3. PACIFIC OCEAN SHRIMP

Review of the Fishery

The commercial trawl fishery for Pacific ocean shrimp, *Pandalus jordani*, commonly referred to as pink shrimp, began in California in 1952 after commercial quantities were found in 1950 and 1951 by California Department of Fish and Game (CDFG) research vessels. The California Fish and Game Commission (Commission) established the first set of regulations for the new fishery in 1952, which included season, net type, and mesh size restrictions. At that time the state was also divided into three regulatory areas, designated A, B, and C. In 1956, Area B was divided into two areas: B-1 extending from False Cape to Point Arena and B-2 from Point Arena to Pigeon Point.

Ocean shrimp take was governed by catch quotas established in each regulatory area from 1952 to 1976. Quotas were based on recommendations of the CDFG and were set each year by the Commission. From 1952 to 1963, ocean shrimp fishermen were limited to the use of beam trawls with a minimum mesh size of 1½-inches (38-millimeters) between the knots. Following the1963 season, the use of otter trawls with the same size mesh was also permitted. In 1975, the mesh size was reduced to 1⅜-inches (36-millimeters) in Areas A, B-1, and B-2. The quota system was abandoned in 1976 and the following regulations were enacted in an effort to protect the resource: 1) a season closure from November 1 through April 14 to protect egg-bearing females; 2) a net mesh size of 1⅜-inches (36-millimeters) to allow for escapement of small zero- and one-year-old shrimp; 3) a count per pound of 170 or less intended to protect one-year-old shrimp; and 4) a minimum catch rate of 350 pounds (159 kilograms) per hour to protect shrimp when the population was at a low level.

In 1981, these regulations were changed based on an agreement with Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fisheries to establish uniform coastwide management measures. The resulting regulations, which are still in effect today, included an open season from April 1 through October 31, a maximum count per pound of 160, and a minimum mesh size of 1⅜-inches (36-millimeters) measured inside the knots (California waters only). Additionally, the state of Oregon has a “reciprocal landing law” which prohibits the landing of ocean shrimp taken in California waters using nets with a mesh size less than 1⅜-inches (36-millimeters). The ocean shrimp fishery off the United States west coast is managed by the states, but incidental groundfish catch limits, trip limits, size limits, a vessel monitoring system starting in 2008, and area restrictions protecting essential fish habitat for groundfish are enforced in the federal open access trawl fishery under Title 50 of the Code of Federal Regulations.

All shrimp boats in California pulled a single rig of one net and two doors prior to the 1974 season, when vessels towing a double rig from outriggers (one net on each side of the boat) entered the fishery. The double-rigged vessels are approximately 1.6 times more effective than single-rigged vessels. Double-rigged

vessels made up approximately 25 percent of the California fleet in the late 1970s, and increased to nearly half the fleet during the 1980s and 1990s. Surveys conducted by ODFW researchers in the early 1990s on the Oregon fleet revealed that nearly 90 percent of the vessels were double-rigged. In recent years, nearly all of the ocean shrimp fishermen in California, Oregon, and Washington used a double-rigged vessel.

Annual landings for ocean shrimp in California are highly variable and have ranged from 140,000 pounds (64 metric tons) to 18,700,000 pounds (8,490 metric tons) in the 55 years of the fishery (Figure 3.1). Average annual landings increased each decade from the start of the fishery in the 1950s up to the end of the 1990s. However, there was a four-fold decrease in average annual landings from 2000 through 2006 compared to the 1990s. The number of active vessels mirrored the trends in annual landings. A record high of 121 active vessels were recorded in

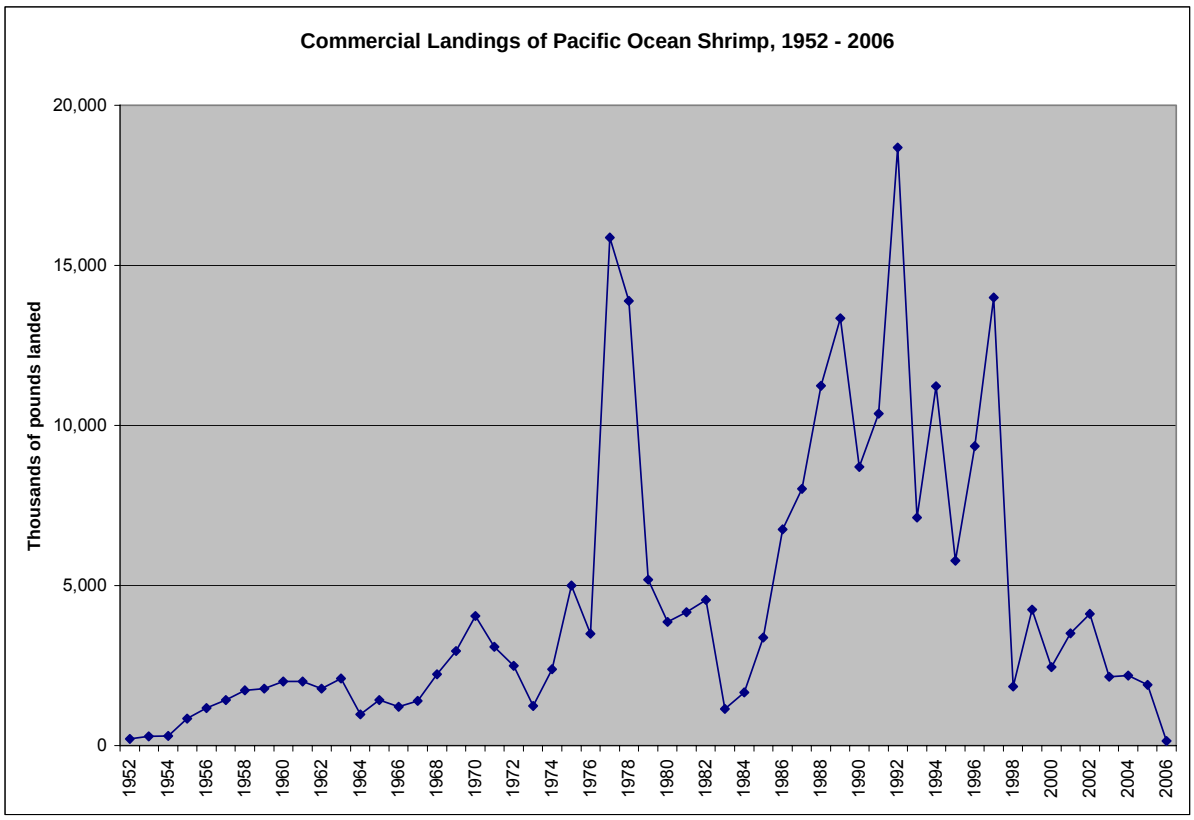

Figure 3.1. Pacific ocean shrimp commercial landings from 1952 to 2006. Data source: CDFG commercial landing receipts.

both 1994 and 1996. Since 2000, the number of active vessels has decreased nearly every year to only four vessels in 2006, which is the lowest mark in the history of the fishery.

The average total annual ex-vessel price increased each decade from the 1950s to the end of the 1990s. From 2000 through 2006, the average total annual ex-vessel price averaged $951,000, which is over a four-fold decrease from the average ex-vessel price of $4,470,000 in the 1990s. Fishing revenue from the 2006 commercial harvest of ocean shrimp was about $66,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $128,000. Likewise, total employment and wages from the harvest of ocean shrimp is estimated to be the equivalent of two jobs and $59,000, respectively.

The price per pound paid to fishermen has ranged from a low of $0.07 per pound in 1955 to a high of $0.87 per pound in 1987. The average price per pound from 2000 through 2006 was $0.42 per pound. The average price per pound paid to Oregon fisherman in the same period was $0.34 per pound. Total annual ex-vessel price for the fishery has also declined in recent years.

The majority of ocean shrimp landed in California are machine cooked and peeled (shell removed), and sold as individually quick-frozen meat, commonly referred to as salad shrimp or cocktail shrimp. A small amount is sold fresh as cooked picked meat or packed in vacuum cans. Most of California's shrimp catch was hand peeled until 1969 when large processing machines were introduced in the Eureka area. These machines have enabled the shrimp industry to process much smaller shrimp than was possible with hand peeling.

Recently, three additional regulatory changes have been implemented in the California ocean shrimp fishery. First, the State was divided into a northern and southern region in 2001, and fishing in each region requires a separate permit. The northern region was designated as a limited entry fishery from the California-Oregon border to Point Conception, and the southern region was designated as an open access fishery from Point Conception to the California-Mexico border. From 2001 through 2006, the average number of active vessels in the northern region was 24 compared to only 3 in the southern region. Additionally, over 99 percent of the annual landings from 2001 through 2006 occurred in ports located in the northern region, particularly the Eureka area, and no landings have been recorded in ports south of Morro Bay since 2003.

The second recent regulatory change was the requirement of an approved Bycatch Reduction Device (BRD) on all nets used in the ocean shrimp fishery in order to protect overfished groundfish species off the United States west coast. In California, this regulation was approved in 2001 and operative in 2002 under Title 14, Section 120 of the California Code of Regulations. In Oregon and Washington, BRDs were required inseason to minimize canary rockfish, *Sebastes pinniger*, catches on August 1, 2001 and July 1, 2002, and then permanently required in 2003. Several types of BRDs may be used in the California fishery, including the Nordmøre grate (rigid-grate excluder), soft-panel excluder, and fisheye excluder. However, rigid-grate BRDs are generally considered to be the most efficient in reducing fish bycatch with minimal ocean shrimp loss. The vast majority of current, active vessel operators in both California and Oregon have been using this type of BRD since 2003 (Figure 3.2).

A recent study conducted in Oregon by ODFW researchers indicates the use of BRDs resulted in a 66 to 88 percent reduction in total fish bycatch, and the use of rigid-grate BRDs is generally more effective at bycatch reduction of groundfish species than soft-panel BRDs. Furthermore, mandatory BRD use has changed the species composition of the bycatch from commercially important large fish species to primarily smaller fish species with little or no commercial value. Rigid-grate BRDs with 1¼-inch (32-millimeter) bar spacing have been the most commonly used BRD in recent years. However, recent experimentation suggests that ¾-inch (19-millimeter) bar spacing may further reduce bycatch rates to well below 5 percent of the total catch with minimal shrimp loss. Largely attributed to the use of BRDs, the ocean shrimp fishery in Oregon was recently certified in accordance with the Marine Stewardship Council (MSC) Principles and Criteria for Sustainable Fishing, which is the world's first sustainable shrimp certification under the MSC certification program. Both Monterey Bay Aquarium and Blue Ocean Institute have recently put ocean shrimp on their lists of good seafood choices for environmentally conscious consumers.

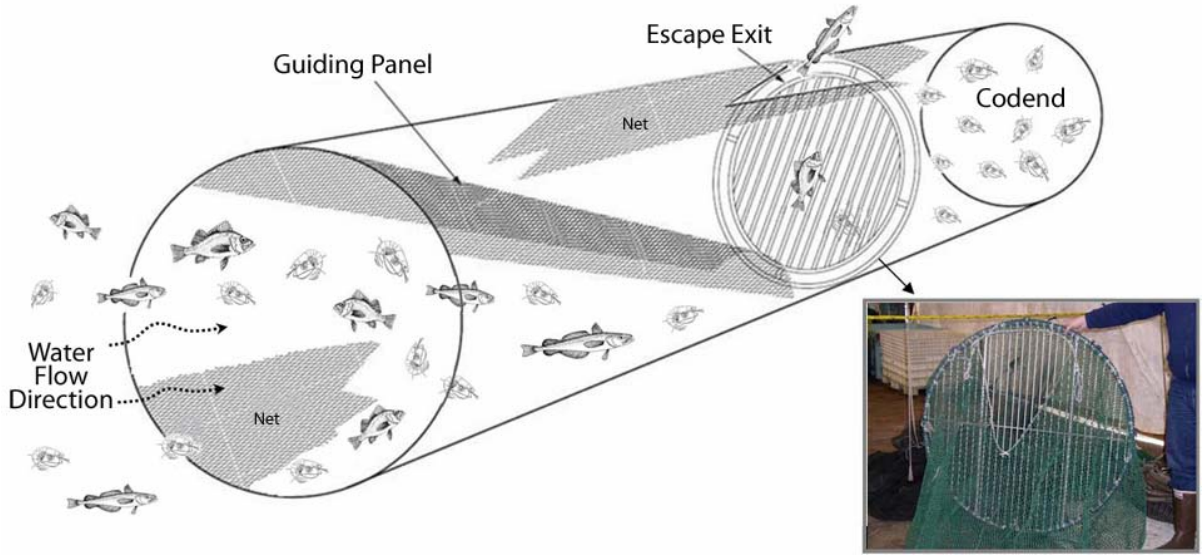

Figure 3.2. Diagram of a typical rigid-grate (double-ring) Bycatch Reduction Device (BRD) used in the ocean shrimp trawl fishery. The diagram depicts shrimp traveling through the BRD, and larger fish species deflected by the BRD and guided through the escape exit opening. The inset picture is a rigid-grate (single-ring) BRD with 1½-inch bar spacing. Credit: Diagram and inset picture modified from Robert W. Hannah, ODFW.

The third recent regulatory change in the California ocean shrimp fishery pertains to fishing in state waters off the north-central coast. In 2004, the State Legislature approved Senate Bill 1459, adding Fish and Game Code (FGC) Section 8841 to statute, and amending Section 8842. The new Section grants the Commission management authority over all state-managed bottom trawl fisheries

not managed under a federal or state fishery management plan. It established that, commencing January 1, 2008, bottom trawling for ocean shrimp was prohibited in state waters between 2 and 3 nautical miles (3.7 and 5.6 kilometers) from the mainland on the north coast of California from Point Reyes to False Cape. These fishing grounds, often referred to as the pink shrimp trawl grounds (PSTG), produced an average of 21 percent of the annual ocean shrimp landings statewide from 2000 through 2006. According to FGC Section 8842, the Commission has the authority to open state waters to bottom trawling for ocean shrimp if it determines, based on the best available scientific information, that bottom trawling in those areas is sustainable, does not harm bottom habitat, and does not unreasonably conflict with other users.

Status of Biological Knowledge

Ocean shrimp are found in waters from Unalaska in the Aleutian Islands to San Diego, California, at depths from 150 to 1200 feet (45 to 366 meters). Off the coast of California, this species is generally found from depths of 240 to 750 feet (73 to 229 meters). Spawning may occur throughout the range, but commercial quantities are limited to the area between Queen Charlotte Sound, British Columbia and Point Arguello, California. High concentrations of ocean shrimp typically occur in well-defined areas from year to year, most commonly referred to as beds. Ocean shrimp beds are generally characterized by green mud or muddy-sand bottoms. Adult shrimp usually remain in one of ten localized beds along the coast. Previous studies suggest some horizontal, onshore-offshore transport may occur within the confines of a single bed due to prevailing currents and feeding activities. However, no convincing evidence exists to believe ocean shrimp exhibit large, coastwide migratory behavior. Nevertheless, larval transport may occur among beds since young-of-the-year shrimp live in the plankton for 7 to 8 months before settling to the bottom. Genetic stock identification work on this species has failed to isolate any genetic differences between ocean shrimp off the coasts of California, Oregon, Washington and British Columbia. It is therefore assumed that there are no genetically distinct subpopulations of ocean shrimp off the coast of western North America.

Ocean shrimp undergo diel vertical migration by inhabiting deeper waters near the bottom during the day and ascending in the water column during the night to feed. Stomach contents of shrimp taken at night consist of primarily smaller planktonic animals, such as euphausiids and copepods. Shrimp stomach contents taken during the day contained little food; identifiable food items included diatoms, sponges, polychaetes, amphipods, and isopods. Ocean shrimp have been reported as prey for many fish species, including Pacific hake, *Merluccius productus*; arrowtooth flounder, *Atheresthes stomias*; sablefish, *Anoplopoma fimbria*; petrale sole, *Eopsetta jordani*; spiny dogfish, *Squalus acanthias*; and several species of rockfish and skates.

Ocean shrimp are protandric hermaphrodites, functioning as males during the first year and a half of their life, then passing through a transitional phase to become females. During some years, a large percentage (up to 60 percent) of one-year-old shrimp become females and never mate as males. Mating takes place during September and October. During the winter, female shrimp produce eggs, usually between 1,000 and 3,000, which are fertilized by packets of sperm from males. Small individuals in their second year have been found bearing as few as 900 eggs, whereas larger shrimp in their third or fourth year of life have been found bearing up to 3,900 eggs.

The female carries the eggs attached to the posterior swimming appendages until the larvae hatch. The peak hatching period occurs during late March and early April. Ocean shrimp go through a larval period which lasts 2 to 3 months. The developing juvenile shrimp occupy successively deeper depths as they grow, and often begin to show up in commercial catches by late summer. Ocean shrimp grow in steps by molting or shedding their carapace. Growth rates vary according to region, sex, age, and year class. There is a clear pattern of seasonal growth despite the variations mentioned, with very rapid growth during spring and summer and slower growth during the winter.

Growth rates of ocean shrimp off the coast of Oregon increased markedly after 1979, suggesting a density-dependent growth response to fishing. During the first, second, and third winters of life, ocean shrimp generally range from 0.5- to 0.7-inches (13- to 17-millimeters) in mean carapace length after one year of life, 0.7- to 1- inches (18- to 25-millimeters) after two years, and 1- to 1.1-inches (25- to 29-millimeters) after three years (Figure 3.3); and survival between fishing seasons (over winter) is estimated to be 46, 76, and 43 percent, respectively. In California, few shrimp survive beyond their fourth year. Natural mortality rates may also change in response to the abundance of predator stocks, such as Pacific hake.

Status of the Population

Population estimates of the various ocean shrimp beds were obtained by CDFG sea-surveys from 1959 to 1969. Catch quotas were set at one quarter of the estimated population. Since the cost of sea-surveys was quite high, another method of estimating the population was needed. A mathematical population model, designed by CDFG statisticians, was used to estimate the population size. The population model set the quota from 1969 until 1976, but it was subsequently dropped the following year because of the variable recruitment, growth, and natural mortality rates associated with ocean shrimp. No further attempts to estimate the population have been made in California.

Figure 3.3. Three size (age) classes of Pacific ocean shrimp, *Pandalus jordani*. Credit: Robert W. Hannah, ODFW.

Ocean shrimp abundance off California varies substantially from year to year, which is largely attributed to environmental factors causing natural fluctuations in recruitment. Annual recruitment success has been linked to the strength and timing of the "spring transition." The spring transition refers to the seasonal change from northward winter winds to southward summer winds which force a shift in coastal currents just following larval release. An early, strong transition is necessary to produce a large year class. Shrimp are short-lived and exhibit flexible rates of sex change that act to maintain a roughly balanced sex composition, despite highly variable mortality rates. Other evidence also suggests that shrimp exhibit a density-dependent growth response to fishing. Nevertheless, the importance of environmental factors on ocean shrimp recruitment and distribution suggests fishing pressure may have relatively less influence on stock status. However, overfishing may be possible if intensive fishing were to be directed at a failed year class. This is considered very unlikely because the low ex-vessel value of small ocean shrimp makes it very difficult to fish profitably on low standing stocks.

Annual landings in California have been exceptionally low since 2003, marked by a record low in 2006 (Figure 3.1). Similarly, annual Oregon landings were below average from 2003 through 2006. A combination of factors may explain the recent reduction in landings, such as a weak market attributed to competition from other warm water and cold water shrimp fisheries, competition from aquaculture production of warm water species worldwide, increased fuel prices, limited shrimp processors available on the U.S. west coast, and environmental conditions negatively affecting recruitment. Moreover, the federal groundfish fishing capacity reduction program, or vessel buyback program, was implemented by the National Marine Fisheries Service in 2003 in an effort to increase productivity, promote economic efficiency, and to help conserve and manage the resources in the groundfish fishery. The program involved a reduction in the fishing capacity of both the Dungeness crab, *Cancer magister*, and ocean shrimp fisheries. As a result, 85 ocean shrimp permits were relinquished coastwide: 31 from California, 40 from Oregon, and 14 from Washington.

For the last several years, fishable concentrations of ocean shrimp in waters off Oregon have been almost exclusively off the northern half of the state. If recruitment off southern Oregon recovers, ocean shrimp in California waters may bounce back as well.

Management Considerations

The mandatory requirement of BRDs on nets used in the ocean shrimp trawl fishery (FGC Section 8841) has proven to be a highly successful method of reducing bycatch. Three types of BRDs are currently allowed in the statewide California ocean shrimp fishery, including rigid-grate, soft-panel, and fisheye excluders; however, the Commission is currently considering changes to BRD regulations in the California ocean shrimp fishery. Recent experimentation by ODFW in Oregon waters has demonstrated that rigid-grate BRDs are the most effective in reducing groundfish bycatch of the three allowable BRD types. A phone survey conducted by CDFG in 2007 on active, ocean shrimp fishermen in California concluded that the majority of vessels in the northern region are double-rigged and use rigid-grate BRDs. The fishermen surveyed also reported the most common bar spacing on rigid-grate BRDs in recent years was 1¼-inches (32-millimeters) to 1½-inches (38-millimeters). Recent experimentation by ODFW in Oregon waters indicated that ¾-inch (19-millimeter) bar spacing on rigid-grate BRDs may further reduce bycatch rates to well below 5 percent of the total catch with minimal shrimp loss. Therefore, reducing the bar spacing on rigid-grate BRDs to ¾-inch (19-millimeter) or less should be considered by managers.

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Further Reading

Dahlstrom, W.A. 1970. Synopsis of biological data on the ocean shrimp *Pandalus jordani* Rathbun, 1902. FAO Fish. Rept. 57(4):1377-1416.

Frimodig, A. 2008. Informational report: Bycatch Reduction Devices used in the pink shrimp trawl fishery. Report to the California Fish and Game Commission. California Department of Fish and Game, Marine Region, State Fisheries Evaluation Project. 12 p. http://www.dfg.ca.gov/marine/pdfs/brd_report.pdf

Frimodig, A., M. Horeczko, T. Mason, B. Owens, M. Prall, and S. Wertz. 2007. Information regarding the pink shrimp trawl fishery off northern California. California Department of Fish and Game, Marine Region, State Fisheries Evaluation Project. 25 p. http://www.dfg.ca.gov/marine/pdfs/pinkshrimp.pdf.

Hannah, R.W. 1993. The influence of environmental variation and spawning stock levels on recruitment of ocean shrimp (*Pandalus jordani*). Canadian Journal of Fisheries and Aquatic Sciences 50(3):612-622.

Hannah, R.W. and S.A. Jones. 2007. Effectiveness of bycatch reduction devices (BRDs) in the ocean shrimp (*Pandalus jordani*) trawl fishery. Fisheries Research 85:217-225.

Marine Stewardship Council. 2007. The Oregon pink (ocean) shrimp trawl fishery. http://www.msc.org/assets/docs/Oregon_pink_shrimp/Final_Report_Oct_2007.pdf. Final Report Version 3. 137 p.

Pacific Fishery Management Council. 1981. Discussion draft fishery management plan for the pink shrimp fishery off Washington, Oregon and California. Pacific Fishery Management Council, Portland, Oregon. 169 p.

Rothlisberg, P.C. and C. B. Miller. 1983. Factors affecting the distribution, abundance and survival of *Pandalus jordani* (Decapoda, Pandalidae) larvae off the Oregon coast. Fishery Bulletin 81:455-472.