Fishery-at-a-Glance: Pink (Ocean) Shrimp

Scientific Name: *Pandalus jordani*

Range: Pink Shrimp are known to inhabit Southeast Alaska to San Diego, California, and most abundant off the coast of Oregon.

Habitat: Pink Shrimp dwell in deep waters,150 to 1,200 feet (45.7 to 365.8 meters), aggregating near the bottom during the day in well-defined areas of muddy habitat called beds and ascending into the water column at night to feed.

Size (length and weight): Pink Shrimp are fast-growing. Individual growth rates vary by sex, location, year class, season, and age. Mean carapace length for 1-, 2-, and 3-year-old shrimp ranges from 0.5 to 0.7 inches (13 to 17 millimeters), 0.7 to 1.0 inches (18 to 25 millimeters), and 1.0 to 1.1 inches (25 to 29 millimeters), respectively.

Life span: Pink Shrimp are short-lived at approximately 5 years. In California, few shrimp survive beyond the fourth year.

Reproduction: Pink Shrimp are protandric hermaphrodites, changing sex from males to females after approximately the first year and a half. Mating occurs during September to October.

Prey: Pink Shrimp feed on zooplankton, including copepods and krill. Stomach contents have also included diatoms, sponges, polychaetes, amphipods, and isopods.

Predators: Many commercially important fish species, including Pacific Hake (*Merluccius productus*), Arrowtooth Flounder (*Atheresthes stomia*), Sablefish (*Anoplopoma fimbria*), Petrale Sole (*Eopsetta jordani*), Spiny Dogfish (*Squalus acanthias*), and several species of rockfish and skates prey on Pink Shrimp.

Fishery: There is only a commercial fishery for Pink Shrimp. Point Conception divides the northern and southern management regions. In 2017 more than 3.4 million pounds (1,542 metric tons) were landed in California and generated more than $1.6 million in revenue. Average ex-vessel price has varied between $0.30 and $0.53 per pound since 2002 and was $0.77 per pound in 2016.

Area fished: Pink Shrimp are sought from British Columbia to Point Arguello, California, with the majority of landings concentrated in northern California. In 2013, 76% of the catch was landed in Crescent City and 24% was landed in Eureka (less than 1% was landed in Santa Barbara). Since 2008, trawling is only allowed in federal waters.

Fishing season: The Pink Shrimp fishery experiences a seasonal closure from November 1 to April 14 to protect egg-bearing females.

Fishing gear: Benthic trawl equipped with a bycatch reduction device via single (southern fleet) or double (northern fleet) rigged vessel are used when fishing for Pink Shrimp. A minimum mesh size of 1.38 inches (36 millimeters) allows for escapement of small 0- and 1-year-old shrimp.

Market(s): Pink Shrimp are primarily exported to Europe, though some domestic consumption occurs. Shrimp are shelled, cooked, and froze prior to sale. They are often used as shrimp for salads or “shrimp cocktails”.

Current stock status: No current estimates of the Pink Shrimp population abundance in California exist. Recruitment varies substantially from year to year in response to environmental factors, causing natural fluctuations in abundance.

Management: Since 2004 the fishery has been principally state-managed, although some federal regulations apply. These include daily and monthly trip limits for incidental catches of groundfish species, use of a vessel monitoring system, onboard observer coverage, and area restrictions protecting groundfish essential fish habitat. A separate permit is needed to fish in the northern and southern management regions. The fishery in the southern region is open access. The fishery in the northern region is limited entry. Regulations are the same for both management regions. Trawling is only allowed in federal waters. No quota or catch limits exist. A seasonal closure exists. Gear must contain a bycatch reduction device and have a minimum mesh size of 1.38 inches (36 millimeters). A maximum count of 160 per pound effectively functions as a size limit.

1 The Species

1.1 Natural History

1.1.1 Species Description

Pink Shrimp (*Pandalus jordani*), also called Ocean Shrimp, is a commercially important species in California. Pink Shrimp are crustaceans in the genus *Pandalus* and are closely related to the Northern Rough Pink Shrimp (*Pandalus eous*). Pink Shrimp have a hard outer shell and jointed legs, and can grow up to 6 inches (in) (152.4 millimeters (mm)) long. They are uniform pink in coloration, with no stripes or spots, though their dark viscera can be seen through their translucent bodies. Pink Shrimp have large, bulbous eyes and breathe through their gills. The rostrum (a horn-like projection between the eyes) is 1.5 to 2 times longer than the carapace (hard plate covering the head and thorax). Pink Shrimp are almost identical in size and coloration to the Northern Rough Pink Shrimp, but lack the spine Rough Pink Shrimp have on their curved abdominal segment.

1.1.2 Range, Distribution, and Movement

Pink Shrimp range from southeast Alaska to Baja California, California, but are only abundant enough to support a commercial fishery from Point Arguello to British Columbia (Hannah and Jones 2007) (Figure 1-1). It is thought that a single genetic stock exists throughout their entire range (OST 2014). Pink Shrimp are most abundant off the coast of Oregon, and since 2007, the majority of landings have been concentrated in the northernmost counties of California. Pink Shrimp are found at depths of 150 to 1,200 feet (ft) (45.7 to 365.8 meters (m)), but tend to be caught between 300 and 600 ft (91.4 and 182.9 m) in California (mean reported depth in logbooks is 444 ft ± 124 (135.3 m ± 37.8 m); mean ± standard deviation). They generally inhabit deep waters, aggregating near the bottom during the day in well-defined areas of muddy habitat called beds and ascending into the water column at night to feed. Historically, most fishing occurred in federal waters, and since 2008 trawling for shrimp in state waters has been prohibited.


Figure 1-1. Range of Pink Shrimp.

Pink Shrimp may be subject to some level of on-shore/offshore transport due to ocean currents. However, there is no evidence that they exhibit large, coast-wide migratory behavior. Larval transport between beds may occur since young-of-the-year shrimp live in the plankton for up to eight months before settling to the bottom.

1.1.3 Reproduction, Fecundity, and Spawning Season

Pink Shrimp are short-lived, fast-growing, highly-fecund species. They are protandric hermaphrodites, meaning they spend the first year and a half as males, and then transition to females. The age at transition can vary in response to environmental or population cues. Mating takes place during September and October. Fecundity (the number of eggs females produce) varies between years and areas (Hannah et al. 2011), and small females in their second year have been found to produce as few as 900 eggs, while larger shrimp in their third or fourth year of life may bear up to 3,900 eggs. After fertilization by packets of sperm, the female carries the eggs attached to the posterior swimming appendages until the eggs hatch during late March and early April. The fishery is closed from November 1 to April 1 to prevent egg-bearing females from being caught. There is a 2 to 3 month pelagic larval phase. Juveniles occupy successively deeper depths as they grow, and recruit to the fishery in the late summer, at about 5 to 6 months of age.

1.1.4 Natural Mortality

Determining the natural mortality (M) of marine species is important for understanding the health and productivity of their stocks. Natural mortality results from all causes of death not attributable to fishing such as old age, disease, predation or environmental stress. Natural mortality is generally expressed as a rate that indicates the percentage of the population dying in a year. Fish with high natural mortality rates must replace themselves more often and thus tend to be more productive. Natural mortality along with fishing mortality result in the total mortality operating on the fish stock.

Pink Shrimp live approximately 5 years (yr), but catches are usually dominated by the age-one year class (Parsons et al. 2013). Natural mortality is high, with the over-winter (between fishing seasons) survival rates estimated to be between 43 and 76% for shrimp aged one to three. Natural mortality may increase after age three (Dahlstrom 1973). In California, few shrimp survive beyond their fourth year (Dahlstrom 1973). Natural mortality rates may also change in response to the abundance of predator stocks, such as Pacific Hake.

1.1.5 Individual Growth

Individual growth of marine species can be quite variable, not only among different groups of species but also within the same species. Growth is often very rapid in young fish and invertebrates, but slows as adults approach their maximum size. The von Bertalanffy Growth Model is most often used in fisheries management, but other growth functions may also be appropriate.

Pink Shrimp experience a pelagic larval period of 2 to 3 months. The developing juvenile shrimp occupy successively deeper depths as they grow, and may appear in commercial catches, which target shrimp inhabiting muddy bottoms, by late summer. Shrimp grow in steps by molting or shedding their carapace. Growth rates vary according to region, sex, age, and year class (Dahlstrom 1973). Pink Shrimp generally grow faster in northern California than they do in Oregon, and age-one shrimp in California are often large enough to meet the minimum shrimp per pound (lb) restriction. 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 (Frimodig et al. 2009). In Oregon, growth rates were found to increase after 1979, suggesting a density-dependent response to fishing.

One-year-old shrimp range from 0.5 to 0.7 in (13 to17 mm) in mean carapace length, 2-year-old shrimp range from 0.7 to 1.0 in (18 to 25 mm), and 3-year-old old shrimp range from 1.0 to 1.1 in (25 to 29 mm) (CDFG 2008) (Figure 1-2). Years with very high abundances can cause competition amongst a cohort for scarce resources, resulting in reduced growth rates.

Figure 1-2. Three size (age) classes of Pink Shrimp (Photo Credit: Robert Hannah, ODFW).

1.1.6 Size and Age at Maturity

As noted, Pink Shrimp are protandric hermaphrodites, meaning that all shrimp are born male and will reproduce first as males and shift to being female at age 1.5, but it is possible to have age groups that are composed of both males and females (Butler 1964). Some shrimp shift their sex earlier in response to changes in the age distribution of the population (Charnov et al. 1978). When population sizes are low, some older shrimp remain male. Conversely, when year-class strength is high, as much as 60% of 1-year-old shrimp will shift to be female, and thus never breed as males. Young-of-the-year shrimp (hatched in the spring of a given year) settle to the bottom by the late summer or early fall. Thus, they may become vulnerable to the fishing gear at the end of the fishing season, prior to achieving sexual maturity. Fecundity increases with size in Pink Shrimp, and thus the age structure of the stock may be a useful indicator of breeding stock health, as well as recruitment in subsequent years.

1.2 Population Status and Dynamics

There is no known stock recruitment relationship for Pink Shrimp, and recruitment is thought to be driven primarily by environmental conditions rather than the size of the spawning stock. Pink Shrimp abundance off California varies substantially from year to year, and this variability is largely attributed to environmental factors that affect the survival of eggs or juveniles. This is a source of major uncertainty and prevents reliable long-term forecasting using traditional demographic models, which do not account for environmental conditions (section 1.2.1). This high variability in stock size is natural, and stock abundance can be low even in the absence of fishing. The short life-span and fast growth rates of Pink Shrimp make it possible to determine year classes based on size, and the age structure of the catch has proven to be a reliable metric of year class strength (section 1.2.2).

1.2.1 Abundance Estimates

At-sea surveys were conducted by the Department between 1959 and 1969 to obtain abundance estimates for the various commercial beds and set regional quotas. These surveys were costly, so a mathematical population model was developed to estimate the population size from 1969 until 1975, but its use was discontinued because Pink Shrimp violate a number of the assumptions in the models due to variable recruitment, growth, and mortality.

In 1981, a comprehensive coast-wide stock assessment was conducted, in which a Schaeffer surplus production model was fit to catch and effort data from 1959 to 1980 (Abrahamson et al. 1981). However, this model was inappropriate for stocks in which biomass changes are driven by environmental fluctuations rather than the effects of fishing (Geibel and Heimann 1976). Equilibrium-based models such as catch-at-age and yield-per-recruit have also been unsuccessful at determining stock status and meaningful reference points for Pink Shrimp. Environmental models have been more successful at accounting for the variation observed in the catch, but have found no significant effects of fishing on future stock size (i.e., a stock-recruitment relationship) (Hannah 1993). The importance of environmental factors on Pink 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.

Catches, which are assumed to reflect the available biomass, have varied widely from year to year, and Catch Per Unit Effort (CPUE) has been relatively high since 2010. From 2011 to 2013, landings on the west coast were also high, but have declined since 2015.

1.2.2 Age Structure of the Population

The age structure of the California portion of the stock was last assessed in the 1990s. At that time, the age structure of the Pink Shrimp off Oregon was found to have been altered by intensive fishing since the 1970s (Hannah and Jones 1991). The proportion of first-time breeders (age-one individuals) had increased from ~30% to ~70% of the catch. This may have impacted the spawning potential of the stock.

Because the Pink Shrimp stock crosses the California-Oregon border, and a sizeable portion of the catch landed in Oregon is caught in California waters, the age structure of the Oregon catches (Figure 1-3) is likely to be representative of stock conditions in California. In the late 2000s and early 2010s, age-two shrimp dominated the catch, and as a result, the age-three component of the 2012 stock was the highest observed since 1978 (ODFW 2013). It is hypothesized that the high population levels have allowed fishermen to avoid the smaller (and less valuable) age-one year class, delaying their capture by one year (ODFW 2014a). A large recruitment class in 2015 caused a very high proportion of the catch to be composed of age-one shrimp in 2016, but in 2017 a more usual age distribution was observed.

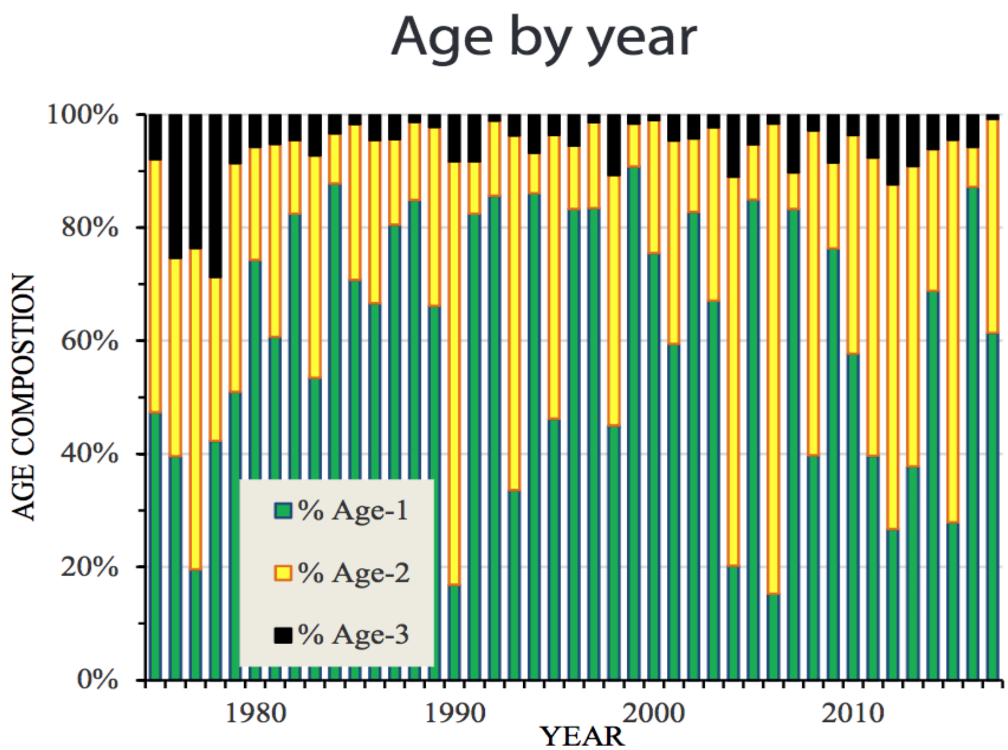

Figure 1-3. Annual age composition (percent) of Pink Shrimp landed in Oregon, 1975 to 2017 (Reproduced from ODWF 2018a).

1.3 Habitat

Pink Shrimp inhabit muddy bottoms at a depth range of 150 to 1,200 ft (45.7 to 36.8 m) along the coast of North America (Dahlstrom 1973). They are most often found in well-defined beds of either sandy mud or what is termed “green mud” (Figure 1-4). They aggregate near the sea floor during the day but ascend into the water column to feed at night. For this reason, they are targeted during the day using benthic trawl gear that drags along the sediment. Beds with commercial densities have been mapped, and while the largest beds occur off the coast of Oregon, commercial beds can be found from southern California to British Columbia.


Figure 1-4. Pink Shrimp habitat (Photo Credit: CDFW).

1.4 Ecosystem Role

Pink Shrimp occupy a central position in the trophic structure of their ecosystem because they feed on zooplankton and are forage for a number of fish species. They are also highly responsive to changing environmental conditions. Due to this sensitivity and their short life histories, species in *Pandalus* genus have been shown to be early indicators of regime shifts, such as from predominantly cool, productive oceanic conditions to warmer, low productivity conditions (Anderson and Piatt 1999).

1.4.1 Associated Species

Pink Shrimp have no known associated species. However, the closely related Aesop Shrimp (*Pandalus montagui*) lives in association with the reef-building polychaete worm known as the Ross Worm (*Sabellaria spinulosa*) (Last et al. 2012).

1.4.2 Predator-prey Interactions

Pink Shrimp ascend into the water column at night to feed on zooplankton, including copepods and krill (Pearcy 1970). Their stomach contents have also included diatoms, sponges, polychaetes, amphipods, and isopods.

Pink Shrimp are likely an important source of prey for a number of fish species, including those of commercial importance. These include Pacific Hake, Arrowtooth Flounder, Sablefish, Petrale Sole, Spiny Dogfish, and several species of rockfish and skates (CDFG 2008; NWFSC 2010).

1.5 Effects of Changing Oceanic Conditions

Pink Shrimp have a high tolerance for a range of salinities, but a fairly narrow optimal temperature range between 8 and 11 degrees Celsius (˚C). Fluctuations in temperature from year to year may impact the survival, metamorphosis and growth of larvae (Rothlisberg 1979). In addition, the bottom temperature may influence the fecundity of shrimp (Hannah 2011). Recruitment of young-of-the-year has been negatively correlated with El Niño Southern Oscillation cycles. Coastal upwelling, which can vary from year to year, may influence the location of shrimp beds (Hannah 2011). The timing of spring transition, marked by increased offshore winds, increased upwelling, and decreased sea level height, has been linked to strong recruitment. The mechanism for this correlation may be related to cool, nutrient-rich waters promoting recruit survival. However, it is thought that very strong upwelling, and associated very low sea levels, transport larvae offshore, reducing recruitment (Hannah 2011).

2 The Fishery

2.1 Location of the Fishery

The Pink Shrimp fishery is currently split into a northern and southern region, with Point Conception as the dividing line. Within the northern region, the primary Pink Shrimp beds have historically been located between Eureka and the Oregon border, in an area immediately north of Fort Bragg (Figure 2-1a). Additionally, commercially harvestable densities of Pink Shrimp are sometimes present off Morro Bay (Figure 2-1b). In the southern region, lower densities of Pink Shrimp are sometimes harvested along the mainland in the Santa Barbara Channel (Figure 2-1b) (CDFG 2007).

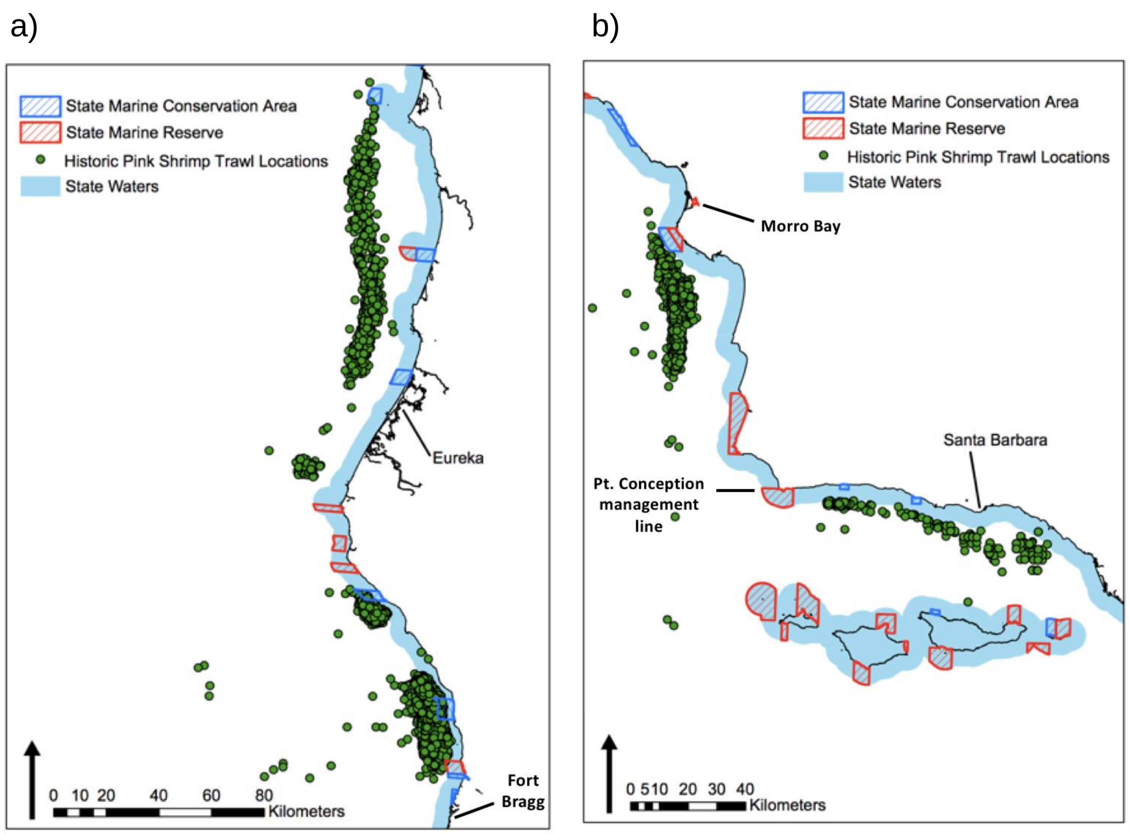

Figure 2-1. Historical Pink Shrimp trawl locations in a) northern California and b) southern California, 1999 to 2007 (CDFW Marine Log System (MLS)).

2.2 Fishing Effort

2.2.1 Number of Vessels and Participants Over Time

The Pink Shrimp fishery developed in the early 1950s after Department research cruises found Pink Shrimp beds that could support a commercial fishery. The number of active vessels increased between the 1970s and mid-1990s, before declining to an all-time low in 2006 (Figure 2-2). The number of active vessels has increased steadily in the last 10 yr.

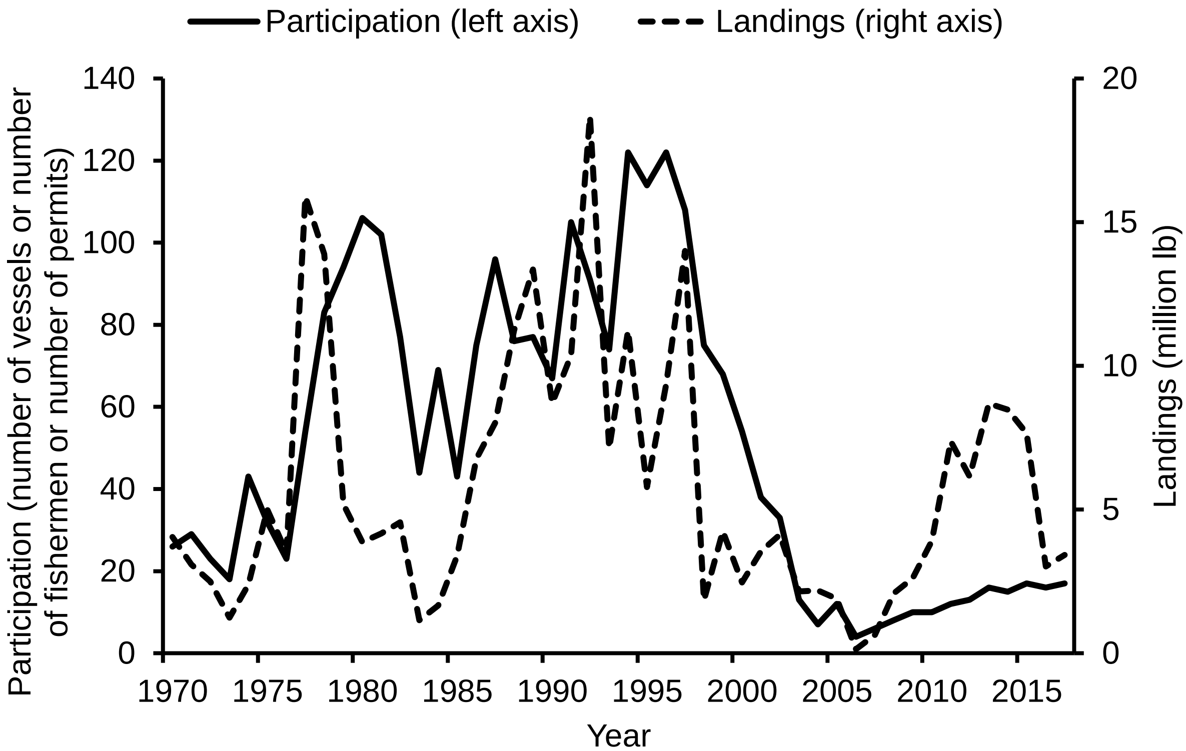

Figure 2-2. Participation (active vessels) and landings (million lb) in the Pink Shrimp fishery, 1970 to 2017 (CDFW Commercial Fisheries Information System (CFIS) 2018).

The total number of permits issued in California peaked at 315 in 1994. 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. The number of permits issued in both the northern and southern regions has declined since 2001, when a restricted access program with a capacity goal of 75 permits was instituted. In 2003, a voluntary federal buyout instituted for groundfish trawl vessel permits removed almost one-half the capacity of the west coast trawl fleet. The total number of permits issued has further decreased since that time, stabilizing at around 35 in the northern region and 15 in the southern region. Thirty-two of the permits in the northern region are transferrable and three are non-transferrable.

Fishing effort can be measured in three different ways: 1) number of vessels fishing per season, 2) number of trips per season, and 3) fishing hours. The number of vessels fishing may vary from year to year in response to fluctuations in either abundance or price per lb. For this reason, number of trips or hours fished may be a more accurate and standardized way to measure fishing effort. More detailed effort data is not currently available for California, but in Oregon the number of fishing hours per season has shown more year to year variation than either the number of vessels or the number of trips (ODFW 2013).

2.2.2 Type, Amount, and Selectivity of Gear

Pink Shrimp are targeted via benthic trawl gear during the day when they are concentrated near the sea floor. The average vessel in the shrimp fleet between 2001 and 2006 was 59 ft (18 m) long (Frimodig et al. 2009).

Prior to 1974 only single-rigged vessels were used (Figure 2-3a). From 1952 to 1963, Pink Shrimp fishermen were limited to the use of beam trawls with a minimum mesh size of 1.5 in (38 mm) between the knots. Following the 1963 season, the use of otter trawls with the same size mesh was also permitted. In 1975, the mesh size was reduced to 1.38 in (36 mm) north of Pigeon Point. After double-rigged vessels entered the fishery, they made up approximately 25% of the California fleet in the late 1970s, and increased to nearly 50% of the fleet during the 1980s and 1990s.

Today, most vessels in the northern fleet use a double-rigged vessel, which has an otter trawl on each side of the vessel (Figure 2-3b), while a majority of fishermen in the southern fleet use single-rigged vessels, which drag a single trawl. It is thought that a double-rigged trawl is 1.6 times more efficient than a single-rigged trawl. All shrimp trawl vessels are required to use Bycatch Reduction Devices (BRDs), and the type of BRD used is influenced by the configuration of otter trawls (CDFG 2007).

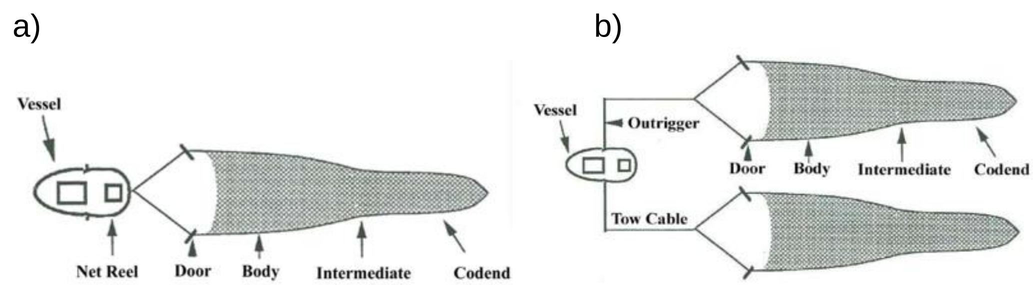

Figure 2-3. Diagrams of a) a single-rigged vessel pulling one otter trawl, and b) a double-rigged vessel pulling two otter trawls used on Pink Shrimp vessels (Reproduced from Jones et al. 1996).

BRDs have been required since 2002 on all nets used in the Pink Shrimp fishery in order to protect overfished groundfish species (§120.1, Title 14, CCR). Several types of BRDs may be used in the California fishery, including the rigid-grate excluders, soft-panel excluders, and fisheye excluders. However, rigid-grate BRDs are generally considered to be the most efficient in reducing fish bycatch with minimal Pink Shrimp loss (Figure 2-4). The vast majority of current, active vessel operators in both California and Oregon have been using this type of BRD since 2003.

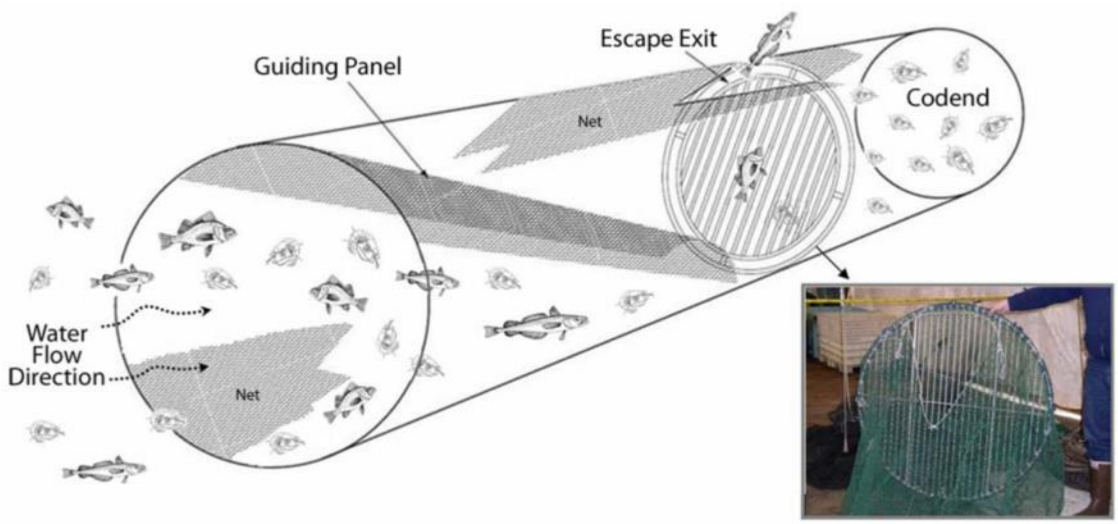

Figure 2-4. Diagram of a rigid-grate BRD used in the Pink Shrimp fishery. The diagram depicts shrimp traveling through the BRD, and larger fish being deflected by the BRD and guided through the escape hatch (Photo Credit: Robert Hannah, ODFW).

2.3 Landings in the Recreational and Commercial Sectors

2.3.1 Recreational

There has never been a recreational fishery for Pink Shrimp (CDFG 2008).

2.3.2 Commercial

Pink Shrimp landings peaked in the late 1980s and 1990s, and decreased from a high of over 18 million lb (18,000 metric tons (mt)) in 1997 to a record low of 0.15 million lb (150 mt) in 2006 (Figure 2-5). Fluctuations in landings are primarily thought to reflect natural variability in the Pink Shrimp population size from year to year due to environmental conditions (Hannah 1993; Hannah 2010), but this decrease in landings also reflects reduced fishing effort (Figure 2-2). Annual landings were below average in both California and Oregon from 2000 to 2010. Landings increased from 2010 to 2015 but have declined since 2015. 90% of the state’s landings have occurred in northern California since 2001.

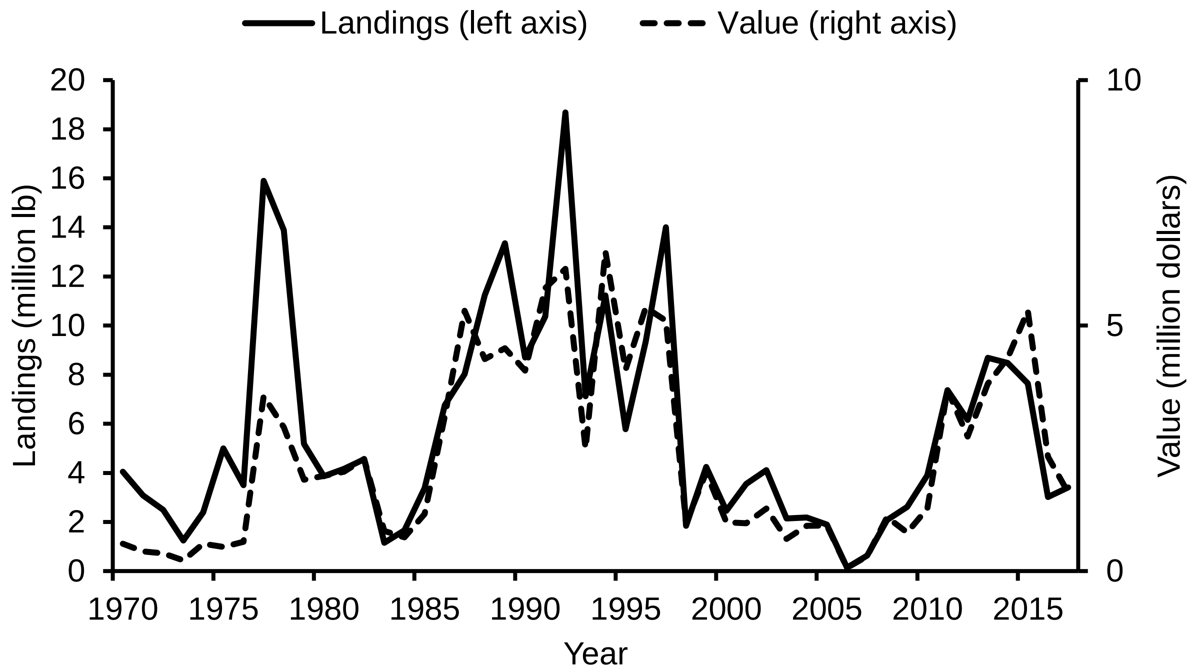

Figure 2-5. Pink Shrimp landings (million lb) and value (million dollars), 1970 to 2017 (CDFW CFIS 2018).

From 1981 through 2006, 18% of the total west coast catch of Pink Shrimp was landed in California ports, 57% was landed in Oregon ports, and 25% was landed in Washington ports (Frimodig et al. 2009). There are also a significant number of vessels licensed in Oregon that fish in California waters but land in Oregon. In 2015, 32 Oregon vessels caught 6.3 million lb (6,300 mt) of Pink Shrimp in federal waters off California (82% of 2015 California landings). California vessels also fish in Oregon waters, but this represents a much smaller percentage of the total landings. Catch per trip has been increasing since the 1980s (Figure 2-6), suggesting that Pink Shrimp trawlers are becoming more efficient (Figure 2-7).

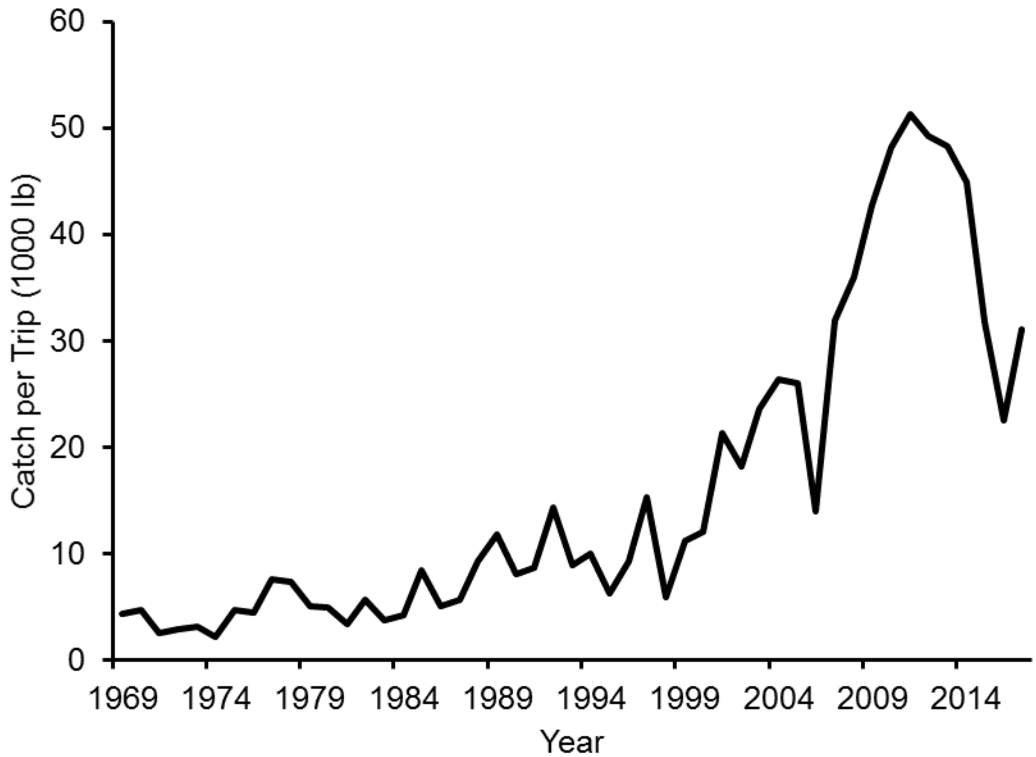

Figure 2-6. Catch per trip of Pink Shrimp, 1970 to 2017 (CDFW CFIS 2018).

Figure 2-7. Pink Shrimp on a trawl vessel deck (Photo Credit: NOAA).

2.4 Social and Economic Factors Related to the Fishery

Pink Shrimp vessels deliver their catch to shore side processors (NWFSC 2010), where they are usually shelled, cooked and frozen prior to sale (CDFG 2008). They are sold as salad shrimp or cocktail shrimp. Currently, most of the Pink Shrimp catch is exported to Europe. European markets place a high value on Marine Stewardship Council (MSC) certification, driving the Oregon fleet to obtain MSC certification in 2007. In 2015 both the Washington and California fisheries applied for Pink Shrimp MSC certification. Washington was approved while California was not due to deficient scores in the Management System category, due in part to a lack of an FMP with clear targets and limits.

The ex-vessel value of the Pink Shrimp fishery has ranged from $0 to 7 million dollars (Figure 2-5). In 2015, California, Oregon, and Washington fishermen harvested 103 million lb (103,000 mt) of Pink Shrimp for a total value of $75.6 million. These numbers dropped by roughly 50% in 2016 to 52.87 million lb and a total value of $36 million, and declined again in 2017 to 33 million lb with a total value of $17.2 million. The majority of landings have come from Crescent City (78%), followed by Eureka (16%) and Morro Bay (6%) (Figure 2-8).

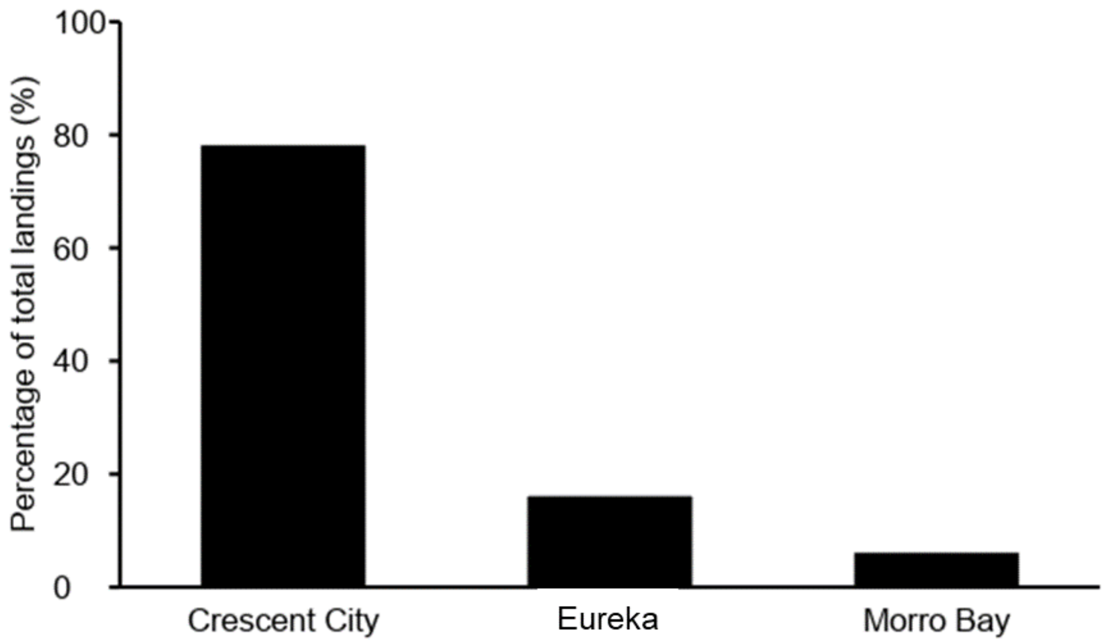

Figure 2-8. Pink Shrimp percentage of total landings by port in 2017 (CDFW CFIS 2018).

Shrimp price and abundance play important roles in determining fleet size in the Pink Shrimp fishery. The price per lb peaked at $0.87 in 1987, coinciding with a time period of very high landings (CDFG 2008). The average ex-vessel price of shrimp has varied between $0.30 and $0.53 per lb since 2002 (Table 2-1). Since 2007, the majority of catch has been from off Eureka in northern California with landings primarily into the Crescent City and Eureka ports. Currently, Eureka is the only port with a shrimp processor and landings in all other ports must be iced and trucked to a processor. Processor capacity has a significant influence on the price paid per lb.

Table 2-1. Poundage, ex-vessel value, and price per lb for Pink Shrimp, from 2001 to 2016 (CDFW CFIS 2017).

Year	Pounds	Value (US dollars)
2001	3,509,326	$961,670
2002	4,116,213	$1,275,015
2003	2,147,198	$655,431
2004	2,187,520	$925,062
2005	1,893,913	$925,203
2006	139,901	$66,296
2007	636,944	$301,695
2008	2,084,404	$1,094,707
2009	2,609,170	$782,876
2010	3,904,052	$1,274,496
2011	7,375,139	$3,684,168
2012	6,152,197	$2,740,417
2013	8,501,520	$3,732,135
2014	8,476,677	$4,334,173
2015	7,646,530	$8,620,665
2016	3,021,074	$2,330,321

A combination of economic factors in addition to poor recruitment levels may explain the reduction in landings during the mid-2000s, including competition from other shrimp fisheries, increased aquaculture production worldwide, higher fuel prices, and limited processor availability (CDFG 2008). Processors can impose trip limits on shrimp fishermen according to the plant's processing ability (Figure 2-9). Pink Shrimp are subject to a landing fee of $.0047 per lb. All of these factors suggest that economics can be just as influential as abundance in dictating fishing behavior in this fishery.


Figure 2-9. Pink Shrimp processing (Photo Credit: CDFW).

In the early 2000s there was a great deal of latent capacity in the Pink Shrimp fishery. Less than 50% of the purchased permits were actively fished in the northern region, and less than 25% were fished in the southern region. Participants in the Pink Shrimp fishery are often also engaged in the groundfish and Dungeness crab fisheries. In 2003, the National Marine Fisheries Service (NMFS) implemented a federal groundfish fishing capacity reduction program, in which 31 vessel permits in California were bought and retired, resulting in a large decrease in the total fleet size and number of trawl fishery participants.

3 Management

3.1 Past and Current Management Measures

In 1952, the Pink Shrimp trawl fishery was divided into three regulatory areas, and a quota was set for each area at 25% of estimated abundance from at-sea surveys (CDFG 2008). Later, a stock assessment model was used to set quotas due to the high cost of yearly surveys, but was ultimately found to be inappropriate given the high levels of environmental variability. In addition to the regional quotas, there were regulations specifying mesh sizes and the type of trawl gear allowed. The quota system was in place until 1976, when the current regulations were enacted.

In response to the declining CPUE rates in the 1970s, the Pacific Fishery Management Council (PFMC) drafted a federal FMP for Pink Shrimp along the entire west coast. It was thought that since most shrimp fishing occurred in federal waters, a federal management plan would provide consistent regulation across the three states. However, the FMP was never adopted, and instead the PFMC recommended a coordinated management system by the three states (Parsons et al. 2013). In 1981, Pink Shrimp regulations were changed to establish uniform coast-wide management measures. The resulting regulations, which are still in effect today, are summarized in the following section.

The PFMC retained authority over the Pink Shrimp fishery until 2004, when management authority was transferred to the Commission (CDFG 2007). At this time, the California Legislature also granted the Commission management authority over California's commercial bottom trawl fisheries. In addition, some state waters previously open to Pink Shrimp trawling were closed. Since 2004 the California Pink Shrimp fishery has been principally state-managed, although some federal regulations still apply, such as daily and monthly trip limits for incidental catches of groundfish, use of a vessel monitoring system, and area restrictions protecting groundfish Essential Fish Habitat (EFH).

There have been three major regulatory changes since 1981. In 2001, the three regulatory areas in California were eliminated and the fishery was divided at Point Conception into northern and southern management regions, with a separate permit required to fish in each region. Second, BRDs were required statewide in 2002 (Frimodig et al. 2009). The configuration of these devices, and their effects on bycatch levels, is discussed in section *3.1.3*. Finally, in 2008 the Commission closed the Pink Shrimp Trawl Grounds (PSTG), effectively banning all Pink Shrimp fishing within state waters. Historically, approximately 10% of Pink Shrimp were caught within state waters, with the rest captured in federal waters (>3 miles (mi) (4.8 kilometers (km)) offshore.

3.1.1 Overview and Rationale for the Current Management Framework

California's Pink Shrimp fishery is currently managed using a suite of static regulations to promote the sustainability of the target species. Aside from the fact that the northern fishery is limited entry and the southern fishery is open access, regulations are identical in both regions and have been in place since 1976. These include:

- A seasonal closure from November 1 to April 14 to protect egg-bearing females.
- A minimum mesh size of 1.38 in (36 mm) to allow for escapement of small 0 and 1 yr old shrimp.
- A prohibition on landing shrimp that do not meet a maximum count-per-lb of 160. This is intended to prevent the take of 1 yr old shrimp.

3.1.1.1 Criteria to Identify When Fisheries Are Overfished or Subject to Overfishing, and Measures to Rebuild

There is currently no direct reference point available to specify the level of fishing that constitutes "overfishing". However, there is a maximum count-per-lb of 160 shrimp in place to prevent the catch of too many small (1 year-old) shrimp. The rationale behind this regulation is that catching large amounts of small shrimp could be an indicator that fishing pressure is too high, and that the larger shrimp have already been caught. Continuing to fish when too many age-one shrimp are in the catch may imperil the sustainability of the resource. The regulation prohibits fishermen from landing shrimp that do not meet the maximum count, but there is no link to a management decision.

There is also no direct reference point available to specify the size at which the Pink Shrimp population would be considered "overfished".

There are currently no pre-specified regulations or procedures in place to halt overfishing when it is found to be occurring, or to rebuild populations when they fall below biomass thresholds. There are no rebuilding targets (specified in either abundance or catch rates) for this fishery. The MLMA specifies that the time period for preventing, ending, or otherwise appropriately addressing and rebuilding the fishery shall be as short as possible, and shall not exceed ten years except in cases where the biology of the population of fish or other environmental conditions dictate otherwise (FGC §7086(c)(1)).

3.1.1.2 Past and Current Stakeholder Involvement

Stakeholder involvement has primarily occurred during regulation changes affecting the Pink Shrimp fleet. Amendments to regulations pertaining to Pink Shrimp trawling (§120, Title 14, CCR) were last made in 2008 when primarily organizational changes were made. Previously, statutory changes were made in 2004 giving regulatory authority to the Commission and requiring BRDs. The restricted access program was developed in 2001. During each of these changes, stakeholders were consulted and had opportunity to comment through the Commission process.

In 2015, the Pink Shrimp fishery in California applied for MSC certification. During the review process it was found that the Department's score was deficient in the category of stakeholder communication. Following the review's recommendations, the Department aims to improve two-way communication with the fleet. This would mean better incorporation of fleet feedback on stock dynamics and management actions as well as more transparent sharing of management decision making by the Department. The Department initiated efforts towards this end with a fleet meeting in Eureka in

March 2017 and discussion of Pink Shrimp capacity at the November 2017 meeting of the Commission's Marine Resource Committee.

3.1.2 Target Species

3.1.2.1 Limitations on Fishing for Target Species

3.1.2.1.1 Catch

There is no quota currently in place for Pink Shrimp, and no pre-determined procedure available for setting or changing a quota.

3.1.2.1.2 Effort

The northern and southern fisheries manage fishing effort differently, and a separate permit is needed to fish in each region.

The fishery in the southern region is open access, with no cap on the number of permits that can be issued (CDFG 2008). The number of permits purchased in the south has increased over the last 5 yr from 15 permits sold in 2012 to 29 permits sold in 2017.

The fishery in the northern region is limited entry to control fishing capacity. In 2014 there were 32 transferable permits purchased and three non-transferable permits. Fifteen of those permits were actively fished as of September 2017. Permits are assigned to a vessel, and the size of the vessels used are tracked by the Department.

3.1.2.1.3 Gear

There is a minimum mesh size of 1.38 in (36 mm) to allow juveniles (young-of-the-year) to escape.

3.1.2.1.4 Time

The fishery is closed from November 1 to March 31 to protect egg-bearing females.

3.1.2.1.5 Sex

There are no restrictions on the sex of shrimp that can be retained.

3.1.2.1.6 Size

A maximum count-per-lb of 160 effectively functions as a size limit and prevents the excessive capture of juvenile shrimp.

3.1.2.1.7 Area

Trawling for Pink Shrimp is currently only allowed in federal waters. State waters previously open to PSTG were closed in 2008. The PSTG was defined as the area in state waters more than two nautical mi from the mainland shore between False Cape (Humboldt County) and Point Reyes (Marin County) (Frimodig et al. 2009). The PSTG encompasses an area of 307 square mi. However, only three beds, comprising 17% of the PSTG, have ever been fished. Two of the beds are located north of Fort Bragg and the third is adjacent to Bodega Harbor. In combination, these three beds span approximately 52 square mi (mi^2) of ocean bottom in state waters. The Commission may reverse the PSTG closure if it is deemed that the trawl gear used meets the following performance criteria (FGC §8842):

- minimizes bycatch
- will not damage seafloor habitat
- will not adversely affect ecosystem health
- will not impede reasonable restoration of kelp, coral, or other biogenic habitats

Members of the fleet have recently petitioned the Commission to re-open the PSTG. However, the Commission concluded that further research is needed in the specific areas under consideration.

3.1.2.1.8 Marine Protected Areas

Pursuant to the mandates of the Marine Life Protection Act (MLPA) (FGC §2850), the Department redesigned and expanded a network of regional Marine Protected Areas (MPAs) in state waters from 2004 to 2012. The resulting network increased total MPA coverage from 2.7% to 16.1% of state waters. Along with the MPAs created in 2002 for waters surrounding the Santa Barbara Channel Islands, California now has a statewide scientifically-based ecologically connected network of 124 MPAs. The MPAs contain a wide variety of habitats and depth ranges.

MPAs created under the MLPA were not designed for fisheries management purposes, however, the following management considerations:

- MPAs can serve as spatial closures to fishing if the species of interest is within their boundaries and is prohibited from harvest.
- MPAs can function as comparisons to fished areas for relative abundance and length or age/frequency of the targeted species.
- MPA can also serve as ecosystem indicators for species associated with the target species, either as prey, predator, or competitor.
- To varying degrees, MPAs displaced fishing effort when they were implemented.

As the Pink Shrimp fishery is prosecuted entirely in federal waters (Figure 2-1), these MPAs, which are located in state waters, are not a significant management consideration.

3.1.2.2 <u>Description of and Rationale for Any Restricted Access Approach</u>

The restricted access program was developed in 2000. Past landings were a criterion for eligibility for northern permits and transferability was given to those participants meeting minimum landing requirements in the first year of holding the permit. The goal of 75 permits was derived as the halfway point between the number of vessels in 1977 (53 permits) and in 1980 (104 permits). Catch was at a record high in 1977 and relatively low in 1980. Regulations state that the Department is to evaluate the capacity goal every 3 yr and report to the Commission, with a recommendation regarding issuance of new permits (§120.2(h), Title 14, CCR). The Department performed a capacity review in 2017 following a constituent petition to the Commission for creation of new permits. Following Department review, the Commission decided at the December 2017 meeting that increasing capacity was not warranted at the time.

3.1.3 Bycatch

3.1.3.1 <u>Amount and Type of Bycatch (Including Discards)</u>

The Fish and Game Code (FGC §90.5) defines bycatch as “fish or other marine life that are taken in a fishery but which are not the target of the fishery.” Bycatch includes “discards,” defined as “fish that are taken in a fishery but are not retained because they are of an undesirable species, size, sex, or quality, or because they are required by law not to be retained” (FGC §91). The term “Bycatch” may include fish that, while not the target species, and are desirable and are thus retained as incidental catch, and does not always indicate a negative impact.

Trawling can result in high bycatch rates, and shrimp fisheries in particular are known for high bycatch rates, with fisheries in some parts of the world catching as much as 30 lb (13.6 kilogram (kg)) of bycatch for 1 lb (0.45 kg) of target species (Frimodig et al. 2009). Data from the Oregon Pink Shrimp fleet indicates that the average bycatch rate for Pink Shrimp is 10% (CDFG 2008). However, managers and fishery participants have been working to reduce bycatch and it has been as low as 2% of the total catch (Hannah and Jones 2007). While these rates are low relative to the retained Pink Shrimp catch, cumulative bycatch rates from multiple trawl fisheries can have adverse effects on biologically sensitive species.

The majority of bycatch in the Pink Shrimp fishery is composed of groundfish species. Since 2004, when the West Coast Groundfish Observer Program (WCGOP) began, an average of 14% of Pink Shrimp trips have been observed (Somers et al. 2016a). On those observed trips, Pink Shrimp trawlers in California caught 40 species of groundfish as bycatch. However, the ratio of catch of non-shrimp species to Pink Shrimp has been less than 5% since 2007 (Somers et al. 2016b). Table 3-1 shows the groundfish species caught by the California fleet in 2014. Pacific Hake had the largest incidental catch, followed by Arrowtooth Flounder and unidentified flatfish.

Table 3-1. Observed catch of groundfish by Pink Shrimp trawlers in California, 2014. Observed total (retained and discard) catch weight (mt), discard weight (mt) and percent discarded from observed vessels. Zeroes represent values rounded to zero (Somers et al. 2016b).

Common name	Species	Total catch (mt)	Discard (mt)	Total percent discarded
Pacific Hake	*Merluccius productus*	9.59	9.59	100
Arrowtooth Flounder	*Atheresthes stomias*	0.8	0.8	100
Flatfish Unid	*Pleuronectiformes*	0.56	0.56	100
Shortbelly Rockfish	*Sebastes jordani*	0.38	0.38	100
Rex Sole	*Errex zachirus*	0.37	0.37	100
Pacific Sanddab	*Citharichthys sordidus*	0.21	0.21	100
Stripetail Rockfish	*Sebastes saxicola*	0.11	0.11	100
Chilipepper Rockfish	*Sebastes goodei*	0.07	0.07	100
Rockfish Unid	*Sebastes*	0.07	0.07	100
Longnose Skate	*Raja rhina*	0.05	0.05	100
Dover Sole	*Microstomus pacificus*	0.05	0.05	100
Sablefish	*Anoplopoma fimbria*	0.04	0.04	100
Greenstriped Rockfish	*Sebastes elongates*	0.03	0.03	100
Lingcod	*Ophiodon elongatus*	0	0	100
Flathead Sole	*Hippoglossoides elassodon*	0	0	100
Petrale Sole	*Eopsetta jordani*	0	0	100
Spiny Dogfish Shark	*Squalus acanthias*	0	0	100
Spotted Ratfish	*Hydrolagus colliei*	0	0	100
English Sole	*Pleuronectes vetulus*	0	0	100
Rougheye Rockfish	*Sebastes aleutianus*	0	0	100
Shortspine Thornyhead	*Sebastolobus alascanus*	0	0	100
Redbanded Rockfish	*Sebastes babcocki*	0	0	100
California Skate	*Raja inornata*	0	0	100
Splitnose Rockfish	*Sebastes diploproa*	0	0	100

The Pink Shrimp fishery also interacts with over 80 non-groundfish species, including both finfish and invertebrates, though the composition of bycatch varies from year to year. Unidentified shrimp species make up the highest proportion of the non-groundfish bycatch (Table 3-2). In 2014, non-Humboldt squid was the second most frequently caught non-groundfish species, followed by Eulachon (*Thaleichthys pacificus*), which is listed as threatened under the Endangered Species Act (ESA).

Table 3-2. Observed catch of non-groundfish by Pink Shrimp trawlers in California, 2014. Observed total (retained and discard) catch weight (mt), discard weight (mt) and percent discarded from observed vessels (Somers et al. 2016b).

Common name	Species	Total catch (mt)	Discard weight (mt)	Total percent discarded
Shrimp Unid.	N/A	7.09	7.09	100
Non-Humboldt Squid Unid.	*Teuthida*	3.39	3.39	100
Eulachon	*Thaleichthys pacificus*	1.02	1.02	100
Slender Sole	*Lyopsetta exilis*	0.68	0.68	100
Non-Eulachon Smelt Unid.	*Osmeridae*	0.45	0.45	100
Squid Unid.	*Teuthoidea*	0.34	0.34	100
Whitebait Smelt	*Allosmesus elongatus*	0.15	0.15	100
Eelpout Unid.	*Zoarcidae*	0.08	0.08	100
Hagfish Unid.	*Myxinidae*	0.06	0.06	100
Pacific Herring	*Clupea pallasii*	0.03	0.03	100
Invertebrate Unid.	N/A	0.03	0.03	100
Anemone Unid.	*Actiniaria*	0.03	0.03	100
Octopus Unid.	*Octopoda*	0.02	0.02	100
Sea Cucumber Unid.	*Holothuroidea*	0.02	0.02	100
Urchin Unid.	*Echinoidea*	0.01	0.01	100
Other Id Fish	N/A	0.01	0.01	100
Salp Unid.	*Tunicata*	0.01	0.01	100
Jellyfish Unid.	*Scyphozoa*	0.01	0.01	100

3.1.3.2 Assessment of Sustainability and Measures to Reduce Unacceptable Levels of Bycatch

Discard Mortality

Due to the depth at which Pink Shrimp trawling occurs (300 to 800 ft) (91.4 to 243.8 m), it is assumed that the mortality of captured groundfish species with swim bladders is 100% due to barotrauma. Discard mortality of other species is unknown.

Impact on Fisheries that Target Bycatch Species

As noted above, the observed West Coast-wide total catch is largely comprised of Pink Shrimp, Pacific Hake, and Arrowtooth Flounder (Somers et al. 2016b). Incidental catches of Pacific Hake by the California Pink Shrimp trawl fleet were less than 0.001% of the total Pacific Hake quota in 2014. Arrowtooth Flounder are commonly caught by trawl fleets off Washington and Oregon, but are frequently discarded due to low flesh quality. The 2017 stock assessment for Arrowtooth Flounder estimated the stock to be at 87% of unfished spawning biomass, and less than 60% of the coast-wide annual catch limit was taken. As a result, it is unlikely that incidental catch of these species by the California Pink Shrimp fleet is detrimental to either stock.

Bycatch of Overfished, Threatened, or Endangered Species

Pink Shrimp beds overlap with the habitat of a number of sensitive species, including rockfish species that are rebuilding or have recently been rebuilt such as Bocaccio Rockfish (*Sebastes paucispinus*), Widow Rockfish (*Sebastes entomelas*), and Yelloweye Rockfish (*Sebastes flavidus*). All overfished rockfish must be discarded. The bycatch rates for all rebuilding rockfish have been less than 0.01%, but it is also necessary to consider the bycatch in terms of each species' Allowable Biological Catch (ABC) levels to understand the impact of the Pink Shrimp fishery on rebuilding or recently rebuilt stocks. Table 3-3 shows the projected ABC levels for 2014 for each species as well as the incidental catch by the Pink Shrimp fleet in California. Darkblotched Rockfish (*Sebastes crameri*) has the highest catch level, but the catch is less than 0.001% of the ABC. At this level the Pink Shrimp fishery is not impacting the ability of Darkblotched Rockfish to rebuild.

Table 3-3. Pink Shrimp bycatch of the California fleet vs. ABC of rebuilding or recently rebuilt species (Accessed 22 May 2018. https://www.pcouncil.org/groundfish/stock-assessments/by-species/).

Common name	**Species**	**Total catch (mt)**	**Allowable biological catch (mt)**
Darkblotched Rockfish	*Sebastes crameri*	0.82	529
Pacific Ocean Perch	*Sebastes alutus*	0	864
Widow Rockfish	*Sebastes entomelas*	0	4,841
Yellowtail Rockfish	*Sebastes flavidus*	--	3,865
Cowcod Rockfish	*Sebastes levis*	0	40
Canary Rockfish	*Sebastes pinniger*	--	741

As shown in Table 3-2, in 2014 the Pink Shrimp fleet caught and discarded 1.02 mt (2,248.7 lb) of Eulachon, an anadromous smelt species inhabiting the Pacific coasts of North America that was the first marine forage fish species to be listed as "threatened" under the ESA. In 2015, the catch rose to 3.13 mt (6,900.5 lb) (Somers et al. 2016b). However, the California fleet's catch of Eulachon is much smaller than that of the Oregon or Washington fleet which in 2015 was 34 mt and 25 mt (74,957.2 and 55,115.6 lb) in 2015, respectively. There is very little data available with which to assess the size of these catches in relation to Eulachon populations, and it is unclear if this increase is due to larger populations of Eulachon or a greater overlap between Pink Shrimp fishing and the Eulachon population. Hannah et al. (2011) estimated the mortality rate imposed by the Pink Shrimp fishery on the Eulachon population at well below the F = 0.1 rate recommended as sustainable by Schweigert et al. (2012) and far below the values determined by setting fishing mortality at the natural mortality rate, a commonly used rule of thumb for sustainability. However, bycatch of Eulachon should be minimized to the extent possible to promote rebuilding.

There have been no significant interactions identified between the Pink Shrimp fishery and threatened or endangered marine species of birds or mammals (Roberts 2005; MSC 2007). The Pink Shrimp fishery is classified as a Marine Mammal Protection Act Category III fishery with no observed or documented take of marine mammals.

Measures to Reduce Bycatch

The PFMC required the use of BRDs for all shrimp vessels in 2002 to reduce finfish bycatch rates. Prior to the required use of BRDs, bycatch rates in Oregon were 32 to 61% of total catch rates (Hannah and Jones 2007). A study conducted in Oregon by the Oregon Department of Fish and Wildlife (ODFW) researchers indicates the use of BRDs resulted in a 66 to 88% 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 (Hannah and Jones 2007). Additionally, the mandatory use of BRDs has altered the species composition of the bycatch from commercially important large fish species to smaller fish species with little to no commercial value, reducing the economic incentives for higher bycatch levels. After implementing BRDs, bycatch rates dropped to an average of 8% (CDFG 2007). While there is limited bycatch data from California prior to 2004 it is thought that, given the similarities between the Oregon fleet and the California fleet, the California fleet may have experienced similar reductions in bycatch. Rigid-grate BRDs with 1.25 in (31.75 mm) bar spacing have been the most commonly used BRD in recent years. However, recent experimentation suggests that 0.75 in (19 mm) bar spacing may further reduce bycatch rates to well below 5% of the total catch with minimal shrimp loss (Hannah and Jones 2007).

Pink Shrimp vessels are subject to federal restrictions on daily and trip limits for incidental catches of federally managed groundfish. Shrimp vessel operators are allowed to retain and sell commercially valuable species. However, to prevent the excessive take of groundfish species by shrimp vessels, Pink Shrimp vessels are allowed to land up to 500 lb (226.8 kg) of groundfish per day for each day of the trip, provided that they do not land more than 1,500 lb (680.4 kg) per trip (NWFSC 2010). Rockfish Conservation Areas (RCAs) are large depth-based area closures implemented in 2002 to protect rebuilding groundfish stocks from trawl gear. Pink shrimp fishermen are required by NMFS to file a declaration report in advance of fishing in any RCA (CDFG 2007).

The mandatory use of BRDs has significantly reduced the impacts of Pink Shrimp bycatch on the ecosystem. The fishery does not appear to have significant negative impacts on rebuilding rockfish species, though the increased take of Eulachon in recent years may be cause for concern. The Oregon fleet has been experimenting with the use of Light Emitting Diode (LED) lights on trawls, and have found that these significantly reduce Eulachon bycatch without affecting the catch of Pink Shrimp (Hannah et al. 2015). Further testing is ongoing to understand how different configurations (number and spacing) of LED lights impact catches of Eulachon, Darkblotched Rockfish, other fishes, and Pink Shrimp (ODFW 2016). In addition, ODFW staff have been testing footrope modifications to understand how these affect bycatch as well as benthic impacts (Hannah et al. 2011). The results of these studies have suggested promising results for reducing environmental impacts of shrimp trawling, especially for reductions in Eulachon bycatch.

3.1.4 Habitat

3.1.4.1 Description of Threats

Benthic trawling, in which fishing gear is dragged along the bottom of the ocean, can be detrimental to a variety of habitats. Relatively stable habitats, such as hard bottom and dense mud, experience the greatest changes and have the slowest recovery rates compared to less consolidated coarse sediments in areas of high natural disturbance (NRC 2002). Heavy trawling in mud habitats has been shown to decrease invertebrate density and diversity (Hannah et al. 2010). Soft bottom habitats are relatively resilient to trawl gear, but mud bottom habitats may have longer recovery times than other soft bottom habitats with larger sediment (NRC 2002; Hannah et al. 2010). The estimated recovery time in the absence of continued trawling is estimated to be 1 yr in shrimp habitat (NPFMC 2010). The 5 month closure of the fishery each year allows some time for recovery of the grounds, but likely not enough for full recovery. A recent study comparing invertebrate densities in closed areas between 2007 and 2013, corresponding to the year following the closure of the fishery and 5 yr of recovery, respectively, found that invertebrate recoveries varied by species and by site (ODFW 2014b). Sea whips, which were the dominant structure-forming macro-invertebrates in the areas surveyed, had increased markedly in density, though it was estimated that it would take another decade to achieve an unfished size structure (ODFW 2014b).

The PFMC and NMFS completed an Environmental Impact Statement (EIS) for designating EFH for the Pacific coast groundfish fishery (NMFS 2005). The EIS indicated that the habitat impacts by bottom trawl gear in areas where Pink Shrimp trawling occurs is rated between 0.5 and 1, which is the lowest sensitivity classification for impacts to seafloor habitat by bottom trawl gears. Additionally, the semi-pelagic trawl gear used is likely to have less impact on bottom habitats than other trawl gear and is considered less damaging than gear used in other cold water shrimp fisheries (Roberts 2005).

Trawling can be extremely detrimental to sensitive species such as corals. Corals are known to occur in California waters, including within and adjacent to the area that formerly made up the PSTG. Here six major taxa of coral or coral-like species that were documented, including hydrocorals (order Stylasterina), black corals (order Antipatharia), stony corals (order Scleractinia), sea fans (order Gorgonacea), true soft corals (order Alcyonacea), and sea pens (order Pennatulacea) (CDFG 2007). However, these species are primarily found on hard bottoms, which Pink Shrimp Trawlers avoid. Since 2008, no trawling has been allowed in state waters. However, the distribution of corals has not been fully mapped in federal waters, and so shrimp trawling may impact coral habitats (CDFG 2007).

Bottom trawling is known to negatively impact biogenic (habitat-forming species) such as corals, sponges, and sea whips/pens, many of which are slow growing and may take decades to recover if broken or removed by a trawl. Biogenic species may provide additional habitat and structure for a number of finfish and invertebrates, including rockfish, so their loss may be especially detrimental to ecosystem function.

There are no significant threats to Pink Shrimp habitat from non-fishing threats other than the potential impacts from climate change discussed in sections 1.5 and 5.4.

3.1.4.2 Measures to Minimize Any Adverse Effects on Habitat Caused by Fishing

The MLMA requires the minimization of adverse effects on habitat from fishing activities. The prohibition of Pink Shrimp trawling in state waters was enacted in part to remove the potential for adverse habitat impacts in nearshore shrimp beds. The Commission has the authority to re-open these beds to fishing if the fishery is found to be sustainable, causing only minimal habitat damage. In addition, the 5 month closed season each winter allows the habitat in shrimp beds in federal waters time to recover from the disturbance caused by trawl gear.

3.2 Requirements for Person or Vessel Permits and Reasonable Fees

The CCR describes the permits required to fish in California waters:

- Commercial Fishing License—All Pink Shrimp fishermen must have a commercial fishing license and a vessel permit. Commercial Fishing Licenses are $141.11 for residents and $417.75 for non-residents, and is required for any resident 16 yr of age or older who uses or operates or assists in using or operating any boat, aircraft, net, trap, line, or other appliance to take fish for commercial purposes, or who contributes materially to the activities on board a commercial fishing vessel.
- Commercial Boat Registration—The commercial boat registration fee is required for any resident owner or operator for any vessel operated in public waters in connection with fishing operations for profit in the state, and is $351.50.
- Pink Shrimp Permit—Fishermen need to have a permit specific to Pink Shrimp. There is only a single permit for the southern region, but there are a number of different types of permits for the northern region due to the limited access program. These are described in Table 3-4.

All fees include a nonrefundable 3 percent application fee.

Table 3-4. List of fees for Pink Shrimp trawl vessel permits (Accessed June 17, 2019. https://www.wildlife.ca.gov/Licensing/Commercial/Descriptions).

Permit	Fee (US dollars)
Northern Pink Shrimp Trawl Vessel Transfer Fee (New Owner)	$1,000.00
Northern Pink Shrimp Trawl Vessel Transfer Fee (Same Owner)	$200.00
Northern Pink Shrimp Trawl Vessel (Temporary)	$100.00

Northern Pink Shrimp Trawl Vessel Permit Fee (Transferable)	$1,494.00
Northern Pink Shrimp Trawl Vessel Permit Fee (Nontransferable)	$751.25
Southern Pink Shrimp Trawl	$45.84

4 Monitoring and Essential Fishery Information

4.1 Description of Relevant Essential Fishery Information

Biological Information

The biology of Pink Shrimp is well understood. Currently, no biological indicators are routinely monitored in the Pink Shrimp fishery. Due to the fact that population fluctuations are thought to be largely driven by environmental variation, environmental indicators may be more useful in predicting stock status than biological ones.

Fishery-dependent Indicators

Currently, no indicators are routinely monitored in the Pink Shrimp fishery. However, there are a number of informative indicators that could be monitored. The standardized CPUE is a proxy for Pink Shrimp abundance. The sex ratio of the catch would provide a way to track the age at which Pink Shrimp shift from males to females, which occurs in response to population densities. The count-per-lb is a proxy for the size distribution of the stock and is an indicator that the catch is targeting mature individuals. The spatial extent of fishing activities provides an indicator of serial depletion due to overfishing.

Environmental Indicators

Environmental variables related to the spring transition in coastal currents, such as April sea level height, during the pelagic larval phase have been found to be negatively correlated with recruitment of age-one individuals in Oregon (Hannah 1993, 2010). In particular, the sea level height has been found to be a major indicator of recruitment strength in Oregon. Currently, no environmental indicators are tracked for use in California's management.

4.2 Past and Ongoing Monitoring of the Fishery

4.2.1 Fishery-dependent Data Collection

Monitoring information currently collected by the Department includes logbooks and market receipts. Trawl logbooks are a mandated system for fishermen to record start and end haul locations, time, depth, and duration of trawl tows, total catch by species market category, gear used, and information about the vessel and crew. Fishery managers and enforcement officers use state-issued sales receipts, referred to as fish tickets, to monitor fishery landings. Fish ticket data are transferred to the Pacific Coast Fisheries Information Network regional database system by state fishery agencies in Washington, Oregon, and California. Data collected by fish tickets include:

- weight of the finfish or shellfish landed by market category (general groupings of fish that are not species-specific)
- price paid to the fisherman by market category

- date the fish was landed
- type of gear used to harvest the fish
- port of landing
- commercial fishing block where the fish were harvested

Monitoring of Bycatch Rates

Since 2004 the fishery has been subject to observation under the federal WCGOP. Observers monitor effort and landings, including the species makeup of both retained and discarded species, allowing for close monitoring of bycatch levels to ensure that they remain within acceptable levels, especially with regard to sensitive species such as rebuilding rockfish populations.

In 2007 the Oregon and northern California fleets were split into two separate sampling units because they had different regulatory requirements, and have been treated as separate sampling units ever since. Licensed vessels in each sampling unit are selected for observation via a stratified random sampling design. Vessels are observed from April 1 to October 31.

Observers record the start time, end time, starting location, ending location, and depth of tows, as well as the gear type and fish ticket number corresponding with each trip. For each tow, observers record total catch weight, weight of discards by category, size composition of discards, reason for discards, species composition of discards, and the weight of the retained catch. They also note the catch of prohibited or protected species. Biological data is also collected, including the length frequency distribution. Observer coverage of the California fleet averages 14%.

California's data collection protocol previously also included dockside market sampling for biological data and count per pound; however, the work was redirected in the early 2000s to other higher priority needs.

4.2.2 Fishery-independent Data Collection

At-sea surveys were conducted by the Department between 1959 and 1969 to obtain abundance estimates for the various commercial beds and set regional quotas. These surveys were discontinued due to costs (Hannah 1999).

5 Future Management Needs and Directions

5.1 Identification of Information Gaps

The primary information gaps for the Pink Shrimp fishery are a lack of reference points that directly relate to indicators of overfishing or an overfished state, and targets or timeframes for rebuilding should the fishery be deemed overfished. The ODFW has implemented an FMP for Pink Shrimp including a Harvest Control Rule (HCR) based on empirical indicators, targets, and limits (ODFW 2018b). The Department is working to determine if a similar HCR should be implemented in California, and if triggers for those indicators should be modified.

No stock assessment model or biomass-based reference points have been developed for the Oregon fishery due to the absence of an established stock-recruitment relationship. Instead, stock status is assessed using empirical indicators, including the CPUE and the size/sex/age composition of the catch (ODFW 2018b). The Oregon HCR combines environmental and biological indicators of strong Pink Shrimp recruitment with early season (June) catch rate to determine the appropriate season length and triggers for season closure (ODFW 2014c). In addition, they have developed a recruitment model to predict the following year's age-one class based on sea level height, which was found to be correlated with recruitment, and the number of age-zero shrimp in the fall catch. This model is used to predict the magnitude of age-one recruitment the following year.

Due to environmental variation, the recruitment predictions by the environmental model, while suggestive of stock trends, are insufficient to understand the true stock biomass during the following season. As a result, catch rates in the early season serve as a secondary indicator. If the catch rate falls below the target average catch per trip of 12,500 lb (5,670.0 lb) during the month of June the fishing season will end early on October 15 (rather than November 1) and start later on April 15 (rather than March 31). This extended seasonal closure provides increased protection for egg-bearing females, and may allow for higher recruitment in the following year.

A second limit reference point is triggered if sea levels are high during the larval year, suggesting low age-one recruitment via the environmental model, and the average June catch per trip falls below 10,000 lb (4,536.0 lb) in the following year. This indicates a year class failure and requires the fishery to be closed in mid-July to protect egg-bearing females and promote high over-winter survival rates. The following season opens on April 15.

Within each fishing season, data on catch, effort, CPUE, age, size and sex composition, year-class strength, and geographic distribution of catch are collected. The information from these data are compared and evaluated against both historical data and the Indicators of Biological Concern (IBC) that were developed as part the draft federal FMP (Abramson et al. 1981). The IBCs listed are as follows:

1. Long-term increases in count-per-lb—An increase in the count-per-lb would suggest a decrease in the mean age or size of shrimp being landed. The current 160 shrimp per lb threshold functions as a size limit to prevent the excessive take

of juvenile shrimp. It is not clear what constitutes long-term, and a time frame would need to be specified.

2. Long-term decrease in average age of females or increase in primary females—As protandric hermaphrodites, Pink Shrimp are born male but shift to female at about a year and a half. However, Pink Shrimp will shift earlier in response to population densities in order to retain sex ratios. A decrease in the average female age might indicate that fishing is removing too many age-two and age-three shrimp from the population.
3. Long-term decrease in catches with equal or increased effort—This would manifest itself as a decrease in the CPUE. However, it is important to determine the best unit of effort, and to track changes in the standardized CPUE, which is assumed to be an indicator of biomass, rather than the raw CPUE. Standardization is necessary to account for variations in the efficiency of the fleet, both over time and within fishing seasons. For example, 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, and CPUE estimates must be standardized to account for both single- and double-rigged vessels. Shrimp trawl fishing effort in Oregon is estimated annually from logbook data and then standardized to single-rig equivalent hours.
4. Long-term decrease in productive shrimp grounds—This indicator tracks the spatial extent of beds with commercial densities. If a long-term contraction in the area where commercial landings are harvested was detected, this could indicate the serial depletion of the resource, as has been detected during low production years.
5. Indication of two year-class failures over a 3-year period—This would suggest that recruitment had failed in two successive years. Given that the majority of the Pink Shrimp in California only live for four seasons, this would indicate a severe decrease in the spawning biomass of the stock.

The primary types of information that would be necessary to enact a similar type of plan in California, along with their priority to management, are summarized in Table 5-1.

Table 5-1. Informational needs for Pink Shrimp and their priority for management.

Type of information	Priority for management	How essential fishery information would support future management
Catch per trip in June	High	Provides information on whether the stock size is above or below the target level, and thus the strength of recruitment for that year. Note that the target and limit catch rate for California stocks may be different than for Oregon.
Monthly size/sex/age composition of the catch	High	Provides information on the number of age-zero shrimp, and is used to predict the magnitude of age-one shrimp the following spring.

CPUE	High	Provides information on long-term increases or decreases in the catch rate. If catch decreases but effort stays the same it suggests a change in the productivity of the stock.
Spatial extent of fishing grounds each year	Medium	If a long-term contraction in the area where commercial landings are harvested was detected, this could indicate the serial depletion of the resource.
Count-per-lb throughout the season	Medium	Size composition of the stock – used to detect decreases in the mean age or size of shrimp being landed, which could suggest excess harvest of juveniles.
Habitat impacts	Low	Impacts to abundance and diversity of fish and macroinvertebrates. Methods could include cameras attached to trawl gear, remotely operated vehicle surveys, drop cameras, and grab samples across a gradient of Pink Shrimp trawl effort. If results indicate minimal impact, the Commission has the authority to allow Pink Shrimp trawling within a region of state waters.

5.2 Research and Monitoring

5.2.1 Potential Strategies to Fill Information Gaps

Port sampling of landings provides an excellent opportunity to collect information on the count-per-lb, sex ratio, and age distribution of the catch. Department staff have renewed efforts to maintain a database of current at-sea log data and to input backlogged information. Staff have also initiated biological sampling efforts in collaboration with processors to monitor shrimp sex, age, and reproductive status in the 2018 fishing season.

Data on a number of environmental conditions are already tracked. These data will be used to perform a correlation analysis similar to that conducted by Hannah (2010) to determine if Pink Shrimp recruitment in northern California exhibits the same environmental relationships as the stock in Oregon. Until a sufficient time series of these data are available, Department staff will utilize catch per trip data on landing receipts to produce a CPUE in place of more detailed log data.

5.2.2 Opportunities for Collaborative Fisheries Research

The Department has collaborated in the past and will continue to work with outside entities such as academic organizations, non-governmental organizations, citizen scientists, and both commercial and recreational fishery participants to help fill information gaps related to the management of state fisheries. The Department will also reach out to outside persons and agencies when appropriate while conducting or seeking new fisheries research required for the management of each fishery.

Biological sampling of Pink Shrimp caught in California waters was initiated in 2018. Data on shrimp size, sex, and reproductive condition will be shared with Oregon and Washington biologists to assess stock-wide patterns. Collaborative monitoring can be used to improve forecasts of future catches, as well as potential changes in correlations between stock biology and environmental conditions that may occur with changing climate.

Pink Shrimp trawl vessels can travel widely between fishing grounds and landing ports across states and many vessels are permitted to land in more than one state. Approximately equal amounts of Pink Shrimp are harvested from federal waters off California and landed into Oregon ports as into California ports. Department and ODFW biologists currently share information from logbooks to track these cross-border landings. Improved data sharing on a more frequent basis could help both states to better understand interactions between effort, capacity, and stock dynamics.

The three states are also collaborating on a grant-funded effort to purchase LED lights for all permitted vessels for use during the 2019 fishing season along with information for permittees on best practices. Results including rates of use, LED light function, and resulting changes in catch of both the target species and bycatch should be shared among the states.

Further research is needed on the habitat impacts of Pink Shrimp trawling, particularly if re-opening the PSTG is to be considered. Methods for assessing habitat impacts could include cameras on trawl gear, remotely operated vehicle camera surveys, drop cameras, and grab samples across gradients of trawl effort. Partnerships among fishermen, the Department, academics and conservation organizations could produce a more efficient and effective research program.

5.3 Opportunities for Future Management Changes

This section is intended to provide information on changes to the management of the fishery that may be appropriate, but does not represent a formal commitment by the Department to address those recommendations. ESRs are one of several tools designed to assist the Department in prioritizing efforts and the need for management changes in each fishery will be assessed in light of the current management system, risk posed to the stock and ecosystem, needs of other fisheries, existing and emerging priorities, as well as the availability of capacity and resources.

Management of the Target Stock

A full risk analysis of this fishery has not yet been conducted. However, the available information suggests that the fishery is not in immediate danger of overfishing or being overfished at current exploitation levels. Pink Shrimp are short-lived and resilient to fishing, with a strong ability to rebuild quickly from low population levels when environmental conditions improve.

While the current management system has been effective in limiting overfishing of Pink Shrimp in the past 15 yr, this system is designed to be more reactive than proactive. The adoption of clear management objectives and a target and limit system based on both catch and environmental indicators would be a more proactive, adaptive, and precautionary approach to fisheries management. This system should clearly specify the indicators that should be monitored (and on what time frame), any targets or limits, and what management actions are required when those thresholds are passed. This includes conditions for closure and re-openings of the fishery.

One of the benefits of this approach is that it would account for the inherent environmental variation in the system. Pink Shrimp have been shown to have recruitment failures and then recover within a single year. Because of this, two indicators (one environmental and one catch-based) would be required to trigger a significant closure of the fishery. Another benefit of this plan is that the limit reference points chosen would avoid being overly reactive. Finally, this approach would have minimal economic impacts. In years with low abundance, effort tends to decline late in the season because catch rates are too low to be economically feasible. As a result, closing the season one to two weeks early is unlikely to result in a large reduction in revenues. Effective enforcement of the count per pound rule could reinforce the effects of use of an environmental and a catch indicator to control effort when necessary to ensure future recruitment. Early season harvest of small shrimp both removes them from the population before their opportunity to spawn and prevents future higher economic gain on larger shrimp. While this rule is already in place, improvement to the regulatory language could make the rule more enforceable.

By adopting the target and limit-based management system the California Pink Shrimp fishery would be closer to attaining MSC certification, which would result in higher prices or demand for Pink Shrimp. However, there is also the likelihood of increased costs associated with increased data collection and a more comprehensive management system.

Bycatch

It is especially important to minimize the bycatch of sensitive species. While shrimp vessels have had no interactions with threatened or endangered marine species of birds or mammals, Oregon and California vessels catch Eulachon (Al-Humaidhi et al. 2012), which was listed as a threatened species in 2010. The factors causing recent declines in abundance of Eulachon are not well understood, however, climate change, predator-prey interactions, changes in the timing of peak river flows due to dams and water diversions, and mortality from the Pink Shrimp trawl fishery may play a role (NWFSC 2010). No estimates of the marine population size are available, and there is extremely limited monitoring data for river runs of Eulachon, making it difficult to understand how much impact the Pink Shrimp trawl fishery has had on the species.

The low mortality rate estimates are in part due to the fact that the shrimp fishery occupies a much smaller spatial scale than the Eulachon population, and this is unlikely to have as much influence on the Eulachon population size as variation in the ocean environment or the abundance and distribution of major predator populations like Pacific Hake. However, effort levels in the Pink Shrimp fishery have been reduced by 50% since their peak in the late 1980s and early 1990s, and Eulachon and other smelt species have historically represented a sizable component of the fishery bycatch (Hannah and Jones 2007; NWFSC 2010). This suggests that the fishery may have had a larger impact in the past, and that if effort were to increase substantially again the impact would increase.

A recent study evaluated trawl system modifications for reducing bycatch of Eulachon below levels already achieved via the mandatory use of BRDs. An experimental footrope, modified by removing the central one-third of the trawl ground line, reduced Eulachon bycatch by 33.9%. It also reduced bycatch of Slender Sole (*Lyopsetta exilis*), other small flatfishes, and juvenile Darkblotched Rockfish by 80% or more without significantly reducing the efficiency of the gear with respect to the target species (Hannah et al. 2011). Recent research by the ODFW indicated that the installation of a series of inexpensive green LED lights on the fishing lines attached to nets reduced Eulachon catch by 90.5% and juvenile rockfish catch by 78%, with negligible impacts on shrimp attainment.

a) b)

Figure 5-1. Eulachon in trawls a) without and b) with LED lights in Pink Shrimp landings (Photo Credit: NOAA).

This research suggests that the bycatch of sensitive species might be avoided by easy and cost-effective modifications to the fishing gear (ODFW 2014d). Shrimpers in Oregon voluntarily embraced the use of LED lights in the second-half of the 2014 season and the state is moving forward with legally requiring their use. In general, this appears to be an effective, low-cost solution to the problem of Eulachon bycatch that California may consider implementing.

Restricted Access

The fishery in the southern region is open access, with no cap on the number of permits that can be issued (CDFG 2008). The number of permits purchased in the south was reduced to 29 permits in 2017. If the number of permits sold were to increase in the southern region it may be necessary to cap the total number of permits available to shrimp vessels. This is unlikely given the lower and more variable amounts of Pink Shrimp in the south as well as the lack of processors in port.

Access is currently restricted in the northern region. Current regulations set a capacity goal for this fishery of 75 vessel permits and a requirement that the Department review capacity every 3 yr. Recent data indicates that less than 50% of the available permits were actively fished as of September 2014, but efficiency (catch per trip) has increased substantially in recent years. There is currently strong interest in purchasing Pink Shrimp permits and few are available. The Department intends to remove this capacity goal from regulation and maintain the permit number at this time given the increase in fishing power, among other considerations. Future management improvements should consider comprehensive revision of the limited entry permit program and establishing rules for capacity adjustment.

Stakeholder Communication

In the recent application for MSC certification, it was found that the Department's score was deficient in the category of stakeholder communication. There are a number of opportunities for improved communication between the management team and the fleet, including surveys, meetings, and season summaries or other newsletters. The Department initiated efforts towards this end with a fleet meeting in Eureka in March 2017 and discussion of Pink Shrimp capacity at the November 2017 meeting of the Commission's Marine Resource Committee.

5.4 Climate Readiness

There are indications that climate change could significantly alter recruitment patterns and distribution of Pink Shrimp over time (Hannah 2011). It is possible that warming waters will drive Pink Shrimp populations further north, which may limit access to the resource. Pink Shrimp recruitment success is considered to be environmentally driven and there is evidence that environmental variability has been increasing since 1980 (Shanks and Roegner 2007).

As noted in section 1.5, Pink Shrimp have a high tolerance for a range of salinities, but a fairly narrow optimal temperature range between 8 to 11˚C (46.4 to 51.8 degrees Fahrenheit (˚F)). Fluctuations in temperature from year to year may impact the survival, metamorphosis and growth of larvae (Rothlisberg 1979). In addition, the bottom temperature may influence the fecundity of shrimp (Hannah 2011). Recruitment of young-of-the-year has been negatively correlated with El Niño Southern Oscillation cycles. Coastal upwelling, which can vary from year to year, may influence the location of shrimp beds (Hannah 2011). The timing of spring transition, marked by increased offshore winds, increased upwelling, and decreased sea level height, has been linked to strong recruitment. The mechanism for this correlation may be related to cool, nutrient-rich waters promoting recruit survival. However, it is thought that very strong upwelling, and associated very low sea levels, transport larvae offshore, reducing recruitment (Hannah 2011).

Pink Shrimp off the coast of California have experienced higher interannual variability than stocks farther north over the last few decades (Hannah 2011), and this may increase in the future. This possibility underscores the need to maintain a consistent fishery monitoring and sampling program for the Pink Shrimp fishery going forward as well as the value of the potential new management approaches described above. Additional research is needed to understand how anticipated climate changes are likely to impact the stock.

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