Fishery-at-a-Glance: Rock Crab (Red, Yellow, and Brown)

Scientific Name: *Cancer productus, Metacarcinus anthonyi,* and *Romaleon antennarium*

Range: Rock crabs inhabit coastal waters across the west coast of North America. Red Rock Crab ranges from Alaska to San Diego, California. Yellow Rock Crab ranges from Humboldt Bay, California into Baja California, Mexico. Brown Rock Crab ranges from Washington into Baja California, Mexico.

Habitat: The three rock crab species in this fishery can be found across similar depths ranging from the low intertidal to at least 500 feet. Red Rock Crab are found in coastal waters as well as bays and estuaries on rock, sand, or mud substrates. Yellow Rock Crab habitat is mainly silty sand substrate and the sand-rock interface around reefs. Brown Rock Crab are predominantly found on reef habitat, but may also inhabit sandy substrates.

Size (length and weight): The maximum carapace widths of Red, Yellow and Brown Rock Crabs are approximately 195, 165 and 155 millimeters, respectively. The maximum carapace width of females is about 10 to 15% smaller than males of each species.

Life span: The maximum longevity for Red Rock Crab was estimated to be at least 5 or 6 years in the waters of Puget Sound, and 7 years for Brown Rock Crab. No studies have estimated the longevity of Yellow, but they are assumed to be relatively short-lived.

Reproduction: Rock crab females mate soon after molting when their shells are soft. Males insert a spermatophore into the female spermatheca. Females form eggs internally then extrude them on to the pleopods beneath the abdominal flap, where they are fertilized. Fertilization may occur between 11 weeks and up to a year after mating. Females brood the eggs for a period of weeks, followed by hatching, and a larval stage. Seasons and development times are not well understood.

Prey: Rock crab are generalist scavengers and predators. Their powerful claws allow them to crush the shells of a variety of gastropods and other crustaceans.

Predators: Many benthic fishes are predators of juvenile rock crab. Predators of adults may include octopuses, Sea Otters, and bottom feeding sharks.

Fishery: Commercial fishing using traps occurs across the state. Point Lopez in Monterey County divides a northern management region, which has open access permits, from the limited entry fishery in the south. Peak landings in the fishery's history occurred in 2015 with nearly 2.4 million pounds. The average annual landings between

2013 and 2017 was 1.8 million pounds. Average ex-vessel price during that period was $1.49 per pound. Recreationally, rock crab bay be taken only by hand or hoop net south of Point Arguello in Santa Barbara County. North of Point Arguello traps may be used recreationally.

Area fished: Rock crab is landed across the state. Landings are higher in the Southern California Bight with concentrations of landings along the mainland of the Santa Barbara Channel, northern Channel Islands, and Point Loma. Landings north of the bight are concentrated around Morro and San Francisco Bays. The average fishing depth is 120 feet.

Fishing season: Rock crab may be taken year-round and there is no seasonal pattern in landings.

Fishing gear: The commercial fishery typically uses rectangular rigid wire mesh traps. Requirements for trap design include escape openings to allow sublegal sized crabs to escape, and destruct devices to prevent lost traps from continuing to fish.

Market(s): Rock crab must be landed whole and most are sold domestically as a live product.

Current stock status: No estimates of the rock crab population abundance in California exist. However, some fisheries-dependent as well as anecdotal information suggest depletion. The stock is relatively data poor due to the lack of an at-sea logbook and fisheries-independent data streams.

Management: Management procedures are minimal for the rock crab fishery. There is no closed season, no requirement for an at-sea logbook, and no trap limit in place. A minimum legal size of 4.25 inches (108 millimeters) carapace width is in place across all three species. Both sexes, as well as females with eggs may be harvested. Effort in the southern region is partially limited by restricted access permits. Addition of latent effort to the fleet is slowed by allowance for only five permit transfers per year. Management changes to establish targets and limits and associated management procedures are needed. Data-limited management strategy evaluation modeling techniques are currently being applied and may identify management procedures robust to the high uncertainty around this stock.

1 The Species

1.1 Natural History

1.1.1 Species Description

Rock crab are the basis for an important, multi-species fishery in California. The three species in the fishery were all previously classified in the genus *Cancer* spp. until recent reclassification of the Yellow and Brown Rock Crabs. They are all similar in appearance to Dungeness Crab (*Cancer magister*) but can be distinguished from Dungeness by their black-tipped claws (Figure 1-1).

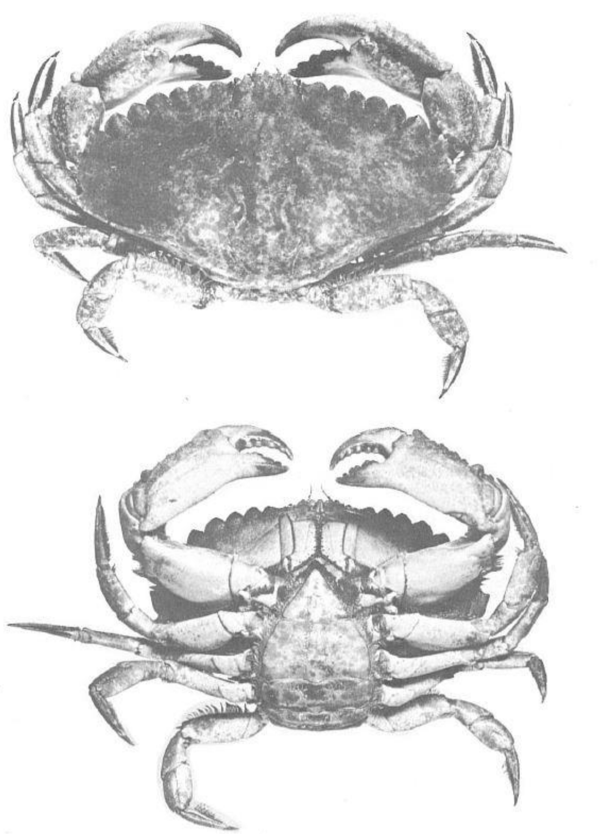

Figure 1-1. Red Rock Crab photograph (CDFG 1973).

Red Rock Crab have a medium to dark red color with splotching on the top of the carapace (similar to Brown Rock Crab). The characteristic that helps distinguish Red Rock Crab (Figure 1-1) from the other species are their five teeth between their eyes (Carroll and Winn 1989).

Yellow Rock Crab are a yellow to brown color without splotching (Figure 1-2), and their walking legs have no hair (Carroll and Winn 1989).

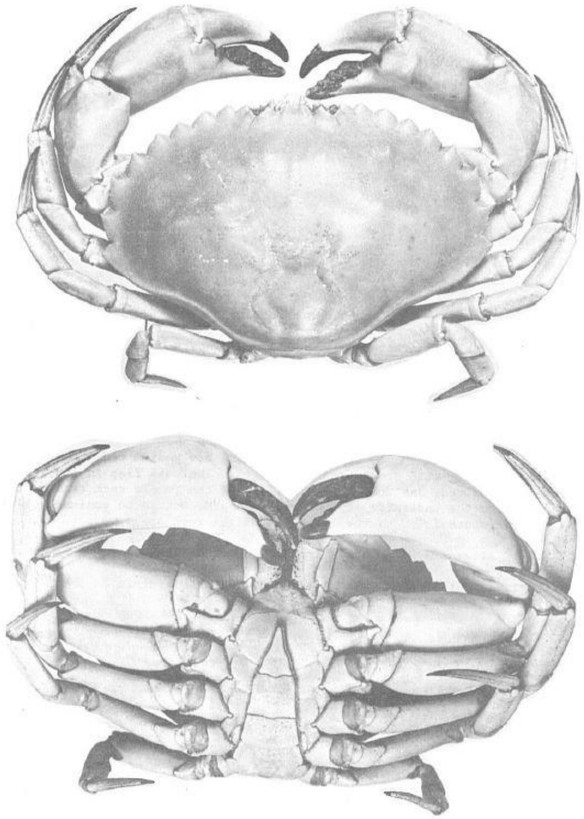

Figure 1-2. Yellow Rock Crab photograph (CDFG 1973).

Brown Rock Crab are a medium to dark red color with splotching on the top of the carapace. A reliable distinguishing characteristic of the Brown Rock Crab (Figure 1-3) are the small red spots on its underside with rough and hairy legs, and their claws have black tips with a spine on their wrist (Carroll and Winn 1989).

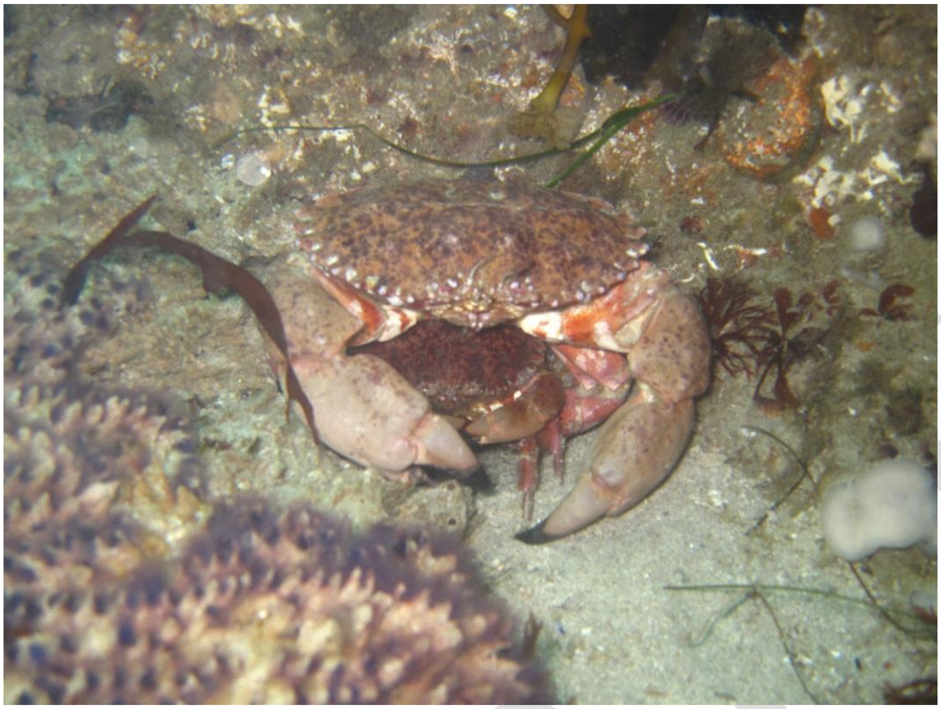

Figure 1-3. Brown Rock Crab image (Photo Credit: Julia Coates, CDFW).

1.1.2 Range, Distribution, and Movement

Red Rock Crab ranges from Kodiak Island, Alaska to Isla San Martin, Baja California (Jensen 1995) (Figure 1-4). It is found in a wide variety of habitat types ranging from subtidal reefs to gravel, sand and mud substrates (Schmidt 1921).

Figure 1-4. Range of Red Rock Crab from Kodiak Island, Alaska to Isla San Martin, Baja California.

Yellow Rock Crab ranges from Humboldt Bay, California to Bahia Magdalena, Baja California, Mexico (Figure 1-5) and typically occupies sandy and muddy substrates as well as the sand-rock interface at reef margins (Winn 1985).

Figure 1-5. Range of Yellow Rock Crab from Humboldt Bay, California to Bahia Magdalena, Baja California Mexico.

Brown Rock Crab ranges from Queen Charlotte Sound, British Columbia to Cabo San Lucas, Mexico (Figure 1-6) and tends to occupy reef habitats though may also be found over sandy substrate. Depth distributions of the three species are not well documented in the literature or fishery-dependent data.

Figure 1-6. Range of Brown Rock Crab from Queen Charlotte Sound, British Columbia to Cabo San Lucas, Mexico.

Winn (1985) summarized information compiled in Department research cruise reports that described trap surveys conducted in 1976 to 1977 between Santa Barbara and San Diego. Yellow Rock Crab dominated the catch at 29 of the 35 sites surveyed. Yellow Rock Crab Catch Per Unit Effort (CPUE) was highest at the medium sample depths from 18.0 to 55.0 meters (m) (59.1 to 180.4 feet (ft)) and lower at depth extremes from 9.0 and 91.0 m (29.5 and 298.6 ft). Brown Rock Crab CPUE decreased with increasing depth. Red Rock Crab CPUE indicated a relatively deeper distribution with the highest catches at 55.0 and 73.0 m (180.4 and 239.5 ft) depth, but catches of the species were generally low. Latitudinal CPUE trends indicated increasing abundance of Brown and Red Rock Crab moving north and Yellow Rock Crab increased in abundance moving south.

Movements of Red and Yellow Rock Crab are unknown as no tagging or telemetry studies designed to track movement have been performed. Carroll (1982) observed movement of Brown Rock Crab that followed a channel into Diablo Cove (Central California, approximately 150 km north of Point Conception). While seasonal trends did not show a migration pattern, crabs recaptured within 1 to 5 days after tagging remained in the release location vicinity and 21% still remained in that area after 2 to 18 months (21% moved to adjacent areas up to 2 km away) (Carroll 1982). Due to the concentration of fishing effort in a small length of the coastline, long distance migrations were not completely monitored, while migrations of up to 7.0 kilometers (km)

(4.35 mile (mi)) were reported from fishing traps outside of the study area for several individuals (Carroll 1982).

There are no known studies of genetic stock structure that might indicate the degree of movement or population mixing for rock crab. Trapping at an offshore oil platform at approximately 200 ft (61 m) depth and surrounding sites found that Brown Rock Crab recruited as juveniles to the structure provided by the platform and associated biogenic habitat where they grew and resided as adults (Page et al. 1999), highlighting the association of this species with reef habitat. Bonkamp (2004) also noted higher densities of Brown Rock Crab on shell mounds with or without oil platforms than on surrounding soft bottom. Page et al. (1999) also found that adult Yellow Rock Crab were attracted to the structure from surrounding soft-bottom habitat and aggregated there, while Red Rock Crab were found at equal densities at the platform as the surrounding habitat.

1.1.3 Reproduction, Fecundity, and Spawning Season

The reproductive biology of the species in California's rock crab fishery aligns generally with other *Cancer* spp. (Warner 1977). Females release a pheromone that attracts males and stimulates mating behavior. Males will carry females through their molting period, and mating occurs after the molt while her shell is soft via the deposition of a spermatophore into her spermatheca. Spermatophores may be carried by females until their eggs are ready to be extruded (oviposition). Fertilization takes place at that time and the eggs are brooded externally under the abdominal flap. Eggs are brooded as the larvae develop and then hatch and are released (eclosion).

The seasonal timing (phenology) of reproductive processes is not well understood for rock crab and what has been observed varies among the species. Shields et al. (1991) trapped female Yellow Rock Crab monthly and held them in the laboratory to observe reproductive timing. Egg bearing (ovigerous) females were found throughout the year but a peak in ovigerous females was observed in March by Reilly (1987). Observations of females held in the laboratory showed that they can extrude eggs three or more times in a year, with egg development times as short as one month, and can fertilize multiple broods from a single mating event. Brooding lasted an average of 40 days at an average temperature of 15 degree Celsius (^{o}C) (59 degree Fahrenheit (^{o}F). Ovigerous female Brown Rock Crab have also been observed throughout the year, but differ from Yellow Rock Crab by showing peak abundance in winter (Carroll 1982). Published reports of seasonality in ovigerous Red Rock Crab are not available from southern California, but they are observed in higher abundance in inland waters of Washington State in October to January (Orensanz and Gallucci 1988).

Table 1-1. Rock crab fecundity and reproduction comparison among species (Shields 1991 and references therein).

Species	Fecundity (eggs/brood)	Reproductive potential (eggs)	Embryonic development (days)	Larval development (days)
Red	Unknown	Unknown	120	95
Yellow	$0.7\text{-}3.3 \times 10^6$	$14.7\text{-}29.4 \times 10^6$	29 to 58	45
Brown	1×10^6	$5\text{-}10 \times 10^6$	50 to 60	--
Dungeness	$0.5\text{-}1.5 \times 10^6$	$3\text{-}4 \times 10^6$	90 to 120	45 to 160

The three rock crab species are similar in the overall larval development steps, but likely differ in timing. Timing is also known to be influenced by water temperature (Anderson and Ford 1976). Larvae hatch as prezoeae and molt to first stage zoeae in under an hour (Figure 1-7) (Carroll and Winn 1989). They have a total of five zoeal and one magalopal developmental stages (Carroll and Winn 1989). The spatial distribution of rock crab larvae and general aspects of larval behavior are not known. Similarities with Dungeness Crab might be assumed, however larval development times of Yellow Rock Crab are less than half that of Dungeness Crab with 45 days for Yellow Rock Crab (Trask 1970) and 110 days for Dungeness (Reilly 1987). Dungeness Crab are widely distributed over the continental shelf (Reilly 1983) but rock crab may not have as broad a larval distribution, with implications for the scope of population mixing and self-recruitment.

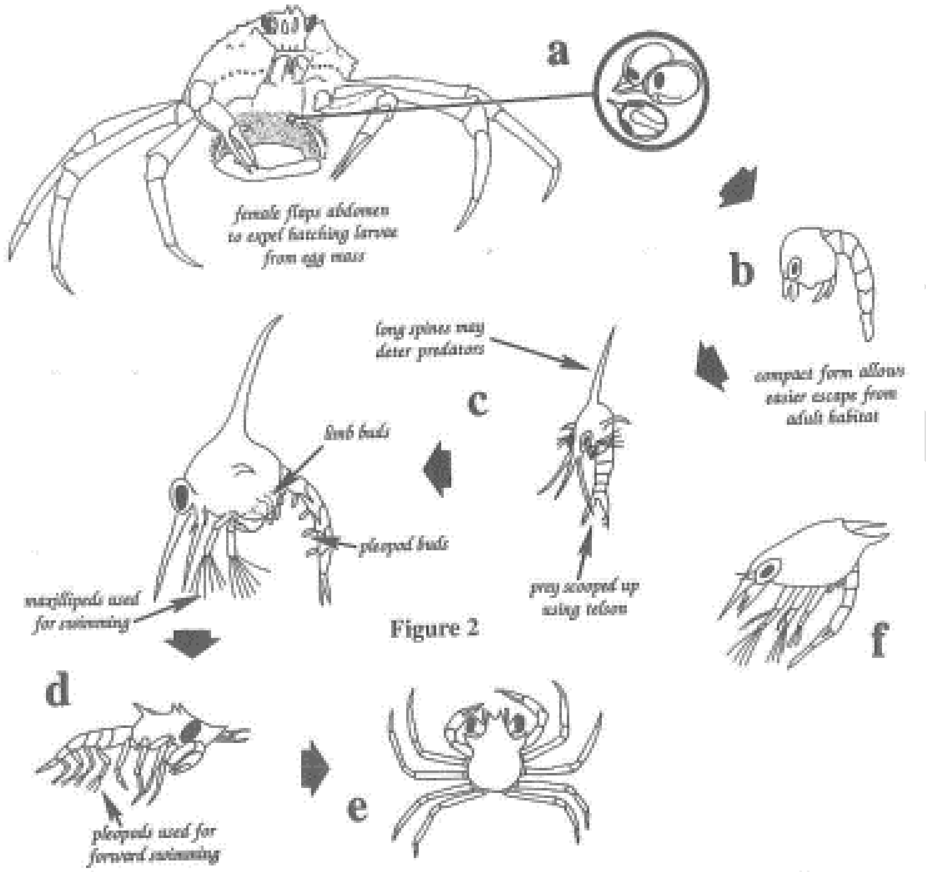

Figure 1-7. Generalized larval development of brachyuran crabs (sub-order of crabs containing Rock Crab). a) eggs; b) prezoea; c) zoea; d) megalops; e) first juvenile instar; f) typical zoea of an anomuran crabs (other sub-order of crabs) (reproduced from Jensen 1995).

Larval settlement to the benthos for Yellow and Brown Rock Crab in southern California was observed to be greatest during spring and summer, which is similar to Dungeness Crab (Winn 1985). This pattern may relate to the influence of temperature and wave energy on the survival of larvae and early post settlers during winter months. Choice experiments set up in the field suggested that Yellow Rock Crab preferentially settled in sandy habitat in 33.0 m (108.3 ft) depth while Brown Rock Crab showed more variability in habitat choice (Winn 1985). The study found settlement of Red Rock Crab to be too low to assess habitat differences.

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.

There are no published natural mortality estimates in the literature for the three species in the California rock crab fishery. Crabs generally have relatively high natural mortality relative to finfish. Based on a theoretical relationship developed by Hoenig (2005), natural mortality can be estimated using information on longevity. A maximum longevity of 7 years (yr) has been estimated for Red (Yamada and Groth 2016) and Brown (Carroll 1982) Rock Crab, which results in a natural mortality of 0.6. Estimates of natural mortality for the closely related Dungeness Crab range from 0.7 to 2.26 (Zheng 2005; Punt and Methot 2005).

Winn (1985) reported that sources of natural mortality on crab populations are highly speculative. Juvenile survival is likely low due to competition, predation and cannibalism, and demersal predation by California Sea Star (*Astropecten verrilli*) and Barred Sand Bass (*Paralabrax nebulifer*) (Winn 1985). However, it is unknown which sources of mortality play the largest role in structuring population abundances (Winn 1985).

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. The growth patterns of invertebrates frequently do not fit the von Bertalanffy model well. Crustaceans exhibit stepped growth patterns resulting from molting that may or may not be smoothed to match von Bertalanffy expectations (Chang et al. 2012).

Rock crab, like other crustaceans, grow in a step-wise fashion with each molt (shedding of the external shell) (CDFG 2003). Yellow and Brown Rock Crab molt 10 to 12 times before reaching sexual maturity at about 3.0 inches (in) (7.62 centimeters (cm)) Carapace Width (CW). Crabs of this size may molt twice a year, but as they grow older and larger they molt less frequently (CDFG 2003). Crabs as large as 6.0 in (15.2 cm) across may molt once a year or less (CDFG 2003). Growth per molt decreases with size and age.

Growth studies have been conducted for each of the three rock crab species. However, additional field and laboratory studies are necessary to improve these estimates. As is common among crustaceans, males and females grow at similar rates until sexual maturity then males grow at faster rates and growth is influenced by temperature (Anderson and Ford 1976). Males of all three species attain sizes 10% to 15% larger than females (CDFG 2003).

Red Rock Crab

Laboratory rearing of Red Rock Crab megalopa larvae found that they reach a CW of 5.0 to 15.0 millimeters (mm) (0.2 to 0.6 in) by the end of their first summer

(Orensanz and Gallucci 1988). Larger sizes were studied by Yamada and Groth (2016) using a combination of size-frequency analysis, monitoring growth of caged crabs, and mark-recapture studies. Growth was found to be highly variable. Before sexual maturity, males and females grew equally and achieved sizes between 60.0 to 95.0 mm (2.4 to 3.7 in) at age 2. At the maximum sizes observed for females of 150 .0mm (5.9 in) and males 171.0 mm (6.7 in), the crabs were estimated to be at least 5 yr old. Carroll and Winn (1989) referred to Department unpublished data for females and males 168.0 and 190.0 mm (6.6 and 7.5 in) respectively, and reported a maximum age of 5 to 6 yr. for Red Rock Crab males CW of 8.0 in (203.2 mm) (CDFG 2003).

Yellow Rock Crab

Anderson and Ford (1976), estimated growth curves for Yellow Rock Crab based on laboratory work alone. Male Yellow Rock Crab grow to exceed a CW of 7.0 in (17.8 cm) (CDFG 2003).

Brown Rock Crab

Carroll (1982) estimated growth curves for male and female Brown Rock Crab based on tag-recapture information on molt increments and asymptotic maximum CW (Figure 1-8). Maximum size of 155.0 mm (6.1 in) for males and 145.0 mm (5.7 in) for females (Carroll 1982). Brown Rock Crab males reach 6.5 in (16.5 cm) in CW (CDFG 2003). Additional laboratory work to confirm molt frequency and increments would help to improve estimates.

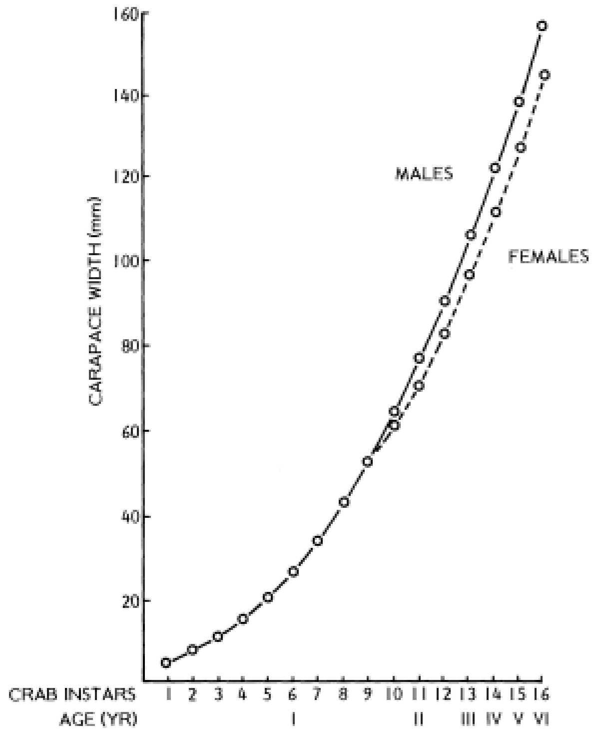

Figure 1-8. Growth curve for male and female Brown Rock Crab. Instars represent molts within each year of age. (Reproduced from Carroll 1982).

1.1.6 Size and Age at Maturity

Female Red Rock Crab are larger at maturity than the other two rock crab species (Winn 1985). They are sexually mature at approximately 65 mm (2.56 in) CW, which occurs between 1 and 2 years of age (Orensanz and Gallucci 1988, Yamada and Groth 2016).

Female Yellow Rock Crab reached maturity at the 13th instar (or molt stage), 139.0 to 188.0 mm (5.5 to 7.4 in) CW, and 188 days after hatching in laboratory settings at 22.0 °C (71.6 °F) (Anderson and Ford 1976). However, females collected from the field were found to be mature as small as 85.0 mm (3.35 in), corresponding to the 12th instar (Winn 1985).

Carroll (1982) noted that male and female Brown Rock Crab growth rates begin to diverge between 60.0 to 80.0 mm (2.4 to 3.1 in) CW (Figure 1-8), indicating the onset of sexual maturity. This may suggest that males at or above the size of the smallest females observed with eggs are also sexually mature, although detailed studies have not confirmed this.

1.2 Population Status and Dynamics

Information is not available on the stock sizes, recruitment rates, mortality rates, the effects of different oceanographic regimes, or potential yield for any of the three of rock crab species (CDFG 2003). Rock crab are relatively short-lived, and like many crustaceans, are generally considered to have high reproductive potential and rapid growth rates making them relatively productive. Mace and Sissenwine (1993) noted that high fecundity is often associated with high resilience and relatively low target values of Spawning Potential Ratio (SPR) in stable fisheries. SPR is the ratio of egg production or recruitment under a fished state relative to a theoretical unfished state. For example, the target SPR for several stable lobster fisheries is substantially lower than for many finfish (Ennis and Fogarty 1997; Puga et al. 2005; Zhang et al. 2011). The commercial fishery, however, has had a localized effect on crab abundance and size (CDFG 2003). Areas intensively exploited over an extended period produce fewer crabs per trap, and have a reduced size-frequency distribution compared to lightly exploited areas (CDFG 2003). In Santa Monica Bay, which has been closed to commercial crab fishing for decades, experimental catch rates were higher, crab sizes larger and size-frequencies broader than in adjacent areas open to commercial trapping (CDFG 2003). Further research should increase our understanding of rock crab population parameters (CDFG 2003).

1.2.1 Abundance Estimates

There have been no estimates of abundance for any of the rock crab species over the course of the fishery history. Catch is known from landings data. However, species-specific landings were not available until 1994 and not required until 2010. There is no at-sea logbook and therefore no reliable effort information. Thus, CPUE abundance estimation techniques cannot be applied.

Landings appear to be negatively correlated with Pacific Decadal Oscillation (PDO), which is an index of climatic oscillation indicating relatively warm or cold regimes, similar to El Niño patterns but on a longer time scale. However, lack of species-specific landings data hinders identification of patterns. Each of the three species show negative correlations between 2 to 6 yr of lag between PDO and landings with a 4 yr lag being strongest (Figure 1-9). Landings of all species combined are weakly negatively correlated with PDO with 2 to 4 yr of lag. Waters off California warmed substantially in 2013 to 2015 coinciding with high rock crab landing, which reached a historic high in 2014. Landings fell dramatically in 2016 to approximately the historic average and have not recovered. In the absence of effort information, the relative importance of environmental influences and harvest cannot be determined.

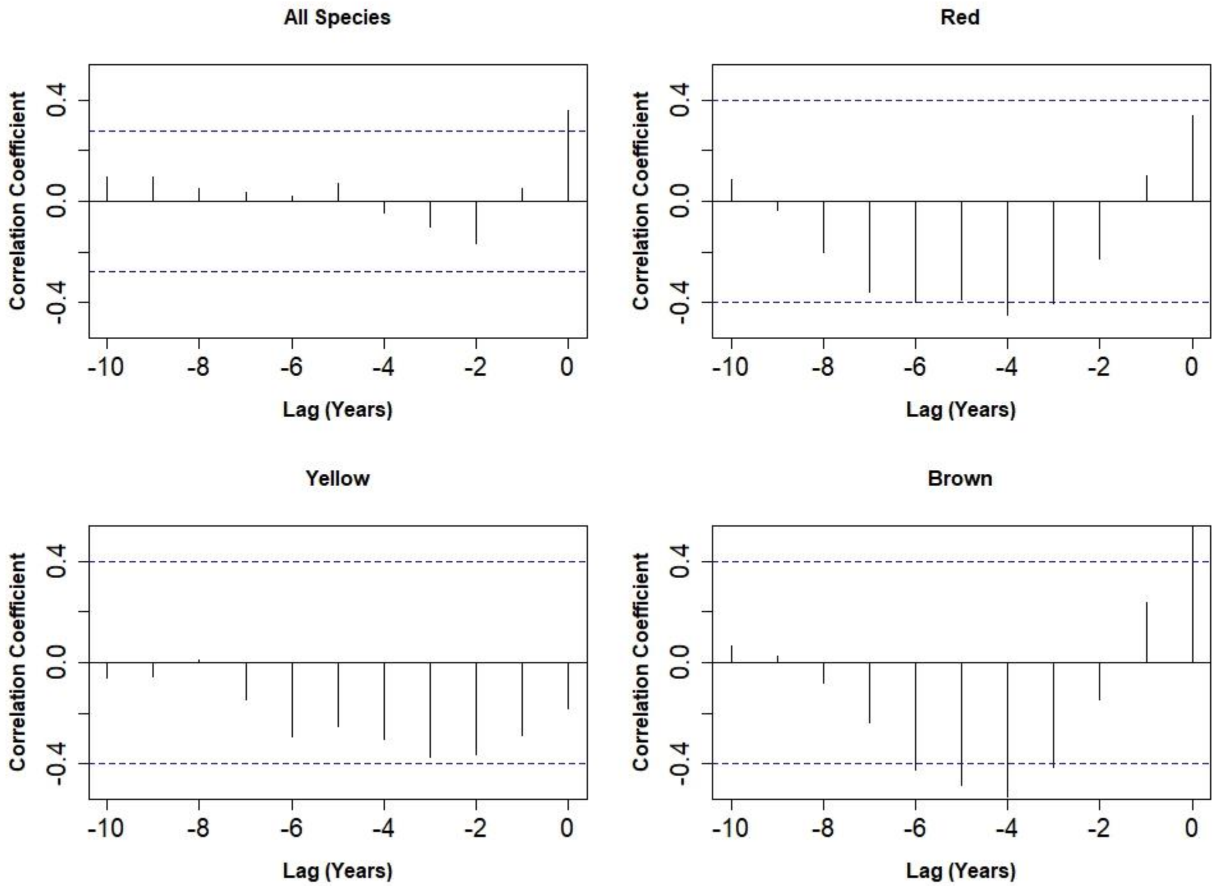

Figure 1-9. Cross-correlation coefficients for relationships between PDO and landings of all rock crab species combined, Red Rock Crab, Yellow Rock Crab, and Brown Rock Crab. PDO and landings are lagged by 0 to 10 yr with landings following PDO. Significance level is indicated by the dashed line. (PDO data: Joint Institute for the Study of Atmosphere and Ocean, http://research.jisao.washington.edu/pdo/; Landings Data: CDFW Commercial Fisheries Information System (CFIS)

Abundance, measured as catch-per-trap-hour, was calculated quarterly at six stations in the Santa Barbara Channel for both Yellow and Brown Rock Crab in Reilly (1987). Yellow Rock Crab abundance had a higher average in the three deeper stations (50, 55, and 60 ft) during the fall and summer quarters, and the stations had increasing averages as depth increased (Reilly 1987). Brown Rock Crab abundance had a higher average in the three shallow stations, with a decrease in relative abundance with depth between 40.0 to 60.0 ft (12.2 to 18.3 m) (Reilly 1987). Additionally, the fall quarter had the highest mean for catch-per-trap-hour and the lowest was in both the winter and summer quarters (Reilly 1987).

1.2.2 Age Structure of the Population

Aging methods for crustaceans are just emerging (Kodama et al. 2006; Mathews et al. 2009; Kilada et al. 2012; Clore 2014) and none have been applied to rock crab. Therefore, directly relating size to age is not possible and analysis of growth rates becomes more complicated. Tag-recapture data can be fit to standard growth equations such as the Von Bertalanffy to estimate a relative size at age relationship. Comprehensive tagging studies of rock crab in California have not been performed. Estimates of age structure of rock crab populations can be made based on tagging studies (Carroll 1982; Yamada and Groth 2016) and studies assessing size structure of the stock (Culver et al. 2010; Fitzgerald et al. forthcoming). However, these studies have been on local scales and short-term time frames. Improved age and growth information is critical for unbiased modeling of population dynamics and stock assessment.

1.3 Habitat

All three species of rock crab inhabit the intertidal area out to depths greater than 100.0 m (328.1 ft) (Carroll and Winn 1989). Brown and Red Rock Crab prefer rocky or reef-type habitat (CDFG 2003). Red Rock Crab inhabit depths to 91.0 m (298.6 ft) that includes low intertidal of bays and estuaries, gravel, rocky substrates, and coarse sand and mud (Carroll and Winn 1989). Yellow Rock Crab habitat includes the intertidal out to the subtidal 140.0 m (459.3 ft) silty sand to mud substrates sand-rock substrate of rocky reef (Carroll and Winn 1989). Brown Rock Crab inhabit substrates of rocky shores subtidal reefs and coarse to silty sands (Carroll and Winn 1989).

1.4 Ecosystem Role

Rock crab play both a predatory and scavenging role in the ecosystem. Rock crab may also display cannibalism within these three species (Carroll and Winn 1989). In the laboratory rock crab have also displayed a planktivorous role: Red Rock Crab larvae fed on sea urchin larvae and barnacle nauplii while Yellow Rock Crab fed on dinoflagellates and diatoms (Carroll and Winn 1989).

1.4.1 Associated Species

Kellet's Whelk (*Kelletia kelletii*) and other crab species are often caught within the traps of California's rock crab fishery. In the Southern California Bight (SCB) rock crab and California Spiny Lobster (*Panulirus interruptus*) as well as Sheep Crab (*Loxorynchus grandis*) are often caught in the same traps. In central and northern California Red Rock Crab and Dungeness Crab (*Cancer magister*) are caught together.

1.4.2 Predator-prey Interactions

Rock crab, especially juveniles, are preyed upon by a variety of other marine organisms. Fishes such as Cabezon (*Scorpaenichthys marmoratus*), Barred Sand Bass and several species of rockfish and invertebrate predators include octopus and certain sea stars are known to feed on rock crab (Carroll and Winn 1989). Cannibalism has been observed in the laboratory (Winn 1985) and is likely to occur in the wild. As rock crab grow, they generally become less susceptible to predators except during the soft-shelled, post-molt period (CDFG 2003). Sea Otters (*Enhydra lutris*) are one of the few effective predators on large, hard-shelled rock crab (CDFG 2003).

1.5 Effects of Changing Oceanic Conditions

Landings of each species appear to be negatively correlated with PDO with about a 4 yr lag (figure 1-8). However, patterns should be interpreted with caution due to minimal species-specific landings data. Peaks total in landings occurred in 1986, 1990, and 2014 and are not clearly associated with temperature or El Nino patterns, but combined landings obscure individual species patterns. Carroll and Winn (1989) reported in a laboratory thermal tolerance study that increased exposure to temperatures resulted in a median effective 50% mortality of adult crabs if temperatures reached 25.4°C (77.7°F). This temperature could be reached in some locations if warming ocean trends continue. Additionally, changes in salinity, due to fluctuations in freshwater inputs, could affect rock crab as they are osmoconformers (they match their internal salinity to their surrounding conditions either actively or passively) (Carroll 1982) and their molting process was reported to be impaired at salinities below 13.7 parts per thousand while no tolerance level has been determined (Buchanan and Milleman 1969). Rock crabs may shift in spatial distribution in response to water temperature but surveys have not been conducted over long enough time periods to demonstrate shifts.

Rock crab accumulate domoic acid, the neurotoxin produced by a planktonic algae (Pseudo-nitzschia). While the toxin is not known to have negative physiological consequences for the crabs, the fishery has been impacted when levels in crab viscera or meat exceed the federal action level for human consumption. Recommendations to close or delay the opening of fisheries are made to the Department by the Office of Environmental Health Hazard Assessment (OEHHA) in consultation the California Department of Public Health. In these cases, crabs cannot be commercially sold and the fishery must be closed by the Department director until samples show that domoic acid levels have returned to levels below the threshold. The frequency and duration of the plankton blooms and their toxin production appears to be linked to shifts in ocean temperature and therefore may also be linked to climate change.

2 The Fishery

2.1 Location of the Fishery

The location of the rock crab fishery spans the length of the state from Crescent City to Mission Beach. Ports with substantially high landings compared to the rest of the state are: Avila/Port San Luis, Morro Bay, Santa Barbara, Oxnard, San Pedro, San Diego, with Avila/Port San Luis and San Diego reporting over 18,000 landings (Figure 2-1). The average fishing depth is 120.0 ft (36.6 m).

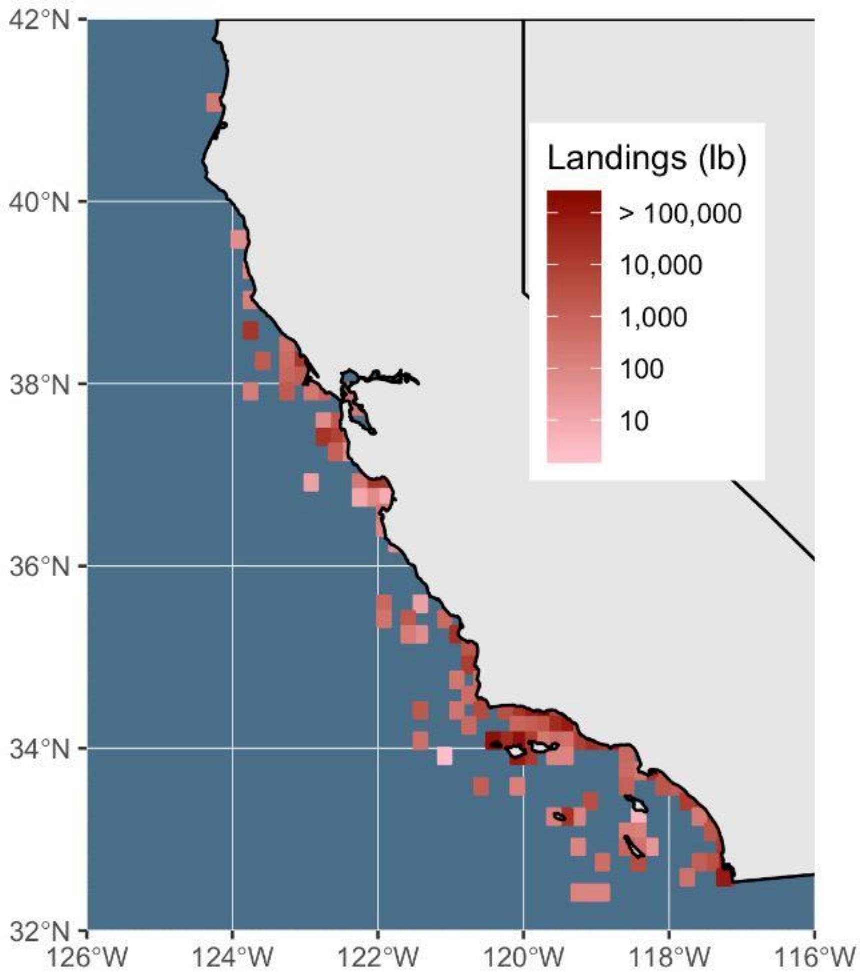

Figure 2-1. Map of reported catch location (CDFW fishing block) for commercial rock crab landings in 2018 (CDFW CFIS).

2.2 Fishing Effort

2.2.1 Number of Vessels and Participants Over Time

Participation in the commercial fishery has fluctuated over time. In 1985, participation was at its highest with 287 vessels landing Rock Crab. Participation generally declined and by 2018 dropped to 153 vessels, as reflected in landing receipt data from (Figure 2-2, CDFW CFIS). A permit specific to Rock Crab was not created until 2005. Limited entry southern rock crab permits declined from 144 in 2005 to 117 in 2018 while northern rock crab permits have been relatively stable.

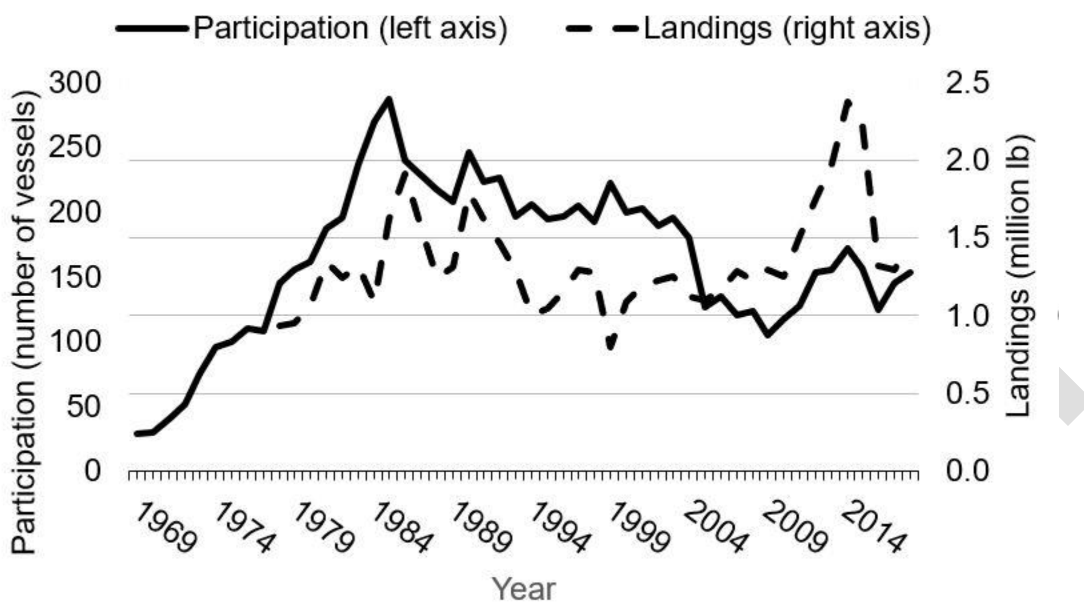

Figure 2-2. Rock crab fishery participation (number of vessels) and landings (million lb), 1980 to 2017 (CDFW CFIS).

2.2.2 Type, Amount, and Selectivity of Gear

Fishermen may use traps of varying dimensions and mesh sizes and number of chambers Fish and Game Code (FGC) §9011. Most fishermen use either 2.0 by 4.0 in (5.08 by 10.16 cm) or 2.0 by 2.0 in (5.08 by 5.08 cm) mesh. Unfortunately, at this time, the Department has no data on how many traps have been used in this fishery. Size structure of the catch is not monitored; thus we can only make assumptions about gear selectivity based on the size structure of landings reported by Culver et al. (2010) discussed in the following section 4.2.1. Rock crab traps with standard mesh sizes must have at least one escape port that is a rigid circular ring of a diameter no less than 3.25 in (8.26 cm) (FGC §9011). It appears that this opening allows most sublegal sized crabs to escape. At-sea monitoring showed that very few crabs less than the legal size of 108.0 mm (4.25 in) CW are caught. The size at full selectivity is likely between 108.0 to 130.0 mm (4.25 to 5.12 in) as this size class was the most abundant in the Yellow Rock Crab catch reported.

2.3 Landings in the Recreational and Commercial Sectors

2.3.1 Recreational

Recreationally, rock crab may be taken only by hand or hoop net south of Point Arguello in Santa Barbara County. North of Point Arguello traditional traps and crab loop traps may be used recreationally. No data on recreational catch is available at this time.

2.3.2 Commercial

Rock crab is landed commercially using traps across the state. Point Lopez, in Monterey County, divides a northern management region with open access permits from a southern region that is limited entry. Peak landings in the fishery's history occurred in 2014 with nearly 2.4 million pounds (lb) (1.09 million kilograms (kg)) (Figure 2-3).

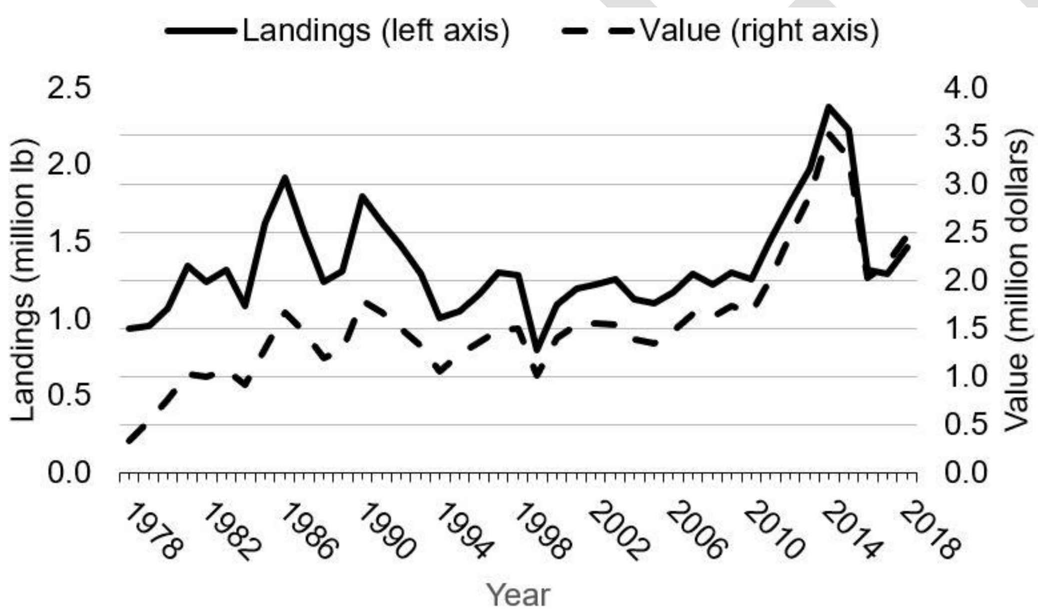

Figure 2-3. Rock crab commercial fishery landings (million lb) and value (million dollars), 1980 to 2017 (CDFW CFIS).

2.4 Social and Economic Factors Related to the Fishery

In 2014, the total ex-vessel value for the fishery was $3.5 million (Figure 2-3). The average annual landings between 2013 and 2017 were 1.8 million lb (816,465.6 kg). Average ex-vessel price during that period was $1.49 per pound. Average annual price per pound increased from approximately 10 cents in 1969 to $1.75 in 2016 (Figure 2-4). However, when adjusted by the Consumer Price Index (CPI), price has been remarkably stable. Landings are higher in the SCB with concentrations of landings at ports along the mainland of the Santa Barbara Channel, near the northern Channel

Islands, and Point Loma (San Diego) (Figure 2-5). Landings north of the bight are concentrated around Morro and San Francisco Bays.

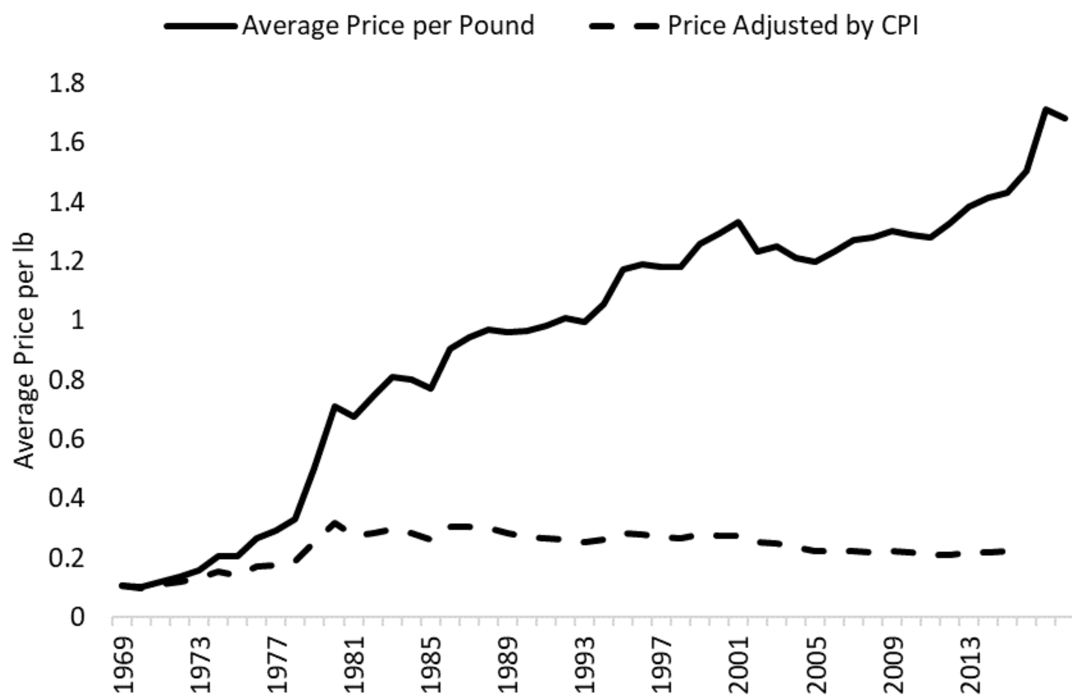

Figure 2-4. Rock crab fishery average price per pound (dollars) adjusted by CPI from 1969 to 2015 (CDFW CFIS).

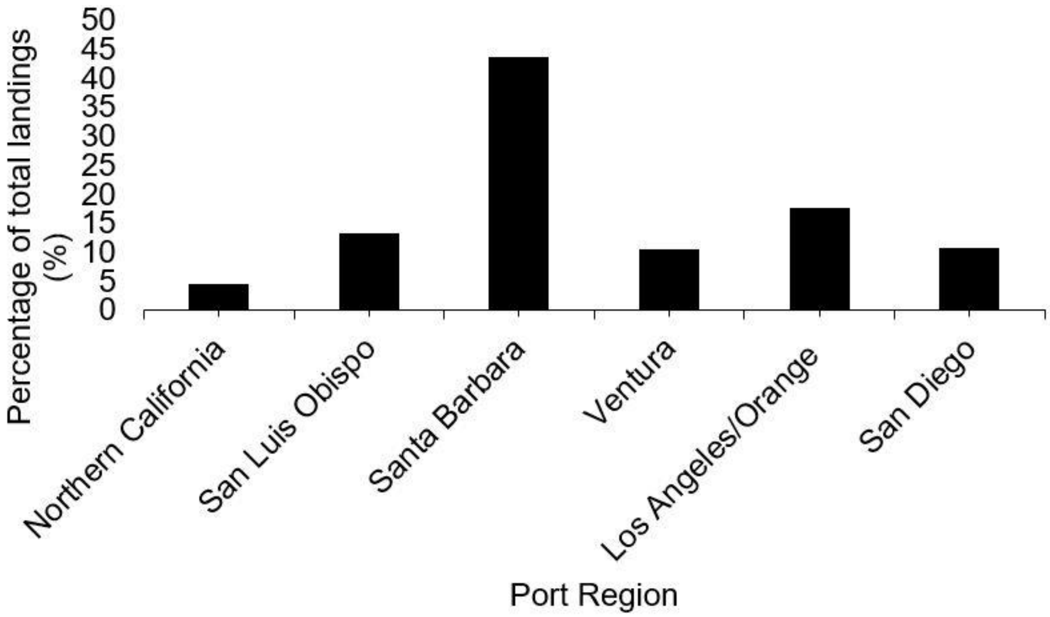

Figure 2-5. Rock crab percentage of total landings by port in 2017 (CDFW CFIS).

The Department does not collect information on markets where products are ultimately sold to the consumer (i.e. past the dock). Landing receipt data on the condition of the product at the first point of sale is available, but is not consistently provided for rock crab. Rock crab for human consumption are predominantly sold live while some fraction may be sold as fresh claws. Rock crab may be used or sold for bait but must be recorded on a landing receipt and kept in a whole state until after the point of sale so that the size limit can be verified and enforced. The relative amount of rock crab sold domestically versus internationally is not known but the domestic market is likely the majority. With such a stable price, it does not appear that the price or abundance of other crabs or lobster has a marked influence on the price of rock crab. Landings of rock crab may be influenced by these other fisheries, particularly because the Dungeness Crab and California Spiny Lobster (*Panulirus interruptus*) fisheries allow incidental take of rock crab.

3 Management

3.1 Past and Current Management Measures

The rock crab fishery has been subject to minimal management measures over its history since landings were first recorded in 1928. There are no seasonal restrictions and no logbook requirement. There are also few spatial restrictions. Rock crab are state-managed species under the Commission management authority. A size limit of 4.25 in (107.95 mm) CW and regulations governing trap design were put in place in 1987. In 1991 fishermen were prohibited from landing claws alone and discarding the rest of the crab's body. Thus, animals were required to be landed whole so that the size limit could be enforced. Species-specific market codes were created in 1994 but their use was not required. Therefore, following 1994 some landings are associated with each of the three rock crab species and some are recorded as unspecified rock crab. This prevents the use of landings as a proxy for abundance of each species. Additionally, landings data cannot reliably be used to examine processes such as environmental influence on catch and serial depletion among the species. Recognition of over-capacity lead to a new permit structure in 2005 which created northern and southern rock crab permits divided at Point Lopez (§125, Title 14, California Code of Regulations (CCR)). Northern permits are open access and southern permits are limited entry. A minimum of 500.0 lb (226.8 kg) landings between 1998 to 2003 was required to be eligible for a southern permit. Southern permits were nontransferable until a regulatory change in 2010 that allowed all southern permits to be transferrable, but only at a rate of five per year. Applications for transfer are granted on a first come first served basis. Use of the species-specific market codes on landings receipts was also required at that time to improve the Department's ability to track the landings of each species separately. Recreational management measures include a daily bag limit of 35 individuals, a minimum size of 4 inches CW, and gear restrictions.

3.1.1 Overview and Rationale for the Current Management Framework

California's rock crab fishery is managed using a size limit to protect the reproductive capacity of the stock and limited entry permits to limit fishing effort in the south. The three rock crab species have different sizes at maturity and therefore may differentially benefit from the size limit. The Department staff is currently exploring this via Management Strategy Evaluation (MSE) using the Data Limited Toolkit.

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

There is currently no reference point available to specify the level of fishing that constitutes "overfishing". There is also no reference point available to specify the size at which the rock crab populations 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 nor 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)). Department staff is currently exploring this via MSE using the Data Limited Toolkit.

3.1.1.2 Past and Current Stakeholder Involvement

Stakeholder involvement has primarily occurred during regulation changes affecting the rock crab fleet. Amendments to regulations pertaining to rock crab regulations (§125.1 and 126(b), Title 14, CCR) were last made in 2018 when limits to the amount of Non-Cancer crabs that could be taken incidentally were put in place. Outreach to the fleet at that time included a constituent meeting held in Ventura, a notification letter and fleet survey sent to permit holders, and discussions at Commission full meetings, as well as their Marine Resources Committee. Regulatory amendments in 2010 instituted transferability for southern permits and stakeholder participation reflected that some fishermen were encouraging a means for new entrants to the fishery and others remained concerned by over-capacity.

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 rock crab, and no pre-determined procedure available for setting or changing a quota.

3.1.2.1.2 Effort

Effort is limited by the permit structure. The fishery in the northern region is open access with no cap on the number of permits that can be issued (§125(d) , Title 14, CCR). The number of permits purchased in the north has increased in 2018 to 58 from an average of 31 over the previous years since the permit was established. The fishery in the southern region is limited entry to control fishing capacity. In 2005, when the southern permit was created, 144 permits were issued. In 2018, 117 were issued, representing a modest capacity reduction resulting from the limited entry program. Recreational effort control is implemented through a daily bag limit of 35 individuals.

3.1.2.1.3 Gear

Traps are subject to requirements that are consistent across all state trap fisheries including the use of destruct devices and marking traps with buoys. Traps must have openings that allow under-sized crabs to escape. If constructed of wire mesh that is 1.88 by 2.88 in (4.8 by 73.03 mm), one rigid circular opening no less than 3.25 in (82.55 mm) in diameter must be located in the rear chamber of the trap and be located such that at least half of the opening is in the upper half of the trap. The 2.88 by 3.88 in (73.03 by 98.43 mm) mesh size represents a standard 2.0 by 4.0 in (50.8 by 101.6 mm) wire mesh that has been coated in a substance to prevent rust. Smaller mesh sizes must have two openings in the top or side of the rear chamber. Again, at least one opening must be in the upper half of the trap. Rock crabs may also be taken incidentally in lobster and Dungeness Crab traps.

Recreational use of traps is restricted to only waters north of Point Arguello, Santa Barbara County (§29.8(e), Title 14, CCR). Traps used in these waters may be traditional traps or crab loop traps with up to six loops (§29.8(d), Title 14, CCR). Traditional trap design specifications are specified in §29.8(c), Title 14, CCR: "(1) Crab traps shall have at least two rigid circular openings of not less than four and one-quarter inches inside diameter so constructed that the lowest portion of each opening is no lower than five inches from the top of the trap. (2) Crab traps shall contain at least one destruct device of a single strand of untreated cotton twine size No. 120 or less that creates an unobstructed escape opening in the top or upper half of the trap of at least five inches in diameter when the destruct attachment material corrodes or fails. (3) Every crab trap except those used under authority of subsection 29.85(a)(5) of these regulations shall be marked with a buoy. Each buoy shall be legibly marked to identify the operator's GO ID number as stated on his/her sport fishing license."

3.1.2.1.4 Time

There are no seasonal or temporal restrictions affecting the rock crab fishery.

3.1.2.1.5 Sex

There are no restrictions on the take of rock crab females or egg bearing females.

3.1.2.1.6 Size

The minimum legal size for commercial take of all three species of rock crab is 4.25 in (107.95 mm) CW to be measured across the widest part of the spines (§125.1(a), Title 14, CCR). The recreational minimum size is 4 in (101.6 mm) CW in most areas except there is no size limit in Districts 8 and 9 within Humboldt and Arcata Bays (§29.85(b)(3), Title 14, CCR).

3.1.2.1.7 Area

There are no spatial restrictions on the commercial take of rock crab except within some MPAs and Districts 9, 19A, 19B, 21, and those portions of District 20 lying on the north and east sides of Santa Catalina Island north of Southeast Rock (FGC §8282). These Districts describe Humboldt Bay, Santa Monica Bay, the Port of Los Angeles, San Diego Bay, and Catalina Island.

3.1.2.1.8 *Marine Protected Areas*

Pursuant to the mandates of the Marine Life Protection Act (FGC §2850), the Department redesigned and expanded a network of regional 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.

Establishment of the MPA network likely did not greatly impact the rock crab fishery. Because there is no logbook requirement, the Department’s understanding of the spatial dynamics of fishing is limited. However, some fishermen have voluntarily submitted California’s general trap log that can be applied to several trap fisheries. The average depth reported on those logs is approximately 270.0 ft (82.3 m). Fishermen describe that most Yellow and Red Rock Crab fishing occurs in relatively deep, soft bottom and soft/rocky interfaces while Brown Rock Crab are in shallower reef habitat, particularly at the northern Channel Islands. A relatively small proportion of deeper soft bottom and soft/rocky interfaces were impacted by the MPAs and therefore red and yellow rock crab fishing likely saw relatively little impact. Some brown rock crab fishing grounds in shallower rocky habitat, particularly at the Channel Islands, were impacted.

3.1.2.2 *Description of and Rationale for Any Restricted Access Approach*

The strategy of creating northern and southern permits was proposed in 2003 due to differences in effort and landings above and below the Morro Bay port area. Lopez Point (Monterey County) was chosen as the boundary because it is approximately equidistant between the ports of Monterey and Morro Bays within a region that was minimally fished for rock crab, and is a distinctive landmark that is a known to fishermen. Restricted access to nontransferable permits was proposed for the southern region due to concern over overcapitalization and potential serial depletion in southern ports. A control date and a minimum landings criterion of 500 lb (226.8 kg) between 1998 and 2003 were set as requirements for application for a permit. Holders of a nearshore fishery permit and trap endorsement could apply and did not need to meet the landings requirement. Not including nearshore permit holders, this landings criterion limited the applicant pool to 183 individuals, and thus met the goal of capping capacity at approximately current levels. In 2007 and 2008 requests from fishermen seeking access to southern rock crab trap permits where brought to the Commission. The first was from a nearshore permit holder wanting the ability to fish for rock crab as bait, and the second was from a son seeking the ability to tend rock crab traps belonging to his father, a southern rock crab trap permit holder. Between 2004 and 2009, the nontransferable, restricted access permit structure achieved a permit reduction from 144 to 127. In response to requests from fishermen wanting access to southern rock crab permits, options for transferability were proposed. The Commission approved the option allowing all current permits to become transferrable at a rate of five per year in 2010. Some fishermen expressed concern over transfer of latent capacity so the limit of five transfers per year was intended to slow any potential increase in fishing power resulting from the transfer of latent permits to more active fishermen.

3.1.3 Bycatch

3.1.3.1 Amount and Type of Bycatch (Including Discards)

Bycatch is defined as "fish or other marine life that are taken in a fishery but which are not the target of the fishery" (FGC §90.5). 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.

Some incidental species are permitted to be landed by fishermen using rock crab traps, including octopus, Kellet's Whelk, and crabs not in the genus *Cancer* spp. (non-Cancer crabs). There is no limit on the amount of octopus, nor for any amount of Kellet's Whelk that may be taken until an annual state-wide quota is reached (§127(c), Title 14, CCR). Non-Cancer crabs may be possessed and landed in amounts no greater than 25.0 lb (11.3 kg) per species (§126, Title 14, CCR). Spiny Lobster and Dungeness Crab may not be taken incidentally in rock crab traps.

Because there is no logbook requirement for the rock crab fishery, there is no self-reported data on bycatch of either under-sized rock crabs or other species. There have also been no focused studies of bycatch for this fishery using observers or dockside samplers. An analysis of species reported on the same landing receipts as those reporting rock crab can provide some information, although this analysis only reflects retained bycatch and not discarded bycatch. A total of 24.2 million lb (11.0 million kg) of rock crab was landed between 2009 and 2018. An analysis of landings of species permitted to be retained in rock crab traps and reported on receipts with rock crab as percentages of the target species showed 7% Kellet's Whelk, 4% Spider Crab (*Loxorhynchus grandis*), 0.5% other non-Cancer crabs, and 0.4% octopus.

Rates of interactions with marine mammals through their entanglement in fixed fishing gear fisheries (e.g. trap) began increasing in 2015. Dungeness Crab traps have been the most common gear observed to be entangling whales, in part because of the depths and locations at which they are set. However, other gears have also been identified that have potential to contribute to the problem. Currently rock crab gear has no required identifying markings and therefore the instances of entanglements in this fishery are unknown. The Department is currently drafting new rules requiring identifying markings on most state managed commercial trap fisheries, including rock crab, so that the extent of the entanglement problem in each fishery can be assessed.

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

The required trap design specifications are thought to reduce the catch of undersized rock crab. Mortality of discarded undersized or recently molted rock crab is thought to be low. An increasing trend in landings of non-Cancer crabs associated with the rock crab fishery began in 2014. The most marked increase was for the Brown Box Crab (*Lopholithodes foraminatus*). A modest increase in California King Crab (*Paralithodes californiensis*) was also observed. Landings of Sheep Crab (*Loxorhynchus grandis*) have been relatively high for decades, but reached a historic peak in 2016. At the time, incidental landings of these species from rock crab traps was permitted with no limit on amount (FGC §8284(c) and; §125.1(c), Title 14, CCR). Little is known about the life history of these species or potentially sustainable harvest levels. Consequently, the Department proposed new limits on incidental landings of these species that took effect in January 2019. Sheep Crab are now subject to a statewide annual total allowable catch of 95,000 lb (43,091 kg) intended to keep incidental landings across all target fisheries that capture these crab comparable to the recent status quo (§126.1, Title 14, CCR). Other non-Cancer crabs are subject to a 25.0 lb (11.3 kg) possession and landing limit per species. Following implementation of these limits, the Department developed a collaborative research program with fishermen and other partners to study the biology and population dynamics of Box Crab and their potential to support a sustainable new target fishery. Fishermen were issued experimental gear permits to target Box Crab, and the first year of fishing and research will be completed in April 2020.

Kellet's Whelk are subject to a statewide annual total allowable catch of 100,000 lb (4,536 kg) which was instituted in 2012 to guard against unsustainable incidental landings in this and other trap fisheries.

3.1.4 Habitat

3.1.4.1 <u>Description of Threats</u>

Trap fisheries are generally thought to have relatively little impact on associated habitats. Red Rock Crab are targeted over soft bottom and soft-rocky ecotones. Yellow Rock Crab are targeted over predominantly soft bottom substrates and therefore these activities likely have the least impact on this type of habitat. Thus, there is modest potential for these traps to damage corals and other biogenic habitats on rocky substrate. Brown Rock Crab are targeted concurrently with Red Rock Crab and also in shallower reef areas. These activities may impact some biogenic habitat forming organisms on the reef and lead to entanglement and dislocation of kelp. However, impacts are likely modest. Lost traps can impact habitat by ghost fishing, or continuing to catch animals that then serve as bait for additional animals. Some of this impact may be mitigated by the requirement for traps to have destruct devices (FGC § 9003 and §180.2, Title 14, CCR). Little information exists to assess these impacts. Lost traps may also impact habitat by rolling across and scouring biogenic habitat. Rates of trap loss among the rock crab fleet have not been assessed but rates among the Spiny Lobster fleet were reported for the 2017/2018 season to be an average of 14% or 38 traps per fisherman. Loss rates for the rock crab fleet may be lower because traps are on average set in deeper water with less wave energy and are often attached to each other in strings and are therefore heavier and less likely to move.

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

The rock crab fishery is subject to a requirement to service trap gear at intervals no greater than 96 hours with exceptions due to weather (FGC § 9004). Adherence to this requirement is thought to decrease trap loss because traps, floats, and lines will be better maintained and are less likely to have shifted in position than if they were unattended for a long period of time. Reducing trap loss reduces the density of gear within the habitat and associated impacts from traps rolling or dragging across the bottom.

3.2 Requirements for Person or Vessel Permits and Reasonable Fees

Participation in the commercial Rock Crab fishery requires a valid general trap permit issued pursuant to FGC §9001 and either a northern or southern rock crab trap permit (§125, Title 14, CCR) (Table 3-1). In addition to a northern or southern rock crab permit, commercial fishermen must also have a commercial fishing license and vessels need to be registered as a commercial fishing boat. Required licenses and fees are outlined below. Recreational take of Rock Crab requires a valid sport fishing license with an ocean enhancement stamp (§700, Title 14, CCR). No licenses are required for fishing on piers or for persons under 16.

Table 3-1. List of fees for commercial take of rock crab. All fees include a nonrefundable 3% application fee (Accessed May 13, 2019 https://www.wildlife.ca.gov/Licensing/Commercial/Descriptions).

Permit	**Fee (US dollars)**
Commercial Fishing Licenses for residents 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.	$145.75
Commercial Fishing Licenses for non-residents 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.	$431.00
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	$379.00
Northern Rock Crab Trap Permit fishermen need to have a permit specific to rock crab. Both the open access northern rock crab and the limited entry southern rock crab trap permit annual renewal fees are.	$373.75
Southern Rock Crab Trap required for any person using traps to take, possess aboard a vessel, use as bait, or land rock crab, including Brown, Yellow and Red Rock Crab for commercial purposes south of 36°N. latitude (at Lopez Point, Monterey County).	$373.75
General Trap Permit (limited entry or restricted access) an annual fee required for any person who uses traps to take finfish, mollusks, or crustaceans for profit, except Spiny Lobster and Dungeness Crab	$54.05

4 Monitoring and Essential Fishery Information

4.1 Description of Relevant Essential Fishery Information

FCG §93 defines Essential Fishery Information (EFI) as “information about fish life history and habitat requirements; the status and trends of fish populations, fishing effort, and catch levels; fishery effects on age structure and on other marine living resources and users, and any other information related to the biology of a fish species or to taking in the fishery that is necessary to permit fisheries to be managed according to the requirements of this code”.

Lack of knowledge about the biology of the three species making up California’s rock crab fishery has resulted in the lack of useful indicators of stock status. Observations of the smallest females with eggs in the field and laboratory suggest that the legal size limit may be appropriately set. However, the proportion of the population that is mature at those sizes, growth rates, and longevity are not well understood. There is no historic information on the size structure of the catch and only localized, limited term studies of size structure have been undertaken in recent years.

In addition, there is limited information from routine monitoring of the kinds of data that are usually used to assess changes in a fishery over time. CPUE cannot be used to track stock status due to the lack of data on the number of traps used by fishermen. Historical catch was not required to be reported to the species level until 2010. There are also no fisheries-independent surveys tracking abundance indicators. This section summarizes the EFI that is collected for this fishery, but overall the rock crab fishery is very data-poor.

4.2 Past and Ongoing Monitoring of the Fishery

4.2.1 Fishery-dependent Data Collection

Monitoring information currently consists solely of landing receipts. Data collected on these receipts include:

- weight by species (some still use the market code for unspecified rock crab)
- 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

Two past academic studies done in collaboration with the commercial fleet have been performed. Culver et al. (2010) focused on the Santa Barbara Channel and northern Channel Islands and reported species compositions, size structure, and CPUE during a 5-month period of 2008. Similar collaborative data collection was repeated in 2018 and results have not yet been published. Fitzgerald et al. (2018) applied a suite of data-limited stock assessment techniques to the landing receipt data. Techniques included productivity susceptibility analysis, cumulative sum control charts, and examining changes in the spatial distribution of the catch, species composition, and catch by permit type. Results suggested evidence for serial depletion among the species, regional overfishing, and effort creep.

4.2.2 Fishery-independent Data Collection

There are currently no rock crab fishery-independent data collection efforts.

5 Future Management Needs and Directions

5.1 Identification of Information Gaps

The rock crab fishery has a number of information gaps. These gaps are described below and summarized in Table 5-1.

Table 5-1. Informational needs for rock crab and their priority for management.

Type of information	Priority for management	How essential fishery information would support future management
CPUE	High	Provides information on long-term increases or decreases in the catch rate, which can provide a proxy for fluctuations in abundance. If catch decreases but effort stays the same it suggests a change in the productivity of the stock.
Species-specific landings	High	Needed to assess serial depletion, recruitment variability, and species-specific range/habitat.
Recruitment variation and distribution	Medium	Needed to determine relative influence of harvest and environmental factors on stock status.
Growth and longevity	Medium	Needed to assess reproductive opportunity provided by size limits and needed for stock assessment application.
Reproductive biology	Medium	Needed to assess benefits of fishing seasons and size limits.
Natural mortality	Medium	Needed to understand the contribution of harvest to total mortality and for stock assessment application.
Size structure of the catch	Medium	Used to estimate total mortality and monitor long term fishing impacts.
Movement	Low	Needed to determine potential for harvest to produce local depletion.

Life History

Much of the critical life history information for rock crab remains unknown. While observations of the size of females with eggs have been reported in the literature, the viability of the eggs produced by small females has not been assessed, nor has the proportion of females at those sizes that are mature. Reproductive seasonality and growth rates are also poorly understood. Therefore, it is difficult to assess the reproductive opportunity between the reported size at maturity and the legal size. Improved reproductive seasonality information would be needed to understand the potential impacts of using one or more fishing seasons as a management tool. Growth and longevity information are necessary for application of many stock assessment techniques. Other basic life history characteristics such as natural mortality, movement patterns, and length-weight relationships have gone unstudied or unreported. There is also little information on recruitment variability. Winn (1985) described habitat choices for settlement of the three species. Improved understanding of distribution and survival of early life history stages and relationships with environmental factors is needed to discern the relative influence of environment and harvest on stock status.

Fishery Data

For most of the history of the rock crab fishery, landings were not reported to the species level. Although reporting by species was required in 2010, 13% of the landings were still being reported as unspecified in 2018. Without accurate species-level landings, the impact of the fishery on each species cannot be assessed, nor can processes like serial depletion. The landings trend is artificially smoothed when the species are grouped, i.e. grouped landings exhibit less year-to-year variability than individual species-level landings. Therefore, they cannot be used as a proxy reflecting recruitment variability or other population dynamics.

Currently, the only available data that may reflect shifts in effort over the history of the fishery is the number of submitted receipts, which provides data on the number of fishing trips per year. Receipts as a proxy for effort do not capture potential changes in the numbers of trap pulls associated with each landing. The time series of receipts submitted, which has been relatively stable the last 10 yr, does not track the increase in rock crab landings that occurred between 2011 and 2015, nor does it reflect the increases in effort anecdotally described by the fleet. As of 2018, the fleet reports gear saturation of the fishing grounds. Implementation of an at-sea logbook, ideally one that can be easily paired with landing receipt data, is needed to fill this data gap.

Due primarily to the fishery data information gaps, there are a lack of reference points that directly relate to indicators of overfishing or an overfished state, as well as targets or timeframes for rebuilding should the fishery be deemed overfished. Efforts to apply data-limited MSE modeling techniques to the fishery are currently under way. This may provide guidance on management procedures that are robust to the various uncertainties for this fishery as well as prioritize data gaps for research attention.

5.2 Research and Monitoring

5.2.1 Potential Strategies to Fill Information Gaps

The most critical information gap is fishery effort and this could be filled by implementing a mandatory at-sea logbook, requiring new rules be placed in the CCR. Species-specific landings are already required so additional outreach and enforcement are needed to meet this need. A combination of collaborative research with the fleet and other academic or Non-Governmental Organization (NGO) partners is needed to fill many of the gaps in life history information. Fleet collaboration would be particularly effective for a tag-recapture study to inform estimates of abundance, growth and movement. Fleet and academic collaboration could be used to monitor reproductive characteristics paired with laboratory analysis of egg count and viability. Academic collaboration would additionally be helpful for testing various methods of aging crabs and improving estimates of growth and longevity (see section 1.2.2). Rock crab larvae may be present in plankton samples collected by the California Cooperative

Oceanographic and Fisheries Investigations (CalCOFI). These samples could provide an extremely valuable long-term time series useful for examining stock-recruitment relationships, population connectivity, and larval survival patterns.

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, NGOs, 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.

Collaboration with volunteers from the commercial fleet is extremely valuable for accomplishing research goals. Commercial fishermen have equipment and critical fishing knowledge that agency and academic institutions often do not. Several in the rock crab fleet have already participated in collaborative studies implemented by researchers at the University of California, Santa Barbara in 2008 and 2018. Others are currently working with the Department on the Box Crab experimental gear permit research program. These past and current programs have demonstrated the power of successful partnerships and the willingness of this fleet to collaborate. A tag-recapture study in collaboration with the fleet could provide valuable information on abundance, growth, molting patterns, reproductive biology and movement. Culver et al. (2010) tested methods for working with fishermen volunteering for trap sampling and data collection at-sea beyond what is required on logbooks and identified sampling levels that accurately reflect the broader catch. Implementing similar methods in long-term monitoring of CPUE and size structure of the catch could provide valuable validation of what is reported on logs along with additional information beyond logs.

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.

The highest priority for management changes should be improvement of fishery-dependent data streams, particularly implementation of an at-sea logbook requirement. This would likely be the most cost-effective way to begin monitoring effort of the fleet. Anecdotal reports from the fleet suggest that effort is high relative to the past and that the population is showing signs of high fishing pressure such as lower average size. Outreach to the fleet through survey mailers and in-person meetings could be used to broaden managers’ perspective on the stock status, confirm these reports, request information on past and current effort levels, and gauge willingness to accept different management approaches. An alternative to logbooks could be implementation of electronic monitoring tools. These tools are currently being tested through the Box Crab experimental gear permit research program that will demonstrate benefits and drawbacks to the technologies. While more expensive than self-reported logbooks, electronic monitoring can provide a broader set of data types that are highly accurate with less burden on fishermen. Reporting of species-level landings on landing receipts should also be a priority. Use of electronic landing receipts will be required for all buyers in July 2019. Outreach associated with use of the electronic system (eTix) could also highlight this need. Removal of the unspecified rock crab market code as an option in the system should be considered.

If research and fleet outreach identified that the stock is exhibiting signs of depletion, additional management actions may be taken. The most easily implemented management procedures will likely be effort (input) controls. These may include a limit on the number of traps each permit holder is permitted to use and an associated trap tag program similar to California's Spiny Lobster and Dungeness Crab fisheries. Trap numbers could be allocated equally across all permit holders or be tiered based on landings history and other factors. Other effort controls might include implementation of one or more closed seasons and revision of the permit transfer process. Specific allowances for new fishery entrants could be considered as a means for mitigating effort creep as latent permits transferred to new fishermen. Such an approach might also be paired with an apprenticeship program that ensures new entrants have the appropriate skills to avoid gear conflicts and other unnecessary resource impacts.

Output controls could also be considered as management measures for the rock crab fishery, although they may be more difficult to implement. The legal size limit could be either increased for all three rock crab species or customized based on their life histories. An annual total allowable catch and/or quota system is not currently recommended. Greater certainty in the sustainable level of take would be needed to implement a total allowable catch and sufficient information to estimate this is currently unavailable. Additionally, allocation of a quota system is complex and may be unnecessarily restrictive.

5.4 Climate Readiness

As noted in section 1.2.1, landings of rock crab appear to be negatively correlated with PDO. However, high landings in 2014 and 2015 coincided with high PDO values and warm temperatures highlighting that the relationship is not consistent. The drop in landings in 2016 may be related to warm temperatures experienced in the previous years. Research into the mechanisms of this relationship is needed to anticipate potential climate change impacts. Mechanisms might include temperature effects on larval or juvenile survival, growth rates across the size distribution, or reproductive output. As noted in section 5.2.1, leveraging existing CalCOFI samples by developing a time series of larval rock crab abundance would be extremely valuable for understanding environmental influences on rock crab population dynamics.

Warming temperatures and/or temperature anomalies in California waters appear to be increasing the frequency and duration of blooms of the diatom Pseudo-nitzschia that produces the neurotoxin domoic acid. However, the precise conditions that foster blooms and toxin production are not well understood (Smith et al. 2017, 2018). Regardless of the precise conditions, we may anticipate that climate change will result in continued increase in these events. Domoic acid concentrations above the allowable human health threshold were detected at an unprecedented scale beginning in 2015 and have impacted California's Rock Crab, Dungeness Crab, and Spiny Lobster fisheries. Since that time the crab fisheries have experienced multiple closures mandated by the state's health agencies and implemented by the Department, which have resulted in Federal disaster relief. Further research into the oceanographic conditions fostering blooms and toxin production will be needed to better predict the impacts of climate change. Studies of the diets and ecological roles of target species impacted by domoic acid are also needed to anticipate specific fishery impacts. Finally, developing permits and procedures for continuing to sell some seafood products safely and within the confines of health agency rules even while domoic acid levels are high may minimize impacts to the fleets.

As we improve our monitoring and understanding of rock crab populations, we may find changes in productivity and distribution linked to climate change. We might consider building flexibility into any new management procedures that are implemented in order to be responsive to change. For example, if the permit structure is revised in the near term to deal with capacity issues, we might anticipate that the boundary between the northern open access and southern limited access permits may need to shift. Any new catch controls related to targets and limits may need to be readily adjustable as targets and limits need to change with changing productivity.

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