1 The Species

1.1 Natural History

1.1.1 Species Description

The Red Sea Urchin, *Mesocentrotus franciscanus*, (previously *Strongylocentrotus*, A. Agassiz, 1863) is the largest sea urchin in the world, a group that encompasses over 900 species. The maximum size for Red Sea Urchin is about 7 in test diameter and their color ranges from various hues of pink, red, burgundy, and purple. Red Sea Urchins belong to the phylum Echinodermata (meaning “spiny-skinned), which includes sea stars, brittle stars, sea cucumbers, and sand dollars. Urchins have a hard, dome-shaped shell known as a “test”, which is covered with spines used for defense, movement, and catching drift kelp. Tube feet cover the test of the sea urchin and are used for locomotion and passing food to the mouth. The mouth is located at the base of the urchin, consists of five plates that make up a jaw structure commonly known as “Aristotle’s lantern”, which is used for scrapping kelp.

Commercial divers harvest Red Sea Urchins for their roe, called ‘uni’, which are sought after both domestically and exported around the world. Beside the Red Sea Urchin, there are other sea urchins in California including the commonly found purple and Coronado sea urchins, both of which are not typically harvested for commercial purposes.

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Figure 1-1. The underside (left) and top (right) of a Red Sea Urchin.

1.1.2 Range, Distribution, and Movement

Red Sea Urchin are found from the Gulf of Alaska near Kodiak Island, Alaska down the tip of Baja California, Mexico (Figure 1-2). This species has also been reported in Japanese waters (Mortensen, 1943). They occupy primarily rocky habitats under ledges, rock piles, and cracks from the shallow intertidal to depths of 300 feet. Juvenile sea urchins are often found underneath an adult "spine canopy" and near adults, most likely for protection from predators (Breen et. al 1985). Red Sea Urchins are typically more abundant on the outside edges of the kelp beds to take advantage of more plentiful drift kelp. In California, Red Sea Urchin are found statewide with the higher concentrations in southern California on the mainland coast and offshore islands; and in northern California near on the Mendocino and Sonoma County coastlines. Significantly fewer Red Sea Urchin are found in the sea otter zone (from south of San Francisco to Point Conception) due to the high rates of invertebrate predation by otters, and thus commercial harvest is mostly void in these areas.

Movement of sea urchin is related to several factors including availability of food, water turbulence, substrate type, depth, light intensity, seasonal cycles, predation, etc. They tend to move more when food is scarce and less when food is abundant. In one study, mean sea urchin movements varied from 7.5 cm/day inside the kelp forest to over 50 cm/day at 15 and 100 meters outside the kelp forest (Mattison 1976). Tagged individuals in shallow habitats were observed in their home "bowls" for six consecutive days, while tagged urchins in deep water were highly mobile, moving 6.5-9.8 feet (2-3 m) in one day (Rogers-Bennett and Bennett, 1995). Following oceanographic events such as El Niños, barrens occur in southern California wherever kelp beds die off, causing shortages of standing and drift algae. These food shortages may trigger urchins to aggregate and move in eating "fronts", denuding the sea floor of kelp and other algae.

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Figure 1-2. Range of Red Sea Urchin.

1.1.3 Reproduction, Fecundity, and Spawning Season

Red Sea Urchins become sexually mature at 2-inch test diameter, when they are approximately two years old (Bernard and Miller, 1973). They can live to be more 50 years old in California (Ebert and Southon, 2003), but show no signs of senescence (Ebert 2008). As a result, Red Sea Urchin are viable and productive reproducers even in old age and the larger the individual, the larger the spawn mass. The spawning season of Red Sea Urchin appears to vary depending on locality and sometimes even from year to year at the same place (Kato and Schroeter, 1985). Food supply (Rogers-Bennett, 2007) and ocean temperatures appear to play major roles in the timing and magnitude of spawning. In most southern California locations, spawning

As with many marine invertebrates, fertilization is external, and success is highly dependent on and sensitive to population parameters and environmental conditions (Levitan et al. 1992) since Red Sea Urchin are broadcast spawners (release egg and sperm in water). The success rate of fertilization, based on laboratory experiments, increases with group size and aggregation, decreased flow velocity, and central and down current positions within an aggregation (Levitan et. al, 1992; Quinn et. al 1993). Subtidal studies suggest that Red Sea Urchins at densities of less than two per square meter can have poor fertilization success. Females spawn up to several million eggs at a time and larval development is

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dependent on temperature and the abundance of phytoplankton (single-celled algae) and is thought to extend for six to eight weeks. As the larvae mature, they settle to the bottom and progress to the juvenile life-stage; however, they can spend a long time drifting with water currents before settling. This allows juvenile sea urchins to disperse long distances from the adults that spawned them.

Recruitment in southern California appears to be relatively constant, while in the north recruitment rates are lower and more sporadic. Settlement patterns have been studied for red and purple sea urchins on artificial substrates at sites in northern and southern California since 1990 (Schroeter et al.). Peak settlement periods tend to be in spring and early summer, although there is substantial year-to-year variation in timing and intensity. Settlement also tends to be less variable south of Point Conception and is depressed during El Niño events. The more variable pattern of settlement in northern California is consistent with the more energetic offshore movement of water during spring periods when larvae are present, especially around headlands. Consequently, El Niño events appear to favor settlement in the north as offshore water movement becomes reduced. Recruitment patterns (that is, the number of individuals reaching a specific life-stage such as legal size) of Red Sea Urchins in northern and southern California generally mirror those of settlement.

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.

Red Sea Urchin are very long lived, attaining ages of 100 years or more in Alaska and Washington State and more than 50 years in California (Ebert and Southon, 2003). Natural mortality is thought to be higher in southern California populations than in northern California. In northern California it has been estimated that 5-20% of the Red Sea Urchin will die per year and in southern California the annual mortality rate is estimated at 8-40%. Likely mechanisms include a greater abundance of predators in southern California (Morgan et al. 2000) and higher rates of disease and temperature-related stresses due to the warmer water in the south.

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.

Sea urchin growth rates are highly variable and are dependent on food availability and geographic locations. Growth rates must be determined by tagging and recapturing by means of internal tags (“PIT” tags), or chemical (fluorescent) markers that bind to calcium, because direct ageing of sea urchins is difficult (Ebert and Southon 2003). Red Sea Urchin are slow growing animals and can take on average 7.2 ± 1.3 years to enter the fishery (at test sizes of 76 mm) with a range of 5.9 to 9.2 years (Rogers-Bennett 2003).

1.1.6 Size and Age at Maturity

Bernard and Miller (1973) found that Red Sea Urchins reach sexual maturity at 40–50 mm test diameter in a study conducted around Vancouver Island in Canada. There does not appear to be any studies directly assessing size-at-maturity from the southern California region. However, Tegner (1989) demonstrated that, in urchins collected near San Diego, California, gonad weight increases exponentially from about 40 mm on (Figure 1-X). This suggests that while urchins in southern California begin to mature between at sizes between 40 and 50 mm, animals at this size are likely to make minimal reproductive contributions to the population (Tegner 1989). It is assumed that all individuals are fully mature by the legal-size limit (76 mm) (Teck et al. 2017).

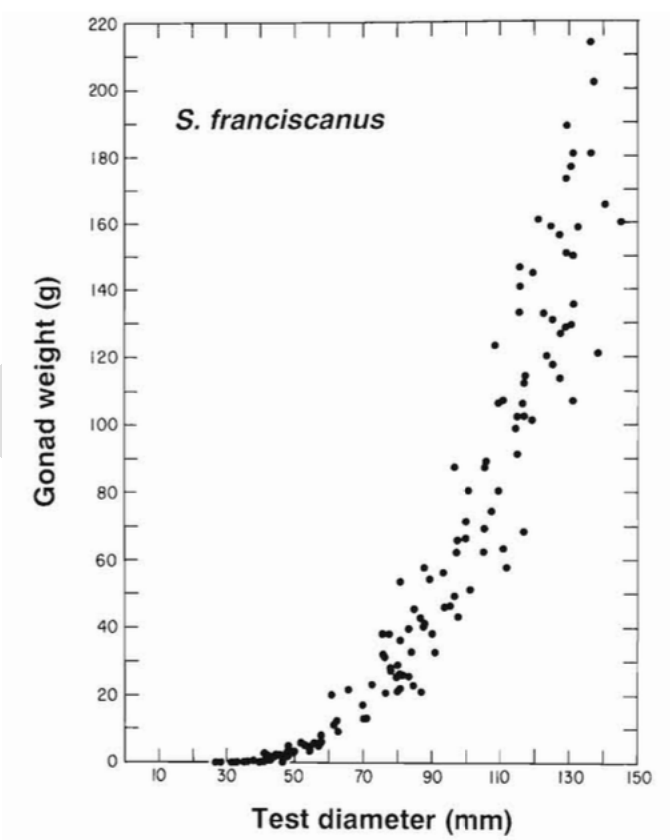

Figure 1-3. Gonad weight (in g) vs. test diameter (in mm) for Red Sea Urchin collected in 1975 from Point Loma, California (Reproduced from Tegner 1989).

1.2 Population Status and Dynamics

Historically the Red Sea Urchin fishery has had its peaks and drops in landings depending on the market and number of participants in the fishery, but recent environmental changes, leading to a significant decrease in kelp beds, has led to drastic landings decreases that have not been seen by this fishery since the beginning (1970s). From 2000-2014, landings were stable and the fishery was productive with statewide landings at 10-15 million pounds per year. The Department and the industry were not greatly concerned about the overall sustainability of the resource given the amount of harvest taking place. However, in 2013-2014 kelp forests were greatly reduced leading to a gradual decline in invertebrates that feed upon bull and giant kelp like Red Sea Urchin and abalone. In northern California, kelp forests became 93 percent smaller compared to previous years, creating starvation conditions for herbivores (Cynthia Catton, CDFW). Other factors contributed to more concern including a dramatic increase of black spot disease showing up in Red Sea Urchin. Some areas in southern California appeared to be wiped out of Red Sea Urchin as a result of disease.

- Summarize reduction in RSU density on north coast, PISCO, and KFM
- Summarize decrease in CPUE from logbooks? And landing receipts
- Summarize in decrease fishery participation (# divers making landings)
- Summarize changes in size (and legal size) of red sea urchin at KFM and PISCO sites

Fleet dynamics have changed in the last decade as well from an increasing concern for the resource by managers and the industry. Typically, less than half of the divers with permits will make most of the landings in this fishery. Because of a growing concern for latency and the potential to overfish the stock, the capacity level dropped to 150 permits in 2017, which will take many years to attain.

Although a decrease in capacity will aid in future surges in market demands, it does not address the current take of Red Sea Urchin because it only prevents future explosions in participation. Divers commonly report that productive reefs with harvestable sea urchin are highly impacted from a decrease in kelp production and fewer fishable areas due to MPAs and military closures, which in turn limits the best areas to fish. So, although MPAs protect future spawning sea urchin, and may increase spillover into fishing zones, MPAs are also contributing to condensing divers into fewer harvestable areas.

The Red Sea Urchin in California has been managed minimally and depends on effort reducing schemes to limit take and ensure multiple spawning years per individual. This strategy has worked up to this point. The management of this fishery does not include biomass estimates required to set a fishery quota or IFQs if that is what the future holds. The fishery does not incorporate harvest control rules using spawning potential, density, biomass, CPUE, harvest rates, etc. Therefore, the Department relies

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on landings and logbook data form the fishery dependent information and dive surveys for looking at changes in size and density between fished and non-fished areas.

1.2.1 Abundance Estimates

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1.2.2 Age Structure of the Population

Current literature does not include an adequate age structure study of Red Sea Urchin populations in California. There are, however, age/growth studies that could be used as a proxy to determine the age structure of select reefs in the most commonly harvested reefs in the state. Because sea urchin are long-lived, it would be difficult to properly assess the age structure of the population without a thorough age evaluation of the studied area. In addition, multiple latitudes of the state would need to be included given that northern sea urchin are most likely older.

In the absence of age structure data, size structure can provide an indicator of population status. A healthy population has a a broad age structure composed of small/young recruits, moderate sized individuals, and large individuals.

1.3 Habitat

Red Sea Urchin are most often found on rocky-reef structure in shallow waters from the low-tide line extending to at least 300 feet, often under ledges, crevices, and cracks. They often live in smooth depressions in the reef created from years of grinding and eroding. Red Sea Urchin prefer more sheltered areas of the coastline and offshore islands and are highly associated with kelp beds and areas of other abundant algae.

1.4 Ecosystem Role

Red Sea Urchin are major grazers in the shallow seas of California and if left unchecked, can denude an area with urchin fronts quickly, changing the kelp bed landscape and affecting many other fish and invertebrate species. The juveniles and adults are eaten by various fish and invertebrates, and they are also a favorite food item for sea otters.

The red sea urchin's ability to survive during periods of food shortage contributes to its ability to persist in high densities in areas devoid of algae, known as "urchin barrens". Based on examination of long-term aerial photos and on kelp forest ecology studies in northern San Diego County, sea urchin grazing at its most severe probably accounts for about 20% of kelp mortality in a given kelp bed. Conversely, the intense fishery for red sea urchins in northern California appears to have had a positive effect on kelp availability. Aerial photographs of surface kelp at one location in northern California showed a 15-fold increase surface canopy from 1982 to 1989 during a period of concentrated urchin fishing.

As with other kelp forest herbivores in California, the sea urchin's role in the ecosystem can appear to be mostly destructive because they consume vast amounts of food, reduce cover, and minimize breeding grounds for other invertebrates and fish that depend on kelp forests. However, they also play a role in harboring and protecting the larvae and juvenile stages of many of the same invertebrates and fish.

1.4.1 Associated Species

Red sea urchins may compete with abalone for both space and food. A recent study on competitive interactions between these species at sites in northern California concluded that there is an inverse relationship between them that favors red sea urchin at sites where neither species is at low densities. Sea urchins may be more successful in competing for limited food because of their aggressive foraging and ability to survive starvation conditions. Fishing for abalone and sea urchins has no doubt altered these relationships.

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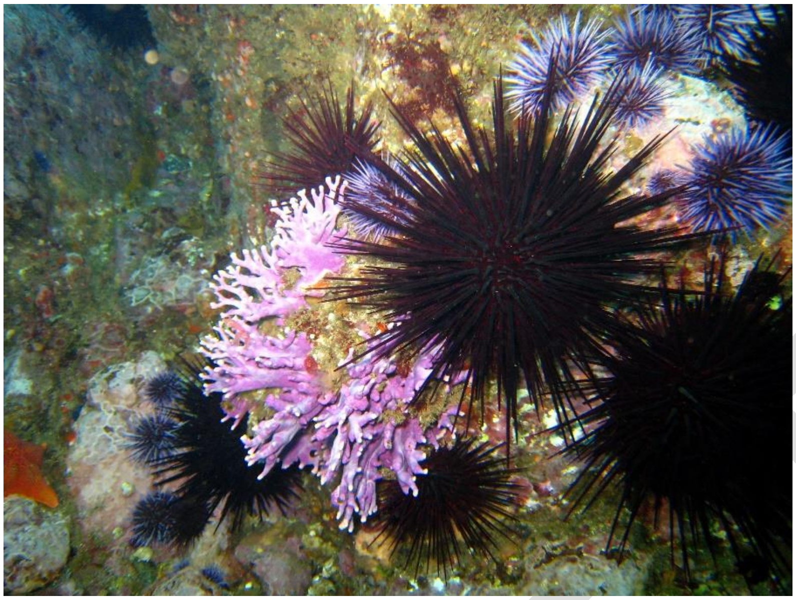

1.4.2 Predator-prey Interactions

Red sea urchins have many predators, including sea otters, spiny lobsters, sea stars, crabs, white sea urchins, and fishes such as California sheephead. Within the sea otter's present range, the Red Sea Urchin resource has been reduced to a level which precludes fishery utilization. There is some evidence that sea urchin in barrens, diminished gonad production, are less appealing to predators (Eurich et al 2014).

Urchin diseases have decimated the sea urchin populations of Caribbean islands; however, the dynamics of sea urchin diseases in California remains poorly understood. Sea urchins in southern California are especially susceptible to disease during warm-water El Niño events

Newly settled juvenile urchins are very vulnerable. uveniles are preyed upon more often in kelp forest habitat, where predators are presumably more abundant than in similar rocky habitats just outside of kelp beds. Adult sea urchins and their spines are important protective structures in subtidal communities. The canopy formed by the spines is a micro-habitat that shelters juvenile sea urchins, shrimps, crabs, brittle stars, fish, abalone, and other invertebrates. The spine canopy is most likely an important habitat for juvenile sea urchins, especially in areas where alternative cryptic habitats (such as crevices and undersides of boulders) are rare or absent.

Sea urchins are omnivorous, but mostly eat leafy algae. The perennial giant kelp is their preferred food in southern California, whereas in northern California urchins feed on the annual bull kelp and perennial brown algae. The red sea urchin's ability to survive during periods of food shortage contributes to its ability to persist in high densities in areas devoid of algae, known as "urchin barrens".

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2 The Fishery

2.1 Location of the Fishery

The Red Sea Urchin fishery is divided between the northern and southern areas of the state with minimal landings occurring between San Francisco Bay and Point Conception. Because of predation by sea otters, Red Sea Urchin stocks in central California occur at densities too low to sustain a commercial fishery. Since the early 2000s, Red Sea Urchin have become fully exploited throughout its range in both northern and southern California.

Since 1971, the northern fishery (Figure 2-1a) has been centered in Mendocino County near the city of Fort Bragg with fewer landings occurring south in Sonoma County. Landings for the southern fishery (Figure 2-1b) have occurred mostly at the northern Channel Islands, San Nicolas and San Clemente islands, and mainland coast mostly near San Diego. The most abundant harvest has occurred at the northern Channel Islands, more specifically at San Miguel and Santa Rosa islands, which exhibit large, accessible kelp beds that nurture a productive stock.

a) b)

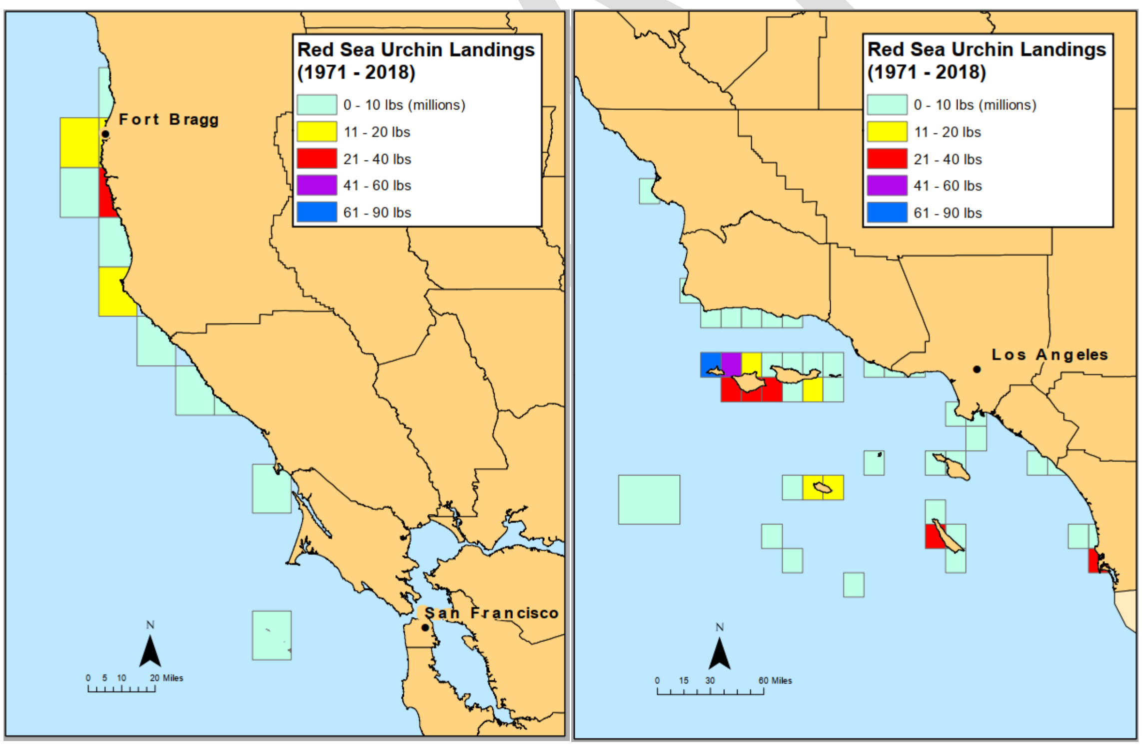


Figure 2-1. Locations of historical Red Sea Urchin landings in a) northern California and b) southern California, 1971-2018 (CDFW Marine Landings Database System (MLDS))

2.2 Fishing Effort

2.2.1 Number of Vessels and Participants Over Time

The Red Sea Urchin fishery was open access at its emergence in the early 1970s, and a permit was not required until 1984. It was not until 1986 when the Fish and Game Commission had the authority to limit the number of sea urchin diving permits, and a moratorium on new permits went into effect in 1987. In that license year, the permit count jumped from 212 to 938, an increase that was most likely due to the upcoming limitation on permits triggering a buying frenzy. In 1989, the restricted access program went into effect and diver participation (divers making landings) peaked from 1990-1994 (Figure 2-2). In subsequent years, the fishery went through a period of steep decline in both participation and landings until it stabilized in the early 2000s with participation dropping below 400 divers. This steep decline may be attributed to many factors, but most likely many of the divers buying into the fishery prior to limited access lost interest and did not renew their permits.

Throughout the 1990s the permit capacity gradually decreased and stabilized to near 300 in each year from 2007-2018. In 2017, another permit capacity reduction program was implemented with a goal 150 permits. The Red Sea Urchin fishery has undergone a series of market shifts, environmental events leading to a limitation of harvestable stock, and changes in fleet dynamics, which all effect the level of participation and landings.

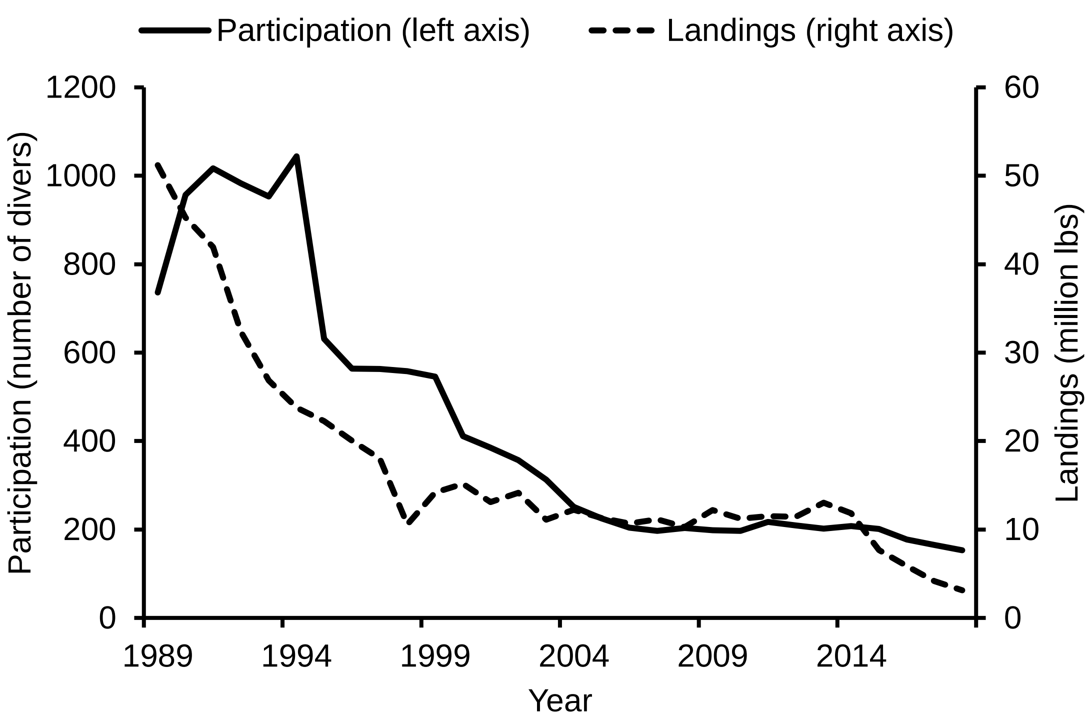
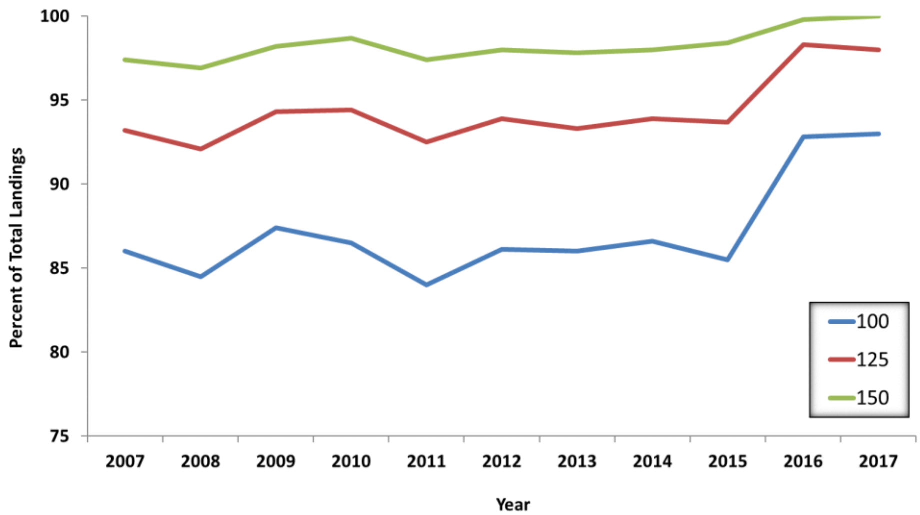


Figure 2-2. Red Sea Urchin fishery participation (number of divers) and landings (million lb), 1989-2018 (CDFW Commercial Fisheries Information System 2018).

This fishery has always had a significant level of latent harvest potential from non-active sea urchin permit holders and this was the major reason for a capacity reduction in 2017. During the years of 2007-2018, when the number of sea urchin permits was near 300 permits, 97-100 percent of the landings were made by 150 divers (Figure 2-3). During that same period, 92-98 percent of the landings were made by 125 divers and 84-93 percent of the landings were made by only 100 divers. A significant portion of the fishery has not been contributing to the total landings and this is becoming more of an upward trend as fishing has become more difficult in recent years.



2.2.2 Type, Amount, and Selectivity of Gear

The Red Sea Urchin fishery is exclusively a diver-based fishery. Sea urchin are harvested by hand using an urchin rake or similar device (Figure xx) so it is a highly selective fishery. Most divers use "hookah" which is a surface-supplied air system consisting of a compressor (gas or electric), a reservoir which maintains a constant volume of air, and a length of hose leading down to a back harness and regulator for the diver to breathe from (Figure xx). The hookah system provides a diver with an almost unlimited supply of air which allows them to stay down longer. Conventional SCUBA gear, used by fewer divers, is used for scouting sites or when divers don't want to be limited by the length of a hose for picking urchins. SCUBA also allows divers to cover more area; however, SCUBA cylinders have a limited supply of air. Some divers also utilize enriched-air Nitrox with SCUBA to maximize bottom times and reduce surface intervals.

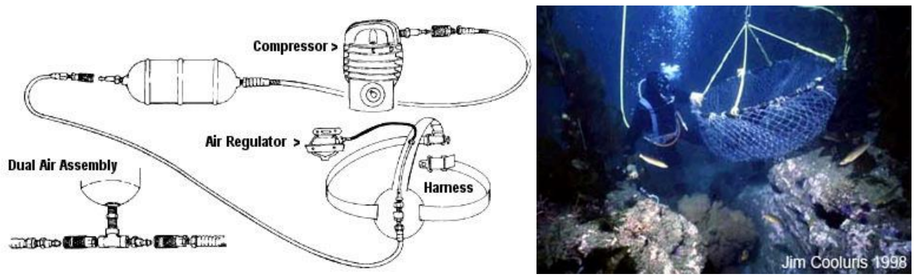


Figure 2-4. Diagram of “hookah” gear keeneeng.com and diver collecting sea urchin into a collection bag.

A typical sea urchin vessel is 20-30 feet long with a carrying capacity of 2,000-6,000 lbs. Historically, these boats have been made by Radon or Wilson. The chief criterion, besides adequate carrying capacity, appears to be speed, which is important because some of the fishing grounds are a considerable distance from port (Kato and Schroeter 1985). Urchin boats will typically fish for one day, but overnight trips are common, especially at the offshore islands in southern California.

2.3 Landings in the Recreational and Commercial Sectors

2.3.1 Recreational

Recreational sport fishermen are currently permitted to harvest 35 Red Sea Urchin per day under the General Invert section of the sport fish regulations 29.05 with no size restrictions or seasonal closures. Harvest is not tracked nor sampled. Communications from sport divers indicate that picking sea urchins is becoming more popular with an increase of ‘uni’ demand along with fewer opportunities to harvest invertebrates such as abalone.

2.3.2 Commercial

There have been two periods of rapid fishery expansion, one in southern California and one in northern California. The first one culminated in 1981 when landings, all in southern California, peaked at 25 million lbs with an ex-vessel value of 4.7 million dollars as commercial abalone fishermen transitioned to urchin fishing as the

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abalone population declined in southern California. Sea urchin landings decreased following the El Niño event of 1982-1983 when warm water weakened or killed kelp, the primary food source for sea urchins. Landings did not recover until the 1985-1986 season, due in part to the strengthening of the Japanese yen relative to the US dollar, which gave California fishermen and exporters more economic incentives.

The northern California commercial sea urchin fishery began in 1972, and remained insignificant until 1977, when 386,000 lbs were landed in the Fort Bragg region. The second major fishery expansion began in 1985, fueled partly by decreasing landings in southern California and favorable monetary exchange rates. The large and unexploited sea urchin biomass in northern California sparked a “gold rush” as hundreds of new fishermen entered the unregulated fishery. In northern California (from Half Moon Bay in San Mateo County to Crescent City in Del Norte County) landings jumped from 1.9 million lb in 1985 to 30.5 million lb in 1988, far exceeding landings from southern California.

In 1988, the California Red Sea Urchin catch peaked at 52 million lbs, ex-vessel value of 13 million dollars and the landings declined steadily to 13.1 million lbs in 2001 with an ex-vessel value of 11.7 million dollars. In the 1990s, the fishery was impacted by two El Niño events (1992-1994 and 1997-1998) and a weakening Japanese economy that lowered demand and ex-vessel prices; both factors contributed to reduced fishing effort and catches.

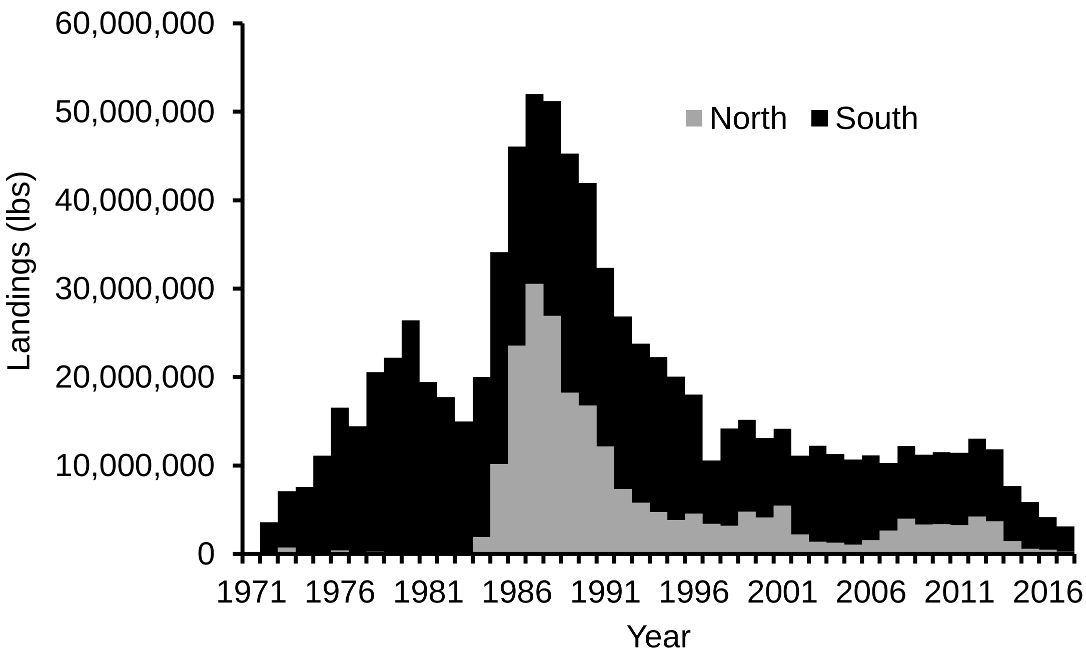


Figure 2.x. Red sea urchin landings (lbs) north and south, 1971-2018.

Throughout the 2000s to 2014, the Red Sea Urchin fishery remained in a period of stability with landings between 10-15 million pounds statewide and an ex-vessel value between 5.1-14.9 million dollars per year. Landings took a turn downward from 2015 at 7.7 million pounds and 6.6 million dollars ex-vessel value and dropped to the lowest landings in the history of the fishery in 2018 with only 3.1 million pounds landed statewide with an ex-vessel value of 5.9 million dollars. This downturn can be attributed to the "warm blob" in 2014 combined with a strong El Niño event starting in 2015, an outbreak of diseased urchin and increased impaction of divers in the remaining harvestable areas.

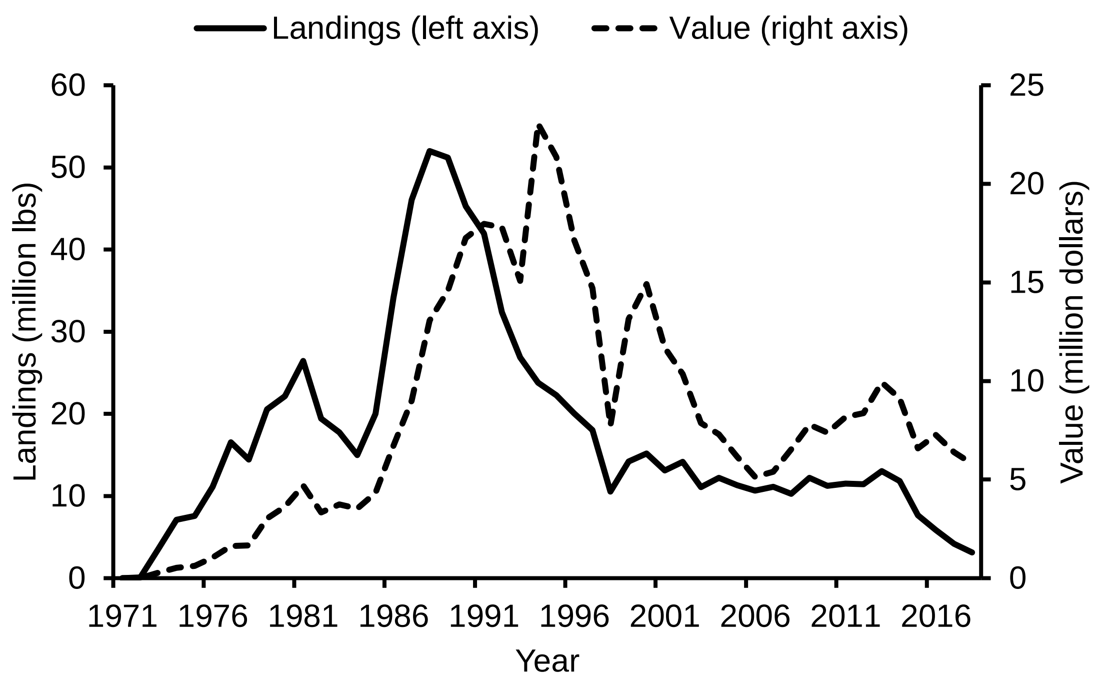


Figure 2-6. Red Sea Urchin commercial fishery landings (million lb) and value (million dollars), 1971-2018 (CDFW Commercial Fisheries Information System 2018).

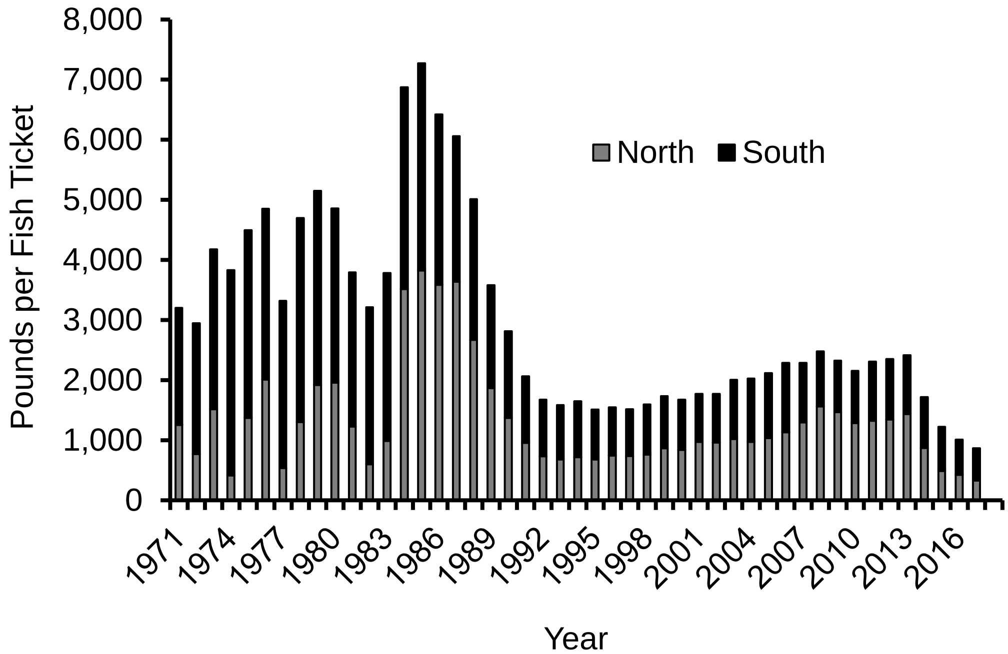
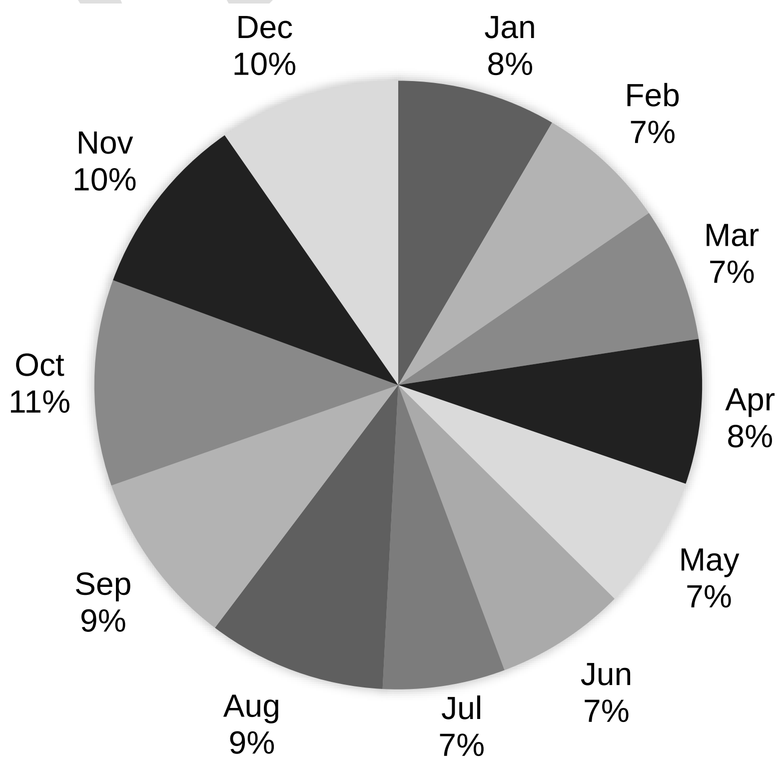


Figure 2-x. Red Sea Urchin commercial fishery landings per fish ticket in the north and south, 1971-2018 (CDFW Commercial Fisheries Information System 2018).



2.4 Social and Economic Factors Related to the Fishery

The commercial Red Sea Urchin fishery began in southern California in 1971 as part of a program to develop fisheries for underutilized marine species by the National Marine Fisheries Service. The fishery was also seen to curb the destructive grazing of sea urchins on giant kelp. The gonads of both male and female are the object of the fishery (Figure 2-7) . Divers are size-selective and check gonad quality while harvesting to ensure marketability. The price paid to the diver for gonads is based on quality and are graded by size, color, texture, and firmness; all of which are affected by the urchin's stage of gonad development and food supply.

Many fishermen target only higher-grade Red Sea Urchin (A or B grade), which fetches a higher price. Some processors encourage divers to harvest the lower grade product for less desirable "uni" products. Many newer divers to the fishery must learn how to find quality sea urchin and often it takes many years to consistently bring in a high-grade product.

The economic importance of the Red Sea Urchin throughout its distribution is shown in Figure 2-8 by the percentage of landings (by weight) by main ports throughout the state.

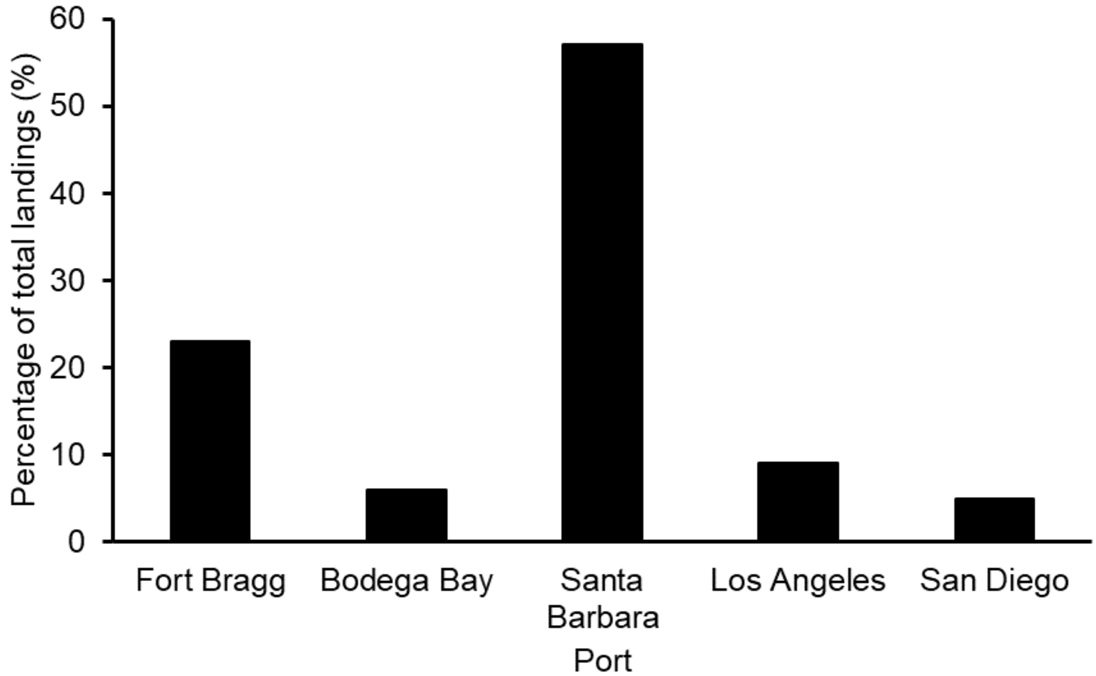


Figure 2-8. Red Sea Urchin percentage of total landings by main ports through 2018 (CDFW Commercial Fisheries Information System 2018).

Historically, Santa Barbara has been the center for the Red Sea Urchin fishery making up 57% of the landings, followed by Fort Bragg at 23%, Los Angeles at 9%, Bodega Bay at 6%, and San Diego at 5%.

Based on logbook data (CDFW MLS), Red Sea Urchin divers typically dive in less than 120 feet of water but have been known to go deeper at times to find quality urchins.

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3 Management

3.1 Past and Current Management Measures

The commercial Red Sea Urchin fishery is state managed. Responsibility for managing the sea urchin fishery originally lay with the California Legislature, but was delegated to the Fish and Game Commission (Commission) in 1973. In the early years of the fishery, management focused on reducing sea urchin densities to increase kelp abundance and urchin gonad yield. However, the rapid expansion of the fishery in the mid-1980s spawned a reassessment of this policy. The primary management measure prior to 1985 was limiting gear to rakes, airlifts and other hand appliances. Since then, the principal management actions for the commercial fishery have consisted of the significant regulations listed in Table 3-1.

Table 3-1. Significant regulations for the Red Sea Urchin Fishery.

Year	Regulatory Change
1987	Moratorium on issue of new permits
1989	Beginning of restricted access program
1988-1992	Minimum size limit introduced and increased to 3.25 in south and 3.5 in north
1990	Northern California fishing restricted to 233 days per year
1990	Effort reduction scheme requiring 10 permits to retire for each new entrant
1992	Southern California fishing restricted to 240 days per year
2008	Statewide fishing restricted to 300 days per year
2017	Southern California fishing restricted to 321 days per year
2017	Preference point drawing system implemented requiring 11 permits to retire for each new entrant; first four permits given to preference group and next one permit given to random group

3.1.1 Overview and Rationale for the Current Management Framework

Since the inception of the Red Sea Urchin fishery, management has relied on three major effort reducing regulations to protect the harvestable stock. These include 1) minimum size restrictions, 2) limited access to the fishery with capacity reduction in the early 1990s and 2017, and 3) limiting open fishing days throughout the year by only allowing fishing on certain days of the week.

Because Red Sea Urchins mature at XX, the size limit of XX allows most individuals to spawn prior to being vulnerable to the fishery. A slot limit for smaller individuals allows divers some leeway for accidentally picking small urchins given how many they measure underwater.

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Creating a limited access permit for this fishery was necessary to curtail the high level of take and excessive number of permittees in the late 80s into the early 90s. However, the effort reduction process was slow and the capacity goal of 300 was not attained until the mid-2000s. Due to the high latent harvest potential in this fishery due to retained but unused permits and degrading environmental conditions significantly affecting this fishery, a new capacity goal of 150 sea urchin permits was implemented in 2017.

Limitations on open fishing days were implemented to protect the spawning biomass and reduce take from June-October. In 2017, Friday was added back to the open days in the southern fishery from June to October. This was requested by the southern fishery to take advantage of market opportunities and allow for another day to dive when foul weather limits fishing days.

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

Currently, there is no direct reference point for determining whether the stock is overfished nor are there procedures in place specific to the Red Sea Urchin fishery to halt overfishing when it is found to be occurring. Landings are monitored using commercial landing receipts, and are used as indicators for the fishery both in the north and south separately and together statewide. The southern Red Sea Urchin fishery was a fishery used as a test case for the DLM toolkit and is an ongoing project to evaluate the risk of the fishery and future potential management strategies.

3.1.1.2 Past and Current Stakeholder Involvement

In 1987, the Legislature established the Director's Sea Urchin Advisory Committee (DSUAC) which consisted of representatives from the fishing industry, California Department of Fish and Game (DFG) now CDFW, and California Sea Grant. DSUAC was the decision-making body for industry-funded research projects aimed at enhancing and managing the fishery and acted as a forum for consensus-based management. In 2002, the self-imposed landing fee law that funded industry-backed research projects was repealed, and DSUAC was reformed through legislation as the Sea Urchin Fishery Advisory Committee. The new committee is charged with disbursing any remaining funds and advising DFG on management matters.

In 2004, the California Sea Urchin Commission (CSUC) was created following a vote of both divers and handlers in the industry. The CSUC is facilitated by the California Department of Food and Agriculture and directed by a Commission, which includes five elected commissioners and one appointed public member. The commissioners represent the most active ports for Red Sea Urchin statewide. The Commission also includes several non-voting members that represent government entities such as CDFW. In 2019, the processors voted themselves back onto the CSUC and now are represented as voting members on the board.

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Commission activities are funded by an assessment on sea urchin harvested and processed in California and which is paid by divers and processors (calurchin.org). Currently, divers and processors will both pay 1.5 cents per one pound of Red Sea Urchin landed. The mission of the CSUC is "to ensure a reliable, sustainable supply of quality sea urchin products to consumers and enhance the performance of California's sea urchin industry." The CSUC works closely with the CDFW and FGC to manage the fishery and make changes to the regulations to promote sustainability. The CSUC also funds various industry initiatives, supports scientific research studies, and other various activities to promote education and expand on existing markets.

3.1.2 Target Species

3.1.1.3 <u>Limitations on Fishing for Target Species</u>

3.1.1.3.1 Catch

Commercial divers are not restricted on how many Red Sea Urchin are harvested.

Recreational catch is limited to 35 Red Sea Urchin per day.

3.1.1.3.2 Effort

The commercial fishery is currently a limited entry access fishery with a capacity goal of 150 sea urchin permits. Currently there are under 300 permits which will be reduced to 150 using a capacity reduction scheme that gives one new permit for every 11 that are retired. Effort is further reduced by limiting fishing to certain days of the week from June through October (see section 3.1.1.3.3).

There are no restrictions on effort in the recreational fishery.

3.1.1.3.3 Gear

Permitted commercial divers may use rakes, airlifts, or other hand-held appliances to take Red Sea Urchin.

Recreational divers do not have gear restrictions.

3.1.1.3.4 Time

Commercial take is closed Friday, Saturday, and Sunday from June through October north of the Monterey-San Luis Obispo county line and Saturday and Sunday from June through October south of the Monterey-San Luis Obispo county line.

There are no restrictions on time for the recreational fishery.

3.1.1.3.5 Sex

There is no restriction on the sex of Red Sea Urchin that can be caught. Male and female Red Sea Urchin cannot be differentiated externally.

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3.1.1.3.6 Size

For the commercial fishery, there is a size limit south of the Monterey-San Luis Obispo county line of no more than thirty (30) Red Sea Urchins between 1.5 and 3.75 inches in shell diameter per permittee per load may be taken, possessed, sold or purchased. North of the Monterey-San Luis Obispo county line, no more than thirty (30) Red Sea Urchins between 1.5 and 3.5 inches in shell diameter per permittee per load may be taken, possessed, sold or purchased.

There are no size limits for the recreational fishery.

3.1.1.3.7 Area

Red Sea Urchin may not be taken in state reserves or state marine parks. There are no other areal restrictions on the take of Red Sea Urchin.

3.1.1.3.8 Marine Protected Areas

Pursuant to the mandates of the Marine Life Protection Act (Fish and Game Code §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.

Even though the use of MPAs as a fishery management tool was not one of the primary goals of the Marine Life Protection Act (MLPA), they can function as one for the following reasons:

1. They serve as adaptive, spatial closures to fishing if the species of interest is within their boundaries and is prohibited from harvest. Under the MLPA, the Department has the authority to evaluate the effectiveness of the closure, possibly resulting in changes in allowance for extractive practices.
2. They function as comparisons to fished areas for relative abundance and length or age/frequency of the targeted species.
3. Many MPAs served to displace fishing effort when they were implemented. MPAs have significant amounts of hard bottom in depths to 100m (328 ft.), which is near the reported maximum depth for Red Sea Urchin. However, divers typically will not dive deeper than 30m or 98 feet. Along the California mainland and island coast there are 230.1 square miles (mi^2) of hard bottom habitat between 0 and 30m (0-98 feet) and 175.5 square miles (mi^2) of hard bottom habitat between 31-100m (102-328 feet) protected within the MPAs (Table 3-2).
4. MPAs also protect the primary food source of the Red Sea Urchin, bull kelp and giant kelp. The average kelp canopy in square miles for eight surveys years from 1989-2008 was 34 square miles (mi^2).

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Table 3-2. Hard bottom habitat for depth of 0-30 meters and 31-100 meters (in square miles); and average kelp canopy for years 1989, 1999, 2002, 2003, 2004, 2005, 2006, and 2008 within California MPAs by region (California Seafloor and Coastal Mapping Project 2017).

Depth (m)	North Coast	North Central Coast	Central Coast	South Coast	Total
0-30	32.24	34.18	51.97	111.73	230.1
31-100	33.56	52.15	42.00	47.79	175.50
Average Kelp	0.97	1.67	11.36	20.02	34.00

3.1.1.4 Description of and Rationale for Any Restricted Access Approach

The commercial fishery currently is managed as a restricted access fishery which began in 1989 when landings and participation were high, and managers were concerned with the level of effort in the fishery. Subsequently a capacity goal of 300 permits was established at a time when permits were near 900. In 2017, another capacity reduction began with a goal of 150 permits. This capacity reduction was established to reduce future landings from latent permits and was enacted during a period of high kelp loss and degrading environmental conditions.

3.1.2 Bycatch

3.1.2.1 Amount and Type of Bycatch (Including Discards)

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.

Because Red Sea Urchin are collected by hand, the bycatch in this fishery is expected to be low. Potential bycatch might include small invertebrates such as juvenile sea urchin, snails, crabs, etc. that inhabit the sea urchin spines for protection. Most likely, the harvester will not be aware of any bycatch from taking adult sea urchin.

Commercial urchin divers take hundreds of sea urchin during a day of harvest and obtaining the minimum size limit for each urchin exactly is difficult. For these reasons, the regulations allow for the take of 30 undersized sea urchin in any given load.

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

Due to the highly selective method of harvest in this fishery, there is little to no bycatch. For this reason there are no management measures to reduce bycatch.

3.1.3 Habitat

3.1.3.1 Description of Threats

The effect on habitat caused by this fishery is minimal since Red Sea Urchin are taken by divers using their hands or a sea urchin rake.

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

Given the minimal habitat impacts from this fishery there was no management measures in place to reduce impacts.

3.2 Requirements for Person or Vessel Permits and Reasonable Fees

Requirements and fees for persons or vessels fishing Red Sea Urchin are described in the FGC and Title 14 of the CCR. Fishermen are required to have the following permits, licenses, and registrations to fish commercially in California water for Red Sea Urchin:

- Commercial Fishing License – All Red Sea Urchin fishermen must have a commercial fishing license and a vessel permit. The 2019 to 2020 fee (valid 01 April 2019 to 31 March 20) for Commercial Fishing Licenses are $145.75 for residents and $431.00 for non-residents. This license 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. The current commercial boat registration fee is $379.00 for a resident and $1,122.00 for a non-resident.
- Sea Urchin Diving Permit – This permit is required for any fisherman that takes sea urchin for profit. The fee for this permit is $498.25 for the 2019-2020 season.
- Sea Urchin Crewmember Permit – This permit is required for each person who is assisting taking sea urchins and who does not qualify for a sea urchin diving permit. The fee for this permit is $45.84 for the 2019-2020 season.

All fees include a nonrefundable 3% application fee.

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Any person sport fishing for Red Sea Urchin is required to obtain the following license and validation:

- Annual Sport Fishing License – An annual sport fishing license (valid 01 January through 31 December, or for the remainder of the year if purchased after 01 January) is required for anyone who is 16 yr of age or older attempting to take any kind of fish, mollusk, invertebrate, amphibian or crustacean in California, except when fishing from a public pier in ocean or bay waters. The current fee is $49.94 for residents and $134.74 for non-residents.
- Sport Ocean Enhancement Validation – A sport fishing ocean enhancement is a required addition to a sportfishing license for any person fishing in ocean waters south of Point Arguello (Santa Barbara County). Currently, the fee is set at $5.66.

  Fees include 5% license agent handling fee and 3% nonrefundable application fee.

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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".

Much of the biological EFI for the Red Sea Urchin is well understood and this species would be considered data moderate for biological information. Research regarding natural mortality, growth, age, recruitment, and size at sexual maturity have been well documented, but more so for northern California populations. Other market and harvest strategy studies are useful to the industry for obtaining a better yield for their product but are not directly used for management. The primary EFI measurements used for this fishery include levels of fishing effort and catch levels associated with landings receipts as well as CPUE measurements from logbooks provided by the dive fleet.

4.2 Past and Ongoing Monitoring of the Fishery

4.2.1 Fishery-dependent Data Collection

The Department uses landing receipt data as the primary source to manage the Red Sea Urchin fishery. Landings and CPUE (landings per trip) are more reliable with landings receipts than with logbooks because landings are estimated by the divers and location of where diving occurred is often missing or inaccurate. Location entries as recorded on logbooks as GPS coordinates, landmarks, and fishing block number have been used as an overview for where harvest is occurring, but the fishing block number on the landings receipts has always been more accurate and thus used for landings summaries and analyses. The most valuable aspect of dive logbooks is information recorded by divers related to dive depths and hours in the water, which can be used for CPUE is the diver logbook can be matched to the landings receipt.

Fishery managers and enforcement officers use state-issued landing receipts, referred to as fish tickets, to monitor fishery landings. Data collected by fish tickets include:

- fishermen and vessel information
- date the fish was landed
- port of landing
- commercial fishing block where the fish were harvested
- weight (in pounds) landed by market category
- price paid to the fisherman by market category
- condition of the fish when sold

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- type of gear used to harvest the fish

Sea urchin divers are required to fill out a dive log for each trip and this log must be turned into a CDFW office each month. Logbooks are used by law enforcement to verify harvest data and by managers to collect information on the following:

- Species harvested
- Month, day, and year of trip
- Permit holder name and ID#
- Vessel information
- CDFW fishing block
- GPS coordinates and landmarks
- Dive depth range and hours of diving
- Port and dealer of landings
- Remarks including incidental species taken

4.2.2 Fishery-independent Data Collection

Multiple organizations conduct independent monitoring for select fish and invertebrate species in California, which includes size and density information for Red Sea Urchin. The Department collects size and density data of Red Sea Urchin on all their red abalone index sites surveys in Mendocino and Sonoma counties and includes counts of sea urchin in their abalone recruitment modules (ARMs) accounting for juvenile invertebrates. The Department also collects recruitment information in southern California at sites along the mainland and offshore islands. In the past, CDFW collected Red Sea Urchin size at processor facilities which gave us size at harvest. This took place from 2002-2006 and mostly occurred at ports in southern California. Reef Check surveys statewide for Red Sea Urchin including sites in northern California. The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) has been collecting Red Sea Urchin information in central and southern California since 2000. The Channel Islands Kelp Forest Monitoring Program collects size frequency and density information using quadrat techniques and monitors recruitment (counts and size) in their Artificial Recruitment Modules at 33 sites around the Channel Islands National Park. Long Term Ecological Research (LTER) surveys Red Sea Urchin along the coast in Santa Barbara County and also supports a sea urchin recruitment study (Schroeter reference) that is also supported by the California Sea Urchin Commission.

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5 Future Management Needs and Directions

5.1 Identification of Information Gaps

According to the MLMA, management of marine resources is to be based upon the best available scientific information and other relevant information. The current knowledge of Red Sea Urchin biology is more extensive than many other fisheries, and data is available from multiple independent monitoring projects as well as within the Department. Other various sources also provide monitoring on larval and juvenile recruitment. Although there is an appearance of plentiful data sources and information on the Red Sea Urchin populations, there is a lack of focus and organization for quantifying the stock and using these data sources for managing this fishery. Historically, this fishery has been monitored using logbooks and landing receipts, more so with the latter, and relying on output restrictions and limited access to prevent overharvesting. This passive approach has worked for many years until the kelp beds were highly depleted starting in 2014-2015 and landings have plummeted since then. The Department needs to evaluate the data currently being collected and determine if the data being collected have meaning. Other information listed in Table 5-1 could be used to supplement our current knowledge and fill information gaps.

Table 5-x. Informational needs for the Red Sea Urchin fishery and their priority for management.

Type of information	Priority for management	How essential fishery information would support future management
Size structure of harvested individuals statewide	High	Information used to determine trends in harvest correlated to effort and changing environmental conditions as well as spatial differences with different levels of fleet effort. Increasing the size minimum statewide and especially in the south is a consideration for future management, so it is imperative to start collecting size frequency data from processors and vessels.
Biomass available in harvest areas, MPAs, and barrens	High	Provides an indication on total stock available to harvest and can be used to develop a Total Allowable Catch or Individual Fishery Quota.
Statewide comparison of size and density from independent monitoring and landings trends	High	Using existing monitoring data, complete an in-depth comparison of independent monitoring and correlate to landings trends. Investigate MPA and non-MPA areas.
Improvement of CPUE from dive logbooks	High	Cross referencing of logbook and landing receipt data is not accurate, so CPUE analysis from logbooks (dive hours and depth) is not accurate because logbook poundage is usually an estimate.
Age structure	Medium	Information would provide age of population and identify recruitment years for localized areas of the state.

Seasonal gonad yield	Medium	Determination of highest yields throughout the year would inform industry on potential seasonal closures and optimization of harvest. Compare barren areas to productive kelp zones.
Yearly and seasonal recruitment	Medium	Identify recruitment classes monitored at current CDFW and CINPS recruitment modules and correlate to fisheries dependent data. Could be used as a predictor and indicator. These data could be related to brush study results (Schroeter et. al).
Spatial analysis of logbooks	Medium	Determine localized harvesting within CDFW fishing blocks using logbook data to determine pressure on specific kelp bed areas.
Kelp canopy and urchin abundance	Medium	Determine if yearly kelp canopy can correlate to urchin biomass
Disease identification	Medium	Disease depleted the population hard from 2013-2015 which contributed to more issues with the fishery. This occurred mostly in southern California. Identifying the cause and specific disease would contribute to our overall knowledge of Red Sea Urchin.
Recreational take	Low	Identify the current take and interest in recreational sea urchin take and determine if new regulatory changes with size and limit need to be established. Currently take is 35 per day with no size minimum.

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5.2 Research and Monitoring

5.2.1 Potential Strategies to Fill Information Gaps

Some of the information gaps could be filled using existing data from independent monitoring. This includes an analysis of size and density information collected from the Department and independent monitoring programs listed in section 4.2.2; and determining how these data can be integrated into management of this fishery and providing indications when significant depletion is occurring. Furthermore, the ongoing recruitment surveys from the Department, KFM, and LTER brush studies can possibly predict future recruitment events if a directed sampling and analysis design can direct a meaningful outcome.

Another possible analysis that could be improved upon is correlating kelp canopy coverage from existing Department aerial surveys with urchin abundance and commercial landings; data which could be used for future spatial management. Kelp canopy could also be used to calculate the biomass of fished and unfished areas in conjunction with an independent study of sea urchin weights, size, and gonad indices. Any survey should consider the proportion of marketable biomass verses urchin barren biomass and the density at which divers would want to exploit or harvest called

Exploitable Biomass (Grabowski et al). Both calculations would be important to determine spawning potential and suitable harvest areas usually associated with healthy kelp beds and subcanopy kelp. Another void in the data relates to the age structure of the Red Sea Urchin harvested and protected within marine reserves. Determining age structure of the population would be considered a project most likely conducted by a university or organization outside of the Department.

Collecting more information from urchin boats and processors would help inform more about the size structure of harvested sea urchins, percent yield of the gonads, and an improvement with our CPUE knowledge. In the past, the Department collected size at harvest data statewide that was useful to determine a percentage of sea urchin harvested at, above, and below the current size restrictions. This information is needed to advance any future considerations of regulatory changes in size and considerations on market dynamics and possible seasonal closures. Dedicated staff to coordinate sampling in ports from San Diego, Los Angeles, Ventura, Santa Barbara, and Fort Bragg would be needed to evaluate representative ports statewide. Another possibility for providing sea urchin size at harvest is to support more fisherman-based independent data collection, which has been done in the past with the San Diego fleet.

Commercial logbook data for Red Sea Urchin is often unreliable for calculating CPUE and use for spatial analysis with any reliability because divers often will not accurately report. For this reason, the Department relies on fish tickets to obtain landings data, however, this cannot be matched to logbooks due to cross referencing issues with the system. Future development of this system within the Department could help with this problem, and then logbooks could be used more often for management. Lastly, two low priority information gaps that are still important to adding to our knowledge for sea urchin management includes getting a handle on recreational take and identifying the virus causing black spot disease. In order to quantify the recreational take of Red Sea Urchin, the Department would have to prioritize seasonal staff to sample at statewide ports, dive boats, and beaches to determine the extant of sea urchin take from free divers and SCUBA divers. This would be a costly and time-consuming endeavor. However, it is important to know how many sport divers are taking sea urchin, the seasons they are getting them, and the sizes in which they harvest them. Given the liberal sport regulations for Red Sea Urchin (35 per day and no size minimum), we may need to gather more information to justify new restrictions if needed.

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.

The Department collects fishery independent sea urchin data on various projects statewide, but the link between these data and independent monitoring projects is

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lacking. More importantly, a plan does not exist for how all these data streams could be integrated and how they can be useful for managing the fishery or establishing indicators to inform the fishery of stock collapses or warning signs. If a collaborative relationship can be established perhaps a clear plan on how to alter or add current sampling practices and procedures could be used as a tool or indicator. This may include adding more sites for collecting sea urchin size and density, changing the sampling design to include more stratified randomized sampling in harvest zones, or creating additional data collections.

Many of the voids in sea urchin information may not be suitable or feasible for the Department but would be so for graduate studies and university researchers. This may include needs for genetics, gonad yield, market dynamics, modeling, development of recruitment indicators, age analysis, and disease work. The Department has collaborated with researchers in many other fisheries, including Red Sea Urchin, in the past and would include future needs.

The Department has a lasting and strong relationship with the CSUC and future opportunities for collaboration exist. The industry commission includes representatives from both the dive fleet and the processors, all with a common goal of sustaining, improving, and promoting this fishery. Many participants are eager to collaborate with the Department on many aspects of the fishery and would be willing to aid in data collections, support meaningful studies, possibly conduct underwater surveys, and development more effective and creative ways for improving the fishery.

5.3 Opportunities for Future Management Changes

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