Red Sea Urchin

History of the Fishery

The commercial fishery for red sea urchins (*Strongylocentrotus franciscanus*) has been one of California's most valuable fisheries for more than a decade. This fishery is relatively new, having developed over the last 30 years, and caters mainly to the Japanese export market. Archaeological evidence however, shows that sea urchins in California have been fished by coastal American Indians for centuries. The gonads of both male and female urchin are the object of the fishery and are referred to as "roe" or "uni," in Japanese. Gonad quality depends on size, color, texture, and firmness. Algal food supply and the stage of gonadal development affect quality and price. Ex-vessel prices during the season typically range from less than $0.20 to more than $2 per pound with the highest prices garnered during the Japanese holidays around the new year. Sea urchins are collected by divers operating in nearshore waters. Divers check gonad quality and are size selective while fishing to ensure marketability. In the last few years the red urchin fishery has become fully exploited throughout its range in northern and southern California. Because of sea otter (*Enhydra lutris*) predation, sea urchin stocks in central California occur at densities too low to sustain a commercial fishery. The purple sea urchin (*S. purpuratus*), which occurs over the same geographical range, is harvested in California, but only on a limited basis.

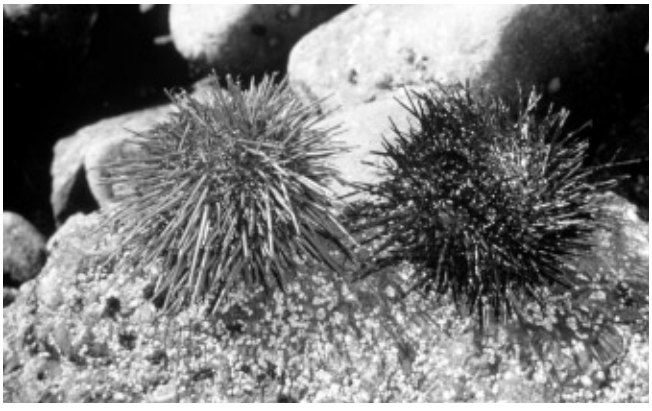
Southern California Fishery

The fishery in southern California began in 1971 as part of a National Marine Fisheries Service program to develop fisheries for underutilized marine species. The fishery was also seen as a way to curb sea urchins destructive grazing on giant kelp. There have been two periods of rapid fishery expansion in California. The first culminated in 1981 when landings peaked at 25 million pounds in southern California. Contributing to this rapid escalation of the fishery was a pool of fishermen and boats involved in the declining commercial abalone dive fishery. Sea urchin landings then decreased following the El Niño of 1982-1983, when warm water weakened or killed kelp, the primary food source for sea urchins. Catches did not recover until 1985-1986, helped in part by the strengthening of the Japanese yen relative to the U.S. dollar, favoring California fishermen and exporters. Prices for urchin from the south are typically higher than for urchins from northern California due to the longer market presence and consistently higher gonad quality of the former.

The majority of sea urchin landings in southern California have come from the northern Channel Islands off of Santa Barbara, where large and accessible stocks once occurred. During the period 1973 through 1977, 80 to 90 percent of the landings originated from these islands. In more recent years, however, there has been a decrease in the contribution from the northern Channel Islands as fishing effort has shifted south to San Clemente Island, San Nicolas Island, and the San Diego area. This spatial shift occurred at the same time that catches decreased throughout the region. In 1990, the southern California sea urchin catch peaked at over 27 million pounds, and has declined steadily to 10.9 million pounds in 1999. In the 1990s, the fishery was impacted by two El Niños and a weakening yen; both factors have contributed to reduce fishing effort and catches.

Northern California Fishery

The northern California commercial sea urchin fishery began in 1972, and remained insignificant until 1977, when 386,000 pounds 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 enter the unregulated fishery. In northern California (Half Moon Bay to Crescent City) landings jumped from 1.9 million pounds in 1985 to 30.4 million pounds in 1988, far exceeding landings from southern California. Northern California sea urchin landings and catch-per-unit effort (CPUE) began a steep decline in 1989, before leveling off in 1996 at about three to four million pounds annually and about 700 pounds per fishing day per diver. Preliminary landings data for 1999 show a catch of 3.2 million pounds with an ex-vessel value of $2.4 million. In northern California, Fort Bragg has remained the center of the fishery, while the ports of Albion, Point Arena, and Bodega Bay accounted for about two-thirds of the catch in 1999. Rocky reefs around Crescent City also support a small fishery.



Red Sea Urchin, *Strongylocentrotus franciscanus*
Credit: Chris Dewees
CA Sea Grant Extension Program

Status of Biological Knowledge

Sea urchins are locally abundant subtidal herbivores that play an important ecological role in the structure of kelp forest communities. Sea urchins belong to the phylum Echinodermata, which includes sea stars, brittle stars, sea cucumbers, and sand dollars. They have a hard calcareous shell called a test, with spines and small pinchers called pedicellariae. Tube feet are located between the spines which are used in respiration, locomotion, and for grasping food and the substrate. On the bottom, or oral side, is the mouth, consisting of five calcareous plates making up a jaw structure called Aristotle's lantern. The mouth leads to the digestive system which voids through the anus on the top, or aboral, side.

Sea urchins are omnivorous, eating primarily foliose algae. The perennial giant kelp is the 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 shortages contributes to the its ability to persist in high densities in areas devoid of algae, known as urchin barrens. The formation of barrens in southern California can follow oceanographic events such as El Niño during which kelp beds die-off resulting in shortages of standing and drift algae. These food shortages may trigger urchins to aggregate and move in fronts denuding the remaining kelp forest. 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 percent 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 during the period of concentrated urchin fishing, showed a 15-fold increase in the surface canopy from 1982 to 1989.

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 red abalone and red sea urchin abundance at sites where urchin density is high. Sea urchins may be more successful in competing for limited food because of their aggressive foraging and ability to survive starvation conditions. Fishing abalone and sea urchins has no doubt altered these relationships.

Packing sea urchin gonads
Credit: California Sea Grant Extension Program

Several significant predators of red sea urchins are known. Sea otters, spiny lobsters, sea stars, crabs, white sea urchins, and fishes such as sheepshead eat red sea urchins. Within the sea otter's present range, the red sea urchin resource has been reduced to a level which precludes fishery utilization. Urchin diseases have decimated sea urchin populations in the Caribbean islands, however the dynamics of sea urchin diseases in California remain poorly understood. Sea urchins in southern California are susceptible to disease during warm water El Niño events.

There are no reliable methods of aging sea urchins since rings on the test plates are not laid down annually. Sea urchin growth rates vary depending on food availability. Growth rates must be determined by tagging and recapturing animals. Internal tags (PIT tags) or chemical (fluorescent) tags that bind to calcium have been used to successfully tag sea urchins. Tagging studies reveal that red urchins are long-lived, are certainly older than 50 years and large individuals may be older than 100 years. Growth to a harvestable size of 3.5 inches (test diameter, exclusive of spines) averages six to eight years. There are no patterns in growth along a latitudinal gradient from Baja California to Alaska, however there is a clear trend in population mortality rates. Mortality estimates for southern populations were found to be greater than for northern populations. Likely mechanisms include higher rates of disease and temperature-related stresses as one moves from north to south.

Red sea urchins become sexually mature at about two inches. The sex ratio in urchins about one to one. Sea urchin spawning is seasonal but can vary from year to year and from one locality to another. Food supply and ocean temperatures play a role in the timing and magnitude of spawning. In most southern California locations, spawning generally occurs in winter. In northern California, major spawning occurs in spring and summer, with some spawning activity also in December.

As for many marine invertebrates, fertilization is external and success is highly dependent on density. Subtidal studies suggest that red 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. Larval development is 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 metamorphose into benthic juveniles. The long planktonic phase suggests that juvenile sea urchins may disperse long distances from the adults that have spawned them.

Settlement patterns have been studied for red and purple sea urchins on artificial substrates at sites in northern and southern California since 1990 and are similar for the two species. Peak settlement periods tend to be in spring and early summer although there is substantial year-to-year variation both in timing and intensity. Settlement tends to be less variable south of Point Conception and is depressed during El Niño events. However, El Niño events appear to favor settlement in northern California. Recruitment patterns of red sea urchins in northern and southern California generally mirror those of settlement. Recruitment in southern California appears to be relatively constant while in the north, recruitment rates are lower and more sporadic. The more variable pattern of settlement in the north is consistent with more energetic offshore advection of water during spring periods when larvae are available, especially around headlands.

Newly settled juvenile urchins are highly susceptible to mortality. Juveniles appear to suffer increased mortality in the kelp forest habitat, where micro-predators are presumably more abundant than in similar rocky habitats just outside of the kelp beds. Adult sea urchins and their spines are important structuring organisms in subtidal communities. The canopy formed by the spines is a micro-habitat in which juvenile sea urchins, shrimps, crabs, brittle stars, fish, abalone and other invertebrates can be found. The spine canopy is most likely an important habitat for juvenile sea urchins especially in areas where alternative cryptic habitats (*e.g.*, crevices and undersides of boulders) are rare or absent.

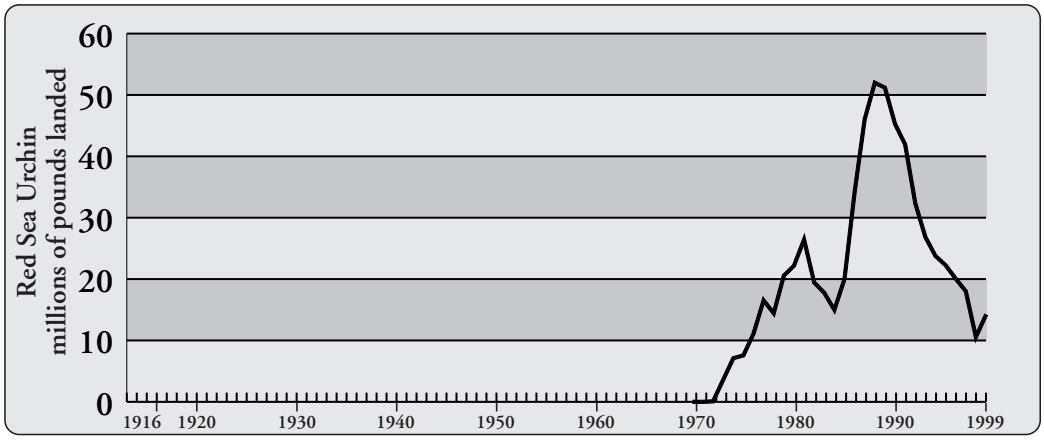
Status of the Population

In southern California, the red sea urchin resource now produces about 10 million pounds annually, with harvestable stocks (defined as exceeding the minimum legal size and containing marketable gonads) in decline since 1990. Between 1985 and 1995, the percentage of legal-sized red sea urchins at survey sites in the northern Channel Islands declined from 15 percent to 7.2 percent. Although fishing has significantly reduced density in many areas and catch-per-unit of effort has decreased, localized juvenile recruitment has, thus far, somewhat mitigated fishing pressure. Consistent recruitment has been noted on artificial settlement substrates and along subtidal transects over the last decade at monitoring stations along the southern California mainland coast and the northern Channel Islands. This may be partly due to ocean current patterns in the Southern California Bight, where water retention may increase the chances for larvae to encounter habitat suitable for settlement. Continued recruitment at present levels, however, is not guaranteed; in fact, intensive sea urchin harvesting in northern California and Baja California could result in a decrease in sea urchin larvae in southern California in the future.

Catches in southern California have exhibited a pattern resembling the serial depletion that characterized the decline and collapse of the abalone fisheries in the mid-1990s. The northern Channel Islands have supplied most of the catch over the years, but beginning in 1992 catches in the northern islands began to decline as effort and harvests started to increase in the southern islands of San Nicolas and San Clemente, signaling a shift away from the northern islands. Recently, San Clemente Island catches have declined precipitously indicating that the fishable stock there may be largely depleted. Whether the harvestable stocks can recover to their previous levels in these heavily fished areas remains a concern, particularly if fishing effort remains largely uncontrolled.

The northern California fishery has been characterized by rapid growth to 30 million pounds in 1988 and decline to less than five million pounds in the late 1990s. Fishery dependent modeling of the sea urchin fishery during the period of rapid decline estimated that the 50,800 tons of red urchins harvested from 1988 through 1994 represented about 67 percent of the fishable stock available at the start of 1988. Effort declined during this period as the 126 divers who had worked exclusively in northern California during 1991 had dwindled to 69 by 1995. Annual catch per permittee declined by 57 percent from 1990 to 1995.

Densities of fishable stocks continue to be depressed at subtidal survey sites examined in the Fort Bragg area since 1988. From 1988 to 1997, legal-sized red urchins surveyed outside of reserves, declined from 47 percent to 20 percent of the population, and from 0.8 per square meter to 0.2 per square meter surveyed. In contrast, during this period densities in two area reserves averaged over 3.0 red urchins per square meter. These patterns were observed to continue during northern California surveys in 1999 and 2000. Episodic and infrequent recruitment combined with intensive harvesting on the north coast have had a serious impact upon catches, as the fishery has evolved into a recruitment fishery, with fishermen targeting harvest of newly recruited sea urchins. For example, in 1999, 47 percent of the catch was less than 3.9 inches, just over the 3.5-inch minimum size limit. The size limit and seasonal closures may help prevent fishery collapse but may not improve recruitment, particularly if its success is primarily a function of oceanographic factors, spine canopy micro-habitat and maintaining large spawners in the population.



Commercial Landings 1916-1999, Red Sea Urchin
Commercial Landings 1916-1999, Red Sea Urchin
Data Source: DFG Catch Bulletins and commercial landing receipts.

Management Considerations

See the Management Considerations Appendix A for further information.

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California red sea urchin catch (lbs) and ex-vessel value.
Data Source: market receipt database.

Northern California landings and catch per unit of effort (CPUE).
Data source: DFG logbooks.