Fishery-at-a-Glance: California Spiny Lobster

Scientific Name: *Panulirus interruptus*

Range: Spiny Lobster range from Monterey, California southward to at least as far as Magdalena Bay, Baja California. The physical center of the range is within Mexico, and population density and fishery productivity is highest in this area.

Habitat: As juveniles (less than 3 years of age), Spiny Lobster live in coastal rubble beds, but as adults, they are found on hard bottomed or rocky-reef habitat kelp forests.

Size (length and weight): Adult Spiny Lobsters average 2 pounds in weight and about 12 inches total length, with males slightly larger than females. Adults more than 5 pounds are currently considered trophy individuals, although records exist from a century ago of 26 pound, 3 foot long lobsters.

Life span: Spiny Lobsters can live up to 30 to 50 years.

Reproduction: Spiny Lobsters mature at about 5 years of age, or 2.5-inch carapace length. They have a complex, 2-year reproductive cycle from mating to the settlement of juvenile lobsters. Fecundity increases with size, and females produce one brood of eggs per year.

Prey: Spiny Lobsters are omnivorous, and act as important keystone predators within the southern California nearshore ecosystem. Adults forage at night for algae, fish, and many marine invertebrates.

Predators: Predators of juvenile Spiny Lobsters include California Sheephead, Cabezon, rockfishes, Kelp Bass, Giant Sea Bass, and octopus. Predators of adult lobsters tend to be the larger individuals such as male California Sheephead and Giant Sea Bass.

Fishery: The commercial fishery accounted for approximately 312 metric tons (688,000 lb) in ex- vessel landings and $12.7 million in ex-vessel value during the 2017-2018 fishing season. The recreational fishery is estimated to contribute between $33 and 40 million in consumer spending to the California economy each year.

Area fished: The commercial Spiny Lobster fishery ranges from Point Conception south to the U.S. and Mexico border. The California recreational fishery ranges from Central San Luis Obispo County south to the U.S. and Mexico border.

Fishing season: The commercial and recreational Spiny Lobster fisheries run from early October to mid-March, with the recreational fishery starting 4 days earlier than the commercial fishery.

Fishing gear: Commercial fishermen catch lobsters using square, wire traps deployed from boats in shallow (less than 300 feet) waters. Recreational fishers catch lobsters either by hand by divers, or by hoop net.

Market(s): A substantial portion of Spiny Lobsters harvested in southern California is exported to markets in Asia, primarily China. Increased demand from overseas markets in recent years has led to a substantial increase in average landing price (price per pound) of the commercial fishery. In the 2017-2018 season, the average price per pound was $17.10.

Current stock status: The abundance of Spiny Lobsters has been stable since the mid-1980s. There is no evidence that the lobster stock is overfished, and overfishing does not appear to be happening.

Management: The Spiny Lobster stock is managed using a number of regulations designed to protect the spawning potential of Spiny Lobster. The current minimum size limit allows many lobsters to reproduce for 1 to 2 years before reaching the legal size limit. The seasonal closure (March through October) protects individuals from harvest during the sensitive spawning period of the species. The limited-entry nature of the commercial fishery restricts the number of commercial participants. Also, a Harvest Control Rule was recently developed to provide an adaptive management framework that provides the Department with flexibility to adjust the management approach as threats to the sustainability of the Spiny Lobster fishery are identified.

1 The Species

1.1 Natural History

1.1.1 *Species Description*

The California Spiny Lobster (*Panulirus interruptus*) is one of approximately 55 Spiny Lobster species found in oceans worldwide (Phillips and Kittaka 2000; Booth 2011). Spiny Lobsters are named after the forward-pointing spiny projections that cover their bodies. The species has two large antennae but lacks the pincers found on clawed lobsters. The body of Spiny Lobster has two readily identifiable parts: (1) a fused head and thorax enclosed in a carapace, to which the legs attach, and (2) the abdomen, or tail. Due to the flexibility of the tail, only the carapace length is used to measure the size of a lobster.

Figure 1-1. External dorsal (top) anatomy of California Spiny Lobster (left), male identifying characteristics (middle), and female identifying characteristics (left). CL = Carapace Length.

1.1.2 *Range, Distribution, and Movement*

The Spiny Lobster is endemic to the North American west coast from Monterey, California southward to at least as far as Magdalena Bay, Baja California (Schmitt 1921; Wilson 1948). The physical center of the range is within Mexico, and population density and fishery productivity is highest in this area. The Southern California Bight population is currently managed as an independent stock due to oceanic currents that help retain the larvae within the U.S. border (Mitarai et al. 2009). Studies of Spiny Lobster genetic population structure generally find high gene flow suggesting well-mixed larvae. Sub-adult and adult Spiny Lobsters are commonly found on hard seafloor at depths ranging from intertidal to 64 meters (m) (210 feet (ft)) (Robles et al. 1987), while the planktonic larvae have been found offshore as far as 530 kilometers (km) (329 miles (mi)) and at depths to 137 m (449 ft) (CDFG 2001).

Spiny Lobsters exhibit two general types of movement: nocturnal foraging and seasonal inshore-offshore movements. Foraging involves nightly movements across spatial scales that range from 1.0 to 1,000.0 m (3.3 to 3,281 ft) (Withy-Allen and Hovel 2013), and increase as lobsters grow (Ling and Johnson 2009). Fishermen target Spiny Lobster during these nightly forays because they are often easier to find and capture. Seasonal inshore-offshore movement is characterized by occupancy of shallow reefs in summer and fall months when surface waters are relatively warm and storm activity is low, followed by movement into deeper water with the arrival of winter swells, storms, or colder surface waters (Mitchell et al. 1969). The physiological advantages of moving into warm shallow water include faster growth (Engle 1979) and accelerated egg development (Mitchell 1971). The timing and intensity of cues that initiate movement out of shallow water have not been rigorously studied. Studies suggest that female Spiny Lobsters tend to exhibit more seasonal movements, potentially due to the need to seek optimal spawning locations (Withy-Allen and Hovel 2013)

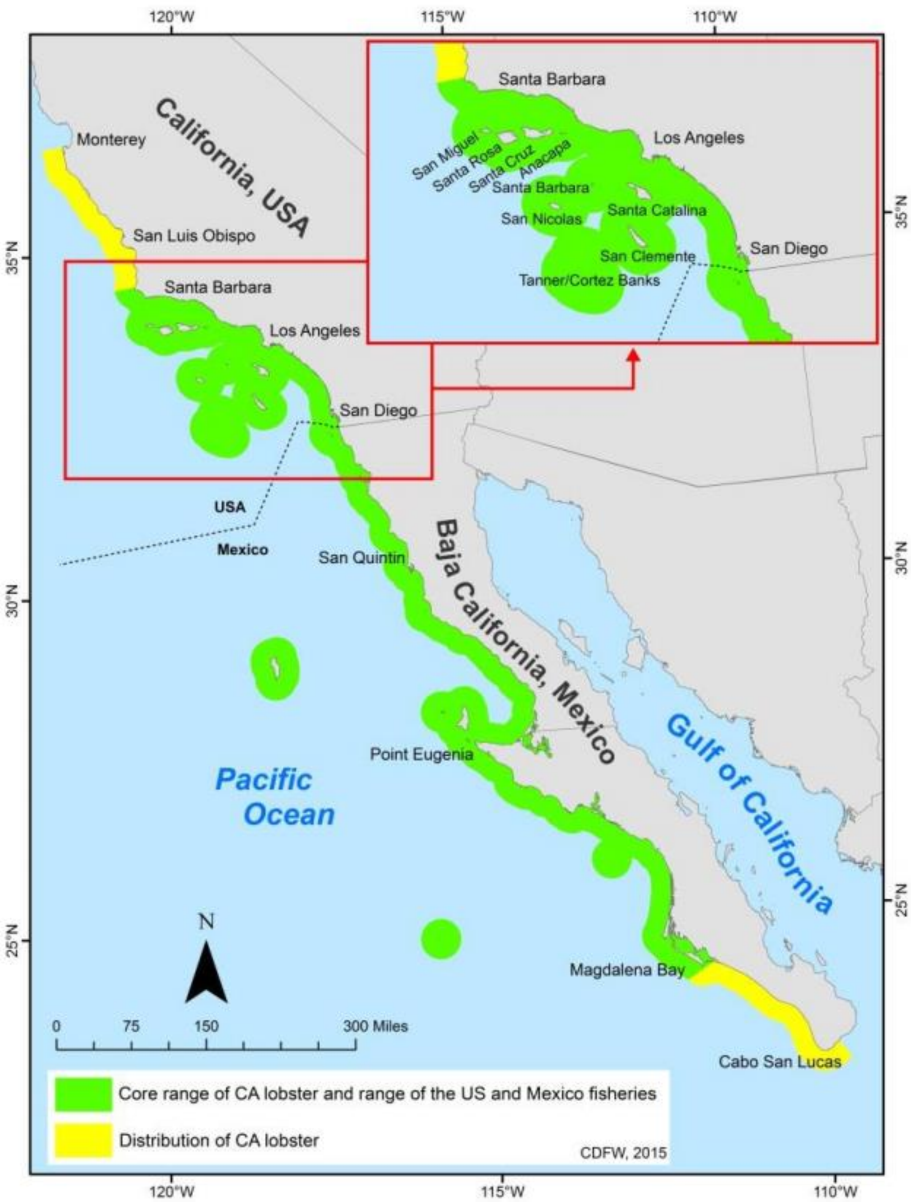

Figure 1-2. Range of California Spiny Lobster. A 20-mile buffer from the coast was used to indicate the approximate range of the species and does not represent fine-scale distribution (Reproduced from CDFW 2016).

1.1.3 *Reproduction, Fecundity, and Spawning Season*

Females produce one brood of eggs per year (George 2005), and the reproductive cycle takes 2 years (yr) from mating to juvenile settlement. Egg clutch size increases with increasing lobster size and can range from 200,000 to 1,600,000 per female and beyond. Mating of Spiny Lobster occurs when a male places a putty-like spermatophore on the sternum of a female. These females are termed “plastered.” The spermatophore can remain in place for months, which allows females to store sperm until eggs in their gonads are fully developed and ready to be fertilized (Ayala 1983). Plastered females are common from January to May, but are most abundant from

February to April (Bodkin and Browne 1992). Females use their hind walking legs to scratch open the spermatophore, which fertilizes eggs as they are extruded. These females then attach the eggs under their pleopods, which are paddle-like structures on the underside of their tail. After an incubation period of approximately 8 to 9 weeks, developing embryos hatch from the eggs on the female's tail and enter the water column as pelagic larvae called phyllosoma (Johnson 1956). Phyllosoma are flattened, transparent, and 1.0 to 2.0 millimeter (mm) long (0.04 to 0.08 in) (4 to 5 mm including appendages) (0.16 to 0.2 in) when they hatch. They then pass through 11 different stages of development and attain a body length of 26.0 to 32.0 mm (1.0 to 1.3 in) (Johnson 1956; Mitchell 1971). Phyllosoma spend 7 to 8 months drifting with ocean currents and feeding on plankton (Mitchell 1971; Dexter 1972) then transform into a puerulus stage that closely resembles adults (Johnson 1960). The pueruli settle on nearshore reefs then molt into juvenile lobsters after 2 to 3 months (Parker 1972). Because peak hatching and settlement in California both occur in August, Spiny Lobsters are assumed to be 1 yr old upon settlement (Parker 1972; Engle 1979).

Females with eggs on their tails are referred to as "berried", and are commonly found in California from late April to August and are most abundant June to July (Bodkin and Browne 1992). There is no fishing of lobster allowed from April through September to prevent the take of berried females.

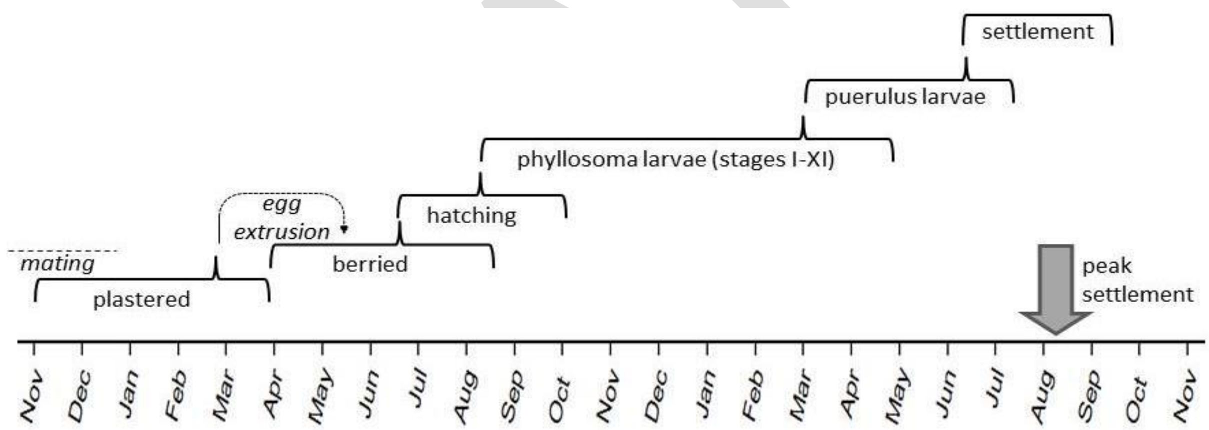

Figure 1-3. Timing of reproduction, larval development, and settlement of Spiny Lobster (Reproduced from CDFW 2016).

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.

Several studies have estimated natural mortality rates for Spiny Lobster at around 0.17 (Chavez and Gorostieta 2010; Kay 2011; Neilson 2011) and they are consistent with estimates for other temperate spiny lobster species (Kay and Wilson 2012). Little is known about juvenile natural mortality. Factors that affect natural mortality include ocean temperature, oceanographic regimes (e.g. Pacific Decadal Oscillation (PDO), El Niño), reef-specific ecology, habitat characteristics, and existence of Marine Protected Areas (MPAs) (Kay and Wilson 2012). Approaches for estimating natural mortality include tag-recapture and examination of populations in MPAs. Estimates for a spiny lobster's lifespan range from 30 to 50 yr (Neilson 2011).

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.

Like all crustaceans, Spiny Lobsters have a rigid exoskeleton that covers the outer surface of their bodies. Once formed, this exoskeleton does not shrink or expand. In order to increase its body size, a Spiny Lobster must shed its exoskeleton and replace it with a larger one (Mykles 1980). The molt frequency and molt increment (size increase during each molt) of a Spiny Lobster determines its growth rate. Rapidly growing young lobsters molt many times per year, but molt frequency decreases with age (Engle 1979). Males and females exhibit different growth rates, with males growing much larger than females. Currently the Department uses the von Bertalanffy growth equation to model growth. The parameters used are derived by Vega (2003) but the Department continues to explore other methods for estimation of von Bertalanffy parameters as well as other types of growth models (CDFW 2016).

1.1.6 *Size and Age at Maturity*

The size at which 50% of female Spiny Lobster in a population are capable of reproduction has been estimated to range from 63.5 to 78.2 mm (2.5 to 3.1 in) Carapace Length (CL). Existing studies suggest that Spiny Lobster reach a sexually mature size before reaching the minimum legal size of 82.5 mm (3.2 in) CL, allowing all lobsters to breed at least once before capture by the fishery. Age at maturity from direct measurement is unknown since it is challenging to age crustaceans. Studies have estimated females reach sexual maturity between 5 and 9 yrs (Table 1-1). Females produce one brood of eggs per year (George 2005), and the total number of eggs carried by individual females (fecundity) increases with carapace length.

Table 1-1. Age at sexual maturity and legal size for California Spiny Lobster. As reported from previous studies and adapted from Engle 1979. Methods used to determine ages include: laboratory study of captive individuals (lab), analysis of length-frequency data (LF), and molting frequency x molt increment (molt).

Age at Maturity*		**Age at Legal Size**		**Source**	**Region**	**Method**
M	**F**	**M**	**F**			
4-5	5-6	7-8		Lindberg 1955	California	Lab, LF, Molt
5	7	11	10	Mitchell et al. 1969	California	LF
3-4	5-6			Serfling 1972	California	Lab, LF
5-6	8-9	11	13	Odemar et al. 1975	California	Tag
		8		Ford and Ferris 1977	California	Lab, Tag
		8-10		Bodkin and Browne 1992	California	Molt
3	5	4	7	Ayala 1983	Baja	Unknown
4.5	6	6.5	8.5	Guzman del Proo and Pineda 1992	Baja	Unknown

*Sexual maturity for CA studies = 58 mm CL (M) and 70 mm CL (F); (Lindberg 1955, in Engle 1979); sexual maturity for Ayala (1983) = 65 mm CL

1.2 Population Status and Dynamics

Spiny Lobsters exhibit high productivity and relatively constant recruitment each year. They are likely to be fairly resistant to fishing pressures provided management ensures their ability to reach sexual maturity and reproduce at least once before they become vulnerable to fishing. Lobsters are difficult to age due to the fact that they molt, but size has been a useful proxy to monitor the impacts of fishing on lobster productivity. Long-term fluctuations in catch and CPUE indicates that productivity is heavily influenced by environmental factors.

1.2.1 *Abundance Estimates*

A 2011 stock assessment suggested that stock abundance levels have been stable since the 1980s, and that the Spiny Lobster population is at a sustainable level where surplus production provides the majority of the harvestable lobster each season (Neilson 2011). This conclusion was based mostly on consistency in the size of captured lobsters, harvest rates, catch totals, and level of fishing effort since 2000. The Department uses CPUE as a proxy for relative abundance (see section 3.1.1).

1.2.2 *Age Structure of the Population*

Data on the age structure of the Spiny Lobster stock in California are currently unavailable. Estimating the age of crustaceans has historically been more difficult than aging finfish because crustaceans shed most of their hard structures that might be used for aging each time they molt. Tag-recapture studies only provide an indirect estimate of the age of individual lobsters. Instead, models of age-length relationships are used to infer the age of lobsters from their size. It is estimated that female lobsters become sexually mature at 5 yr old, and become vulnerable to the fishery at 7 yr old (Table 1-1).

In the absence of age data, the Department uses average weight of landed lobsters to calculate spawning potential ratio (SPR) of the stock to ensure reproductive capacity and monitor the effects of fishing mortality (see section 3.3.1).

1.3 Habitat

Rocky structures/reefs are important habitat for Spiny Lobster, and high quality rocky habitat is often characterized by the presence of brown algae such as Giant Kelp (*Macrocystis pyrifera*) (Engle 1979). Juveniles (less than 3 yr old) and sub-adults/adults (greater than 3 yr old) use different habitats. Larvae prefer to settle on common surfgrass and red algae that are abundant in rubble habitats. Juveniles receive protection from predators in these rubble habitats, and remain for 2 to 3 yr post-settlement until they become sub-adults (Castañeda-Fernández de Lara et al. 2005). Adult and sub-adult Spiny Lobster commonly occupy natural hollow spaces within rocky substrate. Human structures such as pier pilings (Stull 1991), industrial debris (Lindberg 1955), harbor jetties (Neilson et al. 2009), and artificial reefs (Reed et al. 2006) can also serve as habitats. It is important to note that any artificial or natural hard substrate associated with the sea floor can serve as Spiny Lobster habitat. Figure 1-3 shows the location of lobster habitat in the Southern California Bight.

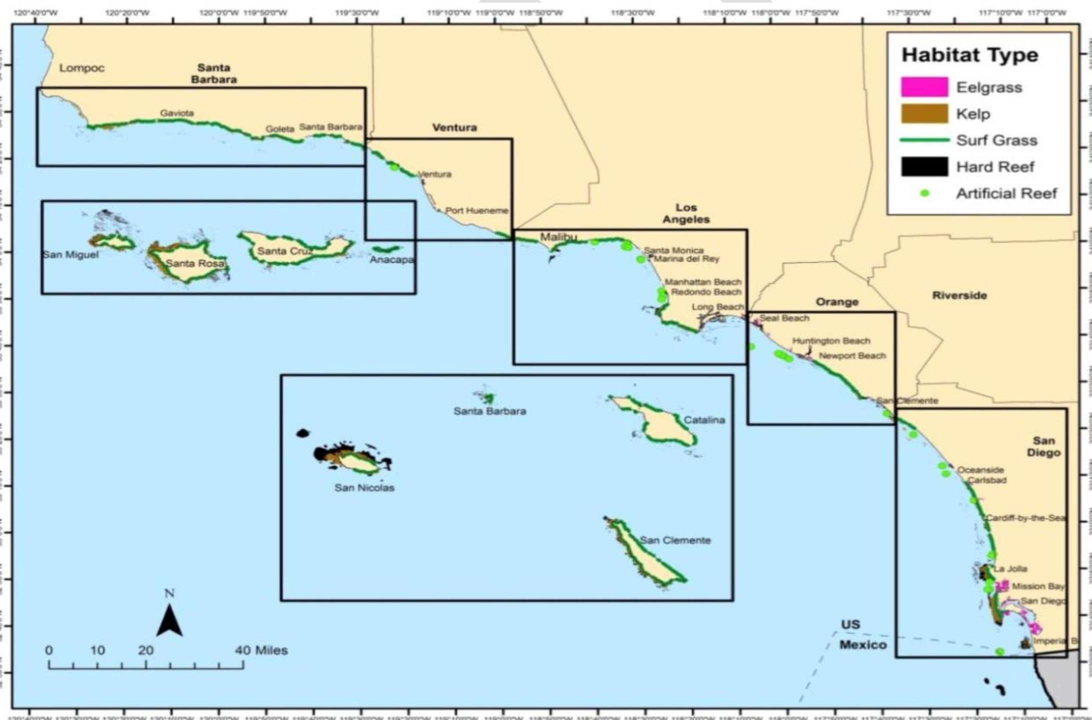

Figure 1-4. Locations of critical Spiny Lobster habitat in the southern California Bight (Reproduced from CDFW 2016). Black boxes indicate insets provided in Appendix I: Habitat maps by area.

1.4 Ecosystem Role

Spiny Lobsters are often considered keystone predator due to their predation on sea urchins in kelp forest ecosystems. They are an omnivorous, mid-trophic level species and are therefore important both as predators and as prey.

1.4.1 *Associated Species*

Lobsters are thought to be a keystone predator within California's rocky reef kelp forests. Through direct predation, Spiny Lobsters have been found to limit the abundance, size, and density of many of their prey items, including top snails, mussels, and urchins in cobble and rocky reef habitats (Schmitt 1982; Robles et al. 2001; Lafferty 2004). Spiny Lobster predation can also trigger indirect effects in marine ecosystems. For example, Spiny Lobster predation upon mussels has been shown to indirectly influence the abundance of algae by freeing up space for algal colonization (Robles and Robb 1993). Spiny Lobster have also been shown to protect Giant Kelp forests indirectly by releasing it from intensive urchin grazing (Eurich et al. 2014).

1.4.2 *Predator-prey Interactions*

Many predators prey on juvenile Spiny Lobster, the most common of which are California Sheephead (*Semicossyphus pulcher*), Cabezon (*Scorpaenichthys marmoratus*), rockfishes, Kelp Bass (*Paralabrax clathratus*), Giant Sea Bass (*Stereolepis gigas*), and octopus. Fish predators of adult lobsters tend to be the larger individuals such as male California Sheephead and Giant Sea Bass. Southern Sea Otter (*Enhydra lutris nereis*) may also become an important predator in the future, and continued range expansion of Sea Otters could have serious effects on the Spiny Lobster fisheries (USFW 2005).

Spiny Lobster diets vary with age and size. Juveniles spend their early years in surfgrass while adults frequent habitats associated with hard-bottom, and food types can vary by locations (Winget 1968). Larger Spiny Lobsters are more capable of consuming larger prey with harder shells. Spiny Lobsters typically forage at night (Stull 1991). Spiny Lobsters are often described as scavengers, but they also function as predators and grazers. Spiny Lobsters routinely attack live prey such as mussels (Robles 1987, 1997), snails (Schmitt 1987), and sea urchins (Tegner and Dayton 1981). Common food items routinely observed in gut and fecal contents include bivalves, echinoderms, small crustaceans, gastropods, and coralline algae.

1.5 Effects of Changing Oceanic Conditions

Sea Surface Temperature (SST) and atmospheric temperatures are predicted to rise in the Southern California Bight as a result of climate change (NOAA 2012). While it is difficult to predict exactly how these changes may impact the Spiny Lobster resource, models have suggested that this may lead to more intense storms and increased runoff along the southern California coast, affecting the kelp forests and sea grass beds lobsters and other species depend on (Stocker 2013). Warmer atmospheric temperature may also change the upwelling and circulation pattern of the region

(Rykaczewski and Dunne 2010), which could affect food availability for larval lobster (Roemmich and McGowan 1995) and alter dispersal and recruitment patterns (Connolly et al. 2001). Climate change may also lead to a more acidic ocean. It is unclear if there will be any direct adverse effects on lobster (Pecl et al. 2009), but it may affect common prey items such as snails and mussels.

Commercial landings of Spiny Lobster appear to be influenced by warm and cold water regimes driven by the PDO, with higher catches occurring in warmer water regimes (Neilson 2011). Warmer SST in the pelagic environment may lead to higher growth and better survivorship. As for fishery effects, warmer coastal environments may make adult Spiny Lobsters more active and easier to capture (Pringle 1986; Koslow et al. 2012). Since California is at the northern edge of the lobster's current domain range, higher SST could extend the population northward. There may also be an increased likelihood of disease with higher water temperatures.

2 The Fishery

2.1 Location of the Fishery

Spiny Lobster supports a valuable commercial fishery and a significant recreational fishery, and has been managed by the state of California for over 100 yr. Commercial fishermen target Spiny Lobsters using traps between Point Conception and the U.S. and Mexico border, and off southern California islands and banks (Barsky 2001). Traps are deployed in shallow (less than 300 ft) coastal waters, and lobsters are landed at a few key ports in San Diego, Los Angeles, Ventura, and Santa Barbara. The recreational fishery extends slightly farther north to Monterey County.

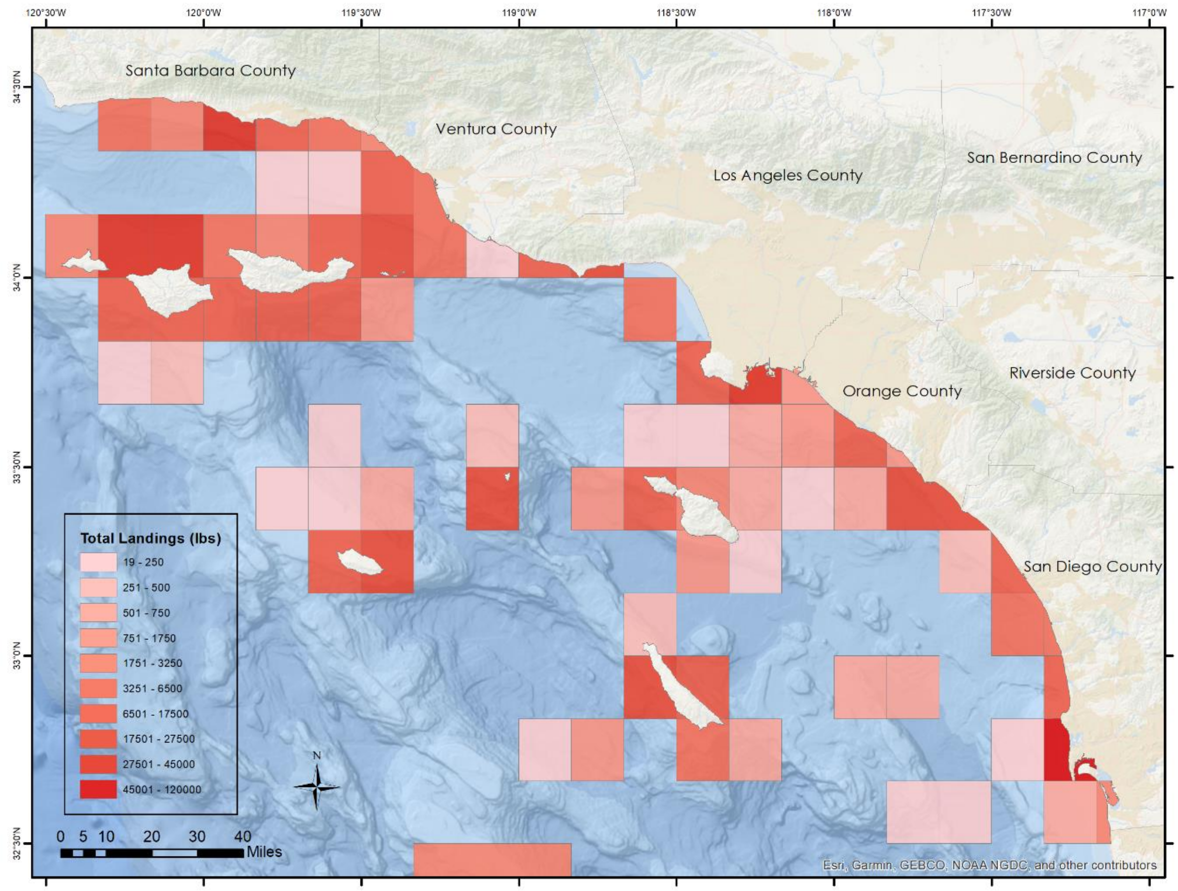

Figure 2-1. Map of commercial fishery landings (pounds) (lb) by fishing block for the 2017-2018 season (CDFW Marine Landings Database System (MLDS)).

2.2 Fishing Effort

2.2.1 *Number of Vessels and Participants Over Time*

The number of permit holders actively fishing has been relatively stable since 2008, but has seen a decrease over the last two seasons. During the 2017-2018 fishing season, 139 transferable permits and 41 non-transferrable permits were renewed; 135 of those permits were actually fished. Permit holders use vessels to deploy traps in shallow (10 to 300 ft) coastal waters. According to a 2013 Department commercial fishery survey, fishermen generally operated 75 to 1,000 traps each season, with a median of 300 traps. Using this information and as a result of the FMP process, a 300 trap limit per permit was implemented in 2017, with fishermen allowed to own two permits for a maximum of 600 traps (§122, Title 14, California Code of Regulations (CCR)).

The number of active permits (those that fished) in the Spiny Lobster commercial fishery peaked in the mid-1990s at around 350, but has decreased since that time due to a limited entry program. Despite this decrease, commercial fishing effort (i.e., number of trap pulls) has increased in recent years (Figure 2-2). Between 1995 and 2009, the annual total trap pulls of the commercial fleet hovered near 800,000 pulls. In 2012, the number increased to just over 1.1 million pulls, while the number of active fishermen remained stable. This effort increase was likely driven by an increase in the ex-vessel price paid per pound that occurred at about the same time (see section 2.4). High effort frequently results in a high harvest rate, which can reduce the spawning potential of the stock, diminishing non-consumptive user experiences, and increasing the risk of undesired ecological interactions (e.g. bycatch, lost gear, ghost fishing). It can also result in economic overfishing, which occurs when fishermen are spending more money to catch the same amount of resource. These were the primary motivators for the development of a FMP for Spiny Lobster.

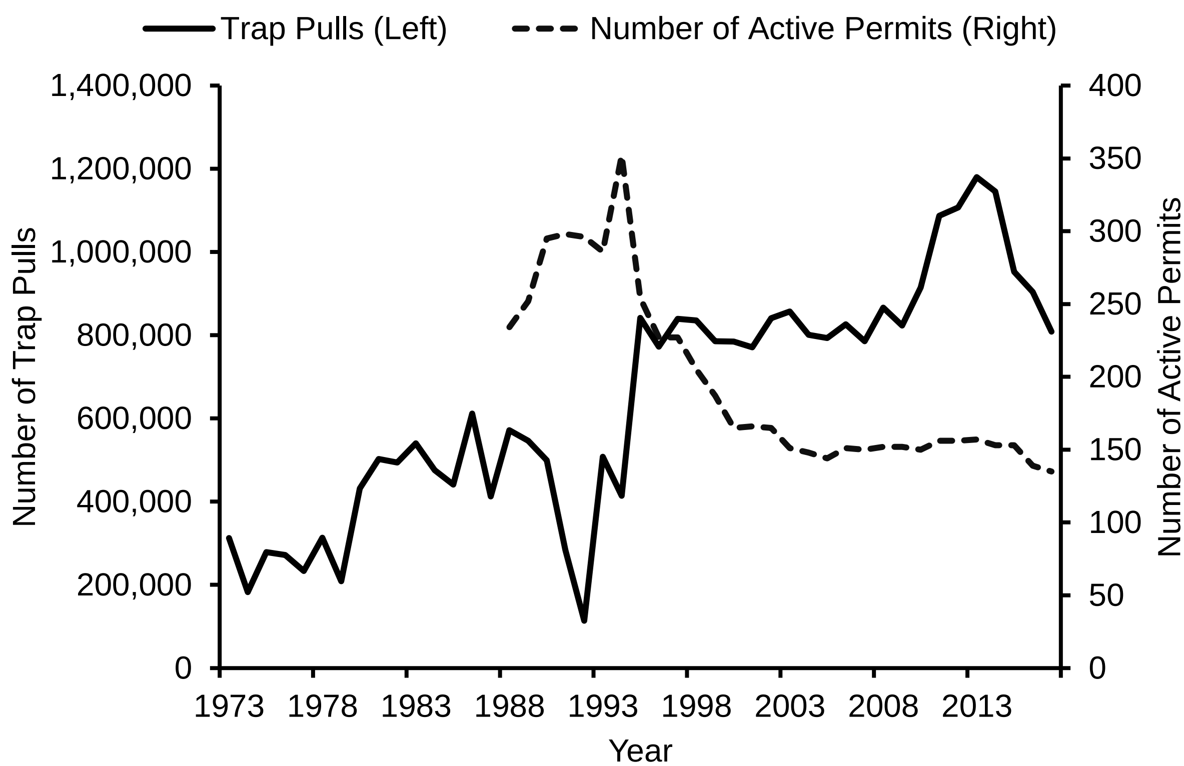

Figure 2-2. California Spiny Lobster fishery participation (number of fished permits) and number of trap pulls 1973-2018 (CDFW Marine Logbook System (MLS) and MLDS).

From 2009, when report cards for recreational lobster fishing was implemented, the estimated number of recreational participants each year has ranged from 25,000 to 29,900. The estimated number of recreational fishing trips each year has ranged from 70,000 to 160,000 (Figure 2-3).

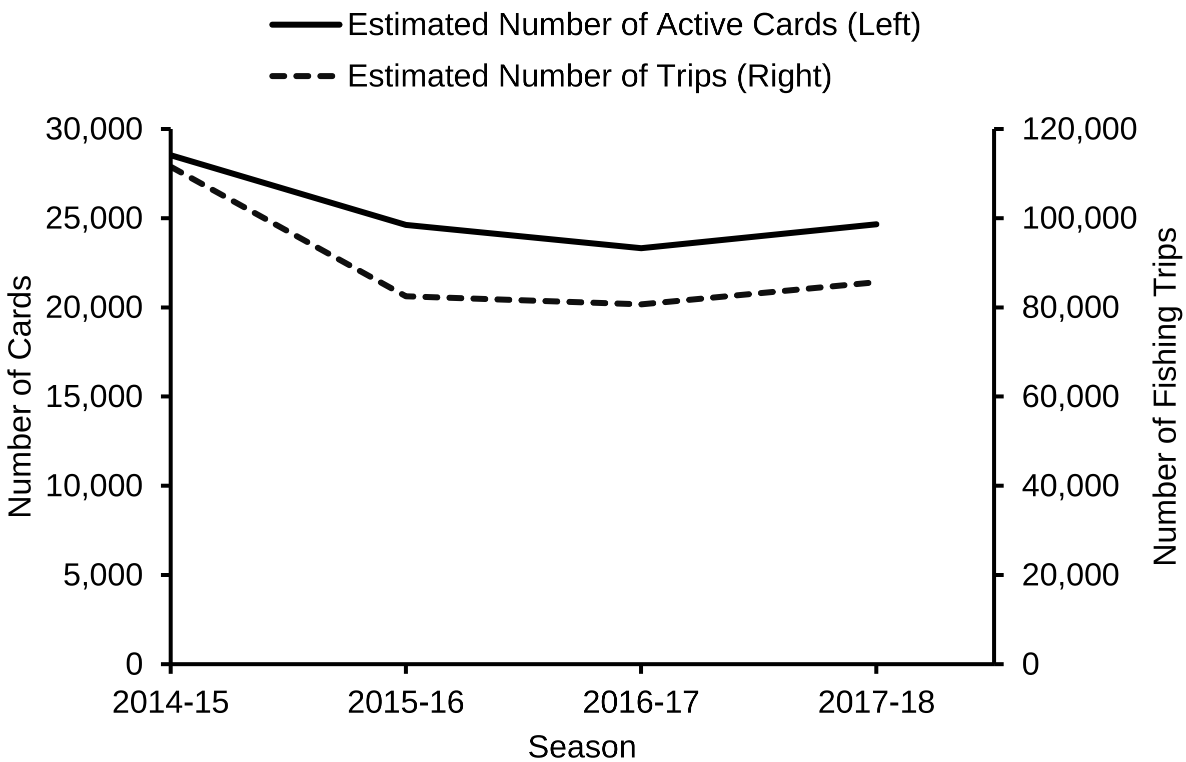

Figure 2-3. The number of active cards (cards that reported an attempt to fish) that were reported and number of fishing trips reported for the California Spiny Lobster recreational fishery 2014-2018. 2014 was the first year where lobster cards represented a full lobster season rather than the calendar year, and thus only data from that season on are presented.

2.2.2 *Type, Amount, and Selectivity of Gear*

Commercial fishermen use wire box-like traps deployed from boats to catch Spiny Lobsters (Figure 2-4). These traps must consist of a rectangular mesh with a minimum inside dimension of 1 1/2 by 3 1/2 in, an escape port with a dimension of 2 3/8 by 11 1/2 in (FGC§ 9010). The escape ports allow for the escape of sublegal lobsters and other non-target species that enter the trap. Traps are usually deployed in less than 31 m (100 ft) of water, but some are deployed as deep as about 93 m (300 ft). Beginning in the 2017-2018 season fishermen were restricted to 300 traps per permit, with the ability to hold a maximum of two permits (and deploy 600 traps).

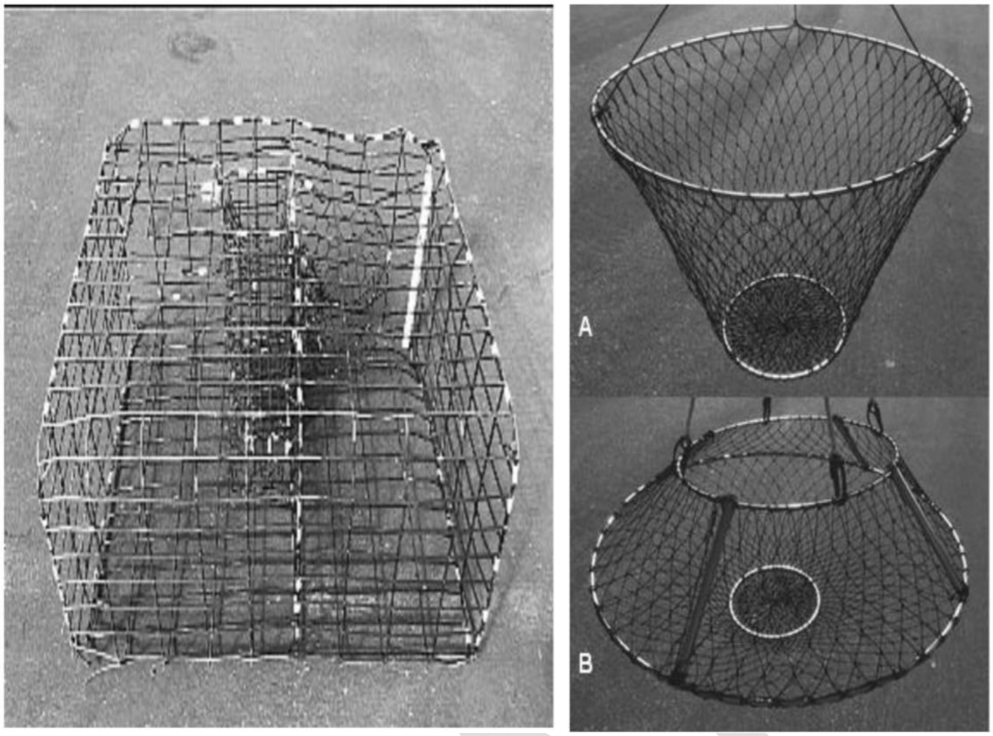

Figure 2-4. Commercial trap (on the left), and recreational hoop nets (on the right). Both the traditional (A) and conical (B) hoop nets are shown.

The recreational fishery targets Spiny Lobsters using hoop nets or by hand when diving (SCUBA or skin diving). Historically, diving has been more prevalent than hoop netting, though the Department has witnessed a switch to majority-hoop net fishery. During a 1992 recreational creel survey, 80% of those surveyed were diving for lobster and 20% used hoop nets. In a 2007 creel survey, that trend had completely flipped with 20% and 80% of those surveyed using diving and hoopnetting, respectively. Recreational report card data from the 2017-2018 season showed 53% of trips used a hoop net, and 47% utilized diving. The Department allows two types of hoop nets: traditional hoop nets and rigid conical hoop nets (§29.80, Title 14, CCR) (Figure 2-4). The traditional hoop nets lie flat on the seafloor and only take their three-dimensional shape when pulled to the surface. A slow or jerky pull can allow lobsters to escape out the top or sides. Conical hoop nets, introduced in 2006, have rigid sides. The lobsters must climb up into the net to reach the bait, and cannot flee when the hoop net is pulled. A 2009 Department study found that the new conical nets catch about 57% more lobsters than traditional hoop nets (Neilson et al. 2009). A recreational creel survey conducted in 1992 found that 80% of recreational fishers were divers, while 20% were hoop netters. A 2007 survey found that 20% of recreational interviewees were divers, which the rest used hoop nets.

2.3 Landings in the Recreational and Commercial Sectors

2.3.1 *Recreational*

The Department was not able to quantify recreational catch until the lobster report card was introduced in 2008. Low report card return rates caused uncertainty in recreational catch estimates. However, return rates have been improving since a non-reporting fee of $20 was implemented in 2014 (§1.74(d)(2) Title 14, CCR). Estimates for recreational catch range from 292,442 lb in 2013 to 527,357 lb in 2009 representing 27 to 43% of the total catch. Starting in 2013, the Department adjusted report cards to track individual lobster fishing seasons which cross consecutive calendar years. Data from the 2017-2018 fishing season lobster report cards estimated the recreational catch to be 125 metric ton (mt) (274,914 lb), or about 31% of the total catch (Figure 2-5). Most recreationally caught lobsters come from areas where commercial fishing is prohibited. The Department will continue to improve data collection on the recreational sector and remain adaptive towards any change.

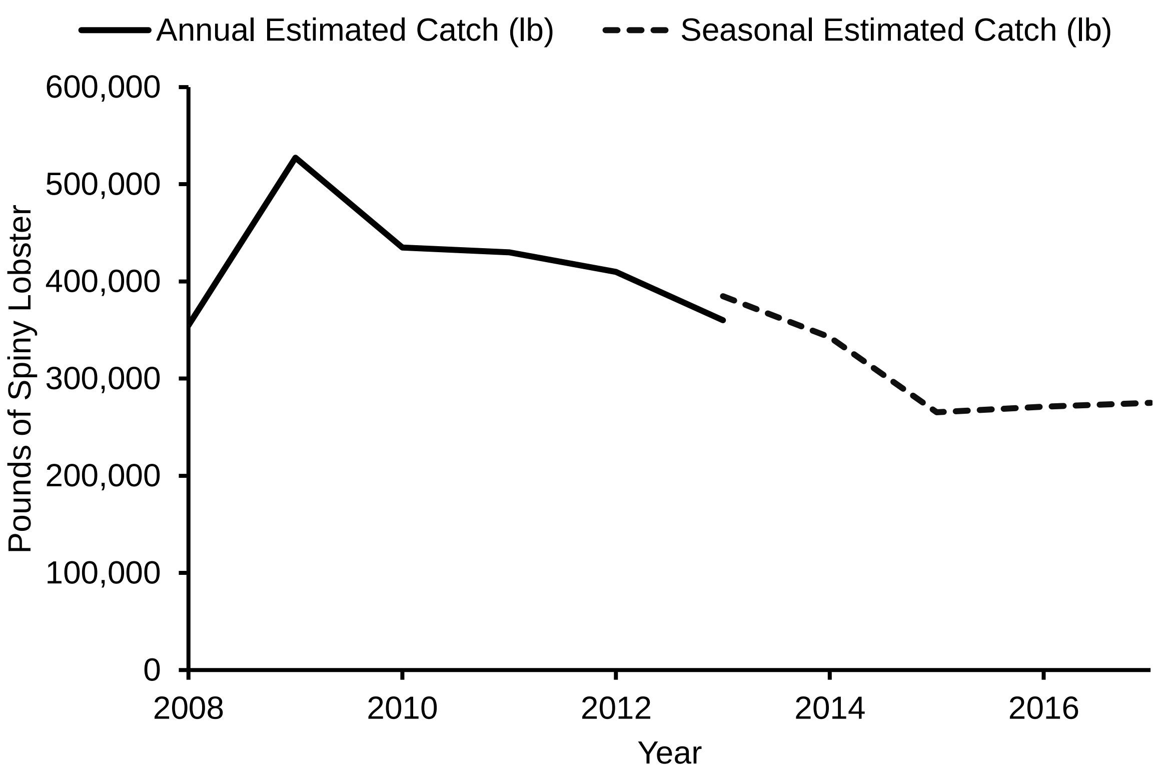

Figure 2-5. California Spiny Lobster estimated recreational catch (lb), 2008-2018 (CDFW Automated License Data System). Recreational lobster report cards were required starting in 2008. Reporting changed from annual catch to seasonal (October – March) in 2013.

2.3.2 *Commercial*

Spiny Lobsters have been fished since the 1800s. Commercial landings peaked at an all-time high of 485 mt (1.07 million lb) during the 1949-1950 fishing season, and declined to a record low of 69 mt (152,000 lb) during the 1974-1975 fishing season. This decline is attributed to the illegal take of sublegal-size adults in prior seasons. Escape ports, which allowed sublegal-size individuals to exit traps, were introduced in 1976 (Barsky 2001). After 1976, the harvest increased and was stable for approximately a decade. Landings then showed further increases but volatility until the 2000-2001 fishing season, when 319 mt (702,000 lb) were landed. Since 2000, landings have fluctuated within a relatively narrow range, exceeding 295 mt (650,000 lb) each season (Figure 2-6).

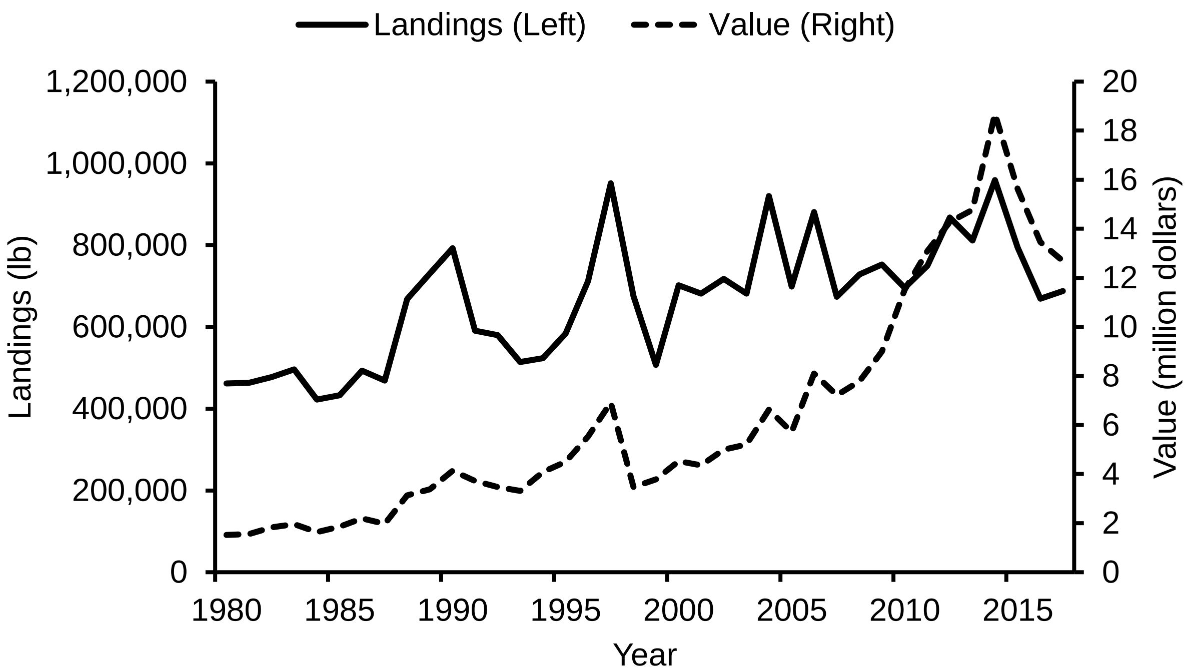

Figure 2-6. Spiny Lobster commercial fishery landings (lb) and value (million dollars), 1980-2018 (CDFW MLDS).

Historically, commercial landings were distributed evenly between San Diego County, Los Angeles/Orange Counties, and Santa Barbara/Ventura Counties. However, since the 2013-2014 season there has been an increase in the percent of total landings landed in Santa Barbara/Ventura Counties. Landings in these northern counties have increased from 35% during the 2013-2014 season to 50% of total landings in the 2016-2017 season (Figure 2-7). In addition, habitat area is not equally distributed, leading to concentrations in fishing effort in specific fishing blocks. In general, 80% of a season's catch is landed in the first half of the season. The majority of lobsters landed by the commercial fishery have reached legal size within the last year (Neilson 2011).

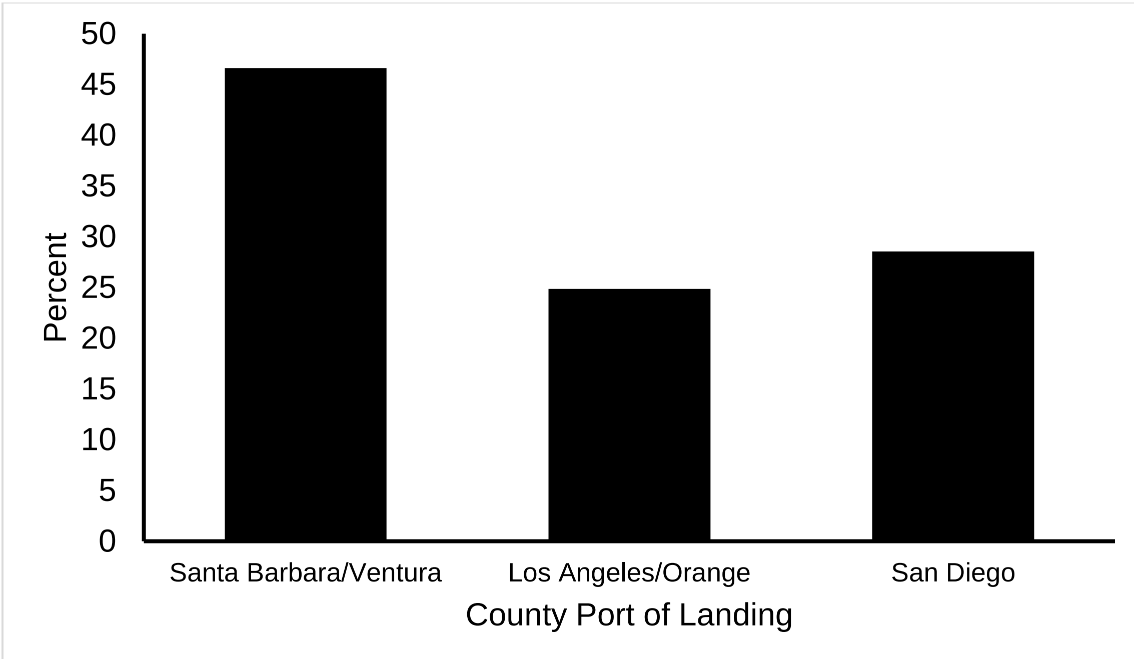

Figure 2-7. Spiny Lobster percentage of total landings by county based on port of landing for the 2017-2018 season (CDFW MLDS).

2.4 Social and Economic Factors Related to the Fishery

The average landing price of Spiny Lobster has consistently increased over each season since the early 1990s. The average landing price (price per lb) of Spiny Lobster increased by approximately $8 per lb between the 1980-1981 and 2009-2010 fishing seasons as domestic demand slowly grew. However, the average price increased by the same amount in just 5 yr between the 2009-2010 fishing season and the 2014-2015 fishing season, reaching a record average seasonal landing price of $19.67 per lb, as foreign markets expanded and export demand grew. Total ex-vessel value reached a record high of $18.7 million in the 2014-2015 fishing season but fell to $12.7 million in the 2017-2018 fishing season (Figure 2-5).

The increase in price starting in 2014 has contributed to an increase in effort, despite the cap on the number of permittees. Some longtime permit holders who formerly contributed little effort to the fishery have become increasingly active in recent years. In addition, permit transferability was adopted in 2005, and transferable lobster operator permits sold for approximately $75,000 to 100,000 in the 2010s. New entrants to the fishery may incur considerable debt to purchase these permits, and as a result may have an incentive to fish harder than unindebted permit holders.

As part of the FMP process, outside consultants were hired to analyze the economic impacts of the lobster fishery in California. The gross ex-vessel value of the fishery from the 2011-2012 season was found to be $12.9 million, and the statewide total economic output was over $22 million. The study also estimated the commercial lobster fishery's yearly operational cost at approximately $10.5 million. Of this, over half (more than $6 million) came from a combination of bait (about $1.6 million), fuel (about $1.3 million), crew wages (about $1.8 million), and federal taxes (about $1.1 million)

(CDFW 2016). Communication with active commercial lobster fishermen suggests that the cost of commercial lobster fishing may have been overestimated in the report.

The recreational fishery also contributes substantially to the local economy. The study found that Californians spent between $33 and 40 million dollars on recreational lobster fishing in 2011 (CDFW 2016). Of this, roughly $7 million was attributed to residents who live in zip codes that border the coastline, $20 million was attributed to other residents living in zip codes within 50 mi of the coastline, and $10 million was attributed to residents living further inland.

User/Industry Demographics

The demographics of the current commercial fishermen have not been analyzed. However, 86% of the recreational fishermen come from zip codes that are within 50 mi of the coastline. Sport fishermen from farther inland spend a disproportionately higher amount of money on their recreational trips (CDFW 2016).

Employment

The commercial Spiny Lobster fishery was responsible for an estimated 323 full-time equivalent jobs during the 2011-2012 fishing season. The commercial fishery was also responsible for a total estimated economic effect of over $22 million in southern California over the same fishing season (CDFW 2016). In an analysis of the operational costs of commercial lobster fishermen, an estimated $695,893 was spent on compensation for deckhands and crewmembers, while licensed Spiny Lobster fishermen took in an estimated income of $3.8 million (CDFW 2016). An analysis of the cumulative distribution of the catch suggests that the amount of lobster landed by each fisherman can vary widely, and that competition between fishermen is high.

3 Management

3.1 Past and Current Management Measures

The State of California has managed the Spiny Lobster fishery for over 100 years. Table 3-1 shows a timeline of the regulatory changes that have been made over that time period. The current size limit was originally instituted in 1955 to allow lobsters time to reproduce before becoming vulnerable to the fishery, while the current fishing season began in 1961 to protect spawning. Escape ports were introduced in 1976 to reduce bycatch of sub-legal lobster, while limited entry began in 1996 to manage effort. The most recent changes were adopted as part of the FMP, and most notably include a 300 trap per permit limit.

Table 3-1. A summary of regulatory changes affecting the commercial California Spiny Lobster fishery.

Year	Regulatory Change Affecting the Commercial CA Lobster Fishery	Type of Change
1894	1 lb minimum size in Los Angeles, San Diego, and Ventura Counties	Size limit
1901	Berried females protected (repealed)	Management
1901	First minimum length implemented (9½ in total length)	Size limit
1913	First slot limit introduced (9 to 13½ in)	Size limit
1917	Slot limit modified (10½ to 16 in)	Size limit
1955	3.25 in carapace length minimum size implemented	Size limit
1957	2 by 4 in wire mesh required or 2 in high openings along two sides of traps to allow escape of undersized lobsters	Gear restriction
1961	Implementation of the modern day open season: the first Wednesday in October through the first Wednesday after 15 March	Season
1961	The Commission given authority to manage the fishery	Management
1961	Lobster permits required. New permits issued by lottery with a capacity goal of 225 fishermen	Management/ Permitting
1973	Logbooks required by law to record essential fishery information; also, permit applications require estimate of number of traps to be fished	Reporting
1976	Escape ports are required for commercial traps	Gear restriction
1986	The Commission given authority to limit the number of permits	Management/ Permitting
1992	The recreational season opener is moved to the Saturday preceding the first Wednesday in October to provide the sport fishery with 4 days of fishing prior to the commercial opener	Season
1994	The Commission places a moratorium on new permits for 2 yr in preparation for a switch to a limited entry permit fishery	Management/ Permitting
1996	Limited entry permit program begins	Management/ Permitting
2003	Lobster permit lottery repealed	Management/ Permitting
2011	Department initiates a Spiny Lobster FMP as mandated by the 1998 MLMA	Management
2012	A network of new MPAs goes into effect in southern California as mandated by the 1999 MLMA	Fishing Area Restriction
2016	Spiny Lobster FMP is approved	Management
2017	A trap limit of 300 traps per permit is implemented as part of the Fishery Management Plan; additionally, each trap must have a Department issued trap tag attached.	Gear restriction

3.1.1 *Overview and Rationale for the Current Management Framework*

Given the population dynamics of Spiny Lobsters and what is known about their fecundity, the primary approach for management of the Spiny Lobster fishery include: 1) allowing them to reach a size so they can reproduce before becoming vulnerable to the fishery, 2) protecting berried females during the spawning season, 3) managing effort through commercial limited entry and trap limits, and hoop net limits in the recreational fishery and 4) monitoring for signs of decline in individual size and population size in order to be able to react accordingly if changes are detected.

Harvest Control Rules: Pre-defined Procedures for Adjusting Fishing Behavior

A Harvest Control Rule (HCR) prescribes management actions when a certain reference point is reached or surpassed (“triggered”). A clearly detailed decision matrix is a formal mechanism for incorporating multiple indicators, which allows for more tailored management responses than could be justified by a single reference point with multiple levels. The matrix also provides guidance on the appropriate management action for each combination of signals, resulting in a pre-determined and transparent decision-making process that preserves scientific and policy decision-making prerogatives.

The Department developed an HCR with substantial input from the Lobster Advisory Committee (LAC) and independent scientific experts. The HCR is composed of three components (described in detail in section 3.1.1.1). Three specific indicators and reference points serve as the metrics to assess the state of the fishery and the Spiny Lobster stock. A Control Rule Matrix details how the reference points will work together to identify an emerging issue within the fishery and its underlying causes. Lastly, a toolbox of eight regulatory options gives the Department and the Commission flexibility to address emerging and ongoing issues.

The HCR is discretionary and not every triggering event will necessarily lead to an immediate regulatory response. Additional evaluation is needed before taking action to determine if external factors (i.e. new regulations, market dynamics, or environmental changes) have caused or contributed to the reference point(s) being exceeded. This process will include consultations with the fishing communities and other stakeholders. The HCR is not guaranteed to capture every possible issue the fishery will face, and like any other management tool, resource managers will need to exercise independent judgment when using the HCR. In the future, the Department will explore ways to improve the HCR, such as modifying reference points, or methods for their calculation, to more accurately reflect the status of the fishery and meet the MLMA management objectives.

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

Assessing Stock Status: Comparing Indicators Against Reference Points

Stock assessments are a crucial element of fisheries management and involve the comparison of past and current data and indicators with reference points to help guide future harvest. Assessment procedures can vary from very simple to highly complex and may integrate many different types of data.

Stock Assessment Procedures

A formal statistical stock assessment procedure, in which a model of the stock dynamics is fit to historical data to estimate the current stock size, was developed for the Spiny Lobster fishery in 2011 (Neilson 2011). The results of this assessment suggested that the post 2000 Spiny Lobster population is at a sustainable level where surplus production provides the majority of the harvestable Spiny Lobster each season (Neilson 2011). This conclusion was based mostly on consistency in the size of captured lobsters, harvest rates, catch totals, and level of fishing effort since 2000.

However, stock assessments are costly to run because they require extensive time, resources, and data, and thus are not feasible to run every year for lobster. As a result, an assessment procedure using fishery-dependent indicators and pre-specified reference points was developed as part of the FMP development process. That analysis relies on the use of the Department-Cable model, a procedure that was developed to estimate the spawning potential of Spiny Lobsters from their average weight, information that the department currently collects. This analysis is simple and should be able to be conducted on a yearly basis.

Three reference fishery-dependent indicators are used to monitor the performance of the Spiny Lobster fishery. Each is explained below.

1) <u>Catch</u> — The first performance indicator is the total catch in a single season, which is sometimes used as a proxy for the size of the stock. While there are a number of biological, ecological, or anthropogenic reasons total catch might change, a significant change in catch provides a clear signal to managers that more investigation is needed to determine what has caused the change and whether a management change is needed. As a result, change in total catch can be informative when paired with other indicators. In order to measure trends in catch, the following ratio is used to calculate a trend in the moving average:

   It is important to note that this reference point is primarily designed to detect trends. Catch can fluctuate drastically from year to year due to socioeconomic, environmental, and biological factors, but normal fluctuations do not warrant management interventions. Averaging the catch from the three most recent seasons for the indicator dampens those fluctuations. The 10-yr running average in the denominator was chosen because long-term environmental changes might alter our expectations for sustainable catch levels (upwards or downwards).

2) <u>Catch Per Unit Effort (CPUE)</u> — The second performance indicator is the CPUE, defined here as the number of legal lobsters caught per trap pull. CPUE is used in two important ways. First, it serves as a proxy for the relative abundance of fish in an area, and long-term trends in CPUE can provide insight into changes in the stock. In addition, CPUE is also very useful for tracking the optimal effort level and detecting economic overfishing. CPUE data are relatively inexpensive and easy to collect, but they can be influenced by factors other than

fish abundance such as new regulations, environmental variability, changes to the vulnerability of the stock to fishing, and increases gear efficiency known as effort creep. As with catch, the following ratio is used to calculate a trend in the moving average:

3) Spawning Potential Ratio (SPR) — SPR is defined as the number of eggs produced by the current fished population divided by the number eggs produced by that same population if it were unfished. Its values range between 0 (no eggs produced in the fished population), and 1 (the same number of eggs produced in the fished and unfished populations). At low harvest rates, SPR values are high because many large animals remain in the population, but at higher harvest rates, SPR declines and may ultimately reach zero if no size limit is in place to protect at least some portion of the breeding stock. Calculating the SPR requires information on the size or age structure of the fished stock, estimates of natural mortality, and fecundity. Although the methods for calculating SPR can vary among different fisheries, the underlying purpose is generally the same: to gauge a fished stock's ability to replenish itself.

Limit Reference Points

In order to use indicators in making management decisions, it is necessary to compare them against predefined reference points. There are reference points associated with each indicator for the Spiny Lobster. If an indicator passes a reference point, further management action is triggered. The reference point for each indicator is described below.

1) Catch — The catch-based threshold reference point is any value for $Catch_{current}$ that is equal to or less than 0.9. Reaching this threshold would indicate that catches for the three most recent seasons are less than 90% of the average catch from the ten most recent seasons, suggesting both a declining trend that warrants consideration and a departure from the stable catches of the last 10 yr. However, because a reference point based on a moving average may not detect small gradual changes, the Department will initiate further analysis whenever $Catch_{current}$ drops for six seasons in a row.
2) CPUE — The CPUE-based threshold reference point is any value for $CPUE_{current}$ that is equal to or less than 0.9. If $CPUE_{current}$ is below 90% of the average CPUE over the past 10 yr, it indicates serious changes in the fisherman behavior and economics of the fishery. In a retrospective analysis, the CPUE and catch-based indicators would have passed the reference point and triggered management action during different years, suggesting that each of these reference points are complementary and not redundant. As is the case with the catch reference point, the Department will initiate an investigation if the $CPUE_{current}$ drops for 6 yr in a row
3) SPR — The SPR indicator has the most biological information content of the three reference points and thus is the best indicator of the potential for recruitment overfishing. The threshold for the SPR reference point is any current value of SPR that is less than the average SPR calculated for the

fishing seasons from 2000-2001 to 2007-2008. These years were deemed stable and productive by the 2011 Department stock assessment and are considered here as “reference” years for calculation of the threshold.

Criteria for Identifying when the Fishery is Overfished

Under the MLMA, “[if] a fish population is depressed, and the principle means for rebuilding the population is reduction of take, then the fishery is to be classified as overfished (FGC §97.5)”. A fishery is “depressed” when “a declining population trend has occurred over a period of time appropriate to that fishery (FGC §90.7)”. The three indicators and associated reference points are designed to alert management to changes in the fishery that may be the result of an overfished population.

Measures to Prevent, End, or Otherwise Appropriately Address Overfishing

The FMP prescribes a control rule toolbox of eight regulatory options (not in order of rank) that are available to decision makers when threshold reference points are triggered, and there is reason to either restrict or ease fishing opportunity. The specific actions in the toolbox are:

1. Change in commercial trap limit
2. Change in recreational bag limit
3. Total Allowable Catch (TAC)
4. District Closures
5. Change in season length
6. Change minimum size limit
7. Impose a maximum size limit
8. Sex selective fishery (male-only fishery or female-specific size restriction)

Each of the eight regulatory options in the control rule toolbox carries specific benefits and limitations that managers will need to carefully evaluate, including impacts to constituents, level of regulatory change, and duration of regulatory change (i.e. how long it will remain in place). The Department will consult with the fishing communities and other stakeholders in order to better inform any management recommendation to the Commission on the proper regulatory response.

Rebuilding Targets and Timeframe

Should the Spiny Lobster population become overfished, a rebuilding plan will be required. A rebuilding plan specifies the reduction in take necessary for the population to recover to a healthy (target) level. There is currently no procedure in place for defining when the fishery is “overfished”, a timeframe for rebuilding, or a target biomass at which the population would be considered recovered. However, there is an indicator-based assessment procedure that is sensitive to declines in various metrics, as well as a toolbox of eight regulatory options for restricting fishing behavior in order to allow for rebuilding.

3.1.1.2 Past and Current Stakeholder Involvement

The Spiny Lobster FMP incorporated input from the LAC. The LAC was formed in early 2012 following a call by the Department for volunteers to represent various public stakeholder groups. The purpose of the LAC was to involve constituent representatives with the development of the FMP. The LAC provided guidance on FMP objectives and end products as well as ideas for management options that addressed the key issues put forth by members of the public. The LAC consisted of representatives from the marine science community, the recreational fishing sector, commercial fishing sector, the non-consumptive recreational sector, the environmental community, and the federal government. A total of nine LAC meetings occurred between June 2012 and September 2013. All meetings were open to the public, and public input was encouraged. Meeting announcements were posted on the Department website, and the public was encouraged to sign up for the Lobster FMP news email service. Meeting summaries as well as various background documents are available on the Department website (www.wildlife.ca.gov/Conservation/ Marine/Lobster-FMP). The LAC reached consensus on several management recommendations for the Department and the Commission (CDFW 2016). Stakeholder involvement in the Spiny Lobster fishery continues with participation in Commission meetings, periodic meetings with commercial fishermen for FMP feedback, and survey participation for improving estimates of recreational catch.

3.1.2 Target Species

3.1.2.1 Limitations on Fishing for Target Species

3.1.2.1.1 Catch

There are no limits on the amount of catch in the commercial fishery. In the recreational fishery, there is a daily bag and possession limit of seven lobsters.

3.1.2.1.2 Effort

The commercial fishery is limited entry (i.e. limited number of permits) and since 2005, fishermen with transferable permits are allowed to sell their permits. Individuals wishing to enter the fishery must purchase a transferable permit from an existing permittee, as no new permits are currently being issued (§122, Title 14, CCR). On the recreational side, measures are in place limiting gear and time, which are discussed below.

3.1.2.1.3 Gear

Traps are the only type of fishing gear allowed for the commercial take of Spiny Lobster. Each trap must be marked with a buoy bearing the fishermen's license number, a unique numbered and colored trap tag, an escape port to reduce bycatch, and a destruct device to prevent ghost fishing in lost traps. Beginning in the 2017-2018 season fishermen were restricted to 300 traps per permit, with the ability to hold a maximum of two permits (and deploy 600 traps) (§122.1 & 122.2, Title 14, CCR).

Fishermen are required to pull and inspect the contents of their traps every 168 hours (7 days).

Two types of hoop nets are allowed in the recreational fishery, and fishermen are restricted to five hoop nets per person (two if fishing from a public pier) and ten hoop nets per vessel. Fishermen are also required to pull and inspect the contents of their hoop nets every 2 hours. Lobsters may also be taken by hand while SCUBA or free diving.

3.1.2.1.4 Time

There are limits on the time of day that commercial fishing can occur, as well as seasonal restrictions for both the recreational and commercial fishery. No commercial lobster traps can be deployed or retrieved from one hour after sunset to one hour before sunrise. This restriction makes it easier for the Department to monitor commercial fishing activity and reduces conflict between commercial and recreational fishermen.

The seasonal closure (March to October) protects individuals from harvest during the sensitive spawning period of the species. The commercial and recreational fisheries run from early October to mid-March. The recreational fishery starts 4 days earlier than the commercial fishery (FGC §8251 and §29.90, Title 14, CCR*)*. This results in a 24-week commercial fishing season and a 24.5-week recreational fishing season.

As a result of the FMP process, some new regulations were implemented during the 2017-2018 season. The recreational fishery now opens at 0600 on the first Saturday in October. In addition, the commercial pre- and post-season gear deployment and recovery periods were extended from 6 days to 9 days for safety purposes.

3.1.2.1.5 Sex

There is currently no restriction on the sex of lobsters that can be taken during the open season. The lobster season start and end dates were carefully chosen with spawning in mind. The season opens after the majority of lobsters have already spawned, and the season closes before the stock moves back into shallow water to repeat the cycle all over again.

3.1.2.1.6 Size

There is a size limit to prevent the take of immature lobster, and to allow all lobster to spawn at least once before capture. The size limit is 3.25 in (82.6 mm) CL. CL is measured in a straight line on the mid-line of the back from the rear edge of the eye socket to the rear edge of the body shell (Figure 3-1). Commercial and recreational fishermen are not allowed to retain sublegal-size lobsters under current California law (FGC §8252 and §29.90, Title 14, CCR*)*, and they must be measured and released immediately.

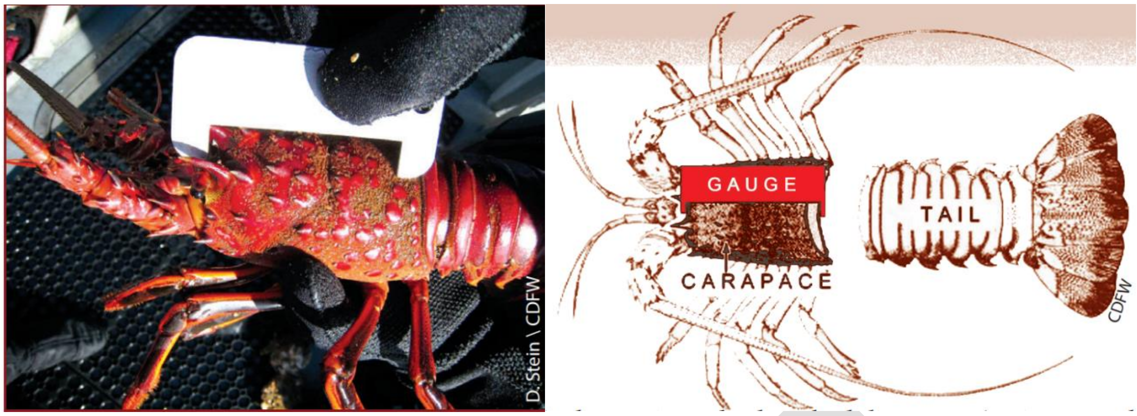

Figure 3-1. How to measure a California Spiny Lobster. A legal size lobster is as large as or larger than the fixed gap of the measuring gauge.

3.1.2.1.7 Area

Commercial Fishing is permitted in all state waters between Yankee Point in Monterey County to the U.S. and Mexico border with a few exceptions. Exceptions include inside Santa Monica Bay (District 19A), LA/Long Brach Harbor (District 19B) and San Diego Bay (District 21), the front side of Catalina Island, within 250 ft (76 m) of navigation channels, within 750 ft (229 m) of public piers and jetties, within 75 ft (23 m) of private piers and jetties, (FGC §8258 and §122 Title 14, CCR) and within some MPA, (§632, Title 14, CCR).

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. Some MPAs prohibit the take of Spiny Lobsters allowing them to reproduce without fishing pressure, but at the same time shift and compress fishing effort to the remaining non-MPA areas. It is estimated that 14.6% of Spiny Lobster habitat is protected by the MPA network. Spiny Lobsters near reserve boundaries may move into fished areas due to the reserve spillover effect, but the further away from the MPA border (> 0.6 mi (1 km)), the more likely they are to remain within the protection of the reserve (Kay et al. 2012).

3.1.2.2 Description of and Rationale for Any Restricted Access Approach

California law controls the commercial fishery's overall fishery effort with a limited entry program, which began in 1996. Permit transferability was adopted in 2005. Individuals wishing to enter the fishery have to purchase a permit from an existing permittee. The number of permittees actively fishing has been stable since 2008. During the 2017-2018 fishing season, 159 transferable permits and 41 non-transferable permits were renewed; 139 of those permits were actually fished.

Description of Rationale for Current Allocation Between Sectors

The Spiny Lobster fishery has two main sectors, a commercial fishery and a recreational fishery. These sectors tend to be separated by location and time of day, with the recreational fishery occurring largely at night, while the commercial sector operates only during the day. Current estimates suggest that the recreational fishery accounts for 30% of the total catch.

3.1.3 *Bycatch*

3.1.3.1 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. Bycatch occurs in both the recreational and commercial Spiny Lobster fisheries. There are generally two types of bycatch in the fisheries: 1) sublegal-size lobster and 2) other non-targeted marine life.

Commercial

A Collaborative At-Sea Sampling program collected data on bycatch in the commercial fishery during the 2012-2013 season and found that sublegal lobsters made up 83.3% of bycatch. The rest was composed primarily of invertebrates, with Kellet’s Whelk (*Kelletia kelletii*), rock crabs (*Cancer* spp.), and Sheep Crab (*Megastraea undosa*) being the three most commonly observed bycatch species, making up 6.0%, 4.2%, and 1.3% of animals caught, respectively. These species are legal to sell and may be retained. Urchins, starfish, and octopus were also common bycatch species. The majority of bycatch is discarded.

Recreational

Data on hoop net bycatch is limited, and diving bycatch is estimated to be extremely minimal or non-existent since the dive fishery is allowed to take Spiny Lobster by hand only. Available information shows that most of the hoop net bycatch is invertebrates such as sublegal-size lobsters, rock crabs, and sheep crabs. Some finfishes are also caught, with round stingrays being the most common (Neilson et al. 2009). Most species are likely discarded, but hoop netters retain an unknown number of crabs every year. All non-crab and non-lobster catch is required to returned to the water and cannot be retained.

Discard Mortality

Since most bycatch that are not legally retained by fishermen can be returned to the ocean alive with proper handling, the ecosystem impact through bycatch for this fishery is limited (Miller 1996; Hovel and Neilson 2011). Live finfishes and invertebrates can usually be released from hoop nets safely (Hovel and Neilson 2011). Survival is high when animals are quickly returned to the water (Miller 1996).

Fishermen may unintentionally damage sublegal-size lobsters when removing them from traps. One Australian study found that Spiny Lobsters with broken appendages become less fecund due to extra energy being exerted for healing and repairing the broken appendages (Melville-Smith and de Lestang 2007). Any similar impact on the fecundity of Spiny Lobster and the survival rates of returned sublegal lobsters is currently unknown.

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

Degree of Threat to the Sustainability of Bycatch Species

There are no data on the impact the lobster fishery has on the sustainability of bycatch species but given that trap fisheries in shallow waters are assumed to have low discard mortality rates, it is assumed that the impact is minimal, and does not threaten the sustainability of these species (Miller 1996; Hovel and Neilson 2011). Live finfishes and invertebrates can usually be released from hoop nets safely (Hovel and Neilson 2011). Survival is high when animals are quickly returned to the water (Miller 1996).

Impact on Fisheries That Target Bycatch Species

Commercial fishermen may retain legal-size crabs and octopuses provided that they have the valid permits (FGC §8250.5) and Kellet's whelk until the whelk annual TAC is reached (§127, Title 14, CCR). Landings of these retained incidental species are reported and included in the calculation of the total annual landings of each species, so that their take can be accurately monitored by the state. Identifying the target species associated with landings of incidentally caught marketable species is challenging as many lobster fishermen participate in multiple trap fisheries that have overlapping seasons. In 2018, 72 out of 180 Spiny Lobster fishermen also held rock crab permits, so it is not possible to separate out landings of incidentally caught rock crab from targeted rock crab or to attribute other landed bycatch to Spiny Lobster over rock crab fishing efforts.

Bycatch of Overfished, Threatened, or Endangered Species

Seabird and otter bycatch is not common within the Spiny Lobster fisheries, and the Spiny Lobster fishery is not expected to contribute to otter mortality if the current geographic extent of the fishery and the current otter range both remain unchanged (USGS 2014). Of the 15 reported instances of trap-related Sea Otter mortalities during 1974 to 2007, only one was due to lobster traps (Carretta et al. 2014). While cormorant bycatch was observed in the Mexican Spiny Lobster fishery, there has not been any cormorant mortality attributed to lobster traps in California (Shester and Micheli 2011), which are all outfitted with escape ports.

Marine mammal mortality as a result of entanglement in lobster fishing gear is rare in the Spiny Lobster fishery. Lobster traps are generally deployed in less than 100 ft of water, a depth range where large marine mammals such as whales are not generally found. Since 2000, there have been five reported incidences of marine mammal entanglement in lobster gear, with one incidence resulting in mortality (Carretta et al. 2014, 2015). In 2016, the National Marine Fisheries Service recategorized the Spiny Lobster fishery from a Category I fishery (remote likelihood of incidental mortality) to a Category II fishery posing an occasional threat to marine mammals (50 Code of Federal Regulations (CFR) §229.2).

Gear Restrictions to Minimize Bycatch

Trap fisheries generally have minimal bycatch of species other than invertebrates (Morgan and Chuenpagdee 2003; Matthews et al. 2005). The trap limit also reduced the overall ecosystem impact of the Spiny Lobster fisheries by providing less opportunity for bycatch. Spiny Lobster traps are required to be constructed of wire mesh of a certain size, and must have escape ports measuring 2.38 in by 11.5 in. Escape ports effectively minimize the retention of undersized lobsters and other bycatch species, and have been required since the 1976-1977 season. In addition, all traps must be fitted with a destruct device to prevent “ghost fishing”, which occurs when traps that have become unanchored and been lost continue to trap sea creatures. These traps will break apart to reduce ghost fishing.

Minimization of Discard Mortality

Commercial fishermen are required to check their traps every 168 hours (7 days), which reduces loss of gear and increases the survival of bycatch species. Federal regulations also require fixed gear (including traps) in federal waters to be serviced at least every 7 days.

Recreational fishers are encouraged to handle lobster properly while measuring to prevent breaking legs or antennae which, which not fatal, reduce the fecundity of lobsters during the healing process. In addition, hoop nets are limited to a 2 hr soak time.

3.1.4 *Habitat*

3.1.4.1 <u>Description of Threats</u>

Activities such as dredge-and-fill programs and urban runoff can adversely affect the coastal habitats where Spiny Lobster are found, which include surfgrass beds, rocky reef kelp forests, and man-made structures such as piers and jetties (Peterson and Bishop 2005). Coastal development can also pose a threat to estuarine habitats (Kennish 2002). Lastly, global climate change will lead to sea level rise and may intensify the impact of El Niño and its associated storm events (Shaughnessy et al. 2012) (Section 5.4). Rising sea level coupled with more intense storms can further erode and destroy existing seagrass beds and kelp beds.

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

Trap fisheries are considered to have lower environmental impacts than other gear types that touch the seafloor. This is because, when properly employed, traps are lowered and lifted without being dragged along the bottom (Cheupagdee et al. 2003). The types of rocky-reef habitats where most traps are deployed are less vulnerable than coral reefs to damage improperly placed traps, though traps that come into contact may still crush, break, or scrape off the epibenthic plants and animals attached to the reef. The trap limit that was first implemented in the 2017-2018 season may reduce these impacts because fewer traps will be deployed, though data to determine this are not yet available. In addition, the network of MPAs, which is estimated to protect 14.6% of lobster habitat, provides additional protection from trap-habitat interactions.

As part of the FMP process regulations changed to make it easier for fishermen to retrieve lost traps (both their own, and those belonging to other fishermen). SCUBA gear is an important tool for recovery of lost traps that otherwise might remain in the marine environment. It can also be used for disentanglement in instances when trap lines are caught on a vessel's propeller. New regulations clarified that commercial fishermen may use SCUBA for the purpose of securing traps, retrieving lost gear, or to unfoul a line from a vessel; it remains illegal to use it for the take of lobster. It is hoped that this will reduce oceanic debris and the destruction that may come from unanchored traps rolling around on the sea floor. The requirement to service traps every 7 days also helps reduce gear loss and thus habitat impacts as well caused by lost gear.

As of the 2017-2018 season, fishermen are required to report trap loss at the end of each season. From the available data, trap loss rates average at 13%, or 38 traps per active fisherman. Only a small percentage of these lost traps are recovered when they are washed up on shore or found by another fisherman.

3.2 Requirements for Person or Vessel Permits and Reasonable Fees

There are three types of permits in the commercial lobster fishery. These include a transferable lobster operator permit, a non-transferable lobster operator permit, and a lobster crewmember permit (Table 3-2). A lobster operator permit can only be obtained by buying a transferable permit from another fisherman on the private market. These are estimated to cost between $75,000 and 100,000. The 2019 annual lobster permit fee is $820.00 which includes the cost of the trap tags. Fishermen can hold up to two permits.

Recreational lobster divers and hoopnetters are required to have a general sport fishing license (if over the age of 16), a lobster report card (all ages), and an ocean enhancement stamp (if fishing south of Point Arguello). General sport fishing licenses must be purchased annually (i.e. once each calendar year) but lobster report cards are purchased at the beginning of the lobster season and are valid until the end of the season, which spans two calendar years.

Table 3-2. 2019 Spiny Lobster annual permit fees.

Permit	Fee
Commercial - General Trap Permit	$54.08
Commercial - Lobster Operator and Trap Tags	$820.00
Commercial - Lobster Crewmember	$125.00
Commercial - Lobster Operator Transfer Fee	$500.00
Recreational – Resident Sport Fishing	$49.94
Recreational – Nonresident Sport Fishing	$134.74
Recreational – Spiny Lobster Report Card	$9.98
Recreational – Ocean Enhancement Validation	$5.66

4 Monitoring and Essential Fishery Information

4.1 Description of Relevant Essential Fishery Information

The MLMA stipulates that FMPs employ the best available scientific information (FGC §7050(b)(5)). This Essential Fishery Information (EFI), which includes information about species life history, habitat requirements, status and trend of the population, fishing effort, catch level, fishery's effect on the fish population, is defined as "any other information related to the biology of a fish species [...] in the fishery that is necessary to permit fisheries to be managed [sustainably]" (FGC §93). The Department gathers EFI from a number of fishery-dependent (e.g. commercial logbooks and recreational report cards) and fishery-independent sources (e.g. research programs conducted by agency staff, academic staff, or Non-governmental Organizations (NGOs). The Department is increasingly interested in developing collaborative programs bringing fishermen together with scientists associated with academic institutions or NGOs to increase the quality and quantity of data collected. This section specifies the types of information that are considered EFI for the Spiny Lobster fishery, and ranks each type of data in terms of its priority level for further study.

Age and Growth

Accurate age and growth data are essential for Spiny Lobster management. Growth rates are used to determine the age of maturity or Size At Maturity (SAM) and to estimate of the number of spawning seasons a lobster would experience before reaching legal size. Estimating the age of crustaceans has historically been more difficult than aging finfish because crustaceans shed most of their hard structures that might be used for aging each time they molt, and currently the Department uses biological parameters based on the Mexican stock to estimate the age-length relationship of Spiny Lobster. However, new advances in aging technology provide opportunities to obtain local age-length data at lower costs (Matthews et al. 2009; Kilada et al. 2012), and MPAs provide opportunities to understand maximum age and size under unfished conditions.

Stock Distribution

The Department currently manages the entire population within the Southern California Bight as one population and one stock. The status of knowledge related to where Spiny Lobsters are found is currently well known and genetic evidence generally points to Spiny Lobster within U.S, borders being well mixed during the larval phase. However there has been some recent genetic evidence of either self-recruitment and/or spatially cohesive larval cohorts. The Department will continue to monitor advancements in genetic work and larval tracking as we seek to confirm Spiny Lobster's place in the spectrum between a single mixed population, a meta-population, or a group of separate sub-populations. The research priority for genetic structure is medium.

Ecological Interactions

Spiny Lobster provides an important role in the ecology of rocky reefs, and it is associated with critical habitats such as surfgrass beds. Management should remain aware of information on the ecology and habitat preference of Spiny Lobster, and encourage related ecological research and monitoring. The FMP does not link ecological metrics directly to the reference points or the HCR, and future research and monitoring of ecological interactions are a medium level priority for the Department at this time.

Indices of Abundance

Indices of abundance (catch and CPUE) are used as reference points that link directly to the HCR in this ESR. The Department currently tracks CPUE and catch and data will be available after each fishing season for the foreseeable future. The knowledge regarding catch and CPUE is rich, and their status as reference points means that the priority for continued monitoring of these parameters is high. Ongoing research in alternative indices of abundance such as visual estimations of lobster densities and larval abundance is low to medium priority.

Movement Patterns

An accurate understanding of movement patterns allows us to better understand fishing impacts, as well for evaluating the effectiveness of MPAs. The level of knowledge on movement patterns is moderate, and their priority is medium. The Department will continue to engage in independent and collaborative tagging studies.

Reproduction

Size and age at maturity are important parameters for both the Cable-Department model and the MSE model. Determining this parameter has primarily been based on observing berried females found in fishery harvests and research trapping. Recent Department measurements during tagging studies suggest that SAM is smaller than previously thought. How this parameter and the timing of reproduction vary regionally is unknown. Fecundity of large female lobsters such as those inside MPAs has also not been thoroughly sampled. For these reasons, determining variability across regions is a future goal. State of knowledge on Spiny Lobster reproduction is moderate, and the priority for obtaining better information is high.

Total Mortality

Total mortality is the rate at which fish die, and it can be separated into two components: 1) natural mortality (causes include predation, disease, and old age), and 2) fishing mortality. Natural mortality is a critical parameter in biological models used in stock assessment. Little is known about juvenile natural mortality, or how it is influenced by factors such as ocean temperature, oceanographic regimes (e.g. PDO, El Niño), reef-specific ecology, habitat characteristics, and existence of MPAs (Kay and Wilson

2012). Approaches for estimating natural mortality include tag-recapture and examination of populations in MPAs. Generating more accurate estimates of total mortality has been identified as one of the highest priorities in the Spiny Lobster FMP (CDFW 2016) (see Table 5-1).

4.2 Past and Ongoing Monitoring of the Fishery

The previous section outlined the Essential Fishery Information (EFI) for the Spiny Lobster fishery as identified through the MLMA and the Spiny Lobster FMP. This EFI has been collected using several fishery-dependent and fishery-independent methods.

4.2.1 *Fishery-dependent Data Collection*

The Department collects substantial fishery-dependent data on Spiny Lobster through commercial logbooks, landing receipts, recreational lobster report cards, creel sampling, and at-sea sampling. These are described in more detail below.

Logbooks

Commercial fishermen have been required to record specific information for each fishing trip in commercial logbooks since 1973, with some additions throughout the years. In the mid-1990s, the Department transitioned from daily logs to new logs that record up to 3 days of fishing. A logbook entry must contain the date, fisherman and crew ID, vessel ID, Department fishing block, latitude and longitude corresponding to the area fished, the number of traps currently fished, the number of legal-size Spiny Lobster retained, and the number of sublegal-size Spiny Lobsters released. Effort is compiled based on the number of trap pulls or the length of the soak time reported on the logbook. Associated landing receipt ID numbers can also be recorded. Each log page has room to record 2 days of fishing with up to five sets of trap pulls per day.

Commercial Landing Receipts

Commercial landings have been recorded since the early 1900s via commercial landing receipts. Landing receipts record the date of sale, species(s) landed, port of landing, fisherman ID, vessel ID, Department fishing block from which the catch was taken, the price paid, and weight landed. Beginning in 2018, the number of lobsters landed must be recorded on landing receipts to allow Department staff to estimate average individual weight of caught Spiny Lobsters. Landing receipts are filled out by fish dealers or by fishermen permitted to sell their own catch. Beginning in 2019, the Department switched to using E-Tix, an electronic landing receipt system. After July 1, 2019 paper landing receipts will no longer be used.

Recreational Report Cards

Report cards must be purchased by every person fishing for lobster in California, including individuals who are not required to possess a valid sport fishing license (e.g.

youths under 16-yr-old, pier fishermen). Report cards record the date, location, gear type, and number of lobster retained. However, the cards do not include the number of nets used nor the amount of time spent fishing. In addition, the Department cannot practically compare the time recreational fishermen spent hoop net fishing directly with the time the community spent diving. Consequently, the Department uses ‘trips’, or a single line from the report cards, as the unit of effort. Due to this, as well as uneven report card return rates, only limited effort comparisons are possible between different gear types using the report card.

At- Sea Fishery Sampling

At-sea sampling refers to instances when fishermen gather data during normal fishing operation. California Sea Grant in collaboration with the Department conducted a three-year project for Spiny Lobster based on a framework developed for the southern California rock crab fishery (Culver et al. 2010) and an earlier effort by the Department. The project collected the same general information as the Spiny Lobster logs but included animal size, sex ratio, reproductive condition, shell condition, and trap density. This has provided important corroboration for the Department’s logbook data (and vice versa) and was used to help refine the Department’s estimates of average weight and subsequent calculations of SPR. At-sea sampling programs can also provide more accurate estimates of CPUE. The program required willing and capable fishery participants and employed financial incentives to offset reduced productivity for those participants. Because there is not continued, dedicated funding for the project, the program’s successful adoption in the future will depend on fishermen who recognize the value of additional data and voluntarily continue the work or additional mandatory reporting requirements.

Creel Sampling

Two creel surveys were undertaken in 1992 and 2007 by the Department targeting the recreational Spiny Lobster fishery. The data collected included fishing mode (type of fishing platform), gear, number of hours fished, fishing location, number of Spiny Lobster released, number kept, carapace length, weight, and sex. The surveys involved intercepting fishermen leaving a site after fishing. Survey sites include launch ramps, piers, jetties, and beach access points. The first survey occurred in 1992 and targeted lobster fishing during the first two weekends of the Spiny Lobster season at four sites. The 2007 survey encompassed the entire SCB and was done in preparation for the launch of the recreational lobster report card and sampled three of the four sites sampled in 1992. The 2007 survey also operated at night over the first 12 weeks. The 2007 sites were based on the Department’s long running finfish-oriented California Recreational Fisheries Survey (CRFS).

4.2.2 *Fishery-independent Data Collection*

Fishery-independent data is generated through scientific research that collects information that is independent of commercial or recreational fishing operations.

Surveys utilizing commercial fishing gear may provide unbiased estimates of abundance. Surveys may also use other methods (e.g. acoustics, SCUBA, video) to collect other biological or ecological information (e.g. movement, migration, growth rates, natural mortality) relevant to a fishery. Programs that collect fishery-independent data that inform the Spiny Lobster fishery include the Northern Channel Islands Kelp Forest Monitoring Program (KFMP) through the National Parks Service (NPS), numerous university-led research programs and projects, and citizen-science programs. Fishery-independent data have been used to estimate many of the critical parameters for the SPR model used as a part of the Spiny Lobster HCRs. In addition, the Department conducts fishery-independent research trapping and dive surveys when possible. These methods are described below.

Research Trapping

Research trapping programs use lobster traps to sample populations. Research trapping is typically collaborative and takes place onboard commercial fishing vessels. In some instances, scientists trained to use commercial fishing gear can work from research vessels, which can reduce scheduling conflicts among partners, especially when commercial vessels are unavailable (Kay et al. 2010). Research trapping is a powerful tool because data are collected in a manner that matches fishery-dependent methods, which makes data directly comparable in statistical analyses and stock assessment. Furthermore, traps allow researchers to sample a relatively large number of lobsters not typically possible with traditional research approaches (e.g., SCUBA). These programs have been employed in California to support MPA monitoring efforts as well as lobster tagging studies in the northern Channel Islands (Kay et al. 2011) and in the southern portion of the SCB (Hovel and Neilson 2011; Hovel et al. 2015).

Dive Surveys

SCUBA diving is an essential method for directly observing Spiny Lobster in their natural habitat. A large number of research groups use SCUBA to monitor reefs in southern California. Department scientists collaborated with other academic researchers on a baseline study for Spiny Lobster within southern California MPAs. The study included a research trapping and tag/recapture component, SCUBA surveys, and a habitat mapping/lobster movement component. The SCUBA survey was used to determine abundance, density, den occupancy, habitat type, and other ecological information at key locations inside and outside select MPAs. While this method is uniquely able to estimate animal densities and their association with particular habitat features, it suffers from several drawbacks. SCUBA surveys are typically conducted during the day when lobsters are in dens and may be difficult to observe. Additionally, the patchy spatial distribution of lobsters necessitates that large areas be surveyed in order to count a sufficient number for statistical analysis.

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. Acquiring essential fishery information (EFI) (e.g., biology of fish, population status and trends, fishing effort, catch levels, and impacts of fishing) that is currently not available or is incomplete for the Spiny Lobster fishery is important to determine if the current levels of fishing effort and harvest are sustainable and whether the stocks are robust enough to support the fishery over the long term. Information needs for the fishery, along with their priority for management is summarized in Table 5-1. For more detailed discussion of all EFI, see the Spiny Lobster FMP.

Table 5-1. Informational needs for Spiny Lobster and their priority for management.

Type of information	Priority for management	How essential fishery information would support future management
Individual growth rates and size-at-age	High	Allows for the development of an alternative growth model that fits Spiny Lobster data better than the von Bertalanffy growth model; will lead to a better estimate of SPR.
Patterns of sublegal-size lobster abundance	High	Allows for predictions of fishery yield for upcoming seasons, and provides assurance that reproduction has been successful in previous years.
Size structure of stock; Selectivity of length frequency sampling gear	High	Used to estimate total mortality, as well as to refine estimates of SPR; length frequency distribution provides a way to corroborate calculations of growth rate, fecundity, and mortality.
Effects of MPAs on size and abundance	High	MPAs provide researchers with an opportunity to correct for the maximum-size/age-related biases associated with fished populations; information on the cumulative biomass and reproductive potential of Spiny Lobster inside reserves can then be incorporated into the estimates of SPR.
Size and age at maturity; fecundity	High	Provides a better estimate of SPR and therefore stock recruitment
Source and sinks for larvae; Larval abundance and recruitment	Medium	Provides information for fisheries management such as: 1) long term trends that provide direct evidence of a stock's ability to replenish itself, 2) the state of the spawning biomass that produces the observed larval abundance, and 3) annual levels of recruitment to predict future catches
Genetic population structure	Medium	Informs whether the stock should be treated as a single US stock, a transboundary stock, or smaller stock units.
Seasonal/annual movement distances; Nightly foraging distances	Medium	The mechanisms by which Spiny Lobster exit MPAs or district closure and become vulnerable to fishing; improves estimates of fishing mortality
Handling mortality and sub-lethal impacts	Medium	Currently not represented in the stock assessment model; improves estimates of fishing mortality and fecundity

Natural mortality	Medium	A critical parameter in biological models used in stock assessment; juvenile natural mortality is not well understood

5.2 Research and Monitoring

5.2.1 *Potential Strategies to Fill Information Gaps*

Port Sampling and Creel Surveys

Port sampling is a method by which samplers meet commercial vessels when they return from fishing and measure some fraction or all of the catch. This is a very efficient and cost-effective method for obtaining large sample sizes, and would allow the Department to obtain information on the size structure of the stock (Table 5-1). During the 2008-09 fishing season, for example, a single researcher working with commercial lobstermen was able to sample 14 fishing trips from Santa Cruz Island and 17 trips from Santa Rosa Island. The catch sampled during these sampling sessions represented approximately 8.5% and 12.5% of the total 2008-09 catch from the Department fishing blocks encompassing Santa Cruz and Santa Rosa Islands, respectively (Kay et al. 2011). Port sampling is ideal for monitoring length frequencies, sex ratios, mean weight of animals in the catch, and condition of animals.

Collecting length frequency data from the recreational fishery would be similarly valuable and is not well represented by lengths in the commercial fishery because recreational fishermen are able to target larger individuals. The Department does not expect that size information could be accurately collected on recreational report cards and creel surveys would be most effective.

At-Sea Sampling

At-sea sampling has several advantages over port-sampling: 1) higher spatial resolution of sampling locations, 2) sublegal-size lobsters are measured and sexed, and 3) bycatch can be recorded. The disadvantage is that it requires more time and resources to collect these data. Currently the Department does not have an at-sea sampling program for collection of individual length frequency data with guaranteed consistency through time. Such a program would expand the Department's options for calculation of fishing mortality with potentially greater accuracy, distinguishing processes effecting Spiny Lobster life stages differentially, and tracking cohorts through time. At-sea sampling also provides an opportunity to conduct tagging studies to fill data gaps on movement and growth and for collecting individuals for use in research to explore new aging methods (Section 5.1).

Larval Collectors

Larval collectors may be able to provide information on larval recruitment and abundance (Table 5-1). Larval collectors are man-made devices upon which pueruli (post-larval lobster) settle. They are typically constructed to resemble preferred settlement surface, and are usually deployed in nearshore waters. The effectiveness of two puerulus collector designs was tested by Miller (2014) in California and Arteaga-Rios et al. (2007) noted significant positive correlation between pueruli in collectors and commercial catch in Baja, Mexico five years subsequent. While these studies are encouraging, the utility of puerulus larval collection for Spiny Lobster is still uncertain, and further research on sampling methodology is needed.

Monitoring recruitment

The California Cooperative Oceanic Fisheries Investigations' (CalCOFI) zooplankton sampling time series has the potential to reveal more information regarding the abundance and distribution of earlier stage phyllosoma larvae across several decades. Koslow et al. (2012) used this time series to identify a relationship between environmental conditions and phyllosoma abundance which were positively correlated. Spiny Lobster landings were also correlated with phyllosoma abundance across much of the time series but the relationship breaks down during recent years under high exploitation rates. This may indicate that recent high removal rates of reproductive individuals are having a negative impact on larval production and potential recruitment. Further work is required to better understand the relationship between phyllosoma abundance and spawning stock abundance before phyllosoma could be confidently used as the basis for a reference point within the HCR. However, the phyllosoma data will be extremely valuable when managers are prompted by the HCR to investigate the underlying causes for the existing reference points crossing their thresholds. The positive correlation between phyllosoma abundance and environmental indicators will help managers to distinguish between fishery and environmental processes impacting the stock and craft appropriate responses. Abundance of earlier stage larvae may serve as an indicator of adult spawning potential while late stage larvae may help forecast changes in stock abundance, identify preferred settlement habitats, and differentiate source and sink areas. The Department will continue to track the CalCOFI data on phyllosoma and will seek to develop collaborations to model larval transport in the SCB and California Current, which can help determine the sources and the destinations of the lobster larvae across southern California.

Oceanography

Oceanography is a broad field within marine science that focuses on the physical properties and processes of the ocean (e.g., water temperature, salinity, depth, nutrient levels, storm activity, currents, and bottom types). This field of study can directly assess the effects of climate change, ocean acidification, and climate driven hypoxia on future Spiny Lobster population. Oceanography can also relate the physical characteristics of the ocean to biological processes such as productivity, trophic structure, population connectivity, distribution of larvae, growth rate and distribution of fish stocks, disease outbreak, and other management relevant issues. Oceanographic data are typically collected with instruments deployed from boats and ships or with satellites; complex modeling is often the mainstay of data analysis.

Genetics

Genetics uses the hereditary material in an organism (e.g., genes coded for by DNA) to help understand a large number of biological processes. Because genes in DNA are passed from parents to offspring, and because certain genes are unique to individuals, populations, or species, they are a powerful tool for studying the relatedness of two or more organisms. This information can provide insight into topics like population connectivity, evolution, and disease susceptibility and resistance.

Disease

Spiny lobsters in the family Palinuridae do not harbor many naturally occurring diseases (Shields 2011), and so there has not been much research on the vulnerability of Spiny Lobster to disease. Lobsters are known to accumulate the toxin domoic acid, which is produced by the diatom *Pseudo-nitzschia*. The prevalence of domoic acid in Spiny Lobster in California has increased and led temporary closure of the commercial fishery in 2017 and 2018. Understanding the mechanisms of accumulation of this toxin in Spiny Lobster could aid in improving the health and safety of the fishery.

Regional Differences in Lobster Biology and Ecology

Both commercial log data and a collaborative At-Sea sampling program (Yaeger 2015) demonstrate that the average size of Spiny Lobsters increases along a south to north gradient within the Southern California Bight. High fishing effort and catch in San Diego likely contributes to reduced average lobster size, but there may also be biological explanations for differences in average size, including temperature, habitat quality, and recruitment patterns. Higher temperatures are known to increase lobster growth rates (Pecl et al. 2009), but they also increase lobster activity and catchability (Ziegler et al. 2003, 2004). The size at maturity may also vary with latitudinal temperature gradients. Genetic studies suggest that larvae are distributed over wide distances, so meta-population dynamics are likely not at play.

5.2.2 *Opportunities for Collaborative Fisheries Research*

Collaborative fisheries research is an effective way to collect EFI (length frequency, sex ratios, tagging studies, etc.) through dockside and creel sampling and at-sea sampling programs as discussed in section 5.2.1. Fishermen are encouraged to collaborate on their own initiatives and to form community organizations to help inform management. An example of this type of arrangement is the California Sea Urchin Commission. Furthermore, interested parties may wish to work with the Department and the Commission to develop innovations not explicitly mentioned in this ESR. These can include, but are not limited to, gear innovations, monitoring tools, regional management, and other technological advances.

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 Marine Life Management Act requires that "[f]ishery management decisions are adaptive and are based on the best available scientific information and other relevant information" (FGC § 7056(g). The Spiny Lobster FMP requires that the Department monitor the status of the HCR thresholds annually and, should they be crossed, evaluate the need for adaptive management as outlined in section 4.3.2 of the Spiny Lobster FMP. The Spiny Lobster fishery is actively monitored via data collection, analysis, and comparison to pre-determined reference points, and no additional management changes are necessary at this time. The Department will analyze and act on the results of research and monitoring efforts as appropriate to better inform the management framework outlined in the FMP. The ongoing and potential research efforts described in the previous section are expected to yield new useful information regarding the CA lobster stock and fisheries.

5.4 Climate Readiness

Impacts of increasing temperatures

Increased SST conditions will likely favor the Spiny Lobster fishery since behavioral changes related to warm temperatures increase harvest (Pringle 1986; Koslow et al. 2012). Even if countered by other climate change factors, variations in catchability would still need to be understood and addressed in stock assessment and modeling efforts for accurate results. Also, California is situated at the northern edge of the lobster's current domain range; lower numbers of lobster north of Point Conception are attributed to the cooler water found there. Increasing SST could therefore result in a general extension northward of lobster, particularly during El Niño years or times of enhanced Davidson Current northward flow. These latter two conditions are also thought to provide episodic transport of larvae north from Mexico that would also increase the Spiny Lobster abundance over time (Pringle 1986).

It is still unclear whether increased stratification or upwelling, which counters stratification, will be the dominant response to climate change. Increased stratification, however, is projected to lead to declines in zooplankton abundance (Roemmich and McGowan 1995), which could adversely affect the zooplankton larval phase of the Spiny Lobster directly or indirectly by reducing food sources. Conversely, upwelling and alongshore transport are strong determinants of dispersal and recruitment (Gaylord and Gaines 2000; Connolly et al. 2001). Harley et al. (2006) cited modeling work that suggested increased offshore movement (e.g. upwelling) can be negatively correlated with population size in benthic species. Therefore, very strong upwelling could reduce the ability of lobster to maintain adult populations in some areas. This is probably more applicable to regions north of Point Conception and, as such, would act to reduce northward movement of the lobster range rather than impact the southern California population.

Impacts on crucial Spiny Lobster habitat

Seagrass beds could be impacted by more frequent, higher intensity storm events damaging part of a bed, or completely destroying it. These events could also become relatively common occurrences. Damage or destruction of seagrass beds would impact lobster through reduction in suitable habitat for puerulus settlement, which is the earliest developmental stage of Spiny Lobster once they settle out of the plankton. This could result in mortality exceeding recruitment, leading to local loss of populations. Similarly, kelp beds could be damaged or destroyed at more frequent intervals. Lobsters are considered, along with urchins and kelp, to be necessary for the health of the kelp forest ecosystem. If kelp is lost at higher frequencies the result could be an imbalance in the kelp/lobster/urchin relationship, leading ultimately to loss of one of the primary regulators of the kelp forest ecosystem (and by extension, the lobster located there). In terms of the fishery, these storm events could also affect the fishermen economically by hindering their ability to fish, and by the destruction of gear.

Impacts on Spiny Lobster larval dynamics

Changes to the lobster stock may also occur via altered larval distribution and settlement, loss or gain of coastal nursery habitats, and altered abundances of strongly interacting species (e.g. predators and prey) (Pecl et al. 2009). Though first-stage larval abundance generally is correlated with SST (Figure 5-1), changes in wind patterns and storm frequency may alter larval dispersion and settlement (Caputi et al. 2010). Because Spiny Lobster larvae spend up to 10 months in the plankton stage, and the final larval stage actively swims from offshore to coastal nursery habitats, settlement success is dependent on the planktonic larvae’s distance offshore at the time of final molt. Any change in currents and storms that result in farther offshore dispersion will have an adverse effect on harvest in the future.

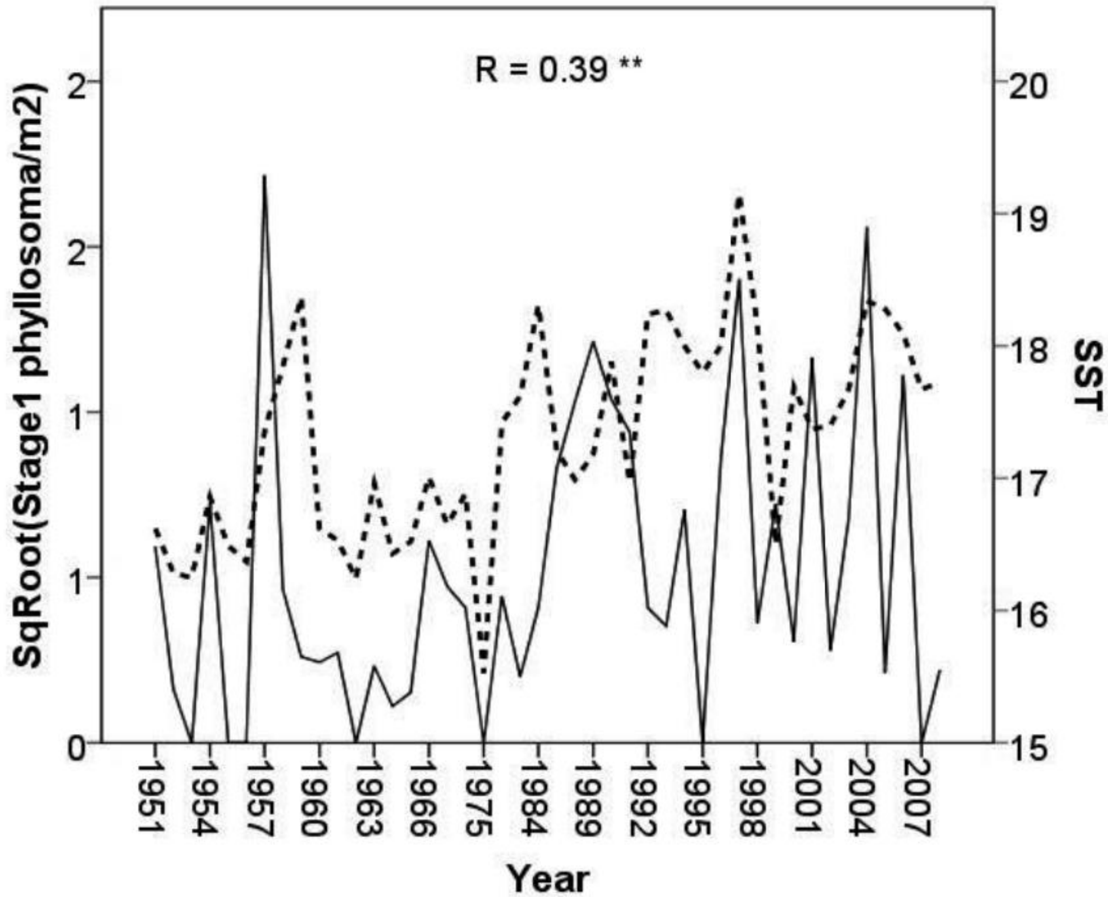

Figure 5-1. Time series of stage 1 phyllosoma abundance (solid line) plotted with mean SST (dashed line). Phyllosoma data were square root-transformed to normalize data distribution. R value indicates the strength of the correlation between the two lines (Modified from Koslow et al. 2012).

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