

Fishery-at-a-Glance: Market Squid

Scientific Name: *Doryteuthis (Loligo) opalescens*

Range: Market Squid range from Baja California, Mexico to southeastern Alaska.

Habitat: Market Squid inhabit inshore and offshore pelagic waters of the California Current Ecosystem but are also associated with bottom substrate during spawning events and egg development.

Size (length and weight): Market Squid are fast-growing. They are less than 3 millimeters at hatching and grow to an average mantle length of 152 millimeters at the time of spawning, approximately 6 months later. Individual growth rates vary.

Life span: Market Squid are short-lived with life spans of approximately 6-10 months.

Reproduction: Market Squid are terminal spawners, and thus de cease after reproducing. Spawning occurs year-round.

Prey: As larvae and juveniles, Market Squid consume copepods and euphausiids. As adults, they feed on fish, polychaete worms, squid (cannibalism) and crustaceans.

Predators: Market Squid are forage for many fish and marine mammal predators in the California Current Ecosystem.

Fishery: Market Squid primarily support a commercial fishery. In 2017 more than 137 million pounds of Market Squid were landed in California, generating roughly \$68 million in revenue. Median ex-vessel price of Market Squid has varied between \$0.10 and \$0.50 per pound since 2000 and remained at \$0.50 per lb. for 2016 and 2017. Landing, processing, and distribution mostly occur in Monterey Bay, Ventura, and Los Angeles port areas.

Area fished: The Market Squid fishery is centered in the nearshore waters of California, typically over sandy bottom habitats. Commercial effort is concentrated in central California around Monterey Bay and in southern California including the Channel Islands, though Market Squid may be available in commercial quantities from British Columbia to Baja, California.

Fishing season: The fishing season for Market Squid is year-round April 1 through March 31.

Fishing gear: Purse seine, drum seine, lampara, and brail gear are used in the Market Squid fishery.

Market(s): Market Squid are primarily exported with minimal domestic retention for processing. They also are used as bait or for consumption. Market Squid are typically

shipped frozen to China, Japan, and Europe for processing prior to sale and exported to international markets from there.

Current stock status: There is minimal concern for this stock as the entire population replaces itself annually. No current estimates of population abundance in California exist for Market Squid. Recruitment varies substantially from year to year in response to environmental factors, causing natural fluctuations in abundance.

Management: Since 2005 the Market Squid fishery has been principally state-managed through the Market Squid Fishery Management Plan. However, some federal regulations apply under the Coastal Pelagic Species Fishery Management Plan.

DRAFT

1 The Species

1.1 Natural History

1.1.1 Species Description

Market Squid (*Doryteuthis (Loligo) opalescens*) or Opalescent Squid (Figure 1-1), are part of the class Cephalopoda and the phylum Mollusca (Berry 1911). There are approximately 750 recognized species of squids alive today and more than 10,000 fossil forms of cephalopods. Market Squid belong to the family Loliginidae. These squid generally have a mixed, iridescent (opalescent) coloration of milky white and purple; however, color changes can occur rapidly. Similar to most squid species, Market Squid possess an ink sac that serves as a defense mechanism by expelling ink to confound predators. Squid have eight arms and two longer feeding tentacles. Squid have large, well-developed eyes and strong parrot-like beaks. Males are larger and more robust than females. Market Squid are terminal spawners; spawning occurs at the end of their life span (6 to 10 months after hatching) (Butler et al. 2001).



Figure 1-1. Identifying features of Market Squid (Photo Credit: CDFW).

At the Cephalopod International Advisory Council Symposium in Phuket, Thailand in February 2003, a consensus was reached that based on morphology and molecular evidence, the scientific name for Market Squid should be changed from *Loligo opalescens* to *Doryteuthis (Amerigo) opalescens* (Anderson 2000, Vecchione et al. 2005). This name change however was not formalized or published (CDFG 2005). The Department currently refers to *Loligo opalescens* as Market Squid in regulation (Fish and Game Code (FGC) §8420) and as Market Squid or *Loligo opalescens* throughout the Market Squid Fishery Management Plan (MSFMP) (FGC §8045).

1.1.2 Range, Distribution, and Movement

Market Squid range from the southern tip of Baja California, Mexico to southeastern Alaska (Figure 1-2). Juveniles and adults range throughout the California and Alaska Current systems (Roper and Sweeney 1984). In California, Market Squid typically spawn in shallow, nearshore areas, and are generally found in central California in summer months, and southern California in winter months (Hardwick and Spratt 1979).

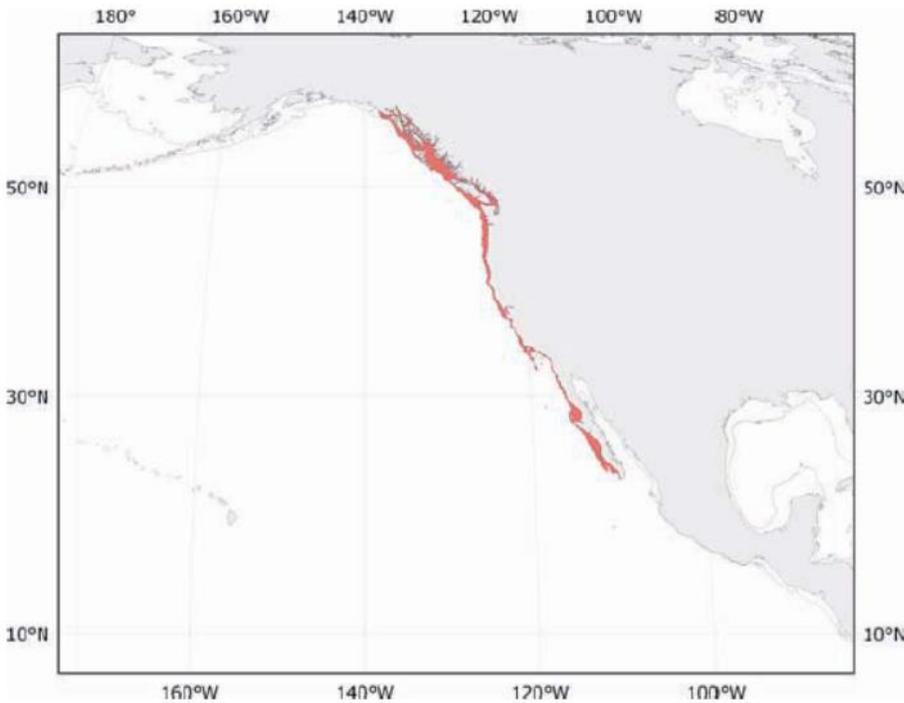


Fig. 92 *Doryteuthis (Amerigo) opalescens*

Known distribution

Figure 1-2. Range of Market Squid (Reproduced from Jereb et al. 2010).

Newly hatched Market Squid (called paralarvae) (Figure 1-3) are dispersed off egg bed areas by ocean currents and are found most commonly 1.0 to 3.0 kilometers (km) (0.6 to 1.9 miles (mi)) from shore, concentrated in areas where water masses converge (Okutani and McGowan 1969; Zeidberg and Hamner 2002). Their distribution is patchy, yet if squid are found at one site, it is likely that additional squid will be found in close proximity (contagious distribution). They are found at depths of 30 meters (m) (98 feet (ft)) by day and 15 m (49 ft) at night, suggesting diurnal movement (Zeidberg and Hamner 2002).



Figure 1-3. Market Squid paralarvae (Photo Credit: CDFW).

Juveniles begin to school at a Dorsal Mantle Length (DML) of 15.0 millimeters (mm) (0.6 inches (in)) (Yang et al. 1986) or 2.5 months of age (based on the growth curve presented in Butler et al. 2001) and occur on the continental shelf just off the bottom by day and throughout the water column at night (Zeidberg et al. 2004). As Market Squid reach 55.0 mm (2.2 in) DML they move off the continental slope (Zeidberg 2004). They are found at depths of up to 600 m (1,969 ft) during the day, but move vertically to the upper 100 m (328 ft) of the water column at night to feed (Hunt 1996; Zeidberg and Hamner 2002). Market Squid use their fins for swimming in much the same way fish do and their funnel for extremely rapid "jet" propulsion forward or backward. This allows them to migrate long distances from offshore pelagic waters to nearshore areas and form dense aggregations for spawning at an age of 6 to 10 months (Butler et al. 2001).

The number of different stocks or subpopulations of Market Squid along the entire Pacific Coast is unknown at this time. Results from Cheng et al (unpublished) provide preliminary support to the existence of smaller genetically distinct cohorts that continually spawn in California, as opposed to the prevailing notion that spawning occurs in two asynchronous peaks in the central California and southern California regions. Both Gilly (2003) and Reichow and Smith (2001) concluded that spawning populations that are commercially harvested from the Channel Islands are not genetically distinguishable from those landed in Monterey Bay. While Gilly et al. (2001) found slight but significant genetic differences between samples taken from central California and southern California, no temporal or spatial genetic differences for Market Squid within the southern California Bight (SCB) and no temporal differences between samples in the Monterey areas were evident.

1.1.3 Reproduction, Fecundity, and Spawning Season

Relatively little is known about the life history of spawning Market Squid. Generally, in central California, Market Squid spawning activity starts around April and ends in October. In southern California, spawning tends to begin around October and ends in April or May. The seasonality of spawning between central and southern California is attributable to ocean bottom temperatures rather than any biological

difference (Zeidberg et al. 2011b). During some years, reproductive activity and landings may occur throughout most of the year along the coast. Year-round spawning in several areas statewide at different times of the year likely reduces the effects of poor local conditions on survival of eggs or hatchlings and indicates that stock abundance is not solely dependent on availability of squid from a single spawning area. Spawning has been observed during daylight hours (Forsythe et al. 2004) as well as during the night.

Squid are terminal spawners, but females can spawn multiple times within a spawning period and may not die immediately after a single spawning event, as was previously believed (Hanlon et al. 2004).

Market Squid aggregate to spawn, usually over sandy habitats where they deposit extensive egg masses. Mating takes place on spawning grounds but may also occur before squid move to their spawning sites. Gametes are exchanged directly, with male squid placing spermatophores into the mantle cavity of females and eggs are fertilized as they are extruded (Hurley 1977). Zeidberg (2004) observed Market Squid mating in groups of 1 to 2 males per female and small males appeared to insert spermatophores into the mantles of females that were being held in a mating embrace by larger males. These interactions were termed “sneaker mating.”

Off California, a female squid produces approximately 20 egg capsules, with each capsule containing about 200 individual eggs that are suspended in a gelatinous matrix. The number of egg cases deposited and the number of eggs within egg cases vary by locale and decline throughout the spawning season. Females attach each egg capsule individually to the bottom substrate. As spawning continues, mounds of egg capsules covering more than 100 square meters may be formed and appear to carpet the sandy substrate.

After fertilization, embryonic development of egg cases at 16.0 degree, Celsius (°C) (60.8 degree, Fahrenheit (°F)) usually takes between 3 to 4 weeks, with hatching occurring on day 22 or 23. Hatching continues for about a week with numerous individuals appearing, but in decreasing volume. In cooler conditions the development time is probably at least a week longer (Fields 1965). While the embryo develops, considerable change takes place in the protective capsule. The capsules continue to take on water and when hatching begins, the volume and weight of each capsule reaches about five times its original value. When a juvenile squid is ready to hatch it makes an opening large enough to escape using strong mantle contractions and then becomes free-swimming. Based on laboratory observations, it is theorized that most of the juveniles emerge during the first several hours of darkness and with upward swimming and tidal drift, they are able to clear the egg beds and spawning grounds before light (Fields 1965).

Macewicz et al. (2001b, 2004) found that female squid have a fixed reproductive output and die before developing and spawning all possible eggs in their ovaries. The fecundity-size relationship was found to be linear, and the potential fecundity is calculated as 29.8 multiplied by the DML (in mm) (Macewicz et al. 2004). For an average female with a DML of 129.0 mm (5.1 in), the potential fecundity is 3,844 eggs. Dorval et al. (2013) found that this linear model did not account for a substantial amount of the total variation in potential fecundity and therefore proposed using mean potential fecundity when exploring egg escapement from the Market Squid fishery.

Market Squid egg hatching rate is determined by temperature, with incubation time ranging from 22 to 90 days at temperatures ranging from 42.0 to 68.0 °F (5.6 to 20.0 °C) (Isaac et al. 2001). Eggs are commonly deposited in areas with water temperatures between 50 and 58 °F (10.0 to 14.4 °C), resulting in incubation periods lasting from 34 to 52 days.

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.

Based on their short life span of 6-10 months, Market Squid appear to exhibit a very high natural mortality rate (Macewicz et al. 2004) and the adult population is composed of almost entirely new recruits. These observations suggest that the entire stock is replaced annually, even in the absence of fishing. Natural mortality is attributed in part to heavy predation, as Market Squid are prey for a variety of fish and marine mammal predators in the California Current Ecosystem (CCE) (Figure 1-3). However, Market Squid also die shortly after spawning occurs, and it is thought that their fast growth and high metabolic rates contribute to these high natural mortality rates (O'dor and Webber 1986).

While there are no studies directly estimating the natural mortality rate of squid, the total mortality (natural and fishing) has been estimated to range from 0.3 to 0.6 per month based on squid ageing data (Maxwell et al. 2005; Butler et al. 2001)

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.

Market Squid are less than 3.0 mm (0.1 in) at hatching and grow to an average mantle length of 152 mm (10 in) at the time of spawning. Butler et al.(2001) found that Market Squid growth increases with age and is best described with an exponential function (Figure 1-4):

$$DML = 0.001342 * Age^{2.132}$$

where DML is in millimeters and age is in days ($r_2 = 0.95$, $df = 275$, $P < 0.001$). Paralarvae growth is slow (0.05 (0.002 in) mm DML per day) during the first month, but growth rates increase dramatically as squid mature. Growth may vary based on location and environmental conditions (Jackson 1994; Butler et al. 1999), with lower growth

observed in years with warmer water conditions, likely due to a reduction in food availability (Jackson and Domeier 2003).

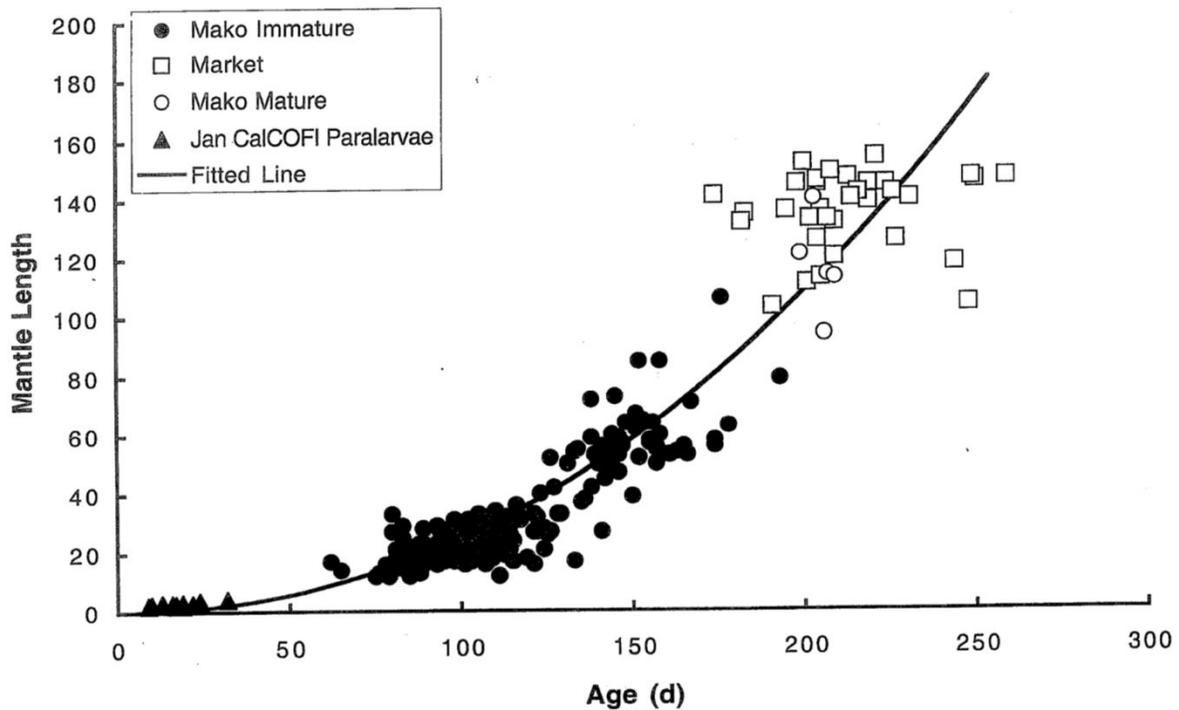


Figure 1-4. Relationship between age (in days) and DML (in mm) of Market Squid for a cohort hatched in November to December 1999 (Reproduced from Butler et al. 2001). In the figure legend above, R/V “Mako” is the name of the vessel, “Market” indicates adult squid were collected from the commercial fishery, and “Jan CALCOFI Paralarvae” indicates paralarvae samples collected from a January CalCOFI cruise.

Macewicz et al. (2004) fit an exponential function to describe the weight-length relationship for female squid (Figure 1-5). Because the body weight of squid declines as eggs are released, this function was fit to data for mature females that had not yet spawned (pre-ovulatory females).

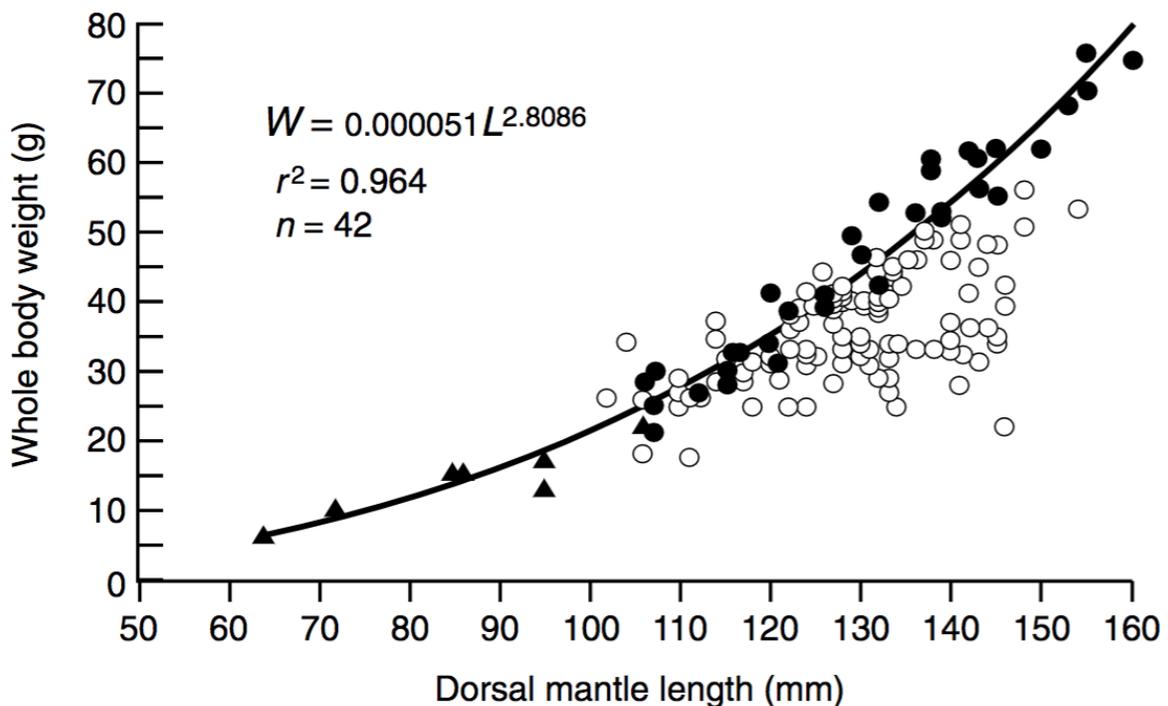


Figure 1-5. Female Market Squid whole body weight as a function of DML length prior to spawning (n=158). Solid triangles represent immature females, solid circles represent mature females that have not spawned, and open circles represent females that have spawned (Reproduced from Macewicz et al. 2004).

1.1.6 Size and Age at Maturity

Market Squid begin to reach sexual maturity 5 or 6 months after hatching (Butler et al. 1999; Butler et al. 2001). At this point they begin to recruit to the fishery and are fully vulnerable by 6 months of age (Butler et al. 2001).

Maturation is thought to be size rather than age dependent, occurring at approximately 100 mm (4 in) in DML for females (Butler et al. 1999; Jackson and Domeier 2003; Maxwell et al. 2005). Females may lay a large proportion of their eggs within the first few days following maturity (Macewicz et al. 2004) and lay less and less over time.

1.2 Population Status and Dynamics

The unique biology of cephalopods such as Market Squid requires a different management approach than other fisheries (Boyle 1990). Market Squid exhibit very fast growth and short life spans. They are most vulnerable to fishing during mating, when males and females pair up to exchange gametes directly. Because Market Squid die shortly after laying eggs, recruitment to the population is entirely dependent on the successful survival of the eggs. This could lead to concerns that a cohort failure, in which reproduction is unsuccessful either due to adult mortality prior to mating or environmental conditions that affect egg/juvenile survival, would be highly detrimental to

the population and the fishery (Boyle and Boletsky 1996; Hibberd and Pecl 2007; Zeidberg et al. 2011a).

Market Squid appear to exhibit large variability in year-to-year abundance. These fluctuations are attributed to environmental conditions influencing survival of recruits (Ralston et al. 2015). However, these fluctuations may also reflect changes in the spatial distribution of the population, making them more available to fishermen or surveys in some years and less available in others. In addition, the fact that the central and southern California landings generally peak 6 months apart suggests that two spawning events occur per year, and the recruits from successful Monterey spawning activity may become the adults taken in the southern California fishery the following winter, and vice versa (Butler et al. 1999; Zeidberg et al. 2011b). It's also possible that there is deeper (70.0 to 150.0 m (229.7 to 492.1 ft)) off-season spawning or that spawning occurs year-round with an annual harmonic of concentrated spawning in the spring in Monterey, and the winter in southern California due to favorable oceanographic conditions (Zeidberg et al. 2011b). Due to these life history characteristics, forecasting abundance or availability using traditional demographic models is impossible, and many squid fisheries are managed based on the concept of "escapement" in which fishing is restricted in order to allow a certain proportion of the population to spawn successfully.

1.2.1 Abundance Estimates

There is information on the coast wide distribution and relative abundance of Market Squid from fishery-independent midwater rockfish trawl surveys that are conducted at night annually between San Diego, California and Gold Beach, Oregon in May and June by the National Marine Fisheries Service (NMFS). These surveys are part of the Southwest Fisheries Science Center (SWFSC) Rockfish Recruitment and Ecosystem Assessment Survey. Data are incorporated into the California Current Integrated Ecosystem Assessment (CCIEA) project available at the National Oceanic and Atmospheric Administration (NOAA) CCIEA website (CCIEA 2018). Due to the timing and location of these trawl surveys, as well as the ability of larger squid to avoid the trawl nets, these surveys only provide an index of relative abundance of juvenile squid (Figure 1-6) (Ralston et al. 2018). This index was paired with a model of egg escapement developed by Dorval et al. (2013) to develop an estimate of total abundance north and south of Point Conception (Table 1-1). This represents the best available index of absolute abundance for the Market Squid population in California.

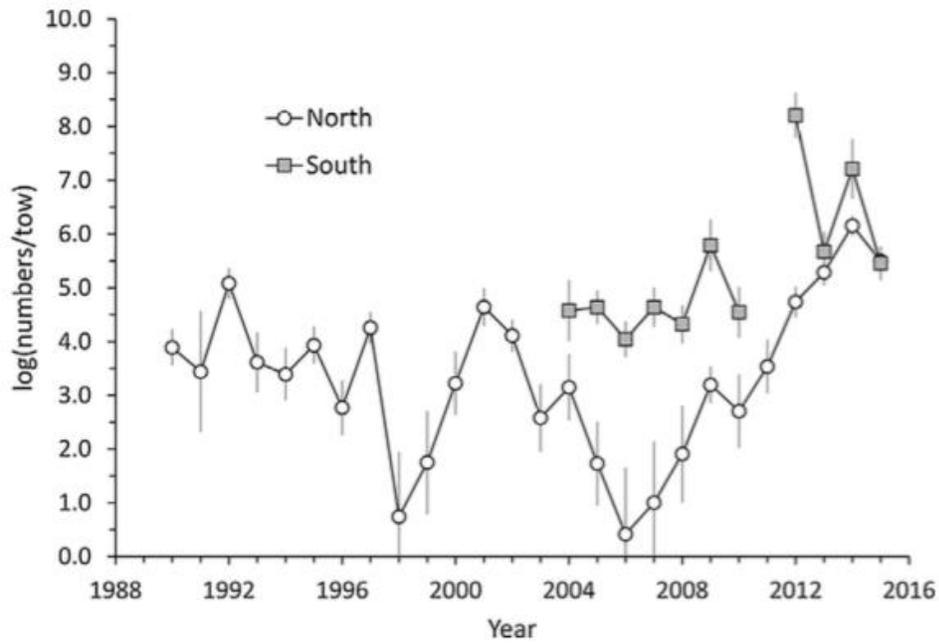


Figure 1-6. Annual variation in the abundance of Market Squid based on standardized midwater trawl survey data (logged numbers of squid per tow) for north and south of Point Conception (see Ralston et al. 2018 for methods). The error bars ± 1.0 standard error (Reproduced from Ralston et al. 2018).

Table 1-1. Year x quarter estimates of Market Squid spawning stock biomass (metric ton) in Regions 1, 2, and 3 (Dorval et al. 2013). Estimates based on the method of Dorval et al. (2013), assuming a natural mortality rate of $M = 0.15$ and an egg laying rate of $v = 0.45$ (Reproduced from Supplementary Appendix A. in Ralston et al. 2018).

Year	Region 1				Region 2				Region 3			
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
1999	-	-	-	-	10,260	19,069	3,095	51,124	2,803	5,704	276	9,566
2000	-	7,631	2,539	440	29,523	11,019	3,187	127,275	11,695	2,593	1,161	21,114
2001	-	1,447	6,473	982	19,081	10,252	3,986	42,345	31,831	701	1,048	51,640
2002	1,876	19,523	6,438	2,864	12,302	1,030	2,458	14,738	70,594	964	135	523
2003	-	6,821	9,656	5,715	4,137	862	1,556	32,561	1,067	727	1,904	2,281
2004	-	6,319	2,766	-	18,905	13,775	-	36,702	31,635	401	-	377
2005	-	3,349	1,126	-	108,656	-	-	6,460	6,952	1,120	1,992	29,451
2006	-	1,446	163	-	5,686	-	656	9,557	70,261	4,501	3,797	-
2007	-	-	-	-	79,634	345	404	-	7,398	-	356	2,918
2008	-	-	-	-	13,149	-	4,420	-	11,927	1,382	2,879	-
2009	-	483	-	-	63,426	-	-	78,918	17,838	2,388	6,908	6,960
2010	-	36,598	9,695	4,543	-	-	5,093	59,113	31,104	-	1,816	78,156
2011	-	6,169	7,257	-	5,669	-	30,367	68,008	4,045	-	9,781	45,882
2012	-	-	9,402	21,354	4,612	1,732	35,799	101,764	8,418	-	0	109,407
2013	-	775	19,944	1,597	-	9,588	42,729	57,741	2,076	5,204	27,047	30,655
2014	-	20,274	31,806	-	-	3,596	-	-	644	3,335	-	-

A time series of the larval abundance (paralarvae) of Market Squid is also available from the California Cooperative Fisheries Investigation (CalCOFI) sampling program (Figure 1-7) (See section 4.2.2 for more information on CalCOFI sampling).

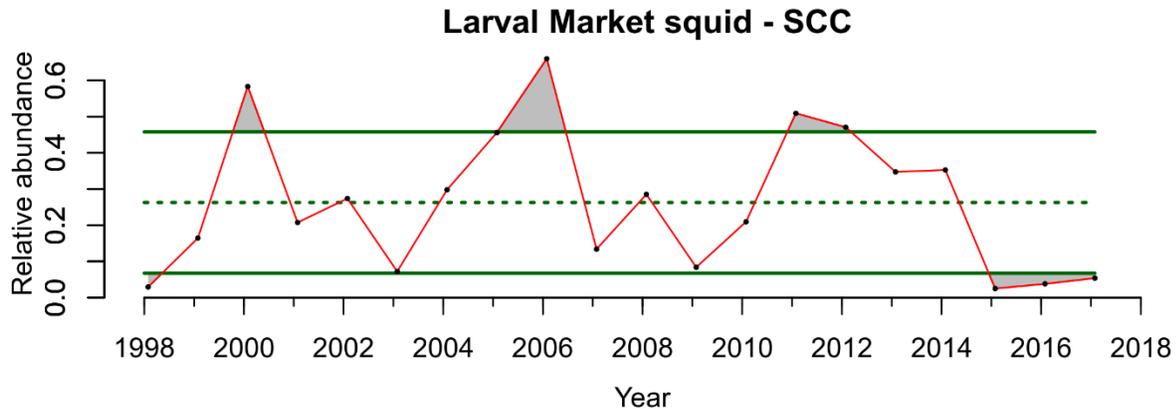


Figure 1-7. Index of larval abundance for Market Squid in central California. These data were collected during spring CalCOFI surveys (CalCOFI 2018). Data are summed across all sampled stations, and units are in number under 10 square meters of surface area; $\ln(\text{abundance}+1)$. The dashed line represents the long-term mean, and the solid lines represent the mean \pm one standard deviation. (Reproduced from CCIEA 2018).

Zeidberg et al. (2006) found a significant linear relationship between a paralarvae density index collected in February in the SCB and Catch Per Unit Effort (CPUE) in southern California the following November from 2000 to 2003. This suggests that the number of paralarvae could be used to predict adult abundance and potentially be used as an indicator in management. Continued efforts to assess this paralarvae index as a potential management tool are on-going by the Department, the California Wetfish Producers Association (CWPA), and the SWFSC. Van Noord and Dorval (2017) found a strong relationship between paralarval density and distribution to local Sea Surface Temperature (SST) and ocean productivity (specifically a measurement of zooplankton abundance). Relative paralarval abundance and fishery landings remained high during cool and productive La Niña conditions. Conversely, a strong El Niño Southern Oscillation (ENSO) drove dramatic declines in relative paralarval abundance followed by a decline in fishery landings (Figure 1-8).

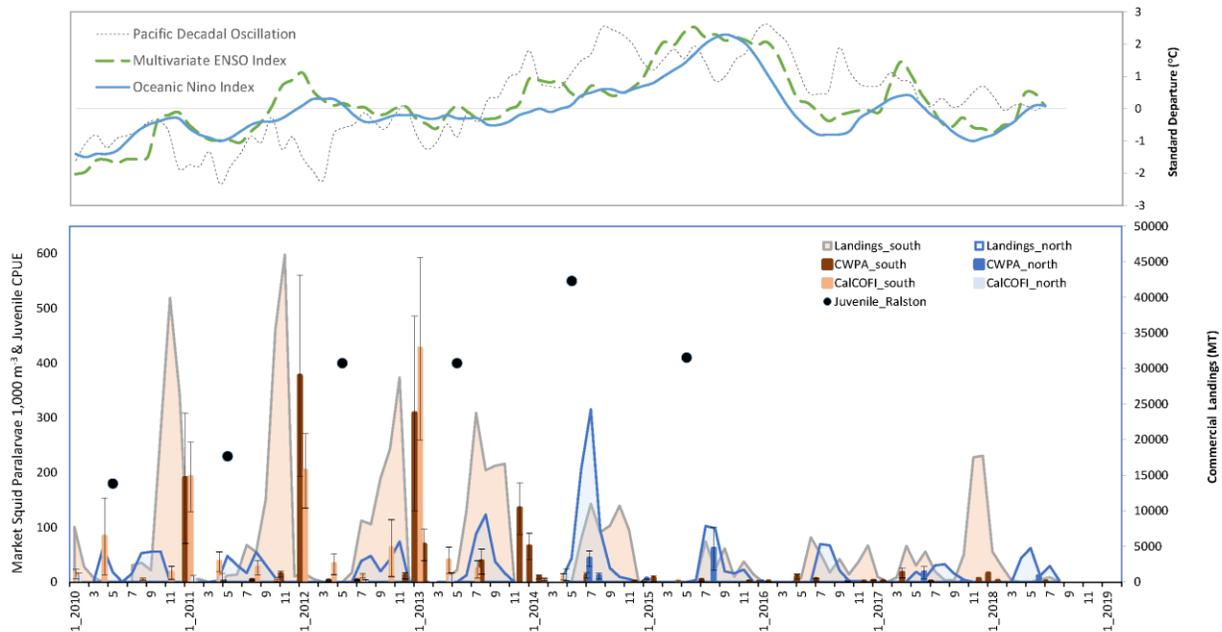


Figure 1-8. ENSO influences on Market Squid in the California Current. Top panel displays the trends in the Multivariate ENSO index, dashed green line, Oceanic Niño Index, solid blue line, and the Pacific Decadal Oscillation, dotted grey line. Negative values indicate temperature that is cooler than the long-term average from 1981 to 2010, while positive values indicate the opposite. Bottom panel displays Market Squid paralarval abundance and juvenile CPUE from Ralston et al. 2018 on the left, and landings on the right y-axis. SCB information is displayed in red and orange, bars for paralarvae, and shaded areas for landings. Monterey Bay Region data are shown in blue, bars for paralarvae, and lines for landings. Error bars indicate two standard error. All data span September 2010 through September 2018. (Figure reproduced from Van Noord and Dorval 2017).

Some information on the status of Market Squid can be drawn from fishery-dependent indicators. Yearly catch in southern and central California can provide some information on recruitment from the previous season, but catches may provide a negatively biased estimate of the population strength unless economic factors are accounted for (Hardwick and Spratt 1979). Yearly catch may be influenced by availability, market demand, and processing capacity. In addition, because fishing occurs on shallow-water spawning aggregations, catches may not consistently reflect the overall stock size. Market Squid embryos have been documented at greater depths than what the fishery targets (Navarro et al. 2018), and adults may spawn outside the temporal and spatial window of the fishing fleet (e.g., further offshore, further north, or further south). The fishery also closes once the maximum catch limit is reached during episodes of high abundance. Thus, catch or CPUE alone may not be a suitable index of abundance.

1.2.2 Age Structure of the Population

Market Squid age can be determined using statoliths, which are hard structures similar to otoliths in fish. Rings are deposited daily on statoliths and used to determine life span. Daily ring deposition has been validated for several squid species including Market Squid and has been shown to be an accurate method for ageing squid (Jackson and Domeier 2003; Hurley et al. 1985; Lipinski 1986; Jackson 1990a, b, 1994, 1998; Bettencourt et al. 1996; Spratt 1979).

Squid are a semi-annual species (individuals live for only half the year), and the average age of squid taken in the fishery is 6 months (range 4 to 10 months) (Butler et al. 2001). Available age data exhibit little variation among months. This strongly suggests that a new cohort, defined as a group of squid spawned during the same period, enters the fishery almost monthly. Figure 1-9 shows the age structure of the Market Squid catch by sex from port samples collected from November 1998 through July 2000. The mean age of harvested Market Squid was 188 days. More than 99% (904/908 or 99.6%) of the squid aged could be sexed, suggesting that the fishery primarily targets mature squid.

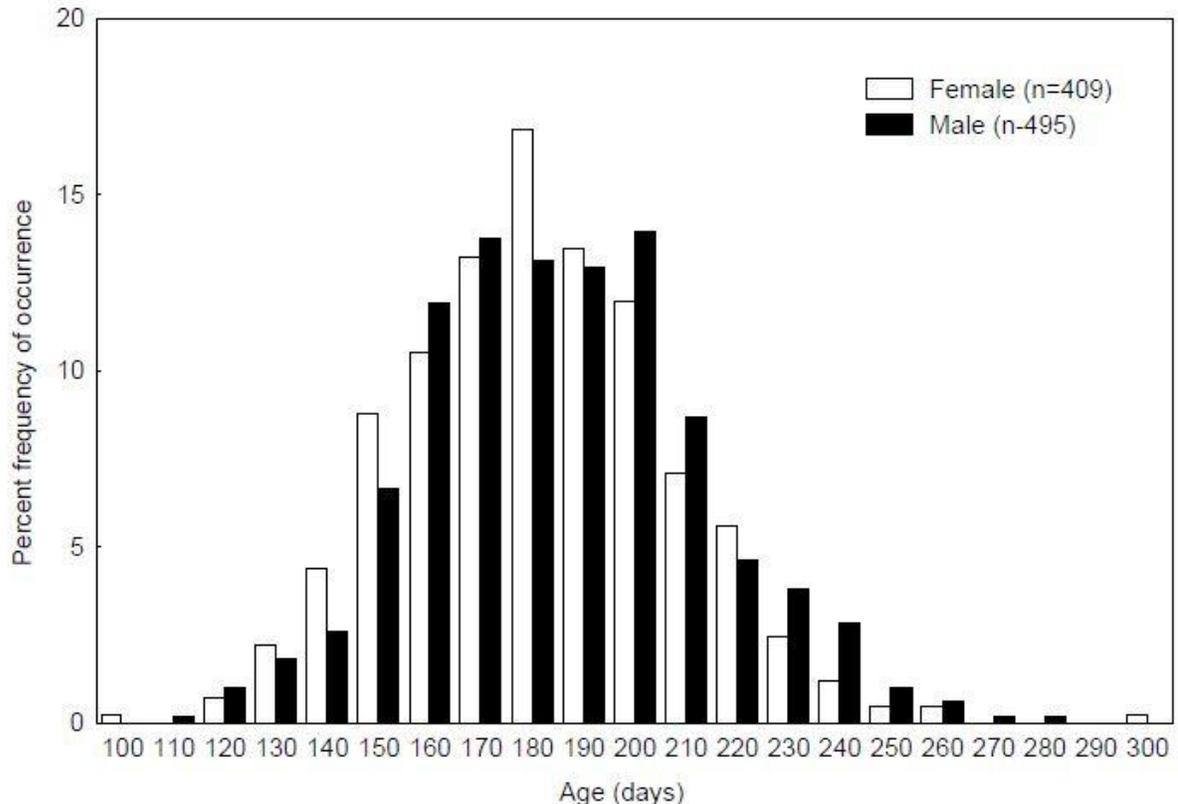


Figure 1-9. Market Squid percent frequency of occurrence by age and sex. Port samples used to determine percent frequency of occurrence were collected from November 1998 through July 2000. (Reproduced from the MSFMP 2005).

Statolith sample collections from commercial catch data from 2000 to 2019 still need to be aged, and thus it is not yet possible to tell if the age structure of the stock has changed over time. Because it is thought that size is a better indicator of sexual

maturity, potential changes in both size and age structure of the stock could provide valuable insight in to fishing mortality and natural mortality. Average size fluctuates between and among fishing seasons, which could be attributed to different cohorts (Protasio et al. 2014). However, since age data have not been analyzed, this cannot be confirmed nor denied. These are key informational gaps.

1.3 Habitat

The definition of Essential Fish Habitat (EFH) for Coastal Pelagic Species (CPS), such as Market Squid (*Doryteuthis opalescens*), Pacific Sardine (*Sardinops sagax caerulea*), Pacific Mackerel (*Scomber japonicus*), Northern Anchovy (*Engraulis mordax*), and Jack Mackerel (*Trachurus symmetricus*), is based on a thermal range bordered by the geographic area where CPS occurs at any life stage, have occurred historically, or where environmental conditions do not preclude colonization by CPS (PFMC 2018). For the east-west geographic boundary, the EFH for CPS includes all marine and estuarine waters from the shoreline along the California, Oregon, and Washington coasts offshore to the limits of the Exclusive Economic Zone and above the thermocline, where SSTs range between 50 to 79 °F (1 to 26 °C), the upper tolerance of CPS finfish (PFMC 2018). The southern boundary is the United States-Mexico maritime boundary. The northern boundary is more dynamic and is defined as the position of the 10°C isotherm, which varies seasonally and annually (PFMC 2018).

Not much is known about the specific pelagic habitat requirements of adult Market Squid, but there is some evidence that their depth is limited by the Oxygen Minimum Zone (OMZ), which is a naturally occurring area ranging from a depth of 500.0 to 1,000.0 m (1,640.2 to 3,280.8 ft) where the amount of dissolved oxygen is less than that needed to support many marine species (Helly & Levin 2004; Stewart et al. 2014).

Some studies have mapped the spatial distribution and extent of egg beds using Remotely Operated Vehicles (ROVs) (Young et al. 2011; Zeidberg et al. 2011b). Major spawning grounds fished in California are located in Monterey Bay and the SCB. Zeidberg et al. (2011b) found that 95% of squid eggs surveyed were found on sandy benthic substrate in temperatures between 10.0 to 14.4 °C (50.0 to 57.9 °F) at depths between 20.0 and 70.0 m (65.6 to 229.7 ft). During spawning, egg capsules are inserted into sand with a thin anchoring strand, and wave surge ventilates the eggs (Zeidberg et al. 2011b). This depth may provide a range where the wave action is enough to provide oxygen, but not so strong that it dislodges the egg capsules. From in-situ observations, Navarro et al. (2018) found that Market Squid embryos require dissolved oxygen levels greater than 160 millimole and a pH greater than 7.8.

Squid eggs have been found significantly shallower in central California (13.0 to 61.0 m (42.7 to 200.1 ft)) than around the Channel Islands (20.0 to 93.0 m (65.6 to 305.1 ft)), in areas having a temperature of 10.0 to 12.0 °C (50 to 53.6 °F). This suggests that substrate and temperature, rather than depth, are the primary features of suitable spawning habitat (Zeidberg et al. 2011b). This temperature preference was also supported by laboratory studies that found that hatch rates are maximized when eggs are reared at temperatures between 9.0 and 14.0 °C (48.2 to 57.2 °F) (Zeidberg et al. 2011a). The upper and lower limits of viability appear to be 25 °C (77 °F) and below 7.0 °C (44.6 °F), respectively (Zeidberg et al. 2011a).

If temperature rather than depth or substrate is the primary determinant of suitable spawning habitat, then the amount of spawning habitat may vary from year to year, and this may impact egg survival rates. This may also explain the variability observed in the fishery, both seasonally and between years. The concentrated spawning aggregations targeted by the southern California fishery in December/January and the central California fishery in May/June, may be triggered by favorable ocean bottom temperatures (Young et al. 2011). Additionally, the year to year variation observed in the population and the low commercial landings seen during and after El Niño events may be due to a lack of suitable spawning habitat in warmer water years (Zeidberg et al. 2011b), a preference for deeper less accessible spawning grounds, or other unknown factors.

1.4 Ecosystem Role

Market Squid are a key nearshore prey species in the California Current Ecosystem (CCE) (Szoboszlai et al. 2015). The CCE is an eastern boundary current upwelling system off the West Coast of the United States, extending from the Strait of Juan de Fuca in the north to the Mexican border in the south. Market Squid play an important role as a mid-trophic level species, in which they transfer energy up the food chain from zooplankton, crustaceans, and small fish (their prey) to large fish, marine mammals, and birds (their predators). Market Squid are classified as a mid-energy taxa and are an important part of the prey assemblage in years in which the CCE experiences cooler waters, strong upwelling, and higher productivity (Harvey et al. 2018).

1.4.1 Associated Species

Several marine worms use squid as a host species. Larval nematodes (roundworms), cestodes (tapeworms) and polychaetes (bristleworms) have all been recovered from squid and/or squid eggs. Nematodes, cestodes, and their larval stages have been found in Market Squid (Walthers and Gillespie 2002). In Monterey Bay, Riser (1949) cited infestation of squid by two types of plerocercoid larvae. These larvae are tetraphyllidean cestodes that infest the large intestine of the squid. At Point Mugu, squid sampled from a commercial seafood outlet exhibited infestation by larval cestodes (orders Tetraphyllidea and Pseudophyllidea) and nematodes. These parasites were found to infect the eye, stomach, intestines, body cavity and tissues at a rate of 76.9% (Dailey 1969). The polychaete worm *Capitella ovincola* was thought to be a predator of Market Squid eggs, because it has been found inside squid egg capsules (MacGinitie and MacGinitie 1949). In fact, *C. ovincola* eat the outer casing of the egg capsule, not the embryo itself (Zeidberg et al. 2011a). This does not appear to affect squid fitness either by decreasing the egg hatching rate or triggering premature hatching (Morris et al. 1980) and was found to slightly increase the hatch rate of Market Squid eggs reared under laboratory conditions, suggesting a symbiotic relationship between these organisms (Zeidberg et al. 2011a).

1.4.2 Predator-prey Interactions

Market Squid as Predators

Market Squid feed on a variety of prey during their life cycle. As larvae and juveniles, squid consume copepods and euphausiids. As adults, Market Squid feed on fish, polychaete worms, squid (cannibalism), and crustaceans such as shrimp and pelagic red crab. Market Squid have also been found in commercial catches of Northern Anchovy, Pacific Sardine, Pacific Herring (*Clupea pallasii*), Pacific Mackerel, Jack Mackerel and Pacific Saury (*Cololabis saira*) where they feed with and most likely upon these fish (Fields 1965).

Prey composition fluctuates with squid age, size, and reproductive status, as well as by depth and location (Karpov and Cailliet 1979). The availability of prey and the behavior of Market Squid at different depths and locations may influence feeding behavior. Karpov and Cailliet (1978, 1979) found that crustaceans and cephalopod fragments were ingested at higher frequencies on spawning grounds than on non-spawning grounds. Inshore versus offshore samples of squid indicated differences in diet composition. In deeper waters, euphausiids and copepods were dominant prey items, while true cannibalism (intake of whole cephalopods) and fish consumption dominated in shallow waters.

Market Squid as Prey

Market Squid are an integral part of the food web to many marine organisms. A meta-analysis of dietary studies in the CCE found Market Squid in the diet of 51 predators (Szoboszlai et al. 2015). Fish, seabirds, and marine mammals all consume squid as a prey item, as does the Humboldt Squid (*Dosidicus gigas*) (Stewart et al. 2014). The sea star (*Asterina miniata*) and the gastropods (*Kelletia kelletii*) and (*Cypraea spadicea*) have also been observed to eat Market Squid eggs (Zeidberg et al. 2004)

Squid has been documented as an important dietary component of marine mammals (Sinclair 1992; Fields 1965) and seabirds (Morejohn et al. 1978). In Monterey Bay, 19 species of fish were found to feed on Market Squid, including many commercially important species such as Pacific Bonito (*Sarda lineolata*), Salmon, Halibut, and Tuna (Fields 1965; Morejohn et al. 1978) (Figure 1-10). In fact, predators from many trophic levels consume both small pelagic fishes, such as Northern Anchovy and Pacific Sardine, and Market Squid as either a primary or supplementary food source (Table 1-2).

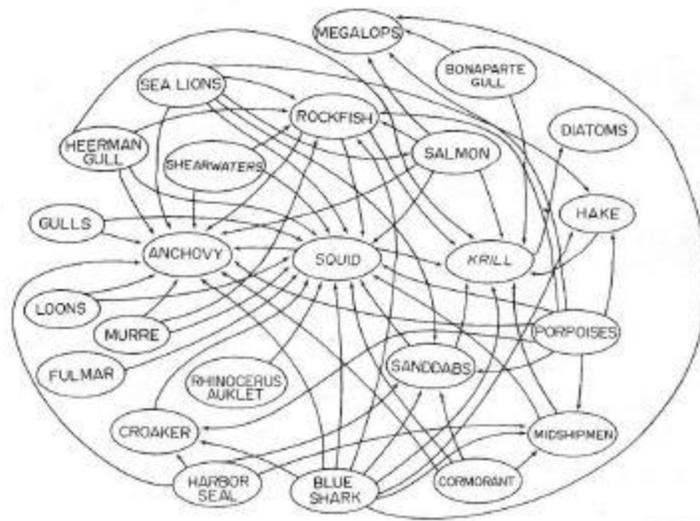


Figure 1-10. Food web for Market Squid involving commercially important or abundant fish, birds, and marine mammals (Reproduced from Morejohn et al. 1978).

Table 1-2. Known fish, bird, mammal and invertebrate predators of coastal pelagic species, including Market Squid (Reproduced from the MSFMP). Updated July 2019 (CDFW 2019).

Marine Mammals			
Northern Fur Seal	<i>Callorhinus ursus</i>	Bottlenose Dolphin	<i>Tursiops truncatus</i>
Guadalupe Fur Seal*	<i>Arctocephalus townsendi</i>	Pilot Whale	<i>Globicephala spp.</i>
Steller Sea Lion	<i>Eumetopias jubatus</i>	Blue Whale*	<i>Balaenoptera musculus</i>
California Sea Lion	<i>Zalophus californianus</i>	Fin Whale*	<i>Balaenoptera physalus</i>
Northern Elephant Seal	<i>Mirounga angustirostris</i>	Sei Whale*	<i>Balaenoptera borealis</i>
Harbor Seal	<i>Phoca vitulina</i>	Minke Whale	<i>Balaenoptera acutorostrata</i>
Common Dolphin	<i>Delphinus capensis</i>	North Pacific Right Whale*	<i>Eubalaena japonica</i>
Harbor Porpoise	<i>Phocoena phocoena</i>	Humpback Whale*	<i>Megaptera novaeangliae</i>
Dall's Porpoise	<i>Phocoenoides dalli</i>	Eastern North Pacific Gray Whale	<i>Eschrichtius robustus</i>
Pacific White-sided Dolphin	<i>Lagenorhynchus obliquidens</i>		
Marine Fish			
Northern Anchovy	<i>Engraulis mordax</i>	Yellowtail	<i>Seriola dorsalis</i>
Pacific Sardine	<i>Sardinops sagax</i>	White Seabass	<i>Atractoscion nobilis</i>
Pacific Whiting	<i>Merluccius productus</i>	Queenfish	<i>Seriphus politus</i>
Common Thresher Shark	<i>Alopias vulpinus</i>	California Corbina	<i>Menticirrhus undulatus</i>
Bonito Shark	<i>Isurus oxyrinchus</i>	White Croaker	<i>Genyonemus lineatus</i>
Soupin Shark	<i>Galeorhinus zyopterus</i>	Surfperches (many species)	<i>Amphistichus spp.</i>
Blue Shark	<i>Prionace galuca</i>	California Barracuda	<i>Sphyræna argentea</i>
Pacific Electric Ray	<i>Torpedo californica</i>	Pacific (Chub) Mackerel	<i>Scomber japonicus</i>
Silver (Coho) Salmon*	<i>Oncorhynchus kisutch</i>	Pacific Bonito	<i>Sarda lineolata</i>
King (Chinook) Salmon*	<i>Oncorhynchus tshawytscha</i>	Albacore	<i>Thunnus alalunga</i>
Steelhead*	<i>Oncorhynchus mykiss</i>	Bluefin Tuna	<i>Thunnus orientalis</i>
Rockfish (many species)	<i>Sebastes spp.</i>	Swordfish	<i>Xiphias gladius</i>
Striped Bass	<i>Morone saxatilis</i>	Striped Marlin	<i>Kajikia audax</i>
Barred Sand Bass	<i>Paralabrax nebulifer</i>	Giant Seabass	<i>Stereolepis gigas</i>
Kelp Bass	<i>Paralabrax clathratus</i>	Lingcod	<i>Ophiodon elongatus</i>
Spotted Sand Bass	<i>Paralabrax maculatofasciatus</i>	California Scorpionfish	<i>Scorpaena guttata</i>
Ocean Whitefish	<i>Caulolatilus princeps</i>	Dogfish	<i>Squalus acanthias</i>
Jack Mackerel	<i>Trachurus symmetricus</i>		

Marine Birds			
Black-footed Albatross	<i>Diomedea nigripes</i>	Black-legged Kittiwake	<i>Rissa tridactyla</i>
Fulmar	<i>Fulmarus glacialis</i>	Common Murre	<i>Uria aalge</i>
Sooty Shearwater	<i>aleuticus</i> <i>Puffinus griseus</i>	Pigeon Guillemot	<i>Cephus columba</i>
Manx Shearwater	<i>Puffinus puffinus</i>	Marbled Murrelet*	<i>Brachyramphus marmoratus</i>
Short Tailed Shearwater	<i>Puffinus tenuirostris</i>	Craveri's Murrelet	<i>Synthliboramphus craveri</i>
Pink Footed Shearwater	<i>Puffinus creatopus</i>	Scripps's Murrelet*	<i>Synthliboramphus scrippsi</i>
Leach's Storm Petrel	<i>Oceanodroma leucorhoa</i>	Guadalupe Murrelet*	<i>Synthliboramphus hypoleucus</i>
Ashy Storm Petrel*	<i>Oceanodroma homochroa</i>	Ancient Murrelet	<i>Synthliboramphus antiquus</i>
Black Storm Petrel	<i>Oceanodroma melania</i>	Cassin's Auklet	<i>Ptychoramphus aleuticus</i>
Brown Pelican	<i>Pelecanus occidentalis</i>	Rhinoceros Auklet	<i>Cerorhinca monocerata</i>
Double-crested Cormorant	<i>Phalacrocorax auritus</i>	Horned Puffin	<i>Fratercula corniculata</i>
Brandt's Cormorant	<i>Phalacrocorax penicillatus</i>	Tufted Puffin	<i>Fratercula cirrhata</i>
Pelagic Cormorant	<i>Phalacrocorax pelagicus</i>	Bald Eagle	<i>Haliaeetus leucocephalus</i>
Glaucous-winged Gull	<i>Larus glaucescens</i>	Osprey	<i>Pandion haliaetus</i>
Western Gull	<i>Larus occidentalis</i>	Elegant Tern	<i>Thalasseus elegans</i>
Heerman's Gull	<i>Larus heermanni</i>	Caspian Tern	<i>Hydroprogne caspia</i>
Ring-billed Gull	<i>Larus delawarensis</i>	Forster's Tern	<i>Sterna forsteri</i>
California Gull	<i>Larus californicus</i>	California Least Tern*	<i>Sternula antillarum browni</i>
* endangered, threatened, or candidate species			

The proportion of the diet that squid makes up varies dramatically between species, geographical location, and environmental conditions. Most squid predators are not squid specialists, e.g., squid is rarely the sole prey item; it cannot be relied on as a stable food source because of its highly variable abundance, and it has limited energetic value (O'Dor and Webber 1986). Therefore, squid predators often must switch to more abundant or energetically profitable prey species (Ainley et al. 1996; Sydeman et al. 1997), or target squid when they are most abundant during spawning aggregations and minimal energy is needed for capture.

For seabirds such as the Common Murre (*Uria Aalge*), squid composes 6 to 20% of the diet (by weight) depending on season and is usually ranked 3rd or 4th after Northern Anchovy, Pacific Herring, and Shiner Surfperch (*Cymatogaster aggregata*) (Ainley et al. 1996). In terms of frequency-of-occurrence, the presence of squid varies dramatically. For diving birds such as Rhinoceros Auklets (*Cerorhinca monocerata*), Common Murres, Artic Loons (*Gavia arctica*), and Brandt's Cormorants (*Phalacrocorax penicillatus*), the frequency-of-occurrence of squid in the diet can range from 33 to 85%

(Baltz and Morejohn 1977). For plunging, surface feeding birds, such as shearwaters and gulls, the frequency-of-occurrence ranges from 0-67% (Baltz and Morejohn 1977).

Market Squid are also important prey for commercial and recreational fishes, such as White Seabass (*Atractoscion nobilis*), Yellowtail (*Seriola lalandi*), Kelp Bass (*Paralabrax clathratus*), Barred Sand Bass (*Paralabrax nebulifer*), California Barracuda (*Sphyræna argentea*), California Halibut (*Paralichthys californicus*), and other nearshore species. For Chinook Salmon (*Oncorhynchus tshawytscha*), squid composed only 7 to 9% of diet (by volume) and ranked 3rd or 4th behind Northern Anchovy, euphausiids, and juvenile rockfish depending on location (Morejohn et al. 1978). At other locations along the west coast, squid is not an important Chinook Salmon prey item since they prey mainly on fish (Groot and Margolis 1991). For Chilipepper Rockfish (*Sebastes goodei*), squid ranked 3rd behind juvenile rockfish and other fishes (Morejohn et al. 1978). Other fish predators in which squid ranked high as a prey item include mainly bottom dwelling species such as Curlfin Turbot (*Pleuronichthys decurrens*), Speckled Sanddab (*Citharichthys stigmatæus*), Pacific Sanddab (*Citharichthys sordidus*), Lingcod (*Ophiodon elongatus*), Petrale Sole (*Eopsetta jordani*), and Pacific Halibut (*Hippoglossus stenolepis*) (Morejohn et al. 1978). Several pelagic species also feed on squid when available such as Blue Shark (*Prionace glauca*), Common Thresher Shark (*Alopias vulpinus*), and Albacore Tuna (*Thunnus alalunga*) (Morejohn et al. 1978).

Squid occurs in 35 to 44% of California Sea Lion (*Zalophus californianus*) scat samples collected at rookery sites in the SCB, which can represent volumes as high as 27% of the diet by weight in non-El Niño years and 16% in El Niño years (Lowry and Carretta 1999). In terms of prey rank, squid was either the primary or secondary Sea Lion prey item after Northern Anchovy, depending on location and environmental conditions.

1.5 Effects of Changing Oceanic Conditions

The CCE is a highly variable ecosystem and is known to fluctuate significantly at annual and longer time scales. At smaller time scales the ENSO is a short-term fluctuation between periods of cooler water, strong upwelling, and high nutrient availability and those characterized by warmer water, delayed or weak upwelling, and lower nutrient availability. Strong El Niño periods can produce considerable reductions in primary production in the CCE, which can alter the abundance and distribution of coastal pelagic species such as Market Squid.

Due to their short life span, Market Squid are likely very responsive to changing environmental conditions that affect juvenile survival and recruitment to the fishery. Emerging research suggests that the larval abundance of Market Squid is lower during warmer periods (Koslow and Allen 2011). Similarly, landings of Market Squid in California's primary fishing grounds are also significantly lower during El Niño events (Zeidberg et al. 2006). The growth rate and maximum size of Market Squid during warmer periods have also been found to be lower (Jackson and Domeier 2003; Reiss et al. 2004), and this may reduce the reproductive output of female squids (Henry et al. 2003). These lower growth rates are likely due to food limitations (Jackson and Domeier 2003). Climate change is expected to alter ENSO frequencies and duration, but the levels are still impossible to predict. The magnitude of variability in the system may increase, leading to more extreme conditions.

Climate change is also altering the physical and chemical properties of ocean water off the coast. Ocean warming, changes to the pH of ocean water via ocean acidification, and changes in the oxygen content of ocean water may alter or compress the availability of suitable habitat for Market Squid spawning (Zeidberg et al. 2011b; Navarro et al. 2018). It is hypothesized that this could lead to increasingly localized and dense spawning, resulting in potentially important changes for both the fishery and Market Squid ecology generally. Naturally occurring hypoxic OMZs off the coast of California have been getting shallower (Bograd et al. 2008) and could compress the depth range for adult Market Squid (Stewart et al. 2014).

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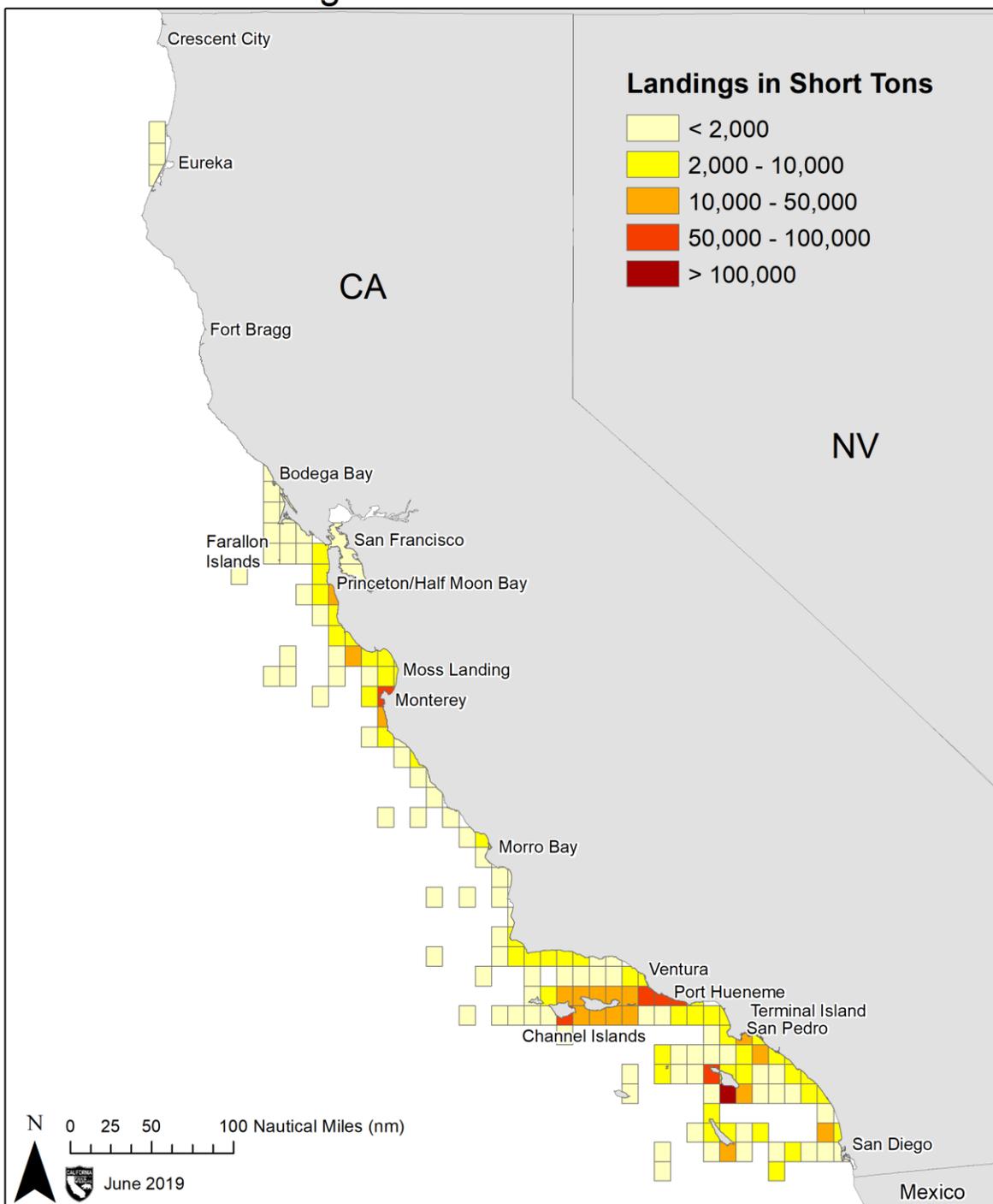
2 The Fishery

2.1 Location of the Fishery

The Market Squid fishery is centered in the nearshore waters of California, though Market Squid may be available in commercial quantities from British Columbia to Baja, California. Market Squid harvest is allowed statewide in all areas defined as ocean water in §27, Title 14, California Code of Regulations (CCR), except where prohibited or restricted, as specified, in state Marine Protected Areas (MPAs) and round haul gear closure areas (FGC §8750-8757). Seasonal shifts in resource availability and timing of peak spawning has produced two distinct fishing areas. Fishing effort in central California is focused around Monterey Bay and tends to occur between April and September, coinciding with the upwelling season (Zeidberg et al. 2006). The southern portion of the fishery encompasses most of the SCB including the northern and southern Channel Islands southward along the coast to La Jolla and is most active from October to February. During this time there is less stratification of the water column and more mixing due to winter storms and colder air temperatures (Zeidberg et al. 2006).

Prior to the 1980s the commercial fishery was primarily focused in Monterey Bay; however, since the 1985-1986 season, the majority of the catch has come from the SCB. Landings spiked dramatically in Monterey Bay area in 2010 and continued through 2014 (Figure 2-1.). Monterey, Ventura, and Los Angeles Counties are the principal counties where squid is offloaded and distributed. While some vessels fish near home ports year-round, in general, the fleets' mobility continues to grow. It's not uncommon for vessels based out of Monterey to travel south and for vessels from Ventura or Los Angeles to travel north to fish. The Ventura ports are typically utilized by many fishermen working the Channel Islands since they are closer and more convenient than Monterey or San Pedro ports (Pomeroy et al. 2002).

CA Commercial Market Squid Landings All Fishing Seasons From 2000 to 2018



Tonnage by CDFW blocks as reported on landings receipts.

The commercial market squid fishery runs on an April through March fishing season.

Figure 2-1. Map of commercial Market Squid fishery landings by block in the 2000 through 2018 fishing seasons (CDFW Marine Landings Data System (MLDS) 2019).

2.2 Fishing Effort

2.2.1 Number of Vessels and Participants Over Time

The commercial Market Squid fishery operates under a Restricted Access (RA) program. Vessel participation is greatest during the late fall and early winter for southern California and during the summer for central California. In most cases, squid purse seine vessels work with light boats. A light boat is typically a smaller vessel with several high-powered lights located around the vessel. The light boat uses lights to aggregate squid in a small area around the boat. Once squid are aggregated, the light boat signals the seiner to deploy its net, encircling the light boat, in order to catch the squid located under the lights.

As one of California's oldest fisheries, the Market Squid fishery began in 1863 when Chinese immigrants harvested small quantities of squid from Monterey Bay (Dickerson and Leos 1992; Fields 1965). Small skiffs were used to encircle a net around another skiff equipped with lit torches used to attract the squid (Walthers and Gillespie, 2002). Immigrant fisherman from Italy introduced the more efficient lampara net for catching squid around 1905 (Vojkovich 1998). From 1916 to 1923, when the Department began keeping records, the fishery caught less than 1,000 tons per year. From 1924 to 1932, landings averaged more than 2,000 tons per year. Most of this catch was dried and exported to China; some was used domestically as canned or frozen product (CDFG 2005). The Asian market closed in 1933 due to financial conditions and the domestic market supported the Monterey fishery for many years. Landings in California were minimal until 1942 when demand from international aid programs triggered a rise in the need for squid. Landings peaked at close to 20,000 tons in the 1946-1947 season, then averaged 9,100 tons until the 1981-1982 season when greater than 25,000 tons were landed. During the 1980s, California's squid fishery grew rapidly as international demand for squid increased, especially from Europe and China, due to declining squid fisheries in other parts of the world (CDFG 2001c). During this time there was a shift in the fleet from mainly brail boats to larger purse seine vessels. Brailing involves a dip net sometimes using the assistance of the vessel's hydraulics. The larger vessels equipped with round-haul gear and a tender vessel more easily met the increasing demands for squid and continue to dominate today's fishery.

Under the RA program of the MSFMP, a permit is required to participate in the fishery. Qualification for different types of permits and transferability options was based on historical participation in the fishery. Market Squid vessel permits allow a vessel to attract squid with lights and use large seine nets or brail to capture squid. Brail permits allow a vessel to attract squid with lights and use brail gear only to capture squid. Light boat permits only allow a vessel to attract squid with lights. Since 1998 and the establishment of the RA program, the number of vessel and light boat owner permits has declined. Conversely, the number of brail boat owner permits has increased. This influx of brail permits, particularly from 2010 to 2013, was the direct result of light boat permit upgrades. Since 2005, there have been 31 upgrades from light boat to brail permits. Additionally, there are a handful of vessels permitted to land squid using round-haul gear that will operate strictly as a brail or light boat. This information suggests that within the current permit structure, the fleet continues to become more homogenous in terms of capacity to land and light for squid. At the start of the 2018-2019 fishing

season, there were 74 vessel, 33 light boat, and 45 brail permits (CDFW Automated License Data System (ALDS)). All non-transferrable brail permits have been retired. As with many fisheries, a select number of vessels make the majority of the catch. For the 2013-2017 fishing seasons, only 32, 34, 26, and 33 permitted vessels, respectively, made approximately 75% of the catch (by volume) (Figure 2-2).

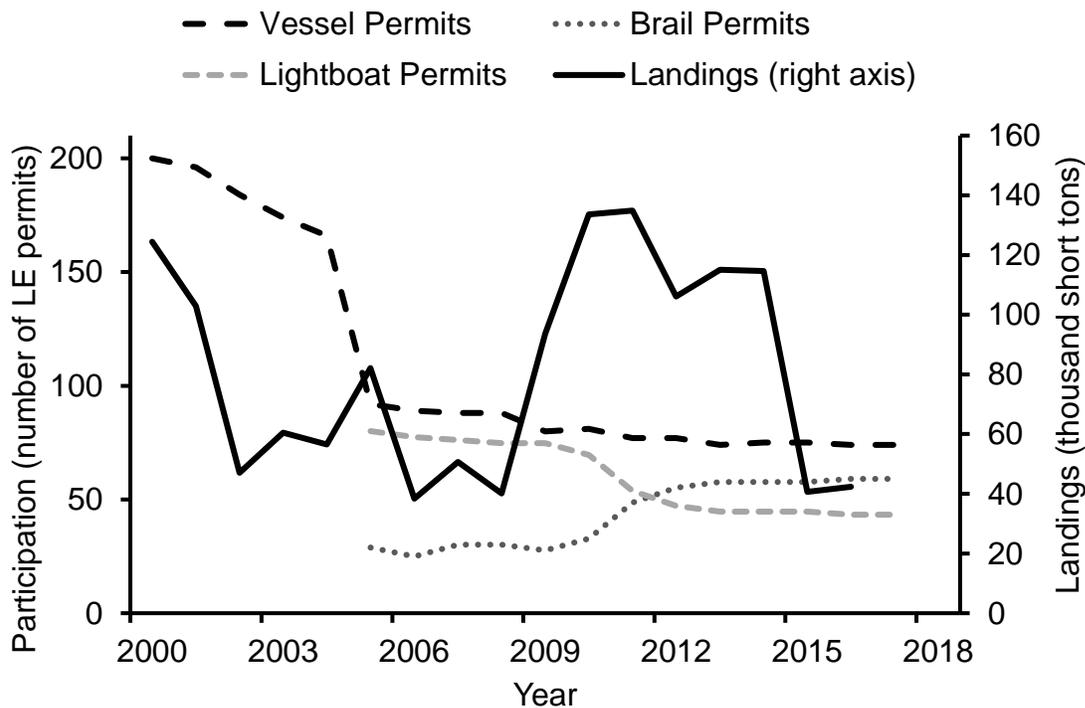


Figure 2-2. Market Squid fishery participation (number of Limited Entry permits by type; left axis) and landings (thousand short tons; right axis) from 1980 to 2017 (CDFW Commercial Fisheries Information System (CFIS)).

As squid availability fluctuates regionally throughout the season many vessels target other fisheries, typically lower-valued CPS (e.g., Northern Anchovy or Pacific Mackerel), salmon, or tuna. When squid are readily available, fishing effort can be driven by market conditions. During “boom” years, if squid processors have full freezers or ex-vessel value drops too low, vessels may be subject to market-imposed limits and effort declines due to lower economic incentive to fish. Under current conditions there is little evidence of market-imposed limits as the international demand for Market Squid remains constant, though with a market preference for larger squid, buyers sometimes impose size-based limits to maintain a higher quality product (Diane Pleschner-Steele personal communication).

2.2.2 Type, Amount, and Selectivity of Gear

The fleet currently uses a combination of round haul gear (purse seine, drum seine, or the less common lampara) or brail/dip net to harvest squid. In the 2017 squid fishing season (April 1, 2017 to March 31, 2018), approximately 96% of directed

landings came from seine fishing, and 4% from brail/dip net fishing (Figure 2-3). Fishing occurs both during the day and at night. At night, light boats are used to aggregate squid to the surface. Nearly all vessels, brail boat, and light boats use side-scan sonar and fathometers (Lutz and Pendleton 2000). The purse seine, drum seine and the less common lampara are encircling type nets. With the help of a tender vessel, the webbing of the seiner net is laid out to encircle a school of squid. When the school is surrounded, the bottom of the net may be closed, and drawn next to the boat (PFMC 2010). A purse seine net has metal rings sewn along its bottom edge and a cable is passed through the rings. When the cable is drawn tight, the net “purses.” A centrifugal pump is lowered into the bagged school of squid, and water and squid are pumped through a separator and into the hold of the fishing vessel (Vojkovich 1998). With brail gear, fisherman lift the fish out of the net with netted scoops.

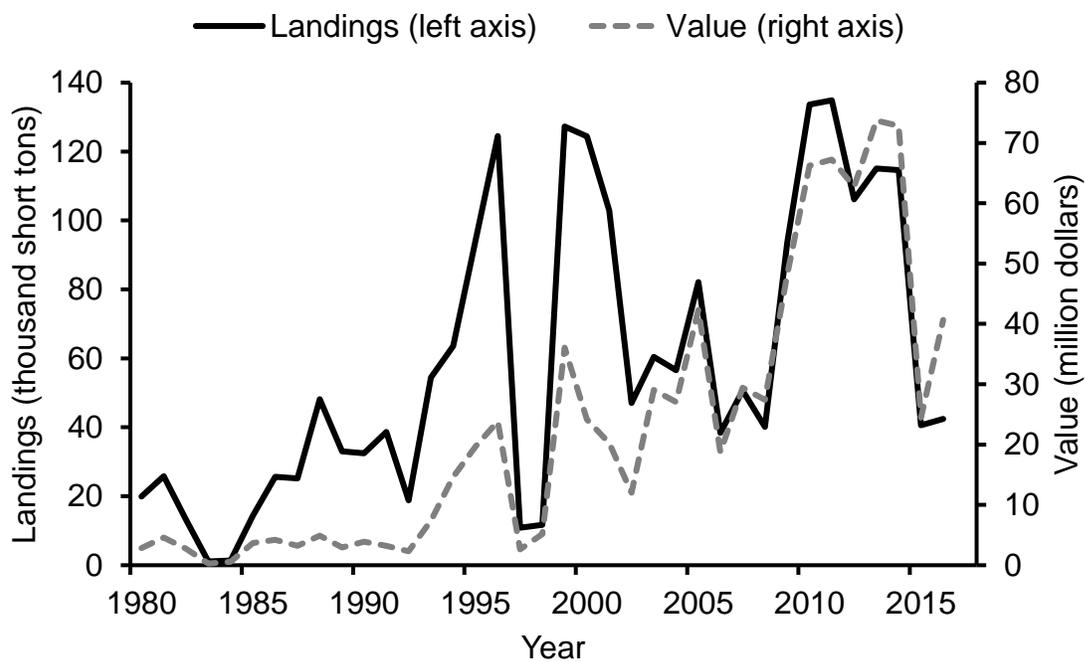


Figure 2-3. Market Squid fishery landings (thousand short tons) and value (million dollars), 1980 to 2016 (CDFW CFIS).

According to Department records during the drafting of the MSFMP, the average purse seine was 18.9 m (62.0 ft) in length and 81 gross tons with an average hold capacity of 84 tons (CDFG 2005). The average light boat length was 11.8 m (39.0 ft) in length with an average gross tonnage of 19 tons (CDFG 2005). At the start of the 2018-2019 season, the average seiner was 18.0 m (59.2 ft) in length with an average gross tonnage endorsement of 80.0 tons. The average light and brail boat length was 12.8 m (41.9 ft) with an average gross tonnage endorsement of 42.9 tons for brail boats. The lampara net was the only legal form of round haul gear in the southern bight of Monterey Bay until 1989. Once the purse and drum seines were legalized for use in this district, the Market Squid commercial fleet switched gear types and the lampara became mostly obsolete. During the 1970s brail vessels were the major harvesters in

the southern California Market Squid fishery, using a power-assisted brail or dip net in conjunction with attracting lights (Kato and Hardwick 1975). By the early 1990s, the purse seine became the dominant gear for the entire coast, with the drum seine gaining popularity by the mid-1990s (CDFG 2005).

2.3 Landings in the Recreational and Commercial Sectors

2.3.1 *Recreational*

Market Squid is important in small volumes to the recreational fishery as either live or dead bait. The bait is caught primarily by commercial live bait haulers using seine or brail nets. There is no record of when recreational fisheries in California started using Market Squid as bait (CDFG 2005). This small volume of squid is a high value fishery, which supplies bait to recreational fisheries along the California coast, primarily in southern California (CDFG 2001b). Live bait is sold from a harbor-based bait barge or from the catcher vessel at sea. Sport fishing vessels and private skiffs also catch their own squid bait by using attracting lights and brail nets and/or rod and reel. Live and dead squid are ideal bait for a variety of California sport fisheries, particularly rockfish and White Seabass. Since the sale of live bait in California was not previously documented in a manner similar to that used for the market landings of squid, accurate estimates of tonnage and value are not available. New reporting requirements will provide data on live bait catch beginning in 2019.

There are insufficient data to accurately describe recreational fishing effort for Market Squid. Commercial vessel operators in the live bait fishery do report catch through live bait logbooks, mostly in southern California, but this information is voluntary and would be considered a minimum amount of squid harvested for bait. Additionally, some light boat operators record scooping live squid for bait in logbooks.

2.3.2 *Commercial*

The commercial fishery for Market Squid is routinely one of the largest in California in terms of volume and value. From 1997 to 2017, Market Squid represented the largest single species fishery by volume in the state for all but 4 years (yr). The fishery was also the largest by ex-vessel value for over half of those years. The 2009 to 2014 period was particularly productive, with landings and ex-vessel revenue averaging over 115,000 metric ton (mt) and \$65 million per year, respectively. Landings in California prior to 1987 rarely exceeded 20,000 mt. The success of the California Market Squid fishery is due in large part to the role of international buyers. New markets, primarily in Europe and Asia, developed over the past three decades and were willing to pay higher prices for California squid. The vast majority of squid is now frozen for export to China, Japan, and Europe where it is mainly sold for consumption. Minor amounts are also sold fresh or canned.

The commercial fishing season for Market Squid lasts from April 1 through March 31 of the following year. The fishery exceeded the 118,000 ton catch limit for two consecutive fishing seasons, 2010-2011 and 2011-2012. As a precaution, the fishery was closed early for the following three seasons (2012-2013, 2013-2014, and 2014-2015) with a voluntary industry closure on November 20, 2014 (Figure 2-4).

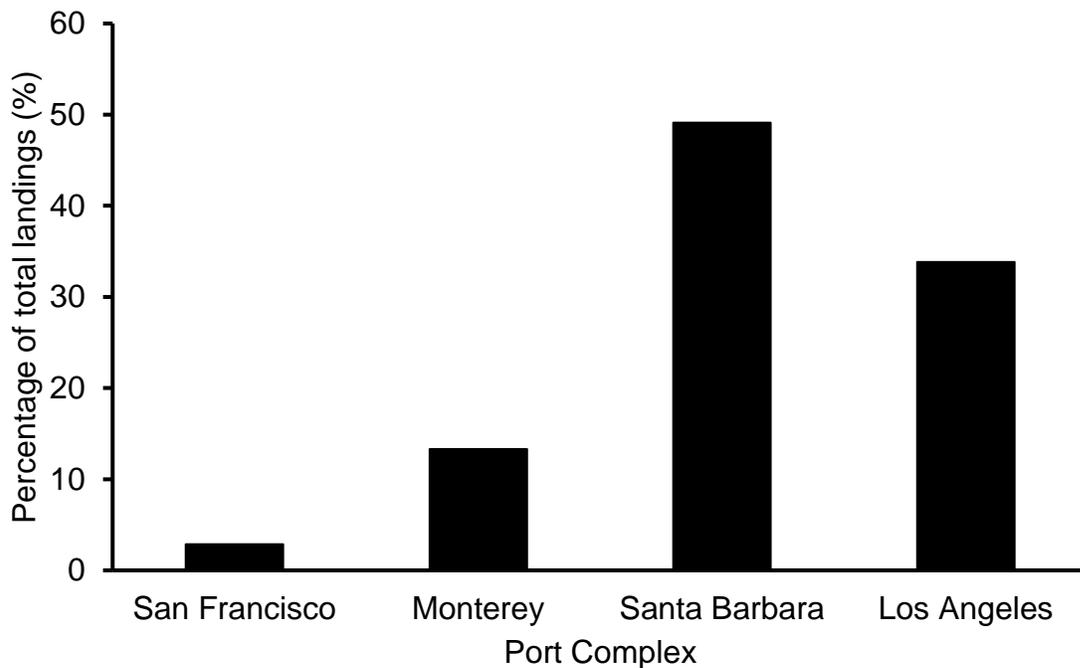


Figure 2-4. Market Squid percentage (%) of total landings (tons) from 1990 to 2016, by port complex. Landings delivered to the North Coast complex, Morro Bay complex, and San Diego complex were negligible at 0.19%, 0.68%, and 0.00%, respectively (CDFW CFIS).

2.4 Social and Economic Factors Related to the Fishery

Squid fishing supplements the income of many seine vessels that also participate in fisheries such as salmon, tuna, herring, and other CPS throughout California, Oregon, Washington, and Alaska. There continues to be a substantial number of Market Squid vessels with home ports outside California likely due to declines in some of these other fisheries. Historically, there have been territorial disputes between “local” and out-of-state fisherman. Some light boats participate in other local fisheries that do not use attracting lights such as herring, hook and line, and live bait.

The number of businesses purchasing squid had remained constant since the early 1980s, however, since the 1994-1995 season, the majority (80% or more) of the squid purchased was bought by nine or fewer dealers. In 2017, at least 95% of the catch was purchased by ten dealers. Currently, the California squid industry is centered on global markets that have placed an increased demand upon California Market Squid. Vessels targeting squid usually have a relationship with one market from which they receive orders for specific amounts of squid. When demand or storage space is limited, fishing is limited regardless of squid availability (Pomeroy and Fitzsimmons 2001). The price paid to vessels depends on the market demand and the availability of the resource. Historically, when volume was low, the price paid per ton was high, exceeding \$600 per ton, but the price is driven down when volume is high, as low as \$220 per ton (Dorval et al. 2013)

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3 Management

3.1 Past and Current Management Measures

The Market Squid fishery was primarily an open-access fishery prior to 1998. Concern over growing harvest rates and a rapid increase in the number of vessels entering the fishery prompted the implementation of industry sponsored legislation in 1997. The following year, the Legislature passed Senate Bill (SB) 364 (Sher), which was incorporated into Fish and Game Code (FGC) §8420-8429.7. The Legislature deemed it necessary to adopt and implement fishery management measures that sustain both the squid population and marine life that depends on squid. SB 364 required the purchase of an annual permit to land more than 2 tons or to attract squid by using light for purposes of commercial harvest. It also placed a moratorium on the number of vessels in the fishery, established a \$2,500 permit for Market Squid vessels and light boats, and initiated a 3-yr study to assess conservation and management of the fishery (CDFG 2005). During this study, researchers and the Department explored several science-based methods for developing fishery management strategies but determined that traditional assessment methods used to estimate biomass were not applicable to Market Squid.

In April 2001, the Department, in collaboration with scientists and stakeholders, submitted a status report with recommendations for Market Squid conservation and a future management plan (CDFG 2001c). During this time the Legislature delegated management authority for the squid fishery to the Commission and required the adoption of the MSFMP. The goals of the MSFMP as dictated by the MLMA are: (1) to manage the Market Squid resource to ensure long term resource conservation and sustainability; and (2) to develop a framework for management that will be responsive to environmental and socioeconomic change (CDFG 2005). The initial analysis and design phases for the MSFMP began in January 2001 with contributions from the Department, NOAA, Non-governmental Organizations (NGOs), university researchers, and industry representatives. Since its completion in 2005, the MSFMP has remained the primary management tool for the Market Squid fishery as directed by §149, Title 14, CCR (Table 3-1.).

Table 3-1. Summary of Market Squid Regulations from 1959 to 2019 (Reproduced and updated from Table 2-13 in the MSFMP 2005). All information included in this table is summarized and not to be considered explicit language for each regulation.

Date	Bill # (Author)	Management Action
1959	§8397	It is unlawful to use any artificial light to lure or attract squid in Districts 16 and 17. This section applies to all artificial lights except those lights necessary for the usual operation of a vessel not used to lure or attract, or intended to lure or attract, squid.
1983	AB 513 (Farr)	Authorizes the Commission to adopt regulations specifying the days of the week and times of the day when squid may be taken north of Point Conception.
1984	§149, Title 14, CCR	The Commission adds CCR Title 14 §149, to prohibit any vessel, using or possessing a roundhaul net in Districts 16 and 17, from taking Market Squid between noon Friday and midnight Sunday and between noon and midnight on any Monday through Thursday.

1987	AB 123 (Farr)	Allows the use of lights to attract squid in District 17.
1988	AB 4055 (Farr)	Allows the use of lights to attract squid in District 16.
1989	SB 1080 (Mello)	Allows the use of all roundhaul nets, including purse seine and half-purse seine nets, to take squid in all portions (including the southernmost portion) of District 16, subject to the same area and season restrictions previously in effect for lampara nets.
1993	AB 14 (Hauser)	Restricts the use of attracting lights in District 10.
1993	SB 1030 (Thompson)	A landing tax of \$0.0019/pound (lb) is imposed.
1997	SB 364 (Sher)	Authorizes the take of Market Squid north of Pt. Conception between noon on Sunday and noon on Friday. Requires a permit for the take of squid with a dip, purse seine, or lampara net for commercial purposes. Requires a permit to attract squid by light from a vessel. Establishes a fee for a commercial squid light boat owner's permit. Allows for transfer of vessel or light boat owner's permits under certain conditions. A 3-yr moratorium on commercial squid vessel permits is established; the possession of a permit from the previous year is required in order to renew.
1998	AB 1928 (Morrow)	No permit is necessary, nor is a landing tax imposed, for the take of live bait. Drum seines and other roundhaul nets excepted from prohibition of rings along lead line and pursing of net bottoms.
1998	AB 1241 (Keeley)	MLMA passes.
2000	§149, Title 14, CCR	Amendment – Prohibits commercial take of Market Squid between noon on Friday and noon on Sunday from Pt. Conception south to the US-Mexico border. Requires commercial squid vessels and light boats to maintain logbooks detailing fishing/lighting activities.
2000	§149, Title 14, CCR	Amendment – Vessels fishing or lighting for squid are restricted to using no more than 30,000 watts of light. Each vessel fishing or lighting for squid must shield the entire filament of each light, directing the light downward, or the vessel must keep the illumination completely submerged underwater.
2000	SB 1544 (Sher)	Establishes a \$400 fee for a commercial Market Squid vessel permit. Extends the sunset date for SB364 to January 1, 2004. Extends existing duties imposed on the Department and the Commission and makes an appropriation.
1	SB 209 (Sher)	Requires the Commission to adopt the MSFMP by 31 Dec 2002, after consideration and public hearings. Requires the Commission to establish fees for commercial Market Squid vessel permits and commercial squid light boat owner's permits annually commencing April 1, 2003. Prohibits each person who is issued a commercial squid light boat owner's permit from selling, trading or transferring the permit to another person. Provides that specified provisions will become inoperative upon the adoption by the Commission of a MSFMP and the adoption of implementing regulations and will be repealed 6 months thereafter.
2001	§149, Title 14, CCR	Proposed regulatory changes establish catch limits in order to protect the squid resource and manage the fishery sustainably; a harvest guideline of 125,000 tons was selected.
2001	§159, Title 14, CCR	Market Squid is included under Commercial Fishing for CPS.
2003	§1.39, Title 14, CCR	Market Squid is included in CPS under General Provisions and Definitions.
2004	§149, Title 14, CCR	Establishes a seasonal (April 1 to March 31 of the following year) catch limit of 118,000 tons (107,047 mt) for commercial catch of Market Squid.

2004	§149, Title 14, CCR	Continues closures between 1200 hours (noon) on Friday and 1200 hours (noon) on Sunday of each week from the U.S.-Mexico border to the California-Oregon border. When the commercial fishery is closed, squid may be taken for commercial purposes only incidentally to the take of other target species or for live bait.
2004	§149, Title 14, CCR	Prohibits take of Market Squid for commercial purposes using attracting lights in all waters of the Gulf of the Farallones National Marine Sanctuary. This regulation also applies to vessels pursuing squid for live bait purposes.
2004	§149, Title 14, CCR	Requires any operator of a commercial Market Squid vessel or permit holder of a commercial Market Squid permit to submit an accurate record of his/her squid fishing, lighting, or brailing activities on market squid logbooks provided by the Department, as appropriate to the type of fishing activity.
2004	§149, Title 14, CCR	Prohibits attracting squid by light except as authorized by Restricted Access Market Squid Fishery permits. This regulation does not apply to seine skiffs of a permitted vessel or to vessels pursuing squid for live bait purposes only.
2004	§149, Title 14, CCR	Allows incidental take of Market Squid when fishing for other target species. This volume shall not exceed 2 tons per trip or 10% of the total volume by weight of all fish landed of possessed.
2004	§149, Title 14, CCR	Prohibits the take of live bait for purposes other than use as live bait or sale as live bait.
2005	§149.1, Title 14, CCR	Establishes a market squid fishery RA program.
2005	§149.3, Title 14, CCR	Allows the commission to issue three-Non-Transferable Market Squid Vessel Permits for purposes of developing a squid fishery in areas previously not utilized for squid production.
2014	§149, Title 14, CCR	Removes an allowance for directed take of up 2 tons of Market Squid

Market Squid is also included under federal management through the CPS FMP implemented in 2001. The CPS fishery includes Market Squid and four finfish species (Pacific Sardine, Pacific Mackerel, Northern Anchovy, and Jack Mackerel) as a fishery management unit. CPS finfish are pelagic because they generally occur or are harvested above the thermocline in the upper mixed layer (PMFC 2018). Market Squid are included in this complex because they are similarly fished as aggregations. The CPS FMP required that Maximum Sustainable Yield (MSY) be established for all species in the plan (CDFG 2005). Setting MSY for Market Squid has proven problematic because an accurate biomass has yet to be determined. Hence, the Pacific Fishery Management Council (PFMC) approved the use of egg escapement as a proxy for MSY for the Market Squid fishery. Details of this method are summarized below and described in section 4.1 of the MSFMP. Under Amendment 8 of the CPS FMP, the PFMC delegated management authority for Market Squid to the State of California in 2005. The CPS FMP requires Status Determination Criteria and management reference points (e.g., Acceptable Biological Catch (ABC) and Annual Catch Limit (ACLs)) for all fishery management unit species. Market Squid are exempt from ACL requirements because their life cycle is less than 1 yr.

3.1.1 Overview and Rationale for the Current Management Framework

The MSFMP was designed to allow the Commission to make changes to regulations without the need for a full amendment to the FMP and provides the Commission specific guidelines for making management decisions. The MSFMP

framework structure is consistent with management of Market Squid by the PFMC outlined in the CPS FMP. To meet the standards of the MLMA for adaptive management, the MSFMP establishes a hierarchical framework within which adjustments to the management of the Market Squid fishery can be made in a responsible and timely manner. The Commission may take four general types of actions within the framework of the MSFMP: (1) FMP amendment, (2) full rulemaking, (3) notice action, and (4) prescribed action.

The Market Squid fishery operates through a RA program that includes provisions for initial entry into the fleet, types of permits, permit fees, and permit transferability. The intent of restricting access to the fishery for the Market Squid resource was to balance the need for a viable economic harvest with the need to protect the squid resource. Additional fishery control rules were established to promote a more sustainable fishery, prevent overfishing, and provide a protocol for managing Market Squid fishing. These include a seasonal catch limit to prevent the fishery from over-expanding; weekend closures to provide for periods of uninterrupted spawning; gear regulations regarding light shields and wattage; and monitoring programs designed to evaluate the impact of the fishery on the resource. Setting a seasonal catch limitation was intended to curtail growth of the fishery should market demand allow for such expansion. The Department felt it was prudent not to allow landings to expand beyond catch levels at the time of FMP development without better methods to assess the status of the resource. Catch trends indicate that the Market Squid resource is quite robust and able to sustain historic catch levels (CDFG 2005).

An MSY model is often used to determine catch limits, but a proxy or substitute for MSY may be used where scientific information is inadequate. Due to a lack of adequate data to make a mathematical MSY determination, the MSFMP uses a proxy for MSY based on historical landings. This guidance was taken from NOAA Fisheries (Restrepo et al. 1998). Restrepo et al. (1998) proposed that in data-poor situations, such as the Market Squid fishery, it is reasonable to use historical average catch from a period when there is no qualitative or quantitative evidence of declining abundance. Using this methodology, the Commission established a statewide seasonal catch limit of 118,000 tons using a 3-yr average catch from the 1999-2000 to 2001-2002 fishing seasons (CDFG 2005). The ability of the Market Squid fishery to support landings of greater than 100,000 tons in the 1999-2000 season with repeat landings of the same magnitude in the following two seasons suggests that the stock is robust enough to withstand this level of landings (CDFG 2005).

This approach assumes that the stock is above the average spawning biomass to sustain MSY (B_{MSY}) and uses a multiplier of 1.0. A multiplier of 1.0 was chosen to be most appropriate for Market Squid as opposed to more precautionary Optimum Yield (OY) multipliers due to its short lifespan. A proxy for OY was then determined by reducing the proxy MSY by a percentage that can vary depending on the amount of information available. This approach to risk management reduces the chance of inadvertent overfishing when little is known about the status of the stock (CDFG 2005). Because exploitation rates are strongly influenced by availability, market demand, and processing capacity, standardized catch-effort data are not reliable proxies for Market Squid population abundance (Dorval et al. 2013).

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

Because no biomass estimate exists for Market Squid, it is not possible to define an overfished condition for this species. Setting a mathematical MSY for Market Squid is impractical for the squid fishery because biological data are inadequate, and landings are strongly influenced by availability and market demand rather than effort. Overfishing is defined as harvest of squid occurring at a time when either the egg escapement threshold is not being met, or when catches are exceeding specified allowable levels and that these catches may not be sustainable (CDFG 2005).

Consequently, the egg escapement method is used as a proxy for MSY/OY. The MSY Control Rule for Market Squid is founded generally on conventional spawning biomass “per recruit” model theory (Gabriel et al. 1989; Macewicz et al. 2004). Specifically, the MSY Control Rule for Market Squid is based on evaluating levels of egg escapement associated with the exploited population. The estimates of egg escapement are evaluated in the context of a “threshold” that is believed to represent a minimum level that is considered necessary to allow the population to maintain its level of abundance into the future (e.g., allow for “sustainable” reproduction year after year) (PFMC 2018).

The egg escapement approach can be used to evaluate the effects of Fishing Mortality (F) on the spawning potential of the stock, and in particular, to examine the relation between the stock’s reproductive output and candidate proxies for the F that results in MSY (F_{MSY}). The egg escapement model is not used as a real-time tool for management, but rather a method of assessing the effectiveness of management, which is an appropriate use in regard to the accuracy of the model (Emmanis Dorval pers. comm).

This threshold is set to a level of egg escapement of at least 30 percent. Therefore, the Overfishing Fishing Limit and ABC for Market Squid are a F_{MSY} proxy resulting in egg escapement $\geq 30\%$. The Market Squid fishery operates under regulations dictated by the Department and the NMFS, as long as egg escapement is equal to, or greater than, the threshold value. The egg escapement model, as a proxy for MSY, was intended to be a temporary measure until an acceptable biomass estimate could be determined for Market Squid. Since an accurate biomass estimate has not yet been developed for Market Squid, NOAA and the Department continue to improve and refine the egg escapement method.

3.1.1.2 Past and Current Stakeholder Involvement

The most well documented stakeholder involvement in the Market Squid fishery was industry-sponsored legislation in 1997. The Department’s initial status report, submitted in 2001, was developed through cooperative efforts of scientists, fishing industry representatives and stakeholders (CDFG 2001c). As part of this process, The Squid Fishery Advisory Committee (SFAC), made up of resource stakeholders, and a Squid Research Scientific Committee (SRSC), consisting of many of the world’s leading squid fishery scientists, were established to advise the Department Director (Director) on recommendations for squid conservation and management and to provide input on

the development of research protocols. These committees were disbanded after the final MSFMP was implemented.

In 2004, the non-profit CWPA was established with the mission to “(1) protect and maintain access to wetfish resources in California; (2) promote sustainable production of wetfish resources, with a focus on supporting collaborative research, and (3) facilitate communication within and outside California’s wetfish industry.” The CWPA Board of Directors consists of processors, vessel owners, and vessel operators. Some of these individuals act as representatives on the Coastal Pelagic Species Advisory Subpanel to the PFMC. CWPA has partnered with the SWFSC and the Department on multiple research projects including, but not limited to, chartering vessels to tow bongo nets near spawning grounds to collect paralarvae and mapping local squid concentrations in relation to environmental indices.

3.1.2 Target Species

3.1.2.1 Limitations on Fishing for Target Species

3.1.2.1.1 Catch

The seasonal catch limit for Market Squid is 118,000 ton. The squid fishery runs year-round on an April 1 through March 31 fishing season. The Department actively tracks landings for the fishery to determine if and when the seasonal catch limit will be reached. Effective closure dates are publicly announced on very high frequency radio channel 16 between the hours of 2200 and 2400 (midnight). When the seasonal catch limit has been reached and the commercial fishery is closed, squid may be taken for live bait or commercial purposes only incidentally to the take of other target species. This incidental allowance is restricted to 2 tons per trip and ten percent of the total volume by weight of all fish landed or possessed on a vessel (§149, Title 14, CCR). Market Squid will occasionally school with CPS finfish and mixed landings are fairly common. An allowance following a seasonal closure prevents squid from being discarded under these circumstances.

3.1.2.1.2 Effort

Limiting entry to the commercial fishery is the major effort restriction. The RA program aims to match the level of effort in the fishery to the health of the resource, providing for a fishery that is diverse, stable, and profitable (CDFG 2005). As directed under the MSFMP RA program, the Commission adopted a vessel-based capacity goal of 55 Market Squid vessel permits, 34 light boat permits, and 18 Market Squid brail permits, with the intent for non-transferable permits to decline through attrition. The fleet size at this time was 165 squid vessels and 40 light boats. The MSFMP defines the fleet capacity goal as an optimal number of vessels where the number of vessels matches the available squid resource (CDFG 2005).

Eligibility was determined after purchase of a permit in the initial 1998-1999 season. Any licensed individual could participate during this initial year if the fisherman presented evidence that he or she had been a licensed California commercial fisherman for at least 20 yr and had participated in the Market Squid fishery. Market Squid light

boat logs were also used as documentation of participation in the fishery. There were three components to the Commission's policy to determine qualification: (1) initiating the program would not increase the recent level of fishing effort, (2) initial issuance of permits would only be to the current owners of qualifying vessels and, (3) it may be desirable to modify the approach of giving permits to current owners of qualifying vessels (CDFG 2005).

Prior to 2014, vessels landing less than two tons of squid on a per trip basis were not required to possess a limited entry permit. This directed allowance was removed in 2014 to prevent directed fishing without an RA permit and continued fishing after the fishing season was closed (§149, Title 14, CCR). Landing of squid beyond the jurisdiction of the state of California is not affected by limited entry requirements. Recreational fishing for squid does not require a limited entry permit, nor does fishing for squid for use as live bait.

3.1.2.1.3 Gear

Major gear regulations revolve around lighting for Market Squid. Regulations require that each vessel fishing for squid or lighting for squid will use a maximum of 30,000 watts at any time (§149, Title 14, CCR). As part of these restrictions, each vessel must reduce the light scatter of its fishing operations by shielding the entire filament of each light used to attract squid. The illumination must also orient directly downward, and the lower edges of shields are required to be parallel to the deck of the vessel. The type of net used to fish for squid is unregulated (CDFG 2005).

3.1.2.1.4 Time

The sole time restriction for the Market Squid commercial fishery is a weekend closure. Market Squid may not be taken for commercial purposes from 1200 hours (noon) Friday to 1200 hours (noon) Sunday of each week (§149, Title 14, CCR). This extends from the U.S.-Mexico border to the California-Oregon border. The weekend closure allows for 2 days of uninterrupted spawning in areas where squid are being harvested. This provides protection to the resource by allowing spawning and ensuring egg cases are deposited without disturbance from the fishery. The use of attracting lights for commercial harvest is also prohibited on weekends. This measure spreads the spawning escapement throughout the year, unlike a seasonal quota or closure. Prohibiting fishing activity on the weekends was also intended to alleviate conflict with other interest groups (e.g., divers, recreational fishermen, commercial passenger fishing vessels, etc.) operating in the same area (CDFG 2005).

3.1.2.1.5 Sex

There are no limitations related to sex when fishing commercially or recreationally for the Market Squid resource.

3.1.2.1.6 Size

There are no size restrictions when fishing commercially or recreationally for the Market Squid resource.

3.1.2.1.7 Area

Squid may not be taken using attracting lights in all waters of the Gulf of the Farallones National Marine Sanctuary at any time. This restriction was established in 2004 and designed to protect not only seabirds that breed and rear on the Farallon Islands, but also protect a large forage area (3,250 square kilometers (km²) (1,255 square miles (mi²)) in the waters surrounding the islands from light disturbance and interactions with squid vessels.

Additionally, there are area restrictions for round haul vessels, those that employ the use of purse seine, drum seine, and lampara net gear to commercially harvest squid. In Districts 1, 2, and 3, round haul nets may not be possessed on any boat except in that part of District 3 lying within the boundaries of the Moss Landing Harbor District, where round haul or any other type of nets may be possessed on any boat, and except in that part of District 2 lying within Marin County (FGC §8751).

Purse seines or ring nets may not be used in that portion of District 19 lying within 3 mi offshore from the line of the high-water mark along the coast of Orange County from sunrise Saturday to sunset Sunday from May 1 to September 10 (FGC §8754). Purse seines or ring nets may not be used at any point from May 1 to September 10 within a 2 mi radius of Dana Point and San Mateo Point, and within 2 mi offshore from the line of the high-water mark along that portion of the coast of Orange County lying between the northernmost bank of the mouth of the Santa Ana River and a point on that coast 6 mi south there from (FGC §8754).

Purse and round haul nets may be used in Districts 20A and 21 except from sunrise Saturday to sunset Sunday, in that portion of District 20 from a line extending 3 nautical miles east magnetically from the extreme easterly end of Santa Catalina Island southwesterly and northerly to a line extending 3 nautical miles southwest magnetically from the most southerly promontory of China Point and at any time during the period commencing on June 1 and ending on September 10 in each year, in that portion of District 20 from a line extending 3 nautical miles east magnetically from the extreme easterly end of Santa Catalina Island southerly to a line extending 3 nautical miles southeasterly magnetically from the United States government light on the southeasterly end of Santa Catalina Island (FGC §8755). These regulations exclude fishing for use or sale of squid for live bait, though in Districts 19A and 19B, round haul nets may not be used within 750.0 ft (228.6 m) of any public pier (FGC §8757).

District 20 includes Santa Catalina Island and that portion of state waters within 3 nautical miles of the island's coast line on the northerly, easterly and southerly sides of the island lying between a line extending 3 nautical miles west magnetically from the extreme westerly end of Santa Catalina Island to a line extending 3 nautical miles southwest magnetically from the most southerly promontory of China Point. District 20A includes the water lying around Santa Catalina Island within 3 nautical miles of the island's coast line which are not included in District 20.

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. MPAs were not designed for fisheries management purposes, however, they present related opportunities and considerations including the following:

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

MPAs function as areas of uninterrupted spawning for Market Squid and as forage reserves for the many species that consume Market Squid. These areas now encompass current large-scale spatial closures, such as the MPA network on the Channel Islands, and provide additional areas where uninterrupted spawning can occur. Several historical ecological reserves were known to be Market Squid spawning sites such as Carmel Bay Ecological Reserve, Point Lobos Ecological Reserve, northeast side of Santa Catalina Island and Santa Monica Bay. This information was considered when designing California's current MPA network (Diane Pleschner-Steele pers. comm.). Key historical reserves with known spawning sites now overlap with some current MPAs including Carmel Bay State Marine Conservation Area (SMCA), Carmel Pinnacles State Marine Reserve (SMR), Point Lobos SMCA, Point Lobos SMR, and Blue Cavern SMCA on the northeast side of Santa Catalina Island. Roughly 14% of available Market Squid spawning grounds (e.g., soft bottom or unknown habitat up to 100 m (328.1 ft) deep) in California are within no-take marine protected areas, but the relative contribution of these MPAs to Market Squid spawning success and recruitment is not known (Van Diggelen 2017).

Fishing for squid using round haul net is allowed in the Bodega Head SMCA, the Pillar Point State SMCA, Point Dume SMCA, Abalone Cove SMCA, Farnsworth Offshore SMCA, and Dana Point SMCA, but not more than 5% by weight of any commercial pelagic finfish or Market Squid catch landed or possessed shall be other incidentally taken species in this SMCA (§632, Title 14, CCR). In the Point Dume SMCA, Abalone Cove SMCA, Farnsworth Offshore SMCA, and Dana Point SMCA, specifically, commercial take with brail gear and light boat is also allowed (§632, Title 14, CCR).

3.1.2.2 Description of and Rationale for Any Restricted Access Approach

The goal of the RA program was to produce a moderately productive and specialized fleet. Restricted access programs are designed to match fishing effort with the sustainability of the resource and to address economic issues associated with excess harvest capacity in open access fisheries. Specifically, the Commission's purposes for restricting access or entry to a fishery are described as: (1) promote sustainable fisheries; (2) provide for an orderly fishery; (3) promote conservation among fishery participants; and (4) maintain the long-term economic viability of fisheries. Fisheries characterized by excess harvesting capacity are described as overcapitalized in terms of the number of vessel and the amount of gear and equipment devoted to harvesting. If the fishery becomes overcapitalized, harvesting costs increase while catches remain the same. This situation represents an economically inefficient use of society's productive resources and causes several problems for managers and the fishing industry when abundance and demand decline, and catches are reduced (CDFG 2005). At the time of its conception, the limited entry program for the Market Squid fishery was widely supported by most members of the SRSC, the SFAC, and other squid fishing industry and conservation groups, with some processors and fisherman in opposition.

3.1.3 Bycatch

3.1.3.1 Amount and Type of Bycatch (Including Discards)

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, are desirable and are thus retained as incidental catch, and does not always indicate a negative impact.

Bycatch is minimal in the commercial Market Squid fishery, although it cannot be avoided entirely. Salmon, steelhead, Striped Bass, or American Shad may not be taken with purse or round haul nets (FGC §8756). It is also unlawful to use any purse seine or round haul net to take Yellowtail, Barracuda, or White Seabass (FGC §8623). Pacific Bonito taken on a vessel by the use of round haul nets may contain 18% or less by number of Pacific Bonito smaller than the minimum size of 24 in (61 centimeters (cm)) fork length or five pounds (lb) by weight (FGC §8377).

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Table 3-2. Preliminary catch summary for vessels targeting Market Squid from NMFS-SWR coastal pelagic species pilot observer program, 2004 to 2008 (Reproduced from PFMC 2011).

Target species - Squid					
Species	Target Catch	Incidental Catch	Bycatch Returned		
			Alive	Dead	Unknown
Squid	1274 mt		28 mt	350 lbs	2 mt
Anchovy		100 lbs	120 lbs		
Jack Mackerel		2 mt	18 lbs	2 lbs	
Pacific Mackerel		20 mt	20 mt	180 lbs	1 lb
Sardine		12 mt	13 mt	1077 lbs	3 lbs
Spanish Mackerel		20 lbs			
Bat Ray			53		1
Bat Star			1		
Blue Shark			2		
Common Mola			1		
Pelagic Stingray			60		
Pacific Butterfish		19			1
Sunstar		30	4		
Squid Eggs					505 lbs
Lobster			3		
Brittle Star				3000	
Unid. Batfish				2 lbs	
Unid. Crab		1	1		93
Unid. Croaker		3	2	16 lbs	
Unid. Flatfish		1	1	6	2
Unid. Jellyfish		4			
Unid. Mackerel		2 lbs	102 lbs		
Unid. Octopus		1			
Unid. Rockfish		1	1	4	
Unid. Ray			4		1
Unid. Sanddab		4	3		4
Unid. Seastar		1			
Unid. Seaslug					21
Unid. Scorpionfish		1			
Unid. Surfperch				3	
Unid. Skate		3		1	
Unid. Smelt		49			
Unid. Stingray		9	17		
Unid. Shark					1
Thresher Shark		1			
CA Sea Lion			98		
Harbor Seal			3		
Common Dolphin				1	
Unid. Gull			16	1	

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

Round-haul fishing seldom results in unintentionally caught fish, primarily because the vessels target specific schools, usually pure schools from one species (PFMC 2010). Incidental catch in the CPS fishery is primarily other CPS (e.g., Pacific Mackerel, Pacific Sardine, or Northern Anchovy). If larger fish are in the net, they can be released alive before pumping or brailing by lowering a section of the cork-line or by using a dip net. Most bycatch is caught when round haul nets fish in shallow water over rocky bottom (PFMC 2010). Operators try to avoid this to protect gear. Also, they may be specifically prohibited to fish these areas because of closures.

Table 3-3. Percent frequency of occurrence of bycatch in observed loads of California Market Squid from 2013 to 2017. Table values represent proportion of each incidental species out of the total incidental observed each year (Reproduced from PFMC 2018).

Common Name	Total All Ports				
	2013	2014	2015	2016	2017
Finfish					
Anchovy, northern	3.5	3.2	4	4.3	4.4
Barracuda, California	0.4	0.4	0.6	1.9	0.74
Bass, kelp	0.3	0.5			0.19
Blacksmith	0.1	0.2		0.5	0.19
Bonito, Pacific	0.1	0.2	0.9	1.4	0.37
Butterfish (Pacific pompano)	10	4.6	5.2	3.4	3
Combfish, longspine	0.1	0.2			
Croaker, white (kingfish)	1	0.4	0.6	1.4	0.93
Eel, wolf (wolf-eel)	0.5	0.2			
Fish, unspecified					
Flatfish, unspecified	0.3	0.9	1.5		2.6
Flounder, starry	0.1	0.4		0.5	
Flyingfish	0.6	0.2		0.5	0.56
Halibut, California	0.1	0.2			0.74
Herring, Pacific	1.3	0.5			0.19
Jacksmelt	2.5	3	4.3	4.3	4.8
Lizardfish, California	2.8	2.3	0.6	1	0.74

Mackerel, jack	2.6	4.9	12.5	11.1	8.3
Mackerel, Pacific	4.3	8.4	14.9	14.5	15.2
Mackerel, unspecified					
Midshipman, plainfin	1.7	1.8	1.2	0.5	1.1
Midshipman, specklefin	0.8	0.2	0.6		
Midshipman, unspecified		0.2			
Poacher, unspecified					
Rockfish, Blue	0.6	0.4	0.3		
Rockfish, chilipepper	0.9	0.9			
Rockfish, unspecified	0.5	0.2	0.3		
Salmon, Chinook	0.5				0.19
Sanddab, longfin	0.1	0.2			0.56
Sanddab, Pacific	2.7	5.3	6.4	2.4	2
Sanddab, speckled	0.9	2.5	0.6	1.4	0.37
Sanddab, unspecified	5.6	0.4		0.5	0.37
Sardine, Pacific	5.3	4.4	9.8	14	10.6
Scorpionfish, California	0.6	0.2	0.3	2.4	1.1
Sculpin, pithead					
Sculpin, staghorn	0.5	0.2			
Sculpin, unidentified	0.3	0.4			
Silversides					
Sunfish, ocean	0.1	0.2			
Surfperch, shiner	1.2	0.4	0.3		
Topsmelt	0.4			0.5	0.18
Turbot, hornyhead	3.4	1.4	0.6	0.5	1.3
Turbot, spotted					
Turbot, unspecified	0.4	0.4			0.19
Whiting, Pacific	0.4	0.2			
Total % Freq. Incidents	57.6	49.6	65.5	67.1	60.91
Elasmobranchs					
Ray, bat	3.8	1.4	3.4	4.3	2.8

Ray, Pacific electric	1.9	1.8	0.6	1.4	1.3
Shark, horn	0.1				0.19
Shark, unspecified					
Skate, long-nosed					0.19
Skate, unspecified		0.2			
Stingray, round					
Total % Freq. Incidents	5.8	3.3	3.9	5.8	4.48
Invertebrates & Plants					
Algae, marine	0.3	0.4	1.2	0.5	0.37
Cnidaria (Sea Anemones)					
Crab, box					0.19
Crab, Dungeness	0.9	3.5	1.8	1	1.1
Crab, rock unspecified	0.3	0.5	0.6		
Crab, sheep	0.1		0.3	0.5	
Crab, Shore					
Crab, swimming		0.2	0.9	2.9	0.55
Crab, unspecified	0.1	0.7	0.9		
Eelgrass	3.2	1.9	0.9	0.5	1.5
Gorgonians (sea fans)					
Grass, Turtle					
Jellyfish	1.9	5.4	3	2.9	6.3
Kelp	12.8	15.9	10.1	7.7	15.5
Kelp, feather boa	1.2	1.1	1.2		0.19
Lobster, California spiny	0.1			1	0.19
Salps	4.4	3.2			0.19
Sea cucumber	0.4				0.19
Sea Cucumber, warty				0.5	
Sea Hare	0.5		0.9		0.56
Sea Slug					
Sea stars	2.5	1.2	1.2		0.56
Squid, jumbo					
Squid, market (Egg Cases)	6.7	8.4	3.7	7.7	3.7
Surfgrass	1	4.7	3.7	1.9	2.4
Tunicates	0.1				0.19

Urchin, Purple					
Total % Freq. Incidents	36.6	47.1	30.5	27.1	33.68
Total All Incidents	773	571	328	207	540
Total Observed Landings	196	135	103	95	181

There have been very few interactions identified between the California Market Squid fishery and threatened or endangered marine species of birds and mammals. The Market Squid fishery is classified as a Marine Mammal Protection Act Category III fishery in terms of impact on marine mammal stocks. This means annual mortality and serious injury of a stock in a given fishery is less than or equal to 1% of the Potential Biological Removal level (e.g., a remote likelihood of or no known incidental mortality and serious injury to marine mammals). The only documented interactions for the California squid purse seine fishery in 2017 include the long-beaked common dolphin (*Delphinus capensis*) and the California Short-beaked common dolphin (*Delphinus delphis*). The California squid brail (e.g., dip net) fishery has no documented interactions (NOAA 2017).

3.1.4 Habitat

3.1.4.1 Description of Threats

During the implementation of the MSFMP, there was concern over the use of chains as a seine weight in the commercial fishery. Chains had the potential of digging deeper into the ocean floor than the suggested alternatives, such as small diameter cables. The squid fleet has moved away from the use of chains and now uses weighted lines. Net bottoms may also scrape the ocean floor and do harm to squid egg beds. Currently, the type of net used to fish for squid is unregulated, although purse seines used for squid typically do not hang as deep as purse seines used for other species, so contact with the bottom is potentially reduced.

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

The MLMA requires the minimization of adverse effects on habitat from fishing activities. Beyond California's MPA network, which affords spawning and habitat protection, seabird closure and special closure areas reduce the potential for interactions between the squid fishery and seabirds that are sensitive to disturbance from lights and noise. The weekend closure also provides statewide habitat protection from squid fishing throughout the year.

3.2 Requirements for Person or Vessel Permits and Reasonable Fees

Any vessel engaged in taking squid, landing squid, or attracting squid by light for commercial purposes must have a valid Market Squid permit. Vessels taking squid for live bait purposes only are exempt from the permit requirements (§149, Title 14, CCR). Market Squid transferrable vessel permits are fully transferable to vessels of

comparable capacity (within 10%). These permits can also transfer to a vessel of larger capacity under a “two for one” permit retirement. Brail permits are fully transferable based on comparable capacity (within 10%). Transferrable light boat permits are fully transferable and permit holders can upgrade to a transferable brail permit on a “one for one” permit retirement (Table 3-4; Table 3-5).

Table 3-4. Annual permits fees and transfer fees as of January 2019 (Reproduced from California Commercial Digest 2018).

Permit Type:	Fee:
Market Squid Vessel (Transferable)	\$2,844.75
Market Squid Vessel (Non-Transferable)	\$1,426.25
Market Squid Brail (Transferable)	\$2,844.75
Market Squid Light Boat (Transferable)	\$858.50
Market Squid Light Boat (Non-Transferable)	\$56.39
Market Squid Transfer Fee	\$500.00
Market Squid Brail (Upgrade from light boat)	\$1,500.00

Table 3-5. Initial annual permit fees established by the MSFMP in March 2005.

Permit Type:	Fee:
Market Squid Vessel (Transferable)	\$2,000
Market Squid Vessel (Non-Transferable)	\$1,000
Market Squid Brail (Transferable)	\$2,000
Market Squid Brail (Non-Transferable)	\$1,000
Market Squid Light Boat (Transferable)	\$600
Market Squid Transfer Fee	\$500
Market Squid Brail (Upgrade from light boat)	\$1,500

4 Monitoring and Essential Fishery Information

4.1 Description of Relevant Essential Fishery Information

Fishery-dependent Essential Fishery Information (EFI) collected through the Department's Market Squid Monitoring and Sampling Program include:

- Landings and effort – tonnage per day and week, number of vessels, and fishing location/block. The Department monitors tonnage to ensure closure of the fishery before the catch limit of 107,048 mt (118,000 ton) is exceeded.
- Biological – individual weight, length, sex, maturity, dried mantle weight, and gonad weight. Gonad weights are used to provide information for the egg escapement model that is intended for use as F_{MSY} proxy.

4.2 Past and Ongoing Monitoring of the Fishery

4.2.1 Fishery-dependent Data Collection

Landing receipts were the earliest form of fishery-dependent data collected from the commercial Market Squid fishery. The Department began collecting receipts in 1927 for all commercial fisheries as a way to provide general knowledge of fishing activity, specifically in terms of amount landed, landing location, gears used, and value of the catch (CDFG, 2005; MSFMP section 1-85 4.2.2.1). The Department actively monitors the commercial Market Squid fishery by collecting dockside port samples and logbook information. The monitoring program began in October 1998, and logbook information became mandatory in 2000. The Commission maintained existing fishery-dependent Market Squid monitoring programs as one of MSFMP Fishery Control Rules in 2004. The primary goal of collecting these data is to monitor changes in the biological characteristics and to characterize California's commercial Market Squid fishery for development of population models.

Sample collection is centered on the major port complexes of landing, which include Monterey (Monterey and Moss Landing), Santa Barbara (Santa Barbara, Ventura, and Port Hueneme), and Los Angeles (San Pedro and Terminal Island). Other ports such as Eureka, Bodega Bay, Half Moon Bay, and San Francisco are included when landings are significant in those areas. Standardized protocols are used to maintain consistent sampling among port complexes. During the offloading process samplers make visual observations of species composition and incidental catch (Figure 4-1). They also record percent composition of Coastal Pelagic Species (Pacific Sardine, Pacific Mackerel, Jack Mackerel, Northern Anchovy) by volume of the total landing. All other incidental species observed in the landing are noted, with special attention paid to prohibited or protected species (e.g., salmon). The observations are reported in PFMC CPS Stock Assessment and Fishery Evaluation reports.



Figure 4-1. Photos of the Market Squid offloading process (Photo Credit: CDFW).

Vessel captains are interviewed during the offload in order to collect fishing effort information. Data collected by the interviews are:

- date of landing
- Department block location where fishing occurred
- how much was captured
- number of sets made
- gear used
- if a light boat was used
- location and market of landing
- landing receipt number
- anecdotal information given that helps to characterize the fishery

A squid sample consists of 30 individuals randomly collected throughout the offload (Figure 4-2). The samples are processed for:

- weight
- length
- sex
- presence of spermatophores and eggs
- gonad weights from the first five females to determine fecundity
- mantle punch samples from the first five females and first male used to determine condition and maturity
- statoliths (calcareous structure) from first five females and the first male used to determine age

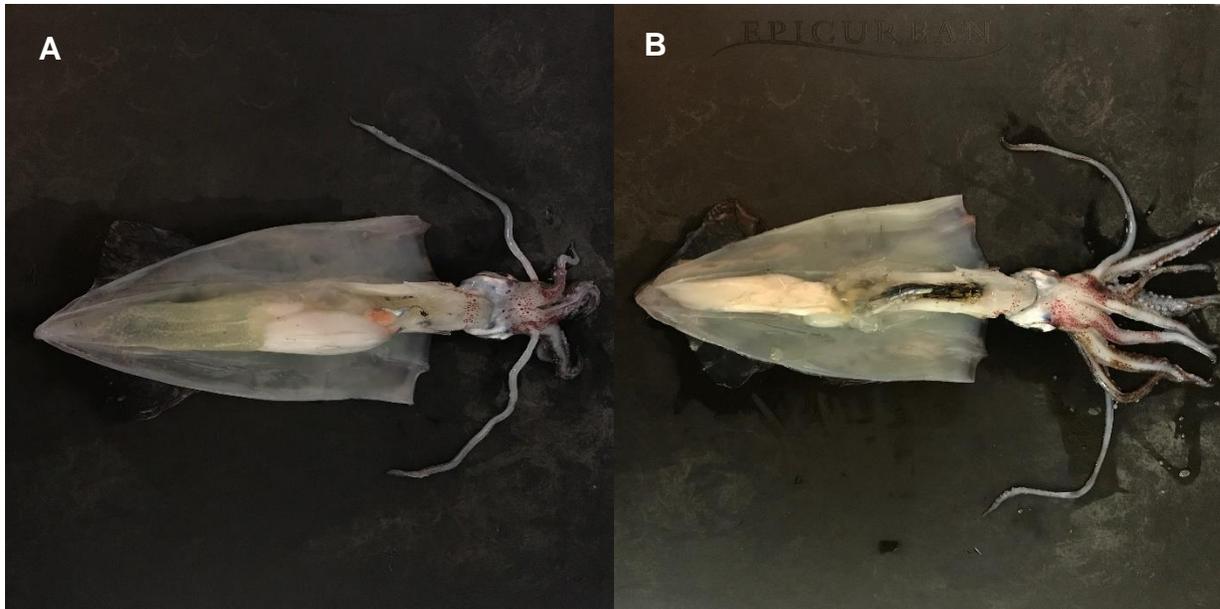


Figure 4-2. Photos of (A) a dissected female Market Squid and (B) a dissected male Market Squid. (Photo Credit: CDFW)

INFORMATION UNDER DEVELOPMENT.

Market Squid Logbook Program

Market Squid Vessel and Light/Brail Boat logbooks (logs) are a mandated system for fishermen to record their fishing activities. These data supplement data gathered from landing receipts. Logbook data are used to monitor fishing locations and conditions, fishing effort, catch amounts, use of catch, and fleet characterization and capacity.

Data collected from Market Squid Vessel and Light/Brail Boat Logbooks are (Figures 4-4 and 4-5):

- vessel identification
- date of fishing activity
- fishing effort (the number of sets made with start and end times of each hours spent searching, hours spent lighting)
- latitude and longitudinal position of location
- SST
- bottom depth
- incidental species



Vessel Name: _____

Vessel Permit Number: _____

Captain's Name: _____

Vessel ID Number: _____

Captain's ID Number: _____

Alpha Code	Date	Set Number (or B if using ball gear)	Set Time: hr:min AM or PM (circle one)		Set Position: decimal minutes to hundredths place				SST (°F)	Bottom Depth (fm)	Name of light boat set upon	Catch Estimate (Short Tons)	Was catch limited by market order? Y/N	Bycatch:		Landing Receipt(s)	
			Start	End	Latitude		Longitude							Species	Amount (lbs)		
			Ex. 34°	Ex. 05.15'	Ex. 120°	Ex. 04.85'											
A			AM / PM	AM / PM													
B			AM / PM	AM / PM													
C			AM / PM	AM / PM													
D			AM / PM	AM / PM													
E			AM / PM	AM / PM													
F			AM / PM	AM / PM													
G			AM / PM	AM / PM													
H			AM / PM	AM / PM													

Comments: List by date any anecdotal information such as additional bycatch information, equipment problems, interference from other boats, weather-related problems, day set activity, etc.

Captain's Signature _____ Date _____
 Certified under penalty of perjury as true and correct

Figure 4-4. Market Squid vessel logbook template. Revised 05/01/15.



Market Squid Vessel Profile

Vessel Name _____

Vessel ID Number _____

Vessel Permit Number _____

Captain's Name _____

Captain's ID Number _____

Attracting Lights Used:

Type: _____ Light Generated: _____ Number: _____

_____ W L (circle one) _____

_____ W L (circle one) _____

_____ W L (circle one) _____

Vessel Characteristics:

Boat Length (ft) _____

Hold Capacity (st) _____

Gross Tonnage _____

Purse Seine / Drum Seine / Lampara / Brail Net (circle one)

Net Depth (fm) _____

Net Length (fm) _____

Mesh Size (in) _____

Electronics Used:

Side-scan Sonar: Yes No (circle one)

Fathometer: Yes No (circle one)

Other: _____

Horsepower:

Main Engine _____

Generator _____

If Brail, scoop capacity (ft): Circumference _____ Depth _____ Volume in lbs per scoop _____

Fish Hold's Water System (circle one): Brine RSW Air SW (live) Other (please specify) _____

Crew members:

Name	ID Number	Name	ID Number

Captain's Signature _____ Date _____
 Certified under penalty of perjury as true and correct

Figure 4-6. Market Squid vessel logbook profile form template Revised 05/01/15.

Additional Sample Collections

The Department has assisted with additional Market Squid sample collections to supplement various independent and collaborative research projects over time. These studies were generally intended to increase understanding of Market Squid life history (Table 4-1).

Table 4-1. Summary of Market Squid sample collections for independent and collaborative research projects over time.

Time Period	Project Lead	Samples Collected	General Purpose
1999-2001	John Butler	Gonad weight, mantle weight, statoliths	To develop the ageing methodology for Market Squid, to look at fecundity in terms of batch fecundity and age at maturity, and to develop a population model for Market Squid.

1999-2002	William Gilly	Gill filaments	To determine if there are separate Market Squid stocks in California specifically between the central and southern California fishing regions, as well as between nearshore and offshore populations in Monterey area.
2008-2009	Robert Warner	Egg cases	To identify geographic differences in trace element concentrations in adult natal core and early larval areas of statoliths, ultimately for use in identifying source populations of stocks.
2008-2009	Mark Lowry	Mantle length	Regression analysis on mantle length to beak size.
2014-2015	Samantha Cheng	Egg cases	To determine if there are separate Market Squid stocks in California specifically between the central and southern California fishing regions, as well as between nearshore and offshore populations.

4.2.2 Fishery-independent Data Collection

Fishery-independent data on juvenile Market Squid come from annual Rockfish Recruitment and Ecosystem Assessment reports (e.g., juvenile rockfish surveys). The CPUE of regional forage (Northern Anchovy, Pacific Sardine, krill, Market Squid, juvenile rockfish, juvenile sanddabs, and juvenile Pacific Hake) in the central CCE (defined as the nearshore region of the eastern Pacific between Crescent City Harbor and Point Conception) is measured annually using NOAA trawl surveys in spring or summer. These data are publicly available at the NOAA CCIEA website.

In addition, there is a long-standing data series of Market Squid paralarvae abundance from surveys conducted through collaborative efforts by multiple agencies and the fishing industry. These data, in part, come from CalCOFI, a multi-agency partnership between the Department, NOAA, and Scripps Institution of Oceanography formed in 1949 to study the ecological aspects of the sardine population collapse off California. Recent focus has shifted to include the overall study of the marine environment off California, the management of its living resources, and monitoring the indicators of climate change. Quarterly surveys are conducted off southern and central California, collecting hydrographic and biological data on static stations over transect lines. Biological data collection methods include Continuous Underway Fish Egg Sampler, trawling, Bongo Net tows for displacement volumes of zooplankton and pelagic invertebrate, and fisheries acoustics. CalCOFI data are accessible to the public through their data server.

Paralarvae abundance surveys makeup the largest fisheries-independent data series for the Market Squid fishery. Sampling was opportunistic prior to 2010, but since then CWPA has maintained standardized paralarval surveys, conducting at least four surveys annually in the SCB (following the CalCOFI schedule when possible) and since 2014 two surveys per year in the greater Monterey Bay and Half Moon Bay area.

Original studies investigated the correlation between paralarvae abundance and CPUE of the fishery (Sakurai et al. 2000; Zeidberg et al. 2006; Koslow and Allen 2011). Zeidberg et al. (2006) used samples from independent research cruises for 2000 to

2003. These samples were collected inshore and were significantly correlated with fishery landings, although collections only spanned 4 yr. Whereas, Koslow and Allen (2011) used manta tow samples taken from quarterly CalCOFI surveys from 1981 to 2008, which are located offshore from the Zeidberg et al. (2006) study. Results from the Koslow and Allen (2011) study were less significant ($r^2=0.35$, $p=0.08$); however, the data spanned 20 years and were only correlated at an annual scale.

The CWPA initially implemented bongo tows in 2005. The original intent of this work was to supplement the CalCOFI survey by providing samples nearshore, adjacent to known spawning sites, since CalCOFI sample sites rarely overlap squid paralarvae habitat. The CWPA trained squid fishermen to tow bongo nets, but comprehensive sampling was not always logistically possible. Beginning in January 2011, CWPA chartered dedicated fishing vessels for the specific purpose of conducting these small net tows on a systematic schedule. There is a difference, however, in the collection methods between these studies. Koslow and Allen (2011) analyzed CalCOFI manta tow data because squid presence was greater in the surface-oriented manta nets than in the offshore obliquely deployed bongo tows. However, bongo tows are considered more appropriate since they tend to sample 2-week-old squid, which have survived the critical stage of first feeding. Manta tows may sample day old squid. Additionally, the older paralarvae begin to migrate to deeper depths, thereby avoiding mortality from radiation and surface predation.

The Market Squid habitat assessment project aims to better understand the physical and ecological factors that control recruitment to major spawning grounds, and to improve the assessment and management of Market Squid stocks off California. CWPA conducts the paralarval surveys at least four times each year in the SCB and twice a year in Monterey; during which they also collect water samples at select sampling stations (Figure 4-7).

INFORMATION UNDER DEVELOPMENT.

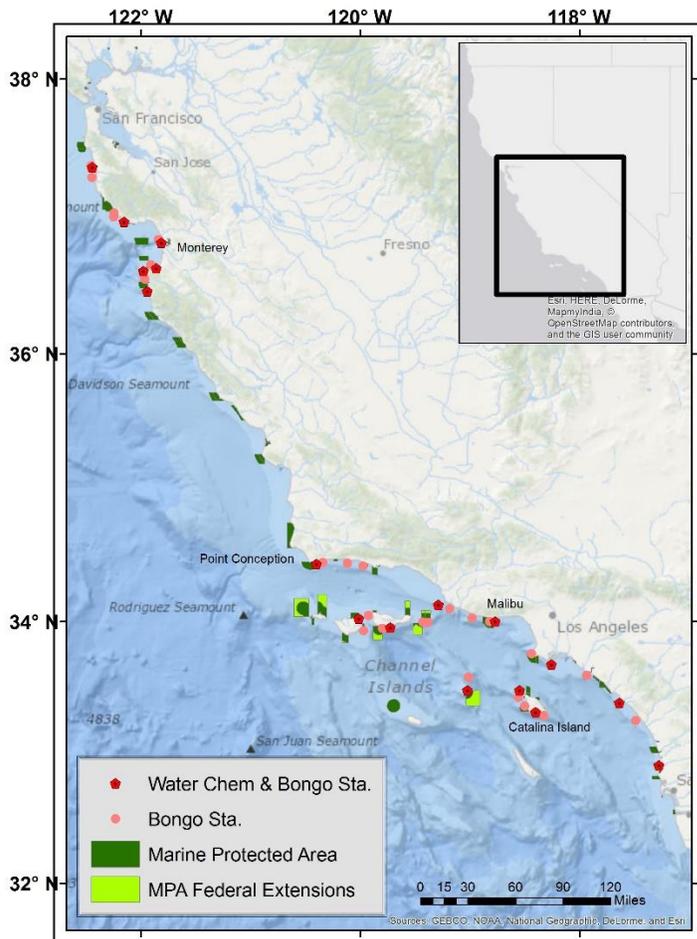


Figure 4-7. Sampling areas off California are shown as pink circles. Five regions are identified across the sampling effort and include Monterey, the north Bight and south Bight of the SCB, and north and south Channel Islands (Reproduced from Van Noord and Dorval 2017).

5 Future Management Needs and Directions

5.1 Identification of Information Gaps

The primary information gaps for the Market Squid fishery include the need to: determine if changes in fishing behavior have altered traditional assumptions for egg escapement, quantify extent of egg mortality from net disturbance, improve estimates of preferred spawning grounds, develop proxies for standardized CPUE data, incorporate oceanographic data in multivariate approaches to analyzing current fisheries-dependent data streams, and quantify age composition of the catch through the statolith backlog (Table 5-1).

TABLE 5-1 UNDER DEVELOPMENT.

5.2 Research and Monitoring

5.2.1 *Potential Strategies to Fill Information Gaps*

INFORMATION UNDER DEVELOPMENT.

5.2.2 *Opportunities for Collaborative Fisheries Research*

INFORMATION UNDER DEVELOPMENT.

5.3 Opportunities for Future Management Changes

INFORMATION UNDER DEVELOPMENT.

5.4 Climate Readiness

Market squid have been shown to be highly responsive to changes in environmental conditions, with populations experiencing dramatic variability in abundance over time and space in response to these changes. This can present challenges to managers even under normal climate variability and is likely to be exacerbated by climate change. Landings of Market Squid in California have been significantly lower during El Niño events (Zeidberg et al. 2006), because warmer periods may reduce reproductive output of females (Henry et al. 2003), the amount of available spawning habitat (Zeidberg et al. 2012), larval abundance (Koslow et al. 2011), and growth rates (Jackson and Domeier 2003; Reiss et al. 2004). Historically, while catches have been low during these periods, the Market Squid fishery has rebounded quickly when conditions improve. However, given the short life span of squid, which allows for little to no overlap between cohorts, there is concern that extended warm water periods could impact the stock's ability to recover.

INFORMATION UNDER DEVELOPMENT.

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