Fishery-at-a-Glance: Warty Sea Cucumber

Scientific Name: *Apostichopus parvimensis*

Range: Warty Sea Cucumber range from Puerto San Bartolome in Baja California, Mexico to Fort Bragg, California, US, but are uncommon north of Point Conception, California.

Habitat: Warty Sea Cucumber occupy waters from the subtidal zone to 180 feet (55 meters) depth. They are commonly found to inhabit both rocky reef and sand/mud substrate.

Size (length and weight): Warty Sea Cucumber can reach 12-16 inches (30.5-40.6 c centimeters) when encountered in their natural state (in-situ) on the seafloor; however, this size measurement is not an accurate measure of body size due to the ability of sea cucumber to extend and contract their bodies. Constricted length and width provide a more accurate estimate of body size. The maximum reported length for Warty Sea Cucumber in a constricted state is 9.5 inches (24.1 centimeters) and a maximum width (excluding soft spines) of 3.5 inches (8.9 centimeters). The maximum individual weight recorded for a Warty Sea Cucumber in a whole or live state is 1.64 lb (743.9 grams), with the maximum weight of individuals in a cut eviscerated state (the predominant commercial landing condition) of .82 lb (371.9 grams).

Life span: The life span of Warty Sea Cucumber is currently unknown. There is currently no way to directly age Warty Sea Cucumber.

Reproduction: Warty Sea Cucumber have separate male and female sexes that reproduce via aggregate broadcast spawning. Spawning occurs from March to July in depths less than 100 feet (30.5 meters), with most spawning occurring less than 60 feet (18.3 meters) depth.

Prey: Warty Sea Cucumber are epibenthic detritivores, feeding on organic detritus and small organisms present within sand and mud sediments, and on detrital layers that accumulate on rock/reef substrates**.**

Predators: Reported predators of Warty Sea Cucumber consist of sea stars, Sea Otters, crabs, and various fish species (examples include Kelp Greenling, California Sheephead); however, predation of Warty Sea Cucumber individuals is rarely observed and is thought to be low in adults.

Fishery: Warty Sea Cucumber are harvested in southern California by permitted divers. In 2011, the fishery reached a record high revenue of $2.3 million, with landings reaching 277 tons that same year. Since 2011, the fishery has experienced consistent declines in both revenue and landings. In 2017, the fishery was valued at $0.7 million, with an associated landing of 61 tons. The average ex-vessel price per pound has drastically increased over the past 10 years, growing from an average of $1.50 per pound in 2007, to an average of $5.00 per pound in 2017.

Area fished: The Warty Sea Cucumber dive fishery spans from Point Conception south to the US and Mexico border. A dive fishery for Warty Sea Cucumber also exists in Baja, Mexico that extends from the US-Mexico border south to at least Isla Natividad. Most landings occur in the ports of Channel Islands (Oxnard), Santa Barbara, Ventura, and Terminal Island, with most of the harvest occurring in the waters around offshore Islands such as Anacapa, Santa Cruz, Santa Barbara, Santa Catalina, and San Clemente Island.

Fishing season: Starting in 2018, a seasonal closure was enacted from March 1 to June 14 to protect spawning aggregations of Warty Sea Cucumber that form annually each spring in shallow depths.

Fishing gear: Warty Sea Cucumber are harvested by hand by divers using SCUBA or hookah (surface supplied air).

Market(s): A majority of Warty Sea Cucumber landed in California are boiled, dried, and shipped to markets overseas in China, Hong Kong, Taiwan, and Korea. A small domestic market has recently developed for live Warty Sea Cucumber sold in sushi and other specialty restaurants.

Current stock status: No formal stock assessments have been conducted on Warty Sea Cucumber in California due to its data-poor nature, especially regarding biological information. While the status of Warty Sea Cucumber has not been assessed using a formal stock assessment, commercial landings data and independent monitoring data suggest that Warty Sea Cucumber populations have reached levels of concern. Independent SCUBA monitoring data demonstrate the rapid decline in population densities after increases in commercial effort and landings in the 1990s. While the status of the stock is unknown, recent declines in catch and Catch Per Unit Effort during a time of high ex-vessel prices suggests that Warty Sea Cucumber may becoming more difficult for divers to find.

Management: Warty Sea Cucumber is a state-managed fishery. Current regulations for the commercial fishery consist of a limit on the number of permittees (currently 82 divers), a requirement to complete and submit a daily dive log, and a closed season from March 1 to June 14 to protect spawning aggregations. Given this uncertainty surrounding the life history and productivity of Warty Sea Cucumber, the Department is conducting research to better understand the biology of the species and the impacts of fishing on this stock.

1 The Species

[redacted]1.1 Natural History

1.1.1 Species Description

Warty Sea Cucumber (*Apostichopus parvimensis*, formerly known as *Parastichopus parvimensis*) is an economically important invertebrate that is harvested by commercial divers in southern California. Warty Sea Cucumber belong to the Phylum Echinodermata, and are related to sea stars, brittle stars, sea urchin, and sand dollars. Individuals are typically orange, brown, or chestnut in color and are cylindrically shaped with a soft outer body wall that is covered in mucous. Warty Sea Cucumber are named after the numerous small black tipped projections known as “papillae” that cover the dorsal (top side) portion of their body, with a small number of these projections being elongated into soft cone or spine like projections (Figure 1-1). Warty Sea Cucumber have branched buccal tentacles at their mouth end for feeding (Figure 1-1). In place of a hard exoskeleton, sea cucumber have loosely arranged microscopic calcareous structures known as “ossicles” that vary in both shape and complexity based on their location within the body (Figure 1-2).

Figure 1-1 Warty Sea Cucumber individual showing black tipped papillae and soft spine like projections (left)(Photo Credit: Clinton Bauder). The buccal feeding tentacles (white branched structure) of a Warty Sea Cucumber (right) (Photo Credit: Udo M. Savalli).

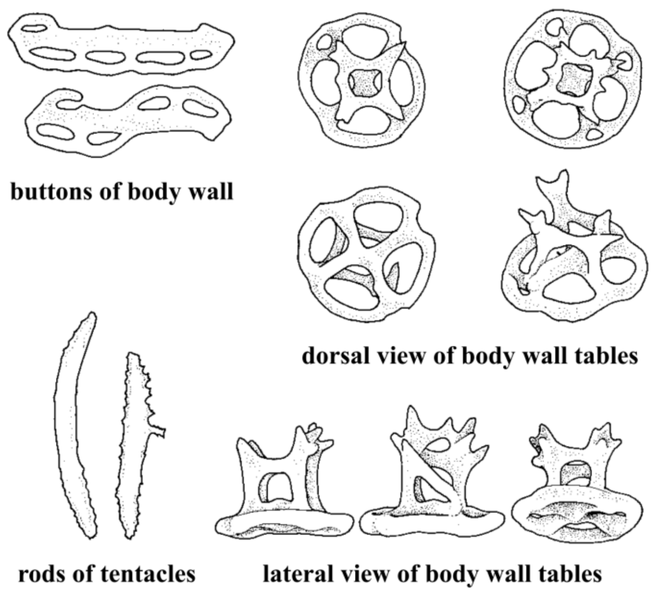


Figure 1-2 Warty Sea Cucumber ossicle shape and size. Tentacle rods are up to 600 micrometers long, body wall tables are about 45 micrometers across, and body wall buttons are about 90 micrometers long (Reproduced from Solís-Marín et al. 2009).

1.1.2 Range, Distribution, and Movement

The range of Warty Sea Cucumber extends from Monterey, California south to Puerto San Bartolomé Baja California, Mexico (Morris et al. 1980) (Figure 1-3). Warty Sea Cucumber are bottom dwelling, and reside on rocky reef and soft bottom habitats from subtidal depths to approximately 180 feet (ft) (60 meters (m)) depths, but are most common between 30 and 75 ft (10 and 25 m) depths. At Santa Catalina Island, Muscat (1983) found densities of Warty Sea Cucumber measured at depths from 40 ft (13 m) to 108 ft (33 m), with the greatest year-round densities at a depth of 67 ft (20 m). A collaborative study between Marine Applied Research and Exploration (MARE) and the Department recently utilized a Remotely Operated Vehicle (ROV) to survey the depth distribution and habitat association of Warty Sea Cucumber during their peak spawning period off Anacapa Island inside the Anacapa State Marine Reserve. Findings demonstrate that densities of Warty Sea Cucumber are greatest between 60 and 98 ft (18 and 30 m) depths on rocky reef habitats, with no individuals observed deeper than 150 ft (50 m) (MARE unpublished data).

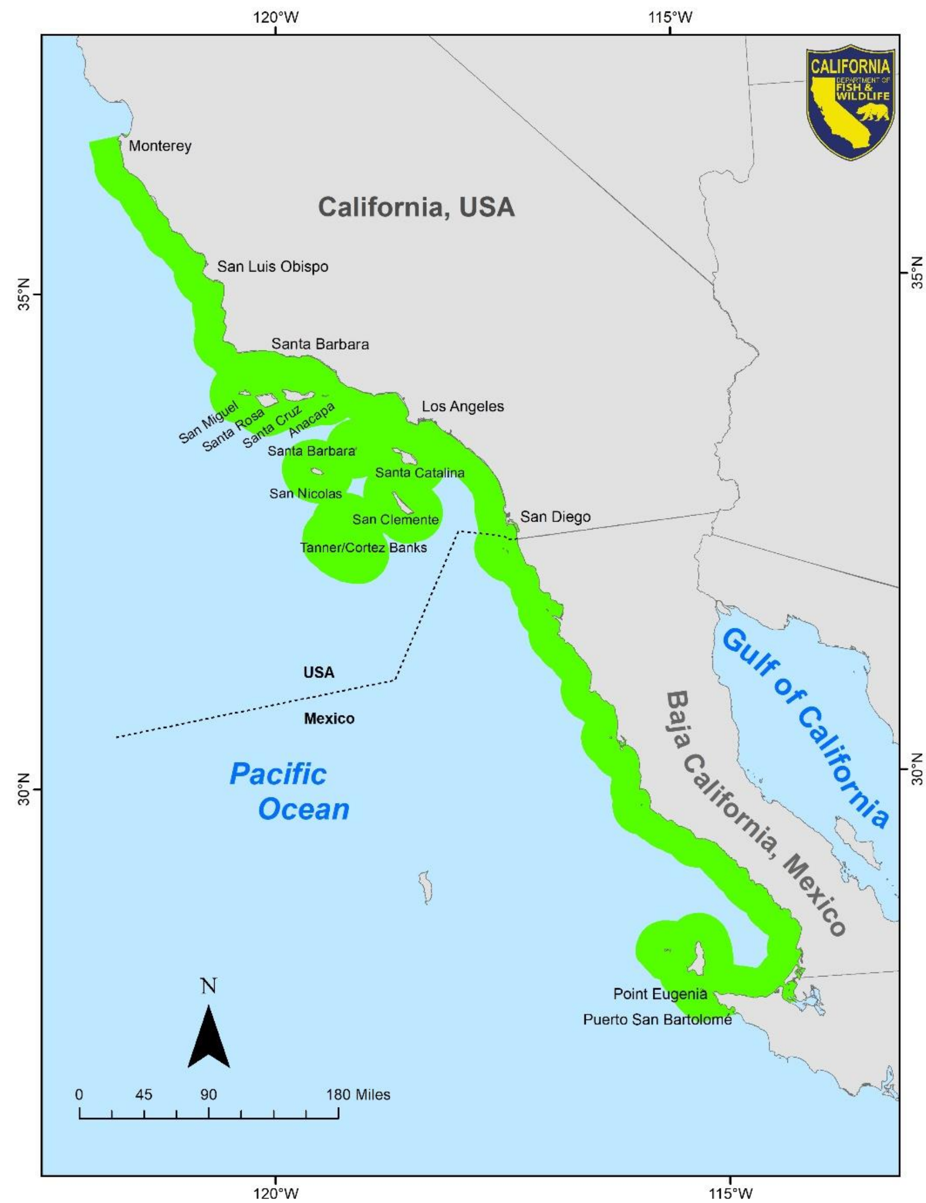


Figure 1-3. Range of Warty Sea Cucumber (Morris et al. 1980).

Warty Sea Cucumber move by crawling along the bottom using tube feet located on their ventral (underside) portion of their body and/or by contracting their body wall. Research suggests that Warty Sea Cucumber can display limited to moderate movement during non-spawning periods, while exhibiting high site fidelity to a specific reef during spawning periods (Muscat 1983). At Santa Catalina Island, tagged Warty Sea Cucumber were found to display movements of up to 0.2 miles (mi) (0.35 kilometers (km)) and remain at the same reef for up to 6 months, with individuals displaying higher site fidelity during the spawning period (May) than during the non-spawning period (December) (Muscat 1983). These differences in movement behavior can likely be explained by recent Department observations that Warty Sea Cucumber start to form spawning aggregations around shallow rocky reef areas in winter and build to peak levels during late spring and/or early summer periods.

On a daily basis, Warty Sea Cucumber have been reported to display less movement when occupying reef habitat 6.0 $\pm$ 0.5 inches (in) (SE) (15.3 $\pm$ 1.3 centimeters (cm)) than sand habitat 17.6 $\pm$ 2.4 in (SE) (44.7 $\pm$ 6.1 cm) (Muscat 1983). These findings may be attributed to dietary requirements, because sediments found on reefs contain higher organic content than those found on sand substrates (Yingst 1982)

1.1.3 Reproduction, Fecundity, and Spawning Season

Warty Sea Cucumber are dioecious (having separate male and female individuals) and reproduce by synchronously broadcasting their gametes (sperm and eggs) into the water column, where fertilization occurs. Warty Sea Cucumber aggregate in shallow areas (< ~80 ft depth (~24 m)) during their spawning periods. This behavior likely makes Warty Sea Cucumber more vulnerable to the dive fishery during these periods, which is supported by historic commercial landings data displaying annual peaks during spawning periods. This aggregation behavior is likely related to individuals seeking other spawning individuals to increase the chances of successful fertilization; however, it is also possible that increased feeding opportunities during this time, or a combination of these factors, play a role in observed aggregation behavior.

The reproductive cycle of Warty Sea Cucumber was first described by Muscat (1983) for individuals collected from Santa Catalina Island from 1980 to 1982. This research found that the annual reproductive cycle of Warty Sea Cucumber consists of five distinct stages. The spawning stage (May through June) consists of the release of gametes (sperm and eggs) via broadcast spawning. The post-spawning stage (July through August) consists of voided or mostly empty gonadal tubules, and these gonadal tubules are completely resorbed during the resorption stage (September through October). During the growth stage (November through February) gonadal tubules begin to re-establish, with growth and development of these gonad structures occurring during the maturation stage (March through April), until they reach their optimal maturity and size in preparation for spawning (Muscat 1983) (Table 1-1). Muscat (1983) stated that Warty Sea Cucumber reach sexual maturity after reaching a total body weight of 40 grams (g) (0.09 pounds (lb)) but determining the weight and size of live sea cucumber can be very difficult (as described in Section 1.1.4).

Table 1-1. Stages of the Warty Sea Cucumber reproductive cycle (Muscat 1983).

Stages of Reproductive Cycle	**Time of Occurrence**	**Gonad Index (%) $\bar{x}$±S.E.**
Spawning	May-June	2.10±0.72
Post-spawning	July-August	0.07±0.03
Resorption	September-October	0.02±0.01
Growth	November-February	1.95±0.95
Maturation	March-April	6.63±0.65

Research conducted by the Department at the Northern Channel Islands from 2013 to 2018 found similar spawning results, with the timing of spawning stages occurring approximately 1 month later than that reported on Santa Catalina Island by Muscat (1983) (Figure 1-4). The 1 month difference in spawning can likely be attributed to spatial differences and possibly the timing of the arrival of warm water. Muscat (1983) believed water temperature to be a driving factor for the timing of spawning, with spawning found to occur during the arrival of warm water. Anecdotal evidence also suggests that spawning may occur earlier in southern parts of the southern California Bight, with similar reports of individuals spawning earlier at Anacapa and Santa Cruz Island than individuals at the western islands of Santa Rosa and San Miguel.

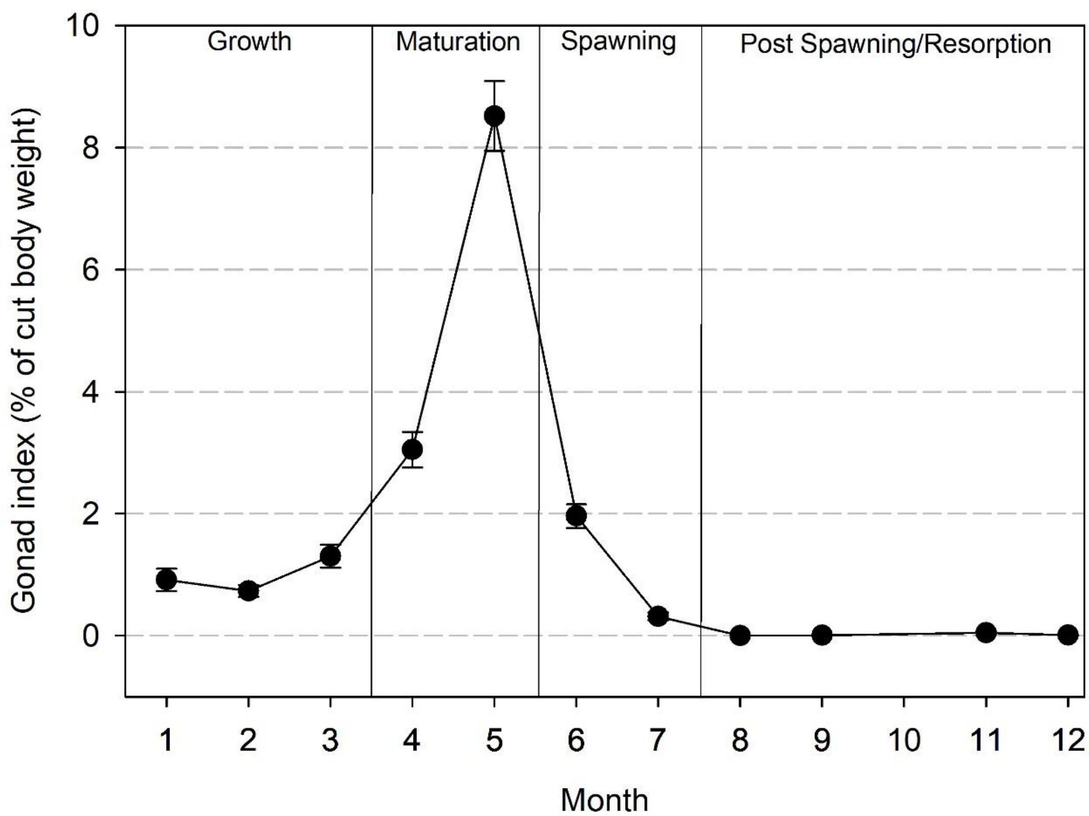


Figure 1-4. Gonad index of Warty Sea Cucumber by month sampled from 2013-2018 at Anacapa and Santa Cruz Island. Note there were no observations from October (CDFW unpublished data).

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 and invertebrates 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 stock.

Current estimates of Warty Sea Cucumber natural mortality are unknown. Estimating natural mortality in this species is complicated by the fact that there is no known method to age sea cucumber, so their maximum lifespan is also unknown. The continued monitoring of densities and size structure of populations within Marine Protected Areas (MPAs) may provide insight into natural mortality rates.

Chavez et al. 2011 estimated the natural mortality of Warty Sea Cucumber using three different estimators developed by Jensen (1996), Hoenig (1983), and Pauly (1980). However, these estimators were primarily developed based on observations of finfish life history traits, and may be inappropriate for a species that exhibits very different growth patterns. For this reason, the Department considers the life span and natural mortality rate of Warty Sea Cucumber to be unknown at this time.

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; however, for invertebrates like Warty Sea Cucumber, other growth functions may be more appropriate.

For many sea cucumber species around the world, weight serves as an important indicator of size due to ability of sea cucumber to change their body shape. Without a reliable method for ageing sea cucumber, weight could also serve as a proxy for age, although age weight relationships for Warty Sea Cucumber have not been developed. In the dive fishery, Warty Sea Cucumber are landed in both a whole (un-cut) state and in a cut (processed) state, in which the water and gut contents are removed prior to landing, a process also known as evisceration. From 2013 to 2018, the Department measured the Whole Weight (WWT), Cut Weight (CWT), and Cut Weight With Viscera (CVWT) of over 2,000 individuals (Table 1-2). The maximum observed weights for WWT, CVWT, and CWT were 1.61 lb (0.73 kg), 1.03 lb (.45 kg), and 0.82 lb (0.44 kg), respectively. The weight distributions off all Warty Sea Cucumber measured by the Department demonstrate a distinct peak in CWT measurements, with less distinct peaks in WWT and CVWT measurements (Figure 1-5). This is likely due to the variability in water and viscera present in WWT and CVWT measurements.

Table 1-2. Summary of the WWT (lb), CVWT, and CWT of all Warty Sea Cucumber measured by the Department from 2013 to 2018.

Variable	N (number of samples)	Mean (lb)	SE Mean	Minimum (lb)	Maximum (lb)
WWT	2,152	0.4659	0.0051	0.0015	1.6065
CVWT	2,198	0.2951	0.0034	0.0011	1.0309
CWT	2,202	0.2408	0.0026	0.0011	0.8221

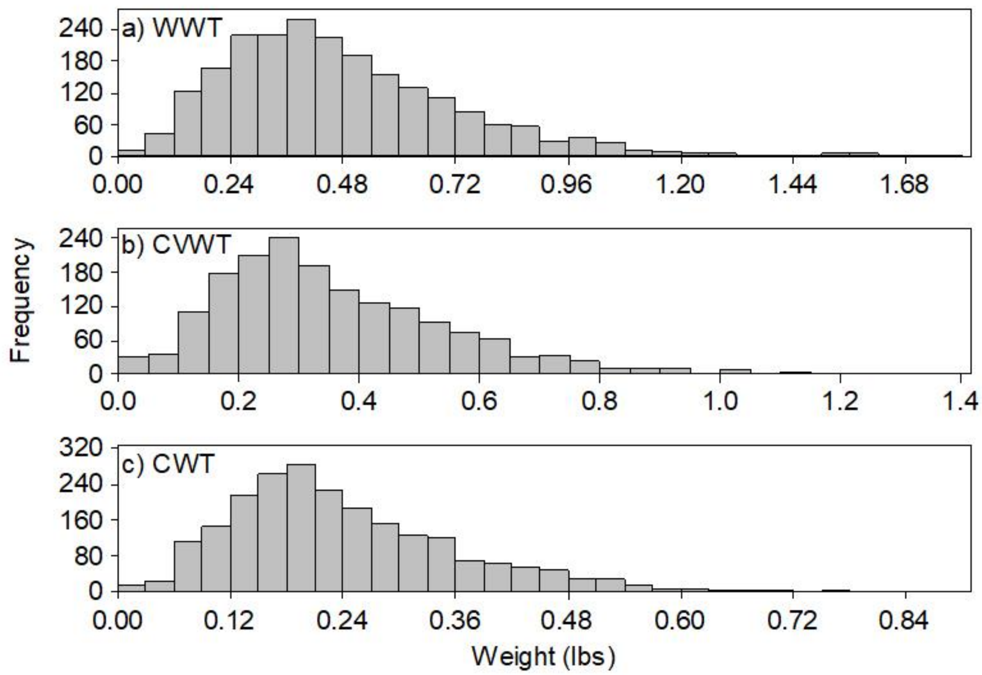


Figure 1-5 The frequency of a) WWT b) CVWT and c) CWT for all Warty Sea Cucumber weighed by the Department from 2013-2018 (CDFW unpublished data).

Estimates of individual Warty Sea Cucumber growth are unknown due to the inability to directly estimate length at age (see Section 1.1.6) and difficulties in tracking the same individual over long enough periods to estimate growth. Currently there is no method to directly age Warty Sea Cucumber, and their soft tissues make long term tag-recapture studies difficult. Muscat (1983) did have success in tagging and tracking individuals for up to 44 months; however, this study was mainly focused on movement behavior and no growth estimates were provided. The continued monitoring of the size structure of populations within MPAs may serve as an important tool for tracking size classes to estimate growth.

When individual Warty Sea Cucumber are encountered on the seafloor in their original “in situ” position, individuals can reach a maximum length of 15 to 20 in (40 to 51 cm) Total Length (TL)); however, this form of measurement is inconsistent due to the fact that Warty Sea Cucumber can bend, extend, and contract their bodies. Yingst (1974) developed a standardized method for measuring Warty Sea Cucumber based on their Contracted Length (CL) and Contracted Width (CW). This measurement is taken underwater at depth of capture after an individual has been handled and agitated, which results in the individual contracting its body into a tight cylindrical like shape (Figure 1-6). At this point, CL, CW, and Contracted Height (CH) measurements can be taken. Department research suggests that this method of measuring size produces the most consistent results.

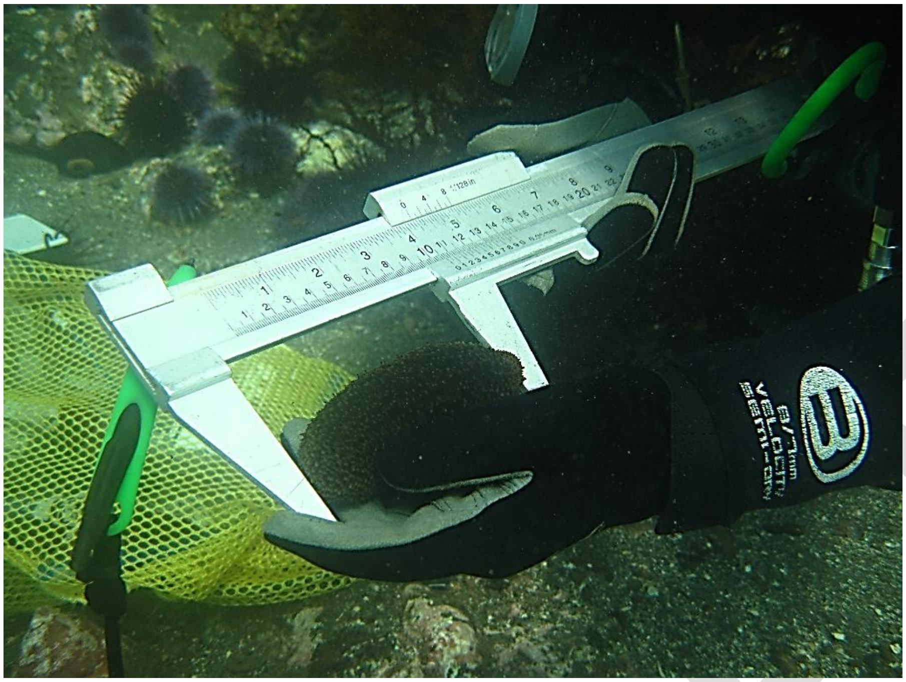


Figure 1-6. Example of a contracted length measurement of a Warty Sea Cucumber individual (Photo Credit: Derek Stein, CDFW).

In Baja California, Mexico, a stock assessment was conducted in 2011. This assessment used catch-at-length data to estimate a growth rate. However, this data was converted from catch-at-weight data by assuming a power relationship between weight and length in the form of

$$W = aL^b$$

where *W* is the weight in grams, *L* is the TL in centimeters, *a* is a constant indicating the intercept and *b* is a constant indicating the slope of the regression line. Preliminary morphometric analysis of Warty Sea Cucumber by the Department has shown that the relationship between CWT (defined as the body wall weight after the viscera has been removed) (CWT) and CL alone is weaker than the relationship between CWT and the product of CL and CW , as described above (Figure 1-7) (CDFW unpublished data). Given this, the method used to estimate growth rates in the Chavez et al. (2011) study may not be accurate for Warty Sea Cucumber in southern California.

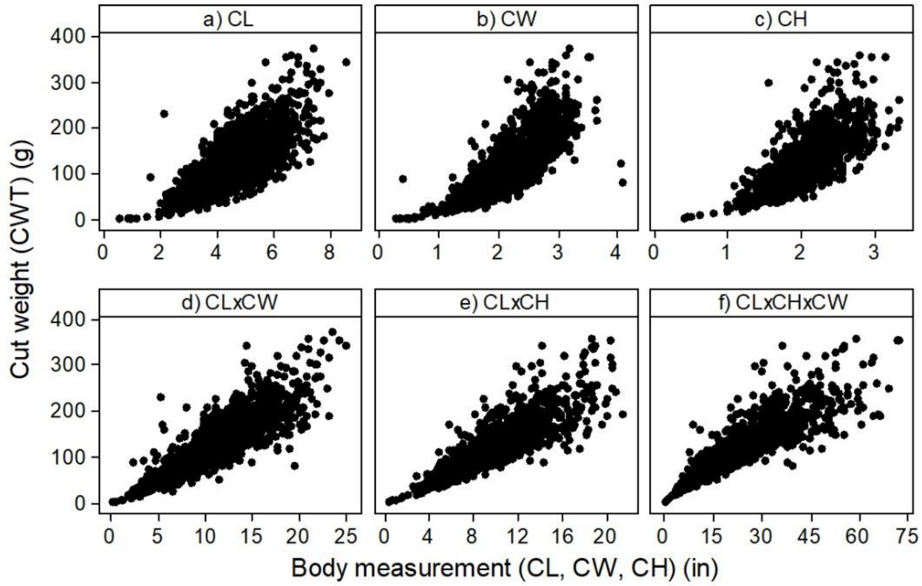


Figure 1-7. The relationship between Warty Sea Cucumber CWT and their a) CL, b) CW, c) CH, and the product of these factors ((d) CLxCW, e) CLxCH, and d) CLxCHxCW) (CDFW unpublished data).

Interestingly, Warty Sea Cucumber have been found to display seasonal visceral atrophy of all internal organs, including their digestive tract and respiratory trees (Yingst, 1974; Muscat 1983). This typically occurs during early fall periods, when internal organs are resorbed, leaving their internal cavity void for 1 to 2 months until re-generation of these organs occurs in late fall or early winter. During this period of atrophy, Warty Sea Cucumber cease to feed until digestive tracts regenerate (Yingst 1974; Muscat 1983). The drivers of visceral atrophy are largely unknown. It has been theorized that this is related to a decrease in food availability (Fankboner and Cameron 1982), This seasonal atrophy likely results in growth completely ceasing during this period, and may potentially lead to negative growth as individuals are not feeding and living off nutrients reserved in their body wall. This seasonal change in growth should be considered in future growth studies.

1.1.6 Size and Age at Maturity

Sea cucumber can stretch and contract, making it difficult to record a consistent size measurement. For this reason, the size of maturity for Warty Sea Cucumber is best estimated using the CWT of individuals after all viscera and water has been removed from the body cavity. The weight at sexual maturity for Warty Sea Cucumber was found to be 40 g (0.09 lb) CWT for individuals collected off Catalina Island (Muscat 1983) and 37 g (0.08 lb) CWT for individuals collected at Anacapa Island (Figure 1-8) (CDFW unpublished data). The weight at 25%, 50%, 75%, and 100% are 40-50 g (0.09-0.1 lb), 60-70 g (0.1-0.2 lb), 80-90 g (0.2 lb), and 150-160 g (0.3-0.4 lb) CWT, respectively. It should be noted that estimating the percentage of sexually mature individuals for each size class is challenging since individuals who have already spawned may be difficult to distinguish from individuals who are sexually immature or are in the process of developing gonads. To account for this, only individuals that were collected during the peak maturity months of March and April were used in this analysis: however, there is a possibility that spawning may have occurred prior to individuals being collected. In Baja Mexico, the size at sexually maturity was estimated to be 120 g (0.3 lb) WWT (~60 g (0.1 lb) CWT) at Bahía Tortuga and 140 g WWT (~70 g (0.2 lb) CWT) at Isla Natividad (Fajardo-León et al. 2008). Because there is no information on age at size or growth rates available for Warty Sea Cucumber, it is unknown how many years it takes an individual to reach the size of sexual maturity.

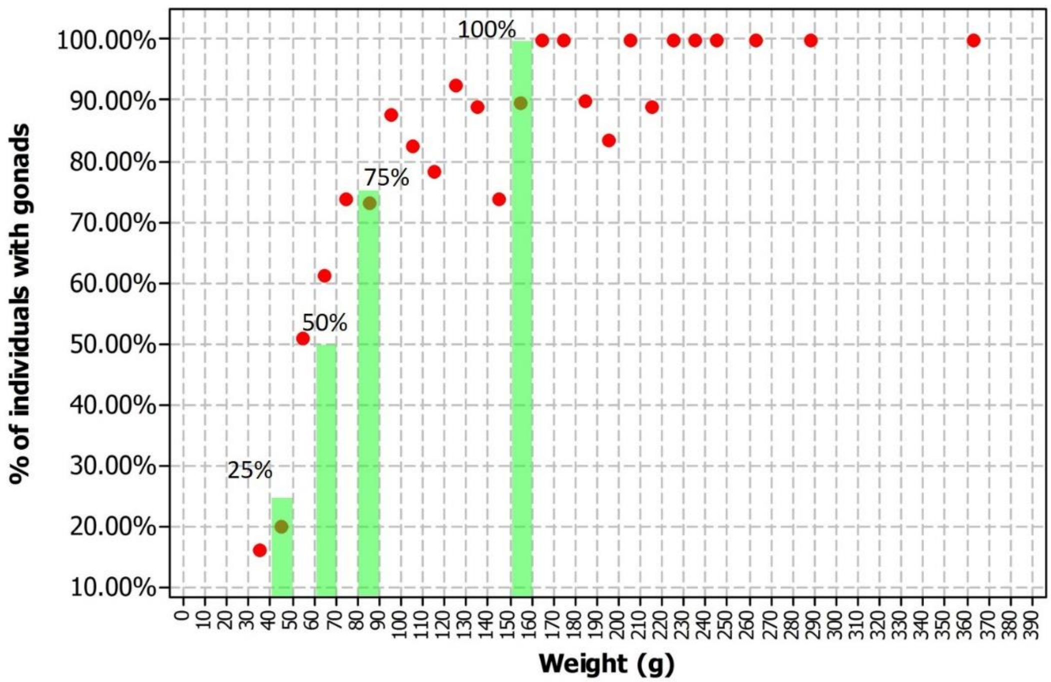


Figure 1-8 The weight at 25%, 50%, 75%, and 100% sexual maturity for Warty Sea Cucumber collect at the Northern Channel Islands based on 10g weight bins. Measurements are reported for CWT (CDFW unpublished data).

[redacted]1.2 Population Status and Dynamics

While the status of Warty Sea Cucumber has not been assessed using a formal stock assessment, commercial landings data and independent monitoring data suggest that Warty Sea Cucumber populations have reached levels of concern. Department commercial landings data demonstrate a 5-year (yr) continuous decline in after 2011, reaching a 24 yr low in 2016 (Section 2.2.4). In addition, between 2009 to 2016, commercial Catch Per Unit Effort (CPUE) also decreased by 51% (see Section 2.2.3). These declines in landings and CPUE have occurred as the average price/pound paid for Warty Sea Cucumber continues to increase each year. These declines are especially concerning given the data-poor nature of this stock.

As described above, very little is known about the life span of Warty Sea Cucumber, how fast they grow, or how productive they are. However, studies of other sea cucumber species suggest that many are long lived, slow growing organisms that are vulnerable to “boom and bust” fisheries, in which stable catches over 10 or 20 yr mask a declining stock size (Anderson et al. 2011). This is in contrast to the findings of a stock assessment conducted for Warty Sea Cucumber in Baja California (Chavez et al. 2011). This study assumed based on a number of different life-history-based estimators that Warty Sea Cucumber exhibit fast growth, maturity at 2 yr of age, and life spans of 5 yr or less. However, the estimators used were primarily developed based on observations of finfish, and may be inappropriate for invertebrates that demonstrate alternative growth patterns, body shapes, and life history strategies. Given this uncertainty surrounding the life history and productivity of Warty Sea Cucumber, the Department is conducting research to better understand the biology of the species and the impacts of fishing on this stock. The following sections describe the available information on abundance and the size structure of the stock, which are two metrics that are commonly used to infer stock status of fisheries.

1.2.1 Abundance Estimates

Long term monitoring data recorded by National Park Service Kelp Forest Monitoring Program (KFMP) at sites around the Northern Channel Islands demonstrate that significant declines in Warty Sea Cucumber densities occurred after the fishery developed in the early 1990s (Figure 1-9). An analysis of KFMP data found that significant declines in Warty Sea Cucumber densities occured within 3 to 6 yr after the start of fishing, with densities inside MPAs remaining relatively unchanged (Schroeter et al. 2001). After establishment of MPAs in 2003 , populations required approximately 10 yr to recover to pre-fishing densities (Figure 1-9) (David Kushner personal communication).

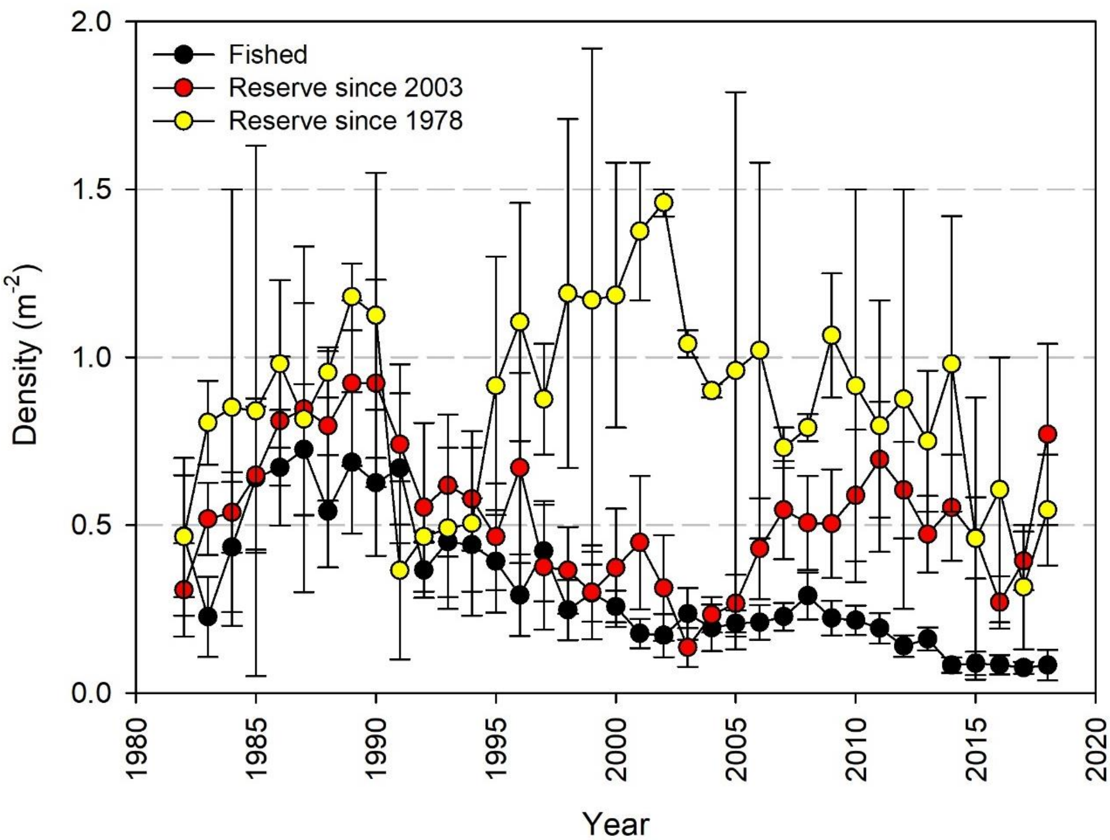


Figure 1-9. Mean densities (+ SE) of Warty Sea Cucumber measured by KFMP at 33 sites located at Santa Barbara Island, Anacapa Island, Santa Cruz Island, Santa Rosa Island, and San Miguel Island from 1982 2017. Sites are grouped by unprotected fished sites (black circles, 19 sites), reserve sites that have been completely closed to fishing since 2003 (red circles, 12 sites), and long-term reserve sites that have been protected since 1978 (yellow circles, 2 sites) (KFMP 2019).

Muscat (1983) reported distinct changes in seasonal densities of Warty Sea Cucumber over a 3-yr period (1979 to 1982) at Santa Catalina Island, with highest densities reported in shallow areas from late winter to early spring (January to April). In 2013, the Department began seasonal dive surveys at six KFMP permanent transect locations at Anacapa Island (Cathedral Cove (MPA), East Fish Camp) and Santa Cruz Island (Cavern Point (MPA), Devil’s Peak Member, Fry’s Harbor, and Yellowbanks) to determine if similar seasonal trends occurred at the northern Channel Islands, where a majority of commercial dive landings have historically occurred, as well as to determine the role that MPAs play in providing refuge to spawning populations of Warty Sea Cucumber. Findings demonstrate clear seasonal patterns in densities within the MPA sites of Cathedral Cove and Cavern Point, with extremely low densities in the fished areas (Figure 1-10). These fished areas previously supported higher densities (approximately 1 square meters (m^2) and above) prior to increases in fishery participation in the early 1990s (Figure 1-10), suggesting that fishing pressure has played a role in suppressing populations.

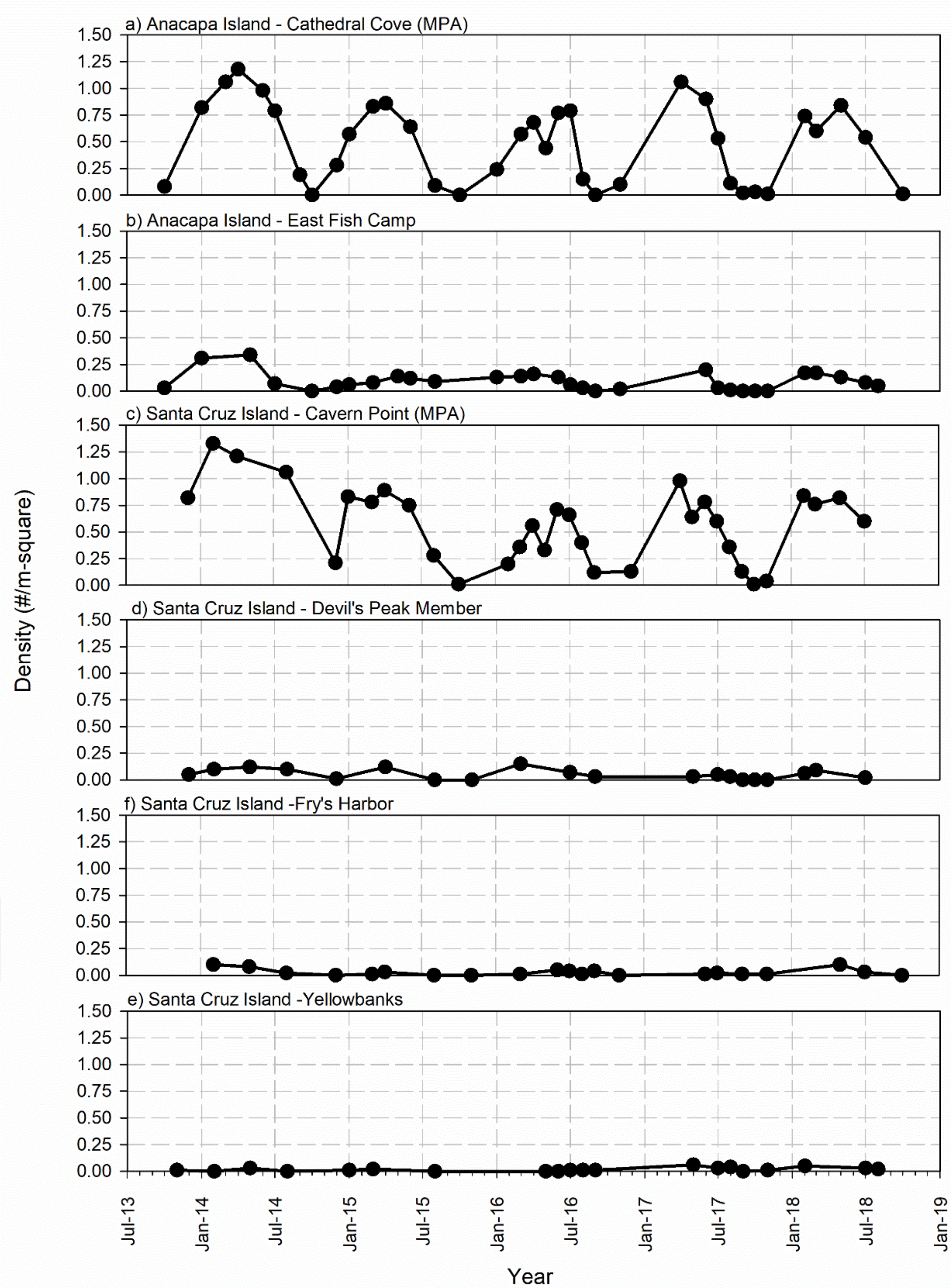


Figure 1-10 Densities of Warty Sea Cucumber measured by the Department from 2013 to 2018 at six locations established by KFMP: a) Cathedral Cove (MPA), b) East Fish Camp, c) Cavern Point (MPA), d) Devil's Peak Member, e)

Fry's Harbor, and f) Yellow Banks. Site names indicate the island where they occur and if they are located within an MPA (CDFW unpublished data).

1.2.2 Age Structure of the Population

The age structure of the Warty Sea Cucumber population is unknown. An accurate method for ageing sea cucumber is lacking due to the absence of suitable aging structures within sea cucumber. However, in the absence of age data size distributions may provide information about the status of the stock, especially in a data-poor fishery such as Warty Sea Cucumber. This section summarizes the available information on the size distribution of Warty Sea Cucumber in California.

Since 2013, the Department has researched the size distributions of Warty Sea Cucumber populations at various offshore locations. Yingst's (1974) method for measuring Warty Sea Cucumber based on their contracted state was used by the Department to measure the CL, CW, and CH of all individuals counted during density surveys performed at Anacapa and Santa Cruz Island from July 2014 to April 2019. Based on findings that the product of CL and CW (CLxCW) provides a more reliable estimate of body weight than CL, CW, or CH alone (see Section 1.1.4), the size distributions of Warty Sea Cucumber populations are best explained using this combined metric. A summary of Warty Sea Cucumber mean sizes based on CLxCW are provided in Table 1-2 for all individuals measured inside fished (unprotected) sites and MPAs. A majority of individuals (n= 3592, 87%) were counted and measured inside MPAs vs fished sites (n= 569,17%), with a larger mean (± SE) size found for individuals measured in fished sites (11.7 in ± 0.17) than in MPAs (9.33 ± 0.04) (Table 1-3). The larger sizes measured at fished sites may be due to spatial differences in size distributions possibly related to food availability, competition in MPA sites where densities are higher, ontogenetic shifts in habitat/depth preference, and/or temperature differences.

Table 1-3. Summary of contracted CLxCW (in) measurements of all Warty Sea Cucumber measured by the Department from 2013 to 2019 during diver density surveys conducted at four Fished (unprotected) sites and two MPA sites (CDFW unpublished data).

Status	Number of samples (% of total)	Mean (in)	SE Mean	Minimum (in)	Maximum (in)
Fished	569 (13%)	11.74	0.17	2.02	30.30
MPA	3952 (87%)	9.33	0.04	2.40	18.41

The size distributions measured in all four of the outside fished areas follow a non-normal distribution, with gaps in particular size classes (Figure 1-11). These gaps in size classes may be due to removal of individuals from fishing, lapses in recruitment, environmental impacts, and/or a combination of these factors. Surprisingly, the smaller size classes found in MPAs (Figure 1-12) are not as evident in the size classes measured in outside fished areas. In contrast, the size distributions of Warty Sea Cucumber measured inside MPAs display normal distributions and specific size classes that may be tracked to estimate growth (Figure 1-12). In the future, the Department will analyze seasonal and yearly changes in size within MPAs to estimate growth parameters.

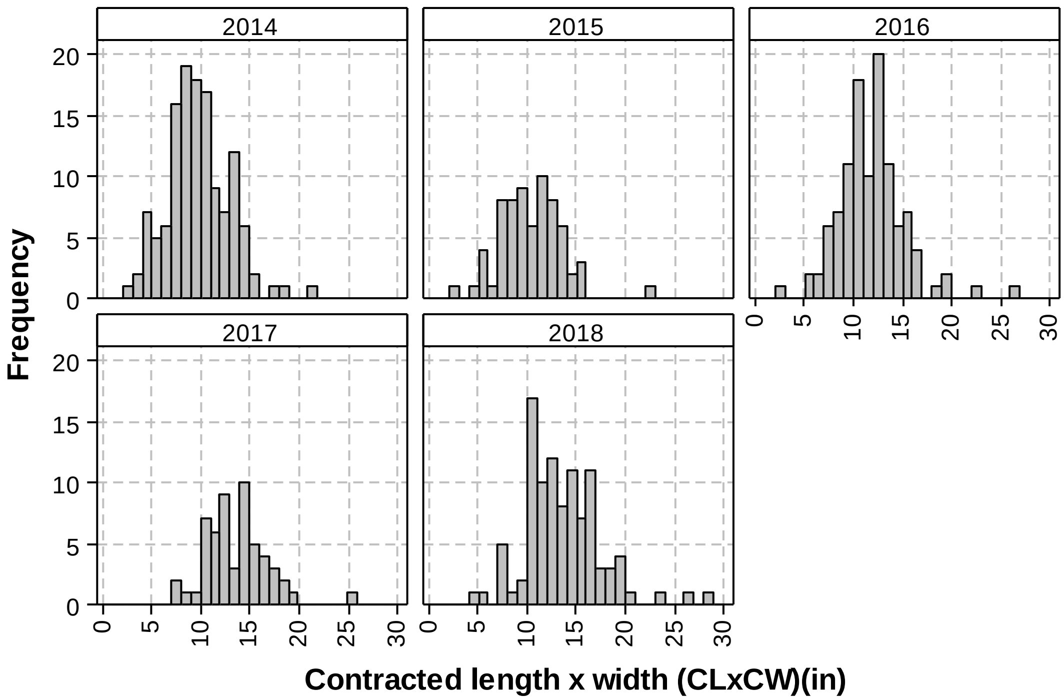


Figure 1-11 The size frequency of contracted CLxCW (in) measurements of all Warty Sea Cucumber measured by the Department from 2014 to 2018 at four fished sites (East Fish Camp (Anacapa Island), Yellowbanks (Santa Cruz Island), Devil's Peak Member (Santa Cruz Island), Fry's Harbor (Santa Cruz Island). Bars represent 1 in size bins (CDFW unpublished data).

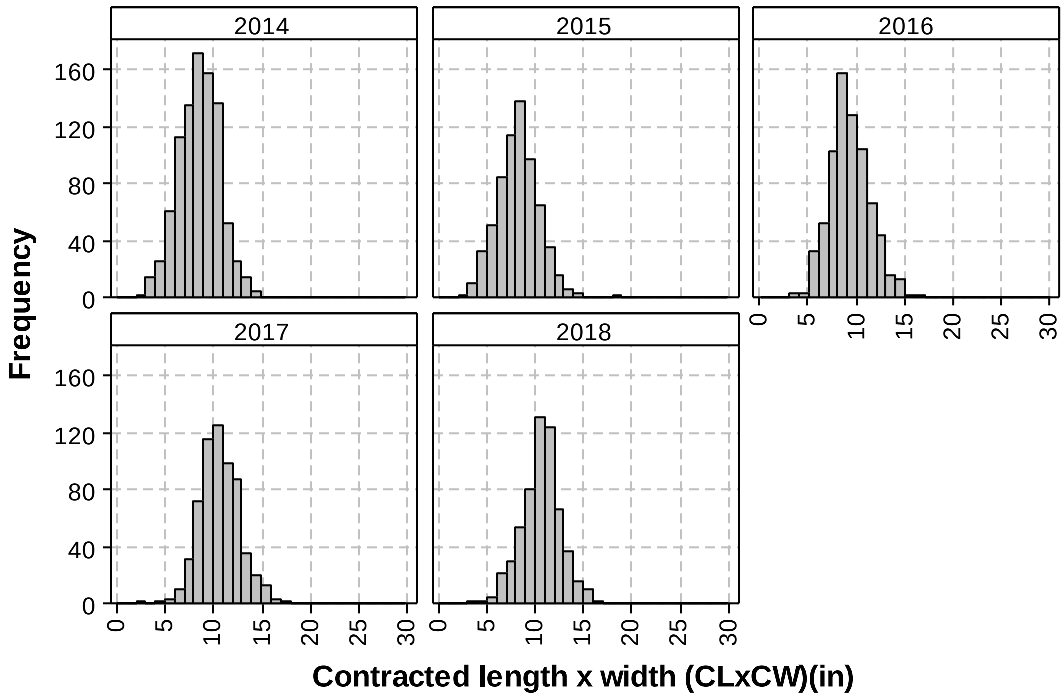


Figure 1-12 The size frequency of contracted CLxCW (in) measurements of all Warty Sea Cucumber measured by the Department from 2014 to 2018 at MPA sites (Cathedral Cove (Anacapa SMR), Cavern Point (Scorpion SMR)). Bars represent 1 in size bins (CDFW unpublished data).

[redacted]1.3 Habitat

Warty Sea Cucumber inhabit waters from the subtidal zone to > 60 m (180 ft). depths. They are commonly found on both rocky reef and sand/mud substrate. To test the preference of Warty Sea Cucumber for rock habitat vs sand habitats, Muscat (1983) placed artificial reefs in sand habitats and found the reefs to display significantly higher densities than adjacent sand habitats. This is likely due to the higher amounts of organic carbon detritus present in rocky habitats (Muscat 1983). Warty Sea Cucumber may also move to deeper habitats in warm summer months, as they are found in greater quantities at depths below the thermocline during this time (Muscat 1983).

Juvenile Warty Sea Cucumber prefer cryptic habitats. Muscat (1983) found small 0.4 to 0.8 in (1 to 2 cm) sized individuals hiding in kelp holdfasts, and Department divers report the common occurrence of recently settled Warty Sea Cucumber inside Baby Abalone Recruitment Traps (BARTs), which are designed to provide cryptic settlement habitat for abalone by resembling rock rubble habitat in a natural environment.

[redacted]1.4 Ecosystem Role

Sea cucumber can make up a large proportion of an ecosystem’s biomass (Birkeland 1988; Bruckner et al. 2003). In addition to serving as hosts for symbiotic species (Section 1.3.1), sea cucumber play a major ecological role in nutrient recycling and the oxygenation of sea floor sediment through bioturbation. Warty Sea Cucumber consume organic detritus in the sediment and release fecal casts and excrete inorganic nitrogen and phosphorus. Their burrowing and feeding activities disturb the upper sediment layer, increasing sediment permeability and sediment oxygen concentration (MacTavish et al. 2012; Purcell et al. 2016). The inorganic nitrogen excreted from sea cucumber can benefit benthic microalgae by resulting in increased primary productivity; however, microalgae is also negatively impacted by sea cucumber consumption of microphytes (MacTavish et al. 2012).

1.4.1 Associated Species

Sea cucumber are often hosts to various commensal and parasitic species from at least nine phyla (Morris et al. 1980; Jangoux 1990; Eeckhaut et al. 2004; Purcell et al. 2016). Warty Sea Cucumber have two commensal macro-organisms that utilize it as a source of shelter and food. The Scale Worm (*Arctonoe pulchra*) is an orange polychaete covered in scales with dark spots, similar in color to their hosts, and are found on the outer body wall of Warty Sea Cucumber (Brusca et al. 2016). Although Scale Worms can be free-living on the sea floor, they are able to locate sea cucumber hosts through water-soluble chemicals that diffuse from the body of their host (Davenport 1950). The density of Scale Worms symbionts is limited by intraspecific aggression; more than two worms are rarely found on a single sea cucumber (Morris et al. 1980). The Mottled Pea Crab (*Opisthopus transversus*) is a small crab that inhabits the cloaca of sea cucumber, and is also a symbiont in a variety of mollusk species and in polychaete tubes (Morris et al. 1980; Ricketts et al. 1985; Campos 2016). It has been suggested that the generalist behavior in host selection exhibited by Mottled Pea Crab may be influenced by size. As the crab symbiont grows, it may move from an initial host to larger host species until the crab reaches full size (Hopkins and Scanland 1964; Campos 2016).

1.4.2 Predator-prey Interactions

Warty Sea Cucumber feed by crawling along the seafloor and using their branched buccal tentacles to ingest sediment and detritus containing organic materials. Muscat (1983) reported that feeding occurs during both day and night periods.

Predators that consume sea cucumber include sea stars, crustaceans, fishes, and to a lesser extent, gastropods, marine mammals, and birds. Previous studies describe sea stars as being the main predator of sea cucumber through direct observations and through examination of gut contents, of which sea cucumber can make up to 90% of prey consumed (Francour 1997). However, predation of Warty Sea Cucumber has rarely been observed, and is thought to be rare.

[redacted]1.5 Effects of Changing Oceanic Conditions

Little is known regarding the effects of changing oceanic conditions on Warty Sea Cucumber populations. Anecdotal evidence suggests that commercial landings tend to decline during warm El Nino water years and increase during cold La Nina years. However, the factors driving these landing trends are not understood. At greater depths (4,100 m (13,451 ft)), sea cucumber communities see population shifts following El Nino events in abyssal plain habitats, as some species become more common while others decrease in number. This change may be linked to shifting patterns in food availability (Ruhl and Smith Jr. 2004). Further study on Warty Sea Cucumber and other sea cucumber of economic and ecological importance in coastal and near-shore habitats may determine if changing ocean temperatures provoke similar population shifts and allow for better management of the fishery.

Although the mechanisms are not well understood, many aspects of climate change could potentially impact Warty Sea Cucumber. Increasing ocean temperatures could alter growth rates, as well as influence abundance and movement of populations as they seek preferred water temperatures. Warty Sea Cucumber could move to deeper waters or higher latitudes to escape warmer temperatures, as they do in summer months when moving below the thermocline (Muscat 1983). The timing of spawning season is likely linked to seasonal increases in water temperatures. Warmer temperatures resulting from climate change could shift breeding seasons for Warty Sea Cucumber. In laboratory studies, Japanese Sea Cucumber (*Apostichopus japonicus*) gametes showed decreased fertilization success when exposed to warmer water (Liu et al. 2016). Sustained warmer water temperatures could have similar effects on reproductive success of Warty Sea Cucumber, although more research is needed. Furthermore, changing temperatures could alter the availability of food sources, further exacerbating changes to movement and abundance. Increased frequency and strength of storms could result in habitat alteration and destruction, thereby affecting Warty Sea Cucumber, particularly in kelp forest and rocky reef habitats.

As sea cucumber play an important role in nutrient cycling by agitating seafloor sediments, changes in their distribution or abundance could result in cascading habitat effects, including shifts in the primary producer community. Sea cucumber species near Australia ingest, dissolve, and release calcium carbonate from the sediment into the water column, allowing it to be taken up by coral and other calcifying organisms. This recycling of nutrients could even provide a buffer against ocean acidification (Schneider et al. 2011). It is unknown if Warty Sea Cucumber play a similar role in cycling calcium carbonate in California ecosystems, but further research could clarify this relationship and provide a better understanding of how loss of sea cucumber species could impact an ecosystem. Future research is needed to determine the impacts of changing oceanic condition on Warty Sea Cucumber behavior and biology. The continued monitoring of MPAs may play a key role in monitoring the effects of changing oceanic conditions on unfished populations.

2 The Fishery

[redacted]2.1 Location of the Fishery

The Warty Sea Cucumber dive fishery began in southern California around Catalina Island in 1978, with divers targeting Warty Sea Cucumber around Santa Catalina Island (Figure 2-1). The fishery soon spread to other offshore islands, including San Clemente, San Nicolas, Santa Barbara, and the Northern Channel Islands (Anacapa, Santa Cruz, Santa Rosa, San Miguel). Between 2000 and 2016, 20% of dive landings were harvested from commercial fishing block 708 off the east end of Santa Cruz Island (Figure 2-1). After block 708, the second highest commercial landing blocks are found around Anacapa Island (block 707), San Nicolas Island (blocks 813 and 814), and San Clemente Island (block 850), with each accounting for 5 to 6% of total landing over the same time period.

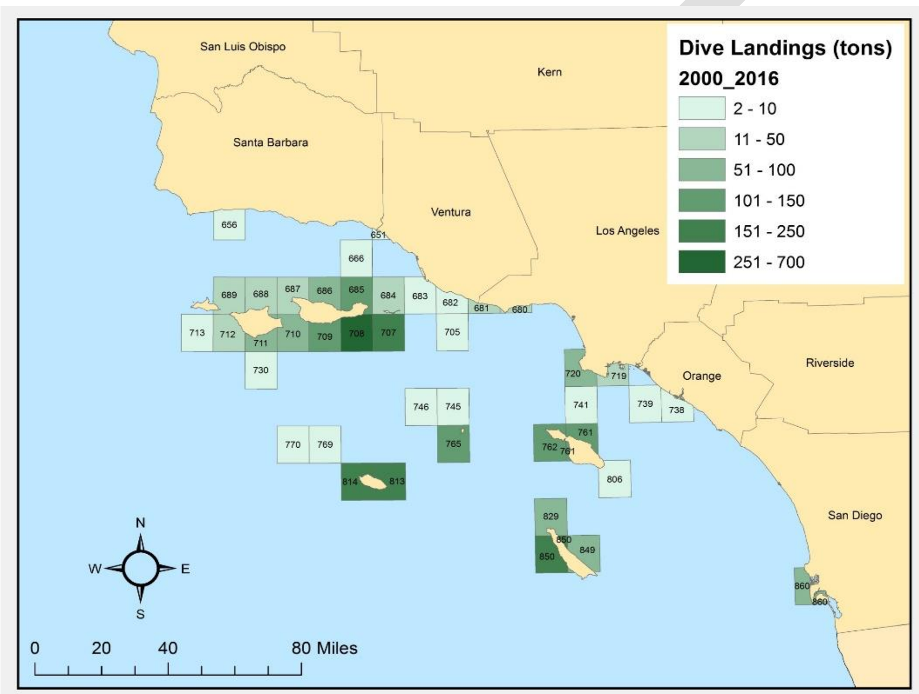


Figure 2-1. Map of commercial fishery landings by block from 2000 to 2016 (CDFW Commercial Fisheries Information System (CFIS)).

[redacted]2.2 Fishing Effort

2.2.1 Number of Vessels and Participants Over Time

During the first 10 yr of the Warty Sea Cucumber dive fishery (1980-1989), participation was extremely limited, with no more than six fishermen and ten individual vessels making at least one landing in a given year (Figure 2-2). This changed rapidly in the early 1990s as the number of active vessels peaked at an all-time record high of 105 vessels in 1991 and 220 active fishermen. This rapid increase in participation was due to the creation of a “general sea cucumber permit” that began in 1992. To qualify for this permit, individuals were required to make at least one 50 lb landing of sea cucumber between 1988-1991. Since then the number of active permittees has ranged between 31 to 82 divers (average 56) (Figure 2-2) and 21 to 57 vessels (average 39) (Figure 2-3).

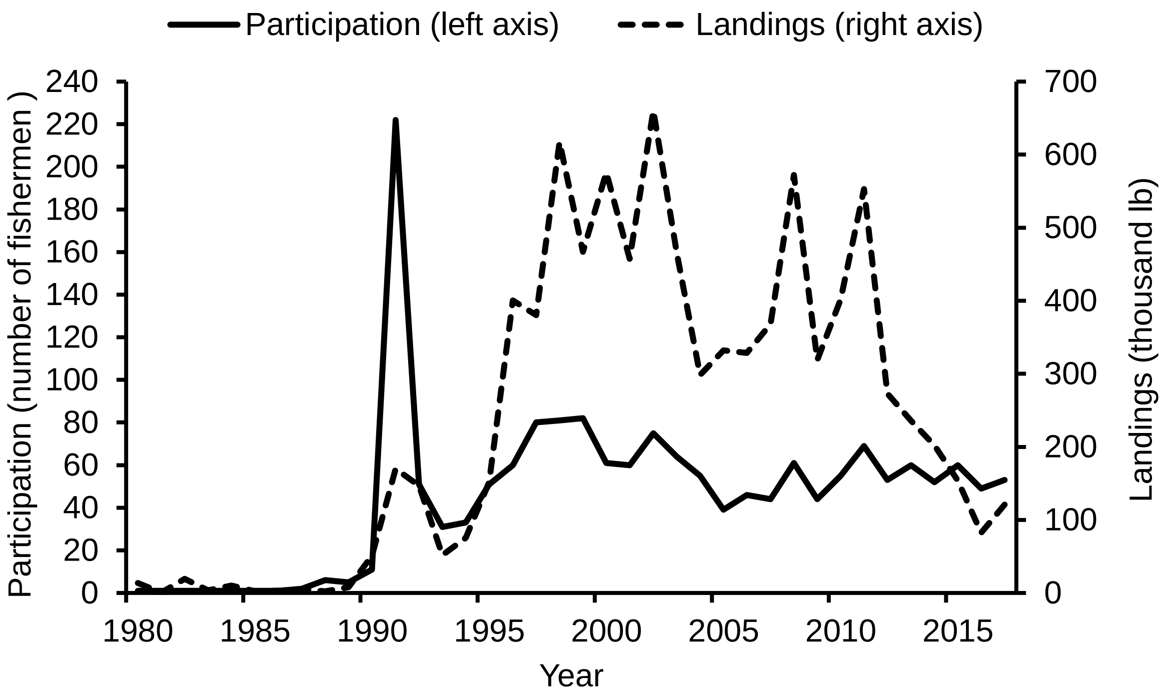


Figure 2-2. Warty Sea Cucumber dive fishery participation (number of fishermen) and landings (thousand lb), 1980 to 2017 (CDFW CFIS).

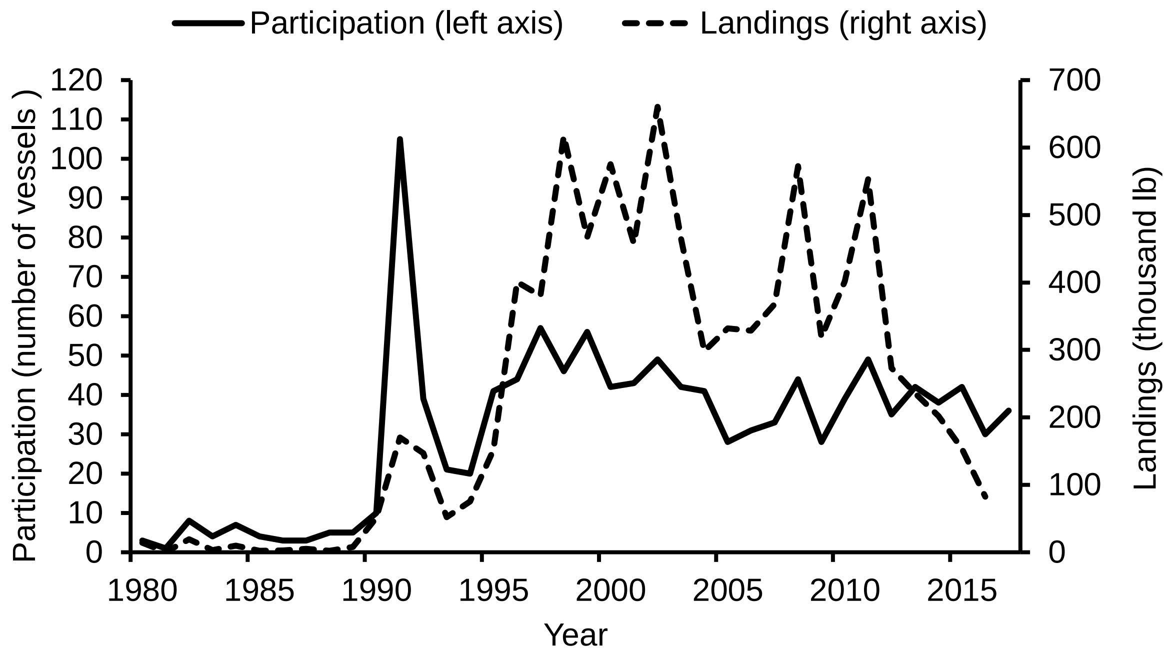


Figure 2-3. Warty Sea Cucumber dive fishery participation (number of vessels) and landings (thousand lb), 1980 to 2017 (CDFW CFIS).

2.2.2 Type, Amount, and Selectivity of Gear

Warty Sea Cucumber are commercially harvested by divers using SCUBA or hookah (surface supplied air), with some divers employing the assistance of underwater scooters. There are currently 82 commercial dive permittees in California. Hand take is the only authorized method of take for this fishery, resulting in high selectivity of the target species. Warty Sea Cucumber are “picked” off the bottom, placed into game bags, and brought to the surface at the conclusion of each dive.

The initial demand for Warty Sea Cucumber in California was to supply a market that specialized in a boiled and dried product. For processors to make a profitable yield off a boiled and dried product, they requested that commercial fishermen only harvest individuals that were greater than a 1/3 of a pound after all water and viscera were removed. This resulted in a de-facto size limit over the history of the fishery until roughly 2009, when new buyers began to request small “baby” sea cucumber for a domestic live market. Juvenile Warty Sea Cucumber are thought to inhabit cryptic habitats (Muscat 1983), and the size of emergence is unknown. It is possible that cryptic habitats provide a refuge for immature sea cucumber from harvest, though this has not been well studied.

[redacted]2.3 Landings in the Recreational and Commercial Sectors

2.3.1 Recreational

A recreational Warty Sea Cucumber dive fishery in California is extremely limited. Since 2012, the Department has only received roughly five inquiries from sport divers regarding recreational take of any sea cucumber species.

2.3.2 Commercial

The first recorded commercial Warty Sea Cucumber dive landing occurred in 1980 in southern California. During the 1980s, the fishery exhibited extremely low landings until the early 1990s, after which time commercial landings continued to increase until reaching a record high of 660,000 lb in 2002 (Figure 2-4). By 2004, the fishery experienced a 50% decline, reaching 298,000 lb, which may be partially explained by the practice of commercial divers cutting sea cucumber prior to landing to better preserve the product and to reduce the amount of water weight (approximately 50%) in each load. This change in the processing and recording of landings occurred gradually over time as more and more permit holders adopted the practice of cutting. This makes it very difficult to compare more recent landings with historical landings.

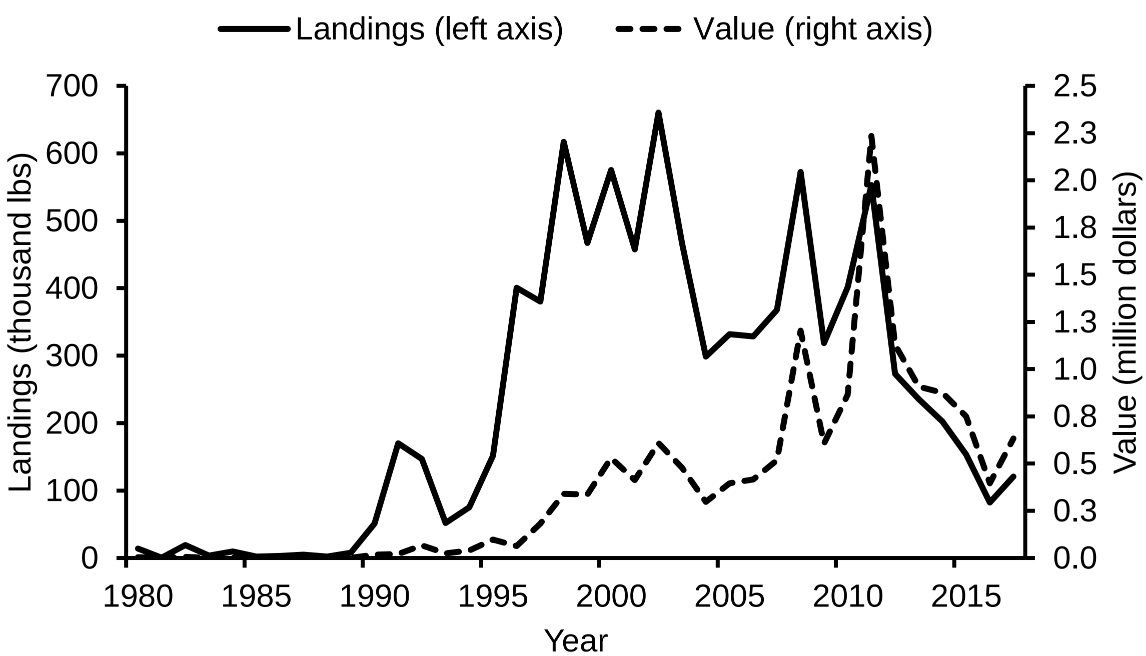


Figure 2-4. Warty Sea Cucumber commercial fishery landings (thousand lb) and value (million dollars), 1980 to 2017 (CDFW CFIS).

From 2004 through 2011, landings fluctuated between 300,000 and 600,00 lb: however, the price per pound paid to divers nearly quadrupled from an average of $1/lb in 2004 to $4.00/lb in 2011 (Figure 2-5). This resulted in the fishery reaching a record high ex-vessel value of $2.3 million in 2011. Since 2011, fishery landings have continued to decline, reaching a 23-yr low in 2016 and an ex-vessel value of $400,000 dollars. This sudden and drastic decline has occurred as the demand and value of sea cucumber continues to reach record setting highs each year (Figure 2-5).

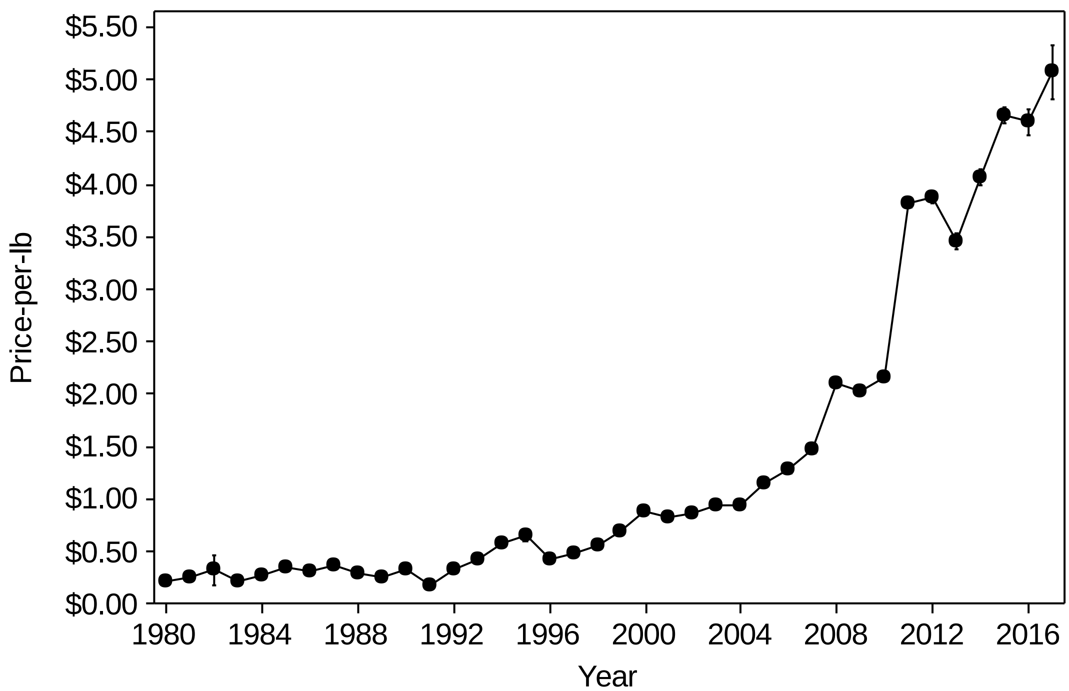


Figure 2-5. The average price per pound (± 95% Confidence Interval of mean) paid for commercially harvested sea cucumber in California by year (1980 to 2017) (CDFW CFIS, 2019).

On a monthly basis, commercial landings peak each year in spring, with 77% of all dive landings occurring between the months of March to July (Figure 2-6). Interestingly, commercial dive landings are virtually non-existent from October to December, before ramping up in January. The seasonal increase in commercial landings is due the aggregative spawning behavior of Warty Sea Cucumber during spring periods. This is confirmed by commercial logbook data that demonstrates that the CPUE of divers reaches its highest levels during spring periods.

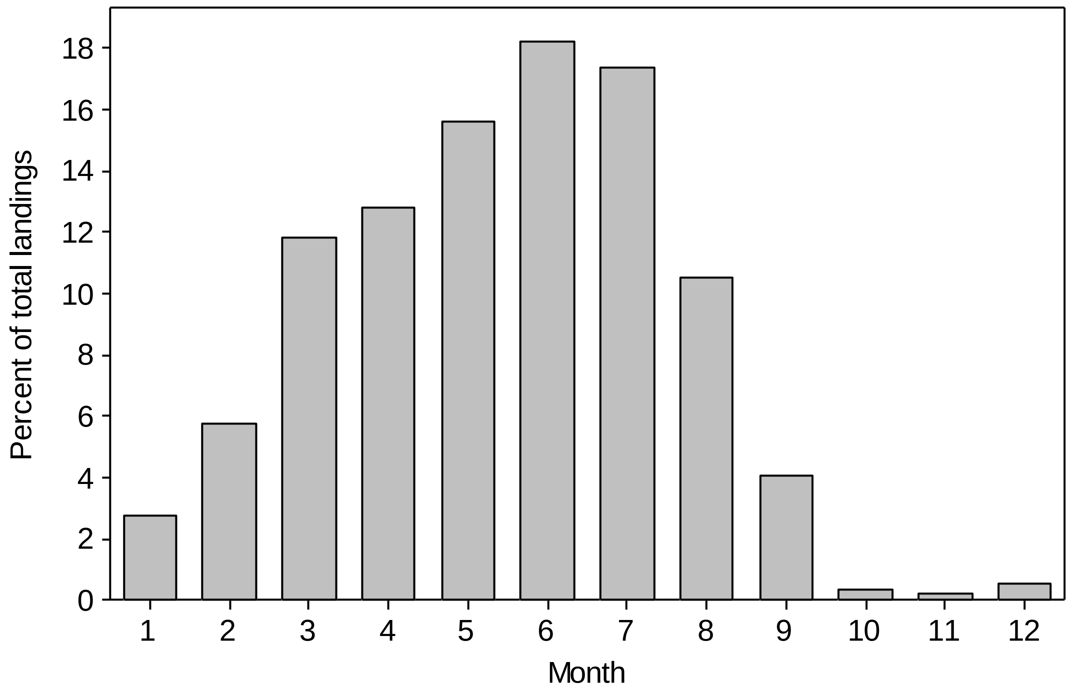


Figure 2-6. Cumulative percentage of monthly dive landings of Warty Sea Cucumber over the history of the fishery (1980 to 2017)(CDFW CFIS, 2019).

[redacted]2.4 Social and Economic Factors Related to the Fishery

A majority of Warty Sea Cucumber and Giant Red Sea Cucumber landed commercially in California are boiled and dried prior to being shipped overseas. Hong Kong accounts for a majority of global sea cucumber imports (80%), with Taiwan, mainland China, and South Korea also importing sea cucumber from California. In Hong Kong and other Asian countries, sea cucumber are considered to be a culturally significant food item, as well as being purported to provide health benefits for such ailments as arthritis, constipation, erectile dysfunction, and high cholesterol. When sea cucumber are consumed after being dried, they are generally reconstituted in soups and other dishes. Small domestic markets have emerged recently in California for whole live sea cucumber. A portion of this whole market is sold in sushi restaurants, with some of this whole product sold at open air markets.

In recent decades, sea cucumber landings by divers have shown an inverse relationship with landings of red sea urchin in the Channel Islands. During declines in the sea urchin fishery related to El Nino conditions, divers shifted to fishing sea cucumber. Following a population rebound of urchins, divers moved away from fishing sea cucumber. This suggest that regulations or conditions in one fishery may affect the other fishery.

Sea cucumber remain a rather small portion of the California fishing economy, with the 2006 harvest producing $188,000 in ex-vessel revenue. California sea cucumber commercial fisheries generated an estimated equivalent of seven jobs and

$167,000 in wages in 2006 (Rogers-Bennet and Ono 2006). Figure 2-7 shows how total landings have been distributed across ports, with the majority of landings at Oxnard, followed by Santa Barbara, Terminal Island, and to a lesser extent, Ventura.

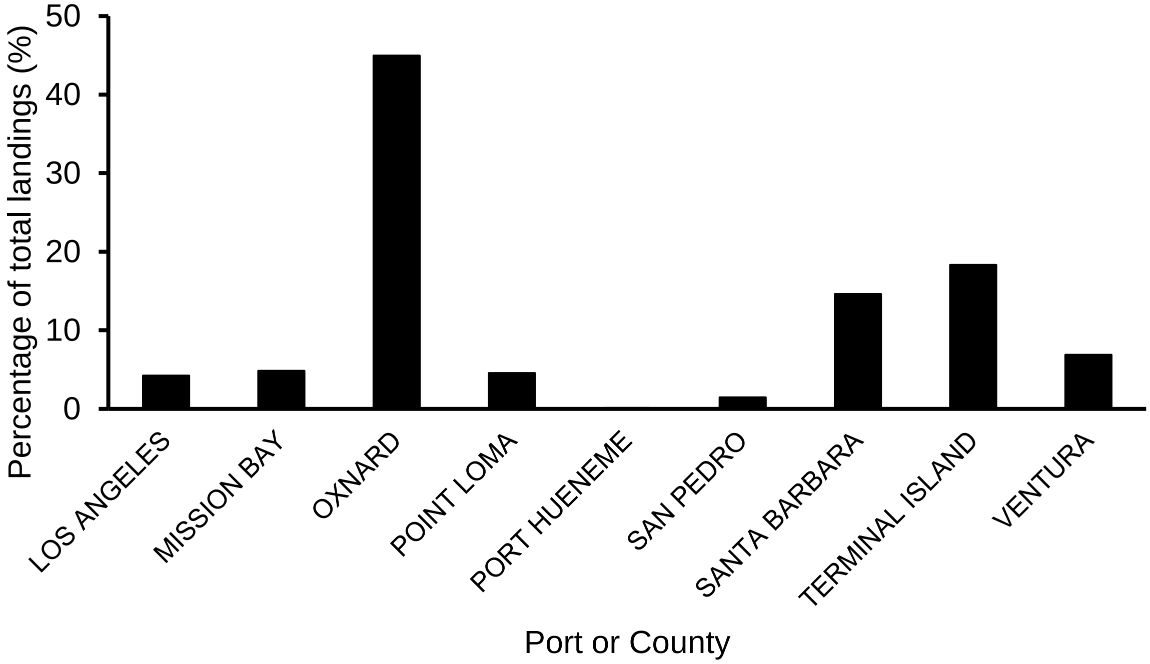


Figure 2-7. Percentage of Warty Sea Cucumber total landings by location in 2017 (CDFW CFIS).

3 Management

[redacted]3.1 Past and Current Management Measures

The commercial sea cucumber dive and trawl fisheries were largely unregulated until the 1992-1993 season, when a general sea cucumber permit was required for trawlers and divers to harvest sea cucumber. This led to a spike in fishing effort as fishermen attempted to meet the landings requirement (see Section 3.1.2.2 for details). The fishery became a limited entry fishery with transferrable permits (provided landing requirements are met) in the 1997-1998 season.

Beginning in 198? sea cucumber dive and trawl permittees were required to complete and submit a commercial fishing log detailing their daily dive and trawl activities to the Department at the end of each month. These logs provide valuable information regarding location of fishing activities, duration of diving and trawl times, depths fished, and estimated landings.

Although recreational take is uncommon, current regulations only authorize the use of hands to harvest sea cucumber, a daily bag limit of 35 individuals, and a requirement that all take must occur greater than 1,000 ft (305 m) from the nearest shoreline.

3.1.1 Overview and Rationale for the Current Management Framework

California’s current management framework for the commercial take of Warty Sea Cucumber consist of three primary measures.

1) A limited entry permit program
2) A requirement to complete and submit a daily commercial logbook
3) A seasonal closure that prohibits all commercial take of Warty Sea Cucumber from March 1 to June 14 to protect vulnerable spawning aggregations that occur in shallow areas.

Together, these three regulations are designed to …

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

Currently there are no formal overfishing targets or limits established for the Warty Sea Cucumber fishery. However, the Dept monitors X and Y data to look for trends. […] Additionally, the sustainability of the fishery is currently being evaluated through various methods, including length at age-based models and the Data Limited Methods Toolkit to conduct a Management Strategy Evaluation (MSE) of alternative management procedures.”

3.1.1.2 Past and Current Stakeholder Involvement

Commercial divers have voiced their interest in collaborating with Department staff to record information needed to address to several management concerns.

3.1.2 Target Species

3.1.2.1 Limitations on Fishing for Target Species

3.1.2.1.1 Catch

There are currently no catch limits in place for Warty Sea Cucumber.

3.1.2.1.2 Effort

The primary tool used to manage effort is a limitation on the number of sea cucumber dive permits issued. There are currently 82 transferable sea cucumber dive permits and 16 sea cucumber trawl permits in California. When separate sea cucumber dive and trawl permits were established for the 1997-1998 permit year, a provision was created that allowed individuals purchasing a sea cucumber trawl permit to either keep the permit as a trawl permit or convert the permit into a dive permit. The conversion of a sea cucumber dive permit to a trawl permit is not permissible. Considering this provision, the maximum number of dive permits would be 98 total permits if all 16 trawl permit holders sold their permits to individuals that converted these permits to dive permits.

3.1.2.1.3 Gear

Hand take via SCUBA or hookah is the primary method of take for Warty Sea Cucumber. Trawl gear may also be used to harvest Warty Sea Cucumber, however, take of Warty Sea Cucumber via trawl is rare.

3.1.2.1.4 Time

In 2018, a seasonal closure prohibiting the take of Warty Sea Cucumber was implemented to protect the spawning activity of this species from March 1 to June 14.

3.1.2.1.5 Sex

There are no sex-based restrictions for this fishery. External identification of sex is not possible.

3.1.2.1.6 Size

There are currently no size-based restrictions for this fishery.

3.1.2.1.7 Area

there are currently no spatial restrictions, other than California’s network of MPAs, used to manage this fishery.

3.1.2.1.8 Marine Protected Areas

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

Due to the spawning aggregation behavior of Warty Sea Cucumber over rocky reef habitat, the current network of MPAs in California likely play an important role in providing refuge to spawning populations. MPAs provide a valuable tool to monitor the health of Warty Sea Cucumber populations with the continued monitoring of MPAs being essential to determining environmental impacts versus fishing impacts on Warty Sea Cucumber populations. In addition, MPAs can be used to investigate many biological information gaps needed improve management of the fishery (see Section 5.2.1).

3.1.2.2 Description of and Rationale for Any Restricted Access Approach

During the 1992-1993 fishing season a general sea cucumber permit was required for trawlers and divers to harvest sea cucumber (both Warty Sea Cucumber and Giant Red Sea Cucumber). To qualify for this permit, fishermen were required to meet a minimum landing requirement of 50 lb during a 4-yr “window” period from 1988-1991. A limited entry program was established by the legislature beginning during the 1997-1998 fishing season, along with the development of two separate permits for the sea cucumber dive fishery, which targets Warty Sea Cucumber, and the trawl fishery, which targets Giant Red Sea Cucumber. The number of total permittees allowed to enter the dive and trawl fisheries was based on the maximum number of permits issued during the 1997-1998 permit year, and the meeting of a minimum landing requirement.

Sea cucumber dive and trawl permits are currently transferable if the permittee can achieve a minimum landing requirement of at least 100 lb of sea cucumber during each of the 4 consecutive years prior to transferring a permit. The rationale behind this requirement is … A sea cucumber dive permit can only be transferred to take sea cucumber by diving. A sea cucumber trawl permit may be transferred to take sea cucumber using trawl nets or diving gear, but once the permit becomes a sea cucumber dive permit, it cannot be reverted to a trawl permit. The maximum possible number of dive permits is 98, which would be achieved if all existing trawl permits were converted to dive permits.

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

Warty Sea Cucumber is harvested by hand, and so there is thought to be no bycatch. It is assumed that discard rates are low in this fishery due to its targeted nature. There is potential for other sea cucumber species to be mistaken for Warty Sea Cucumber, but bycatch impacts as a result of this would likely be minimal.

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

Given the targeted method or harvest and assumed low level of discards there are no additional measures in place to reduce bycatch, and none are needed at this time.

3.1.4 Habitat

3.1.4.1 Description of Threats

Since this fishery is primarily a dive fishery, habitat disturbance in minimal. The fishery is targeted and does not result in habitat alteration seen from other less targeted methods. Infaunal species may be temporarily disturbed by the presence of divers during hand collection of Warty Sea Cucumber, but lasting effects are unlikely to occur.

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

Given the limited habitat impacts of this fishery, there are no measures in place to minimize impacts further.

[redacted]3.2 Requirements for Person or Vessel Permits and Reasonable Fees

Table 3-1. Required permits, licenses and associated fees for commercial and recreational fishing. Fees may change, but the most current license options and fee information may be accessed at https://www.wildlife.ca.gov/Licensing/Fishing.

Permit or License	**Fee**	**Description**
Resident Commercial Fishing License	$145.75	Required for any resident 16 yr of age or older who uses or operates or assists in using or operating any boat, aircraft, net, trap, line, or other appliance to take fish for commercial purposes, or who contributes materially to the activities on board a commercial fishing vessel.
Nonresident Commercial Fishing License	$431.00	Required for any nonresident 16 yr of age or older who uses or operates or assists in using or operating any boat, aircraft, net, trap, line, or other appliance to take fish for commercial purposes, or

		who contributes materially to the activities on board a commercial fishing vessel.
Commercial Boat Registration (Resident)	$379.00	Required for any resident owner or operator for any vessel operated in public waters in connection with fishing operations for profit in this State; or which, for profit, permits persons to sport fish.
Commercial Boat Registration (Nonresident)	$1,122.00	Required for any nonresident owner or operator for any vessel operated in public waters in connection with fishing operations for profit in this State; or which, for profit, permits persons to sport fish.
Commercial Ocean Enhancement Stamp	$54.08	Required for commercial passenger fishing vessels operating south of Point Arguello (Santa Barbara County).
Commercial Passenger Fishing Vessel License	$379.00	Required for any boat from which persons are allowed to sport fish for a fee.
Land CA Fish Outside CA Permit	$22.66	Required to take fish in California and land to ports outside of California.
Commercial Sea Cucumber Diving Permit	$379.00	Each diver must have a valid sea cucumber diving permit issued to that person. When taking sea cucumber by methods other than diving, at least one person aboard each commercial fishing vessel must have a valid sea cucumber trawl permit.
Commercial Sea Cucumber Trawl Permit	$379.00	Each diver must have a valid sea cucumber diving permit issued to that person. When taking sea cucumber by methods other than diving, at least one person aboard each commercial fishing vessel must have a valid sea cucumber trawl permit.
Commercial Sea Cucumber (Dive or Trawl) Permit Transfer Fee	$200.00	Fee for transferring ownership of permit.
Resident Sport Fishing License	$49.94	Available for any resident 16 yr of age or older.
Nonresident Sport Fishing License	$134.74	Available for any nonresident 16 yr of age or older.
Recreational Ocean Enhancement Validation	$5.66	Required to fish in ocean waters south of Point Arguello (Santa Barbara County).

4 Monitoring and Essential Fishery Information

[redacted] 4.1 Description of Relevant Essential Fishery Information

FGC §93 defines Essential Fishery Information (EFI) as "information about fish life history and habitat requirements; the status and trends of fish populations, fishing effort, and catch levels; fishery effects on age structure and on other marine living resources and users, and any other information related to the biology of a fish species or to taking in the fishery that is necessary to permit fisheries to be managed according to the requirements of this code." There are studies on life history EFI for Warty Sea Cucumber as described in Section 1, including development, spawning behaviors, and movement. However, this section summarizes the EFI that is routinely collected and used to monitor the health of the stock and ecosystem. The sudden and unexpected increase in foreign demand for sea cucumber species globally has often outpaced the ability of management to establish effective measures prior to resources being depleted to unsustainable levels. Along with challenges posed by complex and unknown life history characteristics, current management of the Warty Sea Cucumber dive fishery relies heavily on a combination of fishery-dependent and fishery-independent sources to monitor the status of the fishery.

[redacted] 4.2 Past and Ongoing Monitoring of the Fishery

4.2.1 Fishery-dependent Data Collection

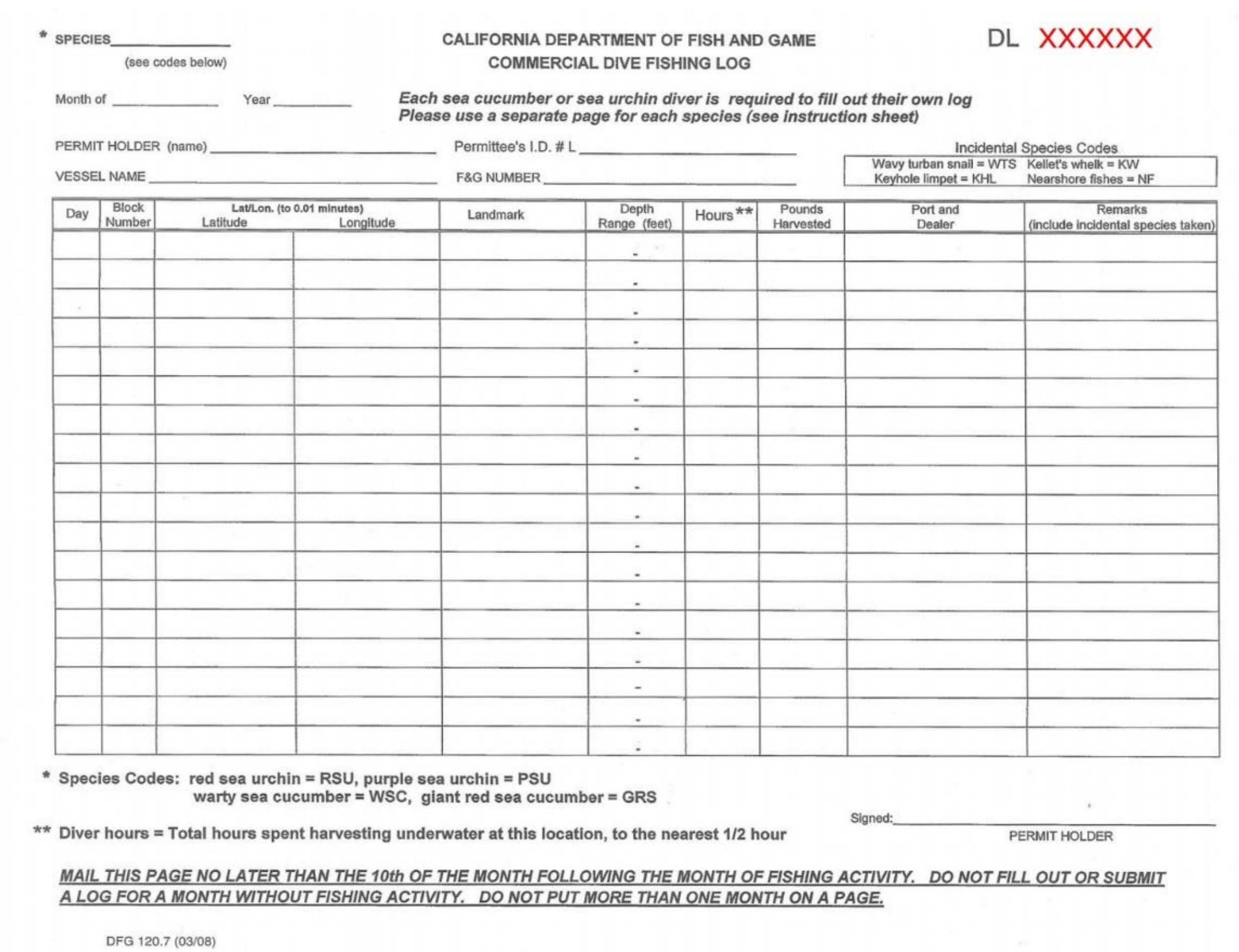
The Department relies on two key sources of fishery-dependent information to monitor the commercial Warty Sea Cucumber dive fishery. Landing receipts are the primary means of monitoring the total take (in pounds) and value of Warty Sea Cucumber harvested by the fishery and the "Commercial Dive Fishing Log" provides detailed information about the dive activities that result in the landings reported on landing receipts. To gain a comprehensive understanding of the status of the fishery, the Department must couple landing receipts with commercial log data and carefully examine these data relative to fishery-independent monitoring data.

Landing receipts are submitted to the Department by the business/entity that purchases Warty Sea Cucumber directly from commercial divers. The business is required to have a certified scale to provide an accurate weight of the amount of product purchased. This accurate weight, along with reporting of condition (whole versus cut), are essential to monitoring the landings of Warty Sea Cucumber. In addition, value serves as an important proxy for demand for Warty Sea Cucumber. The careful tracking of value allows the Department to monitor any sudden or drastic changes that may impact the resource. Data collected on landing receipts include:

- fishermen and vessel information
- date the catch was landed
- port of landing
- commercial fishing block where the catch was harvested
- weight (pounds) landed by market category
- price per pound paid to the fisherman by market category

- condition of the catch when sold (whole versus cut/processed)
- type of gear used (i.e. method of take)

The Department collects detailed information about the daily diving activities of divers on a “Commercial Dive Fishing Log,” which is required to be filled out and submitted on a monthly basis to the Department. These logs provide essential information related to effort, dive time, dive location, and diver depth (Figure 4-1). This information is used to monitor changes in diving activity and CPUE that may be indicative of issues with the resource. Changes in diver depth, CPUE, and movement from nearshore to offshore locations have all been reported in other sea cucumber fisheries that have experienced resource depletion (Anderson et al. 2011).


* SPECIES ____________ (see codes below)

CALIFORNIA DEPARTMENT OF FISH AND GAME
COMMERCIAL DIVE FISHING LOG

DL XXXXXX

Month of ____________ Year ________

Each sea cucumber or sea urchin diver is required to fill out their own log
Please use a separate page for each species (see instruction sheet)

PERMIT HOLDER (name) ____________ Permittee's I.D. # L ____________

VESSEL NAME ____________ F&G NUMBER ____________

Incidental Species Codes
Wavy turban snail = WTS Kellet's whelk = KW
Keyhole limpet = KHL Nearshore fishes = NF

Day	Block Number	Lat/Lon. (to 0.01 minutes) Latitude	Longitude	Landmark	Depth Range (feet)	Hours**	Pounds Harvested	Port and Dealer	Remarks (include incidental species taken)
					-				
					-				
					-				
					-				
					-				
					-				
					-				
					-				
					-				
					-				
					-				
					-				
					-				
					-				
					-				
					-				
					-				

* Species Codes: red sea urchin = RSU, purple sea urchin = PSU
warty sea cucumber = WSC, giant red sea cucumber = GRS

** Diver hours = Total hours spent harvesting underwater at this location, to the nearest 1/2 hour

Signed: ____________ PERMIT HOLDER

MAIL THIS PAGE NO LATER THAN THE 10th OF THE MONTH FOLLOWING THE MONTH OF FISHING ACTIVITY. DO NOT FILL OUT OR SUBMIT A LOG FOR A MONTH WITHOUT FISHING ACTIVITY. DO NOT PUT MORE THAN ONE MONTH ON A PAGE.

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Figure 4-1. The “Commercial Dive Fishing Log” used by Warty Sea Cucumber dive fishermen to submit a record of their daily dive fishing activity.

4.2.2 Fishery-independent Data Collection

The KFMP has performed SCUBA surveys to monitor Warty Sea Cucumber densities along with other invertebrates, fish, and algae at 33 fixed sites throughout the northern Channel Islands since 1982. Each year, the KFMP counts Warty Sea

Cucumber at each site along a 100 m (984 ft) permanently fixed transect line. In addition, the KFMP monitors the recruitment of Warty Sea Cucumber and other invertebrates to 97 individual Artificial Recruitment Modules (ARMs) on an annual basis. During ARM surveys, Warty Sea Cucumber individuals are counted and their sizes are estimated and placed into two separate size categories of less than or greater than 10 cm (4 in) in length. More information about the KFMP and their study protocols can be found at https://www.nps.gov/im/medn/kelp-forest-communities.htm. The KFMP monitoring data provide valuable information related to baseline Warty Sea Cucumber densities prior to fishing, changes to the population once fishing started, the recovery time of Warty Sea Cucumber once they receive protection from a no-take MPA, and recruitment information.

Other independent monitoring groups such as the Partnership for Interdisciplinary Studies of Coastal Oceans, Vantuna Research Group, Reef Check, and the Long Term Ecological Research project also monitor the densities of Warty Sea Cucumber and collect valuable information related to changes in Warty Sea Cucumber densities over time. However, it should be noted that seasonal changes of Warty Sea Cucumber population densities should be considered when interpreting any Warty Sea Cucumber monitoring data.

Since July 2013, the Department has monitored Warty Sea Cucumber on a monthly or bi-monthly basis to quantify seasonal changes in population densities. The Department collaborated with the KFMP to develop a sampling plan that makes use of the permanent fixed transect lines that are maintained and monitored by the KFMP in the waters around the northern Channel Islands. During Department surveys, each Warty Sea Cucumber is individually counted and measured (body size) along the 984 ft (100 m) long transect line. Size measurements of length, width, and height are taken when the individual has reached a constricted state after being handled and slightly agitated. In addition to performing dive surveys, the Department collects and dissects Warty Sea Cucumber individuals on seasonal basis to collect essential biological information related to reproduction, size at sexual maturity, sex ratios, size distributions, and other morphometric parameters. These Department data demonstrate the importance of seasonal surveys to accurately record the densities and spawning condition of Warty Sea Cucumber, as well as the importance of MPAs in protecting spawning aggregations of Warty Sea Cucumber.

5 Future Management Needs and Directions

[redacted]5.1 Identification of Information Gaps

Due to the lack of biological and fishery EFI for most sea cucumber species, as well as the continued loss of global sea cucumber stocks as a result of overexploitation, a conservative approach should be employed when developing a management framework for any sea cucumber fishery (Purcell, Anderson?) According to the MLMA, management of marine resources is to be based upon the best available scientific information and other relevant information; however, the lack of biological EFI related to Warty Sea Cucumber populations prevents the use of various conservation measures that can be used to improve management of the fishery. The primary information needed for this fishery is to determine the age-at-length of Warty Sea Cucumber to inform various potential management decisions. Without this information, it is difficult to determine the growth rate, time to maturity, or lifespan, all of which are important pieces of biological EFI. While age of sea cucumber is not easily obtainable due to a lack of hard ageing structures typically found in bony fishes or shelled invertebrates, estimates of age and longevity may be collected via a combination of a series of tank experiments and a field-based tagging study. Continued monitoring of the size composition at MPA sites and fished areas could also provide an indicator with which to assess population growth rates under unfished conditions and assess fishing impacts. In addition to biological needs, management of this resource would greatly benefit from improvements to landing receipts and commercial logbooks, as well a better understanding of the market dynamics driving this fishery. Table 5-1 describes the informational gaps for the Warty Sea Cucumber fishery and their priority for management.

Table 5-1. Informational needs for the Warty Sea Cucumber dive fishery and their priority for management.

Type of information	**Priority for management**	**How essential fishery information would support future management**
Size structure of individuals harvested by the fishery	High	This information is needed to quantify the extent to which the take of sexually immature individuals is occurring. Recent changes in market demand has prompted the increased take of small sized sea cucumber for live markets. Historically, take of small sea cucumber was likely not an issue since traditional markets for a boiled/dried product required larger individuals. This may have resulted in a de-facto size limit for this fishery until approximately 2010.
Age and Growth	High	Provides information needed to estimate the time needed for individuals to reach the size at sexually maturity and to reach various sizes of interest to inform discussion of harvest strategies and a minimum size limit.

Improved reporting of landing condition (cut vs whole) and species on landing receipts	High	Provides information needed to accurately interpret landings of Warty Sea Cucumber and Giant Red Sea Cucumber. This information will allow for estimation of appropriate catch limits that could be used to establish catch limits or targets for catch.
Market dynamics driving sea cucumber harvest	High	Provides information needed to determine how the resource may be influenced by changes in emerging market forces and how to build resiliency of the resource against these changes.
Improved method for coupling landing receipt and logbook information	High	Provides the information needed to relate landings data to fishing practices of the fishery. In addition, this information can be used to determine compliance with the requirement to submit logs and landing receipts.
Movement	Moderate	Provides information needed to determine the residency times and movement of individuals. Understanding the directionality of movement is also important to determine the degrees to which individuals remain within MPAs or may move across MPA boundaries and become susceptible to harvest. Understanding the residency times of individuals is also necessary to determine if seasonal density and size surveys measure the same individuals overtime.
Gonadal Somatic Index for entire southern California Bight during a given spawning season	Moderate	Used to determine the effectiveness of the current seasonal spawning closure to protect spawning activities throughout the dive fisheries range.

[redacted]5.2 Research and Monitoring

5.2.1 Potential Strategies to Fill Information Gaps

Biological Research

Since 2013, the Department has primarily collected biological EFI related to reproduction and morphometric relationships in order to fill key information gaps surrounding reproductive behaviors and the size at sexual maturity. Other types of research needed to inform biological EFI will require the outside assistance of research institutions and stakeholders. The next major biological gap that should be addressed is the size at age for Warty Sea Cucumber. Initial research related to age and growth is preferably conducted in a tank setting where individual growth can be monitored, and conditions controlled. Warty Sea Cucumber of various sizes could be collected or spawned, placed in tanks, and weighed and measured (body size) at set intervals to assess short-term and long-term growth. This research could be conducted by using flow through tanks that are available at aquariums or at academic marine institutions. A tag retention study could be coupled with an age and growth study to examine the performance of various tag types for tracking individual Warty Sea Cucumber and Giant Red Sea Cucumber. These findings could be used to make recommendations on the most appropriate tag types and anchoring locations for conducting a tag and recapture study to monitor the movements and growth of Warty Sea Cucumber.

To assess the effectiveness of the current seasonal fishery closure in protecting Warty Sea Cucumber spawning populations, a large spatial scale sampling program would be required to determine the Gonadal Somatic Index condition of Warty Sea Cucumber during a given time period. This could be partially accomplished by Department staff, but would likely require the assistance of outside scientific divers. When the Warty Sea Cucumber season re-opens on June 15, it is also possible that Department staff can sample the catch of commercial divers. Since a majority of Warty Sea Cucumber is cut at sea and the viscera including gonads tossed over the side to preserve quality of the body wall, this will likely require staff to conduct sampling at-sea as sea cucumber are being processed. At-sea sampling, coupled with a dockside sampling approach would allow staff to assess the reproductive condition of the catch, while also recording the number of individuals harvested. The information collected at sea could be used along with individual weights recorded dockside to determine the size distribution of the catch. At a minimum, the total count of Warty Sea Cucumber collected on a given day of fishing can be compared to the total weight recorded during the sale to determine the average weight of individuals comprising the load.

Fishery Data Collection Systems and Market Dynamics

Improving the reporting of landing condition (cut versus whole) and accurate species codes on landing receipts can be achieved through a directed outreach effort to businesses purchasing sea cucumber in California. During this same outreach effort, Department staff can question businesses about current and emerging market dynamics that influence commercial harvest. Commercial divers have notified the Department that “special orders” are sometimes requested by businesses for small (likely sexually immature) individuals. Understanding the circumstances and extent of these request are a top priority for sea cucumber management as these practices have the potential to result in long lasting negative impacts on the fishery.

Increasing the Departments ability to tie landing receipts to commercial fishing logs is also high priority for management. The Department often finds cases of missing landing receipt and commercial logbook information. To improve the compliance of required reporting and the quality of data needed for management, the Department could require businesses to report the logbook numbers associated with each landing directly on each landing receipt along with requiring commercial divers to report the landing receipts associated with each log directly on the log form. This requirement is currently being implemented for the California Spiny Lobster (*Panulirus interruptus*) fishery.

5.2.2 Opportunities for Collaborative Fisheries Research

The Department has collaborated in the past and will continue to work with outside entities such as other government agencies, academic organizations, non-governmental organizations, and fishery stakeholders to help fill information gaps related to EFI needed to improve management of this fishery. The nature of these collaborations has ranged from public outreach efforts with fishery stakeholders to engaging in interagency field research with the KFMP. Much of the EFI needed to better understand fishery dynamics and gaps in biological information will require new forms of collaborative research.

Experimental research examining the size structure of Warty Sea Cucumber catch and how this relates to age and growth of Warty Sea Cucumber and Giant Red Sea Cucumber is a potential collaborative project that the Department may pursue with outside research institutions and fishery stakeholders. This information is needed to appropriately assess the cost and benefits of various potential management measures. A collaborative field study could also be conducted with fishery stakeholders to analyze various potential harvest strategies or to test specific management-related technology innovations that could be used to improve management of this fishery. These can include, but are not limited to, gear innovations, monitoring tools, and other technological advances. For example, some commercial divers claim that the current commercial logbook data requirement is too burdensome, raising concerns over the quality of these data for management. Technological advances have resulted in the development of electronic loggers that divers can carry during their diving activities that records most of the information required on dive logs. Technological advances like this have the potential to not only make the commercial logbook requirement easier for divers to comply with, but improve the quality of logbook data for management.

[redacted]5.3 Opportunities for Future Management Changes

This section is intended to provide information on changes to the management of the fishery that may be appropriate, but does not represent a formal commitment by the Department to address those recommendations. ESRs are one of several tools designed to assist the Department in prioritizing efforts and the need for management changes in each fishery will be assessed in light of the current management system, risk posed to the stock and ecosystem, needs of other fisheries, existing and emerging priorities, as well as the availability of capacity and resources.

Resource Protection

While stock status data is limited, the available information from landings data and fishery-independent surveys suggest that the California Warty Sea Cucumber fishery has reached levels of concern, and additional management measures may be necessary. In response to these concerns, the Department initiated a research program to better understand the reproductive biology of Warty Sea Cucumber, and based on these results worked with industry to establish a seasonal closure to protect spawning aggregations, when Warty Sea Cucumber may be most vulnerable to fishing.

Many sea cucumber dive fisheries have reported concerning trends in decreasing size structure of catch (Anderson et al. 2011). In Washington State, a recent assessment of the size structure of individuals harvested by the fishery found a high percentage (~50%) of sexually immature Giant Red Sea Cucumber individuals comprising the catch (Henry Carson pers. comm), despite the fact that the dive fishery has a more robust management than that used in the California Warty Sea Cucumber dive fishery. This highlights how vulnerable sea cucumber fisheries may be to overfishing. Considering these findings, as well as similar decreases in commercial dive

CPUE between Washington and California (Carson et al. 2017), protection of sexually immature individuals is a high priority for future management in California.

Protection of sexually immature individuals can be accomplished directly through a minimum size limit; however, enforcing a size limit for Warty Sea Cucumber will be challenging based on this species ability to change their body shape and the fisheries desire to cut sea cucumber out at sea prior to landing. The Department has developed sizing criteria based on constricted length and width that divers can use to determine the size of individuals during harvesting activities. Since a majority of the product is cut and eviscerated out at sea, enforcement would not be able to obtain accurate length and width measurements when boarding vessels to check for compliance. Considering this issue, a size limit based on weight, in which a minimum average count per pound is established, may be more enforceable. Taking accurate weight measurements at-sea also poses many unique challenges, and so dockside measurements as likely being the only accurate method for enforcement of a minimum weight requirement.

Several indirect methods for creating a de-facto size limit exist. This includes daily trip limits based on the number of individuals that divers can harvest, which can alter harvesting patterns. When divers can take a limited number of individuals, they may focus on harvesting only larger sized more valuable individuals. Another potential de-facto size limit may be accomplished by requiring individuals to land all Warty Sea Cucumber in a processed or cut state. The boiled dried market requires larger sized individuals to be profitable, since the drying process results in only a 10% yield of the original weight. The emerging live market is reported to be responsible for the increase in take of small sexually immature individuals and is thought to be solely dependent on whole uncut product. By requiring all Warty Sea Cucumber individuals to be landed in a cut state, this may eliminate the market for small sexually immature individuals; however, the dynamics driving this live market need to be further explored.

The Department also has concerns regarding several potential issues that could negatively impact this fishery. The assistance of non-permitted sea cucumber divers in harvesting Warty Sea Cucumber along-side permitted divers is an activity that has been reported. This activity is concerning since this fishery is managed via limited entry and the potential impacts of increasing participation, which may increase harvest efficiency during each dive trip, is currently unknown. A management measure that requires all divers on the same vessel to have the same permits or limit the species on the vessel to only species that every diver is permitted to take could address this issue.

Updates to Landing Receipts and Commercial Logs

The development of a management measure that would require the reporting of the logbook number associated with each landing directly on the landing receipts, and vise-versa, would allow the Department to more accurately track changes in CPUE. CPUE is an important fishery parameter to monitor since it describes changes in fishery performance that may indicate changes in catch that result from changes in abundance rather than changes in fishing effort. A management measure that would require each business to report the number of sea cucumber comprising each landing would provide critical information related to the size of catch. This information would serve as an invaluable tool for future management as it would provide the size information needed to interpret changes in landings and CPUE, as well as provide critical information related to the status of the resource that could be used to adaptively manage the fishery.

[redacted]5.4 Climate Readiness

Climate change is a shift in global climate pattern characterized by increasing global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (IPCC 2007). These physical changes may in turn effect ecosystem productivity and function, species abundances and distributions, habitat use and availability, and cues that some species rely on that indicate changes in the season (CDFW 2018). This possibility underscores the need for more research to understand how normal climatic fluctuations have affected Warty Sea Cucumber stocks in the past in order to help managers prepare for and respond to climate change.

Currently, the Department collects information on Warty Sea Cucumber densities and commercial effort and landings. Coupled with the KFMP long term monitoring data and temperature data, the Department will explore potential relationships between environmental conditions and changes in densities and landings. These data can potentially be used to determine if any trend in abundance and distribution of the resource could be attributable to shifts in climate rather than annual fluctuations in the environment. Improvements to commercial landing receipts and logs along with consistent monitoring of Warty Sea Cucumber populations both inside and outside MPAs will be important for detecting impacts due to climate change and designing potential new management approaches to facilitate adaption and resilience in the fishery under changing climate conditions.

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