Fishery-at-a-Glance: Giant Red Sea Cucumber.

Scientific Name: *Apostichopus californicus*.

Range: Giant Red Sea Cucumber range from Baja California, Mexico to the Bering Sea.

Habitat: Giant Red Sea Cucumber occupy waters from the subtidal zone to over 600 feet (183 meters) depth. They are commonly found to inhabit, rocky reef, gravel, shell debris, and sand/mud substrate.

Size (length and weight): Giant Red Sea Cucumber can reach 24 inches (61 centimeters) in length and a weight of 2.2 pounds (1000.0 grams).

Life span: Giant Red Sea Cucumber are estimated to reach a maximum of 12 years of age.

Reproduction: Giant Red Sea Cucumber spawn from July through August in British Columbia, Canada.

Prey: Epibenthic detritivore, feeds on organic detritus and small organisms present within sand sediments and on detrital layers that accumulate on rock/reef substrates.

Predators: Reported predators of Giant Red Sea Cucumber consist of sea stars, crabs, and various fish species. In Alaska, increased predation of Giant Red Sea Cucumber by Sea Otters has been reported.

Fishery: Giant Red Sea Cucumber are primarily harvested by the commercial trawl fishery in southern California, with minor dive take (<1% of historic dive landings) occurring in parts of northern and southern California. Trawl landings of Giant Red Sea Cucumber peaked in 1993 at 594,000 pounds, associated with a revenue of $0.3 million. In 2011, the fishery reached a record high in revenue of $1.2 million, with landings reaching 314,000 pounds that same year. Since 2011, the trawl fishery has experienced consistent declines in both revenue and landings. In 2017, trawl landings of Giant Red Sea Cucumber reached a record low 35,000 pounds, with an associated value of $0.2 million. 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 per pound in 2017.

Area fished: The commercial Giant Red Sea Cucumber trawl fishery spans from Point Conception south to San Diego, with most of the historic landings occurring within the Santa Barbara Channel and San Pedro Shelf. The dive fishery for Giant Red Sea Cucumber occurs primarily in northern California, between the ports of Bodega Bay and Fort Bragg. Minor dive take of Giant Red Sea Cucumber also occurs in the northern most colder regions of Southern California off the mainland coast and around offshore islands like Santa Rosa and San Miguel Island. A vast majority of current trawl landings occur in the port of Santa Barbara, followed by minimal landings in Ventura, Oxnard, and Terminal Island.

Fishing season: The take of Giant Red Sea Cucumber is currently allowed year around; however, a majority of trawl take occurs within the California Halibut Trawl Grounds, an area within state waters where trawling is only allowed each year from June 16 to March 14 (closed March 15 to June 14).

Fishing gear: Giant Red Sea Cucumber are primarily fished with commercial trawl nets. These nets are either single-walled or double-walled and deployed via a single or double rigged trawl vessel. Currently, no net size requirements are established for the directed take of Giant Red Sea Cucumber. However, when fishing within the California Halibut Trawl Grounds or in federal waters outside of the California Halibut Trawl Grounds, trawlers are subject to the net size and configuration requirements established for these areas. Commercial divers use SCUBA or hookah (surface supplied air) to harvest Giant Red Sea Cucumber by hand.

Market(s): A majority of Giant Red Sea Cucumber landed in California are boiled, dried, and shipped to markets overseas in China, Hong Kong, Taiwan, and Korea. Although a small domestic market has recently developed for live Warty Sea Cucumber sold in sushi and other specialty restaurants, it is not known if Giant Red Sea Cucumber are experiencing similar live market demands.

Current stock status: No formal stock assessments have been conducted on Giant Red Sea Cucumber in California due to its data-poor nature, especially regarding biological information about California populations. While the status of Giant Red Sea Cucumber has not been assessed using a formal stock assessment, commercial landings and log data suggest that Giant Red Sea Cucumber populations, like Warty Sea Cucumber populations, have reached levels of concern. 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 Giant Red Sea Cucumber may becoming more difficult for trawlers to find.

Management: Giant Red Sea Cucumber is a state-managed species and has been historically viewed as an incidental species taken by in the California Halibut and Ridgeback Prawn trawl fisheries. Current regulations for the commercial fishery consist of a limit on the number of permittees (currently 16 trawlers), a requirement to complete and submit a daily trawl log, and to adhere to gear restrictions designated for the California Halibut Trawl Grounds and federal waters. Given this uncertainty surrounding the life history and productivity of Giant Red Sea Cucumber populations in California, the Department plans to conduct research to better understand the biology of the species and the impacts of fishing on this stock. Considering recent decreases in landings and Catch Per Unit Effort as market demand and market value continue to increase, additional management specific to the take of Giant Red Sea Cucumber is likely needed.

1 The Species

1.1 Natural History

1.1.1 Species Description

Giant Red Sea Cucumber (*Apostichopus californicus*), formerly known as *Parastichopus californicus*; also known as California Sea Cucumber, is an economically important invertebrate that is harvested by trawling in southern California, and divers in northern California, as well as Oregon, Washington, Alaska, and British Columbia. Giant Red Sea Cucumber belong to the Phylum Echinodermata, and are related to sea stars, Brittle Stars, sea urchin, and Sand Dollars. Individuals are typically red, brown, or yellow in color and are cylindrically shaped with a soft outer body wall that is covered in mucous. Giant Red Sea Cucumber are identified by the numerous red tipped projections known as “papillae” along the dorsal side of the body. The ventral side of the body is covered by rows of tube feet. 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.

1.1.2 Range, Distribution, and Movement

The Giant Red Sea Cucumber can be found from the Gulf of Alaska to Baja California in depths ranging from the intertidal to 250 meters (m) (820 feet (ft)) (Rogers-Bennet and Ono 2001; DFO 2002). Giant Red Sea Cucumber can be found on many substrate types, but may show some preference for hard surfaces over sandy or mud bottoms (Woodby et al. 2000; Hamel and Mercier 2008). The highest densities of Giant Red Sea Cucumber generally occur in areas with high accumulations of organic material in sediment (Cameron and Fankboner 1989; Hamel and Mercier 2008). Giant Red Sea Cucumber can travel up to 4 m (13 ft) per day, and this movement is likely due to food availability with no clear directionality (Rogers-Bennet and Ono 2001; DFO 2002). The species may undertake season depth migrations, but further study is needed on this possibility (DFO 2002).

Figure 1-X. Range of [Common name] (Citation).

1.1.3 Reproduction, Fecundity, and Spawning Season

Giant Red Sea Cucumber are dioecious, meaning that individuals are male or female. The sex ratio for the species is near 1:1 (Cameron and Fankboner 1986). Giant Red Sea Cucumber reproduce by broadcast spawning, in which gametes (eggs and sperm) are released into the water column. The fecundity of an individual sea cucumber is not well understood.

Giant Red Sea Cucumber exhibit reproductive cycles, with gametogenesis and an increase in the gonadal index beginning in January or February, leading to spawning in June, July, and August (Cameron and Fankboner 1986; Muse 1998; Hamel and Mercier 2008). Prior to spawning, Giant Red Sea Cucumber may migrate to shallower depths between April and August, although this movement may also be the result of increased food availability in these habitats (Cameron and Fankboner 1986; DFO 2002; Hamel and Mercier 2008). Populations in depths of less than 16 m (52 ft) may be more likely to engage in spawning behavior (Rogers-Bennett and Ono 2001; Hamel and Mercier 2008). Spawning may be correlated with days of high levels of sunshine and increased phytoplankton productivity (Cameron and Fankboner 1986; Muse 1998; Hamel and Mercier 2008). During spawning, Giant Red Sea Cucumber raise the anterior portion of their body and form an “S-shape” posture seen in many other species of sea cucumber (Rogers-Beckett and Ono 2001; Hamel and Mercier 2008). Following spawning, gonads begin to increase in size through December (Cameron and Fankboner 1986; Hamel and Mercier 2008). Larval Giant Red Sea Cucumber remain suspended in the water column for periods ranging from 35 to 125 days feeding on plankton, before settling on various surfaces, such as rocks, crevices, algae holdfasts, and mats of filamentous red algae (Cameron and Fankboner 1989; Lambert 1997; DFO 2002; Hamel and Mercier 2008).

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.

Current estimates of Giant Red 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; however, this requires the assumption that monitoring methods are equally likely to record peak densities from year to year.

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.

Although there are currently no growth estimates for adult Giant Red Sea Cucumber, estimates of juvenile growth were examined via a caging experiment in British Columbia, which found individual growth rates to change drastically over the course of a year (Hannah et al. 2012). Growth rates based on whole weight were found to peak from May to July at 1.187 grams (g) (0.003 pounds (lb)) per day (1.217% per day), with growth deceasing or becoming negative from August to March when natural food availability and water temperature decreased (Hannah et al. 2012). In laboratory settings, Dong et al. (2006) measured the maximum specific growth rate of juvenile Japanese Sea Cucumber (*Apostichopus japonicus*) as 1.48% per day. This rate did vary with water temperature, and increased water temperatures led to declining growth rates. Similar studies on adult Giant Red Sea Cucumber could better inform management decisions and provide insights into how the species could be impacted by changing ocean temperatures.

These findings demonstrate the importance of accounting for seasonal changes in growth rates when developing growth estimates for sea cucumber.

Currently there is no method to directly age Giant Red Sea Cucumber, and their soft tissues make long term tag-recapture studies difficult. The continued monitoring of the size structure of populations within MPAs may serve as an important tool for tracking size classes to estimate growth. Giant Red Sea Cucumber may reach a maximum length of 50 cm, the largest of any sea cucumber in North America (Lambert 1997; DFO 2002). However, Giant Red Sea Cucumber may grow at slow rates, potentially only growing to 10 centimeters (cm) (4 inches (in)) in length at 2 years (yr) of age (DFO 2004; Hamel and Mercier 2008). Giant Red Sea Cucumber are estimated to reach sexual maturity at age 4, and despite these estimates, improvements in techniques to measure and age sea cucumber would better inform management of this fishery.

1.1.6 Size and Age at Maturity

Sea cucumber can stretch and contract, making it difficult to record a consistent size measurement. Giant Red Sea Cucumber may reach sexual maturity at 4 yr of age, but this remains difficult to ascertain due to the uncertainty in aging sea cucumber (Cameron and Fankboner 1989; Lambert 1997; Hamel and Mercier 2008).

1.2 Population Status and Dynamics

Giant Red Sea Cucumber is considered a “data-poor” species because insufficient resources and data exist for assessing stock status. To an extent, commercial fisheries data can be used to provide an indication of overall abundance, fishing pressure, and recruitment success. While no estimates of biomass or maximum sustainable yield exist for Giant Red Sea Cucumber, commercial landings and both trawl and dive Catch Per Unit Effort (CPUE) may provide insight on the distribution of this species throughout California (See section 2.2.1). Careful consideration must be taken when analyzing trawl fishery landings and logbook for the purpose of assessing population status and dynamics due to Giant Red Sea Cucumber mainly serving

1.2.1 Abundance Estimates

Summary of NPS, Reef Check, Vantuna, Department surveys

1.2.2 Age Structure of the Population

accurate method for ageing sea cucumber is lacking due to the absence of suitable ageing structures within sea cucumber

1.3 Habitat

Giant Red Sea Cucumber inhabit depths ranging from the low intertidal to 250 m (820 ft) (Cameron and Fankboner 1986; Lambert 1997; Hamel and Mercier 2008). Giant Red Sea Cucumber can be found on a wide variety of substrates, but are most commonly found on harder substrates, such as cobbles, boulders, bedrock, and shells. Harder substrates may constitute a preferred habitat, while the cucumber tend to avoid muddy bottoms (Woodby; Smiley; and Larson 2000). Giant Red Sea Cucumber can also be found in greater numbers in areas of moderate current, while avoiding areas of freshwater runoff. The greatest densities of the species are generally found in areas of high accumulation of organic sediment, as these areas are rich in food for the cucumber (Cameron and Fankboner 1989; Hamel and Mercier 2008).

Giant Red Sea Cucumber are not sessile like other species, and can travel up to 4 m in one day. This movement is believed to be random, and is likely related to food availability (Rogers-Bennet and Ono 2001, DFO 2002). However, seasonal movement to shallower depths could be related to spawning behavior or increased food availability (DFO 2002, Hamel and Mecier 2008). Giant Red Sea Cucumber stop feeding and become seasonally dormant from September to early March, greatly reducing movement during this time (DFO 2002; Hamel and Mercier 2008).

1.4 Ecosystem Role

Sea cucumber can make up a large proportion of the ecosystem biomass (Birkeland 1988; Bruckner et al. 2003). In addition to serving as hosts for symbiotic species, sea cucumber play a major ecological role in nutrient recycling and the oxygenation of sea floor sediment through bioturbation. Giant Red 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 1987b; Eeckhaut et al. 2004; Purcell et al. 2016). In Giant Red Sea Cucumber, these include two flatworm species (*Anoplodium hymanae* and *Wahlia pulchella)* (Shinn 1983, 1985a, 1985b, 1986c; Kozloff 1987), a parasitic snail, *Entereroxenos parastichopoli* (Tikasingh 1961, 1962; Kincaid 1964; Mueller 2017), the Red Scale Worm (*Arctonoe pulchra*) (Morris et al. 1980; Brusca et al. 2016; Mueller 2017), and the Mottled Pea Crab (*Opisthopus transversus*) (Morris et al. 1980; Campos 2016). *A. hymanae* is a parasitic flatworm found in the body cavity of Giant Red Sea Cucumber that likely obtains nutrients from Giant Red Sea Cucumber coelomic fluid (Shinn 1983). *W. pulchella* inhabits the intestine of Giant Red Sea Cucumber but are not present in Giant Red Sea Cucumber in the fall and winter when the viscera of Giant Red Sea Cucumber atrophy (Shinn 1986c). In both flatworm species, egg capsules are shed through the rectum and then hatch when consumed by Giant Red Sea Cucumber along with detritus on the sea floor (Shinn 1985a, 1985b, 1986c). *E. parastichopoli* is a shell-less, endoparasitic snail that only infects Giant Red Sea Cucumber (Tikasingh 1961; Mueller 2017). Snails attach to the anterior end of the outer wall of the intestine in the Giant Red Sea Cucumber body cavity and obtain nutrients from coelomic fluid (Tikasingh 1962; Mueller 2017). The coloration of *E. parastichopoli* is similar to Giant Red Sea Cucumber gonads, ranging from transparent yellow to opaque orange (Tikasingh 1962). The commensal Red Scale Worm is an polychaete covered in red or orange scales with dark spots, similar in color to their hosts, and are found on the outer body wall of Giant Red Sea Cucumber (Brusca et al. 2016). Although Red Scale Worm 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 Mottled Pea Crab 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

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 of sea star predation on sea cucumber and through examination of gut contents of which sea cucumber can make up to 90% of prey consumed (Francour 1997).

1.5 Effects of Changing Oceanic Conditions

Little is known regarding the effects of changing oceanic conditions on Giant Red Sea Cucumber populations. 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 Giant Red 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 Giant Red Sea Cucumber. Increasing ocean temperatures could alter growth rates, as well as influence abundance and movement of populations as they seek preferred water temperatures. 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 Giant Red Sea Cucumber. In laboratory studies, Japanese Sea Cucumber 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 Giant Red 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 Giant Red 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 may have effects that are not well known in buffering ecosystems against effects of climate change. 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 Giant Red 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 Giant Red 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

2.1 Location of the Fishery

The commercial Giant Red Sea Cucumber trawl fishery occurs in southern California (Figure 2-1), with a majority of landings occurring in the Santa Barbara Channel. The trawl fishery operates primarily between depths of 90 and 300 ft (30 and 100 m), with an average depth of 150 ft (50 m) (Figure 2-1). The commercial Giant Red Sea Cucumber dive fishery occurs primarily in northern California between Bodega Bay and Fort Bragg, with minor take occurring around the northern Channel Islands by divers that are primarily targeting Warty Sea Cucumber around Santa Rosa and San Miguel Island (Figure 2-1). Divers primarily operate between depths of 30.0 and 100.0 ft (10.0 and 33.3 m), with an average dive depth of 50.0 ft (16.7 m).

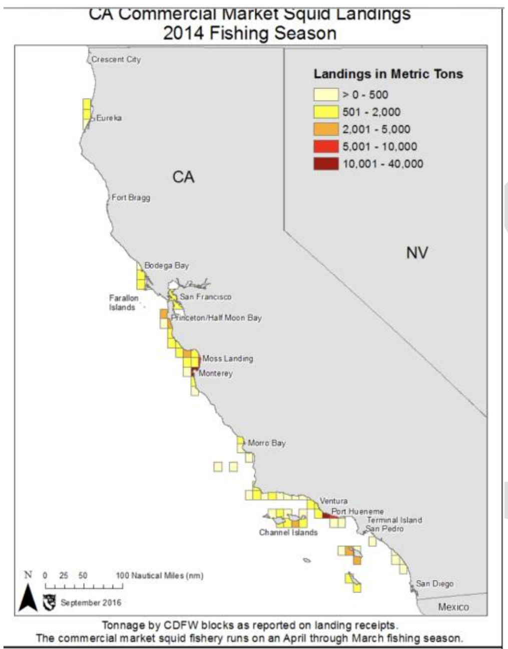

Figure 2-X. Map of commercial fishery landings by block in 2017 (CDFW Commercial Fisheries Information System (CFIS) 2018).

2.2 Fishing Effort

2.2.1 Number of Vessels and Participants Over Time

The Giant Red Sea Cucumber trawl fishery began in the early 1980s, when halibut fishermen began retaining and selling Giant Red Sea Cucumber caught in the Halibut trawl fishery. As the value of Giant Red Sea cucumber increased, the species moved from an incidental species to a target species. During the first 10 yr of the Giant Red Sea Cucumber trawl fishery (1980-1989), participation was extremely limited, with no more than 19 fishermen and 17 individual vessels making at least one landing in a given year. This changed rapidly in the early 1990s as trawl activity peaked at an all-time record high of 71 active trawl fishermen and 46 trawl vessels in 1991 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 (23 kilograms (kg)) landing of sea cucumber between 1988 to1991. In 1997, separate sea cucumber dive and trawl permits were created. These permits capped the number of participants, resulting in a limited entry dive and trawl fishery. A provision was included that allowed trawl permits to be transferred and operated as either a trawl or dive permit, but dive permits to only be transferred and operated as a dive permit.

Sea cucumber dive and trawl permits are tied to participants, not vessels, resulting in different levels of participation based the number of participants (Figure 2-3) and vessels (Figure 2-4) over the course of the fishery. Initially during the 1997-1998 fishing season, 60 trawl permits and 113 dive permits were issued. However, between 1997-1999, 16 trawl permits were permanently revoked due to court cases pursued by the Department that found that trawl permittees had fraudulently obtained their permits by falsifying their landings records. In 2001, 36 trawl permits were issued, with 21 of these permits making at least one landing. Since 2001, the number of trawl permits issued and participation have steady declined, with only 16 total permits issued in 2017, nine of which were active. The decline in trawl participation is partially due to the transfer and conversion of trawl permits to dive permits.

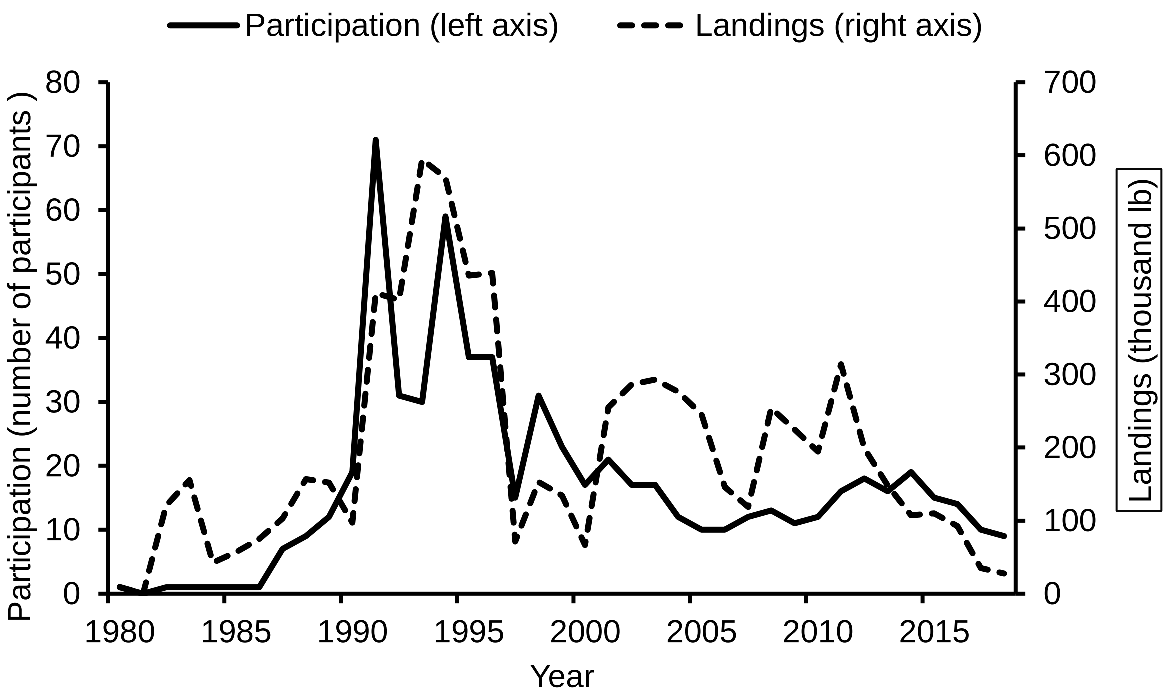

Figure 2-2. Giant Red Sea Cucumber fishery participation (number of participants) and landings (thousand lb), 1980 to 2017 (CDFW CFIS).

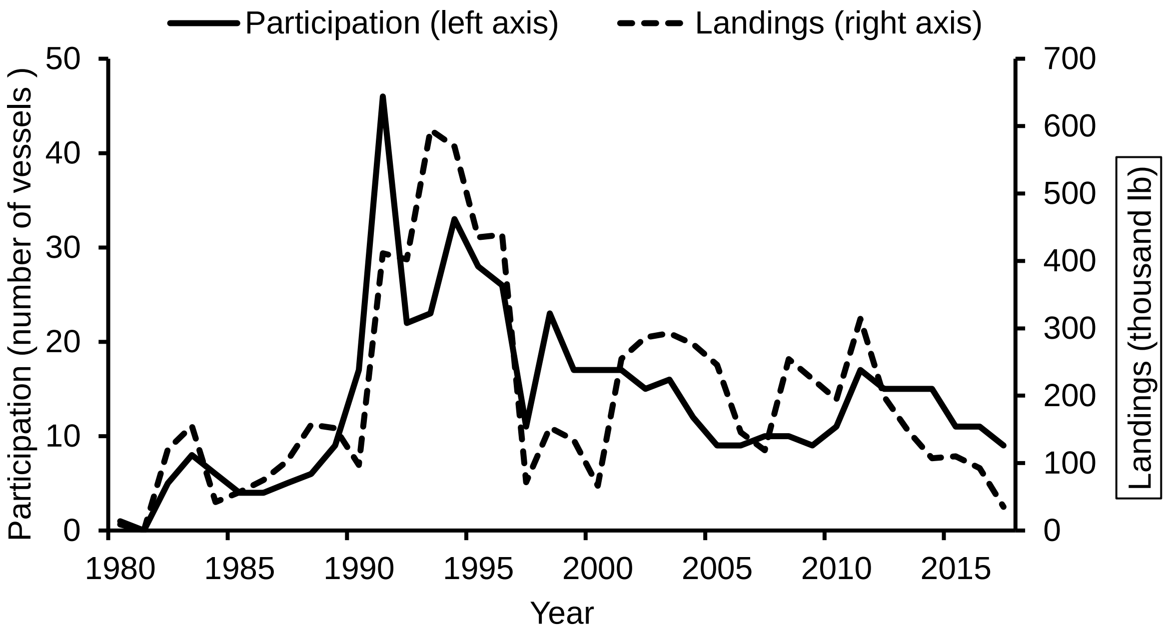

Figure 2-3. Giant Red Sea Cucumber trawl fishery participation (number of vessels) and landings (thousand lb), 1980 to 2017 (CDFW CFIS).

2.2.2 Type, Amount, and Selectivity of Gear

There are two types of trawl gear used to take Giant Red Sea Cucumber.

Larger mesh size in the halibut gear means that larger cucumber are selected. Carlos said on a trip he went on he did not observe any small ones. Ridgeback gear likely selects everything.

Figure 2-4. Typical sea cucumber trawl vessel. (Photocredit: M. Mcorkle, ORGANZATION).

2.3 Landings in the Recreational and Commercial Sectors

2.3.1 Recreational

Landings in the recreational fishery for Giant Red Sea Cucumber fishery are not tracked, and so there is very little information with which to assess the size of the fishery. Chartered dive boats report divers occasionally targeting Warty Sea Cucumber in southern California; but the Department has not received reports of similar activity for Giant Red Sea Cucumber. It is currently assumed that recreational effort and catch are 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 trawl fishery for Giant Red Sea Cucumber originated in the early 1980s as incidental catch in trawls for California Halibut. It was a minor fishery through the 80s with yearly landings not exceeding about 150,000 lb (68 metric tons (mt)) until 1991 when landings increased to 411,000 lb (186 mt) (Figure 2-5). Landings continued to increase dramatically until reaching a record peak in 1993 at 594,000 lb (269 mt), associated with a revenue of $0.3 million. In 2011, the fishery reached a record high in revenue of $1.2 million, with landings reaching 314,000 lb (142 mt) that same year. Since 2011, the trawl fishery has experienced consistent declines in both revenue and landings. In 2017, trawl landings of Giant Red Sea Cucumber reached a record low 35,000 lb (16 mt), with an associated value of $0.2 million. The average ex-vessel price per pound has drastically increased over the past 10 yr, growing from an average of $1.50 per pound in 2007, to an average of over $5 per pound in 2017 (Figure 2-6). The Department has major concerns regarding the future sustainability of this resource considering these trends in decreasing landings and participation as value continues to increase.

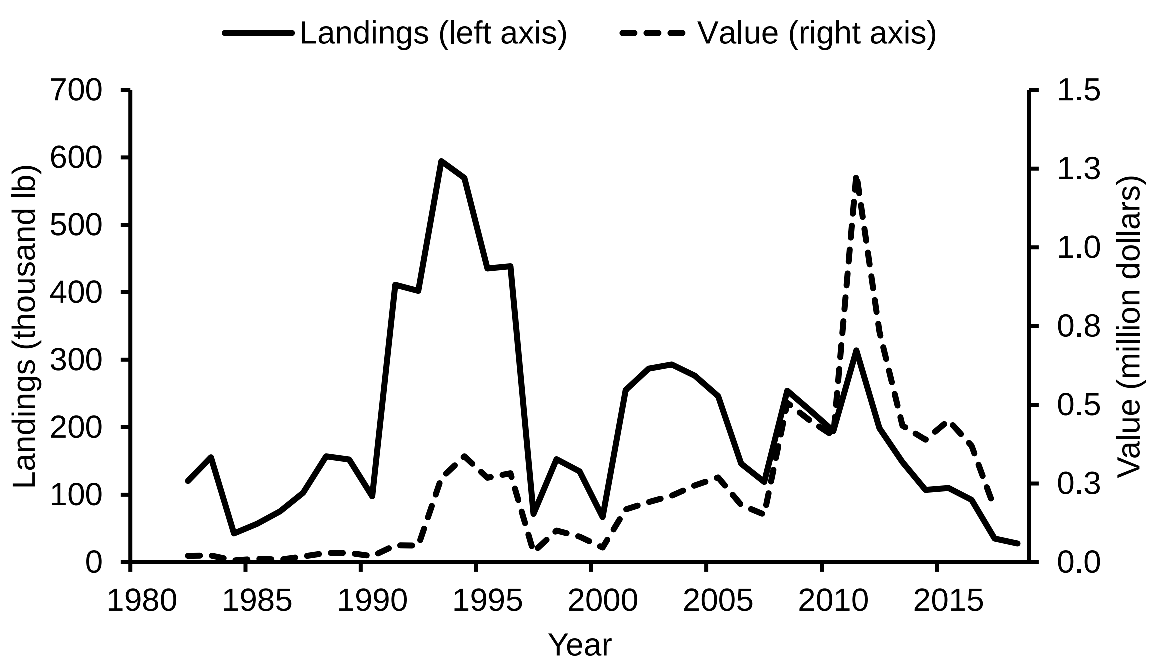

Figure 2-5. Giant Red Sea Cucumber commercial fishery landings (thousand lb) and value (million dollars), 1980 to 2017 (CDFW CFIS).

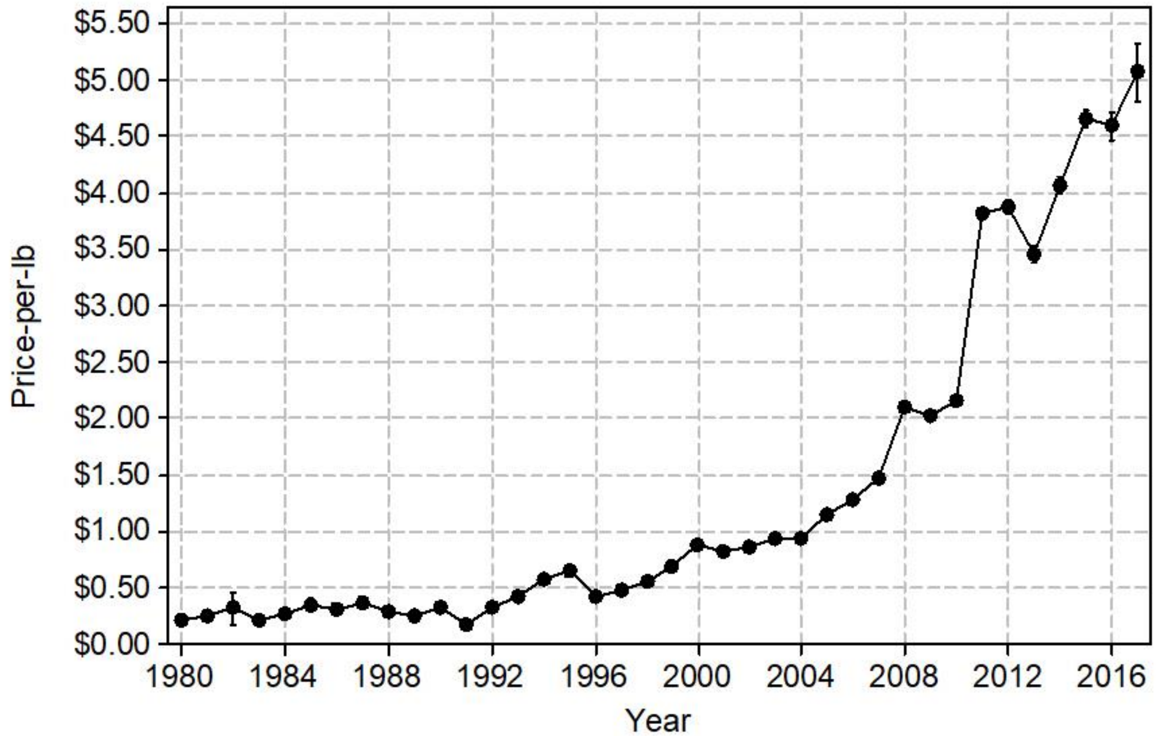

Figure 2-6. The average price per pound (± 95% Confidence Interval of mean) paid for commercially harvested sea cucumber in California by year, 1980 to 2017 (CDFW CFIS).

It should be noted that there is great uncertainty regarding reconstructing the true landing history of Giant Red Sea Cucumber and Warty Sea Cucumber landed by trawl and dive fisheries due to the practice of cutting (aka slitting) sea cucumber prior to landing. Cut sea cucumber became the dominant landing condition of sea cucumber starting in the mid to late 2000s at the request of sea cucumber buyers. This practice reduces the weight of landed sea cucumber by approximately 50%. Prior to cutting, all sea cucumber was landed in whole or live state; however, landing receipts used to report sea cucumber sales did not contain landing condition fields, so landing condition of sea cucumber was not reported over the course of this fishery. Considering this issue, landings data after 2009, is likely double that reported in Department landings. For example, landings in 2011 of 314,000 lb (142 mt) (cut) would result in a converted whole weight of 628,000 lb (285 mt), which is likely similar in magnitude to the peak in 1993 (594,000 lb (269 mt)). In 2018, Department required the reporting of condition codes on landing receipts to improve landing data. This uncertainty about catch is a major data gap for this fishery.

Trawl landings typically peak during summer periods (Figure 2-7) as a result of higher CPUE. These peaks in landings may be related to possible aggregation behavior of Giant Red Sea Cucumber similar to that exhibited by Warty Sea Cucumber, a build-up of individuals during the seasonal closure of the CHTG from March 15 to June 14, and or a combination of favorable weather conditions typically present during summer periods that support trawl activities.

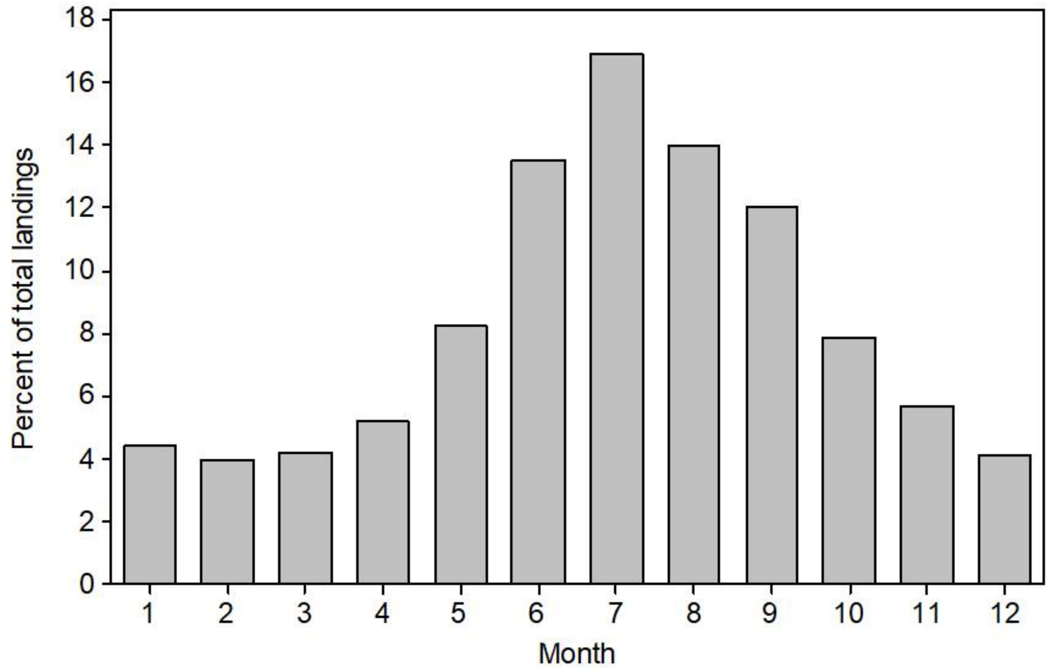

Figure 2-7. Cumulative percentage of monthly trawl landings of Giant Red Sea Cucumber over the history of the fishery, 1980 to 2017 (CDFW CFIS).

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.

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 2-8 shows how total landings have been distributed across ports, with a vast majority of landings at Santa Barbara Harbor, followed by minimal landings at Ventura, Oxnard, and Terminal Island.

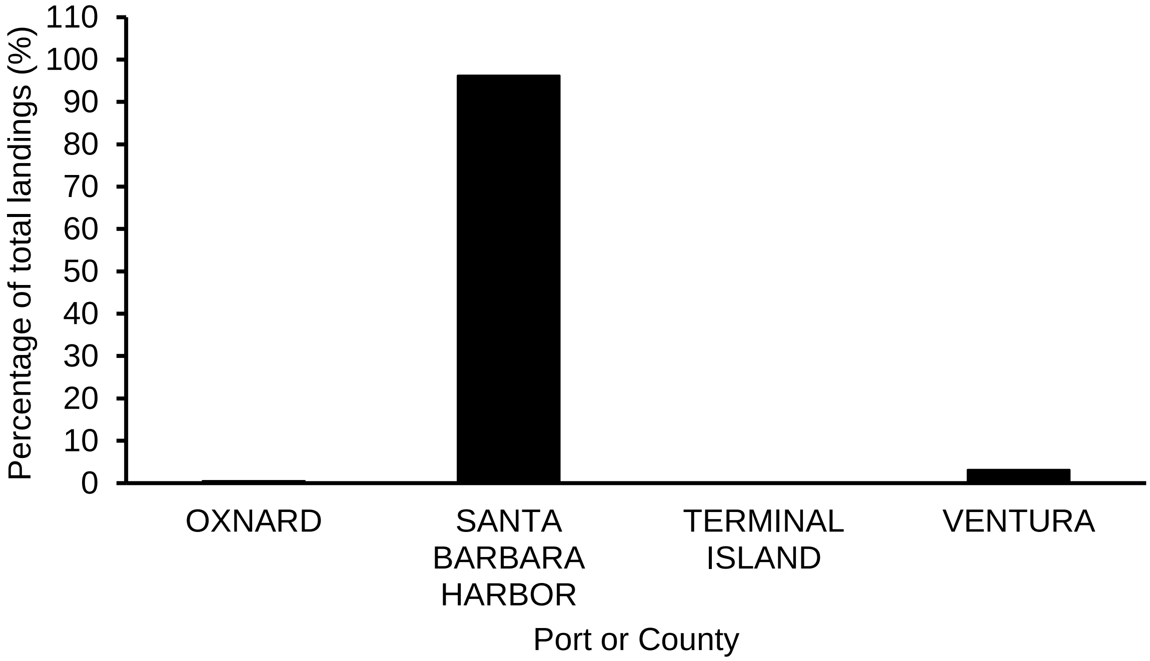

Figure 2-8. Percentage of Giant Red Sea Cucumber total trawl landings by port in 2017 (CDFW CFIS).

3 Management

3.1 Past and Current Management Measures

The commercial sea cucumber dive and trawl fisheries were largely unregulated until the 1992 to 1993 fishing season, at which time, a general sea cucumber permit was required for trawlers and divers to harvest sea cucumber. To qualify for this permit, fishermen were required to meet a minimum landing requirement of 50 lb (23 kg) during a 4-yr “window” period from 1988 to 1991. A limited entry program was established by the legislation beginning during the 1997 to 1998 fishing season, along with the development of two separate permits for the sea cucumber dive and trawl fisheries. 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 to 1998 permit year, and the meeting of a minimum landing requirement.

Sea cucumber dive and trawl permits are transferable if the permittee can achieve a minimum landing requirement of at least 100 lb (45 kg) of sea cucumber during each of the four consecutive years prior to transferring a permit. 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.

Beginning in 198? sea cucumber dive and trawl permittees are 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 Giant Red Sea Cucumber via trawl gear consist of three primary measures:

1. A limited entry permit program
2. A requirement to complete and submit a daily commercial logbook
3. A prohibition on trawling within state waters inside the California Halibut trawl grounds from date x to date x.

3.1.1.1 <u>Criteria to Identify When Fisheries Are Overfished or Subject to Overfishing, and Measures to Rebuild</u>

Currently, there is no direct reference point for determining whether the Giant Red Sea Cucumber stock is “overfished”, nor are there procedures in place specific to the trawl or dive fishery to halt overfishing when it is found to be occurring. However, yields per unit area (e.g., fishing block) and CPUE represent two indicators of exploitation. The yield of Giant Red Sea Cucumber per unit area may reflect changes in the spatial distribution of fishing that can be indicative of trends in Giant Red Sea Cucumber abundance. Moreover, long term increases or decreases in CPUE may provide an indication of whether or not populations of Giant Red Sea Cucumber are being overfished. A decline in both yield per unit area and CPUE can reflect a state of over-exploitation, which may warrant additional investigation by the Department or management changes to enhance the conservation of this resource.

3.1.1.2 Past and Current Stakeholder Involvement

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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 on Giant Red Sea Cucumber.

3.1.2.1.2 Effort

The primary tool used to manage effort is a limitation on the number of sea cucumber trawl permits issued. There are currently 16 transferable sea cucumber trawl permits and 82 sea cucumber dive permits in California. When separate sea cucumber dive and trawl permits were established in 1996, 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.

3.1.2.1.3 Gear

Although not specific to sea cucumber fisheries, trawlers may be subject to gear restrictions enacted on other fisheries. The California halibut trawl fishery must meet the following restrictions when fishing within California Halibut Trawl Grounds:

1. The headrope of the trawl net must not exceed 90 ft (27 m) in length. The headrope is defined as the chain rope or wire that attaches the right and left bridles of the net at the top panel, forming the leading edge of the net.
2. The webbing thickness of the net must not exceed 7.0 millimeters (mm) (0.3 in) in diameter.
3. Each trawl door much way less than 500 lb (227 kg).
4. Chains attached to the footrope must not exceed 0.25 in (0.64 cm) in diameter. The footrope is defined as rope or wire that forms the leading edge at the bottom of the net.

5. The troll net cannot have any rollers or bobbins on the net or foot rope. Bobbins or rollers are devices designed to bounce the bottom edge of the net over hard obstructions or snags (FGC §124).

The sea cucumber trawl fishery may also be subject to gear restrictions placed on the Ridgeback Prawn fishery. Ridgeback Prawn may only be taken by otter trawl nets for commercial purposes. The minimum mesh size for trawl nets with single-walled bag or cod end is 1.5 in (3.8 cm) in length or 3.0 in (7.6 cm) in length for trawl nets with double-walled bag or cod end. The primary gear used in the fishery is a single-rig shrimp trawl with a single-walled net with mesh sizes ranging from 1.75 to 2.25 in (4.5 to 5.7 cm) (CDFG 2008). The net mesh may be no less than 1.38 in (3.51 cm) measured inside the knot. In addition, the net must be equipped with an approved Bycatch Reduction Device.

In the recreational and commercial dive fishery for Giant Red Sea Cucumber, hand take via SCUBA or hookah (surface supplied air) is the primary method of take.

3.1.2.1.4 Time

Although not specific to Giant Red Sea Cucumber, trawlers are not allowed to trawl within California state waters, unless they are within the Halibut Trawl Grounds, which is only open from June 16 to March 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

Several trawl specific closures prevent the trawl take of Giant Red Sea Cucumber. The CHTG provide seasonal protection to Giant Red Sea Cucumber within state waters from March 15 to June 15, with trawling completely prohibited around offshore islands out to ? from shore. California's network of MPAs provide protection to the Giant Red Sea Cucumber resource throughout its range.

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.

Due to the fact that Giant Red Sea Cucumber prefer hard substrate habitats, such as rocky reefs, the current network of MPAs in California may play an important role in providing refuge habitat. MPAs provide a valuable tool to monitor the health of Giant Red Sea Cucumber populations with the continued monitoring of MPAs being essential to determining environmental impacts vs fishing impacts on 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

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3.1.3 Bycatch

3.1.3.1 Amount and Type of Bycatch (Including Discards)

The 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.

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

[Paste Text Here]

3.1.4 Habitat

3.1.4.1 Description of Threats

The impacts from bottom trawling on benthic, or seafloor, habitats and sensitive species are complex. It is widely believed that bottom trawling causes a loss or alteration of important habitats by scouring, crushing, burying, or exposing marine flora and fauna and greatly reducing the complexity and diversity of the seafloor. However, a recent study by Lindholm et al. (2015) found trawling impacts are context dependent, depending on the type of gear used, the types of habitats trawled, and how often trawling occurs. Furthermore, recovery after disturbance varies with habitat characteristics, frequency and intensity of disturbance, and species composition (NRC 2002). Relatively stable habitats, such as hard bottom and dense mud, experience the greatest changes and have the slowest recovery rates compared to less consolidated coarse sediments in areas of high natural disturbance (NRC 2002). The impacts of trawl fishing on soft bottom habitats are considerably lower, as habitat recovery following trawling disturbance may be less than 1 yr (NMFS 2005).

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

The sea cucumber trawl fishery is subject to management actions implemented in other fisheries, specifically the California Halibut fishery, designed to minimize adverse habitat effects. These measures include spatial closures, specifically prohibiting trawling for halibut in all state waters except for the California Habitat Trawl Grounds, and “light touch” gear, which legally define the maximum parameters of trawl nets. The “light touch” parameters are intended to minimize habitat disturbance as a result of trawl fishing. These parameters are described in section 3.1.2.1.3.

3.2 Requirements for Person or Vessel Permits and Reasonable Fees

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Table 3-1. Commercial fees for Giant Red Sea Cucumber. (Accessed Month Day, YEAR. https://www.wildlife.ca.gov/Licensing/Commercial/Descriptions).

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

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 Giant Red Cucumber as described in section 1, including development, spawning behaviors, and movement. This section however summarizes the EFI that is routinely collected and used to monitor the health of the stock and ecosystem. The Department relies on a combination of fishery-dependent and fishery-independent sources to monitor the status of the Giant Red Cucumber fishery. However, this is a data poor fishery, and most EFI can only be gathered through passive monitoring of catch and effort with little biological information being collected.

4.2 Past and Ongoing Monitoring of the Fishery

4.2.1 Fishery-dependent Data Collection

All fish and invertebrates taken (species and weight) under a commercial fishing license are documented on a landing receipt provided by the Department. In many fisheries, landing receipts are the primary means of monitoring, and particularly for those fisheries like Warty Sea Cucumber that do not have a catch quota. When coupled with sample data and a comprehensive understanding of the dynamics of the fishery, landing receipts could be reasonable indicators of the status of the fishery. 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 (lb) landed by market category
- price paid to the fisherman by market category
- condition of the catch when sold
- type of gear used

In addition, the Department collects information from dive logs for dive fisheries such as Warty Sea Cucumber.

4.2.2 Fishery-independent Data Collection

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5 Future Management Needs and Directions

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 Giant Red 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 Giant Red 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. The recording of size measurements of Giant Red Sea Cucumber by independent groups monitoring MPAs 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 Giant Red Sea Cucumber trawl and dive fishery and their priority for management.

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

Type of information	Priority for management	How essential fishery information would support future management
Spawning season		
Size at sexual maturity	High	

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.

5.2 Research and Monitoring

5.2.1 Potential Strategies to Fill Information Gaps

-at sea sampling

5.2.2 Opportunities for Collaborative Fisheries Research

The Department has collaborated in the past and will continue to work with outside entities such as academic organizations, non-governmental organizations, citizen scientists, and both commercial and recreational fishery participants to help fill information gaps related to the management of state fisheries. The Department will also reach out to outside persons and agencies when appropriate while conducting or seeking new fisheries research required for the management of each fishery.

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5.3 Opportunities for Any 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.

[Paste Text Here]

5.4 Climate Readiness

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