Fishery-at-a-Glance: Pacific Angel Shark

Scientific Name: *Squatina californica*

Range: The population extends from southeastern Alaska to the Gulf of California. Within California Pacific Angel Shark are most common south of Point Conception.

Habitat: Pacific Angel Shark are common on the continental shelf and littoral areas at depths of 15 to 40 meters (49 to 131 feet) but are found down to 215 meters (705 feet). They are usually partially buried on flat, sandy bottoms and sand channels between rocky reefs when resting.

Size (length and weight): The largest individual Pacific Angel Shark recorded was 152 centimeters (5 feet) and 27 kilograms (60 pounds). Most Angel Sharks in the fishery range from 100 to 120 centimeters (39 to 47 inches) total length.

Life span: Pacific Angel Shark are slow growing with a late age at maturity. The oldest fish recorded was 35 years old.

Reproduction: Pacific Angel Shark develop inside eggs within the mother's body and are born live. On average six pups are produced annually from March to June with an estimated 10 month gestation period. Age at maturity ranges from 8 to 13 years.

Prey: Pacific Angel Shark mainly eat demersal fishes and invertebrates, but are known to consume mid-water species of reef fish and squid in southern California**.**

Predators: There is no information available on the predators of Pacific Angel Shark.

Fishery: Pacific Angel Shark supported a commercial fishery off Santa Barbara and Ventura counties during the 1980s until their primary habitat was protected by the inshore gill net ban in 1994. As of 2018, a small number are still caught by set gill netters and trawlers targeting California Halibut.

Area fished: Pacific Angel Shark are primarily caught in ocean waters off Ventura and Santa Barbara counties.

Fishing season: Pacific Angel Shark are caught year-round**.**

Fishing gear: Pacific Angel Shark are primarily caught by set gill nets and to a smaller extent, bottom trawl gear.

Market(s): Pacific Angel Shark are sold in the domestic market for the restaurant trade.

Current stock status: There is no stock assessment for this species. Stocks were heavily fished in California in the 1980s, but the majority of the California stock remains protected by the nearshore gill net ban and restricted trawl areas.

Management: No management strategy is currently in place for Pacific Angel Shark because the prohibition of inshore gill netting protects this species from exploitation by eliminating the fishery in its primary habitat. Additionally, a minimum commercial size limit was implemented by the Department in 1989. Based on the available data it appears the current management is effective. Although if landings increase significantly or if it appears anglers begin targeting Pacific Angel Shark, this may indicate the fishery needs management change.

1 The Species

1.1 Natural History

1.1.1 Species Description

The Pacific Angel Shark (*Squatina californica*) is a relatively small, bottom-dwelling species. It is a chondrichthyan in the family Squatinidae, which consists of 11 species of shark found around the world in temperate and tropical waters (Bigelow and Schroeder 1948; Ellis 1975). Pacific Angel Sharks are ray-like, with a dorso-ventrally flattened body and broad pectoral and pelvic fins (Figure 1-1). They have a pair of cone-shaped barbels on their snout, eyes on the dorsal surface and two dorsal fins towards the back of their body (Pittenger 1984; Ebert 2003). Their mouths are at the tip of their snout with nine rows of teeth on their upper jaw and ten rows on their lower jaw. They are grey to dusky above with dark spotting and white below (Miller and Lea 1972).

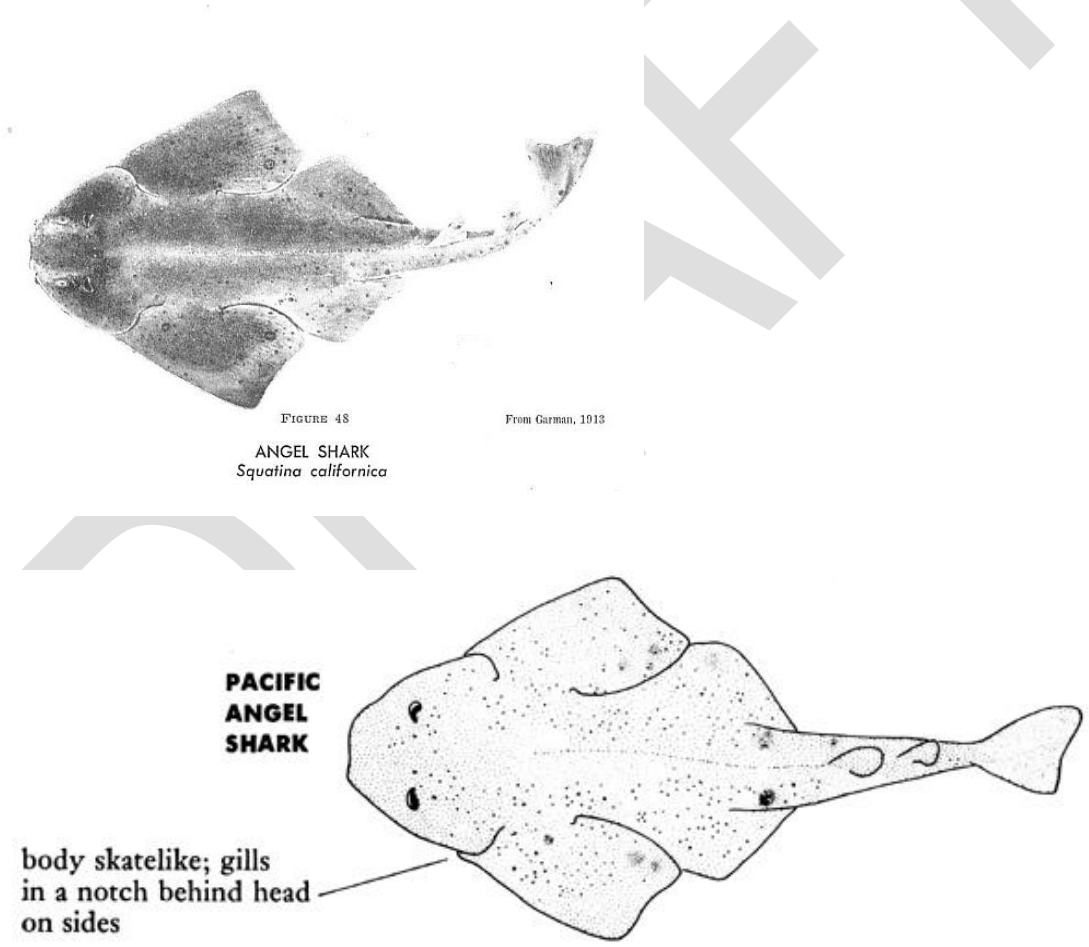

Figure 1-1. Photograph of a Pacific Angel Shark (Reproduced from Roedel and Ripley 1950) and illustration (Reproduced from Miller and Lea 1972).

1.1.2 Range, Distribution, and Movement

Pacific Angel Shark range from southeast Alaska to the Gulf of California (Miller and Lea 1972) (Figure 1-2), but the main fishery is focused in the Channel Islands near Ventura and Santa Barbara counties, especially Santa Cruz and Santa Rosa Islands (CDFW 2001). Genetically distinct stocks may occur between the southern and northern Channel Islands (Gaida 1997) and the Gulf and Pacific coast of Baja, California (Ramirez-Amaro 2017). These studies suggest that populations of Angel Shark are localized due to their low dispersal ability. Tracking data from Catalina Island also suggests they form resident populations, as only localized movements around the island were observed (Pittenger 1984).

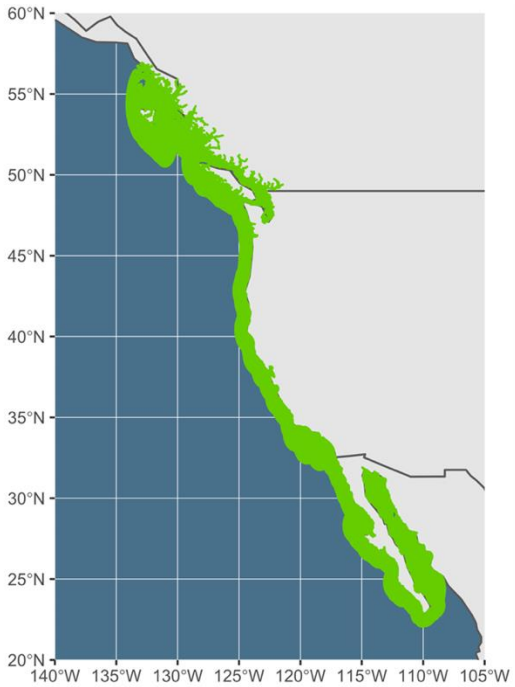

Figure 1-2. Range of Pacific Angel Shark.

Pacific Angel Shark are nocturnal, resting in the sand during the day, but swimming at depths from 27 to 100 meters (m) (89 to 328 feet (ft)) and moving an average of 4 kilometers (km) (2.5 miles (mi)) at a rate of 490.0 m/hour (hr) (0.3 mi/hr) at night (Standora and Nelson 1977). However nocturnal movements are sporadic, and individuals may remain at the same location for several days at a time. This is perhaps due to local prey availability (Pittenger 1984). There is some evidence of an annual offshore migration, as Pacific Angel Sharks are found at the rock-sand interface of rocky reefs during the warmer months and further out over the sand during the winter where squid prey is readily available (Pittenger 1984).

1.1.3 Reproduction, Fecundity, and Spawning Season

Like other sharks, Pacific Angel Shark reproduce via internal fertilization, where the male shark uses extensions of the pelvic fins called “claspers” to transfer sperm to

the female and fertilize her eggs (Natanson and Cailliet 1986; Pittenger 1984). They bear live young that develop inside eggs within the mother's body (ovoviviparity), and the pups depend solely on the yolk in their eggs for development (Compagno 1984). A mean of six pups (with a range of one to 11) are produced annually between March and June with an estimated 10 month gestation period (Natanson and Cailliet 1986). Thus mating season likely occurs during the summer months (May to August). The number of pups produced does not increase with increasing size of mature females. At birth, pups are approximately 25 centimeters (cm) (9.8 inches (in)) (Natanson 1984).

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.

Natural mortality for Pacific Angel Shark is estimated to be 0.2 year (yr) (i.e. approximately 20% of the population is lost each year to natural causes) (Cailliet et al. 1992). This estimate was based on the relationship between the mortality rate of tag recaptures of Pacific Angel Shark and their maximum age using a natural survivorship function (Cailliet et al. 1992).

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, 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. The von Bertalanffy growth function is:

$$L_t = L_\infty(1 - e^{-k(t-t_0)})$$

where L_t is the length at age t, L_∞ is the maximum average length, k is the relative growth rate, t is the age of the fish, and t_0 is the theoretical age when the length of the fish is zero. The values of those calculated parameters for Pacific Angel Shark using both sexes combined are: L_∞ = 127 cm, k = 0.146, t_0 = -1.309 (Cailliet et al. 1992). The maximum observed size for Angel Shark is 5 ft (152 cm) and 60 pound (lb) (27 kilogram (kg)) (Miller and Lea 1972).

The relationship between weight and length for Pacific Angel Shark (both sexes combined) has also been modeled using the exponential equation:

$$W = aL^b$$

where *W* is the weight in grams, *L* is the Total Length (TL) in millimeters, *a* is a constant indicating the intercept and *b* is a constant indicating the slope of the regression line (*a*=7.81E-06 and *b*=3.02 for Pacific Angel Shark) (Williams et al. 2013).

1.1.6 Size and Age at Maturity

Like many shark species, Pacific Angel Shark are slow growing with late maturation, making them vulnerable to overexploitation. Most angel sharks reach sizes from 100 to 120 cm (39 to 47 in). Pacific Angel Sharks reach maturity between 8 to 13 yr old, when females are 102 to 107 cm (40 to 42 in) TL and males are 100 to 109 cm (39 to 43 in) TL (Natanson and Cailliet 1986; Cailliet et al. 1992). In the Gulf of California, Pacific Angel Shark mature at a smaller size of 76 cm (30 in) TL for males and 78 cm (31 in) TL for females (Romero-Caicedo et al. 2016).

1.2 Population Status and Dynamics

The population status of Pacific Angel Shark is unknown. Given their life history characteristics, which include late maturity and low fecundity, they may be vulnerable to overfishing. However, currently very few angel sharks are taken in California's fishery, so there are no concerns about the status of the stock at this time.

1.2.1 Abundance Estimates

There are no known estimates of the absolute or relative abundance of Pacific Angel Shark in California. No fishery-independent datasets of abundance are collected for this species and no stock assessment is available as of 2017. Commercial landings of Pacific Angel Shark are low, with fewer than 500 sharks per year reported landed from 2004 to 2016, compared to a peak of 40,000 sharks recorded landed in 1985 (CDFW Marine Landings Database System (MLDS)). This decline in landings is tied to the concurrent drop in the number of commercial boats targeting them in southern California (from 238 in 1985 to 19 boats in 2017) (CDFW MLDS). Landings by private boaters and Commercial Passenger Fishing Vessels (CPFV) don't show any trend, and the landings remain low, with fewer than 30 Pacific Angel Sharks estimated to be retained in most years. Furthermore, since no commercial gill net fishing is allowed in their primary inshore sandy-bottom habitat and few are landed by recreational anglers, Pacific Angel Shark are largely protected from fishing pressure. Therefore, it is presumed that the population remains relatively stable in California.

1.2.2 Age Structure of the Population

There is currently no stock assessment for Pacific Angel Shark in California and too few are sampled for weight and length from the recreational fishery to sufficiently characterize the age or size structure.

1.3 Habitat

Pacific Angel Shark are bottom dwellers that typically live in muddy and sandy habitats on the continental shelf. Although, no studies to date have directly investigated

changes in habitat use between life stages, juvenile Angel Shark as small as 76 cm (30 in) have been observed in the same habitat as adults (Pittenger 1984). They are common at depths of 15 to 40 m (49 to 131 ft), but have been observed as deep as 215 m (328 ft) (Pittenger 1984). They are found at the edges of rocky reefs and kelp forests, as well as shallow bays and estuaries (Feder et al. 1974). During the day these sharks are inactive, resting partially buried on sandy bottoms (Pittenger 1984). Most activity is observed at night when sharks may move long distances in depths of 27 to 100 m (89 to 328 ft) (Standora and Nelson 1977). Sharks at Catalina Island have been observed to switch from reef-edge to deeper, open-sand habitat in pursuit of prey during the winter months (Pittenger 1984).

1.4 Ecosystem Role

The Department is not aware of any directed research on the ecosystem role of the Pacific Angel Shark. As apex predators, sharks play an important role in regulating trophic interactions. In California, Pacific Angel Shark prey on common reef fish, and thus probably exert some top-down regulation on the distribution and abundance of lower trophic level fishes and invertebrates in inshore food webs (Pittenger 1984).

1.4.1 Associated Species

Pacific Angel Shark do not school or aggregate with other species, but they share habitat with other soft bottom habitat species in California such as flatfish, skates and rays, croaker and sea perch (Allen et al. 2006). They also feed on aggregations of invertebrate prey including Market Squid (*Loligo opalescens*) and Target Rock Shrimp (*Sicyonia penicellata*).

1.4.2 Predator-prey Interactions

Pacific Angel Shark are carnivorous ambush predators, resting in areas adjacent to rock-sand interfaces or patch reefs where their primary prey sources (bottom feeder fishes) lie within striking distance. Both juvenile and adult Pacific Angel Shark use ambush strategies to prey on fishes (Pittenger 1984). They remain buried in the sand, allowing prey to pass by, and then jump to grasp and engulf prey (Fouts and Nelson 1999). In a study based on Catalina Island, Pacific Angel Shark mainly consumed Queenfish (*Seriphus politus*) and Blacksmith (*Chromis punctipinnis*) during the summer months, but their diet was based solely on Market Squid in the winter months (Pittenger 1984). In the Gulf of California, they have also been observed to consume fish such as Daisy Midshipman (*Porichthys analis*) and crustaceans such as the Target Rock Shrimp (Escobar-Sanchez et al. 2006). They are considered specialist predators when their primary prey is available, but become opportunists and feed on other prey when necessary (Escobar-Sanchez et al. 2006).

1.5 Effects of Changing Oceanic Conditions

Oceanic changes due to climatic events impacting water temperature and nutrient availability such as El Niño Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO) and the North Pacific Gyre Oscillation (NPGO) can have profound

effects on fishes and fisheries. No research has been done on the susceptibility of Angel Sharks to climate change. Since Pacific Angel Shark appear most abundant in the warm-temperate waters of southern California and Baja Mexico, and depend on prey found near rocky reefs, long-term warming trends in ocean temperatures could force the population to move farther north through central and northern California. The stocks in Mexico are heavily fished, so this shift could have a positive effect on the abundance of Pacific Angel Shark, which are de-facto protected from fishing by the nearshore gill net ban in California. Alternatively, prey availability may be negatively affected since Market Squid, a primary winter prey source, may undergo large population fluctuations from year to year in response to climate shifts and have low productivity during El Niño years (Jackson and Domeier 2003).

2 The Fishery

2.1 Location of the Fishery

Pacific Angel Shark are found throughout the coast of California, but the commercial fishery has always been focused off Santa Barbara and Ventura counties and the northern Channel Islands, especially Santa Cruz and Santa Rosa Islands. Initially they were targeted by gill net throughout the extent of their depth range, but following the inshore gill net ban under the Marine Resources Protection Act of 1990 implemented in 1994 (Fish and Game Code (FGC) §8610 et seq.), the majority of their habitat (inshore sandy bottom) was protected from commercial fishing. Since the mid1990s Pacific Angel Shark have been caught commercially outside of state waters (greater than 3 mi from shore) in the Santa Barbara Channel by the set-gill net and trawl fisheries targeting California Halibut (*Paralichthys californicus*). A small number of Pacific Angel Shark are also taken in the recreational fishery by private boaters and CPFVs, and the majority of landings are also from southern California. As of 2017 the largest fishery for Angel Shark is the gill net fishery in Baja, Mexico (Ramírez-Amaro et al. 2013).

2.2 Fishing Effort

2.2.1 Number of Vessels and Participants Over Time

Originally considered a useless bycatch species and discarded by the halibut gill net fishery, the Pacific Angel Shark became valued as a food fish in the Santa Barbara Channel during the 1980s (Bedford 1987). Once fishermen figured out a method of cleaning the fish at sea and harvesting fillets that were desirable to fish markets and consumers, the fishery grew rapidly (Bedford 1987). Pacific Angel Shark filled a gap in the availability of Thresher Shark (*Alopias vulpinus*), which was sparsely found in winter months (Bedford 1987). However, following the minimum commercial size limit for Angel Shark adopted by the Department in 1986 (FGC §8388) and the voter initiative to ban gill and trammel nets within state waters in 1994 (FGC §8610 et seq.), landings declined severely, forcing many gill netters to switch fisheries or retire. The fishery was also reduced due to the sale of California's shark processing plant in 1991 (Leet et al. 2001).

Between 1990 and 1994 the number of vessels landing Angel Shark was reduced by 50% from 147 to 71 (Figure 2-1). The number of boats landing Pacific Angel Shark continued to drop through the early 2000s. Since 2013 fewer than 30 boats have annually landed Pacific Angel Shark. In 2017, 19 boats landed Pacific Angel Shark in southern California, with four boats landing the majority of the catch (CDFW MLDS).

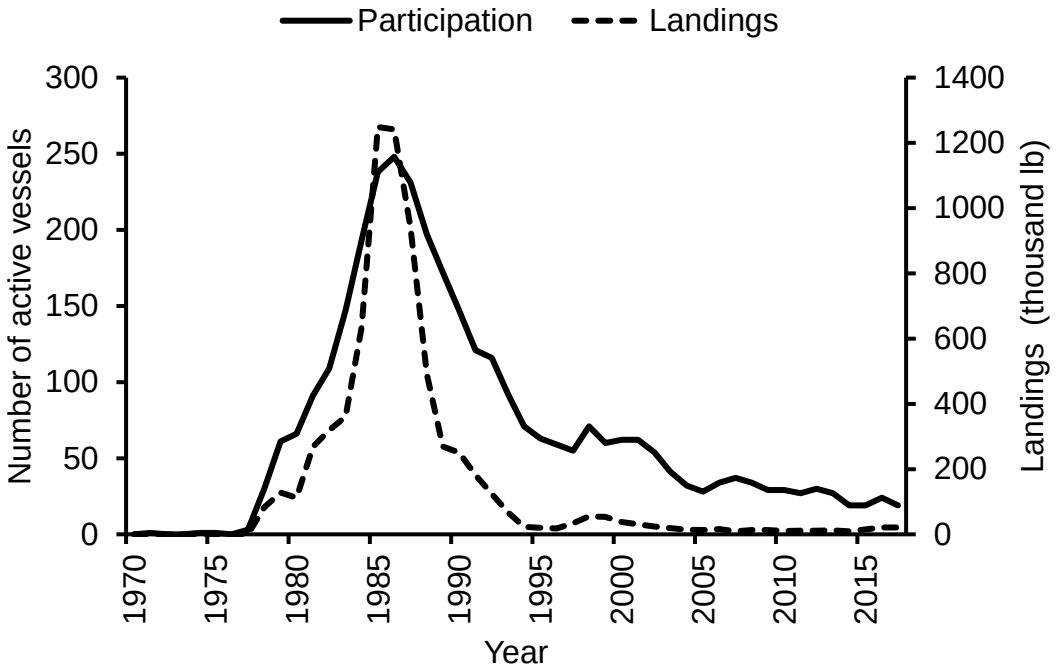

Figure 2-1. Pacific Angel Shark commercial fishery participation (number of vessels) and landings (lb), 1970 to 2017 (CDFW MLDS 2018).

The fishery, which mainly targets California Halibut, occurs throughout the year, though the summer months (June to August) are the most heavily fished. The size of gill net vessels has not changed significantly over time. Most boats range from 29 to 40 ft (9 to 12 m) in length and are crewed by a skipper working alone or with at least one deckhand. Vessels in the fishery are either fan tailed displacement hulls with a hydraulic spool on the aft deck or a planing hull with net reels mounted forward (Bedford 1987) (Figure 2-2).

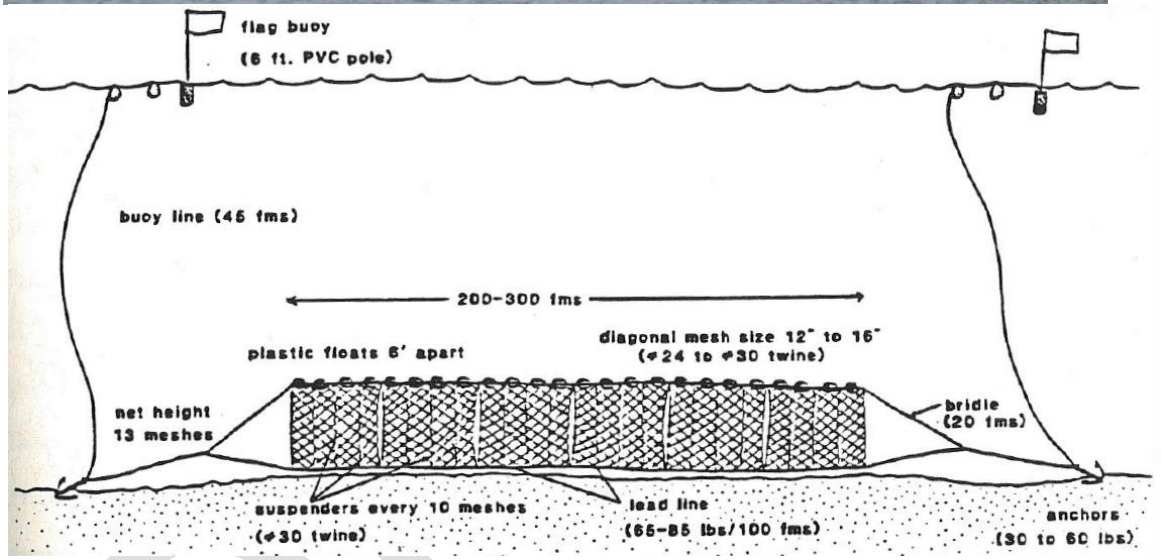

Figure 2-2. Photograph of a boat equipped for set gill netting (Photo Credit: flickr.com) and an illustration of a bottom set gill net anchored to the ocean floor as used in the Pacific Angel Shark fishery (Reproduced from Bedford 1987).

2.2.2 Type, Amount, and Selectivity of Gear

In California, Pacific Angel Shark are targeted primarily in set gill nets that are weighted and anchored to the seafloor in sandy or muddy habitats. Gill nets are constructed of one wall of webbing made of monofilament line and the bottom of the net is held down by lead lines. During the height of California's Pacific Angel Shark fishery in the early 1980s, fishers developed set gill nets with a mesh size larger than that used for California Halibut to target them specifically (Leet et al. 2001). However, these were phased out after the inshore gill net ban in 1994 (FGC §8610 et seq.) made fishing for Pacific Angel Shark less profitable. The nets used for California Halibut continued to be used to capture both species. The monofilament gill nets used to target Pacific Angel Shark in the 1980s were 200 to 300 fathoms (fm) (366 to 549 m) long and 13 meshes deep (mesh sizes were 12 to 16 in (30 to 41 cm)) with plastic floats about 6 ft (2 m)

apart on the corkline and a leadline with 65 to 85 lb per 100 fm (29.5 to 38.6 kg per 182.9 m) (Bedford 1987) (Figure 2-2). A 20 fm (120 ft) long bridle attached to 30 to 90 lb (29 to 39 kg) anchors kept the net set in place while buoy lines were used to flag the gear. Gill nets have poor species selectivity, catching any species of fish small enough to get caught in the mesh openings. Gill nets developed to target Angel Shark captured fish from 7 to 15 cm (2.8 to 6.0 in) alternate length (distance between first and second dorsal fins) (Bedford 1987).The set gill nets used to capture Pacific Angel Shark in the California Halibut fishery have a smaller mesh size near 8.5 in (21.6 cm). These gill nets catch Pacific Angel Shark with a mean weight of 6.35 kg (14 lb) (CDFW MLDS).

Pacific Angel Shark were first landed in large numbers by commercial gill netters in 1976. There were several local prohibitions of gill nets throughout California during the 1980s, but in 1994 FGC §8610.1 through FGC §8610.16 further restricted the use of gill nets through the establishment of a Marine Resources Protection Zone. This regulation essentially prohibited gill nets in nearshore waters. And although this was not directed at the Pacific Angel Shark fishery, it protected them from commercial fishing in their primary habitat and depth-range.

Trawl vessels sometimes incidentally catch Pacific Angel Sharks, but they represent a smaller proportion of the catch (CDFW MLDS). In 2017, 33% of commercially landed Angel Sharks were caught by trawl, while 63% were caught using set gill nets (CDFW MLDS). There is little recreational interest in fishing for Angel Shark by hook and line based on landings data from the Recreational Fisheries Information Network (RecFIN) and the Department's MLDS, which suggest that few to none were retained by recreational anglers in 2017. The average size of retained sharks by recreational boaters based on ten samples from 2006 to 2011 was 98.6 cm (38.8 in).

2.3 Landings in the Recreational and Commercial Sectors

2.3.1 Recreational

Pacific Angel Shark are not a popular species with recreational anglers since they are more commonly discarded as bycatch from private/rental boats. RecFIN estimates from 2005 to 2017 suggest the highest number of Pacific Angel Shark landed annually on hook and line was 59 individuals in 2007 by private/rental boats. Most landings occurred in the Channel Islands (Ventura and Santa Barbara counties) and southern ports (San Diego, Orange and Los Angeles counties). Although the number of private/rental boat angler trips remained relatively stable during the following years, catch estimates suggest less than 20 Pacific Angel Shark were retained annually and that none were landed between 2015 and 2017 (Figure 2-3). CPFV logbook data from 1980 to 2017 show that landings were highest in the 1980s and 1990s with a maximum of 32 Pacific Angel Shark retained in 1983. While the number of fishermen on CPFVs has fluctuated, landings of Pacific Angel Shark declined in the early 2000s and landings remain very low, with only one shark retained in 2017 (Figure 2-4).

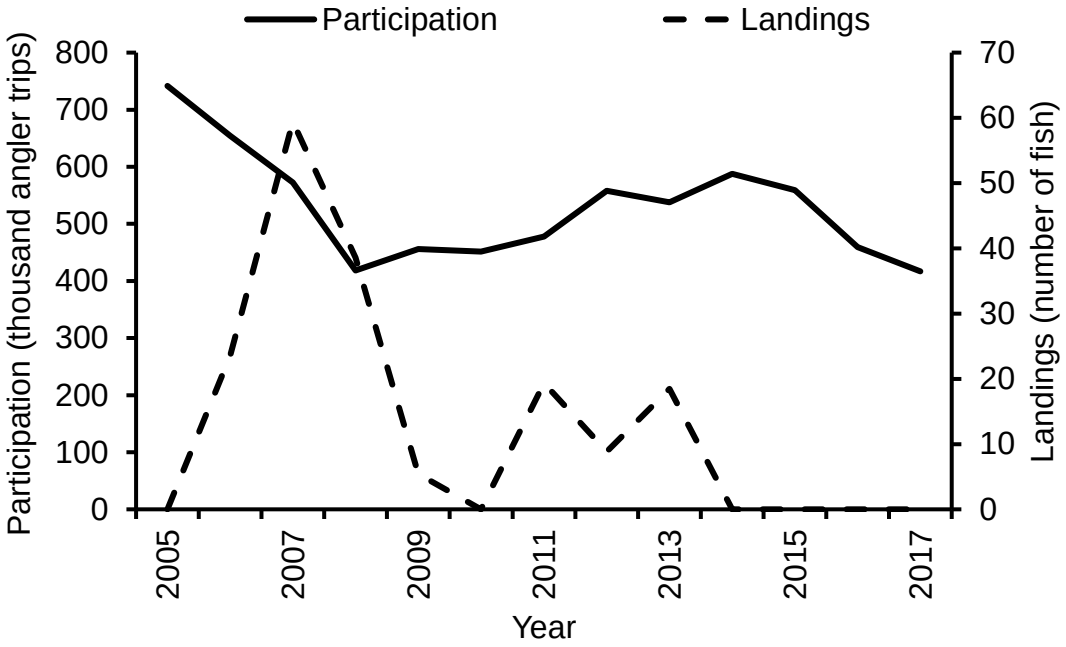

Figure 2-3. Participation (number of thousand angler trips) of private/rental boats and landings (total number of fish) of Pacific Angel Shark from California, 2005 to 2017 (RecFIN 2018).

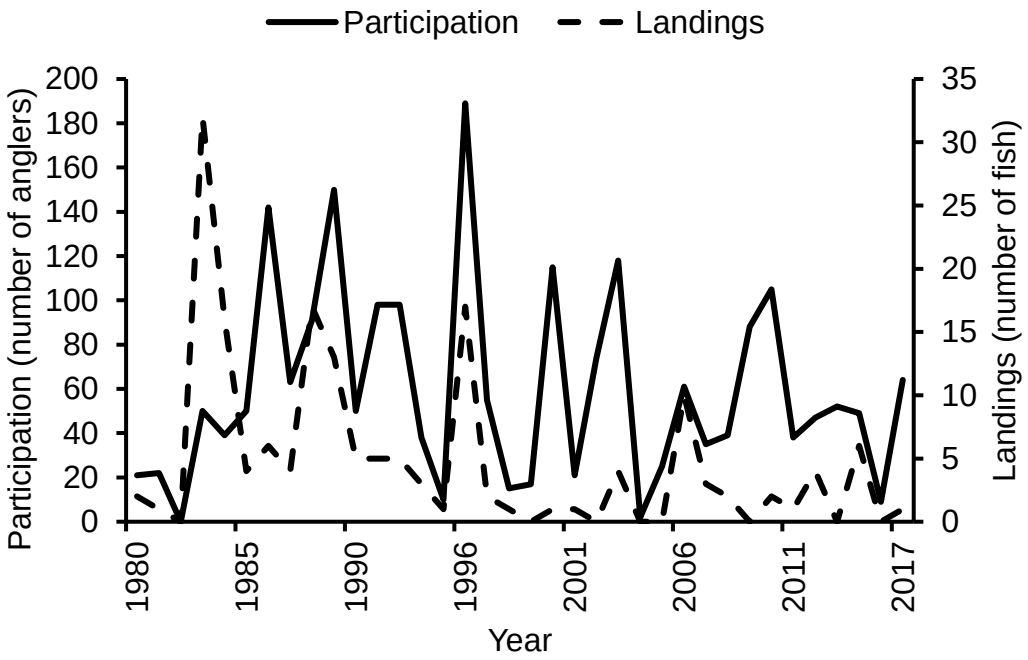

Figure 2-4. Participation (number of anglers) aboard CPFV trips where at least one Pacific Angel Shark was caught and landings from all ports in number of fish kept from 1980 to 2017 (CDFW MLS 2018).

2.3.2 Commercial

Commercial landings of Pacific Angel Shark were minor prior to 1978 but swiftly rose in the early 1980s from 269,000.0 lb (122,016.2 kg) in 1981 to over 1 million lb (453,592 kg) and an ex-vessel value of over $500,000 annually in 1985 and 1986, replacing the Thresher Shark as the number one species of shark taken for food in California (Bedford 1987; Leet et al. 2001) (Figure 2-5).

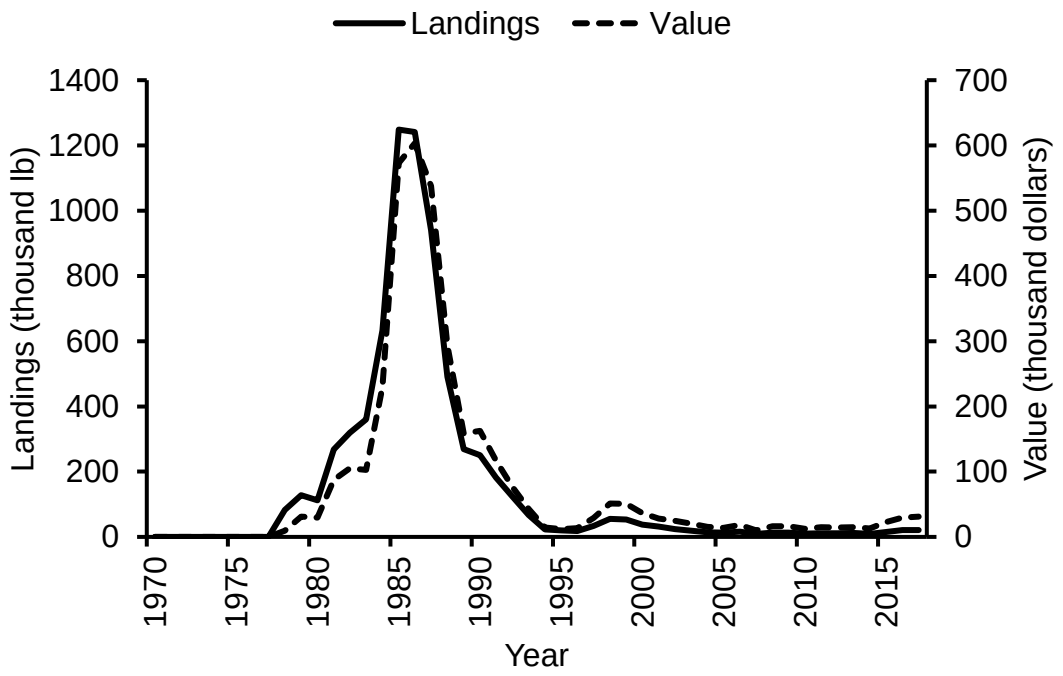

Figure 2-5. Pacific Angel Shark commercial fishery landings (thousand lb) and value (thousand dollars), 1970 to 2017 (CDFW MLS 2018).

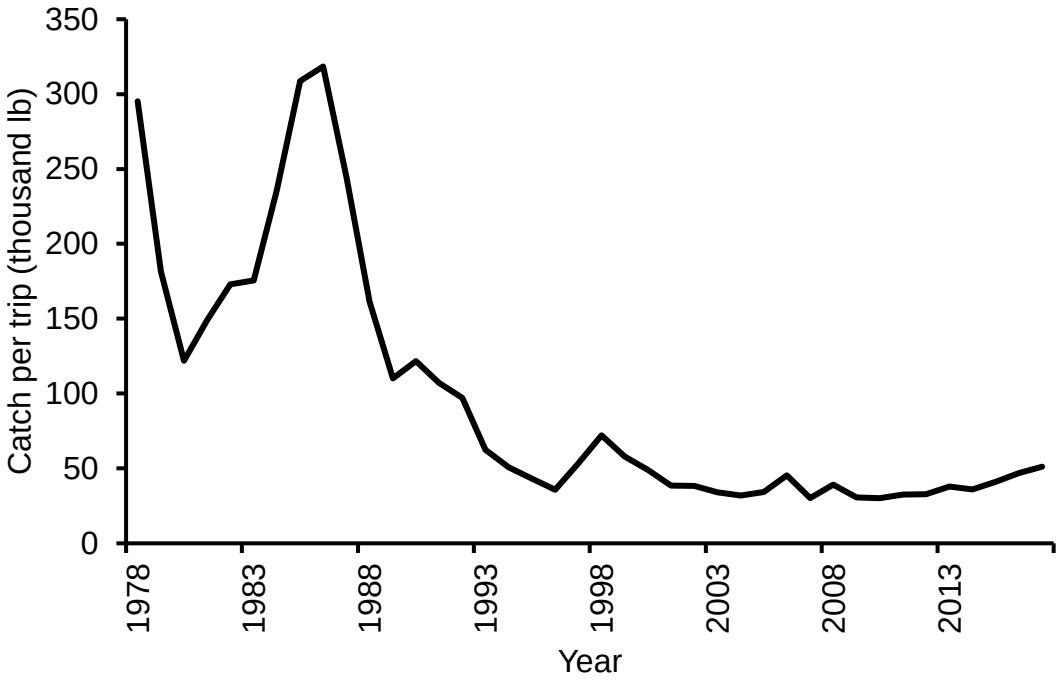

Figure 2-6. Catch per trip of Pacific Angel Shark, 1978 to 2017 (CDFW CFIS 2018).

The majority of these landings were taken in Santa Barbara and Ventura counties (CDFW MLDS). Although some commercial landings were taken by bottom trawl, the majority were taken by set gill net, with 78% of the landings in the 1980s occurring by set gill net and only 22% by bottom trawl (CDFW MLDS). In the second half of the 1980s landings began to decline, dropping from 940,000 lb (426,376.5 kg) in 1987 with an ex-vessel value of $538,000 to 251,000 lb (113,851.6 kg) and an ex-vessel value of $163,000 in1990 (Figure 2-5). This was likely related to the minimum commercial size limit implemented in 1986 (FGC §8388). A second major decline in landings occurred in 1991 when a voter initiative to ban the use of gill and trammel nets within 3 nautical mi (3.5 mi or 5.6 km) of the southern California mainland coast and within 1 mi (1.6 km) around the Channel Islands was passed (FGC §8610 et seq.). In addition, the primary processing plant for Angel Shark closed in 1992. Many gill netters switched to other fisheries, left or retired (Leet et al. 2001). By 1994, the catch had declined 91% from 1990 with vessels landing 23,000 lb (10,432.6 kg) and $14,000 in ex-vessel value) of Pacific Angel Shark (Figure 2-5). There was a small increase in landings between 1998 and 1999, reaching over 50,000 lb (22,679.6 kg) ($51,000 in ex-vessel value), but landings have remained below 30,000 lb (13,607.8 kg) since 2002 with a total of 21,000 lb ($31,156 in ex-vessel value) landed in 2017 (CDFW MLDS). Trends in catch per unit effort match those observed in the landings (Figure 2-6) indicating the drop in catch is not simply due to a drop in the number of targeted trips. In 2017, the method of commercial fishing remains primarily bottom set gill net from boats in Ventura and Santa Barbara counties, with 84% of commercial landings taken by set gill net and 16% taken by bottom trawl (CDFW MLDS) (Figure 2-7).

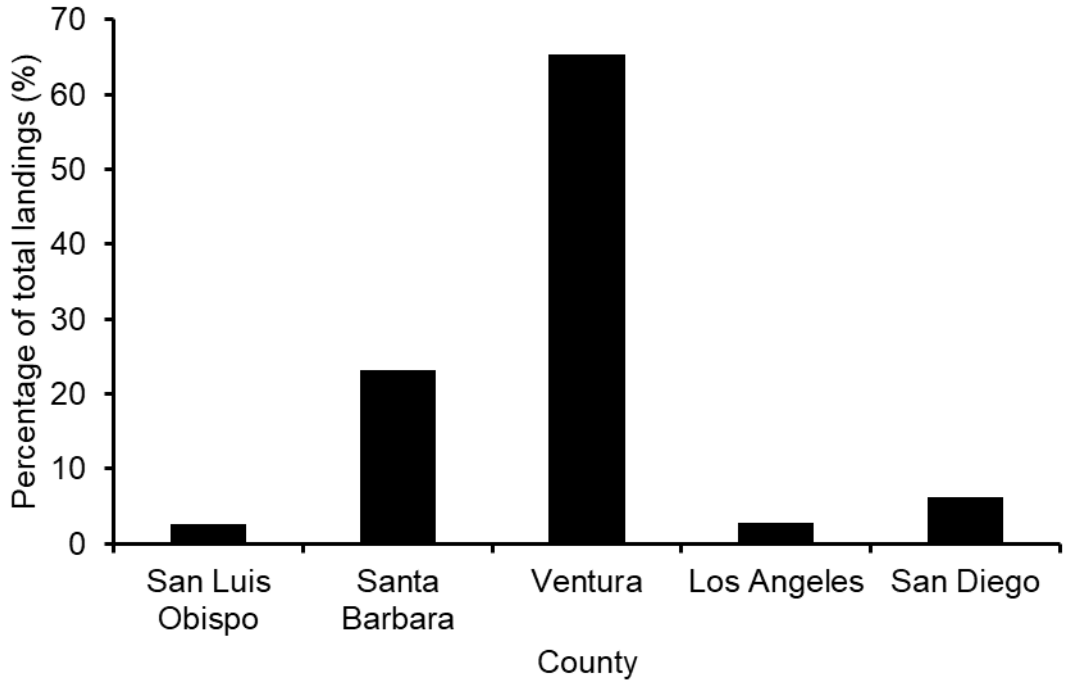

Figure 2-7. Percentage of total commercial landings of Pacific Angel Shark by county in 2017 (CDFW MLS 2018).

2.4 Social and Economic Factors Related to the Fishery

Despite being a good quality fish for consumption, Pacific Angel Shark were originally discarded as a bycatch species because filleting the fish was difficult due to their tough skin and irregular body shape. After a seafood broker and processor in Santa Barbara developed a method of filleting in 1977 (Bedford 1987), almost every part of the shark was found in markets (Leet et al. 2001). The head and fins are sold as crab bait, fillets are cut from the trunk and tail and used in fish and chips dishes, and smaller pieces are used to make shark jerky. Fish were originally processed in Santa Barbara and marketed locally, but following the inshore gill net ban and subsequent relocation of the major processing plant to the Gulf of California in the early 1990s (Leet et al. 2001), Pacific Angel Shark have mainly been caught and processed in Mexico.

In 1978 the average ex-vessel unit price for Pacific Angel Shark was 16 cents per pound, rising to 44 cents per pound in 1985 as demand increased (CDFW MLDS). Prices increased to 64 cents in 1991 and 91 cents in 1999, but remained between $1.00 and $1.50 from 2002 to 2017 (Table 2-1). Mexican imports totaled over 413,000 lb (187,333.5 kg) in 1999, and they provided 87% of the market share for the state of California (Leet et al. 2001). This indicates the market demand for Pacific Angel Shark remained high in the late 1990s despite the fishery shifting south to Mexico. Following the surge in fishing effort in Mexico, landings of Pacific Angel Shark declined rapidly and in surveys done in Baja California between 2000 and 2010 they were absent from the catch in areas where they were once common. These surveys raised concerns that the species may be in serious decline in Mexico (Ramírez-Amaro et al. 2013).

Table 2-1. Poundage, ex-vessel value, and price per pound for Pacific Angel Shark, 2000 to 2017 (CDFW MLDS 2018).

Year	Pounds (thousands)	Ex-vessel value	Price per pound
2000	37	$36,642	$0.96
2001	31	$28,037	$0.89
2002	24	$24,916	$1.02
2003	19	$20,170	$1.07
2004	14	$15,330	$1.06
2005	13	$14,018	$1.12
2006	16	$18,373	$1.08
2007	9	$10,014	$1.09
2008	13	$16,542	$1.17
2009	13	$16,182	$1.24
2010	10	$12,433	$1.23
2011	11	$15,121	$1.29
2012	11	$14,220	$1.18
2013	12	$14,697	$1.21
2014	9	$12,935	$1.45
2015	15	$22,742	$1.50
2016	21	$29,580	$1.38
2017	21	$31,156	$1.38

The Pacific Angel Shark fishery is of low economic value relative to other California fisheries. As of 2018, Pacific Angel Shark provide supplemental income to gill netters targeting California Halibut in federal waters, especially at ports in Ventura and Santa Barbara counties, but they are not a target species since their primary habitat is farther inshore. In 2017, the ex-vessel price was $1.38 per pound and the Pacific Angel Shark fishery was worth $31,156 with 23% of the landings occurring in Santa Barbara County and 65% of the landings occurring in Ventura County (Figure 2-6).

3 Management

3.1 Past and Current Management Measures

A minimum size limit for commercial landings was adopted by the Department in 1986 due to concerns about the status of the stock, although anglers and biologists suggested that the regulation was implemented too late to achieve a sustainable yield following the high levels of harvest in the early 1980s (Leet et al. 2001). The ban on gill and trammel nets within 3.0 mi (4.8 km) of the California mainland coast and within 1.0 nautical mi (1.85 km) around the Channel Islands in 1994 (FGC §8610 et seq.), although not targeted at Pacific Angel Shark, effectively created a large no-take reserve for the species in its primary habitat.

3.1.1 Overview and Rationale for the Current Management Framework

Since Angel Shark are common throughout California, are not frequently targeted or retained in the recreational fishery, and commercial take was greatly reduced with the banning of nearshore gill nets in 1994, no fishery management plan or harvest control rules are currently in place for this species. Commercial landings of Pacific Angel Shark are monitored using data from the Department's MLDS, which are reported through landing receipts. Landings data in the recreational fishery are recorded on CPFV logbooks and by California Recreational Fisheries Survey (CRFS) samplers. Stock health is monitored based on fluctuations in reported landings and discards from these sources.

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

There are no formal overfishing threshold criteria for Pacific Angel Shark. However, landings are tracked in both the commercial and recreational sectors, and given the low landings that have occurred since the ban on gill net and trammel nets in the early 1990s there are currently no concerns about overfishing occurring in this stock. Based on this available data it appears the current management is effective. Although if landings increase significantly or if it appears anglers begin targeting Pacific Angel Shark, this may indicate the fishery needs management changes to ensure sustainability.

3.1.1.2 Past and Current Stakeholder Involvement

Stakeholders were likely involved in the implementation of the 1986 minimum size limit (FGC §8388) as part of standard public hearings. Due to the incidental nature of the fishery and the lack of management changes in recent years there has been no opportunities for stakeholder input. However, should a management change be needed stakeholders will be given the opportunity to comment on the proposed change.

3.1.2 Target Species

3.1.2.1 Limitations on Fishing for Target Species

3.1.2.1.1 Catch

The default limit for recreational anglers is no more than ten fish of a single species. No catch limit exists for the commercial Pacific Angel Shark fishery. The public are advised not to eat Pacific Angel Shark caught in Tomales Bay and to limit their consumption to three servings per week for those taken from Mission Bay due to high levels of mercury (CDFW 2019 California Ocean Sportfish Regulations).

3.1.2.1.2 Effort

There are no regulatory limitations on effort. However, a permit is required to use a set gill net for commercial take (see section 3.1.2.2), and this is the primary gear type used to take Angel Sharks.

3.1.2.1.3 Gear

There are gear restrictions placed on the commercial California Halibut set gill net fishery which lands Pacific Angel Shark, including minimum mesh size and total maximum net length: “(a) Except as otherwise provided in this code, set gill nets and trammel nets with mesh size of not less than 8 ½ inches may be used to take California halibut. (b) Except as provided in subdivision (c), not more than 1,500 fathoms (9,000 feet) of gill net or trammel net shall be fished in combination each day for California halibut from any vessel in ocean waters. (c) Not more than 1,000 fathoms (6,000 feet) of gill net or trammel net shall be fished in combination each day for California halibut from any vessel in ocean waters between a line extending due west magnetic from Point Arguello in Santa Barbara County and a line extending 172° magnetic from Rincon Point in Santa Barbara County to San Pedro Point at the east end of Santa Cruz Island in Santa Barbara County, then extending southwesterly 188° magnetic from San Pedro Point on Santa Cruz Island” (FGC §8625).

Minimum mesh sizes for commercial trawl and set gill nets allow small reproductively immature fish to avoid capture through appropriate mesh openings, which allows for the chance to reproduce before being harvested. This mesh size also reduces the amount of bycatch. Restrictions on set gill net length limits catch of the target species – also reducing bycatch.

3.1.2.1.4 Time

The Pacific Angel Shark fishery is open year-round.

3.1.2.1.5 Sex

There are no restrictions based on the sex of Pacific Angel Shark, and thus either sex may be retained.

3.1.2.1.6 Size

A commercial size limit established in 1986 requires “No female angel shark measuring less than 42 inches in total length or 15 ¼ inches in alternate length and no male angel shark measuring less than 40 inches in total length or 14 ½ inches in alternate length may be possessed, sold, or purchased, except that 10 percent of the angel sharks in any load may measure not more than ½ inch less than the minimum size specified herein” (FGC §8388(a)). This measure was created to ensure that sharks had a chance to reproduce at least once before being retained in the catch.

3.1.2.1.7 Area

There are no restrictions on where Pacific Angel Shark may be fished other than within Marine Protected Areas (MPAs). However, set gill netting, the primary fishing method for this species may only occur outside of state waters (i.e. outside of 3 mi (4.8 km) from the mainland and 1 mi (1.6 km) from the Channel Islands).

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.

Although the MPAs were not designed to expressly benefit habitat of the Pacific Angel Shark, which is primarily soft-bottom sand or muddy habitat from shallow water out to 30 m (100 ft) depth, several do contain this habitat. To date, none of the MPAs have been surveyed for the relative abundance of Pacific Angel Shark. Vandenberg State Marine Reserve (SMR) in Santa Barbara County is the largest MPA containing habitat specific to Pacific Angel Shark, including 19.6 square nautical miles (nm^2) (36.3 square kilometer (km^2)) of soft bottom habitat in less than 30 m (98.4 ft) depth. In the South Coast Region, 145.5 nm^2 (269.5 km^2) of soft-bottom habitat is protected by state MPAs, though only 28 nm^2 (51.9 km^2) of this habitat is in the 0 to 30.0 m (0 to 98.4 ft) depth range. Of the South Coast MPAs, Carrington Point SMR off of Santa Rosa Island covers the most potential Angel Shark habitat, protecting 7.1 nm^2 (13.1 km^2) of soft bottom habitat in 0 to 30.0 m (0 to 98.4 ft) depth.

3.1.2.2 Description of and Rationale for Any Restricted Access Approach

The commercial set gill net fishery has restricted access, which was introduced as part of the regulations on the use of gill nets in 1990 (FGC §8610 et seq.). These regulations were developed in response to extensive bycatch of seabirds and marine mammals in central California’s set gill net fisheries (Forney et al. 2001). Gill net anglers must be experienced in the use of those nets (FGC §8680(a)) and they must obtain a permit and keep an accurate record of fishing operations by logbook (FGC §8681(a)).

No new gill net permits may be issued (FGC§8681.5(a)), but they may be transferred to a qualified person for a fee no greater than the permit fee (FGC §8682) as long as they remain in use (FGC §8682). As of 2017, 122 general gill net permits remain for the commercial Halibut set gill and trammel net fishery, and 19 of these had Pacific Angel Shark landings (CDFW MLDS).

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.

Recreational Bycatch

Pacific Angel Shark are not specifically targeted by recreational anglers, and most are discarded. RecFIN estimates suggest most discards from private/rental boats occur in southern California (Orange, Los Angeles and San Diego counties). An estimated average of 69 angel shark were released annually from private/rental boats between 2005 and 2017 (Figure 3-1). Fewer Pacific Angel Sharks are discarded from CPFVs, with an average of 37 estimated to be released annually over the same time period (Figure 3-1) (CDFW RecFIN). Some Pacific Angel Sharks are also discarded from man-made/jetty and beach/bank fishing modes, but the number of anglers sampled from these modes is too low to generate accurate estimates. All Pacific Angel Sharks observed were released alive in the recreational fishery (RecFIN). There is limited size information available on discarded fish and too few Pacific Angel Shark are sampled to get an accurate size distribution (RecFIN). Given their slow growth, late maturity and small litter size, discard mortality could have a negative effect on the population if the number of discards were to increase. No estimate of post-release discard mortality is available for this species however, so it is unknown what proportion of discards survive.

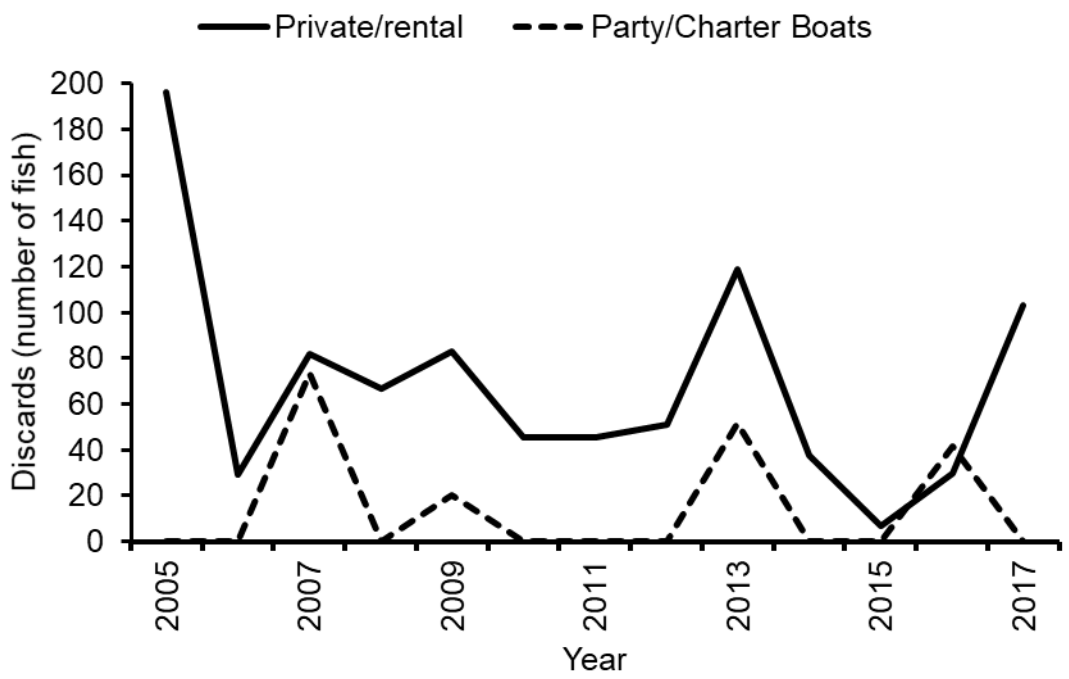

Figure 3-1. Estimated discards (number of fish) for Pacific Angel Shark from private/rental and party/charter modes, 2005 to 2017 (CDFW RecFIN 2018).

Commercial Bycatch

The most frequent catch and bycatch species as recorded by federal observers in the set gill net fishery for California Halibut in southern California between 2007 and 2017 are listed in Table 3-1. Other than California Halibut and Pacific Angel Shark, Pacific Mackerel (*Scomber japonicus*), other sharks, skates and rays were the most abundant finfish species in the catch (Table 3-1). Several species of crab, sea stars and whelks were the most common invertebrates in the catch (Table 3-1). Most non-target species were discarded, as listed in Table 3-1. Although Pacific Angel Shark are a target species in the set gill net fishery, on many observed trips more than half of them are discarded. In 2017, 67% of Pacific Angel Shark observed in the Halibut set gill net fishery were discarded (88 fish were discarded from 151 sets) (Charles Villafauna, personal communication). These discards may include both legal and sublegal fish of the target species, however since the length data are unavailable, it is unknown whether the discards from the gill net fishery are sublegal fish or unwanted catch. Additionally, since only a subset of trips is sampled, the total number of angel sharks discarded from set gill net catch is also unknown. Currently, target species discards are not a concern for Pacific Angel Shark, but if the number of discarded Pacific Angel Shark increased and/or they are found to suffer substantial post-release discard mortality, this unaccounted mortality could require additional management attention to ensure the sustainability of the stock.

Table 3-1. Most frequently observed finfish species associated with the California Halibut (and by default Pacific Angel Shark) gill net fishery as retained catch and discards, 2007 to 2017 (WCGOP 2018). Counts based on observations of 553 gill net sets.

Common name (Finfish)	**Scientific name**	**Count**	**% of catch**	**Total % discarded**
Pacific Mackerel	*Scomber japonicus*	2227	21.9	91
California Halibut	*Paralichthys californicus*	1050	10.3	9
Bat Ray	*Myliobatis californica*	631	6.2	54
California Skate	*Raja inornata*	487	4.8	78
Pacific Angel Shark	*Squatina californica*	428	4.2	43
Longnose skate	*Raja rhina*	341	3.4	81
Spotted Ratfish	*Hydrolagus calliei*	168	1.7	100
Swell Shark	*Cephaloscyllium ventriosum*	156	1.5	82
Leopard Shark	*Triakis semifasciata*	149	1.5	28
Spiny Dogfish	*Squalus acanthias*	103	1.0	63
Common name (Invertebrates)	**Scientific name**	**Count**	**% of catch**	**Total % discarded**
Rock Crab	*Cancer atennarius*	981	9.7	78
Spider Crab	*Majidae spp.*	783	7.7	69
Box Crab	*Lopholithodes foraminatus*	480	4.7	96
Sea Star	*Echinodermata spp.*	234	2.3	100
Whelk	*Kelletia kelletii*	205	2.0	65
Red Rock Crab	*Cancer productus*	161	1.6	99
Yellow Rock Crab	*Cancer anthonyi*	81	0.8	98
Unidentified Crab		59	0.6	100

There is limited information on the bycatch associated with the southern California trawl fishery for California Halibut, which lands a small proportion of Pacific Angel Shark. Most bottom trawls that catch angel sharks occur in state waters in the California Halibut Trawl Grounds (CHTG) and few federal observers are assigned to these boats. In 2008 the Department conducted a fishery-independent trawl survey targeting Halibut within the CHTG (Bell and Tanaka 2008) with a contracted commercial fishing vessel. All trawl tows were observed, and all fish were enumerated to species. A total of 635 fish were observed, representing 38 species. Fifteen species were observed in addition to Halibut where each species comprised at least 1% of the total finfish catch (Table 3-2). Pacific Angel Shark were tenth most commonly observed species and other common species included flatfish, sharks, skates and rays. Further observations of the trawl fishery would be required to determine if the number of Pacific Angel Shark discarded from the southern California Halibut trawl fishery pose a resource concern.

Table 3-2. Most frequently observed species (in order of rank) associated with California Halibut trawl gear, in decreasing frequency of occurrence, from Department fishery-independent bottom trawl surveys where Pacific Angel Shark were landed in the CHTG, 2008.

Common name	Species
Shovelnose Guitarfish	*Rhinobatos productus*
California Skate	*Raja inornata*
Longspine Combfish	*Zaniolepis latipinnis*
Pink Seaperch	*Zalembius rosaceus*
Thornback Ray	*Raja clavata*
Brown Smoothhound	*Mustelus henlei*
Hornyhead Turbot	*Pleronichthys verticalis*
Pacific Sanddab	*Citharichthys sordidus*
English Sole	*Parophrys vetulus*
Pacific Angel Shark	*Squatina californica*
White Croaker	*Genyonemus lineatus*
Fantail Sole	*Xystreurys liolepis*
California Scorpionfish	*Scorpaena guttata*
Pacific Electric Ray	*Tetronarce californica*
Queenfish	*Seriphus politus*

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

To minimize unacceptable levels of bycatch, the MLMA requires the Department to manage every recreational and commercial marine fishery in a way that limits bycatch to acceptable types and amounts (FGC §7056(d)). Once the magnitude and disposition of bycatch have been identified, the next step is to determine if that bycatch is acceptable. There is also no formal method for determining acceptable levels of bycatch for Pacific Angel Shark, so whether or not the bycatch discussed here is a resource issue is unknown. However, the mesh size limits and area restrictions likely reduce bycatch levels in this fishery.

Fishes

Many of the species identified as bycatch in the gill net fishery are managed under federal or state fishery management plans. West Coast Groundfish Observer Program (WCGOP) data show several species are discarded dead from set gill nets that have life history strategies vulnerable to overfishing (i.e. late maturing and producing few young), including Soupfin Shark (*Galeorhinus galeus*), Leopard Shark (*Triakis semifasciata*) and Swell Shark (*Cephalosycllium ventriosum*). Soupfin Shark and Leopard Shark are managed by a federal FMP. Swell Shark are a state-managed species, but there is no directed fishery for them so the level of bycatch is not a concern.

Only one species that is critically endangered, the Giant Sea Bass (*Stereolepis gigas*), was included in the Halibut set gill net bycatch. Eleven were observed by the WCGOP from 2007 to 2017 with nine retained and two discarded. There is no official estimate of the total population size of Giant Sea Bass in California, but the number occurring as bycatch were not considered a resource concern in 2018.

Mammals and Birds

Gill nets capture sea birds such as cormorants and marine mammals such as the California Sea Lion, sea otters, porpoises and harbor seals (Julian and Beeson 1998). Observer data is very sporadic for seabird and marine mammal bycatch in the California Halibut trawl and set gill net fisheries that catch Pacific Angel Shark, so their relative impact on these species is poorly defined. Based on the most recent observer data reported from 2012, an estimated 326 sea lions and 72 cormorants were caught as bycatch in the California Halibut and White Seabass set gill net fishery that year (Carretta et al. 2014). Under the Marine Mammal Protection Act participants in these fisheries must obtain a marine mammal authorization certificate each year from the National Oceanic and Atmospheric Administration (NOAA) and are required to report within 48 hours all incidental deaths or injuries of marine mammals during commercial fishing operations to NOAA Fisheries. They must also accommodate observers onboard their vessels upon request.

3.1.4 Habitat

3.1.4.1 Description of Threats

There are no major known threats to the sand and mud soft-bottom habitat where Pacific Angel Shark live. If organisms are present on the seafloor then weights on the bottom of set nets can snag the structure of the habitat and pull up or break fragile species (Auster 1998) and bottom trawl gear can kill biogenic habitats and burrowing species (Bergman and Santbrink 2000). There are no major effects of set gill nets or trawl gear on sandy bottom habitat given there is no complex habitat, either reef or algal, that may be damaged by these gear types. There is no information at this time on lost gear and its associated habitat impacts.

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

The area restriction on set gill nets protect a substantial amount of soft-bottom habitat from any adverse effects of fishing within three nautical miles of the mainland and one nautical mile of the islands. There are no gear restrictions on set gill nets in California to mitigate habitat interactions. For bottom trawling, the trawl area is limited to the California Halibut trawl grounds and boats are required to use light touch gear (FGC §8494 to §8497). Footrope regulations and closures of Essential Fish Habitat areas also protect sensitive habitat from trawl gear (§27.51, Title 14, California Code of Regulations (CCR).

3.2 Requirements for Person or Vessel Permits and Reasonable Fees

Commercial Fishery

There are no specific permits for the Pacific Angel Shark fishery. Personal fishing licenses, gear permits, and vessel permits are required to fish for Pacific Angel Shark depending on the fishery sector. A commercial fishing license is required to target Pacific Angel Shark for commercial purposes, regardless of gear type. If a vessel is used to commercially target Pacific Angel Shark, then the vessel must be registered as a commercial fishing vessel. Fishers using gill nets to land Pacific Angel Shark are additionally required to obtain an annual limited entry and restricted access gill net permit, as well as submit a complete and accurate record of fishing activities on forms provided by the Department. The most current license options and fees for the commercial fishery (Table 3-3) may be accessed at https://www.wildlife.ca.gov/Licensing/Commercial/Descriptions.

Table 3-3. Annual commercial fishing license fees from January 1 to December 31, 2019. Accessed June 20, 2019 at https://www.wildlife.ca.gov/Licensing/Commercial/Descriptions.

License	Cost	Requirement
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 years 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 Ocean Enhancement Stamp	$54.08	Required for commercial passenger fishing vessels operating south of Point Arguello (Santa Barbara County). Any commercial fisherman who takes, possesses aboard a commercial fishing vessel, or lands any White Seabass south of Point Arguello.
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.
Gill/Trammel Net Permit	$498.25	Required for the owner or operator of a registered commercial fishing vessel to use a gill or trammel net. At least one person aboard each commercial fishing vessel must have a valid general gill net permit when engages in operations authorized by the permit.

Recreational fishery

Unless recreationally fishing off a public pier, all anglers 16 yr-old or older are required to purchase a fishing license to fish for Pacific Angel Shark. Anglers fishing south of Point Arguello must also have an ocean enhancement validation. Captains operating their vessels as CPFVs or private charters must purchase a permit. In 2019,

the cost of an annual resident sport fishing license is $49.94 and an ocean enhancement validation is $5.66 (Table 3-4). The most current license options and fees for the recreational fishery may be accessed at https://www.wildlife.ca.gov/Licensing/Fishing and https://www.wildlife.ca.gov/Licensing/Commercial/Descriptions.

Table 3-4. Annual sport fishing license fees from January 1 to December 31, 2019. Accessed June 20, 2019 at https://www.wildlife.ca.gov/Licensing/Fishing and https://www.wildlife.ca.gov/Licensing/Commercial/Descriptions.

License	Fee	Description
Commercial Passenger Fishing Vessel License	$379.00	Required for any boat from which persons are allowed to sport fish for a fee.
Resident Sport Fishing	$49.94	Required for any resident 16 years of age or older to fish.
Nonresident Sport Fishing	$134.74	Required for any non-resident 16 years of age or older to fish.
Ocean Enhancement Validation	$5.66	Required to fish in ocean waters south of Point Arguello (Santa Barbara County). An Ocean Enhancement Validation is not required when fishing under the authority of a One or Two-Day Sport Fishing License.
Reduced-Fee Sport Fishing License – Disabled Veteran	$7.47 at CDFW offices. $7.82 from license agents	Available for any resident or non-resident honorably discharged disabled veteran with a 50 percent or greater service-connected disability. After you prequalify for your first Disabled Veteran Reduced-Fee Sport Fishing License, you can purchase disabled veteran licenses anywhere licenses are sold.
Reduced-Fee Sport Fishing License – Recovering Service Member	$7.47	Available for any recovering service member of the US military. The Recovering Service Member Reduced-Fee Sport Fishing License is only available at CDFW License Sales Offices.
Reduced-Fee Sport Fishing License – Low Income Senior	$7.47	Available for low income California residents, 65 years of age and older, who meet the specified annual income requirements. The Reduced-Fee Sport Fishing License for Low Income Seniors is only available at CDFW License Sales Offices.

4 Monitoring and Essential Fishery Information

4.1 Description of Relevant Essential Fishery Information

FCG §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”. This section summarizes the EFI that is routinely collected and used to monitor the health of the Pacific Angel Shark stock.

Fishery-dependent data on commercial landings of Pacific Angel Shark are collected by the Department via landing receipts and logbook data. FGC §8043 requires every commercial fisherman that lands fish, and every person that is licensed as a fish receiver, submit a landing receipt. Additional data on the commercial catch of Pacific Angel Shark are obtained by federal observers under the WCGOP, which conducts onboard sampling of catch and discards on gill net boats.

Fishery-dependent data on the recreational fishery for Pacific Angel Shark are recorded on CPFV logbooks and collected for all fishing modes by the CRFS staff.

4.2 Past and Ongoing Monitoring of the Fishery

4.2.1 Fishery-dependent Data Collection

Commercial Fishery

California gill net logbooks are a mandated system for commercial fishers to record fishing locations, time, depth, net length, mesh size, buoy line depth, soak time, total catch by species, market category, gear used, and information about the vessel and crew. These data are used by fishery managers to track the amount of fish landed and where the fishery is focused. California gill net logbooks are collected by the Department, edited and entered by federal and state staff and entered into a database. However, the data collected from these logbooks are often inaccurate due to self-reporting, and frequently do not contain information on incidentally caught species such as Pacific Angel Shark. For this reason this data stream is not very informative, and is not currently used in the management of this fishery.

Fishery managers and enforcement officers use state-issued sales receipts, referred to as fish tickets or landing receipts, to monitor fishery landings. Landing receipt data are transferred to the Pacific Coast Fisheries Information Network regional database system by state fishery agencies in Washington, Oregon, and California. Beginning in July 2019, landing receipt data must be submitted electronically. In California, this information is housed in the MLDS. Landing receipts record the weight of the fishes landed, price paid to the fishermen, date the fish were landed, type of gear used, port of landing and the fishing block location where the fish were harvested.

Federal fishery observers (via the WCGOP) monitor effort and landings, including the species makeup of both retained and discarded species, allowing for close monitoring of bycatch levels to ensure that they remain within acceptable levels

(Somers et. al 2018). Observers record the start time, end time, starting location, ending location, and depth of tows, as well as the gear type and fish ticket number corresponding with each trip. For each net deployment, observers record total catch weight, weight of discards by category, size composition of discards, reason for discards, species composition of discards, and the weight of the retained catch. They also note the catch of prohibited or protected species. Biological data are also collected, including the length frequency distribution.

Recreational Fishery

Catch data for the recreational fishery are provided by two sources: (1) CPFV logbooks within the Department's MLS database and, (2) CRFS estimates on all fishing modes available from the RecFIN website.

CPFV logbook data are important for monitoring long-term trends in the catch of party boats. Beginning in 1935, CPFV operators were required to keep daily catch logs and submit them to the Department on a monthly basis. These data have been collected continuously as of 2018, except for the years during World War II (1941 to 1946) when most CPFVs were not fishing (Hill and Schneider 1999). Logbook data have always included the date of fishing, port code, boat name, Department fishing block, angler effort and the number of fish kept by species, and after 1994 included discarded fish, bait type and Sea Surface Temperature (SST). These data are accessible to Department scientists as part of the MLS database.

4.2.2 *Fishery-independent Data Collection*

CRFS data provide essential, standardized data for the recreational fishery. Current CRFS estimates (2004 to 2018) use catch and effort data collected by samplers from all fishing modes (beach/bank, man-made structures, private/rental boats, and CPFVs). In addition to the data listed above, CRFS also collects size (length and weight) information on kept fish. Numbers of discards are also recorded for all modes and discard lengths are obtained opportunistically on CPFVs. From 1980 to 2003, catch and effort data on all fishing modes were collected by the federal Marine Recreational Fisheries Statistical Survey (MRFSS) conducted by the National Oceanic and Atmospheric Administration. Estimates from CRFS and MRFSS are not directly comparable due to differences in methodology.

No known targeted fishery-independent studies routinely monitor the abundance of Pacific Angel Shark in California. Incidental monitoring of angel shark may occur in any fishery-independent studies targeting California Halibut using trawl or gill net gear such as the bycatch study for halibut gear done in 2008 (Bell and Tanaka 2008) and a long-term monitoring study started in 2018 by the Department to assess the abundance of California Halibut in southern California waters.

5 Future Management Needs and Directions

5.1 Identification of Information Gaps

Information gaps have been identified that could assist in the overall management of the fishery. More information on mortality, size distribution, indices of abundance, recruitment indices, discard indices, and population structure would all be valuable for management.

Table 5-1. Informational needs for Pacific Angel Shark and their priority for management.

Type of information	Priority for management	How essential fishery information would support future management
Discard mortality – post release	High	Used to determine whether high rates of discarded fish pose a threat to the population.
Size distribution	High	Used to monitor the health of the population (e.g. whether there is an even distribution of older reproductively mature fish and successful cohorts of younger/juvenile fish recruiting to the population).
Fishery independent index of abundance	Medium	Used to determine relative abundance of Pacific Angel Shark. Unlike fishery-dependent data, this information is not affected by fluctuation in market price, regulation changes etc.
Recruitment index	Medium	Used to monitor the number of young fish entering the population and whether this is affected by climate shifts and other large-scale changes to the ecosystem. This information can help forecast fluctuations in abundance.
Discard index (southern California trawl fishery)	Medium	Used to assess the impact of trawl fishery on Pacific Angel Shark (e.g. whether there is high degree of discard mortality).
Population structure in California and northern Mexico	Low	Used to determine how many stocks of Pacific Angel Shark exist and whether to manage them as a single population or as multiple units.

5.2 Research and Monitoring

5.2.1 Potential Strategies to Fill Information Gaps

A fishery-independent index of abundance could be gathered through annual surveys using divers in shallow waters less than 20 m (65.6 ft) or by using remotely operated vehicles at indicator sites near rocky reefs in areas where Pacific Angel Shark are historically abundant. Focal areas for surveys would be sandy inshore habitat of islands and the mainland in southern California. Recruitment data could also be sampled through similar visual survey methods to quantify young of the year fish, since there is no planktonic phase for Pacific Angel Shark young. Assessing the rate of discards in the southern California trawl fishery could be addressed by deploying more fishery observers on boats in the CHTG. To determine population structure, DNA samples from Pacific Angel Shark throughout California and northern Mexico would

need to be collected for genetic analysis. An estimate of discard mortality could be obtained by catching Pacific Angel Shark on hook and line and/or in a gill net and monitoring their reaction in a controlled setting, or via tagging captured fish and recapturing them, either physically or visually over a measured time period to record post-release mortality. A better estimate of the size distribution of Pacific Angel Shark could be collected with directed effort by fishery observers to collect length data on a larger portion of the set gill net 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 academic organizations, non-government 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. Several of the information gaps identified above are potential areas for collaboration. Developing a fishery independent index of abundance, collecting DNA samples, assessing size-frequency distribution, and estimating discard mortality are good subjects for collaborative studies on Pacific Angel Shark involving a variety of stakeholders.

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.

No management changes are suggested at this time for Pacific Angel Shark. The inshore gill net ban in 1994 indirectly but permanently protected the majority of the population from commercial harvest. Additionally, Pacific Angel Shark are not heavily targeted inshore by the recreational fishery. A Productivity Susceptibility Analysis ranked Pacific Angel Shark the least productive finfish, with moderate susceptibility to overfishing (Swasey et al. 2016). Their late maturation and low reproductive rate make them vulnerable to overfishing (Ramirez-Amaro 2017).The California Halibut (and by default: Pacific Angel Shark) commercial gill net fishery ranked highest for its cumulative risk to several bycatch guilds along with the Halibut trawl fishery (Ramanujam et al. 2017). If a resource concern developed for Pacific Angel Shark, a re-evaluation of the minimum size limit might be an option for the Department to consider. As of 2018, there is no directed commercial fishery for Pacific Angel Shark in their primary habitat, so no further action is recommended.

5.4 Climate Readiness

Little is known about how climate change may affect Pacific Angel Shark populations and habitats in the future. To incorporate climate readiness into Pacific Angel Shark management, it is important to increase our understanding of the possible impacts of climate variability. California's coastal waters are already subject to high variability due to episodic events such as ENSO, PDO, and NPGO. Climate change will bring even further uncertainty to these trends, with potentially extreme implications for ecosystem function and fishery sustainability in coastal areas.

Pacific Angel Shark prefer warm temperate waters, with the largest fishery focused in Baja Mexico, as of 2017. As noted in section 1.5, Climate driven fluctuations in ocean temperature may affect the distribution of Pacific Angel Shark in California, perhaps pushing the focus of the population farther north as the SST rises. In addition, warm water years may reduce the growth and reproduction of invertebrate prey such as Market Squid, thus reducing prey availability for Pacific Angel Shark. To manage Pacific Angel Shark populations effectively under climate change, it will be important to take a proactive approach to management. This may entail increased or targeted monitoring of populations and/or placing a higher priority on collecting data to fill in information gaps on the demography and biology of this species.

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