Fishery-at-a-Glance: Pacific Bonito

Scientific Name: *Sarda chiliensis.* Previously classified as subspecies, *Sarda chiliensis* and *Sarda chiliensis lineolata.*

Range: Pacific Bonito (Bonito) range from Chile to the Gulf of Alaska, with the greatest abundance occurring in warm waters between Magdalena Bay, Baja California, Mexico and Point Conception, California.

Habitat: Bonito are a highly migratory, pelagic, schooling fish that occupy habitats ranging from the open ocean to nearshore kelp forests. Younger Bonito spend more time in nearshore surrounding kelp forest habitats, and may even enter bays and harbors, whereas larger individuals are more often found offshore in the coastal, pelagic environment at depths up to 300 feet (91 meters).

Size (length and weight): The largest observed Bonito was 48 inches (121.9 centimeters) and 24.9 pounds (11.3 kilograms).

Life span: Bonito live approximately 6 to 8 years.

Reproduction: Depending on the water temperature, Bonito may not spawn every year in California, but spawning in southern California primarily occurs from late January through May. Bonito are broadcast spawners and have free-floating eggs that take about 3 days to hatch at average spring water temperatures.

Prey: Bonito eat small fishes, such as anchovies and sardines, as well as invertebrates like squid when available.

Predators: Bonito are prey for larger pelagic fishes like Striped Marlin, Bluefin Tuna, Swordfish, and marine mammals such as California Sea Lions and Common Dolphins, and pelagic sharks such as Shortfin Mako and Thresher Sharks.

Fishery: Bonito is primarily targeted by the commercial purse seine fishery and is also a popular recreational fishery in southern California.

Area fished: Fishing for Bonito generally takes place offshore in up to 300 feet of water, but may also occur next to kelp beds when conditions are warm and the fish are near shore.

Fishing season: Bonito generally arrive off the California coast as the ocean temperature warms in the spring, but they may show up later or not at all if there are colder than average ocean temperatures.

Fishing gear: The primary commercial fishing gear used for Bonito is the purse seine, but they are also caught by gill nets. Recreational gear is hook and line, trolling and live bait fishing using anchovies, sardines or squid pieces.

Market(s): Commercially caught Bonito are sold fresh or frozen, or processed by curing or smoking, for human consumption. The market demand for Bonito is relatively low compared to other more desirable tuna species.

Current stock status: There is no current stock assessment for Bonito. Determining an accurate stock status of Bonito off the California coast is challenging as they are not resident species and abundances fluctuate greatly with environmental conditions.

Management: Bonito were removed from the federal Highly Migratory Species Fishery Management Plan in 2011 and are currently managed by the state. Both commercial and recreational fisheries have minimum size limits and restrictions on the amount of take. Based on the available data, and their fast growth rate and high productivity, current management appears to provide enough protection to maintain Bonito's highly variable population off the California coast. Although if landings decrease in warm water periods, when Bonito abundance typically increases, this may indicate the fishery needs management change to protect Bonito from further decline.

1 The Species

1.1 Natural History

1.1.1 *Species Description*

Pacific Bonito (Bonito) (*Sarda chiliensis*) are a temperate coastal pelagic schooling fish. They are a popular recreational as well as commercially caught species off the coast of southern California. Bonito are in the Scombridae family with other species of mackerels and tunas. They have a cigar shaped body with a pointed, conical head and a large mouth. Their color changes from dark blue above fading to silvery below, with a number of dark slanted stripes along their backs (Figure 1-1). They are easily identified, as they are the only tuna-like fishes on the California coast with slanted dark stripes on their backs.

Figure 1-1. Pacific Bonito (Photo Credit: CRFS, CDFW).

1.1.2 Range, Distribution, and Movement

Bonito were previously classified as two separate subspecies, *Sarda chiliensis lineolata* off California occurring from southern Alaska to Banderas Bay, Mexico and *Sarda chiliensis* from Peru to Chile. The subspecies classification was largely based on geographic separation given the gap in the species range from the central coast of Mexico south to Panama. However, molecular analysis does not support the subspecies status, as no genetic difference was detected between the northern and southern populations of Bonito (Vinas et al. 2010). In addition to the geographic separation, the range of the Bonito is split by the occurrence of another Bonito species, the Striped Bonito (*Sarda orientalis*), off Baja California and northern Peru (Figure 1-2). Despite the geographic separation and the population of Striped Bonito occurring within the Pacific Bonito's population range, the Bonito caught off California is classified as one species: *Sarda chiliensis,* ranging from southern Alaska to northern Chile. The northern population of Bonito, which this ESR is primarily based upon, is typically centered between southern California and central Baja California, and shifts northward during warm water periods (Collins et al. 1980).

Figure 1-2. Range of Pacific Bonito, showing the divide in occurrence from southern Baja to northern Peru.

Bonito can migrate up to 600 miles (mi) (966 kilometers (km)) along the coast, moving south in the winter and north in the summer. Bonito can be found at very shallow depths in nearshore environments in kelp forests, bays and the coastal zone up to depths of 300 ft (91 m) offshore in the pelagic environment. Bonito are most abundant within 15 mi (24 km) of the coast, but can also be caught several hundred miles out (CDFG 2010). Younger individuals are typically caught by California fishers near kelp forests within 50 mi (80 km) of the coast and surrounding the islands. A tagging study conducted by the Department beginning in 1968 tagged 11,200 Bonito from Monterey to Baja California (Collins et al. 1980). Tag recovery showed younger Bonito may spend more time nearshore off kelp forests and bays, whereas older individuals migrate further offshore. They also found that heated water discharges from coastal electric generating stations may influence Bonito migration, as young individuals stayed in California for 3 years (yr) in the same heated water where they were originally tagged.

1.1.3 *Reproduction, Fecundity, and Spawning Season*

Bonito are broadcast spawners, releasing large amounts of eggs and sperm into the water column multiple times per season. Spawning typically occurs within a 3 to 5 month period, depending on the year, ranging from February to August. The majority of spawning typically occurs off Baja California at the center of their range, but larval surveys show spawning does occur off southern California in warm water years (Klawe 1961; Yoshida 1975). Studies show 100% of males greater than 19.7 inches (in) (50

centimeters (cm)) or 2 yr of age are mature, whereas 97% of females larger than 21.6 in (55 cm) and over 2 yr of age are mature (Black 1979). Males are typically ready to spawn earlier in the season than females, who limit the duration of the spawning season, and Bonito over 3 yr of age that have been mature for multiple seasons typically begin spawning earlier in the season than fish that have just reached maturity. Mature females can produce from 104,900 to 894,200 free floating eggs per season, which take about 3 days to hatch at average spring water temperatures (Yoshida 1975). Bonito's eggs and larvae occur in the same zone, and are most abundant at 5.0 meters (m) (16.4 feet (ft)) from the surface. Upon hatching the larva is large, approximately 4.0 millimeters (mm) (0.2 in) in length, and grows slightly until day 6 of larval development when the nutritional yolk sac is resorbed and they reach the post-larval stage around 7.2 mm (Yoshida 1975).

There are no defining physical characteristics to distinguish between male and female Bonito, although behavioral and coloring differences have been seen during courtship and spawning. An observational study of Bonito courtship conducted in an aquarium found that, when spawning, females swim in a unique, unpredictable pattern and males follow behind competing for position. While releasing gametes, the successful male and female swim in tight circles. During this time males display a very distinct vertical color barring, whereas females do not exhibit any coloration changes (Magnuson and Prescott 1966). Because Bonito spawning primarily occurs in waters south of California, there is very little information known about aggregations and if populations might be more vulnerable to fishing during this time.

1.1.4 Natural Mortality

Bonito are fast growing and short lived. Their maximum life span is approximately 6 to 8 yr (Campbell and Collins 1975). Determining the natural mortality (*M*) of fish is important in understanding the health of their stocks. Natural mortality of a fish results from all causes of death not attributable to fishing such as old age, disease, predation, environmental stress, etc. Natural mortality is generally expressed as a rate that indicates the percentage of the population dying in a year. Natural mortality along with fishing mortality results in the total mortality operating on a fish stock. Estimating natural mortality is difficult and often relies on evaluation of life history traits. Using the various age and growth parameters, natural mortality for Bonito has been estimated as a range of $M = 0.6$ to 0.8 (Collins et al. 1980).

1.1.5 Individual Growth

Individual growth of fishes is 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 are also appropriate. Bonito grow quickly and within a year they can reach 20 in (51 cm) Fork Length (FL) and weigh up to 4.0 pounds (lb) (1.8 kilograms (kg)). At 2 yr of age the average size is 25 in (64 cm) or 8.0 lb (3.6 kg). At around 6 yr they have reached a maximum size of 32 to 48 in (81 to 122 cm), although individuals over 36 in (91 cm) or

17 to 25 lb (7 to 11 kg) are uncommon. Growth parameters for Bonito have been calculated in three studies by fitting data to a von Bertalanffy growth model:

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

where L_t = length at age, L_∞ = maximum asymptotic length, k = relative growth rate, t = age of fish, and t_0 = theoretical age at time when length is zero. The values of those estimated parameters varied between studies, although two of them used Bonito from the northeastern Pacific and combined sexes (Table 1-1). Bartoo and Parker (1983) used the von Bertalanffy growth equation values provided by Campbell and Collins (1975) and applied a stochastic equation to improve the age-frequency estimations.

Table 1-1. Von Bertalanffy growth parameters for Pacific Bonito in the northeastern Pacific, sexes combined. L_∞ is fork length (cm).

	L_∞	k	t_0
Kuo (1970)	266.1	0.038	-0.60
Campbell and Collins (1975)	76.87	0.6215	-0.41
Bartoo and Parker (1983)	76.87	0.6215	-0.785

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

$$W = aL^b$$

where W is the weight in grams, L is the FL in millimeters, and a and b are estimated parameters. The parameters for Bonito are estimated at a=0.00000762728 and b=3.0892 (Recreational Fisheries Information Network (RecFIN) 2017). On average a legal 24 in (610 mm) Bonito weighs 6.7 lb (3.07 kg).

1.1.6 Size and Age at Maturity

Most females reach maturity around 3 yr, whereas males can mature as young as 1 yr of age. Studies show 100% of males greater than 19.7 in (50 cm) or 2 yr of age are mature, and 97% of females larger than 21.6 in (55 cm) and over 2 yr of age are mature (Black 1979).

1.2 Population Status and Dynamics

The status of Bonito off the California coast is challenging to assess, as both their abundance and spatial extent are highly variable from year to year and dependent on environment conditions such as water temperature. This means that in some years Bonito are present in large numbers in California waters, and in other years they are not, and this variability is reflected in the landings and Catch Per Unit Effort (CPUE). However, because they are a highly productive and fast-growing species, their

populations appear to be stable and while the status of Bonito is unknown, there are no concerns about the population at this time.

1.2.1 Abundance Estimates

The abundance of Bonito off the coast of California is highly variable and dependent on environmental factors, fluctuating naturally in response to decadal oceanographic conditions. The availability of their primary prey species, the Northern Anchovy (*Engraulis mordax*) is also highly affected by oceanographic conditions, which may in turn impact Bonito abundance. From 1962 to 1969, an aerial survey on the apparent abundance of several pelagic fish species including Bonito was conducted (Squire 1972). The total Bonito abundance across the first 4 years was estimated at 238,247 tons and appeared to slightly decline during the survey period. The average weight per school during this time was estimated at 17.1 tons (Squire 1972). Assessing the population of Bonito off the California coast is challenging due to their high mobility and shifting geographic range with varying environmental conditions. There is no current assessment of Bonito populations off California.

1.2.2 *Age Structure of the Population*

The age structure of the Bonito population has not been formally assessed by the Department. However, the size structure of recreational Bonito catch can be used to assess possible changes in age classes occurring in the waters off California over time. Due to their fast growth rates and highly variable abundances off the California coast, the Bonito fishery is comprised of few age classes. A study assessing the age composition of Bonito using Commercial Passenger Fishing Vessel (CPFV) length data from 1972 to 1974 found in some years the fishery exploits a single year-class (Maxwell 1997). They found in 1972, which was a strong year-class, young of the year fish dominated 77% of the catch. The following two seasons the 1972 year class continued to comprise the majority of the fishery. This was before the minimum size limit regulation of 24 in was put into place in 1982, which may decrease the proportion of undersized Bonito being removed from the population, although five undersized Bonito are allowed to be kept. Looking at the size structure of recreational Bonito catch from 2004 to 2018, 94% of the measured landings are from fish under 24 in, with approximately 9 to 31% of these (depending upon sex) being sexually mature (Figure 1-3). A study assessing changes in size of trophy sized pelagic and coastal pelagic fishes found Bonito haven’t displayed any long-term (~50 yr) decreases in size and found trends in trophy-sized individuals were driven by oceanographic conditions (Bellquist et al. 2016).

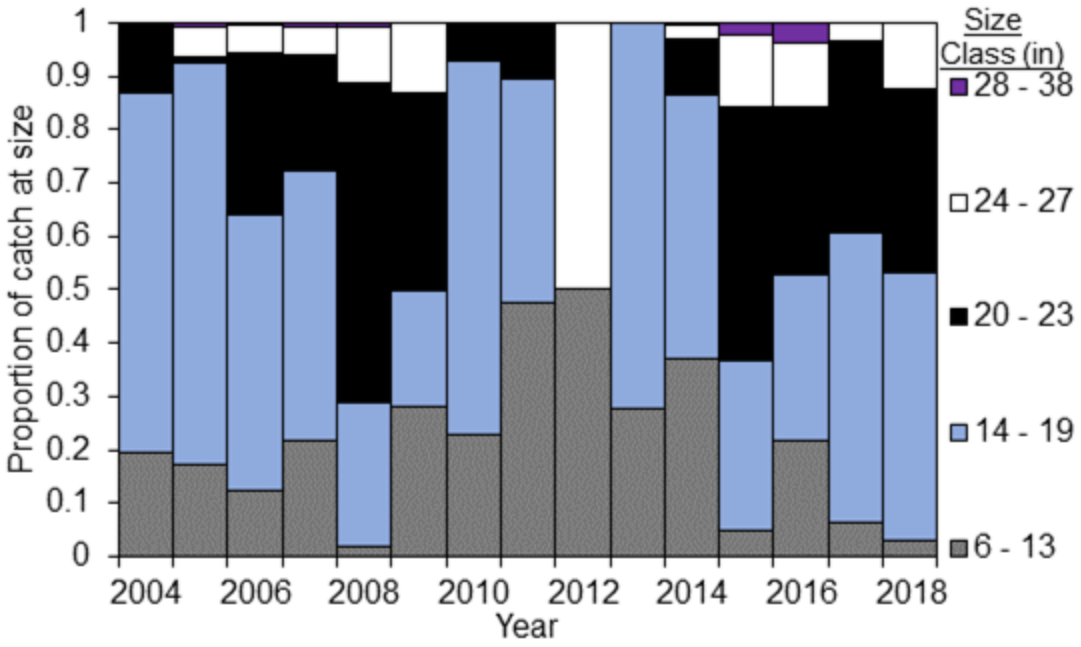

Figure 1-3. The size structure of the Bonito stock from 2013 to 2018 based on the recreational catch of retained Bonito in California (RecFIN 2019).

1.3 Habitat

Bonito are a highly migratory, pelagic, schooling fish that occupy habitats ranging from the open ocean to nearshore kelp forests. Younger Bonito spend more time in nearshore kelp forests, and may even enter bays and harbors, whereas larger individuals are more often found offshore in the pelagic environment at depths up to 300 ft (91 m) (Pinkas et al.1970; Love 2011).

1.4 Ecosystem Role

Little is known about the ecosystem role of Bonito as they are not resident species, and only spend short periods in the various habitats they reside. As a large schooling species, they provide an important food source to the many predators that consume them.

1.4.1 *Associated Species*

Bonito are primarily associated with other highly migratory pelagic species that are also common in southern California in the spring and summer months of most years (Allen et al. 2006). They are most highly associated and commonly school with Pacific Yellowtail (*Seriola lalandi*) and California Barracuda (*Sphyraena argentea*) (Love 2011).

1.4.2 Predator-prey Interactions

The Bonito's diet varies according to the availability of prey. Multiple diet studies in southern California spanning years in the 1960s to 1970s found Northern Anchovy

comprised the majority, from 76% to 98%, of the Bonito's diet (Pinkas et al. 1970; Mearns et al. 1981). Other prey items found in their stomach contents included Market Squid (*Doryteuthis opalescens*) and other fish species such as Pacific Saury (*Cololabis saira*), Jack Mackerel (*Trachurus symmetricus*), Pacific Sardine (*Sardinops sagax*), Pacific Hake (*Merluccius productus*) and species of rockfish. Bonito prey heavily on Market Squid when they are spawning from January to June; during this time Market Squid and Northern Anchovy can comprise about equal proportions of the Bonito's diet. Bonito also prey upon pelagic Red Crabs (*Pleuroncodes planipes*), and Bernard et al. (1985) found that crustaceans comprised 26% of their diet by frequency of occurrence.

As secondary carnivores, Bonito are prey for a suite of higher order carnivores, including larger pelagic fishes like Striped Marlin (*Kajikia audax*), Bluefin Tuna (*Thunnus thynnus*), Swordfish (*Xiphias gladius*), and marine mammals such as California Sea Lions (*Zalophus californianus*) and Common Dolphins (*Delphinus delphis*) (Love 2011), as well as pelagic sharks such as Shortfin Mako (*Isurus oxyrinchus*) and Thresher Sharks (*Alopias vulpinus*) (Preti et al. 2012). During commercial fishing activities, Bonito is the fish species most frequently lost to Sea Lions (Demaster et al. 1985). Bonito may be higher order predators than previously considered, as a study using stable isotopes to assess trophic connectivity in the California pelagic ecosystem classified Bonito in the highest trophic group along with their predators listed above (Madigan et al. 2012). This is most likely due to their mixed diets, in which they feed on both planktivorous, or plankton eating prey, as well as higher trophic level fish and squid.

1.5 Effects of Changing Oceanic Conditions

The geographic range of Bonito is highly dictated by water temperature. In most years they arrive off the southern California coast in the spring and summer months and are only present in northern California, Oregon and Washington during El Niño Southern Oscillation (ENSO) periods when water temperature increases (Collins et al. 1980). As a result, Bonito may be highly affected by changing oceanic conditions, as warm water events tend to increase their apparent population size, and may shift their range northward and closer to the California coast. If warm water periods increase, the seasonality of Bonito off California may lengthen and populations may even become resident, as has been seen with individuals in the warm water surrounding power plants (Collins et al. 1980). The abundance of Bonito is also highly reliant on the abundance and distribution of their primary prey sources, Northern Anchovy and Market Squid, whose ranges may be affected by changing conditions as well.

2 The Fishery

2.1 Location of the Fishery

The Bonito fishery began in the early 1900s. Both the commercial and recreational Bonito fishery is centered in southern California, with the highest concentration of landings seen south of Point Conception (Figure 2-1).

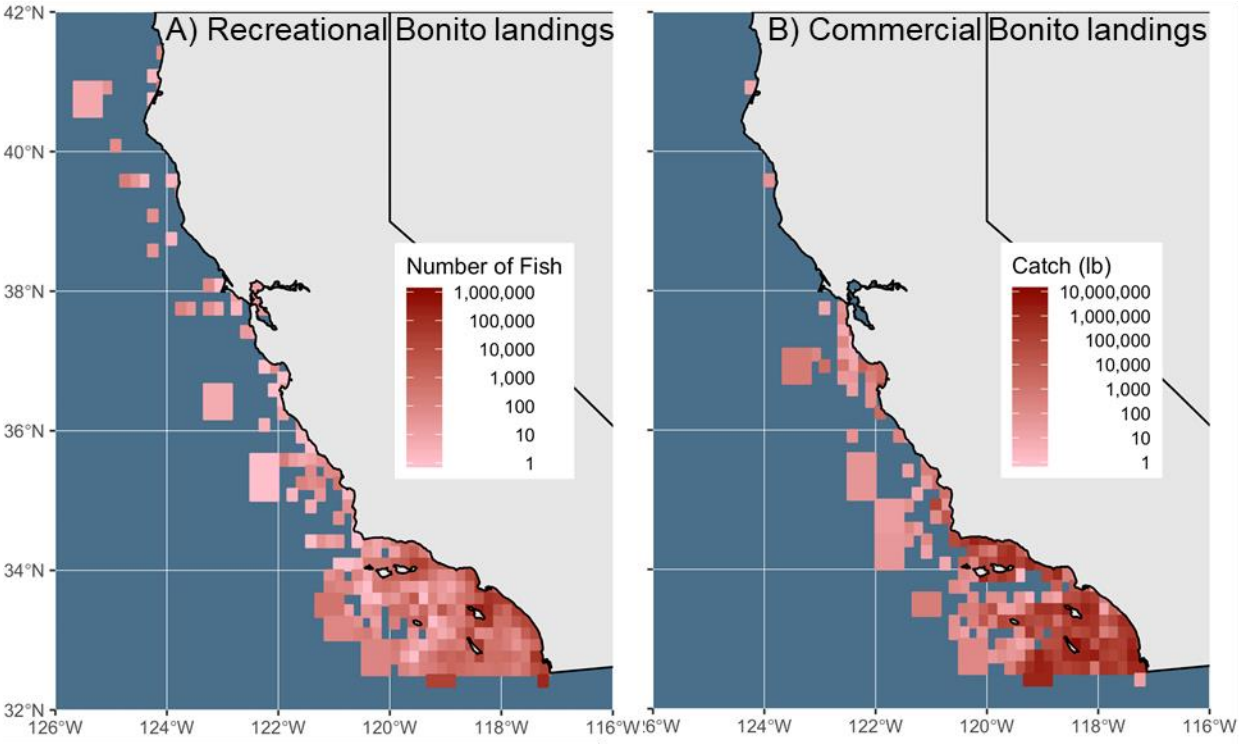

Figure 2-1. CPFV landings of Pacific Bonito (kept fish) from the a) recreational fishery (RecFIN) and, b) the commercial fishery from 1995 to 2017 (CDFW Marine Landings Database System (MLDS) 2018).

2.2 Fishing Effort

2.2.1 *Number of Vessels and Participants Over Time*

The number of active commercial fishing vessels landing Bonito each year has declined from a high of 980 vessels in 1983 to as low as five in 2011, although a spike to over 100 vessels was seen in the warm-water year of 2015 (Figure 2-2). There is no available information on commercial fishing effort prior to 1980.

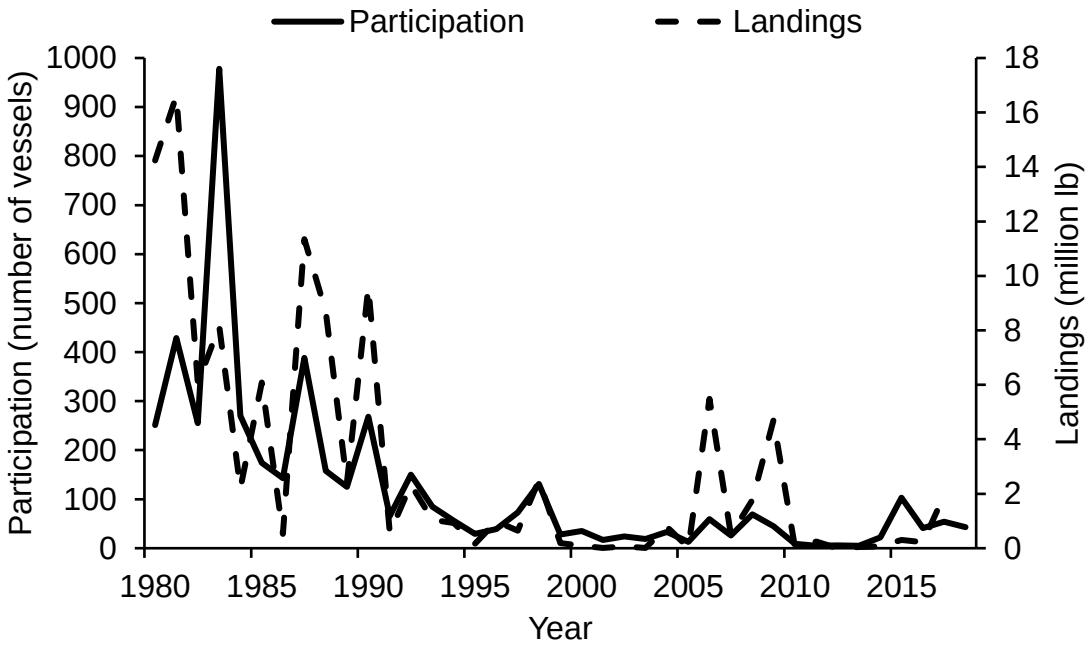

Figure 2-2. Pacific Bonito commercial fishery participation in number of vessels and landings in millions of pounds from 1980 to 2018 (CDFW MLDS 2019).

The expansion of the CPFV fleet in the 1960s caused an increase in the number of recreational anglers targeting Bonito. The number of CPFV trips catching Bonito also fluctuates annually corresponding with warm water events, with a spike of over 5,000 trips seen in 2015 (Figure 2-3). The strong seasonal component in the Bonito fishery can easily be seen looking at the proportion of yearly landings by month. The CPFV fishery on average lands 80% of their annual Bonito catch from July to October (Figure 2-4).

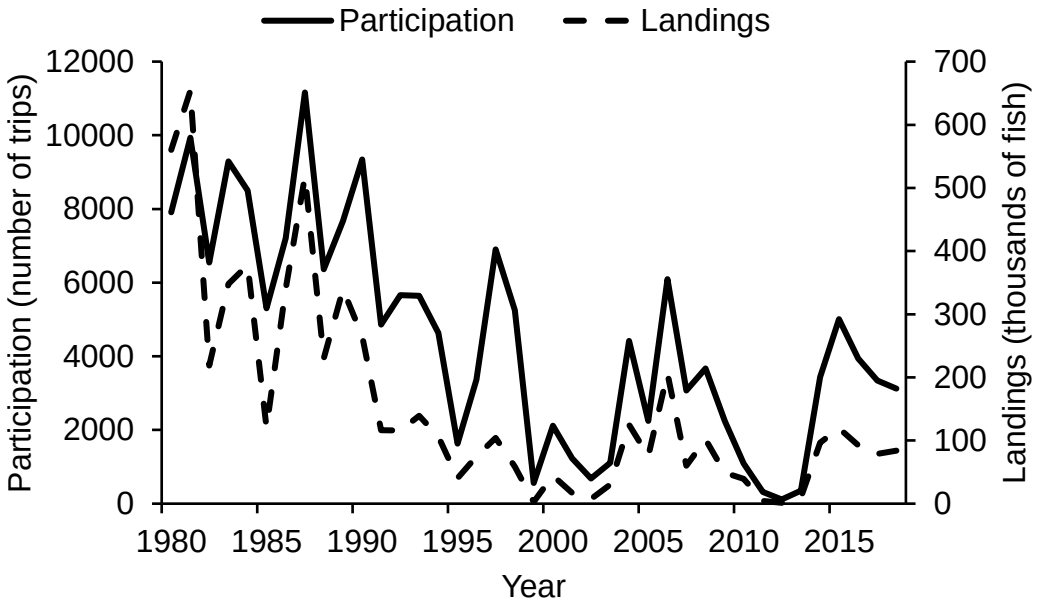

Figure 2-3 Number of CPFV trips targeting Pacific Bonito (at least one caught) and landings in thousands of fish kept from 1980 to 2018 (CDFW Marine Log System (MLS) 2019).

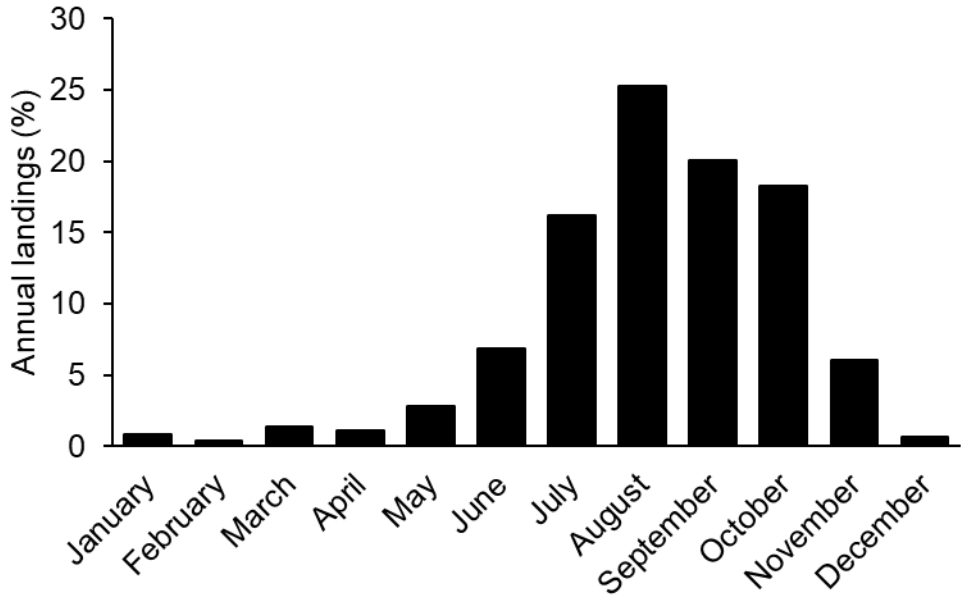

Figure 2-4. Proportion of the yearly CPFV landings of Pacific Bonito (kept fish) by month in southern California from 2013 to 2018 (CDFW MLS 2019)

The variability of the Bonito fishery is also reflected by the large fluctuations in the rankings of the recreational catch compared to other fisheries. From 2005 to 2018, Bonito landings vary from being the fourth most abundant species caught in warm water years such as 2006 and 2015, to as low as rank 141 in 2012, which was a cold-water year (Figure 2-5). Additionally, the landings and participation in the Bonito fishery over

time may not be a good reflection of their abundance, as the presence of more desirable species such as other tuna species during warm water events may reduce the number of fishers targeting Bonito.

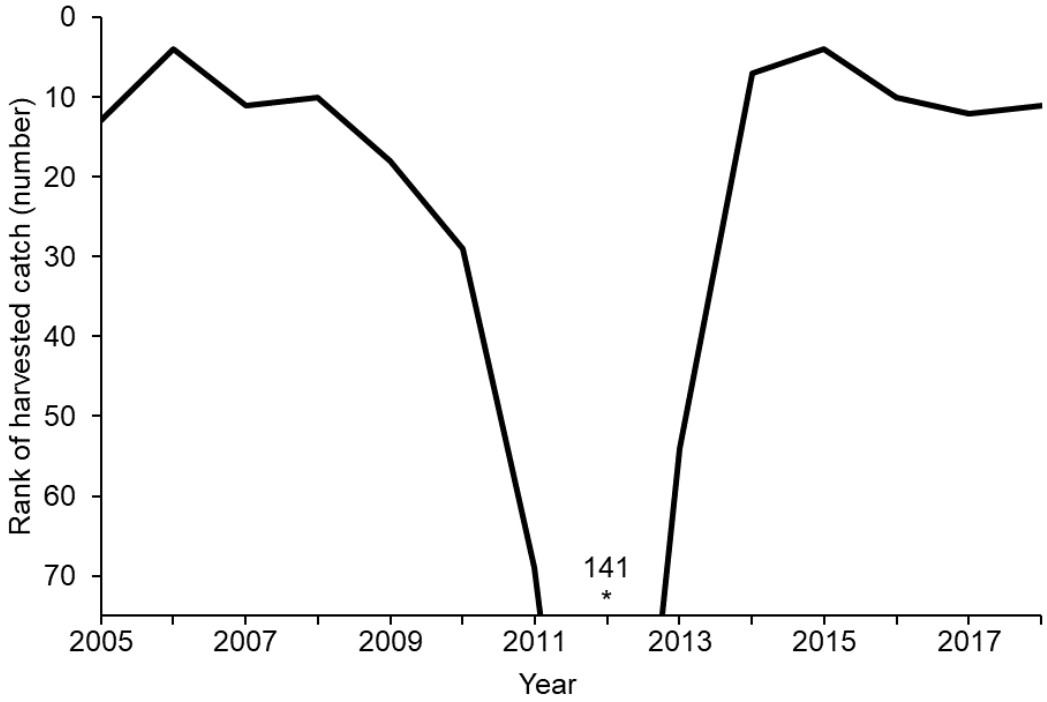

Figure 2-5. Ranking of Pacific Bonito catch relative to other finfish species in the landings in southern California from 2005 to 2018. Results are based on the estimated retained catch for all fishing modes (RecFIN 2019).

2.2.2 *Type, Amount, and Selectivity of Gear*

Bonito are primarily targeted in the commercial fishery using purse seine gear, but are also incidentally caught by gill nets, trawl and hook and line. Since 1980, an average of 85% of the Bonito fishery was landed by purse seiners, increasing to 98% between 2013 and 2018. Purse seines are a type of round haul net with a “purse” line used to close the bottom of the net to prevent fish from swimming down and out. One end of the seine is attached to a skiff that aids by encircling the school of fish and bringing the other end back to the vessel where the purse line is drawn closed (Figure 2-6). The purse seine fleet off the California coast has been termed the small coastal purse seine fleet, as it operates almost exclusively in US waters and the vessels are much smaller than the large purse seine fishery that operates in the high seas and in foreign economic zones.

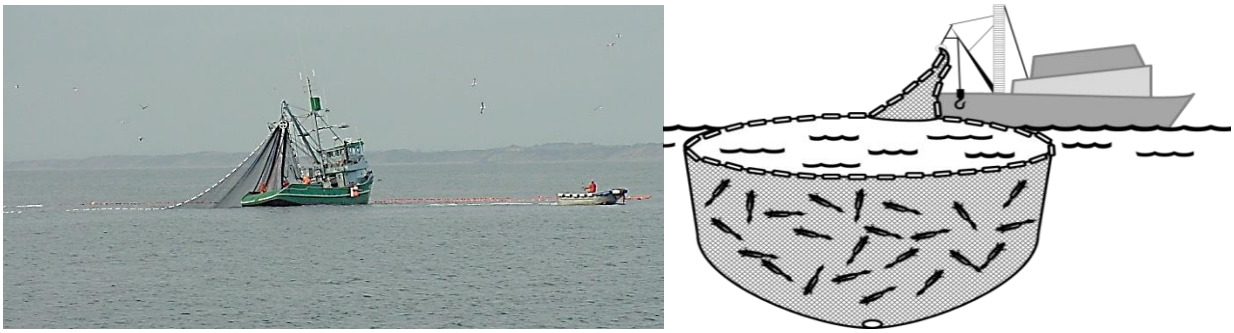

Figure 2-6. Image of purse seine vessel with skiff aiding in deployment, and diagram of purse seine enclosing a school (Photo Credit: Steve Wertz (left); Amanda Van Diggelen, CDFW (right)).

Based on limited port sampling of Bonito lengths from the commercial catch, 79% of Bonito caught between 1984 and 2006 were mature fish over 22.0 in (55.9 cm) (Figure 2-7). Since Bonito are primarily caught by purse seines that fish offshore in deeper waters where adults are found schooling, the majority of the commercial fishery is likely comprised of mature Bonito. Depending on availability, the same commercial fishing fleet that harvest Bonito also target Market Squid, Northern Anchovy, Chub Mackerel (*Scomber japonicas*), Jack Mackerel, Pacific Sardine, Bluefin Tuna and other species of tuna (Jacobsen and Thomson 1993). Fish spotter aircraft are used in the southern California purse-seine fishery to locate these pelagic schooling fishes (Chyan-huei et al. 1992). While the majority of commercial sampling effort focused on the purse seine fleet, other gear types were also sampled, and fish under 22.0 in (55.9 cm) were primarily caught by gill net or hook and line.

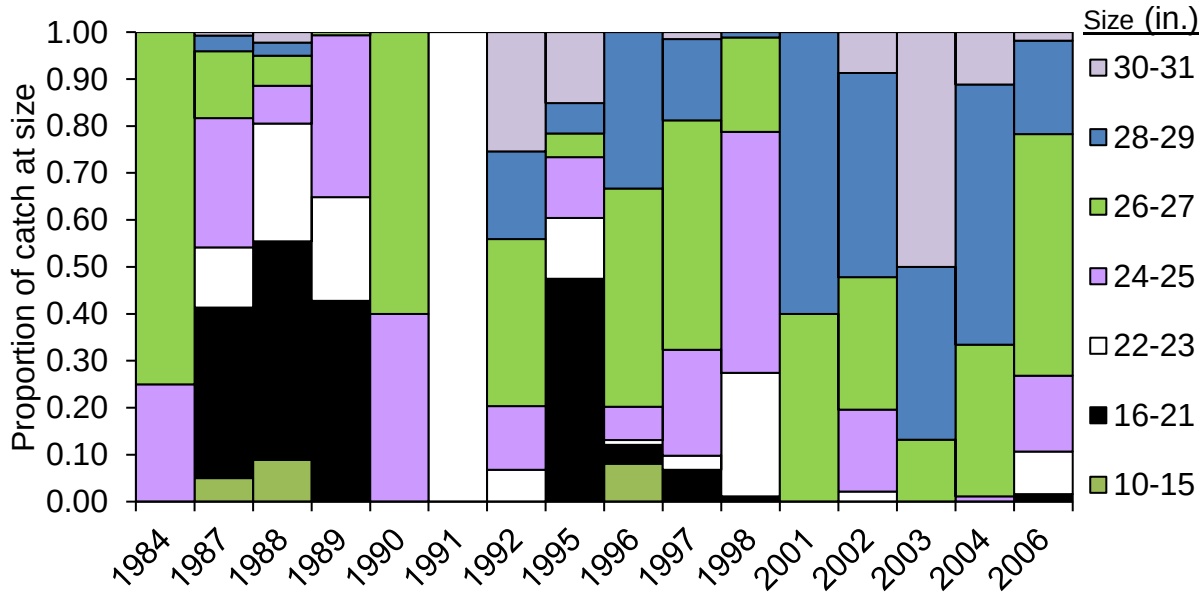

Figure 2-7. Size class data of Pacific Bonito from commercial sampling from 1984 to 2006, n=4,066 (CDFW Highly Migratory Species-Coastal Pelagic Species project unpublished data).

The recreational fishery for Bonito is mainly hook and line, and undersized fish are often caught due to fishing in shallow, nearshore waters where juveniles reside.

2.3 Landings in the Recreational and Commercial Sectors

2.3.1 *Recreational*

Catch data for the recreational fishery are provided by two sources: (1) CPFV logbooks within the Department's MLS database and, (2) California Recreational Fisheries Survey (CRFS) estimates on all fishing modes available from the RecFIN website. Current CPFV logs (1980 to present) provide self-reported data on catch and effort from CPFV captains per vessel trip. These data include the trip date, fishing location (Department fishing block), port code, number of anglers, number of fish kept by species, number of fish discarded (since 1995), time fished, and other relevant information.

Current CRFS estimates (2004 to present) 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, so data from these two time periods are presented in separate figures in this ESR (see Section 4 for more details on these datasets).

The recreational fishery for Bonito primarily uses hook and line gear off party/charter and private/rental boats, but fishing off jetties and other man-made structures like piers makes up a large proportion of the catch as well. The total landings are highly variable, and in cold water years (e.g. 2011 and 2012) as few as 1,000 Bonito are caught, while in warm water years (e.g. 2006 and 2015) over 150,000 Bonito are landed (Figure 2-8). Historically this has been a trend as well, with spikes in CPFV catch in warm water years (e.g. 1960, 1964 and 1969) to over one million Bonito landed (Figure 2-10). Recreationally boat-caught Bonito displayed a significant decrease in landings from over one million in most of the 1980s to less than 500,000 in the 1990s (Figure 2-9). This could be due to a variety of factors including natural population fluctuations, shifting distribution in response to oceanographic changes, or availability of prey species (CDFG 2010). Additionally there was an increase in popularity of private boating in the 1980s, and CPUE decreased from the 1980s to the 1990s (Jarvis et al. 2004). The level of Bonito landings off Baja California, Mexico could also be playing a large role in their abundances off the California coast.

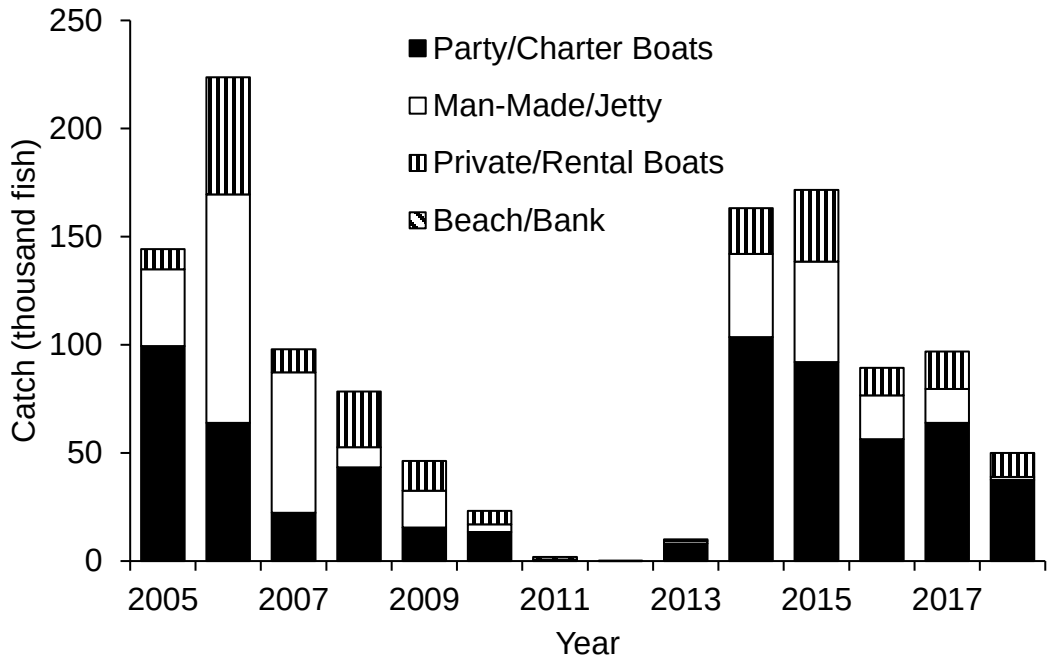

Figure 2-8. Pacific Bonito recreational catch in thousands of fish kept by mode from 2005 to 2018 (RecFIN 2019).

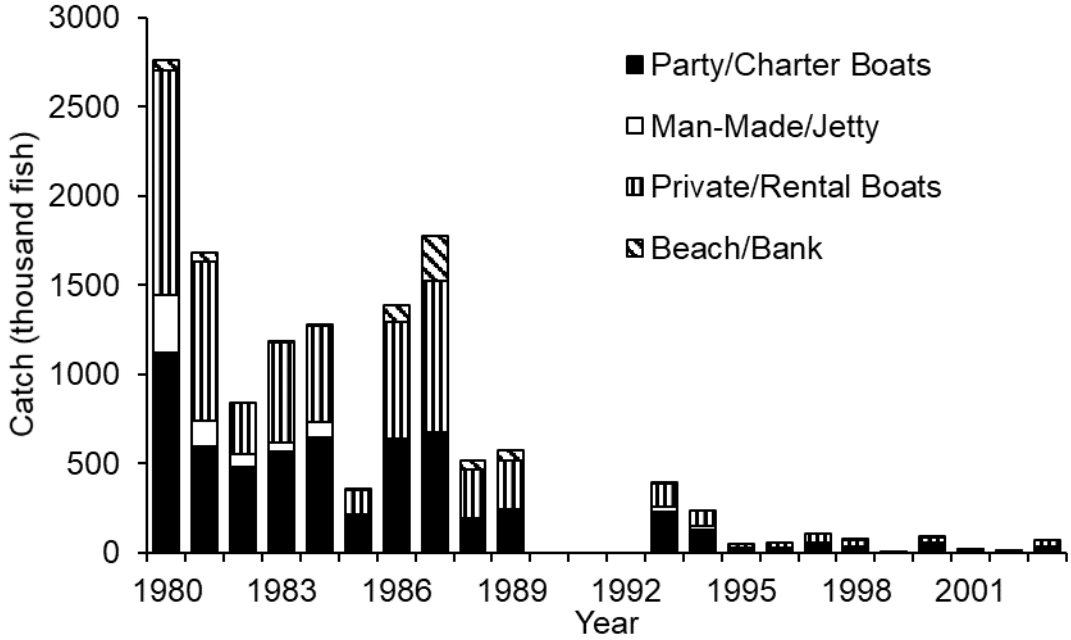

Figure 2-9. Pacific Bonito recreational catch in thousands of fish kept by mode from 1980 to 2003. No data were collected from 1990 to 1992 (RecFIN 2018).

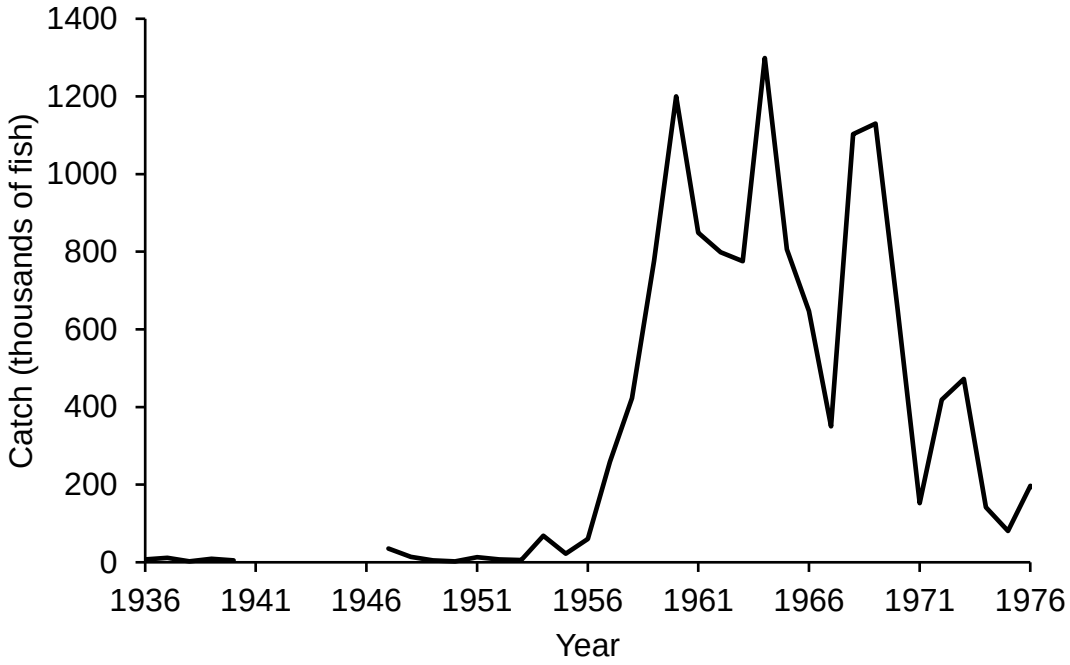

Figure 2-10. Historical recreational landings of Pacific Bonito in thousands of fish kept off CPFVs from 1936 to 1979. No data collected from 1941 to 1945 (Hill and Schneider 1999).

2.3.2 Commercial

Landings in the commercial fishery for Bonito have fluctuated through time (Figure 2-11, Figure 2-12). Commercial landings were first recorded in 1916, and increased steadily from around 500,000 lb (23 ton) to 10.9 million lb (4,944 ton) in 1941. After World War II fishing effort increased and there was a spike in landings, followed by a low period throughout the 1950s. Bonito landings increased by four times between 1965 and 1975 (Figure 2-11). These fluctuations in landings could have been caused by shifting efforts due to the availability of other more desirable species, as well as warm-water events increasing the availability of Bonito nearshore off California. Landings dropped slightly in the 1980s with an average of 8 million lb (4,000 ton), and continued to drop in the 1990s with landings ranging from 157,000 to 9.58 million lb (78.5 to 4790 ton) (Figure 2-12, Figure 2-13). The steep drop in Bonito landings in the 1990s and beyond can be attributed to the location of the Bonito catch. Prior to the 1990s it was not uncommon for up to 99% of the catch landed in the US to come from Mexican waters. In 1982, Mexico began restricting access to foreign vessels fishing in nearshore waters, and by the 1990s less than 10% of the total annual landings were from Mexico. The CPUE from the purse seine fishery has averaged 38,514 lb of Bonito caught per trip from 1980 to 2018 (Figure 2-12). Despite some large fluctuations in recent years due to decreased effort of less than five purse seine trips from 2000 to 2003 and under ten from 2010 to 2016, the average CPUE in pounds per trip has remained stable at 37,456 from 1985 to 2000 and 39,994 from 2001 to 2018.

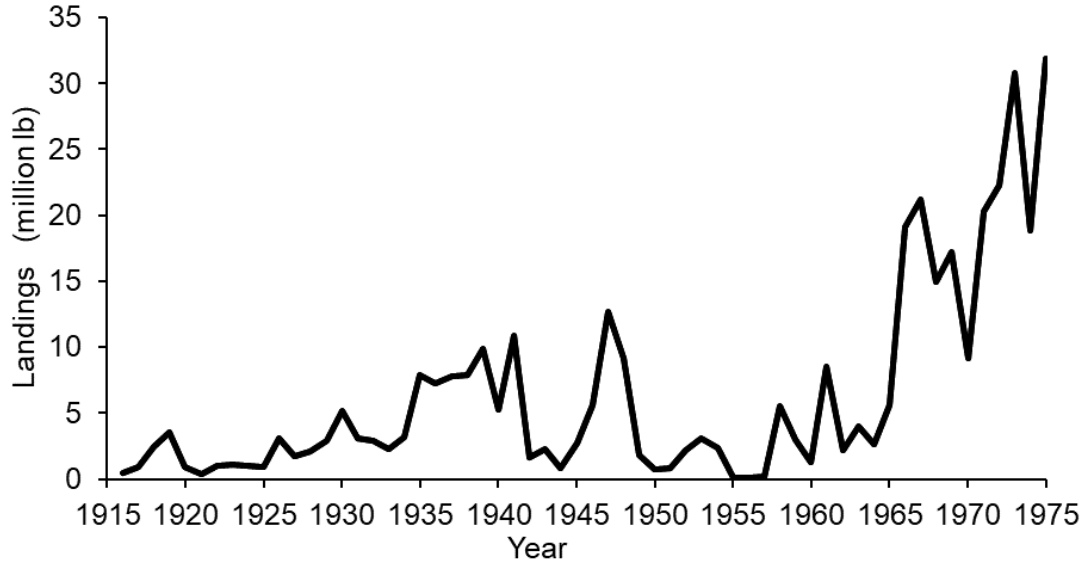

Figure 2-11. Historical commercial landings of Pacific Bonito in millions of pounds from 1916 to 1975 (Collins et al. 1980).

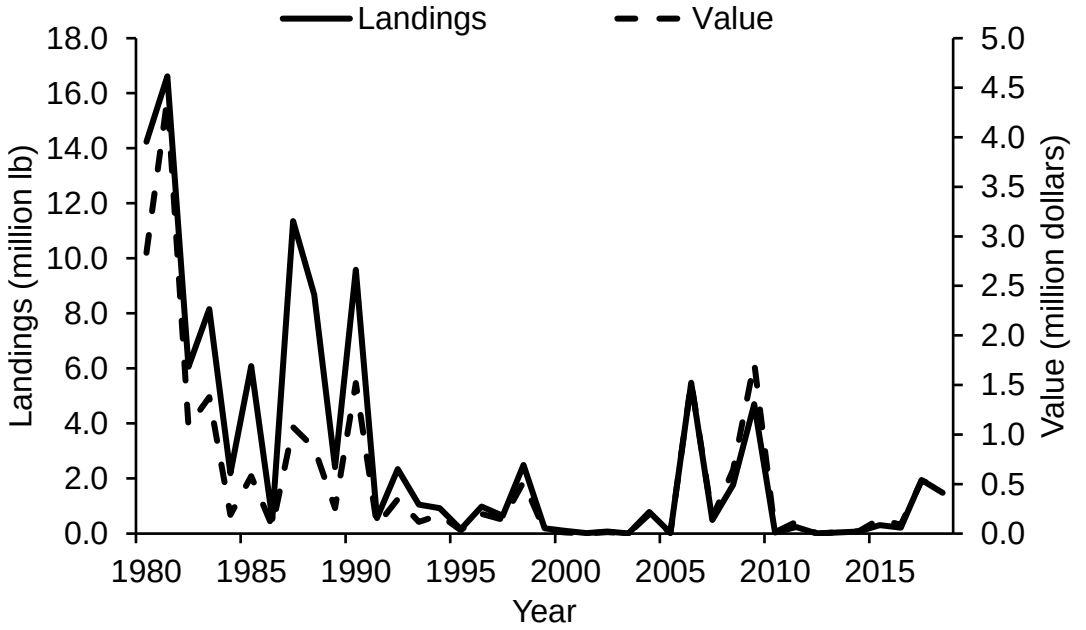

Figure 2-12. Pacific Bonito commercial fishery landings in millions of pounds and value in millions of dollars from 1980 to 2018 (CDFW MLDS 2019).

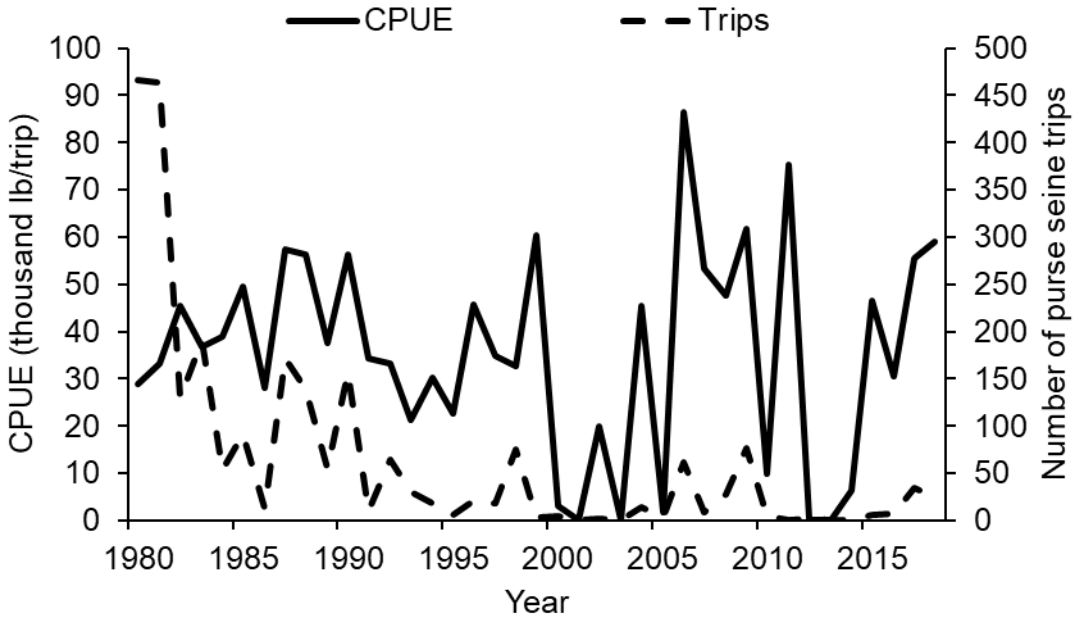

Figure 2-13. Pacific Bonito purse seine fishery CPUE (lb) per trip and number of purse seine trips from 1980 to 2018 (CDFW MLDS 2019).

2.4 Social and Economic Factors Related to the Fishery

The popularity as well as the economic value of the commercial Bonito fishery fluctuates greatly from year to year depending on conditions and Bonito availability. During high catch years, like in 2006, the Bonito fishery ranked eighth in the number of pounds landed at 5.5 million lb (2,741 tons) and 13th in value at $1.53 million. Similarly, in 2009 the Bonito fishery ranked ninth for pounds and 12th for value. During years where Bonito catch is low the fishery has ranked as low as 204th in 2012 with only 456 lb (0.2 ton) landed, and 60th in 2013 with 21,504 lb (10.8 ton) landed. The average price per pound of Bonito has fluctuated from the year 2000 to 2018 from $0.45 in 2001 to a high of $1.94 in 2015 (Table 2-1).

Table 2-1. Total pounds, value, and price per pound of Pacific Bonito from 2000 to 2018 (CDFW MLDS 2018).

Year	Pounds	Value	Price
2000	96,192	$10,467	$0.63
2001	13,005	$1,579	$0.45
2002	73,444	$15,842	$0.56
2003	5,410	$2,703	$0.56
2004	780,209	$196,127	$0.55
2005	23,020	$5,762	$0.55
2006	5,481,546	$1,530,008	$0.56
2007	488,454	$158,886	$0.74
2008	1,770,432	$643,423	$0.66
2009	4,702,371	$1,727,072	$0.52

2010	40,657	$14,373	$0.86
2011	243,487	$116,738	$0.76
2012	456	$297	$0.46
2013	41,504	$13,497	$1.69
2014	70,982	$24,731	$1.61
2015	306,608	$146,112	$1.94
2016	217,868	$87,672	$1.48
2017	1,948,470	$533,397	$1.47
2018	1,487,421	$458,382	$1.48

Commercially caught Bonito are primarily used for human consumption. Bonito is either sold fresh or frozen, or processed by curing or smoking. On average from 1978 to 2018, 98% of the Bonito landed was sold for un-canned human consumption (MLDS). The remaining percentage is used as bait, sold as canned food, or personally consumed by the commercial fisher. The market demand for Bonito is relatively low compared to the higher demand for other tuna species such as Yellowfin, Skipjack (*Katsuwonus pelamis*), Albacore (*Thunnus alalunga*) and Bluefin Tuna, although this may change with changes in California's demographics.

The popularity of the recreational Bonito fishery is also highly dependent on oceanic conditions and their availability off the coast of California. Shore fishing, CPFV trips and private boat trip expenditures together comprise California's $923 million annual recreational fishing industry (Lovell et al. 2013). In warm water years when Bonito can be caught close to shore, the angling popularity spikes which probably contributes to the large recreational fishing industry. This seasonal availability of Bonito may cause shifting effort away from other target species during the summer months when Bonito catch increases. Bonito have ranked in the top ten species caught by CPFVs in southern California, ranking second after the basses from Ensenada, Mexico to Oceanside, California, comprising 16% of the total catch in that zone (Dotson and Charter 2003).

Both the commercial and recreational Bonito fisheries provide economic benefits to California residents through direct commercial sales or via the income generated by recreational fishing operators and associated tourism. The distribution of landings can provide information on which areas in California are most likely to benefit. In 2018, all of the Bonito catch from CPFVs was landed in southern California, with the majority, 49%, from Los Angeles County (Figure 2-14). In the commercial fishery, the majority of landings (99%) occurred in Los Angeles at Terminal Island and San Pedro ports (Figure 2-15)

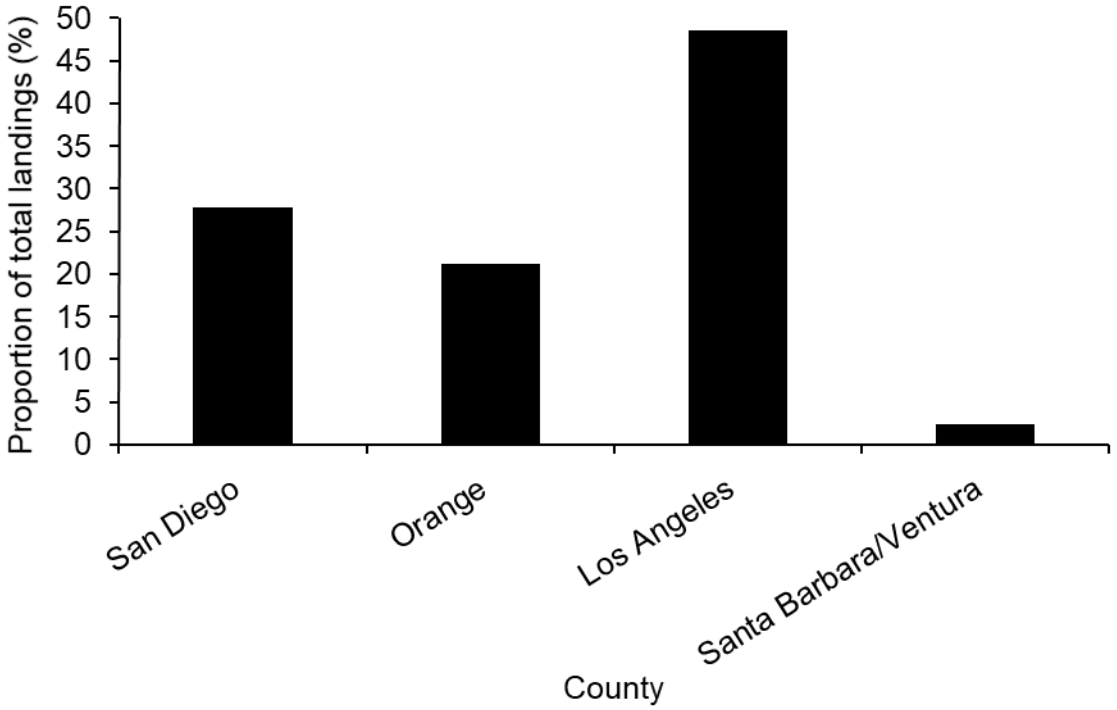

Figure 2-14. Percentage of total Pacific Bonito recreational landings kept from CPFVs by port in 2018 (CDFW MLS 2019).

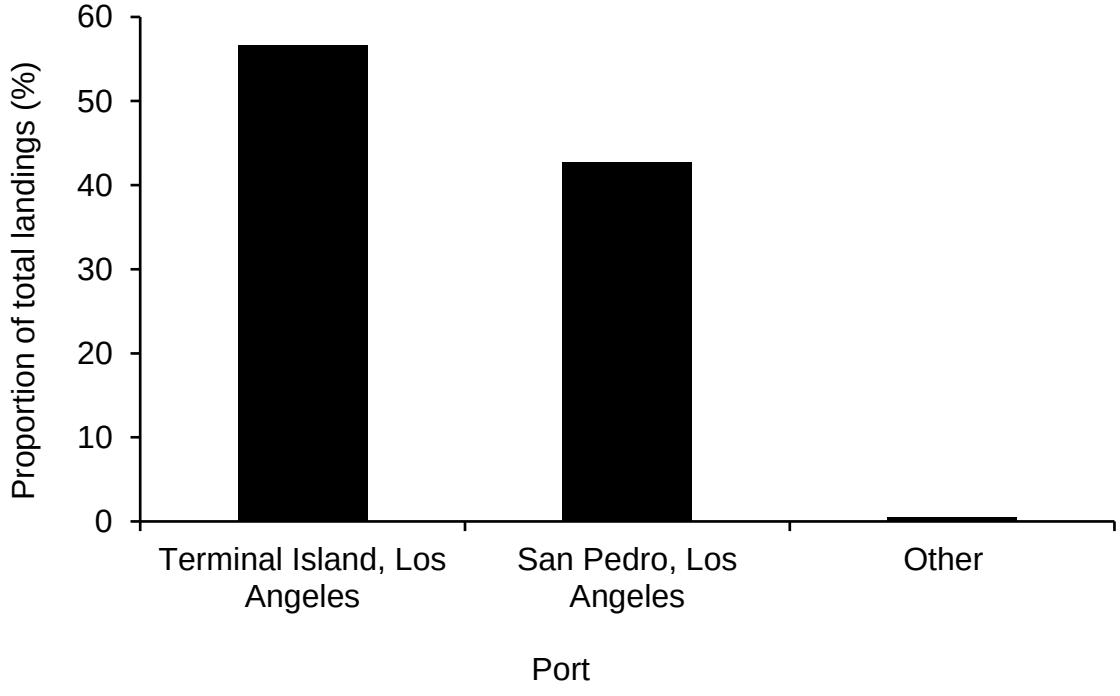

Figure 2-15. Percentage of total Pacific Bonito commercial landings by port in 2018. (CDFW MLDS 2019).

A study conducted in 1980 on the potential health hazards of fish consumed in polluted waters off Los Angeles County found 77% of anglers consumed the Bonito they caught (Puffer et al. 1982). The most popular methods of consumption were baking, barbequing or frying, and of the 8% of anglers who consumed raw fish, Bonito was the common species to eat. Bonito were also seen to accumulate trace organics like polychlorinated biphenyls (PCBs) at an average of 0.31 parts per million (ppm) from wastewater discharge sites. The health effects of contamination at this level were unknown at the time and further studies were warranted.

3 Management

3.1 Past and Current Management Measures

In 1982, Mexico began restricting foreign vessel access to its nearshore fisheries. Prior to this closure, 50 to 90% of Bonito landed in the US was caught off the coast of Baja California, Mexico. Now less than 10% of Bonito catch originates in Mexican waters. However, landings in Mexico may still greatly impact the Bonito fishery off the California coast because Bonito are commonly caught in the Mexico purse seine fishery and are a shared stock that seasonally migrate across the California-Mexico border.

Bonito were part of the federal Highly Migratory Species Fishery Management Plan (HMS FMP) as a monitored, but not actively managed, species until 2011 when they were removed via the HMS FMP Amendment 2 (PFMC 2010). Many of the other species that were removed from the HMS FMP were reclassified because their average annual landings were less than 1 metric ton (mt). Although significant quantities of Bonito are landed both commercially and recreationally, they were removed from the HMS FMP under the rationale that this level of fishing was unlikely to result in adverse impacts as Bonito have no conservation concerns and the state manages their fishery with bag and size limits. Additionally, it was stated that, if necessary, future action could re-include Bonito in federal management.

3.1.1 Overview and Rationale for the Current Management Framework

Pacific Bonito are primarily managed by a minimum bag and size limit established in 1982. The minimum size limit allows most individuals to reproduce before entering the fishery, and the bag limit was based on a general bag limit put in place for many species during that time. A ten fish bag limit was considered a satisfying number for sport take without risking stock depletion.

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

The Department has not established overfishing criteria for the Bonito fishery. Due to Bonito's wide geographic range, highly migratory nature and shared stock with the Mexico purse seine fishery, their landings fluctuate greatly. Thus, the types of fishery-dependent data currently collected by the Department may not be indicative of their population status, which makes it challenging to actively manage. Based on their fast growth rate, high productivity, and available fishery-dependent data discussed in Sections 2 and 4, there are currently no concerns about the status of Bonito and the existing regulations appear to provide enough protection to maintain the sustainability of the highly variable population off the California coast. However, if landings decrease in warm water periods, when Bonito abundance typically increases, and if the recreational fishery continues to consist mostly of immature fish, this may indicate the fishery needs management changes to ensure sustainability.

3.1.1.2 Past and Current Stakeholder Involvement

There has been little need for stakeholder involvement with the Bonito fishery, as the last regulation change was in 1982 and involvement typically occurs during regulation change processes. If there is need for change in Bonito management strategies, the Department will work with various stakeholder groups including tribes, CPFV operators, recreational and commercial anglers, Non-Government Organizations (NGOs), scientists, and the public to ensure input from all groups is considered.

3.1.2 *Target Species*

3.1.2.1 Limitations on Fishing for Target Species

3.1.2.1.1 Catch

There is a maximum limit of ten Bonito for the recreational fishery (§28.32, Title 14, California Code of Regulations (CCR)). This was put in place in 1982 as a general bag limit for many species, as ten was considered a satisfying number for sport take without risking stock depletion. There is currently no quota in place for the commercial Bonito fishery but there are some size restrictions (see below).

3.1.2.1.2 Effort

The purse seine fishery, which commonly catches Bonito has no limit on days at sea, trip length or number of participants.

3.1.2.1.3 Gear

At this time, there are no gear specifications for purse seines, or regulations specific to targeting Bonito for other gear types.

3.1.2.1.4 Time

Purse seines, a common commercial gear for targeting Bonito, are seasonally restricted during specific times in specific areas. For example, “In Districts 16, 17, 18, and 19, purse and round haul nets may be used, except that purse seines or ring nets may not be used in that portion of District 19 lying within three miles offshore from the line of the high–water mark along the coast of Orange County from sunrise Saturday to sunset Sunday from May 1 to September 10, inclusive. Purse seine or ring nets may not be used from May 1 to September 10, inclusive, in the following portions of District 19: (a) Within a two–mile radius of Dana Point. (b) Within a two–mile radius of San Mateo Point. (c) Within two miles offshore from the line of the high–water mark along that portion of the coast of Orange County lying between the northernmost bank of the mouth of the Santa Ana River and a point on that coast six miles south therefrom.” (FGC §8754). Additionally there are specific areas in District 20 where purse seining is restricted: “(1) from sunrise Saturday to sunset Sunday, in that portion of District 20 from a line extending 3 nautical mi east magnetically from the extreme easterly end of

Santa Catalina Island southwesterly and northerly to a line extending 3 nautical mi southwest magnetically from the most southerly promontory of China Point and, (2) at any time during the period commencing on June 1 and ending on September 10 each year, in that portion of District 20 from a line extending 3 nautical mi east magnetically from the extreme easterly end of Santa Catalina Island southerly to a line extending 3 nautical mi southeasterly magnetically from the US government light on the southeasterly end of Santa Catalina Island" (FGC §8755).

3.1.2.1.5 Sex

There are no restrictions on the sex of Bonito that can be retained.

3.1.2.1.6 Size

The minimum size limit for the recreational fishery is 24 in (61 cm) FL or 5.0 lb (2.3 kg), except that: "Five fish less than twenty-four inches fork length or weighing less than five pounds may be taken and possessed" (§28.32, Title 14, CCR). As most Bonito are mature at 22.0 in (55.9 cm) the size limit allows individuals to reproduce before entering the fishery. In compliance with this regulation, "No more than 10 fillets of any length may be possessed. All bonito fillets possessed shall be considered a part of the allowable undersized tolerance of five bonito per day less than 24 inches fork length or weighing less than five pounds as provided in Section 28.32 of these regulations. All fillets shall bear intact a one-inch square patch of skin." (§27.65(5), Title 14, CCR).

The minimum size limit for the commercial fishery is 24 in (61 cm) FL or 5.0 lb (2.3 kg). There are exceptions permitting a limited take of Bonito under the minimum size limit, including "none less than 24 inches fork length or 5 pounds in weight may be taken or possessed except a load of bonito taken by a round haul net may contain 18 percent or less by number of bonito smaller than the size limit and a load of fish taken by a gill net or trammel net may contain 1,000 pounds or less of bonito smaller than the size limit" (FGC §8377). There is no information available on the rationale behind these exceptions.

3.1.2.1.7 Area

Purse seines, a common commercial gear for targeting Bonito, are seasonally restricted in a couple of areas in southern California described in the time section above (FGC §8754 and FGC §8755). Additionally, there are restrictions on where Bonito may be fished inside Marine Protected Areas (MPA) described below.

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.

The commercial and recreational take of pelagic finfish, of which Bonito is included, is permitted in a subset of MPAs listed in the commercial digest and ocean sport fishing regulations manuals. When targeting pelagic finfish during commercial fishing in MPAs, no more than 5% of the catch landed (by weight) can be other incidentally taken species. Considering Bonito's wide geographic spread and highly migratory nature they are not likely to greatly benefit from protection within those MPAs where no pelagic fishing is allowed.

3.1.2.2 Description of and Rationale for Any Restricted Access Approach

The purse seine fishery, which produces most of the Bonito catch, is an open access commercial fishery. Commercial fishers using a gill net to catch Bonito are required to obtain an annual limited entry and restricted access permit, as well as submit a complete and accurate record of fishing activities on forms provided by the Department (FGC §8681). Since January 1, 1990 the Department shall issue no new gill net permits, although any person with an existing, valid permit that has landed fish for commercial purposes in at least 15 of the preceding 20 yr may transfer that permit to a qualified person (FGC §8681.5).

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, they are desirable and are thus retained as incidental catch.

In order to assess the most commonly caught species with Bonito, all CPFV trips where at least one Bonito was caught were analyzed. The most common species caught in 2018 on CPFV trips where Bonito was caught included Kelp Bass, Ocean Whitefish unspecified species of rockfish, Yellowtail, and California Sheephead (Table 3-1). Although Bonito were caught on 100% of these trips and are the most abundant species caught, they may not be the primary target. These other species may be primary targets or secondary targets on CPFV trips that may, or may not be, targeting Bonito. Many of these species reside in kelp forests and rocky reefs, which are not Bonito's primary habitat. Although, as young Bonito often reside in nearshore habitats, it is common for them to be caught on trips that are targeting kelp forest species such as rockfish, Kelp Bass, and California Sheephead. It is also possible that some of these species are caught on the same trips as Bonito due to switching between fishing nearshore and offshore areas. All species listed in Table 3-1 have state or federal management measures in place.

Table 3-1. Number caught and percent of trips (frequency of occurrence) for the top ten most abundant species on CPFV trips (n=3,371) where at least one Pacific Bonito was also caught in 2018 (CDFW MLS 2019).

Species	Number Caught	Percent of Trips	Number of Bonito caught on associated trips
Pacific Bonito	96,569	100	96,569
Kelp Bass	87,191	57	51,715
Ocean Whitefish	67,866	39	40,081
Rockfish, unspecified	59,007	35	31,517
Yellowtail	33,131	43	38,630
California Sheephead	13,467	34	36,116
Halfmoon	12,490	14	12,174
Pacific Barracuda	9,430	25	20,486
Bocaccio Rockfish	5,675	9	68,42
Barred Sand Bass	4,625	12	13,148
Copper Rockfish	2,264	4	2,412

Species that are the most commonly caught with Bonito in purse seines include Market Squid, Pacific Mackerel, Bluefin Tuna, Pacific Sardine, and Jack Mackerel. Using landing receipts to assess the associated species caught with Bonito in purse seines from 2007 to 2018, it appears when Bonito are the target species there is very little bycatch given that 71% of trips caught 100% Bonito. From the 29% of trips that caught other species, Bonito appear to be the bycatch of other targeted fisheries, as they comprise the minority of the catch. On trips where Bonito were caught with Market Squid, Bonito comprised on average less than 1.6% of the catch. Trips where Pacific Mackerel or Pacific Sardine were caught, Bonito comprised on average 18% of the catch, and on trips where Bluefin Tuna was caught, Bonito comprised 55% of the catch. However, because these percentages are based on landing receipt data that records the total catch per gear type trip, it is not clear if these species were caught in the same purse seine haul or in different hauls on the same trip. Additionally, as there is no required logbook or observer coverage for the purse seine fishery, the level of discarded bycatch and whether discards are returned alive is unknown. While some sublegal bonito can be kept in both the commercial and recreational sectors, it is unknown if these levels are reached and if sublegal catch is also being discarded. Due to lack of observer coverage at this time, the level of interactions with possible species of concern with the purse seine fishery is also unknown.

“It is unlawful to use any purse seine or round haul net to take yellowtail, barracuda, or white sea bass. (b) it is unlawful to possess any yellowtail, barracuda, or white sea bass, except those taken south of the international boundary between the United States and Mexico, and imported into the state under regulations of the commission as provided in Section 2362 , on any boat carrying or using any purse seine or round haul net, including, but not limited to, a bait net as described in Section 8780 .(FGC §8623). Additionally, when commercial pelagic finfish fishing in MPAs no more than 5% of the catch landed by weight can be other incidentally taken species.

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

There is not enough information known about the level of bycatch associated with the Bonito fishery to assess the level of sustainability. As the level of bycatch is unknown, there are no management measures in place to reduce unacceptable levels of bycatch at this time.

3.1.4 Habitat

3.1.4.1 Description of Threats

As Bonito primarily reside in the coastal pelagic environment there are few habitat threats from fishing. Purse seine gear does not touch the sea floor. The recreational fishery is primarily hook and line, with the most vulnerable habitat being kelp forests and rocky reefs where juvenile Bonito commonly occur. Adverse impacts to kelp forests or marine invertebrates associated with rocky reefs can result from the anchoring of vessels or fishing gear snagging on structure or organisms; however, this is likely minimal. Compared to other fishing gear types, such as bottom trawls or traps, the impacts of a hook and line fishery on habitats is likely very minor.

Pollution from wastewater discharge can have negative impacts on kelp forest habitats, but these are thought to be less than the impacts observed for bays and estuaries as environmental conditions play a larger role in kelp ecosystem health (North and Hubbs 1968; Schiff et al. 2000). These threats are most likely to impact juvenile Bonito given they spend more time in nearshore waters closer to potential pollution impacts than adults.

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

Given the minimal threats to habitat from the fishing gears used in the Bonito fishery, no measures to minimize adverse habitat effects are used at this time.

3.2 Requirements for Person or Vessel Permits and Reasonable Fees

Commercial Fishery

There are no specific permits for the Bonito fishery. Any vessel commercially fishing must obtain a commercial fishing license to be permitted to fish in California waters. In 2019, the cost of this license is $379. Fishers using gill nets to land Bonito 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 (Table 3-2). The most current license options and fees for the commercial fishery may be accessed at https://www.wildlife.ca.gov/Licensing/Commercial/Descriptions.

Table 3-2. Annual commercial fishing license fees from January 1 to December 31, 2019. Accessed June 24, 2019 at https://www.wildlife.ca.gov/Licensing/Commercial/Descriptions.

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.
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 currently 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 engaged in operations authorized by the permit.
Drift Gill Net Permit Transfer fee	$1500.00	Required for gill net permits to be transferred following all restrictions described in the Commercial regulations Transferring Permit Requirements (FGC §8561.5)
Drift Gill Net Vessel Transfer fee	$130.00	Required for gill net vessels to be transferred following all restrictions described in the Commercial regulations Transferring Permit Requirements (FGC §8561.5)

Recreational Fishery

Unless recreationally fishing off a public pier, all anglers 16 yr or older are required to purchase a fishing license to fish for Bonito. 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 3-3). 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 3-3. Annual sport fishing license fees from January 1 to December 31, 2019. Accessed June 24, 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 yr of age or older to fish.
Recreational Non-resident Sport Fishing	$134.74	Required for any non-resident 16 yr of age or older to fish.
Recreation 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 Department offices. $7.82 from license agents	Available for any resident or non-resident honorably discharged disabled veteran with a 50%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 Department License Sales Offices.
Reduced-Fee Sport Fishing License – Low Income Senior	$7.47	Available for low income California residents, 65 yr 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 Department License Sales Offices.

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.”

Fishery-dependent data collected by the Department provides a way to monitor fishing effort, catch levels, and the size structure of retained Bonito. However, because the presence of Bonito off the California coast is highly variable, many of these datasets are data-poor and not informative indicators of Bonito’s population status. The Department’s Coastal Pelagic Species program has sampled ports in the past to measure the commercial catch. Although Bonito were never the primary focus, as they are not actively managed with a quota or total catch limit, they were included in this port sampling from 1984 to 2006. With shifting focuses to other species of greater management concern, commercial Bonito landings are no longer actively sampled by the Department.

4.2 Past and Ongoing Monitoring of the Fishery

4.2.1 Fishery-dependent Data Collection

The Department relies on a combination of fishery-dependent sources to monitor the status of the Bonito fishery. Recreational fishery data are reported in the form of CPFV logbooks and are also collected from all fishing modes by CRFS staff. Beginning in 1935, CPFV operators were required to keep daily catch logs and submit them monthly to the Department. These data were collected continuously to present day, 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. Although initially recorded on paper, as of December 2017, 70% of all CPFV logs are voluntarily entered via the MLS electronic application, which is accessible to Department scientists.

All modes of recreational fishing were surveyed by MRFSS for estimates of catch and effort between 1979 and 2003. The Pacific States Marine Fisheries Commission ran these surveys with both federal and state funding. A combination of dockside surveys, CPFV sampling and phone interviews were used to generate the estimates. In January 2004, the Department implemented its own sampling survey, CRFS, to replace the MRFSS surveys using similar methods. CRFS data on catch estimates and mortality are available electronically to the public within 40 days of collection on the updated RecFIN website (https://www.recfin.org).

Commercial landing receipts, CPFV logbooks, and CRFS data collected by the Department continue to contribute valuable estimates of catch and effort that help staff monitor the status of Bonito. Although there is no logbook required for purse seining, all commercial fishers are required to submit landing receipts that are 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.

4.2.2 Fishery-independent Data Collection

Fishery-independent data can provide a better, less-biased assessment of relative abundance since sampling can be standardized and information on all life stages can be collected. However, there is currently no known ongoing fishery-independent data collection for Bonito.

5 Future Management Needs and Directions

5.1 Identification of Information Gaps

Although there are no signs of concern for the Bonito population, they are a data-poor fishery that is challenging to actively monitor due to their highly fluctuating variability off the California coast. Currently the Department does not use any fishery-independent methods to monitor the Bonito resource; however, development of these methods could help determine the relative size of the Bonito population and how it might vary with changing environmental conditions (Table 5-1). Establishing an index of abundance for Bonito would need to consider their abundances fluctuate seasonally, they are greatly impacted by the Mexico purse seine fishery, and they are a shared stock that seasonally migrate across the California-Mexico border. Additionally, there is little known about post-release survival of Bonito that are caught and released, both recreationally from hook and line as well as in the commercial purse seine fishery. These data would aid in informing the effectiveness of the size limit regulation. Spawning surveys to increase knowledge on the location and spatial extent of Bonito spawning grounds would also be informative, as there is very little information known about potential aggregations since spawning primarily occurs in waters south of California. Considering spawning locations may shift with changing environmental conditions, this information could aid in informing if Bonito populations might be more vulnerable to fishing during this time. Continued fishery-dependent data collection on the size and age composition of the commercial catch would also help inform the size structure of the Bonito stock as well as the effectiveness of the size limit regulation, and how it may change with changing environmental conditions. Also, improved data on possible bycatch associated with the small, coastal purse seine fleet would aid in understanding the sustainability of the Bonito fishery. Lastly, updating the stock assessment of Bonito using updated EFI and potential fishery-independent research could be helpful in the sustainable management of the fishery.

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

Type of information	Priority for management	How essential fishery information would support future management
Relative abundance of Bonito population off California coast	High	Provides information on the health of the Bonito population, and how it changes with changing environmental conditions.
Bycatch associated with commercial purse seine fishery	High	Quantifies the level of bycatch and condition of discarded catch from the small coastal purse seine fleet, which would aid in understanding the sustainability of the Bonito fishery.
Size/age composition of commercial catch	High	Provides information on the effectiveness of the commercial minimum size limit regulation, which allows 18% of undersized fish.

Short term and long term post-release mortality	Medium	Quantifies discard mortality, which would aid in informing the effectiveness of both the recreational and commercial minimum size limit regulation.
Location and spatial extent of spawning grounds	Low	Provides information on where the key spawning habitats for Bonito are located, and how they have changed over time.

5.2 Research and Monitoring

5.2.1 Potential Strategies to Fill Information Gaps

As Bonito are not currently an actively managed species by the Department there are no plans to conduct studies to address the information gaps listed in Table 5-1, and instead these research gaps may benefit from collaboration with academics or other research institutions. Most of the information gaps listed could be addressed by both fishery-independent or fishery-dependent methods, and either long term or short term studies to provide a snapshot of the fishery. This may require a combination of efforts led by the Department and independent researchers through various grants or other funding sources. Quantifying a relative index of abundance for Bonito would aid in providing information on the status of the Bonito population off the California coast and how it changes with changing environmental conditions. This could be done by a variety of methods and should allow for standardization with ocean temperature or other environmental variables. Currently researchers in Mexico are using multiple models to analyze Bonito's stock status and assess the environmental factors that affect their abundance (Ortega-García and Jakes-Cota 2019). As Bonito is a shared stock with Mexico, incorporating their findings could inform their population status off the California coast as well as throughout their entire range.

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, NGOs, citizen scientists, and both commercial and recreational fishery participants to help fill information gaps related to the management of state fisheries. If management priorities shift focus to actively monitor Bonito, the Department may reach out to outside persons and agencies when appropriate while conducting or seeking new fisheries research beneficial for their management. Several of the information gaps identified above (Section 5.1) are potential areas for collaborative studies. In particular, short term and long term monitoring of Bonito survival after capture and release may be well-suited for collaborative studies involving Department staff with both recreational and commercial fisheries participants.

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.

Currently, there are no suggestions for management change for Bonito. Bonito landings fluctuate greatly with changing environmental conditions; however, the fishery appears to be sustainably managed. Although with increased research and potentially updating their stock assessment, suggestions to better manage Bonito may be revealed. With changing environmental conditions, Bonito abundances, and thus the Bonito fishery, may increase or decrease off the California coast and possibly warrant management change. The Department may consider reduction of bag limits, especially regarding the allowed take of undersized fish. When necessary, the Department will collaborate with outside entities such as academic organizations, NGOs, citizen scientists, and both commercial and recreational fishery participants to help fill information gaps related to their management. The Department will also reach out to outside persons and agencies when appropriate while conducting or seeking out new fisheries research beneficial for the management of Bonito.

5.4 Climate Readiness

To incorporate climate readiness into Bonito management it is important to increase our understanding of possible impacts of climate variability. California's coastal waters are already subject to high variability due to episodic events such as ENSO, Pacific Decadal Oscillation, and North Pacific Gyre Oscillation. Climate change may bring further uncertainty to these trends, with potentially implications for ecosystem function and fishery sustainability in coastal areas.

Climate change may result in the increased frequency of warm water events, or increase the duration of warmer water periods, which may have a positive or negative effect on Bonito populations. With warmer water, Bonito's geographic range may expand, their population abundance center may shift northward, spawning events could increase off the California coast, and their fishing season could be extended. However, climate change, invasive species and the predicted increased variability in the cool and warm regimes may also have detrimental effects on the health of nearshore kelp forest ecosystems on both natural and artificial reefs (Caselle et al. 2017; Provost et al. 2017; Ramírez-Valdez et al. 2017). Although Bonito primarily occupy coastal pelagic habitats, these changes could impact prey availability and have larger impacts on juveniles who occupy nearshore habitats. Increased monitoring of environmental variables, fish abundance and distribution from all available data sources will be important to anticipate change and take proactive management actions.

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