PACIFIC SARDINE REBUILDING PLAN

INCLUDING REBUILDING PLAN SPECIFICATIONS, ENVIRONMENTAL ASSESSMENT, AND MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ANALYSIS

DRAFT

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LIST OF ACRONYMS AND ABBREVIATIONS

ABC	acceptable biological catch
ACL	annual catch limit
ACT	annual catch target
AM	accountability measure
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CPS	coastal pelagic species
CCE	California current ecosystem
CPFV	California Passenger Fishing Vessel
CPSMT	Coastal Pelagic Species Management Team
DPS	distinct population segment
EA	Environmental Assessment
EEZ	exclusive economic zone (from 3-200 miles from shore)
ESA	Endangered Species Act
FMP	fishery management plan
FONSI	Finding of No Significant Impacts
HCR	harvest control rule
HG	harvest guideline
LE	limited entry
MBTA	Migratory Bird Treaty Act
MMPA	Marine Mammal Protection Act
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSST	minimum stock size threshold
MSY	maximum sustainable yield
NEPA	National Environmental Policy Act
NS1	National Standard 1
NSP	northern subpopulation
NMFS	National Marine Fisheries Service
OFL	overfishing limit
PacFIN	Pacific Fisheries Information Network
SSC	Scientific and Statistical Committee
SWFSC	Southwest Fisheries Science Center
U & A	Usual and Accustomed Area (Tribal)

1. INTRODUCTION

NOAA's National Marine Fisheries Service (NMFS) declared the northern subpopulation (NSP) of Pacific sardine (Pacific sardine) overfished in June 2019. This determination was based on the results of an April 2019 stock assessment (Hill et al. 2019), which indicated that the biomass of Pacific sardine had dropped below the overfished threshold of 50,000 metric tons (mt), as defined in the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP). NMFS notified the Pacific Fishery Management Council (Council) about the overfished declaration on July 9, 2019. The Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires that NMFS and the Council prepare and implement a rebuilding plan within two years of NMFS' overfished notification to the Council that specifies a rebuilding timeframe (T_{target}) within 10 years, except where the biology of the stock or other environmental conditions dictate otherwise (*see* MSA 304(e)). NMFS' National Standard (NS) 1 guidelines (*see* 50 CFR §600.310(j)(3)) provide direction on determining certain rebuilding reference points in order to specify T_{target}, including a target rebuilt biomass level, T_{min} (the minimum time to rebuild the stock assuming zero fishing morality), and T_{max} (the maximum time allowable for rebuilding). More details on rebuilding plan requirements are discussed in Section 5.0 and can be found in the MSA Section 304(e) and in NS1 at 50 CFR §600.310.

This Environmental Assessment (EA) is being prepared using the 2020 Council on Environmental Quality (CEQ) National Environmental and Policy Act (NEPA) Regulations. The effective date of the 2020 CEQ NEPA Regulations was September 14, 2020, and reviews begun after this date are required to apply the 2020 regulations unless there is a clear and fundamental conflict with an applicable statute (85 Fed. Reg. at 43372-73 (§1506.13, 1507.3(a)). This EA was logged as federal action on September 17, 2020, and accordingly proceeds under the 2020 regulations.

1.1. PURPOSE AND NEED

The purpose of the proposed action is to develop a rebuilding plan for Pacific sardine. The rebuilding plan is needed to comply with MSA requirements to rebuild stocks that have been declared overfished.

1.2. ACTION AREA

The action area is inclusive of and limited to the United States West Coast Exclusive Economic Zone (EEZ), from 3 to 200 nautical miles offshore of Washington, Oregon, and California. The range of Pacific sardines can extend beyond the U.S. West Coast EEZ. However, U.S. jurisdiction and management for CPS stocks does not extend beyond the EEZ.

2. REBUILDING PLAN SPECIFICATIONS

To meet the 2-year rebuilding plan implementation timeline, the Council considered a range of rebuilding alternatives at its June 2020 meeting and provided guidance to its Coastal Pelagic Species Management Team (CPSMT) on a final set of alternatives to be analyzed. The underlying model and assumptions used in the biological and economic analyses were reviewed by the Council's Scientific and Statistical Committee's (SSC) CPS Subcommittee in July 2020. The CPSMT then compiled a preliminary environmental analysis that was considered by the Council at its September 2020 meeting. The CPSMT and Council analyzed three alternatives, each representing a fishery management strategy: Alternative 1 Status Quo Management, Alternative 2 Zero U.S. Harvest Rate, and Alternative 3 Five Percent Fixed U.S. Harvest Rate. The Council selected its final preferred alternative at the September 2020 meeting. The Council recommended Alternative 1 Status Quo Management and a resulting T_{target} of 14 years to reach the target rebuilding biomass level of 150,000 metric tons (mt) age 1+ Pacific sardine biomass. This T_{target} is in the context of a T_{min} of 12 years and a T_{max} of 24 years and was determined to be the shortest time possible to rebuild the stock, taking into account the biology of the stock, the needs of fishing communities and the interaction of the stock within the marine ecosystem. These Rebuilding Reference Points are summarized in the table below:

Rebuilding Reference Points
T_{min} = 12 years
T_{target} = 14 years
T_{max} = 24 years
Rebuilt biomass = 150,000 mt age 1+ biomass

More information on the determination of these rebuilding reference points is available in Section 5.0.

3. DESCRIPTION OF ALTERNATIVES

During the scoping process for this action, the Council determined that the type and scope of alternatives for potential consideration would be narrow because the management framework in the CPS FMP already dictates management actions that would typically be implemented under a rebuilding plan to minimize fishing mortality on an overfished stock. Per the requirements of the CPS FMP, the primary directed fishery for Pacific sardine was first closed in 2015 when the stock dropped below the 150,000-mt CUTOFF threshold for allowing a primary directed fishery (*see* Section 4.6.1 of PFMC 2019a). In addition, per the requirements in the CPS FMP, incidental landing limits of Pacific sardine in other CPS fisheries were reduced from 40 percent by weight per landing to 20 percent (*see* Section 5.1.1 of PFMC 2019a) in 2019 when the stock's biomass dropped below the 50,000-mt overfished threshold (also referred to as the minimum stock size threshold (MSST)), further limiting the allowable harvest of Pacific sardine. Although this decrease in biomass below 50,000 mt triggered the requirement to declare the stock overfished, overfishing has never occurred for this stock, as Pacific sardine catch has been well below both the acceptable biological catch (ABC) and the overfishing limit (OFL) since and before the closure of the primary directed fishery.

With regard to the alternatives presented below, Alternative 1 represents status quo management and therefore maintains the implicit rebuilding measures and catch restrictions that are already in effect per the CPS FMP. Alternative 2 would set the U.S. Pacific sardine quota at zero, thereby prohibiting landings of Pacific sardine in all CPS and non-CPS fisheries. Alternative 3 would allow some harvest, but limited to five percent of the biomass. As stated above, all three management alternatives assume a target rebuilt biomass level of 150,000 mt age 1+ biomass. All three of the alternatives require NMFS to adopt a rebuilding plan and therefore are action alternatives. The "no action" alternative is not adopting a rebuilding plan, which would not meet the requirements of the MSA. The environmental effects of no action are identical to those described for Alternative 1 and, therefore the no action alternative is not discussed further. The

Council and NMFS only have the ability to implement fishery management regulations in Federal waters (*i.e.*, from 3 to 200 nautical miles offshore). The analysis of the three management alternatives below assumes the states would adopt complementary regulations for state waters as has been common practice for CPS fisheries.

3.1. Alternative 1 (Preferred Alternative)

Status Quo Management

Alternative 1 maintains the current management process, harvest control rules (HCRs), and other FMP provisions currently in place for Pacific sardine. This includes the prohibition of the primary directed fishery for Pacific sardine when the biomass is at or below 150,000 mt, and the automatic reduction in incidental allowances in other CPS fisheries when the biomass is at or below 50,000 mt.

Alternative 1 also maintains the Council's annual harvest specifications process for Pacific sardine, such that an OFL and ABC are calculated annually based on an estimate of that year's estimated biomass from annual stock assessments. The ABC HCR accounts for scientific uncertainty in the estimate of OFL and any other scientific uncertainty, and thus represents a level of harvest that ensures overfishing will not occur. An annual catch limit (ACL) is then set at or below the ABC to account for any management uncertainty.

The Pacific sardine HCRs include the following:

OFL = Biomass * E_{MSY} * Distribution
ABC = Biomass * $BUFFER_{P\text{-}star}$* E_{MSY} * Distribution
ACL = LESS THAN OR EQUAL to ABC
ACT = OPTIONAL; LESS THAN ACL

- BIOMASS is the age 1+ biomass of the Pacific sardine estimated in annual stock assessments.
- E_{MSY} is an estimate of the exploitation rate at maximum sustainable yield.
- Recognizing that Pacific sardine ranges beyond U.S. waters and, therefore, is subject to foreign fisheries, the HCRs include the DISTRIBUTION term which equals 0.87 and is intended on average to account for the portion of the NSP of Pacific sardine in U.S. waters.

In addition to the HCRs and management measures prescribed by the CPS FMP, Alternative 1 would allow the Council the ability to incorporate various additional management measures to limit Pacific sardine harvest, if warranted. For example, in 2017, before the Pacific sardine stock was declared overfished, the Council chose to adopt automatic inseason actions for CPS fisheries that progressively reduced the incidental per landing allowance from 40 percent Pacific sardine to 10 percent with decreases triggered by landing thresholds being reached. Additional accountability measures (AMs) can be implemented when the biomass falls below 50,000 mt. As stated above, the CPS FMP requires that the incidental landing limit for Pacific sardine not exceed 20 percent by weight per landing. In addition to this requirement, the Council and NMFS have implemented additional AMs in the two years since the stock fell below 50,000 mt. For example, for the 2020-2021 fishing year, the Council adopted an annual catch target (ACT) of 4,000 mt that, if attained, will trigger a per trip limit of 1 mt of Pacific sardine for all CPS fisheries. The Council also adopted an AM specific to the 2020-2021 live bait sardine fishery that limits the per landing limit to 1 mt of Pacific sardine if landings in the live bait fishery attain 2,500 mt. Since Pacific sardine was declared overfished, the AMs have not been triggered, reflecting the relatively conservative nature of the fishery, but they exist as safeguards should fishery dynamics shift towards increased harvest.

3.2. ALTERNATIVE 2

Zero U.S. Harvest Rate

Alternative 2 would adopt a U.S. zero-harvest approach and entails a complete closure of the remaining fisheries that target Pacific sardine, including the live bait and minor directed fisheries, both of which are small sectors but dependent on some level of directed Pacific sardine harvest. Alternative 2 would also eliminate incidental landing allowances in other CPS and non-CPS fisheries, including Pacific mackerel, market squid, northern anchovy, and Pacific whiting. It is difficult for these fisheries to completely avoid incidental catch of Pacific sardine, therefore eliminating incidental landings in these fisheries would likely force their complete closure or result in a high level of discarding at sea. The Council and NMFS only have authority to implement Alternative 2 in Federal waters (*i.e.*, 3 to 200 nautical miles from shore). Fully implementing Alternative 2 would also require additional state regulations to close fishing for Pacific sardine in state waters.

The Council considered this alternative primarily for modeling and analysis purposes to aid in determining a T_{min} for a rebuilding timeline (*see* Section 5.0). Per NMFS' NS1 Guidelines, T_{min} is the expected time it would take to rebuild the stock in the absence of fishing (*see* 50 CFR §600.310(j)(3)). It is difficult to specify how this alternative would be implemented in practice (*i.e.*, what specific regulatory restrictions could be adopted, such as closure of minor directed fisheries and elimination of incidental landing allowances in all fisheries) to reduce Pacific sardine catch to zero. Thus, in practice, this alternative would likely be difficult to fully implement from a fishery management perspective. In addition, tribal treaty fisheries are established via Government to Government consultation and could potentially include Pacific sardine harvest. As proposed, the concept of this alternative was primarily to provide a comparative analysis given that status quo management already restricts harvest to low levels well before the stock is estimated to be below MSST.

3.3. ALTERNATIVE 3

Five Percent Fixed U.S. Harvest Rate

Alternative 3 would set the ACL at five percent of total age 1+ biomass for that year. The OFL and ABC would be computed using existing HCR formulas; however, under this alternative, the allowable harvest level (*i.e.*, the ACL) would be fixed at five percent and it incorporates no other HCR parameters. Specifically, it bypasses the DISTRIBUTION term for the portion of the stock in U.S. waters. It also bypasses the BUFFER parameter in the ABC HCR, which is a risk policy choice determined by the Council as part of its annual specifications process. This alternative was intended to represent a harvest level between Alterative 1 Status Quo Management and Alternative 2 Zero U.S. Harvest to explore the differences in rebuilding timelines of a reduced harvest level. To illustrate, Table 2 in Section 4.3.2 compares the ACLs used for management since 2015 with the ACLs this alternative would have produced.

3.4 ALTERNATIVES CONSIDERED BUT REJECTED

The CPSMT had originally proposed an alternative "Reduced Status Quo", similar to Alternative 3, to provide an option with a harvest level in between Alternative 1 Status Quo Management and Alternative 2 U.S. Zero Harvest. However, the "Reduced Status Quo" alternative did not include a specific level of reduction (*see* PFMC 2020b). The CPSMT considered the management outcomes of the two alternatives to be similar, so only the Five Percent Fixed U.S. Harvest Rate alternative was retained as a third alternative for further consideration by the Council.

4. AFFECTED ENVIRONMENT AND ANALYSIS OF ALTERNATIVES

This section combines the Affected Environment and the Analysis of Alternatives sections that are traditionally separated in EAs. First, this section provides a description of the biological modeling conducted to examine potential rebuilding timelines and management strategies, and explains how the results from this modeling were used as one aspect of analysis for each management alternative. Then, a description of each component of the Affected Environment is provided, followed by an analysis of how each management alternative may impact that component of the Affected Environment. As stated above, the analyses take into consideration more than just the results of the biological modeling work (Hill et al. 2020); it was also necessary to rely on what is known about the basic biology and life history of Pacific sardine, including estimates of its large population fluctuations over thousands of years, and the history of the Pacific sardine fishery on the west coast of North America.

For the purposes of this action, the general action area is the West Coast EEZ. The state waters of Washington, Oregon and California may also be indirectly affected by this action.

4.1. MODELING DESCRIPTION AND USE IN ANALYSIS OF ALTERNATIVES

The "Rebuilder" modeling platform (hereafter referred to as the "Rebuilder tool" or "the model") is an age-structured population dynamics simulator that projects a fish population forward in time, accounting for recruitment, growth, natural mortality, and fishing mortality. The Rebuilder tool was originally designed to analyze rebuilding groundfish stocks (Punt 2012), but was revised to allow for rebuilding projections based on Pacific sardine HCRs (Punt 2020). These revisions included simulating the Pacific sardine ABC HCR in conjunction with accounting for catch outside the U.S. (*i.e.*, Mexican catch). The modeling was performed by a team from NMFS' Southwest Fisheries Science Center (SWFSC) and details of the methods, model inputs, and results are included in Hill et al. 2020. The intent of this modeling was, in part, to help guide the analysis of management alternatives for rebuilding Pacific sardine; however, since Pacific sardine recruitment and productivity are largely driven by environmental conditions, which cannot be accurately predicted, it was expected that the modeling results would have limitations in informing realistic rebuilding timelines.

For each management alternative, the Rebuilder tool was used to calculate: 1) the probabilities (at least 50 percent chance) of rebuilding the Pacific sardine stock to a modeled SB_{MSY} (spawning stock biomass at maximum sustainable yield (MSY)) and the selected target rebuilding biomass level (expressed in terms of age 1+ biomass – see 5.3.1 for further detail), 2) median spawning stock values, and 3) median catch values. These values were calculated based on two different time periods that represent moderate and low Pacific sardine productivity and two different levels of potential harvest by Mexico (Table 6 through Table 13 of Hill et al. 2020). The Rebuilder tool used data inputs from the 2020 benchmark stock assessment that covers the time period 2005-2020 (Kuriyama et al. 2020). The two modeled time periods, 2005-2018 and 2010-2018, were chosen to represent different levels of potential future productivity (*i.e.*, recruitment scenarios, also referred to as states of nature) for this stock. The two Mexican harvest scenarios included a fixed tonnage (6,044 mt) and a fixed rate (9.9 percent of Pacific sardine biomass).

The Rebuilder tool was also used to estimate virgin spawning biomass (SB_0, *i.e.*, the average spawning biomass that the stock is capable of attaining in the absence of fishing), for the two different time periods 2005-2018 and 2010-2018. The resulting average SB_0 estimates were 377,567 mt and 104,445 mt for 2005-2018 and 2010-2018, respectively (Table 4 of Hill et al. 2020).

The modeling work explored different scenarios of productivity and catch by Mexico, however the Analysis of Alternatives for each component of the Affected Environment below considers only the modeling results that drew from recruitments for the period from 2005-2018. This period represents a broader range of recruitment observed for this stock than the modeled subset of years 2010 to 2018, which include only years with low Pacific sardine productivity. The modeling results for 2010-2018 also provide a relatively low spawning stock biomass target of only 38,122 mt (Table 4 of Hill et al. 2020), therefore no further consideration was given to modeling results calculated for the low productivity 2010-2018 recruitment scenario. The decision was also made to utilize the modeling runs based on the fixed rate assumption for Mexico versus a fixed catch level on the presumption that it is reasonable to assume Mexican catch might go up and down based on stock size. Therefore, modeling results relevant to the Analysis of Alternatives below are the rebuilding probability, median catch, and median spawning stock values for the longer, moderate productivity time period (2005-2018) and fixed rate Mexican catch scenario. These modeling results are presented in Tables 6, 8, 10, and 12 of Hill et al. 2020.

Although the modeling results from the 2005-2018 time period were deemed more appropriate for analyzing the management alternatives because the 2005-2018 time period captured a broader range of recruitment, there are still recruitment patterns that the model was unable to capture even in this longer time period. The 2020 assessment authors stated, “recruitment has declined since 2005-2006 with the exception of a brief period of modest recruitment success in 2009-2010. In particular, the 2011-2018 year classes have been among the weakest in recent history.” Therefore, modeling only this time period was inadequate to capture the biological pattern of a stock that is known to go through boom and bust cycles driven by environmental conditions. This stock exhibited much greater productivity and recruitment in the years leading up to its most recent peak in abundance in 2006, and this occurred in the years after it came under federal management in the year 2000. These years are not covered by the modeling. The model also assumes the entire ABC is caught each year; however, that has not been the case in recent years when less than half of the ABC was taken in U.S. fisheries and much of that is thought to be from the southern subpopulation and not from this stock. Given these uncertainties, the modeling results were used as only one analytical tool. However, despite its limitations, the modeling platform and its results do provide useful guidance and insights that are considered in the following Analyses of Alternatives. The model results were also used for determining T_{min}, T_{max} and T_{target} values as well as an appropriate proxy for the biomass level that represents a rebuilt stock. For a discussion of how the model results were used to determine the rebuilding reference points, see Section 5.0.

4.2. Pacific Sardine Resource

4.2.1. Affected Environment – Pacific Sardine Resource

Pacific sardine (*Sardinops sagax*) are small schooling fish and are found from the ocean surface down to 385 meters. Pacific sardine, along with other species such as northern anchovy, Pacific hake, jack mackerel, and Pacific mackerel can achieve large populations in the California Current Ecosystem (CCE) as well as in other major eastern boundary currents. However, as noted above Pacific sardine, as well as other CPS populations, have undergone boom and bust cycles for roughly 2,000 years, even in the absence of commercial fishing (*see* Figure 1).

Pacific sardine form three subpopulations (*see* review by Smith 2005). The NSP, which ranges from southeast Alaska to the northern portion of the Baja Peninsula, is most important to U.S. commercial fisheries and is the stock managed by the CPS FMP. The southern subpopulation ranges from the southern Baja Peninsula to southern California, and the third subpopulation is in the Gulf of California. Off the U.S. West Coast, sardines are known to migrate northward in spring and summer and southward in fall and winter. This is true for both the NSP and the southern subpopulation. Although these two subpopulations overlap, they are considered to be distinct subpopulations (Felix-Uraga et al. 2004, Felix-Uraga et al. 2005, Garcia-Morales et al. 2012, Demer and Zwolinski 2014). The Pacific sardine NSP ranges from the waters off northern Baja California, Mexico to southeast Alaska and commercial fishing occurs on this transboundary stock by fleets from Mexico, the U.S., and Canada during times of high abundance. The stock's range is reduced when population levels are low with the bulk of the biomass and harvest typically centered off southern/central California and northern Baja.

<u>Factors Contributing to Overfished Status</u>

The recent population decline of Pacific sardine appears to be due to poor recruitment. Specifically, the 2020 assessment states that recruitment has declined since 2005-2006 except for a brief period of modest recruitment success in 2009-2010, with the 2011-2018 year-classes being among the weakest in recent history (Kuriyama et al. 2020). Such declines in population are by no means unprecedented. The Pacific sardine has undergone large population fluctuations for centuries even in the absence of industrial fishing (*see* Figure 1) as evidenced by historical records of scale deposits (Soutar and Issacs 1969, Baumgartner et al. 1992). Although there is general scientific consensus that environmental conditions are a critical factor driving the population size of this stock, as well as how quickly it recovers from low levels, the specific environmental conditions and variables that are most important and the degree to which fishing may affect population fluctuations has long been investigated and is still debated (Clark and Marr 1955, Baumgartner et al. 1992, Mantua et al. 1997, Minobe 1997, Schwartzlose et al. 1999, McFarlane et al. 2002, Smith and Moser 2003, Rykaczewski and Checkley 2008, Field et al. 2009, MacCall 2009, Zwolinski and Demer 2012, Lindgren et al. 2013).

There is less evidence that harvest has been a factor leading to the overfished status of Pacific sardine. The U.S. harvest of this stock is highly regulated based on the CPS FMP and the HCRs contained therein are considered to be quite conservative as well as responsive to declines in the biomass. For example, an approximately 33 percent decline in biomass from 2012 to 2013 resulted in an approximately 60 percent decrease in the 2013 allowable harvestcompared to 2012 and a subsequent 44 percent decline in biomass from 2013 to 2014 resulted in a 66 percent decrease in the 2014 allowable harvest compared to 2013. These reductions were primarily a result of the CUTOFF parameter in the HCR, which was designed to keep more fish in the ocean for reproductive purposes as the stock biomass declines and reduces allowable harvest in the directed fishery as biomass gets closer to 150,000 mt.

Each year since the directed fishery closure, ACLs have been set (*see* Table 1 in Section 4.3.2). However, total harvest has remained relatively constant since 2015, averaging about 2,200 mt/year, which is well below any year's ACL. This is due primarily to closure of the directed fishery, but also other explicit regulatory measures in the CPS FMP such as limits on minor directed fishing and the amount of Pacific sardine that can be caught incidental to other fisheries. Additionally, all U.S. Pacific sardine catch is counted against the ACL, even though some portion is composed of the southern subpopulation of Pacific sardine. For example, the most recent stock assessment retroactively assigned only a portion of the U.S. catch to the NSP (*see* Table 1 in Kuriyama et al. 2020). This suggests that U.S. harvest of NSP Pacific sardine has likely been less than 1 percent of the stock biomass in the years since the closure of the primary directed fishery.

As stated above, harvest of Pacific sardine also occurs off northern Baja with catch landed into Ensenada, Mexico. This catch from Mexican waters includes fish from the NSP. The catch from this fishery also appears to be comparatively low in recent years. Using the apportioned landings information in the 2020 stock assessment, from 2015-2019 the Ensenada fishery is assumed to have caught under 5,000 mt/year of NSP sardine on average. This compares to an annual average of approximately 136,500 mt of NSP sardine for the 2010-2014 time period. However, there is considerable variability in the catch of NSP over these last 10 years and after zero landings were reported in 2015 and 2016 the trend has been upward through 2019.

Stock assessment results suggest that even in the absence of any fishing, the NSP sardine stock would be expected to decline significantly (Figure 2). These results suggest that environmental conditions and ecosystem constraints contributing to low recruitment, rather than fishing, are the most important factors contributing to the overfished status of this stock, even if the specific mechanisms and environmental conditions that affect recruitment remain poorly understood.

4.2.2. Analysis of Impacts – Sardine Resource

As noted previously, there is scientific consensus that environmental conditions will play a critical role in both the amount of time it takes and to what extent the Pacific sardine biomass rebounds from its current low levels. The modeling work provides insight into the alternatives being considered, but as noted above the assumptions made in the modeling limit its usefulness. Additionally, even if further refinements could be made, it is virtually impossible to predict when environmental conditions might produce favorable recruitment and therefore allowing the stock to increase in size. For the purpose of this analysis, the effects analyzed on the Pacific sardine resource include how each management alternative may affect the ability of Pacific sardine to rebuild in the near and long term.

According to the model results, under Alternative 1 Status Quo Management, when the full ABC is assumed to be taken, there is never a greater than 50 percent probability that the stock will rebuild to the selected rebuilding biomass target of 150,000 mt 1+ biomass (Table 8 in Hill et al. 2020) or the modeled SB_{MSY} of 137,812 mt before the year 2050, which is the last year that was modeled (Table 6 in Hill et al. 2020). However, the modeling results should be viewed in the context that they do not capture the full range of productivity of which this stock is capable. They also assume that under Alternative 1 Status Quo Management, U.S. fisheries harvest the full ABC, which has not been the case due to the prohibition on primary directed fishing, restrictions on incidental harvest, and to some degree market dynamics, all of which cannot be captured in the modeling. This is important to note, because due to the restrictions in place, landings of Pacific sardine are likely to remain similar during the rebuilding timeline as they have been over the past five years (*i.e.*, 2,200 mt/year on average) and therefore would be well below the modeled status quo landings, accruing more benefit to the resource than was modeled. Because the Rebuilder tool could not accurately represent true status quo management, the SWFSC performed additional modeling that calculated rebuilding probabilities assuming a constant catch of 2,200 mt, which is the average catch over the past five years even at varying biomass levels (*see* Table 1 in Section 4.3.2), largely due to the FMP requirements and additional management measures implemented by the Council under status quo management. Under this model run, the stock had at least a 50 percent chance of rebuilding to 150,000 mt age 1+ biomass in 17 years, or in the year 2038. The Council analyzed this model run because it was considered a more realistic representation of Alternative 1 than the originally modeled Alternative 1 Status Quo Management, which assumes the full ABC is harvested each year. Although the initial model results for Alternative 1 Status Quo Management are discussed throughout this document, the model results for a constant catch of 2,200 mt are considered to represent a more realistic projection of fishery landings in the near term, and therefore more appropriate for selecting a management strategy for the rebuilding plan.

Under Alternative 2 U.S. Zero Harvest, the modeled time to rebuild Pacific sardine with a greater than 50 percent probability to the selected rebuilding biomass target of 150,000 mt age 1+ biomass (*i.e.*, equivalent to an SB_{MSY} of approximately 121,650 mt) is 12 years, or in the year 2033 (Table 8 in Hill et al. 2020). The modeled time to rebuild to the modeled SB_{MSY} of 137,812 mt is 15 years, or in the year 2036 (Table 10 of Hill et al. 2020). This is the fastest rebuilding timeline of any of the alternatives. The projected median spawning biomass values under Alternative 2 are presented in Table 10. Like Alternative 1, the modeling results do not capture the full range of productivity of which this stock is capable, nor can the modeling work predict future productivity. It is difficult to determine if this zero-fishing option would rebuild Pacific sardine faster than any of the other highly restrictive alternatives presented here; historical studies have shown that the stock can stay low even with no fishing. Therefore even though fishing mortality associated with this alternative would be lower and fewer removals would occur on an annual basis, it is difficult to know if or how much faster the stock would rebuild under this alternative despite the modeling results.

Under Alternative 3 U.S. Five Percent Harvest Rate, the modeled time to rebuild Pacific sardine with a greater than 50 percent probability to the selected rebuilding biomass target of 150,000 mt 1+ biomass is 16 years or in the year 2037 (Table 8 in Hill et al. 2020). The modeled time to rebuild to the modeled SB_{MSY} of 137,812 mt is 26 years, or in the year 2047 (Table 10 of Hill et al. 2020). The projected median spawning biomass values under Alternative 3 are presented in Table 10. Similar to Alternative 1, the modeling assumes that the full five percent is harvested each year. The modeling also does not account for restrictions on incidental catch that might restrict harvest, or the fact that industry may not take the full five percent for other socioeconomic reasons.

Compared to the initial model results for Alternative 1 (*i.e.*, when the full ABC is assumed to be caught), which do not project the stock to rebuild, Alternative 3 is projected to rebuild to the selected rebuilding target of 150,000 mt age 1+ biomass in 16 years. However, as stated above, the modeled results for Alternative 1 when total Pacific sardine landings are assumed to remain similar to recent years (*i.e.*, 2,200 mt per year) project the stock to rebuild to 150,000 mt age 1+ biomass in 17 years. Therefore, Alternative 3 is only projected to rebuild 1 year faster than what actual status quo management would achieve under Alternative 1. Additionally, the actual expected rebuilding timeline under a constant catch of 2,200 mt per year is expected to be 14 years as opposed to 17 years. Although recent average catch of Pacific sardine is 2,200 mt, this value includes catch from the southern subpopulation of Pacific sardine, which ranges from the southern tip of Baja, Mexico to the Southern California Bight off the U.S. West Coast. The southern subpopulation overlaps with the NSP in the summertime in U.S. waters; all landings in U.S. waters are counted against the ACL for the NSP Pacific sardine stock under U.S. management. Recent U.S. harvest of the NSP of Pacific sardine has averaged only 472 mt annually, which only averages 0.6 percent of the biomass. Therefore, actual status quo landings over the last five years are actually less than what was modeled for Alternative 3 Five Percent U.S. Harvest Rate. It is likely that, similar to Alternative 1, the actual harvest rate under Alternative 3 would be less when considering that only a portion of U.S. landings are attributed to the NSP of Pacific sardine. Therefore, the rebuilding timeline under Alternative 3 is expected to be longer than the 12 years for Alternative 2, but potentially shorter than the 16 years initially modeled. However, as described in Section 4.2.1, the environment will likely be the primary determinant for the stock increasing. The fishery is already being heavily restricted under status quo management, and it is unclear if the reductions in annual catch under Alternative 3 Five Percent Fixed U.S. Harvest Rate compared to Alternative 1 Status Quo Management would allow the stock to realistically rebuild any faster.

In conclusion, no management alternative is expected to significantly impact the ability of the Pacific sardine resource to rebuild in the near or long term, as fishing mortality is not the primary driver of stock biomass.

4.3. Fishing Industry

4.3.1. Affected Environment – Fishing Industry

California's Pacific sardine fishery began in the 1860s as a supplier of fresh whole fish. The fishery shifted to canning from 1889 to the 1920s in response to a growing demand for food during World War I. Peaking in 1936-37, Pacific sardine landings in the three west coast states plus British Columbia reached a record 717,896 mt. In the 1930s and 1940s, Pacific sardine supported the largest commercial fishery in the western hemisphere, with sardines accounting for nearly 25 percent of all the fish landed in the U.S. by weight. The fishery declined and collapsed in the late 1940s due to extremely high catches and changes in environmental conditions, and remained at low levels for nearly 40 years. The fishery declined southward, with landings ceasing in Canadian waters during the 1947-1948 season, in Oregon and Washington in the 1948-1949 season, and in the San Francisco Bay in the 1951-1952 season. The California Cooperative Fisheries

Investigations (CalCOFI), a consortium of state and federal scientists, emerged to investigate the causes of the Pacific sardine decline. Analyses of fish scale deposits in deep ocean sediments off southern California found layers of sardine and anchovy scales, with nine major sardine recoveries and subsequent declines over a 1700-year period (Baumgartner et al. 1992, *see* Figure 1).

The decline of the sardine fishery became a classic example of a "boom and bust" cycle, a characteristic of clupeid stocks (*i.e.*, certain small pelagic fish like sardines). In 1967, the California Department of Fish and Game implemented a moratorium that lasted nearly 20 years. Sardines began to return to abundance in the late 1970s, when the Pacific Decadal Oscillation shifted to a warm cycle again, but this time fishery managers adopted a highly precautionary management framework. California's Pacific sardine fishery reopened in 1986 with a 1,000 short ton quota, authorized by the Legislature when the biomass exceeded 20,000 mt. The sardine resource grew exponentially in the 1980s and early 1990s, with recruitment estimated at 30 percent or greater each year. By 1999, the biomass was estimated to be around 1 million mt (Conser et al. 2001). The Pacific sardine biomass appeared to level off during 1999-2002. In 2005, Oregon landings surpassed California for the first time since the fishery reopened. California caught nearly 81,000 mt of the 152,564-mt harvest guideline (HG) in 2007 – the highest landings since the 1960s. Around this time, recruitment began to decline. The 2020 base model stock biomass was projected to be 28,276 mt in July 2020 (Kuriyama et al. 2020).

For the purpose of this analysis, the effects analyzed on the affected fishing industry include the near and long term economic impacts associated with loss of fishing opportunity under each management alternative.

4.3.1.1. PRIMARY DIRECTED COMMERCIAL FISHERY

The primary directed fishery comprises the largest component of the CPS fisheries that harvest Pacific sardine and represents the historical fishery dating back to the 1920's in California and the contemporary expansion from the late 1990's of the fishery into the Pacific Northwest. The primary directed fishery is the main fishery that operates in federal waters. As described above in Section 3.1, fishing opportunity in the primary directed fishery is determined by the output of the harvest guideline HCR, which has imposed a closure of the fishery since 2015. Prior to its closure, the ex-vessel value of this fishery averaged over $14.7 million (in 2018 dollars) from 2009 through 2014 (PFMC 2019b). Because the primary directed fishery has been closed since 2015 and will remain closed until the sardine biomass exceeds the Council's selected target rebuilding level of 150,000 mt age 1+ biomass, it will not be affected by any of the rebuilding alternatives and therefore will not be evaluated relative to impacts of the alternatives.

4.3.1.2 LIVE BAIT FISHERY

Live bait fisheries typically use various types of roundhaul gear such as purse seines to capture relatively small-sized CPS schools and deliver the catch alive to receiver vessels (or 'live bait barges') that have holding tanks or dockside net pens. Private and charter recreational vessels and commercial vessels then purchase live bait by the scoop from these receiver vessels or pens, as they depart for fishing trips. Although the live bait fishery harvests a very small amount of Pacific sardine, it is dependent on the ability to directly target pure schools of Pacific sardine to meet the needs of recreational fisheries. The live bait fishery is authorized in the EEZ, but is primarily conducted in state waters.

CALIFORNIA

The Southern California recreational fishery is part of an extremely valuable statewide fishery generating over $1.3 billion in value added impact to California in 2016 (NMFS 2018). Live bait is primarily used by recreational anglers on commercial passenger fishing vessels (CPFVs) and private boats. There are a total of 308 CPFVs that operate throughout California. From this total, 206 vessels (68 percent) operate in southern California (South of Point Conception) and 102 vessels (34 percent) operate in northern California (North of Point Conception). In San Diego County alone, 117 vessels operate out of three ports and accounts for the majority of sportfishing activity that occurs in California.

The California sportfishing industry relies on Pacific sardine for live bait. Between 2005 and 2015, reported sardine live bait catches averaged 2,522 mt per year, comprising 75 percent of total live bait catch in California (See Table 4-12 in PFMC 2019b Appendix A). Pacific sardine are preferred for long-range trips to Mexico, as they are heartier and more likely to survive and be active than other bait species for the duration of extended trips, which can be several days or longer. Anglers often check fishing reports and will plan trips based on catch by species, which can be strongly affected by available bait species. Therefore, the appeal of sportfishing trips can be adversely affected by an inconsistent supply of varied bait species. A reliable and varied supply of live bait (including Pacific sardine) is an essential component of this fishery.

OREGON

In Oregon, fishing for CPS to use as live bait is minimal with small amounts, including Pacific sardine, from the minor directed fisheries sometimes sold as live bait.

WASHINGTON

In Washington, the sole opportunity to target Pacific sardine is in the federal primary directed sardine fishery which has been closed by moratorium since 2015. Therefore, although baitfishing for other species is allowed, directed baitfishing for Pacific sardine is currently prohibited. Total incidental landings of Pacific sardine by baitfish licenses are less than 0.5 mt per year.

4.3.1.3 MINOR DIRECTED FISHERY

Amendment 16 of the CPS FMP, implemented in 2018, allows minor directed commercial fishing on CPS finfish to continue when the primary commercial fishery is otherwise closed. This sector accounts for a very small portion of the overall catch of any particular CPS stock and has a negligible impact. However, it is an important source of income for some small ports and producers, especially when the directed fishery is closed. Minor directed fishing occurs in California, averaging less than 50 mt per year, and in Oregon state waters, averaging 3.6 mt per year. Washington's state regulatory framework essentially precludes minor directed fishing when the 1+ biomass estimate is below 150,000 mt. The amendment included a maximum of 1 mt per vessel per day, with a one-trip-per-day limit. Although the minor directed fishery harvests a small amount of Pacific sardine, it is dependent on the ability to directly target pure schools of Pacific sardine to accommodate its markets (*i.e.*, dead bait and restaurant sales). In addition, small-scale fishermen that participate in the minor directed fishery typically do not participate in any other fishery and are therefore heavily reliant on this fishing opportunity from a socioeconomic aspect.

4.3.1.4 INCIDENTAL HARVEST

CPS FISHERIES

Incidental harvest of Pacific sardine in CPS fisheries targeting northern anchovy, Pacific mackerel, and Market squid was restricted to 40 percent per landing for the 2015-2016 to 2018-2019 seasons and then 20 percent per landing starting with the 2019-2020 season. When possible, fishermen avoid mixed schools because the markets often prefer to have landings without high levels of incidental species in order to reduce the time to sort fish. In recent years California CPS fishermen have indicated increased difficulty catching fish because they have encountered mixed schools frequently and must release the school if Pacific sardine comprise over 20 percent in the school. Since the closure of primary directed Pacific sardine fishing, an average of 300 mt of incidental sardine has been landed per year in California. These mixed landings averaged over $1.8 million in value (PFMC 2020a).

NON-CPS FISHERIES

Incidental harvest of Pacific sardine also occurs in other fisheries such as the groundfish trawl fishery where fishermen do not have the ability to avoid capturing Pacific sardine. Annual management measures for Pacific sardine include an incidental catch allowance of sardine for non-CPS directed fisheries, expressed as a limit in metric tons per landing. The limit has been up to two mt. The Pacific whiting fishery accounts for most non-CPS directed fishery incidental catch.

The Pacific whiting trawl fishery is composed of at-sea and shoreside fisheries. The at-sea sector is subdivided between mothership processing vessels accepting fish from catcher boats and catcher-processor vessels. The Pacific whiting fishery begins in May; shoreside sector landings peak in August while the at-sea sectors show higher landings in May, a steep drop in the summer, and a resurgence in the fall.

The shoreside fishery delivers to processing plants on land; with Westport and Ilwaco, Washington; and Astoria, Oregon being the principal ports for shoreside landings. These vessels catch almost exclusively Pacific whiting, amounting to 99 percent of the catch by weight. The incidental landings of Pacific sardine coastwide across the Pacific whiting fishery (at-sea and shoreside) have averaged 1.9 mt total from 2000 through 2019. During that same period, annual incidental landings ranged from no reported Pacific sardine in 2003 to 8.8 mt in 2005. Since 2015, when Pacific sardine biomass fell below CUTOFF or 150,000 mt, incidental landings in the Pacific whiting fishery while still small have trended up, particularly in the at-sea fishery. The average in the at-sea fishery prior to 2015 was 0.12 mt, increasing after 2015 to 1.4 mt. In the shoreside fishery which typically lands more incidental Pacific sardine, the average prior to 2015 was 1.3 mt and 1.8 mt in the years following. The combined whiting sectors averaged $51.5 million in value from 2012-2016 (PFMC 2018).

4.3.1.5 Tribal Fishery

The CPS FMP recognizes the rights of treaty Indian tribes to harvest Pacific sardine and provides a framework for the development of a tribal fishery. Pacific Ocean waters and estuaries north of Point Chehalis, Washington include the usual and accustomed (U & A) fishing areas of four treaty Indian tribes which may initiate their right to harvest Pacific sardine in any fishing year by submitting a written request to the NMFS Regional Administrator at least 120 days prior to the start of the fishing season.

Treaties between the United States and Pacific Northwest Indian Tribes reserve the rights of the Tribes to take fish at usual and accustomed fishing grounds. The Council's CPS FMP, as amended by Amendment 9 and codified in NMFS regulations (50 CFR 660.518), outlines a process for the Council and NMFS to consider and implement tribal allocation requests for CPS.

The Quinault Indian Nation has exercised their rights to harvest Pacific sardine in their Usual and Accustomed Fishing Area off the coast of Washington State, pursuant to the 1856 Treaty of Olympia (Treaty with the Quinault). The Quinault U & A is defined in § 660.50(c)(4) and represents an area directly off Westport/Grays Harbor, Washington, and waters to the north of this area.

4.3.2. Analysis of Impacts – Fishing Industry

Since the closure of the primary directed fishery in 2015, Pacific sardine has only been harvested in the smaller-scale sectors of the CPS fishery (*i.e.*, the live bait, minor directed, and tribal fisheries), and as incidental catch in other CPS (*e.g.*, Pacific mackerel) and non-CPS (*e.g.*, Pacific whiting) fisheries. With these fisheries in mind, this analysis considers the potential effects of each of the three proposed alternatives both from an evaluation of past fishery performance and based on the Rebuilder tool modeling results, respectively. The CPS fishing industry has already been significantly restricted since the closure of the primary directed fishery and the reduction in incidental landing limits, therefore the below analysis considers the current state of the fishery as the baseline comparison for any additional restrictions that may be imposed by each management alternative.

Under Alternative 1 Status Quo Management, the smaller-scale directed fishing sectors can expect a consistent and familiar management strategy in the near and long term, which will provide these sectors the necessary stability to plan for the future and maintain certain markets. The Council's small ACLs since the closure of the primary directed fishery in 2015 (*see* Table 1) have more than adequately accommodated the minor amount of catch needed to maintain these sectors. The small amount of harvest that remains is mostly in the live bait fishery. Between 2005 and 2015, reported Pacific sardine live bait catches averaged 2,522 mt with a minimum of 1,562 mt in 2014 and a maximum of 3,561 mt in 2006 (See Table 4-12 in the 2019 CPS SAFE Appendix A). Due to the input role that live bait landings play in the recreational sector, an expansion in demand outside the historical range is unlikely and would be necessitated by an increase in demand from the recreational fishing industry. Additionally, fishermen in other CPS and non-CPS fisheries that catch Pacific sardine incidentally are mostly able to land Pacific sardine contained in mixed loads within the incidental percentages and tonnage amounts that have been set by Council. Members of the CPS industry have expressed continued frustration with having to be more selective with the other CPS schools that they are allowed to capture to be sure that the proportion of Pacific sardine mixed in with the load is not over the incidental percentage limit. If these other CPS fisheries were to be further limited, many fishermen have said it would not be economically viable for them to continue, as they would have to spend more time and resources searching for schools with few Pacific sardine. Therefore, further restrictions to the smaller sectors would only be anticipated if Pacific sardine biomass declined to levels so low that the Council's ACLs were reduced to 2,200 mt or below (*e.g.*, at 15,000 mt biomass, *see* Table 3). Because Alternative 1 is not expected to further restrict the smaller directed sectors or incidental catch, the potential negative impacts to the associated industries (including the recreational and groundfish fisheries) are expected to be accordingly minimal.

Table 1. Annual Pacific sardine harvest specifications and landings for the fishing years following closure of the primary directed fishery.

Fishing Year	Biomass	OFL	ABC	ACL	ACT	Landings
2014-15	369,506	39,210	35,792	23,293 28,646*	23,293	19,440
2015-16	96,688	13,227	12,074	7,000	4,000	2,329
2016-17	106,137	23,085	19,236	8,000	5,000	2,217
2017-18	86,586	16,957	15,479	8,000	-	2,190
2018-19	52,065	11,324	9,436	7,000	-	2,505
2019-20	27,547	5,816	4,514	4,514	4,000	2,063
2020-21	28,276	5,525	4,288	4,288	4,000	-

Landings information is sourced from CA, OR and WA landings receipt databases. These values differ from and are higher than PacFIN reported landings. Some landings data do not appear to be getting reported to PacFIN.
*Harvest guideline for the primary directed fishery

Based on the modeling results, the smaller-scale sectors of the fishery and the incidental fishery for other CPS and non-CPS, would not be expected to be severely limited under the initially modeled Alternative 1 (*i.e.*, assuming the full ABC is harvested) through approximately 2040. The median U.S. catch levels presented in Table 12 of Hill et al. 2020 indicate that catch will remain high enough to accommodate the modest harvest needs of the smaller-scale sectors through approximately 2046. However, past 2046, median catch values decrease below recent average landing levels, indicating that the smaller sectors of the fishery may be constrained. However, as explained in Section 4.1, the Rebuilder tool calculates its projections using years with only low to moderate recruitment data. In a more realistic scenario, the model would include years with high recruitment data, and thus would likely produce higher median catch values for years with more favorable environmental conditions.

Under Alternative 2 Zero U.S. Harvest, the smaller fishery sectors are expected to be severely and adversely impacted in the near term and would continue to be impacted until the stock reached its target rebuilding level of 150,000 mt age 1+ biomass. Additionally, these near term impacts would come without an expectation of when they could be potentially mitigated by a shorter rebuilding timeframe. A zero harvest U.S. fishing approach (assuming that it would be adopted by the states) would completely eliminate Pacific sardine harvest in the live bait and minor directed fisheries, and curtail other fisheries that catch Pacific sardine incidentally, including other CPS fisheries and the Pacific whiting fishery. This could have far-reaching negative socioeconomic effects on the various user groups that rely on these fisheries, including non-sardine CPS, groundfish, and live bait fisheries. From a fishery management perspective, it would be difficult implement a true zero catch alternative and it would likely have substantial adverse economic effects. In addition, NMFS regulates only the portion of the fishery that occurs in the EEZ and therefore could not fully implement this alternative. However, this alternative is further explored below for its potential impacts to the fishing industry.

Pacific sardine is one of the primary species harvested for live bait in the Southern California recreational fishery, which as stated in Section 4.3.1.2, is part of an extremely valuable statewide recreational fishery generating over $1.3 billion in value added impact to California in 2016 (NMFS 2018). Under Alternative 2, the live bait fishery would no longer be able to provide Pacific sardine as live bait to recreational fisheries. Between 2005 and 2015, reported sardine live bait catches averaged 2,522 mt per year, comprising 75 percent of total live bait catch (See Table 4-12 in 2019 PFMC 2019b, Appendix A). The live bait fishery contributes economically to several live bait user groups that would be severely affected economically, including vessels that harvest live bait, CPFVs and private vessels that purchase live bait for recreational fishing trips, CPFV and private boat based recreational anglers, bait and tackle shops stores, and tourism-related businesses that benefit from the California sportfishing industry (*e.g.*, hotels and restaurants).

The minor directed fishery consists of a small number of niche-level harvesters that do not participate in other fisheries. They are allowed to harvest no more than 1 mt of Pacific sardine per trip. Under Alternative 2, these fishermen would be unable to provide their product; therefore, this alternative would likely have negative impacts on this sector. At the time of the 2015 primary directed fishery closure, this small sector of the fishery was adversely impacted because it was not exempt from the closure. In 2017, the Council voted to implement Amendment 16 to the CPS FMP specifically to alleviate this economic harm. Since Amendment 16 was implemented in 2018, an average of 39 mt of sardine has been harvested in the minor directed fishery coastwide.

An average of 294 mt and 6 mt of Pacific sardine has been harvested incidentally in other CPS fisheries and non-CPS fisheries, respectively, since 2015 (see PFMC 2020b). Other CPS fisheries that commonly catch sardine incidentally include market squid, northern anchovy, and Pacific mackerel. The Pacific whiting fishery, valued at $51.5 million (2012-2016) accounts for a significant portion of incidental harvest in non-CPS fisheries; however, its harvest of Pacific sardine is relatively minor (see Section 4.3.1.3). If incidental catch of Pacific sardine were prohibited, these fisheries, as they currently operate, would either be severely constrained or prohibited.

The modeling results in Table 12 of Hill et al. 2020 provide median catch values under Alternative 2, however these values represent potential median catch by Mexico, as Alternative 2 assumes zero U.S. harvest. Therefore, the modeling results were not used to further analyze potential impacts on the U.S. fishing industry under Alternative 2.

Under Alternative 3 Fixed Five Percent U.S. Harvest Rate, there would inevitably be negative economic impacts to the smaller-scale fishery sectors when biomass is at 50,000 mt and below, compared to Alternative 1 Status Quo Management (*see* Table 3). For example, had a policy like Alternative 3 been in place for the 2020-2021 fishing year, the result would have been an ACL of 1,414 mt compared to an ACL of 4,288 mt adopted by the Council. As previously stated, Pacific sardine landings have averaged around 2,200 mt since 2015 with a maximum of 2,505 mt. Therefore under the harvest policy of Alternative 3, in 2020 the Council would have had to allocate only 1,414 mt (or some lower level to provide a buffer) across both the CPS fisheries that target Pacific sardine (*i.e.*, live bait and minor directed) and those that rely on the ability to incidentally land sardine in order to prosecute other important CPS and non-CPS fisheries. Most likely, the Council would have been forced to set an incredibly small sector-specific catch limit for the live bait fishery, which has harvested an average of 2,000 mt per year since the closure of the primary directed fishery. Cutting the live bait fishery's already small harvest in half or more would certainly have drastic adverse impacts to not only the live bait industry, but would also seriously disrupt various recreational fisheries, most notably in Southern California. The likely impacts to these fishing communities would also have negative impacts to the associated community infrastructure (*i.e.*, tackle shops, restaurants, hotels, fuel docks, marinas). This potential for severe negative impacts to fishing communities, additional to those the communities have dealt with since 2015, was a major factor in the Council's decision in picking Alternative 1 for the rebuilding plan. The Council previously recognized the potential economic harm to fishing communities as a result of further restrictions on the live bait fishery when it voted in 2018 to pass Amendment 17 (PFMC 2019a), which changed the CPS FMP to allow directed fishing on an overfished stock, specifically to avoid this unnecessary economic harm to the live bait fishery and interdependent recreational fisheries.

Table 2. Recent ACL values compared with ACL values for Alternative 3.

Fishing Year	1+ Biomass	Status Quo/Actual ACL	Alt 3 ACL	Actual Landings
2015-2016	96,688	8,000	4,834	2,329
2016-2017	106,137	8,000	5,307	2,217
2017-2018	86,568	8,000	4,328	2,190
2018-2019	52,065	7,000	2,603	2,505
2019-2020	27,547	4,514	1,377	2,063
2020-2021	28,276	4,288	1,414	--

Landings information is sourced from CA, OR and WA landings receipt databases. These values differ from and are higher than PacFIN reported landings. Some landings data do not appear to be getting reported to PacFIN.

Thus, the question is whether Alternative 3 provides some future economic advantage if the stock reaches the target rebuilding biomass level faster. Setting a predetermined percentage also reduces the flexibility that is found in Alternative 1 and reduces the potential for landings to increase over previous years if conditions change. A summary of hypothetical Pacific sardine stock biomass estimates and corresponding ABC values under Alternative 1 and ACL values under Alternative 3 are presented in Table 3.

Table 3. Hypothetical sardine biomass estimates and corresponding ACL values (metric tons) under Alternative 3 – Five Percent Fixed U.S. Harvest rate.

1+ Biomass	Alt 1 ABC	Alt 3 ACL
5,000	608	250

1+ Biomass	Alt 1 ABC	Alt 3 ACL
10,000	1,216	500
15,000	1,823	750
20,000	2,431	1,000
50,000	6,078	2,500
75,000	9,116	3,750
100,000	12,155	5,000
150,000	18,233	7,500
500,000	60,776	25,000
750,000	91,165	37,500
1,000,000	121,553	50,000

In conclusion, although Alternative 1 would maintain the current adverse economic impacts that are already being experienced by the affected fishing industry, it would minimize additional economic impacts in the near and long term. Alternative 2 would impose significant adverse economic impacts in the near and long term (*i.e.*, from now until the stock is declared rebuilt and the fishery opens). Alternative 3 would likely impose significant adverse economic impacts in the near term, and potentially the long term (*i.e.*, for as long as the biomass remains below 50,000 mt). Since the modeled rebuilding timeline under Alternative 1 Status Quo Management is only one year longer than for Alternative 3 (*i.e.*, 17 years for an expected constant catch of 2,200 mt annually versus 16 years for a five percent fixed harvest rate), Alternative 3 would impose unnecessary economic impact to the industry with minimal change in the rebuilding timeline. Additionally, the actual expected rebuilding timeline under Alternative 1 when considering only the landings from the NSP of Pacific sardine is 14 years (*see* Section 5.5.3).

4.4. Sardine in the Ecosystem

4.4.1. Affected Environment – Sardine in The Ecosystem

Pacific sardine and other CPS populations are important to the trophic dynamics of the entire CCE. For example, anchovy and Pacific sardine are key consumers of large quantities of primary production (phytoplankton) in the ecosystem and all five species of CPS are significant consumers of zooplankton. Additionally, all five species, particularly the mackerels and squid, are important predators of the early stages of fish. The juvenile stages of CPS, and in many cases the adults, are important as forage for seabirds, pinnipeds, cetaceans, and other fish.

Trophic interactions between CPS and higher-trophic-level fish are complex, and the extent to which predator populations are affected by CPS abundance and distribution is difficult to measure. The value of CPS as forage to adult predators versus the negative effects of CPS predation (on larvae and juveniles of predator fish species) and competition (removal of phytoplankton, zooplankton, and other fish) is unknown.

Diet information and food web analysis for major taxa within the CCE, including fish, marine mammals, birds, and invertebrates has been collected periodically and compiled (Dufault et al. 2009, Szoboszlai et al. 2015) and studies on bioenergetics are underway. Modeling efforts have enhanced our understanding of trophic linkages (Ruzicka et al. 2012, Koehn et al. 2016) and ecosystem-based management approaches for managing these species (Kaplan et al. 2013, Punt et al. 2016). However, it has been pointed out that trophic modeling efforts have sometimes ignored important factors that need to be considered before drawing conclusions about any direct effects of the overall abundance of a particular forage fish population on its predators' populations (Hilborn et al. 2017).

Pacific sardine are prey for several commercially important marine fishes, including Pacific salmonids, albacore tuna, and Pacific hake, as well as dogfish and several shark species (Szoboszlai et al. 2015). In addition, a number of seabirds have been identified that forage on Pacific sardine. These birds include grebes and loons, petrels and albatrosses, pelicans and cormorants, gulls, terns, auks, and some raptors which are all non-Endangered Species Act (ESA) listed (PFMC 1998). One ESA-listed seabird, the marbled murrelet, is also known to consume Pacific sardine, but there is little information on quantities of Pacific sardine consumed or the relative importance in its diet. Marbled murrelets are known to consume many different prey species including other CPS and, like many predators, are capable of prey switching (Burkett 1995, Becker and Beissinger 2006, McShane et al. 2004, USFWS 2009). Pacific sardine are also forage for a dozen marine mammals, including ESA-listed humpback whales (Appendix D of Szoboszlai et al. 2015).

For the purpose of this analysis, the effects analyzed on Pacific sardine in the ecosystem include prey removal and the potential impacts to relevant marine predators.

4.4.2. Analysis of Impacts – Sardine in The Ecosystem

The types of fluctuations in abundance observed in CPS populations are common in species such as herring, Pacific sardine, and mackerel, which generally have higher reproductive rates, are shorter-lived, attain sexual maturity at younger ages, and have faster individual growth rates than species such as rockfish and many flatfish. As such, predators that prey on CPS (marine mammals, birds, and other fish) have evolved in an ecosystem in which fluctuations and changes in relative abundances of these species regularly occur. Consequently, most of them are generalists who are not dependent on the availability of a single species but rather on a suite of species, any one (or more) of which is likely to be abundant each year. Often many of them also have other life history traits, such as being long-lived or adaptive reproductive strategies, to help mitigate against years of low prey availability. This was noted in a recent multi-modeling effort that demonstrated Pacific sardine play a greater role in the diets of brown pelicans, halibut and dolphins, than in the diet of California sea lions that have a broader diet (Kaplan et al. 2019). Koehn et al. (2016) found that due to the broad distribution of predator diets, dynamic models would generally not predict widespread ecological effects from depleting individual forage fish species, but did identify "key" forage assemblages, such as Pacific sardine and anchovy together.

As stated above, most Pacific sardine predators are generalists that are not dependent on the availability of a single species but rather on a suite of species, any one (or more) of which is likely to be abundant each year. For example, while the biomass of Pacific sardine is currently low, the central population of northern anchovy biomass is high (approximately 800,000 mt in 2019, *see* Stierhoff et al. 2020). Therefore, it is unclear whether there would be any measurable difference in benefits between the rebuilding timelines for Pacific sardine from the aspect of prey availability. Accordingly, none of the proposed management strategies associated with each alternative are expected to significantly affect forage availability, as Pacific sardine removal would be according to status quo removal or less. However, the alternatives are further explored below for their potential impacts to prey availability.

According to the model results, under Alternative 1 Status Quo Management, when the full ABC is assumed to be taken, there is never a greater than 50 percent probability that the stock will rebuild to the selected rebuilding biomass target of 150,000 mt 1+ biomass (Table 8 in Hill et al. 2020) or the modeled SB_{MSY} of 137,812 mt before the year 2050, which is the last year that was modeled (Table 6 in Hill et al. 2020). However, as discussed in Section 4.2.2, the modeling results should be viewed in the context that they do not capture the full range of productivity of which this stock is capable. They also assume that under Alternative 1 Status Quo Management U.S. fisheries harvest the full ABC, which has not been the case due to the prohibition on primary directed fishing, restrictions on incidental harvest, and to some degree market dynamics, all of which cannot be captured in the modeling. This is important to note, because due to the restrictions in place, landings of Pacific sardine are likely to remain similar during the rebuilding timeline as they have been over the past five years (*i.e.*, 2,200 mt/year on average) and therefore would be well below the modeled status quo landings, accruing more benefit to the resource than was modeled. Because the Rebuilder tool could not accurately represent true status quo management, the SWFSC performed additional modeling that calculated rebuilding probabilities assuming a constant catch of 2,200 mt, which is the average catch over the past five years even at varying biomass levels (*see* Table 1 in Section 4.3.2), largely due to the FMP requirements and additional management measures implemented by the Council under status quo management. Under this model run, the stock had at least a 50 percent chance of rebuilding to 150,000 mt age 1+ biomass in 17 years, or in the year 2038. The Council analyzed this model run because it was considered a more realistic representation of Alternative 1 than the originally modeled Alternative 1 Status Quo Management, which assumes the full ABC is harvested each year. Although the initial model results for Alternative 1 Status Quo Management are discussed throughout this document, the model results for a constant catch of 2,200 mt are considered to represent a more realistic projection of fishery landings in the near term, and therefore more appropriate for selecting a management strategy for the rebuilding plan.

Under Alternative 2 U.S. Zero Harvest, the modeled time to rebuild Pacific sardine with a greater than 50 percent probability to the selected rebuilding biomass target of 150,000 mt age 1+ biomass (*i.e.*, equivalent to an SB_{MSY} of approximately 121,650 mt) is 12 years, or in the year 2033 (Table 8 in Hill et al. 2020). The modeled time to rebuild to the modeled SB_{MSY} of 137,812 mt is 15 years, or in the year 2036 (Table 10 of Hill et al. 2020). This is the fastest rebuilding timeline of any of the alternatives. The projected median spawning biomass values under Alternative 2 are presented in Table 10. Like Alternative 1, the modeling results do not capture the full range of productivity of which this stock is capable, nor can the modeling work predict future productivity. It is difficult to determine if this zero-fishing option would rebuild Pacific sardine faster than any of the other highly restrictive alternatives presented here; historical studies have shown that the stock can stay low even with no fishing. Therefore even though fishing mortality associated with this alternative would be lower and fewer removals would occur on an annual basis, it is difficult to know if or how much faster the stock would rebuild under this alternative despite the modeling results.

Under Alternative 3 U.S. Five Percent Harvest Rate, the modeled time to rebuild Pacific sardine with a greater than 50 percent probability to the selected rebuilding biomass target of 150,000 mt 1+ biomass is 16 years or in the year 2037 (Table 8 in Hill et al. 2020). The modeled time to rebuild to the modeled SB_{MSY} of 137,812 mt is 26 years, or in the year 2047 (Table 10 of Hill et al. 2020). The projected median spawning biomass values under Alternative 3 are presented in Table 10. Similar to Alternative 1, the modeling assumes that the full five percent is harvested each year. The modeling also does not account for restrictions on incidental catch that might restrict harvest, or the fact that industry may not take the full five percent for other socioeconomic reasons.

Compared to the initial model results for Alternative 1 (*i.e.*, when the full ABC is assumed to be caught), which do not project the stock to rebuild, Alternative 3 is projected to rebuild to the selected rebuilding target of 150,000 mt age 1+ biomass in 16 years. However, as stated above, the modeled results for Alternative 1 when total Pacific sardine landings are assumed to remain similar to recent years (*i.e.*, 2,200 mt per year) project the stock to rebuild to 150,000 mt age 1+ biomass in 17 years. Therefore, Alternative 3 is only projected to rebuild 1 year faster than what actual status quo management would achieve under Alternative 1. Additionally, the actual expected rebuilding timeline under a constant catch of 2,200 mt per year is expected to be 14 years as opposed to 17 years. Although recent average catch of Pacific sardine is 2,200 mt, this value includes catch from the southern subpopulation of Pacific sardine, which ranges from the southern tip of Baja, Mexico to the Southern California Bight off the U.S. West Coast. The southern subpopulation overlaps with the NSP in the summertime in U.S. waters; all landings in U.S. waters are counted against the ACL for the NSP Pacific sardine stock under U.S. management. Recent U.S. harvest of the NSP of Pacific sardine has averaged only 472 mt annually, which only averages 0.6 percent of the biomass. Therefore, actual status quo landings over the last five years are actually less than what was modeled for Alternative 3 Five Percent U.S. Harvest Rate. It is likely that, similar to Alternative 1, the actual harvest rate under Alternative 3 would be less when considering that only a portion of U.S. landings are attributed to the NSP of Pacific sardine. Therefore, the rebuilding timeline under Alternative 3 is expected to be longer than the 12 years for Alternative 2, but potentially shorter than the 16 years initially modeled. However, as described in Section 4.2.1, the environment will likely be the primary determinant for the stock increasing. The fishery is already being heavily restricted under status quo management, and it is unclear if the reductions in annual catch under Alternative 3 Five Percent Fixed U.S. Harvest Rate compared to Alternative 1 Status Quo Management would allow the stock to realistically rebuild any faster.

In conclusion, none of the proposed management alternatives are expected to significantly affect forage availability, as most Pacific sardine predators are generalists that are not dependent on the availability of a single species but rather on a suite of species, any one (or more) of which is likely to be abundant each year.

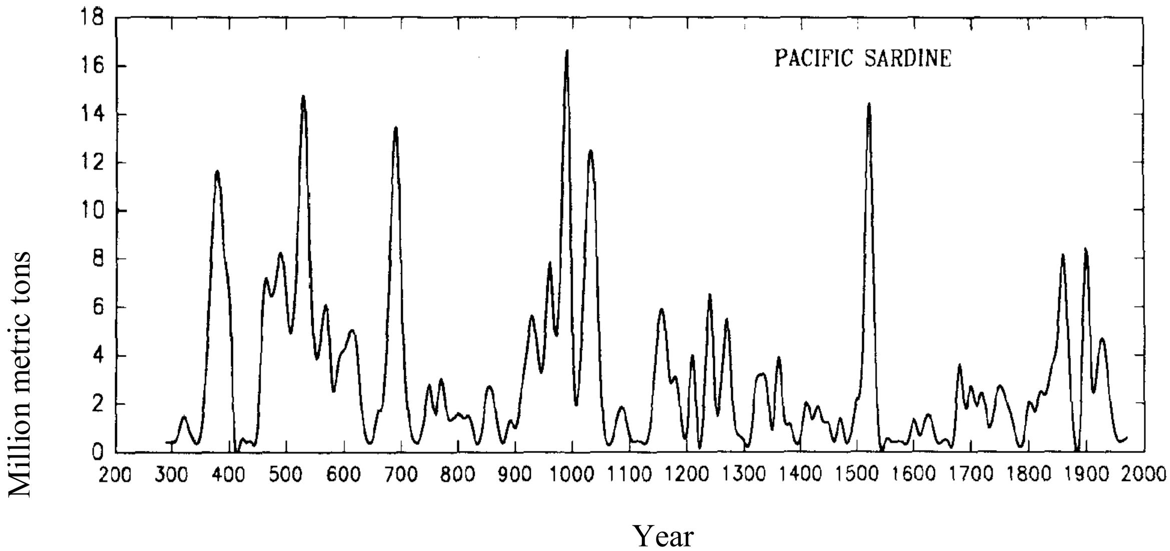

Figure 1. 1700-year hindcast series of Pacific sardine biomasses off California and Baja California (figure reproduced and modified to exclude Northern anchovy, from Baumgartner et al. 1992).

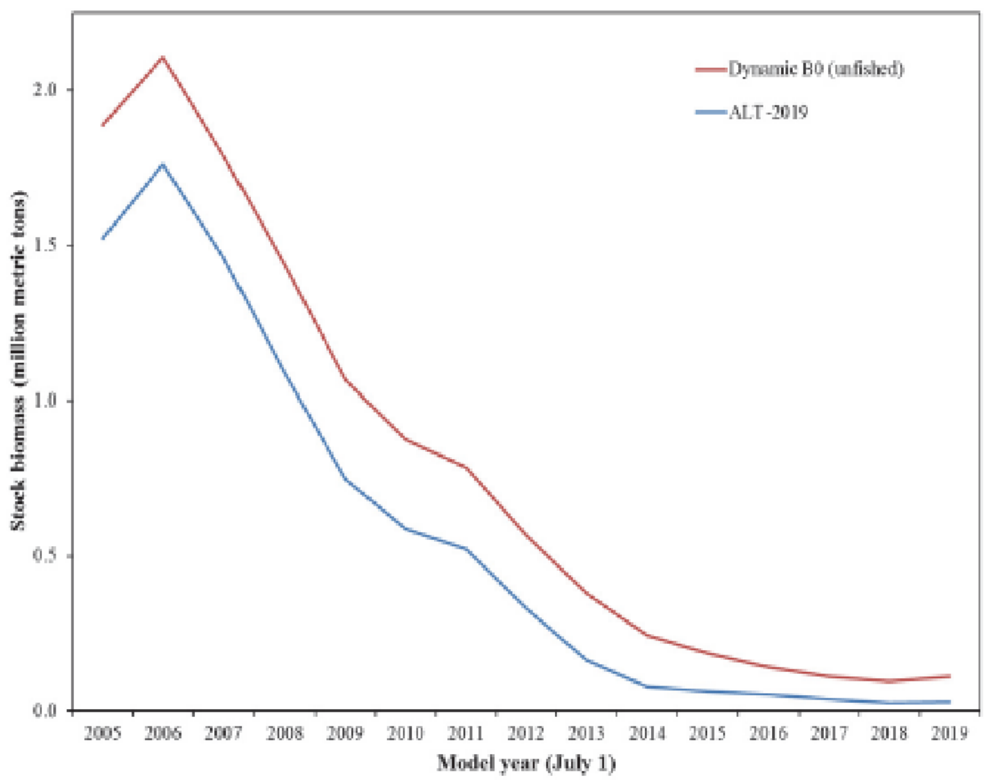

Figure 2. Estimated stock biomass (age 1+ fish, mt) time series and dynamic B_0 (unfished population) from model ALT-2019 (from 2019 Pacific Sardine stock assessment, Hill et al. 2019).

5. MAGNUSON ACT ANALYSIS AND FISHERY MANAGEMENT PLAN CONSIDERATIONS

5.1. NATIONAL STANDARDS

Below are the 10 National Standards (NS) as contained in the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and a brief discussion of how the Preferred Alternative is consistent with the National Standards, where applicable. In recommending the preferred alternative, the Pacific Fishery Management Council (Council) considered the alternatives and the analysis of impacts in the above Environmental Assessment, which demonstrate consistency with the national standards.

National Standard 1 — Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery.
The Preferred Alternative selects the existing harvest control rules (HCRs) and management measures for the northern subpopulation of Pacific sardine (Pacific sardine) as the rebuilding plan. The HCRs have been determined to prevent overfishing by the Council's Scientific and Statistical Committee (SSC), and the fishery is managed so that catch does not approach the overfishing limit. Additionally, the existing HCRs and management measures for Pacific sardine include measures intended to help rebuild the Pacific sardine stock, while also allowing access to limited amounts of Pacific sardine and the ability to access other profitable fish stocks that interact with Pacific sardine. Alternatives 2 and 3 however would not take into account the needs of fishing communities because of their highly restrictive nature, and thus do not comply with National Standard 1.

For overfished stocks, the MSA's National Standard 1 guidelines (*see* 50 CFR §600.310(j)(3)) provide direction on determining certain rebuilding reference points in order to specify T_{target}, including a target rebuilt biomass level, T_{min} (*i.e.*, the minimum time to rebuild the stock assuming zero fishing morality), and T_{max} (*i.e.*, the maximum allowable time to rebuild the stock). The Council's determination on these reference points are discussed in detail below in Section 5.3.

National Standard 2 — Conservation and management measures shall be based upon the best scientific information available.
The best scientific information available was used as a basis for selecting the Preferred Alternative. The Council based its selection on a holistic analysis of the Rebuilder modeling results, the basic biology and life history of Pacific sardine, and the history of the Pacific sardine fishery on the U.S. West Coast. The Preferred Alternative includes setting Pacific sardine harvest specifications via the Council's annual harvest specifications process, in line with the requirements contained in the Fishery Management Plan (FMP) for when the biomass is below certain thresholds (*i.e.*, 50,000 metric tons (mt) and 150,000 mt). Additionally, the information and data used to inform annual harvest specifications and management measures for Pacific sardine, which will now be set under the terms of the rebuilding plan, include the results of NOAA's acoustic-trawl surveys, which span much of the U.S. West Coast Exclusive Economic Zone, from Mexico to Canada. The resulting annual stock assessment is reviewed by the Council's SSC and/or a panel of independent experts known as a stock assessment review panel. Other indices of abundance are sometimes incorporated into the stock assessment. For example, cooperative research using aerial

surveys has been incorporated into the stock assessments and resulting biomass estimates in the past, subject to a determination by the SSC to ensure consistency with National Standard 2. It is not clear that Alternative 2 (Zero U.S. Harvest) or Alternative 3 (Five Percent Fixed U.S. Harvest Rate) would be consistent with National Standard 2, because these alternatives would not allow any flexibility in harvest rate based on the best scientific information available. Essentially, Alternatives 2 and 3 would ignore fluctuations in biomass estimates or other science-based information.

National Standard 3 — To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.
This action is related to an existing management unit stock in the Coastal Pelagic Species (CPS) FMP, Pacific sardine, and is not changing how that stock is managed according to its range or relationship to other stocks. The northern subpopulation of Pacific sardine is the stock under U.S. management, and is managed as a unit throughout its range within U.S. waters. The stock is seasonally present off Baja, Mexico, and during times of abundance can be found as far north as Vancouver Island, Canada, and Southeast Alaska. The HCR includes a DISTRIBUTION term estimating the average long-term distribution between U.S. and Mexican waters. Under the Preferred Alternative and Alternative 2, the stock would continue to be assessed throughout its entire range and would managed based on U.S. distribution. Alternative 3 would ignore the DISTRIBUTION term in the HCR and would therefore not be consistent with National Standard 3.

National Standard 4 — Conservation and management measures shall not discriminate between residents of different states. If it becomes necessary to allocate or assign fishing privileges among various U.S. fishermen, such allocation shall be (A) fair and equitable to all such fishermen, (B) reasonably calculated to promote conservation, and (C) carried out in such a manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.
The Preferred Alternative would not discriminate between residents of different states. Under the Preferred the Alternative, the Council would set an acceptable biological catch (ABC) and annual catch limit (ACL) to accommodate the smaller fishery sectors. Per the Council's annual harvest specifications process, the Council may choose to implement an annual catch target and/or accountability measures, all of which could be sector-specific if necessary. All catch from the smaller sectors would be counted against the ACL. Under Alternatives 2 and 3, when the Pacific sardine biomass is below 50,000 mt, the ACL would be constrained such that the Council would be forced to unnecessarily allocate lower quotas (zero quota in the case of Alternative 2) to the small remaining sectors of the CPS fishery.

National Standard 5 — Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources, except that no such measure shall have economic allocation as its sole purpose.
The Preferred Alternative would allow for efficient utilization of the Pacific sardine resource while still allowing the stock to rebuild. The Preferred Alternative selects the existing HCRs and management measures for Pacific sardine in the CPS FMP for when the stock is at low biomass levels as the rebuilding plan; thus, the Preferred Alternative would allow the Council to manage

the remaining sectors of the Pacific sardine fishery with minimal administration or enforcement change and no additional costs. Alternative 2 would unnecessarily disallow any utilization of fishery resources, and Alternative 3 would restrict access to Pacific sardine in such a way that could result in both inefficient fishery operations for Pacific sardine, but also prevent other fisheries from achieving their optimum yield as those fisheries would be restricted from harvesting their target stock because of Pacific sardine bycatch restrictions.

National Standard 6 — Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.
Although the Preferred Alternative adopts a specific management framework for setting harvest levels each year, it also allows the Council to adapt these annual harvest specifications and management measures, if necessary, based on the best scientific information available on the resource and the associated fisheries. Alternative 2 would not allow the Council for any variations among, and contingencies in, fisheries, fishery resources, and catches because Pacific sardine harvest would be prohibited. Alternative 3 would allow for some variation in fishery resources and catches, but to a lesser extent than Alternative 1.

National Standard 7 — Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.
The Preferred Alternative selects the existing management measures for Pacific sardine as the rebuilding plan. This strategy avoids duplication efforts in minimizing fishing mortality on Pacific sardine, as the CPS FMP already provides mechanisms to reduce harvest concurrently with a decrease in biomass. The Preferred Alternative does not impose any additional regulatory costs to industry in addition to the adverse socioeconomic impacts already imposed by the closure of the primary directed fishery and the reduction in incidental catch allowances. Alternatives 2 and 3 would ignore the existing management efforts and science research, and impose pre-determined harvest rates. Thus, Alternatives 2 and 3 would appear to be inconsistent with National Standard 7.

National Standard 8 — Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to (A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts on such communities.
As discussed in the above Environmental Assessment, the CPS fishing industry has already been suffering adverse socioeconomic impacts since the closure of the primary directed fishery in 2015 and the subsequent reductions in incidental allowances. Both of these measures were mandated by the CPS FMP in response to decreasing Pacific sardine biomass. Using the fishery's current state as a baseline comparison for selecting a rebuilding plan, the Preferred Alternative will adequately provide for sustained participation for the smaller sectors of the fishery, thus minimizing additional and unnecessary adverse economic impacts. Alternatives 2 and 3 would impose additional and unnecessary socioeconomic impacts, and thus do not comply with National Standard 8.

National Standard 9 – Bycatch
Alternatives considered in the Environmental Assessment do not impact the CPS FMP's treatment of bycatch in the Pacific sardine fishery.

National Standard 10 – Safety at Sea
Alternatives considered in the Environmental Assessment do not impact safety at sea in the Pacific sardine fishery.

Fishery Impact Statement
Section 303(a)(9) of the MSA requires that a fishery impact statement be prepared for each FMP amendment. A fishery impact statement is required to assess, specify, and analyze the likely effects, if any, including the cumulative conservation, economic, and social impacts, of the conservation and management measures on, and possible mitigation measures for (a) participants in the fisheries and fishing communities affected by the plan amendment; (b) participants in the fisheries conducted in adjacent areas under the authority of another Council; and (c) the safety of human life at sea, including whether and to what extent such measures may affect the safety of participants in the fishery.

The Environmental Assessment prepared for this plan amendment constitutes the fishery impact statement. The likely effects of the proposed action are analyzed and described throughout the EA (see Section (insert). The effects of the proposed action on safety of human life at sea are discussed above under National Standard 10, in Section 5.1 Based on the information reported in this section, there is no need to update the Fishery Impact Statement included in the FMP.

The proposed action affects the Pacific Coast sardine fishery in the Exclusive Economic Zone off the U.S. West Coast, which is under the jurisdiction of the Pacific Fishery Management Council. Impacts on participants in fisheries conducted in adjacent areas under the jurisdiction of other Councils are not anticipated as a result of this action.

5.2. Determination of Rebuilding Reference Points

5.2.1. Target Rebuilt Biomass Level

The Rebuilder modeling results determine the rebuilt level to be met when the spawning stock biomass (SSB) has a greater than 0.5 (50 percent) probability of rebuilding to SB_{MSY} (*i.e.*, the spawning stock biomass at maximum sustainable yield) under a given harvest scenario. To calculate options for SB_{MSY}, Hill et al. 2020 multiplied the average SB_0 (*i.e.*, the unfished spawning stock biomass) estimates for the two modeled states of nature (*i.e.*, moderate and low productivity) by the weighted average target depletion level for Pacific sardine:

- SB_0(2005-18): 377,567 * 0.365 = 137,812 mt
- SB_0(2010-18): 104,445 * 0.365 = 38,122 mt

The above results (also listed in Table 4 of Hill et al. 2020) indicate that under the moderate productivity state of nature, B_{MSY} would be 137,812 mt SSB, and under the low productivity state of nature, B_{MSY} would be 38,122 mt SSB. Although selecting a B_{MSY} of 38,122 mt would have resulted in a significantly shorter rebuilding timeline (*see* Table 7 of Hill et al. 2020), the CPS Management Team (CPSMT) determined that this option is inconsistent with the objectives of the CPS FMP, as 38,122 mt is lower than the overfished threshold of 50,000 mt defined in the CPS FMP. In addition, the low productivity scenario included a smaller range of years and those years only reflected low productivity values for Pacific sardine. As a result, the CPSMT determined that the model results from the low productivity state of nature do not adequately represent the fluctuating Pacific sardine population, and therefore developed all of its management alternatives based on analysis of the model results for the moderate productivity state of nature.

Although the moderate productivity state of nature resulted in an average (mean) B_{MSY} of 137,812 mt SSB (referred to as SB_{MSY} in Hill et al. 2020), the SSC recommended utilizing the median SB_{MSY} value of 116,374 mt. The CPSMT recommended a target rebuilding biomass level of 150,000 mt age 1+ biomass, which is a reasonable approximation of a B_{MSY} proxy for the purpose of this rebuilding plan. Based on an output from the 2020 stock assessment (Kuriyama et al., 2020), the 150,000 mt age 1+ biomass is currently equivalent to 121,650 mt of SSB. The CPSMT recommended this value as the target rebuilding level because: 1) age 1+ biomass is the same biomass metric used in the overfished threshold and in annual stock assessments, while spawning stock biomass is not a metric typically provided to the Council, and 2) 150,000 mt age 1+ biomass is higher than the median SB_{MSY} of 116,374 mt, which was calculated by the Rebuilder model under the moderate productivity state of nature. In addition, 150,000 age 1+ biomass is the threshold at which the CPS FMP allows a harvest guideline for the primary directed fishery.

5.2.2. T_{MIN} AND T_{MAX}

Per NMFS' National Standard 1 Guidelines at §600.310(j)(3)(A), T_{min}[1] must be determined based on zero fishing mortality. The National Standard 1 guidelines provide two applicable methods to determine T_{max}: 1) T_{min} plus the mean generation time for the stock (*i.e.*, three years for Pacific sardine based on model results in Hill et al. 2020), or 2) T_{min} multiplied by two (*see* §600.310(j)(3)(B)). To determine the most appropriate way to calculate T_{min} and T_{max} the CPSMT and SSC discussed various methodologies including:

1) Based on the modeling results using recruitment data for the full 2005-2018 time period and a rebuilding target of SB_{MSY} = 137,812 mt, the minimum time to rebuild the stock if no fishing occurred would be eight years (in the year 2029) (*see* Total F=0 column of Table 6 in Hill et al. 2020). The MSA and NS1 Guidelines specify that if T_{min} is less than 10 years, then T_{max} can be no more than 10 years (*see* §600.310(j)(3)(B)(1)); therefore, given a T_{min} of eight years, the T_{max} is 10 years. The Rebuilder tool calculated this value assuming there would be no fishing on the stock by the U.S. or Mexico. However, a no fishing scenario on Pacific sardine in Mexico is not realistically achievable through U.S. fishery management actions. Therefore, the Council did not consider T_{min}=8 and T_{max}=10 to be a viable option.
2) Based on the modeling results using recruitment data for the full 2005-2018 time period and a rebuilding target of SB_{MSY} = 137,812 mt, the minimum time to rebuild the stock

[1] *T_{min}* means the amount of time the stock or stock complex is expected to take to rebuild to its MSY biomass level in the absence of any fishing mortality. In this context, the term "expected" means to have at least a 50 percent probability of attaining the B_{msy}, where such probabilities can be calculated. The starting year for the T_{min} calculation should be the first year that the rebuilding plan is expected to be implemented.

assuming zero fishing by the U.S. and a fixed rate catch by Mexico (consistent with Alternative 2's management strategy), is 15 years (in the year 2036) (*see* US=0 column under Fixed Mex. Rate 9.9 of Table 6 in Hill et al. 2020). Given a T_{min} of 15 years, T_{max} could be either 18 or 30 years. The Council did not select this option because it chose a different target rebuilding biomass level (*see* #3 below and Section 5.3.3).

3) Based on the modeling results using recruitment data for the full 2005-2018 time period and a rebuilding target of 150,000 mt 1+ biomass, the minimum time to rebuild the stock assuming zero fishing by the U.S. and a fixed rate catch by Mexico (consistent with the management strategy under Alternative 2), is 12 years (in the year 2033) (see US=0 column under Fixed Mex. Rate 9.9 of Table 8 in Hill et al. 2020). Given a T_{min} of 12 years, T_{max} could be either 15 or 24 years.

The CPSMT recommended, and the Council concurred with a T_{min} of 12 years because this result was based on the stock rebuilding to the selected target biomass level of 150,000 mt 1+ biomass and because it assumed likely fishing by Mexico. The Council selected a T_{max} of 24 years as opposed to 15 years based on the known history of Pacific sardine biomass fluctuations, which show that Pacific sardine may remain at low levels for multiple decades.

The T_{min} and target spawning biomass values provided by the modeling results may not be realistic given the model's limitations. As discussed in Section 4.1, these Rebuilder tool modeling results are based on a relatively short time period and are in stark contrast to work done by McClatchie et al. (2017). McClatchie et al. (2017) examined scale records for a 500-year period before commercial exploitation of this stock occurred, and found that average times for the stock to rebound from low population levels that would support directed commercial fisheries similar in scale to the most recent ones off the U.S. West Coast when tens of thousands of metric tons or more were taken annually, averaged 22 years. The Rebuilder tool model results were also not able to capture how quickly the stock can recover to high levels in a relatively short time frame when conditions are favorable, as witnessed in the late 1980's and early 1990's. Consequently, in determining targets for this stock, both in terms of the time frame to rebuild and the biomass to rebuild to, the natural, environmentally driven fluctuations in stock size and the periodicity of these fluctuations may be important considerations. However, there was no way to model environmental conditions that affect stock productivity in the future.

5.2.3. T_{TARGET}

Per the MSA's National Standard 1 Guidelines, T_{target} must not exceed T_{max} (see §600.310(j)(3)(C)). The CPSMT considered two options for T_{target}:

1) T_{target}=17 years: Based on the modeling results using recruitment data for the 2005-2018 time period, a constant catch rate for Mexico, and an average constant 2,200 mt catch level for the U.S., the stock has at least a 50 percent chance of rebuilding to 150,000 mt age 1+ biomass in 17 years (in the year 2038). The Council analyzed this model run specifically to see how soon the model predicted the stock could rebuild under the most recent average U.S. harvest level (*i.e.*, 2,200 mt), which was considered more realistic than the modeled Alternative 1 Status Quo Management, which assumes the full ABC is harvested each year.

2) T_{target}=14 years: A T_{target} of 14 years is halfway between the Council's recommended T_{min}=12 and 16 years, which is the timeframe in which the stock has at least a 50 percent chance of rebuilding to 150,000 mt age 1+ biomass under Alternative 3 Five Percent U.S Harvest Rate (Table 8 of Hill et al. 2020).

The CPSMT recommended, and the Council concurred with, a T_{target} of 14 years. Although the model indicated that the stock would rebuild in 17 years until the model run for a constant catch of 2,200 mt (*i.e.*, a more realistic expectation of landings under status quo management), the actual rebuilding timeline is expected to be shorter. Although recent average catch of Pacific sardine is 2,200 mt, this value includes catch from the southern subpopulation of Pacific sardine, which ranges from the southern tip of Baja, Mexico to the Southern California Bight off the U.S. West Coast. Although the southern subpopulation overlaps with the NSP in the summertime in U.S. waters, all landings in U.S. waters are counted against the ACL for the Pacific sardine stock under U.S. management. Recent U.S. harvest of the NSP of Pacific sardine has averaged only 472 mt annually. The recommendation for T_{min}, T_{max}, and T_{target} assume future harvest levels of the northern subpopulation of Pacific sardine roughly equivalent to this most recent average northern subpopulation catch. While this observed average catch of 0.6 percent is greater than Alternative 2 Zero U.S. Harvest Rate, it is less than Alternative 3 Five Percent Fixed U.S. Harvest Rate. Based on the model results for a target rebuilding biomass (Table 8 of Hill et al. 2020), the target timeline for the northern subpopulation portion of catch under Alternative 1 should be longer than 12 years (minimum time to rebuild based on modeling Alternative 2 Zero U.S. Harvest) and less than 16 years (modeled for Alternative 3 Five Percent Fixed U.S. Harvest Rate). A T_{target} of 14 years should provide adequate time to evaluate progress toward rebuilding for a stock whose population dynamics are primarily driven by environmental conditions.

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