PACIFIC SARDINE REBUILDING PLAN

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

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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)).

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 would adopt a rebuilding plan maintaining 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

<u>Zero U.S. Harvest Rate</u>
Alternative 2 would adopt a rebuilding plan using 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

<u>Five Percent Fixed U.S. Harvest Rate</u>
Alternative 3 would adopt a rebuilding plan that sets 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 (Appendix A); 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 Appendix A – Pacific Sardine Rebuilding Analysis. 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 Appendix A). 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 Appendix A).

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 Appendix A), 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 Appendix A.

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.

Factors Contributing to Overfished Status

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 harvest compared 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 Appendix A) or the modeled SB_{MSY} of 137,812 mt before the year 2050, which is the last year that was modeled (Table 6 in Appendix A). 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 (*see* Table 8 in Addendum of Appendix A). 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 Appendix A). 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 Appendix A). 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 Appendix A). 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 Appendix A). 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 Pacific sardine primary directed fishery has historically comprised the largest component of CPS fisheries 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. In addition to Pacific sardine, the CPS complex includes market squid, Pacific mackerel, jack mackerel, and northern anchovy fisheries; in total the CPS complex accounted for an average of over $94 million of ex-vessel value (in 2018 dollars) from 2010 through 2014. 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 Appendix A 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 Appendix A 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
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 Appendix A) or the modeled SB_{MSY} of 137,812 mt before the year 2050, which is the last year that was modeled (Table 6 in Appendix A). 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 Appendix A). 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 Appendix A). 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 Appendix A). 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 Appendix A). 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.

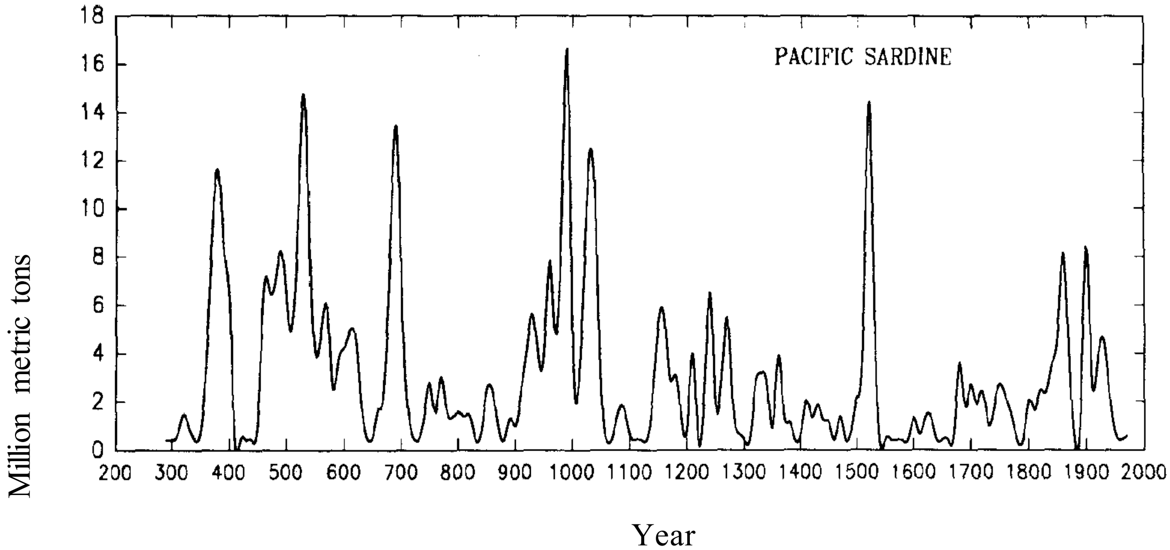

Figure 1. 1700-year hindcast series of Pacific sardine biomasses off California and Baja California (figure reproduced and modified to exclude Northern anchovy, from Baumgartner et al. 1992).

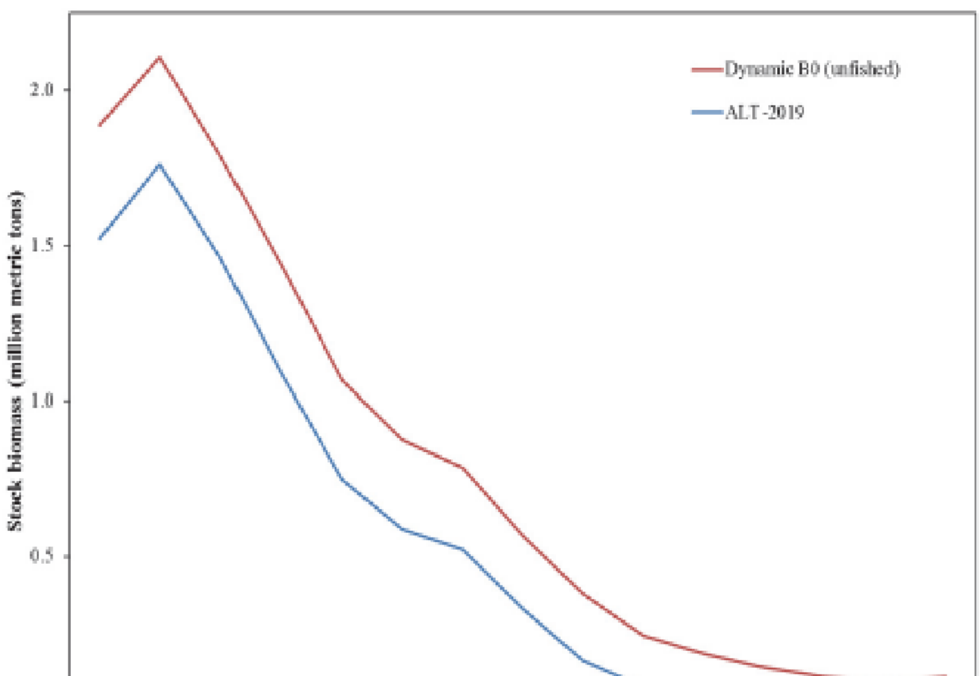

Figure 2. Estimated stock biomass (age 1+ fish, mt) time series and dynamic B_0 (unfished population) from model ALT-2019 (from 2019 Pacific Sardine stock assessment, Hill et al. 2019).

5. PUBLIC INVOLVEMENT

At the June 2020 Council meeting, the Council accepted and considered public input on the range of management alternatives to be analyzed by the CPSMT for inclusion in the EA.

On March 16, 2021, NMFS published a Notice of Availability of Amendment 18 and the draft EA and solicited public comments on the draft EA. The public comment period on the draft EA ended April 15, 2021.

NMFS received two letters during the draft EA comment period – one letter from the California Wetfish Producers Association (CWPA), a prominent CPS industry group, and one letter from Oceana, an environmental nongovernmental organization. Both letters are included in this final EA as Appendix B.

Oceana's letter contained several comments related to general Pacific sardine management, which NMFS will respond to in the Notice of Agency Decision Federal Register Notice. NMFS summarizes and responds only to the NEPA-related public comments in both letters below.

CWPA

Comment: The CWPA supported the preferred management alternative as the Pacific Sardine Rebuilding Plan in the draft EA. Their letter contains a summary of each EA section with supportive comments relevant to the EA's analysis. The CWPA commented that the EA understated the value of CPS fisheries in its discussion of economic impacts. NMFS added an estimate of the ex-vessel value of all federally managed CPS fisheries in Section 4.3.1.1.

Oceana

Comment 1: Oceana states that NMFS must prepare an Environmental Impact Statement (EIS) prior to finalizing the rebuilding plan if NMFS approves Alternative 1 Status Quo Management as the rebuilding plan management strategy. Oceana supports this argument by claiming that Alternative 1 Status Quo Management does not have at least a 50 percent chance of rebuilding the stock within the modeled timeframe, and therefore will significantly affect the human environment, triggering the requirement to prepare an EIS.

Response: The analysis in this EA demonstrates that Alternative 1 Status Quo Management will *not* have a significant adverse impact on the human environment, and therefore the preparation of an EIS is not necessary to comply with NEPA. To support their claim, Oceana highlights the results of the preliminary model run for this management scenario, which had an output that the stock would not rebuild before 2050. However, NMFS does not rely on these initial modeling results because they do not realistically reflect the biological impacts that would result from management under Alternative 1. Instead, NMFS relied on several sources of information when selecting T_{target}. First, additional modeling results using a 2,200 mt constant catch level predict that the stock has at least a 50 percent chance of rebuilding in 17 years, only one year later than the 16 years predicted under Alternative 3 (Five Percent Fixed U.S. Harvest Rate). Second, both rebuilding timelines under Alternative 1 and Alternative 3 are likely overestimated by the modeling results since both alternatives do not account for the fact that in recent years only a small portion of the already-small U.S. Pacific sardine landings are from the northern subpopulation of Pacific sardine (*i.e.*, the population managed under the CPS FMP), with a greater proportion coming from the southern subpopulation. Third, NMFS took into account the biology of the sardine stock and its changing productivity based on ocean conditions. In addition, Alternative 1 Status Quo management allows the stock to rebuild on a similar timeline as Alternative 3, but also prevents further economic harm to the fishing industry, which has already been declared a federal disaster since 2015 when NMFS closed the primary directed fishery.

Comment 2: Oceana claims that NMFS incorrectly evaluates and mischaracterizes Alternative 1 Status Quo Management in the EA because NMFS discusses and relies on results from an additional model run of 2,200 mt constant catch (average U.S. catch over the last five years since the closure of the primary directed fishery) and further discusses that only a portion of that 2,200-mt catch -- 472 mt on average, is from the northern subpopulation.

Response: When analyzing the effects of Alternative 1 Status Quo Management, NMFS relied on several sources of information to support its conclusion. These are not separate characterizations of the alternative, as the comment suggests. Instead, NMFS recognized that the model available was not capable of capturing all aspects of the Pacific sardine stock and that other sources of information should be used to evaluate the alternatives and select rebuilding criteria. First, analyzing model results from the actual recent catch (2,200 mt average catch), which is the expected average catch under this alternative through the rebuilding period, is more representative of the biological impacts that will result from Alternative 1 Status Quo Management. Second, NMFS considered and discussed 472 mt because it is the average small portion of that 2,200 mt catch that is from the northern subpopulation. These are important considerations in analyzing the real world impact of the Alternative and its effect on rebuilding. The model results for Alternative 1 Status Quo Management assuming a constant catch of 2,200 mt project the stock to have at least a 50 percent chance of rebuilding in 17 years. This timeline is likely overestimated because this timeline does not account for the fact that only a small portion of landings are from the northern subpopulation, which is how a lower T_{Target} of 14 years (in between the 12 years projected for Alternative 2 Zero U.S. Harvest and the 16 years projected for Alternative 3 U.S. Five Percent Fixed Harvest Rate) was determined. NMFS notes that the rebuilding timeline under Alternative 3 is also likely overestimated for the same reasons, however this does not change the fact that the modeling shows Alternative 3 only rebuilding slightly faster than Alternative 1. NMFS' approval of Alternative 1 Status Quo Management is based on the determination that its rebuilding target is appropriately calculated, falls within T_{min} and T_{max}, and also minimizes further economic harm to the fishing industry and allowing the stock to rebuild.

Comment 3: Oceana states that NMFS must analyze a range of additional management measures that includes varying incidental catch limits on Pacific sardine.

Response: With regard to the scope and range of alternatives, the three alternatives analyzed in the EA was a reasonable number and covered an appropriate scope based on the nature of this action, which is described in Section 3 of the EA. As stated above, the Council sought public input on the range of alternatives at the June 2020 Council meeting. The three alternatives (including the proposed action) were objectively evaluated in recognition of the purpose and need of this action, the restrictive management measures already dictated by the CPS FMP when the Pacific sardine population is low and the best scientific information available on Pacific sardine, which for the purposes of developing a rebuilding plan includes 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. Therefore, analyzing a range of varying incidental catch limits or additional total annual removal level alternatives is not necessary to comply with NEPA. However, NMFS points out that although the existing alternatives represent an appropriate scope and range, alternatives such as specific incidental catch values or other static catch levels as suggested by Oceana, already fall within the scope of alternatives analyzed. Specified lower incidental catch rates would simply represent lower total Pacific sardine removals within the range of removals already examined. The CPS FMP dictates that incidental catch limits must be restricted between 0 and 20 percent when Pacific sardine biomass is below 50,000 mt (*i.e.*, the overfished threshold), with an annual decision on where that level should be set based on the status of the stock and the needs of the fishery in that year.

Comment 4: Oceana claims that NMFS must evaluate the effect of various international catch rates by Mexico for each management alternative.

Response: The supporting rebuilding plan analysis prepared for this action analyzed two Mexican catch scenarios for each management alternative – a fixed catch of 6,044 mt per year and a fixed catch rate of 9.9 percent per year (*see* Page 5 and Tables 6 through 13 of Appendix A). These scenarios were based on recent observed catch from Mexico. NMFS does not have jurisdiction to enforce catch limits for Pacific sardine outside of the U.S. EEZ, and therefore the Council determined that analyzing Mexican catch levels and rates from recent years was the most appropriate way to determine potential biological impacts to the stock from international fishing.

Comment 5: Oceana states that the draft EA violates NEPA because the supporting analysis has not been made publicly available.

Response: The primary document that NMFS cites, which is the Pacific Sardine Rebuilding Plan analysis prepared by the SWFSC, is publicly available on the Council's website. NMFS added the analysis to the final EA as Appendix A for ease of reference. That document, in addition to the 2020 Pacific sardine stock assessment (Kuriyama et al. 2020), are the two main sources of data and analysis to inform the modeling work discussed throughout this EA. The remaining documents cited are listed in Section 7.0 References and include publically available Council documents and scientific papers. NMFS notes that the economic analysis cited by Oceana was not cited in the EA because it was entirely based on the output of the Rebuilder Tool modeling results, which NMFS explains in the EA is limited in its usefulness to inform realistic rebuilding timelines for Pacific sardine. NMFS includes a discussion of economic impacts to the fishing industry in Section 4.3.2.

Comment 6: Oceana claims that NMFS omitted consideration of a five percent coast-wide harvest rate that was analyzed by the SSC's CPS Subcommittee at a July 2020 workshop. Oceana includes screen shots of two figures from a presentation at the workshop to support this claim.

Response: This model run referenced by Oceana was not an option for a management alternative for consideration by the Council, therefore NMFS has not omitted it from the EA. Additionally, and as stated above, for the purposes of complying with NEPA, NMFS has determined that an appropriate range of alternatives has been included.

NMFS notes that, under a five percent coast-wide harvest rate, catch from Mexico would also be counted against the harvest limit. NMFS only has jurisdiction to set catch limits in the U.S. EEZ and cannot enforce a harvest limit beyond that geographic range. Therefore this scenario could have never been carried forward as a viable management alternative for consideration in the EA to meet the purpose and need. This scenario was only included in the SSC Subcommittee's analysis as a sensitivity run. NMFS also notes that team meetings are working sessions for drafting materials for Council review. Draft work product, reports, or statements prepared and discussed at these meetings are draft and pre-decisional. They have not undergone the review and vetting to ensure their reliability, nor do they represent the considered judgment of the CPSMT or CPS SSC Subcommittee.

6. MAGNUSON ACT ANALYSIS AND FISHERY MANAGEMENT PLAN CONSIDERATIONS

6.1. 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.

6.2. Determination of Rebuilding Reference Points

6.2.1. 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}, Appendix A 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 Appendix A) 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 Appendix A), 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 Appendix A), 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.

6.2.2. 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 Appendix A), 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 Appendix A). 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 Appendix A). 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 Appendix A). 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.

6.2.3. 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 Appendix A).

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 Appendix A), 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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APPENDIX A – PACIFIC SARDINE REBUILDING ANALYSIS

PACIFIC SARDINE REBUILDING ANALYSIS
BASED ON THE 2020 STOCK ASSESSMENT

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Introduction

The Pacific sardine (*Sardinops sagax caerulea*) northern subpopulation (NSP) has been managed under the PFMC's CPF-FMP since 2000. Stock assessments have been conducted to support annual management specifications since 1995. The stock underwent a rapid increase throughout the 1980s and 1990s, peaking in 2000 and again in 2005, and declining from 2006 to present low levels. The stock was declared overfished in July 2019. The following analysis, the first of its kind for Pacific sardine, evaluates harvest alternatives for the full rebuilding plan.

Overview of the 2020 benchmark stock assessment

The 2020 benchmark assessment (Kuriyama et al. 2020) was developed using Stock Synthesis (SS version 3.30.14) and included fishery and survey data collected from mid-2005 through 2019. The model was based on a July-June biological year (aka 'model year'), with two semester-based seasons per year (S1=Jul- Dec and S2=Jan-Jun). Catches and biological samples for the fisheries off ENS, SCA, and CCA were pooled into a single MexCAL fleet, for which selectivity was modeled separately in each season (S1 and S2). Catches and biological samples from OR, WA, and BC were modeled by season as a single Pacific Northwest (PNW) fleet. A single AT survey index of abundance from ongoing SWFSC surveys (2006-2019) was included in the model.

The 2020 base assessment model incorporated the following specifications:

- Sexes were combined; ages 0-8+.
- Two fisheries (MexCal and PacNW fleets), with an annual selectivity pattern for the PNW fleet and seasonal selectivity patterns (S1 and S2) for the MexCal fleet.
- MexCal fleets: domed age-based selectivity (time-varying and non-parametric [option 17 in Stock Synthesis]).
- PNW fleet: asymptotic age-based selectivity (time-varying for the inflection point).
- AT survey age compositions with effective sample sizes set to 1 per cluster (externally).
- Age compositions for the spring AT survey omitted.
- Fishery age compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=1 (internally);
- Initial equilibrium ("SR regime" parameter) estimated with the 'lambda' for this parameter set to zero (no penalty contributing to total likelihood estimate).
- Natural mortality (M) estimated with a prior.
- Recruitment deviations estimated from 2005-2018.
- Virgin recruitment estimated, and total recruitment variability (σR) fixed at 1.2.
- Beverton-Holt stock-recruitment relationship with steepness fixed at h=0.3.
- Initial fishing mortality (F) estimated for the MexCal S1 fleet and assumed to be 0 for the other fleets.
- F for the 2020-1 to 2020-2 model years set to those for the 2018 (S2) and 2019 (S1) model years.
- AT survey biomass 2006-2019, partitioned into two (spring and summer) surveys, with catchability (Q) set to 1 for 2005-2014 and 0.733 for 2015-2019.
- AT survey selectivity is assumed to be uniform (fully selected) above age 1 and estimated annually for age-0.

Spawning biomass, recruitment, and stock biomass (ages 1+) time series from the 2020 benchmark stock assessment are shown in Figures 1-3, respectively.

Recent management performance

The Pacific sardine NSP underwent a decline beginning in 2006. The directed commercial fishery was closed in July 2015 when age 1+ biomass dropped below 150,000 mt 'Cutoff' threshold in the harvest guideline control rule. The stock dropped below the 50,000 mt minimum stock size threshold (MSST) in 2019 and was declared overfished in July 2019. OFLs, ABCs, ACTs, and realized landings (total and NSP) since the 2015-16 management year are provided in Table 1. Ensenada landings of NSP sardine, also included in this analysis, are provided in Table 1.

Rebuilding calculations

1. Rebuilding software: Pacific sardine rebuilding analyses were conducted using Rebuilder package version 3.12g (June 2020). Rebuilder is an age-structured population dynamics simulator that projects the population forward in time, accounting for recruitment, growth, natural mortality, and fishing mortality. It calculates the probabilities of rebuilding the stock to SB_{MSY} (rebuilt) for a given range of recruitment and fishing scenarios. Rebuilder was written by Dr. Andre Punt for conducting groundfish rebuilding analyses (Punt 2012) and recently revised to allow for projections based on Pacific sardine harvest control rules. Sardine rebuilding analyses were conducted from March through July 2020, and the SSC provided recommendations for revisions to the analysis at their June 2020 meeting. Subsequently, the SSC's CPS Subcommittee held a meeting July 15-16 to review preliminary rebuilding model results. Both the SSC and CPS Subcommittee recommendations have been incorporated in the following analyses. The Rebuild.dat file is provided in Appendix A, and the multiple parameter line file (Rebuild_samp.sso), used to set starting values and target depletion levels over a range of steepness values, is provided in Appendix B.

2. Definition of SB_0: SB_0 was estimated with Rebuilder by averaging recruitments over two ranges of model years to characterize outcomes based two states of nature. The first, '$SB_{0(2005\text{-}18)}$', was based on all estimated recruitments from the assessment model (2005-18), and the second scenario, '$SB_{0(2010\text{-}18)}$' based on a subset of years with low recruitments (2010-18). Resulting distributions of SB_0 for the two productivity scenarios are shown in Figure 4. Average SB_0 was 377,567 mt for the $SB_{0(2005\text{-}18)}$ model and 104,445 mt for the $SB_{0(2010\text{-}18)}$ model.

3. Biological data: Biological data by age were taken from Kuriyama et al. (2020). Data included natural mortality rate, weight-at-age, maturity-at-age, fecundity-at-age, selectivity-at-age, population numbers-at-age for 2019 (year declared overfished), and population numbers-at-age for the 2020. Vectors of biology-at-age are provided in Table 2. Mean generation time in this rebuilding analysis was estimated to be 3 years. In order to transition the modeled time step from seasonal (SS) to annual (Rebuilder), it was necessary to change fecundity at age zero from 0.0046 to 0.0000 (Table 2). Net spawning output-at-age is highest at age-2 (Figure 5). Natural mortality rate was ~0.584 for all ages, but this value varied slightly over the full range of profiled steepness. Steepness was profiled in SS, providing different initial numbers-at-age for 2020 based on each steepness level (see Section 5.c below).

4. Fishing mortality and selectivity: A single fleet (fishery) was modeled using selectivity and weight-at-age from the MexCal Season 2 (S2; Table 2). MexCal-S2 (Jan-Jun) best typifies the selectivity pattern for the overall MexCal fleet, and most of the northern sub-population (NSP) sardine catch is taken by this fishery at that time of year. The PNW fleet was not modeled given the low probability that sardine will be taken for live bait or incidentally in the foreseeable future.

   The MexCal fleet includes catches for both US and Mexico (Ensenada) fisheries. Mexican sardine catch was treated in two ways for these analyses: 1) as a fixed amount of catch (mt) added to the US control rule, or 2) as a fixed rate added to the US fishing rate, i.e., proportionate to the age 1+ biomass.

   For the constant Mexico catch scenarios, total catch was modeled using the ABC control rule for Pacific sardine, with addition of a constant tonnage to account for Mexico removals. We based Mexico's constant catch (6,044 mt) on the average of NSP landed in Ensenada between 2015-16 and 2018-19 (Table 1). Total catch was defined:

   Catch = ($\text{Biomass}_{\text{age1+}}$ * US Exploitation Rate * Buffer * US Distribution) + Mexico catch

   where Buffer=0.7762 (Tier 2, Pstar 0.4), US Distribution=0.87, and Mexico catch=6,044 mt per year for all fixed Mexico catch strategies.

   For the constant Mexico harvest rate scenarios, a single constant exploitation rate of 9.9% was applied as opposed to assuming a constant catch of 6,044mt. The value was calculated from stock assessment models with steepness values ranging from 0.3 to 0.8 (with intervals of 0.05). Specifically, the stock assessment model was run with a single fixed steepness value, and the season 1, age 1+ biomass values were averaged from the 2015-15 to 2018-19 management years. The assumed average NSP catch of 6,044 mt was divided by the average biomass value to calculate average exploitation rates at each steepness value. The steepness-specific exploitation rates were then averaged, weighted by relative probabilities (Table 3a) to calculate a single exploitation rate of 9.9%. Relative exploitation rates for the US and Mexico fisheries for the three harvest alternatives are shown in Table 3b.

5. Inclusion of uncertainty: Uncertainty in the rebuilding analysis was accounted for in several ways:
   a. The spawner-recruit relationship used a high σR value (1.2; from Kuriyama et al. 2020), allowing for large fluctuations in recruitment in all rebuilding projections.
   b. Uncertainty was explored by rebuilding under two different productivity states of nature (see '2. Definition of SB_0' above). Projections between the two productivity scenarios differ with respect to the level of the rebuilding target (SB_{MSY}), and the magnitude of potential recruitments generated when rebuilding to that level. In addition, each state of nature draws from a distribution of SB_0 as opposed to a single value.

c. Uncertainty in Mexico's annual NSP sardine catch was partially addressed by applying a constant harvest rate versus a constant tonnage per year (see Section 4 above). Note this does not address larger questions regarding actual stock source of Ensenada landings from year to year or general hypotheses regarding subpopulation structure of the transboundary stocks.
d. Finally, uncertainty in spawner-recruit calculations was accounted for by profiling on the Beverton-Holt steepness parameter (h). This was accomplished by first profiling h in the Stock Synthesis model to provide new starting values for the multiple parameter file (Appendix B). Steepness was profiled from 0.3 to 0.8 in 0.05 intervals. Attempts to model steepness at values lower than 0.28 resulted in runtime errors in Rebuilder, so the profile was constrained to steepness values of 0.3 and higher. For sardine, changing steepness affected the initial numbers-at age in 2020 and, to a trivial extent, natural mortality (Appendix B). Steepness was poorly estimated in Stock Synthesis, with negative log-likelihoods ranging from 91.6851 at h=0.3 to 94.2932 at h=0.8 (Figure 6). To calculate relative probabilities for constructing the multiple parameter line file (Rebuild_samp.sso; see Appendix B), the difference between the lowest and highest likelihood was calculated and the differences were normalized. Relative probabilities associated with each normalized likelihood value were calculated and multiplied by 100. Steepness of 0.3 had the highest relative probability (19/100) whereas parameters associated with steepness of 0.8 had the lowest relative probability (0/100) (Table 4, Figure 6).

6. <u>Definition of rebuilt:</u> Rebuilding is determined to be met when the spawning stock has a greater than 0.5 probability of rebuilding to SB_{MSY} under a given harvest scenario. Rebuilder makes this determination when the stock has reached the target depletion level (0.X*SB_0). For most groundfish stocks, target depletion is 0.4*SB_0 based on a meta-analysis of groundfish productivity. No such meta-analysis exists for Pacific sardine, so it was necessary to use Rebuilder to determine an appropriate target depletion level. This was accomplished by running the model as follows:
   a. Sardine control rule was reset to: E=0.XX, Buffer=1, Distribution=1, and Mexico catch=0.
   b. σR was set to 0.
   c. Target depletion was set to 1.0.
   d. The simulation was run, and the population rebuilt to SB_0 for F=0. SB_{MSY} was the equilibrium biomass while fishing at E_{MSY} with the above sardine control rule settings.
   e. Target depletion was then equal to SB_{MSY}/SB_0.

   Since Rebuilder samples across a range of steepness levels, and steepness and E_{MSY} are linked, it was necessary to iteratively search for an $\mathrm{E_{MSY}}$ corresponding to each steepness. Once E_{MSY} was found, simulations were rerun, as above, and steepness-specific target depletions were determined. The above analyses were conducted for both the high and low productivity models, and results are presented in Table 4. Estimates of E_{MSY} and target depletion were nearly identical for both scenarios. E_{MSY} ranged from 0.075 at steepness=0.3, and 0.64 at steepness=0.8. Target depletion ranges from 0.42983 for steepness=0.3 to 0.2057 for steepness=0.8. As expected, median catch and SB_{MSY} were markedly different for the two states of nature (Table 4). While it is possible to model multiple target depletion levels in Rebuilder, the SSC's CPS Subcommittee recommended running all simulations with a single target depletion value. A single target depletion value was calculated as the average, weighted by relative probabilities (Table 4), at each steepness value. Weighted averages from the two scenarios were then averaged resulting in a single target depletion value of **0.365**. Based on this single target depletion level and average SB_0 estimates for the two states of nature, the average target SB rebuilding levels are:

- $SB_{0(2005\text{-}18)}$: 377,567 * 0.365 = **137,812 mt**
- $SB_{0(2010\text{-}18)}$: 104,445 * 0.365 = **38,122 mt**

7. Alternate rebuilding strategies:
Three alternative harvest strategies were analyzed for the rebuilding plan:
Alt 1: 'Status quo' US management.
Alt 2: Zero US harvest.
Alt 3: US reduced harvest rate.

For the constant Mexico catch runs, harvest strategies were:
Alt 1: US E=0.18 (prorated by Buffer and US Distribution) + Mexico catch=6,044 mt
Alt 2: US E=0.00 + Mexico catch 6,044 mt
Alt 3: US E=0.05 (not prorated) + Mexico catch=6,044 mt

For the constant Mexico harvest rate runs, strategies were:
Alt 1: Total E=0.2202 (where US E=0.1216 and Mexico E=0.0986)
Alt 2: Total E=0.0986 (where US E=0.0000 and Mexico E=0.0986)
Alt 3: Total E=0.1486 (where US E=0.0500 and Mexico E=0.0986)

The above strategies were evaluated for both productivity states of nature.

Note that the current harvest control rules (HCRs: i.e. OFL, ABC, HG) for Pacific sardine modulate exploitation rate based on CalCOFI sea surface temperature. The Rebuilder package is unable to incorporate environmental effects, nor do reliable environmental forecasts exist for the coming decades. So, for purposes of this rebuilding analysis, the static stochastic E_{MSY}= 0.18 yr^{-1} from the recent management strategy evaluation (Hurtado and Punt 2013) was be used to project the population forward under the 'Status Quo' harvest strategy.

Results

Interpretation of the results should consider the different target biomass levels for both states of nature (see SB_0 distributions in Figure 4). The difference between these two states of nature arises from the number and magnitude of annual recruitments considered for each state of nature. Average SB_0 levels were 377,567 mt for $SB_{0(2005\text{-}18)}$ and 104,445 for $SB_{0(2010\text{-}18)}$ (Tables 4 and 5). Average target SB_{MSY} levels were 137,812 mt for $SB_{0(2005\text{-}18)}$ and 38,122 mt for $SB_{0(2010\text{-}18)}$ (Tables 4 and 5). It is important to note that individual rebuilding simulations (2,000 per run) were based on draws from the broad respective distributions of SB_0 (Figure 4), and probabilities of rebuilding were based on a corresponding range of $SB_{0.365}$ target biomass values. For the

$SB_{0(2005\text{-}18)}$ state of nature, SB_0 values ranged from 77,476 to 1,606,085 mt (Figure 4) and corresponding $SB_{0.365}$ values ranged from 28,279 to 586,221 mt. For the $SB_{0(2010\text{-}18)}$ state of nature, SB_0 values ranged from 34,849 to 455,497 mt (Figure 4) and corresponding $SB_{0.365}$ values ranged from 12,723 to 166,256 mt.

Rebuilding probabilities were examined with two metrics: 1) with respect to rebuilding to target SB_{MSY}, and 2) rebuilding to the 150,000 mt of age 1+ biomass ('Cutoff' level in the sardine harvest guideline control rule). With Total F=0, the spawning stock rebuilds above target depletion by 2029 for $SB_{0(2005\text{-}18)}$ and 2022 for $SB_{0(2010\text{-}18)}$ (Tables 6 and 7, resp.). For $SB_{0(2005\text{-}18)}$ and fixed Mexican catch (6,044 mt), the spawning stock rebuilds by 2041 with US exploitation rate=0 (US 0%) and does not rebuild with higher exploitation rates (Table 6). For $SB_{0(2005\text{-}18)}$, with fixed Mexican exploitation rate=9.9%, the spawning stock rebuilds by 2036 with US 0% and 2047 with US 5% (Table 6; Figure 7a). For $SB_{0(2010\text{-}18)}$, with fixed Mexican catch, the spawning stock rebuilds by 2023 with US 0%, or 2024 with US 5% (Table 7; Figure 7a). For $SB_{0(2010\text{-}18)}$, with fixed Mexican exploitation rate=9.9%, the stock rebuilds by 2022 with US 0%, 2023 US 5%, and 2024 US 18% (Table 7; Figure 7a). Based on these results, T_{MIN} for $SB_{0(2005\text{-}18)}$ is 2029, and T_{MAX} (2031) would be 10 years from the onset of the rebuilding plan, anticipated to be implemented by 2021 (Table 5). For the $SB_{0(2010\text{-}18)}$ state of nature, T_{MIN} is 2022 and T_{MAX} would also be 2031 (Table 5). Probabilities of rebuilding to $SB_{0.365}$ by T_{MAX} are provided for the three harvest alternatives and two states of nature in Table 5. Under the $SB_{0(2005\text{-}18)}$ scenario, none of the three harvest alternatives rebuild by T_{MAX}, whereas all three of the harvest alternatives rebuild the stock by T_{MAX} under the $SB_{0(2010\text{-}18)}$ scenario (Table 5).

With respect to 'Cutoff', the age 1+ stock rebuilds above 150,000 mt with Total F=0 by 2027 for $SB_{0(2005\text{-}18)}$ and 2037 for $SB_{0(2010\text{-}18)}$ (Tables 8 and 9, Figure 7b). For $SB_{0(2005\text{-}18)}$ and fixed Mexican catch, the stock only rebuilds above 150,000 mt by 2036 when US E=0% (Table 8; Figure 7b). For $SB_{0(2005\text{-}18)}$ and fixed Mexican exploitation, the age 1+ stock rebuilds by 2033 (US E=0%) and 2037 (US E=5%; Table 8). For $SB_{0(2010\text{-}18)}$, the stock did not rebuild above 150,000 mt under any harvest scenarios (Table 9; Figure 7b). Note, for the $SB_{0(2005\text{-}18)}$ models, the age 1+ stock rebuilds above 150,000 mt sooner than rebuilding to target SB levels.

Median spawning stock biomass (SB) was greater than 50,000 mt by 2023 with Total F=0 and 2026 with fixed rate and US 0% with the $SB_{0(2005\text{-}18)}$ scenario (Table 10; Figure 8). With Total F=0, the median spawning stock biomass exceeded 150,000 mt by 2033 (Table 10). In no other harvest scenarios did the median SSB exceed 50,000 nor 150,000 mt. In the $SB_{0(2010\text{-}18)}$ scenario, median SB exceeded 50,000 mt by 2027 (Table 11) and did not exceed 50,000 mt in any other harvest scenario (Table 11). Detailed figures including values of 5th, 25th, 50th, 75th, and 90th percentiles are included for $SB_{0(2005\text{-}18)}$ (Figure 9) and $SB_{0(2010\text{-}18)}$ (Figure 10).

The definition of rebuilding does not require the population to sustain a biomass greater than reference biomass values once that level has been attained. As a result, scenarios with fixed catch and fixed exploitation rate show SB declining through time despite probabilities of recovery remaining above 0.5 (see gray shaded values in Tables 10 and 11). In these cases, the population exceeded a particular biomass level at some point and was recorded as rebuilt.

Scenarios with fixed Mexican catches severely depleted the population, whereas scenarios with a fixed Mexican harvest rate sustained some level of catch. Median total catch values ranged from 0 to ~8,000 tons for $SB_{0(2005\text{-}18)}$ (Table 12, Figure 11) and 0 to 6,044 mt for $SB_{0(2010\text{-}18)}$ (Table 13; Figure 11). Detailed figures including 5th, 25th, 50th, 75th, and 90th percentiles are shown for $SB_{0(2005\text{-}18)}$ (Figure 12) and $SB_{0(2010\text{-}18)}$ (Figure 13). Note that the catch values in Tables 12 and 13 represent the total catch (Mexico and US combined), and do not represent US portions of that catch. US portions of the total catch can be calculated by subtracting 6,044 mt from the fixed Mexico catch columns. For the fixed Mexico rate columns, the reader should multiply the total catch by the US portions in the last column of Table 3b.

Finally, it is important to reiterate the high degree of variability in the sardine rebuilding projections and the extent to which rebuilding depends upon productivity assumptions for the two scenarios. For example, Figure 14 illustrates *SB* projections in the complete absence of fishing (US and Mexico E=0) for the two productivity scenarios. Both the large σR (1.2) and profiled range of steepness contributed to this uncertainty. The absolute magnitude of rebuilding is highly dependent upon the choice of recruitments selected to base SB_0. In the $SB_{0(2005\text{-}18)}$ scenario, more than 50% of the projections exceed the 150,000 mt threshold, whereas in the $SB_{0(2005\text{-}18)}$ scenario approximately 10% of the projections exceed that threshold (Figure 14).

Discussion

These rebuilding results are difficult to interpret as the target biomass levels and times to achieve rebuilding are strongly dependent on assumptions of the state of nature. Rebuilding above 150,000 mt with greater than 50% probability was achieved by 2037 with US (5%) and Mexico (9.9%) harvest for $SB_{0(2005\text{-}18)}$, whereas rebuilding to this level occurred by 2037 only with Total F=0 for $SB_{0(2010\text{-}18)}$.

This rebuilding analysis is limited to the available data from the current stock assessment and does not include early historic high recruitment estimates from the 1980s and 1990s or early 20th century. The analysis represents a relatively narrow time frame (15 years) relative to the number of projection years, and likely represents a limited snapshot of the long-term population fluctuations. Pacific sardine are members of the coastal pelagic species (CPS) assemblage of the northeastern Pacific Ocean, which represents an important forage base in the California Current. Pacific sardine biology is characteristic of CPS in general, including relatively small body size, short-lived, mature early, tendency to form large schools, seasonally migratory, and most importantly, highly variable recruitment success and related population abundance based primarily on oceanographic factors (environmental drivers). Further, although there is general consensus in the marine ecology community that oceanographic dynamics are likely the key drivers of year-to-year variation in recruitment and stock abundance exhibited by small pelagic fish populations (e.g., Glantz 1992; McGinn 2002; Checkley et al. 2009; NMFS 2019), detailed understanding of the relationship between specific environmental drivers and a stock's productivity is generally lacking or at the very least, refuted when evaluated over longer time periods (Bakun 1985; Walters and Collie 1988; Myers 1998; Francis 2006; Keyl and Wolff 2008; Haltuch and Punt 2011; Koslow et al. 2013; Subbey et al. 2014; Zwolinski and Demer 2019). Pacific sardine are illustrative of the challenges associated with using oceanographic data to forecast future abundance for management purposes, given repeated research resulting in inconsistent findings of meaningful statistical correlation between the stock's recruitment success and various sea-surface temperature-related indices evaluated over time (Jacobson and MacCall 1995; McClatchie et al. 2010; Lindegren and Checkley 2013; Zwolinski and Demer 2014).

The required analysis by the Pacific Fishery Management Council for rebuilding a formally declared overfished stock is based on a population dynamics model that ultimately provides projected estimates of catch/fishing mortality and associated time periods that would be needed to allow the overfished stock to realize a specified level of abundance or 'rebuilt' (Punt 2012, PFMC 2019). An important parametrization in the rebuilding program concerns the generation of future recruitment, which represents the most critical estimates from the analysis, and the basis for determining abundance (rebuilding levels) from varying trajectories of projected fishing intensities/time periods. The inherent recruitment uncertainty exhibited by CPS likely due to environmental forcing mechanisms necessarily confounds straightforward interpretation of rebuilding programs in general for these highly variable stocks. That is, rebuilding programs for longer-lived species that are generally subject to much less variation in recruitment from year-to-year driven largely by underlying biological mechanisms (e.g., parental stock size or spawning stock biomass), such as groundfish stocks that inhabit the continental shelf/slope off the U.S. Pacific coast (e.g., Dick and MacCall 2014, Gertseva and Cope 2018), are more likely to provide meaningful results regarding levels of fishing pressure and amounts of time needed to effectively rebuild an overfished stock to desired sustainable abundance levels. Additionally, the profile on steepness may or may not be realistic for the stock over the past 15 years. Steepness would be expected to shift toward higher levels in a rebounding stock and was poorly estimated in the 2020 benchmark assessment. The median value for our steepness profile was 0.4, while meta-analysis of life history parameters predicts Clupeiformes have steepness around 0.72 (Thorson 2019).

In the above context, it is important to note that although reasonable/documented estimates of historical recruitment patterns (rebuilding scenarios) from the most recent Pacific sardine stock assessment were used here, this species' biology and substantial recruitment variation in any given year based primarily on unaccounted for environmental factors translates to increased uncertainty surrounding the generated results from the overall rebuilding analysis. Thus, the results presented here are likely to be more accurate in capturing short-term projected stock and fishery dynamics as opposed to the longer term since there is an absence of critical environmental data generally believed to be the underlying/overriding factors that influence this species' population dynamics.

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Table 1. Management quantities and landings (metric tons) since the 2015-16 management year (July-June).

	U.S. Management					
Mgmt Year	OFL	$ABC_{0.4}$	ACT	U.S. Total Landings (mt)	U.S. NSP Landings (mt)	Ensenada NSP Landings (mt)
2015-16	13,227	12,074	4,000	1,919	260	0
2016-17	23,085	19,236	5,000	1,885	601	6,936
2017-18	16,957	15,479	5,000	1,775	372	6,032
2018-19	11,324	9,436	2,500	2,282	655	11,210
2019-20	5,816	4,514	4,000	incomplete	incomplete	nd
2020-21	5,525	4,288	4,000	---	---	---
		Average for 2015-19:		1,965	472	6,044

Table 2. Rebuilding input parameters by age. Note that initial numbers-at-age and natural mortality will vary with steepness for the multiple parameter projections. In order to transition the modeled time step from seasonal (SS) to annual (Rebuilder), it was necessary to change fecundity at age zero from 0.0046 to 0.0000.

Age	Fecundity	*M*	Init N	Init N Tmin	Weight	Selectivity
0	0.0000	0.585	438996.00	580925.00	0.034	0.49003
1	0.0354	0.585	194984.00	222512.00	0.059	1.00000
2	0.0773	0.585	44087.50	46832.80	0.083	0.25724
3	0.1100	0.585	19995.00	12386.50	0.160	0.03762
4	0.1339	0.585	6617.46	47853.50	0.170	0.05343
5	0.1515	0.585	25027.30	11486.90	0.172	0.04378
6	0.1644	0.585	5931.46	5723.79	0.183	0.01445
7	0.1739	0.585	3052.62	4551.15	0.186	0.01366
8	0.1808	0.585	2481.45	1750.78	0.191	0.00306
9	0.1858	0.585	970.42	8726.19	0.195	0.00306
10	0.1939	0.585	6040.54	2171.82	0.200	0.00306

Table 3a. Respective harvest rates for U.S. and Mexico for the constant harvest rate simulations.

Steepness	Relative Probability	Assumed MX Catch (mt)	S1 Age 1+ Biomass (mt)	S1 MX Exploitation Rate
0.30	0.19	6,044	61,240	0.0987
0.35	0.17	6,044	61,219	0.0987
0.40	0.15	6,044	61,214	0.0987
0.45	0.13	6,044	61,229	0.0987
0.50	0.11	6,044	61,260	0.0987
0.55	0.09	6,044	61,307	**0.0986**
0.60	0.07	6,044	61,367	0.0985
0.65	0.05	6,044	61,436	0.0984
0.70	0.03	6,044	61,513	0.0983
0.75	0.01	6,044	61,596	0.0981
0.80	0.00	6,044	61,683	0.0980

Table 3b. Respective exploitation rates (*E*) for U.S. and Mexico for the constant harvest rate simulations.

Harvest Alternative	MX *E*	US *E*	Total *E*	US Portion
Alt 1 (US *E*=18%)	0.0986	0.1216	0.2202	0.5520
Alt 2 (US *E*=0)	0.0986	0.0000	0.0986	0.0000
Alt 3 (US *E*=5%)	0.0986	0.0500	0.1486	0.3364

Table 4. MSY references points and relative probabilities over the profiled range of steepness for two productivity states of nature. SB_0 values and the single weighted target depletion level are provided at the bottom of each table.

SB $_{0(2005\text{-}18)}$					
Steepness	E_{MSY}	Median Catch (mt)	SB_{MSY} (mt)	Target Depletion	Relative Probability
0.30	0.075	16,112	162,286	0.42983	19%
0.35	0.110	22,791	155,613	0.41213	17%
0.40	0.150	28,880	143,687	0.38057	15%
0.45	0.190	34,538	134,826	0.35710	13%
0.50	0.230	39,897	127,896	0.33870	11%
0.55	0.280	45,058	117,800	0.31200	9%
0.60	0.330	50,109	110,394	0.29240	7%
0.65	0.390	55,125	101,953	0.27000	5%
0.70	0.455	60,198	94,656	0.25070	3%
0.75	0.535	65,423	86,664	0.22950	1%
0.80	0.640	70,942	77,650	0.20570	0%
		SB_0=	**377,567**	**0.36500**	**<-Wtd Value**
		SB_{MSY}=	**137,812**		

SB $_{0(2010\text{-}18)}$					
Steepness	E_{MSY}	Median Catch (mt)	SB_{MSY} (mt)	Target Depletion	Relative Probability
0.30	0.075	4,465	44,975	0.43062	19%
0.35	0.110	6,307	43,066	0.41233	17%
0.40	0.150	7,990	39,751	0.38059	15%
0.45	0.190	9,554	37,296	0.35710	13%
0.50	0.230	11,037	35,379	0.33870	11%
0.55	0.280	12,464	32,587	0.31200	9%
0.60	0.330	13,861	30,538	0.29240	7%
0.65	0.385	15,249	28,588	0.27370	5%
0.70	0.455	16,652	26,184	0.25070	3%
0.75	0.535	18,098	23,974	0.22950	1%
0.80	0.640	19,624	21,480	0.20570	0%
		SB_0=	**104,445**	**0.36500**	**<-Wtd Value**
		SB_{MSY}=	**38,122**		

Table 5. Pacific sardine rebuilding reference points for the $SB_{0(2005\text{-}18)}$ and $SB_{0(2010\text{-}18)}$ states of nature and fixed Mexico fishing rate models. Probabilities of rebuilding to T_{MAX} are shown for the three harvest alternatives being considered in the rebuilding plan.

Parameter	$SB_{0(2005\text{-}18)}$	$SB_{0(2010\text{-}18)}$
Year declared overfished	2019	2019
Current year	2020	2020
Year 1 rebuilding plan (anticipated)	2021	2021
T_{MIN}	2029	2022
T_{MAX}	2031	2031
Alt 1 probability of rebuilding by T_{MAX}	25.8%	56.7%
Alt 2 probability of rebuilding by T_{MAX}	40.6%	69.3%
Alt 3 probability of rebuilding by T_{MAX}	33.3%	62.8%
Mean generation time	3	3
Average SB_0	377,567	104,445
Average rebuilding target ($SB_{36.5\%}$)	137,812	38,122

Table 6. Probabilities of recovery for rebuilding alternatives for $SB_{0(2005\text{-}18)}$ scenario. Mexico catch was fixed at 6,044 mt or at an exploitation rate of 9.9. Probabilities of recovery with no Mexico or US harvest is also shown. Grey shading indicates probabilities greater than 0.5.

	Fixed Mex. Catch (6,044mt)			**Fixed Mex. Rate (9.9)**			**Total F=0**
Year	**US rate=0**	**US rate=5**	**US rate=18**	**US rate=0**	**US rate=5**	**US rate=18**	
2019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2021	0.0315	0.0300	0.0295	0.0310	0.0305	0.0295	0.0335
2022	0.0850	0.0710	0.0600	0.0760	0.0665	0.0565	0.1000
2023	0.1440	0.1200	0.0970	0.1290	0.1095	0.0915	0.1810
2024	0.1970	0.1670	0.1330	0.1805	0.1550	0.1240	0.2530
2025	0.2380	0.2040	0.1630	0.2240	0.1950	0.1510	0.3155
2026	0.2795	0.2350	0.1805	0.2620	0.2240	0.1705	0.3825
2027	0.3090	0.2575	0.2015	0.2955	0.2485	0.1920	0.4330
2028	0.3380	0.2805	0.2180	0.3280	0.2750	0.2110	0.4810
2029	0.3670	0.3045	0.2300	0.3620	0.3020	0.2315	0.5210
2030	0.3865	0.3195	0.2390	0.3870	0.3200	0.2435	0.5620
2031	0.4050	0.3315	0.2500	0.4060	0.3330	0.2580	0.6005
2032	0.4235	0.3450	0.2610	0.4285	0.3515	0.2715	0.6310
2033	0.4405	0.3610	0.2710	0.4560	0.3750	0.2850	0.6560
2034	0.4525	0.3705	0.2770	0.4765	0.3900	0.2965	0.6750
2035	0.4630	0.3780	0.2835	0.4935	0.4080	0.3065	0.7005
2036	0.4725	0.3830	0.2910	0.5090	0.4205	0.3180	0.7160
2037	0.4800	0.3895	0.2940	0.5260	0.4320	0.3275	0.7300
2038	0.4860	0.3970	0.2970	0.5370	0.4450	0.3360	0.7500
2039	0.4905	0.4050	0.3000	0.5505	0.4550	0.3425	0.7640
2040	0.4965	0.4075	0.3040	0.5620	0.4625	0.3465	0.7725
2041	0.5015	0.4095	0.3070	0.5690	0.4670	0.3530	0.7825
2042	0.5045	0.4135	0.3085	0.5800	0.4730	0.3575	0.7965
2043	0.5065	0.4150	0.3095	0.5880	0.4825	0.3650	0.8085
2044	0.5090	0.4185	0.3125	0.5940	0.4870	0.3690	0.8220
2045	0.5105	0.4195	0.3155	0.6010	0.4920	0.3765	0.8355
2046	0.5110	0.4210	0.3180	0.6075	0.4965	0.3815	0.8455
2047	0.5150	0.4240	0.3200	0.6155	0.5015	0.3860	0.8525
2048	0.5160	0.4245	0.3205	0.6225	0.5080	0.3930	0.8610
2049	0.5175	0.4245	0.3210	0.6265	0.5120	0.3960	0.8670
2050	0.5195	0.4250	0.3225	0.6315	0.5140	0.3995	0.8720

Table 7. Probabilities of recovery for rebuilding alternatives for $SB_{0(2010\text{-}18)}$ scenario. Mexico catch was fixed at 6,044 mt or at an exploitation rate of 9.9. Probabilities of recovery with no Mexico or US harvest is also shown. Grey shading indicates probabilities greater than 0.5. Rebuilding occurs earlier than in scenario $SB_{0(2005\text{-}18)}$ because the biomass target is lower for $SB_{0(2010\text{-}18)}$. See Figure 4 for the difference in SB0 target values between scenarios.

	Fixed Mex. Catch (6,044 mt)			Fixed Mex. Rate (9.9)			Total F=0
Year	**US rate=0**	**US rate=5**	**US rate=18**	**US rate=0**	**US rate=5**	**US rate=18**	
2019	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
2020	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600
2021	0.4445	0.4340	0.4225	0.4580	0.4465	0.4295	0.4905
2022	0.4885	0.4680	0.4500	0.5150	0.4960	0.4645	0.5730
2023	0.5195	0.4940	0.4635	0.5595	0.5300	0.4915	0.6485
2024	0.5375	0.5110	0.4755	0.5940	0.5570	0.5115	0.6960
2025	0.5495	0.5215	0.4790	0.6185	0.5715	0.5250	0.7250
2026	0.5555	0.5255	0.4830	0.6360	0.5885	0.5325	0.7560
2027	0.5610	0.5285	0.4830	0.6530	0.5980	0.5410	0.7780
2028	0.5650	0.5295	0.4845	0.6645	0.6085	0.5500	0.7955
2029	0.5665	0.5315	0.4855	0.6755	0.6150	0.5575	0.8085
2030	0.5685	0.5325	0.4855	0.6855	0.6230	0.5620	0.8210
2031	0.5685	0.5330	0.4855	0.6925	0.6280	0.5665	0.8315
2032	0.5700	0.5335	0.4855	0.7005	0.6330	0.5695	0.8440
2033	0.5705	0.5335	0.4855	0.7060	0.6385	0.5725	0.8610
2034	0.5710	0.5335	0.4855	0.7125	0.6460	0.5775	0.8690
2035	0.5710	0.5335	0.4860	0.7215	0.6505	0.5785	0.8785
2036	0.5710	0.5335	0.4860	0.7320	0.6585	0.5840	0.8855
2037	0.5710	0.5335	0.4860	0.7355	0.6640	0.5865	0.8965
2038	0.5710	0.5335	0.4860	0.7395	0.6665	0.5875	0.9035
2039	0.5710	0.5335	0.4860	0.7460	0.6705	0.5885	0.9100
2040	0.5710	0.5335	0.4860	0.7505	0.6745	0.5895	0.9150
2041	0.5720	0.5335	0.4860	0.7540	0.6765	0.5900	0.9195
2042	0.5720	0.5335	0.4860	0.7590	0.6795	0.5910	0.9235
2043	0.5720	0.5335	0.4860	0.7630	0.6800	0.5910	0.9275
2044	0.5720	0.5335	0.4860	0.7670	0.6820	0.5915	0.9325
2045	0.5720	0.5335	0.4860	0.7695	0.6825	0.5930	0.9335
2046	0.5720	0.5335	0.4860	0.7715	0.6865	0.5935	0.9370
2047	0.5720	0.5335	0.4860	0.7780	0.6865	0.5935	0.9390
2048	0.5720	0.5335	0.4860	0.7815	0.6885	0.5940	0.9420
2049	0.5720	0.5335	0.4860	0.7845	0.6900	0.5945	0.9460
2050	0.5720	0.5335	0.4860	0.7855	0.6910	0.5955	0.9490

Table 8. Probabilities of recovery above 150,000 mt of age 1+ biomass for rebuilding alternatives for $SB_{0(2005\text{-}18)}$ scenario. Mexico catch was fixed at 6,044 mt or at an exploitation rate of 9.9. Probabilities of recovery with no Mexico or US harvest is also shown. Grey shading indicates probabilities greater than 0.5.

	Fixed Mex. Catch (6,044mt)			**Fixed Mex. Rate (9.9)**			**Total F=0**
Year	**US rate=0**	**US rate=5**	**US rate=18**	**US rate=0**	**US rate=5**	**US rate=18**	
2020	0	0	0	0	0	0	0
2021	0.0655	0.0635	0.0615	0.066	0.0635	0.0615	0.071
2022	0.1275	0.115	0.104	0.129	0.1125	0.1035	0.1525
2023	0.196	0.1785	0.152	0.198	0.1775	0.153	0.244
2024	0.253	0.2245	0.19	0.255	0.2255	0.1925	0.326
2025	0.2985	0.257	0.22	0.299	0.2635	0.2215	0.3995
2026	0.3335	0.2895	0.2395	0.342	0.294	0.2455	0.459
2027	0.3645	0.316	0.2585	0.3735	0.325	0.264	0.5105
2028	0.3925	0.3365	0.2725	0.4075	0.35	0.2845	0.5505
2029	0.417	0.3555	0.2865	0.44	0.3785	0.307	0.591
2030	0.432	0.368	0.2945	0.4595	0.398	0.3225	0.6275
2031	0.449	0.377	0.3005	0.48	0.4125	0.3315	0.6555
2032	0.466	0.388	0.3105	0.4995	0.4305	0.3455	0.6775
2033	0.4815	0.4005	0.3175	0.526	0.4485	0.3585	0.7015
2034	0.4865	0.4095	0.3235	0.5435	0.4655	0.371	0.7225
2035	0.4955	0.4145	0.3275	0.5585	0.48	0.3795	0.744
2036	0.504	0.4195	0.332	0.5755	0.49	0.39	0.757
2037	0.5085	0.426	0.334	0.5885	0.5025	0.3985	0.772
2038	0.515	0.4325	0.3355	0.5995	0.5135	0.4065	0.789
2039	0.5175	0.436	0.3385	0.6085	0.525	0.414	0.8
2040	0.521	0.438	0.3395	0.618	0.533	0.419	0.809
2041	0.524	0.4385	0.342	0.625	0.54	0.423	0.8185
2042	0.527	0.4425	0.343	0.634	0.545	0.4275	0.833
2043	0.5285	0.4435	0.344	0.64	0.55	0.4345	0.8425
2044	0.5285	0.4435	0.345	0.6455	0.554	0.437	0.8545
2045	0.5315	0.4445	0.3465	0.6525	0.5575	0.442	0.8645
2046	0.532	0.446	0.3475	0.657	0.5645	0.4435	0.8725
2047	0.534	0.4465	0.348	0.664	0.57	0.4465	0.8775
2048	0.5345	0.447	0.3485	0.671	0.5705	0.452	0.885
2049	0.535	0.447	0.3485	0.676	0.5745	0.455	0.89
2050	0.5355	0.4475	0.35	0.6805	0.579	0.4585	0.896

Table 9. Probabilities of recovery above 150,000 mt of age 1+ biomass for rebuilding alternatives for $SB_{0(2010\text{-}18)}$ scenario. Mexico catch was fixed at 6,044 mt or at an exploitation rate of 9.9. Probabilities of recovery with no Mexico or US harvest is also shown. Grey shading indicates probabilities greater than 0.5.

	Fixed Mex. Catch (6,044mt)			Fixed Mex. Rate (9.9)			Total F=0
Year	**US rate=0**	**US rate=5**	**US rate=18**	**US rate=0**	**US rate=5**	**US rate=18**	
2019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2021	0.0250	0.0240	0.0220	0.0260	0.0235	0.0220	0.0280
2022	0.0410	0.0380	0.0345	0.0435	0.0380	0.0345	0.0535
2023	0.0650	0.0575	0.0505	0.0665	0.0585	0.0520	0.0935
2024	0.0895	0.0730	0.0620	0.0890	0.0740	0.0650	0.1380
2025	0.1045	0.0850	0.0700	0.1035	0.0880	0.0735	0.1715
2026	0.1225	0.0975	0.0785	0.1260	0.1030	0.0840	0.2100
2027	0.1420	0.1105	0.0880	0.1480	0.1195	0.0945	0.2410
2028	0.1550	0.1225	0.0945	0.1630	0.1330	0.1035	0.2755
2029	0.1680	0.1305	0.0980	0.1805	0.1465	0.1125	0.3105
2030	0.1765	0.1335	0.1020	0.1935	0.1535	0.1180	0.3360
2031	0.1850	0.1405	0.1055	0.2075	0.1650	0.1260	0.3580
2032	0.1940	0.1470	0.1095	0.2215	0.1765	0.1360	0.3850
2033	0.1995	0.1520	0.1110	0.2340	0.1865	0.1420	0.4170
2034	0.2095	0.1590	0.1150	0.2510	0.1975	0.1490	0.4385
2035	0.2130	0.1620	0.1155	0.2615	0.2035	0.1540	0.4635
2036	0.2205	0.1645	0.1175	0.2765	0.2135	0.1585	0.4915
2037	0.2265	0.1685	0.1185	0.2890	0.2235	0.1615	0.5065
2038	0.2305	0.1735	0.1195	0.3020	0.2370	0.1705	0.5270
2039	0.2325	0.1755	0.1215	0.3125	0.2420	0.1735	0.5470
2040	0.2345	0.1765	0.1225	0.3170	0.2470	0.1760	0.5600
2041	0.2385	0.1785	0.1230	0.3250	0.2520	0.1795	0.5685
2042	0.2425	0.1805	0.1250	0.3340	0.2610	0.1850	0.5860
2043	0.2470	0.1805	0.1255	0.3405	0.2655	0.1875	0.6030
2044	0.2485	0.1815	0.1255	0.3465	0.2700	0.1895	0.6180
2045	0.2505	0.1830	0.1260	0.3545	0.2775	0.1930	0.6335
2046	0.2520	0.1840	0.1275	0.3615	0.2830	0.1970	0.6470
2047	0.2530	0.1845	0.1280	0.3655	0.2865	0.1995	0.6640
2048	0.2550	0.1845	0.1280	0.3735	0.2925	0.2015	0.6800
2049	0.2565	0.1845	0.1285	0.3800	0.2985	0.2065	0.6910
2050	0.2585	0.1850	0.1285	0.3930	0.3060	0.2110	0.6985

Table 10. Median spawning stock biomass (mt) for rebuilding alternatives for $SB_{0(2005\text{-}18)}$ scenario. Mexico catch was fixed at 6,044 mt or at an exploitation rate of 9.9. Probabilities of recovery with no Mexico or US harvest is also shown. Gray shading indicates years in which the probability of recovery was greater than 0.5 (based on probabilities in Table 4).

	Fixed Mex. Catch (6,044mt)			Fixed Mex. Rate (9.9)			Total F=0
Year	**US rate=0**	**US rate=5**	**US rate=18**	**US rate=0**	**US rate=5**	**US rate=18**	
2019	25,879	25,879	25,879	25,879	25,879	25,879	25,879
2020	29,598	29,598	29,598	29,598	29,598	29,598	29,598
2021	33,372	31,509	28,881	35,055	33,122	30,418	38,877
2022	35,113	30,509	25,152	37,730	33,867	28,298	47,007
2023	37,177	30,269	21,784	41,633	34,991	27,326	56,350
2024	37,684	28,087	17,628	45,365	36,564	26,198	67,391
2025	39,095	26,290	13,643	47,036	35,943	23,932	76,492
2026	41,052	24,557	9,360	49,628	36,332	22,197	88,273
2027	42,838	23,165	6,360	51,792	36,591	21,372	97,579
2028	43,371	20,122	4,155	53,898	36,529	20,042	109,517
2029	46,100	18,720	2,399	56,132	36,043	18,180	119,732
2030	46,096	16,216	1,514	58,819	37,270	17,803	130,959
2031	47,985	12,522	883	60,556	36,980	17,127	140,751
2032	47,713	8,705	543	61,399	37,587	16,379	147,730
2033	48,194	5,263	287	62,813	36,351	15,597	154,344
2034	49,143	3,011	163	61,038	35,600	14,210	159,140
2035	47,250	1,808	98	63,922	35,757	13,524	163,850
2036	46,615	1,003	55	64,624	35,722	13,416	171,223
2037	45,184	593	32	65,286	35,588	13,088	179,906
2038	39,576	326	17	66,074	35,186	12,463	183,075
2039	36,632	186	9	67,704	35,571	11,879	187,576
2040	36,561	108	5	66,133	34,895	10,997	188,222
2041	38,561	62	3	65,706	33,671	9,757	187,551
2042	35,637	36	2	66,693	31,988	9,205	190,559
2043	33,449	19	1	65,268	31,210	8,744	190,788
2044	28,748	12	1	64,371	30,536	8,208	190,213
2045	29,926	6	0	64,005	29,386	7,962	192,664
2046	24,725	3	0	62,368	29,093	7,275	200,334
2047	21,019	2	0	62,426	27,685	6,660	201,381
2048	17,921	1	0	63,063	28,550	6,294	200,019
2049	15,550	1	0	62,605	28,549	5,898	201,301
2050	12,453	0	0	65,031	28,349	5,413	198,358

Table 11. Median spawning stock biomass (mt) for rebuilding alternatives for $SB_{0(2010\text{-}18)}$ scenario. Mexico catch was fixed at 6,044 mt or at an exploitation rate of 9.9. Probabilities of recovery with no Mexico or US harvest is also shown. Gray shading indicates years in which the probability of recovery was greater than 0.5 (based on probabilities in Table 5).

	Fixed Mex. Catch (6,044mt)			**Fixed Mex. Rate (9.9)**			**Total F=0**
Year	**US rate=0**	**US rate=5**	**US rate=18**	**US rate=0**	**US rate=5**	**US rate=18**	
2019	25,879	25,879	25,879	25,879	25,879	25,879	25,879
2020	29,598	29,598	29,598	29,598	29,598	29,598	29,598
2021	31,594	29,557	26,726	33,042	30,989	28,217	37,110
2022	28,916	25,000	20,100	31,639	27,859	23,149	39,706
2023	26,213	20,751	14,646	30,875	25,748	19,617	42,936
2024	22,597	16,095	9,694	29,709	23,764	16,952	44,856
2025	19,497	12,298	6,122	28,740	22,077	14,833	46,577
2026	16,558	8,445	3,771	27,835	20,590	13,182	48,217
2027	12,795	5,381	2,252	27,256	19,312	11,679	50,173
2028	9,940	3,367	1,340	26,169	18,112	10,639	51,160
2029	7,254	2,033	807	25,764	17,558	9,569	51,889
2030	4,575	1,218	465	25,467	16,768	8,953	53,379
2031	2,873	708	265	25,370	16,631	8,425	54,524
2032	1,621	445	157	24,880	15,894	7,801	55,188
2033	986	243	90	24,474	15,440	7,205	55,887
2034	556	144	50	23,665	14,347	6,364	56,050
2035	330	84	29	23,416	13,991	6,078	57,317
2036	182	47	16	23,298	13,551	5,619	58,743
2037	106	27	9	23,618	13,460	5,343	58,343
2038	62	16	6	23,822	13,352	4,970	58,573
2039	35	9	3	23,187	12,944	4,658	59,633
2040	20	5	2	22,418	12,380	4,515	59,371
2041	12	3	1	21,933	12,006	4,053	58,814
2042	6	2	1	21,896	11,721	3,646	58,824
2043	3	1	0	21,343	11,180	3,435	58,247
2044	2	1	0	21,321	10,858	3,215	59,268
2045	1	0	0	20,813	10,415	3,137	58,704
2046	1	0	0	20,479	10,065	2,780	60,412
2047	0	0	0	20,160	9,668	2,553	59,710
2048	0	0	0	20,426	9,955	2,496	59,834
2049	0	0	0	20,378	9,630	2,341	58,446
2050	0	0	0	20,008	9,445	2,109	58,442

Table 12. Median catch (mt) for rebuilding alternatives for $SB_{0(2005\text{-}18)}$ scenario. Mexico catch was fixed at 6,044 mt or at an exploitation rate of 9.9. Gray shading indicates years in which the probability of recovery was greater than 0.5 (based on probabilities in Table 4 for $SB_{0(2005\text{-}18)}$ scenario). Catch values represent the total catch (Mexico and US combined), and do not represent only US catches.

	Fixed Mex. Catch (6,044mt)			Fixed Mex. Rate (9.9)		
Year	**US rate=0**	**US rate=5**	**US rate=18**	**US rate=0**	**US rate=5**	**US rate=18**
2019	7,500	7,500	7,500	7,500	7,500	7,500
2020	6,044	7,963	10,709	3,785	5,704	8,452
2021	6,044	8,132	10,702	4,549	6,499	8,846
2022	6,044	8,117	10,105	5,026	6,738	8,296
2023	6,044	8,003	9,357	5,418	6,884	7,849
2024	6,044	7,835	8,626	5,805	6,983	7,320
2025	6,044	7,749	7,715	6,002	6,894	6,703
2026	6,044	7,609	6,914	6,251	6,840	6,167
2027	6,044	7,476	4,944	6,502	6,944	6,047
2028	6,044	7,319	3,037	6,793	6,847	5,600
2029	6,044	7,177	1,801	6,992	6,896	5,166
2030	6,044	6,954	1,191	7,426	7,084	4,978
2031	6,044	6,621	659	7,543	6,905	4,717
2032	6,044	5,755	375	7,772	6,995	4,651
2033	6,044	3,429	189	7,944	6,932	4,269
2034	6,044	2,038	119	7,671	6,661	3,912
2035	6,044	1,037	67	7,893	6,848	3,865
2036	6,044	629	40	8,137	6,597	3,801
2037	6,044	429	21	8,318	6,832	3,541
2038	6,044	191	13	8,166	6,559	3,453
2039	6,044	94	6	8,412	6,588	3,203
2040	6,044	69	3	8,306	6,570	3,124
2041	6,044	38	2	8,068	6,162	2,694
2042	6,044	21	1	8,165	6,077	2,545
2043	6,044	14	1	8,027	5,850	2,305
2044	6,044	7	0	7,914	5,839	2,331
2045	6,044	4	0	7,956	5,433	2,214
2046	6,044	3	0	7,798	5,431	1,974
2047	6,044	1	0	7,870	5,175	1,853
2048	6,044	1	0	7,831	5,392	1,721
2049	6,044	0	0	7,769	5,407	1,593
2050	6,044	0	0	8,025	5,287	1,520

Table 13. Median catch (mt) for rebuilding alternatives for $SB_{0(2010\text{-}18)}$ scenario. Mexico catch was fixed at 6,044 mt or at an exploitation rate of 9.9. Gray shading indicates years in which the probability of recovery was greater than 0.5 (based on probabilities in Table 5 for $SB_{0(2010\text{-}18)}$ scenario). Catch values represent the total catch (Mexico and US combined), and do not represent only US catches.

	Fixed Mex. Catch (6,044mt)			Fixed Mex. Rate (9.9)		
Year	**US rate=0**	**US rate=5**	**US rate=18**	**US rate=0**	**US rate=5**	**US rate=18**
2019	7,500	7,500	7,500	7,500	7,500	7,500
2020	6,044	7,963	10,709	3,785	5,704	8,452
2021	6,044	7,955	10,274	4,199	5,969	8,141
2022	6,044	7,707	9,124	4,179	5,546	6,810
2023	6,044	7,355	7,887	3,935	4,938	5,532
2024	6,044	6,983	6,514	3,672	4,394	4,538
2025	6,044	6,620	4,480	3,476	4,016	3,964
2026	6,044	6,122	2,677	3,478	3,862	3,579
2027	6,044	4,023	1,651	3,368	3,595	3,206
2028	6,044	2,498	1,008	3,223	3,393	2,844
2029	5,169	1,552	607	3,184	3,305	2,610
2030	3,422	982	349	3,143	3,156	2,480
2031	2,060	576	200	3,142	3,092	2,295
2032	1,196	336	123	3,111	2,974	2,150
2033	653	182	68	3,036	2,874	1,985
2034	462	117	42	2,876	2,664	1,724
2035	256	65	23	2,936	2,596	1,724
2036	137	35	13	2,916	2,563	1,559
2037	89	20	7	2,935	2,600	1,491
2038	43	11	4	2,864	2,459	1,352
2039	24	6	2	2,860	2,455	1,301
2040	14	3	1	2,764	2,349	1,221
2041	8	2	1	2,746	2,203	1,104
2042	5	1	0	2,744	2,185	1,003
2043	3	1	0	2,629	2,074	953
2044	1	0	0	2,569	2,030	895
2045	1	0	0	2,550	1,949	844
2046	1	0	0	2,535	1,905	740
2047	0	0	0	2,499	1,808	690
2048	0	0	0	2,509	1,803	680
2049	0	0	0	2,475	1,807	628
2050	0	0	0	2,516	1,775	577

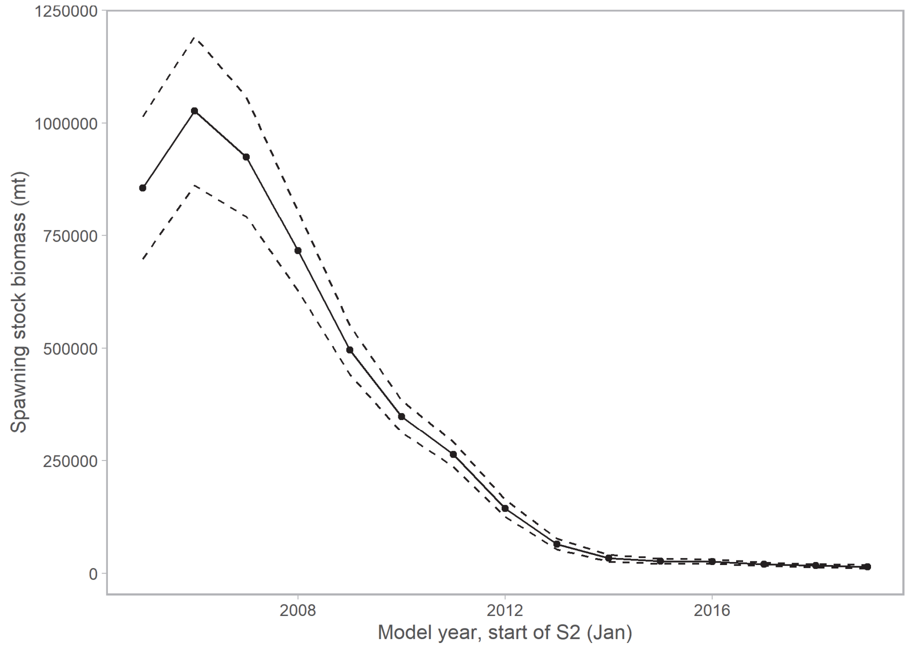

Figure 1: Spawning stock biomass time series (95% CI dashed lines) from the 2020 benchmark assessment (Kuriyama et al. 2020).

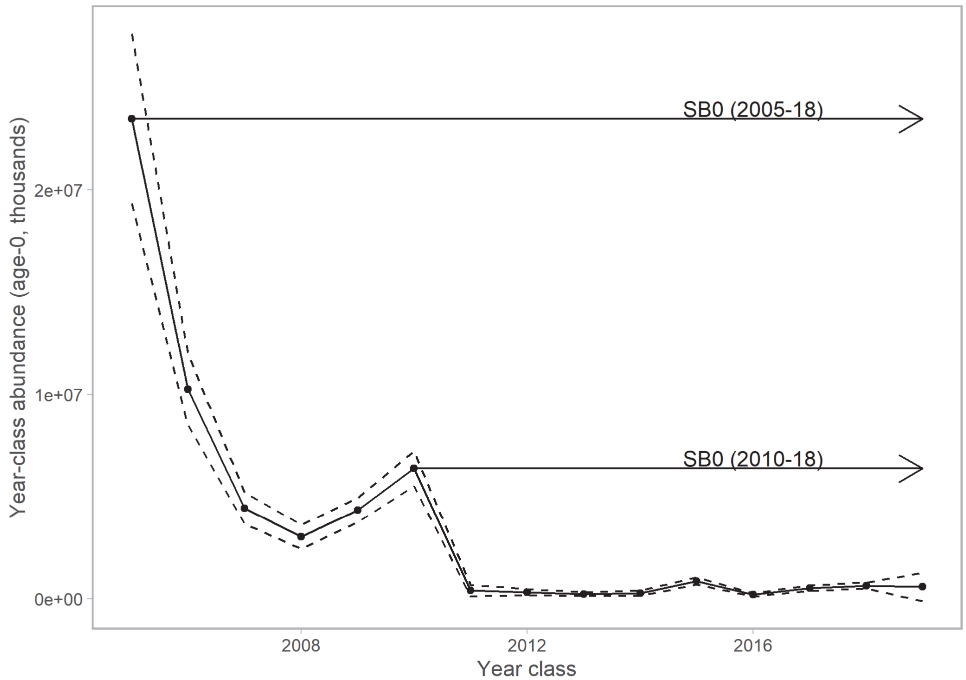

Figure 2. Estimated Pacific sardine recruitment time series from the 2020 Pacific sardine benchmark assessment (Kuriyama et al. 2020). Arrows indicate the two states of nature considered in the rebuilding analysis: SB0 sampled from 2005-18 (top arrow) and SB0 sampled from 2010-2018 (bottom arrow).

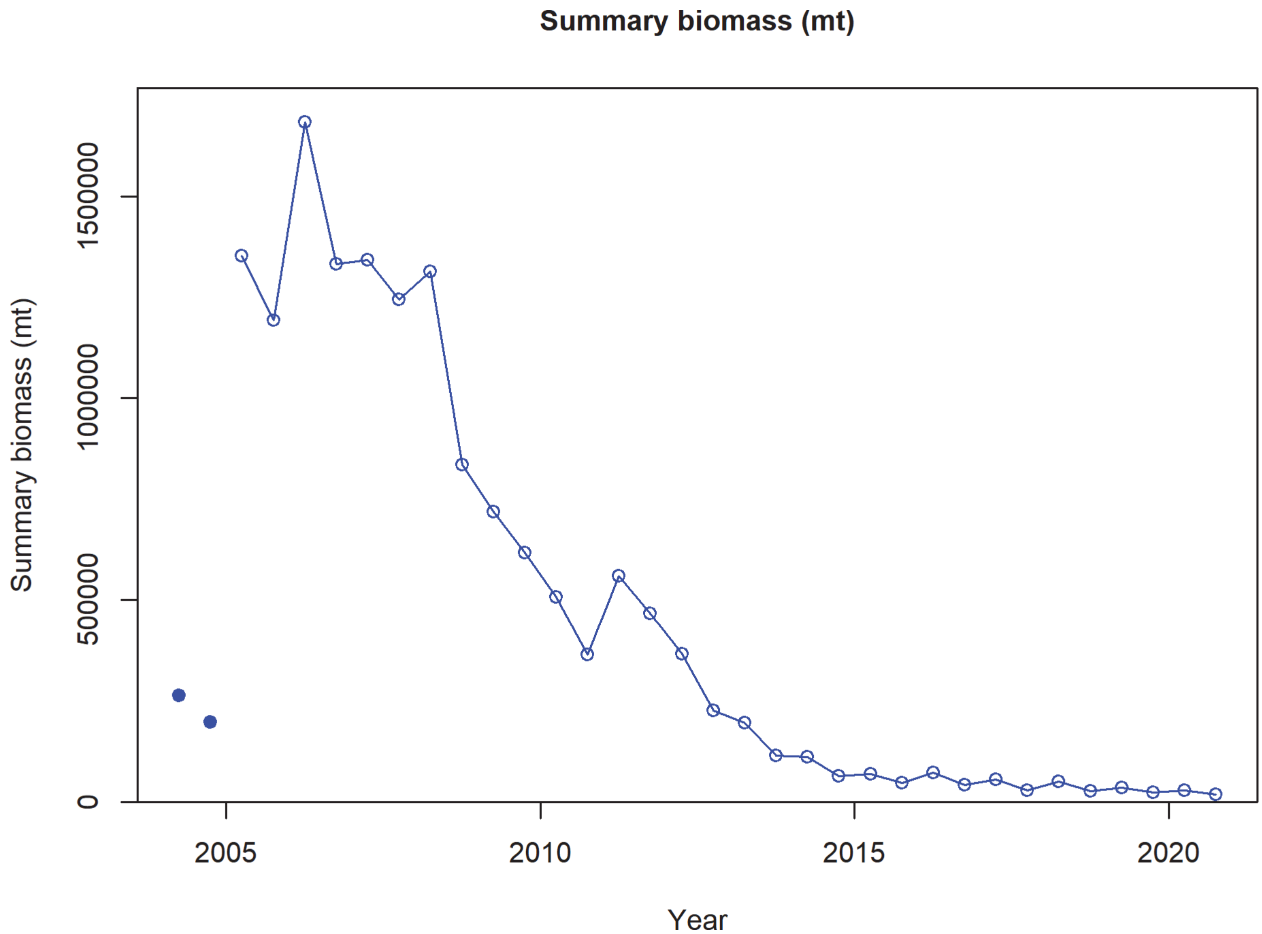

Figure 3. Estimated stock biomass (age 1+ fish; mt) time series from the 2020 benchmark assessment model (Kuriyama et al. 2020).

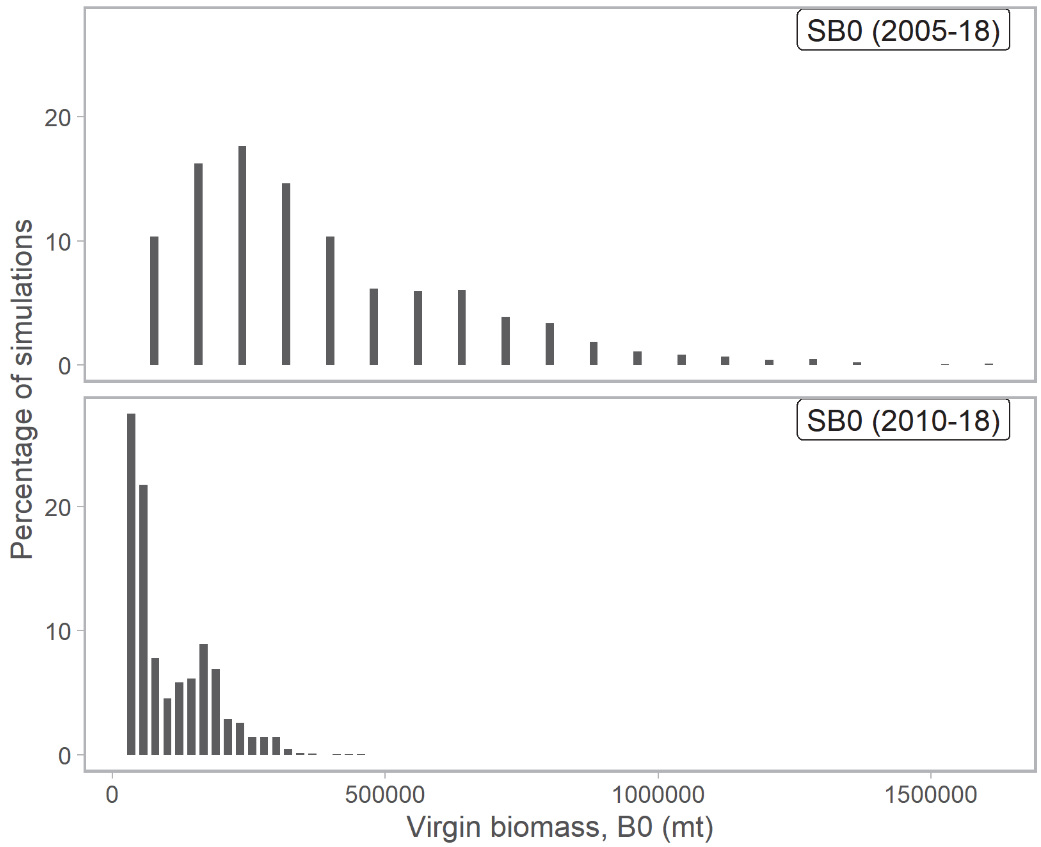

Figure 4. Virgin spawning biomass (SB_0) for the two states of nature.

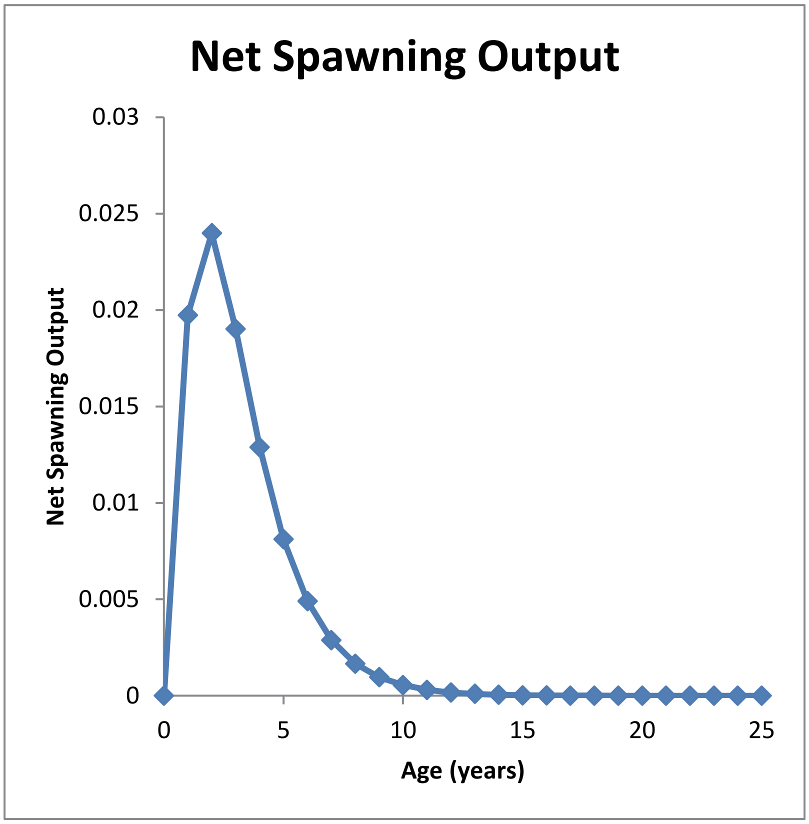

Figure 5. Pacific sardine net spawning output by age.

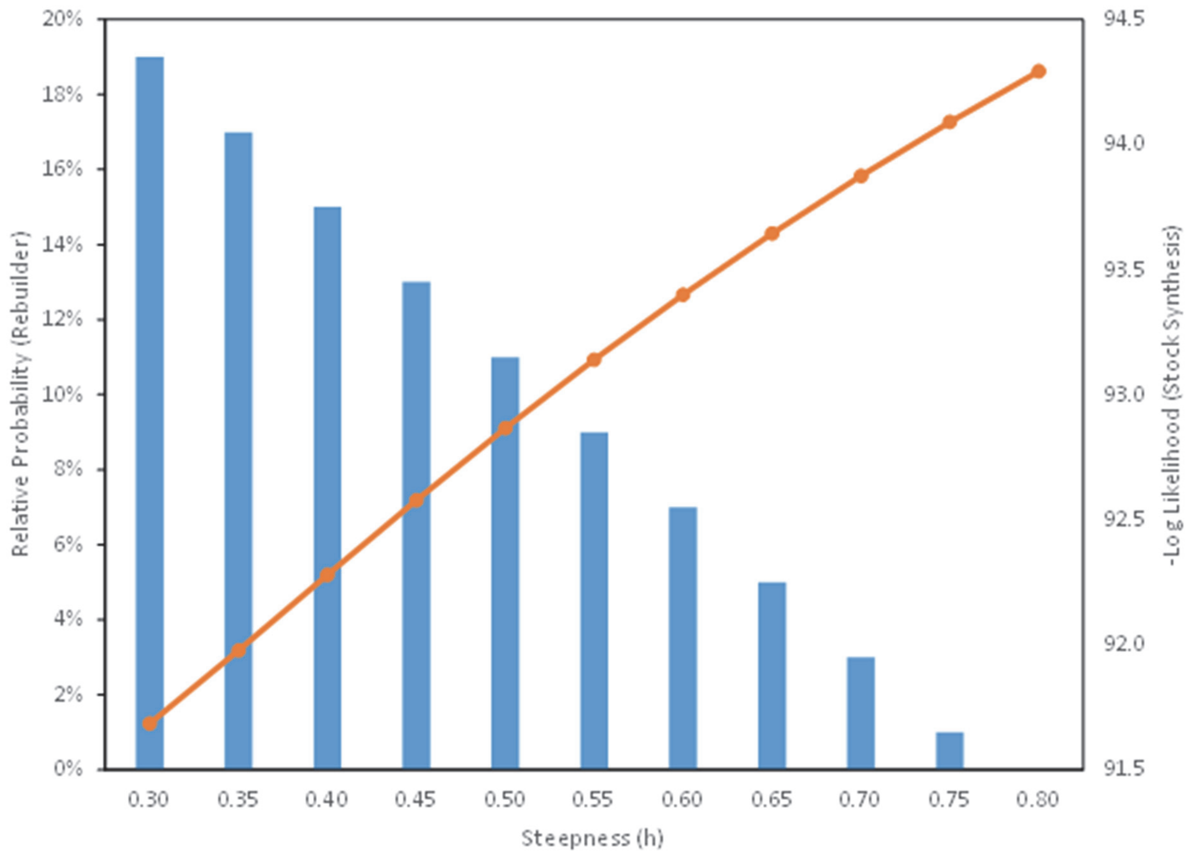

Figure 6. Relative probabilities (blue bars) for steepness levels profiled in rebuilding projections. Relative probabilities were based on negative log likelihood estimates from Stock Synthesis steepness profiles (orange line).

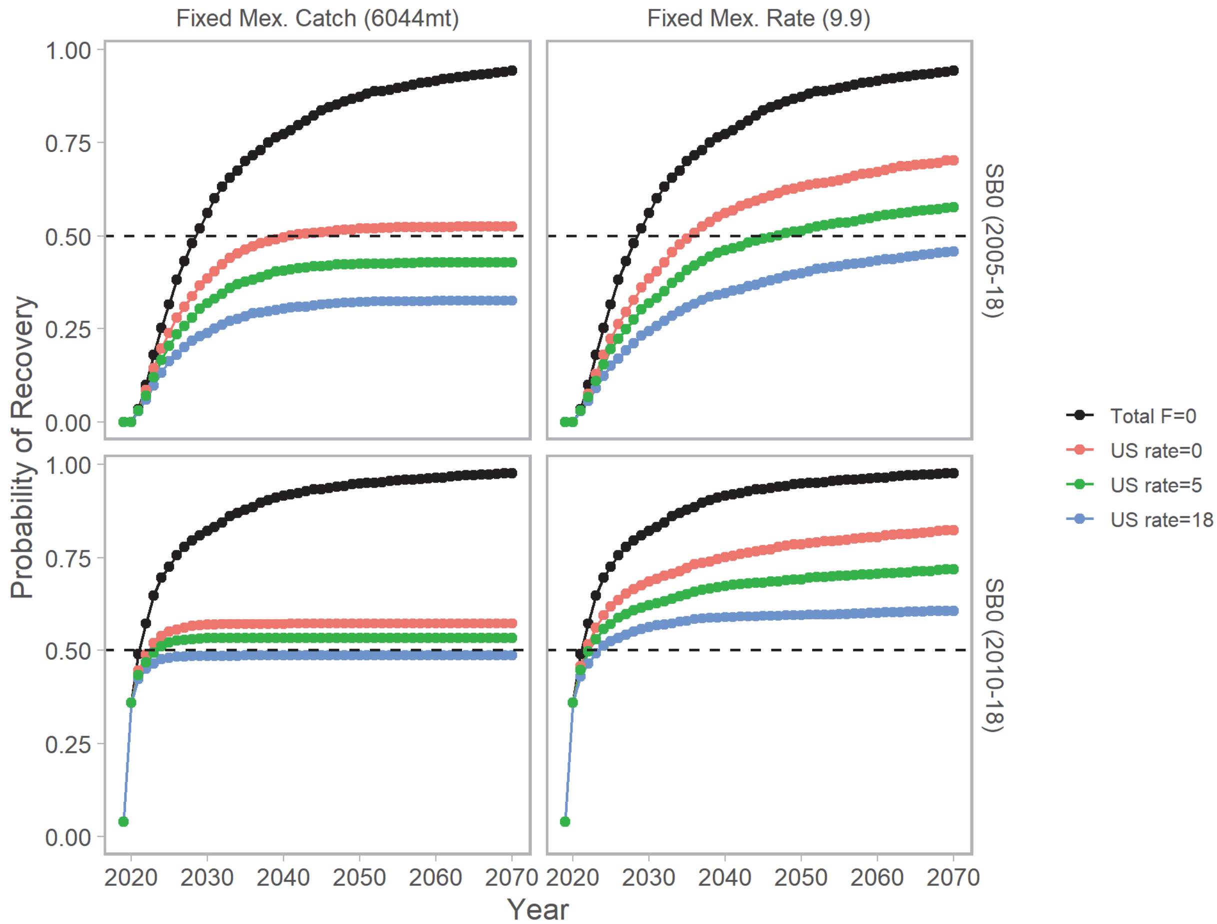

Figure 7a. Probabilities of recovery for Pacific sardine rebuilding alternatives. Panels are arranged by state of nature [$SB_{0(2005\text{-}18)}$ – top row; $SB_{0(2010\text{-}18)}$ – bottom row]. Mexico catch was fixed at 6,044 mt (left column) or assumed to have a fixed harvest rate of 9.9 (right column). The Total F=0 (black) had no harvest from Mexico nor the US. US harvest rates were 0 (red), 5 (green), and 18 (blue). The probability of recovery threshold was 0.5 (dashed black line). Note, the probability of recovery is higher with the $SB_{0(2010\text{-}18)}$ scenario because the target depletion level (as a fraction of B0; see Figure 4) is lower than that from the $SB_{0(2005\text{-}18)}$ scenario.

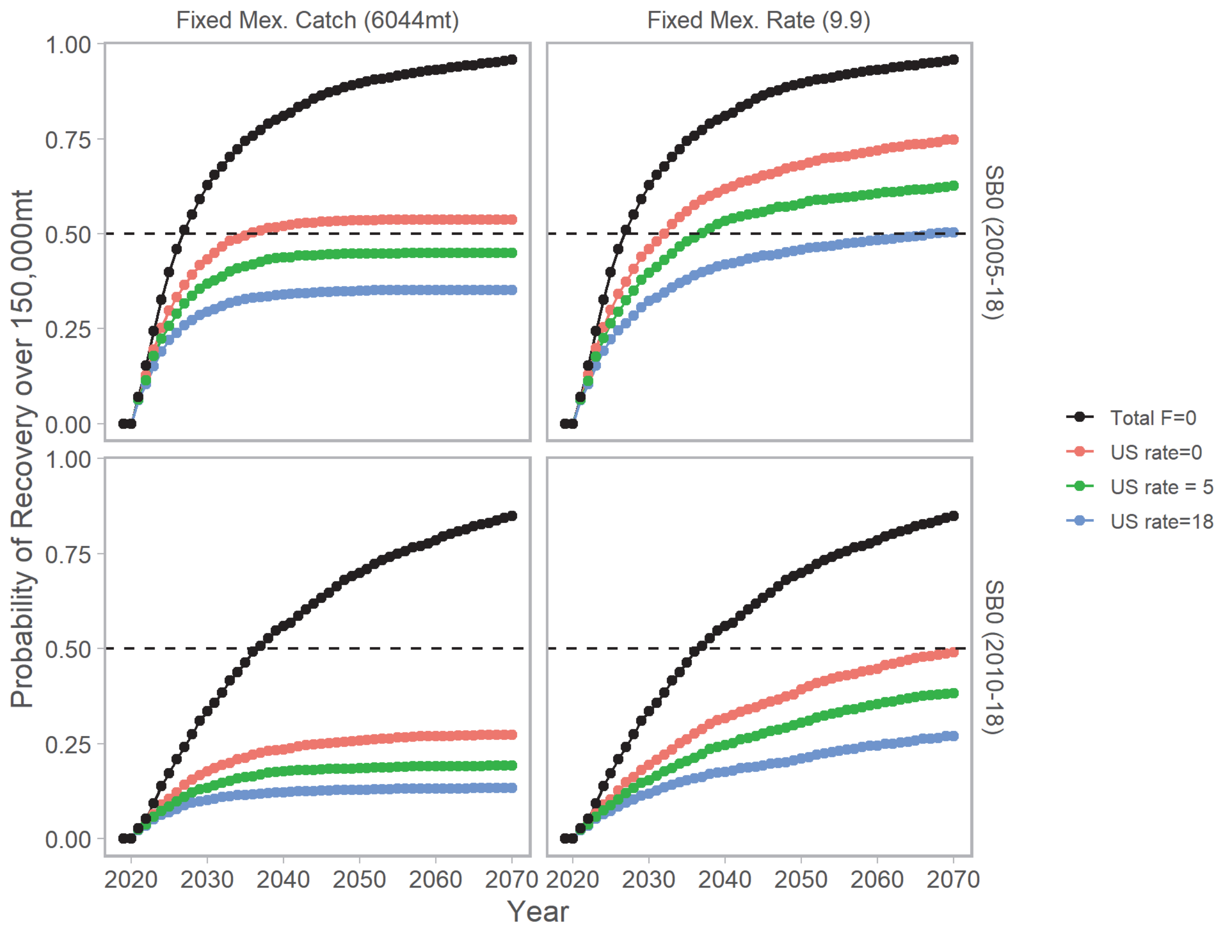

Figure 7b. Probabilities of recovery to the 150,000 mt Cutoff threshold for Pacific sardine rebuilding alternatives. Panels are arranged by state of nature [$SB_{0(2005\text{-}18)}$ – top row; $SB_{0(2010\text{-}18)}$ – bottom row]. Mexico catch was fixed at 6,044 mt (left column) or assumed to have a fixed harvest rate of 9.9 (right column). The Total F=0 (black) had no harvest from Mexico nor the US. US harvest rates were 0 (red), 5 (green), and 18 (blue). The probability of recovery threshold was 0.5 (dashed black line). Note, the probability of recovery is higher with the $SB_{0(2010\text{-}18)}$ scenario because the target depletion level (as a fraction of B0; see Figure 4) is lower than that from the $SB_{0(2005\text{-}18)}$ scenario.

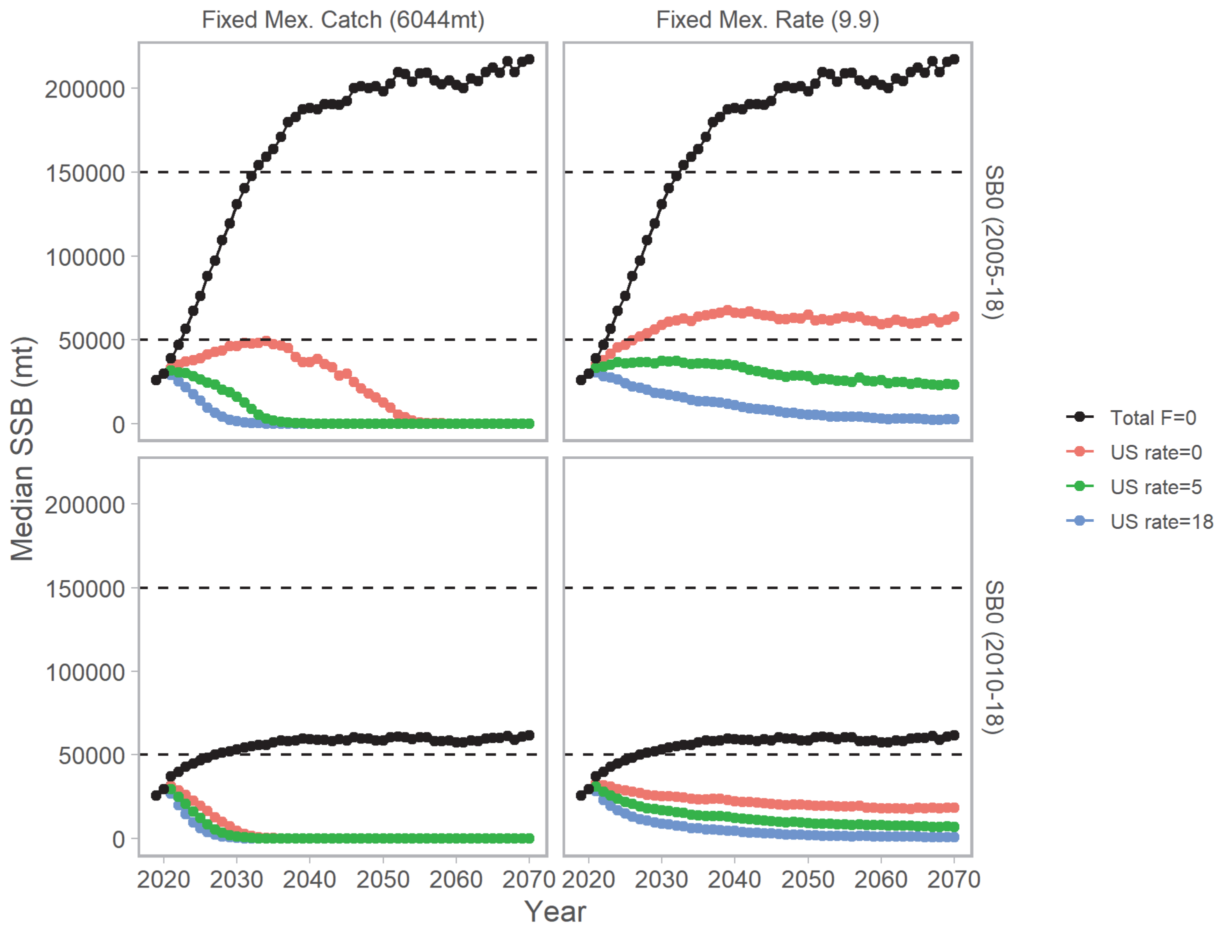

Figure 8. Median spawning stock biomass (mt) for Pacific sardine rebuilding alternatives. Panels are arranged by state of nature [$SB_{0(2005\text{-}18)}$ – top row; $SB_{0(2010\text{-}18)}$ – bottom row]. Mexico catch was fixed at 6,044 mt (left column) or assumed to have a fixed harvest rate of 9.9 (right column). The Total F=0 (black) had no harvest from Mexico nor the US. US harvest rates were 0 (red), 5 (green), and 18 (blue). The management thresholds of 50,000 mt and 150,000 mt are shown in black horizontal dashed lines. For the $SB_{0(2010\text{-}18)}$ scenario, even with Total F=0, the median SSB values do not get higher than 150,000 mt.

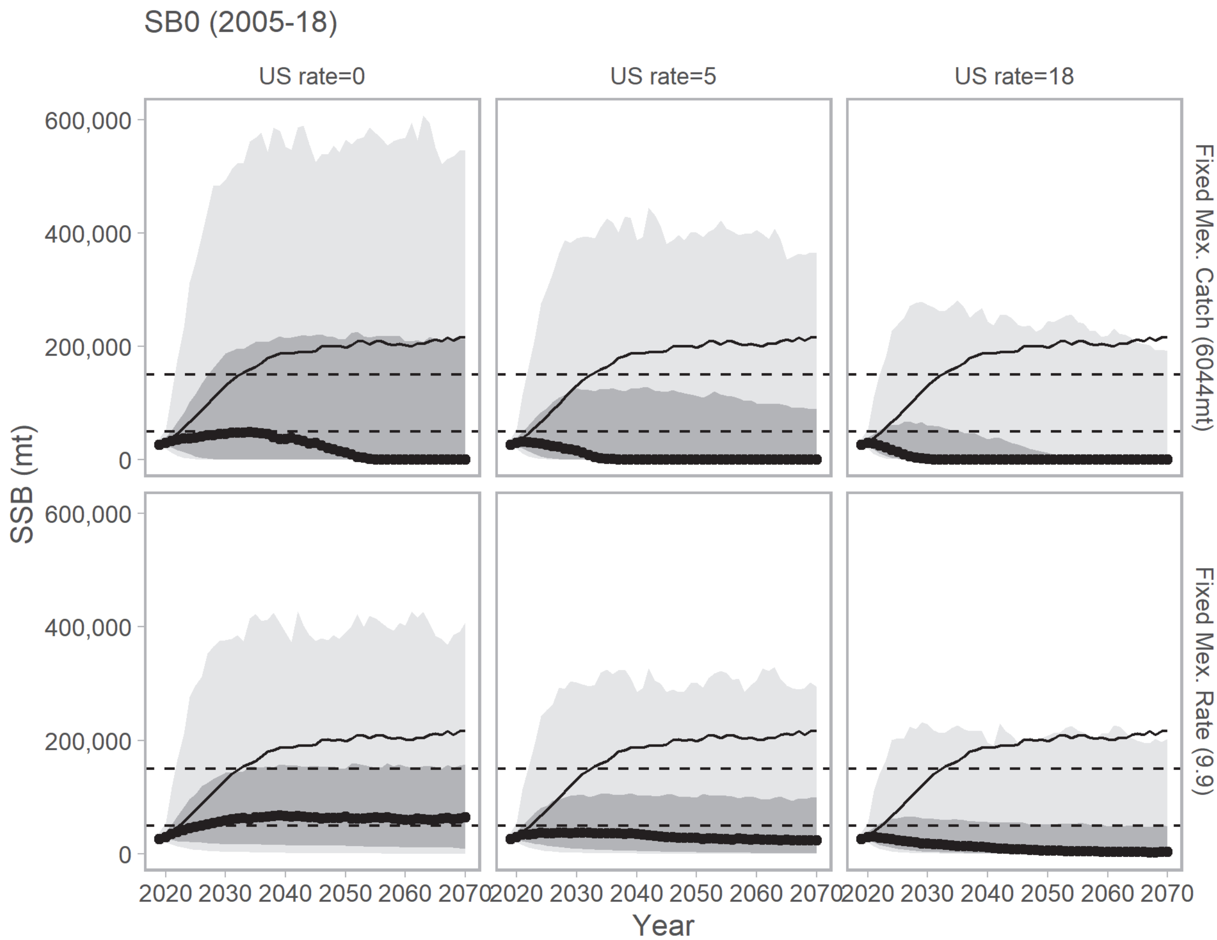

Figure 9. Projected spawning stock biomass (mt) for $SB_{0(2005\text{-}18)}$ scenario. Mexico catch was either fixed at 6,044 mt (top row) or fixed at a harvest rate of 9.9% (bottom row). US harvest rate was 0, 5, or 18% (left to right columns). Values displayed are median SSB values (black points), 25-75 percentiles (dark gray shading), and 5-95 percentiles (light gray shading). Median SSB values with total F=0 (black line), i.e. no harvest from US or Mexico, and Management thresholds at 50,000 and 150,000 mt (horizontal dashed lines) are shown in the figure.

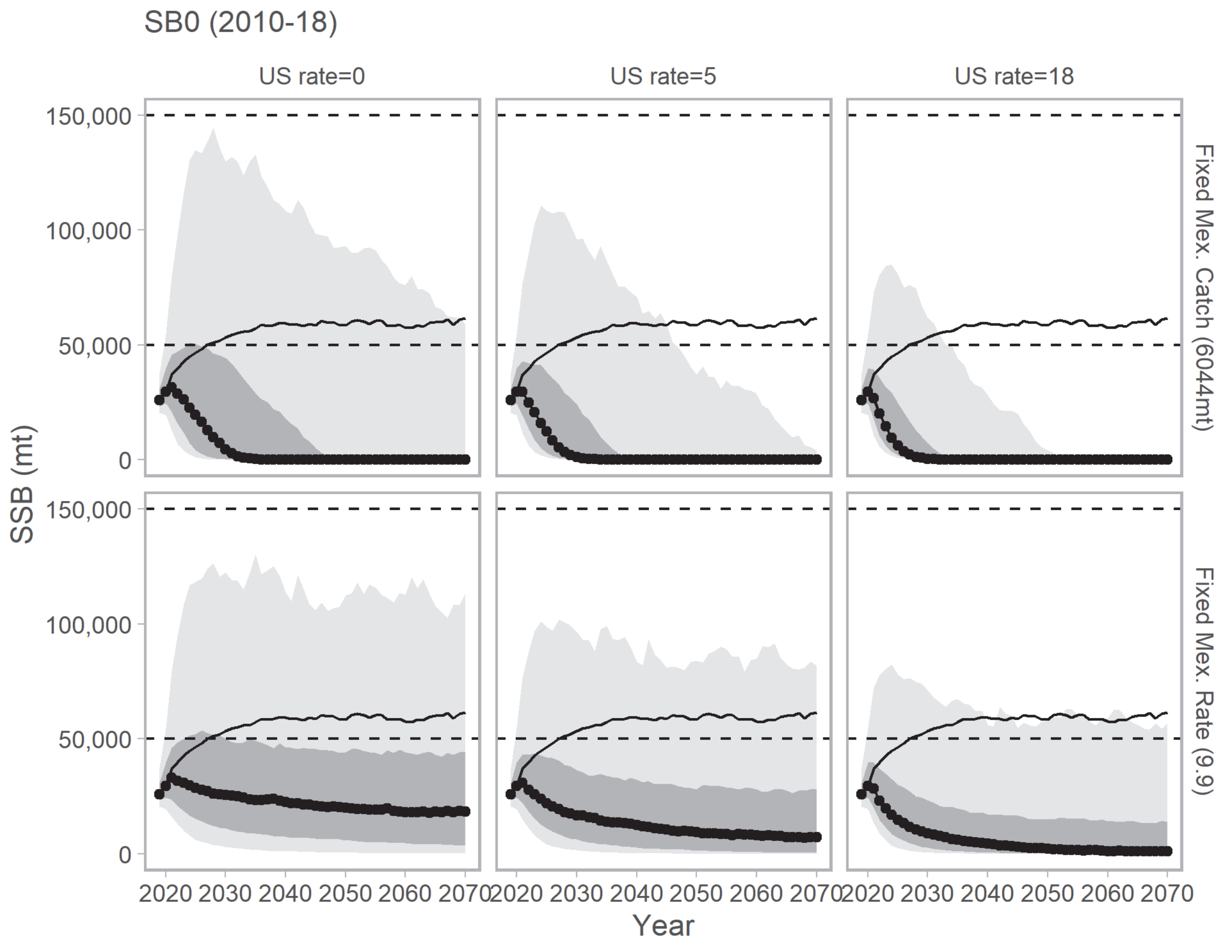

Figure 10. Projected spawning stock biomass (mt) for $SB_{0(2010\text{-}18)}$ scenario. Mexico catch was either fixed at 6,044 mt (top row) or fixed at a harvest rate of 9.9% (bottom row). US harvest rate was 0, 5, or 18% (left to right columns). Values displayed are median SSB values (black points), 25-75 percentiles (dark gray shading), and 5-95 percentiles (light gray shading). Median SSB values with total F=0 (black line), i.e. no harvest from US or Mexico, and Management thresholds at 50,000 and 150,000 mt (horizontal dashed lines) are shown in the figure.

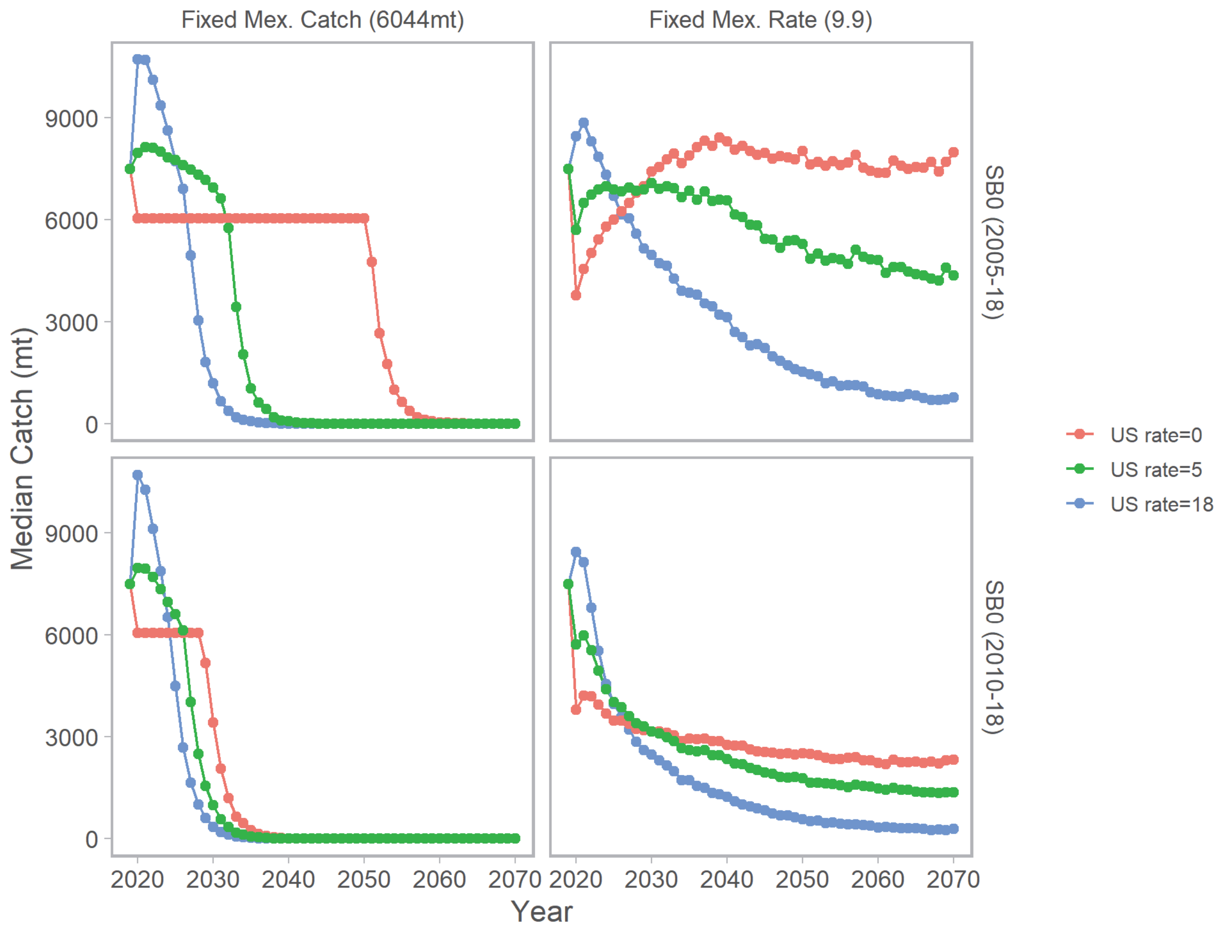

Figure 11. Median projected catch (mt) for Pacific sardine rebuilding alternatives. Panels are arranged by state of nature: $SB_{0(2005\text{-}18)}$ – top row; $SB_{0(2010\text{-}18)}$ – bottom row. Mexico catch was fixed at 6,044 mt (left column) or assumed to have a fixed harvest rate of 9.9 (right column). US harvest rates were 0 (red), 5 (green), and 18 (blue).

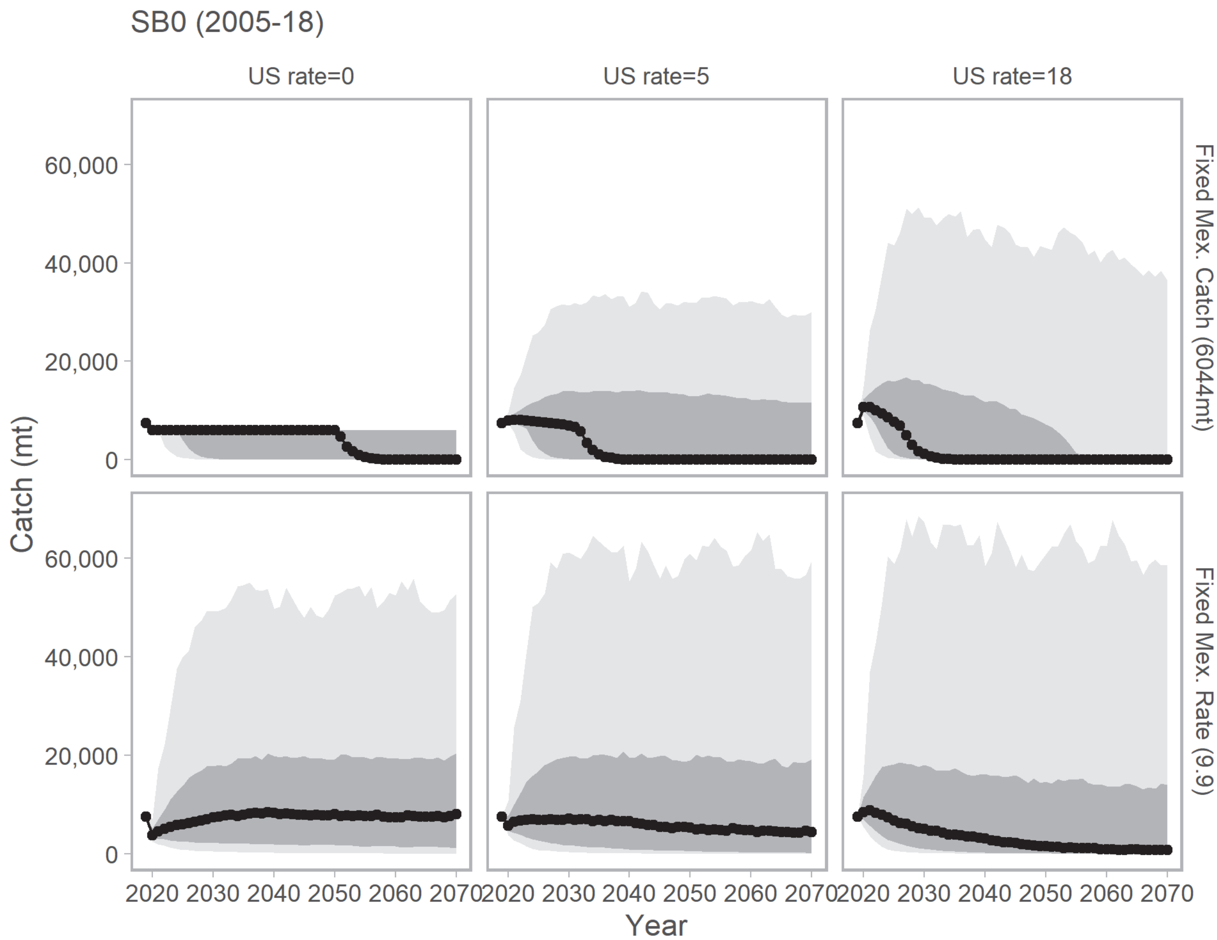

Figure 12. Projected catch (mt) for $SB_{0(2005\text{-}18)}$ scenario. Mexico catch was either fixed at 6,044 mt (top row) or fixed at a harvest rate of 9.9% (bottom row). US harvest rate was 0, 5, or 18% (left to right columns). Values displayed are median catch values (black points), 25-75 percentiles (dark gray shading), and 5-95 percentiles (light gray shading).

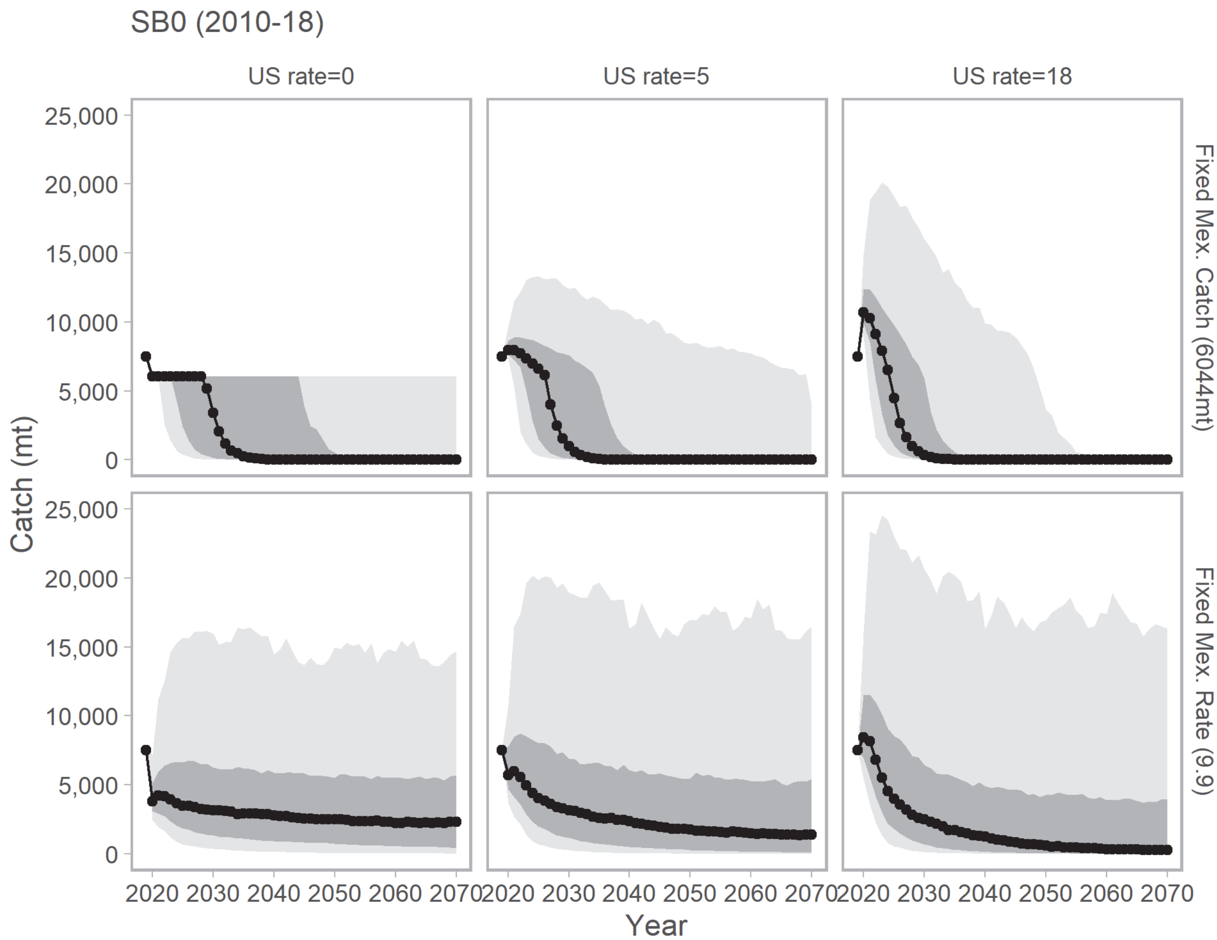

Figure 13. Projected catch (mt) for $SB_{0(2010\text{-}18)}$ scenario. Mexico catch was either fixed at 6,044 mt (top row) or fixed at a harvest rate of 9.9% (bottom row). US harvest rate was 0, 5, or 18% (left to right columns). Values displayed are median catch values (black points), 25-75 percentiles (dark gray shading), and 5-95 percentiles (light gray shading).

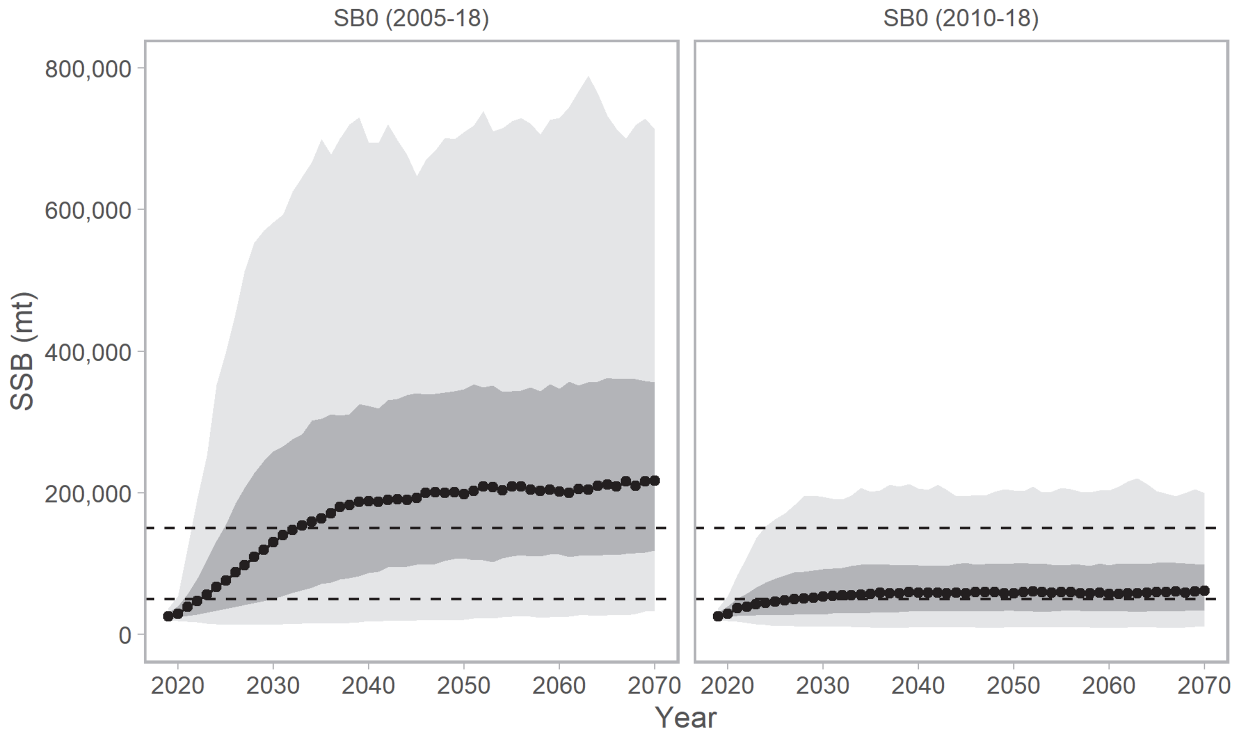

Figure 14. Projected spawning stock biomass (mt) for the $SB_{0(2005\text{-}18)}$ and $SB_{0(2010\text{-}18)}$ scenarios in the complete absence of fishing (Total E=0 for the US and Mexico). Values displayed are median SSB values (black points), 25-75 percentiles (dark gray shading), and 5-95 percentiles (light gray shading). Management thresholds at 50,000 and 150,000 mt are shown as horizontal dashed lines.

Appendix A. Rebuild.dat file for sardine rebuilding projections. The only difference between the high productivity and low productivity Rebuild.dat was the range of years selected for averaging recruitment for calculating SB0 (see input (22)).

```
# (1)Title
Sardine_2020_Rebuilding
# (2)Number of sexes
1
# (3)Age range to consider
0 10
# (4)Number of fleets
1
# (5)First year of projection (Yinit)
2019
# (6)First year the OY could have been zero
2020
# (7)Number of simulations
2000
# (8)Maximum number of years
500
# (9)Conduct projections with multiple starting values (0=No;else yes)
1
# (10)Number of parameter vectors
100
# (11)Is the maximum age a plus-group (1=Yes;2=No)
1
# (12)Generate future recruitments using historical recruitments (1)
historical recruits/spawner (2)  or a stock-recruitment (3)
3
# (13)Constant fishing mortality (1) or constant Catch (2)
1
# (14)Fishing mortality based on SPR (1) or F (2)
1
# (15)Pre-specify the year of recovery (or -1) to ignore
-1
# (16)Fecundity-at-age
# 0 1 2 3 4 5 6 7 8 9 10
0.0000 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
# (17)Age specific information (females then males) weight / selectivity
#
0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.183 0.186 0.1913 0.1947 0.1995
0.490027 1 0.257237 0.0376225 0.0534343 0.0437764 0.0144477 0.0136617
0.00306224 0.00306224 0.00306224
# (18)M and current age-structure
#
0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221
0.585221 0.585221 0.585221
438996 194984 44087.5 19995 6617.46 25027.3 5931.46 3052.62 2481.45 970.423
6040.54
# (19)Age-structure at the start of year Yinit^0
580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78 8726.19
2171.82
# (20)Year Ynit^0
2019
#  recruitment and biomass
# (21)Number of historical assessment years
```

```
16
# (22)Historical data
# year, recruitment, spawner, in B0, in R project, in R/S project
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019
1864030 23481700 10243900 4440300 3036910 4349860 6382960 400378 320608
230611 267296 874285 198698 533748 644242 580925
186412 1341469 1590355 1476111 1102498 758713 543791 424294 282412 141519
65602 41595 45097 36936 32953 27771
0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
# (23)Number of years with pre-specified catches
1
# (24)catches for years with pre-specified catches
2019 7500
# (25)Number of future recruitments to override
1
# (26)Process for overiding (-1 for average otherwise index in data list)
2019 1 2019
# (27)Which probability to produce detailed results for (1=0.5; 2=0.6;
6=sardineHCR)
6
# (28)Steepness sigma-R, and auto-correlation
0.3 1.2 0
# (29)Target SPR rate (FMSY Proxy)
0.75
# (30)Discount rate (for cumulative catch)
0.1
# (31)Truncate the series when 0.4B0 is reached (1=Yes)
0
# (32)Set F to FMSY once 0.4B0 is reached (1=Yes)
0
# (33)Maximum possible F for projection (-1 to set to FMSY)
3
# (34)Defintion of recovery (1=now only;2=now or before)
2
# (35)Projection type (1, 2, 3, 4, 5, 11 or 12)
1
# (36)Definition of the ""40-10"" rule
10    40
# (37)Sigma Assessment Error
0.607
# (38)Pstar
0.40
# (39)Constrain catches by the ABC (1=Yes;2=No)
2
# (40)Implementation error (0=No;1=Lognormal;2=Uniform)
0
# (41)Parameters of Implementation Error
1 0.3
# (42)Calculate coefficients of variation (1=Yes)
0
# (43)Number of replicates to use
10
# (44)Random number seed
-99004
```

```
# (45)File with multiple parameter vectors
rebuild_samphi.sso
# (46)User-specific projection (1=Yes); Output replaced (1->9)
0   5
# (47)Catches and Fs (Year; 1/2 (F or C); value); Final row is -1
2020 2 7500
-1    -1    -1
# (48)Fixed catch project (1=Yes); Output replaced (1->9); Approach (-1=Read
in else 1-9)
2 8 9 -1 -1
# (48a) Special catch options (1-Yes) [CUT_OFF, Emsy, distribution, MAXCAT,
Add, replace_code]
1 0.2202 1 1 0 6
# (48b) B1Target
150000
# (49)Split of Fs
2019 1
-1    1
# (50)Five pre-specified inputs
0.5 0.6 0.7 0.8 0.9 # 200 300 400 500 600 2048 2036 2030.0 2026.7 2036
# (51)Years for which a probability of recovery is needed
2027 2028 2029 2030 2031 2032 2033 2034
# (52)Time varying weight-at-age (1=Yes;0=No)
0
# (53)File with time series of weight-at-age data
HakWght.Csv
# (54)Use bisection (0) or linear interpolation (1)
0
# (55)Target Depletion
0.365
```

Appendix B: Multiple parameter input file (Rebuild_samp.sso) used for sardine rebuilding projections.

```
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.490027 1 0.257237 0.0376225 0.0534343 0.0437764 0.0144477 0.0136617
0.00306224 0.00306224 0.00306224 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221
0.585221 0.585221 0.585221 #mean M for year Yinit: 2020 sex: 1
 438996 194984 44087.5 19995 6617.46 25027.3 5931.46 3052.62 2481.45 970.423
6040.54 #numbers for year Yinit: 2020 sex: 1
 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1864030 23481700 10243900 4440300 3036910 4349860 6382960 400378 320608
230611 267296 874285 198698 533748 644242 580925 #Recruits
186412 944409 1136270 1010600 760343 508691 346715 265112 148558 69619.8
37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
0.3 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.490027 1 0.257237 0.0376225 0.0534343 0.0437764 0.0144477 0.0136617
0.00306224 0.00306224 0.00306224 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221
0.585221 0.585221 0.585221 #mean M for year Yinit: 2020 sex: 1
 438996 194984 44087.5 19995 6617.46 25027.3 5931.46 3052.62 2481.45 970.423
6040.54 #numbers for year Yinit: 2020 sex: 1
 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1864030 23481700 10243900 4440300 3036910 4349860 6382960 400378 320608
230611 267296 874285 198698 533748 644242 580925 #Recruits
186412 944409 1136270 1010600 760343 508691 346715 265112 148558 69619.8
37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
0.3 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.490027 1 0.257237 0.0376225 0.0534343 0.0437764 0.0144477 0.0136617
0.00306224 0.00306224 0.00306224 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221
0.585221 0.585221 0.585221 #mean M for year Yinit: 2020 sex: 1
 438996 194984 44087.5 19995 6617.46 25027.3 5931.46 3052.62 2481.45 970.423
6040.54 #numbers for year Yinit: 2020 sex: 1
 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
```

```
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1864030 23481700 10243900 4440300 3036910 4349860 6382960 400378 320608
230611 267296 874285 198698 533748 644242 580925 #Recruits
186412 944409 1136270 1010600 760343 508691 346715 265112 148558 69619.8
37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
0.3 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.490027 1 0.257237 0.0376225 0.0534343 0.0437764 0.0144477 0.0136617
0.00306224 0.00306224 0.00306224 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221
0.585221 0.585221 0.585221 #mean M for year Yinit: 2020 sex: 1
 438996 194984 44087.5 19995 6617.46 25027.3 5931.46 3052.62 2481.45 970.423
6040.54 #numbers for year Yinit: 2020 sex: 1
 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1864030 23481700 10243900 4440300 3036910 4349860 6382960 400378 320608
230611 267296 874285 198698 533748 644242 580925 #Recruits
186412 944409 1136270 1010600 760343 508691 346715 265112 148558 69619.8
37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
0.3 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.490027 1 0.257237 0.0376225 0.0534343 0.0437764 0.0144477 0.0136617
0.00306224 0.00306224 0.00306224 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221
0.585221 0.585221 0.585221 #mean M for year Yinit: 2020 sex: 1
 438996 194984 44087.5 19995 6617.46 25027.3 5931.46 3052.62 2481.45 970.423
6040.54 #numbers for year Yinit: 2020 sex: 1
 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1864030 23481700 10243900 4440300 3036910 4349860 6382960 400378 320608
230611 267296 874285 198698 533748 644242 580925 #Recruits
186412 944409 1136270 1010600 760343 508691 346715 265112 148558 69619.8
37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
0.3 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.490027 1 0.257237 0.0376225 0.0534343 0.0437764 0.0144477 0.0136617
0.00306224 0.00306224 0.00306224 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221 0.585221
0.585221 0.585221 0.585221 #mean M for year Yinit: 2020 sex: 1
```

```
 438996 194984 44087.5 19995 6617.46 25027.3 5931.46 3052.62 2481.45 970.423
6040.54 #numbers for year Yinit: 2020 sex: 1
 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1864030 23481700 10243900 4440300 3036910 4349860 6382960 400378 320608
230611 267296 874285 198698 533748 644242 580925 #Recruits
186412 944409 1136270 1010600 760343 508691 346715 265112 148558 69619.8
37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
0.3 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.490027 1 0.257237 0.0376225 0.0534343 0.0437764 0.0144477 0.0136617
0.00306224 0.00306224 0.00306224 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.585221 0.585221 0.585221 #mean M for year Yinit: 2020 sex: 1
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37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
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#female fecundity; weighted by N in year Y_init across morphs and areas
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8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
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 0.490027 1 0.257237 0.0376225 0.0534343 0.0437764 0.0144477 0.0136617
0.00306224 0.00306224 0.00306224 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.585221 0.585221 0.585221 #mean M for year Yinit: 2020 sex: 1
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 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
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#female fecundity; weighted by N in year Y_init across morphs and areas
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
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6040.54 #numbers for year Yinit: 2020 sex: 1
 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
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#female fecundity; weighted by N in year Y_init across morphs and areas
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
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#female fecundity; weighted by N in year Y_init across morphs and areas
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186412 944409 1136270 1010600 760343 508691 346715 265112 148558 69619.8
37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
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#female fecundity; weighted by N in year Y_init across morphs and areas
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37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
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6040.54 #numbers for year Yinit: 2020 sex: 1
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8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
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0.585221 0.585221 0.585221 #mean M for year Yinit: 2020 sex: 1
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6040.54 #numbers for year Yinit: 2020 sex: 1
 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
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#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1864030 23481700 10243900 4440300 3036910 4349860 6382960 400378 320608
230611 267296 874285 198698 533748 644242 580925 #Recruits
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37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
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#female fecundity; weighted by N in year Y_init across morphs and areas
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
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6040.54 #numbers for year Yinit: 2020 sex: 1
 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
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230611 267296 874285 198698 533748 644242 580925 #Recruits
186412 944409 1136270 1010600 760343 508691 346715 265112 148558 69619.8
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#female fecundity; weighted by N in year Y_init across morphs and areas
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
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6040.54 #numbers for year Yinit: 2020 sex: 1
 580925 222512 46832.8 12386.5 47853.5 11486.9 5723.79 4551.15 1750.78
8726.19 2171.82 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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1864030 23481700 10243900 4440300 3036910 4349860 6382960 400378 320608
230611 267296 874285 198698 533748 644242 580925 #Recruits
186412 944409 1136270 1010600 760343 508691 346715 265112 148558 69619.8
37557.4 30991.3 33300.3 27434.9 24561.4 20622.8 #SpawnBio
0.3 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.488545 1 0.256608 0.0374046 0.0531285 0.0434869 0.0143483 0.0135713
0.00303927 0.00303927 0.00303927 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.584744 0.584744 0.584744 0.584744 0.584744 0.584744 0.584744 0.584744
0.584744 0.584744 0.584744 #mean M for year Yinit: 2020 sex: 1
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 540137 253807 50357.6 20853 6797.19 25224 6021.69 3067.65 2481.46 946.908
6029.35 #numbers for year Yinit: 2020 sex: 1
 709374 223811 47227 12654.5 47866.3 11586.4 5737.45 4540.56 1706.83 8698.09
2170 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1901660 23445000 10215200 4428990 3026940 4342540 6363040 393946 318724
230364 268743 871837 201858 534819 645658 709374 #Recruits
190450 942720 1134740 1009490 759631 508244 346375 264726 148170 69306.1
37345.9 30874.1 33239.5 27446.9 24622.7 21150.6 #SpawnBio
0.35 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
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0.584744 0.584744 0.584744 #mean M for year Yinit: 2020 sex: 1
 540137 253807 50357.6 20853 6797.19 25224 6021.69 3067.65 2481.46 946.908
6029.35 #numbers for year Yinit: 2020 sex: 1
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230364 268743 871837 201858 534819 645658 709374 #Recruits
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.488545 1 0.256608 0.0374046 0.0531285 0.0434869 0.0143483 0.0135713
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 540137 253807 50357.6 20853 6797.19 25224 6021.69 3067.65 2481.46 946.908
6029.35 #numbers for year Yinit: 2020 sex: 1
 709374 223811 47227 12654.5 47866.3 11586.4 5737.45 4540.56 1706.83 8698.09
2170 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1901660 23445000 10215200 4428990 3026940 4342540 6363040 393946 318724
230364 268743 871837 201858 534819 645658 709374 #Recruits
190450 942720 1134740 1009490 759631 508244 346375 264726 148170 69306.1
37345.9 30874.1 33239.5 27446.9 24622.7 21150.6 #SpawnBio
0.35 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
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 0.487126 1 0.25616 0.0370913 0.0526866 0.043096 0.0142145 0.0134458
0.00300868 0.00300868 0.00300868 #selex for gender,fleet: 1 / 2 MexCal_S2
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921.271 6041.06 #numbers for year Yinit: 2020 sex: 1
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229837 269680 870159 204407 535724 646816 835707 #Recruits
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 0.487126 1 0.25616 0.0370913 0.0526866 0.043096 0.0142145 0.0134458
0.00300868 0.00300868 0.00300868 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.584341 0.584341 0.584341 0.584341 0.584341 0.584341 0.584341 0.584341
0.584341 0.584341 0.584341 #mean M for year Yinit: 2020 sex: 1
 647359 313702 55665.3 21526.5 6942.53 25390.1 6090.42 3076.17 2478.38
921.271 6041.06 #numbers for year Yinit: 2020 sex: 1
 835707 224885 47541.6 12871.7 47901 11660.2 5741.96 4526.63 1659.42 8704.79
2176.53 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1877690 23416100 10192200 4420380 3019140 4337600 6352700 387178 316738
229837 269680 870159 204407 535724 646816 835707 #Recruits
188279 941409 1133610 1008700 759158 507972 346199 264560 147983 69129.9
37214.1 30796.9 33201.1 27464.6 24678.3 21659.3 #SpawnBio
0.365 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.48577 1 0.255826 0.036735 0.0521844 0.0426627 0.0140661 0.013305
0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989
0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
 759500 373554 60182.6 22068.5 7063.02 25536.2 6144.85 3080.96 2474.26
895.762 6066.9 #numbers for year Yinit: 2020 sex: 1
 958782 225790 47798.8 13052.3 47954.2 11717.6 5741.68 4512.44 1612.5 8733.27
2187.98 #numbers for year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1835470 23392400 10172900 4413510 3012780 4334170 6348480 380556 314832
229188 270308 869059 206512 536495 647763 958782 #Recruits
184242 940351 1132730 1008110 758834 507807 346124 264529 147926 69047.3
37139.7 30750.7 33181.5 27488.7 24731.2 22148.7 #SpawnBio
0.45 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
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 0.48577 1 0.255826 0.036735 0.0521844 0.0426627 0.0140661 0.013305
0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989
0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
 759500 373554 60182.6 22068.5 7063.02 25536.2 6144.85 3080.96 2474.26
895.762 6066.9 #numbers for year Yinit: 2020 sex: 1
 958782 225790 47798.8 13052.3 47954.2 11717.6 5741.68 4512.44 1612.5 8733.27
2187.98 #numbers for year Ydeclare: 2019 sex: 1
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37139.7 30750.7 33181.5 27488.7 24731.2 22148.7 #SpawnBio
0.45 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
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 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.48577 1 0.255826 0.036735 0.0521844 0.0426627 0.0140661 0.013305
0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989
0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
 759500 373554 60182.6 22068.5 7063.02 25536.2 6144.85 3080.96 2474.26
895.762 6066.9 #numbers for year Yinit: 2020 sex: 1
 958782 225790 47798.8 13052.3 47954.2 11717.6 5741.68 4512.44 1612.5 8733.27
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#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
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0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989
0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
 759500 373554 60182.6 22068.5 7063.02 25536.2 6144.85 3080.96 2474.26
895.762 6066.9 #numbers for year Yinit: 2020 sex: 1
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.48577 1 0.255826 0.036735 0.0521844 0.0426627 0.0140661 0.013305
0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989
0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
 759500 373554 60182.6 22068.5 7063.02 25536.2 6144.85 3080.96 2474.26
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37139.7 30750.7 33181.5 27488.7 24731.2 22148.7 #SpawnBio
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.48577 1 0.255826 0.036735 0.0521844 0.0426627 0.0140661 0.013305
0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989
0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
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0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
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 0.48577 1 0.255826 0.036735 0.0521844 0.0426627 0.0140661 0.013305
0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
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0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989
0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
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0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989
0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
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 759500 373554 60182.6 22068.5 7063.02 25536.2 6144.85 3080.96 2474.26
895.762 6066.9 #numbers for year Yinit: 2020 sex: 1
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0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.00297502 0.00297502 0.00297502 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989 0.583989
0.583989 0.583989 0.583989 #mean M for year Yinit: 2020 sex: 1
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895.762 6066.9 #numbers for year Yinit: 2020 sex: 1
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
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 0.484472 1 0.255577 0.0363654 0.0516644 0.0422194 0.0139143 0.0131602
0.00294066 0.00294066 0.00294066 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583677 0.583677 0.583677 0.583677 0.583677 0.583677 0.583677 0.583677
0.583677 0.583677 0.583677 #mean M for year Yinit: 2020 sex: 1
 875251 432455 64044 22512.2 7164.61 25668.4 6189.41 3083.66 2470.04 871.194
6101.81 #numbers for year Yinit: 2020 sex: 1
1077590 226560 48013 13205 48022 11764 5739 4499 1567 8776 2202 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1789290 23372400 10156400 4407830 3007440 4331750 6348380 374241 313075
228502 270749 868407 208279 537154 648535 1077590 #Recruits
179777 939471 1132020 1007670 758608 507711 346113 264588 147956 69030.6
37107.7 30728.9 33177.9 27518.9 24782.7 22617.7 #SpawnBio
0.5 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.484472 1 0.255577 0.0363654 0.0516644 0.0422194 0.0139143 0.0131602
0.00294066 0.00294066 0.00294066 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583677 0.583677 0.583677 0.583677 0.583677 0.583677 0.583677 0.583677
0.583677 0.583677 0.583677 #mean M for year Yinit: 2020 sex: 1
 875251 432455 64044 22512.2 7164.61 25668.4 6189.41 3083.66 2470.04 871.194
6101.81 #numbers for year Yinit: 2020 sex: 1
1077590 226560 48013 13205 48022 11764 5739 4499 1567 8776 2202 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1789290 23372400 10156400 4407830 3007440 4331750 6348380 374241 313075
228502 270749 868407 208279 537154 648535 1077590 #Recruits
179777 939471 1132020 1007670 758608 507711 346113 264588 147956 69030.6
37107.7 30728.9 33177.9 27518.9 24782.7 22617.7 #SpawnBio
0.5 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
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 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.483226 1 0.2554 0.0359994 0.0511502 0.0417846 0.0137653 0.0130174
0.00290705 0.00290705 0.00290705 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396
0.583396 0.583396 0.583396 #mean M for year Yinit: 2020 sex: 1
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 993250 489722 67359.1 22880.4 7251.37 25790.3 6227 3085.23 2466.15 847.832
6142.57 #numbers for year Yinit: 2020 sex: 1
1191380 227222 48193 13337 48102 11804 5736 4488 1525 8828 2219 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1744340 23355100 10141900 4403030 3002860 4330040 6351090 368279 311487
227829 271078 868106 209777 537718 649160 1191380 #Recruits
175410 938722 1131450 1007320 758452 507664 346146 264706 148047 69061.1
37107.4 30726.4 33187.2 27554.5 24833.4 23065.1 #SpawnBio
0.55 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.483226 1 0.2554 0.0359994 0.0511502 0.0417846 0.0137653 0.0130174
0.00290705 0.00290705 0.00290705 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396
0.583396 0.583396 0.583396 #mean M for year Yinit: 2020 sex: 1
 993250 489722 67359.1 22880.4 7251.37 25790.3 6227 3085.23 2466.15 847.832
6142.57 #numbers for year Yinit: 2020 sex: 1
1191380 227222 48193 13337 48102 11804 5736 4488 1525 8828 2219 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1744340 23355100 10141900 4403030 3002860 4330040 6351090 368279 311487
227829 271078 868106 209777 537718 649160 1191380 #Recruits
175410 938722 1131450 1007320 758452 507664 346146 264706 148047 69061.1
37107.4 30726.4 33187.2 27554.5 24833.4 23065.1 #SpawnBio
0.55 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
```

```
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.483226 1 0.2554 0.0359994 0.0511502 0.0417846 0.0137653 0.0130174
0.00290705 0.00290705 0.00290705 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396
0.583396 0.583396 0.583396 #mean M for year Yinit: 2020 sex: 1
 993250 489722 67359.1 22880.4 7251.37 25790.3 6227 3085.23 2466.15 847.832
6142.57 #numbers for year Yinit: 2020 sex: 1
1191380 227222 48193 13337 48102 11804 5736 4488 1525 8828 2219 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1744340 23355100 10141900 4403030 3002860 4330040 6351090 368279 311487
227829 271078 868106 209777 537718 649160 1191380 #Recruits
175410 938722 1131450 1007320 758452 507664 346146 264706 148047 69061.1
37107.4 30726.4 33187.2 27554.5 24833.4 23065.1 #SpawnBio
0.55 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.483226 1 0.2554 0.0359994 0.0511502 0.0417846 0.0137653 0.0130174
0.00290705 0.00290705 0.00290705 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396
0.583396 0.583396 0.583396 #mean M for year Yinit: 2020 sex: 1
 993250 489722 67359.1 22880.4 7251.37 25790.3 6227 3085.23 2466.15 847.832
6142.57 #numbers for year Yinit: 2020 sex: 1
1191380 227222 48193 13337 48102 11804 5736 4488 1525 8828 2219 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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227829 271078 868106 209777 537718 649160 1191380 #Recruits
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37107.4 30726.4 33187.2 27554.5 24833.4 23065.1 #SpawnBio
0.55 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.483226 1 0.2554 0.0359994 0.0511502 0.0417846 0.0137653 0.0130174
0.00290705 0.00290705 0.00290705 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396 0.583396
0.583396 0.583396 0.583396 #mean M for year Yinit: 2020 sex: 1
 993250 489722 67359.1 22880.4 7251.37 25790.3 6227 3085.23 2466.15 847.832
6142.57 #numbers for year Yinit: 2020 sex: 1
1191380 227222 48193 13337 48102 11804 5736 4488 1525 8828 2219 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1744340 23355100 10141900 4403030 3002860 4330040 6351090 368279 311487
227829 271078 868106 209777 537718 649160 1191380 #Recruits
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175410 938722 1131450 1007320 758452 507664 346146 264706 148047 69061.1
37107.4 30726.4 33187.2 27554.5 24833.4 23065.1 #SpawnBio
0.55 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.482026 1 0.255284 0.0356464 0.0506552 0.0413681 0.0136224 0.0128801
0.00287489 0.00287489 0.00287489 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314
0.58314 0.58314 #mean M for year Yinit: 2020 sex: 1
1112170 544890 70219 23189 7326 25904 6260 3086 2463 826 6187 #numbers for
year Yinit: 2020 sex: 1
1299710 227796 48347 13450 48192 11840 5732 4478 1484 8886 2236 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1702480 23340100 10129100 4398880 2998860 4328840 6355740 362669 310067
227194 271345 868081 211060 538202 649661 1299710 #Recruits
171333 938074 1130970 1007050 758345 507649 346208 264866 148180 69125.2
37130.5 30738.8 33207 27594.4 24883.6 23490.1 #SpawnBio
0.6 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.482026 1 0.255284 0.0356464 0.0506552 0.0413681 0.0136224 0.0128801
0.00287489 0.00287489 0.00287489 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.58314 0.58314 #mean M for year Yinit: 2020 sex: 1
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year Yinit: 2020 sex: 1
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year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
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227194 271345 868081 211060 538202 649661 1299710 #Recruits
171333 938074 1130970 1007050 758345 507649 346208 264866 148180 69125.2
37130.5 30738.8 33207 27594.4 24883.6 23490.1 #SpawnBio
0.6 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.482026 1 0.255284 0.0356464 0.0506552 0.0413681 0.0136224 0.0128801
0.00287489 0.00287489 0.00287489 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.58314 0.58314 #mean M for year Yinit: 2020 sex: 1
1112170 544890 70219 23189 7326 25904 6260 3086 2463 826 6187 #numbers for
year Yinit: 2020 sex: 1
1299710 227796 48347 13450 48192 11840 5732 4478 1484 8886 2236 #numbers for
year Ydeclare: 2019 sex: 1
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#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1702480 23340100 10129100 4398880 2998860 4328840 6355740 362669 310067
227194 271345 868081 211060 538202 649661 1299710 #Recruits
171333 938074 1130970 1007050 758345 507649 346208 264866 148180 69125.2
37130.5 30738.8 33207 27594.4 24883.6 23490.1 #SpawnBio
0.6 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.482026 1 0.255284 0.0356464 0.0506552 0.0413681 0.0136224 0.0128801
0.00287489 0.00287489 0.00287489 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.58314 0.58314 #mean M for year Yinit: 2020 sex: 1
1112170 544890 70219 23189 7326 25904 6260 3086 2463 826 6187 #numbers for
year Yinit: 2020 sex: 1
1299710 227796 48347 13450 48192 11840 5732 4478 1484 8886 2236 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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227194 271345 868081 211060 538202 649661 1299710 #Recruits
171333 938074 1130970 1007050 758345 507649 346208 264866 148180 69125.2
37130.5 30738.8 33207 27594.4 24883.6 23490.1 #SpawnBio
0.6 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.482026 1 0.255284 0.0356464 0.0506552 0.0413681 0.0136224 0.0128801
0.00287489 0.00287489 0.00287489 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.58314 0.58314 #mean M for year Yinit: 2020 sex: 1
1112170 544890 70219 23189 7326 25904 6260 3086 2463 826 6187 #numbers for
year Yinit: 2020 sex: 1
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1702480 23340100 10129100 4398880 2998860 4328840 6355740 362669 310067
227194 271345 868081 211060 538202 649661 1299710 #Recruits
171333 938074 1130970 1007050 758345 507649 346208 264866 148180 69125.2
37130.5 30738.8 33207 27594.4 24883.6 23490.1 #SpawnBio
0.6 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.482026 1 0.255284 0.0356464 0.0506552 0.0413681 0.0136224 0.0128801
0.00287489 0.00287489 0.00287489 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314
0.58314 0.58314 #mean M for year Yinit: 2020 sex: 1
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1112170 544890 70219 23189 7326 25904 6260 3086 2463 826 6187 #numbers for
year Yinit: 2020 sex: 1
1299710 227796 48347 13450 48192 11840 5732 4478 1484 8886 2236 #numbers for
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#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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1702480 23340100 10129100 4398880 2998860 4328840 6355740 362669 310067
227194 271345 868081 211060 538202 649661 1299710 #Recruits
171333 938074 1130970 1007050 758345 507649 346208 264866 148180 69125.2
37130.5 30738.8 33207 27594.4 24883.6 23490.1 #SpawnBio
0.6 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.482026 1 0.255284 0.0356464 0.0506552 0.0413681 0.0136224 0.0128801
0.00287489 0.00287489 0.00287489 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314 0.58314
0.58314 0.58314 #mean M for year Yinit: 2020 sex: 1
1112170 544890 70219 23189 7326 25904 6260 3086 2463 826 6187 #numbers for
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1702480 23340100 10129100 4398880 2998860 4328840 6355740 362669 310067
227194 271345 868081 211060 538202 649661 1299710 #Recruits
171333 938074 1130970 1007050 758345 507649 346208 264866 148180 69125.2
37130.5 30738.8 33207 27594.4 24883.6 23490.1 #SpawnBio
0.6 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
#
 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.480866 1 0.255223 0.0353117 0.0501863 0.0409751 0.0134875 0.0127502
0.00284456 0.00284456 0.00284456 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.582905 0.582905 0.582905 0.582905 0.582905 0.582905 0.582905 0.582905
0.582905 0.582905 0.582905 #mean M for year Yinit: 2020 sex: 1
1230790 597677 72698 23451 7391 26012 6288 3087 2460 805 6233 #numbers for
year Yinit: 2020 sex: 1
1402380 228297 48478 13550 48287 11872 5729 4469 1446 8948 2254 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1664240 23326800 10117600 4395260 2995330 4328020 6361730 357398 308802
226608 271579 868274 212167 538617 650057 1402380 #Recruits
167605 937506 1130560 1006830 758275 507659 346291 265051 148341 69213.1
37170.8 30762.7 33235.1 27637.8 24933.2 23892.5 #SpawnBio
0.65 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
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 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
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 0.480866 1 0.255223 0.0353117 0.0501863 0.0409751 0.0134875 0.0127502
0.00284456 0.00284456 0.00284456 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.582905 0.582905 0.582905 #mean M for year Yinit: 2020 sex: 1
1230790 597677 72698 23451 7391 26012 6288 3087 2460 805 6233 #numbers for
year Yinit: 2020 sex: 1
1402380 228297 48478 13550 48287 11872 5729 4469 1446 8948 2254 #numbers for
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0.00284456 0.00284456 0.00284456 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.582905 0.582905 0.582905 #mean M for year Yinit: 2020 sex: 1
1230790 597677 72698 23451 7391 26012 6288 3087 2460 805 6233 #numbers for
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0.00284456 0.00284456 0.00284456 #selex for gender,fleet: 1 / 2 MexCal_S2
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0.582905 0.582905 0.582905 #mean M for year Yinit: 2020 sex: 1
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 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
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226608 271579 868274 212167 538617 650057 1402380 #Recruits
167605 937506 1130560 1006830 758275 507659 346291 265051 148341 69213.1
37170.8 30762.7 33235.1 27637.8 24933.2 23892.5 #SpawnBio
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#female fecundity; weighted by N in year Y_init across morphs and areas
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.479742 1 0.255208 0.0349976 0.0497466 0.0406077 0.0133612 0.0126284
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1499390 228737 48592 13637 48387 11902 5726 4462 1410 9011 2273 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1629630 23314900 10107100 4392040 2992180 4327470 6368590 352444 307675
226075 271799 868635 213128 538974 650365 1499390 #Recruits
164227 937001 1130210 1006660 758232 507685 346386 265254 148520 69317.2
37223.5 30795.2 33269.6 27683.6 24981.9 24272.7 #SpawnBio
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#female fecundity; weighted by N in year Y_init across morphs and areas
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year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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1629630 23314900 10107100 4392040 2992180 4327470 6368590 352444 307675
226075 271799 868635 213128 538974 650365 1499390 #Recruits
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#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
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year Yinit: 2020 sex: 1
1499390 228737 48592 13637 48387 11902 5726 4462 1410 9011 2273 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
1629630 23314900 10107100 4392040 2992180 4327470 6368590 352444 307675
226075 271799 868635 213128 538974 650365 1499390 #Recruits
164227 937001 1130210 1006660 758232 507685 346386 265254 148520 69317.2
37223.5 30795.2 33269.6 27683.6 24981.9 24272.7 #SpawnBio
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 0.0 0.0354 0.0773 0.11 0.1339 0.1515 0.1644 0.1739 0.1808 0.1858 0.1939
#female fecundity; weighted by N in year Y_init across morphs and areas
 0.0344 0.0591 0.0833 0.1601 0.17 0.1721 0.083 0.186 0.1913 0.1947 0.1995
#bodywt for gender,fleet: 1 / 2 MexCal_S2
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year Yinit: 2020 sex: 1
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year Ydeclare: 2019 sex: 1
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2019 #years
1598390 23304200 10097600 4389170 2989340 4327130 6376000 347786 306672
225595 272016 869126 213969 539281 650600 1590890 #Recruits
161178 936549 1129910 1006510 758208 507723 346490 265465 148710 69431.9
37284.9 30834 33308.7 27731.1 25029.8 24631.4 #SpawnBio
0.75 1.2 0 0.365 # spawn-recr steepness, sigmaR, autocorr , targetdep
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ADDENDUM TO SARDINE REBUIDLING DOCUMENT*

Table 8. Probabilities of recovery above 150,000 mt of age 1+ biomass for rebuilding alternatives for $SB_{0(2005\text{-}18)}$ scenario. Mexico catch was fixed at 6,044 mt or at an exploitation rate of 9.9. Probabilities of recovery with no Mexico or US harvest is also shown. Grey shading indicates probabilities greater than 0.5.

	Fixed Mex. Catch (6,044mt)			**Fixed Mex. Rate (9.9)**				**Total F=0**
Year	**US rate=0**	**US rate=5**	**US rate=18**	**US rate=0**	**US rate=5**	**US rate=18**	***US= 2,200 mt**	
2020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2021	0.0655	0.0635	0.0615	0.0660	0.0635	0.0615	0.0635	0.0710
2022	0.1275	0.1150	0.1040	0.1290	0.1125	0.1035	0.1165	0.1525
2023	0.1960	0.1785	0.1520	0.1980	0.1775	0.1530	0.1810	0.2440
2024	0.2530	0.2245	0.1900	0.2550	0.2255	0.1925	0.2320	0.3260
2025	0.2985	0.2570	0.2200	0.2990	0.2635	0.2215	0.2685	0.3995
2026	0.3335	0.2895	0.2395	0.3420	0.2940	0.2455	0.3050	0.4590
2027	0.3645	0.3160	0.2585	0.3735	0.3250	0.2640	0.3345	0.5105
2028	0.3925	0.3365	0.2725	0.4075	0.3500	0.2845	0.3610	0.5505
2029	0.4170	0.3555	0.2865	0.4400	0.3785	0.3070	0.3860	0.5910
2030	0.4320	0.3680	0.2945	0.4595	0.3980	0.3225	0.4015	0.6275
2031	0.4490	0.3770	0.3005	0.4800	0.4125	0.3315	0.4185	0.6555
2032	0.4660	0.3880	0.3105	0.4995	0.4305	0.3455	0.4315	0.6775
2033	0.4815	0.4005	0.3175	0.5260	0.4485	0.3585	0.4500	0.7015
2034	0.4865	0.4095	0.3235	0.5435	0.4655	0.3710	0.4620	0.7225
2035	0.4955	0.4145	0.3275	0.5585	0.4800	0.3795	0.4735	0.7440
2036	0.5040	0.4195	0.3320	0.5755	0.4900	0.3900	0.4840	0.7570
2037	0.5085	0.4260	0.3340	0.5885	0.5025	0.3985	0.4920	0.7720
2038	0.5150	0.4325	0.3355	0.5995	0.5135	0.4065	0.5005	0.7890
2039	0.5175	0.4360	0.3385	0.6085	0.5250	0.4140	0.5060	0.8000
2040	0.5210	0.4380	0.3395	0.6180	0.5330	0.4190	0.5135	0.8090
2041	0.5240	0.4385	0.3420	0.6250	0.5400	0.4230	0.5185	0.8185
2042	0.5270	0.4425	0.3430	0.6340	0.5450	0.4275	0.5215	0.8330
2043	0.5285	0.4435	0.3440	0.6400	0.5500	0.4345	0.5270	0.8425
2044	0.5285	0.4435	0.3450	0.6455	0.5540	0.4370	0.5300	0.8545
2045	0.5315	0.4445	0.3465	0.6525	0.5575	0.4420	0.5315	0.8645
2046	0.5320	0.4460	0.3475	0.6570	0.5645	0.4435	0.5350	0.8725
2047	0.5340	0.4465	0.3480	0.6640	0.5700	0.4465	0.5365	0.8775
2048	0.5345	0.4470	0.3485	0.6710	0.5705	0.4520	0.5375	0.8850
2049	0.5350	0.4470	0.3485	0.6760	0.5745	0.4550	0.5395	0.8900
2050	0.5355	0.4475	0.3500	0.6805	0.5790	0.4585	0.5410	0.8960

**Probability of recovery results from a model run of 2,200 mt constant U.S. catch. This additional model run was requested by the CPSMT at the September 2020 Council meeting as an alternative way to model Alternative 1 Status Quo Management.*

APPENDIX B – PUBLIC COMMENTS

CALIFORNIA WETFISH PRODUCERS ASSOCIATION
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April 13, 2021

Ms. Jennifer M. Wallace
Acting Director, Office of Sustainable Fisheries
National Marine Fisheries Service
Attn: Lynn Massey
lynn.massey@noaa.gov

Re: NOAA-NMFS-0008-2021 Comments on Environmental Assessment (EA) for Pacific Sardine Rebuilding Plan, Amendment 18 of the CPS FMP

Dear Ms. Wallace and Ms. Massey,

I'm submitting comments on behalf of the California Wetfish Producers Association (CWPA) and the coastal pelagic species (CPS) / sardine fishermen and processors in California. Until recent years, CPS represented, on average, more than 80 percent by volume and 30 percent by dockside value of all commercial seafood landings in California. For more than a century, sardines have cemented the foundation of this historic wetfish industry, as well as California's fishing economy.

Fishermen have testified since 2015 that they're seeing an increasing abundance of sardines on their nearshore fishing grounds, in both Monterey and Southern California. However, this increase has not been accounted for in recent year stock assessments, even worse, sardines have been subtracted from 'northern' sardine biomass estimates on the assumption that those fish were 'southern' stock sardines, migrating up from Mexico. Independent scientific surveys also have documented sardine recruitment and an increase in adult sardines since 2015. But NOAA acoustic trawl surveys, conducted mainly offshore, have not, and acoustic trawl survey biomass estimates have underpinned recent year stock assessments. Thus, the sardine population model has perpetuated assumptions of declining biomass and low recruitment. Those assumptions caused the directed sardine fishery to be closed in 2015, and 'northern' sardines to be declared 'overfished' in 2019, which automatically reduced the incidental take of sardine in other fisheries to 20 percent. The Pacific Fishery Management Council (Council) also was required to develop a rebuilding plan for Pacific (aka northern) sardines.

Even though at the Council's April 2021 meeting the Science and Statistical Committee (SSC) questioned the sardine model and related assumptions about northern and southern sardines, and rejected the model's catch-only projection for 2021, the sardine rebuilding plan process has already left the station. Therefore, we offer the following comments on the draft Environmental Assessment (EA) and Magnuson-Stevens Fishery Conservation and Management Act (MSA) Analysis.

In short, we support the CPS Management Team and Council's recommendation for **Alternative 1, "status quo" management, as the appropriate rebuilding plan for sardines**. As stated in the EA, Alternative 1 encompasses all the flexibility and maintains all the implicit rebuilding measures and catch restrictions that are already embedded in the CPS FMP. Moreover, Alternative 1 is the only option that meets all 10 National Standards in the Magnuson Act, in particular, taking into account the needs of fishing communities, and providing flexibility to achieve harvest rates based on best available science.

Section-by-section comments in support of Alternative 1 follow:

1. *Introduction*

The EA stated that the "overfished" determination was based on the results of an April 2019 stock assessment (Hill et al 2019). This model and related assumptions are now being questioned by the SSC.

3. *Description of Alternatives*

The EA acknowledged that "*the management framework in the CPS FMP already dictates management actions that would typically be implemented under a rebuilding plan…*" Explicit examples of the requirements were listed, i.e. closing the directed fishery in 2015, when the stock dropped below the 150,000 mt CUTOFF; reducing the incidental allowance to 20 percent when the stock dropped below the 50,000 mt MSST.
The EA also recognized that, although the decline in biomass below 50,000 mt triggered the "overfished" designation, "*…overfishing has never occurred for this stock, as Pacific sardine catch has been well below the acceptable biological catch (ABC) and the overfishing limit (OFL) since before the closure of the primary directed fishery*."

3.1 *Alternative 1 (Preferred Alternative)*

This section highlighted the flexibility of "status quo" management, but status quo means allowing the Council the ability to consider conditions on the ground and incorporate other management measures, if warranted. No other alternative provides this flexibility to both address the needs of fishing communities and to adjust harvest rates to conform with best available science.

4.1 Modeling Description and Use in Analysis of Alternatives

The EA correctly recognized that the "Rebuilder" modeling platform had serious limitations:
…"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." The Rebuilder model was based on moderate recruitment years 2005-2018, but "*…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*."
Moreover, Rebuilder assumed that ABC was captured every year, *"…however, that has not been the case in recent years when less than half of the ABC was taken in US fisheries and much of that is thought to be from the southern subpopulation…"*

4.2 Pacific Sardine Resource

The EA acknowledged scientific consensus that environmental conditions are a critical factor driving population size, as well as how quickly it recovers from low levels… *"There is less evidence that harvest has been a factor leading to the overfished status…"*
Additionally, it recognized the management practice: *"…all US Pacific sardine catch is counted against the ACL, even though some portion is composed of the southern subpopulation… This suggests that US harvest of NSP [northern subpopulation] sardine has likely been less than one percent of the stock biomass in the years since closure of the primary directed fishery*."
Also, "*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."*

To this statement we add the fact that current stock surveys, and biomass estimates, have missed what fishermen believe is a substantial portion of the sardine population that they are observing inshore of NOAA acoustic trawl surveys. That omission is finally being addressed through cooperative surveys involving industry partners, including CWPA.

4.2.2 Analysis of Impacts – Sardine Resource

Again, we concur with the EA: "*…the assumptions made in the modeling limit its usefulness… it is virtually impossible to predict when environmental conditions might produce favorable recruitment…"*

We note that this uncertainty is all the more reason to adopt a rebuilding plan that provides maximum flexibility to adjust harvest limits based on evolving best available science. The only alternative that meets that description is Alternative 1, "status quo."

The EA analysis of alternatives stated that Rebuilder modeling results should be viewed in context: results do not capture the full range of productivity and assume that US fisheries capture the full ABC, neither assumption is realistic. The U.S. catch is thought to be less than one percent of NSP sardine (average only 472 mt annually), which is very close to the 0 U.S. harvest analysis.
We also agree with the conclusion expressed in the EA: *"… 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."*

4.3.1.4 Incidental Harvest – CPS Fisheries

CWPA and fishermen appreciate recognition in the EA that in recent years they've suffered increased difficulty catching other CPS due to the increasing mix of sardine. The EA acknowledged:
"[fishermen] have encountered mixed schools frequently and must release the school if Pacific sardine comprise over 20 percent in the school." In addition, fishermen have had to forego capturing mixed schools entirely if they saw more than a handful of sardines in the net. This restriction has also impacted California's market squid fishery, where incidental rates approaching 20 percent have been on the rise in recent years. The squid fishery is now really the only fishery keeping boats on the water and market doors open in California, where before 2015 the fleet and markets were able to harvest and process a complex of CPS.

We question the low value of CPS fisheries mixed landings reported in the EA – only $1.8 million in value (page 18).
As reported in the CPS Advisory Subpanel statement in September 2020:
"The average ex-vessel value of the California squid fishery in 2012-2016 was $54.7 million. (CDFW Commercial Landings Data). The 2012-2016 ex-vessel value of the Pacific whiting fishery, which also takes sardines incidentally, was $51.5 million [this was correctly reported in the EA]. *In addition, the multiplied value of the live bait fishery, whose direct catch landings represent the bulk of the sardine harvest, is an estimated $1.3 billion* [also correctly reported in the EA]. *(Agenda Item G.1, Attachment 1, September 2020)".*
The point we're making here is that we believe the value of CPS fisheries is seriously understated, particularly in California. The socio-economic impact of restrictions on California's market squid fishery needs to be considered as part of the analysis of economic impacts. And those impacts must be considered, in addition to biology, when approving a rebuilding plan for sardine. The only rebuilding option that has flexibility to address the needs of communities is Alternative 1.

4.3.2 Analysis of Impacts – Fishing Industry

The EA correctly stated that the CPS fishing industry has already been significantly restricted since the closure of the primary directed fishery and the reduction in incidental landing limits. However, we point out that landings data used to generate the economic analysis under-represent actual socio-economic impacts because many mixed schools with an incidental landing rate approaching or exceeding 20 percent are not landed at all.

Once again, only Alternative 1 minimizes, to the extent possible, the economic impacts to the fisheries under the sardine rebuilding plan. Alternative 2 would curtail all U.S. sardine fishing and create economic chaos, while Alternative 3 does not meet MSA National Standards, as noted in the EA. In addition, in analyzing the impacts of Alternative 3, the EA stated: "*This potential for severe negative impacts to fishing communities, additional to those the communities have dealt with since 205, was a major factor in the Council's decision in picking Alternative 1 for the rebuilding plan.*" Further, "*Alternative 3 would impose unnecessary economic impact to the industry with minimal change in the rebuilding timeline.*"

4.4 Sardine in the Ecosystem

This section discussed the importance of sardine as a forage species and the complexity of trophic interactions, but noted that the extent to which predators are affected by abundance and distribution is difficult to measure because most predators are adept at prey switching, having evolved with the dynamic population cycles of all CPS, including sardine. "*Consequently, most of them are generalists who are not dependent on the availability of a single species, but rather on a suite of species…*"

5. *Magnuson Act Analysis and FMP Considerations*

This section evaluated the three alternatives and their consistency with MSA National Standards. Only Alternative 1 met all the guidelines. In contrast:

NS 1 – Alternatives 2 and 3 would not take into account the needs of fishing communities due to their highly restrictive nature, thus would not achieve, on a continuing basis, the optimum yield from the fishery.

NS 2 – Alternatives 2 and 3 would not allow any flexibility in harvest rate based on the best scientific information available. The EA stated: "*Essentially, Alternatives 2 and 3 would ignore fluctuations in biomass estimates or other science-based information*." This would not be consistent with NS 2, requiring management to be based on best available science.

NS 3 - Provides that individual stocks be managed as a unit throughout their range, to the extent practicable, but Alternative 3 would ignore the DISTRIBUTION term in the HCR, therefore not consistent with NS 3.

NS 4 – Alternatives 2 and 3 would force the Council to unnecessarily allocate lower quotas (or 0 quota) to remaining sectors of the CPS fishery, which would necessitate discrimination, counter to NS 4.

NS 5 – Alternative 1, preferred, would allow for efficient utilization of the sardine resource while allowing the stock to rebuild. In contrast, Alternative 2 would unnecessarily disallow any use and Alternative 3 would restrict access in a way that would prevent other fisheries from achieving OY.

NS 6 – Alternative 1 allows the Council to adapt annual harvest specifications based on best scientific information. Alternative 2 would not allow for any variation, and Alternative 3 would allow for small variation but to a lesser extent than Alternative 1.

NS 7 – Alternative 1 avoids duplication as the CPS FMP already provides mechanisms to reduce harvest concurrently with decreases in biomass. However, Alternatives 2 and 3 would ignore existing management efforts and scientific research and impose pre-determined harvest rates (or 0 U.S. harvest), inconsistent with the guideline to minimize costs and avoid duplication.

NS 8 – This standard requires management measures to "…***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.***"

Only Alternative 1 complies with NS 8.

5.2 *Determination of Rebuilding Reference Points*

The MSA requires all rebuilding plans to include reference points to guide the rebuilding program. In our view, the EA struck the balance required in developing rebuilding plan reference points that satisfied MSA guidelines, recognizing that the biology of sardines dictate an exception to the rule.

The Magnuson Act generally allows a ten-year period for rebuilding an overfished stock. It does not require instant recovery. 16 U.S.C. §1854(e). Courts have upheld rebuilding plans that allow overfishing to continue for a certain number of years in order to mitigate economic hardships. (In this case, the EA recognized that overfishing has never occurred; the overfished designation was due to environmental factors, not fishing.)

So long as OY is achieved over time and rebuilding targets can be met within the statutory period, the Secretary enjoys significant latitude in designing a rebuilding program … ." *Oceana v. Evans*, 2005 WL 555416, *12 (D.D.C. 2005).

The EA incorporated extensive work compiled by the CPS Management Team, and analyzed by the CPSMT, SSC and Council. Analyses considered not only the results of biological modeling work (Hill et al 2020) but also the biology and life history of sardine and the history of the west coast sardine fishery.

We support the outcome of these analyses as they recognized and accounted for substantial limitations in both the sardine model and the Rebuilder model, as well as the dynamic fluctuations of Pacific sardines. We note the EA conclusion: "*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*."

In Summary

In approving a rebuilding plan for the sardine fishery, we would appreciate consideration of the following observations:

- The assessment model on which the Rebuilder platform was based excluded evidence of recent recruitment and seriously underestimated the sardine biomass.

- Rebuilder modeling results are not able to capture environmental fluctuations, and how quickly the stock can recover to high levels in a short time when conditions are favorable. Further, the Rebuilder model assumed full capture of ABC every year, which did not occur, hence its projections were unrealistic.
- **Recent US landings of sardine have averaged less than 2,000 mt since 2015 and only one quarter of this is NSP.**

According to the Rebuilding Analysis, average U.S. NSP sardine landings for 2015-19 were only 472 mt and average total US sardine landings were 1,965 mt – an exploitation rate of 0.77% when the total biomass is less than 150,000 mt. An exploitation rate of E=0.0077 is close to the Alternative 2 Zero U.S. harvest strategy.

California fishermen and processors are grateful that the Council considered the issues raised and combined scientific underpinning with common sense. Balance is a key mandate of the Magnuson-Stevens Fishery Conservation and Management Act. The Council and NMFS are required to consider the needs of fishing communities, not just biology, in developing rebuilding plans. The future of California's historic wetfish industry hangs in the balance.

Thank you for your consideration of these comments.

Best regards,

Diane Pleschner-Steele

Diane Pleschner-Steele
Executive Director

CC: Barry Thom, NMFS West Coast Regional Administrator
Ryan Wulff, NMFS Assistant Regional Administrator
Joshua Lindsay, Branch Chief, NMFS West Coast Regional Office

April 15, 2021

Lynn Massey
Sustainable Fisheries Division
National Marine Fisheries Service
lynn.massey@noaa.gov
(562) 436-2462

RE: Pacific Sardine Rebuilding Plan Environmental Assessment NOAA-NMFS-0008-2021

Dear Ms. Massey:

The proposed rebuilding plan for the northern subpopulation (NSP) of Pacific sardine and the draft Environmental Assessment (EA) for the plan fall far short of the National Marine Fisheries Service's (NMFS) legal obligations to rebuild this overfished stock and provide scientifically accurate, transparent analyses for its rebuilding proposal. Instead, the EA attempts to rationalize maintaining status quo management, even though the stock has continued to decline under that regime. Overall, the draft EA lacks transparency, omits basic analyses of impacts and supporting information, incorrectly assesses management alternatives, and does not analyze important scientific information that suggests a greater impact of fishing on sardine rebuilding than the document acknowledges.

NMFS's rationale for its preferred alternative to continue status quo management suffers from several basic flaws. First, the analysis in the draft EA shows that NMFS's preferred alternative does not rebuild the Pacific sardine population with a 50% probability within the target or maximum rebuilding times. NMFS attempts to veer around that conclusion by basing the rest of the EA analysis not on the actual status quo management measures in place and the amount of fishing mortality they authorize, but on the assumption that catch levels will remain well below authorized levels for the next 10+ years.

Second, NMFS sets an inappropriately low rebuilding target by relying on a model fundamentally ill-suited to analyzing sardine population dynamics because it does not accurately reflect the boom-and-bust nature of the sardine population. By analyzing the impacts of the alternatives as if the sardine population will remain indefinitely in a low productivity state, NMFS lowers the bar for the rebuilding target to levels significantly below previous levels of biomass that would enable sardine to produce the maximum sustainable yield (B_{MSY}) and sets a longer maximum rebuilding period (T_{max}) than otherwise allowed by law.

NMFS further undermines the likelihood that this population will rebuild in a timely manner by authorizing vessels to land the highest proportion of sardine as incidental catch the fishery management plan allows (thereby reducing critical incentives to avoid netting mixed coastal pelagic schools with significant numbers of sardines) and approving a fishery management plan

(FMP) amendment to allow continued directed fishing which is currently the highest contribution to total landings. These are not appropriate actions for an agency charged with rebuilding the Pacific sardine population and protecting the ecosystem that depends on a healthy sardine population.

NMFS must correct the errors in their analysis and select an alternative based on the best available science that will rebuild the population in the shortest time possible as required by law. NMFS must develop a rebuilding plan that meets the requirements of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the National Environmental Policy Act (NEPA), and the Endangered Species Act (ESA), and which sets Pacific sardine fishery management on a path toward healthy fisheries and a resilient ocean ecosystem.

To that end, NMFS must:

1. Implement an alternative that has at least a 50% probability of rebuilding the stock within the target timeframe.
2. Accurately reflect status quo by basing analysis on the amount of catch authorized by status quo management, not recent average catch levels, and by using the mean E_{MSY} and corresponding U.S. ABC catch rates NMFS has adopted in catch specifications in recent years rather than artificially low assumed E_{MSY} and catch rates.
3. Base the analysis, including the B_{MSY} used to establish the rebuilding target, on a productivity scenario that fully reflects best available science on the known long-term boom and bust dynamics of the sardine population.
4. Establish a rebuilding target consistent with the long-term population dynamics, including the most recent management strategy evaluation (Hurtado & Punt 2014)[1] calculated mean B_{MSY} of 571,000 metric tons (mt), nearly fourfold higher than the rebuilding target currently proposed by NMFS in this rebuilding plan.
5. Analyze a range of incidental catch allowances and the impact on expected incidental catch and rebuilding.
6. Evaluate the differences between alternatives under various international exploitation rates.
7. Ensure any fishing allowed under the rebuilding plan is not likely to jeopardize marine predators protected under the ESA.
8. Analyze the effects of each alternative on essential fish habitat (EFH) for salmon, groundfish, and highly migratory species (HMS).
9. Review previous efforts to rebuild Pacific sardine, and the rebuilding analysis in the Coastal Pelagic Species (CPS) FMP.

[1] Hurtado-Ferro and Punt. 2014. Revised analyses related to Pacific sardine harvest parameters. Agenda Item I.1.b, Revised Analysis. March 2014. Pacific Fishery Management Council. Available at: https://www.pcouncil.org/documents/2014/03/i-coastal-pelagic-species-management-march-2014.pdf/

10. Fully explain the agency's conclusions based on data and analyses and include the supporting data and analyses in the NEPA analysis.
11. Prepare an Environmental Impact Statement (EIS) because the current preferred alternative is likely to have a significant environmental impact.

LEGAL REQUIREMENTS

I. Magnuson-Stevens Fishery Conservation and Management Act

The MSA requires NMFS, first and foremost, to prevent or end overfishing and rebuild overfished stocks to healthy levels.[2] Once NMFS declares a stock overfished, it must implement a rebuilding plan within two years. The rebuilding plan for Pacific sardine must end overfishing immediately and "specify a time period for rebuilding the fishery that shall (i) be as short as possible, taking into account the status and biology of any overfished stocks of fish, the needs of fishing communities… and the interaction of the overfished stock of fish within the marine ecosystem; and (ii) not exceed 10 years, except in cases where the biology of the stock of fish, other environmental conditions, or management measures under an international agreement in which the United States participates dictate otherwise."[3] When it is possible to rebuild a species within ten years, the Agency "may consider the short-term economic needs of fishing communities" but "may not use those needs to go beyond the ten year-cap set in subsection (ii)."[4] "Part of the reason Congress elevated conservation over economic interests is that conserving fish populations yields the double benefit of both improving the environment and providing long-term economic return."[5]

In establishing a rebuilding target for the population, NMFS must use long-term data and ensure the population will rebuild to a healthy level. NMFS guidelines specify that "the abundance of an overfished stock or stock complex must be rebuilt to a level that is capable of producing MSY."[6] MSY is defined as the largest long-term catch that can be taken from the stock under prevailing environmental conditions.[7] NMFS guidelines thus specify that NMFS set B_{MSY} at a level that reflects "the long-term average size of the stock . . . measured in terms of spawning biomass or other appropriate measure of the stock's reproductive potential that would be achieved by fishing at Fmsy."[8]

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[2] 16 U.S.C. 1851(a)(1); *NRDC v. NMFS*, 421 F.3d 872, 879 (9th Cir. 2005) ("The purpose of the Act is clearly to give conservation of fisheries priority over short-term economic interests.").
[3] 16 U.S.C. 1854(e)(4)(A).
[4] *NRDC v. Locke*, 2010 U.S. Dist. LEXIS 157577, at *14 (N.D. Cal. Apr. 22, 2010) (citing Natural Resources Defense Council v. NMFS, 421 F.3d 872, 880 (9th Cir. 2005)).
[5] *Id*. ("Without immediate efforts to rebuild depleted fisheries, the very survival of those fishing communities is in doubt.") (citing *NRDC v. NMFS*, 421 F.3d at 879).
[6] 50 C.F.R. 600.310(b)(2)(I).
[7] 50 C.F.R. 600.310(e)(1)(i)(A).
[8] 50 C.F.R. 600.310(e)(1)(i)((C).

As with all conservation and management measures, NMFS must base rebuilding measures on the best scientific information available.[9]

II. National Environmental Policy Act

Enacted by Congress in 1969, NEPA establishes a national policy to "encourage productive and enjoyable harmony between man and his environment" and "promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man."[10] NEPA has a dual purpose. "First, it places upon [a federal] agency the obligation to consider every significant aspect of the environmental impact of a proposed action. Second, it ensures that the agency will inform the public that it has indeed considered environmental concerns in its decisionmaking process."[11]

To achieve its broad goals, NEPA mandates that "to the fullest extent possible" the "policies, regulations, and public laws of the United States shall be interpreted and administered in accordance with [NEPA]."[12] Central to NEPA is its requirement that, before any federal action that "*may* significantly degrade some human environmental factor" can be undertaken, agencies must prepare an environmental impact statement (EIS).[13]

If an action is not likely to have a significant impact on the environment or the environmental impact is unknown, agencies must prepare an EA.[14] If the EA demonstrates that the action *is* likely to significantly affect the environment, then the agency must prepare an EIS.[15] To determine whether an action is likely to have a significant impact on the environment and thus whether an EIS is required, agencies must 1) "analyze the potentially affected environment" and 2) analyze the "degree of the effects of the action."[16] In analyzing the potentially affected environment, the agency should consider "the affected area … and its resources, such as listed species and designated critical habitat under the Endangered Species Act."[17] In analyzing the degree of the effects of the action, the agency should consider 1) short and long-term effects 2) beneficial and adverse effects 3) effects on public health and safety; and 4) effects that would violate Federal, State, Tribal, or local law protecting the environment.[18]

NEPA and the Council on Environmental Quality ("CEQ") regulations implementing NEPA are meant to ensure that environmental considerations are "infused into the ongoing programs and

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[9] 16 U.S.C. 1851(a)(2).
[10] 42 U.S.C. § 4321.
[11] *Kern v. U.S. Bureau of Land Mgmt.*, 284 F.3d 1062, 1066 (9th Cir. 2002).
[12] 42 U.S.C. § 4332.
[13] *Steamboaters v. F.E.R.C.*, 759 F.2d 1382, 1392 (9th Cir. 1985).
[14] 40 CFR 1501.15(a).
[15] 40 CFR 1501.15(c).
[16] 40 CFR 1501.15(c).
[17] 40 CFR 1501.3(b)(1).
[18] 40 CFR 1501.3(b)(2).

actions of the Federal Government."[19] In order to achieve this, environmental review must be prepared "at the earliest possible time to insure that planning and decisions reflect environmental values."[20]

DISCUSSION

I. Implement an alternative that has at least a 50% probability of rebuilding the stock within the target timeframe.

NMFS must implement an alternative that will rebuild the Pacific sardine population.[21] Based on NMFS's analysis, Alternative 1 (status quo) does not result in a greater than 50% probability of rebuilding the stock. In fact, NMFS's analysis shows that under status quo management the stock will not rebuild at all within the modeling time frame.[22] In fact, the CPS Management Team (CPSMT) presented analysis that Alternative 1 would not reach a 50% chance of rebuilding until 2068 under a high productivity scenario, which would be a 48-year rebuilding period, which is double the Tmax.[23, 24]

The rebuilding plan selects a rebuilding target biomass of 150,000 mt (age 1+ biomass) with a Tmin of 12 years, Ttarget of 14 years, and Tmax of 4 years (EA Section 5.2). Alternative 3 is the only one of the three alternatives that the NMFS Rebuilding Analysis shows will rebuild within Tmax while still allowing continued incidental catch and live bait fishing.

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[19] *Marsh v. Or. Nat. Res. Council,* 490 U.S. 360, 371 n.14 (1989) (internal citation omitted).
[20] *Metcalf v. Daley,* 214 F.3d 1135, 1142 (9th Cir. 2000) (quoting *Andrus v. Sierra Club,* 442 U.S. 347, 351 (1979)).
[21] 16 U.S.C. 1854(e)(2).
[22] Draft EA at 25.
[23] CPS MT Presentation to PFMC on Rebuilding Alternatives, *available at* https://www.pcouncil.org/documents/2020/09/g-1-a-supplemental-cpsmt-ppt-1-cpsmt-presentation-on-the-pacific-sardine-rebuilding-plan.pdf/
[24] Draft EA at 7 ("The "no action" alternative is not adopting a rebuilding plan, which would not meet the requirements of the MSA.").

	Rebuilding Time (≥50% probability)
Alt 1	Does not rebuild
Alt 2	12 yrs
Alt 3	16 yrs
Tmin	12 yrs
Ttarget	14 yrs
Tmax	24 yrs

Table 1. *Rebuilding times for each Alternative in EA and proposed rebuilding times in Sardine Rebuilding Plan.*

As stated in the draft EA: "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."[25] However, the EA tries to downplay this result by again presenting false and misleading analyses of Alternative 1 that incorrectly limit catch to 2,200 mt and 472 mt.

The EA then further downplays the significant differences between rebuilding alternatives by concluding that "fishing mortality is not the primary driver of stock biomass."[26] This statement fundamentally contradicts the modeling results presented in the EA, particularly those that show Alternative 1 will not rebuild the stock, while Alternatives 2 and 3 will. It also contradicts the extensive scientific information that shows that fishing on dynamic forage fish can worsen natural declines and delay recovery. [27] documented a significant relationship between catch ratios and sardine recovery for Pacific sardine, and that this relationship held across a wide range of temperature and productivity scenarios.

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[25] Draft EA at 15.
[26] *Id*. at 14.
[27] Essington et al. 2015. Fishing amplifies forage fish population collapses, *available at* www.pnas.org/cgi/doi/10.1073/pnas.1422020112; Lindegren et al. 2013. Climate, fishing, and fluctuations of sardine and anchovy in the California Current. Proceedings of the National Academy of Sciences, *available at* www.pnas.org/cgi/doi/10.1073/pnas.1305733110.

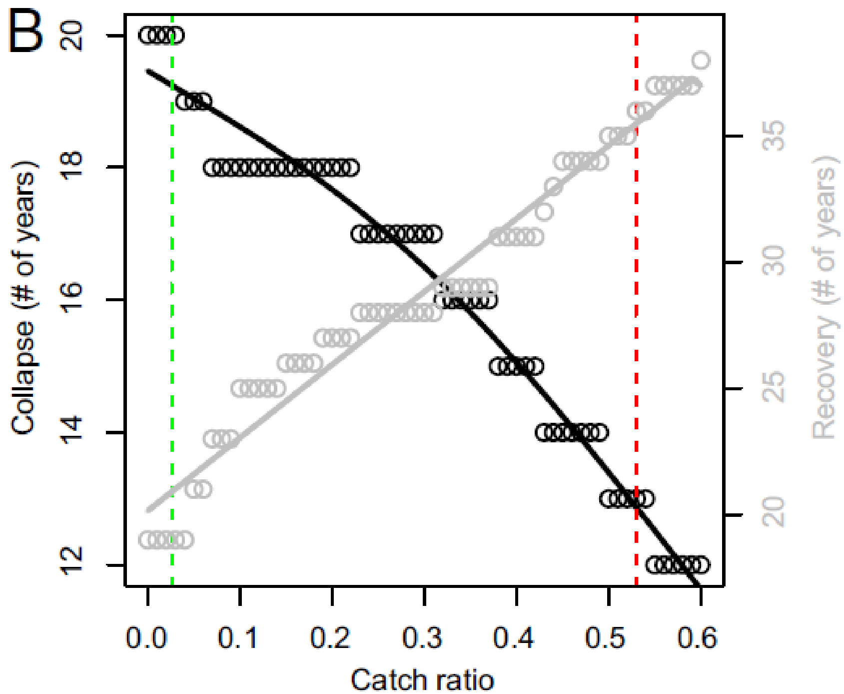

Figure 1. *From Lindegren et al. 2013. "Climate, fishing, and density-dependent effects. (B) the mean number of years until collapse and subsequent recovery above 0.09 MMT for each combination of SST (±1 °C change relative to observed SST; Fig. 1B) and catch ratios. Dashed lines show the observed SST (gray), maximum catch ratios (red) before the collapse, and mean catch ratios in the 1980s (green)."*

The fundamental explanation for why catch levels allowed under status quo management fail to rebuild the sardine population is that the stock is currently in a low productivity state, yet status quo management is setting catch levels appropriate only for a highly productive stock. This is because the E_{MSY} fishing rate used to set the OFL is currently using a temperature index that is falsely predicting high recruitment.[28] Both the CPSMT and the SSC acknowledged this problem in April 2021 and recommended a re-evaluation of E_{MSY} to correct the problem.

> **CPSMT Statement:** *The CPSMT recommends evaluation of the Emsy term based on the California Cooperative Oceanic Fisheries Investigations (CalCOFI) temperature index because it no longer appears to adequately reflect sardine productivity. The value for the Emsy term applied to the OFL formula is capped at 0.25 which corresponds to the upper quartile of CalCOFI temperatures. This environmental proxy was designed to reflect stock*

[28] *See* Oceana and Earthjustice letter to PFMC, April 5, 2021. PFMC Agenda Item E.4 Public Comment. https://pfmc.psmfc.org/CommentReview/DownloadFile?p=398a32ba-9c0a-4c09-9287-1ac8cfcc855b.pdf&fileName=E4sardine_EJ-Oceana_PFMC-4-5-21.pdf

> *productivity, yet it has been near that upper cap for the last five years, while the most recent benchmark assessment stated that actual recruitments have been some of the lowest on record during that same time period.*[29]
>
> **SSC Statement:** *The value for EMSY based on the CalCOFI temperature index suggests a productive stock but this is not evident from recent assessments, suggesting the need to re-evaluate the best way to calculate EMSY for the northern subpopulation sardine stock.*[30]

Furthermore, the CalCOFI index currently used to set E_{MSY} has been shown in published analysis by NMFS scientists to be a poor, invalid indicator of sardine productivity.[31]

Therefore, until the sardine population shifts to a more highly productive state, the rebuilding plan must limit catch rates to those appropriate for a stock in a low productivity regime. This could be done by setting E_{MSY} equal to 5% or by calculating the E_{MSY} based on recent observed recruitment from surveys and stock assessments.

An alternative that combines precautionary management and international coordination could provide the optimal rebuilding outcome through a 5% coastwide harvest rate ("Total E = 5%"). At the July 15-16, 2020 SSC CPS Subcommittee workshop, NMFS analyzed this alternative and found it was the *only one* that allowed continued fishing while preventing further declines in the sardine population under the low productivity scenario and allowed for increases in the population under the high productivity scenario (see below Figures). No other alternative was able to meet both goals of allowing continued fishing while preventing further decline in a low productivity scenario. Given the utility of this alternative and its performance, it is unclear why NMFS removed it from the EA. We request that the NMFS add this alternative to the range and conduct a full analysis before finalizing the rebuilding plan. This alternative should describe the actions that NMFS could take to ensure a 5% coastwide harvest rate including international scientific and management coordination.[32]

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[29] CPSMT Report on Pacific Sardine Stock Assessments, Harvest Specifications, and Management Measures Final Action. April 2021. Supplemental CPSMT Report 1. Agenda Item E.4.a, https://www.pcouncil.org/documents/2021/04/e-4-a-supplemental-cpsmt-report-1.pdf/

[30] SSC Supplemental Report 1. Pacific Sardine Stock Assessments, Harvest Specifications, and Management Measures Final Action Agenda Item E.4.a, https://www.pcouncil.org/documents/2021/04/e-4-a-supplemental-ssc-report-1-2.pdf/

[31] Zwolinski and Demer (2019). Re-evaluation of the environmental dependence of Pacific sardine recruitment. Fisheries Research. https://doi.org/10.1016/j.fishres.2019.03.022

[32] D.A. Demer & J.P. Zwolinski (2017) A Method to Consistently Approach the Target Total Fishing Fraction of Pacific Sardine and Other Internationally Exploited Fish Stocks, North American Journal of Fisheries Management, 37:2, 284-293

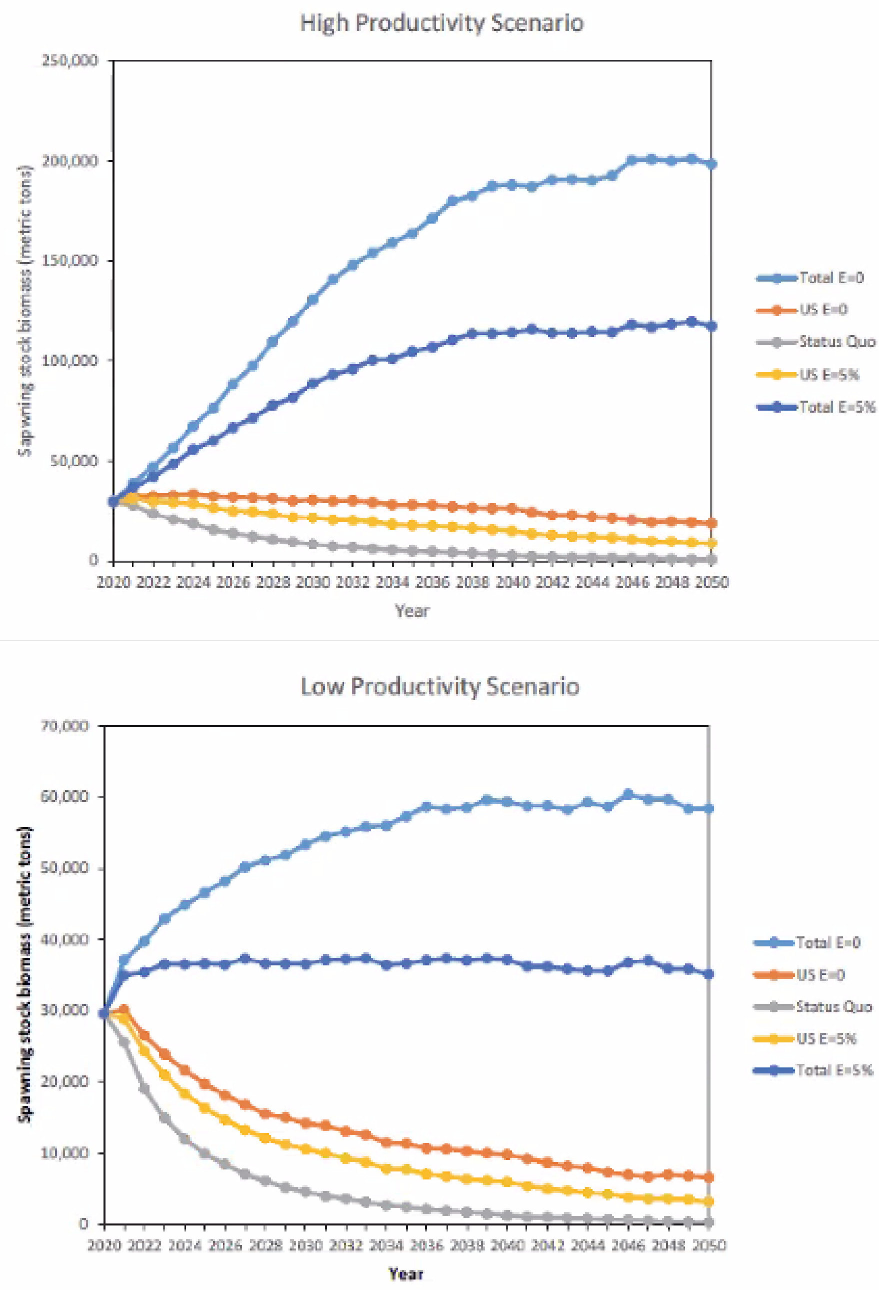

Figure 8. Projected median spawning biomass (mt) for Pacific sardine rebuilding alternatives.

Figures 2 and 3. *These figures presented by NMFS SWFSC staff at the July 16, 2020 SSC CPS subcommittee webinar on rebuilding alternatives, include a "Total E = 5%" alternative (dark blue) that outperformed other alternatives under high and low productivity scenarios.*

II. Correct the assumptions used to define and analyze status quo management in the rebuilding analysis.

The rebuilding analysis incorrectly evaluates the status quo alternative by a) using a lower harvest rate than what current management allows and has been implemented in recent management and b) analyzing average recent catch levels instead of the total catch authorized by status quo management. In doing so, NMFS biases the results of the analysis toward its preferred outcome and justifies its decision to continue status quo management on flawed premises. This misleads the public and decisionmakers by underestimating the effect of fishing on the stock and rebuilding times relative to other alternatives and reduces the differences across alternatives.

Furthermore, NMFS analyzes and arbitrarily toggles among results from three separate constructions of Alternative 1 to evaluate the effects of what it characterizes as status quo management on future rebuilding, none of which reflect recent management under the status quo:

1. A constant U.S. harvest rate of 12%, using a fixed E_{MSY} of 18% to set Overfishing Limits (OFL).
2. A constant U.S. catch of 2,200 mt, reflecting recent total U.S. catch.
3. A constant U.S. catch of 472 mt, reflecting the assumed amount of recent U.S. catch from the northern subpopulation only.

NMFS must analyze the status quo as a single alternative. And that alternative must reflect the full amount of catch authorized under the current management regime.

a. The exploitation rate used to analyze status quo is significantly lower than the maximum rate allowed under current management and the exploitation rate used in harvest specifications in recent years.

Under the current management regime, the E_{MSY} used to calculate OFLs may be set from 0-25%.[33] Over the last five approved stock assessments (2016-2020), the E_{MSY} adopted by NMFS has been greater than 18% and has averaged 24% (Table 1). The rebuilding analysis must use the mean E_{MSY} of 24% from NMFS stock assessments to evaluate status quo, not a constant E_{MSY} of 18%. The Pacific sardine rebuilding analysis states: "for purposes of this rebuilding analysis, the static stochastic E_{MSY}= 0.18 yr-1 from the recent management strategy evaluation . . . was be

[33] PFMC. 2014. SSC Report on Pacific sardine temperature parameter review. Agenda Item I.1.c. " The SSC recommends that overfishing limits (OFLs) for the northern subpopulation of Pacific sardine be based on an Emsy proxy derived from the relationship between estimated Emsy and the 3-year moving average of the CalCOFI temperature index, restricted to an Emsy range of 0-25 percent" Available at https://www.pcouncil.org/documents/2014/03/i-coastal-pelagic-species-management-march-2014.pdf/

used to project the population forward under the 'Status Quo' harvest strategy."[34] This is then pro-rated by the Tier 2, P* = 0.40 ABC buffer (0.7762) and U.S. distribution (0.87) to develop the U.S. exploitation rate of 12.16% used in the rebuilding analysis. This harvest rate, however, is lower than allowable harvest rates in recent years and does not accurately reflect status quo management.

After the completion of the 2014 management strategy evaluation, NMFS changed the formula used to set the OFL and ABC, allowing it to exceed 18% and be set as high as 25%. In fact, under the last five years of status quo management, NMFS consistently set E_{MSY} well above 18% based on the CalCOFI index, which predicted a highly productive stock. As recently as April 9, 2021, the PFMC adopted an E_{MSY} of 22.46% to set the 2021-22 OFL.

NMFS's continued use of the CalCOFI index conflicts with the best available science. A 2019 analysis by NMFS SWFSC scientists found the CalCOFI index to be a poor and invalid indicator of sardine productivity.[35]

Nonetheless, if NMFS continues to use status quo management as the basis for its preferred alternative and bases the rebuilding analysis on constant catch rates, it must analyze the catch rates actually authorized and implemented under status quo management. In other words, the analysis of Alternative 1 must use the mean E_{MSY} applied in recent management to set ABCs. Over the last five seasons, NMFS stock assessments have set OFLs and ABCs based on E_{MSY} values with a mean of 23.8% (see below). Prorating this value by the Tier 2, Pstar 0.4 Buffer (0.7762) and U.S. Distribution (0.87) yields a U.S. exploitation rate of 16.1%.

Season	**E_{MSY}**
2020-21	0.224584
2019-20	0.242675
2018-19	0.25
2017-18	0.225104
2016-17	0.25
mean	**0.238473**

Table 2. *CalCOFI-based E_{MSY} values used in U.S. Pacific sardine management from the last five approved final NMFS stock assessments to set OFLs and ABCs.*[36]

[34] PFMC Agenda Item G.1.a NMFS Report. September 2020. https://www.pcouncil.org/documents/2020/08/g-1-a-nmfs-report-1-pacific-sardine-rebuilding-analysis-based-on-the-2020-stock-assessment.pdf/
[35] Zwolinski and Demer. 2019. Re-evaluation of the environmental dependence of Pacific sardine Recruitment. Fisheries Research 216 (120-125).
[36] Kuriyama, P.T., Zwolinski J.P., Hill, K.T., and Crone, P.R. 2020. Assessment of the Pacific Sardine resource in 2020 for U.S. management in 2020-2021. PFMC April 2020 Briefing Book Agenda Item D.3 Attachment 1. 189 p.

Alternatively, similar to the way the analysis calculates mean harvest rates for Mexico, NMFS could determine the status quo harvest rate by taking the average ABC harvest rate over 2015-2020. Table 1 in the EA[37] lists the U.S. ABC values set from 2015 to 2020, of which the mean is 10,838 mt. Consistent with how Mexican harvest rates were calculated by dividing by the Average Age 1+ biomass over this period of 61,240 mt, the mean U.S. ABC was 17.7%. Again, this results in a higher status quo exploitation rate than the 12.16% rate used to analyze the status quo in the EA. The analysis in the EA must be corrected to reflect the mean harvest rate of U.S. ABCs set in recent years to adequately reflect status quo management.

The underlying rebuilding analysis is also misleading because Alternative 1 is labeled as "US E = 18%," however, Table 3b (copied below) indicates the "U.S. *E*" used in the simulations for this alternative is 12.16%. Not only is this misleading, it is also inconsistent with how Alternative 3 is analyzed because there was not an assumed ABC buffer. Therefore, Alternative 1 should be corrected and relabeled to reflect the actual mean harvest rate of U.S. ABCs set in recent years and labeled to reflect the U.S. harvest rate being simulated.

Harvest Alternative	MX *E*	US *E*	Total *E*	US Portion
Alt 1 (US *E*=18%)	0.0986	0.1216	0.2202	0.5520
Alt 2 (US *E*=0)	0.0986	0.0000	0.0986	0.0000
Alt 3 (US *E*=5%)	0.0986	0.0500	0.1486	0.3364

Table 3. *Respective exploitation rates (E) for U.S. and Mexico for the constant harvest rate simulations.*[38]

b. NMFS must analyze the full amount of catch authorized under status quo management

The correct level of catch for the purposes of analyzing the impacts of status quo management is the total *allowable* catch. However, NMFS repeatedly relies on the assumption that catch will remain below the ABC in the future based on an analysis of average recent catch levels (2,200 mt) as equivalent to the status quo alternative and that therefore status quo management is sufficient to rebuild the population while at the same time admitting that if the full ABC is taken,

[37] Draft Sardine Rebuilding Plan EA, Table 1. Annual Pacific sardine harvest specifications and landings for the fishing years following closure of the primary directed fishery, p. 20 *available at* https://media.fisheries.noaa.gov/2021-03/Sardine-Rebuilding_draftEA_v4.pdf?null https://media.fisheries.noaa.gov/2021-03/Sardine-Rebuilding_draftEA_v4.pdf?null.

[38] Hill, K.T., P.T. Kuriyama, and P. R. Crone. 2020. Pacific sardine rebuilding analysis based on the 2020 stock assessment. La Jolla, California: National Marine Fisheries Service Southwest Fisheries Science Center.

the stock will not rebuild.[39] Under the CPS FMP, the ACL may be set equal to the ABC.[40] Because the CPS FMP allows the ACL to be set up to ABC, it is essential that NMFS analyze catch levels equal to the full ABC in order to accurately evaluate the status quo. As NMFS is well-aware, it must analyze status quo at ABC because that is the level of catch that is authorized in any given year and there is no guarantee that catch will remain below the ABC in the future.[41]

Further, NMFS creates yet another analysis of the "status quo" that asserts that the actual adjusted U.S. catch of the NSP of sardine is only 472 mt and that this level of catch is predicted to rebuild the stock within the target timeframe selected by the Council (14 years). This is yet another definition of status quo management that conveniently gives NMFS the result it seeks: a rebuilding time of 14 years. However, there is no data or analysis detailed in the EA to back up this claim and a constant catch of 472 mt is not analyzed as an alternative. If NMFS is confident that the actual catch of NSP is only 472 mt and that level of catch will rebuild the stock in the target timeframe, then NMFS should provide the scientific analysis to support that conclusion and implement a constant 472 mt ACL for the northern subpopulation as the approach with the highest probability to rebuild the population in as short as time as possible.

III. Base the analysis on a productivity scenario representing the known long-term boom and bust dynamics of the sardine population

NMFS bases the rebuilding analysis on an assumption that that the stock will remain indefinitely in a state of low productivity, an assumption that is not consistent with the best available science on sardine population dynamics. NMFS's incorrect analysis of productivity manifests in at least two ways. First, NMFS chose to base its rebuilding analysis on a model, the "rebuilder tool," that is fundamentally ill-suited to analyze sardine. The rebuilder tool was designed to analyze groundfish, which are long-lived and experience relatively constant productivity over time. In contrast, the best available science has long shown that sardine populations experience wide fluctuations in abundance, recruitment, and productivity over decadal scales.[42] The CPSMT

[39] *See, e.g.,* Draft EA at 14 ("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"); *Id.* at 15 ("the actual expected rebuilding timeline under a constant catch of 2,200 mt per year is expected to be 14 years as opposed to 14 years"); *Id*. at 25 ("landings of Pacific sardine are likely to remain similar during the rebuilding timeline as they have bene 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 resources than was modeled."); *Id*. at 25 ("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.").

[40] CPS FMP Section 4.6.1.

[41] *See Oceana v. Ross*, 2020 WL 5232566, *16-*17 (N.D. Cal. Sept. 2, 2020).

[42] *See, e.g.*, Appendix B to CPS FMP Amendment 8 and Zwolinski and Demer (2012).

states: "Rebuilder modeling does not fully capture environmental dynamics because it does not include data from high productivity time periods."[43]

Second, NMFS's rebuilding analysis only uses data from years when the population was declining. As stated in the September 2020 NMFS report to the PFMC: "This rebuilding analysis is limited to the available data from the current stock assessment and does not include early historic high recruitment estimates from the 1980s and 1990s or early 21st century. The analysis represents a narrow time frame (15 years) relative to the number of projection years, and likely represents a limited snapshot of the long-term population fluctuations."[44] The EA also underscores this problem with the rebuilding analysis, stating:

> modeling only this time period [2005-2018] 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.[45]

The EA acknowledges that "The Tmin and target spawning biomass values provided by the modeling results may not be realistic given the model's limitations. . . 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)."[46]

The EA acknowledges studies showing that the average time for the sardine population to rebound from low levels to healthy levels is about 22 years.[47] Despite that best available science, NMFS assumed the population would remain in low productivity for at least 50 years. Rather than assuming a constant state of low productivity through the year 2070, as the NMFS analysis does, a more realistic assumption is that the sardine population will experience high productivity at some point in the next two decades. While we cannot know exactly when this shift will occur, it is possible to analyze sardine rebuilding over a longer period. For example, the CPS FMP Amendment 8 conducted a cursory analysis of the time to rebuild the stock from different initial biomass levels using a simple compound interest model assuming 40% annual net increase in abundance.[48] This model is the basis of the 50,000 mt MSST currently in place and NMFS has not proposed updating this important status determination criterion. The original CPS FMP Amendment 8 also conducted a MSE that included long-term fluctuations in productivity, and

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[43] https://www.pcouncil.org/documents/2020/09/g-1-a-supplemental-cpsmt-report-4.pdf/
[44] PFMC Agenda Item G.1.a NMFS Report. September 2020. https://www.pcouncil.org/documents/2020/08/g-1-a-nmfs-report-1-pacific-sardine-rebuilding-analysis-based-on-the-2020-stock-assessment.pdf/
[45] Draft EA at 11.
[46] *Id*. at 34.
[47] *Id*. (citing McClatchie et al. (2017)).
[48] CPS FMP Amendment 8 Appendix B., Table 4.2.5.1-1.

that operating model was updated in Hurtado-Ferro and Punt 2014. This demonstrates that there are models available to calculate long-term average B_{MSY} to establish rebuilding targets and to conduct rebuilding analysis that are more appropriate for the highly fluctuating sardine stock.

Importantly, the best available science also shows that the rebuilding times vary greatly depending on what the initial biomass of sardine is when the environmental conditions shift to support high productivity. The further the population is diminished, the longer it will take to rebuild. Continued fishing under the current low productivity regime is likely to further reduce sardine biomass below current levels, well below levels that would occur without fishing (F = 0) meaning the initial biomass for rebuilding will be lower in the future when the stock becomes more productive. Using the simple compound interest model, as done in the Amendment 8 rebuilding analysis, could allow an evaluation of the differences in the time to rebuild to any rebuilding target under a high productivity scenario for levels below the current biomass. Using the most recent MSE's operating model to project stock biomass forward under a variety of productivity scenarios could also be used to more accurately model sardine rebuilding under the various alternatives in the EA.

We are especially concerned that NMFS relies on assumptions in the rebuilding analysis that are inconsistent with the assumptions it has used to set annual specifications. Again, NMFS assumes the stock will remain in a low productivity state with high relative levels of Mexican catch for the purposes of the rebuilding analysis, but NMFS continues to set annual specifications (e.g., U.S. OFL and U.S. ABC) based on the assumption that the stock is highly productive (E_{MSY} > 20%) and does not consider Mexican catch at all. It is arbitrary and inconsistent for the Council and NMFS to base the rebuilding plan on the assumption that that the stock is and will remain in a low productive state with high relative levels of Mexican catch, while setting annual specifications (e.g., U.S. OFL and U.S. ABC) based on the assumption the stock is highly productive stock (E_{MSY} > 20%) and without accounting for Mexican catch at all.

IV. Establish a rebuilding target consistent with the long-term B_{MSY} from previous management strategy evaluations (MSE)

Selecting a rebuilding target that is far below the B_{MSY} calculated in the most recent MSE and other similar analyses and which does not allow for a directed commercial fishery is inconsistent with MSA rebuilding requirements and is not based on the best available science. As noted above, NMFS's regulatory guidelines specify that rebuilding timelines must be defined in terms of "the amount of time the stock or stock complex is expected to take to rebuild to its *MSY **biomass.***"[49] MSY biomass is defined as a "*long-term* average stock size, measured in terms of spawning biomass or other appropriate measure of the stock's reproductive potential that

[49] 50 CFR §600.310 (j)(3)(A) (emphasis added).

would be achieved by fishing at Fmsy."[50] NMFS's own guidelines thus require it to analyze rebuilding timelines in light of long-term data that reflect the stock's full productivity cycle—not a limited snapshot of a collapsed stock in a low productivity phase.

The rebuilding analysis modeled a rebuilt stock as one that has reached a spawning stock biomass (SB_{MSY}) of 38,122 mt for the low productivity scenario and 137,812 mt for the high productivity scenario.[51] We note that both the 'low' and 'high' productivity scenarios in this context are relative based on data from 2005-2018 during a period of stock decline. This time series excludes previous years when there was a major increase due to much higher recruitment having occurred prior to 2005.[52] As a result, the rebuilding plan sets a rebuilding target of 150,000 mt of age 1+ biomass, equivalent to the CUTOFF in the harvest control rule. Defining rebuilding at these low values is non-sensical and violates the MSA. Under the harvest control rule, directed sardine harvest by the commercial fishery (the "harvest guideline") would be set at 0 mt when the stock is at or below CUTOFF. Clearly the stock is not producing MSY when the stock is too low to support a commercial fishery. It is widely recognized that the long-term stock dynamics of sardine require setting the rebuilding target at much higher levels than CUTOFF. Setting the rebuilding target based only on the period when the stock productivity is low does not reflect the best available science on stock dynamics and results in the rebuilding target being set at levels that reflect an overfished, unhealthy sardine population.

The EA discounts that there are several available methods to more accurately model rebuilding for Pacific sardine than the rebuilder tool. The EA states: "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."[53]

Studies by NMFS scientists provide the best available scientific information for NMFS to use in selecting the rebuilding target. For example, Zwolinski and Demer (2012) identified a critical biomass threshold of 740,000 mt spawning stock biomass.[54] The CPS Amendment 8 rebuilding

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[50] 50 C.F.R. 600.310(e)(1)(C).
[51] PFMC Agenda Item G.1.a NMFS Report. September 2020. https://www.pcouncil.org/documents/2020/08/g-1-a-nmfs-report-1-pacific-sardine-rebuilding-analysis-based-on-the-2020-stock-assessment.pdf/
[52] Draft EA at 11 ("Therefore, modeling only this time period [2005-2018]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.").
53 Draft EA at 34.
[54] Zwolinski, J. and DA Demer. 2012. A cold oceanographic regime with high exploitation rates in the Northeast Pacific forecasts a collapse of the sardine stock. Proceedings of the National Academy of Sciences (PNAS) 109 (11). 4175-4180. Available at: http://www.pnas.org/content/early/2012/02/24/1113806109.full.pdf

analysis used a SB_{MSY}[55] Hurtado & Punt (2014) calculated an unfished biomass (B0) of 1.572 million mt with a mean (1+) biomass of 572,000 mt.[56] Notably, the EA uses the static E_{MSY} from Hurtado & Punt (2014) to determine E_{MSY} in lieu of the Rebuilder Model. The CPSMT report references a definition of recovery from McClatchie et al. (2017) that defines recovery to levels that could support commercial fishing, which would be one half of its peak biomass.[57] Since the peak biomass for Pacific sardine is well over 1 million tons, this would be much higher than the 150,000 mt CUTOFF. It is unclear why NMFS did not use these existing reference points for setting the rebuilding target based on long-term stock dynamics and biomass needed to produce MSY over the long term.

V. Analyze a range of incidental catch allowances for Pacific sardine

The CPS FMP establishes an incidental catch allowance range from 0-20% of landed weight when the Pacific sardine stock is overfished.[58] However, NMFS did not conduct any analysis of the effects of different incidental catch allowances on expected take or how that may affect sardine rebuilding. The Rebuilder analysis only examines the effects of different cumulative catch rates but does not consider how incidental catch allowance levels affect catch rates or rebuilding if fishermen were further incentivized to avoid mixed schools. In addition, NMFS did not analyze incidental catch allowances throughout the 0-20% range established in the FMP and appears to only be considering the 20% by default. NMFS should analyze incidental catch allowances including 0%, 5%, 10% and 20% to better understand the potential benefits to the resource and the impact on rebuilding timelines from restricting incidental catch in other CPS fisheries.

NMFS nonetheless asserts without any supporting analysis that the 20% incidental catch allowance under status quo management is sufficiently protective,[59] even though status quo management allows levels of catch that will not rebuild the stock. NMFS further indicates that any further reductions in the incidental catch allowance will have unacceptable adverse economic impacts.[60] However, data presented in reports to the PFMC[61] shows that most

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[55] CPS FMP Amendment 8 Appendix B. Table 4.2.5.1-1.
[56] Hurtado-Ferro and Punt. 2014. Revised analyses related to Pacific sardine harvest parameters. PFMC Agenda Item I.1.b March 2014. Table 4: mean B1+ under scenario "M":Demy.
[57] CPSMT Report on Sardine Rebuilding Plan. Agenda Item G.1.a. June 2020.
[58] CPS FMP as Amended by Amendment 17. Section 5.1.1 Incidental catch allowances when stocks are overfished.
[59] *See, e.g.*, Draft EA at 15 ("The fishery is already being heavily restricted under status quo management").
[60] *See, e.g.*, Draft EA at 19 ("Members of the CPS industry have expressed 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 theses 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.").
[61] CDFW Report on Pacific sardine landings 2015-2019, April 2019, Agenda Item E.3.a, Supplemental CDFW Report 2, *available at* https://www.pcouncil.org/documents/2019/04/agenda-item-e-3-a-supplemental-cdfw-report-2-pacific-sardine-landings-2015-2019.pdf/

landings with incidental sardine catch have less than 10% sardine by weight. Furthermore, the EA does not provide sufficient information on the amount or value of CPS landings that occurred without incidental catch of sardines and does not provide the amount or value of CPS landings that would be affected by incidental catch allowances of 0%, 5%, or 10%. It also does not describe or analyze potential changes in CPS fishing behavior resulting from alternative levels of allowed incidental sardine catch.

Without additional analysis, it is not clear that limiting incidental catch allowances would have adverse economic impacts or that those impacts would not be outweighed by the benefits to the sardine stock and the predators that rely on a healthy sardine population. Instead of making unsupported, conclusory statements, NMFS must analyze the economic and environmental impacts of a reasonable range of additional management measures under the rebuilding plan including limits on incidental catch.

VI. Evaluate the differences between alternatives under various international exploitation rates

Pacific sardines are a transboundary stock fished by the U.S., Mexico, and Canada. Prior to 2013, Canada took significant levels of Pacific sardines, and more recently, Mexican catch of sardines has been estimated to exceed U.S. catch. Given the uncertainty over past and future catch rates outside the U.S., the EA must evaluate the effect of various international catch rates by Mexico on the likelihood that each alternative will rebuild the stock. Instead, however, the EA assumes a fixed catch rate of Pacific sardines by Mexico, based on recent landings data apportioned to the NSP.[62] Under all analysis runs, the assumed Mexican catch has a significant effect on the results, indicating that the stock will not rebuild and may further decline under low productivity conditions. This highlights the long-standing concern that the current distribution of 87% used in the U.S. harvest control rule to set ABC is not based on best available science. This has been echoed by NMFS scientists in peer-reviewed, published journals. Yet NMFS refuses to update the flawed distribution parameter even when superior published methods are available.[63] Furthermore, it demonstrates the need for U.S. fishery managers to engage with Mexico to develop a common understanding and recognition of the current overfished population status of Pacific sardine, as well as develop a coordinated management approach to rebuild the stock. The U.S. rebuilding analysis makes clear that Mexican catch cannot be ignored.

The analysis should include a sensitivity analysis demonstrating how the performance of the alternatives change depending on different international exploitation rates.

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[62] Draft EA at 11 ("The decision was made to utilize modeling runs based on the fixed rate assumption for Mexico").
63 David A. Demer & Juan P. Zwolinski (2014) Optimizing Fishing Quotas to Meet Target Fishing Fractions of an Internationally Exploited Stock of Pacific Sardine, North American Journal of Fisheries Management, 34:6, 1119-1130, DOI:10.1080/02755947.2014.951802

VII. Ensure any fishing allowed under rebuilding plan is not likely to jeopardize marine predators protected under the Endangered Species Act

Because Pacific sardine are a critical prey species for many marine predators, fishing on this species may affect marine predators listed under the ESA, including Chinook salmon, California least tern, marbled murrelet, and humpback whales. ESA Section 7(a)(2) requires federal agencies to ensure that no action they authorize, fund, or carry out is likely to "jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [critical habitat]."[64] Therefore, regulations implementing Section 7 provide that: "[e]ach Federal agency shall review its actions at the earliest possible time to determine whether any action *may affect* listed species or critical habitat. If such a determination is made, formal consultation is required . . . ."[65] The "may affect" standard "is a relatively low threshold for triggering consultation."[66] If the proposed action has a "possible" effect on listed species, the consultation requirement is triggered.[67] Formal consultation may only be avoided if, as a result of the preparation of a biological assessment under 50 C.F.R. § 402.12, or as a result of informal consultation under 50 C.F.R. § 402.13, "the Federal agency determines, with the written concurrence of [the Service], that the proposed action is not likely to adversely affect any listed species . . . ."[68]

Where the agency has previously completed ESA consultation on an action, it must reinitiate consultation when, among other circumstances, "new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered."[69] NMFS has not consulted on the effects of CPS fisheries, including Pacific sardine, on ESA-listed marine predators. In particular, NMFS has not evaluated the effects of taking these species when one or more forage species' populations have declined. These effects were recently evident in 2009-2016, when multiple predators experienced mass starvation and breeding failures due to lack of forage (anchovy and sardine). NMFS must apply recent scientific evidence regarding the significant adverse effects of low forage abundance on marine predators, including changes in marine predator behavior, the synergistic effects of potentially simultaneous low anchovy abundance and low abundance levels for sardines and other prey species, reduced breeding success, and starvation events to assess the effects of its rebuilding alternatives on listed species. Conducting this this kind of analysis would clearly demonstrate that the action crosses the "may affect" threshold and therefore NMFS must reinitiate consultation.

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[64] 16 U.S.C. § 1536(a)(2).
[65] 50 C.F.R. § 402.14(a) (emphasis added).
[66] *Karuk Tribe of California v. United States Forest Service,*681 F.3d 1006, 1027 (9th Cir. 2012) (*en banc*).
[67] *Id., citing Cal ex. Rel. Lockyer v. U.S. Dep't of Agric.*, 575 F.3d 999, 1018 (9th Cir. 2009).
[68] 50 C.F.R. § 402.14(b).
[69] 50 C.F.R. § 402.16(b).

The EA selectively and inappropriately cites scientific literature, by cherry picking scientific findings in an attempt to discount the importance of sardines. For example, the EA cites Becker and Beissinger (2006) as evidence for the marbled murrelet that:

> 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."[70] However, that study specifically linked the decline of marbled murrelets to the collapse of the sardine fishery in the late 1940s, and showed through stable-isotope mixing models that the proportion of energetically superior, high-trophic level prey (e.g., sardines) declined strongly whereas energetically poor, low-trophic level and midtrophic level prey increased in the prebreeding diet in cool years when murrelet reproduction was likely to be high. Decreased prey resources have caused murrelets to fish further down on the food web, appear partly responsible for poor murrelet reproduction, and may have contributed to its listing under the U.S. Endangered Species Act.[71]

While the EA discounts the potential effect of Pacific sardine declines in ESA-listed predators based on prey switching, the actual study NMFS cites concludes that the prey switching actually contributed to the listing.

Furthermore, although the draft EA acknowledges sardines are prey for multiple marine mammals, it concludes "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."[72] However, the draft EA omits key research by NMFS scientists directly linking the unusual mortality event of California sea lions to the simultaneous low sardine and anchovy biomass.[73]

Finally, NMFS uses the same faulty assumptions that the full ABC will not be taken and that the model does not accurately capture the full range of sardine productivity to justify its conclusion that the status quo alternative will not affect forage availability.[74]

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[70] Draft EA at 24.
[71] Becker & Beissinger 2006.
[72] Draft EA at 25.
[73] McClatchie, S. et al. 2015. Food limitation of sea lion pups and the decline of forage off central and southern California. Available at: https://www.researchgate.net/publication/267899031_Food_limitation_of_sea_lion_pups_and_the_decline_of_forage_off_central_and_southern_California
[74] Draft EA at 25.

VIII. Analyze the effects of each alternative on EFH for salmon, groundfish, and HMS.

In adding the EFH requirement to the MSA, Congress recognized that

> [o]ne of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of fishery resources of the United States."[75]

Congress required that every FMP "describe and identify essential fish habitat" and "minimize to the extent practicable adverse effects on such habitat caused by fishing," while also identifying "other actions to encourage the conservation and enhancement of such habitat."[76] The MSA therefore requires three categories of actions with respect to EFH: (1) designating EFH; (2) minimizing harmful fishing impacts to EFH; and (3) actively protecting and enhancing EFH.

To protect EFH, Councils are required to "prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable, if there is evidence that a fishing activity adversely affects EFH in a manner that is more than minimal and not temporary in nature."[77] Adverse effects mean "any impact that reduces quality and/or quality of EFH," and may include "direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH."[78]

Current EFH designations for HMS recognize that Pacific sardine is a major prey item for common thresher shark, shortfin mako shark, bluefin tuna, and striped marlin.[79] In addition, Pacific sardine are EFH for groundfish and salmon.[80]

The NMFS regulatory guidance on EFH explains that prey species are a component of EFH and that fishing removals of prey may be an adverse impact to EFH:

> (7) *Prey species*. Loss of prey may be an adverse effect on EFH and managed species because the presence of prey makes waters and substrate function as feeding habitat, and the definition of EFH includes waters and substrate necessary to fish for feeding.

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[75] 16 U.S.C. § 1801(a)(9); *see also id.* § 1801(a)(2) (recognizing that direct and indirect damage to habitat diminishes the capacity to support fishing).
[76] 16 U.S.C. §§ 1801(9), 1853(a)(7).
[77] *Id.* § 600.815(a)(2)(ii).
[78] *Id.* § 600.810(a).
[79] PFMC 2003. Life History Accounts and Essential Fish Habitat Descriptions. Appendix A to the Fishery Management Plan and Environmental Impact Statement for U.S. West Coast Fisheries for Highly Migratory Species. https://www.pcouncil.org/documents/2003/08/hms-fmp-essential-fish-habitat-life-history-accounts-and-essential-fish-habitat-descriptions.pdf/
[80] *See,* Salmon FMP Appendix A (Sept. 2014); Groundfish FMP Appendix B, Part 2 (June 2019).

> Therefore, actions that reduce the availability of a major prey species, either through direct harm or capture, or through adverse impacts to the prey species' habitat that are known to cause a reduction in the population of the prey species, may be considered adverse effects on EFH if such actions reduce the quality of EFH. FMPs should list the major prey species for the species in the fishery management unit and discuss the location of prey species' habitat. Adverse effects on prey species and their habitats may result from fishing and non-fishing activities.[81]

According to the EFH guidance, "Each FMP must minimize to the extent practicable adverse effects from fishing on EFH, including EFH designated under other Federal FMPs."[82]

The EA fails to analyze how the various alternatives will affect EFH. Indeed, the EA never discusses the potential impacts to common threshers, shortfin makos, bluefin tuna, or striped marlin, making only generalized statements that "several shark species" feed on sardines and that "most Pacific sardine predators are generalists."[83] The fact that "most" sardine predators are generalists does not excuse NMFS and the Council from analyzing the amendment's impact to each species' EFH. The final EA must include this missing analysis.

We note that NMFS and the Council are currently undertaking a review of HMS EFH, and our organizations requested a review of how fishery removals of HMS prey species may affect HMS EFH in March 2021.[84] The Council and NMFS indicated that the appropriate venue to analyze and address such impacts of fishery prey removals would be in the existing management processes for any HMS prey species within the Council's purview.[85] Because the sardine rebuilding plan is an existing management process for an HMS prey species, the rebuilding analysis must include an analysis of the effects of the rebuilding alternatives on EFH for other Council managed species.

IX. Review previous efforts to rebuild Pacific sardine

Pacific sardine famously were the foundation and the demise of the Cannery Row era of the 1930s to 1950s. However, as the population dwindled due to low recruitment and excessive harvest rates in the 1950s and 60s, fishery managers incrementally took steps to reduce fishing mortality on Pacific sardine. Those measures ultimately proved to be too little, too late as continued incidental catch in other fisheries and catch of sardines for bait continued to drive the

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[81] 50 C.F.R. § 600.815(a)(7).
[82] *Id.* at § 600.815(a)(2)(ii).
[83] Draft EA at 24-25.
[84] Oceana and Earthjustice. 2021. Letter to Chair Gorelnik., March 1, 2021. Agenda Item H.2. https://pfmc.psmfc.org/CommentReview/DownloadFile?p=86da5364-b530-4fdd-b5cc-54f9a3a0f741.pdf&fileName=H2-oceana-earthjustice-hmsefh_3-1-21.pdf
[85] HMS MT Report on Review of EFH - Phase 2. March 2021 Agenda Item H.2.a https://www.pcouncil.org/documents/2021/03/h-2-a-supplemental-hmsmt-report-1.pdf/

population down. Eventually, the California legislature instituted a complete moratorium on all sardine fishing in 1974.

Nearly two decades after the initial moratorium, the directed fishery resumed in 1986 with a harvest limit of only 1,000 mt, while the live bait quota was set at 150 mt.[86] The directed fishery catch limit remained at 1,000 mt until 1991. In 1993, management authority was transferred to the Council with the implementation of the CPS FMP. Optimistically the author reports, "[a] bilateral management agreement with Mexico to facilitate the cooperative management of coastal pelagic species is a high priority for the plan."[87] Unfortunately, fishery managers did not prioritize such an agreement and the lack of coordinated management with Mexico and Canada continues to plague sustainable fishery management. As we now know, the sardine population never came close to the peak abundance seen off the West Coast in the 1930s before once again collapsing with changing ocean conditions and high exploitation rates.[88] As is oft quoted, those who cannot remember the past are condemned to repeat it. NMFS should consider the history of sardine management off our coast as a warning for what could happen if precautionary, science-based management measures are not implemented to rebuild the species.

X. Support conclusions in the EA with data and analysis

Under NEPA, agencies must take a "'hard look' at the likely effects of the proposed action. Taking a 'hard look' includes 'considering all foreseeable direct and indirect impacts.'" An EA also 'must fully assess the cumulative impacts of a project.'"[89]

The EA fails to take a hard look at the impacts of the preferred alternative. As discussed above in Section I, the preferred alternative, status quo management, allows annual catch up to the ABC.[90] The EA states that annual catch equal to the ABC would result in a sardine population that never rebuilds.[91] However, the EA does not analyze the impacts to sardines or the ecosystems that depend on sardines if the population never recovers. Instead, the agency claims that the stock will rebuild because recent catch levels have been below the authorized amount.[92] But status quo management does not constrain catch to these lower levels, and neither NMFS nor the Council proposes to constrain catch to these levels in the preferred alternative. NMFS

[86] Wolf, P. 1992. The Recovery of the Pacific sardine and the California Sardine Fishery. CalCOFI Rep., Vol. 33,1992. Table 2, Available: http://calcofi.org/publications/calcofireports/v33/Vol_33_Wolf.pdf.
[87] *Id*. at p. 10.
[88] Zwolinski, J. and DA Demer. 2012. A cold oceanographic regime with high exploitation rates in the Northeast Pacific forecasts a collapse of the sardine stock. Proceedings of the National Academy of Sciences (PNAS) 109 (11). 4175-4180. Available at: http://www.pnas.org/content/early/2012/02/24/1113806109.full.pdf
[89] *Ctr. for Biological Diversity v. Salazar*, 695 F.3d 893, 916–17 (9th Cir. 2012).
[90] Draft EA at 8 ("An [ACL] is then set at or below the ABC to account for any management uncertainty.").
[91] *Id*. at 14 ("when the full ABC is … taken, there is never a greater than 50 percent probability that the stock will rebuild").
[92] *Id*. at 25-26.

must analyze the impacts of authorized activity, not the expected outcome. Because the authorized action will result in a population that never recovers, the EA must analyze how an indefinitely depleted sardine stock will affect sardines, the ecosystems that depend on sardines, listed species that depend on sardine species, and the fishing community over the long term.

The EA also fails to take a hard look at the economic impacts of the action, relying instead on conclusory statements to justify the preferred alternative. For example, the EA concludes that Alternative 2 would destroy multiple industries that rely on the live bait fishery.[93] The EA likewise concludes that Alternative 3 would "have drastic adverse impacts to not only the live bait industry, but would also seriously disrupt various recreational fisheries, most notably in Southern California."[94] But the EA fails to support these conclusions with analysis. Notably the EA does not discuss the economic impact of shorter rebuilding timeframes or whether the live bait fishery could switch to other forage fish such as anchovy. The discussion in the EA contradicts results from analysis by the CPS MT showing that Alternative 3 (5% US catch) outperforms Alternative 1 (status quo) by keeping the stock at higher levels:

> *In comparison, Alternative 1 initially allows higher levels of Pacific sardine catch to the input fisheries, but estimated catch levels fall below the 2015-2019 1,965 mt benchmark leading to a constrained fishery earlier (in 2037 versus 2043), while Alternative 3 is associated with lower levels of projected catch initially and maintains estimated catch above the 1,965 mt benchmark for a longer period of time. Upon classification as input constrained, median projected catch under Alternative 1 falls to 43 percent of the benchmark, whereas under Alternative 3 it falls to 88 percent of benchmark. Under the assumption that for the input fishery increases in catch above the benchmark have a low marginal value, it is argued that the annual value of the associated fisheries is roughly on the same order of magnitude between Alternatives 1 and 3. If the limits are not constraining for either Alternative 1 or 3, then there may be no meaningful difference between these alternatives for years where catch is above the benchmark. However, catch allotments under Alternative 1 would provide a larger buffer.*
>
> *In this case, the projected present value of the stream of value associated with Alternative 1 and 3 is driven by the number of years that the fishery operates in input status before being constrained, the degree that the associated fisheries will be constrained, and the discount rate.* ***By both measures, the fisheries under Alternative 3 are projected to have a higher value than under Alternative 1****. First, under Alternative 3, it is projected that the fishery operates in unconstrained input status for 6 years longer; second, under Alternative 3, the associated fisheries face a reduction in catch to 88 percent of benchmark versus to 43 percent of benchmark*. Lastly, under Alternative 3, Pacific sardine is projected to rebuild at a 50 percent probability by 2047, whereas under Alternative 1 the Pacific

[93] *Id.* at 21.
[94] *Id*. at 22.

> sardine is not projected to rebuild at a 50 percent probability by the end of the reporting period in 2050.[95]

These statements indicate that at least a cursory quantitative economic analysis was conducted. However, nowhere in the EA does this analysis appear nor is it referenced, and in fact the draft EA contradicts these results by inappropriately comparing Alternative 3 to a 2,200 mt constant catch approach.[96]

The economic analysis is not only scant; it is also flawed. To minimize the negative economic impacts of Alternative 1, the EA states that the model is unrealistic, and that under "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."[97] But this would be true under all the alternatives, not just Alternative 1. If NMFS wants to incorporate the possibility of higher recruitment values when analyzing Alternative 1, NMFS must also incorporate the possibility of higher recruitment values when analyzing Alternatives 2 and 3. To do otherwise arbitrarily favors Alternative 1 and presents an inaccurate picture of the economic impacts of each alternative in relation to the others.

Finally, NMFS relies on prey switching to conclude that there would not be "measurable difference in benefits between the rebuilding timelines" for predators.[98] Yet, NMFS does not apply this same logic to the live bait fishery. NMFS cannot say that those predators will simply switch to anchovy while at the same time concluding that fish targeted by the live bait fishery would not also be attracted by anchovy to support the recreational fishermen while sardine are at low levels. In fact, live bait switching to anchovy was contemplated in the CPS FMP. Moreover, NMFS fails to explain why predators, including protected species, should be expected to simply switch to other prey without adverse impacts but live bait users cannot.

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[95] CPS MT Supplemental Report 3. September 2020 (emphasis added). https://www.pcouncil.org/documents/2020/09/g-1-a-supplemental-cpsmt-report-3.pdf/

[96] Draft EA at 23 ("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.").

[97] *Id*. at 20.

[98] *Id*. at 25.

XI. Because the population never rebuilds under the preferred alternative, the action results in a significant environmental impact and NMFS must prepare an EIS

As discussed above, when an "EA reveals that the proposed action will significantly affect the environment, then the agency must prepare an EIS."[99] To trigger the need for an EIS, a "plaintiff need not show that significant effects will in fact occur [;] raising substantially questions whether a project may have a significant effect is sufficient."[100]

When determining whether an impact is significant, agencies should consider the impact to listed species, whether the action will violate other environmental laws, and various other factors. Here, the EA demonstrates that the preferred alternative will violate another environmental law, the MSA. The MSA requires decision-makers to use the best available science. As previously explained above in Sections II(b) and III, NMFS and the Council have failed to meet this bar. In addition, the MSA requires NMFS to rebuild overfished stocks.[101] As explained above in Section I, the EA's preferred alternative fails to rebuild this stock. In fact, the agency's own model shows that the sardine population does not rebuild by 2050, the last year modeled.[102] Thus, the action at issue in the EA violates another environmental law and is therefore significant, requiring an EIS.

The action's impact to listed species under the ESA also influences whether an action is significant under NEPA. Sardines are an important food sources to multiple listed species, such as humpback whales and marbles murrelets. The EA dismisses this impact, stating "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 …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."[103] However, this analysis ignores the impact of an indefinitely depleted stock. If sardines never rebuild before 2050 as the model indicates, and anchovies fluctuate downward, then presumably listed species dependent on this "suite of species" may still be affected. Because the action affects listed species, the action is significant and an EIS is required.

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[99] *Kern v. U.S. Bureau of Land Mgmt.*, 284 F.3d 1062, 1067 (9th Cir. 2002)).
[100] *Idaho Sporting Cong. v. Thomas*, 137 F.3d 1146, 1149–50 (9th Cir.1998).
[101] 16 U.S.C. 304(e)(3).
[102] EA at 14.
[103] EA at 25.

XII. The EA's rebuilding analysis is confused, misleading and frustrates NEPA's purpose to inform and include the public in environmental decision-making

As stated above, one of NEPA's main goals is to inform and include the public in the government's environmental decision-making.[104] The public must therefore be able to understand NEPA documents. "When the public reviews an EIS to assess the environmental harms a project will cause and weighs them against the benefits of that project, the public should not be required to parse the agency's statements to determine how an area will be impacted, and particularly to determine which portions of the agency's analysis rely on accurate and up-to-date information, and which portions are no longer relevant."[105] Indeed, "[t]his lack of clarity likely renders … [an] EIS deficient."[106]

Here, the EA is so confused and misleading, it frustrates the public's ability to understand and participate in the NEPA process. Specifically, the EA misrepresents the status quo management, which is the preferred alternative. The EA refers to two additional management options (an ACL of 2200 MT and an ACL of 472 MT) as part of Alternative 1 to conclude that the stock will rebuild within 17 years.[107] But, in reality, NMFS authorizes annual catch up to the ABC, and the model shows that annual catch up to the ABC results in a sardine population that does not rebuild.[108] If NMFS is contemplating a catch limit of 2200 mt or 472 mt, the EA should present those management options as two additional alternatives and analyze them as such. Failing to do so misrepresents the preferred management option the EA is actually proposing, misleading the public and decision-makers.

The EA is further confusing by presenting results from a rebuilding model that the agency clearly believes is not best available science, then bringing in qualitative narratives that call its own results into question. Furthermore, the EA does not contain any of its analyses or a comprehensive presentation of their results. The public is instead required to refer to a series of other documents as well as analysis that has not been made public at all, which violates NEPA.[109]

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[104] *Dep't of Transp. v. Pub. Citizen*, 541 U.S. 752, 768, 124 S.Ct. 2204, 159 L.Ed.2d 60 (2004).
[105] *League of Wilderness Defs./Blue Mountains Biodiversity Project v. Connaughton*, 752 F.3d 755, 761 (9th Cir. 2014).
[106] *Id*.
[107] Draft EA at 26.
[108] *Id*.
[109] See *Siskiyou Reg'l Educ. Project v. Rose*, 87 F. Supp. 2d 1074, 1098 (D. Or. 1999), stating "CEQ regulations permit, under certain conditions, incorporation by reference in an EIS, but there are no provisions allowing such a procedure in an EA. Even if incorporation by reference is allowed in an EA, "[t]he propriety of such incorporation is dependent upon meeting three standards: 1) the material is reasonably available; 2) the statement is understandable without undue cross reference; and 3) the incorporation by reference meets a general standard of reasonableness."

CONCLUSION

As described above, the draft EA and the rebuilding plan it purports to analyze are fundamentally flawed and unlawful. NMFS must remedy the issues explained above to ensure the sardine rebuilding plan complies with the law and ensures the recovery of this ecologically crucial species.

Sincerely,

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Cc: Chuck Bonham, Director, California Department of Fish and Wildlife

Attachments:

1. Zwolinski, J. and DA Demer. 2012. *A cold oceanographic regime with high exploitation rates in the Northeast Pacific forecasts a collapse of the sardine stock. Proceedings of the National Academy of Sciences (PNAS) 109 (11). 4175-4180.* Available at: http://www.pnas.org/content/early/2012/02/24/1113806109.full.pdf
2. D.A. Demer & J.P. Zwolinski (2017) *A Method to Consistently Approach the Target Total Fishing Fraction of Pacific Sardine and Other Internationally Exploited Fish Stocks*, North American Journal of Fisheries Management, 37:2, 284-293.
3. Zwolinski, JP and DA Demer. 2019. *Re-evaluation of the environmental dependence of Pacific sardine recruitment*. Fisheries Research 216, 12-125. Available: https://usa.oceana.org/sites/default/files/593/zwolinski_and_demer_-_2019_-_re-evaluation_of_the_environmental_dependence_of_p.pdf
4. Lindegren et al. 2013. *Climate, fishing, and fluctuations of sardine and anchovy in the California Current*. Proceedings of the National Academy of Sciences www.pnas.org/cgi/doi/10.1073/pnas.1305733110
5. Essington et al. 2015. *Fishing amplifies forage fish population collapses*. www.pnas.org/cgi/doi/10.1073/pnas.1422020112
6. Becker and Beissinger. 2006. *Centennial Decline in the Trophic Level of an Endangered Seabird after Fisheries Decline*. Conservation Biology Volume 20, No 2, 470-479.
7. Hurtado-Ferro and Punt 2014. *Revised Analyses Related to Pacific Sardine Harvest Parameters*. In April 2014 PFMC Coastal Pelagic Species Briefing Book.