REVISED DRAFT PACIFIC SARDINE REBUILDING PLAN

INCLUDING REBUILDING PLAN SPECIFICATIONS, PRELIMINARY DRAFT 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

SSP southern subpopulation

SWFSC Southwest Fisheries Science Center

U & A Usual and Accustomed Area (Tribal)

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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, Crone, & Zwolinski, 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)). The Council adopted a rebuilding plan (Amendment 18 to the CPS FMP) on June 15, 2020. The plan was approved by NMFS on June 14, 2021.

On April 22, 2024, the U.S. District Court for the Northern District of California (Court) issued a decision holding that NMFS violated the MSA in establishing the rebuilding timeframe by assuming catch levels significantly below the annual catch limit (ACL) based on historic catch data and management measures used in the fishery. The Court also held that the associated Environmental Assessment (EA) violated the National Environmental Policy Act (NEPA) due to NMFS' reliance on flawed assumptions in comparing alternatives, and by failing to take a hard look at impacts to the humpback whale and its critical habitat. On June 28, 2024, the Court issued its order on remedy, vacating the portions of Amendment 18 (Rebuilding Plan for Pacific Sardine) that it found invalid and remanding the remainder to NMFS without vacatur. The Court also vacated the EA in its entirety. The Court required NMFS to prepare a compliant rebuilding plan and EA by June 1, 2025. In this remedy, the Court only vacated portions of Amendment 18, meaning the entire original amendment and related analysis does not need to be abandoned. Rather, the revised Pacific sardine rebuilding plan and related EA can closely follow the original amendment, making revisions as necessary, to respond to the court's order. In response to the court order this document analyzes new proposed alternatives for the rebuilding plan that rely on Acceptable Biological Catch (ABC)/ACLs to achieve the rebuilding target for Pacific sardine. The Council will also need to consider if T_{TARGET} should be revised to align with the new rebuilding strategy.

Additionally, the Court found that NMFS violated the MSA in setting the overfishing limit (OFL) because NMFS relied on a scientific methodology, relying exclusively on the California Cooperative Fisheries Investigations (CalCOFI) temperature index, that had been shown to result in artificially high OFLs that do not reliably indicate when overfishing is occurring, without accounting for that bias. The CPS FMP Section 4.6.4 describes the current OFL and ABC harvest control rules (HCRs) for Pacific sardine, which are also described in Section 1.4. Changes to E_{MSY} or the HCRs are not considered in this document and will be considered as a part of the upcoming 2025-2026 harvest specifications. Ultimately though, the harvest specifications are dependent upon the recommendation of the Scientific and Statistical Committee (SSC). Therefore, to comply with the court orders, methodology for setting the harvest specifications will be considered in April 2025.

This document is intended to meet the analytical needs and statutory requirements associated with an EA/MSA analysis. An EA/MSA provides assessments of the environmental impacts of a proposed action and its reasonable alternatives (the EA), and analysis of how the alternatives align with the National Standards (MSA). An EA/MSA is a standard document produced by the Council and the NMFS West Coast Region to provide the analytical background for decision-making.

1.1 PURPOSE AND NEED

The purpose of the proposed action is to develop a revised rebuilding plan for Pacific sardine in response to recent Court decisions.

1.2 HISTORY OF THIS ACTION

NMFS declared the NSP of the Pacific sardine overfished in June 2019. 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 CPSMT then compiled a preliminary EA that was considered by the Council and took final action at its September 2020 meeting. In June 2021, NMFS approved the plan (86 FR 33142).

Amendment 18 set a rebuilding target for Pacific sardine at 150,000 mt age 1+ biomass (hereafter referred to as "stock biomass" or "biomass"). The rebuilding plan maintained "Status Quo" management processes including HCRs and other FMP provisions already in place for Pacific sardine. 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 value, automatically triggering a preemptive closure of the fishery (see Section 4.6.1 of CPS FMP). 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 CPS FMP) 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 ABC and OFL since and before the closure of the primary directed fishery.

On April 22, 2024, the U.S. District Court for the Northern District of California issued a decision holding that NMFS violated the MSA in establishing the rebuilding timeframe by assuming catch levels significantly below the ACL based on historic catch data and management measures used in the fishery. The Court left portions of the rebuilding plan intact, including the rebuilding target age 1+ biomass of 150,000 mt. In order to comply with the Court's June 28, 2024 order on remedy and implement a compliant rebuilding plan by June 1, 2025, the Council needs to take final action at this meeting to make modifications to their rebuilding plan. The revised rebuilding plan builds off the original rebuilding plan, and the existing analysis. Due to the limited scope of the revisions and precedence of the original analysis, it is possible for the Council to take final action in this compressed timeline.

1.3 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.

1.4 CURRENT MANAGEMENT

1.4.1 REBUILDING PLAN SPECIFICATIONS

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). The rebuilding target was established at 150,000 mt age 1+ Pacific sardine biomass- which aligned with the CUTOFF threshold already defined in the CPS FMP. T_{MIN} and T_{MAX} were determined via the rebuilding analysis documented in the Addendum to the Sardine Rebuilding Document and the Pacific Sardine Rebuilding Analysis Based on the 2020 Stock Assessment (Hill, Kuriyama, & Crone, 2020); available in Appendices A and B.

These Rebuilding Reference Points are summarized below:

Rebuilding Reference Points

T_{MIN} = 12 years

T_{MAX} = 24 years

Rebuilt biomass = 150,000 mt age 1+ biomass

Additionally, rebuilding plans must contain a T_{TARGET} which is defined in NS 1 as the specified time period for rebuilding a stock that is considered to be as short a time as possible, taking into account the factors described in paragraph (j)(3)(i) of Section 50 CFR 600.310. T_{TARGET} shall not exceed T_{MAX}. In 2020, the Council recommended Alternative 1 as its final preferred alternative and a resulting T_{TARGET} of 14 years to reach the target rebuilding biomass level of 150,000 mt age 1+ Pacific sardine biomass. This T_{TARGET} was 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. In consideration of a new rebuilding plan, the Council will need to reconsider an associated T_{TARGET}.

1.4.2 SARDINE MANAGEMENT

Management of Pacific sardine is described in Section 4.6.4 of the CPS FMP. Management measures include 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 (MSST). According to the FMP, a rebuilding plan may be implicit in maintaining “status quo” management due to the closure of the fishery and additional restrictions on incidental harvest.

HCRs for the OFL and ABC sardine are calculated annually based on an estimate of that year’s estimated biomass typically 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.

The Pacific sardine HCRs include the following:

OFL = Biomass * E_{MSY} * Distribution

ABC = Biomass * BUFFER * 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 and the value used for it is determined annually based on recommendations from the Council’s SSC.
- 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, the Council can incorporate various additional management measures to limit Pacific sardine harvest, if warranted. For example, the Council and NMFS have implemented additional voluntary accountability measures (AMs) in years when the stock fell below 50,000 mt. For the 2022-2023 fishing year, the Council adopted an annual catch target (ACT) of 3,800 mt where if attained, a 1 mt per-trip limit of Pacific sardine landings would apply to all CPS fisheries. The Council also adopted an AM specific to the 2023-2024 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

Table 1. Landings vs. ABC since implementation of Amendment 18. Data retrieved from the 2024 PacFIN SAFE Portal. Retrieve online here.

Fishing Year	Landings (mt)	ABC (mt)	OFL (mt)	ACL (mt)
2019-2020	2,085.26	4,514	5,816	4,514
2020-2021	2,497.72	4,288	5,525	4,288
2021-2022*	1,769.16	3,329	5,525	3,329

2022-2023	1,617.47	4,274	5,506	4,274
2023-2024	1,773.83	3,953	5,506	3,600

* = year Amendment 18 rebuilding plan was implemented

2 DESCRIPTION OF ALTERNATIVES

The scope of alternatives for potential consideration will be narrow because the management framework in the CPS FMP already dictates the closure of the fishery when the biomass is below 150,000 mt, as well as other management actions that would typically be implemented under a rebuilding plan to minimize fishing mortality on an overfished stock. Further, the entirety of the Amendment 18 rebuilding plan was not vacated. Additionally, NMFS has been ordered to implement a compliant rebuilding plan by June 1, 2025, leaving the Council limited time to respond.

Therefore, the range of alternatives presented below are based on these existing elements of the CPS FMP, including those associated with the Amendment 18 rebuilding plan that were not invalidated by the court (i.e., the 150,000 mt rebuilding target and the original T_{MAX}, T_{MIN} as independent components of the rebuilding plan as described in Section 1.4.1), but are also responsive to the Court's orders and in compliance with the MSA. Alternatives 1-3 were included in the original rebuilding plan, and Alternatives 4-6 were drafted based on analysis that occurred in support of the original rebuilding plan but are responsive to the court's orders.

Regarding the alternatives presented below, Alternative 1 represents "No Action," maintaining status quo management and therefore the implicit rebuilding measures and catch restrictions that are already in effect per the CPS FMP. Alternatives 2 - 6 present ACLs that are intended to achieve the rebuilding target of 150,000 mt age 1+ biomass within the rebuilding timeframe. All five of these alternatives would require NMFS to adopt a revised rebuilding plan and therefore are action alternatives. 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 set an ACL at five percent of the biomass for that year. Alternative 4 would have a constant catch ACL of 2,200 mt. Alternative 5 would set a constant catch ACL of 3,200 mt. Alternative 6 is a modified Alternative 3 that uses mixed ACLs based on tiered levels of stock biomass.

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

2.1 ALTERNATIVE 1 (NO ACTION)

Alternative 1 (No Action) would maintain the conservation and management measures in the CPS FMP adopted under the Amendment 18 rebuilding plan, which are the "status quo" management processes, HCRs, and other provisions already 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. According to the FMP, a rebuilding plan may be implicit in maintaining "status quo" management due to the closure of the fishery and additional restrictions on incidental harvest.

Alternative 1 also maintains the Council's existing annual harvest specifications process, the "status quo" from the Amendment 18 rebuilding plan 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 and recommendations on those values from the Council's SSC. 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. Alternative 1 would not set a specific ACL to support rebuilding, but rather annually set an ACL at or below the ABC to account for any management uncertainty.

While this alternative assumes Pacific sardine catch will never reach the ABC/ACL due to the conservation and management measures required by the FMP (specifically, the closure of the sardine fishery), it does not set a specific ACL at that expected level of harvest.

2.2 ALTERNATIVE 2 – ZERO HARVEST RATE

Alternative 2 (Zero Harvest) would adopt a revised rebuilding plan using a U.S. zero-harvest approach that would entail 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.

This alternative was originally considered and is primarily considered here now for modeling and analysis purposes to aid in determining a T_{MIN} for a rebuilding timeline. Per NMFS' National Standard 1 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. The ACL would be set to zero under this alternative, and management measures would be required to be developed to achieve this. 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.

2.3 ALTERNATIVE 3 – FIVE PERCENT FIXED U.S. HARVEST RATE

Alternative 3 would revise the rebuilding plan to set the ACL at five percent of total age 1+ biomass for that year. The OFL and ABC would be computed using existing HCR formulas; however, under this alternative, the allowable harvest level (i.e., the ACL) would be fixed at five percent and incorporate 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 recommendation process. This alternative was intended to represent a harvest level between Alternative 1 (No Action) and Alternative 2 Zero U.S. Harvest to explore the differences in rebuilding timelines of a reduced harvest level. To illustrate, Table 2 compares the ACLs used for management since 2015 with the ACLs this alternative would have produced.

2.4 ALTERNATIVE 4 – CONSTANT CATCH

Under Alternative 4, the OFL and ABC would continue to be set using the default HCRs as described in the CPS FMP. The ACL would be set at 2,200 mt or the calculated ABC if that result is lower than 2,200 mt. This alternative was modeled in the original rebuilding analysis to represent the average catch of 2,200 mt (average of 2015-2020 catches) in an attempt to better understand the true rebuilding timeline under status quo management.

2.5 ALTERNATIVE 5 – MODIFIED CONSTANT CATCH

Under Alternative 5, the OFL and ABC would continue to be set using the default HCRs as described in the CPS FMP. The ACL would be set annually at 3,200 mt or the calculated ABC if that result is lower than 3,200 mt.

The 3,200 mt constant catch value that would be implemented under Alternative 5 is based on historical catch data (see Table 1), which defines the current level of industry operation, but would allow the interannual flexibility and opportunity that Alternative 4 (a static ACL of 2,200 mt) might not. Because the 2,200 mt value is an average catch value, there are inherently years when catch has been above 2,200 mt and years when catch has been below. A buffer was added to the highest annual catch since 2015 (2,865 mt in the 2020-2021 fishing year) to propose the 3,200 mt ACL. A modified constant catch harvest allows for a buffer above recent average annual catch, while limiting the ability of ACLs to increase as they would under a five percent rate (Alternatives 3 and 6). This alternative would allow for rebuilding while providing for those years when, while the directed fishery remains closed, the live bait fishery and the other CPS fisheries that incidentally catch sardine need flexibility to adapt to changes in the environment, stock dynamics, incidental encounter rates, or market/economic. When the Council originally chose status quo, the primary reasoning was to allow for the interannual variability in catches that is seen in the fisheries that incidentally catch sardine due to different mixing rates among years and changing market demand in the live bait fishery. Alternative 5 seeks to meet this goal by buffering the recent average catch and allowing those fluctuations in catch levels.

2.6 ALTERNATIVE 6 – MIXED RATE U.S. HARVEST

Under Alternative 6, annual OFLs and ABCs would continue to be set using the default HCRs as described in the CPS FMP; however, an ACL would be set conditional upon certain tiered biomass levels, allowing the ACL to adjust based on the status of the stock. This is a modified version of Alternative 3 to address concerns that the static five percent harvest rate would result in negative economic consequences to the fleet at lower biomass levels.

UNDER 50,000 MT (Overfished Status)

If the stock biomass is less than 50,000 mt in a given fishing year, the ACL would be set annually at 2,200 mt or the calculated ABC (if that result is lower than 2,200 mt, as the ACL cannot be higher than the ABC).

OVER 50,000 MT (Rebuilding Status)

If the stock biomass is greater than 50,000 mt in a given fishing year, the ACL would be set annually at five percent of total age 1+ biomass for that year.

Alternative 6, which modifies Alternative 3, was added to the range of alternatives to address the economic restrictions of Alternative 3 under low biomass levels and provide more flexibility than a constant catch ACL may permit. As mentioned above, when the Council took action to select Alternative 1, status quo, for implementation of Amendment 18, the primary reasoning was to allow for the interannual variability in the fisheries that incidentally catch sardine due to different mixing rates among years and a changing market demand in the live bait fishery. Therefore, Alternative 6 factors in some of the economic considerations the Council used in selecting status quo management. Additionally, Alternative 6 may provide additional flexibility to go above the recent average catch as the stock biomass increases and there becomes the potential for higher incidental encounter rates. In comparison to Alternative 4, Alternative 6 would allow more flexibility above 50,000 mt. In comparison to Alternative 3, ACLs under Alternative 6 would be less restrictive when stock biomass is below 50,000 mt, allowing for up to recent average annual landings to avoid restriction of economically important sectors and/or reduce the potential for discard at sea.

Table 2. Annual Pacific sardine harvest specifications and landings from fishing years following closure of the primary directed fishery. Landings information is sourced from PacFIN database. All weight values in mt.

Fishing Year	Biomass	OFL	ABC	Actual ACL	ACT	Landings	Proposed ACL under Alt 3	Proposed ACL under Alt 4	Proposed ACL under new Alt 5	Proposed ACL under new Alt 6
2014-15	369,506	39,210	35,792	23,293 28,646*	23,293	19,440	18,475	2,200	23,293 28,646*	23,293 28,646* 3,200
2015-16	96,688	13,227	12,074	7,000	4,000	2,329	4,834	2,200	3,200	4,834
2016-17	106,137	23,085	19,236	8,000	5,000	2,217	5,307	2,200	3,200	5,307
2017-18	86,586	16,957	15,479	8,000	-	2,190	4,329	2,200	3,200	4,329
2018-19	52,065	11,324	9,436	7,000	-	2,505	2,603	2,200	3,200	2,603
2019-20	27,547	5,816	4,514	4,514	4,000	2,063	1,377	2,200	3,200	2,200
2020-21	28,276	5,525	4,288	4,288	4,000	2,865	1,413	2,200	3,200	2,200
2021-22*	28,276	5,525	3,329	3,329	3,000	1,750	1,413	2,200	3,200	2,200
2022-23*	27,369	5,506	4,274	4,274	3,800	1,777	1,368	2,200	3,200	2,200
2023-24*	27,369	5,506	3,953	3,953	3,600	1,713	1,368	2,200	3,200	2,200
2024-25*+	58,614	5,506	3,953	3,953	3,600	-	2,930	2,200	3,200	2,931

* Year/specifications after Amendment 18 rebuilding plan implemented
+ Interim rule

2.7 FINAL PREFERRED ALTERNATIVE

To be completed after November 2024

2.8 COMPARISON OF ALTERNATIVES

Table 3. Comparison of Range of Alternatives.

	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**Alternative 6**
	No Action	Zero Harvest	5% Fixed Harvest Rate	Constant Catch	Modified Constant Catch	Mixed Rate
Description	Current rebuilding plan, management practices, HCRs, and other FMP provisions in place	Complete closure of fisheries targeting sardine and elimination of incidental landing in CPS and non-CPS fisheries	Set the ACL at five percent of total age 1+ biomass for that year	Set the ACL to the lesser of ABC or 2,200 mt	Set the ACL to the lesser of ABC or 3,200 mt	Biomass < 50,000 mt: set the ACL to the lesser of 2,200 mt or ABC Biomass > 50,000 mt: set the ACL to 5% of total age 1+ biomass for that year
ACL	Determined Annually	0	5% biomass (1+)	2,200 mt	3,200 mt	Biomass < 50,000 mt: 2,200 mt Biomass >50,000 mt: 5% biomass (1+)
Chance of Rebuilding by T_{MAX}	< 50%	> 50%	> 50%	>50%	> 50%	Likely > 50%
Years to Rebuild	Not within modeled timeframe	12 years	Less than 16 years	Less than 17 years	Less than 17 years	Less than T_{MAX}

2.9 ALTERNATIVES CONSIDERED BUT NOT ANALYZED FURTHER

The CPSMT originally proposed an alternative "Reduced Status Quo" in the rebuilding plan considerations for Amendment 18, which, similar to Alternative 3, provided an option with a harvest level in between Alternative 1 Status Quo Management and Alternative 2 U.S. Zero Harvest. However, this "Reduced Status Quo" alternative did not include a specific level of reduction. By adding and describing Alternatives 4 and 5, the Council may reconsider what "reduced status quo" would look like in practice, setting ACLs at recent average catch rates, with some room for flexibility as the stock expands.

3 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, in the context of rebuilding timelines, may impact that component of the Affected Environment. The analyses take into consideration more than just the results of the biological modeling work (Hill, Kuriyama, & Crone, Pacific sardine rebuilding analysis. PFMC September 2020 Briefing Book Agenda Item G.1.a, 2020); it was also necessary to rely on what is known about the basic biology and life history of Pacific sardine, including estimates of its large population fluctuations over thousands of years, and the history of the Pacific sardine fishery on the west coast of North America.

The analysis below focuses on impacts to sardine (target species), including their role in the ecosystem as prey for a variety of other fish, marine mammals and seabirds, and relevant CPS and non-CPS fishing industries. As there are no proposed changes to fishing gear types, fishing areas and seasons, or other key aspects of how the affected fisheries are or will be prosecuted and the primary directed fishery will remain closed, the scope of the affected environment analysis is narrow. For example, no effects are presumed for non-target or prohibited species or for the habitat of Pacific sardine or other Council managed fish stocks. This action, as noted above, does not change the fact that the directed sardine fishery is closed, and beyond the total number of sardines harvested in any given year, other operational aspects of fisheries will not be changing with this action.

3.1 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 A. E., 2012) but was revised to allow for rebuilding projections based on Pacific sardine HCRs (Punt, et al., 2016). 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 to Amendment 18 - Pacific Sardine Rebuilding Analysis

Based on the 2020 Stock Assessment (Hill, Kuriyama, & Crone, 2020). The intent of this modeling was, in part, to help guide the analysis of management alternatives for rebuilding Pacific sardine; however, since Pacific sardine recruitment and productivity are largely driven by environmental conditions, which cannot be accurately predicted, it was expected that the modeling results would have limitations in informing realistic rebuilding timelines.

For alternatives included in the original rebuilding plan (1-3), the Rebuilder tool was used to calculate: 1) the probabilities (at least 50 percent chance) of rebuilding the NSP of Pacific sardine stock to a modeled SBMSY (spawning stock biomass at maximum sustainable yield (MSY)) and the selected target rebuilding biomass level (expressed in terms of age 1+ biomass – see 5.3.1 for further detail), 2) median spawning stock values, and 3) median catch values. These values were calculated based on two different time periods that represent moderate and low Pacific sardine productivity and two different levels of potential harvest by Mexico (Table 6 through Table 13 of Hill, Kuriyama, & Crone, 2020). The Rebuilder tool used data inputs from the 2020 benchmark stock assessment for the NSP of Pacific sardine that covers the time period 2005-2020 (Kuriyama, Zwolinkski, Hill, & Crone, 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 (SB0, 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 SB0 estimates were 377,567 mt and 104,445 mt for 2005-2018 and 2010-2018, respectively (Table 4 of Hill, Kuriyama, & Crone, 2020).

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

Although the modeling results from the 2005-2018 time period were deemed more appropriate for analyzing the management alternatives because the 2005-2018 time period captured a broader range of recruitment, there are still recruitment patterns that the model was unable to capture even in this longer time period. The 2020 assessment authors stated, "recruitment has declined since 2005-2006 with the exception of a brief period of modest recruitment success in 2009-2010. In particular, the 2011-2018 year classes have been among the weakest in recent history." Therefore, modeling only this time period was inadequate to capture the biological pattern of a stock that is known to go through boom-and-bust cycles driven by environmental conditions. This stock exhibited much greater productivity and recruitment in the years leading up to its most recent peak in abundance in 2006, and this occurred in the years after it came under federal management in the year 2000. These years are not covered by 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 (SSP) 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 1.4.1

Alternatives added into the revised rebuilding plan (4-6) were not analyzed by the Rebuilder tool. However, as explained below, these alternatives were derived in such a way to rely on the outputs of the previous analysis. Note that all rebuilding timelines begin in the year 2021, which was the starting year for the rebuilding analysis. Tables referenced in the following analysis containing outputs from the Rebuilder tool are available in Appendices A and B.

3.2 TARGET SPECIES – PACIFIC SARDINE RESOURCE

3.2.1 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 whiting, 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, 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). 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, Soutar, & Ferreira-Bartrina, 1992, see Figure 1). These boom/bust cycles are heavily influenced by the inter-annual and intra-annual climate cycles, such as the Pacific Decadal Oscillation (PDO), shaping the CCE.

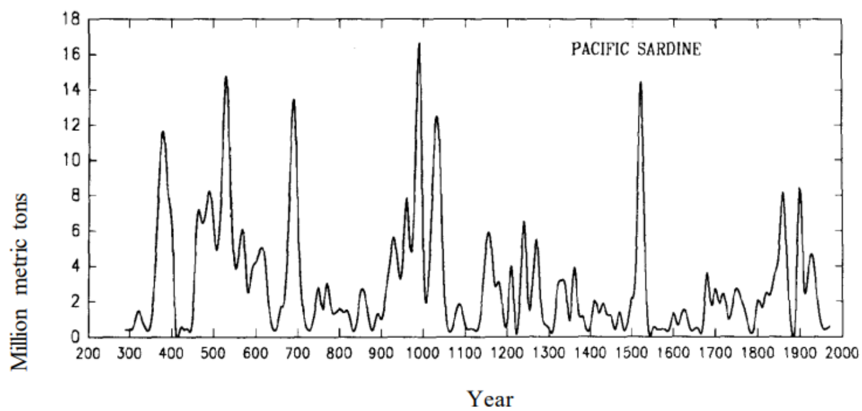

Figure 1. 1700-year hindcast series of Pacific sardine biomasses off California and Baja California (figure

reproduced and modified to exclude Northern anchovy, Baumgartner, Soutar, & Ferreira-Bartrina, 1992).

Pacific sardine form three subpopulations (see review by Smith & Moser, 2003). The northern subpopulation (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 (SSP) 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 SSP. Although these two subpopulations overlap, they are considered to be distinct subpopulations (Feliz-Uraga, Gomez-Munoz, Quinonez-Velasquez, Melo-Barrera, & Garcia-Franco, 2004; Felix-Uraga, Gomez-Munoz, Quinonez-Velazquez, Melo-Barrera, & Garcia-Franco, 2005; Demer & Zwolinski, 2014). The Pacific sardine NSP ranges from the waters off northern Baja California, Mexico to southeast Alaska and commercial fishing occurs on this transboundary stock by fleets from Mexico, the U.S., and Canada during times of high abundance. The stock's range is reduced when population levels are low with the bulk of the biomass and harvest typically centered off southern/central California and northern Baja

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

The recent population decline of Pacific sardine appears to be due to poor recruitment. Specifically, the 2020 assessment stated 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, Zwolinkski, Hill, & Crone, 2020). The 2024 assessment shows that since 2020, while spawning stock biomass has largely increased, stock biomass and recruitment rates continue to vary (Kuriyama, Akselrud, Zwolinski, & Hill, 2024) The 2024 benchmark update also provided a stock biomass (age 1+) estimate of 58,614 mt on July 1, 2024, reflecting a continuing trend of low productivity in the northern subpopulation, but indicating a potential upward trend.

Fluctuations and declines in population are by no means unprecedented. As described above, the Pacific sardine has undergone large population fluctuations for centuries even in the absence of industrial fishing (see Figure 1). 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 & Marr, 1955; Baumgartner, Soutar, & Ferreira-Bartrina, 1992; Mantua, Hare, Zhang, Wallace, & Francis, 1997; Minobe, 1997; Schwartzlose, et al., 1999; McFarlane, Smith, Baumgartner, & Hunter, 2002; Smith & Moser, 2003; Rykaczewski & Checkley, Jr., 2008; Field, et al., 2009; MacCall, 2009; Demer & Zwolinski, 2014; Lindgren, Checkley, Jr., Rouyer, MacCall, & Stenseth, 2013). Further, recent climate change-related events, such as marine heat waves in the Pacific have altered the structure of the greater pelagic ecosystem (Peterson, Fisher, Strub, & Du, 2017). No one environmental condition is the sole driver of population abundance. Additionally, recent research (Koenigstein, et al., 2022) has hypothesized that the lack of recovery of the sardine population since 2014, a period that has included warm ocean conditions, may be explained by reduced food availability for the early life stages of sardine. Therefore, the complexity of the CCE and the difficulty in understanding the exact mechanisms driving life history dynamics has created difficulties predicting stock biomass and recruitment success, but it is established that environmental conditions are critical drivers of Pacific sardine populations.

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; the HCRs and management measures 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.

The directed fishery was closed in 2015, four years prior to the fishery being declared overfished in 2019. Since the closure, total harvest has remained relatively constant since 2015, averaging about 2,200 mt/year from 2015-2020 and about 2,000 mt/year since, through 2023, well below any year's ACL (see Table 2). 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 landed into West Coast ports is counted against the ACL, even though some portion is composed of the SSP of Pacific sardine. For example, the 2024 stock assessment retroactively assigned only a portion of the U.S. catch to the NSP (see Table 1.5 in Kuriyama et al. 2024). Compared to stock assessments prior to 2024, a smaller proportion of total U.S. catch was attributed to NSP due to updates in the habitat model since the 2020 benchmark assessment. This suggests that U.S. harvest of NSP Pacific sardine has likely been less than one 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 can also include 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 was assumed to have caught under 5,000 mt/year of NSP sardine on average. The 2024 stock assessment, which incorporated the updated habitat model, estimated that zero NSP have been caught in the Ensenada fishery since 2012.

Stock assessment results suggest that even in the absence of any fishing, the NSP sardine stock would have been 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.

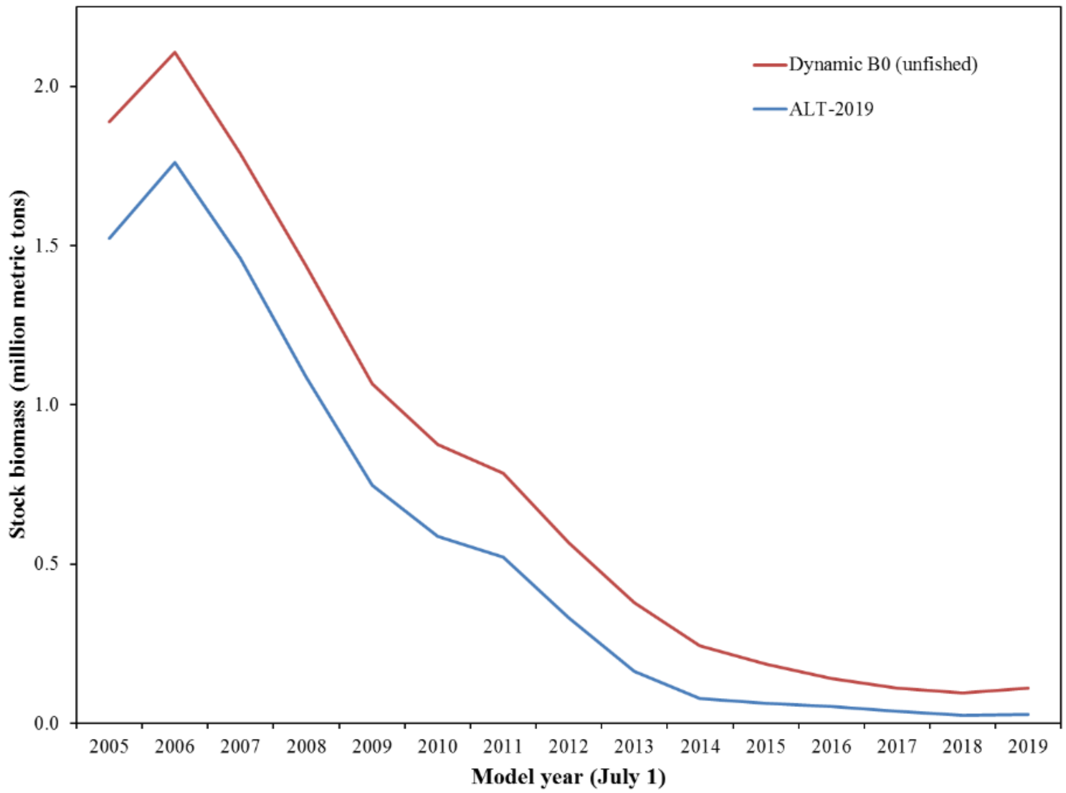

Figure 2. Estimated stock biomass (age 1+ fish, mt) time series and dynamic B0 (unfished population) from model ALT-2019 (via 2019 Pacific sardine stock assessment, Hill, Crone, & Zwolinski, 2019).

3.2.2 ANALYSIS OF IMPACTS – PACIFIC 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 allow the stock to increase in size. Given the dynamic nature of such conditions affecting the stock, the assumptions informing these alternatives may need to be revisited at each benchmark assessment.

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 (No Action), when the full ABC is assumed to be taken, there is never a greater than 50 percent probability that the stock will rebuild to the selected rebuilding biomass target of 150,000 mt 1+ biomass (Table 8 in Hill, Kuriyama, & Crone, 2020) or the modeled SBMSY of 137,812 mt before the year 2050, which is the last year that was modeled (Table 6 in Hill, Kuriyama, & Crone, 2020). It is important to note that model results assume that under Alternative 1, U.S. fisheries would 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. However, in light of the recent Court ruling, for the purposes of this analysis it assumed that under Alternative 1, annual landings would equal the calculated ABC level, despite evidence that actual landings would likely average closer to 2,200 mt. When this scenario of hypothetical ABCs was previously modeled, Alternative 1 did not show the Pacific sardine stock rebuilding within the appropriate time frame (i.e., less than T_{MAX}). The outcome of the Rebuilder tool where 2,200 mt is landed annually has been shifted to Alternative 4.

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 SBMSY of approximately 121,650 mt) is 12 years, or in the year 2033 (Table 8 in Hill, Kuriyama, & Crone, 2020). The modeled time to rebuild to the modeled SBMSY of 137,812 mt is 15 years, or in the year 2036 (Table 10 of Hill, Kuriyama, & Crone, 2020). This is the fastest rebuilding timeline of any of the alternatives. The projected median spawning biomass values under Alternative 2 are presented in Table 10 of Hill, Kuriyama, & Crone (2020). 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 due to environmental conditions 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 (Five Percent Fixed U.S. Harvest Rate), the modeled time to rebuild Pacific sardine with a greater than 50 percent probability to the selected rebuilding biomass target of 150,000 mt 1+ biomass is 16 years or in the year 2037 (Table 8 in Hill, Kuriyama, & Crone, 2020). Similar to Alternative 1, this modeled rebuilding timeline assumes that the full five percent is harvested each year, which when the biomass is above about 58,000 mt (ACL = 2,900 mt), will likely not be true due to the closure of the fishery if recent high catches (ranging up to about 2,900 mt) are representative of the future. Additionally, 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.

Similar to Alternative 1, the modeled rebuilding time for Alternative 3 assumes that the modeled sardine landings will be all from the NSP. While average catch of Pacific sardine from 2015 to 2020 was 2,200 mt, this value includes catch from the SSP of Pacific sardine, which ranges from the southern tip of Baja, Mexico to the Southern California Bight off the U.S. West Coast. The SSP 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. U.S. harvest of the NSP of Pacific sardine has averaged only 367 mt annually from 2015 to 2023, which only averaged 0.69 percent of the biomass. Therefore, actual landings from 2015 to 2023 were much less than what they would be under the modeled Five Percent U.S. Harvest Rate. It is likely that similar to Alternative 1, the actual harvest rate under Alternative 3 would be less than the modeled harvest rate 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.

Under Alternative 4 (Constant Catch), the modeled time to rebuild Pacific sardine with a greater than 50 percent probability to reach the selected rebuilding biomass target of 150,000 mt 1+ biomass is 17 years, or in 2038 (see Table 8 in Addendum of Appendix A of PFMC 2020c). This specific run was done as a more representative model of real-world conditions while analyzing the original range of alternatives for Amendment 18, modeling that calculated rebuilding probabilities assuming a constant catch of 2,200 mt, which was the average catch from 2015-2020 even at varying biomass levels. Like Alternatives 1 and 3, the modeled rebuilding timeframe for Alternative 4 assumes all landings will be from the NSP, though actual landings of the NSP are likely much lower. Based on the assumption that a portion of the modeled landings would be from the SSP, when status quo was adopted under Amendment 18 based on the 2,200 constant catch scenarios, instead of adopting a T_{TARGET} of 17 years, as modeled, a T_{TARGET} of 14 years was chosen. This T_{TARGET} of 14 years was considered reasonable given actual recent landings of NSP proportionally and was considered adequate time to evaluate rebuilding.

Under Alternative 5 (Modified Constant Catch), it is likely that the modeled time to rebuild Pacific sardine with a greater than 50 percent probability to reach the selected rebuilding biomass target of 150,000 mt 1+ biomass is near 17 years, or by 2038. Alternative 5 sets a constant catch ACL of 3,200 mt and similar to Alternative 6 was not explicitly modeled previously. As with each of the alternatives that permit harvest discussed in this EA, it is likely that the actual harvest would be less than the ABC or ACL, as SSP landings are counted towards the ACL and management measures are likely to keep catch lower. According to data from the 2024-2025 stock assessment, from the 2015-2016 fishing year through the 2023-2024 fishing year, only an average of about 23 percent (with a maximum of 32 percent) of catch counted towards the ACL was estimated to be from the NSP, with the remaining 77 percent from the SSP (Kuriyama, Akselrud, Zwolinski, & Hill, 2024). Based on this assessment data, even if a 3,200 mt ACL is fully attained, only about 725 mt of landings would be from the NSP. The buffer added to the highest recent catch to derive the 3,200 mt ACL is therefore conservative, as average NSP landings will remain below the previously analyzed 2,200 mt ACL. Given that true landings of NSP would be less than 2,200 mt annually, it can reasonably be assumed that with a 3,200 mt ACL, the stock will still rebuild in under 17 years (i.e. the modeled rebuilding time for Alternative 4), before 2038.

The time to rebuild for Alternative 6 is more uncertain than the other alternatives given that it is a modified version of Alternative 3. However, using the previous modeling of catch scenarios under Alternatives 1 and 3 (see Addendum of Appendix A to PFMC 2020c and Hill, Kuriyama, & Crone, 2020), an estimated range and rationale is provided here for consideration. Alternative 3 resulted in a 50 percent probability of reaching the biomass target within 16 years. However, that analysis assumed lower total removals in years where the biomass was lower and was not held to a constant catch value of 2,200 mt, which would occur at age 1+ biomass levels less than 44,000 mt, under Alternative 6. On the other hand, assumed harvest under Alternative 6 would be less than Alternative 3 between 44,000 mt and 50,000 mt. The constant catch value of 2,200 mt was analyzed to rebuild (under the Alternative 1 analysis, now described under Alternative 4) as rebuilding in 17 years. Like Alternatives 1 and 3, this modeled rebuilding timeline assumes that the full five percent is harvested each year, which, when the biomass is above about 58,000 mt (ACL = 2,900 mt), will likely not be true due to the closure of the directed fishery, assuming the recent maximum catches reflect the future.

While Alternative 6 would permit higher removals in lower biomass years (noting exception between 44,000 to 50,000) compared to Alternative 3, it is likely that the total removals of NSP would be less than 2,200 mt given that a portion of that removals would be of the SSP. As described above, only an average of about 23 percent of catch counted towards the ACL can be attributed to the NSP, with the remaining 77 percent from the SSP (Kuriyama, Akselrud, Zwolinski, & Hill, 2024). Overall, if the full 2,200 mt ACL is removed annually when the stock is under 50,000 mt, only about 506 mt of these landings would be NSP (on average). Therefore, when the biomass is between 11,000 and 50,000 mt, landings would be less than what was modeled under Alternative 3 (see Table 5 in Appendix). As Alternative 3 was projected to rebuild within 16 years, it can reasonably be assumed that, given removals of NSP under Alternative 6 will be less than the ACL modeled under Alternative 3, the stock is likely to rebuild within 16 years, or in the year 2037, under Alternative 6. At very low stock biomass levels, the ACL will be set to the lesser of 2,200 or the ABC under Alternative 6, as it would with Alternatives 1, 3, and 4. Therefore, while a rebuilding model was not explicitly run for Alternative 6, it can be reasonably assumed that the rebuilding timeline will be less than T_{MAX} of 24 years, or before 2044.

Table 4. Recent ACL values compared with ACL values for Alternatives 3-6. Shaded cells show where actual landings would have exceeded the ACL under that alternative. All ACL and landings values in mt.

Fishing Year	Biomass (mt)	Status Quo/Actual ACL	Alt 3 ACL	Alt 4 ACL	Alt 5 ACL	Alt 6 ACL	Actual Landings
2015-2016	96,688	8,000	4,834	2,200 mt	3,200	4,834.4	2,329
2016-2017	106,137	8,000	5,307	2,200 mt	3,200	5,306.85	2,217
2017-2018	86,568	8,000	4,328	2,200 mt	3,200	4,329.3	2,190
2018-2019	52,065	7,000	2,603	2,200 mt	3,200	2,603.25	2,505
2019-2020	27,547	4,514	1,377	2,200 mt	3,200	2,200	2,063
2020-2021	28,276	4,288	1,414	2,200 mt	3,200	2,200	2,865
2021-2022	28,276	3,329	1413.8	2,200 mt	3,200	2,200	1,750
2022-2023	27,369	4,274	1368.45	2,200 mt	3,200	2,200	1,777
2023-2024	27,369	3,953	1368.45	2,200 mt	3,200	2,200	1,713
2024-2025	58,614	3,953	2930.7	2,200 mt	3,200	2,930.7	-

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. As described in Section 3.2.1, the environment will likely be the primary determinant for the stock increasing. The fishery is already being heavily restricted under current management, as the fishery is currently closed and will remain so under all alternatives, and it is unclear if the reductions in annual catch under Alternatives 3, 4, 5, or 6 would allow the stock to realistically rebuild any faster than other alternatives.

3.3 SARDINE IN THE ECOSYSTEM

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

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, Marshall, & Kaplan, 2009; Szoboszlai, Thayer, Wood, Sydeman, & Koehn, 2015) and studies on bioenergetics are ongoing. 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, such as Pacific salmonids, including endangered Chinook stocks, albacore tuna, and Pacific whiting, as well as Pacific spiny dogfish and several shark species (Szoboszlai, Thayer, Wood, Sydeman, & Koehn, 2015). A number of seabirds have been identified that forage on Pacific sardine, including 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 endangered 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 & Bessinger, 2006; McShane, et al., 2004; Szoboszlai, Thayer, Wood, Sydeman, & Koehn, 2015). Anecdotal evidence documents how marbled murrelets' prey flexibility and opportunistic feeding strategies were essential to allowing the species to persist through other Pacific sardine population crashes (Burkett, 1995).

Pacific sardine are also forage for a dozen marine mammals, including threatened and endangered ESA-listed humpback whales and are considered part of their designated critical habitat (see 86 FR 21082). Humpback whales are generalist predators, but substantial data shows their primary prey in the CCE consists of Pacific sardine, northern anchovy, Pacific herring, euphausiids, and occasionally juvenile rockfish (see 86 FR 21082). Like murrelets and other CPS predators, humpback whales are known to switch between target prey species depending on what is most abundant. Data from a study by Rice (1963) showed that during the mid-century crash of sardine, humpbacks made a distinct shift in the schooling fish they targeted (cited in National Marine Fisheries Service 2020).

3.3.2 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 (such as marine mammals, birds, and other fish) have evolved in an ecosystem in which relative abundances of prey species frequently fluctuate. Consequently, most predators are generalists who are not dependent on the availability of a single species but rather on many species, anyone (or more) of which is likely to be abundant in a given year. Often many of them also have other life history traits, such as being long-lived or having adaptive reproductive strategies, to help mitigate against years of low prey availability. This was noted in a recent multi-modeling effort which demonstrated that Pacific sardine play a greater role in the diets of brown pelicans, halibut, and dolphins, compared to the diet of California sea lions, which have a broader diet (Kaplan, et al., 2013). Further, 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.

Overall, prey availability under any of the alternatives is not expected to significantly impact overall prey availability for ESA-listed humpback whales foraging in the CCE as they all are expected to rebuild Pacific sardine by very similar timeframes. Barlow and colleagues (2008) estimated that humpbacks in the CCE consume approximately 157,735 tons, or 143,095 mt of prey annually. Further, it is estimated approximately 15 percent of humpbacks’ diet is composed of small pelagic fish, like sardines (Barlow, Kahru, & Mitchell, 2008). This assumption would bring total consumption of small pelagic fish, only a portion of which is from the NSP, by humpbacks in the CCE to approximately 21,464 mt annually. Considering humpbacks can readily switch prey to consume other CPS and more krill in times of low sardine availability, it can be assumed much less than 21,464 mt is actually Pacific sardine (and therefore even less of the NSP), though it is uncertain what this exact proportion would be.

While the biomass of Pacific sardine is currently low, the central population of northern anchovy biomass is high (approximately 800,000 mt in 2019, and 2,879,010 mt in June 2022, see Stierhoff, Zwolinski, & Demer, 2020; Kuriyama, 2022). Therefore, it is unclear whether there would be any measurable difference in benefits between the rebuilding timelines for Pacific sardine from the aspect of future prey availability, as the central subpopulation of northern anchovy provides ample forage availability within the humpbacks’ diet. Accordingly, none of the proposed management strategies associated with each alternative are expected to significantly impact forage availability within the ecosystem.

Under any of the alternatives, certain protections will remain in place under the CPS FMP. For instance, krill removal is already prohibited by the CPS FMP. Though not specific to the humpback whale, Amendment 16 specifically took action to protect krill species from harvest in order to safeguard prey for marine predators.

According to the model results, under Alternative 1 Status Quo Management, when the full ABC is assumed to be taken, there is never a greater than 50 percent probability that the stock will rebuild to the selected rebuilding biomass target of 150,000 mt 1+ biomass (Table 8 in Hill, Kuriyama, & Crone, 2020) or the modeled SBMSY of 137,812 mt before the year 2050, which is the last year that was modeled (Table 6 in Hill, Kuriyama, & Crone, 2020). However, as discussed in Section 3.1, 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. The model outcomes should also be interpreted to consider the proportion of the ACL accounted for by SSP. Under No Action, the full removal of the ABC must be assumed, which has averaged 4,072 mt/year for the years 2019 to 2024. Little to no impact can be expected for humpback whales or seabirds under no action.

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 SBMSY of approximately 121,650 mt) in the year 2033 (Table 8 in Hill, Kuriyama, & Crone, 2020). This is the fastest rebuilding timeline of any of the alternatives. The projected median spawning biomass values under Alternative 2 are presented in Table 10 of Hill, Kuriyama, & Crone (2020). 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, resulting in fewer removals of prey 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. As a result, it is difficult to determine whether Alternative 2 would result in significantly higher prey availability compared to the other alternatives. Further, zero removal by fisheries does not guarantee there will not be a decline in prey availability due to other causes, as the stock can stay low or decline even in the absence of fishing. Ultimately, little to no significant positive impact on marine predators can be expected under this alternative.

Alternatives 3-6 are projected to rebuild to the target biomass within the appropriate timeframe, unlike the initial model results for Alternative 1, which do not project the stock to rebuild. According to model results, Alternative 3 had at least a 50 percent chance of rebuilding to 150,000 mt age 1+ biomass in the year 2037. Alternative 4 had at least a 50 percent chance of rebuilding to 150,000 mt age 1+ biomass in the year 2038. Alternative 5, while not directly modeled, may reasonably have a 50 percent chance of rebuilding to 150,000 mt age 1+ biomass in the year 2038, based on the results from other model runs. Alternative 6 is also uncertain on its time to rebuild, but based on the rationale presented in Section 3.2.2, it has a high likelihood of rebuilding prior to T_{MAX}.

Further, as described in Section 3.2, the environment will likely be the primary determinant for the stock increasing. The directed fishery is already closed under status quo management, and it is unclear if the reductions in annual catch under Alternative 3 Five Percent Fixed U.S. Harvest Rate or Alternative 4 Constant Catch, compared to Alternatives 5 and 6 would allow the stock to rebuild any faster.

Overall, none of the proposed management alternatives are expected to significantly affect future forage availability, as all alternatives rebuild in similar timelines, and it also known that the environment will be the primary driver for increases in sardine abundance. Directed fishing is therefore not the primary driver of fluctuations in sardine stock biomass. Additionally, because most Pacific sardine predators are generalists, they 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. Therefore, slight differences in the proposed ACLs in this range of Alternatives would be negligible. Specifically, humpback whales, an endangered species of interest, can switch to other prey species (schooling fish or krill/euphausiids) when available and feed flexible areas spatially when possible. The CA/OR/WA stock of humpbacks is increasing, despite the crash of the Pacific sardine population. Consequently, we expect that the removal of prey under any of the proposed alternatives, considered in the context of the existing baseline, would be insignificant for marine predators, including ESA-listed humpbacks and seabirds. Therefore, no management alternative is expected to significantly impact prey availability for marine predators, including impacting the ability for endangered seabird and marine mammal populations to rebuild in the near or long term.

3.4 FISHING INDUSTRY

3.4.1 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 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, Soutar, & Ferreira-Bartrina, 1992, 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 in state waters 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 California state 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, Hill, Crone, Lo, & Bergen, 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 directed fishery for sardine has been closed since 2015, when the projected biomass fell below the CUTOFF value of 150,000 mt. Biomass has remained below this value since, precluding the re-opening of the directed fishery. The 2024 base model stock biomass was projected to be 58,614 mt in July 2024 (Kuriyama, Akselrud, Zwolinski, & Hill, 2024). However, minor directed fisheries and the live bait fishery have been allowed some harvest of Pacific sardine. Incidental catch in CPS and non-CPS (i.e, Pacific whiting) has also been allowed.

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. A determination of significant impact will be completed following final action by the Council.

3.4.1.1 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 $117 million of ex-vessel revenue (in inflation-adjusted 2023 dollars) from 2010 to 2014. The primary directed fishery is the main fishery that operates in federal waters. As described above in Section 1.4.2, fishing opportunity in the primary directed fishery is determined by the output of the harvest guideline HCR, which has imposed a closure of the sardine fishery since 2015. Prior to its closure, the ex-vessel value of this fishery averaged over $18.35 million annually (in 2023 dollars) from 2009 through 2014 (PFMC 2019b, adjusted for inflation). 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, the rebuilding plan will impact the timeline of re-opening of the fishery, but the fishery will not be affected in the interim. With the primary directed fishery closed, the CPS stock complex has landed a total of $49 million of ex-vessel value (in 2023 dollars) from 2015 through 2023 (PFMC 2024a).

3.4.1.2 LIVE BAIT FISHERY

Live bait fisheries typically use various types of round haul 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 $510 million in value added impact to California in 2022 (National Marine Fisheries Service 2024). Live bait is primarily used by recreational anglers on commercial passenger fishing vessels (CPFVs) and private boats. There is a total of 321 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 2015 and 2020, reported sardine live bait catches averaged 1,404 mt per year, comprising 85 percent of total live bait catch in California (See Table 4-12 in PFMC 2022a Appendix). The ratio of anchovy to sardine in the southern California live bait harvests does shift significantly as the populations of these two fish expand and contract over periods of years or decades. However, sardine comprise the vast majority of catch and from 2015-2023, the proportion of sardine in reported live bait catch averaged 86.56 percent, ranging from 73 percent to 93 percent (PFMC 2024a). 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. Public comments at the April 2021, April 2022, April 2023, and April 2024 PFMC meetings, on the Pacific Sardine Assessment, Harvest Specifications, and Management Measures agenda items, detail the importance of this fishery. In particular, stakeholders from multiple industries (recreational, live bait, and non-governmental organizations) have commented on the essential role the live bait fishery plays in supporting the California recreational sector of millions of fishers and how crucial it is for CPS management to support the continued existence of the live bait sector.

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.

3.4.1.3 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. The amendment included a maximum of 1 mt per vessel per day, with a one-trip-per-day limit. 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. Under the trip limits implemented by

Amendment 16, the majority of historical small-scale sardine fishing activities are allowed. When the Council took final action to implement Amendment 16, the number of participants coastwide with targeted sardine landings of less than one metric ton per day ranged from five to 12 per year for years 2005 - 2015. In the same years, 95 percent of the landings by beach seine operations and 100 percent of hook-and-line operations were less than 1.0 mt per day. Only 39 mt of sardine were landed in California and Oregon in 2022-2023 (PFMC 2024a). Washington's state regulatory framework essentially precludes minor directed fishing when the stock 1+ biomass estimate is below 150,000 mt. 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.

3.4.1.4 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. As of 2024, the projected stock 1+ biomass reached over 50,000 mt (Kuriyama, Akselrud, Zwolinski, & Hill, 2024). Given the CPS FMP allows the incidental landing limit to range up to 45 percent when the stock is above the minimum stock size threshold age of 50,000 mt, per landing restrictions could increase in future harvest specifications. 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 comprises over 20 percent in the school. From the closure of primary directed Pacific sardine fishing through 2020, an average of 300 mt of incidental sardine was landed per year in California. These mixed landings averaged over $1.8 million in value (PFMC 2020a). From the 2019-2020 through 2023, an average of 155 mt incidental sardine was landed annually (PFMC 2023). Landings that incidentally caught sardine averaged $4,344,915 in value from 2019-2022 (PFMC 2022b). In their April 2024 Reports, the CPSMT and CPSAS conferred that an increase in the incidental landing limit, now that the stock is above the minimum stock size threshold of 50,000 mt would provide more flexibility for other CPS fisheries that incidentally catch sardine (PFMC 2024b).

NON-CPS FISHERIES

Incidental harvest of Pacific sardine also occurs in other fisheries such as the Pacific whiting fishery where fishermen do not have the ability to avoid capturing Pacific sardine and operate under a maximized retention model. 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. Since 2015, when Pacific sardine biomass fell below CUTOFF or 150,000 mt, incidental landings in the Pacific whiting fishery have varied widely- ranging from less than one mt to nearly 30 mt over the 2021-2022 sardine fishing year. Between the at-sea and shoreside sectors, there is interannual variability on which sector has more incidental catch of sardine- likely due to the differences in operation between the at-sea and shoreside fisheries as well as location of Pacific whiting schools and Pacific sardine. On average, the whiting sectors caught 6.8 mt of Pacific sardine combined. Incidental landings in six of the nine fishing years since 2015 were under that average. The average in the at-sea fishery prior to 2015 was 0.12 mt, increasing after 2015 to 1.4 mt. The shoreside fishery typically lands more incidental Pacific sardine than the at-sea sector on average; prior to 2015, it was 1.3 mt, and in the years following, it was 1.8 mt. The combined whiting sectors were valued at $64 million in 2022 (PFMC 2022b).

3.4.1.5 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.

Tribal treaty fisheries are established via Government-to-Government consultation and could potentially include Pacific sardine harvest. 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.

3.4.2 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 six 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.

Small ACLs set since the closure of the primary directed fishery in 2015 (see Table 2) 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 (PFMC 2019b)). Since the closure of the directed fishery in 2015, live bait catches have been slightly lower, averaging 1,326 mt in the years 2015-2023 and ranging from 1,075 mt in 2019 to 1,996 mt in 2015 during the same period (See Table 4-12 in the 2022 CPS SAFE Appendix A (PFMC 2022c)). 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.

Under Alternative 1 (No Action), the smaller-scale directed fishing sectors would expect a consistent and familiar management strategy. However, this alternative does not set catch limits that would rebuild the Pacific sardine population within the statutory timeframe, if annual catch levels reached the limits authorized.

Based on the modeling results, the smaller-scale sectors of the fishery and the incidental fishery for other CPS and non-CPS, would not be expected to be severely limited under the initially modeled Alternative 1 (i.e., assuming the full ABC is harvested) through approximately 2040. The median U.S. catch levels presented in Table 12 of Hill, Kuriyama, & Crone (2020) indicate that catch will remain high enough to accommodate the modest harvest needs of the smaller-scale sectors through approximately 2046. However, past 2046, median catch values decrease below recent average landing levels, indicating that the smaller sectors of the fishery may be constrained. However, as explained in Section 3.1, 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 and their communities 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 and communities that rely on these fisheries, including non-sardine CPS, groundfish, and live bait fisheries. From a fishery management perspective, it would be difficult to 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 3.4.1, is part of an extremely valuable statewide recreational fishery generating over $510 million in value added impact to California in 2022 (National Marine Fisheries Service 2022). Under Alternative 2, the live bait fishery would no longer be able to provide Pacific sardine as live bait to recreational fisheries. Between 2015 and 2023, reported sardine live bait catches averaged 1,075 mt per year, comprising 83 percent of total live bait catch (See Table 2-3 in PFMC 2024a, Appendix A). Most recently in 2023, reported live bait catches have remained similar, totaling 1,136 mt in 2023 and accounting for 88 percent of total live bait catches. (PFMC 2024a). While the live bait fishery also targets anchovy, current preference for sardine in the live bait fishery would make sole reliance on anchovy highly disruptive to the sector. 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 49 mt of sardine has been harvested in the minor directed fishery coastwide through 2023. Implementation of Alternative 2 would reverse the economic relief given to fishers in the minor directed sector by Amendment 16.

An average of 294 mt and 6 mt of Pacific sardine was harvested incidentally in other CPS fisheries and non-CPS fisheries, respectively, from 2015 to 2020 (see PFMC 2020b, Table 3). From 2020-2023, an average of 151.75 mt and 11.5 mt, respectively (PFMC 2024b). Other CPS fisheries that commonly catch sardine incidentally include market squid, northern anchovy, and Pacific mackerel. The Pacific whiting fishery, valued at $64 million (National Marine Fishery Service 2024) accounts for a significant portion of incidental harvest in non-CPS fisheries; however, its harvest of Pacific sardine is relatively minor (see Section 3.4.1). If incidental catch of Pacific sardine were prohibited, these fisheries, as they currently operate, would either be severely constrained or prohibited.

The modeling results in Table 12 of Hill, Kuriyama, & Crone (2020) provide median catch values under Alternative 2, however these values represent potential median catch by Mexico, as

Alternative 2 assumes zero U.S. harvest. Therefore, the modeling results were not used to further analyze potential impacts on the U.S. fishing industry under Alternative 2.

Under Alternative 3, Fixed Five Percent U.S. Harvest Rate, which serves as a policy and modeling intermediary between Alternatives 1 and 2, there would be some negative economic impacts to the smaller-scale fishery sectors when biomass is at 50,000 mt and below, compared to current management measures. 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. The 2020-2021 fishing year saw 2,865 mt in total landings (PFMC 2022c). Therefore, under the harvest policy of Alternative 3, in 2020 the Council would have needed 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 pursue 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 harvested an average of 1,404 mt per year from 2015 to 2020 and averaged about 1,161 mt from 2020 to 2023 (PFMC 2022c, PFMC 2024a). 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).

Based on the modeling results, Alternative 3 would not restrict catch in the smaller-scale sectors in the near or long term because the projected median catch values in Table 12 of Hill, Kuriyama, & Crone (2020) never decrease below recent average landings; however, the model assumes a very specific biomass trajectory that may or may not be realistic, depending on environmental conditions. If the spawning stock values presented in Table 10 (Hill, Kuriyama, & Crone, 2020) for Alternative 3 are true, then the fixed five percent ACL would restrict catch to much lower levels than reflected in the median catch values in Table 12 (Hill, Kuriyama, & Crone, 2020). Rebuilder tool results then indicate that based on these median values, the only alternative to rebuild the stock in the presence of fishing was Alternative 3. Given that fishing is not the likely cause of the stock decline, it is uncertain that the reduction in sardine landings for Alternative 3 compared to Alternative 4, 5, and 6 would cause the stock to rebuild any faster.

Under Alternative 4 (ACL of 2,200 mt), there is potential for some negative economic impacts to small-scale sectors, particularly in terms of accommodating variation in annual harvest. Annual landings of Pacific sardine averaged 2,157 mt from 2015 to 2023, ranging from 1,713 mt in the 2023-2024 fishing season to 2,865 mt in the 2020-2021 fishing season. Therefore, a 2,200 mt constant catch ACL under Alternative 4 can reasonably accommodate the majority of current landings. Therefore, while Alternative 4 utilizes the recent average catch expected under status quo to set a reasonable constant catch guideline to ensure long term persistence of small-scale sectors, Alternative 4 lacks the flexibility to reduce economic restriction in years of high variability.

Though not modeled in the original rebuilding analysis, Alternative 5, ACL of 3,200 mt, is not expected to significantly restrict the small-scale sectors, based on the modeling results for Alternative 4 (2,200 mt constant catch), and Alternative 3 (5 percent harvest rate). Given that actual landings since 2015 have largely remained below 2,200 mt since 2015 (except for the 2020-2021 fishing year), Alternative 5 would likely accommodate the current status quo for active sectors. Under Alternative 5, landings may remain at current levels, protecting short-term economic viability of affected sectors. Further, the addition of a buffer to the recent average catch ACL and above the maximum since the closure of the directed fishery will allow some flexibility for affected sectors, while setting a responsible maximum to ensure long term viability of the stock and the fisheries. In the years since 2015, through 2023, actual landings would not have exceeded the proposed ACL for Alternative 5 (see Table 4).

Given that actual landings have not exceeded 3,200 mt since the closure of the directed fishery in 2015 (see Table 1), a 3,200 mt constant catch ACL is not expected to limit or negatively impact the live bait fishery or those fisheries that incidentally encounter sardine while prosecuting other fisheries. The only recent year where total landings exceeded the ACL that would have been in place under Alternative 5 was in the 2020-2021 fishing year (See Table 4). In the years since 2015, through 2023, when biomass has been greater than 50,000 mt, actual landings would not have exceeded the proposed ACL for Alternative 5 (see Table 4). In comparison, actual landings would have exceeded ACLs under Alternatives 3 and 4 in 5 multiple years since the 2019-2020 fishing year (see Table 4).

Under Alternative 6 Mixed Rate U.S. Harvest, there would be potential to provide the affected small-scale sectors with some flexibility and opportunity to persist in the short and long term. While Alternative 6 was not modeled in the original rebuilding analysis, based on modeling results for Alternatives 3 and 4, it is not expected to significantly restrict small-scale sectors. Compared to Alternative 3, small-scale sectors could expect the same 5 percent fixed harvest rate above 50,000 mt, while avoiding potential negative economic impacts below 50,000 mt. As seen in Table 4, actual landings exceeded the proposed ACL under Alternative 3 in the five fishing years where stock biomass was below 50,000 mt. In comparison, it was only in the 2020-2021 fishing year that actual landings exceeded the proposed ACL under Alternative 6. Setting a five percent fixed harvest rate above a stock biomass of 50,000 mt would allow affected sectors to maintain flexibility and long-term viability as the stock rebuilds. As with Alternative 3, this would avoid a situation where the stock expands, and landings may vary to be greater than 2,200 mt due to market demand, but the live bait and minor fisheries are restricted below 2,200 mt, stunting these sectors and increasing discards of mixed hauls. If stock biomass drops below 50,000 mt again, these affected sectors can expect a constant ACL of 2,200 mt, which supports recent actual landings. Actual landings from 2020 to 2024 averaged 2,034 mt/year. Based on this average, the proposed mixed 5 percent harvest rate and 2,200 mt constant catch ACL would not severely limit the ability for small-scale harvesters and non-CPS fisheries that incidentally catch sardine to continue to operate.

Thus, the question is whether Alternatives 3-6 provide some future economic advantage to industry and the communities that they support if the stock reaches the target rebuilding biomass level faster. Alternative 2 was modeled to rebuild the stock quickest but would essentially eliminate all active fishing sectors during the rebuilding process. Setting a predetermined percentage or a lower constant catch under Alternatives 3 and 4 allows for the persistence of small-scale sectors but may reduce the inter-annual economic flexibility. A constant catch ACL reflecting a historical average may restrict access to Pacific sardine in such a way that could result in both inefficient fishery operations and prevention of other fisheries from achieving their optimal yield due to Pacific sardine bycatch restrictions. Alternatives 5 and 6 seek to potentially mitigate this shortcoming of Alternatives 3 and 4 by providing some flexibility to account for interannual variabilities. Alternative 4-6 may also provide more long-term economic stability if the stock does temporarily decline as they would maintain a set level of opportunity, preventing the long-term consequences of short term restriction on the remaining fishing sectors.

The 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 (Status Quo) for the rebuilding plan implemented under Amendment 18. The Council also 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. However, in response to the court decision, the Council may consider how Alternatives 3-6 meet the economic intentions of a "status quo" alternative, while relying on acceptable harvest control rules in their implementation.

3.4.3 VESSEL SAFETY

None of the alternatives are expected to impact vessel safety.

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5 APPENDIX A

Table 5. Comparison of ACLs and NSP removals under Alternatives 3 and 5. Note that the stock biomass age 1+ biomass has never dropped below 27,000 mt. Alternatives 3 and 5 produce the same ACL above a stock age 1+ biomass of 50,000 mt. Shaded rows show biomass

Biomass Level (mt)	ACL under Alt 3 (5%) (mt)	ACL Under Alt 6 (mt)	NSP removal under Alt 6, Accounting SSP (mt)
9,000	450	2,200	506
10,000	500	2,200	506
11,000	550	2,200	506
12,000	600	2,200	506
13,000	650	2,200	506
14,000	700	2,200	506
15,000	750	2,200	506
16,000	800	2,200	506
17,000	850	2,200	506
18,000	900	2,200	506
19,000	950	2,200	506
20,000	1000	2,200	506
21,000	1050	2,200	506
22,000	1100	2,200	506
23,000	1150	2,200	506
24,000	1200	2,200	506
25,000	1250	2,200	506
26,000	1300	2,200	506
27,000	1350	2,200	506
28,000	1400	2,200	506
29,000	1450	2,200	506
30,000	1500	2,200	506
31,000	1550	2,200	506
32,000	1600	2,200	506
33,000	1650	2,200	506

34,000	1700	2,200	506
35,000	1750	2,200	506
36,000	1800	2,200	506
37,000	1850	2,200	506
38,000	1900	2,200	506
39,000	1950	2,200	506
40,000	2000	2,200	506
41,000	2050	2,200	506
42,000	2100	2,200	506
43,000	2150	2,200	506
44,000	2200	2,200	506
45,000	2250	2,200	506
46,000	2300	2,200	506
47,000	2350	2,200	506
48,000	2400	2,200	506
49,000	2450	2,200	506
50,000	2500	2,200	506
51,000	2550	2550	586.5
52,000	2600	2600	598
53,000	2650	2650	609.5
54,000	2700	2700	621
55,000	2750	2750	632.5
56,000	2800	2800	644
57,000	2850	2850	655.5
58,000	2900	2900	667
59,000	2950	2950	678.5
60,000	3000	3000	690
61,000	3050	3050	701.5
62,000	3100	3100	713
63,000	3150	3150	724.5
64,000	3200	3200	736

65,000	3250	3250	747.5

6 APPENDIX B – PACIFIC SARDINE REBUILDING ANALYSIS BASED ON THE 2020 STOCK ASSESSMENT AND ADDENDUM TO THE SARDINE REBUILDING DOCUMENT

Table 8 from the Addendum to the Sardine Rebuilding Document: Probabilities of recovery above 150,000 mt of age 1+ biomass for rebuilding alternatives for *SB*0(2005-18) 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.

**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.*

	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	*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	0.2385	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	0.2240	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	0.5157	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

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 = ($Biomass_{age1+}$ * 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(2005-18)**					
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(2010-18)**					
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

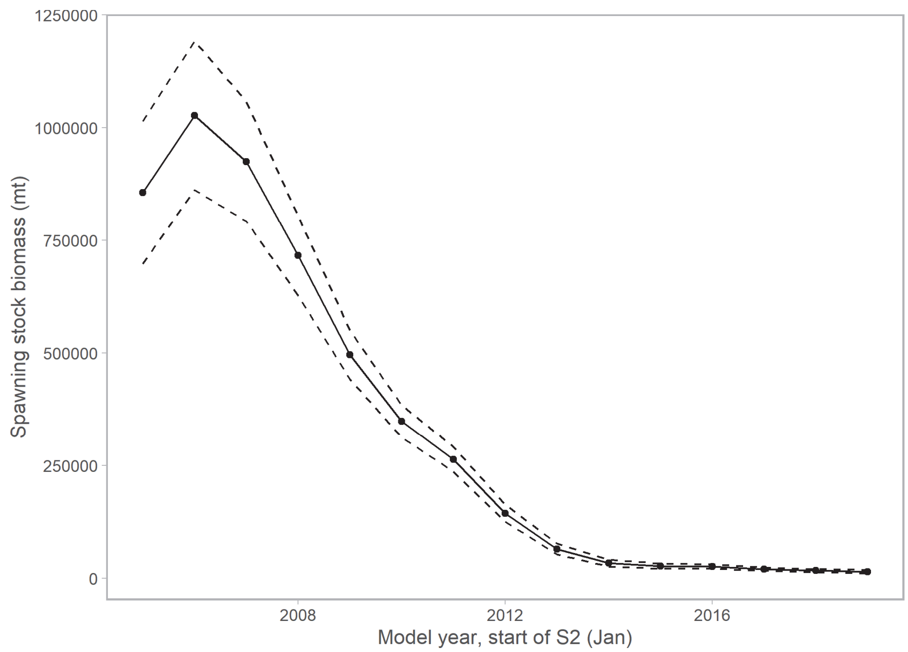

Figure 1: Spawning stock biomass time series (95% CI dashed lines) from the 2020 benchmark assessment (Kuriyama et al. 2020).

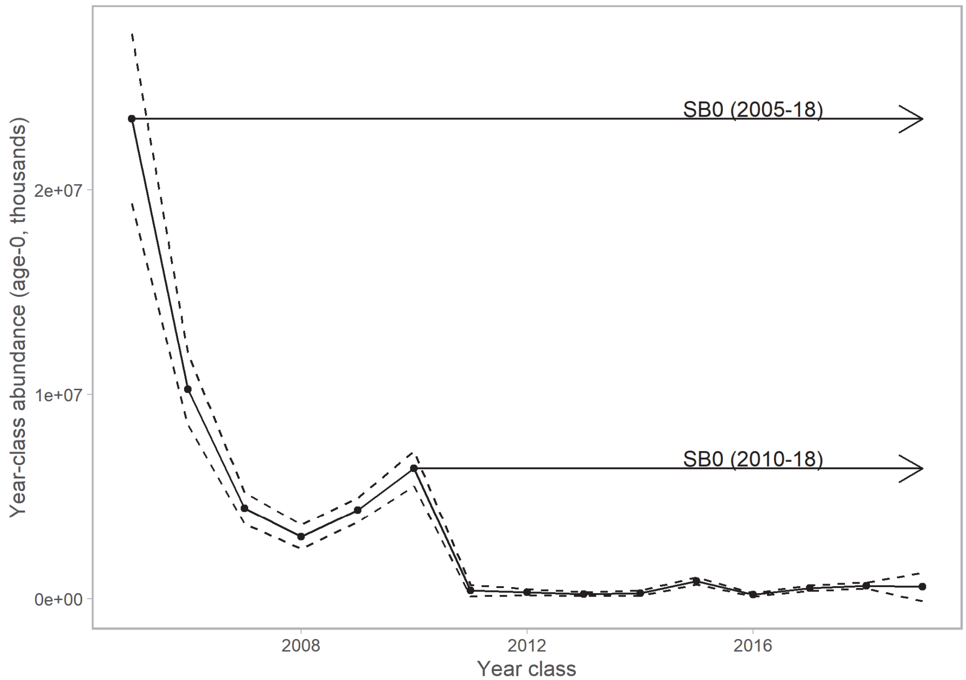

Figure 2. Estimated Pacific sardine recruitment time series from the 2020 Pacific sardine benchmark assessment (Kuriyama et al. 2020). Arrows indicate the two states of nature considered in the rebuilding analysis: SB0 sampled from 2005-18 (top arrow) and SB0 sampled from 2010-2018 (bottom arrow).

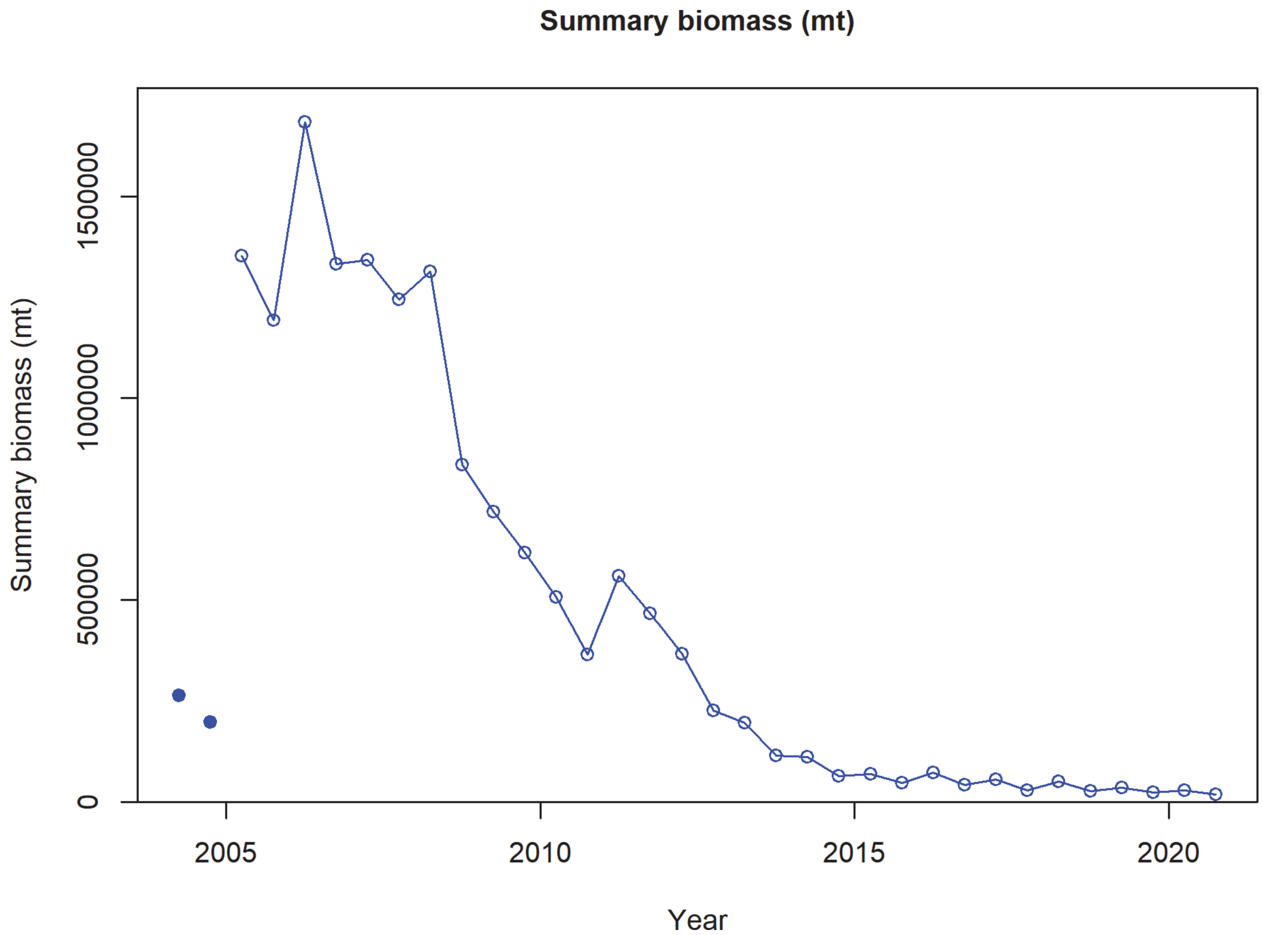

Figure 3. Estimated stock biomass (age 1+ fish; mt) time series from the 2020 benchmark assessment model (Kuriyama et al. 2020).

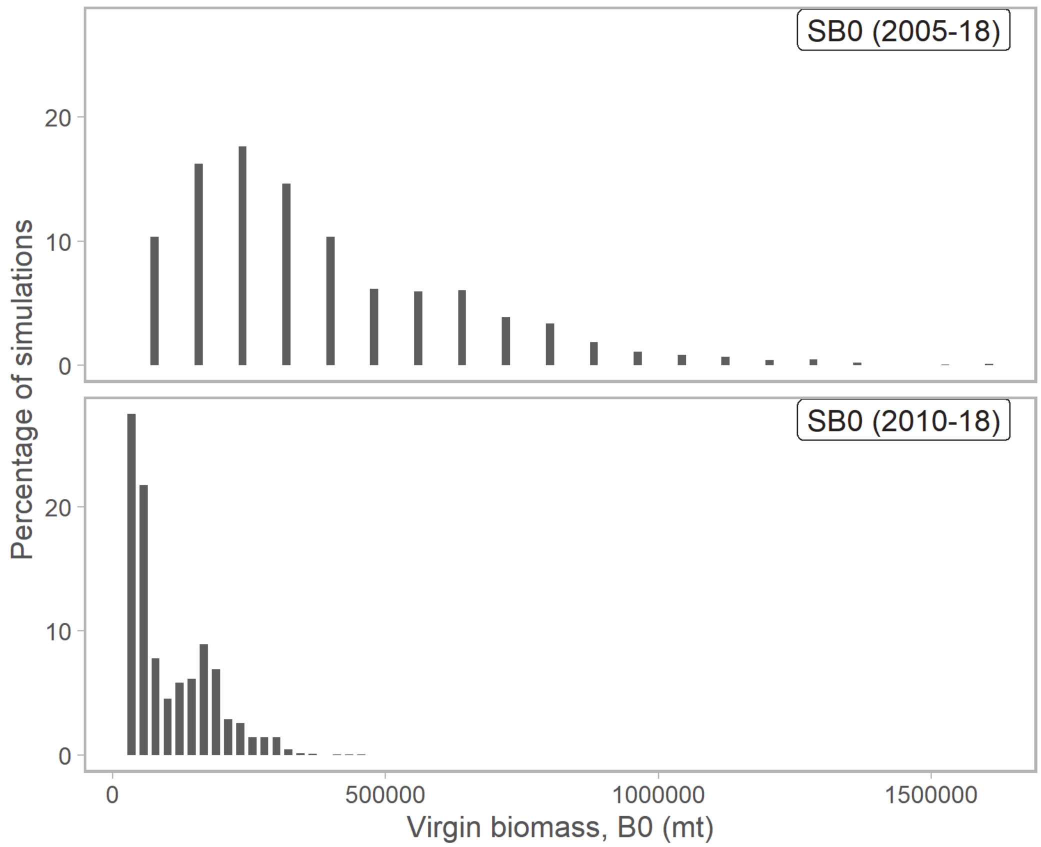

Figure 4. Virgin spawning biomass (SB_0) for the two states of nature.

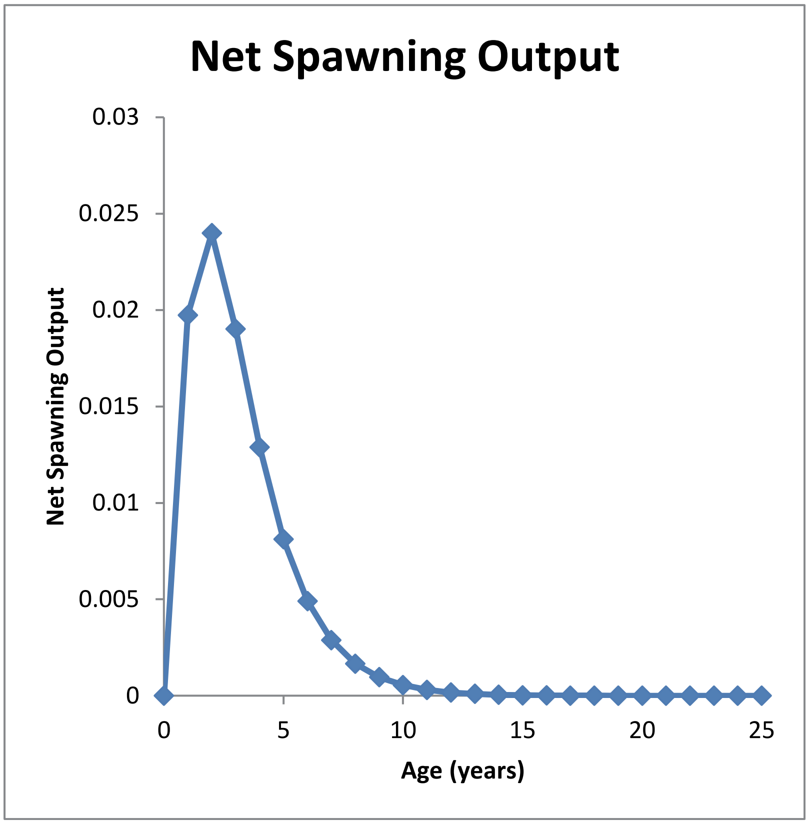

Figure 5. Pacific sardine net spawning output by age.

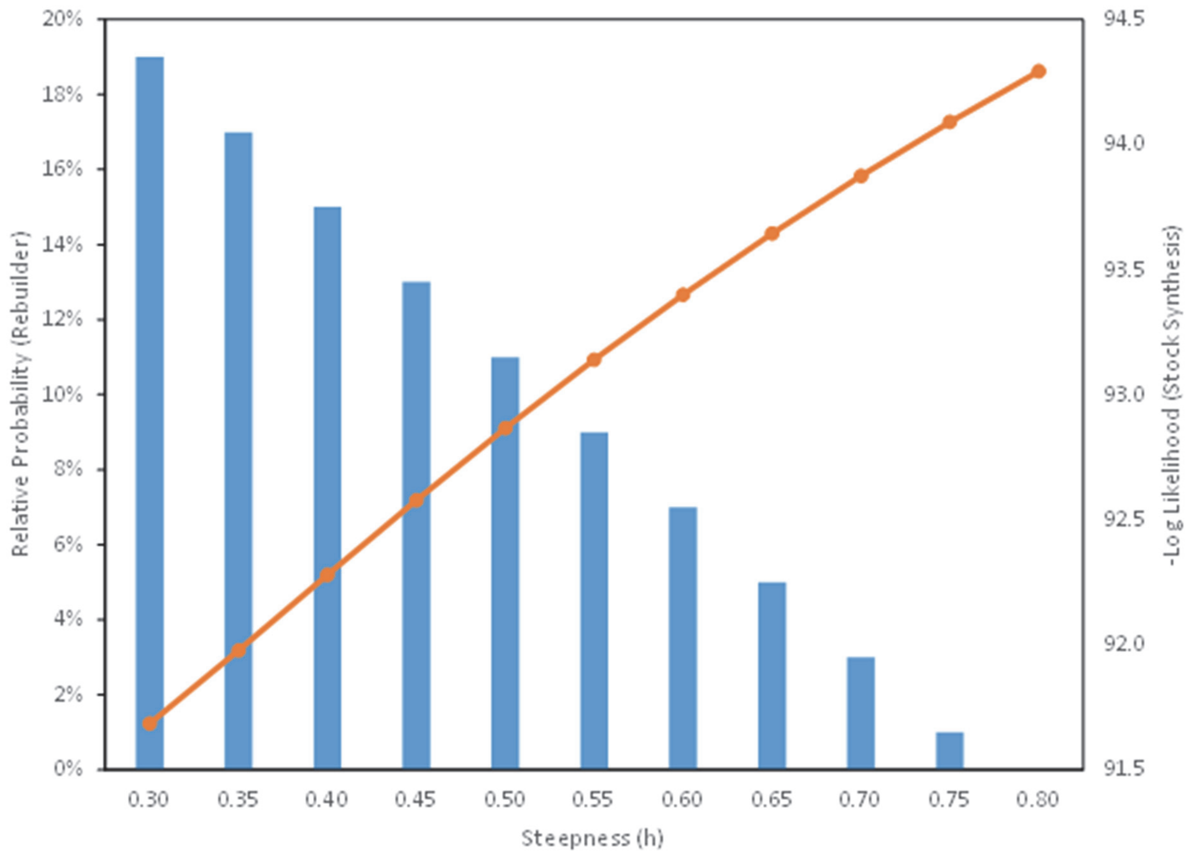

Figure 6. Relative probabilities (blue bars) for steepness levels profiled in rebuilding projections. Relative probabilities were based on negative log likelihood estimates from Stock Synthesis steepness profiles (orange line).

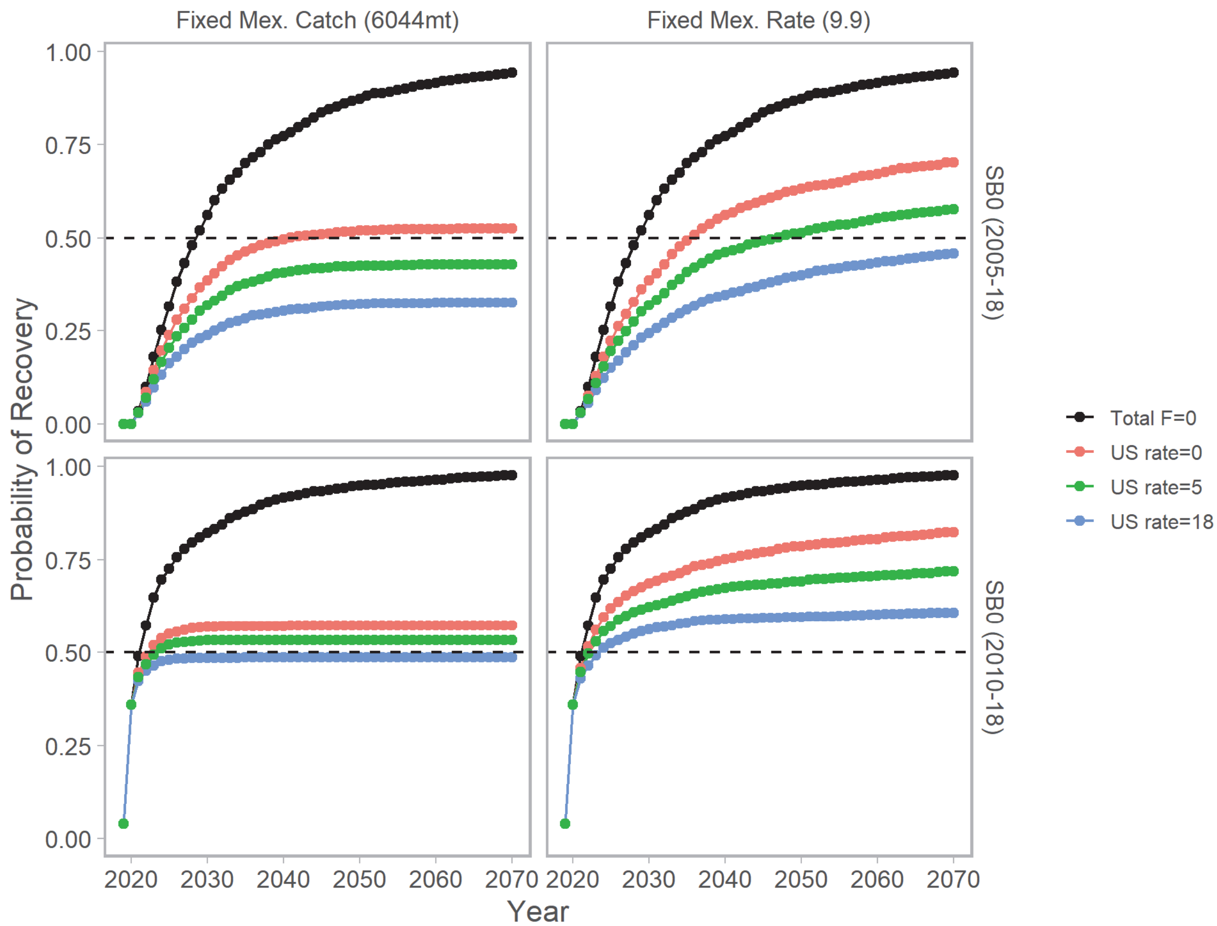

Figure 7a. Probabilities of recovery for Pacific sardine rebuilding alternatives. Panels are arranged by state of nature [$SB_{0(2005\text{-}18)}$ – top row; $SB_{0(2010\text{-}18)}$ – bottom row]. Mexico catch was fixed at 6,044 mt (left column) or assumed to have a fixed harvest rate of 9.9 (right 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.

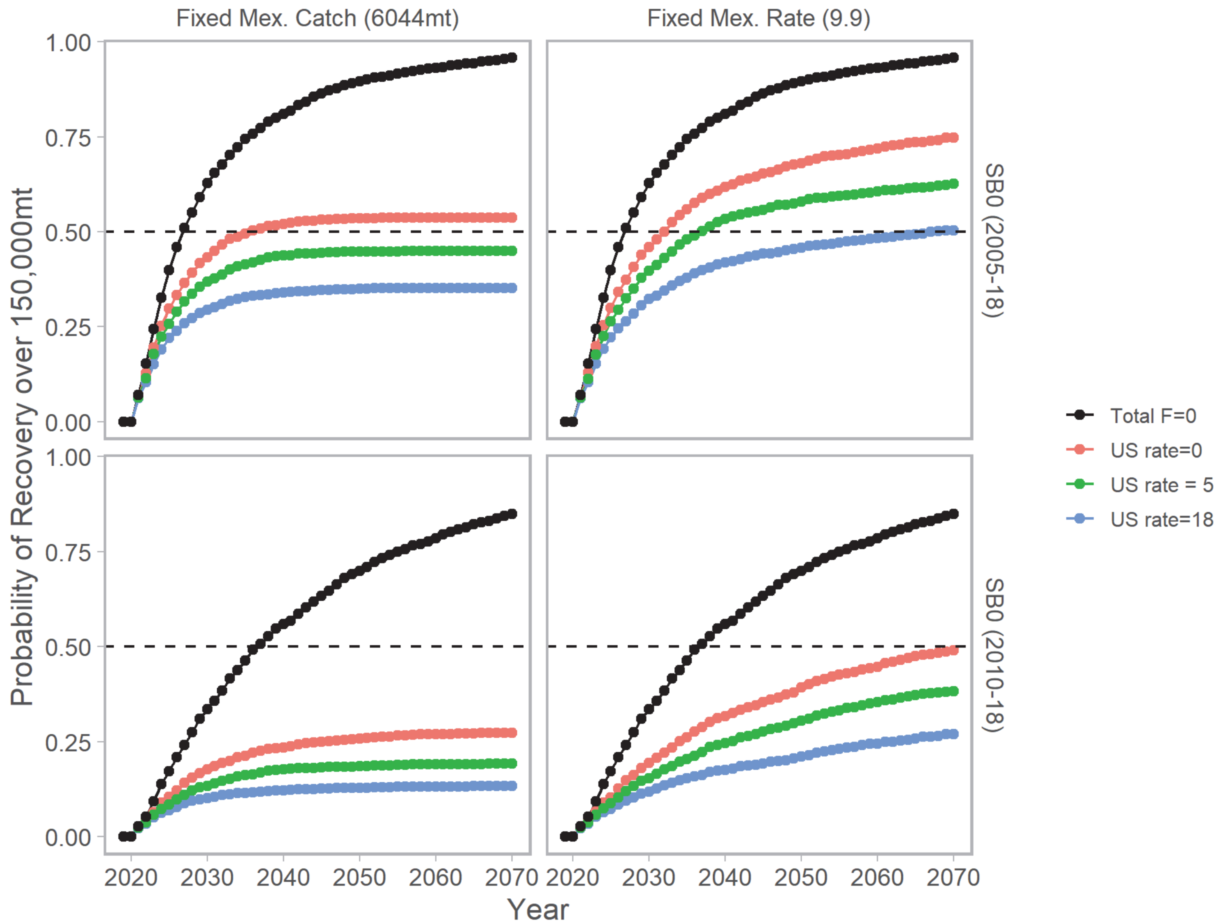

Figure 7b. Probabilities of recovery to the 150,000 mt Cutoff threshold for Pacific sardine rebuilding alternatives. Panels are arranged by state of nature [$SB_{0(2005\text{-}18)}$ – top row; $SB_{0(2010\text{-}18)}$ – bottom row]. Mexico catch was fixed at 6,044 mt (left column) or assumed to have 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.

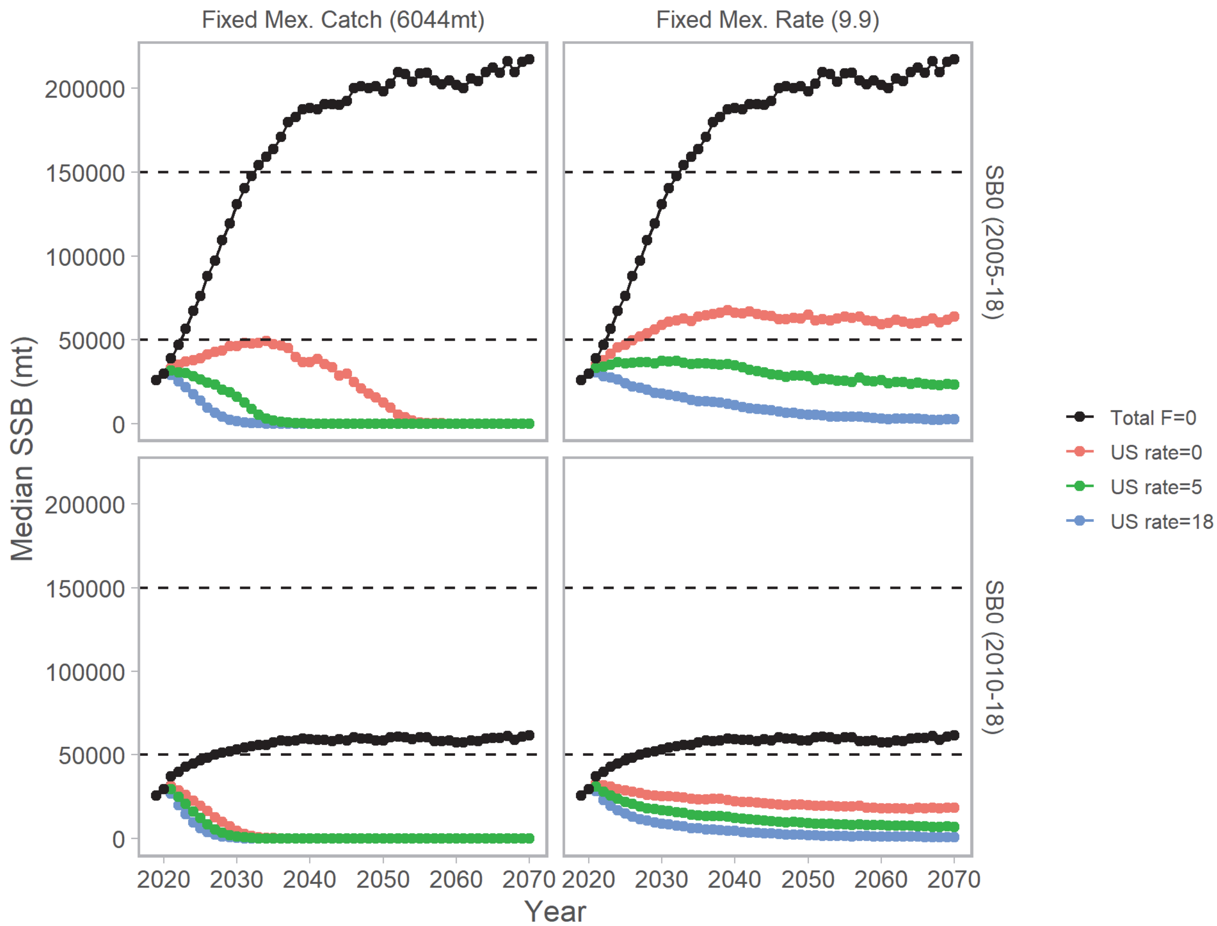

Figure 8. Median spawning stock biomass (mt) for Pacific sardine rebuilding alternatives. Panels are arranged by state of nature [$SB_{0(2005\text{-}18)}$ – top row; $SB_{0(2010\text{-}18)}$ – bottom row]. Mexico catch was fixed at 6,044 mt (left column) or assumed to have a fixed harvest rate of 9.9 (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.

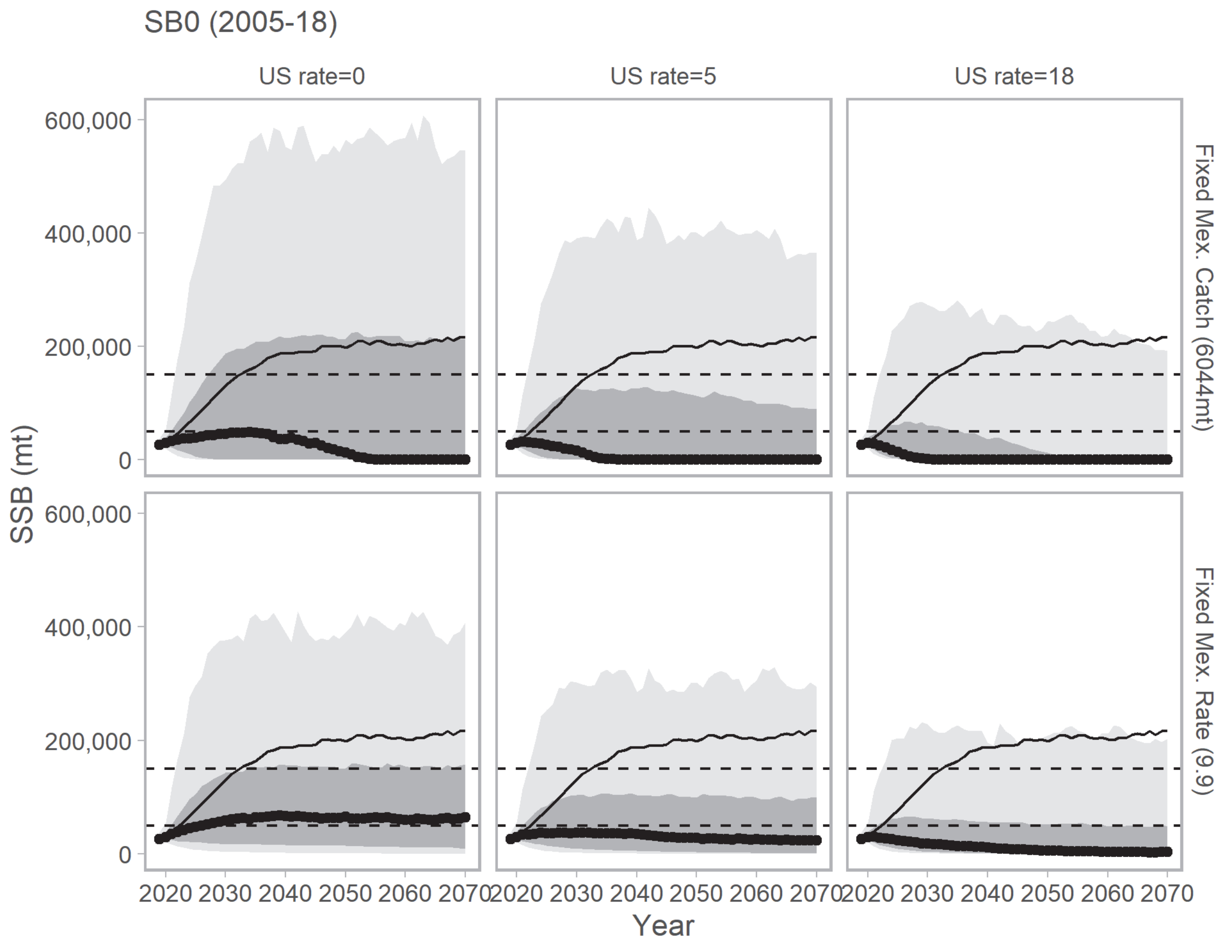

Figure 9. Projected spawning stock biomass (mt) for $SB_{0(2005\text{-}18)}$ scenario. Mexico catch was either fixed at 6,044 mt (top row) or fixed at a harvest rate of 9.9% (bottom row). US harvest rate was 0, 5, or 18% (left to right columns). Values displayed are median SSB values (black points), 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.

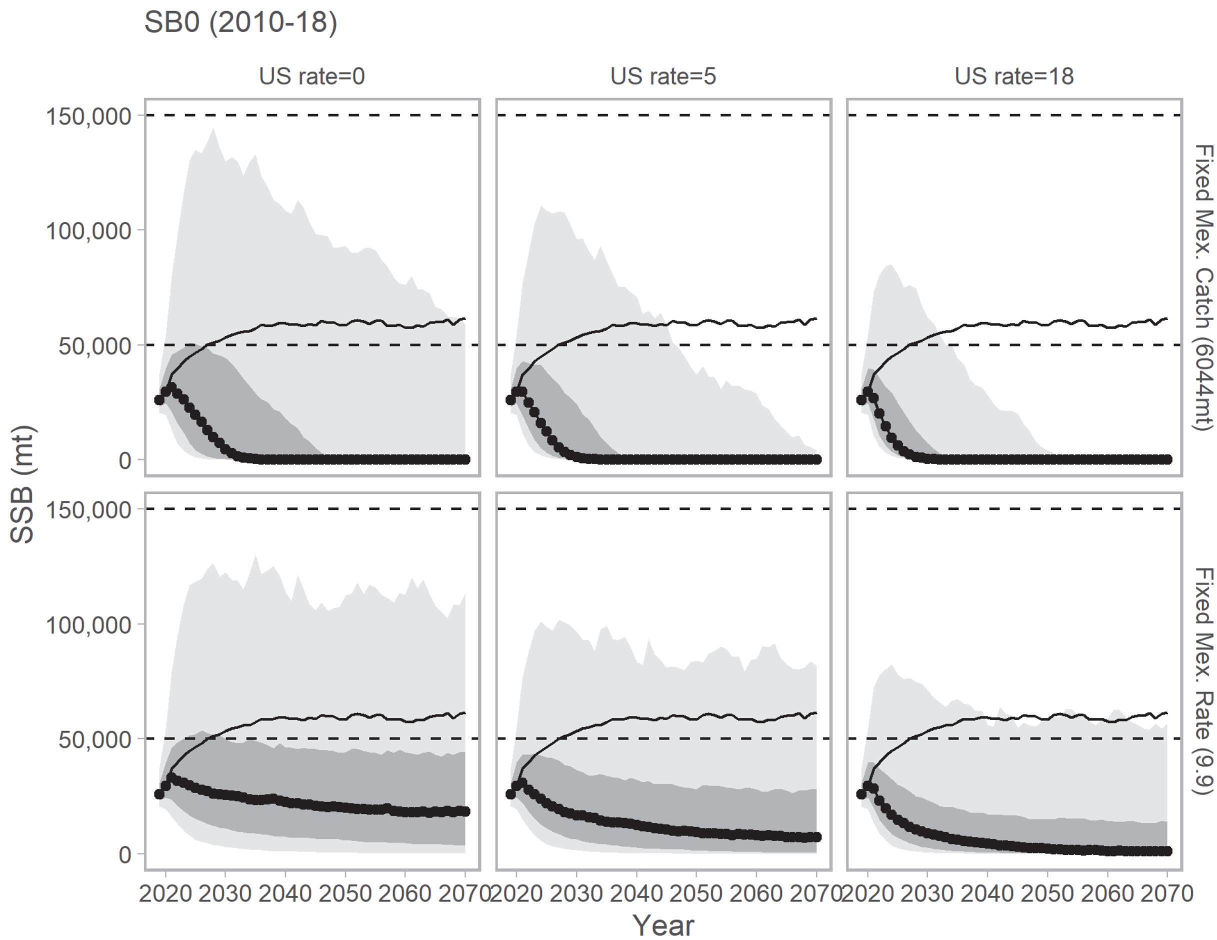

Figure 10. Projected spawning stock biomass (mt) for $SB_{0(2010\text{-}18)}$ scenario. Mexico catch was either fixed at 6,044 mt (top row) or fixed at a harvest rate of 9.9% (bottom row). US harvest rate was 0, 5, or 18% (left to right columns). Values displayed are median SSB values (black points), 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.

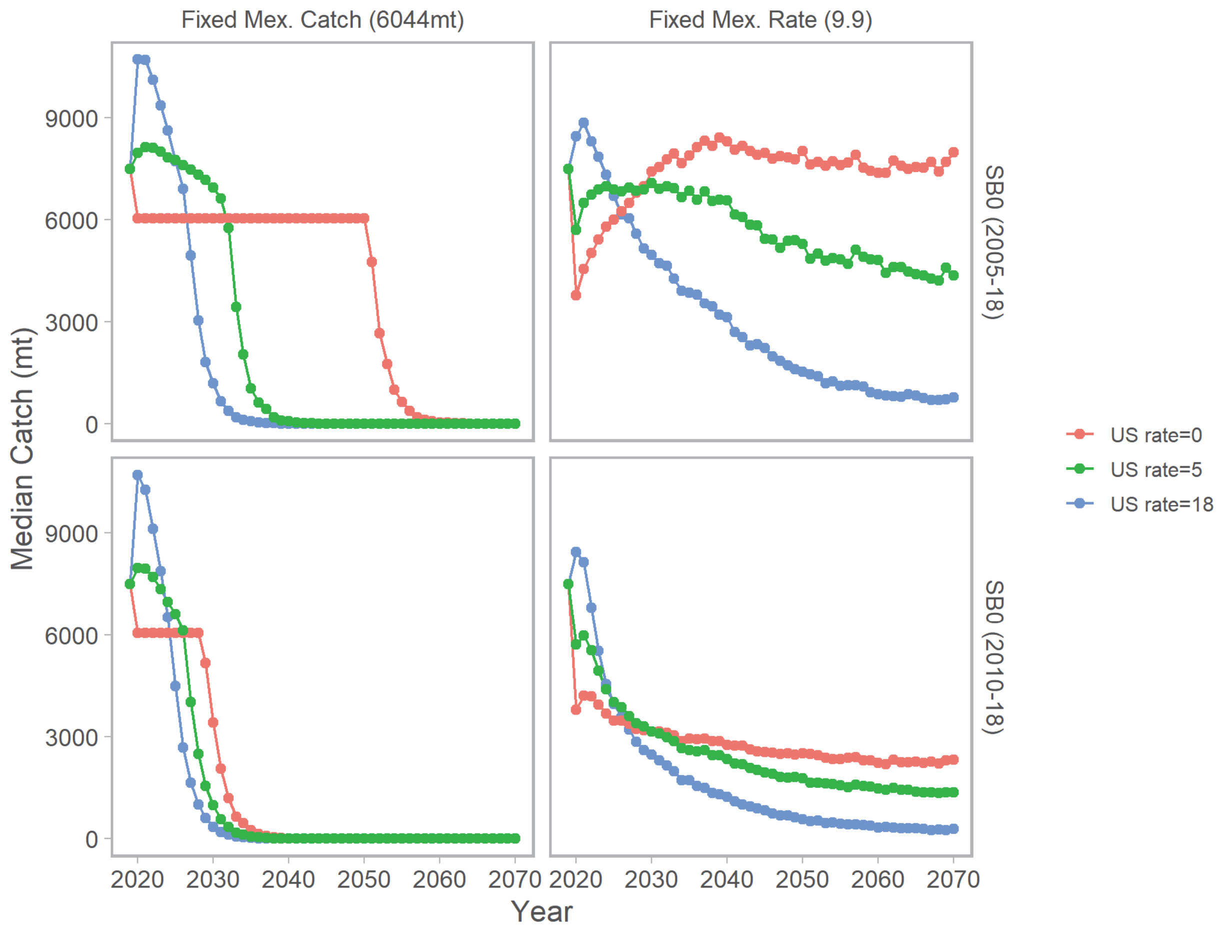

Figure 11. Median projected catch (mt) for Pacific sardine rebuilding alternatives. Panels are arranged by state of nature: $SB_{0(2005\text{-}18)}$ – top row; $SB_{0(2010\text{-}18)}$ – bottom row. Mexico catch was fixed at 6,044 mt (left column) or assumed to have a fixed harvest rate of 9.9 (right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

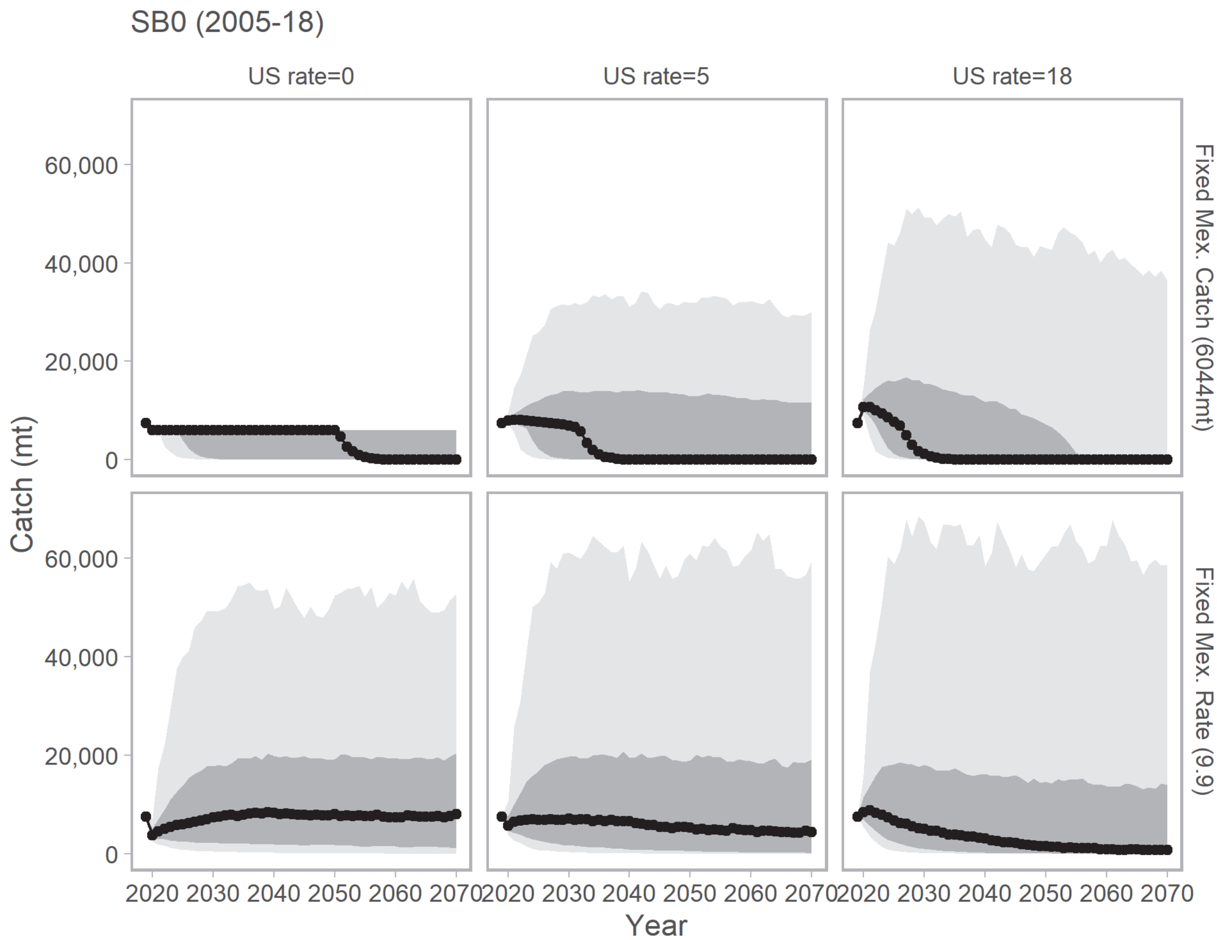

Figure 12. Projected catch (mt) for $SB_{0(2005\text{-}18)}$ scenario. Mexico catch was either fixed at 6,044 mt (top row) or fixed at a harvest rate of 9.9% (bottom row). US harvest rate was 0, 5, or 18% (left to right columns). Values displayed are median catch values (black points), 25-75 percentiles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

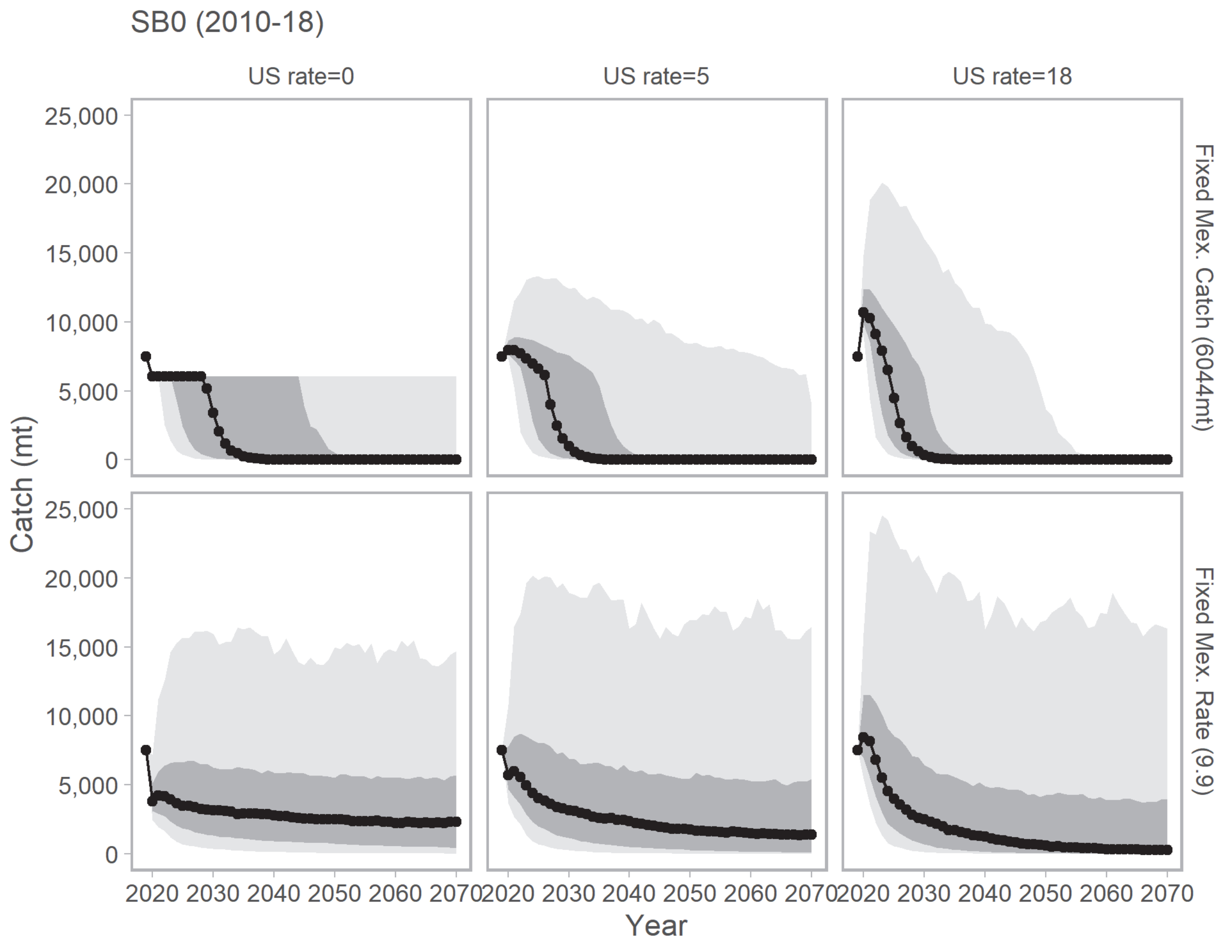

Figure 13. Projected catch (mt) for $SB_{0(2010\text{-}18)}$ scenario. Mexico catch was either fixed at 6,044 mt (top row) or fixed at a harvest rate of 9.9% (bottom row). US harvest rate was 0, 5, or 18% (left to right columns). Values displayed are median catch values (black points), 25-75 percentiles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

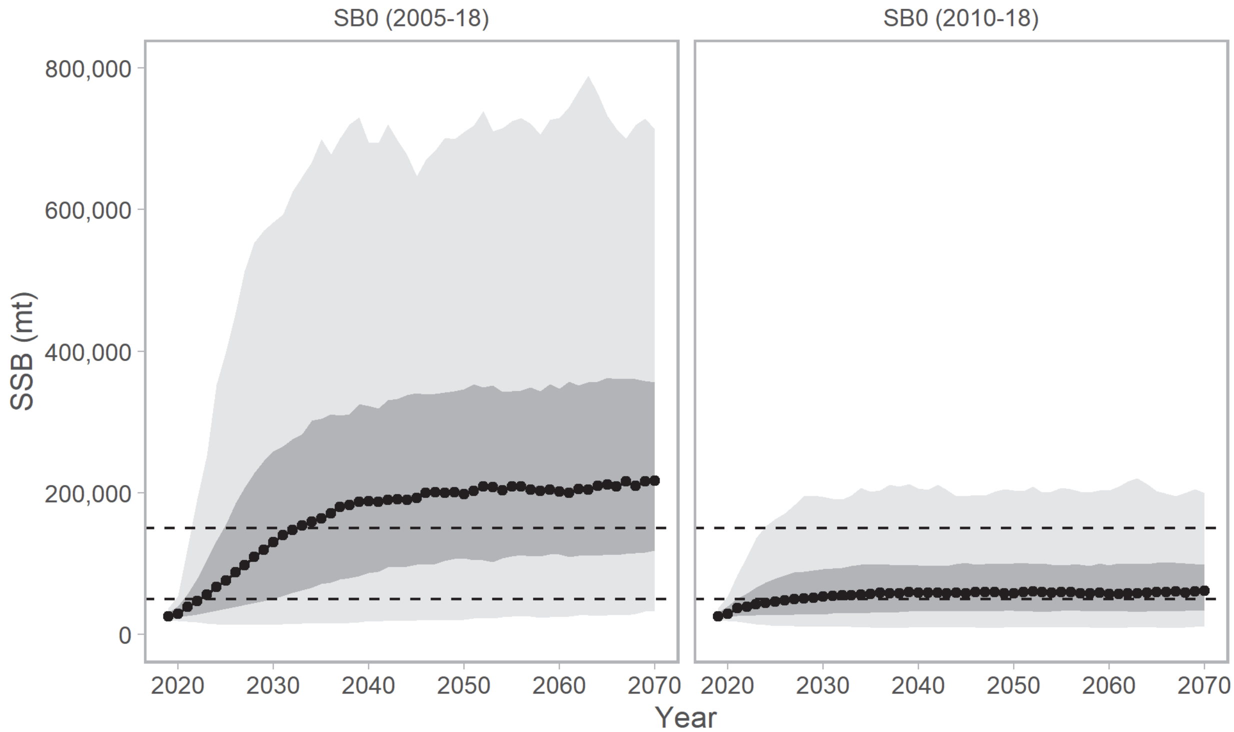

Figure 14. Projected spawning stock biomass (mt) for the $SB_{0(2005\text{-}18)}$ and $SB_{0(2010\text{-}18)}$ scenarios in the complete absence of fishing (Total *E*=0 for the US and Mexico). Values displayed are median SSB values (black points), 25-75 percentiles (dark gray shading), and 5-95 percentiles (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
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.490027 1 0.257237 0.0376225 0.0534343 0.0437764 0.0144477 0.0136617
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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
 0.490027 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
```

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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
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
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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
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
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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
 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
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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
 0.488545 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
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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
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37345.9 30874.1 33239.5 27446.9 24622.7 21150.6 #SpawnBio
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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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#bodywt for gender,fleet: 1 / 2 MexCal_S2
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 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
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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
 709374 223811 47227 12654.5 47866.3 11586.4 5737.45 4540.56 1706.83 8698.09
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#female fecundity; weighted by N in year Y_init across morphs and areas
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0.00303927 0.00303927 0.00303927 #selex for gender,fleet: 1 / 2 MexCal_S2
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 540137 253807 50357.6 20853 6797.19 25224 6021.69 3067.65 2481.46 946.908
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 709374 223811 47227 12654.5 47866.3 11586.4 5737.45 4540.56 1706.83 8698.09
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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
 0.488545 1 0.256608 0.0374046 0.0531285 0.0434869 0.0143483 0.0135713
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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
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 540137 253807 50357.6 20853 6797.19 25224 6021.69 3067.65 2481.46 946.908
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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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#female fecundity; weighted by N in year Y_init across morphs and areas
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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
 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
 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
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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
 0.488545 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
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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
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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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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
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 540137 253807 50357.6 20853 6797.19 25224 6021.69 3067.65 2481.46 946.908
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 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
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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
 0.488545 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
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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
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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
 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
 0.487126 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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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
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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
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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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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
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1877690 23416100 10192200 4420380 3019140 4337600 6352700 387178 316738
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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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#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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 835707 224885 47541.6 12871.7 47901 11660.2 5741.96 4526.63 1659.42 8704.79
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37214.1 30796.9 33201.1 27464.6 24678.3 21659.3 #SpawnBio
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2176.53 #numbers for year Ydeclare: 2019 sex: 1
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2019 #years
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188279 941409 1133610 1008700 759158 507972 346199 264560 147983 69129.9
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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
 0.487126 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
 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
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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
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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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#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.48577 1 0.255826 0.036735 0.0521844 0.0426627 0.0140661 0.013305
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229188 270308 869059 206512 536495 647763 958782 #Recruits
184242 940351 1132730 1008110 758834 507807 346124 264529 147926 69047.3
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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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 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
#
 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
```

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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
 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
#
 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
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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
#
 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
 0.48577 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
 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
#
 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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 0.484472 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
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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
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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
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#
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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
 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
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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
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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
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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
 0.484472 1 0.255577 0.0363654 0.0516644 0.0422194 0.0139143 0.0131602
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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
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year Ydeclare: 2019 sex: 1
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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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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
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179777 939471 1132020 1007670 758608 507711 346113 264588 147956 69030.6
37107.7 30728.9 33177.9 27518.9 24782.7 22617.7 #SpawnBio
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#
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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
 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
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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
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228502 270749 868407 208279 537154 648535 1077590 #Recruits
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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
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#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
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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
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228502 270749 868407 208279 537154 648535 1077590 #Recruits
179777 939471 1132020 1007670 758608 507711 346113 264588 147956 69030.6
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#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
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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
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1789290 23372400 10156400 4407830 3007440 4331750 6348380 374241 313075
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179777 939471 1132020 1007670 758608 507711 346113 264588 147956 69030.6
37107.7 30728.9 33177.9 27518.9 24782.7 22617.7 #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
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#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
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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

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#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
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#bodywt for gender,fleet: 1 / 2 MexCal_S2
 0.484472 1 0.255577 0.0363654 0.0516644 0.0422194 0.0139143 0.0131602
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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
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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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 0.484472 1 0.255577 0.0363654 0.0516644 0.0422194 0.0139143 0.0131602
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 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
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179777 939471 1132020 1007670 758608 507711 346113 264588 147956 69030.6
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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
 0.483226 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 #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
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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
 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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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
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#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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2019 #years
1702480 23340100 10129100 4398880 2998860 4328840 6355740 362669 310067
227194 271345 868081 211060 538202 649661 1299710 #Recruits
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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
 0.480866 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
#
 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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 0.480866 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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year Yinit: 2020 sex: 1
1402380 228297 48478 13550 48287 11872 5729 4469 1446 8948 2254 #numbers for
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37170.8 30762.7 33235.1 27637.8 24933.2 23892.5 #SpawnBio
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#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
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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
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
#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
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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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#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
2019 #years
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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
0.65 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
 0.479742 1 0.255208 0.0349976 0.0497466 0.0406077 0.0133612 0.0126284
0.00281626 0.00281626 0.00281626 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.582688 0.582688 0.582688 0.582688 0.582688 0.582688 0.582688 0.582688
0.582688 0.582688 0.582688 #mean M for year Yinit: 2020 sex: 1
1348030 647950 74860 23675 7448 26114 6315 3088 2458 785 6281 #numbers for
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
0.7 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
 0.479742 1 0.255208 0.0349976 0.0497466 0.0406077 0.0133612 0.0126284
0.00281626 0.00281626 0.00281626 #selex for gender,fleet: 1 / 2 MexCal_S2
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1348030 647950 74860 23675 7448 26114 6315 3088 2458 785 6281 #numbers for
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
```

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164227 937001 1130210 1006660 758232 507685 346386 265254 148520 69317.2
37223.5 30795.2 33269.6 27683.6 24981.9 24272.7 #SpawnBio
0.7 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
 0.479742 1 0.255208 0.0349976 0.0497466 0.0406077 0.0133612 0.0126284
0.00281626 0.00281626 0.00281626 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.582688 0.582688 0.582688 0.582688 0.582688 0.582688 0.582688 0.582688
0.582688 0.582688 0.582688 #mean M for year Yinit: 2020 sex: 1
1348030 647950 74860 23675 7448 26114 6315 3088 2458 785 6281 #numbers for
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
0.7 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
 0.478652 1 0.255233 0.0347047 0.0493371 0.0402662 0.0132437 0.012515
0.00278996 0.00278996 0.00278996 #selex for gender,fleet: 1 / 2 MexCal_S2
 0.582487 0.582487 0.582487 0.582487 0.582487 0.582487 0.582487 0.582487
0.582487 0.582487 0.582487 #mean M for year Yinit: 2020 sex: 1
1462960 695680 76755 23868 7499 26210 6339 3089 2456 767 6328 #numbers for
year Yinit: 2020 sex: 1
1590890 229125 48691 13715 48490 11930 5724 4456 1377 9075 2291 #numbers for
year Ydeclare: 2019 sex: 1
#R0  2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
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
```

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.*