Agenda Item J.3
Attachment 1
November 2025

Reviewing the Fishery Management Unit in the Coastal Pelagic Species Fishery Management Plan and its Stock Definitions for Sardine off the U.S. West Coast

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The following is a standard document produced by the Pacific Fishery Management Council (PFMC, Council) and the National Marine Fisheries Service (NMFS) West Coast Region to provide the analytical background for decision-making. Due to a lack of appropriations, NMFS West Coast Region staff were unable to review and provide input on the final version of this document. As outlined in the Regional Operating Agreement, review of documents such as these is one responsibility of the NMFS.

Contents

Acronyms and Abbreviations

ABC	Acceptable Biological Catch
ACL	Annual Catch Limit
AM	Accountability Measure
ATM	Acoustic Trawl Method (survey)
BSIA	Best Scientific Information Available
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CCE	California Current Ecosystem
Chl-a	Sea surface concentrations of Chlorophyll *a*
CPS	Coastal Pelagic Species
CPSAS	Coastal Pelagic Species Advisory Subpanel
CPSMT	CPS Management Team
CWPA	California Wetfish Producer's Association
DEPM	Daily Egg Production Method
EC	Ecosystem Component
EEZ	Exclusive Economic Zone
EFP	Experimental Fishing Permit
EMSY	Environmental Maximum Sustainable Yield
ESA	Endangered Species Act
FMP	Fishery Management Plan
FMU	Fishery Management Unit
HCR	Harvest Control Rule
HG	Harvest Guideline
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSY	Maximum Sustainable Yield
mt	Metric Ton
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NS	National Standard
NSP	Northern Subpopulation (of Pacific sardine)
OFL	Overfishing Limit
OY	Optimum Yield
PFMC	Pacific Fishery Management Council
SDC	Status Determination Criteria
SSC	Scientific and Statistical Committee
SSP	Southern Subpopulation (of Pacific sardine)
SST	Sea Surface Temperature
SWFSC	Southwest Fisheries Science Center
U.S.	United States

1 Introduction

Pacific sardine (*Sardinops sagax*) have supported an economically valuable fishery off the U.S. West Coast for over 100 years. In fact, the species once supported the largest commercial fishery in the Western hemisphere, immortalizing California's iconic "cannery row." Pacific sardine were landed off all three West Coast states, with landings peaking in the 1930s. The biomass of this stock eventually contracted, leading to successive fishery closures in the mid 20th century. In the late 1990s and early 2000s, a directed fishery began to expand once again, with operations off Oregon, Washington, and British Columbia, Canada returning. The northern subpopulation of Pacific sardine was defined as a stock subject to management via the Coastal Pelagic Species Fishery Management Plan (CPS FMP) during this time of the late 90s and early 2000s. However, the estimated stock biomass fell below the CUTOFF value of 150,000 mt in 2015, closing the directed fishery, with only live bait, small-scale, and incidental catch permitted since. In 2019, the stock biomass dropped below 50,000 mt, leading to an overfished declaration and implementation of a rebuilding plan.

The Coastal Pelagic Species Advisory Subpanel (CPSAS) recently noted that the 2,200 mt annual catch limit (ACL) recommended under the rebuilding plan for low biomass years is "barely sufficient to support several important fisheries including live-bait, minor directed, and other CPS and Pacific whiting fisheries that incidentally catch sardine" and that there is potential for this ACL to be constraining in the future (Agenda Item J.2.a, Supplemental CPSAS Report 1, November 2024). In seeking remedy, fishermen have brought increased attention to a southern subpopulation (SSP) of Pacific sardine that is not managed under the CPS FMP. These fish mix with and are operationally indistinguishable from individuals of the northern subpopulation (NSP), on which the Pacific sardine stock is currently defined under the CPS FMP. Under a regime where the NSP biomass has been low, post-season apportionment of catch shows that the SSP are a substantial portion of southern California landings, reigniting questions about whether they should be included in the CPS FMP management framework. Given the ongoing restriction of the fishery and low stock status, there is growing interest from the Council in addressing the potential remedies brought forth.

Moreover, newly available scientific information, including new genetics work on Pacific sardine and a review of all preceding research on these subpopulations reveal a lack of scientific evidence to support the long-held hypothesis that NSP and SSP are truly distinct subpopulations - the hypothesis that underlies current management of sardine. Finally, the emergence of Japanese sardine (*Sardinops melanosticta*) in U.S. waters in 2022 is another factor complicating the question of how sardine should be managed in U.S. waters.

Considering these complex factors–the prolonged fishery closure, publication of new science on the population structure of Pacific sardine, and the emergence of Japanese sardine in the California Current–the Council has determined it appropriate to reevaluate the management unit of sardine in the CPS FMP. This action is also prioritized by the Council in the context of taking actions that are intended to stabilize markets, improve access, enhance economic profitability, and prevent closures of fisheries in response to Executive Order 14276 (Agenda Item H.2, Attachment 5, September 2025).

1.1 History of Action

In April 2025, the Council agendized the topic of Pacific sardine stock definitions via a prioritization process of CPS science and management topics. This prioritization of the stock definition topic followed the recommendation of the CPSAS and the Coastal Pelagic Species Management Team (CPSMT; Agenda Item G.4.a, Supplemental CPSMT Report 1 and Supplemental CPSAS Report 1, April 2025); In their April 2025 report, the CPSAS called for a review of the stock definitions used in current management of Pacific sardine in order to explore alternatives that may alleviate the restrictions industry continues to face in light of the stock decline, closure of the directed fishery, and implementation of the rebuilding plan. However, these recent statements are not the first time stakeholders have brought forward this issue; in April 2021, the CPSAS recommended that the Council, "Assess and manage all sardines found in U.S. waters," suggesting current management, only attached to the NSP, restricts the ability of the fishery to access the full resource available in U.S. waters (Agenda Item E.4.a, Supplemental CPSAS Report 1, April 2021), reiterating concerns brought up in 2020 (Agenda Item C.2.a, Supplemental CPSAS Report 1, September 2020. Therefore, this action arises in the midst of an ongoing discussion on the population structure of Pacific sardine and whether current management aligns with the scientific information available. Since at least 2021, stakeholders have suggested that current management may not cover the full sardine resource that is accessible to U.S. fisheries. Concerns had been raised over the *Catch-only projection of the Pacific sardine resource in 2021 for U.S. management in 2021-2022* (Agenda Item E.4, Attachment 1, April 2021) from which the Scientific and Statistical Committee (SSC) raised that the Mexico catch attributed to the NSP was on the same order of magnitude as the entire NSP population size from the 2020 benchmark assessment (Supplemental SSC Report, Agenda Item E.4.a, April 2021). In response, the Southwest Fisheries Science Center (SWFSC) hosted a 2022 stock structure workshop to reconsider issues of attribution among NSP and the SSP, which is not defined in or managed via the CPS FMP. The workshop included five presentations of ongoing research related to Pacific sardine stock structure, which were summarized in a workshop report and highlighted to the Council in April 2023 (Yau, 2023). The workshop report described the operative definition for both the NSP and SSP, supporting the working hypothesis that there are two distinct subpopulations. It was also discussed and supported at the workshop that there exist alternative hypotheses, primarily one that defines a single Pacific sardine stock ranging from British Columbia to Baja California, with no differentiation between northern and southern subpopulations.

Building on those preliminary findings, several papers from SWFSC scientists and other researchers have been published in the past year (2024-2025), concluding that there is a lack of evidence to support the currently operationalized subpopulation hypothesis (Craig & Adams, 2024, Erisman, Adams-Herrmann, Craig, James, & Thompson, 2025, Erisman, Craig, James, Schwartzkopf, & Dorval, 2025; Longo et al. 2025a). In February 2025, scientists at the SWFSC published a NOAA Technical Memorandum (Tech Memo) detailing an extensive literature review to revisit the working population structure hypothesis (Craig, Erisman, Adams-Herrmann, James, & Thompson, 2025). The review, covering a century of scientific literature on spawning areas, migration and growth patterns, and genetics, concluded that 'there is little, if any, evidence supporting a hypothesis of multiple subpopulations of Pacific sardine throughout their North American range.' The authors also found no evidence against the idea of a single coastwide population of the species. The first full genome analysis of Pacific sardine (Longo et al. 2025a), published several months later provided new genetic evidence of a single Pacific sardine

population with no structure or groupings by subpopulation. Aside from Pacific sardine, the emergence of Japanese sardine (*Sardinops melanosticta*) in U.S. waters is another subject of recent research and an interesting aspect of considering what species and populations of sardine are fished in U.S. waters, and should potentially be managed. Genetic samples first detected the presence of Japanese sardine in U.S. waters in 2022, an introduction currently hypothesized to have occurred due to shifts in frequency and intensity of warm water anomalies and marine heat waves facilitating shifts in the species' range (Longo et al. 2024). Japanese sardine remain present in U.S. waters, though it is uncertain to what extent, with 18.3 percent of biological samples taken in the 2024 CPS survey containing Japanese sardine (Longo et al. 2025b).

1.2 Why this Action is Considered by the Council

In April 2025, the CPSAS and CPSMT recommended that the Council prioritize a review of sardine stock definitions and any follow-on actions that may be warranted. The Council agreed, recognizing that reevaluating the management unit for sardine in U.S. waters is a fundamental and timely fishery management priority.

Identifying and defining a stock is one of the most basic and essential steps in sustainable fishery management. The Magnuson–Stevens Fishery Conservation and Management Act (MSA or Magnuson-Stevens Act) and National Standard 1 (NS1) require that fisheries be managed to prevent overfishing and to achieve, on a continuing basis, optimum yield. Meeting these goals depends on correctly identifying the biological population units being managed. Inaccurate stock definitions can undermine assessments of biomass and yield, leading to management measures that do not align with the true population structure or dynamics (Cope and Punt 2009; Cadrin et al. 2023).

Recent scientific evidence and a review of historical information indicate that the sardine management unit described in the CPS FMP may not accurately represent the biological population(s) occurring in U.S. waters. Current management based on a two-subpopulation hypothesis for Pacific sardine does not capture all sardine harvested domestically and emerging data questions whether these subpopulations are distinct, suggesting that Pacific sardine along the West Coast may instead comprise a single, coastwide population. Complicating this further, Japanese sardine—a closely related and morphologically indistinguishable species—has recently become more prevalent in U.S. waters and often appears in mixed landings.

If Council management were to define the Pacific sardine stock at a scale inconsistent with its true biological extent, the result can be misaligned harvest limits, inaccurate stock status determinations, and lost opportunities for sustainable yield. Ecologically, such mismatches can affect predator-prey relationships and ecosystem dynamics, while economically and socially these same mismatches can lead to lost fishing opportunity.

To ensure that the CPS Fishery Management Unit (FMU) reflects the biological realities of sardine in U.S. waters, the Council must address two key questions:

1. Which species and populations of sardine should be included in the FMU?
2. How should those stocks be identified and delineated to align management with the true geographic and biological extent of the resource?

Put in other words, the Council's task is to determine whether the current FMU and the stocks defined within it adequately encompasses the population structure of Pacific sardine—and whether Japanese sardine should be added—so that management actions remain consistent with the principles of the MSA, NS1, and sound fishery science.

1.3 Management of Sardine

Beginning January 1, 2000, Pacific sardine came under Federal management through Amendment 8 to the Northern Anchovy FMP, which was renamed the CPS FMP (64 FR 69888, December 15, 1999). The amendment was intended to provide comprehensive management of CPS in response to rapid development in harvests, primarily because of a resurgence of Pacific sardine along the Pacific coast and an increase in the market demand for squid. The amendment cited an increase in abundance of Pacific sardine, and their presence off Mexico, California, Oregon, Washington, and Canada, placing management of this species beyond the authority of any individual state.

Table 1. Table 1-1 of the CPS FMP includes the fishery management unit species which are "in the fishery" and subject to provisions of the FMP, including stocks managed under this FMP. The CPS FMP does not restrict the definition of its FMU to the U.S. EEZ

Common Name	Scientific Name
Pacific sardine	*Sardinops sagax*
Northern subpopulation	
Pacific (chub) mackerel	*Scomber japonicus*
Northern anchovy	*Engraulis mordax*
Central and northern subpopulations	
Market squid	*Doryteuthis opalescens*
Jack mackerel	*Trachurus symmetricus*
Krill or Euphausiids	*All Species in West Coast EEZ*
Including these eight dominant species.	*Euphausia pacifica*
First two species are common and are	*Thysanoessa spinifera*
most likely to be targeted by fishing	*Nyctiphanes simplex*
	Nematocelis difficilis
	T. gregaria
	E. recurva
	E. gibboides
	E. eximia

When Pacific sardine was defined in the CPS FMP, knowing that Pacific sardine range from the southern tip of Baja California to Alaska and into the Gulf of California, the Description of the Coastal Pelagics Fishery (Appendix A to the CPS FMP; PFMC 2024c), cited a general acceptance that sardine off the West Coast of North America form three subpopulations or stocks: a northern subpopulation (northern Baja California to Alaska), a southern subpopulation (off Baja California), and a Gulf of California subpopulation: "Although the ranges of the northern and southern subpopulations overlap, the stocks may move north and south at similar times and not overlap significantly. The northern stock is exploited by U.S. fisheries and is included in this FMP." Accordingly, the CPS FMP defined the stock within its jurisdiction as the northern subpopulation of Pacific sardine. However, over time, the Council has recognized the NSP stock does not

constitute the entire Pacific sardine resource in U.S. waters, as fish categorized as SSP are also known to be present in Southern California, particularly in summer months, and caught in U.S. fisheries.

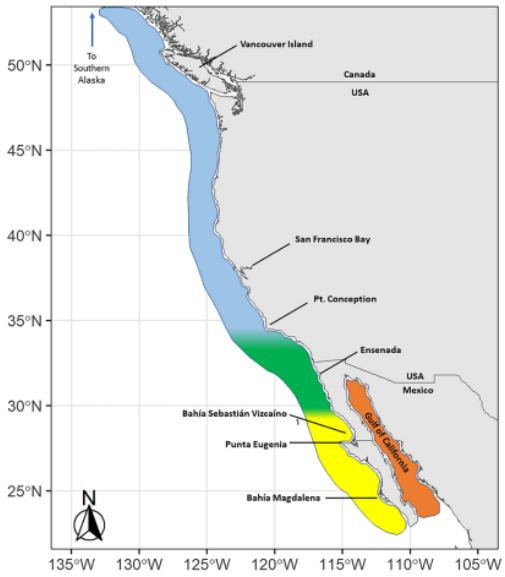

Figure 1. Generalized distributions of the hypothesized Northern subpopulation (blue), Southern subpopulation (yellow), and Gulf of California subpopulation (orange) of Pacific sardine (Sardinops sagax). While the Northern and Southern subpopulations show overlap, the two-stock hypothesis considers that they may move north-south at similar times and have limited overlap. Their potential overlap is shown in green (via Craig et al. 2025).

1.4 Current Management

The management of the northern subpopulation of Pacific sardine continues to align stock structure with the hypothesized three distinct subpopulations (NSP, SSP, and Gulf of California). Annual surveys and assessments (described more in the following section) support annual harvest specifications for the sardine fishing year that extends from July 1 to June 30 and apply only to the NSP stock. Harvest specifications are based on a precautionary harvest control rule (HCR) that include an environmental parameter and transboundary considerations.[1] The Council recently specified the ACL HCR under Amendment 23 to the CPS FMP to support rebuilding of the NSP stock. Within the HCR formulas for the overfishing limit (OFL) and acceptable biological catch (ABC), a DISTRIBUTION term accounts for the proportion of NSP in U.S. waters, as it is a transboundary stock that extends into Mexico. The DISTRIBUTION term, estimating that 87 percent of NSP is in U.S. waters, has not been changed since it was first defined in 1999. As no HCRs are set for SSP, a distribution approximation has never been calculated for it. In April 2025,

[1] The current HCR for Pacific sardine (described in Section 4.6.4 of the FMP) is as follows:
OFL = BIOMASS * EMSY * DISTRIBUTION; where EMSY is bounded 0.00 to 0.25
ABC= BIOMASS * BUFFERP-star * EMSY * DISTRIBUTION; where EMSY is bounded 0.00 to 0.25 ACL= UNDER 50,000 MT (Overfished Status) If the age 1+ biomass is 50,000 mt (minimum stock size threshold) or less in a given fishing year, the ACL for that year would be set at 2,200 mt or the calculated ABC, whichever is less. OVER 50,000 MT (Rebuilding Status) If the age 1+ biomass is greater than 50,000 mt (minimum stock size threshold) but less than 150,000 mt (rebuilding target) in a given fishing year, the ACL would be set at five percent of the age 1+ biomass for that year or the calculated ABC, whichever is less.

the SSC and the Council recommended re-evaluating parameter terms in the HCR formulas, including the DISTRIBUTION term, in coordination with the sardine stock definitions action (Agenda Item G.5.a, Supplemental SSC Report 1, April 2025).

1.5 Stock Assessments and Habitat Index

Annual stock assessments are conducted for the stock in the California Current and set harvest limits for the U.S. Pacific sardine fishery. Prior to 2014, Pacific sardine stock assessments did not differentiate between northern and southern subpopulations, and all landings, biological samples, and survey data collected between Ensenada, Mexico, to British Columbia were attributed to the northern subpopulation (Hill et al. 2013).

Annual stock assessment reports for Pacific sardine (e.g., Hill et al. 2008, 2013) had identified research and data needs that included "further developing methods (e.g., otolith microchemistry, genetic, morphometric, temperature-at-catch analyses) to improve our knowledge of sardine [stock] structure," and "Temperature-at-age could provide insight into stock structure and the appropriate catch stream to use for assessments, because the southern subpopulation is thought to inhabit warmer water than the northern subpopulation." These research and data needs reflected research recommendations made during methodological peer reviews by independent experts in annual Stock Assessment Review panels.

The habitat index method developed by Demer and Zwolinski (2014) to apportion annual catch between northern and southern subpopulations of Pacific sardine, referred to as the "habitat model," has been utilized in benchmark and update stock assessments since developed in 2014. The 2014 stock assessment using satellite oceanography data to partition catch from Ensenada and southern California ports in order to exclude landings and biological compositions attributed to the southern subpopulation (Hill et al. 2014). First, in an effort to optimize the time and location of sardine surveys (egg production, acoustic-trawl), Zwolinski et al. (2011) mapped the monthly average distributions of the optimal and good potential sardine spring spawning habitat for the northern stock by matching distributions and densities of sardine eggs from 1998 to 2009 spring daily egg production method (DEPM) surveys to satellite images of sea surface temperature (SST), sea surface concentrations of Chl-*a*, and sea surface altitude deviation. Then, to differentiate landings of the northern and southern stock, Demer and Zwolinski. (2014) refined a method for using those monthly, SST-based indices of potential habitat for the northern stock (SST ≤ 16.4–16.7 ℃). For months when the SST index was more than 50 percent (i.e., when the average SST that month fell within the "optimal habitat" range) for a fishing port area (see shaded region in Figure 3), the landings into that port, reported regionally and monthly, were attributed to the northern stock, and vice versa. The result indicated that for summertime landings in San Pedro, CA, between 2006 and 2011, 32–36 percent may be from the southern stock.

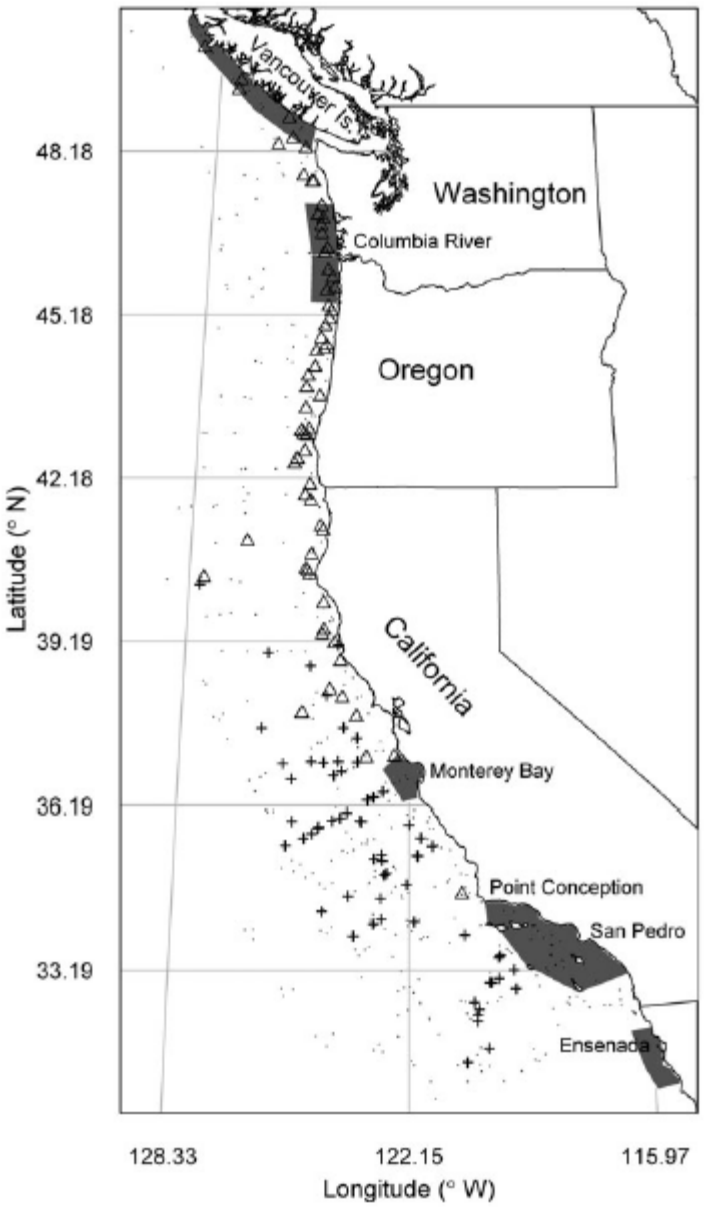

Figure 2. Figure 1 from Demer and Zwolinski (2014), showing the locations of sardine fisheries and associated analysis regions (grey; north to south; Vancouver Island, Canada; Washington; Oregon; Monterey and San Pedro, California; and Ensenada, Mexico), and the locations of surface-trawl catches without (dots) and with Pacific sardine during the spring (crosses) and summer (triangles) acoustic-trawl-method surveys, 2006-2011

Figure 3. Monthly average SST is indexed for the Southern California Bight area shaded in grey to attribute monthly landings to the northern or southern subpopulation, via Zwolinski and Demer (2023).

This apportionment via the habitat model, however, only occurs during annual assessments. During the extent of the Pacific sardine fishing season, all catch of sardine in U.S. waters is attributed to the NSP. Practically, this catch accounting system means that while all catch may contribute to approaching the NSP's ACL, ABC, or OFL inseason, and to the related restrictions or even closures that could follow suit, only a portion of this catch is later attributed to the NSP. As shown in Table 2, below, the proportion of catch attributed to NSP via the updated habitat index has declined since the closure of the directed fishery in 2015. Multiple factors may have contributed to this decline; a shift in the proportion of sardine caught for live bait purposes, a geographic contraction of the fishery to almost solely occur in Southern California, and a decrease in the stock size of NSP may all contribute.

In 2020, the biomass of sardine that was landed in Mexico and attributed to the northern stock exceeded the biomass estimate for the entire northern stock. To investigate this error, Zwolinski and Demer (2023) updated the potential habitat index through 2019 with presence and absence of sardine eggs and concomitant satellite SST and Chl-*a* concentration.

*Table 2. Total U.S. Pacific sardine landings (mt) by fishing year since the onset of federal management and NSP landings (mt and percentage of total) using the updated habitat model. Source: 2025 Stock Assessment Update for Pacific Sardine. *Landings for the 2024-2025 fishing year are incomplete.*

Fishing Year	Total Landings	NSP Landings	% NSP
2009	72,847	61,220	84
2010	60,862	49,751	82
2011	55,017	43,725	79
2012	86,230	76,410	89
2013	69,833	63,832	91
2014 (1)	6,806	6,121	90
2014-2015	23,113	19,969	86
2015-2016	1,919	75	4
2016-2017	1,885	602	32
2017-2018	1,775	351	20
2018-2019	2,278	525	23
2019-2020	2,062	627	30
2020-2021	2,276	657	29
2021-2022	1,772	298	17
2022-2023	1,620	565	35
2023-2024	1,774	844	48
2024-2025*	772	267	35

1.6 Description of the Fishery

In the period since Pacific sardine was added to the CPS FMP and before the closure of the primary directed fishery (2000–2015), the Pacific sardine fishery saw a resurgence, mostly an expansion in the Pacific Northwest from catch used as bait and for human consumption. During this time, despite many early closures, sardine was a major fishery in California with landings totaling 660,400 mt and an ex-vessel revenue estimated at $75.8 million. Participation in the limited entry fleet varied during this period but often exceeded 80 vessels. Off Oregon, the fishery saw high landings during early years of this time period, which were reduced through state permits and landing limits, landing approximately 384,500 mt with an ex-vessel revenue of $65.7 million over the 15-year period. Similar to Oregon, the fishery off Washington had higher landings early in the 15-year period which were then tapered through the implementation of state permits and area closures. In total, the fishery off Washington landed approximately 177,370 mt with an ex-vessel revenue of $34.4 million.

When the directed fishery was open, it operated via a limited entry program and three distinct quota periods (as detailed in Section 4 of the CPS FMP). Quota was allocated between three periods of the calendar year, with Tribal and exempted fishing permit set-asides allocated in advance, and states and NMFS tracking landings as they approached that period's quota. In some periods, state staff would coordinate daily with processing plants to ensure landings did not exceed the quota. Unused allocation could be carried forward into the next period. Because of the migratory nature of sardine, opportunity did vary between different areas of the coast during different times of the year, but fisheries operated off all three states. During the winter months, opportunity existed solely in southern California, whereas in the summer months, sardine was often fished off Washington and Oregon. The distribution of sardine in state and Federal waters also varied by year - which was particularly important off Washington, where commercial fisheries are not permitted in state waters. For the purposes of catch accounting and assessment, all sardine accessed by the fishery were assumed to come from the northern subpopulation and the stock assessment modeled the northern subpopulation stock, assuming it ranged from northern Baja, Mexico, to British Columbia, Canada. Based on the acceptance of multiple subpopulations, it was generally acknowledged that some of the catch off Mexico and Southern California was mis-attributed in the assessment model, but that these uncertainties essentially cancelled each other out.

In 2015, the stock assessment estimated the biomass to be 96,688 mt, below the CUTOFF value of 150,000 mt. The directed fishery was closed for the 2015–2016 fishing year and has remained closed as the estimated biomass remains below CUTOFF. In 2018, Amendment 16 to the CPS FMP was implemented to allow small amounts of harvest in the minor directed fishery while the primary directed fishery is closed. In 2019, Amendment 17 to the CPS FMP was implemented to allow flexibility in setting landings limits for the live bait fishery while the primary directed fishery is closed; however, the Pacific sardine stock was also determined to be overfished in 2019 when the biomass was estimated to be 27,547 mt, below the minimum stock size threshold of 50,000 mt, and work began on a rebuilding plan. In 2021, the Pacific Sardine Rebuilding Plan was implemented as Amendment 18, which continued to allow minimal retention in the minor directed, live bait, and incidental fisheries. The directed commercial fishery remains closed while the stock is rebuilding, and the ACL and other reference points apply to the live bait, minor directed, and incidental fisheries.

While current management follows best scientific information available (BSIA) to date, new information may be reviewed to determine whether management, and the FMU in particular, needs to be re-adjusted to address concerns that management only covers NSP, despite additional sardine being available to the fleet.

2 Framework for Defining a Fishery Management Unit

2.1 Definition of Terms

In order to understand the framework for defining a FMU it is important to clearly define several key terms:

Stock
The term "stock of fish" means a species, subspecies, geographical grouping, or other category of fish capable of management as a unit. (MSA § 3 104-297(42)). Section 1.2 of the CPS FMP defines the stocks included in the FMP. National Standard 3 (NS3) states that to the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination. The purpose is to induce a comprehensive approach to fishery management. The geographic scope of the fishery, for planning purposes, should cover the entire range of the stocks(s) of fish, and not be overly constrained by political boundaries.

Population Structure
While a stock is an operational unit delineated for management purposes, a population or subpopulation is a biological unit, a group of individuals of the same species that are separated from others within the same species. These terms are often synonymous, as current literature (and the advice of the PFMC SSC) has suggested that population structure is foundational to defining stocks and delineating boundaries for management (see Craig et al. 2025; Fogarty and Botsford, 2007; Cadrin and Secor, 2009; Cadrin, 2020; Agenda Item E.8.a, Supplemental SSC Report 1 November 2023, Agenda Item H.5.a, Supplemental SSC Report 1, November 2022; Agenda Item E.3.a, Supplemental SSC Report 1, November 2021).

Fishery Management Units
Stocks comprise FMUs, which provide a scope for which the FMP is responsible. The term "management unit" means a fishery or that portion of a fishery identified in an FMP as relevant to the FMP's management objectives, including biological geographic, economic, technical, social, or ecological perspectives (NS3). Table 1-1 in Section 1.2.1 of the CPS FMP (reproduced below in Table 1 in Section 1.3, above) lists the FMU species which are considered "in the fishery" and subject to provisions of the CPS FMP. The FMU does not include ecosystem component (EC) species, which are infrequently encountered by the fishery and defined separately in Tables 1-2 and 1-3 of the CPS FMP. As described in the paragraph above, interrelated stocks of fish should be managed as a unit or in close coordination.

The choice of a management unit depends on the focus of the FMP's objectives, and may be organized around biological, geographic, economic, technical, social, or ecological perspectives. A management unit may contain stocks of fish for which there is not enough information available to specify maximum sustainable yield (MSY) and optimum yield (OY) or their proxies. A less-than-comprehensive management unit may be justified if, for example, complementary management exists or is planned for a separate geographic area or for a distinct use of the stocks, or if the unmanaged portion of the resource is immaterial to proper management.

Stock Complex
An additional tool to manage interrelated stocks of fish in an FMP in close coordination is a stock complex. Stocks that require conservation and management can be grouped into stock complexes for various reasons, including where stocks in a multispecies fishery cannot be targeted independent of one another; where there is insufficient data to measure a stock's status relative to status determination criteria (SDC); or when it is not feasible for fishermen to distinguish individual stocks among their catch. Where practicable, the group of stocks should have a similar

geographic distribution, life history characteristics, and vulnerabilities to fishing pressure such that the impact of management actions on the stocks is similar. The vulnerability of individual stocks should be considered when determining if a particular stock complex should be established or reorganized, or if a particular stock should be included in a complex. Currently, stock complexes are not used to coordinate management of any CPS stocks.

2.2 Meeting the Objectives of an FMP

MSA § 302(h)(1) requires a Council to prepare an FMP for each fishery under its authority that requires (or, in other words, is in need of) conservation and management. Each FMP should identify what the FMP is designed to accomplish (i.e., the management objectives to be attained in regulating the fishery under consideration). In establishing objectives, Councils balance biological constraints with human needs, reconcile present and future costs and benefits, and integrate the diversity of public and private interests. To reflect the changing needs of the fishery over time, Councils should reassess the FMP's management objectives on a regular basis.

Councils should also periodically review their FMPs and the best scientific information available and determine if the stocks are appropriately identified. As appropriate, stocks should be reclassified within an FMP, added to or removed from an existing FMP, or added to a new FMP, through an FMP amendment that documents the rationale for the decision. This action seeks to review the CPS FMP and its FMU as well as updated scientific information on sardine off the U.S. West Coast to determine whether stock(s) of sardine should be reclassified and/or added to the CPS FMP.

2.3 Review and Definitions Process

An analytical process to review and define stocks in the Council's FMPs was first developed in the Amendment 31 and the ongoing stock definitions process for the Pacific Coast Groundfish FMP.[2] This process is rooted in the MSA requirement to conserve and manage the fishery resources[3] found off the coasts of the United States[4] and for FMPs to be prepared and implemented to achieve and maintain, the optimum yield from each fishery[5] on a continuing basis. When reviewing and defining the stocks in an FMP's FMU, the Council thus must consider the BSIA, the MSA and National Standards as well as the goals, objectives, and existing frameworks of the CPS FMP.

In the stock review and definitions processes for the Council's groundfish FMP, the current scientific literature and the advice of the SSC has been utilized to define a range of stock definitions options based on the idea that population structure is a foundation for defining a species as a stock.

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[2] Groundfish FMP Amendment 31: Phase 1 Stock Definitions

[3] **Fishery resource** means *any fishery, any stock of fish, any species of fish*, and any habitat of fish. (50 CFR 600.10)

[4] Purposes (1) To take immediate action to conserve and manage the fishery resources found off the coasts of the United States, … by exercising (A) sovereign rights for the purposes of exploring, exploiting, conserving, and managing *all fish, within the exclusive economic zone* (16 U.S.C. 1801 MSA § 2 109-479 (b))

[5] **Fishery** means (1) *one or more stocks of fish which can be treated as a unit* for purposes of conservation and management and which are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics; (50 CFR 600.10)

Best practices for defining stock boundaries suggest that stocks should be aligned with information on discrete population structure (Cadrin et al. 2023), guidance that was reiterated specifically for Pacific sardine by Craig at al. (2025). In reviewing the FMU defined in the CPS FMP and the stocks defined within this FMU, the Council should consider the information presented herein via this framework: a combination of the information available on sardine population structure, conformance with the obligations under the MSA and its National Standards, the ability to achieve the goals of the FMP, and the management burden (including related uncertainties and risks) associated with various delineation options.

2.4 Basis for Defining a Fishery Management Unit Outlined in the MSA and its National Standards and the Objectives of the CPS FMP

The MSA's implementing regulations at 50 CFR 600 Subpart D establish guidelines, based on the National Standards, to assist in the development and review of FMPs, amendments, and regulations prepared by the Councils and the Secretary in order to meet the requirements of §302(h)(1). National Standard 1 addresses preventing overfishing and achieving optimum yield.

2.4.1 Goals and Objectives of the FMP

Section 1.6 of the CPS FMP outlines the plan's goals and objectives. Of particular interest in relation to this action are the following goals and objectives:

- Promote efficiency and profitability in the fishery, including stability of catch.
- Achieve OY.
- Accommodate existing fishery segments.
- Prevent overfishing.
- Acquire biological information and develop a long-term research program.
- Foster effective monitoring and enforcement.
- Use resources spent on management of CPS efficiently.

According to the stakeholder concerns introduced above, current management's definition of only the NSP in the CPS FMP may be restricting the sardine fishery to the point of limiting the profitability of the fishery, reducing stability of opportunity to access the resource, and potentially restricting fishery segments such as the live bait sector in southern California. A review and potential readjustment of the stock definitions in the FMP may investigate and alleviate these concerns. Further, this review may help the Council determine whether amendments to the stock(s) included and defined in the FMP could better allow the FMP to achieve OY of Pacific sardine and prevent overfishing of all stocks of sardine in need of conservation and management. During the process of a review and potential re-definition of the stocks in the CPS FMP, several other goals and objectives of the FMP should be considered including the implications on the ability to acquire biological information, foster effective monitoring and enforcement and efficiently use management resources. These objectives are covered in Section 4 "Operational and Implementation Considerations."

2.4.2 Legal and Regulatory Compliance Considerations under MSA and the National Standards

Several sections of the MSA's implementing regulations and the National Standards apply to the task of reviewing an FMP to determine whether its FMU and related stock definitions should be readjusted and whether additional stocks should be added to the FMU.

2.4.2.1 600.305(c) Factors

§ 302(h)(1) of the MSA requires the Council to prepare an FMP for each fishery under its authority that requires conservation and management. Per 50 CFR 600.3005(c)(1)((i)-(x)), not every fishery and every stock requires Federal management; Councils should consider the following non-exhaustive factors (the '10 Factors') when deciding whether stocks require conservation and management in the EEZ.

(i) The stock is an important component of the marine environment
(ii) The stock is caught by the fishery
(iii) Whether an FMP can improve or maintain the condition of the stock
(iv) The stock is a target of a fishery
(v) The stock is important to commercial, recreational, or subsistence users
(vi) The fishery is important to the Nation or to the regional economy
(vii) The need to resolve competing interests and conflicts among user groups and whether an FMP can further that resolution
(viii) The economic condition of a fishery and whether an FMP can produce more efficient utilization
(ix) The needs of a developing fishery, and whether an FMP can foster orderly growth
(x) The extent to which the fishery is already adequately managed by states, by state/Federal programs, or by Federal regulations pursuant to other FMPs or international commissions, or by industry self-regulation, consistent with the requirements of the Magnuson-Stevens Act and other applicable law

When considering removing a stock from an FMP, a thorough evaluation of all 10 Factors should be completed to inform whether a stock is in need of conservation and management in the EEZ. However, when considering adding a stock to an FMP, evaluation of those factors most relevant to the context of the fishery may be sufficient. Further, Factor (x) should be evaluated to ensure efficiency in management and reduce duplication of efforts between the FMP, the states, state/Federal programs, international commissions, or by industry self-regulation.

When considering the 10 Factors at §600.305(c), it is possible that Pacific sardine considered 'SSP' and Japanese sardine, which is indistinguishable on the water from Pacific sardine, are in need of conservation and management and there may be reasoning to bring these fish into the FMP. Several factors, evaluated below, may provide the basis for determining that a stock of Pacific sardine not currently under the jurisdiction of the CPS FMP requires conservation and management and should thus be added to the FMP. Further, it is not clear whether Japanese sardine, as a novel species in U.S. waters, "requires" Federal conservation and management, or whether there is even enough information to make that determination. Still, this species is indistinguishable from and caught in

mixed schools with Pacific sardine. Therefore, conservation and management of Japanese sardine, or consideration of Japanese sardine in the management of Pacific sardine, may facilitate conservation and management benefits for Pacific. Summarized below are brief analyses of the factors relevant to sardine for the Council to consider in determining which stocks are in need of conservation and management.

Factor (i) The stock is an important component of the marine environment
Pacific sardine and other CPS populations are very important components of the California Current Ecosystem (CCE), contributing to trophic dynamics. Pacific sardine are key consumers of primary producers (phytoplankton) and zooplankton. They also serve as important forage species for seabirds, pinnipeds, cetaceans, including ESA-listed populations of humpback whales, and other fish in both their early life and adult stages. Sardine are important prey for several commercially important fish, including Pacific salmonids, albacore tuna, Pacific whiting, Pacific spiny dogfish, and others (Szoboszlai et al., 2015; PFMC 1998). While it is difficult to discern the exact value of sardine within the CCE, it is clear that they are a vital component of the overall forage species assemblage and important to the marine environment of the CCE as a whole. In fact, the goals and objectives of the CPS FMP (Section 1.6) specify providing adequate forage for dependent species as a management objective. It is not known whether the introduction of Japanese sardine has resulted in positive, negative, or neutral contributions to the marine environment.

Factor (ii) The stock is caught by the fishery and Factor (iv) The stock is a target of a fishery
While only the NSP is subject to the management provisions of the CPS FMP, and therefore the only stock defined as "within the fishery," recent stock assessments demonstrate that a large proportion of annual catch is apportioned to the SSP. Therefore, while SSP is not defined as 'in the fishery' via inclusion in the CPS FMU, it is caught alongside NSP in the live bait, EFP, and small-scale sardine fisheries. NSP is indiscernible from SSP other than estimation via application of the habitat model in the NSP stock assessment, making it impossible for the fleet to determine whether they are catching NSP or SSP while on the water. Therefore, SSP may be considered caught within the same fishery as NSP and targeted by the fishery targeting NSP. Pacific sardine is not currently targeted in a directed fishery, as it is closed, but live-bait, EFP, and small-scale vessels actively target Pacific sardine, including in regions and during time periods (i.e., summer months in Southern California) where and when the habitat model indicates that the majority proportion of catch is from SSP. When the directed fishery was open, it was also assumed that a proportion of catch came from the SSP, though this was not directly accounted for via the habitat model until 2014. It is likely that if and when a directed fishery is re-opened, at least some proportion of catch will be SSP. Additionally, Japanese sardine, also visually indiscernible from NSP, are likely caught in mixed schools with Pacific sardine, based on mixed hauls in the CPS survey, and therefore are likely indiscriminately targeted alongside Pacific sardine. Thus, overall, all sardine caught by vessels in U.S. waters could be considered 'caught by the fishery,' and could be included in the FMU.

Factor (iii) Whether an FMP can improve or maintain the condition of the stock
Based on Factor (iii), if the amount and/or type of catch that occurs in Federal waters is a significant contributing factor to the stock's status, such information would weigh heavily in favor of adding a stock to an FMP. In the process of reviewing the stocks defined in the Council's groundfish FMP, Factor (iii) was interpreted to consider whether a stock occurs principally in

Federal waters, as the FMP includes the jurisdiction of the U.S. EEZ. However, in this case for sardine and the CPS FMP, this precedent may not apply. Compared to certain groundfish species like nearshore rockfish, coastal pelagic species, including Pacific sardine, have much larger ranges in individual movement and more dynamic patterns of spatiotemporal distribution. Further, the dynamics of the small-scale sardine fishery present today, including area of catch, are much different compared to those during the prosecution of a directed fishery before 2015 or what may occur in a future directed fishery. Therefore, it is likely that the FMP can improve and maintain the condition of the Pacific sardine stock defined in the FMP on a long-term basis, even if the proportion of biomass and catch varies in location year-to-year. Given that the proportion of sardine attributed to 'SSP' via the habitat model has increased since 2015 (see Table 2 in Section 1.5), it is also likely that this portion of the Pacific sardine population (whether a unique subpopulation or not) could benefit from inclusion in the FMP, similar to its northern counterpart. This interpretation aligns with the objectives of the CPS FMP, which, unlike the Council's Groundfish FMP, does not explicitly restrict the definition of its FMU to the U.S. EEZ. It is still unclear whether Japanese sardine requires inclusion in the FMP to maintain or improve its condition in U.S. waters. With such little information available on the species and its dynamics in U.S. waters, it is not clear whether it is possible to determine the stock size, stock status, or whether it is possible or even necessary for the FMP to improve or maintain the condition of the stock. However, it is notable that Japanese sardine are indistinguishable on the water from Pacific sardine, and therefore inclusion of Japanese sardine in the FMP, or at least acknowledgement of Japanese sardine in the management of Pacific sardine, may help improve or maintain the condition of the Pacific sardine stock.

Factor (v) The stock is important to commercial, recreational, or subsistence users and Factor (vi) The fishery is important to the Nation or to the regional economy

The Pacific sardine primary directed fishery has historically been the largest contributor to CPS fisheries, dating back to the 1920s. Though the primary directed fishery has been closed since 2015, as recently as 2009-2014, the ex-vessel value of the fishery averaged over $18.95 million (adjusted to 2025$) annually. Live bait and minor directed fisheries have continued to operate since the closure of the primary directed fishery. Live bait fisheries typically use round haul gear to capture live fish and deliver the catch alive to receiver vessels, ultimately delivering the sardine as live bait to use in recreational fisheries. This sector supports the Southern California recreational fishery, which generated over $510 million in value added impact to California in 2022 (National Marine Fisheries Service 2024). Between 2015 and 2023, live bait catches of Pacific sardine averaged 1,326 mt per year, making up 87 percent of total live bait catches in California. (see PFMC 2024b Appendix). While anchovy is also used as live bait, Pacific sardine makes up the vast majority, comprising an average of 86.56 percent from 2015 to 2023. Amendment 16 of the CPS FMP also permitted minor directed commercial fishing on CPS finfish during the closure of a primary directed fishery, allowing for minor directed fisheries targeting Pacific sardine to continue since 2015. While this sector accounts for a very small portion of catch, it is an important source of income for some small ports and producers, especially while the primary directed fishery is closed. NMFS has also approved harvest via experimental fishing permits (EFPs) since the closure of the primary directed fishery, for instance allowing for the California Wetfish Producer's Association (CWPA) to fish Pacific sardine in order to collect biological samples in the nearshore area. The fishery-dependent data collected by this program has been vital to collecting enough data to produce accurate estimates of stock biomass in the absence of a primary directed fishery.

Overall, Pacific sardine off the West Coast are highly important to the commercial sectors (primary directed, minor directed, and live bait) that target the species, as well as the California recreational sector that relies on live bait. Based on the high value of impact of the primary directed fishery (when it was operating) and the Southern California recreational sector, it is evident that Pacific sardine contributes a high net value to the Nation and particularly to the Southern California economy. The concentration of value within Southern California in the current era with limited fishing opportunity is particularly relevant to SSP; according to the habitat model (Zwolinski and Demer 2023), the majority of catch in the summer months (when recreational fishing activity is the highest) is attributed to SSP in Southern California.

It is still unclear what proportion of catch, and therefore economic benefit derived thereof, is comprised of Japanese sardine. Based on its recorded presence, however, it is clear that at least some portion of the value derived from the sardine fishery can be attributed to landings of Japanese sardine.

Factor (viii) The economic condition of a fishery and whether an FMP can produce more efficient utilization

As described in Section 1 of this document, the directed fishery for Pacific sardine has been closed since 2015 and remaining fisheries have been confined to low annual catch limits and the threat of closures. Further, the current inseason management structure attributes all catch of sardine in U.S. waters to the NSP during the fishing season, while revising this attribution via the habitat index during the annual stock assessment. Practically, this system may contribute to premature impression of the fishery approaching the NSP's ACL, or ABC. Related restrictions or even closures could follow suit, only to find out later that a portion of the catch is made up of SSP and Japanese sardine. Further, the NSP's ACL, ABC and OFL may not be efficient to manage the entire portion of the sardine population that is present in U.S. waters. Given the large proportion of SSP caught in U.S. waters in recent years, the Council may wish to consider updated information on population structure (see Section 3 below) and whether a revision to the FMU and to the delineation of stock boundaries, and therefore HCRs would be more efficient to manage sardine. Overall, bringing what is currently attributed post-season as SSP, indistinguishable from NSP, into the FMP may produce a more efficient utilization of the sardine resource in U.S. waters. Further, while it is not clear what proportion of landings are comprised of Japanese sardine, given that it is indistinguishable from Pacific sardine, bringing this species into the FMP, or at least acknowledging it in the management of Pacific sardine may provide more efficient utilization of the overall sardine resource.

Factor (x) The extent to which the fishery is already adequately managed by states, by state/Federal programs, or by Federal regulations pursuant to other FMPs or international commissions, or by industry self-regulation, consistent with the requirements of the Magnuson-Stevens Act and other applicable law

Factor (x) should be considered when bringing in a new stock, in order to ensure that the FMP would not duplicate existing efforts to manage that stock by states or other programs. However, SSP and Japanese sardine, while not currently included in the CPS FMP's FMU, are also not currently managed by any other entities in the U.S. EEZ.

2.4.2.2 The National Standards

The National Standards and their Guidelines further provide principles for ensuring sustainable and responsible fishery management that should be followed in evaluating and readjusting, if necessary, the FMU if stocks must be adjusted or added based on the above Factors.

National Standard 1 - Optimum Yield

The National Standard 1 (NS1) states that conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield (OY)[6] from each fishery for the U.S. fishing industry.

For all stocks and stock complexes that require conservation and management, Councils must evaluate and describe the following items in their FMPs and amend the FMPs, if necessary, to align their management objectives to end or prevent overfishing and to achieve OY:
(1) MSY and SDC to determine overfishing status. MSY may also be specified for the fishery as a whole.
(2) OY at the stock, stock complex, or fishery level and provide the OY specification analysis
(3) ABC control rule
(4) Mechanisms for specifying ACLs
(5) Accountability measures (AMs)
(6) Stocks and stock complexes that have statutory exceptions from ACLs and AMs

Based on the principles of NS1, the outcomes of revising the FMU and stock definitions within it will result in changes to the tools used to prevent overfishing and achieve OY. MSY, status determinations, and control rules such as ABCs and ACLs will be confined to the delineation of the stock definition. Additional AMs may be put in place for the stock to achieve objectives for the stock as a whole while accounting for variable dynamics within the stock (i.e., subpopulations). Therefore, the stock delineations themselves should align with the objectives of preventing overfishing and achieving OY and the tools outlined to do so. Under NS1 guidelines, multiple stocks may also be managed together as a unit if they are caught within the same fishery and cannot be easily identified and separated. This is relevant to both the hypothesized subpopulations of Pacific sardine and Japanese sardine, all of which are indistinguishable and impossible to separate within the fishery. Therefore, management of sardine can and should account for this condition, whether in delineating stock boundaries or coordinating management of multiple stocks. However, it is not yet clear whether Japanese sardine, a novel species in U.S. waters should be managed to optimum yield in U.S. fisheries. It is clear however, that managing Pacific sardine to optimal yield may be complicated by the presence of Japanese sardine.

NS1 guidelines state that in meeting the objectives of NS1, Councils must take an approach that considers scientific information and management control of the fishery, including addressing

[6] Optimum yield (OY). Magnuson-Stevens Act section (3)(33) defines "optimum," with respect to the yield from a fishery, as the amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems; that is prescribed on the basis of the MSY from the fishery, as reduced by any relevant economic, social, or ecological factor; and, in the case of an overfished fishery, that provides for rebuilding to a level consistent with producing the MSY in such fishery.

uncertainty in a manner such that there is a low risk to exceeding limits. This approach must also be taken in defining stocks, which have a flow through effect on meeting the objectives of NS1. Aligning stock definitions with scientific information on population structure is considered best practice, and this information is outlined in Section 3. Management control and risk is addressed in Section 4.

National Standard 2 - Scientific Information

NS2 states that conservation and management measures shall be based upon the best scientific information available. Based on the NS2 guidelines, scientific information used to inform decision making should also be pertinent to the current questions or issues under consideration and should be representative of the fishery being managed. In this case, scientific information utilized to support decision making on reviewing and potentially revising the FMU and its stock definitions should rely on best practices for identifying and defining stocks as well as the particular context of sardine and the sardine fishery. Historical information should also be evaluated for its relevance to inform the current situation at hand. The review of information on sardine population structure, provided in Section 3 and supported by publications incorporated by reference, follows the principles and guidance of NS2 to support the Council in their decision-making on this action.

National Standard 3 - Management Units

NS3, stating that to the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination, is pertinent to this action. The overall purpose of NS3, according to its guidelines, is to "induce a comprehensive approach to fishery management" wherein the geographic scope of the fishery and its management covers the entire range of the stocks of fish in need of conservation and management. NS3 is the standard that defines a "management unit" as the fishery or portion of the fishery identified in an FMP as relevant to the FMP's management objectives. As outlined in Section 2.4.2.2, the Council's choice of a management unit should be organized around biological, geographic, economic, technical, social, and ecological perspectives and consider the range and distribution of the stocks defined within it as well as the patterns for harvesting these stocks. As described in Section 1, there are a multitude of social and economic drivers that have led to a review of the management unit in the CPS FMP, and in particular, which stock(s) of sardine should be defined in the FMU. While the portion of Pacific sardine classified as SSP and Japanese sardine are not currently included in the FMU, updated information on population structure and fishing patterns suggest that these fish are relevant to the sardine fishery and management of these fish would be relevant to the FMP's management objectives (see Section 2.4.1). While the economic and social perspectives may be the drivers behind initiating this review, biological and ecological perspectives are also important; new scientific information on population structure and ecological concern over unmanaged, but targeted, fish could be sufficient reasoning to review the current management unit, based on the Factors outlined at §600.305(c) and the principles of NS2. While the objectives of NS3 include ensuring that fishery management is not overly constrained by political boundaries, it is also clear in specifying that FMPs should include conservation and management measures for that part of the management unit within U.S. waters. Therefore, while the distribution of both Pacific and Japanese sardine extends beyond U.S. jurisdiction, revision of the FMU would be relevant to conservation and management measures applied to the portion of the species' range in the U.S. EEZ (even if accounting for biomass and mortality of the population outside U.S. waters).

NS 3 guidelines (50 C.F.R. § 600.320) provide guidance on how management units themselves should be defined, based on the requirement of the MSA specifying that "to the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination" (16 U.S.C. § 1851(a)(3)). In practice, this means several things. NS3 sets 'stocks' as the building blocks of the management unit. Stocks should include a whole biological population and should not be arbitrarily divided. Further, stocks that interact ecologically or within a common fishery should be managed within the same FMU or within coordinated FMPs. Councils must justify why such stocks are grouped together within an FMU. Lastly, as described under NS1, above, multiple stocks may be managed together as a unit if they are caught within the same fishery and cannot be easily identified and separated.

2.5 Application of the Framework to this Action

Based on this framework, the Council will need to consider two sequential questions in their review of the FMU defined in the CPS FMP under this action: (1) Which species of sardine should be included in the FMU? And (2) How should stocks of those species be identified and delineated?

Which species of sardine should be included in the FMU?

In this review, the Council will need to determine which species and which population or subpopulation(s) of species (if applicable) to include in the FMU, as defined in Table 1-1 of the CPS FMP. The northern subpopulation of Pacific sardine is currently included in the FMU. However, this stock does not cover the full extent of Pacific sardine present in U.S. waters and caught in the fishery. Based on NS3 and its guidelines, the entire range of Pacific sardine present in U.S. waters, relevant to the objectives of the FMP, and in need of conservation and management, should be included in the FMU. Based on the evaluation of the Factors at §600.305(c), as well as the driving purpose of reviewing the FMU to ensure the stocks defined within it include the sardine fished in U.S. waters, Pacific sardine currently classified as SSP, in their extent within U.S. waters, are relevant to the objectives of the CPS FMP and should be added to the FMU. The Council may determine whether Japanese sardine, also fished in U.S. waters, though it is not clear to what extent, could be added to the FMU.

How should stocks of those species be identified and delineated?

Next, the Council will then need to determine how to identify, delineate, and define the stocks of these species, based on further consideration of the requirements of a management unit guided by the National Standards (including both science and management considerations). These definitions should align with the best scientific information available, as relevant to this action and following the guidelines of NS2. Definitions should also consider the goals and objectives of NS1 and the CPS FMP and the ability to manage stocks as individual units to these principles. Uncertainties and risks related to meeting these objectives should also be considered. In the next two sections (3 and 4) of this document, we outline the considerations that may support the Council in following this framework to define the stock(s) of sardine in the FMU, upon potential addition of SSP and Japanese sardine to the FMU.

2.5.1 Additional Considerations

In addition to the framework for defining FMUs and their stocks set by the MSA and the National Standards, several other considerations apply to a review of an FMU based on the need to rely on the best scientific information available (NS2). Specifically, the literature and previous

recommendations by the Council's SSC provide additional considerations relevant to scientific information on stock identification and definition. The practice of incorporating the scientific information available into stock definitions, which have flow-through effects on all aspects of fishery management, supports the principles outlined in NS1, NS2, and NS3 guidelines.

As discussed above (Section 3), current literature (and the advice of the PFMC SSC) has suggested that population structure is foundational to defining stocks and delineating boundaries for management (see Craig et al. 2025; Fogarty and Botsford, 2007; Cadrin and Secor, 2009; Cadrin, 2020; Agenda Item E.8.a, Supplemental SSC Report 1, November 2023, Agenda Item H.5.a, Supplemental SSC Report 1, November 2022; Agenda Item E.3.a, Supplemental SSC Report 1, November 2021).

Prior to the stock definitions process for the Council's Pacific Coast Groundfish FMP, the Council's SSC held a discussion related to the issue of groundfish stock definitions (Agenda Item E.3.a, Supplemental SSC Report 1, November 2021) and made recommendations on how to inform definitions of stocks. These recommendations included an analytical framework for the review of scientific information, considering population structure of species; genetic differences (if they exist) were recommended as the most conclusive source of information on population structure, while information on larval dispersal and adult movement provide less conclusive, though still helpful, evidence (Agenda Item E.3.a, Supplemental SSC Report 1, November 2021).

Literature has also provided recommendations on best practices and additional considerations to make when identifying and delineating stocks. As defined by Cadrin et al. (2023), these include:

1) Identification and delineation of stocks to represent spatially discrete populations or complex population structure
2) Stock boundaries aligned with the most plausible population structure according to best available science
3) Accounting for heterogeneity, fishing patterns, and movement within a stock
4) Revisiting analyses of overlapping populations
5) Testing the performance of assessments with uncertain population structure

Craig et al. (2025) reference these best practices in their review of literature related to population structure and stock definitions of Pacific sardine. Cope and Punt (2009; 2011) also previously investigated the task of defining stocks, noting that stock designation should promote the goals of NS1, looking to "unit" groups of populations with similar characteristics to achieve such goals. Stock definitions should thus be based on a geographic scope that supports modelling population dynamics of a reproductively isolated population, informed by BSIA on population structure. As reflected in Cadrin et al.'s (2023) best practices and Cope and Punt's work (2009; 2011), population connectivity is not the only criteria for defining a stock, however; a stock should consist of all individuals that interact enough to create a coherent population trend, including multiple subpopulations within a stock if they demonstrate comparable recruitment patterns, life history values, and exploitation histories. Movement, exploitation patterns, and uncertainty of population structure should be accounted for (Cadrin et al. 2023). Stock complexes are another tool to manage interrelated stocks of fish, but stocks must first be defined on a science-supported basis before coordinating management via a complex. Cope and Punt (2009; 2011) and Palacious-Abrantes et al. (2025) note that changes in exploitation and environmental conditions (like large scale climate

shifts) are expected to impact the distribution of marine species. Widely distributed transboundary species like sardine are particularly susceptible to significant changes in distribution as a result of climate change and management boundaries should anticipate these changes (Palacios-Abrantes et al. 2025).

Overall, delineation of a stock must combine both scientific information and management considerations to support the goals and objectives of the MSA, National Standards, and the CPS FMP. The relevant scientific information and management considerations are summarized in the following two sections.

3 State of the Science on Sardine in the California Current Ecosystem

This section provides a summary of relevant available scientific information on the distribution, life history, and population structure for Pacific sardine (*Sardinops sagax*) and aims to support a stock definition decision that follows the broad recommendations of the SSC for defining stocks (Agenda Item H.5.a, Supplemental SSC Report 1, November 2022). The review of scientific literature in this document differs in that it is tailored to the context of clupeids (the family of fish that includes sardine) and the CPS fishery, which differ from groundfish in terms of life history and fishery dynamics. Further, the drivers for this action differ from other stock definition actions PFMC has taken up; it intends to identify which sardine off the U.S. West Coast should be included within the FMU defined in the CPS FMP, and how stocks of sardine should be defined within that unit. Therefore, this review covers information not only on stocks currently present in the CPS FMP, but also species and potential sections of the sardine resource that are found in U.S. waters but are not covered by the FMP. Another specificity to the review provided here is that within the past year (2024-2025), several studies have been published reviewing the existing body of literature on sardine population structure and new scientific insights on sardine population structure and sardine species present in U.S. waters has been produced. Therefore, this review intends to briefly summarize the immense work that has already been done to review the existing body of literature and update the literature with new findings.

To understand which population(s) of Pacific sardine need to be managed off the U.S. West Coast, and to then define the stock(s) based on this need, the population structure of Pacific sardine should be considered as a basis. As Craig et al. (2025) note, and as defined in Section 2.1, the term ‘stock,’ which denotes the spatial boundaries of management, should not be conflated with ‘subpopulation’ or ‘population,’ which denote spatial boundaries of biological characteristics. Several attributes are often used to indicate population structure and connectivity. Population connectivity and spatial structure are typically indicated by the level of genetic differentiation between individuals across geographies. Gene frequency differences among samples from different geographic areas can be used to indirectly estimate patterns in gene flow and therefore the estimated population structure (PFMC 2024a). Homogeneity in genetic markers, indicating a homogenous population, assumes connectivity between geographic regions, with no isolation between reproductive units. The opposite instance would be a heterogenous population structure, in which isolated reproductive units are identified via clear genetic differentiation. Population connectivity can also be measured on shorter time scales using information on dispersal and movement in various life stages of the species. In addition to population connectivity, population dynamics such as recruitment patterns, dispersal, life history, and exploitation histories may shape population trends and generate

subpopulations in which individuals interact on a smaller scale even within a connected population.

3.1.1 Background on Pacific Sardine

The species considered in this action are species of sardine. Pacific sardine has been present in waters off what is now the U.S. for thousands of years and has a unique population dynamic, common to small pelagics. Populations of Pacific sardine off the West Coast of the U.S. and Mexico have undergone large fluctuations, colloquially termed 'boom and bust cycles,' for thousands of years (Baumgartner et al. (1992)) The distribution and migratory patterns of Pacific sardine also shift with changes in abundance. In periods of high abundance and expansive migratory behavior, Pacific sardine can range along the coast of North America from southern Alaska to the southern tip of Baja California Sur and into the Gulf of California. In periods of low abundance, the distribution shrinks, with refuge populations restricted between southern California and Baja California Sur (Mcfarlane et al. 2002). Aspects of reproduction and life history stages may similarly shift with changes in abundance; spawning activity has been observed as far north as Washington during periods of high abundance but is concentrated in the southern portion of the species' range (Mcfarlane et al. 2002).

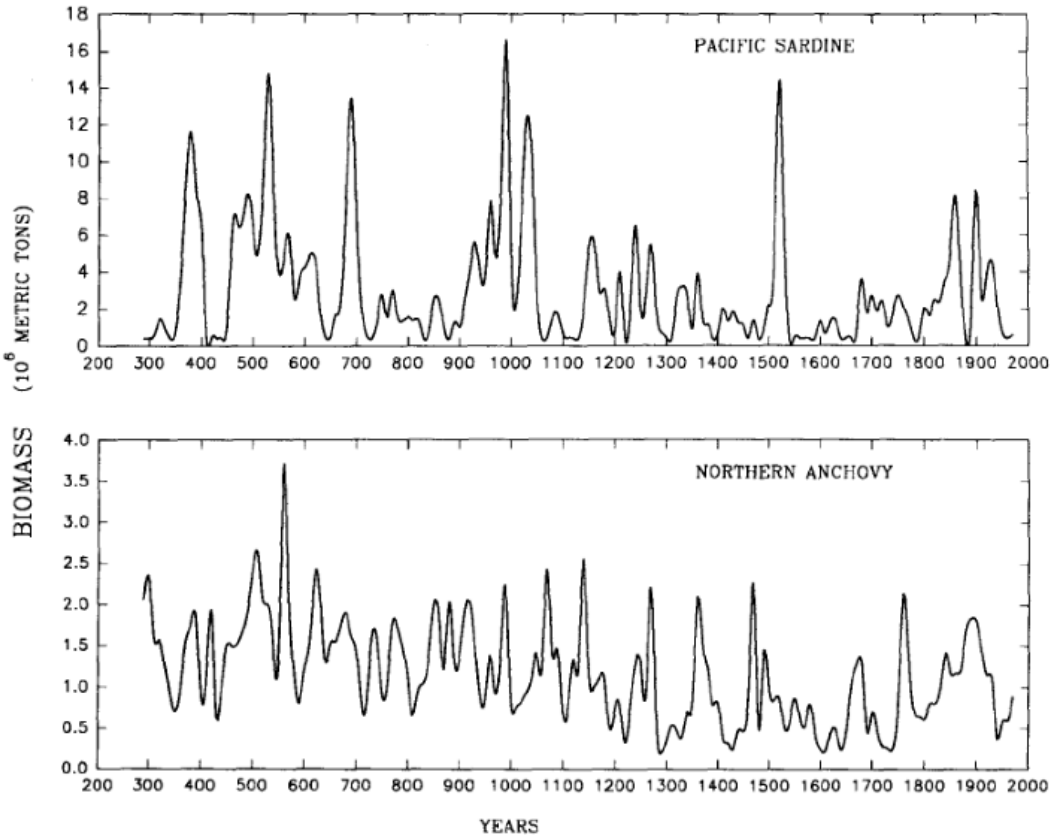

Figure 7. 1700-year hindcast series of Pacific sardine and northern anchovy biomasses off California and Baja California obtained by conversion of SDR data in figure 4 to units of biomass with the regression equations in figure 6.

Figure 4. Hindcast series of Pacific sardine and northern anchovy biomasses off California and Baja California generated by Baumgartener et al. (1992)

As described in Section 1.4, current management of Pacific sardine is based on the working hypothesis of three distinct subpopulations within the California current ecosystem: a NSP that ranges from northern Baja California to Alaska, a SSP that ranges from the southern tip of Baja California to Southern California, and a subpopulation that is restricted to the Gulf of California (Yau 2023). These subpopulations are thought to share some spatial extent, but undergo distinct, simultaneous migrations that limit their overlap and segregate spawning areas (Demer and Zwolinski 2014). Early studies on movement and phenotypic expression led to the formalization of this theory. The subpopulation hypothesis was formalized by John Marr in the 1950s (Marr 1957) but has been investigated and debated as scientific technology and information on the species has progressed over time, particularly with the advent of advanced genetic technology.

3.1.2 Literature Regarding the Subpopulation Question

As described in Section 1.1, in 2022, the SWFSC held a stock structure workshop (Yau, 2023) following comments from the SSC related to the supposed NSP catch attributed to Mexico. While the workshop was grounded in the assumption of the working hypothesis – that there are two distinct subpopulations off the West Coast – workshop participants also discussed alternative hypotheses, primarily one defining a single coastwide population ranging from British Columbia to Baja California and no differentiation between northern and southern subpopulations. Preliminary findings of ongoing research into sardine population structure was presented at this workshop, but many of those findings have been peer-reviewed and published since. These recent publications are covered in this review.

Notably, in February 2025, Craig et al. published an extensive, critical literature review "revisiting" the subpopulation hypothesis covering literature from 1925 to present. The review, covering a century of scientific literature on spawning areas, migration and growth patterns, and genetics, concluded that 'there is little, if any, evidence supporting a hypothesis of multiple subpopulations of Pacific sardine throughout their North American range.' Craig et al.'s review frames the subpopulation question from the words of the author who formalized the working hypothesis – John Marr – dissecting assumptions that built a body of self-referencing literature that adheres to the status quo as a result of its own inertia. The authors also found no evidence against the idea of a single coastwide population of the species. This review, and the literature covered, is further expanded on below. In the past two years, Erisman et al. (2025) also published a systematic review of somatic growth patterns across geographic regions, investigating whether distinct somatic growth patterns support a hypothesis of two biologically distinct subpopulations. Further, Adams and Craig (2024) and Longo et al. (2025a) investigated the subpopulation question from a genetic angle. The study by Longo et al. (2025a) is particularly seminal, as it is the first whole genome sequencing for Pacific sardine, representing a large shift in the understanding of the species' genetic population structure, now that the technology is available to investigate it more fully. The sections below will further review early studies that led to the formalization of the subpopulation hypothesis and recent literature covering genetics and biological traits (including growth patterns, adult movement, and spawning patterns) that explore the possibility of alternative population structure hypotheses.

3.1.2.1 Adult Movement

Craig et al.'s review covered literature detailing evidence for Pacific sardine population structure based on adult movement, including both tagging data and studies utilizing parasites as natural

tags to track movement of individual fish. Tagging data is one of the earliest forms of evidence of adult movement and distribution of Pacific sardine. In the 1930s and 1940s, researchers tagged more than 140,000 individual sardines which were then recovered in fish reduction plants. Studies by Clark and Janssen (1945) and Hart (1944) utilized this early data to show extensive movement of Pacific sardine along the West Coast, from Vancouver Island, Canada, to southern California to Baja California, Mexico, particularly studying movement patterns from north to south. These studies showed that at least a portion of sardine that starts in Baja California makes it to the Pacific Northwest, though a much larger proportion were recovered in southern California than the Pacific Northwest. Further, longer distance movements were associated with larger-bodied individuals. Overall, evidence from these early studies on adult movement support a single, broadly distributed population, with a potential for partial migration within this population. More recent papers (such as Lo et al. 2010 and Demer et al. 2012) have focused on indirect evidence of adult movement, as there is no longer sufficient reduction infrastructure available to be able to collect tagging data in the same manner. Recent studies have also used parasites as "natural tags" to track sardine distribution and movement (Baldwin 2010, Baldwin et al. 2012, Jacobsen et al. 2019). These studies show additional evidence for north-south partial migration as well as "overwintering" patterns by a portion of the population in the Pacific Northwest. Data collected from parasites also provides evidence for localized recruitment events. However, despite this migratory and recruitment information, the parasite data does not necessarily confirm the existence of multiple subpopulations over the existence of a coastwide population with partial migration and localized recruitment.

3.1.2.2 Biology, Growth, and Morphology

The comprehensive literature review completed by Craig et al. (2025) is exhaustive in reviewing literature utilizing biological traits to support hypotheses of population structure. It covers studies on vertebral counts, serological antigen response, tagging data, otolith morphology and morphometry, spawning location, timing, and temperature, growth patterns, and demographics. This document aims to incorporate the review of this information covered by Craig et al. by reference, as it provides the most comprehensive review of literature regarding Pacific sardine population structure to date. Erisman et al. (2025) also provides key updates on reviewing literature on growth rates and as such, is also incorporated by reference. Some of the key points are summarized below.

First, Craig et al. reviewed literature focused on examining vertebral counts. Many early studies focused on using analyses of vertebral counts to support a subpopulation hypothesis (Hubbs 1925, Thompson 1926, Hart 1933, Clark 1936, Clark 1947, Wisner 1960). However, while these studies concluded that there was weak, if any, evidence of subpopulation structure in Pacific sardine, the very same studies were later reinterpreted to support the subpopulation hypothesis. Further, these early studies focused on small differences in the mean number of vertebral elements counted, which creates uncertainty in their interpretation. Overall, from a review of these early studies and an examination of nearly 70,000 published vertebral counts, Craig et al. (2025) ultimately concluded that "vertebral count data cannot be used to reject the null hypothesis of a single population along the west coast."

Otolith morphology and morphometry is another area of study that has been conducted since the early 2000s to ascertain the origin location of Pacific sardine and understand their stock identity.

However, based on Craig et al.'s (2025) review of several studies (Felix-Uraga et al. 2005; Valle and Herzka 2008; Javor et al. 2011; Javor 2013; Vergara-Solana et al. 2013; Javor and Dorval 2017; Elsdon et al. 2008; Dorval et al. 2015), otolith morphology and microchemistry are unable to reject a null hypothesis of a single sardine subpopulation, though they also do not support alternative hypotheses. In sum, Pacific sardine is not a species for which otolith morphology and microchemistry have a high predictive power for an individual's stock identity or location of origin (Campana & Casselman 1993).

Several other biological characteristics were used in early studies to better understand population structure in Pacific sardine. Vrooman (1964; Sprague and Vrooman 1962) took blood samples to study serological antigen response (a.k.a blood clotting). While data from this study does appear to suggest two groups within the West Coast Pacific sardine population based on their presentation, a north/south grouping of samples was completed post-hoc in Vrooman (1964) and a re-evaluation of all data independently does not present a specific pattern. External morphology was another characteristic, examined by several papers, from 1972 through 2013 (Mais 1972, Hedgecock et al. 1989, Garcia-Rodriguez et al. 2011, Vergara-Solana et al. 2013). However, nearly all these studies indicate that the external morphology characteristics they examine are shaped by environmental conditions resulting in phenotypic plasticity, or flexibility in how an organism looks and behaves, based on the environment, rather than a change in its DNA. As sardine are a highly mobile species, any individual may experience fluctuations in environmental conditions in their lifetime that could influence their external morphology. Therefore, overall, these characteristics are not well-suited to indicate population structure.

Growth patterns and length at age frequency have also been used in studies since the 1940s to evaluate whether variation in growth indicates the existence of subpopulations. Phillips (1948) initially found that the average length of fish caught in southern California was greater than those caught in central California, Oregon, and Washington. Craig et al. (2025) note that the most commonly cited studio on spatiotemporal growth patterns is Felin (1954) This study used length at age data to investigate whether sardine from southern California to British Columbia Canada come from a single, homogenous population or multiple subpopulations. However, Felin (1945) also noted potential shortfalls of this investigation, for instance noting that variation could be related to phenotypic plasticity. Phillips (1948), Felin (1954) and Marr (1960) also evaluated differences in the age/length structure of sardine fishery samples to evaluate population heterogeneity, which was later interpreted to indicate subpopulation structure. Ultimately, in Erisman et al.'s (2025) systematic literature review examination of whether distinct somatic growth patterns across geographic regions support the management assumption of two subpopulations determined that length-at-age and growth information should not be used to delineate subpopulations or apportion biomass of Pacific sardine. These conclusions are rooted in the fact that length-at-age datasets demonstrate variability by environmental conditions, leading to phenotypic variation.

3.1.2.3 Spawning, Landings, and Temperature

Spawning and larval distribution of Pacific sardine have been known to be vastly distributed since early studies, but have also been used to understand the population structure. Ahltstrom (1954, 1959) noticed two centers of spawning (one off Southern California and one off Baja California, Mexico) and that two spawning seasons separated these centers; from January through July,

spawning occurred in both areas, but from July through December, spawning was restricted to the southernmost spawning area. Ahlstrom emphasized the importance of knowing if "late season" spawners were a distinct subpopulation, but put forth multiple hypotheses for this pattern. Further work noted that spawning density occurred with warmer temperature water, impacting the spatiotemporal characteristics of spawning (1965). Based on the assumption of multiple subpopulations and contemporary evidence (Sprague and Vrooman 1962, discussed above), Ahlstrom determined that the higher temperatures at which late season spawning occurred could indicate a subpopulation, though his results themselves don't provide evidence. Overall, the early CalCOFI survey provided a comprehensive description of the spatiotemporal dynamics of sardine spawning, revealing changing dynamics over time, with spawning occurring anywhere from California to Baja California, Mexico, though Punta Eugenia was identified as a consistent center. Papers by Lluch-Belda et al. (1991; 2003) found that temperature is a weak predictor of spawning alone, and is best explained by a combination of temperature and productivity. Further, peaks in egg occurrence that were identified at 15 and 23 degrees Celsius were thought to be environmental artifacts, not evidence of two stocks (Lluch-Belda et al. 9991; 2003). The 'hotspot' in Punta Eugenia appears to be a year-round refuge where the same population of Pacific sardine can persist through unfavorable oceanographic conditions, rather than a separate subpopulation. Several regional studies have also evaluated spawning patterns, with several showing links to environmental conditions like El Nino (Watson 1992; Lynn 2003; Emmett 2005; Lo 2010). Overall, based on Craig et al.'s critical review of the body of literature covering spatiotemporal spawning patterns, they conclude that dynamics are best explained by a combination of temperature and oceanographic productivity, rather than distinct subpopulations capable of maintaining long term reproductive isolation.

Studies have also linked temperature to landings, with conclusions later cited as evidence of multiple subpopulations. For instance, Felix-Uraga et al. (2004) is one of the most-cited papers, analyzing a 20-year long dataset of landings with sea surface temperature and proposing multiple groups (cold, temperate, and warm) of sardine along the West Coast based on peaks in covariates between temperature, landings, and month. However, the authors do not provide a statistical analysis of their proposed groupings of sardine and even indicate that their data are not necessarily evidence of population structure, but rather a practical approach to partitioning groups of catch data in different zones. Combined with several other factors (i.e., landings data used as a proxy for abundance, no difference in means based on a 95 percent confidence interval, relatively small levels of landings in ports sampled, lack of data from certain ports, potential distance from landing area of sardine and port) create uncertainties that require the authors' conclusions on temperature-based groups to be regarded as speculative and not linked to biological or genetic evidence. Overall, while widely cited, as the authors themselves indicate, Felix-Uraga et al. (2004) does not provide evidence to indicate multiple subpopulations of Pacific sardine based on thermal preferences.

3.1.2.4 Genetic Differentiation

Several recent studies, including Adams and Craig (2024) and Longo et al. (2025) review and produce new information on sardine population structure using genetic techniques. Adams and Craig (2024) took a similar approach to Craig et al. (2025) and Erisman et al. (2025), expanding on previous work using evolutionary genetic studies of population structure to test if population structure is present in Pacific sardine. In Adams and Craig (2024), 434 individual sardine were

examined, ranging from British Columbia, Canada, to Baja California, Mexico and the Gulf of Mexico. The results of this study showed low, but statistically significant genetic differentiation overall, with mostly panmictic gene flow between areas, but with a detectable structure. Overall, these results support a hypothesis of a lack of genetic structure within the Pacific sardine population, suggesting a single, cohesive population. Longo et al. utilized novel methods to perform whole genome sequencing to assess the population structure of Pacific sardine. Overall, Longo et al.'s (2025a) results revealed panmixia, or a population where every member of the population has equal mating chances with any other individual, but high amounts of genomic structural variation. None of the variants detected appeared to be related with subpopulations or sampling site. The authors go as far to say, *"Our results do not provide support for the current management framework of Pacific Sardine in the U.S. and suggest that multiple management units have been defined for a single biological population."* (Longo et al. 2025a). Further, the results are conclusive in showing no genetic population structure for Pacific sardine, demonstrating that *"current management practices suffer from incoherent dimensionality"*[7] (Longo et al. 2025a).

3.1.2.5 Conclusion

Ultimately, a review of historical literature and the addition of new genetic findings indicate that there is little, if any evidence of subpopulation structure in Pacific sardine. Given these finding, and an understanding of the declining fishery conditions that preceded Amendment 8, bringing the "northern subpopulation" into the CPS FMP, it becomes evident that the idea of two different groups within the larger sardine population off the West Coast may be an artifact of management decisions, rather than a scientific delineation. Therefore, a review of the FMU may be appropriate to determine whether these management decisions should be adjusted to fit new scientific information. Overall, looking at the same historical literature that has served as evidence for population structure, there is now little evidence to prove a homogenous population structure, and the Council may need to consider whether management is coherent with population dynamics or needs to be re-adjusted.

New research does provide sufficient evidence that the hypothesis of a homogenous population structure cannot be rejected. Longo et al. (2025) note that their genetic findings, combined with the lack of data supporting population structure in other recent publications (Craig et al. 2025, Erisman et al. 2025), together support this conclusion. Aligning with the SSC's previous recommendations on how to define stocks, genetic differences (or lack thereof) should be considered the most conclusive source of evidence in considering the population structure of a species to design a management unit. Other biological considerations, such as adult movement or spawning location may also provide evidence for population structure, but in this case, there appears to be none. Overall, recent updates to the literature provide a strong case to conclude that the management unit for Pacific sardine is not currently aligned with its biological unit.

3.1.3 Emergence of Japanese sardine

Recent studies have documented the presence of Japanese sardine (*Sardinops melanosticta*) in U.S. waters, a species historically absent from the West Coast. Pacific sardine was previously the only species of sardine known to be present in U.S waters. However, a 2024 report indicated that

[7] Incoherent dimensionality denotes a mismatch, or lack of logical relationship, between different aspects of a system

Japanese sardine had first been discovered in U.S. waters in 2022 and 2023, with continued observations through 2024. In that year, 18.3 percent of 613 sardine samples taken during the annual CPS survey were identified as Japanese sardine though it is unknown what proportion of total sardine biomass off the West Coast is made up of Japanese sardine (Longo, James, Hinton, Topping, & Craig, 2025). Research suggests that frequency and intensity of warm water anomalies and marine heatwaves are the hypothesized cause for the change in Japanese sardine's species range across the Pacific (Longo et al. 2024).

A draft update on the presence of Japanese sardine in the California Current was provided at the Coastal Pelagic Species Subcommittee of the SSC's February 2025 meeting. The draft update report (Longo et al. 2025b) noted several findings from the 2024 survey samples. First, the distribution of Japanese sardine has extended further south compared to the first year it was observed, in 2022. Further, the relative proportion of Japanese sardine to Pacific sardine has decreased in samples over time, though this trend may be an artifact of changes in the sampling itself; as mentioned above, the proportion of samples comprised of Japanese sardine is not necessarily representative of the proportion of total biomass comprised of Pacific sardine. The distribution of Japanese sardine ages has also changed since 2022, showing a cohort effect, with the most common age class becoming older over the years of collection. Further, there were no age zero fish collected in 2022, but age zero fish have been collected since, indicating that only adult fish made the journey across the Pacific, but these individuals have since been able to reproduce to some extent. It is still unknown exactly how much Japanese sardine biomass is present off the West Coast and whether there is potential for hybridization (though none has been recorded or analyzed) or resource competition, though it is evident from trawl samples that Pacific and Japanese sardine occur in mixed schools (Longo et al. 2025b).

4 Operational and Implementation Considerations

When considering redefining stock(s) of sardine in the CPS FMP, the Council should consider factors related to managing sardine both in the short and long term. Per the goals and objectives of the MSA and the CPS FMP, these factors have implications for acquiring biological information on the defined stock(s), fostering effective monitoring and enforcement, reducing uncertainty, and efficiently using management resources. The following is a high-level summary of some considerations.

4.1 Catch Accounting, and Enforcement

Section 1.5 describes the current method of inseason accounting for the NSP of Pacific sardine and the post-season accounting against relevant reference points via the habitat model. If sardine were to be managed as a single coastwide stock (without delineations between subpopulations), the relative burden would be similar to status quo. Current inseason accounting practices and enforcement could continue, as all sardine landed could be counted towards a single ACL (or allocation, as appropriate). Catch would not need to be attributed to different stocks or subpopulations post-season, either. This practice could apply towards both a fishery with limited opportunity (as currently operating) and in the future circumstance of a directed fishery resuming if the stock were to be above CUTOFF.

If multiple stocks were defined and managed, there would need to be an accounting and enforcement system implemented in order to assign catch to specific stocks and associated limits

resulting in a higher burden overall compared to status quo or defining and managing sardine as a single stock. As Cope and Punt (2009) recommend, the stock identification technique should rely on population dynamics, without much additional cost beyond that associated with monitoring the fishery, necessitating clear differentiation of population dynamics between stocks in order to reduce the burden of monitoring those stocks. Further, the NSP and SSP are indistinguishable physically, requiring some sort of delineation in the stock definition and management measures to attribute catch between stocks (i.e., use of habitat model, north/south of geographic boundaries, catch in various months, flat percentage of each stock, etc.). The need to create an accounting and enforcement system would apply if both stocks were below CUTOFF and no directed fishery were permitted coastwide or if all stocks were operating under a directed fishery. If one stock were to be in a different stock status than another, then additional measures would need to be considered to allow fishing on both stocks at differential levels and account for uncertainty in attributing landings to each stock. Overall, the catch accounting and enforcement burden of managing two stocks would be greater than a single stock.

4.2 Assessment and Surveys

Under status quo or any potential change in the stock definition of sardine, the CPS acoustic trawl method survey that collects data to inform stock assessments would require no changes. The survey would continue to collect data on sardine from the U.S.-Canada border to the U.S.-Mexico border. However, while a shift to a single stock management would require similar resources to collect and process biological samples as the status quo (sample sizes would remain the same), managing two stocks of Pacific sardine would require additional sampling and assessment resources (such as developing an assessment for the SSP) and additional sampling on the acoustic trawl method (ATM) survey for SSP samples.

4.3 Uncertainty and Risk

Stock definitions should align with the best scientific information available on the species' population structure; the stock unit should align with the biological unit. However, in instances with an uncertain 'biological unit,' i.e., where population structure is uncertain or environmental conditions may change population structure and distribution in the future, there may be risks delineating stocks in a particular manner. 'Incoherent dimensionality' is the misalignment of management and biological units (Longo et al. 2025a). This misalignment can occur and create risk when managing discrete units as a single population and when managing a single population as distinct units (Berger et al. 2021; Cadrin 2020; Cadrin et al. 2023; Kerr et al. 2017; Laikre et al. 2005). This risk is highest when ignoring underlying population structure and processes, especially ignoring disproportionate fishing mortality on a vulnerable population, ignoring heterogenous demographic parameters (growth and maturity), and ignoring connectivity (via recruitment or movement) between management areas (Berger et al. 2021). Therefore, both situations should be avoided when possible, as either can result in management that is not delineated at the appropriate scale to capture spawning, recruitment, and movement. Managing multiple biological units as a single population can lead to management that does not capture reproductive isolation, allowing for localized depletion of reproductive units. Splitting a single biological population into multiple units also incurs risk; units that are convenient for political, jurisdictional, or other reasons may generate biased reference points and fail to capture migration, movement, and connection across space and time.

In the case of Pacific sardine, under the status quo, only the northern subpopulation of Pacific sardine is managed. Whether the southern subpopulation is a separate, isolated population or not, it is present in U.S. waters, but not accounted for and therefore there is risk to this portion of the population. Bringing in the SSP as its own stock or creating a single, coastwide stock would ensure that all Pacific sardine in U.S. waters are accounted for; as described in the section above, measures like the DISTRIBUTION term may be used to mitigate risk incurred by mortality outside U.S. waters. If Pacific sardine is managed as multiple stocks, there is risk in not capturing connectivity of the population and the north-south movement of individuals. If managing one coastwide stock of Pacific sardine, there is risk in not capturing structure that could potentially lead to disproportionate mortality of vulnerable portions of the population.

Further, the SSC noted that stock delineation should consider potential shifts in distribution due to changing climate when making recommendations for the Groundfish stock definition process (Agenda Item H.6.a, Supplemental SSC Report 1, March 2025). The SSC recommended that stock definitions should allow for potential northward shifts in distribution and that for species with no evidence of stock structure, the boundary be delineated as "coastwide."

4.4 Harvest Control Rules

In general, any change or new stock definition could require a change in or development of new HCRs and reference points compared to the status quo. The degree of that change is currently unknown and would be investigated further following the Council's decision on stock definitions.

Given changes in ocean conditions, potential changes in stock distribution, the ongoing evolution of scientific understanding, and the desire for more adaptability and flexibility by the Council[8], the Council should also consider how to make the HCR adaptable to change and able to account for uncertainty, including uncertainty in population structure and distribution of the stock(s) over time. For example, the SSC and the Council recommended that the Emsy and DISTRIBUTION terms in the formulas used to calculate HCRs for Pacific sardine be reviewed in coordination with the stock definitions process, noting that their ability to accurately reflect stock conditions may have changed since first added to the HCRs (see Agenda Item G.5 in April 2025; Agenda Item G.5.a, Supplemental SSC Report 1, April 2025)

A change in the stock definition could also require the Council to consider the area by which the stock (or stocks) are delineated and how that impacts various aspects of assessment and management. As described in Section 1.4, the DISTRIBUTION term, a parameter in the HCR formula, has historically accounted for the proportion of the northern subpopulation in Mexico waters. In assessing the stock, mortality of the stock in foreign waters may also be accounted for. In applying this consideration to the purpose of this action, the Council should consider whether a single, coastwide stock would be defined as the population in U.S waters only (i.e., drawing a line at the Mexican and Canadian borders), or if the status quo methodology of setting a DISTRIBUTION term and accounting for the portion of the stock in U.S. waters should be used. If defining multiple stocks, the same considerations as a single stock would apply, although the degree of uncertainty in defining the proportion of SSP in U.S. waters would be high, as it is

[8] See PFMC Staff Report on Council Special Project 1 - Adaptive Management and Flexibility, Agenda Item H.1 Attachment 1, September 2025

believed that only a small proportion of what is classified as SSP is in U.S. waters, though that proportion varies throughout the year and may be changing over time due to changing environmental conditions. This decision on delineation would also impact the model and assumptions for stock assessments and potentially introduce uncertainty in the ability to estimate an entire population biomass based only on limited data in U.S. waters.

4.5 Japanese sardine

The presence of Japanese sardine also has important implications for fisheries management. Considering Japanese sardine were caught in mixed hauls on the CPS survey (Kuriyama et al. 2024; Longo et al. 2025b), fishermen targeting Pacific sardine likely frequently catch Japanese sardine, which are morphologically indistinguishable from Pacific sardine when caught at sea and when landed onshore (unless genetic identification is done). Still, while the proportion of samples that are composed of Japanese sardine is known via genetic testing, it has not yet been possible to extrapolate this information to the biomass or catch of all sardine off the West Coast. Therefore, the presence of Japanese sardine can complicate stock assessments and management, as catch estimates will likely include multiple species. If unaccounted for, this could affect Pacific sardine population estimates, biomass projections, and the sustainability of catch limits. Since Japanese sardine first appeared in U.S. waters, catch estimates and the Pacific sardine stock assessment therefore have not differentiated Japanese sardine from Pacific sardine. However, to address the challenges of two indistinguishable species, there could be several future pathways. For instance, species of sardine could be managed jointly (i.e., in a complex), conducting a single stock assessment and applying fishery-wide reference points and management measures. Or, if possible, management may take a species-specific approach, maintaining a separate stock assessment for Pacific sardine and taking into account the proportion of biomass and catch composed of Japanese sardine. The simplified approach may obscure species-specific dynamics, while the latter approach could make assumptions about such dynamics and incur additional scientific and management burdens. Both approaches would aim to ensure sustainable management of the sardine fishery while accounting for the presence of Japanese sardine. Regardless of whether Japanese sardine is added to the FMU or how the Pacific sardine stock(s) are defined, it is possible to adjust Pacific sardine harvest limits based on the presence of Japanese sardine. Ultimately, the Council's decision on how to address the challenges presented by Japanese sardine will need to balance scientific rigor, management feasibility, practical considerations, and the potential for future environmental change.

5 Synthesis

Overall, this action relates to the question of reviewing the FMU in the FMP, including which stocks of sardine off the U.S. West Coast should be defined within it. Reviewing the FMU as outlined in Table 1-1 of the CPS FMP through the framework established by the MSA and the National Standards (Section 2) suggests that including all sardine in U.S. waters in the FMU would support the goals and objectives of the CPS FMP and NS1 and meet the principles of a management unit required by NS3 guidelines. Updated scientific information and the framework for defining stocks in a management unit also provides information to support a Council decision to identify and define stocks given these potential additions to the FMP.

If the Council elects to make a change to the FMU, it would require an amendment to the CPS FMP as well as a regulatory amendment. Addition of a new species to management would also

require a regulatory amendment[9]. It is important to remember that the FMU and stock definitions can be reviewed and re-adjusted if necessary if there are changes in the scientific information available or changes in the ability to manage individual stocks as a unit. This ability should not preclude the Council, however, from considering potential shifts in distribution as a result of changing environmental conditions or changing fishery dynamics when a directed fishery is re-opened in their decision making. Further, following this action, there may be a need for follow-on action, which may consider adjustments to reference points and HCRs, coordination of management of multiple stocks, or even delegation of management.

New research on the population structure of Pacific sardine demonstrates that there is little, if any, evidence to support the hypothesis of a subpopulation structure that has been the basis of sardine management for the last 25 years. Genetic research (Longo et al.) provides evidence of panmixia and a lack of reproductive isolation between groups within the population. Given the lack of evidence for multiple subpopulations, and the inability to distinguish between individuals of supposed subpopulations on the water, the stock delineation that is best supported by scientific information on sardine population structure and the ability to reduce uncertainty and resource burden in management practices would likely be a single stock coastwide.

While there is new science supporting a single coastwide stock, there may be some benefit in the Council continuing to consider delineating multiple stocks of Pacific sardine based on finer-scale population structure. Based on the scientific information available, there may be some differences among portions of the population, though not to the extent of creating distinct subpopulations that cannot reproduce together. Further, there may be risks associated with localized depletion if managed on such a large scale. It is important to consider that the existence of potential subpopulations does not necessitate managing each subpopulation as individual stocks. A single stock may include multiple subpopulations, though multiple stocks may account for differences in population dynamics exhibited by subpopulations. Further, despite the delineation of multiple stocks, in practice it would remain impossible to distinguish between these stocks on-the-water for each individual fish landed. Therefore, some method would need to be established to attribute catch towards each population, generating uncertainty in the ability of management to prevent overfishing on individual stocks and increasing the complexity of management- impacting both industry and managers. Overall, defining multiple stocks would increase management burdens. The Council should consider whether that extra burden would, as Longo et al. (2025) put it, increase or alleviate “incoherent dimensionality” in management.

Given a lack of evidence of hybridization with Pacific sardine and based on the scientific information that is available, Japanese sardine should likely be considered a reproductively isolated and separate stock from Pacific sardine. However, given these species are also indistinguishable and targeted together in mixed landings, these stocks should be managed in close coordination with Pacific sardine, regardless of how the Council elects to manage Pacific sardine. The Council action at hand, however, does not require a determination of how to coordinate this management, as that may occur after stocks have been defined in the FMU. This coordination and recognition of Japanese sardine may also occur whether or not the Council determines that Japanese sardine should be added to the FMU.

[9] 50 CFR 660.502 only lists Pacific sardine as within the FMU

6 Purpose and Need and Proposed Range of Alternatives

Given the information presented above, staff have developed the following purpose and need and range of alternatives for the Council to consider.

Purpose and Need

Due to the prolonged closure of the sardine fishery, industry concerns over limited fishing opportunities, recent attention to landings of the southern subpopulation of Pacific sardine (SSP), newly published research on the population structure of Pacific sardine, and the recent occurrence of Japanese sardine in the California Current, this action aims to reevaluate the fishery management unit (FMU) for sardine in the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP). Specifically, the action will reconsider which sardine species and populations are included in the fishery management unit and how stocks for these species are defined.

Properly defining the stock is fundamental to the conservation and sustainable utilization of sardine, providing the scientific and management basis for setting harvest limits, protecting population health, and supporting long-term fishery stability. Recent scientific literature suggests that there is evidence that Pacific sardine found off the West Coast are comprised of one single population, rather than the two subpopulations that underlie current management. This action is therefore necessary to ensure sardine management is consistent with the goals and objectives of the Magnuson-Stevens Act, including National Standards 1, 2, and 3, and the objectives of the CPS FMP.

Range of Alternatives

No Action - The Council would not define stocks other than those currently defined in the CPS FMP (Section 1.2, Table 1-1). Only the northern subpopulation of Pacific sardine would continue to be defined as a stock in the FMU.

Alternative 1 - The Council would amend the CPS FMP (Section 1.2, Table 1-1) to include all Pacific sardine in U.S. waters in the FMU. The FMU would include one stock of Pacific sardine, delineated coastwide.

> ***Option (a)*** – The Council would also amend the CPS FMP to add Japanese sardine in U.S. waters to the FMU.

Alternative 2 - The Council would amend the CPS FMP (Section 1.2, Table 1-1) to include all Pacific sardine in U.S. waters in the FMU. The FMU would include two stocks of Pacific sardine, delineated by northern and southern subpopulations.

> ***Option (a)*** – The Council would also amend the CPS FMP to add Japanese sardine in U.S. waters to the FMU.

The potential alternatives cover the two major decision points for the Council under this action: (1) Which species of sardine should be included in the FMU? And (2) How should stocks of those species be identified and delineated? The No Action alternative takes no action on either of these questions. Action Alternatives 1 and 2 would add additional Pacific sardine present on the U.S. West Coast to the FMU, potentially also including Japanese sardine under option (a). Action Alternatives 1 and 2 differ in how the stock(s) of Pacific sardine are defined.

These alternatives simply cover the definition of the FMU and its stocks. Under any of these alternatives, there are several ways in which conservation and management of these stock(s) may

be implemented. These implementation factors could be determined in a future action following the determination of a stock definition. The Council may also take future action to develop harvest control rules, coordinate management between stocks, adjust for complications of a newly introduced species (Japanese sardine), delegate management if desired, and account for dynamics such as transboundary populations, changing environmental conditions, and exploitation patterns like localized depletion. The Council may also take future action to coordinate management of stock(s) defined in this action with related species and/or stocks, should they require it.

Ultimately, these alternatives represent a policy decision tasked to the Council. Adopting a range of alternatives and even a preliminary preferred alternative does not necessarily provide a "conclusion" on the scientific evidence for population structure, as that is not the purpose of this action. Rather, the alternatives provide a range from which the Council may determine which stock definition most closely aligns with the best information available on population structure of Pacific sardine and with the ability to manage the fishery to the goals and objectives of the MSA, NS1, NS2, NS3, and the CPS FMP, allowing the Council to adjust the FMU as outlined in Table 1-1 of the CPS FMP, as appropriate.

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