Agenda Item G.1
Attachment 1
September 2020

PACIFIC SARDINE REBUILDING PLAN

PRELIMINARY ENVIRONMENTAL ANALYSIS

PREPARED BY THE PACIFIC FISHERY MANAGEMENT COUNCIL'S (COUNCIL) COASTAL PELAGIC SPECIES MANAGEMENT TEAM FOR CONSIDERATION AT THE SEPTEMBER 2020 COUNCIL MEETING

AUGUST 2020

Contents

INTRODUCTION

On July 9, 2019, the National Marine Fisheries Service (NMFS) determined the northern subpopulation (NSP) of Pacific sardine to be overfished based on the results of the April 2019 stock assessment, which estimated the population to be less than the 50,000 metric tons (mt) minimum stock size threshold (MSST) specified in the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP). To meet the two-year timeline for implementing a rebuilding plan as specified in the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the Pacific Fishery Management Council (Council) intends to submit a proposed rebuilding plan to the National Marine Fisheries Service (NMFS) within 15 months to ensure sufficient time for implementation of the plan, if approved.

1.1 PURPOSE AND NEED

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

1.2 ACTION AREA

The action area is inclusive of and limited to the United States West Coast Exclusive Economic Zone (EEZ).

1.3 REBUILDING REQUIREMENTS

The MSA serves the need for a national program to prevent overfishing, to rebuild overfished stocks, to ensure conservation, and to realize the full potential of the nation's fishery resources. Once a stock is determined to be overfished, the Council is informed and a rebuilding plan consistent with MSA requirements and the applicable FMP is to be implemented within two years. The rebuilding plan may take the form of an FMP amendment or regulations designed to rebuild the affected stock. The rebuilding plan must specify a rebuilding time period of less than 10 years except in cases where the biology of the stock, other environmental conditions, or international management measures dictate otherwise.

The MSA National Standard 1 (NS1) guidelines provide the Council with specific guidance on how to determine the following rebuilding plan elements:

- Tmin: the minimum time for rebuilding the stock. Tmin is defined as the time that the stock is expected, with a greater than 50 percent probability if that probability can be calculated, to take to rebuild to its biomass at maximum sustainable yield (Bmsy) level in the absence of any fishing mortality.
- Tmax: the maximum time for the stock to rebuild to Bmsy level. Tmax is either 10 years (if Tmin is less than or equal to 10 years) or can be more than 10 years if Tmin is also more than 10 years.
- Ttarget: The target time for rebuilding the stock. Ttarget should be selected to be the shortest time to rebuild the stock to its Bmsy level considering the status and biology of the stock, the needs of fishing communities, and interaction of the stock within the marine ecosystem; and it must not exceed Tmax. The fishing mortality that is associated with achieving Ttarget is referred to as Frebuild.

After implementation, the rebuilding plan is to be reviewed by NMFS at least every two years to ensure that adequate progress toward rebuilding is being achieved. The review "could include review of recent stock assessments, comparisons of catches with the ACL, or other appropriate performance measures" per NS1 guidelines. Revising the rebuilding timeframes (e.g., Ttarget, Tmin) is not necessary unless adequate progress is not being made.

The CPS FMP addresses rebuilding requirements for overfished stocks in Section 4.5. Unlike some FMPs (groundfish and salmon), the CPS FMP does not include specified processes to follow when a stock is declared overfished. The CPS FMP instead provides general guidance and states that the rebuilding plans may be implicit in existing HCRs. Section 4.5 reads in part:

> "It is impossible to develop a rebuilding program that would be guaranteed to restore a stock to the MSY level in ten years, because CPS stocks may remain at low biomass levels for more than ten years even with no fishing. The focus for CPS is, therefore, on the average or expected time to recovery based on realistic projections. If the expected time to stock recovery is associated with unfavorable ecosystem conditions and is greater than ten years, then the Council and the U.S. Secretary of Commerce (Secretary) may consider extending the time period…
>
> [and]
>
> Rebuilding programs for CPS may be an integral part of the harvest control rule (HCR) or may be developed or refined further in the event that biomass of a CPS stock reaches the overfished level."

1.4 BACKGROUND

1.4.1 STOCK OVERVIEW

Pacific sardine form three subpopulations (see review by Smith 2005). The NSP, which ranges from southeast Alaska to the northern portion of the Baja Peninsula, is most important to U.S. commercial fisheries and is the stock managed by the CPS FMP. The southern subpopulation ranges from the southern Baja Peninsula to southern California, and the third subpopulation is in the Gulf of California. Off the West Coast, sardines are known to migrate northward in spring and summer and southward in fall and winter. This is true for both the NSP and the southern subpopulation. These two subpopulations overlap, but can be distinguished from each other (Felix-Uraga et al. 2004, Felix-Uraga et al. 2005, Garcia-Morales et al. 2012, Demer and Zwolinski 2014). The Pacific sardine NSP ranges from the waters off northern Baja California, Mexico to southeast Alaska and commercial fishing occurs on this transboundary stock by fleets from Mexico, the U.S., and Canada during times of high abundance. There are no international agreements or treaties among these nations that formally coordinate management of fisheries for this stock. Rather, each country sets its own fishery regulations for sardine. However, biological information when available, as well as catch by other countries, are included in the annual U.S. stock assessment. The stock's range is reduced when population levels are low with the bulk of the biomass and harvest typically centered off southern/central California and northern Baja.

1.4.2 MANAGEMENT OVERVIEW

Management of Pacific sardine is accomplished through an annual assessment and management specifications process to calculate the annual overfishing limit (OFL), the acceptable biological catch (ABC), the annual catch limit (ACL) and the primary directed fishery harvest guideline (HG) for the U.S. commercial fishery and adopt management measures. Management measures are set at the April Council meeting using the following control rules:

OFL	Biomass * E_{MSY} * Distribution
ABC	Biomass * $BUFFER_{P\text{-}star}$* E_{msy} * Distribution
ACL	LESS THAN OR EQUAL to ABC
HG	(Biomass - CUTOFF) * FRACTION * Distribution
ACT	OPTIONAL; LESS THAN HG OR ACL

- BIOMASS is the age 1+ biomass of the NSP of Pacific sardine estimated in annual stock assessments.
- $E_{MSY,}$ is an estimate of the exploitation rate at maximum sustainable yield using sea surface temperatures and serves as a proxy for the influence of environmental conditions on stock biomass. For the OFL and ABC control rules, E_{MSY} is bounded from 0 to 25 percent. E_{MSY} also informs the FRACTION term used in the HG control rule but with a range bounded from 5 to 20 percent.
- Recognizing that NSP of Pacific sardine ranges beyond U.S. waters and, therefore, is subject to foreign fisheries, the HCRs include the DISTRIBUTION term which equals 0.87 and is intended on average to account for the portion of the Northern subpopulation of Pacific sardine in U.S. waters.

In addition to these parameters, the ABC control rule incorporates a BUFFER term. By incorporating BUFFER, the ABC control rule serves as a threshold against overfishing (i.e., exceeding the OFL). The ABC is a percent reduction of the OFL that incorporates both the scientific uncertainty from the assessment, as determined by the Scientific and Statistical Committee (SSC) and the Council’s policy choice level of risk aversion to overfishing known as P-star.

Unique to the HG control rule is the CUTOFF parameter. This term reduces the fishable biomass of sardine by 150,000 mt and is intended to serve as a safeguard to protect the spawning stock, making it available for rebuilding if the stock becomes overfished. If biomass falls to or below 150,000 mt the computed HG is zero and the primary directed sardine fishery is prohibited.

The Pacific sardine stock was first projected to fall below CUTOFF on July 1, 2015 and has remained below CUTOFF since that time. Consequently, there has not been a primary directed fishery in U.S. waters since 2015. In the intervening years as specified in the FMP, with the HG equaling zero, Pacific sardine harvest has been managed under the OFL/ABC control rules, and with ACLs and annual catch targets (ACTs). The Council has adopted ACLs equal to or below the

ABC to accommodate the needs of the live bait, minor directed, and tribal fisheries, as well as incidental catch in other CPS fisheries and in non-CPS fisheries (e.g., Pacific whiting).

In combination with catch limits prescribed by the harvest control rules (HCRs), accountability measures (AMs) have been used as secondary management measures to manage directed and incidental fishery harvests of Pacific sardine. These AMs reflect fixed provisions of the CPS FMP and Council decisions made each year based on input from advisory bodies. The AMs include incidental catch limits on directed CPS fisheries and non-CPS fisheries, and additional triggers that further restrict catch when specific levels of harvest are reached. Incidental allowances are limits on the amount of sardine that may be landed in other CPS directed fisheries such as northern anchovy, Pacific mackerel, and market squid, as well as non-CPS fisheries. For example, the CPS FMP reduces the per landing incidental allowance for overfished stocks, in this case Pacific sardine, from up to 45 percent to 20 percent by weight in other directed CPS fisheries, e.g., mackerel and anchovy.

The Council has also adopted AMs that further reduced the incidental allowance to 10 percent when a specific harvest threshold was attained. Incidental landing allowances recognize the mixed schooling nature of CPS while also constraining catch to the target species. However, because mixing may increase at low biomasses, the incidental landing allowance may effectively curtail fishing altogether if fishermen are unable to locate schools with sufficiently low proportions of the limiting stock. Through the annual specifications process, the Council has set the incidental per landing allowance of Pacific sardine for non-CPS fisheries, e.g., Pacific whiting, at 2 mt. The Council has also implemented ACTs in some years since 2015 when Pacific sardine biomass fell below 150,000 mt (i.e., CUTOFF; Table 1). Expressed as a specific value, the ACTs if reached would have triggered reduced landings limits in CPS fisheries to 1 mt per landing. Thus far, ACTs have not been set at a catch level that resulted in closure of a fishery.

To a large extent, CPS fisheries have not been fully impacted by these secondary management measures. The ACTs, when in place, have not been triggered. The 20 percent incidental landing allowance prescribed by the FMP (and not a secondary measure) has likely had some impact, given reports from fishermen of the prevalence of mixed CPS schools. But other factors have constrained sardine catch, such as limited markets in other CPS fisheries and the bait fish fishery, low CPS abundance for incidental sardine fisheries such as squid or Pacific mackerel, and a relatively small number of mt of sardine needed to prosecute other CPS fisheries. These have contributed to constrained fishery landings since 2015, as evidenced by catches well below ABC/ACLs presented in Table 1.

As noted in the Rebuilding Requirements section (1.3), the CPS FMP does not include explicit rebuilding requirements and instead includes management approaches wherein features or aspects of a rebuilding plan are implicit. For example existing Pacific sardine management incorporates such features: the primary directed fishery for sardine is closed at a level when estimated biomass is three times the level at which the stock is deemed overfished, and this is accomplished through automatic actions due to the CUTOFF parameter in the HG control rule; and, provisions in the CPS FMP that automatically reduce the incidental allowance of sardine in other CPS directed fisheries when the stock is overfished. Thus, management actions the Council might otherwise need to undertake such as closures of major fisheries and restrictions on incidental catch when a stock is declared overfished are hardwired for Pacific sardine.

1.4.3 FACTORS CONTRIBUTING TO OVERFISHED STATUS

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

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

Each year since the directed fishery closure, ACLs have been set as Council policy decisions, in part to accommodate anticipated non-primary directed fishery needs even as the biomass declined. However, as described under Management Overview (Section 1.4.2), due in part to other regulatory measures such as limits on minor directed fishing, as well as the amount of sardine that can be caught incidental to other fisheries, total harvest has remained relatively constant since 2015, averaging about 2,200 mt/year, which is well below any year's ACL. Additionally, all U.S. sardine catch is counted against the ACL, even though some portion is likely composed of the southern subpopulation of Pacific sardine. For example, the most recent stock assessment retroactively assigned only a portion of the U.S. catch to the NSP (e.g. see Table 1 in Kuriyama et al. 2020). This suggests that U.S. harvest of NSP sardine has likely been less than 1 percent of the stock biomass in the years since the closure of the primary directed fishery.

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

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

2.0 DESCRIPTION OF ALTERNATIVES

Key steps or actions that might be considered under a rebuilding plan to modify fishing activities in an attempt to rebuild the stock have already been implemented in the Pacific sardine fishery. Notably, the primary directed commercial fishery has been closed for five years, consistent with NSP stock biomass falling below the CPS FMP's CUTOFF value of 150,000 mt. Additional restrictions - reduced incidental landing limits - in the FMP were triggered in 2019 when the stock dropped below the MSST of 50,000 mt. Falling below MSST triggered an overfished designation; however, overfishing has not been occurring for this stock, as Pacific sardine catch has been well below both the ABC and the OFL. Unlike groundfish or salmon, which have numerous sectors, species, or river systems, all with unique impacts and characteristics, the sardine fishery has few sectors, and operates on large regional scales. The small amount of harvest that remains is mostly in the live bait fishery. Between 2005 and 2015, reported sardine live bait catches averaged 2,522 mt with a minimum of 1,562 mt in 2014 and a maximum of 3,561 mt in 2006. The live bait fishery has seen an overall decline in total catch of sardine and anchovy of 36.5 percent between 2005 and 2015, with an annual average decrease of 3.7 percent[1]. Over this time period, sardine landings declined 28.1 percent (annual average of 2.8 percent) and anchovy landings declined 52 percent (annual average of 5.2 percent). Due to the input role that live bait landings play in the recreational sector, an expansion in demand outside the historical range is considered unlikely and would be accompanied by an increase in demand from the recreational fishing industry. Sardine has few interactions with other fisheries except for other CPS and a small amount of bycatch in other non-CPS fisheries such as the Pacific whiting fishery.

With regards to the alternatives presented below, Alternative 1 represents status quo management and therefore maintains the implicit rebuilding measures built into the CPS FMP, and Alternative 2 would set the Pacific sardine quota at zero, thereby prohibiting landings of Pacific sardine. Alternative 3 falls between these two alternatives by allowing some harvest but bounded at a much lower level compared to Alternative 1.

[1] Note, the catch reporting methodology changed in 2016.

2.1 PROPOSED ALTERNATIVES

2.1.1 Alternative 1

Status Quo

Alternative 1 maintains the management process, HCRs, and other FMP provisions currently in place for the NSP of Pacific sardine, such as the prohibition of the primary directed fishery and limits on incidental catch of sardine in other fisheries. The Council would retain existing flexibility to consider resource and fishery needs on an annual basis. Hence, Alternative 1 represents the status quo relative to the overall management of sardine, and not any particular recent action or period.

As described in the Management Overview (Section 1.4.2), harvest specifications for sardine are set each year based on an estimate of biomass from stock assessments conducted annually. The OFL, ABC and HG are computed directly and when biomass is at or below CUTOFF (150,000 mt), the primary directed fishery is prohibited. However, other harvest opportunities such as live bait, incidental (in CPS and non-CPS fisheries), tribal, minor directed, and recreational are allowed under the CPS FMP when Pacific sardine biomass is below CUTOFF and the MSST. Unlike for the primary directed fishery, the CPS FMP does not include a unique, prescriptive HCR comparable to the HG to manage these other fishing opportunities. Instead, the ABC control rule establishes maximum catch and the Council, at its discretion, sets an ACL equal to or lower than the ABC and may include sector specific ACLs. To date the Council has not used sector specific ACLs but has set ACLs equal to and below the ABC.

In addition to the suite of HCRs and AMs prescribed by the CPS FMP, the Council will retain the ability to incorporate various additional management measures to limit sardine harvest. Since 2015, the Council has adopted discretionary AMs that have included directed and incidental fishery catch restrictions, and in some years an ACT. For example, in 2017, before the sardine fishery was declared overfished, the Council chose to adopt automatic inseason actions for CPS fisheries that progressively reduced the incidental per landing allowance from 40 percent Pacific sardine to 10 percent with decreases triggered by landing thresholds being reached. For the 2020-2021 sardine fishery the Council adopted an ACT of 4,000 mt that, if attained, will trigger a per trip limit of 1 mt of Pacific sardine for all CPS fisheries. The Council also adopted an AM specific to the 2020-2021 live bait sardine fishery that limits the per landing limit to 1 mt of Pacific sardine if landings in the live bait fishery attain 2,500 mt. Since sardine was declared overfished, the AMs have not been triggered, reflecting the relatively conservative nature of the fishery, but they exist as safeguards should fishery dynamics shift towards increased harvest.

As noted in the Rebuilding Requirements and Management Overview sections (1.3 and 1.4.2, respectively), rebuilding measures in the CPS FMP may be implicit. Given the conservative management measures the CPS FMP already dictates when Pacific sardine biomass decreases (i.e., the 150,000mt CUTOFF and the automatic reduction in incidental harvest below the 50,000mt MSST), status quo management may be viewed as a rebuilding plan without further refinement.

2.1.2 Alternative 2

Zero Harvest Rate

For analysis and modeling purposes, Alternative 2 would adopt a U.S. zero-harvest approach and entails complete closure of the remaining fisheries that target Pacific sardine including live bait and minor directed sardine fisheries as well as elimination of incidental landing allowances in other fisheries such as Pacific mackerel, market squid, northern anchovy, and Pacific whiting.

It is difficult to specify what this alternative would look like in practice (i.e., what specific regulatory restrictions could be adopted, such as closure of minor directed fisheries and elimination of incidental landing allowances in all fisheries) to reduce sardine catch to zero. Thus, in practice, this alternative would likely be difficult to implement from a fishery management perspective. In addition, tribal treaty fisheries are established via Government to Government consultation and could potentially include sardine harvest. As proposed, the concept of this alternative was to provide a comparative analysis given that status quo management already restricts harvest to low levels well before the stock is estimated to be below MSST.

2.1.3 Alternative 3

5 percent Fixed Harvest Rate

Alternative 3 would set the ACL at five percent of total age 1+ biomass for that year. The OFL and ABC would be computed using existing formulas. Under this alternative, the exploitation rate is fixed at five percent regardless of total stock biomass level and it incorporates no other HCR parameters. Specifically, it bypasses the DISTRIBUTION term for the portion of the stock in U.S. waters. This alternative was designed to reduce the maximum harvest allowed under the presumption it could rebuild the stock faster and reflects the low level of recruitment observed in recent years. To illustrate, Table 2 compares the ACLs used for management since 2015 with the ACLs this alternative would have produced.

This alternative was adopted as part of the range of alternatives by the Council at its June 2020 meeting to provide an alternative with a specified harvest rate between the status quo alternative and the zero-harvest alternative. The CPSMT had originally proposed a third alternative “Reduced Status Quo” to similarly provide a middle option. However, the “Reduced Status Quo” alternative did not include a specific level of reduction (see PFMC June 2020b, Agenda Item G.1.a). The CPSMT deemed the management outcomes of the two alternatives to be similar, so only the five percent fixed harvest rate alternative was retained for further consideration.

3.0 AFFECTED ENVIRONMENT

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

3.1 PACIFIC SARDINE

Pacific sardine (*Sardinops sagax*) are small schooling fish and are found from the ocean surface down to 385 meters. Sardines may live as long as 13 years, but most commercially caught fish are three to six years old. Sardine, along with other species such as northern anchovy, Pacific hake, jack mackerel, and Pacific mackerel can achieve large populations in the California Current Ecosystem (CCE) as well as in other major eastern boundary currents. However, as noted above the Pacific sardine NSP, as well as other CPS populations, has undergone boom and bust cycles for roughly 2,000 years, even in the absence of commercial fishing.

California's sardine fishery began in the 1860s as a supplier of fresh whole fish. The fishery shifted to canning from 1889 to the 1920s in response to a growing demand for food during World War I. Peaking in 1936-37, sardine landings in the three west coast states plus British Columbia reached a record 717,896 mt. In the 1930s and 1940s, Pacific sardine supported the largest commercial fishery in the western hemisphere, with sardines accounting for nearly 25 percent of all the fish landed in the U.S. by weight. The fishery declined and collapsed in the late 1940s due to extremely high catches and changes in environmental conditions and remained at low levels for nearly 40 years. The fishery declined southward, with landings ceasing in Canadian waters during the 1947-1948 season, in Oregon and Washington in the 1948-1949 season, and in the San Francisco Bay in the 1951-1952 season. The California Cooperative Fisheries Investigations (CalCOFI), a consortium of state and federal scientists, emerged to investigate the causes of the sardine decline. Analyses of fish scale deposits in deep ocean sediments off southern California found layers of sardine and anchovy scales, with nine major sardine recoveries and subsequent declines over a 1700-year period (Baumgartner et al. 1992).

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

3.2 FISHING INDUSTRY

3.2.1 PRIMARY DIRECTED COMMERCIAL FISHERIES

The primary directed fishery comprises the largest component of the CPS fisheries that harvest Pacific sardine and represents the historical fishery dating back to the 1920's in California and the contemporary expansion from the late 1990's of the fishery into the Pacific Northwest. As described above in Management Overview (Section 1.4.2), fishing opportunity in the primary directed fishery is determined by the output of the HG control rule which has imposed a closure of the fishery since 2015. Prior to its closure, the ex-vessel value of this fishery averaged over $14.7 million (in 2018 dollars) from 2009 through 2014 (PFMC 2019b).

3.2.2 LIVE BAIT FISHERIES

Live bait fisheries typically use various types of roundhaul gear such as purse seines to capture relatively small-sized CPS schools and deliver the catch alive to receiver vessels (or 'live bait barges') that have holding tanks or dockside net pens. Private and charter recreational vessels and commercial vessels then purchase live bait by the scoop from these receiver vessels or pens, as they depart for fishing trips.

CALIFORNIA

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

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

OREGON

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

WASHINGTON

In Washington, the live bait fishery targets anchovy or herring, and similar to the California live bait fishery, serves economically significant recreational fisheries, as well as the commercial albacore tuna fishery. State bait fishing regulations prohibit targeting sardine in state waters (0-3 miles), allowing only incidental landings. Additionally, the state's LE license for Pacific sardine which is required to target sardine authorizes fishing in federal waters (3-200 miles) only. Therefore, the sole opportunity to target sardine is in the primary directed sardine fishery which is closed by moratorium. Annually the number of bait licenses issued is less than 20. Total incidental landings of Pacific sardine by baitfish licenses are less than 0.5 mt per year.

3.2.3 MINOR DIRECTED FISHERIES

Amendment 16 (2018) of the CPS FMP allows minor directed commercial fishing on CPS finfish to continue when the primary commercial fishery is otherwise closed. This sector accounts for a very small portion of the overall catch of any particular CPS stock and has a negligible impact.

However, it is an important source of income for some small ports and producers, especially when the directed fishery is closed. The amendment includes a maximum of one ton per vessel per day, with a one-trip-per-day limit.

CALIFORNIA

Minor directed fishing in California is a minor component of the commercial CPS fishery. Smaller purse-seine vessels will fish for CPS to be sold mostly for dead bait. Landings usually occur around the major fishing ports but smaller ports will have landings as well and it is usually to support the other fisheries with bait. Since Amendment 16 was approved in 2018, less than 50 mt of sardine have been landed each year in the minor directed fishery.

OREGON

Beach seine operations that harvests CPS and other species for bait for recreational anglers are allowed only in the Umpqua River estuary. Most are sold as dead bait, but some are sold alive, with total bait harvest reported on fish tickets. Landings of sardine, as well as of other species, have fluctuated over the years. For the period from 2000 to 2019, the highest sardine harvest was 11 mt in 2004 and the lowest was 0 mt in 2010 with the average being 3.6 mt per calendar year. Pacific sardine have been relatively abundant in the Umpqua River estuary since Amendment 16 was adopted with an average harvest of 7.8 mt landed during 2018 and 2019.

WASHINGTON

The Washington state regulatory framework as described in the Live Bait Fisheries section only allows minor directed opportunity when federal waters are open for the primary directed fishery. Participants in the minor directed fishery would be required to hold a limited entry license. It is unlikely that fishermen would pursue minor directed fishing when the primary fishery was open.

3.2.4 INCIDENTAL HARVEST

CPS FISHERIES

Incidental harvest of sardine in CPS fisheries targeting northern anchovy, Pacific mackerel, and Market squid was restricted to 40 percent per landing for the 2015-2016 to 2018-2019 seasons and then 20 percent per landing starting with the 2019-2020 season. When possible, fishermen avoid mixed schools because the markets often prefer to have landings without high levels of incidental species in order to reduce the time to sort fish. Incidental harvest of sardine also occurs in other fisheries such as the groundfish trawl fishery where fishermen do not have the ability to avoid capturing sardine. In recent years California CPS fishermen have indicated increased difficulty catching fish because they have encountered mixed schools frequently and must release the school if Pacific sardine comprise over 20 percent in the school. Since the closure of directed Pacific sardine fishing, an average of 300 mt of incidental sardine has been landed per year in California. These mixed landings averaged over $1.8 million in value (PFMC 2020a).

NON-CPS FISHERIES

Annual management measures for Pacific sardine include an incidental catch allowance of sardine for non-CPS directed fisheries, expressed as a limit in metric tons per landing. The limit has been up to two tons. The Pacific whiting fishery accounts for most non-CPS directed fishery incidental catch.

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

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

3.3 TRIBAL FISHERY

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

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

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

3.4 SARDINE IN THE ECOSYSTEM

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

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

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

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

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

3.5 PROTECTED SPECIES AND BYCATCH

Protected species include species protected by three federal laws; the Marine Mammal Protection Act (MMPA), the Migratory Bird Treaty Act (MBTA), and the ESA. There are more than 30 species, evolutionarily significant units or distinct population segments listed as threatened or endangered in the CCE. In general, the harvest of Pacific sardine has the potential to affect protected species in two ways: direct take of the animals during the prosecution of the fishery (incidental catch/bycatch) or indirectly due to reductions in prey base that serve as forage. However, direct interactions through targeted sardine fishing are either de minimis or non-existent and protected species known to utilize sardine as part of their forage base are also known to switch prey depending on the relative availability of suitable prey species.

In 2010 the CPSMT did a thorough review of observer records and landing records to look at bycatch species in CPS fisheries and confirmed that bycatch in CPS fisheries is dominated by other CPS and that bycatch/incidental catch of non-CPS is extremely low. If larger fish are in the net, they can be released alive by lowering a section of the cork-line or by using a dip-net. Grates can be used to sort larger non-CPS from the catch. Detailed accounts of landed bycatch can be found in the Appendix of the 2019 CPS SAFE (PFMC 2019b).

4.0 ANALYSIS OF ALTERNATIVES

The CPSMT offers the following analysis of the alternatives for Council consideration. In drafting these analyses, the CPSMT considered what is known about the NSP of Pacific sardine, including estimates of its large population fluctuations over thousands of years, the history of the sardine fishery on the west coast of North America, the role as forage that sardine play in the CCE, the biological modeling work (Hill et. al. 2020) as well as socioeconomic considerations; a more expansive socioeconomic analysis is anticipated to be submitted as a supplemental report under this Agenda item specifically to help inform Council decision making on a rebuilding plan for this stock. The CPSMT also considered guidance and perspectives offered by a number of esteemed statisticians regarding use of models and their results to inform real world choices. We start by offering some perspective on using model results to inform decision making. In 2009, statisticians George Box, Alberto Luceño, and Maria del Carmen Paniagua-Quiñones wrote:

> “All models are approximations. Assumptions, whether implied or clearly stated, are never exactly true. *All models are wrong, but some models are useful.* So, the question you need to ask is not "Is the model true?" (it never is) but "Is the model good enough for this particular application?"
>
> *Box, G. E. P., Luceño, A., del Carmen Paniagua-Quiñones, M. (2009), Statistical Control by Monitoring and Adjustment, John Wiley and Sons, Inc., Hoboken, New Jersey.*

4.1 MODELING CONSIDERATIONS

The ‘Rebuilder’ modeling platform, originally designed for analyzing rebuilding groundfish stocks (Punt 2012), was modified specifically for the purpose of examining the proposed alternatives for rebuilding the NSP sardine stock (Punt 2020). The modification included simulating the sardine ABC control rules and the ability to include information on catch outside the U.S., among others. The analyses were performed by a team from the Southwest Fisheries Science Center (SWFSC) and details of the methods, model inputs, and results are included under this agenda item (see Hill et al. 2020). Here, the CPSMT provides the reader with a brief overview. The model used data inputs from the 2020 benchmark assessment that covers the time period 2005-2020 (Kuriyama et al. 2020). The average recruitments from the assessment for two different time periods, 2005-2018 and 2010-2018, were used to estimate virgin spawning biomass (SB_0), the average spawning biomass that the stock is capable of attaining in the absence of fishing, for the rebuilding analysis of each scenario. The two time periods were chosen to represent different levels of productivity for this stock and resulted in average SB_0 estimates of 377,567 mt for the full time period and 104,445 mt for the shorter time period. These estimates provide the basis for determining the rebuilt level for each productivity level as well. Fishing mortality each year was modeled to be equal to the ABC, plus estimated catch of NSP sardine in Mexico modeled either as a constant catch or as a fixed proportion of stock biomass. The U.S. five percent catch alternative (Alternative 3) was not modeled using the ABC control rule that incorporates the BUFFER and DISTRIBUTION terms, but rather as straight five percent of the total 1+ biomass that is assumed to be taken in U.S. fisheries.

The CPSMT is faced with the task of analyzing the alternatives for a plan to rebuild the NSP stock of Pacific sardine. The intent of this modelling was, in part, to help guide this analysis. Although the CPSMT has concerns about the modeling being able to directly inform these decisions, the CPSMT does have preferred assumptions (e.g. recruitment time period) and has focused on the results of those model runs. To that end, the CPSMT considers the biological modeling results that drew from recruitments provided in the 2020 assessment for the period from 2005-2018 as the most applicable. This period represents a broader range of recruitment observed for this stock than the subset of years 2010 to 2018 that was also modeled. The modeling results for 2010 to 2018 also provide a relatively low spawning stock biomass target of only 38,122 mt. which the CPSMT finds inconsistent with the objectives of the CPS FMP, so it was not given any further consideration. The assumption that catch in Mexico is related to stock biomass and modeling it as a constant rate is also more reasonable than assuming that catch will be constant regardless of how many fish are available to the Mexican fleet as biomass changes. The CPSMT considers the 2005-2018 results using the constant fishing rate in Mexico to be the best representation available from the model.

The CPSMT recognizes using the years 2005-2018 for modeling recruitment in this stock poses problems. The 2020 assessment authors stated, “recruitment has declined since 2005-2006 with the exception of a brief period of modest recruitment success in 2009-2010. In particular, the 2011-2018 year classes have been among the weakest in recent history.” So the CPSMT asked if modeling this time period was adequate enough for a stock that is known to go through boom and bust cycles that are thought to be driven by environmental conditions, noting that this stock exhibited much greater productivity and recruitment in the years leading up to its most recent peak in abundance that occurred in the years after it came under federal management. These years are not covered by the modeling. The model also assumes the entire ABC is caught each year although that has not been the case in recent years when less than half of the ABC was taken in U.S. fisheries and much of that is thought to be from the southern subpopulation and not from this stock. With these assumptions the model results are quite sensitive to the level of fishing. The model results output is presented as median values in the tables. These median values represent a very wide range of values because of the skewed distribution of the data inputs. Given that knowledge and the limitations of the assumptions in the model, the CPSMT concluded that while the model is useful, it certainly is not able to definitively provide probabilities for recovery in any given time frame, nor accurate and precise biomass estimates for future years for any of the alternatives under consideration. Nevertheless, the CPSMT notes that despite its limitations, the modeling platform and its results do provide useful guidance and insights that are considered in these analyses of alternatives. Specifically, the CPSMT examined possible ways to utilize the model results for determining Tmin, Tmax and Ttarget values as well as the biomass that represents a rebuilt stock.

Based on the modeling results using recruitment data for the full 2005-2018 time period, the minimum time to rebuild the stock if no fishing occurred would be 8 years. The assumption for that value of Tmin is that there will be no fishing on this stock, including in Mexico. Given a Tmin of 8 years, the MSA and NS1 guidelines specify that the Tmax is 10 years. The modeling results also provide a rebuilt spawning stock biomass of 137,812 mt. A no fishing scenario on the NSP of sardine in Mexico is not realistically achievable through U.S. fishery management actions, however, and using the Tmin and Tmax determined by strictly following NS 1 guidelines in this manner is not one of the rebuilding plan alternatives under Council consideration.

However, if Tmin were to be calculated based on a U.S fishing rate of zero (i.e., consistent with Alternative 2), the modeling results do indicate a greater than 50 percent probability that the stock will rebuild in 2036, which would equate to a Tmin of 15 years. Because this Tmin is greater than 10 years, the NS1 guidelines provide two applicable methods to determine Tmax for this stock: 1) Tmin plus the mean generation time for sardine which is 3 years based on model results; or 2) Tmin multiplied by two. The CPSMT notes that the model results also provide a greater than 50 percent probability of rebuilding by the year 2047 under Alternative 3, the U.S. 5 percent harvest rate of the total 1+biomass, which is 26 years. Thus, the rebuilding timeline (i.e., a potential Ttarget) of 26 years would be within the second method of calculating Tmin that results in Tmax=30 years, but would not be utilizing the first method which results in a Tmax of 18 years.

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

The CPSMT provides an overview of the potential effects of fishing activities on the sardine resource, the fishing industry, ecosystem, and protected species for each of the alternatives. Although these analyses of alternatives are largely qualitative in nature, together with both the biological modeling done with the Rebuilder tool (Hill et al. 2020) and the economic modeling being conducted (anticipated to be submitted as a supplemental report under this Agenda item), the CPSMT is confident the Council will have the information necessary to choose the most appropriate rebuilding plan to submit to NMFS.

4.2 SARDINE RESOURCE

As noted previously, there is scientific consensus that environmental conditions play a critical role in both the time and the level to which the sardine biomass rebounds from its current low levels. The modeling work provides insight into the alternatives being considered, but as noted above the assumptions made in the modeling limit its usefulness. Additionally, even if further refinements could be made, it is virtually impossible to predict when conditions might produce favorable recruitment.

Under Alternative 1, the status quo alternative, there is never a greater than 50 percent probability that the stock will rebuild, based on the median values, before the year 2050, which is the time period that was modeled (see Table 4 in Hill et al. 2020). However, the median values do not tell the whole story of when the biomass may reach the target level. The modeling work results are based on simulations done over a very broad range of SB_0 values (see Figure 4 in Hill et al. 2020). The wider distribution of results, both the 25-75 percentiles and the 5-95 percentiles, from the modeling of biomass projections over time can be seen in Hill et al. (2020) Figure 9. The broader range of model results include some runs in which the projected spawning biomass may reach levels over 200,000 mt well before 2030 and more or less stabilizing around that level.

Furthermore, the modeling results should be viewed in the context that they do not capture the full range of productivity of which this stock is capable. They also assume that under status quo management U.S. fisheries harvest the full ABC, which has not been the case due to the prohibition on directed fishing, market dynamics, and restrictions on incidental harvest that cannot be captured in the modeling. This is important to note, because absent significant changes in regulations or market forces in the future, landings of Pacific sardine are likely to remain similar during the rebuilding timeline as they have been over the past five years (i.e., 2,200 mt/year on average) and therefore would be below the modeled status quo landings, accruing more benefit to the resource than was modeled. Catches would need to increase, that is approach or attain the ABC before the modeled impacts to the sardine resource would be relevant. Separate from the modeling, the status quo alternative is expected to constrain catches to levels, whether at Council adopted ABCs or lower, that will not likely impede the resource from rebuilding under favorable conditions.

Alternative 2, the zero U.S. harvest alternative, has the fastest modeled rebuilding time (see Table 4 in Hill et al. 2020). The modeled time to rebuild with a greater than 50 percent probability is 15 years, as noted above. However, again the median values do not provide a complete picture of when the biomass may reach the target level. The modeling work results are based on simulations done over a very broad range of SB_0 values (see Figure 4 in Hill et al. 2020). The wider distribution of results, both the 25-75 percentiles and the 5-95 percentiles, from the modeling of biomass projections over time can be seen in Hill et al. (2020) Figure 9. The broader range of model results include some runs in which the projected spawning biomass may reach levels over 300,000 mt well before 2030 and more or less stabilizing around that level. Like Alternative 1, the modeling results do not capture the full range of productivity of which this stock is capable, nor can the modeling work predict future productivity. It is difficult to determine if this zero-fishing option would rebuild sardine faster than the other alternatives presented here; historical studies have shown that the stock can stay low even with no fishing. Therefore even though fishing mortality associated with this alternative would be lower and on an annual basis less removals would occur, it is difficult to know if or how much faster the stock would rebuild under this alternative despite the modelling results. However, the impact on the sardine resource would be expected to be positive, leaving more sardine in water relative to Alternatives 1 and 3.

Alternative 3, with its constant five percent harvest of total 1+biomass, is projected to rebuild the stock with a greater than 50 percent probability in the modeling results (see Table 4 in Hill et al. 2020) by 2047. However, as just described above, the median values provide an incomplete picture of when the biomass may reach the target level. The broader range of model percentile results include some runs in which the projected spawning biomass may reach levels of nearly 400,000 mt well before 2030 and more or less stabilizing around that level (Hill et al. 2020, Figure 9). Again, the modeling assumes the full five percent is harvested each year, does not capture the full range of productivity of which this stock is capable, nor does it account for restrictions on incidental catch that might restrict harvest, or the fact that industry may not take the full five percent for other socioeconomic reasons.

Compared to the modeled results of Alternative 1 which does not rebuild the stock, this alternative is projected to rebuild the stock in 26 years. However, as has been previously noted, the modeled median timelines to rebuild should not be looked at as definitive dates, as the broader range of results suggest that a wider range of dates are possible for all scenarios. Given that actual landings in the CPS fisheries since 2015 are lower than what was modeled for status quo and the presumption that these are unlikely to change substantially, a rebuilding timeline for status quo harvest could have a similar timeline as that modeled for Alternative 3. The environment will likely be the primary determinant for the stock increasing. The fishery is already being heavily restricted under status quo, and it is unclear if the reductions in annual catch of this alternative compared to status quo would allow the stock to actually rebuild any faster. This alternative is anticipated to have a positive effect on the sardine resource relative to Alternative 1 by leaving more fish in the water and a negative effect compared to Alternative 2 by removing more fish.

4.3 FISHING INDUSTRY

Since the closure of the primary directed fishery in 2015, Pacific sardine has only been harvested in the smaller-scale sectors of the CPS fishery (i.e., the live bait, minor directed, and tribal fisheries); and as incidental catch in other CPS (e.g., Pacific mackerel) and non-CPS (e.g., Pacific whiting) fisheries. With these fisheries in mind, the CPSMT is considering the potential effects of each of the three proposed alternatives. Although the CPSMT has not yet reviewed the economic impacts modeling, the impacts are likely to range from positive or neutral to substantially negative. The average annual sardine commercial ex-vessel revenue has been $371,524 (2018 dollars) between 2015-2018 (PFMC 2019b). This figure does not include the value associated with being permitted to incidentally catch sardine in non-sardine CPS and groundfish fishery operations, nor the value to the recreational fishing sector of sardine caught in the live bait fishery.

Sardine is one of the primary species harvested for live bait in the Southern California recreational fishery, which as stated in Section 3.2.2, is part of an extremely valuable statewide recreational fishery generating over $1.3 billion in value added impact to California in 2016 (NMFS 2018). Between 2005 and 2015, reported sardine live bait catches averaged 2,522 mt per year, comprising 75 percent of total live bait catch (See Table 4-12 in 2019 CPS SAFE Appendix A). The live bait fishery contributes economically to a several live bait user groups that would potentially be economically affected under a rebuilding plan, including vessels that harvest live bait, CPFVs and private vessels that utilize purchase live bait, for recreational fishing trips, CPFV and private boat based recreational anglers, bait and tackle shops stores, and tourism-related businesses that benefit from the California sportfishing industry (e.g., hotels and restaurants).

Upon rebuilding and exceeding the CUTOFF value, the sardine primary directed fishery would likely resume, and is therefore mostly beyond the scope of this analysis. It is also expected that regulations pertaining to the catch of sardine in other fisheries may be relaxed relative to their current state. Under an open primary directed fishery, the average annual sardine commercial ex-vessel revenue has been $14,755,561 (in 2018 dollars) between 2009-2014 (PFMC 2019b). This figure includes fishery landing revenues from the non-primary directed sardine fishery. This figure does not include the value associated with being permitted to incidentally catch sardine in non-sardine CPS and groundfish fishery operations, nor the value to the recreational fishing sector of sardine caught in the live bait fishery.

Evaluation of the alternatives should weigh the near term through long term costs and benefits of each alternative while taking discounting and uncertainty into consideration. For each alternative there are near term expected costs and benefits of implementing the alternative now, which should ultimately be weighed against the long term expected costs and benefits of the fishery in the future.

Alternative 1 - This alternative represents the current management structure for Pacific sardine under the CPS FMP which allows for Council flexibility in setting management measures according to existing HCRs, as determined by the annual biomass estimate. Within the constraints of the OFL/ABC, this alternative maintains the Council's ability to consider fishery needs on an annual basis in conjunction with the status or trends of the sardine resource. For example, conditional on biomass levels, this alternative supports the Council's ability to respond to a future increased live bait fishery needs, say for an additional 500 mt, and consider whether this would impede rebuilding the sardine fishery given an understanding of the resource status, environmental conditions, and state of the ecosystem at that time. Based on the rebuilding analysis, in the near term the non-sardine components of the CPS fishery, the groundfish fishery, and the live bait fishery are not expected to be severely limited under Alternative 1. The CPS fishery typically catches schools of other CPS mixed with small amounts of sardine and is mostly able to land the fish with the incidental percentages that have been set by Council. Industry members have expressed some frustration with having to be more selective with the other CPS schools that they are allowed to capture to be sure that the proportion of sardine mixed in with the load is not over the incidental percentage limit. If the CPS fishery were to be further limited, many fishermen have said it would not be economically viable for them to continue, as they would have to spend more time and resources searching for schools with few sardine. The groundfish fishery is similarly not expected to be constrained in the near term due to expected modeled sardine biomass levels. Additionally, in the near term this alternative would not further restrict the live bait fishery, and by extension, the potential negative impacts to the recreational fisheries and connected industries are expected to minimal in the near term.

However, in later periods (the long term), this alternative is expected to constrain the current fishery sectors (live bait, minor directed, and incidental). Based on Rebuilder analysis results, median expected U.S. catch levels fall below the recent average landing levels in the long term. Periods of allowable catch below current levels would constrain multiple fisheries which land sardine; negative economic and community impacts may be minimized through careful management.

Based on the Rebuilder results, Alternative 1 does not result in a greater than 50 percent probability of rebuilding during the model period. Although the Rebuilder results suggest it only happens at a low percentile of model runs and therefore at a much lower probability, if environmental conditions are favorable, this alternative is unlikely to impede rebuilding of the stock, and in the near term it maintains the current economic benefits accruing to fisheries harvesting sardines directly or incidentally. Additionally, because this alternative is unlikely to further restrict the live bait fishery, by extension, potential negative impacts to the recreational fisheries and connected industries are similarly minimized.

Alternative 2 - The zero harvest U.S. fishing alternative would completely eliminate sardine harvest in the live bait and minor directed fisheries, and curtail other fisheries that catch sardine incidentally, including other CPS fisheries and the Pacific whiting fishery. This could have far-reaching negative socioeconomic effects on the various user groups that rely on these fisheries, including non-sardine CPS, groundfish, and live bait fisheries. From a fishery management perspective, it would be difficult implement a true zero catch alternative and it would likely have substantial adverse economic effects. However, this alternative is explored for its potential impacts to resources, including the fishing industry.

Under this alternative, the minor directed fishery, which is allowed to harvest less than 1 mt of sardine per trip, would be unable to provide sardine bait for other fisheries and would likely have negative impacts on the sector. At the time of the 2015 primary directed fishery closure, this small sector of the fishery was adversely impacted because it was not exempt from the closure. In 2017, the Council voted to implement Amendment 16 to the CPS FMP specifically to alleviate this economic harm. Since Amendment 16 was implemented in 2018, an average of 39 mt of sardine has been harvested in the minor directed fishery.

An average of 294 mt and 6 mt of sardine has been harvested incidentally in other CPS fisheries and non-CPS fisheries, respectively, since 2015 (see PFMC April 2020b Supplemental CPSMT Report 1 Agenda Item D.3.a). Other CPS fisheries that commonly catch sardine incidentally include market squid, northern anchovy, and Pacific mackerel. The Pacific whiting fishery, valued at $51.5 million (2012-2016) accounts for a significant portion of incidental harvest in non-CPS fisheries; however, its harvest of sardine is relatively minor (see Section 3.2.4). If incidental catch of Pacific sardine were prohibited, these fisheries, as they currently operate, would either be severely constrained or prohibited.

The Rebuilder model results indicate a greater than 50 percent probability that under Alternative 2, with a U.S. fishing rate of zero (0), the stock will rebuild in 2036. Upon rebuilding and reaching CPS FMP requirements, the sardine primary directed fishery and all associated fisheries may resume as permitted by their relevant FMPs.

Alternative 3 - The ACL under this alternative would be predetermined at five percent of the total 1+ biomass and would remain a fixed percentage until the Pacific sardine stock was rebuilt. By providing a formulaic approach, this alternative decreases existing management flexibility and precludes the Council from exercising many of its usual policy choices.

In the near term, based on model results, this alternative could be more likely to constrain sardine landings relative to Alternative 1 (status quo) when biomass is at 50,000 mt and below, and therefore has the potential for significant economic impacts compared to status quo. Under Alternative 3 there is potential for negative economic impacts when biomass is at 50,000 mt and below, compared to Alternative 1 (status quo). For example, had a policy like this been in place for the 2020-2021 fishing year, the result would have been an ACL of 1,414 mt compared to an ACL of 4,288 mt adopted by the Council. As previously stated, sardine landings have averaged around 2,200 mt since 2015 with a maximum of 2,505 mt. Therefore under the harvest policy of Alternative 3, in 2020 difficult decisions would have had to be made in how to allocate 1,414 mt (or some lower level to provide a buffer) across both the CPS fisheries that target Pacific sardine (i.e., live bait) and those that rely on the ability to incidentally land sardine in order to prosecute other important CPS and non-CPS fisheries.

In the longer term, preliminary modeling indicates this alternative may constrain the fishery less than Alternative 1. While the Rebuilder tool results indicate that based on median values, the only alternative to rebuild the stock in the presence of fishing and produce a stable SB and catch was U.S. five percent (Alternative 3). It is uncertain that the reduction - less than 2,000 mt - in sardine landings between Alternatives 1 and 3 would actually cause the stock to rebuild any faster than status quo management.

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

4.4 ECOSYSTEM

The Pacific sardine HCRs are already conservatively designed to limit sardine harvest such that adequate forage remains in the ecosystem for dependent marine predators via reductions in allowable harvest in conjunction with biomass declines. Therefore, none of the proposed management alternatives are expected to adversely affect forage availability, as sardine removal would be according to status quo removal or less. As stated in Section 3.4, predators (marine mammals, birds, and other fish) that prey on CPS have evolved in an ecosystem in which fluctuations and changes in relative abundances of CPS have occurred. Consequently, most predators of sardine are generalists that are not dependent on the availability of a single species but rather on a suite of species, any one or more of which is likely to be abundant in a given year. For example, while the biomass of the NSP of Pacific sardine is currently low, the central population of northern anchovy biomass is high (approximately 800,000 mt in 2019, see Stierhoff et al. 2020).

4.5 PROTECTED RESOURCES

A formal section 7 consultation and Biological Opinion on the operation and prosecution of the Pacific sardine fishery were completed in 2010. The Biological Opinion determined at that time that fishing activities conducted under the CPS FMP and its implementing regulations are not likely to jeopardize the continued existence of any endangered or threatened species under the jurisdiction of NMFS or result in the destruction or adverse modification of critical habitat of any such species. However, the ESA listing for the humpback whale as a single species was changed in 2016 to evaluate the need for individual listings of 14 Distinct Population Segments (DPS). Two of the 14 newly designated DPS are ESA-listed and occur in the affected area. However, fishing for sardine in U.S. waters has decreased substantially in recent years with the decline in biomass of the stock and the subsequent closure of the primary directed fishery in 2015.

Alternative 1, the status quo alternative, would not change management or fishing activities and would thus have no changes to the effects on Protected Species.

Alternative 2, the zero U.S. fishing alternative, would eliminate all fishing activities that harvest sardine. This alternative may affect protected species in an indirect positive way by, possibly making more sardine available to protected species that prey on sardine. But the effects of such a change are difficult to analyze, given that these predators are known to rely on a broad suite of species for forage and to switch prey based on relative availability and the annual difference in the level of removals between this alternative and the other alternatives is so minor that it is unlikely perceptible in the environment.

Alternative 3, the five percent U.S. harvest alternative, could reduce fishing activity and landings from status quo if the limits on catch fall below what has been landed in fisheries since 2015 (Table 1). Alternative 3 may affect protected species in similar ways as Alternative 2. The magnitude of the effects on protected species in any given year would be in between status quo and zero-fishing and dependent on the biomass estimate. The effects of Alternative 3 would likely take place over a longer time period than the zero-fishing alternative, but that would largely depend on environmental conditions driving stock productivity. Most of the sardine harvest since the closure has occurred in southern California as part of the live bait fishery and incidental harvest in other CPS fisheries in southern and central California as noted above. Consequently, any effects on protected species from this alternative would likely be regional in nature and less throughout its entire range.

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

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

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

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

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

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

Table 3. Hypothetical sardine biomass estimates and corresponding ACL values (metric tons) under Alternative 3 - 5 percent exploitation rate.

1+ Biomass	Alt 3 ACL
5,000	250
10,000	500
15,000	750
20,000	1,000
50,000	2,500
75,000	3,750
100,000	5,000
150,000	7,500
500,000	25,000
750,000	37,500
1,000,000	50,000

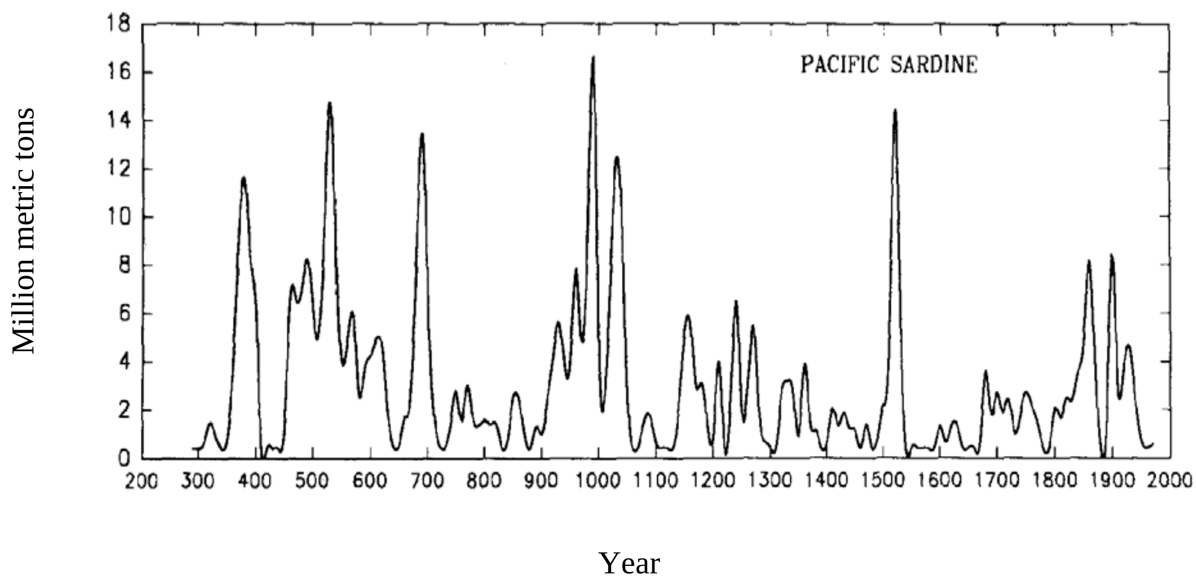

Figure 1. 1700-year hindcast series of Pacific sardine biomasses off California and Baja California (figure reproduced and modified to exclude Northern anchovy, from Baumgartner et al. 1992).

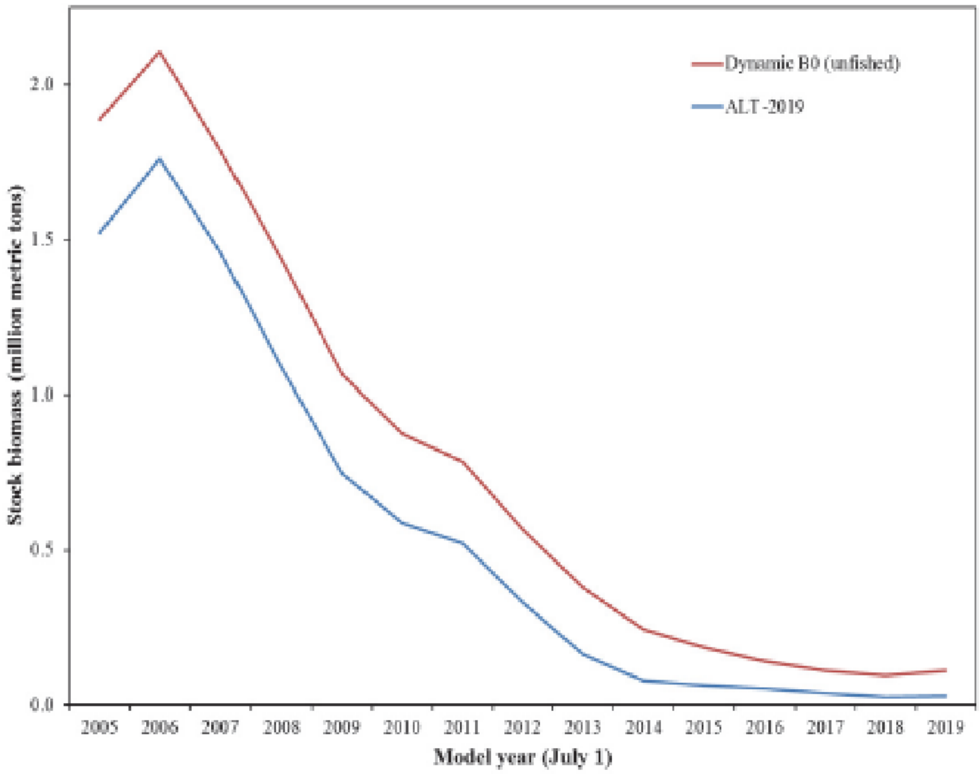

Figure 2. Estimated stock biomass (age 1+ fish, mt) time series and dynamic B_0 (unfished population) from model ALT-2019 (from 2019 Pacific Sardine stock assessment, Hill et al. 2019).

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