COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON ESSENTIAL FISH HABITAT REVIEW

Introduction

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires fishery management plans (FMPs) to describe and identify essential fish habitat (EFH) for each species in the FMP's fishery management unit (FMU). Federal regulatory guidance at 50 CFR §600.805 provides requirements to identify adverse impacts from fishing and non-fishing activities, to recommend conservation measures, to consider habitat areas of particular concern (HAPC), and to address other EFH components. These EFH components should be reviewed and updated at least every five years. EFH for coastal pelagic species (CPS) was incorporated in the CPS FMP in 1998 (Amendment 8, Appendix D). CPS EFH components were reviewed in 2010 and it was determined that no modifications were warranted at that time. Pacific Fishery Management Council (Council) Operating Procedure (COP) 22 provides guidance on developing the process, scope, and personnel to carry out EFH periodic reviews.

EFH reviews are typically divided into two phases. The first phase is focused on determining whether there is new information related to species biology, migration, prey, habitat needs, distribution, and human activities that may adversely affect EFH and warrant a revision to existing EFH provisions. If the Council concludes that revisions to the existing EFH provisions are not warranted, the review is concluded. However, should the Council determine that new information warrants changes to the current EFH provisions, the Council may embark on a second phase, during which specific changes to EFH provisions are developed for Council, advisory body, and public consideration.

In 2020, the Council, in coordination with NOAA Fisheries West Coast Region and the Southwest Fisheries Science Center (SWFSC), initiated Phase 1 of a review of the EFH provisions in the CPS FMP. Originally, the Council was scheduled to adopt a process and schedule at the April 2020 meeting. However, due to the COVID-19 pandemic, this item was removed from the Council's agenda. Although the Council did not have the opportunity to formally adopt a process and schedule for Phase 1, the Coastal Pelagic Species Management Team (CPSMT) and the SWFSC have been following the guidance in COP 22, and provided updates to the Council at the April, June, and September 2020 meetings. The SWFSC and CPSMT undertook and completed a literature review and an evaluation of the CPS FMP for required EFH components. This report presents the results of the reviews and provides a basis for deciding if the new information warrants proceeding to Phase 2 and potentially making changes to the EFH provisions in the CPS FMP.

Literature review

The CPSMT received an update at their February 2-4, 2021 work session on the literature review conducted by the SWFSC's Fisheries Resources Division's Life History Program staff as part of the initial step in accomplishing Phase 1. The report (attached) summarizes and lists published and unpublished research papers and reports from 2010 forward that provide information on the distribution and habitat of the CPS stocks, namely Pacific sardine, Pacific mackerel, jack mackerel, northern anchovy, and market squid; and from a broader time period, the two most abundant krill species (*Euphasia pacifica* and *Thysanoessa spinifera*) that occur in the California Current Ecosystem (CCE). Although six other krill species (*E. eximia, E. gibboides, E. recurva Nematocelis difficilis, Nyctiphanes simplex*) are managed under the CPS-FMP, these species are not well represented in most surveys conducted in US waters, so few US-based studies have been published about them compared to *Euphasia pacifica* and *Thysanoessa spinifera*. Because *T. spinifera* is the only euphausiid species that commonly occurs in shallow waters of < 150 m, and because the widespread distribution of *E Pacifica* is in subarctic waters, the report assumed that *E. pacifica* distribution and habitat would overlap with the habitats of the other 6 krill species in US waters. Thus, protecting essential habitat of *E. pacifica and T. spinifera* would likely protect the habitats for the whole krill assemblage under the CPS-FMP. The original designation of EFH for krill in Amendment 12 was also based on these two principal species.

The literature review did not discover any information that indicates the current description of EFH boundaries, copied below, requires changing for CPS finfish, although it found this definition does not fully address each life stage for market squid.

> "The east-west geographic boundary of EFH for each individual CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the exclusive economic zone (EEZ) and above the thermocline where sea surface temperatures range between 10°C to 26°C. The southern boundary of the geographic range of all CPS finfish is consistently south of the US-Mexico border, indicating a consistency in sea surface temperatures at below 26°C, the upper thermal tolerance of CPS finfish. Therefore, the southern extent of EFH for CPS finfish is the United States-Mexico maritime boundary. The northern boundary of the range of CPS finfish is more dynamic and variable due to the seasonal cooling of the sea surface temperature. The northern EFH boundary is, therefore, the position of the 10°C isotherm which varies both seasonally and annually."

Further, the literature review report identifies a fairly substantial amount of published new information on CPS particularly for northern anchovy, the two krill species *E. pacifica* and *T. spinifera*, and to a lesser extent for market squid and Pacific sardine. Comparatively little new information for Pacific mackerel and jack mackerel was found. In all cases, the new information has potential to enhance our present understanding and characterization of these species distributions, spawning habitats, and habitat use.

The literature review also looked for papers that might present new evidence of adverse impacts on EFH from CPS fishing activities managed under the MSA. There was scant new information on this topic.

The following paragraphs highlight the key findings from the report; see the report for further details and specific reference sources.

Pacific Sardine
Many papers have been published on the distribution and habitat use of Pacific sardine since the 2010 EFH review of this species. Analysis of fishery-independent and fishery-dependent survey data collected since the 2000s provide new insights on this species' habitat use as related to its

growth dynamics, ontogenetic distribution, spawning dynamics, and stock structure along the U.S. Pacific coast. While the papers may present data on populations of Pacific sardine throughout its range, any EFH regulatory designation or action will apply only to stocks managed in the CPS FMP, i.e., the northern subpopulation of Pacific sardine. New papers have improved our understanding of the seasonal migration of Pacific sardine, particular during their northward summer-fall feeding migration and southward winter-spring spawning migration.

- New data also indicate that the location of spawning habitats shows more complex dynamics over time. During low abundance in the 1960-1980s the adult spawning stock was mostly located off southern California and Ensenada, but since 2015 most of this spawning stock was located off northern California and Southern Oregon.
- New models have combined satellite and survey data, allowing the prediction of seasonal habitats of Pacific sardine and potential shift in this species' habitat due to climate change.

Pacific Mackerel
Few research papers have been published on the distribution and habitat of Pacific mackerel since the 2010 EFH review of this species.

- Although there is a general lack of survey-independent data to determine the full extent of the adult stock in Mexican waters, recent analyses of oceanographic and ichthyoplankton data have postulated the existence of two types of mackerel spawners: one group that prefers spawning in April at about 15.5°C in the Southern California Bight (SCB), and another group that spawns in August near Punta Eugenia at 20°C or greater. Note that in Amendment 8, Appendix D it was reported that larvae were mostly encountered at about 14°C.
- These recent papers also provide new information on the spatial distribution of larvae in spring (1951-2008), juvenile habitat, and adult habitat in spring, summer, and fall.

Northern Anchovy
Since 2010 many papers have been published, providing new and/or corroborating information on the distribution, habitat, and the functional role of this species in the CCE.

- Remotely sensed oceanographic data have been modeled to predict the seasonal location of the spawning stocks along the US Pacific coast, providing new ecological indicators for defining spawning habitats or predicting spawning patterns.
- New studies have also combined satellite and survey data to predict potential shifts in this species' habitat range due to climate change.
- Patterns in the distribution of anchovy life stages and their association with major oceanographic features and regime shifts are also better understood.

Jack Mackerel
Relatively little research has been conducted on jack mackerel, but the literature review found some information that may help better understand the distribution of this species, especially the dynamics under climate change, and its spawning habitats. The biomass of jack mackerel occurs mostly outside the US EEZ and although research surveys since 2000 document a significant increase from British Columbia to California, landings remain incidental to other CPS and groundfish fisheries. Within the CCE, jack mackerel consume ichthyoplankton and are not a major prey species for top predators.

Market Squid
Since 2010 several papers have been published, providing better insights on the spatial distribution and habitat use of this species during major oceanographic events such as El Niño and La Niña, and squid's functional role in the CCE.

- Recent genetic studies showed that the spawning groups in the SCB and Monterey Bay might not be genetically homogenous, as market squid seemed to exhibit more complex population structure, with the existence of genetically different micro cohorts that spawned off California.
- Recent publications provide new data on the distribution and abundance of life stages and their association with major oceanographic features and ranges of physical ocean conditions.

Euphausia pacifica and Thysanoessa spinifera
The essential fish habitat of krill was added to the CPS FMP in 2009; the distribution and habitat of these species were first described in Amendment 12. Since then an abundance of scientific papers have been published on these species. As the most dominant euphausiid species in shelf waters, *T. spinifera* is mostly distributed along the eastern Pacific coast from the Bering Sea to central California, although it does occur off Baja California between Ensenada and Punta Eugenia. *E. pacifica* is an oceanic species that is most abundant along and seaward of the continental shelf break.

- New studies have elucidated the mechanisms that control the formation of significant aggregations and how essential krill species habitats could be resolved by using seasonal upwelling and oceanic models. As a forage species, *T. spinifera* are preyed upon by marine mammals, birds, and fishes that interact with its spatial aggregations on the shelf. *E. pacifica* aggregations have been found in the vicinity of marine canyons and this association between krill and canyon has been proposed as a potential "hotspot network'' that could enhance foraging opportunities for marine predators.

Review of components required to be in the FMP
Federal EFH regulations describe 10 areas to be addressed in FMPs (50 CFR 600.815(a)). As part of the Phase 1 process, the CPSMT examined the CPS FMP, including appendices, and the CPS SAFE to determine whether all the required components were adequately addressed. EFH for CPS is described in Amendment 8, Appendix D "Description and Identification of Essential Fish Habitat for the Coastal Pelagic Species Fishery Management Plan." For the purposes of EFH, the four CPS finfish species and market squid have been treated as a complex given their similar life histories and habitat requirements. Krill EFH is described in Amendment 17 and Amendment 12, and not Appendix D. This organization reflects that krill were not brought under Council management until Amendment 12 in 2009.

The CPSMT found the information presented in the FMP, its appendices, and/or the SAFE is largely sufficient for most components. The habitats and geographic extent of habitats that comprise EFH for CPS with the possible exception of market squid are clearly identified. Potential adverse effects from fishing are documented, and the FMP's suite of harvest control rules, the management measures that can be implemented under the point-of-concern framework, and the prohibition of fishing for krill all function "to minimize to the extent practicable adverse effects from fishing on EFH (50 CFR 600.815(a)(2)(ii) and "encourage the conservation and enhancement of EFH" (50 CFR 600.815(a)(6)). The CPSMT notes, however, that coverage of EFH provisions in the FMP generally would benefit from organizational improvements (currently provisions are spread across amendments and appendices) and further content review and updates as described below.

Appendix D includes maps depicting EFH boundaries. Because EFH for CPS is temperature based, the boundaries were mapped using seasonal summer (July-September) and winter (January-March) average sea surface temperatures from the warmest and coldest years spanning from 1950 to 1995. The maps as drawn use warm winter data from 1958, 1981, and 1983; cold winter data from 1950, 1971, and 1972; warm summer data from 1983, 1990, and 1992; and cold summer data from 1950, 1952, and 1955. Undertaking a mapping exercise with either an expanded or contemporary temperature time series could be useful to illustrate isotherm shifts. Even if the data remain unchanged, updating these maps with the more sophisticated software available today should be considered.

FMPs are to describe each fishing activity and provide conclusions as to whether or how each adversely affects EFH. Appendix D of the CPS FMP contains fishery descriptions, but these are outdated. CPS fisheries are dynamic and older descriptions may misrepresent (i.e., overstate) potential adverse effects on EFH. For example, the fishery description for northern anchovy references the reduction fishery which no longer exists. Similarly, a more contemporary description of the Pacific sardine fishery would be able to capture the dynamics of the fishery since 2000, including the closure of the primary directed fishery in 2015 due to low biomass. Further it isn't clear that fishing activities not managed under the Magnuson-Stevens Act (MSA), i.e., state or tribal fisheries, that may adversely affect CPS EFH have been fully identified and addressed.

Non-fishing activities that may adversely affect EFH must be addressed in FMPs as well. Appendix D addresses a range of non-fishing activities that may impact CPS finfish and squid EFH, however, non-fishing impacts specific to krill were not included in Amendment 12. The range of non-fishing activities appears to be reasonably comprehensive but could be updated to account for potential effects from renewable energy projects.

CPSMT Recommendation on need for Phase 2

Under this agenda item, the Council is to decide whether there is sufficient new information to warrant proceeding with Phase 2. If the Council chooses not to take action, the EFH review process will conclude at the April 2021 meeting. Alternatively, should the Council decide to proceed, the next step would be to adopt a process and schedule for Phase 2. Per COP 22 each phase of the EFH review has a separate scoping process and set of objectives.

The CPSMT **recommends** the Council advance this EFH review to Phase 2. In combination, the literature review and examination of the required components support the current CPS finfish and krill EFH spatial boundary designations. The body of literature reviewed indicates these remain consistent with the best available science, but there is substantial new literature that can be incorporated to improve the EFH provisions in the FMP and substantial new information about market squid life history and habitat use. In addition, fishing and non-fishing effects on CPS EFH, and mapping as noted above could be updated. Finally, more robust and contemporary descriptions of fisheries and non-fishing activities may be particularly beneficial in light of the potential new ocean uses.

The CPSMT anticipates providing additional input to help inform ideas for a Phase 2 process and schedule for Council consideration at the April meeting. In the meantime, the CPSMT offers the following tasks to facilitate the consideration of the scope and objectives that the Council might want to include in the second phase.

a. Consider and incorporate changes proposed in the literature review (see attached report).
b. Consider alternative approaches for treating species: maintain the current finfish and squid complex, separate squid from finfish, or use a species- specific approach; and evaluate scientific literature to determine if/how species habitat boundaries and other information could be refined accordingly.
c. Analyze and address gaps noted in required component review, e.g., lack of non-fishing activity impacts on krill descriptions, lack of non-MSA managed fishery effects.
d. Revise/update fishery descriptive language in EFH section.
e. Evaluate need to update time series and information used to inform maps and produce new maps.
f. The current CPS FMP does not include appendices. This task would create an appendix for EFH and add it to the FMP to consolidate information currently found in Amendment 12 for krill and Appendix D of Amendment 8 for the other species.
g. Update bibliography to ensure that EFH information is current and to advance the level of data used to describe the life histories, habitats, habitat utilizations, etc., to the extent possible for each species.

Attachment:

Coastal Pelagic Species Essential Fish Habitat Phase I Literature Review Report

By

Emmanis Dorval

Lynker Technologies LLC,
Under contract with Southwest Fisheries Science Center

Submitted to the Coastal Pelagic Species Management Team

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Background

The Magnuson-Stevens Act (MSA) requires fishery management plans (FMPs) to describe, identify, and protect essential fish habitat (EFH) for each species in the FMP's fishery management unit (FMU). Federal regulatory guidance at 50 CFR §600.805 provides further requirements to identify adverse impacts from fishing and non-fishing activities, to recommend conservation measures, to consider habitat areas of particular concern (HAPC), and to address other EFH components. These EFH components should be reviewed and updated at least every five years. EFH for Coastal Pelagic Species (CPS) was incorporated in the CPS FMP in 1998 [1, Appendix D]. CPS EFH components were reviewed in 2010 and it was determined that no modifications were warranted at that time. Council Operating Procedure 22 provides guidance on developing the process, scope, and personnel to carry out EFH periodic reviews.

EFH reviews are typically divided into two phases. The first phase is focused on new information related to species biology, migration, prey, habitat needs, distribution, and human activities that may adversely affect EFH. If the Council concludes that revisions to the existing EFH provisions are not warranted, the review is concluded. However, should the Council determine that new information warrants changes to the current EFH provisions, the Council may embark on a second phase, during which specific changes to EFH provisions are developed for Council, Advisory Body, and public consideration.

Objectives

The overarching objectives for all EFH reviews are to ensure that the EFH provisions in the Council's FMPs are consistent with the best scientific information available, and to ensure a transparent and efficient science-based process for review of new information and consideration of any potential changes to EFH provisions.

The specific objectives of Phase 1 of the CPS EFH review are 1) to evaluate published and unpublished scientific literature and reports, information from interested parties, and previously unavailable or inaccessible data, and 2) to make a recommendation to the Council as to whether the body of new information warrants consideration of changes to EFH provisions. As part of Phase 1, the Council may issue a call for information to support the review, which was issued by the Pacific Council in October 2020.

Scope

Federal EFH regulations describe required elements to be included in FMPs. These include identification and description of EFH, fishing and non-fishing activities that may adversely affect EFH. This report focuses on (1) reviewing scientific publications or other information that can support or improve the elements of CPS EFH. These include identification and description, fishing and non-fishing activities that may adversely affect CPS EFH, and several other provisions described at 50 CFR §600.805.

Target Species

In this report we summarize and list published and unpublished research papers and reports that provide information on the distribution and habitat of: (1) the five main exploited CPS, namely Pacific sardine, Pacific mackerel, jack mackerel, northern anchovy, and market squid; and (2) the two most abundant krill species (*Euphasia pacifica* and *Thysanoessa spinifera*) that occur in the California Current Ecosystem (CCE) (Table 1). Although six other krill species (*E. eximia, E. gibboides, E. recurva Nematocelis difficilis, Nyctiphanes simplex*) are managed under the CPS-FMP these species are not well represented in most surveys conducted in US waters, making it difficult for scientists to make adequate inference on their population dynamics. For example, over a 16-year time series data of *all euphausiids* collected off Oregon, *E. pacifica* and *T. spinifera* represented 82.5% and 15.3% of the samples, respectively [2]. So, few US-based studies have been published on these species, *i.e.* compared to *Euphasia pacifica and Thysanoessa spinifera*. Because *T. spinifera* is the only euphausiid species that commonly occurs in shallow waters of < 150 m [3], and because the widespread distribution of *E Pacifica* in subartic waters, this report assumed that *E. pacifica* distribution and habitat would overlap with the habitats of the other 6 krill species in US waters. Thus, protecting essential habitat of *E. pacifica and T. spinifera* would likely protect the habitats for the whole krill assemblage under the CPS-FMP.

Description and Identification of CPS EFH

Essential fish habitats of CPS were first described in 1998 and were generally based on Level 1 information (i.e. presence/absence data, as described in the federal EFH regulations) and upon a thermal range within the broader geographic area in which CPS stocks occur. CPS EFH was linked to ocean temperatures, which shift temporally and spatially, providing a dynamic description of CPS EFH [1, 4]. This description is as follows:

> *The east-west geographic boundary of EFH for each individual CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the exclusive economic zone (EEZ) and above the thermocline where sea surface temperatures range between 10^0C to 26^0C. The southern boundary of the geographic range of all CPS finfish is consistently south of the US-Mexico border, indicating a consistency in SSTs below 26^0C, the upper thermal tolerance of CPS finfish. Therefore, the southern extent of EFH for CPS finfish is the US-Mexico maritime boundary. The northern boundary of the range of CPS finfish is more dynamic and variable due to the seasonal cooling of the SST. The northern EFH boundary is, therefore, the position of the 10^0C isotherm which varies both seasonally and annually.*

Methods

The last review on CPS EFH was conducted in 2010, and the CPSMT generally reviewed "*information contained in several recent publications (i.e. from 1998 to 2010) relevant to CPS; and concluded that "the new information continues to support the strong linkage between CPS distribution and sea surface temperature, which varies spatially and temporally, and thus does not present any significant change in existing documented habitat associations."* A summary of the 2010 EFH review is included in PFMC (2020).

Given time constraint, this Phase I literature review assumed that the 2010 CPS EFH review was exhaustive, and hence there was no need for additional review of most papers published on CPS finfish and market squid prior to 2010. Likewise, this report focused on reviewing papers that were published during the 2010-2020 period for the four finfish species and market squid. However, because the Krill EFH was described in Amendment 12 of the CPS FMP in 2008, and because the CPSMT has not yet conducted extensive "*investigation in reviewing information on which EFH designations for krill are based*," this Phase I review was expanded to include papers published on the krill assemblage prior to and after the 2010 review. For each species included in this review, this report provides a list of publications (categorized by type of papers) and a short summary of the most important information and data that these papers may contain on the distribution and habitat of this species, and on the environmental factors that may affect its spatial distribution and aggregation over time.

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Pacific Sardine

Many papers have been published on the distribution and habitat use of Pacific sardine since the 2010 EFH review of this species (Table 1). While the geographic boundaries of the distribution of Pacific sardine have not significantly changed, analysis of fishery-independent and fishery-dependent survey data collected since the 2000s provided new insights on this species habitat use as related to its growth dynamics, ontogenetic distribution, spawning dynamics, and stock structure along the US Pacific coast [1-48]. New papers have improved our understanding of the seasonal migration of Pacific sardine, particularly during their northward summer-fall feeding migration and southward winter-spring spawning migration [1-10]. Hypotheses on sardine stock structure are more refined, strongly supporting the existence of 3 stocks from Mexico to Canada, i.e. cold, temperate, and warm stocks [3-5]. Thus, recent data do not show any evidence of a fourth "far northern stock" as postulated by some previous authors. The cold stock, also known as the northern subpopulation, is the only stock managed by PFMC, but for the purposes of this review, EFH are described for all populations that occur in US waters. Recent papers have also provided a new understanding of the spatio-temporal distribution of length-at-age, showing that Pacific sardine migration may be age-dependent, and that this species may start migrating earlier to northern feeding areas than previously thought [10-16]. New data also indicate that the location of spawning habitats shows more complex dynamics have evolved over time. During low abundance in the 1960-1980s the adult spawning stock was mostly located off southern California and Ensenada, but since 2015 most of this spawning stock has been located off northern California and Southern Oregon [2]. As a result, the temporal distribution of larvae has changed with much earlier occurrence of this life stage in the Northern California Current Ecosystem (NCCE) [e.g. 10]. Patterns in the nearshore and offshore distribution of sardine eggs and larvae and their association with major oceanographic features, such as El Niño events and the Pacific Decadal Oscillation (PDO) are also better understood [17-30]. Beyond temperature, data collected remotely (via satellite) on chlorophyll, salinity, and dynamic heights have been used to predict the seasonal location of the spawning stock along the US Pacific coast and to define new ecological indicators of spawning of this species [17-30]. New models have combined satellite and survey data, allowing the prediction of seasonal habitats of Pacific sardine [25, 29, 30] and potential shift in this species' habitat due to climate change [33]. Paleo-markers, and biological and geochemical proxies have been developed to retrospectively infer the habitat use of sardine and/or the fluctuation of its population over millennia [38-48]. Long time series of sardine predator diets provide new information to identify critical habitats for marine mammals, fish, and birds [49-56], while allowing impact assessment of sardine abundance on its predators and the overall CCE using new ecosystem models [31-34]. Following its natural cycle, the northern stock of sardine is now at its lowest abundance since 2009. Hence, in 2020 the fishery was declared overfished by PFMC, and accordingly a rebuilding plan is being developed.

Potential changes: update Appendix D, SAFE and associated management documents:

- To remove obsolete references and information
- To account for new published data, and to create better maps to delineate sardine spawning habitat, egg, larval and juvenile habitat within the geographic boundaries of this species.

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Pacific Mackerel

Few research papers have been published on the distribution and habitat of Pacific mackerel since the 2010 EFH review of this species (Table 1). Survey data suggest that the distribution of the Pacific mackerel off US and Canada remains within expected geographic boundaries observed from historical studies. Nevertheless, recent published papers have documented the distribution of the northwest stock in US coastal waters, particularly when most of this population was located off the US in summer and fall [1-4]. Although there is a general lack of survey-independent data to determine the full extent of the adult stock off Mexican waters, recent analyses of oceanographic and ichthyoplankton data have postulated the existence of two types of mackerel spawners: one group that prefers spawning in April at about 15.5°C in the Southern California Bight (SCB), and another group that spawns in August near Punta Eugenia at 20°C or greater [8]. Note that in Appendix D it was reported that larvae were mostly encountered at about 14°C. These recent papers also provide new information on the spatial distribution of larvae in spring (1951-2008), juvenile habitat, and adult habitat in spring, summer, and fall. Although based on a period of low biomass and low harvest [post 2008], ecosystem modeling has revealed that fishing mackerels may have little impact on the CCE [11]. Indeed, compared to other pelagic species, abundance of mackerel in some surveyed areas and offshore banks were relatively low throughout the past decade [1].

Potential changes:

- Update information regarding temperature at peak spawning in the spring in the SCB.
- Update information regarding the distribution of the spring spawning habitat in the SCB.

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Survey data/Biological and physical oceanography

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Survey data/Statistical & Ecosystem modeling

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Survey data/Pacific mackerel as prey

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Jack mackerel

The jack mackerel remains one of the least studied CPS species in US waters, and thus there are limited publications on this species (Table 1). However, starting in the 2000s survey research has documented the distribution of this species in coastal waters from British Columbia to San Diego [1, 5-7]. Biomass of this species occurs mostly offshore and outside of the US EEZ [3, 4], although in recent years survey research has reported a significant increase in the abundance of this species from British Columbia, Canada to California [5-7]. New published papers contain data that can be used to enhance our understanding of the distribution and habitats that jack mackerel occupy in spring and summer along the US Pacific coast [1, 5-7]. Data collected on jack mackerel from 2007-2020 have been used to map the quality of this species' habitat along the US west coast during this period. Based on these data, the thermal habitat of jack mackerel has been projected to shift by more than 1300 km northward by the end of this century in 2081–2100, as this species expands into Alaska and eastern Bering Sea under climate change [13]. Dynamic height has been identified as a potential physical parameter that can be used to identify jack mackerel spawning habitats [8]. As an ichthyoplankton predator jack mackerel seems to prefer feeding shoreward of fronts [11], but as a prey this species contributes little, i.e. compared to other pelagic species, to the maintenance of top marine predators in CCE [14-17]. Likewise, the abundance of jack mackerel has been assessed to have little impact on this ecosystem [12].

Potential changes:

- Update the geographic distribution and habitat quality of jack mackerel along the US Pacific coast, based on new available data.

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Survey data/Biological and physical oceanography, feeding ecology

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Survey data/ Jack mackerel as prey

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Northern Anchovy

As one of the most important forage species in the CCE, northern anchovy continued to be one of the most studied species in this ecosystem. Since 2010 many papers have been published, providing new and/or corroborated information on the distribution, habitat, and the functional role of this species in the CCE (Table 1). Managed in the CPS FMP as a monitored species (i.e., not subject to frequent harvest specification adjustments), northern anchovy has not been assessed since 1995 and as a result no published papers have revisited hypotheses regarding its stock structure along the North American Pacific coast. Hence, northern anchovy is still assumed to be structured in 3 subpopulations along this coast: northern, central, and southern northern. (Of the three, only the northern and central subpopulations are managed under the CPS FMP.) Based on survey data collected since 2000s, the geographic boundaries of the distribution of the northern subpopulation (located north of Cape Mendocino) and central subpopulation (located south of Cape Mendocino to Ensenada) does not appear to have significantly changed [1-8]. Spring spawning of the central subpopulation, for example, generally occurs at the same temperature range and locations as observed in the 1980s in the SCB [1]. However, remotely sensed oceanographic data have been modeled to predict the seasonal location of the spawning stock along the US Pacific coast, providing new ecological indicators for defining spawning habitats or predicting spawning patterns [19, 25]. New studies have also combined satellite and survey data to predict potential shift in this species' habitat range due to climate change [66]. Patterns in the distribution of anchovy life stages and their association with major oceanographic features and regime shifts are also better understood [9-25]. Genetics studies have been used to study the evolutionary history of this species coast-wide [26, 27, 31]; whereas paleo-markers, and biological and geochemical proxies have been also developed to retrospectively infer the habitat use of northern anchovy and/or the fluctuation of its population over past millennia [28-36]. Recent research has particularly focused on determining the trophic interactions of northern anchovy within the CEE food web, and on quantifying the impact of its abundance on population sizes and the temporal variability in the habitat range of top marine predators [36-66]. Various indices have been developed to assess the value of anchovy in the diets of marine predators toward elucidating the most important factors that control foraging habitats of fish [35, 40, 45, 51, 52, 56, 61], birds [41, 42, 44, 54, 55, 60, 62, 63], and mammals [49, 58, 59], which ultimately determine their population size and productivity. Potential interactions of the abundance of some species with anchovy biomass have been also assessed [47, 65, 66]. As a result, time series of anchovy predator diets are available, which could be used to pinpoint the most critical foraging habitats for marine fish, birds, and mammals. These time series have been used in ecosystem models for evaluating the impact of forage species abundance on the CEE [64, 65]. After a low period of abundance during the 2009-2015 period [4], the central subpopulation has rebounded in the most recent years [1, 6, 9].

Potential changes:

- Update Append D and SAFE to better identify anchovy distribution and major aggregations or hotspots.
- Update old maps to better delineate anchovy spawning, juvenile and adult habitats.

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Survey data/Statistical & Ecosystem modeling

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Market Squid

Market squid is currently the most valuable commercial CPS in California and Oregon. However, compared to other CPS such as sardine and anchovy, fewer studies have been conducted on the distribution and habitat of this species (Table 1). Based on PFMC recommendations, significant research effort has been made to increase knowledge on recruitment, growth and spawning dynamics, stock productivity and habitat use, and their relationship with oceanographic conditions. As a result, since 2010 several papers have been published, providing better insights on the spatial distribution and habitat use of this species during major oceanographic events such as El Niño and La Niña, and its functional role in the CCE [1-27]. In general, the geographic boundaries of the population remain similar to historical ranges (Southeast Alaska to the tip of Baja California). Squid spawning habitats are centered off California in shallow sandy bottoms (< 70m), where spawning peaks in the SCB during La Niña years and in Monterey Bay during El Niño years. However, recent genetic studies showed that these spawning groups might not be genetically homogenous, as market squid seemed to exhibit more complex population structure, with the existence of genetically different micro cohorts that spawned off California [15]. Recent publications also provide new data to refine the distribution of egg beds, paralarvae in nearshore and offshore waters, and juveniles on the continental shelf [5-7, 11-15]. Patterns in the abundance and distribution of these life stages and their association with major oceanographic features are also better understood [8, 9, 11-15]. Improved data are available on the ranges of depth, temperature, salinity, pH, and DO that this species can tolerate, allowing better characterization of essential habitats of egg capsules/embryos [5, 9,18], paralarvae [8, 11, 14,15], juveniles [4,13], and adult spawners [1, 15]. The distribution of juvenile habitat on the continental shelf is also better known from long time series of survey data [13]. A recent study of market squid population found that northward spatial shifts in the market population were primarily influenced by marine heat waves [28]. Recent research has also studied the trophic interactions of market squid in the CEE food web, while quantifying the impact of its abundance on the population size and temporal variability in the habitat range of top marine predators [10-27, 29]. These data have been used in species distribution models to predict habitat suitability for major marine predators such as sea lions off California [22].

Potential changes: update Appendix D and associated documents to:

- Better identify essential spawning and egg beds habitats; and market squid aggregations or hotpots to inform distribution and potentially HAPCs.
- Update data on environmental parameters to better characterize habitat quality for market squid life stages.

Reference

Survey data/biomass &Catch/Egg bed

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Survey data/ Market squid as prey

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Survey data/Statistical & Ecosystem modeling

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Survey data/Fishing effects

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Euphausia pacifica

As the essential fish habitat of krill was established in 2008, the description of the distribution and habitat of *E. pacifica* in the CPS-FMP and SAFE documents has not yet fully reflected the abundance of scientific papers that have been published on this species (Table 1). *E. pacifica* is one of the most important and critical forage CPS that sustains the health of the CCE, and accordingly it has been categorized as a prohibited species in the CPS-FMP. Direct harvests are not allowed on its population, and thus most of the published data on this species were collected from fishery-independent surveys. Accordingly, published papers have primarily focused on improving the understanding of the environmental factors that regulate the distribution and habitat range of *E. pacifica* and its functional role as the dominant euphausiid in the CCE food-web [1-63]. *E. pacifica* is an oceanic species that is most abundant along and seaward of the continental shelf break [1-11]. This species is broadly distributed over the subarctic Pacific Ocean and seas [1]. Across its most preferred habitats *E. pacifica* are distributed by body size, and these spatial ontogenetic patterns and associated biomass are regulated by oceanographic processes, climate forcing [6,7, 9, 13, 18, 20, 27], and the presence of predators [53-58]. Hence, temporal shifts in the location *E. pacifica* habitats have been reported to be determined by inter-annual variability in oceanic conditions under the influence of atmospheric forcing such as ENSO and PDO [27, 31, 33, 34, 35, 36, 49, 51]. A recent study has also provided fine scale spatial data regarding the physical characteristics of *E. pacifica* habitats in the SCB [36]. Despite the spatiotemporal dynamics of *E. pacific,* new studies have elucidated the mechanisms that control the formation of *E. pacifica* hotspots and how essential krill species habitats could be resolved by using seasonal upwelling and oceanic models [28, 32, 39, 40, 59, 60, 62, 63]. Recent modeling research has shown that *E. pacifica* hotpots coincided with hotpots of various species of marine mammal, birds, and fishes [40, 62]. For example, krill hotpots have been found in the vicinity of marine canyons and this association between krill (dominated by *E. pacifica*) and canyon has been proposed as a potential "hotspot network'' that could enhance foraging opportunities for marine predators [40]. Risk assessments have shown that the depletion of euphasiids and forage species in the CEE could lead to dramatic declines in the abundance of top marine predators, and in particular of commercial fishes [61]. Data from these recent studies underscore the critical role that *E. pacifica* and the krill assemblage plays in the maintenance of the CCE.

Potential changes:

- Update Append D, CPS SAFE and associated management documents to better describe and identify *E. pacifica* hotspots, and better characterize krill essential habitats based on current available data and information.

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Thysanoessa spinifera

Similar to *E. pacifica*, the description of the distribution and habitat of *T. spinifera* in the CPS-FMP and SAFE documents have not yet captured the wealth of scientific papers that have been published on this species (Table 1). Like all other krills in the CPS assemblage *T. spinifera* is a prohibited ecosystem species in the CPS-FMP, as it plays a critical role in maintaining the CEE. Hence, fishery-independent surveys have been the primary means for collecting data, with preys captured from nesting birds being a major source of data to study the population dynamics of *T. spinifera* [1-57]. As the most dominant euphausiid species in shelf waters, *T. spinifera* is mostly distributed along the eastern Pacific coast from the Bering Sea to central California, although it does occur off Baja California between Ensenada and Punta Eugenia [2-4, 11, 21, 26, 33]. Like *E. pacifica* ontogenetic patterns in the distribution of *T. spinifera* in coastal waters are influenced by oceanographic processes and climate forcing [5, 10, 21, 28, 34]. For example, off coastal Oregon, larvae and juveniles mainly occupy nearshore waters (>18 km from shoreline), whereas older stages are primarily distributed offshore (18-108 km from the shoreline) [3]. Such habitat segregation may shift across the shelf under the influence of atmospheric events such as ENSO and PDO. Indeed, a recent study [5] reported that *T. spinifera* were more abundant in nearshore habitats during cold years, but rare in these habitats during warm years. However, abundances in offshore waters were similar during cool and warm years [5]. Although local, new research has also provided fine scale spatial data regarding the physical characteristics of habitats of *T. spinifera* and other krill species during Niño and Niña years in the SCB [28]. As a forage species, *T. spinifera* are preyed upon by marine mammals, birds and fishes that interact with its spatial aggregations on the shelf [43-51]. Ecological factors that control the formation of these spatial aggregations or hotspots among *krill species* and their predators are now better understood, using seasonal upwelling and oceanic models [24, 25, 52, 55, 31-33, 56]. Recent studies have found good correlation between *T. spinifera* abundance, sea bird density and reproduction success [56], as well as between *T. spinifera* and volume of krill in the diet of fishes [51]. Risk assessments have also shown that the depletion of euphasiids and forage species in the CEE could lead to dramatic declines in the abundance of top marine predators, and in particular of commercial fishes [54]. Data from these recent studies underscore the critical role that *T. spinifera* and the krill assemblage play in maintaining the health of the CEE.

Potential changes:

- Update Appendix D, CPS SAFE and associated management documents to better describe and identify *T. spinifera* hotspots and essential habitats for the krill assemblage based on current available data.

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General summary

- Although spawning, juvenile, and adult habitats may have shifted under environmental conditions, most CPS are still distributed within their expected geographic boundaries.

- Since 2010, new information has been published on the characteristics of most CPS habitats. Beyond temperature new physical and biological parameters have been used to model and predict seasonal and/or interannual variations in the distribution of CPS habitats.

- Long time series of CPS predator' diets have been developed, allowing better identification of CPS hotspots and better assessment of the impact of the abundance of CPS on the maintenance of the CCE.

- Few recent papers have directly studied the impact of fishing activities on CPS habitats, and there was no new evidence of MSA fishing activities that may significantly impact CPS EFH. However, direct studies on fishing activity effects on CPS or other species' EFH may be warranted in the future.

- Finally, this report points out potential changes that may be needed to update Appendix D, CPS SAFE and associated management documents in order to better describe and identify CPS EFH.

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Table 1. Published and unpublished papers on coastal pelagic species in the California Current Ecosystems

Common name	Scientific name*	Period	Published/Unpublished Papers	Distribution & Habitat Identification Papers**
Pacific Sardine	***Sardinops sagax***	***2010-2020***	> 72	57
Northern Anchovy	***Engraulis mordax***		> 82	67
Pacific Mackerel	***Scomber japonicus***		>26	12
Jack Mackerel	***Thrachurs symetricus***		>40	17
Market Squid	***Doryteuthis opalescens***		>29	29
Krill	***Euphausia Pacifica*** ***Thysanoessa spinifera*** *Nyctiphanes simplex* *Nematocelis difficilis* *T. gregaria* *E. recurva* *E. gibboides* *E. eximia*	***Prior to 2021***	> 107	75

Note: *Bold scientific names indicate the primary target species of the EFH Review, whereas the names in italic indicate species whose habitats are assumed to overlap with E. *Pacifica* habitats.

** Papers that contain relevant information on the distribution and habitat of CPS