MANAGEMENT OF KRILL AS AN ESSENTIAL COMPONENT OF THE CALIFORNIA CURRENT ECOSYSTEM

AMENDMENT 12 TO THE COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN

ENVIRONMENTAL ASSESSMENT, REGULATORY IMPACT REVIEW & REGULATORY FLEXIBILITY ANALYSIS

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Environmental Assessment and Amendment 12 to the Coastal Pelagic Species Fishery Management Plan

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Abstract: The Pacific Fishery Management Council (Council) recommended, and NMFS approved, an amendment to the Coastal Pelagic Species Fishery Management Plan (CPS FMP) to ensure the preservation of a key trophic relationship between fished and unfished elements in the California Current ecosystem by protecting krill resources off the U. S. West Coast. The proposed action would implement Amendment 12 to the CPS FMP by issuing regulations proposed by NMFS that:

- Add krill to the management unit species of the CPS FMP
- Establish a "prohibited harvest species" category of management unit species in the CPS FMP
- Place all species of krill that occur in the EEZ off the U. S. West Coast in the "prohibited harvest species" category
- Designate essential fish habitat for krill
- Deny the use of the exempted fishing permit process under the CPS FMP to allow krill fishing

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1.0 INTRODUCTION

1.1 Summary

The Coastal Pelagic Species (CPS) fishery in the Exclusive Economic Zone (EEZ) off the U. S. West Coast (e.g., California, Oregon and Washington) is managed under the Coastal Pelagic Species Fishery Management Plan (CPS FMP), which was developed by the Pacific Fishery Management Council (Council) pursuant to the Magnuson-Stevens Fishery Conservation and Management Act (MSA). The CPS FMP was approved by the Secretary of Commerce and was implemented by regulations that can be found at 50 CFR Part 660, Subpart I.

The Council has expressed interest in and support for ecosystem-based fishery management programs that recognize the relationships between different components of the marine environment. Whether looking at management of multi-species fisheries or of fisheries for species that are both predators and prey, or at conservation of habitat that is essential for healthy fish stocks, the Council is attempting to incorporate ecosystem conservation principles into its management programs. This ecosystem-based approach was acknowledged by Congress when it reauthorized the MSA in 2006. Congress first noted that "A number of Fishery Management Councils have demonstrated significant progress in integrating ecosystem considerations in fisheries management under the existing authorities provided under this Act." (16 U.S.C. 1801(b)(11)). It also provided the Councils even more explicit authority to include management measures in any fishery management plan "to conserve target and non-target species and habitats, considering the variety of ecological factors affecting fishery populations." (16 U.S.C. 1853(b)(12)).

In this context, the Council and NOAA's National Marine Fisheries Service (NMFS) are interested in preserving key trophic relationships between fished and unfished elements of the food web in order to maintain the integrity of the ecosystem and to minimize the risk of irreversible adverse impacts on managed fish stocks and other living marine resources from adverse impacts. Euphausiids, commonly known as krill, serve as one of the most important channels for the movement of energy through the California Current ecosystem and function as a key forage resource for federally managed fishes including hake, rockfish and salmon (Field and Francis, 2006). Consequently, it is desirable and advantageous to the Council and NMFS' fishery management objectives to maintain krill stocks within the bounds of natural environmental variability to the extent practicable.

At its October 31, 2005 meeting, the Council agreed to complete for public review and comment a draft CPS FMP amendment to conserve and manage krill resources. The Council subsequently took public comment and recommended the conservation and management measures for krill with Amendment 12 to the CPS FMP. NMFS approved the amendment on May 25, 2007. This combined FMP Amendment and environmental assessment (EA), which is proposed to achieve the goal of the Council, supports NMFS proposed rule to implement the amendment.

Summary of Environmental Impacts of the Proposed Action

The proposed action, if implemented, is expected to have the following impacts:

Krill stocks would remain at levels associated with prevailing environmental conditions and within the bounds of natural environmental variability.

Species of fish that are dependent on or sensitive to the abundance and availability of krill would be sustained to the extent that natural populations of krill support such species.

Species of other animals (marine mammals, seabirds) that are dependent on or sensitive to the abundance and availability of krill would be sustained to the extent that natural populations of krill support such species.

Fisheries for species that are dependent on or that are sensitive to the abundance and availability of krill in the natural environment would be protected from any adverse effects that krill fishing might have on krill and associated and dependent species.

Fishermen would not be adversely affected because there is now no fishing for krill off the U.S. West Coast. However, the potential future benefits of krill fishing would be precluded as long as the prohibition of harvest remains in place.

Eco-tourism businesses (e.g., whale watching cruise providers) that serve non-consumptive users for a fee would be protected from any harm that krill harvest might have on the living marine resources which those users enjoy viewing.

2.0 PROPOSED ACTION

The proposed action would implement Amendment 12 to the CPS FMP by issuing regulations intended to preserve key trophic relationships by managing all species of krill off the U.S. West Coast (e.g., California, Oregon and Washington). Amendment 12 adds all species of krill as a management unit species under the CPS FMP and places krill under a newly established "prohibited harvest species" category. This new category differs from the existing "prohibited species" definition in the FMP because “prohibited harvest species” may not be taken by any fishery or gear type in the U.S. EEZ. In contrast, “prohibited species” may not be taken and retained incidentally by CPS fishery participants, but are legally harvested under provisions in Federal regulations implementing other Pacific Fishery Management Council (Council) FMPs. The intent of this action is to preserve integral ecological processes in the flow of energy between unfished and fished components of the California Current ecosystem by implementing a management strategy that is more robust to environmental and ecological variability and change. Specifically, the proposed action would implement Amendment 12 to the CPS FMP as follows:

- **Add krill (all species) to the management unit species under the CPS FMP**

The Council has initially determined that the CPS FMP is the appropriate mechanism for preserving krill resources. The CPS FMP embodies the principle of protecting key forage stocks; for stocks with harvest limits, harvest is only permitted after the spawning biomass is above a minimal level necessary to ensure stock sustainability and meet the forage needs of associated species. The CPS FMP is a coastwide fishery management program and will have effect throughout the U.S. West Coast EEZ for all fishery interests.

- **Establish a “prohibited harvest” species category for management unit species, place krill in that category, and thus prohibit the harvest of krill**

The CPS FMP currently has two categories of management unit species: managed and monitored. Managed stocks are subject to annual harvest guidelines, with the level of harvest tied to the size of the spawning biomass. Monitored stocks are stocks for which harvests are not bound by harvest guidelines. Fisheries for these stocks are very small, not at levels which threaten the stocks or any species that rely on those stocks in a significant way. The Council’s Amendment 12 adds a third category: “prohibited harvest species” and places krill in that category. This means that the harvest of krill would be prohibited in the U.S. West Coast EEZ. This will ensure that, to the extent practicable, fisheries will not develop that could put krill stocks and other living marine resources that depend on krill at risk. Krill abundance and availability will be driven by natural environmental conditions only, which are known to fluctuate considerably over time.

This new category is different from the existing “prohibited species” designation which is given to species (e.g., salmon, trout, and halibut) which may not be taken and retained incidentally by CPS fishery participants, but which are subject to fishery controls under other Federal regulations.

- **Designate essential fish habitat**

Section 3.3 presents the proposed designations and the rationale for them.

- **Deny the availability of the EFP process for krill fishing in the regulations implementing the CPS FMP**

EFPs are generally available in fisheries to provide authority to fish in a manner that would otherwise be prohibited by Federal fishery management regulations. The Council has considerable experience in reviewing and recommending action on EFPs in its managed fisheries. The CPS FMP currently contains procedures under which the Council would review and recommend approval (with such conditions that the Council would conclude are necessary) or disapproval of EFP applications. Under this FMP amendment, that procedure would not be available to persons who want to engage in fishing for krill. The intent of this proposal is to discourage prospective applicants by clearly indicating that the Council has no interest (at least at this time) in considering applications for EFPs. In the Council's experience, EFPs have been used to develop and test new fishery procedures or gear that might result in lower bycatch or lower rates/numbers of interactions with protected species. Because the Council is proposing to prohibit a fishery targeting krill, the Council sees no merit in currently allowing experimental fishing for krill. This would not affect legitimate fishery research by government or academia to better understand the characteristics and population dynamics of krill and the relationship of krill to other ecosystem resources.

- **Optimum Yield**

After considering all the above information, including the major and critical uncertainties associated with the productivity of krill, its sensitivity to environmental conditions, and its importance to the ecosystem off the West Coast, the optimum yield (OY) for krill is proposed to be set at zero (0).

The MSA requires OY to be set at the level of fish that "will provide the greatest overall benefit to the nation particularly with respect to food production, recreational opportunities, and taking into account the protection of marine ecosystems (16 U.S.C. 1802(33). Further, the determination of OY should take into consideration the following principles found at 50 CFR 600.310 (f)(2):

> *(2) Values in determination. In determining the greatest benefit to the Nation, these values that should be weighed are food production, recreational opportunities, and protection afforded to marine ecosystems. They should receive serious attention when considering the economic, social, or ecological factors used in reducing MSY to obtain OY.*
>
> *(i) The benefits of food production are derived from providing seafood to consumers,*

> *maintaining an economically viable fishery together with its attendant contributions to the national, regional, and local economies, and utilizing the capacity of the Nation's fishery resources to meet nutritional needs.*
>
> *(ii) The benefits of recreational opportunities reflect the quality of both the recreational fishing experience and non-consumptive fishery uses such as ecotourism, fish watching, and recreational diving, and the contribution of recreational fishing to the national, regional, and local economies and food supplies.*
>
> *(iii) The benefits of protection afforded to marine ecosystems are those resulting from maintaining viable populations (including those of unexploited species), maintaining evolutionary and ecological processes (e.g., disturbance regimes, hydrological processes, and nutrient cycles), maintaining the evolutionary potential of species and ecosystems, and accommodating human use.*

This rule sets the OY for krill, based on the above factors and in particular (b)(iii) regarding the benefits of protection for marine ecosystems, in order to preserve the existing OY in the fisheries that depend on krill as an important food source. The greatest benefit to the Nation is achieved by preserving the benefits to the economy of the existing fisheries. The potential benefits from development of a krill fishery are outweighed by the value of krill in the natural environment as forage for fish and other living marine resources. If at some time in the future there is new information that demonstrates that a krill fishery can be prosecuted at some level with an acceptable level of risk, the Council will consider amending its position.

2.1 Purpose and Need

There are several species of krill in the EEZ off the U. S. West Coast (see Chapter 3 for a full discussion). Krill are a critical component of the ecosystem off the West Coast. They are a principal food source for many fish species that are subject to management under Council fishery management plans, including several overfished groundfish species, salmon, and hake or whiting (Field and Francis, 2006). They are also a principal food source for many non-fish species, including baleen whales and some species of seabirds (see sections 3.2). Some of these species are listed as threatened or endangered and warrant special efforts for protection and recovery.

At this time, while there is no krill fishery, there also are no Federal regulations that provide protection to krill in the EEZ. The States of Washington, Oregon, and California prohibit their vessels from fishing for krill, and prohibit landings of krill into West Coast ports. However, these prohibitions would not prevent a vessel from another state from engaging in krill fishing and delivering the product to a port in another area or processing at sea. As is discussed in section 3.4 and 3.6, there are fisheries for krill and krill products in Japan, Canada and the Antarctic, and there is a potential for development of a fishery off the West Coast. Also, krill fisheries in certain areas such as the Antarctic have been conducted by large-scale harvester/processor vessels that process their catch at sea, and such vessels would not have to depend on West Coast ports to handle their products. International markets exist for krill and krill products, and while foreign fishing in the EEZ is currently not authorized, it may be that this market could or would be met by a West Coast krill fishery. Sources of information on the market for krill products show that the market for krill and krill products appears to be on the verge of major growth. New fishing and processing techniques have recently been introduced that coincide with the escalating demand for krill, particularly in the aquaculture and pharmaceutical industries and as a source of food additives. Krill oils are currently the subject of expanding markets in the nutraceutical, cosmetic and pharmaceutical industries. This growth in demand is currently being met by significant investments in the harvest capacity of existing fisheries. For example, a Norwegian company that fishes for krill in the Southern Ocean recently invested $100 million in the purchase and rebuilding of a factory trawler previously used to harvest hake to allow it to harvest krill in the Southern Ocean at levels previously unattainable. Also, as reported at the Convention on the Conservation of Antarctic Marine Living Resources annual meeting in October 2007, seven Dutch-owned pair trawlers, along with vessels from another seven countries are planning to enter the Antarctic krill fishery as well in an attempt to capitalize on the growing industry. Such trends may indicate further fishery development in unexploited locations in other parts of the world.

The Council and NMFS have considered the potential for development of a krill fishery off the West Coast and the potentially drastic effects a fishery could have on the fish and other species, including species listed under the Endangered Species Act (ESA), that are dependent on or that are sensitive to the abundance and availability of krill (see section 3.2 and Appendix B). Disruption of the vital trophic linkage between krill and other fish and non-fish stocks that rely on krill could adversely affect the consumptive and non-consumptive benefits currently derived from these other resources. Therefore, NMFS proposes to issue draft regulations to protect existing Federal fisheries, protected species, marine mammals and birds that depend on krill. This is intended to ensure the long-term health and productivity of the ecosystem off the West Coast by protecting, to the extent practicable, a unique primary building block of that ecosystem.

2.2 Management Issues

2.2.1 Krill Conservation

The first and foremost issue is the preservation of key trophic relationships between fished and unfished elements in the California Current ecosystem. Protecting krill resources off the West Coast will help to ensure that their stocks are not reduced to levels that might place other living marine resources that depend on krill at risk. As Chapter 3 indicates krill stocks can vary greatly both between and within years; with krill exhibiting extremes in both abundance and distribution patterns depending on seasonal, annual, or multi-annual oceanographic conditions and regimes. While certain conditions can lead to an abundance of krill, others lead to numbers so low that ecosystem needs are not meet. In 2005, oceanographic conditions in central California were reminiscent of the physical and biological changes that occur during El Nino events. Under these circumstances, there were massive die offs of several species of seabirds and the complete reproductive failure of Cassin's auklets on California's Farallon Islands which appeared to be in response to the reduced krill biomass north of Point Conception occurring at the same time.

Reduced abundances of commercially important fish stocks, including "young of the year" rockfishes and salmon, which similarly depend on krill, were also noted (Sydeman et al. 2006). These 2005 ocean conditions may also have played a role in the poor returns of Chinook salmon to the Central Valley in the fall of 2007. Currently, abundance and distribution cannot be predicted with any certainty except in general terms, and there is no sound scientific basis for a point estimate of MSY. Further, the factors that promote greater or lesser reproductive success are not well understood, and a stock-recruitment relationship cannot be quantified. Thus any fishing is likely to result in risk to the stock, and while this risk cannot be specified in precise terms, it is reasonable to hypothesize that the higher the level of fishing allowed, the greater the risk. Given the uncertainties, a very conservative management policy is appropriate.

2.2.2 Fishery Sustainability

The second issue is to ensure that impacts to krill would not adversely affect (directly or indirectly) other fisheries by reducing krill abundance or availability to levels that would not support survival, growth or sustainability of dependent or associated fish species. Chapter 3 discusses the many fish species that are dependent on or sensitive to the abundance and availability of krill. Most West Coast fisheries pursue stocks in this category, and many of the stocks are found in all four of the Council's managed fisheries (i.e., West Coast groundfish, Pacific salmon, CPS FMP and Highly Migratory Species (HMS) FMP).

2.2.3 Protection of Sensitive Species

The third issue is to ensure that fishing for krill would not adversely affect (directly or indirectly) the maintenance and health of other living marine resources that depend on or are sensitive to the abundance and availability of krill. Chapter 3 presents information on the number of non-fish species that are dependent on or sensitive to the abundance and availability of krill. Society, as expressed in a variety of laws, has recognized many of these species as having great importance, and programs and regulations are in effect to try to ensure that these species will survive and even increase in the wild. The food supplies that these animals depend on need to be protected and conserved. Given the variability of krill populations, it would seem even more important to take such actions to minimize the risk of human-induced perturbations that could exacerbate natural variability of the stocks. It would seem more prudent to take a very conservative approach to achieve the highest abundance of forage for these animals to the extent practicable.

2.3 Management Objectives

The following are the objectives for this action:

- Ensure that krill resources are managed in a way that maintains natural ecological relationships and ecosystem integrity.

This objective means that krill stocks should continue to fulfill their essential role as forage for commercial and recreationally important fish and other species to the extent possible within the limits of natural environmental variability. Krill also would, to the extent practicable, remain at levels at which they would support other essential ecological functions. The recently amended MSA provides authority to include management measures in any fishery management plan "to conserve target and non-target species and habitats, considering the variety of ecological factors affecting fishery populations." (16 U.S.C. 1853(b)(12)). As a species that significantly affects the populations of other fisheries, the conservation and management of krill is clearly authorized by this provision. The conservation of krill at current and natural (unexploited) levels is essential due to its unique and important role in the food chain for commercially and recreationally important fisheries as well as marine mammals and seabirds.

- Provide protection for key krill habitat areas, that is, areas with topographic and oceanographic features that consistently serve to concentrate krill and support stock productivity (while incidentally supporting predator feeding)

Key krill habitat areas are areas in which krill repeatedly concentrate, most likely in response to environmental conditions conducive to feeding and reproduction. These areas also make krill most available to predators, so that krill concentrations will often result in predator concentrations. These areas need protection from potential adverse effects of human activities (which could include fishing) to ensure that the krill life functions enhanced by such environmental characteristics and conditions are not harmed or threatened by those activities. There would be ancillary benefits to the extent that predator species are thus given protection from potential adverse effects of interactions with fishing gear. The management program is intended to ensure that adverse effects on krill habitat areas from direct and indirect effects of human activities are avoided to the extent practicable.

- Provide a foundation for future research and data collection

This amendment and the information in it are meant to promote and support further research into the population dynamics of krill, the role of krill in the environment, and the potential biomass and productivity of krill in the natural environment. Section 3.1.3.5 of this amendment presents many recommendations for additional research and modeling and collaboration between scientists engaged in study of krill and other resources off the West Coast.

2.4 Krill Conservation and Management Alternatives

2.4.1 Alternative 1: No action

Every assessment of potential management strategies by the Council for consideration of implementation by Federal regulation includes a “no action” baseline required by National Environmental Policy Act (NEPA) Implementing Regulations and against which other alternatives are compared. Under this alternative, no action is taken. This means that the States’ prohibitions of landings of krill by their vessels would remain in place (see section 3.5), but that a fishery by vessels from out of the region could develop in the EEZ as long as landings were not made into a West Coast port. As there would be no Federal regulations controlling krill fishing, there would be no need to consider issuance of EFPs to allow fishing that otherwise would be prohibited by such regulations. If a krill fishery developed, the Council would likely develop conservation and management measures at that time.

2.4.2 Alternative 2: Manage Krill Fishing by Issuing Regulations that Implement CPS FMP Amendment 12 (Proposed Action)

Under this alternative, NMFS would issue regulations to manage krill (all species) under the CPS FMP. The regulations establish a new category of management unit species - "prohibited harvest species" - under the FMP and place krill in that category. This means that OY for krill would be zero, and the harvest of krill would be prohibited. Changes to the appropriate management category for each species can be made annually by the Council based on all available data, including acceptable biological catch (ABC) levels and MSY control rules, and the goals and objectives of the FMP. There would be no EFPs issued under the EFP procedures of the CPS FMP to allow individuals to harvest krill as an exception to the prohibition of harvest. These actions would fully achieve the objectives of the amendment to the extent practicable, recognizing that environmental conditions and the responses of krill and other resources to changes in environmental conditions are beyond the purview of MSA.

2.4.3 Alternative 3: Prohibit Krill Fishing but Establish Process for Allowing Future Fishing

This alternative would add krill to the management unit species under the CPS FMP. The amendment would have to meet MSA requirements to specify MSY and OY and to establish SDC for krill (i.e., minimum spawning stock threshold and maximum fishing mortality threshold). The initial OY would be zero (0); no directed fishery would be permitted. Essential fish habitat would have to be established. The FMP would set up a procedure (process and criteria) by which the Council could consider additional information (possibly including information from EFP fishing) and determine whether to allow fishing in the future, and if so at what level and under what conditions. Initial harvest limits would presumably be low, and fishing would be closely monitored (likely including observers). Harvest limits could be adjusted up or down depending on the results of fishing, other research results, and observers' records of any bycatch or protected species interactions. Harvest limits also might be adjusted up or down depending on the anticipation of unusual oceanographic/climatologic events (e.g., El Niño years would likely support higher harvests). EFPs could be considered under the procedures of the CPS FMP. There would be permit and reporting requirements for any fishing consistent with existing provisions of the CPS FMP.

2.4.4 Alternative 4: Allow Small-scale Krill Fishery

This alternative would add krill to the management unit species under the CPS FMP and establish harvest guidelines. Under this alternative a limited fishing strategy similar to the approach authorized in the British Columbia krill fishery, which has an allowable harvest divided among specific locations, would be initiated. For the British Columbia fishery, a total annual catch of 500 mt is divided among several inlet areas and the Strait of Georgia. Applying this same approach for the U. S. West Coast, total annual catches of 500 mt would be initially authorized to each of the six areas (3,000 mt total) where dense krill populations are known to aggregate (section 3.3.3). To comply with MSA requirements, available information would be used to estimate MSY, OY and SDC for krill. However, because of the uncertainty in krill distributions and the extreme annual, season, and intra-decadal variability in abundances of krill species, standardized EEZ-wide stock assessment surveys would need to be undertaken over multiple years to begin the process of truly quantifying the average annual standing biomass of krill (i.e., all species, all stages). Initial harvest levels would be closely monitored and could be adjusted up or down depending on the results of stock assessment surveys.

2.5 Alternatives Considered but not Analyzed Further

The Council considered several other alternative mechanisms for exercising preservation of the key trophic pathway in the California Current ecosystem. One was to designate krill as forage for groundfish and possibly other species of fish under Council management. This approach had been taken in Alaska to provide protection to a number of species that filled that role. The Council decided that this approach was complex and could result in substantial delays in final implementation.

Another alternative was to designate krill as a component of essential fish habitat (EFH) for groundfish and perhaps other species under management by the Council's fishery management plans. This was explored in the Environmental Impact Statement for Establishment of Essential Fish Habitat (NOAA, 2005). The Council in June 2005 rejected this alternative when reviewing comments on and making selection of final proposed specifications of groundfish EFH. There was some concern that this approach would only limit persons in the groundfish fishery and would still leave open the possibility of krill fishing by persons in other fisheries or even by persons not subject to any FMPs. Further, the Council determined it wanted to be consistent with the decision relative to groundfish. The Council concluded it was not necessary to explore this alternative further as a means to conserve and manage krill resources because an amendment of the CPS FMP would be more complete and direct.

Therefore, these alternatives were not evaluated in more detail than shown in the Alternatives Analysis that was the basis for selection of the preliminary preferred alternative in the draft amendment that was circulated for public review and comment.

3.0 DESCRIPTION OF KRILL RESOURCE AND THE AFFECTED ENVIRONMENT

3.1 Krill Biology and Status

3.1.1 Species of Concern and Definition of Krill

The word "krill" comes from a Norwegian term meaning "young fish" but it is now the common term used for all euphausiids, a taxonomic group of shrimp-like marine crustaceans found throughout the oceans of the world. The term krill was probably first applied to euphausiids found in stomachs of whales caught in the North Atlantic, and later became a popular term for Antarctic krill (*Euphausia superba*). For the purpose of this document and analysis, the term ‘krill’ is synonymous with ‘euphausiid’.

Eight species of euphausiid shrimp dominate the krill community in the Transition Zone of the California Current System (Brinton and Townsend 2003). However, only the two cold-water species, *Euphausia pacifica* and *Thysanoessa spinifera* (Figure 1), form large, dense surface or near-surface aggregations and would have some potential to become fishery targets, as high catch densities (e.g., greater than 3 g wet weight $m^{-3)}$ are usually required to support commercial harvesting (Fulton and Le Brasseur 1984). These two species are also the most common euphausiids reported in the diets of a wide variety of California Current seabird, marine mammal and fish species (see section 3.2.1 below).

The daytime near-surface aggregating behavior of *E. pacifica* and *T. spinifera* has been documented by Boden et al. (1955), Barham (1956), Pearcy and Hosie (1985), Smith and Adams (1988), and others. The sub-tropical and marginally tropical *Nyctiphanes simplex* also aggregates at the surface in large swarms, occurring predominantly to the south in Mexico waters (Gendron 1992; Brinton and Townsend 2003); it is only abundant in U.S. West Coast waters during strong El Niño years. Another euphausiid, *Nematocelis difficilis*, is very abundant in the California Current, however it does not a vertically migrate, preferring the deeper layers of the thermocline where it is less accessible to harvest than *E. pacifica* and *T. spinifera*. Based on current (limited) data, the remaining species (*T. gregaria, E. recurva, E. gibboides, E. eximia*) are less abundant and are even less likely candidates for exploitation.

All krill species are proposed to be included under the CPS FMP. However, most of the discussion of krill in this document refers to *E. pacifica* and *T. spinifera*. These are the only species for which there is substantial information with respect to abundance, distribution, and life history characteristics. Even for these species, there is insufficient information for a scientifically sound specification of maximum sustainable yield (MSY)(see 3.1.3.4). This is not indicative of the relative importance of the different species in the environment; it simply reflects what is known about krill at this time. However, for any prospective fishing enterprise, it could be expected that any significant concentration of krill would be exploited if available, regardless of the species. It is not likely that a fisherman would be able to distinguish between species until it was on a vessel or in a laboratory. It would not make sense to control the harvest of the principal species and allow uncontrolled harvest of other species; this would simply invite difficulties of unintended incidental catches of principal species and likely result in enforcement problems and/or substantial discards. Therefore, all species would be in the “prohibited harvest” category proposed in this amendment.

3.1.2 Biology

3.1.2.1 Range

E. pacifica ranges throughout the subarctic Pacific, including the Gulf of Alaska as far south as 25º N latitude (Brinton 1962a, 1981) (Fig. 2). *T. spinifera* occurs from the southeastern Bering Sea south to northern Baja California, with regions of high density associated with centers of upwelling (Boden et al. 1955; Brinton 1962a) (Fig. 3). The ranges of other species are not known.

3.1.2.2. Horizontal Distribution in the EEZ

Distribution of the two principal species within the EEZ is thought to be closely related to bathymetric, topological and oceanographic features favorable for retaining adults, juveniles and larvae in optimum grazing areas. Periodically, distribution and occurrence can also be strongly affected by changes in local and large-scale physical and biological conditions such as anomalously strong upwelling events or extreme El Niño conditions. It is not known whether animals transported offshore are lost to the system, or whether transport of some individuals to the south and west via upwelling filaments or eddies may help to interconnect regional subpopulations and enhance gene flow among isolated stocks. The Scripps Institution of Oceanography (SIO) has recently assembled a 50-year time series of maps showing spatial densities of these and other euphausiid species in the CalCOFI sampling area (Point Reyes, California, south to the California-Mexico border, E. Brinton, SIO, unpub. data, personal commun. 6/8/05). Similar data on a real distribution have been and are continuing to be gathered off Oregon (Smiles and Pearcy 1971; Gómez-Gutiérrez et al. 2005; Peterson et al. NWFSC, pers. commun., Newport, OR 6/8/05). These recently available data and previously published distributional data indicate that *E. pacifica* generally occurs within the West Coast EEZ over bottom depths greater than 100 fathoms (183 m). It can also occur (especially in the larval form) further shoreward over the deeper waters of the continental shelf. It is known to occur seaward to the outer boundary of the EEZ from the U.S.-Mexico border north to the U.S.-Canada border and beyond (Boden 1955), but highest densities appear to occur within the inner third of the EEZ (E. Brinton, SIO, unpub. data, pers. comm. 6/6/05). Within this area (< 60-100 nm from the coast), adults and juveniles reportedly can be found throughout both the inshore and offshore area, whereas larvae are often most abundant in upwelled areas much nearer the coast, generally inshore of the 1000 fm (Brinton 1976; Brinton 1967; Smiles and Pearcy 1971; Gómez-Gutiérrez et al. 2005). Off Oregon, the greatest concentration of adults appears to be located near the shelf break (~200 m isobath) (Gómez-Gutiérrez et al. 2005; W. Peterson, NWFSC, Newport Oregon, pers. comm. 6/6/05). Aspects of its life history may differ in the lower part of its range south of 40°N than to the north of that latitude, where environmental characteristics show stronger seasonality than to the south (Brinton 1976).

T. spinifera is more coastal, occurring mainly shoreward of the shelf break, usually over bottom depths less than 200 m deep, although catches can occur further offshore beyond the shelf, especially off central California (Fig. 3). Daytime surface swarms have been observed off California in the San Diego, Santa Barbara Channel Islands, Monterey Bay, Gulf of the Farallones, Cordell Bank, and Tomales Bay areas, and off Oregon (Pearcy and Hosie 1985; Smith and Adams 1988; Brinton et al. 2000; Adams 2001; Howard 2001).

Gómez-Gutiérrez et al (2005) have described the cross-shelf life stage segregation of *E. pacifica* and *T. spinifera* off central Oregon, which appear to be more tightly associated with the shelf break than in other areas, e.g., off southern California. *E. pacifica* tends to be more offshore extending from 3 to 60 nm miles (5.6-111 km) and beyond from the coast, whereas *T. spinifera* is more coastal, with highest concentrations over the continental shelf and slope. High densities of early life stages (nauplius to juveniles) of both species were primarily recorded in the inshore shelf zone (<18 km from the coast), but older stages were mainly recorded in the outer shelf, slope, and to some extent, beyond. Adult *E. pacifica* (and to some extent, older larval stages) were distributed over the shelf, slope and beyond, with reproductive swarms common along the shelf- break area. *T. spinifera* occurred primarily over shelf and shelf-break waters from 2-74 km (1- 40 nm) from the coast, especially between 5.6- 27.8 km (3 and 15 nm) from shore in water less than 100 m deep. Larvae and juveniles of *T. spinifera* were also generally restricted to relatively shallow inner shelf waters within < 18 km from the coast; while adults occurred generally in outer shelf, shelf break and slope waters beyond 18 km from the coast. They concluded that a strong cross-shelf gradient in euphausiids assemblages and age-segregated distributions for both *T. spinifera* and *E. pacifica* may represent maintenance of egg, nauplius, and metanauplius stages in the rich nearshore area; the offshore drift of older larval stages; and concentration of reproductive adults at the shelf break linking inshore and offshore segments of the populations. Off southern California, larvae of both species occur offshore beyond the shelf as well as inshore (Brinton 1967, 1973). Brinton and Townsend (2003) reported *T. spinifera* (mostly furcilia; rarely adults) disperses extensively offshore toward the main flow of the California Current. While it is possible that these individuals (especially *T. spinifera)* may be advected there by currents and represent individuals lost from the coastal population (Brinton and Townsend 2003), there may also be significant latitudinal differences in the inshore-offshore dispersion patterns and retention mechanisms off Oregon and California.

Gómez-Gutiérrez et al (2005) and others have suggested that the shelf-break is an important ecological region for both these species, with larger euphausiid patches often recorded there. Off Oregon, the main populations are thought to be concentrated within 10 to 20 nm either side of the shelf break (Peterson, W.T., pers. comm. NMFS, NWFSC, Newport Oregon, 6/6/05), though distribution may be further offshore to the south off central and southern California. Additionally, certain features have been associated with important “hot spots” of krill concentration. These are islands, banks, canyons, and promontories that enhance retentive water circulation patterns that tend to retain and concentrate krill and phytoplankton biomass in nutrient-rich upwelled water. Sometimes, these “hotpots” can also occur far offshore, contained in the meanders of upwelling jets that originate further inshore over the shelf or slope. Krill fishing is likely to be most profitable in these high krill density areas, but also likely to be in direct competition with associated fish, seabird and cetacean predators concentrated there. Known high krill and krill predator areas include, but may not be limited to the Olympic Coast, Washington (Calambokidis et al. 2004); Heceta Bank and Cape Blanco areas, Oregon (Ainley et al. 2005; Ressler 2005; Tynan et al 2005); Bodega Canyon, Cordell Bank, Gulf of the Farallones, Pescadero Canyon, Ascension Canyon, and Monterey Bay Canyon off northern California (Chess et al 1988; Smith and Adams 1988; Kieckhefer 1992; Schoenherr 1991; Adams 2001; Howard 2001); and around the southern California Channel islands (Armstrong and Smith 1997; Fieldler et al. 1998; Croll et al 1998).

3.1.2.3 Vertical Distribution in the EEZ

E. pacifica performs extensive vertical migrations, usually over depths greater than 200 m. The adults live at a daytime depth of 200-400 m (occasionally down to 1000 m) rising to near the surface at night (Brinton, 1976; Youngbluth 1976), often concentrating in the upper 20 to 50 m. It occasionally amasses near the surface during the day as well (Hanamura et al 1984; Endo et al. 1985; Brinton and Townsend 1991).

T. spinifera generally occurs from the surface to about 200 m deep but most frequently at vertical depths of less than 100 m (Ponomareva 1966; Brinton et al 2000; Alton and Blackburn 1972). It also undertakes diel vertical movements within its relatively shallow range (Alton and Blackburn 1972; Chess et al. 1988). It is the most predictable and extensive daytime surface swarmer along coastal California from Tomales Bay south to the Channel islands off southern California (Brinton 1962a; Smith and Adams 1988; Fielder et al 1998; Howard 2001; Adams 2001). Mass strandings of the species have also been reported along Oregon beaches (Pearcie and Hosie 1985) and as far south as La Jolla, California (Brinton 1962a).

3.1.2.4 Food Requirements and Trophic Transfer

Both species are grazers on microscopic plants and animals and provide an important link in the oceanic food web between phyto- and nanoplankton and upper trophic levels (Figure 1). Phytoplankton is thought to be a major component of the diet, but fish eggs and larvae are also thought to be consumed in large quantities. Theilacker et al (1993) suggests this predation may significantly affect fish recruitment. Field et al (2001), using a top-down Ecopath assessment model for the northern California Current ecosystem[a] (NCCE), estimated euphausiid average annual phytoplankton biomass consumption to be 650 g wet weight m^{-2} during the early 1960s (a cool, productive regime), and 400 g wet weight m^{-2} in the mid-1990s (a warm regime characterized by low productivity).

The phytophagous role of krill has a negative aspect. Bargu et al. (2002) found evidence that California krill (e.g., *E. pacifica*) may be a potential transfer agent of the phycotoxin domoic acid to higher trophic levels in the marine food web in Monterey Bay.

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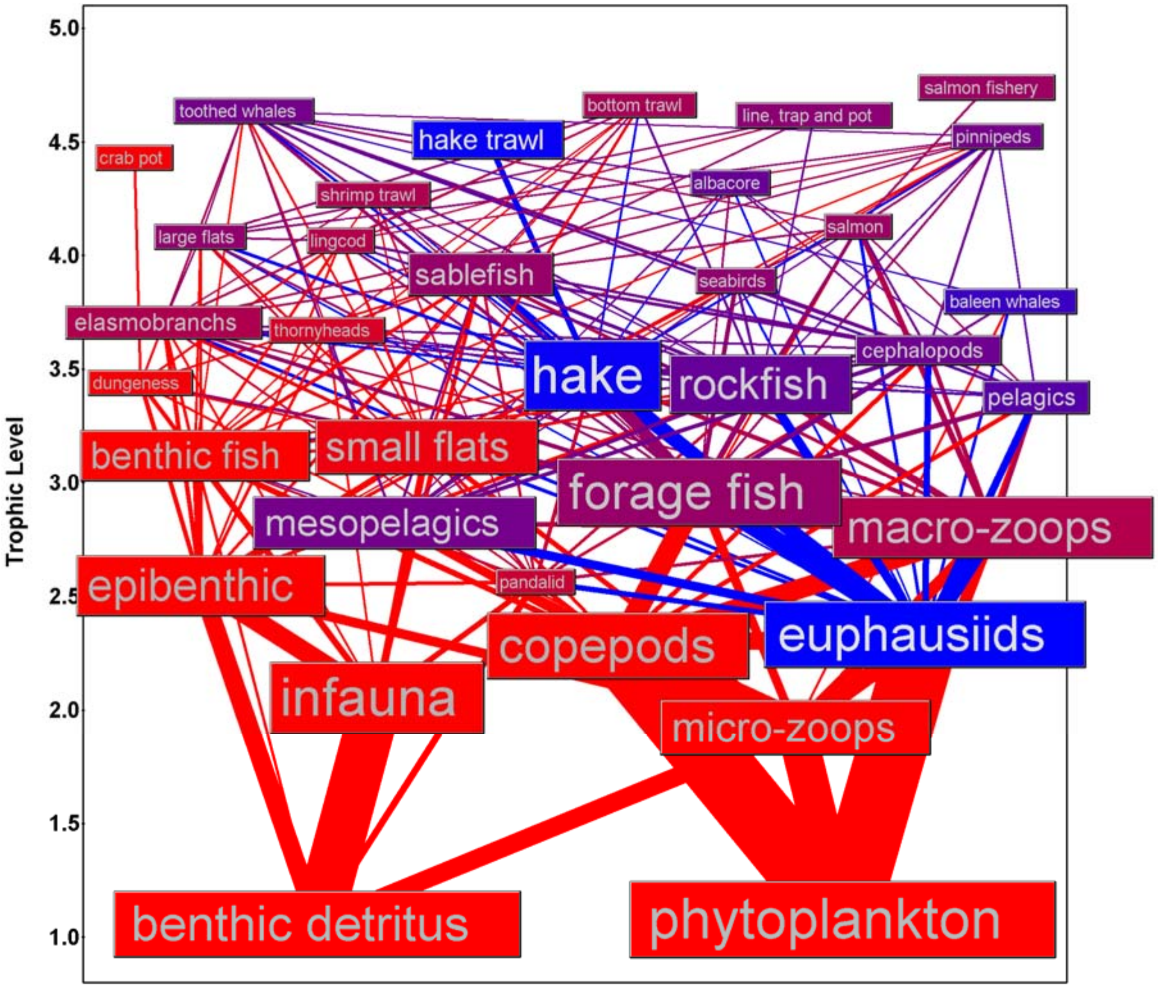
[a] Defined as Cape Mendocino, CA north to the tip of Vancouver Island, Canada.

In the figure below, estimated trophic level is along the y axis, and colors represent energy pathways, with energy derived from euphausiid (i.e., krill) production in blue and from other sources in red. The size of the boxes and the width of the bars connecting various boxes are scaled to the log of the standing biomass and biomass flow respectively. Functional groups include: 11 higher trophic level predators; 27 commercially important species; 20 functional groups for zooplankton, nekton, benthic fauna; and 7 commercial fisheries (Field, J.C. and R. C. Francis. 2006).



3.1.2.5 Growth, Sexual Maturity, Longevity, and Natural Mortality

Analysis of length at age is complicated by the fact that krill can shrink in size as an ecological adaptation to temporarily unfavorable environments (Marinovic and Mangel 1999). Both species are known to shrink in winter when food is scarce; *E. pacifica* is also known to shrink in summer during the reproductive season (W. Peterson and L. Feinberg, NMFS, SWFSC and OSU, pers.

commun, 6/6/05). California Current krill can also regressively lose their sexual characteristics, skip developmental stages, or molt several times while remaining at the same stage (ibid). *E. pacifica* can also exhibit a large range of ages at any given size, and females at a given age can vary in size as much as 10 mm (ibid.). These characteristics can have a big impact on field calculations and complicate length frequency progression analyses.

Throughout its range, *E. pacifica* exhibits large variation in longevity and age at first sexual maturity (Table 3.1). According to Brinton (1976), the more abundant spring-summer cohort of E. *pacifica* off southern California generally reaches a maximum length of 22 mm in about 12 or 13 months, and has a one-year life span. Life expectancy for the lesser abundant winter cohort off southern California is shorter at 8 months. Individuals from 10 to 15 mm carapace length tend to predominate in the population. Growth rates of *E. pacifica* off southern California appear similar to those off Oregon (Smiles and Pearcy 1971). Under optimum conditions, sexual maturity could be attained at 11.6 mm length (Brinton 1976), and an adult cohort off southern California can reproduce about three times over a life span of about three years . Growth is thought to be slower and of longer duration to the north in the Subarctic North Pacific.

T. spinifera grows to a larger size—males to 20 mm, females to 38 mm. The difference in male and female growth is observed from the first year. Life span has been variously reported from 10 months to two years or more (Boden et al. 1955; Nemoto 1957; Summer 1993; Tanasichuk 1998). In subarctic Alaskan waters, Nemoto (1957) reported a two-year life cycle (or at least 1+ yrs), with individuals growing to 10 mm in the first year and attaining sexual maturity at about 20-24 mm at one year of age, with a spawning season from June to September. He found large unfertilized specimens (26-30 mm) in mid July and was unsure whether these specimens represented ages 2+. Mauchline (1980) also estimated the maximum life span to be 2+ years with breeding maturity reached at 2 years of age. Summers (1993), using length frequency analyses of individuals collected in Barkley Sound, B.C., found that *T. spinifera* matures in one year, and some individuals survive to two years of age (most maximum-sized adults she found in the field were closer to 1 year of age). Tanasichuk (1998b) monitoring population structure in Barkley Sound, British Columbia, estimated a shorter life span of 10 months using length frequency progressions and certain initial assumptions about larval stage durations and furciliar growth. He also found more variable and protracted spawning. Annual and seasonal progression in size classes observed in *T. spinifera* collected in the Gulf of the Farallones and Channel Islands off southern California indicate that a 1 to 2 year life span may also be true for populations to the south, but more work is needed.

Few quantitative estimates of instantaneous natural mortality M are available for species of krill, although *E. pacifica* off California and Oregon has been better studied than most, and mortality found to be quite high. Brinton (1976) estimated that only 16 percent of *E. pacifica* larvae survive per month, then survival increases to 67 percent per month after the larval stage is complete, then mortality increases once again in adulthood, with only about 60 percent surviving per month. Siegel and Nicol (2000) calculated M values based on data published in Brinton (1976) and Jarre-Teichmann (1996), and found $M = 3.0\ y^{-1}$ off California, and much higher (M = 8.7 $^{y-1}$) off Oregon. Siegel and Nicol (2000) suggest the high mortality rates off Oregon may have been due to data collected under unusually severe El Niño conditions, and may not be representative of an ‘average’ year. No natural mortality estimates are available for *T. spinifera*.

Table 3-1. Estimates of maximum age, age at first maturity/spawning, spawning frequency and natural mortality rate (*M*) of the euphausiids *E. pacifica* and *T. spinifera*.

Species	Cohort	Area	MaxAge	1stMat	Spawning frequency a/	*M*	References
E. pacifica	**Spring**	**S. Calif.**	**6-8 months**	**4 months**	**3 yr^{-1}; ~ max. every 2 months** b/	**3.0 y-1**	**Brinton 1976 Siegel&Nicol 2000**
E. pacifica	**Autumn**	**S. Calif.**	**10-13 months**	**7 months**	**Max. every 2 months**	**3.0 y-1**	**Brinton 1976 Siegel&Nicol 2000**
E. pacifica	**---**	**Ore. &Wash.**	**1+yr**	**~1 yr**	**1 yr^{-1}**	**---**	**Smiles&Pearcy 1971**
E. pacifica	**---**	**Ore**	**---**	**---**	**---**	**8.7y-1**	**Siegel&Nicol 2000 Jarre-Teichmann 1996**
E. pacifica	**---**	**Wash**	**-- -**	**---**	**2 yr^{-1}; mostly spring, less in late summer.**	**---**	**Bollens et al 1992**
E. pacifica	**---**	**B.C.**	**---**	**---**	**4-6 yr^{-1} Mar-Oct**	**0.6-1.9 y^{-1}**	**Tanasichuk 1998a; Siegel&Nicol 2000 Jarre-Teichmann 1996**
E. pacifica	**---**	**Aleutians; Kam-chatka**	**2+ yr**	**~ 1 yr**	**1yr^{-1} for 2+ years**	**---**	**Siegel&Nicol 2000; Iguchi&Ikeda 1995**
E. pacifica	**---**	**NW Pacific; Kam-chatka**	**2+ yr**	**~ 1+ yr**	**1 yr^{-1} for 2+ years**	**---**	**Ponamareva 1966; Nemoto 1957**
E. pacifica	**---**	**NE Japan**	**15 months**	**---**	**1 yr^{-1}**	**---**	**Iguchi et al 1993**
E. pacifica	**---**	**SW Japan**	**21 months**	**---**	**---**	**---**	**Iguchi et al 1993**
E. pacifica	**---**	**N Japan**	**2+yr (female) 1+yr (male)**	**1+yr**	**---**	**---**	**Nicol&Endo 1997**
T. spinifera	**---**	**Barkley Sound, B.C.**	**1-2 yr**	**1 yr**	**2 pulses yr^{-1} Mar-July**	**---**	**Summers 1993**
T. spinifera	**---**	**Barkley Sound, B.C**	**10 months**	**---**	**3-4 pulses yr^{-1} Mar-Oct**	**---**	**Tanasichuk 1998b**
T. spinifera	**---**	**North Pacific**	**2+ yr**	**2 yr**	**---**	**---**	**Mauchline 1980**
T. spinifera	**---**	**Subarc-tic Alaska**	**1+ to 2+ yr**	**1 yr**	**1 y^{-1} June-Sept**	**---**	**Nemoto 1957**

a/ distinct cohorts; egg release pulses

b/ depending on available food conditions

3.1.2.6 Reproduction and Recruitment

Both species are batch spawners; eggs are broadcast freely into the water, which sink in the water column. Males must transfer a spermatophore packet to the female for fertilization to take place. After hatching, larvae move toward the food-rich surface layers.

Recruitment of *E. pacifica* can occur year-round off Oregon and California, but distinct peaks are associated with upwelling periods (Brinton 1967; Brinton 1973; Barham 1957). *E. pacifica* appears to be more seasonal in the subarctic North Pacific and off Japan (Nemoto 1957; Ponomareva 1966). Recruitment typically crests off mid Baja California February-April; off southern California May-July; in Monterey Bay also spring and summer, and off Oregon, August-December (Brinton 1976). It may be that under optimal feeding conditions, a female, carrying 20-250 eggs which hatch into larvae could spawn every two months – first at about 11.5 -mm length; second at about 16 mm, and third at 20 mm – during which time it might produce a maximum of 650 eggs. The long duration of maturity (about half of the species' short life expectancy) is thought to contribute to population stability and continuity. Recruitment in California occurs after about 30 days when larvae enter the juvenile phase. There are at least 4 generations each year, at least off southern California. Due to the short life span and relatively few cohort pulses, the maximum stock size is reached immediately after successful recruitment of a single cohort (Brinton 1976; Siegel and Nicol 2000). In general, there is no spawning stock-recruitment relationship, in most years highest recruitment occurs from spring and summer cohorts, lesser recruitment occurs in autumn and winter. Off Washington, there is one large recruitment pulse in spring, and a lesser one in late summer (Bollens et al. 1992) and none in winter. This pattern is attributed to reduced phytoplankton levels in summer and low survival of adults into winter to spawn at that time.

Less is known of the population biology of *T. spinifera*. Brinton (1981) reported that the spawning season off California extended from May to July, coincident with the strongest upwelling. During this time, fully mature adults form extensive inshore surface swarms during the peak of the upwelling season off California (Brinton 1981, Smith and Adams 1988). These adults are thought to swarm, breed over a protracted spawning season, then presumably die at the end of their life cycle (Nemoto 1957). Off San Francisco, breeding appears to occur primarily from April through June-July. Spring reproductive swarms in this area contain mostly 18-30 mm fertilized adults in breeding condition, which presumably spawn (probably at intervals) and then die by late summer, when specimens of the size disappear from seabird and salmon diets, and from plankton collections. Swarms off central and southern California have also been sampled during late summer and fall (Aug-October) in association with blue and humpback whales, but these late summer and fall individuals are mostly immature or sexually developing individuals (14-20 mm). Maturing subadults are also known to swarm near the surface in late summer and fall (Schoenherr 1991; Kieckhefer 1992; Fiedler et al. 1998). Summers (1993) describes a distinct and extended spawning period off British Columbia from March through July with a late May peak. Unlike *E. pacifica*, the eggs of *T. spinifera* are quite adhesive, a possible mechanism to maintain recruits in the neritic zone and prevent offshore dispersal to less productive waters (Summers 1993).

To the north of the U.S. EEZ, Tanasichuk (1998b) has studied the population biology of *T. spinifera* in Barkley Sound, Canada, including stock recruitment, biomass and productivity. He found neither the Ricker nor Beverton and Holt stock-recruitment models described the relationship between larval and parental abundances of this species he observed. Population production to biomass ratios (P:B) fluctuated between 14.4 and 44.7,with variations following the proportion of the biomass accounted for by larvae (e.g., the lowest P:B ratio was in 1994 when larvae accounted for only 0.05 of mean annual biomass).

3.1.3 Status of Principal Species

3.1.3.1 MSA Requirements and Available Data

Under section 303(a)(2) and 303(a)(10) of the MSA, an FMP is to specify the MSY and OY from the stock or stocks in a fishery, and summarize the information on which these determinations are made. In addition, the FMP shall identify objective and measurable SDC for each stock or stock complex covered by that FMP and provide an analysis of how the SDC were chosen and how they relate to reproductive potential.

In the case of krill, if the proposed action is implemented, the stocks will not be subject to fishing. Therefore, specifications of MSY and of SDC do not have any operational purpose. Notwithstanding, the following sections provide the best available information about krill abundance, distribution, and potential productivity, including discussion about potential MSY levels. This discussion is limited to the two principal species (*T. spinifera* and *E. pacifica)*. There is no comparable information available on any of the other krill species; therefore, there is no summary of the missing information. The information that is presented here is intended to further understanding of the rationale for the proposed action and its impacts; to promote scientific research and collaboration and additional stock assessment and modeling efforts; and to demonstrate the uncertainty about what is and is not known about krill. It also provides the basis for the determination that krill harvests are inappropriate (i.e., that OY is zero), both to prevent adverse effects of krill fishing and to prevent adverse effects on other living marine resources. It is emphasized that the scientific information available at this time does not provide a basis for setting harvest limits or other controls based on productivity measures such as MSY for the two principal species or other species of krill.

In the process of developing the Alternatives Analysis that was used by the Council as a basis for determination of its preliminary preferred alternative, NMFS invited California Current krill experts from Federal and State government agencies, academia, and the private sector to a discussion in September 2005 about their research and their ideas as to the abundance, distribution and productivity of krill (see Appendix A). It was generally agreed that reliable input parameters for a suitable model to determine minimum stock size threshold and maximum fishing mortality threshold (the required SDC for managed fish stocks), based on spawning biomass or other measure of productive capacity, still need to be developed and agreed upon for the two principal species of krill found off the West Coast. Benchmark status determination could not be made at that time. No catch histories or sufficient information on stock and recruitment (e.g., percent spawning potential ratio, or proxies based on spawning potential ratios) are available on which to make calculations of such measures as the level of biomass B relative to its initial biomass level B_0 and relative to B_{MSY} , or to determine the potential level of mortality F relative to some target level like F_{MSY}. *MSY* levels of *B* or *F* could possibly be estimated as fractions of B_0 but no comprehensive EEZ-wide or stock-wide biomass estimates for any California krill species have been made for these species.

Even if reliable data were readily available, the MSY yield model based on traditional surplus production theory is inappropriate to set quantitative catch limits for krill, for the following reasons:

- Most current single-species modeling assumes the equilibrium condition from which a MSY can be derived and applied for managing harvest. This condition rarely if ever exists for these two species, which exhibit constantly fluctuating and extreme ranges of standing stock densities, depending on what environmental regime is prevailing that particular season, year, or group of years. It is not possible to predict in advance with any confidence what the krill abundance will be in time or space.
- One of the goals of the proposed action is to ensure sufficient production and remove the risk of stock depletion so that krill can satisfy the forage requirements of predators, including not only commercially important fishes and invertebrates such as Pacific hake, salmonids, rockfishes and squid, but also recreationally important species, as well as seabirds and marine mammals under Council and/or Federal management.
- Krill have unusual growth and molting patterns, and lengths at maturity vary (unlike other commercially important crustaceans). This makes it difficult to estimate vital rates and to derive an estimate of MSY for krill.
- No information exist on the extent to which population ‘seeding’ occurs from populations that lie to the north and west outside the U.S. EEZ and the year-to-year variability of the rate of immigration or emigration from the system.
- The lack of a harvest history precludes using average stock-wide catch levels as rough proxy MSY values.
- Data are available from diverse sources on average densities for certain EEZ areas and times, and even the historical range of densities of these species (especially off central and southern California and central Oregon), but there is no consensus on overall representative densities or range of densities, and habitat area utilized over which to expand these densities into EEZ-wide or range-wide B_0 estimates.

While a reliable point estimate of MSY cannot be specified at this time, there are considerable data available on natural variability of abundance, food web dynamics, and preliminary data on vital rates that can be used to obtain bounding values for initial modeling. These are based on rough estimates of average adult krill densities and presumed habitat occupied and are presented in section 3.1.3.4. Other measures of abundance and potential MSY, expressed as a range of average densities (all life phases) during El Niño versus La Niña years, are provided in section 3.1.3.3. These estimates are provided below consistent with the requirement of section 303(a)(3) of the MSA to assess and specify the MSY for the fishery (if one were permitted). Again, these estimates are only for the two principal species; there is no information to support similar estimates for other species of krill. The cumulative MSY for all krill species, which may be higher than the MSY for the principal species, is not known and cannot be estimated.

It also should be noted that available methods to determine abundance and units for measuring abundance are far from standardized, and estimates are based on many assumptions that may or may not be valid, including a lack of accounting for predator needs. More thorough analyses and standardization of density and biomass estimates are required to obtain more valid biomass estimates, as well as analyses to determine impacts on dependent predators and the ecosystem. Nonetheless, the information presented may be taken to represent the available range of estimates of MSY for the two principal species. In the case of krill, however, even for the two principal species, there are no specific MSY estimates on which scientists can agree at this time. As will be discussed later (see 3.1.3.5 Research Needs), there are some approaches by which agreed upon estimates might be developed, but these efforts have not yet been initiated. It is noted that NMFS uses such recommendations as a basis for seeking additional research funds and setting research priorities. The Council urges that this work receive a high priority in NMFS' research.

3.1.3.2 Annual and Decadal Variability in Abundance

Both species exhibit extremes in abundance and distribution patterns, depending on seasonal, annual, or multi-annual oceanographic conditions and regimes (e.g., Abraham et al 2004; Ainley et al 1966; Brinton 1981; 1996; Mullin and Conversi 1989; Brinton and Townsend 1991,2003; Marinovic et al. 2002). Brinton and Townsend (2003), using the CalCOFI data series, published a time series analysis of fluctuations in abundance of the major California Current euphausiid species relating to decadal oceanographic variability over the last 52 years. They studied fluctuations in densities (log10 +1 number animals 10m -2) of dominant euphausiids in four sectors between about 26º and 38ºN (central California, southern California, northern Baja California, and central Baja California) between 1951 and 2002 (Fig. 4). In the southern and central California areas, cold-water *E. pacifica* and *T. spinifera* declined dramatically during extreme warm water events, although they appeared to be quite resilient in an ability to rebound from periods of unfavorable oceanographic conditions (Figs. 5-7). Abundances varied similarly over the five survey decades, both species having marked post-El Niño recoveries once cooler water periods returned. Periods of population depletion became increasingly frequent, though irregular, after a cool water regime shifted to a warm water regime in the 1970s. The more numerically abundant *E. pacifica* uniformly collapsed by as much as 90 percent during warm-water El Niño periods, but recovered to irregular but distinct bi-decadal peaks in abundance during six strong cold-water La Niña episodes, including the most recent cool-water episode from 1999 through at least spring 2002. Although both species reacted negatively to extreme El Niño conditions (slightly less so off central than southern California), abundance relationships with the Pacific Decadal Oscillation (PDO) varied, with *E. pacifica* showing a weak but significant ($P < 0.05$) negative association with the PDO, and *T. spinifera* showed no relationship. *T. spinifera* mean pre-and post-climate shift abundances off southern and central California were similar, although this species' central and southern California numbers greatly decreased during the 1983 El Niño, and certain positive anomalies were associated with cooler years, especially during the most recent 1999-2002 cooling period. Over five decades, the more abundant *E. pacifica* approached or surpassed a high baseline density of 20,000 x 10m -2 (log 4.30) off southern California in spring once per decade (except twice in the 1980s), at intervals varying from 4 to 11 years, and these high density years (1957, 1968-69, 1980, and 1996) were followed by declines to densities of 2,000 x 10m -2 (log 3.30), and were associated with 3 of the strongest recorded El Niño events in 1957-58, 1982-83, 1997-1998, and a weaker one in 1969-70. CalCOFI net sampling off southern and central California suggests *E. pacifica* occurs at greater than 100 times *T. spinifera* amounts, although relative densities of the latter species which is larger and more efficient at avoiding nets, are likely underestimated.

3.1.3.3 Frequency Distributions of Krill Abundance off California

The above time series (Brinton and Townsend 2003) has recently been updated through spring 2004, and presented as a series of frequency distributions of abundances (Mark D. Ohman and Annie Townsend, unpub. analysis, 8/5/05, Pelagic Invertebrates Collection, Scripps Institution of Oceanography Long Term Ecological Research LTER Site).

Frequency distributions of abundances for both species for the two regions are illustrated in Figs. 8-11. Only spring nighttime collections are used, with all life history phases combined. The data are subdivided in two ways, first chronologically into three successive time periods: 1950-1976, 1977-1998, and 1999-2004, chosen because these have been hypothesized to reflect different ecosystem states in the Northeast Pacific. The second subdivision is by El Niño versus non-El Niño years. In the latter comparison, data from only the relatively strong El Niño's in mid-latitudes (1958, 1978, 1983, 1993, and 1998) are grouped together according to the springtime of the year when the Niño effect was the most pronounced. Samples were not available for Central California in 1993. All other years are grouped together as non-Niño years.

Statistical analysis by Analysis of Variance, following log (X+1) transformation of the euphausiid abundances has revealed the following:

- During El Niño springs, mean abundances of *E. pacifica* were significantly lower than in non-Niño springs in both Southern California ($P< 0.00001$) and Central California ($P< 0.01$).
- During El Niño springs, the mean abundance of *T. spinifera* was lower than in non-Niño springs in Southern California ($P< 0.0001$), but there was no significant El Niño effect in central California ($P>0.10$).
- For both euphausiid species and both regions of the California Current, there was significant heterogeneity of mean abundances among the 3 time periods hypothesized to represent different regimes of the California Current ($0.00001 < P < 0.05$). In all cases, mean abundances were significantly higher in the most recent time period (1999-2004) that in the two preceding time periods (1950-1976, 1977-1998).

Note that the sample sizes for some of these comparisons are small, especially in Central

California in more recent years when only abundances from 2003 and 2004 are available. Therefore these comparisons should be treated with caution. Also note that data are not yet available for 2005, and there is some suggestion that oceanographic conditions were anomalous in this year.

The implications of these summaries are that both the presence of strong El Niños and the longer term "regime" state of the California Current influence expected abundances of these two species of euphausiids. Accordingly, any guidelines for euphausiid harvest should explicitly take into consideration the oceanographic conditions in the California Current.

Average numbers of *E. pacifica* (larvae, juveniles, adults) within southern and central California sectors during El Niño years were estimated to be 105 individuals 1000 m^{-3} and 566 individuals 1000 m^{-3}, respectively; while during non-El Niño years, were 1,471 individuals 1000 m^{-3} and 1,565 individuals 1000 m^{-3}, respectively. It must be noted that very large confidence limits are associated with these mean values. Approximately 7 percent (± 4 percent) of these individuals were estimated to be adults (Brinton and Townsend (2003, their Table 1). The average number of *T. spinifera* off southern and central California during El Niño years was 1.6 individuals 1000 m^{-3} and 6.7 individuals 1000 m^{-3}, respectively, while during more productive non-El Niño years, was 4.8 individuals 1000 m^{-3} and 15.7 individuals 1000 m^{-3}, respectively. *T. spinifera* densities are quite likely underestimated because adults and large juveniles of this larger species are thought to be very mobile and adept at avoiding towed nets, and thus likely to be underestimated when extrapolating abundance from net tows (Brinton 1965; and Brinton and Townsend 2003). These average densities, considered within the context of their respective distributions (Fig. 8-11) and averaged for the northern and southern California areas, provide an estimate of standing stock density and MSY expressed as a range of average densities (all life phases combined) observed during El Niño versus and non- El Niño years (1950-2004) (Table 3-2).

Table 3-2. Estimates of standing stock (D_0) and potential MSY ($0.5D_0$) expressed as overall average springtime densities, based on CalCOFI net sampling data (life phases combined) off central and southern California, El Niño versus non-El Ni2o years (1950-2004). Data based on Brinton and Townsend (2003) and M. Ohman and A. Townsend (8/2005, unpubl. data, Pelagic Invertebrates Collection, Scripps Institution of Oceanography LTER site). These average values do not reflect regional differences in abundances, which may be considerable, see text and Figures 6-11.

Species	Regime years	D_0 (indiv. 1000m^{-3})	0.5 D_0 (indiv.1000 $m^{-3)}$
E. pacifica	**El Niño (warm)**	**335**	**168**
E. pacifica	**Non-El Niño (cooler)**	**1,518**	**759**
T. spinifera	**El Niño (warm)**	**4.15**	**2**
T. spinifera	**Non-El Niño (cooler)**	**10.25**	**5**

3.1.3.4 Point Estimates of Unfished Biomass (B_0) and Preliminary Estimates B_{MSY}

Because of the extreme annual, seasonal, and intra-decadal variability in abundances of these species, lack of standardized EEZ-wide surveys, and poorly known distributional differences coastwide, few attempts have been made to estimate unfished biomass of these two species, separately or collectively. The following summarizes various available estimates of krill biomass.

In 1983, a NMFS guide to underutilized fisheries resources (NMFS 1983) estimated the population of *E. pacifica* at "probably over 100 million tons in California," but no supporting data were provided. Furthermore, this number seems unusually high, considering the collective biomass of krill worldwide (~ 85 species) has been estimated at about 300 million tons (Pitcher 1995).

Field et al. (2004) estimated euphausiid mean annual standing biomass (all species, stages) in the northern California Current ecosystem (Cape Mendocino north to Cape Flattery, an area of 70,000 km^2) to be 1,890,000 tons during the early 1960s (a cool, productive regime), compared with 1,450,000 tons in the early-1990s (a warm regime characterized by low productivity). The estimates were based on a top-down estimate of consumption requirements of upper-trophic level predators, calibrated to the extent possible by existing assessments of plankton and nektonic standing stocks and productivity for the two time periods in question. These estimates are dependent on accurate estimates of predator biomass (which are lacking or need updating), and would benefit from a starting estimate of krill standing stock to adjust the model.

Brinton (1976), in his study of the population biology of *E. pacifica* off southern California, described reproduction, growth and development of cohorts, and successions in population structure and biomass over a four year period (1953-56). He estimated *E. pacifica* general densities in the southern California Bight CalCOFI study area (covering approximately 1235 km^2) to be 10-1,000 mg wet weight m^{-2} , which suggests a biomass of from 12,350 to 1.2 million kg (12-1235 mt) for the Bight study area. The minimum average density estimate of 10mg wet weight m^{-2} extrapolated to the Pacific Coast EEZ (812,201 km^2), would amount to over 8 million kg (8122 mt), but again, such extrapolations mean little without knowledge of relative densities within the extrapolated area. Even less is known of the population biology and status of *T. spinifera*.

W. T. Peterson (pers. commun. ongoing studies, 6/6/2005 and 9/9/05, NMFS,NWFSC, Newport, Oregon) made some preliminary first order calculations of adult krill biomass, based on average adult densities of both *E. pacifica* and *T. spinifera* observed at two stations off Newport, Oregon, each sampled monthly since 2001. One station is located just offshore of the shelf break (300m depth) and the other just inshore of the break over the shelf (140 m depth). Overall mean density of adult *E. pacifica* was 10.0 adults m^{-3} and 3.6 adults m^{-3} at the shelf break and shelf stations, respectively, averaging 6.8 adults m^{-3} for both. These stations are sampled at night, when the majority of krill are thought to reside in the sampled upper 20 m, suggesting an area density of 136 *E. pacifica* adults under each m^{-2} (Table 3). Peterson then estimated the area of maximum krill concentration along the U.S. West Coast to be centered around the shelf break, along the length of the EEZ (7.0176×10^{10} m^2). Assuming this reflects the area occupied, and converting average adult length to weight, the observed density extrapolates to a total EEZ B_0= 1,031,584 mt after conversion from preserved to fresh weight (Table 4). Overall mean density of adult *T.*

spinifera was 0.8 adults m^{-3} at both shelf break and shelf stations, and extrapolates to $B_0 =$ 189,717 mt of EEZ fresh-weight biomass. Alternately, one could assume a broader habitat is occupied, taking into account higher densities off California that can occur further offshore of the shelf break, as indicated by CalCOFI densities charted for these two species over the past 50 years (E. Brinton, Scripps Institution of Oceanography, La Jolla, CA, 6/6/05, ms. in prep.). Accounting for a broader distribution off central and southern California, the primary area occupied by these two species may be closer to one-quarter of the EEZ area. Based on these estimates and other assumptions, two alternative rough estimates of standing stock (B_0) and B_{MSY} (0.5 B_0) are presented in Tables 3-3 and 3-4. Again, these should not be taken to represent potential MSY levels for other species of krill; no estimates are available for those species.

Table 3-3. Preliminary estimates of standing stock (*B_0*) and B_{MSY} (0.5 *B_0*) based on assumption of average adult densities of 136 m^{-2} and 16 m^{-2} for *E. pacifica* and *T. spinifera*, respectively [a/], for two habitat area assumptions [b/]. Uses length-biomass conversions of Miller (1966) and conversion of combined species totals to fresh wet weight from W.T. Peterson and L. Feinberg (NMFS, NWFSC, Newport Oregon).

Species	Est. avg. density[1], adults m^{-3}	Est. avg. density[1], adults m^{-2}	Est. avg. Adult weight [c/] (g)	Kg Km^{-2}	Est. B_0 (mt) Habitat Assumption A[2]	Est. B_0 (mt) Habitat Assumption B[2]	0.5 B_0 (MSY) Habitat Assump. A (mt)	0.5 B_0 (MSY) Habitat Assump. B (mt)
E. pacifica	**6.8**	**136**	**0.064**	**8700**	**610,531**	**1,766,535**	**305,266**	**883,268**
T. spinifera	**0.8**	**16**	**0.100**	**1600**	**112,282**	**324,880**	**56,141**	**162,440**
Total Metric Tons Preserved Weight (Miller 1966)					**722,813**	**2,091,415**	**361,407**	**1,045,708**
Total Metric Tons Fresh Weight (Peterson et al)[d/]					**1,221,301**	**3,533,759**	**610,651**	**1,766,880**

a/ *E. pacifica* and *T. spinifera* avg. overall mean adult density from W. T. Peterson, NMFS,NWFSC, Newport OR, pers. comm, 9/8/05 (see text).

b/ Habitat assumption A assumes area main krill concentration 70, 176 km2 (W. Peterson, ibid., see text); Assumption B assumes area of main krill concentration within inner quarter EEZ (~203,050 km2)

c/ Avg. adult E. pacifica (11-25 mm TL) from A. Townsend (Scripps Inst. Oceanogr., Invertebrate Collections); avg. adult T. spinifera 22 mm TL from Summers (1993); all weights calculated in preserved weight (Miller 1966) and converted to fresh for combined total (see Table 4).

d/ W.T. Peterson and L. Feinberg, NMFS,NWFSC, Newport OR. Carbon weight mg x 2.22=Dry Weight (DW) assuming carbon 45% of DW ; DW x 10 = WW (90% water). Fresh biomass est. approx. 1.7 x preserved biomass.

Table 3-4. Preliminary biomass estimates under two wet weight conversion assumptions presumed to reflect preserved (Miller 1966) and fresh (W.T. Peterson, NMFS, NWFSC, pers. commun., 9/9/05) weights. Provisional MSY estimates given in 'fresh' weight to approximate fresh-landed euphausiids.

Species	Est. B_0 Habitat Assumption A Miller 1966 Preserved (mt)	Est. B_0 Habitat Assumption A 90% H_20 Fresh (mt)	Est. B_0 Habitat Assumption B Miller 1966 Preserved (mt)	Est. B_0 Habitat Assumption B 90% H_20 Fresh (mt)	0.5B_0 (*MSY*) Habitat Assump. A 90% H_20 Fresh (mt)	0.5B_0 (*MSY*) Habitat Assump. B 90% H_20 Fresh (mt)
E. pacifica	**610,531**	**1,031,584**	**1,766,535**	**2,984,826**	**515,792**	**1,492,413**
T. spinifera	**112,282**	**189,717**	**324,880**	**548,933**	**94,859**	**274,467**
TOTALS	**722,813**	**1,221,301**	**2,091,415**	**3,533,759**	**610,651**	**1,766,880**

The above are not intended to be used as a basis for establishing quantitative limits on krill harvest. Among many tentative assumptions, the estimates of potential fishery yield do not account for ecosystem needs, habitat size differences between the two species, and possible geographic differences in the proportions and densities of adult, juvenile and larval phases. Oregon densities were sampled during 2001-2004, a favorable cool water period, when productivity was presumably high. Thus standing stock and MSY during a less favorable warm water period may be 22 percent and 40 percent of the above estimates, for *E. pacifica* and *T. spinifera* respectively, and reduced as much as 90 percent, judging from the range of densities observed for these species in warm versus cool water periods (Table 3; Brinton and Townsend 2003). Thus a maximum constant yield, the catch estimated to be sustainable with an acceptable level of risk at all possible future levels of biomass, might be as much as 0.9*MSY*. Stochastic population modeling is needed to better define these reference points once agreement is reached on the model parameters or parameter ranges.

Density-to-biomass conversions of the SIO CalCOFI time series are needed to compare with the Oregon data and adjust EEZ-wide krill biomass estimates accordingly, as appropriate. The SIO data represent an extremely valuable 50+ year record of krill population abundance and variability, data that are seldom available for most managed stocks, yet always so crucial to manage them effectively. Biomass conversions based on size distribution of krill found in the samples and applying allometric conversions of standard length to euphausiid weight still needs to be done. Presumably, working back from the size group composition of each spring collection, proportion of adults could be extracted to approximate estimates of annual adult, or adult and juvenile biomass. Preserved weight to fresh wet weights conversions are also needed, as fresh weight is most appropriate for simulating potential landings. Conversion factors by size group are better known for *E. pacifica*; less known for *T. spinifera*, although limited raw data are available from Summers (1993) on *T. spinifera* sampled off British Columbia, Canada. Work is planned at the NMFS/NWFSC Newport Lab to refine standard length to fresh wet weight conversions for both species, but results are still pending as of this writing.

Most krill sampled by nets are larvae and early juveniles, with the proportion of adults (fishable stock) varying with sampling depth, time, season, year, and geographical area. Brinton and Townsend (2003) reported that off southern California, decadal averages (1950-2002) of the proportion of adults to the rest of the sampled population (spring nighttime samples) ranged from 1.7-13 percent (mean 7; s.d. =4). Off Oregon, Peterson and Feinberg[4] report about 3 times the overall average volume densities of *E. pacifica* than off California. The Ohman and Townsend data (Table 2) show an average of 1,518 individuals 1000 m^{-3} off central and southern California in cool water years. Off Oregon, during generally cooler years 2001-2004, the Peterson and Feinberg average was 3,300 individuals 1000 m^{-3}, of which 20-78 percent were adults. According to Brinton and Townsend (2003), area densities of *E. pacifica* along southern California CalCOFI station lines 77-93 averaged ~1,210 individuals under each square meter of sampled ocean during cool years. This would suggests an average density of roughly 85 adults m^{-2}, given a proportion of 7 percent adults, which compares with a density of 137 adults m^{-2} off Oregon (Table 3- 3). Researchers to the north may be more consistently sampling aggregated adult individuals in shelf-break areas, whereas CalCOFI may be more consistently sampling dispersed individuals (including a greater proportion of calyptopes, furcilia and juveniles) over a wider sampling area. But to some extent, differences could be real, as net California Current surface flow is thought to transport many larvae predominately southward, and southern California Bight circulation patterns favor retainment or accumulation of larvae and juveniles there. Larger juveniles and adults, which undergo vertical migration, can take better advantage of subsurface, northerly-flowing currents during the day.

3.1.3.5 Research Needs

3.1.3.5.1 Need for Standardizing Biomass Assessment Methodology

No coordinated coastwide survey, especially one using the recommended combination of multi-beam acoustics technology and standardized net sampling, has ever been undertaken to assess U.S. Pacific Coast krill. The assessment and measurement of krill abundance presents challenges to both existing sonar and net collecting technology and to mathematical modeling (Brinton and Townsend 1981; Pitcher 1995, Macaulay 1995). Estimating krill biomass cannot be done using standard fisheries acoustics techniques, most of which are designed for larger fin fish and higher target strengths. Krill bioacoustics involve careful selection of equipment, frequencies, target identification, calibration of gear, and consideration of measurement error. Even with scrupulous calibration and accurate information on the reflective properties of individual krill, the acoustic signal can change greatly with the orientation of the animals and condition (i.e., lipid content). Nonetheless, multibeam hydroacoustic surveys appear to offer the best solution for assessing abundance and distribution over large areas.

Net sampling, which has its own set of biases, is usually combined with acoustic sampling to obtain demographic, physiological, and relative density estimates. Obtaining a representative sample can be confounded by the varying net-avoidance abilities of different krill species and life phases, abilities that change with light level, water clarity, net speed and type, and hour of day. Daily day/night vertical migration of krill from the depths to the surface can further confound the interpretation of net sampling data. When simultaneous assessment methods are used, density estimates for a given krill aggregation using direct visual counts, net sampling and hydroacoustics often vary considerably. For accurate determinations to be made, various artificial variables need to be identified and krill estimates subsequently corrected, although a standard for this kind of correction has been difficult to establish. Even in recent times, the mechanisms that affect and determine distribution and density of krill are still under discussion in most cases (Siegel 2000). While estimating density or abundance using nets is prone to bias, standardized net sampling is still very important for obtaining information on species, life phase, and their relative densities which can seldom if ever be obtained from acoustics alone.

Standardization of collecting and processing methods used in surveying California Current krill is needed so that net collection and acoustic data are comparable and can be combined for different geographic areas. This would include:

- A meeting among a team of krill bioacoustic experts to decide on and develop standardized methodology for calibrating, measuring, surveying and interpreting zooplankton acoustic backscatter for the primary purpose of estimating distribution and biomass of both species in the West Coast EEZ, and integrating with net collection data.
- Standardization of krill body length to weight/carbon conversion to wet fresh weight factors by krill species and size group is needed for better and more consistent biomass conversions.
- Expert agreement as to the spatial bounds of primary krill habitat from which density and subsequent biomass conversions can be expanded to obtain initial estimates of biomass of *E. pacifica* and *T. spinifera* standing stocks.
- Analyses (and scientific agreement) to determine which krill life phase of what species might best serve as a proxy of adult abundance in future sampling.
- Lab physiological experiments to refine estimates of productivity, growth and turn-over rates.

Modeling krill population dynamics is also subject to considerable uncertainty, especially with regard to recruitment, individual and population rates of growth, mortality, and the effects of swarming behavior. Krill recruitment and distribution within the California Current system is thought to be strongly influenced by environmental factors (e.g., the position of frontal systems, and changes in intensity and direction of major currents and ocean forcing) as well as behavioral adaptations by krill themselves, including a strong tendency to aggregate in layers and in schools, swarms and patches. Vertical migration may be a mechanism by which krill effectively shuttle between multidirectional surface and subsurface currents in order to maintain their populations in highly productive core areas (and to separate developmental stages). Offshore Ekman transport via upwelling plumes, jets, and filaments is thought to contribute to large losses from the system (especially larvae), but this transport may also serve as a mechanism to genetically link a substock with another downstream, allowing for greater genetic diversity. Also, in addition to changes in the physical environment, inter-annual variability in abundance may also be affected by changes in predation pressure.

3.1.3.5.2 Need for Probabilistic and Ecosystem Modeling

Because of the large range of uncertainty concerning input parameters, one option would be to take a probabilistic modeling approach for determining the likelihood of safe harvest occurring. The model would estimate the probability of a highly productive krill year occurring, when a harvest of either or both species might be made with acceptably low risk of harm. Certain very cool, biologically rich oceanographic years might produce adequate surplus production (beyond predator and system needs) to support limited amounts of removals, but presumably these events (with probabilities greater than zero), would be relatively rare. The likelihood of this fishable surplus occurring could be estimated by using probability density functions for biomass, productivity, and predator demand in the following or similar model equation

$$Y = K * (r - M) - P$$

where Y is krill yield, K is krill biomass, r is the instantaneous krill growth rate, P is predation from predators, and M is natural mortality other than predator removals (R. Hewitt, NMFS, SWFSC La Jolla, CA; A. Leising, NMFS, SWFSC Pacific Grove, CA, pers. commun. 6/10/05). For each parameter, instead of a single value being specified (for the most part these values are poorly known), probability distributions would be specified that would allow for uncertainty. At the time of this writing, starting values or suggested bounds for these parameters to initiate computer runs were not yet available. Further work to run Monte Carlo simulations and obtain the probability distributions is still pending assignment of resources. Potential data sources for bounding estimates for this model include: M for *E. pacifica* (Brinton 1976); Siegel and Nicol (2000) citing Jarre-Teichmann and data from Brinton (1976) ; K - M. Ohman, E. Brinton, A. Townsend, SIO, La Jolla, CA; W.T. Peterson NMFS , NWFSC and Leah Feinberg, Oregon State University, Newport, OR; *r – E. pacifica* (Brinton 1976); Ross 1982; P - John Field, NMFS, Santa Cruz, Ca; krill consumption rates, Don Croll, UC Santa Cruz.

Ecosystem modeling provides another potential management tool for looking at possible harvest impacts on krill and predator stocks. Field et al (2001) constructed a mass balance snapshot of ecosystem consumption and production rates in the Northeast Pacific Ecosystem; krill being an important component of the model. Additional work has been provided by J. Field (NMFS,SWFSC Santa Cruz, CA unpub. pers. commun. 6/2005) in collaboration with Robert Francis, Kerim Aydin, and Sarah Gaichas (doing similar work in the Gulf of Alaska and Bering Sea). The modeling framework uses Ecopath with Ecosim and a static, mass-balance snapshot of energy flow through the system where the production of a prey species is more or less equal to the consumption of that species by predation. Ecosim is a dynamic model that turns these properties into a series of rates that are consumption-based, and the main factors that change abundance are food availability and predation. Top-down estimates of consumption requirements for upper trophic level predators are derived and calibrated to the extent possible using existing assessments of plankton and nektonic standing stocks and productivity.

Field[b] recently described an approach using ecosystem modeling as a tool for evaluating harvest impacts. Preliminary simulations were run of a krill harvest of 300,000 mt/yr (roughly equivalent to the scale of the Pacific hake fishery) and the potential impacts on krill stocks and krill predators. The response was an average decline of 5 percent in krill stocks (with a range of roughly 3 to 14 percent), and an average decline of 2 to 4 percent (range 1 to 8 percent) in most commercially important predators of krill (coastal pelagics, hake and rockfish). However, certain adjustments are needed, including a better range of estimates for both predator and krill standing stocks, as well as expansion of the Eastern North Pacific Ecosystem Ecopath/Ecosim Model to include the entire West Coast EEZ. To apply a derivation of this model to estimate effects of various harvest levels off the West Coast, the following items are needed:

- More reliable data on predator abundance (a problem with existing "top-down" models is that the high demand estimated for krill predators often does not agree well with available estimates of krill biomass, and this may be due to overestimates of predator standing stocks);

- 'Bottom-up' runs (based on rough estimates of adult krill biomass from observed krill densities) are to compare with 'top down' runs; and

- Council/NMFS resources (funding, staff time of 6 mo-1 yr) to assemble additional data, run the models, and document the results.

Resulting sustainable yield estimates suitable for use in establishing quotas or total allowable catches through such modeling also would need to be used in conjunction with other management approaches, such as area closures, to ensure adequate protection of species that are dependent on or sensitive to the abundance of krill or which could be directly affected through fishery interactions.

3.2 Role of Krill in the Ecosystem off the West Coast

3.2.1 Importance as Forage

Krill provide a critical link in oceanic food webs between phytoplankton food and upper level predators, many of which are commercially important fish species and ecologically important protected marine mammals and birds (see Appendix B for a complete description of species listed as endangered and threatened that occur in areas in which krill also occur and that may be

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[b] Presentation, California Current Krill Meeting, June 6, 2005, NOAA, NMFS, Southwest Fisheries Science Center, La Jolla, CA 92037. J. Field, K. Aydin, R. Francis and S. Gaichas. "Modeling Northeast Pacific Ecosystems."

dependent on krill to some degree). As major California Current herbivores, krill act as particularly efficient conduits of nutrients and primary production from the upwelling zone off the coast to the higher trophic levels of the broader marine ecosystem at large, as well as a buffer against the possible development of a degraded ocean system that might result from a buildup of excessive algal blooms in our coastal waters (Bakun and Weeks 2004). Some contend that the removal of apex predators such as large whales in the previous century of whaling is thought to have increased the availability of krill to other consumers in the North Pacific, but whatever 'surplus' that resulted has already been absorbed into the system. Furthermore, the dynamics of this shift are difficult to understand even in hindsight, especially against a backdrop of a host of other changes (environmental and man-induced) that have taken place in the North Pacific over the last 60 years which may have affected the energy flow dynamics within the system. Intensive, direct harvesting of such a pivotal component in the food web would undoubtedly have ecological impacts on the stability of our current trophic system, especially regional systems. Thus the possible extent of these impacts needs to be critically evaluated if large-scale fisheries are contemplated (Pitcher and Chuenpagdee 1995). Possible impacts could include:

- Negative impacts on krill-dependent predators
- Subsequent lower abundance of commercial fish and squid stocks
- Reduced food levels for federally protected marine mammals and birds
- Algal blooms of unharvested phytoplankton, whose growth in nutrient-rich upwelling systems like the California Current may be held in check largely by grazers.
- Degraded ocean conditions caused by unutilized phytoplankton biomass sinking to the sea floor, resulting in thick accumulations of deposited unoxidized organic matter with low or non-existent dissolved oxygen concentrations (Bakun and Weeks 2004) fed by nutrient rich eastern boundary current waters
- Loss of associated goods and services that depend on our regional ecosystem resources and quality.

As with other CPS, California Current krill are eaten by a number of predators, but their importance as forage may vary from predator to predator. Individual consumption rates for even the most krill-dependent species have been difficult to obtain, and almost nothing is known about the extent to which krill predators can switch to other prey.

Within the U.S. Pacific Coast EEZ, *E. pacifica* and/or *T. spinifera* are preyed upon by market squid, *Loligo opalescens*; octopus, *Octopus rubescens* ; Pacific hake, *Merluccius productus*; Pacific herring, *Clupea harengus*; spiny dogfish, *Squalus acanthias*; blue shark, *Prionace glauca*; sablefish, *Anoplopoma fimbria*; myctophids (family: Myctophidae); jack mackerel, *Trachurus symmetricus*; various juvenile and adult rockfishes, *Sebastes spp.*, which prey on eggs, larvae and adult krill; various flatfishes (e.g., Pacific sanddab, *Citharichthys sordidus*, slender sole, *Lyopsetta exilis*; Pacific halibut, *Hypoglossus stenolepis*; Pacific salmon *Oncorhynchus* spp.; albacore, *Thunnus alalunga*; humpback whale, *Megaptera novaeangliae*; blue whale, *Balaenoptera musculus*; Grey whale, *Eschrichtius robustus*; and various seabirds, especially Cassin's auklets, *Ptychoramphus aleuticus*; sooty shearwater, *Puffinus griseus*; and common murre, *Uria aalge* (Phillips 1964; Alversen and Larkins 1969; Gotshall 1969; Alton and Nelson 1970; Pinkas et al. 1971; Cailliet 1972; Manuwal 1974; Tyler and Pearcy 1975; Baltz and Morejohn 1977; Jones and Geen 1977; Karpov and Cailliet 1978; Vermeer 1981; Chu 1982; Peterson et al. 1982; Livingston 1983; Lorz et al. 1983; Brodeur and Pearcy 1984; Briggs et al. 1988; Chess et al. 1988; Smith and Adams 1988; Ainley and Boekelheide 1990; Ainley et al. 1990, 1996, 2005; Tanasichuk et al. 1991, 1999; Kiekeffer 1992; Reilly et al. 1992; Laidig et al. 1995; Tanasichuk 1995a,b, 1999; Ware and McFarlane 1995; Robinson 2000; Benson et al. 2002; Hewitt and Lipsky 2002).

Hake and Cassin's auklet appear so dependent on these species for food that the distributions of euphausiids determine those for hake and auklets (Vermeer 1981; Tanasichuk 1995a,b; Ainley et al. 1996; Briggs et al. 1988). Results of diet analyses conducted by Tanasichuk et al (1991) along the southWest Coast of Vancouver Island, Canada, showed that euphausiids *E. pacifica* and *T. spinifera* account for 93 and 64 percent of the daily ration for the dominant pelagic fish species, Pacific hake and spiny dogfish, respectively. Adult Pacific herring are known to feed exclusively on euphausiids. Additionally, *T. spinifera* has persisted as the preferred euphausiid prey of Pacific hake even though numbers of this species declined from representing 60 percent to 16 percent of the available population of adult euphausiids (Tanasichuk 1998). Krill of both species are known to comprise >50 percent of the diet of yellowtail rockfish, 21-50 percent of the diet of bocaccio and widow rockfish, 98 percent of the diet of hake in fall, and almost 97 percent of the diet of market squid (Reilly et al. 1992; Dark et al 1983; Pereyra et al 1969; Livingston 1983). Krill are also important food of salmon, preparatory to their ascending tributaries to spawn. When the rust-colored swarms appear off central California, commercial sport fishing boats, guided by flocks of feeding seabirds, seek krill swarms out in search of salmon, which feed heavily on krill from April to July, especially *T. spinifera* (Smith and Adams 1988; Adams 2001). Blue and humpback whales also converge on krill-rich upwelling centers such as off the Olympic Peninsula, Heceta Bank, around the Farallon Islands, Monterey Bay, and the Point Conception/Channel Islands area to feed on *T. spinfera* and *E. pacifica* during summer and fall, since at least the mid-1980s and early 1990s (Smith and Adams 1988; Schoenherr 1991; Fiedler et al. 1998, Croll et al. 1998).

Ecopath-Ecosim Modeling --- A model of the basic trophic components of the northern California Current ecosystem food web (Fig. 12) has been constructed by Field et al. (2001), with subsequent work by Field et al. 2005 using top-down biomass balance estimates of euphausiid production and consumption. Two time periods, representing different oceanographic regimes, were compared. Krill consumption by predators (and production) was estimated to be higher during the early 1960s (a cool, productive regime) when krill total annual production amounted to 207.3 g wet weight m^{-2}. It was lower during the mid-1990s (a warm regime characterized by low productivity) when krill total production amounted to 123.5 g wet weight m^{-2}.

The important role of these two species in the food web was also revealed in Jarre-Teichmann's (1995) trophic flow model of the British Columbia, Canada, shelf area. She found that krill appeared to constitute about 50 percent of the diet of herring (the dominant predator in that area), followed by hake, with other species being of minor importance (Table 3-5).

Table 3-5. Preliminary assessment of role of krill, *Thysanoessa spinifera* and *Euphausia pacifica* in the food web on the shelf off southern British Columbia, Canada (from Jarre-Teichmann 1995).

Fraction krill total diet (%)		Fraction total predation on krill (%) a/
51-100	Pacific hake	11
26-50	Herring	88
	Ocean perch	<0.1
0-25	Sablefish	0.2
	Sharks	0.2
	Marine birds	<0.1
	Baleen whales	<0.1
a/ initial estimates as of original publication, 1995.		

In a more recent modeling exercise, Field et al. estimated krill compose >10 percent of the diet by volume for 24 species groups and >50 percent of the diet for 9 species groups in the area between Cape Mendocino and Cape Flattery. Pacific hake and certain groundfishes (e.g., Pacific Ocean perch, canary rockfish, etc.) are particularly krill-dependent in this area. Baleen whales accounted for a relatively small portion of total krill consumption in the presented model, but since runs were based on 1960s data, may not reflect current consumption of baleen whales, which are now much more abundant in the EEZ and may account for up to 4 percent of total annual krill consumption (J. Field, NMFS, SWFSC, Santa Cruz, CA, pers. comm. 6/6/05). Model results for total annual consumption in the northern California Current by different forage assemblages are provided in Figure 13. Because the southern California Current area between Cape Mendocino and the Mexican border differs considerably to the northern area, this model or models need to be expanded for the entire EEZ, or constructed similarly for the area south of Cape Mendocino to the Mexico border.

One problem with existing top-down models is that the high demand estimated for krill predators often does not agree well with available estimates of krill biomass, and it is unclear as to whether this is due to an overestimate of predator biomass or underestimate of krill biomass or both. Better predator biomass estimates are needed.

3.2.2. Assessing Predator Requirements

In addition to Field et al's (2001, 2005) top-down estimates of consumption of major krill consumers mentioned above, Croll and Kudela (In press) have recently assessed current and pre-exploitation prey biomass requirements (kg individual^{-1} day^{-1}) for North Pacific large whale populations, obtaining a mean of estimates from five different prey requirement models. The mean estimates for the two major krill consumers, the blue and humpback whale, were 1120 (S.D.= 359, CV=0.32) and 532 kg (S.D.= 123, CV=0.23) individual^{-1} day^{-1}, respectively.

3.2.3. Krill Predator Harvest and Effects

Selective fishing pressure on krill predators may also have a dramatic but not easily predictable effect on the ecosystem. The Bering Sea ecosystem was thought to have been drastically changed by whaling, sealing and fishing efforts over the last 40 years (D. Bowen cited in Head (1997). Between the 1950s and 1970s, some 300,000 sperm and baleen whales were taken by whalers, together with large numbers of fur seals. Subsequently Pacific Ocean perch were fished to negligible levels, followed by herring and saith. When the "natural" fish species had gone, the area was taken over by pollock, and its levels increased from 2 million metric tons in the 70s to 16 million metric tons in the 80s, when it was 80 percent of the fish biomass. During this period the Stellar sea lion and harbor seal populations declined, perhaps in response to decreases in the abundance of capelin and sand lance, the latter being forage for the pollock. The suggestion is that the removal of the baleen whales may have led to an increase in zooplankton (and krill) levels, which in turn may have led to the proliferation of species that competed for forage with the sea lions and harbor seals.

3.2.4 Other Ecosystem Roles

In addition to the considerable importance as prey, largely unknown are the ecosystem needs for the huge detritus and effluvia contributed by krill populations. Krill casts, which contain nitrogen, carbon, Vitamin A and other materials, as well as associated chitinoclastic bacteria, form an important food source for other organisms (Ackman et al. 1970). Molting once every five days, krill can produce weight equal to seven times the dry weight produced in one year. Krill are also important contributors to the Vitamin A cycle in the sea, and can synthesize and store Vitamin A in high concentrations in their bodies, especially in the eyes. As major consumers of phytoplankton and other microplankton, krill also remove and recycle vast quantities of primary production from coastal waters. To what extent this grazing helps to hold algal and dinoflagellate blooms in check and aid in maintaining stability and health of the system is not known. This function may become increasingly important as harmful blooms increase along our coast with the increased fertilization from urban run-off. Euphausiids are also thought to influence carbon flux and food availability to pelagic and benthic organisms in the sea by physically fragmenting sinking organic particles called "marine snow," with the collective rapid beating of their appendages. Marine snow can comprise as much as 60 percent of water column particulate organic carbon, which would otherwise sink out of reach of the upper ocean where light is available for photosynthesis, and before bacteria could break down the organic matter into dissolved nutrients to sustain phytoplankton. The krill in their massive swarm numbers, especially in upwelling zones such as off the U.S. West Coast, are thus able to fragment much larger organic particles into smaller particles (which sink more slowly), a process thought to increase the residence time of carbon in the upper water column, enhancing attached bacterial production and helping to enrich the upper ocean zone (Goldthwait et al 2004).

3.3 Essential Fish Habitat

3.3.1 MSA Requirements

Section 303(a)(7) of the MSA requires that FMPs describe and identify EFH, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat. The MSA provides the following definition:

> "The term 'essential fish habitat' means those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." (16 U.S.C. § 1802 (10)).

NMFS has published regulations for implementation of the EFH requirements. These regulations (at 50 C.F.R. 600 Subpart J) provide additional interpretation of the definition of essential fish habitat:

> "'Waters' include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include aquatic areas historically used by fish where appropriate; 'substrate' includes sediment, hard bottom, structures underlying the waters, and associated biological communities; 'necessary' means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and 'spawning, breeding, feeding, or growth to maturity' covers a species' full life cycle."

The NMFS guidelines intended to assist councils in implementing the EFH provision of the M-SA set forth the following four broad tasks:

- Identify and describe EFH for all species managed under an FMP;
- Describe adverse impacts to EFH from fishing activities;
- Describe adverse impacts to EFH from non-fishing activities; and
- Recommend conservation and enhancement measures to minimize and mitigate the adverse impacts to EFH resulting from fishing and non-fishing related activities.

In sum, the EFH regulations require that EFH be described and identified within the U.S. EEZ for all life stages of each species in a fishery management unit if they occur within that zone. FMPs must describe EFH in text and/or tables and figures which provide information on the biological requirements for each life history stage of the species. An initial inventory of available environmental and fisheries data sources should be taken to compile information necessary to describe and identify EFH and to identify major species-specific habitat data gaps. The EFH regulations also suggest that where possible, FMPs should identify Habitat Areas of Particular Concern (HAPCs) within EFH for habitats which satisfy the criteria of being 1) sensitive or vulnerable to environmental stress, 2) are rare, or are 3) particularly important ecologically.

The Council proposes that EFH be established consistent with option 2 below. The following discussion is provided to summarize the alternatives considered and presented to the public to solicit public comment.

3.3.2 Data Sources and Methods

Data and information to describe krill EFH were obtained primarily from the scientific literature, as well as through consultation with krill researchers (Appendix A) and examination of data on geographic catch densities off California for the years 1950-2002 provided by E. Brinton and A. Townsend, SIO, Pelagic Invertebrates Collection (pers. comm., La Jolla, CA 6/6/2005). The majority of these data are level 1 data, where all that is known is where a species occurs based on distribution data for all or part of the geographic range of the species (presence/absence). Some preliminary data are also available on aerial densities of relative abundance (Level 2, see SIO reference above). Little is known of growth, reproduction or survival rates within habitats (Level 3); or habitat-dependent production rates quantified by habitat quantities, qualities and specific locations (Level 4).

3.3.3 Description and Analysis of EFH Alternatives: Proposed Action and Options Considered

Option 1. Status Quo. Do not designate EFH.

Because Amendment 12 incorporated krill as a MUS in the CPS FMP; the option of not identifying EFH is not acceptable. The MSA requires designation of EFH for all MUS in FMPs.

Option 2. Adopt EFH as described below (Proposed Action)

The designation of essential habitat for krill is based on information about EFH for the two principal species. It was not possible at the time that this amendment was being developed to discern consistent differences in distribution of the various life stages, other than coastwide, the larvae of both species tend to occur closer to shore, often over the shelf. It is recommended that these designations be updated on final analysis and publication of the SIO 50-year time series of maps showing spatial densities of these and other euphausiid species in the CalCOFI sampling area (E. Brinton, SIO, unpub. data, personal commun. 6/8/05).

Isobaths (depth contours) are used below as outer boundaries of EFH, but only because they roughly approximate the outer bounds of reported densest concentrations of the populations, and because static boundaries are preferred for the legal definition of EFH. These contours also roughly form the outer boundaries of some of the major upwelling areas (though perhaps not some of the larger offshore jets), within which consistently high concentrations of phytoplankton occur (Fig. 15). The boundaries are not meant to imply the strict association of these highly dynamic macroplanktonic species with fixed bottom topography.

A review of the literature and available data on krill aggregating areas and reproductive swarms, with high densities of predators such as salmon, seabirds and large baleen whales, revealed certain krill-rich upwelling areas to be especially important. Dense krill swarms and predator aggregations are reported most consistently within the ocean boundaries of the following NOAA National Marine Sanctuaries (NMS): Olympic Coast NMS off Washington (Calambokidis 2004) and Cordell Bank NMS, Gulf of the Farallones NMS (Chess et al 1988; Smith and Adams 1988; Kieckhefer 1992; Schoenherr 1991; Adams 2001; Howard 2001) and Channel Islands NMS in California (Armsrong and Smith 1997; Fiedler et al. 1998; Croll et al 1998). (Fig. 14). Additionally, the following other high-density krill and krill predator areas have been reported: Heceta Bank and Cape Blanco areas, Oregon (Ainley et al. 2005; Ressler 2005; Tynan et al 2005) and Bodega Canyon (Howard 2001). A confluence within these areas of rich, upwelled unstratified water and topological features such as submarine canyons, banks, and island shelves may not only provide rich feeding areas for krill, but may also contain features necessary for krill patches to be exploited by baleen whales, fish and seabirds, by concentrating and trapping krill over the shelf as they attempt to descend to the depths during the day (Chess et al. 1988; Fieldler et al. 1998; Ressler et al. 2005)

After considering this information, the Council agreed to propose the following designations of EFH for krill.

Euphausia pacifica EFH (Fig. 16)

Larvae, juveniles and adults: From the baseline from which the shoreline is measured seaward to the 1000 fm (1,829 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 400 m deep, from the U.S.- Mexico north to the U.S.-Canada border (Fig. 16). Highest concentrations occur within the inner third of the EEZ, but can be advected into offshore waters in phytoplankton-rich upwelling jets (Fig. 15) that are known to occur seaward to the outer boundary of the EEZ and beyond.

Thysanoessa spinifera EFH (Fig. 17)

Larvae, juveniles and adults: From the baseline from which the shoreline is measured to the 500 fm (914 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 100 m deep. Largest concentrations in waters less than 200 m deep, although individuals, especially larvae and juveniles, can be found far seaward of the shelf, probably advected there by upwelling jets (Figs. 15, 17).

Other krill species

Larvae, juveniles and adults: From the baseline from which the shoreline is measured seaward to the 1000 fm (1,829 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 400 m deep, from the U.S.- Mexico north to the U.S.-Canada border. No biological, social or economic impacts are expected beyond administrative costs of reviewing federally regulated projects for potential impacts on this habitat, where krill and krill predators concentrate.

Option 3: Designate the full EEZ as EFH

There is little statistical basis for designating EFH beyond the areas identified above. However, it is conceivable that krill exist throughout the EEZ even if not in concentrations that support a forage role or that support reproduction or other life stages.

3.3.4 Habitat Areas of Particular Concern (HAPCs)

The Council considered the following HAPC options:

HAPC Option 1. Status Quo–Do not designate HAPCs

HAPC Option 2. Designate HAPC to consist of the ocean area within the boundaries of Cordell Bank, Gulf of the Farallones, Monterey Bay, Channel Islands, and Olympic Coast NMS. These sanctuaries encompass the most important consistently krill-rich areas around California islands as well as important submarine canyons, bank, shelf and slope areas (e.g., Gulf of the Farallones, Pescadero Canyon, Ascension Canyon, Monterey Bay Canyon area, Channel Islands).

HAPC Option 3. Designate HAPC for krill to consist of the ocean area within the boundaries of Cordell Bank, Gulf of the Farallones, Monterey Bay, Channel Islands and Olympic Coast NMS, and Heceta Bank area (east of longitude 125˚ 30' W Long, between 43˚50' and 44˚ 50' Lat), off Cape Blanco (east of longitude 125˚ 30' between 42˚20' and 43˚ 000' Lat), and the Bodega Canyon area as HAPCs. This is similar to Option 2, but also includes three additional known important krill areas outside of Sanctuary boundaries.

HAPC Option 4. Designate HAPC for krill to consist of the ocean area within the boundaries of Cordell Bank, Gulf of the Farallones, Monterey Bay, Channel Islands and Olympic Coast NMS as HAPCs and all other waters of the EEZ Federal coastal and island waters off Washington, Oregon and California out to 60 nm from shore. This would cover all the areas Option 1, the highest krill density areas in Option 2, and add other inshore island, shelf, bank and slope areas along the coast suspected of supporting high densities of krill and krill predators within the EEZ.

In the process of reviewing the literature and available data on habitat use and preferences of krill, an effort was made to determine specific areas within U.S. West Coast EEZ EFH that satisfied the criteria of being 1) sensitive or vulnerable to environmental stress, 2) rare, or 3) particularly important ecologically. As noted above, this included a review of the literature and available data on krill aggregating areas and reproductive swarms, with high densities of predators such as salmon, seabirds and large baleen whales, revealed certain krill-rich upwelling areas to be especially important.

The Council concluded that it was not necessary at this time to propose designation of any specific HAPC. All the prospective high quality areas identified in the literature review and meetings with scientists would be included in the proposed designations of EFH.

3.3.5 Affected Environment

The California Current marine ecosystem offshore Washington, Oregon and California is home to vast variety of fishery, seabird, marine mammal, and sea turtle resources, many of which depend on krill directly or indirectly to sustain their populations. These include groundfish species (shelf and slope rockfishes, Pacific whiting, flatfishes, sablefish, lingcod, greenlings, sturgeon; sharks; skates, rays); four species of Pacific salmon; steelhead; highly migratory pelagic species (tunas, marlin, swordfish, pelagic sharks, dorado); other relatively large pelagic fishes (louvar, oarfish, lancet fishes, escolar, oilfish, opah, saury, common mola, spearfish, sailfish, blue marlin, wahoo, bonito, black skipjack and others); small CPS (sardines, herring, anchovy, mackerels, smelts, and squid); marine mammals (California sea otter and various whales, porpoises and dolphins, sea lions, and seals); pelagic seabirds (including northern fulmar, brown pelican, albatrosses, shearwaters, loons, murres, auklets, storm petrels and others) (Leet et al. 2001).

The California Current system is particularly rich in microscopic organisms (diatoms, tintinnids and dinoflagellates) which form the base of the food chain, especially in areas where consistent ocean upwelling occurs, enhancing primary production. The California Current area is an eastern boundary current ecosystem, one of the most productive regions of the world. As with other eastern boundary current systems, primary production is not nutrient- limited except in extreme El Niño years because of a relatively constant supply of nutrients upwelled from the depths and supplemented by nutrients from estuarine and urban runoff. This rich supply of diatoms and other small plankters provides food for euphausiids and many other zooplanktonic organisms such as shrimps, copepods, ctenophores, chaetognaths, oceanic squids, salps, siphonophores, amphipods, heteropods, and various larval stages of invertebrates and fishes. Grazers like small coastal pelagic fishes and squid depend on this planktonic food supply, which in turn provide forage for larger species nearer the apex of the food chain. Certain seabirds and turtles and also baleen whales also depend on the euphausiid food supply, and many fishes, seabirds and toothed cetaceans feed on fishes that are plankton feeders.

Episodic oceanographic events such as El Niño (warm water incursion) and La Niña (cooler water incursion) may affect the occurrence and distribution of organisms and productivity of the system. Longer periods of certain ocean temperature regimes that persist for decades can also affect reproduction and recruitment of marine species (e.g., sardine, rockfish) for several generations and result in substantial changes in abundance over time (Leet et al. 2001). During episodic or persistent warm periods when cold water euphausiids decline or shift north, the more tropical species may become more abundant within the EEZ, along with some of the more tropical prey species upon which they feed. For example, pelagic red crab and the neritic warm-water euphausiid, *Nyctiphanes simplex,* may shift northward from Mexico waters, displacing *T. spinifera* from its usual habitat over the continental shelf off California and Oregon to the more northerly parts of its range.

3.3.5.1 Protected Species

The following list of endangered or threatened species, as determined by NMFS and USFWS, may be present in the action area:

Species		**Status**
Marine Mammals		
Blue whale *(Baleaenoptera musculus)*		Endangered
Fin whale *(Baleranoptera physalus)*		Endangered
Humpback whale (*Megaptera novaeangliae*)		Endangered
Sei whale (*Balaenoptera borealis*)		Endangered
Sperm whale (*Physeter macrocephalus*)		Endangered
Steller sea lion, eastern population (*Eumetopias jubatus*)		Threatened
Killer whales, southern resident population (*Orcinus orca*)		Endangered
Southern sea otter (*Enhydra lutris nereis*)		Threatened
Birds		
Short-tailed albatross (*Phoebastria albatrus*)		Endangered
California brown pelican (*Pelecanus occidentalis*)		Endangered
Marbled murrelet *(Brachyramphus marmoratus marmoratus)*		Threatened
Bald eagle *(Haliaeetus leucocephalus)*		Threatened
Western snowy plover *(Charadrius alexandrinus nivosus)*		Threatened
California least-tern *(Sternum antillarum browni)*		Endangered
Xantus's murrelet *(Synthliboramphus hypoleucus)*		Candidate
Sea turtles		
Leatherback turtle (*Dermochelys coriacea*)		Endangered
Loggerhead turtle (*Caretta caretta*)		Endangered
Olive Ridley (*Lepidochelys olivacea*)		Endangered/Threatened
Green Sea Turtle (*Chelonia mydas*)		Endangered/Threatened
Fish		
Green Sturgeon, southern DPS		Threatened
Tidewater goby *(Eucyclogobius newberryi)*		Threatened
Bull trout *(Salvelinus confluentus)*		Threatened
Santa Ana sucker *(Catostomus santaanae)*		Threatened
Salmonids		
Chinook (*Oncorhynchus tshawytscha*)	Puget Sound	Threatened
	Sacramento River winter	Endangered
	Snake River Fall	Threatened
	Snake River Spring/Summer	Threatened
	Lower Columbia River	Threatened
	Upper Willamette River	Threatened
	Upper Columbia River Spring	Endangered
	Central Valley Spring	Threatened
	Central California Coastal	Endangered
Chum (*Oncorhynchus keta*)	Hood Canal Summer Run	Threatened
	Columbia River	Threatened
Coho (*Oncorhynchus kistuch*)	Central California Coastal	Threatened
	S. Oregon/N. CA Coastal	Threatened
	Lower Columbia River	Threatened
Sockeye (*Oncorhynchus nerka*)	Snake River	Endangered
	Ozette Lake	Threatened
Steelhead (*Oncorhynchus mykiss*)	Southern California	Endangered
	South-Central California	Threatened
	Central California Coast	Threatened
	Upper Columbia River	Threatened

	Snake River Basin	Threatened
	Lower Columbia River	Threatened
	California Central Valley	Threatened
	Upper Williamette River	Threatened
	Middle Columbia River	Threatened
	Northern California	Threatened

A number of non-ESA listed marine mammals may also occur in the affected area, these include: northern fur seal, California sea lion, harbor seal, Guadalupe fur seal, northern elephant seal, bottlenose dolphin, Pacific white-sided dolphin, common dolphin, harbor porpoise, Dall's porpoise, and minke whale. These species, like all marine mammals, are protected under the MMPA. In addition, a number of non-ESA listed seabirds have been identified that forage on krill and therefore may be affected directly or indirectly by a krill fishery.

Critical habitat for ESA listed sea turtles and cetaceans has not been designated or proposed within the action area. Critical habitat for listed salmonids does not include marine waters and therefore it is not within the action area. However, critical habitat has been designated for Steller sea lions in California at and near the rookeries at Año Nuevo Island, Sugarloaf Island, and the southeast Farrallon Islands, which is a known area of high krill concentrations off the California coast.

3.4 Krill Fisheries

3.4.1 Existing Krill Fisheries: Global Perspective

There are at least six commercial fisheries that now harvest (or have harvested in the recent past) six different species of euphausiid. These are the fisheries for Antarctic krill (*E. superba*) fished in the Antarctic; for North Pacific krill (*E. pacifica*) fished off Japan and off western Canada; for E. nana, fished off the coast of Japan; for *Thysanoessa inermis* fished off the coast of Japan and off eastern Canada; and for *T. raschii* and *Meganyctiphanes norvegica*, which have been experimentally harvested off eastern Canada (Nicol and Endo 1999). The largest quantities of krill are harvested off Antarctica and Japan. The current world catch of all species of krill is over 150,000 tons per annum, although few fisheries are being exploited to their maximum theoretical potential. The size of the world krill harvest is currently limited by lack of demand, although some fisheries are being deliberately managed at low levels because of ecological concerns or to control prices (Nicol and Endo 1999).

3.4.2 Krill Product Uses and Markets

The products of the krill industry have been variously reviewed by Budzinski et al (1985), Eddie (1977), Everson (1977), Grantham (1977), Suzuki (1981), Suzuki and Shibata (1990), Nicol and Endo (1997, 1999), and most recently by Nicol et al. (2000) and Nicol and Foster (2003). Krill products are mostly used for the aquaculture and sport fishing bait market but considerable effort has also been put into developing products for human consumption, particularly from Antarctic krill. Krill products are also currently being promoted for pharmaceutical, industrial and the so-called ‘nutraceutical’ industry as a nutritional/health supplement.

The Japanese Antarctic krill fishery, which takes most of the current catch, produces four types of product: Fresh frozen (34 percent), boiled frozen (11 percent), peeled krill meat (23 percent) and meal (32 percent). Yields in the manufacture of these products are 80-90 percent for fresh frozen and boiled frozen, 8-17 percent for peeled krill and 10-15 percent for meal in 1995 (T. Ichi, cited by Nicol and Endo 1997).

3.4.2.1 Human Consumption

The use of krill for human consumption has been reviewed and the nutritional value of krill has been assessed (Suzuki and Shibata 1990; Nicol and Endo 1997). The Japanese Antarctic fishery produced boiled, frozen krill and peeled tail meat for human consumption and 43 percent of the catch is used for this market. All of the peeled tail meat is now frozen in blocks on board. Information on other nations’ Antarctic krill fisheries is not generally available. A small amount of *E. pacifica* caught off Japan is also used for human consumption. Although much effort in the past has gone into producing krill products for human consumption, there have been few recent developments in this area (Nicol and Endo 1997).

3.4.2.2 Bait for Recreational Fisheries

Approximately 70 percent of the fresh frozen portion of the Japanese Antarctic krill catch is sold whole as bait, and 10 percent of this is used as chum for sport fishing. Nicol and Endo (1997) citing Kuroda and Kotani, report there is little competition between Antarctic krill, *E. superba*, and *E. pacifica* used for sport fishing, because the smaller *E. pacifica* is used as chum (about 50 percent of the total catch), whereas the larger *E. superba* is mostly used as bait.

3.4.2.3 Aquarium food

A small quantity of Antarctic krill is freeze dried for the home aquarium market. An estimated 50 percent of the catch of *E. pacifica* from the British Columbia fishery is used as aquarium food (Nicol and Endo 1997).

3.4.2.4 Aquaculture

Currently most krill caught in all commercial fisheries is used for aquaculture feed. For Antarctic krill, 34 percent of the Japanese catch is fresh frozen, of which 20 percent is used for aquaculture and 32 percent is used to produce meal which is used in fish culture; 50 percent of the Japanese *E. pacifica* catch and much of the Canadian catch of this species is used as an ingredient in feed for fish culture (Nicol and Endo 1997). Krill provide a nutritious diet and can be used successfully as a source of protein, energy and flesh pigmenting carotenoids. Carotenoids are found in krill at around 30 ug g^{-1} and can deteriorate rapidly during storage if not refrigerated below 0º C. The Japanese *E. pacifica* catch destined for aquaculture is used in feed to add reddish color to the skin and meat of fishes such as bream, salmon, trout, yellowtail and others, since *E. pacifica* contains large amounts of carotenoid pigments, especially astaxanthin. Extracts from Antarctic krill have also been used as pigmenting agents for yellowtail (*Seriola quinqueradiata*) and coho salmon (*Oncorhynchus kisutch*). Japanese people perceive the color red as an indication of good luck, and they often choose red fish and shellfish for celebrations and holidays. Krill amino acids are thought to have growth-promoting properties (Storbakken 1988) and krill are known to stimulate both feeding and growth in some fish (Shimizu et al 1990). Diets supplemented with krill meal stimulated feeding behavior in sea bream (*Pagurus major*), an effect probably due to the presence of the amino acids proline, glycine and glucosamine. The growth promoting factors seem to be steroids located in the cephalothorax region, thus are available in non-muscle meal. The use of *E. pacifica* as a food source has also contributed to increased disease resistance in hatchery reared salmon smolts (Haig-Brown 1994). This has been attributed to the early development of the immune system when using krill as a food source. Krill-fed salmon were also found to have a superior taste and did not significantly accumulate fluoride from the krill exoskeletons in their flesh. Krill products are also thought to be a good source of minerals for aquatic animals. Rainbow trout feeds containing krill as the principal protein source has led to significantly less dorsal fin erosion than those fed a fish meal based control food (Nicol at al 2000).

3.4.2.5 Autoproteolytic precipitates

Krill precipitate is produced using autoproteolysis, making use of krill's high level of proteolytic enzymes to produce a high yield (80 percent protein recovery) krill concentrate or precipitate. The final product has a very low fluoride content (< 29 mg F kg^{-1}), a protein content of 18-22 percent, fat less than 7 percent and a high level of carotenoid pigments. This product is used mainly as a colorant and flavourant additive to fish feeds and other products for human consumption.

3.4.2.6 Biochemical use/ food additive/ health supplement

A freeze-dried krill concentrate is prepared from peeled tail meat and marketed as a food additive and health food supplement. It is promoted as having a major revitalizing effect on the body, with a high n-3 fatty acid content, moderate caloric content, high nutritional value, and easy to digest. It is advertised by the manufacturers to be an important source of antioxidants and minerals required to prevent dental cavities and osteoporosis and have anti-aging properties. It is promoted as being 100 percent natural and free of any side effects, even when taken at higher doses, and low in contaminants such as PCBs. Krill oil, sold in gel caps, is also sold and marketed as a clean, pure source of special antioxidants not found in other products and having a higher content of Omega-3 fatty acids than other fish oils. It purportedly maintains healthy heart, joints and even regulates symptoms of premenstrual syndrome (Aquasource Products 2005). It is anticipated that this market, while probably expanding, requires relatively low volumes of high quality krill product compared to the aquaculture feed and supplement market (S. Nicol, Australian Antarctic Division, Tasmania, Australia, pers. commun, 21 Mar 2005, La Jolla, CA.) In addition, a Chilean company recently announced (Aquafeed.com, 5/17/05) that it has launched a patent for assisting in calcium intake and deposition on bones for helping osteoporosis prevention and cure through a combination of krill and salmon byproducts with other specific ingredients. It is not known if this product has in fact cleared all regulatory hurdles for sale. The claim is that this new dietary nutraceutical organic supplement is a rich source of calcium and fluorine. It would be available in a pate form for direct human consumption. As with other additives, it is unlikely that this product would establish a very large market for krill or krill products in the near term.

3.4.3 Potential for Market Expansion

Nicol and Foster (2003) reviewed recent trends in the fishery for Antarctic krill, and also speculated on possible expansion of krill fisheries worldwide, examining records of krill patents lodged by year and country of origin. Fisheries for krill have shown much potential for expansion, yet have not reached anticipated levels. The slow development of fishing for krill over the years has allowed environmental considerations to be taken into account when developing management strategies. The fishery for Antarctic krill has been relatively stable for a decade at 100,000 tons per year; the Japanese coastal krill fisheries are probably near capacity at ~ 70,000 tons per year (Endo 2000); and the British Columbia fishery has been essentially capped at 500 tons per year. Nonetheless, commercial focus on products derived from krill has continued to develop, with interest in aquaculture, pharmaceutical and medical products apparently overtaking those for human consumption.

By all appearances the market for krill products is rapidly growing. In terms of demand, new growth is likely to come from the aquaculture industry and the pharmaceutical industries. The aquaculture industry has been increasingly pursuing natural food additive sources to enhance flesh color as well as promote rapid and healthy growth of cultured fish and invertebrates. Aquaculture itself is a growing and important industry in the U.S. With the expected growth in demand for new and improved aquaculture feeds and supplements, as well as other sources of demand, it is reasonable to assume that demand for krill sources closer to aquaculture operations on the West Coast will increase.

In addition, krill oils are currently the subject of expanding markets in the nutraceutical, cosmetic and pharmaceutical industries. This growth in demand appears to be being met by significant investment in harvest capacity and new technologies to catch and process krill. As reported at the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) annual meeting in October, seven Dutch-owned pair trawlers, along with vessels from another seven countries are planning to enter the Antarctic krill fishery as well in attempt to capitalize on the growing industry. Also, recently a Norwegian company that fishes for krill in the Southern Ocean invested 100 million dollars in the purchase and rebuilding of a factory trawler previously used to harvest hake to allow it to harvest krill in the Southern Ocean at levels previously unattainable. Under this new technology, krill is being caught using a pumping system that allows for higher catch rates and reduces product deterioration. CCAMLR's scientific body has recognized that with these new economic and technological drivers are in place, the fishery could significantly transform in the near future. Lack of comprehensive information about the characteristics and use of these harvesting methods is hampering relevant CCAMLR bodies from assessing the potential effects of these developments on the Southern

Ocean marine ecosystem. Similar concerns for potential impacts to the ecosystem would exist if a krill fishery were to take place in the California Current.

3.5 Existing Management of Krill Fisheries off the West Coast

3.5.1 California

There has never been a krill fishery in California. California imposed a ban on landing and krill fishing in State waters in 2000.

3.5.2 Oregon

There has never been a krill fishery in Oregon. In 2003, Oregon imposed a ban on landing of krill by State-registered vessels, and banned krill fishing in State waters as well.

3.5.3 Washington

There has never been a krill fishery in Washington. Under Washington law, it is unlawful to deliver krill taken for commercial purposes from state or offshore waters into Washington and it is unlawful to possess krill taken for commercial purposes. It also is unlawful to traffic in krill.

3.5.4 Federal Regulations

There are currently no Federal regulations constraining krill fisheries off the West Coast. As directed by section 305(a) of the MSA, NMFS has published a national list of fisheries at 50 CFR 600.725. The list of fisheries identifies fisheries that existed at the time of the rule. Under the list of fishery regulations, a person is prohibited from fishing in an unlisted fishery. An individual who wanted to engage in "unlisted" fishing activities could notify the appropriate regional fishery management council (regional council) of the intent to use a gear or participate in a fishery not on the list. Ninety days after such notification, the individual could use the gear or participate in that fishery as proposed unless the regional council has proposed regulatory action to prohibit or otherwise control the use of the gear or participation in the fishery (e.g., through emergency or interim regulations). This provides regional councils with an opportunity to take action in the event a new fishery is proposed that might pose new fishery management problems. A general category of "fishing with trawl gear" for unspecified species was among the fisheries listed by NMFS for waters under the jurisdiction of the Council. Thus, someone wanting to engage in fishing for krill with trawl gear (the principal gear used in other krill fisheries) off the West Coast would not need any permits from NMFS and would be subject only to state controls in states where the catch would be landed. Someone wanting to engage in krill fishing with other gear (e.g., purse seine gear) would have to notify the Council 90 days in advance. The Council would then have opportunity to advise NMFS whether to control the activity or allow it as proposed. No such proposals have yet been directed to the Council. Thus, it appears that this rule would not constrain or prevent a trawl fishery for krill at this time.

3.6 Krill Fisheries and Management in Other Areas – Lessons Learned

Krill was little known until the middle of the nineteenth century, and then mainly as a food item found in the stomachs of whales. The first krill fishing was likely done by Mediterranean fishermen who harvested daytime surface swarms of krill for use as bait in the mid to late 1800s. Krill was promoted as a food alternative during World War II by the British (Haig-Brown 1994), and in the late 1960s and early 1970s, commercial fishing began in Antarctic waters and in the North Pacific off Japan and British Columbia, Canada. Exploratory and scientific permit fishing also began in the early 1970s off eastern Canada in the Gulf of St. Lawrence.

The following is a brief description of each species:

Euphausia superba (Antarctic krill) is one of the bigger species, growing to a maximum size of 6.5cm and weighing up to 2g. Antarctic krill grow to their maximum size over a period of approximately 3-5 years. The fishery concentrates on the larger adults in the 40-65mm size range. Antarctic krill occurs throughout most of the waters south of the Antarctic Convergence but is most abundant closer to the Antarctic continent and around some of the Antarctic and sub Antarctic islands. It has been commercially harvested all around the Antarctic although the current fishery concentrates in the South Atlantic with summer fisheries along the Antarctic Peninsula and winter fisheries around South Georgia Island (Miller 1991).

E. pacifica is commercially harvested off the coast of Japan (Odate 1979; Odate 1991) and off the coast of British Columbia, Canada (Haig-Brown 1994).

Euphausia nana, closely related to *E. pacifica*, is only found in the waters off southern Japan and in the East China Sea. *E. nana* reaches a total length of 12mm and is harvested commercially off the Japanese coast (Hirota and Kohno 1992).

Thysanoessa inermis is found in the North Pacific and in the North Atlantic, particularly in the colder waters but does not breed north of 65ºN-70ºN. It reaches a length of 30mm. It has been commercially harvested in the Japanese coastal zone (Kotori 1994) and in the Gulf of St. Lawrence, Canada (Runge and Joly 1995).

Thysanoessa raschii is found in the North Pacific and in the North Atlantic, particularly in the colder waters and in Arctic regions. It was commercially harvested on an experimental basis in the Gulf of St. Lawrence, Canada (Runge and Joly 1995). It reaches a length of 25mm.

Meganyctiphanes norvegica is found over a large climatic range, from the subarctic in the waters surrounding Greenland, Iceland and Norway to the warmer waters of Cape Hatteras in the West and the Mediterranean in the East (Mauchline 1969). It has been commercially harvested in the Gulf of St. Lawrence and there was a proposal to fish for this species on the Scotian Shelf, Eastern Canada in 1995 (Runge and Joly 1995). Small scale harvesting of *M. norvegica* has also occurred in the Mediterranean (Fisher et al. 1953). *M. norvegica* is a medium-sized krill reaching a total length of over 40mm.

3.6.1 Antarctic Krill (*Euphausia superba)* and the CCAMLR Management Approach

Nicol (1995), Nicol and Endo (1997), Kock (2000) and others have summarized the development of the Antarctic krill fishing industry. Krill fishing on a commercial scale started in the 1972/73 season. Results of scientific exploration revealed the size of the krill resource, and interest grew in exploiting the so-called "surplus" krill left remaining after removal of their chief predators— baleen whales— by commercial exploitation. Another important factor in the development of the fishery was the declaration of 200 mile Exclusive Economic Zones in the late 1970s, which prompted distant water fishing nations to turn to international waters for new fishing grounds. The fishery soon concentrated in localized areas in the Atlantic Ocean, with the main fishing grounds to the east of South Georgia, around the South Orkney Islands and off the north coast of the South Shetland Islands. After peaking at more than 500,000 mt in 1981/82, catches dropped substantially because of problems in processing krill and more effort being diverted to finfishing. From 1986/87 to 1990/91, annual catches stabilized at between 350,000 and 400,000 mt, which was about 13 percent of the world catch of crustaceans. When economic factors forced the Russian fleet to stop fishing, catches declined dramatically after 1991/92 to about 80 000 mt per annum. Since then, Chile has also stopped fishing for krill. The current krill catch is in the range of 90,000–100,000 mt per year. The South Orkney Islands and the Antarctic Peninsula region are usually fished in summer, while the South Georgia fishing grounds are mainly fished in winter, when the more southerly grounds are covered by ice. The amount of krill harvested to date totals slightly more than 5.74 million mt, of which the former Soviet Union and two of its succeeding states (Russia and Ukraine) took almost 84 percent and Japan 14.5 percent. More than 90 percent of the catch was from the western part of the Atlantic Ocean area.

In the first 10 years of krill fishing, catches, in particular those made by vessels from countries of the former Soviet Union, were largely used for animal feed. In the mid-1980s, difficulties in processing krill were overcome. Today, most krill is processed for aquaculture feed, bait and human consumption. Its use in aquaculture and its potential in biochemical products is increasing interest in krill fisheries.

CCAMLR manages the Antarctic krill fishery; the system is considered the most sophisticated and comprehensive of krill management schemes. It addresses CCAMLR's Article II objectives to 1) manage fisheries so harvested stocks maintain stable recruitment, 2) maintain ecological links between harvested and dependent species, and 3) prevent changes that cannot be reversed within 20-30 years.

In managing krill, it was concluded that an MSY model was inappropriate to set adequate catch levels of krill, since it assumes stability in natural systems, considers the exploited stock as coming from a single species, and relies on a predictable relationship between stock size/growth and fishing effort. Furthermore, MSY does not account for interactions between exploited stocks and other species, which is crucial to address the CCAMLR objectives.

In 1990, CCAMLR's Scientific Committee identified general operational management principles for setting catch limits for krill that were subsequently endorsed by the Commission. These were to 1) aim at keeping krill biomass at a level higher than would be the case for single-species harvesting considerations, and, in so doing, to ensure sufficient escapement of krill to meet the reasonable requirements of predators; 2) focus on the lowest biomass that might occur over a future period, rather on the average biomass at the end of the period, as might be the case with a single-species context; and 3) ensure that any reduction of food to predators which may result from krill harvesting does not disproportionately affect land-breeding predators with restricted foraging ranges as compared to predators in pelagic habitats (CCAMLR 2004).

CCAMLR has approached krill management using a model that enables calculation of a precautionary catch limit, and a program to monitor the health of dependent species. The approach uses three primary elements described below:

The Krill Yield Model--A single species model is used to assess the potential yield available for the krill stock that has the lowest risk to the stock itself (Agnew 1997). Based on the approach of Beddington and Cooke (1983), the model projects the dynamics of a krill population over a period of time with random recruitment to establish the probability distribution of risk of population decline for a number of fixed harvesting strategies. The approach calculates the proportional value of γ in the formula

$$\text{Yield} = \gamma B_0 \quad 1$$

where B_0 is the estimated pre-exploitation biomass of the krill population. The modeling exercise can proceed in the absence of an estimate of B_0, since this is taken to be 1.0, and will yield a value of γ. To be applied in management so that a precautionary total allowable catch (TAC) can be set, an estimate of B_0 is required; this has been estimated from acoustic surveys, the most recent being carried out in 2000. Subsequent biomass assessments are not needed on a regular basis, because the model uses the pre-exploitation biomass estimate, plus various parameters (variation in population age structure, recruitment, mortality, etc), which can be refined over time. The higher level of uncertainty in any parameter, the more conservative the estimate of TAC.

Decision rule requirements--These involve straightforward decision rules for defining acceptable long-term catch from the yield model calculations.

- Rule 1: Choose $\gamma 1$ where probability of spawning stock biomass dropping below 20 percent of its median level in the absence of fishing, over a 20 year simulation, is <10 percent.

- Rule 2: Choose $\gamma 2$ where the median spawning stock biomass after 20 years is 75 percent of its median level in the absence of fishing.

- Rule 3: Select the lower of $\gamma 1$ and $\gamma 2$ for the calculation of krill yield.

Ecosystem monitoring--CCAMLR's Ecosystem Monitoring Program (CEMP) monitors predator species, and uses the information to differentiate between changes due to krill harvest, and due to environmental change. This monitoring provides ongoing feedback on trends in the ecosystem, so that management adjustments can be made in light of changes and needs of dependent species.

The yield model and its decision rules offer a method of setting precautionary catch limits which consider both the harvested species and its predators, when there is some uncertainty in the assessment of the stock. The system was developed in consultation with Convention members and arrived at by consensus. In general, the higher the level of uncertainty in any parameter, the more conservative will be the estimate of Total Allowable Catch (TAC). One of its advantages is that it sets a fixed catch for a 20-year period. Agnew (1997) reports that the choice of limits, especially the limit of 75 percent of unexploited biomass of Rule 2, is somewhat arbitrary, but Rule 1 limits are becoming accepted internationally as appropriate for a precautionary approach. And Rule 2 limits, along with the continued ecosystem monitoring, are considered by CCAMLR to be a pragmatic interim solution to the problem of estimating the escapement from the fishery required to maintain predator populations where data are lacking.

In addition to the model and decision rules, catch "triggers" have been established to enable managers to respond quickly to any rapid increases in the fishery, especially in areas that support dependent species. Currently, Antarctic krill catch limits amount to about 9 percent of the estimated biomass in two major statistical areas. These two areas, which together cover just over 51 percent of the CCAMLR Area, consist of the Atlantic sector of the Southern Ocean (Area 48 and its subareas) and in the South East Indian Ocean sector (area 58.4.1). In Atlantic Area 48, the overall precautionary catch limit has been set at 4 million tons; subdivided into regional limits of 0.832 million, 1.104 million, 1.056 million and 1.08 million tons for South Sandwich Islands (48.4), South Georgia (48.3), South Orkneys (48.2), and Antarctic Peninsula (48.1) subareas, respectively. These subareas, especially the Antarctic Peninsula and South Georgia, include large colonies and breeding sites of land-based krill predators, so that catch limits are also augmented by the provision that if the total catch in Area 48 in any fishing season exceeds a "trigger" level of 620,000mt (catches over the past decade have been relatively stable at around 100,000 t^{-yr}), the precautionary limits could be subdivided into even smaller management units following the advice from the Scientific Committee. This would allow the Commission to partition the overall limit into even smaller areas, for more effective management and protection of predator populations, in the event a rapid expansion of the fishery should occur. In the South Indian Ocean statistical area, the overall limit is set at 440,000 mt subdivided into 277,000 mt west of 115ºE, and 163 000 mt east of 115ºE, respectively.

3.6.2 Japan

The Japanese commercial fishery, which began in the mid 1940s, concentrates on highly visible daytime surface swarms in coastal waters. It operates without quotas to fulfill the needs of local aquiculture operations, and amounts to some 100,000 mt (Nicol 1997). There is external regulation by the number of licenses, the size of boats, and the duration of fishing effort and self-regulation, to keep the prices up. Of the three species commercially exploited in Japanese waters (*E. pacifica*, *E. nana*, and *T. inermis*), the catch of "Isada," or *E. pacifica*, is much larger than the other two and more important. The average annual catch of *E. pacifica* was 60,427 mt in the late

1980s and 1990s with a value of 1.5 to 3.6 billion yen. It is especially abundant in Sanriku waters, the sea area off northeastern Japan, where many endemic and migrant predators including pelagic and demersal fishes, marine mammals, seabirds and benthic organisms also depend on this species for food (Nicol and Endo 1997). Early in the fishery, a sand lance dip net fishing method (using a bow-mounted trawl with a small mesh size) was used when fishing conditions for sand lance were poor. In the late 1960s, increasing demand for food for sea bream culture and sportfishing bait caused the fishery to expand to the northern and southern coasts of Miyagi Prefecture, and in 1972 expanded to Ibaraki Prefecture and to the south. Thus the fishery which began in Miyagi Prefecture developed into an important fishery in the Sanriku and Joban coastal waters.

The fishery requires a license from a prefectural governor. Small boats (less than 20 t) are predominantly engaged in the fishery. One or two-boat seines are used in all prefectures except Miyagi, where both one-boat seines and bow-mounted trawls have been used. A bow-mounted trawl can only catch swarms with 8m of the surface, while the seines can catch subsurface swarms as deep as 150 m by using echo sounders to detect swarms. The fishing grounds are over the continental shelf (< 200m) within 10-20 m from shore.

The total annual catch of *E. pacifica* has increased steadily over the last 20 years, exceeding 40,000 mt in 1978, 80,000 mt in 1987, and 100, 000 mt in 1992. This increase followed the introduction of plastic containers in about 1975 and by the use of fish pumps in the 1980s. In 1993 the total catch decreased to 60,881 mt, when catch regulations were imposed in certain prefectures to obviate price declines (Nicol and Endo 1997).

For fishermen, the most important factor related to the fishery is the ability to predict the length of the fishing season and the area of occurrence of the fishery. The fishing ground is formed near the front between the coastal branch of the Oyashio Current and the coastal waters with optimal surface water temperatures of 7-9° C. Various researchers have classified various types of oceanographic conditions that influence optimum catches in the fishery.

E. pacifica fishery regulations are set separately for each prefecture. The license of the prefecture governor decides the fishing period, the time limit to come back to port, operation time, fishing area, boat size and other factors. Other regulations include total catch limit per season, and maximum number of plastic storage containers per boat per day. Fishermen regulate catches in order to keep the price high, collaborating with their counterparts in adjacent prefectures.

Thysanoessa inermis and *Euphausia nana* are two other species harvested in Japanese waters. *T. inermis* has been fished since the early 1970s along the western coasts of Hokkaido. Reproductive surface swarms of this species are fished during the day, usually from early March to early April. A spoon net, with a 1-m diameter and 3-4 m handle is used to catch the swarms. The price varies from 75 to more than 3,000 yen per kg. The yearly catch varies from several mt to 200 mt. The neritic species *E. nana* has been commercially fished also since the 1970s in Uwajima Bay, Ehime Prefecture, Shikoku. The yearly catch varies from 2,000 to 5,000 mt from 1981-1991, and two fishing methods are used. One is nighttime purse seining from March through July using a netting boat, a transport boat, and up to three light boats equipped with attracting lamps. The other method is a daytime seining operation during spring through early summer that uses two netting vessels, a boat with hydroacoustics to locate swarms, and a transport vessel. Landed *E. nana* is used as feed for red sea bream and the price is about 50 yen per kg (Nicol and Endo 1997).

3.6.3 British Columbia, Canada

The only krill fishery along the U.S.-Canada Pacific Coast exists in the Strait of Georgia, British Columbia (Fulton and Le Brasseur 1984; Nicol and Endo 1997). *E. pacifica* is typically one of the dominant species, accounting for over 70 percent of the euphausiid biomass where the commercial fishery occurs (Nicol and Endo 1997). Fishermen deploy fine mesh plankton trawl nets that are towed several meters below the surface after dusk. The catch is either frozen at sea on board the catcher vessel, or placed in totes and iced for transport to a land-based facility for further processing and freezing. Most of the product is used as a feed supplement in fish food for the fin fish aquaculture industry and for aquarium needs. There are also limited and developing markets for uses of euphausiids as a human food product in Canada and abroad. The Department of Fisheries and Oceans Canada conducts biomass surveys annually in the Strait of Georgia in the area of greatest harvest to monitor abundance and to ensure that the impact of the commercial harvest is negligible.

Two types of vessels participate: smaller freezer vessels whose catches are limited due to freezing capacity (5-6 t of krill a day) and larger vessels that land large quantities of krill for onshore processing and freezing (Nicol and Endo 1997). The catch must be frozen within 24 hrs to avoid a significant deterioration of product quality. The fishing season can be as short as 20 days (actual fishing days) and individual vessels may land as little as 32 mt in a season. Nets used have mouth areas of around 80 m^2, the trawl mouth is kept open by means of a beam and is buoyed to keep it from flipping when the ship turns. There are weights on the footline to maintain the net's shape. Fishing is carried out close to the surface - often less than 20 m deep and on moonless nights when the krill rise to the surface forming layers less than 10 m in vertical extent. The krill are located by echosounders. The larger vessels use a seine net and are usually out-of-season salmon fishing boats with no onboard freezing capacity. The presence of these vessels in the fishery is usually dependent on the success of the salmon fishery. If there has been a bad salmon catch, then krill are fished to increase revenues.

Information on the history of the British Columbia fishery has been summarized by Nicol and Endo (1997). It began on an experimental basis in 1972, confined to the Strait of Georgia and the east coast of Vancouver Island. Quotas were established in 1976 in response to concerns about harvesting an important forage species upon which salmon and other commercially important finfish depend. The annual catch was set at 500 mt with an open season from November to March to minimize the incidental catch of larval and juvenile fish and shrimp. This quota was reportedly derived from an estimate of the annual consumption of euphausiids by all predator species in the Strait of Georgia, and is 3 percent of this estimate. In 1983, participation in this fishery was restricted to those individuals who had applied for, and held, a certain category license, which was not subject to limited entry. Until 1985, annual landings were less than 200 mt, with fishing concentrated initially in Saanich Inlet, then Howe Sound and most recently in Jervis Inlet. Due to continued concentration of fishing effort in Jervis Inlet rather than the adjacent waters in the Strait of Georgia, separate inlet quotas were introduced in 1989. The annual TAC increased to 785 mt; 500 mt for the Strait of Georgia and 20 to 75 mt for each of the major mainland inlets.

In 1990, due to concerns of local stock overfishing, the overall annual quota was reduced again to 500 mt; 285 mt for the mainland inlets and 215 mt for the Strait of Georgia. That year, 56 licenses were issued, of which 17 reported landings of 530 mt for a landed value of CAD $415,000. This was the first year since the beginning of this fishery that the annual quota had been reached. Only 53 mt of euphausiids were reported landed in 1993 with a total landed value of CAD $41,000. This decline in landings from 381 mt reported in 1992 was a function of market conditions rather than any decline in krill stocks. Preliminary landings of euphausiids reported for 1994 were in excess of 300 mt, with a value of CAD $ 259,000, as markets stabilized somewhat from the previous year. The number of licenses issued for this fishery increased annually from 7 in 1983 to 56 in 1990, then declined to 45 in 1991. In 1993, licenses were limited to 25 vessels upon the advice of industry and because the annual quota was being taken by the current fleet. Only one vessel during 1993 and three vessels during 1994 reported euphausiid landings. Bycatch consists of larval and juvenile fish and myctophids (Lee 1995).

In late 1995, a workshop was held at the University of British Columbia on "Harvesting Krill: Ecological Impact, Assessment, Products and Markets " (Pitcher and Chuenpagdee 1995). The workshop dealt in some detail with the British Columbia euphausiid fishery, the importance of euphausiids to the coastal marine ecosystem, and improvements in assessments methods of the potential yield of British Columbia krill stocks. The Regional Executive Committee of the Canadian Department of Fisheries and Oceans has stated that as a matter of policy the region is not prepared to support additional developmental fisheries on forage species such as krill, and the 500 mt quota for the Strait of Georgia and mainland inlets is expected to remain fixed for the foreseeable future (Morrison 1995).

3.6.4 Atlantic Coast of Canada (Gulf of St. Lawrence Fishery and Scotian Shelf Permit Request)

Exploratory scientific fishing was started on the Atlantic coast of Canada in 1972 to locate large harvestable concentrations of krill (*Meganyctiphanes norvegica, Thysanoessa raschii* and *T. inermis*) in the Gulf of St. Lawrence (Nicol and Endo 1997). The estimated biomass of krill in two areas of the Gulf where the krill were most concentrated was 75,000 mt and an estimated catch rate for trawlers fishing a 100 m^2 mouth opening trawl was estimated to be 379 kg h^{-1} based on a biomass estimate of 1 g m^{-3}. The estimated potential for exploitation of all three krill species in the Gulf, based on an exploitation rate of 50 percent of the biomass, was 37 500 mt estimated in 1975 to be worth CAD $3.75 million (Sameoto 1975).

The first experimental, pre-commercial fishery to harvest krill was permitted in the Gulf of St. Lawrence in 1991. New acoustic studies determine the abundance of krill in the Gulf ranged from 400,000 mt to 1 million mt (Nicol and Endo 1997). It was determined that the allowable catch level of 300 mt would have a negligible effect on the krill populations and on the populations of natural predators on krill, but there was concern about the possible impacts of taking the whole of the catch from a restricted area, the effect on the populations of whales that feed in that area, and concern over the incidental bycatch, particularly of juvenile fishes. The Gulf fishery produced frozen krill and freeze dried krill for ornamental fishes and for public aquariums and freeze dried krill as an ingredient in salmon feed and as a flavourant for food for human consumption. But interest in this fishery declined and catches were quite low, and the fishery became inactive after 1998.

Another permit request was received in 1995 to fish 1,000 mt of krill (primarily *M. norvegica)* on the Scotian Shelf and Gulf of Maine, off Nova Scotia, Canada. The krill was to be used to produce a product to coat fish pellets to be fed to young salmon in fish farming. Concerns were voiced about effects on krill-dependent fish species of the region that have a major portion of krill in their diet. There was also concern over the significant by-catch of larval and juvenile forms of other commercial species that could be taken with the krill catch and possible interactions with populations of the endangered right whale. In 1998, Canada’s Minister of Fisheries and Oceans announced that he would not consider authorizing a fishery for krill (or any other untapped forage species) on the Atlantic Coast of Canada until more information was known about the effects on the food chain for harvesting forage species, and before an ecosystem approach and plan was developed.

4.0 PROPOSED ACTION AND ALTERNATIVES AND THEIR IMPACTS

4.1 Impacts of the Proposed Action (Alternative 2)

4.1.1 Effects on Status of Krill

This alternative would provide maximum protection for krill in the EEZ. The future productivity of krill would be affected only by variability in natural environmental conditions and events other than fishing. Essential fish habitat designations should support the conservation of krill at natural levels.

4.1.2 Effects on Other Fish Species

The alternative would likely provide benefits to, or at least prevent adverse effects on, other fish species by ensuring that krill fishing would not cause a decline in the availability of krill to other fish species.

4.1.3 Effects on Other Living Marine Resources

This alternative would likely provide benefits to, or at least prevent adverse effects on, other living marine resources by ensuring that fishing would not cause a decline in the availability of krill to these resources as well as preventing any direct interaction between the activities of krill fishing and these other living marine resources.

4.1.4 Effects on Other Fisheries

This alternative would likely provide benefits to other fisheries to the extent that the prohibition of fishing for krill protects other fish stocks that rely on krill directly or indirectly as forage from any adverse effects of krill stock reduction due to fishing.

4.1.5 Economic Effects

This alternative would provide benefits to existing fisheries and to eco-tourism businesses and entities involved in such activities (e.g. whale watching). It would preclude development of a fishery for krill and thus any potential economic benefits from such fishing.

The value of krill is associated with existing fisheries, and other living marine resources dependent on krill that generate revenue. Many target fish stocks and marine mammals are dependent on krill or are sensitive to the abundance and availability of krill. These organisms could be adversely affected by a krill fishery. For example, krill make up to 65 percent of the diet of California market squid, a species managed under the CPS FMP. Market squid are not only extremely important commercially off California (typically in the top three in value and tonnage in California; largest in 2005 in both volume and ex-vessel value at $31.6 million) but like krill, play a crucial role in the West Coast ecosystem acting as a major forage item for a variety of marine mammals, birds and fish. Further, there are eco-tourism businesses that provide services to non-consumptive resource users such as whale watching cruise companies. Some species of whales are dependent on krill abundance and availability and are more likely to be the subject of whale watching excursions when they occupy areas where krill concentrate. It is very possible that localized krill fishing could deplete or disrupt krill aggregations and thereby lessen the likelihood of whales foraging in such areas. This in turn could lower the demand for or value of whale watching cruises in these areas. Hoyt (2001) estimated that there were 101 operators that had some involvement with whale watching within Washington, Oregon and California and boat based and land based total whale watching expenditures were approximately $63 million and $21 million, respectively.

4.1.6 Effects on Data Collection

This alternative would have no benefits in terms of added data collection. However, the documentation for this action includes recommendations that may result in enhanced collaboration between researchers and in additional research directed at a better understanding of krill resources and their role in the environment.

4.1.7 Effects on Bycatch

This alternative would preclude the potential for bycatch that may occur by fishing for krill in the EEZ.

4.1.8 Effects on Habitat

This alternative would prevent any adverse impacts on habitat from fishing in the EEZ. Further, to the extent krill provide an ecosystem support function (see 3.2.4), the prohibition of krill fishing ensures that this function will be carried out to the maximum extent practicable in the natural environment.

It is not known if other types of fishing gear and techniques used in other federally managed fisheries (i.e. HMS, CPS, groundfish, and salmon) off the West Coast might adversely affect krill EFH. Midwater gear and techniques would not be expected to cause harm. In any event, the consultation process for looking at the effects of fishing on EFH under the regulations governing EFH administration should provide a mechanism for ensuring that any such impacts would be fully considered and mitigation would be sought for any adverse effects

4.1.9 Effects on Protected Species

This alternative would provide benefits to, or at least prevent adverse effects of krill fishing on protected species. Krill abundance and availability would not be affected by fishing and krill would be available as forage to protected species to the maximum extent practicable in the natural environment.

4.1.10 Administrative Considerations

This alternative would be relatively simple to carry out under existing procedures for implementing fishery management plans and amendments under the MSA. It would provide clarity to the public and facilitate enforcement by implementing a consistent regime off the West Coast. There is no krill fishing now that would be eliminated because California, Oregon, and Washington have krill landing prohibitions in place so there would not be adverse social impacts that would raise concerns.

4.1.11 Consistency with Management Objectives

This alternative would meet all the management objectives (see section 2.2).

It would ensure that, to the extent practicable, the stocks of krill off the West Coast are maintained within the bounds of natural variability and at maximum levels supported by environmental conditions. There would be no risk of fishing resulting in disruption of krill populations or their distribution and availability in the environment.

It would provide protection for key krill predator foraging areas (i.e., topographic and oceanographic features that consistently serve to concentrate krill and facilitate predator feeding). There would be no risk of fishing that would directly or indirectly affect the availability of krill to predators or would interact with the predators and disrupt their feeding patterns in key foraging areas.

It would provide a foundation for future research and data collection. Sections 3.1.3.1 and 3.1.3.5 contain a number of recommendations for further research and for collaboration among researchers to better understand the size and dynamics of krill populations off the West Coast and the relationship between krill and other resources off the West Coast. NMFS uses such recommendations to support funding of research proposals and to set priorities for research. Given the interest in krill, academic scientists also appear willing to collaborate with NMFS on krill research. The Council has urged NMFS to give high priority to such work.

4.2 Alternatives and Their Impacts

4.2.1 No Action (Alternative 1)

4.2.1.1 Effects on Status of Krill

This alternative would provide no protection for krill in the EEZ and would have the highest risk of adverse effects on the stock. There would be no limit on the amount of krill that could be harvested, nor on the times and areas in which harvest could occur.

4.2.1.2 Effects on Other Fish Species

This alternative would result in increased risk to other fish species by allowing fishing that could result in reduced abundance and availability of krill to fish resources dependent on or sensitive to such conditions. As there would be no limit on the amount of krill that could be harvested or on times and areas of harvest, the potential for adverse impacts would be substantial, especially in years in which environmental conditions might be less suitable for krill productivity.

4.2.1.3 Effects on Other Living Marine Resources

This alternative would result in increased risk to other living marine resources that are dependent on or sensitive to the abundance and availability of krill. Fishing could cause a decline in the availability of krill to these resources. Also, there could be a potential for direct interactions between krill fishing vessels and protected species if fishing were to occur in proximity to such species.

4.2.1.4 Effects on Other Fisheries

The effects on other fisheries would depend on the extent of krill fishing and the impact on other fish stocks that are harvested in these other fisheries. To the extent krill harvest resulted in lower abundance (numbers and/or size) of other target species, there would be adverse effects on these other fisheries.

4.2.1.5 Economic Effects

This alternative would result in increased risk to existing fisheries as well as to businesses that may supply fishing enterprises. As mentioned, a number of high-value fisheries, such as hake, rockfish, albacore and salmon are dependent upon krill. The average (1998-2005) total West Coast commercial fishing ex-vessel revenue for all federally managed species is approximately $262 million. Over half of this revenue, approximately $143 million, is generated from species that depend heavily on krill (Figure 15). The most recent recreational fisheries survey showed that the total expenditures of saltwater recreational anglers participating in Washington, Oregon and California combined comprised approximately $795 million (U.S. Dept. of Interior, 2001). Many highly prized and targeted recreational fish, such as rockfish and salmon, depend heavily on krill as a forage source. Also, eco-tourism businesses that provide services to non-consumptive users of other living marine resources (e.g., companies providing whale watching cruises) could be harmed if krill fishing resulted in changes in the abundance and distribution of such resources. For example, if krill fishing resulted in less frequent use of West Coast waters close to ports from which whale watching cruises depart, there would likely be less demand for whale watching cruise services. The extent to which this would occur would depend on the amount, timing and location of krill harvest. As there would be no krill harvest restrictions, this alternative would pose the greatest probability of economic harm in this area. Hoyt (2001) estimated that there were 101 operators that had some involvement with whale watching within Washington, Oregon and California and boat based and land based total whale watching expenditures were approximately $63 million and $21 million, respectively. On the other hand, this alternative could result in krill harvest and associated economic benefits. The value of the krill fishery off of British Columbia in the early 1990s, for example, ranged annually from CAD $41,000 to $415,000.

4.2.1.6 Effects on Data Collection

This alternative would have no effect on data collection and research. There would be no requirement for any krill fishing businesses to report or make their fishing available for observers.

4.2.1.7 Effects on Bycatch

This alternative would have the highest risk of bycatch. As no krill fishing in the EEZ has occurred in the past, there is no basis for determining the extent to which there would be a bycatch problem off the West Coast. However, krill concentrations that would attract fishing also are likely to attract other species (e.g., fish, marine mammals, seabirds); therefore, there is reason to expect that there would be bycatch at some level. In existing krill fisheries the bycatch of early life stages of fish has been of particular concern to scientists (Moreno, 1995). In the Antarctic krill fishery, there has been bycatch of fur seals, so much so that seal excluder devices have been proposed.

4.2.1.8 Effects on Habitat

This alternative would have the potential for adverse habitat impacts. While the likelihood that fishing gear would adversely affect habitat is low, the removal of krill may result in disrupting or even precluding krill from carrying out their ecosystem or habitat enhancement role (see 3.2.4).

4.2.1.9 Effects on Protected Species

This alternative has the potential to have significant adverse impacts on protected species of whales and seabirds. If fishing occurred in proximity to cetaceans or in areas in which cetaceans and seabirds would normally feed, then feeding patterns could be seriously disrupted. In the case of seabirds, this could be especially harmful given the need for forage supplies in close proximity to nesting areas during reproductive periods.

4.2.1.10 Administrative Considerations

This alternative has no administrative impacts or costs.

4.2.1.11 Consistency with Management Objectives (see section 2.2)

This alternative would not meet all the management objectives. Krill abundance and availability could be at risk due to new fishing enterprises. Key foraging areas for predators could be impacted by fishing. As with the proposed action, this action (as it would be based on this document and others that identify research needs) would support improved research into the abundance and dynamics of krill and associated resources.

4.2.2 Prohibit Krill Fishing but Establish Process for Allowing Future Fishing (Alternative 3)

This alternative adds krill to the species under management through the CPS FMP and would initially prohibit directed fishing for krill in the EEZ (i.e., OY would have been zero), but a procedure would be established by which krill fishing in the future could be permitted (subject to conditions). That procedure would involved such steps as completing the modeling described in section 3.1.3.5, establishing a MSY estimate(s), prohibiting the direct harvest of krill but possibly setting an initial low harvest allowance for EFPs with a complete monitoring and evaluation program (likely including observers) to determine if limited fishing were having any adverse effects, and setting future harvest limits at appropriate levels. EFPs could be available under this alternative to help provide data needed to carry out the process of allowing future fishing.

4.2.2.1 Effects on Status of Krill

This alternative would provide reasonable protection for krill in the EEZ and would have little risk of adverse effects on the stocks. There would be no harvest permitted at this time, and to the extent harvest was permitted in the future, it would presumably be based on additional information that demonstrated that there would be very little risk to krill stocks from the fishing permitted. To the extent EFPs were considered and issued, there could be very useful information for making decisions about future fishing risks to krill and for reducing uncertainty about the abundance, distribution and potential productivity of krill. However, there would still be substantial gaps in knowledge about such things as how critical different areas of occurrence of krill may be, or the linkage between areas inside and outside sanctuaries; it is likely that the broad distribution of krill reflects the overall importance of all areas. Therefore, this alternative would possibly result in some higher risk of adverse effects on krill than the proposed action. The risk cannot be quantified because of the limited knowledge about krill and the inability to predict if a fishery would actually develop and, if so, at what level or in what times and areas fishing would occur.

4.2.2.2 Effects on Other Fish Species

This alternative would result in limited risk to other fish species by allowing some fishing that could result in reduced abundance and availability of krill to fish resources dependent on or sensitive to such conditions. As there would initially be no allowance for krill fishing, there would be no initial risk to other fish species. However, to the extent krill fishing were allowed in the future, there could be some risk of adverse effects. The level of impact would depend on the level of fishing allowed and the times and areas in which fishing was permitted. There would be a potential for fishing (especially if closely monitored under an EFP or with observers) to result in some improvement of the understanding of the linkage between krill and other fish species. However, it would take much time and fishing for a substantial reduction of uncertainty about the abundance, distribution and potential yield of krill and the relationship with other fish species. Therefore, this alternative would result in a higher risk of adverse effects on other fish species than the proposed action. The risk cannot be quantified because of the limited knowledge about krill and their dependence on different waters, the relative dependence of these other fish species on krill in the open waters, and the inability to predict if a fishery would actually develop and, if so, at what level or in what times and areas fishing would occur.

4.2.2.3 Effects on Other Living Marine Resources

This alternative would result in low initial risk to other living marine resources that are dependent on or sensitive to the abundance and availability of krill. Fishing would initially be prohibited and thus could not cause a decline in the availability of krill to these animals. Also, there would not be a potential for direct interactions between krill fishing vessels and protected species. In the future, however, there could be some krill fishing with a risk of adverse effects on other living marine resources. This risk cannot be quantified because of the limited knowledge about krill and their dependence on and productivity in different waters, the dependence of other living marine resources on krill in these waters, and the inability to predict if a fishery would actually develop and, if so, at what level or in what times and areas fishing would occur.

4.2.2.4 Effects on Other Fisheries

The effects on other fisheries would depend on the extent of krill fishing ultimately permitted by the Council. Initially, however, this alternative would have no impact on other fisheries. To the extent future krill harvest resulted in lower abundance (numbers and/or size) of other target species, there would be adverse effects on the other fisheries. Fishing for krill could adversely affect (directly or indirectly by forage reduction) fish stocks occurring in other fisheries by reducing krill abundance and/or availability to levels that would affect the recruitment of these fish species to their respective fisheries. Chapter 3 discusses the extent that many fish species depend on or are sensitive to the abundance and availability of krill. Therefore, this alternative would result in a higher risk of adverse effects on other fisheries than the proposed action.

4.2.2.5 Economic Effects

This alternative would not have any direct economic impacts initially. As no krill fishing would be permitted initially, there would be neither economic benefits from a fishery nor adverse effects on any businesses engaged in other fisheries. To the extent this alternative helps maintain krill stocks that sustain species of interest to non-consumptive users (e.g., whale watchers), this alternative would preserve the revenues and profits to eco-tourism businesses. Future fishing could have economic impacts, both beneficial and harmful. If a fishery were to develop, it could generate revenues and profits to participating fishermen and to support businesses. A fishery could also result in higher risk of adverse effect than the proposed action on existing fishing enterprises as well as on businesses that supply fishing enterprises. Also, eco-tourism businesses that provide services to non-consumptive users of other living marine resources (e.g., companies providing whale watching cruises) could be harmed if krill fishing resulted in changes in the abundance and distribution of such resources. Therefore, this alternative would result in a higher risk of adverse effects on existing businesses than the proposed action. The risk cannot be quantified because of the limited knowledge about krill and their dependence on different waters, the response that will be shown by the businesses that are ultimately dependent on the fish and other resources associated with krill as the populations of those animals change, and the inability to predict if a fishery would actually develop and, if so, at what level or in what times and areas fishing would occur.

4.2.2.6 Effects on Data Collection

This alternative would initially not generate additional data, but could if a fishery were to develop. This would most likely occur if there were efforts to obtain EFPs to engage in trial fishing for krill subject to stringent controls on times and areas of fishing, observer coverage, and reports of catch, effort, and possibly other information. Observers also would document fishing gear and techniques and monitor any effects on habitat, bycatch, or protected species interactions.

4.2.2.7 Effects on Bycatch

This alternative would initially ensure that there would be no bycatch, but could in the future result in increased risk of bycatch. As no krill fishing in the EEZ has occurred in the past, there is no basis for determining the extent to which there would be a bycatch problem. To the extent observers were placed on krill fishing vessels, especially under EFPs, there would be an improved basis for estimating bycatch and assessing its seriousness.

4.2.2.8 Effects on Habitat

This alternative would have little potential for adverse habitat impacts. Even if fishing were to occur, the fishing gear would not likely adversely affect habitat. However, the removal of krill, depending on the size of any harvest allowed, could result in the ecosystem role of krill (see 3.2.4) being disrupted or precluded altogether. The risk of adverse effects cannot be quantified at this time.

4.2.2.9 Effects on Protected Species

This alternative would initially have no impacts on protected species of whales and seabirds. If fishing were to be permitted in the future, there could be adverse effects if fishing occurred in proximity to cetaceans or in areas in which cetaceans and seabirds would normally feed, such that feeding patterns could be disrupted. In the case of seabirds, this could be especially harmful given the need for forage supplies in close proximity to nesting areas during reproductive periods. The Council would likely seek to control this risk (which cannot be quantified) by restricting areas known to have concentrations of whales or known to be primary feeding areas for whales and/or seabirds.

4.2.2.10 Administrative Considerations

This alternative has substantially higher administrative impacts or costs than the proposed action. Like the proposed action alternative, this alternative would require amendment of the CPS FMP; however, there are some significant differences. This alternative would add only the two principal species of krill identified in Chapter 3 to the management unit species of the CPS FMP; other krill would not be added. Under this alternative, these species of krill would be designated as managed or monitored, consistent with the current classifications in the CPS FMP. Initially, while there would be no harvest of krill, a procedure would have to be developed for ultimately allowing harvest. This would have to specify information requirements as well as a process and criteria for determining when or under what conditions fishing would be permitted. This could include establishment of harvest guidelines or perhaps quotas based on formulas. In sum, these administrative burdens would be quite substantial. There would be additional, substantial administrative burdens resulting from the need to designate EFH and to comply with the Coastal Zone Management Act (CZMA), ESA, and NEPA.

4.2.2.11 Consistency with Management Objectives (see section 2.2)

This alternative would not meet all the objectives of the proposed action. This action would, however, still contribute to achieving the objective of furthering scientific research and collaboration and ultimately might generate additional information about krill resources.

4.2.3 Allow Small-scale Krill Fishery (Alternative 4)

This alternative adds krill to the management unit species under the CPS FMP and establishes harvest guidelines. Under this alternative a limited fishing strategy similar to the approach authorized in the British Columbia krill fishery (section 3.6.3), which allows a total harvest of 500 metric ton (mt) divided between specific areas/regions, would be initiated. Applying this same approach for the U. S. West Coast, total annual catches of 500 mt could be initially authorized at each of the six areas (3,000 mt total) where dense krill populations are known to aggregate (section 3.3.3). In order to meet MSA requirements, estimates of MSY, OY and status determination criteria (SDC) for krill (i.e., minimum spawning stock threshold and maximum fishing mortality threshold) would need to be made.

4.2.3.1 Effects on Status of Krill

This alternative would result in a higher risk of adverse effects on krill than the proposed action. Harvest would be permitted with a similar strategy used in the British Columbia fishery and so there is some basis to assume that risk would be manageable. However, the exact risk is difficult to determine because of the limited knowledge of krill population dynamics on the West Coast. Until the necessary stock assessments were undertaken (as described in 4.4.3.10) the ultimate risk would be largely unknown. Also, due to the extreme annual and seasonal variations in krill populations the effects of fishing removals would likely vary annually and seasonally as well.

4.2.3.2 Effects on Other Fish Species

The marine ecosystem offshore Washington, Oregon and California is home to vast variety of fish species which depend on krill directly or indirectly to sustain their populations. These include groundfish species (e.g., shelf and slope rockfishes, Pacific whiting, flatfishes, sablefish, and lingcod); four species of Pacific salmon; steelhead; highly migratory species (i.e., tunas, marlin, swordfish, pelagic sharks, dorado); other relatively large pelagic fishes and small CPS (sardines, herring, anchovy, mackerels, smelts, and squid).

The effects of this alternative on these fish stocks would largely be unknown at first due to the lack of information regarding standing stock size of the krill population not only within the California Current, but also on the regional foraging scales that many of these fishes depend. During low productivity years/months, the cumulative effects of fishing pressure and natural variability could have detrimental effects on localized fish populations.

This alternative could also have negative impacts on fish species through the incidental catch and bycatch of adult, juvenile and larval fishes due to the trawl-type gear used to catch krill. One of the primary undesired effects of the Antarctic krill fishery is the continuing catch of juvenile and larval fish that occurs due to the use of non-selective pelagic trawls (Moreno, 1995). This would be of particular concern on the West Coast due to the fact that multiple species of commercially exploited groundfish depend on euphausiids as prey during both larval and juvenile stages.

To the extent krill fishing were allowed there would be some risk of adverse effects to other fish species. The level of impact would depend on the level of fishing allowed and the times and areas in which fishing was permitted. Initially the risk would be difficult to quantify because of the limited knowledge about krill and their dependence on different waters, the relative dependence of these other fish species on krill in open waters, and to what level or in what times and specific areas fishing would occur.

4.2.3.3 Effects on Other Living Marine Resources

The California Current marine ecosystem offshore Washington, Oregon and California is utilized by a vast variety of fishery, seabird, marine mammal, and sea turtle resources, many of which depend on krill directly or indirectly to sustain their populations such as: marine mammals (California sea otter and various whales, porpoises and dolphins, sea lions, and seals); pelagic seabirds (including northern fulmar, brown pelican, albatrosses, shearwaters, loons, murres, auklets, storm petrels and others) (see Leet et al. 2001).

This alternative could result in an increased risk to these living marine resources that are dependent on or sensitive to the abundance and availability of krill as forage. Fishing could cause a decline in the availability of krill and thereby reduce the forage biomass to these resources. The potential also exists for direct interactions between krill fishing vessels and these living marine resources. Krill concentrations attract marine mammal and bird predators, and due to the trawl-type gear used to catch krill, bycatch and/or disturbance of these predators would likely occur. In the Antarctic krill fishery there has been bycatch of fur seals to the extent that seal excluder devices have been discussed as a necessity on trawl nets.

Currently this risk is difficult to quantify because of the limited knowledge about krill and their dependence on and productivity in different waters, the dependence of other living marine resources on krill in these waters and at what level or in what times and areas fishing would occur.

4.2.3.4 Effects on Other Fisheries

Fishing for krill could adversely affect (directly or indirectly by forage reduction) fish stocks occurring in other fisheries by reducing krill abundance and/or availability to levels that would affect the recruitment of these fish species to their respective fisheries. Chapter 3 discusses the extent that many fish species depend on or are sensitive to the abundance and availability of krill. Most West Coast fisheries pursue stocks in this category, and many of the stocks are found in all four of the Council’s fishery plans (i.e., West Coast groundfish, Pacific salmon, CPS, and HMS). Given the value of the fisheries involved and the fishing community hardships suffered when fishery restrictions are imposed (the West Coast groundfish fishery is an example) to deal with stock declines, it is reasonable to assume that such management actions may be taken to ensure that necessary balance between forage and the fish stocks that utilize them remains intact.

Therefore, this alternative could result in a higher risk of adverse effects on other fisheries than the proposed action. The risk cannot be quantified because of the limited knowledge about krill and their dependence on different waters, the relative dependence of these other fish species on krill in the open waters and at what level or in what times and areas fishing would occur.

4.2.3.5 Economic Effects

A number of high-value commercial and recreational fisheries, such as Pacific whiting, squid, rockfish, albacore and salmon are dependent upon krill (see Figure 13). The 2005 Pacific whiting fishery generated peak landings of 259,000 tons worth $29 million ex-vessel at $112 per ton (71 FR 29262). Krill have been shown to comprise approximately 90 percent of the diet of Pacific whiting (Tanasichuk,1999). Market squid, which also rely on krill as forage, are not only an extremely important commercial fishery off California (typically in the top three in value and tonnage in California; largest in 2005 in both volume and ex-vessel value at $31.6 million) (Sweetnam 2006), but like krill, play a crucial role in the West Coast ecosystem acting as a major forage item for a variety of marine mammals, birds and fish. The average (1998-2005) total West Coast commercial fishing ex-vessel revenue for all federally managed species is approximately $262 million. Over half of this revenue, approximately $143 million, is generated from species that depend heavily on krill (Figure 15). The most recent recreational fisheries survey showed that the total expenditures of saltwater recreational anglers participating in Washington, Oregon and California combined comprised approximately $795 million. Many highly prized and targeted recreational fish, such as rockfish and salmon, depend heavily on krill as a forage source.

Also, eco-tourism businesses that provide services to non-consumptive users of other living marine resources (e.g., companies providing whale watching cruises) could be harmed if krill fishing resulted in changes in the abundance and distribution of such resources (i.e., baleen whales utilize krill as a main component of their diet). Hoyt (2001) estimated that there were 101 operators that had some involvement with whale watching within Washington, Oregon and California and boat based and land based total whale watching expenditures were approximately $63 million and $21 million, respectively. Baleen whales such as blue and humpback, which occur off the West Coast, almost exclusively forage upon krill.

A krill fishery would generate revenues and profits to participating fishermen and to support businesses. Based on the ex-vessel revenues obtained in the Canadian krill fishery (i.e., average ex-vessel value between 1995-2002 was CAD $426,000), and assuming that a U.S. West Coast krill fishery would select no more than six known “hot-spots”, NOAA estimates that total ex-vessel values could generate up to $2.6 millon annually. However, these benefits could come at the cost of reducing the known economic benefits currently provided by existing, well-developed fisheries and businesses on the West Coast. A decline in krill biomass could lead to a proportional decline in species that depend on krill and hence a decline in the revenue gained by the fisheries for those species.

Based on an EEZ wide krill biomass of one million tons (section 3.1.3) a 3,000 mt krill fishery could reduce krill biomass by 3,000/1,000,000 or 0.003 annually. The average total West Coast commercial fishing ex-vessel revenue for federally managed species that depend heavily on krill is approximately $143 million per year. Although complex ecosystem modeling has been examined as a tool to evaluate krill harvest impacts on other species, do to a lack of data, reliable models currently do not exist. However, as way to begin to examine the possible effects, we can make the assumption that a reduction in these species that depend heavily on krill will be proportional to the reduction in krill biomass. Therefore, the reduction in commercial value that would occur under this alternative is $143 million * 0.003 or $430,000 (Figure 15). This does not take into account the indirect effects that would occur due to the reduction in those stocks that are themselves important forage for other commercially valuable species.

A similar impact would likely be witnessed in the recreational fishing industry. As previously stated the total expenditures of saltwater recreational anglers participating in Washington, Oregon and California combined comprised approximately $795 million in 2001. Using the same proportional assumption as above this alternative would lead to approximately $2.4 million in costs. Economic losses would likely be seen throughout coastal eco-tourism businesses that rely on whale watching as well. If krill fishing resulted in less frequent use of West Coast waters by whales that feed on krill, there could likely be less demand for whale watching cruise services. Under this assumption, revenue created by whale watching in California, Oregon and Washington could likely see a reduction by $250,000 per year. The total possible reduction in revenue that would occur across the various dependent commercial fisheries, total recreational fisheries and whale watching industries under this proportionality assumption is approximately $3 million annually. While these figures are approximations, considering that fishing under this alternative could potentially generate only an estimated $2.6 million in ex-vessel revenue, the net benefit of this alternative is either zero or even slightly negative.

4.2.3.6 Effects on Data Collection

This alternative would generate additional fishery dependent data that would provide new information on distribution and abundance of krill. However, the collection of this data would involve new administrative costs (section 4.4.3.10). In addition, observers may also need to be placed on the fishing vessels to estimate bycatch events especially to monitor protected species interactions.

4.2.3.7 Effects on Bycatch

Krill concentrations attract marine mammal, bird, and fish predators, and due to the trawl-type gear used to catch krill, bycatch and/or disturbance of these predators could occur. In the Antarctic krill fishery, there is known bycatch of fur seals as well as various seabirds. In the British Columbia krill fishery, quotas were established due to concerns for harvesting a forage species upon which salmon and other commercially important finfish depend.

As no krill fishing in the EEZ has occurred in the past, it is difficult to determine the extent to which there would be a bycatch problem off the West Coast. However, krill concentrations that would attract the fishery also are likely to attract other species (fish, mammals, seabirds); therefore, there is reason to expect that there would be bycatch at some level, especially of early life stages of fish. In the Antarctic situation, there has been bycatch of fur seals; to the extent that seal excluder devices have been discussed as a necessity on trawl nets. There also could be interactions with baleen whales and possibly other marine mammals.

4.2.3.8 Effects on Habitat

This alternative would have the potential for adverse habitat impacts to the biological EFH of species managed under both the CPS FMP as well as the Council's three other FMPs. For example, krill is listed as an important prey source for juvenile (marine stage) coho and Chinook salmon and for multiple life stages of over ten groundfish. While krill fishing gear would not likely adversely affect habitat in a physical sense, the removal of krill may result in disrupting or even precluding krill from carrying out their ecosystem or habitat enhancement role thereby creating a biological impact (see section 3.2.4).

4.2.3.9 Effects on Protected Species

This alternative has the potential to have significant adverse impacts on protected species of salmon, whales and seabirds. If fishing occurred in proximity to marine mammals or in areas in which marine mammals and seabirds would normally feed, then feeding patterns could be seriously disrupted. In the case of seabirds, this could be especially harmful given the need for forage supplies in close proximity to nesting areas during reproductive periods. As seen in the Antarctic fishery, the take of seals due the trawl gear type is also a possibility. With regards to protected salmon species, the risk of take to occur is highly likely due to the non-selective trawl gear type that is used to catch krill and the fact that juvenile Chinook and coho salmon are often found feeding in the krill swarms that occur at the continental shelf break. These areas of high krill concentration are likely the same areas that fishermen would target. The fine-mesh trawl gear used to catch krill would increase the risk of take occurring. NOAA would likely seek to control this risk (which cannot currently be quantified) by restricting areas known to have concentrations of whales or known to be primary feeding areas for whales and/or seabirds.

4.2.3.10 Administrative Considerations

This alternative has substantially higher administrative impacts or costs than the proposed action. For a fishery to occur, the Council would be required to specify MSY and OY for the principal krill stocks, and establish specific SDC for determining if overfishing of any stock was occurring or if a stock was overfished. As mentioned in section 3, there is extreme annual, seasonal, and intra-decadal variability in abundances of krill species off the U. S. West Coast. Consequently, standardized EEZ-wide, stock assessment surveys would need to be undertaken over multiple years to begin the process of estimating the average annual standing biomass (i.e., all species, all stages). In the interest of reducing confidence intervals around the estimates, two-month long cruises would likely be undertaken and because of the poorly known annual distributional differences coastwide, these would be undertaken at least three times per year. For the purpose of understanding inter-annual differences in biomass variability, the minimal sampling frame would consist of at least two years in a row.

In determining annual survey costs, NOAA estimates a $20,000 per day charge for use of a research vessel. Based upon shiptime equivalent to six-months at sea, the annual cost for shiptime is estimated at $3.64 million per year. Cruises would be led by a senior scientist working six months at sea and six months in the laboratory to process net samples as well as interpret acoustic samples. The annual cost for a senior scientist is estimated at $80,000 per year including overtime. The senior scientist would be supported with five biological technicians who similarly would spend six months at sea and six months in the lab processing data. The annual cost per technician is estimated at $65,000 with all five technicians costing $325,000. In summary, the total cost to perform a coastwide, krill stock assessment is estimated at $ 4.04 million per year.

Like the proposed action alternative, this alternative would require amendment of the CPS FMP; however, there are some significant differences. Under this alternative, krill would be designated as managed or monitored, consistent with the current classifications in the CPS FMP. This would have to specify information requirements as well as a process and criteria for determining when or under what conditions fishing would be permitted. This could include establishment of harvest guidelines or perhaps quotas based on formulas. In sum, these administrative burdens would be quite substantial. There would be additional, substantial administrative burdens resulting from the need to comply with the CZMA, ESA, and NEPA. To the extent the krill fishery impacted other fisheries such as rockfish which are subject to strict rebuilding plans, the Council and NMFS would need to revise these plans as necessary.

4.2.3.11 Consistency with Management Objectives (see section 2.2)

This alternative would not meet all the objectives of the proposed action. Krill abundance and availability could be at most risk under this alternative. The exact risk, however, is difficult to determine because of the limited knowledge of krill population dynamics on the West Coast. Until the necessary stock assessments were undertaken (as described in section 4.4.3.10) the ultimate risk to krill continuing to fulfill their essential role as forage for commercial and recreationally important fish and other would be largely unknown. Key foraging areas for predators could also be impacted by the fishing allowed under this alternative as described in section 4.4.3.8.

This alternative would, however, still contribute to achieving the objective of furthering scientific research and collaboration and ultimately might generate additional information about krill resources.

4.2.4 Cumulative Impacts of Proposed Action and Alternatives

4.2.4.1 Cumulative Impacts on Status of Krill

The proposed action is more likely than the other alternatives to preserve krill resources over the long-term as future productivity of krill would be affected only by variability in natural environmental conditions and events other than fishing. This in turn would create the greatest opportunity to meet the action objective of maintaining natural ecological relationships and ecosystem integrity within the West Coast EEZ. Alternative 3 could provide full protection in the short-term but there would be some future risk if a krill fishery were allowed under the selected procedure. Alternative 1 could have the greatest potential for negative cumulative effects on krill populations, as it would provide no protection for krill in the EEZ. Alternative 4 would also pose a risk to krill populations due to the uncertainty surrounding krill stock status off the West Coast and acceptable catch levels. A fishery would be much more likely to pose a risk to krill stocks, both short-term and long-term, especially if exacerbated by a period of low krill productivity.

4.2.4.2 Cumulative Impacts on Other Fish Species and Other Fisheries

The proposed action would benefit other fisheries and fish stocks by indirectly protecting those fish species that directly or indirectly rely on krill as forage from any adverse effects of krill stock reduction due to fishing and by preventing the direct capture of juvenile fish that is known to occur in other krill fisheries. Alternative 3 could provide similar benefits, at least in the short-term, as fishing would be prohibited until conditions were determined suitable. Alternatives 1 and 4 would result in higher risk of adverse cumulative impacts both indirectly through the reduction of prey availability to fish stocks and existing fisheries, particularly during low krill production, and directly through incidental catch of such species.

4.2.4.3 Effects on Other Living Marine Resources

The proposed action would likely provide the most benefits to, or at least prevent adverse effects on, other living marine resources, including protected resources, by ensuring that fishing would not cause a decline in the availability of krill to these resources as well as preventing any direct interaction between the activities of krill fishing and these other living marine resources.

The proposed action is more likely than the other alternatives to provide indirect benefits to other living marine resources by ensuring that the krill stocks are as productive as natural conditions allow and direct benefits by reducing the possibility of incidental catch. Alternative 3 could provide similar benefits, at least in the short-term as fishing would be prohibited until conditions were determined suitable. Alternatives 1 and 4 would result in higher risk of adverse cumulative impacts both indirectly through the reduction of prey availability to these protected resources, particularly during low krill production, and directly through incidental catch.

The proposed action is least likely to result in cumulative effects on seabird species whose range includes the West Coast. This alternative would prohibit krill fishing and therefore have no effect on the abundance and availability of krill off the West Coast. Alternative 3 would have some potential in the future to have a cumulative effect through adding fishery mortality to natural krill stock size changes in response to changing environmental conditions. Alternative 1 would have the highest likelihood of some impact on krill stocks which, when added to natural fluctuations in response to environmental changes, could affect abundance and availability of krill to seabirds at important nesting areas or during important nesting seasons.

There has been no krill fishery off the West Coast and thus no reported or observed incidental captures of whales in krill fishing. However, there are numerous marine mammal populations that occur off the West Coast, and there is a history of takings in many fisheries as well as records of marine mammal takes in krill fisheries in other regions. Further, some cetaceans are most likely to be present in the same time/space strata in which krill concentrations would occur. Therefore, it would not be unreasonable to hypothesize that marine mammal interactions with krill fishing would occur if a fishery were permitted. The proposed action would prevent any cumulative effects of fishing with other exogenous factors on marine mammals.

4.2.4.4 Economic Effects

This proposed alternative could provide benefits to existing fisheries and to eco-tourism businesses and entities involved in such activities as whale watching, by not increasing cumulative impacts to krill stocks, particularly during low production times. However, it would preclude development of a fishery for krill and thus any potential economic benefits from such fishing that could occur under the other three alternatives. Development of a fishery as under Alternative 3 or 4 could generate new income for participants (which might offset recent declines in other fisheries to some extent), but also could result in declines in fisheries for other resources (if krill fishing led to krill declines which led to declines in other harvested stocks) and in non-consumptive but economically valued resource uses linked to krill (e.g., whale watching in places where whales might seek out or feed on krill). While a new krill fishery could improve the economic climate for a small group of vessels/operators, the majority of fishermen and businesses on the West Coast would either not be affected or could be adversely affected if krill fishing resulted in problems for other fish stocks or for non-fish resources of economic importance.

4.2.4.5 Effects on Habitat/EFH

Alternatives 1, 3 and 4 would have the potential for adverse habitat impacts to the biological EFH of species managed under both the CPS FMP as well as the Council's three other FMPs. For example, krill is listed as an important prey source for juvenile (marine stage) coho and Chinook salmon and for multiple life stages of over ten groundfish. While krill fishing gear would not likely adversely affect habitat in a physical sense, the removal of krill may result in disrupting or even precluding krill from carrying out their ecosystem or habitat enhancement role thereby creating a biological impact (see section 3.2.4). The proposed action would prevent the cumulative take impact of an important prey source. The exogenous factor relating to fluctuating environmental conditions is less likely to have long-term adverse effects under the proposed action and Alternatives 3 and 4 as these actions would identify EFH for krill and identify prospective actions to protect EFH.

4.3 Relationship to the Magnuson-Stevens Act (MSA) and other Applicable Laws

Final determinations of consistency of the proposed action and associated documentation with requirements of the MSA and other applicable law have not been made. However, this section assesses the likely determinations based on current information.

4.3.1 Magnuson-Stevens Act

The CPS FMP as originally prepared was determined to be consistent with the MSA, and all amendments have been similarly consistent with that act as amended. Available information suggests that this amendment would also be found consistent for the following reasons.

4.3.2 National Standards for Fishery Conservation and Management

Section 301 of the MSA establishes ten National Standards for fishery conservation and management. FMPs and their associated regulations must be consistent with the National Standards. The Council's assessment of the degree of consistency of the proposed actions relative with the national standards is discussed below.

Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.

The proposed action would prohibit fishing for krill and thus prevent overfishing. At this time, in the Council's view, the optimum management strategy is to prevent fishing for krill to promote optimum natural conditions for krill and species that depend on or are sensitive to the abundance and availability of krill, and thus promote the sustainability of other fish stocks to the extent practicable. Thus, the proposed action would support achievement of optimum yield for other fisheries.

Conservation and management measures shall be based upon the best scientific information available.

The information in this document and appendices constitutes the best scientific information available about krill and the associated resources.

To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.

The proposed action would prohibit fishing for all species off krill off the West Coast and thus would address all interrelated stocks of krill.

Conservation and management measures shall not discriminate between residents of different States. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be (A) fair and equitable to all such fishermen; (B) reasonably calculated to promote conservation; and (C) carried out in such manner that no *particular individual, corporation, or other entity acquires an excessive share of such privileges.*

The proposed action would not discriminate between residents of different States as the prohibition of krill fishing in the EEZ would apply to any and all U.S. vessels.

Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.

The proposed action would discourage the development of a krill fishery and thus promote the maintenance of healthy fisheries for stocks that are dependent on or sensitive to the abundance and availability of krill.

Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.

The proposed action would recognize the important uncertainties about the abundance and productivity of krill resources off the West Coast and about the potential responses of other fish stocks and other living marine resources to potential declines in krill abundance. The action would be aimed primarily at preventing adverse effects of krill fishing on associated resources such as other fish stocks and other living marine resources. The largely preemptive measure would be taken because of the apparent importance of krill and the inability to predict the effects of krill fishing on krill stocks and on associated and dependent species, including other targeted fish stocks.

Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.

The proposed action would not impose any costs on any existing fisheries. It would be consistent with but would not duplicate any existing State regulations and requirements.

Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to (A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts on such communities.

To the extent the proposed action would help maintain the stocks of harvested fish species, it would contribute to maintenance of fishing communities and prevent future adverse impacts on such communities.

Conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.

The proposed action would prevent the development of a krill fishery off the West Coast and thus would ensure that no bycatch occurs in any such fishery

Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.

The proposed action would prohibit krill fishing and would have no effect of the safety of human life at sea.

4.3.3 Treaty Indian Fishing Rights

There is currently no Treaty Indian fishing for krill in the EEZ, and there is no known interest in krill fishing. Amendment 9 to the CPSFMP established a regulatory process to deal with any future expressions of interest in fishing for CPS species and that process is codified in 50CFR660.518. That process would apply in the event any tribal interest in krill fishing is expressed.

4.3.4 Bycatch Reduction and Reporting

The proposed action would prohibit fishing for krill. Therefore, there would be no bycatch in krill fisheries and the requirement for a standardized bycatch reporting methodology is moot.

4.4 Coastal Zone Management Act (CZMA)

The CZMA requires a determination that a proposed management measure has no effect on the land, water uses, or natural resources of the coast zone, or is consistent to the maximum extent practicable with an affected state's approved coastal zone management program. A copy of this document will be submitted to the State coastal zone management agencies in Washington, Oregon and California with a request for consistency determinations. It is noted that the proposed action is to prohibit krill fishing, which is consistent with the States' prohibitions of harvest and landing of krill by state vessels. Therefore, it is expected that the States will confirm consistency with their coastal zone management plans

4.5 Endangered Species Act (ESA)

The ESA, as amended (Public Law 93-205; 87 Stat. 884) prohibits the taking of endangered species except under limited circumstances. In 1986, 1991, and 2002, formal Section 7 consultations were completed by NMFS for the FMP (addressing sea turtles and marine mammals, but not seabirds). The results of the consultations are Biological Opinions as to whether the action – in this case, fishing under the FMP – is likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species. As no krill fishing would be permitted, the proposed action would ensure that krill will be available to ESA listed species off the West Coast to the maximum extent possible subject to natural environmental conditions. Therefore, it is believed that informal consultations will be sufficient to conclude that this action is not likely to adversely affect any ESA listed species or any designated critical habitat for listed species.

Appendix B lists the species listed as endangered or threatened under the ESA that have been observed in the EEZ off the West Coast.

4.6 Marine Mammal Protection Act (MMPA)

The proposed action would prohibit fishing for krill off the West Coast. This would preclude both direct impacts of a fishery on marine mammals (thus obviating any need for a take authorization permit) and indirect impacts (e.g., by removing forage) on marine mammals.

4.7 Regulatory Flexibility Act (RFA)

The RFA requires government agencies to assess the effects that various regulatory alternatives would have on small entities, including small businesses, and to determine ways to minimize those effects. A fish-harvesting business is considered a "small" business by the Small Business Administration (SBA) if it has annual receipts not in excess of $4 million. For related fish-processing businesses, a small business is one that employs 500 or fewer persons. For marinas and charter/party boats, a small business is one with annual receipts not in excess of $5.0 million. The Chief Counsel for Regulation certifies that this proposed rule would not have a significant impact on a substantial number of small entities. The factual basis for this certification follows:

Basis and Purpose of the Rule

The proposed action would be taken under the authority of the MSA (16 U.S.C. 1801 et seq.). The purpose and need for the proposed action are discussed in section 2.0. The objective of the proposed action is to maintain ecological relationships and ecosystem integrity through the management of krill, provide protection for key krill predator foraging areas (i.e., topographic and oceanographic features that consistently serve to concentrate krill and facilitate predator feeding), and provide a foundation for improved research and data collection. Krill are an important component of the marine environment of the U.S. West Coast, supporting many species of fish and other living marine resources (see section 3). There is no fishing now for krill, but there is a potential for a krill fishery to develop in the absence of action to prevent it. A krill fishery could severely impact many other resources and the persons and businesses that benefit from use and/or protection of those resources. The context of the proposed action is the need to protect fish and non-fish resources and the users (consumptive and non-consumptive) of those resources from the adverse effects that could result from declines in krill populations that might occur if krill fishing were permitted. Although there is currently no fishing for krill in the U.S. EEZ there are currently no restrictions or limitations to fishing for krll in the EEZ and there are krill fisheries in other parts of the world that are expanding.

Estimated Number of Small Entities to Which the Rule Would Apply

No small entities would be directly affected if this action were taken. There are currently no entities engaged in fishing for krill off the West Coast. It is possible that, in the absence of this action, a krill fishery could develop, but it is not possible to estimate the number of entities (large or small) that might engage in such fishing in the future.

Estimated Economic Impacts on Small Entities by Entity Size and Industry

The proposed action would not have any direct economic impacts on any small entity. There is no fishing now for krill, and thus no entities (large or small) would be displaced from or otherwise affected by the proposed action. However as stated in section 4.2.3.5 a small krill fishery could conceivably generate $2.6 million in ex-vessel revenue although this could be at the cost of approximately $3 million dollars to existing businesses.

Criteria Used to Evaluate Whether the Action Would Impose "Significant Economic Impact"

No criteria for such an evaluation were used as no entities (large or small) will be directly affected by the proposed action. No entities now fish for krill so no entities would be disproportionately affected or suffer reductions in profits.

Criteria Used to Evaluate Whether the Action Would Impose Impacts on a "Substantial Number" of Small Entities

No criteria were used for such an evaluation as no entities (large or small) would be directly affected by the proposed action. No entities now fish for krill so a "substantial number" of small entities would not be affected.

Assumptions Used in the Analysis

No assumptions were used in the analysis. No fishing for krill currently occurs and there have been no indications of active interest in development of a krill fishery off the West Coast. It is not necessary to make assumptions about future behavior to determine that the proposed action will not directly affect any entities given that no entities currently engage in krill fishing.

4.8 Executive Order 12866 - Regulatory Impact Review (RIR)

The purpose of an RIR includes determining whether any of the proposed actions could be considered "significant regulatory actions" according to E.O. 12866. This action has been determined to be significant for the purpose of E.O. 12866. The proposed action could have beneficial impacts on fishermen who target stocks dependent on or sensitive to the abundance and availability of krill by preventing adverse effects on krill stocks. It also could have beneficial impacts on providers of whale watching services and other tour providers who benefit indirectly from the ability of krill to meet forage needs of other living marine resources. To the extent there would be economic effects, they would be expected to be positive relative to the No Action Alternative.

A market failure does not currently exist. The proposed action, if implemented, would address the anticipated market failure that would occur throughout existing fisheries and businesses, if a krill fishery was to develop. Although there is no current fishery for krill off the West Coast, global market demand is growing making the future development of a fishery a distinct possibility. The information available indicates that prosecution of a krill fishery would likely result in significant negative externalities. A number of high-value commercial and recreational fisheries, such as Pacific whiting, squid, rockfish, albacore and salmon are dependent upon krill (see Section 3.2.1, Figure 13 and 15). The 2005 Pacific whiting fishery generated peak landings of 259,000 tons worth $29 million ex-vessel at $112 per ton (71 FR 29262). Krill have been shown to comprise approximately 90 percent of the diet of Pacific whiting (Tanasichuk,1999). Market squid, which also rely on krill as forage, are not only an extremely important commercial fishery off California (typically in the top three in value and tonnage in California; largest in 2005 in both volume and ex-vessel value at $31.6 million) (Sweetnam 2006), but like krill, play a crucial role in the West Coast ecosystem acting as a major forage item for a variety of marine mammals, birds and fish. As described in FAO Fisheries Technical paper 368, "Fisheries bioeconomics theory, modeling and management," a predator-prey interdependence can guide the direction of an externality. An increase in fishing effort of fishery A, which has prey S_p as the target, will generate a decrease in the abundance of predator S_d, harvested by fishery B. This type of external effect constitutes a trophic-based externality. Management measures are necessary to preserve this key trophic relationship between krill and the other components of the California Current food web, including these commercially important species. These externalities would not be taken into account in the developing market for krill.

4.9 National Environmental Policy Act (NEPA)

This document has been prepared as a combined amendment to a fishery management plan and environmental assessment. As required by NEPA, this document identifies management problems and issues, sets forth alternatives to address those problems and meet objectives of management, and evaluates and compares the effects and effectiveness of the alternatives. Other specific analytical requirements of NEPA are set out in guidelines or administrative directives by NOAA and the Council on Environmental Quality (CEQ) and are addressed in the following sections.

4.9.1 Significance of Impacts of the Proposed Action

The Council believes that, if adopted, the proposed action will not have a significant impact on the human environment. This conclusion is based on consideration of NOAA and Council on Environmental Quality Significant Impact Criteria (as outlined in NOAA Administrative Order 216-6) as follows:

1) Can the proposed action reasonably be expected to jeopardize the sustainability of any target species that may be affected by the action?

The proposed action is not expected to jeopardize the sustainability of any target or non-target fish stock. It would prevent the development of a fishery for krill off the West Coast. This would ensure that (to the extent practicable) the krill stocks will remain as healthy and productive as possible under prevailing (and changing) environmental conditions. In turn, the ability of krill stocks to fulfill their role in the environment will be maintained and fishing for krill will not adversely affect other species that are dependent on, or sensitive to the abundance of, krill. These other species include a number of species (some of which are overfished) managed under the Council's FMPs as well as under the MMPA and ESA.

2) Can the proposed action reasonably be expected to jeopardize the sustainability of any non-target species?

The proposed action is not expected to jeopardize the sustainability of any non-target species. As indicated above, species that are dependent on or sensitive to the abundance of krill will not be affected by any change in krill abundance or distribution due to a krill fishery. Krill fishing will be prohibited.

3) Can the proposed action reasonably be expected to cause substantial damage to the ocean and coastal habitats and/or essential habitat as defined under the MSA and identified in FMPs?

The proposed action is not expected to cause substantial damage to the ocean and coastal habitats or essential fish habitat as defined under the MSA and identified in FMPs, as it is not likely to lead to substantial physical, chemical, or biological alterations of these habitats (section 4.1.2).

4) Can the proposed action reasonably be expected to have a substantial adverse impact on public health or safety?

The proposed action is not expected to have a substantial adverse effect on public health or safety. It would prevent a krill fishery and, to the extent practicable, ensure that krill will support populations of other marine resources that are dependent on or sensitive to the abundance of krill resources.

5) Can the proposed action reasonably be expected to adversely affect endangered or threatened species, marine mammals, or critical habitat of these species?

The proposed action is expected to contribute to the health of populations of marine mammal species protected under the ESA and their critical habitat and of species protected under the MMPA. It would not be possible for a krill fishery to develop, and therefore krill stocks would remain as healthy and productive as possible under prevailing (and changing) environmental conditions. This should ensure the availability of krill as forage for any species protected under the ESA and MMPA that are dependent on or affected by the availability and abundance of krill.

6) Can the proposed action be expected to have a substantial impact on biodiversity and/or ecosystem function within the affected area (e.g., benthic productivity, predator-prey relationships, etc.)?

The proposed action is expected to contribute to the maintenance of biodiversity and ecosystem function off the West Coast. Krill are forage for a wide variety of species (fish, marine mammals, seabirds), and reduction of krill stocks could have a substantial adverse impact on biodiversity or ecosystem function within the affected area. However, the proposed action would prevent development of a krill fishery and thus ensure that krill stocks remain as healthy and productive as possible under prevailing environmental conditions.

7) Are significant social or economic impacts interrelated with natural or physical environmental effects?

The proposed action is not expected to have significant economic effects associated with physical environmental effects. There is currently no fishery for krill, so no business entities or other economic activities would be directly affected by the proposed action. It is noted that the prohibition of krill fishing would preclude a fishery that could have direct economic benefits in the future. The level of such benefits cannot be estimated with available information. However, to the extent prohibition of krill fishing helps in maintenance or rebuilding of fish stocks that are harvested (and that might not be as productive without krill for forage), the proposed action would contribute to the economic health and productivity of West Coast fisheries. There also are businesses that provide services for non-consumptive beneficiaries of healthy marine mammal stocks. To the extent that the protection of krill from fishing contributes to the productivity or abundance of krill and in turn support the presence of such marine mammal stocks, the proposed action would contribute to the value of such businesses.

8) Are the effects on the quality of the human environment likely to be highly controversial?

The effects of the proposed action are not likely to be highly controversial. There is broad support within the Council and the fishing community as well as the conservation community for action to protect krill stocks due to their importance for other living marine resources. The action was developed in response to a request for consideration of a less protective regime (i.e., prohibition of krill fishing in EEZ waters in selected NMS). The Council ultimately concluded that prohibition of krill fishing throughout the EEZ was appropriate and necessary, and this action has been supported by virtually all who have commented.

9) Can the proposed action reasonably be expected to result in substantial impacts to unique areas, such as historic or cultural resources, park land, prime farmlands, wetlands, wild and scenic rivers or ecologically critical areas?

The proposed action would result in substantial protection of krill and associated marine resources in NMS off the West Coast and thus will contribute to the quality of those unique resources. There are no other known historic and cultural resources, park land, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas that will be affected by the implementation of the proposed action.

10) Are the effects on the human environment likely to be highly uncertain or involve unique or unknown risks?

The effects on the human environment are uncertain due to the inherent variability of the marine environment. As documented, krill resources are extremely sensitive to changes in environmental conditions, and the prohibition of fishing will not guarantee that krill resources will be productive in the future. However, the proposed action would reduce the risk that a combination of fishing and unfavorable environmental conditions will result in long-term (and possibly irreversible) reduction in krill stocks with ensuing adverse effects on other living marine resources. The approval and implementation of the proposed action involves unique or unknown risks associated with the effects of fishing on the abundance and distribution of krill stocks. The proposed action is intended to preclude risks to the sustainability of target and non-target fish stocks by preventing fishing on krill, a principal food source of those fish stocks.

11) Is the proposed action related to other actions with individually insignificant, but cumulatively significant impacts?

The proposed action is not expected to result in any significant cumulative adverse effects (section 4.3). Because the proposed action would not result in direct or indirect adverse effects, there likewise would be no incremental effects to any resource of concern.

12) Is the proposed action likely to adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural or historical resources?

There are no districts, sites, highways, structures, or objects within the EEZ, or significant scientific, cultural or historical resources that would be adversely affected by the proposed action. The proposed action would result in substantial protection of krill and associated marine resources in NMS off the West Coast.

13) Can the proposed action reasonably be expected to result in the introduction or spread of a nonindigenous species?

There are no reasons to expect that the proposed action would result in the introduction or spread of nonindigenous species.

14) Is the proposed action likely to establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration?

The proposed action is precedent setting in establishing a “prohibited harvest” species category in a Council FMP. It is possible that other species may ultimately be placed in this category in the CPS FMP or that this category could be established in other Council FMPs. It is also possible that this approach (which can be considered an “ecosystem-based approach” to resource management) is just the first instance of explicit incorporation of ecosystem management principles in fishery management by the Council. However, a fundamental concept of the action (i.e., recognition of the forage importance of species in an FMP) has already been adopted in the CPS FMP and is applied in the harvest management strategy for CPS, which considers the forage importance of such species as Pacific sardine and Pacific mackerel in the harvest guideline formulas for those species. The incorporation of ecosystem management principles into fisheries management is being promoted within NOAA and NMFS as well as by Congress, and this action may further advance that effort.

15) Can the proposed action reasonably be expected to threaten a violation of Federal, State, or local law or requirements imposed for the protection of the environment?

This action is not likely to impose or cause a violation of Federal, State, or local law or requirements imposed for the protection of the environment. West Coast states already prohibit krill fishing by their residents. The proposed action will reinforce the states' prohibitions.

16) Can the proposed action reasonably be expected to result in cumulative adverse effects that could have a substantial effect on the target or non-target species?

As indicated in the previous section, the proposed action would ensure that there would be no adverse effects on the new management unit species, and would not be expected to result in cumulative adverse effects that could have a substantial effect on non-target species.
The proposed action is more likely than the other alternatives to provide indirect benefits to other living marine resources by ensuring that the krill stocks are as productive as natural conditions allow. A fishery would be much more likely to pose risk to krill stocks, both short-term and long-term, especially if exacerbated by a period of low krill productivity. The proposed action is the least likely to result in a combination of increased natural mortality and fishing effects, and therefore would likely have a lower risk of adverse effects on krill.

4.10 Paperwork Reduction Act (PRA)

The proposed action would not impose any new collection-of-information requirements that would be subject to approval by the Office of Management and Budget (OMB), pursuant to the PRA.

4.11 Migratory Bird Treaty Act (MBTA)

The MBTA does not apply in the EEZ. However, the proposed action if implemented would reinforce states' prohibitions of krill harvest and ensure maximum protection of krill resources to the extent practicable off the West Coast. To the extent any species covered by the MBTA that occur off the West Coast are dependent on or sensitive to the abundance and availability of krill, and could be adversely affected by reductions in krill stocks due to krill fishing, those potential effects would be precluded by the proposed action.

4.12 Environmental Justice

The proposed action will have no impacts or implications in terms of environmental justice. As noted in 4.11.2.7.4, however, it is possible that allowing a krill fishery could result in adverse effects on other fisheries. If so, this could exacerbate problems arising from declines that have already occurred in other fisheries (e.g., groundfish), and this would most likely have greater effect on fishermen who are less educated and have fewer employment options. These would typically be fishermen with low incomes and low savings.

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6.0 AGENCIES AND ORGANIZATIONS CONSULTED

National Marine Fisheries Service, NOAA, DOC
National Ocean Service, NOAA, DOC
U.S. Fish and Wildlife Service, U.S. Department of the Interior
Washington Department of Fish and Wildlife
Oregon Department of Fish and Wildlife
California Department of Fish and Game
Scripps Institution of Oceanography
University of California at Santa Cruz
Point Reyes Bird Observatory

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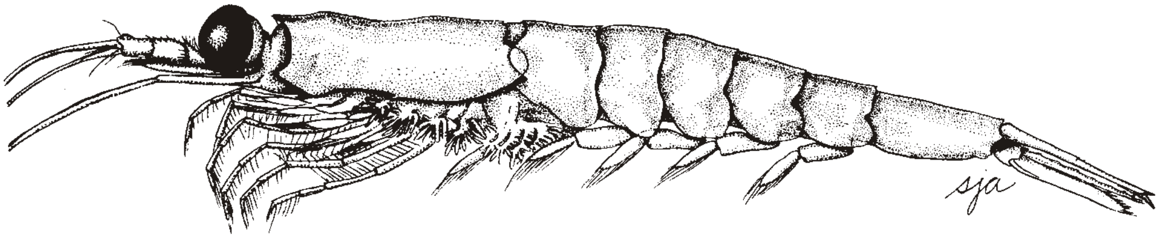
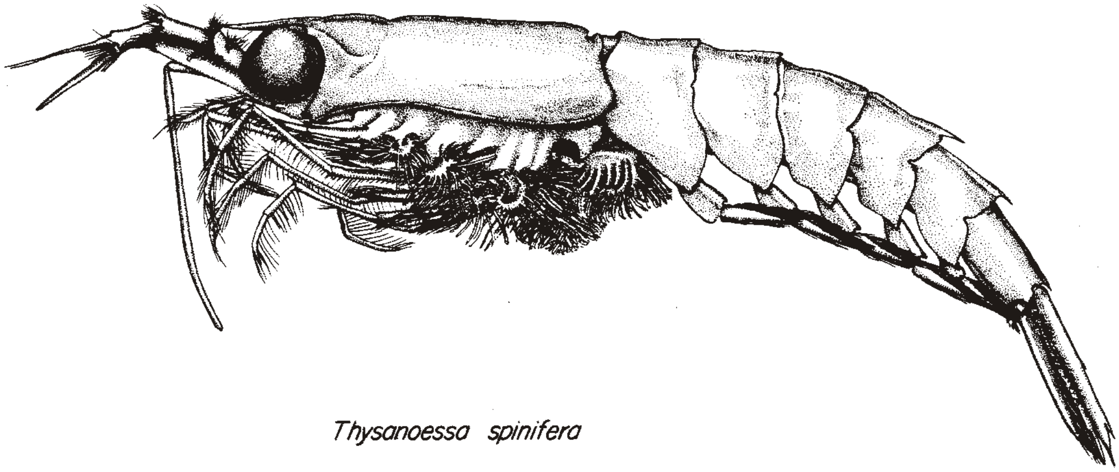


Euphausia pacifica



Thysanoessa spinifera

6 mm / 0.25 inches

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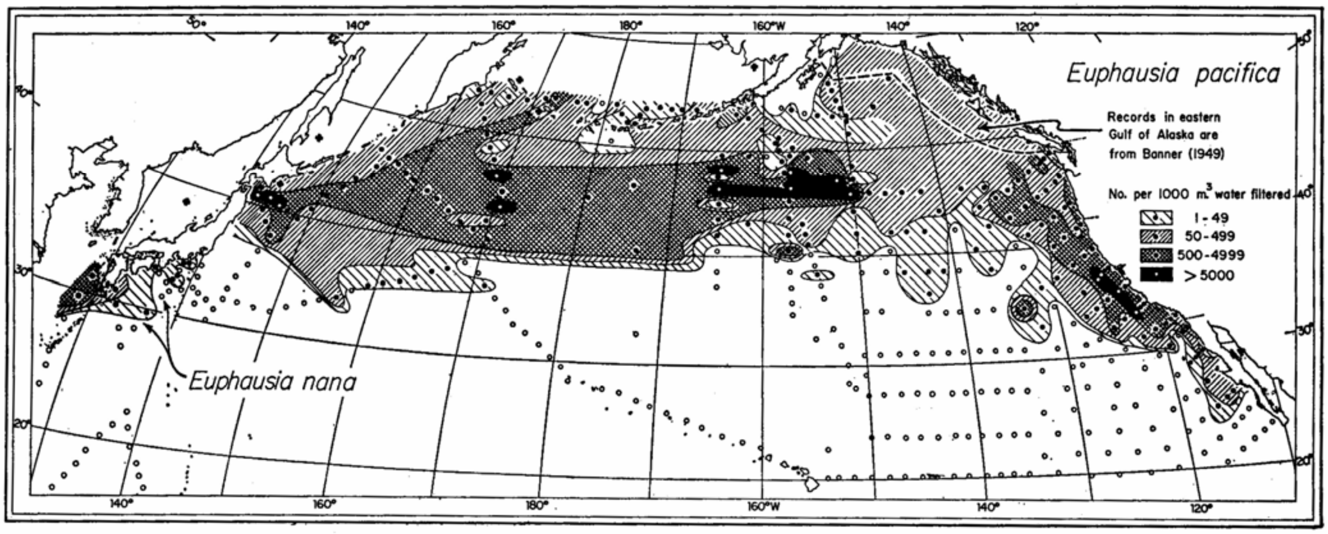

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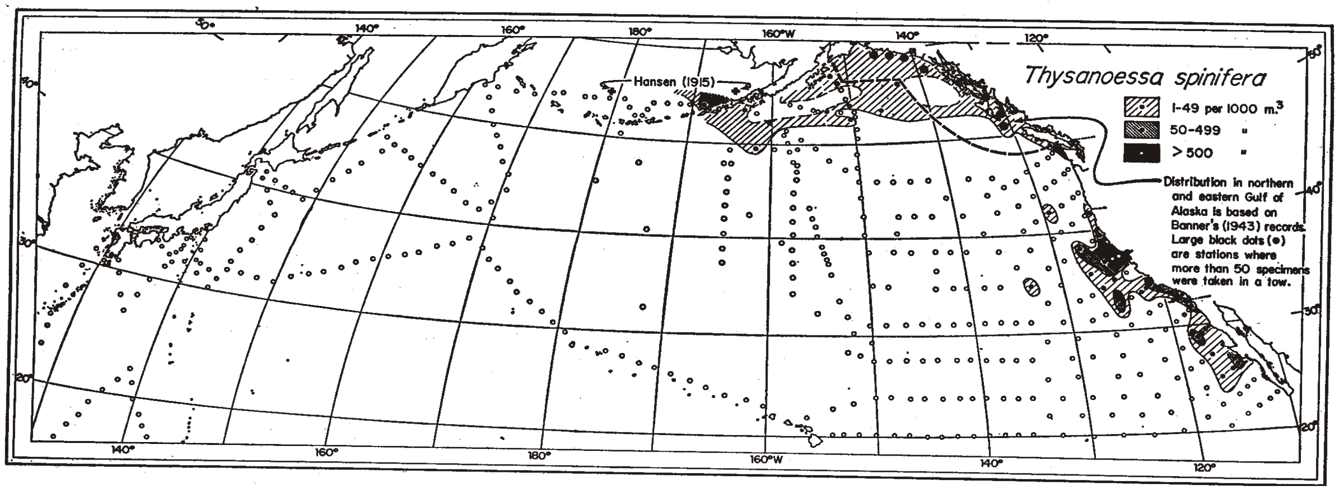

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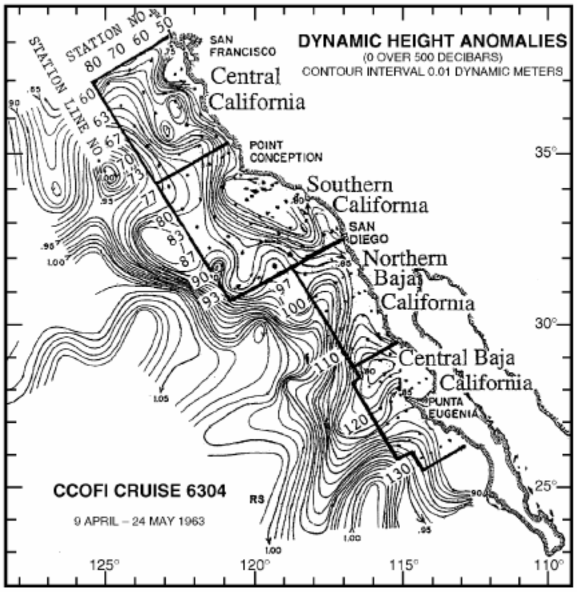

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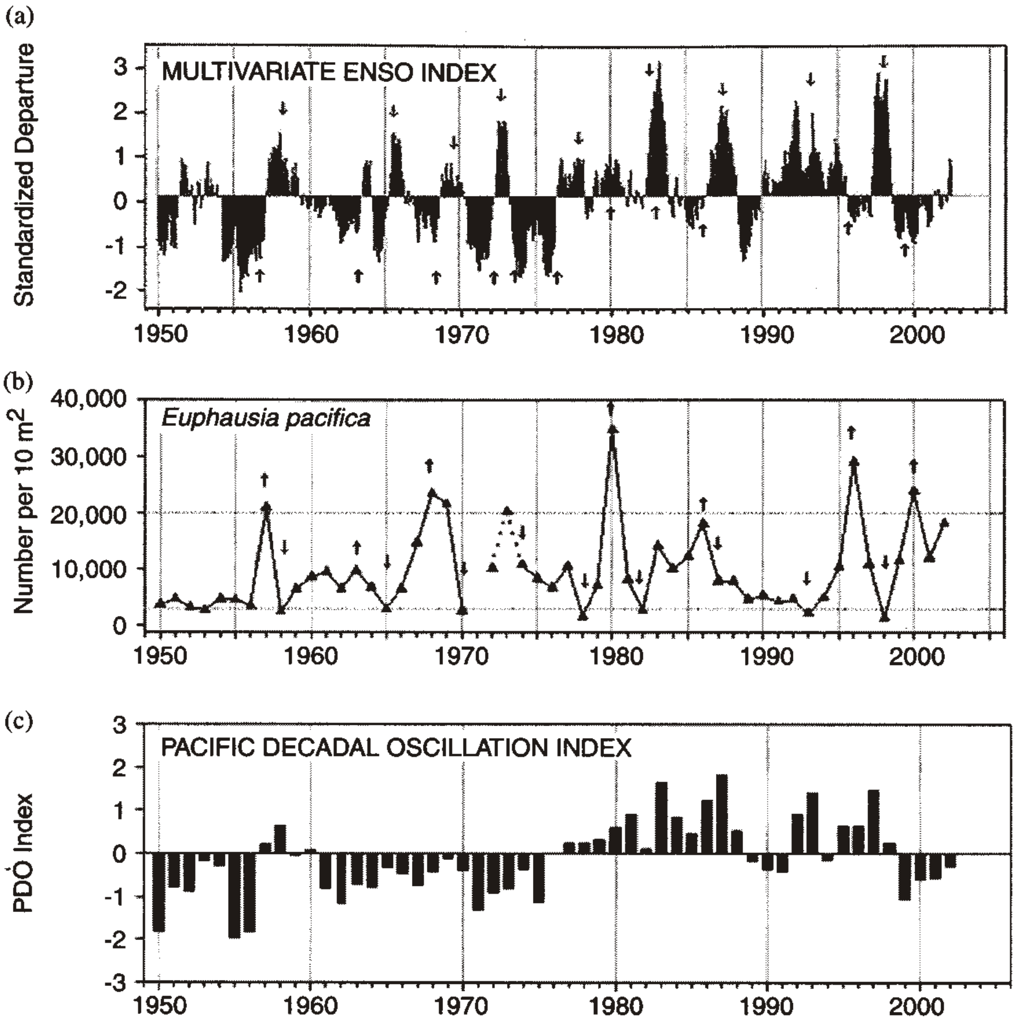

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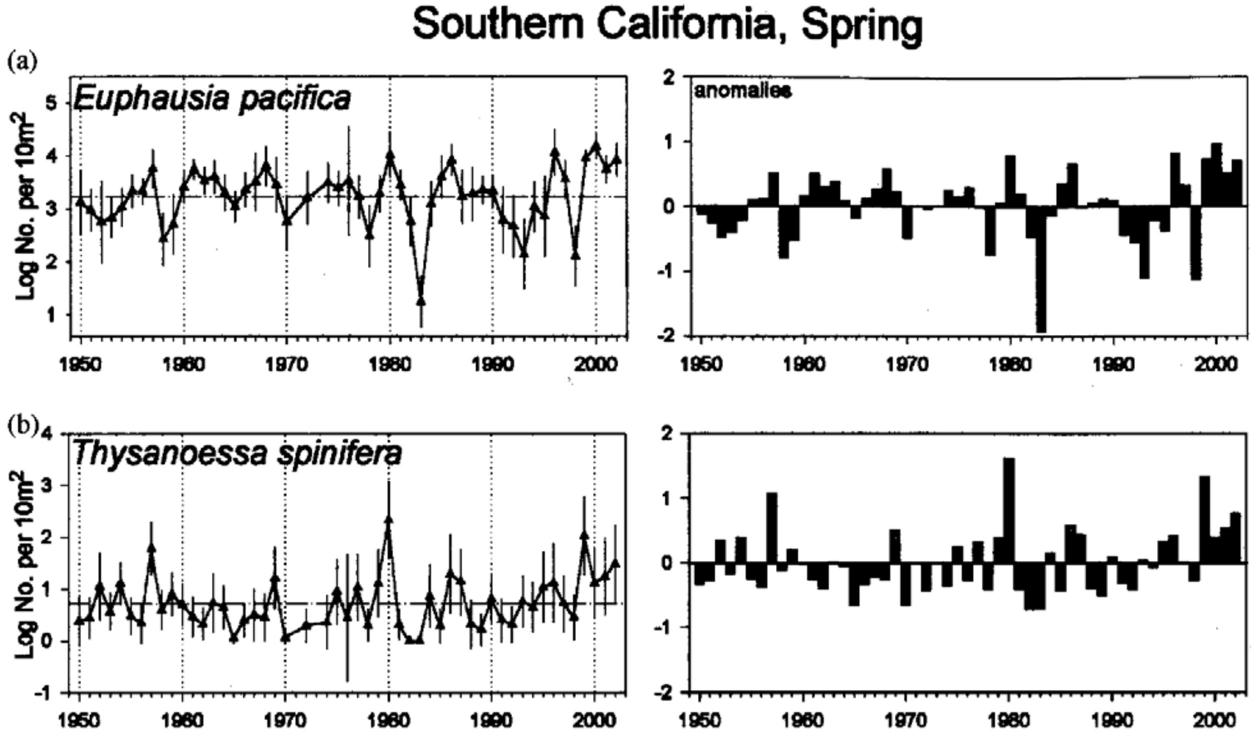

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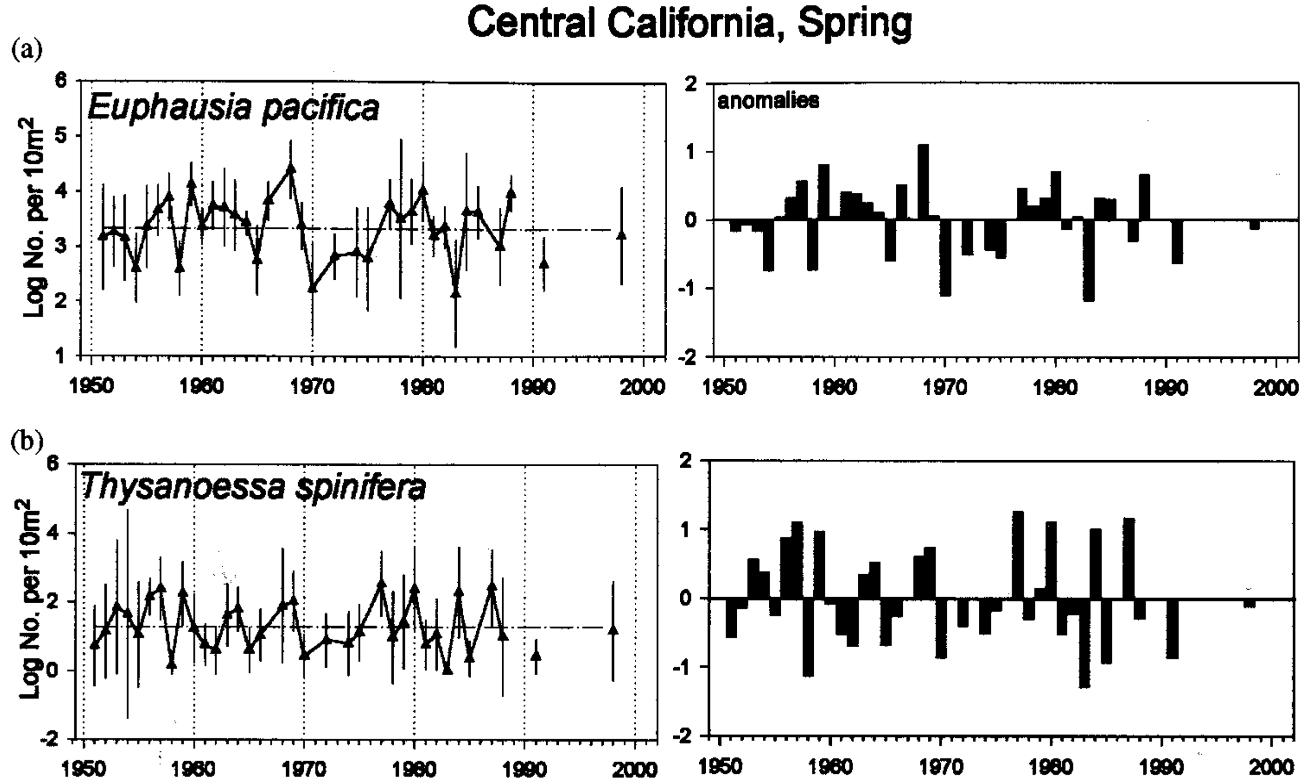

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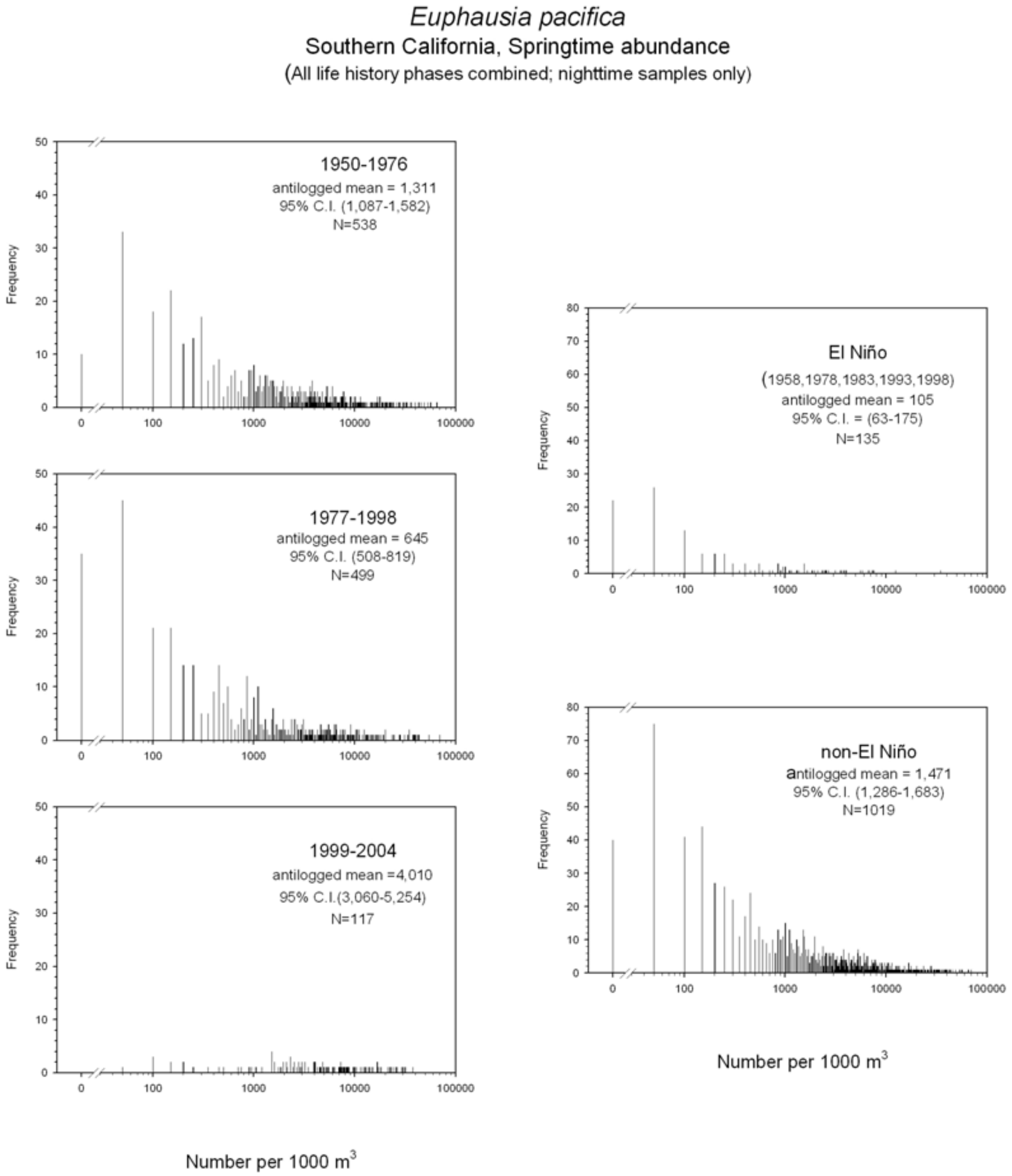

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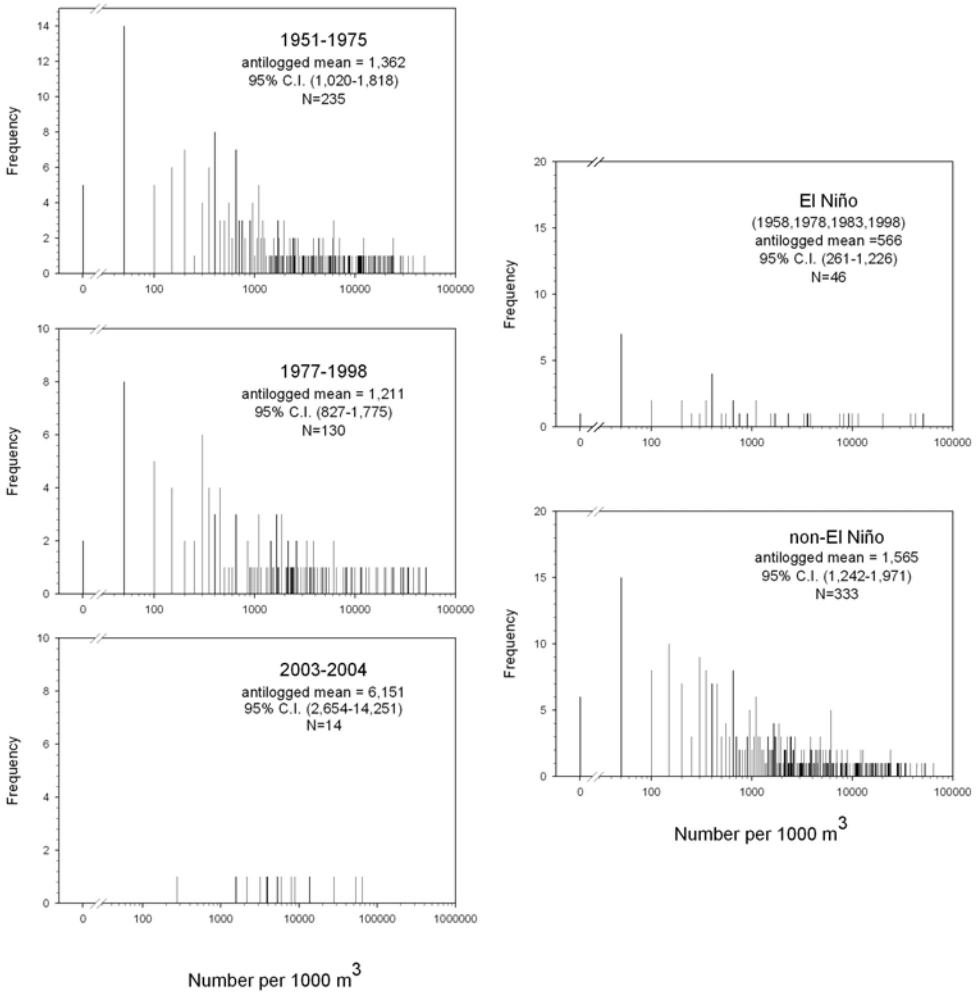
Euphausia pacifica
Central California, Springtime abundance
(All life history phases combined; nighttime samples only)



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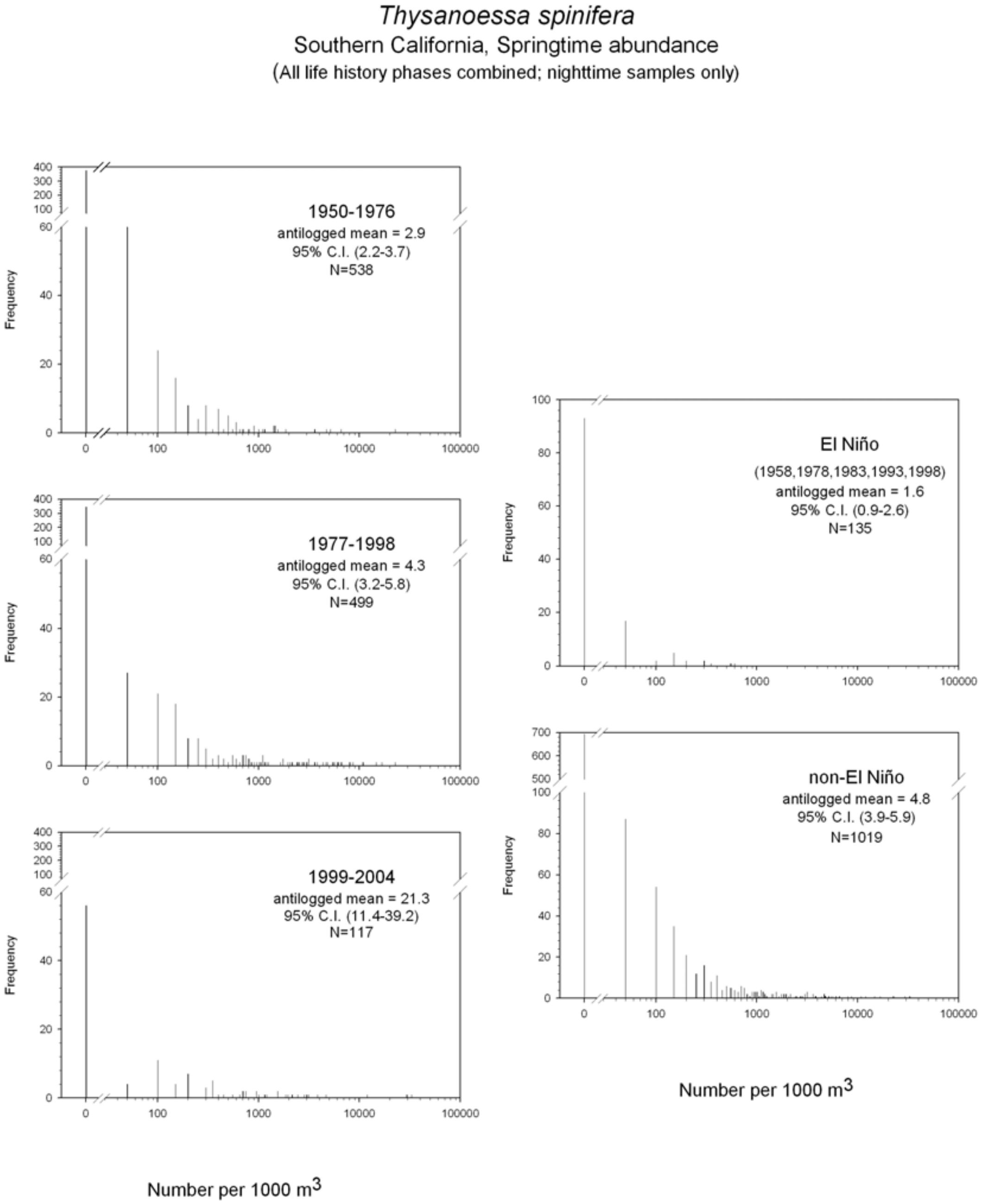

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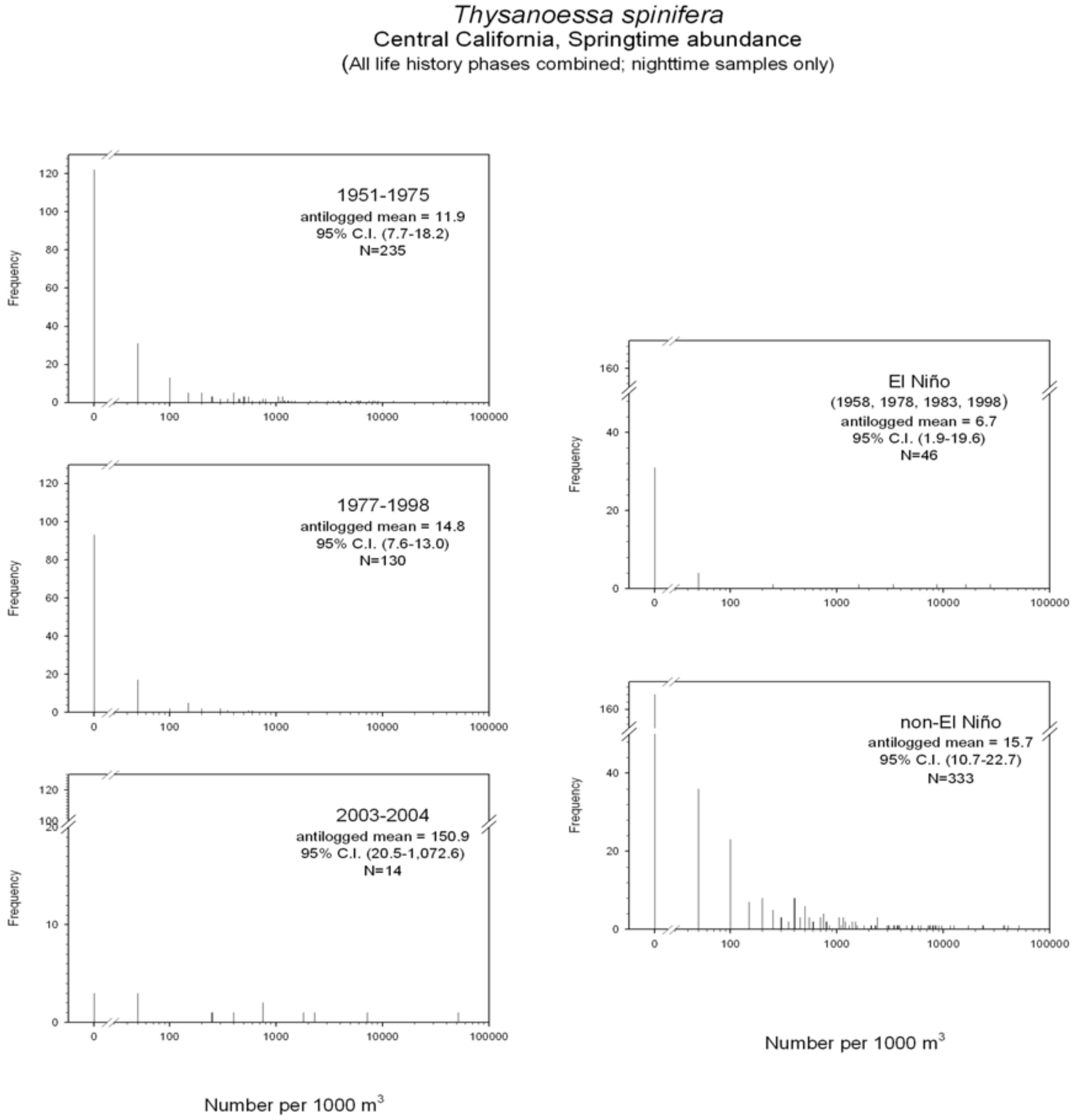

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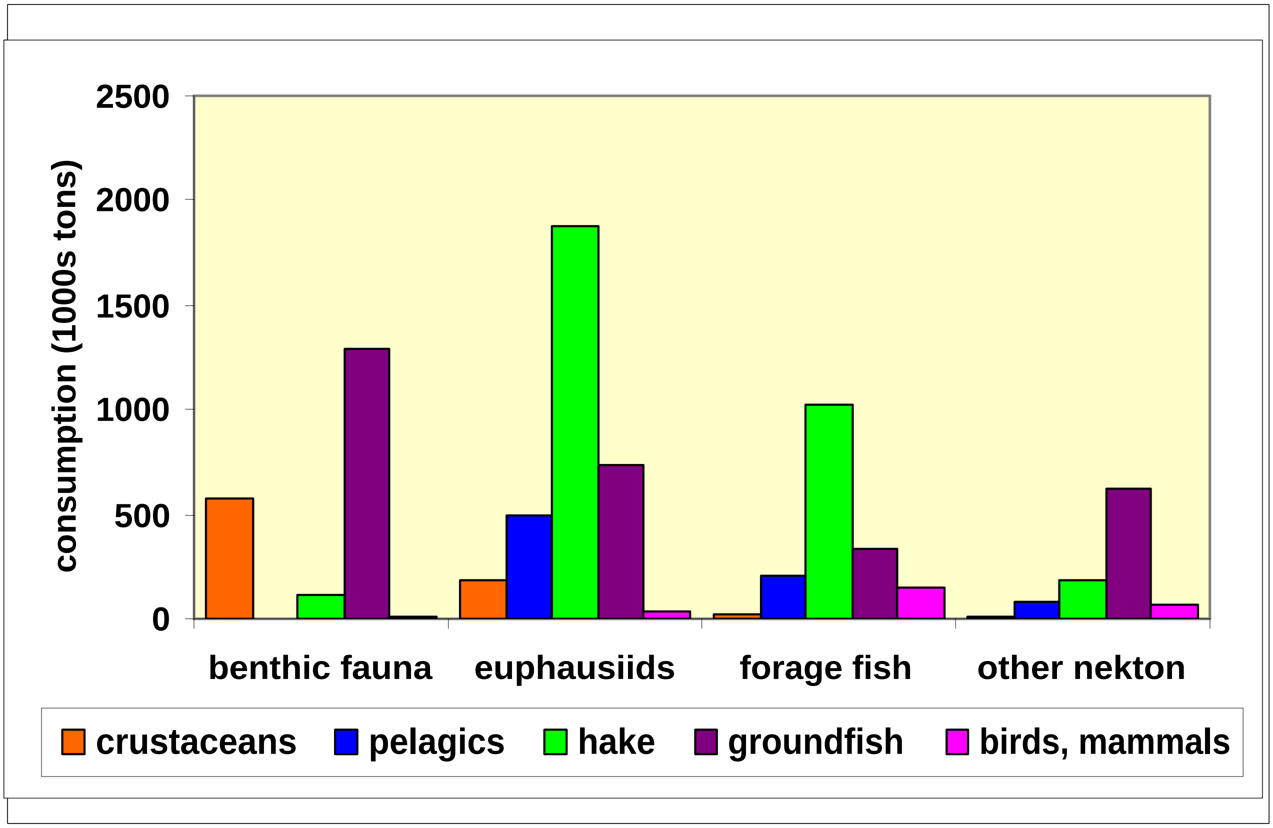

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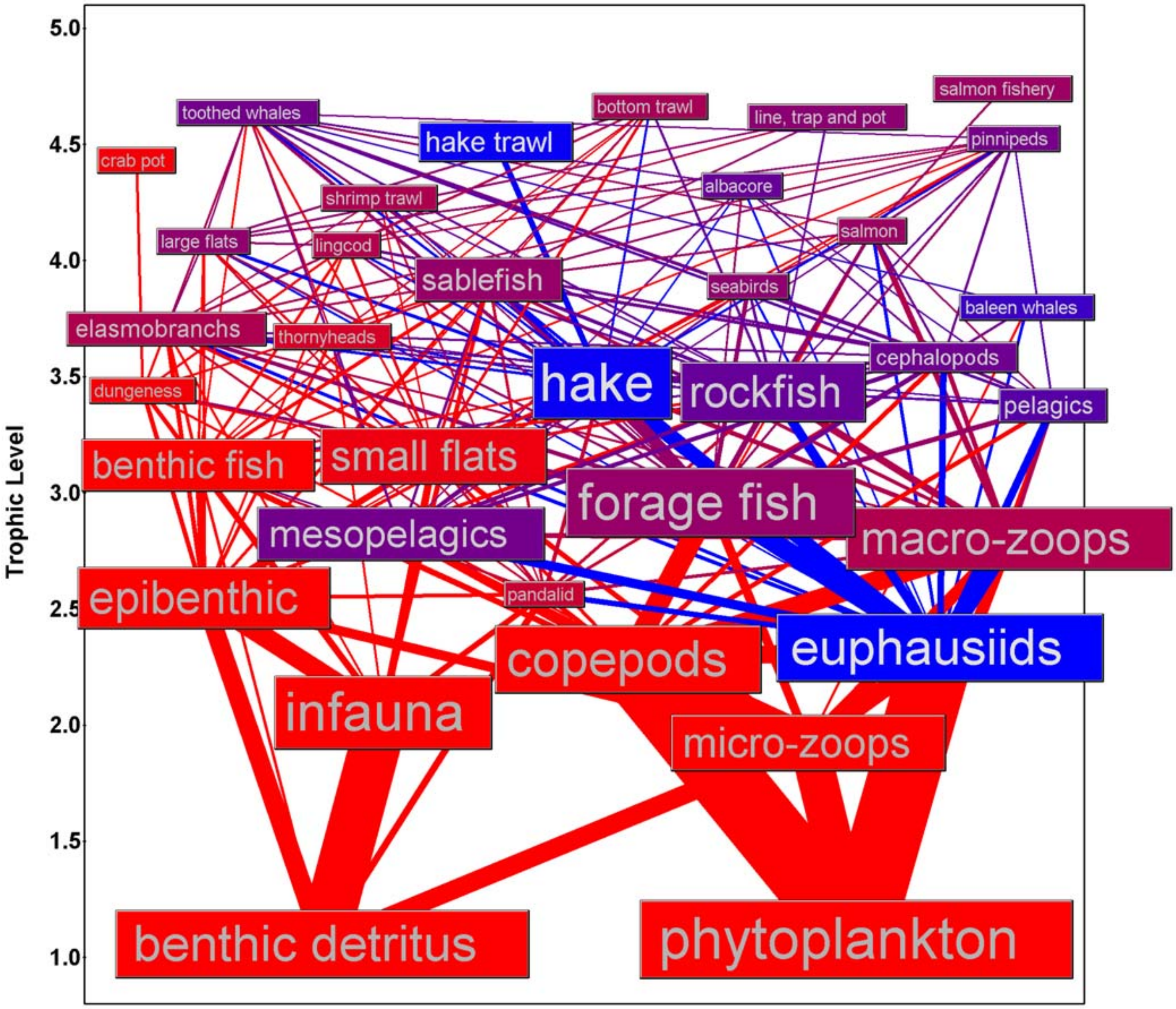

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	Salmon	Squid	CPS	Whiting	Rockfish	Lingcod	Flatfish	Sablefish	Groundfish	Albacore	Cal. Halibut	Pac. Halibut	**Total**
exvessel revenue ($)	16,000,000	21,500,000	10,500,000	18,700,000	13,500,000	500,000	13,000,000	16,700,000	2,600,000	26,000,000	2,000,000	1,800,000	142,800,000
Reduced revenue	48,000	64,500	31,500	56,100	40,500	1,500	39,000	50,100	7,800	78,000	6,000	5,400	428,400

8.0 ABBREVIATIONS AND ACRONYMS

CFR	Code of Federal Regulations
CZMA	Coastal Zone Management Act
DEIS	Draft Environmental Impact Statement
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EO	Executive Order
ESA	Endangered Species Act
FMP	Fishery Management Plan
HAPC	Habitat of Particular Concern
IRFA	Initial Regulatory Flexibility Analysis
MFMT	Maximum Fishing Mortality Threshold
MMPA	Marine Mammal Protection Act
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSST	Minimum Stock Size Threshold
MSY	maximum sustainable yield
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PRA	Paperwork Reduction Act
PRIA	Pacific Remote Island Areas
RIR	Regulatory Impact Review
RFA	Regulatory Flexibility Act
SDC	Status Determination Criteria