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ECOSYSTEM FISHERY MANAGEMENT PLANNING FOR U.S. WEST COAST FISHERIES

ECOSYSTEM PLAN DEVELOPMENT TEAM DRAFT REPORT

1 Introduction

This report addresses tasks the Pacific Fishery Management Council (Council or Pacific Council) assigned to its Ecosystem Plan Development Team (EPDT) at the Council's November 2009 meeting. The EPDT met with the Ecosystem Advisory SubPanel (EAS) on February 10-11, 2010, to discuss assignments received from the Council, receive informational briefings, and collectively brainstorm on how to best help the Council initiate an Ecosystem Fishery Management Plan (EFMP) development process. This report is divided into the following sections:

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This report is the EPDT's first product for Council and public review, and it concerns a subject that has a broad range of interpretations both within and beyond the Council family. Therefore, the EPDT considers this report and any suggestions or recommendations herein as preliminary guidance intended to help and inform the Council as it initiates its discussions on ecosystem-based fishery management.

2 Background on Ecosystem-Based Fishery Management and Council History on Ecosystem Fishery Management Plan Development

> *Ecosystem-based fishery management recognizes the physical, biological, economic and social interactions among the affected components of the ecosystem and attempts to manage fisheries to achieve a stipulated spectrum of societal goals, some of which may be in competition.*
>
> -- *definition from PSMFC 2005, subsequently adopted by Council*

In recent years, several nationwide bodies have reviewed U.S. ocean policy and approaches to marine resource management. Reports from these discussion processes have supported expanding fisheries management thinking so that it better accounts for the relationships of managed species with each other, with other species within their ecosystems, and to their biophysical environments (POC 2003, USCOP

2004, OPTF 2009.) These national discussions sync with international trends, particularly with work from the United Nations Food and Agricultural Organization (FAO,) which describes the ecosystem approach to fisheries as:

> *the merging of two different but related and—it is hoped— converging paradigms. The first is that of ecosystem management, which aims to meet its goal of conserving the structure, diversity and functioning of ecosystems through management actions that focus on the biophysical components of ecosystems (e.g. introduction of protected areas). The second is that of fisheries management, which aims to meet the goals of satisfying societal and human needs for food and economic benefits through management actions that focus on the fishing activity and the target resource (FAO 2003).*

The FAO described the purpose of an ecosystem approach to fisheries as "to plan, develop and manage fisheries in a manner that addresses the multiplicity of societal needs and desires, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems." (FAO 2003). This idea of not jeopardizing the options for future generations to benefit from marine resources has been a guiding principle behind U.S. fishery management at least since the 1976 Fishery Conservation and Management Act first defined conservation and management measures as being designed to assure that: "a supply of food and other products may be taken and that recreational benefits may be obtained, on a continuing basis; irreversible or long-term adverse effects on fishery resources and the marine environment are avoided; and there will be a multiplicity of options available with respect to future uses of these resources." (FCMA 1976).

Fundamentally, ecosystem-based fishery management recognizes that fisheries both affect and are affected by the marine environment, and that what we do to address these effects via policy-making is a matter of societal choice. The purpose of the ecosystem approach is not to prescribe particular policy choices, but rather to promote better understanding of those policy choices. Ecosystem-based fishery management is also not about replacing single-species approaches to fisheries management, but instead about continuing to improve them. Finally, ecosystem-based fishery management does not create additional mandates to protect the marine environment, but instead seeks to better understand fishery effects on the marine environment through improved information on ecosystem structure, processes and functions.

Most resource management decisions typically involve taking action in the face of competing objectives, as well as balancing the potential risk of undesirable outcomes with the probability of achieving their objectives. The objectives of ecosystem-based management for fisheries go beyond maintaining sustainable yields of living marine resources, to include maintaining biological diversity and habitat integrity, considering food web interactions, and avoiding activities that may cause long term or irreversible harm to ecosystem structure and function, and supporting human communities dependent on fishery-based economies. Decision-makers can also use ecosystem-based management to address the human dimension and society's interest in the benefits it derives from the full range of goods and services that marine ecosystems provide. Conservation and management measures should, for example, consider harvest levels for commercially and recreationally targeted species that take into consideration their interactions with other species having commercial, recreational, cultural, or existence value. People have often conflicting ranges of goals for and benefits from marine resources, creating a need for analyses that evaluate the tradeoffs among different ecosystem services. As discussed in Section 7 of this report, the role of science is to compile information and develop analytical tools to evaluate societal tradeoffs across the alternative ecological services that fishery resources provide.

In recent years, U.S. fishery management councils have expressed broad interest in ecosystem-based fishery management, with each council taking a different approach to incorporating ecosystem information into their fishery management processes. In keeping with published literature, the Pacific Council has discussed implementing ecosystem-based fishery management in a deliberative and iterative fashion, gradually adopting ecosystem goals, objectives and management actions, rather than a revolutionary upheaval in which current management structures, criteria and objectives are replaced (EPAP 1999, Link et al. 2002, Pikitch et al. 2004, Field and Francis 2006, Francis et al. 2007, Murawski 2007, Marasco et al. 2007). The Council has already implemented ecosystem-based fishery management principles through several existing actions, including a krill fishing ban, conservative harvest control rules for forage species, implementation of extensive area closures and marine protected areas, and the use of ocean survival indicators for determination of allowable fishery effects on coho salmon. The Council has also employed spatial management concepts for years and has recommended closed areas to rebuild overfished species, minimize bycatch, and preserve essential fish habitat. However, spatial management efforts are somewhat limited under the Council's existing fishery management authority, because the Council's decisions are made within single species or species-focused frameworks.

In November 2006, the Council moved to begin development of an ecosystem fishery management plan (EFMP) for waters off Washington, Oregon, and California. The Council envisioned an EFMP as an umbrella document for providing the fishery management process with additional ecosystem information, enabling comprehensive and coordinated fishery regulation in the exclusive economic zone (EEZ,) while allowing more species-specific management to continue under the Council's four fishery management plans (FMPs). The Council has expressed an intent that the EFMP help with long-term planning, particularly in improving and coordinating spatial management initiatives.

The Council maintains a detailed history of its EFMP considerations on its ecosystem-based management timeline website (http://www.pcouncil.org/ecosystem-based-management/ecosystem-management-timeline/). Since 2006, the Council has worked primarily through its Habitat Committee and with the Scientific and Statistical Committee and that committee's Ecosystem SubCommittee to discuss bringing ecosystem science and ecosystem-based fishery management into the Council process. In the fall of 2009, the Council acquired funds to initiate EFMP development and subsequently appointed members of an Ecosystem Plan Development Team and an Ecosystem Advisory Subpanel, providing initial tasks for these two new advisory groups.

The EPDT is a 13-member group of State, Federal, and Tribal scientists and policy analysts. The EAS is an 11-member multi-disciplinary group representing industry, policy, and conservation interests from the States and Tribes. The EPDT and the EAS will apply their unique perspectives and broad expertise in close coordination to provide the Council with analyses and recommendations on science in support of ecosystem-based fishery management principles and to develop goals, objectives, and policy alternatives for Council consideration as the EFMP takes shape over the next few years.

The Council assigned the following initial tasks to the EPDT, the EAS, and Council staff:

- Schedule presentations by scientists from the NMFS Northwest and Southwest Fisheries Science Centers on the state of the science in support of ecosystem-based fishery management.
- Review the Council record of dialogue on ecosystem-based fishery management including statements by the Council, its advisory bodies, and the public.
- Review the existing Council FMPs to identify existing approaches and commonalities regarding ecosystem approaches to management.
- Inventory ecosystem-related management tools for their applicability to the EFMP process.
- Review existing ecosystem-based management efforts of other regional fishery management councils.
- Prepare a report to the Council that includes statement of purpose and need; a list of initial goals and objectives; a range of options on the geographic range of the EFMP, the regulatory scope of the EFMP, and the management unit species within the EFMP; and list miscellaneous issues to be addressed by an EFMP.

The EPDT and the EAS held their first meeting as a joint session in Portland, Oregon on February 10-11, 2010. The meeting focused on the Council's initial tasks and ways the group could most effectively develop the requested report. The meeting also allowed some time to discuss the broad range of perspectives from members of the EAS and the EPDT on EBFM and how it could be applied to the Council process.

3 EFMP Straw Statement of Purpose and Need

The guiding principles and philosophies behind marine resource management in the United States are evolving from species-by-species fishery management to ecosystem-based fishery management. Ecosystem-based fishery management recognizes that social choices among different uses of living marine resources can result in a variety of tradeoffs between future resource uses and their effects on the environment. Council decisions on fisheries management throughout the California Current Ecosystem (CCE) will be improved with more and better information on the biophysical and socio-economic systems that support West Coast fish and fisheries. The Council's purpose in exploring ecosystem-based fishery management and in developing this initial EFMP is to improve the quality of information it uses to conserve and manage CCE fisheries.

This initial Ecosystem Fishery Management Plan (EFMP) will provide a framework for integrating information and understanding of: the natural and technological interactions that Council-managed species and fisheries have with each other and with the rest of the ecosystem; the effects of fishing on the environment, including the interactions between harvest rates for different Council-managed species and effects on nursery and rearing habitat; and the roles of fisheries in shaping socio-economic conditions within their communities. Ultimately, the EFMP will help the Council to identify the effects of fishing activities on the broad suite of marine ecosystem services people care about, including fisheries harvest opportunities and other consumptive and non-consumptive ocean uses.

This EFMP will provide a framework for improving understanding of ecosystem functions and fisheries interactions within the CCE and for identifying gaps in scientific data collections, analyses, and expertise.

An EFMP will also provide additional insights into tradeoffs that may be associated with alternative harvest policies where those policies affect interactions among Council-managed species. This EFMP is also needed to integrate the Council's different essential fish habitat management approaches for a diverse array of species. Finally, this EFMP can help to reduce the economic vulnerability of fisheries participants by minimizing dramatic shifts in harvest opportunities through better predictions of both near- and longer-term ecosystem trends.

This EFMP also has a role in national and West Coast governance of ocean resources. National and regional programs on coastal and marine spatial planning will require input from fishery management councils. This EFMP is needed to articulate Council priorities for a healthy ocean ecosystem, to improve the effectiveness of Council engagement with external entities that manage non-fishing activities that may affect the CCE. By articulating Council priorities, and their potential interactions with other human activities in the CCE, the EFMP could also aid in resolving some conflicts that may exist among Council FMPs, or among different management agencies or fishing sectors.

4 EFMP Straw Goals and Objectives

The goal of this EFMP is to bring a greater understanding of the California Current Ecosystem to the Council family and the public. The EFMP and its associated scientific products are intended to support Council decision-making in more fully addressing the common goals across all of its FMPs for a healthy ecosystem with productive and sustainable fisheries, and vibrant fishing communities.

Specific objectives of this EFMP are to:

- Provide the Council with tools that complement, rather than replace, Council decision-making processes for its species group FMPs.
- Provide the Council with an ecosystem context for its decisions that supports assessments of cumulative ecological, social and economic impacts, and understanding of trade-offs between multiple policy goals.
- Provide the Council with a framework for long-term strategic planning on management changes needed to move toward a healthier ecosystem with thriving fisheries and fishing communities.
- Integrate information and data across FMPs so that the Council can address common management concerns and objectives across FMPs (e.g. area-based management measures and marine spatial planning, socio-economic health, essential fish habitat).
- Develop measurable environmental/ecosystem indicators and corresponding thresholds for Council information and action.
- Use interdisciplinary approaches (e.g. integrated ecosystem assessments, and ecosystem models) to help implement conservation and management strategies that are robust to environmental, ecological, and socio-economic variability and change.
- Provide the Council process with information on short- and long-term climate and ocean conditions and trends.
- Provide the Council process with information on the status of target stocks, their prey and predators, and on trophic and non-trophic interactions among fished and unfished species.
- Identify and address gaps in ecosystem knowledge.

- Assess whether non-fishing activities could affect the health of the CCE to the detriment of Council-managed resources, so that the Council can more effectively engage in processes that manage those activities.
- Provide a mechanism for engaging other national and regional management bodies (e.g. West Coast Governors Agreement, Regional Fishery Management Organizations) on CCE issues.
- Maximize socio-economic value of ecosystem resources across species and habitats.
- Support international management efforts for Council-managed species by providing U.S. representatives with needed ecosystem science.
- Ensure that the EFMP itself and its supporting documents are clear, understandable, and useable.

5 Regulatory Scope and Management Unit Species

Fishery management councils are established by the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and their authority is granted and bounded by the MSA. Under the MSA, fishery management councils exercise authority over fish and fisheries by the development and amendment of fishery management plans (FMPs) and the adoption of fishery conservation and management measures. The North Pacific, South Atlantic, and Western Pacific fishery management councils have developed fishery ecosystem plans (FEPs). Each of those three councils has taken a different approach to fishery ecosystem planning and to the regulatory scopes of their FEPs (reviewed in NMFS 2009b). For example, the South Atlantic Fishery Management Council (SAFMC) recently completed its first comprehensive amendment to its FEP, which will be implemented through FMP amendments to seven separate species-specific or species group FMPs. The Western Pacific Fishery Management Council has converted all its species group FMPs into geography-based FEPs, which have all of the required characteristics of FMPs, yet are arranged by geography rather than taxonomy.

Neither the MSA nor its implementing regulations require or provide guidance on the contents of FEPs or EFMPs, which provides some flexibility for fishery management councils crafting these documents. For a Council to derive regulatory authority from an FEP or EFMP, however, that document would have to meet all of the MSA's requirements for managing any species, fishery, or area under any FMP, ecosystem-based or otherwise. In its early discussions of ecosystem fishery management planning, the Pacific Council expressed interest in crafting a vehicle for coordinating Council fishery regulation throughout the West Coast EEZ. More particularly, the Council sought the authority to manage fishery effects across all living marine resources. This discussion reviews potential Council authorities for ecosystem-wide planning and fishery regulation.

Fishery Management Unit

At its November 2009 meeting, the Council tasked the EPDT with reviewing alternative approaches to defining the fishery management unit (FMU) species for an EFMP or FEP. As discussed above, whether the EFMP or FEP has management unit species, and what species those might be, depend largely on how the Council wants to exercise its management authority. If the Council wishes to retain its management authority within its FMPs, similar to the SAFMC, it will develop an FEP with no FMU species and will use that FEP primarily as an advisory document. If, however, it wishes to have management authority over additional species and fisheries beyond those currently managed under its four FMPs, it can either amend one or more of those FMPs to add new species, or can develop an EFMP with its own set of FMU species separate from those of the four FMPs. The following terms help define FMUs and the bounds of Council management authority:

MSA Section 3, Definitions, (13):

> *The term fishery means – (A) one or more stocks of fish which can be treated as a unit for purposes of conservation and management and which are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics; and (B) any fishing for such stocks.*

MSA Section 3, Definitions, (12):

> *The term fish means finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds.*

Federal regulations at 50 CFR 600.10, definitions:

> *A fishery management unit (FMU) means a fishery or that portion of a fishery identified in an FMP relevant to the FMP's management objectives. The choice of an FMU depends on the focus of the FMP's objectives, and may be organized around biological, geographic, economic, technical, social, or ecological perspectives.*

Ecosystem-based fishery management for the CCE will bring new information into the Council process on a broad range of marine species, including species not defined as fish under the MSA, and species for which there is no fishery. Some species may be of interest to the Council for their roles as indicators of CCE health and productivity, even if those species are neither under Council management (e.g. state-managed fisheries or lower trophic level species,) nor under potential Council jurisdiction except as bycatch to be avoided (like marine mammals, turtles, and seabirds.) In describing alternative potential FMUs for the FEP or EFMP, this document assumes that the Council may request and discuss information on any species and its ecosystem relationships with other species (or even recommend action by other entities outside MSA authority to conserve and manage those species,) regardless of whether it has the authority or inclination to name that species to an FMU in any of its FMPs.

Ecosystem Component Species

In 2009, NOAA Fisheries published amended regulatory guidelines (74 FR 3178, January 16, 2009) for the MSA's National Standard 1, codified at 50 CFR 600.310. Among other things, those guidelines separate stocks within a fishery into target and non-target stocks, and then provide a sub-category of "ecosystem component species" within the non-target stock category. These regulations consider ecosystem component (EC) species to be species within a particular fishery management plan, not simply components of the larger ecosystem within which the fishery occurs. For example, the Council has considered listing several rarely caught rockfish species as EC species within the Groundfish FMP under draft Amendment 23. Those species are properly considered part of the Groundfish FMP's FMU, because they meet the FMP's definition of groundfish, but they also meet the federal regulations' definition of EC species at 50 CFR 600.310(d)(5)(i):

To be considered for possible classification as an EC species, the species should: (A) Be a non-target species or non-target stock; (B) Not be determined to be subject to overfishing, approaching overfished, or overfished; (C) Not be likely to become subject to overfishing or overfished, according to the best available information, in the absence of conservation and management measures; and (D) Not generally be retained for sale or personal use.

The MSA at Section 303(b)(12) grants the Council discretion to "include management measures in the [fishery management] plan to conserve target and non-target species and habitats, considering the variety of ecological factors affecting fishery populations." If the Council develops an EFMP and recommends management measures for species that are not subject to fishery targeting yet are important to the healthy functioning of the CCE, a conservative approach would be to identify those stocks as part of the fishery managed by the EFMP and list those species as FMU species. All of the MSA's requirements for managing FMU species would apply to any FMU species of the EFMP. If the criteria for EC at 50 CFR 600.310 are met, some of those stocks might also be identified as EC species.

The North Pacific Fishery Management Council completed an Arctic FMP in 2009 (NPFMC 2009,) implemented at 50 CFR 679. Very little data or analyses are available on any fish species within the U.S. Arctic EEZ. The Arctic FMP provides an example of an FMP primarily intended to close a large geographic area to fishing for fish stocks about which little is known. The Arctic FMP has three so-called target species for its FMU, none of which are subject to targeting, and a suite of EC species.

Additional Area Management Considerations

In addition to the general provisions applicable to all species meeting the MSA definition of "fish," the 2006 revisions to the MSA added authority for Councils to "designate zones where, and periods when, fishing shall be limited, or shall not be permitted, or shall be permitted only by specified types of fishing vessels or with specified types and quantities of fishing gear." Under Section 303(b)(2)(C), any area closure that prohibits all fishing would be required to "ensure that such closure:

(i) is based on the best scientific information available;

(ii) includes criteria to assess the conservation benefit of the closed area;

(iii) establishes a timetable for review of the closed area's performance that is consistent with the purposes of the closed area; and

(iv) is based on an assessment of the benefits and impacts of the closure, including its size, in relation to other management measures (either alone or in combination with such measures), including the benefits and impacts of limiting access to: users of the area, overall fishing activity, fishery science, and fishery and marine conservation."

The 2006 MSA revisions also added authority for fishery management councils to designate fishery closure zones to protect deep sea corals from physical damage by or interactions with fishing gear (MSA at Section 303(b)(2)(B).) In support of this provision, the 2006 reauthorizing act also added Section 408 to the MSA, which requires NOAA Fisheries to establish a deep sea coral research and technology program. The agency's 2007 report, *The State of Deep Coral Ecosystems of the United States*, discusses the current state of scientific information on deep sea corals and includes a chapter on West Coast deep sea corals (NMFS 2007.) The SAFMC has recommended establishing Coral Habitat Areas of Particular Concern with Amendment 1 to its FEP, which include some fishery closures for the protection of South Atlantic deep sea corals (SAFMC 2009). Should the Pacific Council wish to pursue fishery closures for coral protection, it could either do so under one or more of its species group FMPs, or under an EFMP with regulatory authority.

The 2006 revisions to the MSA did not alter the Act's essential fish habitat (EFH) provisions. Fishery management councils continue to have the authority to use FMPs to identify EFH for managed species and any adverse effects on EFH. Councils are also still permitted to comment on and make recommendations to the Secretary of Commerce or any Federal or State agency "concerning any activity authorized, funded, or undertaken or proposed to be authorized funded or undertaken, by any Federal or State agency that, in view of the Council, may affect the habitat, including essential fish habitat, of a fishery resource under its authority." (Section 305(b)(3)(A).) Councils are required to comment on and make recommendations regarding activities that are likely to substantially affect the habitat of anadromous species, such as Pacific Coast salmon (Section 305(b)(3)(B).). Through developing an FEP or EFMP, the Council may find that it wishes to revise the ways that it exercises these EFH-related authorities, potentially using the authorities to make Council priorities for ocean ecosystem management more broadly known to a range of ocean resource and activity management entities.

Alternative Fishery Ecosystem Plan (FEP) and Ecosystem Fishery Management Plan Formats				
	Advisory FEP	**Umbrella EFMP with Selected FMU and EC Species**	**Regional Omnibus EFMP**	**Coastwide Omnibus EFMP**
Plan Format Summary	Similar to the NPFMC's Aleutian Islands FEP and the SAFMC's FEP, this FEP would provide information on the biophysical processes of and West Coast community ties to the CCE. The FEP would not be a framework for regulations, but would provide information that could be used to support regulations under the Council's species group FMPs.	Fishing activities for Council-managed species would continue to be managed under species group FMPs. Select species that are important to the CCE as a whole would comprise the EFMP's FMU, and could be targeted (or not) according to Council management recommendations. Species for which there is no target fishery and minimal to no bycatch, but which are important to Council fishery management for reasons that meet National Standard 1 guidelines could be managed as EC species under this EFMP. Unless designated as an EFMP FMU species, all targeted and non-target bycatch species would continue to be managed under appropriate species group FMPs.	Similar to the WPFMC's FEPs, the West Coast EEZ would be split into several biogeographic provinces, with management frameworks for all of the current Council-managed species merge into region-specific FMPs. EC species and management frameworks for those species could be added to the appropriate FMPs under this EFMP format.	This omnibus EFMP would merge all of the current FMPs to provide regulatory authority for all Council-managed species within the CCE within the same document. EC species and management frameworks for those species could be added to the FMP under this EFMP format.
		All of the ecosystem information available under the Advisory FEP would also be available under any of these EFMP formats. In addition, the existing FMPs could incorporate ecosystem information available under the Advisory FEP through FMP or regulatory amendment.		
Fishery Management Unit (FMU) Species	None. Because this format is informational, no species would be subject to management under this FMP.	FMU would include any species that does not now easily fit within one of the Council's species group FMPs, or which is currently beyond any of those FMPs but in need of Council management. EC species may be included in the EFMP for any of the following reasons: For data collection purposes; for ecosystem	All species from current Council FMPs for a given geographic region, plus any additional predators or prey species the Council may wish to add and that fall within the definition of "fish" under the MSA, including EC species.	All species from current Council FMPs, plus any additional predators or prey the Council may wish to add that fall within the definition of "fish" under the MSA, including EC species.

		considerations related to specification of OY for the Council-managed fisheries; as considerations in the development of conservation and management measures for the Council-managed fisheries; or to address other ecosystem issues. Species that are vulnerable to Council-managed fisheries would continue to be included in the appropriate species group FMP.		
Potential activities regulated and range of authorities	No fishing activity would be regulated under the FEP format.	All fishing activity currently authorized for management under the MSA would continue to be authorized for FMU species.	All fishing activity currently authorized for management under the MSA would continue to be authorized for these regional omnibus EFMPs. EC species could be added to the appropriate EFMPs.	All fishing activity currently authorized for management under the MSA would continue to be authorized for this omnibus FMP. EC species could be added to the EFMP.

6 Geographic Range and Scale

The geographic range of an EFMP for U.S. west coast fisheries may be defined by three major boundaries in terms of management authority, physical and ecological characteristics, and socio- economics. The Council has management authority over fisheries within the U.S. West Coast EEZ, which ranges from the Canadian border to the Mexican border and from state marine boundaries (3 nautical miles) seaward to 200 nautical miles offshore. Council authority also extends to U.S. vessels fishing for FMP-managed highly migratory species when those vessels fish within or seaward of the EEZ and land their fish in California, Oregon, or Washington. Landward of the EEZ, Council authority is seated in essential fish habitat (EFH) designation, and in its responsibility to comment on and make recommendations regarding activities that may affect habitats of fishery resources under its authority.

The U.S. defines the biophysical realm of the CCE using the Large Marine Ecosystem (LME) concept, which is based on four linked ecological criteria: bathymetry, hydrography, productivity, and tropic relationships. Globally, the California Current LME is one of 64 distinct LMEs (UNEP 2008.) Like most ecosystems, the boundaries of the California Current LME are not strictly delineated, but it can be generally defined as extending from north-central Vancouver Island southward to southern tip of the Baja California. The ecosystem is characterized by its temperate climate and strong coastal upwelling, coupled with El Niño Southern Oscillations and Pacific Decadal Oscillations. These characteristics and dramatic short- and longer-term climatological shifts result in highly variable inter-annual and inter-decadal ecosystem productivity. Strong oceanographic forces play a large role in regulating the CCE's biological populations and communities, and its energy flow and ecological dynamics.

The socioeconomic boundaries of interest to the Council are shaped by the large and small coastal communities and fisheries of California, Oregon, Washington and Idaho. These include the economies of major estuaries, such as the San Francisco Bay, the Columbia River and the Puget Sound, but also those of smaller ports and economies of the four states.

In developing the geographic range of an EFMP, the Council should consider the dynamic relationship between the three major interacting elements of the ecosystem: the geographic scope and spatial scale of management, biophysical processes, and socioeconomic regions. As with the EFMP's management unit species, there are geographic areas that are not under Council authority or influence, but which are of interest to the Council for informational purposes. Two examples are the biophysical boundaries of the ecosystem, including the EEZ itself, plus upland watersheds for Council-managed salmon stocks, and marine waters beyond the U.S. EEZ for highly migratory species. If the EFMP is to be an evolutionary and living document, the Council might limit the initial geographic scope of the EFMP to the U.S. EEZ, with the intent that later EFMP iterations include marine and terrestrial systems beyond the EEZ.

In addition to beginning with the EEZ and anticipating further expansion outward, the Council might also consider subdividing the EEZ into smaller biogeographic regions, based on the Cape to Cape concept (Francis et al., 2008). A nested approach to defining smaller, cohesive, segments of the CCE may help the Council to best match the spatial scales of biological populations, ecological communities and human communities for particular management issues.

Maps: (add maps of EEZ, CCE, upland salmon EFH, others?)

7 The State of Ecosystem Science

Comprehensive reviews of ecosystem philosophies, principles, modeling approaches and other strategies abound in the scientific literature, as well in as the grey literature of management documents and records. This short review of the state of science for ecosystem-based management is by no means comprehensive, but rather is intended to illustrate the general scope of ecosystem science in a manageable manner. Three basic types of ecosystem science products that can be used by decision makers and stakeholders are considered. These include: (1) philosophical guidelines or principles for implementing an ecosystem approach to fishery management, (2) the role and availability of multispecies and ecosystem models to provide strategic management advice with respect to ecosystem issues and trade-offs among policy objectives, (3) the development and role of ecosystem indicators, including reports on ocean and climate conditions and integrated ecosystem assessments, and (4) ecosystem based management in practice. There is overlap among these broad and general types of tools, but they are distinct enough to frame a short review of how such tools have evolved and could be used by managers.

(1) Philosophical guidelines or principles for implementing Ecosystem based management

Throughout the published literature it is commonly stated that ecosystem-based fisheries management will require a suite of research efforts and products before it can be successfully implemented. However, many of the more philosophical research efforts and associated publications on ecosystem-based management have addressed management more broadly, rather than on a laundry list of data sources, methodologies and models. This literature argues that broad principles could be adopted to guide management decisions regardless of the quantity and quality of data available to managers. In principle, an ecosystem-based approach to management could be adopted without abundant information, data and precise knowledge of ecosystem interactions, by simply making management decisions in the context of those principles.

One guiding principle addresses the issue of poor knowledge of ecosystem interactions directly, by recommending that management "be cognizant of the levels of ignorance in which it is working" (Mangel et al. 1996). This comment recognizes the common criticism that it would be folly to adopt an ecosystem based approach to management due to the presumed immaturity of the science. All management actions involve making decisions in the face of uncertainty, ecosystem-based management simply expands the scope of the uncertainty and trade-offs to a broader scale. Thus, successful implementation of EBFM may be seen as management within the existing legal and institutional structure, but with additional guiding principles for decision-making. These guiding principles provide a holistic approach to fisheries management by emphasizing the relationships between the parts of ecosystem and the whole, informed by data, models and formal quantitative evaluation of tradeoffs and uncertainty that characterize most management decisions.

While the literature on ecosystem principles is voluminous, key themes emerge. Grumbine (1994) highlighted the need to maintain viable populations and ecosystem types, as well as evolutionary and ecological processes. Similarly, the Ecosystem Principles Advisory Panel (EPAP 1999) highlighted the importance of diversity to ecosystem function and recognized that exceeding ecosystem thresholds or limits can lead to ecosystem reorganization. Pikitch et al. (2004) and Francis et al. (2007) list sets of guiding principles, and also recommend the use of indicators to evaluate environmental quality and status.

Indicators are recommended to account for both ecosystem changes through time and evolutionary changes caused by fishing, and to constantly question key assumptions, no matter how basic they might seem. These principles, along with those developed by Grumbine and EPAP, are listed in Appendix A, recognizing that these are a subset of similar lists available in the literature.

Lists of ecosystem principles can provide meaningful guidance and insight for managing with an ecosystem context. These principles might also be reduced into a key overarching principle, for example Holling and Meffe (1996) described the "golden rule" of ecosystem management as "management should strive to retain critical types and ranges of natural variation in resource systems in order to maintain ecosystem resiliency." That golden rule is based on the observation that ecosystems have thresholds and can flip between alternative states when thresholds are breached – such states may or may not be reversible. Given a more socioeconomic perspective, McEvoy (1996) contends that the most important target for achieving sustainability is the "long-term health of the interaction between nature, the economy, and the legal system," recognizing the importance of evaluating the social and economic needs while maintaining ecological structure and dynamics.

(2) Multispecies and ecosystem models

Typically, the role of all fisheries models, whether single or multispecies, is to understand and inform decision-makers of the consequences of fishing or other human activities to living resources and the ecosystem in which they exist (Hollowed et al. 2000). While there have been attempts to model the inter-specific and community dynamics of ecosystems, the complexity of these interactions, coupled with the data requirements needed for model validation and the computing power needed to run complex models, have historically been limiting factors in the development of models for use by managers. However, in recent decades, the science of modeling ecosystem interactions has advanced tremendously and monitoring efforts have assembled data appropriate for developing relatively data rich single and multispecies models for many ecosystems. Consequently, there has been resurgence in the development and application of ecosystem models in recent years.

A wide range of multispecies and ecosystem models have been developed and published in peer-reviewed literature, and a limited (but growing) number have been used to help inform marine resource management decisions. Comprehensive reviews of the multispecies and ecosystem modeling tools available to marine researchers, with detailed consideration of their strengths, drawbacks, and best practices for developing such models, are available from both NMFS (Townsend et al. 2007, Link et al. 2009) and the United Nations Food and Agriculture Organization (Plagyani 2007). In short, ecosystem models are complex, predictability is limited, and formally addressing uncertainty poses a unique set of challenges. Yet the science behind such models has significantly improved in recent years, and many regions now have sufficient data to begin applying these models in resource management. Given the increasing number of ecosystem modeling approaches clearly defined management goals and questions are important. As Hill et al. (2007) state, "Predictive models, especially in ecology, are rarely intended to provide an all-encompassing description of how a system actually works, but they are intended to forecast how certain characteristics of the system respond to a specific set of conditions." Models can also serve as a stimulus and focus for initiating dialogues and discussions on future ecosystem trade-offs among management decisions.

Several published models are available for resources managed by the PFMC; an *Ecopath with Ecosim* model of the Northern California Current (north of Cape Mendocino) developed by Field et al. (2006), a seasonal model of the Oregon shelf ecosystem to evaluate the role of jellyfish (Ruzicka et al. 2007), and an *Atlantis* model of the California Current north of Point Conception documented in Brand et al. (2007). Some recent model applications include informing decisions such as the krill harvest ban (PFMC 2008), exploration of the role of Humboldt (jumbo) squid in the California Current (Field et al. 2007), analyses of potential ecosystem indicators (Samhouri et al. 2009), and comparative evaluations of ecosystem status from both single and multispecies perspectives (Worm et al. 2009). The *Atlantis* model in particular is likely to play a central role in quantifying trade-offs in future efforts to develop Integrated Ecosystem Assessments (IEAs) for the California Current (Levin et al. 2009).

Ecosystem models have also been used to formally evaluate tradeoffs between Pacific sardine as a directed fishery target and as forage for other commercially and ecologically important species (Hannesson et al 2009; Hannesson and Herrick, 2010). The sardine example represents a growing body of efforts to develop models that account for ecological and economic interactions (Finnoff and Tschirhart, 2003, 2004; Eichner and Tschirhart 2007). Such models consider the benefits and costs related to the use of fishery resources: (1) consumptive use (2) non-consumptive use; and (3) indirect use of the resource in its natural state, and explore the consequences of alternative management actions to facilitate comparisons and trade-offs among management decisions. Extending this framework to more complex situations (e.g. multiple ecosystem functions, uncertainty, and dynamics) will require a great deal of detailed economic and ecological data, a commonality among all ecological and socioeconomic modeling approaches.

(3) Ecosystem indicators, status reports, and integrated ecosystem assessments

The third type of ecosystem information for potential Council consideration includes ecosystem status reports, ecosystem indicators, and the results of integrated ecosystem assessments (IEAs). There are several products that could be adopted or otherwise incorporated into the Council EBFM framework in order to inform decision making on the significance of environmental conditions to productivity and possible risk, as well as possible trade-offs among competing management objectives.

The *State of the California Current* (e.g., McClatchie et al. 2009) report is a comprehensive summary of physical climate and oceanographic trends (e.g. ocean temperatures, upwelling, basin scale indices such as El Nino) as well as biological productivity (zooplankton abundance, forage fish abundance, seabird and marine mammal productivity) taken from a wide range of monitoring and research efforts throughout the CCE. While the report is technical in nature, it provides an example of a publication that distills trends in ocean conditions and productivity in a way that may be informative for decision-makers. Similar documents are prepared for the North Pacific Fishery Management Council (The NPFMC Ecosystem Considerations Chapter, Boldt and Zador 2010), for the Department of Fisheries and Oceans in Canada (DFO 2009), and for the entire suite of ecosystems that comprise the North Pacific Ocean (PICES 2005). The Council has already begun to consider a summary of indicators for Pacific salmon management, based on work by Peterson et al. (2008) linking a suite of productivity metrics (ocean temperatures, timing of the spring transition, species composition and abundance of zooplankton communities). While these indicators are qualitative, they provide general guidance on the relative degree of productivity to be expected by salmon in the coastal ocean. Similarly, Wells et al. (2008) developed a statistical model that relates physical ocean and climate conditions with the productivity of lower, middle and higher trophic level species off of Central California, which could be used as an indicator of ecosystem productivity.

In addition to empirical indices or indicators of ocean conditions and productivity, both single and multispecies models provide estimates of resource productivity and status. The Council is currently familiar with single species reference points regarding stock status and trends. Ecosystem models are increasingly being used to develop indicators of ecosystem status, state or health, with one of the most cited criteria for useful indicators being that they can characterize the effects of fishing relative to standing biomass and productivity in an unambiguous and quantifiable manner (Murawski 2000). While the development of meaningful indicators remains a focal area of research, particularly through the use of simulation testing, suites of indicators may provide the most robust results. In general, it seems that indicators of key functional groups or at the level of community organization, such as zooplankton, forage fish and jellyfish, are most likely to characterize ecosystem state most reliably, possibly due to their rapid response to both direct and indirect changes in fishing pressure (Fulton et al. 2005; Samhouri et al. 2009). By contrast, indicators such as seabird biomass, or trophic level of the (fisheries) catch and total catch perform relatively poorly in simulation studies, although it remains necessary to validate these indicators with empirical data.

Socio-economic indicators could represent the varied benefits that society derives from ecosystem services. Evaluating stakeholder interests will define these benefits, which in the case of ecosystem-based fisheries management can be broadly categorized as: commercial fishing, recreation, and the environment. Each group benefits from better commercial fishing, better recreational fishing, bird watching, and other activities, and better stewardship, respectively. These indicators can provide practical and defensible measures of relative ecosystem value that can then be used to evaluate EBFM alternatives.

In recent years, the concept of integrated ecosystem assessments (IEAs) has been promoted as a means to provide an appropriate interface between ecosystem science and the management community. The IEA approach builds upon risk analysis methods, and is best described as "A formal synthesis and quantitative analysis of information on relevant natural and socioeconomic factors, in relation to specified ecosystem management objectives" (Levin et al. 2008, Levin et al. 2009, deReynier et al. 2010, Tallis et al. 2010). IEAs are not meant to replace current management approaches, but rather to highlight the tradeoffs and conflicts among competing objectives that are associated with management decisions. IEAs would likely draw upon both ecosystem models and model-based or empirical ecosystem indicators, by using risk analysis approaches to determine the probability that a given indicator may shift to, or stay in, an undesirable state in response to human activities and/or natural processes. IEAs could also use a management strategy evaluation (MSE) approach to simulate ecosystem behavior and allow the ability to forecast changes in ecosystem state in response to management scenarios or decision rules, simultaneous with assessment of the empirical indicators based on in-situ ecosystem monitoring efforts. Recently, the NWFSC and the SWFSC have together secured funding to support preliminary development of IEA products for West Coast marine resources, which should provide opportunities for the Council and its advisory bodies to become exposed to and provide feedback upon such initiatives.

(4) Ecosystem based management in practice

While the science and the literature regarding ecosystem-based management are broad, examples of these products being applied in practice are limited (Tallis et al. 2010, Lester et al. 2010). The Alaska Fishery

Science Center is a world leader in compiling both the data necessary to develop quantitative food web models (e.g., Aydin and Mueter 2007, Gaichas et al. 2009, Kinsey and Punt 2009). Results from AFSC ecosystem research are regularly brought before the NPFMC, and have been used to qualitatively guide decisions in conjunction with the results of traditional single species assessments. For example, in 2006 the NPFMC SSC recognized that while the Eastern Bering Sea Pollock stock was above the target (MSY) level, the stock had been declining due to poor recruitment, and ecosystem indicators suggested declines in zooplankton (prey), while an ecosystem model indicated an increase in juvenile predation by arrowtooth flounder (predators). The SSC consequently recommended adopting a reduction in the maximum permissible ABC to account for these concerns.

Ecosystem advice has also been developed to inform management of Antarctic krill, by the Commission for the Conservation of Antarctic Marine Living Resources. Key management questions for Antarctic krill revolve around how to spatially allocate the allowable catch in a manner that minimizes the potential effects on krill-dependent predators. As the key uncertainties in this question relate to krill movement and advection rates, as well as the functional relationships between krill and their predators, several biophysical models have been developed in order to address these questions, and with which to explore competing hypotheses regarding krill movement and advection. As resource managers continue to be confronted with complex issues and trade-offs related to managed species and their complex interactions with climate conditions, other elements of the food web, and direct and indirect human activities, there is clearly a role for greater application of ecosystem principles, models, indicators and assessments of many flavors. Among the greatest challenges now is how to incorporate such guidance into the existing and continually evolving management framework in order to better understand the tradeoffs associated with management decisions.

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9 Appendix A

Examples of ecosystem principles and guidelines for management, some of which have been paraphrased, refer to originals for the author's precise language.

Grumbine (1994) detailed five specific goals for sustaining ecological integrity

- Maintain viable populations of all native species in situ.

- Represent, within protected areas, all native ecosystem types across their natural range of variation.
- Maintain evolutionary and ecological processes (disturbance regimes, hydrological processes, nutrient cycles, etc.).
- Manage over periods of time long enough to maintain the evolutionary potential of species and ecosystem.
- Accommodate human use and occupancy within these constraints.

The Ecosystem Principles Advisory Panel (EPAP 1999) outlined eight guiding principles for marine ecosystem management:

- The ability to predict ecosystem behavior is limited.
- Ecosystems have real thresholds and limits which, when exceeded, can affect major system restructuring.
- Once thresholds and limits have been exceeded, changes can be irreversible.
- Diversity is important to ecosystem functioning.
- Multiple scales interact within and among ecosystems.
- Components of ecosystems are linked.
- Ecosystem boundaries are open.
- Ecosystems change with time.

Pikitch et al. (2004) propose that the overarching objective of EBFM is to sustain healthy marine ecosystems and the fisheries they support, which can be done with the following guidelines:

- Avoid degradation of ecosystems, as measured by indicators of environmental quality and system status
- Minimize the risk of irreversible change to natural assemblages of species and ecosystem processes
- Obtain and maintain long-term socioeconomic benefits without compromising the ecosystem
- Generate knowledge of ecosystem processes sufficient to understand the likely consequences of human actions

Francis et al. (2007) outlined ten “commandments” for implementing EBFM:

- Keep a perspective that is holistic, risk-averse, and adaptive.
- Question key assumptions, no matter how basic.
- Maintain old-growth age structure in fish populations.
- Characterize and maintain the natural spatial structure of fish stocks.
- Characterize and maintain viable fish habitats.
- Characterize and maintain ecosystem resilience.
- Identify and maintain critical food web connections.
- Account for ecosystem change through time.
- Account for evolutionary change caused by fishing.
- Implement an approach that is integrated, interdisciplinary, and inclusive.