Pacific Fishery Management Council Implementation of Ecosystem-Based Fisheries Management

Erik Young

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Marine Affairs

University of Washington

2013

Committee:

David Fluharty (chair)

Penelope Dalton

Yvonne deReynier

Program Authorized to Award Degree:

School of Marine and Environmental Affairs

Abstract

Eight Regional Fishery Management Councils, together with the National Marine Fisheries Service, are responsible for Federal fisheries management in the U.S. Exclusive Economic Zone. They do so in accordance with many statutory mandates, including the Magnuson-Stevens Act and the National Environmental Policy Act. The Ecosystem Principles Advisory Panel, established by the Sustainable Fisheries Act, recommended that the Regional Fishery Management Councils adopt an ecosystem-based management approach. This recommendation was endorsed and reiterated by the U.S. Commission on Ocean Policy, the National Ocean Council, and the Pew Oceans Commission, each recommending that fisheries managers adopt management methods to transition from a single species approach to one that is ecosystem-based. The Regional Fishery Management Councils are afforded considerable discretion, and approaches to fisheries management can include elements of both single species and ecosystem-based management strategies. The extent to which an ecosystem-based approach has been adopted can be assessed based on (1) the presence of ecosystem-based management characteristics, and (2) the adoption of a comprehensive plan to implement those characteristics. The Pacific Fishery Management Council, which manages fisheries on the U.S. West Coast at the Federal level, is following a hybrid approach, utilizing in large part a single species approach to management in its fishery management plans, but also incorporating many elements of ecosystem-based management. Recently, it has taken additional concrete steps to advance ecosystem-based management through the development and adoption of a Fishery Ecosystem Plan, and by bringing information generated by NOAA's Integrated Ecosystem Assessment into the Pacific Fishery Management Council process. The cumulative effect of these efforts

indicates that a transition towards ecosystem-based fishery management is being made gradually. Additional actions focusing on functional coordination and the development of a single set of measurable objectives may facilitate this transition.

TABLE OF CONTENTS

INDEX OF FIGURES AND TABLES

I. Introduction

The ocean area comprising the U.S. Exclusive Economic Zone is larger than the combined land area of the fifty states (NOAA 2011). Prudent stewardship of its resources is imperative. Ecosystem-based management of the oceans, originally endorsed by the Ecosystem Principles Advisory Panel (EPAP) in a 1999 Report to Congress (Ecosystem Principles Advisory Panel 1999), was subsequently endorsed by a number of influential groups, among them the U.S. Commission on Ocean Policy (U.S. Commission on Ocean Policy 2004), the National Oceanic and Atmospheric Administration (NOAA) (NOAA 2010), and the Pew Oceans Commission (Pew Oceans Commission 2003). The purpose of this paper is to summarize and evaluate the activity undertaken by the Pacific Fishery Management Council (Pacific Council) to implement ecosystem-based management. As a result, its scope will be limited to ecosystem-based management relating to fishing, since that is the scope of Pacific Council authority. However, in order to do so, the discussion that follows first addresses the following issues:

- What constitutes ecosystem-based fisheries management?
- Is ecosystem-based fisheries management a good idea?
- What are the characteristics of ecosystem-based fisheries management, and what is a good process for implementing it?
- Can it be implemented by the Regional Fisheries Management Councils under the existing regulatory structure?

A general consensus statement was developed in 2005 regarding the definition and characteristics of ecosystem-based fisheries management (McLeod et al. 2005). Subsequent studies have further developed the subject, and a number of analyses have also focused on

implementation strategies. According to the Food and Agricultural Organization of the United Nations (FAO), the purpose of an ecosystem approach to fisheries is to "plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems" (FAO 2003). In its current Strategic Plan, NOAA has defined ecosystem-based management as one that "accounts for the complex connections between organisms (including humans); their physical, biotic, cultural, and economic environments; and the wide range of processes that control their dynamics" (NOAA 2010). In its stewardship role, NOAA has adopted objectives that include an "improved understanding of ecosystems", in order to "inform management decision-making", resulting in "healthy habitats that sustain resilient and thriving marine resources and communities" (NOAA 2010).

A synthesis of these and other definitions of ecosystem–based management for the oceans suggests that any management strategy requires consideration of both natural and human factors. Ideally, governance should be performed in a coordinated way across all sectors of human activity that affect the oceans (Rosenberg and McLeod 2005). Fishing is only one of these sectors. However, historical evidence indicates that it has the largest impact on ocean biodiversity of any human activity (Jackson et al. 2001). Given the major impact of fishing, coupled with the overall fragmented U.S. regulatory structure governing the environment, adoption of ecosystem-based management principles as an element of fisheries management is a critical step towards a comprehensive adoption of ecosystem-based management for the oceans.

Several of the Regional Fishery Management Councils other than the Pacific Council have taken steps to accelerate the adoption of ecosystem-based fisheries management principles. The North Pacific Fishery Management Council has adopted many approaches that are consistent with an ecosystem-based approach. These include establishing conservative catch limits even where populations are abundant, using bycatch management measures that include catch limits and gear restrictions, setting up marine protected areas by closing certain areas to bottom trawling and scallop dredging, protecting marine mammals and seabirds by setting low catch levels for pollock and Atka mackerel, and banning directed fishing for important forage fish including capelin and krill (Witherell et al. 2000). The North Pacific Fishery Management Council has also adopted a fishery ecosystem plan for the Aleutian Islands Fishery (NPFMC 2007). The Aleutian Islands were chosen as a "pilot ecosystem area" for this initial fishery ecosystem plan for Alaska, because of their ecological and historical uniqueness. The fishery ecosystem plan goal is to "provide enhanced scientific information and measurable indicators to evaluate and promote ecosystem health, sustainable fisheries, and vibrant communities in the Aleutian Islands region" (NPFMC 2007). The fishery ecosystem plan conducted its evaluation of ecosystem functions and relationships based on the Aleutian Islands ecosystem area, and any recommendations are to be implemented after consideration and adoption through the existing fishery management plan process. It is intended to function as an educational and "early warning" system to provide an "ecosystem context" to fishery management decisions (NPFMC 2007). It functions as a guidance document, but does not have any legally binding authority. The fishery ecosystem plan recommends that a

framework be adopted for indicators to serve as this early warning system, and intends to match the indicators to fishery management objectives.

The Western Pacific Regional Fishery Management Council has also adopted a fishery ecosystem plan approach (WPRFMC 2012). In 2010 it replaced its five species-based fishery management plans (Bottomfish and Seamount Groundfish, Crustaceans, Precious Corals, Coral Reef Ecosystems, and Pelagics), with five fishery ecosystem plans (Pelagics, American Samoa, the Marianas, Hawaii, and the Pacific Remote Islands Area) (WPRFMC 2012). The fishery ecosystem plans have adopted boundaries that are ecosystem-based, except for the Pelagics group. Although they have adopted this place-based approach, at this point the fishery ecosystem plans simply incorporate and regroup on a regional basis the regulations previously contained in the fishery management plans. The fishery ecosystem plans do not currently contain any new management regulations (WPRFMC 2012). As a result, although the fishery management plans have been regrouped based on ecosystems rather than species, their substance from a regulatory perspective has not really changed at this early stage.

The South Atlantic Fishery Management Council (SAFMC) adopted a fishery ecosystem plan in 2009 (SAFMC 2009). It expanded the prior existing SAFMC Habitat Plan, and provided a description of all managed species including their roles in the ecosystem, summarized the socioeconomic characteristics of the relevant fisheries, described the criteria used for Essential Fish Habitat and Habitat Areas of Particular Concern, and described existing data needs. Actual implementation of ecosystem-based management is being accomplished through Comprehensive Ecosystem-Based Amendments (CE-BAs). Two have been approved. The first included actions to protect deep-water corals (SAFMC

and NMFS 2009); and the second adopted steps to protect octocorals, established special management zones, and put gear restrictions in place to protect sea turtles (SAFMC and NMFS 2011)

The Pacific Council manages U.S. fisheries within the Exclusive Economic Zone off the coasts of Washington, Oregon, and California. The analysis that follows reviews the extent to which the Pacific Council has taken steps to implement these elements and processes that are characteristic of ecosystem-based fisheries management. Although its Fishery Management Plans are organized based on broad species groups rather than ecosystem boundaries, ecosystem-based factors and analysis can be found within those fishery management plans, and the related stock assessment work that forms the basis for establishing fishing limits. Recently, a new initiative, the Pacific Coast Fishery Ecosystem Plan, has been approved. In addition, ecosystem-based science efforts are also occurring as part of NOAA's Integrated Ecosystem Assessment for the California Current Ecosystem. What is the current status of these initiatives, and do they form part of an integrated strategic process?

II. What are the characteristics and the implementation process for an ecosystem-based approach for fisheries management?

Any evaluation of ecosystem-based fisheries management requires both an understanding of the definition of ecosystem-based management, and how it differs from a single species management approach. Ecosystem-based management and single species management can be viewed as being on opposite ends of a continuum. Any assessment must recognize that choices between the two are not necessarily binary; fishery

management systems may simultaneously incorporate elements from both ecosystem-based and single species based systems. They can range from: a simple, single stock/single species approach; to systems that evaluate multiple species, others that include analysis of a food chain; and at the other end of the scale, very complicated methodologies that take into account the total ecosystem (Link 2002). However, even multi-factor ecosystem modeling will continue to rely upon the data generated by single species management. One possible approach is to use a single species management strategy, while incorporating enough precautionary buffers that would be sufficient to cover the uncertainties arising due to ecosystem factors (Pikitch et al. 2004). As more data become available, reliance on precautionary principles could decrease (Pikitch et al. 2004).

Single species management focuses on the goal of maintaining sustainable yield from individual populations. It has advantages due to its minimization of model input factors, making application less complicated than an ecosystem methodology. Its weaknesses include the fact that it omits consideration of many other variables that could be taken into account in assessing fishery impacts. These include the relationship between stocks, issues associated with bycatch, and habitat impacts (Link et al. 2002). Diversity, and the maintenance of species relationships within a trophic system, which are important in an ecosystem approach, are not objectives in single species management (Murawski 2000).

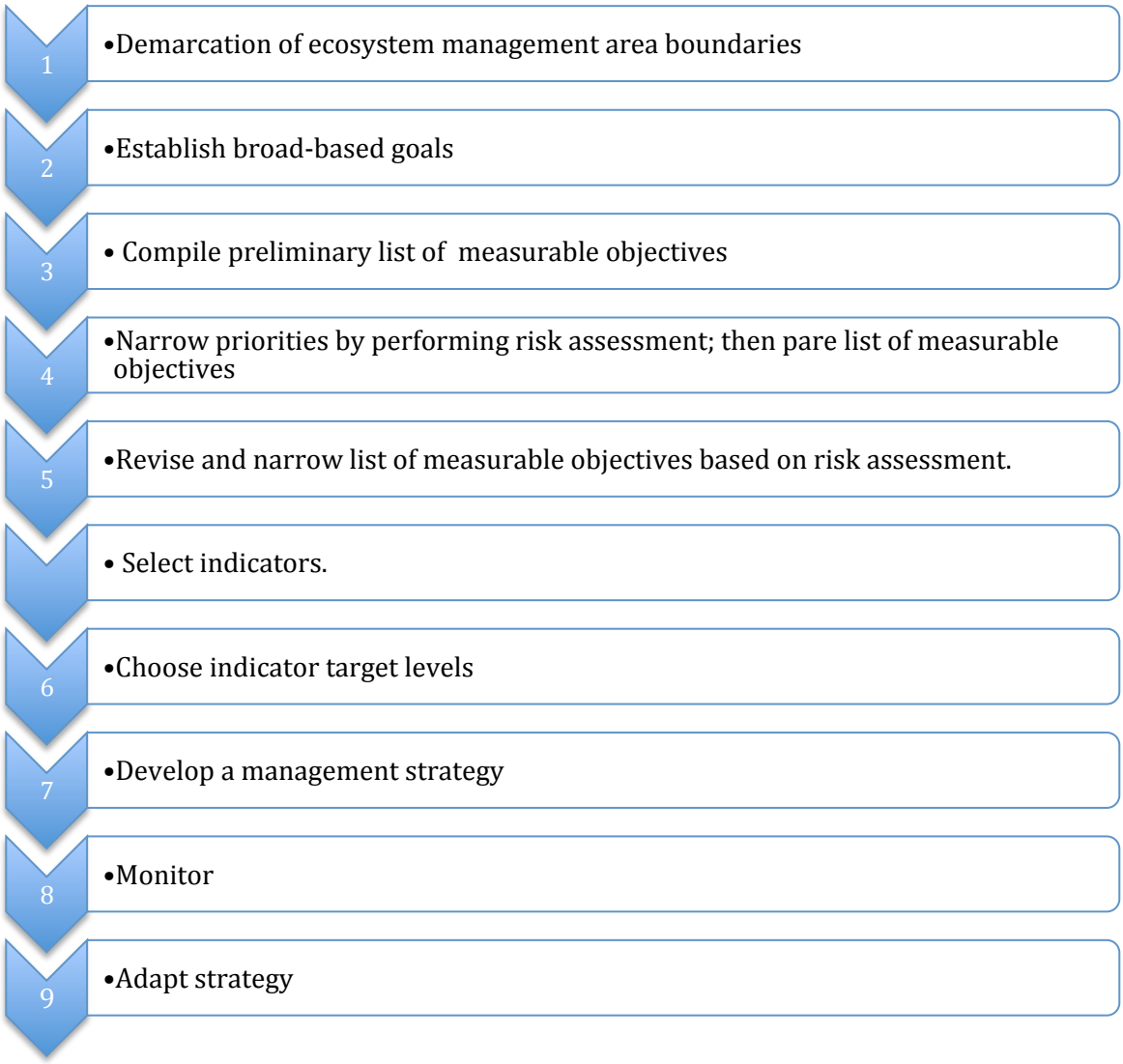
Fishing has an effect that radiates throughout a food chain. Its potential impact on a stock is self-evident when consideration is limited to the targeted species. How a particular level of catch can affect overall ecosystem health is a more complicated question. Multivariate analysis has shown the importance of fishing as a key determinant in predicting ecosystem status (Link et al. 2002, Link et al. 2009). The specific impact of

fishing on biodiversity is also important, as is the distinction between taxonomic and "functional" diversity (Micheli and Halpern 2005). Functional diversity is present where, despite the similarity between two species due to their performing a similar ecological function, one exhibits higher ecosystem resilience and a greater ability to recover from fishing. A small change in the species diversity of a marine ecosystem can result in a large change in functional diversity (Micheli and Halpern 2005). Therefore, a good understanding of that relationship is needed to be able to accurately forecast fishing impacts, to the extent that such understanding can be feasibly obtained. Biodiversity is also important because of its impact on system resilience. A review of Large Marine Ecosystem fisheries suggests that fishery collapses at the large ecosystem level occur at a higher rate where species diversity is limited (Worm et al. 2006).

Ecosystem-based fishery management must not only identify the characteristics of an ecosystem-based approach, but also address how it can be implemented (Link 2005). The basic components of an implementation process include first establishing broad objectives, followed by a system assessment. Next, decision criteria are identified in order to determine the steps required to attain the objectives (Link 2005). A logical framework that elaborates and expands on this three-step process has been recommended in several studies (Gregr and Chan 2011, Lester et al. 2010, Tallis et al. 2010). These approaches adapt the steps recommended in NOAA's Integrated Ecosystem Assessment (Levin et al. 2008, Levin et al. 2009). The discussion that follows further amends the Integrated Ecosystem Assessement approach by moving risk assessment to an earlier stage in the process. The steps are listed below in sequential order, and are coupled with examples of

ecosystem-based management characteristics that may apply to the specific implementation step.

FIGURE 1 – SEQUENTIAL STEPS IN ADOPTING ECOSYSTEM-BASED MANAGEMENT



A. Management boundaries

Single species management is often based on the temporal analyses, or age-based studies (Marasco et al. 2005). However, the life history of the species and overall biodiversity are dependent on the spatial distribution of a species (Marasco et al. 2005) . As a result, ecosystem-based management should be based on natural spatial boundaries (Marasco et al. 2005). Boundaries based on the geography of an ecosystem, rather than political lines (unless those political lines coincide with ecosystem boundaries), are a key element of ecosystem-based management (Ecosystem Principles Advisory Panel 1999, Marasco et al. 2005, Ruckelshaus et al. 2008) . They need to also conform to the issue being addressed, and the area over which a solution can be applied (NOAA 2012b). In this way management decisions can correspond to the identified spatial area (NOAA 2012b). However, even though the areas assigned to Regional Fishery Management Councils generally correspond to large marine ecosystem areas, jurisdictional and ecosystem boundary mismatches still occur frequently (Crowder et al. 2006), due to state, local, and tribal jurisdictions and the presence of international treaties. Ultimately, matching governance to a natural ecosystem boundary is difficult.

B. Broad goals

Broad goals should be established that include both natural and socio-economic needs (Ruckelshaus et al. 2008). This process of setting goals should both solicit and include contributions from all interested parties (deReynier et al. 2010, Ecosystem Principles Advisory Panel 1999, NOAA 2012b, Pikitch et al. 2004, Ruckelshaus et al. 2008).

When establishing goals and objectives, several characteristics of ecosystem-based management are important:

The choice of goals and objectives should encompass:

- The natural components of the ecosystem in a way that includes food webs, ocean and climate impacts, habitat (Marasco et al. 2005), and biodiversity (Leslie and Kinzig 2009);
- Human priorities that reflect diverse social objectives and the ecosystem services that contribute to reaching those objectives (Rosenberg and McLeod 2005); and
- The interactions between the natural components of the ecosystems and human social systems (McLeod and Leslie 2009), with tradeoffs identified and evaluated (Barbier 2009, Liu et al. 2007).

Analysis should focus on the food webs present in the management area selected (Ecosystem Principles Advisory Panel 1999, Marasco et al. 2005), address bycatch (Pikitch et al. 2004), account for ocean and climate impacts, and consider habitat issues relevant to both target and non-target species using relevant modeling techniques (Ecosystem Principles Advisory Panel 1999, Marasco et al. 2005).

Biodiversity of native species should be a primary objective, since it is tied to system resilience (Leslie and Kinzig 2009, Levin and Lubchenko 2008). From a practical perspective, restoring species diversity at the large ecosystem level can be achieved by methods that include area closures and the establishment of marine reserves (Worm et al. 2006), in addition to habitat restoration, time-based closures, gear restrictions, and other strategies.

The full range of ecosystem services derived from the ocean that should be considered includes: provisioning (food), supporting (primary production, nutrient recycling), regulating (climate, erosion), and cultural services (aesthetic, recreational) (Levin and Lubchenko 2008, Marasco et al. 2005, McLeod and Leslie 2009). This necessarily involves the identification and weighing of tradeoffs between ecosystem services that may be in competition (Barbier 2009, Link 2010). If habitat requires restoration in order to rebuild stocks, what are the costs? In setting total allowable catch, what mix of species is optimal? As a result of regulatory and jurisdictional fragmentation, from a practical perspective ecosystem-based management can only deal with a subset of ecosystem services. However, that does not mean that coordination is not possible. As an example, consider the requirement in the Magnuson-Stevens Act (MSA) (16 U.S.C. §§ 1801-1884) that requires all Federal agencies to consult with the National Marine Fisheries Service before approving any action that may have an adverse effect on Essential Fish Habitat (16 U.S.C. 1855(b), defined in 16 U.S.C. §1802(10)).

How should one establish goals given the inevitable tradeoffs generated by the aforementioned considerations? One approach that has been suggested is to first establish a set of fixed rules, which could include the following concepts (Link 2010):

- Management strategies that are simple.
- Biological limits in setting fishing take are to be set at a fixed level, based on the best scientfic information available. These limits would be based upon amounts that are sustainable, and which otherwise comply with the ten requirements set forth under the MSA.

- Conservation of endangered species requires resource set-asides. This is consistent with the requirements of the Endangered Species Act.

Then, deal with the set of negotiable items that fall into two groups (Link 2010):

- Allocations should achieve a mix of species and harvest levels that maximizes productivity without jeopardizing sustainability of species or habitat.
- Allocations should be assigned fairly between groups.

C. **Measurable objectives**

After setting conceptual goals, managers should select clear and measurable objectives (Margolus and Salafsky 2010). One of the key needs in ecosystem-based management is to clearly define objectives and develop the standards by which progress will be evaluated (Murawski 2000). Specific objectives need to have an impact, be time limited, specific, and practical (Margolus and Salafsky 2010). Specificity is particularly important. Vague and nonspecific objectives, such as "sustainability" and "biodiversity", must be translated into objective and measurable objectives (Murawski 2000).

D. **Risk assessment**

A failure to assess risk can result in an unmanageable set of objectives, and therefore an increase in the overall level of risk itself (Link 2010). Ecosystems are complex and adaptive because of the multiple ways in which different factors interact and because these interactions trigger feedback loops (Levin and Lubchenko 2008). Consequently, a major challenge in identifying key threats and establishing priorities is how to account for these complexities. In theory, risk assessment is accomplished by identifying all known

risks that threaten attaining an objective, determining the likelihood of their occurrence, and then assessing the resilience of the ecosystem based on indicators in responding to the identified risks (Levin et al. 2008, Tallis et al. 2010). The large number of factors that affect an ecosystem, and the way in which they can interact, can potentially generate such a large number of risks and questions that the implementation of a management strategy becomes difficult. Identifying which risks are the most important is part of risk assessment. Stated succinctly, "in effect, what risk assessment does is to identify those attributes of the ecosystem that are deemed worth evaluating" (Link 2010). Prioritization of those identified risks becomes important, because the resources available to address the risks are limited. Some analyses advocate conducting risk assessment following the identification of indicators (Levin et al. 2008), but it may be advisable to elevate risk assessment to an earlier stage, so that indicator selection can be prioritized. A variety of methods are available to quantify risk, and it can be done at various stages in the process, but the problem in fisheries is that data is frequently limited, and the number of factors to assess is daunting. One possible way to address this problem is to employ qualitative methods. A qualitative approach to risk assessment has been used successfully in Western Australia (Fletcher 2005, 2006), where a risk assessment process for ecosystem-based fisheries management was adopted by following these steps :

1. A workshop was convened comprised of representatives from science, government agencies, stakeholder and community groups, commercial fishing, recreational, conservation and indigenous groups.

The workshop identified common issues within each of three groups: (a) retained species, (b) non-retained species, and (c) the general ecosystem.

2. Values based on the consequence of the risk materializing, and the likelihood of it occuring were assigned to each identified risk by qualitatively assigning a scale value; ranging from one to five for consequence, and from one to six for likelihood. These were based on objectives and goals set by the fisheries management agency in Western Australia. The product generated by multiplying the consequence and likelihood values resulted in risk factors ranging between one and thirty.

3. These risk factors were then ranked and grouped, with those risk factors grouped into the highest risk category given the highest priority for the adoption of significant additonal management measures. The analysis process was repeated for each of seven fisheries located in the region, including 19 target stocks.

The net result of this effort in Western Australia was the initial identification of 115 issues. However, after assigning risk and probability values, only 27 of these yielded a risk value that was moderate or higher, resulting in the need for management action.(Fletcher 2005).

E. **Revise measurable objectives**

Based on the results of the risk analysis, the list of measurable objectives can be narrowed by simply selecting those issues that yield the highest totals obtained by

multiplying the risk value by the probability value. The intention is to finalize a manageable list of measurable objectives which can be feasibly addressed through management action given budgetary and time constraints.

F. Indicators relevant to the goals

There are two basic categories of indicators (Link 2010). One group measures ecosystem factors in order to measure key ecosystem processes. The other category measures management actions in order to evaluate management performance (Link 2010). Indicators should be chosen that are relevant to the chosen objectives, and which are responsive to management actions. Relevancy means that they both address the ecological functions that impact the chosen objectives, and are consistent with the applicable legislative framework (Link 2010). They can fall into a number of categories, including biotic, abiotic, economic, or sociological. (Garcia and Cochrane 2004). Modeling efforts have suggested that biotic indicators include representatives from each of the following categories (Fulton et al. 2005):

- Species that have short life cycles, including phytoplankton and zooplankton;
- Species that are targeted by fisheries;
- Species that are identified with particular types of habitat; and
- "Sensitive" or "charismatic" species that are at the top of the food chain.

Indicators may be at a multispecies level, based on a trophic structure, or measure an entire ecosystem (Link et al. 2002), but are more predictive of ecosystem health if they are selected at a community level (Fulton et al. 2005). They should also be directional in nature and be responsive to change, and include uncertainty (Link et al. 2002). They should be

analytically sound and measurable (OECD 1993). A key element in implementation is the establishment of indicators that can be used to predict the outcome of specific management measures (Murawski 2000). Because this paper is focusing on U.S. fisheries management at the Federal level, the indicators must link ecosystem goals with those factors under the control of a Regional Fishery Management Council. The Councils have a variety of management tools, including the imposition of harvest goals, quotas, size limits, landing limits, trip frequency limits, seasonal restrictions, gear limitations, cessation of directed fishing on identified species, area or subarea closures, time closures, requirements for observer or other monitoring coverage, reporting requirements, and permit requirements (PFMC 2011d). Important ecosystem attributes that need the assignment of indicators so that management actions can be evaluated include: biomass and total production, biodiversity, species resilience, recovery times of depleted stocks, social and economic benefits, and the variability of each of these factors over time and space (Murawski 2000). Possible biological indicators could measure species size, aggregate biomass, trophic system measurements, and intra-species and inter-species diversity (Link 2005) Indicators relevant to human social systems might include total landings from each major fishery, and various measures of fishing community well-being, including indicators that are based on economics.

The use of multivariate statistical techniques applied to empirical indicators has also demonstrated the value of using indicators to empirically assess the status of a marine ecosystem (Link et al. 2002). The use of statistical multi-variate analysis has shown that it may be it may be possible to replace the current practice of using control rules that govern a single species, with one that imposes control rules that are ecosystem-based, and which

are applied to the factors which are under human control (Link et al. 2002). Catch limits would still need to be set for each individual species, however.

The selection of indicators requires a thorough understanding of the relationship of the indicator to the desired objective. This relationship should be demonstrated over time. In one study that underscored the need to adopt ecosystem-based management in a gradual, adaptive process, a review of prior published statistical correlations between environmental variables and juvenile fish and shellfish recruitment was undertaken. When these correlations were re-examined later in subsequent studies, the overall result demonstrated that a track record for similar conclusions was "dismal". In addition, only one of 47 correlations originally determined to be significant was being used currently at the time of the review in estimating recruitment (Myers 1998).

G. **Target levels for the indicators**

To implement ecosystem-based management for fisheries, the indicators need to be evaluated to determine the extent to which they are affected by the level of fishing, with that evaluation being conducted simultaneously in a parallel effort in order to simulate real ecosystems (Link 2005). The management strategy should adopt targets that acknowledge and respond to appropriate levels of uncertainty (Ecosystem Principles Advisory Panel 1999, Marasco et al. 2005, McLeod and Leslie 2009). This is frequently described as requiring the adoption of a "precautionary approach" (NOAA 2012b, Pikitch et al. 2004). Such buffers may be particularly important if statistical analysis of the indicator indicates that the magnitude of change cannot be established by the setting of a control rule, but the direction of change can be determined (Link et al. 2002).

The identification of the current level of an indicator requires empirical data. The selection of a reference point which would trigger the application of management measures is also difficult and requires analysis of trends over time (Fulton et al. 2005). Finally, setting target levels for indicators only makes sense if the indicator is one that can be influenced by management activity. For example, an indicator tracking ENSO cycles in the Pacific may be useful and necessary for predicting population levels and setting catch limits, but the Pacific Council can only respond to those cycles – it cannot set targets for when ENSO events should occur.

H. **Management strategy**

Strategic frameworks for the adoption and evaluation of management strategies have been described as "management procedures" (Rademeyer et al. 2007), and as "management strategy evaluations" (Sainsbury et al. 2000). Management strategy evaluations require the setting of monitoring specifications, and the development of decisions regarding how the monitoring data, the results of the assessment, and the management decisions will be used (Sainsbury et al. 2000). Most implementation frameworks anticipate the use of a model that simulates the ecosystem that is being managed. They can use models that either incorporate alternative data assumptions and scenarios for population dynamics, or use empirical data in a way that minimizes the reliance on models (Rademeyer et al. 2007). When used for ecosystem-based management, modeling can be challenging. The data that is required frequently cannot be obtained, ecosystem relationships are difficult to identify, and the selection of appropriate species to include in the model can be problematic (Sainsbury et al. 2000). If a model is too complex,

it may yield a high level of uncertainty and be difficult to interpret. Too simple, and its predictive value decreases (Fulton et al. 2003). Predictions are particularly difficult if as a result of feedback loops, everything is dependent on everything else (Sainsbury et al. 2000). Nonetheless, current levels of ecosystem knowledge are probably sufficient to conduct ecosystem-based analysis, since implementation is an iterative process (Lester et al. 2010). The biggest obstacle is not the level of scientific information, it is the need to link data to goals and objectives in a way that is organized and structured (Gregr and Chan 2011). The management measures must be applied across all sectors, and coordinated at a local, national, and international level. As discussed above, this is difficult in the current regulatory environment.

I. **Monitoring the indicators and strategy effectiveness**

Monitoring of indicators is necessary in order to reduce uncertainty and to facilitate adaptive management (Kaufman et al. 2009). Monitoring needs to include not just target species population levels, but also cumulative effects, levels of non-target species, and relevant environmental factors that interact with the target species (Ecosystem Principles Advisory Panel 1999). Monitoring should be used to track ecosystem status, the provision of ecosystem services and the effectiveness of management strategies (Pikitch et al. 2004, Ruckelshaus et al. 2008).

Regional Fishery Management Councils prepare data and information concerning the biological status and condition of stocks, the status of marine ecosystems, along with socioeconomic data in the form of Stock Assessment and Fishery Evaluation (SAFE) reports (50 C.F.R. 600.315e(1)). The SAFE reports are required to use the best available science.

The information in the reports forms the basis for determining harvest levels, indicates stock and ecosystem trends, and evaluates management strategies (50 C.F.R. 600.315e(1)). If a transition to ecosystem-based management is to occur, this is a key focal point for adopting scientific methodologies that will generate the information that can be acted upon by the Regional Fishery Management Councils.

J. **Adaptive management**

Periodic reassessment should result in strategy modifications necessary to achieve objectives (Ruckelshaus et al. 2008). Overall, successful implementation is more likely to be accomplished if it is done gradually as part of an iterative process. Ecosystem-based management can and should be adopted as part of an evolutionary process, rather than by attempting to force an abrupt shift (Goodman et al. 2002, Marasco et al. 2005). Transitioning from a single species approach to an ecosystem-based management approach can be accomplished in three phases (Goodman et al. 2002, Marasco et al. 2005). The first involves assessment of the target species and their prey and predators. The second phase adopts consideration of environmental effects that affect the target species and expands beyond fishing to include habitat, bycatch, and incidental catch. The third stage involves integrating the first two stages into a comprehensive assessment that is used to set catch limits and establish other management measures (Marasco et al. 2005).

The adoption of a phased approach is a good one, as long as it addresses the need to establish priorities within an inherently complicated system. Otherwise, budgetary limitations may cause the process to stall when an unmanageable number of issues are

identified. One method of addressing this problem is to narrow priorities by performing a qualitative risk assessment, as discussed above.

III. Can ecosystem-based management be achieved by the Regional Fishery Management Councils given the regulatory constraints under which they operate?

Any evaluation of the extent to which ecosystem-based fisheries management has been adopted for the fisheries managed by the Pacific Council should consider the following questions:

1. Does the current regulatory framework allow for the adoption of an approach that includes ecosystem-based management?
2. Is a framework in place that will ultimately result in a process that generally follows the steps outlined above, even if it currently does not incorporate all characteristics of ecosystem-based management?
3. What transitional steps have been taken to adopt ecosystem-based management characteristics as part of the overall plan?

When assessing a regulatory framework for fisheries, an initial limitation exists as a result of scope. Ecosystem-based management is focused on the maximization and long-tem sustainability of the provision of ecosystem services, but fisheries management by definition is focused only on a subset of these ecosystem services (Levin et al. 2008). In addition, fisheries operating along the U.S. West Coast are subject to a variety of regulatory constraints imposed by the Federal government, States, tribal authorities and international agreements and are not necessarily integrated or coordinated. This generates the following problems:

- Laws that only apply narrowly to a single sector affecting the marine ecosystem cannot consider the cumulative impacts of an action.
- Laws and regulations that overlap can foster inconsistency. If, for example, a depleted species is governed by state, federal, and international regulations regarding recovery, which apply?
- Governance shared by multiple agencies can also create enforcement gaps. If Federal authorities believe that enforcement is being conducted by a State based on its laws protecting a species, and that State believes that the Federal government is conducting enforcement, enforcement may not occur in an effective manner.
- Governance and ecosystem boundaries may not coincide.
- Governmental bodies work under time frames that are not consistent with ecosystem considerations. Elections do not necessarily correspond with biologically based recovery periods for a species.

(Environmental Law Institute 2007)

A comprehensive evaluation of the implementation of ecosystem-based principles for the area managed by the Pacific Council that includes all the governance bodies, laws and regulations that have jurisdiction would require a review of each of these authorities, and an assessment of their interaction and coordination. Such an examination is beyond the scope of this paper. The Regional Fishery Management Councils operate under the requirements of a number of statutes, but two are of primary importance in applying ecosystem principles. The objectives and latitude available under the MSA, applied together with the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. §§ 4321-

4346), is broad, particularly when they are applied along with other environmental legislation. Other legislation is also relevant to the conservation of marine resources, such as the Endangered Species Act of 1973, the Marine Mammal Protection Act, and the Oil Pollution Act of 1990, but these statutes are narrower in focus than the MSA and NEPA with respect to the range of species or the activities that they cover. In short, the broad and significant impact of fishing together with the broad discretion afforded under the MSA applied in tandem with NEPA makes it a primary focus for any implementation of an ecosystem-based fisheries management approach.

Fisheries in the U.S. are managed by Regional Fishery Management Councils, established by the MSA (16 U.S.C. 1852(a)). The MSA sets forth a comprehensive set of rules that must be followed by the Regional Fishery Management Councils, including ten National Standards. Does the current regulatory system in place under the MSA and NEPA allow for the adoption of ecosystem-based principles? In many ways it does, based on the managerial discretion it allows the Regional Fishery Management Councils. Nonetheless, the guidance provided is in large part non-specific, and involves objectives that often compete, requiring a balancing that is left to the discretion of the Councils. Both ecosystem-based fisheries management and application of the MSA require a balancing of objectives, but those sets of objectives being balanced are different. Ecosystem-based fishery management is not broadly mandated under the MSA, but the Councils must consider many of its components, and certain elements are required. Two examples of mandated provisions are the designation of Essential Fish Habitat and the implementation of a standardized bycatch monitoring methodology.

A. Management areas correspond roughly with large ecosystem boundaries under the regulatory structure established by the MSA.

The MSA established eight Regional Fishery Management Councils (Councils), which were assigned jurisdiction geographically that approximately follow the boundaries of Large Marine Ecosystems (Sherman 1991). Large Marine Ecosystems are large oceanic areas, separated on the basis of hydrography, topography, productivity, and food webs (Sherman 1991). As such, they conform to the desired goal of place-based boundaries. However, the extent of U.S. jurisdiction extends only from the outer limits of state boundaries (three nautical miles, in most cases) out to two hundred nautical miles from the coast. As a result, the jurisdiction of the Councils in general roughly conforms to the desired place-based approach, however one that is necessarily somewhat circumscribed by political boundaries. In the case of the Pacific Council, its jurisdiction covers an area comprising the California Current Ecosystem, a highly productive coastal upwelling zone along the U.S. West Coast.

On a smaller scale, the regulations implementing National Standards 2 (best available scientific information) and 3 (stocks managed as units throughout ranges) of the MSA also emphasize the need to select management areas based on natural boundaries. The regulations implementing National Standard 2 state that planning should be done based on the range of the stock, and not be based on political boundaries (50 C.F.R. § 320(b)). In addition, fishery management plans should seek to manage "inter-related stocks of fish" (50 C.F.R. § 320(b)). The National Standard 3 regulations provide that the range of the fishery, for planning purposes should cover the entire range of the stock, and "not be overly constrained by political boundaries" (50 C.F.R. §600.320(a)).

B. The regulatory structure allows for the adoption of goals and objectives that reflect both natural and human systems, but Regional Fishery Management Councils must balance competing priorities

An examination of the regulations that implement the MSA and an overview of NEPA will be helpful in determining whether the law provides sufficient latitude to support the adoption of ecosystem-based management. Each Council is required to prepare and submit to the National Marine Fisheries Service (NMFS) for approval fishery management plans and plan amendments, and to review and revise assessments and specifications with respect to optimum yield (16 U.S.C. § 1852(h)). Fishery management plans must contain management measures that are "necessary and appropriate for the conservation and management of the fishery, to prevent overfishing and rebuild overfished stocks, and to protect, restore, and promote the long-term health and stability of the fishery" (16 U.S.C. § 1853(a)), and must "assess and specify the present and probable future conditions of, and the maximum sustainable yield and optimum yield from, the fishery…" (16 U.S.C. § 1853(a)(3)). Therefore, before assessing the MSA further in the context of ecosystem-based management, a brief summary of how catch limits are set is helpful. Two cascading systems are established under the MSA and are defined in Federal Regulations; one based on optimum yield and the other based on annual catch limits (ACL). Both operate under the requirements of ten national standards that are also established by the MSA and detailed in corresponding regulations.

The first of these, optimum yield (O Y), is determined by starting with maximum sustainable yield (MSY), defined under the MSA regulations as the largest long-term

average catch or yield that can be taken from a stock or stock complex "under prevailing ecological, environmental conditions and fishery technological characteristics…" (50 C.F.R. §600.310(e)(1)(i)). Optimum yield is in turn defined as the "amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems", and is determined by reducing MSY by "economic, social, or ecological factor[s]"(50 C.F.R. §600.310(e)(3)(i)(A)). Catch levels in achieving optimum yield should have the effect of "producing, from each stock, stock complex, or fishery a long-term series of catches such that the average catch is equal to the OY, overfishing is prevented, the long term biomass is near or above Bmsy, and long term average biomass is near or above Bmsy, and overfished stocks and stock complexes are rebuilt…" (50 C.F.R. §600.310(e)(3)(i)(B)).

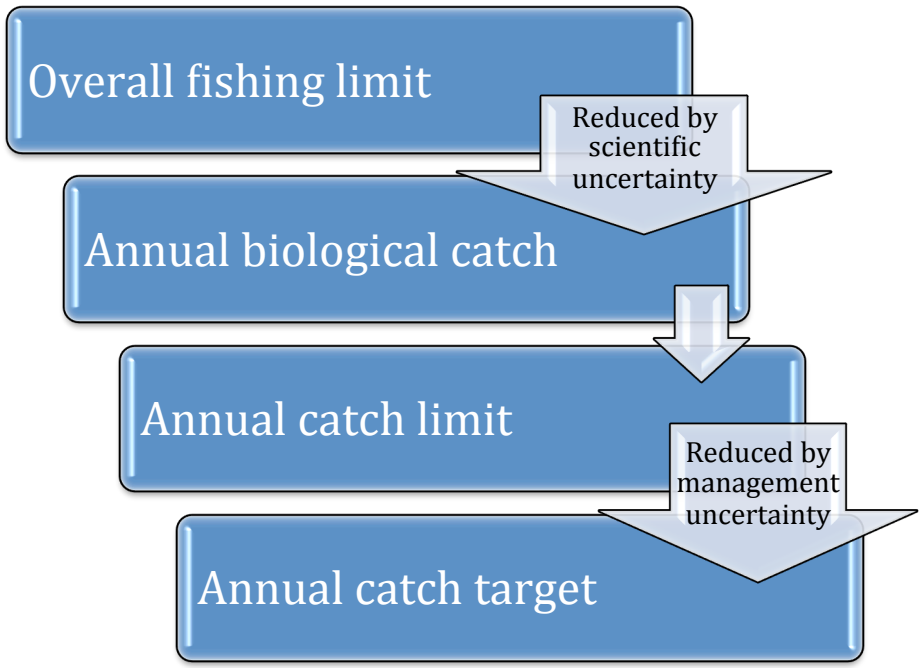
Councils must also determine annual catch limits, which are the levels actually used to determine fishing limits. They are determined by the following relationship based on overfishing limit (OFL), acceptable biological catch (Pikitch et al.), annual catch limit (ACL), and annual catch target (ACT).

Briefly:

- OFL is a catch level beyond which overfishing occurs (50 C.F.R. § 600.310(e)(2)(i)(E)).
- ABC is equal to OFL, reduced by an amount that reflects scientific uncertainty (50 C.F.R. § 600.310(f)(2)(ii))

- ACL is an amount set by the Council, equal to or less than ABC, to further protect against overfishing. It is set for each stock, and if it is exceeded, accountability measures are to be applied (50 C.F.R. §600.310(f)(5)).
- ACT is equal to ABC, reduced by an amount that reflects management uncertainty (50 C.F.R. § 600.310(f)(v)).

FIGURE 2 – RELATIONSHIP OF OFL, ABC, ACL AND ACT



To what extent do these limits incorporate ecosystem-based management characteristics and allow for the implementation of those characteristics? The specific references to the EBM related concepts of economic, social, and ecological factors found in the definition of OY are not present in the definitions of OFL, ABC, ACL, and ACT. As a result, the connection between MSY and OY, on the one hand, and OFL, ABC, ACL, and ACT on the other hand, is not clear. This may be addressed in the near future by NMFS, which at the

time of this writing is soliciting comments from the public on this issue in an Advance Notice of Proposed Rule-Making (77 Fed. Reg. 26238-01 (May 3, 2012)).

Meanwhile, NEPA requires Federal agencies to prepare an environmental impact statement whenever a proposal is made for all "major actions significantly affecting the quality of the human environment" (42 U.S.C. § 4332). Fishery management plans are major Federal actions, and must be assessed to determine whether their effect is significant. If a fishery management plan is considered to have a significant impact, the EIS that is prepared must "rigorously explore and objectively evaluate all reasonable alternatives" to the proposed action (43 U.S.C. §1502.14)(a)). If an EIS is required, it must include connected actions, cumulative actions, and similar actions (40 C.F.R. 1508.25). The process must involve the public (40 C.F.R. 1501.7). The analysis of the environmental impact must include its direct, indirect, and cumulative impacts; any adverse environmental effect that cannot be avoided; mitigation measures, and alternatives to the proposed action, including a no-action alternative. A detailed discussion of mitigation is also required.

However, the U.S. Supreme Court has stated that the purpose of an EIS is only to inform, it does not require any specific action to be taken (Robertson v. Methow Valley Citizens Council, 490 U.S. 360 (1989)). Nonetheless, it succeeds in focusing attention on the environmental effects of fishery management decisions, through a process that is transparent and allows for public participation.

Procedures for implementing environmental reviews under NEPA with respect to the marine environment have been promulgated by NOAA (NOAA 1997, 2013).

C. The regulatory structure allows for the analysis of natural systems that encompass trophic analysis, habitat, ocean and climate impacts, biodiversity, but there is no specific mandate.

In addition to the elements found within the National Standards and their applicable regulations that allow ecosystem-based management approaches, the MSA was amended by the Sustainable Fisheries Act of 1996 to include new protections for habitat. Councils were directed to "describe and identify essential fish habitat for the fishery based on the guidelines established by the Secretary under [the Act], 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" (16 U.S.C. ¶ 1853(a)(7)). Essential fish habitat is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. ¶ 1802(10)), with "fish" expansively defined as "finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds" (16 U.S.C. ¶ 1802(12)). Regulations set forth the scope of information required to be in fishery management plans concerning Essential Fish Habitat, and state that "[e]cological relationships among species and between the species and their habitat require, where possible, that an ecosystem approach be used in determining the EFH of a managed species" (50 CFR 600.815(a)(1)(E)). They also require that fishery management plans identify "habitat areas of particular concern", based on four factors (50 CFR 600.815(a)(8)). Management options to address the adverse effects of fishing on Essential Fish Habitat include fishing equipment restrictions, time and area closures, and harvest limits (50 CFR 600.815(a)(2)).

Although they are not actively managed, the regulations allow, but do not require, the identification of "ecosystem component" (EC) species (50 CFR §600(d)(5)). These are non-target species that are not overfished or subject to overfishing, and not generally retained for sale or personal use. They may be included in a fishery management plan for any one of several purposes, which include "ecosystem considerations related to specification of OY for the associated fishery". Councils "should consider" measures to minimize bycatch of these species, and to "protect their associated role in the ecosystem". If necessary, they should be reclassified as 'in the fishery' (50 CFR §600(d)(5)(iii)). EC species are currently the subject of an Advance Notice of Proposed Rule-Making, where NMFS is soliciting public comment on the criteria for classifying EC species, and the usefulness of the concept (77 Fed. Reg. No. 26238-01 (May 3, 2012)).

In determining MSY, "MSY for a stock is influenced *by its interactions with other stocks in its ecosystem* and these interactions may shift as multiple stocks in an ecosystem are fished. These ecological conditions should be taken into account, to the extent possible, when specifying MSY" (50 C.F.R. §600.310(e)(1) (Emphasis added).

National Standard 3 provides that to the extent practicable, a stock of fish should be managed as a unit throughout its range, and interrelated stocks should be managed as a unit. This falls short, however of a specific endorsement of analyzing entire trophic systems. Finally, National Standard 9 requires the minimization of bycatch.

D. The regulatory structure allows for the analysis of human factors and ecosystem services, but its focus is limited to fishing effort and activity.

National Standard 8 requires that fishing communities be taken into account by utilizing economic and social data. Also, as discussed above, National Standard 1 determines optimum yield by reducing maximum sustainable yield by "economic, social, or ecological factors". Those that are to receive "serious attention" in setting optimum yield include the benefits of food production, the benefits of recreational opportunities, and the benefits of protecting marine ecosystems (50 C.F.R. §600.310(e)(3)(iii)). Additional guidance is provided in the regulations in the form of a "non-exhaustive list of potential considerations" for each of the factors.

- Social factors are to include community and way of life considerations, the cultural value of subsistence fishing, Native American treaty obligations, impact on low income and minority groups, and worldwide nutritional needs. Specific indicators are offered.
- Economic factors include the risk of overharvesting, fulfilling consumer and recreational needs, and supplying export markets. Again, several possible indicators are suggested.
- Ecological factors include:

> "Impacts on ecosystem component species, forage fish stocks, other fisheries, predator-prey or competitive interactions, marine mammals, threatened or endangered species, and birds. Species interactions that have not been explicitly taken into account when calculating MSY should be considered as relevant factors for setting OY below MSY. In addition, consideration should be given to managing forage stocks for higher biomass than Bmsy to enhance and protect the marine ecosystem. Also important are ecological or

> environmental conditions that stress marine organisms, such as natural and manmade changes in wetlands or nursery grounds, and effects of pollutants on habitat and stocks" (50 C.F.R. §600.310(e)(3)).

However, as previously discussed, the factors set forth above that may be given consideration may fall short of incorporating all applicable ecosystem services. This gap is primarily attributable to the fact that the MSA is limited in scope to fisheries management.

E. The regulatory structure permits the selection of indicators, but selection and monitoring is necessarily delegated to the individual Councils.

Management within each Council area is based on the development of fishery management plans that use assessments of stocks or "stock complexes" (50 C.F.R. § 600.310(d)). A "stock complex", is defined as "a group of stocks that are sufficiently similar in geographic distribution, life history, and vulnerabilities to the fishery such that the impact of management actions on the stocks is similar" (50 C.F.R. §600.310(d)(8)), and may be comprised of one or more "indicator stocks" which may be used to help manage stocks where data may be lacking (50 C.F.R. §600.310 (d)(9)).

National Standards 2 and 6 also suggest that the usage of indicators and precautionary buffers is appropriate. National Standard 2 requires that conservation and management measures be based on the best scientific information available. In satisfying this objective, The regulations require that a Stock Assessment and Fishery Evaluation (SAFE) report be prepared for each stock or stock complex (50 C.F.R. § 600.315). The SAFE report "provides Councils with the most recent biological condition of stocks *and the marine ecosystems* in the FMU and the social and economic condition of the recreational and commercial fishing interests, fishing communities, and the fish processing industries"

(emphasis added) (50 C.F.R. § 600.315 (e)). The report should provide "information to the Councils for determining annual harvest levels, from each stock, documenting significant trends or changes in the resource, marine ecosystems, and fishery over time, and assessing the relative success of existing state and Federal fishery management programs" (50 C.F.R. § 315 (e)). The regulations specify the categories of data to be collected, and also point out that "[e]ach SAFE report may contain additional economic, social, community, essential fish habitat, and ecological information pertinent to the success of management or the achievement of objectives of each FMP" (50 C.F.R. § 600.315 (e)(4)) and that [e]ach SAFE report may contain additional economic, social, and ecological information pertinent to the success of management or the achievement of objectives of each FMP." (50 C.F.R. § 600.315 (e)(5)). National Standard 2 also encourages coordination between all regulatory entities that manage a fish stock, from the local to the international level (50 C.F.R. §600.320(c)).

National Standard 6 requires that conservation and management measures take into account uncertainties, and provide for adaptive management. Uncertainty is estimated through the stock assessment process and is taken into account in setting the ABC control rule (50 C.F.R. § 600.310 (e)).

In summary, the MSA provides substantial latitude and guidance for the implementation of ecosystem-based management by the Regional Fishery Management Councils. The selection of indicators, target levels, risk factors, and the details of a specific management plan are necessarily delegated to the individual Councils, provided that they comply with the multiple objectives described in the ten National Standards.

IV. Ecosystem-based fishery management initiatives being coordinated at the national level

The revisions to the MSA made by the Sustainable Fisheries Act led to the establishment of the Ecosystem Principles Advisory Panel (EPAP), a group composed of experts from academia, fishery and conservation groups and management agencies. EPAP issued a report in 1999 recommending that existing fishery management plans be amended "to incorporate ecosystem approaches consistent with an overall Fisheries Ecosystem Plan" (Ecosystem Principles Advisory Panel 1999). The report envisioned that fishery ecosystem plans would be developed for each major ecosystem and would have three objectives:

1. Provide the Councils with ecosystem information.
2. Direct how that information should be used in the fishery management plans.
3. Set policy governing the development and implementation of management decisions.

The U.S. Commission on Ocean Policy was formed pursuant to the Oceans Act of 2000. This group issued its final report in 2004, which recommended the adoption of ecosystem-based management for U.S. ocean and coastal resources (U.S. Commission on Ocean Policy 2004). The Pew Charitable Trusts around the same time established the Pew Oceans Commission, which issued a report in 2003 also endorsing ecosystem-based management (Pew Oceans Commission 2003). Several years later, on June 12, 2009, President Obama established the Interagency Ocean Policy Task Force. It consists of 24 officials from executive departments and agencies and was led by the head of the Council on Environmental Quality (CEQ 2010). It issued its recommendations following 38 expert

roundtables, six regional public meetings, and after receiving over 5,000 public comments (CEQ 2010). It issued its final recommendations on July 19, 2010, which included nine National Priority Objectives (CEQ 2010). The first two of these objectives emphasized the importance of an ecosystem approach, recommending:

- The adoption of ecosystem-based management as a basic principle in the management of the oceans, coasts, and the Great Lakes; and
- The implementation of ecosystem-based coastal and marine spatial planning and management (CEQ 2010).

Executive Order 13547, signed in July 2010 by President Obama, adopted the recommendations of the Interagency Ocean Policy Task Force, and directed federal agencies to implement those recommendations under the oversight of a National Ocean Council. It called for the development of integrated and comprehensive coastal and marine spatial plans that would include the states, tribal, and local authorities together with the public. This comprehensive approach would have required management based on consideration of all ecosystem services and the complete array of human impacts on the oceans, and would have substantially reduced the legal fragmentation discussed above. However, in May of 2012 the House of Representatives passed an amendment to H.R. 5326 to terminate funding for the implementation of this Executive Order, indicating opposition by the House of Representatives to the Order.

The National Ocean Council recently released its National Ocean Policy Implementation Plan (National Ocean Council 2013). An initial review reveals that there is no direct emphasis on the importance of ecosystem-based management, since no individual section is devoted to the topic. However, a closer read shows that the concept permeates the

discussion. The 30 page report includes the word "ecosystem" 55 times, and the phrase "ecosystem-based management" 10 times.

V. Adoption of ecosystem-based fishery management principles by the Pacific Council

A. Incremental adoption of ecosystem-based fisheries management by the Pacific Council from within the fishery management plans

As previously discussed, although the area managed by the Pacific Council is based on political boundaries (areas offshore of Washington, Oregon, and California), it also conforms to one large ecosystem, since it is an area that is generally consistent with the California Current Ecosystem. The Pacific Council manages five fisheries (PFMC 2013d). Four of the five consist of species groups - Groundfish, Salmon, Highly Migratory Species (HMS), and Coastal Pelagic Species. (CPS) The fifth, Pacific Halibut, is managed through a different process. Halibut stocks are managed jointly by the U.S. and Canada through the International Pacific Halibut Commission, which determines total allowable catch for the two countries. NMFS establishes regulations for U.S. waters off of Washington, Oregon, California, and Alaska, and the Pacific Council administers a Catch Sharing Plan that divides the U.S. West Coast catch between different state and tribal fisheries.

The Pacific Coast Fishery Ecosystem Plan that was approved in the April 2013 meeting points out that each of the four fishery management plans already incorporates five goals and objectives that are consistent with ecosystem-based management (PFMC 2013c). They include avoiding overfishing, minimizing bycatch, achieving stable fishing yields, avoiding adverse habitat impacts, and assisting existing fisheries (PFMC 2013c). In

addition to these objectives, each of the existing fishery management plans contains other specific measures that are also consistent with ecosystem-based management. A number of these elements have been summarized in the fishery management plan. As previously discussed, the Councils have a variety of tools available with which they can manage fishing and the ocean environment. Selected examples are grouped below into six broad categories.

TABLE 1 – EXAMPLES OF ECOSYSTEM-BASED MANAGEMENT MEASURES IN PACIFIC FISHERY MANAGEMENT COUNCIL FISHERY MANAGEMENT PLANS AND STOCK ASSESSMENTS

Category	**Examples of measures adopted in fishery management plans**
Habitat	Essential Fish Habitat (EFH) has been identified for each of the fishery management plans. Groundfish – Long term closed areas to protect EFH from bottom gear. Long term closed areas for use of trawl gear. Trawl gear regulations limit habitat damage by imposing a small footrope requirement (PFMC 2011d). HMS – EFH designated for each species, and further subdivided based on life stages. Some are temperature based (PFMC 2011c). Salmon – EFH extended inland to include freshwater rivers and streams (PFMC 2012c). CPS – EFH designation is temperature based (PFMC 2011a).

Table 1 continued	
Category	**Examples of measures adopted in Fishery Management Plans**
Indicators	HMS and CPS have selected Ecosystem Component Species (PFMC 2011a, c). CPS – MSY control rule has incorporated ocean temperature information (PFMC 2011a). HMS – at the March 2013 meeting the Council directed the Highly Migratory Species Management Team to identify biological reference points and potential measures that should be adopted in connection with the precautionary management framework being developed at the international level (PFMC 2011c). Salmon – geographic control zones close fishing annually based on local conditions. Juvenile ocean survival used to predict ocean conditions, allowing total fishing impact to be determined based on returns of jacks to spawning streams. For coho, SSC has recommended a new methodology for predicting abundance that includes sea surface temperature and copepod population levels (PFMC 2012c).
Precautionary principles	Each fishery management plan employs buffers to provide for scientific uncertainty. Conservative buffers used for species where data is weak or where stock is rebuilding. Groundfish – harvest levels become more conservative when little scientific information is available (PFMC 2011d). CPS – Most conservative harvest control rule chosen, ABC control rule is based on a 75% reduction from overfishing level (PFMC 2011a).

Table 1 continued	
Category	**Examples of measures adopted in Fishery Management Plans**
Bycatch	Each fishery management plan has implemented bycatch reduction measures, monitoring, and standardized reporting methodologies. Groundfish – trawl rationalization has led to increases in retention levels (NOAA 2012a). Seasonal closures of Rockfish Conservation Areas minimize bycatch of rebuilding species. Some closure areas are species specific. Whiting fisheries are closed in salmon conservation areas to minimize salmon bycatch. Limitations placed on take of abundant species to minimize take of recovering species. Juvenile take minimized by minimum mesh size requirement. Fixed gear regulations minimize amount of lost gear (PFMC 2011d). Salmon – Trolling has been restricted in yelloweye rockfish conservation areas. Use of nets offshore banned to reduce overall bycatch and take of juvenile salmon (PFMC 2012c). HMS – Measures have been adopted to protect seabirds, sea turtles, and marine mammals, including closures, gear restrictions, and handling requirements (PFMC 2011c).
Non-target species protections	CPS – krill harvest has been prohibited (PFMC 2011a). Groundfish – low catch restrictions placed on shortbelly rockfish because it is a significant prey species (PFMC 2011d).
Use of ecological data in stock assessments	Fishery management plans acknowledge ecological effects, but data is lacking.

The progression over time of the implementation of these ecosystem-based management measures is shown in Table 2 below.

TABLE 2 - TIMELINE OF THE ADOPTION OF ECOSYSTEM-BASED MEASURES IN THE PACIFIC FISHERY MANAGEMENT COUNCIL FISHERY MANAGEMENT PLANS AND STOCK ASSESSMENTS (A PARTIAL LIST)

Date	**Fishery management plan**	**Action taken**
June 1997	CPS	EFH identified (PFMC 2011a).
Oct. 1998	Groundfish	EFH first described and identified. Bycatch management objective, standardized reporting methodology, and procedures for implementing bycatch reduction adopted (PFMC 2011d).
1999	Groundfish	Council begins a two-stage process to evaluate the value of marine reserves in managing groundfish stocks (PFMC 2011d).
May 2000	Salmon	EFH identified and described. Guidance provided for minimization of bycatch and a standardized bycatch reporting methodology (PFMC 2012c).
Jan 2003	Groundfish	Rockfish conservations areas adopted (PFMC 2011d).
2004	Groundfish	Completion of a white paper by the SSC on the merits of marine reserves.
Feb. 2004	HMS	EFH identified by species (PFMC 2011c).
Jan 2005	Groundfish	Habitat conservation framework adopted. HAPC designated. Time/area closures to reduce incidental catch of protected species and mitigate adverse effects of fishing in EFH (PFMC 2011d).
March 2005	CPS	Harvest of krill prohibited to ensure that marine resources that depend on it are not put at risk (PFMC 2011a).
June 2010	Groundfish	Trawl rationalization approved (PFMC 2011d).
June 2010	CPS	Jacksmelt and Pacific herring were added as ecosystem component species. Incidental catch monitored. 75 percent buffers retained. Language added to specify that the Council will add ecological considerations when reviewing or adopting status determination criteria and ACTs. Decision to retain a 75% buffer in the ABC control rule (PFMC 2011a).
July 2011	HMS	Eight species designated as ecosystem component species (PFMC 2011c).
Dec. 2011	Salmon	Four ecosystem component stocks identified (PFMC 2012c).
Feb 2013	CPS	Workshop held which discussed the status of California Current ecosystem models in relation to Pacific sardine fisheries (Punt and Hurtado-Ferro 2013).

In addition to the ecosystem elements found in the four fishery management plans, the review of harvest specifications under the National Environmental Policy Act also results in the consideration of ecosystem-based elements. For example, the 2012 Harvest Specifications for groundfish used habitat as a proxy, and concluded, "[a]ny alternative under consideration is unlikely to have a discernible impact on the CCLME and other oceanographic and climate functioning" (PFMC and NMFS 2012). A brief discussion is included that examines the impact of the alternatives on Essential Fish Habitat and Marine Protected Areas. In addition, certain socioeconomic consequences are examined, specifically the effects of the alternatives on fishery participants and fishing communities.

The goals and objectives contained in the fishery management plans and corresponding Harvest Specifications must follow the ten National Standards set forth in the MSA. As discussed above, this gives discretion to the Council to incorporate ecosystem principles. Stock assessments do consider food webs, ocean and climate impacts, and habitat, thus providing input on natural systems. The 2012 Groundfish Harvest Specifications (PFMC and NMFS 2012) also considered a limited range of human factors. Those factors can also be subjected to review as part of a fishery management plan amendment, such as Amendment 20 and 21 to the groundfish fishery management plan (trawl rationalization and intersector allocation).

Management through the fishery management plan process is adaptive. Fishery management plans are subjected to frequent amendment and harvest specifications are subjected to periodic review (biennial in the case of groundfish). Catch limits are subject to in-season adjustments, and stock assessments are revised frequently. Management

strategy techniques are employed with the fishery management plans. One example is the use of Management Strategy Evaluation methodology for rebuilding overfished rockfish stocks (Punt and Ralston 2007).

In addition to ecosystem elements contained in the individual fishery management plans; the Pacific Council has adopted several other broad initiatives that focus on elements of ecosystem-based management. As discussed previously, some of the weaknesses inherent in a single species management approach include failing to consider the relationship between stocks, insufficient focus on bycatch minimization, lack of emphasis on biodiversity, and not maintaining trophic system relationships (Murawski 2000). Many of these issues have been recognized, and are being addressed in varying degrees, by the Pacific Council. These include projects on habitat, conservation areas, marine reserves, marine protected areas, and fishing communities.

The Pacific Council's work on habitats has included the identification of Essential Fish Habitat, the description of Habitat Areas of Particular Concern (HAPC), and the adoption of a number of specific rules that protect sensitive habitat, including closing areas to bottom trawling, bottom contact, and the establishment of a Habitat Committee. Reserves (defined by the Pacific Council as areas where no fishing or only certain types of fishing is allowed) have been focused on addressing issues within the groundfish fishery, including stock rebuilding, biological productivity, long-term economic productivity, buffers for management uncertainty and fluctuations in the natural environment, habitat protection, and the establishment of control areas for future research (PFMC 2013a).

Efforts have been initiated to address ecosystem services and human well-being. Fishing community profiles have been developed by the Northwest Fisheries Science Center (NWFSC 2012, PFMC 2013b).

In addition, the Pacific Council has initiated action that is intended to protect forage fish that are not currently targeted by fisheries. The effort is based on a recognition that they play a key ecosystem role as part of trophic systems. In June 2012, the Council adopted an objectives and intent statement that included a goal of "prohibiting development of new directed fisheries on forage species that are not currently managed by the Pacific Council or the West Coast States" (PFMC 2012a). The issue was approved as an initiative included within the Pacific Coast Ecosystem Plan at the April 2013 meeting, and is scheduled for further discussion at the June 2013 meeting. .

The initiatives summarized above show that although the fishery management plans are in large part still based on a single species approach, they have incorporated a number of ecosystem-based characteristics, resulting in an approach that combines elements of both types of management systems.

B. The Integrated Ecosystem Assessment for the California Current LME and the Pacific Coast Fishery Ecosystem Plan

Two major efforts are being pursued by the Pacific Council and NMFS to directly advance ecosystem-based management in addition to those elements of ecosystem-based management that have been adopted from within individual fishery management plans.

The two direct efforts applicable to the U.S. West Coast include: the Integrated Ecosystem Assessment, which is being developed by NOAA's Northwest Fisheries Science Center and Southwest Fisheries Science Center; and the Pacific Coast Fishery Ecosystem

Plan, which the Pacific Council adopted in April 2013. The Pacific Council has requested that the NOAA Science Centers provide it with annual reports on the state of the California Current Ecosystem, "tailored to providing information on indicators directly relevant to Council decision-making" (PFMC 2013c). Information within that annual report would come from work conducted under the Integrated Ecosystem Assessment.

1. The Integrated Ecosystem Assessment

The first of these two efforts, the Integrated Ecosystem Assessment, is a NOAA-led initiative, and is described as "a formal synthesis and quantitative analysis of information on relevant natural and socioeconomic factors in relation to specified ecosystem management goals" (Levin et al. 2008). It intends to follow a five-step process for implementation:

1. Scoping, which includes the development of objectives, identifies the ecosystem, the elements of that ecosystem that are at risk, and the source of those risks.
2. Identification of indicators that correspond to ecosystem characteristics and factors that threaten the viability of that ecosystem.
3. Qualitative and quantitative analysis of the risk factors that affect the identified indicators.
4. A quantification of the overall status of the ecosystem, which compares current status with historical and future desired levels.
5. An evaluation of the anticipated relative effectiveness of different management strategies and actions intended to reach the identified objectives (Levin et al. 2008).

NOAA intends to roll out the program in eight Large Marine Ecosystems (LME's) in the U.S. The first LME to begin adoption of the program was the area defined by the California Current Ecosystem. This Integrated Ecosystem Assessment was initiated by the National Marine Fisheries Service Northwest Fishery Science Center in 2007 (Horne et al. 2010). The NOAA Northwest Fisheries Science Center has formed an Ecosystem Science Program to spearhead data collection efforts associated with this process (Levin 2012). The program is divided into four research teams (Human Dimensions, Integrative Marine Ecology, Nearshore Ecology, and Marine Mammal and Seabird Ecology), each of which focuses on issues related to coupled natural and human ecosystems (NWFSC 2012). The group's stated objectives include identifying relevant indicators for ecosystem functions, evaluating risks threatening those indicators, assessing alternative management strategies, and utilizing adaptive management resulting from the monitoring of the natural and human systems. These are all consistent with ecosystem-based fishery management, but until there is a linkage of each of these elements to the Pacific Council process, no implementation can occur. The group makes extensive use of ATLANTIS, a software-modeling tool that simulates ecosystem interactive dynamics (Levin 2012). The 2012 CCIEA report is in peer review at the time of this writing [April 2013]. It is intended to include five ecosystem components (habitat, wild fisheries, ecosystem structure and function, coastal communities, and protected resources), and its objective is "to understand the web of interactions that links ecosystem drivers and pressures to components of the California Current Ecosystem and use this knowledge to estimate how changing environmental conditions and management actions affect the status of its ecosystem components" (NWFSC and SWFSC 2012a). Presently, the Council has used some Integrated

Ecosystem Assessment work products. Examples include a report on the status and trends of major components of the California Current ecosystem, a risk assessment of the impact of the groundfish fishery on marine mammals, and a contributing analysis used in the review of groundfish Essential Fish Habitat designation.

Table 3 summarizes the extent to which the California Current Integrated Ecosystem Assessment effort to date compares with the ecosystem-based fisheries management criteria summarized above.

TABLE 3 – INTEGRATED ECOSYSTEM ASSESSMENT ADOPTION OF ECOSYSTEM-BASED MANAGEMENT IMPLEMENTATION STEPS

Implementation step	**Status**
Usage of ecosystem boundaries	The Integrated Ecosystem Assessment has adopted regional boundaries that conform to an ecosystem, the California Current Ecosystem.
Establishment of goals	Goals are set forth which are consistent with Pacific Council goals, but measurable objectives have not been set.
Setting measurable objectives	An objective has been identified, but specific goals that are strategic and measurable have not been defined. The objective, in order to be effective, needs to be linked to and consistent with the Pacific Council and its management processes.
Risk analysis	Risk analysis has been listed as a goal but requires further development and execution.
Adoption of indicators	Indicators are identified, but need to be tied to measurable objectives. An initial set of indicators has been identified in the State of the California Current Ecosystem Report. A number of physical and biological indicators are included. In addition, several have been provided to track human well-being. However, these indicators are not tied to specific goals that have been approved by the Council. In addition, many are not capable of being controlled by the Council. As an example, oceanographic conditions may be a good indicator of future fish abundance, but they will not respond to management measures or a strategy implemented by the Council.

Table 3 continued	
Implementation step	**Status**
Indicator target levels	Specific indicator target levels have not yet been set. The State of the California Current Ecosystem Report contains a good summary of the status of indicators that have been selected, but the indicators themselves need revision (see discussion above), and target levels have not been set.
Choice of management strategy	Tools are available that may useful when used in conjunction with a management strategy, but that strategy needs to be endorsed by the Council followed by linkage to the available tools. A number of robust ecosystem modeling and analysis tools have been developed and are available (ATLANTIS is an example). Unless the process is linked to the Council, the management strategy cannot be implemented, making evaluation problematic.
Monitoring	The Integrated Ecosystem Assessment recognizes that monitoring needs to be part of the process, but a monitoring plan must await the selection of indicators.
Adaptive management	The development of an adaptive management process, would be premature at this stage. The Integrated Ecosystem Assessment managers recognize that this effort is in an early stage that will be amended and adopted in the future to address Council needs.

2. The Pacific Coast Fishery Ecosystem Plan

The Pacific Council has been developing a Pacific Coast Fishery Ecosystem Plan, which is designed and intended to inject ecosystem principles into the Fishery Management Plans promulgated by the Council, and also to potentially serve as a springboard to expand Council authority over species and matters not currently covered by the existing fishery management plans. A good example is the current initiative that proposes placing a ban on the commercial fishing of forage fish species that are not being currently targeted.

Efforts towards the development of the Pacific Coast Fishery Ecosystem Plan were initiated in November 2009, when the Pacific Council established two advisory bodies: the Ecosystem Plan Development Team (EPDT) and the Ecosystem Advisory Subpanel (PFMC 2009). These ad hoc committees drafted a preliminary plan during the period from 2010 to 2012.

The Pacific Council first took action on the plan in its June 2011 meeting, where it approved a draft purpose and need statement that had been proposed by the EPDT (PFMC 2011b). The Council agreed to develop an ecosystem plan that was limited to an advisory function, but which could be expanded to include regulatory authority in the future. It also required that the EPDT compile a list of species that were neither included in an existing fishery management plan managed by a State, nor listed under the Endangered Species Act, and to identify which of these species might be targeted by future fishing efforts. The purpose and needs statement that was approved stated that it was intended to "enhance the Council's species-specific management programs" by using ecosystem science and ecosystem considerations to "coordinate Council management across its fishery management plans and the California Current Ecosystem (CCE)" (PFMC 2011b). The Council's informational needs that the plan is intended to address include:

- The provision of "biophysical and socio-economic information on CCE climate conditions, climate change, habitat conditions, and ecosystem interactions…"
- The inclusion of "adequate buffers against the uncertainties of environmental and human-induced impacts to the marine environment…"
- The development of management measures that will take into account ecosystem impacts on CCE species and habitat, and how the CCE affects fishery management

- Coordination across fishery management plans and consultation with other "regional, national, or international entities…"
- The identification and prioritization of research needs in a manner that includes the "cumulative effects of fisheries management on marine ecosystems and fishing communities" (PFMC 2011b).

In June 2012, the Council reviewed a draft plan and provided guidance (PFMC 2012a). It was revised, and reviewed again by the Pacific Council at their November 2012 meeting (PFMC 2012b). The plan that was reviewed included new chapters discussing forage fish and suggested specific potential initiatives. Further guidance was provided by the Council, resulting in the issuance of a draft for public comment being issued in February 2013. The plan was approved at the April 2013 meeting, subject to revisions to be made by the EPDT to reflect comments made by several Pacific Council subcommittees. The plan emphasizes that it is intended to be informational only, and includes a set of objectives that use the existing four fishery management plans as a foundation on which to develop an ecosystem approach (PFMC 2013c).

The plan divides its objectives into three groups. These objectives include: improving and integrating information across the fishery management plans; how to achieve and maintain optimum yield; and identifying a management strategy that can coordinate these activities. The plan's discussion of these objectives recognizes and includes many of the ecosystem-based fisheries management characteristics that have been discussed above including physical, biological, and socioeconomic factors, identification and monitoring of indicators, a place-based approach, analysis of trophic structures, assessment of ecosystem benefits, methods to evaluate the cumulative effects of

fisheries on the ecosystem, and coordination of efforts across regional, national, and international scales.

The plan then proceeds to include chapters discussing:

- An overview of the California Current Ecosystem. This includes a description of its oceanographic features, biological subregions, political geography and human demography, biological components and relationships, species interactions and food webs, abiotic environment and habitat, the human effects on Council-managed species, historical and current fisheries, fishing communities and management structure.
- A discussion of the impacts of human activity, environment and climate on fish abundance and the abundance of species other than fish, and the direct and indirect impacts of fishing on habitat, the dependence of fishing communities on fishing, and how climate change is expected to change marine ecosystems.
- A summary of the Pacific Council's priorities, intended to guide other agencies that govern activities that have ocean impacts so that they take Pacific Council priorities into account when evaluating the cumulative effects of their actions on the ocean ecosystem.
- A discussion of how to improve the incorporation of ecosystem science into the Council decision-making process. Identification of science needs has been moved into a March 2013 Research and Data Needs report. Significantly, this periodically updated Research and Data Needs report now includes sections detailing the need for additional data to support ecosystem-based fishery management efforts. The plan recommends three ways that ecosystem science could be incorporated into

stock assessments in the near term. The three methods include expanding the discussions of ecosystem considerations in the overview text of the assessment documents, the use of stock assessment models that use parameters, indices, and equations that reflect ecosystem interactions, and the analysis of ecosystem considerations by incorporating them into the decision tables used for single species stock assessments. A recommendation is also made to use the Annual Report as a template for future efforts.

- Finally, Appendix A to the Fishery Ecosystem Plan includes ten proposals detailing "how the Council could address issues that affect two or more Council fishery management plans or coordinate major Council policies across the fishery management plans to fulfill identified FEP needs". These proposed initiatives have been separated out into an Appendix so that they may be amended annually without triggering a need to revise the entire plan.

  The first would place a moratorium under the authority of the existing fishery management plans on fishing activity directed at forage fish species that presently are unfished, until sufficient scientific research has been conducted on the impact of such a fishery. The second would analyze the current harvest control rules across all fishery management plans for their effects on managed stocks' age and size distribution. Specifically, it would evaluate alternative age and length parameters, with a goal of maintaining older and larger fish. The next proposed initiative would explore the possibility of subdividing the region governed by the Council into a number of sub-regions, with the objective of managing fisheries on smaller scales. This could help in the management of species subpopulations, facilitate interactions

with other regional management bodies, and adapt management actions to better conform to local conditions. Another initiative would examine bycatch information and methodology across the fishery management plans, focusing on consistency issues, interactions, and best practices. Other proposals include a cross fishery management plan analysis of Essential Fish Habitat, studies of safety issues across all fisheries, the demographics of the industry, cumulative effects of Council actions on fishing communities, and effects of climate change across the fishery management plans. The final initiative would study the selection of indicators to evaluate the cumulative effects of Council actions on the California Current ecosystem. This proposal, if pursued, would seem to address the deficiencies inherent in the current list of indicators discussed in the State of the California Current Ecosystem Report, discussed above.

Where does the Fishery Ecosystem Plan stand with respect to the process and characteristics previously discussed?

TABLE 4 – FISHERY ECOSYSTEM PLAN IMPLEMENTATION OF ECOSYSTEM-BASED MANAGEMENT IMPLEMENTATION STEPS

Implementation step	**Status**
Usage of ecosystem boundaries	The plan covers a region that conforms to a large ecosystem, the California Current Ecosystem. A description of this ecosystem is included within the plan.
Establishment of goals Setting measurable objectives	The plan's objective is to serve as a coordinator and foundation for the implementation of ecosystem-based fishery management, which is intended to be implemented through the existing fishery management plan process. As such, it is not intended to unilaterally impose ecosystem-based management independently of the fishery management plans. Viewed in its broadest sense, the plan is intended to inform, not regulate, at least at this point. Given that role, the plan has made large strides toward defining objectives in a manner that is consistent with ecosystem-based management. Where measurable objectives are ultimately established (in the Pacific Coast Fishery Ecosystem Plan or the fishery management plans) may not matter, as long as the fishery management plan objectives are made consistent and are tied to ecosystem goals.
Risk analysis	A risk analysis has not been undertaken at this point. One should be conducted at an early stage so that informational efforts can be narrowed, targeted, and achievable given current budgetary constraints.
Adoption of indicators	The FEP recognizes the need to identify indicators for the objectives set forth in Chapter 2. Many potential indicators are set forth in the Annual State of the California Current Report. It is unclear whether the final selection of indicators and indicator target levels will be accomplished within the Pacific Coast Fishery Ecosystem Plan, or as part of each individual fishery management plan, or how they will be tied in to objectives or goals. This effort should be closely coordinated and tied to the same need within the Integrated Ecosystem Assessment.
Indicator target levels	Indicator target levels have not been set. To do so would be premature until measurable goals have been prioritized and the Council has endorsed the resulting strategy.

Table 4 continued	
Implementation step	**Status**
Choice of management strategy	The plan is intended to serve as a foundation through which ecosystem-based management would be implemented through the four existing fishery management plans. As a result, it cannot and does not present a comprehensive management strategy that is independent or intended to function on a stand-alone basis separate from the fishery management plans. In Chapter 6, the plan sets forth a three-pronged strategy through which it will play a defined role in facilitating ecosystem-based fishery management in tandem with the fishery management plans. The first part of the strategy is to bring ecosystem information into the stock assessment process. The second is to bring ecosystem considerations into the Council process, via the California Current Report. The third prong is to identify and address ecosystem data and information gaps.
Monitoring	Any discussion of monitoring is premature and should only be developed following the selection of key indicators and a specific management strategy. This may be a function that could be assigned to the fishery management plans if it carried out in a consistent, integrated manner.
Adaptive management	As discussed above, the FEP and fishery management plans play a dual role in implementing ecosystem-based management. Both are periodically reviewed and revised. The FEP will be periodically reviewed and revised based on a six-year cycle, although the initiatives included within the Appendix will receive annual review.

3. Annual State of the California Current Report

In the November, 2011 meeting the Council directed the EPDT to prepare a proposed outline for an Annual State of the California Current Report, which would discuss biophysical trends which may cause changes in the abundance of Council-managed species. This outline was prepared and submitted to the Council in June 2012 (PFMC 2012a). The first draft of the annual report was prepared in a joint effort between the EPDT and the Integrated Ecosystem Assessment and presented to the Council in November 2012 (NWFSC and SWFSC 2012b).

The Annual Report included a number of ecosystem indicators that measure physical attributes, regional climate and lower trophic levels, regional biological and higher trophic levels, and human dimensions. The Council, in its November 2012 meeting, indicated its appreciation for the report, which it found informative (PFMC 2012b). The plan includes a request by the Council that NMFS update this report annually and provide it at the Council's March meeting (PFMC 2013c)

VI. Conclusion

Ecosystem-based fishery management by the Pacific Council is in an evolutionary, highly adaptive stage that is proceeding from multiple directions. The Council's present management strategy, while fundamentally based on a single species approach, contains many elements of ecosystem-based management. The Integrated Ecosystem Assessment incorporates all of the necessary elements of ecosystem-based fisheries management, and has compiled an impressive database and set of tools to support its effort. However, it requires better linkage to the management process that takes place at the Council level. The Pacific Coast Fishery Ecosystem Plan's ultimate role is evolving, based in large part on the direction taken in the proposals contained in the Appendix. It could be a source of ecosystem information to the Council for its use in management decisions, it might serve coordinating function that links together the existing fishery management plans, or it could develop into a management tool that has direct regulatory authority. Any or all options are possible.

VII. Recommendations

Based on the current status of the efforts to integrate ecosystem information into the Pacific Council process, cautious, gradual movement towards the adoption of ecosystem-based management principles is being made through efforts involving the Pacific Coast Fishery Ecosystem Plan, the Integrated Ecosystem Assessment, and the Council and its committees. The cautious pace is appropriate given the stakes, and the state of the science. Based on the analysis summarized above, several recommendations follow.

1. Efforts towards the implementation of ecosystem-based management are fragmented. Broad conceptual goals are included in each fishery management plan, in the Pacific Coast Fishery Ecosystem Plan and in the Integrated Ecosystem Assessment. They need to be brought into alignment and steps taken to ensure consistency, forming one set of ecosystem goals that are overarching and cover all three efforts. This would facilitate the assignment of roles and resources, and allow a set of measurable objectives to be developed. Presently, none of the three contain measurable objectives that relate to ecosystem-based management, although the fishery management plans incorporate some elements. Even those are not being coordinated across the fishery management plans. The roles of the Pacific Coast Fishery Ecosystem Plan and the Integrated Ecosystem Assessment in particular should be reconciled in a manner that clarifies more precisely each of their respective roles, and how that role fits in to the existing fishery management plan process. A fishery ecosystem plan can be a document that summarizes issues without establishing enforceable guidelines, a coordinating mechanism that establishes consistency and direction for other fishery management plans that

contain binding regulations, or a governance document that manages the entire ecosystem with binding regulations (Link 2010). If the primary function of this Integrated Ecosystem Assessment is to develop and generate ecosystem data, and the primary role of the Pacific Coast Ecosystem Plan is a coordination function between the fishery management plans and third party governance bodies, with management implementation of their output taking place in existing fishery management plans, this should be made more explicit.

2. Future direction should be clarified. A review of the Research and Data Needs Report issued by the Pacific Council highlights this need. Section 2.0 of the report covers ecosystem-based fisheries management, and briefly describes 24 items. These range from the very broad ("develop a comprehensive plan to integrate ecosystem-based processes and information into all aspects of assessment, monitoring, and evaluation") to the very specific ("identify key physical and biological indicators for prediction of salmon early ocean survival and groundfish recruitment, as well as other conditions that are directly applicable to management"). Some of the items may warrant revision. For example, the development of biological indicators is mentioned, but indicators relating to human dimensions and ecosystem services are not. (PFMC 2013e). Some, but not all, of the issues have been prioritized based on the level of benefit and relative cost, which is helpful. However, matters should be tackled in a logical sequence. If a threshold issue that bears a high cost requires resolution before addressing lower cost matters, then it should be addressed first. Hence, the need to approach the overall goal in a systemized manner.

3. A risk management analysis should be performed, based on the amendment of the goals as set forth above. Critics of ecosystem-based fisheries management rightfully point out that one of its challenges is its inherent complexity. It might be useful to perform a qualitative analysis, similar to that used in Western Australia to identify the full set of risks that face each fishery and assign each identified risk a value based on (a) the management objectives currently set forth in the current fishery management plans, (b) identifying the inventory of risks which may prevent the attainment of those objectives; (c) the magnitude of those risks and (d) the likelihood of their occurrence, resulting in (d) a set of risks that have been prioritized for purposes of developing and adopting appropriate management measures. The qualitative analysis could be adjusted later to reflect empirical data generated following the monitoring of key indicators.
4. A revised set of measurable objectives should follow. These objectives should be based on the refined set of goals, set forth above, and be consistent with those management measures that are under the control of the Council. The present list of goals set forth in Chapter 2 of the Pacific Coast Fishery Ecosystem Plan should be amended and made more specific to reflect the risk assessment analysis.
5. The list of indicators contained in the current Annual State of the California Current Report should be revised in three respects. First, the indicators must also be chosen based on factors that respond to the decisions that are under Council control. Second, they should reflect both the prioritization resulting from the risk management analysis and the revised goals. Finally they should be subjected to

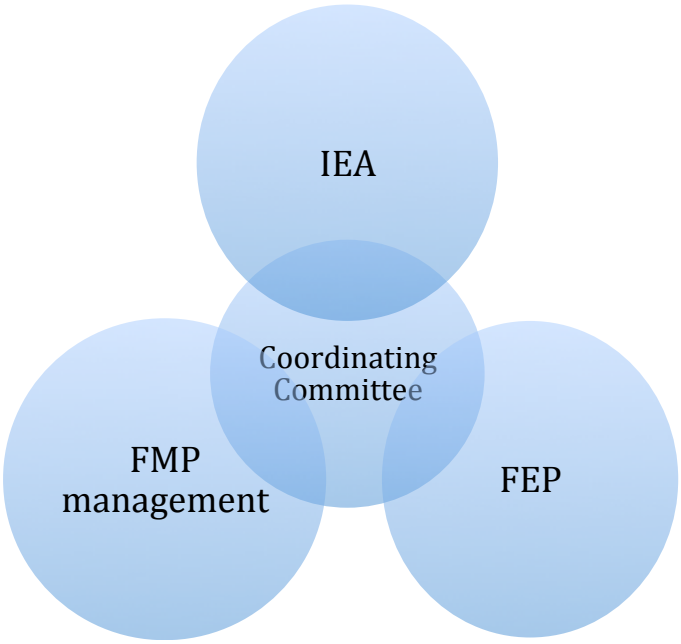
quantitative multivariate analysis that tests their predictive value. The final initiative found in the Pacific Coast Fishery Ecosystem Plan seems to address this need.

6. Indicator target levels and measurable goals should be set by the SSC based on these indicators. The indicators and their target levels should be the focus of a Pacific Coast Fishery Ecosystem Plan initiative which would review them to ensure internal consistency, and in addition benchmark each of them against efforts being made both by other Regional Fishery Management Councils, the states, and foreign fishery governance bodies. Informational gaps should then be identified, prioritized, and reviewed by the Council SSC and NMFS.
7. As explained above, optimum yield is determined under the MSA by reducing maximum sustainable yield by "economic, social, and ecological factors. A comparison should be made of the economic, social and ecological factors considered in each fishery management plan to ensure that they are consistent, and that any interactive effect has been considered.
8. The Pacific Coast Fishery Ecosystem Plan is currently slated for revision every six years, while the State of the California Current Ecosystem Report will be updated annually. The Pacific Coast Fishery Ecosystem Plan contains an analysis of the California Current ecosystem and other issues that will rapidly become decoupled from the work done in the California Ecosystem Report unless the Pacific Coast Fishery Ecosystem Plan is revised more frequently to ensure consistency.

9. A checkpoint along the way needs to be implemented, probably just after the setting of measurable objectives, to estimate the cost involved with implementing ecosystem-based management. A study released by NOAA in 2001 estimated the increase in headcount and budget that would be required to upgrade the then-current stock assessment process (Mace et al. 2001). Tier 3 of this projected enhanced effort included stock assessments that explicitly incorporated ecosystem considerations. The report estimated that an additional 201 full-time employees or contractors would be necessary, at an incremental cost that exceeded $91 million. This estimate was put together over a decade ago, and represents a single possible approach, but is indicative of the possible budgetary hurdle that might be faced in fully upgrading the stock assessment process to incorporate ecosystem-based management. If political support for the implementation of the program is not feasible for budget reasons, it may be prudent to build the necessary support before further pursuit of the initiative.
10. Accomplishment of these steps will require close coordination between the teams responsible for the Pacific Coast Fishery Ecosystem Plan, the Integrated Ecosystem Assessment, and the Council's Ecosystem Plan Development Team. In order to maximize consistency and minimize any redundancies, a regularly scheduled meeting should be considered between the heads of each of these three groups. Ideally, a jointly agreed strategic plan could be developed that would incorporate both specific actions to be taken in the upcoming year, and a five year plan that incorporated goals and objectives. This group might also conduct a periodic "best

practices" review, assessing and comparing ecosystem management based efforts being made by other Regional Fishery Management Councils.

FIGURE 3 – COORDINATION BETWEEN THE PACIFIC COAST FISHERY ECOSYSTEM PLAN, THE INTEGRATED ECOSYSTEM ASSESSMENT, AND FISHERY MANAGEMENT PLAN EFFORTS



VIII. WORKS CITED

Barbier, E.B. 2009. Ecosystem Service Trade-offs. *In* Ecosystem-Based Management for the Oceans. *Edited by* K. McLeod and H. Leslie. Island Press, Washington, D.C. pp. 129-144.

CEQ. 2010. Final Recommendation of the Interagency Task Force. Council on Economic Quality, Washington, D.C.

Crowder, L.B., Osherenko, G., Young, O.R., Airame, S., Norse, E.A., Baron, N., Day, J.C., Douvere, F., Ehler, C.N., Halpern, B.S., Langdon, S.J., McLeod, K.L., Ogden, J.C., Peach, R.E., Rosenberg, A.A., and Wilson, J.A. 2006. Sustainability: Resolving mismatches in U.S. ocean govenance. Science **313**: 617-618.

deReynier, Y.L., Levin, P.S., and Shoji, N.L. 2010. Bringing stakeholders, scientists, and managers together through an integrated ecosystem assessment process. Marine Policy **34**(3): 534-540.

Ecosystem Principles Advisory Panel. 1999. Ecosystem-based fisheries management: A report to Congress by the ecosystem principles advisory panel. National Oceanic and Atmospheric Administration, Silver Spring, NOAA.

FAO. 2003. Fisheries management: The ecosystem approach to fisheries. FAO.
Fletcher, W.J. 2005. The application of qualitative risk assessment methodology to prioritize issues for fisheries management. ICES Journal of Marine Science(62): 1576-1587.

Fletcher, W.J. 2006. Frameworks for managing marine resources in Australia through ecosystem approaches: Do they fit together and are they useful. Bulletin of Marine Science **78**(3): 691-704.

Fulton, E.A., Smith, A.D.M., and Johnson, C.R. 2003. Effect of complexity on marine ecosystem models. Mar. Ecol. Prog. Ser. **253**: 1-16.

Fulton, E.A., Smith, A.D.M., and Punt, A.E. 2005. Which ecological indicators can robustly detect effects of fishing? ICES Journal of Marine Science **62**: 540-551.

Garcia, S.M., and Cochrane, K.L. 2004. Ecosystem approach to fisheries: A review of implementation guidelines. ICES Journal of Marine Science **62**
311-318.

Goodman, D., Mangel, M., Parkes, G., Quinn, T., Restrepo, V., Smith, T., and Stokes, K. 2002. Scientific review of the harvest strategy currently used in the BSAI and GOA groundfish fishery management plans, Anchorage, Alaska.

Gregr, E.J., and Chan, K.M.A. 2011. Making science relevant to marine ecosystem-based management. Biological Conservation **144**: 670-671.

Horne, P.J., Kaplan, I.C., Marshall, K.N., Levin, P.S., Harvey, C.J., Hermann, A.J., and Fulton, E.A. 2010. Design and parameterization of a spatially explicit ecosystem model of the central California Current. NOAA.

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndahl, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., and Warner, R.R. 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems Science **293**(5530): 629-638.

Kaufman, L., Karrer, L.B., and Peterson, C.H. 2009. Monitoring and Evaluation. *In* Ecosystem-Based Management for the Oceans. *Edited by* K. McLeod and H. Leslie. Island Press, Washington, D.C. pp. 115-128.

Leslie, H.M., and Kinzig, A.P. 2009. Resilience Science. *In* Ecosystem-Based Management for the Oceans. *Edited by* K. McLeod and H. Leslie. Island Press, Washington, D.C. pp. 55-74.

Lester, S.E., McLeod, K.L., Tallis, H., Ruckelshaus, M., Halpern, B.S., Levin, P.S., Chavez, F.P., Pomeroy, C., McCay, B.J., Costello, C., Gaines, S.D., Mace, A.J., Barth, J.A., Fluharty, D.L., and Parrish, J.K. 2010. Science in support of ecosystem-based management for the U.S. West Coast and beyond. Biological Conservation **143**(3): 576-587.

Levin, P. 2012. Ecosystem Science Program.

Levin, P.S., Fogarty, M.J., Matlock, G.C., and Ernst, M. 2008. Integrated Ecosystem Assessments. NOAA.

Levin, P.S., Fogarty, M.J., Murawski, S.A., and Fluharty, D. 2009. Integrated Ecosystems Assessments: Developing the Scientific Basis for Ecosystem-Based Management of the Ocean. PLoS Biology **7**(1).

Levin, S.A., and Lubchenko, J. 2008. Reslience, Robustness, and Marine Ecosystem-Based Management. BioScience **58**(1): 27-32.

Link, J.S. 2002. What Does Ecosystem-Based Fisheries Management Mean? Fisheries **27**(4): 18-21.

Link, J.S. 2005. Translating ecosystem indicators into decision criteria. ICES Journal of Marine Science **62**: 569-576.

Link, J.S. 2010. Ecosystem-Based Fisheries Management - Confronting Tradeoffs. Cambridge University Press, Cambridge, U.K.

Link, J.S., Brodziak, J.K.T., Edwards, S.F., Overholtz, W.J., Mountain, D., Jossi, J.W., Smith, T.D., and Fogarty, M.J. 2002. Marine ecosystem assessment in a fisheries management context. Can. J. Aquat. Sci.: 1429-1440.

Link, J.S., Yemane, D., Shannon, L.J., Coll, M., Shin, Y., Hill, L., and Borges, M. 2009. Relating marine ecosystem indicators to fishing and environmental drives: An elucidation of contrasting responses. ICES Journal of Marine Science **67**: 787-795.

Liu, J., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenko, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H., and Taylor, W.W. 2007. Complexity of Coupled Human and Natural Systems. Science **317**: 1513-1516.

Mace, P.M., Bartoo, N.W., Hollowed, A.B., Kleiber, P., Methot, R.D., Murawski, S.A., Powers, J.E., and Scott, G.P. 2001. Marine Fisheries Stock Assessment Improvement Plan. NOAA.

Marasco, R., Goodman, d., Grimes, C., Lawson, P., Punt, A., and Quinn, T. 2005. Strengthening Scientific Input and Ecosystem-Based Fishery Management for the Pacific and North Pacific Fishery Management Councils. Pacific States Marine Fisheries Commission.

Margolus, R., and Salafsky, N. 2010. Measures of Success - Designing, Managing, and Monitoring Conservation and Development Projects. Island Press, Washington, D.C.
McLeod, K.L., and Leslie, H.M. 2009. Why Ecosystem-Based Management? *In* Ecosystem-Based Management for the Oceans. *Edited by* K. McLeod and H. Leslie. Island Press, Washington, D.C. pp. 3-12.

McLeod, K.L., Lubchenco, J., Palumbi, S.R., and Rosenberg, A.A. 2005. Scientific Consensus Statement on Marine Ecosystem-Based Management. Communication Partnership for Science and the Sea.

Micheli, F., and Halpern, B.S. 2005. Low functional redundancy in coastal marine assemblages. Ecology Letters **8**(4): 391-400.

Murawski, S.A. 2000. Definitions of overfishing from an ecosystem perspective. ICES Journal of Marine Science **57**: 649-658.

Myers, R.A. 1998. When do environment-recruitment correlations work? Reviews in Fish Biology and Fisheries **8**: 285-305.

National Ocean Council. 2013. National Ocean Policy Implementation Plan. National Ocean Council, Washington, D.C.

NOAA. 1997. Revised Operational Guidelines. *Edited by* NOAA.

NOAA. 2010. NOAA's Next-Generation Strategic Plan. NOAA.

NOAA. 2011. The United States is an Ocean Nation. Available from www.gc.noaa.gov/documents/2011/012711_gcil_maritime_eez_map.pdf [accessed May 10, 2013 2013].

NOAA. 2012a. The West Coast Groundfish IFQ Fishery: Results from the first year of catch. NOAA.

NOAA. 2012b. Why an Ecosystem Approach to Management (EAM)? Available from www.ecosystems.noaa.gov/why_an_eam.htm.

NOAA. 2013. Policy Directive. *Edited by* NOAA. NOAA. p. 22.

NPFMC. 2007. Aleutian Islands Fishery Ecosystem Plan. North Pacific Fishery Management Council, Anchorage, Alaska.

NWFSC. 2012. Ecosystem Science Program. Available from www.nwfsc.noaa.gov/researh/divisions/cbc/popbio.cm.

NWFSC, and SWFSC. 2012a. Discussion Document: Development of an Annual Report on Conditions in the California Current Ecosystem. NOAA.

NWFSC, and SWFSC. 2012b. Report to Pacific Council Nov. 2012. NOAA, Seattle, WA.
OECD. 1993. Environmental indicators for environmental performance reviews. OECD.

Pew Oceans Commission. 2003. America's Living Oceans: Charting a Course for Sea Change. Pew Oceans Commission.

PFMC. 2009. Decisions of the Pacific Fishery Management Council October 31- November 5, 2009. Pacific Fishery Management Council, Portland, Oregon.

PFMC. 2011a. Coastal Pelagic Species Fishery Management Plan As Amended Through Amendment 13. Pacific Fishery Management Council, Portland, Oregon.

PFMC. 2011b. Decisions of the Pacific Fishery Management Council June 8-13, 2011. Pacific Fishery Management Council, Portland, Oregon.
PFMC. 2011c. Fishery Management Plan For U.S. West Coast Fisheries For Highly Migratory Species as Amended Through Amendment 2. Pacific Fishery Management Council, Portland, Oregon.

PFMC. 2011d. Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery. Pacific Fishery Management Council, Portland, Oregon.

PFMC. 2012a. Decision Summary Document - Pacific Fishery Management Council Meeting June 21-26, 2012. Pacific Fishery Management Council, Portland, Oregon.

PFMC. 2012b. Decision Summary Document - Pacific Fishery Management Council Meeting November 3-7, 2012. Pacific Fishery Management Council, Portland, Oregon.

PFMC. 2012c. Pacific Coast Salmon Fishery Management Plan. Pacific Coast Fishery Management Council, Portland, Oregon.

PFMC. 2013a. Habitat and Communities: Marine Reserves and Marine Protected Areas. Available from www.pcouncil.org/habitat-and-communities/marine-protected-areas/ [accessed March 11, 2013 2013].

PFMC. 2013b. Habitats and Communities: Fishing Communities. Available from www.pcouncil.org/habitat_and_communities/2013].

PFMC. 2013c. Pacific Coast Fishery Ecosystem Plan. Pacific Fishery Management Council, Portland, Oregon.

PFMC. 2013d. Pacific Fishery Management Council. Available from www.pcouncil.org [accessed April 13, 2013.

PFMC. 2013e. Research and Data Needs. Pacific Fishery Management Council, Portland, Oregon.

PFMC, and NMFS. 2012. Proposed Harvest Specifications and Management Measures for the 2013-2014 Pacific Coast Groundfish Fishery and Amendment 21-2 to the Pacific Coast Fishery Management Plan - Final Environmental Impact Statement. Pacific Fishery Management Council, Portland, Oregon.

Pikitch, E.K., Santora, C., Babcock, E.A., Bakun, A., Bonfil, R., Conover, D.O., Dayton, P., Doukakis, P., Fluharty, D.L., Heneman, B., Houde, E.D., Link, J., Livingston, P.A., Mangel, M., McAllister, M.K., Pope, J., and Sainsbury, K.J. 2004. Ecosystem-Based Fishery Management. Science **305**: 346-347.

Punt, A., and Hurtado-Ferro, F. 2013. Supplemental Workshop and Risk Assessment Powerpoint. Pacific Fishery Management Council, Seattle, WA.
Punt, A.E., and Ralston, S. 2007. A Management Strategy Evaluation of Rebuilding Revision Rules for Overfished Rockfish Stocks. *In* Biology, Assessment, and Management of North Pacific Rockfishes. *Edited by* J. Heifetz, J. DiCosimo, A.J. Gharrett, M.S. Love, V.M. O'Connell and R.D. Standley. Alaska Sea Grant College Program. pp. 329-351.

Rademeyer, R.A., Plaganyi, E.E., and Butterworth, D.S. 2007. Tips and tricks in designing management procedures. ICES Journal of Marine Science **64**.

Rosenberg, A.A., and McLeod, K.L. 2005. Implementing ecosystem-based approaches to management for the conservation of ecosystem services. Mar. Ecol. Prog. Ser. **300**: 270-274.

Ruckelshaus, M., Klinger, T., Knowlton, N., and DeMaster, D.P. 2008. Marine Ecosystem-Based Management in Practice: Scientific and Governance Challenges. BioScience **58**(1): 58-63.

SAFMC. 2009. Fishery Ecosystem Plan of the South Atlantic Region. South Atlantic Fishery Management Council.

SAFMC, and NMFS. 2009. Comprehensive Ecosystem-Based Amendment 1 for the South Atlantic Region. South Atlantic Fishery Management Council, North Charleston, South Carolina.

SAFMC, and NMFS. 2011. Comprehensive Ecosystem-Based Amendment 2 for the South Atlantic Region. South Atlantic Fishery Management Council, North Charleston, South Carolina.

Sainsbury, K.J., Punt, A.E., and Smith, A.D.M. 2000. Design of operational management strategies for achieving fishery ecosystem objectives. ICES Journal of Marine Science **57**: 731-741.

Sherman, K. 1991. The Large Marine Ecosystem Concept: Research and Management Strategy for Living Marine Resources. Ecological Applications **1**(4): 350-360.

Tallis, H., Levin, P.S., Ruckelshaus, M., Lester, S.E., McLeod, K.L., Fluharty, D.L., and Halpern, B.S. 2010. The many faces of ecosystem-based management: Making the process work today in real places. Marine Policy **34**(2): 340-348.

U.S. Commission on Ocean Policy. 2004. An Ocean Blueprint for the 21st Century. USCOP, Washington, D.C.

Witherell, D., Pautzke, C., and Fluharty, D. 2000. An ecosystem-based approach for Alaska groundfish fisheries. ICES Journal of Marine Science **57**: 771-777.

Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., and Watson, R. 2006. Impacts of biodiversity loss on ecosystem services. Science **314**(5800): 787-790.

WPRFMC. 2012. Fishery Plans, Reports, and Policies. Available from www.wpcouncil.org/hot/ [accessed March 19, 2013.