Federal Fisheries Management: An Adaptive Ecosystem-based Perspective

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I. Abstract:

Marine ecosystem health has been severely degraded by years of overfishing and ineffective management. Fisheries provide a source of food, jobs, and products and are backed by significant commercial, social, and industrial interests. Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) was a major legislative benchmark for fisheries management, establishing regional management councils and national fishing standards. Single species, or target-focused management practices have been ineffective at preventing overfishing, bycatch, and habitat degradation. Fisheries continue to be unsustainable. The Sustainable Fisheries Act (SFA - 1996 MSFCMA amendments) and the MSFCMA reauthorization in 2006, seek to shift management's perspective to an ecosystem-based approach. The SFA formed the Ecosystem Principles Advisory Panel (EPAP) to research federal fisheries and management and to develop a model to advise Congress and managers.

The panel identified basic principles of marine ecosystems and developed policies for ecosystem-based management, promoting health and sustainability. The high degree of uncertainty associated with ecosystem-based management has created considerable opposition. Fishermen and industries are unwilling to trade current economic benefits for future marine health, despite the benefits of stable, sustainable harvests. The EPAP seeks to shift the burden of proof to the fishing industry, requiring fishing practices be shown not to harm ecosystem health before permitting them. Further research should consider the ecosystem effects of fishing, trends and dynamics to align science, policy, and management goals.

Panel recommendations extend current fishery management plans (FMPs) to consider fisheries on an ecosystem scale (fishery ecosystem plans, FEPs). FEPs consider interactions between target and non-target species, habitat, and human activities through precautionary management. There is no mandate for the adoption of FEPs, but the framework exists and policy is catching up with science. Many ecosystem principles are marginally applied in current management (i.e. marine protected areas). Progress has recently been made to transition from single-species fisheries management to ecosystem-based, but there is still room for improvement. Conservation groups and consumers can aid the implementation of regulation by rewarding sustainable fishing and management efforts. Only through future research, public support, inter-disciplinary cooperation, and risk-averse practices can fisheries management rebuild overexploited stocks and return fishery ecosystem health.

II. Introduction:

Ocean health is widely considered to be severely damaged. This is a cause for concern because marine ecosystems are socially and economically significant (i.e. food source, jobs). Fisheries have caused growing concern with the continued declines of fish stocks worldwide. It has become clear that fisheries management has fallen short of its goal to stabilize stocks and promote sustainable fishing practices. This project seeks to examine past progress, success, and failures in US federal fisheries management in the face of legislative progress and recent ecosystem-based management perspectives for fisheries, and to provide some recommendations to aid the implementation of recent regulatory measures. The major fisheries management legislation, the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA, Table A1), was reauthorized in December 2006 with significant changes. At the same time ecosystem approaches to management are gaining popularity, although there is still controversy over the lack of a clear definition.

From the conservation perspective, ecosystem based management pertains to the management of all threats to the ocean ecosystem due to fisheries as well as pollution and habitat destruction based in non-fishery sources. Conservation organizations seek to maintain diversity and structure within marine ecosystems including: apex predators, age-structured fish populations and complex living benthic habitat. They also seek to maintain the utilization of resources at levels that are within capacities that maintain ecosystem function throughout the entire marine system (Hirschfield 2005).

As for ecosystem approaches to fisheries management (EAF), managers would be required to consider all components, both fish and non-fish, within ecosystem-based fisheries management. Non-fish components include “charismatic” organisms such as sea turtles, whales and dolphin as well as other members of ocean communities such as non-target fish species. This is in contrast with the production-focused management based on exploitation potential alone (often in the short-term, i.e. annual). Conservationists view healthy ecosystems hand in hand with fisheries only when managers have successfully dealt with overfishing, bycatch and habitat destruction. An ecosystem-based approach to management may not only be the critical factor in solving these problems, but also a way to incorporate precautionary management and account for the cumulative impacts of anthropogenic factors with the hope of improving the health of ocean systems (Hirschfield 2005).

In 1871, Congress established the U.S. Commission of Fish and Fisheries (USCFF), the precursor to today’s National Marine Fisheries Service (NMFS). Spencer Baird, the first Commissioner, made marine ecology a top priority arguing that our understanding of fish “…would not be complete without a thorough knowledge of their associates in the sea, especially of such as prey upon them or constitute their food…" (Fluharty 2005). He understood that the abundance or lack of fish was determined by physical and chemical changes in the ocean in addition to removal by fishing. In spite of this early recognition of the complexity of fisheries management, society still consistently fails to achieve sustainable management of marine ecosystems. Seeking to resolve this recurrent failure, Congress charged the National Marine Fisheries Service (in the Sustainable Fisheries Act) with establishing a panel to assess and develop what principles of ecosystems are used in fisheries management and research. Additionally, the panel should recommend implementation of these principles to further improve management of marine ecosystems and their resources (EPAP 1999).

This Ecosystem Principles Advisory Panel (EPAP) sought a more holistic approach, drawing its members from industry, academia, conservation and fishery management interests. The purpose of this panel was to compound the advancements of past efforts and to seek to expand ecosystem-based management within current fisheries management systems (EPAP 1999). Significant progress was made by the 1996 Sustainable Fisheries Act (SFA) amendments to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). These amendments require Regional Fishery Management Councils to: align harvest rates at or below maximum sustainable yields; develop plans to recover species that are currently below long-term sustainable yields; better tracking and minimization of bycatch; identification and protection of essential fish habitat; study of environmental effects of fishing. The implementation of these guidelines is imperative to the realization of ecosystem-based management. However, it is important to understand that visible progress will take time to produce (EPAP 1999).

The Advisory Panel concurred on the expanded use of ecosystem principles in fishery management. The Panel was also charged to identify ecosystem principles. Although there is no clear solution, they have developed a practical combination of principles and actions to promote sustainable management. The panel seeks to broaden the extent of management by examining the interrelationships between fisheries and ecosystems with the hope of improving sustainability through more effective management policies based in ecosystem principles. Ecosystem-based management of fisheries could, for example, increase the abundance of overfished species, though it may require a short-term reduction in harvest rates. A reduction in harvest rates may pertain not only to the species in question, but also to a species of critical importance to the ecosystem and food web (EPAP 1999).

The Panel seeks to evaluate how ecosystem principles are currently used in the management and study of fisheries and to examine the potential for expanded application in future management and research. It is the hope and the expectation that an ecosystem-based management of fisheries will contribute stability and economic activity to the industry and protection to the ecosystems on which it is centered (EPAP 1999). These efforts are representative of our recognition that the oceans are an extensive but finite resource and our hope as a society that we are capable of adapting to levels of consumption that are within its limits. There has been increasing social pressure towards the sustainable management of fisheries (Valdimarsson and Metzner 2005).

Marine and fisheries policies are often the result of scientific alarms, highlighting a typically human-induced imbalance in an ecosystem. If the scientific evidence is strong enough, then awareness spreads from research circles to policy and management arenas. For fisheries, this is fundamental, but has primarily taken a supporting role. This is frustrating on all accounts, but inevitable due to a time lag in scientific advancement. Ecosystem management involves a complex web of problems. Resource users (i.e. fisheries) desire stability in order to have logical plans for operations. The fishing industry struggles enough under changing market conditions without having to be concerned with changing regulations. Scientists prefer to develop stable, but adaptive forms of management based in monitoring and the achievement of particular goals. One major deficiency of the policy system is the gap between realistic needs and the legislative time required to formulate realistic changes in policy and regulations. However, because of this time lag, major changes in policy are not high-risk prone (Rice 2005).

Policy and management reactions to science do vary with the current degree of importance placed on a problem by society. Society has, however, become more concerned with environmental issues as it faces increasing climate change, population issues, etc. (Watson-Wright 2005). A new approach to fisheries management will not result in a major policy change without a pre-existing wave of support amongst constituents. Otherwise, the government will have to make its own case in favor of a policy change. This is not likely without some confidence that disturbing the status quo will provide some benefit. Even when change is warranted, political processes will rely more heavily upon public consultation rather than scientific endorsement. Science must convince policy makers that costs and benefits of a change in policy are known and justified, in order to significantly influence future policies (Rice 2005).

As environmental problems compound and society's demand for goods and services continues to increase, management is beginning to realize that focused policies may prove to be too specific and fall short of effective management. Sustainable practices may warrant an ecosystem-based perspective to management. This will require combining the interests of fisheries, tourism, energy development, and other industries based in marine environments in order to consider total combined impacts on the health and resources of the ecosystem (Murawski 2005). Both research and policy may join management in a transition to a more ecosystem-based focus to evaluate problems and their ramifications within the system as a whole rather than centering only on the problems themselves. Conservation groups and consumers (the general public) can play an integral role in promoting the implementation of sustainable practices. Providing monetary and management rewards (i.e. protected fishing rights) to eco-friendly fisheries and penalizing detrimental practices (i.e. fines) will further the move to ecosystem-based management and healthy fisheries.

III. Literature Review:

a. Marine Ecosystems and Fisheries –

What is an ecosystem? “An ecosystem is a geographically specified system of organisms, including humans, the environment, and the processes that control the system’s dynamics” (Sumalia 2005).

For some time, the majority of the world’s fisheries have been at or near maximum sustainable yields and the number of overexploited stocks in rapidly increasing. Globally sustained yields are achieved by increasingly fishing for species at lower trophic levels. The hope of a continually increasing yield is baseless. The consequences of continuous overfishing outweigh the direct or indirect employment of some 200 million people due to the social, economic, and ecological changes that result. Ecological consequences themselves often go undocumented and unnoticed (EPAP 1999).

The majority of US fisheries harvests come from two fisheries: menhaden and Alaskan Pollock, contributing nearly half to annual totals of over 4.5 million metric tons for more than fifteen years. The US NMFS states that 86 of 727 US managed stocks are overfished. Another 10 are approaching this status, and only 183 are not overfished. Status is unknown for the remaining 448 stocks, although the NMFS indicates that the amount of overfished stocks is likely to increase under the new definition of overfishing in the Magnuson-Stevens Fisheries Conservation and Management Act (MSFCMA) (EPAP 1999).

Recoveries (i.e. Atlantic striped bass), record setting yields (i.e. Alaska salmon) and management successes (i.e. Pacific halibut) are encouraging, but remain exceptions. Globally, overfishing is a common trend amongst fisheries. This is urgent because current harvest levels remain high and new fisheries follow the common pattern to unsustainable catch levels before management can adjust. Ecological consequences of new fisheries are virtually unknown until after the fact. They are not considered in decision-making, and ecosystem changes from exploitation are not monitored. These problems are not unique to fisheries, but rather are universal to ecosystem-based management approaches (EPAP 1999).

Maximum yields are determined based on fisheries science so that fisheries industry may remove surplus production without endangering the overall productivity of the fishery. In an ecosystem context, however, the theory behind surplus harvesting is somewhat ambiguous. Marine ecosystems excel at energy capture, nutrient cycling, and biomass production. Very little biomass is truly ever surplus within a system. Naturally, or pre-fisheries, it is recycled within the system. Fisheries harvesting induces changes within predator-prey cycles and competition complexes and the ecosystem responds to changes induced by harvesting and trophic level responses. The changes may affect future production levels, potentially resulting in limited or no surplus populations (EPAP 1999).

Fisheries are a necessity because of the food, the social and economic benefits that they provide, and the cultural traditions they represent. Exhausted fisheries however are a serious threat to these traditions and benefits. Management agencies seek to implement sustainable yield policies for open-access marine resources, but are met with conflict when fishery effects extend to endangered species, and protected marine mammals. Also, recent conservation and management interests seek to shift the burden of proof to the fishing industry. For instance, to prove that exploitation does not induce large-scale and long-term ecological differences. Management seeks to find a balance, but each fishery is unique and will have its own solutions (EPAP 1999).

Social, economic, political, cultural, and ecological factors influence decisions concerning fisheries. A holistic view requires the recognition of fishery management and utilization as a part of the marine ecosystem. Fishing actively removes a proportion of one or several species and can have a major effect on habitat and predator-prey relationships relative to that species. Harvesting of a species also influences changes in growth or mortality rates of target and non-target species. Because of these influences, fisheries can change the structure and function of an entire marine ecosystem. Humans are the primary source of these influences and thus have an obligation to effectively manage fisheries not only as the top of the global marine food chain, but also to benefit and maintain stability of the marine environment itself. There are two conditions for the management of human interaction with marine systems. The first is the development of an understanding of the patterns and functions of characteristics within the ecosystem. Secondly, cultivate the ability to manage activities that impact marine ecosystems, within the bounds of ecosystem principles and societal goals for ecosystem behavior (i.e. health and sustainability) (EPAP 1999).

Fishing is generally a size and species selective agent of mortality and consequently is not a natural influence on species mortality. Most fish harvested are in the middle or near the top of food webs for their respective habitats. It therefore plays the role of a keystone predator; creating significantly greater and more complex effects on the ecosystem than a mere loss of biomass. Anthropogenic changes must be controlled because nature has functional, past, and evolutionary limitations. Although nature reacts within a range of stability, human changes must reside within these limits (EPAP 1999).

The Sustainable Fisheries Act mandated the formation of the NMFS Ecosystem Principles Advisory Panel. Congress required the NMFS to appoint a panel to advise Congress on ways to increase the application of ecosystem principles in conservation and management of fisheries. This panel of not more than 20 people included members with expertise in the structure, function, physical and biological characteristics of ecosystems. It also included spokespersons from regional councils, states, fisheries, conservation organizations, and others with expertise in managing marine resources. Following a year of research, the panel provided an analysis of the extent to which ecosystem principles are applied in fishery management, including research activities, and proposed actions for Congress and the secretary of commerce to expand the application of ecosystem principles in management (Fluharty 2005).

The panel's report was written on a consensus basis to control its content. Its first assignment was to determine the definition of "ecosystem principles", a term left undefined by Congress. The panel was careful to distinguish their goal of ecosystem-based management, regarding the application of our knowledge of marine ecosystems and their processes in fisheries management. This as opposed to "ecosystem management", given the vastness of uncertainties. It was determined, however, that effective ecosystem-based management of marine resources requires effective fishery management, the best available scientific information, and the political willingness to make tough decisions in favor of sustainable practices.

Each fisheries ecosystem is unique. Each system, however, also exhibits four basic problems: there is an incomplete knowledge of ecological systems surrounding fisheries production; weather and climate are unpredictable factors affecting ecosystems; systems evolve with time; our policy system is not currently adapted to management at the ecosystem scale. Fish and fisheries often transcend the political and jurisdictional boundaries in which their management is based. Considering these limitations, the Ecosystem Principles Advisory Panel developed eight principles describing our understanding of fisheries ecosystems (Fluharty and Cyr 2001). The following principles were intended to aid the evaluation of current fisheries management and develop future recommendations for ecosystem-based methods in order to maintain ecosystem health and sustainability (EPAP 1999).

1. **The ability to predict ecosystem behavior is limited.**

Uncertainty is an inevitable characteristic of a complex adaptive system like marine environments. It is impossible to flawlessly predict the behaviors of such systems, regardless of the amount of scientific investments. However, we can learn the range over which behavior operates and expand our knowledge of the primary dynamics. While ecosystems are not entirely predictable, they can be managed within the limits of their predictability (Fluharty and Cyr 2001).

Time scale plays a significant role in variance amongst marine ecosystem properties. Climate change events may displace species, affect community structure and alter productivity in ocean communities. Our ability to predict such phenomena is only now evolving and reflects a high degree of uncertainty. Management policies, however, can be guided by our expansive knowledge of marine ecosystems. Our ability to predict anthropogenic influences is limited, but progressing. Patterns form in annual fishing habits, market responses to price change, and fishermen response to policy and regulatory changes. Global markets produce trends based on economic changes, social preferences, and cultural philosophies. The increasing amount of scientific and social data regarding fisheries is improving our ability to predict and explain human behaviors with respect to fisheries systems. (EPAP 1999).

2. Ecosystems have real thresholds and limits, which when exceeded, can affect major system restructuring.

Ecosystems are limited resources, though exceptionally hardy under stress. Stress, and subsequently, deterioration of a system is typically evident after a critical threshold has been passed. Ecosystems are finite and exhaustible, although they usually have a high buffering capacity and are fairly resilient to stress. Stress tolerances are difficult to predict because there is little initial change (Fluharty and Cyr 2001).

The idea of limits or thresholds has been abused within the context of single-species fishery management as they have been viewed as catch targets as opposed to levels to avoid. Single-species management has been the consistent trend within fisheries, and limits or thresholds have rarely been applied to ecosystem contexts. Limits are often set based on specific fishing yields or mortality rates with no regard for other factors within the system. Most limits are thresholds, that when exceeded, affect the flexibility of managed stocks. Maximum sustainable yields are often set too close to critical thresholds and result in declines in stock populations, or damage to ecological communities. Thresholds should be avoided in order to maintain ecosystem health at species and community levels. Fishery targets need to be conservative and well below critical thresholds in order to maintain productive potential and ecosystem stability (EPAP 1999). Recent legislation including: the Marine Mammal Protection Act, the Endangered Species Act, and the new definitions of overfishing levels, bycatch and essential fish habitat (EFH) as provided by the MSFCMA, has only begun to consider limits and thresholds for non-target species (EPAP 1999).

3. **Once thresholds and limits have been exceeded, changes can be irreversible**.

Extreme change to an ecosystem may be impossible to completely reverse, even if the cause of stress is removed. This problem is common to many complex, adaptive systems (Fluharty and Cyr 2001). Fishing industry practices have most likely altered sensitive ecosystems irreversibly (i.e. estuaries and coral reefs), as they are habitat-destructive. Farther offshore, the effects of the fishing on species abundance of both target and non-target species may seriously change community and ecosystem composition. We are still unsure whether or not some severely fished systems will return to previous stock levels if fishing efforts should be reduced (i.e. Georges Bank). Fisheries scientists and managers have an enduring faith in fisheries ability to recover stock levels from the effects of fishing by compensating with increased productivity. That assurance extends to ecosystems that support utilized stocks. Recoveries are possible, within reason, for most populations. In some systems, however, habitat destruction and overfishing thresholds have been exceeded and return to original conditions is unlikely (EPAP 1999).

Ecosystem changes may have a long-term effect on human behavior. Disruptions in fisher business, fishing seasons, or market flow are often difficult to reestablish. Some aspects of anthropogenic behaviors can be reestablished with enough time and patience. Management policies are constantly subject to change, as opposed to ecosystems, to which variations are much more permanent (EPAP 1999).

4. **Diversity is important to ecosystem functioning**.

Ecosystem behavior is dictated by the diversity of individual, species, and landscape components. Ecosystem productivity does not always differ with the addition or removal of particular species, but their stability and/or resilience is often affected (Fluharty and Cyr 2001). Overfishing or unsustainable fishing practices may result in long-term losses in diversity in marine ecosystems. However, certain components of catch change economic value as other stocks are overfished and are replaced by lower-valued species. Alterations to ecosystem diversity result in redirection of biological productivity to alternate species. It is not clear, however, whether or not these ecosystems are less productive or efficient than the original ecosystem composition. Such ecosystems are, however, typically valued less, as changes in biodiversity reduce resiliency of species, communities, and ecosystems, particularly over long time scales. Communities that lose diversity are more likely to be influenced by changes due to stress (EPAP 1999).

5. Multiple scales interact within and among ecosystems.

Ecosystems cannot be understood based in a single scale of time, space, or complexity. In the least, larger and smaller scales must be considered when analyzing the effects of disturbances (Fluharty and Cyr 2001). Scale plays a major role in the apparent effects of disturbances within a marine system. Local disruptions such as the overfishing of one species may have large scale and relatively unknown effects on its predators among other trophic web interactions. The marine system is an open, fluid environment in which, small, localized human disturbances are often unknowingly magnified across an ecosystem scale. The apparent impacts of stresses over a range of scales is still a relatively new concept that we are only now beginning to focus on as a major factor in ecosystem health. Human impacts cannot be understood when limited to a single temporal or spatial scale. Fishing communities are subject to influences both from within the community itself, and from outside forces due to changes in environmental, social, economic, and regulatory pressures. These factors seem far removed from local fishery conditions, markets dictate the interactions of all these forces (EPAP 1999).

6. **Components of ecosystems are linked**.

Complex flows of matter, energy and information link components within an ecosystem (Fluharty and Cyr 2001). Predator-prey relationships maintain vital connections within marine ecosystems. Each organism contributes significantly to marine fish catches. Heavy fishing may result in species replacements, at higher and lower trophic levels (i.e. shark and ray populations increasing with overfishing of Atlantic cod). The loss of upper-level predators within an ecosystem is a major concern because of the top-down control they exercise on lower trophic levels. Fishing down food webs, at progressively lower trophic levels, upsets natural relationships between predator and prey species. At first this may lead to increasing catches (due to species replacement), but then continues to stagnating or decreasing yields. Only recently have we begun to realize that the disruption of these ecosystem connections may have severe and continuous impacts on human economies. The worst instances may result in severe impacts on ecosystem stability and productivity. Further progress in fishing technology for example, may cause severe adverse reactions amongst dependent human communities (EPAP 1999).

7. **Ecosystem boundaries are open**.

Equilibrium within an ecosystem cannot be understood without an effective knowledge of boundary conditions, energy flow and nutrient cycling within the system. Environmental fluctuations can vary the spatial boundaries and energy inputs of the system (Fluharty and Cyr 2001). The productive potential of marine ecosystems is susceptible to environmental fluxes across time and space. Marine ecosystems are typically open systems and community boundaries shift with climate patterns. Species range and abundance also vary with temporal shifts in ocean characteristics. Open systems react poorly to major changes, particularly in combination. For example, heavy fishing on a local level may lead to fishery collapses and trophic shifts in energy or biomass when combined with significant changes in ocean conditions such as El Niño. Human behaviors also fluctuate over temporal and spatial scales. Determination of the boundary of these interactions is important to understanding the stability (or instability) of the system (EPAP 1999).

8. **Ecosystems change with time.**

Natural and human influences produce changes within an ecosystem over time. Different mechanisms change at different paces and influence the structure of the ecosystem itself, affecting ecosystem services such as fish catch, income and employment (Fluharty and Cyr 2001). Anthropogenic changes are especially common is estuarine, coastal, or enclosed systems (i.e. bays, seas, lakes, etc.). Factors that induce change include invasive species, nutrient loading, poor stewardship of resources, bad management, etc. Rapid progress in navigation and gear technology has enhanced fishermen's abilities to selectively harvest species with byproducts of excessive amounts of bycatch and unintended destruction of ecosystem structure (i.e. Georges Bank). Trophic cascades, affecting community structure, result from the selective fishing of upper-level predatory species. Industrial fishing of bottom-feeding species, however, has unintended consequences for top predators, particularly marine mammals and others that cannot quickly adapt. Human perception, value, preferences, knowledge, expertise, and patterns of utilization may change over time with respect to interactions within ecosystems. Human components change so quickly (i.e. technology) that they often exceed an ecosystems ability to adjust for changes in any other ecosystem component. Communities often outgrow an ecosystem's capacity for meeting consumption rates. Fisheries management policies seek to consider all these factors (EPAP 1999).

b. Fisheries Management Legislation –

Magnuson-Stevens Fishery Conservation and Management Act (1976)

In 1976, the Fishery Conservation and Management Act (FCMA) was passed in order to regulate the management of fisheries within US federal waters. Later known as the Magnuson-Stevens

Fishery Conservation and Management Act (MSFCMA), this act placed fisheries under the authority of eight regional councils consisting of representatives from the regions fishing interests, state officials, and the federal regional fisheries administrator. Council decisions advise the secretary of commerce, charged with overseeing national level fisheries management and implementing decisions through the National Marine Fisheries Service (NMFS). Congress stated that fishing interests should be represented primarily by management councils because of their local knowledge of fisheries concerns and locally responsibility for their decisions. This balance of interests would ideally therefore provide incentives for conservation (Fluharty and Cyr 2001).

Magnuson-Stevens allows managers to take ecosystems into account when setting management objectives. The act sets forth national standards for federal fisheries management. National Standard 1 requires conservation measures to "prevent overfishing, while achieving, on a continuing basis, the optimum yield from each fishery" (Sec. 301(a)(1)). Optimum yield is defined as offering "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" (Sec. 3(28)(A)) and "the maximum sustainable yield from each fishery, as reduced by any relevant economic, social or ecological factor" (Sec. 3(28)(B)). The stated purpose of the Act is "to promote the protection of essential fish habitat" (Sec. 2(b)(7)). If ecosystems are not effectively being considered within fishery management plans (FMPs), it is not because of a lack of legislative authority, but rather of information and how to incorporate it into management actions (EPAP 1999).

Sustainable Fisheries Act (1996)

In 1996, Congress signed the Sustainable Fisheries Act (SFA) to amend the Magnuson-Stevens Fisheries Conservation and Management Act (MSFCMA). As a result, several changes have been made with respect to overfishing, bycatch, essential fish habitat, and the development of ecosystem-based management. Congress changed the formula defining optimum yield to help reduce overfishing. Prior to SFA, regional management councils permitted overfishing by setting total allowable catch greater than the maximum sustainable yield. Economics took precedence over biology for catch limits. There was no standard definition for "overfishing" leaving the NMFS virtually helpless to stop regional council decisions allowing overfishing. Fishing interests skirted NMFS scientifically based challenges by navigating political channels (Fluharty 2005). Councils could no longer set total allowable catch above the maximum sustainable yield (MSY) for fish stocks. Congress also set MSY as a limit, promoting more conservative policy decisions amongst fisheries councils. The new bycatch requirements under SFA aimed to contend with the biological destruction and waste from discarded fish in certain fisheries, seeking to "minimize bycatch to the maximum extent practicable" (Fluharty and Cyr 2001).

Councils were required to develop plans for rebuilding overfished stocks within ten years. This ten-year policy, however, is difficult to adapt to all species. The SFA given NMFS a basis for review of management decisions and permitted legal leverage for environmental advocacy groups to challenge the effectiveness of catch levels and rebuilding plans. As a result, almost all federally overfished stocks are subject to rebuilding, although recovery rates may vary by species. There are still some concerns amongst the environmental community, because the SFA only applies to species fished in management plans with stock assessments, as opposed to all other commercially and non-commercially fished species. Some stock assessments do include variations of an ecosystem approach to management (EAM) through the consideration of environmental risk, variation, etc. (Fluharty 2005).

Fishery management has struggled with bycatch issues for some time. The SFA standards focus on the minimization of bycatch and additionally to lower the mortality of bycatch, but these requirements have been difficult to monitor. The National Marine Fisheries Service (NMFS) was requested to annually develop a bycatch report to Congress (Fluharty and Cyr 2001). NMFS is developing a national approach to standardized monitoring of bycatch. Bycatch results in a variety of effects depending on the fishery, region, and season. There are very few fisheries where bycatch is reliably known to exist. Alaskan fisheries are an exception, industry-funded observers monitor more than three-fourths of total catch (Fluharty 2005). Fishing practices are altering to reduce bycatch, but determining what is realistic is difficult. Gear modifications are lowering bycatch in some fisheries. SFA deals primarily with bycatch in commercial fisheries, but the NMFS approach went so far as to encompass some recreational fisheries, migratory species, and non-fish species such as sea birds, marine mammals, sea turtles, etc. where bycatch issues are most critical (Fluharty 2005).

NMFS was charged with developing habitat protection guidelines within 6 months of the passage of the Act. Essential Fish Habitat was defined as, "habitat used by managed species of fishes through all life history stages (i.e. necessary to fishes for the purpose of spawning, breeding, feeding, or growth to maturity), rather than habitat per se" (Fluharty 2005). This amendment charged councils with evaluating and avoiding the effects of fishing on ecosystems, thus increasing the spatial and temporal understanding of fisheries dynamics, a major advancement in ecosystem-based marine management. The Essential Fish Habitat requirements were intentionally broad to promote proactive policies by fisheries councils to reduce nutrient run-off into coastal areas, and to curtail other practices potentially harmful to fish habitats (Fluharty and Cyr 2001). EFH designations provide stepping-stones for an ecosystem-based approach to management. For example, the Aleutian Islands region in Alaska (~95% of federal waters) is closed to trawling and other bottom gear, as are seamounts off the coast. These conservation areas help to provide additional data for comparison on habitats and fishing impacts identify gaps in the data, and with research prioritization (Fluharty 2005).

In addition to these amendments, Congress solicited the National Academy of Sciences (NAS) to assess the use of fishing quotas and community development quotas, and to examine Northeast (US) fishery stock assessments. (Fluharty and Cyr 2001). Marine Protected Areas (MPAs) are also being used more and more in fishery management. These management policies tend to target single species or species groups, but include a larger range of ecosystem factors and functions thereby mimicking an EAM (Fluharty 2005).

2006 Magnuson-Stevens Reauthorization & Recent Progress

The reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act was a major regulatory priority for 2006, which Congress passed on December 9 of the same year. This legislation included provisos to end overfishing, reduce bycatch, conserve habitat and rebuild damaged fish stocks. It increased the market-based, limited access programs and sought to improve communications with constituents, hurricane response efforts, recreational fishing data, and ecosystem approaches to fisheries management. NOAA Fisheries Service undertook numerous actions in 2006 to inform its constituents of the Magnuson-Stevens Reauthorization priorities. These actions included deadlines to end overfishing, market-based limited access programs, recreational fishing data, streamlining NEPA implementation, and furthering ecosystem approaches to fisheries management.

NOAA Fisheries Service and regional fishery management councils have the ability to influence overfishing levels. In 2006, they enacted many actions intended to end or prevent overfishing, in federally managed fisheries. Ending and prevent overfishing is vital to the health of our nation's fish stocks as are other factors such as environmental pollution, inconsistency, and harvesting. Ending overfishing and rebuilding overfished stocks are key aspects to the conservation and management mandates of the 1996 Sustainable Fisheries Act, and is stressed by Congress. The MSFCMA reauthorization requires that fisheries councils take measures to end overfishing within two years of an overfishing determination. The following examples indicate a national effort supported by regional councils and NOAA Fisheries Service prior to the December passage of the 2006 Act. A stock update in 2006 concluded that overfishing of Atlantic sea scallops had ended after years of strict management. Harvest provisions for summer flounder will take effect in 2007 with the hope of ending overfishing. NOAA Fisheries Service and Gulf Council worked to end overfishing of red snapper in the Reef Fishery FMP, with actions to be implemented in 2007 (NOAA 2006).

The Magnuson-Stevens reauthorization also strengthened market-based approaches to management. The major obstacle to meeting objectives for sustainable fisheries is excess fishing capacity. In November 2006, fishing tournament directors informed NOAA Fisheries Service of the need to refine standards and develop a universal definition for circle hooks, in order to comply with conservation and regulatory standards. Circle hooks are used to reduce mortality of released fish (NOAA 2006).

Government Performance Results Act (GPRA) performance measures are a significant measure of how public tax dollars are spent to achieve agency responsibilities and goals. NOAA Fisheries Service had five GPRA performance measures in 2006, that addressed specific management and science issues: number of major fish stocks that are overfished; number of major stocks with an unknown status; number of protected species with sufficient population assessments and predictions; number of protected species assigned as threatened, endangered, or exhausted with steady or growing population levels; and number of acres of habitat restored (NOAA 2006).

In 2006, NOAA Fisheries Service met or surpassed its goals for four of five measures. The goal of reducing the number of unknown fish stocks by three stocks in 2006 was reduced by two. However, success in meeting their goals demonstrated NOAA's progress in establishing stewardship of living marine resources; performance measures will be updated for 2007. The measure of major overfished stocks will be changed to a Fish Stock Sustainability Index, designed to collect information on the majority of NOAA's most important managed species. It combines four factors encompassing key aspects of fisheries management into a 920-point index. Fish stocks of unknown stock status and protected species with adequate assessments will be replaced with a Percentage of Living Marine Resources with sufficient population assessments and prediction measures (NOAA 2006).

Various actions have taken place on a more localized level, with respect to individual fisheries. The North Pacific Fishery Management Council adopted a standard requiring vessels to meet a calculated catch level on an annual basis. This standard was adopted to decrease regulatory and economic discards and increase the utilization of catch populations, thereby hopefully reducing bycatch off the coast of Alaska. In August 2006, mangers of the Gulf of Mexico Fishery reef fish population implemented Amendment 18A requiring reef fish craft owner and operators to adopt sea turtle and smalltooth sawfish release policies and have specific gear to ensure this policy on board fishing vessels. Both of these species are protected under the Endangered Species Act (ESA), implemented as a realization of NOAA's Fisheries Service-issued biological opinion to minimize impacts of incidental take of sea turtles and smalltooth sawfish during fishing operations (NOAA 2006). Gear and techniques required under this rule are regulated according to gear and fishing techniques research. Another action that took effect in North Atlantic Fisheries in September 2006, required dredge modification in order to promote sea turtle conservation in the sea scallop dredge fishery. NOAA determined that dredges modified with chain mats would prevent most sea turtle captures and reduce the number of injuries as a result of dredge capture (NOAA 2006). Amendment 18 of the Pacific Coast Groundfish Fishery Management Plan (FMP), November 2006, requires open access groundfish fisheries ships to carry observers if they are directed by NOAA Fisheries Service. FMP revisions also focus on bycatch minimization, including measures for reporting total catch, and compliance programs. Bycatch alleviation actions also include time/area closures, capacity control, and the development of enforcement and safety standards (NOAA 2006).

On January 12, 2007, President Bush signed H.R.5946 into law 109-479 stating: " the Act sets a firm deadline to end overfishing in America; contributes to replenishing America's fish stocks; strengthens enforcement of America's fishing laws; and implements international agreements on fishery management" (NOAA 2006). In January 2007, NOAA Fisheries Service met with the Executive Directors of eight regional fishery management councils to review implementation requirements, and will be working with constituents to meet requirements in a public process (NOAA 2006).

c. Economics –

A country's decisions for the use of marine resources is directed by how the country weighs market and non-market values from the ecosystem, and the discount rate that is applied to future ecosystem services. Society's preferences are based in the value they place on the benefit of making one choice over another. Accounting for a society's preferences is essential to fully understanding the decision making process regarding the utilization of ecosystem resources. Environmental resources are difficult to develop into logical economic values. Total economic value should include both direct or market values, indirect use values, and existence values. Market value, for example, may pertain to the selling value of a fish catch. Indirect uses may be ecosystem services such as water cycling and the potential for future benefits to be provided by an ecosystem. Existence value refers to the value granted for non-use of the ecosystem, regardless of its market value. Rather, its mere existence is valued for aesthetic, religious or ethical motivation. Different countries place different weight on market and non-market values depending on the net unit price of market goods, and consideration of non-market values. Countries that focus more on market value tend to maintain lower fish biomass levels in marine systems (i.e. the US). This tends to create more of an opportunity for policy disagreements, for example in terms of implementation of management plans (Sumalia 2005).

Discount rate is a number per unit time that converts future values to present values. Societies discount for several reasons, including our typical desire for instant gratification, preferring to use now instead of saving for later, and opportunity costs of capital: if money is currently in hand, it can at least earn interest in a bank account. Discount rates therefore echo how much influence a country places on receiving benefits now vs. in the future, providing an analytical basis for value-based decisions and uncertain potentials of future benefits. Discount rate can also be described as a measure of risk aversion. Countries reluctant to take risks adhere more closely to the precautionary principle and avoid major changes to the marine ecosystem, but prefer lower discount rates. High uncertainty about future outcomes and markets promotes high discount rates. Resistance to conservative fishing policies and increasingly widespread poverty and debt amongst fishing communities tends to encourage a country to apply high discount rates to benefits from marine ecosystems (Sumalia 2005).

High uncertainty, debt and poverty all contribute to an imbalance of influence on receiving benefits from the marine ecosystem in the present. Countries with this focus establish policies that forego long-term sustainability in favor of short-term benefits. Discounting is increasingly controversial as a tool for decision-making processes, as it is said that discounting future benefits from marine resources affects countries' ability to manage marine ecosystems sustainably both now and in the future. The problem is further complicated when more than one country shares a marine system, but they do not necessarily share the same discount rates for the resource. If the discount rates for two countries are different, then so are their inclinations with respect to the moment at which they want to receive their benefits from the ecosystem. The difference is most evident in the diverse social objectives for the countries, and difficulties in implementing an ecosystem-based approach to policies and management for the shared ecosystem (Sumalia 2005).

d. Ecosystem-based Fisheries Management –

An ecosystem approach to fisheries management can be defined simply as "using what is known about the ecosystem to manage fisheries" (Fluharty 2005). A more detailed definition states, "An ecosystem-based approach to the management of marine resources (EAM) is geographically specified; it is also adaptive and takes account of ecosystem knowledge and uncertainties. It considers multiple external influences, and strives to balance diverse societal objectives. EAM requires that the connections between people and the marine ecosystem be recognized, including the short- and long-term implications of human activities along with the processes, components, functions, and carrying capacity of ecosystems" (Sumalia 2005). Over 200 academics from US institutions agreed upon a definition of marine ecosystem-based management: "ecosystem-based management is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors" (Rosenburg and McLeod 2005).

This perspective recognizes that ecological knowledge of marine ecosystems can facilitate management of fisheries production and the effects of fishing on these ecosystems. This sort of management can begin to be practiced before there is legislative agreement as to the proper methodology. Rather, the regulatory directives may be more comprehensive with experience (Fluharty 2005). There is a global focus on fisheries problems. The International Council for Exploration of the Sea (ICES) held an international conference on the ecosystem effects of fishing. The North Pacific Marine Science Organization created an appraisal of marine ecosystem approaches and assembled two groups to study and develop EAM (Fluharty 2005).

Fisheries management has long considered goals of profits, employment, and maintenance of cultural lifestyles. These goals should be expanded to encompass ecosystem health and sustainability. Ecosystem health refers to an ecosystem's capacity to support and maintain a stable, adaptive community whose organisms exhibit species composition, diversity, and function equivalent to those of a natural ecosystem complex in the region. This concept reflects the biotic integrity of a system, or its "wholeness" (i.e. the presence of all necessary elements and processes at proper rates). Although the concept of health is relatively new in its application to marine systems, it is an essential part of management theory for forest ecosystems, desert ecosystems, etc.

> "A healthy ecosystem provides certain ecosystem goods and services, such as food, fiber, the capacity for assimilating and recycling wastes, potable water, clean air, etc. How do we extract from, and otherwise utilize ecosystems, while maintaining their health and the array of non-use services that they also provide into the indefinite future. The challenge to scientists and managers is to develop useful, quantitative measures of ecosystem health, which can guide management. What level of fishing, for example, can a "healthy" ecosystem sustain? How can vigor and resilience be expressed quantitatively so that

managers can maintain them within healthy limits" (EPAP 1999).

The Ecosystem Principles Advisory Panel agreed on the purpose of maintaining ecosystem health and sustainability, but could not compromise on a precise definition of the terms "health" and "sustainability." Recognizing that this goal for an ecosystem approach to fisheries management was broad also meant that it could potentially be reached by a variety of methods. Erring in favor of a broader concept (not wanting to be too vague), "maintain ecosystem health and sustainability" has become a standard for management actions to avoid, in order to achieve this goal. Certain efforts such as overfishing, disregarding bycatch, and habitat degradation are clearly adverse to ecosystem health and sustainability (Fluharty and Cyr 2001).

The geographic specification attached to ecosystems implies the necessity for trans-boundary policies to achieve successful management. Globally there are 64 large marine ecosystems, of which most are shared by at least two countries. Attempting to compromise between diverse social objectives and implement cooperative EAMs is a political problem that must be met if EAM is to be applicable on a worldwide scale (Sumalia 2005). Fisheries are a practical place to focus ecosystem management efforts as they are a major concern and are already managed in an ecosystem context (Fluharty 2005).

Bycatch reduction has been a major focus of NOAA Fisheries Service efforts to rebuild fish stocks. These actions are intended to permit managers to meet rebuilding goals while still permitting fishing. Bycatch can be reduced in a variety of ways. Fishermen provide more information to managers, which permits manager to target specific bycatch reduction. Minimum size restrictions and catch limits are also effective measures (NOAA 2006). Bycatch is viewed as a waste issue (i.e. of non-target species) or a legal issue (i.e. penalties for protected species). Bycatch management typically ignores all species that are not affected by commercial or recreational fisheries and not endangered or subject to legal protection. Effective management actions are only permissible when protected status is declared. By then, conservation measures may be too late to be effective and the ecosystem will not be capable of recovering. Increased monitoring by observers; hard caps for significant bycatch species; and incentives for changing gear technology are possible management measures. Under the ecosystem-approach these methods would pertain to all species (Hirschfield 2005).

Fisheries management has had a mixed history of successes and failures. The same rules, science, structure, and agencies apply to both scenarios. Failure is most often traced to council decisions made on short-term economic and social pressure not on the best available science for the management of fish stocks. Pressure is mounting to reform US fisheries management, to be more conservative and ideally sustainable (Fluharty and Cyr 2001). A common perspective of “responsible management” requires that four criteria of fisheries be met: produce human benefits, be sustainable, distribute benefits fairly, and not cause harm to marine ecosystems, “people, products, profits, and planet” (Valdimarsson and Metzner 2005).

Ecosystem-based management should complement existing fisheries management methods. Understanding ecological and socioeconomic environments, in which fisheries reside, may facilitate the anticipations of fisheries management on the marine ecosystem and the subsequent effects of ecosystem change on fisheries. Ecosystem-based management does not however, solve all the problems of existing fisheries management policies (Table A2). An ecosystem approach will fail without political support to stop overfishing, protect habitat, expand research and monitoring, etc. Ideally, a comprehensive ecosystem-based approach to fisheries management would require managers to consider a multitude of factors affecting fish stocks. These may include predator-prey interactions, species competition, the effects of weather and climate, habitat, the effects of fishing, etc. However, management would quickly become over-complicated by the complexities of specific interactions within the ecosystem. Managers can consider how harvesting one species may impact other species in the ecosystem. At this level, decisions can help prevent major changes in marine ecosystems caused by fishing (EPAP 1999).

The Ecosystem Principles Advisory Panel was established to assess how much ecosystem principles are applied in current management and research, and to make recommendations for the integration of ecosystem principles into future management and fisheries research. The Panel modeled a management system based on ecosystem principles, goals, and policies as a basis for the evaluation of current utilization of ecosystem-based management and research. This assessment concluded that the NMFS and Regional Fishery Management Councils (RFMC) already consider some of the principles, goals, and policies outlined by the panel, but not all are broadly applied across regional, jurisdictional or ecosystem boundaries (EPAP 1999). They found the best example of ecosystem-based management was the ground-fish fishery in the Alaska region (North Pacific). This management effort caps total removals, sets conservative harvest quotas, develops annual ecosystem reports to aid management decisions, has an Ecosystem Committee to sponsor public discussions on EAM, manages bycatch with penalties for it against harvest quotas, uses marine protected areas (i.e. spatial limits for permissible gear types), and has a well-established observer program (Fluharty 2005). This inconsistency in application across regional and ecosystem boundaries demonstrates a lack of clear directives and resources from Congress to carry out this ecosystem-based approach (EPAP 1999). This is the policy gap between knowledge (science) and practice (management) that the Ecosystem Principles Advisory Panel now seeks to close.

The primary recommendation of the Panel was that the regional management councils should develop Fishery Ecosystem Plans (FEPs). The intention of these plans is to consolidate available ecosystem information and trends into a format to generally advise management and expressly be applied under each fishery's management plans. The FEP was also developed under the notion that at first it should be adapted as an experimental tool in US fishery management, not as an action-obligatory policy. It would be more expansive in range and time than the required National Environmental Policy Act (NEPA) environmental impact assessments. The FEP would delineate spatial ecosystem boundaries; create a food web model; describe habitat needs of the "significant food web"; calculate total removals and their relationship to standing biomass, production, optimum yield, natural mortality, and trophic structure, to make certain they are not extreme; examine uncertainty and the inclusion of buffers within conservation and management efforts; develop ecosystem health indices for management targets; define long term monitoring and its use; identify factors outside of fishery management processes that affect marine ecosystems and cooperate with other management institutions to alleviate any adverse impacts (Fluharty 2005).

A bottom up approach to ecosystem-based management plans was favored for its additive and adaptive nature. The panel sought full implementation of SFA stipulations as a basis for the implementation of EAM, seeking a management process that could be carried out under current NMFS standards. The panel hoped to demonstrate the effectiveness of an ecosystem-based approach to management in fisheries. The EPAP expectation was for the NMFS to promote "pilot" FEPs amongst regional councils in order to gain experience to serve as a basis for future legislative applications. Management and legislative bodies responded well to recommendations, fishing interests were wary, and environmental interests considered it too affable towards fisheries. The biggest detractions from immediate application of panel recommendations were that NMFS was bogged down in employing SFA initiatives and that NMFS was involved in a legal defense of challenges to NEPA mandates and compliance records (Fluharty 2005).

The National Marine Fisheries Service organized the Marine Fisheries Advisory Committee to develop technical support for the execution of fisheries ecosystem-based management. The subsequent report supplemented that of the Ecosystem Principles Advisory Panel. Since 2000, Congress has initiated bills including provisions similar to EPAP proposals. Recent national ocean commission reports and the US Ocean Action Plan continue to promote support for ecosystem approaches for fisheries management (Fluharty 2005).

As a result of collective approval of EAM, NOAA initiated efforts to develop a "universal" EAM that would apply across marine regulatory, science, and resource management efforts. In 2004, they held a workshop on the delineation of ecosystems on a regional level. Regional fishery management councils are seeking to be more involved in NMFS, NOAA, and congressional activities developing EAMs. Regional councils are, however, making a series of advancements for implementing EAM, with NMFS funding. The South Atlantic Fisheries Management Council for example, is adapting current Habitat Management Plan to a model FEP. The North Pacific Fisheries Management Council (NPFMC) is considering EAM for Alaskan ecosystems and area-specific management programs similar to FEPs (Fluharty 2005). The original FEP idea was intended for the eight regional fisheries management councils. The National Oceanic and Atmospheric Administration (NOAA) produced the first FEP proposal for the Chesapeake Bay in 2000, to provide a summary of ecosystem information, to aid state and regional management. The Chesapeake Bay FEP offered valuable encouragement for the theory behind ecosystem-based management (Fluharty 2005).

US management efforts are shifting to ecosystem-based approaches for fisheries and marine ecosystems. This is primarily due to the following factors: better scientific knowledge of fisheries dynamics; reactions to unsustainable fisheries; increased public involvement and legal action; tangible success in application of conservative fishery management tools; protection of additional marine species such as sea birds, sea turtles, marine mammals, and other rare or endangered species; and toughened management requirements. There are many other factors, outside of fisheries themselves that promote improved management of marine ecosystems. Ecologically, anoxic zones, algal blooms, and climate change have significant effects on fisheries and marine ecosystems. Socio-economically, energy prices are on the rise, technology is constantly improving, and invasive imports are all anthropogenic influences increasing the vulnerability of fisheries. Along with these factors, our inability to effectively predict change in ecosystems has created an awareness of the need to evaluate the incentive structure in fisheries. EAM provides a framework for establishing incentives to balance human wants with ecosystem needs for sustainable fisheries and marine ecosystems (Fluharty 2005).

Ecosystem-based management methods are preferable, but complicated. There is not enough funding, time, or expertise to a complete view of fisheries operations from an ecosystem perspective. There will always be some level of uncertainty and unpredictability. Also, new approaches to management cannot substitute compliance with existing regulations. Though each fishery is unique, there are fundamental problems that operate within each ecosystem: our understanding of the ecosystem is incomplete; weather and climate effects are unpredictable; fisheries are dynamic systems that adapt and evolve with time; political and jurisdictional disjunction with fisheries and ecological boundaries. These problems hold true not only for fisheries, but also for all management efforts on an ecosystem level. We know many factors about fisheries, such as, the removal of one species affects other species, fisheries have a limited carrying capacity, and habitat loss affects abundance. However, we do not always understand how the effects of such changes are manifested within a fishery, or how to manage them (EPAP 1999).

Globally, fisheries management policies serve to mitigate coastal degradation from development, improve water quality, etc. Some management policies have aided the recovery of marine ecosystems. Although the overall pattern is one of degradation and escalating human impacts, there are several local examples of significant progress. For example, large marine protected areas in Georges Bank have led to the partial recovery of some species. Stringent catch controls in Alaska have allowed for the maintenance of stable harvests (Rosenburg and McLeod 2005).

An ecosystem approach to fisheries management is an extension of basic principles for sustainable development. It requires management to consider ecosystem issues like resource conservation, habitat protection, environmental impacts, etc. On the other hand, invasive species have long influenced native ecosystems. More strict preventative measures should be enacted to detect invasives as early as possible. The goal is to ensure the production of marine ecosystems and the corresponding ecosystem services, despite uncertainty (Valdimarsson and Metzner 2005). As governments shift to executing ecosystem-based approaches to management, certain changes will by necessary to progress from a single-sector approach to a more all-encompassing approach to management:

(1) Management goals should be formatted with respect to the conservation of ecosystem services including: provisioning (i.e. food and water), services (i.e. climate), cultural (i.e. aesthetic values), and supporting service (i.e. nutrient cycling). For most management this requires a change in perspective. Ecosystem-based goals focus on the long-term potential of systems and the services they provide, as opposed to maximizing catch and economic gain under current policies. This ecosystem focus acknowledges the fact that humans cannot be sustained without sustaining ecosystems as a whole.

(2) An ecosystem approach to management considers the interactions amongst sectors (Figure A1). Current approaches disregard these interactions and consequently detract from ecosystem services. For example, coastal development adversely affects habitat and water quality, thereby altering the coastal productivity of fisheries. Policies themselves also interact: waterfront areas for fishing businesses may be affected by coastal development. Ecosystem-based management must balance the impacts of management policies and human interactions in order to be effective.

(3) Management must consider cumulative impacts to the ecosystem. Collective human activities impact ecosystem services. Even if individual fisheries are well managed, the cumulative impacts

are probably greater than the sum of the effects for the individual fisheries. Cross-sector effects may also undercut ecosystem services. For example, the effects of fishing gear on habitats may seem minor until combined with sedimentation from coastal developments. Sector impacts on overall ecosystem structure, function, and processes must be considered with respect to simultaneous effects on other parts of the ecosystem to evaluate the overall impact.

(4) The creation of more integrated management policies is critical, due to the complexity of fisheries regulations. Setting goals for the conservation of ecosystem services should permit managers to develop logical management practices. For example, fishery closed areas are used to protect habitat, restrict development, prevent mining or drilling, and create marine parks. However, each closed area is designed with individual restrictions, with no regard for other management plans, resulting in a multifarious web of overlapping regulations. One alternative is to create ocean zones with specific permissible activities, where the overall goal is conservation and regulatory clarity. Ideally, such zones would include areas under full protection from extraction, habitat protection, and other intensive areas for activities that don't undermine sustainability of the ecosystem's services (Rosenburg and McLeod 2005).

The objectives of fisheries management tend to deviate, but there is one basic principle: to ensure that there are enough fish to produce new generations. Though seemingly simple, this has proved difficult in practice. Most fisheries have little or no restrictions. Even in the presence of limitations, landings frequently surpass catch limits due to the lack of commercial incentives to adhere to regulations. Financial pressures exceed penalties or incentives to respect regulations. Consequently, 25% of harvested stocks are overfished; most often by countries that are technically capable of complying with regulations. Most governments manage fisheries from the top-down, although these methods consistently fail. It is difficult to believe that we as a society can hope to achieve advanced management systems when we cannot convince fishers to maintain enough fish in the stock for future harvests. Despite years of fisheries development, it is still difficult to obtain even the most basic capture data (i.e. the basic landing statistics). The Food and Agriculture Organization (FAO) has mandated a global strategy to improve global landing statistics, as fisheries management has not implemented regulatory requirements or incentives for fishermen to provide such data (Valdimarsson and Metzner 2005).

Maximum Sustainable Yield has historically been considered a target for global fisheries yields. Recent science, however, has argued that it would be more effective as a limit, and would hopefully help to reduce overfishing. The dictionary definition of "to overfish" is in fact, more considerate of ecosystem issues: "to fish (a body of water) to such a degree as to upset the ecological balance or cause depletion of living creatures" (Hirschfield 2005). The balance of inter-related factors in an ecosystem is hugely important to maintain for the health of the system as a whole. Ecosystems are not meant to be "preserved". They are active systems that operate under complex pressures of resistance, resilience, and disturbance. Conservation of this natural balance however, is vital to ecosystem function and the services they provide.

It is hoped that EAF will provide management with much needed information about ecosystem dynamics. Consequently, EAF should consider current problems resulting from MSY-based species management: fishing targets of 50-70% below unfished biomass may be insufficient to maintain the health of slow-growing or long-lived species; mature female fish are equally important to the population and its viability, regardless of size or age; heavy fishing of fast-growing, hyper-productive species may ravage the food supply for higher level species (Hirschfield 2005).

Opposition of MSY as a mortality or biomass standard has had difficulty determining an acceptable alternative. Management struggles to determine the appropriate levels at which to set fishing rates in order to attain optimum yields without exceeding ecosystem capacities. What is the right level of unfished biomass to maximize fishing takes without causing stock or ecosystem collapse? Science has begun to promote the precautionary approach (Figure A2): if only one species is considered, an acceptable target level may be 50% of unfished biomass. If, however, predator-prey and competitor interactions are considered, then 100% unfished would be ideal. Fisheries targets are therefore set halfway between these "extremes", 75% of unfished biomass considering the addition of human influences to predatory interactions. This is in contrast to the original precautionary recommendation that fishing rates should be set at 75% of the fishing rate to achieve optimum yield. Conservationists support this more reserved approach, until we improve our understanding of fisheries dynamics (Hirschfield 2005).

Solving the problem of overfishing is not as simple as shifting scientific recommendations from single species to ecosystem benchmarks. Rather, it requires navigating political circles and to ensure that conservative policy and decision-makers do not ignore scientific counsel. Management is subject to a complex web of influences. Managers are often unwilling to reduce catch limits below maximum sustainable yield due to the political ramifications resulting from a short-term decrease in catches. Long-term benefits to the fishery and the ecosystem are difficult to effectively promote in the face of current economic gain. Ultimately, the public, including fishermen and conservationists, will have to decide what level of fishing is "acceptable" (Hirschfield 2005).

Habitat protection is a major focus of the ecosystem-based approach to fisheries management. Habitat refers to the environment in which an organism normally lives or occurs within an ecological community. Protection of habitat areas has been considered primarily for the purpose of conserving commercially and recreationally valuable species. Conservationists, however, seek to have all organisms valued intrinsically, and preserved in their own right, regardless of obvious economic value. The concept of habitat protection within management manifests itself in closed areas, either entirely, or to particular gear types and fishing methods (i.e. trawling). Habitat protection can be furthered by preventing the expansion of destructive fishing practices into unfished areas, and by closing areas containing vulnerable biological communities. Ecosystem-based management seeks to shift to a protective focus, guarding species against fishing impacts unless they are proven not to be adverse (Hirschfield 2005).

The adoption of ecosystem-based management is evolving with increased interest in the effects of bycatch, habitat interactions with fishing methods and energy exploration (marine). Although there may be insufficient information to be certain about the effects of policy choices, knowledge is extensive enough to qualitatively identify likely interactions amongst species and the directionality of human actions with respect to ecological, social, and economic impacts. As scientific information and public awareness expand, management seeks to adapt and encompass these issues more explicitly. There are local, regional, and international examples where EAM principles have been successfully implemented. One such example is the Convention for the Conservation of Antarctic Marine Living Resources, an international consensus to protect significant predator-prey species and their interactions (i.e. krill). On a national level, the US National Environmental Policy Act (NEPA) requires that proposed management actions include evaluations of potential additive ecological and social effects in ecosystems (Murawski 2005). Extensive monitoring and continued research is, however, necessary to verify current ecosystem-based management policies, and to respond and adapt to changes in the environment and our interaction with it.

It is relatively straightforward to establish management standards for conservation and exploitation on a species by species basis (i.e. population size and maximum harvest rates). Transitioning to ecosystem-based benchmarks is much more complicated. For marine systems, ecosystem health indices have many more dimensions than species-based standards. Water quality, productivity of lower trophic levels, trophic level interactions, and other services are considered in ecosystem-based assessments. Which indicators are most appropriate depends on the social priorities and practical feasibilities, or in other words, is context specific (Murawski 2005).

Complex models can be used to quantify risks of management and policy alternatives, but are not always necessary if simple qualitative models of ecosystem function (i.e. key species distributions, “who eats whom”) provide sufficient guidance of potential outcomes for management decisions. This can be especially significant when qualitative considerations are better than an absence of any consideration for the effects of management actions on habitat and species interactions. Certain alternatives, however, are obviously damaging to ecosystem health and the services that it provides, without requiring a detailed understanding of the effects (i.e. overfishing) (Murawski 2005).

The appropriate scale of ecosystem-based management is dependent upon the set of problems being addressed. Certain marine ecosystem issues (i.e. pollution) require focus on specific bays or harbors, whereas, others may apply over a larger scale (i.e. species spatial distribution). These scales, however, are nested in progressively larger scales up to the global level. Some argue that ecosystem-based management should progress "downscale" to allow management at the local level. However, the number of large-scale interactions acting within an ecosystem suggests that a cooperative management system is needed, incorporating adjacent local ecosystems into the larger marine ecosystem (i.e. entire fishery) as a whole. The larger perspective actually decreases the amount of policy elements necessary for management as opposed to the local level focus (Murawski 2005).

In 2006, NOAA scientists developed and implemented ecosystem-based modeling to evaluate living marine resources. These assessments and predictions are key to reaching NOAA's goal of ecosystem-based management practices. The first of these assessments centered on the Bering Sea, Gulf of Alaska, and the Gulf of Maine/Georges Bank/Mid Atlantic Bight ecosystems. Future assessments will include sub-regions of the California Current, Pacific Islands, South Atlantic, Gulf of Mexico, Caribbean, and Antarctica Regional Marine Areas. NOAA has sought to create a guide for ecosystem-based management, a framework that supports the incorporation of ecosystem principles into the management of fisheries resources (NOAA 2006).

e. Policy –

The eight Ecosystem Principles were designed to achieve specific goals through ecosystem-based management policies. The following six policies consider the recuperative ability of ecosystems, uncertainty about them, and anthropogenic interactions within ecosystems.

1. **Change the burden of proof.**

Humans are a major force operating in all ecosystems. Current management perspectives are beginning to shift from restricting fishing actions only after adverse impacts have arisen, to permitting only those practices that operate without producing undesirable effects (Fluharty and Cyr 2001). That is, applying our understanding that marine fisheries are in fact, finite resources, and that without careful management, fisheries stocks will progress to states of overfishing and collapse. More and more, authors and experts agree that the fishing industry should be responsible for a large part of providing the information and support necessary to manage fisheries sustainably. Also, future fishing should be allowed only after the ecosystem risks have been considered and provided for in regulation. Current fishing should not be expanded for target, or "under-utilized" species when ecosystem effects are relatively unknown (EPAP 1999).

2. **Apply the precautionary approach.**

Uncertainty and risk are unavoidable because of the complexity of ecosystems by nature. Scientists and fishery managers have concluded that many current problems in fisheries (i.e. increasing number of overfished species) are the result of liberal, risk-prone management decisions. The precautionary approach promotes risk-averse decision-making (i.e. err in favor of conservation), and behaviors that reduce risk (EPAP 1999).

3. **Purchase "insurance" against unexpected, undesirable ecosystem impacts.**

Insurance is a common method of guarding against potential impacts of the unexpected, and has been proposed as a tool for ecosystem management. Requiring the purchase of insurance may be an incentive for fisheries to avoid risky practices to reduce costs. Even with the precautionary approach, however, there is still a chance of adverse impacts on ecosystems. Marine reserves and other forms of "insurance" can help to mollify these effects. By protecting certain areas from exploitation, a baseline is established to assess natural variation in an ecosystem and indemnify a certain level of future productivity and sustainability. Other insurance measures include environmental bonds and a detection system to respond to adverse impacts within an ecosystem (EPAP 1999).

4. **Learn from management experiences.**

Management and policy actions are experiments, based on our knowledge and expectations of ecosystem responses. Close monitoring is required to determine to how well founded our expectations may or may not be (Fluharty and Cyr 2001). Sustainable management must be adaptive, in order to effectively conserve the complex systems they seek to sustain. The willingness to learn from past mistakes, to respond with innovative alternatives, and institutional capabilities are critical to the success of adaptive management policies (EPAP 1999).

5. **Make local incentives compatible with global goals.**

There is a lack of consistency in local incentives and international goals. Aligning local motivations with national and international social goals is one of the most effective methods of altering human behavior. It complex, however, and must be done within the scope of culturally and socially accepted methods (Fluharty and Cyr 2001).

6. **Promote participation, fairness, and equity in policy and management**.

Ecosystem-based management requires the participation and support of multiple interests. Policies that consider and promote the participation of all constituencies (including future generations), in both their development and implementation, are more likely to be fair and impartial (Fluharty and Cyr 2001).

There is a global cooperation amongst scientists, and International marine science groups are thriving. Both will hopefully serve to further understanding of emerging marine science challenges and the corresponding management efforts. Policy efforts will also require extensive cooperation of departments, coastal communities, industry, fisheries regions and science. Socially or economically expensive policies may be abandoned without scientific support. Likewise, some marine fisheries policies may prove ineffective without scientific guidance. Science and policy alike consult experts and institutions, but rarely the same ones. Marine science is international in its reach, but within areas of expertise. Policy-makers, however, seek information across governance systems (i.e. local, regional, national), but remain primarily within a national context (with the exception of economic issues, i.e. trade). Political departments and scientists rarely discuss the trade and economic aspects of marine issues (Watson-Wright 2005).

There is a serious competition of interests in the formation of marine and fisheries policy. Conservationists are battling the intensive exploitation of marine ecosystems by the fishing industry. There is a question as to how much concern the industry has for ecosystem health, biodiversity, endemic species, etc. There are moral, ethical, social, economic and political factors to consider in addition to the scientific. Scientists, however, are often considered to be ignorant or naïve with respect to the formation and implementation of policy issues (Browman and Stergiou 2005). Dunbar stated: “There is a belief that the body scientific cannot judge these important matters, that scientists live in a confounded ‘ivory tower’ dreaming of test tubes, high theory or the genitalia of insects, and that it takes lawyers, businessmen or perhaps emancipated economists to come down to practicalities. This is a myth fomented and perpetuated by those same lawyers, businessmen, etc. It is poppycock; no one can know better than scientists how to get the best results and the most mileage out of science. A scientist looking for advice on the stock market goes to the relevant professional, and rightly expects lawyers and politicians to come to him for guidance in science" (Dunbar 1987).

Some ideas are slow to gain support and others are difficult to document enough to guide management. Rather scientific support tends to accumulate over time. For example, since the early years of fisheries science, it has been known that understanding predator-prey interactions is important to effective management. The scientific time scale, however, necessary to collect the supporting data and models is at least a decade. Scientific proposals are rarely formatted to be useful in advising policy. Incomplete scientific knowledge (i.e. early research) is not effective due to the lack of information about risks and consequences of policy decisions (Rice 2005).

As the scientific support for ecosystem-based management improves, there are still two unresolved issues between science and policy:

(1) The amount of scientific uncertainty increases with ecosystem-level considerations. As model complexity increases, so does the uncertainty associated with it. True uncertainty associated with policy decisions includes model uncertainty (i.e. unknown species interactions and population levels) as well as uncertainty from an unpredictable future. Consequently policy makers and managers are not excited about the change. Scientists will need time to learn to rephrase their terminology for non-scientists and in the meantime both parties will be frustrated.

(2) In the face of uncertainty, scientists more interested in policy impacts gain the spotlight (regardless of the soundness of their science). These advocates deemphasize the uncertainty, guiding policy to seemingly simple solutions to complex issues. Enthusiasm is likely to underemphasize the costs of transition to an ecosystem-based approach to fisheries management, in favor of accelerating change. Science has been given rare, privileged access to policy processes because it seeks to be non-biased and objective. Scientists can be openly opinionated about their beliefs, but it must maintain its objectivity and basis in research processes and results or it loses its inherent value (Rice 2005).

Science faces a new problem. Once policy commits, policy makers and managers will expect sound guidance. Practical science advisors are aware that much more research and monitoring is required for the full implementation of an ecosystem approach. Experienced scientists stress that implementation of this approach must be done in phases, a comfort to managers, as it gives them time to adapt. As scientific understanding and management experience grow and constituencies adapt to change, assessments and advice can examine environmental impacts on stock dynamics. Science can expand the identification and characterization functional relationships of environmental factors and predator-prey interactions to better consider for the ecosystem effects of fishing (Rice

2005). Decision-makers must determine which ecosystem considerations are mandatory (must be addressed operationally), and which, if any, could be optional within an ecosystem-based approach to fisheries. Progress is slow due to the complexity of considerations. While all parties seek to make timely progress, they are also concerned with understanding the connotations of an ecosystem approach to management to prepare for interactions with their stakeholders (Watson-Wright 2005).

Policy addressing governance changes (i.e. integrated management) must receive as much attention as ecological procedures. Governance issues allow for an adaptive approach based in expanding scientific knowledge. There is, however, a question of the appropriate rate at which to implement incremental policy advancements. If policy is implemented too quickly, it will face strong opposition. Existing knowledge has been implemented slow enough that environmental damage has been allowed to continue. The question is how to ensure that the ecosystem-based fisheries management is implemented quickly enough to show tangible results in marine ecosystem health, but not so quickly as to inhibit social adaptation and generate opposition that could potential stall or squelch changes completely (Rice 2005).

The current advisory situation is difficult with respect to ecosystem-based management of fisheries. The basic principle is to reduce any activity that may damage the health and sustainability of the ecosystem. Though it finds widespread support, the sound science is not yet extensive enough to fully advise an ecosystem-based policy framework, although scientists can extrapolate trends from the current knowledge base. Most apprehension amongst experienced policy makers concerns the fact that although hard information may not be required to change policy, it will be answering difficult questions about the implementation of new policies. Overemphasizing scientific basis and the opportunity, but underselling transition costs creates problems when, as a result, policy experts are led to believe that potential policy changes are based in sound science. The US Commission on Ocean Policy (USCOP) Report and the Pew Ocean Commission Report (POC) reveal that policy makers believe that the scientific basis for a marine ecosystem approach to management is complete (Rice 2005).

Scientific advising in fisheries management from an ecosystem context is difficult for several reasons. The requests are often poorly structured, and advisory bodies cannot provide clear answers to vague questions. Additionally, scientific work is not integrated as well in advisory contexts. Members of an advisory body have different histories, and therefore different perspectives on how to reach solutions result in piecemeal advice that may seem to be inconsistent. These gaps and apparent inconsistencies do not inspire confidence in managers. They also give resource users the opportunity to oppose the basis for new ecosystem-based management actions (Rice 2005).

Management considering advice must become more risk averse in practice. Despite all harvest implications of an ecosystem approach to fisheries not currently being known or understood, there will still be a need to harvest less to account for target species interactions within the ecosystem, and intervals of decreased environmental productivity. Uncertainty has increased in assessments and scientific advice. If management does not become more risk-averse, this greater uncertainty could result in more aggressive harvesting instead of more conservative. Many fisheries management failures (traditionally single-species) have failed from risk prone management policies. If this pattern continues, an ecosystem approach to fisheries management will only further reduce the health and sustainability of marine ecosystems (Rice 2005). In light of this risk, society cannot afford to fail in our management of marine ecosystems. Science is consistently demonstrating the increasingly degraded state of these systems, and highlights the potential impacts on the world's future food supplies. The science, however, is expected to aid the management of these global food sources in the face of increasingly overfished stocks (Tudela and Short 2005).

Ecosystem-based management considers the complexity of exploited marine systems and requires the maintenance of ecologically viable populations responsible for structural and functional factors that favor ecosystem elasticity and the provision of ecosystem services. The precautionary principle and adaptive management schemes are critical features of this approach to management. Ecosystem-based reference levels should be developed based on indicators of ecosystem structure and function, and used to establish ecosystem-wide thresholds for overfishing. The development of these ecosystem-based indicators is key to the practical application of the ecosystem-based approach. It is the first step to defining reference levels for the marine ecosystem, a critical factor in fisheries management, and potentially essential to the success of a complete transition to a new management perspective (Tudela and Short 2005).

In 2003, the FAO Committee on Fisheries (COFI) presented the FAO Guidelines on the Ecosystem Approach to Fisheries. These guidelines devote significant attention to ecosystem manipulations such as the creation of artificial habitat, restock, stock enhancement, culling, and intentional introductions; considering these factors appropriate factors in an ecosystem approach to fisheries. The FAO guidelines supply a framework to consider ecosystem-based indicators. The indicator should be an ecosystem property modified (or presumed to be modified) by the fishery, such that there is a controllable impact on fisheries for which target levels of change can be recognized. If setting target reference points is not appropriate, than a limit should be set. Scientific uncertainty should not prevent the identification and consideration of important indicators and reference points. These guidelines do, however, lack concretion and are of little practical use. Although this limitation has been recognized, little progress has been made towards making the ecosystem-based management plan operational (Tudela and Short 2005).

Our understanding of the complex nature of exploited fisheries systems should reduce our expectations of science, and its ability to accurately predict quantitative measures. Studies have provided excessive scientific evidence of the "fisheries footprint" on marine ecosystems and the significant role of overfishing in the degradation of ecosystem structure and functions. Even so, there is a large disconnect between traditional fisheries management and more recent ecosystem approaches to management. A natural development of mature ecosystem-based fisheries management systems will be inhibited by several factors: (1) there is a lack of confidence that this new management approach will translate into effective and realistic tools; (2) there will be a natural resistance to change; (3) fisheries scientists, ecologists and other academics are competing for research areas and funding; and (4) political proposals (Tudela and Short 2005).

Current catch levels exceed estimated maximum sustainable levels according to primary assessments with ecosystem-based overfishing criteria in coastal and shelf areas. An ecosystem-based approach to management is likely to impose harsher restrictions on total allowable catch levels. This will be met with significant resistance in political and industrial sectors. Substantial implementation of an ecosystem-based approach to fisheries management will require significant political momentum. Otherwise it will be resigned to aesthetic improvements in the form of limited reduction of bycatch and small marine reserves strewn about the landscape. Experts hypothesize that "common sense" elements of fisheries management such as constituent involvement and adaptive management will be key elements of the new ecosystem-based approach. Ecosystem-based fisheries management can be operationalized on a fishery, marine ecosystem, or ocean scale (Tudela and Short 2005).

Several EBM tools are gaining popular approval, despite the lack of consensus on an operational structure for marine ecosystem-based management. Technical improvements are beginning to increase gear discrimination in many fisheries. Marine protected areas (MPAs) are growing in favor as tools for rebuilding ecosystems and benefiting fisheries. Globally, several countries are seeking an oceans policy approach founded on an ecological perspective of marine management concerns. The challenge for management systems is to shift to an understanding of complex and finite marine resources and to decrease what we harvest from ocean ecosystems (Tudela and Short 2005). Successfully making this transition will require a collective effort from managers, fishers, consumers, etc.

f. Fisheries Constituents –

More and more, marine ecosystems are viewed as an integral part of our natural heritage. The general expectation is that protection of certain marine areas (i.e. reef systems) and species (i.e. endangered) should be increased. Consequently both public and environmental interests expect ecosystem-based management approaches to limit or restrict these fishing effects. The general public expects to reap the benefits of safe, quality seafood at affordable rates, while continually demanding more of fish products. Sustainably harvested, “feel good” eco-products are emerging and beginning to influence the tracking of fish and fish products from “deck to dish.” Fisheries biologists tend to focus on developing scientific information to further knowledge our complex marine ecosystems. They aim to understand ecosystem processes, patterns, and thresholds to aid managers and to maintain viable fisheries. This perspective will help to further research opportunities and face challenges within marine science (Valdimarsson and Metzner 2005).

Fishermen have long been hyped as the last surviving rugged free spirits, fighting to conquer the sea. Over the past few decades, this image has begun to fade into one of marine pillagers, plundering its resources for the sake of private gain. This image is not completely unfounded. Increasing restrictions and operation costs create pressure to forego future benefits for meeting current expenses and consumer demands. Time and area restrictions on fisheries create additional pressures (Valdimarsson and Metzner 2005). Tolerance of profitability, regulatory conditions, risk and uncertainty are real stresses on fishermen, their communities, and management systems. However, human systems are quite resistant to change (EPAP 1999). Fishermen need incentives to fish responsibly (i.e. environmentally) and provide up to date data on each fishing voyage (i.e. for fishery specific research). They need an operating environment that does not promote competition or incentives to cheat to maximize profits with little concern for the environment (Valdimarsson and Metzner 2005).

The fish products industry seeks to continually generate profit and employment. Successful ecosystem-based fisheries management would alleviate certain commercial production issues such as having a consistent supply of raw materials available, obtained at the lowest possible cost. Industries also have to satisfy shareholders and customers. While regulated by political organizations, market forces shape industry actions. Stakeholders are calling for a focus on animal welfare and environmentally ethical behavior. Corporations are responding by conforming to environmental standards and providing social and environmental reports. Ultimately, if consumers want sustainably managed fisheries products, industrialists will work to provide products from environmentally “friendly” fisheries (Valdimarsson and Metzner 2005).

Many countries are tending towards a focus on fisheries and aquaculture as a source of employment, income, and food. Traditionally, fisheries have not occupied a major economic role, but export profits are globally on the rise. Local small-scale fisheries are often left open as a form of social security for the weakest members of society, in spite of risks of overfishing and environmental degradation. Fishing issues, however are combined with other coastal industries including tourism, transportation, and recreation and consumer concern for safe, quality fish products. Together these create an immense political pressure to balance consumer, commercial, environmental, and policy needs. These influences increase stress for political support for ecosystem-based approaches, but decrease their ability to withstand demands to alter marine ecosystems at a local level. As a result, what is often considered a lack of political motivation to improve fisheries legal and institutional frameworks may in fact reflect the difficulty of such a complex task (Valdimarsson and Metzner 2005).

Fisheries managers often implement conservation measures based on their environmental benefits, without necessarily considering the economic impacts of their actions on commercial fishing operations. Management seeks to understand and combine commercial fishing, financial, and business operations. Simple administrative control does not align conservation and commerce issues, but results in conflicts amongst fishermen, managers, and other stakeholders; decreased productivity; and weakened sustainability. The best management compromises between conservation and commercial issues occur where there is significant representation by economists in government and fisheries agencies (Valdimarsson and Metzner 2005).

Ecosystems are too complicated to manage all processes, interactions, and functions. However, we are becoming increasingly efficient at managing human activities through incentive-based frameworks. These frameworks permit the effective management of anthropogenic influences on marine ecosystems. Management does need to comprehend and utilize stakeholder perspectives and expectations, especially for those involved in fisheries (Table A3). Ideally, management proposals can alter the fishing process from hunting to a commercially friendly enterprise, with incentives (i.e. user rights) for increasing the use of environmental objectives in fisheries. An ecosystem-based approach to management alone will not guarantee socially responsible but sustainable fishing. It is good business as it ultimately seeks to align consumer, industrial, economic, and conservation interests (Valdimarsson and Metzner 2005).

IV. Method of Analysis:

Current literature and legislation were reviewed as a basis for a qualitative assessment of current federal fisheries status. Research included policy and management goals (health and sustainability) for adaptation to environmental needs while placating commercial and industrial interests. This information was considered to determine current progress in fisheries management considering Sustainable Fisheries Act implementation, a shift from single-species to ecosystem-based management of fisheries, and the reauthorization of Magnuson-Stevens Fishery Conservation and Management Act. Based on this information, recommendations were made relative to potential measures to facilitate the implementation of legislation in management.

V. Results:

Federal fisheries management is currently insufficient to effectively conserve the health and sustainability of US fisheries. Under single-species or target species focused management, fisheries stocks continue to decline or show negligible improvement. There are many complex interests involved that are difficult for management to balance. More research is needed on the ecosystem effects of fishing and ecosystem dynamics and trends. Monitoring is a key to learning from experience and determining if precautionary approaches are truly “healthy” and risk-averse. We have the framework for applying ecosystem approaches to fisheries management, but there is no Congressional mandate to necessitate its use.

VI. Management Implications:

An ecosystem approach to management is not the same as a Marine Protected Area (MPA). It does not even have to include an MPA to be a successful form of management. Marine protected areas are tools for fishery and ecosystem management. They vary from short term and long-term prohibitions on gear and fishing activities to “no take” reserves and management areas where nearly all human impacts are restricted or forbidden. While ideal on many levels the social and environmental benefits should be weighed carefully as most MPAs are costly for constituencies. Technology has improved to include vessel tracking systems and other boundary enforcement techniques. Other management tools include prohibitions of specific gear or harvest actions, fishing seasons for particular species, and input (i.e. number of licensed vessels) and output (harvest quotas) controls on the system (Murawski 2005).

Regional ecosystem-based management programs are popping up in many of the world’s large marine ecosystems (LMEs). Large marine ecosystems (LMEs) are used as a way of defining natural marine biodiversity, productivity, and hydrography boundaries in coastal regions. The majority of coastal states bordering LMEs, as well as several international marine conservation and environmental organizations support the concept. These efforts are cooperative, as many LME regions cross multiple jurisdictional boundaries. Many are emerging in developing countries, collectively improving their scientific and management abilities. This growth is supported by the combined financial support of 121 developing and developed countries. Over $650 million dollars are invested in 17 Large Marine Ecosystem projects globally (planned and in progress). The US and other countries have provided the technical expertise to help create and enact these programs. One example is the Gulf of Guinea LME (west Africa) involving: Benin, Cameroon, Cote d'Ivoire, Ghana, Nigeria, and Togo. LME projects seek to integrate marine resource management and restoration activities in a cooperative ecosystem-based project. Similarly, for the US, marine ecosystems and their resources (fisheries) cross political boundaries amongst states, and in some cases countries (i.e. Canada in the North Atlantic region). Any cooperative agreement requires methods to assess and allocate resources for effective adaptive management (Murawski 2005). Ideally, a balance can be reached between conservation and utilization of resources.

Understanding the nature of marine ecosystems is important to setting realistic management goals, to avoid delays in reversing current trends. It will be important to expand precautionary ecosystem-based research (i.e. data-poor) in order to develop management frameworks. Studies should also focus on the proper structure and utilization of marine reserves as a tool for ecosystem-based fisheries management. Management from an ecosystem-based perspective faces the challenge of understanding and integrating knowledge of non-target species and ecosystem function for dynamic marine systems. This will require a transition to multidisciplinary management, incorporating experts outside of traditional fisheries science, to align fisheries research and marine ecology goals (i.e. economists, ecologists, etc) (Tudela and Short 2005).

Scientists have a tendency to remain within their areas of expertise. Few ecologists and oceanographers attend meetings for fish stock assessments (Rice 2005). Fisheries managers and scientists, for example, do not often collaborate with coastal development experts or water quality scientists. Developing a complete picture of marine ecosystems will require the combined knowledge of a variety of experts in marine related areas of research. Integrated scientific and political communities will aid efforts to understand and manage the effects of human activities in marine ecosystems (Rosenburg and McLeod 2005). There are a few examples of some progress in science-policy integration. ICES has created the Working Group on Regional Ecosystem Description and the Regional Ecosystem Group for the North Sea, composed of experts in a variety of disciplines. However, many cooperative research projects devolve into subject-focused subprojects, there is much room for improvement to fully integrate science and policy efforts (Rice 2005).

Despite the challenge of implementing an ecosystem-based approach to fisheries management, delaying action for the sake of better information may mean policy changes will never be made.

There is a pressing need to understand the cumulative effects of human impacts on the marine ecosystem. This is a complicated necessity, requiring an analysis of the cumulative impacts of key activities on a variety of ecosystem services. There are currently no functional measurement systems for fundamental ecosystems attributes (i.e. biodiversity) on scales broad enough to aid management's understanding of the provision of marine ecosystem services. Incorporating biological aspects in marine ecosystem evaluations complicates efforts formerly focused only on physical and chemical factors. Most research is temporally and spatially to narrow to be of use to broader management initiatives (i.e. larger than local). These measurement systems will be vital to our understanding marine ecosystem function and management effectiveness. Extensive research and model development will support policy advances. Marine ecosystems may continually degrade and shift in nature, to the point that ecosystem adaptations are irreversible if policy and management changes are not made in time (Rosenburg and McLeod 2005).

Determining an appropriate baseline for comparing degraded ecosystems and their services is highly important, but difficult. Baselines should not be set based on recent observations of marine ecosystems that are already degraded. Key commercial species show overwhelming levels of depletion, despite a variety of research methods. North Atlantic Cod estimates, for example put current biomass at less than five percent of historical estimates (150 years ago). While fishery management policies do include biomass-rebuilding goals, they are based on relatively recent (a few decades at most) biomass and population dynamics. In other words, management reference points are severely degraded themselves, inaccurately representing the potential high-value biomass, species, and services that may be present in a restored marine ecosystem. Developing a complete picture of healthy, sustainable marine ecosystems will require an interdisciplinary consideration further into their past (Rosenburg and McLeod 2005).

Although the amount of uncertainty in ecosystem approaches to marine and fisheries management is controversial, it is essential to remember we do understand some factors well because of an overwhelming amount of evidence. For example, though we are unsure of the accuracy of our population estimates and stock assessments, we are positive that overfishing is occurring in many stocks. Thus, despite uncertainty policy and management must account for marine dynamics and ecosystem interactions that are known to be major problems (though they may be difficult to measure). For example, if habitat impacts inhibit stock rebuilding efforts, then an ecosystem approach to management would seek to minimize habitat impacts in the areas the target species most utilizes. Detailed studies are not necessary to identify the presence of an obvious problem and can supplement management decisions after actions have been taken to avoid apparent adverse influences (Rosenburg and McLeod 2005).

One approach to avoiding the collapse of exploited ecosystems (i.e. fisheries) is to preserve functional population levels of a variety of species (biodiversity) and functionality of the species themselves. This approach also favors the preservation of species that are essential for the maintenance of ecosystem function and structure, but difficult to identify in evolving systems (i.e. keystone species). Conserving biodiversity, therefore, is one of the first priorities for precautionary ecosystem-based fisheries management. Blending conservation and fisheries management will also confront issues of overfishing as a driver of ecosystem change, and the difficulty of developing a “stable” reference baseline for ecosystem status. Both conservation and fisheries management seek to rebuild overexploited marine ecosystems to a structurally and functionally “healthy” systems capable of providing maximum conservation of biodiversity and ecosystem services to society (i.e. fisheries production) (Tudela and Short 2005).

Ecosystem-based management can quickly become bogged down in debates over cultural, jurisdictional, and ecosystem boundary interactions and delineations. Marine ecosystem management may be most practical at relatively large regional spatial scales. Boundaries will have to be designated with an understanding that they are not perfectly static, as some processes occur at larger and smaller spatial scales. The most effective approach to marine ecosystem and fisheries management therefore should include multiple interconnected scales of local, regional, and ecosystem-wide management efforts (Rosenburg and McLeod 2005).

Human interactions with marine ecosystems (i.e. fisheries) are managed under separate agencies and authorities. In the US, the National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS) are predominantly responsible for fisheries management under the Magnuson-Stevens Fisheries Conservation and Management Act. The Environmental Protections Agency (EPA) is responsible for water quality management under the Clean Water Act. State and local programs are in charge of coastal development issues, primarily guided by the Coastal Zone Management Act. However, no one agency is responsible for ensuring cohesion amongst management efforts, or overall impacts and interactions of human activities with ecosystem dynamics. While there need not be a single agency responsible, cooperation between existing agencies is key to the development of joint, ecosystem-based solutions. There are significant barriers to interagency cooperation, including budget and resource allocations. While it is still hugely important to manage single sector effects of human impacts, the authority and legal requirement to work across political boundaries is also needed to conserve the collective services marine ecosystems provide (Rosenburg and McLeod 2005).

The integration of conservation into ecosystem-based management frameworks implies new responsibilities for conservation organizations. Their challenge is to contribute knowledge based on their experience in conservation, multidisciplinary work, stakeholder networks, academics, and public awareness. Educating the public as to the current levels of overfishing and real ecological limits to fish production and other ecosystem services. Conservation groups are fully aware of the potential opportunities associated with ecosystem-based management of marine resources. They are fully involved in promoting and integrating ecosystem-based policies (Tudela and Short 2005).

Conservationists are hopeful that ecosystem approaches to fisheries management will finally allow for the implementation of precautionary principles. There is some concern that fisheries supporters will delay action until science supplies the data necessary to augment complex ecosystem models. Admittedly, there is a generous lack of understanding of community and ecosystem dynamics for marine systems. Ocean research is extremely expensive and difficult, so ignorance must not prevent action on the part of management. Certain harmful effects are known, though without detail, and should be managed appropriately. For example, we know an increasing number of stocks are overfished. Therefore fishing efforts should be reduced even though we are uncertain as to how much. By implementing caution, conservationists are hopeful that management will increasingly become based on ecosystem indicators to determine overall health of the marine environment, not just individual species assessments (Hirschfield 2005).

Ecosystem-based fisheries management assures the thorough consideration of cumulative human impacts on ecosystem processes. Cumulative landings and bycatch, for example, would be of significant importance as measures of the maximum sustainable extraction levels for a fishery. Together with ecosystem models, this data can also be used to provide information on the amount of primary and secondary production extracted (useful for determining capture limits). If “every fish” is accounted for then cumulative impacts can be addressed. In the US, environmental impact statements (EISs) are being used more frequently to supplement fisheries management. Many important conservation measures were made as a result of environmental impact assessments that considered alternative solutions to management issues. One example is the protection of over 60,000 km2 fishable habitat in the Aleutian Islands, as a bottom trawl-free zone (Hirschfield 2005).

Ecosystem-based fisheries management will come at the cost of fewer fisheries jobs and increased production costs. The duration and extent of these socio-economic effects is uncertain. However, scientists have long since advised that the short-term struggles will be worth the long-term ecological benefits in improved yields and ecosystem services. Policy makers seek to be responsible in the face of uncertainty, and their willingness to take risks is directly related to the supposed amount of uncertainty associated with management decisions for marine ecosystems. The science of ecosystem effects is much less developed than that of single-species. Uncertainty therefore remains a steady impediment to effective change in policy and management actions

(Watson-Wright 2005).

Reversing the burden of proof is a method of counteracting excess uncertainty, by specifying that potentially harmful activities cannot be permitted unless it is shown that harm will not jeopardize the recovery of protected species. This concept is an extension of the precautionary approach, which is included in accords from the World Summit on Sustainable Development, the United Nations (UN) Conference on Environment and Development (Watson-Wright 2005), the UN Agreement for Straddling Stocks and Highly Migratory Species, and the Food and Agriculture Organization of the United Nations (FAO) Code of Conduct for Responsible Fisheries. The United States signed both the straddling stocks agreement and the FAO code of conduct (Fluharty and Cyr 2001). In the US, the National Oceanic and Atmospheric Administration's discussion paper on ecosystem-based fisheries management proposes to extend this reversal of proof to ecosystem-based policies and management. It may be the only practical method of dealing with major scientific uncertainties, but it will be difficult to gain support from stakeholders and other government groups who will bear the larger short-term costs from ecosystem-based fisheries management (Watson-Wright 2005).

The reversal of burden of proof is not a new theory, but historically has been used for drug marketing and the protection of human health. From an environmental perspective, however, reversing the burden of proof is very expensive for industries and consumer groups who are not accustomed to bearing the costs. Fisheries industry is still composed of many small independent operators who tend to feel they have inadequate financial resources (i.e. compared to pharmaceutical companies) for large short-term investments. Many coastal communities are economically and culturally based in fisheries, and are often protected by the government for their historical and cultural value, and for the economic viability of these small communities (Watson-Wright 2005).

Most fishery managers understand approximate levels of fishing effort necessary for sustainability, but are pressured by politics to exceed them for short-term economic benefits. Setting conservative maximum sustainable yield (MSY) and optimum yield (OY) goals, and abiding by them is crucial to ecosystem-based fisheries management. Fishery management plans (FMPs) for single species and species complexes should remain fundamental parts of future fisheries management. However, these measures alone are not enough for an ecosystem-based perspective. The Ecosystem Principles Advisory Panel (EPAP) divided its recommendations to Congress into two parts: that a fisheries ecosystem plan (FEP) be developed by each regional council to guide management and that FEP concepts should be implemented immediately under current management (Fluharty and Cyr 2001).

The success of an ecosystem approach to fisheries management is dependent upon full implementation of current measures (i.e. essential fish habitat requirements), and it is believed that legislation will be required to impose measures such as the fisheries ecosystem plan (FEP). Fishery Ecosystem Plans are intended to: (1) provide regional councils with a clear understanding of basic physical, biological, and human-related factors related to fishery management of marine ecosystems; (2) guide the use of information in FMPs; and (3) set policies for the advance and execution of management actions. They serve as umbrella documents, providing information to management on marine ecosystem structure and function, so that managers may better understand the effects of their decisions of marine ecosystems and fisheries (EPAP 1999). The Fishery Ecosystem Plan should serve as measuring stick for Fishery Management Plans to determine if their management approach incorporates ecosystem-focused principles, goals, and policies effectively. FEPs, should include required management measures that extend across FMP jurisdictions, and provide context for council actions regarding marine resources, managed or not (Fluharty and Cyr 2001). The panel recommends that interim actions be taken by the Secretary of Commerce to develop model FEPs and promote voluntary participation until legislative processes have time to pass proposed regulations. Ecosystem-based management of fisheries will not only promote more sustainable fisheries and marine ecosystems, but will also improve the economic viability of coastal communities (EPAP 1999).

Regional Fisheries Management Councils should develop a Fishery Ecosystem Plan (FEP) for each major ecosystem within their jurisdiction. The North Pacific Fishery Management Council, for example, would have one FEP for the Bering Sea and Aleutian Islands area and another for the Gulf of Alaska. In instances of overlapping ecosystem boundaries, or species migration, councils would develop a collaborative FEP. If ecosystems should cross national boundaries, then international agreements should be sought to utilize an ecosystem approach to marine management. The primary purpose of these ecosystem plans is to stipulate how to manage fisheries from an ecosystem point of view, with significance placed on structure and content to develop realistic, but significant plans. The EPAP highlighted the National Marine Fisheries Service as the appropriate agency to develop guidelines for FEPs (the specifics being beyond the panel’s mandate). The Ecosystem Principles Advisory Panel did, however, identify specific actions to be taken by fisheries councils when guidelines are prepared (Fluharty and Cyr 2001). Each Fishery Ecosystem Plan (FEP) should:

(1) Define the geographic boundary of the ecosystem(s) within their jurisdiction. Ecosystem characterization of biological, chemical, and physical dynamics should be included in this designation. A variety of factors qualify for consideration: hydrography, bathymetry, productivity,

trophic structure, food web dynamics, and climate influences (on all of these). The amount of transfer across boundaries should be considered for each ecosystem. Councils should “zone” ecosystem areas for alternate uses including marine protected areas, environmentally sensitive areas (i.e. to gear impacts), and known areas of adverse fishing effects (i.e. trophic dynamics).

(2) Conceptually model the food web (especially with respect to target species). The model should include descriptions of predator and prey species at all life-history stages to address harvest effects on predator-prey interrelationships.

(3) Evaluate habitat requirements of the “significant food web,” both plants and animals, at various life-history stages and how they are accounted for in management efforts. Determine essential fish habitat (EFH) at various life stages for both target and non-target species. Develop zone-based management systems using ecosystem information (i.e. habitat). FEPs should consider gear alternatives and the use of habitat refuges (i.e. trawl free zones) to alleviate habitat degradation.

(4) Estimate total removals including reported and unreported landings, bycatch, and contact gear mortality (i.e. not caught). Demonstrate how total removal relates to production and yields, standing biomass, natural mortality and trophic structure. Incorporate this information into food web and stock assessment models. Models aid management decisions by reducing uncertainty, evaluate ecosystem health and more accurately estimating the relative abundance of species affected by target species removal.

(5) Evaluate uncertainty and the inclusion of buffers in conservation and management efforts. Use risk-averse, adaptive management plans to account for uncertainty and variability.

(6) Determine management targets for ecosystem health (i.e. indices). Management should strive to maintain a balanced, interactive, adaptive community with a naturally evolved species composition, diversity, and functionality. Target indices should include explanations of unhealthy states for each ecosystem.

(7) Examine long-term monitoring options for chemical, physical, and biological characteristics of ecosystems and their relative efficacy for management (as measures of change). Monitoring may be particularly useful for comprehending the effects of climate change and marine variability of species abundance for target species and their trophic interactions.

(8) Evaluate ecological and anthropogenic influences affecting fisheries ecosystems, outside of management authority (i.e. regional councils, Department of Commerce). Develop strategies to

address these influences within FMP and FEP goals (Fluharty and Cyr 2001).

Ecosystem Principles Advisory Panel's proposed measures to enact FEPs:

(1) Councils should apply ecosystem principles, goals, and policies in current FMP activities, but especially: fishing effects on predator-prey interrelationships; bycatch and species, community, and ecosystem effects of removal; and alleviating fishing effects on essential fish habitat (EPAP 199). Current implementation of these factors will not only benefit the ecosystem, but will facilitate transition to an ecosystem approach. Congress should develop a direct mandate for ecosystem-based fisheries management.

(2) Train Council members and staff to aid the development and enactment of FEPs. The National Marine Fisheries Service should provide all Council staff with a basic education of ecological principles, as well as providing instructional materials to industry, environmental, and other fisheries-related interests.

(3) The NMFS and fishery councils should regularly perform a process to develop and amend FEP guidelines and ensure that they are practical and adaptive (EPAP 1999).

(4) Develop model FEPs, to facilitate rapid application of the FEP. The NOM Chesapeake Bay office began developing an FEP for the Chesapeake Bay in July 2000 (Fluharty and Cyr 2001).

(5) Ensure development and compliance of FEPs. The Secretary of Commerce should set up an FEP implementation review panel to determine compliance with timelines, and recommended revisions before an FEP becomes policy.

(6) Require FEPs. Congress should mandate full FEP implementation to provide NMFS and Fisheries Councils with legislative responsibility to design and enact Fishery Ecosystem Plans (EPAP 1999).

Three bills were introduced into the House of Representative or Senate in 2000, with provisions to require FEPs for US fisheries under the MSFCMA reauthorization. Senator Snowes' bill is extremely close to the Ecosystem Principles Advisory Panel's recommendations. Representative Gilchrest's bill is similar, but mandates FEPs on a short timeline following passage of the legislation. Senator Kerry's bill revises the recommendations, but with comparable purpose. Congress took no action on any of the measures, but their appearance was significant progress (Fluharty and Cyr 2001).

The Ecosystem Principles Advisory Panel seeks to require and support agencies (i.e. NMFS, NOAA) to research critical themes to provide information support for ecosystem-based fisheries management (and FEPs): (1) establish the ecosystem effects of fishing on target and non-target species, habitat, and entire ecosystems; (2) study marine ecosystem dynamics and trends with the best available technology; and (3) investigate ecosystem approaches to governance. Fishing affects species (both target and non-target), habitat, and likely marine ecosystems themselves. Monitoring can be used to detect, comprehend, and responds to ecosystem changes. Many current fisheries problems are rooted in governance systems that create incentives unaligned with maintaining health and sustainability of ecosystems. Altering governance to provide fishermen and industry with "eco-friendly" is important to the success of an ecosystem approach to fisheries management (EPAP 1999).

VII. Management Recommendations:

While recent legislation and science have made significant progress towards an ecosystem-based approach to fisheries management, implementation will take time. Most fisheries councils are still struggling to comply with requirements under the Sustainable Fisheries Act, much less the recent Magnuson-Stevens reauthorization. Money (or economics) is the ultimate driver behind any industry. Economics, however, can also be the quickest promoter of change. I propose the enactment of several provisions (in no particular order) to promote an integrated system to incentivize fisheries management and aid the implementation of recent legislation and scientific theories.

1. Provide funding for observer programs.

A significant way for conservationists to aid the implementation of recent regulatory provisions is to provide funding for fisheries observer programs. This removes the cost from the industry and decision-makers, while providing an active role for conservation groups. It also benefits environmental efforts by providing more information on bycatch, harvest totals, etc. Scientists could join conservationists to further their own knowledge of fisheries and stock status. There need not be a precise structure for observer programs. Too many fisheries are without any significant number of observers, so at least initially, regular monitoring of total catches would provide annual reports and improve our overall knowledge of individual fisheries and the marine ecosystem itself.

2. Educate the public.

Consumer demands and pressures are drivers of change in any market-based industry. Fisheries are no different. Conservation and management efforts should seek to promote public awareness of fisheries issues. Sustainability labels on fish products for instance, would aid the public's understanding of fishing practices. Labels could rate fishery practices on a scale (i.e. 1-5) from sustainable to unsustainable. Ideally, funding could also be provided to defray the costs of the most sustainable goods, making them competitive and affordable for consumers relative to unsustainable fish products.

3. Reward sustainable fishers and fisheries.

Fisheries committed to the use of eco-friendly gear and fishing practices should be rewarded for their efforts to promote the expansion of sustainable practices throughout fisheries. For instance, the prohibition of destructive gear such as bottom trawls and j-hooks (cause of many non-target species deaths or bycatch) and the use of circle-hooks (i.e. turtle friendly fishing) would be a pro-ecosystem change in fishing practices. Fishing technology often out-competes the reproductive capacity of stocks. Fisheries that take less than the maximum sustainable yield or harvest quotas should be rewarded for their risk-averse actions. Rewards could be monetary (funding to defray the costs of gear, for example), or regulatory (protection of sustainable fisher grounds from other fishermen). Rewards should also be applied to management programs that "successfully" manage sustainably, particularly across political boundaries. For example, a reward might include providing management with extra funding (i.e. from conservation groups) for protecting habitat and promoting integrated ecosystem-based perspectives.

4. Penalize unsustainable fishing practices.

Fisheries and fishermen that practice unsustainable fishing should be penalized to promote change within the industry. Penalties could take a variety of forms. Bycatch, for example, could be penalized by subtracting bycatch totals from harvest quotas (perhaps by a factor of two, for a harsher effect). Monetary penalties (i.e. fines) could be applied for unsustainable practices, such as the use of habitat destructive gear (i.e. bottom trawls), making it more expensive to use unsustainable technology. Enforcement would currently be difficult, but if observer programs are developed, more consistent information will be available. Repeat offenders should lose their fishing licenses at least for some time, if not permanently.

Conservation groups and the public (consumers) can do the most to change the fishing industry and management practices in the midst of a time lag in legal mandates and policy. They can provide monetary or motivational incentives for sustainable fishing practices driving a shift in perspectives within fisheries management and practices: from singles-species, unsustainable practices to the adaptive ecosystem-based cooperative management of marine resources. Ultimately, there is still a need for legal mandates for public education on fisheries issues and requiring ecosystem-based management and fishing practices. However, conservationists and consumers can promote industry change and aid implementation before policy, regulations, and management efforts can effectively catch-up and address marine ecosystem management issues.

VIII. Conclusion:

There is an increasing awareness that current single-species based management efforts fall short of effectively conserving the health and sustainability of our nation's fisheries. Demands for ecosystem services are on the rise. Overfishing, bycatch, habitat degradation, and other human-induced effects are on the rise, rapidly diminishing the ocean's ability to provide important services. If we act now, if may still be possible to prevent further degradation and to rebuild damaged stocks (Rosenburg and McLeod 2005). Science and policy are in the midst of a tug-of-war for knowledge and the development of practical management processes in the face of increasing uncertainty. The precautionary principle and the reversal of burden of proof seek to alleviate these political challenges, but are still limited by scientific uncertainty (Watson-Wright 2005).

An ecosystem approach to management seeks to improve fisheries management and facilitate the alleviation of the harmful effects of fishing on marine ecosystems. While ecosystem-based management is not limited to fisheries, fisheries provide a logical basis for furthering the concept. Fisheries managers are familiar with making decisions on both local, regional and ecosystem scales (Fluharty 2005). Unsustainable practices such as harmful gear types will be altered or discontinued and replaced by "cleaner" technology. Fisheries will inevitably have to be fished at lower catch levels in order to maintain ecosystem services. Certain areas may be set aside as reserves for spawning stock or other susceptible life-history stages (Fluharty and Cyr 2001).

There is no mandate for ecosystem-based management policies to consider the cumulative impacts of human activities and interactions within an ecosystem. Ocean policies need to adapt to the goal of the long-term maintenance of the provision of ecosystem function and services, rather than focusing on individual services (Rosenburg and McLeod 2005). The short-term ramifications of a transition to ecosystem-based management will be difficult, but the future benefit of sustainable marine ecosystems and fisheries is immeasurable for fishing communities and the provision of ecosystem services (Fluharty and Cyr 2001). There will be a higher degree of uncertainty for ecosystem-based approaches to fisheries management. This must be balanced by more risk-averse decision-making processes, or EAF may worsen the condition of marine ecosystem rather than improve it (Rice 2005).

The next few years are crucial for US fisheries. Management is making important changes to comply with the Sustainable Fisheries Act (SFA) and the recent reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). Effective implementation of a precautionary ecosystem-based approach to management will require time, and a willingness to learn from our mistakes. Policy-makers, managers, industry, fishers, and the public all need to be educated about the costs and benefits of shifting to an ecosystem perspective. One of the hardest policy changes will be shifting the burden of proof to fisheries, to prohibit practices whose effects are not proven not to have harmful effects on marine ecosystems. Society will be faced with helping define ecosystem health and determining what changes in marine ecosystems are acceptable, while allowing sustainable fishing practices (Fluharty and Cyr 2001).

IX. Acknowledgements:

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XII. Appendix A:

Table 1. Alphabetical list of acronyms.

EAM	Ecosystem Approach to Management
EBM	Ecosystem-Based Management
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EMSC	Ecosystem-based Maximum Sustainable Catch
EPAP	Ecosystem Principles Advisory Panel
FAO	Food and Agriculture Organization
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
ICES	International Council for Exploration of the Sea
LME	Large Marine Ecosystem
MPA	Marine Protected Area
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSY	Maximum Sustainable Yield
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPFMC	North Pacific Fishery Management Council (Anchorage, AK)
POC	Pew Oceans Commission
SFA	Sustainable Fisheries Act
USCFF	U.S. Commission of Fish and Fisheries
USCOP	U.S. Commission on Ocean Policy

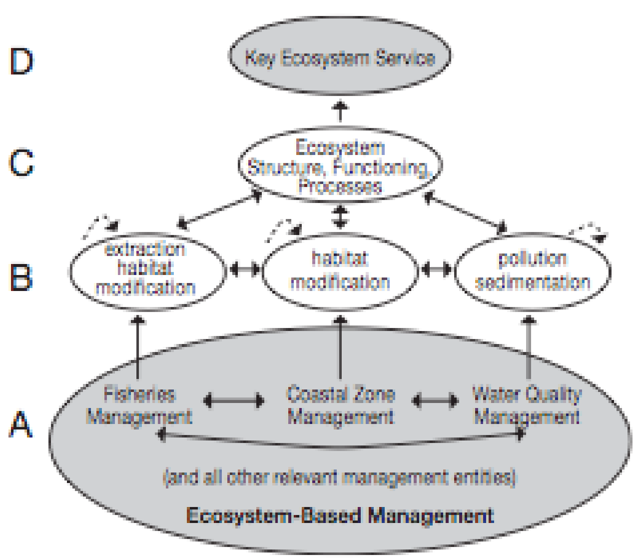

Figure 1. Key characteristics of ecosystem-based management. Current management centers on localized regulation of impacts on ecosystem services. Ecosystem-based management considers cumulative impacts and ecosystem interactions that affect the production of key ecosystem services. Characteristics include: " (A) interactions amongst policies, without negating the need for individual sector management, (B) examination of interactions among the impacts of individual sectors (arrows between impacts) as well as the cumulative impacts of individual and multiple sectors through time (dotted feedback loops), and (C) monitoring the effects of these cumulative impacts on ecosystem structure, functioning, and key processes, as well as the way in which reciprocal changes to ecosystems modify those impacts. (D) The goal of ecosystem-based

management is to maintain the flows of key ecosystem services that result from ecosystem structure, functioning, and processes" (Rosenburg and McLeod 2005).

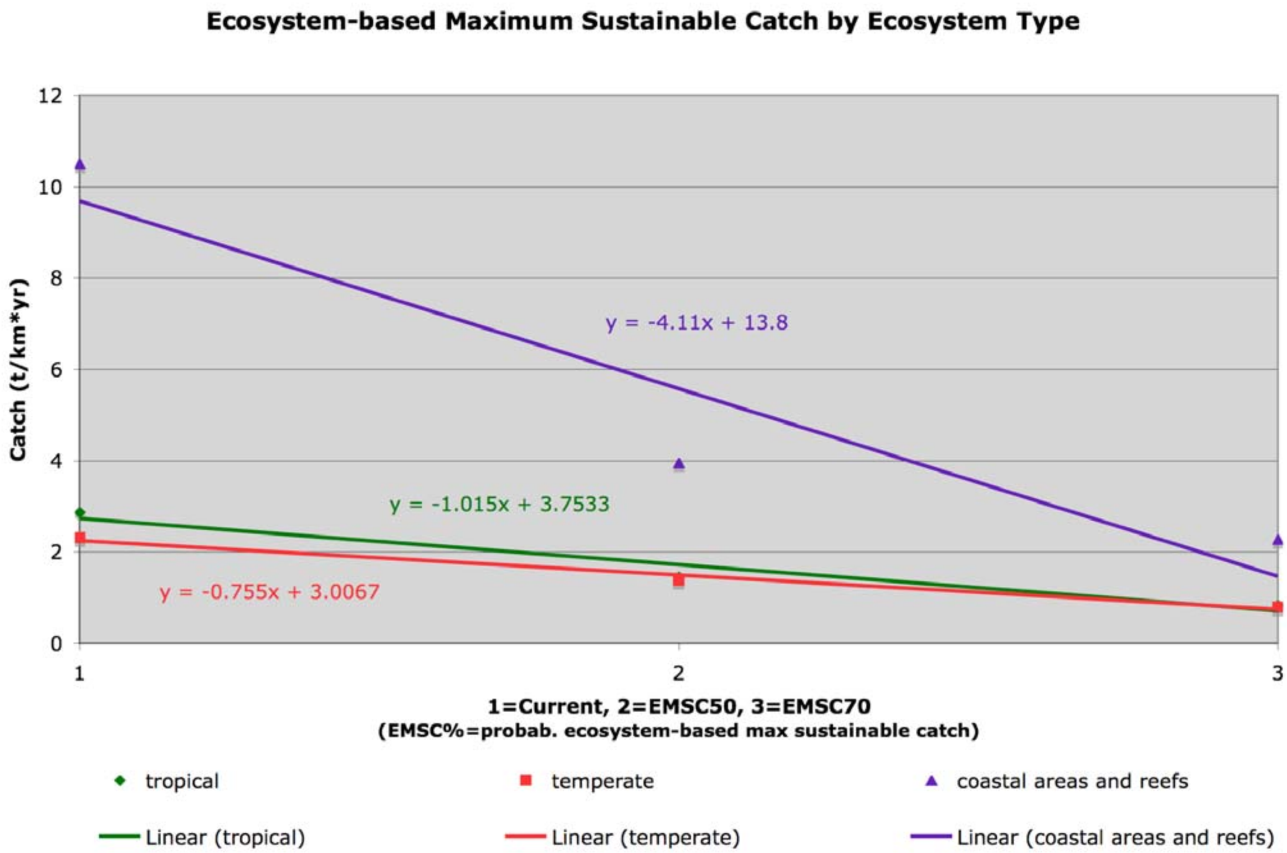

Figure 2. Ecosystem-based maximum sustainable catches (EMSC; t km–2 yr–1) at 50 and 70% probability of sustainable exploitation for different ecosystem types, compared with current levels of catch and discards. Trends corresponding to potential changes from an ecosystem-based management perspective. Adapted from Tudela et al. data (2005).

Table 2. Matrix of possible scenarios for ecosystem-based fisheries management, as a function of its relationship with commercial profits and social welfare (Adapted - Rosenburg & McLeod 2005).

	EAFM increases SW	**EAFM decreases SW**
EAFM increases CP	**Successful EAFM (+,+)** *cooperative regulatory environment *fisher incentives for env. considerations *sustainability, biodiversity, quality products	**Destructive EAFM (-,+)** *expensive regulatory environment *mandated compliance (no incentives) *uncertain social/env. Benefits
EAFM decreases CP	**Superficial EAFM (+,-)** *unwilling compliance (opposed) *uncertain product *questionable quality	**Delusional EAFM (-,-)** *expensive regulatory environment *uncertain sustainability *questionable products/quality

*EAFM = Ecosystem Approach to Fisheries Management
*CP = Commercial Profits
*SW = Social Welfare

Table 3. What is important to constituents? (Rosenburg and McLeod 2005)

	Stakeholder Concerns			
	People	**Production**	**Profit**	**Planet**
Fisheries Biologists				X
Civil Society	X			X
General Public				X
Fishery Industrialists		X	X	X
Politicians	X	X	X	X
Fisheries Managers	X	X	X*	X
Fishers		X	X	X**

*Managers can set rules to balance fishers' costs and profits within catch limits
**Fishers will be environmentally responsible if conservation is economically practical.