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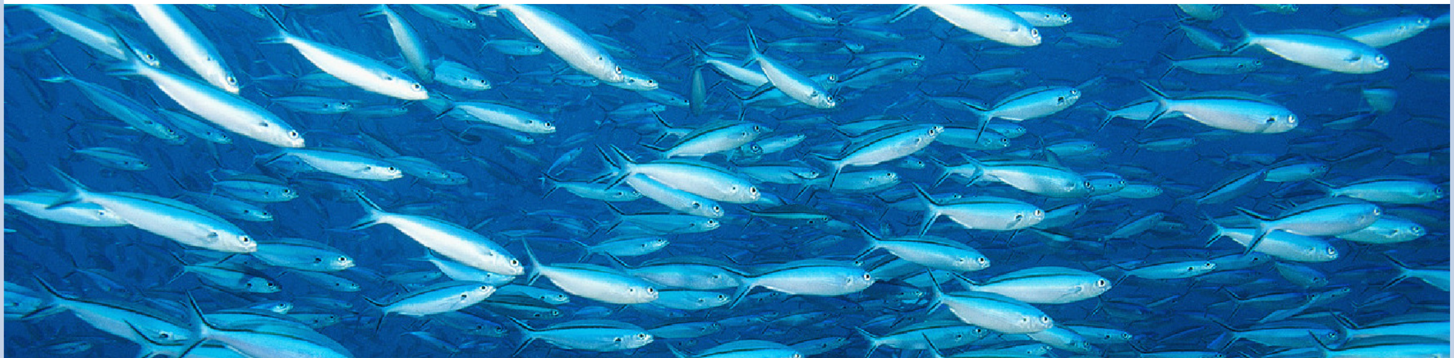

Best Practices in U.S. Fishery Management

A report of the Lenfest Best Practices Working Group

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About This Report

In 2007, under contract to the Lenfest Ocean Program, MRAG Americas, Inc. convened a working group of fisheries experts to review the best management practices of U.S. fisheries. This consensus report describes the primary features of fisheries management, best practices for each of those features, and examples from the United States and abroad that illustrate those practices.

What Are Best Practices?

We define "Best Practices" as existing management approaches that have been successful and appear likely to produce success elsewhere if implemented more widely. When there are no appropriate existing examples, best practices are those approaches that show the most promise. Classification as a best practice does not suggest that there is not room for improvement, but rather describes what seems to be the best that is currently being used in the United States with some illustrations from other countries.

For any method to be considered a best practice, it should include active stakeholder involvement, and it should provide a mechanism for measuring results to ensure accountability. A best practice should also be adaptive to new information and changing circumstances because as the state of scientific information and fishery operations evolves, there will always be a need to improve on processes. In many cases, a technique that once proved efficient will become outdated due to advances and improvements, for instance in gear technology.

Best Practices are not rigid approaches that can only be accomplished if applied uniformly, but instead require adjustment for use in different fisheries. For example, the current state of a fishery will have major implications. Capacity control is essential in all fisheries but should be applied differently in a developing fishery, an existing sustainable fishery, and a fishery in need of rebuilding.

Best practices are most successful if they are designed, implemented, and evaluated as part of an integrated management system that addresses all the key elements of marine resource management described in this report. In other words, best practices should be applied to all elements of management for each fishery. Employing best practices for only one or a few elements does not imply that the fishery is well managed.

Goals for this Report

The Working Group did not intend this report to establish methods that must be used in every fishery, because each fishery is unique, with differing ecosystem, social, and economic structures. Given that, the method best employed in one area for one fishery may not be the best for another. The goal for this report, therefore, was to identify the elements that should be incorporated into management systems to effectively achieve stability and sustainability.

The best practices examples given here are not described in detail, nor is there any intention to present one fishery as better managed than another overall. Rather, features of the fishery management system in particular cases were selected to illustrate specific points as succinctly as possible. Readers should bear in mind that the working group did not set out to do an exhaustive review of all U.S. fisheries management practices. So, the selection of one fishery to illustrate a point does not imply that other fisheries management systems are not employing similar techniques. International examples are intended to broaden the discussion and, in some cases, to offer a guide when no U.S. example sufficed.

Four Essential Components of Effective Fisheries Management

After considering fisheries management systems across the United States and internationally, the Working Group agreed that effective fisheries management involves four critical components. Each of these is described below along with secondary topics that carry equal weight and importance in fisheries management.

1) GOALS: Goal setting expresses the vision of what the fishery will be in the future and lays the framework for implementing strategies and tactics for management. This is a key feature of a successful management plan. When the goals of a management plan have been clear from the beginning, the subsequent actions can be more explicitly related to results.

Primary goals, linked to sustainability of the marine ecosystem and the resources within it, should take precedence over goals that address the interests of user-groups for social and economic stability. Primary goals hold conservation constraints that are often established by statute, for instance through the Magnuson-Stevens Act National Standards. These goals are aimed at preventing overfishing, and minimizing bycatch and habitat impacts. Fishery management plans must adhere to such statutes before development of secondary goals that address the needs of user groups.

These secondary goals must be balanced for all participants in a fishery and be adaptive to social and environmental changes. To avoid future conflicts, goal setting should be established as an open participatory process. Participants and their communities should share the responsibility of establishing the goals and agreeing on them, bearing in mind that these goals must always comply with conservation constraints.

2) STRATEGIES: Clear goals should lead to implementation of the strategies to achieve those goals. It is best practice to conduct some form of a management strategy evaluation to assess effectiveness in achieving the goals for the fishery. A thorough evaluation will maintain the primary conservation goals and examine tradeoffs among the secondary goals. The Working Group identified a number of items to include in strategy implementation that have been effective at producing desired, positive outcomes. These include: 1) a clear allocation and capacity management strategy, 2) appropriate incentive structures, 3) planning for uncertainty, 4) a process for obtaining scientific advice and using it in policy-making, and 5) an ecosystem-based approach to fisheries management.

Access to and allocation of a resource are privileges that must be carefully managed. To meet the secondary goals, strategies designated for allocation and capacity management must be clearly articulated and shared with all participants. The best practices for resource allocation and capacity management include: 1) establishing access privileges that provide for clear allocation of fishing opportunities and address community needs without risking the resource, 2) adhering to conservation limits which ensure that capacity does not exceed resource productivity, and 3) supporting incentives that reduce costs rather than increase capacity.

Management strategies that achieve set goals also create incentives that affect the behavior of participants. That behavior, in turn, can either support or undermine the goals. Regulators must consider those incentives when establishing strategies. A best practice for incentive structures will support the effectiveness of management by rewarding compliance, penalizing non-compliance, promoting advancement of fishing gears with lower impact, and reducing excess capacity. The incentive structure should improve conservation while adding to the value and stability of the fishery.

3) TACTICS: Fishery management is inevitably complicated by information gaps, leading to uncertainty about the ecosystem and the fishery, variability in the environment, the response of the ecosystem to various events or pressures, and imperfect ability to control human activities and impacts on the ecosystem. Uncertainty must be addressed directly and be a factor in management decisions. Scientists and regulators need to continually account for and adjust to uncertainty in science and implementation when managing a resource. Contingency plans should be developed to assure that unanticipated events do not undermine sustainability, and extra caution must be applied when managing fisheries undergoing rebuilding and when developing resources about which information is lacking.

All aspects of fisheries management rely on accurate and timely information for the development of scientific advice. Scientific information must be available to respond to the needs of the management system and must utilize an objective peer review process to maintain quality and transparency.

Ecosystem-based fisheries management (EBFM) goes well beyond policies that simply seek to manage the yield from a small set of target species. EBFM is critical in the development of new management plans and the revision of existing plans. Managers must recognize that a targeted resource is substantially affected by more than just harvest rates. Management of broader ecosystem-level effects of fishing must consider and maintain the structure and function of marine ecosystems, while taking into account the cumulative impacts of human activities and the connections between ecosystem elements. An ecosystem-wide strategy that protects productive habitats and minimizes bycatch and fishing impacts should be developed and implemented for every marine ecosystem and its fisheries.

Management tactics that should be employed by every fishery management plan include, for example, the combination of input and output controls on overall fishing mortality and the use of gear selectivity to minimize bycatch. Control of the overall fishing mortality rate on fishery resources is fundamental to achieving the goals of any fishery management plan and must include all sectors in the fishery. Secondary goals established to allocate access to the resource or maintain fishing communities cannot be achieved in the face of a depleted resource. Therefore, controlling fishing mortality is of primary importance. In order for management to function appropriately, data collection and availability must be as near real time as possible.

A major component of fishing mortality that can remain largely unaccounted for is the incidental capture and discarding of juveniles, and non-marketable and non-target species. Bycatch reduction is essential to the sustainability of marine ecosystems. Reduction of bycatch and habitat impacts should be achieved through bycatch limits, incentives to develop new technology and improve fishing practices, and comprehensive monitoring and inspection programs.

To provide adequate protection, immediate management action is needed in cases where stocks are depleted, and where newly developing fisheries can overexploit fish populations before sufficient information exists. Rebuilding of stocks should be initiated without delay, and must include an immediate end to overfishing to avoid future depletion. Plans must include interim measures and effective surveillance and monitoring, along with the shortest recovery timeframes possible. Tactics must be employed to account for and manage the catch in recreational fisheries as this can contribute a substantial portion of the catch in many fisheries.

"While individual best practices are laudable, we reiterate that it is critical that the management system strive for best practices throughout—in all the areas described in this review—in order to sustain marine fishery resources."

Newly developing fisheries face challenges because new opportunities can arise faster than information regarding the resource and its ecosystem can be collected. It is essential that newly developing fisheries be controlled from the outset. In all cases, it is considered good practice to develop a feedback system to ensure that management systems are achieving desired results as measured against established goals.

4) MONITORING AND ENFORCEMENT: Comprehensive monitoring of fishing activities, practices, and performance on an ongoing basis is an essential aspect of an effective management system. Monitoring, control, and enforcement systems should be consistent across fisheries and regions, and access to information should be as broad as possible. Confidentiality provisions should be minimized to improve transparency and accountability. Participants providing accurate and timely data to the management authority and complying with management rules should be conditions for continued access to the resource.

Conclusion

Best practices in fishery management set standards that lead to a balanced system that satisfies socioeconomic desires while achieving sustainability and security for the resource. A best practices approach will deliver a better outcome than other management methods.

Many fisheries possess features of these best practices, and management in some areas has made considerable progress. While individual best practices are laudable, we reiterate that it is critical that the management system strive for best practices throughout—in all the areas described in this review—in order to sustain marine fishery resources.

2 — GOAL SETTING

2.1 ESTABLISHING PRIMARY AND SECONDARY GOALS

Best Practices Summary
A fishery management plan will be most effective if it is established using distinct goals developed not as an afterthought, but during the planning process. The process of goal setting should be adaptive to accommodate changes in the environment and social structures. Conservation constraints are the primary management goals, and these must not be compromised for secondary goals that address the needs of user groups. Goals that serve the needs of the users must be balanced to benefit all participants in a fishery.

Establishing and implementing effective goals, or goal setting, is the first step in making a good fishery management plan (FMP). Goal setting expresses the vision of what the fishery will be in the future, including the hoped for state of the marine ecosystem upon which a fishery depends. Goal setting also

> *"Goal setting must not be an afterthought to deciding strategies and tactics."*

creates the context for strategy development and the resulting tactical decisions for management. For example, consider goals of long-term sustainability for a given marine ecosystem, and sustainability of fishery catches in order to provide commercial and recreational opportunities. Related strategies might include overall control of fishing mortality rates for target stocks, minimizing habitat impacts, reducing conflicts with other sectors of human activity, and maintaining local community access, among others. The tactics employed to achieve those goals might be overall catch limits, gear requirements and closed areas, development of an incentive structure to improve monitoring and compliance with the plan, and allocation of resource access to groups or interests.

Thus, *goal setting must not be an afterthought to deciding strategies and tactics.* Best practices for an FMP instead require an explicit goal-setting process in which the relevant factors guiding the fishery are examined, debated, and analyzed. This process leads to the negotiated agreements—and compromises—needed to make the FMP a fair and acceptable approach to management for fishermen, regulators, conservation groups, and scientists alike.

Best Practices for Goal setting

- Make goal setting for a management plan the first step in policymaking, followed by strategy development and accompanying tactics.
- Prioritize goals into primary and secondary categories. The primary goals are the conservation constraints on the fishery. No fishery can operate successfully in the long term unless the marine ecosystem upon which it depends is functioning to produce the fishery resources and other ecosystem services. This means that there must be limits, set through primary goals, to fishery impacts, in order

to ensure that abundance of a given species does not fall below a certain level. Such goals are included in the Magnuson Stevens Fishery Conservation and Management Act (MSFCMA) as well as in the principles of sustainable development.

- Establish secondary goals that fall within the conservation constraints given by the primary goals. Secondary goals should relate to needs and desires of interest groups for a specific fishery or multiple fisheries within a region. These goals may relate to access for specific communities, employment considerations, recreational opportunities, conservation of particular areas or resources, and other concerns. In some cases, secondary goals such as providing recreational opportunities, fair and equitable allocation among U.S. fishermen, and sustained participation by fishing communities, may also be mandated by the MSFCMA or other statues.
- Make tradeoffs between user-group desires among the secondary goals, but never with the primary constraints. In other words, it is inappropriate to try to address allocation concerns or resolve competing interests by compromising on conservation and sustainability.
- Make goal setting adaptive, and conduct periodic reevaluation and revision.
- Make goal setting transparent and participatory, reflecting the broad interests of fisheries, communities, and constituents.

Description and Examples of Goal Setting

Regional fishery management councils have the responsibility of recommending management strategies to achieve both primary and secondary goals, which are the crux of the decision-making process.

Primary goals address maintenance of the marine ecosystem and the resources within that ecosystem. The MSFCMA mandates in National Standard 1 that "Conservation and management measures shall prevent overfishing …" Concurrently, goals to maintain fish stocks above depletion limits, to recover overfished stocks, and to reduce bycatch to the extent practicable, are within the primary category.

Secondary goals express the interests and objectives of user groups. As such, they must be distinguished from—and not supersede—the primary sustainability constraints. For example, a secondary goal might be to maintain stability of annual catches by limiting annual variability to 20%, recognizing that the catches must be sustainable to maintain resource levels above prescribed limits. Another secondary goal might be to achieve a balance between commercial and recreational fishery users, such that recreational catches are a specified proportion of the total. Other goals might be to develop sustainable markets accentuating the unique characteristics of a fishery and/or to maintain employment within specified sectors.

The working group identified several good examples of tiered goal setting for management:

- The South Atlantic Fishery Management Council is moving from current habitat and single-species plans toward Ecosystem-Based Fisheries Management (EBFM) by adopting a proactive approach to protecting and enhancing Essential Fish Habitat for all managed species under its jurisdiction. In incremental steps, the Council will characterize the system, and the relationships among humans, harvested fish and their prey, other marine life, essential habitat, and the environmental characteristics of the system. The Council is holding public workshops to address a range of ecosystem considerations, including: 1) establishing ecological (biological, chemical and physical) boundaries; 2) human and institutional elements of the ecosystem; 3) habitat needs of different life history stages for managed species; 4) metrics of ecosystem health; and 5) monitoring needs. This effort will provide the Council with a foundation on which to develop ecosystem management of these fisheries (SAFMC, 2007).

- The state of California enacted the Marine Life Management Act (MLMA) with the overarching goal of ensuring conservation and the sustainable use and restoration of California's living marine resources. The MLMA aims to encourage only those activities that are sustainable and that promote a healthy ecosystem (Weber and Heneman, 2007). To further the primary goal of the act, the state is developing management plans that embody ecosystem-based fishery management. In addition to limiting bycatch and rebuilding depressed fish populations, these plans are designed to maintain long-term benefits rather than opting for short-term benefits, and to set more precautionary catch levels for data-poor fish populations. This provides a good example of where a state established a clear goal upfront and designed policies to achieve that goal. However, obstacles like lack of funding have stalled progress on plans for of plans for more than a few significant fisheries.

- Internationally, the Convention for the Conservation of Antarctic Living Marine Resources (CCAMLR) has implemented Ecosystem-Based Fisheries Management plans that address both direct and indirect fishery effects. The Convention has moved rapidly to eliminate direct interactions. For instance, bird bycatch in nearly all its fisheries is now zero, and the group has recently agreed on an approach for avoiding benthic impacts in vulnerable marine ecosystems that is consistent with United Nations General Assembly guidelines (CCAMLR, 2007).

  In Antarctica, indirect trophic interactions are of particular concern with the krill fishery, since krill is a key component of Antarctic ecosystems. After many years of research, CCAMLR is now on the verge of being able to use plausible ecosystem models and feedback monitoring of the fishery and ecosystem to apportion the krill catch to different areas of the Antarctic depending upon the predator demand and distribution of krill in those areas (CCAMLR, 2008). CCAMLR also takes a precautionary view and has set the target limit for krill biomass at 75% of the long-term average biomass value expected in the absence of fishing mortality, also known as virgin biomass and designated B_o (Constable et al. 2000). This level is probably more than twice the size of the biomass corresponding to Maximum Sustainable Yield (B_{MSY}). The goal-setting process has therefore specifically considered the need to maintain the functioning of the Antarctic ecosystem as the overriding priority for sustainability. But, within this overall total allowable catch (TAC)—3.7 million tons in the South Atlantic—CCAMLR does not set national allocations.

*"When goals are ambiguous, strategies and management tactics become **ad hoc** and are perceived as arbitrary."*

- Internationally, six countries and the European Community established the Southern Indian Ocean Fisheries Agreement (SIOFA) of 2006, which ensured the long-term conservation and sustainable use of fishery resources (other than tuna) that fall outside natural jurisdictions. Actions to implement this agreement include establishing an effective fishery monitoring system, annual reporting on fishery operations including all catches and discards, and regular inspections to verify compliance with the agreement. Among their important efforts, SIOFA mandates regular studies of fishery environmental impacts and establishes management and conservation measures for the SIOFA area (FAO, 2006).

Potential/Existing Problems with Goal setting

Goals must be clearly specified to avoid problems in the fishery. *When goals are ambiguous, strategies and management tactics become **ad hoc** and are perceived as arbitrary.* Of particular concern is when secondary user-group goals are achieved at the expense of sustainability. This will compromise the viability of the resource by increasing the risks of overfishing and depletion, and will sacrifice the long-term benefits of the resource for short-term exploitation.

2.2 PARTICIPATION AND GOVERNANCE

Best Practices Summary

The best practice for participation and governance is to establish a transparent process that includes all participants. The process must have clearly stated secondary objectives, and it must be clear that conservation limits stemming from primary goals are not negotiable. Agreement on goals can lead to increased implementation responsibility on the part of participants and their communities.

Goal setting goes beyond statutory definitions of optimum yield (OY) and maximum sustainable yield (MSY); it must incorporate the interests of all parties through a visible process of negotiation.

Best Practices for Participation and Governance

- When setting goals, consider broad interests in the fishery to account for all participants and the public.
- Make negotiation of secondary goals transparent so that all affected parties understand the process and how they can effectively participate.

Description and Examples of Participation and Governance

Broad stakeholder participation in goal setting may allow aspects of management, especially those related to secondary goals, to be entrusted to specific areas, interest groups, or communities.

For example:

- The Georges Bank Cod Hook Sector collectively determines how to harvest their 20% share of the total allowable catch (TAC). This example of community-based management has prevented derby-style fishing and has given the fishermen the opportunity to participate in the management of the stock (NEFMC, 2003).

Once primary goals have been established and adhered to, there are a number of mechanisms available to discern resource shares.

For example:

- The Nova Scotia Southwest longline fishery employs both individual transferable quotas (ITQs), where individual vessels are the quota recipients, and community quotas, where a quota is allocated to an entire community, which then decides how to allocate the quota (Fanning, 2007).

- The Pacific Fishery Management Council responded to excess catch capacity in the groundfish fishery in the late 1990s by adopting a strategic plan aimed at reducing capacity in all groundfish gears by 50% (PFMC, 2000). While the goal was shared, the details of capacity reduction varied in each of the gear sectors.

Conversely, community governance is often not viable in states or regions with large populations that are highly mobile. In these situations, regionalizing management is most appropriate, rather than delegating management responsibilities to individual states or individual communities.

For example:

- Migratory coastal pelagic fisheries in the southeast United States, where both the fish and fishermen move between local jurisdictions, demand use of a regional approach.
- The Department of Fisheries and Oceans Canada, Maritimes Region established the Eastern Scotian Shelf Integrated Management (ESSIM) Initiative to forge a collaborative ocean planning process for the development of the ESSIM plan. The entire stakeholder community was involved in deciding the goals of the management plan. The initiative has proven successful in that all interested parties have been included in the discussions from the beginning, and potential interactions and conflicts were considered during the planning process (DFO, 2007).

Potential/Existing Problems with Participation and Governance

If secondary goals are not thoroughly vetted and settled through an open process, then allocation of participation between user groups will be revisited repeatedly, consuming huge amounts of human resources and freezing the management process. This, too, can increase the probability that appropriate conservation measures are not implemented, placing the resources at risk. When participation in governance and goal setting is limited, then users feel that goals are being forced upon them without an appropriate mechanism for their views to be heard. This will lead to problems in enforcement that can affect maintenance of sustainability and the achievement of optimum yield expressed in the secondary goals.

3 — STRATEGY DEVELOPMENT

3.1 ELEMENTS OF A MANAGEMENT STRATEGY

Best Practices Summary

The best practice for strategy development is to use some form of management strategy evaluation and risk assessment to examine the system. This evaluation should compare performance with regard to the full set of goals for the fishery. It should maintain conservation goals as the highest priority, but enable comparison of tradeoffs among the secondary goals.

Strategies bridge the gap between management goals and their achievement through implementation. They are essential to ensuring that tactical decisions made for the fishery, such as quota levels, move the management system toward the stated goals. For instance, to achieve objectives related to industry stability, it might be prudent to minimize the year-to-year variability of the catch.

"With stable, well-developed resources… new strategies to improve profitability or to adjust allocation to communities might be introduced without compromising conservation."

Different goals may obviously require different strategies, but differing conditions between fisheries may as well. For example, dealing with depressed populations requires immediate reductions in exploitation to halt declines and enable rebuilding. *With stable, well-developed resources, on the other hand, new strategies to improve profitability or to adjust allocation to communities might be introduced without compromising conservation.*

Best Practices for Strategy Development

- Prioritize management goals (conservation, social, economic, institutional) and link them with actions needed to achieve these goals, while recognizing the imperative of using primary goals to set conservation limits.
- Ensure that overexploitation is addressed immediately and that resources are rebuilt as rapidly as possible so that other goals can be addressed once conservation is assured.
- Incorporate the emerging approach of ecosystem-based fisheries management (EBFM).
- Incorporate uncertainty into all strategic decisions related to information and management controls.
- Formally and explicitly address resource sharing and allocation decisions without undermining sustainability.
- Provide the right incentives for participants in order to improve the efficacy of the management system.
- Regularly review the strategy against its ability to deliver fishery management goals and revise it as new information becomes available.

Description and Examples of Strategy Development

Systems approaches to management have been in use in other parts of the world since the 1980s, but are only starting to be more widely used in fisheries. The following examples illustrate ways such strategies have been developed and incorporated:

- The Management Procedures developed by the International Whaling Commission are one of the earliest examples of a systems approach in the marine environment. These procedures were also intended to establish clear, enforceable guidelines for harvesting.
- Harvest Control Rules, developed under the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), highlight attempts during the mid to late 1980s to develop harvesting strategies that incorporate broader effects of fishing on the ecosystem (Mace and Gabriel, 1999).
- Clear harvest control rules, which specify harvest rates according to resource condition, are applied strategically within the North Pacific groundfish fishery and have been linked together through overall groundfish quota caps. This overall control has been a key factor in fishery sustainability.

Recently, a management system-wide approach, termed management strategy evaluation (MSE), has been applied in some fisheries outside the United States. This approach provides a mechanism to explore the response of a system to different management strategies. Such information can help identify scientific research priorities.

Using MSE, the assumptions and uncertainties implicated in each component of the management system are explicitly stated and, through simulation, alternative management strategies are investigated. The goal is to determine which strategy leads to the robust achievement of the objectives (McAllister et al., 1999; Smith et al., 1999). The MSE approach considers not only the biological components of the management system, but also those related to monitoring and implementation.

A number of MSEs have been conducted in various parts of the world. Most recently, this approach is being applied at the level of a whole fishery with the southern and eastern scalefish and shark fisheries off Australia (Smith et al., 2007). This pioneering work conducted by scientists at Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) has entailed a qualitative MSE similar to the approach taken by Fletcher (2005) and allowed the team to identify the low, medium, and high priority issues in a management system. This was followed by more detailed investigation of the medium and high priority issues through quantitative MSE as well as Ecological Risk Assessment (Smith et al., 2007).

Potential/Existing Problems with Strategy Development

Many problems in current management systems reflect a failure to follow best practices. Strategies to achieve the full suite of goals are sometimes de-coupled, resulting in efforts to seek fishery stability without ensuring that the resource upon which it is based is sustainable. Too often, the argument is made that changes should be phased in slowly, even though the cost of this approach can be much higher than more rapid adjustments. In many cases, ecosystem approaches to fisheries are assumed subordinate to management of target species catches—even though target species productivity is inextricably linked to overall ecosystem productivity. A systems approach to management, in which managers and fishery participants recognize the linkages between various strategies, could help avoid these pitfalls.

3.2 CAPACITY AND ALLOCATION MANAGEMENT

Best Practices Summary

The essential best practices for resource capacity and allocation management are: 1) Specify access privileges, with clear allocation of fishing opportunities, expressed in catch or effort or both, that address community needs and engender stability in the fishery; 2) Ensure that allocation decisions do not compromise conservation limits; and 3) Ensure that fishing capacity does not greatly exceed the productivity of the principal resources and that there is incentive to reduce costs rather than increase harvesting capacity.

To meet the secondary goals of fishery management, resource access and allocation strategies must be clearly articulated. Access privileges that specify, as far as possible, who can fish and under what conditions are one important means of improving accountability and can help avoid over-exploitation. Catch and/or effort allocations to communities, groups, or individuals should be explicit and the allocation strategy should respect the primary goals that set conservation limits for the fishery. For instance, to address objectives related to coastal community support, it might be necessary to make catch or effort allocations by fleets and geographic areas.

To address economic objectives, it is important that all the earned revenue not be dissipated through investment in fishing capacity, as is frequently the case in heavily exploited fisheries. Excess fishing capacity also endangers the biological objectives because it leads to intense pressure from participants to raise catch and effort levels, and this in turn causes difficulties in enforcing catch limits. Further, participants in a fishery are more likely to be engaged in the management of its long-term sustainability if both their access and their harvest privilege allocations are kept stable. A capacity management plan should be part of the strategy for fishery management.

"To address economic objectives, it is important that all the earned revenue not be dissipated through investment in fishing capacity, as is frequently the case in heavily exploited fisheries."

Best Practices for Capacity and Allocation Management

- Set out access privileges for use of a resource in the management strategy, to specify who can fish and the responsibilities of those obtaining access to public resources.
- Establish formal resource sharing arrangements that clearly identify how the catch will be allocated among all fishery participants.
- Involve all participants with an interest in the resource in sharing arrangements.
- Account for long-term ecosystem goals and documented impacts on depleted species and ecosystems when making allocation decisions, rather than basing them simply on historical participation or on target species catches.
- Set overall exploitation capacity goals within each region or fishery and review them regularly to take account of changing fishery and ecosystem productivity and the increasing fishing power of vessels.
- Set clear procedures for entry and exit from the fishery. These rules must be as stable as possible.

Description and Examples of Capacity and Allocation Management

These best practices for capacity and allocation management help in addressing some outstanding problems in U.S. fisheries. In some fisheries, not all fleet sectors receive a specific, managed catch allocation. This makes it difficult to rationalize the benefits of catch controls on, for instance, a commercial fleet, when the perception is that a recreational or other fleet is not being properly regulated. Many fisheries still have no formal means to allocate catch amongst their participants. This can lead to each participant trying to maximize their share of catch through increased investment in capacity, creating a "race for fish".

While maintaining a large fleet of vessels in a fishery is by itself not necessarily bad, there are many resultant problems from high fleet capacity. *If the fishing capacity of vessels operating at any point in time is much larger than the allowable catch, then the economic viability of the industry as a whole is in jeopardy because there will be intense pressure to utilize the excess capacity by compromising the conservation limits.* The result is an ever downward spiral of overexploitation, further increases in capacity, and stock declines, all guaranteeing both economic and social instability.

There are several successful allocation and capacity management approaches from the United States and elsewhere that can be used as a guide to best practices:

- Community quota systems in the North Pacific groundfish fishery (NRC, 1999a) and the Southwest Nova Scotia groundfish fishery (Fanning, 2007; McCay et al., 1998) and cooperative fisheries allocations in Alaska (Witherall, 2004) are all good examples. In these programs, industry groups manage their own capacity according to specific quota applications they receive. This is in contrast to the more common practice of managers setting capacity rules and fishing tactics. Instead, communities or cooperatives make these decisions in order to stay within their allocation because the group has collective responsibility for adhering to the quota.
- Individual vessel quota systems in, for example, the North Pacific and the Mid-Atlantic surf clam fisheries (NRC, 1999b), and company allocations in the Canadian East Coast offshore trawl fishery (Gardner, 1988), are also important examples. In these cases, capacity and tactical decisions become part of the business plans for companies or vessels because they are responsible for a specific allocation and have a longer-term stake in the resource.
- In the Southwest Nova Scotia groundfish fishery, allocations have been first made separately to the inshore and offshore fleets, and then further segregated to portions of those fleets. (Fanning, 2007). Sharing arrangements can be adjusted when the fleet structure of a fishery involves many different fleets and communities.

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Many of these allocation systems have extensive catch monitoring protocols, supported by fishery participants, to prevent resource share abuse. The consequence of most of these systems has been reduced fishing capacity and thus, more orderly management of these fisheries. In many cases, clear allocation of fishing opportunities has reversed the economic pressures to increase capacity because it becomes more advantageous to decrease capacity and, as a result, the costs of fishing.

Effective catch monitoring plans are essential to making these systems work to stay within catch quotas and reduce bycatch. In addition, some allocation systems allow transfer between shareholders, while others do not. Transferability has the advantage of allowing greater efficiency in businesses, but the potential disadvantage of allowing accumulation of fishing privileges by a small number of companies or owners. Interestingly, some systems, such as the Atlantic sea scallop fishery, started with non-transferability but are evolving to allow transferability as a means to help stabilize the fishery.

Potential/Existing Problems with Capacity and Allocation Management

It is hard to reduce fishing capacity once it exists, because communities, bank loans, and social structure all rely on this capacity. Frequently, capacity reductions cannot be achieved through simple amendments to fisheries management plans, which are implemented over a one- or two-year period. Actions to address excess capacity are often lengthy, extensive, costly—as in the cases of vessel buybacks in New England and on the Pacific coast—and a result of Congressional action. Even when capacity can be reduced, the question remains whether reduction in the number of vessels in *this* fishery is simply passing the problem on to *that* fishery, often further complicating the situation.

For all the reasons given above, capacity increases for developing fisheries must be managed carefully. If fishing capacity is allowed to exceed the resource's productive capacity as a fishery is emerging, it will be very difficult to reduce this capacity once established. It is important to consider that capacity can increase even when the number of vessels stays constant or decreases. This is because capacity is directly linked to the fleet's fishing power, which will usually increase over time with improving technology.

On a similar note, for a depleted fishery where rebuilding is required, all fishery participants must share the burden of capacity decreases for any level of recovery to succeed. If one sector or gear type is increasing while another is decreasing, recovery will be undermined and the fishery will be unstable.

3.3 INCENTIVE STRUCTURES

Best Practices Summary

The best practices for incentive structures are those which reward compliance, severely penalize non-compliance, promote more selective fishing practices with lower impact, and reduce excess capacity. Incentive strategies, both regulatory and non-regulatory, should be a positive force in improving conservation, value, and stability in the fishery.

Once a set of rules is created for any fishery, participants immediately begin to plan their personal and business strategies. The management strategy itself creates incentives for participants to behave in certain ways that may support or undermine the plan's success. For example, where there is excess capacity, catch limitation without clear allocation creates incentives for each fishery participant to maximize catch and push the rules to their limits and beyond. However, clear allocation of fishing opportunities may create incentives to reduce costs, which can in turn reduce fishing capacity.

"The creation of incentives must be viewed as a part of the strategic structure of any plan, not a substitute for science-based catch limits, closed areas, and other regulations."

In addition, linking fishing privileges to data reporting requirements can create incentives to improve monitoring. Strong monitoring and enforcement programs, and stiff penalties for major violations, such as loss of access, create incentives to work within the rules. *Given these potential benefits, the creation of incentives must be viewed as a part of the strategic structure of any plan, not a substitute for science-based catch limits, closed areas, and other regulations.*

Best Practices for Incentive Structures

- Develop incentives for all participants in a fishery that improve management and the effectiveness of the management plan.
- Align strategies with incentives for participants in the fishery to improve management performance.
- Use restriction or exclusion from access to the fishery resources as a punishment for persistent or egregious non-compliance with management plans.
- Use subsidies only to achieve management goals by catalyzing needed changes, for instance in fishing methods or strategies to lower impact or improve energy efficiency. In particular, eliminate subsidies that undermine sustainability goals.
- Use access, subsidies, and allocation to promote the development and implementation of more selective fishing gear and practices.
- Dedicated access privileges, correctly enforced, can help create incentives to improve fishery management performance, manage capacity, and improve economic performance.
- Market-based incentives such as eco-labeling can create non-regulatory incentives to improve fishery conservation by increasing value while promoting sustainability.

Description and Examples of Incentives

Access to a fishery has historically been assumed as a right, not a privilege, for fishermen. Best practices should establish a system where participants have an equal responsibility for the fishery's success. Continued willingness to comply with regulations, provide data, and cooperate in management should be a condition for access to public fisheries resources. In general, there is a need to structure economic and sociological incentives to align with ecological and sustainability goals.

Non-compliance with the management plan rules and requirements must be considered very serious, and the penalty structure must be severe enough to discourage participants from circumventing the rules. If a management plan is to work effectively, those who work within the system should be rewarded for doing so and those that violate the rules must have their access and business viability reduced. Severe penalties can keep enforcement costs within reasonable bounds, as long as penalties are applied fairly and unambiguously.

Unlike other fines such as those imposed for highway speeding, financial penalties for fisheries infringements are often viewed by fishermen as business expenses, rather than financial penalties. Withdrawal or limitation of access is therefore a much more effective deterrent in serious cases, since it removes the possibility of financial benefit from engaging in more illegal activity to cover the financial penalty. Such deterrents are also very easy to enforce.

Identifying the right incentive structure can steer the future direction of the fishery. The right incentive structure, when developed through a management action for one sector, can encourage other sectors to develop their own improved methods to gain comparable benefits.

For example:

- The development of a Dedicated Access Program (DAP) in the Gulf of Alaska groundfish fishery increased the value of the resource, reduced bycatch, protected the habitat, and above all, ended the 'race for fish' (Witherall, 2004).
- The allocation of limited fishing opportunities for scallopers in parts of the closed areas on George's Bank in New England led to the development of bycatch reduction gear on scallop dredges.
- In the Falkland Islands squid fishery, in the 1990s, access to the fishing grounds within the EEZ was directly linked to providing accurate and timely data and each fishing company in the fishery limiting its overall fishing capacity in the South Atlantic (Beddington et al., 1990).
- In east and west coast Canadian groundfish fisheries, stable quota sharing arrangements provide incentives, through allocation, for the fishing industry to protect the resource by staying within the Total Allowable Catch and following other conservation measures.

Eco-labeling by non-governmental groups can also create positive incentives for conservation, particularly when conservation standards are transparent and members of the public have oversight roles. Strategic marketing can create public demand for a product and improve a fishery's economic condition. Labeling in general can be a non-regulatory incentive to improve fishery conservation because it increases value and promotes sustainability.

> *"When defining management strategies, it is important to consider and address through management actions the ways subsidies and other activities that may be outside the control of the management authority distort management efforts."*

For example:

- The international Marine Stewardship Council (MSC) has developed and implemented a third-party, non-governmental process that certifies fisheries judged sustainable based on well-developed and publicized criteria. Products certified by the MSC are then entitled to carry the Council's logo for marketing.
- Eco-labeling of Alaska salmon has illustrated that there is substantial consumer demand for high quality and high value products (Alaska Department of Fish and Game, 2007). Seafood products that

are sustainably harvested can demand a higher price in the marketplace, appealing to environmental as well as quality concerns among consumers.

Potential/Existing Problems with Incentive Structures

This study does not assess whether or not subsidies are an appropriate means for government agencies to achieve specific goals, because this is the prerogative of national governments and their constituents. However, when defining management strategies, it is important to consider and address through management actions the ways subsidies and other activities that may be outside the control of the management authority distort management efforts.

For example:

- Coastal states used direct subsidies after federal jurisdiction was extended post-1977 to replace foreign fishing capacity with domestic fishing capacity (Garcia and Newton, 1997). In the United States, the Fisheries Capital Construction Fund, which gives fishermen a tax break on money they save and then spend on increasing the capacity of their fishing operation, has had this effect, which continues today. The speed at which growth in capacity occurred was generally not closely linked to growth in understanding of the resources and political will, and resulted in overcapacity in many fisheries, contributing to long-term resource declines.
- Governments also use indirect subsidies such as income stabilization schemes to support coastal communities. Again, if not linked to the fisheries management system, these can lead to excessive pressure on the resource through illegal fishing and reporting activities.

Not all subsidies are negative, however. In the European Union, subsidies are used as an incentive for fishermen to use more selective gears. The European Fisheries Fund (EFF) supports the implementation of a Common Fisheries Policy by supporting the industry as it adapts its fleet to become more competitive and to promote measures to protect and enhance the environment. These activities can include development and testing of methods to improve gear selectivity, and reduce by-catches and discards. Targeted local management initiatives and pilot projects on a fishery basis are encouraged under the new EFF (European Commission, 2007). There are also opportunities in this program for extended aid and compensation for both permanent and temporary cessation of fishing activities, for the purposes of converting vessels to non-fishing activities, the creation of artificial reefs, and closure of fisheries for public health reasons or due to high concentration of juveniles or spawning fish.

3.4 PLAN FOR UNCERTAINTY

Best Practices Summary

Best practices require directly addressing uncertainty when establishing management actions. Both management and scientific uncertainty should be considered when formulating buffers between targets and limits. Contingencies should be put in place, and implemented as needed, to assure that unanticipated events do not undermine sustainability. While management and science must cautiously account for uncertainties in all fisheries, extra caution should be used in fisheries undergoing rebuilding and when developing resources for which information is lacking.

Uncertainty is an inevitable component of any human endeavor, and fishery management is no exception. Uncertainty results from many sources, including: 1) imperfect information concerning the ecosystem and the fishery, 2) variability in the environment, 3) the response of the ecosystem to various events or pressures, and 4) the imperfect ability to control human activities and impacts on the ecosystem.

For example, information on the catch of even the principal species is usually imperfect because there may be unaccounted for mortality of fish because of inadequate discards sampling or landings underreporting or other reasons. In addition, because scientific information on the response of the system to fishing or to environmental changes is never exact, efforts to model future recruitment of young fish to the population may be uncertain, providing poor information to management.
Another challenge is that management controls never work perfectly. Typically, some management measures, such as quotas or effort controls, are mismanaged, and too much catch is landed or too much effort is exerted before the fishery can be closed.

Uncertainty must be accepted and planned for in the fishery management process. Contingency strategies and tactics must be available to address unpredictable, but foreseeable, events, such as future recruitment. Best practices require that there always be a "Plan B". Without these contingencies, response to harmful events will be ad hoc and ineffective.

It is important to consider these multiple sources of uncertainty when managing fishery risk, which in this context refers to the probability of something bad happening to the resource or the fishery. Potential risks include those to the marine resource populations of concern, and to the ecosystem in question, and there is also risk of imperfect implementation of management strategies and tactics.

> *"Management targets can only coincide with the conservation limits if there is no uncertainty in the system, and this is never the case. "*

Best Practices for Planning for Uncertainty

- Consider all sources of uncertainty in managing risk to the ecosystem, including both uncertainty in management results, and scientific uncertainty.
- Ensure that uncertainty and unanticipated events do not undermine sustainability by establishing a buffer between management targets the plan aims to achieve and the conservation limits set. This means that management exploitation rates must be below exploitation rate limits, and biomass targets must be greater than biomass limits for all species impacted by the fishery. *Management targets can only coincide with the conservation limits if there is no uncertainty in the system, and this is never the case.* The greater the uncertainty, the larger the buffer required between targets and limits. The buffer should be large enough that probability of exceeding any conservation limit is low.
- Take even greater caution to account for uncertainty in rebuilding fisheries and newly developing fisheries where information is very limited than with fisheries operating sustainably or those with a great deal of available information. This in effect means increasing the uncertainty buffer between management targets and limits.

- The consequences of management actions that only make minor changes to the fishery will likely not be measurable given uncertain information. Making such changes within the range of the existing uncertainty will therefore not be predictable. If, for example, exploitation rates need to be reduced, then the reduction should be large enough that it will be possible to detect a real change in the fishery.
- Management must respond quickly to new information to address unanticipated impacts on the ecosystem.
- Strategies that buffer against unforeseen events, for instance by relying on more than one control method for all fisheries such as output controls and protected areas, will usually work better than a single control method if there is substantial management or information uncertainty.
- Determine research priorities according to management needs revealed through analysis of uncertainty. Focus research programs on reducing uncertainty in those areas that will most improve management performance, balancing short- and long-term research efforts.

Description and Examples of Best Practices for Planning for Uncertainty

In planning for uncertainty, the first priority is ensuring that unanticipated events do not undermine sustainability. This implies that best practices require that there be a buffer between management targets and limits to reflect the amount of uncertainty in the entire management process, not just the scientific uncertainty. This may require some redundancy in management controls such as backup systems. For example, a fishery may rely on protected areas as their main control feature, but an overall catch quota should also be implemented to assure that changes in fish distribution patterns or migration paths do not undermine sustainability. Planning for uncertainty is illustrated by the following examples:

- The Coastal Pelagics Fishery Management Plan of the Joint Gulf and South Atlantic Fishery Management Councils established management actions for two migratory groups of king mackerel, but the boundary between the migratory groups was uncertain. To promote recovery of that resource, the Councils chose a boundary that provided the Gulf migratory group more protection because higher fishing effort was focused on that population, placing it at higher risk (GMFMC and SAFMC, 1987).
- The buffer between the science advice on Acceptable Biological Catch (ABC) and the overall Total Allowable Catch (TAC) for groundfish in the North Pacific fisheries (Witherall, 2004) is substantial, assuring that there is a negligible probability that the ABC will be exceeded.
- In 1994, the New England Fishery Management Council closed three large areas off of New England to almost all demersal fishing in response to a collapsing groundfish fishery and severely overfished scallop resource (NEFMC, 1994). The closures resulted in large decreases in fishing mortality rates for some stocks and subsequently increased biomass for some flatfish species, most notably haddock and sea scallops (Rosenberg et al., 2006). Other large area closures in New England and the Mid-Atlantic that were added later had similarly substantial and measurable positive effects on fishing mortality rates and, therefore, management performance.

> *"Inconsequential actions waste resources and erode credibility in the management process. "*

Potential/Existing Problems with Planning for Uncertainty

Management actions should be consequential and responsive. For example, if implementation of management responses is relatively poor or delayed, then expectations of resource responses to regulations must be reduced, and management adjusted accordingly. In addition, an action should be substantial enough that it will measurably affect the fishery. *Inconsequential actions waste resources and erode credibility in the management process.* Delays in implementation can lead to ecosystem impacts requiring more severe actions over an extended time.

In any consideration of scientific uncertainty, there will be discussions of information needs. Research should be prioritized to address management needs, and focused on areas that will improve management performance through reductions in uncertainty. Short- and long-term priorities should be recognized, with particular attention to ecosystem effects as they tend to be longer term in their scope and impact.

> *"When uncertainty is not considered explicitly, sustainability is undermined."*

While any fishery management activity requires caution and reasoned planning for contingencies, greater caution is needed to account for uncertainty in rebuilding fisheries. The first priority is to recover these resources. Therefore, the uncertainty buffer between management targets and limits in depleted (and/or rebuilding) fisheries needs to be increased over that in well managed fisheries. Similarly, developing fisheries where information is very limited must be exploited with caution and therefore require larger buffers with frequent evaluation before further development is allowed.

When uncertainty is not considered explicitly, sustainability is undermined. When Total Allowable Catch decisions are made based on overly optimistic expectations for the resource—for instance recruitment—or assumptions that management measures will be implemented without error, then the status of the resource inevitably deteriorates. Disregarding uncertainty in the scientific advice can also have this effect. If meaningful management actions aimed at responding to unforeseen events are delayed, then the resource will continue to be impacted. To plan for contingencies, mechanisms for regulatory implementation should be established ahead of time and appropriate buffers should be utilized to assure that management is not ad hoc and operating in a crisis mode. Effective planning for uncertainty will include a mechanism for accountability. This will ensure that as a fishery improves its performance and uncertainties (and risk) are reduced, positive activities will be reinforced.

3.5 DEVELOPMENT OF SCIENTIFIC ADVICE AND ITS USE IN THE MANAGEMENT PROCESS

Best Practices Summary

Best practices require collection of enough scientific information to respond to the needs of the management system. The scientific advisory process in place must: 1) draw on current methodologies for data collection and generation, 2) be responsive to management needs, 3) be open to new information with an independent peer review process in place, 4) allow the addition of new perspectives, and 5) provide detailed analyses of sources of uncertainty.

Fisheries management planning, implementation, and monitoring are dependent on scientific advice to establish resource conditions, the likelihood of particular tactics achieving management goals, and the results of management efforts. While scientific advice is only one component of the input for management, it is the basis, in both law and practice, of sound management. Other significant components include goals and values, public input, and legal and technical advice.

The process of obtaining scientific advice for management should be transparent, credible, and timely, using the best information available. There are, in particular, some new procedural requirements in the United States regarding the scientific process. The 2006 reauthorization of the Magnuson Stevens Fishery Conservation and Management Act (MSFCMA) requires Fishery Management Councils to:

> *"… develop, in conjunction with the scientific and statistical committee, multi-year research priorities for fisheries, fisheries interactions, habitats, and other areas of research that are necessary for management purposes, that shall— (A) establish priorities for 5-year periods; (B) be updated as necessary; and (C) be submitted to the Secretary and the regional science centers of the National Marine Fisheries Service for their consideration in developing research priorities and budgets for the region of the Council."*

Currently, there are well-developed scientific advisory processes for fisheries around the United States and internationally, such as the International Council for the Exploration of the Sea. However, in many cases, the focus is primarily on target resources and management systems that may be inconsistent in incorporating science advice into policy. Most assessments produced within the advisory process are peer reviewed, but many outside analyses that may be given weight by policy makers, such as the U.S. regional fisheries councils, do not go through independent peer review. For a variety of reasons, including accepted practices in many regions and resource limitations, new analyses, and particularly new results, are slow to be adopted in many fisheries.

Science program costs can represent a significant percent of the overall cost of the management system (e.g. O'Boyle and Zwanenburg, 1997), but they are not limitless. It is important to have a process that allocates funding to studies where they will have the most benefit. This is becoming an even more urgent issue with the emergence of ecosystem-based management (EBM). Without a formal means to prioritize needs, science resources could be spread too thin.

Best Practices for the Development of Scientific Advice

- Scientific advice should be consistent, peer reviewed, and transparent.
- Incorporate the best current methodology and data into the advisory process for evaluating the status, trends, and impacts of fishing on target and non-target stocks; environmental impacts of fishing; and the effects of external (to the fishery) factors on the marine resources under management.
- Generate scientific advice in a way that is responsive to management needs by addressing management questions directly, to the extent possible, and by providing the most complete picture possible of the projected impact of management strategies on the ecosystem as a whole.
- Make the process of incorporating scientific advice open to new information, methodologies, and alternative analyses, and ensure an equivalent level of independent peer review, whatever the source. Analyses that have not been peer reviewed should be given lesser weight in decision-making, but the process should not give greater weight to standard procedure without fairly considering alternative approaches.

- Periodically add new people, expertise, and perspectives to the advisory process, including review panels, to ensure diversity of perspectives, openness to new approaches, and objectivity.
- Analyze the impacts of uncertainty from various sources, including model, measurement, environmental, and implementation uncertainties. Advice should clearly indicate well-supported and less well-supported conclusions based on these analyses.

Description and Examples of Best Practices for the Development of Scientific Advice

- The scientific advisory process in the Northeast United States illustrates good practices in many respects, with a regular peer-review process, broad participation from scientists around the region, and a structure that allows review of external analyses when they are presented (NEFSC, 2007). Most other regions of the country now utilize a similar stock assessment review process.

"Effective fisheries management is largely dependant on accurate, complete, and timely data."

Although data collection is usually considered the management authority's responsibility, users of the resource, both commercial and recreational, collect and are responsible for much of the data used in assessments. It should be a condition of access to the resource that data are timely and accurately reported. The data collection systems must be consistent across fisheries. For example:

- In the Alaska groundfish fishery, the fishing cooperatives take the responsibility for meeting governmental requirements for the accuracy and timeliness of data reporting, improving data reliability and reducing costs.
- In the Canadian Maritimes, data reporting is a strict requirement of landing. A certified weigh master meets each vessel, by personal arrangement, at the point of landing, and submits data to the management authority within 24 hours. Landing is prohibited without a weigh master (O'Boyle and Annand, 1994).

Potential/Existing Problems for the Development of Scientific Advice

Effective fisheries management is largely dependant on accurate, complete, and timely data. For many fisheries, such information is not available, and data collection methods across sectors and fisheries are inconsistent. In many cases, baseline information is absent, forcing management authorities to default to a less efficient management regime because of high uncertainty in the data. Poor data resources may also force managers to group stocks into assemblages that consequently increase the risk of overexploiting more vulnerable species. While status information is available for many target stocks in most regions, time and financial constraints often control the frequency and completeness of assessment updates. Information availability, along with the translation of available information, limits options for management authorities.

Even scientific advisory programs without such systematic challenges are typically not fully considering the broader impacts of fisheries and other human activities on marine ecosystems on a regular basis. There are still major data barriers to obtaining improved scientific advice, including the difficulty of collecting information on non-target species and a lack of timeliness for data and analyses. Data from other sectors of human activity such as water quality, coastal development, or habitat modification are not readily available, nor are integrative models of the impacts of these activities.

3.6 ECOSYSTEM-BASED FISHERIES MANAGEMENT

Best Practices Summary

Best practices for managing broader ecosystem level effects of fishing must include consideration of the structure and function of marine ecosystems to ensure that those functions are maintained. Cumulative impacts and the connections between ecosystem elements, including food web structure, must be explicitly considered. Productive habitats should be protected, and the broader impacts of fishing through habitat destruction and bycatch should be minimized. An ecosystem wide strategy should be developed and implemented for every marine ecosystem and its fisheries.

Fisheries managers are adopting a new approach that goes well beyond policies aimed at simply managing the yield from a small set of target species. Ecosystem-based fisheries management (EBFM), which is gaining wider acceptance, goes much further to account for ecological as well as socioeconomic factors affecting fisheries. EBFM provides for geographically specific, holistic resource management of habitats, target and non-target species, and ecosystem level effects of fishing such as food web impacts. EBFM should be incorporated into existing management regimes as well as developing management plans.

"Ecosystem-based fishery management demands a shift in management priorities, with highest priority given to maintaining the integrity of ecosystem structure, function, and processes, recognizing that robust fisheries depend on healthy marine ecosystems."

Best practices for Ecosystem-Based Management

Best practices for the development of ecosystem-based management for fisheries include the following elements:

- Develop strategies to control cumulative impacts of fisheries on each marine ecosystem by:
  - Basing decisions on ecological footprints of fisheries in a region
  - Using ecosystem level indicators, reference points, and targets such as biodiversity, trophic structure, and habitat complexity
  - Minimizing non-target species impacts by setting specific progressive bycatch reduction goals.
  - Eliminating, to the extent possible, impacts on vulnerable or endangered species to avoid any possibility that the fishery is preventing their recovery.
  - Relating habitat attributes to resource productivity and minimizing habitat impacts
  - Accounting for trophic interactions and food web structure in setting harvest limits

- Develop explicit spatial management strategies by:
  - Defining ecological boundaries for management areas
  - Protecting highly vulnerable and ecologically critical habitats
  - Providing a framework for allocation decisions with respect to habitat and ecosystem level impacts
  - Using gear modification and area closures as tools to reduce ecosystem level impacts
  - Designating a system of habitat reference areas that receive little or no fishing impact, to serve as a hedge against uncertainty

Description and Examples of Best Practices of Ecosystem-Based Management

Ecosystem-based fishery management demands a shift in management priorities, with highest priority given to maintaining the integrity of ecosystem structure, function, and processes, recognizing that robust fisheries depend on healthy marine ecosystems. The main elements include: 1) avoiding the degradation of ecosystems, 2) minimizing the risk of irreversible change, 3) obtaining long-term socio-economic benefits from fishing, and 4) generating knowledge and adopting a robust, precautionary approach to account for uncertainty (Pikitch et al., 2004).

To do this, EBFM explicitly considers the connections between species and habitats within the ecosystem, as well as the potentially cumulative impacts from fishing and other human activities on an ecosystem. Therefore, the management plan must consider the full structure and function of an ecosystem, not just a few species, as if they were disconnected from each other. For example, forage species such as herring or sand lance serve a key role in the productivity of higher trophic level species such as cod or tuna in the northeast shelf ecosystem. Conversely, higher trophic level species including large pelagic predators can exert top-down control on some ecosystem functions. Maintaining these connections is imperative to the sustainability of the system, and fishing can impact these connections and functions (NRC, 2006a). In effect, this means that best practices will consider more than the yield of a few principal species. Rather, management strategies will explicitly consider the broader impacts of fishing in particular areas, with specific gears targeting various species and, based on indicators of overall ecosystem productivity, manage fishing impacts within the area across all fisheries.

Aside from more specialized fisheries management, the general concept of ecosystem-based management (EBM) is rapidly developing. (Rosenberg and MacLeod, 2005). Under an EBM system, fishery management is linked to management of human activities other than fishing that also impact marine ecosystem productivity, such as wetland destruction, coastal development, water quality impacts, transportation, sand and gravel mining, and energy production. Such linkage is aimed at achieving the common goal of maintaining functioning, healthy marine ecosystems that can continue to support sustainable fisheries as well as other activities important to society.

The implementation of EBFM and EBM is in its infancy in the United States and elsewhere, but examples of early practice are available. A suite of California laws has laid the foundation for a best practice in EBFM at the state level. Like the federal Sustainable Fisheries Act, California's Marine Life Management Act (MLMA) requires development of fishery management plans, and it contains provisions to end overfishing, reduce bycatch, and protect habitat. However, the act also includes several important ecosystem-oriented features:

- The MLMA broadens the goals of management to include sustaining marine life populations, instead of achieving "maximum" sustainable yield for actively managed species only.
- Fishery management plans must contain area-based management strategies, such as marine protected areas and index areas, to help sustain the full range of affected species as well as a more natural age range. California is currently designing those areas pursuant to the companion Marine Life Protection Act, which requires networks of marine reserves and other protected areas throughout state waters for a variety of purposes, including biodiversity and habitat protection. A network is now in place for one of four regions of the state, and the process is scheduled for completion in 2011.
- The MLMA calls for very conservative catch rates in data-poor and data-moderate situations, and for increasing reductions in catch as population abundance declines (Weber and Heneman, 2007).

This system is a work in progress; its most significant limitation is lack of funds for developing new management plans and conducting stock assessments that could move species out of the data-poor category. The state is working to address that problem with help from a third law, the California Ocean Protection Act. This act established an inter-agency coordinating council and an ocean protection fund that supports cooperative research and innovative science and management projects.

Other U.S. examples of proactive habitat protection include:

- In the North Pacific, large areas of cold-water corals have been closed to all fishing activities.
- Along the Pacific coast, the Coastal Pelagics Fishery Management Plan has a conservation policy limiting the fishery to 25% of maximum sustainable yield, which was established because of the importance of coastal pelagic species as forage for larger predators.
- In several fishery management plans all around the country, Habitat Areas of Particular Concern have been designated.

Internationally, ecosystem-based fishery management strategies are developing in many areas. A notable example of best practice is fisheries policy in Australia, where the Australian Fishery Managers Forum has adopted EBFM as its guiding approach for future management activities (Smith et al., 2007).

Potential/Existing Problems with Ecosystem-Based Management

Many fisheries in the United States are still managed primarily for maximum yield of target species, and integration with management of other human activities beyond fishing is rare. While there are some emerging examples of ecosystem-based management, none of these plans have been fully implemented or embraced by the managers or their constituents. While habitat and bycatch impacts of fishing are established in the fisheries management context, the interaction of fisheries management with coastal development, water quality, transportation, and energy production is still, too often, on an ad hoc basis.

4.1 CONTROL OF FISHING MORTALITY

Best Practices Summary

Best practices for controlling fishing mortality in any fishery can only be achieved using a combination of input and output controls that account for all portions of the fishing mortality. Real-time data collection allows management to make appropriate decisions regarding catch limits, avoiding after the fact regulations enforcement. Monitoring all species and stocks, at least for catch and size composition, is essential, and more vulnerable stocks as well as protected or endangered species merit special attention.

Controlling the overall fishing mortality rate (F) in a region, or the proportion of the stock removed by the fishery, is a fundamental aspect of any fishery management plan. When establishing the resource allocation management plans that will govern that mortality rate, many secondary goals may be considered, including maintaining fishing communities and enhancing the safety of fishing operations. Indeed, the U.S. Magnuson Stevens Fishery Conservation and Management Act requires such consideration. However, none of these goals can be achieved if the primary goals of avoiding overexploitation and maintaining a sustainable fishery are not met.

The overall mortality rate for a particular stock, including both landings and other losses, must be controlled for a fishery to be sustainable, according to the theory of fishing and a review of the actual results for fisheries around the world. A recent review of rebuilding plans for U.S. fisheries clearly indicates that stocks that have been overexploited and depleted do not recover without sustained reductions in fishing mortality rates (Rosenberg et al., 2006). This was further supported in a review of factors associated with successful stock recovery plans in the United States, Australia, New Zealand, and Europe. Case studies showed that a significant and rapid reduction in fishing mortality at the start of a recovery plan was a key factor in the success of the stock's ability to recover (Wakeford et al., 2007).

"The overall mortality rate for a particular stock, including both landings and other losses, must be controlled for a fishery to be sustainable, according to the theory of fishing and a review of the actual results for fisheries around the world."

Best Practices for Controlling Fishing Mortality

- Control fishing mortality rate directly through catch and effort limits on target and non-target species in all sectors of the fishery, including commercial, recreational, artisanal, and ranching activities. Combining input controls with output controls is the most effective buffer against uncertainty. Not all controls must be regulatory.

- Employ real-time data collection for all sectors and for all species in the catch, not just landings. Size composition data for all species in the catch must be sampled and data must be verified and available as quickly as possible to ensure effective monitoring.
- Manage assemblages of species cautiously when only a single set of measures is in place, because different species may have very different vulnerabilities to fishing pressure. To the extent possible, fishing impacts on each stock or species should be evaluated separately, though a full assessment is not essential.
- Prohibit all catch on protected or endangered species and minimize catch of less productive, highly vulnerable species.
- Annual catch limits, as an output control, should take into account risk and level of information available for each species and serve as a performance measure for each stock and fishery (see Rosenberg et al. 2007).

Description and Examples of Best Practices for Controlling Fishing Mortality

Tactically, fishing mortality can be controlled either by: 1) limiting the *inputs* to the fishery, such as restricting fishing areas, regulating the gear used, or limiting fishing effort; or 2) by limiting the *outputs* from the fishery, which include landings, discards, and any other incidental death. Nonetheless, both inputs and outputs are imperfect and uncertain to a degree in all managed fisheries because the actual inputs and outputs that determine fishing mortality cannot be perfectly known or controlled. For example, even if input controls are part of the management strategy, the actual fishing effort that generates a specific amount of fishing mortality is imperfectly known. Similarly, the number of fish killed in the course of fishing is not directly observable, meaning the output from the fishery is not perfectly known.

Despite this uncertainty, input and output controls are critical in fishery management because of the importance of controlling the fishing mortality rate, and because of the uncertainty, input and output controls are expected to work better in combination than either would alone (Stefansson and Rosenberg, 2005; 2006). Input controls affect the amount of pressure on the resource and output controls reflect fishery impact on the resource. Both are sensible tactics for ensuring that the fishery is sustainably exploited. Section 104 (a)(15) of the 2007 Magnuson-Stevens Reauthorization Act (MSRA) establishes the need for "a mechanism for specifying annual catch limits in the plan (including a multiyear plan), implementing regulations, or annual specifications, at a level such that overfishing does not occur in the fishery, including measures to ensure accountability". This provision will establish catch limits as performance measures for fishery management for all fisheries under federal management.

The following examples illustrate best practices in the control of overall fishing mortality rates:

- With Alaska groundfish, monitoring outputs for all sectors of the commercial fishery is accomplished through a fishery cooperative system set up under the American Fisheries Act. The monitoring includes the use of onboard observers to ensure bycatch limits are not exceeded, and recreational fisheries are not a factor. Inputs for the fishery are controlled through dedicated access privileges (DAPs), gear restrictions and sector allocations, and large closed areas to protect ecologically sensitive areas (NOAA Fisheries, 2007). It should be noted that because of the dedicated access privilege system, inputs control is non-regulatory because it is handled through the cooperatives, maximizing efficiency and profit to the benefit of the cooperative members as a whole. In this fishery, all major sources of fishing mortality are controlled and monitored. Of course, sustainability of this fishery also depends on having an appropriately precautionary catch limit.

- In the Surf Clam and Ocean Quahog fishery in the Mid-Atlantic region of the United States, dredge gear use is expected to limit bycatch, but bycatch has not been fully monitored. Nevertheless, the output in terms of landings is fully controlled through a quota setting and allocation system with timely monitoring that guides closures when output limits are reached. The output control system is effective in this case because the allocation is through dedicated access privileges, which also result in non-regulatory input controls from the industry to improve efficiency and profitability.
- The best practice for input controls is used in the Northeast Peak of George's Bank, a limited access area shared with Canada. Within this area, there are limits on fishing time, important area closures for habitat protection, and limited access to some areas of high fish concentrations. Monitoring with satellite systems is required and there is an overall limit on catch in this area. However, the Northeast Peak area does not contain a unit stock, so the overall fishing mortality rate is also affected by fishing outside this restricted area.

"Control is incomplete if the commercial fishery is regulated by limited access and fishing time limitations, but the recreational fishery is not, or if some types of vessels are restricted from closed areas, but others are not."

Potential/Existing Problems for Controlling Fishing Mortality

To successfully accomplish fishery goals using management tactics, it is crucial to control all substantial sources of inputs and to monitor and control all outputs. Incomplete control can be a result of leaving out portions of the fishery when regulating effort or monitoring output. With input controls, it is essential that all sectors are included. *Control is incomplete if the commercial fishery is regulated by limited access and fishing time limitations, but the recreational fishery is not, or if some types of vessels are restricted from closed areas, but others are not.* In particular, if there is no limit on capacity or participation, it is extraordinarily difficult to control overall fishing mortality. Of course, each sector of the fishery does not have to use the same control tactics, as long as the input from that sector is limited in some way and can be adjusted to prevent overexploitation. In other cases, input controls are in place, but vessel efficiency continually improves, or the controls work for some species but not for others. The result is a spiraling race to tighten the controls to catch up to innovation and retargeting in the fishery, such as has occurred in the Northeast groundfish fishery.

Similarly, for output controls, if bycatch or discard is not counted against catch limitations, or if some sectors are only limited by trip or bag limits, but the number of trips or bags is not limited, control is incomplete and overexploitation can occur. The best management tactics ensure that there are no major parts of a fishery that are uncontrolled for input and output.

4.1.1 REBUILDING DEPLETED FISHERIES

Best Practices Summary

For rebuilding to progress as intended with stocks recovering from once depleted situations, managers must be conservative and act immediately when a depleted resource is identified. Best practices in the development and implementation of rebuilding plans and associated regulations should include: 1) immediate establishment of appropriate interim measures, 2) cessation of overfishing, 3) increased monitoring and surveillance, 4) establishment of timeframes that are as short as possible while still allowing for recovery, 5) adoption of performance metrics for fishing mortality and biomass with regulatory adjustments to improve stock condition, and 6) conservative decision making with respect to uncertainties in depleted resources.

Despite the clarity of U.S fisheries law and the renewed mandates in the Magnuson-Stevens Reauthorization Act to prevent and end overfishing and rebuild stocks, many resources remain depleted. In addition, rebuilding plans are inadequate and there is limited information to support successful recovery of the stock. Above all, control of fishing mortality is essential for any level of recovery to proceed. In too many instances, rebuilding plans have allowed overfishing to continue (Rosenberg et al., 2006). While increases in biomass may occur even as overfishing continues, full recovery is highly unlikely unless reference levels are extremely conservative (Wiedenmann and Mangel, 2006). Lag time in plan implementation, which is common, strongly influences the success of stock recovery. Management actions that restrict removal of the resource should therefore be implemented immediately once there is notification that stock status has deteriorated.

"Successful rebuilding in most cases has been the direct result of a quick and substantial reduction in fishing mortality rates in response to deteriorating stock status."

Best Practices for Rebuilding Depleted Fisheries

- Implement rebuilding plans as quickly as possible once an overfished stock is identified. Overfishing should be ended as soon as it is detected, which may demand strong interim measures while full plans are developed. Reductions in fishing mortality must be substantial—generally below the fishing mortality target for Maximum Sustainable Yield (FMSY)— and rapid.
- Increase monitoring and compliance enforcement for stocks under rebuilding. The rebuilding plan to achieve this imperative goal must enable rapid response to the changing condition of stocks to ensure that rebuilding occurs.
- Make rebuilding plan timeframes as short as possible following immediate cessation of overfishing. Avoid phasing in reductions, which inevitably requires more severe restrictions later on, greatly prolonging actual stock rebuilding.
- Establish standards for fishing mortality and biomass to monitor plan performance and make rapid adjustments to improve stock conditions. Include binding milestones that trigger action in every recovery plan.

- Take greater caution regarding uncertainty for depleted resources, erring on the side of conservation in decision making to recover the resource.
- Include biomass, age or size structure, and spatial distribution of the stock to sustainable levels in the performance standards for rebuilding.

Descriptions and Examples of Best Practices for Rebuilding

Successful rebuilding in most cases has been the direct result of a quick and substantial reduction in fishing mortality rates in response to deteriorating stock status. But in too many instances, effort is not reduced immediately, prolonging recovery and forcing much larger eventual reductions. The following examples illustrate how stocks responded positively to immediate and effective cuts in fishing mortality rates:

- Following a period of North Atlantic swordfish stock overexploitation, catches were reduced by 45% in the late 1990s to prevent further degradation. Subsequently, in 1999, an international rebuilding program was established that called for additional reductions in fishing quotas for International Commission for the Conservation of Atlantic Tunas (ICCAT) member countries and a requirement of accounting for dead discards in each country's Total Allowable Catch. These measures resulted in a nearly rebuilt resource; North Atlantic swordfish are presently estimated at 99% of the biomass required to produce Maximum Sustainable Yield, and 14% below the maximum fishing mortality threshold (ICCAT, 2006).
- Strict input controls have led to considerable improvement in a depleted Georges Bank haddock stock. The stock fell to record low levels in the 1990s and management responded by closing three areas on Georges Bank in 1994 (NEFMC, 1994). These closed areas, combined with a moratorium on permits and days-at-sea restrictions, led to a considerable drop of more than half in fishing mortality, allowing for subsequent increases in biomass. Biomass has increased substantially since the 1990s and the 2003 year class was the largest on record (TRAC, 2007).
- Wakeford et al. (2007), in a review of North American, European and Australasian experiences with recovery, identified rapid and large reductions in catches at the start of the recovery process. Biological characteristics of the species were key in determining the ability of populations to recover. This is well illustrated by the current failure of the North Sea cod recovery program, which allowed for only gradual reductions in catch and has only recently, 4 years after its implementation, managed to reduce fishing mortality to the levels considered necessary for a recovery (ICES, 2008).

A successful rebuilding plan will also include mechanisms to monitor stock status regularly and adjust management accordingly.

For example:

- The response to overfishing of the Gulf of Mexico king mackerel was a management system, instituted through a Total Allowable Catch (TAC) system, in which allocations were given to both recreational and commercial fisheries. Implementation of the TACs was achieved through bag limits, trip limits, size limits, and other actions that have been adjusted over the years (Powers, 1993; 1996; Legault et al., 2002). While implementation has not been perfect, actions have been consistent and stringent, resulting in successful rebuilding.

Potential/Existing Problems with Rebuilding

For many stocks there remain large gaps in information, creating uncertainties in science (stock status) and effectiveness of management. Wiedenmann and Mangel (2006) found that rebuilding can be delayed or even prevented when management fails to accurately account for uncertainty, allows for prolonged overfishing, and/or fails to consider the implications of a skewed age distribution when assessing a population's status. Insufficient accounting for uncertainty in stock assessments leads to inaccurate predictions. Coupled with the tendency of managers to adopt rebuilding plans that satisfy the minimal requirements of the law, this has limited the overall success of federal rebuilding programs (Rosenberg et al. 2006).

4.1.2 RECREATIONAL FISHERIES

> **Best Practices Summary**
>
> Recreational fishing can comprise a substantial portion of the catch in many fisheries. Best practices must include overall control on the fishing mortality on all species resulting from recreational fishing as well as commercial fishing. A feedback system should be in place that ensures performance in the fishery and rewards participants accordingly.

Recreational fishing has become a large component of many fisheries in the United States on both coasts (Coleman et al., 2004). In some cases the recreational catch for a particular area may be half or more of the total removals from the fishery, and an even greater share of the economic value. In state waters, within three miles of the coast, recreational fisheries may be even more dominant. While this fishing activity is for recreation, much of the "recreational" catch may be taken on chartered boats or so-called head boats, and these vessels are important coastal businesses. The management measures used for recreational fisheries are often simple input controls such as bag limits, or seasonal closings, but the overall number of participants is not controlled. Management plans must control the recreational portion of the fishery to manage resources sustainably.

Best Practices for Controlling Recreational Fisheries

- Manage recreational fisheries according to the same principles as commercial fisheries (control of fishing mortality, access control, data collection and monitoring, bycatch control, and avoidance of ecosystem impacts). This means that access must be controlled either by restricting the number of participants or by restricting the times and/or areas for access, and closing a recreational fishery must be an option if the overall output exceeds the allocation. In addition, minimize bycatch using gear modifications as needed, restrict fishing in sensitive habitat areas, and require more complete participant reporting on catch and effort.
- Design performance measures for the output of recreational fisheries that allow accountability for the effectiveness of the management plan.
- Monitor, inspect, and control recreational fisheries, as these are essential management tools for many stocks.

Description and Examples of Controlling Recreational Fisheries

The best practices for controlling recreational fisheries depend upon the ability to control the number of fishing trips by anglers. There are currently over 70 million fishing trips per year by recreational anglers in the United States, according to conservative estimates (NMFS, 2007). Thus, even if individual catches are relatively small, the impact on fishery resources can be large. For this reason, as well as for straightforward monitoring purposes, several reviews have recommended mandatory licensing of marine recreational fishermen (U.S. Commission on Ocean Policy, 2004). The recreational halibut fishery in Alaska has attempted to limit access using a specific enforceable allocation to the recreational sector as an output control. This is a reasonable restriction, considering that in the United States both season limits and licensing requirements are used for freshwater fisheries as well as most, if not all, hunting.

Best practices are illustrated by the regulations imposed on the recreational fishing sector in Denmark, which is managed through a combination of input and output controls that successfully limit fishing mortality through a license system, minimum size controls, and closed seasons. Revenue from the licenses is used for research, stocking, and habitat restoration.

- About 300,000 people are engaged in recreational fishing activities in the territorial sea of Denmark.
- Those between the ages of 18 and 65 are required to purchase an annual, weekly, or daily state license that permits the holder to use rod and reel gear.
- The license fee is used for fish stocking projects, research on stock enhancement, ensuring stock rebuilding, and fish habitat restoration and conservation.
- Regulations imposed on the fishermen limit gear type and use. Hobby fishing, involving passive fishing tackle such as hook and line, nets, and traps, does not require a license and is restricted to residents and non-residential foreigners working in Denmark who are at least 12 years old.
- Recreational fishermen are required to comply with minimum fish sizes and obey closed seasons that coincide with spawning activities of certain species.
- All non-commercial fishermen and any unregistered fishermen—both anglers and net and trap fishermen—are prohibited from selling any of their catch (The Danish Directorate of Fisheries, 2007).

Potential/Existing Problems for Controlling Recreational Fisheries

A major issue arising from recreational fisheries is the incomplete control of fishing mortality. There are no direct limitations on access and the output controls, often in the form of bag limits, do not necessarily restrict output. This lack of full control of mortality is evidenced by the fact that the allocated recreational quotas are often exceeded, as has been the case with the red snapper fishery in the Gulf of Mexico and the summer flounder fishery in the Mid-Atlantic.

4.1.3 NEWLY DEVELOPING FISHERIES

Best Practices Summary
Very conservative input and output controls should be used in newly developing fisheries, and these controls should only be relaxed as new information justifying expansion is substantiated. In addition, clear and complete monitoring of input and output from the fishery should be in place, and there should be procedures to allow rapid adjustment of tactics to respond to new information.

Management tactics for fisheries involving newly marketable or obtainable species, or those that are in new fishing areas, deserve special attention. *Modern fisheries can rapidly develop exploitation capacity well before information is available to put management plans in place.*

Best Practices for Newly Developing Fisheries

- Manage all fisheries to some degree.
- Proceed slowly with newly developed fisheries on both the management and industry sides until detailed fishery impact assessments are available.
- Clearly delineate access privileges and responsibilities for a fishery from the outset, with clear rules for new entrants, and stringent data reporting requirements.

Description and Examples of Best Practices for Newly Developing Fisheries

It is essential to control newly developing fisheries from the outset. This is particularly important because many new fisheries are developing in deep water where, in general, species have low productivity rates and can easily be overfished. This low productivity can be masked by very high initial catch rates and catches because the fishery may be operating on accumulated stock from many generations. Once this initial biomass is fished down, if production is low, it will take a very long time to recover. This has been the situation with fisheries such as some rockfish on the West Coast, and sharks nationally and internationally.

Best practices are illustrated in the development of the Atka mackerel fishery in Alaska, which included a limited entry system, output controls, and monitoring to ensure that the fishery did not expand too rapidly (Alaska Department of Fish and Game, 2007).

"Modern fisheries can rapidly develop exploitation capacity well before information is available to put management plans in place."

Potential/Existing Problems for Newly Developed Fisheries

Effort can develop very rapidly in a new fishery as soon as the product is accepted in the market. Orange roughy fisheries on seamounts are a clear example of this problem with high effort leading to rapid stock depletion and fishing out of areas—without any knowledge of the ecological consequences of doing so. This build up of effort becomes very hard to manage once a fishery is established as there will be political and economic pressure to allow the vessels to continue to fish on depleted stocks or on other new stocks. The "gold rush" potential for new resources can leave sustainability concerns unaddressed.

4.2 SELECTIVITY AND BYCATCH MINIMIZATION

Best Practices Summary

Best practices to reduce bycatch and environmental impacts include strong bycatch limits that provide incentives to change fishing practices, incentives to develop new technology for bycatch reduction and comprehensive monitoring, and inspection programs to monitor progress.

The incidental capture of juveniles and non-target species caused by many fishing methods can be a major component of fishing mortality. Fishing can also damage vulnerable habitats and disrupt ecosystem structure and function, though the severity and type of environmental impacts varies greatly between fisheries and according to the fishing techniques used. Technological advancements are designed to ameliorate these impacts to a resource and the associated habitats and ecosystem. There has been considerable developmental work on impact mitigation, with particular focus on the size selectivity of fishing gears by mesh size manipulation. These measures have been used to protect juvenile fish in overexploited stocks, but widespread use of this technology has not halted the decline of many fish stocks.

Over the last decade, more and more management plans have included stricter regulations on fishermen to minimize impacts on target and bycatch species. Debates on improved gear selectivity, and the need to reduce unwanted bycatch and environmental impacts are common among industry, gear technologists, scientists, and managers. However, there are conflicting attitudes on the success or failure of gear modifications within the regulatory framework. Fishermen and gear technologists largely believe that practical technical gear measures are critical to improving the state of fish stocks. Many scientists and managers are more skeptical, however, given that such measures are too easily and openly circumvented to have any real benefit. Additionally, impacts on the ecosystem are difficult to quantify and there is often a time lag before the impacts are measurable.

Despite effectiveness concerns, there has been widespread and extensive research over many years into gear technology, and in particular gear selectivity. While this research has identified the basic concepts of how to improve selectivity, minimize bycatch, or reduce environmental impact, there are still major gaps in the data and uptake by fishermen has been slow. In some fisheries bycatch and irreversible habitat destruction by fishing gears remain extensive. Therefore, the 2006 Magnuson-Steven Reauthorization Act (MSRA) has established the development of a Bycatch Reduction Engineering Program, to begin no later than one year after enactment of the Act. The Program will use "the best scientific information available …including grants [as a part of the program], to develop technological devices and other conservation engineering changes designed to minimize bycatch, seabird interactions, bycatch mortality, and post-release mortality in federally managed fisheries".

"The incidental capture of juveniles and non-target species caused by many fishing methods can be a major component of fishing mortality."

Best Practices for Selectivity and Bycatch Minimization

- Include progressively more stringent standards for minimizing the allowable bycatch and discarding of all species in bycatch reduction programs.
- Improve gear selectivity and controls on overall fishery inputs to reduce bycatch.
- Adopt strict, continuous monitoring of overall bycatch levels to ensure verification and enforcement.
- Promote more selective fishing gear and fishing practices through a fishery's incentive structure, for example by restricting access to certain areas unless low impact gear is used.
- Promote technology development to improve methodologies for reducing bycatch and environmental impacts.

Description and Examples of Best Practices of Selectivity and Bycatch Minimization

The environmental impacts of fishing alter ecosystem structure and function that is essential for productive resources. Such impacts are controlled by both the level of fishing effort and the ways in which effort is applied, such as the gear used and the area fished. Management structure and incentives provided for fishermen can influence the creation of improved technologies that are less environmentally damaging. With competitive fishing, the main demand is for technology that increases the fishermen' ability to take larger shares of the catch and reduce costs. Stricter measures to reduce environmental damage such as Strategic Environmental Assessments can generate more interest in developing environmentally friendly gear to reduce restrictions and increase revenues.

The public sector has developed most environmental impact mitigation technologies, which have been implemented by managers on many occasions in recent decades. Examples of successful technologies include:

- Longline fisheries have reduced incidental catches of birds through the development of streamers, sinker weights, and setting tubes.
- Back-down maneuvers used in combination with fine mesh webbing inserts referred to as "Medina panels" are credited with resolving cetacean bycatch in many purse-seine fisheries.
- Pingers, grids, and modified sieve nets are under development to reduce the incidental capture of mammals in some pelagic and static gear fisheries.

Successful technologies to reduce benthic impacts and damage to vulnerable habitats are probably the least developed in the field of impact mitigation. However, fairly simple technologies can reduce the impact of lost and abandoned fishing gears, including retrieval programs that address the causes of loss and abandonment, and biodegradable release mechanisms on fish traps and pots.

Considerable amounts of juvenile bycatch strongly impact the future potential of a resource. The use of bycatch limits (or caps), with future targets that decline over time, can alleviate a large portion of the problem. However, the limits must be coupled with industry incentive and implementation of bycatch reduction methods. The MSRA established that a Council or the Secretary may institute "a system of incentives to reduce total bycatch and seabird interactions, amounts, bycatch rates, and post-release mortality in fisheries…including:

1. Measures to incorporate bycatch into quotas, including the establishment of collective or individual bycatch quotas
2. Measures to promote the use of gear with verifiable and monitored low bycatch and seabird interactions and rates
3. Measures that, based on the best scientific information available, will reduce bycatch and seabird interactions, bycatch mortality, post-release mortality, or regulatory discards in the fishery."

Few fisheries presently have hard bycatch caps, and without such a cap, there is little incentive for fishermen to avoid bycatch.

Specific examples of best practices in the United States include:

- In the New England groundfish fishery, using pinger technology has reduced marine mammal bycatch.
- In Alaska and Hawaii, using streamers and other methods has reduced seabird bycatch.
- In the Bering Sea groundfish fishery, an annual cap on Pacific salmon species is leading the pollock fishery to find more effective ways to harvest pollock while avoiding salmon bycatch (DOC, 2000). Retention of Pacific salmon is prohibited, so when the bycatch cap is reached, a large area of the pollock grounds in the southeastern Bering Sea known as the Chinook Salmon Savings Area (CSSA) is closed. In this case, the established bycatch caps, along with a program to reduce the caps over time, are pushing the industry to improve its performance in order to maintain the targeted catch. However, sometime after the establishment of the area in 1990, managers discovered that bycatch outside of the CSSA was higher than that within the area, when open. The industry, operating as a co-op, developed a voluntary rolling hotspot closure system under the American Fisheries Act of 1999, providing exemption from the CSSA closure. Members of the program share real time information on salmon bycatch rates, which is in turn used to identify bycatch hotspots for the fleet to avoid (NPFMC, 2007).

Potential/Existing Problems with Best Practices of Selectivity and Bycatch Minimization

One of the major issues with bycatch reduction and selectivity methods such as those described above is the difficulty of monitoring and enforcement. These techniques have the ability to successfully ameliorate the current problems with bycatch and habitat destruction if properly deployed with responsible use, but can also be undermined easily with little chance of detection by authorities. There is an increasing need to develop a program of incentives for compliance and penalties for non-compliance as a necessary component to any best practices in this area. In many cases, gears exist that provide for their intended purpose. But, the results are likely less than could be achieved with more responsible use and adherence to the rules. However, there should be a continued effort to develop more efficient gears and improve on monitoring and surveillance. Bycatch and discard is still quite high in U.S. fisheries, and monitoring is far from sufficient (Harrington et al., 2005).

5 — MONITORING, CONTROL, AND ENFORCEMENT

5.1 SURVEILLANCE, ENFORCEMENT, AND DATA COLLECTION

Best Practices Summary

Best practices for monitoring and enforcement include comprehensive monitoring of fishing activities through data reporting requirements that are stringently enforced and that must be complied with as a condition of access to the resource. Electronic reporting technology should be used to ensure timeliness in data reporting. Monitoring and enforcement systems should be consistent across fisheries and regions, and data should be made publicly available to the greatest extent possible. Users and the government should jointly fund monitoring and enforcement activities. Sanctions for circumventing the regulations should be severe, including lost access to the resource for major violators.

Fishery management strategies and tactics cannot be effective without extensive monitoring of fishing activities, practices, and performance on an ongoing basis. Monitoring needs to be comprehensive and should provide as much information as possible to ensure that: 1) the system is continually improved, 2) the data can be analyzed by all concerned in a timely manner, and 3) that all stakeholders can engage in the management process.

Whatever the management tactics, sustainability will be undermined if the rules are not followed. Those fishermen trying to make the system work as well as possible must be assured that they will not suffer competition from those who circumvent the rules. Accomplishing this demands that surveillance and enforcement systems be in place. To be sure, some monitoring and surveillance can be conducted by participants, and the burden should not just be on government to obtain data and ensure that participants comply with the rules. Given that all marine resources are held in the public trust, a condition of participation in any fishery, whether recreational or commercial, must be full and timely reporting of inputs and outputs for that fishery, and compliance with all rules and regulations. Since it is a public resource, the data from the fishery should be public as well.

Regulations should be adopted and implemented to establish rules ranging from the use of fishing gear, the quantities of fish that can be legally caught, and the areas and seasons closed to fishing, to the catch information that must be recorded in fishing vessel log-books and in landing declarations. Monitoring and surveillance should aim to deter and detect infringements while encouraging compliance with the rules. The data required from fishing vessels, both recreational and commercial, enable fisheries managers to monitor catch levels and allow inspectors to cross check data from various sources to ensure that no infringements have taken place.

Best Practices for Effective Surveillance and Enforcement

- Monitor all sectors of a fishery across regions and states comprehensively and consistently.
- Establish severe penalties for non-compliance across regions, fisheries and states.
- Make enforcement data publicly available and comparable across regions and fisheries to improve accountability.

- Make electronic reporting the standard for all fishery activities and outputs, with data verified and available as quickly as possible—in days, not months.
- Require that participants in the process provide comprehensive and accurate data as a condition of access to the resource.
- Conduct sampling analyses to determine the best ways to estimate all relevant quantities at an acceptable level of precision, as well as analyses to determine the levels of at-sea monitoring, dockside monitoring, and self reporting needed to achieve overall monitoring goals. Sampling designs should meet the needs of both the science program and enforcement.
- Conduct research and development on monitoring and enforcement technology and data management.

> *"Fishery management strategies and tactics cannot be effective without extensive monitoring of fishing activities, practices, and performance on an ongoing basis."*

Description and Examples for Effective Surveillance and Enforcement

Surveillance and monitoring of fishing in U.S. waters are currently based on several data sources: 1) observers, 2) vessel monitoring systems (VMS), 3) vessel trip reports for commercial vessels and recreational party and charter boats, 4) dockside landings and dealer reporting, 5) the voluntary Marine Recreational Fisheries Statistics Surveys (MRFSS) reporting system for private recreational fishermen, and 6) patrols by states, the National Marine Fisheries Service (NMFS), and the U.S. Coast Guard. Each of these sources has significant limitations.

The ideal monitoring, surveillance, and enforcement regime would:

- Incorporate "real-time" data with comprehensive coverage of fishing activity
- Be based on uniform data
- Employ automatic reporting systems such as VMS and electronic logbooks that fully document fishing activities

The current overall best practices in U.S. fisheries are used in the Alaska groundfish fishery. In Alaska, fishery cooperatives set up under the American Fisheries Act have responsibility for accurate and timely reporting. There is 100% observer coverage on larger vessels and substantial coverage on smaller vessels. Third party companies provide these observers, but the fishing vessels pay for them. Data are timely under the regulations, but data access is still quite restricted and may not be widely available outside of the cooperatives and government for some time after fishing occurs, due to confidentiality rules.

Observer programs, in place in the United States since 1972 (though the National Observer Program was only officially established in 1999), are an invaluable tool for accurate reporting and monitoring of fishery activities. These programs should be analyzed to determine the most effective means of collecting data for comparability across fisheries and regions. There are observers working in 42 commercial fisheries in 6 NMFS regions. Coverage in most regions is limited or absent and coverage on fleets varies greatly, from less than 1% to full coverage (fishery dependant), which makes for great inconsistencies in monitoring across regions. For example, there is 100% coverage in Alaska fishing vessels greater than 125 feet and

30% coverage on vessels 60 to 124 feet, while coverage in the West Coast groundfish fishery is 10 to 20% (National Observer Program, 2007). Babcock, et al. (2003) demonstrated that, for fisheries where there are no endangered or threatened species, coverage of at least 20% is required to generate meaningful information. For fisheries that involve endangered or threatened species, this study recommends at least 50% observer coverage.

The majority of funding for data collection programs, including at-sea observer programs, comes from Congressional appropriations, though industry supplies additional funding in the Alaska groundfish fishery and the West Coast at-sea hake fishery. Typically, programs are underfunded and costly, resulting in limited coverage overall.

Information provided by VMS would prove especially useful in monitoring activities on rebuilding stocks and providing real-time information necessary to ascertain when overfishing is occurring, enabling immediate action. VMS track vessel movements, transmitting locations at regular intervals. Monitoring authorities can use VMS to determine a range of factors including whether a vessel: 1) operates in a prohibited area, 2) holds the necessary licenses and quotas to fish in the relevant area, and 3) has sailed to a port without declaring its landings. VMS can be used to transmit other information securely and quickly by linking to logbook functions. A vessel monitoring system can also be a compliance criterion such that fishing is not allowed unless the system is functioning properly.

Vessel monitoring systems are not universal. In 2000, the total number of U.S. commercial fishing vessels was 70,000 (Hogarth Testimony, 2002). At present, there are approximately 4,000 VMS in use on U.S. commercial fishing vessels, with that number expected to grow to roughly 7,000 by the end of 2009 (Murawski, 2007). Presently, there are roughly 17 million recreational fishermen in the US, and virtually no recreational fishing vessels in U.S. waters employ VMS (Hogarth Testimony, 2002).

Best Practices examples for VMS use include:

- In the Northeast and Mid-Atlantic Sea Scallop fishery, and in the groundfish fishery on the Northeast Peak of George's Bank, the use of VMS is a requirement to participate, and vessels bear the costs of the systems. In these fisheries, VMS data have been used specifically in enforcement cases in recent years as an important addition to Coast Guard surveillance at sea. Unfortunately, the current VMS in the Northeast are not linked to electronic logbooks, nor are their data widely available.

Electronic reporting would allow for efficient real-time catch monitoring for all fisheries. In contrast, vessel trip reports are often not considered accurate or timely by government, participants, and the courts. It is not uncommon for fishermen to testify at public hearings complaining that the logbooks and other data they themselves generate are inaccurate.

With internet access and computers widely available throughout the United States, electronic reporting is feasible and low cost for users in all fisheries. Timely reporting is essential and can be easily accomplished if it is a condition of participation in the fishery, just as requiring safety equipment; vessel registration; licensing; and navigation, communication and other equipment has become standard and accepted practice.
Best Practices for Electronic Submission include:

- In Alaska, observers submit reports electronically on a daily basis. These data, combined with the use of VMS, provide real-time information on actual fishing activities.

Consistency in monitoring needs to begin with standardization of programs and protocols. In addition to observer programs, much information can be attained through dockside monitoring of landings and at-sea monitoring of catches and other activities such as gear use. Dockside monitoring of landings and dealer reports are often paper systems, with much of the data collected in cooperation with states. For some fisheries, it is difficult to obtain even basic fishing effort and landings data given the complications that arise when dealing with a paper system and multiple ports. The American lobster fishery, in which there are inshore and offshore components crossing multiple state boundaries, is one of the most valuable fisheries in the United States. However, because of the lack of coordinated systems, differing rules on confidentiality, and other barriers, even basic landings data are difficult to obtain for this fishery.

In many regions, recreational fishing is responsible for a large share of the catch from some stocks. Tracking this catch is complicated at best, and relies in part on field and phone surveys to collect effort data on recreational fishing activities. One example of this is the voluntary Marine Recreational Fishery Statistics Survey (MRFSS) reporting system, which is deficient because it only provides information on a sub-sample of fishermen and precludes some activities. In a 2006 review, the National Research Council (NRC) concluded that this survey system suffers from serious flaws and does not satisfy the needs of many state, regional, and federal fisheries managers for monitoring fishery output for management purposes (NRC, 2006b).

It is important to note that a substantial fraction of many recreational fishery catches is taken by charter and party boats. These are required to file logbooks in the same way as commercial vessels, but there remain large inconsistencies and gaps in the data collected. Monitoring of the recreational catch could be substantially improved if regulations were effectively enforced to achieve full compliance by charter and party boats.

Another important 2006 legislative action was passage of the Reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act. This included provisions for creating a registry of recreational fishermen, and for upgrading the surveys themselves (DOC, 2007). As a result, NMFS and the states are working on improving recreational fishing information. This is critical, because in order for management to be effective at controlling fishing mortality, there must be consistent and complete data collection across all sectors.

Data need to be widely available for stakeholders as well as analysts, and the data must be comparable across regions and fisheries. Confidentiality rules have limited use and can protect those seeking to circumvent the regulations or other requirements. Reporting data quickly and making it generally available need not raise privacy issues.

There are, at least, minimum data requirements that will apply to all fisheries, both commercial and non-commercial. They should be included in all scientific evaluation surveys that have been identified as having an "ecosystem potential", as well as in all at-sea sampling programs on commercial vessels.

Best Practices regarding Data Availability include:

- In the European Union, there is a system that allows public access and compatibility of fishery data. The Data Collection Regulation manages data quality, control, harmonization, and management, access to

data by scientists and the public, and provides financial assistance for these activities. The regulation is being revised to allow implementation of an ecosystem approach to fisheries management (Commission of the European Communities, 2007).
- In order to improve public awareness of the performance of member states and to guide funding decisions, the European Commission is planning the regular publication of a Scoreboard on each state's compliance with reporting rules.

Though constricted by funding, enforcement should be consistent across regions and penalties should be considerable and promptly applied when infractions are made. There is a lack of assumed responsibility in most fisheries because fishermen are often not held accountable for their actions. By developing a protocol to make enforcement data public, in-fleet pressure will hopefully encourage fishermen to comply with regulations. Enforcement actions should include restricted fishing privileges for violators through temporary or permanent suspension of licenses and access to the resources.

Best Practices for enforcement include:
- In the New England fisheries, permit sanctions are increasingly used as part of the enforcement program.

Potential/Existing Problems with Best Practices for Monitoring and Enforcement

In the United States, the monitoring and enforcement efforts of the National Marine Fisheries Service (NMFS) are under-funded and understaffed. Monitoring efforts are often designed for individual fisheries, with data collection programs differing between regions, and there is no national consistency in fishery monitoring or data availability. Cooperation with state fishery agencies is an important part of monitoring programs, but this cooperation varies state by state, with different rules applying in different areas. In many cases, reporting on basic fishery landings or vessel activities relies on paper systems including trip tickets, logbooks, and other forms of reporting that are slow, costly, and error prone.

Relatively few fisheries use electronic reporting extensively. The timeliness of reporting catch, activity, landings, bycatch, and other essential information varies widely from days to months, depending on the fishery, state cooperation, and participant compliance. Much of the fishery data collected is treated as confidential, and is only generally available in aggregate form many months later, though under confidentiality agreements some analysts may use the data more quickly if they don't reveal the detailed information.

NMFS relies heavily on the United States Coast Guard, and on cooperative enforcement agreements with states, for at-sea enforcement (Hogarth, 2002). However, fishery enforcement is not a first priority of the Coast Guard, and many states lack funds to deploy adequate enforcement personnel. As a result, enforcement of fishery regulations is incomplete and inconsistent. An example of what this problem can lead to comes from the State of Washington, where regulators recently discovered that a fishing vessel had illegally dumped 3,000 pounds of rockfish only after the fish washed ashore (The Oregonian, 2007).

6 — ACRONYMS

ABC: Acceptable biological catch

ACL: Annual catch limit

B_{MSY}: Biomass corresponding to maximum sustainable yield

B_0: Virgin biomass

BP: Best practices

CCAMLR: Convention for the Conservation of Antarctic Living Marine Resources

EFF: European Fisheries Fund

EBFM: Ecosystem-based fisheries management

EBM: Ecosystem-based management

F: Fishing mortality rate

F_{MSY}: Fishing mortality rate corresponding to maximum sustainable yield

FMP: Fishery management plan

ICCAT: International Commission for the Conservation of Atlantic Tunas

ITQ: Individual transferable quota

MLMA: Marine Life Management Act

MRFSS: Marine Recreational Fisheries Statistics Surveys

MSFCMA: Magnuson Stevens Fishery Conservation and Management Act

MSRA: Magnuson-Stevens Reauthorization Act

MSE: Management strategy evaluation

MSY: Maximum sustainable yield

NMFS: National Marine Fisheries Service

OY: Optimum yield

SIOFA : Southern Indian Ocean Fisheries Agreement

TAC: Total Allowable Catch

VMS: Vessel Monitoring Systems

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