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NFCC Consensus Statement

Integrating Marine Reserve Science and Fisheries Management

NFCC Consensus Conference

June 7-9, 2004
Long Beach, California

Consensus Statement
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Integrating Marine Reserves Science and Fisheries Management

National Fisheries Conservation Center

Photo of Fuca Pillar, Cape Flattery, Olympic Coast National Marine Sanctuary courtesy of NOAA Photo Library

What is A Consensus Conference?

In late 2002, NFCC proposed a two-and-a-half-day consensus conference—modeled after the National Institutes of Health Consensus Development Conferences—to improve the integration of marine reserve science and fisheries management.

This style of consensus conference is designed to answer questions that require weighing scientific evidence in dispute. The consensus statement that emerges is intended to advance understanding of the scientific issues in question and to be useful to marine resource managers and the public.

As convenor, NFCC empanelled a planning committee to draft the questions and recommend review panelists. The non-advocate panel of experts based its findings on (1) presentations by investigators working in areas relevant to the consensus questions during a 2-day public session, (2) questions and statements from conference attendees during open discussion periods that were part of the public sessions, and (3) closed deliberations by the panel during the remainder of the second day and morning of the third.

This statement is an independent report of the consensus panel and is not a policy statement of NFCC or the organizations or institutions of the panelists.

Reference Information

For making bibliographic reference to this consensus statement, it is recommended that the following format be used, with or without source abbreviations, but without authorship attribution:

Integrating Marine Reserve Science and Fisheries Management. NFCC Consensus Statement, June 7-9, 2004, Long Beach, California.

Publication Information

The marine reserve science consensus statement, background materials prepared for the conference, and other NFCC publications are available by visiting our web site at http://nfcc-fisheries.org.

Disclosure Statement

All of the panelists who participated in this conference and contributed to the writing of this consensus statement were identified as having no financial or scientific conflict of interest, or any prior decision-making record on designation of marine reserves. Unlike the expert speakers who presented scientific data at the conference, the individuals invited to participate on the review panel were selected because they were not professionally identified with specific positions or research directions with respect to marine reserves science.

Abstract

Objective

The objective of this Consensus Statement is to inform the fishery management, ecological research, and marine protected area management communities of the results of the NFCC Consensus Conference on Integrating Marine Reserve Science and Fisheries Management. The statement provides an objective examination and assessment of the information regarding potential biological, social, and economic consequences of marine reserves, their potential effectiveness as a fishery management tool in the U.S., the methods for integrating their application with existing U.S. fisheries management and how marine reserves might be designed, monitored and evaluated. In addition, the statement addresses sources and magnitudes of uncertainty associated with marine reserves and conventional management approaches, and recommends areas for further study.

Participants

The conference included scientists and policy experts representing the fields of biological oceanography, marine ecology, fish biology, population dynamics, stock assessment, fishery management, fishery economics, and marine environmental law. The conference's seven-member review panel was made up of scientists and policy experts not currently engaged in research or advocacy in the field of marine reserves. The conference's ten-member presentation panel was made up of scientists and policy experts that are currently engaged in research or advocacy in the field of marine reserves. In addition to conference panelists, an audience of about 100 fishers, scientists, and policy makers was observed and contributed comments.

Evidence

The Communication Partnership for Science and the Sea (COMPASS) at Oregon State University conducted the literature search for the planning committee and the consensus conference and prepared an extensive bibliography for the panel and conference audience. COMPASS staff also prepared abstracts and topic syntheses for the panel with relevant citations from the literature.

Consensus Process

The panel, answering predefined questions, developed their conclusions based on the scientific evidence presented in open forum and the scientific literature. The panel composed a draft statement that was summarized and presented to the experts and the audience for comment. Thereafter, the panel resolved conflicting recommendations and released a summary of its revised statement at the end of the conference. The panel finalized the revisions after the conference. The draft statement was made available on the World Wide Web after panel revisions.

Conclusions

Marine reserves should be considered in the broader context of the development of ecosystem-based management in the U.S. From that perspective, marine reserves have clear application for meeting objectives for ecosystem conservation and protection of marine biodiversity in addition to whatever benefits they may have for achieving fishery management objectives. Furthermore, marine reserves are a category of area management options—including less restrictive and less permanent alternatives—that may be used in order to achieve ecosystem- or species-based management objectives.

With regard to fishery effects, studies of marine reserves and other area closures, most of which are from lower latitudes, have now shown that fishery target species have increased in abundance and expanded age structure within the closed area in a preponderance of cases (the so-called "reserve effect."). This is particularly the case where the resource species are significantly overfished. Evidence for effects outside closed areas, either by movement of adults across the reserve boundaries ("spillover") or larval "export" is more limited and effects on stocks within larger regions can only be deduced by models at this point. This is because of the limited size of existing reserves and inherent difficulties in measuring and interpreting such broader effects. In general, knowledge is sufficient to proceed with the design and evaluation of marine reserves and other marine protected areas and their incorporation into regional ecosystem-based management. More sophisticated modeling and analysis is required for better understanding of spatial movement rates, export of reproductive products, and adaptations by fishers.

Marine reserves clearly offer some advantages for simultaneously incorporating habitat protection and maintenance of ecosystem structure and function within the protected area. They may offer some advantages for multi-species management and as a hedge against environmental surprise or management failure.

Marine reserves are most likely to be an effective management tool for relatively sedentary species with broad larval dispersal, which are recruitment limited, and for mobile species with high site fidelity. They may also be effective for protecting rare habitats vulnerable to human disruption or in protecting aggregations of animals (e.g., when spawning), when exploited populations have been severely depleted, or where bycatch is high. Closed areas may also be useful in achieving broad demographic representation in spawning populations if large animals have limited movement potential relative to reserve boundaries, and when they can maintain populations of highly fecund, older females with strong reproductive potential. They may be more feasible to implement either when reduced yields have already restricted fishing activities and other management measures have been ineffective or when they address special needs within otherwise productive regions.

Marine reserves and other protected areas should be integrated with existing and emerging management measures as part of a coherent ecosystem-based approach to management of commercial and recreational fisheries and should not be simply layered over existing regulations. Careful consideration of the effects on allocation of resources among users, displacement of fishing activity, the requirements for surveys and stock assessment, and the costs of monitoring and enforcement should be made in considering protected area options and design.

The Panel found it difficult to limit its considerations to marine reserves as strictly defined, i.e. areas permanently protected from all extractive activities. We found that management actions need to be openly evaluated against stated goals and where goals are not being met changes in management must at least be considered. The design requirements for marine reserves depend heavily on the environmental context and specific management goals, including the overriding goal of sustainability and high yields of economically important species. Robust experimental design will be critical in order to determine the effects of displaced fishing pressures and enhancement effects on populations outside of reserves in before-after-control-impact assessments.

We have been hampered in evaluating the use of marine reserves as a tool for fishery management by the lack of experiments explicitly designed to address reserve effects on fisheries. These explicit experiments are urgently needed. There are numerous uncertainties associated with our understanding both of important biological and socioeconomic processes and with monitoring, analysis, prediction, and implementation. Some important uncertainties for marine reserves include the degree of effective dispersion and reproductive seeding and the ability to resolve spatial and temporal interactions in monitoring and modeling.

Further study is required on several key issues if closed areas are to assume a more important role in ecosystem approaches to fisheries management and biodiversity protection. These include high quality, synthetic bottom mapping with which to define vulnerable habitats that closed areas might best protect; study of dispersal rates; synthesis of effects of closures in northern temperate and boreal systems.

Many authors have speculated that marine reserves offer more precaution against management and scientific uncertainty than traditional measures. At this point, this is an assertion, and no studies using common definitions and metrics of precaution have been conducted. Given the importance of this issue, there is a need to conduct such work, applying biology and social science, particularly as it relates to findings from existing marine closures.

Introduction

The widespread degradation of coastal ocean ecosystems, attendant losses in biodiversity, and depleted status of many fishery stocks led the U.S. Commission on Ocean Policy to call for a new era of ecosystem-based management. Ecosystem-based management encompasses all ecosystem components, including human and non-human species and their environments. In its July, 2004 report, the Commission recommends such management be based on principles of sustainability, precaution, adaptation, and participatory governance and use the best available science.

Marine reserves, areas completely protected in perpetuity from all extractive and destructive activities, are being widely considered as a component of ecosystem-based management. While using marine reserves for biodiversity and ecosystem conservation is generally accepted, their potential role in fisheries management is controversial. Conservation advocates and some scientists have argued that marine reserves protect multiple stocks from over-exploitation in ways that conventional management methods that limit fishing effort or catches cannot or have not been able to do. Commercial and recreational fishing interests consider marine reserves as one more means to permanently limit their access to renewable resources. Some fishery scientists have argued that many fishery management objectives of marine reserves can be attained by effectively employing conventional measures and that marine reserves alone do not ensure sustainable fisheries management.

This two-and-a-half-day conference examined the current state of knowledge regarding the integration of marine reserve science and U.S. fisheries management. Experts presented the latest research findings to an independent Consensus Development Panel. After weighing this scientific evidence, the panel drafted a statement, addressing the following key questions:

1. What is the current state of knowledge of the potential biological, social, and economic consequences, both positive and negative, of marine reserves?
2. Under what circumstances could marine reserves be an effective fishery management tool in the U.S.?

3. How could marine reserves be integrated with existing fisheries management tools?

4. What general approaches to reserve design would meet fisheries objectives, taking into account social, economic, biological, and environmental factors?

5. What are the sources and magnitudes of uncertainty associated with marine reserves and conventional management approaches, and what are their implications for practical application of reserve design tools within the fishery management system?

6. What monitoring actions are needed to evaluate the results of marine reserves as a fishery management tool?

The Panel found it difficult to limit its considerations to marine reserves as strictly defined, i.e. areas permanently protected from all extractive activities, and found the issue of permanence the most highly contentious part of its overall charge.

(1) What is the current state of knowledge of the potential biological, social, and economic consequences of marine reserves?

Spatial closures have a long history as fishery management tools. They have been established to protect spawning aggregations, lower overall fishing mortality rates, minimize bycatch interactions, and reduce human impacts on vulnerable bottom habitat types. In the last decade, their use has expanded as fishery management objectives have widened, for example, to include essential fish habitat (EFH) protection. These closures range from narrowly focused prohibitions for particular gears to large-scale marine reserves prohibiting any removals from the three-dimensional reserve areas. Spatial closures by themselves are not marine reserves. However, since there are few studies examining the broad impacts of marine reserves explicitly, we also considered studies of closures. There have been many such closures and their results can inform us of the likely impacts of marine reserves on the species within them and the fisheries around them.

Knowledge about the biological and human-related consequences of marine reserves comes from two primary sources: (1) case studies of existing spatial closures, and (2) modeling studies evaluating the potential effects of reserves, either alone or in combination with other management measures. In general, these studies concentrate on impacts on yields and stock sizes of fishery target species, although some case studies have evaluated wider effects on associated species. Evidence presented to the panel indicates that available case studies for marine reserves are concentrated in the lower latitudes. Relatively few case studies exist from northern temperate and boreal waters. Many reserves and closures may not have existed for sufficient time to evaluate the potential consequences on long-lived component species.

Analysis of existing closures reveals that “reserve effects” (increased abundance and expanded age/size structures of resources and increased diversity in biological communities within the closed areas) commonly occur following spatial closures. Although this is not universal for all monitored species, in all regions, it is nonetheless surprisingly consistent. In many cases, significant, “reserve effects” have occurred where resource species were extensively overfished; thus the closure dramatically reduced fishing mortality on part or all of the stock. Such contrasts may not be observed with closures in areas where resource species are currently well managed. Other potential reserve effects include “spillover” (density-induced movement of adults across reserve boundaries into open areas) and larval “export” (movement of eggs and larvae to areas outside the reserve). Evidence for these latter effects is more limited than that for reserve effects; in particular, documenting export is a daunting technical challenge.

Spatial closures have been designed and established either to rebuild and maintain fishery populations, or to protect ecosystems and resources. In the case of closures for fishery enhancement, the federal fishery management process establishes target and threshold levels for stock size and fishing mortality as performance criteria, enabling evaluation of a closure’s (or a combination of measures) efficacy. Performance criteria for overall ecological effects of closures have no similar well-defined (statutory) targets and thresholds.

In general, we find that there currently is sufficient knowledge to proceed with the design and evaluation of reserves for the purposes of addressing primary fishery management goals (achievement of fishing mortality rate targets and stock biomass maintenance). In the United States (and in most of the developed world) detailed data exist on where target species are located, the spatial pattern of species abundance, general life history data (including longevity, maturity, dispersal of reproductive products, fecundity, and somatic growth rates), and some limited information on habitats in which the various life history stages occur. The design and evaluation of potential marine reserves requires these data in order to make first-order calculations of the biological impacts that alternative closed areas could have.

More sophisticated modeling and analysis of marine reserves require information on spatial movement rates, particularly across reserve boundaries; potential for export of reproductive products; and the likely behavioral adaptations by fishers (e.g., effort redistribution and its biological and socioeconomic impacts) to the establishment of marine reserves. Additionally, there are important, but unresolved, scientific questions regarding the functional value (relative productivity) of various habitat types, density-dependence at high levels of stock biomass (e.g., associated with reserve effects), and sub-stock structure within species. Few empirical studies exist with which to make generalizations regarding these effects. The Panel considers that studies of these factors represent a critical but heretofore-unmet research need. The lack of both a commonly agreed-to set of goals and clear performance measures regarding the effects of marine reserves on ecosystem function hampers the design and evaluation of closures for these purposes.

Below we briefly comment on the state of knowledge with respect to specific consequences of closures for the:

Population resilience of exploited species: Resilience measures are derived from life history information, stock-recruitment curves and similar knowledge. Such information exists for many species of fishery interest. Information regarding the relative efficacy of closures vs. alternative precautionary management measures to affect resiliency comes exclusively from modeling studies.

Variation in yield over time: Relatively low fishing mortality rates should result in less variability in annual yields, while high fishing mortality rates result in more dependency on variable incoming recruitment. Rotating open-closed areas can effectively buffer against yield variation where spatial patterns of recruitment may be variable, as in the management of some bivalve populations. There is little current information on the effects of reserves on yield variation (e.g., from adjacent open areas as a result of spillover and export), with the exception of some modeling studies.

Multispecies management: Bycatch avoidance has motivated the establishment of many existing closures, and such closures can be an effective strategy to reduce problematic bycatch in mixed species fisheries, and to avoid interactions with protected species. The consequences of closures on trophic dynamics have been evaluated in models, but few empirical case studies have produced information on this issue.

Habitat protection: Obviously spatial closures can afford high degrees of protection to benthic habitats, and some case studies document habitat changes following closures. However, the consequences of habitat protection to productivity of harvested species are generally poorly known. Some modeling studies have addressed the potential for fishing effects to reduce carrying capacity, and the effects that reserves might have on catch and biomass production under such conditions.

Protection of ecosystem services, structure, and function: Goals for ecosystem services, structure, and function have generally not been specified, nor have the effects of existing closures on these attributes been documented. In general, some modeling results indicate reserves should enhance these services and modifications of structure and function are more likely for reserves than other forms of spatial closures.

Insurance against environmental "surprise" or management failure: The concept of "insurance" in the context of resource management is ill-defined and thus a continuing source of ambiguity and contention. Overall, there is an open question regarding the proposition that marine reserves should, a priori, afford greater protection against perturbations or management failure than do precautionary management alternatives.

(2) Under what circumstances could marine reserves be an effective fisheries management tool?

Below, we outline the situations when marine reserves are likely to be ecologically beneficial and socio-economically feasible tools for fishery management. We assume that reserves will not be used alone for fisheries management but will be used in conjunction with other tools. Our discussion highlights the most critical and obvious circumstances; it is not intended to be an exhaustive list.

Biologically, the reserves may be most likely to be an effective tool for fishery management when:

♦ Species are sedentary or have high site fidelity (post-settlement) and have high larval dispersal. These species are the most likely to achieve long-term benefits (growth and survival) within reserves and to export these benefits through larval dispersal.

♦ Populations are recruitment limited.

♦ There are impacts to rare or key habitats. When the distributions of these habitats are limited, they are easier to manage with marine reserves.

♦ There are aggregations that can be managed within specific areas. The utility of reserves increases as more species occur in the aggregations and the aggregations occur at critical life history stages (e.g., nursery or spawning grounds).

♦ There is spatial consistency in the use of areas (e.g., in spawning grounds) by the population(s) to be managed. When there is less spatial overlap among populations, it will require a larger total area of reserves to protect the same amount of each population.

♦ When the protection of highly fecund (i.e., older and larger) individuals is desirable. These individuals have a disproportionately large contribution to larval supply in many populations and reserves can contribute to their development and/or protection. Traditional management measures (e.g., slot sizes) can also offer protection to these size classes but not if there are high post-release impacts (e.g., mortality) to released fishes.

♦ When stocks are depleted. Theoretical work indicates that the yield from reserves is most likely to be demonstrable when the MSY has been exceeded.

♦ Bycatch is high.

Socio-economically reserves are more likely to be an effective tool for fishery management when:

♦ Reserves meet multiple objectives (e.g., either for several stocks, fishery sustainability, habitat protection).

♦ Stocks are in sufficiently poor condition that limits on fishing have little added consequence.

♦ The economic condition of the fishery is good and reserves will have little direct economic impact.

♦ Spatial enforcement is feasible (e.g., there has been a history of spatial management).

♦ Their implementation does not add to a cumulative burden of regulations.

♦ Effort can be displaced with little economic impact.

♦ Fixed spatial management offers simplicity. In countries without complex fishery management systems, reserves are simpler to implement than stock-specific time, area, and gear regulations, which can be difficult to develop, communicate, and enforce.

♦ Information is limited and precaution is mandated.

♦ Other management measures have been ineffective.

♦ Fleet overcapacity is concurrently addressed.

(3) How could marine reserves be integrated with existing fishery management tools?

Several contextual elements underlie the integration of marine reserves with fishery management. The panel assumes that marine reserves would not be implemented as independent management tools in the absence of other management measures, but would be added to existing management. The panel finds, therefore, that they should be designed and implemented to integrate with existing management, create an internal coherence, and contribute to meeting the objectives of a fishery management plan. As with all fishery management tools, the cost and benefits of marine reserves should be evaluated in the context of their application within the specific fishery management plan.

Because they are layered over a set of regulations already in place, marine reserves will contribute to the cumulative effects of regulation. The economic condition of the fishery will be critical to the impact of these cumulative effects. The more economically healthy the fishery, the more likely that its participants will support marine reserve development and comply with its implementation. To this end, the panel finds the existence of ITQs or other forms of property rights will promote the economic conditions that encourage long-term investments in conservation.

(3A) Under what circumstances could marine reserves enhance or detract from conventional management approaches?

Marine reserves have the potential to enhance conventional fishery management in several ways. Setting aside areas from use can provide a buffer against management mistakes and scientific uncertainty. These areas can serve not only as hedges against risk, they can also be a means to provide direct protection for multiple species when this is required. In cases where weak stock protections limit harvest of other species, reserves could also provide the needed protection to these stocks so that outside-reserve harvest could continue. We note that an obvious area in which reserves can enhance conventional management is in cases where fishing disrupts or damages habitat in ways that diminish productivity of the resource. Finally, the panel finds that establishing marine reserves on a regional, rather than fishery-specific, basis could enhance management across several fishery management plans.

Marine reserves also have the potential to detract from conventional fishery management by increasing management costs without concomitant increases in benefits. The creation of additional costs may occur through the added complications resulting from poor design and a failure to integrate them into the fishery regulatory and economic context.

The panel finds that implementing marine reserves in fully utilized fisheries will have allocative effects that may detract from management effectiveness. Depending on their extent and location, reserves may alter the distribution of seafood landings in ways that diminish economic activity in fishing communities. The removal of areas from fishing may also create differential impacts on particular gear types or scales of operation. For example, marine reserves in nearshore areas can force small vessels to fish farther offshore under less safe conditions. Regulatory impacts on both communities and safety are addressed in National Standards 8 and 10, which fishery management plans must meet.

The displacement of fishing effort out of marine reserve areas and its concentration in outside-reserve areas is another potential detractor from fishery management effectiveness. The magnitude of this effect depends on the relative size of the area removed and the extent to which vessels have alternative areas to fish. In fully capitalized or overcapitalized fisheries, concentrating fishing effort could damage non-reserve areas. The potential for displacement to work against the management objectives requires attending to the potential for capacity management in conjunction with the development of reserves.

Finally, we note that marine reserves introduce additional requirements for monitoring and enforcement. Monitoring is necessary to assess the within-reserve response to protection and the progress toward meeting management objectives. Enforcement of reserves either through at-sea policing or vessel monitoring systems systems (VMS) on fishing vessels is necessary to ensure full protection. Both monitoring and enforcement introduce additional costs to management.

(3B) Would the use of marine reserves affect the application of conventional management and stock assessment?

The Magnuson-Stevens Fishery Conservation and Management Act requires that stocks be assessed individually. It is reasonable to expect that this requirement will continue, even with the multiple-species protections provided by marine reserves. Stock assessments make use of both fishery dependent (from landings) and fishery independent (from at-sea surveys) data. Depending on the size and extent of marine reserves, methods for collecting data from both sources may need to be changed to ensure adequate representation. Marine reserves, by setting aside areas from fishing, weaken the basic assumption under which fishery-dependent data are used—that the demographics of the fishery reflect the demographics of fish stocks. If reserve areas are large, stock-wide, rather than fishery-represented, abundance will need to be surveyed. This will increase the importance of fishery independent data and decrease the importance of fishery dependent data in stock assessment. The panel finds that new and restratified survey designs will need to be developed to reflect the new spatial patterns of the fishery. These changes will carry costs for redesign, new data collection, and analysis.

(4) What general approaches to reserve design would meet fisheries objectives?

Design of marine reserves, or any spatial management system, will be driven by specific goals. For fisheries management, sustainability is an overriding goal. We note, however, that more explicit, and occasionally non-fisheries, management goals may be sought. Consequently, the design process will be unique for each occasion; yet, for any management decision process, certain general guidelines will likely diminish confusion and maximize consensus among stakeholders. These include:

- Concisely articulating management goals
- Ensuring objectives are measurable and scientifically verifiable
- Allowing and planning for changes if objectives are not met
- Engaging all stakeholders in the process from the onset.

Inherent in these guiding principles is an adaptive management plan built on specific goals. As multiple spatial and conventional management actions may be applied to achieve objectives, there must be a view of the whole process that ensures separate management actions are coherent, and ideally, synergistic. Moreover, there should be an explicit plan for monitoring and assessing specific performance indicators (see Question 6 for more detail).

The panel recognized that many design criteria relevant to spatial management options (e.g., area, location, duration, etc.) are highly specific to explicit management goals. Therefore, it is only possible to make general recommendations concerning design criteria. First, because reserves will affect multiple species and multiple users, associated costs and benefits may introduce conflicts. Therefore, to minimize costs, efforts to reduce conflicts with and among users should be applied without compromising the management goals. Second, the concept of permanence with respect to reserves implies inflexibility when applied to fisheries management goals. Where possible, management planning should invoke the option for adaptive change in reserve design on a timeframe that allows for realistically assessing reserve effectiveness. However, it must be recognized that the multi-species and ecosystem nature of some management goals may require long time frames. Third, under circumstances of a given total area requirement, multiple, smaller reserves (i.e. networks) will generally better spread risks and costs than will a single large reserve. While ensuring individual reserves are large enough to be effective, placement of multiple reserves across the entire management region will reduce localized costs while simultaneously offering expanded benefits by spreading the risk of reduced reserve effectiveness that may result from localized perturbations.

Use of marine reserves and other spatial management options is likely to increase as management focus trends toward ecosystem-based options and processes. Expanded oversight of the management process should include efforts to minimize duplication by recognizing where different management goals may overlap and/or compete. The Panel finds that management processes that follow the above approaches including both planning and evaluation should facilitate realization of desired effects while minimizing negative impacts and conflict.

(5) What are the sources and magnitudes of uncertainty associated with marine reserves and conventional management approaches?

We recognize that the biological and socioeconomic processes related to the full range of fishery management approaches are all inherently knowable. All approaches, however, contain uncertainties that, if left unacknowledged or unaddressed, will lead us to misrepresent both our knowledge about these systems and our ability to manage them with reasonable confidence. It is important, therefore, to try to provide a framework for characterizing this uncertainty so that we might better understand and address it.

We also recognize that knowledge, and therefore uncertainty, in the context of fisheries management expresses itself at several levels.

Specifically, uncertainty exists in our fundamental understanding about the processes governing the ecosystem, the fishery that uses ecosystem resources, and the management methods used to govern the fishery. Uncertainty also exists in our ability to monitor these processes through data collection; analyze this information through estimation, modeling, and interpretation; make predictions given this analysis; and then implement and enforce management controls once the state of the system has been reasonably determined.

The panel proposes a means to contrast the various sources and magnitudes of uncertainty as illustrated in the table below. The descriptions in Table 1 (at right) are meant as a starting point for characterizing the uncertainty associated with these systems rather than an exhaustive presentation of the subject.

Uncertainty among several of the factors appears lower for use of marine reserves than for conventional methods. However, this perception may reflect our greater experience with conventional methods. More experience with marine reserves will better characterize both the sources and degree of uncertainty associated with their use.

Some suggest marine reserves will reduce the level of monitoring and evaluation needed for management. However, even areas closed to fishing require monitoring and evaluation to apprise managers of population and ecosystem trends. Given this continual need, the loss of information otherwise typically available from fishery dependent sources, and the higher dimensionality inherent in evaluating spatially referenced information, the effort and costs required to achieve reasonable information levels may prove higher than expected

Implementation uncertainty is not clearly identifiable at this time, but may be generally examined at various levels. We know that regulatory structures associated with conventional methods can become quite convoluted. Gear regulations, in particular, often prompt changes in fishing methods in response, resulting in a series of ad hoc modifications to existing policies. Regulations identifying no-fishing zones for marine reserves would seem inherently simpler and less subject to alteration through the evolution of fishing practices, and this may be so. Other aspects of implementation, such as the political will to site a marine reserve in contrast to imposition of stricter catch or effort control measures would also appear simpler. However, implementing reserves at the

Table 1. Comparison of Uncertainty

	Marine Reserves	Conventional
Ecological & socioeconomic processes		
Sources of uncertainty	Movement Dispersion Spillover Export Reserve size and location Home range Reproductive capacity	Natural mortality Fishing mortality Growth Selectivity Catchability Reproductive capacity
Magnitude of uncertainty	Low to moderate	Moderate to high
Monitoring		
Sources of uncertainty	Spatial and temporal Commercial and sport CPUE Survey indices Total harvest	Temporal Commercial and sport CPUE Survey indices Total harvest
Magnitude of uncertainty	Moderate	Moderate
Analysis		
Sources of uncertainty	Spatial-temporal modeling Production models Size or age structured models Stock recruitment Yield per recruit Growth	Temporal modeling Production models Size or age structured models Stock recruitment Yield per recruit Growth
Magnitude of uncertainty	High	High
Prediction		
Sources of uncertainty	Spatial-temporal modeling	Temporal modeling
Magnitude of uncertainty	High	High
Implementation		
Sources of uncertainty	Political will to initiate Regulation structure Enforcement	Political will to initiate Regulation structure Enforcement
Magnitude of uncertainty	High	High

locations and sizes needed to reduce fishing mortality to levels comparable to those currently sought through reductions in catch or effort may not be as easy to achieve.

In the end, the panel finds that identifying one of these approaches as being more precautionary than the other may be premature, strictly in terms of fishery management. Taking a broader set of factors into account, such as stabilizing trophic structure or preserving biodiversity, may tip the weighted risks and benefits in favor of utilizing a marine reserve. This forces us again to consider a broader set of goals and objectives with regard to managing these systems, and these must be clearly specified for each case prior to the debate over which mix of management procedures to consider.

(6) What monitoring actions are needed to evaluate the use of marine reserves as fishery management tools?

Monitoring and evaluating the ecological and socioeconomic impacts of marine reserves are essential aspects of the process of creating and implementing these spatial management tools. A monitoring plan should be developed during the design phase for the marine reserve and should clearly reflect its objectives.

The panel finds that any monitoring program should be based on clearly measurable and verifiable performance criteria or indicators that reflect reserve objectives and consider both socioeconomic and ecological aspects. Fishers and other interested groups should be involved in the selection of the performance indicators, as well as in the design and implementation of the monitoring program. We note that fishers can play a special role in data collection, assisting with the need for high resolution, spatially-oriented information.

The designers of the marine reserve must agree on the characteristics and timeframe of "success" as reflected by the measurable performance indicators. Management decisions and adaptations will follow from the monitoring plan and the evidence offered by the performance indicators. We note further, particularly in the context of federal legislation, that a variety of management alternatives to the proposed closures must be evaluated for their ability to meet biological objectives and all ten of the national standards under the Magnuson-Stevens Fishery Conservation and Management Act.

Performance indicators must embody the objectives of the marine reserve and should evaluate short- and long-term, positive and negative socioeconomic and ecological effects. They must consider the internal and external effects of the reserve. Economic indicators should attempt to quantify both market and non-market values and attempt to isolate benefits and costs to different users, e.g. displacement of effort; changes in fleet size, target species, and overall income. Ecological indicators must reflect both spatial and temporal changes in appropriate parameters, e.g. species and genetic diversity, abundance, biomass, and age structure. All indicators must be quantifiable and scientifically rigorous.

The monitoring plan should be linked to a broader research program that will address key uncertainties and causal linkages. The panel recommends that such a research program must embody careful experimental designs with control and replication experiments that recognize the limitations of "Before-After-Control-Impact" designs, as well as correct for potential effects due to displaced effort and export and or spillover to areas outside of the reserves.

We have been hampered in evaluating the use of marine reserves as a tool for fishery management by the lack of experiments explicitly designed to address reserve effects on fisheries. We have instead evaluated closures and marine reserves—often in ad hoc or crisis situations—the effects of which in these contexts is confounded and difficult to evaluate. Reserves show enough promise as fishery management tools to justify the explicit development of experiments to directly evaluate their effectiveness.

Conclusions

Marine reserves, areas of the ocean completely protected in perpetuity from all extractive and destructive activities, should be considered in the broader context of the development of ecosystem-based management for the Exclusive Economic Zone of the United States. From that perspective, marine reserves have clear application for meeting objectives for ecosystem conservation and protection of marine biodiversity in addition to whatever benefits they may have for achieving fishery management objectives. Furthermore, marine reserves are a category of area management options—including less restrictive and less permanent alternatives—that may be used in order to achieve ecosystem- or species-based management objectives.

With regard to fishery effects, many studies of marine reserves and other area closures, most of which are from lower latitudes, have now shown that fishery target species increased in abundance and their age structure expanded within the closed area in a preponderance of cases (the so-called “reserve effect.”). This is particularly the case where the resource species are significantly overfished. Evidence for effects outside closed areas, either by movement of adults across the reserve boundaries (“spillover”) or larval “export” is more limited and effects on stocks within larger regions can only be deduced by models at this point. This is because of the limited size and duration of existing reserves and inherent difficulties in measuring and interpreting such broader effects. Reserves show enough promise as fishery management tools to justify the explicit development of experiments to directly evaluate their effectiveness. More sophisticated modeling and analysis is required for better understanding of spatial movement rates, export of reproductive products, and adaptations by fishers.

Marine reserves clearly offer some advantages for simultaneously incorporating habitat protection and maintenance of ecosystem structure and function within the protected area. They may offer some advantages for multi-species management and as a hedge against environmental surprise or management failure in contrast to other precautionary fisheries management approaches, but these have not yet been empirically demonstrated and are likely to be context-specific.

Marine reserves are most likely to be an effective management tool for relatively sedentary species with broad larval dispersal, which are recruitment limited, and for mobile species with high site fidelity. They may also be effective for protecting rare habitats vulnerable to human disruption or in protecting aggregations of animals (e.g., when spawning), when exploited populations have been severely depleted, or where bycatch is high. Closed areas may also be useful in achieving broad demographic representation in spawning populations if large animals have limited movement potential relative to reserve boundaries, and when they can maintain populations of highly fecund, older females with strong reproductive potential. They may be more feasible to implement either when reduced yields have already restricted fishing activities and other management measures have been ineffective or when they address special needs within otherwise productive regions.

Marine reserves and other protected areas should be integrated with existing and emerging management measures as part of a coherent ecosystem-based approach to management of commercial and recreational fisheries and should not be simply layered over existing regulations. In general, the coupling of quotas or effort control with protected areas will likely produce more benefits to stocks and help foster the economic conditions that encourage such conservation approaches. Careful consideration of the effects on allocation of resources among users, displacement of fishing activity, the requirements for surveys and stock assessment, and the costs of monitoring and enforcement should be made in considering protected area options and design.

The Panel found it difficult to limit its considerations to marine reserves as strictly defined, i.e. areas permanently protected from all extractive activities. We found that management actions need to be openly evaluated against stated goals and where goals are not being met changes in management must at least be considered. The design requirements for marine reserves depend heavily on the environmental context and specific management goals, including the overriding goal of sustainability and high yields of economically important species. Management goals should be clear, objectives measurable and scientifically verifiable, and plans adaptable if objectives are not met. Development of the design should involve stakeholders at the outset, identify specific performance outcomes, and include sufficiently rigorous monitoring and assessment. Because most reserves would be intended to address multiple conservation, species-specific, and user goals, designs will require clear optimization procedures that do not unduly compromise key goals. Moreover, designs will have to take into account the regional network perspective in which the proposed specific reserve is included.

There are numerous uncertainties associated with our understanding both of important biological and socioeconomic processes and with monitoring, analysis, prediction, and implementation of all fishery management approaches. Although these uncertainties may be different between marine reserves and conventional management approaches, in general they are no greater for marine reserves and in some respects may be lower. Some important uncertainties for marine reserves include the degree of effective dispersion and reproductive seeding and the ability to resolve spatial and temporal interactions in monitoring and modeling.

Monitoring and evaluating the ecological and socioeconomic consequences of marine reserves is essential in this stage of their development as an ecosystem-based management tool. Monitoring should assess indicators of the performance outcomes included in the reserve design that support evaluations of "success" and subsequent adaptive management. Robust experimental design will be critical in order to determine the effects of displaced fishing pressures and enhancement effects on populations outside of reserves in before-after-control-impact assessments.

Research Recommendations

There are a number of specific and general areas requiring additional research if marine reserves are to assume a more important role in ecosystem approaches to fisheries management and biodiversity protection:

1. Throughout the U.S. there is limited information on bottom substrates and communities that structure fish habitats. There is a pressing need for high quality bottom mapping and assessment in order to define vulnerable habitats that might merit closure.

2. The fidelity of species to particular habitats is a major issue in designing effective areal closures. Spillover of harvestable animals requires that boundaries be established that allow some animals to range beyond the reserve, while building spawning populations within the closure area may depend on low dispersal rates. The use of modern technologies (chemical, molecular, etc.) to determine dispersal patterns and rates should be expanded.

3. While there are a number of well-documented studies of marine reserves and their effects in tropical or low latitudes, the amount of information for northern temperate and boreal systems is limited. Given that most of the high volume fisheries exist in these more poleward waters, there is a pressing need to develop a synthesis of the effects of area closures in such environments.

4. Few empirical studies, sophisticated modeling or analyses exist with which to make generalizations regarding the effects of marine reserves on spatial movement rates, particularly across reserve

boundaries; potential for export of reproductive products; and the likely behavioral adaptations by fishers (e.g., effort redistribution and its biological and socioeconomic impacts). Additionally, there are important, but unresolved, scientific questions regarding the functional value (relative productivity) of various habitat types, density-dependence at high levels of stock biomass (e.g., associated with reserve effects), and sub-stock structure within species. The Panel considers that studies of these factors represent a critical but heretofore-unmet research need.

5. Many authors have speculated that marine reserves offer more precaution (insurance) against management and scientific uncertainty than do traditional measures. At this point, this is an assertion and no studies using common definitions and metrics of precaution have been conducted. Given the importance of this issue, there is a need to conduct such work, applying biology and social science, particularly as it relates to findings from existing marine closures.

Review Panel

Don Boesch, Chair President, Center for Environmental Science, University of Maryland

http://www.umces.edu/President/

Dr. Boesch is an internationally known marine ecologist who has conducted extensive research in coastal and continental shelf environments. He has published two books and more than 60 papers on a wide range of scientific and science policy topics. He has been a member of the Marine Board and the Ocean Studies Board of the National Research Council, and he has chaired three prominent NRC committees. Dr. Boesch has also served on national advisory boards for the Department of the Interior, Environmental Protection Agency, National Science Foundation, the National Oceanic and Atmospheric Administration and the President's National Science and Technology Council.

Mike Beck, Senior Scientist, Marine Initiative, The Nature Conservancy

www.nature.org/initiatives/marine

Since 1998Mike has led several marine programs and initiatives atThe Nature Conservancy and isa research associate at the University of California Santa Cruz. Mike has trained and worked at the University of Virginia, Dauphin Island Sea Lab, Florida State University, and the University of Sydney. In his research, Mike examines factors that control the diversity and abundance of animals in seagrass, mangrove, rocky intertidal, and salt marsh habitats. He has served as a member of advisory committees for EPA, the Heinz Center, the European Union, NatureServe, and the Commission for Environmental Cooperation.

Bob Cowen, Professor and Maytag Chair of Ichthyology, University of Miami

His research has concentrated on ecology and early life history of fishes and the biological and physical oceanographic processes affecting the retention and transport of larval fishes, in terms of examining larval dynamics, population replenishment and connectivity. Dr. Cowan also worked on the reproductive and population biology of hermaphroditic (sex-changing) fishes, as well as community ecology of kelp bed systems. Recently he has focused on the role of juvenile habitat in the recruitment of fishes, population connectivity in marine fishes, and early life history dynamics of billfish.

Susan Hanna, Professor, Dept. of Agricultural and Resource Economics, Oregon State University

http://marineresearch.oregonstate.edu/assets/page_folders/faculty_page/hanna_hp.htm

Dr. Hanna teaches fishery economics, fishery management, history of fishery policy, and property rights. Her writing has focused on promoting the economic and ecological productivity of marine resources by improving management performance. She has served as a scientific advisor to the Pacific Fishery Management Council, Northwest Power Planning Council, National Marine Fisheries Service, Minerals Management Service, and National Oceanic and Atmospheric Administration. She is a member of the National Research Council's Ocean Studies Board and several NRC Committees, including the Committee to assess Pacific Northwest salmonids and the committee to Review Individual Quotas in Fisheries. She is president of the International Association for the Study of Common Property and a member of the Executive Committee of the International Institute of Fisheries Economics.

Steve Murawski, Chief, Population Dynamics Branch, Northeast Fisheries Science Center, NOAA Fisheries.

Dr. Murawski’s areas of concentration are in fisheries science and management. He has led numerous stock assessment projects for the Northeast Fisheries Science Center in Woods Hole. He has direct experience with design and evaluation of large closed areas in New England.

Patrick J. Sullivan, Professor Dept. of Natural Resources, Cornell University

http://www.dnr.cornell.edu/people/faculty/profiles/sullivan.html

The dynamics of natural populations and communities is the central focus of his teaching and research. Using statistical methods, such as survey sampling, nonlinear population modeling and assessment, and spatial statistics, to observe and model the dynamics of natural systems in a quantitative way, he is particularly interested in how variation can be used to characterize natural systems, address uncertainty and determine risk in order to improve environmental management. His research has focused mainly on fisheries problems in marine and freshwater environments. These include statistical methods for population assessment and modeling, methods for data acquisition and utilization, spatial modeling of habitat and abundance, and formulating mechanisms for making better use of information in the management arena.

Daniel Suman, Professor of Marine Affairs and Policy, University of Miami

http://www.bio.miami.edu/info/ESC/suman.html

A member of the IUCN Commission on Environmental Law, Dr. Suman’s research Interests include adaptability of the fishing sectors in Chile, Peru, and Ecuador to ENSO ("El Niño") climate variability, mangrove management in Latin American and Caribbean countries, and establishment of MPAs. His work places emphasis on integrating ecological, policy, economic, and legal aspects of complex resource management problems.

Presenters

Dick Allen is a New England fisherman with a 36-year commercial fishing career, in lobster, surf clam, groundfish, herring, and menhaden fisheries. He holds a BS in Natural Resource Development and MS in Marine Affairs from the University of Rhode Island. He served on the New England Fishery Management Council for 9 years, was a commissioner on Atlantic States Marine Fisheries Commission for 11 years, a member of the US Department of Commerce Marine Fisheries Advisory Committee. Most recently Allen was awarded a Pew Fellowship focusing on facilitating science-industry collaboration by introducing computer simulation models of the lobster fishery to the lobster fishing community. www.fisheryconservation.com

Jon Kurland is the Assistant Regional Administrator for Habitat Conservation with the National Marine Fisheries Service in Juneau. He oversees the Habitat Conservation Division, which carries out the agency's mandates to conserve habitats that support living marine resources. His group identifies and conserves Essential Fish Habitat (EFH) through fishery management, and provides technical advice to other agencies and the public on ways to minimize the effects of development activities on habitats that support commercially harvested fish as well as marine mammals. Before moving to Alaska in 2002, Jon was the national EFH Coordinator for NMFS in the headquarters office in Silver Spring, Maryland.

Loo Botsford is Professor of Wildlife, Fisheries and Conservation Biology at the University of California, Davis. His Research focus is the application of age, size and spatially structured population models to practical problems, usually problems in marine conservation of fisheries. Combines modeling approaches with field work to better understand critical aspects of dynamics. Retrospectiveanalyses of past data includes primarily calculations of the degree of covariability between environmental and biological variables. Has developed influential models that describe and predict the performance of marine reserves under different situations.http://wfcb.ucdavis.edu/www/faculty/Loo/BotsfordSiteFiles/BotsfordMain.html

Ken Frank is with Canada's Department of Fisheries and Oceans Bedford Institute of Oceanography. His Many years of management experience with DFO,include stock assessments of haddock fishery and evaluation of the large haddock closure in the North Atlantic. Current research focus on fisheries ecology, resource conservation, biogeographic theory, fisheries oceanography, and marine ecosystem assessment.

Arne Fuglvog is President of the Petersburg Vessel Owner's Association. A lifelong resident of Petersburg, Alaska, he has been fishing commercially since 1975, primarily longlining for halibut and sablefish, but has participated in salmon, herring and crab fisheries throughout the state of Alaska. He is a member of the North Pacific Fishery Management Council after serving 9 years on its advisory panel. Fuglevog also serves on the Research Advisory Board to the International Pacific Halibut Commission. He was named one of National Fisherman's "highliners of the year" for 2003.

Rod Fujita is a Senior Scientist at Environmental Defense. He has worked on acid rain, ozone depletion, global climate change, and protecting marine ecosystems. Fujita initiatedEnvironmental Defense's Coral Reef Project, and played a lead role in establishing the Florida Keys National Marine Sanctuary. He leads efforts to create sustainable fisheries along the Pacific coast of the U.S., in Hawaii, and in international waters. Fujita is currently working to stop overfishing and to create networks of marine reserves to increase fishery yields while protecting marine biodiversity and ecosystem health.

Mark Hixon is a Professor in the Department of Zoology at Oregon State University. He is a marine ecologist expert on coastal marine fishes, with research on mechanisms that naturally regulate populations and sustain biodiversity of marine fish. Collated research on potential fisheries benefits of existing West Coast marine reserves. Hixon serves on several advisory boards, including the MPA Federal Advisory Committee. http://oregonstate.edu/~hixonm/index.htm

Steve Palumbi is a Professor at Hopkins Marine Station of Stanford University. He has conducted research on genetics, evolution, population biology, and systematics of a diverse array of marine organisms. His major focus is genetics of marine populations in the context of marine protected areas for conservation and fisheries enhancement. Palumbi also investigates the use of molecular genetic techniques for the identification of whale and dolphin products available in commercial markets, and mechanisms of reproductive isolation and their influence on patterns of speciation and degree of genetic structure in marine systems. http://www-marine.stanford.edu/HMSweb/palumbi.html

Andy Rosenberg is a professor in the department of Life Sciences and Agriculture at the University of New Hampshire. His research focus is on marine science, marine policy, and marine fisheries. Former deputy director of the National Marine Fisheries Service, Rosenberg was a key agency policymaker and liaison to Congress, the administration, resource management partners, and the public. Implemented protection plans for marine mammals such as harbor porpoise and right whales, and endangered species like Atlantic salmon. Prior head of delegation to the North Atlantic Salmon Conservation Organization and the Northwest Atlantic Fisheries Organization, and is a member of the U.S. Commission on Ocean Policy.

Vidar Wespestad is President of Resource Analyst International. He consults in area of global marine resource assessment and serves as Chief Fisheries Scientist for the Pacific Whiting Conservation Cooperative. From 1977 to 1997 he was a fishery research biologist with the U.S. National Marine Fisheries Service and led. the Bering Sea stock assessment group at the Alaska Fishery Science Center. He is a recipient of the American Fisheries Society's Distinguished Service Award for organizing and co-chairing the First World Fishery Congress and has received fellowships from the Fishery Research Council, the Norwegian Marshall Fund, and the Rockefeller Foundation. He received his Ph.D. in fisheries from the University of Washington.

Planning Committee

Bill Eichbaum (chair), World Wildlife Fund, Washington, D.C.

Loo Botsford, University of California, Davis, California

Mike Fogarty, NOAA Fisheries, NE Fisheries Science Center, Woods Hole, Massachusetts

Steve Gaines, University of California, Santa Barbara, California

Churchill Grimes, NOAA Fisheries, SW Fisheries Science Center, Santa Cruz, California

Ben Halpern, University of California, Marine Science Institute, Santa Barbara, California

Trevor Kenchington, Gadus Associates, Musquodoboit Harbour, Nova Scotia Canada

Ralph Larson, San Francisco State University, San Francisco, California

Mark Lundsten, Queen Anne Fisheries, Seattle, Washington

Rick Methot, NOAA Fisheries, Alaska Fisheries Science Center, Seattle, Washington

Mark Powell, The Ocean Conservancy, Bainbrige Island, Washington

Steve Scheiblauer, City of Monterey Harbormaster, Monterey, California

Priscilla Weeks, Houston Advanced Research Center, The Woodlands, Texas

James Wilen, University of California, Social Sciences and Humanities, Davis, California

Lead Organization

National Fisheries Conservation Center, Brock B. Bernstein, President

Supporting Organizations

Communication Partnership for Science and the Sea, Oregon State University
National Marine Fisheries Service
National Marine Protected Areas Center

Contributors

Aquarium of the Pacific
City of Monterey Harbor
City of Morro Bay Harbor
City of Santa Barbara Waterfront
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Port San Luis Harbor
The Surdna Foundation

Bibliography

Anderson, L. G. 2002. A bioeconomic analysis of marine reserves. Natural Resource Modeling 15:311-333.

Gerber, L. R., L. W. Botsford, A. Hastings, H. P. Possingham, S. D. Gaines, S. R. Palumbi, and S. Andelman. 2003. Population models for marine reserve design: a retrospective and prospective synthesis. Ecological Applications 13(Supplement):S47- S64.

Hilborn, R., K. Stokes, J. Maguire, T. Smith, L.W. Botsford, M. Mangel, J. Orensanz, A. Parma, J. Rice, J. Bell, K.L. Cochrane, S. Garcia, S.J. Hall, G.P. Kirkwood, K. Sainsbury, G. Stefansson, and C. Walters. In press. When can reserves improve fisheries management? Ocean and Coastal Management 47(2) available online in June 2004.

Hixon, M. A. 2002. Existing small marine reserves can indicate whether a larger network is feasible: case study from the west coast of the United States. MPA News 4(3):5. Followed by full report: Fishery effects of existing west coast marine reserves: the scientific evidence. Report submitted to the Oregon Ocean Policy Advisory Council and the California Fish and Game Commission.

Holland, D. S. 2002. Integrating marine protected areas into models for fishery assessment and management. Natural Resource Modeling 15:369-386.

Pacific Fishery Management Council (PFMC). 2001. Scientific and Statistical Committee Report on Status of Marine Reserves Proposals for Channel Islands National Marine Sanctuary (CINMS).

Pomeroy, C. 2002. Effectiveness of marine reserves: Socio-economic considerations. In: Starr, R. M., M. H. Carr, J. Caselle, J. A. Estes, C. Pomeroy, C. Syms, D. A. VenTresca, M. M. Yoklavich. A Review of the Ecological Effectiveness of Subtidal Marine Reserves in Central California. Report to the Monterey Bay National Marine Sanctuary. Part I: Synopsis of Scientific Investigations, pp. 73-87.

Smith, M. D. and J. E. Wilen. 2004. Marine reserves with endogenous ports: empirical bioeconomics of the California sea urchin fishery. Marine Resource Economics 18:85-112.

Wallace, R. K. and K. M. Fletcher. 2001. Understanding fisheries management: A manual for understanding the federal fisheries management process including analysis of the 1996 Sustainable Fisheries Act. 2nd edition. Mississippi-Alabama Sea Grant Consortium, Publication 00-005.

Ward, T. J., D. Heinemann, and N. Evans. 2001. Table 4: Potential fishery benefits of marine fisheries sanctuaries that are not restricted to areas inside or outside a sanctuary. In: The role of marine reserves as fishery management tools: a review of concepts, evidence, and international experience. Bureau of Royal Sciences, Canberra, Australia. 192 pp.

National Fisheries Conservation Center
308 Raymond Street
Ojai, California 93023
805 646-8369
http://www.nfcc-fisheries.org

nfcc national fisheries conservation center