MARINE RESERVES TO SUPPLEMENT MANAGEMENT OF WEST COAST GROUNDFISH RESOURCES

PHASE I TECHNICAL ANALYSIS

PREPARED FOR
THE PACIFIC FISHERY MANAGEMENT COUNCIL
BY (IN ALPHABETICAL ORDER):

DR. RICHARD PARRISH, NATIONAL MARINE FISHERIES SERVICE,
SOUTHWEST FISHERIES SCIENCE CENTER, PACIFIC FISHERIES
ENVIRONMENTAL LABORATORY;
MR. JIM SEGER, PACIFIC FISHERY MANAGEMENT COUNCIL;
MS. MARY YOKLAVICH, NATIONAL MARINE FISHERIES SERVICE,
SOUTHWEST FISHERIES SCIENCE CENTER, SANTA CRUZ LABORATORY

PACIFIC FISHERY MANAGEMENT COUNCIL
2130 SW FIFTH AVENUE, SUITE 224
PORTLAND, OREGON 97201
(503) 326-6352
http:/www.pcouncil.org

FEBRUARY 2001

ACKNOWLEDGMENTS

Our discussions with Dr. Alec MacCall (National Marine Fisheries Service, Tiburon Lab), Mr. Tira Foran, and Dr. Rod Fujita (Environmental Defense) helped in early development of this document. The final draft of this document was improved by the contributions of several people; we especially thank Mr. Dave Fox (Oregon Department of Fish and Wildlife), Mr. Mark Helvey (National Marine Fisheries Service, Southwest Region), Dr. Robert Lea (California Department of Fish and Game), Dr. Fujita (Environmental Defense), Mr. Rod Moore (Council Groundfish Advisory Subpanel Chair), Ms. Yvonne de Reynier (National Marine Fisheries Service, Northwest Region), Ms. Michele Robinson (Washington Department of Fish and Wildlife), CDR John Schott (U.S. Coast Guard), LT Brian Corrigan (U.S. Coast Guard), and the entire Ad Hoc Marine Reserve Committee for their thoughtful comments (Appendix A). Thanks also to Ms. Heather Munro (Council Coastal Pelagic Species Advisory Subpanel Vice Chair) for assistance with the section on enforcement, and to the Council secretariat for assistance with preparation of the final document.

A report of the Pacific Fishery Management Council pursuant to National Oceanic and Atmospheric Administration Award Number NA17FC1048.

TABLE OF CONTENTS

GLOSSARY OF SELECTED TERMS

Bycatch[1/]. Fish that are harvested in a fishery, but that are not sold or kept for personal use, and includes economic discards and regulatory discards.

Commercial fish[1/]. Fishing in which the fish that are harvested, either in whole or in part, are intended to enter commerce or enter commerce through sale, barter, or trade.

Discard mortality[1/]. Fish that are the target fishery are not retained, because they are of undesirable size, sex, or quality, or for other economic reasons.

Essential fish habitat[1/]. Those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.

Fishery[1/]. One or more stocks of fish that can be treated as a unit for purposes of conservation and management and that are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics; and any fishing for such stocks.

Fishery management plan (FMP). A plan developed by a regional fishery management council to manage fishery resources in the U.S. exclusive economic zone pursuant to the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act).

Fishery resource[1/]. Any fishery, any stock of fish, any species of fish, and any habitat of fish.

Fishing[1/]. The catching, taking, or harvesting of fish; the attempted catching, taking, or harvesting of fish; any activity that can reasonably be expected to result in the catching, taking, or harvesting of fish; or any operations at sea in support of any activity described above. This term does not include any scientific research conducted by a scientific research vessel.

Groundfish. Broadly, fish that are caught on or near the seafloor, including a wide variety of bottom fishes, rockfishes, and flatfishes. The Groundfish FMP of the Pacific Fishery Management Council (Council) also includes some species (e.g., Pacific whiting and widow rockfish) that occur in large aggregations in mid-water and excludes some species such as Pacific halibut and California halibut.

Incidental catch/landings. Catch or landings that contribute to the value of the fishery, but are not the primary target species of the fishery. For example, halibut retained by trollers while trying to harvest salmon would be considered incidental catch/landings; however, for the purpose of the Magnuson-Stevens Act the halibut would generally be considered as one of the target species of the fishery.

Marine reserve. A resource management area that prohibits fishing.

Observer[1/]. Any person required or authorized to be carried on a vessel for conservation and management purposes by regulations or permits under the Magnuson-Stevens Act.

Overfishing or overfished[1/]. A rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis.

Recreational fishing. Fishing for sport or pleasure.

Stock of fish[1/]. A species, subspecies, geographical grouping, or other category of fish capable of management as a unit.

1/ Defined in the Magnuson-Stevens Act, as amended through October 11, 1996.

Target species/stocks (with respect to reserves). The fish species or stock(s) a reserve is intended to protect or rebuild through protection from fishing in the reserve area or the preservation of habitat.

Threatened or endangered. Defined under the Endangered Species Act (ESA), a species is considered endangered if it is in danger of extinction throughout a significant portion of its range; it is threatened if it is likely to become an endangered species.

LIST OF ACRONYMS

Council	Pacific Fishery Management Council
CPUE	catch per unit of effort
EFH	essential fish habitat
ESA	Endangered Species Act
ETS	endangered and threatened species
FMP	fishery management plan
FTE	full-time employee
GIS	Geographic Information System
ITQ	individual transferable quota
Magnuson-Stevens Act	Magnuson-Stevens Fishery Conservation and Management Act
MMPA	Marine Mammal Protection Act
MSY	maximum sustainable yield
MRC	Ad Hoc Marine Reserve Committee
NMFS	National Marine Fisheries Service
NURP	National Undersea Research Program
POP	Pacific Ocean perch
RecFIN	Recreational Fishery Information Network
USCG	United States Coast Guard

EXECUTIVE SUMMARY

Introduction

For the purpose of this Council process, a marine reserve is an area where the take of certain species is prohibited. The prohibition may apply to all fish species or only certain species covered by Council FMPs (e.g., groundfish, but not salmon). The Council's current consideration of marine reserves is motivated by concerns related to the groundfish fishery.

The Council has specified a two-stage process to consider marine reserves as part of an integrated scheme to sustain a healthy ecosystem and more effectively manage the West Coast groundfish fisheries. The first phase is a conceptual evaluation that will conclude with the Council's decision on whether or not marine reserves have a role in fishery management. This document is a technical analysis intended to assist the Council with that decision. During the first phase, an Ad Hoc Marine Reserve Committee (MRC) was appointed by the Council to develop management objectives for marine reserves. Options to meet these objectives were identified and evaluated. During the second phase, if pursued by the Council, options for the design and location of specific marine reserves will be developed. Several West Coast states are independently considering the use of marine reserves as a management tool for nearshore fisheries. If the Council decides to continue with the development of marine reserves, it would be critical to coordinate this federal effort with the state, tribal, and local agencies.

The Council authority to create marine reserves is limited. The Council has the authority to regulate fisheries that take species managed under a Council FMP, identify essential fish habitat (EFH), and establish habitat areas of particular concern. The Council/federal authority to manage fish is generally exercised in cooperation with the states and tribes. State fishery regulations must be consistent with federal regulations established through the Council process. However, the Council does not have the authority to regulate fisheries not covered under a Council FMP nor does it have authority to regulate nonfishing activities. Thus creation of marine reserves and protection of the reserves from other nonfishing human activities will likely require cooperation with other state, tribal, and local jurisdictions. Coordination and cooperation with the tribes will be particularly important if marine reserves include tribal usual and accustomed fishing grounds or otherwise impact tribal fisheries. Marine reserve development will need to be consistent with applicable law regarding treaty Indian fishing rights in usual and accustomed fishing areas.

Marine reserves are being considered to address a number of problems in the groundfish fishery. Estimated biomasses of the majority of West Coast groundfish species, for which assessments are available, have long-term downward trends. Such trends are primarily the result of fishing down stocks that previously were lightly exploited. This process is largely over, and the Council is now in the difficult position of trying to move to a harvest policy that must balance catch against low annual production. The transformation to lower harvests did not occur quickly enough for a number of important species. Five Council-managed species (bocaccio, lingcod, Pacific Ocean perch [POP], cowcod, and canary rockfish) currently are considered to be overfished, and stock rebuilding plans either have been developed or are in progress. There are no stock assessments for most of the 83 species included in the West Coast groundfish FMP. Because many of these unassessed species co-occur with the overfished species and are targeted by the same types of fishing gear, it is expected their populations are experiencing similar declines in biomass; biomass of some of these species may also be in need of rebuilding.

Effective management of marine fisheries is being attempted in an environment where there are many unknowns and uncertainties about the status of the stocks, and indeed, about the entire ecosystem supporting them. It is apparent increased scientific knowledge and research of marine ecosystems will be necessary to successfully manage these resources. Failure could prevent rebuilding overfished stocks and could lead to ESA listings that would have dramatic negative consequences for the fishery.

Fishery managers are concerned with maintaining the biological and economic productivity of those stocks that benefit West Coast fishing communities. Sustained productivity depend on rational harvest rates and healthy ecosystems and fish habitat. It is clear traditional management efforts alone are not successfully protecting and sustaining many of our coastal groundfish populations and habitats. Marine reserves are being promoted worldwide to mitigate overfishing and the impacts of fishing activities on seafloor habitats. Rowley (1992), among others, has suggested marine reserves can be most beneficial to species that have been overfished, reach great sizes or ages, and have limited movements or sedentary behavior, all of which apply to many West Coast groundfish species. Marine reserves demonstrably conserve and enhance fish populations within their borders by, (1) increasing fish abundance, size, and relative age composition; (2) protecting critical spawning stocks and habitats; (3) providing multi-species protection; (4) contributing to the preservation and maintenance of the natural diversity of individual species and habitats; and (5) providing undisturbed, reference sites against which we can evaluate the effects of fishing and other human activities on marine ecosystems. The capacity of marine reserves to enhance fishery yields outside their boundaries is less well documented, primarily due to the lack of research on this effect. Until recently, we have had no long-term marine reserves of adequate size with which to test these potential benefits and understand their contribution to enhancement and conservation of fish populations.

Objectives

Following the recommendations of the MRC, the Council adopted six fishery management objectives that might be addressed by marine reserves as a supplemental tool for management of groundfish fisheries. These objectives are interlinked. The following are the objectives that marine reserves might help address, ranked in order beginning with the top priority objective.

Objective 1: Stock Rebuilding. Assist in rebuilding overfished stocks and maintaining them at productive levels.

Objective 2: Biological Productivity. Enhance long-term biological productivity.

Objective 3: Economic Productivity. Assist in achieving long-term economic production, while minimizing short-term negative economic impact on all users.

Objective 4: Insurance. Provide protection for the resource, as a hedge against the realities of management uncertainty and the effects of natural environmental variability.

Objective 5: Habitat Protection. Conserve and protect EFH.

Objective 6: Research and Education. Provide unfished areas for research that will serve as controls for assessment of the effects of long-term environmental variations and the potential habitat alterations due to fishing, and also increase our understanding of the role marine reserves may play in fishery management.

Options

There are four marine reserve options covered in this analysis (Options 2, 3a, 3b, and 4). ***These options are not mutually exclusive and may be implemented serially over time.*** The reserve options are described primarily on a qualitative basis (page 3). The options are summarized here in a title format with some ballpark percentages provided to give a rough sense for the size of the reserve system that might be entailed for each option. Status quo (Option 1) is continued management under the rebuilding policy established by the Council in 1999; it does not include marine reserves or areas with fishing gear exclusions.

Option 1: Status Quo Rebuilding (With No Marine Reserves).

Option 2: Heritage and Research Reserves (Small Reserves, Encompassing a Minimum of Approximately 5% of Habitat or Biomass).

Option 3a: Rebuilding Reserves with Harvest Reductions Proportional to the Amounts Set Aside in Reserves (Encompassing Approximately 20% of Habitat or Biomass).

Option 3b: Rebuilding Reserves with No Harvest Reduction (Encompassing Approximately 20% of Habitat or Biomass)

Option 4: Establishing Alternative Management Reserves That Are Large Enough to Allow for a More Liberal Management Regime Outside the Reserve (Large Reserves, Encompassing Substantially More than 20% of Habitat or Biomass, Possibly 35% to 50%).

The objectives that marine reserves may help achieve might also be addressed by nonreserve policies. These nonreserve alternatives are addressed in Section 5 of the document.

Relation of Marine Reserve Options to Objectives

The expected impacts of each option in terms of the objectives that have been identified for marine reserves are summarized below, based on assessment of available empirical and theoretical evidence. Comparisons are made with respect to current (status quo) rebuilding policies.

Rebuilding and Biological Productivity

Stock rebuilding for relatively sedentary species within the borders of marine reserves is well established from empirical evidence. Lower total mortality rates within the protected area result in an increase in the average density, size, and age of the protected species. The reproductive output of the fish within the reserve will increase faster than the biomass, because of exponential size-fecundity relationships. With sedentary species, production outside the reserve will primarily be due to larval export. In contrast, the density, size, age, and fecundity of relatively mobile species within the reserve will increase less than that of sedentary species, with correspondingly less export of larvae. More mobile species will have a larger contribution to the area outside of the reserve due to movement of young and adult fish. Reserves will provide little protection to highly mobile or migratory fishes, unless the reserves are quite large; protect critical life history stages such as spawning or rearing aggregations; or protect stocks at a time that their catch per unit of effort (CPUE) would be exceptionally high,.

The most relevant evidence of marine reserves specifically serving to rebuild groundfish populations is that of the large area closures off New England (about 17% to 29% of cod, haddock and yellowtail flounder distributions); these closed areas were accompanied by overall harvest reductions, and thereby, closely related to Option 3a. Since the closure in 1995, groundfish spawning stock biomass has increased steadily within the closed areas. Harvestable biomass of scallops has increased 14-fold within the closures. While the experience in New England is encouraging, the relatively rapid recovery rates observed for haddock and cod in New England should not be expected for West Coast rockfish, because the species have very different life histories. Marine reserves will require a long-term commitment of management, enforcement, and research. When considering reserves for rebuilding individual species, it should be noted the effects on biomass outside the reserve will depend on the biology and behavior of the target species, the size of area taken out of production, and the harvest management, including habitat protection, in the area outside the reserve.

Small reserves (Option 2) likely will not significantly increase biomass outside the reserve or significantly increase the concentration of harvest (except possibly in localized areas adjacent to reserves). Medium-sized reserves may result in larval transport or adult spillover sufficient to enhance rebuilding outside the reserve. This is most likely if the harvest rate outside of the reserve is not increased (Options 3a). If reserves of substantial size are created and total harvest is not decreased (Option 3b), the same amount of fish will be taken out of a smaller portion of the habitat. Fishing rates outside the reserve would, therefore, increase; and biomass outside the reserve may well decrease. Changes in biomass outside the reserve would depend on the amount of larval export and adult spillover from reserve areas, and potential increases in growth/survival rates as a compensatory response to the reduced density of biomass. Total fishing effort may increase if biomass and availability outside the reserve decline (CPUE declines) and allowable catches remain constant. There would also be an associated increase in the concentration of gear/habitat interactions as harvest would be concentrated in a smaller area.

Very large reserves, created to substitute for other management regulations, would likely result in substantial reduction of the targeted stock biomass outside the reserve, because effort would be less constrained (Option 4). While production rates in the areas outside the reserve might increase, total annual production in the unprotected area would likely decline. At the same time, substantially larger biomasses would accumulate within the large reserve areas, potentially contributing to the outside areas through larval transport or adult spillover. The population response of individual species to this type of management is unpredictable with current knowledge, and it is likely to be species specific. The same concern over increased gear/habitat impacts outside the reserve, as stated for the preceding option, is a consideration for this option as well.

Economic Productivity (Harvest Related)

Outside the reserve, the **short-term** impacts are expected to range from negligible (Option 2) to negative (Options 3 and 4), depending on the size of the reserve. Negative impacts are expected based on initial harvester displacement and depletion of the stock as a result of the concentration of harvest over a smaller area (Option 3b and 4) or from reductions in the allowable harvest (Option 3a). Over the **long term**, based on theoretical models and on our understanding of the long distance dispersal potential of groundfish larvae, some rebuilding might be expected outside the reserve or a liberalization of regulations based on the existence of protected population within the reserve. For Option 2 and 3a, some long-term positive effects may be expected. For Options 3b and 4, the magnitude and direction of the net effects over the long term are uncertain. Based on present knowledge, the dramatic management changes associated with implementing Option 4 are probably risky.

The creation of a reserve that proves successful in protecting stocks of concern may enable managers to recommend higher exploitation rates on other stocks in the areas outside the reserve. Stocks of concern may be those with lower production rates than other stocks in a complex of overfished stocks or stocks listed under the ESA. Higher harvest rates for stocks of concern outside the reserve may allow fishers to access other species that are more productive or in better condition. If biomass increases outside the reserves area (i.e., there is a positive effect on rebuilding) cost-per-unit catch may decline (CPUE increase), thereby increasing the economic productivity of the stock without increasing total removals. However, there may be little change in the CPUE if stocks have been fished down in a serial process (i.e., vessels have fished out an area and moved on to another without experiencing a substantial long-term decline in CPUE).

Insurance

Properly designed and adequately enforced marine reserves can provide a buffer of biomass that can insure against uncertainties in stock assessments, overharvest of species for which little assessment information is available, and harvest controls that do not adequately restrain harvest. The primary effectiveness, and hence insurance, provided by marine reserves would be for species with sedentary life stages that would be afforded protection from fishing within the reserve. The greater the area set aside within marine reserves, the more insurance provided. However, as discussed above, harvest regulations outside the reserve area could diminish overall biomass levels (Options 3b and 4).

Habitat

Habitat within reserves should be afforded significant protection from interactions with fishing gear, and species diversity should also be enhanced. The impacts on habitat outside the reserves would depend on harvest regulations in that area. If the same amount of harvest is concentrated over a smaller area (Options 2, 3b, and 4) or reductions in biomass result in an increase in effort to harvest the same amount of fish (Options 3b and 4), gear interactions with habitat are likely to increase. If these interactions have a negative effect, there may be negative impact to the species using the habitat and the ecosystem in areas outside the reserve. Designation of a marine reserve and the associated awareness of its importance, may provide some protection against impacts from nonfishing, and industrial activities within the reserve that are outside the Council's purview.

Research and Education

All marine reserve options would provide significant research and education opportunities. Research opportunities include development of improved population parameters to assist in stock assessments and a better understanding of fishery/habitat interactions and ecosystem processes. Part of the research and education opportunity is provided by the contrast of areas within and outside the reserve.

Other Social and Economic Impacts

Monitoring Reserve Effectiveness

Good baseline and post-implementation studies of the reserve areas are necessary to determine the effects of the reserve. Knowledge of fishing effort prior to creation of the reserves, as well as in control areas before and after the creation of reserves, will be important for interpretation of results. There is substantial risk in improperly evaluating reserve effectiveness. Negative impacts could ensue if inadequate monitoring and evaluation resulted in (1) finding reserves are effective when they are actually ineffective, or (2) finding reserves are ineffective when they are actually effective. In the former case, harvest regulations outside the reserve might be liberalized under the false belief reserves are providing some protection. In the latter case, all the costs of developing and implementing reserves, along with the benefits that would be derived, might be inappropriately abandoned.

The costs of monitoring reserve effectiveness are difficult to evaluate at this general level of discussion and will primarily be dependent upon the number and size of reserves and the number of significant types of habitat encompassed in the reserves. There is considerable potential for planned and ongoing habitat and stock evaluation efforts to be modified or enhanced, so the results would be of use in the evaluation of reserves. The West Coast groundfish surveys and future NURP research may be of particular use for this purpose. With the larger reserve options there is also some potential for using cooperative industry/agency research platforms for extractive monitoring.

Enforcement

Marine reserves will not be effective if compliance with regulations is inadequate. It has been suggested there is not much sense in creating reserves of greater size or number than that for which enforcement resources are sufficient to ensure compliance. From experience, it is important to clearly identify and assign enforcement responsibilities. Public and industry acceptance are key to adequate enforcement over the long term. However, there is substantial risk and uncertainty associated with assuming informal public surveillance will be adequate to ensure compliance. Some design features make marine reserves more enforceable than others. The New England closures are being effectively enforced using a satellite vessel monitoring system.

Information Value

The greater uncertainty there is about how a system is operating, the greater the value of new information about that system. In the late 1980s and early 1990s, managers believed they were on the way toward sustained yields. The recently documented depressed conditions of those few stocks for which we have information raise concern and uncertainty regarding the numerous stocks for which little information is available. Considering the increased uncertainty in assessment of fishery resources, the value of implementing marine reserves to improve our understanding of fishery resources may be much greater than it was a number of years ago.

Existence, Bequeathal, Option Values

The objective related to sustained economic productivity was evaluated primarily in terms of harvest. However, other values will be generated from the creation of marine reserves, including (1) existence value derived from knowing a fish population or ecosystem is protected[2/] without intent to harvest, observe, or otherwise derive direct benefits from the resource; (2) bequeathal value placed on knowing a fish population, habitat, or ecosystem is protected for the benefit of future generations; and (3) options value placed on knowing a fish population, habitat, or ecosystem has been protected and is available for use, regardless of whether the resources are actually used. These values may be closely related and overlap with values the general public places on wildlife and natural parks. Some consideration of these values should be included in the impact assessment for specific marine reserves.

Non-Marine Reserve Alternatives

A number of non-marine reserve alternative measures that could address the objectives for marine reserves were identified by the MRC. Not all committee members endorsed all of the alternatives. The alternatives are not mutually exclusive, and none (together or in combination) completely substitute for marine reserves. Marine reserves, similarly, are not a complete substitute for any of the nonreserve alternatives. However, the non-marine reserve alternatives could reduce the need for such reserves, thus affecting the decision on whether or not to implement marine reserves. For example, given the risks and uncertainties of the current fishery management system, an individual might make the qualitative judgement the likely benefits of marine reserves warrant their costs. On the other hand, if a comprehensive observer program were in place, and the fleet and allowable catch had been reduced, the same individual might conclude the additional benefits from marine reserves would not warrant their costs. It is important to consider all expected benefits of the reserve system such as enhanced ecosystem, multispecies, and habitat protection. Similarly, the existence of an extensive marine reserve system may not substitute for an observer program or for lower target harvest levels, but might affect the balance of the expected costs and benefits from implementing an observer program or reducing capacity and harvest. The non-marine reserve alternatives identified by the MRC are:

a. Time and area closures.
b. Fleet reduction in combination with reduction in allowable catch: buyback, individual transferable quotas, status quo (economic attrition).
c. Zero fishing mortality on target spp including no bycatch mortality.
d. Lower total fishing mortality.
e. More conservative stock assessment parameters.
f. More and better data for stock assessments.
g. Reduce capability of individual vessels to impact critical habitat.
h. Gear restrictions in certain areas (stated in terms of performance standards; (e.g., no gear with impact on critical habitat).
I. Allocation toward gear types with less impacts to habitat.
j. Observer program (including better documentation of removals).
k. More effective enforcement (better control of removal)

2/ The term "protection" includes consideration of precautionary values afforded by different degrees of protection of the resource both within and outside the reserve.

1.0 INTRODUCTION

The Pacific Fishery Management Council (Council) has specified a two-phase process to consider marine reserves (also known as no-take areas, marine protected areas, harvest refugia, and defined in this document as an area that prohibits fishing) as part of an integrated scheme to sustain a healthy ecosystem and more effectively manage the West Coast groundfish fisheries. The first phase is a conceptual evaluation of marine reserves and it will conclude with a decision on whether or not marine reserves have a role in Council fishery management. During the first phase, an Ad Hoc Marine Reserve Committee (MRC) appointed by the Council developed management objectives that might be addressed by marine reserves. Major marine reserve options were identified for analysis as well as nonreserve options that might address similar objectives. This report provides a technical analysis of the expected impacts of marine reserves, particularly with respect to the identified objectives and the major options that have been developed by the MRC. During the second phase, if pursued by the Council, full specification and siting for marine reserves would be developed, including considerations of number, size, shape, location, and other design criteria. The second phase also would include development of a public outreach program to ensure that all interested parties have an opportunity to be involved early in this process.

1.1 Problem Statement: Some Current Challenges to Meeting Fishery Management Plan Goals

The Council has three main goals for management of the groundfish fisheries on the West Coast, in order of priority:

> **Goal 1 - Conservation.** Prevent overfishing by managing for appropriate harvest levels and prevent any net loss of the habitat of living marine resources.
>
> **Goal 2 - Economics.** Maximize the value of the groundfish resource as a whole.
>
> **Goal 3 - Utilization.** Achieve the maximum biological yield of the overall groundfish fishery, promote year-round availability of quality seafood to the consumer, and promote recreational fishing opportunities.

The groundfish fishery management plan (FMP) states that these goals are to be considered in conjunction with the national standards of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act).

Of particular emphasis in the Sustainable Fisheries Act[1/] are goals related to the identification and prevention of overfishing and the identification, description and protection of essential fish habitats.[2/] The prevention of overfishing and the protection of habitats also are the top priority goal of the Council.

Five Council-managed species (bocaccio, lingcod, POP, cowcod and canary rockfish) currently are considered to be overfished, and stock rebuilding plans either have been developed or are in progress. Estimated biomasses of the majority of other groundfish species for which stock assessments are available have long-term downward trends. However, there are no stock assessments for most of the 83 species included in the West Coast groundfish FMP. As many of these unassessed species co-occur and are caught by the same types of fishing gear, it is expected their populations may be experiencing similar declines.

Such downward trends in biomass likely are due to natural variability in the marine environment and the resultant levels of survival of young fish, as well as being the result of fishing down stocks that previously were

---

1/ The Sustainable Fisheries Act of 1996 reauthorized the Magnuson-Stevens Act.

2/ Any fishery management plan . . . shall . . . . (7) . . . minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat; . . . . (Section 303[a]).

lightly exploited. This fishing-down process is largely over, and the Council is now in the difficult position of trying to move to a harvest policy that must balance catch against the very low annual production of these stocks.

Fishery managers are concerned with maintaining the biological and economic productivity of those stocks that benefit West Coast fishing communities. Long-term economic productivity from the fishery is dependent in large part on long-term biological productivity. Maintaining appropriate levels of biological productivity depends on rational fishing mortality rates and healthy ecosystems and fish habitat. Habitat degradation resulting from human-induced activities, such as possible dumping, pollution, and fishing-gear disturbance as well as increasing coastal development, are a continuing concern for fishery managers on the West Coast and the subject of ongoing deliberations of the Council's Habitat Steering Group.

Effective management of marine fisheries is being attempted in an environment where there are many unknowns and uncertainties about the status of the stocks and indeed about the entire ecosystem that supports them. It is apparent that successful resource management must work toward reducing uncertainty through increased scientific knowledge and research of marine ecosystems and adopting management measures that are more robust to uncertainty. Failure to do so could prevent rebuilding overfished stocks, could lead to Endangered Species Act (ESA) listings, and could have dramatic negative consequences for economic productivity of the fishery.

1.2 Why Consider Marine Reserves as a Tool for Fishery Management?

It is clear that traditional management efforts alone are not successfully protecting and sustaining many of our groundfish populations and their habitats. Marine reserves are being promoted worldwide to mitigate overfishing and the impacts of fishing activities on seafloor habitats. Rowley (1992), among others, has suggested that marine reserves can be most beneficial to depressed species that reach great size or age and have limited movements or sedentary behavior; these attributes apply to many West Coast groundfish species, some of which have been overfished. Marine reserves demonstrably conserve and enhance fish populations within their borders by, (1) increasing fish abundance, size, and age composition; (2) protecting critical spawning stocks and habitats; (3) providing multi-species protection; (4) contributing to the preservation and maintenance of community structure and function, especially protecting the natural diversity of species and habitats; and (5) providing undisturbed, reference sites against which we can evaluate the effects of fishing and other human activities on marine ecosystems. These unharvested sites could provide researchers with a valuable means to separate the effects of fishing from those caused by natural changes in the environment. Data from unfished reference sites also could be used to improve estimates of population parameters for harvested species, thereby directly improving management of the fisheries. The capacity of marine reserves to enhance fishery yields outside their boundaries is not as well documented, primarily due to the lack of research on this effect. Until recently we have had no long-term marine reserves of adequate size with which to test these potential benefits and understand their contribution to enhancement and conservation of fish populations.

1.3 Objectives

Following the recommendations of the MRC, the Council adopted six fishery management objectives that might be addressed by marine reserves as a supplemental tool for management of groundfish fisheries. These objectives are interlinked and not mutually exclusive. Implementing a network of reserves to address one objective most likely will achieve various aspects of all objectives. The following are the objectives that marine reserves might help address, ranked in order beginning with the top priority objective.

Objective 1: Stock Rebuilding. Assist in rebuilding overfished stocks and maintaining them at productive levels.

Objective 2: Biological Productivity. Enhance long-term biological productivity.

Objective 3: Economic Productivity. Assist in achieving long-term economic production, while minimizing short-term negative economic impacts on all users and still meeting the major goals of the marine reserves.

Objective 4: Insurance. Provide protection insurance for the resource as a hedge against the realities of management uncertainty and the effects of natural environmental variability. This is intended as a supplement to other precautionary fishery management policies.

Objective 5: Habitat Protection. Conserve and protect essential fish habitat.

Objective 6: Research and Education. Provide unfished areas for research that will increase our understanding of the functions and contributions of marine reserves, and will serve as controls for assessment of the effects of long-term environmental variations and potential habitat alterations due to fishing.

1.4 Options

This report is intended to assist the Council in the conceptual evaluation of the role of marine reserves as a management tool. The role of marine reserves as a fishery management tool must be evaluated in the context of the full suite of expected effects, including those impacts that may have little or indirect relation to the task of managing the fisheries. Four options have been developed in considering the implementation of marine reserves, with a primary focus on the first objective (i.e., stock rebuilding). Section 5.0 provides a brief review of nonreserve alternatives for addressing the objectives listed for marine reserves.

Option 1: Status Quo Rebuilding (With No Marine Reserves)

This is a "status quo" management option. Under this option no action would be taken to accelerate the primary objective of rebuilding overfished stocks above that which is expected from the rebuilding plans already adopted by the Council. This approach attempts to reduce targeted fishing mortality for certain depleted stocks, while continuing to allow substantial associated bycatch and discard mortalities.

Option 2: Heritage and Research Reserves (Small Reserves, Encompassing a Minimum of Approximately 5% of Habitat or Biomass)

This option would entail the smallest size-class of marine reserves. While small, the reserves would be substantially larger than existing no-fishing reserves. These marine reserves must be large enough to achieve and maintain the ecological integrity (e.g., abundances, size composition, species, and habitat diversity) within the protected area. These small reserves would be intended to be effective at protecting highly sedentary species and representative essential, unique or sensitive fish habitats. If sited correctly they may help to avoid future ESA listings. If maintained for a sufficiently long period of time, these small protected areas would allow individuals to achieve their natural life span, thereby helping to preserve genetic diversity of some assemblages. These areas would enhance and protect species and assemblage diversity within the boundaries of the reserves. These reserves would be located regionally along the West Coast, in consideration of the distribution of key fish species and essential habitats, onshore-offshore movements and home ranges of key species. Consideration should also be given to integration or co-location of these reserves with potential natural refugia and existing protected areas under other management jurisdictions. The recommendation from fishery scientists and managers is that this type of reserve should protect a minimum of 5% of targeted habitats or populations (Carr et al. 1998). Reserves of this size would not be large enough to significantly contribute to rebuilding stocks or to supplement traditional fisheries management, but could be sufficiently large to enhance fishing opportunities along the reserve boundaries on those individual fish moving out of the reserve.

Heritage and research reserves should be essentially no-take areas, allowing research and monitoring by permit only. A valuable role for these relatively small marine reserves is that of "reference or benchmark sites," which would provide necessary controls for monitoring local trends in populations and ecosystem processes. They would be particularly effective as controls for evaluating the effects of fishing activities in nearby unprotected areas. These reserves also would facilitate discrimination between the effects of long-term climatic fluctuations and fishing on local populations.

Option 3: Create Marine Reserves to Rebuild Depressed Stocks

The next size-class of marine reserves would be designed and located primarily to promote the rebuilding of overfished stocks and, because of their increased size, would address all other objectives as well. Two options are provided under this size class (3a, reserve and harvest reduction, and 3b, reserve only). The use of marine reserves to rebuild stocks would be evaluated species by species based on life history characteristics. Size, in this context, refers to the total area encompassed by a network of reserves. A reserve network, which could include individual reserves of various sizes, is likely to be more effective in accomplishing multiple objectives than a single large reserve. Reserves meeting these objectives might include about 20% of targeted habitats or populations.

Option 3a: Rebuilding Reserves with Harvest Reductions Proportional to the Amounts Set Aside in Reserves (Encompassing Approximately 20% of Habitat or Biomass)

Under this option, the biomass available for harvest would initially be reduced by the estimated biomass inside the reserves so as not to simply redistribute and concentrate fishing effort into the unprotected areas. Thus, harvest rates would be applied to smaller biomasses, implying a reduced amount of fish available for harvest. One likely approach is to estimate the amount of within-reserve appropriate habitat for the species as a percentage of such habitat throughout the exploited range of the population. Estimated harvestable biomass for a particular species would be reduced by the percentage of habitat protected within the reserve. Adjustments to the harvestable biomass should be considered, though not necessarily implemented, for all fish stocks protected by the reserve, including those that are not targeted for rebuilding. No adjustments would be required for fish stocks that are transient through the reserve, as reserves would provide little protection to these stocks (e.g., salmon, albacore, small pelagics, etc.), except in the case of pelagics that form spawning or rearing aggregations on specific oceanographic and seafloor features. If habitat is the basis for assessing distribution of biomass, separate habitat-specific estimates of biomass would be required for each species.

Over time, depending on the age-dependent fecundity and density-dependent recruitment mechanism of the individual stock, biomass may rebuild more quickly with marine reserves than would occur without them. Hence, if effective in rebuilding biomass, harvest levels may be higher and regulations less restrictive than would otherwise occur.

Option 3b: Rebuilding Reserves with No Harvest Reduction (Encompassing Approximately 20% of Habitat or Biomass).

Marine reserves would be designed and located to promote the rebuilding of overfished stocks, and other objectives listed in Section 1.3 would be achieved to varying degrees. Option 3b is similar to 3a except that harvest policies would be applied to the entire population biomass, including that occurring inside the marine reserve, thus there would be no initial reduction in allowable harvests, as compared to status quo management. Harvest levels similar to those in place prior to the creation of reserves would be concentrated in smaller geographic areas (previous fishing areas less the reserve areas). The use of marine reserves to rebuild stocks would be evaluated species by species based on life history characteristics. Over time, depending on the age-dependent fecundity and density-dependent recruitment mechanism of the individual stock, biomass may rebuild more quickly with marine reserves than would occur without them. Hence, if effective in rebuilding biomass, harvest levels may be higher and regulations less restrictive than would otherwise occur. Rebuilding likely would be slower under Option 3b than under Option 3a, and therefore it is possible that long-term total allowed harvests could be lower than under Option 3a but higher than status quo.

If reserves are in place, a more liberal rebuilding policy might be adopted on the assumption that while the complete effects of marine reserves on rebuilding are unknown, these effects are likely to be positive. Such decisions of fishery managers from the Council and NMFS would depend on their assessment of the likelihood that reserves will accelerate rebuilding.

Option 4: Establish Alternative Management Reserves That Are Large Enough to Allow for a More Liberal Management Regime Outside the Reserve (Large Reserves, Encompassing Substantially More than 20% of Habitat or Biomass, Possibly 35% to 50%).

This size-class of marine reserves would collectively comprise an area that is sufficient in size to sustain fisheries of targeted species in nearby fished areas. From conceptual and theoretical modeling efforts, it has been suggested that a network of reserves incorporating substantially more than 20% (35%-50%) of appropriate habitats or of total spawning biomass could maximize long-term sustainable yields and reduce annual catch variability (Carr et al. 1998; Mangel 1998; Sladek Nowlis and Yoklavich 1998; Sladek Nowlis and Roberts 1999), while allowing more liberal rates of fishing mortality than would be prescribed without large reserves (Lauck et al. 1998). The contributions from a large network of closed areas to fish populations would allow a wider variety of fishing management strategies outside the reserves and reduce the need for precautionary measures. Measures to prevent localized depletion might be considered. The expected benefits of this type of reserve are realized largely from transport of young rather than from adult spillover out of the reserves, suggesting these reserves should be designed to comprise sufficient spawning populations of the target species.

2.0 BIOLOGICAL INFORMATION LIMITS

While there is abundant evidence that many species (especially exploited species) substantially increase in biomass, abundance, average size, and reproductive capacity within reserve boundaries, there is limited information to evaluate the merits of marine reserves as a fishery management tool and their potential contribution to West Coast groundfish stocks. Marine protected areas that exclude some types of exploitation while allowing others, such as those in California that either restrict fishing in spawning/nursery grounds, prohibit trawling within three nautical miles off shore, or exclude gillnetting for nearshore rockfishes, have been established for many years. Unfortunately, there has been no evaluation of the contribution of these types of closures to the productivity or protection of relevant stocks.

Designated no-take reserves (those that prohibit the harvest of all species) are uncommon along the West Coast, and are insufficient in size, number, and location to adequately evaluate their effects on fished populations. Most of these reserves were established for general conservation purposes, without the specific objective of effective fisheries and ecosystem management. Monitoring biological resources in many of these small areas has just begun. There are 17 very small marine reserves in California that prohibit either recreational, commercial, or all harvest. These areas cover a total of 32 km of coastline and comprise a mere 44 km^2 or 0.26% of state waters (McArdle 1997; McArdle 1998). Off Washington, there are four very small reserves in Puget Sound that prohibit recreational and commercial bottomfishing. These areas range in size from 0.002 to 5.5 km^2 (Palsson 1998). Off Oregon, there is only one very small marine reserve that is closed to taking fish and invertebrates and located in Whale Cove along the central Oregon coast (Didier 1998). There are no marine reserves in water deeper than 100 meters anywhere off the West Coast.

Modeling may provide some insight into the effectiveness of marine reserves to manage fishery resources, particularly in comparing age-dependent growth and reproductive rates of populations inside reserves versus those in exploited areas. However, the lack of basic information on fish mobility, larval transport, recruitment mechanisms, and habitat-dependent life history parameters hinders the development of realistic species-specific models. Most of the available models of the effects of marine reserves assume total protection within the reserve and either unregulated or constant, above-optimum fishing mortality outside the reserve. In these situations reserves theoretically can enhance yield, protect habitat, and decrease annual catch variability (see above). Several modeling studies have suggested that reserves occupying 50% of a species habitat may result in increased yields (Polacheck 1990, DeMartini 1993). However, it has not been demonstrated that a fishery that is regulated to achieve optimum yield can be improved by implementation of marine reserves. It is equally important to note that it has not been demonstrated the regulatory intent of achieving optimum yield has been met through conventional management for any of the West Coast groundfish stocks. **This emphasizes that those information-limitations to successful application of a marine reserve network are not necessarily greater than those information-limitations to conventional management.**

While noting the limits to our scientific knowledge, many scientists and managers have recognized there is sufficient understanding of the problems facing effective groundfish management and conservation to proceed with the process of marine reserve implementation (consolidated recommendations in Yoklavich 1998; Murray et al. 1999a).

2.1 Information that will Contribute to Successful Application of Marine Reserves for Fisheries Management

2.1.1 Mobility and Larval Dispersal

Some knowledge of the movements of individual species will assist in the design of effective marine reserves, and this is of particular importance if the goal of the reserve is to rebuild stocks of specific species. Successful application of marine reserves is based on the assumption that fishes will remain in the reserves for extended periods of time (DeMartini 1993). However, for marine reserves to benefit a fishery it is necessary that these fish do not stay in the marine reserve during their entire life history. Movement between reserve and open areas is likely to occur differentially during larval, juvenile, and adult life stages. Most Pacific Coast groundfish have pelagic early-life stages that disperse during several months over a broad geographical area and then settle to benthic habitats (Love et al. 1991). Little is known about the mobility of post-settlement juveniles. In general, most of these species exhibit ontogenetic movements from shallow water as juveniles to deeper water depths as adults. Some species may have extensive juvenile movement; others may settle in a specific bottom habitat or depth range suited to their juvenile stage, remain there until nearly mature and then move to adult habitat. Some species may never move any significant distance from the initial site of settlement. The adults of many demersal species have limited movement. Some species, such as yellowtail (Carlson and Haight 1972; Pearcy 1992), copper and quillback rockfishes (Matthews et al. 1987), return to their home site after being displaced various distances, depending on seafloor topography, depth, and bottom types.

Species that have limited geographical movement as juveniles but more extensive movement as adults, and species that occur in different habitats as juveniles and adults, are particularly good candidates for reserve management. This is because reserves will reduce growth overfishing by protecting young fish that are collectively growing in weight faster than they are lost to natural mortality. The reserve effect is, therefore, similar to trawl mesh-size limits, and perhaps more effective, as there is likely to be some mortality of fish that pass through trawl nets.

Marine reserves likely will not achieve any protection for highly mobile species of groundfish unless the size or geographical placing of the reserve precludes the fishery from reaching annual quotas for this species or certain life stages are protected. For example, adults of the main stock of Pacific whiting annually migrate from spawning grounds in the vicinity of Point Conception, California to feeding grounds off Oregon, Washington, and British Columbia (Bailey et al. 1982). Marine reserves will offer much less protection for this species than for more sedentary species.

Mechanisms of larval transport (including patterns of dispersal, retention, and redistribution) could be used in the design of marine reserves to achieve significant enhancement of some stocks (Carr and Reed 1993; Morgan and Botsford 1998). For example, placing reserves in geographic areas of relatively high productivity and high reproductive success could result in higher recruitment rates than a situation without reserves. A strategy of protecting areas with high reproductive success, and fishing those with low reproductive success, would be one of high priority. However, little is known about area-dependent reproductive success and subsequent settlement and recruitment.

Understanding the connection between adult source populations and sites of successful settlement and recruitment of the young is critical in designing effective reserves. Larval transport of groundfish populations can cover great distances, and is thereby influenced by broad oceanographic conditions. Consequently, adult populations can be dependent on larval recruitment from distant sources. For continued replenishment of local populations, the source of these pelagic stages (eggs and larvae) needs to be hydrographically linked to the sites of settlement. Because of these connections or linkages, comprehensive networks of marine reserves throughout the range of groundfish species have been recommended (Murray et. al., 1999a). Interestingly, the larvae of at least some tropical reef fish species recruit back to the reefs where they were spawned (Swearer et al. 1999; Jones et al. 1999). Larval retention and self-recruitment processes such as these suggest that in certain environments marine reserves may not have to be very large to be self-sustaining.

2.1.2 Growth Rates

Marine reserves could provide fishery benefits at opposite ends of the growth rate scale. As mentioned in the previous section, protection of young fishes that move out of the reserves and are harvested at a larger size could increase the productivity of a fishery and also enhance rebuilding of relatively fast growing species such as bocaccio and lingcod. Slow growing species, such as POP, cowcod, and canary rockfish currently experience substantial bycatch mortality during the 6-12 years before they are fully recruited to the fishery. Marine reserves could significantly reduce this mortality, particularly if they are placed in areas having high concentrations of young fish.

2.1.3 Age-Specific and Size-specific Fecundity

Fecundity increases exponentially with age and size for most West Coast groundfish species. Most groundfish species also have considerable longevity, delayed age-at-maturity and low to very low natural mortality rates (once settlement takes place). With this type of life history, even modest exploitation rates result in a large reduction in the average age and reproductive output of the stock. Reserves are certainly one tool that could prevent major declines in reproductive output for species with size-dependent and age-dependent fecundity and that reproduce annually over a long lifetime. The effect of increased annual fecundity with age/size is likely to be most significant for species that produce multiple batches of eggs/larvae per year. This is, because the number of batches increases with age. Although more than one spawning per year has been observed in some rockfish species, it is not known if the incidence of multiple spawning is size/age dependent. Information on multiple spawning is not available for most of the West Coast groundfish.

2.1.4 Density-Dependent, Compensatory Factors

It is generally agreed that decreasing a population by fishing will result in beneficial, or compensatory, density-dependent alterations in population rates. The long-term productivity and stability of exploited species are primarily regulated by compensation caused by increased growth, reproduction, and survival rates that are a response to lowered population densities. Recruitment is the process that is usually assumed to have the most compensation and most of the Beverton and Holt stock-recruitment models in use for Pacific Coast groundfish have very high compensation at low stock sizes. Managing fisheries with marine reserves has the potential to either decrease, increase, or have little effect on recruitment, contingent on the density-dependent recruitment mechanism of the managed species (Parrish 1999). Density-dependence could occur at three life history stages (i.e., egg or larval production, pelagic larval stage, or the post-settlement juvenile stage). In most Pacific Coast groundfish, it is unlikely to occur in the pelagic larval stage, because the densities of pelagic larvae in zooplankton surveys are very low. If density-dependence occurs at the egg or larval production stage it will most likely be caused by improved condition of the adults due to decreased competition. In this case, a significant proportion of the spawning stock would concentrate at high densities inside the reserves, thereby potentially reducing survival rates of young; this reduction may or may not be compensated for by increased reproductive output within the reserve. In contrast, if the density-dependence occurs at the post-settlement juvenile stage, due to competition among juveniles or between juveniles and older fish, concentrating adults inside the reserves could increase recruitment in the areas open to fishing where there are low adult densities. Knowledge of the source of compensation in recruitment will, therefore, be important in the assessment of the value of marine reserves, just as it also is important in assessing the value of conventional catch management.

2.2 Modeling Stock Rebuilding

Only two fisheries in the California Current System have been successfully rebuilt, Pacific mackerel (chub mackerel) and Pacific sardine. Both were rebuilt under moratoriums on landings in California. However, it could be said that both of these stocks were rebuilt with area closures as there was no moratorium on landings in about 50% of the sardine's range (i.e., Baja California, Oregon, and Washington). Rebuilding rates are dependent on the amount of protection given to the targeted population and, as seen in the two examples above, the fastest recovery will occur when landings are prohibited. Reserves are one way to provide protection while allowing a continuing fishery. Because crucial information on recruitment, mobility, and bycatch is sparse, it will be very hard to establish valid model formulations and parameters to assess the relative merits of reserves versus traditional quota management. With limited information, it is possible to demonstrate with one model that reserves will significantly assist in stock rebuilding, while another model with different assumptions could suggest that reserves will not help.

2.2.1 Limitations of Stock Assessments

The majority of stock assessments for Pacific Coast groundfish have been based on single box models that necessarily incorporate the simplifying assumptions that fish habitat, natural population dynamics, and behavior are homogeneous and stationary. While these assumptions likely are not valid, there is little information to document the geographic or temporal variability of these factors. Unfortunately, the merits or disadvantages of using marine protected areas as part of a new management regime will largely depend on the variability of these factors.

The stock synthesis model has become the standard for assessing the past and current stock sizes of most Pacific Coast groundfish stocks. It also is used in a forecast mode to estimate future population parameters under different exploitation rates. Like many other cohort analysis models, the stock synthesis model is most useful when estimating stock size several years in the past. An estimate of current stock size is significantly less accurate due to limited data on young year-classes. Thus, there is increasing dependence of estimated year-class size on recruitment functions, with the youngest year-classes often entirely dependent on estimated recruitment. For this reason, forecasts become increasingly less accurate the farther they are projected into the future.

When recruitment success is relatively constant from year-to-year, current assessment models can forecast approximate optimum yields from a groundfish stock for several years in the future. When annual recruitment success is highly variable, and particularly when recruitment consists of long runs of below average recruitment interspersed with single, exceptional year-classes, current models will tend to significantly over-estimate more than underestimate future productivity of the stock. This is very likely if the forecasts are made with optimistic estimates of recruitment (Ralston et al. 1996).

The fishing industry, fishery biologists, and managers are aware that the accuracy of current stock assessment models are limited by less-than-adequate fishery and fishery-independent data, caused largely by a lack of adequate funds for monitoring programs. If lack of information continues, a mixed mode management system utilizing stock assessments, annual quotas, and moderate sized marine reserves could offer significant protection against setting quotas that were reasonable but, in hindsight, too high.

2.2.2 Limitations of Reserve Models

Modeling of marine reserves has received only minor attention in comparison to stock assessment modeling and the majority of published reserve models do not contain sufficient species-specific data and estimates of population dynamics parameters. This is, because the data requirements of more complicated and realistic reserve models exceed current knowledge. Accurate assessment of optimum reserves for a given species requires geographically specific population estimates, area-dependent population rates and estimates of age-specific mobility.

Modeling recruitment for populations with a significant proportion of their biomass in reserves will be more problematic than for current stock assessments, because the reserves will have different age structures, population densities, and possibly different recruitment success than areas open to fishing. Information necessary to develop these area-specific parameters currently is not available. It will require significant data analysis and probably additional monitoring to acquire this information.

Reserve modeling should include some analysis of the effects of the reserve on non-target species, habitats and fisheries, including social and economic effects. If moderate or large marine reserves are proposed and implemented, an important part of the modeling will include the multispecies effects of the reserves. For example, it is clear that reducing exploitation of bocaccio by setting aside 30% of its habitat as a marine reserve will have a much larger effect on the entire ecosystem than that which would occur with a 30% reduction in the annual bocaccio quota. It also is likely that the adjunct effects of a reserve designed to protect 30% of the bocaccio habitat will greatly exceed the effects on bocaccio.

2.3 Empirical Evidence for Impacts of Marine Reserve

The best example of marine reserves specifically serving to rebuild groundfish populations is that of the large area closures on Georges Bank and vicinity (Murawski et al. In Press). Following the stunning failures in several groundfish stocks, 17,000 km^2 (from 17% to 29% of the area occupied by cod, haddock, and yellowtail flounder off New England) were closed to the use of any gear that caught groundfish species. These were year-round closures starting in 1995, located to protect significant proportions of cod, and haddock spawning stocks. These closures, together with a moratorium on new vessel permits, an increase in minimum mesh size and reduced trip limits, resulted in a significant reduction in exploitation rate (i.e., percentage of stock removed per year). The actions of closing an area and reducing harvest would be similar to the actions proposed in Option 3a. The latest stock assessments indicated significant increases in spawning stock biomass for Georges Bank haddock and yellowtail flounder and smaller increases in cod biomass; these increases were attributed to increased adult survival due to protection within the closed areas. The closed areas also protect young cod and haddock throughout the year, as well as a number of unfished species. Extremely large and valuable increases in scallop abundance within and near the closed areas (up to 14-fold), with associated increases in catch, were an unexpected benefit.

There is growing empirical evidence on the West Coast that some fish species protected within some of the few existing no-take marine reserves have greater abundance and size, and consequently increased spawning biomass, compared with those in adjacent fished areas. For example, reproductive potential of copper rockfishes inside a 27-year-old marine reserve in shallow water of Puget Sound, Washington was 55 times greater than that of coppers subject to heavy fishing pressure outside the reserve. This enhanced reproductive potential derived from greater densities and larger sizes of coppers inside the reserve (Palsson 1998). Similarly, significantly more and larger lingcod and copper rockfishes were observed inside a tiny 6-year-old no-take reserve in the San Juan Islands, Washington compared to adjacent unprotected areas (Palsson and Pacunski 1995). Reproductive potential for black-and-yellow rockfishes inside two small longtime reserves in Monterey Bay, California was 2 times greater for one reserve and 10 times greater for the other, as compared to the reproductive potential for this species in heavily fished areas immediately outside the reserves (Paddack 1996). Even within the relatively new Big Creek Ecological Reserve off central California (closed to harvest since 1994), size distributions of several economically valuable rockfish species appear to be significantly greater than for those in adjacent fished sites; species that were not being harvested did not show these differences in size (M. Yoklavich, R. Lea, and G. Cailliet, unpublished data). Despite their small size and lack of scientific siting criteria, all of the West Coast reserves that have been studied exhibit significant increases in abundance, size, or reproductive capacity of exploited species.

Similar increases in abundance and size have been reported for species associated with natural refugia (i.e., those areas that naturally afford protection from fishing) and other unintentional reserves. Examples include refuge for a healthy red abalone population off northern California at water depths that preclude harvest (Tegner et al. 1992), and high numbers of large rockfishes locally associated with isolated rock outcrops in deep water of narrow submarine canyons that are less accessible to fishing (Yoklavich et al. In Press). Restricted fishing access for security reasons at the Kennedy Space Center at Cape Canaveral over the last two decades has resulted in greater diversity, density, and size of economically valuable fishes in two unfished areas compared to nearby fished areas; tagging studies demonstrated movement of fishes from the de facto reserves to the fished areas (Bohnsack 1998; Johnson et al. 1999). It seems clear the portion of a population protected from the effects of fishery selection will live longer, achieve larger sizes and a more natural size distribution, and; therefore, produce more young over their lifetime than counterparts in unprotected fished areas.

Similar effects of no-take reserves have been documented in those tropical and temperate systems where the majority of these protected areas have existed for many years. Abundance, size, and reproductive output increased for protected populations of many species of reef fishes and various invertebrates worldwide (see Roberts and Polunin 1991; Dugan and Davis 1993; and Rowley 1994 for review of these studies). Increased catch-per-unit-effort was reported for 6 of 10 harvested fish species inside a newly established marine reserve off South Africa (Bennett and Attwood 1991). A recent review of data from over 80 marine reserves in both tropical and temperate waters reported that some 80% of the reserves exhibited the "marine reserve effect", that is fish and shellfish species inside reserves increased in abundance and size relative to populations outside (Halpern, 2000). Various explanations have been cited for those species that did not exhibit these enhancements within the reserve, including, (1) protection of inappropriate habitats, (2) behavior of the targeted species is not conducive to management by marine reserves, (3) inadequate reserve design, (4) inadequate recovery time or time of closure to reflect significant effects, and (5) lack of enforcement.

There is less empirical evidence that supports enhancement of fish populations in adjacent unprotected areas, primarily due to the lack of research on this effect. Enhancement of fished populations could occur from spillover of adult fishes moving from the reserve to unprotected areas, and from transport of young fishes that are produced by high numbers of spawning adults within the reserve and subsequently recruit to adjacent areas. Most marine reserves have been established for conservation and research purposes and are too small to significantly replenish unprotected populations. Some of the strongest evidence of export of adult fish from a reserve to unfished areas is that of increased yields and abundance of several species of large predatory coral reef fishes associated with two small marine reserves off the Philippines (Alcala and Russ 1990; Russ and Alcala 1996). Many more studies on the effects of reserves on populations in adjacent fished areas are needed, especially as related to our fishery resources in the temperate waters of the northeast Pacific. In addition to 'spillover' or export of adults from reserves, increased spawning stock (i.e., high numbers of larger individuals having increased reproductive output) within the reserve could enhance the overall reproductive potential of particular species, especially those with extreme recruitment variability. From limited theoretical studies (see above) and life history characteristics, enhancement of fished populations, especially those with relatively sedentary adults as is the case for many West Coast groundfish species, is expected to come most likely from the supply of young to unprotected areas.

3.0 BIOLOGICAL IMPACTS OF MARINE RESERVES AND ALTERNATIVES

The impacts and design characteristics of any network of marine reserves will be dependent to a large degree on the philosophy of the resource managers. Until the goals of a reserve program are established and a number of experimental reserves are proposed, it will be very difficult to address impacts on target species, other healthy exploited stocks, bycatch, or the ecosystem.

3.1 Impacts on Overfished Stocks

The impacts and design of a marine reserve network will depend on the life history characteristics of those species intended to receive protection with marine reserves. For the purpose of considering potential impacts of reserves on rebuilding depleted stocks, this report focuses on three groundfish species that are currently designated as overfished (bocaccio, POP, and lingcod). Canary rockfish and cowcod meet the 'overfished' criteria as well, have similar life histories to bocaccio and POP, and can be considered similarly in this discussion of protection via marine reserves.

Bocaccio (*Sebastes paucispinis*)

Bocaccio have been taken from the Alaska Peninsula to central Baja California, but have been most abundant historically from Oregon to northern Baja California. Currently, there are just a few sites that still hold numbers of bocaccio, off British Columbia, along the southern California coast, and off northern Baja. These sites probably represent the remnants of a once-coastwide bocaccio population. Adults are most abundant in 50-250 m water depth, and juveniles generally occur at shallower depths.

During much of the 20th century substantial numbers of bocaccio were taken commercially and recreationally along the Pacific Coast, particularly off California. They have been fished with trawls, gillnets, and hook and line. There has been an alarming decline in bocaccio population biomass and commercial and recreational catches of bocaccio during the 1980s and 1990s. Exploitable biomass and spawning biomass of the bocaccio population off California are now 2-4% of those estimates from the mid-1960s (MacCall 1999a). Recreational catches of bocaccio off California in the late 1990s were about 3% of peak catches in the early 1980s. Average size of bocaccio in the recreational fishery off central California has declined over the last 35 years, and has been below the size-at-maturity-for-50%-females for most years since 1987 (Mason 1998). Average surplus production, which roughly approximates potential productivity of the population, was estimated to be 5.7% during 1969 through 1999. Average annual exploitation rate was 17.2% in that same time period, clearly, an unsustainable rate. Bocaccio recently have been identified as a candidate for National Marine Fisheries Service's (NMFS) List of Endangered and Threatened Species (ETS).

Bocaccio achieve a maximum size of 91 cm (3 feet) and, although difficult to age, conceivably live to about 50 years old. The age of female bocaccio about 86 cm in length recently has been validated to be 30 years using radiochemical techniques (Cailliet et al. 1999). They are vulnerable to the trawl fishery at about 40 cm. Females probably live longer than males, and are sexually mature starting at about 3 years old. Fifty percent of the females off southern California are mature at 36 mm in length, and all are mature by 44 cm; size at maturity increases northward with females off Oregon just beginning to mature at 54 cm in length. As with most other fishes, fecundity of bocaccio increases exponentially with age and size; while a female of 38 cm in length produces about 20,000 eggs per year, a 77.5-cm long female can produce 2.3 million young every year.

Bocaccio have infrequent recruitment success; in most years relatively few young survive to reproductive age. It is likely that an outstanding year class may occur only once in about 20 years. For example, the last strong year class for bocaccio was 1977, which has been harvested since the early 1980s. Recruitment success is linked to environmental factors (Ralston and Howard 1995), and has been depressed since the onset of coastal ocean warming in the late 1970s. To sustain the resource, spawning biomass needs to be high enough to produce a large year class during those few years when environmental conditions are conducive to high recruitment success.

Pelagic larval and juvenile bocaccio are found in surface waters from nearshore to as far offshore as 480 km. They often associate with drifting kelp, and settle to benthic nearshore habitats after 3-5 months. Juveniles occur over rocks and sand patches with vegetation; in some years high numbers of young bocaccio recruit to oil platforms and piers off southern California. Juveniles (22-24 cm long) tagged in water <55 m moved up to 148 km over 2 years as they settled to deeper habitats (135-220 m depth); (Hartmann 1987). Significant movements of adults have not been documented, but it is conceivable that young adults (35-60 cm long) move limited distances (of 16 tagged fish, 6 stayed in the 10 km^2 study area at least 45% of the time; 5 stayed in the area more than 75% of the time; 10 bocaccio occupied the study area less than 10% of the time; R. Starr, pers. comm.). Adults aggregate over rocks of relatively high relief, and have been observed well off the bottom in mixed-species groups of chilipepper, and widow, canary, and vermilion rockfishes. The largest individuals of the population likely are sedentary and most abundant under rock ledges and in crevices of boulder fields, in association with lingcod, cowcod, and greenspotted and yelloweye rockfishes (Yoklavich et al. In Press).

Typically, stock assessment models include only that component of the population available to trawl survey techniques (i.e., the semi-pelagic young-adult segment of the population). The larger, older bocaccio, those most closely associated with deepwater rock banks and reefs, are poorly represented in these models; this leads to erroneous natural mortality estimates and, perhaps more importantly, an unestimated contribution that these larger fishes make to recruitment of the fished portion of the population. While these older members of the population are not accurately surveyed and included in assessments, they are effectively harvested with longline, setnet, and recreational hook-and-line gear. If this segment of the population is not protected and replenished with the younger bocaccio, it will be lost over time. From submersible surveys in deepwater habitats off southern and central California, there are very few sites that still harbor large bocaccio (R.N. Lea, M. Love, and M. Yoklavich, pers. obs.).

Three modeling efforts recently have addressed potential effects of marine reserves on the bocaccio population and the bocaccio fishery. Sladek Nowlis and Yoklavich (1998) incorporated size-specific life history information (i.e., growth, survival, fecundity, recruitment to the fishery) into a model that predicted moderate-to-great potential for enhancement of bocaccio catch with reserves, depending on the magnitude of fishing mortality outside the reserve and size of the reserve. They also suggested that, because larval survival varied from year-to-year, variability in annual catches generally decreased with increased size of reserve due to contribution of young from the protected area. They concluded that benefits of the reserves likely derive from transport of young rather than spillover of adults, and reserve design should accommodate protection of spawning biomass. Key assumptions in this model were that larvae dispersed widely from their source, and that adults remained in the areas of initial settlement (i.e., did not move in or out of the reserve). Models with size-specific movement rates and realistic transport patterns of larvae will assist in determining effective reserve size and location.

Parrish's (1999) analysis concluded that maintaining catches while establishing marine reserves will require significant increases in fishing effort and fishing mortality rates in the unprotected areas. He points out that effort and mortality rates will increase exponentially with the size of the reserve, and that the potential impact or disturbance to benthic ecosystems in the exploited areas will be dependent upon the increased trawling rates. Parrish also concluded that the highly variable recruitment success of bocaccio could result in more variable catches under a management system utilizing large reserves. This would be caused by the increased dependence on incoming year-classes resulting from the reduced age structure in the exploited areas due to the increased fishing mortality rates.

A recent modeling effort by Tira Foran (Environmental Defense, Oakland, California; unpubl. report) specifically considers how closed area policies affect the time to rebuild bocaccio stocks given various fishing mortality rates. Based on Foran's model, there are two principal conclusions. First, with a constant total exploitation rate (that is as in our Option 3b) there is little or no evidence that reserves will decrease the time (years) to rebuild the stock. Fishing mortality rates necessarily increase outside of the reserve as reserve area increases, thereby increasing the risk of fishing gear damage to benthic habitats and associated fauna. Second, with a constant fishing mortality rate outside of the reserves (our Option 3a), there is a large reserve-effect that primarily is due to a reduction in total exploitation rate. For example, with 20% of suitable habitat closed to fishing the stock rebuilds 34 years earlier than without reserves. Catch with 20% of habitat closed is predicted to be 88% of that without reserves. This model set movement of fish in and out of the reserve at 0.5; that is, half the catch comes from resident fish in the open area and half comes from the total of fish in open area and fish moving out of the reserve. This mixing rate very likely is too high, and with lower mixing of fishes there is likely an even more positive effect of reserves on rebuilding time. From this model, it is important to note that decreased time to rebuild the bocaccio stock can be achieved either by implementing reserves or by reducing the overall exploitation rate. However, as stated above, reducing exploitation by establishing reserves will have a much greater positive effect on the entire ecosystem than that which would occur by simply reducing the annual quota for a single species. In addition, reserves have the potential to produce more recruits per fish than policies that only reduce overall exploitation rate, due to the exponential increase in reproductive contribution made by the fishes that are expected inside reserves.

Pacific Ocean Perch (*Sebastes alutus*)

POP occur from Japan to the Bering Sea to San Diego, California. They dominate rockfish biomass in the Gulf of Alaska, and generally are abundant to southern Oregon and northern California. Adults are most abundant in 200 m to 275 m water depth on summer feeding grounds, and 300 m to 450 m on winter spawning grounds. Juveniles occur as shallow as 37 m water depth, and move deeper with age.

POP historically have been one of the most important species of rockfishes taken commercially almost exclusively with bottom trawls primarily along Washington and Oregon. POP frequently are caught with shortspine thornyheads, arrowtooth flounder, and darkblotched, sharpchin and splitnose rockfishes. POP are not important to the recreational fishery. They were severely overfished by foreign vessels during the 1960s, and have been managed with a stock rebuilding plan since 1981; estimated time to rebuild was 20 years. Population biomass and reproductive output have remained depressed (i.e., about 13% of initial estimates) regardless of a moratorium on targeted fishing since 1987 (Ralston 1998). Their exploitation rate continues to be set to incidental take (bycatch) only. Average surplus production of the West Coast POP population estimated over the period 1967 through 1997 was only 5.7%, and their maximum annual production was 9.2%; average exploitation rate was 10.2% (Parrish pers. comm.). Maximum annual production, estimated in 1992, was 9.2%. Under the most recent rebuilding plan, exploitation rate is expected to be less than 2%.

POP achieve a maximum size of 51 cm (20 inches) and live to at least 90 years old. Most of their growth occurs in the first 20 years of life. Most females are sexually mature at 5-9 years old. As with most other fishes, fecundity of POP increases exponentially with age and size; while a female of 25 cm produces about 10,000 eggs per year, a 47 cm long female can produce 300,000 young every year. Maximum fecundity is 505,000 eggs. POP recruitment in recent years has been at a steady low level compared with estimated recruitment during pre-fishery years. There have been no strong year classes during the last 30 years.

Aggregations of females form at the heads of submarine canyons and gullies to release young in deep water (500 m to 700 m). Pelagic larval POP remain at depth of release for several months and then move to shallow waters; juveniles aggregate in schools near the surface (0 m to 30 m) over rock features at the shelf-slope break. Subadults and adults are benthopelagic. Adult POP aggregations are localized and associated with rocky steep bathymetry. These schools can be 30 m wide, 80 m deep and 1300 m long. POP behavior and movements throughout their life history are affected by water temperature (larger aggregations at 4°C to 7°C), coastal upwelling, and tidal currents (Scott 1995). Adult migrations likely are of a limited distance.

Many of their life-history characteristics (i.e., extremely long lifespan, late maturity, infrequent recruitment success, low productivity, and local aggregations in specific habitats) have contributed to the overfished status of POP. From Gunderson (1997), responses to overfishing (such as reduced abundance and catch rate, change in species composition) occur over relatively small spatial scales for POP. Fishermen target those localized habitats that harbor high numbers of POP in order to meet their bycatch allotment (i.e., 'topping off their catch' as described by Gunderson 1997). Therefore, the management strategy since 1981 that set ABC=0 but allowed incidental allotment of POP is not meeting the Council's goal to successfully rebuild the stock.

A recent modeling effort by T. Foran and R. Fujita (Environmental Defense, Oakland, CA; unpubl. Report) specifically considers the impact of a no-take reserve policy on the time to rebuild POP stocks given various fishing mortality rates and various recruitment scenarios. From the model, protecting 25% of POP habitat in marine reserves, combined with a fishing mortality rate of 0.12 outside the reserves, resulted in the highest potential yield among the various scenarios. Similar to the conclusions of their bocaccio model, decreased time to rebuild the POP stock can be achieved either by implementing reserves or by reducing the overall exploitation rate. However, as stated above, reducing exploitation by establishing reserves will have a greater positive effect on the entire ecosystem than that which would occur by simply reducing the annual quota for a single species. In addition, reserves have the potential to produce more recruits per fish than policies that only reduce overall exploitation rate, due to the exponential increase in reproductive contribution made by the larger fishes that are expected inside reserves.

Lingcod (*Ophiodon elongatus*)

Lingcod occur from the western Gulf of Alaska (Shumigan Islands) to northern Baja California, and possibly into the Bering Sea. They are most abundant from Point Conception to southeast Alaska. Adults are most abundant from intertidal to 305 m water depth, occurring in the shallower depths from central California northward. Juveniles occur to at least 200 m, and move deeper with age.

Lingcod have been harvested commercially with hook and line, trawls and set-nets along the entire Pacific Coast, but catches have been highest from Oregon to Vancouver Island at depths 70 m to 150 m. Lingcod have been important to the recreational fishery throughout their range. Total catch has declined coastwide from a peak of 4814 mt in 1983 to 819 mt in 1998 (Adams et al. 1999). Biomass of the lingcod population off Washington, Oregon, and California recently has been estimated to be about 19% of the initial biomass of the 1970s. Management has responded by reducing recreational catch (bag limits) and imposing a minimum size limit (22 inches) in early 1980s. There have been coastwide reductions in commercial quotas and an imposed commercial size limit of 22 inches since 1995 (there now are commercial and recreational size limits of 24 inches off California since 1998). Lingcod are caught along with a variety of rockfishes.

Lingcod achieve a maximum size of 1.5 m (5 feet) and live to at least 20 years old. Females grow faster and larger than males. Most females are sexually mature at 3 years old and 76 cm in length; males mature at 2 years and 50 cm. As with most other fishes, fecundity of lingcod increases exponentially with age and size, from about 40,000 eggs per 76-cm female to about 500,000 eggs per 97-cm female. Lingcod recruitment has steadily declined from 1985 (Adams et al. 1999).

Aggregations of territorial males form to spawn in late fall to early spring, depending on latitude. Egg masses are laid in rock crevices and under rock ledges in water from intertidal depth to at least 125 m. Males guard nests during egg incubation (5 weeks to 11 weeks). Pelagic larvae and young juveniles occur near the surface in nearshore waters; older juveniles settle to a variety of benthic habitats including sand, gravel, shell debris, and eelgrass beds in relatively shallow water (down to about 70 m). Adult lingcod are mostly associated with rocks, although have been found over soft bottom especially in deep water. Older juveniles and adults likely are sedentary, although they seasonally migrate to shallow water to spawn. Some movement to at least 100 km has been noted. These movements are thought to be made largely by immature fish.

One preliminary modeling effort has explored the use of marine reserves for rebuilding lingcod populations (T. Foran and R. Fujita, Environmental Defense, Oakland, CA; unpubl. report). Their model indicated that a fishing rate of 0.08 and 20% of the biomass protected within marine reserves could achieve the rebuilding target of 40% unfished egg production by year-10, without sacrificing any catch. As with the models for bocaccio and POP, the basic conclusion is that exploitation rates need to be reduced in order to increase rebuilding of lingcod populations. These authors suggest that while marine reserves alone may not rebuild the stocks, they could work in combination with other methods to reduce overall fishing mortality and also increase management robustness (that is, reserves would help in reducing the impact of significant error associated with estimates of total fishing mortality).

3.2 Reserve Options for Rebuilding the Targeted Species

Many life-history characteristics (i.e., relatively long lifespan, infrequent recruitment success, low mobility, and aggregation in specific habitats) have contributed to the overfished status of these groundfish species. These characteristics also may make them particularly amenable to spatial management via marine reserves. Well-designed marine reserves that protect rock habitats harboring large, older, more fecund, sedentary adults could maintain a minimum spawning stock that could significantly contribute new recruits to unprotected areas and thereby assist in rebuilding and sustaining populations. The closed areas would protect young adults that are now being harvested prior to size or age at sexual maturity, allowing them to achieve older ages and higher reproductive output, thereby replenishing the older segment of sedentary fishes. Incidental take of overfished species (and other species that might be vulnerable to overfishing) would be eliminated within the reserve boundaries and essential habitat would be protected. In addition, species that are currently unassessed would be afforded some level of protection. Considering the above life history characteristics and the five options (as described in previous sections) to rebuild these overfished populations as well to address all objectives for implementing marine reserves:

Option 1: Do Not Create Reserves

As per the rebuilding plan developed for the bocaccio population off California (MacCall 1999a), the median time to rebuild the population to 40% of its initial spawning biomass with a fishing rate (F) of zero is estimated to be 20 years to 76 years (depending on strength of 1999 year class). Time to rebuild will increase with increasing F; when F is 0.04, time to rebuild is 22 to 162 years (depending on strength of 1999 year class).

From the 1999 rebuilding plan for POP (MacCall 1999b), the estimated time to reach a target of 40% of initial biomass, with F=0, is a minimum of 18 years to 27 years (depending on the time period used in the model to resample reproductive success; i.e., 'all years since the mid-1950s', 'all years since 1970', or 'all years since 1980'). Time to rebuild increases with increasing F; when F is about 0.03, time to rebuild is 39 years to 97 years (depending on time period used in the model).

From the rebuilding plan for lingcod (Jagielo 1999), the estimated time to reach a target of 40% initial biomass, with F=0, is 4 years to 8 years (median=5 yrs). Time to rebuild increases with increasing F; with an exploitation rate of 3.2%, the population is estimated to reach 40% of initial biomass in 4-12 years, with an estimated 99% rebuilt in 10 years.

Option 2: Create Heritage or Research Reserves

As stated above, these small reserves likely would not significantly improve the schedule to rebuild these overfished populations per se. However, there are several important roles that well-designed heritage reserves can play in protecting these species as well as all co-occurring species (including several that are on their way to an 'overfished' designation). If sited correctly, these reserves could help to avoid ESA listing of bocaccio (currently on the candidate ESA list). Species diversity and biological productivity will likely be enhanced within the boundaries of the reserves. Some of these small reserves could be located to protect those sites that still harbor the large, more sedentary segment of the population, thereby insuring some level of protection for spawning stock. Others could protect overfished sites of appropriate habitat, which would offer a means to monitor rehabilitation of overfished species to those sites. In the case of lingcod, small reserves could protect high-density spawning and feeding aggregations and their habitat (as is the case for a no-take reserve covering the pinnacles off Cape Edgecumbe in the eastern Gulf of Alaska [O'Connell et al. 1998]). Reserves of this size definitely will provide control sites for evaluation of effects of fishing on habitats and fish populations and related research. These reserves should be located regionally along the West Coast, in consideration of the distribution of key fish species and essential habitats, onshore-offshore movements and home ranges of key species.

These small reserves could assist in stock rebuilding in the specific cases where a significant proportion of the surviving component of the depleted stock is concentrated in localized geographical areas (e.g., 'hotspots' of rougheye and shortraker rockfishes in the Gulf of Alaska [Soh et al. 1998]). In this case, properly placed small reserves likely could increase the recovery rate by reducing exploitation rate on the depleted stock while continuing to allow optimum exploitation rates on healthy species outside the reserves.

Option 3a: Create Marine Reserves and Apply Amendment 11 Standard Precautionary and Rebuilding Harvest Policies Only to Biomass Outside the Reserve

The conclusion from the only model specifically focused on rebuilding the bocaccio population suggests that establishing marine reserves would serve the same purpose in terms of reducing time required to rebuild the population as would lowering overall exploitation rate. However, rebuilding the population by spatially managing fishing effort with marine reserves would protect those areas of high fish abundance and guard against directed fishing on these sites (as discussed for Option 2 as well). This would be especially important if exploitation rate for overfished species is reduced to only a bycatch allocation (as is already the case for POP); this type of management encourages vessels to "top-off" their catch or direct their efforts on these areas of high abundance (see Gunderson 1997). The "incidental allotment only" management strategy has been in affect for POP since the 1980s, and this population has yet to show signs of rebuilding. Establishing reserves rather than management by exploitation reduction also will meet several of the other objectives, as stated under Option 2 above.

Option 3b: Create Marine Reserves and Apply Amendment 11 Standard Precautionary and Rebuilding Harvest Policies to the Entire Biomass, Including That Inside the Reserve

As stated above, with a constant exploitation rate, there is little or no evidence that reserves will decrease the time (years) to rebuild the stock(s). Fishing mortality rate (F) necessarily increases significantly outside the reserve to maintain exploitation rate, thereby hindering rebuilding. Concerns associated with increased fishing effort in the unprotected areas include the increased potential for negative effects of fishing gears to other open area fisheries and habitats, and the truncation of age composition of the exploited portion of the population (Parrish 1999).

Option 4: Create Reserves of Sufficient Size to Justify More Liberal Harvest Policies Applied to the Portion of the Stock Outside the Reserve

This option results in the same the situation as in Option 3b. The most significant element in rebuilding the overfished stocks is the total exploitation rate (E). In this option, the decrease in (E) achieved by establishing large reserves would be offset by more liberal harvest policies outside of the reserves. This liberal policy will result in significant increases in fishing effort outside of the reserves, accompanied by potential of increased damage to habitats and ecosystem.

3.3 Impacts on Healthy Exploited Stocks

Establishment of marine protected areas (of any design and reasonable size) will obviously impact the targeted species, other healthy exploited stocks, and fish and invertebrate stocks that are taken but not retained by traditional fisheries. The significance of these impacts on the non-targeted species will be a function of the sizes and locations of the protected areas and the similarity of the protected habitat to the depth and bottom type preferences of the non-targeted stocks. Protected areas specifically designed to occupy a small portion of the prime habitat of the targeted species are likely to have no impact on stocks that primarily live in other habitat types. Moderate sized protected areas will necessarily include a mixture of habitat types and will have more significant impacts on the fisheries for other exploited stocks. Again the impacts will be a function of the amount of that species habitat being protected. Protected areas occupying up to 20% of the habitat of a targeted species could probably be designed in such a way that a minimum percentage of closed area covers the habitat type preferred by the healthy exploited stocks.

In contrast it is highly unlikely that large reserves, which occupy 35+% of the habitat, can be designed to avoid having significant impacts on many healthy, exploited species. Reserves of this size are poor candidates for the narrow goal of protecting a single overfished species. A typical example is the bocaccio/chilipepper fishery in central California. These two species have overlapping depth ranges and habitat preferences and co-occur in catches, making it very difficult to design a large reserve to protect the depressed bocaccio stock that would not adversely affect a fishery for the relatively healthy chilipepper stock. On the other hand, this class of reserves is well suited to a philosophy that is based on multispecies, habitat-oriented, precautionary management approach. It is also a potential candidate for addressing the present condition of groundfish stocks, where biomass levels for many exploited stocks have dropped below target levels and are continuing their downward trend. Further, large reserves that protect representative habitats offer perhaps the best insurance against future depletions (and associated constraints on fisheries) of unassessed and non-target populations. In any case, the design objective would probably be to protect a significant percentage of a wide range of habitat types rather than to protect the habitat of a single depressed species (although several of these overfished species co-occur in the same habitats). Large marine protected areas are also likely to be beneficial where serial depletion, genetic selection, and recruitment overfishing are potential problems (Bohnsack,1998). One could argue the West Coast groundfish fishery has experienced all three of these problems (i.e., serial depletion of low productivity stocks; selection for smaller body size and earlier age at first reproduction; and recruitment overfishing).

3.4 Impacts on Physical Habitat

The principal impact of marine reserves on the physical habitat is that they will prevent the physical alteration of the sea-floor that results from disruptive fishing activities. Some level of recovery of damaged habitat also would be expected to occur within the protected areas (Collie et al. 1997; Auster and Langton 1999), especially with regard to the biogenic components of habitat (e.g., attached epifauna like sponges, hydroids, bryozoans, etc.). There also may be additional effects associated with reserve status, such as potential exclusion of oil and gas exploration and communication cable or pipe laying activities. There are a few localized cases where very nearshore marine reserves have resulted in increased public access and destruction of intertidal habitat; however, this type of problem is not a concern for the offshore species presently addressed by the Council.

3.5 Impacts on Ecosystem

Any discussion of the ecosystem effects of marine reserves is severely limited by the lack of knowledge concerning the long-term effects of the selective removal of specific components of the fauna, alteration of the benthos by fishing gear and inter-specific interactions. However, it is generally assumed that some level of recovery could be expected if an area is protected from exploitation. Murawski et al. (In Press) and Collie et al. (1997) suggested 5-10 years for benthic habitats within large closed areas off New England to recover from disturbance by trawl and dredge fishing. Parrish (1999) has suggested that small reserves are likely to tend towards a state that has a higher proportion of sessile and territorial species and a lesser proportion of pelagic, mobile, and migratory species than the original state. This is, because small reserves are more likely to provide protection to species that remain within the reserve than to those that move in and out of the reserve.

It could also be assumed that a management strategy that puts part of the ecosystem in marine reserves would have fewer impacts on the ecosystem than one that allows exploitation of the entire ecosystem. This assumption is valid if reserve implementation does not result in significant increases in fishing effort in the unprotected areas. However, if fishing gear has detrimental impacts on the ecosystem and if the establishment of reserves results in significant increases in fishing effort in the exploited areas the likely consequences will be an increase in the quality of the ecosystem within the protected areas and significant decreases elsewhere.

4.0 SOCIAL AND ECONOMIC IMPACTS

Evaluating the economic (see Thomson, 1999) and social (see Pomeroy et al. 1998) effects of a system of marine reserves will be complicated by uncertainties associated with:

1. The biological effects of the refuge.
2. Difficulties in predicting how user groups or stakeholders are likely to respond to the reserves.
3. Shortcomings of models used to estimate economic effects.
4. Lack of appropriate data.
5. Lack of experience with this approach to fishery management.

Some of the key questions to be addressed in this section are:

1. Who are the stakeholders?
2. What is the value of information in situations of risk and uncertainty?
3. What are the research costs and expected time frame for collecting information on marine reserves?
4. What are the enforcement costs of marine reserves?
5. What are the administrative costs of marine reserves?
6. What are the effects of marine reserves on production in the private sector?

Most of the analysis of impacts assumes there will be sufficient compliance (voluntary or enforced) to ensure there is no substantial harvest in the no-take marine reserve areas and appropriate harvest levels in any control areas.

4.1 Stakeholders

The creation of marine reserves is about managing the resource by managing people. Assessing the impacts of "managing people" requires consideration of social, cultural, economic, and political environment (Pomeroy et al., 1998).

Stakeholders are those groups affected by decisions of whether or not to implement marine reserves. Stakeholders include consumptive users of specific stocks such as commercial and recreational fishers; nonconsumptive users of the stock and habitat such as recreational divers (nonfishing); and nonusers, such as members of the general public who don't intend to use the resource or habitat but value their existence in a healthy state (existence value). Other types of values placed on the resource include option values (the option to use the resource in a consumptive or nonconsumptive manner, even if that option is never exercised) and bequeathal values (a value placed on the opportunities for future generations to utilize or enjoy a resource). Additionally, those involved in the fishery management profession (including stock assessment scientists, management specialists, educators, and enforcement personnel) have job responsibilities and personal career motivations that may be affected by decisions about marine reserves.

The following is a general characterization of the common interests among stakeholder groups. This first attempt will be expanded as the public comment process better identifies some of these interests. ***It should be recognized that individuals may be part of more than one group and may have interests that overlap.*** For example, some commercial fishers may have priorities and interests that are similar to those of conservation groups, and all commercial fishers will have at least some interests that overlap with the nonconsumptive general public (the payment of taxes for management of the fishery). Similarly, some fish consumers are also members of conservation groups and the public that pays taxes for management of the fish resources. The emphasis of this section is mainly on the immediate short-term impacts that these groups may be facing. Potential longer term effects, such as accelerated rebuilding would likely benefit most these groups. Longer term economic effects are discussed elsewhere in the analysis.

Consumptive Users

Most consumptive users will have certain interests in common, 1) the size of any short-term reductions in harvest, 2) whether or not marine reserves will enhance long-term production from the resource, and 3) whether or not entities operating in specific locations will be disproportionately impacted compared to similar entities in other locations. These groups will also have an interest in the preservation of habitat for the purpose of ensuring viability of target species and preventing the unintended depletion of unassessed species.

Commercial Fishers

Commercial fishers will be concerned with increased operational costs and time away from port (including home and family) that may occur if travel distances to productive fishing grounds increase. Another likely concern will be the relative catch per unit effort (CPUE) at the alternative fishing grounds and whether increased concentration of effort on the alternative fishing ground will cause localized depletion and further increase travel distances to sufficiently productive grounds. On the other hand, if populations rebuild within reserves and there is some enhancement of fishery resources in open areas, CPUEs may increase for some species in some locations close to the reserve.

Processors

The processing companies interests will depend in part on changes in local supply and how processors have adapted to current supply situations. Processors that have continued to rely on local supply to maintain operations at a particular plant will be most impacted by any change in local supply. Processors that have adapted to current fishery conditions by centralization of processing and distribution activities may be somewhat less affected.[3/]

Treaty Indian Tribes

The National Marine Fisheries Service recognizes four Washington coastal Indian tribes (the Makah, Quileute, Hoh, and Quinault tribes) as having treaty fishing rights in their usual and accustomed fishing grounds south of the Canadian border and north of Point Chehalis, Washington (46° 53'18" N latitude). The treaty fishing right is place-specific for individual tribes, i.e., each tribe has its own usual and accustomed fishing grounds and needs to be contacted regarding impacts of the reserves. Tribal allocations for species of groundfish, including sablefish, black rockfish, and Pacific whiting, have been made in recent years. In general, the tribes regulate fishing by their own members after allocations are set through the Council process. Establishment of marine reserves in the tribes' usual and accustomed fishing grounds would require appropriate coordination with tribal governments. Marine reserve development will need to be consistent with applicable law regarding treaty Indian fishing rights in usual and accustomed fishing areas.

Recreational Fishing Charter Boat Operations

While not completely immobile with respect to a port of operation, recreational fishing charter boat operations are location dependent both in terms of their reliance on location specific marketing channels to bring them customers and the effects of distance to fishing grounds on profit. Increased distance to fishing grounds may affect both the cost and revenue side of their profit function (increased distance and travel time increases the fuel and labor opportunity costs and at the same time is likely to decrease willingness of customers to take a trip [decrease demand]). Charter vessels that work as independents, relying on charter offices to book their clients and have somewhat more locational flexibility than those vessels that serve as their own booking agents. Charter booking offices on the other hand are more closely tied to the fishing opportunities available in the port that they serve.

As with commercial vessels, there could potentially be some short and/or long term negative effects from increased crowding and localized depletion in good sites that serve as alternate to reserve sites, and in

---

3/ By shipping raw product to centralized locations some processors have maintained a more consistent product supply and better utilized their factory capital and work force. They are likely to be less affected by localized disruption in supply but will still be impacted by policies that change the total amounts of fish available for harvest. Some centralized locations also make use of infrastructure, labor pools and other services that are in place primarily for other industries (e.g., agriculture).

contrast, over the long-term there could be some increase in local catch rates and fish size due to spillage of adults out of the reserve. Fishery enhancement from adult spillover would be in addition to the theoretical possibility of increases in biomass outside the reserve through larval and juvenile export.

Recreational Fishers

Recreational fishers would face the same situation as described for charter vessels except that recreational fishers may be more mobile in their choice of fishing ports. The likelihood that fishers will change fishing ports depends on the degree to which fishing is the primary purpose of a trip and the distance to alternative ports. Recreational fishers include recreational divers who pursue and capture fish.

Seafood Consumers

The seafood consumers' primary interest is likely to be in the effect of marine reserves on local fresh supply over the short-term and long-term. Most impacted would be retail or restaurant patrons who place a premium on knowing the product they are purchasing is locally caught. For other consumers demand for frozen and some fresh seafood may be met through supply in coastal and international markets.

Nonfish-Resource Developers or Users

Another consumptive group are those with an interest in the utilization or disturbance of ocean resources other than fish. Such entities may extract oil/gas, discharge wastes, lay communications cable or otherwise engage in activities in ocean or adjacent areas. In areas where marine reserves are created it may be more difficult for these groups to justify the impacts of their activities.

Nonconsumptive Users

Wildlife/Nature/Ecosystem Tourists

The interest of ecotourists and associated businesses involved in the non-consumptive on site use of marine reserves will likely depend on the degree to which the reserve is visibly different from other areas (although sometimes the mere designation of a marine protected area may draw tourists). The differences are likely to be greatest for those interested in underwater experiences and for those interested in wildlife populations that tend to congregate in the reserves (e.g., possibly sea birds and marine mammals). There will likely be some interest from people who experience marine wildlife primarily through aquariums and other educational forums, including increasing interest in virtual marine reserves on world wide web sites. Those with an interest in ecotourism are also likely to be members of the public that place a nonuse value on the resource (e.g., existence or bequeathal values).

Transit Users

Those who use an area solely as part of a transit route may be affected if the rules of the marine reserves prohibit transit or impose some requirement on vessels transiting the area.

Non-Users

General Public (Local, Regional, National, International)

The general public within the U.S. has an interest in the issue of whether or not to create marine reserves and the management of marine resources in they are part owners of the resource and pay taxes that support its management. Additionally, the public within the U.S. together with the international public have an interest in the ecosystem functions provided by the marine environment. Members of the general public may also place nonuse values on the resource, habitat, and ecosystem processes preserved by marine reserve (existence, bequeathal, and option values). These values may be closely related and overlap with values the general public places on wildlife and natural parks. Some consideration of these values should be included in the impact assessment for specific marine reserves.

Conservation Groups

Conservation groups represent their membership and supporters in advocacy for policies to preserve natural resources, habitat, and ecosystem processes. These organizations are often comprised of members of the general public with nonuser and user interests in the management of the natural marine environment. A 1999 survey conducted by the Mellman Group for SeaWeb[4/] found that 75% of Americans favored having certain areas of the ocean as protected areas, 60% believed that there should be more marine sanctuaries and 3% believed there were already too many marine sanctuaries. With respect to fishing, 82% opposed trawling in marine protected areas and 59% opposed commercial fishing in such areas. Cited as "convincing" reasons for creating marine protected areas were; (1) distinctive areas should be protected similar to what is done for national parks (65%); (2) less than 1% of US waters are in marine protected areas (MPAs) (63%); (3) MPAs would be an important step in improving the health of oceans (58%); (4) harmful activity should be restricted to preserve ocean beauty for future generations (57%). Support for marine protected areas diminished by only 1% when respondents were first read a statement outlining potential negative socioeconomic effects of creating marine protected areas and increased by 6% when respondents were first read a statement outlining potential positive effects of creating marine protected areas.

Public Employees

Public employees are charged with representing the public interest in conservation and management of the ocean resources. For the most part, the public interests include all of those listed above. The public employees include educators, fishery managers and scientists, and enforcement personnel.

Educators and researchers. One of the social charges given to educators is to help keep the public (including fishers) informed of the status and use of its resources so the public can determine whether or not stewardship is being carried out in an acceptable manner. The importance of this task is greatest for those members of the general public who eventually become commercial and recreational users of the resource. Outreach and extension programs are two of the instruments used to perform this charge. Another charge given educators is to teach professionals who are charged with conservation and management of the ocean resources. The effectiveness of the job performed by educators depends, in part, on the quality of research and information about the ocean environment.

One of the keys to advancement of information in the ocean environment is the availability of undisturbed areas and control areas with known measured disturbances for the purpose of study. The groups of public employees listed above have a stake in the creation of marine reserves to develop better information for carrying out their charge.

Enforcers. Enforcement personnel ensure the public interest is carried out as identified through governmental processes. On the one hand the creation of marine reserves may coincide with the interests of some of those in the enforcement community to the degree to which reserves provide information that allows managers to identify better ways to conserve and manage the ocean resources. On the other hand, additional enforcement responsibilities from the creation of marine reserves could detract from enforcement personnel ability to pursue other assigned responsibilities.

Summary of Stakeholders and Types of Interests in Marine Reserves

The following table summarizes the stakeholders, their association or likelihood of close ties to particular fishing sites (on-site or off-site users), and their use of the resource (that is consumptive or non-consumptive).

4/ SeaWeb is a project of the Pew Charitable Trusts. SeaWeb is a non-partisan, multimedia educational initiative on the ocean.

	On-Site		Off-Site	
	Consumptive	Non-Consumptive	Consumptive	NonConsumptive
Commercial Fishers	X			
Commercial Processors	X		X	
Tribes	X		X	
Recreational Fishing Charter Operations	X			
Recreational Fishers	X			
Fish Consumers			X	
Nonfish-Resource Developers or Users	X (habitat)			
General Public				X
Wildlife/Nature/Ecosystem Tourists		X		
Conservation Groups				X
Public Employees	X (sampling)	X	X (market samples)	X

Fishing Communities

One group not included in the above list is fishing communities. Fishing communities are comprised of members of the above groups. As defined for the purposes of the Magnuson-Stevens Act, fishing communities are tied to location. Included as part of fishing communities are those in the local community who benefit from indirect and induced activities associated with the fishing resources. Indirect benefits include those received by gear and bait suppliers for recreational and commercial fisheries. Induced benefits include those received by those with owner, employee, or other interests in grocery stores, movie theaters, social organizations, and other activities patronized by those directly and indirectly benefitted by fishing activities. Members of the general public who are resident in the area of the fishing community have an interest in the fishing communities contribution to the tax base and the maintenance of school, hospital, road, and other services and socioeconomic infrastructure.

4.2 Risk, Uncertainty, and Knowledge

One of the major conservation concerns imbedded in the marine reserve objectives listed in Section 1 is reduction of threats to target species and ecosystems. Before moving ahead with a discussion of specific costs and benefits, this section will deal with:

1. Issues of risk and uncertainty.
2. The value of information in an uncertain environment.
3. Management in the face of uncertainty.
4. Potential conflicts between reserves and the current fish/fishery information system.
5. The opportunity to improve understanding of the value of marine reserves.

4.2.1 Risk and Uncertainty

Risk is generally defined as a situation in which the probability of different outcomes is known while uncertainty is a situation in which the probability of different outcomes is unknown. Additional knowledge may change a situation from one of uncertainty to one of risk, and in some situations additional knowledge may be used to minimize or eliminate risk or uncertainty. However, additional knowledge may also change what was perceived to be a situation of known risks to one perceived to be largely uncertain. It may be argued that over the last 10 years additional information has appropriately increased uncertainty about the management of West Coast groundfish stocks.

4.2.2 Value of Knowledge as Uncertainty Changes

When uncertainty about the fishery or ecosystem increases, the value of additional information increases. The more certain a person is about knowledge of a situation, the less value that person will place on acquiring new information. Thus, the value of new information about fish or a biological system depends on our expectation the new information might change our ideas about the status and characteristics of the resource(s) of concern. During a time when stock assessments and other information about the fishery indicate a fairly stable resource condition, a lower value may be placed on new information about the resource than when existing information sources begin to indicate greater variation or unexpected results (this line of reasoning follows a review of uncertainty literature by Hanna, 1983).

In the late 1980s and early 1990s, stock assessments yielded fairly stable results from year to year and most fishery managers believed the groundfish fishery was moving toward sustained yields, though some scientists, environmentalists and fishermen challenged this point of view. Instead of stabilizing biomass levels near 35% of the original stock levels, as theorized by the specialists advising fisheries managers, a number of valuable stocks fell rapidly through this theoretically stable level and a number are now well below 10% of their original level (Ralston, 1998; MacCall et al. 1999, among others). While research continued on stock assessment methods and development of greater understanding of the resource during the 1980s and 1990s, the urgency for such new information was probably not as great as it has been in the late 1990s. The recently documented depressed conditions for those stocks for which we have information, raises concern and uncertainty regarding the numerous stocks for which little information is available. In this environment of greater uncertainty, efforts and techniques for gaining better understanding have greater value. It has been suggested that marine reserves will provide the needed baseline data for a more accurate understanding of marine ecosystems. Murray et al. (1999a) proposed a network of replicated reserves to allow for scientific testing of resource management strategies. Thus, considering the increased uncertainty in assessment of fishery resources the value of implementing marine reserves to improve our understanding of fishery resources may be much greater than it was a number of years ago.

The value of reliable information about the status of the resource and function of the ecosystem is not just that it allows fishery managers to impose harvest restrictions compatible with what the resource can sustain, hence yielding greater benefits over the long term. The more the information is trusted by stakeholders the easier and less controversial will be the management decisions (whether the decision is one to decrease or increase harvest). Easier and less controversial decisions are cheaper to make. Less time is spent accommodating and responding to agency, industry, and public uncertainty and comment at the levels of: day-to-day agency and Council staff operations; Council meetings; Congress; and the courts. In addition, it is clear that uncertainty and questions concerning the reliability of information increases the time necessary to accomplish management decisions. This delay in implementing critical management decisions puts the resources at even greater risk. These are real costs that not only involve the expenditures of tax dollars but also degrade the abilities of fishery managers and other policy bodies to appropriately respond to other issues needing attention (see Council workload priorities, Exhibit G.12., November 1999).

4.2.3 Management Under Uncertainty

Recent information on West Coast groundfish has increased uncertainty about appropriate management approaches. The current system of management can be thought of as an experimental or incrementally-adaptive probing of the ecosystem in order to determine levels of sustainable fishing under varying environmental conditions. The success of such an approach depends in large part on four factors, 1) the degree of risk and damage to the resource and ecosystem during this type of management; 2) the magnitude and duration of environmental variation, 3) the information feedback needed to make reasonably accurate estimates of conditions of the fish stocks and various other aspects of the ecosystem and environment; and 4) the speed with which management agencies respond to the information feedback.

Experimental/incrementally-adaptive management can involve “stress treatments” (the taking of fish at a higher rate). This management approach can also involve the reduction of fishing activities in certain areas (precautionary experimental management). The current management system can be thought of as a stress treatment, though without control or reference areas it is difficult to draw inferences across time due to uncertainties about previous conditions, changing intensity of fishing and variation in ocean conditions. Stress treatments can also be conducted by increasing fishing intensity in certain areas (for example see Leaman, 1998). The decision to pursue experimental management using stress treatments or precautionary management is based on a balance between the knowledge to be gained verses the degradation, strain, or threats to the resource or ecosystem. “Experimental treatments that limit or remove fishing activities from plots and leave fishing practices unchanged in other areas . . . . can provide both knowledge and conservation benefits. . . . Increased replication is a main reason that the notion of marine protected areas is compelling in an experimental context, in addition to the need for ecological baseline controls." (Oakey and Harrington, 1999).

Marine reserves can be a management tool that helps ensure species survival and avoids endangered species listings and the consequent impacts on fishing communities. Marine reserves can be considered an insurance policy, hedging against the uncertainties associated with management strategies and limited information about human behavior,[5/] fluctuations of the stocks, and environmental changes affecting habitat in unpredictable ways. Whether or not the insurance policy is taken out depends on the costs of the policy, the perceived potential for disaster, and the payoff if the disaster occurs. In this application the disaster would be a general failure of recruitment due to overfishing or other causes affecting only populations outside the reserve and the insurance payoff would be the continued production from stocks within the reserve (either in the form of adult spill-over or dispersal of young stages) (this discussion follows Caribbean Fishery Management Council, 1998).

4.2.4 Effects on Stock Assessment Modeling and Fishery Independent Surveys

The long-term series of NMFS triennial trawl data may be affected if marine reserves encompass areas covered by these surveys. The triennial trawl survey has been conducted since 1980 and is used to develop estimates of biomass for species such as shelf rockfishes, flatfishes, and sablefish. Survey areas and stock assessment areas should generally coincide. If a reserve is included in these areas, a reduction in the estimated total stock biomass available for harvest (as in Option 3a) may be most consistent with the stock assessment. Adjusting exploitable biomass downward also assumes there is not substantial migration of adults out of the reserve. If the reserve area is excluded from the survey and stock assessment area then making no adjustment to harvestable stock biomass (as in Option 3b) may be most consistent with the assessment approach. The greatest conflict between the reserve and triennial survey would occur if a reserve encompassed one or more of the triennial survey sampling stations.

One issue to be addressed is whether or not the triennial survey would proceed in the reserve. If sampling is not allowed within the reserve, the samples from that area may have to be eliminated from the survey time series. Depending on the station eliminated there could be substantial effects on the time series and consequently stock assessment results. Because catch is not evenly distributed among sampling stations and it is likely that reserves intended to protect rockfish would be located in areas of greater rockfish abundance, it may be anticipated the stations eliminated from the time series would be those with higher rockfish counts in the samples.

If sampling is allowed in the reserve, an adjustment to account for the effects of the reserve would have to be considered. The number of triennial survey samples from within the reserve would not likely be enough to allow researchers to adjust survey results based on triennial survey observed differences from within and outside the reserve. Any adjustments would depend on comprehensive studies to evaluate effects of the reserve. If the area within reserves is 5% or less (Option 2), the effect of the reserves on the triennial surveys may be of little concern. As the area within reserves moves closer to 35% the need to treat reserves as separate areas for the purpose of stock assessment increases. The impacts of carrying out the triennial surveys with the reserves decreases as the size of the reserve increases. Reserves in the 35% class would be little altered by the removal of fish by the triennial surveys and the continuation of sampling within the reserves may allow the surveys to be used to assess the results of the experimental management.

Another factor that may complicate stock assessments is the migration of adults from the reserve (spillover). Incoming year classes may have different migratory tendencies at different ages. For example younger bocaccio may migrate into areas subject to surveys and then become more sedentary and locate in reserve

---

5/ Human behavior includes responses to the natural, economic and regulatory environment that may influence such things as amounts of fish taken, discard and discard mortality, gears used and the ways they are used, and areas fished.

areas as they age. This may confound interpretation of survey results. It should be noted that interpretation of survey results is difficult and confounded already, especially with respect to rockfishes associated with rocky habitats that are generally inaccessible to trawl surveys.

4.2.5 Improving Understanding of Marine Reserves

There is substantial empirical evidence that abundance and size of fish species will increase and disturbed habitats will recover within marine reserves, and there are numerous conceptual and quantitative theoretical models on the effects of marine reserves on areas outside the reserve. The large year-round closures established to protect spawning stock biomass for two depleted groundfish stocks on Georges Bank have resulted in significant increases in spawning stock biomass for two depleted groundfish stocks on Georges Bank, protection of young stages of these stocks throughout the year, and comprehensive protection of most unfished species as well (Muawski et al. In Press). However, until marine reserves are created and evaluated in terms of protecting resources on the West Coast, it is unlikely the quality of information on the external impacts of marine reserves will substantially improve specifically for our depleted groundfish stocks. Buoys, cables, military, and other exclusion areas may provide some opportunity for studying pseudo marine reserves. However, the sizes, locations, and shapes of these pseudo reserves, along with the habitats encompassed and types of gear restricted, may not represent the types of reserves that need to be tested. For example, military areas are often open to fishing except during certain restricted activities; also, these areas are almost entirely in shallow water adjacent to land thereby offering limited protection solely to very nearshore resources. Communication cables are often laid on soft bottom rather than the rocky area habitat for which it is thought reserves are most needed.

In order to evaluate the current understanding of marine reserves and the degree of improvement needed, the quality of information about marine reserves should be compared to the quality of information about other management approaches. One of the other major conclusions from Sections 2 and 3 is that while there is substantial uncertainty about the effects of marine reserves it is arguable there is similar or even greater uncertainty about the effects of conventional harvest management for assessed stocks, not to mention the numerous stocks for which there are no stock assessments.

4.2.6 Summary Comparison of Information and Threats Associated with Reserve Options

The following is a summary of the above discussion with respect to each of the options identified in Section 1 of this document. The options are summarized in terms of the potential information gains, information losses, and threat to the resource related to management uncertainty. Note that options 3a and 3b are presented in reverse order.

Option	Potential Information Gains	Potential Information Losses	Threat to the Resource
1. Status Quo–No Reserves			Substantial uncertainty and threat to resource
2. Heritage and Research Reserves (5% of habitat or species biomass)	As compared to status quo, there will be a substantial gain in information on life history and ecological relationships for the sedentary or less mobile fauna protected within the reserve. Measured fishing in control areas will provide comparative information on fishery impacts.	No substantial losses as compared to status quo.	Less threat to the resource than status quo.
3b. Rebuilding Reserves (20%), Harvestable Biomass Does Not Includes Reserve	As compared to Option 2, greater protection will be afforded a greater number of species (i.e., as reserve size increases, more mobile species are afforded more protection).	Possible loss of information if reserves coincide with triennial survey sampling stations, thereby complicating the interpretation of survey results.	Less threat to the resource than Option 2

Option	Potential Information Gains	Potential Information Losses	Threat to the Resource
3a. Rebuilding Reserves (20%), Harvestable Biomass Includes Reserve (i.e., greater harvestable biomass than 3b)	As compared to Option 3b, greater harvests rates outside of the reserve and control areas may increase negative impact to fishery habitats in certain geographic areas, offering a greater contrast that may help us understand fishing impacts.	Approximately the same as 3b.	Greater threat to the resource as compared to Option 3b.
4. Harvest Management Reserves (>>20%, up to 50%), More Liberal Regulations Outside the Reserve	As compared to Option 3a and 3b, a greater number of species and longer periods of the life history contained within the reserve (more sedentary relative to the reserve). As compared to Options 3a and 3b, greater harvests rates outside of the reserve and control areas may stress certain geographic areas, generating information over a broader range of exploitation rates.	Same as 3a or 3b, plus greater numbers of more mobile life stages of a sedentary species may end up in triennial survey areas, complicating the interpretation of survey results. May require redesign of survey and assessment areas and/or methods.	Threat to the resource may increase or decrease depending on the degree to which uncertainty in the modeling of reserve impacts and harvest impacts are taken into account in determining the percentage of area to be set aside. If implemented immediately, there may be greater risk to the resource than under Options 1, 2, 3a, or 3b because of uncertainties in modeled effects.

4.3 Costs of Measuring Reserve Effectiveness

The costs and difficulties of measuring the effectiveness of marine reserves should not be underestimated. This section touches on some of the difficulties and indicates possible costs. These issues are being considered in depth as part of a project on “The Theory of Marine Reserves” being conducted under the auspices of the National Center for Ecosystem Analysis and Synthesis. This project has brought together leading experts on marine ecosystems and marine reserves from across the nation and results should be available for incorporation in analyses if the Council proceeds with the second phase of its program for considering marine reserves.

Periodic studies may be needed to determine whether, or the degree to which, progress is being made toward meeting reserve objectives. The exact design of the studies will depend on the objectives for the reserves (Pomeroy et al., 1998).

> “ . . . how success or effectiveness will be evaluated should be established prior to refugia implementation.” (Pomeroy et al., 1998)

We will make an attempt in this section to estimate costs for evaluating the performance of marine reserves. Such an evaluation would likely involve fairly intense studies of reserve and control sites. The costs of such studies will need to be considered in the context of the question of whether or not marine reserves reduce the amount of information needed to appropriately conserve all West Coast groundfish stocks. Additionally, in weighing the costs of these studies the prospect for successful reserve evaluation studies needs to be considered.

4.3.1 Difficulties of Measuring of Reserve Effectiveness

In order to properly assess the effectiveness of reserves, baseline studies will need to be conducted prior to reserve implementation. These baseline studies will likely include both areas within and outside the reserve if contribution of the reserve to resources outside the reserve is to be evaluated. Studies of the effectiveness of marine reserves will need to address numerous difficult issues, such as, (1) appropriateness of the control areas against which marine reserves are to be compared in terms of habitat and oceanographic characteristics, (2) year to year variation in the abundances and/or geographic distribution of target species,

(3) adequate sample sizes, based on amount of variability, (4) likely time lag between the establishment of the marine reserves and measurable effects on population abundances, and (5) differences in the history of activity in the control area as compared to the reserve area. Projections are that some species such as bocaccio and POP may take up to 100 years to recover. If marine reserves are effective in assisting in rebuilding, it may take several decades for those effects to be detected by studies of reserves and control areas. Some indicators of reserve performance, such as changes in size distribution and abundance of certain species, could respond relatively quickly, thereby giving some idea of reserve effectiveness. Difficulties in evaluating the effectiveness of reserves should be compared to the difficulties in measuring the effectiveness of conventional management techniques, which include: (1) interpretation of fishery-dependent data, which is confounded by the effects of market, weather, management strategies, etc.; (2) lack of data on total mortality; (3) inadequate surveys; (4) time lag between implementation of management measures and population response; (5) lack of information on the impacts of fishing on the ecosystem; (6) lack of reference or control conditions.

The following is a list of factors that will affect our ability to determine whether or not reserves are effective (if reserves are implemented).

Factors Affecting Ability to Determine of Reserve Effectiveness
• Accurate baseline study of habitats and faunal assemblages over all seasons and over several years, in reserve and control areas
• Measurement of fishing intensity in reserve and control areas before and after reserve implementation
• Size of changes in fishing intensity as a result of reserve implementation (if there was little fishing in the area before reserves are implemented, little affect would be expected from creation of the reserve).
• Proper identification of habitat and comparison of habitat quality between reserve and control areas.
• Amount of natural variation in the total abundance and local distribution of target populations.
• Length of time from reserve implementation to occurrence of strong year classes and oceanographic conditions affecting geographic distribution of recruits at the time that strong year classes occur
• Effectiveness of survey/sampling techniques used to assess reserve effects. Intensity of the study.

4.3.2 Social and Economic Costs of Measuring Reserve Effectiveness

An answer to whether or not marine reserves are effective with respect to some of the major objectives (such as an overall increases in biological and economic productivity) is unlikely to be definitive within the first decade. The issues discussed in the previous section are likely to cloud results from a study of reserves, cause ambiguities that take a long time to resolve and make it more difficult to maintain political support for continuation of the reserve. If reserves are created, it should be recognized that results of studies of reserve effectiveness may be uncertain, particularly during early periods or if baseline studies are inadequate. A false belief that results of reserve studies will be forthcoming in fairly short order could lead to a high cost policy under which the costs and dislocations caused by the creation of a reserve are incurred but the reserve is not maintained long enough to determine its degree of, or lack of, effectiveness (Carr and Raimondi, 1998). Possible causes and policy risks associated with inadequate study of reserve effects are laid out in the following matrix.

	Alternative Truths About Reserves	
Possible Study Conclusions	Reserves Are Ineffective Tools	Reserves are Effective Tools
Reserves Are Ineffective		Poor study design or flawed evaluation. Underfunding. In fortuitous/undetected variation in natural cycles and stock distribution that invert study results. Poor reserve design. Illegal fishing. Policy Risk: Effective management tool abandoned.
Reserves Are Effective	Poor study design, flawed evaluation. Underfunding. In fortuitous/undetected variation in natural cycles and stock distribution that invert study results. Policy Risk: Regulations are inappropriately relaxed on remainder of fishing grounds.	

This matrix is mainly designed after a line or reasoning presented by Carr and Raimondi (1998).

The expense of monitoring the effectiveness of reserves will increase more rapidly with the number of reserves and control areas than with the size of the reserves and control areas. As size of reserves and control areas increase the cost of monitoring will likely increase with the number and amount of different habitat types encompassed within the reserve.

The cost of monitoring reserves will be a function of:

1. Number of reserve areas and control areas.
2. Depths of the reserves and control areas.
3. Indicators to be monitored.
4. Number of significant types of habitat areas encompassed in the reserve and control areas.
5. Size of the significant types of habitat areas encompassed in the reserve and control areas.
6. Size of reserve areas and control areas.

As an example of expected costs, $80,000 was spent for a one-time only survey of the bottom habitat in deep water (25 m to 100 m) inside and outside the Big Creek Ecological Reserve off central California; this represented about 25 square kilometers of total study areas. An additional $300,000 was spent to collect baseline information on fish abundance, diversity, and size composition in and out of the reserve in deep water over two years following establishment of the reserve.

Many of the costs may not require the acquisition of new funds but rather the repositioning of ongoing or planned stock, habitat, and ecosystem studies into reserve areas and reallocation of existing budgets. Examples of projects that may be used to help assess marine reserves include NMFS base funding going to each science center for EFH, a Sea Grant habitat proposal to integrate existing habitat data into a single GIS database, a Sea Grant proposal to establish consistency in the classification of habitat types, budget initiatives for habitat mapping and gear impact research, S-K fishing gear impact studies, money made available as part of impact compensation for laying communication cables (Olympic National Marine Sanctuary). For example, the Big Creek reserve relied on funding from:

- California Sea Grant College Program
- NOAA NMFS,
- Moss Landing Marine Laboratory
- California Department of Fish and Game
- NOAA Monterey Bay National Marine Sanctuary

For measurement of reserve effectiveness the first priority will be to conduct baseline studies in reserve and control areas, the second priority will be to ensure that levels of fishing effort in control areas is understood and that any fishing allowed in reserve areas is monitored, the third priority will be to conduct followup studies in reserve and control areas in order to determine differences.

4.4 Enforcement

Enforcing closed areas can be expensive. Compliance is often difficult to maintain, particularly if there isn't wide public acceptance of the Marine Protected Areas.

The success of marine reserves depends on compliance with regulations (e.g., Causey 1995; Ticco 1995; Proulx 1998), yet too often reserve management and enforcement practices have been insufficient (Beatley 1991; Alder 1996). Previous research on enforcement and compliance in commercial fisheries suggests that enforcement is the "Achilles heel" of fisheries management and conservation, because enforcement efforts are expensive and often ineffective (Sutinen, 1988).

Empirical studies of the commercial fisheries (e.g., Sutinen, 1988, Sutinen & Gauvin, 1989, Sutinen et al., 1990, and Sutinen et al., 1992) suggest the success of enforcement is influenced by many variables that include: the process of creating regulations and the types and level of enforcement, users' perceptions of the effectiveness of enforcement, the types and levels of penalties for noncompliance, social pressure exerted on user groups, and last but by no means less important, users' perceptions of the fairness of the regulations and the enforcement process (Crosby).

While enforcement resources are limited and there may be concerns about enforcing marine reserves, these concerns should not be considered a barrier to implementation of marine reserves (United States Coast Guard [USCG] Commander John Schott in a statement to the Ad Hoc Marine Reserve Committee, May 1999). The combination of education and effective tools such as vessel monitoring systems can help insure more effective compliance with marine reserve restrictions.

4.4.1 Variables Affecting Enforcement Success

Some of the main variables affecting enforcement success and costs include, 1) public and industry acceptance; 2) ease of detecting violators; 3) violation penalties; and 4) existence of an enforcement plan.

Public and Industry Acceptance

Anecdotal evidence on marine and coastal protected areas in other countries suggests that public attitudes change from initial opposition to strong support (Bohnsack, 1993; Ballantine, 1989). However, there are no documented studies of enforcement implementation strategies to explain this transformation (Crosby). Enforcement resources are most likely to be inadequate when there is overwhelming public opposition. Such opposition often results in lawsuits against the program, case dismissal against violators and congressional intervention. Successful programs must emphasize community involvement and education (Proulx, 1998).

The potential for reserve networks to serve as successful resource management tools will be limited if the ways people value and use resources associated with reserves are not taken into account (Fiske, 1992). This is, because resource users frequently resist establishment of marine reserves or other conservation measures that restrict human activities. Part of this resistance is because the goals and economic and social benefits of marine reserves are often not well articulated by those promoting reserve protection or well understood by users who resist reserve establishment (Murray et al., 1999b).

In the case of the Florida Keys, the Enforcement Action Plan Goals include increasing public understanding of the importance of sanctuary regulations, achieving voluntary compliance, and promoting public stewardship of marine resources through interpretive enforcement. Enforcement officers apply an "interpretive enforcement" strategy when patrolling waters or speaking to citizens. This approach seeks voluntary compliance with sanctuary regulations by educating sanctuary users about regulations, why they should comply, and how they can comply (Florida Keys National Marine Sanctuary Draft Management Plan).

Factors Likely to Increase Industry Acceptance	Factors Likely to Decrease Industry Acceptance
Understanding of why the reserve is needed.	Convoluted goals.
Understanding of how the reserve will accomplish its specific goals.	Feeling alienated from the development process.
Specific monitoring programs in place to determine if the reserve is meeting its goals.	Reserves that appear to be allocative in nature.
Procedures for removing reserves if they do not meet their intended goals.	Location.

Ease of Detecting Violators

On the one hand, the large number of entry and exit points make it harder to control illegal activities in marine reserves than in many terrestrial parks, on the other hand, air surveillance can be easier in marine reserves compared to tree-covered terrestrial parks (Tisdell and Broadus, 1989).

However, the ease of detecting violators in marine reserves is depending on the following factors:

1. Location of marine reserves: The location of marine reserves will have an effect on the amount of traffic encountered in these reserves. If the reserves are located near highly populated ports or in the vicinity of traditional fishing grounds, the enforcement burden will be increased, due to the increased vessel traffic.
2. Configuration of marine reserves: Certain design characteristics can make it easier to enforce marine reserves. For example, straight line borders as opposed to contours and reserves large enough to provide a buffer for key areas that need to be protected (USCG CDR John Schott, statement to the Committee, May 1999).
3. Regulations within marine reserves: If all vessel presence is prohibited, enforcement will be easier. If only fishing vessels are prohibited, then enforcement must show that any fish found on board a vessel were caught in the reserve (Thomson, 1998). Enforcement can deal with reserves that allow some gear types and not others, however, such measures will make enforcement through overflights more difficult (USCG CDR John Schott, statement to the Committee, May 1999).
4. Enforcement resources: The probability of detection of violators within a marine reserve will be heavily dependent on the types and proximity of enforcement resources available. Monitoring marine reserves with aircraft can be effective if certain regulations are implemented within the reserves, as mentioned above. The use of surface cutters may be less effective than aircraft but can provide a significant deterrent when they are present.
5. Requiring vessels to carry transponders may be another way to make it easier for enforcement to detect violators. Transponders may also be more effective and efficient, as well. The Georges Bank closure was located 150 Km offshore and relied on satellite-based vessel monitory system as well as traditional methods of enforcement (i.e., USCG and aircraft, see Murawski et al. In Press).

Violation Penalties

Compliance with reserve rules can be voluntary but in many cases may occur only with realistic levels of enforcement by responsible agencies and the threat of meaningful penalties for poaching. Poaching can have high payoffs when reserves successfully protect valuable fishery populations, especially if social or legal institutions are inadequate (Tegner et al. 1992, 1996). For example, in southern California, where most rocky shores are easily accessible, unlawful collecting and poaching of intertidal organisms have been widespread in existing reserves, because enforcement has been virtually nonexistent (Murray et al. 1999). During the 15 years the Florida Middle Ground has been protected (an area roughly the size of Monterey Bay), bottom trawling vessels are routinely detected despite severe penalties and loss of catch Heavy fines and penalties are often viewed as a business cost that determined poachers are willing to bear. (Proulx, 1998)

Enforcement Planning

Enforcement responsibilities should be clearly specified during the process of designating marine managed area sites. Scientists participating in a working group on socioeconomic considerations for marine reserves noted the importance of considering enforcement in the design and implementation process. (Pomeroy et al., 1998).

Common false assumptions regarding enforcement:

1. Lawful users will provide sufficient policing to keep violators out of the reserve.
2. "Other agencies" will contribute to the success of enforcement.
3. Aerial and surface patrols will be more frequent than will realistically occur with available enforcement resources. (Proulx, 1998).

There is also the potential for confusion regarding enforcement responsibilities when multiple agencies are involved in establishing and managing sites or specific resources within an area, which can lead to partial enforcement or none at all. Creative ways for improving compliance should be pursued, such as using more volunteer staff, additional interagency agreements, or increasing education and outreach.

> "In practice, the reaction to the regulations enacting a closed area is always different and more clever than what was expected or predicted by managers. . . . The level of enforcement resources, particularly traditional enforcement resources such as officers, boats and planes is usually recalculated in an emergency setting by enforcement managers desperate to curtail frequent and blatant violations with the closed areas. . . . . refugia along the Pacific Coast will require nontraditional enforcement approaches combined with an appropriate background level of traditional enforcement to have a realistic probability of [success] . . . . Even matters as simple as routing patrol must be closely examined with regard to the likelihood of implementation under the usual budgetary restraints. (Proulx, 1998)"

Planning for enforcement should include a detailed and peer reviewed threat analysis.

4.4.2 Enforcement Funding

Overall funding for fisheries enforcement needs to be adequate to cover any additional burden that may be imposed by marine reserves, without substantially diminishing effort on other high priority activities. Enforcement presence and resources must be sufficient to detect violators with sufficient frequency and impose sufficient penalties that there is public confidence in the program. Proulx (1998) observes that "the classic formula for maintaining a closed area has never succeeded. Eventually enforcement resources are taxed beyond their ability to keep a physical presence within the closed area and complaints of little or no law enforcement begin to surface in front of managers . . . ." The need for additional funding for enforcement of marine reserves will depend on the level of enforcement activity and public surveillance already in and around a closed area. If adequate funds are not available for enforcement of a proposed reserve or reserve network, it may be better to have a smaller reserve that is adequately enforced (Tisdell and Broadus, 1989)

4.4.3 Enforcement Cost

Enforcement costs will vary with number, size, and shape of the refuges; types of activities restricted and allowed; degree of change the reserve requires as compared to current usage of the area; proximity of the refuge to other activities such that public surveillance can occur or there will be an enforcement presence in the area for other reasons; and the types of activities enforcement is diverted from in order to enforce reserves (unless new funds are made available for enforcement).

"Informal public surveillance may mitigate some of the enforcement costs associated with a harvest refuge. However, the probability of this occurring and the risks associated with wrongly assuming that such surveillance will in fact occur should be carefully evaluated." (Thomson, 1998).

The following is provided as an example estimate of enforcement costs. This estimate is for the annual enforcement costs for Hind Bank south of St. Thomas (Caribbean Fishery Management Council, 1998). The Hind Bank Marine Conservation District makes up about 16 square miles.

NMFS Agent response/investigation and oversight 18 days annually	$6,000
NMFS reimbursement for U.S. VIRGIN Island patrol expense 4 hours per week equipment and personnel	$8,500
U.S. Coast Guard surface patrol 110' cutter 2 hours per week	$47,500[6/]
Total Estimated Annual Enforcement Costs	$62,000

The cost of operating Coast Guard aircraft ranges between $4,500 and $7,500 per hour, depending on the type of aircraft. Monitoring marine reserves with surface cutters may be less effective than aircraft, but provides a significant deterrent when present. However, depending on how factors mentioned in Section 4.4.1 affect the reserve, enforcement with surface cutters can be optimized, especially through the effective use of radar. The cost of operating Coast Guard cutters ranges between $800 and $3000 per hour, depending on the type of cutter.

4.4.4 Enforcement Cost Summary

While enforcement costs should not be viewed as a barrier to the creation of marine reserves, they must be taken into account. Any time new regulations are created without the elimination of other regulations, there will likely be an increase in the burden on enforcement. Marine reserves will not be effective if compliance with regulations is inadequate. It has been suggested there is not much sense in creating reserves of greater size or number than that for which enforcement resources are sufficient to ensure compliance. From experience, it is important to clearly identify and assign enforcement responsibilities. Public and industry acceptance are key to adequate enforcement over the long term. However, there is substantial risk and uncertainty associated with assuming informal public surveillance will be adequate to ensure compliance. Some design features make marine reserves more enforceable than others. The New England closures are being effectively enforced using a satellite vessel monitoring system.

4.5 Administration Costs

Once marine reserves are created, the primary administrative costs would be related to oversight of research, monitoring, and enforcement and possibly the issuance of permits for special activities in the reserve.

4.6 Private Sector Costs and Benefits (Including Producer and Consumer Surpluses)

Private sector costs and benefits are defined here to include producer surplus and consumer surplus in the commercial seafood and recreational fishing industries. Generally, when we examine producer surplus in the commercial seafood fishery we assume the surpluses are occurring at the level of the primary producer. As the product works its way into the wholesale and retail distribution networks, the number of substitute products available increase rapidly diminishing the impact of changes in West Coast seafood supply on price.

Additionally, to the degree that the current system of management is based on input controls (limits on the number of boats, gear used, amount of time spent fishing, etc.) any increases in harvester surplus that might result from marine reserves would generally stimulate more investment in the fishery, dissipating benefits that might initially accrue. Such dissipation will be less of a problem where output controls are used, such as individual quotas (or cumulative limits that are restrictive enough so as not to provide any incentive for vessels to increase their capacity to harvest fish).

While this analysis focuses primarily on surpluses at the harvesting level some commercial seafood fishers land their product partially processed. Therefore, processors are included in the analysis in order to provide a common basis for comparison (i.e., processed fish).

6/ This value appears to be substantially lower than a current estimate for 110 hours of time for a cutter operating on the West Coast. Assuming a cost of $1,010 per hour the total cutter cost would be $105,000.

4.6.1 Seafood Harvesters

Short-Term Impacts

Total gross revenue earned by fishers will depend on price and the amount of commercial harvest. Amount of commercial groundfish harvest is generally limited by direct harvest limits imposed on the fleet as a whole and implemented by cumulative limits placed on individual vessels or season closures for a few groundfish species and gear types. Harvest costs and exvessel value will affect the amount of fish harvested. Harvest costs, properly measured, are subtracted from gross revenue to determine producer surplus.

Allowed harvests would be immediately reduced by regulation under Option 3a, and may be reduced under Option 4, relative to the harvests that would be allowed in the immediate future under status quo. While the longterm intent of Option 4 is to liberalize regulations, initially harvests under Option 4 might be regulatorily constrained, because of substantial uncertainty about the impacts of creating such large areas of marine reserves. Harvest reductions would cover those species targeted for rebuilding and may cover other species for which the creation of a reserve removes a portion of the population from exploitation. Additionally, it may be necessary to further constrain harvest of other species caught in a complex with the protected species in order to avoid the conversion of harvest mortality to discard mortality with no real net effect on total fishing mortality. These changes in allowable harvest would impact all vessels including those vessels that did not generally fish in the newly protected reserve areas. No immediate changes would be imposed by regulation under Option 2 or 3b.

The main nonregulatory cause for a reduced harvest and hence reduced revenue may be a reduction in fisher effort due to a decrease in CPUE. The decreased CPUE would increase costs per unit catch, potentially reducing producer surplus per unit of catch. Vessels transferring their effort to other fishing areas may expect to experience a reduction in CPUE for a variety of reasons. A lower CPUE may be related to pre-existing lower CPUEs on the alternative grounds as compared to the marine reserve area, increased crowding and gear conflict on the alternative grounds, or localized depletion on alternative fishery grounds as a result of a transfer of effort from the reserve area.[7/] Increased crowding and localized depletion are also possible results for vessels in other fisheries to which dislocated vessels transfer effort. Whether dislocated vessels maintain the same targeting strategy in a different fishing area or change their target species, it is likely that over the short term their net revenues will decline since the alternative activities are by nature "second choice" alternatives as compared to their activity in the marine reserve area.

The short-term effects of dislocated effort are expected to be the strongest under Option 4 and negligible under Option 2, except to the extent that a reserve created under Option 2 occupies a substantial portion of an area on which a local port depends. For Options 3a and 3b, amount of dislocation would be expected to be intermediate between Options 2 and 4.

If there is a short-term reduction in harvest, to the extent that fish are caught for markets that also receive supply from other areas, the price of fish landed in areas near the reserve may not increase substantially. If catch is for very localized markets in which fish from other areas do not serve well as substitutes, or buyers compete for fish to fill the need of local fish plants, there may be some increase in the exvessel price that offsets some of the harvest cost increases or reductions in total catch. Such localized increases in CPUE would decrease harvest costs around the edges of the reserve.

Long-Term Impact

The short-term negative effects on total catch and cost per unit catch may be reversed over the long term. Increases in total biomass would most likely be expected under Option 3a (see Sections 2 and 3). Option 3a would, by regulation, directly reduce total harvest mortality (this assumes discard mortality is properly accounted for and controlled). The decrease in harvest mortality would be expected to increase rebuilding rates, resulting in greater annual harvest revenues and possibly lower cost per unit harvest at some point in

---

7/ Assuming that exploited segments of stocks targeted by the reserve are sedentary, increased harvest on similar segments of the stock outside the reserve would likely result in some localized depletion decreasing CPUE.

the future (assuming market prices remain stable). Increased opportunity to harvest species protected by the reserve may also increase opportunity to harvest other species in the complexes with which the protected species are caught.

Uncertainty about the timing of recovery, current levels of net benefits and interactions with healthy stocks make it difficult to determine the present value of the accelerated stock recovery (comparing on a present dollar basis the value of harvest foregone to the value of future harvests over a specified period of time). Under Option 3a, based on theoretical and largely qualitative models of reserve effects, it is hoped that rebuilding over the longer term would occur at a faster rate than a similar amount of catch reduction achieved without the implementation of reserves.

Option 4 would likely take an amount of area out of production sufficient to result in harvest reductions, however, with the amount of area placed in reserve, redistribution of harvest to open areas would substantially increase harvest rates in the open areas (likely reduce CPUE). Additionally, Option 4 specifies liberalized harvest rules in the open areas. Given the lack of knowledge about density dependent stock spawner-recruitment relationships in a dynamic marine system, the long-term net effect on sustained yield levels and CPUE in open areas for Option 4 are uncertain.

The long-term effect of Option 3b on biomass outside the reserve and CPUE is also uncertain but theoretically positive. The result depends largely on (1) the degree to which segments of the target populations are sedentary within the reserve and increase their fecundity per unit of biomass; (2) larval transport and survival; and (3) growth rates outside the reserve area (see discussions in Sections 2 and 3). Option 2 is unlikely to have a significant impact on rebuilding but may provide some insurance against reproductive disasters related to causes that can be controlled by marine reserves.

Localized increases in CPUE around the edges of reserves due to some adult spillover (and hence the possibility of lower costs per unit catch) is likely under any of the reserve options. Empirical evidence is strong for increases in biomass within reserves and some increase in the concentration of harvestable fish just outside reserve boundaries seems likely.

		Short-Term		Long-Term	
Option		Cost Per Unit Harvest	Allowable Total Harvest	Cost Per Unit Harvest	Allowable Total Harvest
2	Heritage Reserves	- or 0	0	+ or 0	+ or 0
3a	Rebuilding w/harvest reduction	-	-	+	+
3b	Rebuilding w/no harvest reduction	- -	0	+ ?	?
4	Alternative management	- - -	- ?	?	?

Key: + = a potential positive effect (e.g., costs decline)
- = a potential negative effect

4.6.2 Seafood Processors

If coastwide supply remains stable but local supply diminishes in some areas there may be some redistribution of harvest between processors. In areas of the reserve, competition among local buyers could lead to localized increases in exvessel prices. The degree of competition would depend on availability, substitutability, and costs for transporting product from other ports to the port experiencing a reduction in landings. Assuming little change in the overall supply in the market to which processors sell, if exvessel prices increase, processor margins for plants dependent on local supply could be diminished. If product supply diminishes on a coastwide basis, in the short term, average processing costs may increase, diminishing producer surplus.

An additional problem faced by processors is the maintenance of a skilled workforce. Diminished work opportunities could diminish processor abilities to attract and maintain a skilled workforce. This could lead to either increased costs related to less efficient workers or additional expenditures to recruit or retain skilled workers.

Under Option 3a, there would likely be immediate reductions such that plants dependent on West Coast harvest may suffer reduced revenues. Under Options 2 and 3b, there would not be any harvest reductions imposed by regulation, however, Section 4.6.1 outlines how changes in harvester costs may cause harvesters in particular locations to reduce the amount of product landed. If Option 4 were adopted for immediate implementation there may be some immediate short term reductions in harvest either as an indirect result of decreased CPUE in remaining open areas or as a precautionary measure taken until reserve effectiveness is demonstrated. As with all reserve options, the long-term consequences depend on reserve effectiveness in either rebuilding populations outside the reserve or preventing the total collapse and declaration of endangered species status for targeted populations.

Processor Impacts

Option	Short Term	Long Term
2.	Little coastwide impact. Possible localized negative impact.	Possible positive coastwide impact. Possible localized negative impact.
3a.	Negative coastwide impact. Possible localized negative impact.	Likely positive coastwide impact. Possible localized negative impact.
3b.	Little coastwide impact. Possible localized negative impact.	Possible positive coastwide impact. Possible localized negative impact.
4.	Likely negative coastwide impact. Localized negative impact.	Possible positive coastwide impact. Possible localized negative impact.

4.6.3 Seafood Consumers

Effects on seafood consumers will primarily depend on the effects of the options on supply. Section 4.6.1 outlines short-term and long-term effects on amounts of fish supplied. Decreases in amounts supplied will generally increase prices and decrease consumer surplus and increases in amount supplied are likely to decrease prices and increase consumer surplus. The size of the effects relative to national and international markets in which there are large numbers of substitutes are likely to be small for the individual consumer. Where there are localized markets for local products, the effects on price and on the individual consumer are likely to be greater.

4.6.4 Recreational Charter Vessel Operations and Fishers

Producer surplus for charter vessels will depend on the impacts of the reserve on regulations outside the reserve area, recreational fisher demand, and charter vessel operation costs. Regulations on total catch, seasons, bag, and size limits are likely to vary under each reserve option in directions similar to those described for the commercial fishery in Section 4.6.1. Consumer surplus and demand for fishing trips are directly related. A reserve that eliminates a recreational fishing area may, over the short-term, increase crowding and decrease CPUE. Depending on the locations of the reserves vessel travel times may also increase. The net effects may be to decrease demand for trips in a particular area (decrease consumer surplus) and increase the costs of charter operations (shift the supply curve, decreasing producer surplus). In addition to a decrease in consumer surplus, a decrease in demand for trips implies a decrease in charter vessel clientele and/or the average price charged for charter trips (a decrease in producer surplus). Over the long-term, marine reserves may result in an increase in CPUE or the average size of fish taken outside the reserve, particularly in fishing areas close to the reserve. This might increase the demand for trips out of a particular port. Regulations may also be more liberal than they would otherwise have been. The degree of such effects in the long term is at present uncertain (see Sections 2 and 3).

4.7 Transit Users

Those who use an area solely as part of a transit route may be affected if the rules of the marine reserves prohibit transit or impose some requirement on vessels transiting the area. Restrictions on transit may apply to recreational and/or commercial activities related or unrelated to fishing. The costs will depend on the costs of going around the areas or the costs of complying with any rules that provide conditional access to an area. Refuge size and location will affect degree of inconvenience (cost) to any vessel that has its presence in the reserve restricted, and consequently likely degrees of compliance and amounts of enforcement required.

4.8 Offsite Nonconsumptive Users (Existence values, Bequethal Values, and Option Values)

Offsite nonconsumptive uses of resources that may be protected in marine reserves is discussed in Section 4.1. These values are public in nature in that no one is excluded from deriving the identified benefits. Magnitude of the offsite nonconsumptive values for potential marine reserve areas and related ecosystems will be positively related to:

1. Qualities of the protected area.
2. Condition of the protected area.
3. Uniqueness of the protected area on a national and global scale.

(After Spurgeon, 1992, as cited in Caribbean Fishery Management Council, 1998.)

Where the marine reserve is being used to protect and recover fishing stocks, the value placed by offsite nonconsumptive "users" on the fish stocks independent of the place of those stocks as a component of the ecosystem will also affect total offsite nonconsumptive value. Total value placed on offsite nonconsumptive use of the stock or component of the ecosystem set aside will also depend on:

1. The size of the human population.
2. The level of income.
3. Education levels.
4. Environmental perceptions and preferences.

(After Spurgeon, 1992, as cited in Caribbean Fishery Management Council, 1998).

The above relationships imply that as human populations and the welfare of those populations increase and as the amount of quality habitat remaining in good condition decreases, the nonconsumptive values associated with the creation of marine reserves is likely to increase. Also implied is that once the basic integrity of ecosystem processes and marine fisheries components are preserved, the likely additional benefit from incremental expansion of marine reserves will decrease; i.e., as uniqueness decreases, the nonuse values of additional reserves may decline.

Value may also be placed on biological diversity. The value on biological diversity may be part of the value placed on a site by nonconsumptive users (onsite or offsite). Three levels of biological diversity have been identified, 1) genetic diversity within a species, 2) species diversity (richness, abundance, and taxonomic diversity), and 3) ecosystem diversity. Ecosystem diversity encompasses the variety of habitats, biotic communities, and ecological processes (Caribbean Fishery Management Council, 1998).

4.9 Other Social Impacts

The loss of fishing grounds can have substantial impacts on fishery dependent families and the communities in which they reside through either the stresses of lost income or the additional time some family members spend away from home required in order to travel to areas open to fishing. Any beneficial impacts from marine reserves in terms of recovery of stocks and potential for increased harvest outside the reserve areas are likely to be long in coming (particularly when depressed stocks are long lived with highly variable recruitment). The impacts of lost and reduced income on families in terms of loss of self esteem, stresses resulting from changing roles of family members, and various social abuses are extensively documented. These changes in families, in turn, stress communities both through increased strain on social services and the disruptive effects of disturbed families on other members of the community. The potential long-term social impacts of marine reserves should be addressed when specific sites are considered.

4.10 Data Needed for Socioeconomic Analysis

Much of the data needed for analysis of marine reserves is not available from traditional fishery data systems. Details on area of catch are not recorded on a fine enough scale to be useful in modeling the effects of marine reserves. For this reason, it is likely that reserve location and assessment of socioeconomic impacts would have to be based largely on key informant and anecdotal information. The collection and summarization of such information may require the assistance of individuals with social science expertise from outside fishery management agencies.

4.10.1 Location of Current Harvest

Information on the location of current harvest relative to a proposed marine reserve area is needed in order to begin to evaluate the degree of impact from creation of marine reserves. Location of harvest information would allow statements to be made about:

1. The number of harvesters and amount of harvest that will be dislocated by the creation of a marine reserve area.
2. The number of harvesters and amount of harvest by harvesters in the area that may be secondarily impacted by the shift of harvest effort out of the marine reserve area.

Information about the location of alternative fishing grounds would allow analysts to begin to analyze some differences in travel costs to the different fishing grounds.

Knowledge about amounts of displaced effort and catch as a proportion of the effort and catch in alternative fishing areas would begin to indicate the magnitude of cost increases related to the additional competition on the alternative fishing grounds.

Some information of this nature is available from trawl logbooks and some from charter vessel logs in California. In 1999 and 2000 there has been an effort to collect specific fishing location information from recreational fishers.

	Groups				
	Nonconsumptive on site (e.g., ecotourism)	Recreational Fishers	Charter Vessels	Seafood Harvesters	Processors
Ocean Area	None Identified	California Charter Vessel Logs 1999-2000 RecFIN Data (sample data–not expanded)	California Charter Vessel Logs	Trawl Logbooks	If information is available on seafood harvesters, it can be tied to a processor identification

4.10.2 Current CPUEs For Different Harvest Areas

A second piece of information needed for an economic analysis is the size of alternative fishing areas and CPUEs in those alternative fishing areas. With this information a short-term initial assessment might be made of the differences in costs of fishing between the marine reserve area and the alternative areas. This information may be available for groundfish trawl vessels coast wide and recreational charter vessels in California (Thomson, 1998).

Stock movement and total abundance information for the ranges of the stocks in the alternative fishing area; stock recruitment and growth parameters, and relationships of these and other factors to CPUE would be needed to assess the ability of alternative fishing areas to absorb displaced effort over the long term. This information is unlikely to be available.

4.10.3 Harvester Costs and Differentials Between Harvest Areas

It may be possible to construct some harvester cost functions by the time analyses are needed for the siting of specific marine reserve. However, the impacts that need to be modeled with respect to short term costs have to do with how costs vary between fishing sites. Over the long-term, ability to assess changes in costs depends on the effectiveness of marine reserves in preserving and rebuilding stocks and the relationship of stock abundance to CPUE. As discussed in Sections 2 and 3, prediction of such changes is problematic. Other than changes in travel time and costs to fishing grounds, it is unlikely that we will be able to estimate changes in harvest costs resulting from marine reserves.

4.10.4 Recreational Harvester and Site Specific Demand

A completely quantitative economic analysis would need information on expected changes in recreational harvester demand associated with the changes in CPUE (if CPUE predictions could be made). These values could be used to generate estimates of total trips expected with changing fishing opportunities and changes in consumer surplus. A recent Recreational Fishing Information Network (RecFIN) socioeconomic survey of West Coast anglers collected information on hypothetical responses to hypothetical changes in rockfish and lingcod bag limits. This data might be useful in gaining some insight into changes in demand with changes in harvest opportunity.

4.10.5 Processors

If the impacts of a marine reserve on commercial landings to a specific port can be estimated, the next question is whether product is processed locally or shipped to another location for processing or direct sale. Information required for a full quantitative assessment of impacts on processors would include amounts of product processors acquire from local and outside sources, processor variable costs, fixed and variable costs, and exprocessor prices.

4.10.6 Offsite Nonconsumptive Values

Estimates of existence, bequeathal, and option values are difficult to derive. The methods most generally used to estimate such values are surveys. Another indicator of such values might be the portion of environmental organization budgets dedicated to the creation of marine reserves on the West Coast.

4.10.7 Family Dependence

Information will be needed on the dependence of families in the community on income from fishing, alternative sources of income, and resources available in the community to assist families in adapting to change.

5.0 DISCUSSION OF ALTERNATIVES TO MARINE RESERVES

A number of non-marine reserve alternatives that could address the objectives specified for marine reserves were identified by the marine reserve committee. Not all committee members endorsed all of the alternatives. The alternatives are not mutually exclusive, and none (together or in combination) could completely substitute for marine reserves, nor could marine reserves likely be a complete substitute for any of the nonreserve alternatives. However, the non-marine reserve alternatives could reduce the need for such reserves, thus affecting the balance on the decision on whether or not to implement marine reserves. For example, given the risks and uncertainties of the current fishery management system, an individual might make the qualitative judgement that the likely benefits of marine reserves warrant their costs. However, if a comprehensive observer program were in place, and the fleet and allowable catch had been reduced, the same individual might conclude that the additional benefits from marine reserves (keeping in mind all other benefits including habitat protection) would not warrant their costs. It is important to consider all expected benefits of the reserve network such as enhanced ecosystem, multispecies, and habitat protection. Similarly, the existence of an extensive marine reserve network may not substitute for an observer program or for lower target harvest levels, but might affect the balance of the expected costs and benefits from implementing an observer program or reducing capacity and harvest.

The following are the non-marine reserve alternatives identified by the committee and the marine reserve related objectives toward which the nonreserve alternatives might make progress over the long-term.

	Objective Addressed					
Non-Marine Reserve Alternatives	Stock Rebuilding	Biological Productivity	Economic Productivity	Insurance	Habitat	Research and Education
a. Time and area closures.	x	x	?		?	?
b. Fleet reduction in combination with reduction in allowable catch: buyback, ITQs, status quo (economic attrition).	x	x	x	x		
c. Zero fishing mortality on target spp including no bycatch mortality.	x	x	?	x		
d. Lower total fishing mortality.	x	x	?	x		
e. More conservative stock assessment parameters.	x	x	?	x		
f. More and better data for stock assessments.		x	x			
g. Reduce capability of individual vessels to impact critical habitat.	x	x	?		x	
h. Gear restrictions in certain areas, stated in terms of performance standards, (e.g., no gear with impact on critical habitat).	x	x	?		x	x
I. Allocation toward gear types with less impacts to habitat.	x	x	?		x	
j. Observer program (including better documentation of removals).	x	x	?			x
k. More effective enforcement (better control of removals).	x	x	?			

x = some progress **would likely** be made toward objective.

? = some progress **might** be made, but the result is uncertain and could be negative.

5.1 Time Area Closures

When an overfished species is taken as part of a multispecies fishery it can be difficult to reduce take of the overfished species without reducing take of other species in the fishery complex. At the same time, there is variation in the mix of stocks taken in the multispecies fisheries. There are reports that in some situations fishers will go to an area where the overfished species is more available in order to take as close as possible to the full amount of the overfished species allowed under the cumulative limit regulations. If these areas can be identified, it might be possible to close the area for a period of time, reducing the "incidental" harvest of the overfished species without substantially reducing the harvest of other economically valuable species. If there are seasonal patterns in the congregation of overfished species, time area closures could be a particularly useful tool. However, time area closures can be used to reduce bycatch for a period of time even if there are no seasonal patterns. It has been suggested there may be certain canyon areas along the North Coast where POP shows up more frequently as bycatch and that POP bycatch might be reduced by closure of these areas. Time area closures might also be warranted if there are certain times of the year that fishing tends to disrupt reproductive activities (i.e., when male lingcod are nesting).

5.2 Reduction of Allowable Catch

The central focus of alternatives to marine reserves is to find some other means of accelerating stock rebuilding beyond what would occur under the status quo rebuilding plan. Under Alternatives b, c, and d, rebuilding would be accelerated by reducing total catch mortality through direct regulation. Alternatives c and d would lower total harvest with no other changes. Alternative c could impose some dramatic reductions in the harvest of many species caught in complexes with the species in need of rebuilding. That some harvest of overfished species is allowed necessarily implies that the current rebuilding plans could have reduced harvest further than they did. These rebuilding plans implicitly incorporate a balance between reduced harvest to facilitate stock rebuilding and the negative economic and social consequences for the fishing industry, communities and the nation. Alternative b would propose to achieve further reduction in mortality by providing a program to mitigate for some of the economic consequences, such as a buyback program or the creation of individual transferable quotas (ITQs).

Buyback Program

Industry funded buyback programs have been explored by the Council. The Magnuson-Stevens Act authorizes buyback funded by industry, the states, or other public or private sources. An industry funded program requires a business plan and a referendum among industry members on whether or not the program should be implemented. A business plan for the trawl fleet was approved by the Council; however, NMFS guidelines specified that all related FMP amendments for the business plan need to be in place before the Council submits its request for the development of a buyback package. Part of the business plan proposed for the trawl buyback program involved the allocation of fish to the trawl sector in order to provide assurance that the sector would be able to repay the loan. The allocation portion of the proposal combined with the substantial declines in allowable harvest in the last two years have stalled progress on submission of the buyback proposal. The proposal dated July 1998 requested a maximum of $28 million to fund the purchase of between 80 and 90 of the 280 trawl permits (28%-32% of the permits).

Reduction of fleet capacity would improve the health of the industry and possibly allow some further reduction of fishing mortality while at the same time liberalizing management measures in such a way that bycatch discard mortality could be reduced. Overall, health of the trawl sector of the industry would improve. While the trawl sector would be better able to sustain further cuts in harvest, the buyback program would provide little mitigation for the impacts of reduced landings for the processing sector or communities with economic ties to the processing sector.

Individual Transferable Quotas

The allocation and free trade of individual quotas has generally been shown to result in windfall profits for those selling the quota and increased fishing profits for participants in the fishery. The windfall profits may provide the compensation necessary for some to leave the fishery without taking on excessive debt. In most fisheries, the most contentious aspect of implementing ITQs is the initial allocation. For multispecies fisheries there are complexities related to mixes of ITQs that must be held. There is concern that fishers may species highgrade (retain species for which they have the requisite ITQs while discarding bycatch). Tracking, monitoring, and enforcement programs may be expensive. The most difficult and possibly costly aspect of the program is ensuring that multispecies landings are properly recorded. Other aspects of tracking landings and ITQ trading are reasonably tractable given today's computer technologies.

5.3 More Precautionary Stock Assessment Parameters

The alternative of using more precautionary parameters in the stock assessments (Alternative e) is somewhat similar to the option of directly reducing the allowable harvest, as discussed in Section 5.2. A decision to use more precautionary parameters in place of best estimates is a policy decision. As compared to the direct reductions of harvest discussed in Section 5.2, use of a more conservative parameter in a stock assessment or harvest model may be a somewhat less arbitrary method for reducing harvest because it relates the reduction more closely to the areas and amounts of uncertainty in the model.

5.4 More and Better Data for Stock Assessments

The main objectives addressed by developing better data for stock assessments (Alternative f) would be increasing long-term biological and economic productivity by better estimating appropriate harvest levels. The draft NMFS NWFSC groundfish research plan identifies the following research funding shortfalls:

Additional critical research related to status of stocks
- Improved survey frequency and coverage $3,500,000
- Improved biological studies and stock assessments $2,000,000
- Enhanced fishery sampling and electronic data collection $1,500,000
- Fishery observer program $4,700,000

Additional critical research related to socioeconomic analysis
- Collect economics data $700,000
- Build socioeconomic analysis capability $500,000

5.5 Reduce Gear Impacts on Habitat

Alternatives g, h, and I are all proposed as different methods of reducing the use of gear with negative impacts on habitat. The expectation is that reducing habitat degradation would also improve biological productivity and accelerate stock rebuilding. There is still considerable debate over the degree of impact different gears have on habitat and, in some situations, whether the impacts are negative or positive. Localizing the gear restrictions to certain areas (Alternative f) might provide some opportunity for research on the issue.

5.6 Observer Program

An essential component of effective, science-based fishery management is the documentation and quantification of bycatch, total catch, and total fishery-related mortality. An observer program would contribute to stock rebuilding and biological productivity by helping to ensure the total fishing mortality is properly measured and controlled. The Council has expressed the need for a comprehensive observer program for many years. It has consistently voted to pursue an at-sea observer program. The lack of an observer program has contributed to uncertainty in stock assessments and rebuilding plans and has undermined the credibility of management decisions. Because existing information is lacking, assumed discard rates have been applied to all sectors. In addition, incentives for selective fishing gear that minimizes bycatch and discards are difficult to implement, because they cannot be effectively evaluated.

The effects of an observer program on economic productivity would depend on the costs of the observer program compared to any gain from better monitoring of the fishery. The observer program would also provide some opportunity for research, though on topic somewhat different from those that would be investigated with marine reserves.

Framework regulations for an observer program are being published in the *Federal Register*. In 1999, the cost for an observer program was estimated at between $4 million and $5 million for 20 observers. The program does not specify the number or types of vessels that might be covered by this program. In the groundfish fleet, there are approximately 270 limited entry trawl catcher vessels, 235 limited entry longline and pot vessels and between 1,000 and 2,000 active open access vessels. The open access fleet with significant groundfish take is a relatively small portion of the total number of open access vessels. For additional discussion on issues related to an observer program, see the Council's draft strategic plan.

5.7 More Effective Enforcement

Good enforcement ensures the harvest targets set by the Council are not exceeded. To the degree that landings are not reported even the best conservation efforts may be compromised. Alternative k would improve fisheries enforcement.

The USCG is short about $5 million from its annual request for resources needed to meet enforcement goals (this shortfall is the equivalent of approximately 129 days for Medium Endurance Cutter). However, increased cutter hours may not be the final solution to the most optimal enforcement of the fisheries. The $5 million may be better spent to fund other enforcement programs, such as vessel monitoring systems, increased dockside observers from NMFS and the states, at-sea observers, etc. Increased cutter days would result in an increased number of at-sea boardings. However, the USCG is somewhat limited as to what it can enforce at sea, i.e., it cannot effectively enforce trip limits. Trip limits need to be enforced during offload monitoring.

For fiscal year 2000, the NMFS Northwest Region Enforcement division reports a $52,500 base program shortfall for ESA enforcement and a $20,000 funding base program shortfall for Washington, Oregon, and California groundfish fishery enforcement. Due to past full-time employee and budgetary cutbacks, NMFS enforcement presence in Oregon and Washington has been limited to one Special Agent in Aberdeen, Washington, and one Supervisory Special Agent and one Enforcement Officer in Astoria, Oregon. Time expended by these agents is carefully prioritized. With the proposed FY2000 cuts, travel for the agents and officers was expected to be strictly curtailed, resulting in the inability to provide even minimal prioritized coverage for groundfish monitoring outside the local commuting areas around Aberdeen and Astoria. The number of NOAA Fisheries, Washington, Oregon, California investigations reported by the NWR has declined steadily with reduced enforcement resources:

Year	1995	1996	1997	1998	1999
Number of Investigations	107	110	17	28	8

6.0 REFERENCES

Adams, P. B., E. H. Williams, K. R. Silberberg, and T. E. Laidig. 1999. Southern lingcod stock assessment in 1999. pp. 1-80. In: Appendix to the Status of the Pacific Coast Groundfish Fishery Through 1999 and Recommended Acceptable Biological Catches For 2000: Stock Assessment and Fishery Evaluation. Pacific Fish. Mngmnt. Council, 2130 SW Fifth Ave., Suite 224, Portland, OR 97201.

Alcala, A. C. and G. R. Russ. 1990. A direct test of the effects of protective management on abundance and yield of tropical marine resources. J. du Cons. Int. Expl. Mer 46:40-47.

Alder, J. 1996. Costs and effectiveness of education and enforcement, Cairns Section of the Great Barrier Reef Marine Park.Environ. Manag. 20:541-551.

Auster, P. J. and R. W. Langton. 1999. The effects of fishing on fish habitat. Amer. Fish. Soc. Symp. 22:150-187.

Bailey, K.M., R.C. Francis, and E.R. Stevens. 1982. The life history and fishery of Pacific whiting, *Merluccius productus.* CA Coop. Oceanic Fish. Invest. Rets. 23:81-98.

Ballantine, W. J. 1989. Marine reserves: Lessons from New Zealand. Progress in Underwater Science 13:1-14.

Beatley, T. 1991. Protecting biodiversity in coastal environments. Coastal Management 19:1-19.

Bennett, B. A. and C. G. Attwood. 1991. Evidence for recovery of a surf-zone fish assemblage following the establishment of a marine reserve on the southern coast of South Africa. Marine Ecology Prog. Series 75:173-181.

Bohnsack, J. A. 1993. Marine reserves: They enhance fisheries, reduce conflicts, and protect resources. Oceanus 36(3):63-71.

Bohnsack, J. A. 1998. Marine reserves: lessons from Florida. Pages 89-99 in M.M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA-TM-NMFS-SWFSC-255.

Cailliet, G. M., K. H. Coale, A. H. Andrews, and E. J. Burton. 1999. Radiometric age validation of the bocaccio rockfish, *Sebastes paucispinis.* Final Rpt. R/F-174, California Sea Grant College System. 20 p.

Caribbean Fishery Management Council. 1998. Regulatory Impact Review and Initial Regulatory Flexibility analysis for the Draft of Amendment 1 for the Fishery Management Plan for Corals and Reef Associated Plants and Invertebrates of Puerto Rico and the Unites States Virgin Islands. DRAFT. August, 1998.

Carlson, R. H. and R. E. Haight. 1972. Evidence for a home site and homing of adult yellowtail rockfish, *Sebastes flavidus.* J. Fish. Res. Bd. Canada 29:1011-1014.

Carr, M. H., and D. C. Reed. 1993. Conceptual issues relevant to marine harvest refuges: examples from temperate reef fishes. Can. J. Fish. Aquat. Sci. 50:2019-2028.

Carr, M.H. and P. T. Raimondi. 1998. Concepts relevant to the design and evaluation of fishery reserves. pp. 27-31. In M.M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA-TM-NMFS-SWFSC-255.

Carr, M. H., L. Ziobro, T. Hourigan, D. Ito, D. McArdle, L. Morgan, W. Palsson, R. Parrish, S. Ralston, P. Reilly, J. Sladek Nowlis, and R. Starr. 1998. Working group II. Science-based design considerations. Pages 143–148. In M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA–TM–NMFS–SWFSC–255.

Collie, J.S., G.A. Escanero, and P.C. Valentine. 1997. Effects of bottom fishing on the benthic megafauna of Georges Bank. Mar. Ecol. Prog. Ser. 155:159.172.

Causey, B. D. 1995. Enforcement in marine protected areas. pp. 119-148. In S. Gubbay, ed. Marine protected areas. Principles and techniques for management. Chapman & Hall, London.

Crosby, M.P. A Proposed Approach for Studying Ecological and Socioeconomic Impacts of Alternative Access Management Strategies for Marine Protected Areas.

DeMartini, E. E. 1993. Modeling the potential of fishery reserves for managing Pacific coral reef reserves. Fish. Bull. U.S. 91:414-427.

Didier, Jr. A.J. 1998. Marine protected areas of Washington, Oregon, and California. Pacific Fishery Management Council Contract No. 98-08. 74 p.

Dugan, J. E., and G. E. Davis. 1993. Applications of marine refugia to coastal fisheries management. Can. J. Fish. Aquat. Sci. 50:2029-2042.

Fiske, S.J. 1992. Sociocultural aspects of establishing marine protected areas. Ocean Coast. Manag. 17:25-46.

Gunderson, D. R. 1997. Spatial patterns in the dynamics of slope rockfish stocks and their implications for management. Fishery Bull. 95:219-230.

Halpern, 2000. The impact of marine reserves: does reserve size matter? Ecological Applications (In Press).

Hanna, Susan S. 1983. The Economic of Uncertainty: A Survey of the Literature on Uncertainty with Particular Reference to the Fishery. NOAA Technical Memorandum NMFS F/NWC-47.

Hartmann, A.R. 1987. Movement of scorpionfishes (Scorpaenidae: *Sebastes* and *Scorpaena*) in the southern California Bight. Calif. Fish and Game 73:68-79.

Jagielo, T. 1999. Lingcod rebuilding. Pacific Fisheries Management Council. 13 p.

Johnson, D.R., N.A. Funicelli, and J. A. Bohnsack. 1999. Effectiveness of an existing estuarine no-take fish sanctuary within the Kennedy Space Center, Florida. North Am. J. Fisheries Management.

Jones, G.P., M.J. Milicich, M.J. Emslie, and C. Lunow. 1999. Self-recruitment in a coral reef fish population. Nature 402(6763):802-804.

Lauck, T., C. W. Clark, M. Mangel, and G. R. Munro. 1998. Implementing the precautionary principle in fisheries management through marine reserves. Ecol. Appl. 8 (Supplement):72-78.

Leaman, B. M. 1998. Experimental rockfish management and implications for rockfish harvest refugia. pp. 17-26. In M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA-TM-NMFS-SWFSC-255.

Love, M.S., M. H. Carr and L. J. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus *Sebastes.* Environmental Biology of Fishes. 30: 225-243.

MacCall, A.D. 1999a. Bocaccio Rebuilding. Pacific Fisheries Management Council. 8 p.

MacCall, A.D. 1999b. Pacific Ocean Perch Rebuilding. Pacific Fisheries Management Council. 5 p.

MacCall, A.D., S. Ralston, D. Pearson, and E. Williams. 1999. Status of bocaccio off California in 1999 and outlook for the next millennium. pp. 1-45. In Appendix to the Status of the Pacific Coast Groundfish Fishery Through 1999 and Recommended Acceptable Biological Catches For 2000: Stock Assessment and Fishery Evaluation. Pacific Fish. Mngmnt. Council, 2130 SW Fifth Ave., Suite 224, Portland, OR 97201.

Mangel, M. 1998. No-take areas for sustainability of harvested species and a conservation invariant for marine reserves. Ecology Letters 1:87-90.

Mason, J.E. 1998. Declining rockfish lengths in the Monterey Bay, California, recreational fishery, 1959-94. Marine Fish. Rev. 60:15-28.

Matthews, K.R., B.S. Miller, and T.P. Quinn. 1987. Movement studies of nearshore demersal rockfishes in Puget Sound, Washington. In Proceedings of the international rockfish symposium, p. 63-72. U. Alaska Sea Grant Rep. 87-2. U. Alaska, Fairbanks. 393 p.

McArdle, D. A. 1997. California Marine Protected Areas. Publication No. T-039. California Sea Grant College System, La Jolla, California.

McArdle, D.A. 1998. Restrictions on rockfish fishing in existing California marine protected areas. Pages 133-136. In M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA–TM–NMFS–SWFSC–255.

Morgan, L. E., and L. W. Botsford. 1998. The influence of larval transport and retention zones on recruitment patterns and the design of harvest refugia for rockfish. pp. 41–49. In M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA–TM–NMFS–SWFSC–255.

Murawski, S. A., R. Brown, H.L. Lai, P. J. Rago, and L. Hendrickson. (In Press). Large-scale closed areas as a fishery management tool in temperate marine systems: the Georges Bank experience. The Proceedings of the 1998 Mote International Symposium on Essential Fish Habitat and Marine Reserves, 4-6 November 1998, Sarasota, FL.

Murray, S. N., R. F. Ambrose, J.A . Bohnsack, L. W. Botsford, M. Carr, G. E. Davis, P.K. Dayton, D.Gotshall, D. R. Gunderson, M.A. Hixon, J. Lubchenco, M. Mangel, A. MacCall, D. A. McArdle, J. C. Ogden, J. Roughgarden, R. M. Sarr, M.J. Tegner, and M. M. Yoklavich, 1999. No-take Reserve Networks: Sustaining Fishery Populations and Marine Ecosystems. Fisheries 24(11): 11-25.

Murray, S. N., T. G. Denis, J. S. Kido, and J. R. Smith. 1999b. Human visitation and the frequency and potential effects of collecting on rocky intertidal populations in Southern California marine reserves. CalCOFI Rep. 40:100-106.

Okey T. A. and G. A. Harrington. 1999. Criteria for Designing Ecosystem-Based, Experimental Management: Bottom Trawling and the Bering Sea Ecosystem. In Ecosystem Approaches for Fisheries Management. Alaska Sea Grant. pp 425-446. Publication Number: AK-SG-99-01

O'Connell, V., W.W. Wakefield, and H.G. Greene. 1998. The use of a no-take marine reserve in the eastern Gulf of Alaska to protect essential fish habitat. pp. 125-132. In M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA–TM–NMFS–SWFSC–255.

Paddack, M. J. 1996. The influence of marine reserves upon rockfish populations in central California kelp forests. Master's Thesis, University California, Santa Cruz. 40 p.

Palsson, W.A. 1998. Monitoring the response of rockfishes to protected areas. Pages 64-73. In M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA–TM–NMFS–SWFSC–255.

Palsson, W.A. and R.E. Pacunski. 1995. The response of rocky reef fishes to harvest refugia in Puget Sound. In Puget Sound Research '95, Vol. 1, pp. 224-234. Puget Sound Water Quality Authority, Olympia, Washington.

Parrish, R. 1999. Marine reserves for fisheries management: why not. CA Coop. Oceanic Fish. Invest. Rept. 40:77-86.

Pearcy, W.G. 1992. Movements of acoustically-tagged yellowtail rockfish *Sebastes flavidus* on Heceta Bank, Oregon. Fish. Bull. 90:726-735.

Polacheck, T. 1990. Year around closed areas as a management tool. Nat. Res. Model. 4:327-354.

Pomeroy, C., G. Cailliet, P. Auster, J. Bohnsack, G. Darcy, B. Leaman, M. Love, J. Mason, R. Saunders, W. Silverthorne, D. Suman, and E. Ueber. 1998. Working Group III: Socioeconomic considerations and implementation. pp. 149-153. In M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA–TM–NMFS–SWFSC–255.

Proulx, E. 1998. The role of law enforcement in the creation and management of marine reserves. Pages 74–77 in M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA–TM–NMFS–SWFSC–255.

Ralston, S. 1998. The status of federally managed rockfish on the U.S. West Coast. pp. 6–16. In M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA–TM–NMFS–SWFSC–255.

Ralston, S., and D. F. Howard. 1995. On the development of year-class strength and cohort variability in two northern California rockfishes. Fish. Bull. U.S. 93:710-720.

Roberts, C.M. and N.V.C. Polunin. 1991. Are marine reserves effective in management of reef fisheries? Reviews in Fish Biology and Fisheries 1:65-91.

Rowley, R.J. 1992. Impacts of marine reserves on fisheries: A report and review of the literature. Dept. Conservation, Wellington, NZ, 51 p. (ISBN 0-478-01432-5).

Rowley, R.J. 1994. Case studies and reviews: marine reserves in fisheries management. Aquatic Conservation: Marine and Freshwater Ecosystems 4:233-254.

Russ, G.R. and A.C. Alcala. 1996. Do marine reserves export adult fish biomass? Evidence from Apo Island, central Philippines. Marine Ecology Prog. Series 132:1-9.

Scott, B. 1995. Oceanographic features that define the habitat of Pacific ocean perch, *Sebastes alutus*. Fisheries Oceanography 4:147-157.

Sladek Nowlis, J., and C. M. Roberts. 1999. Fisheries benefits and optimal design of marine reserves. Fish. Bull. U.S. 97:604-616.

Sladek Nowlis, J., and M. Yoklavich. 1998. Design criteria for rockfish harvest refugia from models of fish transport. Pages 32–40. In M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAA–TM–NMFS–SWFSC–255.

Soh, S. K., D.R. Gunderson, and D.H. Ito. 1998. Closed areas to manage rockfishes in the Gulf of Alaska. pp. 118-124. In M. M. Yoklavich, ed. Marine harvest refugia for West Coast rockfish: a workshop. NOAAÐTMÐNMFSÐSWFSCÐ255.

Spurgeon, J.P.G. 1992. The Economic Valuation of Coral Reefs." Marine Pollution Bulletin 24(11):529-536.

Sutinen, J.G. 1988. Enforcement economics in exclusive economic zones. GeoJournal 16:273-281.

Sutinen, J. G., J. Yahaya, and V. Hirunruk. 1992. "Fisheries Law Enforcement Programs, Practices and Problems in Malaysia, Philippines, and Thailand," in James B. Marsh (ed.), Resources and Environment in Asia's Marine Sectors, Taylor and Francis Publishers.

Sutinen, J. G., A. Rieser, and J. R. Gauvin. 1990. "Measuring and Explaining Noncompliance in Federally Managed Fisheries," Ocean Development and International Law, 21:335-372.

Sutinen, Jon G. and John R. Gauvin. 1989. "An Econometric Study of Regulatory Enforcement and Compliance in the Commercial Inshore Lobster Fishery of Massachusetts," in P. A. Neher, R. Arnason and N. Mollett (eds.), Rights Based Fishing. Dordrecht: Kluwer Academic Publishers.

Swearer, S. E., J. E. Caselle, D. W. Lea, and R.R. Warner. 1999. Larval retention and recruitment in an island population of a coral-reef fish. Nature 402(6763):799-802.

Tegner, M. J., J. D. Martini, and K. A. Karpov. 1992. The California red abalone fishery: a case study in complexity. pp. 370-383. In S. A. Shepherd, M. J. Tegner, and S. A. Guzmán del Próo, eds. Abalone of the world. Blackwell Scientific Publications, Oxford.

Tegner, M. J., L. V. Basch, and P. K. Dayton. 1996. Near extinction of an exploited marine invertebrate. Trends Ecol. Evol. 11:278-280.

Ticco, P. C. 1995. The use of marine protected areas to preserve and enhance marine biological diversity: a case study approach. Coastal Management 23:309-314.

Tisdell, C. and J.M. Broadus. 1989. “Policy Issues Related to the Establishment and Management of Marine Reserves.” Coastal Management, 17:37-53.

Thomson, C. 1998. “Evaluating Marine Harvest Refugia: An Economic Perspective.”In Marine Harvest Refugia for West Coast Rockfish: A Workshop. Mary Yoklavich, ed. NOAA-TM-NMFS- SWFSC-255. USDOC, NOAA, NMFS, SWFSC, Pacific Fisheries Environmental Laboratory. Pacific Grove CA. pp. 78-83.

Thomson, C. J. 1999. Economic and management implications of no-take reserves: an application to *Sebastes* rockfish in California. CalCOFI Rep. 40:107-117.

Yoklavich, M. M. 1998. Marine harvest refugia for West Coast rockfish: a workshop. NOAA–TM–NMFS–SWFSC–255. 159 pp.

Yoklavich, M., H. G. Greene, G. Cailliet, D. Sullivan, R. Lea, and M. Love. (In Press). Habitat associations of deep-water rockfishes in a submarine canyon: an example of a natural refuge. Fishery Bulletin, U.S. 98(3).

APPENDIX A: MEMBERS OF THE AD HOC MARINE RESERVE COMMITTEE

Name/Affiliation	Seat
Cedergreen, Mr. Mark (Salmon Charter Boat Operator, Chair of the Council Salmon Advisory Subpanel)	Recreational Salmon
Corrigan, LT Brian (USCG)	Enforcement
de Reynier, Ms. Yvonne (NMFS, NWR)	NMFS, Region
Ellis, Mr. Stuart (Northwest Indian Fisheries Commission)	Tribal
Fox, Mr. Dave (Oregon Department of Fish and Wildlife [ODFW])	Oregon Department of Fish and Wildlife
Fujita, Dr. Rod (Environmental Defense)	Environmentalist
Hansen, Mr. Donald (Groundfish Charter Boat Operator, Chair of the Council Groundfish Advisory Subpanel)	Recreational Groundfish
Hanson, Dr. David (Pacific States Marine Fisheries Commission [PSMFC])	PSMFC (Committee Chair)
Helvey, Mr. Mark (NMFS, SWR)	NMFS, Region
Lea, Dr. Robert N. (California Department of Fish and Game [CDFG])	CDFG
Maclean, Mr. Duncan (Commercial Salmon Troller, Salmon Advisory Subpanel)	Commercial Salmon
Munro, Ms. Heather (West Coast Seafood Processors Association, Vice Chair of the Council Coastal Pelagics Species Advisory Panel)	Processor
Ponts, Mr. James (Commercial groundfish longliner, member of the Council Groundfish Advisory Subpanel)	Commercial Nontrawl Groundfish
Robinson, Ms. Michelle (Washington Department of Fish and Wildlife [WDFW])	WDFW
Smotherman, Mr. Kelly E. (Commercial groundfish trawler, member of the Council Groundfish Advisory Subpanel)	Commercial Trawl Groundfish
Yoklavich, Ms. Mary (NMFS, SWFSC)	NMFS, Science Center