

STAFF REPORT ON PHASE I CONSIDERATIONS
OF MARINE RESERVES AS A MANAGEMENT MEASURE

Situation: The Council is evaluating marine reserves as a fishery management tool. The Council adopted a two-phase process in April, 1999. The first phase is a conceptual evaluation of the utility of marine reserves. The second phase, if pursued, would involve the siting of specific marine reserves.

The Ad-Hoc Marine Reserve Committee (Committee) has met four times. The Committee developed objectives and a conceptual framework for marine reserves to guide the technical analysis. The last meeting of the Committee was September 14, 1999 and another meeting will be held April 4, 2000. The National Marine Fisheries Service Southwest Fisheries Science Center provided the Council staff with the support needed to conduct an analysis of the Committee's conceptual framework.

The analysts will present a summary of their findings and recommendations to the Council. The intent of this initial presentation of findings and distribution of a preliminary draft to Council committees, is to move the process forward by stimulating committee and Council discussion prior to a final decision on Phase I in June 2000.

Council Direction: Provide guidance, if needed.

Reference Materials: None.

PFMC
03/20/00

Marine Reserves, April 2000

Council Update and Initial Presentation of Results

- **Review of Council process**
- **Summary of technical analysis**
- **No Council action required at this meeting**
- **Reserve definition: no-take of relevant species**
- **Council authority: limited to FMP species**

Two Phase Process

● ***Phase I--Conceptual Evaluation***

– **Ad hoc Committee work**

Identify objectives, alternatives, studies

– **Technical staff**

- Evaluate likelihood of meeting objectives

- Evaluate design

- Outline issues/elements/approach for Phase II analysis

– **Council**

Select options for Phase II or end process

● ***Phase II--Full Specification and Siting***

Next Steps

- **April—no action, initial review and comment on analysis, heads up on main findings**
- **June—approve draft analyses for public review**
- **September—final Phase I decision**

Objectives--(priority order)

- **Accelerate stock rebuilding**
- **Enhance biological productivity**
- **Enhance economic productivity**
- **Provide insurance**
- **Conserve and protect habitat**
- **Improve opportunities for research and education**

Options

- 1 Status Quo
- 2 Heritage/Research Reserves (5%)
- 3a Rebuilding Reserves with Harvest Reduction (20%)
- 3b Rebuilding Reserves without Harvest Reduction (20%)
- 4 Alternative Management Reserves (20%-35%+)
- 5 No Reserves (Other Ways)

Objectives

- **Accelerate Stock Rebuilding**
 - Likely within reserve, uncertain outside
- **Enhance Biological Productivity**
 - Uncertain
- **Enhance Economic Productivity**
 - Uncertain
- **Provide Insurance**
 - Likely
- **Conserve and Protect Habitat**
 - Yes within reserve, uncertain outside reserve
- **Improve Opportunities for Research and Education**
 - Yes

General Conclusion

- Empirical evidence exists but is sparse
- Much uncertainty but probably some movement toward all objectives except with very large or very small reserves
- Information level on reserves not much different than most stock assessments

Enhance Econ Productivity

- **Short-term harvest productivity will depend on**
 - outside harvest policies and
 - alternative grounds (availability and CPUE)
- **Long-term harvest productivity will increase**
 - if biological productivity is enhanced
 - if presence of low productivity stocks in reserves allow higher prod stocks outside the reserve to be harvested at a higher rate
 - not if CPUE declines outside reserve
 - not if reserves are ineffective in protecting stock or habitat of concern
- **Could be more variability in harvest**

Other Impacts—Some Costs

- **Impact Study and Eval (baseline, control, complex, no instant result, errors can be costly)**
- **Enforcement (cooperation, planning and resources)**
- **Stock Assessment and Surveys (sampling stations in the reserve)**
- **Other restricted activities (e.g. non-fish resource mining)**

Other Impacts—Some Benefits

- **Information (biological parameters, uncertainty and value, process)**
- **Nonconsumptive Recreational Values**
- **Existence, Bequethal and Option Values**
- **Ecosystem Services**

Data Shortfalls for Socio-Economic Assessment

- **Fishing Ground & Rec Port Data: Scant**
 - Rec Data (What port? What catch area? CPUE? Site values? CA Charter, RecFIN)
 - Seafood Data (What catch area? CPUE? Trawl logs)
 - Processor Data (Where is raw product from?)
 - Nonconsumptive users (How many, what is activity, what is the value?)
- **Existence Bequethal and Option Values**
 - Need to identify studies
- **Local Key Informant and Anecdotal Information Will Be Important**

Considerations for Initiating Phase II

- **Involve all stakeholders early in the process**
 - (consider nonCouncil fisheries and nonfishing activities)
- **Integrate local and regional input**
- **Clearly identify goals and objectives**
- **Determine realistic expectations for levels of impacts**
- **Identify how monitoring and enforcement will be achieved**
- **Who will coordinate Phase II, in what forum(s), resources needed**
 - Council as lead
 - Council as participant

Next Steps

- **April—no action, initial review and comment on analysis**
- **June—approve draft analyses for public review**
- **September—final Phase I decision**
 - **If go ahead is given**
 - Which of the four reserve options should be developed?
 - How should Phase II process be organized?

Limitations To Management

Interdecadal Variability in Recruitment

Multi-species Assemblages

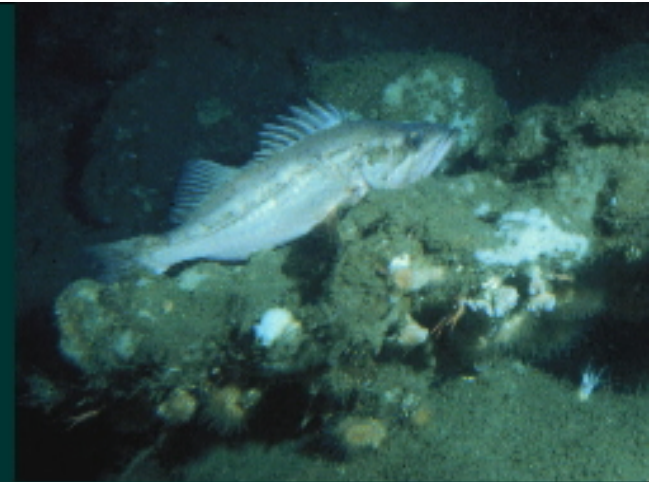
Lack of Baseline Information

No Reference Sites for Research/Monitoring



Current Circumstances:

- Total Fishing Mortality Needs To Be Reduced
- EFH Should Be Identified and Protected
- Undisturbed Areas Are Essential For Monitoring and Research
- Insurance Is Necessary To Hedge Against
 - management uncertainties
 - information deficits
 - longterm environmental change



Benefits of Establishing Marine Reserves:

- Might Be The Only Way To Rebuild The Overfished Component(s) of Multi-species Fisheries
- Protects Essential Fish Habitats
- Provides Undisturbed Reference Sites For Research and Monitoring
- Takes a Precautionary Approach To Management (Providing Insurance)
- Incorporates Ecosystem Principles Into Management (Enhancing Biological Productivity)

If Adopted:

**MARINE RESERVES NEED TO BE AN INTEGRATED PART
OF THE GROUNDFISH MANAGEMENT PLAN**

New England's Experience

- Failure of Several Groundfish Stocks
- Management Philosophy Changed
(took direct control of fishing effort and mortality)
- Established Large (17,000 km²) Year-Round Closures
Days-at-Sea Reductions (effort reduced by 50%)
Minimum Mesh Sizes Increased
Moratorium on New Vessel Entrants
- Objective: Protect Spawning Stocks of Haddock, Cod, Yellowtail Flounder
Results:
 - Significant Reduction In Exploitation Rate
 - Increased Spawning Biomass (GB haddock, Yellowtail Flounder, Cod)
 - Harvestable Biomass of Scallops Increased by 15X Inside Closures
 - Increased diversity, biomass, numbers of benthic fauna
(will take 5-10 yrs for benthic communities to recover)
 - Year-round protection of Shallow-water Sedentary Assemblage on Bank/Shelf
(yellowtail, winter, and windowpane flounder, winter and little skate, etc.)
 - Protected Important Nursery Areas for Juvenile Cod and Haddock (HAPC)
(increased no. of recruits per unit spawning biomass)



8/1/2014



ENVIRONMENTAL DEFENSE

finding the ways that work

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Jim Lone
Chair, Pacific Fishery Management Council
2130 SW Fifth Avenue, Suite 224
Portland, OR 97201

RE: MARINE RESERVES

Dear Jim:

There have been some exciting developments in marine reserve science that I wanted to share with you, as the Council considers whether to move forward with establishing marine reserves. These comments may also be germane to your upcoming discussion on harvest policy. I've also attached my report on the fishery enhancement potential of marine reserves for your perusal. **All of these results and materials support the conclusion that the PFMC should establish reserves to: (1) meet the mandate of the Magnuson-Stevens Act to take into account the protection of marine ecosystems (Sec. 104-297(28); (2) to help rebuild depleted fish populations; (3) to hedge against management errors; and (4) to learn about the impacts of fishing on habitat.**

1. There are now over 500 scientific studies on marine reserves. A comprehensive literature review by scientists at the University of California at Santa Barbara of the best of these indicates that the vast majority of studies looking at the response of marine organisms to marine reserves show the "marine reserve effect": higher populations levels, larger sizes, and higher reproductive capacity than in comparable habitats that are fished.
2. A recent study of a 40 square kilometer marine reserve near the Kennedy Space Center in Florida shows the marine reserve effect and also demonstrates that fish move out of the reserve to be captured in adjacent fishing grounds (D.R. Johnson, N.A. Funicelli, and J.A. Bohnsack, 1999. North Am. J. Fisheries Management. Effectiveness of an existing estuarine no-take fish sanctuary within the Kennedy Space Center, Florida).
3. A recent evaluation of large closed areas on Georges Bank, off New England, shows that such large closed areas (totaling 17,000 square kilometers) can rebuild populations *and* increase yield significantly outside their borders. Scallop biomass increased 14-fold within the closed areas in 4 years, and densities have increased significantly near the closed areas. The closed areas have proven to be far more effective than other management tools for increasing yield per recruit and in damping year-to-year variation in catch. The closed areas have also been a significant factor in increasing the abundance of haddock and yellowtail flounder. (Murawski, S.A., R.

Brown, H.L. Lai, P.J. Rago, and L. Hendrickson, 1999. Large scale closed areas as a fishery management tool in temperate marine systems: the Georges Bank experience. 1998 Mote International Symposium on Essential Fish Habitat and Marine Reserves).

4. Independent studies in Australia and in the Caribbean Sea indicate that the larvae of at least some reef fish species are not distributed by currents; unexpectedly large proportions of the larvae recruited back to the reefs where they were spawned. (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* 402:799-802; Jones, G.P., M.J. Millcich, M.J. Emslie, and C. Lunow, 1999. Self-recruitment in a coral reef fish population. *Nature* 402:802-804). This finding suggests that marine reserves may not have to be very large to sustain themselves. This may explain why so many marine reserves are effective, even though they are not sited very carefully. In addition, the results imply that nearly any good habitat might be considered a "source" area, making the problem of choosing reserve sites that might act as sources and sinks much easier.

My report simply summarizes similar research, all of which points to the same conclusion: marine reserves can definitely rebuild depleted fish and shellfish populations within their borders, sometimes quite quickly, and reproductive capacity increases disproportionately for fish in marine reserves because of the exponential relationship between fish size and fecundity. For example, while rockfish biomass doubled or quadrupled in west coast marine reserves, egg production increased 20-50 fold. Similarly, a fish protected in a marine reserve would yield a disproportionate number of eggs and potential recruits relative to a fish protected by a fishing rate reduction, because the fish in the marine reserve would be allowed to mature to a larger size.

Heritage reserves for protecting patches of biodiversity and habitat can be quite small. Reserves for rebuilding fished populations to significant levels and for enhancing fisheries will probably need to be much larger. I believe the Georges Bank closed areas comprise about 25% of the Bank.

Closed areas and marine reserves can be viewed as just another way to control fishing mortality. However, these tools offer several advantages over conventional harvest policies:

1. Marine reserves are more reliable than harvest policies. Fishing rate is hard to control, and total mortality is even harder to control because of undocumented discards. Marine reserves are relatively easy to enforce with aerial surveys and/or satellite-based vessel monitoring (as in the case of the Georges Bank closed areas).
2. Marine reserves provide a large disproportionate enhancement of egg and larvae production relative to harvest policies.
3. Marine reserves could provide a high quality sport-fishing experience near their borders, due to spillover of very large adult fish.

4. Unassessed species and bycatch species could be protected in marine reserves, hedging against uncertainty in discard rates and capacity to withstand exploitation.
5. The evidence for marine reserve effectiveness is now just as strong, or stronger, than the evidence indicating that conventional harvest policies without reserves can attain fishery management objectives.

Marine reserves are not a panacea. They will work best in combination with capacity reduction (to reduce or eliminate displacement of effort from the marine reserves to other fishing grounds), a sound harvest policy (that uses marine reserves as a buffer and complementary way to protect spawning stock biomass), bycatch minimization measures, etc. I strongly recommend that you give them a try.

Sincerely,

Rod

Rodney M. Fujita, Ph.D
Marine Ecologist

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THE FISHERIES ENHANCEMENT POTENTIAL OF MARINE RESERVES

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Environmental Defense Fund

October, 1999

Abstract

Do marine reserves enhance fishery yields outside their borders? There is good reason to believe that they do. There is strong evidence from both temperate and tropical waters, including areas off California, Washington, and British Columbia (Canada) that fish populations increase in abundance (by factors of 2 to 13), size, and reproductive capacity (by factors of 20 to 55) in marine reserves, in which fishing is banned. Species that respond well to marine reserve management include lingcod and rockfish. Fewer studies of the effects of marine reserves on catches are available. Of the 8 field studies we reviewed, catches increased significantly near marine reserves in 5 of them. Compliance with reserve regulations was relatively poor in one marine reserve that did not enhance catches; another had degraded habitat. The third reserve that did not enhance catches did increase catch-per-unit effort outside the reserve after 2 years of protection; total catch may increase over baseline levels with time. These results are consistent with the results of modeling studies, which project that marine reserves will increase fishery yields and accelerate rebuilding of depleted populations. Recommendations for reserve size range from 10% to 25% of the fished area.

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Introduction

All along the Pacific coast of the United States, people take pride in the beauty and bounty of their ocean. Fishing, both commercial and recreational, plays a particularly important role in the interactions between West Coast communities and their marine resources. Overfishing, habitat degradation, and pollution, however, threaten the populations that sustain Pacific coast fisheries. In an analysis of forty years (1947-1986) of fisheries activity in California, Dugan and Davis (1993) identify a 64% decline in landings for 9 of the 12 nearshore taxa important in fishing (these taxa include mainly species of rockfish). Currently, 3 species of groundfish appear to experience overfishing. The populations of two of these species, lingcod (*Ophiodon elongatus*) and bocaccio (*Sebastes paucispinis*), fall below 10% of their unfished levels, despite traditional management programs such as fleet reductions, catch limits, seasonal restrictions, and quota plans (Ralston, 1998).

Traditional regulatory plans have failed to protect fish populations adequately because these plans do not hedge against economic, ecological, and climatic variation. Furthermore, these regulatory programs rely on stock assessments made uncertain by the use of incomplete population data, conflicting indices of relative abundance, and simplifications necessarily made in modeling (Fujita *et al.*, 1998; Fujita *et al.*, 1997). In addition, conventional fishery regulations do not always protect the age structure of fish populations, and hence may reduce reproductive capacity, since reproductive capacity usually increases exponentially with age and/or size (Fujita *et al.*, 1997; Dugan and Davis, 1993). Mean body size and/or age has been declining for many exploited Pacific fish populations (Ralston, 1998). The Pacific coast thus requires new management tools to hedge against uncertainty, to protect and rebuild age structure and reproductive capacity, and to ensure sustainable populations and harvests in the future.

Marine reserves, a new tool based on traditional management principles, promise to hedge against uncertainty and environmental variation and to protect age structure and reproductive capacity better than traditional management techniques. Rather than set aside stock by regulating fishing mortality, managers may set aside stock by establishing a marine reserve, which is an area closed to fishing. A large body of modeling studies, empirical data, and anecdotal evidence describes increased abundance, average size, and reproductive capacity within reserves (See Tables 1 and 2). Potential ancillary benefits of reserves include protection of bycatch species which are not understood well, prevention of serial depletion of low-productivity species, and increased understanding of the natural limits of marine ecosystems (Fujita *et al.*, 1998; Dugan and Davis, 1993).

Table 1. A summary of modeling studies of the effects of marine reserves on fisheries adjacent to the reserves.

Larval Export Studies

Taxa/area	Reference	Results
Red hind, white grunt, spiny lobster	Sladek Nowlis (1999)	For red hind and white grunt, reserves produce few short-term costs beyond those of other management tools; reserves generate greatest stable catch.
Not specified	Hastings and Botsford (1999)	Reserve management, traditional management, and reserve + traditional management all produces the same maximum sustainable yield.
Not specified	Sladek Nowlis and Roberts (1999)	Reserves enhance productivity, especially in heavily fished areas, and reserves reduce annual catch variation.
Red snapper, from Gulf of Mexico	Holland and Brazee (1996)	Establishment of a reserve increases present value of cumulative harvest from 3.6% to 8%.
Coral reef fish	Man <i>et al.</i> (1995)	Fisheries with intense fishing activity benefit most from reserves.
Red snapper, from Gulf of Mexico	Bohnsack (1990)	Total egg production within the fishery increases by 1200% with the establishment of a reserve.

Adult Emigration Studies

Taxa/area	Reference	Results
Tropical Pacific reef fish	DeMartini (1993)	Gains in spawning stock biomass per recruit outweigh losses in yield per recruit.
Not specified	Polacheck (1990)	Spawning stock biomass increase in all models, each with different reserve size and transfer rates.

Larval Export and Adult Emigration Studies

Taxa/area	Reference	Result
Pacific Ocean Perch	Foran and Fujita (1999)	Reserve policies produce egg and catch outputs greater than or equal to fixed rate policies, regardless of good or bad recruitment.

Table 2. A summary of empirical studies of the effects of marine reserves on populations within the reserves.

Taxa / area	Reference	Reserve size	Effects
Coral reef fish			
Australia	Rigney (1990)	Not listed	Abundance of legal-size and juvenile coral trout 2x greater in reserve.
Florida	Clark <i>et al.</i> (1989)	Not listed	93% increase in snapper abundance and 439% increase in grunt abundance in reserve.
New Caledonia	Bohnsack (1982) Wantiez <i>et al.</i> (1997)	Not listed	Densities higher in reserve. 67% increase in species richness, 160% increase in density, and 246% increase in biomass in reserve.
Philippines	Russ and Alcala (1996b)	0.75 km (Sumilon) 0.45 km (Apo)	Sumilon: Density decreased significantly when reserve reopened to fishing. Density increased 300% in the 5 years after reclosure. Apo: Density increased 6 years after reserve created.
Temperate reef fish			
California	Paddack (1996)	6.8 km ² (Big Creek)	No difference in rockfish size in reserve (but reserve less than 4 years old).
	Paddack (1996)	1.4 km ² (Hopkins Marine)	Larger and more abundant rockfish in reserve.
	Paddack (1996)	1.25 km ² (Point Lobos)	Larger and more abundant rockfish in reserve.
Mediterranean	Francour (1997)	0.72 km ²	Number of spp nearly 2x higher in reserve; abundance and biomass 5x greater in reserve.
	Bell (1983)	7 km ²	Overall density of 18 target spp 2x higher in reserve.

Table 2 (cont). A summary of empirical studies of the effects of marine reserves on populations within the reserves.

Taxa/area	Reference	Reserve size	Effects
Temperate reef fish			
New Zealand	Cole <i>et al.</i> (1990)	Not listed	Increase in abundance for some species (snapper, blue cod and red moki) in reserve; increased size of snapper in reserve.
	McCormick and Choat (1987)	5 km ²	62% of individuals larger than 300mm in reserve, compared to 38% in fished area.
South Africa	Buxton and Smale (1989)	300 km ²	Abundance of 2 of 3 spp studied 4x and 13x higher in reserve.
Vancouver	Martell, 1998	<1 km ² (Porteau)	Greater lingcod spawning in reserve.
	Martell, 1998	<1 km ² (Whytecliff)	Above average lingcod spawning in reserve.
Washington	Palsson and Pacunski (1995)	<2 km ² (Edmunds)	Larger coppers, quillbacks, and lingcod in reserve.
	Palsson and Pacunski (1995)	<2 km ² (Shady Cove)	Number of spp almost 2x higher in reserve; number of lingcod and lingcod nests nearly 3x higher in reserve.
Lobster			
Florida	Davis (1977)	95 km ² (29 mos)	Abundance declined 60% upon reopening of reserve.
New Zealand	Cole <i>et al.</i> (1990)	Not listed	Increased abundance in reserve.
Conch			
Venezuela	Weil and Laughlin (1984)	4 km ²	Individuals 12% larger on average in reserve.
Abalone			
California	Tegner <i>et al.</i> (1992)	Not listed	Pink and green abalone did not respond after 10 years of protection, but green abalone juvenile abundance increased after managers placed adult transplants in reserves.

In addition, modeling studies and empirical and anecdotal evidence strongly suggest that reserves can enhance fishing yields outside reserve limits (See Tables 1 and 3). First, reserves allow fish to grow to full reproductive potential, thereby increasing spawning biomass (Fujita *et al.*, 1998; Dugan and Davis, 1993). For example, one blue rockfish (*Sebastes mystinus*) that is 25 cm long produces 50,000 eggs, while one blue rockfish that is 32.5 cm long produces 300,00 eggs (6 times more). The exponential increase in fecundity with larger size is particularly striking for Pacific ocean perch (*Sebastes alutus*). One female that is 23 cm long generates 10,000 eggs, while one that is 45 cm long generates 300,000 eggs (30 times more) (Casillas, *et al.*, 1998). Given the low natural mortality of rockfish, a reserve that allows fish to mature fully will enhance stocks for many years (Fujita *et al.*, 1998; Dugan and Davis, 1993).

The greater reproduction, growth, and survival within the reserve have the potential to enhance catches outside the reserve by transport of larvae via currents and by emigration of adult and juvenile fish (Rowley, 1994; Carr and Reed, 1993; DeMartini, 1993; Alcala and Russ, 1990; Polacheck, 1990). Rockfish larvae remain in the water column for about 18 months, thereby allowing dispersal from a reserve to adjacent fishing waters. For example, young Pacific Ocean perch (POP) are generally distributed between 360 meters and 400 meters, while young bocaccio are distributed at about 100 meters, and move up to 2 kilometers a day (Casillas, *et al.*, 1998). While adult emigration can also contribute to increased stocks outside reserves, larval transport would likely play the primary role in fisheries enhancement for rockfish, given their sedentary adult lifestyle (Fujita *et al.*, 1998; Dugan and Davis, 1993).

Table 3. A summary of empirical studies of the effects of marine reserves on fisheries adjacent to the reserves.

Taxa / area	Reference	Reserve size	Effects
Coral reef fish			
Caribbean	Polunin and Roberts (1993)	Not listed	Saba and Hol Chan Reserves: Greater abundance, size, or biomass
Kenya	McClanahan and Kaunda-Arara (1996)	10 km ²	110% increase in catch per unit effort after 2 years of protection, although 35% decrease in total fish landed.
Philippines	Russ and Alcala (1996a)	0.45 km (Apo)	Significant positive correlation for mean density with duration of protection, and for species richness with duration of protection. Fishers reported increased catches.
	Alcala and Russ (1990)	0.75 km (Sumilon)	Catches 54% higher while reserve intact, compared to 1 year after reserve reopened.
Surf fish			
South Africa	Bennett and Attwood (1991)		Within 2 years of protection, catch rates of 2 spp increased 4-5x, reaching unexploited levels. Catch rates of 4 other spp approached 30-60% of unexploited levels 2.5-4.5 years after protection.
Shrimp			
California	Schlining (1999)	Not listed	Median catch per unit effort close to reserve significantly greater than median catch per unit effort far from reserve ($p < 0.043$).
Gulf of Mexico	Klima et al. (1986)	Not listed	No increase in yield, but compliance by fishers only 65%.
Crab			
Japan	Yamasaki and Kuwahara (1989)	13.7 km ²	46% increase in catch per unit effort in areas adjacent to reserve after 5 th year of protection.
Trochus			
Palau	Heslinga et al. (1984)	Not listed	No improvement after 20 yrs (perhaps due to degraded habitat within reserve).

The modeling studies and empirical and anecdotal evidence of the potential for reserves to enhance fisheries cover a variety of marine taxa (Tables 1-3). The following discussion highlights some of the more widely known investigations, with a focus on coral and temperate reef fish. The number of studies on temperate reef fish is low compared to the number of studies on coral reef fish. Managers of Pacific coast fisheries will find the coral reef research germane, however, because some coral reef fish, such as snapper (lutjanids) and grouper (serranids), share with rockfish the characteristics of slow growth, an exponential relationship between size and fecundity, a prolonged pelagic larval stage, low natural mortality, and a sedentary adult lifestyle (Casillas *et al.*, 1998; Anderson, 1987; Leis, 1987; Manooch, 1987). These lifestyle traits make both coral reef fish and rockfish good candidates for marine reserves, as mentioned above (Fujita *et al.*, 1998; Polunin and Roberts, 1993; Dugan and Davis, 1993).

Modeling Studies

Larval Export

Modeling studies of a variety of fish species indicate that reserves would enhance fisheries adjacent to reserves through larval export (Table 1). In a model of a red snapper fishery, Holland and Brazee (1996) find that a reserve would raise the present value of cumulative harvests from 3.6% to 8%, compared to management with no reserve. Under an intense fishing scenario, a reserve that covers 29% of a fishery would rebuild catches to 75% of maximum sustainable yield, while management without a reserve would result in a fishery collapse (Holland and Brazee, 1996). Holland and Brazee also state that annual harvests would fall by 10-14% with the closing of 20% of fishery, but that the fishery would recover in 6-9 years. In another red snapper model, Bohnsack (1990) concludes that reserves guarantee that total abundance and fecundity would be at least 20% of what would occur in if the snapper population never entered a fishery. Bohnsack also describes a 1200% increase in total egg production within the fishery after the establishment of a reserve that covers 20% of the fishery.

In a recent model of larval export, Hastings and Botsford (1999) report that reserve management, traditional management, or a combination of the two, each generates the same maximum sustainable yield. This finding, however, rests upon two simplifying assumptions that may underestimate the benefits of marine reserves. First, Hastings and Botsford assume that larval distribution is so broad that the density of settling juveniles is independent of location. Second, they assume that overall density dependence occurs only at the time of settlement. Yet, actual juvenile settlement, as well as adult distribution, may depend on habitat quality. If managers create a reserve in an area with quality habitat, they may protect a greater number of juveniles and adults, and therefore better enhance productivity, than if they practiced conventional management techniques.

In another recent model, Sladek Nowlis and Roberts (1999) investigate the response of queen trigger fish (*Balistes vetula*), red hind (*Epinephelus guttatus*), white grunt (*Haemulon plumieri*), and spiny lobster (*Panulirus penicillatus*) to reserves. They conclude that reserves enhance productivity, especially in heavily fished areas. They also

find that reserves reduce annual catch variation, thereby promising to simplify management and improve fish abundance projections (Sladek Nowlis and Roberts, 1999).

In a related study, Sladek Nowlis (1999) compares the effect of different management techniques in a model of red hind, white grunt, and spiny lobster fisheries. He concludes that for the red hind and white grunt, which mature prior to entering the fishery, reserves produce few short-term costs beyond those created by temporary closures or size limits, and that reserves generate the highest stable catch levels. For the spiny lobster, which enters the fishery while still immature, minimum size limits best aid the fishery (Sladek Nowlis and Roberts, 1999). These results indicate that reserves, while perhaps not ideal for species caught before they reach maturity, can improve fisheries for species caught primarily as adults.

Adult Emigration

Models of adult emigration from reserves to fisheries also suggest the potential of reserves to improve fishery productivity. In a 1993 study, DeMartini examines the effects of permanently closed reserves of different sizes on net changes in spawning stock biomass (SSB) and catches for several tropical Pacific reef fish. The model describes a positive association between SSB per recruit and reserve size, particularly at lower rates of adult emigration. A negative association exists, however, between fishery yield per recruit and reserve size, although the progressive gains in SSB per recruit outweigh the progressive losses in yield per recruit with increasing reserve size (DeMartini, 1993). In addition, Polacheck's (1990) model of coral reef fish suggests that reserves improve catches by 8-20%.

Pacific Ocean Perch Case Study

In a case study of Pacific ocean perch (POP) that considers both larval export and adult emigration, Foran and Fujita (1999) report that reserve management techniques produce egg and catch outputs greater than or equal to traditional management policies, regardless of good or bad recruitment. POP, with its low natural mortality rate, sedentary lifestyle, and currently depleted population, is representative of many Pacific coast rockfish. Foran and Fujita state that if managers place 25% of suitable POP habitat in reserve, with a fishing mortality rate of 0.04 outside the reserve, then egg output would rebuild to 14% of its unfished level in 10 years. Furthermore, under the same reserve regime, with an optimistic assumption of recruitment, a fishing mortality rate of 0.12 maximizes yields at 2200 metric tons per year. With a pessimistic assumption of recruitment, a mortality rate of 0.05 generates a maximum yield of 600 metric tons (Foran and Fujita, 1999).

Empirical Evidence

Studies of fish populations within reserves

Empirical evidence strongly suggests that marine reserves increase stocks within their borders by decreasing fishing mortality, bycatch, and habitat disturbance (Dugan and

Davis, 1993). One group of studies examines fish populations only within reserves (Table 2), while another group also investigates the effects of reserves on yields in adjacent fisheries (Table 3). Also, tagging studies of lobster (Davis and Dodrill, 1980; 1989), snow crab (Yamasaki and Kuwahara, 1989), and reef fish (Davies, 1995; Attwood and Bennet, 1994; Beinssen, 1989; Bryant *et al.*, 1989; Rutherford *et al.*, 1989) show that target species do indeed move from reserves to fished areas.

Many of the studies that evaluate populations within reserves describe more robust numbers within protected waters. For instance, in one of the first studies of a reserve's effect on targeted populations, Davis (1977) compares lobster abundance in the waters around the Dry Tortugas, Florida, before and after the reopening to fishing of a 29-month-old, 95 km² reserve. He reports a 60% decline in abundance after the reserve reopened to fishing, as well as catch rates 22% below preharvest levels even 1 year after reclosure of the reserve. These results indicate the rapidity with which fisheries can impact targeted species, especially those with sedentary, nearshore lifestyles (Dugan and Davis, 1993; Davis, 1977). In another Florida study, both Bohnsack (1990) and Clark *et al.* (1989) report significant increases in abundance and density for 15 target species (lutjanids (snapper), serranids (grouper), and haemulids) just two years after the Looe Key National Marine Sanctuary closed to spearfishing.

A study of lutjanids (snapper), serranids (grouper), lethrinids, and carangids before and after the reopening of a reserve in the Philippines also indicates that reserves protect stock biomass. Russ and Alcala (1996b) report significant decreases in density when the Sumilon reserve (25% of the Sumilon reef) reopened to fishing in 1985. They also cite a 300% density increase in the five years following reclosure (1987-1991). Density declined again when the reserve broke down in 1993. Density also increased in the Apo reserve (10% of the Apo reef) 6 years after its creation (Russ and Alcala, 1996b).

In a study of snapper, grouper, and other coral reef fish, Wantiez *et al.* (1997) reported a 160% increase in density, as well as a 67% increase in species richness and a 246% increase in biomass, after 5 years of protection in a New Caledonia reserve. Polunin and Roberts (1993) examined the response of 25 demersal species such as snappers, groupers, and grunts to the creation of two small reserves in the Caribbean. They reported greater abundance, size, or biomass in 59% of targeted species within the Saba reserve in the Netherlands Antilles, with similar increases in 45% of targeted species in the Hol Chan reserve in Belize (Polunin and Roberts, 1993).

The same trends occur in temperate water reserves. Cole *et al.* (1990) examined temperate reef fish populations inside and outside the Leigh Marine Reserve in northeastern New Zealand. They cited higher abundance for some, but not all species, in the reserve. Some of the species that responded favorably to protection were rock lobster (*Jasus auratus*), red moki (*Cheilodactylus spectabilis*), blue cod (*Parapercis colias*), and snapper (Lutjanidae). Snapper were also larger inside the reserve (Cole *et al.*, 1990).

Other studies of temperate reef fish also indicate increases in abundance within reserves. Francour (1997) describes 5 times the abundance and biomass inside a 0.72

km² reserve in Corsica, and McCormick and Choat (1987) report 2.3 times the total abundance inside a 5 km² reserve in New Zealand. Also, Bell (1983) reports overall densities of 18 targeted species to be 2 times higher inside a 7 km² Mediterranean reserve.

Studies that focus on rockfish populations within the Pacific coast's eight no-take reserves also confirm the efficacy of marine protected areas. Porteau Provincial Park, Vancouver, boasts greater lingcod spawning after 10 years of protection (Martell, 1998). Whytecliff Park, Vancouver, also enjoys above average lingcod spawning after 4 years as a reserve. Both Porteau and Whytecliff are less than 1 km², indicating that protection of proper habitat can yield great benefits (Martell, 1998). In the Shady Cove reserve in the San Juan Islands, Washington, total fish numbers are almost 2 times higher, and the number of lingcod and lingcod nests are nearly 3 times higher after 7 years of protection (Palsson and Pacunski, 1995). Palsson and Pacunski also report larger coppers, quillbacks, and lingcod at the 27-year-old Edmunds Underwater Park in Puget Sound, Washington. Both Shady Cove and Edmunds protect less than 2 km² of habitat (Palsson and Pacunski, 1995).

At Hopkins Marine Reserve, Monterey, California, a 1.44 km² area closed 13 years to fishing, houses larger and more abundant rockfish (Paddack, 1996). Paddack reports similar results for Point Lobos Reserve, Carmel, California, which is 1.25 km² and 37 years old. Only Big Creek Reserve in Big Sur, California, does not show significant differences in size or abundance of rockfish. This 6.75 km² reserve, however, is adjacent to relatively lightly fished waters that may house stable fish populations. Also, Big Creek is a young reserve, and longer protection time may allow populations inside the reserve to grow in size and number (Paddack, 1996).

In southern California, red sea urchin density is higher at the Anacapa Island reserve than elsewhere in the Channel Islands National Park (Davis, pers. comm.). In a study of abalone in the Channel Islands area, Tegner (1992) reports that while pink (*Haliotis corrugata*) and green (*H. fulgens*) abalone did not respond to 10 years of protection, the green abalone quickly increased in juvenile abundance once managers placed mature adult transplants in protected areas. Abalone larvae disperse minimally, and Tegner suggests that this lack of mobility prevented recovery throughout reserve waters prior to the introduction of fecund adults. Protection, however, allowed the newly added adults and their offspring to repopulate the Channel Islands waters (Tegner *et al.*, 1992).

Studies of fisheries enhancement

Because fish abundance and reproductive capacity generally increase significantly within reserves, it would follow logically that adult, juvenile, and larval export to fishing grounds should be relatively high, unless the reserves were sited very poorly for this purpose. Research on the fisheries enhancement potential of reserves indicates that reserves can indeed improve yields in waters close to reserves. In one of the first studies of this kind, Alcala and Russ (1990) compared catches of lutjanids (snappers), serranids (groupers), lethrinids, and carangids in a coral reef fishery off of Sumilon Island, Philippines, before and after the reopening of a 10-year-old reserve. They found that

catches were 54% higher in waters near the reserve while the reserve was intact, compared to the year after the reserve reopened to fishing (Alcala and Russ, 1990). In a study of the Apo Island reserve, Russ and Alcala (1996a) reported significant positive correlation of mean density with duration of protection, and of species richness with duration of protection ($r^2 = 0.91$, $p = 0.0009$; $r^2 = 0.81$, $p = 0.006$, respectively). Furthermore, fishers unanimously reported higher yields in adjacent waters (Russ and Alcala, 1996a).

In an analysis of a Kenyan fishery of snappers, parrotfish, and rabbitfish, McClanahan and Kaunda-Arara (1996) compared catch per unit effort (CPUE) before the creation of a 10 km² reserve to CPUE two years later. They reported a 110% increase in CPUE in areas adjacent to the reserve. Total catches, however, declined by 35%, although perhaps total catch would have risen given more time. Also, the reserve's low edge to park area ratio may have hindered adult emigration and therefore limited improvements in productivity (McClanahan and Kaunda-Arara, 1996).

Bennett and Attwood (1991) reported sustained increases in CPUE for 6 of 10 targeted surf fish species near a reserve that covers 46 km of coastline in South Africa. These 6 species represented 97% of total catch (galjoen, *Coracinus capensis*; dassie, *Diplodus sargus*; wildeperd, *D. cervinus*; white steenbras, *Lithognathus lithognathus*; Cape stumpnose, *Rhabdosargus holubi*; and musselcracker, *Sparodon durbanensis*). During the 2 years after the creation of the reserve, catch rates for galjoen and dassie increased 4-5 fold from the level prior to the reserve's establishment. These rates approximated rates common early in the fishery's history. Within 2.5-4.5 years after reserve creation, catch rates for the other 4 species approached 30%-60% of the levels typical for the fishery in its infancy (Bennett and Attwood, 1991).

In a recent study of California spot prawns, Schlining (1999) compared catch per unit effort inside, close to, and far from the Carmel Bay Ecological Reserve. For purposes of the study, reserve managers permitted placement of traps within the reserve for a short time. Using this reserve catch data, along with data from the relatively intense fishery near the reserve, Schlining found that median CPUE within the reserve was significantly greater than median CPUE close to the reserve ($p < 0.012$). Also, median CPUE (kg per trap) for areas 0.5-2.0 km from the reserve was significantly greater than median CPUE for areas 6.5-9.0 km from the reserve ($p < 0.043$).

To our knowledge, no empirical studies of the impact of reserves on temperate reef fisheries have been published, although several investigations that cover Washington and California waters are in progress. Although coral reef studies suggest that reserves will enhance fisheries, managers of temperate reef fisheries should note that some coral reef fish, such as some of those in the Philippines studies, are more mobile than rockfish (Alcala and Russ, 1990). Adult emigration rates may therefore differ for temperate reef fish, thereby limiting reserves' fishery enhancement effect through adult emigration. With respect to fisheries enhancement, larval export is likely to be much more significant than adult emigration in most cases.

Larval tracking and genetic analysis would help managers to understand the effects of reserves on Pacific coast fisheries (Dugan and Davis, 1993). Palsson (1998) suggests that to monitor the response of rockfish fisheries to reserves, researchers should compare abundance, size, and yield inside and outside reserve waters both before and after the creation of reserves. Palsson also recommends that measurements take place within fixed transects that span an entire ecosystem, in order to minimize variability due to microhabitat differences.

Conclusion

Modeling, empirical, and anecdotal evidence all indicate that marine reserves can help rebuild depleted populations within their borders, and improve fishing yields outside their borders. Unfortunately, a lack of temperate fisheries enhancement studies, along with environmental variability, limit accurate predictions of the impact of reserves on rockfish fisheries. The uncertainty that accompanies reserve management, however, is probably less than the uncertainty associated with conventional management techniques. Reserves therefore offer Pacific coast fisheries a relatively reliable tool with which to rebuild stocks, especially given the sedentary lifestyle of long-lived rockfish (Fujita *et al.*, 1998; Fujita *et al.*, 1997; Dugan and Davis, 1993).

Ballantine (1991) recommends placing 10% of a fished area in reserve, while Bohnsack (1990) suggests closing 20% of a fished region. Holland and Brazee (1996) recommend that reserves cover 15-19% of an area when fishing is intense. A dense network of reserves would probably protect rockfish best, given these species' limited movement and clustering in semi-isolated populations along the Pacific coast (Gunderson, 1997). A reserve network would quickly release different populations of rockfish from fishing pressure. A network would therefore conserve a reliable rockfish stock while managers refine policies designed to strengthen west coast fisheries.

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RE: AGENDA ITEM E1: Marine Reserves

Dear Chairman Lone and Other Members of the Council:

On behalf of the Center for Marine Conservation, I thank you for the opportunity to comment on the use of marine reserves as a federal fishery management tool. I hope the Council will consider the view of CMC and our members in deciding whether to pursue marine reserves as a management tool. My views also represent nearly 10 years of experience performing science on marine reserves, mostly in the academic environment, and I hope that by sharing some of my technical experience I can help the Council make progress on this issue.

Reserves are often misunderstood. Some advocates of reserves oversell their benefits without revealing their limitations, while some opponents dismiss their proven benefits and hold them to higher standards than we do any other management tool. I hope this letter can help to clarify what is fact and what is fiction about marine reserves.

Closed area management has been time-tested and as well studied as any management tool, with real-world experiments and theory dating back decades. When closed areas have been established and studied, the response of the natural environment has been remarkably consistent. With almost no exceptions, closed areas have resulted in increases in the abundance, size, and diversity of exploited species within the reserve. Dozens of studies have demonstrated these responses from all around the world, including several examples along the west coast.

Few studies have examined the responses of the natural environment outside of reserves. The few existing studies do show increases, although common sense and theory suggest that we shouldn't expect these increases under all circumstances. Key elements of the theory to note are that increased *catches* are only likely to result when three conditions are met: (1) adults stay within reserve boundaries, (2) their offspring disperse to fishing areas (two conditions that are achievable for most rockfish species), and (3) the stock would experience overfishing if it were not for the protection of the reserve. The third condition is particularly important from a management perspective, because the same theory demonstrates that the need for larger reserves is highly dependent on the rest of the management plan. If fishing is carefully controlled using other tools, reserves are less necessary to achieve maximum catches.

The scientific findings about marine reserves have important implications for fisheries and conservation management. Reserves are a proven rebuilding tool, and theory suggests that a reserve designed to keep adults in but allow their offspring to repopulate surrounding fishing grounds will rebuild stocks more efficiently than other tools. In particular, they can achieve rebuilding targets more quickly and with less short-term sacrifice than other management tools under many circumstances. Marine reserves have also been shown to be effective at providing management insurance. By keeping viable populations safe from inadvertent overfishing, they provide a buffer against management mistakes for studied species and an even more vital protection for the many species we categorize as unknown. By protecting viable populations, reserves can also maintain desirable stock characteristics, including a more natural size

structure and range of genetic diversity. While reserves won't necessarily reduce the overall rates of bycatch, they can effectively reduce the impacts of bycatch by providing a safety zone for vulnerable or depleted species. Reserves can also protect fish habitat within the reserve areas, although they could increase damage outside of reserves so that the overall impacts on habitat are uncertain. Finally, by serving as natural control areas, reserves can provide vital information to fishery managers. Among other information, reserves can help us learn about the habitat impacts of fishing and provide improved estimates of key fishery parameters, such as the natural mortality rate, that are fundamental to stock assessments yet virtually impossible to measure without reserves.

Reserves do have disadvantages. Like any tool designed to allow rebuilding, reserves will exact a temporary loss of catch opportunities. Moreover, reserves do not address every problem. For example, if a species is regularly caught prior to reaching maturity, the best tool to address this problem is one that ensures fish will grow larger prior to being caught, such as gear restrictions or size limits. Most significantly, reserves have the disadvantage that certain fishing communities will suffer the disadvantages more than others, so managers have a difficult task of establishing a fair system. Despite these disadvantages, reserves do manage to address a surprisingly wide range of management challenges with a high degree of effectiveness.

Perhaps the most significant fiction suggested about marine reserves is that they are an experimental and unproven management tool. Studies have shown time and again that reserves do allow stocks to flourish within the reserve borders. Though very limited documentation exists to show that these changes ultimately result in enhanced fish catches, other management tools are equally unproven. For example, even though we regularly change quotas or adopt size limits, we do so without proof that these measures will ultimately increase fish catches. For these other tools, we are usually willing to accept their success based on the logic that they will increase the number or size of fish of interest, and that these changes are ultimately helpful to the fishery.

The key question for the Council at this juncture is whether or not marine reserves are a valuable tool to utilize for west coast fishery management. Reserves are effective rebuilding tools and the Council is facing a situation where five of the eighteen known groundfish species will be under rebuilding plans by the end of this year. Reserves can play a crucial role in these plans. Reserves are also a valuable tool to buffer against uncertainty. The Council manages 82 groundfish species, yet 64 remain of unknown status. Even for the species that are categorized as known, all are managed using proxies because there are substantial uncertainties about their productivity. Reserves can play a crucial role in providing a buffer against this large amount of uncertainty. Reserves are also an effective tool at reducing the impacts of bycatch, particularly for vulnerable or depleted species. Given the overfished and multispecies nature of the groundfish fishery, reserves can play a crucial role in reducing these impacts. Finally, reserves provide an opportunity to learn crucial fishery parameters by providing control areas. Given the gaps in our knowledge about the groundfish stocks and fishing impacts on the west coast, reserves can play a crucial role in improving our overall management efforts by filling some of these gaps. In sum, reserves are an extremely valuable tool to address many of the challenges the Council currently faces.

I hope these comments help to clarify some of the confusion about this subject, and would be happy to answer any questions or respond to any comments.

Sincerely,



Joshua Sladek Nowlis
Senior Scientist, Fish and Ecosystems



Mark Powell
Pacific Fisheries Manager

AD-HOC MARINE RESERVE COMMITTEE REPORT ON
MARINE RESERVES

The Ad-Hoc Marine Reserve Committee (Committee) met April 4, 2000 and received a summary presentation of the preliminary draft technical analysis for Phase I. The Committee believes the analysis is generally moving in the right direction and will provide comments to the authors of the document by April 21. The Committee endorses the proposed decision schedule with Council approval of a public review draft in June and a final Phase I decision in September. Another meeting of the Ad-Hoc Marine Reserve Committee will be scheduled prior to the June Council meeting.

PPMC
04/05/00