A Benefit-Cost Perspective on Marine Reserves

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The Benefits And The Costs Of Marine Reserves Are Highly Uncertain, Distributed Unevenly And Dependent Of Reserve Design

1. Marine reserves, in which all extractive activities are prohibited, have been widely promoted as an important marine conservation tool. New Zealand's Minister of Conservation proposes to greatly expand the number marine reserves throughout the New Zealand EEZ including both coastal and offshore sites.
2. The literature on marine reserves provides substantial evidence from both empirical and modelling studies that marine reserves can contribute to protection of marine species and habitat <u>within</u> their boundaries. In some cases this can yield benefits including amenity values associated with enhanced viewing opportunities inside reserves and existence value associated with preservation of threatened species or, more generally, of biodiversity.
3. It has also been shown that, <u>under certain circumstances</u>, marine reserves can increase the benefits derived from marine fisheries. However, no studies show that benefits will accrue to fisheries where catches are already constrained to optimal levels using output controls as is the case for the New Zealand's fisheries managed within the Quota Management System (QMS).
4. A number of studies also identify costs associated with the creation of marine reserves and note that the distribution of costs and benefits is likely to be uneven in most cases. Costs are generally borne by excluded extractive users while benefits accrue to non-extractive users of the reserve and what it protects.
5. The most general conclusion that can be distilled from the plethora of empirical and modelling studies on marine reserves is that the impacts of a marine reserve, both positive and negative, will vary greatly depending on its design and on the physical, biological and socioeconomic characteristics of the environment in which it is imposed. In addition, the biological effects of a given marine reserve will vary across species, and the economic impacts will vary across individuals and groups. This suggests that a generic evaluation of the benefits and costs of marine reserves is unlikely to provide general conclusions regarding the net value of marine reserves. It also suggests that any specific marine reserve may or may not be in the public interest, and that an evaluation of costs and benefits should be undertaken for each specific proposal.
6. We are unaware of any studies that have rigorously compared the benefits and costs of marine reserves in New Zealand, and no such analysis is currently being undertaken for existing or proposed marine reserves in New Zealand. Benefit-cost analysis, of individual marine reserves and the overall system of reserves, is of critical importance. It is critical to ensure that the non-extractive benefits of a system of marine reserves are achieved effectively and efficiently and that marine reserves do not compromise or interfere with other marine management systems already in place.

Benefit-Cost Analysis For Marine Reserves

7. An economic evaluation of a marine reserve must go beyond the identification of various benefits and costs that may result from its creation. As Farrow (1996) notes, "what is important is the process that draws all impacts together in a summary analysis and the delivery of a bottom line result." To do this, benefits and costs must generally be quantified and expressed in monetary terms so that they can be compared.
8. As with many projects and policies, marine reserves are likely to generate costs immediately while benefits may not be realised for some time. This should be explicitly considered when

undertaking a benefit-cost analysis. Standard procedure is to compare the present value of all cost and benefit streams, which requires discounting future costs and benefits by the appropriate discount rate[1]. There is often disagreement about what the appropriate discount rate should be, and there is apparently no standard rate used for public policy evaluation in New Zealand. A report commissioned by the Ministry of Fisheries (Harte et al. 2000) states that "no valid argument exists for zero or very low discount rates" and recommends real discount rates of between 4% and 15% as appropriate for applied fishery models. The report notes that "the predominant consensus in the literature supports the use of discount rates near inflation-adjusted market interest rates (e.g., rates between 4% and 12%)."

9. In general, a benefit-cost analysis should attempt to determine whether the proposed reserve provides greater net benefits that some alternative policy. The basis for comparison might be the status quo or might include alternative policies designed to achieve similar objectives. Quantification and valuation of costs and benefits from a marine reserve is likely to be difficult and imprecise due to uncertainty about the direct and indirect impacts of a reserve and of what would happen in the absence of a reserve. However, the difficulty of this task should not be used as an excuse to avoid it completely.

10. A complete economic evaluation of a marine reserve should also explore the probable distribution of benefits and costs. Even if a marine reserve does have positive net benefits overall, it is likely to disadvantage some individuals and groups. Compensation of losers in some form may be necessary or advisable to ensure the acceptance and success of the marine reserve. Marine reserves perceived as unfairly imposed are likely to require higher compliance costs and may generate political action that will block the creation of a reserve or lead to its failure or repeal. It may also be legally necessary to identify parties who are harmed by the creation of a reserve if the marine reserve significantly reduces the value of existing property rights.

Categories Of Benefits And Costs

11. Although it is not sufficient to simply identify the types of costs and benefits that may result from implementation of a marine reserve, it is useful to categorise these cost and benefits and consider how they might be affected by the physical, biological and socioeconomic environment in which a reserve is imposed. This will help to facilitate and organise the appropriate scientific and economic analysis for a specific marine reserve proposal. The debate over the merits of marine reserves, whether general or with respect to a particular reserve, is often polarised in terms of extractive and non-extractive uses. It is generally argued that appropriately designed reserves will generate net benefits to non-extractive users,[2] while it is the perception of many extractive users of the marine environment (e.g., commercial and recreational fishermen and aquaculturists) that marine reserves will result in a net loss of benefits to them. The two groups need not be mutually exclusive, but categorising costs and benefits in this way best facilitates policy analysis.

12. Non-extractive benefits include both use values and nonuse values. Use values that are non-extractive are primarily amenity values associated with a viewing experience of some sort (e.g., the value of a diving experience inside a marine reserve). Nonuse values are benefits derived without actually experiencing the reserve physically or visually (e.g., someone may derive value in knowing there are wilderness areas even though they have no desire to visit them). Marine reserves may generate nonuse values if they conserve habitat, species or natural features that might be lost in the absence of the reserve. These nonuse values are arguably the primary motivation for increasing the number of marine reserves in New Zealand but are also the most ambiguous and difficult to measure.

13. There may also be costs to non-extractive users. Sanchirico, Cochrane and Emerson (2002) note that non-extractive activities such as diving and snorkelling or anchoring of pleasure

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[1] For example a benefit of $10 a year from now would just offset a cost of $9.51 incurred today assuming a discount rate of 5% [PV=10*exp(-.05)]

[2] This in no way suggests that a poorly designed reserve might not result in a net loss of non-extractive value.

boats may cause damage to habitat reducing the some of the nonuse benefits the marine reserve was meant to provide. The development associated with tourism attracted by a reserve can lead to environmental degradation that may reverse initial conservation benefits. A marine reserve that excludes fishing from a large area may also result in the disappearance of traditional fishing communities which local residents, tourists and the general public may perceive as a loss of value.

14. It is outside the scope of this discussion to estimate the magnitude of non-extractive values or losses of various types that might be generated by a system of reserves in New Zealand, and this would of course depend on the design of that system. Notwithstanding the caveats mentioned above, it is probably fair to say that there may be significant non-extractive benefits that will accrue to the general public and to visitors to some well designed marine reserves. However, the level of benefits and the cost of providing them will depend critically on sound siting and design decisions. Furthermore, many of these benefits might be achieved by restricting some but not all extractive activities in certain areas. For example, it may provide little benefit and add significant cost to prohibit purse seining or pelagic longlining in an offshore area where the motivation for a reserve is protecting benthic habitats and species.

15. It is quite likely that benefits to non-extractive users of marine reserves will be offset by losses to extractive users. In particular, benefits from commercial and recreational fishing and aquaculture are likely to be negatively impacted[3].

16. The potential losses to aquaculture are reasonably strait forward to evaluate. Aquaculture is likely to be prohibited in marine reserves, and it is hard to see how the aquaculture industry will benefit from marine reserves. To date, no proposed marine reserves will exclude existing aquaculture operations. The 1971 Act specifically precludes a marine reserve being declared where there is a marine farm. It is not clear that this protection extends to aquaculture permits under the RMA. If existing aquaculture permits are withdrawn or are not renewed due to siting of a marine reserve, there will be a clear loss equal to the stream of forgone profits from the aquaculture operation. Marine reserves may also be sited in areas that would have been preferred aquaculture sites. While this may not result in a direct loss to particular individuals and companies, it may result in a loss of benefits to New Zealand to the extent that it limits the growth of the aquaculture industry. This may be particularly problematic if a marine reserve is declared next to an existing aquaculture operation. The recently declared Te Matuku Marine Reserve (Waiheke Island) effectively surrounds an existing oyster farm and clearly precludes any additional expansion of that farm or new developments in the bay.

17. Marine reserves are likely to displace recreational fisheries and may result in significant loss of value to recreational fishers. Recreational fisheries provide substantial amenity benefits to users as well as highly valued seafood. A variety of methods can be used to estimate these benefits including stated preference and revealed preference techniques that have been widely applied to recreational fisheries. A study undertaken in New Zealand in 1999 by the South Australian Centre for Economic Studies (SACE) on behalf of the New Zealand Ministry of Fisheries estimated that the value of recreational fishing totals nearly \$220 million annually[4]. Elimination of recreational fishing in areas where marine reserves are sited may also have secondary effects on a variety of support industries including hotels and restaurants, gear retailers, charter operations, etc.

18. Marine reserves have the potential to significantly reduce net benefits for commercial fisheries. This is an increasing concern if large reserves in both inshore and offshore areas are to be created. An extensive review of empirical studies of marine reserves noted that “there are no well-documented examples where marine fishery sanctuaries have been shown to provide and maintain net economic benefits for previously existing fisheries” (Ward et al. 2001).

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[3] Seabed mining or oil and gas exploitation may also be affected by a marine reserve depending on its location, but we will not explore that issue at this time.

[4] SeaFIC does not endorse the veracity or accuracy of these findings and, in fact, there appear to be substantial methodological problems with this study. However, the study does demonstrate clearly that there are large expenditures associated with recreational fishing and suggests that net benefits resulting from recreational fishing may be substantial.

19. The benefits from commercial fishing can be divided into two primary categories, consumer surplus and producer surplus. Consumer surplus is the aggregate difference between what consumers would have been willing to pay for the seafood they consumed and the price they actually paid. Essentially this is the net benefit that consumers received from purchasing seafood rather than spending that money on the next best thing. For the purpose of policy analysis, New Zealand will probably only be interested in consumer surplus accruing to New Zealand residents, such that consumer surplus on exported seafood can be ignored. Again, we are not aware of any studies on the level of consumer surplus associated with domestic seafood consumption, and it difficult to say how substantial they may be. It is only possible to say that there may be some decrease in consumer surplus if catches sold domestically decrease. Whether or not the total impact on consumer surplus is large, it is quite possible that large marine reserves could reduce consumer surplus for individuals in the vicinity of the reserve for whom the supply of fresh fish might be reduced.

20. The more direct concern to SeaFIC and its stakeholders, is the impact of marine reserves on producer surplus from commercial fisheries and the resulting effect on the value of quota holdings. Producer surplus generated by fisheries is the economic profit attributable to exploitation of the fisheries. It can be defined quite simply as the difference between revenues and the opportunity cost of inputs used in generating those revenues. This includes the costs of inputs such as fuel and labour as well as the opportunity cost of capital used in fishing. Quota values should, in principal, reflect the net present value of the expected stream of producer surplus attributable to those catch rights for the foreseeable future. Consequently we would expect any loss in producer surplus to be reflected in a diminution of quota values and a loss of wealth to quota owners.

21. Marine reserves could impact the producer surplus from commercial fisheries in a variety of ways. The most obvious impact is the effect on total catch. As we discuss below, the modelling literature on marine reserves suggests that marine reserves may very well decrease catches in well managed fisheries, but are not likely to increase them. In general, a decrease (increase) in catch will result in a decrease (increase) in revenues and producer surplus.

22. The percentage decrease in producer surplus is likely to be greater than the decrease in revenues since fixed costs are spread out over a smaller total catch.

23. Reductions in revenues due to reduced catches may be partly offset if decreased supply leads to increased prices. However, for products exported to large international markets one would not expect to see significant price effects resulting from decreased supply. This is the case for much of New Zealand’s seafood. Prices may also be affected by changes in the quality of product, and these changes might be either positive or negative. For example, a marine reserve that prevents targeting of larger size fish and results in a smaller average individual size might bring a decline in average price. It has been suggested that the opposite could also occur in the long run as a result of large fish spilling over from the reserve. However, if there are substantial benefits to selecting for larger fish, this might be achieved more efficiently in other ways.

24. Marine reserves will also impact producer surplus on the cost side. Marine reserves can, in most cases, be expected to increase the cost of taking a given amount of fish from the fishery (Hannesson 1998, Holland 2000). In the short run, this is an obvious outcome. Fishermen are presumably fishing in the location they find most profitable. This site preference could be because the fish caught there are more valuable (e.g., they are larger or the proximity to market allows them to be delivered in better condition). Alternatively, the site preference might be due to safety reasons or to the expectation of higher catch rates there than at alternative sites. In the latter case, reducing catch rates results in a higher cost per unit of catch. Any of these reasons suggest a loss in producer surplus following exclusion from the preferred fishing areas.

25. The situation is likely to compound over time. If the same level of total catch is maintained after creation of the marine reserve the displacement of effort from the marine reserve to other areas may result in crowding and gear conflicts as well as local depletion. Over time, if the reserve is effective at protecting a resident fish population, the density of fish inside the reserve will build up relative to the density outside. Obviously catch rates would be higher and

unit costs lower, if fishing were concentrated where fish are concentrated, but this will not be possible if those areas are inside the reserve and closed to fishing.

26. The discussion above makes clear that both the costs and benefits resulting from a marine reserve are in fact streams of costs and benefits over time. The cost and benefits streams are unlikely to be constant or simultaneous. For example, the marine reserve is likely to increase fishing costs immediately while any gains resulting from the emigration of large fish from a reserve are likely to be several years down the road. Non-extractive benefits such a fish viewing will also only be fully realised after many years. An appropriate economic evaluation of a marine reserve must take the timing of costs and benefits into account by transforming cost and benefits streams into present value terms so that they can be compared.

A Brief Review Of The Literature On The Impacts Of Marine Reserves On Fisheries

27. The literature that focuses expressly on the impacts on marine fisheries of marine reserves and year-round closed areas is large and growing. We do not attempt to undertake a comprehensive review here, but focus particularly on the literature that explores the impacts of marine reserves on fishery performance (e.g. total catches, variability of catches and profitability).

Empirical Studies of Marine Reserves

28. The literature on marine reserves includes a large number of empirical studies that explore the impacts of closures on fish populations inside the closures but relatively few that document the effects on catches outside them. Though they have been used in many fisheries (Ward et al. 2001), the impacts of marine reserves are not well understood. A study of the use of time and area closures in over fifty fisheries in eleven countries produced little clear evidence of improved resource conservation (OECD 1997).

29. A recent comprehensive study of marine fishery reserves worldwide (Ward et al. 2001) concludes “there appear to be few well documented examples of fisheries that have been shown to benefit from the introduction of reserves. The experiences often cited in support of reserves are limited to either the recovery of stocks from a highly depleted state, using temporary closures of various forms, or involve mainly subsistence-scale tropical reef fisheries. Experiences in neither of these categories can be related directly to the world’s commercial capture fisheries, and there is little documented evidence that in a well managed fishery, no-take reserves offer additional advantages to a fishery over and above those offered by better classical management techniques.

30. Nearly all of the empirical studies that document increased catches after creation or elimination of a marine reserve are isolated examples of fisheries with very different physical and socio-economic characteristics to any in New Zealand.

31. The often cited case of the Leigh marine reserve in New Zealand provides some evidence of spillover of lobster into the surrounding fishery, but fails to provide evidence of how the productivity of the overall lobster fishery and other fisheries in the area were affected by the reserve.

Modelling Studies Marine Reserves Impacts On Fisheries

32. As Holland (2002) notes, there are serious limitations to our ability to answer these questions with empirical research. Doing so rigorously would require a number of replications over long periods with comparisons to controls, and even then might only provide conclusions valid for very specific sets of circumstances. The full impacts of reserves can take many years to be realised and will be confounded by environmental and regulatory changes. Modelling studies provide an alternative approach to evaluate basic questions about how reserves of various designs in various environments might affect fisheries.

33. Several published modelling studies of marine reserves and closed area for fisheries suggest that a correctly sized marine reserve may increase yields in fisheries that are subject to growth or recruitment overfishing, but that little if any yield increases can be achieved in fisheries where effort is already at the level that produces maximum sustainable yield or maximum yield per recruit (e.g., Beverton and Holt 1957, Guénette and Pitcher 1999, Hannesson 1998 and 2002, Hastings and Botsford 1999, Holland and Brazee 1996, Nowlis and Roberts 1999, Polacheck 1990, Rodwell et al. 2002, Sanchirico and Wilen 1998, 1999 and 2002, Smith and Wilen 2003).

34. In these models increased yields are achieved through two possible mechanisms. Fishing mortality and growth overfishing are reduced by decreasing the efficiency of effort. This is achieved by closing a proportion of fishable area which, over time, leads to an increase in the density of the stock inside the marine reserve. Catch per unit effort is reduced relative to what it would be if the fish stock or fishing effort was evenly distributed spatially or concentrated where fish are concentrated. If fishing mortality was above the maximum yield per recruit level prior to implementation of the marine reserve, this may lead to increased yield per recruit, but only if mature fish eventually leave the protection of the marine reserve and are caught. Modelling studies have shown that this requires fairly high rates of migration out of the reserve (Polacheck 1990, Holland and Brazee 1996).

35. Models that incorporate a stock-recruitment function explore the possibility of increasing yields through a second mechanism. If the marine reserve protects a resident stock of fish it may allow an older, more fecund spawning stock to develop, potentially increasing recruitment. However these benefits are likely to be small unless the spawning stock is at low levels since recruitment per spawner is generally considered to be a decreasing function of total spawning stock.

36. Most of the models cited above compare only equilibrium catches with and without reserves. However, as Holland and Brazee (1996) show, there will generally be an initial drop in catches and it be many years before catches return to or exceed pre-reserve levels. Thus even, if equilibrium catches are higher post-reserve, the present value of the stream of revenues over time might be lower with a reserve than without it. Holland and Brazee (1996) also show that equilibrium catches with a reserve are unlikely to exceed catches without one if the fishing mortality is already set at the level that yields the highest catch in the absence of a reserve.

37. Nearly all of the models and empirical studies of marine reserves have focused on open access fisheries or fisheries managed with input controls. While these studies have shown that marine reserves can lead to increased catches in heavily exploited fisheries, they have failed to demonstrate the reserves can increase either catches or profits for fisheries that are optimally managed (with either input or output controls). Furthermore marine reserves do nothing to correct the incentives that lead to dissipation of resource rents and may actually lead to increases in fishing capacity (Hannesson 1998).

38. Only one modelling study has examined the effects of spatial controls on efforts in an optimally managed fishery. This study by Sanchirico and Wilen (2002b) shows that the distribution of effort might not be optimal in a fishery managed with ITQs or with a spatially homogeneous landings tax. Optimal effort distribution might be achieved with a spatially specific landings tax or with spatially specific ITQs. However, it suggests that marine reserves, which are equivalent to an infinite landings tax for that area, are generally not optimal policies in terms of economic efficiency.

39. It is important to keep in mind, that imposing a marine reserve is only one method of reducing fishing mortality and probably not the most efficient or effective method in most cases. Marine reserves may be the only option is some developing countries where resources to control effort or catches directly are not available. However, in New Zealand the QMS already in place provides and effective means of controlling fishing. The QMS not only controls fishing mortality, but does so efficiently by providing incentives for fishermen and quota holders to generate the greatest net value from the specified total catch.

40. Although models shed some light on how reserves might affect fisheries, the generality of results from existing models of marine reserves is limited by the uniqueness of different marine systems. Comparing different marine reserve models, one can conclude that results are

highly sensitive to the specifics of the biological and socio-economic systems embodied in the implicit and explicit assumptions of the models. Results from explicitly spatial models of marine reserves demonstrate that the location and shape of the marine reserve in the context of the larger fishery system is likely to be just as important as its relative size in determining outcomes (Guénette, Pitcher and Walters 2000, Holland 2000, Walters and Bonfil 1999). This is particularly true when the fishery system includes multiple, spatially heterogeneous species and user groups. Holland (2000) shows that even when a marine reserve increases the productivity of fish stocks directly impacted by it, other biologically separate fisheries and the incomes of fishermen dependent on them may fall as a result of displaced effort those fisheries absorb. The benefits and costs of a marine reserve must be addressed in the context of the larger system.

41. Most of the modelling of marine reserves has utilised single species models. Even in fisheries where it is possible to tightly control the level of fishing effort there may be a limited ability to manipulate the relative levels of fishing mortality on different species that are caught together. Consequently, any level of fishing effort may be too high for some species and too low for others. Fisheries controlled by total allowable catches (TACs) for individual species may be subject to the same problem leading to regulatory discards for species with lower TACs relative to their catchability. If there are consistent heterogeneous patterns in the distribution of different species it may be possible to tune the relative fishing mortality of species using spatial controls on effort (either marine reserves or seasonal closures). Holland (2003) explored this possibility with a linear advection/diffusion model of three intermingling groundfish stocks (cod, haddock and yellowtail flounder). The model suggested that potential equilibrium revenue gains from using area closures to manipulate the distribution of effort were quite limited. This was partly the case because redistributions of effort away from areas with the highest concentrations of cod increased the total cost of achieving a given level of combined revenues from the three stocks. Controls on nominal effort and appropriate mesh size were shown to be the most important management measures.

42. There are alternative and more efficient means to control the relative catch rates of different species and stocks. The QMS provides strong financial incentives to do just this. Quota values and ACE prices for species which are constraining will tend to rise reducing the net benefits accruing to individuals who catch them. This provides incentives to individual fishermen to alter the species mix of catch of their catch by changing fishing locations or other aspects of their fishing strategy. Appropriately set deemed values will remove incentives to catch fish for which ACE is unavailable.

43. One argument for including marine reserves as part of an optimal fishery management system is their potential utility as a hedge against management failures. However, the evidence that marine reserves are an effective tool for this purpose is equivocal.

44. One of the most cited papers supporting the use of marine reserves as a hedge against management failures is Lauck et al. (1998); however this paper makes a number of strong and unrealistic assumptions that bring into question the validity of the results. This paper shows that, under some very specific conditions, a marine reserve combined with catch controls can achieve a given level of fish stock protection (modelled as the probability the fish stock is maintained above 60% of virgin biomass over a 40 year time horizon) with a higher average catch than a strategy that relies solely on catch controls. The model assumes that catch varies randomly around a mean equal to the TAC. A key assumption is that, after each fishing season, the stock redistributes itself evenly over the fishable area and the reserve. This assumption is equivalent to assuming a zero diffusion rate during the fishing seasons and an infinite diffusion rate between seasons. This seems quite unrealistic and is key to the results of the model. Although the authors do not develop the point, they show that a greater level of total effort is required to achieve a given level of catch with a reserve in place. This is consistent with other models and suggests that gains in revenues are likely to be offset by increased harvesting cost.

45. It should also be noted that poorly designed marine reserves have the potential to increase risks in some cases. By displacing fishing effort they may increase pressure in certain areas critical to particular species. They may also serve to concentrate spawning stock biomass

spatially. The changes in spatial distribution of adult animals may affect average spawning success and may alter the survivorship of larvae and juveniles by effectively changing the average oceanographic conditions and the predation they face at various pre-recruit stages. Sinclair (1988) argues that the spatial distribution of spawners and ocean conditions that impact retention of eggs and larvae may be much more important than resource limitations or predation in determining recruitment. Larson and Julian (1999) point out that if there is stochastic spatial variation in the sources of successful recruits, spatial concentration of the spawning stock may increase the variance of the stock recruitment relationship and thereby increase the risk of fishery collapse. Under these circumstances, having a number of substocks of spawners distributed spatially is acting as a hedge against spawning failures of other substocks. The value of this portfolio may be reduced by concentrating most of the total spawning stock inside the closed area.

46. There can be little disagreement that stock assessments are often highly uncertain and that actual catches will often diverge from TACs. This indeed suggests the need for precautionary approaches to management. But, while marine reserves may play some role in applying the precautionary approach in some cases, they too are an imperfect means of compensating for management failures and only one tool among many. Many prominent fisheries scientists argue that classical management tools, augmented with modern risk management procedures, can overcome the fisheries-management problems experienced in the past (Rosenberg et al. 1993, Mace 1997).

Summary Conclusions

47. A conceptual exploration of the impact of reserves and a review of the literature suggest that few general conclusions can be drawn regarding the net value of marine reserves. It seems clear that total net benefits of a marine reserve (including both extractive and non-extractive uses) could be either positive or negative depending on the design and location of the reserve and the degree to which the reserve or system of reserves complements or conflicts with other marine management methods (e.g., the QMS).
48. Both the benefits of a well-designed system of reserves and the costs of a poorly designed one could be substantial. Due to the importance of this issue and the potentially large magnitude of costs and benefits that may result, a serious effort should be undertaken to assess the costs and benefits of specific marine reserves when they are proposed.
49. It is clear that the benefits and costs of marine reserves will not be evenly distributed. There will be both winners and losers in most cases. Non-extractive users are most likely to benefit while extractive users are most likely to suffer a loss of value.
50. Marine reserves are likely to results in losses of benefits to recreational fishers.
51. Marine reserves are likely to results in losses of benefits and to the aquaculture industry.
52. There is no empirical or modelling evidence that suggests that marine reserves will increase yields for well managed fisheries. Modelling studies suggest that marine reserves are likely to increase the cost of maintaining a given level of overall harvest from a fishery. Consequent reductions in producer surplus will reduce the net value of the fishery and the value of existing quotas.
53. For practical and legal reasons, there may be a need to identify and compensate individuals and groups who are unfairly harmed by a marine reserve.
54. Attention should be paid to designing a system of reserves and other less extreme marine management measures to achieve conservation objectives at the lowest cost. This work will require substantially more resources than have been allocated to the task to date and suggests that a more centrally planned approach to siting reserves is required. The opportunistic approach taken to date is likely to yield far fewer benefits at far greater cost than a carefully planned system of marine conservation measures of which marine reserves are but one tool.

References

Alcala, A.C. 1988. Effects of Marine Reserves on Coral Fish Abundances and Yields of Philippine Coral Reefs. *Ambio* 17(3): 194-199.

Beverton, R.J., and S.J. Holt 1957. On the dynamics of exploited fish populations fishery investigations (series II). **19**: 1-533 p.

Farrow, S. 1996. Marine Protected Areas: Emerging Economics. *Marine Policy* 20(6):439-446.

Guénette, S., T.J. Pitcher and C.J. Walters 2000. The Potential of Marine Reserves for the Management of Northern Cod in Newfoundland. *Bulletin of Marine Science* 66(3):831-852.

Guénette, S. and T. Pitcher 1999. An Age-structured Model Showing the Benefits of Marine Reserves in Controlling Overexploitation. *Fisheries Research* 39:295-303.

Hannesson, R. 1998. Marine Reserves: What would they accomplish? *Marine Resource Economics* 13(3): 159-170.

Hannesson, R. 2002. The Economics of Marine Reserves. *Natural Resource Modelling* 15(3):273_290.

Harte, M., S. Larkin, G. Sylvia and K. Quigley 2000. Discount Rates, Decision Making and Obligations to Future Generations under the Fisheries Act 1996. Final Project Report SEC 1999/04.

Hastings and L. W. Botsford 1999. Equivalence in Yield from Marine Reserves and Traditional Management, *Science* 284:1537-1538.

Holland, D.S. 2000. A bioeconomic model of marine sanctuaries on Georges Bank. *Canadian Journal of Fisheries and Aquatic Sciences* 57: 307-1319.

Holland, D.S. 2002. Integrating Marine Protected Areas into Models for Fishery Assessment and Management. *Natural Resource Modelling* 15(3):369-386.

Holland, D.S. 2003. Integrating spatial management measures into traditional fishery management systems: The case of the Georges Bank multispecies groundfish fishery. *ICES Journal of Marine Science*, forthcoming.

Holland, D.S., and R.J. Brazee 1996. Marine Reserves for Fisheries Management. *Marine Resource Economics* 11: 157-171.

Larson, R.J. and R.M. Julian [1999], Spatial and Temporal Genetic Patchiness in Marine Populations and Their Implications for Fisheries Management, CalCOFI 40, 94-99.

Lauck, T., C. Clark, M. Mangel, and G. Munro. 1998. Implementing the precautionary principle in fisheries management through marine protected areas. *Ecological Applications* 8:s72-s78.

Mace, P.M. 1997. Developing and sustaining world fisheries resources: the state of the science and management. In: *Developing and Sustaining World Fisheries Resources: The State of Science and Management*.

McClanahan, T.R., and B. Kaunda-Arara 1996. Fishery Recovery in a coral reef marine park and its effect on the adjacent fishery. *Conservation Biology* 10:1187-1199.

Nowlis, J.S. and C.M. Roberts 1999. Fisheries Benefits and Optimal Design of Marine Reserves, *Fishery Bulletin* 97:604-661.

NRC. 2000. *Marine Protected Areas: Tools for Sustaining Ocean Ecosystems*. Washington, D.C.: National Research Council.

OECD. 1997. *Towards Sustainable Fisheries*. Paris: Organization for Economic and Cooperationand Development.

Polacheck, T. 1990. Year Round Closed Areas as a Management Tool, *Natural Resource Modelling* 4, 327-353.

Rodwell, L.D., E.B. Barbier, C.M. Roberts and T.R. McClanahan 2002. A Model of Tropical Marine Reserve-Fishery Linkages. *Natural Resource Modelling* 15(4):453-486

Rosenberg, A.A., M.J. Fogarty, M.P. Sissenwine, J.R. Beddington and J.G. Shepherd. 1993. Achieving sustainable use of renewable resources. *Science* 262: 828–829.

Sanchirico, J.N., K.A. Cochran and P.M. Emerson 2002. Marine Protected Areas: Economic and Social Implications *Resources for the Future, Discussion Paper, 02-26*.

Sanchirico, J.N., and J.E. Wilen. 1998. Marine Reserves: Is there a free lunch? *Resources for the Future, Discussion Paper, 99-02*.

Sanchirico, J.N., and J.E. Wilen. 1999. Bioeconomics of Spatial Exploitation in a Patchy Environment. *Journal of Environmental Economics and Management* 37: 129-150.

Sanchirico, J.N. and Wilen. J.E. 2002. The Impacts of Marine Reserves on Limited-Entry Fisheries. *Natural Resource Modelling* 15(3):291-310.

Sanchirico, J.N. and J.E. Wilen 2002b. Spatial Management of Renewable Resources: Matching Policy to Ecosystem Scale. *Resources for the Future Discussion Paper 02-32*.

Sinclair, M.1988. *Marine Populations: An Essay on Population Regulation and Speciation*. University of Washington Press, Seattle, WA.

Smith, M.D. and J.E. Wilen 2003. Economic Impacts of Marine Reserves: the Importance of Spatial Behavior. *Journal of Environmental Economics and Management* forthcoming

South Australian Centre for Economic Studies (SACE) 1999. Value of New Zealand Recreational Fishing. Project Report REC9801

Walters, C.J. and R. Bonfil 1999. Multispecies Spatial Assessment Models for the British Columbia Groundfish Trawl Fishery, *Canadian Journal of Fisheries and Aquatic Sciences* 56(4), 601-628.

Ward, T. J., Heinemann, D. & Evans, N. 2001. *The role of marine reserves as fisheries management tools: A review of concepts, evidence and international experience*. Bureau of Rural Sciences, 184 pp.