NOAA Technical Memorandum
NMFS-SEFSC-376

REVIEW OF THE USE OF MARINE FISHERY RESERVES IN THE U.S. SOUTHEASTERN ATLANTIC

Proceedings of a Symposium at the American Fisheries Society

125th Annual Meeting, 28-29 August, 1995, Tampa, Florida

Moderator : Dr. Callum Roberts

Eastern Caribbean Center, University of the Virgin Islands

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U. S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

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OCTOBER 1995

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PURPOSE

At the request of the South Atlantic Fishery Management Council (SAFMC), a panel of scientists was assembled at a special symposium at the 1995 annual American Fisheries Society meeting in Tampa, Florida, U.S.A. The specific objectives of the symposium were to provide the SAFMC and the National Marine Fisheries Service with recommendations and guidance on the possible use of permanently protected areas for fisheries management in the southeastern U.S.

HISTORICAL BACKGROUND

The need for this symposium arose as the result of a 1990 report by the Snapper-Grouper Plan Development Team (PDT) of the SAFMC. The team concluded that area closures were needed to protect the ecosystem and maintain reef fisheries. The report recommended closing some coastal areas to all fishing. NOAA was requested by the SAFMC to produce an independent review of the concept because the PDT's recommendations were a radical departure from traditional management measures to reduce fishing effort (i.e. quotas, bag limits, gear restrictions, limited entry, etc.).

The Snapper-Grouper Plan Development Team (PDT) was assembled in 1989 to review the status of trends in the snapper-grouper fishery and make management recommendations to the U.S. South Atlantic Fishery Management Council (SAFMC). The snapper-grouper plan included approximately 100 species with direct commercial and recreational importance. After reviewing available data the PDT concluded that:

A. There were sufficient evidence and data to show widespread declines in landings for several species. Certain species were or had become very rare (i.e. warsaw grouper, jewfish, speckled hind, Nassau grouper, red snapper).

B. F;'isheries and biological data were insufficient to do a stock assessment for most species. There were sufficient data for only one species, the black sea bass.

C. There would never be sufficient data to do traditional stock assessments for most species.

D. Traditional bag limits, quotas, and size limits were unlikely to be sufficient to maintain stocks for some species in this open-access, multispecies, multigear fishery.

E. That a system of permanently closed areas (marine fishery reserves, MFRs) when combined with traditional methods appeared to be the most

Two important items had recently occurred which influenced the PDT: the development of a minimum 20% spawning stock ratio (SPR) as a minimum guideline for stock protection and the release of a red snapper stock assessment for the Gulf of Mexico (Goodyear, 1989; 1993). The latter assessment was of particular concern because it showed that under current fishing practices that the SPR for red snapper, the most important commercial reef fish in the Gulf of Mexico, was below 1%. Clearly, this level of mortality could have possible genetic consequences if fishing was selective.

When initially proposed, the idea of closing areas to fishing was not taken seriously because nobody thought that the Council would seriously consider closing an area. However, as more problems were discussed, marine reserves kept surfacing as a potential solution to specific problems. Also, traditional approaches appeared to have fatal flaws that would prevent them from being effective. The biggest problems of concern to the PDT were:

1. Insufficient fisheries data. Present data combined with insufficient historical data mitigated against the use of traditional catch and effort based management of this multi-species fishery. In addition, for many species, there was a lack of fundamental biological information (growth, reproductive biology, fecundity, behavior, ecological interactions, social structure), which is a necessary requirement for the establishment of accurate quotas, bag limits, closed seasons, and size limits. These data were unlikely to become available in the foreseeable future.

2. Growth and recruitment overfishing. Several stocks had been depleted or were in severe danger of becoming depleted.

3. Bycatch mortality. Release mortality would be high because of the depths fished over much of the region.

4. Genetic overfishing. Genetic changes in stocks because of selective fishing was an important concern and a possibility although the effects could not be measured or evaluated.

5. Serial overfishing. Despite concerted management efforts (bag limits, size limits, closed seasons) the fishery was characterized by serial overfishing. This illustrated the inability of current management to effectively protect spawner population biomass needed to sustain the fishery. In addition, rare and depleted species would continue to be harvested in the nonselective multispecies fisheries.

6. Hermaphroditism. Uncertain effects of size-selective fishing on sex-changing species.

7. Unknown ecological effects. Ecology and interactions between species were largely unknown. Impacts of selective removal of top predators and other species on biodiversity were unknown, partly because no undisturbed natural areas existed for comparative study.

Marine fishery reserves seemed to be an ideal biological solution to several fishery related problems because:

A. MFRs are an appropriate way of providing protection to a multispecies assemblage and are compatible with the typical ecology and life history of most reef species in which adults are relatively sedentary and dispersal is primarily accomplished by eggs and larvae.

B. If large enough, MFRs could protect spawning potential ratios of individual stocks.

C. Closed areas would benefit surrounding fisheries by exporting larvae and adult and juvenile biomass, providing insurance against stock collapse.

D. MFRs eliminated selective fishing from closed areas.

E. On the water enforcement would be simplified in MFRs.

F. Bycatch mortality would be eliminated in reserves.

G. MFRs would provide control areas for monitoring and for better understanding natural processes and the biology of exploited species (This was difficult or impossible at the time because all areas were impacted by fishing).

H. MFRs could function and provide stock protection without data intensive collection programs.

The SAFMC chose to use a cautious approach to using MFRs because of:

1. The approach had not been tested or used in fisheries management, particularly in the U.S.;
2. Perceived resistance to closing areas by current users;
3. Concerns about enforceability;
4. Faith that current, more traditional approaches would solve problems;
5. Questions about the scientific basis of the PDTs recommendation; and
6. Biological uncertainty that existed about how many, how big, how much total area, and where reserves should be located.

Management Actions Since 1990.

Since 1990, the council has increased restrictions on more species and tightened up on size and bag limits for some reef species. A 10-yr experimental MFR closure was established in June of 1994 over the Oculina Banks habitat area of particular concern off Ft. Pierce Florida. Separately, the Florida Keys National Marine Sanctuary has submitted for public comment a management plan that would include three large Replenishment Reserves and 19 very small Sanctuary Protected Areas that would be "no-take" and could function as marine fishery reserves.

Trends Since 1990.

Since 1990, fishery data continues to be insufficient to properly assess the stock condition of most species. More species are showing signs of overfishing and no species that was previously overfished has shown significant improvement. Significantly, red porgy, Pagrus pagrus, a main target of the headboat fishery, has demonstrated a dramatic decline in SPR, average size and landings since 1990 (Huntsman et al. 1992, 1994). Vermilion snapper Rhomboplites aurobens has also become overfished based on definitions used by the SAFMC[1]. Epperly and Dodrill (1995) demonstrated the ability of the fishery to rapidly deplete a newly discovered local stock of snowy grouper, Epinephelus niveatus, in less than one year of fishing. The scientific literature and interest in using permanently closed areas in fishery management has increased greatly with the publication of numerous studies and at least 5 major review papers since 1990 (Roberts and Polunin 1991, 1994; Dugan and Davis 1993; Bohnsack 1994, in press; Rowley 1994).

METHODS

International experts with different experience in fishery science, marine reserves, ecology, fish genetics, sociology, and economics were invited to participate in a symposium to provide comments on the PDT report (Appendices A and B). Participants were asked to use the best available scientific information from their disciplines to come to a consensus in answering specific questions.

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CONCLUSIONS

After reviewing documents and discussing available information based on current scientific knowledge, the review participants reached the following consensus:

General Preamble:

There is an emerging consensus among fisheries scientists and managers throughout the world that marine fisheries reserves (sanctuaries, no take refuges) if well placed and of the appropriate size can achieve many of the goals that fishery management has failed to achieve using conventional methods. Particularly, there is overwhelming evidence from both temperate and tropical areas that exploited populations in protected areas will recover following cessation of fishing and that spawning biomass will be rebuilt. Also, there is widespread recognition throughout the world that loss of biodiversity is largely driven by ecosystem modifications and the habitat loss that ensues. Hence preserving biodiversity implies the maintenance or reestablishment of the natural ecosystems as in marine reserves in which no extractive anthropogenic effects are allowed or are minimized.

Properly designed marine reserves in combination with other management measures can be an effective management tool for reef fish resources in the U.S. South Atlantic region subject to the following conditions:

(a) Biological, ecological, social and economic objectives of the reserves are clearly specified.

(b) The relative biological, ecological, social and economic impacts of reserves in the context of other fishery management measures have been estimated for various constituents.

(c) The development of marine reserve proposals proceed with the involvement of all constituencies and stakeholders.

Recognizing the alarming declines in stocks of key fishery species, the panel would urge that reserve options be considered immediately as part of a comprehensive fisheries management plan to prevent irreversible loss to species and fisheries. The following points are relevant.

1. What is the potential of marine reserves to retain reef community biodiversity?

Marine reserves have great potential to retain or restore biodiversity at the species and community level primarily by preventing depletion of harvested species from direct harvest, indirect bycatch, and habitat alteration and by providing habitat protection and maintenance of ecological processes. Within species genetic diversity is also important and discussed under item #3.

2. Can marine reserves help maintain populations of non-target species vulnerable to fishing mortality under other management schemes?

Because of bycatch mortality and the multi-species and multi-gear nature of reef fisheries, marine reserves offer the best option for protecting particularly vulnerable reef species from fishing.

3. Can marine reserves facilitate preservation of innate stock characteristics?

There is a general lack of data on genetic impacts of fishing although there is sufficient information to believe that the risk of genetic selection by fishing gears is real, particularly for serial hermaphrodites in which one sex is more vulnerable to fishing. The precautionary principle suggests protecting some areas from harvesting would be prudent until more information is gained.

Marine reserves can contribute to the preservation of fish stock characteristics associated with long life spans. Size-selected mortality from fisheries has been linked to reduced size at maturation, size at sex change, diminished size at maturity, and increased reproductive effort early in life in a number of species. Protected areas can compensate for these size-selective influences of fisheries, depending on the area protected and its location relative to the dispersal patterns of fish species.
More research on larval and adult fish movement is needed to optimally plan reserves. The degree of protection is predicted to depend on the movement patterns of individual species. Species with large home ranges or large areas of activity are expected to need larger reserves. Protection is predicted to be greater for more sedentary species as compared to more mobile species. The degree of protection is predicted to depend on the size and number of reserves established although there are not sufficient data available to accurately predict what size or number would be optimum. If the total protected areas are small, then reserves are unlikely to provide much genetic protection because individuals will be exposed to fishing during part or all of their life cycle. A network of small reserves however may provide some genetic benefits.

4. Can marine reserves help reestablish natural population age structure?

A considerable body of research evidence in many parts of the world shows that marine reserves offer the best option for protecting particularly vulnerable reef species from fishing.

5. What is the potential of marine reserves to enhance production and export fertilized eggs and larvae?

Marine reserves have great potential for exporting eggs and larvae from reserves although the contribution to the total stock will depend on the species, size, location, and total area of reserves. It was recognized that reserves could play an important role in insuring against collapse of stocks.

6. What is the potential of marine reserves for improving fishing success through emigration of adults from the reserve?

The potential for "spill-over" of juveniles and adults will be species-specific and will depend on the size of reserves, the vagility and behavior of each species, and the total area protected. Where such spill-over occurs this will be a direct benefit to fisheries.

ACKNOWLEDGMENTS

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APPENDIX A. List of participants in 1995 American Fisheries Society Symposium: "The Status of Reef Resources of the Southeastern United States and Options for Management."

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APPENDIX B. Abstracts of presentations given at the 1995 American Fisheries Society Symposium: "The Status of Reef Resources of the Southeastern United States and Options for Management." August 28-29, 1995. American Fisheries Society 125th Annual Meeting, Tampa, Florida.

THE NEW ZEALAND EXPERIENCE WITH 'NO-TAKE' MARINE RESERVES

Dr. W. J. Ballantine, Leigh marine laboratory, Box 349, Warkworth, New Zealand, 649/422-6111

Marine fisheries management is trapped by two assumptions. First, that fishing must be allowed everywhere, and all the time, unless or until serious and demonstrable problems occur. Second, that detailed scientific data on fish species and stocks could define and then solve these problems in some acceptable way. In fact, there is no convincing factual evidence for either assumption, and the first would prevent the operation of the second, even if the latter was true (no unconfounded controls).

New Zealand's experience with marine reserve suggests a practical way out of this trap. The success of the first marine reserves has led to a demand for more, based on the following principles:

1. Marine ecosystems must be sustained. Marine reserves with a policy of 'no-take' and minimal disturbance are required to ensure this.
2. A network design is needed, which is ecologically and biogeographically representative.
3. Benefits to fisheries will accrue, and these principles will maximize the benefits. But specific benefits cannot be accurately predicted, should not be promised, and are not a sensible basis for the design.

Insurance policies are based on an admission of ignorance, not on an assumption of detailed knowledge.

THE STATUS OF REEF RESOURCES OF THE SOUTHEASTERN UNITED STATES AND OPTIONS FOR MANAGEMENT

James A. Bohnsack (Co-Presenter) and Gene R. Huntsman (Co-Presenter), Beaufort laboratory, Southeast Fisheries Science Center, National Marine Fisheries Service, 101 Pivers Island Road, Beaufort, NC 28516-9722, 919/728-8718

Of the nineteen most important reef fishes occurring in the Atlantic Ocean between Cape Hatteras, North Carolina and the Dry Tortugas, Florida, eleven are considered overfished and some are dangerously depleted. Inherent ecological rarity of some high order predators or complex reproductive patterns, especially protogyny, may make some species, especially groupers *Epinephelus* and *Mycteroperca* and red porgy *Pagrus pagrus* especially sensitive to fishing. Traditional management schemes (size and bag limits, seasons, etc.) may not be effective in managing reef fishes. Marine reserves, geographic areas closed to fishing for some or all species therein, are gaining increased attention worldwide as a device for solving otherwise intractable marine fishery management problems. Establishment of marine reserves for managing reef fisheries is under long-term consideration by the South Atlantic Fishery Management Council (SAFMC). A panel of biologists from the region advised the SAFMC that both logic and the then (1990) limited experiential evidence indicated that marine reserves would enable; l) retention of reef community biodiversity; 2) preservation of genetic properties associated with long life spans of reef fishes and concomitant survival of the species through long-term environmental perturbations; 3) maintenance of populations of rare, high-order predator species subject to a lethal by-catch under other management schemes; 4) reestablishment of populations of old, large fish necessary for normal behavioral interactions including spawning; 5) enhancement of production and export from the reserve of fertilized eggs and larvae, and 6) possible improvement of fishing success through "spill-over" effects from the reserve.

GUIDELINES PROVIDED BY THE SOUTH AFRICAN EXPERIENCE WITH MARINE FISHERY RESERVES

Colin D. Buxton, Department of Ichthyology and Fisheries Science. Rhodes University, P.O. Box 94, 6140 Grahamstown, SOUTH AFRICA, 0461-318416

Linefishing in South Africa dates back to the 1600's, but research into the biology of the target species only began in the late 1970's. In 1985, a National Linefish Management Plan was instituted to manage this resource on a sustainable basis. This plan involved a system of size limits, bag limits and closed seasons for target species. A decade later, despite the plan, the fishery for reef associated species has dwindled. An examination of the biology of many of the target species suggests that characteristics such as slow growth, sex change and residency mitigate against the use of these methods to sustain the fishery, given the ever increasing effort.

It has been suggested that marine protected areas (MPA's) offer an effective alternative for the management of reef fish stocks. Research has shown that they are capable of protecting spawner stock biomass of several species which, with time, results in a more natural population age structure. As a consequence it is argued that MPA's offer two major benefits to inshore fisheries; firstly as a recruitment source of eggs and larvae and secondly by enhancing fishing through the movement of surplus adults into adjacent areas.

This paper reviews recent research in South Africa that supports the MPA option for reef fish management

PROCEEDING FROM GENERAL PRINCIPALS AND *EX SITU* EXPERIENCES TO *PREDICTION OF THE VALUE OF MARINE* RESERVES TO REEF FISHERY MANAGEMENT IN THE UNITED STATES

Larry B. Crowder, Department of Zoology, North Carolina State University, Box 7617, Raleigh, NC 27695, 919/515-4588

Fishery management is almost invariably an exercise in extrapolation. Because of the innumerable variables associated with geography, species, annual variability in weather, social conditions, etc., fishery managers are forced to move beyond the data that establish existing models to predict outcomes under conditions never before experienced. With much fishery management, especially of freshwater fisheries, the required extrapolations are small, and the predictability of the outcome high. In the marine environment, and especially when management involves reef fisheries, our experience is small and the degree of necessary extrapolation is high.

The choice of whether to engage in large extrapolations must be based on the amount of benefits that might be expected, the negative consequences of an erroneous prediction, and the degree of variability surrounding the general principles upon which the extrapolation is based. The experiences and principles associated with the establishment of marine reserves are evaluated with respect to associated variability and their value in predicting the efficacy of marine reserves in managing the United States' reef fisheries.

PRINCIPLES OF FISH COMMUNITY STRUCTURE EMPLOYED IN ESTABLISHING MARINE RESERVES

Paul Dayton, Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, Dept. 0201, La Jolla, CA 92093-0201, 619/534-6740

The ultimate success of marine reserves in maintaining healthy populations of economically valuable reef fishes in spite of intense fishing will depend upon recognition of the principal factors shaping reef fish community structure. These factors include physical attributes of the environment, intrinsic characteristics of the life histories of resident species, interspecies relationships including predation, and very importantly, intraspecies relationships, especially those concerned with establishment of territories, dominance orders, and courtship. Reserve designs not reflecting in size and/or configuration, will not assist in sustaining fisheries of the region.

ECONOMIC PRINCIPLES FOR THE DESIGN OF MARINE RESERVES

J. Walter Milon, P.O. Box 110240, FRED, University of Florida, Gainesville, FL 32611-0240, 904/392-1883

Policies to promote and establish marine reserves and protected areas have been based primarily on biological criteria. However, the eventual extent and success of reserves will also depend on economic and social factors. In this paper, the author provides an overview of economic criteria that may justify reserves and links these criteria to biological characteristics of marine ecosystems. Examples based on ongoing research in the Florida Keys National Marine Sanctuary will be used to illustrate the main issues.

QUANTITATIVE AND QUALITATIVE PREDICTIONS OF OPTIMAL FISHERY RESERVE DESIGN

Joshua Sladek Nowlis (Presenter) and Callum M. Roberts, Eastern Caribbean Center, University of the Virgin Islands, St. Thomas, VI 00802-9990, 809/693-1389

Despite the growing interest in using marine fishery reserves-- areas in which fishing is prohibited in order to maintain a breeding stock-- as a fishery management technique, no scientific predictions guide managers in designing reserves. This study provides the first such guidelines. We used computer simulation models to find the reserve size, shape, and spatial arrangement that optimized long-term sustainable fishery yields for a variety of species. Each species was characterized by size-specific fecundity, natural mortality, fishing mortality (experienced only outside the reserve), and movement rates. We ran each species under reserve designs varying from 0 to 90% of the coastal waters protected, and from one large to many small reserves. We stored the long-term sustainable yields and compared them to make predictions about optimal reserve design for each fish species. Our results provide several insights. First, reserves can be effective for many species, especially those that experience high fishing pressure. Second, quantitative predictions of optimal reserve size were often significantly larger than typical existing reserves. Finally, if a manager could control both fishing intensity and reserve size, catches remained consistently higher if they erred on the side of slight overfishing with a compensatory reserve than underfishing with no reserve.

THE SOCIAL AND CULTURAL IMPACT OF MARINE FISHERY RESERVES

Michael K. Orbach (Presenter) and Leah L. Bunce, Duke University Marine Laboratory, 135 Duke Marine Lab Road, Beaufort, NC 28516-9721, 919/504-7606

The concept of marine reserves is gaining in popularity worldwide. Although the principal objective of marine reserves is conservation or protection of marine resources, one of the principal impacts of such reserves is on the people who historically participate in the consumptive or non-consumptive use of those resources. In addition, the policy and planning process for marine reserves has not always included all of the relevant stakeholders or constituencies of the potential reserves and their resources. This paper will outline the principal categories of social and cultural impacts from existing marine reserves on traditional and potential users of the marine resources in the reserve areas, and suggest a format for evaluation of such impacts as part of the reserve policy and planning process.

PRINCIPLES OF MARINE ECOLOGY APPLIED TO THE ESTABLISHMENT OF MARINE FISHERY RESERVES

Daniel Pauly, Fisheries Centre, 2204 Main Hall, University of British Columbia, Vancouver BC. Canada V6T 1Z4, 604/822-6320

The literature provides numerous arguments in favor of sanctuaries as fisheries management tools, most structured around the difficulties in designing, implementing and enforcing conventional management measures (gear and effort restrictions, closed seasons, etc). An example from the Philippines will be briefly presented.

Another line of argument also exists, which emphasizes the potential role of sanctuaries in maintaining "islands" of biodiversity, both within and among species. This presentation will develop that line of thought, by showing that, on a global basis, 25-35% of the primary production occurring over shelves is required to maintain the present fisheries catches (plus discarded bycatch) of about 120 millions metric tonnes per year.

The massive impacts on marine food webs that this percentage figure implies will be illustrated by a few examples emphasizing marine mammals, and the case then made for large sanctuaries, as presently exemplified by Antarctica, and as proposed - if in a slightly different context - for the Spratleys Islands, in the South China Sea.

Acceptance of such large reserves from a political standpoint may be possible once structural similarities with analogous programs, that have been highly successful, are realized. For example the U.S. Conservation Reserve Program has funded farmers to take 36 million acres of land out of production since 1985. Similar rehabilitation programs exist in the European Union as well, and although not appreciated by all, they have helped reestablish, in western Europe, the highest forest cover since the Middle Ages.

APPLICATION OF MARINE RESERVE PRINCIPLES TOWARDS REEF FISHERY MANAGEMENT IN THE SOUTHEASTERN U.S.

Callum M. Roberts (Presenter), Eastern Caribbean Center, University of the Virgin Islands, St. Thomas, USVI 00802, 809/693-1391; and Joshua Sladek Nowlis

Steep declines have been recorded in reef fishery stocks throughout the southeastern U.S. and Caribbean despite the implementation of a broad array of "traditional" fishery management measures. Declines have been most severe for the high value species which represent the mainstay of commercial and recreational fisheries. It has become clear that traditional measures alone cannot ensure sustainability. Marine fishery reserves offer the most promising new tool available with which to maintain and enhance fishery stocks. Experience with pilot-scale reserves in the region and elsewhere has shown that biomass of fishes can build up very rapidly. High value species, particularly those from high in the food chain such as groupers and snappers, show especially strong response to protection from fishing. Reserves may be the only viable means of maintaining spawning stocks of such species in the multi-species, multi-gear fisheries prevailing in the region. Modeling studies reveal that economic benefits of reserves may increase with increasing area protected up to a surprisingly large proportion of total reef area,

APPLICATION OF GENETIC PRINCIPLES TOWARDS THE EMPLOYMENT OF MARINE RESERVES FOR REEF FISHERY MANAGEMENT IN THE SOUTHEASTERN U.S.

Joel Trexler, Department of Biological Science, Florida International University, Miami, FL 33199, 305/348-2201

One motivation for creating marine reserves is to halt the depletion of genetic variation in fish life history traits resulting from fishery-induced selective mortality. Fisheries mortality has been linked to reduced age at maturation, diminished size at maturity, and increased reproductive effort early in life. Knowledge of gene flow patterns, the strength of selection and the genetic architecture of life history traits is required to evaluate the impact of marine reserves on fish life histories. Theories of evolution in metapopulations permit development of some predictions regarding the success of marine reserves. These include that marine preserves will not be equally effective for all species in stemming the loss of genetic diversity, depending on species-specific patterns of larval dispersal. The effectiveness of the reserves will also depend on their orientation with regards to currents that carry drifting larvae. Finally, marine reserves can only slow the loss of genetic variation in life histories, not prevent it, because most economically-important species have vagile larvae. Size, stage, or age-based catch limits should be coupled with marine reserves to maintain historical levels of genetic variation for life history traits in fish stocks.

APPENDIX C

The New Zealand experience with 'no-take' marine reserves.

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Abstract

Marine fisheries management is trapped by two assumptions. First, that fishing must be allowed everywhere until demonstrable problems occur. Second, that detailed scientific data on fish stocks can define and then solve these problems in some acceptable way. In fact, there is no convincing factual evidence for either assumption, and the first would prevent the operation of the second, even if the latter was true (no unconfounded controls on which to base valid analysis).

New Zealand's experience with 'no-take' marine reserves suggests a practical way out of these traps, based on the following principles:

- Marine ecosystems must be sustained for a wide range of reasons, including the maintenance of fisheries, but not restricted to this.
- Marine reserves with 'no-take' and minimal disturbance are a practical and effective management tool for sustaining marine ecosystems.
- The benefits of marine reserves depend on full ecological and biogeographical representation and a network design.
- Marine reserves will provide benefits to fisheries, and these principles will maximise the benefits. But specific benefits cannot be accurately predicted, should not be promised, and are not a sensible basis for the design of the reserve system.
- Marine reserves provide a necessary insurance against unpredictable and unpreventable events. Detailed resource management will always be necessary but it is not sufficient. Insurance is based on risk-spreading and an admission of ignorance. We can never assume sufficient knowledge to cover all eventualities.

New Zealand has 18 years of practical experience with 'no-take' marine reserves - areas of the sea in which no one can fish, but where people are encouraged to come and observe the full natural marine life. The first reserves proved socially-popular, scientifically-useful and are widely regarded as a support to fisheries. As a result, more are being created, and a full system is being planned - representing all marine habitats in each region. The aim is to have a network of reserves that is self-sustaining and provides a wide range of benefits, including the support of fisheries.

The New Zealand experience is extensive in time, covers a wide range of marine habitats, and has tested the principles. This experience supports the recommendations of the PDT 1990 report but strongly suggests that social and political acceptance requires fisheries management to upgrade its aims and responsibilities. The success of 'no-take' marine reserves depends on clear statements of broad principle and hence a good view of the full range of potential benefits.

Contents:

1. INTRODUCTION:

During a visit in 1994, I asked everyone I could the simple question -
In North America, is there any piece of freshwater - lake, river or stream - which is not fished on principle?

I never got a quick answer. It was obvious that almost no one (politicians, administrators, resource managers, biologists, teachers, journalists, fishermen or general public) had ever considered the question. This is both remarkable and informative. Common sense and ecological theory suggest many advantages in knowing the intrinsic properties and dynamics of any major habitat.

Since no one ever asked themselves the question seriously, it is not surprising the answer was no. Everyone tried to think up a positive response - places too remote to reach, prohibited defence areas, some eccentric private owners, situations of high pollution, etc., - but essentially the answer was no.

If this is true for freshwater, where physical separation and specific ownership make it easy to have different management aims, it is not surprising that the idea of 'no-take' areas in the sea has received little serious attention.

Widespread non-events do not necessarily have any particular or precise explanation. Although plausible reasons can be invented, it is more likely that some mind-set prevented the possibility being considered. Trying to provide a simple logical explanation is probably not very helpful. If marine reserves fall in the bracket of 'non-events', we need not waste time on local or specific details. Instead, we can direct our attention to the mind-set, the erroneous or irrelevant assumptions and thought patterns that prevented serious evaluation of the idea (Ballantine, 1995).

2. THE HISTORY OF MARINE RESERVES IN NEW ZEALAND

It is extremely difficult to alter mind-sets. Although the history of marine reserves in New Zealand exceeds 30 years, it is an on-going story, and far from complete. Events to date show that some principles have been clearly established, and that others are slowly but steadily emerging. It is these principles which are important and valid elsewhere, rather than the details of the actual reserves (Ballantine, 1991).

Ideally, each principle should be tested separately and sequentially. The process with marine reserves in New Zealand was more complicated. Simultaneous tests occurred covering the full range of marine resource management including standard fisheries regulations, highly-restricted fishing areas, and 'no-take' marine reserves.

During the past 30 years, many fisheries, including the most important, showed evidence of declining stocks, despite the application of a wide range of management techniques. The establishment of some highly-restricted fishing areas, although initally favoured by management and some fishing interests, produced steadily increasing management problems. Despite difficulties in getting them set up, 'no-take' marine reserves have received a steady increase in public support and a demand for more.

The established principles are:

- Marine reserves are a practical and publically-acceptable management tool.
- Acceptability and practicality are highly dependent on the 'no-take' rule.
- 'No-take' marine reserves have a wide range of important uses in conservation, science, education and recreation, as well as in resource management.
- Most of these uses are 'new' and basically unavailable without 'no-take' reserves.
- Because the benefits are 'new', developing public understanding and support for 'no-take' reserves is a slow process, but it is steady and progressive. It proceeds faster after the actual enactment of some reserves, and when clear statements of principle are provided at all times.
- Highly-restricted fishing areas become publically-unacceptable over time, since they fail to support any general principle, while creating new sectional interests. It is very difficult to up-grade such areas later to a 'no-take' status, even when this has strong and widespread public support, because of actual or implied agreements with fishing interests during the imposition of the special restrictions (Department of Conservation, 1994).

The emerging principles are:

- Detailed resource management (e.g. stock-specific fisheries regulations) is necessary but not sufficient.
- Specific, knowledge-based management is always vulnerable to rare, sudden or unpredicable changes in the system - whether natural or human-induced.
- Some additional and differently-based management methods are required as insurance.
- The general public, standing back from the sharp realities of day-to-day use and management, are more likely to be able to appreciate these points than established interest groups, and are more willing to try new approaches.

- The traditional focus on established interest groups (whether users or managers) reduces the chances of adopting additional and different measures.
- 'No-take' marine reserves are essential for valid conclusions in much of marine science and in most marine resource management.
- 'No-take' marine reserves are required for all habitats and all regions.
- This ecological and biogeographic representation must include replication.
- A network design is needed because of remote dispersal in most marine biota.
- The density of the network must be sufficient to ensure self-sustainability.
- The general public tends to be more receptive of these points (and their practical linkage) than those with a long experience in detailed resource management (e.g. stock-specific fisheries).

3. FISHERIES MANAGEMENT IN NEW ZEALAND

The overall status of fisheries in any region is hard to determine, and New Zealand is no exception. However, New Zealand fisheries are isolated in physical, biogeographic, and political terms. They are significant in geographic and economic size; and in social importance, both commercially and as recreation. They are a good case for assessing the general results of fisheries management. However, any such analysis is full of traps for the unwary, and New Zealand situation illustrates these well.

Serious problems do not produce a concensus for action

Virtually any opinion on fisheries management can be supported by reference to some selected stocks. If we select fisheries that are long-established, economically-important, well-studied and of high recreational interest (i.e. the ones where research and management have been concentrated) we are likely to see the system at its best.

The most valuable and best studied inshore fisheries in New Zealand are for:
Snapper or seabream (*Pagurus auratus*, Sparidae)
Crayfish or rock lobster (*Jasus edwardsii*, Palinuridae).

It is generally agreed, by all interested parties (see Annala,1994 and 1995) that:

(a) These fisheries are very important, commercially and recreationally.
(b) The detail and precision of the available data have steadily improved.
(c) The standard and detail of management have been continuously improved.
(d) The stocks of both species are now well below the levels that are sensible in economic or biological terms.
(e) The decline of the stocks has a long and complex history.
(f) Without major management changes, further stock declines are likely.

However, there is no agreement between the scientists, the user groups or the administrators on what changes should be made. Indeed there is no agreement within the various 'user groups'. A careful examination of the literature shows that this state of affairs is common in well-studied and fully-managed fisheries, not just in New Zealand (Horwood, J. 1994; Cochrane, 1995).

The shifting databases - improved methods prevent simple comparisons

A literature search does require great care, however, because it is difficult to obtain properly comparative data. There are many reasons for this. Comparisons can be confounded by differences in the actual biology of the species or stocks; by the use of different data collecting systems (and there is a very large range); by the different statistical and analytical techniques adopted; and simply by the physical differences between geographic locations. Even for a single stock, there are still complications. Methods improve, and these improvements are naturally applied to the collection and analysis of the data. The result is that the basis for comparison shifts.

As we sub-divide fisheries into species, then stocks, breeding areas, year-classes, and other cohorts, the precision of the data improves, but the problems of comparability increase. As we analyse variations in sex-ratios, growth rates, physical factors, etc., strictly comparable baselines recede, and the capacity to make general statements diminishes. Even for undisturbed populations this is a serious problem (which occupies a lot of time in ecology). Fisheries deals with exploited populations, subject to continuous manipulation, and this complicates the matter still further.

Policy changes - political and economic changes prevent rational comparisons

If the manipulation due to fishing was a constant or changed in a linear fashion, it would be possible to make adequate adjustments in the analysis of the dynamics to allow for, and hence predict, the effects. But the manipulations are rarely single, constant or linear in their effects. There are several aspects to this.

First, there is often more than one 'user group' doing the fishing, and they can behave quite differently. Commercial and recreational interests are not the same, and each includes different sub-groups. Large trawlers supplying supermarkets with frozen fish have little in common with small long-liners providing fresh fish to expensive banquet tables, even when they are catching the same species in the same area. Divers with spear-guns, anglers on boats, and shore-based seiner-netters can react very differently to the same circumstances.

Second, economic and practical considerations often shift the aims, methods, locations and intensity of a fishery, even for a single stock. These can produce major changes in a fishery without any prior change in the stock itself. Oil prices, new markets for fish, and the fashion in tourist destinations are examples of the huge range of potentially-important factors.

Third, policy changes in fisheries management, or at higher levels of government, can at any time shift the entire basis of a fishery. Although policy changes may relate to changes in fish stocks, they are often quite independent of this. The introduction of ITQs (individual transferable quotas, i.e.saleable or leasable quotas) in New Zealand across all stocks, virtually doubled the costs of long-line snapper fishing in a few years. Tax provisions, licencing, and port development subsidies are other examples which are not necesssarily stock-specific, while there is huge range of regulatory methods that are usually species or stock related (e.g. closed seasons, minimum size limits, total allowable catches, etc.).

One important result of all these changes is that there is no clear or rational basis for comparison. Not only is it impossible to make accurate predictions for a fishery, it is not even possible to get any agreement on the reasons for observed events (Ludwig et al, 1993). Given this degree of uncertainty, it is not surprising that political and social conerns actually determine policy, despite all the data and analysis of the the scientists and managers.

The illusion of the average

At any one time a region's fisheries consist of a mixture of:

some known but unexploited species and stocks
starting-up fisheries, still small and/or underdeveloped
well-fished stocks that seem in reasonable condition
hard-pressed species and stocks, perhaps holding but vulnerable
declining stocks, in serious trouble
defunct fisheries, just historical memories

The majority of species and stocks fall in the middle groups. If the situation is re-examined a decade or so later, it seems the same. But is it? The overall picture obscures the processes involved by focusing attention at the median. In fact potentially-fishable species or stocks are being discovered all the time, and in each period the final demise of a few remnants occurs. Different stocks and species move at different speeds but the tendency is one way. New Zealand's fisheries now catch much more than they did 30 or even 10 years ago. But most of the stocks and species caught previously have declined and the 'increase' is in new species, some stocks of which have already sharply declined. The serial depletion of stocks within one species is routinely recorded in fisheries, and 'fishing down the food chain' - the reduction high-order predators first - is often mentioned. In fact, these points seem just part of the process, serial depletion is a general feature of fisheries.

The total effect of these features of fisheries management is that it becomes almost impossible to produce an informative overall critique. Unless someone properly appreciates the highly technical data and complex scientific analysis involved, any criticism they offer can be set aside as being ignorant. But almost the only way this detailed knowledge can be obtained is by training for professional fisheries management, and anyone doing so is then constrained by the economic consequences. Employment and grants are naturally controlled by those who believe in the professional methods. It is difficult to have a knowledgeable but independent opinion.

Even expert *general* views of fisheries management are rendered questionable by the other problems. The data are never strictly comparable between species or stocks. Locations, collecting methods, systems of analysis and actual biology vary significantly. Even if this can be sorted out, or approximated to a reasonable degree, the shifts of economic and political policy over time cloud any general conclusions. The only general conclusion that can be made about fisheries management (and its scientific basis) is that no simple, easy-to-use, general conclusion is possible.

This idea was stated by fisheries experts in a recent viewpoint (Ludwig *et al*, 1993) and is strongly supported by the first worldwide review of marine biological management, edited by Norse (1993). We should not be surprised or upset by all this, indeed the only worry is that it took so long to see that it applied to fisheries. Science is an important and powerful system for gaining knowledge, but it has real limitations, as well as temporary frontiers. As Medewar (1984) pointed out some time ago, it is necessary to recognise the limitations of science, and to state them in clear terms to the public and decision-makers. If this is not done, expectations are unreasonably inflated and science then falls in disrupute. Good management also recognises that it is not perfect and can never be so. Mature management systems carefully define their own limitations and develop proceedures that cope sensibly with the resulting problems, without pretending these will *solve* them.

4. BASIC ASSUMPTIONS IN MARINE FISHERIES MANAGEMENT

The basic assumptions of marine fisheries management, worldwide, are:
(i) that fishing must be allowed (by anyone, at any place, and any time) unless or until serious and demonstrable problems occur ('universal fishing rights').
(ii) that the use of detailed scientific data on fish species and stocks can define, and then solve these problems in some acceptable way ('stock-specific problem solving').

Although these assumptions are widely held, and often considered to be unchallengable, they are:

(a) merely the result of historical accidents
(b) unjustified by any coherent theory (scientific, economic or social)
(c) unsupported by any persuasive body of factual data
(d) inconsistent as an operational set
(e) subject to the problem of infinite regression

Individual fisheries scientists or managers may not hold these assumptions personally, but since they believe that politicians and the public do, the effects on policy are much the same.

A frontal attack on these assumptions is unlikely to be immediately successful, but *practical* ways to weaken confidence in such ideas should be sought. 'No-take' marine reserves occupy a key position in this. The creation of any useful marine reserve denies both assumptions, or at least suspends their local operation. So each established 'no-take' marine reserve demonstrates that the assumptions are unnecessary, and introduces the idea that they are actually counter-productive.

(a) UNIVERSAL FISHING RIGHTS

Arose by accident

No one ever planned, or really wanted, 'universal fishing rights'. The situation arose because of a breakdown in 'local' control before the development of 'central' control (i.e. at national or international levels). This changeover was complicated by simultaneous increases in technology, the development of distant markets, increases in the mobility of people and capital, and a wide range of other factors. The details of this can be debated at length, but should not be allowed to obscure the basic point. During the development of the idea of 'universal fishing rights' no one was in full and continuing control of the situation. The idea developed by default.

They have no theoretical justification

No one has ever put forward a plausible theory which said that **given** full and continuous control of the situation, it would be **generally** advantagous to arrange fishing everywhere until problems arose. A particular fishery might be encouraged to operate over the whole available stock area, for a time and for special reasons; but there is no economic, social or biological suggestion that this need apply everywhere, all the time, for all stocks. Many theories have been proposed on fisheries management but they all relate to some compromise between the actual power of control (or its cost) and the desirable amount of regulation.

They are not supported by the facts

There may be some advantage to the authorities (at particular times and places) in not trying to control some marine exploitation, especially when no 'problems' have been perceived; but no one has produced any factual evidence that this leads to the best **long-term** result.

On the contrary, the list of situations where control was too little or too late to avert serious damage to a fishery is depressingly long. Scientific reviews of the subject (e.g.Ludwig *et al*, 1993) have suggested that such disasters are actually the norm. Long-term success in fisheries management may be rare. Appearances to the contrary are often temporary (e.g. for a new stock or after some recruitment pulses), accidents (e.g. technological or market 'inefficiency'), or simply insufficient data to realise what is happening.

They are irrelevant to the real issue

The important point is not where fishing is permitted, but what can be achieved when fishing is carried out. Fishing at a location is only a means to an end. The catch (plus profit or fun) is the end. 'Restrictions' on fishing location are not, in fact, restrictions on fishing, although at present they are commonly perceived as such.

The right to travel 'without let or hindrance' on the public highway is an extremely important right. Laws that require traffic to drive one side of the road and prevent driving over median strips are not generally seen as 'restrictions', but as protection and support for the essential right of travel.

(B) PROBLEM SOLVING WITH SCIENTIFIC DATA

Science requires unconfounded controls

The idea that detailed scientific data on stocks could define any problems that might arise in a fishery, and hence suggest specific methods of solving these, is at least a plausible notion. However, the application of science requires a 'control' - an unconfounded situation of the same type, that is compared to the manipulated one. If this is not available, due to universal fishing rights, then while a mass of data can still be acquired, there is no strictly scientific way of assessing it. Many scientists would also require 'replication', both for the manipulation and the controls, before they would accept the results as proper science.

Even if these rules are dismissed as too pedantic, common sense strongly suggests that if the whole stock is continuously manipulated in various ways by different people, the probability of being able to predict the result of further changes is not good. Informed or expert opinion is likely to be better than pure guesswork, but such opinions are not scientific statements.

Detailed prediction is not possible

In situations under rigorous experimental control, it is possible to improve prediction by limiting the range of considerations. This method, the reductionist approach in science, is very powerful in improving our understanding about mechanisms and controlling factors, but its ability to predict in real world situations is limited. Biologists used to accept this, even if it implied a 'lower' status than the more 'precise sciences'.

Recently, however, some biologists (including some fisheries scientists) have become confident they can evade the effects of biological complexity. This is ironic, because over the same period, the physicists whom they wished to emulate, showed that complex systems predominate in the real world, even in physics (Davies, 1987).

Away from the laboratory bench, 'complex systems' - i.e. non-linear systems involving feed-back and sensitivity to initial conditions - are the rule, especially in biology which is concerned with open systems operating far from physical equilibium. One characteristic of complex systems is that while 'broad brush' prediction may be possible, more detailed knowledge does not lead to more precise prediction. Ordinary people always knew this, now it can be rigorously demonstrated (Cohen and Stewart, 1994).

Social acceptability is not based on precision prediction

Although politicians like to pretend that they only act when the outcomes can be predicted, this is generally recognised as a polite fiction designed to encourage rational discussion. While the public is often gullible or cynical, their instinctive distrust of detailed promises is sensible and wise. This is not just because factual knowledge is unlikely to be sufficient for the purpose. Human behavioural reactions are particularly susceptible to infinite regression.

However logical people are on larger issues or principles, they tend to become much less so as the cases becomes smaller and more particular. This is quite reasonable, since the perceived risks tend to be smaller. The important point is that, socially, people are less logical in detail, not more. The idea that, if detailed effects could be demonstrated in advance, restrictions would be more acceptable, has no basis in politics or social affairs.

Fisheries management must be based on broad principles because there is no actual alternative. All other approaches are based on unwarranted assumptions based on historical accidents or complex forms of wishful thinking. Even if all this was accepted, practical people, especially fisheries managers could still argue that the assumptions, however nonsensical, are so deeply entrenched and widely held that we have no option but go along with them and to tinker within the existing system.

Being a pragmatist myself, I have great sympathy with this point, and would not have raised any of the above if there was no practical alternative. But there is. It will not be the answer to everything, but it does point in the right direction. It will not overturn all the assumptions at once, but it will start the process. It will not make a large difference quickly, but this means it is politically and socially viable. And it is specifically what is needed for this symposium.

The bad news is that those most experienced in detailed resource management will find it hardest to shift their perspective. The good news is that the voting public will, for once, tend to be more receptive than the experts.

5. PRINCIPLES BEFORE PARTICULARS - AVOIDING REGRESSION

The organisers of this symposium are professional, careful and modest. But virtues can be misapplied. Consider the original title of this symposium and its implicit assumptions. The organisers are trying to keep the discussion within bounds of our professional expertise. This is understandable, but may not be appropriate when discussing a major change in the overall use of a large area of public domain.

*"...the value of marine reserves ....for **managing**... fisheries"*
The unstated implication is that if marine reserves do not provide useful advantages to the managment, we would lose interest in the matter. This could be true, but there seems no advantage in saying so, or implying it. The average citizen believes that the convenience of management is not the main, or even a particularly relevant point when discussing what should be done with an important system. Why could omit the word "*managing*".

*".....the value of marine reserves for ... **fisheries**"*
The underlying assumption is that if marine reserves provided no advantage to one class of existing users, we would not bother with them. Again this could be true, but the wisdom of implying it is doubtful. An increasing number of citizens feel that the marine ecosystems do not actually belong to the present users, and that management should not be controlled or limited by the present interests of any particular class of user. Why risk alienating those who potentially control the political decisions? Are we really so confident that no other interest count to any significant degree? Why not omit the word "*fisheries*"?

*"the value of marine reserves for ... **reef**..."*
Here the implication is that reefs are the important part of the ecosystem and any others do not really matter. The public does think reefs are much more interesting and important than sediments flats or plankton, but this is part of the problem, not a step to a solution. The idea has no scientific basis, and is unhelpful in a scientific sysmposium. As scientists we must begin by affirming that marine ecosystems include more than top predators or reef systems, and that any sensible management will have to include a wider viewpoint. I would simply omit the word "*reef*".

*"**Predicting** the value of marine reserves....."*
This suggests that if we were unable to predict what marine reserves would do, in some specific sense, then we would not recommend action. I emphatically deny this, and insist that there is no point in implying it. Most political decisions are made in terms of some kind of perceived principles, rather than detailed predictions. Furthermore, the public is understandably wary of detailed predictions, but can react positively to suggestions that we need effective insurance against error and ignorance.

What would be wrong with a title that read -

"The value of marine reserves for the southeastern United States."

To some extent my point has already been recognised. The organisers of the sysmposium invited " economists, sociologists, ecologists and conservationists" as well as fisheries experts. This is certainly a good idea, but it should be carried further. We don't just need their views on *"predicting the value.... to reef fisheries management"* - we need their views on *"the value of marine reserves"*.

Suppose we found that marine reserves provided no *predictable* benefit to the *management* of *reef fisheries*, indeed the probability was more work for the managers. Would this decide the matter, or would we take in account the probability of major improvements to

conservation at all levels (genetic, species, habitat and ecosystem)
marine science (provision of unconfounded controls)
marine education and training (from public awareness to professional levels)
non-destructive recreation and tourism
monitoring (and separation) of natural and human-induced effects
marine resource management
support and insurance for all extractive uses (including all fisheries).

Government and the voting public are interested in reef fisheries management, but they also have much wider ranging and more important interests. When advising government, professionalism requires care in two directions. We must base our advice on evidence and professional knowledge, but we must avoid restrictions based on departmental boundaries or accidents of employment.

Not so long ago, fisheries science and management was equated in the public mind with all marine life and all the habitats. This was mostly a mixture of ignorance and indifference, but it did have great practical value. When any question of policy arose that involved marine life, the politicians knew who to consult and the public felt they were getting, if not the right answers, at least the best available information.

Since then we have progressed in logic, but regressed in practise. Fisheries science and management has become much more precisely defined and, hence, more professional and knowledgable in this narrower bracket. However, the broader issues have been cast adrift. If you now want advice on policy for marine ecosystems, there is no clear source. Large numbers of agencies are involved in many different ways, but there is no focus, no simple hierarchy and, hence, no principles.

I spend a lot of time apparently criticising fisheries scientists and managers, but I am not antagonistic. Quite the opposite, I am trying to persuade them to upgrade their status. There are good practical reasons for this and marine reserves provide a straightforward route to do it. Simply by recognising the traps inevitably formed by detailed management and the opportunities offered by 'no-take' marine reserves, fisheries science and management could become much more effective.

The public at large would welcome the change. They want to believe that someone is looking after their sea , its life and habitats. Indeed they get very cross if you carefully explain that, at present, the 'responsible professionals' are fully occupied in sorting out conflicts amongst the user groups. The politicians will (sooner or later) take their cue from the voting public, which has a built-in majority of 'non-users' for each locality. The 'user groups' in each case will not be directly converted. They will continue to demand all kinds of impossible things. But these demands will be seen a new perspective. Instead of being the only point of interest, as at present, they will become simply one of a range of issues to be considered.

This may sound impossibly idealistic, but it has already started to happen to 'fisheries' in New Zealand, and is well-developed in other branches of resource management in the U.S.A.

6. THE HISTORY OF NATURAL RESOURCE MANAGEMENT

It is very difficult to predict precisely when and where new mind-sets will develop in natural resource management, but it is quite simple to see the trend. All branches of exploitive resource management are following the same route, some much faster than others. Whether we look at mining, forestry or waste disposal, the story is very similar. Some nations or regions are farther down the track, but there is very little variation in the route. The stages have even been labelled and defined as principles (Landner, 1995).

Hodges (1995) writing about mining in the USA, states quite firmly that the days are gone when the profitable extraction of a useful mineral from public lands was automatically regarded as the 'highest and best use". Bill Bentley, the executive director of the 7th American Forest Congress, is reported in New Zealand newspapers (N.Z. Herald, 28th July 1995) saying "the congress is seeking an environmental and economical policy acceptable to all Americans". A multi-national oil company and the British government was recently forced by public opinion to reverse a plan to dump a redundant oil storage platform in the deep waters of the North Atlantic.

All these matters involve a change in mind-sets. They all move in the same direction. These paradigm shifts are not a matter of new information. They do not depend on detailed data or accurate predictions. This aspect annoys many scientists and managers. An editorial in *Nature* (29th June 1995) claimed the "decision not to sink a used oil rig at sea is a needless deriliction of rationality". This simply misses the point. It is true that dumping at sea was perfectly feasible. It was the cheapest option and there was no real evidence that it would harm any particular marine life to any significant degree. But large numbers of the public said they did not want that junk in their ocean. Whether this is more or less 'rational' than just dumping things until problems arise (and are scientifically verified) is a matter of opinion. The fact is the public increasingly rejects the idea that user-group cost-benefit calculations and provable damage should be the *only* way of deciding how ecosystems are used.

Slowly but steadily the public is starting to say - We don't *have* to chop *all* the trees that could profitably be made into useful things. We don't *have* to mine *all* the land that contains worthwhile minerals. We don't *have* to dump rubbish in *all* the available spaces, because it would be cheaper. Very soon they will be saying - We don't *have* to fish *all* the sea, just because it would be fun or profitable. They already are saying so in New Zealand, and the idea is likely to spread. It would be very unfortunate if this spread was slowed down by the misapplication of scientific ideas. This could occur in at least four ways.

First, although science is prediction, it is not social judgement. It is scientifically improper to imply opposition to marine reserves on the grounds that we cannot predict their outcome to any particular level of detail. Science can and should provide factual background to political decisions, discuss the possible outcomes, indicate the likely variables, etc. but, even if it can accurately the detailed results, its practictioners are in the same class as other citizens when decision time comes - they are entitled to their opinion. If the other citizens wish to give knowledgeable opinion a higher value that is their perogative, but they are not obliged to do so, and probably should not if the knowledge is only being used in a very narrow frame.

Second many scientists are (like this panel) engaged in reviewing marine reserves and their effects (e.g. Dugan and Davis, 1993; Rowley, 1994) . This is reasonable up to a point. But the implications are disturbing. Science does not consist of reviewing the pre-existing evidence, it consists of determining the facts directly. If we want to know the effects of marine reserves in the USA (or anywhere else) the scientific method requires us to run some trials. Discussing previous trials elsewhere is only useful if it results in some actual tests.

Third, a considerable amount of scientific effort is being expended to try and determine whether marine reserves 'work', without applying basic scientific rules to the question itself. Even when this question is posed in scientific reviews (e.g. Roberts and Polunin, 1991), it can miss the point. While a scientist may be pleased to find a significant difference between population densities or size structures between a marine reserve and its surrounds, this should not be confused with managerial or social success. Ordinary citzens do not feel happier when the marine reserves are bursting with life and the rest of the ocean is a desert. On the contrary, they hope that the existence of reserves will *reduce* any difference between the 'exploited' and 'natural' levels in marine life. It is not helpful to define 'success' scientifically in an opposing sense.

Fourth, marine reserves are social experiments but they are not in fact scientific experiments at all. Socially, politically and in management terms, they are experiments in the simple sense of being new and different from previous practise. However, they are not experiments in the proper scientific sense. Marine reserves are controls - the unmanipulated pieces, the 'blanks', the references for comparison. They may be part of an experimental design - involving manipulation(s) and control - but they are not the manipulation. This affects the scientific rules quite markedly. A properly-designed experiment is expected to ask one clear question - to test some strictly-defined hypothesis i.e. you should be able to say what is *the* purpose of *this* experiment. But controls are not like that. The same 'unmanipulated' part of the design can be a control for any number of other and different experiments, it simply has to remain 'unmanipulated'. So it does not make scientific sense to ask 'what is *the* purpose of this marine reserve'. Furthermore, while in a social or managerial senses a marine reserve can be measured for 'success' in many ways; scientifically 'success' simply means remaining unmanipulated and available for further comparisons.

7. MANAGEMENT PRINCIPLES AND INSURANCE

Detailed management cannot take into account changes that are relatively rare, large, sudden or unpredicable. The responsible and professional management reaction to such phenomena is take out some form of insurance. Effective insurance is deliberately different from normal management both in its basic assumptions and its actual design. This is clearly recognised in well-studied situations - such as fire risks to buildings.

Normal detailed management is concerned with fire exits, smoke detectors, hose reels, staff-training, storage of inflammable materials, etc., all of which are highly specific to the particular building, its purpose and locality. This is generally effective, but there it leaves out a range of relatively rare and unpredictable 'accidents' (e.g. lightning strikes, riots, mechanical breakdowns, personal vendettas, etc.) that are capable of causing severe fires. Insurance against these is feasible, without detailed knowledge or prediction, provided the arrangements are not closely related to the particular building, its purpose or precise location.

Effective fire brigades cover whole districts and, moreover, are networked to provide highly flexible (but rarely used) backups. Effective monetary fire insurance depends on widespread risk-spreading. The principle is that it is worthwhile to pay continuous small amounts to cover unknown, relatively rare, but potentially severe risks. We should note that while (for fire risks in buildings) the need for fire brigades and monetary insurance is generally accepted, deductive principles cannot be proved.

Insurance systems are rooted in general probabilities and background information on possibilities. While actual premiums or effort can be argued in detail, the assumption that any cost or effort in these directions is worthwhile depends on a mind-frame. The relevant mind-frame focuses on the areas of ignorance rather than the areas of knowledge and is more concerned with the severity of possible effects than determining actual causes.

Although insurance is essentially a hedge against ignorance, effective insurance systems are largely restricted to well-studied and relatively stable situations. To date fisheries management has been preoccupied with data collection and coping with change - technological, economic, sociological changes as well as biological changes to stocks. When this is coupled with the practical necessity to investigate stocks separately, it is not very surprising that the mind-frame required for broad insurance systems rarely occurred.

None of the discussion above involves criticism or blame for any individual, it is just a flat statement that fisheries management, like all other management systems, cannot be perfected by attention to detail, and hence needs forms of broad insurance.

Inter-year variations: an example of the need for insurance

My own research interests cover a wide range - which is criticised by some - but the common thread is natural variation with time, epecially non-periodic inter-year variations. At all space scales, from biogeographic regions down to small pieces of reef habitat, there exist biologically-important variations between years, which can easily be missed by specialists or dismissed as rare accidents.

Most marine studies are short-term (less than 5 years). Most of the variation found is relatively small and/or regular (e.g. seasonal). Any exceptions cannot be properly investigated within the limited time-frame and tend to be ignored as 'noise' or explained away be special circumstances. Most long term-studies (including most fisheries data) are confounded by changes in methods, observers, aims, or other human-induced effects. However all the reliable long-term data sets we have show major, irregular interannual variations. Some of the changes are widespread and may be correlated with climate patterns like El Nino episodes, others are local and may reflect chaotic dynamics. This is true for all factors (physical and biotic) and all space scales. The available evidence strongly suggests that important but unpredictable interyear variations are the rule, not the exception.

Detailed, stock-specific, data-dependent, fisheries management is not equipped to cope with this type of variation. In the New Zealand snapper fishery, considerable work over the past 15 years established a strong correlation between sea temperatures and recruitment, which for a few years was successfully used to predict some of the dynamics. But the last 4 *successive* years have been cold to very cold (bad for recruitment). Snapper reach reproductive maturity and legally-takable size in about 4 years. No one can predict the *cummulative* effects of the recruitment losses. Even a doubling of the database (in time series or precision) would not have made any real difference. Four successive cold years have not occurred in the past 50 years. How much would you cut the quota? Would you have been less worried if 20% of the stock area was in 'no-take' reserves?

Postscript: Invented problems

After insisting that fisheries management should consider some new and wider issues, it is pleasant to close on a different note. Some problems now being posed are not worth any effort. One example is 'displaced fishing'. The idea is that something must be done to cope with the fishing that will be displaced from 'no-take' marine reserves. This is a classic invented problem. It assumes that fishing is a 'given', that displacement will occur, that this will cause problems, and that these need solving. Well, maybe, but first consider the other side of the coin.

The creation of 'no-take' marine reserves, will encourage divers, naturalists, students, tourists, photographers, scientists and families to visit these sites. The displacement of this educational /tourist/ recreational activity into the reserves could cause all sorts of problems within the reserves and deprive existing locations of their custom. What should be done about these problems? I submit that the only way to win these games is not to play. Fishing 'displaces' all the time, and in many ways. We have no real measure of this, still less any good evidence for the reasons. People displace their recreation and education too, for at least as many reasons and in even more directions. It is absurd to suppose that either of these possible sources of potential problems could be handled by detailed analysis, prediction and specific remedies.

The only viable approach is by principle:

If a few small marine reserves were located in selected places, these would probably maximise fishing displacement problems outside and tourist damage within, while minimising any chance of enhancement.

However, a network of marine reserves that represented all habitats and had sufficient total cover to ensure ecosystem support, would probably create better fishing along the boundaries, displace some into non-extractive recreation, minimise the chance of tourist pressure damage, and maximise the probability of restoration.

These principles and probabilities clearly indicate the way to go, but do not depend on any detailed specific predictions.

The assumption of the PDT report that " heavily populated areas" should be avoided when locating marine reserves (page A3) is understandable, but is not bourne out by New Zealand experience. The two most recent marine reserves established there are within the city limits of Auckland (population 1 million).

8. Conclusions and Recommendations

The New Zealand experience with 'no-take' marine is relevant to the south-eastern USA. In socio-political terms, New Zealand is reasonably similar. A 'western', democratic country with a pioneering tradition, moderate affluence, and a medium population density, where fishing is very important both in commercial and recreational terms, and the freedom to fish is generally regarded as a 'right'.

In New Zealand the first 'no-take' marine reserves were created only after lengthy campaigns by some sectional interests (scientists, divers and conservationists). The values of 'no-take' marine reserves were discovered by the general public and other sectional interests from experience with the first reserves. This, and comparisons with other marine resource management systems, has led to an increasing demand for more. The authorities are steadily moving to do this. All the major political parties now endorse the creation of further reserves and some are committed to 10%.

The history of New Zealand marine reserves is a story of slowly developing principles. In particular, it shows that fisheries science and management was trapped by assumptions about fishing rights and stock-related, data-based regulations. These assumptions are now unnecessary and are frequently counter-productive. While detailed management will always be needed, we also require non-specific insurance based systems - including a network of representative 'no-take' marine reserves.

The New Zealand experience supports the recommendations of the 1990 report by the Plan Development Team on the Marine Fisheries Reserves for Reef Fish Management, but strongly suggests that in order to achieve the public and political acceptance of 'no-take' marine reserves, it will be necessary to do two things:

Widen the appeal.

Talk about the sea, its range of life and its ecosystems, not just about catching fish.
Argue that the natural properties of the sea have many values other than extraction.
Insist that maintaining this system is essential and has many benefits.
Address the general public, especially the youngest, not just 'user-groups'.
Show that 'fisheries' is only one of many important issues in managing marine life.

Focus the discussion on principles

Avoid details. Make it clear that we are very ignorant about the sea, its life and processes, hence we need insurance.
Show that science, education, conservation, and recreation need undisturbed reserves.
Demonstrate that common sense and ordinary business practise require the provision of unexploited marine areas.
Admit that management has been too narrow in its aims. Upgrade 'managing fisheries' to 'managing marine ecosystems'.
Indicate potential benefits to various user groups, but insist that we cannot predict these in detail.

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