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An assessment of the threats to marine biodiversity and their implications for the management of State and Commonwealth fisheries

Colin D Buxton and Robert Kearney

FRDC Project 2010/226

August 2014

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FISHERIES RESEARCH & DEVELOPMENT CORPORATION

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TABLE OF CONTENTS

TABLE OF CONTENTS i
NON-TECHNICAL SUMMARY 1
ACKNOWLEDGEMENTS: 2
BACKGROUND 3
NEED 5
PLANNED OUTCOMES 6
OBJECTIVES 7
METHODS 7
RESULTS 7
CHAPTER 1 - Questionable Interpretation of the Precautionary Principle in Australia's Implementation of 'no-take' Marine Protected Areas 8
Abstract 8
1 Introduction 8
2 International development and use of the Precautionary Principle 9
3 Increased precaution in fisheries management 10
4 The evolution of no-take MPAs in Australia 10
5 Australia's selective interpretation of the Precautionary Principle to support MPAs 11
6 Australia's disproportionate representation of the threats from fishing 12
7 MPAs and precautionary fisheries management in Australia 14
8 International benchmarking of Australia's precautionary management of the effects of fishing 15
9 Concluding comments 16
Acknowledgements 17
References 17
CHAPTER 2: Australia's No-Take Marine Protected Areas: Appropriate conservation or inappropriate management of fishing? 20
Abstract 20
1 Introduction 20
2 The development of MPAs in Australia 20
3 Does closing areas to fishing provide adequate and appropriate protection against the effects of fishing? 23
4 The threats to marine biodiversity 24
5 Transposition of terrestrial paradigms into the marine realm 25
6 What does declaring an area as 'protected' actually mean? 26
7 Why did Australia assume fishing was the primary threat to be managed in MPAs? 27
8 The role of fisheries managers 29
9 Conclusions 30
Acknowledgements 31
References 32
CHAPTER 3: How terrestrial management concepts have led to unrealistic expectations of marine protected areas 37
Abstract 37
1 History of Reserves 37
2 Evolving Goals for Reserves 38
3 Primary differences between Marine and Land Environments 40
4 Measurement of Protection 41
5 Resource Use and Conservation 42
6 Terrestrial and Marine Conservation Management Practices 43

7 The Prominence of the CAR Principle in Australia's MPA Process 44
8 Conclusions 48
Acknowledgements 48
References 49
CHAPTER 4: When is spillover from marine reserves likely to benefit fisheries? 53
Abstract 53
1. Introduction 53
2. Methods 55
Population Dynamics 55
Spillover 56
Fishing 56
Net effect of the reserve on catch 57
3. Results 59
4. Discussion 61
Model outcomes 61
Empirical context 63
5. Conclusions 64
Acknowledgements 65
References 65
Appendix 1- Detailed derivation of Logistic MPA equilibrium 69
Population dynamics without a reserve 69
Population dynamics with a reserve 70
CONCLUSIONS 72
BENEFITS 75
Fisheries managers, the fishing industry, science and the community will all benefit from the outputs of the project 75
FURTHER DEVELOPMENT 75
APPENDICES 75
APPENDIX 1 – Intellectual property 75
APPENDIX 2 – Project staff 75

NON-TECHNICAL SUMMARY

2010/226	**An assessment of the threats to marine biodiversity and their implications for the management of State and Commonwealth fisheries**

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OBJECTIVES:

1. Investigate cases of real threats from fishing to fish stocks and/or biodiversity more generally in Australian waters, and alternative management strategies for sustainable fishing and the recovery of populations and areas that have been previously overfished.
2. Assess and discuss the threats to marine biodiversity from non-fishing related activities and the management strategies (or lack thereof) to combat these. This will include consideration of the principles of cost and effectiveness of potential amelioration strategies for fishing and non-fishing related activities (Note: It was not within the scope of this project to carry out cost-benefit analyses for individual strategies or fisheries).
3. Align the accepted benefits of 'reserves' where all fishing is excluded (such as for scientific reference points) with realistic expectations for 'off-reserve' benefits and the degree to which area management is an appropriate ecosystem-based approach to fisheries management for individual fisheries across the whole area of selected fisheries.

OUTCOMES ACHIEVED:

The main aim of the project, the publication of at least two peer-reviewed articles to defend the credentials of the Australian fishing industry, was achieved. At the time of writing three papers had already been published a fourth was in press.

With the announcement of the final configuration of a national system of marine protected areas in 2012 by the Commonwealth Government it is difficult to evaluate how this work has

influenced government policy, if at all. Hopefully, this will be more evident during the zonation process when decisions on the relative threat of fishing to the various areas are considered in the context of spatial closures and particularly no-take areas.

Through the life of the project we have activity engaged in the debate on how effective spatial management is, as well as the debate on the effectiveness of fisheries management in Australia. For example, much of the work in this study contributed to the formal evaluation of the MPA system in NSW through submissions by Robert Kearney (http://www.marineparksaudit.nsw.gov.au/submissions/submissions-received/), and with one of us (CB) serving on the panel of the NSW MPA enquiry.

This report and its associated publications have been widely disseminated to both Industry and Government to address common misconceptions about the sustainability of fishing as managed in Australia.

KEYWORDS:

marine protected areas, marine reserves, marine conservation, spatial management, fishery management, over-fishing, spillover, precautionary principle.

ACKNOWLEDGEMENTS:

This project was funded by the Fisheries Research and Development Corporation (FRDC), grant number 2010/226. Further financial and logistical support was provided by the Sydney Fish Market and the Institute for Marine and Antarctic Studies at the University of Tasmania.

We acknowledge the support of three post-doctoral researchers, Drs Paris Goodsell, Graham Fairbrother and Zoe Doubleday who worked on various aspects of the project.

Drs Klaas Hartmann and Caleb Gardner were co-authors on Chapter 4 and provided considerable support and advice on other aspects of the work.

Thanks are also given for the advice and editorial support offered freely by several reviewers of the papers.

We specifically acknowledge the contribution of Dr Paris Goodsell, who sadly and tragically passed away before the study was completed.

BACKGROUND

The debate over the commitments that Australia has made or should make to the conservation of marine biodiversity and how these should be incorporated into fisheries management is active, but the issues are by no means resolved. Unfortunately, there is considerable uncertainty surrounding the application of the basic approach - bioregional planning - and even what the term itself means for current fisheries management. Many stakeholders, particularly commercial and recreational fishers, remain confused and consequently sceptical of the espoused benefits for marine biodiversity from area management of fishing. This is particularly because the current approach is not based on aligning identified threats from fishing with the areas proposed for closure. The authors remain deeply concerned that area management is particularly ineffective for the management of the major threats to marine biodiversity, notably pollution and introduced organisms and that this is not recognised in the bioregional planning process.

It is widely claimed and uncritically accepted that well-designed, spatial management of fishing and other threats can have benefits for marine biodiversity and that marine protected areas or marine parks have a role to play in resource conservation and allocation. Unfortunately, much of the argument for spatial closures to conserve biodiversity is based on examples drawn from overseas, often from third world countries where fisheries are poorly managed. Furthermore, results from a particular situation, for example increased biomass in reef areas previously subjected to excessive or inappropriate fishing, have been uncritically used to promote reserves in unrelated situations such as estuaries and ocean beaches and in all types of areas where fishing has been assessed to be sustainable. There is an urgent need to synthesise the relevant science about the threats to marine biodiversity, the benefits of effective fisheries management and the role of area management (Marine Parks and Marine Protected Areas) in the conservation of Australia's marine biodiversity and the impact of such actions on fisheries management. To play an appropriate and impacting role in the debate and on policy decisions, it is imperative that this assessment is of a standard acceptable for publication in the peer-reviewed scientific literature and that it is publicly debated by those qualified to provide constructive comment.

Australia's fishing industries (commercial and recreational) are under constant pressure from an Environmental Non-Government Organisations (ENGOs) sector calling for the establishment of more Marine Protected Areas (MPAs), much of which argues without providing evidence that fishing remains a key threatening process for marine biodiversity in all areas in which closures are proposed. Proposals for additional closures often ignore the substantial improvements that have been made in the management of Australian fisheries over the past decade and the progressive decrease in the number of species overfished or threatened by fishing[1]. Importantly, in recent years the management of Australian fisheries has given much greater priority to the conservation and sustainability of targeted resources, reduction in the amount and type of by-catch and the protection of the environment which supports targeted resources, under the accepted banner of ecosystem-based management of fisheries. The environmental performance of Australia's fisheries is assessed under relevant conservation acts, such as the Commonwealth EPBC Act 1999, and most fisheries have been approved and under a process of continuous improvement. Thus there are very different

[1] Wilson D, Curtotti R, Begg G (2010). Fishery status reports 2009: status of fish stocks and fisheries managed by the Australian Government. Bureau of Rural Sciences & Australian Bureau of Agricultural and Resource Economics, Canberra

management approaches that are not well integrated – the EPBC accreditation process tends to be based on regulation of harvests and gear in specific fisheries to protect biodiversity, while the MPA approach is based upon complete exclusion within spatial closures.

Australia has a definite commitment to a system of marine protected areas in Australian waters[2], but the terms 'Marine Protected Areas' and 'Marine Parks' (MPs) are frequently confused and incorrectly asserted to be synonymous. Marine Parks or Marine Reserves is a term used to denote an area of non-extractive use or even higher levels of protection, whereas fishing and other extractive uses may be allowed in an MPA. Australia's current commitment also requires that conservation measures be cost-effective and proportionate to the identified risk[3], but relevant alignment of costs with properly assessed benefits is sadly, often lacking. Fishing has been assumed by most advocates of MPs to be a significant threat to biodiversity. This is despite the fact that there are very few cases in Australia where fishing of all types has been documented as a significant threat. The degree to which MPs are an efficient and cost-effective way to protect marine biodiversity in every situation even against those forms of fishing which may be a threat needs to be assessed. Area management is seldom an adequate management tool for individual fisheries and the same area is even less likely to be relevant to a collection of fisheries. Unfortunately, many MPAs in Australia project only fishing closure as a biodiversity conservation measure, even though fishing was not identified as the major threat to the relevant ecosystems. In reality, spatial closures or restrictions of fishing are being repeatedly confused with proper protection of marine biodiversity.

Key stakeholders in the fishing industry have raised concern about the demonisation of fishing by advocates of MPAs. Much of the case against the fishing sector is based on high-profile fisheries collapses in other parts of the world (e.g. cod in Canadian waters, pilchard and white abalone in Californian waters and anchovy in Namibian waters), which had been caused by inadequate, or in many cases a complete absence of, fisheries management. Most fisheries management in Australia using traditional techniques is far from inadequate and has collectively been lauded as among the best in the world[4] and it continues to improve. Where fishing has been identified as a threat, good fisheries management across the entire area of the fishery will most often provide appropriate protection against fishing. The prevention of fishery collapses obviously has benefit for fishing harvests and for protection of biodiversity – however the policy choice is what tools best reduce this risk of collapse. One research need here is to evaluate to what extent MPAs protect against fishery collapses and whether they represent the most appropriate management tool for this objective.

Much misinformation about Australian fisheries management has been put forward by advocates of fishing closures and supported by sensationalised media. This has fuelled subsequent public misconception about the management and sustainability of commercial and recreational fisheries in Australia. It also distracts management attention away from identifying and addressing all of the numerous threats to Australian marine biodiversity. It is necessary therefore, to have defensible and transparent assessment of the actual threats to

[2] DEWHA (1992). National Strategy for Ecologically Sustainable Development. Department of the Environment, Water, Heritage and the Arts, Canberra

[3] DEWHA (1992). Intergovernmental Agreement on the Environment. Department of the Environment, Water, Heritage and the Arts, Canberra

[4] Alder J, Cullis-Suzuki S, Karpouzi V, Kaschner K, Mondoux S, Swartz W, Trujillo P, Watson R, Pauly D (2010). Aggregate performance in managing marine ecosystems of 53 maritime countries. Marine Policy 34: 468-476

biodiversity from fishing and other activities in Australian waters and demonstration of the effectiveness of the management response. Assessments of fisheries management as a conservation tool will not only be a vital component of better information for the general public but they will also greatly help to identify where additional biodiversity conservation measures are necessary and appropriate. Likewise, there should be review and evaluation of the suggestions that marine parks are an appropriate biodiversity conservation measure regardless of the situation and that fishing can be managed in isolation from other threats to biodiversity.

It is nationally acknowledged in legislation that Marine Protected Areas are not intended to be the only means of conservation of marine resources, but to date governments have largely ignored the need to address all threats at their source to better 'protect' marine biodiversity. In recent debates about establishing MPAs in Australia, the threat of fishing to marine biodiversity is highlighted disproportionately to other threats such as pollution, introduced organisms, habitat degradation and climate change. Likewise the management of biodiversity threats from fishing have disproportionately focussed on the use of MPAs. Management of biodiversity threats from non-fishing related sources are sometimes mentioned, but seldom addressed and few studies have explicitly attempted to tease out the relative impact of different threats. Governments are unfortunately often unwilling to address marine biodiversity issues for which the solutions could be expensive and in many cases unpopular.

This research project was designed to address several strategic challenges confronting the sector including understanding the impacts of fishing and demonstrating the improvements in fisheries management. It will build on years of research and publications and presentations (including those in the grey literature) to produce valid, defensible assessments of the impact of spatial closures and area management on commercial and recreational fishing industries. It aims to help identify the most appropriate role of these industries in conserving marine biodiversity throughout Australia. By providing these assessments to the standard demanded by quality scientific journals, their contribution to the public policy debate will be greatly enhanced.

NEED

This research addresses many priorities under FRDC strategic RD&E themes. The project will: "provide information to the community to demonstrate improvements in the fishing industry's environmental performance" (Theme 2. Habitat and ecosystem protection) and "incorporate understandings of the cumulative impacts of fishing into fisheries management plans" (Theme 4 - Ecologically sustainable development) via detailed and careful evaluation of the potential and real threats of fishing to the marine environment. In addition, 'user-friendly' versions of the publications will "better inform the community's perceptions of the industry and to increase support for the industry". The possibilities for better presenting Australia's credentials as responsible fisheries managers will be enhanced.

One of the goals of AFMA as outlined in their Corporate Plan 2010-2014[5] is to improve the

[5] AFMA (2010). Corporate Plan 2010-2014. Australian Fisheries Management Authority, Canberra

efficacy and cost-effectiveness of fisheries administration (this concept is echoed in all Australian states and territories but the actual wording differs). The research proposed here will provide an evaluation of the degree to which fishing does actually represent a threat to marine biodiversity and the cost-effectiveness of traditional fisheries management for ameliorating that threat(s) compared as far as possible with the threats to biodiversity and fisheries from other sources. This will be vital to clarifying the current confusion between fisheries management and biodiversity conservation. These assessments are critical to improving fisheries management strategies and making them more cost-effective and proportionate to environmental problems (a requirement of the Intergovernmental Agreement on the Environment). In light of national commitments to establish a comprehensive system of representative marine protected areas by 2012, peer-reviewed publications will prove an invaluable and urgently needed tool to defend the credentials of the Australian fishing industry and to more appropriately position fishing interests in the decision making process.

PLANNED OUTCOMES

The project intends to provide industry and governments with scientifically verified assessments of the commitments Australia has to biodiversity conservation and the correct role of fisheries and biodiversity management including the role of reserve management. This is an essential step in balancing and progressing the debate about how marine biodiversity is most effectively managed including the understanding of the conservation benefits of proper fisheries management and the need and utility of reserves. The publications produced will be extremely important for the defence of the effective management of fisheries in Australia. The failure of fisheries management agencies and the fishing industries (commercial and recreational) to publicly counter claims that Australia's fisheries management is not sustainable, is one of the most critical deficiencies in Australia's strategic approach to the future of fishing.

Consumer-targeted versions of the information will allow public access to the science that underpins Australia's biodiversity conservation and the management of fisheries and biodiversity. This will promote the environmental credentials and perception of the fishing industries and address common misconceptions about the sustainability of fishing as managed in Australia.

OBJECTIVES

1. Investigate cases of real threats from fishing to fish stocks and/or biodiversity more generally in Australian waters, and alternative management strategies for sustainable fishing and the recovery of populations and areas that have been previously overfished.
2. Assess and discuss the threats to marine biodiversity from non-fishing related activities and the management strategies (or lack thereof) to combat these. This will include consideration of the principles of cost and effectiveness of potential amelioration strategies for fishing and non-fishing related activities (Note: It was not within the scope of this project to carry out cost-benefit analyses for individual strategies or fisheries).
3. Align the accepted benefits of 'reserves' where all fishing is excluded (such as for scientific reference points) with realistic expectations for 'off-reserve' benefits and the degree to which area management is an appropriate ecosystem-based approach to fisheries management for individual fisheries across the whole area of selected fisheries.

METHODS

The project was a desk top study based on information abstracted from government policy documents, scientific publications and grey literature reports. More detail on the methodology is provided in the individual chapters below.

Prof. Kearney was supported by a post-doctoral research fellow (Dr Paris Goodsell from 1/1/2011-8/7/2011 and Dr Graham Fairbrother 1/8/2011-30/6/2012) who assisted with analyses, document acquisition and review. Dr Goodsell was based at the Sydney Fish Markets and Dr Fairbrother at the University of Queensland.

Prof. Buxton was supported by a post-doctoral research fellow, Dr Zoe Doubleday, for the period 1/3/2011-7/10/2011 and worked at the Sydney Fish Markets for periods of the project.

RESULTS

The study produced four publications (three already published and accepted), each of which is the subject of an individual chapter in the sections below. They are:

Chapter 1 – Questionable Interpretation of the Precautionary Principle in Australia's Implementation of 'no-take' Marine Protected Areas. Published in *Marine Policy* **36** (2012) 592–597.

Chapter 2 – Australia's no-take marine protected areas: Appropriate conservation or inappropriate management of fishing? Published in *Marine Policy* **36** (2012) 1064–1071.

Chapter 3 – How terrestrial management concepts have led to unrealistic expectations of marine protected areas. Published in *Marine Policy* **38** (2013) 304-311.

Chapter 4 – When is spillover from marine reserves likely to benefit fisheries? Published in *PLoS ONE*. (2014) 10.1371/journal.pone.0107032

CHAPTER 1 - Questionable Interpretation of the Precautionary Principle in Australia's Implementation of 'no-take' Marine Protected Areas

R. Kearney, C.D. Buxton, P. Goodsell and G. Farebrother

Abstract

Marine protected areas (MPAs) have been promoted as viable measures to conserve marine biodiversity and ensure the continuance of ecological processes. Within the realm of environmental management, precautionary approaches to ameliorate specific threats are encouraged when scientific understanding of these threats is not complete. In expanding, or overextending, accepted definitions of the Precautionary Principle, the utilisation of precautionary approaches, within Australia, has been re-defined and used to promote the establishment of 'no-take' MPAs. This overextension has the unintended consequence of undermining the value of existing and on-going assessments and management of marine impacts and threats. It is also not consistent with accepted international norms and intergovernmental agreements within Australia that stipulate the implementation of proportionate, cost-effective measures to manage human environmental impacts. The introduction of MPAs in Australia has been closely associated with an increase in 'no-take' zones that affect all forms of commercial and recreational fishing, despite international recognition that Australian fisheries are well managed according to ecological sustainable development guidelines. Furthermore, it is recognised within Australia that most MPAs are not designed to provide protection from the full suite of known threats that can affect biodiversity and long-term ecosystem viability. By directing MPAs towards comprehensive no-take zones that affect a fishing industry that is already required by state and federal legislation to adhere to sustainable practices, other threats affecting both protected and unprotected areas can be left unmanaged. It is shown in this paper that Australia's modified definition of the Precautionary Principle is not in keeping with accepted international definitions and guidelines for its utilisation. It is argued that its use to justify a predetermined output (MPAs) devalues the sound use of scientific assessment and diminishes the conservation outcome. Furthermore, by distracting efforts from determining and managing the full suite of recognised threats, the value of what protection is provided in Australia's marine *protected* areas is eroded further.

Keywords: marine protected areas, conservation, precautionary principle

1 Introduction

The Precautionary Principle rose to international prominence following its inclusion in the *Rio Declaration on Environment and Development* [1]. In fact its acceptance as a 'principle' appears to be, at least in part, a result of the precautionary approach having been described as *"Principle 15"* in the Rio Declaration [1]. However, different views exist on the fundamental bases of the Principle, including what precaution actually is [2]. Consequently, the Principle and how it should be used are subject to much interpretation. In its laudable pursuit of sound marine conservation, Australia has interpreted the need for a precautionary approach as a requirement to create more marine protected areas (MPAs). It has taken this to the extent of

developing a significantly variant definition of the Principle. The justification for this action and the wisdom in taking it are questioned in this paper. In view of Australia's prominence in the global push for MPAs the Australian case is of international significance.

2 International development and use of the Precautionary Principle

The Rio Declaration [1 (Principle 15)] describes the precautionary approach and its use in the context of environmental conservation as, "*[w]here there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation"*. The subsequent FAO paper which further described conditions for the application of the precautionary approach to fisheries management and species introductions [3] endorses this definition and the principles implied in it.

Multiple negative notions in the common definitions of the Principle cloud its purpose and intent and weaken the compulsion for action [2]. There are four negative notions in the Rio Declaration; *lack* of certainty shall *not* be used to *postpone* measures to *prevent degradation*. The diminution of precision resulting from these negatives also creates difficulty in achieving uniform understanding of when and how the Principle should be applied. This, in turn, increases scope for its misuse. It also increases the difficulty in identifying where or when the Principle has been inappropriately invoked.

In spite of imprecision and some ambiguity in most commonly used definitions of the Principle, the intent of the Principle is clearly not to allow the lack of (scientific) certainty to be used to prevent action that should be taken against identified threats of serious or irreversible damage. Recent reviews (e.g., UNESCO 2005 [2] and IUCN 2007 [4]) confirm that identification of a threat, and determination that that threat is significant, should be key prerequisite steps in accepting the application of the Principle. Logical management practice would determine that the first precautionary response to the recognition that there is a problem would be to determine, in so far as possible, the cause of the problem; that is to identify the threat(s). Following the identification of significant threat(s), threat analyses should then determine how best to address them.

It is not consistent with the Principle to allow scientific uncertainty to negate the necessity to assess whether any particular action or event is a threat. Nor is it appropriate to assume that a threat, once identified, is sufficiently significant to uncritically trigger precautionary action. The need for precaution should not be used to provoke or justify an assumption that something is a threat without sufficient evidence: UNESCO 2005 states, "*Some form of scientific analysis is mandatory; a mere fantasy or crude speculation is not enough to trigger the PP*" [2 p.13].

Equally importantly, under international guidelines the Precautionary Principle does not mandate what management strategy needs to be taken after a significant threat has been identified; presumably because it is assumed that management measures will be selected on the basis of which measure is assessed to be the most appropriate to address each significant threat in each situation.

In accordance with the specific wording of the Rio Declaration [1], quoted above, and also in accordance with normal good governance, actions that are taken should be cost-effective.

Accepting that an action is cost-effective implies that the relative merits and costs of alternative actions have been equally assessed. It is not good management, precautionary or otherwise, to take action against an assumed threat while ignoring other threats about which there may be less uncertainty.

3 Increased precaution in fisheries management

Through the 1980s and 1990s there was increasing global recognition of escalating threats to marine ecosystems [3, 5-7]. Assertions that the world's fisheries were being overexploited, particularly in large industrial fisheries and fisheries adjacent to high human population densities [5, 8, 9] fuelled concerns that existing fisheries management was inadequate to protect ecosystems that were being threatened by destructive fishing practices and/or excessive fishing effort. Existing acceptance of benefits from terrestrial reserve-type conservation measures reinforced the call for similar area-based approaches in marine environments. The assertion that traditional fisheries management had failed strengthened the perception that exclusion of fishing from at least key areas was an essential, or at least precautionary, action to conserve fisheries resources and protect marine biodiversity (see for example [7, 10, 11]). Uncritical combination of these individually supportable notions spawned an international movement for more area management in most marine environments, primarily by restricting fishing, in no-take MPAs.

4 The evolution of no-take MPAs in Australia

Under the National Strategy for Ecologically Sustainable Development [12], Australia confirmed its commitment made in the 1991 Ocean Rescue 2000 initiative [cited in 12], to "develop a National Representative System of Marine Protected Areas" [12 p.27]. All states and territories agreed to this approach through the Inter-Governmental Agreement on the Environment [13]. This planning framework enabled Australian governments, both state and Commonwealth, to work towards Australia's international commitments later agreed to within the Convention on Biological Diversity [14]. The commitment progressively evolved to become part of the Marine Bioregional Planning process [15, 16]. During this evolution MPAs were uncritically promoted as being an internationally recognised effective mechanism for conserving marine biodiversity and promoting the continuance of ecological processes [17].

Australia has been at the forefront in declaring marine parks (13.2% by area of the global total were under Australian administration by 2005 [18]) with fishing closures in 'sanctuary zones' being the prominent management action within parks. The strong commitment to MPAs is further demonstrated by the area of the national MPA estate more than doubling between 1995 and 2007 to an estimated total of some 920,000 km2 [19]. The overall intention of this implementation process was clearly to provide a framework that was in line with international commitments and to provide conservation benefits. The acceptance by governments of the political benefits of having public awareness and favourable opinions of 'marine protected areas' has, however, resulted in areas being declared as 'protected' well in advance of scientific assessments of the provision of actual protection or determinations of cost-effective environmental or social outcomes being performed.

Fishing closures were the primary management measures in sanctuary zones in most marine parks in spite of a lack of assessments that confirmed that fishing actually represented a threat, let alone the primary threat. When doubts concerning the effectiveness of existing management were expressed, the need for precautionary action in the form of MPAs was a common defence, even when there was scientific uncertainty about the efficacy of such action. Such a defence was not consistent with accepted definitions of the Precautionary Principle, including the Rio definition. A new definition of the Principle was developed specifically for the implementation of the National Representative System of Marine Protected Areas (NRSMPA) [17]. This definition states that "The absence of scientific certainty should not be a reason for postponing measures to establish MPAs to protect representative ecosystems" [17 p.16]. Australia's development and use of this definition and its deviation from more common interpretations of the Principle are questioned in this paper. Also considered is the degree to which this new definition of the Precautionary Principle justifies, or supports, actions such as 'no-take sanctuary zones' within Australia's MPAs under the assertion that they will 'protect representative ecosystems', [17].

5 Australia's selective interpretation of the Precautionary Principle to support MPAs

Within Australia the InterGovernmental Agreement on the Environment [13 pp.13-14] defined the Precautionary Principle and conditions for its application in environmental management as:
"Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by: (i) careful evaluation to avoid, wherever practicable, serious and irreversible damage to the environment; and (ii) an assessment of the risk-weighted consequences of various options." This definition is very closely aligned with internationally accepted definitions of the Principle [2, 4]. However, the definition of the Principle that was developed (as quoted above) specifically for the NRSMPA [17 p.16] is not. By stating that "[t]he absence of scientific certainty should not be a reason for postponing measures to establish MPAs …" [17 p.16], this later variant definition appears to seriously distort both the intent and the internationally agreed definition of the Principle [1, 2, 4]. It is also at odds with the version of the definition that Australia had agreed should be used for environmental management [13]; it demands an output in the form of MPAs as opposed to facilitating the outcome of precautionary protection against thoroughly assessed threats. There is seldom scientific certainty about environmental or ecosystem issues and to claim, as ANZECC TFMPA 1999 [17] does, that this uncertainty should be used to drive a predetermined course of action in the establishment of MPAs, the efficacy of which for variant situations is itself uncertain, is contrary to the intent of the Principle.

Furthermore, by asserting that MPAs should be used "to protect representative ecosystems" [17 p.16 & 50] the specific ANZECC TFMPA definition of the Precautionary Principle is clearly based on a fundamental, but scientifically questionable, assumption that MPAs, as implemented in Australia, will actually 'protect representative ecosystems'. Such an unqualified claim implies acceptance that MPAs will provide protection of all designated representative ecosystems against significant threats, including those about which there is scientific uncertainty. The resulting assumption has been accepted to the extent that the definition requires that MPA implementation should not be delayed even in the absence of

scientific certainty about the adequacy of MPAs to protect representative ecosystems, or their cost-effectiveness to do so.

A component statement in the expanded ANZECC TFMPA 1999 definition states, "[i]f an activity is assessed to have a low risk of causing serious or irreversible adverse effects, or if there is insufficient information with which to assess fully and with certainty the magnitude and nature of the effects, decision making should proceed in a conservative and cautious manner" [17 p.16]. The first alternative in this statement describes an intent that is diametrically opposed to agreed interpretations of the Precautionary Principle. If an activity has been assessed to have low risk the need for precautionary management has been removed. In such circumstances it is not appropriate to invoke the Precautionary Principle to slow or otherwise influence decision making [2].

Further flaws in the ANZECC TFMPA interpretation of the Principle and how it has been used specifically for the NRSMPA are demonstrated by consideration of Australia's stated conditions for the use of the Precautionary Principle specifically for environmental management [13], quoted above. The 1992 definition is itself not immune from imprecision and uncertainty. This uncertainty arises, at least in part, from the multiple negative notions in the definition that are similar to those discussed above for the definition in the Rio Declaration. As a consequence additional importance must be assigned to the guidelines for the application of the 1992 definition that follow its definition.

The first guideline, quoted above, begins with a requirement for "careful evaluation" of how best to avoid "serious or irreversible damage to the environment" [13 p.14]. Unfortunately there is little evidence that this requirement was met adequately in the development or implementation of Australia's NRSMPA. The process of developing the NRSMPA appears to have failed this requirement on two primary counts: first, evaluation of which threats were most likely to cause serious or irreversible damage to the environment appears not to have been sufficiently 'careful' (rigorous or holistic); and second, careful evaluation of how best to avoid the impacts of each of the most significant threats, if carried out, appears not to have been given appropriate prominence in the NRSMPA process. Support for circumventing these two basic requirements of careful evaluation within the NRSMPA process was specifically provided by the change in the definition of the Precautionary Principle to state that "[t]he absence of scientific certainty should not be a reason for postponing measures to establish MPAs…" [17 p.16].

6 Australia's disproportionate representation of the threats from fishing

Australia appears to have failed to ensure careful evaluation of which threats were most likely to cause severe or irreversible damage and failed to base conservation measures on addressing these threats. A number of key threats to Australia's marine ecosystems had been identified in documentation used to guide the development of the NRSMPA. These threats were determined to include habitat loss and degradation, declining water quality and sedimentation, the unsustainable use of marine and coastal resources, and impacts from introduced marine pests [20]. The Strategic Plan of Action for the NRSMPA lists a series of goals for the NRSMPA, "[t]he primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative system of MPAs to contribute to the long-term ecological viability of marine and estuarine systems, maintain ecological processes and systems, and protect Australia's biological diversity at all levels." [17 p.1]. Actions that were

taken by the states and Commonwealth in implementing MPAs show that even if there was a careful and uniform evaluation of each and every threat to 'maintain ecological processes (...) and protect Australia's biodiversity (...)' these were not translated into actions in the NRSMPA process. For example, in New South Wales, it was acknowledged that the very serious threats from factors such as pollution and introduced pests were deliberately not accommodated in the design and declaration of MPAs, "(...) while marine park zoning arrangements currently are not designed to address all the threats to the oceans such as pollution, disease, invasive species, and climate change, they can contribute (emphasis added) to an improvement in the overall health of marine ecosystems" [21 p.10]. Detail on how, when and where they could contribute was not provided.

In all states and the Commonwealth, detail was not provided on how threats that would not be addressed by MPAs would be ameliorated by other management actions. As such, there was no mechanism to assess that commitments to conservation and protection would "not be disproportionate to the significance of the environmental problems being addressed" as required under the InterGovernmental Agreement on the Environment [13 p.13].

Australia's agreed definition of the Precautionary Principle for environmental management [13], that is in agreement with other global definitions, states that the Principle should be applied to address serious or irreversible damage. In accordance with this agreement, all Australian MPAs that include 'sanctuary zones' where all fishing is prohibited inherently imply an assumption that all forms of fishing are a threat of serious or irreversible damage. It also appears to have been unjustifiably assumed that blanket bans on all forms of fishing are an expression of proportionate management of threats as required under the InterGovernmental Agreement on the Environment [13]. Fundamental to the consequent inappropriate allocation of management effort is the failure to differentiate the severity and reversibility of the individual threats from each of the many different forms of fishing and to assess their varying impacts in different types of environments.

The second guideline for Australia's use of the Precautionary Principle [13 p.14] requires "an assessment of the risk-weighted consequences of various options". 'Various options' for managing key known threats, such as introduced organisms, the impacts of which are commonly irreversible in marine environments, and pollution, which is often extremely serious and may be effectively irreversible, were not obviously identified. 'Risk-weighted assessments' of the consequences of management options for each of these threats in each of the areas proposed to be 'protected' if carried out, appear not to have been included in the MPA process. Again the modification of the definition of the Precautionary Principle that was specifically developed for the NRSMPA [17] supports avoidance of these critical steps.

Had the options for managing each threat been the subject of appropriate assessments it would likely have been apparent that area management, such as is incorporated in the NRSMPA, represented an inappropriate or at least inefficient mechanism for the management, precautionary or otherwise, of many recognised threats, including those from certain forms of fishing. The highly interconnected and/or mobile nature of many marine or estuarine environments and the species therein renders area management relatively ineffective against numerous threats, particularly those from invasive vectors such as pollution and introduced organisms.

7 MPAs and precautionary fisheries management in Australia

Instead of assuming that fishing closures were an essential requirement in the management of Australian MPAs, consideration of the alternatives for managing identified adverse effects of fishing would appear to have been a better priority. Assessment of the likelihood of subsequent action being appropriately precautionary and of producing cost-effective outcomes is another essential step that appears not to have been given appropriate priority.

Fisheries legislation covering the waters of each state and the Commonwealth of Australia was either in place or being refined in parallel to the development of the NRSMPA. Current legislation mandates that fisheries must be sustainably managed and that they must be routinely assessed as being so [22]. Furthermore, the various fisheries management acts require protection of marine habitats and environments that might be impacted by fishing. Where overfishing or other significant damage from fishing occurs, a recovery plan is usually mandatory (see for example the NSW Fisheries Management Act 1994 [23]).

In Australia, the assessment of fisheries is made according to the principles of Ecologically Sustainable Development (ESD) [12, 22]. In the case of Commonwealth managed fisheries and other fisheries from which products are exported, they must not only comply with the relevant fisheries management acts but they must also meet the conservation requirements of the overarching Environment Protection and Biodiversity Conservation (EPBC) Act [24]. This mechanism "allows the Australian Government to assess the environmental performance of fisheries and promote ecologically sustainable management" [22]. As a result, fisheries are required to be assessed to be sustainable and not be a serious or irreversible threat to either fishery resources or to biodiversity more generally. Where even minor threats are identified as a result of these assessments, it is usually prescribed under the Act that actions must be taken to address such threats.

Fishing that is inadequately managed can represent serious threats to fish stocks and some ecosystems. This has been most clearly demonstrated wherever there have been destructive fishing practices and/or there has been little if any governance of fishing, such as in some developing countries and in some internationally managed fisheries where effective cooperative management has remained elusive [25]. However, Australia is effectively an island and it has sovereignty over almost all of its fisheries resources. Its various fisheries management and conservation acts require conservative use of resources and mandate regulation of undesirable impacts. When these acts are adequately enforced, as they are required to be by all state and Commonwealth governments, fishing should by law not represent a serious ongoing threat. As previously indicated, where and when threats from fishing are determined to be unacceptable recovery plans are mandated.

Furthermore, Australia's fisheries had been internationally recognised to be well managed well before any influence from MPAs [26]. Where there have been shortcomings the effectiveness of recovery action by traditional fisheries management measures is impressive and improving (discussed below). Such measures have in some cases included area closures for certain gear types. In correct combinations and with firm governance, traditional fisheries management techniques have been demonstrably effective for addressing the problems for species that had been previously overfished, or where fishing had caused excessive incidental impacts. The most recent report on the status of Commonwealth managed fisheries [27] confirms that in the six most recent years for which data are available, 2004-2009 inclusive, the percentage of fisheries that were assessed and were found to be sustainably managed has more than doubled (27.0% - 58.4%). During the same period the percentage of total assessed

stocks found to be overfished fell by more than a third (18.9% - 11.9%) [27 p.14]. The record of fisheries management in the states is arguably even more impressive: for example the most recent assessment (data up to 2008/09) in New South Wales states that only four of the 104 assessed species that are managed by that State (108 species were assessed but at least two of these were managed by the Commonwealth and several were jointly managed) are 'overfished' and recovery plans are already either under-way or being developed for three of these and will soon be developed for the fourth [28 p.v].

The recent record of the use of existing fisheries management techniques in Australia confirms that few if any forms of fishing currently in use in this country represents a serious, irreversible threat to at least the target species that have been assessed. The stability of fisheries production in most fisheries also suggests that threats from fishing to the sustainability of the habitats that are essential for the wellbeing of these species are also not serious. The record of recovery of those species that had been overfished and then subjected to recovery management confirms that even where the threats are serious they are not irreversible. Furthermore, the wide variety of gear-types used and species fished in Australia that have been demonstrated to be responsive to traditional management suggests that ancillary species or ecosystems that may be impacted, but not yet assessed, would be equally responsive to appropriate, targeted controls by traditional fisheries management methods. Where other serious and undesirable impacts of fishing on habitats or ecosystems are detected these are required to be rectified under fisheries legislation and/or the EPBC Act. Information on the performance of fisheries management in recent years strongly suggests that fishing in Australia is not a poorly managed or irreversible threat.

8 International benchmarking of Australia's precautionary management of the effects of fishing

The degree to which Australia's traditional management and conservation of fisheries and associated marine resources meets international expectations for precaution can be gauged by assessment against the UNESCO Working Definition of the Precautionary Principle. This working definition gives greater emphasis to the social and ethical requirements for precaution and the needs and measures for morally responsible action. It states:
"When human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm.
Morally unacceptable harm refers to harm to humans or the environment that is
(a) threatening to human life or health, or
(b) serious and effectively irreversible, or
(c) inequitable to present or future generations, or
(d) imposed without adequate consideration of the human rights of those affected." [2 p.14].

The need for additional precaution in the form of MPAs, against the effects of fishing, is considered against each of the components of this working definition:
(a) Fishing in Australia is not in itself 'threatening to human life or health', except to some individuals who fish. To these individuals, assuming they fish voluntarily, the potential harm is not morally unacceptable. Fishing does, however, provide considerable benefits to human life and health through the lifestyle and, increasingly acknowledged, health benefits of seafood. Thus, where there are well-managed fisheries, the Precautionary Principle should

not be applied to invoke additional types of management, such as MPAs, on account of threat to human life or health.
(b) As discussed above, most forms of fishing as managed in Australia do not represent 'serious and effectively irreversible' harm to humans or the environment.
(c) Fisheries that are sustainably managed according to Australia's underlying principles of ESD, that contain a core objective to "provide for equity within and between generations" [29 p.8] are, by definition, required not to be 'inequitable to present or future generations'. Fisheries that are appropriately assessed to be sustainably managed in accordance with ESD should not be subjected to additional forms of management on the grounds that it is necessary according to the Precautionary Principle.
(d) Fishing in Australia is not 'imposed without adequate consideration of the human rights of those affected'; indeed well managed fishing provides either an essential service in the form of the sustainable supply of seafood to the total population, or a source of recreation and supplement of seafood to indigenous and recreational fishers who constitute approximately 20% of the population [30].

As discussed above Australia continues to improve its fisheries management by traditional techniques. Fisheries management is certainly becoming increasingly effective and is not becoming more elusive or difficult. It is significant that the UNESCO review of the Precautionary Principle [2 p.51] identified three primary scenarios when the Principle is not appropriate. The third of these conditions is met "when the harm is reversible and it is likely that effective counter-action is not becoming more difficult or costly (...)".

It is also apparent from international norms that the burden of proof for the justification of action under the Precautionary Principle rests with the proposers of the new activity (see for example UNESCO 2005). The FAO definition of the precautionary approach in relation to fisheries also states that "the standard of proof to be used in decisions regarding authorization of fishing activities should be commensurate with the potential risk to the resource, while also taking into account the expected benefits of the activities" [3 p. 7]. The burden should not be placed on those carrying out existing activities that are sustainably managed and have been assessed as not creating serious and irreversible harm, such as fishing performed in accordance with Australian law. In the case of proposed closures of fishing activities that have been certified by governments as sustainable, in the absence of evidence that these assessments are incorrect, the burden of proof should rest with the proponents of fishing closures in MPAs, and not with the fishing industries or fisheries management agencies. If such closures are proposed as a necessary precautionary response then to be consistent with internationally accepted definitions this proof should include compelling evidence that all fishing activities for which closures are proposed constitute a serious or irreversible threat. It should also include proof that where there are identified threats from fishing, blanket bans on all forms of fishing in no-take components of MPAs represent a more cost-effective management option than the refinement of traditional fisheries management that is targeted at the specific fishing technique(s) that represents the threat, across the whole area in which that threat exists.

9 Concluding comments

In the early 1990s Australia recognised the need for more precautionary management of biodiversity and natural resources generally. In the marine realm more stringent management of fishing, primarily by tighter controls on catches and gear modifications in areas where

these were assessed to be necessary, achieved obvious and almost immediate results. However, Australia's impressive fisheries management performance did not dampen enthusiasm by proponents of marine parks for more areas to be closed to all forms of fishing, even in the absence of assessed threats from fishing.

In Australia to date, there is a paucity of scientific assessment of actual benefits from closing areas to all forms of fishing but the lack of scientific certainty has been commonly countered by the claim that fishing closures in MPAs are a necessary precautionary action. The alignment of the call for more fishing closures with precaution appears to have been of such priority for proponents of MPAs that a specific definition of the Precautionary Principle was developed and adopted for the implementation of the NRSMPA. This specific definition distorts the intent of both the internationally accepted definition and Australia's pre-existing nationally agreed definition of the Precautionary Principle. It exposes advocacy for fishing closures in MPAs at the expense of appropriate resolutions of the scientific uncertainty relating to how best to achieve cost-effective conservation outcomes.

Australia appears to have allowed mis-interpretation of the Precautionary Principle to support the call for more 'no-take' MPAs. This has in turn helped distract efforts from adequately assessing the full range of threats to marine ecosystems and the provision of precautionary management of each of them.

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CHAPTER 2: Australia's No-Take Marine Protected Areas: Appropriate conservation or inappropriate management of fishing?

R. Kearney, C.D. Buxton and G. Farebrother

Abstract

The absence of properly identified mechanisms to adequately protect the marine environment remains a major shortcoming in Australia's commitment to biodiversity conservation. The current commitment to a National Representative System of Marine Protected Areas (NRSMPA) falls far short of providing adequate protection against the suite of existing and potential threats even though areas are designated as being 'protected'. In this paper it is argued that the actions taken under the NRSMPA are disproportionately concentrated on regulating fishing, including the closing of areas in so called 'sanctuary zones' to all types of fishing. In the absence of clearly identified threats from most forms of fishing and without assessment of how best to manage those few fishing threats that have been identified, such actions are inefficient and mostly inappropriate. Moreover, they do not provide adequate protection against the full suite of threats to marine environments. Adequate measures for the proper conservation of these areas and/or the protection of marine biodiversity more generally are not being provided and in most cases threats are not even adequately described and evaluated.

Keywords: Marine conservation, fishery management, marine protected areas

1 Introduction

The terms 'marine protected area' (MPA) and 'sanctuary zone' continue to be used inappropriately in Australia and indeed most other countries. Misuse of these terms, either in ignorance or deliberately, is part of the overstatement of the value of so-called 'protected' areas. This misrepresentation can lead to unrealistic expectations which in effect 'hoodwink' the public into supporting the concept, arguably at the expense of other more necessary and appropriate conservation measures [1-3]. However, in accepting that much of the documentation to which we must refer uses the term MPA, albeit often incorrectly and in instances where little tangible protection is provided, in this paper the expression MPA(s) has been used for consistency with the cited literature.

2 The development of MPAs in Australia

International efforts aimed at instigating marine conservation, that have resulted in calls to establish a system of representative MPAs, began in the early 1960s [4]. Their promotion is now a key component of work undertaken by the IUCN World Commission on Protected Areas [5]. In 1993, Australia signed the Convention on Biological Diversity (CBD), internationally committing the country to establish a system of protected areas. Objectives in this and other international policies for the conservation of biodiversity and ecologically sustainable use of resources [e.g. 6], have been integrated into Australia's national policies and law. In the process Australia has accepted, apparently without adequate critical analysis of the likely effectiveness and implications, that a series of 'marine protected areas' be

established in accordance with the National Strategy for Ecologically Sustainable Development [7]. Agreement on this action was provided by all states and territories through the Inter-Governmental Agreement on the Environment [8]. Thus, with little evaluation of the ability of MPAs to protect marine areas from properly identified threats and even less evaluation of the actual socio-economic and biological benefits that would accrue, or how benefits would be assessed and what the costs would be in achieving them, the NSRMPA was born.

In December 1998, the Australian Government launched its Oceans Policy [9, 10] which was based on earlier legislation [8, 11, 12]. Within the context of maintaining a healthy marine environment this policy also promoted efficient and secure marine industries. A primary element of the Oceans Policy was the establishment of Regional Marine Plans, the ten objectives of which were defined as:

1. *'identify ocean resources and economic and other opportunities;*
2. *identify current and emerging threats to ecosystem health and determine planning and management responses to those threats;*
3. *within the region, set out what is known of ecosystem characteristics and a broad set of objectives for those systems;*
4. *identify the requirements and priorities for environmental baseline and basic biological inventory and other surveys in the development of Regional Marine Plans;*
5. *identify priorities and put in place measures to meet conservation requirements and determine those areas that should be assessed for marine protected area declaration;*
6. *identify community and sectoral interests, including the interests of Aboriginal and Torres Strait Islander communities;*
7. *identify priorities for industry and economic development of the region;*
8. *put in place a planning regime to prevent conflict between different sectors over resource access and allocation;*
9. *provide a framework within which there is increased certainty and long-term security for marine-based industries; and,*
10. *establish indicators of sustainability and requirements for monitoring, reporting and performance assessment'* [10 p.13].

The prominence given to the identification of economic and other opportunities, and the need to identify current and emerging threats to ecosystem health and to base management responses on them, (the first two objectives) is noteworthy. Commitment to these objectives does not appear to be reflected in the priorities given to subsequent conservation actions.

The contribution of the NRSMPA to several other objectives is also questionable. For example, contrary to objective 8, the preferential allocation of areas to recreational fishers over commercial users in many multiple-use marine parks has created major new divisions and heightened pre-existing tensions (note that the parks were created for conservation purposes and not fisheries allocation). Furthermore, the process of 'buying out' commercial fishers has been ill-considered and poorly managed in many parks [discussed for NSW in 2]. As a result it has created a totally new form of conflict between a minority of commercial fishers and the broader seafood industry; some individual fishers or localised catching sectors wish to be cashed-out for short-term personal gain. There are also selected aquaculture interests who when their areas of operation are outside proposed closures, pursue the personal, or enterprise-specific, benefit of having other areas closed to additional competition. The seafood industry more generally wishes to promote an optimum long-term,

complete range of sustainable seafood supplies to consumers and does not support reducing the aggregate resource access right to benefit a few individuals.

Objective 9 remains particularly elusive. The continuing declaration of large parks with multiple zones which are changeable, often depending on the political wind of the day, has resulted in serious damage or at least threats to the long-term security of many fishing and seafood industries (Buxton *et al.* 2006b).

Subsequent to the Oceans Policy, the Environment Protection and Biodiversity Conservation (EPBC) Act [13] was adopted as the primary piece of national legislation to conserve biodiversity. This Act provided for the protection and conservation of biodiversity while promoting ecologically sustainable development (ESD) [13 part 1, 3]. It also emphasised the importance of identifying the processes that actually threaten biodiversity and the development of plans to address them.

The development of bioregional plans is outlined in the EPBC Act [13]. It appears, however, that in the roll-out of the NRSMPA the original goals of bioregional plans have been marginalised, or even circumvented. These earlier agreed goals, quoted above, were primarily designed to better understand biodiversity, to identify current and potential threats, and to determine priorities for conservation. This was to be followed by the development of effective strategies that do not conflict with other goals of ESD as subsequently outlined in the EPBC Act. Importantly, it is explicit in the EPBC Act that threats should be identified and addressed, but it is not explicit that amelioration of these threats in bioregional plans or elsewhere requires the declaration of MPAs. The Act introduces processes of *'identifying and monitoring components of biodiversity that are important for its conservation and ecologically sustainable use', 'assessing strategies and techniques for the conservation and ecologically sustainable use of biodiversity',* and *'systematically determining biodiversity conservation needs'* [13 part 12, 171]. Requirements for bioregional plans and their *'objectives relating to biodiversity and other values'* including options to assess *'important economic and social values'* and *'measures for* monitoring and reviewing the plan' were further elaborated in the Act [13 part 12, 176].

It can be argued that the establishment of MPAs was incorporated into Australian agreements, law and policy without adequately defining: a) which of the total suite of threats MPAs would actually address; or, b) what the consequences would be if MPAs did not adequately address all of the many threats affecting the marine environment. Thus the required level of protection to be provided by MPAs was not determined. Nor was there provision for describing and measuring protection outcomes. Assessment of the cost-effectiveness of alternative management strategies for addressing each and every threat in proportion to the magnitude of the threat, as required in the Inter-Governmental Agreement on the Environment 1992 [8] and the National Strategy for Ecologically Sustainable Development [11], appears to have been neglected. National legislation to support the concept of ESD, requires the cost-effectiveness and efficacy of various management strategies to be determined [13]. Rather than adhering to these requirements it appears that unjustified assumptions about the provision of protection have been based on describing what marine biodiversity and habitat types are represented around Australia and having a 'comprehensive, adequate and representative' (CAR) sample of each proclaimed within a marine park, and preferably within a sanctuary zone. Over a decade later Australia has still not described how protection against the major threats is to be provided by zoning or any

other means and how achievement of that protection is to be assessed, monitored and adapted as needed.

3 Does closing areas to fishing provide adequate and appropriate protection against the effects of fishing?

There is little doubt that in areas where habitats have been devastated by destructive fishing practices or grossly excessive and/or unmanaged fishing effort, any measure which addresses the primary cause is likely to result in anticipated change that is usually easily interpreted to be a benefit [for example 14, 15]. Where more precise forms of management of the effects of fishing, such as well designed, assessed and enforced controls on effort and/or catch have not been developed, area closures may be an effective, even if inefficient, management measure. Where critical spawning or nursery areas have been assessed to require special protection, area closures can be effective, but could be expected to be more efficient if done seasonally and targeted at identified problem gear types. Preferential area closure to selected activities can also be particularly effective as a resource allocation measure; underwater observers will likely see more of at least some species in areas where fishing is excluded, and anglers' catches for species that are shared are likely to be increased as a result of having areas selectively closed to commercial fishing. Areas closed for well-designed research can also deliver benefits [e.g. 16, 17]. But area closure is not a ubiquitous form of protection for all species, even for those species that may have been the target of excessive fishing pressure in the area that is proposed for closure [17]. Nor do indiscriminate or total closures against all types of fishing normally represent a necessary or cost-effective response to an identified problem; case-specific measures that target identified threats are logically more efficient. Unfortunately, putative benefits of closing areas to all forms of fishing continue to be biased by the inappropriate transposition, or misinterpretation, of results from other areas [e.g. 18] as previously documented [2]. Such misrepresentation represents even greater bias when results from damaged or overfished areas are uncritically transposed to areas where there is good fisheries management including the existing requirement and ability to precisely address threats that might arise from specific forms of fishing. Such requirements exist in Australian state fisheries legislation [19-21].

MPAs can protect sedentary individuals against fishing within an area but they cannot usually be expected to protect more mobile individuals or species against the effects of fishing outside the closed area. Many fish species are relatively mobile, at least at some stage of their life-cycle, particularly in comparison with their terrestrial counterparts. Consequently, effective protection from undesirable impacts of fishing normally requires sound management across a large part of the distribution of each species. Even if an MPA represented the bulk of the distribution of a species, it would seldom cover the majority of the distribution of multiple species. To make them sufficiently large for all species would require the inclusion of the great majority, if not all, of marine environments. Furthermore, by displacing fishing effort from a 'sanctuary zone' additional stress can be placed on adjacent areas, to the extent that the overall outcome for fisheries management and even biodiversity conservation can be negative [e.g. 22]. Unless the concept of optimum sustainable yield is abandoned, the greater the fraction of the area of distribution of a species closed to fishing, the greater the stress placed on adjacent areas is likely to be. Displaced or translocated effort is particularly problematic with recreational fisheries because, unlike with commercial fisheries, in the marine environment effort controls can seldom be used to prevent a concentration of recreational fishing.

4 The threats to marine biodiversity

International and national initiatives have collectively identified habitat loss and degradation; declining water quality and sedimentation; unsustainable use of marine and coastal resources; land-based development; and, introduced marine pests as the main threats to marine biodiversity [23-25]. These are typical of the threats occurring in Australia's oceans and estuaries.

Area management of the type proposed for most Australian MPAs is singularly inappropriate for addressing the impacts of most of these threats, particularly those of declining water quality, sedimentation and introduced organisms, and the more recently emphasised threats from ocean acidification and climate change [26, 27]. Furthermore, from the list of major threats, the only one that has been demonstrated to be already appropriately addressed in multiple pieces of state and Commonwealth fisheries and environmental legislation in Australia is unsustainable fishing, this being one component of the threat identified as the 'unsustainable use of marine and coastal resources'. Yet fishing closures which, even if necessary, could be enacted and enforced under pre-existing fisheries and environmental legislation, remain the primary management action in most MPAs. Appropriate and adequate management measures to address other threats have not been enacted.

Conservation of fisheries resources and the ecosystems which support them to standards consistent with ESD principles have been an ever-increasing commitment under Commonwealth and state fisheries legislation [such as 19, and 28], particularly in the last two decades. In combination, existing fisheries and related environmental conservation legislation, such as the numerous state fisheries acts and conservation acts and the EPBC Act, have been more than adequate to address the current or potential threats from fishing; although in some areas governments may have been slow to adequately enforce some components of legislation.

Waters do not have to be closed to all forms of fishing to be effectively protected against the adverse effects of fishing [29]. For unexplained reasons Australia remains reluctant to accept that its well managed fisheries qualify most of the country's marine waters to be determined as already protected against the effects of fishing. Most Australian MPAs provide little protection against other threats, while fishery management is relatively robust and demonstrably effective throughout Australia's marine realm [e.g. 30, 31]. To the extent that fisheries management dominates actions in Australian MPAs, and that the whole of Australia's exclusive economic zone (EEZ) has adequate legislation and effective management of fishing, the entire EEZ could be designated an MPA.

From Australia's initial adoption of the foundation definition of protected areas [32 p.4], it is apparent that the process was biased by inadequately contested beliefs. The most prominent belief was that describing the biodiversity in a region (often through geomorphological surrogates), then simply dedicating a representative area of each region for the protection of biological diversity and initiating some fishing closures, was an appropriate proxy for real and adequate protection from threats. The inflated and misguided confidence in this assumption, and the assertion that it is applicable to each and every area, is indicative of the uncritical, faith-like [33, 34] acceptance of putative benefits of MPAs that continues to plague the process. Sound scientific inquiry, logical management procedures and indeed, existing Australian legislation, should have required accurate assessment of existing and potential threats to the underlying ecosystems, followed by evaluation of what management measures would be the most appropriate for addressing each of them. Even where some form

of area management was identified as potentially appropriate, the biological individuality of each area should have necessitated assessment of what action was specifically required within each area, or at least each type of habitat, to address each threat to that area. Alternative measures to address threats that were not amenable to area management, including introduced organisms and pollution, should have been prioritised in accordance with the magnitude of the threat [8].

In view of the prominence that was given to the biological individuality of areas in the Bioregional Planning process [35] it is most surprising that blanket bans on fishing were considered as the preferred, or even a necessary, management action in each and every MPA. Clearly, it had been assumed that areas could be deemed 'protected' without first determining from what existing or potential threat each area most needed protection from, how this was to be provided, and how the effectiveness of 'protection' was to be assessed, monitored and adapted.

5 Transposition of terrestrial paradigms into the marine realm

The concept of having 'marine protected areas' has inherent appeal, particularly to supporters of terrestrial national parks who would like similar apparent protection of areas provided for marine environments. It is, as discussed above, however, highly questionable whether MPAs in the form currently being proclaimed in Australia are actually providing adequate protection from the suite of major threats. It is also questionable whether area management is an appropriate strategy for addressing many of the major categories of threats, such as pollution, invasive species, and the effects of accelerated climate change, or even the specific threats from fishing that are assessed to affect marine environments. The apparent inappropriate reliance upon area management is compounded by the prominent assumption that a total ban on fishing in so called 'sanctuary zones' provides a complete, or even significant, level of protection [for example 36] . In the absence of proven effective protection against properly identified existing and potential threats, claims that closing areas to fishing provides total, or even appropriate partial, protection in areas that already have well managed fisheries are largely wishful and usually misleading.

The uncritical assumption that reserve-type management would be effective for the conservation of marine biodiversity has been based, at least in part, on the unjustified transposition of terrestrial paradigms into marine environments. This is despite warnings that such uncritical transfer is often illogical [37, 38]. Furthermore, the efficacy of reserve-type management even in many terrestrial environments continues to be highlighted and contested [e.g. 39, 40]. Land-based threats, such as the clearing of land for agriculture and urban development, can often dramatically transform the whole ecosystems in the relatively static terrestrial realm. These threats and the methods used for their management commonly have little relevance to the management of highly interconnected, volatile and mobile aquatic ecosystems. Impacts such as those caused by extensive land clearing for agriculture and urban development, against which area management can be particularly effective and the benefit clearly evident, are much less common types of threats in the marine environment; inadequately managed trawling and dredging of bottoms with vulnerable habitats can be notable exceptions. In such circumstances where trawling or dredging is assessed to be a destructive fishing practice it would ideally be managed over the whole area in which it is a threat. This is possible in countries such as Australia that possess competence for fisheries management in the whole area of the distribution of their fisheries.

Compared to their terrestrial counterparts, marine systems, particularly those in high energy areas (e.g. shallow, high current coastal areas, ocean beaches and estuaries) have immensely greater dynamism and connectivity. This further underscores the limitations, or even futility in many areas, of attempting to provide ecosystem protection or fishery benefits through blanket bans on fishing. Again, these limitations are even more acute in areas that already have appropriate existing legislation and quality management that target the specific effects of individual forms of fishing.

6 What does declaring an area as 'protected' actually mean?

Throughout the process of establishing MPAs there has been uncritical acceptance that declaring areas 'protected' does, in itself, largely accomplish the mission. For managers, including politicians and proponents of area management, declaring an area 'protected' at least provides the benefits that come from fuelling public perception that necessary action has been taken. Assessment of actual protection provided by MPAs does not appear, however, to have been a priority for environmental or fisheries managers, including politicians, in Australia.

The NRSMPA [35, 41] provides the nationally agreed set of indicators to assess protection. At the bioregional level these include:

- *'the number of MPAs present in a bioregion;*
- *the area covered by the MPAs;*
- *the IUCN protected area management categories;*
- *the degree to which comprehensiveness, adequacy and representativeness have been achieved; and*
- *the degree of effectiveness of cross-jurisdictional planning and management arrangements within* bioregions' [35 p. 37].

These indicators largely refer to the number, size and content of MPAs. None directly cover the original reason for establishing the NRSMPA, i.e. the actual provision of conservation of biodiversity and/or protection of the ecosystem. In combination they confirm the prominence of the assumption that declaration of MPAs implies protection. This may well explain why little priority was given to precisely designing MPAs as effective and efficient tools for either conservation or fisheries management, or to ensuring that their effectiveness could be adequately assessed, monitored and adapted.

The principles used as the basis for the NRSMPA [35, 41] were modified from terrestrial models and were never adequately justified for marine systems. For example, the requirement that the system be comprehensive, adequate and representative (CAR) was uncritically transposed from terrestrial environs and even there, its application has been extended from its origin [12, 42]. It began in forestry management where its use was aimed at protecting relatively long-lived and immobile vegetation [43]. Its relevance to a network of area closures underpinning the provision of good conservation of marine systems has not been adequately demonstrated, nor even defined in unambiguous and practical terms. Furthermore, it is difficult to find a marine ecosystem where, even in the unlikely event that a representative part of it could be completely isolated from the effects of fishing, and it could be protected against other threats, these actions would, in themselves, actually represent the most effective and efficient protection of species, biodiversity or ecosystems.

Unfortunately, uncritical calls to establish marine 'protected' areas without adequate assessment of their efficacy have largely ignored other legislated (and arguably more logical) requirements and guidelines to conserve biodiversity. For example the InterGovernmental Agreement on the Environment [8 p. 14] defines that precautionary management should be predicated on identification of threats and '*an assessment of the risk-weighted consequences of various options*' for addressing these threats. The CBD requires management measures to be based on clear identification of threats and subsequent management that is appropriate to address each threat cost-effectively. These requirements are echoed in Australian legislation including the EPBC Act [13]. In many cases, both state and Commonwealth, cursory identification of threats was attempted but other than management of the stated, but often presumed, threat from fishing, additional management of other threats is not obvious.

The repeated claim that best-practice science would be used to underpin the MPA development process [e.g. 44, 45] has not been substantiated. In NSW the 'Science Paper', that was promoted to the public as scientific justification for the parks, systematically distorted interpretation of the available science [2]. The continued prominence of assumptions, such as; that simply because fishing kills fish we must have MPAs that include total fishing closures [46]; that fisheries and fishers would generally benefit from restricting fishing in MPAs [e.g. 47]; or, that sustainable fisheries require MPAs [48] do not logically follow sound scientific practice.

7 Why did Australia assume fishing was the primary threat to be managed in MPAs?

The call for more MPAs in the early 1990's arose in part out of a belief that fisheries management was failing worldwide [49-56]. Traditional fisheries management was assumed inadequate even for the conservation of fisheries resources, let alone marine biodiversity and ecosystems more generally. Australia indeed had at that time examples of inadequately managed effects of fishing, including damaging by-catch in some fisheries and precipitous stock declines: the collapse of the gemfish (*Rexea solandri*) fishery off south-eastern Australia, the closure of localised orange roughy (*Hoplostethus atlanticus*) fisheries around Tasmania, the acknowledged overfishing of species of abalone in many areas, and the continuing decline of southern bluefin tuna (*Thunnus maccoyii*) in the internationally managed fishery provided high-profile examples. The limited debate on how best to improve fisheries management was biased by lobbying from the catching and processing sectors towards avoiding catch or effort reductions, and maintaining the *status quo*. This short-term, self-interest was unfortunately, initially effective in helping to prevent the introduction of long-term, sustainable and adequate control of fishing effort. This failure was most obvious in fish-trawl fisheries and those targeting high value, sedentary species such as rock-lobster and abalone. More stringent management of fishing was unquestionably necessary and for as long as the failure of fisheries managers remained obvious it was appropriate to pursue and promote alternative means to conserve fisheries resources and to protect ecosystems.

In reality it was not that traditional fisheries management had failed, but rather that governments had failed to use properly the best-practice fisheries management tools available to them. It was this governance failure that fuelled continued calls for alternative management practices. Alternatives did indeed appear necessary, at least until such time as governments ensured that traditional fisheries management techniques were effectively applied and adequately enforced.

Most Australian states began strengthening their fisheries legislation in the 1990s, for example, both NSW and Western Australia updated their Fisheries Management Acts in 1994. Catalysed by the development of the EPBC Act, the numerous pieces of state and Commonwealth fisheries legislation were then used remarkably successfully to accelerate critical reviews of fisheries management practices and to force industry restructuring. Recovery plans for many previously overexploited stocks were initiated. Most declines in fisheries resources were arrested and many recoveries quickly became obvious [e.g. 31]. Unfortunately the anti-fishing momentum created in response to previously inadequate fisheries management was not arrested.

Even after the effectiveness of the proper use of traditional fisheries management techniques throughout Australia became apparent, public mistrust of the sustainability and environmental responsibility of Australian fisheries continued. In fact it escalated, fueled by high-profile, but largely irrelevant and often exaggerated examples of the effects of continued overfishing in countries that did not have Australia's commitment to fisheries management and conservation (for example, as seen in the film 'The End of the Line' [57]). Unfortunately Australian governments have been indifferent to the need to balance their social and economic commitments under ESD by complementing the conservation achievements and strategies of the EPBC Act with an equivalent commitment to engendering public confidence in Australia's fisheries management. As a result public opinion of the sustainability of Australia's fishing practices is contrary to reality; aided by numerous NGOs who prosper from promoting 'guides for consumers' that exaggerate negative assessments of overfishing, it continues to deteriorate.

Progressively, and particularly over the last decade, Australia has been assessed as having very good and improving fisheries management [58-60] that includes protection of the ecosystems that support fisheries resources against the effects of fishing. Among the many different forms of fisheries management in use, area closures are used where they are demonstrated to be the most appropriate form of management [e.g. closing areas to scallop dredging; 61].

Despite continuing improvement in fisheries management and resulting recovery and improved status of many fish stocks, lobbying for MPAs based on the need for supposedly tighter controls on fishing has continued to increase [for example 62]. It has been continually asserted that MPAs are not only essential for marine conservation [e.g. 63], but that they would actually benefit fisheries by enhancing recruitment and spill-over and provide protection against stock collapse [48, 64]. Claims that such benefits, which are most unlikely or even impossible in areas where there are well managed fisheries, have been used by marine park advocates to negate the inadequately expressed concerns from the fishing sector (commercial and recreational). Australian fishing industry representatives generally believe that there are already adequate levels of management and regulation of their activities. This view is confirmed by the positive national and international assessments of the efficacy of the numerous state and Commonwealth fisheries management acts and environmental acts, including the EPBC Act 1999.

Biodiversity conservation benefits from MPAs remained largely hypothetical while examples given of fisheries benefits have come predominantly from countries or areas where fish resources had been seriously over-fished, for example the Mediterranean [65] where international cooperation is essential but remains elusive, or subjected to destructive fishing practices, as has occurred in some developing countries [66]. Little evidence has been

provided to support the argument that area closures to all fishing offer benefits to already well managed fisheries. This had actually already been acknowledged in a review of MPAs that was commissioned as part of the development of the NSRMPA [64]. In this review, it was accepted that potential fisheries benefits of MPAs were mostly theoretical and had not been demonstrated in practice, but it was suggested benefits should be accepted as a reasonable assumption based, not on empirical evidence, but on general knowledge of marine ecology. This is surprising given that significant benefits to fisheries had already been assessed to be unlikely in areas with well managed fisheries [e.g. 67, 68]. In more recent years the much vaunted expectations of benefits to fisheries from MPAs have been increasingly acknowledged to be elusive [69-72].

While changes in abundances of key species in areas closed to fishing are common, definitive assessments that confirm that these changes are cost-effective benefits are extremely few. Goñi *et al.* [65] claim theirs to be the first published assessment that incorporates the costs to fisheries production from closing part of the fishing area. Most importantly, they stress that their study, which identified only marginal benefit (10% increase in weight of catch and a slight decrease in numbers), was in a region that was so seriously overfished it was impossible to assess input of the target species (lobster) into the closed area. Their study was not suggested to have relevance to areas with already-existing well managed fishing.

Confirmation of true benefits from MPAs in Australian waters is similarly limited. Buxton *et al.* [73] and Penn and Fletcher [1] questioned whether there even can be fisheries benefits from MPAs of the type proposed in Australia to areas where fisheries are already well managed. According to Buxton *et al*. [22], because of the impacts of redistribution of fishing effort, stock collapse could even be hastened by the declaration of MPAs, at least for relatively sedentary reef species such as lobsters. Buxton *et al.* [73], on the basis of work in Tasmania, went so far as to suggest that traditional fisheries management *'offers a potentially better outcome than no-take MPAs* [even] *for biodiversity conservation'*. Such a suggestion is consistent with the hypothesised biodiversity benefits of intermediate disturbance [74, 75].

Most MPA studies examined the effects inside reserves of fishing closures and few considered the associated effect of the displacement of fishing effort to non-reserve areas [76]. The failure to take a more holistic approach is telling [77]. This shortcoming parallels the approach historically followed with terrestrial reserves, where 'on-reserve' conservation tended to take precedent over 'off-reserve' actions [5, 78, 79]. It is indeed most unfortunate as it had been recognised that even for terrestrial systems complementary conservation effort must be directed both inside and outside reserves [e.g. 80]. Hall [81] noted that setting up MPAs may make us feel better but unrestrained fishing outside MPAs may still eventually lead to stock collapse [e.g. 82], including within an MPA.

Despite growing evidence of the elusiveness of benefits from fishing closures in areas where there are well managed fisheries a common assertion prevailed among supporters of MPAs in Australia, that closing areas to fishing is essential because all fishing was assumed to be inherently damaging to at least some components of marine ecosystems. This belief continues [e.g. 46].

8 The role of fisheries managers

Australia's fisheries management legislation, particularly in the states, gives priority to *'(a) conserving fish and protecting their environment'* and *'(b) ensuring that the impact of fishing*

and aquaculture on aquatic fauna and their habitats is ecologically sustainable (...)' [20 p.2] or '*(a) to conserve* fish *stocks and key* fish habitats*, and (b) to conserve* threatened species*,* populations *and ecological communities of* fish *and* marine vegetation*, and (c) to promote* ecologically sustainable development*, including the conservation of* biological diversity (...)' [19 part 1, section 3] above requirements to optimise yields from resources.

Fisheries management in Australia is thus strongly focused on conservation of resources, habitats, ecosystems and biodiversity. Not only does the relevant legislation negate the argument that fisheries management is primarily concerned with maximising yields it unequivocally demonstrates that such legislation is more than adequate to empower governments to regulate and manage all effects of fishing, including when the assessed most appropriate action is area closures. Moreover, regardless of the reasons for implementing restrictions on fishing, or the effectiveness of such restrictions in addressing threats from fishing, fishing closures still represent manipulation of fishing. To do so they have fisheries management inputs that produce some fisheries management outcomes, even if unintended or undesirable. They thus constitute fisheries management, intentional or otherwise. The claims by many marine park agencies and advocates that MPAs are not focused on fisheries management [e.g. 46, 83, 84, 85] are not consistent with the prominence given in MPAs to fishing closures. Stating that the primary reason for having a fishing closure is for biodiversity conservation does not magically empower a fishing closure to deliver asserted conservation benefits while not impacting fisheries management.

In spite of some individual efforts in Tasmania and Western Australia, fisheries management agencies have been, as the collective custodians of Australia's fisheries resources, unfortunately silent during the development of MPAs. Even though there have been very positive international reviews of the standard of, and improvement in, Australia's fisheries management [58, 60, 86], fisheries management agencies have provided inadequate detailed debate concerning the impacts that MPAs might have on the productivity and management of Australian fisheries. In their review of the interaction between the implementation of Australia's Oceans Policy and ongoing fisheries management, Weaver & Alden [87] explained that, to some extent, there existed a certain fatalism within Commonwealth fisheries management agencies that the 'environmentalists' had already won the day. The continuing failure of fisheries managers to respond effectively, even when the performance of Australia's fisheries management improved further and was internationally recognised as amongst the best in the world [58, 86], has allowed the debate to become even more unbalanced. Fisheries management agencies have not complemented the ecological sustainability successes of the EPBC Act by similarly addressing their responsibilities to the sustainable development side of ESD or by developing strategies for optimum sustainable fishing in the context of Australia's food security.

9 Conclusions

The NRSMPA is commonly perceived to be a necessary means of conserving biodiversity and protecting marine ecosystems. Yet the primary specific management action taken in MPAs is the zonation of the multiple-uses in the area and particularly the exclusion of all forms of fishing from no-take 'sanctuary' zones. This action does not address the major known threats to biodiversity and in areas where fishing is already well managed it is of limited value even for addressing what few threats fishing may pose.

International calls for more MPAs have been fuelled by a belief that on a global scale fisheries management has failed and that fishing not only threatens the world's fish stocks but also the ecosystems that support them. Much of the questionable evidence to support this popular perception is based on the observation that if fishing is removed from an area there is a demonstrable change in the abundance and mean size of the target species in that area. Increases in abundance and average size of some species can be expected in most areas where destructive fishing practices are prevented or excessive fishing effort is removed, regardless of the management measure that is used to eliminate destructive practice or control effort. But in areas where fisheries are well managed to ESD principles, increases in size and number of key species do not represent a fisheries benefit. The actions which cause them, restriction and redistribution of fishing effort, will most likely result in a decrease in the total sustainable yield from impacted fisheries and may well be accompanied by negative conservation outcomes as off-reserve sites are subjected to greater fishing pressure.

In most situations in Australia, MPAs are not designed to, and are not appropriate for, addressing most threats to marine environments, especially invasive threats such as pollution and introduced organisms. These threats are arguably more serious than those from most forms of fishing, particularly when fishing is already well managed; not a single species of fish has been reported as fished to extinction in Australia but 429 introduced or cryptogenic marine species had been reported in Australia by 2008 [88]. There is little doubt that in Australia, unlike the effects of fishing [89], these invasive threats are extremely difficult to control and that the impacts of invasion are often irreversible.

By concentrating on the spatial management of extraction, the NRSMPA does little to address the major threats to marine biodiversity in Australia. As such it represents little more than a park system and its outputs represent little more than resource allocation. This allocation has not been based on sound assessments of the costs and benefits to society nor the adequacy of the network as a primary tool for biodiversity conservation and/or the management of marine resources. It does however, provide the political comfort that arises from the public perception that areas have been protected, misguided though this perception may be.

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CHAPTER 3: How terrestrial management concepts have led to unrealistic expectations of marine protected areas

R. Kearney, G. Farebrother, C.D. Buxton and P. Goodsell

Abstract

Terrestrial reserves and national parks have taken many forms and they continue to be directed toward variable and often imprecisely defined outcomes. A prominent contemporary focus is to pursue the continuance of biodiversity. To this aim the concept of protecting comprehensive, effectively managed and representative areas from overt development, such as urban sprawl and agriculture, has been globally adopted. Within Australia 'effectively managed', has been replaced by 'adequate', a poorly defined term which is interpreted optimistically and combined with 'comprehensive' and 'representative' to create the CAR principle. This principle was first developed within the Australian forestry sector to guide management in addressing a very specific threat to a clearly identified component of biodiversity in limited and well defined areas; the preservation of declining stands of some tree species within limited old growth forests. Even though the CAR principle is central to Australia's process of developing a network of marine protected areas (MPAs) its relevance to marine systems has not been demonstrated. Its efficacy for the conservation of marine environments is questioned. The uncritical transposition of terrestrial management paradigms, including the CAR principle, to the marine realm has misled marine management. It is argued that disproportionate commitment to terrestrial principles, including CAR, and unjustified advocacy for MPAs generally have biased public perception and management efforts to the detriment of effective marine conservation and sustainable use of marine resources.

Keywords: marine conservation; fishery management; marine protected areas

1 History of Reserves

The first formal reserves were established in ca. 700 BC by Assyrian nobles to provide enhanced hunting and exclusive riding amenity for a privileged minority [1]. Individuals of high status were also afforded exclusive access to reserved areas within ancient Roman and medieval European societies [2]. This practice continued and was typified by the establishment of game preserves for the use of ruling classes, for example the area now known as Sherwood Forest in England [1].

In addition to the reservation of areas for the exclusive recreational use of society's elite, areas have historically been excised from broader human development and use in an attempt to protect unique features and secure food supply. At the community level, reserves have been used to enhance continuity in the supply of food; in some South Pacific islands, area closures under 'customary marine tenure' reserved readily accessible seafood for use only during times when access to other resources was prevented by extreme weather [3].

As humans have reflected upon both societal inequity and environmental impacts, the implementation of measures to improve well-being and promote sustainable resource

utilisation has evolved. In the mid-20th century 'development' was promoted as being the panacea for the world's major problems and issues. Outcomes of development were anticipated to include, reduced poverty, improved living conditions, standardised national and global equity levels and hence enhanced global stability [4-6]. This projection was modified within a few decades with the promotion of sustainable development (SD) [7]. The push for sustainability was driven by a growing recognition that excessive resource use and despoiling of the environment could impact the wellbeing and possibly the viability of both current and future generations [8]. Concerns were collectively formalised in areas of excessive natural resource depletion, disruption of ecosystem services, and loss of biodiversity.
Australia's response was the instigation of Ecologically Sustainable Development (ESD) [9], a strategy focussed on *"using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased"* [9 p.6]. Core components of ESD, and SD globally, are the pursuit of the sustainable use of resources and the avoidance of practices that threaten the ongoing viability of ecosystems. While these goals are linked to maintaining biodiversity structures, principally through habitat conservation, the primacy of the word 'using' in the NSESD definition is noteworthy.
This historical context, alongside more measured evidence-based assessments of recent impacts to landscapes, seascapes, biodiversity, and ecosystem services demonstrates progressive acceptance of the need for regulation and management strategies that promote conservation in the context of the sustainable and equitable utilisation of natural resources [8, 10-14].

2 Evolving Goals for Reserves

At the first and second International Union for Conservation of Nature and Natural Resources (IUCN) World Parks Congresses, held respectively in Seattle in 1962 and Yellowstone in 1972, national parks were regarded as areas that should be *"set aside for protection"* [15 p.6]. In the 1970s there was an increasing level of *"ambiguity over the purpose for which areas were being managed"* [2 p.5]. In the 1980s, a fundamental change was made where the concept of 'set aside' was replaced with the idea that national parks could be important components of SD [2]. At the third *World Congress on National Parks* in 1982, the term *"protected area"* [2 p.6] was introduced with the aim of developing a *"more all-inclusive idea"* [2 p.6] that linked to the global *"development agenda"* [2 p.6, 15 p.6]. During the 1990s, ecological economics was championed and advances were made in knowledge regarding complex relationships between natural and economic systems, and policies that collectively aimed to preserve natural capital [1]. Within this agenda, protected areas were promoted as an integral component of the wider push for sustainability with calls for measures to integrate protected areas into larger planning frameworks [2].
In acknowledging the expanding consideration of terrestrial conservation concepts, that themselves had evolved as humanity's collective environmental ethic had grown and matured, and in conjunction with agreements stemming from the 2002 World Summit on Sustainable Development [16], the 2003 *World Parks Congress* provided a major stimulus for the implementation of marine protected areas (MPAs) [17]. Wide support was garnered for the *"establishment and maintenance by 2010 for terrestrial and 2012 for marine areas of comprehensive, **effectively managed*** (emphasis added), *and ecologically representative national and regional systems of protected areas*" [2 p.9]. Slow progress in achieving the initial global MPA target by 2010, however, has resulted in a new target of 2020 that is aligned to the *Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Target*s [18 Decision X/2].

Within Australia, commitment to the implementation of MPAs was explicitly demonstrated by the creation of the National Representative System of Marine Protected Areas (NRSMPA). *"The primary goal of the NRSMPA is to establish and manage a comprehensive,* ***adequate*** (emphasis added) *and representative system of MPAs to contribute to the long-term ecological viability of marine and estuarine systems, maintain ecological processes and systems, and protect Australia's biological diversity at all levels"* [19 p.1]. Australia's replacement of 'effectively managed', from the globally accepted definition, with 'adequate', is most significant. It is discussed below.
In an attempt to align the objectives of the diverse forms of protection and to catalogue and classify the types of protection that are desired, many definitions and descriptions of protected areas have evolved. An initial, internationally agreed definition, developed for terrestrial systems, stated that protected areas consisted of a "*defined area which is designated or regulated and managed to achieve specific conservation objectives*" [14 p.4]. A revision that included marine systems was approved by the IUCN General Assembly in 1994. It defined a protected area as *"an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means"* [20 p.4, 21 p.6]. The determination at these early stages that the mere dedication of an area to the protection and maintenance of biodiversity entitled the area to be called 'protected' is noteworthy. It represents uncritical continuation of the 'set aside' [15] concept. It is indicative of the continuing prominence of nurturing the appearance of a commitment to protection without actually defining what protection is necessary, how it is to be cost-effectively achieved and how its achievement is to be confirmed and evaluated.

In 1999, the IUCN introduced a specific MPA description as *"[a]ny area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by la*w or other effective means to protect part or all of the enclosed environment" [22 p.xviii]. The influence of earlier terrestrial-specific definitions, including that the simple act of declaration of a reserve entitles the area to be called 'protected', is unmistakable. The 1999 version was itself superseded and the most recent IUCN definition is designed to be applicable to terrestrial, freshwater, brackish-water, and marine systems [23]. It defines a protected area as being within *"[a] clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values"* [20 p.8]. A notable development in this definition is the stipulation that effective management, by legal or other means, is a requirement for protected areas. The evolving global definitions have progressively recognised that the mere dedication of an area for protection and/or the declaration that an area is 'protected', are not adequate
The current IUCN definition of a protected area, including its reference to 'geographical space', recognises the three-dimensional attributes of environments. It encourages more flexible forms of protection whereby, for example, *"a certain water depth is protected or the seabed is protected but water above is not"* [20 p.8]. As such, it recognises the need to address specific activities more precisely in the area, or part of an area, that they impact, thereby obviating the need for non-specific management, such as closures to all activities, based on two-dimensional boundaries.

In establishing protected areas, recent IUCN guidelines state that *"the only principle that should apply in assigning categories is the appropriateness of a protected area's assigned management purpose within the system relative to the ecological* ***needs of, and threats to*** (emphasis added), *the species or ecosystems in the context of the entire landscape or*

seascape where that biodiversity occurs" [20 p.44]. The fundamental necessity to assess the ecological 'needs of and threats to' species or ecosystems in the context of their total distribution is globally progressively acknowledged. In contrast it is usually overlooked or deliberately avoided in the Australian MPA process. Australian governments acknowledge, either overtly or by subsequent actions, that the MPA process within their jurisdictions is not designed to address threats (explicit examples include the New South Wales MPA 'science paper' [discussed in 24] and South Australian Ministerial correspondence [25]). The resulting MPA processes are therefore, not consistent with the recent development of global objectives which are based on the logical approach to problem solving by first identifying the cause of the problem and then addressing it.

The most prominent and popular form of 'protection' within MPAs, both politically and from an advocacy stance, has been the promotion of closures to all types of fishing, no matter how sustainable or environmentally benign particular forms of fishing may be. Areas closed to all fishing in 'no-take' zones are then called 'sanctuaries' (a term that is emotive in its implication that an effective, and therefore commendable, level of protection has actually been provided). The contrast with the most prominent action in terrestrial protected areas, the prevention of extreme landscape modification for human housing, industrial development and agriculture, is extreme.

Although all hunting (harvesting or culling) may be prohibited in some terrestrial protected areas this is seldom the primary reason for the creation or subsequent popularity of such areas. Furthermore, the value of excluding all hunting in protected areas is globally contested; some hunting is argued to be essential in national parks for management of population levels of selected species, for example elk [26]. It is noteworthy that fishing is allowed in various Australian terrestrial national parks [27-29] and even some World Heritage Areas [28].

3 Primary differences between Marine and Land Environments

Land is fundamentally different to water. A set of differences between terrestrial and marine ecosystems that relate to the management of each has been compiled by Carr *et al.* [30]. Many major differences between the two domains have been described, including, their physical and chemical structure, their underlying environmental function, ecological aspects and processes, population attributes, trophic structuring, and genetic characterisation [30-32]. Effective and efficient conservation logically requires a commitment to understanding not only the nature of what it is that is to be conserved, but also what impacts exist or can be anticipated, and how each impact arises and can be managed. Cities, roads, rail links, agriculture, mines, dams, settlements and industrial complexes are extremely visible impacts that can not only completely alter terrestrial landscapes but can also greatly affect the structure and functioning of ecosystems. Respite from these impacts for the sake of ecosystems, habitats, species, and for the physical, aesthetic and spiritual needs of humans can therefore be justified on many levels. Perceptions of terrestrial protected areas by the public and their consequent related political significance can be strongly associated with their obvious role in preserving visible natural structure and to *"save emblematic species"* [33 p.14]. However, there is typically a lower level of occupation, knowledge, heritage and biological assessment associated with the marine realm. Most importantly, visual exposure [33], particularly of threats, is immensely lower. The lack of accumulated knowledge and direct observation facilitates distortion of both the significance of different threats and public perception toward the transposition of terrestrially-oriented conservation measures that have been visibly successful on land.

Not only are marine and terrestrial domains vastly different in their basic geomorphology and ecology but they also vary in the way in which environmental threats are manifest. Extraction, as expressed by removal of ecosystems in extreme land modification resulting from many forms of mining, urban development and agriculture, is usually the fundamental threat to terrestrial environments. Area management on land is a logical and effective approach to this threat. In contrast, injection, often invisible, in the form of pollutants and exotic organisms, is the mechanism whereby most major serious and/or irreversible threats affect the marine realm. Area management is a notably ineffective approach to addressing these threats within highly interconnected and dispersive marine environments.

The relevance of area management in the two realms is also influenced by the substantial differences that result from marine environments having *"much lower absolute range in diurnal and seasonal cycles"* [31]. Consequently, compared to their terrestrial counterparts, there is much less requirement for marine fauna to possess, create and maintain internal or localised habitats. The manner in which reproduction relies upon *"physical dispersal and relatively predictable food cycles"* [31] in the marine environment and the decoupled egg, larval and juvenile stages from those of the adult state of most species are also fundamentally different to what is found on land [31, 34].

The fundamental differences between the two realms, such as the differences in reproduction and dispersal, also impact the claim that 'critical habitats' or *"ecological processes and systems"* [19 p.1] can be appropriately protected by area management that is designed to *"build on the forest reserve criteria and the National Reserve System scientific guidelines for terrestrial areas"* [19 p.23]. It has been recognised by the IUCN that in the marine realm, *"[t]he concept of a critical habitat for an endangered species is only applicable with marine mammals, sea turtles, seabirds and the occasional endemic species"* and *"[t]here are virtually no authenticated records of recent extinctions of completely marine species with planktonic larvae"* [22 p.37]. This critical distinction between the role and value of specific component areas of terrestrial and marine environments and the questionable relevance of movable regional boundaries to *"physical dispersion in the sea"* [31], while being internationally recognised, have been largely ignored in Australia's approach to MPAs. Also misrepresented has been the need for connectivity between isolated habitats and/or populations of species. Maintaining connectivity can be a major problem for conservation in terrestrial environments [35]. In contrast, it is the prevention of connectivity, particularly the spread of pollutants and introduced organisms, that is the much greater management issue for marine environments. The claim that networks of no-take MPAs are necessary in all types of areas to ensure populations remain connected, without demonstrating that biodiversity or ecosystems will suffer in the absence of continuous or proximal areas closed to well-managed extraction, must be questioned.

The extreme differences between terrestrial and marine ecosystems coupled with the differences in the types of human threats and how they affect the respective systems [30], make uncritically relating terrestrial ecology and management concepts, particularly area management, to the marine environment problematic [31] and generally unwise.

4 Measurement of Protection

A typical assessment of the level of terrestrial protection has become the quantification of area under management. Comparisons between countries of the proportion of their territory

that is designated as protected are common, as are comparisons of the proportions of total land and marine areas that are designated as protected. The NRSMPA provides Australia's nationally agreed set of indicators to assess protection provided by MPAs. At the bioregional level these include: *"the number of MPAs present in a bioregion; the area covered by the MPAs; the IUCN protected area management categories; the degree to which comprehensiveness, adequacy and representativeness have been achieved; and the degree of effectiveness of cross-jurisdictional planning and management arrangements within bioregions"* [19 p.37]. These indicators are completely dominated by reference to the number, size and content of MPAs. None directly cover the original reason for establishing the NRSMPA, i.e. the actual provision of conservation of biodiversity and/or protection of ecosystems. In combination they confirm the prominence and promotion of the unjustified assumption that the mere declaration of MPAs equates to protection [36] at the expense of provision of appropriate protection of marine environments.

5 Resource Use and Conservation

In contrast to historic evidence of unsustainable impacts caused by human activities on land or in rivers, it was generally assumed, at least until the 1950s, that ocean productivity was largely immune to human intervention [37-40]. Initially, as technology and fishing methods developed, and fishing effort increased in line with the growing demands from an increasing human population, total yields from fishing continued to increase. Global increases began to taper off in the 1980s, however, and by the 1990s production had plateaued [39, 41]. The timing of the globally recognised declines in many poorly managed individual fisheries coincided with international efforts aimed at introducing broader sustainability strategies initiated for terrestrial environments. As with other anthropogenic environmental impacts that had been associated with doom and gloom scenarios [42-45], fishery collapses and despoiling effects of the marine environment have been widely publicised [e.g. 46] and incorrectly projected to be global in distribution. Existing fisheries management techniques and practices were considered inadequate and as a consequence, an extension of the earlier terrestrial model of setting aside areas from development and human impact had begun to be projected into the marine environment [47]. Imprecise and often inaccurate but emotive analogies were also made between land based wildlife impacts and the effects of fishing; one view being that *"[f]ishing is the catching of aquatic wildlife, the equivalent of hunting bison deer and rabbits on land"* [48] or the more emotive and extreme *"…bottom trawling, the equivalent of using a nuclear bomb to catch rabbits"* [Bohm, C., Australian Marine Conservation Society, cited in 49]. This being despite evidence indicating that while humans have been responsible for many terrestrial extinctions , impacts from fishing are limited to declines in the numbers of individuals of certain species [50]. Australia has reported the extinction of 27 terrestrial mammals, 23 birds and four frogs, but not a single species of marine fish [51]. The extreme (numerically infinite) contrast in the number of recorded extinctions in Australia's terrestrial and marine environments (54:0), in spite of Australia having had many large terrestrial protected areas since the Royal National Park was established in 1879, and until recently, few MPAs, provides testimony to the fundamental differences in the environments themselves, the biology of the component parts, the threats to them and the effectiveness of traditional management efforts.

In spite of differences in how terrestrial marine environments should be managed, that should have been obvious, the need for, and supposed efficacy of, no-take MPAs continues to gain public and political acceptance. This acceptance has been based primarily on a progression of

inadequately questioned assumptions, including that the types of benefits visibly affirmed by terrestrial area protection would simply transfer to marine environments.

6 Terrestrial and Marine Conservation Management Practices

The way that humans utilise land-based resources, the way that landscapes are completely altered by habitation, many forms of agriculture and forestry and the obvious impacts that these have on terrestrial ecosystems justifies setting aside portions of the landscape in the form of protected areas; there is no known practical alternative way to attempt to maintain examples of habitats and ecosystems that underpin biodiversity. It is important to recognise, however, that the sustainable utilisation of marine resources, particularly by well-managed fishing, and the subsequent impacts on marine environments are fundamentally different. Consequently, in order to deliver cost-effective ESD, including biodiversity conservation, different forms of management must be anticipated in the marine realm.

In spite of the huge areas of land that are impacted it is generally accepted that severe ecosystem manipulation and change resulting from agriculture are acceptable human impacts from legitimate activities. Agriculturalists are promoted as being landscape managers and are recognised as being an integral part of the drive for sustainability [52]. This recognition exists because society has accepted that environmental compromises are necessary to secure food production, even though it is obvious that land clearing for agricultural purposes and subsequent cultivation change local environmental conditions dramatically and usually irreversibly. In the transposition of terrestrial management paradigms to marine environments it has not been adequately acknowledged that sustainable food production from oceans entails the controlled harvesting of existing ecosystems, not their deliberate alteration. Where this harvest is taken by well-managed fishing, the process sustainably exploits surplus production and does not seriously threaten biodiversity. Destructive fishing practices and/or grossly excessive fishing effort do represent threats to at least some marine ecosystems and some expressions of biodiversity but the impacts of such illegal or uncontrolled practices must not be confused with those from well-regulated fishing. Fishing is not in itself a key threatening process. It does not deliberately remove native ecosystems and cultivate and manipulate introduced, or at least translocated, animals and plants, as does agriculture.

Even in terrestrial environments the need to not over-regulate, for example against fire, was recognised as far back as the 1960s, while the need for the management, and not uncritical protection, of populations of certain species in protected areas was also becoming evident [26]. It was realised that optimum conservation outcomes that included accepting aspects of natural disturbance alongside active human management could be achieved. Based initially on outcomes from forestry management some degree of natural disturbance has been promoted as being beneficial for biodiversity conservation [26, 53-55]. In marine environments where controlled harvesting can promote optimum, sustainable surplus production [56] without threatening the continuance of species, biodiversity benefits from intermediate disturbance could be anticipated. Acknowledgement of such possible benefits is not evident in the Australian MPA process.

Most widely-pervasive impacts on marine environments, such as from pollution, sediment movement, nutrient loading, pesticides and invasive organisms, are derived, directly or indirectly, from terrestrial activities [57]. Such impacts can seldom be ameliorated effectively through management of areas, other than management in those areas in which the problem arises. Management of marine areas that are pre-determined based on characteristics not

related to the efficacy of their management against specific threats is most unlikely to be efficient or effective in addressing such threats.

Good governance of fishing practices, based primarily on effective catch and effort controls that can include targeted localised area closures to specifically identified gear types or fishing practices, either permanently or on a seasonal basis, have the demonstrated ability to adequately and efficiently control impacts from fishing activities in marine environments. Most importantly, unlike area management measures on land or in the sea, traditional fisheries management techniques such as effort and catch controls are able to be applied across the whole area of distribution of the ecosystem that may be threatened and/or the whole area of distribution of an identified threat from fishing. The most recent IUCN requirement for conservation is for management that is targeted to the *"ecological needs of and threats to"* biodiversity "*in the context of the entire landscape or seascape where that biodiversity occurs"* [20 p.44]. Thus traditional fisheries management is more in keeping with modern concepts than is management based on only part of the area of distribution of biodiversity and/or the threats to it. Good fishery governance by traditional fisheries management techniques, including compliance with specific and targeted management measures, is the most effective and efficient means of providing protection against the effects of fishing. When used correctly it negates the need for the introduction of widespread, non-specific no-take zones for conservation purposes.

7 The Prominence of the CAR Principle in Australia's MPA Process

Under the *National Strategy for Ecologically Sustainable Development* [9], Australia confirmed its commitment made in the 1991 *Ocean Rescue 2000* initiative [cited in 9], to *"develop a National Representative System of Marine Protected Areas"* [9 p.27]. All states and territories agreed to this approach through the *InterGovernmental Agreement on the Environment* [58]. This planning framework enabled Australian governments, both state and Commonwealth, to work towards Australia's international commitments progressively agreed to within the Convention on Biological Diversity (CBD) [59, 60]. Australia's management of marine conservation increasingly relied on the NRSMPA as the principal component of the *Marine Bioregional Planning* process [61, 62]. The concept of bioregional planning itself appears to have been first used within Australia for forestry management [63]. Uncritical transposition of this area-management concept into marine management was at the expense of first identifying or anticipating specific needs and/or problems and designing management to address each in proportion to its magnitude, regardless of where it may occur. The resulting marine bioregions themselves are described by boundaries that are subjective and based on what is in them. They are not defined, nor apparently influenced, by how best to provide protection.

One particular terrestrially-derived concept that has been given extreme prominence in the bio-regional planning and NRSMPA processes in Australia is the assumption that the areas chosen for protection should be comprehensive, adequate and representative (CAR). The concept engenders immediate appeal, for it would indeed enhance biodiversity conservation and public confidence if enough (adequate) of everything (comprehensive) was protected. Having a 'representative' sample included in areas further enhances appeal by implying that only a sample of areas is being reserved. Thus the suggestion of cost-effectiveness is invoked. But in spite of its pre-eminence in the Australian process of justifying and declaring MPAs the effectiveness of a CAR approach in delivering appropriate and cost-effective conservation in marine environments has not been demonstrated.

The combination of comprehensive, adequate and representative as one principle was developed in Australia. The three components were originally combined and the CAR principle adapted to assist in the management and preservation of old-growth stands within forests [64]. The initial use of CAR underpinned the basis for conservation of a very specific form of natural terrestrial system, old-growth trees that were demonstrably threatened with removal that constituted an effectively irreversible threat. Acceptable alternatives for managing the competing objectives of extraction and conservation could not be identified. Of particular relevance was the acknowledged need to ensure that enough (adequate numbers, or areas, of specific types of trees) were protected from uncontrolled extraction. A specific problem and its cause had been clearly identified and the form of area management proposed was specific to this situation; old-growth trees are a stationary component of relatively immobile environments that are logically amenable to area management. A national agreement to pursue the CAR principle for forestry stated, *"[g]overnments agree that, conditional on satisfactory agreement on criteria by the Commonwealth and the States, the comprehensive, adequate and representative reservation system to protect old-growth forest and wilderness values will be in place by the end of 1995"* [64 p.10].

This CAR principle was subsequently, uncritically transferred into other areas within Australia. By 1996 it was being applied, through the National Strategy for the Conservation of Australia's Biodiversity, to terrestrial and marine protected areas with commitments to "*undertake a 10-year Commonwealth, State and Territory cooperative program, which includes the provision of adequate resources, to ensure that the terrestrial and marine protected area systems are comprehensive, adequate and representative"* [61 p.10]. Such action was said to be *"[c]entral to the conservation of Australia's biological diversity…"* [61 p.6].

In response to growing recognition in the 1990s of the need for marine conservation, the Australian Commonwealth Government established a *"long term marine conservation program to ensure the conservation and sustainable use of Australia's marine and estuarine environments"* [65 p.3]. A *"key component"* [65 p.3] of this was stated as being the establishment of the NRSMPA. Illustrating how terrestrial experience influenced marine conservation decision-making is the statement that although previous terrestrial development had prevented the inclusion of many terrestrial ecological communities in land-based reserves, this would not be the case with the MPA program [65]. A form of collective guilt for the inadequacy and ineffectiveness of terrestrial conservation efforts, including area management to that time, was accepted. A primary outcome of this guilt was the acknowledgement of more idealistic (comprehensive and adequate) conservation objectives for marine environments. Unfortunately however, in the absence of appropriate risk-analyses and subsequent quantification of projected costs and benefits, these idealistic objectives were, and remain, tied to wishful assumptions about the effectiveness of the protection provided to all types of marine environments by controlling extraction. They were not based on recognition of a specific problem in a clearly defined area and the identification of the cause and appropriate solution, as had been the case for old-growth forests for which the CAR principle had been developed.

The underlying differences between ownership of terrestrial and marine areas facilitated implementation of marine management based on these idealistic objectives. As most marine areas were not inhabited or the subject of terrestrial-style property rights or conflicting claims, that had restricted conservation efforts on land, more comprehensive and representative marine areas were amenable to being reserved. The ease with which they could

be declared as reserves and claimed to be 'protected', was seductive. The relatively, low cost of displacing only fishing industries that were small (eg the Coral Sea Proposal [66]), disparate and not unified in their opposition (many individual fishers actually supported area closures because of the generous compensation payments, or because competition from other fishers who fish for shared stocks of mobile and/or migratory species in areas adjacent to their own, would be removed), was also an attraction of MPAs. Projection of belief in the assertion that areas closed to extraction were 'protected', by the common definition of 'protected areas', was used to counter the need for evidence-based assessment that such reservation would actually provide necessary protection. On the basis of public perception that adequate conservation action was being taken the CAR principle was immediately attractive to policy makers, including politicians. It was however, not a well-researched response to a properly described problem.

In asserting that Australia's international agreements and commitments support the NRSMPA and ongoing declaration of more and bigger marine parks the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) stated that the United Nations (UN) CBD [14] *"introduced the phrase 'comprehensive, adequate and representative' (CAR) reserves"* [67]. As documented above, this is factually incorrect. The phrase is Australia-centric; CAR elements did not filter into the CBD until 2002 in relation to forest conservation [68] and 2004 in relation to inland waterway management [59]. The CAR principle does not have international acceptance in the marine realm. It does not carry international obligations for Australia. It is actually at odds with Australia's commitment to international conventions, such as the CBD, which require effective management that addresses identified threats. As discussed above, the CAR concept had actually been introduced in Australian forestry management before the UN CBD was ratified [64]. The claim by SEWPaC distorts the genesis of the CAR concept in relation to conservation generally and more specifically its relevance to marine conservation in Australia, particularly MPAs.

Distortion of concepts and principles by Australian governments in the advocacy for, and implementation of, MPAs has not been restricted to the CAR principle. The use of precaution in environmental management is prescribed in Australia's relevant legislation, such as the Environment Protection and Biodiversity Conservation (EPBC) Act [69]. This Act is consistent with accepted international definition of the precautionary principle in that it states that precaution is to be applied where threats have been identified and there is scientific uncertainty. To support the implementation of the NRSMPA, however, Australia chose not to adhere to international convention or existing national commitments but rather to develop a specific definition of the Precautionary Principle. This specific definition [19] mandates the creation of MPAs at the expense of targeting specifically identified threats and systematically addressing scientific uncertainty [70]. As such it represents distortion of logic and internationally agreed management principles in the cause of advocacy for MPAs. This distortion is at the expense of evidence-based precautionary conservation.

Despite the absence of evidence of relevance to the marine environment of a concept that was developed for a very specific conservation purpose in forestry management the CAR principle remains the central plank of Australia's system of MPAs. In the formation of the NRSMPA it was stated that, *"[t]he primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative system of MPAs to contribute to the long-term ecological viability of marine and estuarine systems, maintain ecological processes and systems, and protect Australia's biological diversity at all levels"* [19 p.1]. The lack of evidence of how the NRSMPA would actually meet these objectives, particularly how it

would protect 'Australia's biodiversity at all levels', exposes the whole system as being wishful.

In spite of the lack of science to support the relevance and effectiveness of the CAR principle in marine environments it has been further endorsed within the 2010 National Strategy for Conservation of Australia's Biological Diversity by all Australian governments [71]. It has even been elevated to the status of the scientifically accepted objective of the National Reserve System, whereby *"[t]he scientific framework has a clear objective: to develop a 'comprehensive, adequate, and representative' system of protected areas - commonly referred to as the 'CAR' reserve system"* [71]. This elevation of the principle to the status of the objective of the scientific framework in the absence of demonstration of its scientific credibility is inappropriate. It appears as an attempt to circumvent scientific scrutiny of the principle.

Consistent with the distortion of the CAR principle itself, the science that has been projected to support it has been disproportionately directed towards descriptions of what is in reserves and how what is contained in them can be espoused to be 'comprehensive, adequate and representative'. This is at the expense of evidence-based assessment of what is in need of protection, what it needs protection from, what level of protection is appropriate, and how that level of protection can be cost-effectively delivered, monitored and adapted as necessary. Mere description of what is in areas, and/or a declaration that they are 'protected' does not quantify what protection is being provided. It is also not an appropriate proxy for assessment of what benefits are actually being achieved [72].

It is most significant that global objectives for protected areas continue to be defined as *"marine areas of comprehensive, **effectively managed,*** (emphasis added) *and ecologically representative national and regional systems of protected areas"* [2 p.9]. Globally there is increasing recognition that effective management is fundamental to sound conservation. Simple declaration of areas that are asserted to be adequate does not constitute provision of adequate protection. Australia, however, appears rooted to an ill-informed commitment to describing areas that are comprehensive and representative and claimed to be adequate. In the absence of effective management declaration of an area, no matter how large, will not in itself provide 'adequate' conservation.

As discussed above, Australia's replacement of 'effectively managed' with 'adequate' is neither accidental nor temporary. The most recent public consultation document for the establishment of Australia's next major marine reserve, 989,842 km^2 of the Coral Sea [66], is completely dominated by commitment to 'adequacy' of the size and content of areas; the goals and principles in this Proposal refer, almost exclusively, to what is included in areas that are to be closed to selected activities, not what protection is to be provided. It uses as its justification the unreserved commitment to CAR in the NRSMPA.

The inappropriateness of uncritically adopting a CAR system that encompasses all marine environments is further re-enforced by the extreme differences between the many types of marine environments, the threats to each, and the vastly different management measures that would most cost-effectively provide protection in each of them. For example, the most cost-effective management measures for the biodiversity of high-energy, soft bottom in-shore areas, such as ocean beaches and riverine estuaries, must not be assumed to be the same as those necessary for off-shore coral reefs or deep-sea canyons. In spite of the great diversity in marine environments it is difficult to identify any where the most effective and efficient

management is likely to be the same as that appropriate for the preservation of old-growth stands within forests, for which the CAR principle was developed. However, in the Australian NRSMPA, representative examples of comprehensive types of areas have been assumed necessary to be closed to all types of fishing and other extraction in order to supposedly meet a predetermined, but scientifically unjustified, commitment to adequacy. This commitment is at the expense of appropriate risk assessment and determination of effective management. As a result it is most unlikely to represent cost-effective protection.

Also of significance to Australia's failure to embrace the global protected area goal of "*comprehensive, effectively managed, and ecologically representative*" [2 p.9] is that fishing is the only threat to marine ecosystems in Australia that is already effectively managed. Australia's fisheries management has been nationally and internationally assessed to be effective [73-75] and it is improving. Yet Australia appears reluctant to acknowledge the achievements of its fisheries management in providing effective management. It would be logical for Australia to meet its international commitments to the global standard of effectively managed areas to declare the whole of Australia's waters effectively managed against threats from fishing; the comprehensiveness and representativeness of the area could not be disputed. Australia would then be extremely well placed to concentrate on the real purpose of protected areas as described in the international agreement; to identify and manage "*the ecological* ***needs of, and threats to*** *the species or ecosystems in the context of the entire landscape or seascape where that biodiversity occurs"* [20 p.44].

8 Conclusions

Terrestrial and marine ecosystems differ fundamentally. In the absence of adequate evaluation of these differences terrestrial area management paradigms have been uncritically transposed to marine environments. The highly visible benefits of terrestrial area management have helped to distort managers' expectations and public perception of the likely outcomes from area management in marine environments. Spatial assessment that illustrated that marine areas had not been well represented in the total area of the planet proclaimed as protected helped fuel calls for the establishment of more and bigger MPAs. Advocacy for MPAs has been aided by uncritical transposition of results from irrelevant areas and/or exaggerated claims of benefits from closing areas to fishing in optimistically titled 'sanctuary zones'. The threat from fishing can be more efficiently addressed by targeted, traditional fisheries management techniques. MPAs are also notably ineffective for the management of other threats to marine ecosystems, such as pollution and introduced organisms.

Australia's replacement of 'effectively managed' with 'adequate' in the definition that drives its marine conservation strategy has led the MPA process to become decoupled from the pursuit of cost-effective management. Persistent and uncritical commitment to the CAR principle has been used to justify more and bigger MPAs at the expense of evidence-based assessment of their effectiveness for protecting marine ecosystems and their relevance to ESD.

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CHAPTER 4: When is spillover from marine reserves likely to benefit fisheries?

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Abstract

The net movement of individuals from marine reserves (also known as no-take marine protected areas) to the remaining fishing grounds is known as spillover and is frequently used to promote reserves to fishers on the grounds that it will benefit fisheries. Here we consider how mismanaged a fishery must be before spillover from a reserve is able to provide a net benefit for a fishery. For our model fishery, density of the species being harvested becomes higher in the reserve than in the fished area but the reduction in the density and yield of the fished area was such that the net effect of the closure was negative, except when the fishery was mismanaged. The extent to which effort had to exceed traditional management targets before reserves led to a spillover benefit varied with rates of growth and movement of the model species. In general, for well-managed fisheries, the loss of yield from the use of reserves was less for species with greater movement and slower growth. The spillover benefit became more pronounced with increasing mis-management of the stocks remaining available to the fishery. This model-based result is consistent with the literature of field-based research where a spillover benefit from reserves has only been detected when the fishery is highly depleted, often where traditional fisheries management controls are absent. We conclude that reserves in jurisdictions with well-managed fisheries are unlikely to provide a net spillover benefit.

Keywords: marine reserves, over-fishing, spatial management, spillover

1. Introduction

Marine reserves (MR) also known as no-take marine protected areas (MPA) are widely acknowledged as a conservation tool and their utility in a variety of situations is well established (Edgar *et al.* 2009). In particular over-exploited fish populations are shown to recover in the absence of fishing and generally become more abundant and attain a larger mean size in the reserve (Lester *et al*. 2009). MPAs are also frequently promoted for the management of fisheries (Roberts 1997, Roberts *et al.* 2001, Gell & Roberts 2003, Halpern *et al.* 2009, Russ & Alcala 2011), even though compelling evidence in support of a net fisheries benefit is lacking (Kervath *et al.* 2013). Fisheries are proposed to benefit from reserves through increased production of eggs and larvae from the reserve (recruitment effect) and the net movement of adults into adjacent fishing grounds (spillover effect) (Russ 2002).

In this study we focus on the spillover effect and to avoid confusion over the use of these terms, we define *spillover* as the net movement of fish across the boundary of a reserve into the fished ground, which would be expected to occur on the basis of fundamental physical principles of random movement. This is in contrast to *net spillover benefit* which involves spillover of sufficient magnitude to compensate for lost productivity due to the closure of

fishing grounds, resulting in an overall benefit to the fishery through higher catch or economic yield.

Our review of the extensive literature reporting fisheries benefits reveals that there are surprisingly few empirical studies that attempt to quantify either the recruitment effect or a net spillover benefit. For example, Goni *et al.* (2010) claims to be the first study to demonstrate a net spillover benefit in a fishery. Harrison *et al.* 2012 make a similar claim with respect to the recruitment benefit of reserves in terms of larval export. Whilst spillover has been shown in several other studies, most do not accommodate the reduction in catch that results from reducing the area of the fishery, and consequently do not demonstrate a net spillover benefit.

Fishers are generally opposed to the introduction of reserves because they reduce the size of their fishing grounds, which is inferred to result in a loss of yield. Spillover is a common counter argument from reserve proponents, including Government agencies in the US, Europe and Australia, claiming that it will compensate for the lost fishing grounds to the extent that a net improvement in fisheries yield occurs (DEH 2003, Revenga & Badalamenti 2008; NOAA 2011).

The impact of the introduction of reserves on yield has been addressed in a number of theoretical studies (for example Sladek-Knowlis & Roberts 1999; Sladek Nowlis 2000, Steele & Beet 2003), several of which progressively conclude that under broad assumptions well-managed fisheries should not benefit from the introduction of reserves (Polacheck 1990, Hilborn *et al.* 2006, Le Quesne & Codling 2009, Barnes and Sidhu 2013). Hart (2006) quantifies this result to some degree by using an age-structured model, concluding that a benefit from spillover should not be anticipated unless open area fishing mortality considerably exceeds that which produces MSY.

The assumptions underlying these studies primarily concern the homogeneity of fish stocks and are reasonable for a large range of species. The obvious exception occurs in fish stocks with strong variability in spatial structure, for example where source-sink relationships exist or where reserves may result in the closure of disproportionately productive areas (Apostolaki *et al.* 2002). Such spatial heterogeneity is the basis of traditional spatial management of fisheries, and is a well-established and understood technique. Targeted spatial closures can be expected to benefit fisheries for selected species if the closed area is of disproportionate significance to the productivity of the species in question. Not surprisingly some models have shown that, at least under certain conditions, higher sustainable yields can be achieved with a marine reserve than without (e.g., Apostolaki *et al.* 2002; Steele & Beet 2003, Ralston & O'Farrell 2008). But despite the common demonstration that special circumstances are required to achieve a spillover benefit from reserves, the implication of these findings have received limited attention and appear to have contributed little to the international public debate over fisheries benefits and to current management policy.

In this paper we use a widely applied fisheries population dynamics model which minimizes assumptions in order for the outputs to be applicable to a broad range of fisheries in non-structured environments (‘normal’ or ‘average’ fisheries). We modify this model to incorporate a MR and consider the management circumstances under which a non-specific reserve is likely to provide a benefit to the fishery. Our work highlights the effect that the degree of mismanagement under conventional fisheries management practices has on the

ability of a reserve to provide a net fisheries benefit. It also investigates how this relationship changes with the rate that fish move between the reserve and the main population.

2. Methods

We consider an effort-controlled fishery with a fish stock governed by the Logistic model. Stock size is measured in biomass; consequently growth encompasses both individual growth and recruitment. We assume that the population is homogenous and that introduction of the reserve will concentrate the effort in the remaining fishing grounds. The latter would be expected in a poorly managed fishery.

Population Dynamics

The population dynamics were modelled using a deterministic difference equation of the form:

$$N_{t+1} = f(N_t)N_t - C(N_t), \tag{1}$$

where N_t is the stock size at time t, $f(N_t)$ is the biological model that defines population growth and $C(N_t)$ is the catch. Common examples for the biological component of this model include the Ricker model:

$$f(N) = e^{r(1-N/K)}, \tag{2}$$

and logistic model:

$$f(N) = 1 + r(1 - N/K). \tag{3}$$

In both models r is the maximal growth rate and K the carrying capacity (maximum population size).

Throughout this analysis we assume that the population is homogenous - a small proportion, δ, of the population will behave identically in isolation to a larger proportion of the population. Mathematically, this implies that the carrying capacity can be reduced to δK. Alternatively we can consider the biological model to be a function of population density, in this case our model becomes:

$$N_{t+1} = f(N_t/\delta)N_t - C(N_t/\delta). \tag{4}$$

The divisor in the catch term indicates that catches are proportional to the population density (or constant).

Consider splitting a population into two areas: (i) a reserve occupying a proportion, α, of the original habitat size and (ii) the remaining fishing grounds of size $1-\alpha$. Denoting the two population sizes by R_t and M_t respectively, the model becomes:

$$\begin{aligned} R_{t+1} &= f(R_t/\alpha)R_t - S_t \\ M_{t+1} &= f(M_t/(1-\alpha))M_t - C(M_t/(1-\alpha), M_t) + S_t, \end{aligned} \tag{5}$$

where S_t denotes the spillover from the reserve into the fished population.

Spillover

We assume that a proportion, μ, of the population in the reserve moves into the fishing ground at each time step. As the population in the reserve is R_t, then μR_t will migrate out of the reserve. Similarly a proportion, ν, of the population in the main fishing ground will migrate into the reserve. This results in the net movement from the reserve into the main fishing ground (the spillover) being:

$$S_t = \mu R_t - \nu M_t. \tag{6}$$

The values $\mu$and ν will depend on both the size and geometry of the reserve, however given the homogeneity of the population we also require that the net spillover is zero ($S_t = 0$) when the population density in the reserve and the fishing ground is equal (i.e. $R_t/\alpha = M_t/(1-\alpha)$). With this requirement and (6) we have:

$$\begin{aligned} S_t &= \mu R_t - \nu M_t \\ 0 &= \mu \frac{\alpha}{1-\alpha} M_t - \nu M_t \\ \nu &= \frac{\alpha}{1-\alpha}\mu. \end{aligned} \tag{7}$$

As a direct result of the assumption of spatial homogeneity, a single parameter, μ, is sufficient to define the strength of the movement both in and out of the reserve. The net spillover from the reserve therefore becomes:

$$S_t = \mu\left(R_t - \frac{\alpha}{1-\alpha} M_t\right). \tag{8}$$

Note that we assume that μ (and ν) are independent of the population density in and outside of the reserve. While there may be evidence to suggest that some individuals do follow a density gradient (Zeller *et al.* 2003, Abesamis *et al.* 2006b) this does not substantially alter our findings, as it is akin to an increase in μ.

Fishing

We have specified the catch as a function of the population density and population size, $C_t = C\left(M_t/(1-\alpha), M_t\right)$. One common catch model is constant catch, as found, for example,

in a subsistence fishery where a certain catch must be obtained each year to feed the population:

$$C\left(M_t/(1-\alpha), M_t\right) = P. \tag{9}$$

Well managed fisheries either have natural restrictions that prevent over-exploitation of the fish stock (e.g. limited demand of a niche product) or management controls to prevent over-exploitation. Management controls can be divided into two broad categories – input and output controls. Input controls limit the effort applied in the fishery. Denoting this by E we have:

$$C\left(M_t/(1-\alpha), M_t\right) = \frac{qEM_t}{1-\alpha}, \tag{10}$$

where q is a constant of proportionality. With this formulation, catch is directly proportional to the effort and population density (hence division of M by $1-\alpha$ to obtain a density). Other functional forms may be more appropriate for certain fisheries and fishing methods (e.g. purse seining of schooling fish). We considered all effort applied to the fishery to shift instantaneously from the reserve to the open area.

Output controls limit the catch that can be taken from a fishery and were not explored, as the existence of an effective output control (that does not cause a fishery collapse at equilibrium) implies effective fisheries management (Costello *et al.* 2008). In reality there are many examples of ineffective output controls in fisheries that have not collapsed. These fisheries persist as the output controls are adjusted through time or, when the stock is in low abundance and effort controls (whether through management or limited numbers of participating fishers) restrict the fishery. Modelling such systems requires many assumptions, hence we have focused on input controlled fisheries in this analysis.

Net effect of the reserve on catch

We assume that the population was at equilibrium prior to the introduction of a reserve and compare this with the post-reserve equilibrium. During the transient time between these two states spillover will be less. Since we are considering the equilibrium states we have $N_{t+1} = N_t$ which we simply denote by N, similarly for M, R and S.

Firstly, consider a fishery with a level of effort corresponding to near extinction, $E = E_E$. Introduction of a reserve will increase surplus production unless the population is beyond recovery.

At the other extreme, consider a pre-reserve fishery that is producing maximum sustainable yield (MSY) from the total area: $E = E_{MSY}$. By definition at this point, surplus sustainable production cannot increase. Therefore introduction of a reserve must decrease overall catch.

At E_{MSY} the spillover effect is less than the lost productivity and at E_E it exceeds the lost productivity. At some level of effort in between, the reserve must switch from having a net negative effect on the fishery to a net positive effect due to spillover. The level of effort at which this occurs is dependent on the model and its parameters. We now establish the point at which this occurs for a logistic model (Equation(3)).

If spillover equals lost productivity in the fishing area, the pre-reserve and post-reserve catches must equal $qEN = qEM/(1-\alpha)$; hence $M = N(1-\alpha)$. Simply put, the population density in the fishing grounds must remain unchanged. Substitution in equation (5) yields:

$$N(1-\alpha) = f(N)N(1-\alpha) - qEN + S \tag{11}$$

subtracting equation (1) (at equilibrium) and solving for *S* gives:

$$S = \alpha qEN \tag{12}$$

Consequently, the spillover must equal the surplus production of the original fishing grounds that has now been encompassed in the reserve.

For a given level of effort, the pre-reserve fishery given by equation (4) will possess a solution, the nature of which depends on the population dynamics model. For example the non-zero solution for the logistic model is:

$$N = (r - qE)K/r \tag{13}.$$

Using the full two area logistic model with effort controlled fishing (equations (5), (8) and (10)) and substituting equations (11) and (12) permits us to eliminate several of the unknowns. In this case we choose to eliminate *N, M, R* and *S* since conceptually we consider these to be determined by the remaining parameters. After algebraic manipulation (not shown here) we obtain the level of effort at which the introduction of the reserve does not change the overall catch:

$$qE = \left(r - 2\mu + \sqrt{r^2 + 4\mu^2}\right)/2. \tag{14}$$

Note that $qE = 0$ is also a solution (if no fishing is taking place, introduction of a reserve will not reduce the catch). A negative solution also exists but is of no further interest as the population would be extinct and negative densities are merely a mathematical curiosity. The same approach can be used for other population dynamics models, however for some models (e.g. the Ricker model) straight-forward analytic solutions do not exist. Qualitatively we would expect similar results for other population dynamics models and found this to be the case for numerical solutions to the Ricker model (results not shown here).

The optimal effort for this fishery without a reserve is $r/2q$. We divide equation (14) by this and subtract 1 to obtain the minimum excess effort (as a proportion) required for a reserve to be beneficial:

$$\hat{E} = \sqrt{1 + (2\mu/r)^2} - 2\mu/r. \tag{15}$$

This depends only on the ratio of the movement rate out of the reserve to the growth rate of the stock (μ/r), and not on the proportion of the area dedicated to the reserve (α). However it should be noted that the movement rate out of the reserve, μ, is likely to depend on the

reserve size. This link has not been explicitly explored here, however for a given choice of μ, there is likely to be only a limited range of values of α that is possible.

Equations (14) and (15) are derived in more detail in Appendix 4.1.

3. Results

Figure 1 shows an example where a 10% reserve is introduced with 5% movement out of the reserve (μ) and a maximum growth rate (r) of 10%. This figure explores the effect of a reserve for different levels of initial effort applied to the fishery. The maximum sustainable yield (MSY) is obtained with an effort of 0.05 (E_{MSY}).

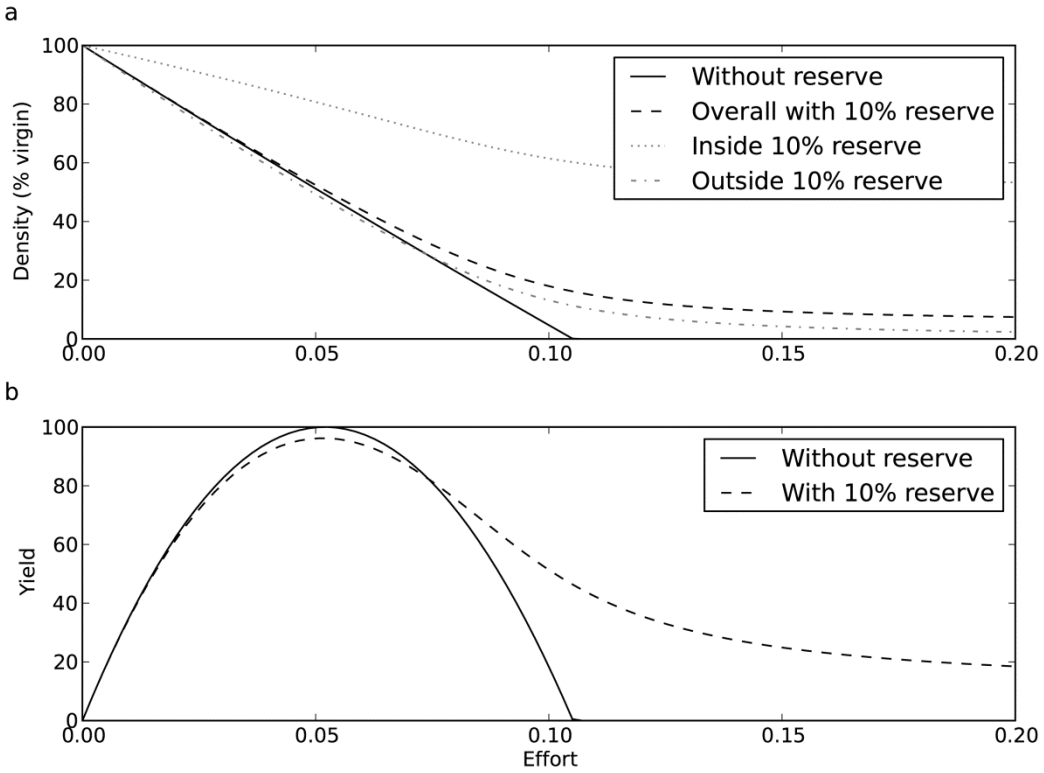

Figure 1. (a) The equilibrium biomass density as a function of fishing effort. The density is shown for the whole stock without a reserve and with a 10% reserve. For the reserve scenario the density inside and outside of the reserve is also shown. (b) Yield as a function of fishing effort both with and without a reserve.

Introduction of the reserve decreases the yield at E_{MSY} and by definition there is no alternative effort that produces the same maximal yet sustainable yield. The point of

intersection in the bottom panel corresponds to a level of effort, E_I, where the yield is the same with or without a reserve. At levels of effort above E_I, the introduction of a reserve increases yield. In this scenario, E_I is 150% of E_{MSY}, so a fishery would have to have 50% excess effort for the reserve to be beneficial in terms of the yield of the target species. At even higher levels of effort (>150% E_{MSY}) the MPA mitigates the impact of overfishing and permits sustainable (but substantially reduced) yield.

The level of excess effort at which a reserve has a neutral impact on fisheries yield depends only on the ratio of movement out of the reserve (μ) to the maximum growth rate (r) (Equation(15)). This relationship is shown in Figure 2a, when the movement rate is high relative to the growth rate, a reserve is beneficial at low levels of excess effort. The extreme situation where μ / r approaches infinity corresponds for example to a miniscule reserve, which clearly will have negligible impact on a fishery. At the other extreme, $\mu / r = 0$, there is no movement out of the reserve, consequently it will always have a negative impact.

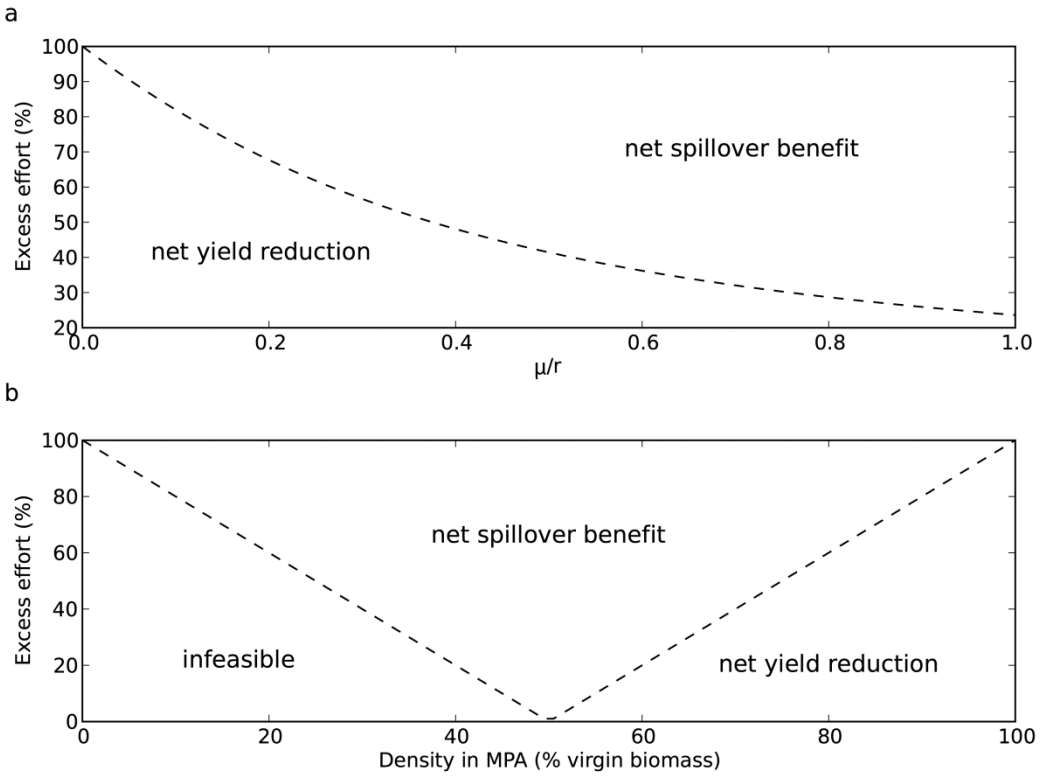

Figure 2. (a) The excess effort required for a reserve to improve fishery yield. For our simple model this was found to depend only on the ratio of the movement rate out of the reserve (and thus on reserve size) to the growth rate of the stock (μ / r). (b) The excess effort required for optimality as a function of the reserve density (at equilibrium). For example a reserve with 80% virgin biomass at equilibrium will provide a net economic benefit for a fishery that has more than 60% excess effort relative to optimal management. Combinations of excess effort and reserve density that fall in the bottom left region are infeasible; in these situations a reserve would have to decrease in population density after being formed (not possible in our model). Inside the "V" the reserve provides a net increase in fishery yield. In the right region the reserve decreases yield

Alternatively we consider the excess effort required for a reserve to be beneficial as a function of the reserve density at equilibrium (Figure 2b). If the reserve is at 50% virgin biomass density it has neutral effect on the fishery. This is because 50% virgin biomass corresponds to MSY in this model and all surplus production is moved to the main population through spillover. At reserve densities above this, a fishery must have more excess effort to benefit from a reserve. In particular if reserves have a high percentage of virgin biomass (a common conservation goal for reserves) they will only benefit fisheries that have greater mismanagement. For example, at 80% virgin biomass a reserve will only benefit fisheries with more than 60% excess effort.

4. Discussion

Model outcomes

The model presented here examines the circumstances under which spillover from a reserve is sufficient to increase fishery yield (thus providing a net spillover benefit). As expected, density of exploited species was higher in the reserve than the fished area, which may be mistaken in itself as evidence that the reserve has created a net beneficial increase in larvae production (eg Harrison *et al.* 2012). However, it is important to consider the net effect, which in our model case was a decline in average density and a loss of yield except where effort exceeded E_{MSY}. While models are by necessity a simplification of ecological complexity, we show that the extent to which effort must exceed E_{MSY} for any yield benefit to occur from the reserve depends on the ratio of the rate of movement out of the reserve and the growth rate of the species concerned. Highly mobile / slow growing species received relatively less benefit from reserves where effort was above management targets compared to species with low movement / fast growth.

Our model is a relatively simple one chosen to illustrate a fundamental principle that is applicable across a broad range of fisheries. Different formulations for the biological model, $f(N_t)$, can be specified and similar results were obtained for the Ricker model (not shown here). Three major assumptions were made to maintain model simplicity: spatial homogeneity, density dependence and steady state dynamics.

Spatial homogeneity is an inappropriate assumption for some species. For example, where there are clear source-sink relationships protecting the source in a reserve is likely to provide an overall benefit (Stockhausen *et al.* 2000). The location of source areas can be consistent across different species and trophic levels, and in rare cases where these locations are known, it becomes possible to locate reserves that provide benefit to numerous, and theoretically all, species (White & Samhouri 2011).

Density dependence in our model is a function of the total biomass in the local area (i.e. the fished population or the reserve population). This does not adequately capture the dynamics of species where density dependence varies substantially with age (e.g. density dependence

occurring primarily during larval stages) and where different age classes have different movement rates across the reserve boundary. In such situations it could be possible for the reserve to provide a greater benefit by providing a recruitment increase to the fished region.

Steady state dynamics are widely used to explore fundamental fisheries principles. In the context of reserves, some models have shown that biological stochasticity may lead to theoretical net spillover benefits in fisheries where the biomass can be determined accurately on an annual basis and corresponding perfect catch limits set each year (Yamazaki *et al*. 2012, Grafton *et al*. 2006). Given the unrealistic nature of this assumption for most management situations there would be some value in further research that explored reserve benefits in a stochastic setting with realistic management. After the introduction of a reserve, it will take some time for the reserve population to build to the final density. Consequently it is expected that the reduction in yield will initially be much greater than predicted by our steady state model. With the concentration of effort the fished population would initially decrease before increasing some time later due to spillover from the reserve.

Our model did not consider that the introduction of a reserve may result in an effort reduction due, for example, to decreased accessibility or increased fishing costs. This would be beneficial for stock status and overall production in over-exploited fisheries, however, it would result in a reduction of production in well-managed fisheries.

Under our model there were no combinations of growth rate or movement where a net spillover benefit from reserves could occur unless effort exceeded E_{MSY}. Where effort is less than E_{MSY}, a loss of yield always occurs when reserves are implemented. The level of excess effort beyond E_{MSY} at which a reserve provides net spillover benefits was shown to depend only on the ratio of movement out of the reserve to the rate of growth of the population (μ / r). We also showed that reserve configurations that achieve higher densities of stock are only beneficial for mismanaged fisheries (Figure 2b). For example, a reserve that ultimately increases biomass density to 75% of unfished levels would benefit a fishery if the initial effort exceeds E_{MSY} by more than 50%. These results show that reserves will generally negatively impact yield for well managed fisheries. However reserves could minimize their impact on a well managed fishery by reducing the density increase of the fishery's target species in the reserve. For example, a reserve could be of a sufficient size to protect species with small home ranges whilst being small enough that individuals of the target species frequently move beyond reserve boundaries (a high movement rate, μ). This could also be achieved by having high reserve boundary length to total area ratios. The feasibility of this outcome will depend on the movement characteristics of the species involved.

Our finding that reserves cannot improve the yield of a well-managed fishery is consistent with several other theoretical studies (Polacheck, 1990, Le Quesne & Codling, 2009, Hilborn *et al.* 2006). The work here extends these findings by exploring the extent to which a fishery must be mismanaged before introduction of a reserve provides a benefit to the fishery in terms of yield.

Many fisheries have management objectives that constrain catch below the target of MSY assumed here, for example to manage risk from stochastic processes such as recruitment, or where there is an objective to target a maximum economic yield (MEY) that is variant to

MSY. In these fisheries, effort and catch are lower than would occur with the MSY target (Grafton *et al.* 2007), which reduces the negative impact of reserves on total yield, but also shifts the fishery further away from the level of depletion required for a net spillover benefit to occur.

Empirical context

The results from this study are consistent with other studies that have modeled the impact and/or benefits of reserves on fisheries in terms of improvements in yield. Following the publication of the early models on the potential net spillover benefits from reserves (Polacheck 1990, DeMartini 1993, Sladeck Nowlis 2000), there have been surprisingly few empirical studies that have attempted to demonstrate the effect. Most of the reserve literature has concentrated on the changes within reserves, showing an increase in size and abundance of resident fish and crustaceans, particularly of reef associated species (for a review see Halpern and Warner 2002). Despite the lack of empirical evidence the argument persists that reserves will confer a net spillover benefit to fisheries (e.g. Gell and Roberts 2003). This view is actively promoted by government agencies (DEH 2003; Revenga and Badalamenti 2008; NOAA 2011). However, the literature confirms that the evidence for such a benefit is far from conclusive. Several studies report a lack of evidence for spillover due to the low movement at the scale of the reserve (e.g. Davidson *et al.* 2002, Tewfik & Bene 2003, Tupper 2007), while others showed that spillover occurred but not that lost yield was compensated to produce a net benefit (e.g. Rowe 2001, Pillans *et al.* 2005, Folesa *et al.* 2009).

While density dependent export from reserves is considered to be a rational expectation (Abesamis & Russ 2005), no studies have been able to conclusively demonstrate a net spillover benefit, and leakage from reserves is probably more related to random movement within species (eg Cole *et al.* 2000, Kelly *et al.* 2002, Tupper 2007, Folesa *et al.* 2009). Several studies fail to provide conclusive evidence for net spillover benefits, yet argue that reserves are needed to provide fishery benefits (eg Pillans *et al.* 2005, Rowe 2001). Spillover has been inferred from observations of a density gradient between the reserve and adjacent fished area (eg, Ashworth & Ormond 2005, Abesamis *et al.* 2006) even though evidence was acknowledged to be equivocal (eg Russ & Alcala 1996, McClanahan & Mangi 2000, Abesamis & Russ 2005), and where confounding factors such as a change in fishing practices (eg McClanahan & Kuanda-Arara 1996) or changed fisheries management strategies over the study period were ignored (eg Roberts *et al.* 2001, Russ and Alcala 2011). Few of these studies consider whether the purported spillover to the fishery (as inferred from catch rates) has actually resulted in a net spillover benefit for the fishery. Even if CPUE goes up in a fished area it may be insufficient to result in a net production gain for the whole of the fishery.

Several studies have been able to demonstrate that spillover has contributed to an improvement in biomass and thus catch rate adjacent to the reserve (Stobart *et al.* 2009, Forcada *et al.* 2009, Goni *et al.* 2010, Vanderpere *et al.* 2011). These examples, all in the Mediterranean, were conducted in areas where the total fishery had been severely depleted. In this respect they are similar to several studies in other areas that, on multiple lines of evidence, infer a net spillover benefit to fisheries. Examples come from Africa (McClanahan and Mangi 2000) and Asia (Russ & Alcala 1996, 2011, Abesamis & Russ 2005) where the fisheries in question were over-exploited and where there was limited application and/or enforcement of standard fisheries management controls. The result was that the proclamation of a reserve resulted in a recovery of the population in the reserve and a subsequent

improvement in catches close to the reserve boundary. This is consistent with our conclusion that reserves can provide a net spillover benefit for severely depleted stocks. It does not, however, provide evidence that the declaration of the reserve was the most efficient means of achieving that benefit.

There are many possible variations on the biological assumptions made in our model. Aspects such as stock heterogeneity and variant density dependence assumptions will influence the impacts of a reserve as well as the level of mismanagement, where a reserve switches from being beneficial to being detrimental for a fishery.

The model results presented here are for a general case, which is appropriate for consideration of reserves where a large number of species with variable life histories and spatial distributions are affected by change in management. Closed areas for traditional fishery management purposes are applied on a species by species basis and may have very different management outcomes to reserves because they can be designed and located to affect an individual stock. There are numerous cases where species with spatial heterogeneity, such as spawning aggregations or larval source-sink dynamics, benefit from fishery closures that target important source areas (e.g. Wakefield 2010). A total fishing closure would achieve the same result for those species, but can be expected to have less beneficial results for other exploited species.

5. Conclusions

We conclude that in fisheries where there is effective management, marine reserves are unlikely to produce a net spillover benefit for the total fishery, whereas they may be beneficial where the fishery has been mismanaged and severely depleted. These results expand the implications of previous work by providing estimation and evaluation of the degree of mismanagement of fisheries that is necessary for non-specific closures to provide net benefits to fisheries.

The conclusions from the modeling presented here are supported by review of empirical studies, where spillover benefits have only been conclusively demonstrated in highly depleted areas. Together with the combined weight of earlier modeling work, they suggest that a net benefit from spillover should not be expected in areas already benefiting from quality traditional fisheries management.

These generalised findings in relation reserves should not be confused with the use of targeted spatial closures for single fisheries, where it is possible to increase yield through closures by taking account of the spatial heterogeneity of life history traits.
While reserves may be proclaimed for a range of conservation objectives (including addressing impacts such as the effect of fishing on benthic environments, interactions with threatened species and catch of non-target species), we contend that it is misleading for governments to promote reserves on the basis of net spillover benefit in the context of well-managed fisheries. Reserves are only likely to be an effective strategy for fisheries management where effort is not or cannot be effectively controlled across the wider stock.

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Appendix 1- Detailed derivation of Logistic MPA equilibrium

This section provides a detailed derivation of equations (14) and (15) which characterize the level of effort at which introduction of a reserve provides no change to the fishing catch.

To determine whether the reserve introduces a positive change to the fishery it is first necessary to consider the dynamics without a reserve. This establishes what optimal management would have been without a reserve and what catch this would have produced.

Population dynamics without a reserve

The population dynamics for the fished area without a reserve is a classic model that has been broadly studied and is detailed in many introductory mathematical ecology textbooks. The model is produced from our generalized single area model (equation (4)) by substituting the equation for fishing dynamics (equation (10)) and population dynamics (equation (3)):

$$N_{t+1} = \left[1 + r\left(1 - \frac{N_t}{K}\right)\right] N_t - qEN_t, \tag{16}$$

at equilibrium we have $N_{t+1} = N_t$ and this becomes:

$$N = \left[1 + r\left(1 - \frac{N}{K}\right)\right] N - qEN. \tag{17}$$

The non-zero solution of this is readily solved to give:

$$N = K\left(1 - \frac{qE}{r}\right) \tag{18}$$

The equilibrium catch is:

$$C = qEN \tag{19}$$

$$C = qEK\left(1 - \frac{qE}{r}\right). \tag{20}$$

This is maximized when:

$$E = r/2q, \tag{21}$$

which corresponds to the maximum sustainable yield (MSY).

Population dynamics with a reserve

The population dynamics of the two areas found by substituting the equation for spillover (equation (8)), fishing dynamics (equation (10)) and population dynamics (equation (3)) in the generalized two area model (equation (5)):

$$R_{t+1} = \left[1 + r\left(1 - \frac{R_t}{\alpha K}\right)\right] R_t - \mu\left(R_t - \frac{\alpha}{1-\alpha} M_t\right) 70 \quad (22)$$

$$M_{t+1} = \left[1 + r\left(1 - \frac{M_t}{(1-\alpha)K}\right)\right] M_t - \frac{qEM_t}{1-\alpha} + \mu\left(R_t - \frac{\alpha}{1-\alpha} M_t\right). \quad (23)$$

To find the equilibrium solution we have $M_{t+1} = M_t$ and $R_{t+1} = R_t$ so the above becomes:

$$R = \left[1 + r\left(1 - \frac{R}{\alpha K}\right)\right] R - \mu\left(R - \frac{\alpha}{1-\alpha} M\right) \quad (24)$$

$$M = \left[1 + r\left(1 - \frac{M}{(1-\alpha)K}\right)\right] M - \frac{qEM}{1-\alpha} + \mu\left(R - \frac{\alpha}{1-\alpha} M\right). \quad (25)$$

For the introduction of this reserve to have no net impact on the catch, the catch from the pre-reserve fishery must equal the catch from the post-reserve fishery:

$$qEN = \frac{qEM}{1-\alpha} \quad (26)$$

$$M = N(1-\alpha). \quad (27)$$

Substitution in equation (10) yields:

$$N(1-\alpha) = \left[1 + r\left(1 - \frac{N(1-\alpha)}{(1-\alpha)K}\right)\right] N(1-\alpha) - \frac{qEN(1-\alpha)}{1-\alpha} + \mu\left(R - \frac{\alpha}{1-\alpha} N(1-\alpha)\right)$$

$$N(1-\alpha) = \left[1 + r\left(1 - \frac{N}{K}\right)\right] N(1-\alpha) - qEN + \mu\left(R - \alpha N\right) \quad (28)$$

Subtracting equation (13) from $1-\alpha$ times equation (2) gives:

$$0 = 0 + qEN - (1-\alpha)qEN - \mu\left(R - \alpha N\right) \quad (29)$$

$$\alpha qEN = \mu\left(R - \alpha N\right) \quad (30)$$

As noted in equation (12) in the main manuscript, this implies that the spillover must equal the surplus production of the original fishing grounds that has now been encompassed in the reserve.

This can be re-arranged to give R as a function of N:

$$R = \frac{\alpha qEN}{\mu} + \alpha N \tag{31}$$

Substitution of equation (15) in equation (9) gives:

$$R = \left[1 + r\left(1 - \frac{R}{\alpha K}\right)\right]R - \alpha qEN \tag{32}$$

$$0 = r\left(1 - \frac{R}{\alpha K}\right)R - \alpha qEN \tag{33}$$

Substitution of equations (16) and (3) in equation (18) after simplification yields:

$$\begin{aligned} 0 &= \mu^2 r\left(\frac{1}{\mu}\left[1 + \frac{\mu qE - \mu r + q^2E^2 - qEr}{\mu r}\right]\left[\mu qE - \mu r + q^2E^2 - qEr\right] - qE\left[1 - \frac{qE}{r}\right]\right) \\ 0 &= \mu^2(qE - r) - (\mu + qE - r)\left(\mu qE - \mu r + q^2E^2 - qEr\right). \end{aligned} \tag{34}$$

A cubic in qE which has a real, positive solution:

$$qE = \left(r - 2\mu + \sqrt{r^2 + 4\mu^2}\right)/2 \tag{35}$$

This is the level of effort at which a reserve does not alter the catch and is equal to equation (14) in the main paper. The relative level of excess effort that this corresponds to is found by dividing by the optimal effort, equation (6), and subtracting 1, yielding:

$$\hat{E} = \sqrt{1 + (2\mu/r)^2} - 2\mu/r, \tag{36}$$

equation (15) in the main paper.

CONCLUSIONS

The Commonwealth, State and Territory governments' commitment to the creation of a National Representative System of Marine Protected Areas (NRSMPA) by 2012 is commonly perceived to be a necessary means of conserving biodiversity and protecting marine ecosystems. Yet the primary specific management action taken in MPAs is the zonation of the multiple-uses in the area and particularly the exclusion of all forms of fishing from no-take 'sanctuary' zones.

Through the 1980s and 1990s there was an increasing global recognition of escalating threats to marine ecosystems (see Chapter 1), and although threats to the marine environment are relatively well understood, opinions differ on the relative importance of various threats.

The need for more precautionary management of biodiversity and natural resources catalysed more stringent management of fishing in the 1990s, primarily through tighter controls on catches and gear modifications in areas where these were assessed to be necessary. This achieved obvious and almost immediate results. The current status of Australia's fisheries, both State and Commonwealth, clearly demonstrates an impressive improvement in the status of stocks and the sustainability of the underlying fisheries[6]. The number of stocks subject to overfishing has been reduced across Australia, for example in Commonwealth managed fisheries the percentage of stock subject to overfishing has been reduced from approximately 40% in 2000 to 10% in 2009. In addition stocks that are assessed to be significantly overfished anywhere in Australia are required to be the subject of recovery plans based on catch and effort restrictions. These plans have already been shown to be extremely effective.

Notwithstanding the above, assertions that the world's fisheries are overexploited, particularly in large industrial fisheries and fisheries adjacent to high human population densities have fuelled assertions that existing fisheries management is inadequate to protect ecosystems that were being threatened by destructive fishing practices and/or excessive fishing effort. International calls for more MPAs have been fuelled by a belief that on a global scale fisheries management has failed and that fishing not only threatens the world's fish stocks but also the ecosystems that support them.

Australia's impressive fisheries management performance has not dampened enthusiasm by proponents of marine parks for more areas to be closed to all forms of fishing, even in the absence of assessed threats from fishing. In Chapters 1&2 we argue that this action does not address the major known threats to biodiversity and in areas where fishing is already well managed it is of limited value even for addressing what few threats fishing may pose.

In Australia to date, there is a paucity of scientific assessment of actual benefits from closing areas to all forms of fishing but the lack of scientific certainty has been commonly countered by the claim that fishing closures in MPAs are a necessary precautionary action. The alignment of the call for more fishing closures with precaution appears to have been of such priority for proponents of MPAs that a specific definition of the Precautionary Principle was developed and adopted for the implementation of the NRSMPA. This specific definition

[6] Flood M, Stobutzki I, Andrews J, Begg G, Fletcher W, Gardner C, et al. (2012). Status of Key Australian Fish Stocks Reports 2012. Canberra: Fisheries Research and Development Corporation Australia. 420pp

distorts the intent of both the internationally accepted definition and Australia's pre-existing nationally agreed definition of the Precautionary Principle to the detriment of sound conservation of marine biodiversity. It exposes advocacy for fishing closures in MPAs at the expense of appropriate resolutions of the scientific uncertainty relating to each and every threat, and how best to achieve cost-effective conservation outcomes (see Chapter 1).

The problem has been exacerbated by the transposition of terrestrial management concepts to the marine realm, without sufficient consideration of how these two ecosystems differ. Terrestrial reserves and national parks take many forms and although directed toward variable and often imprecisely defined outcomes, a prominent contemporary focus is to pursue the continuance of biodiversity. To this aim the concept of protecting *comprehensive, effectively managed and representative areas* from overt development, such as urban sprawl and agriculture, has been globally adopted.

Australia's replacement of 'effectively managed' with 'adequate' in the definition that drives its marine conservation strategy has led the MPA process to become decoupled from the pursuit of cost-effective management. Persistent and uncritical commitment to the CAR principle has been used to justify more and bigger MPAs at the expense of evidence-based assessment of their effectiveness for protecting marine ecosystems and their relevance to ESD.

In Chapter 3 we argue that the highly visible benefits of terrestrial area management have helped to distort managers' expectations and public perception of the likely outcomes from area management in the marine environment. Spatial assessments that illustrate marine areas to be under- represented in the total area of the planet in parks and reserves helped fuel calls for the establishment of more and bigger MPAs.

Advocacy for more MPAs is often aided by exaggerated claims of fishery benefits from no-take marine protected areas, often incorrectly espoused as 'sanctuary zones'. Much of the questionable evidence to support this popular perception is based on the observation that if fishing is removed from an area there is a demonstrable change in the abundance and mean size of at least one of the target species in that area. Increases in abundance and average size of some species can be expected in most areas where destructive fishing practices are prevented or excessive fishing effort is removed, regardless of the management measure that is used to eliminate destructive practice or control effort. But in areas where fisheries are well managed to ESD principles, increases in size and number of key species that result from no take MPAs do not necessarily represent a fisheries benefit. This can only be demonstrated by an improvement in catch in adjacent fished areas. On the other hand the actions which cause them, restriction and redistribution of fishing effort, will most likely result in a decrease in the total sustainable yield from impacted fisheries and may well be accompanied by negative conservation outcomes as off-reserve sites are subjected to greater fishing pressure.

The net movement of individuals from a no-take MPA or reserve to the remaining fishing grounds is known as spillover and is frequently used to promote MPAs to fishers on the grounds that it will provide a net improvement for a fishery beyond the closed area. In Chapter 4 we show that for exploited species with reasonably effective management, no-take MPAs are extremely unlikely to produce a net spillover benefit for the fishery. This provides a general guide to the outcomes of MPAs and shows that it is misleading for Governments to promote MPAs on the basis of net spillover benefit where they have existing management to

constrain effort at or below maximum sustainable yield. This is especially relevant to Australia where it is widely acknowledged that fisheries are well managed.

MPAs are only an effective strategy for fisheries management where effort cannot or is not controlled across the wider stock. This conclusion regarding MPAs should not be confused with the use of spatial closures for single fisheries, where it is possible to increase yield through closures by taking account of the spatial heterogeneity of life history traits.

Several overall conclusions can be drawn from our study:

- Fishing in Australia is well managed and does not represent a serious or irreversible threat to fish stocks and /or biodiversity more generally. Unfortunately the marine parks movement in Australia continues to confuse the threats from well-managed fishing with those from destructive fishing practices and/or inadequately managed fishing which are no longer serious problems in Australia.

- In most situations in Australia, MPAs are not designed to, and are not appropriate for, addressing most threats to marine environments, especially invasive threats such as pollution and introduced organisms. These non-fishing threats are arguably more serious than those from most forms of fishing, particularly when fishing is already well managed; not a single species of fish has been reported as fished to extinction in Australia but 429 introduced or cryptogenic marine species had been reported in Australia by 2008.

- By concentrating on the spatial management of extraction, the NRSMPA does little to address the major threats to marine biodiversity in Australia. At best the NRSMPA represents little more than a park system and its outputs represent little more than resource allocation. This allocation may benefit dive tourism but it is not usually based on sound assessments of the total costs and benefits to society nor the adequacy of the network as a primary tool for biodiversity conservation and/or the comprehensive management of marine resources.

- The present primary motivation for the establishment of an NRSMPA appears to be a misguided commitment to international conventions rather than a considered response to the protection of the marine environment, driven by the explicit understanding and mitigation of threats. The actual international commitment is to the wise management of threats and the only threat to marine biodiversity that has already been well managed in Australia is fishing.

- MPAs provide a political comfort that arises from the public perception that proclamation equates to protection, misguided though this perception may be. The major risk arising from this perception is that the real threats to marine environment health will be ignored in the belief that they are being adequately mitigated by the NRSMPA.

BENEFITS

Fisheries managers, the fishing industry, science and the community will all benefit from the outputs of the project.

The project has provided several peer reviewed articles to contribute to the debate on how marine biodiversity is most effectively managed, the understanding of the conservation benefits of good fisheries management and the need and utility of reserves. We believe they will provide some support to fisheries management agencies, the fishing industries (commercial and recreational) and seafood sector alike, to publicly counter claims that Australia's fisheries are not sustainable.

FURTHER DEVELOPMENT

Despite the outputs achieved in the Project, which exceeded the stated objectives, the work is not complete. Much more needs to be done to promote the environmental credentials of the fishing industry and to address common misconceptions about the sustainability of fishing as managed in Australia.

Consumer-targeted versions of the information presented here would allow public access to the information, but were beyond the scope of the Project.

APPENDICES

APPENDIX 1 – Intellectual property

There are no intellectual property issues associated with this project.

APPENDIX 2 – Project staff

Prof Robert Kearney – Principal Investigator

Prof Colin Buxton – Principal Investigator

Dr Neville Barrett – Co-investigator

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