Submission
No 931

INQUIRY INTO RECREATIONAL FISHING

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Dear Committee

Index:

SUBMISSION TO INQUIRY INTO RECREATIONAL FISHING

> [B]oth recreational and commercial fishing sectors deserve consideration as contributors to the exploitation of fish in marine and inland waters. The lack of global monitoring and compiling of statistics on recreational fishing participation, harvest, and catch-and-release has retarded our ability to understand the magnitude of this fishing sector. Using data from Canada, we estimate that the potential contribution of recreational fish harvest around the world may represent approximately 12 percent of the global fish harvest. Failure to recognize the potential contribution of recreational fishing to fishery declines, environmental degradation, and ecosystem alterations places ecologically and economically important resources at risk. Elevating recreational fishing to a global conservation concern would facilitate the development of strategies to increase the sustainability of this activity. *Cooke & Cowx (2004:857)*:

Basis of submission:

My submission to the Inquiry by the Select Committee (hereafter "the Inquiry") is largely based on a detail review of pertinent literature, complemented by research I have conducted into the effects of recreational spearfishing at a shallow marine reef located in Victoria. With regard to marine issues, a core reference is Nevill (2009) – a doctoral thesis completed at the University of Tasmania. Although devoted to wider themes, the thesis contains chapters which review specific issues of concern regarding the management of recreational fisheries in Australia. With regard to freshwater issues, key references are major consultancy reports I have worked on, particularly Nevill (2004) and Kingsford et al. (2005).

National and international commitments towards well-managed recreational fisheries:

The ecological impacts of recreational fisheries are often assumed to be minimal; in fact the reverse is often the case. Lewin et al. (2006) and Cooke & Cowx (2004) have drawn attention to the potential of recreational fisheries to cause major ecosystem damage. Balon (2000) has discussed related ethical issues, with a plea to close or limit recreational fisheries. My thesis supports arguments by these authors in that the two recreational case studies examined suggest that Australian regulation of recreational fisheries falls well short of clearly stated international and national standards (Nevill 2009 chapters 15 & 16). Specifically, the recreational fisheries I studied (spearfishing in Victoria, and gillnetting in Tasmania) do not meet international FAO[1] guidelines for the application of the precautionary principle to fisheries management. These guidelines apply to Australian jurisdictions, as they follow from Australia's formal endorsement of the FAO Code of Conduct for Responsible Fisheries 1995.

With regard to national benchmarks, it should be noted that all Australian States, including of course New South Wales, through endorsement of the *National Strategy for the Conservation of Australia's Biological Diversity 1996,* committed themselves (amongst other matters) to:

- review the appropriateness of current [fisheries] management strategies, techniques, standards, jurisdictions and legislation;
- develop and adopt practical and acceptable codes of practice for the management and monitoring of commercial and recreational fishing, for the harvesting of invertebrates, for the rehabilitation of depleted stocks, and for key habitat and spawning areas; and
- develop through the Australian and New Zealand Fisheries and Aquaculture Council, in consultation with relevant ministerial councils, a national strategy and guidelines for managing recreational fishing on an ecologically sustainable basis.

In the course of my thesis I examined material available from the Department of Primary Industries Victoria, and the Department of Primary Industries, Water and the Environment Tasmania, in order to ascertain if these commitments have been kept. I found that, for Victoria and Tasmania:

- no reviews have been undertaken of the appropriateness of management strategies, techniques, standards or legislation specifically applicable or relevant to recreational spearfishing or recreational gillnetting;
- no code of practice has been developed specific or relevant to the management and monitoring of recreational spearfishing or recreational gillnetting; and
- no guidelines are in place pertinent to the management of recreational spearfishing or gillnetting on an ecologically sustainable basis.

For Victoria and Tasmania it appears that the commitments made in 1996, listed above, have not been kept, at least in regard to the case studies I examined. I have not investigated the situation in New South Wales, but I suggest to you that a close look may find the same result – these 1996 commitments, I imagine, have not been actioned in an effective way by any Australian State.

Impact of recreational spearfishing:

My studies on the impact of spearfishing (Nevill 2009 Appendix 6, included below as Attachment Three) found that spearfishing pressures on accessible reefs can result in the entire removal of obligate reef-dwelling species from a site. At other sites, credible anecdotal evidence indicates that the abundance of some species at many sites has been reduced so far that these species now play no part in the ecology of the reef – referred to as ecological extinction at that site. On a wider scale, spearfishing has played an important role in reducing the abundance of the East Coast population of the grey nurse shark to a level that is likely to result in the ultimate regional extinction of that species (Nevill 2009 Appendix 6).

Precautionary management of data-poor fisheries:

The precautionary principle states that, where serious environmental degradation is a possibility, decision-makers should not wait for full scientific certainty regarding the danger before taking prudent measures to prevent or mitigate possible damage. The implications of the principle have been explored in an important Australian court case (Mohr 2006; New South Wales Land and Environment Court, Justice CJ Preston).

Fishery managers within Australian jurisdictions are obliged to apply the precautionary principle, flowing from Australia's endorsement of the FAO *Code of Conduct for Responsible*

Fisheries 1995. The NSW *Fisheries Management Act 1994* – s.3 (Objects of the Act) includes "to promote ecologically sustainable development, including the conservation of biodiversity." The Act creates a "TAC Committee" which (s.30) "is to have regard to the precautionary principle" in making determinations. As NSW endorsed the *National Strategy for Ecologically Sustainable Development* (Commonwealth of Australia 1992) which endorsed the precautionary principle, it appears implicit that precaution must be applied within activities sanctioned under the NSW *Fisheries Management Act.*

On the global scene, there is no doubt that recreational fisheries can cause serious environmental damage (Cooke & Cowx 2004, 2006). At a personal level, I have witnessed major impacts from recreational spearfishing (Nevill 2009 appendix 6) on shallow marine reefs. There is also little argument that high levels of uncertainty apply to the management of recreational fisheries: due to the costs and difficulties of enforcing compliance, monitoring multi-species stocks, and measuring overall recreational catch – management decisions are always made against high levels of uncertainty regarding critical management parameters.

In this circumstance, the only way to apply precaution is to 'err on the safe side'. The single most effective management strategy is to set aside 'comprehensive, adequate and representative' examples of marine ecosystems in large no-take protected areas (sometimes referred to as marine reserves). These reserves, apart from protecting viable examples of ecosystems with their important (and largely unknown) biodiversity values, provide important reference areas needed to evaluate the impacts of fishery management regimes in the wider marine environment. Moreover, if networks of reserves are extended to protect all important spawning and nursery sites, fishermen themselves will benefit from healthy and relatively stable fish stocks. There are other fishery management parameters which can 'err on the safe side': for example: catch limits, boat limits, gear restrictions, and minimum legal length. Fish can also be given greater protection through the use of closed seasons covering the full spawning period, as well as permanently or temporarily closing spawning sites, and here precaution dictates erring to expand the size and duration of the protected zones.

The role of marine protected areas:

Returning to the subject of the establishment of no-take marine protected areas (marine reserves), it is noteworthy that fishermen often oppose the closure of fishing areas, but later come to support the reserves. This has certainly been the case regarding the well-known marine reserve at Goat Island in New Zealand, which I visited a few years ago. Local crayfishers regard the reserve as an important source of recruits to fishing areas adjacent to the reserve (see Cole et al. 1990).

Fishing, including recreational fishing, is an important threat to marine ecosystems. While acknowledging the importance of climate change as a long-term threat, in the short term fishing activities appear to be the primary threat to Australian fishes (Pogonoski et al. 2002) and the second most important threat to Australian marine invertebrates (Ponder et al. 2002) after habitat degradation. No-take marine reserves can provide protection from the impacts of fishing, provided they are effectively enforced.

Fishermen sometimes question the quality of the science behind marine reserves. Where these comments are made by people who have actually read the literature, they are dishonest and mischievous – especially when you consider the pervasive (and widely acknowledged) lack of scientific backing behind recreational fisheries management. The Australian Marine Science Association (AMSA) published two important documents in December 2008 relating to marine protected areas: a short 'position statement' and a longer 'position paper' which discusses the scientific basis of marine reserves in some detail. While marine reserves as management tools have their problems (for example relating to enforcement) the AMSA documents make it clear that the establishment of marine reserves rests on a strong scientific backing. There is considerable on-going work assessing marine reserves in Australia and around the world, and evidence of their effectiveness continues to mount (see for example McCook et al. 2010, Hamilton et al. 2010, Costello et al. 2010, and Dalton 2010).

Many factors can undermine the effectiveness of marine reserves. Some marine reserves have been in place in Japan for over 30 years, but monitoring has shown no significant difference comparing fish abundance inside and outside the reserves. However, fishing controls at the reserves are not enforced (pers.comm. T. Kimura, Japan Wildlife Research Center, February 2010).

Small no-take reserves may be expected to benefit sedentary organisms with short larvae phases, but little else, as fishing pressures at the boundaries will be likely to impose high mortality on more mobile species. Reserves may be expected to provide much better protection for mobile species if they are considerably larger than the regular movements of the species they are designed to protect, and where reserves are established in networks which, at least to some extent, cater for the large-scale dispersion of many of the resident species, and include areas critical to different life-cycle stages (eg: nursery, feeding and spawning areas). For further detail see Attachment One below – the AMSA MPA position paper.

The AMSA position statement recommends “a goal should aim to protect all major marine ecosystems, with a minimum target of 10% of all habitat types under full no-take protection by 2012. Rare and vulnerable ecosystems or communities should be provided with greater protection – up to 100% where an isolated ecosystem or habitat type is endangered.” However, it should be noted that most scientists who have published estimates of the necessary extent of MPA networks favour much higher figures, generally 20% to 40% of habitat types fully protected (see Nevill 2007, included as Attachment Two below).

Need for the establishment of networks of freshwater protected areas:

Australia’s freshwaters, particularly over the southern half of the continent and along the heavily-populated eastern seaboard, are degraded by water extraction, pollution from catchment developments, and the effects of exotic pests (including trout). These freshwaters are also heavily overfished. As in marine waters, the most important action necessary to increase the benefits of the recreational fishing experience is to reduce fishing pressures. This is most important with respect to the provision of refuges which could allow native fish populations to rebuild.

The provision of protected areas in rivers, wetlands and lakes, which would benefit native fish populations could be meshed with the creation of networks of protected areas whose primary purpose is to protect *comprehensive, adequate and representative* examples of all natural aquatic ecosystems (Nevill 2004). While freshwater protected areas present several important management difficulties, these problems are not insurmountable (Saunders et al. 2002). While all Australian governments (Commonwealth and State) are committed on paper to the development of representative networks of freshwater protected areas, in practice little has been achieved so far. Many scientists have called for urgent action to fulfil these long-standing commitments (Kingsford & Nevill 2006).

Canada has had, since 1984, a successful community-driven system for protecting rivers of special ecological, historical or cultural significance – the Canadian Heritage Rivers System (Nevill 2004, Kingsford 2007). While this system is not specifically aimed at the development of representative freshwater protected areas (above), it is compatible with it. There are strong arguments on many grounds for Australia to develop a similar system for protecting its special rivers (Nevill 2004, Kingsford et al. 2005; Kingsford 2007).

Recommendations:

Most recreational fish stocks are probably well below the benchmark points of maximum sustainable yield or maximum economic yield – due to pervasive overfishing. The most important way to improve recreational catches, and improve the recreational fishing experience, is to reduce fishing effort to allow stocks to build in size and abundance. This strategy will benefit both fishers, fish, and the ecosystems they live in. Fishing effort should be reduced in ways which protect biodiversity, and/or enhance reproduction and recruitment. The use of a variety of protected area zones should be applied:

1. The State of NSW should formally adopt a goal of placing 10 – 40% of each major aquatic ecosystem or habitat type within a State-wide network of no take areas – noting the recommendations made by AMSA for "at least" 10% (see above). Vulnerable or threatened ecosystems should be protected at higher levels – up to 100% for ecosystem types which are both rare and threatened. With respect to freshwater ecosystems, the degraded state of many ecosystem types places a special urgency on such an action. With respect to the marine environment, these no-take areas should form the core of a much larger network of marine protected areas occupying 60% to 80% of State waters. While both commercial and recreational fishing should be permitted, under certain conditions and seasons, within this wider network, destructive fishing practices (such as bottom trawling over vulnerable habitat, or seine netting with its high juvenile mortality rate) should be entirely banned from the larger network. Given the difficulties of ensuring full compliance with fishing bans, as far as practical, each no-take area should contain a smaller core zone in which even entry (without written permit) is excluded. These no-entry zones form the only true reference areas, and should also include the most important critical habitats.

2. New South Wales should make specific budgetary provisions to action long-standing commitments to develop freshwater protected areas representative of all major freshwater ecosystem types found within the State. The protection of environmental flows, especially groundwater flows, for such protected areas is of critical importance.

3. New South Wales should work with the Commonwealth and other State governments towards the development of an Australian *Heritage Rivers System* modelled on the successful Canadian system (see above).

4. All identified spawning and nursery areas within State waters should be highly protected by some effective mechanism. Such mechanisms should include gear and anchoring restrictions to protect habitat, permanent closure of areas of special importance, and seasonal restrictions during spawning seasons, covering all other areas.

5. Accessible shallow-water habitats, especially rocky reefs, have been seriously overfishing along the entire NSW coastline. A series of rolling closures should be implemented entirely outside the permanent MPA network mentioned above. The purpose of these closures would focus only on rebuilding stocks for recreational fishing. Reefs should be closed from 5 to 10 years, then re-opened to recreational fishing. Once these closed areas are re-opened, adjacent areas which have been subject to fishing should be closed. Areas should be identified where this system is likely to produce significant benefits for recreational fishers; areas will need to be large enough[2] to avoid significant attrition of fish stocks through edge effects.

6. All recreational and commercial fishing, except 'catch-and-release' should be banned inside National Parks, and within State waters adjacent to National Parks. It is a travesty of logic to protect terrestrial animals but not aquatic animals within parks dedicated, at least in part, to the protection of natural environments.

7. NSW has numerous coastal estuaries which open intermittently to the sea. These areas are often highly productive, are often nursery and spawning areas, and are under increasing threat from urbanization and recreational over-use. Commercial fishing should be phased out of *all* coastal estuaries, including the large ones like Sydney harbour. Commercial fishing in Sydney harbour has been restricted due to concerns over contamination; this provides an opportunity to phase commercial fishing out permanently. With the exception of identified spawning and nursery areas, and areas of special ecological significance, Sydney harbour should be promoted as a recreational fishing venue.

8. All forms of destructive fishing practice should be phased out of all NSW coastal waters, and all fisheries managed by the NSW State Government. This should take place between 2010 and 2020. Within a decade, bottom trawling should only be permitted on areas which have been assessed and identified as resilient to this type of gear. Shark net protection of swimming beaches should be phased out on the grounds of unacceptable bycatch. Beach seining should be phased out on the

grounds of unacceptable mortality of juvenile fish. NSW should continue its State-wide ban on spearfishing with SCUBA, and introduce an new ban on spearfishing at night – an equally destructive practice.

9. All recreational fishing should be licensed, and a system of catch reporting via the internet should be introduced over a decade. The first phase should start with a voluntary system targeting top predators such as game fish, and this should be extended by the end of the decade to a mandatory system covering all recreational catch, including freshwater, estuarine and marine.

I would be happy to discuss these recommendations, or other aspects of my submission, with the committee.

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Endnotes:

[1] FAO – United Nations Fisheries and Agriculture Organization, based in Rome, Italy.
[2] Probably in the order of 10 km2 or larger.

Attachment One: The AMSA MPA position paper 2008:

Position paper on marine protected areas

1. Preamble:

Australia is at the forefront of marine conservation internationally, both in terms of legislation enacted to protect the marine environment, and in terms of the spatial extent of proclaimed marine reserves. The Australian (Commonwealth) Government, and all State and Territory Governments, are committed to the development of a national system of representative marine protected areas (NRSMPA) by 2012 (ANZECC 1999).

AMSA is Australia's largest professional association of marine scientists with over 900 members nationally. The AMSA mission is to advance marine science in Australia. AMSA's objectives are to:

- promote, develop and assist in the study of all branches of marine science in Australia;
- provide for the exchange of information and ideas between those concerned with marine science; and
- engage in public debate where we have specialist knowledge.

Marine scientists are not only participants in the NRSMPA through delivering scientific information and advice to assist with the development and evaluation of the protected area network, they are also a key stakeholder group since they use the marine environment for research. AMSA wishes to emphasise the importance of this dual role for marine scientists, because a special effort by governments is needed to include them as stakeholders in the NRSMPA process.

Marine protected areas are *areas of the ocean or coastal seas, securely reserved and effectively protected from at least some threats*[1]. "Effective protection" focuses on identified values, and a management plan (and budget) should be in place. The level of protection, and the intent of protection can both vary. The Great Barrier Reef Marine Park (GBRMP) in Queensland is an example of a large protected area (345,000 km^2) which contains extensive multiple-use areas (covering 66.6% of the marine park) where a variety of fishing activities are allowed, as well as core areas (covering 33.4% of the marine park) which are protected from all extractive activities. In addition, approximately 45% of the multiple use areas are closed to the most ecologically damaging form of fishing – bottom trawling.

The most widely accepted definitions of protected areas are those recommended by the World Conservation Union, or IUCN (Dudley 2008). In their original form they are discussed in an Australian context in IUCN Australia (2000). IUCN categories Ia and Ib are strict no-take areas or sanctuaries, with the categories grading to category VI, incorporating "traditional natural resource management" (Dudley 2008:22). In this paper the word 'reserve' is taken to include protected areas in the first four categories, whose purpose is primarily nature conservation[2]. Areas protected from all harvesting are referred to here as "no-take areas".

Marine reserves must not be seen as a substitute for well-managed fisheries – we need both. The use of marine protected areas to protect biodiversity values is well documented, and MPAs have been accepted at the international level as essential marine conservation tools for nearly three decades. Statements suggesting that the biodiversity conservation benefits of no-take marine protected areas have not been demonstrated are incorrect and misguided – as are statements suggesting fishing activities do not present significant threats to marine ecosystems. Moreover, long-established marine reserves, such as major reserves in tropical Queensland and Western Australia, or the Leigh (Goat Island) and Poor Knights reserves in New Zealand, are important tourist attractions, and produce substantial economic benefits for local and regional communities.

There are two parts to this document (apart from the preamble). The position statement is the first part, and is intended to be a clear statement of AMSA's position on marine protected areas – with recommendations. The second part of the paper provides both background and rationale supporting the statement, and is referenced to scientific and policy literature.

2. Position statement

2.1 AMSA endorses the government's national representative system of marine protected areas (NRSMPA) program, and encourages its timely completion. This should be done for both present and future generations of Australians, as well as to provide undisturbed habitat for at least a proportion of the plants and animals with which we share this planet. AMSA also identifies (below) key areas where further government efforts are urgently needed to maximise the benefits of the NRSMPA to all Australians.

2.2 When an MPA is declared, AMSA believes there should be clearly articulated aims for the MPA, and that the specific MPA be planned for, and managed accordingly.

2.3 Australia's marine biota are poorly studied and in spite of efforts such as the global census of marine life, there are few comprehensive data sets that can be used for MPA design and performance measurement purposes. AMSA encourages governments to invest in taxonomic support and training, ecological modelling studies and especially building national and regional biological data sets, including habitat mapping, to support MPA design, performance measurement and evidence-based decision making. Baseline monitoring before, or at the time of MPA creation[3] is a vital tool for the study of long-term MPA effects, and such ongoing studies must be adequately funded.

2.4 Similarly, the physical aspects of Australia's marine environment are poorly studied. For example, modern multibeam sonar bathymetry data have been collected (at mid-2008) over less than 10% of Australia's EEZ (and over less than 1% of the continental shelf). AMSA encourages governments to invest in building better marine environmental data sets to support all forms of marine management.

2.5 In establishing and expanding networks of marine protected areas, consultation with all stakeholders is vital, combined with adequate education, information and awareness programs. Stakeholders should be able to provide a variety of inputs including both baseline information on ecosystem[4] values and usage, as well as the expression of preferences for reservation options. The selection of options, however, must be framed within Australia's national and international commitments to the protection of biodiversity, and must be based on the best scientific evidence available. Where evidence is inadequate, a precautionary stance must be taken, in line with Australia's commitment to the precautionary principle (Government of Australia 1992).

2.6 Where declaration of MPAs removes substantial and valuable legal entitlements, and where stakeholders suffer significant financial hardship as the result of reserve proclamation, adequate compensation should be paid.

2.7 Networks of marine protected areas must be adequately resourced from the start to ensure they are properly maintained and managed, and to protect them from illegal harvesting and other threats. Well-designed scientific monitoring programmes should be part of their management. It is important to document ecosystem changes following protection to provide information to managers and the wider community on their performance. Such baseline information will also help improve our ability to manage the wider marine environment in a productive and sustainable way.

2.8 AMSA believes that MPAs are vital for the conservation of Australia's marine environment and threatened species. AMSA recommends the following:

a) Given national commitments set out within the NRSMPA strategy, we urge all Australian governments to establish networks of marine protected areas, with the objective of comprehensive, adequate and representative protection of Australia's marine biodiversity assets. National or State marine reserve area targets are only useful in the absence of systematic regional conservation plans. Where detailed planning has not been undertaken, a goal should aim to protect all major marine ecosystems, with a minimum target of 10% of all habitat types under full no-take protection[5] by 2012. Rare and vulnerable ecosystems or communities should be provided with greater protection – up to 100% where an isolated ecosystem or habitat type is endangered. Such no-take reserves should lie within larger multi-use protected areas, designed to provide limited harvesting opportunities which will not prejudice biodiversity assets, especially those within the core no-take zones. A figure of 10% under no-take protection would slow but not prevent loss of biodiversity: the current no-take level in the GBRMP of 33% is more likely to achieve substantial and sustained biodiversity benefits.

b) To be effective, MPA designation should be accompanied by a net reduction in fishing effort for affected fisheries which are at or near full exploitation[6], and AMSA endorses Commonwealth and State use of structural adjustment and industry buyout packages where appropriate (eg: Government of Australia 2004).

c) Although MPAs are an essential tool for marine conservation, AMSA emphasises that MPAs must be complemented by effective management strategies across the marine environment, including (urgently) climate change impact programs, well-managed fisheries, control of spread of invasive species, and control of pollutants, especially nutrients and sediments.

d) AMSA stresses the importance of MPA planning principles set out in several important government documents, especially documents *a,c,f,h,q,s,x & y* listed under the 'guidelines' heading in section 3 below. Several of these documents stress the role and importance of stakeholder consultation, which should take place within a framework of alternative approaches constrained by the essential goals and objectives of the NRSMPA.

2.9 There are (and will continue to be) costs in establishing the NRSMPA, and it is proper that efforts should be taken to minimise these costs. However these costs are predominantly short-term, and should not overshadow the long-term benefits accruing from an effective national MPA network. It is essential that alternative options put to stakeholders do not compromise the fundamental goals, and essential design principles of the network.

2.10 Australia's marine environment has been impacted by a range of human activities. AMSA considers that the cumulative impact of multiple stressors on the marine environment constitutes a key knowledge gap not adequately addressed by existing scientific programmes. A quantitative assessment of cumulative human impacts is required to underpin comprehensive evidence-based decision making.

2.11 While most attention has focussed on the ecological and fisheries values of MPAs, it is also possible that in future MPAs could be created to protect sites of geological or physical oceanographic significance. AMSA encourages consideration of these values.

2.12 AMSA has been disappointed[7] by the small portions of MPAs zoned as totally protected (no-take) particularly on the continental shelf. Only 0.75% of the South East Region shelf is protected by Commonwealth no-take MPAs, noting that about 6% of the SE Region is shelf (on average around 22% of Australia's EEZ is continental shelf). The shelf contains important habitats not found elsewhere. AMSA encourages the inclusion of more shelf areas within existing and future MPA networks, and increased use of full (no-take) protection as the main tool to achieve high-quality conservation outcomes.[8]

2.13 AMSA encourages improved coordination between Commonwealth and State-Territory governments in the design of the NRSMPAs. There is a risk that poor coordination will result in inadequate protection of some ecosystems, particularly those situated near jurisdictional boundaries. Without coordination the placement of MPAs is unlikely to be optimised in terms of cost or effectiveness.

2.14 Systematic network design must be based on biological complementarity, and must consider issues of connectivity, efficiency, uncertainty, replication and effectiveness on a regional basis. Issues relating to rare or endangered species, habitats or ecosystems must be considered, as well as critical habitat, and migratory pathways.

2.15 Good fisheries management is essential to the protection of marine biodiversity. AMSA supports improved fisheries management in conjunction with the development of MPA networks. Of particular importance is the wide application of the ecosystem and precautionary approaches to the management of both commercial and recreational fisheries. AMSA also notes that Australia is committed to the phase-out of all destructive fishing practices by 2012.

2.16 It is unfortunate that Australia lacks an up-to-date consolidated reporting mechanism on protected areas. The collaborative Australian protected area database (CAPAD), maintained by the Commonwealth (at mid-2008) lacked comprehensive information on State marine protected areas past 2004. Further, the database lacks reporting on the extent of protection of marine habitat, ecosystem, geomorphic province, or even bioregion. These are important gaps and should be addressed by the Commonwealth Government as a matter of urgency.

2.17 Marine protected areas assist in maintaining healthy ecosystems. Important ecosystem services supplied by the marine environment include the supply of seafood, passive and active recreational opportunities, dilution and assimilation of wastes (including greenhouse gases), the regulation of coastal climate, and vessel passage – almost all depending heavily on healthy marine ecosystems.

3. Supporting material: protecting marine biodiversity

The following sections provide summary information on:

- important principles and guidelines relating to marine protected areas;
- Australia's marine biodiversity values,
- threats to marine biodiversity values,
- national and State commitments to protect marine biodiversity values,
- general management strategies for protecting marine biodiversity values, and
- the specific role of MPA networks in protecting those and associated values (eg fisheries, scientific and recreational values).

Biodiversity is one of the key conservation values that marine protected areas aim to protect. Other conservation values vary between particular regions and may include key ecological features (eg. upwelling zones), threatened-endangered-protected species (TEPS), geomorphological features having conservation interest (eg. submarine canyons, seamounts, reefs, banks), iconic features (eg. Perth Canyon, Macquarie Island), archaeological or cultural features (eg. historic shipwrecks), and rare or vulnerable marine ecosystems (RVMEs).

Guideline documents

A variety of documents have been published in recent years which seek to provide advice to governments, scientists and stakeholders in respect to the establishment and management of marine reserve networks. Among the most important (from an Australian viewpoint) are (in chronological order – italics mark documents of special note):

a) *Goals and principles for the establishment of the National Representative System of Marine Protected Areas in Commonwealth waters* (Government of Australia 2008) – noting that these represent a revision of the goals originally stated in Government of Australia (1998);

b) Establishing marine protected area networks: Making it happen: Full technical version (Laffoley et al. 2008);

c) *Guidance on achieving comprehensiveness, adequacy and representativeness in the Commonwealth waters component of the National Representative System of Marine Protected Areas* (SPRPNRSMPA 2006);

d) Establishing representative no-take areas in the Great Barrier Reef: large-scale implementation of theory on marine protected areas (Fernandes et al. 2005);

e) The international legal regime of the high seas and the seabed beyond the limits of national jurisdiction and options for cooperation for the establishment of marine protected areas (MPAs) in marine areas beyond the limits of national jurisdiction (Kimball 2005);

f) *Marine protected areas and displaced fishing: a policy statement* (Government of Australia 2004);

g) Designing marine reserves for fishery management (Meester et al. 2004);

h) *Technical advice on the establishment and management of national systems of marine and coastal protected areas* (SCBD 2004);

i) Marine protected areas as a central element of ecosystem-based management: defining their circulation, size and location (Bowman & Sergio 2004);

j) Incorporating marine protected areas into integrated coastal and ocean management: principles and guidelines (Ehler et al. 2004);

k) Reserve selection in regions with poor biological data (Gaston & Rodrigues 2003);

l) *Towards a strategy for high seas marine protected areas: proceedings of the IUCN, WCPA and WWF Experts Workshop on High Seas MPAs, January 2003* (Gjerde & Breide 2003);

m) *Principles for the design of marine reserves* (Botsford et al. 2003);

n) A user's guide to identifying candidate areas for a regional representative system of marine protected areas: south-east marine region (Government of Australia 2003);

o) Population models for marine reserve design: a retrospective and prospective synthesis (Gerber et al. 2003);

p) *Application of ecological criteria in selecting marine reserves and developing reserve networks* (Roberts et al. 2003);

q) *Biophysical Operational Principles* (Great Barrier Reef RAP) (SSC 2002);

r) Marine protected areas: tools for sustaining ocean ecosystems (NRC 2001);

s) *Australian IUCN reserve management principles for Commonwealth marine protected areas*: Schedule 8 of the EPBC Regulations 2000 (Government of Australia 2000);

t) Fully-protected marine reserves: a guide (Roberts & Hawkins 2000);

u) Marine and coastal protected areas: a guide for planners and managers (Salm et al. 2000);

v) Selecting marine reserves using habitats and species assemblages as surrogates for biological diversity (Ward et al. 1999);

w) *Guidelines for marine protected areas* (Kelleher 1999);

x) Australia's Oceans Policy 1998: *Policy guidance for oceans planning and management (Government of Australia* 1998).

y) *Guidelines for establishing the national representative system of marine protected areas* (ANZECC 1998);

z) Guidelines for establishing marine protected areas (Kelleher & Kenchington 1991)

In 1995 the Jakarta Mandate of the *Convention on Biological Diversity 1992* (CBD) established a program within the CBD Secretariat specifically to pursue the protection of marine and coastal biodiversity. Each year the CBD Conference of Parties (CoP) considers this program, and issues a decision statement. These statements are important documents, and Australia (as a strong supporter of the CBD) is committed to their implementation within Commonwealth and State programs[9].

3.1 Australia's marine biodiversity:

Australia's Exclusive Economic Zone (EEZ) obtains its legal validity from our ratification of the United Nations *Convention on the Law of the Sea* in 1994. Australia's EEZ is the world's third largest, with a total area of 11.38 million km^2 (excluding the EEZ attached to Australia's Antarctic Territory). The oceans surrounding Australia are mostly oligotrophic and relatively unproductive. However, the biodiversity of Australia's EEZ is amongst the highest in the world.

Australia's marine flora and fauna encompass a very broad range of latitudes and include tropical, temperate and sub-Antarctic bioregions. These bioregions contain ecosystems which are:

- highly endemic, particularly in the southern temperate zone;
- highly diverse and less damaged when compared to many other places in the world; and
- still poorly documented.

Australia's marine biota also belong to three oceanic systems, including assemblages from the Indo-West Pacific marine fauna, which is of high taxonomic and evolutionary significance, the Indian Ocean, and those of the Southern Ocean (polar) seas.

Given the lack of available information on marine biodiversity, the design of MPAs to date has been substantially based on IMCRA[10] bioregions, with the aim of having representative portions of each bioregion contained within the MPA network for each planning region. Zoning will need to be re-visited in future decades as more information comes to light.

Australian seas are home to marine biodiversity of great international significance. These are assets of great environmental, economic and moral importance, to us and to future generations.

All Australian States endorsed the *National Strategy for the Conservation of Australia's Biological Diversity* 1996[11]. This strategy includes an important paragraph acknowledging the intrinsic value of our biodiversity:

> There is in the community a view that the conservation of biological diversity also has an ethical basis. We share the Earth with many other life forms that warrant our respect, whether or not they are of benefit to us. Earth belongs to the future as well as the present: no single species or generation can claim it as its own.

We have a moral duty to provide undisturbed habitat for at least a proportion of the plants and animals with which we share this planet.

3.2 Threats to marine biodiversity:

Broadly speaking, the living inhabitants of the marine realm face five major threats:

- *climate change*: changes to oceanic temperatures, acidity, patterns of water movement (including currents, eddies and fronts), storminess and sea level, largely caused by *increasing atmospheric carbon dioxide*, as well as impacts from damage to the ozone layer;
- *overfishing* with attendant bycatch problems, both from commercial fishing, recreational fishing, illegal unregulated or unreported fishing (IUU), and ghost fishing;
- *habitat damage* largely caused by fishing gear, especially bottom trawling, but also including effects often associated with coastal development: destruction of coral

reefs, mangroves, natural freshwater flows (and passage), coastal foreshores, coastal wetlands and sometimes entire estuaries – which all support coastal marine ecosystems;

- *pollution* (in-sea and land-based, diffuse and point source) including nutrients, sediments, plastic litter, noise, hazardous and radioactive substances; discarded fishing gear, microbial pollution, and trace chemicals such as carcinogens, endocrine-disruptors, and info-disruptors; and
- ecosystem alterations caused by the introduction of *alien organisms*, especially those transported by vessel ballast water and hull fouling.

Amongst these five major threats to marine biodiversity, fishing has, until the present time, been the most damaging on a global scale (Millennium Ecosystem Assessment 2005a:67, 2005b:8, 2005c:12, 2006). The destructive impacts of fishing stem chiefly from overharvesting, habitat destruction, and bycatch. Over the 21st century the threats posed by increasing atmospheric greenhouse gases pose huge dangers to the marine environment (Veron 2008, Koslow 2007, Turley et al. 2006). At smaller scales, other threats (particularly pollution and habitat damage) are dominant at different localities. Coral reef, mangrove, estuarine, seagrass, mud-flat, and sponge-field habitats have been (and are being) extensively damaged. River passage, essential for anadromous and diadromous species, has been impaired or destroyed around the globe.

In Australia, fishing activities appear to be the primary threat to fishes (Pogonoski et al. 2002) and the second most important threat to marine invertebrates (Ponder et al. 2002) after habitat degradation.

3.3 Commitments to protect marine biodiversity:

Australia, and Australian States, have made many strong commitments to protect marine biodiversity.

Principle 2 of the Stockholm Declaration (UN Conference on the Human Environment 1972) states: "The natural resources of the earth, including the air, water, land, flora and fauna and *especially representative samples of natural ecosystems*, must be safeguarded for the benefit of present and future generations through careful planning or management, as appropriate" (emphasis added).

The emphasised section provides, essentially, a commitment to the development of protected area networks focused in large part on the conservation of representative examples of major natural ecosystems. An examination of the wording of the Declaration reveals that it places wide obligations, not only on governments, but on all agencies of governments as well as individuals to act so as to achieve the stated objectives.

Australia was one of many nations endorsing the Stockholm Declaration. Australia later endorsed other important international agreements which reaffirmed our nation's commitment to the development of networks of protected areas – placing particular emphasis on the protection of representative samples of all major ecosystem types:

- the *World Charter for Nature 1982*;
- the *Rio Declaration 1992* (UN Conference on Environment and Development);
- the *Convention on Biological Diversity* (CBD) 1992; and
- the *Johannesburg Declaration* 2002 (UN World Summit on Sustainable Development);

Australia ratified the United Nations *Convention on Biological Diversity* (CBD) in 1993, and in 1999 the Government enacted the *Environment Protection and Biodiversity Conservation Act* (EPBC Act) which promotes the conservation of biodiversity by providing protection for threatened species and ecological communities, migratory birds, marine mammals and other protected species.

A key requirement of the CBD is for all member nations to establish systems of protected areas, and to develop guidelines for the selection, establishment and management of protected areas. Australia's support of the CBD extends to subsequent agreements under the Convention, in particular the *Jakarta Mandate on Marine and Coastal Biological Diversity (1995)* which provides a strong commitment to the development of marine protected area networks incorporating core no-take reserves within larger multi-use MPAs.

At the seventh meeting of the CBD CoP (Conference of Parties), in Decision VII/30 Annex II (UNEP 2004) the Parties adopted a target: "at least 10% of each of the world's ecological regions effectively conserved". Through Decision VII/5:18-19, the parties also agreed to establish (by 2012) and maintain a network of marine and coastal protected areas that are *representative, effectively managed, ecologically based, consistent with international law, based on scientific information, and including a range of levels of protection*.

At the tenth meeting (2005) of the CBD Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA) an 'application of the targets to the CBD programme of works on marine and coastal biodiversity' repeated this target in the marine context: "At least 10% of each of the world's marine and coastal ecological regions effectively conserved" (by 2012) (UNEP 2005:44).

Australia, and all Australian States are committed to the establishment of networks of marine protected areas representing all major marine ecosystems within Australian jurisdiction. This fundamental commitment is spelt out in increasing detail in three major policy statements: (a) the InterGovernmental Agreement on the Environment 1992 (Government of Australia 1992), (b) the National Strategy for the Conservation of Australia's Biological Diversity (Government of Australia 1996) and, most importantly (c) the Strategic Plan of Action for the National Representative System of Marine Protected Areas 1999 (ANZECC TFMPA 1999).

The goal of the National Strategy for the Conservation of Australia's Biological Diversity is "to protect biological diversity and maintain ecological processes and systems". Principle 8 of the strategy states: "Central to the conservation of Australia's biological diversity is the establishment of a comprehensive, representative and adequate system of ecologically viable protected areas integrated with the sympathetic management of all other areas, including agricultural and other resource production systems."

Commonwealth, State and Territory governments are committed to create a national representative system of Marine Protected Areas (NRSMPA) for the conservation of marine ecosystems by 2012. As at 2004 the CAPAD[12] database listed 200 MPAs in Australian waters covering approximately 648,000 km^2 or ~ 5.7% of Australia's marine jurisdiction, excluding the Australian Antarctic Territory[13]. The MPAglobal website[14], checked in September 2008, listed 359 Australian MPAs, of which 310 were reserves[15], and 81 were no-take[16].

3.4 Protection strategies

What practical steps are available to protect marine biodiversity values in line with existing commitments? Where do MPAs lie in this suite of protective strategies?

Each Australian jurisdiction (at the State and Commonwealth levels) has a relatively similar set of tools at their disposal that are used (to varying extents and effectiveness) for the purposes of management and protection of marine biodiversity. Note here that we use, for the sake of convenience, the term "State" to include the Northern Territory. These tools fall into the three general categories of environment protection, natural resource management, and conservation. The main exceptions to this are the Great Barrier Reef World Heritage Area which is managed under its own Commonwealth Act, and the intertidal areas that are contiguous with aboriginal lands which fall under indigenous management arrangements.

The systems of *environment protection* include controls on point source pollution as well as diffuse broad-scale pollution of watersheds, estuaries, and coastal foreshores/wetlands; controls on development/disturbance, alienation and modification of estuarine, wetland and shallow marine water habitats; and controls on developments of structures to be placed in deeper waters, including aquaculture facilities, oil exploration/production structures, and tidal/wave/wind energy facilities. These forms of environment protection provide a critical framework to reduce and constrain the pressures imposed by human development on the natural systems of the estuaries and coastal waters, and the structure and processes of marine biodiversity.

Natural resource management principally involves the management of wild capture fisheries, both commercial, recreational, and indigenous. Some harvesting of marine vegetation occurs, but this is mostly beach-cast, and has insignificant effects. Virtually no seabed mining, other than drilling for oil and gas, some sand dredging, and mining of seagrass beds in Cockburn Sound WA for calcareous sand, takes place in Australian waters at the present time[17].

The States are almost wholly responsible for the management of recreational and indigenous fisheries, as well as fisheries substantially confined to State waters. The Commonwealth manages fisheries in Australia's Exclusive Economic Zone, off-shore from the three nautical-mile State limit. This includes the larger of the commercial fisheries, some of which overlap State waters. However, there is a complex set of arrangements between the States and the Commonwealth for delegated management of many fisheries that overlap State and national jurisdictions (noting that the State-waters boundary, aka the 3-nm limit, may be many kilometres offshore in some parts of Australia due to coastal contortions or islands)[18].

Each of the jurisdictions imposes spatial and temporal closures for specific gear types as one aspect of their management system (typically in support of other tools such as minimum and maximum size limits, closed seasons, and controls on bycatch) but the forms of space/time closure normally deployed are both focused on production objectives and are easily revoked should a commercial or recreational need arise. The one dominant exception to this is the protection of coastal wetlands habitats such as mangrove and seagrass beds, which are now more or less well protected (physically) under fisheries management systems because of their important role as spawning, nursery and feeding grounds for targeted species. Overall, the natural resource management systems provide little real protection or commitment to the conservation of marine biodiversity, with (amongst other key biodiversity issues) target stocks being routinely fished down to very low levels within fisheries management systems (so-called 'regulatory over-fishing') leading to likely major ecological consequences for species that are dependent on populations of the various target species. In addition, fisheries-related bycatch and habitat damage are real and significant threats.

Marine protected areas almost invariably fall within the *conservation toolkit* in Australia (in other countries they are also used for sustainable fishing purposes). In Australia, MPAs may comprise a number of different zones, from total protection for strict conservation purposes to sustainable use zones where controls on activities are typically minimal (derived from the tools discussed above). To ensure adequate protection of marine biodiversity values, either MPAs with a high level of protection need to be large, or MPA sustainable use zones need to be very large with strict constraints on the type of permitted uses (eg: bans on trawling).

Overall, conservation of Australia's marine biodiversity requires a mix of all the tools and measures discussed above. Both off-reserve and on-reserve tools and constraints need to be applied to cater for the conservation needs of the vast diversity of life-history strategies, feeding, reproduction, migration and recruitment requirements, and to provide for resilience in the face of the broad-scale pressures being applied by changes in ocean conditions.

MPAs may be deployed at a number of spatial scales, providing a number of types/levels of protection. However, where MPAs provide protection for only a small proportion of the ocean habitats, the importance of off-reserve protective measures becomes critical to the overall conservation of marine biodiversity. Where the MPAs are large relative to their local biogeographic region (currently the only examples are the GBR, Ningaloo, and Heard & McDonald Islands) such areas should be zoned to include both substantial no-take areas (the GBR figure of 33% is a good guideline) as well as multi-use areas permitting activities such as low impact tourism, or small scale wilderness fishing activities. Destructive fishing practices should be entirely excluded. Rare or vulnerable biological communities or habitats within such large multi-use MPAs should be fully protected.

Marine protected areas, no matter how well policed or managed, can be degraded by land-based pollutants, such as nutrients, sediments or pesticides. Estuaries can be degraded by inappropriate land filling or drainage, or the effects of polluted or overdrawn aquifers or rivers. Dams across rivers and creeks can block the spawning pathways of fish. Integrated coastal management programs should be developed to manage the effects of coastal development on the marine environment (see “threats” discussed above). Land use planning, water resource legislation, and pollution controls are key tools in developing such integrated programs.

Of the tools available and used in Australia, only MPAs with high levels of protection (such as no-take or no-access zones) can provide effective conservation that takes into account the high levels of uncertainty that surround our present-day knowledge of the structure, the functional relationships, and the ocean and land-based processes that maintain marine ecosystems (Lester & Halpern 2008, Lubchenco et al. 2007). Small MPAs will provide protection for only a very limited suite of species, noting that even small sedentary species may require secure habitats over large geographic ranges to support their meta-populations. Large MPAs (relative to their bioregion) with large areas of high protection provide the least risk that the MPAs will fail to provide adequate protection for both the known diversity of species and those that have yet to be discovered or understood (Lubchenco et al. 2007).

Systematic conservation planning[19], where conservation objectives are expressly articulated, provides the most robust planning and design of MPAs in the face of limited existing knowledge and high levels of risk. See comments under ‘History’ below.

3.5 Marine protected area networks

3.5.1 Introduction

Like terrestrial parks, MPAs have important recreational, aesthetic and educational benefits, and can protect important cultural sites such as shipwrecks. In some cases tourism generated by MPAs can have substantial local and regional economic benefits.

Overall, the most general values of MPA networks are those relating to biodiversity conservation, fisheries, and as research and management tools. MPA networks can help to protect rare, vulnerable or threatened species or communities. Protection of community diversity within healthy ecosystems should increase the resilience of these ecosystems, and should offer protection against invasive species. Substantial MPA networks should be able to assist marine communities adapt to some aspects of climate change.

Conservation benefits within MPAs are evident through increased habitat heterogeneity at the seascape level, increased abundance of threatened species and habitats, and maintenance of a full range of genotypes. Fisheries can benefit through protection of spawning populations, spillover, increased dispersal of egg and larval propagules, and as insurance against stock collapse. Scientific benefits primarily relate to the use of MPAs as reference areas to assess the scale of human impacts on the environment, and as locations for the collection of data that are unobtainable in fished systems. Nevertheless, MPAs can also involve costs to human society through displaced fishing effort, short-term reductions in catches, and through creating a false sense of security. MPAs do not represent a universal panacea for all threats affecting marine ecosystems, but are an important tool in the marine manager's toolbox. For marine conservation biologists, they are the most important tool.

It has been estimated that a global MPA network covering 20-30% of the seas would cost \$5-19 billion per year to maintain (Balmford et al. 2004). However, returns on this investment would be substantial. Such reserves would promote continued delivery of largely unseen marine ecosystem services with an estimated gross value of \$4.5-6.7 trillion each year and have the potential to lead to financial gains from both increased catches and tourism (Badalamenti et al. 2002, Balmford et al. 2004). Marine ecosystem services include the supply of seafood, passive and active recreational opportunities, dilution and assimilation of wastes (including greenhouse gases) and vessel passage – almost all of which depend entirely on healthy marine ecosystems.

On a local scale, the implementation of MPAs can have major social, cultural and economic impacts on communities, which vary considerably according to site and wider social factors within industrialized, developing, or underdeveloped nations (Badalamenti et al. 2002). Careful consideration of socio-economic factors is now considered to be an integral and essential part of MPA network planning and implementation.

3.5.2 History

Marine protected areas have been used by traditional cultures, for example around the Pacific, for hundreds if not thousands of years (Johannes 1978). In fifteenth century Europe trawling was banned in Flanders, with a clear ecological rationale. Different types of trawling were banned throughout the sixteenth and seventeenth centuries in other parts of Europe. Trawling in prohibited areas was made a capital offence in France (WHOI 2002:s1). Clearly, potential damage to marine environments by fishing has been widely recognised for a long time.

In the late nineteen century, concerns over damage caused by fishing led to a decade-long experiment starting in 1885 in Scotland, where open and closed areas were implemented in the Firth of Forth in St. Andrews Bay, with the idea of testing the impacts of fishing on these ecosystems. The final conclusion of that study was that there were serious impacts of harvesting on these ecosystems, and that protection was required (WHOI 2002:s1). Since these early days the concept of marine reserves has received much academic and political scrutiny, and MPAs are now accepted worldwide as a essential marine management tool (see above).

The design and implementation of MPAs has also evolved. Historically the designation of marine reserves was carried out on a site-by-site 'ad hoc' basis, with location, size and spacing of MPAs primarily based on opportunistic socio-economic factors rather than a systematic consideration of the conservation requirements of marine ecosystems or organisms (Stewart et al. 2003, McNeill 1994). It is now recognized that good taxonomic and ecological data are imperative for the systematic design of comprehensive, adequate and representative networks of MPAs (Margules & Pressey 2000, Roberts et al. 2003), and there has been considerable discussion on the types of data required (Palumbi 2003, Roberts et al. 2003, Parnell et al. 2006, Gladstone 2007). There has also been a steady increase in studies which collect and interpret data in this context, including the application of mathematical algorithms to reserve system design (Possingham et al. 2000, Curley et al. 2002, Griffiths & Wilke 2002, Stewart et al. 2003, Gladstone 2007).

It is now considered that systematic network design must be based on biological complementarity, and must consider issues of connectivity, efficiency, uncertainty, replication and effectiveness (Laffoley et al. 2008, Halpern et al. 2006, Carwardine et al. 2006, Stewart & Possingham 2005, Fernandes et al. 2005, Pillans et al. 2003). Issues relating to rare or endangered species, habitats or ecosystems must also be considered, as well as critical habitat and migratory pathways (Dobbs et al. 2008, Fernandes et al. 2005; Shaugnessy 1999). Consideration of boundary effects and compliance issues is also necessary in the design phase.

3.5.3 Biogeographic issues

A critical step in the NRSMPA was the development of a national bioregionalisation, which divides Australia's marine environment into unique bioregions, each characterised by endemic species and distinguishing ecological attributes (Government of Australia 2005). The national bioregionalisation complements the Interim Marine and Coastal Regionalisation of Australia (IMCRA V.3.3; Thackway and Cresswell, 1998) management framework by extending the system of bioregions beyond the continental shelf to cover all of Australia's EEZ. The Interim Marine and Coastal Regionalisation of Australia (IMCRA V.4.0; 50), divides the Australian EEZ into 24 separate Provinces that are separated by 17 Transition Zones making a total of 41 different bioregions. The Provinces are characterised by endemic species, as determined from the distribution of demersal fish. The Transition Zones contain overlapping populations that occur in adjacent Provinces. Distributions of fish species were recorded as 'strings' along the 500 m depth contour. For the analyses, the string was partitioned into smaller segments of about one degree latitude length (about 120 km) into which tabulations of species occurrences were maintained. The similarity or difference between adjacent string segments was measured using the Jaccard statistic , which identified boundaries between different provinces (Government of Australia 2005).

Boundaries between Provinces are locally highly complex because they are based on biophysical information from the lower orders of the classification hierarchy (biomes and, in particular, geomorphological units). Biome boundaries include the shelf break and foot of slope whereas geomorphological units are based on an analysis of seabed geomorphic features (Heap & Harris, 2008).

Following the completion of the South East Regional Marine Plan and declaration of 13 new MPAs in that region, the Australian Government has reviewed the goals and principles that will be used to establish MPAs in Commonwealth waters in the remaining planning regions. The 4 goals and 20 guiding principles specify the criteria that will be used to choose MPA locations, design the MPA boundaries and classify the MPAs into different zoning categories (Government of Australia 2008).

3.5.4 Benefits and costs of MPAs for marine conservation

A primary objective of most MPAs declared to date is the conservation of biological diversity. This may be expressed in terms of the conservation of representative ecosystems, or the protection of important ecological processes, rare or vulnerable habitats, or threatened or important species.

Reserve network area targets

The essential purpose of area targets is to identify the approximate extent of reserves necessary to insure the persistence of both a region's biodiversity, and the processes on which that biodiversity depends. While 'scientific' targets can be developed for single species and areas for which extensive information is available, most studies of targets applying to broader measures of biodiversity, such as habitats or ecosystems, rely on a variety of assumptions and surrogates in the absence of detailed information. In this context a broad arbitrary national target has strengths and weaknesses. In the absence of detailed regional studies it can set a minimum benchmark if applied at a sufficiently fine scale (eg habitat type). However there is also the likelihood that a low target will create false expectations about sufficient reserve areas (Rodrigues & Gaston 2001), and the risk that a target applied at too coarse a scale (e.g. state or national waters) will lead to no-take areas that are not representative of marine regions and habitats, and ineffective at promoting the persistence of important processes.

Such national targets are only useful in the absence of detailed conservation planning at the regional level – once this process has begun a national area target should be abandoned (for that region). Defensible regional targets are an essential component of systematic conservation planning (Pressey et al. 2003:101) The Great Barrier Reef Representative Areas Program (Fernandes et al. 2005) is a good example of such a regional planning exercise. According to Pressey et al. (2003:102) "a basic requirement of [regional] targets is that they should not be constrained or revised downward to accommodate perceived limitations on the feasible extent of conservation areas". The areas important for conservation *and* areas important for extractive uses need to be explicitly identified so that trade-offs are transparent to both decision-makers and stakeholders.

As at 2006 around 0.65% of the global marine realm was classified as protected area, with no-take areas accounting for only a small fraction of this[20]. The World Parks Congress 2003 (WPC) recommended the establishment of national networks of marine no-take areas (NTAs) covering 20-30% of habitats by 2012, a recommendation in marked contrast to the general target set by the *Conference of the Parties to the Convention on Biological Diversity* in 2004, which requires (from participating nations) 10% of all bioregions under protection by 2012. Agardy et al. (2003) however argued against the over-zealous application of the WPC target, suggesting that haste leads to poor planning, and that a focus on targets does little to convince sceptical stakeholders including fishers and politicians[21].

However, while the targets proposed by the WPC remain controversial (Ray 2004) the biodiversity crisis affecting the planet leaves little doubt that an urgent expansion of marine no-take areas is necessary if the global loss of biodiversity is to be addressed in an effective way. This reality is the backdrop against which arguments over marine protected area network targets take place. Soule & Sanjayan (1998) make the point that fully protecting 10% of habitats will not stop biodiversity loss – the target is far too small.

Although Soule & Sanjayan focus mainly on the plight of tropical forests, their discussion of the dilution of scientific reserve selection criteria applies strongly in the marine realm, as recently witnessed in Australia with regard to the protection of Commonwealth waters in Australia's southeast region. Here important representative areas, like the Cascade Plateau, were identified in the initial scoping phase, but later excluded from protection apparently on account of their perceived value to fisheries. A tiny proportion of shelf area was protected within no-take zones (Edgar et al. 2008). The trade-offs made between fisheries and conservation values were not described or justified in any government report, providing the lack of transparency which all too often cloaks poor government decision-making.

Some scientists have proposed reversing the current situation – closing most of the seas, with only a small proportion, perhaps ~ 20%, open to intensive fishing (Walters 1998, 2000). According to Walters (2000): "A revolution is underway in thinking about how to design safe and sustainable policies for fisheries harvesting". Fish stocks repeatedly declining in the face of modern management, major ecosystem damage, and an awareness of the degradation of global biodiversity resources call for a new approach. According to Walters: "Sustainable fisheries management may eventually require a reversal of perspective, from thinking about protected areas as exceptional to thinking about fishing areas as exceptional. This perspective is already the norm in a few fisheries, such as commercial salmon and herring net fisheries along the British Columbia coast". Walters points out that, historically, many apparently sustainable fisheries were stabilised by the existence of 'effective' protected areas, and the erosion of these areas through adoption of new technology subsequently resulted in the collapse of the fishery. Russ & Zeller (2003), in their call for ocean zoning, reinforce Walters ideas.

Literature reviewed by Nevill (2007) reveals a general consensus amongst marine scientists that a massive increase in no-take areas will be necessary if agreed international conservation goals[22] are to be met. Many modelling studies included in this review recommended that targets of 20-40% of habitat should be fully protected. A common assumption in these modelling studies is that fish stocks outside no-take zones are seriously over-exploited, and that these areas essentially provide no protection. While fishery scientists often argue that this need not be the case (Grafton et al. 2007, Hilborn 2007) in practice it remains, unfortunately, all too common worldwide (Pauly & Palomares 2005, Pauly 2005).

It should be noted that Australian governments have, at this stage, not set marine reserve area targets. However a number of nations have set targets. According to Nevill (2007), targets (commonly applying to a proportion of marine ecosystems or habitats) used internationally include:

- South Africa – an official government target of 10% under marine reserves (referenced to the international goal) by 2012. A South African biodiversity protection strategy, released in 2001, recommended 20% under protection by 2010; this recommendation does not appear to have been adopted;
- New Zealand – 10% of marine areas under protection within a network of representative marine protected areas – by 2010;
- Brazil – 10% of each major ecosystem under no-take protection by 2015;
- Fiji – 30% within a representative reserve network by 2020;

- the Bahamas, the Galapagos Islands, Guam – targets of 20% under no-take protection;
- Micronesia – 30% within a marine reserve network by 2020;
- Grenada – 25% within a marine reserve network by 2020;

AMSA endorses the following extract from the *Ecological Society of Australia's* Position Statement on Protected Areas (2003):

> Australian governments have produced and endorsed numerous policies and conventions relating to the conservation of biodiversity. These documents promote broad goals such as comprehensiveness, adequacy, representativeness, persistence and sustainability. Planning and management of protected areas require these goals to be translated into quantitative targets for conservation action on the ground. Targets developed for the Regional Forest Agreements remain controversial scientifically and, in any case, have questionable relevance to agricultural and pastoral regions or marine environments. The more recent retention target of 30% of the pre-1750 extent of ecological communities, even where achieved, will result in further loss of biodiversity in many regions.
>
> The ESA considers that quantitative targets for retention and restoration of biodiversity pattern and process should be the subject of ongoing research, debate and improvement. Targets framed as percentages of regions, subregions or jurisdictions, because of their broad scale, are not useful for planning new protected areas or reviewing established ones. Targets are necessary for land[23] types and species at finer scales. Targets should not be constrained by political or economic considerations because meaningful tradeoffs between nature conservation and competing land uses require areas important for both to be identified and compared.

Conservation of ecosystems

Substantial no-take MPAs can increase ecosystem diversity at large geographical scales. The tools available to modern fishers have created the situation where fish and large invertebrates are captured from virtually all open-access coastal areas of the planet plus trawlable seabeds to over 2000 m depth. The removal of large carnivorous species targeted by fishers in turn affects populations of prey species, with consequent flow-on effects throughout the food web (Pauly et al. 1998, 2000; Okey et al. 2004). Creation of an effective MPA thus adds a new ecosystem component to the regional seascape mosaic in the form of a patch that is ecologically structured by the large commercially exploited fishes that are virtually absent elsewhere.

A second conservation benefit of MPAs is that they protect habitats from physical damage caused by fishing gear. Trawls and dredges, in particular, and to a lesser extent anchors, traps and pots, directly damage the seabed (Watling 2005). Scarring by propellers, boat hulls and anchor chains can also degrade shallow seagrass beds and sandbanks. Until recently, impacts of trawls and dredges were largely out-of-sight and overlooked; however, these fishing techniques are now known to affect huge areas of seabed (Jenkins et al. 2001; Hall-Spencer et al. 2002; Thrush & Dayton 2002).

An extreme example of physical damage to seabed habitats relates to the trawl fishery for orange roughy on deepwater seamounts off south-eastern Tasmania. The complex coral matrix that provided habitat for numerous species on all investigated seamounts shallower than 1000 m depth has been found destroyed by trawl chains and nets, with some small seamounts trawled up to 3000 times during the initial 'goldrush' period (Koslow & Gowlett-Holmes 1998; Koslow et al. 2001). Similar destruction has been documented in New Zealand (Clark & O'Driscoll 2003) and has presumably occurred world-wide.

Another impact of fishing excluded from MPAs is the effect of bycatch and bait discards. Populations of some scavenging species increase significantly in fishing grounds as a consequence of the capture and discard from boats of dead unwanted organisms, plus animals killed or wounded by trawls or dredges passing over the seabed (Wassenberg & Hill 1987; Bradshaw et al. 2002).

In theory, MPAs should also assist efforts to safeguard biodiversity through increasing local ecosystem resilience to invasive species and climate change. Human-induced stresses that affect biological communities rarely operate on their own but often act in a synergistic manner, such that the net impact of threats such as fishing plus catchment nutrification, sedimentation, invasive species and climate change is greater than the sum of these threats if acting individually. Modelling studies support this view, indicating that communities with the full complement of species should possess greater stability and resistance to threats such as invasive species than disturbed communities (Case 1990; Stachowicz et al. 1999, 2002; Occhipinti-Ambrogi & Savini 2003) including those affected by intense fishing.

Field studies on this topic are, however, limited; hence general support for theoretical predictions that MPAs increase ecosystem resistance requires more data, particularly on the scale of ecosystem response to threats. Work from the California coast has shown that fished areas are less stable than adjacent marine reserves, since high density populations of urchins are much more susceptible to disease epidemics (Behrens & Lafferty 2004). In another example, populations of the invasive, habitat-modifying sea urchin *Centrostephanus rodgersii* appear to be rapidly expanding through the eastern Tasmanian region as a consequence of warming water temperatures (Crawford et al. 2000); however, the presence of high densities of predatory lobsters has the potential to constrain recruitment and survival within the Maria Island MPA. Thus, the Maria Island MPA is likely to resist sea urchin invasion better than adjacent fished coasts (Buxton et al. 2005). Because of a paucity of sea urchin barrens, this MPA is also likely to better resist invasion by the exotic kelp *Undaria pinnatifida* (Valentine & Johnson 2003; Edgar et al. 2004a).

Highly protected areas do not operate in isolation and external pressures must also be managed. The protected areas will remain as dynamic ecological systems after their change in zoning status. Apart from natural variation, biological populations in highly protected areas can become depleted under the influence of disturbances emanating from outside the zone, whether they are caused by humans (e.g. pollution, global warming) or by nature (a cyclonic storm), or by events whose cause is debateable (crown of thorns starfish)[24]. There should be more than one protected area declared for each major ecosystem type (ie: replication).

Conservation of species

The most obvious conservation benefit of MPAs is the protection of exploited animals, including both targeted and bycatch species. For the majority of exploited species, this benefit translates to increased local abundance inside MPAs relative to outside rather than the persistence of a species that is fished elsewhere to extinction. Increases inside reserves in both fish abundance and biomass are regularly reported (eg: Pande et al. (2008) and discussion elsewhere in this paper). Once populations of targeted fishery species decline below a certain point then continuation of the fishery is no longer economically viable ('commercial extinction'), and that species generally continues to persist at low levels. Nevertheless, extinction of local populations and even species is possible in circumstances where the target is highly valuable and lacks a refuge from hunting, as in the case of Steller's sea cow, or where an animal concentrates in a small area to breed. For this reason, boundaries of MPAs are often delineated to include and protect spawning aggregations of fishes, such as Nassau grouper (Chiappone & Sealey 2000; Sala et al. 2001).

A major conservation benefit of MPAs at the species level relates to bycatch. Exploitation of species caught incidentally during fishing operations does not necessarily decline as their populations decline, providing that the fishery for the main target species remains economically profitable. Thus, populations of albatross caught incidentally in the tuna long-line fishery (Brothers 1991) for example, could decline to extinction, as long as the tuna population persists and fishers actively continue to set baited lines.

Perhaps the most effective use of MPAs to protect bycatch species relates to trawling grounds, where the ratio of target to non-target species killed by fishing can exceed 1:10 (Andrew &.Pepperell 1992). Shark and ray species appear particularly vulnerable to trawl bycatch threats because of very low fecundity, slow growth, and late onset of sexual maturity. During the first 20 years of fishing on the New South Wales continental slope trawl grounds, for example, the catch per unit effort declined from 681 to 216 kg hour^{1} (68%) for all fish species combined, but from 139 to 0.6 kg hour^{1} (99.6%) for slow-growing dogshark *(Centrophorus* spp.) (Graham et al. 2001). Populations of dogshark continue to decline towards extinction because the NSW trawl fishery remains viable for other species.

MPAs will also indirectly benefit some species because of the complexity of food-web interactions. Declaration of the Leigh Marine Reserve (NZ) indirectly benefits *Sargassum* plants, for example, because sea urchin grazing pressure has declined as a consequence of increased numbers of lobsters and other predators within the MPA, which have consumed most local sea urchins (Shears & Babcock 2002). Similarly, predation pressure exerted by abundant lobsters in a South African protected area caused a major ecosystem shift, with resultant higher abundance of some invertebrate species (Barkai & Branch 1988).
On the other hand, some species will decline in population numbers following the declaration of MPAs. In general, for every positive response shown by species to protection from fishing, some prey species will show a negative response, with ripple effects through the ecosystem. As a consequence of summing up negative as well as positive responses, changes in species richness measured at the site scale are rarely predictable, other than the minor increase caused by the addition to fish and invertebrate counts of large exploited species that become common in the seascape, and species greatly affected by fishing-related damage to habitat structures.

The prevalence of indirect effects within MPAs highlights the importance of ecological monitoring programs for assessing MPA effectiveness. As an example, MPAs may not provide the best mechanism to protect critically endangered white abalone *(Haliotis sorenseni)* in California (Tegner 2000) because of increased predation risk from sea otters and other shellfish consumers. Abalone populations declined following declaration of Tasmanian MPAs (Edgar & Barrett 1999) probably as a result of increase in abundance of rock lobsters and other large predators of juvenile abalone.

Protection from the effects of recreational fishing can provide some species with important benefits (Cooke & Cowx 2004). The grey nurse shark, once the second most commonly caught shallow-water shark off Australia's eastern seaboard, is now under serious threat, partly from recreational angling and spearfishing (Nevill 2005).

Conservation of genotypes

When fishing mortality is greater than natural mortality, as occurs for the majority of fished stocks, then fishing exerts a strong evolutionary pressure on populations (Law & Stokes 2005). For example, individuals of fished populations that grow slowly and reach maturity at a relatively small size, particularly if that size is below the minimum legal size of capture, will have a greater chance of spawning and passing their genetic code to the next generation than fast growing individuals. Fishing mortality can cause the mean size of maturity of fished populations to decline significantly within less than four generations (Conover & Munch 2002; Conover et al. 2005).

Because declining growth rate and size at maturity negatively affects fishery production, fishery-induced selection is sometimes counterbalanced by specific management actions, such as maximum as well as minimum size limits, which allow some large spawners to pass on their genes. However, new regulations directed at individual species cannot counteract the full range of selective pressures induced by fishing, such as behavioural adaptations that decrease probability of capture.

Effective no-take MPAs provide the best management tool for conserving genetic diversity because populations within MPAs are not affected by fishing mortality or fishery-induced evolutionary pressures. In most situations, populations within MPAs will be genetically fitter than fished populations because through millennia the population has evolved specific characteristics that maximise long-term survival of the species in the natural environment. Populations consisting of slow-growing individuals as a result of fishing selection, for example, will suffer higher rates of natural mortality than populations of fast-growing individuals because animals take longer to reach spawning size. Populations with reduced size at maturity tend to have lower total egg production than an unfished population where individuals spawn at a large size with many more eggs released per female. Populations where individuals forage less often because they stay longer in crevices to avoid capture by divers will have reduced food consumption rates, growth rates and net egg production.

Maintenance of genetic diversity within a network of MPAs should prove particularly important for the persistence of species in the face of changing environmental conditions, such as during a period of rapid climate change.

Costs of no-take marine protected areas for biodiversity conservation

As well as providing benefits, MPA establishment can negatively affect biodiversity in some circumstances, and managers should try to minimise any such losses. As discussed above, populations of species such as abalone may decline within MPAs as a result of increases in populations of fished predatory species. More importantly, the declaration of MPAs results in changed human behaviour, with potential negative consequences.

The exclusion of fishers from MPAs will, unless action is taken to reduce overall fishing effort, result in displacement of fishing effort and greater fishing pressure within open-access areas outside the MPA network. If the total fishing catch is finely regulated using total allowable quotas, then such displaced effort could potentially cause overfishing and a gradual decline in fish populations within the open-access areas, ultimately resulting in protected 'islands' of high biodiversity that are surrounded by a 'sea' of low fish production (Buxton et al. 2005). Such a scenario is clearly undesirable from a resource management perspective, and also from a conservation perspective for species with little connectivity between the MPAs.

The declaration of MPAs can also concentrate divers and other users of the marine environment into localised areas. Whereas accidental damage to corals and other organisms caused by diver contact may have little environmental impact when spread over a large area, such impacts can be catastrophic when localised along popular dive trails. Clearly, management prescriptions within MPAs must take into account the potential impacts on marine biodiversity of concentrations of 'passive' users. Management planning should also pre-empt any race by fishers to extract as many fish as possible before MPA regulations come into force, and recognise that spawning aggregation and other important sites may be targeted for illegal fishing if locations are advertised within MPAs.

One pervasive threat to biodiversity that accompanies MPA creation is a false sense of security. The general public frequently assume all necessary protection is in place once a MPA network is declared regardless of the size or spread of the reserves, the level of protection, or the level of poaching. Well designed and executed field monitoring studies should indicate whether MPAs are actually working or not.

Scientific and tourism benefits of marine reserves

Marine protected areas generate economic benefits. The tourism economy of Queensland’s Great Barrier Reef Marine Park, including flow-on effects, exceed $5 billion pa. These revenues, of course, include recreational fishing – an important activity within the multi-use park. The Leigh (Goat Island) no-take reserve in New Zealand attracts over 300,000 visitors each year – generating significant benefits to the local economy.

In addition to economic impacts, MPAs provide opportunities and potential benefits for education and recreation. They also generate scientific benefits of importance to fishery and conservation managers, and to the wider community.

The immediate scientific value of effective MPAs is that they act as reference areas for understanding effects of fishing on marine communities (Dayton et al. 2000). Our present understanding of this topic is poor, hence information on the unexpected population changes that almost inevitably occur within MPAs greatly enhances our understanding of ecosystem processes. To date, a general understanding of the effects of fishing has been severely compromised by complexities of interactions between species and by the 'sliding baseline syndrome' – the phenomenon whereby slow incremental changes may amount to massive environmental changes over several human generations but are not noticed because each generation starts with a different, albeit slightly worse, conception of the 'natural' state of the environment (Dayton et al. 1998).

In this context, it is important to recognise that the study of MPAs not only provides information on how fishing affects the environment, but can also alleviate concerns about fishing where this activity has little effect. For example, fisheries for a variety of south-eastern Australian species – including school shark, striped trumpeter, jack mackerel, barracouta, gemfish and warehou – collapsed during the second half of the twentieth century. In some cases the collapse was probably due to overfishing; however, fisheries may also have declined as a consequence of increasing water temperatures, coastal degradation, or a combination of factors. Without MPAs as reference areas, the contributing factors can only be guessed, and fishing possibly blamed in some cases when not a major contributing factor.

An additional scientific benefit of MPAs is that they provide access to subjects that are so rare that they cannot be rigorously studied elsewhere. For example, if large predators have been overfished across the coastal seascape, then without study of protected populations their potential role in the ecosystem cannot be assessed. Similarly, without MPAs it is often impossible to accurately measure basic parameters used for modelling stock dynamics of fished species, such as rates of natural mortality, growth rates of large individuals, and size at maturity for unfished stocks.

MPAs are also useful in providing a controlled environment for scientific experiments, particularly when public access is restricted and experiments can be undertaken without interference. The Leigh (Goat Island) Marine Reserve in New Zealand was originally planned with this scientific aim as its primary goal, although the reserve was subsequently found to also generate many conservation-, fishery- and recreation-related benefits over the long term.

From an ecological perspective, MPAs represent a large-scale manipulative experiment where predation by humans is excluded from particular plots (Walters & Holling 1990). If appropriately monitored, results can provide profound insights into structural connections within food webs at regional, continental and global scales. These spatial scales differ markedly from those traditionally studied in ecological investigations, such as when plant and animal densities are modified at the scale of metres on patches of shore. Processes operating at small scales often differ from those operating at larger scales (Andrew & Choat 1982; Andrew & MacDiarmid 1991; Babcock et al. 1999) so conclusions reached cannot be extrapolated to the more interesting larger domains without validation (Eberhardt & Thomas 1991; Menge 1992). MPAs provide prime opportunities to validate experiments at scales relevant to management intervention.

3.5.5 Significance of no-take MPAs in fisheries management

Most marine protected areas globally are established to conserve biodiversity through the protection of ecosystems, habitats, and species (Roberts et al. 2005). The majority are not declared with fisheries enhancement as a primary goal. While the biodiversity benefits of marine protected area networks are accepted worldwide through (for example) international agreements and the resolutions of the United Nations General Assembly, the fishery benefits of marine reserves are not as well documented, and are more hotly debated.

High levels of uncertainty characterise fisheries management. Uncertainty stems from many factors, including environmental fluctuations over short, medium and long time periods, lack of knowledge of the dynamics of single species, and their role and relationship to the ecosystems which support them, data uncertainties from statistical and sampling bias, and uncertainties in predicting of the activities of fishers. When some of these uncertainties are included in modelling studies, results indicate that the establishment of significant areas under no-take protection can result in increased fish catches in adjacent areas (Grafton et al., 2005; 2006).

Australia's best-known MPA is the Great Barrier Reef Marine Park (GBRMP) in Queensland (Day et al. 2003). In 2004 the GBRMP was rezoned under the Representative Areas Program (RAP), a Commonwealth Government initiative. The objective of RAP was to protect at least 20% of each of 70 bioregions in the GBRMP (Day et al. 2003). While the RAP was not established for fisheries management purposes, which are the responsibility of the Queensland State Government, it increased the no-take (no fishing) zones from 4.5% to 33.4% of the GBRMP, closing an area of approximately 115,000 km^2. At the time this was the largest single spatial closure to fishing in the world. Furthermore, for the first time, many of the no-take zones are now close to the coast, where many people fish, particularly for recreation. Not surprisingly, the public debate over the implementation of RAP centred on fishing, not biodiversity, issues. The debate helped to bring into sharper public focus the potential benefits of no-take zones as fisheries management tools, particularly the potential benefits for reef fisheries.

Many fish stocks worldwide are currently over-exploited by marine capture fisheries (Pauly et al. 2002). To many people no-take reserves represent one potential solution to enhance the long-term sustainability of many of these fisheries. To others they represent a 'fencing off of the seas' attitude, a denial of people's 'rights' to fish. Thus, the use of no-take reserves as fisheries management tools is a highly controversial topic in fisheries science and fisheries management.

The popularity of marine reserves as fisheries management tools, at least in the literature, stems partly from a frequent failure of 'traditional' catch and effort controls to prevent overfishing in many developed nations, and the difficulty in applying such 'traditional' options in many developing nations. It also reflects a growing interest in a more holistic approach to fisheries management, particularly the concept of protecting the habitats and ecosystems on which fish productivity depends. MPAs have attracted a great deal of interest from a remarkably broad cross-section of disciplines, for example conservation, ecology, economics, environmental science, fisheries science, fisheries management, mathematical modelling, and social science. The topic is popular since it offers, simultaneously, conservation and sustainable exploitation, two objectives that many have viewed in the past as often conflicting. It proverbially offers us a chance to have our fish and eat them too.

Expectations of no-take marine protected areas as fisheries management tools

There are seven expectations of the effects of no-take marine reserves on organisms targeted by fisheries (Russ 2002):

Effects inside reserves

- lower fishing mortality
- higher density
- higher mean size/age
- higher biomass
- higher production of propagules (eggs/larvae) per unit area.

Effects outside reserves

- net export of adult (post-settlement) fish (the 'spillover' effect)
- net export of eggs/larvae ('recruitment subsidy').

Good evidence indicates that the abundance and average size of organisms targeted by fisheries increases inside no-take marine reserves. However, to be useful as fisheries management tools, no-take marine reserves need to become net exporters of targeted fish biomass (export of adults and/or propagules) to fished areas or provide other forms of benefit for fisheries management (such as increased profits, or reduced levels of uncertainty). The use of marine reserves as fisheries management tools remains controversial, since clear demonstrations of such export functions and benefits are technically and logistically difficult to demonstrate. However, the potential remains for a wide array of benefits to be secured by fisheries from carefully designed and strategically located MPAs (Ward 2004).

Protection of aggregations, and stock recovery

Marine animals aggregate for a variety of reasons, most commonly to do with spawning, feeding, 'safety in numbers' and migration (Allee 1931). Many such aggregations occur at predictable times and places. Such aggregations are often targeted by fishers, and many important aggregations have been so heavily harvested that they have been effectively eliminated. Populations and sub-populations are sometimes at great risk, and the scale of damage to date suggests that genetic variation within many populations has been lost – however evidence for this is lacking, and the extent of damage may never be assessed (Sadovy 2003).

In Australia, for example, spawning populations of orange roughy have been decimated across its Australian range, with the Cascade Plateaux population the only one remaining above 10% of its virgin biomass (Nevill 2006). Protection of spawning sites, and curtailment of fishing effort was instigated only after populations had crashed. In South Australia, a massive spawning aggregation of giant Australian cuttlefish near Whyalla was almost extirpated before fishing effort was restricted by a temporary reserve.

The protection of critical spawning areas and populations, and nursery habitat is of particular importance. The protection of such areas are important commitments under the Rio Implementation Statement 1992 and the UN FAO Code of Conduct for Responsible Fisheries 1995 – both endorsed by the Australian Government.

With respect to the general issue of recovery of depleted stocks, there is a growing scientific literature which supports the notion that MPAs, and particularly fully-protected (no-take) MPAs, can be effective in promoting the recovery of stressed ecosystems and of depleted fish-stocks (eg. Lindholm et al. 2004; Wooninck and Bertrand, 2004; Bohnsack et al., 2004). Crowder et al. (2000) found in a review of 28 MPAs that most exhibited increased fish density, biomass, average fish size and diversity after the MPA was declared. Similarly, in an analysis of 89 studies of fully-protected reserves, Halpern (2003) showed that, in almost every case, the creation of a reserve promoted increases in abundance, biomass, size and diversity of organisms. Furthermore, these increases appeared to be (contrary to the predictions of modelling studies) independent of the size of the reserve (i.e. small reserves appeared to be as effective as large reserves), suggesting that the biological benefits of declaring reserves are directly proportional to the amount of area protected rather than the size of individual reserves (Roberts et al., 2003). This is an issue which needs further study, as both species/area relationships, as well as our understanding of habitat complexity and the movements and habitat needs of large marine animals, argue that large reserves should be more effective than small reserves in several important respects (Laffoley et al. 2008:58-61; Lubchenco et al. 2007:13-15).

Compelling evidence of the effectiveness of one MPA network comes from recent reports on the status of the George's Banks MPA (Murawski et al. 2004; Fogarty and Murawski 2005) which had been heavily overfished and largely closed to fishing in 1994. The MPA is concluded to have had the following affects over a ten-year period:

- the biomass (total population weight) of a number of commercially important fish species on Georges Bank has sharply increased, due to both an increase in the average size of individuals and, for some species, an increase in the number of young surviving to harvestable size;
- some non-commercial species, such as longhorn sculpin, increased in biomass;
- by 2001, haddock populations rebounded dramatically with a fivefold increase;
- Yellowtail flounder populations have increased by more than 800 percent since the establishment of year-round closures;
- Cod biomass increased by about 50 percent by 2001; and
- Scallop biomass increased 14-fold by 2001, an unintended benefit of the establishment of closed areas to protect groundfish.

Examples of expected effects of no-take marine protected areas

Higher density, average size and biomass

Williamson et al. (2004) demonstrated that no-take zones on inshore coral reefs of the Great Barrier Reef (GBR) increased the density and biomass of coral trout, the major target of the recreational and commercial line fisheries on the GBR, two- to four-fold over a period of around 13 years. Coral trout were, on average, much larger in no-take zones. No-take zoning was the likely cause of these differences between no-take and fished areas, since Williamson et al. (2004) had data on density, biomass and average size before zoning was implemented in 1987. Edgar and Barrett (1999) surveyed reef biota in four Tasmanian no-take marine reserves, and at various control (fished) sites. They also collected data at the time these reserves were established and then monitored the changes over a six-year period. In the largest of these reserves, Maria Island (7 km in length), rock lobsters increased in biomass tenfold, and trumpeter (a reef fish) a hundredfold. The number of fish, densities of larger fish, mean size of blue-throat wrasse and mean size of abalone, increased in this reserve. Such changes were not as obvious in the smaller reserves studied. Similar large increases in abundance of spiny lobster and snapper have been recorded in northern New Zealand no-take reserves over more than two decades (Babcock 2003).

A key question regarding no-take marine reserves is what duration of protection is required for full recovery of abundance of species targeted by fishing. Some authors have suggested that many targeted species may display significant levels of recovery in no-take reserves in just a few years (Halpern & Warner 2002). Other evidence suggests that duration to full recovery of large predatory reef fish in Philippine no-take reserves may take three to four decades (Russ & Alcala 2004; Russ et al. 2005).

Higher propagule production

A key requirement for no-take reserves to become net exporters of propagules (and thus net exporters of potential recruits to fisheries) is that the per unit area production of propagules is substantially higher in reserves well protected in the long term. Since density and average size of targeted species should increase in well-protected reserves, egg production per unit area also should increase. Evidence for this simple expectation remains fairly limited, despite it being reasonable (even obvious). Some of the best evidence for this comes from New Zealand no-take reserves. Snapper *(Pagrus auratus)* egg production was estimated to be 18 times higher inside than outside three New Zealand reserves over three years (Willis et al. 2003a). Kelly et al. (2002) used empirical data to predict that egg production of lobster, *Jasus edwardsii,* would be 4.4 times higher in New Zealand no-take reserves after 25 years of protection. Paddack & Estes (2000) showed that egg production of rockfish were often two to three times higher in no-take compared with fished reefs in California. While these differences in egg production are substantial it is less clear whether they translate into measurable differences in recruitment, either locally or to the wider stock. Further study is needed.

Spillover

Do no-take reserves, well protected in the long term, become net exporters of adult targeted organisms? Some of the best evidence for such export (spillover) comes from studies that have demonstrated increased abundance of targeted fish inside reserves and in adjacent fished areas over time (McClanahan & Mangi 2000; Roberts et al. 2001; Russ et al. 2003; Abesamis & Russ 2005). Many of these studies report the development of gradients (from higher inside reserves to lower outside reserves) of abundance and catch rates. However, not all studies indicate the potential for spillover. Kelly et al. (2002), for example, could not detect any enhanced catch rate of lobsters adjacent to a well-protected marine reserve in New Zealand; however, their results also showed that there was no reduction in catch in the region. This suggests that conservation goals were being achieved without negatively affecting local fisheries.

A substantial literature on movements of marine fish and some invertebrates establishes the strong potential for spillover (Gell & Roberts 2003). Computer modelling studies suggest that if spillover occurs, its contribution to overall fishery yield will likely be modest (Russ 2002). Most models of spillover suggest that such a process will rarely, if ever, compensate for the loss of fishery catch caused by the loss of fishing area required to set up the reserve in the first place.

The key question is what happens to local fishery catch, in both the short and long term, when part of the area is declared no-take? One of the few studies to address this question was that of Alcala et al. (2005) at two small Philippine islands. They demonstrated that closure to fishing of 10-25% of fishing area of these two islands did not reduce total fishery catch at the islands in the long term (two decades), similar to the results for lobsters in New Zealand (Kelly et al. 2002). On the contrary, the experimental evidence suggested that the total catch was sustained, or even enhanced, in the long term. These results are particularly significant, given that municipal (subsistence) fishing is such a major human activity at each island.

Where spillover does occur, although it may have a fairly modest impact on local fish yields, commercial fisheries stand to secure a range of other benefits, including higher monetary returns from fewer but larger individuals, and long term stability of yields (Ward 2004, Grafton et al. 2006, 2004). In addition, the potential also exists for net export of propagules from reserves to fished areas, the 'recruitment subsidy' effect.

Recruitment subsidy

Evidence for recruitment subsidy (net export of propagules from no-take marine reserves) is still extremely limited. The main reasons for this are that propagules (eggs, larvae) are extremely difficult to sample, tag, and track. Marine ecologists still have very limited knowledge of the 'dispersal kernels' of most marine larvae. Furthermore, recruitment of marine organisms is notoriously variable, making both the identification and statistical testing of trends in recruitment difficult.

Some empirical evidence for recruitment subsidy comes from a scallop fishery in the northern hemisphere, although a good deal of disagreement remains about the interpretation of the evidence. The abundance of scallops *(Placopecten magellanicus)* increased substantially following the 1994 closure to fishing of three large areas of the Georges Bank, north-eastern USA (Murawski et al. 2000). Total catch of the scallop fishery increased between 1994 and 1998, despite the reduced fishing area. Fishing effort concentrated outside the boundaries of the closed areas, particularly in places most likely to receive scallop larvae exported from the closed areas (Gell & Roberts 2003). These results suggest that the no-take reserves have had a positive effect on total yield of scallops on the Georges Bank, by exporting propagules to fished areas. Recruitment subsidy from no-take reserves to fished areas is by far the most likely mechanism to sustain, or even enhance, fisheries outside the boundaries of the no-take reserves. While many marine ecologists believe that such an expectation is reasonable, given that marine larvae can often disperse distances much greater than the spatial scale of most no-take marine reserves (Baker et al. 1996), empirical evidence in support of this export process is still rare.

Insurance against management failure and unpredictable stochastic events

A particularly powerful argument in support of establishing no-take marine protected areas or reserves is that they serve as insurance against future fisheries management failure and unpredictable stochastic events (Grafton et al. 2006). The record of 'traditional' fisheries management to maintain spawning stocks of exploited organisms at levels most marine scientists would consider to be sufficient to ensure long-term sustainable harvest is fairly dismal (Pauly et al. 2002).

Many people now argue that the only way to ensure sufficient spawners is to set aside a reasonable proportion of the stock in no-take zones (Grafton et al. 2005). Others argue that the economic and social cost of such an insurance policy is too high. Such arguments have to be weighed against the considerable economic and social hardships that occur if a fishery is so depleted that it is no longer economically viable. Such a debate is one of the trade-offs between short- and long-term costs and benefits, and the ability of 'traditional' fisheries management to maintain enough spawning fish in the water.

Information on important parameters for stock assessment

A clear benefit of no-take reserves, protected properly in the long term, is that they provide scientists with sites for study of unexploited populations, communities, and ecosystems. They are some of the few places where scientists can directly make reasonable estimates of such key parameters as natural mortality rates or growth rates (Buxton et al. 2005). They are also places that show us what natural marine communities and ecosystems actually look like, and how they function. No-take reserves can also provide novel means of independently estimating parameters, such as fishing mortality, that are vital for the effective management of fisheries. For example, by comparing seasonal fluctuations in abundance of New Zealand snapper in reserves and fished areas on coastal reefs it has been estimated that between 70 and 96% of legal-sized snapper are being taken, mostly by recreational fishers (Willis & Millar 2005).

Costs of no-take marine protected areas as fisheries management tools

Displaced effort

An argument against the use of no-take MPAs as fisheries management tools, at least at first sight, is that reserves will simply move fishing effort away from the no-take area and concentrate it in the remaining fished area. If steps are not taken to reduce fishing effort, the short-term cost is likely to be very real, particularly if the fishery is fully exploited or over-exploited. In many cases, the implementation of no-take reserves involves financial compensation to some displaced fishers – and in some cases these costs can be substantial. Recent experience in Victoria has shown that early calculations of compensation were over-estimated, and that in fact actual compensation payouts were easily afforded by the State Government (Phillips 2005). In Queensland, however, the reverse was the case, with compensation payouts following the expansion of no-take areas in the Great Barrier Reef Marine Park exceeding early estimates. However such short-term costs must be weighed up against the longer-term benefits likely to flow from recruitment subsidy, insurance against management failure, and tourism income generated by Australia having some of the best and largest well-protected marine ecosystems in the world. The key point with respect to displaced effort is weighing up short-term costs against long-term gains.

Locked-up resources

Another argument against no-take MPAs as fisheries management tools is that they simply make part of the resource unavailable to the fishery, and thus make that portion of the resource useless to the fishery. Such an argument ignores two things. First, export functions may, in the long term, compensate for initial loss of 'locked-up' resources. Such export functions may even enhance fishery yields, particularly if the resource is already heavily fished. Second, those 'locked-up' resources are possibly one of the best insurance policies we can have against the possibility of future fisheries management failures. These areas also provide refuges for genetic diversity at risk in heavily fished populations (see discussion above).

False sense of security

If no-take MPAs are poorly protected (e.g. poor compliance with no-take regulations) or, due to specific life-history characteristics of some target species, do not develop export functions, they may well create a false sense of security for fisheries managers and the public. The remedy to this problem is to ensure adequate compliance, enforcement and monitoring. If adequate enforcement is not carried out, the inevitable long-term consequence is that most fishers will ignore the rules. Conversely, with adequate enforcement, it is in the interests of honest fishers to comply with the rules and to report illegal fishing. Monitoring is also essential. Appropriate and effective monitoring of reserve performance is necessary to determine if the stated goals of the MPA are being achieved. If MPAs are established partly on the basis of assumptions of fisheries benefits (and this may be advisable in some cases as a precautionary measure) these assumptions should be scrutinized by ongoing monitoring programs.

Uncertainty, and the importance of long time-frames in planning

Fisheries are important, but so are the values of marine biodiversity. Although there is no doubt that a reasonable balance between marine resource exploitation and nature conservation has rarely been achieved across the planet, it is important to start from a position which seeks ways to protect *both* marine biodiversity and fisheries. Marine reserves and fisheries are often seen in a 'win-lose' way, where the establishment of reserve networks is assumed to prejudice the interest of fishers. This simplification may often be incorrect, and fails to acknowledge that in many cases reserves can provide fishery benefits. While it is important that such benefits should not be overstated (Sale et al. 2005) to neglect them ignores important benefits of reserves, especially over long time scales (Grafton et al. 2006).

3.5.5 How effective are Australia's existing MPA networks?

In developing the NRSMPA framework in 1999, all Australian jurisdictions were committed to the creation of MPA networks which would provide comprehensive, adequate and representative protection for Australia's marine ecosystems. The principles on which the NRSMPA strategy was based, as well as planning and management principles incorporated in *Australia's Oceans Policy* 1998 (see the 'guidelines' listed in section 3 above) are sound. Two questions are important: (a) have the principles been properly applied so far in the creation of existing MPA networks, and (b) are the networks meeting their objectives in practice? This section provides an answer to the first question, and outlines an approach for answering the second.

Australia has eight State/Territory jurisdictions[25], who carry very considerable responsibilities for natural resource management. They depend heavily on the Australian (Commonwealth) Government for funds – thus providing the Commonwealth with the leverage needed to encourage States in meeting international obligations.

In examining progress over the last decade, it is clear that the design principles of the NRSMPA have been followed in some cases; in others they have been abandoned. In considering whether protection has been "comprehensive, adequate and representative" there are two key issues: the use of zoning which provides effective protection, and the extent of habitat representation within the regional network.

Queensland is Australia's best example of the development of effective MPA networks. As discussed above, the substantial Great Barrier Reef Marine Park (developed principally by the Commonwealth Government) includes 33% no-take zones, which provide effective protection for representative habitats. The GBRMP occupies a very substantial portion of the continental shelf adjacent to Queensland. Most habitat types within the Park are protected to the 20% level (or better) by no-take zones. At the State level, the Queensland Government has protected most Moreton Bay[26] habitats at 9% or better, with a total of 16% of the Bay in no-take zones. In Western Australia, the large Ningaloo Marine Park protects around 30% of its area in no-take zones. Victoria also provides an example of effective protection of representative habitat, although at a considerably smaller scale, and with less comprehensive coverage of habitat types. Here about 5% of habitat within State jurisdiction is zoned as no-take[27]. Habitat maps are available for the bulk of Victorian marine waters, with high-resolution mapping within MPAs.

On the other hand, the progress made by the Tasmanian Government, as well as the Commonwealth MPAs in the South East Region around Tasmania, provide examples of ineffective protection. In the absence of comprehensive habitat maps for this region, geomorphic province can be used as a coarse biodiversity surrogate – the shelf for example contains important habitats not found elsewhere. Commonwealth MPAs include only 0.75% of the region's shelf in no-take zones. Remaining MPAs are IUCN category VI, providing little effective protection from fishing activities – a key threat in the region. At the State level, the Tasmanian Government's Bruny Bioregion MPA network (announced in 2008) is entirely category VI, and fishing activities continue within the MPA network essentially unrestricted. This approach provides virtually no protection from one of the most important threats in the bioregion.

In the case of the Commonwealth's South East Region, considering only the area covered by the MPA network creates a misleading impression. MPAs of all zones (in this case almost entirely two categories: IUCN class Ia and VI) cover a substantial proportion of the region:

~5.5%. This seems like a good outcome, until the detail is examined. Coverage of shelf habitats is in fact far from 'adequate'.

Any national assessment must take into account the extent of effective protection, and here no-take MPAs should be used as an indicator. Secondly, the extent of representative habitat protection must be assessed. Future habitat mapping programs will assist greatly in this regard.

The Commonwealth-managed Collaborative Australian Protected Area Database (CAPAD) fails to provide important basic information on Australia's MPA network. Different States have used different reporting formats within the CAPAD framework. Some States list every MPA, while others list only MPAs grouped into State categories (eg: 'marine nature reserve') which are terms which have no national meaning. Some States list the IUCN categories of each MPA (which is useful) while others do not. In terrestrial protected area reporting, some States list the bioregions and subregions within protected areas (which is at least a start in reporting surrogates for representation) however no State reports this information for MPAs. The database is not updated regularly: the most recent marine data in mid-2008 was for 2004. *CAPAD is in urgent need of major improvement*.

All MPAs should be managed (within a dedicated budget) monitored and assessed. Management plans must identify key values to be protected, and establish indicators by which these values can be monitored. Any national or regional assessment of a MPA or a MPA network must be based at least in part on the extent to which identified values are maintained or enhanced over time. Assessments of the effects, and effectiveness, of MPAs at zone, reserve or system level should be placed within a transparent adaptive management framework, allowing progressive improvement of MPA design and implementation.

Assessments must also take into account both the intent of management (the zoning), the extent to which such management is effective (including the extent of compliance enforcement) and the extent to which the combined set of zones within an MPA network contributes to conservation outcomes for species, assemblages and habitats across the region. Where models to assess the different levels of contribution of conservation outcomes delivered by the different management zones are weak, or the data are lacking, it is appropriate to consider the success of a MPA system cautiously, and restrict the assessment and reporting of effectiveness to only the zones of high-protection (eg: no-access or no-take). In the zones of high-protection, given evidence of effective compliance enforcement, assessment and reporting on effectiveness then becomes an issue of measuring and reporting on intrinsic conservation parameters appropriate to the species, assemblages habitats or processes that are intended to be protected.

Compliance cannot be taken for granted. Even in Australia, where fisheries are often perceived to be well-managed, there is ample evidence not only of non-compliance, but of cultures of non-compliance. For example, Poiner et al. (1998:s2) in a study of prawn trawling in the Great Barrier Reef World Heritage Area reported: "there has been a high level of illegal trawling in the Green Zone and evidence that 40 to 50 boats regularly trawl the area. Misreporting of catch has taken place with catches from inside the Green Zone being credited to adjacent open areas." Cultures of non-compliance will arise where absence of enforcement is predictable.

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> We consider it is part of our professional duty as marine biologists to state publicly and frequently the need for a representative, replicated, networked and sustainable system of highly protected marine reserves. We doubt if our grandchildren will accept any excuses if we fail.
>
> Ballantine & Langlois 2008:35

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3.8 Endnotes

[1] The concept of "effective protection" is important. To demonstrate effective protection key values must be identified, managed and tracked over time. This implies that a protected area should have a management plan which identifies key values, and the plan should explain how management will seek to protect these values. Monitoring programs should track the values over time (through measurable indicators) and the results of monitoring programs

should be regularly and publicly reported. Only then will “effective protection” be demonstrated.

The IUCN used a more detailed definition of a marine protected area: “any area of the intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment” (Kelleher 1999). This was replaced by a general protected area definition: “A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.” (Dudley 2008).

[2] Note that the word ‘reserve’ is often used in marine literature to mean a fully protected or no-take area.

[3] Such monitoring should take place across a sufficient spatial scale.

[4] Readers unfamiliar with the rather vaguely defined terms referring to spatial units should note that a rough hierarchy exists starting with "large marine ecosystems" (LMEs) which lie within ocean basins (generally along continental margins), to bioregions, subregions, ecosystems, habitats and, at the scale of meters to kilometres, communities. The term 'ecosystem' is also used in different situations independent of scale, according to its strict definition which is an area characterised by coherent trophic and energy pathways, and species interactions.

[5] Noting that an area target of 20% of habitat types was included in the biophysical operating principles used in the Representative Areas Program (2002) of the Great Barrier Reef Marine Park Authority – along with other princples such as replication and inclusion of whole reefs. The 2004 re-zoning saw 32% of the coral reefs in the GBRMP protected in no-take reserves (which accounts for 15% of coral reefs in the NE Marine Planning Region, and about 10% of coral reefs offshore from the Queensland coast). In the terrestrial scene, a protected area target of 15% of pre-European vegetation communities was set as a central conservation goal of Australia’s Regional Forest Agreements, to be expanded for rare and/or vulnerable vegetation communities (Mendel & Kirkpatrick 2002).

[6] An important point of definition arises immediately. Overfishing is defined in this discussion as *a level of fishing which puts at risk values endorsed either by the fishery management agency, by the nation in whose waters fishing takes place, or within widely accepted international agreements*. A point of critical importance in this regard is that a level of fishing intensity which successfully meets traditional stock sustainability criteria (for example fishing a stock at maximum sustainable yield) is likely to be considerably higher than a level of fishing intensity which meets maximum economic yield criteria (Grafton et al. 2007) which in turn is likely to be considerably higher than a level designed to protect marine biodiversity (Jennings 2007, Walters et al. 2005, Murawski 2000, May et al. 1979). The wide endorsement of the *Convention on Biological Diversity 1992* implies that the latter level is the critical level by which overfishing should be measured.

[7] See the AMSA submission on the South East Region MPAs: http://www.amsa.asn.au/

[8] The area of the SE Marine Planning Region is 1,192,500 km^2, (Harris 2007) or 1,632,402 km^2 including Macquarie Island, of which 226,458 km^2 are covered by Commonwealth MPAs. Of these, 96,435 km^2 are no-take, with the rest mostly classed as IUCN category VI – multiple use (where nature conservation is not the primary objective). However, almost all of the no-take areas cover slope and deep sea habitats. Commonwealth no-take reserves cover only 0.75% of regional shelf areas, or 692 / 92175 km^2 (pers.comm. Barbara Musso 16/10/08; see also Edgar et al. 2008:972).

[9] The CBD CoP decisions can be accessed at http://www.cbd.int/marine/decisions.shtml. If this link doesn't work, go to the homepage (www.cbd.int) and follow the links: programmes & issues>marine and coastal>programme>decisions.

[10] IMCRA: interim marine and coastal regionalisation of Australia (IMCRA Technical Group 1998).

[11] Government of Australia (1996).

[12] The Commonwealth CAPAD (Collaborative Australian Protected Area Database), accessed in September 2008, contained MPA data current to 2004.

[13] Australia's marine jurisdiction, including Antarctic zones, is around 16 million km^2. Without Antarctic areas it is around 11.4 million km^2

[14] The MPAglobal website is currently (Sept 2008) under development and data may not be accurate.

[15] In this paper "reserves" includes IUCN categories I-IV.

[16] Here "no-take" MPAs includes IUCN categories Ia and Ib.

[17] This neglects a few insignificant mining operations, for example for diamonds in Joseph Bonaparte Gulf (WA), gold in the Gulf of Carpentaria (Qld) and sapphire around Flinders Island (Tas).

[18] States have jurisdiction over 3.6% of Australia's marine jurisdiction comprising 410,677 sq km in coastal waters that are within 3 nautical miles (5.5 km) of the coast. The remaining 10.97 sq km in Commonwealth waters is administered by the Australian Government.

[19] Of particular note in defining systematic conservation planning are the papers by Margules & Pressey (2000) and Pressey et al. (2003).

[20] Up-to-date information on global MPAs was hard to locate in 2008. The IUCN published a estimate in 2008: "as of the end of 2006 only 0.65% of the area of the seas and oceans and 1.6% of the area within exclusive economic zones worldwide is covered by marine protected areas." (World Conservation Congress 2008 statement on marine protected areas).

The World Database on Protected Areas (WDPA) (www.unep-wcmc.org) accessed 19/9/08 did not contain global consolitated data. An estimate of 1.4% of the marine realm within MPAs was obtained from the WDPA when accessed on 18/1/06 - it contained MPA area data to 2003. IUCN categories Ia and Ib were used as identifiers for no-take areas, and adjusted by the 2004 expansion of no-take areas in the Great Barrier Reef Marine Park. This produced a figure of 0.18% of the marine realm within no-take areas. The 'total' percentage is based on summing the global areas under categories I-VI, and includes the 184,000 km^2 Kiribati Phoenix Islands MPA (announced March 2006) and the 360,000 km^2 North-western Hawaiian Islands National Monument (announced 15 June 2006) but does not include the area managed by the Commission for the Conservation of Antarctic Marine Living Resources (35.7 million km$^{2)}$. If it can be assumed that IUU fishing, and fishing by non-Party States has negligible impact on this area, the zone qualifies as a category IV marine protected area. Even taking these two important factors into account, the Convention Area probably qualifies as a category VI protected area. The global area percentage under general MPA management would then increase (dramatically) to 12 %. It should be noted that internal CCAMLR papers at this stage support the 'IV' classification; however CCAMLR has not requested entry to the WDPA. Note that at this stage no information is available on the area under categories Ia and Ib in the Phoenix Islands or NW Hawaiian MPAs, so these new MPAs were not included in the calculation of 0.18% NTAs.

[21] Agardy has major concerns over the possibility of a rapid and poorly planned expansion of marine protected areas. "The desire for quick fixes has led to a proliferation of MPAs – many in areas where they are not needed, executed in a way that does not address the threats at hand, and planned with little consideration of long-term financial and social feasibility." (Tundi Agardy, *MPA News* October 2005 p.3).

[22] In particular goals relating to the slowing of biodiversity loss, such as those incorporated in the Johannesburg Declaration 2002 'key outcomes' statement.

[23] In the marine context, substitute "habitat" for "land".

[24] Noting that no-take marine reserves appear less prone to crown-of-thorns attack (Sweatman 2008).

[25] Australia has three 'territories'. The Australian Capital Territory, under an agreement with the Commonwealth Government, manages the territory at Jervis Bay on the NSW coast. Although all eight State/Territory jurisdictions manage marine environments, this responsibility is insignificant in the case of the ACT. The marine protected area at the south side of Jervis Bay is managed by the Commonwealth Government.

[26] Queensland's large Moreton Bay lies adjacent to the major city of Brisbane, and receives the outflow of the Brisbane River.

[27] Victoria's no-take MPA network occupies 53,776 ha, or 5.3% of marine waters under State jurisdiction.

Attachment Two: Notes on no-take areas (Nevill 2007):

Marine no-take areas:
How large should marine protected area networks be?

Jon Nevill **4 Nov 2007**

Summary
Currently around 1.4% of the global marine realm is classified as protected area, with no-take areas accounting for only 0.18%[1]. Such areas are created mainly to protect marine biodiversity or to assist the sustainability of fisheries[2]. The World Parks Congress 2003 (WPC) recommended the establishment of national networks of marine no-take areas (NTAs) covering 20-30% of habitats by 2012, a recommendation in marked contrast to the general (and somewhat vague) target set by the *Conference of the Parties to the Convention on Biological Diversity* in 2004 (see below). Agardy et al. (2003) however argued against the over-zealous application of the WPC target, suggesting that haste leads to poor planning, and that a focus on targets does little to convince sceptical stakeholders including fishers and politicians[3].

However, while the targets proposed by the WPC remain controversial (Ray 2004), the biodiversity crisis affecting the planet leaves little doubt that an urgent expansion of marine no-take areas is necessary if the global loss of biodiversity is to be addressed in an effective way. This reality is the backdrop against which arguments over marine protected area network targets take place.

The purpose of this paper is to provide further background for a continuing discussion of area targets ("dangerous targets") for MPA networks, by listing and briefly commenting on all major papers published since 2000 dealing with no-take area network size. Some key references on size in relation to planning individual no-take areas, and the spacing of areas within a network, are also included in the discussion.

The literature reviewed below reveals a general consensus amongst marine scientists (summarized in Table 1) that a massive increase in no-take areas will be necessary if agreed international conservation goals[4] are to be met.

Terminology
Protected areas, as defined by the World Conservation Union (IUCN 1994) are areas of land or water "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". Close examination of the logic[5] underpinning the IUCN definition reveals three key elements. The area should be under defined management (i.e. an agreed management plan should exist). Secondly, actual management arrangements should effectively reduce at least one major threat to the area's values (i.e. value and condition should be monitored and reported over time). Thirdly the area should have secure tenure (preferably through statute). In summary, protected areas are areas where (a) management regimes are in place designed to protect the natural ecosystems and features (ie 'values') within an area against threats, and (b) those management regimes are effective and secure.

The full IUCN definition lists six different categories of protected area, with category one having the highest, and category six the lowest level of protection. Category 1 are strict no-take areas. Category 2 (wilderness areas) are also highly protected, but do allow indigenous harvesting. Within this paper the term 'no-take area' means an area where no harvesting occurs. Such an area will meet the IUCN protected area category 1a and 1b definition (IUCN 1994). Within this paper the term 'marine protected area' is used to encompass all IUCN categories (1-6), while the term ‘reserve’ is used to encompass IUCN categories 1-4 (where conservation is a primary goal).

International commitments to MPAs and NTAs:
According to the *Convention on Biological Diversity 1992*, the conservation of biodiversity requires two fundamental strategies: the establishment of protected areas, together with the sympathetic[6] management of exploited ecosystems outside those areas (CBD articles 7 and 8).

Marine protected areas were un-known in an era when it was generally considered that the oceans needed no protection[7]. However, as the damage to the marine environment has become more widely understood, marine protected area programs have featured in international agreements as well as national conservation programs. One of the most widely quoted international statements calling for the acceleration of marine protected area programs around the world is that from the World Summit on Sustainable Development (WSSD Johannesburg 2002). The marine section of the WSSD Key Outcomes Statement provides basic benchmarks for the development of marine protected areas as well as other key issues:

> Encourage the application by 2010 of the ecosystem approach for the sustainable development of the oceans. On an urgent basis and where possible by 2015, maintain or restore depleted fish stocks to levels that can produce the maximum sustainable yield.
>
> Put into effect the FAO international plans of action by the agreed dates:
> - for the management of fishing capacity by 2005; and
> - to prevent, deter and eliminate illegal, unreported and unregulated fishing by 2004.
>
> Develop and facilitate the use of diverse approaches and tools, including the ecosystem approach, the elimination of destructive fishing practices, the establishment of marine protected areas consistent with international law and based on scientific information, including representative networks by 2012.
>
> Establish by 2004 a regular process under the United Nations for global reporting and assessment of the state of the marine environment. Eliminate subsidies that contribute to illegal, unreported and unregulated fishing and to over-capacity.

The same statement also contains a commitment: “Achieve by 2010 a significant reduction in the current rate of loss of biological diversity.”

Worldwide, the most important threat to marine biodiversity, generally speaking, is fishing (MEA 2005) – including the effects of overfishing, bycatch, habitat damage, ecosystem effects, and ghost fishing[8]. While fishing constitutes the major global threat, climate change, pollution, and the effects of alien organisms also present major (and in some cases intractable) problems . The exclusion or reduction of fishing activities – and the control of other threatening processes – through networks of marine protected areas is recognised worldwide (through the Johannesburg statement) as essential to national marine protection programs.

While no-take area targets have not been set so far by international agreements, the World Parks Congress (2003) recommended the establishment of national networks of marine no-take areas (NTAs) covering 20-30% of habitats by 2012. Greenpeace International have called for a similar area target of 40% (2006:26).

A few scientists, however, are not only opposed to the use of no-take area targets, but question the widespread use of marine protected areas, particularly as fishery management tools. The fishery benefits of no-take areas remain subject to debate. Shipp (2003) for example argued that most commercial fish stocks are too mobile to obtain protection from NTAs, although his views have few supporters amongst marine scientists. In spite of on-going failures in fishery management, Steele & Beet (2003) suggested that controlling fishing impacts may generally be more effective at protecting marine biodiversity than MPA protection. Jones (2006) stressed the need for participatory democracy within MPA governance arrangements, and Sale et al. (2005) identified critical information needs for effective MPA functioning. There is, however, amongst the differing views of marine scientists a general consensus (consolidated through the CBD's Jakarta Mandate) that MPA networks are essential to any national marine conservation program. With respect to the fishery benefits of MPAs, most "agree that MPAs will complement other management tools" (Browman & Stergiou (2004).

According to Jake Rice: "We have largely emerged from the "polarized period" when discussion of MPAs was too often a non-dialogue between believers (who often verged on the fanatic in their enthusiasm) and non-believers (who had a comparable share of fanaticism in their denial). *MPA News*, October 2005, p.2.

The science underpinning MPA design suffers from some of the same problems as the science underpinning fisheries models. In spite of such concerns, the worldwide acceptance of marine protected areas as vital conservation tools is now well consolidated, at least at the levels of academic science and international law (if not national politics)[9].

Protection of representative marine ecosystems:
Attention needs to be given to the use of the word "representative" in the WSSD text above. Requirements to provide adequate and comprehensive protection for representative examples of all major types of ecosystems date back many years. Clear requirements for action are contained in:

- the 1992 international Convention on Biological Diversity (United Nations)
- the 1982 World Charter for Nature (a resolution of the UN General Assembly), and
- the 1972 Stockholm Declaration of the United Nations Conference on the Human Environment.

The 1982 World Charter for Nature states: "Principle 3: All areas of the earth, both land and sea, shall be subject to these principles of conservation; special protection shall be given to unique areas, to representative samples of all the different types of ecosystems, and to the habitat of rare or endangered species."

Principle 2 of the Stockholm Declaration 1972 states: "The natural resources of the earth, including the air, water, land, flora and fauna and especially representative samples of natural ecosystems, must be safeguarded for the benefit of present and future generations through careful planning or management, as appropriate."

An examination of the wording of both the Charter and the Declaration reveals that they place wide obligations, not only on governments, but on all agencies of governments as well as individuals.

National governments have, however, been slow to action these important commitments. Australia's *representative area program* on the Great Barrier Reef, for example, although in planning for many years, was not initiated until 2002 – thirty years behind the Stockholm Declaration.

Targets and logic:
Within a terrestrial framework, Pressey et al. (2003, 2004) stressed the need for the development (and size) of protected area networks to follow a logical approach based on defined goals and ecological criteria, arguing that the effectiveness of conservation efforts are reduced by "focussing conservation efforts on landscapes with least extractive value" (Pressey 2004:1044). The real objective of such programs is not the establishment of reserve networks of a specific size, but the protection of biodiversity. Pressey points out that targets framed in general terms can be met by the inclusion of the least productive (least fished) areas, which may also be of little value for the protection of biodiversity. He also argues that specific rare, highly vulnerable ecosystems may require high levels of protection. Following Pressey's logic could well result in reserve network designs with NTAs considerably in excess of 30% in some cases – depending on the core objectives –

particularly if a precautionary approach (incorporating redundancy) was to be adopted in regard to naturally rare, vulnerable ecosystems within the region of interest.

Using similar arguments, the Ecological Society for Australia (ESA 2001) stressed the need for area targets to rest on broad policy goals (relating to the conservation of biodiversity) through evolving scientific understanding – suggesting that reserve networks may need to shrink or expand or change shape and location as knowledge of ecosystem values and processes changes over time.

Fernandes et al. (2005) point out that, while a broad area target may be a useful first step, the identification and design of possible NTA sites needs to be based on more detailed goals and principles incorporating a variety of 'input' targets. For example, in the GBR Representative Area Program, the Scientific Steering Committee set 20% as a minimum required habitat target. While this remained a primary goal, the establishment of NTAs was substantially based on 11 'biophysical operational principles' (BOPs) supported by decision rules. Principle Eight was: "Represent all habitats: represent a minimum of each community type and physical environment type in the overall network". One decision rule supporting this BOP was "capture about 50% of all high-priority dugong habitat". Other rules for different habitats set targets (for common habitats under relatively low threat) as low as 5%. The decision rule targets set minimum figures, not desirable figures. The overall outcome of the program saw NTAs within the Great Barrier Reef Marine Park increase from 4.5% to 33% of the park's area. This result is entirely consistent with the input targets and BOPs, and is a result which saw most BOPs and most design targets met or closely approached.

Pressey et al. (2004) use a variable target which is worthy of further discussion, if not widespread use. Here the target is given by a simple formula which takes into account the rarity and vulnerability of the ecosystem in question:

$$\text{Target \%} = 10\% + (10\% \times NR) + (20\% \times V)$$

Here NR is the natural rarity of the ecosystem, and V is the vulnerability, both indices scaled from 0 to 1. The outcome is that naturally common ecosystems under no threat will be subject to a target of 10% of their naturally occurring area protected. Highly vulnerable and naturally rare ecosystems will accrue a target of 40%.

MPAs and no-take areas: recent history

We live in a world where community perceptions, folklore and ethics are lagging behind the reality of increasing human domination of the planet's ecosystems – and the science of conservation biology. Only a century ago the oceans were perceived by most as so vast as to defy human degradation. The idea of setting aside protected marine areas would have made little sense. Today marine scientists at least are only too aware of the degradation which has occurred and which in many cases is escalating in intensity.

In Australia and New Zealand, marine protected areas were still almost unknown four decades ago. Although they often receive considerable community support where they have been established for many years (the Leigh Marine Reserve in New Zealand, for example) community perceptions (and thus the perceptions of politicians) is that protected areas are the exception rather than the rule. No-take areas are perceived as occupying minor fractions of the seascape. It is here that there is divergence between the ideas of the community and the ideas of many of the scientists whose work is reviewed in this paper.

The modern era of marine protected area management dates from Resolution 15 of the First World Conference on National Parks (Adams 1962). Since then marine protected areas have been created around the world, and their effects over time have been studied and reported (eg: Lubchenco et al. 2003, Murray et al. 1999). An extensive literature exists on the effects of MPAs. Marine protected areas serve five main functions, not all of which necessarily apply simultaneously:

(a) to protect biodiversity;
(b) to enhance fishery production outside NTA boundaries;
(c) to protect cultural, recreational, spiritual, educational and scientific values;

(d) to provide benchmarks against which the modification of the planet under human hands can be measured and assessed, and, last but not least,

(e) to protect from disturbance the homes of other living inhabitants of the planet.

Sufficient evidence has accumulated on the benefits of marine protected areas to allow the publication in 2001 of a definitive scientists' consensus statement, affirming the use of protected areas as an essential tool for the conservation and management of marine biodiversity (AAAS 2001).

According to Walters (2000): "A revolution is underway in thinking about how to design safe and sustainable policies for fisheries harvesting". Fish stocks repeatedly declining in the face of modern management, major ecosystem damage, and an awareness of the degradation of global biodiversity resources call for a new approach. According to Walters: "Sustainable fisheries management may eventually require a reversal of perspective, from thinking about protected areas as exceptional to thinking about fishing areas as exceptional. This perspective is already the norm in a few fisheries, such as commercial salmon and herring net fisheries along the British Columbia coast". Walters points out that, historically, many apparently sustainable fisheries were stabilised by the existence of 'effective' protected areas, and the erosion of these areas through adoption of new technology subsequently resulted in the collapse of the fishery. Walter's views are reinforced by Russ & Zeller (2003).

One of the reasons why many MPA practitioners advocate large no-take areas so strongly is that the history of fishery management over the last century is marked by a variety of failures which have regularly led to fishery collapse and/or major ecosystem change (Jackson et al. 2001). Although well known and the subject of agreements and guidelines[10], these failures are in many cases still not effectively addressed, and include compliance enforcement, failure to regulate new fisheries or new technology, inappropriate single-species modelling, massive bycatch, illegal fishing, fishing down the food web, lack of precaution in the face of uncertainty, and perhaps most importantly massive damage to benthic habitats by bottom trawling. Many conservation biologists have simply lost faith in the ability of fishery managers to apply the sympathetic management called for by the Convention on Biological Diversity. The models which scientists use to support NTA targets often assume, with a good deal of justification, that organisms living outside NTAs have no effective protection.

This cultural divide between fishery managers and conservation biologists has the potential to be enormously destructive – and could lead to a situation where the need to protect biodiversity at varying levels across the entire marine realm is all-but abandoned (instead of intensified) leaving biodiversity conservation the sole responsibility of marine reserve managers. Such a situation would be disastrous, with severe ramifications for the essential oceanic processes on which marine biodiversity ultimately depends.

Marine habitat should be protected everywhere, and we should not expect to harvest fish populations at maximum sustainable yield. With the planet's human population expected to continue its increase for most of this century – with consequently increasing demands for food, precaution demands less intensive harvesting over the marine realm generally if the health of ocean ecosystems is to be maintained. Friedlander and DeMartini (2002) have shown, for example, that lightly fished areas in Hawaii supported far more fish than some small no-take areas surrounded by high exploitation.

Protecting biodiversity

Generally speaking, protected areas are the most important single tool available for the protection of biodiversity (ESA 2001). Their development on land preceded their development in the seas, with freshwater protected areas lagging further behind (Nevill & Phillips 2004). As already mentioned, the *Convention on Biological Diversity 1992* (CBD) rests on the idea that the conservation of biodiversity, including aquatic biodiversity, requires the protection of representative examples of all major ecosystem types, coupled with the sympathetic management of ecosystems outside those protected areas. These twin concepts underpin, in theory at least, all biodiversity protection programs. The need to protect the processes on which biodiversity depends (broadly relating to flows of energy, nutrients[11],[12] and information[13]) form a vital part of protection strategies both within and beyond reserves.

Many misunderstandings rest on over-simplifications of the meaning of the key elements of conservation strategies. As far as biodiversity protection goes, protected areas must be seen as one element amongst the many protective mechanisms used to conserve biodiversity in the wider landscape (seascape). It is not a question of protecting a few areas together with unfettered exploitation of the rest of the planet – this has never been seriously proposed. It is a question of applying a mix of appropriate tools to a given situation to achieve a range of defined conservation, social and economic goals. Ray (2004) refers to a century-old debate between protagonists of the 'preservationist' and 'wise use' approaches in forest management. Expressed in these over-simple terms, such a debate can never be resolved. As Ray points out: "we must be reminded of the 30-year old 'biosphere reserve' concept, which calls for large-scale multiple-use planning and zoning, motivated by a no-take area at its core".

NTAs created largely for ethical reasons – to provide habitat for some of the non-human inhabitants of this planet – are rare, and at this point in time may be restricted to whale sanctuaries created over the last decade in various locations. Australia's support for the Southern Ocean Whale Sanctuary was based partly on the recommendations of a public inquiry (Frost 1978) which used ethical arguments to justify its recommendations[14]. In my view, the ethical basis for establishing protected areas needs much more public discussion, both within Australia and internationally.

The size of NTA networks, and the size of individual NTAs *are important issues* – unfortunately. In an ideal world, size targets would not exist. The size and shape of NTAs, and the overall size of NTA networks, should ideally be driven by the core objectives underlying the establishment of MPA systems, such as the protection of biodiversity, and the protection of processes underpinning that biodiversity (Cowling et al. 1999, Margules and Pressey 2000; Pressey et al. 2003, 2004 – these are all terrestrial references xx). In some cases, the objectives of establishing NTAs focus on the enhancement of adjacent fisheries, rather than the protection of natural values such as biodiversity. However we do not live in an ideal world, but a world where the protection of ocean biodiversity has, historically, been hugely misunderstood and under-resourced. As the Millennium Ecosystem Assessment reports: "Human activities have taken the planet to the edge of a massive wave of species extinctions" (MEA 2005:3). We live in a world where the gap between the biodiversity targets set in international agreements, and the actions necessary to achieve those targets, is enormous. In this context, size targets should be an important part of strategic programs for marine biodiversity conservation.

Conference of the Parties to the Convention on Biological Diversity
At the sixth meeting[15] of the CBD CoP, in decision VI/26 (UNEP 2002) the Parties adopted the *Strategic Plan for the Convention on Biological Diversity*. In its mission statement, Parties committed themselves to more effective and coherent implementation of the objectives of the Convention, *"to achieve by 2010 a significant reduction of the current rate of biodiversity loss at global, regional and national levels as a contribution to poverty alleviation and to the benefit of all life on earth".*

This target was subsequently endorsed by the Johannesburg *World Summit on Sustainable Development* (WSSD[16]) (United Nations 2002a:33). The Summit's 'key outcomes' statement committed participating nations to: "achieve by 2010 a significant reduction in the current rate of loss of biological diversity" – notably omitting the final section of the CBD statement which, importantly, contains an explicit validation of the 'intrinsic value' concept.

The WSSD outcomes statement also contained a commitment with regard to 'oceans and fisheries' which included the development of MPA networks:

> Develop and facilitate the use of diverse approaches and tools, including the ecosystem approach, the elimination of destructive fishing practices, *and the establishment of marine protected areas consistent with international law and*

> *based on scientific information, including representative networks by 2012* (United Nations 2002b:3, my emphasis).

Although most nations are committed to the establishment of representative protected area networks, no global statistics on representation of marine ecosystems with protected area networks are available, largely as the collection of this information, in the marine realm, has only recently been addressed by nations themselves.

At the seventh meeting of the CBD CoP, in Decision VII/30 Annex II (UNEP 2004) the Parties adopted a target: “at least 10% of each of the world’s ecological regions effectively conserved”. Through Decision VII/5.18, the parties also agreed to establish (by 2012) and maintain a network of marine and coastal protected areas that are representative, effectively managed, ecologically based, consistent with international law, and based on scientific information – thus providing a slight expansion of the 2002 WSSD commitment.

Notably the 10% target does not mention protected areas, or provide a target timeframe. It could, however, be argued that, read in conjunction with the above WSSD commitments, a specific target for the development of MPA networks covering at least 10% of ecoregions by 2012 is implied. In decision VII/5 Annex I (UNEP 2004) the Parties requested that: “the Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA) at its tenth or eleventh meeting *further refine the proposal for the integration of outcome-oriented targets into the programme of work on marine and coastal biodiversity*…”.

This recommendation provided the SBSTTA (an organ of the UNEP CBD program) with the opportunity to expand the implicit meaning and time-frames of the target, especially given the 2003 recommendations of the World Parks Congress; however in its tenth meeting (2005) it did not do so. In it’s ‘application of the VII/30 targets to the CBD programme of work on marine and coastal biodiversity’ it chose to simply repeat the original general target within the marine context: “At least 10% of each of the world’s marine and coastal ecological regions effectively conserved” (UNEP 2005:44).

Leaving the original CoP target expressed in these general terms, without specific measurable goals (relating, for example, to the establishment of no-take area networks - or more generally protected area networks - within defined timeframes) means that *the target cannot be effectively monitored and reported* – the different meanings which can be attributed to the phrase “effectively conserved” are simply too broad, and the timeframe too vague.

Targets in current use

According to AHTEG (2003:16), the Bahamas, the Galapagos Islands and Guam have set no-take area (‘reserve’ in the AHTEG’s language) targets “of 20% for the primary network”. At this stage I have no further information on targets from these nations.

California is in the process of establishing an MPA network covering about 18% of State waters (to 3 nm). See Appendix Two below.

Australia:

As discussed in the analysis below, the Australian (Commonwealth) Government has adopted a conservation goal of the protection of 30% of remaining natural terrestrial ecosystems; however this cannot be construed as a accountable target as most responsibility for protecting terrestrial ecosystems lies with Australia’s State governments. These governments have not endorsed the Commonwealth target. The Australian Government has not developed a similar goal or target for the marine realm.

The Great Barrier Reef Marine Park Authority (GBRMPA) commenced a consultation process in 2002 to underpin the establishment of no-take protection of a comprehensive selection of representative examples of the marine ecosystems making up the Great Barrier Reef. This program was named the Representative Areas Program (RAP). The program’s Scientific Steering Committee recommended the protection of: “at least 20% of the area [of each bioregion]” SSC 2002:4. The committee stated: “…the SSC expects that around 25-

30% of the Great Barrier Reef Marine Park will be protected … in no-take areas…" SCC 2002:5.

Prior to the commencement of the RAP, only one political party had endorsed a target: "The Australian Democrats… [support] the expansion of highly protected areas to cover at least 50% of the Marine Park …." (Democrats election platform, October 2001). The Democrats are a minority party.

The SSC recommendations were subsequently accepted by the GBRMPA, and later endorsed by both the Australian and Queensland State governments. The final plan reserved 33% of the 348,700 km^2 park within no-take zones. Displaced fishers are being provided with financial assistance as part of a major program of fishery structural adjustment in the region.

South Africa:
The South African government has set a target of at least 10% of each ecosystem type to be reserved within protected areas:

> The Government is committed to the establishment of a comprehensive, representative system of protected areas and will build on current initiatives. In collaboration with interested and affected parties, the Government will [e]stablish a national co-operative programme to strengthen efforts to identify terrestrial, aquatic, and marine and coastal areas that support landscapes, ecosystems, habitats, populations, and species which contribute or could contribute to South Africa's system of representative protected areas. It will aim to achieve at least a 10 percent representation of each habitat and ecosystem type within each biome (DEATSA 1998:46).

According to WWF-South Africa, around 540 km of South Africa's 3000 km coastline is currently reserved within protected areas (18% by length)(WWFSA 2004). The proportion in no-take areas was not reported.

The document *A Bioregional approach to South Africa's protected areas* was released in May 2001 by the Minister of Environmental Affairs and Tourism. This document establishes the objective of maximizing benefits of South Africa's natural heritage for all South Africans, both now and in the future, through establishing a comprehensive and representative system of protected areas covering South African biological diversity. It sets a goal of increasing the terrestrial protected area estate from the current 6% of South Africa's land surface to 8% and the marine protected area from 5% to 20% by 2010 (DEATSA 2003:13).

The Minister for Environmental Affairs and Tourism, Marthinus van Schalkwyk, as reported by a DEATSA press release (DEATSA 2004) stated:

> These [four] new marine protected areas will bring South Africa much closer to achieving the targets set at the World Summit on Sustainable Development and the World Parks Congress for the protection of coastal waters (20% of national water). In future our efforts will also be directed at conserving substantial components of the continental shelf, extending into our economic exclusion zone.

The South African government, in its report to the United Nations on the Millennium Development Goals, listed a target of 10% of the nation under protected area status by 2015 as "potentially attainable" (RSA 2005:44).

New Zealand:
The *New Zealand Biodiversity Strategy* states (Government of New Zealand 2000:67):

> *Objective 3.6 Protecting marine habitats and ecosystems:*
>
> Protect a full range of natural marine habitats and ecosystems to effectively conserve marine biodiversity, using a range of appropriate mechanisms, including legal protection.
>
> *Actions:*

a) Develop and implement a strategy for establishing a network of areas that protect marine biodiversity, including marine reserves, world heritage sites, and other coastal and marine management tools such as mataitai and taiapure areas, marine area closures, seasonal closures and area closures to certain fishing methods.

b) Achieve a target of protecting 10 percent of New Zealand's marine environment by 2010 in view of establishing a network of representative protected marine areas.

The New Zealand Government published a *Draft Marine Protected Area Policy Statement* in 2004 which suggested that the 10 percent target should be seen as a minimum standard. Although this emphasis was removed in the final policy statement (Government of New Zealand 2005) the commitment to the 10 percent target remains. It is noteworthy that, unlike other similar targets, the 10 percent applies not to the protection of representative ecosystems, but to the marine realm overall (although development of a representative network is also a specific target). Such an area target is difficult to justify on scientific grounds (Pressey 2004) and is open to the creation of biologically ineffective 'paper parks'.

Brazil:

This section contributed by Patricia von Baumgarten, DEH South Australia.

The Brazilian Government released a draft *National Plan for Protected Areas* for public consultation in January 2006 (MMA 2006, available in Portuguese only on www.mma.gov.br/forum). The plan defines objectives, targets and strategies for the establishment of a comprehensive system of ecologically representative and effectively managed protected areas, which will integrate terrestrial and marine landscapes, by the year 2015. The Plan includes specific objectives for marine areas. Although it specifies that the final percentage of total protection to be given for each ecosystem will depend on further research on the representativeness of specific ecosystems, the Plan proposes a minimum target of 10% fully protected for each major ecosystem type.

The Plan includes sixteen objectives for coastal and marine areas that provide direct guidance for: system planning, site selection, establishment of participative decision making, establishment of the system, its monitoring and evaluation, institutional capacity building, and equality of opportunity for sharing benefits.

Fiji:

According to a briefing paper from WWF (WWF-Fiji 2005) Fiji's Minister for Foreign Affairs, Kaliopate Tavola, issued a statement in January 2005 which read in part:

> By 2020 at least 30% of Fiji's inshore and offshore marine areas will have come under a comprehensive, ecologically representative network of marine protected areas, which will be effectively managed and financed.

According to a news column in *MPA News* vol.7 no.5 November 2005:
"Local chiefs of Fiji's Great Sea Reef have established five marine protected areas with permanent no-take (tabu) zones as a step towards meeting the nation's commitment to build a MPA network protecting 30% of Fijian waters by 2020."

Micronesia:

According to *MPA News* April 2006, government leaders in the Micronesia region[17] have pledged to protect 30% of their nearshore marine ecosystems by 2020. Termed "The Micronesia Challenge", the commitment is being led by Palau, the Federated States of Micronesia, the Marshall Islands, and the US territories of Guam and Northern Marianas Islands. It was formally announced at the Eighth Conference of the Parties to the Convention on Biological Diversity (CBD), held in Curitiba, Brazil, in March 2006. The pledge also includes a commitment to protect 20% of their terrestrial ecosystems by 2020. Palau President H.E. Tommy Remengesau said his nation intends in the intervening years to be the first in the world to achieve, and surpass, having at least 10% of each of its ecological regions effectively conserved.

Also at the CBD meeting, the Caribbean island nation of Grenada pledged to put 25% of its nearshore marine resources under effective conservation by 2020.

Table xx: ***Summary: national MPA/NTA targets:***

Nation	Type	Target	Timeline	Reference
Bahamas	NTA	20%		AHTEG (2003:16); this is a secondary reference and ideally should not be quoted. Can we get more information?
Brazil	NTA	10%	10% 2015	MMA 2006
Fiji	MPA	30%	30% 2020	WWF-Fiji 2005
Galapagos Is	NTA	20%		AHTEG (2003:16); this is a secondary reference and ideally should not be quoted. Can we get more information?
Guam	NTA	20%		AHTEG (2003:16); this is a secondary reference and ideally should not be quoted. Can we get more information?
Micronesia	MPA	30%	30% 2020	*MPA News* April 2006
New Zealand	MPA	10%	10% 2010	Government of New Zealand 2000:67
South Africa	MPA	>10%	8% 2010	DEATSA 1998:46

Network size and reserve size

The borders of NTAs should, ideally, derive from the purpose and mechanism of the NTA – eg: what is to be protected, how that protection is to be achieved, and what security such protection should have. Protected areas are essentially about the control of threats. If there were no threats, or no threats relevant to area management (or no such threats likely) then there would be no need for MPAs, or protective NTAs (setting aside for the moment other goals like the establishment of scientific benchmark sites). However, harvesting activities in the marine environment, generally speaking, do pose threats to ecosystems – largely from the direct removal of organisms and from damage to habitat by gear. Historically, these threats have often resulted in gross changes to ecosystems[18], and sometimes to the extinction of species[19]. The greater the harvesting pressures on the local or regional environment, the greater the threat, and thus the more need there is for MPAs, and particularly protective NTAs. The larger the desired scope of protection, and the greater the need for that protection to be secure in the long-term, generally speaking, the larger the NTA network will need to be to achieve those goals.

On an individual basis, the size and shape of an NTA is directly related to edge effects which may threaten values within the NTA. In over-simplistic terms, the larger the NTA, and the more the shape of the NTA resembles a circle, the lower the edge effects will be – as a result of simple geometrics (Walters 2000). However, the design of NTAs as fisheries management tools may involve the enhancement, rather than the minimisation, of edge effects. Edge effects are, of course, only one of many issues relevant to size and shape. Ease of policing is another obvious consideration: fishers (and ‘police’) need to be able to identify boundaries – hopefully with ease and accuracy. Small NTAs may protect sedentary species, but are unlikely to protect important processes on which their survival ultimately depends. Halpern et al. 2006 relate the spacing of reserves within a network to larval dispersal distances (see Table and endnotes).

We do not live in an ideal world, where MPA network objectives and targets can precisely define NTA boundaries, and thus the size of both individual NTAs and NTA networks. Even if the science was that good, the history of MPA creation has shown that stakeholders would still argue over larger goals and timing. Habitats and micro-habitats may be poorly understood, categorised and mapped. Trophic and dispersion effects within the ecosystem may be poorly understood, and may be difficult to model. In the surrounding seas, fishing pressures may be difficult to control, and their direct and indirect effects may be poorly understood – with significant differences between short and long term effects. Uncertainties relating to long term climatic or oceanographic changes may be significant. Natural variability in ecosystem parameters may be high, temporarily masking anthropogenic effects. Catastrophes may degrade or even destroy local ecosystems. The need for redundancy within a NTA network must be considered.

We must bear in mind that, so far, national networks of marine NTAs do not live up to either the commitments contained in the *Convention on Biological Diversity 1992* (especially in regard to the creation of fully representative networks) nor do they line up with the science behind accepted MPA goals – as illustrated by a perusal of the papers reviewed below. In this context, size targets are important, and, in my view, *the establishment of large protected area networks should remain a core objective of nation-state marine strategies – as should the sympathetic management of biodiversity across the entire sea-scape*. While Agardy et al. may be right to highlight the dangers and difficulties of using size targets, the simple and urgent message from current MPA literature is, as Jake Rice[20] (2003) has said: "we need MPAs to be large and we need them soon" [21].

Table 1: NTA network size targets

Percentages refer generally to coverage within major ecosystem or habitat type, however see footnote below.

AUTHOR	NTA TARGET [22]	COMMENTS
Agardy et al. 2003	not specified	The authors warn against the universal application of a single (20%) target for NTAs[23].
Airame et al. 2003	30-50%	A recommendation from scientists to a community-based panel of stakeholders[24].
Allison et al. 2003	not specified	The author's arguments and methods require a planning authority to specify an initial area target, which is then expanded by an insurance factor to meet possible catastrophes.
Ardron 2003	10-50%	Review of earlier studies[25]
Beger et al. 2003	at least 20%	Examined reserve selection options to protect corals and reef fishes[26].
Bellwood et al. 2004	not specified	Authors describe a USA coral reef protection goal of 20% NTAs by 2012 as "too little too late".
Bohnsack et al. 2000	20-30%	Recommend at least 20-30% NTA.
Botsford et al. 2003	>35%	Not a recommendation: a theoretical (modelled) maximum based on species survival assumptions[27].
Commonwealth of Australia 2001	30%	Recommends a target of 30% of the pre-1750 ('pre-disturbance') extent of terrestrial ecological communities. Can similar logic be applied to marine systems? See Rodrigues & Gaston 2001 discussion of terrestrial issues[28], and Pressey et al. 2003, 2004.
Fogarty et al. 2000	35-75%	Not a recommendation. Fogarty et al. review a number of studies which suggest a range of 35% to 75% of an area should be protected to optimise fishery yield outside the reserves. As quoted by AHTEG 2003.
Gell and Roberts 2003b	20-40%	Not a recommendation: authors present evidence suggesting these sizes work best for some (mostly local) fisheries enhancements.
Gladstone (in press)	>30%	Modelling of coastal reef fish communities finds that a 30% MPA target will cover 75% of surveyed species[29].
Halpern 2003	not specified	Author reviews studies on the related issue of reserve size and MPA performance, and finds size is important[30] (larger is more effective).
Halpern et al. 2006	not specified	Authors review modelling approaches accounting for uncertainty in effective dispersal, within a framework of variable persistence. A 'rule of thumb' for reserve spacing of around 25 km is suggested[31].
Hughes et al. 2003	>30%	Not a recommendation: authors present evidence from ecological modelling studies – greater than 30% reef NTAs needed[32] to protect coral ecosystems.
Leslie et al. 2003	20% +	Not a recommendation: figure selected for illustrative purposes (model demonstration).

AUTHOR	NTA TARGET [33]	COMMENTS
Lockwood et al. 2002	not specified	Authors model population persistence inside coastal reserves assuming zero populations outside reserves. To ensure persistence "[the] upper limit for the minimum fraction of coastline held in reserve is about 40%."
Mangel 2000	~5-50%	Modelling analysis of reserves as a fishery enhancement tool depends on selecting a time horizon, fishing pressure and a probability of ecological extinction of the population[34].
McClanahan & Mangi 2000	not specified	"Our field survey, combined with previous modelling studies, based on adult emigration rates from marine reserves, suggests that tropical fisheries dominated by rabbitfish, emperors and surgeonfish should be enhanced by closed areas of around 10 to 15% of the total area" – also adding that a larger area may be calculated if larval export is important.
National Research Council 2001	20-50%	Figures from a literature review[35] relating to enhancement of fisheries effects.
Palumbi 2004	not specified	Author reviews information on the scale of marine neighbourhoods, and discusses the relevance of MPA size and spacing[36].
Pandolfi et al. 2003	not specified	The authors talk about a need for "massive protection" and "protection at large spatial scales" (coral reefs).
Pew Fellows 2005	10-50%	"Place no less than 10% and as much as 50% of each ecosystem in no-take zones, according to identified needs and management options in a particular ecosystem"
Pressey et al. 2003, 2004	variable	See papers: target proportion selected for modelling (2004) depends on natural rarity and vulnerability (10-40%). See text above.
Ray 2004	Implicitly supports (high) targets	Ray's paper is a critique of Agardy et al. suggesting that (a) MPAs in general need much more attention, and (b) to argue about the rights or wrongs of particular views on targets is counter-productive.
RCEP 2004	>30%	Authors call for the urgent creation of massive NTAs to allow marine habitat / ecosystem recovery[37].
Roberts et al. 2003ab	>20%	Not a recommendation; authors provide a comprehensive review of NTA design methods and parameters.
Rodwell & Roberts 2004	20 – 40%	Fishery models indicate that: "reserve coverage of between 20% and 40% prevent stock collapse in most cases."
Shanks et al. 2003	NTA size & spacing	Authors deal only with size and spacing using analysis and modelling of dispersal data[38].
Sala et al. 2002	40%	Gulf or California rocky reef habitat[39]
Sale et al. 2005	20 – 35%	Not recommendations – paper includes brief review[40].

AUTHOR	NTA TARGET [41]	COMMENTS
UNEP 2004	>10%	Not a NTA, or even a MPA target. CBD CoP VII/30 annex II (see discussion above): “at least 10% of each of the world’s ecological regions effectively conserved”.
Walters 2000	NTA size	No recommendations on habitat targets. The paper deals with the relative benefits of a few large vs. many small NTAs. For mobile species, many tiny fragmented NTAs are likely to have negligible benefits[42].
Watson et al. 2000	20%	Paper models fisheries impacts of MPAs using Ecopath. “Within the range of exchange rates simulated, the maximum increases in catch and overall biomass levels were reached when 20% of the system was protected.”
Worm et al. 2006	23%?	Check this
World Parks Congress 2003	20-30%	WPC recommendation 5.22 to be considered by the UN General Assembly[43].

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Note that not all cited references are reviewed: some are referenced in endnotes.

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Appendix One to Attachment Two

Extract from the Appendix of: Ecological Society of Australia (2003) *Protected areas: a position statement by the Ecological Society of Australia*. ESA; Alice Springs Australia.

3. Formulating protection targets for biodiversity – *specific considerations*

The ESA considers that:

* Explicit, quantitative targets are essential for planning and managing protected areas and off-reserve protection mechanisms.

* Quantitative targets should be the subject of ongoing debate and refinement. The primary concern of this debate should be the scientific interpretation of broad goals stated in policy, not the political and economic constraints on targets. New data and new understanding will require continuing refinement of targets.

* Targets should concern not only elements of biodiversity pattern but the spatial and temporal aspects of natural processes, including population sizes, movements, metapopulation dynamics, disturbance regimes, ecological refugia, adjustments to climate change, and diversification.

* Refinement of conservation targets will largely depend on research into spatial surrogates for biodiversity pattern and process and the effects of alteration of habitats outside protected areas.

* Appropriate scales for formulating targets will vary, but targets expressed as percentages of regions or subregions are essentially meaningless unless they are tied to, and preceded by, targets for habitats at the finest available scale of mapping. Targets for regions, subregions or jurisdictions should emerge from targets at finer scales.

* Targets for protected areas should be complemented by ceilings for loss of habitat with the balance comprising multiple-use under appropriate forms of off-reserve management.

* Protection targets should not be constrained by areas of extant habitats but should, where necessary, indicate the need for restoration to extend and link fragments of habitat and improve their condition.

* Constraints on the rates of expansion of protected areas within regions require individual targets to be prioritised so that early protection is given to those biodiversity features that are most irreplaceable and most vulnerable to threatening processes.

Appendix Two to Attachment Two

Californian marine protected areas
Extract from MPA News, September 2006

In August 2006, the Fish and Game Commission of the US state of California unanimously approved a proposal to designate a network of marine protected areas along the state's central coast, encompassing 18% of Central California's coastal waters. Totaling 204 square miles (528 km2), the proposed network of MPAs will now undergo environmental and regulatory review before taking effect, which could occur in early 2007, say officials. The proposed network consists of 29 MPAs each extending seaward from the coast for three nautical miles, the outer boundary of state waters. Approximately 94 square miles (243 km2) of the network would be no-take marine reserves, while the remainder would allow limited recreational or commercial fishing.

The proposed network is the first product of California's seven-year process so far to build a state-wide system of marine reserves in its waters. The California state legislature passed the Marine Life Protection Act (MLPA) in 1999 with a goal of redesigning and strengthening the state's fragmented system of MPAs (MPA News 1:3). But the MLPA-based process to plan and designate a marine reserve network got bogged down in stakeholder opposition (MPA News 3:9) and budget shortfalls (MPA News 5:7). California Governor Arnold Schwarzenegger revived the process in 2004 with funding contributed by private foundations, appointing a special task force of experts to spearhead the planning. In a statement following the Commission's approval of the proposed network, Schwarzenegger said, "[This] milestone makes California a national leader in ocean management and is proof of what can be done when all those involved - the fishing industry, environmentalists, and others - work together."

Fishing groups, however, have expressed disappointment with the proposed network. United Anglers of Southern California (UASC), which represents nearly 50,000 recreational fishermen, said in a press statement that although the proposed network was "not the worst possible outcome" (there had been larger reserve packages on the table for consideration), the reserves would have an unnecessarily large impact on sport boat operators who depend on access to areas now slated for closure. UASC Fisheries Specialist Bob Osborn specified that the proposed network focused disproportionately on rocky reef habitats, thereby limiting anglers' opportunities to catch rockfish, a popular target. Zeke Grader, executive director of the Pacific Coast Federation of Fishermen's Associations, said that despite no-take regulations, the proposed reserves would still be vulnerable to the threat of coastal pollution and runoff from the region's major cities and farming areas, and called for stricter controls on these impacts.

The Commission's proposed network provided less protection than several environmental groups would have liked, but these organizations applauded the step forward. "This is a solid start toward restoring our ocean and implementing ecosystem-based management," said Kaitlin Gaffney of The Ocean Conservancy. "Although we believe that a higher level of protection is warranted, the Commission action does protect important central coast habitats like kelp forests, nearshore reefs, and submarine canyons, consistent with science guidelines on preferred size [of reserves] and protection levels."

In January 2007, the California Department of Fish and Game is expected to begin meetings with stakeholders about possible marine reserves in the Southern California region.

For links to more information:

The proposed network for Central California, including maps and regulations:
http://www.dfg.ca.gov/mrd/mlpa/commissiondocs.html

Response from United Anglers of Southern California:
http://www.unitedanglers.com/news.php?extend.5

Response from The Ocean Conservancy:
http://www.oceanconservancy.org/site/News2?abbr=issues_&page=NewsArticle&id=8731.

Endnotes

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[1] The World Database on Protected Areas (WDPA) (www.unep-wcmc.org accessed 18/1/06) contains MPA area data to 2003. IUCN categories Ia and Ib were used as identifiers for no-take areas, and adjusted by the 2004 expansion of no-take areas in the Great Barrier Reef Marine Park. The 'total' percentage is based on summing the global areas under categories I-VI, and includes the 184,000 km^2 Kiribati Phoenix Islands MPA (announced March 2006) and the 360,000 km^2 Northwestern Hawaiian Islands National Monument (announced 15 June 2006) but does not include the area managed by the Commission for the Conservation of Antarctic Marine Living Resources (35.7 million $km^{2)}$. If it can be assumed that IUU fishing, and fishing by non-Party States has negligible impact on this area, the zone qualifies as a category IV marine protected area. Even taking these two important factors into account, the Convention Area probably qualifies as a category VI protected area. The global area percentage under general MPA management would then increase (dramatically) to 12 %. It should be noted that internal CCAMLR papers at this stage support the 'IV'classification; however CCAMLR has not requested entry to the WDPA. Note that at this stage no information is available on the area under categories Ia and Ib in the Phoenix Islands or NW Hawaiian MPAs, so these new PAs has not been included in the calculation of 0.18% NTAs.
[2] According to Evans & Russ 2004: "Adjacent fisheries may benefit from no-take marine reserves due to spillover (net export) of adult individuals (Russ and Alcala, 1996; McClanahan and Mangi, 2000; Roberts et al., 2001; Galal et al., 2002) and net export of propagules via larval dispersal (Stoner and Ray, 1996; Roberts, 1997; Gell and Roberts, 2002). See Evans & Russ for citations.
[3] Agardy has major concerns over the possibility of a rapid and poorly planned expansion of marine protected areas. "The desire for quick fixes has led to a proliferation of MPAs – many in areas where they are not needed, executed in a way that does not address the threats at hand, and planned with little consideration of long-term financial and social feasibility." (Tundi Agardy, *MPA News* October 2005 p.3).
[4] In particular goals relating to the slowing of biodiversity loss, such as those incorporated in the Johannesburg Declaration 'key outcomes' statement – see discussion.
[5] The word 'area' implies defined and constant boundaries over time. The word 'protected' implies conscious protection. Conscious protection from what? Threats to an area's values. This implies that a management plan exist which identifies both threats and values. 'Protected' also implies effective protection – which implies the existence of monitoring and reporting programs.
[6] Semantically, the word "sympathetic" is not used in the CBD, although the logic is explicit. A concise statement capturing the two core concepts may be found in Principle Eight of the *National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth of Australia 1996) which states: "Central to the conservation of Australia's biological diversity is the establishment of a comprehensive, representative and adequate system of ecologically viable protected areas, integrated with the sympathetic management of all other areas, including agricultural and other production systems."
[7] This era came to an end at the close of the 19^{th} century. The World Protected Area Database's first MPA entry is dated 1888.
[8] Ghost fishing refers to the continued effects of lost and abandoned fishing gear.
[9] The acceptance by the scientific community of the importance of MPAs as conservation tools is illustrated by several major scientific consensus statements, such as those published by the Marine Conservation Biology Institute in 1998, and the American Association for the Advancement of Science in 2001 (both avaliable at http://www.ids.org.au/~cnevill/marine.htm).
[10] Such as the FAO Code of Conduct for Responsible Fisheries 1995.
[11] An example of an important ecological process under threat globally relates to ocean chemistry. Aquatic organisms which create calcareous structures, such as coral, depend on complex chemical reactions to extract calcium carbonate from surrounding water (calcium here listed as a nutrient). Increasing levels of atmospheric carbon dioxide are increasing

aquatic acidity, placing in jeopardy this essential process. Clearly protected areas will do little in some cases to protect essential ecological processes.
[12] Here water is defined as a nutrient for the purposes of terrestrial ecosystems.
[13] Processes of information flow include larvae dispersal and pollination, for example.
[14] The ethical arguments of the Frost Report where echoed in the findings of a more recent inquiry (NTFW 1997). However the arguments Australia used in the International Whaling Commission were based purely on scientific grounds: that the sanctuary would assist in rebuilding depleted stocks (Commonwealth of Australia 2002, 2004)
[15] The sixth CoP CBD meeting was held in April 2002.
[16] WSSD: August-September 2002.
[17] An IUCN press release on the Micronesia Challenge is available online at http://www.iucn.org/en/news/archive/2006/03/28_pr_islands.htm.
[18] Jackson et al. 2001.
[19] Stellar's Sea Cow (Anderson 1995) and the Caribbean Monk Seal are amongst the best known.
[20] Jake Rice is the director of the Canadian Science Advisory Secretariat for the Department of Fisheries and Oceans. He manages the peer review and application of marine and fisheries science to policy formation and management decision-making. Contact address: 200 Kent Street, Stn 12036, Ottawa, Ontario K1A OE6, Canada.
[21] Rice adds: "…we also need to be prepared to act without full information and full consensus when the decision system is receptive, and to make some mistakes due to incomplete knowledge. What matters then is that we admit the mistakes later when more information becomes available, and do our best to correct them."
[22] The percentages listed below are not recommended on a strictly equivalent basis. Some (eg DEH 2001) apply to specify ecological communities, while others apply to a total area under jurisdiction (like the New Zealand target). The former (more common) approach follows a specific rationale concerned with the protection of biodiversity through the protection of representative examples of habitat (see Appendix 1).
[23] The authors also make the important point that MPA system design should go hand in hand with measures aimed at sympathetic management of the remaining matrix.
[24] "After consideration of both conservation goals and rhe risk from human threats and natural catastrophes, scientists recommended reserving an area of 30-50% of all representative habitats in each biogeographic region". Page S170.
[25] Ardron 2003:18 "A variety of marine reserve sizes ranging from 10% to 50% have been suggested as being efficacious as a conservation and/or fisheries management tool (MRWG 2001, NRC 2000, Roberts & Hawkins 2000, Ballantine 1997, Carr & Reed 1993), with an emphasis on larger reserves coming from the more recent literature. Furthermore, it has been found that larger reserves often have beneficial effects disproportionate to their size (Halpern 2003)".
[26] Beger et al. found that over 80% area protection would be required to protect 100% of both coral and fish species at their Kimbe Bay study site. Their recommendation of 20% coverage was based on protecting just under 80% of all surveyed species.
[27] The authors present modelling analysis suggesting that, based on larvae dispersal and survival assumptions, together with assumptions about reserve size and distribution, 35% of coastal habitat would need to be reserved if no survival occurred in the remaining areas (the remaining 65%).
[28] Rodrigues and Gaston 2001 examine the application of complementarity-based network design methods for identifying a minimum reserve network area to contain all species of identified terrestrial taxa. They found that the minimum area depends (in part) on type of taxa, regional endemism, and the size of the selection unit used in the design. At this level of generality their findings are likely to apply to marine ecosystems. Assuming every terrestrial plant needs to be represented at least once within a reserve network, a selection unit size of 12,000 km^2 leads to a reservation requirement of 74% of the global land area, while a selection unit size of 270 km^2 leads to a reservation requirement of 10% of the global land area. As the authors state, it is most unlikely that such small reserves would protect the processes which underpin biodiversity persistence, let along evolution. There is however a major difference between terrestrial conservation and marine conservation. Mankind has succeeded in not only modifying most pristine terrestrial habitats, but in destroying them and replacing them with highly modified and simplified ecosystems, where only highly adaptable

organisms continue to survive. The analysis of Rodrigues and Gaston assumes that the greater part of terrestrial biota need protected areas to survive – a reasonable assumption. While global marine ecosystems have been pushed into ecological crisis, it may be that, if harvesting impacts can be sufficiently reduced, most marine ecosystems can continue to function as 'homes' for resident biodiversity. If this is the case, the need for strictly-protected no-take areas may be somewhat reduced. It is important to note, however, that the processes which underpin marine biodiversity *often* operate at regional and global scales, and the means for their comprehensive protection is at present well outside the scope of current science. Under these circumstances, a precautionary approach to marine protected area network design is appropriate. If we are to adequately protect marine biodiversity, we must now err on the side of creating reserves which are too large rather than too small.

[29] Gladstone concludes: "…the upper range of currently promoted targets for MPA establishment (i.e. 30%) should be regarded as a minimum for biodiversity conservation."

[30] Halpern 2003 concludes: "The most important lesson provided by this review is that marine reserves, regardless of their size, and with few exceptions, lead to increases in density, biomass, individual size, and diversity in all functional groups. The diversity of communities and the mean size of the organisms within a reserve are between 20% and 30% higher relative to unprotected areas. The density of organisms is roughly double in reserves, while the biomass of organisms is nearly triple. These results are robust despite the many potential sources of error in the individual studies included in this review. Equally important is that while small reserves show positive effects, we cannot and should not rely solely on small reserves to provide conservation and fishery services. Proportional increases occur at all reserve sizes, but absolute increases in numbers and diversity are often the main concern. To supply fisheries adequately and to sustain viable populations of diverse groups of organisms, it is likely that at least some large reserves will be needed."

[31] Halpern et al. 2006 argue: "unless we are fairly certain about our estimate of dispersal distance, reserves should be spaced around 25 km from each other." They note: "Botsford et al. 2001 developed a similar rule of thumb using a different approach to modelling dispersal distance." Halpern's findings are supported by Cowen et al. 2006, who report: "typical larval dispersal distances of ecologically relevant magnitudes are on the scale of only 10 to 100 kilometers for a variety of reef fish species."

[32] Pandolfi et al. 2003:933 "Ecological modelling studies indicate that, depending on the level of exploitation outside NTAs, at least 30% of the world's coral reefs should be NTAs to ensure long-term protection and maximum sustainable yield of exploited stocks".

[33] The percentages listed below are not recommended on a strictly equivalent basis. Some (eg DEH 2001) apply to specify ecological communities, while others apply to a total area under jurisdiction (like the New Zealand target). The former (more common) approach follows a specific rationale concerned with the protection of biodiversity through the protection of representative examples of habitat (see Appendix 1).

[34] The upper 50% figure derives from selecting a high fishing pressure outside the NTA network, a planning time horizon of 100 years, and an acceptable probability of population extinction of 1%. Assuming lower fishing pressures, a shorter time horizon, and an increased acceptable risk of extinction will all produce a smaller NTA network size target.

[35] "For fisheries, the benefit of a reserve does not increase directly with size. The maximum benefit of no-take reserves for fisheries, in terms of sustainability and yield, occurs when the reserve is large enough to export sufficient larvae and adults, and small enough to minimize the initial economic impact to fisheries (see review in Guenette et al. 1998). Data from harvested populations indicate that species differ greatly in the degree to which they can be reduced below normal carrying capacity before they are not self-sustainable in the long term (e.g., Mace and Sissenwine 1993, Hilborn, personal communication). If reserves are designed for fisheries enhancement and sustainability, the vast majority of studies done to date indicate that protecting 20% to 50% of fishing grounds will minimize the risk of fisheries collapse and maximize long term sustainable catches (NRC 2001, Table 1)".

[36] Palumbi concludes: "[Available studies] suggest adult neighbourhood sizes for many demersal fish and invertebrates as small as kilometers and up to 10 to 100 km. Larval dispersal may be shorter than previously suspected: neighbourhood sizes of 10 to 100 km for invertebrates and 50 to 200 km for fish are common in current compilations. How can small reserves protect such species? One conceptual framework is to set reserve size based on adult neighbourhood sizes of highly fished species and determine spacing of a reserve

network based on larval neighbourhoods. The multispecies nature of fisheries demands that network designs accommodate different life histories and take into account the way local human communities use marine resources."

[37] Recommendation 8.96.

[38] "We suggest that reserves be designed large enough to contain the short-distance dispersing propagules and be spaced far enough apart that long-distance dispersing propagules released from one reserve can settle in adjacent reserves. A reserve 4-6 km in diameter should be large enough to contain the larvae of short-distance dispersers, and reserves spaced 10-20 km apart should be close enough to capture propagules released from adjacent reserves."

[39] "We describe a means of establishing marine reserve networks by using optimization algorithms and multiple levels of information on biodiversity, ecological processes (spawning, recruitment, and larval connectivity), and socio-economic factors in the Gulf of California. A network covering 40% of rocky reef habitat can fulfil many conservation goals while reducing social conflict."

[40] According to Sale et al. (Box 1) "Protecting 20% of the area [available habitat type] has become a commonly cited target. This arbitrary target relies on the assumption that protecting 20% of the area protects 20% of the original spawning stock, and on the argument that protecting 20% of the stock would prevent recruitment overfishing. More recent models suggest that >35% of the total area needs to be in no-take reserves to prevent recruitment overfishing of sedentary species, such as sea urchins or many reef fishes, and area requirements differ among species with differing biology."

[41] The percentages listed below are not recommended on a strictly equivalent basis. Some (eg DEH 2001) apply to specify ecological communities, while others apply to a total area under jurisdiction (like the New Zealand target). The former (more common) approach follows a specific rationale concerned with the protection of biodiversity through the protection of representative examples of habitat (see Appendix 1).

[42] According to Walters: "The message is simple: for relatively mobile species, single large MPAs can be much more effective than many small ones".

[43] "Therefore, PARTICIPANTS in the Marine Cross-Cutting Theme at the Vth World Parks Congress, in Durban, South Africa (8-17 September 2003): CALL on the international community as a whole to:

Establish by 2012 a global system of effectively managed, representative networks of marine and coastal protected areas, consistent with international law and based on scientific information, that: (a). greatly increases the marine and coastal area managed in marine protected areas by 2012; these networks should be extensive and include strictly protected areas that amount to at least 20-30% of each habitat, and contribute to a global target for healthy and productive oceans;" The full text of the recommendation is available from www.iucn.org.

Attachment Three: The impacts of recreational spearfishing
(from Nevill 2009):

Notes on the effects of recreational diving on shallow marine reefs in Australia.

> "In the old days (1940's and 1950s) my friends and I used to be able to go to Rottnest (Perth's holiday island) and spear a boat load of dhuies (best fish around). These days there's nothing there - I don't understand it."
>
> 85 year old veteran Western Australian spear fisherman Maurie Glazier quoted by niece Jo Buckee[1], 2004.

A6.1 Abstract:

On the basis of anecdotal information (as little other information is available) I argue in this appendix that recreational diving (in particular spearfishing) has had devastating effects on the fish and crayfish (southern rock lobster[2]) populations of accessible shallow reef environments along much of the Australian coastline. Spearfishing in Australia is almost entirely recreational. This appendix briefly reviews the global scientific literature on the subject, providing a backdrop against which local anecdotal information may be judged. My involvement, as a teenager, in overfishing Victorian reefs is described. Overfishing of a similar nature appears to have taken place in other Australian States where reefs are within ready access (by car or boat) from population centres of all sizes. Damage to shallow reef environments along Australia's sparsely populated coastline (eg: in northern Western Australia, north-western Queensland, the Northern Territory, western South Australia and western Tasmania[3]) seems likely to be concentrated at the more accessible or attractive[4] sites. These impacts are significant in a national context, yet appear to have been ignored or under-estimated by both spearfishers and the government agencies[5] charged with conserving and regulating marine environments[6]. This relaxed managerial approach runs counter to the voluntary *FAO Code of Conduct for Responsible Fisheries*, which Australian governments claim to support. Current government management of the sport of spearfishing fails internationally accepted precautionary benchmarks in all Australian States. Further controls over spearfishing by State Governments are recommended, covering nine specific issues.

Keywords: spear, spearfishing, effects, impacts, Australia, recreational diving, lobster.

Citation: Nevill, Jon (2006) *The impacts of spearfishing: notes on the effects of recreational diving on shallow marine reefs in southern Australia*. OnlyOnePlanet Australia; Hampton Melbourne. Available online at http://www.tucs.org.au/~cnevill/marine.htm, accessed [date].

A6.2. Introduction:

Before discussing spearfishing in detail, it is important to note that 'passive' recreational diving and snorkelling (while important in developing an informed public voice for marine conservation) can also result in damage to marine habitats. Ponder et al. provide a review which highlights the need for awareness instruction, particularly for novice divers, as well as management limits on the number of divers at popular sites (Ponder et al. 2002:381-382).

Commercial spearfishing is banned in all Australian States, and illegal commercial spearfishing has been rare for over two decades. Relatively little use of spearfishing is made within Australia's small artisanal fisheries. The bulk of spearfishing in Australia is recreational.

Spearfishing is one the few fishing techniques where each target is individually selected, so bycatch should be zero – a positive feature. It should also be acknowledged immediately that far more Australians go angling than go spearfishing (Henry and Lyle 2003[7]) and that recreational gill-netting is still permitted in Western Australia and Tasmania[8],[9]. The effects of these activities are widespread and significant[10]. However, while spearfishing has the potential to be one of the most environmentally-sound fishing activities, it is a mistake to believe that the effects of the sport have not been important – and in many cases disastrous. Spearfishing activities are often concentrated at particular sites, and the activity is, in the right conditions, an extremely effective and efficient method of harvesting target fish – being far more time-efficient than angling in many situations.

Where reef species are heavily targeted, local populations of adult fish can be completely removed, and recruitment from deeper reefs may be low or non-existent. These locations are particularly vulnerable, and anecdotal evidence indicates local extinctions have occurred. A significant regional extinction is approaching[11] (the grey nurse shark: see below).

The Australian situation, where recreational spearfishing predominates, is different from the situation in many Pacific island States. Here substantial commercial and artisanal spear-fisheries operate under little effective control. According to Gillett & Moy (2006):

> The ten most important spearfishing difficulties [in Pacific island States] appear to be the contribution of spearfishing to inshore over-fishing, the use of scuba in spearfishing, night spearfishing, industrial spearfishing, negative interaction with line fishing, poaching and difficulties of surveillance, devastation of certain species, devastation of spawning aggregations, incompatibility of spearfishing with marine tourism, and increased [detrimental] algal growth due to the removal of herbivores.

Johannes (1978) discussing the demise of traditional fish conservation in oceania, refers to damage to fish populations by spearfishing, and cites examples of formal and informal bans on spearfishing in certain locations.

Judging by information presented by Gillett & Moy (2006) viewed in conjunction with local studies, heavy spearfishing pressures across the tropical Pacific have caused, and continue to cause severe declines and local extinctions of reef fish. Local extinctions, and possible regional extinctions of the giant humphead parrotfish (*Bolbometopon muricatum*) have been documented by Dulvy & Polunin (2004). Many less prominent fish than the humphead have, without doubt, suffered in a similar way. Dulvy & Polunin identify spearfishing as a primary threat to these reef fish.

Fisheries managers can ignore important anecdotal information which looks “unscientific”. Pauly (1995) refers to a ‘shifting baseline’ which has in part resulted from an apparent inability of fisheries science to use anecdotes to establish historical baselines[12]. Johannes et al. (2000) stressed the importance of considering fishers’ ecological knowledge. Saenz-Arroyo et al. (2005) after a detailed examination of historical evidence on the abundance of the Gulf Grouper in the Gulf of California, concluded:

> We should start rethinking our criteria for assessing marine species at risk, not just in the context of the shifting baseline, but also with respect to the type of information we require for these assessments. By only trusting the evidence that we are trained to use as ecologists or fisheries scientists we continue to run the risk of failing to adequately protect species that have been depleted without our noticing.

Discounting anecdotal information, even when no scientific[13] information is available, may be one of the reasons behind the failure of many fisheries management programs. This appendix rests largely on fishers’ knowledge. It deals with the environmental impacts of recreational diving, focussing principally on spearfishing. Recreational harvesting of crayfish and abalone are also briefly discussed.

By way of background, it is important to note that, globally, the importance of recreational fishing has been consistently understated and under-reported (Cooke & Cowx 2004) and that recreational fishing can cause ecosystem degradation of similar scales and types compared with commercial fishing (Cooke & Cowx 2006). These authors provide examples of declines caused by recreational fishing that “were largely unnoticed by fisheries managers, a characteristic that may be widespread in recreational fisheries.” (2006:94). This comment certainly applies to the management of spearfishing in all Australian States.

Spearfishing on SCUBA (self-contained underwater breathing apparatus) while banned in Queensland, New South Wales, and South Australia, is still permitted in Western Australia, Victoria, Tasmania and the Northern Territory. As far as I am aware, night spearfishing is still permitted in all Australian States. In my view this situation needs urgent review, and displays an absence of understanding (on the part of the agencies charged with regulating fishing activities) of the potential damage the sport can do to reef environments. Again, in my view, massive increases in marine no-take areas are needed to provide adequate protection for marine ecosystems, and spearfishing should not only be excluded from these areas, but from buffer zones around these areas as well.

A6.3. International benchmarks:

The cavalier attitude to spearfishing common amongst Australia’s fishery management authorities is underlined by a comparison of existing management frameworks with FAO[14] fishery guidelines. The voluntary *FAO Code of Conduct for Responsible Fisheries 1995*, echoing the *Rio Declaration 1992* (both endorsed by the Australian Government), requires all compliant States to apply the precautionary principle. The FAO precautionary principle guideline (the Lysekil Statement[15]) advocates (paragraph 7) that:

> (a) all fishing activities have environmental impacts, and it is not appropriate to assume that these are negligible until proved otherwise,

and that:

> (c) the precautionary approach to fisheries requires that all fishing activities be subject to prior review and authorization; that a management plan be in place that clearly specifies management objectives and how impacts of fishing are to be assessed, monitored and addressed; and that specified interim management measures should apply to all fishing activities until such time as a management plan is in place.

The failure of all Australian State fishery agencies to develop management plans for spearfishing, or to monitor effects and publish findings, places these agencies in clear contravention of the precautionary elements of the *Rio Declaration* and the *Code of Conduct* in this respect.

The Lysekil Statement contains a number of other recommendations which are relevant to the management of spearfishing:

Para.	Recommendation	State fishing agency response
6b	Prior identification of undesirable outcomes and of measures that will avoid them or correct them promptly.	Recommendation ignored.
6c	Any necessary corrective measures are initiated without delay.	Recommendation ignored.
6d	Where the likely impact of resource use is uncertain, priority should be given to conserving the productive capacity of the resource.	Recommendation ignored.
Para.	**Recommendation**	**State fishing agency response**
25	For all fisheries, plans should be developed or revised to incorporate precautionary elements.	Recommendation ignored.

28	To be precautionary, priority should be accorded to restoration of overfished stocks, avoidance of overfishing, and avoidance of excessive harvesting capacity.	Ignored – with the partial exception of the GBRMPA[16].
41	Precautionary monitoring of fishing should seek to detect and observe a variety of ancillary impacts, eg: environmental changes, fish habitat degradation…	Ignored – with the partial exception of the GBRMPA.

To comply with the FAO Code of Conduct, a fishery must be precautionary. The Lysekil Statement presents accepted benchmarks which together define precautionary fishery management. No Australian State or Territory currently manages spearfishing in accordance with the precautionary approach.

A6.4. Back in the old days ...

Humans have been spearing fish for thousands of years. However spearfishing as a popular sport is a post World War II phenomenon, underpinned by the technical innovations of SCUBA and neoprene wetsuits reaching the consumer marketplace. Spearfishing as a popular sport in Australia began in Queensland and New South Wales in the mid-1940s, and in my home State of Victoria (where water temperatures were lower) in the late-1940s. Neoprene wetsuits had, however, not yet reached the consumer market at this time, seriously limiting diver time in the cool waters of southern Australia.

When my father and I started spearfishing in 1959 (I was 13 years old) my first spear was a home-made affair, a length of bamboo with a steel barb at the tip and two straps of rubber cut from a car inner-tube fixed to the rear. Mass-produced masks, snorkels and fins had been available for about fifteen years. Wetsuits had only recently appeared in shops selling sporting equipment, although these early suits had no linings, with the disadvantage that a lot of talcum powder was needed to don the suit, and the neoprene foam was easily damaged by contact with rocks. Within a year we had replaced our sling spears with home-made trigger-mechanism spearguns constructed from broom handles and rubber straps, with 5/16 inch stainless steel spears. Although mass-produced spearguns were available, they were expensive. The popularity of the sport at that time was increasing rapidly.

My family lived in Hampton, a suburb of Melbourne, on the eastern shore of Port Phillip Bay. Close by a 300 m breakwater had been constructed from basalt boulders to provide a small harbour for a number of swing-moorings. The breakwater was built over shallow sand, but joined a section of natural sandstone reef at the point where it met the shore. Our house was only five minutes walk from the Bay. In those days, snorkelling beside the Hampton breakwater, I could count on catching enough fish in 20 minutes to feed five people – generally 3 to 5 fish between 0.35 and 1.0 kg in weight each. Leather jackets[17] and luderick[18] were abundant, as were several other species of reef dwelling fish. Large flathead[19] and flounder[20] could be easily caught on the sand beside the breakwater. Like most others spearing fish, we simply assumed that the fish we took would be replaced by fish moving in from deeper reefs. We were wrong.

There is no doubt in my mind that spearfishing in reef environments is hugely more effective as a harvesting mechanism compared to angling. Angling had taken place along the breakwater since it was built decades earlier. Although flathead and snapper were the primary angling target (fishing on the sand beside the artificial reef formed by the boulder breakwater) a few anglers targeted reef species, using floats to keep baits above the rocks. I participated in both angling and spearfishing at that location over several years.

Within five years of my first observation in 1959, the populations of reef fish along the breakwater were decimated. I undertook a visual census in 1964, and reconstructed 1959 population levels from memory[21]. Within about ten years the species targeted by spearfishers were gone, for all intents and purposes. Even the marblefish[22], easy to catch but poor eating, were gone. Several fish species, by my observation, were entirely eliminated from this site. During this period there was no noticeable increase in recreational angling pressures, which remained almost non-existent in relation to reef fish. No commercial harvesting or recreational netting of reef fish took place at this site before, during or after the period in question. Because I lived with the breakwater so close by, during my childhood I was there almost every day (usually accompanied by my dog) and I can remember no changes – pollution episodes or dramatic weather events[23], for example, which could account for the decline I witnessed. There is no river or creek nearby which might have effected the site. I believe that spearfishing pressure was the single cause of the decline in fish populations in the 1960s[24]. A rapid increase in spearfishing pressures, starting during the late 1950s, coincided with a rapid decrease in fish numbers. Aquatic vegetation at the breakwater did change, but this change followed rather than preceded the decline in fish numbers.

Figure A6.1 Hampton breakwater and marina, 2009. Source: Google Earth 23/3/2009.

Later on, about 1990, the swing moorings were removed and a marina was constructed inside the breakwater to protect mainly recreational yachts and motor vessels. This would have resulted in an increase in local pollution by anti-fouling agents; however no site-specific water quality data is available. I estimate that the wetted-hull area after the marina was constructed increased by around a factor of 10[25]. It should be noted that this expansion post-dates the demise of the species in question by many years.

Ten years later still, creation of an artificial beach (just visible at the top of Figure 1) released millions of tonnes of sand into the immediate vicinity of the breakwater (discussed below). In an attempt to maintain depth in the marina, sand was pumped by the Sandringham Yacht Club (owner of the marina) to the outside edge of the breakwater, substantially reducing the water depth, and smothering the rock habitat at the foot of the breakwater. However, well before this had happened, fish populations on the outside breakwater wall had collapsed.

With the rapid decline of shore-based reef spearfishing in Port Phillip Bay, I switched my attention to ocean locations. One of my favourite spearfishing sites was Flinders back-beach, near the entrance to Westernport Bay, a little over one hour's drive from my home in the suburbs of Melbourne. Flinders probably has the most extensive accessible shallow ocean reefs of any site along the Victorian coastline. Other easily accessible ocean sites were the rocky shores at Inverloch, Eagles Nest and Cape Liptrap, and shallow reefs near Tidal River at Wilson's Promontory.

Figure A6.2 Flinders shallow reef, 2009. Source: Google Earth 23/3/2009.

As I have said, spearfishing became a popular weekend pastime at Victorian ocean locations at the close of the 1950s. In the early 1960s, the shallow (2-6 m) reef ledges at Flinders[26] were still so packed with fish that a spear shot into a ledge would often take two fish with the one shot. Large crayfish and abalone were abundant. At Eagles Nest, I can remember – along with two friends – filling a 50 kg flour-sack with crayfish in under one hour, snorkelling in water only 2-4 metres deep. By the time I started studying at university (1966) I had noticed a dramatic decline in both fish and crayfish in these shallow ocean reefs.

The crayfish populations in shallow water, although prolific in the early 1960s, were without doubt already well below pristine abundance. According to O'Hara (2000) the first European settlers on the Mornington Peninsula[27] in 1802 "reported catching up to 500 crayfish in a single evening from the shoreline of Point Nepean"[28]. It is clear that the abundance of crayfish in very shallow water, prior to the onset of fishing, was extremely high. Today adult crayfish have been (for all intents and purposes) entirely removed from these near-intertidal waters.

In Tasmania, when James Kelly called at Port Davey in 1815 he traded swans he had shot for crayfish; the local aborigines quickly collected over 1000 crayfish by hand from the water's edge. In 1905, James Rattenbury caught 480 crayfish from his ship the Rachel

Thompson in six hours using only six ‘cray rings’ in Wineglass Bay (Gardner et al. 2005). I snorkelled the shallow reefs on each side of Wineglass Bay in 2003, without finding a single crayfish.

Others were also concerned at the rapid decline of Australia’s shallow water fauna. In 1966 Pollard and Scott wrote:

> In many parts of the world, particularly along the coasts of Spain, Southern France, Italy, Jamaica and the Bahamas, spear fishermen have decimated populations of edible reef fishes. The same is now happening in parts of Australia. The inshore reefs for more than twenty miles each side of Sydney Harbour have been almost denuded of edible fish, and much of the remaining New South Wales coastline is also beginning to suffer (Pollard and Scott 1966:106 – see Attachment One for further details).

Similar damage to reef environments from spearfishing was observed in the USA. According to Hale & De Sylva (1992): “In 1957, extensive spearfishing and coral dynamiting aroused conservationists, resulting in the establishment of the first aquatic preserve in the US – the John Pennekamp Coral Reef State Park, off Key Largo.”

I wrote, with some alarm, to the Victorian Minister for Fisheries, suggesting that urgent controls needed to be implemented to reduce the impact of the sport. I suggested that spearfishing on SCUBA needed to be banned[29], and that licences should be introduced for spearguns, conditional on a display of knowledge concerning fishing regulations such as legal bag and size limits[30].

The Minister wrote back, politely replying that he was advised that there was no scientific evidence to justify my concerns. His response left me with the sense that no action would be taken by the Department to investigate the matter further. At that time Victoria had no fully protected marine reserves[31] other than a tiny circle of 100m radius at Pope’s Eye near the entrance to Port Phillip Bay. The Pope’s Eye reserve protects an artificial reef environment which has grown up around the foundations of a navigational marker.

As no scientific data appear to exist which would indicate natural abundance levels for reef fish, crayfish or abalone, historical anecdotes are important sources of information on ‘natural’ ecosystem levels. In the shallow reef ledges along Victoria’s coastline in the late 1950s, my own experience suggests that it was common to see layers of abalone two-deep in places, as well as groups of six to twelve crayfish in the deeper ledges. Most of these shallow ledges are empty today. When commercial abalone fishing started in Australia in the 1960s, it was not uncommon for divers to harvest a full boat-load without moving their anchor. Local abalone clusters were estimated by divers at more than $100/m^2$. These and similar anecdotes (compared with modern abundances) indicate a precipitous decline in both abalone and crayfish populations along Australia’s eastern seaboard. Accurate declines are impossible to calculate, but it is not unreasonable to believe overall abundance levels for both these groups are now between 5% and 1% of their un-fished levels, and certainly lower still in many local areas where they are all but absent.

Anecdotes from temperate reef environments in other parts of the world support this view. According to Dayton et al. (1998) along the Californian coast:

> Both abalones (*Haliotis* spp.) and spiny lobsters (*Panulirus interruptus*) were extremely abundant before diving and effective trap fisheries. Divers of the 1950s reported green abalones stacked on top of each other in shallow water and describe the Point Loma kelp forest as ‘‘paved with red abalones’’. Abalones are now so scarce that all five species fished in southern California have been closed to both sport and commercial harvest, and there is good reason to believe that one, *H. sorenseni,* will become the first marine invertebrate known to become biologically extinct as a result of human fishing. Probably because the spiny lobster source population has yet to be rendered ecologically extinct in Mexico, the lobster fishery has persisted, but abundance and size distributions are clearly different

from historical patterns. In 1888, 260 traps yielded 104,807 kg of lobsters. By 1975, 19,000 traps were required to harvest almost the same mass, 105,768 kg.

In the summers of 1982 and 1983 I was able to re-visit most of my old spearfishing locations. I wished to ascertain what changes had taken place at sites I was familiar with, as I was considering the preparation of a short article dealing with shallow reef environments[32]. In Port Phillip Bay, I found that several species appeared to have been entirely eliminated from accessible shallow reefs. Even tiny juveniles had disappeared. Abalone were still reasonably abundant[33] in a few locations, but they were small, and generally below the legal size limit – and were being harvested illegally at unprecedented levels. On weekends I saw families removing large plastic rubbish bins (around 70 L capacity) overflowing with undersize abalone. At that time there was a bag limit for recreational abalone of 10 per person per day as well as a size limit. Each bin would have held around 200 abalone, in my estimation. There were no bay-side information signs relating to fishing regulations in those days – multi-lingual signs were to appear a few years later. I never saw a fisheries enforcement officer, nor did I hear or see relevant information on radio, television or through newspapers, aimed at educating the public about fishing restrictions.

Clearly, fishers like myself (as well as government experts) had under-estimated the ability of these reefs to recruit stock from deeper, less accessible habitats[34]. We had over-estimated reproductive capabilities, and under-estimated fishing pressures. Are similar mistakes still being made today?

I was also surprised by a dramatic decline in large specimens of flathead and flounder – a matter I still fail to fully understand. They certainly were heavily harvested by both anglers and spearfishers, but there are huge areas of sandy habitat in the Bay. Commercial fishers did (and still do) target these fish, and I have not attempted to obtain further information on commercial harvesting pressures. Perhaps these bottom-dwelling fish are more territorial, or less mobile than I had imagined. These observations were made long before the very recent reports of major declines in fish populations of the Bay[35], thought to be the result of major ecosystem changes brought about by introduced invertebrate pest species.

As an aside, during the 1950s I had watched huge schools of 'whitebait' (a schooling fish 70 – 100 mm in length) streaming past the end of the breakwater. These schools were so large they would take around a whole day to move past – a stunning sight of great areas of sea turned silver. I have never seen such schools again.

My survey of shallow reefs in 1982/83 revealed that the situation was a little better at ocean locations. Although crayfish had disappeared completely from the shallow ledges, vestiges of the former populations of reef dwelling fish remained – however the fish were generally much smaller and fewer compared with populations I had observed 10 years earlier. It was particularly sad to see the ledges at Flinders, which had been so thick with fish and crayfish, now virtually deserted.

A6.5. The decline of two spearfishing target species in New South Wales.

Many reef-dwelling fishes have attributes which make their populations vulnerable to overharvesting – they are large, territorial, highly edible and have slow reproductive strategies[36]. Those that have restricted ranges are especially vulnerable. Apart from the three species discussed in this section, Pogonoski et al. (2002) implicated spearfishing in the decline of a number of other vulnerable species: the camouflage grouper (*Epinephelus polyphekadion*) – also targeted in the Pacific for the Asian life fish trade; the potato cod (*Epinephelus tukula*) – spearfishing is banned in Natal, South Africa; the western blue grouper (*Achoerodus gouldii*) – spearfishing is banned in South Australia; and the double-header (*Coris bulbi*) – restricted to Lord Howe Island and the NSW coast.

This section focuses on two species which were heavily targeted by spearfishers until they were protected by legislation – the black rockcod and the grey nurse shark. Unfortunately, populations have not recovered, and the eastern seaboard population of the grey nurse appears to be moving towards extinction. The resurgence of eastern blue groper[37] populations, however, provides a different story from the same general area: this animal too was heavily harvested by spearfishers prior to protection, and populations have recovered well in some areas[38].

The **black rockcod**, *Epinephelus daemelii,* has been a protected species in New South Wales (NSW) waters since 1983, and was listed as a 'vulnerable species' under the NSW *Fisheries Management Act 1994* in 1999. It is also listed under section 15 of the Commonwealth *Fisheries Management Act 1991*, making its take in fishing operations illegal unless covered by a scientific permit. The Australian Society for Fish Biology (ASFB) lists the species as potentially threatened (ASFB 2004).

Roughley (1916) reported specimens to 100 pound in weight, and that "at one time it was fairly plentiful in the vicinity of Port Jackson, but has become very scarce in recent years, owing to the havoc wrought by fishermen…" McCulloch (1922) reported that *E. daemelii* was "a valuable food fish" in NSW, indicating that the species was still reasonably common in the State at that time. Today, according to the ASFB, "abundance is low, and large males are considered to be rare." (ASFB 2004).

The overfishing reported by Roughley would not, presumably, have included spearfishing, as the sport did not achieve widespread popularity for another 40 years. However, the inquisitive and territorial nature of the animal, as well as its size, make it highly vulnerable to spearfishing (Leadbitter 1992). The total fishing ban in NSW was initiated after substantial anecdotal evidence of continued and major decline in population numbers; spearfishing was identified as a major threat (ASFB 2004).

The **grey nurse shark** *Carcharias taurus* was once relatively common along Australia's east and southeast coasts, with the largest adults reaching over 4 m in length. According to Roughley (1951:261) "the most prevalent shark at Port Stephens (NSW) was the whaler, followed by the grey nurse…". The shark, which is neither fast nor aggressive, became a spearfishing trophy target in the 1960s, with its territorial nature and its fondness for shallow reefs making it particularly vulnerable. At that time explosive spearheads were both readily available and unrestricted by government regulation, and were routinely used to kill the larger adults.

The grey nurse is now listed as an endangered species under the NSW *Fisheries Management Act 1994*, and listed as a threatened species under the Queensland *Nature Conservation Act 1992.* The east coast population of the shark is listed as critically endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. This shark was the first shark protected by legislation in the world when the NSW government initiated a fishing ban in 1984, following a dramatic decline in numbers credited to line and spearfishing (Fisheries NSW 2003). An overview of conservation issues is provided by Pollard et al. (1996) who identify spearfishing as a primary driver of decline.

Rather than recovering, population numbers have continued to decline. Numbers are now so low (probably 300-400 adults) that serious concerns must be held for the survival of the east coast population (Otway et al. 2004). Limited habitat protection has been provided through marine protected areas, however these protected areas are comparatively small and not regularly policed, and illegal line and spearfishing continue[39]. Accidental kills are continuing to occur from beach shark meshing programs in NSW, which are designed to reduce the incidence of shark attacks on swimmers. The grey nurse has not been implicated in such attacks in Australia.

A6.6. Fisher experience:

Ron and Valerie Taylor are amongst Australia's best known underwater photographers, and have had a long association with both fishing and conservation. They have dived extensively in all Australian States. According to Valerie[40]:

> We were both Australian Spearfishing Champions several times and Ron was world champion once. We however would know better than most the detrimental effects of spearfishing, specially competitions where an entire reef system is decimated, and from our 50 years of experience never ever returns to how it was or how nature intended it to be. I have seen a beautiful rich coral reef denuded of all the big fish in just 3 days. (off Maroochydore) during the Australian Spearfishing Championships.
>
> The spearo who swims out and takes a selected fish or two to eat does less harm than a line fisherman, but a bunch of up to 60 or 70 good freedivers with guns shooting everything in sight can cause irreparable damage. We know, we used to do it. We used to believe that there were so many fish off the coast that no amount of harvesting could make a difference. It took us over a decade to really see the damage we in our ignorance were doing to life in our coastal waters.
>
> As for wanting scientific evidence, in the 1960s there were no scientists monitoring what was happening off the coast. We know very well how quickly a species of reef fish can be wiped out in a large area. Ron and myself did all our spearfishing holding our breath.
>
> When good eating fish in the shallows became scarce, many spearos began using SCUBA to hunt commercially in deeper water, which was a disaster for our reef dwelling fish who all have a territory in which they live. Many species do not live below say 200 feet and were extremely vulnerable to SCUBA divers with guns.
>
> In 1970 Ron and myself along with the NSW politician Eric Willis had the practice of taking fish and crayfish using any form of self contained breathing apparatus banned in NSW. The uproar from the spearfishing clubs was enormous, but we were at the time Australia's two top spearfishing champions so there was little to argue about. We were out there and we knew first-hand what we were doing and we knew it was wrong. This made us very unpopular in spearfishing circles, although today many of the old timers now agree with us.

Valerie Taylor's experiences fit exactly with my own experiences, and are, I believe, typical of accessible reef areas around Australia.

In South Australia, for example, an unpublished report by Shepherd (1967) suggested that excessive spearfishing was responsible for the denudation of inshore reefs along the South Australian coast.

Another unpublished report from South Australia (Ottaway et al. 1980) commented "Whether or not spearfishing could kill off all the larger fish of particular species on particular reefs has not been studied rigorously, but it is the personal opinion of three of us who did spearfish in South Australia some 15 years ago that it was happening then and it is still happening now on reefs further and further away from the main areas of population". The three giving this opinion, based on their personal observations, were John Ottaway, then a Queen's Fellow in Marine Science at Flinders University, Igor Oak, then the President of the South Australian Underwater Photographic Society, and R.B. Gardiner, then the Chairman of the SCUBA Divers Association of South Australia. These three highly experienced divers were among the first spearfishers and SCUBA-divers in South Australia.

According to John Ottaway more recently (personal communication, 2005):

> I have no doubt that the popularity of spearfishing in the 1960s, and no controls (when scuba gear became readily available) on spearfishing on scuba in the mid to late 1960s,

> was the major factor in the staggering decline in near-shore fish populations along the South Australian coastline, starting with the reef areas near Adelaide, and then radiating away from Adelaide as the nearer reefs became depleted.
>
> There were many reefs along the Hallett Cove to Port Stanvac area where during the early 1960s I always saw many hundreds of fish, and commonly saw reef and pelagic specimens that would have been 5 kg plus and occasionally 10 kg plus. We left those big fish alone because the smaller fish were abundant, better eating, and we thought the big fish were probably important breeding stock. We also saw sharks reasonably often, ranging from 60 cm wobbegongs (frequently) to 4-5 metre white pointers (rarely).
>
> In 1978, I went back to that same area on several occasions to have a look around, and was shocked to find the whole area where I used to spearfish was now a 'wasteland' with not a single fish over a couple of hundred grams to be seen. Even the big schools of pelagics were absent.[41]

It seems surprising that government regulatory agencies could turn a blind eye to the major changes that spearfishing was creating in accessible coastal ecosystems – yet this happened consistently not just in Australia but around the world.

Describing the situation at Goat Island (once a popular spearfishing location, then newly declared as the Leigh Marine Reserve) in New Zealand, Russell – writing twenty years after the start of recreational spearfishing – wrote:

> Although reef areas support large numbers of fishes and high standing crops, they are very vulnerable to exploitation. Most reef fishes are non-migratory, many species spend their whole lives on the same small patch of reef, and they are thus more susceptible to fishing pressures than stocks of pelagic or wandering demersal species. The problem is especially severe for small isolated reefs, and there are numerous examples where reef fish populations have suffered marked local depletion through overfishing (e.g. Clutter 1971; Johannes 1975).
>
> Certain methods of exploitation such as spearfishing may be particularly damaging. At Goat Island, the effects of spearfishing were evident in two areas (Areas D and E), both of which are within easy swimming distance of Goat Island Beach and are heavily spearfished during summer. Compared with less accessible reef areas (e.g., Area A) there was a notable scarcity of larger fishes such as *Cheilodactylus spectabilis* (red moki) and *Navodon convexirostris* (leatherjacket). These species are commonly taken by skindivers and, like most reef fishes, can be virtually eliminated from an area by indiscriminate spearfishing. The long-term effects of removal of these larger fishes from reef communities is difficult to assess, but possible consequences include reduced stocks, depressed age-size structure of the populations, and, by removal of the larger predators, alteration of the reef community as a whole. For some species (e.g. *Coris sandageri,* Sandager's wrasse) which occur only in small localised populations at Goat Island and other coastal areas of northern New Zealand, the threat of local extinction also is very real.
>
> The establishment of marine national parks provides protection for fishes in some areas, but there remains the need for many species to be protected from spearfishing outside these areas. The recognition of marine fishes as native wildlife and according legal protection similar to other endangered wildlife might be a first step. Because the majority of reef fishes can be classified as residents and are therefore endangered by spearfishing, a large list of protected species is likely to be impracticable and from a management point of view, a declared list of fishable species is probably more feasible. As a basis it might include only transient species (Russell 1977).

More information on the Leigh Marine Reserve is contained in Attachment Two below.

Alan Curley started spearfishing the central coast of New South Wales in 1970, at least a decade after the sport gained popularity. At that time abalone were still common, with densities of 10-20 per m^2 in caves and 30-40 per m^2 in ledges around The Entrance. Abalone have all but disappeared from this area today, which Alan explains largely in terms of professional harvesting pressures. Fin-fish abundance today shows a precipitous decline since the early 1970s. According to Alan (pers. comm. 2/6/06):

> Toowoon Bay[42] (southern headland and deep hole) is a common spear and line fishing site even today. Thirty years ago the hole was full of pelagic fish, Silver Sweep, Silver Trevally, large Silver Drummer, Port Jackson sharks, Baitfish including Yellowtail and the occasional Kingfish and Snapper. Red Morwong and Rock Blackfish[43] were abundant together with Bream, Leatherjackets, Grouper and Luderick. I can remember lying on the bottom waiting for a 400 mm Grouper (a protected species) to clear the end of my gun to enable me to shoot a 400 mm Red Morwong, with a 900 mm Kingfish swimming in the background. Large Red Morwong lived in families of 4 to 8 per hole, and at least 2 individuals could be found within any 100m stretch of reef which had weed, boulders or ledges for cover.
>
> My daughter and I surveyed the same area in 2004-2005. The pelagic fish were non-existent and Red Morwong were rare despite the fact we were using SCUBA tanks and could search the reef thoroughly. There were also few large Rock Blackfish of any size and numbers of Luderick were well down. An estimate of around 50 Luderick per 100 meters of shallow reef would have been conservative for 30 years ago. The Groupers and Leatherjackets were almost non-existent. The reef is almost barren compared to when I speared there 30 years ago.

Such changes are dramatic but unfortunately typical. While angling and commercial fishing have undoubtedly played a part, the decline in the sedentary reef species, especially the Luderick which generally do not take a bait, are in my opinion principally due to spearfishing pressure.

A6.7. Removal of larger fish – is it important?

Spearfishing is a selective sport, and spearfishers tend to harvest larger individuals within a species – partly driven by the 'trophy status' of the larger fish. In some cases the larger individuals are less timid and are easier to spear.

Birkeland and Dayton (2005) have reviewed the effects of removing larger individuals from populations. At least as far as long-lived reef fish are concerned, the available data indicate a variety of important effects:

- larger females are proportionately more fecund, yielding more eggs per gram of body weight;
- the larvae of larger females of some species have better survival rates;
- larger females spawn over an extended period, thus providing more resilience to changing environmental conditions;
- larger fishes can be more experienced and more successful in spawning;
- larger fishes of some species provide leadership in migrations to spawning aggregation sites;
- reduction of larger fishes may reduce genetic heterogeneity; "potentially leading to reduced adaptability, population productivity and persistence";
- for sequential hermaphrodites, where all the larger individuals may be of the same sex, significant removal of large fishes may prejudice spawning success of the metapopulation; and

- larger fishes can have different and important ecological effects; Birkeland & Dayton quote studies showing larger parrot-fish create important erosive effects which smaller individuals do not.

Birkeland & Dayton conclude that: “the selective removal of larger individuals probably contributes significantly to the impact of recreational fisheries, and to the difficulty that some populations experience in recovering from overfishing”.

Birkeland & Dayton suggest that “spearfishermen could also be encouraged to take intermediate-sized fishes” rather than larger individuals. Speaking from my personal experience as a spearfisher, I believe such “encouragement” would undoubtedly fall on deaf ears – this approach is likely to be completely useless. In my view, the only way to protect larger individuals is through two strategies: either ban the spearing of the species in question, or create large networks of marine no-take areas.

It is sometimes suggested that the culture of recreational spearfishing in Australia has changed over the years, to embody more thoughtful and more environmentally-conscious ideas. A perusal of Australia’s spearfishing magazines (see for example www.spearfishingdownunder.com.au) in July 2006 found no evidence to support this suggestion. In fact letters to the editor and editorials were dominated by “more and bigger catches are better” ideas, coupled with outright antagonism to any form of restriction on the so-called sport. The Underwater Federation of Australia’s policy statement on spearfishing, published in July 2006, contains little evidence of any awareness of the ecological impacts which the activity can cause[44].

A6.8. Site and specie risk factors:

There is not enough information in the available literature to make definitive statements about risk factors; however these are my suggestions for identifying species and sites at high risk:

Specie:
Obligate reef dweller; seeks shelter in caves and ledges; preferred habitat in shallow water (<20 m depth); territorial; edible flesh; edible size (over 20 cm fork length) or trophy target size; low reproductive rate; sequential hermaphrodite; forms breeding aggregations; active during the day.

Site:
Accessible (within an hour’s travel by boat or car from a population centre); window of visibility (>5 m visibility for at least 20 days per year); easy to locate (presence of rocks above low water mark identifies reef location); isolated from adjacent reef habitat (by >1 km of different habitat (eg: sand, seagrass); relatively safe (regular currents < 0.3 m/sec); relatively comfortable (water temperature > 10 Celsius).

A6.9. Spearfishing impacts – the literature:

Should I have been surprised by the destruction of fish populations at my favourite reefs? With hindsight, no. The pelagic environment is a dangerous place, there’s really nowhere to hide. Pelagic fish need high-powered reproductive strategies. The reef environment is different, and it seems likely that much slower reproductive strategies might generally apply to sedentary reef-dwellers. The reef environment used to be a comparatively safe place…

Degrading reef environments[45] have not, of course, escaped the attention of the diving community – although many spearfishermen do not wish to acknowledge the decline or their part in it (Recfishwest 2003). Grovermann (1982) described changes to reef fauna in Western Australia and South Australia. Local groups lobbied to have particular sites declared speargun free (eg: Bail 1983), and competition spearfishing was the target of strident criticism from some divers (eg. Cahill 1979). Andrewartha (1972, 1981) drew attention to the dramatic decline of reef fish and crayfish around Wilsons Promontory in Victoria, as did McCallum (1982).

Although the effects of spearfishing have been so dramatic at those localities where fishing pressure has been focused, both fishing management agencies and marine scientists have generally ignored the issue. Only a handful of papers have appeared in the scientific literature over the last few years dealing with the effects of spearfishing on reef-dwelling fish. The usual research method involves a comparison of population density and size structure of spearfishing target species at similar protected and unprotected sites. Generally speaking, these investigations have all found the same thing: that spearfishing has a marked effect on target fish populations, reducing both the size of the population and the proportion of large animals[46]. Depending on the study site, the size of the effect varies from the significant to the severe (Bohnsack 1982, Bohnsack 1983, Oakley 1984, Harmelin et al. 1995, Chapman & Kramer 1999, Jouvenel & Pollard 2001). Other studies, while comparing abundance data inside and out of protected areas, do not attempt to discriminate between spearfishing and other forms of fishing (eg: Buxton & Smale 1989).

Jouvenel & Pollard (2001) examined abundance and size structure of populations of two highly sought-after spearfishing target species in the north-western Mediterranean, inside and outside a protected area. Abundances were consistently higher inside the marine reserve: with *Dicentrarchus labrax* (European sea bass) averaging 3.92 individuals per 400 m transect compared with 0.69 outside, and *Sparus aurata* (guilt-head sea bream) averaging 0.68 inside and 0.05 outside the reserve. The average length of *D. labrax* inside the reserve was almost twice that outside the reserve. These results show a massive difference in biomass between fished and unfished areas.

Harmelin et al. (1995) in a similar study of fished and unfished areas, selected two target groups of fish – the first group of 16 species ('type A') were highly targeted by spearfishing, while the second group of two species ('type B') was highly targeted by angling. The unfished reserve was only 85 ha in size; nevertheless significant differences were found in the visual census surveys, which were carried out on 24 occasions over 3 years. Of the 16 spearfishing target species, eight were not detected in fished areas, supporting arguments that local extinction is possible. According to the authors: "the missing species are top carnivores, particularly threatened by spearfishing." Overall, abundance and biomass of both types (A and B) were significantly greater within the reserve, with average abundance in the reserve around twice that of the unprotected site. When only type A fishes were considered, "the mean number of individuals was 3-fold higher in the reserve than in the fished site" with this difference increasing to 10-fold when only large individuals were considered. Within the type A group, sargo bream populations (*Diplodus* spp.) were found to be particularly damaged by spearfishing, with abundance ratios inside/outside the reserve varying between about 4:1 to 30:1. That such large differences can be found within such a small reserve is a testament to the destructive power of spearfishing as a harvesting technique.

Dayton et al. (1998) discussing the disappearance of large fish from kelp forests in California, remark: "…for broomtail groupers [*Mycteroperca xenarcha,* large territorial fish], mortality caused by a few spearfishermen may easily explain their loss from the ecosystem". The authors continue: "… historical comparisons of spearfishing contest results with present populations suggests major changes in abundance and size distribution of species such as California sheephead, *Semicossyphus pulcher.*"

Oakley (1984) reports an investigation of the effect of spearfishing on grouper in the eastern Red Sea, through a short visual survey. Census sites of similar habitat were graded according to fishing pressure, and grouper abundance and size recorded. Large grouper were six times as abundant, and medium sized grouper (200-400 mm length) three times as abundant in the low pressure sites compared to the high pressure sites. Small grouper, however, were more than twice as abundant in the high pressure sites – an effect which

Oakley attributed to reduced competition with larger animals. Oakley concluded that spearfishing pressure had a significant affect on grouper populations in this area. It would be interesting to revisit Oakley's census sites after twenty years. I suspect his 'low pressure' site average abundance figure of 6 large grouper per 250 m transect could not be repeated today.

Chapman and Kramer (1999) examined fish density and size within and outside the Barbados Marine Reserve – a small reserve protecting 2.2 km of coast to around 500 m offshore. The reserve was, at the time of the study, subject to illegal fishing. Given the small size of the reserve and the acknowledged enforcement difficulties, it would not be surprising to find little difference between sites inside and outside the protected area. Nevertheless, the authors found evidence of more large individuals (of species targeted by spearfishing) within the reserve, an effect which they attributed principally to spearfishing mortality.

Data from spearfishing competitions provides unreliable evidence on Catch per Unit Effort (CPUE) changes over time, for the reasons discussed elsewhere in this appendix. Very few studies have tracked spearfisher CPUE over time in a reliable way. Harper et al. (2000) is one such study, which surveyed recreational fisheries in Biscayne Bay National Park (Florida) between 1976 and 1991.

Unfortunately the study start date is around 25 years after the commencement of spearfishing as a popular recreation – so the initial impact has undoubtedly been lost. Nevertheless the study produces some interesting information. Spearfishers, in comparison to anglers, accounted for about 10% of all fish caught, although anglers spent comparatively more time catching each fish – a not unexpected finding, and one which, in my view, is likely to apply over substantial areas of Australia's eastern seaboard. Species information is also informative. Nassau groupers, targeted by both spearfishers and anglers, showed a steeply declining CPUE, from around 22 to 1 (number landed per 100 trips) over the 15 years of the study. Hogfish, targeted principally by spearfishers, declined more slowly, with CPUE dropping from 65 to 32. These findings suggest that spearfishing has had a major impact on this area, in combination with other pressures. It is also worth noting that reef fish in the Florida Keys are known to have undergone intense exploitation (overfishing) during the twentieth century (Ault et al. 1998).

In a marine protected area at Looe Key, Florida USA, all 15 species that were spearfishing targets increased in abundance after spearfishing was banned: snappers (*Lutjanus spp.)* by 93%, grunts (*Haemulon spp.)* by 439% (Clark et al. 1989). Looe Key Reef was the site of an earlier study (Bohnsack 1982) which found significant depletion of spearfishing target species in the period before the site was protected in 1981. So far I have not been able to obtain the full version of Bohnsack 1983, however the summary states: "In particular, the observed frequency of grey snapper (*Lutjanus griseus*) increased dramatically [following the spearfishing ban in 1981] although population levels remain well below those on the control reefs [fully protected since 1960]." Clearly spearfishing had a major impact on local populations of this target fish. The summary continues: "*Thalassoma bifasciatum*, the most abundant prey species, showed a drop in abundance correlated with increased predator populations. *T. bifasciatum* population levels at Looe Key Reef prior to sanctuary establishment had been double those on control reefs."

At a marine protected area in Banyuls-Cerbere, France (on the Mediterranean) six years after the implementation of a spearfishing ban, target reef fish abundance within the MPA increased to approximately twice that outside. Amongst target fishes, differences in abundance of 'small' individuals were marginal or non-significant, while for medium and large fishes the differences were highly significant. No difference in diversity or species richness was detected. (Bell 1983 quoted by Charton et al. 2000).

Sluka and Sullivan (1998) examined the effects of spearfishing on grouper populations in the Florida Keys. They surveyed two sets of similar habitats; all areas were open to line-fishing, but one set was closed to spearfishing in 1960 while the other remained open. They suggest that line fishing effort was roughly 10 times spearfishing effort, and they assume that line fishing effort was uniformly distributed across all areas. The Nassau grouper, resident at all locations, is a protected species, banned from take by both line and spear fishers.

The key findings of their report relate to abundance and size distribution. The abundance of the most commonly targeted groupers did not differ significantly between open and closed areas, although the abundance of the Nassau grouper was significantly reduced at sites open to spearfishing. The authors suggest that illegal spearfishing may be taking place for the Nassau, and may account for this effect. A significant difference between closed and open areas related to the presence of large fish, with generally smaller individuals present in the open areas. The authors conclude that: "the ban on spear fishing in the upper Florida Keys has significantly benefited the size distribution of groupers. However, it appears that a ban on spear fishing alone has not resulted in recovering population levels of grouper in this region." The authors recommend that, if grouper recovery is a management aim, all forms of fishing need to be excluded.

The difficulty with this study is the lack of information on line-fishing pressure. It seems highly likely that line-fishers will select areas where they know they are not competing with spear-fishers – yet the study assumes a constant high level of line-fishing pressure across both closed and open zones (closed and open to spear-fishers). If line-fishers are preferentially selecting closed areas, this is likely to compensate for the lack of spear-fishing pressure.

An Australian study by Lowry and Suthers (2004) provides limited information on the ability of a species to recolonise local depletion, indicating that, at two sites studied in NSW, red morwong (*Cheilodactylus fuscus*) successfully recolonised small reef areas depleted by high levels of experimental spearfishing. This paper is discussed in more detail below.

An electronic search of refereed scientific journals (August 2004) failed to locate any Australian publications dealing with the impacts of spearfishing, other than the papers by Lincoln-Smith et al. (1989) and Lowry and Suthers (2004).

Lowry and Suthers obtained population estimates at reef sites for red morwong, a common reef fish found along the NSW and southern Queensland coast. According to Lowry and Suthers: "Fish re-colonized the same location 2 to 4 months after a summer and a winter experiment removed >70% of the adults by intense spear fishing." This finding demonstrates that (at least for red morwong) recolonisation can occur fairly quickly where small sites undergo intense fishing pressure for a limited period of time. As the authors acknowledge, the study has several limitations. The two experimental sites were small – a total of 68 fish were removed from the two sites. Adjacent habitat was unaffected, supplying accessible areas to support recruitment. The authors did not conduct (or did not report) an observational study to determine 'background' levels of spearfishing pressure at the sites. The authors conclude that more information is needed to determine the effects of spearfishing on the species. They note: "spearfishing may have a significant impact on such a long-lived resident population. There is evidence that spearing is responsible for the localised depletion of cheilodactylid populations in New Zealand (Cole et al. 1990)".

Belinda Curley also studied red morwong in NSW: "One of the MPA's I studied was Gordons Bay near Sydney. The MPA covers 0.1 km^2 and fish have been protected from spearfishing since 1992. Line fishing is still permitted. I found that the abundance and size of red morwong (Cheilodactylus fuscus) was greater inside Gordons Bay when compared to three ecologically similar control areas. Given that red morwong are relatively sedentary and heavily spearfished in NSW this provides strong evidence that spearfishing does effect local populations of this species." (pers. comm. 10/5/06). I concur with Ms Curley's view, particularly given the small size of the reserve. To demonstrate an effect in such a small area requires very strong pressure on the animals concerned.

Papers such as Edgar & Barrett (1999) referring to the Tasmanian situation, do not attempt to separate spearfishing impacts from other harvesting activities – although confirming significant differences in fish populations across marine reserve boundaries. Not surprisingly, Edgar and Barrett note that small marine protected areas are relatively ineffective[47]. My personal observations of areas near their study site at Maria Island suggest that recreational gill-netting as well as spearfishing and crayfish collection pressures are significant immediately beyond the boundaries of the protected area. Between the declaration of the Maria Island protected area in 1992 and their 1997 survey, crayfish biomass increased by over an order of magnitude, and biomass of legal-size crayfish increased by over 20 times.

Catch per unit effort (CPUE) data in relation to the capture of reef fish is available from spearfishing competitions; however this data means little in itself, as the selection of competition site and prior access by spearfishers to this site are critical in establishing logical conclusions. The data, moreover, is prone to certain inaccuracies stemming from the way it is reported.

Competition data can be used in two ways: (a) if a site is under constant spearfishing pressure, competitions held, say, at 10-year intervals can provide surrogate measures of changes to the health of reef populations over time, or (b) if large competitions are held regularly at the same site, and spearfishing pressure between competitions is low, the impact of the competitions themselves can be measured.

Competition CPUE data are most useful if the first data come from fishing a virgin site (thus establishing a baseline) and where that site then becomes subject to significant and ongoing spearfishing pressure. In this case, the next time a competition is held at that site the CPUE data (provided other aspects like competition rules and weather remain more or less unchanged) can provide a measure of the effect of that regular pressure on the site. Here the competition itself is not the pressure measured, it is the yardstick - as it provides a surrogate measure of species density and the presence of large individual fish.

Papers by Johnson (1985a, 1985b) highlight difficulties in using competition CPUE data in an attempt to measure changes in fish populations. Spearfishing competitions in South Australia were documented in 1977/78 and again in 1983/84. Comparing data across these two events, catch rates decreased (effort increased) and the proportion of reef-dwelling fish caught decreased (compared with open-water species). However, no conclusions could be drawn as the competitions used different rules (eg: for ineligible and eligible species) and were held at differently defined sites, under different access conditions. It is also worth noting that the organisers “estimated” diver water time by guessing an overall figure averaged across all competitors – a technique prone to considerable inaccuracy.

The discussion of competition data by Lincoln-Smith et al. (1989) highlights other problems in using competition data: for example where rules allow only one or two fish per species to be weighed-in, discarded fish go unreported in both number and weight, and in fact unobserved by competition officials[48]. Competition catches are heavily influenced by competition rules, and may bear little relation to regular spearfisher catches in both species and weight per unit effort; thus comparisons between spearfisher impacts and angler impacts cannot be reliably based on competition data.

Problems with the use of competition statistics can be illustrated by examining the coral trout (*Plectropomus leopardus*) CPUE data from Smith and Nakaya (2003). Their Great Barrier Reef CPUE data (p.20) indicate that, over the 1980-2000 period, fish per diver hour CPUE declined by about 30% while the average weight of each fish caught declined by about 25%. While these figures suggest a steady decline in abundance commensurate with unsustainable fishing rates, they are moderate over the timescale, and perhaps do not support the sense of alarm which I am expressing. The actual situation, however, is that these figures disguise the fact that there has been a major decline in coral trout abundance due to fishing pressures on the Great Barrier Reef, particularly the heavily fished reefs of the inner South. The rigorous abundance surveys reported by Hughes (2004) “found a 4-5 fold depletion of the biomass of this targeted fish in fished areas [compared to adjacent no-take areas].” [49]

And what about fishing pressure? It's sometimes said that the spearfishing participation rate is low, and rocky reefs are often protected by weather, or difficulty of access. The NSW Fisheries Department, while dismissing claims of overfishing as "anecdotal", did not seek to even investigate the environmental impacts of spearfishing until 1997 (Minister for Fisheries NSW 1997). As far as I can ascertain, the studies promised by the Minister in 1997 have either not been undertaken, or not been published. Other State Fisheries agencies have generally followed the same lines in turning a blind eye to the impacts of spearfishing.

Fisher lobby groups tend to underplay the effects of spearfishing – arguing both lack of 'scientific evidence' and, paradoxically, recommending continued access to marine reserves by spearfishers (Recfishwest 2003). The Australian Underwater Federation (AUF) has produced a number of reports on spearfishing and its effects (Saenger and Lowe 1975, Hyde 1986). The AUF's paper by Smith & Nakaya (2003) presents data on spearfishing CPUE (catch per unit effort) out of the necessary spatial, temporal and pressure context, thus failing to establish any logical conclusion other than a general inference. No information is presented indicating that the competitions in question were held at the same or systematically comparable locations, at the same time of year, under the same rules, and under similar weather conditions.

In commenting on the bad press received by spearfishing competitions, Schmeissing (1997:58) pointed out that "on land the suggestion to kill native fauna for competition points would undoubtedly be met with public outcry". Schmeissing also noted that angling competitions had received better press coverage following the introduction of tag and release rules, but that tag and release would never be possible for spearfishing competitions.

Schmeissing's thesis (1997:59) noted that "catch records from the 1996 NSW State Spearfishing Titles indicate that 82% of species caught during the competition were sedentary reef species". His central recommendations at the close of his study included the removal of sedentary reef species from competition eligibility rules, after highlighting concerns that spearfishing pressures, both within competitions and more generally, were widely unsustainable.

A6.10. Spearfishing: a sport out of control?

Have the impacts of spearfishing on accessible shallow reefs been underestimated? I believe they have been grossly underestimated – partly perhaps because fishery agency staff tend to focus on issues which they see as more important, particularly commercial fishery issues. Partly also because conservation lobby groups in Australia tend to be preoccupied with issues which they perceive to have wider public support – such as forest conservation or wilderness protection, for example.

A cursory examination of spearfishing pressures suggests that severe local impacts are predictable. As no reliable historical information on participation rates in the sport exists, it is necessary to make some assumptions[50],[51]. Given that the population of Victoria in the early 1980s was around four million, an assumption of a participation rate of point one percent actively engaged in spearfishing over the summer months would yield a spearfisher population of 4,000 people. During one Saturday morning in February 1982, I counted 8 spearfishers on the Hampton breakwater[52], and by my experience that would have been typical for a summers day at the weekend. The remaining 3,992 spearfishers were presumably somewhere else at the time (there are perhaps 100 similarly attractive spearfishing sites along the shore of the Bay and the nearby ocean coast). An assumption that the breakwater received 32 fishing visits per week, taking into account bad weather and a lower rate of participation during the week, seems realistic. My catch rate at that site in the early days was around 5 fish in half an hour, decreasing as the fish population dropped. So it's likely that spearfishing pressure on the virgin site *could* remove around 160 fish each week over the warmer half of the year, or around 4000 fish per year, conservatively. Effort to remove those fish would have been a minimum of around 800 hours. The breakwater site itself has only one open side, so the artificial reef in question forms a strip about 300 metres long by 6-12 metres wide (average 10). Visibility on the inside of the breakwater was, and remains, too poor to either spearfish or survey. If we assume a virgin resident population density of 2 edible fish per metre of length, that's 600 mature fish resident on the site (prior to the onset of spearfishing pressure). It's clear that the pressure imposed by recreational spearfishing is considerable - easily enough to remove all the breeding stock from the site over a period of three or four years – and, even taking recruitment from deeper reefs into account, that's exactly what happened.

In terms of access, as one site goes downhill, spearfishing pressure turns to less accessible sites. Easy access to small boats and SCUBA gear compound these pressures. Controls on spearfishing, where they exist, are seldom enforced – partly due to obvious difficulties related to enforcement effort.

In my estimation, most of Victoria's accessible shallow reefs were decimated between 1960 and 1985. They have not recovered. Without a knowledge of historical accounts, those entering the sport over the last twenty years can have no conception of the environment which existed forty years ago. This is the 'shifting baselines' effect referred to by Dayton (1998) where (due to pervasive environmental degradation) successive generations loose track of the meaning of a pristine environment.

A6.11. Precautionary management of spearfishing:

After a detailed examination of the effects of fishing on the marine environment, the UK Blundell Report (RCEP 2004:Summary:10) stated:

> The precautionary approach needs to be applied comprehensively to fisheries management. Currently, the marine environment is regulated on the basis of a presumption in favour of fishing. Unless harm to ecosystems or habitats can be demonstrated by whatever organisation regulates fisheries, then it is usually acceptable for activities to continue. This approach has not prevented marine ecosystems from being severely damaged.
>
> **Therefore, we recommend that the presumption should be reversed; applicants for fishing rights (or aquaculture operations in the marine environment) should have to demonstrate that the effects of their activity will not harm the sea's long-term environmental sustainability.** This change would place the burden of justification on those seeking fishing rights and make both the industry and its regulator focus much more on the biological state of the marine environment. The new approach could operate through a system of licensing and marine planning. There will be areas that need to be entirely protected in order to fulfill the precautionary principle and achieve recovery of ecosystems.

This reversal of the burden of proof is being partially implemented in Commonwealth fisheries through the Australian Government's assessment program under the *Environment Protection and Biodiversity Conservation Act 1999* - with regard to some sections of the commercial fishing industry.

It is time to introduce the concept of precautionary management to recreational fishing, including spearfishing. First, the steps outlined above (section A6.3) should be put in place as a matter of urgency. Secondly, a longer-term and more wide-ranging strategy is needed, and a national taskforce should be convened by the Australian Government to plan the introduction of a precautionary approach to all recreational fisheries over the coming decade. The taskforce would lay the policy foundation for an exercise which would essentially rest with State fishery management agencies to implement. Implementation should include an extensive community education and consultation program which might span the best part of ten years.

In my view, State governments, acting in unison, should announce that *all* waters will be closed to recreational fishing on a target date some years in the future, with the exception of waters which are being fished under an agreed sustainable regime. Studies would need to be undertaken to demonstrate that particular local fishing regimes are in fact sustainable. Such studies should be funded in equal shares by recreational fishing organisations, the relevant State government, and the Commonwealth government. The target date, given the magnitude of the education and consultation task, should in my view be 2020.

A6.12. Conclusions and recommendations:

While the above recommendations on introducing a precautionary approach to the management of recreational fishing would involve a massive shift in consciousness by both the fishing public and politicians (which could only take place over a period of several years) there are urgent short and medium term issues which need to be addressed immediately.

Australian agencies responsible for regulating marine harvesting activities have been lulled into a false sense of security in relation to spearfishing in particular. While participation rates related to harvesting by recreational divers and snorkellers are low (in the order of perhaps 1 in 1000), and bycatch from such harvesting activities is also close to zero, there is strong anecdotal evidence that the concentration of harvesting activities on shallow reef environments has caused major damage. Extensive local extinctions have almost certainly occurred, and entire reef ecosystems have been degraded. A significant regional extinction (the eastern coast grey nurse shark population) is approaching, brought on in large part by historical spearfishing pressures.

Harvesting activities by recreational divers and snorkellers need much tighter control – as a matter of urgency. The current management of these activities by the States breaches the Food and Agriculture Organisation *Code of Conduct for Responsible Fisheries 1995* – particularly article 7.5 which requires the adoption of a precautionary approach to fisheries management. Australia has endorsed the FAO code, although it should be noted that compliance with the code is voluntary.

No national voluntary code of conduct exists to guide the sport of spearfishing. Such a code is needed and should be developed. While spearfishing is almost solely under the control of Australian States and Territories, national coordination is required. Initially, discussions need to be held between the Commonwealth Departments of the Environment, Water, Heritage and the Arts (DEWHA) and Agriculture, Fisheries and Forestry (DAFF) with a view to devising a program to engage both fisheries agencies and stakeholders from the States. The next step would be to expand these discussions to include State fisheries and environment agencies, as well as environment and fishing stakeholders. The list of stakeholders should include the Australian Underwater Federation, large State spearfishing and diving clubs, the Australian Marine Conservation Society, the Australian Society for Fish Biology, WWF Australia and the Australian Marine Science Association. The ultimate aim of the program would be to create, through a stakeholder-driven consensus process, a code of conduct which would (a) emphasize the vulnerability of reef ecosystems and their permanent residents, (b) encourage responsible fishing behaviours, and (c) initiate stakeholder-driven monitoring and reporting programs designed to track changes in reef ecosystems.

State fishery management agencies should develop management plans for spearfishing, in line with FAO recommendations (see above). Generally speaking, I believe nine key actions are urgently required to control spearfishing activities in Australia, and these issues need to be addressed within State fishery management frameworks:

1. There is an urgent need for a massive expansion of permanent marine no-take areas – principally to address biodiversity conservation and benchmarking concerns. Spearfishing activities should of course be banned in such areas. However, where buffer zones are established around such areas, spearfishing activities should be excluded from these zones as well, in order to increase the level of protection of ecosystems inside the no-take areas from harvesting edge effects. At the very least,

in States where spearing on SCUBA and night spearfishing are still legal, these activities need to be totally excluded from buffer zones around no-take zones.

2. Temporary no-take areas, of substantial size, should be established specifically for the purposes of re-building fish stocks. The experimental use of such no-take areas should begin immediately, with closures of both 5 and 10 years. A selection of heavily-fished reefs should be immediately protected across Australia. The entire reef, plus lateral and longitudinal buffer zones, should be protected. Other significant habitats, such as seagrass areas, should also receive similar temporary protection for the same purpose.
3. The FAO Code advocates the use of ‘interim’ measures while a fishery management plan is being developed and finalised. One of the key areas where more knowledge is needed relates to the relative effect of angling compared with the potentially more effective (and more damaging) techniques of spearfishing and gill-netting. Quite apart from MPA programs, fishery agencies should institute partial closures of a variety of reef types (and locations) to netting and spearfishing in an experimental impact monitoring program. Such closures need to be for periods of at least a decade in order for reef populations to stabilise, and, for the same reason, they need to be substantial (> 10 km^2) in extent. Natural variations are high in marine systems.
4. Spearfishing on compressed air[53], and night spearfishing should be banned immediately in all Australian waters, including all of the Australian EEZ. These techniques increase the vulnerability of reef fish, or open water aggregations ,already under severe pressure. Spearfishing on SCUBA is currently banned in Queensland, New South Wales, and South Australia.
5. The sale of speared or damaged fish should be banned outright in all Australian jurisdictions. Such sales are currently banned in Queensland, New South Wales, Victoria and South Australia. Coherent fishery management requires a general regulation prohibiting the sale of fish by anyone not possessing a professional fishing licence, and this is the case on Australia’s eastern seaboard. Due to the small chance of apprehension, high penalties should apply as a deterrent, even though in some cases the offence will appear trivial.
6. According to the FAO Lysekil Statement: “an open access fishery is not precautionary”[54]. The sport of spearfishing should be permitted conditional on the participant holding a current recreational fishing licence issued by a State government fisheries agency[55]. The costs of providing and administering the licence should be recouped via a licence fee. The licence should be provided after the fee has been paid, and the applicant has demonstrated knowledge both of relevant State statutory controls, as well as familiarity with the voluntary code of conduct (see below). Licences could be issued on an annual basis. Re-issue of a licence should be conditional on the applicant making annual internet-based catch reports at least one a year, even if catch has been zero.
7. There are obvious issues in enforcing compliance across fisheries generally. For this reason punishments for breaching regulations must have strong deterrent elements: punishments where the chance of apprehension is remote need to be severe. Breaches of regulations need to be categorised as minor or major. Those convicted of two major breaches should be banned from holding a fishing licence of any kind again. This should be a *requirement* of the relevant legislation.
8. Spearfishing competitions should be phased out over a 5-year period. Immediate bans should be placed, Australia-wide, on competitions which allow the catch of species which are substantially dependent on reef environments.
9. A voluntary *national code of responsible conduct for spearfishing* should be developed by a joint State/Commonwealth working party, in consultation with spearfishing, fishing and marine conservation groups. Existing club codes are not widely circulated or used, and have not been prepared in consultation with government or conservation stakeholders[56]. State regulations should be introduced requiring that all sales of spearguns, and the issue of all spearfishing licences, should be accompanied by distribution of copies of the code of conduct.

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Endnotes

[1] Jo Buckee, pers. comm. 8 September 2004.

[2] *Jasus edwardsii.*

[3] The relatively unrestrained recreational use of gill nets in Tasmania (see endnote below) has been responsible for major impacts on reef fish populations, making it difficult to untangle the various effects of gill net, line and spear fishing – all of which are probably significant in reducing reef fish populations in this State. Schaap & Green conducted limited visual surveys of matched lightly fished and heavily fished reefs, and found "…a consistent trend towards decreased diversity, species richness and number of individuals at the more heavily fished sites". Although the limited nature of the surveys made definitive conclusions difficult, the authors remarked: "the trend is consistent with the removal of vulnerable species by gill netting and other fishing activities such as spear fishing and line fishing" (1988:39). They concluded that there was "circumstantial evidence that fishing activities have had a major impact on reef fish communities in areas which have been subjected to relatively heavy fishing pressure" (1988:40).

[4] The coral patches of Shark Bay in Western Australia are not readily accessible sites, but they are attractive. Shark Bay is a full day drive north of Perth (although the regional cities of Geralton and Carnarvon are closer) and a small boat is required to access the patches. I spent three weeks in Shark Bay in 1984, researching a paper (Nevill and Lawrence 1985). Shark Bay is predominated by seagrass and sand habitats, with coral making up a tiny fraction (probably less than 0.01%) of the total area. My interviews with Denham locals indicated that all the coral patches had been heavily fished by commercial or semi-commercial spearfishers, as well as anglers, during the 1970s. By the early 1980s they were denuded of fish and all had suffered substantial anchor-damage to corals.

[5] Australia has a three-tiered government structure. The Australian Government (also called Federal or Commonwealth) is responsible for taxation, defence, economic regulation and international affairs, including Exclusive Economic Zone (EEZ) fisheries. Six States and two territories form the second layer, and are responsible for most health, education, law enforcement, social services, and resource management functions – including fisheries management (sole jurisdiction to the 3 nm boundary). Local governments form the third tier.

[6] Three recent publications of the Department of Fisheries Western Australia (2003a, 2003b and 2004) do not even contain the word "spearfishing".

[7] According to the 2001 recreational fishing survey: "Line fishing (including the use of bait, artificial lures and jigs as well as set-lines) accounted for 19.7 million fishing events, i.e. nearly 85% of the overall annual fishing effort. Fishing with pots and traps (7%), harvesting bait with pumps, rakes and spades (4%), fishing with nets (3%) and diving with spears or hand collecting (1%) followed in importance. Diving (using spears or underwater hand collection) contributed 266,000 events or just 1% of the overall effort. SCUBA/surface air and

snorkel diving (hand collection) was the primary activity (55% of dive events) although spearfishing (36%) was also significant. Spearing fish from the surface accounted for the balance of the 'dive' effort (9%). Tasmania and Western Australia reported above average levels of dive effort (3-4%) (Figure 5.19, Appendix 5.8). In Tasmania, Western Australia, Victoria and South Australia dive (hand) collection (mainly for rock lobster and abalone) using snorkel, scuba or surface air supply accounted for the bulk of the dive effort. Spearfishing was the main dive activity in New South Wales and Queensland but was also of significance in Western Australia. Dive effort accounted for about 582,000 hours nationally or less than 1% of the total. Event duration for dive activity ranged from an average of 2.7 hours for spearfishing to slightly less than 2 hours for hand dive collection". The survey figures for South Australia and Tasmania both recorded total annual fishing effort at under 2000 hours for each State, with a figure for the Northern Territory of under 300 hours total effort (Appendix 5.9, p.158). Australia's population in 2001 was just under 20 million. Population by State/Territory (2001): New South Wales 6,580k, Victoria 4,800k, Queensland 3,630k, Western Australia 1,900k, South Australia 1,510k, Tasmania 471k, Aust Capital Territory 319k, Northern Territory 198k.

[8] Baker et al. 2002:83-84.
[9] Brothers et al. 1996.

[10] According to Rees 1995: "Recreational fishing using gill nets is comparatively unregulated in Tasmania…". "[T]his practice has been recognised as decimating reef fish stocks and is banned or heavily controlled in all other States and Territories in Australia". "The Division of Sea Fisheries estimates net numbers at between 15,000 and 45,000, each up to 50 m long."
[11] Although spearfishing played a major role in the dramatic decline of the grey nurse shark, it seems unlikely to be a major current threat, even though illegal spearfishing of the shark is continuing at a low level. The key issue here is that the east coast population is now so small (2003 estimate: 400-500 adults), due mainly to historic fishing, that the animal may not be able to recover. Adult females usually produce 2 pups every second year. Many other sharks have similarly low reproductive capacities.

[12] According to Pauly (1995): "Essentially, this syndrome has arisen because each generation of fisheries scientists accepts as a baseline the stock size and species composition that occurred at the beginning of their careers, and uses this to evaluate changes. When the next generation starts its career, the stocks have further declined, but it is the stocks at that time that serve as a new baseline. The result is a gradual shift of the baseline, a gradual accommodation of the creeping disappearance of resource species, and inappropriate reference points for evaluating economic losses resulting from overfishing…" An exception to this general rule is the study by MacIntyre F, Estep KW and Noji TT (1995) NAGA (the ICLARM Quarterly) 18(3)7-8, which used anecdotes from Mowat F (1984) *Sea of slaughter*. Atlantic Monthly Press.

[13] 'Scientific' is usually interpreted in this context as meaning 'obtained and presented in an objective, verifiable and systematic manner'.
[14] Food and Agriculture Organisation of the United Nations, Rome.
[15] See reference list under "Technical Consultation… "
[16] In 2004 the Great Barrier Reef Marine Park Authority established no-take reserves over 33% of the Authoritiy's area, partly to allow recovery of natural ecosystems from fishing pressures – including spearfishing amongst other fishing pressures.
[17] *Aluteridae* family.
[18] *Girella tricuspidata.*
[19] *Platycephalus spp.*
[20] *Rhombosolea tapirina.*
[21] In my view, these figures are accurate to plus or minus 10%.
[22] *Dactylosargus arctidens.*
[23] An examination of Bureau of Meteorology records (www.bom.gov.au) shows no climate or weather abnormalities or changes which might account for a decline in fish populations.
[24] Although, with hindsight, I regret it, I was originally one of the most active participants in this sport at this site.

[25] The construction of the marina replacing the original swing moorings resulted in about a six-fold increase in stored boats, and these boats over the last decade have increased in size, reflecting the increasing affluence of the nearby suburbs.
[26] Flinders is a small township slightly over an hour's drive from the south side of suburban Melbourne.
[27] The Mornington Peninsula forms the eastern side of Port Phillip Bay.
[28] Pers. comm. T. O'Hara 15/8/05: "The 500 rock lobster abundance figure is from the short-lived Collins settlement at Sorrento in 1802. I have never seen the original, only heard it referred to verbally (by Tim Allen). Early sailors also noted the abundance of osyters in Western Port (abundant enough to be able to reach down and collect them by the handful from a rowboat".
[29] Spearfishing on SCUBA is now banned in Victoria, although still legal in the Northern Territory, Western Australia and Tasmania.
[30] Schmeissing (1997) reported that (in 1997) "there are no conditions or restrictions on the purchase of spearguns in NSW". His study recommended that the NSW government introduce regulations requiring retailers to include an information brochure (covering both government regulations as well as guidance on good spearfishing practice) with the sale of every speargun (Schmeissing 1997:65).
[31] Victorian marine waters extend 3 nautical miles from the shore. Today, over 5% of these waters are within protected areas meeting the IUCN protected area class I and II criteria.
[32] Later published as Nevill 1984.
[33] A quick check I made of these areas in January 2003 suggested that abalone abundance had declined by about two orders of magnitude in the preceding 20-year period.
[34] According to Valerie Taylor (pers. comm. 10/9/04: "Most rocky reefs off the coast of NSW that we fished (and we fished most of them) hit sand between 150 and 250 feet, some much shallower at say 30 to 80 feet so there appears to be little deep water reef habitat out of scuba range for the animals to trickle up from and repopulate the shallower water".
[35] A 40% drop in populations of some commercial species in the period 2000-2003. Fyfe (2003).
[36] Groper, for example, have been identified as particularly vulnerable to spearfishing pressures (Oakley 1984, Morris et al. 2000).
[37] *Achoerodus viridis* – Eastern blue grouper. Spearfishing for EBG banned in NSW in 1969, and commercial fishing in NSW was banned following a continued population decline in 1980.

[38] According to Bruce Wallner (pers. comm. 22/9/04): "With respect to the [decline of the grey nurse shark] it would [be] good to compare the spectacular recovery of blue groper in recent decades since the application of spearing bans as another case study. Blue groper are an excellent example of the impact that spearing can have on reef populations, but why have they bounced back when others have not? It might well be that blue groper have been less available to other forms of fishing like recreational angling. That is anglers find them hard to catch – they are selective feeders both in terms of prey type and time of day and because they are powerful reef dwellers they more often break off the lines of the casual generalist angler. It might be that their niche is more plastic, or social structuring and sex-changing has allowed them to increase, or it just might be that stringent bag limits applied to the recreational anglers have actually worked. Whatever the reason, my point is that reef ecology is mostly pretty complex and the interactions between nature and human forms of mortality can be hard to predict."

[39] AUF website accessed 22 August 2004 www.auf-inc.com.au.
[40] Personal communication, 8 September 2004.
[41] John Ottaway, Assistant Director, Western Australia Department of the Environment, pers. comm. 10/2/2005.
[42] Toowoon Bay lies between Sydney and Newcastle, on Australia's heavily-populated east coast.
[43] *Girella tephraeops* -rock blackfish.
[44] Although extremely weak in the environmental area, the AUF policy statement does acknowledge that spearfishing in marine protected areas *on SCUBA* is not a good idea – hardly indicating progressive or thoughtful attititudes.
[45] In temperate environments such as those found across southern Australia, physical damage by recreational divers does not appear to be a major problem, although it is

noteworthy that a study of a Spanish marine protected area in a temperate environment found significant local damage to colonial bryozoans, with slow recovery (Garrabou et al. 1998). In coral environments, anchor damage, trampling and fin damage to fragile coral structures are issues of concern (Hawkins & Roberts 1992, Harriott et al. 1997, Rouphael & Inglis 2001, Tratalos & Austin 2001).

[46] The large fish are comparatively more fecund than smaller individuals, and therefore more effective as individuals for maintaining populations (see review of this effect in Gell & Roberts 2003b:449.

[47] A view now widely held: see for example Bellwood et al. (2003) who also present evidence suggesting that the overfishing of a spearfishing target species, the giant coral-eating parrot fish (*Bolbometopon muricatum*) is likely to have major effects on coral ecosystem structure and function. This large and mobile reef-dweller is unlikely to receive significant protection from small sanctuaries.

[48] According to Valerie Taylor (pers. comm. 10/9/04): "In our day during competition spearfishing we could weigh in 2 fish of each edible species (they are nearly all edible) over a certain weight. The heavier the fish the more points it is worth. In competitions we would spear the first fish of each species we saw then the second if it was larger, then a third if it was larger than the other 2 dumping the smallest and so it went. The number of dumped fish was usually quite extensive. I do not know if the rules have changed since then but the discarding of the smallest and replacing it with a larger specimen worth more points I am sure is still the practice. This would make it almost impossible to judge the number of fish killed in a spearfishing competition".

[49] Coral trout (members of the genus *Plectropomus*) are the most heavily targetted finfish species on the GBR. Of the *Plectropomus* group, the common coral trout, *Plectropomus leopardus*, is the most heaviy fished. It is targetted (generally at different intensities at different places) by commercial line fishing, by recreational angling, and by recreational spearfishing. A detailed examination of fish size/abundance data supports the view that fishing can have a major impact on coral trout populations. In several areas coral trout are no longer 'abundant' when compared with levels in the early 1990s. Sweatman et al. 2003, for example, state in relation to Border Island: "Numbers of most fish taxa were relatively stable. Although numbers have fluctuated over the 9-year study period there has been little tendency for prolonged increases or decreases. One exception may be the commercially important coral trout (*Plectropomus leopardus*). Numbers have declined since 1994 and are currently stable but low. Evidence of fishing activity has been noted (presence of snagged lures and hooks) even though this reef has protected status."

Comparative (closed / open zone) data for southerly inner-reef areas in fact reveals a substantial difference between fished and unfished areas for coral trout. This difference is reduced for northerly and outer-reef areas, where both fishing pressures and compliance/enforcement are likely to be lower. Evans & Russ 2004 report: "The biomasses of *Plectropomus* spp. and *L.utjanus carponotatus* were significantly greater (3.9 and 2.6 times respectively) in the protected zones than fished zones at all three island groups [Palm, Whitsunday and Keppel]. Using before-reserve and after-reserve creation data, Williamson et al. 2004 report: "Density and biomass of coral trout increased significantly (by factors of 5.9 and 6.3 in the Palm Islands, and 4.0 and 6.2 in the Whitsunday Islands) in the reserve sites, but not the [control] fished sites..."

[50] Schmeissing 1997:56 made comparable assumption for NSW: 10,000 participants, on average fishing on 26 days per year, catching around 6 fish averaging about 1 kg each.

[51] These assumptions are not unrealistic compared to participation rates in the only available national study: Henry and Lyle 2003.

[52] Taken from notes prepared during the preparation of a small article for the *Environment Victoria* newsletter (Nevill 1984).

[53] Spearfishing on compressed air includes the use of SCUBA and air delivered by hose.

[54] Paragraph 47. See references under "Technical Consultation…".

[55] The Victorian Government currently requires that spearfishers, like any other recreational fisher, hold a recreational fishing licence (RFL). This licence carries no reporting obligations, although the government does facilitate the submission of voluntary recreational fishing reports through the internet – see for example http://www.fishvictoria.com/pyoursay/reports/port_albert_sthgipp.php, accessed 20/3/06.

[56] Existing club codes are extremely weak concerning environmental matters. None warn against the possible ecological effects of night or SCUBA spearfishing (see Gillett & Moy 2006) and none carry information about the ecological dangers of targetting the biggest fish (see discussion above). The Australian Underwater Federation *Spearfishing Code of Conduct* for example, contains only one sentence in environmental issues: "Respect our marine life by never taking more game than for your immediate personal needs". Recfishwest have a *Policy on Compressed Air Spearfishing* which, far from carrying warnings, attempts to justify the activity.

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Attachment Four: Kingsford & Nevill (2006)

Urgent need for a systematic expansion of freshwater protected areas in Australia

A scientists' consensus statement

Revised: 11 February 2006

This statement has been prepared by an informal working group of Australian scientists, and is supported by additional scientists from academia and private industry, with over 50 total signatories. The spokesman for the group is Professor Richard Kingsford from the University of New South Wales. The corresponding author is Jon Nevill from OnlyOnePlanet Consulting, Hampton Melbourne. More details may be found below under 'authorship'.
This document is available from www.onlyoneplanet.com.au or
www.bees.unsw.edu.au/school/staff/kingsford/kingsfordpublications.html

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Abstract
Freshwater ecosystems (including inland saline wetlands and mound springs) are among the more imperilled ecosystems in the world. Australia is no exception, but their protection has lagged behind programs of terrestrial protection. Freshwater protected areas are an essential component of biodiversity conservation programs, but a systematic approach to their development in Australia has been slow, and hindered by incomplete ecosystem inventories at State and national levels. We examine this problem and suggest avenues for action. Further, while there is no shortage of relevant legislation and policy for protecting inland aquatic ecosystems in Australia, some protective mechanisms have not yet been used, many years after their development. In some places 'protection' has been only partially applied without regard to important issues of hydrologic connectivity – with species extinction as a direct consequence. The most urgent priority is to identify those aquatic ecosystems most at risk. A comprehensive national assessment of the conservation status of freshwater ecosystems should be undertaken immediately. Such an assessment would provide both a platform and an impetus for the systematic expansion of the nation's freshwater protected areas. Political will and community support are then essential for effective conservation, utilising the plethora of conservation and management tools available.

Keywords:
Inland aquatic, freshwater, protected areas, biodiversity, reserves, biodiversity conservation, governance, representative, ecosystems.

Introduction
Most Australians are familiar with the protection provided by national parks in terrestrial environments, and marine reserves in our oceans. However the concept of protected rivers is seldom discussed – or the more general concept of freshwater protected areas (here 'freshwater' means 'inland aquatic', including saline wetlands and mound springs[1]). This is despite evidence that freshwater biota are particularly imperilled both globally and in Australia[2] (Boulton and Brock 1999, Revenga and Kura 2003).

The world's biodiversity is in serious decline[3]. According to the international *Convention on Biological Diversity 1992* (CBD, www.biodiv.org) the conservation of biodiversity, including aquatic biodiversity, requires the protection of representative examples of all major ecosystem types, coupled with the sympathetic management of ecosystems outside those protected areas[4]. These twin concepts[5] underpin, in theory at least, all Australian biodiversity protection programs (Commonwealth of Australia 1996:Principle 8). They are fundamental to the development of a coherent and effective framework for the protection and management of high conservation value aquatic ecosystems (Kingsford *et al.* 2005).

The importance of protected areas
Protected areas are the single most important tool used in biodiversity conservation programs throughout the world (ESA 2003). They also support ecosystem functions beyond their boundaries, and have other economic and cultural benefits (Nevill and Phillips 2004:s4.3). Systematic conservation planning approaches are now accepted as essential tools in protected area identification and selection (Margules and Pressey 2000) and have been used in Australia for 30 years and 15 years in terrestrial and marine environments respectively. Such approaches are essentially aimed at getting the best value (in terms of biodiversity conservation) from a reserve system which comprises a relatively small part of the total landscape. At this stage they have *not* been applied to the establishment of freshwater protected areas in a cohesive and focused way by Australian State agencies (Nevill and Phillips 2004).

Protected areas, as defined by the World Conservation Union (IUCN 1994) are areas of land or water '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'. The logic underlying the IUCN definition has three key elements. The area should be under defined management (i.e., with an agreed management plan). Secondly, actual management arrangements should effectively reduce at least one major threat to the area's values (i.e., value and condition should be monitored and reported over time). Thirdly, the area should have secure tenure (preferably through statute). The IUCN lists 6 categories of protected area, from full protection through to multiple use.

The long-term benefits of creating freshwater protected areas[6], if properly managed, are likely to far outweigh short term costs[7] (Balmford *et al.* 2002, MEA 2005:39). Many marine protected areas enhance fisheries outside the protected zone (Gell and Roberts 2003, Ward and Hegerl 2004), and some freshwater protected areas will have similar effects, with consequent benefits for recreational fishers. Australian hunters' organisations have helped fund the purchase of freshwater areas to provide breeding grounds for ducks and other waterbirds. Tourism in Canada has benefited from the Canadian Heritage Rivers System, and is now one of the key drivers of system expansion. Australian tourist operators will benefit from healthy and impressive rivers and wetlands. Fledgling tourism operations in places like the Macquarie Marshes struggle because of river degradation. Farmers will benefit from the protection of aquifer recharge areas. Indigenous groups supported the formation of the first listed Ramsar site in the world: Coburg Peninsula in the Northern Territory. All Australians will benefit from the protection of our living freshwater environments – which have huge economic, cultural, recreational, educational, spiritual and scenic values.

Freshwater ecosystems supply major (often unprotected) ecosystem services such as water supply, flood mitigation and groundwater regulation[8]. Fully protected ecosystems provide essential environmental benchmarks by which the management of utilised ecosystems may be measured and refined. The cost of rehabilitating such areas after degradation far exceeds the cost of protecting these services (according to Bernhardt *et al.* 2005, over US$14 billion has been spent rehabilitating degraded streams in the USA since 1990).

International initiatives
The Ramsar *Convention on Wetlands 1971* created the world's largest and most widely applied protected area system for freshwater habitats, with 145 of the world's 192 nations participating[9]. In its decisions and guidance, to which the Australian Government is party[10], the Ramsar Convention has committed to (among other things) a *Strategic Framework for the Ramsar List* based on criteria that include 'representative wetland types' [11](www.ramsar.org). The potential for the Ramsar framework to provide protection to all types of aquatic ecosystem has not been fully developed in Australia (see below).

The Conference of Parties to the CBD, meeting in February 2004, developed a revised program of work on inland waters. The adopted measures include Goal 1.2: 'to establish and maintain comprehensive, adequate and representative (CAR) systems of protected inland water ecosystems within the framework of integrated catchment/watershed/river-basin management' (Conference of the Parties 2004). This measure was adopted in part to meet the 2002 World Summit on Sustainable Development's implementation target of 'a significant reduction in the rate of loss of biodiversity' by 2010.

This emphasis on freshwater ecosystems was reinforced by the World Conservation Congress, meeting in November 2004, which recommended that all nation-states 'establish protected areas representative of all freshwater ecosystems, including but not limited to riverine, lacustrine, wetland, estuarine and groundwater-dependent ecosystems, in cooperation with local communities and resource users, so as to safeguard the biodiversity of each of their freshwater ecosystems…' (www.iucn.org).

Some countries have made significant advances in protecting freshwater ecosystems, with a few notable developments relating to rivers. The United States passed their *Wild and Scenic Rivers Act* in 1968 after a vigorous public campaign to stop the damming of several major rivers (172 rivers or river reaches are now listed). In Canada, the *Canadian Heritage Rivers System* (1984) is now so popular that nominations for further protected rivers come entirely from community pressure (40 rivers or river reaches are listed) (www.chrs.ca).

The 1968 USA legislation helped support a 'wild and scenic rivers' campaign starting in New Zealand (NZ) in 1976, which resulted in *Water Conservation Order* (WCO) legislation being passed in 1981. With minor amendments, National WCOs have been investigated and gazetted as 'protected waters' since then. To date 13 river catchments and 2 stand-alone coastal lakes are largely protected. Ramsar candidate sites (i.e., meeting Ramsar criteria) in NZ total 103 at this stage and include many rivers, some of which are already protected through WCOs and/or terrestrial reserves and other protected areas. New Zealand embarked on a *Waters of National Importance* project in 2003, with a stated objective to protect: 'water bodies with nationally significant natural, social and cultural heritage values'. A major study (Chadderton *et al*. 2004) has identified nationally significant rivers for biodiversity protection. This study has, as yet, no Australian equivalent.

The European Union has recently promoted freshwater ecosystem protection as a component of its wide-ranging 'water framework directive' and 'water initiative'[12] programs, which complement the earlier *Conservation of Natural Habitats and Wild Fauna and Flora Directive* 1992[13]. It is too early to judge the success of these endeavours (which rely heavily on river basin management for improved water quality) but they seem likely to re-enforce commitments within the *Convention on Biological Diversity 1992* towards the protection of 'comprehensive, adequate and representative' aquatic ecosystems (Conference of the Parties 2004).

Australian freshwater ecosystems
Australia is the driest inhabited continent, and southern river systems have been extensively degraded by water extraction and regulation, and by other forms of habitat destruction (Arthington and Pusey 2003; Kingsford 2000; Kingsford and Thomas 2004). The National Audit reports 2001 show extensive and continuing degradation of Australia's rivers and estuaries. Many major river systems are in a state of ecological crisis, and their inhabitants – like the iconic Murray Cod[14], colonial waterbirds, floodplain eucalypts, and Tasmania's Giant Freshwater Crayfish[15] – are in decline. Increased protection for the ecosystems of Australia's rivers – and lakes, wetlands, springs, subterranean ecosystems and estuaries – is long overdue[16].

Climate change is also an issue which needs consideration during the process of protected area network development. Apart from temperatures, rainfall patterns are also changing (Pittock 2003). In the southwest of Western Australia, rainfall over the last three decades has been around 15% lower than historic long-term trends[17], and in some catchments this has translated into a 20-30% decline in surface runoff. Further declines are predicted – according to Berti *et al*. (2004): "… an 11% reduction in annual rainfall by the middle of this century could likely result in a 31% reduction in annual water yield." Where surface waters have already been over-committed to extractive use (through binding water licence entitlements) river ecosystems are placed under extreme pressure. Massive damage to freshwater ecosystems in areas of declining rainfall and high existing extractions, such as the Murray-

Darling River, is almost inevitable[18], unless governments undertake licence buy-back to supply adequate environmental flows.

An increase in the severity and frequency of extreme events, floods and especially droughts, is also predicted (Pittock 2003) – an increase that will severely strain current water management and biota conservation practices. Overall, the distribution of species is likely to change, and where species movements are constrained, extinction is a possibility. This may be an issue of considerable concern for small localised endemic populations (freshwater molluscs, for example). Precautionary redundancy in reserve design is likewise an important and related issue.

Of special concern are those ecosystems typically supporting short-range endemic taxa (e.g., groundwater systems and mound springs). Australian subterranean aquatic ecosystems and other groundwater-dependent ecosystems (GDEs) have been largely neglected by scientists and by planning frameworks. Biodiversity in some Western Australian aquifers is high by world standards (Humphreys and Harvey 2001). The stygofauna of the limestone and calcrete 'underground wetlands' of the western half of Australia are little known outside the specialist scientific group who study them, despite their fascinating links to our long geological history as both evolutionary and distributional relicts. Many species are confined to a single cave system or karst area (Eberhard and Humphreys, 2003).

Existing water planning, land use planning, and development assessment frameworks are not providing adequate protection for Australia's freshwater ecosystems (Morton *et al.* 2002, Nevill 2001, Wentworth Group 2002, 2003).

There is still much scope for improving water resource management at the State level (Kingsford *et al.* 2005). Apart from the issues of over-allocation[19] of water to extractive use, protected areas, and alien species, the most serious concern is a failure (principally on the part of State governments) to effectively control the cumulative effects of incremental water infrastructure development - particularly farm dams, levee banks, agricultural drainage[20], extraction of groundwater and surface water, and GDE matrix removal[21] (Nevill 2003, see also 'comprehensive water accounts' in Wentworth Group 2003). Nevill proposed five key management principles which, while often accepted, are seldom applied in practice. Even for new developments, there is little evidence of the application of the precautionary principle, although all governments are committed to it on paper (Coffey 2001; Stein 1999).

Australian flood-plain graziers, fishers, hunters, indigenous groups and conservationists generally support river and wetland protection. However they are often suspicious of each other's motives, with the result that (to date) there has been no united voice for protection which can be clearly heard at the level of national politics. Threats are compounded in Australia by the relative scarcity of freshwaters and the low commercial value placed on their biota in comparison with other continents – making the development of a strong 'river protection' constituency more difficult than in other countries such as New Zealand or Canada.

Overview of aquatic protected areas in Australia

The history of freshwater protected areas in Australia is, in large part, a story of good intentions not carried through. There is a plethora of different conservation tools that can be used – but have largely remained under-utilised (Kingsford *et al.* 2005, Nevill and Phillips 2004:ss.1.5 & 7).

Australia's three-tiered government system places most resource management responsibilities in the hands of the eight States and Territories (hereafter referred to as 'States'). The Australian (Commonwealth) Government is responsible for international treaty obligations, and consequently seeks the cooperation of the States as well as local government (where most land use planning responsibilities lie) – and, where they exist, regional resource management planning bodies[22]. The Australian government can establish protected areas on Commonwealth land, and can encourage or require limited protective action from the States where values of national importance (eg: Ramsar sites[23]) are threatened (Nevill and Phillips 2004:s.6.1).

Australia signed the international Ramsar Convention on Wetlands in 1971, which requires the conservation and 'wise use' of all wetland types – which, under the Ramsar definition of 'wetlands', includes rivers and groundwater ecosystems. After 34 years, few Australian rivers[24] have been directly protected under Ramsar provisions, although some have been listed in the *Directory of Important Wetlands in Australia* (DIWA) (DEH 2001). The DIWA contains State-by-State lists of nationally (and internationally) important wetlands, including Australia's 64 Ramsar-listed wetlands[25].

Australia's obligations under the Ramsar convention include the preparation of ecosystem inventories. Although none of the State-wide inventories are comprehensive in the sense of containing up-to-date information on value and condition, work is progressing slowly. New South Wales has digital coverage of all wetlands (including floodplains) and their protective status (Kingsford *et al.* 2004). Victoria, Tasmania and the Australian Capital Territory also have reasonably good State-wide inventories of wetlands, with floodplains variously mapped. Other jurisdictions are preparing State inventories, apart from Western Australia and the Northern Territory where the focus is on regional inventories (Nevill and Phillips 2004). Queensland has embarked on the most comprehensive inventory yet attempted in Australia.

State governments have listed[26] some wetlands as Ramsar sites or (more often) included them within the DIWA. Ramsar sites receive limited protection under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999,* as well as some State legislation such as Victoria's *State Environment Protection Policy (Waters of Victoria) 2003.* DIWA listing constitutes a referral trigger in Queensland's *Integrated Planning Act 1997*[27]*.* While the DIWA itself is not formally linked to any Commonwealth or State protection policies other than in Queensland, it is taken into account by many local government and regional resource planning bodies in making land use planning decisions. However, it does not yet include rivers or underground ecosystems in a comprehensive way, despite the Ramsar Secretariat's broad 'wetland' definition.

The most comprehensive data analyses in New South Wales (NSW) show that about 0.8% of wetland area is listed under Ramsar[28], 3% lies within terrestrial protected areas, and 20.7% is listed in the DIWA (Kingsford *et al.* 2004). A similar situation may be expected in other States. By far the bulk of wetlands lies outside formal protective frameworks, thus relying on State government provisions for 'sympathetic' management – largely within land and water planning mechanisms. Here serious problems in the delivery of environmental flows need to be addressed[29] (Ladson and Finlayson 2004).

Several discharge springs from the Great Artesian Basin (GAB) as well as four other aquatic ecosystems[30] are listed as 'threatened ecological communities' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) – another protective mechanism albeit not very effective at present. While in theory the EPBC Act can protect against major new developments that may constitute a threat to an area's values, it cannot force proactive biodiversity management, nor can it control a multitude of small widespread activities draining water flows from a site. Many GAB springs, known to include endemics (Ponder 2004), are already extinct as a result of drawdown resulting from over-use of artesian water[31]. Failure to effectively control the cumulative effects of incremental water development is causing major problems for biological reserves worldwide (Pringle 2001).

Australia's existing reserve system has some profound achievements (particularly with respect to the protection of terrestrial biodiversity) but inherent limitations now demand new approaches to ensure adequate representation of freshwater ecosystems. While some reserves in Australia were created to protect lakes and wetlands and also a few rivers (e.g., Shannon River National Park, and Prince Regent River Nature Reserve in WA), these areas constitute only a small proportion of the total protected area estate. An additional limitation is that many terrestrial protected areas provide little protection to enclosed freshwater ecosystems – for example from hydroelectric regulation, beyond-boundary water diversion, or recreational fishing (including the introduction of alien predators such as trout[32]). These are all issues identified more than 20 years ago (Lake 1978). For example in Kosciusko National Park, rivers or creeks are not protected, with the result that the Snowy Mountains

Hydroelectric Scheme damaged seven major rivers and left only two medium-sized rivers unregulated[33]. The Menindee Lakes within Kinchega National Park are similarly not protected, except when they have no water in them. Another similar situation applies to Tasmania's Wilderness World Heritage Area in the State's southwest.

We are not protecting all of our most important aquatic ecosystems. Certainly the existing reserve system includes some important freshwater areas (e.g., Ramsar sites) and other freshwater ecosystems are contained within large terrestrial reserves (Nevill 2005a). However the reserve system has not been created with the benefit of a systematic analysis of wetland types, and *little published information is available on the extent to which representative freshwater ecosystems are protected within existing reserves***.** Here it is worth noting the exception of studies such as those in the Wimmera[34] and northern Victoria (Fitzsimons and Robertson 2003, Robertson and Fitzsimons in press) and in NSW where there is an analysis of the conservation status for broad wetland types (Kingsford *et al.* 2004). A comprehensive assessment would identify the original[35] extent of different ecosystem types at a finer level, their current extent, and the degree to which they are now protected (Fitzsimons and Robertson 2005). The methodology for such studies is well established as similar investigations were undertaken for forest ecosystems some years ago, as part of the Regional Forests Agreement (RFA) process[36].

Bioregions: issues of representation

Australia's existing terrestrial bioregionalisation does not provide a detailed guide for freshwater ecosystem protection. Wells and Newall (1997) found that the terrestrial *Interim Bioregionalisation of Australia* (IBRA) was 'not effective in representing aquatic ecosystem patterns across Victoria', and suggested an approach to delineating aquatic bioregions based partly on physical and biological data, and partly on expert opinion. It is possible to develop aquatic bioregions – for example, aquatic ecoregions exist for North America (Abell *et al.* 2000, 2002).

The biodiversity elements that would underpin a freshwater bioregionalisation would be different from, and would not necessarily have the same boundaries as, those used in the existing terrestrial bioregionalisation. In addition, freshwater systems are by their nature more connected than terrestrial systems. The connections are largely linear and directional, whereas terrestrial connections tend to be non-linear and weakly directional. Selecting priority sites for freshwater protected areas needs to accommodate these, and other, unique aspects of freshwater biodiversity, ecology, and system function. The need to develop agreed surrogates[37] and units to map and measure freshwater biodiversity is an important related issue (Robertson and Fitzsimons 2004). Issues of ecosystem process and scale need to be taken into account, particularly when selecting taxa[38] as biodiversity surrogates.

Development of an 'interim freshwater bioregionalisation of Australia' is an important step in the processes of objective conservation assessment (Kingsford *et al.* 2005; Tait *et al.* 2002; Tait 2004;). Such a regionalisation would provide a platform for a national conservation status assessment of freshwater ecosystem types (Kingsford *et al.* 2005). Systematic conservation planning approaches will need to be modified to take account of the connected nature of rivers[39] in particular. The identification of Australian freshwater biodiversity hotspots is also important, and is now proceeding.

State programs

All States are, in theory at least, committed to the establishment of systems of protected areas which contain representative examples of *all* major ecosystem types, including aquatic ecosystems. Victoria[40] holds the earliest of these commitments (1987) and South Australia the most recent (2003) (Nevill and Phillips 2004). Such programs are in line with Australia's obligations under the *World Charter for Nature 1982* (a resolution of the United Nations General Assembly) and the *Convention on Biological Diversity 1992*. However, it is the *timing* which is at issue – there have been extended delays in implementing policy. With respect to freshwater protected areas, these obligations have not yet been carried through in a systematic way in any Australian jurisdiction other than the Australian Capital Territory[41].

Protection measures for entire rivers can be devised, but are poorly implemented in Australia. The Victorian government identified 15 ‘representative rivers’ for protection in 1992; 13 years later, four of these rivers remain without management plans (Nevill and Phillips 2004). Victoria passed a *Heritage Rivers Act* in 1992, nominating 18 rivers and 25 ‘natural catchments’[42] to be protected[43]. The Act established a management sequence: (a) preparation of draft management plans, (b) public comment and review, (c) ministerial endorsement of the plans, and (d) implementation. Draft management plans for these 18 rivers were published for stakeholder comment in 1997. However, after 8 years, all river management plans remain as drafts without the required ministerial endorsement (Nevill and Phillips 2004) in spite of a government commitment to have them complete by 1998[44].

Several States have legislation in place aimed specifically at the protection of threatened species and ecological communities; however the area-protection provisions of these statutes have rarely been used to protect freshwater environments[45]. The ‘critical habitat’ provisions of Victoria’s *Flora and Fauna Guarantee Act 1988*, for example, have not yet been used to protect freshwater habitats (Nevill and Phillips 2004). It is however worth noting that Victoria is the only State so far to extend the concept of ‘no net loss’ to ‘net gain’ in relation to developments impacting on important areas of native vegetation – including wetland vegetation (Nevill and Phillips 2004:A3.15).

In line with the international *Code of Conduct for Responsible Fisheries* (FAO 1995:6.8) Queensland, New South Wales, Victoria, South Australia and Tasmania all have fisheries legislation providing for the establishment of aquatic protected areas. However (in spite of progress in the marine environment) none of these provisions have been used to protect freshwaters (Nevill and Phillips 2004).

Both Western Australia and New South Wales considered legislation similar to Victoria’s *Heritage Rivers Act 1992*, but there was inadequate parliamentary support in the face of opposition by farmer and fisher groups. Western Australia developed a *Wetlands Conservation Policy* in 1997 which covered rivers using the Ramsar definition; however, seven years later, the protective provisions foreshadowed in this policy have not yet been put in place in a comprehensive way (Nevill and Phillips 2004). In the mid-1990s New South Wales amended the *National Parks and Wildlife Act 1974* to provide for the declaration of ‘wild rivers’. A discussion paper was prepared by the NSW National Parks and Wildlife Service in 2004 on the Act’s wild river provisions, and in December 2005 the NSW Government announced the listing of five rivers within existing terrestrial protected areas (Nevill 2005a).

The Queensland Government started work on a rivers policy in 2000, which developed into a commitment to provide legislative protection for wild rivers. Nineteen rivers were proposed for consideration in 2004, and a policy implementation paper was provided to stakeholders. The *Wild Rivers Act 2005* came into effect on 14 October 2005; it is to be hoped that wild river declarations under this statute will be fully implemented and effective. The recent history of native vegetation protection legislation in several States[46], as well as Victoria’s Heritage Rivers Act, has indicated that effective implementation can be a major stumbling-block.

South Australia and the Northern Territory (NT) both have government policy statements committing to the protection of representative examples of all major freshwater ecosystems, however at this stage neither jurisdiction has funded a program to carry these commitments through in a systematic way (Nevill and Phillips 2004). The NT’s draft *Parks and Conservation Masterplan* 2005 reinforces earlier commitments. The final is planned for release in April 2006.

In the NT, as in northern Queensland and Western Australia, significant areas of land (around 50% in the case of the NT) are under the custodianship of Indigenous groups. The Commonwealth’s long-standing Indigenous Protected Area (IPA) program has achieved successes, and could be extended to assist Indigenous groups protect freshwater ecosystems. The recent Tropical Rivers Program (a Commonwealth initiative under Land

and Water Australia) is providing increased knowledge of tropical freshwater ecosystems and measures needed to protect them .

Tasmania's *Nature Conservation Strategy 2000* and the subsequent *State Water Development Plan* established a commitment to develop comprehensive protection for all freshwater ecosystem values, and so far the program is moving in a systematic way. The Conservation of Freshwater Ecosystem Values (CFEV) Project has undertaken the design phase of this work, which, when completed, will establish the scientific basis for the identification and selection of freshwater protected areas across the State, as well as providing information for regional natural resource planning initiatives. The CFEV project is expected to produce its final report in mid-2006. No specific funds were allocated for project implementation in the 2005/6 State budget, in spite of the fact that the project is expected to identify priority sites for protection. The above discussion indicates that excellent scientific preparation and good policy development do not guarantee effective implementation.

Conclusion

There are solutions. Techniques are available for managing highly connected linear reserves (Saunders *et al.* 2002). There is a variety of under-utilised 'conservation tools' for protecting and managing Australia's aquatic ecosystems, including environmental flows, protected areas, natural resource management plans and landholder incentives (Kingsford *et al.* 2005, Whitten *et al.* 2002). Australia should implement existing State policies to establish systems of representative protected areas for freshwater ecosystems, in line with our international commitments under the *Convention on Biological Diversity 1992* (Dunn 2000; Georges and Cottingham 2001; Nevill 2001). Furthermore:

a) Major rivers where ecosystems remain substantially intact should be protected (Morton *et al.* 2002; Wentworth Group 2002, 2003). Models of protection have been proposed. These include the establishment of a four-tiered river classification, including 'heritage rivers' and 'conservation rivers' which would both receive special protection (Cullen 2002; Wentworth Group 2003). There is potential for introducing an Australian Heritage River system loosely based on the *Canadian Heritage River System* (Kingsford *et al.* 2005). Already some whole catchments receive protection from specific agreements (e.g., Lake Eyre Basin Agreement; Paroo River Agreement). The inclusion of rivers within the Ramsar framework could also be promoted (Nevill and Phillips 2004).
b) The 2004 Sydney *Conference on Freshwater Protected Areas* (WWF Australia and the Inland Rivers Network) recommended that all Australian jurisdictions accelerate the development of freshwater protected areas.
c) Ecosystem inventories also need accelerated development, partly to underpin protected area identification and selection, and partly to support 'sympathetic' management of biodiversity values within regional resource planning frameworks. Classification and mapping techniques must be used thoughtfully in reserve design and selection (Fitzsimons and Robertson 2005) to ensure an adequate CAR protected area system. Inventories should be constructed to support a variety of classification methods (Blackman *et al.* 1992; Finlayson *et al.* 2002; Ramsar Secretariat 2002[47]).
d) The control of cumulative effects, particularly within catchment-scale management, needs much greater attention (Collares-Pereira and Cowx 2004; Nevill 2003; Pringle 2001). The precautionary approach, generally accepted but not applied, needs strong support especially where high conservation values remain intact.
e) The rehabilitation[48] of significant aquatic sites should remain a priority (Koehn and Brierley 2000, Rutherfurd *et al.* 2000).
f) Stakeholders with common interests need to start building consensus and raising awareness. Adequate stakeholder consultation in the selection of protected areas is essential to allow for the inclusion of local and regional values, and to build community support for protected area programs and the wider sympathetic management of utilized ecosystems (Kingsford *et al.* 2005).

The National Reserve System (NRS) *Directions Statement* (NRMMC 2005) signalled a new emphasis on freshwater ecosystems (Direction 7): *'Review the current understanding of* *freshwater biodiversity in relation to the NRS CAR [comprehensive, adequate and representative] reserve system, and finalise an agreed approach, which may include future amendments of the NRS Guidelines, to ensure freshwater ecosystems are appropriately incorporated within the NRS.'* This initiative needs strong support, as does the Murray Darling Basin Commission native fish strategy (MDBMC 2003).

The need to establish comprehensive and representative freshwater protected areas is urgent, given increasing concerns about limited water availability for Australia's cities, industries and agriculture - and the ongoing degradation of aquatic ecosystems. This should be accompanied by effective land and water management that pays more than lip service to the environmental requirements of aquatic ecosystems. State governments should act with the support and collaboration of the Commonwealth.

The most urgent initiative appears to be a national reserve system 'gap analysis' which would identify those ecosystems most at risk. A comprehensive national assessment of the conservation status of freshwater ecosystems should be undertaken immediately[49]. Such a study would provide a platform for the systematic expansion of the nation's freshwater protected areas, as well as a catalyst for innovative 'bottom-up' conservation approaches driven by local stakeholders. This could include establishment of an Australian Heritage River system, coordinated by governments, and supported by regional communities.

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Endnotes:

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[1] . 'Freshwater' is a commonly used keyword for current literature dealing with inland aquatic ecosystem management.
[2] see also: Master et al. 1998, Harrison & Stiassny 1999, Ricciardi & Rasmussen 1999, Myers & Knoll 2001[2], Cowx 2002, Barmuta 2003, MEA 2005.
[3] According the the Millennium Ecosystem Assessment "Human activities have taken the planet to the edge of a massive wave of species extinctions" (MEA 2005:3). The critical nature of the biodiversity crisis facing the planet was acknowledged when representatives of 190 countries at the 2002 Johannesburg World Summit on Sustainable Development committed themselves to "…achieving by 2010 a significant reduction of the current rate of biodiversity loss at global, regional and national levels…" UN (2002) Key outcomes from the Summit, UN, New York. See also UNEP, "Report on the Sixth Meeting of the Conference of the Parties to the Convention on Biological Diversity (UNEP/CBD/COP/6/20/Part 2) Strategic Plan Decision VI/26" (CBD 2002); overview available at http://www.biodiv.org/2010-target/default.asp (accessed 20/8/2005).
[4] See CBD articles 7 and 8.
[5] These two core concepts of biodiversity conservation have been enunciated in several major international statements apart from the CBD, including the Stockholm Declaration 1972, the World Charter for Nature 1982, the Rio Declaration 1992 and the Johannesburg Declaration 2002. Further detail may be found in Declaration implementation statements. In the Australian context they are contained in Principle 8 of Commonwealth of Australia 1996.
[6] The literature assessing the effects of freshwater protected areas suggests that the size of the protected area, and the management of the surrounding catchment are critical factors in the success of such areas in protecting biodiversity. Judging by the scant available literature, some groups of biota, such as fishes, in general do not appear to have derived significant benefit from existing protected areas (Nevill 2005b). Less mobile biota are likely to have faired better, however.
[7] The ubiquitous use of 12-month accounting cycles (based on readily measurable financial attributes and current interest/discount rates) under-values the importance of ecosystem services, which in many cases are difficult to calculate, and depend on ecosystem processes operating on time-scales of decades or centuries. Where they are calculated, long term ecosystem service benefits are systematically undervalued by the use of standard discount-rate accounting procedures (Goulder & Stavins 2002). Attempts to measure the value of long-term ecosystem services accurately often show that the conservation of natural ecosystems yields higher overall benefits than their destruction for short term gains (see the examples discussed in MEA 2005 p.39, and Balmford et al. 2002). An overview of recent literature on the effects of freshwater protected areas (Nevill 2005b) suggests that benefits depend substantially on both reserve size and complementary management of the surrounding catchment beyond the reserve boundaries, as well as the size and mobility of conserved target species. Small reserves in poorly managed catchments are likely to be of limited value.
[8] Including major salinity mitigation functions.
[9] Refer: http://www.ramsar.org/key_guide_list_e.htm, accessed 20/4/05.
[10] Australia signed the Ramsar Convention in 1974.
[11] Refer: http://www.ramsar.org/key_criteria.htm, accessed 20/4/05.
[12] See http://europa.eu.int/comm/research/water-initiative/index_en.html, accessed 30/4/05.

[13] See http://europa.eu.int/comm/environment/water/water-framework/index_en.html, accessed 30/4/05. Note however that the European Council Directive 92/43/EEC (21.5.92) *Conservation of Natural Habitats and Wild Fauna and Flora* does *not* require the *comprehensive* protection of *representative* ecosystems. This Directive precedes national commitments to the Convention on Biological Diversity 1992, which would thus appear to require a expansion of the scope of the Natura 2000 programs currently funded under the older EC Directives. Cowx & Collares-Periera recommend an extension of the Natura 2000 programs (2002:448).

[14] *Maccullochella peeli.*

[15] *Astacopsis gouldi.*

[16] [16] Calls such as those by Pollard & Scott (1966) and Lake (1978) for the protection of Australia's freshwater ecosystems continue to be ignored. Lake wrote in 1978: "…the conservation of rivers in Australia needs urgent and effective treatment".

[17] Indian Ocean Climate Initiative: http://www.ioci.org.au/what/index.html.

[18] Changes brought about by agricultural or rural-residential landuse can create dramatic change to catchment hydrology – with the ability to magnify reductions in streamflow caused by climate change. The growth of farm dams, groundwater bores, land-levelling, or significant planting of fast-growing deep-rooted vegetation within a catchment (for example) can hugely reduce runoff to streams – the water is simply diverted (and ultimately transpired) before it can appear as streamflow (see pp. 305-317 of David Ingle Smith (1998) "Water in Australia" Oxford University Press, Oxford, for a discussion of these effects). Landuse can have other important effects – soil porosity in an undisturbed native forest can be much higher than that of adjacent land which has been ploughed, planted and cropped – thus encouraging surface groundwater uptake. Across southern Australia, rivers feed from surface groundwater most of the time. Extensive forest can alter meteorological surface roughness, creating direct impacts on local climate (Pitman et al. 2004, Herron et al. 2002).

[19] "Over-allocation" refers to the over-allocation of available water supplies by State water management agencies (see Nevill & Phillips 2004 section 4.2.1). Both surface waters and groundwaters have often been over-allocated and used with excessive waste, a legacy which remains a major ongoing problem over much of Australia.

[20] Agricultural drainage includes drainage of wetlands and their surrounds, as well as land levelling and reshaping.

[21] Groundwater dependent ecosystem (GDE) matrix removal includes, for example, the extraction of river gravels and groundwater calcretes.

[22] Including, in some jurisdictions, formal or informal integrated catchment planning groups (Maher, Nevill & Nichols 2002).

[23] Ramsar sites are defined by the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as having national environmental importance – thus bringing them under the scope of the Act.

[24] Australia has hundreds of rivers, but only a handful are well protected (Nevill 2005a). The largest Ramsar-listed river is the South Alligator River in the Northern Territory, where 91% of the river catchment lies within the Kakadu National Park and associated Ramsar site. Within the Murray-Darling Basin, the Ramsar sites on rivers such as the Paroo and the Murray provide a measure of legal protection against new deleterious developments, and form five of the six 'significant ecological assets' that underpin the Murray Darling Basin Commission's *Living Murray Initiative* action program to restore some measure of environmental health to the Murray River system.

[25] Australia's 64 Ramsar sites (2004) are viewed as 'internationally significant' and cover a total of approximately 7.3 million hectares. More info: http://www.deh.gov.au.

[26] Strictly speaking, State governments do not 'list' Ramsar sites. While in practice State governments recommend areas to the Commonwealth Government, who then recommends listing to the Ramsar Secretariat, this is the result of the Commonwealth's policy of bilateral cooperation. Legally the only role of State governments (under the EPBC Act) is to be consulted by the Australian Government on proposed listings. Only the Australian Government can 'declare' Ramsar sites which the Ramsar Secretariat then lists.

[27] See Schedule 8 of the *Integrated Planning Regulations 1998.*

[28] Most of the Ramsar areas are within State terrestrial protected areas. Note however that Ramsar wetland listing does not constitute 'protected area' status in its own right, other than through the provisions of the EPBC Act. A small number of Ramsar sites are declared over

constructed wetlands not managed primarily for biodiversity conservation (e.g. the Western Sewage Treatment Plant at Werribee, Victoria).

[29] In some cases, agreed environmental flows have not been delivered as a direct result of poor management arrangements and inadequate State funding.

[30] The five listed freshwater *threatened ecological communities* (at the close of 2005) can be found at http://www.deh.gov.au/cgi-bin/sprat/public/publiclistchanges.pl. Apart from the GAB springs, the remaining four communities are lentic wetlands.

[31] Many GAB stock bores have a wastage rate of 90% or more (see http://www.gabcc.org.au/tools/getFile.aspx?tblContentItem&id=50, accessed 18/9/05).

[32] Trout have caused major impacts to native fauna where they have been introduced, and introductions are widespread (Tilzey 1976). Raadik (2005), discussing the Dorrigo Plateau in NSW, states: "[Control of t]rout predation, a significant threat to upland, non-migratory galaxiids, should have a high management priority. There should be a cessation of trout stocking into streams on the plateau, followed by trout eradication or population reduction in significant galaxiid streams." At the time of writing, the NSW Government continues to subsidise and support the activities of the *New England Trout Acclimatisation Society* in re-stocking streams in this general area with trout.

[33] An additional complication is created by secrecy surrounding key management information. According to A/Prof Brian Finlayson (pers. comm. 13/5/05): "All the river gauging in the Kosciusko National Park is now done by the newly 'corporatised' Snowy Hydro and all the data they collect are 'Commercial in Confidence' and they will not release it to anyone. So we have the situation where all the flow data for rivers in one of our major national parks (a 'protected area') is kept secret."

[34] The Wimmera lies in western Victoria.

[35] "Original" in this context means pre-European (prior to 1750).

[36] According to Pressey et al. (2004): "Recent Australian guidelines for expanding forest reserves [Commonwealth of Australia 1995; Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee (JANIS) 1997] stipulated a baseline conservation target of 15% of the pre-European extent of each forest type. The guidelines also recognized that larger targets would be necessary for rare and/or threatened types and that reductions below the 15% baseline might be appropriate for extensive, secure types."

[37] Robertson and Fitzsimons (2004) found that different surrogates for the same ecosystem can produce very different results for measuring and mapping representation.

[38] O'Meally & Colgan (2005): "… single taxa are not usually good surrogates for the prediction of genetic value in other groups".

[39] Here "river" is defined as including headwater streams. The minor spring-fed tributaries of many coastal rivers contain significant invertebrate endemism – quite different and often arguably more significant than the rivers themselves (W. Ponder, pers. comm. 19/4/05, Meyer et al. 2003).

[40] Victoria was an early leader in respect to representative terrestrial ecosystem reservation, with its *Reference Areas Act 1978* and the program of systematic reservation commenced under the Land Conservation Council. Victoria's *State Conservation Strategy 1987* and its biodiversity strategy 1997 both contain commitments to the development of a fully representative reserve system. Although implementation problems have dogged freshwater protection under these policies, the commitments themselves were repeated again in the *Healthy Rivers Strategy 2003* (Nevill & Phillips 2004). There is a clear gap between rhetoric and reality in relation to freshwater ecosystem protection; nevertheless many significant wetland additions to Victoria's Nature Conservation Reserves have occurred through land purchases over the last decade (Fitzsimons et al. 2004).

[41] Conservation in the ACT has some unusual aspects, including the large proportion (~52%) of the total land area under some form of protected area management (Nevill & Phillips 2004, CAPAD 2000 database at www.deh.gov.au.)

[42] Largely headwater catchments already protected by large national parks or reservations within utilised forests.

[43] According to A/Prof Brian Finlayson (pers. comm. 13/5/05): "The Thomson River is a Heritage River yet the Victorian government apparently had no qualms about reducing the scientifically determined environmental flow allocation. The Thomson Expert Panel process recommended an environmental flow regime of 47 GL annually. The Task Force (made up of water managers and water users) eventually agreed to an environmental flow of 12 GL/yr

initially rising to 25 GL/yr in 5-6 years. The fact that it was a Heritage River appeared to carry no weight in this decision and was not mentioned in the Task Force report." According to Jon Nevill: "The Thomson River feeds one of Melbourne's major water supply dams. Given that the Victorian Government has never reported on the management of Victoria's Heritage Rivers, there appears the possibility that the 13-year delay in implementing protective management is not an administrative oversight".

[44] Commonwealth of Australia (1999) National report of Australia for the seventh Ramsar Convention on Wetlands Conference of Parties CoP7; Department of Environment and Heritage; Canberra. http://www.ramsar.org/cop7/sop7_nr_australia.htm, accessed 20/11/05.

[45] It is worth noting that that Fisheries NSW has supported the declaration (as threatened) by the NSW Government of some species and aquatic communities in the Murray-Darling and Lochlin Rivers. Recovery plans will (hopefully) be developed and fully implemented in the near future.

[46] The substantial failure of the NSW government to enforce its native vegetation protection legislation was documented on the Australian Broadcasting Commission Radio National *Background Briefing* of 14/9/2003.

[47] See clause 37.

[48] River restoration must be planned and conducted within a catchment context (Lake 2005) and should be undertaken within a framework of adaptive management over a timeframe commensurate with the catchment's ecological processes (Palmer et al. 2005).

[49] Australia is not alone: such investigations are needed in other nations, and ideally should be carried out in such a way that data can be assimilated globally (Brooks et al. 2004:1090).