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Submission Two

to

Senate Environment, Communications, Information Technology and the Arts Committee

Inquiry into Australia's national parks, conservation reserves and marine protected areas

Submission Two addresses terms of reference (b) and (d), and focusses on MARINE PROTECTED AREAS.

Marine no-take areas:

How large should marine protected area networks be?

Summary

The World Parks Congress 2003 (WPC) recommended the establishment of national networks of marine no-take areas (NTAs) covering 20-30% of habitats, a recommendation in marked contrast to the 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 focus on targets does little to convince sceptical stakeholders including fishers and politicians.

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. 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 was to be adopted in regard to naturally rare, vulnerable ecosystems. 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 over time.

However, while the targets proposed by the WPC remain controversial (Ray 2003), the biodiversity crisis affecting the planet leaves little doubt that an urgent and massive expansion of marine no-take areas is necessary. This reality is the backdrop against which arguments over marine protected area networks take place. **The literature reviewed below reveals a general consensus amongst scientists (summarized in Table 1) that a massive increase in no-take areas will be necessary if agreed international conservation goals are to be met.**

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

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[1] 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 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). Here 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).

Marine 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.

Marine protected areas were 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.

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.

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). According to the international *Convention on Biological Diversity 1992* (CBD) 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[2],[3] and information[4]) 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. 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 solved. 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”.

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.

NTAs created for purely 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. Even here, the proponents of these sanctuaries initially argued substantially along utilitarian grounds: the sanctuaries will assist the recovery of whale stocks to levels which could allow a resumption of harvesting. The ethical basis for establishing protected areas needs much more public discussion, both within Australia and internationally.

Conference of the Parties to the Convention on Biological Diversity
At the sixth meeting 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) (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).

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". Notably this 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 within defined timeframes) means that the target cannot be effectively monitored and reported – the different meanings which can be attributed to the phrase "effective conservation" are simply too broad.

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. However, harvesting activities in the marine environment, generally speaking, 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[5], and sometimes to the extinction of species[6]. 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.

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 MPA strategies*. 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[7] (2003) has said: "we need MPAs to be large and we need them soon" [8].

Table 1: NTA network size targets

Percentages generally refer to coverage within major ecosystem type

AUTHOR	NTA TARGET[9]	COMMENTS
Agardy et al. 2003	not specified	The authors warn against the universal application of a single (20%) target for NTAs[10].
Airame et al. 2003	30-50%	A recommendation from scientists to a community-based panel of stakeholders[11].
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[12]
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[13].
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[14], and Pressey et al. 2003, 2004.

AUTHOR	NTA TARGET	COMMENTS
Gell and Roberts 2003	20-40%	Not a recommendation: authors present evidence suggesting these sizes work best for some local fisheries enhancements.
Halpern 2003	not specified	Author reviews studies on the related issue of reserve size and MPA performance, and finds size is important[15] (larger is more effective).
Hughes et al. 2003	>30%	Not a recommendation: authors present evidence from ecological modelling studies – greater than 30% reef NTAs needed[16] to protect coral ecosystems.
Leslie et al. 2003	20% +	Not a recommendation: figure selected for illustrative purposes (model demonstration).
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[17].
National Research Council 2001	20-50%	Figures from a literature review[18] relating to enhancement of fisheries effects.
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%).
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.
Roberts et al. 2003	>20%	Authors provide a comprehensive review of NTA design methods and parameters.
Shanks et al. 2003	NTA size & spacing	Authors deal only with size and spacing using analysis and modelling of dispersal data[19].
Sala et al. 2002	40%	Gulf or California rocky reef habitat[20]
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[21].
World Parks Congress 2003	20-30%	WPC recommendation 5.22 to be considered by the UN General Assembly[22].

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

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Appendix One

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.

Endnotes

[1] 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.

[2] 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.

[3] Here water is defined as a nutrient for the purposes of terrestrial ecosystems.

[4] Processes of information flow include larvae dispersal and pollination, for example.

[5] Jackson et al. 2001.

[6] Stellar's Sea Cow (Anderson 1995) and the Caribbean Monk Seal are amongst the best known.

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[8] 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."

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

[10] 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.

[11] "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.

[12] 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)".

[13] 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%).

[14] 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.

[15] 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."

[16] 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".

[17] 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.

[18] "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)".

[19] "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."

[20] "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."

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

[22] "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.