Marine Policy 34 (2010) 197–207

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Implementing marine reserve networks: A comparison of approaches in New South Wales (Australia) and New Zealand

Simon A. Banks *, Greg A. Skilleter

Marine and Estuarine Ecology Unit, School of Biological Sciences, The University of Queensland, St. Lucia Campus, Brisbane, Qld. 4072, Australia

ARTICLE INFO

Article history:
Received 12 December 2008
Received in revised form
22 May 2009
Accepted 20 June 2009

Keywords:
Marine conservation planning
Marine reserves
Reserve networks
Conservation policy

ABSTRACT

Marine reserve networks are an essential and effective tool for conserving marine biodiversity. They also have an important role in the governance of oceans and the sustainable management of marine resources. The translation of marine reserve network theory into practice is a challenge for conservation practitioners. Barriers to implementing marine reserves include varying levels of political will and agency support and leadership, poorly coordinated marine conservation policy, inconsistencies with the use of legislation, polarised views and opposition from some stakeholders, and difficulties with defining and mapping conservation features. The future success of marine reserve network implementation will become increasingly dependent on: increasing political commitment and agency leadership; greater involvement and collaboration with stakeholders; and the provision of resources to define and map conservation features. Key elements of translating marine reserve theory into implementation of a network of marine reserves are discussed based on approaches used successfully in New Zealand and New South Wales (Australia).

1. Introduction

Protected areas have been recognised as an essential and effective approach to conserving biodiversity in both the terrestrial and marine environments [1,2]. They contribute to the conservation of living resources to achieve three conservation objectives: (1) maintenance of essential ecological processes, (2) preservation of genetic diversity, and (3) ensuring sustainable utilisation of species and ecosystems [3]. They are also considered to contribute to broader marine management objectives through habitat conservation, rebuilding depleted fish stocks and species viability, enhancing productivity and insuring against fisheries management failure [4–7]. To achieve these objectives the aspirational goal of marine biodiversity conservation is to conserve the full range of marine biodiversity in marine reserves (no-take areas), from gene pools to populations, species, habitats and ecosystems, and to ensure their long-term persistence [8–11].

International agreements and conventions (e.g. Convention on Biological Diversity) have called for the establishment of a network of marine protected areas that protects 10–30% of each habitat type in marine reserves by the year 2012 [12–19]. Such targets are important in providing guidance and stimulating political leadership for marine reserve network establishment (but see [20]). Many countries have responded to these commitments by developing conservation policy frameworks to guide the establishment of national and regional networks of marine protected areas (see for example [21–25]). There is concern, however, that the lack of coordination and consistent policy frameworks for marine conservation at international, national and regional levels is a problem affecting progress [17,26,27]. Even where national and regional conservation policy frameworks are in place, the pragmatic implementation of conservation goals has been difficult to achieve because of the complexities with establishing marine reserves. Conservation outcomes are a result of decision-making that is influenced by polarised views and lobbying by stakeholders (see for example [28–30]).

Increased public interest in the use of marine protected areas to conserve and manage the marine environment [9] has led to considerable growth in their use around the world. There are approximately 4600 marine protected areas established around the world, providing some level of protection to an estimated 0.6% (2.2 million km^2) of the world's marine habitats, but only 0.08% (36,000 km^2) of this area is no-take [16,17,31]. These no-take areas are referred to as marine reserves. The existing collection of marine reserves is a result of a fragmented approach to establishment that has generally been based on iconic species or sites [10,32,33]. This has led to claims that the current size and placement of marine reserves and marine protected areas falls far

* Corresponding author. Current address: Aquatic and Threats Unit, Department of Conservation, PO Box 10-420, Wellington 6143, New Zealand.
Tel.: +64 4 471 3192; fax: +64 4 381 3057.
E-mail address: simon.banks@uqconnect.edu.au (S.A. Banks).

0308-597X/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpol.2009.06.006

short of comprehensive or even adequate to achieve conservation objectives [18,34,35]. Hence, many argue that we need to take a more systematic approach to conservation planning [36].

Conservation planning is usually based on surrogates for biodiversity in the absence of comprehensive data on ecosystems, habitats and species [37,38]. Surrogates are biodiversity features used to guide planning with an expectation that their protection will be effective for the conservation of unknown or poorly understood biodiversity [38]. While there remains a lot of uncertainty associated with the use of biodiversity surrogates for conservation planning, many authors believe that significant progress can be made towards establishing networks of marine reserves through their use [39–43]. There is also a view that stakeholders and politicians need to accept that a surrogate or suite of surrogates is an effective approach to representing biotic diversity for the purposes of planning a marine reserve network (set of connected marine reserves) [1,43–46]. Sites valuable for their biodiversity need to be identified based on the best information available [1,47,48], which is likely to be reliant on surrogate measures of biodiversity.

The design and implementation of a global network of marine reserves is considered to be the next great challenge for marine conservation policy and conservation practitioners [10,16,49]. One reason for this being a significant challenge is because determining where to place marine reserves requires data on the location of marine ecosystems, habitats and species whose distribution is a result of poorly understood ecological processes that are impossible to define precisely, particularly over large geographic areas [35,50,51]. The identification of areas suitable for marine reserves requires biodiversity features or their surrogates to be spatially defined [38,39,52]. Collecting such information can be expensive, time consuming and often impractical when trying to meet timeframes for establishing reserve networks [1,2,33,37,51,53–57].

This paper discusses how to move from scientific and theoretical approaches for establishing a network of marine reserves to a practical plan for forming a network of marine reserves. The paper discusses: (1) the role of reserve network goals and criteria for identifying sites for marine reserves; (2) the scale (i.e. fine- and large-scale) at which surrogate measure of biodiversity can be applied and the relative importance of identification criteria in decision-making; and (3) provides guidance on the pragmatic implementation of marine reserve networks.

2. Marine reserve network establishment: translating theory into practice

There is growing recognition of a gap (the 'implementation gap') between scientific and theoretical approaches to reserve design, and their subsequent implementation (i.e. designation of networks of reserves) [58]. There are many conservation plans (see for example [29,30,58–66]), but achieving a systematically designed marine reserve network in the real world is more challenging. This is because implementation of conservation action must also address social, political and economic complexities of regional and local communities, in addition to the core goals of preserving biodiversity. This section discusses issues associated with implementing marine reserve networks in New South Wales (Australia) and New Zealand. In New South Wales the marine reserve network has been guided by national and regional conservation goals, site identification and selection criteria. New Zealand's approach until 2006 has been focused on iconic sites resulting in a scatter of marine reserve around the mainland [35]. The approach in New South Wales has been to establish large multiple-use marine parks that contain a network of marine reserves. In comparison, New Zealand's approach has been to establish small individual marine reserves around the mainland to comprise the network. In both cases there have been limitations with spatially defining and mapping biodiversity to support the creation of the marine reserve networks.

2.1. Implementing marine reserve network goals

In order to develop networks of marine reserves, many countries have established frameworks for marine conservation policy (see for example [22,23]). These frameworks attempt to translate broad political commitments for biodiversity conservation into goals and objectives for marine reserve network design to be implemented at national and regional scales. Conservation goals are typically broad, defining the outcome for the network as a whole. The goal of both New South Wales and New Zealand networks is to establish a comprehensive, adequate and representative system of marine protected areas that includes the full range of marine biodiversity at ecosystem, habitat and species levels [24,25].

The application of ecological and network design theory that was developed to meet national and regional goals may be difficult to implement at local scales [10], but it is at this scale that it is possible to identify the biodiversity features to be protected and the levels of protection that are needed. For example, while conservation goals that seek to protect all levels of biodiversity in marine reserves provide a vision for the network as a whole (see for example [22,23,25]), they do not provide conservation practitioners or stakeholders direction on the types of biodiversity features to be protected or of the levels of protection that are needed. Further work is needed in order for regional goals to be placed in a local context.

Conservation goals are an important factor in the successful implementation of networks of marine reserves. In 1991, Australia commenced developing a marine conservation program to guide the establishment of a network of marine protected areas (including marine reserves) [67]. Following this, New South Wales released a regional scale policy that outlined goals for conservation of marine biodiversity [24]. Prior to completion of the policy there were nine marine reserves covering approximately 710 ha (i.e. no-take sanctuary zones) (Fig. 1) [68]. Commencement of legislation (i.e. Marine Parks Act 1997) and completion of the policy led to the establishment of a further 65,129 ha of marine reserves (representing approximately 7% of state waters, which extends to three nautical miles offshore). The development of legislation, conservation policy and associated goals has been important in the rapid progress of implementing marine reserves in New South Wales over the last 6 years.

In contrast, New Zealand has had a long history (since 1971) of marine reserve establishment. Progress in New Zealand has been continuous since legislation (i.e. Marine Reserves Act 1971) was introduced in 1971 and the creation of Cape Rodney-Okakari Point (Leigh) Marine Reserve (518 ha) in 1975, but the system is considered to be far from adequate [35,69,70]. After 38 years of implementation there is approximately 32,775 ha of marine reserve around New Zealand's mainland (representing 0.2% of the mainland territorial sea, which extends to 12 nautical miles offshore) (Fig. 1) and 1,246,000 ha around remote offshore islands. A conservation policy to guide marine protected area network establishment has only recently been released [25]. The policy established conservation goals and guidelines for implementation of a network of marine protected areas with marine reserves as the centrepiece for biodiversity protection. A feature of the policy was the proposal to use a range of legislative tools (e.g. Marine

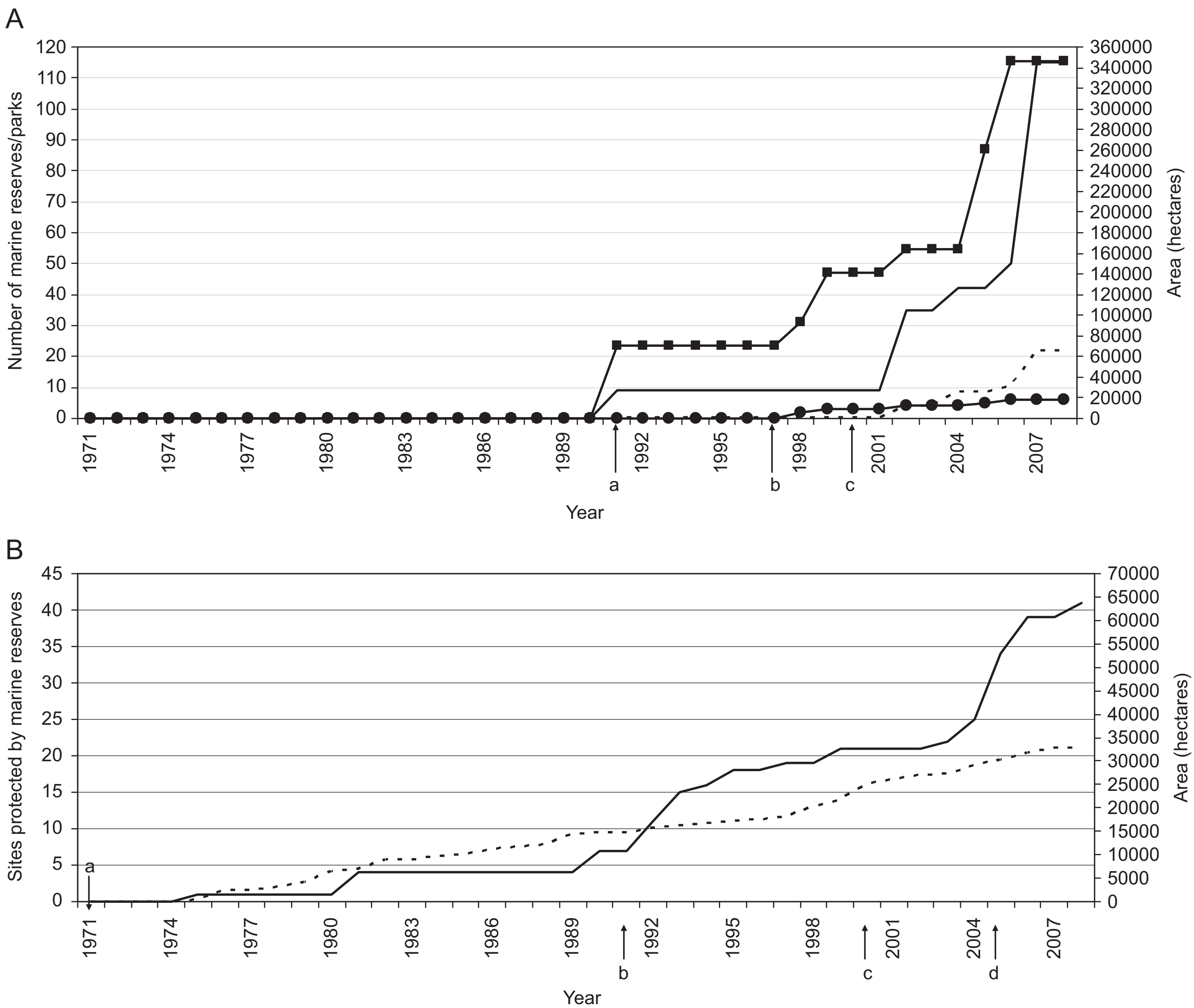

Fig. 1. Cumulative growth in marine reserves. (A) New South Wales (Australia)—number of marine reserves (no-take sanctuary zones) (solid line), total area of marine reserves (dashed line), number of multiple-use marine parks (solid line with dots) and total area of multiple-use marine parks (solid line with boxes). *Note*: (a) commencement of coordinated bioregional approach to MPA planning by Australian governments; (b) NSW Marine Parks Act 1997 commenced; and (c) release of New South Wales's MPA policy [24]. (B) New Zealand (excluding two large and remote offshore island marine reserves)—number of marine reserves (solid line) and total area of marine reserves (dashed line). *Note*: (a) Marine Reserve Act 1971 commenced; (b) commencement of bioregional approach to MPA planning collaboratively with Australia; (c) New Zealand Biodiversity Strategy released [23]; and (d) New Zealand's MPA Policy and Implementation plan released [25].

Reserves Act; Fisheries Act) to contribute to New Zealand's target of protecting 10% of the marine environment by 2010 [23,25]. Divergent stakeholder views exist on the proportion of this target that needs to be included in no-take marine reserves, compared with protection provided by other legislative tools.

2.2. The role of ecological criteria and planning principles

Specific ecological criteria and guidelines have been developed to bridge the gap between national and regional conservation goals and the implementation of marine reserves networks [12,71–74]. Criteria focused on ecological factors of the marine environment include representativeness, comprehensiveness, ecological importance, naturalness and biogeographic importance (Table 1). These criteria define the ecological factors that should be used to identify locations of ecological or biological importance [3,16,47,75,76], independent of region or political boundaries [35].

There are, however, significant challenges in obtaining information to assess these ecological criteria because they depend on the availability of data on the distribution, abundance and life histories of marine biota or at least on appropriate surrogate measures (Table 1). For example, a conservation practitioner assessing ecological importance of an area may require data about its importance for migration, breeding and feeding for a range of species (Table 1), information which is likely to be difficult to obtain. Similarly, ecological importance may also involve categorising a habitat as unique, which requires information on the extent and distribution of the habitat. It also depends on the scale (e.g. national, regional or local) at which the habitat is to be assessed as unique. Further work is required on the use of ecological criteria when data are absent

Table 1
Criteria for identification of marine reserve networks and their application using fine- and regional-scale surrogates measures for biotic diversity.

Criteria	Surrogates	
	Fine-scale (10–100 s of m)	Regional-scale (10–100s of km)
Representative—identify		
Representative ecosystem types	Yes	Yes
Representative habitat types	Yes	Assumed
Areas that contain the range of known species (ability to predict species distributions)	Assumed	Assumed
Representative examples of genetic diversity	Assumed	Assumed
Comprehensiveness—identify		
Biogeographic extent of ecosystems	Yes	Yes
Biogeographic extent of habitats	Yes	No
Ecological importance—identify		
Unique habitats	Yes	No
Areas important for spawning or nursery grounds	No	No
Areas important for migration	No	No
Areas important for feeding, breeding or rest areas	No	No
Areas that contain rare, threatened or depleted species	No	No
Threatened species habitats	Yes	No
Areas of high species diversity	Assumed	Assumed
Areas for depleted species and threatened ecological communities	Assumed	Assumed
Naturalness—identify		
Areas vulnerable to natural processes	Yes	Yes
Areas vulnerable to, or protected from human-induced change	Yes	Yes
Biogeographic importance—identify		
Rare biogeographic qualities	Yes	No
Unique or unusual geologic features	Yes	No
Application scale(s)	Site to regional	Regional to provincial
Application of surrogate to conservation planning—identify		
Sites at a local scale (10–100 s of m)	Yes	No
Locations at a regional scale (100–1000 s of km)	Yes	Yes
Replicate sites for habitat conservation within a region	Yes	Assumed
Condition or state as a result of ecological factors	No	No
Condition or state as a result of anthropogenic factors	Yes	No
Cost effectiveness		
Cost of mapping within bioregion(s)	Low-mod	Low-mod
Cost of mapping across multiple bioregions	Low-mod	Low-mod
Time required to collect information over large geographic areas	Mod	Low-mod

Source: [12,22,33,74,76,77,81,82,99].

or limited to enable conservation practitioners to use them effectively in design and implementation of marine reserve networks [48].

In an attempt to narrow the 'implementation gap', planning principles have been developed to define the ecological and scientific requirements of a reserve network (see for example [74,77,78]). These principles have been used in conjunction with ecological criteria (Table 1) with the aim of developing a more ecologically sound marine reserve network. For example, to support the rezoning of the Great Barrier Reef Marine Park, biophysical operational principles were developed to underpin the choice of the number, size and location of marine reserves that were incorporated in the zoning plan [74,75]. The biophysical operational principles were also supported by socio-economic operational principles, which sought to maximise biodiversity conservation with consideration of detrimental impacts to local communities and stakeholders [79]. The proposed marine reserves were publicly exhibited to provide stakeholders the opportunity to comment on the scale, location and potential impacts of the marine reserve proposals. The development of planning principles appears to have evolved as an alternative to ecological criteria that are often difficult to define or measure in practice. Conservation practitioners have used planning principles to translate ecological criteria into measurable principles that contribute to successful implementation of marine reserve networks.

2.3. Defining and mapping biodiversity

To establish networks of marine reserves, the marine landscape needs to be sub-divided into conservation features that can be mapped. Conservation features are most often defined and mapped using surrogate measures, which assume the distribution and abundance of biota is explained at regional and local scales by these surrogates [77,80–83]. It has been concluded that the true effectiveness of surrogates and their ability to predict biodiversity, between and within regions, will never be achieved [1,84]. This is because our knowledge of the marine environment is based on patchy and unrepresentative (i.e. in both time and space) information and limited in terms of details on the distribution, abundance and taxonomy of species [1,55,85]. This means that network design decisions and site selection is often made in the face of considerable uncertainty [86]. Choice of surrogates should be guided by the presumed effectiveness of the surrogate(s) in representing non-surrogate taxa (and processes), and based on the availability of data to define the surrogate in a cost-effective way [1]. Carefully selected and mapped biodiversity surrogates can assist conservation practitioners to identify sites for marine reserves, particularly where surrogates have the potential to be defined at local scales (10–100 s of m) and mapped across bioregional scales (100–1000 s of km) in a cost-effective way (see for example [82]).

Maps allow conservation features to be identified, located and described and their relative extent to be determined [84,87]. Knowing the type and extent of conservation features also helps understand how trade-offs amongst stakeholders will affect network implementation [10,28,88]. Maps also enable stakeholders to gain rapidly an enhanced understanding of the marine environment in which they have an interest, as well as contributing their knowledge in developing data sets to inform decision-making. Conservation features have been defined and mapped using (1) physical properties of the environment (i.e. environmental surrogates) [82,89]; (2) combinations of oceanographic and physical processes [90]; and (3) biophysical features that include physical properties and predicted or known distributions of species and other elements of the marine environment [48,74,77,91–93]. The quality and extent of information to support mapping is influenced by expense, time and the practicalities to obtain information in order to meet community and political timeframes for establishing marine reserve networks [37]. Maps of conservation features also enable the success of implementation of conservation goals to be measured and reported [87].

3. Key elements for successful implementation of marine reserve networks

To guide improvements to marine reserve planning and management four broad steps have been defined to support

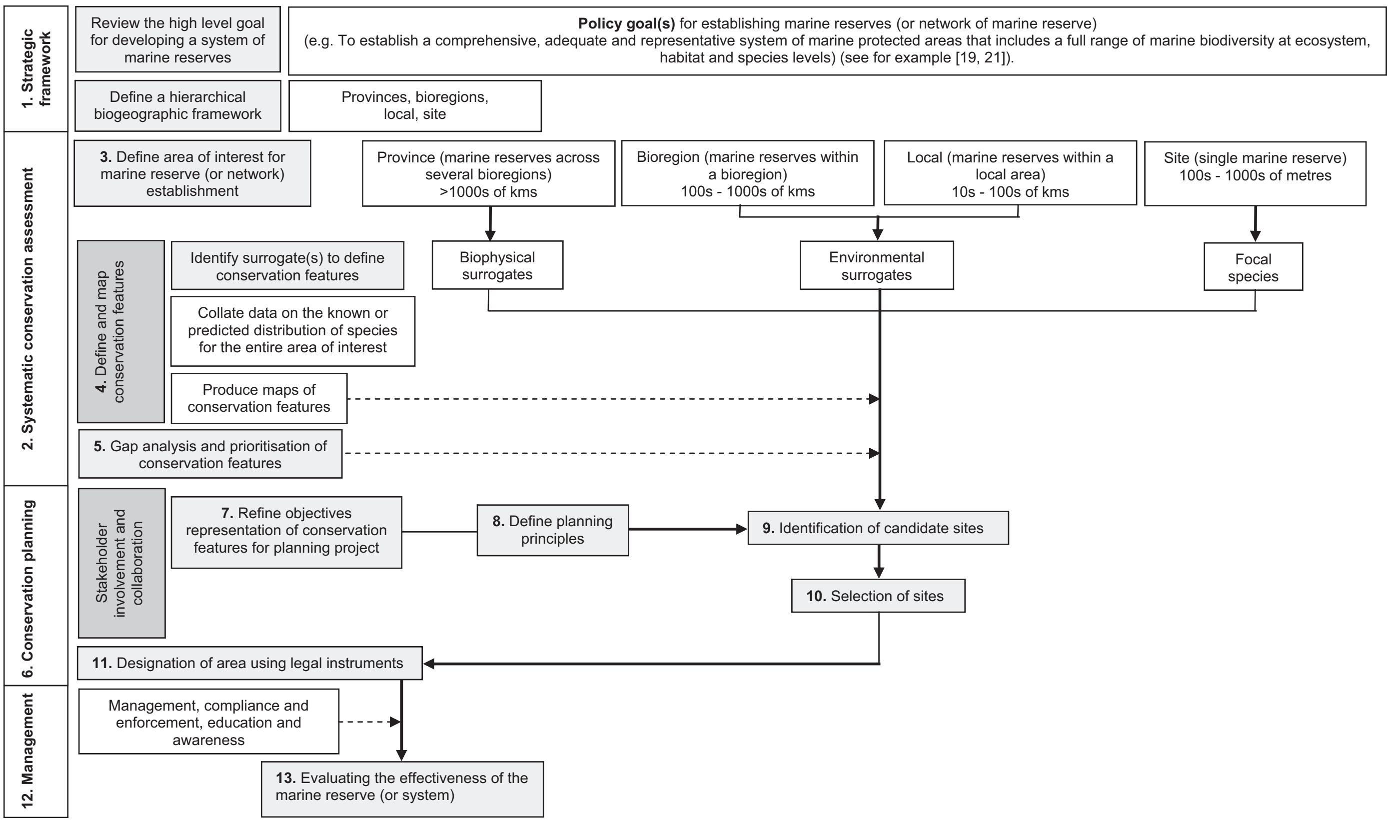

Fig. 2. Key steps to identify and select marine reserves.

implementation: (1) establish a strategic framework (i.e. defining goals and objectives of the network), (2) systematic conservation assessment (e.g. mapping biodiversity features, identifying gaps, network identification and design), (3) conservation planning (e.g. stakeholder involvement and collaboration, site selection, designation), and (4) management (e.g. compliance, monitoring, ensuring regulation of uses) (Fig. 2) [3,24,25,65,94–98]. However, despite guidance on steps to implement marine reserve networks, progress continues to be slow and fragmented [18,28,35,96]. This is because implementation of marine reserves generates opposition by stakeholders and local people that might be affected by their establishment and the restrictions placed on user behaviours [28,30,99–101]. In this paper, we discuss network establishment in New South Wales and New Zealand, and argue that there are four essential elements to successful implementation of marine reserve networks: (1) political and agency leadership, (2) dedicated marine conservation legislation, (3) information on natural and social sciences, and (4) processes for stakeholder involvement and collaboration. It is important that these elements are considered before embarking on a marine protection planning process.

3.1. Political and agency leadership

Implementation of marine reserve networks requires leadership and commitment at the political level and by the agencies responsible for their establishment [100–102]. As pressure on marine resources continues, the future of marine reserve network implementation will increasingly depend on a strengthening commitment of governments to protect the oceans and their commons [103], which has developed through countries ratifying commitments to international targets [13,14,19]. Implementation is often the responsibility of fisheries and/or conservation agencies that either have a primary mandate for fisheries management or terrestrial protected area management, with marine conservation as a secondary priority. A key factor required for success is there must be a willingness amongst these government agencies and decision-makers to protect marine ecosystems, habitats and species [103].

In Australia, the Commonwealth's marine protected areas program, which was developed in cooperation with State and Territory governments, was a factor that led to an initial increase in marine reserves in New South Wales and development of conservation policy and dedicated marine park legislation (Fig. 1) [22,24,28]. The momentum shifted towards establishment of reserves in the early 1990s after Australian governments made commitments to a national representative system of marine protected areas [22]. This demonstrated that where political will and leadership exists progress will be made. The importance of political will and commitment to implementation of marine reserves was further demonstrated, in New South Wales, where political leadership led to the declaration and zoning of two large multiple-use marine parks (i.e. Batemans and Port Stephens-Great Lakes marine parks) in less than 18 months. Prior to this it took on average approximately 4.5 years to develop a zoning plan following declaration of a marine park.

In contrast, New Zealand has not had a coordinated approach to marine reserve establishment until recently [25], despite having the necessary legislation in place since 1971. A factor that contributed to the slow progress in New Zealand has been the view that marine reserve implementation prevents the Ministry of Fisheries from taking action to provide for sustainable utilisation, as required by the Fisheries Act 1996 [104]. Rather than seeing marine reserves as part of ocean sustainability they have been viewed as impeding the potential for utilisation of resources. Thus, the situation exists that the government agency charged with the responsibility to maximise utilisation of marine resources is also asked to protect biodiversity in marine protected areas, or in the case of marine reserves in New Zealand, must provide concurrence to their establishment. This overlap in jurisdictional authority between and within government agencies is a factor hindering progress in marine reserve establishment [105]. It leads to greater difficulties with implementing a network of marine reserves and is based on fishing (both commercial, recreational and customary) being recognised as the main sector of the community to have a 'right' to the oceans. This must change to enable progress to be made and requires political and agency leadership to implement the necessary changes.

3.2. Dedicated marine reserve legislation

Legislation with a primary purpose of protecting marine biodiversity has been developed to protect single no-take marine reserves (see for example Marine Reserves Act 1971 (New Zealand)) or to establish large multiple-use marine parks that contain a network of marine reserves (see for example Marine Parks Act 1997 (New South Wales)). There has been considerable debate about the role of single no-take marine reserves versus marine protected areas that allow multiple-uses in biodiversity conservation [1]. There is a view that single no-take marine reserves are unlikely to achieve biodiversity goals alone [1,106]. The same might be said of poorly designed multiple-use marine parks though, especially where the no-take zones are of insufficient size to contribute to biodiversity protection goals. Implementation of networks using these approaches is either through recognising a collection of single marine reserves (possibly planned as a network) or as a network established by zoning a multiple-use marine park. Both approaches aim to achieve the broad aspirational goal of biodiversity conservation.

3.2.1. New Zealand: single no-take marine reserves

New Zealand has established no-take marine reserves (IUCN Category II [46]), using the Marine Reserves Act 1971, for the purpose of preserving areas in their natural state for scientific study. The network includes 31 marine reserves (protecting 37 sites) around mainland New Zealand and two large marine reserves surrounding remote offshore islands (Auckland Islands (498,000 ha); Kermadec Islands (3 sites protecting 748,000 ha)). The average size of the marine reserves (37 sites) around mainland New Zealand is 886 ha ranging in size from 20 to 2452 ha. The network consists of a collection of single marine reserves that have been established independently of each other. They protect iconic areas or areas of known scientific interest but have not been designed based on any systematic design criteria or principles.

There is a view that single marine reserves are considered to be rarely of adequate size or scope to be able to achieve conservation of marine biodiversity and there is a critical need to establish representative reserve networks [1]. There are, however, research findings that small single marine reserves may be effective in increasing local population size and protecting biodiversity (see for example [35,107–109]). The assumption used by those promoting reserve networks is that any positive effects from single reserves may be strengthened through a network of marine reserves systematically designed to include representative examples of ecosystems, habitats and species. Further research is required though to investigate the ecological changes resulting from a systematically designed network of marine reserves.

Despite marine reserves only protecting a small fraction of mainland New Zealand (0.2% of the territorial sea) there is a high level of opposition to their establishment from the fishing industry and many recreational fishers [104,105]. In order to develop a more systematic approach to marine biodiversity conservation and to increase stakeholder involvement and collaboration, the New Zealand government released a marine protected areas policy [25]. The objective of the policy was to develop a representative network of marine protected areas. The policy sought a broader approach to biodiversity conservation by recognising that other legislative tools might have a role in protecting some elements of biodiversity (e.g. benthic habitats). This approach establishes different levels of protection comparable to zones in multiple-use marine parks. However, in New Zealand it involves multiple pieces of legislation covering, for example, areas that do not have a biodiversity focus but are closed to some fishing methods using the Fisheries Act 1996 [104].

The New Zealand marine protected areas policy proposes the retro-fitting of the Fisheries Act and other legislative tools to biodiversity protection rather than the creation of dedicated legislation that accommodates multiple-uses. Such areas have been referred to as 'de facto' or ancillary marine protected areas [110]. There is little known about the effectiveness of these marine protected areas for protection of biodiversity (but see for example [111,112]). The use of a range of tools results in inconsistencies in application of legislative obligations for government agencies, which have led to disagreements about implementation of marine protected areas [104], slowing progress towards achieving conservation goals.

3.2.2. New South Wales: multiple-use marine parks

New South Wales has adopted a multiple-use approach to achieve the goals of a representative network of marine protected areas. Marine parks are established under the Marine Parks Act 1997, which provides a network of marine reserves (i.e. sanctuary zones equivalent to IUCN Category II [46]) within a marine park. The multiple-use approach establishes a management regime over a large area (New South Wales marine parks range in size from 22,000 to 97,200 ha) where biodiversity protection is a primary purpose. The implementation of marine reserves (i.e. sanctuary zones) representative of biotic/abiotic diversity is a core part of multiple-use marine parks.

Six marine parks have been established in New South Wales containing 115 individual marine reserves (i.e. individual sanctuary zones) with an average size of 573 ha. The size of the marine reserves ranges from 0.01 to 6580 ha. Approximately 60% of the marine reserves are smaller than 100 ha and 15% are larger than 1000 ha. It is unknown whether each individual marine reserve will protect marine biodiversity; however, it is assumed that the collection of marine reserves in a network will lead to biodiversity protection (see for example [113,114]). Further work is required to investigate the benefits of such an approach to marine biodiversity conservation (but see for example [115]).

3.3. Spatial information on natural and social features

Information on the natural and social features of an area is essential for implementation of marine reserve networks (see for example [30,63,97,102,116]). Spatial information on the natural features of an area would include, for example, maps of conservation features (e.g. ecosystems and habitats), species' distributions and features or locations important to marine species. This helps stakeholders gain a better understanding of: (1) the complexity and location of conservation features in the marine environment; and (2) the consequences of human influences on ecosystems, habitats and species [116]. Geographic information systems (GIS) are increasingly enabling the presentation of such information in a form that is readily understood by stakeholders and decision-makers. Involvement of stakeholders in deriving this information also provides the opportunity to gain additional data on the distribution of conservation features and areas important for commercial and recreational use (i.e. social features).

Spatial information on the natural and social features of an area, required to support implementation of marine reserves, has been difficult to obtain at local scales (10–100 s of m) in both New South Wales and New Zealand. This, however, has not impeded progress in making decisions about selection of areas for marine reserves. Available information has been collated and additional data obtained to assist decision-making. A key feature of both approaches has been an increasing use of GIS to present information on the spatial extent of habitats and the distribution of species to stakeholders and politicians. There remain considerable challenges with obtaining information on the spatial extent of habitats in the marine environment over large geographic areas. However, technological advances in mapping systems (e.g. side scan sonar, multi-beam sonar) are increasingly allowing shallow and deep water habitats to be mapped in a more cost-effective way [117]. Further work is required to develop these cost-effective approaches to map the spatial extent of habitats to support marine reserve selection.

Gathering information on social features (e.g. the location and effort of commercial and recreational fishing) at a local-scale is essential to evaluating the potential impacts of marine reserves on users. It also enables the reserve network design to be adjusted to minimise these impacts. In both New South Wales and New Zealand it has not been possible to include local-scale information on commercial fishing because such data are only available for administrative areas defined for fisheries management. These fisheries management areas are usually defined at regional scales (10–100 s of km) compared with marine reserves that are implemented at local scales. There is even less known about recreational fishing effort and the locations targeted by these users. In the absence of such information, commercial and recreational fishers are likely to continue to overstate the impacts of even small marine reserves on their activities and income. Describing the fishing effort and location of these activities is a significant challenge for marine reserve practitioners; however, it is also essential for further development and use of decision-support tools in the future. Establishing a requirement for commercial fishers to install vessel monitoring systems and to report accurately the location of their fishing activities will be increasingly essential for marine reserve network implementation. Similarly, developing reporting systems to help understand areas of importance to recreational fishing will assist planning.

3.4. Stakeholder involvement and collaboration

Collaboration and involvement of stakeholders is essential when planning the identification and selection of sites for marine reserves [30,97,118]. The challenge for conservation practitioners is striking a balance between achieving conservation policy goals and providing for access to marine resources. Conservation practitioners have adapted approaches to consultation and planning for the location of marine reserves by providing greater opportunity for stakeholders and local people to contribute to decisions on the location of marine reserves.

The location of marine reserves is as much about social sciences as it is about seeking representation of biodiversity. Implementing marine reserve networks will result in a change to, or restrictions on, behaviours, and such changes are challenged by some stakeholders [99]. It is well known that there will generally be polarised views towards marine reserve establishment (see for example [28]). An impediment to progress has been the debate, often led by a vocal minority opposed to the marine reserves, on placing restrictions on the 'right' of access to fishing resources [104,105]. To overcome such barriers, there has been recognition of the importance of collaboration and involvement of stakeholders in selecting areas for marine reserves and also mapping the distribution of different types of fishing [28,95,97,105,116,119]. Despite high levels of involvement and consultation with stakeholders to identify the location of marine reserves in New South Wales and New Zealand there are some stakeholders who will continue to oppose their establishment. Such opposition is something that is unlikely to change despite the efforts of conservation practitioners to provide all information, and involve and collaborate with stakeholders during site selection. Often dissatisfaction with outcomes, and a failure to understand consultative processes, is likely to lead to concerns from some stakeholders about the adequacy of consultation and decision-making [120].

While broad-based involvement of the community is essential to successful implementation of marine reserves, timely decisions on the location of marine reserves are also important. The establishment of marine reserves in New Zealand has followed lengthy and complex discussions. For example, it took 12 years to establish the first marine reserve, Cape Rodney-Okakari Point (Leigh) Marine Reserve (518 ha), and most recently Taputeranga Marine Reserve took close to 17 years to establish from when it was first mooted [121]. The length of time it has taken to establish marine reserves has resulted from many unhelpful side-tracks [35], additional consultation (required by the Ministry of Fisheries) with stakeholders, and changing views in communities including a diminishing of support in some cases. Following establishment, marine reserves have been found though to be socially popular and scientifically useful in conservation terms [35]. A lack of political commitment and agency leadership is likely to be a key factor in these lengthy processes to establish marine reserves in New Zealand.

In New South Wales it has taken between 14 months to 6 years to implement a network of marine reserves (i.e. sanctuary zones) following declaration of a multiple-use marine park. On average, the development of a zoning plan following establishment of a marine park has taken 3.5 years. Implementing a network involves extensive consultation with stakeholders on an advisory committee, which precedes a 3 month statutory consultation period. During the statutory consultation period, conservation practitioners hold further stakeholder meetings and open days for the general community to gain an understanding of the marine reserve network. There is also extensive media coverage of the proposals for a network of marine reserves.

Despite extensive efforts by conservation practitioners to gain an understanding of the potential impacts of different marine reserve network proposals there is often a minority of stakeholders who do not support any closures to fishing. Opposition to marine reserves can be disguised, by opponents, as requests for delays to their establishment until their effectiveness is proven in the local area or region. Further research on the effectiveness of marine reserves is important. However the need to do this in every part of the world and for every type of ecosystem/habitat is not necessary as the ecological benefits of marine reserves have been demonstrated in many areas (see for example [107,108,111,122]). Following implementation of a network of marine reserves there has been a high level of support from residents and users that live adjacent to the marine parks [123,124].

4. Progressing implementation of marine reserve networks

Increasing political commitment to progress establishment of marine reserve networks requires conservation practitioners to build urgently further understanding by politicians of the practical issues associated with implementation. Politicians need to accept that a minority of users will not support any restrictions on their activities no matter how much stakeholder collaboration and consultation occurs, but effective stakeholder participation in marine reserve network design is crucial and can reduce the size of this minority and support political will to designate such networks in the face of objections. Other issues that politicians should understand include the need to make timely decisions on the location of marine reserves and ensuring a separation of fisheries management and conservation in the agency mandated to implement a marine reserve network.

Making final decisions on the location of marine reserves in a timely manner, and following an extensive consultation program is essential to ensure support for their establishment does not diminish. It is essential to help politicians understand that there are likely to be minimal and only short-term political consequences of their decisions. For example the broad support shown by the community to networks of marine reserves in the Jervis Bay and Solitary Islands marine parks [123,124] demonstrated that over longer timeframes communities and stakeholders broadly accept that marine reserves are important for biodiversity conservation. To further assist politicians evaluate support or opposition to marine reserve networks additional research on community views following their implementation is needed.

Politicians and agency leaders need to ensure there is a clear separation of fisheries/stock management and conservation responsibilities in decision-making related to the establishment of marine reserve networks. Fisheries management agencies should not have a decision-making role in determining the location of marine reserves where the primary goal of these reserves is biodiversity conservation due to a divergence of goals [125]. Involvement of fisheries management agencies in marine reserve decision-making leads to confusion over trying to implement conflicting objectives for biodiversity conservation compared with promoting utilisation of fish stocks. A single agency should be mandated to implement marine reserve networks, develop policy and legislation, define and map biodiversity features, engage and collaborate with stakeholders and advise politicians on site selection. A good example of such a model is the Great Barrier Reef Marine Park Authority (the Authority), which is mandated for management of the Great Barrier Reef Marine Park. The Authority has used an ecosystem-based approach to management with a primary purpose of biodiversity conservation [120].

The development of dedicated marine conservation legislation for marine reserve network implementation is more likely to lead to progress than using a collection of legislative tools that do not have biodiversity conservation as a primary purpose. Through this legislation it can be made clear that there is a separation of the biodiversity conservation goals from those of fisheries management, which can then be implemented through an appropriately mandated agency. From the analysis here it appears that legislation for multiple-use marine parks is likely to result in more rapid progress towards achieving conservation goals than legislation for single no-take marine reserves. Conservation practitioners should aim to develop dedicated marine conservation legislation that clearly defines the purpose, consultation process and management arrangements to secure biodiversity protection.

Spatial information on the natural environment and patterns of use by stakeholders will become increasingly important in the future. New technology will enable habitats to be mapped in increasingly cost-effective ways. Further research should be undertaken to develop approaches to broad-scale habitat mapping. Whilst such research is occurring, conservation practitioners should continue to gather and use existing information to build an understanding of the spatial extent of habitats using cost-effective approaches (e.g. new technology, surrogates measures). Completing mapping of the spatial extent of habitats over large geographic areas should not be a factor that delays the decision-making process.

There is an urgent need to develop requirements for commercial fishers to install vessel monitoring systems or similar reporting mechanisms. This would lead to accurate reporting of the location of fishing activities at fine spatial scales. Similarly, developing reporting systems or surveys to help understand areas important for recreational fishing will be increasingly important. In the absence of fine-scale spatial information on commercial and recreational fishing activities there is likely to be a continued over statement of the impacts of a marine reserves on fishing. Knowing the spatial extent of fishing activities would provide evidence for conservation practitioners to assess the potential impacts of marine reserves on these users. This would reduce the reliance on anecdotal evidence provided by fishers themselves, who may be philosophically opposed to marine reserve establishment due to perceived effects on their 'right' to access all areas for resource extraction and because of their motivation to maximise potential compensation for perceived displacement. This information will also support the use of decision-support tools in the future. Further research should focus on cost-effective ways to obtain accurate information on the location and effort of commercial and recreational activities. A participative approach to stakeholder involvement in designing a network of marine reserves also provides a good basis for mapping various commercial and recreational activities.

5. Conclusion

There is no easy solution to the implementation of marine reserve networks. The marine environment is a common resource that is over-exploited by many parties with little or no accountability for continuing degradation [126]. Polarised views of stakeholders, inconsistencies in legislation and lack of political and agency leadership will mean that implementation of marine reserve networks is likely to continue to be slow and fragmented. At the same time, fisheries can be expected to decline from over-exploitation and failure of management systems (see for example [127]), and habitats will continue to be degraded. The future of marine reserve network implementation requires further integration of marine conservation policy, science and decision-making. This requires political commitment and strong agency leadership, dedicated marine conservation legislation and information on the spatial extent and effort of commercial and recreational fishing. This should lead to increased resources to better define conservation features, sound consultation processes to engage stakeholders in site selection, and timely decisions by agencies and politicians. These factors will also assist conservation practitioners to overcome philosophical opposition to marine reserves which should enable more rapid progress on implementation.

Acknowledgements

We would like to thank Professor Hugh Possingham and an anonymous reviewer for providing useful comments on this manuscript. We thank Dr Rodney James and Greg West for providing information on marine parks for New South Wales and Ann McCrone for proving information on marine reserves in New Zealand.

References

[1] Possingham HP, Wilson KA, Andelman SJ, Vynne CH. Protected areas: goals, limitations and design. In: Groom MJ, Meffe GK, Carroll CR, editors.

Principles of conservation biology, 3rd ed.. Sunderland, MA: Sinauer Associates Inc.; 2006. p. 509–33.
[2] Grantham HS, Moilanen A, Wilson KA, Pressey RL, Rebelo TG, Possingham HP. Diminishing return on investment for biodiversity data in conservation planning. Conservation Letters 2008;1:190–8.
[3] Kelleher G. Guidelines for marine protected areas. World commission on protected areas. Best practice protected area guidelines series no. 3. Gland, Switzerland: IUCN-The World Conservation Union; 1999 107pp.
[4] Kripke A, Fujita RM. Marine reserve design considerations. Oakland, CA: Environmental Defense Fund; 1999 10pp.
[5] Tuck GN, Possingham HP. Marine protected areas for spatially structured exploited species. Marine Ecology Progress Series 2000;192:89–101.
[6] Gerber LR, Botsford LW, Hastings A, Possingham HP, Gaines SD, Palumbi SR, et al. Population models for marine reserve design: a retrospective and prospective synthesis. Ecological Applications 2003;13(1):S110–18.
[7] Claudet J, Osenberg CW, Benedetti-Cecchi L, Domenici P, Garcia-Charton J, Perez-Ruzafa A, et al. Marine reserves: size and age do matter. Ecology Letters 2008;11:481–9.
[8] World Resources Institute. Global biodiversity strategy. Washington, DC: WRI; 1992.
[9] Halpern BS, Warner RR. Matching marine reserve design to reserve objectives. Proceedings of the Royal Society of London B 2003;270:1871–8.
[10] Lubchenco J, Palumbi SR, Gaines SD, Andelman S. Plugging a hole in the ocean: the emerging science of marine reserves. Ecological Applications 2003;13:S3–7.
[11] Secretariat of the Convention of Biological Diversity. Technical advice on the establishment and management of a national system of marine and coastal protected areas, SCBD. CBD technical series no. 13; 2004. 40 pp.
[12] Kelleher G, Bleakley C, Wells SC, editors. A global representative system of marine protected areas: Antarctic, Artic, Mediterranean, Northwest Atlantic and Baltic. Washington, DC: The International Bank for Reconstruction/The World Bank; 1995 212pp.
[13] United Nations. Draft plan of implementation of the World Summit on Sustainable Development. Report no.: A/CONF.199/L.1, Johannesburg, United Nations, 2002.
[14] United Nations. Report of the World Summit on sustainable development. Report no.: A/CONF.199/20, Johannesburg, United Nations, 2002.
[15] IUCN. Recommendations of the Vth IUCN World Parks Congress. Gland, Switzerland: IUCN; 2003 85 pp.
[16] Laffoley Dd'A, editor. Towards networks of marine protected areas. The MPA plan of action for IUCN'S world commission on protected areas. Gland, Switzerland: IUCN WCPA; 2008 28pp.
[17] Wood LJ, Dragicevic S. GIS-based multicriteria evaluation and fuzzy sets to identify priority sites for marine protection. Biodiversity and Conservation 2007;16:2539–58.
[18] Wood LJ, Fish L, Laughren J, Pauly D. Assessing progress towards global marine protection targets: shortfalls in information and action. Oryx 2008;42(3):340–51.
[19] Convention on Biological Diversity. Decisions adopted by the conference of the parties to the convention on biological diversity at it's eighth meeting (Decision VIII/15, Annex IV). Convention on Biological Diversity, Curitiba, Brazil, 2006.
[20] Agardy T, Bridgewater P, Crosby MP, Day J, Dayton PK, Kenchington R, et al. Dangerous targets? Unresolved issues and ideological clashes around marine protected areas. Aquatic Conservation: Marine and Freshwater Ecosystems 2009;13:353–67.
[21] Mercier M, Mondor C. Sea to sea to sea: Canada's national marine conservation areas system plan. Parks Canada, 1995. 106 pp.
[22] Australian and New Zealand Environment and Conservation Council. Strategic plan of action for the national representative system of marine protected areas: a guide for action by Australian governments. Canberra, Australia: Australian and New Zealand Environment and Conservation Council Task Force on Marine Protected Areas, Environment Australia; 1999. 80 pp.
[23] Anonymous. The New Zealand biodiversity strategy: our chance to turn the tide. Department of Conservation and Ministry for the Environment, Wellington, New Zealand, 2000. 144pp.
[24] NSW Fisheries, NSW National Parks and Wildlife Service, NSW Marine Parks Authority. Developing a representative system of marine protected areas—an overview. Sydney, Australia: NSW Government; 2000. 33 pp.
[25] Department of Conservation and Ministry of Fisheries. Marine protected areas policy and implementation plan. Wellington, New Zealand, 2005. 24 pp.
[26] Tisdell C, Broadus JM. Policy issues related to the establishment and management of marine reserves. Coastal Management 1989;17:37–53.
[27] Roff JC. Conservation of marine biodiversity: too much diversity, too little cooperation. Aquatic Conservation: Marine and Freshwater Ecosystems 2005;15:1–5.
[28] Wescott G. The long and winding road: the development of a comprehensive, adequate and representative system of highly protected marine protected areas in Victoria, Australia. Ocean & Coastal Management 2006;49:905–22.
[29] Klein C, Chan A, Kircher L, Cundiff AJ, Gardner N, Hrovat Y, et al. Striking a balance between biodiversity conservation and socioeconomic viability in the design of marine protected areas. Conservation Biology 2007;22(3): 691–700.
[30] Klein CJ, Steinback C, Scholz AJ, Possingham HP. Effectiveness of marine reserve networks in representing biodiversity and minimising impact to fisherman: a comparison of two approaches used in California. Conservation Letters 2008;1:44–51.
[31] Partnerships for Interdisciplinary Studies of Coastal Oceans. The science of marine reserves, 2nd ed., International Version. 〈www.piscoweb.org〉; 2007. 22 pp.
[32] Kenchington RA, Bleakley C. Identifying priorities for marine protected areas in the insular Pacific. Marine Pollution Bulletin 1994;29:3–9.
[33] Ward TJ, Vanderklift MA, Nicholls AO, Kenchington RA. Selecting marine reserves using habitats and species assemblages as surrogates for biological diversity. Ecological Applications 1999;9(2):691–8.
[34] Boersma PD, Parrish JK. Limiting abuse: marine protected areas, a limited solution. Ecological Economics 1999;31:287–304.
[35] Ballantine WJ, Langlois TJ. Marine reserves: the need for systems. Hydrobiologia 2008;606:35–44.
[36] Mace GM, Balmford A, Boitani L, Cowlishaw G, Dobson AP, Faith DP, et al. It's time to work together and stop duplicating conservation efforts. Nature 2000;405:393.
[37] Pressey RL. Conservation planning and biodiversity: assembling the best data for the job. Conservation Biology 2004;18(6):1677–81.
[38] Rodrigues ASL, Brooks TM. Shortcuts for biodiversity conservation planning: the effectiveness of surrogates. The Annual Review of Ecology, Evolution, and Systematics 2007;38:713–37.
[39] Zacharias MA, Roff JC. Zacharias and Roff vs. Solomon et al.: who adds more value to marine conservation efforts?. Conservation Biology 2001;15(5): 1456–8.
[40] Sarkar S, Margules C. Operationalizing biodiversity for conservation planning. Journal of Biosciences 2002;27(4):S299–308 [Supplement 2].
[41] Sarkar S, Justus J, Fuller T, Kelley C, Garson J, Mayfield M. Effectiveness of environmental surrogates for the selection of conservation area networks. Conservation Biology 2004;19(3):815–25.
[42] Williams P, Faith D, Manne L, Sechrest W, Preston C. Complementarity analysis: mapping the performance of surrogates for biodiversity. Biological Conservation 2006;128:253–64.
[43] Post AL. The application of physical surrogates to predict the distribution of marine benthic organisms. Ocean & Coastal Management 2008;51:161–79.
[44] IUCN/WCMC. Guidelines for protected area management categories. Gland, Switzerland: IUCN; 1994.
[45] Halpern BS, Regan HM, Possingham HP, McCarthy MA. Accounting for uncertainty in marine reserve design. Ecology Letters 2006;9:2–11.
[46] Dudley N, editor. Guidelines for applying protected area management categories. Gland, Switzerland: IUCN-The World Conservation Union; 2008 86pp.
[47] Roberts CM, Branch G, Bustamante RH, Castilla JC, Dugan J, Halpern BS, et al. Application of ecological criteria in selecting marine reserves and developing reserve networks. Ecological Applications 2003;13(1):S215–28.
[48] Beger M, McKenna SA, Possingham HP. Effectiveness of surrogate taxa in the design of coral reef reserve systems in the Indo-Pacific. Conservation Biology 2007;21(6):1584–93.
[49] Young OR, Osherenko G, Ekstrom J, Crowder LB, Ogden J, Wilson JA, et al. Solving the crisis in ocean governance place-based management of marine ecosystems. Environment 2007;49(4):22–32.
[50] Gray JS. Marine biodiversity: patterns, threats and conservation needs. Biodiversity and Conservation 1997;6(1):153–75.
[51] Sarkar S, Pressey RL, Faith DP, Margules CR, Fuller T, Stoms DM, et al. Biodiversity conservation planning tools: present status and challenges for the future. Annual Review of Environment and Resources 2006;31:123–59.
[52] Zacharias MA, Roff JC. A hierarchical ecological approach to conserving marine biodiversity. Conservation Biology 2000;14:1327–34.
[53] Pressey RL, Ferrier S. Types, limitations and uses of geographic data in conservation planning. The Globe 1995;41:45–52.
[54] Schoch GC, Dethier MN. Scaling up: the statistical linkage between organismal abundance and geomorphology on rocky intertidal shorelines. Journal of Experimental Marine Biology and Ecology 1996;201:37–72.
[55] Ferrier S. Biodiversity data and reserve selection: making best use of incomplete information. In: Pigram JJ, Sundell RC, editors. National parks and protected areas: selection, delimitation and management. Armidale: Centre for Water Policy Research, University of New England; 1997. p. 315–29.
[56] Ferrier S. Mapping spatial pattern in biodiversity for regional conservation planning: where to from here?. Systematic Biology 2002;51(2):331–63.
[57] Gladstone W. The potential value of indicator groups in the selection of marine reserves. Biological Conservation 2002;104:211–20.
[58] Knight AT, Cowling RM, Rouget M, Balmford A, Lombard AT, Campbell BM. Knowing but not doing: selecting priority conservation areas and the research-implementation gap. Conservation Biology 2008;22(3):610–17.
[59] Possingham HP, Ball I, Andelman S. Mathematical methods for identifying representative reserve networks. In: Feron S, Burgman M, editors. Quantitative methods for conservation biology. New York: Springer; 2000. p. 291–305.
[60] Leslie H, Ruckelshaus M, Ball IR, Andelman S, Possingham HP. Using siting algorithms in the design of marine reserve networks. Ecological Applications 2003;13(Suppl. 1):S185–98.
[61] Stewart RR, Noyce T, Possingham HP. Systematic marine reserve design: the opportunity cost of ad hoc decisions. Marine Ecology Progress Series 2003;253:25–38.

[62] Banks SA, Skilleter GA, Possingham HP. Intertidal habitat conservation—identifying conservation targets in the absence of detailed biological information. Aquatic Conservation: Marine and Freshwater Ecosystems 2005;15:271–88.
[63] Stewart RR, Possingham HP. Efficiency, costs and trade-offs in marine reserve system design. Environmental Modeling and Assessment 2005;10: 203–13.
[64] Banks SA, Skilleter GA. The importance of incorporating fine-scale habitat data into the design of an intertidal reserve system. Biological Conservation 2007;138:13–29.
[65] Knight AT, Smith RJ, Cowling RM, Desmet PG, Faith DP, Ferrier S, et al. Improving the key biodiversity areas approach for effective conservation planning. BioScience 2007;57(3):256–61.
[66] Leathwick J, Moilanen A, Francis M, Elith J, Taylor P, Julian K, et al. Novel methods for the design and evaluation of marine protected areas in offshore waters. Conservation Letters 2008;1:91–102.
[67] Ray GC, McCormick-Ray MG. Marine and estuarine protected areas: a strategy for a national representative system within Australian coastal and marine environments. Report for the Australian National Parks and Wildlife Service, Canberra, 1992. 52 pp.
[68] Clayton D. Solitary Islands marine reserve: a guide to recreational and commercial use of the marine reserve. Coffs Harbour, Australia: NSW Agriculture & Fisheries; 1991 40pp.
[69] Walls K. Leigh marine reserve, New Zealand. PARKS 1998;8(2):5–10.
[70] Shears NT, Smith F, Babcock RC, Duffy CAJ, Villouta E. Evaluation of biogeographic classification schemes for conservation planning: application to New Zealand's coastal marine environment. Conservation Biology 2008;22(2):467–81.
[71] Kenchington RA. Establishing a framework for management. Managing marine environments. New York: Taylor & Francis; 1990 p. 60–93.
[72] Salm R, Price A. Selection of marine protected areas. In: Gubbay S, editor. Marine protected areas: principles and techniques for management. London: Chapman & Hall; 1995. p. 15–30.
[73] Done TJ, Reichelt RE. Integrated coastal zone and fisheries ecosystem management: generic goals and performance indices. Ecological Applications 1998;8(1):S110–18.
[74] Fernandes L, Day J, Lewis A, Slegers S, Kerrigan B, Breen D, et al. Establishing representative no-take areas in the great barrier reef: large-scale implementation of theory on marine protected areas. Conservation Biology 2005;19(6):1733–44.
[75] Roberts CM, Andelman S, Branch G, Bustamante RH, Castilla JC, Dugan J, et al. Ecological criteria for evaluating candidate sites for marine reserves. Ecological Applications 2003;13(1):S199–14.
[76] National Marine Protected Areas Center. Revised draft framework for developing the national system of marine protected areas. Maryland: NOAA's Office of Ocean and Coastal Resource, Silver Spring; 2008 39pp.
[77] Day J, Fernandes L, Lewis A, De'ath G, Slegers S, Barnett B, et al. The representative areas program for protecting biodiversity in the great barrier reef world heritage area. In: Kasim Moosa M, Soemodihardjo S, Soegiarto A, Romimohtarto K, Nontji A, Soekarno, Suharsono, editors. World coral reefs in the new millennium: bridging research and management for sustainable development. In: Proceedings of the ninth international coral reef symposium, October 2000. Ministry for the Environment, Indonesian Institute of Sciences, International Society for Reef Studies, Bali, Indonesia, 2002.
[78] Queensland Government. Have your say Moreton Bay Marine Park. Draft zoning plan including regulatory impact statement and draft public benefits test. Brisbane: Environmental Protection Agency; 2007. 125 pp.
[79] Great Barrier Reef Marine Park Authority. Social, economic, cultural and management feasibility operational principles. Representative Areas Program background and history. Technical information sheet #7, 2002. 2 pp.
[80] Margules CR, Nicholls AO, Pressey RL. Selecting networks of reserves to maximise biological diversity. Biological Conservation 1988;43:63–76.
[81] Zacharias MA, Roff JC. Explanations of patterns of intertidal diversity at regional scales. Journal of Biogeography 2001;28:471–83.
[82] Banks SA, Skilleter GA. Mapping intertidal habitats and an evaluation of their conservation status in Queensland, Australia. Ocean & Coastal Management 2002;45:485–509.
[83] Stevens T, Connolly RM. Local-scale mapping of benthic habitats to assess representation in a marine protected area. Marine and Freshwater Research 2005;56:111–23.
[84] Flather CH, Wilson KR, Dean DJ, McComb WC. Identifying gaps in conservation networks: of indicators and uncertainty in geographic-based analysis. Ecological Applications 1997;7(2):531–42.
[85] Harris J, Haward M, Jabour J, Woehler E. A new approach to selecting marine protected areas (MPAs) in the Southern Ocean. Antarctic Science 2007;19(2):189–94.
[86] Ludwig D, Hilborn R, Walters C. Uncertainty, resource exploitation, and conservation: lessons from history. Science 1993;260(5104):17–36.
[87] Pressey RL, Bedward M. Mapping the environment at different scales: benefits and costs for nature conservation. In: Margules CR, Austin MP, editors. Nature conservation: cost effective biological surveys and data analysis. Australia: CSIRO; 1991. p. 7–13.
[88] Shafer CL. National park and reserve planning to protect biological diversity: some key elements. Landscape and Urban Planning 1999;44:123–53.
[89] Dethier MN. Classifying marine and estuarine natural communities: an alternative to the Cowardin System. Natural Areas Journal 1992;12(2):90–100.
[90] Zacharias MA, Howes DE. An analysis of marine protected areas in British Columbia using a marine ecological classification. Natural Areas Journal 1998;18:4–13.
[91] Valesini FJ, Clarke KR, Eliot I, Potter IC. A user-friendly quantitative approach to classifying nearshore marine habitats along a heterogeneous coast. Estuarine, Coastal and Shelf Science 2003;57:163–77.
[92] Valesini FJ, Potter IC, Clarke KR. To what extent are the fish compositions at nearshore sites along a heterogeneous coast related to habitat types?. Estuarine, Coastal and Shelf Science 2004;60:737–54.
[93] Gladstone W, Alexander T. A test of the higher-taxon approach in the identification of candidate sites for marine reserves. Biodiversity and Conservation 2005;14:3151–68.
[94] Thackway R. Approaches taken in identifying and selecting terrestrial protected areas in Australia as part of the national reserve system. In: Thackway R, editor. Developing Australia's representative system of marine protected areas: criteria ands guidelines for identification and selection. Proceedings of a technical meeting held at the South Australian Aquatic Sciences Centre, West Beach, Adelaide, 22–23 April 1996. Department of the Environment, Sport and Territories, Canberra; 1996. p. 34–44.
[95] Lundquist CJ, Granek EF. Strategies for successful marine conservation: integrating socioeconomic, political, and scientific factors. Conservation Biology 2005;19(6):1771–8.
[96] Knight AT, Cowling RM, Campbell BM. An operational model for implementing conservation action. Conservation Biology 2006;20(2):408–19.
[97] Gilliland PM, Laffoley D. Key elements and steps in the process of developing ecosystem-based marine spatial planning. Marine Policy 2008;32:787–96.
[98] Pressey RL, Bottrill MC. Opportunism, threats, and the evolution of systematic conservation planning. Conservation Biology 2008;22(5):1340–5.
[99] Airame S, Dugan JE, Lafferty KD, Leslie H, McArdle DA, Warner RR. Applying ecological criteria to marine reserve design: a case study from the California Channel Islands. Ecological Applications 2003;13(1):S170–84.
[100] Jentoft S, van Son TC, Bjorkan M. Marine protected areas: a governance system analysis. Human Ecology 2007;35:611–22.
[101] Weible CM. Caught in a maelstrom: implementing California marine protected areas. Coastal Management 2008;36:350–73.
[102] Ehler C. Conclusions: benefits, lessons learned, and future challenges of marine spatial planning. Marine Policy 2008;32:840–3.
[103] Agardy T. Creating havens for marine life. Issues in Science and Technology 1999;16(1):37–44.
[104] Bess R, Rallapudi R. Spatial conflicts in New Zealand fisheries: the rights of fishers and protection of the marine environment. Marine Policy 2007;31:719–29.
[105] Cocklin C, Craw M, McAuley I. Marine reserves in New Zealand: use rights, public attitudes, and social impacts. Coastal Management 1998;26: 213–231.
[106] Reid WV. Beyond protected areas: changing perceptions of ecological management objectives. In: Szaro R, Johnston DW, editors. Biodiversity in managed landscapes: theory and practice. Washington, DC: Oxford University Press; 1996. p. 442–53.
[107] Babcock RC, Kelly S, Shears NT, Walker JW, Willis TJ. Changes in community structure in temperate marine reserves. Marine Ecology Progress Series 1999;189:125–34.
[108] Shears NT, Babcock RC. Continuing trophic cascade effects after 25 years of no-take marine reserve protection. Marine Ecology Progress Series 2003;246:1–16.
[109] Parsons DM, Shears NT, Babcock RC, Haggitt TR. Fine-scale habitat change in a marine reserve, mapped using acoustically positioned video transects. Marine and Freshwater Research 2004;55:257–65.
[110] National Marine Protected Areas Center. In: Grober-Dunsmore R, Woonick L, editors. State of the Nation's de facto marine protected areas. Maryland: Silver Spring; 2008. 84 pp.
[111] Shears NT, Grace RV, Usmar NR, Kerr V, Babcock RC. Long-term trends in lobster populations in a partially protected vs. no-take Marine Park. Biological Conservation 2006;132:222–31.
[112] Lester SE, Halpern BS. Biological responses in marine no-take reserves versus partially protected areas. Marine Ecology Progress Series 2008;367:49–56.
[113] Roberts CM, Bohnsack JA, Gell F, Hawkins JP, Goodridge R. Effects of marine reserves on adjacent fisheries. Science 2001;294:1920–3.
[114] Russ GR, Cheal AJ, Dolman AM, Emslie MJ, Evans RD, Miller I, et al. Rapid increase in fish numbers follows creation of world's largest marine reserve network. Current Biology 2008;18(12):514–15.
[115] Butcher PA, Boulton AJ, Smith SDA. Mud crab (Scylla serrata: Portunidae) populations as indicators of the effectiveness of estuarine marine protected areas. World Congress on Aquatic Protected Areas Proceedings 2002:421–7.
[116] Pomeroy R, Douvere F. The engagement of stakeholders in the marine spatial planning process. Marine Policy 2008;32:816–22.
[117] Jordon A, Lawler M, Halley V, Barrett N. Seabed habitat mapping in the Kent group of islands and its role in marine protected area planning. Aquatic Conservation: Marine and Freshwater Ecosystems 2005;15:51–70.
[118] Mize J. Lessons in State implementation of marine reserves: California's Marine life protection act initiative. Environmental Law Reporter 2006;36(5):10376–91.

[119] Compas E, Clarke B, Cutler C, Daish K. Murky waters: media reporting of marine protected areas in South Australia. Marine Policy 2007;31:691–7.
[120] Commonwealth of Australia. Conserving Australia: Australia's national parks, conservation reserves and marine protected areas. Senate report: Standing Committee on Environment, Communications, Information Technology and the Arts, Canberra, Australia, 2007. 354 pp.
[121] Pande A, Gardner JPA. A baseline biological survey of the proposed Taputeranga Marine Reserve (Wellington, New Zealand): spatial and temporal variability along a natural environmental gradient. Aquatic Conservation: Marine and Freshwater Ecosystems 2009;19:237–48.
[122] Pande A, Macdiarmid AB, Smith PJ, Davidson RJ, Cole RG, Freeman D, et al. Marine reserves increase the abundance and size of blue cod and rock lobster. Marine Ecology Progress Series 2008;366:147–58.
[123] Anonymous. Jervis Bay Marine Park community Survey–final report. McGregor Tan Research. Report prepared for New South Wales Marine Parks Authority, Sydney, Australia, 2008. 119 pp.
[124] Anonymous. Solitary Islands Marine Park community Survey–final report. McGregor Tan Research. Report prepared for New South Wales Marine Parks Authority, Sydney, Australia, 2008. 122 pp.
[125] Jones PJS. Point-of-view: arguments for conventional fisheries management and against no-take marine protected areas: only half the story?. Reviews in Fish Biology and Fisheries 2007;17:31–43.
[126] Gravestock P, Roberts CM, Bailey A. The income requirements of marine protected areas. Ocean & Coastal Management 2008;51:272–83.
[127] Quentin Grafton R, Kompas T, McLoughlin R, Rayns N. Benchmarking fisheries governance. Marine Policy 2007;31:470–9.