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10 Geographic Information Tools for Fine Scale Planning in the Cape Byron Marine Park

"How do you know how much to pay if you don't know what it's worth?"

Peter Carey (2006) 'Theft.' Random House, Sydney, Australia.

10.1 Introduction

Planning for marine conservation often involves many ecological and social objectives. Multiple use, marine protected areas (MPAs) aim to manage for many different species, ecosystem processes and human activities. An open and accountable planning process aims to use the best available scientific information to address these goals and to fully involve the knowledge and input of local communities. However collecting and making use of such information is challenging, especially for a wide audience of managers, stakeholders and communities.

The previous chapter discussed a systematic approach to plan the establishment of a broad scale network of MPAs in the state of NSW, Australia. This chapter describes how systematic assessments and participatory GIS (Geographic Information Systems) were used in fine scale planning for the Cape Byron Marine Park. GIS and decision support tools are used to assist community representatives communicate and interpret information on ecological, social, economic and cultural values and select areas in the marine park for different levels of protection. The software tools ArcView, C-Plan, and Marxan are used to integrate information from diverse scientific and anecdotal sources and assist managers and community representatives to develop draft zoning boundaries for the park.

Marine parks in NSW are zoned for multiple use. The zoning aims to manage a range of sustainable human use while protecting some areas from extractive activities like commercial and recreational fishing. Once a multiple-use marine park is declared in NSW, a zoning plan is required to define highly protected 'no-take' sanctuary zones where all fishing and collecting is prohibited, habitat protection zones where some forms of fishing are allowed, and general use zones where most sustainable forms of fishing are allowed. This zoning aims to spatially segregate conflicting uses, manage or exclude some of the more potentially damaging activities, create buffers around fully protected zones, and provide a regionally integrated approach to managing networks of marine protected areas.

The location of the Cape Byron Marine Park was identified using information from a broad scale biodiversity assessment of the Tweed–Moreton marine bioregion conducted by Avery (2000). The study, like the bioregional assessments for the Manning, Hawkesbury, Batemans and Twofold Shelf bioregions (Breen *et al.* 2003), relied predominantly on broad scale data for estuary types, ocean depth zones, habitats and some information on species, coastal condition and adjacent land use. The bioregional assessments aimed to identify options for new MPAs on the basis of ecological criteria alone (Breen *et al.* 2003, 2003, 2005, 2006). They were conducted on the assumption that a separate selection process would be required before implementing protection. This would involve a detailed

site assessment and consultation with the community to consider social, economic and cultural criteria (NSW Marine Parks Authority 2001, Breen *et al*. 2003, 2004, 2005, 2006).

After the Cape Byron Marine Park was established in 2002, a zoning plan was required to be developed as soon as was practicable. An initial meeting of a Marine Park Steering Group (consisting of officials from the Marine Parks Authority, NSW Fisheries and the NSW National Parks and Wildlife Service) reviewed C-Plan planning models in ArcView using broad scale habitat data. The group agreed to trial these techniques at the fine scales relevant to local planning decisions.

It was however, evident that existing data sources were not detailed enough to assess biodiversity or social, economic or cultural values at the scale required for zoning. This chapter describes how several projects were instigated to collect data at this scale and how this information was integrated within systematic planning tools, and used in participatory GIS workshops by local community representatives and managers.

10.2 Methods

10.2.1 Planning Units

The planning area for the marine park was clipped from the state-wide model of NSW marine waters developed in Chapter 8 using the newly declared northern and southern boundaries of the marine park. An additional boundary to the south was also investigated in relation to a proposed extension to the park. Initial trials were conducted with fine scale (maximum sizes[1] of 1 km^2 and 10 ha) hexagonal planning units in the 'C-Plan' conservation planning software (NPWS 2001).

The trial aimed to identify 'no take' sanctuary zones representing various percentages of broad scale 'ecosystem' (estuary types and ocean depth zones) and 'habitat' classes (seagrass, saltmarsh, mangrove, reef, island, rocky shore, beach and subtidal sediments). The planning units used were substantially smaller than the 4 km^2 planning units used in the broad scale bioregional assessments as the Cape Byron Marine Park Steering Committee indicated that smaller units would be required to model fine scale planning decisions within the park.

These exercises provided approximate models of irreplaceability throughout the marine park and an initial opportunity to model different scenarios for zone plans. The models were also useful in subsequent negotiations when community representatives requested estimates of levels of representation within a bioregional and state-wide context. Ultimately, even these fine scale plan units were too coarse to accurately define detailed zone boundaries for community representatives and detailed editing of vector-based polygons was required during workshops.

[1] Size is a maximum as planning units adjoining the coast and other marine park boundaries are only parts of hexagons.

10.2.2 Biodiversity surrogates

Initial community consultation indicated that the broad scale data collected for the bioregional assessments were not sufficiently detailed to designate zones within the marine park and that information collected at finer spatial and taxonomic scales would be required. It was also apparent that there were gaps in the coverage of mapped habitats in offshore areas where reefs well known to commercial and other fishers existed (Figure 10.1).

The park's management therefore contracted scientists from the Coastal and Estuarine Cooperative Research Centre (Bickers 2004) to survey offshore benthic habitats and assemblages throughout the entire park using a combination of sidescan sonar and dropped underwater video camera. Recent maps were also available for a detailed classification of shoreline types (S. Banks and D. Scotts pers. comm.), fine scale aerial photograph interpretations of near shore reef (Avery 2000) and estuarine vegetation recently digitized from orthorectified aerial photographs (G. West and D. Morrison pers. comm.)

Attributes from the survey of shoreline types were transferred from an original linear coverage to the intertidal polygons derived from the state cadastre for the broad scale models of NSW waters. All of these GIS coverages were then merged and clipped within the marine park boundaries derived from the digital model for state waters developed in Chapter 8. Any overlaps between the data sets were eliminated with priority given to land over intertidal areas, intertidal areas over near shore reefs and near shore reef over offshore areas. This process produced a continuous map of mutually exclusive, fine scale environmental surrogates to represent general patterns in the distribution of biodiversity throughout the marine park (Figure 10.2).

This map provided the primary biodiversity data for consultation and decision making but was supplemented with other more specific data on birds, sharks (Otway and Parker 2000, Otway *et al.* 2003), mammals, reptiles, fishes (R.J. Williams pers. comm.) and invertebrates (Harriot *et al.* 1990).

Measures reflecting the potential condition and vulnerability of areas in the marine park were also made available to decision makers. These were derived primarily from information on adjoining terrestrial areas and included the proximity of adjacent terrestrial national parks and nature reserves, state forest, wetlands, wilderness, land capability, built-up areas, acid sulphate soils, and indices derived from the Australian river and catchment condition database (Stein *et al.* 2000). The results of previous conservation assessments for wetlands (ANCA 1996), estuaries (Bell and Edwards 1980, Digby *et al.* 1998, Frances 2000, Healthy Rivers Commission 2002), rock platforms (Short 1995, Otway 1999) and coastal management plans were also summarised and related to MPA identification and selection criteria.

Many individual research papers, reports and theses for particular sites, species and assemblages in the marine park were also made available (e.g. Smith and James 2003). This information was provided directly to managers and community representatives in digital and paper formats and to the broader community through the marine park website and background documents prepared by Marine Park's staff (NSW Marine Parks Authority 2003). Members of the advisory committee also provided supporting documents including a comprehensive review of the benefits of marine protected areas written by a conservation representative (D. Pugh, unpublished report to the NSW Marine Parks Authority).

10.2.3 Socioeconomic information

Planning for the zone plan also required consideration of social, economic and cultural values. While some information on commercial fisheries, recreation and tourism was available at regional scales, there was very little quantitative information available on the distribution and nature of human activities within the park itself. However, during consultation it was evident that anecdotal information was available from the many stakeholders and communities that frequently used the area.

Recreational users and commercial fishers were therefore surveyed as part of the consultation process for the zoning plan. Maps within the surveys were used to obtain information on the nature and spatial distribution of different activities. The Marine Park's staff circulated surveys for recreational users through all regional newspapers and through many regional clubs, businesses, mail lists and community information meetings. Those communities most likely to have a direct interest in planning the marine park were targeted. As the survey was likely to underepresent people less likely to be directly involved in consultation, random telephone surveys were conducted (CDM Telemarketing) to estimate the types and levels of use in the marine park for all people living in the region. Other independent studies (Boykett in prep., Wellington in prep.) estimated recreational use at different locations and times using visual surveys at different locations in the park.

Surveys mailed to recreational users included a section on demographics, a detailed map of the marine park and room to comment freely on issues of concern. On the map, respondents were asked to draw where they participated in different activities (e.g. fishing, horse riding, and swimming) and indicate how frequently they used these locations.

All commercial fishers licensed to fish in the area were mailed a survey which included a map on which they were asked to draw where different types of fishing were carried out, the types of gear used, the species taken and the approximate average annual catch taken over the last 10 years. This survey was required to supplement the commercial catch data (e.g. Tanner and Liggins 1999) available from mandatory catch reports routinely returned to NSW Fisheries for each legal fishing license. This data is, unfortunately, only reported for zones of one degree of latitude (60 nautical miles). As the marine park spans only 16 nautical miles of latitude, catch records for the area therefore included commercial catch from inside and outside of the marine park. In the voluntary survey, fishers were therefore asked to estimate what proportion of their catch was caught inside the marine park and to

map which areas were regularly used. This information was used to identify the fisheries licenses most affected by proposed sanctuary and habitat protection zones and estimate the cost of *ex gratio* payments to 'buy-out' commercial fisheries and prevent the displacement of fishing pressure to other areas.

Hand drawn maps from the commercial fishing surveys were digitised by selecting and assigning survey codes and answers to 10 hectare hexagonal planning units in ArcView GIS 3.2 and Microsoft Access using customised macros, Arcview scripts and selection tools. The planning units were identical to those used to represent ecological values in C-Plan and Marxan and this enabled both of these data sets to be linked spatially within the same grid and database. Ecological values and commercial fishing costs could then be integrated in reserve selection algorithms that aimed to represent biodiversity values and minimise 'buy-out' costs and impacts on commercial fishing.

10.2.4 Analysis

All data were stored in Microsoft Access relational databases and ArcView GIS shape files. Data on recreational use were linked to medium scale plan units comprised of sections of beach, rocky shore, estuary and major depth zones. Data for broad scale and fine scale biodiversity surrogates, and data from the surveys administered to commercial fishers were linked to 2,580 fine scale, 10 hectare hexagonal plan units.

The NSW National Parks reserve selection software 'C-Plan' (NPWS 2001) was used to estimate irreplaceability for plan units linked to areas of different broad scale and fine scale biodiversity surrogates. Irreplaceability estimates 'the likelihood that an area will be required as part of a conservation system that achieves a set of given 'feature targets' (Pressey *et al.* 1994). It represents the 'complementary' value of a site to a reserve network and is related not only to the area of different features (e.g. species or habitats) a site includes, but to how that site can complement the range of features already represented in the network.

Marxan, the simulated annealing software adapted for the Great Barrier Reef Marine Park Authority (Ball and Possingham 2000, Day *et al.* 2000) was trialled during planning workshops by Matthew Watts (then NSW National Parks and Wildlife Service). I then later used this software to explore the range of different scenarios presented here in this chapter. Marxan was used to model reserve networks representing targeted percentages of each environmental class in a zone while minimising boundary length and costs measured as square metres of reserve or the number of commercial fishery entitlements reporting use of a planning unit.

As the results of combining different parameters and coefficients are sensitive to the units used, trials were run for a range of different targets and coefficients. The algorithm was run one hundred times for each combination of percentage targets (10%, 20%, 30%, 40% and 50%) and boundary length modifiers (blm) for cost measured as the area in m^2 (for blm=1, 10, 100, 500, 1000) or cost measured as the number of fishing commercial licenses (for blm=0.001, 0.01, 0.1, 1, 10).

Each run involved 1 million iterations with 10,000 temperature decreases using the adaptive cooling schedule provided in Marxan and a species penalty factor of 1. Boundary length modifiers were selected that minimized boundary lengths and costs while meeting at least 90% of each environmental target by assessing:

- scatter plots of cost against boundary length (adapted from McDonnell *et al.* 2002)
- maps of the 'best' solution of plan units and
- maps of how frequently plan units occurred in near-optimal solutions generated from 100 repeated runs of the algorithm.

Simulations were then run 100 times for each set of biodiversity targets (10, 20, 30, 40 and 50%) and for cost modelled as area (m^2), cost as the number of licenses for all types of commercial fishing and costs as the number of licenses for each individual fishery including: prawn trawling; spanner crab trapping; line fishing; purse seining (live bait for tuna fishing); and beach hauling. The frequency with which different planning units occurred in 100 solutions for each target and cost were then mapped in ArcView GIS.

10.2.5 Community workshop

Data and printed maps were provided to stakeholder and community representatives and to the general community during consultation. Technical assistance with data and GIS tools was provided to community representatives to manipulate and display information, and to help draw maps of initial zoning options. Objectives and criteria, information sources, decision support tools and the zoning process were discussed at several advisory committee meetings for the marine park. This committee aimed to provide advice to the Marine Park Authority and to the NSW government to represent the views of commercial and recreational fishers, conservationists, divers, tourism, local councils, marine scientists, indigenous interests and other users.

A two day workshop with the Cape Byron Marine Park Advisory Committee was then held with the aim of developing joint options for a draft marine park zoning plan. The workshop was chaired by an independent facilitator and additional technical input was provided, on request, by observers from NSW Fisheries, the NSW National Parks and Wildlife Service, NSW Marine Parks and from individuals with special experience in local fisheries, conservation, diving, tourism, science and the interests of indigenous people.

The facilitator defined clear objectives and terms of reference, coordinated processes to develop and examine options and helped maintain the rights of members to freely express their opinions and ideas in an atmosphere conducive to open discussion and cooperation. Independent facilitation played a major role in the workshop and was necessary to maintain discussion when arguments became contentious.

Data layers, reserve design software and zoning options were displayed on screens and whiteboards in the main workshop using a data projector. Separate rooms with GIS operators were also provided for

groups to develop specific planning options. As options and compromises became more detailed, different approaches to mapping and assessing options were required. The context for representation ranged from within the marine park, to within the bioregion and within all state and commonwealth waters. The planning units used included 1 km, 10 ha and 1 ha hexagons. However, during the latter stages of the workshop, GIS operators were required to directly edit individual vector polygons to map and assess detailed zoning options defined at scales of a few metres.

10.3 Results

10.3.1 Fine scale environmental surrogates for Cape Byron Marine Park

Figure 10.1 shows the broad scale environmental surrogates available at the time of the park's declaration. Figure 10.2 shows the fine scale classification developed to help plan zones in the new multiple use marine park. In particular, Figure 10.2 shows detailed maps of offshore reef and sediment habitats provided by Andrew Bickers (Bickers 2004) and Katrina Baxter using sidescan sonar and underwater video surveys.

This technique was used to sample, within a few days, an almost continuous coverage of seabed types within the Cape Byron Marine Park and some surrounding areas. It detected many areas of reef that had not been mapped previously, accurately defined substratum boundaries and identified a diversity of physical and biological features on hard and soft substrata. Drop video surveys within acoustically defined substrata were able to identify distinct biological assemblages and classify surrogate categories within offshore subtidal environments (Bickers 2004). The surveys also identified significant areas of reef to the north and south of the declared marine park (Bickers 2004) that might have been useful in designating the original park boundaries.

The inshore areas of reef in Figure 10.2 are mapped from detailed aerial photo interpretation carried out by Ron Avery as part of the bioregional assessment process. Figure 10.2 also includes data from projects underway at the same time as the zoning process. Over fifteen different intertidal beach and rocky shore classes were identified by Banks and Scotts (pers. comm.) and recent, detailed maps of estuarine seagrass, mangrove and saltmarsh (G. West pers. comm.) were used to update information for these habitats that had last been collected over 20 years ago (West *et al.* 1985).

The continuous coverage and level of precision in these data sets meant that this information could be combined to provide a single, holistic overview of marine environments for the entire marine park. Features in this fine scale environmental classification include:

- seagrass, mangrove and saltmarsh habitats in the Brunswick River and other smaller estuaries
- extensive near shore reefs in Byron Bay and around Cape Byron, Broken Head and Lennox Head
- extensive rocky reefs at a range of depths and coarse sediments around Julian Rocks
- small islands and rocks at Julian Rocks and off Broken Head
- rocky pinnacles between 35 and 50m to the north of Cape Byron
- boulder, platform and rocky cliff areas at Cape Byron, Broken Head and Lennox Head

- an enclosed oceanic lagoon at Lennox Head
- beach types at Brunswick, Belongil, Byron, Tallows, Broken Head and Seven Mile beaches
- tongues of coarse sediment offshore of Tallow and Seven Mile Beaches
- offshore coarse sediment and scattered rocky reef at depths greater than 50m
- extensive fine sand throughout the majority of the marine park (Figure 10.2).

Many of these features were either not evident or only mapped at a limited resolution in previous work (e.g. Figure 10.1). Most of the new data were mapped as a result of recent projects for marine biodiversity conservation (G. West pers. comm., S. Banks and D. Scotts pers. comm.), for the bioregional assessments conducted by the Marine Parks Authority (Avery 2000) or for the Cape Byron Marine Park planning process (Bickers 2004).

10.3.2 Recreation in the Marine Park

Over 1400 volunteers responded to the questionnaire on recreational use of the marine park. Most (93%) were resident in the region. Maps summarising the number of respondents involved in activities at different locations in the park were used to help identify competing recreational, commercial, cultural and conservation interests and develop zoning options to mitigate conflicts. Independent observational surveys by Boykett (in prep.) and Wellington (in prep.) confirmed the spatial patterns in recreational use at the locations where these studies were carried out.

The random telephone survey however reported much lower percentages of respondents using the marine park than indicated by the voluntary questionnaire returns. This difference was apparent for all activities but most evident for activities including whale and dolphin watching, snorkelling and bait collecting (Figure 10.3). This result indicates that the voluntary questionnaire sample may have been biased towards returns from individuals actively using the marine park and reflects more a subset of the local community rather than the general population.

The most frequently reported activities in the marine park were swimming, walking and running, beach going, whale and dolphin watching, surfing and recreational fishing (Figure 10.3). Swimming occurred throughout the marine park but was especially common on beaches in Byron Bay (Figure 10.4), while SCUBA diving was strongly focused around Julian Rocks (Figure 10.5).

Figure 10.6 shows high numbers of recreational fishers reporting use of areas in, and south of the Brunswick River, and at Broken and Lennox Heads. These areas were also identified as locations with high conservation values. As a result, consultation to zone these areas was contentious and required particular attention to meet conflicting demands.

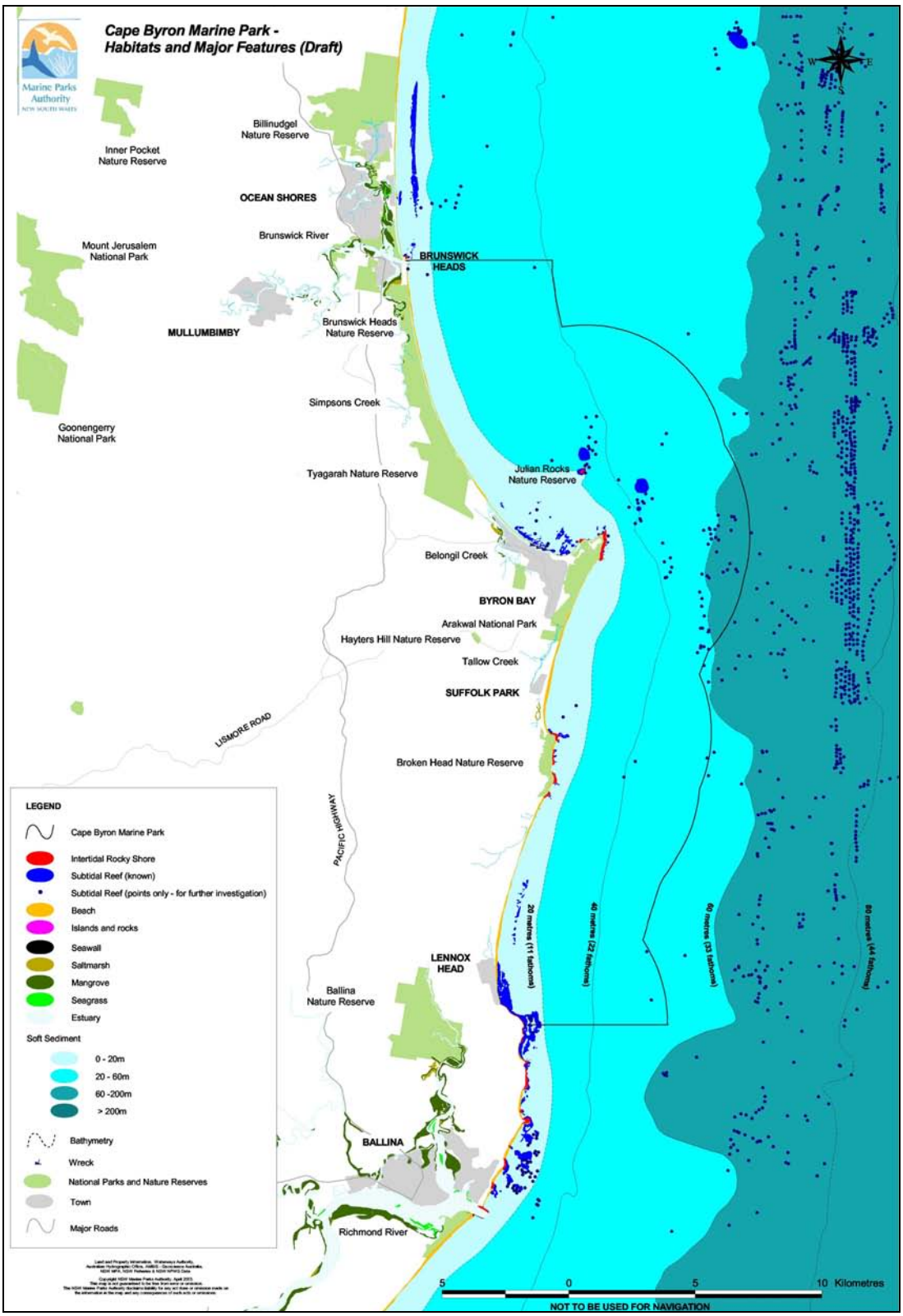

Figure 10.1. Broad scale marine environmental classes in Cape Byron Marine Park. Inshore reefs mapped from aerial photographs by Ron Avery (NSW National Parks). Estuarine vegetation mapped from West *et al.* (1985). Intertidal beaches and rocky shores identified from NSW Land and Property cadastre by Dan Breen and Natalie Taffs (NSW Fisheries). Offshore depth zones from NSW Waterways. Points for hard substrata provided to NSW Marine Parks by local commercial fishers. Map by Vanessa Mansbridge (NSW Marine Parks).

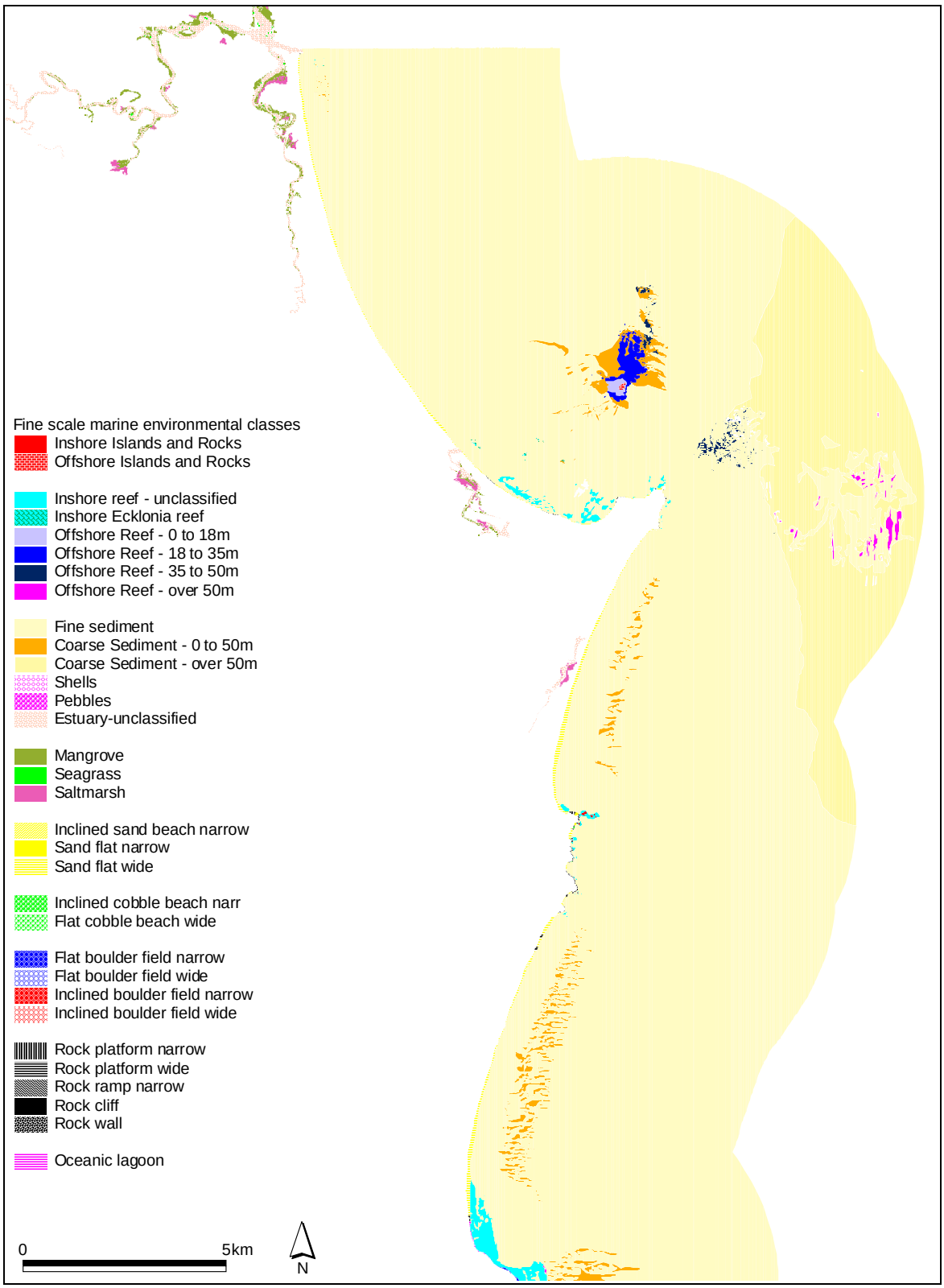

Figure 10.2. Fine scale marine environmental classes in Cape Byron Marine Park. Nearshore reefs were mapped from aerial photographs by Ron Avery (NSW NPWS). Other seabed types were mapped from sidescan sonar, differential GPS and dropped underwater video by Andrew Bickers (University of Western Australia) and Katrina Baxter (University of Melbourne). Shorelines were classified by Simon Banks and David Scotts (NSW National Parks) as line shape files and transferred to polygons of the intertidal zone (D. Breen) derived from NSW Land and Property Information cadastre data. Estuarine vegetation was mapped from aerial photographs by Greg West and Danielle Morrison (NSW Fisheries).

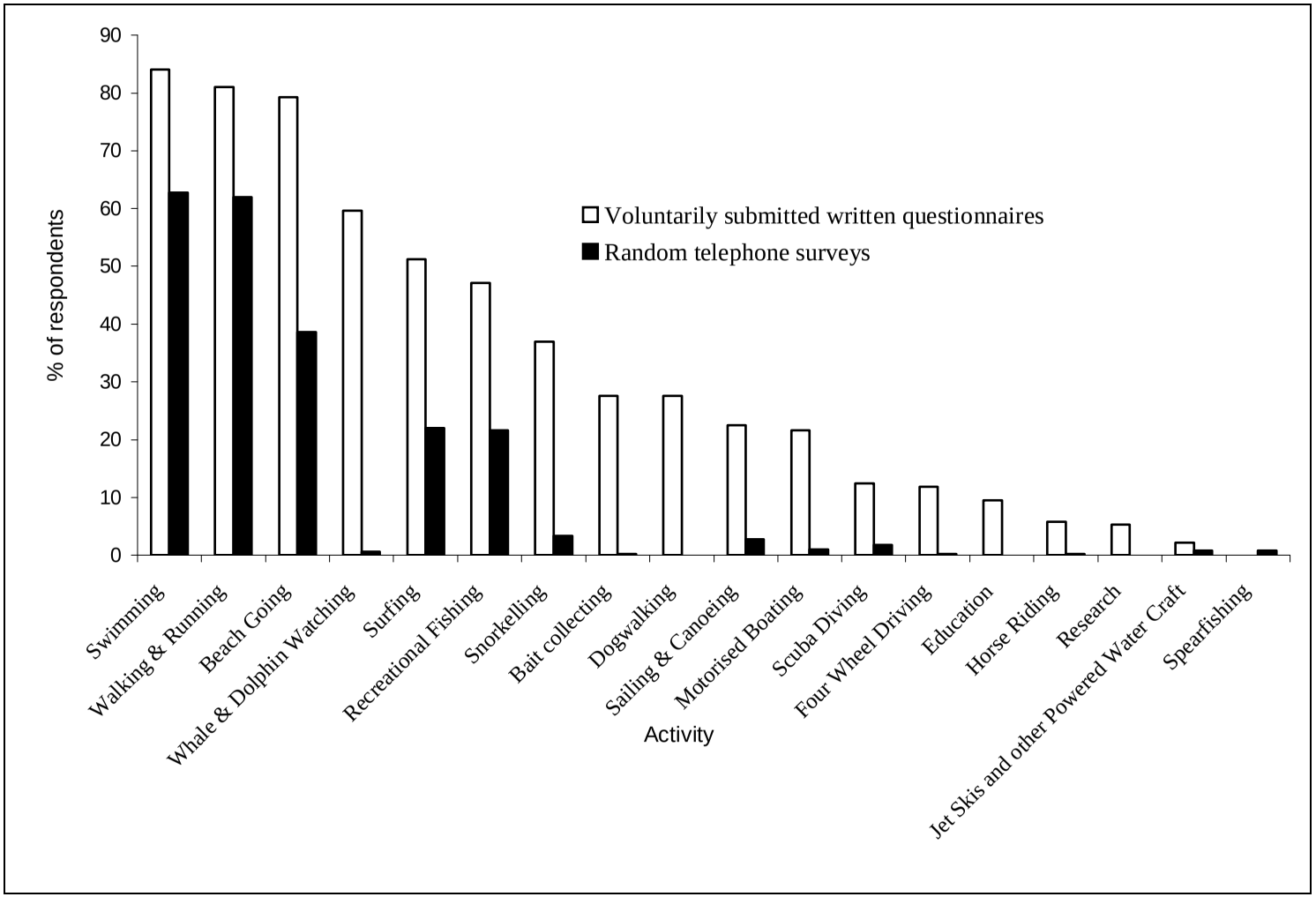

Figure 10.3. Percentage of respondents using the Cape Byron Marine Park for various activities according to a written questionnaire returned voluntarily by respondents (white) and to a random telephone survey of residents in the region (black). Note that percentages add to over 100% as respondents can reply for more than one activity (Telephone survey from CDM Telemarketing, questionnaire data collated by Kellie Lobb and staff of Cape Byron Marine Park).

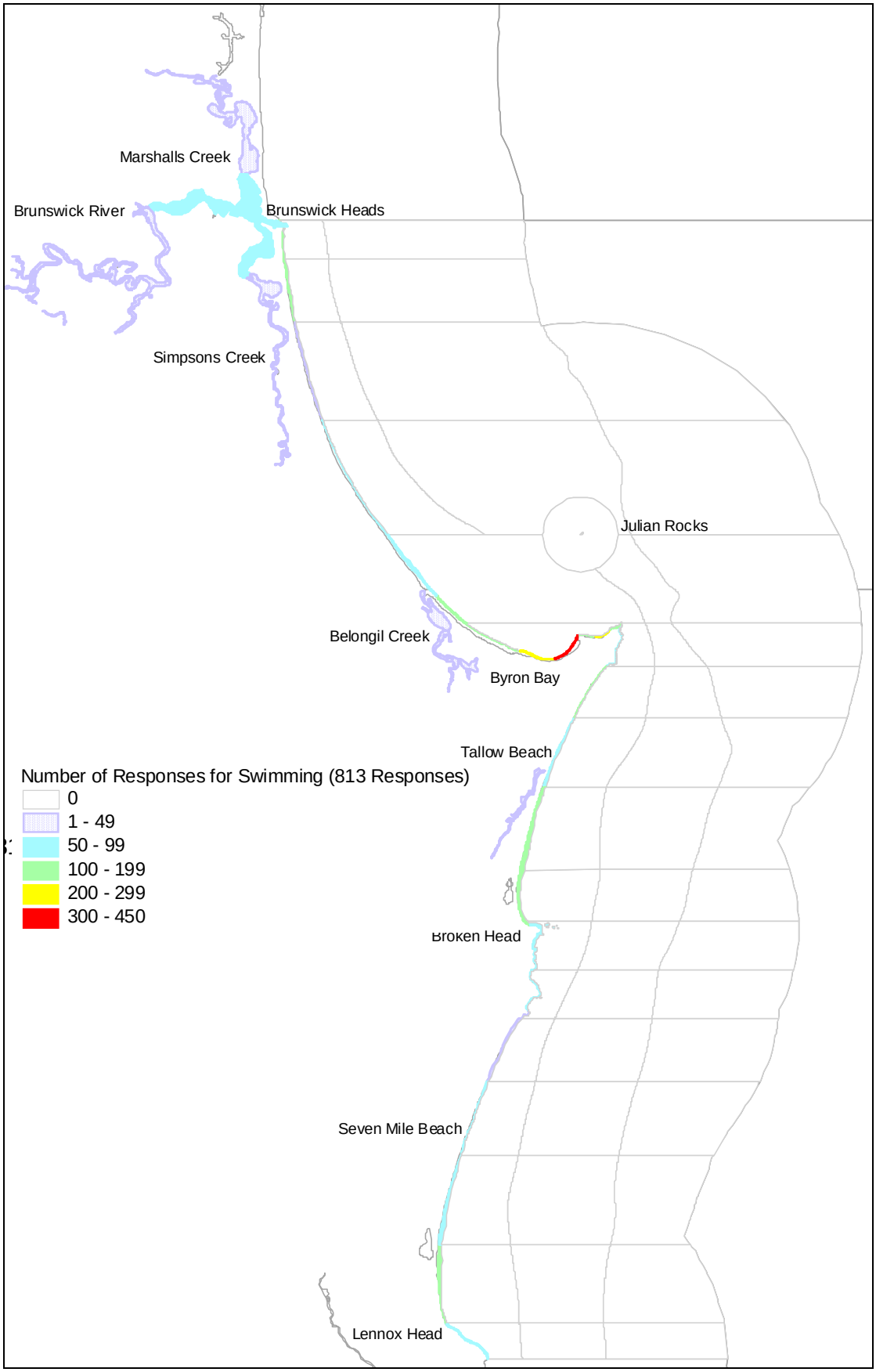

Figure 10.4. Number of questionnaire respondents reporting use of different areas of Cape Byron Marine Park for swimming (map by Kellie Lobb and Dan Breen).

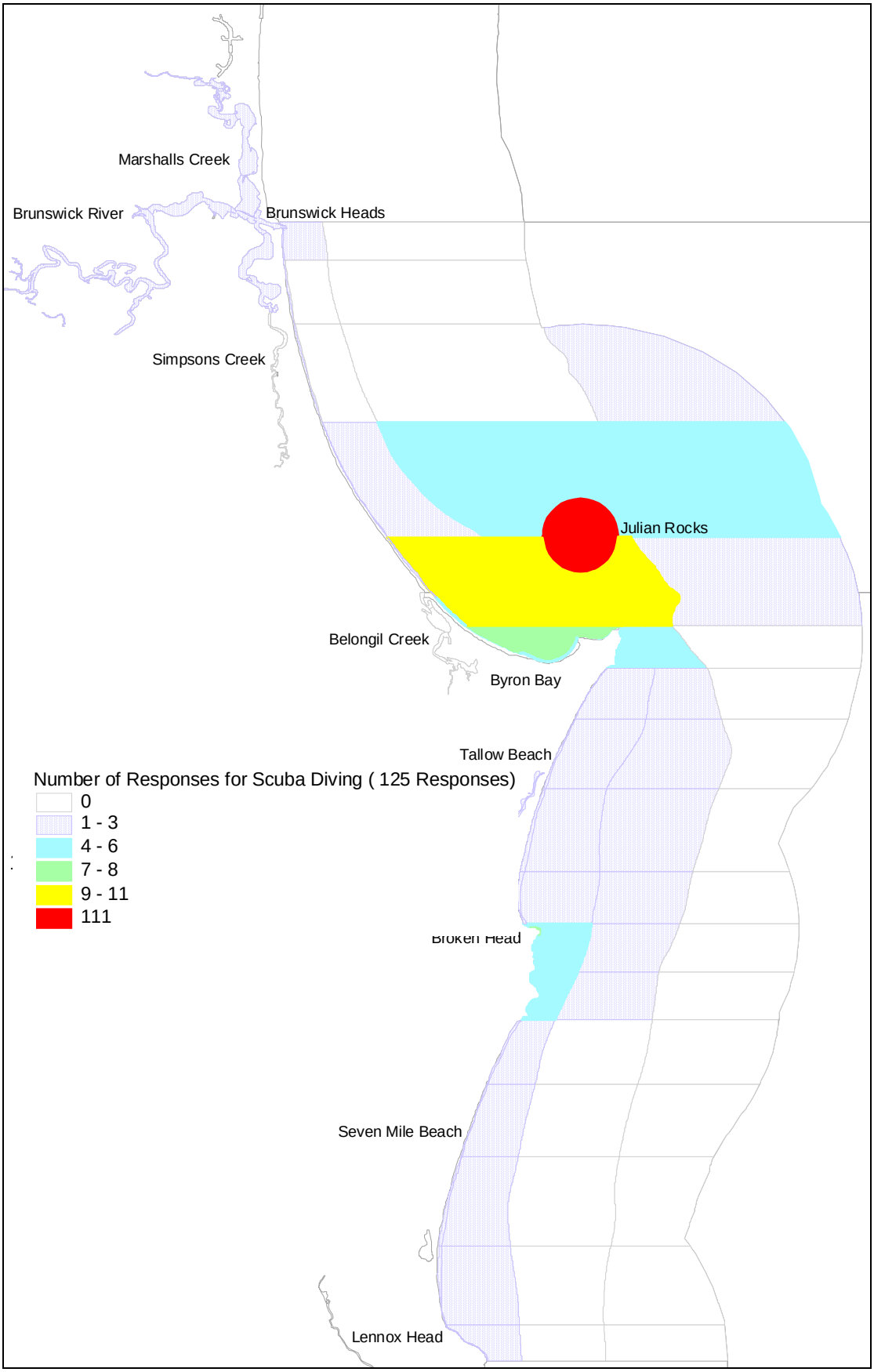

Figure 10.5. Number of questionnaire respondents reporting use of different areas of Cape Byron Marine Park for SCUBA diving (map by Kellie Lobb and Dan Breen).

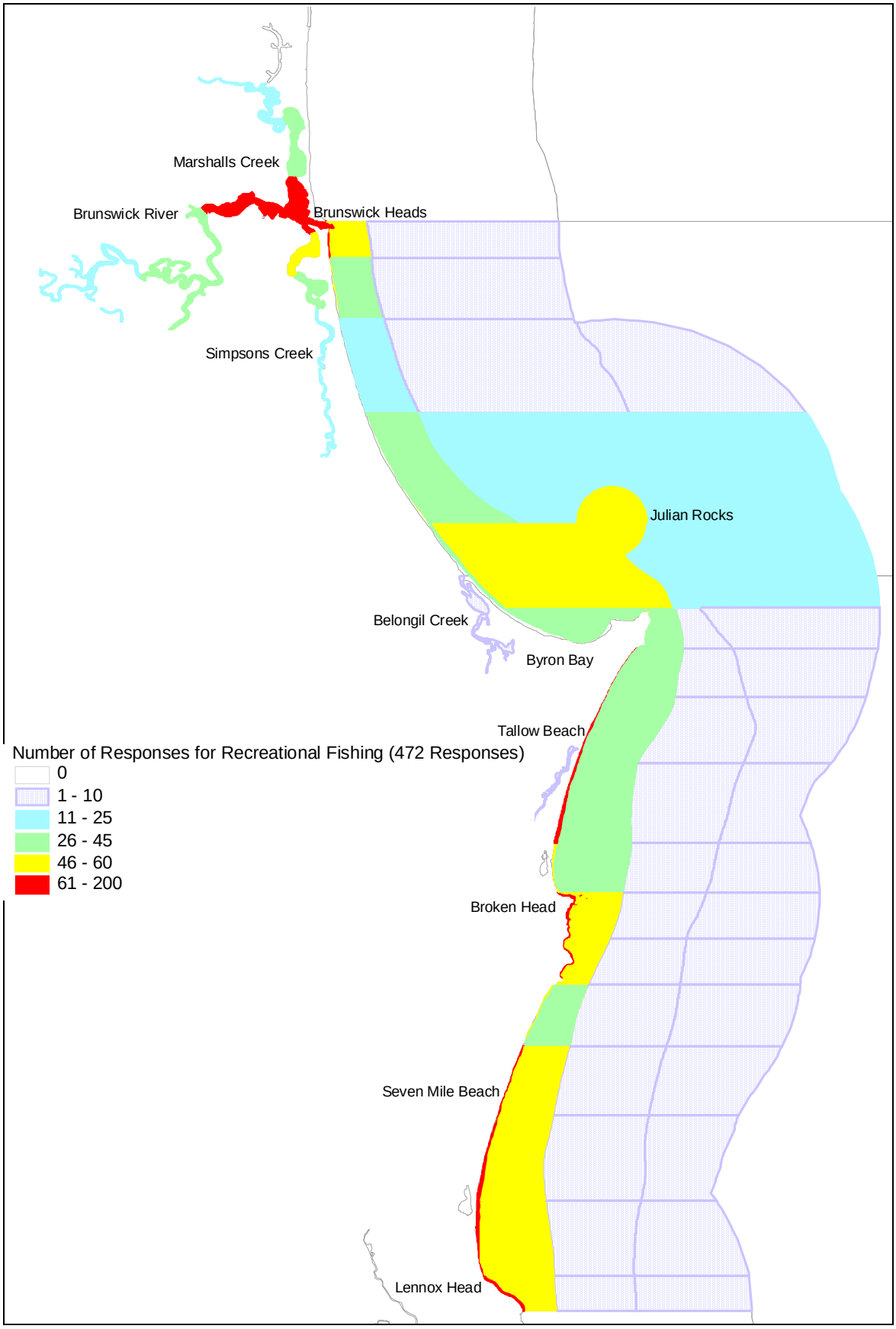

Figure 10.6. Number of questionnaire respondents reporting use of different areas of Cape Byron Marine Park for recreational fishing (map by Kellie Lobb and Dan Breen).

10.3.3 Commercial fishing in the Marine Park

Figure 10.10a to Figure 10.15a show the number of commercial fishing licenses reporting use of different areas in the marine park for prawn trawl, spanner crab, purse seine (live bait for tuna), line fishing, beach hauling and for all fisheries combined. The total for all fisheries also includes licenses to collect pipis (shellfish), mud crab, eels and lobster. Only a few licenses for the latter fisheries operated in the marine park and these are not mapped here.

It is evident that different fisheries favour different locations and habitats in the marine park according to the occurrence of the target species and the methods of fishing. Prawn trawling (Figure 10.9a) and trapping for spanner crabs (Figure 10.10a) occurred most frequently in offshore areas south and north of Cape Byron. Purse seining (Figure 10.11a) for live bait occurred mainly in sheltered inshore areas to the north of major headlands, and especially in Byron Bay. Line fishing (Figure 10.12a) occurred mostly on inshore reefs and hauling (Figure 10.13a) occurred mostly on beaches. Other fisheries were also restricted to specific locations. Eel and mud crab trapping occurred only in estuaries and lobster trapping focussed on particular areas of reef.

These data and the fisher's estimates of the proportion of their catch caught within the marine park were used with mandatory catch return data for the region by Doug Chapman (NSW Fisheries) to assess the cost of buying out commercial fishing licenses in the marine park. The assessments included estimating the cost of buying commercial fishing licenses affected by different zoning options and the allocation of *ex gratia* payments to fishers that might otherwise be displaced to surrounding areas.

The maps of commercial fishing licenses were also used in Marxan simulated annealing simulations as relative measures of the potential impact of different reserve designs on different commercial fisheries. They provided an alternative to using the area occupied by highly protected areas as the sole indicator of the relative cost of different reserve systems. The use of these values had significant effects on the reserve network designs described in Section 10.3.5.

10.3.4 Irreplaceability analyses in C-Plan

Figure 10.8a shows a map of site irreplaceability calculated using the C-Plan conservation planning software to represent 30% of the area of each environmental biodiversity surrogate. The low irreplaceability values throughout the park indicate that for most conservation features there is a high degree of flexibility in the number of potential areas that could be selected to meet feature targets. The exceptions are for small areas around Julian Rocks, Cape Byron, Broken Head and Lennox Head. In each case, these areas include environmental classes (offshore island, inclined boulder field, inshore island, oceanic lagoon and pebbles) that are found at only a few locations in the marine park.

C-Plan allows an operator to easily add and subtract plan units to and from hypothetical reserve systems while immediately seeing the effect of these changes on irreplaceabilities, percentage goals and the areas included for different conservation features and sites. C-Plan was used throughout the planning process with managers and community representatives to provide rapid estimates of the areas of different environmental classes included in alternative reserve network options. C-Plan also provides tools to build heuristic iterative algorithms to automatically select candidate reserve systems that meet a set a feature targets while minimising costs. However, at the time of the draft zoning process, C-Plan had no way to easily aggregate plan units into larger reserves. Without specific rules to preferentially select adjacent units, solutions tended to include planning units scattered over a wide area. The following section describes solutions produced by the simulated annealing algorithm in Marxan which is able to minimise reserve boundary length and generate reserve networks of more compact clusters of planning units.

10.3.5 Simulated annealing in Marxan

Using a range of boundary length modifiers in the Marxan simulated annealing algorithm produced reserve network solutions with plan units aggregated to varying degrees between widely dispersed and tightly clustered. Figure 10.7 is a scatter plot of total cost in area plotted against total boundary length for reserve networks aiming to meet targets of between 10 and 50% of all fine scale environmental classes using boundary length modifiers that range between blm=1 and blm= 1,000.

Each point represents a simulation of 1,000,000 iterations with 10,000 temperature decreases and 100 replicate simulations of each point are plotted for each combination of percentage goal and boundary length modifier. Points towards the right hand side of the x-axis are solutions with relatively large total reserve boundary lengths made up of many scattered plan units, while points to the left, represent solutions with progressively smaller boundary lengths and larger, more compact reserves of aggregated planning units.

For each combination of boundary length modifier and feature target, the algorithm generated a range of solutions (n=100) with relatively little variation in boundary perimeter or cost in area. As expected, area costs increased with the size of the percentage feature target and the boundary perimeters of reserve networks decreased as the boundary length modifier increased.

However, there was almost no increase in area cost with boundary length modifier until blm=1,000 and the greatest reductions in boundary perimeter occurred at less than blm=500. Therefore targets could be met within a relatively compact network of reserves without necessarily increasing the total area protected.

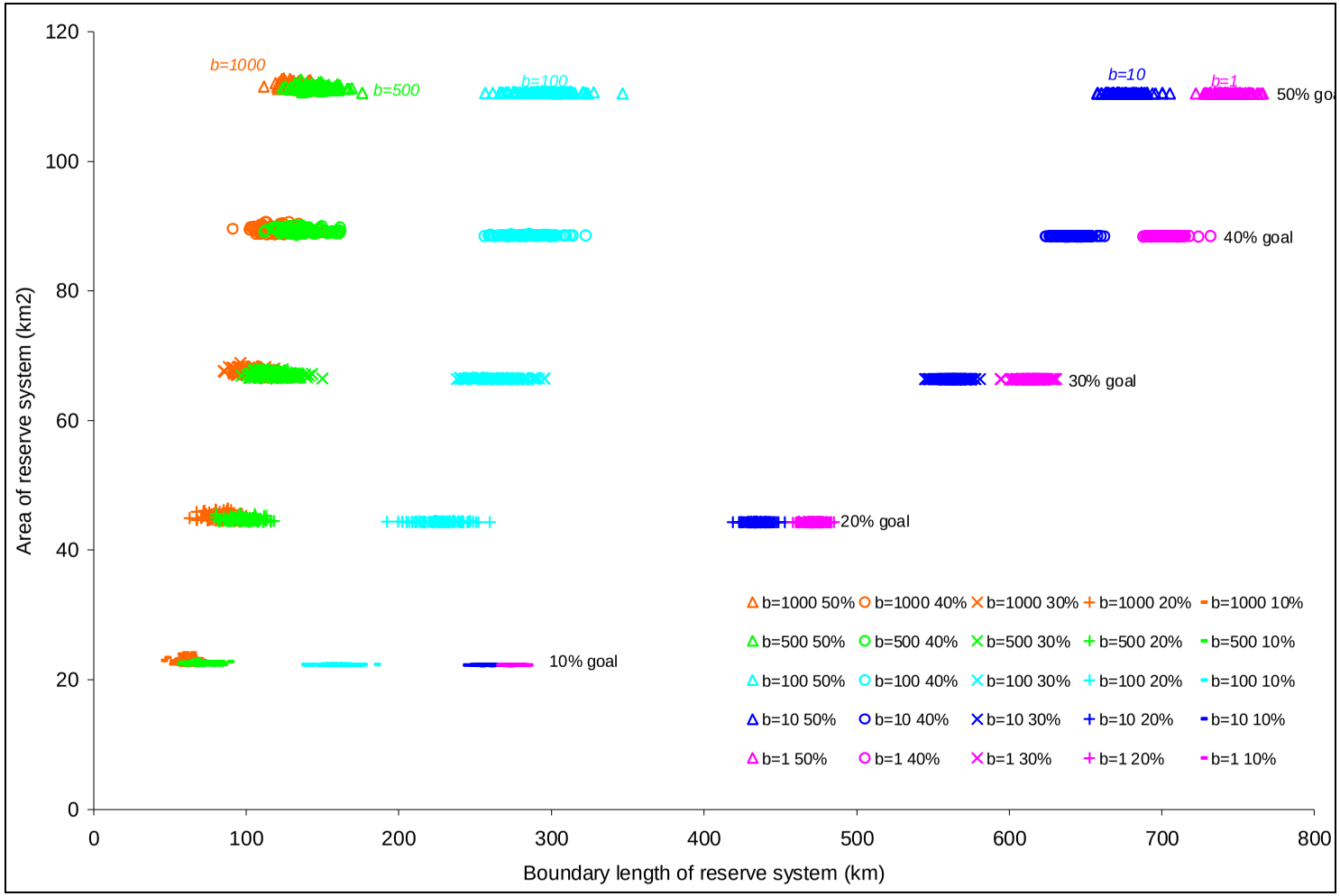

Figure 10.7. Areas of hypothetical reserve systems aiming to represent between 10 and 50% of all environmental habitat classes in Cape Byron Marine Park for a range of boundary length modifiers (blm=1 to 1,000) using Marxan simulated annealing and iterative improvement (Ball and Possingham 2000). Each point represents a simulation of 1,000,000 iterations with 10,000 temperature decreases. 100 replicate simulations are plotted for each combination of percentage goal and boundary length modifier. Total area of the marine park is approximately 224 km^2.

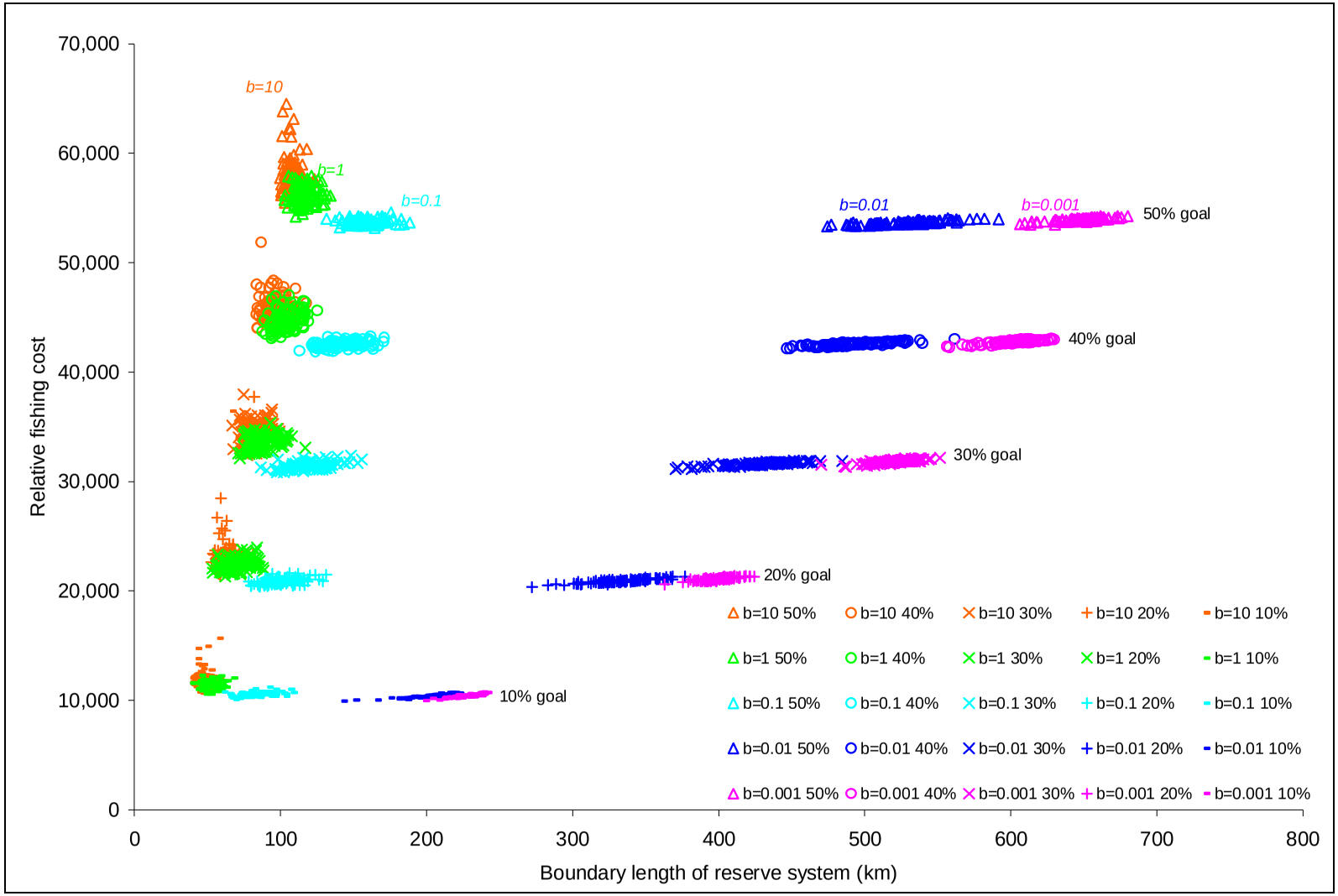

Figure 10.8. Relative impact on commercial fishing grounds (derived from how frequently plan units were used by fisher's) in Cape Byron Marine Park of reserve systems aiming to represent between 10 and 50% of all environmental habitat classes for a range of boundary length modifiers (blm=0.001 to 10) using Marxan simulated annealing and iterative improvement. Each point represents a simulation of 1,000,000 iterations with 10,000 temperature decreases. 100 replicate simulations are plotted for each combination of percentage goal and boundary length modifier.

A similar pattern occurred when using commercial fishing as a cost (Figure 10.8). Cost increased with the size of the target and boundary length decreased as the boundary length modifier increased, but again, there was no substantial increase in cost until the boundary length modifier became greater than 1. When using either area or commercial fishing use as a cost, the total area occupied by each solution (e.g. Figure 10.7) was not substantially greater than the area met for each individual feature target. Therefore for each scenario, a range of reserve network options were available that achieved targets within reduced boundary perimeters without substantially increasing the total area occupied by reserves or the relative impact on commercial fishing.

This information, and maps of the 'best' and the 'most frequently selected' planning units from 100 replicate runs were used to select boundary length modifiers to generate networks of reserves with a relatively high degree of insulation from external influences, and which could be feasibly enforced, while still providing geographic replication throughout the marine park. A boundary length modifier of blm=500 was chosen for simulations using area as the reserve cost (Figure 10.7) and a boundary length modifier of blm=1 was used for simulations using the frequency of commercial fishing (Figure 10.8) as a cost.

Figures 10.9b - Figure 10.15 show maps of different costs, and of irreplaceabilities mapped as the frequency of each planning unit in solutions from 100 runs of the Marxan simulated annealing algorithm. Each individual result from the algorithm is a 'near optimal' solution which represents all environmental classes at a specified percentage target (between 10 and 50% of the area of each fine scale environmental class) while minimizing cost in boundary length and cost as either area or commercial fishing use. Irreplaceabilities are presented for a range of percentage targets as the size of these targets was a topic of debate among managers and community representatives. This range of targets identifies potential sites for highly protected, 'no-take' sanctuary zones but can also be used to identify potential locations for other levels of protection such as habitat protection zones where most commercial fishing is excluded.

If area is used as a cost (Figure 10.9b-f), Marxan irreplaceabilities for representation of 10% of all environmental classes resemble the irreplaceabilities calculated by C-Plan (Figure 10.8a). The sites most frequently included in solutions occur in the Brunswick River, and at Julian Rocks, Cape Byron, Broken Head and Lennox Head. As goals increase towards 50%, additional sites around these areas are added to the reserve systems. Most selected sites occurred in an arc linking the inshore reefs of Byron Bay with the diversity of habitats around Julian Rocks (offshore island, reef 0-18m, reef 0-35m) and the reef pinnacles (35-50m) and scattered deep reef and coarse sediment (>50m) offshore of Cape Byron.

If cost is calculated as the number of prawn trawlers using a site, the solutions are quite different. The algorithm tends to avoid the 'high cost', heavily trawled areas that occur south of Cape Byron and approximately 2 km out from the coast (Figure 10.9a). Instead, the sites most frequently selected for protection occur between Cape Byron and the Brunswick River and out to the 3 nautical mile limit and along a narrow band of inshore sites on the coast between Broken Head and Lennox Head (Figure 10.9b-f).

Marxan solutions for the commercial spanner crab fishery show a similar pattern with sites selected most frequently between Cape Byron and the Brunswick River and along a narrow inshore band north of Lennox Head. However, for the spanner crab fishery, there is a more pronounced concentration of fishing licenses in the narrow passage between Cape Byron and the deep reef to the east. This is reflected in a gap in selected reserve sites to the east of Cape Byron in Figures Figure 10.10b-f. This area is known to commercial fishers as the 'mad mile.' This location and areas to the south were identified during consultation as some of the most important areas for commercial fishing. The importance of the 'mad mile' is also evident in the gap at this location in the initial draft sanctuary zone proposed by commercial fishers (Figure 10.15a).

The areas used for purse seining (Figure 10.11) and line fishing (Figure 10.12) and the resulting Marxan solutions are different again. These fisheries favour the protected inshore areas to the north-west of Cape Byron and Broken Head. The annealing algorithm avoids selecting these areas with the exception of small areas of habitat that can not be found anywhere else. Instead it builds reserve systems around offshore examples of reefs and sediments.

Hauling operations are usually shore based and fishing is reported most frequently from beaches in the marine park (Figure 10.13). The resulting Marxan selections are therefore different again. They resemble the solutions using area as a cost, except that the algorithm avoids including beaches within the reserve system.

When the total frequency of all types of commercial fishing licenses is used to represent cost (Figure 10.), the Marxan solutions include several of the features described for the individual fisheries above. These include the large area of selected sites between Cape Byron and Brunswick River, the inshore band of selected sites between Cape Byron and Lennox Heads and the gap in protection midway between Cape Byron and the deep (>50m) offshore reefs.

These general solutions allow for the maintenance of the larger prawn trawl and spanner crab fisheries in the Marine Park. However, they do not necessarily allow for smaller fisheries such a purse seining and line fishing in the sheltered areas of Byron Bay or for hauling along the ocean beaches. This indicates that treating all commercial fisheries as the same may not provide a reliable indication of the potential impacts for the different types of fisheries. Unless fisheries are assessed individually, the larger fisheries may drive the selection algorithm towards general solutions that favour particular areas. These solutions may however, impact on the grounds of fisheries with fewer licenses.

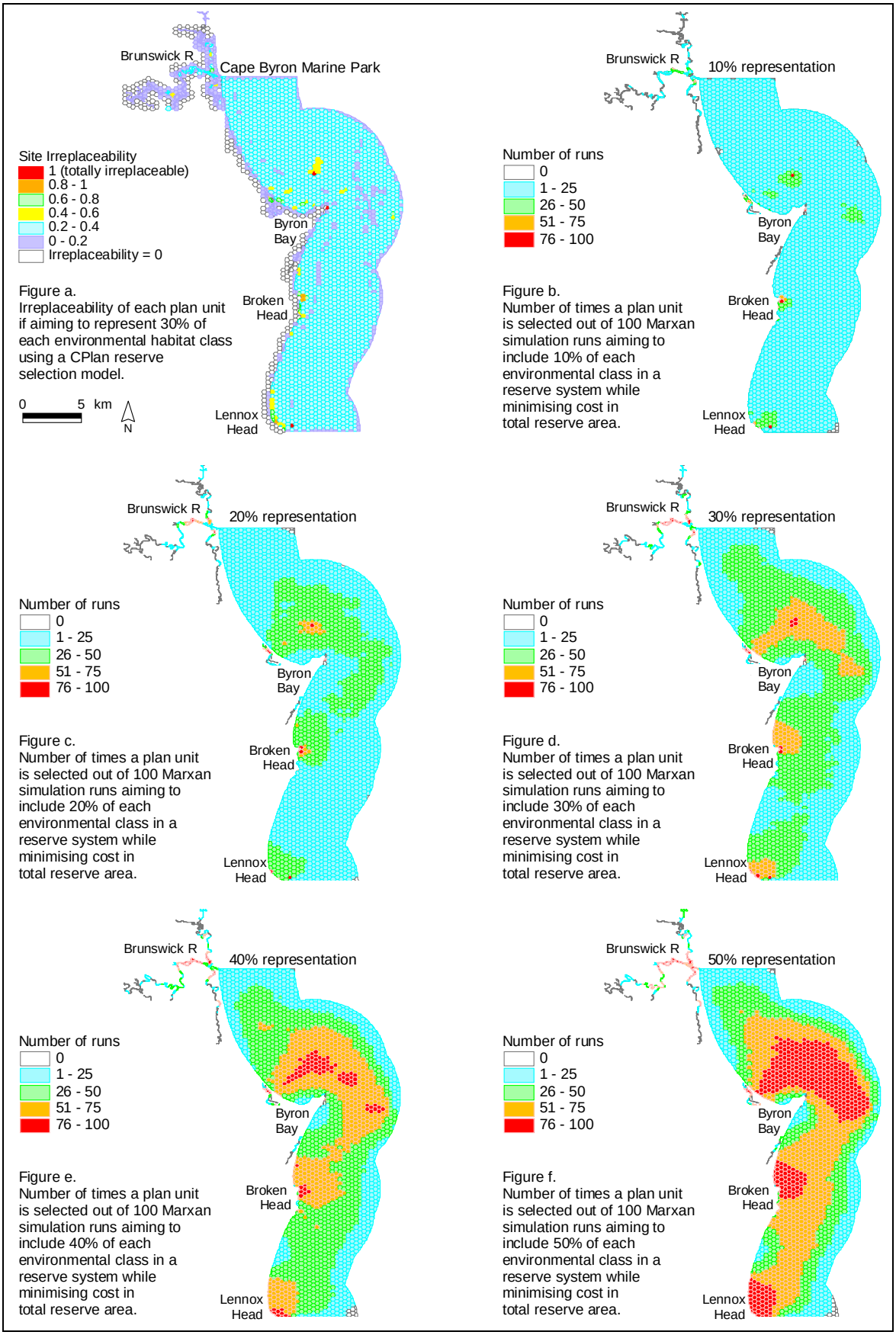

Figure 10.8a. Site irreplaceability for representation of 30% of each environmental class in Cape Byron Marine Park calculated using C-Plan (NPWS 2000). Figures b-f. The number of times a planning unit is selected out of 100 Marxan simulations (Ball and Possingham 2000) aiming to represent between 10 and 50% of all environmental classes in highly protected zones while minimising their total area and boundary length.

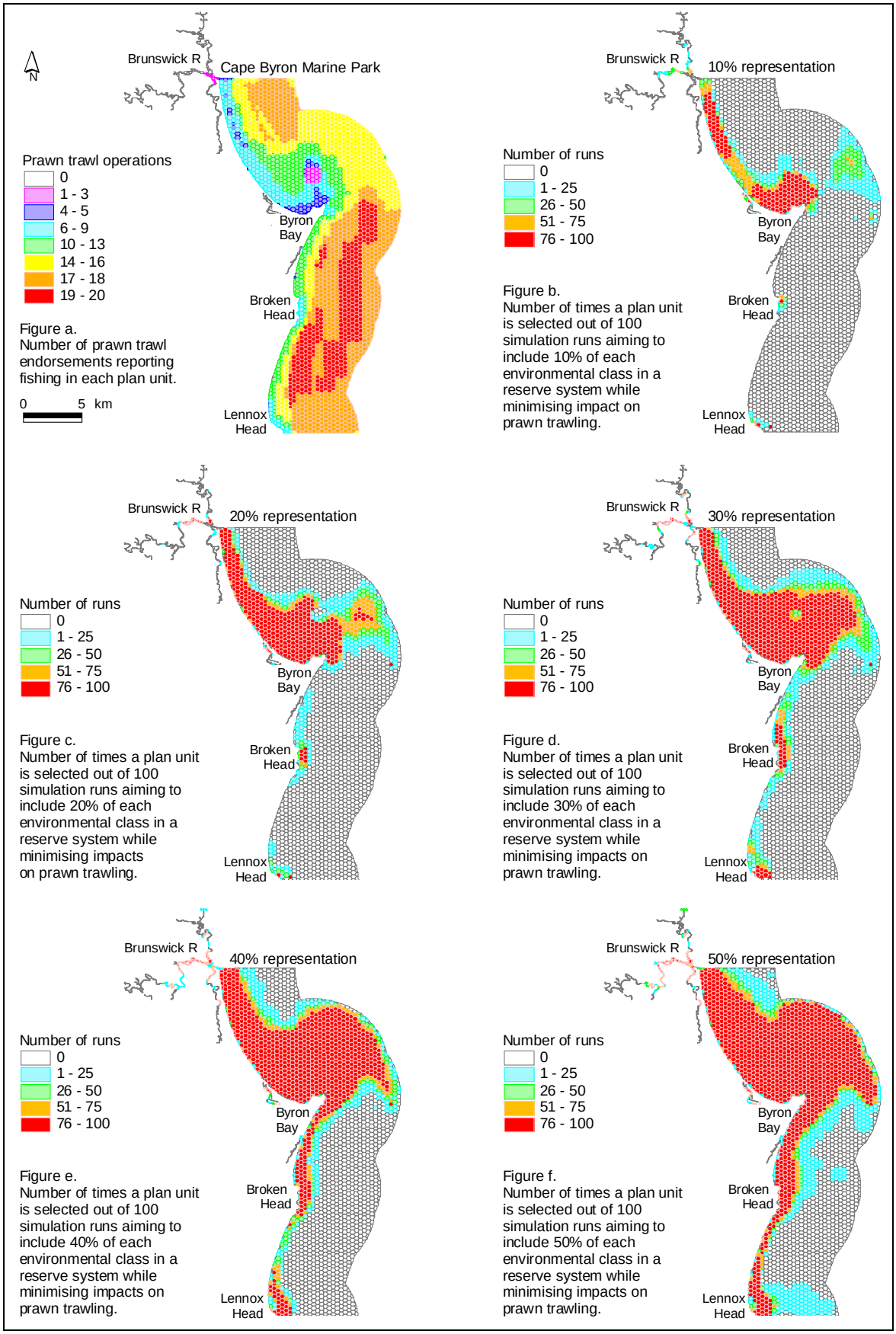

Figure 10.9a. Number of prawn trawl licenses reported in Cape Byron Marine Park. Figures b-f. The number of times a planning unit is selected out of 100 Marxan simulations (Ball and Possingham 2000) aiming to represent between 10 and 50% of all environmental classes in highly protected zones while minimising total boundary length and impacts on prawn trawling.

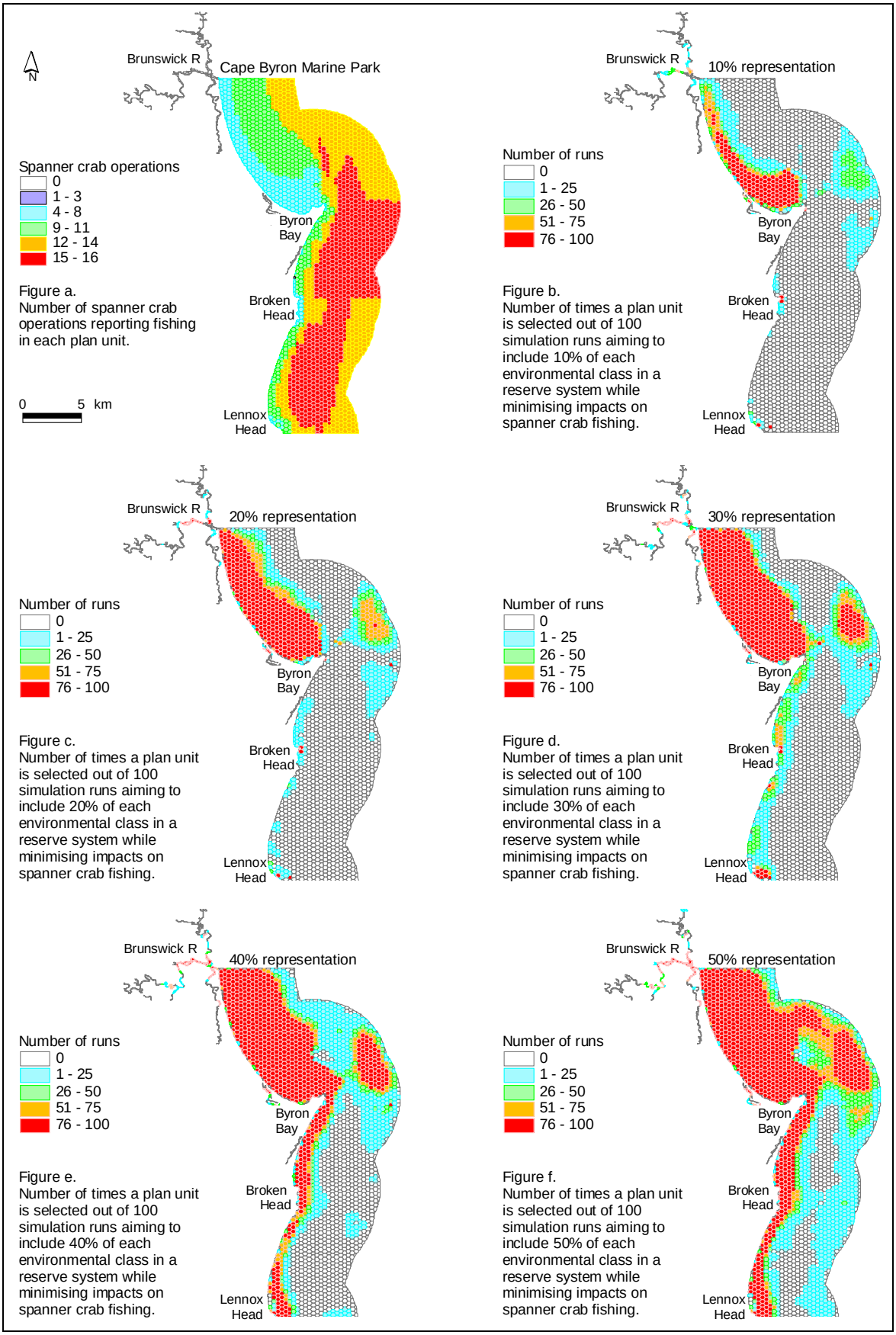

Figure 10.10a. Number of spanner crab licenses reported in Cape Byron Marine Park. Figures b-f. The number of times a planning unit is selected out of 100 Marxan simulations (Ball and Possingham 2000) aiming to represent between 10 and 50% of all environmental classes in highly protected zones while minimising total boundary length and impacts on commercial fishing for spanner crabs.

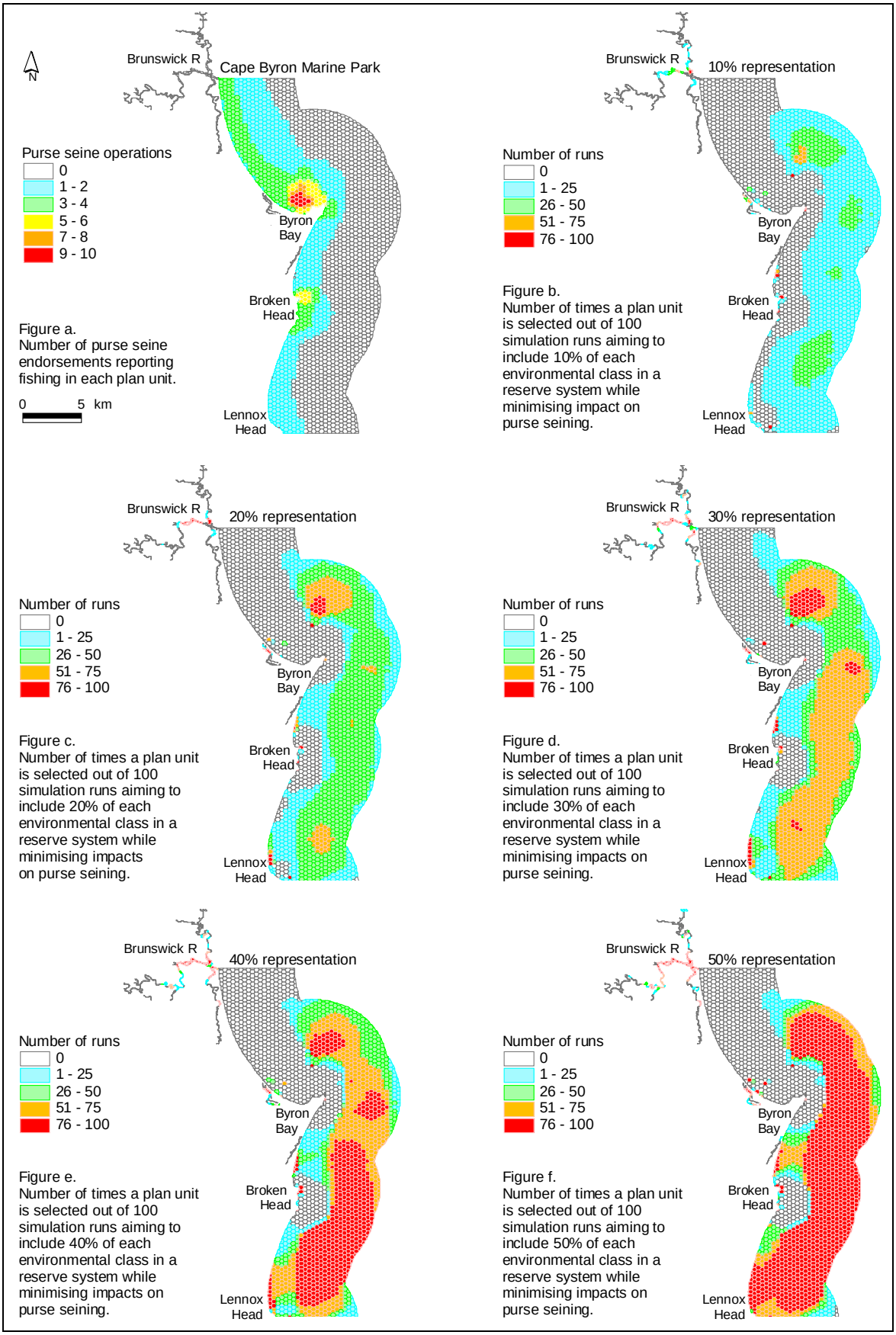

Figure 10.11a. Number of purse seine licenses reported in Cape Byron Marine Park. Figures b-f. The number of times a planning unit is selected out of 100 Marxan simulations (Ball and Possingham 2000) aiming to represent between 10 and 50% of all environmental classes in highly protected zones while minimising total boundary length and impacts on purse seining.

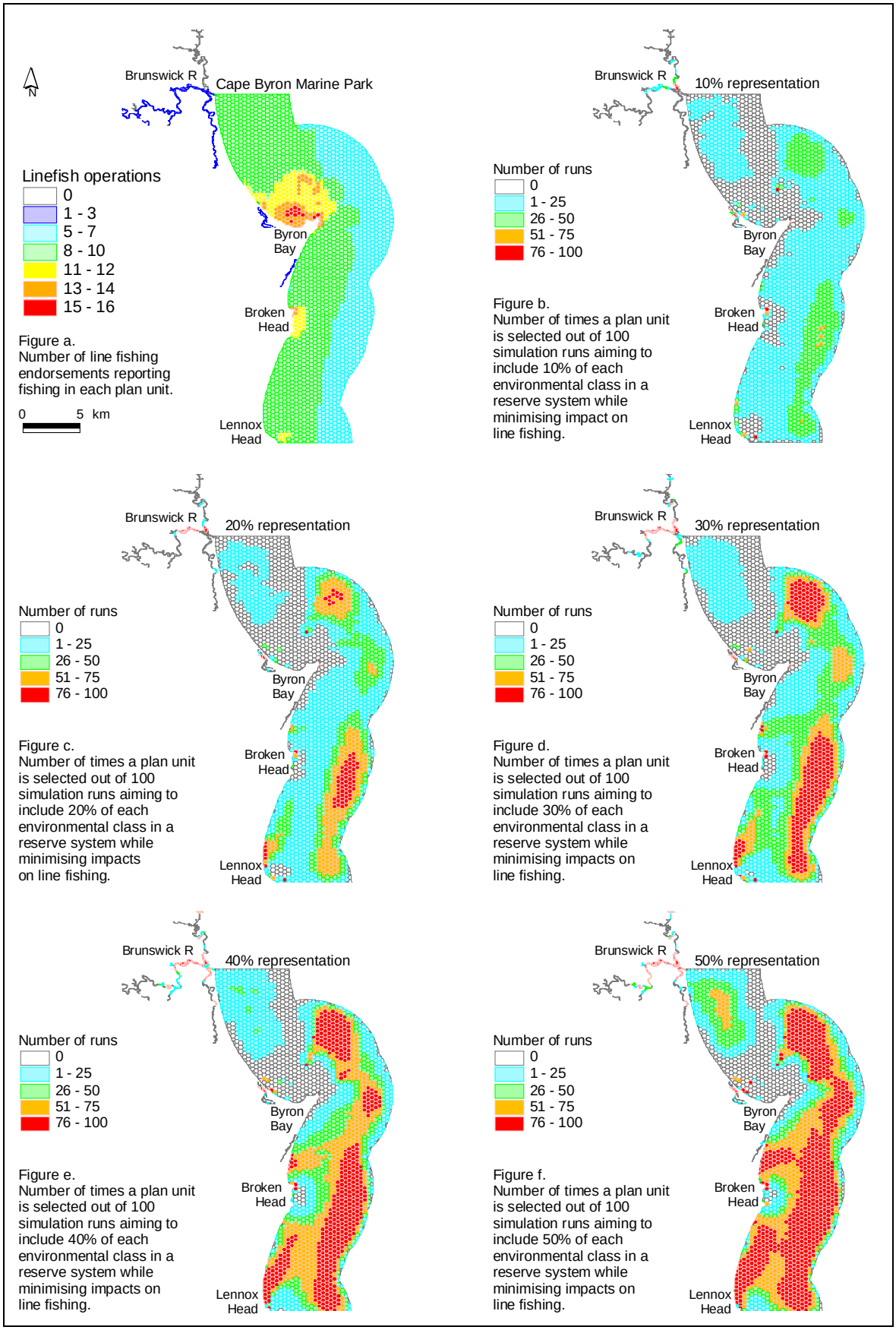

Figure 10.12a. Number of commercial line fishing licenses reported in Cape Byron Marine Park. Figures b-f. The number of times a planning unit is selected out of 100 Marxan simulations (Ball and Possingham 2000) aiming to represent between 10 and 50% of all environmental classes in highly protected zones while minimising total boundary length and impacts on commercial line fishing.

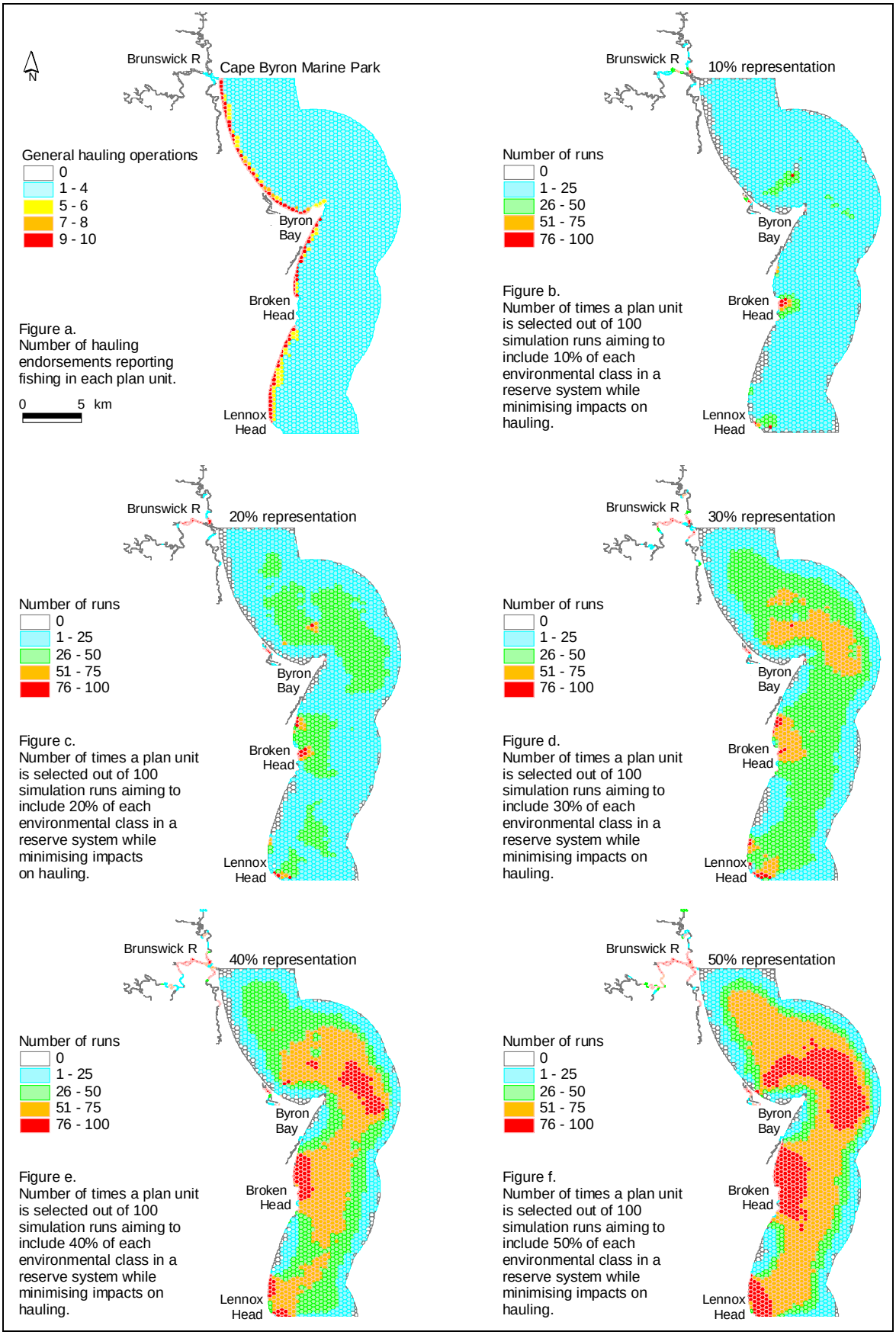

Figure 10.13a. Number of commercial hauling licenses reported in Cape Byron Marine Park. Figures b-f. The number of times a planning unit is selected out of 100 Marxan simulations (Ball and Possingham 2000) aiming to represent between 10 and 50% of all environmental classes in highly protected zones while minimising total boundary length and impacts on commercial hauling.

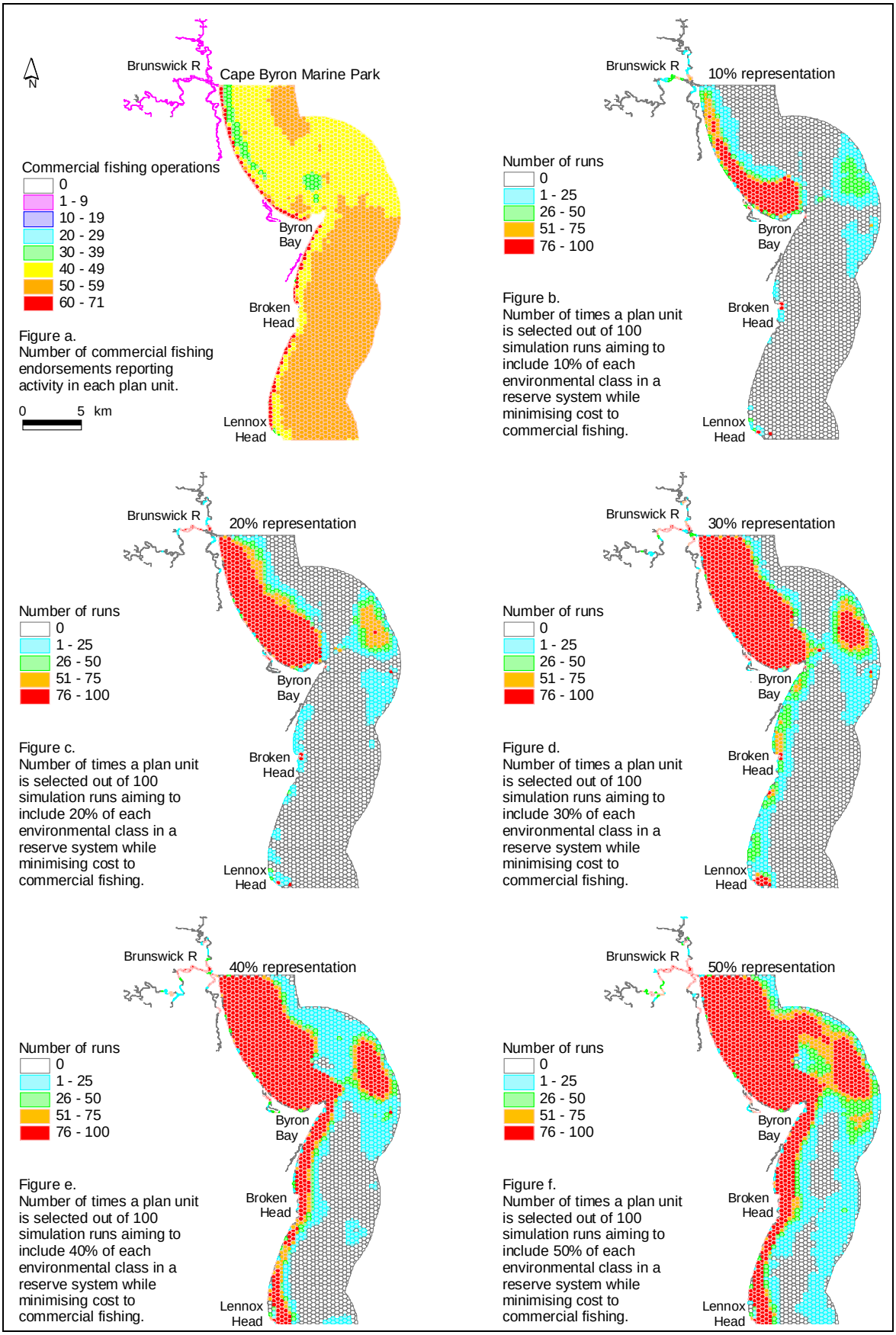

Figure 10.14a. Total numbers of reported commercial fishing licenses for Cape Byron Marine Park. Figures b-f. Maps of the number of times a planning unit is selected out of 100 Marxan simulations (Ball and Possingham 2000) aiming to represent between 10 and 50% of all environmental classes in highly protected zones while minimising total boundary length and impacts on commercial fishing.

10.3.6 Advisory committee and draft zoning workshop

The early involvement of the Cape Byron Marine Park Advisory Committee allowed time for the Committee to request and receive data and information tools, and to provide feedback and develop independent GIS maps of zoning options (Figure 10.15ab). Consultation during this time also provided management with detailed information on conservation and recreational values. This included local knowledge of offshore areas (e.g. GPS points for the offshore reefs in Figure 10.1) and other information that was not available from existing datasets.

Reviews of existing data by the community and the Advisory Committee also provided support for marine parks managers to commission more detailed surveys on environments in the marine park and their use. Early consultation also allowed time to develop and assess objectives and options for the draft zone plan and prepare materials, terms of reference and support staff for a two day workshop.

At the workshop, discussions among stakeholders, community and management frequently focused on opposing options. However compromises were often negotiated between extremes, although most of these occurred for relatively small areas (e.g. to provide access for recreational fishing or protection of other values at specific sites). Figure 10.15a, b, c and d show how the designs proposed by fishing and conservation interests retained most of their initial features with minor modifications for particular areas.

Most discussion focussed on the location and extent of ‘no-take’ sanctuary zones. Conservation and fishing interests tended to favour designs with respectively, more or less area, in these ‘no-take’ areas (Figure 10.15). Conservation representatives argued strongly for networks of large sanctuary zones which included a range of entire habitats and provided protection for species such Grey Nurse Shark and shorebirds. Sanctuary zones (coloured pink in Figure 10.15) prohibit all forms of fishing, collecting or other extractive use and prohibit anchoring over reef. Conservation representatives advocated for sanctuary zones as the only meaningful form of protection in the marine park and on several occasions proposed designs that ignored lesser forms of protection such as habitat protection zones because of their alleged inadequacy (Figure 10.15d).

Habitat protection zones in the marine park (coloured yellow in Figure 10.15) permit most forms of recreational fishing but prohibit many commercial fishing activities, including trawling. Recreational fishers proposed various forms of habitat protection zone within larger sanctuary zones to maintain access to specific fishing sites. Much effort during the workshop went into drafting small, localised habitat protection zones to provide access for recreational fishing from specific headlands, reaches of estuaries, and beaches (Figure 10.16, Figure 10.17, Figure 10.18 and Figure 10.19).

More complex planning arrangements included habitat protection zones with restrictions that are seasonal (e.g. when endangered Grey Nurse Sharks are most abundant, Figure 10.16), species based (e.g. permitting only recreational fishing for pelagic fishes on inshore reefs that supply bait, Figure 10.16) or prohibit collecting, but allow recreational line fishing (Figure 10.19).

Commercial fishing representatives provided substantial input into the extent and location of habitat protection zones, and how these excluded trawling off Cape Byron, restricted the movements of vessels travelling along the coast and limited trawling to offshore areas of the park. General use zones (coloured blue in Figure 10.15) permit most commercial and recreational fishing (including trawling) in this marine park but exclude setline, dropline, longline and purse seine fishing activities which are prohibited throughout the marine park.

Special purpose zones were also drafted to provide for restoration activities, protect indigenous cultural values (Figure 10.16), allow existing aquaculture leases and port facilities to continue (Figure 10.17) and permit special access to fishing for the disabled (Figure 10.19). Figure 10.15 shows just six draft zone plans from the many alternatives developed and reviewed before, during and after the workshop and draft planning process.

Figure 10.15e and f are draft and final plans developed by the Marine Park Authority in consultation with community groups and managers from NSW Fisheries and the NSW National Parks and Wildlife. It is apparent from comparisons with the designs submitted by community representatives that these represent compromises between the extremes. The draft zone plan in Figure 10.15e for example includes 27.5% of the marine park in sanctuary zone, a percentage precisely halfway between options negotiated by management agencies to include either 25% (NSW Fisheries) or 30% (NSW National Parks) of the park in sanctuary zones.

The total area in sanctuary zone appears to be determined by government agencies negotiating among extremes proposed by conservation and fishing interest groups while attempting to represent approximately equal proportions of each fine scale environmental class. However, the individual locations and boundaries of zones were determined primarily through negotiation among the stakeholder groups to select those areas most important to their particular interests.

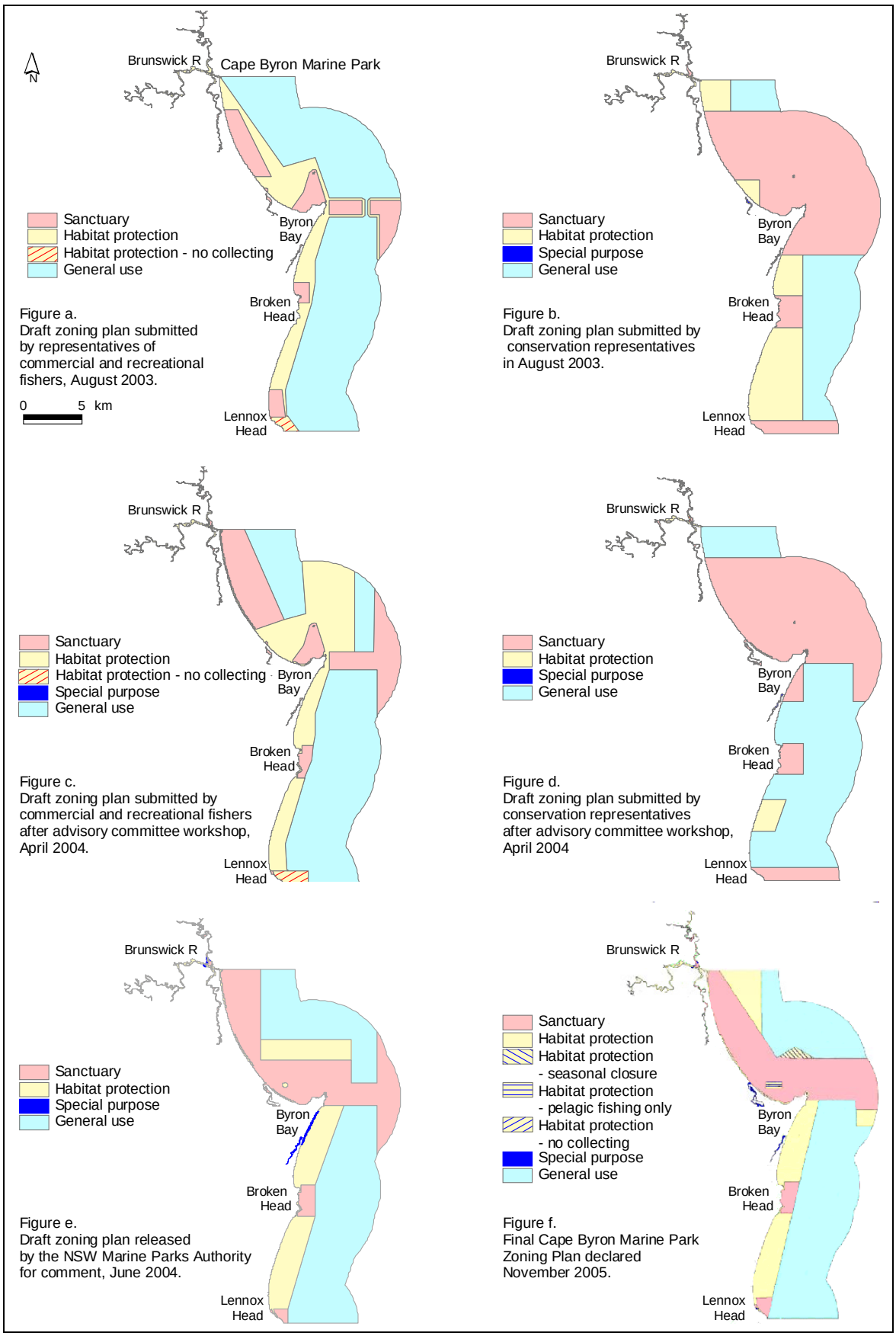

Figure 10.15. Draft zoning plans for Cape Byron Marine Park submitted by fishing (a and c) and conservation (Figures b & d) representatives before and after an advisory committee workshop and the draft (e) and final (f) zoning plans accepted by the NSW Marine Parks Authority (Maps a, b & f by Vanessa Mansbridge NSW MPA).

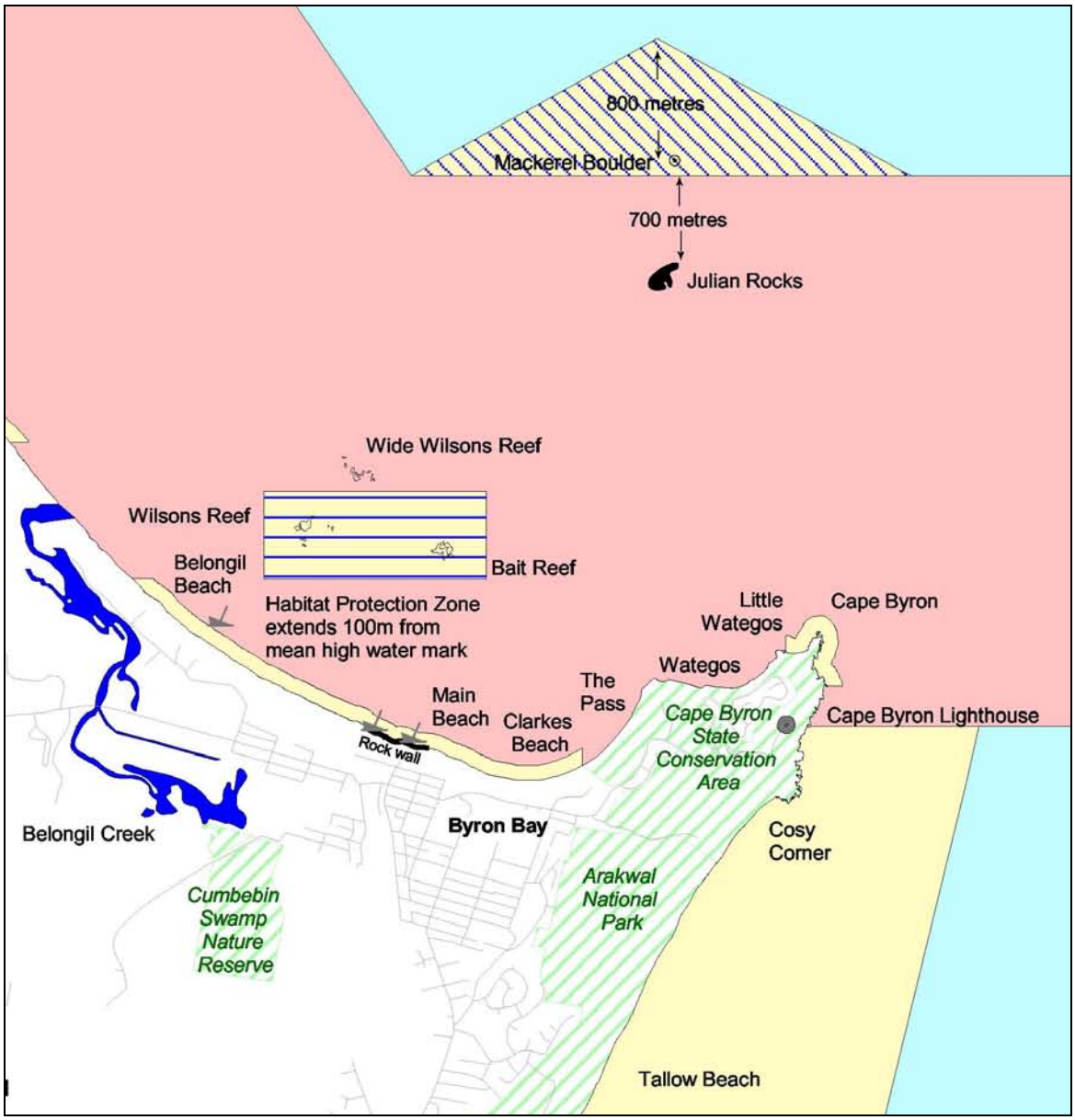

Figure 10.16. The 'no-take' Sanctuary zone (pink) offshore of Byron Bay and around Julian Rocks and Wide Wilsons Reef. Within this area, there are smaller Habitat Protection zones (yellow) within 100 m of the mean high water mark on Belongil Beach, Main Beach, Clarkes Beach, Little Wategoes Beach and Cape Byron. These zones permit most recreational fishing activities but prohibit spear fishing and commercial netting. A much larger Habitat Protection zone (yellow) extends south of the Cape Byron Lighthouse. This zone prohibits commercial trawling along Tallow and Broken Head Beaches but permits recreational fishing. A Habitat Protection zone (yellow with blue hatching) around Mackerel Boulder prohibits all fishing between the 1st of May and the 31st of December to help protect endangered Grey Nurse Sharks (*Carcharias taurus*). Another Habitat Protection zone around Wilsons Reef and Bait Reef allows only recreational fishing for certain pelagic fishes. Belongil Creek is zoned as Special Purpose to allow for recovery of this area and indigenous cultural activities. (Adapted from a map of the Cape Byron Marine Park final zoning plan produced by Vanessa Mansbridge, NSW Marine Parks Authority, www.mpa.nsw.gov.au).

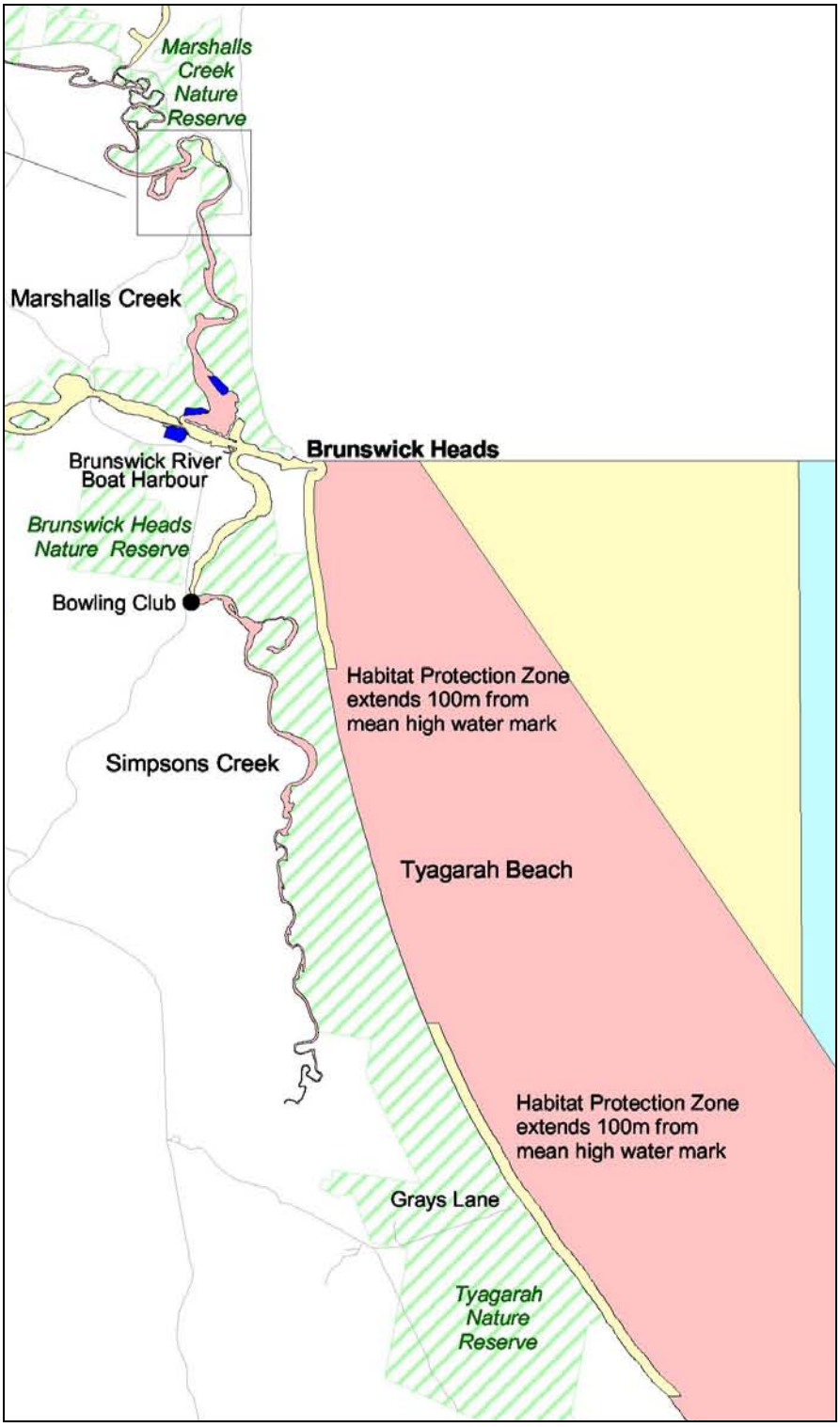

Figure 10.17. The 'no-take' Sanctuary zone (pink) extends north from Cape Byron to the northern wall of the Brunswick River mouth with the exception of two Habitat Protection zones (yellow) that permit recreational fishing and commercial collecting within 100m of the mean high tide mark. Sanctuary zones (pink) in Marshalls and Simpsons Creek prohibit all fishing in these tributaries but recreational fishing is allowed within the Habitat Protection zone (yellow) of the main Brunswick River. Special purpose zones (dark blue) allow for port activities in the Brunswick River Boat Harbour and existing oyster leases in Marshall Creek. The area adjoins Marshalls Creek Nature Reserve and Tyagarah Nature Reserve. (Adapted from a map of the Cape Byron Marine Park final zoning plan produced by Vanessa Mansbridge, NSW Marine Parks Authority, www.mpa.nsw.gov.au).

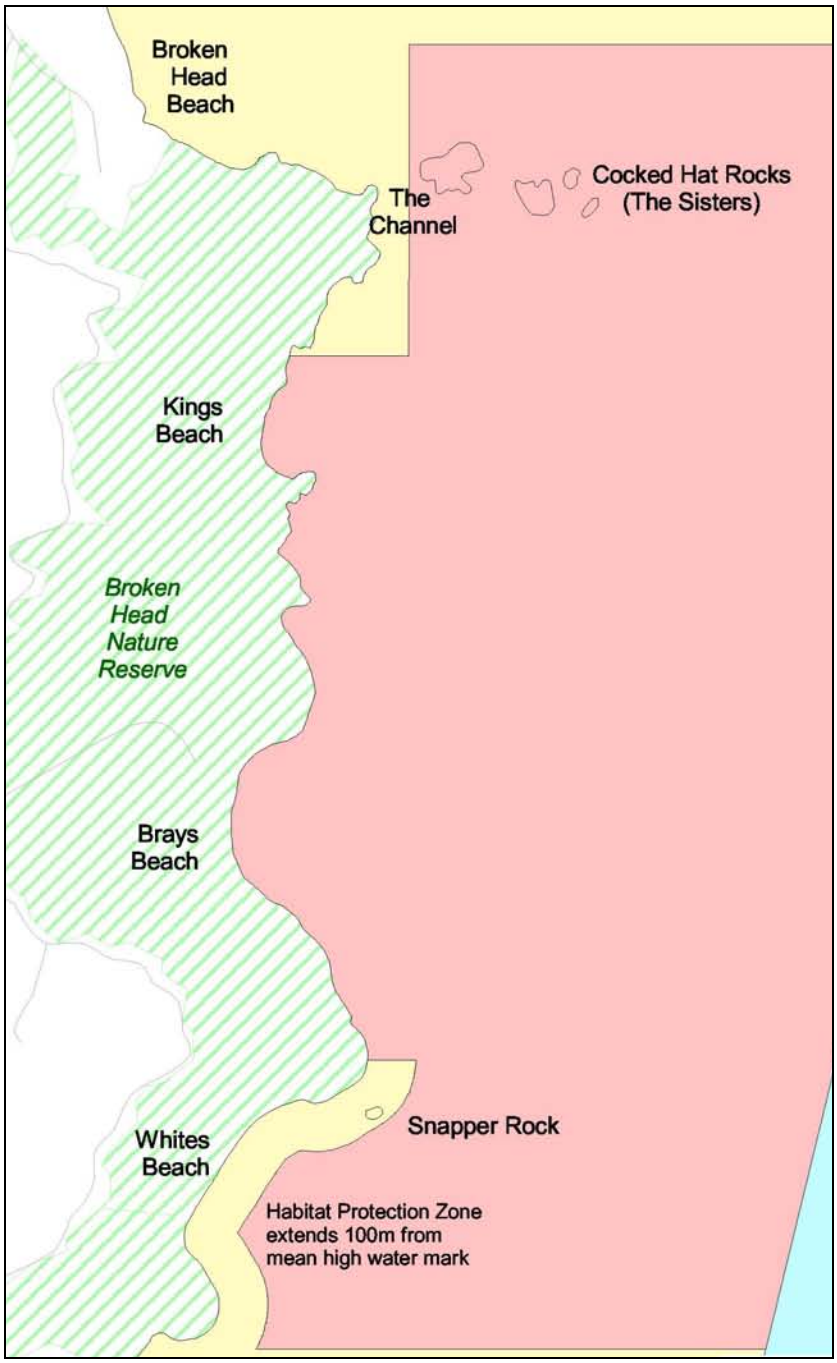

Figure 10.18. A 'no-take' Sanctuary zone (pink) offshore of Broken Head with Habitat Protection zones (yellow) where recreational fishing is allowed within 100 m of the mean high water mark at Broken Head (inside Cocked Hat Rocks), Whites Beach and Jews Point. The area adjoins the Broken Head terrestrial nature reserve (green diagonal hatching). (Adapted from the Cape Byron Marine Park final zoning plan maps produced by Vanessa Mansbridge, NSW Marine Parks Authority, www.mpa.nsw.gov.au).

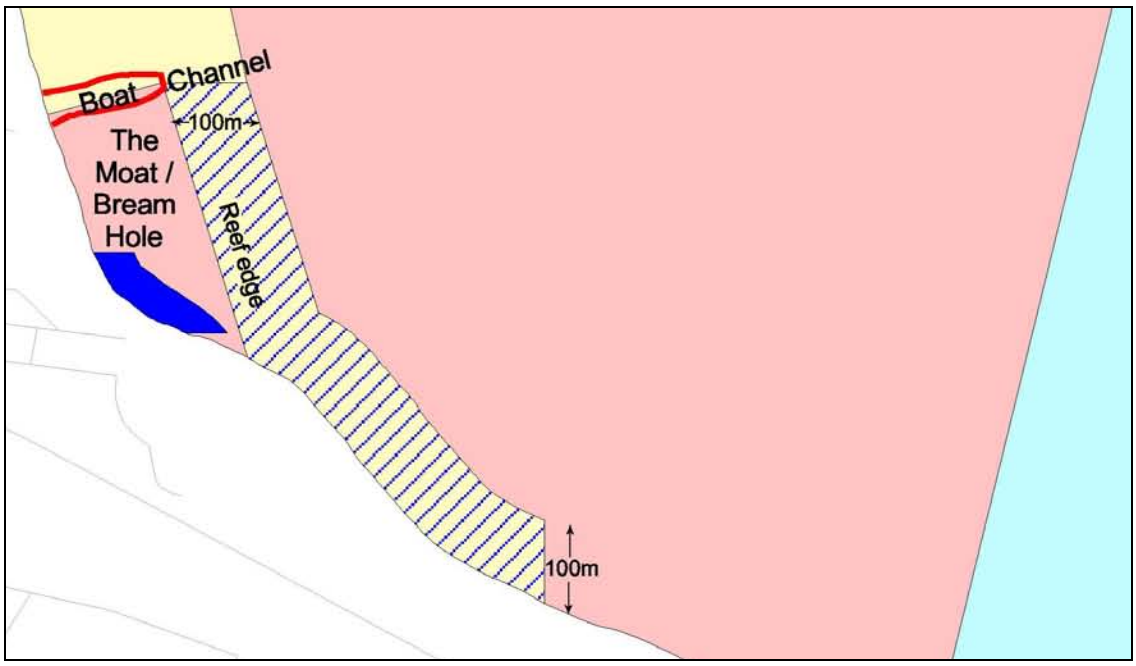

Figure 10.19. 'No-take' Sanctuary zones (pink) off Lennox Head and in 'The Moat' or 'Bream Hole' (oceanic lagoon) and a Habitat Protection zone (hatched area) which permits recreational line fishing within 100 m to seaward of the reef edge of 'The Moat' and the boulder foreshore of Lennox Head but prohibits collection of invertebrates or algae. A Special Purpose zone (dark blue) allows recreational fishing within 50 m of the Lennox Head boardwalk for those with a disability permit issued by the Marine Parks Authority. Trawling and other commercial fishing is permitted in the General Use zone offshore (light blue). (Adapted from a map of the Cape Byron Marine Park final zoning plan produced by V. Mansbridge, www.mpa.nsw.gov.au).

10.4 Discussion

Explicit goals and criteria and the systematic use of information provided an accountable and repeatable framework to guide the Cape Byron Marine Park planning process. The generic goals and criteria developed for the bioregional assessments provided direction and priorities for information gathering and a protocol to assess alternative zone plans.

Broad scale data from the bioregional assessment were useful in providing a state-wide context for planning but were not detailed enough to accurately assess values and assign boundaries within the marine park. This exercise demonstrates however, that it is feasible to collect reasonable data on fine scale habitats and species assemblages within an MPA of this size (224 km^2). This was made possible largely through the use of remote sensing methods.

Sidescan sonar proved to a highly efficient tool. Scientists from the Estuarine Cooperative Research Centre (A. Bickers and K. Baxter) used this method to acoustically map seabed textures in continuous swathes extending up to hundreds of metres each side of the survey vessel's path. The high resolution acoustic images that were returned were then classified using a dropped or towed underwater video. Within a relatively short time, and for a reasonable cost, this method provided an almost continuous map of subtidal habitats in the marine park and mapped many previously undescribed features at a range of depths (Bickers 2004). High resolution (1:8-12,000) aerial photographs were also used to provide accurate, continuous maps of near shore reef (Avery 2000) and estuarine vegetation (G. West and D. Morrisson pers. comm.) and field surveys provided detailed maps of rocky and sandy intertidal habitats (Banks and Scotts unpublished data., Banks *et al.* 2005)

Each of these surveys is distinctive in that outlines of major features were mapped directly, rather than interpolated between widely spaced samples. Although the habitats mapped are relatively broad, they now provide a stratified seascape to guide more detailed surveys of species composition. Combining this information into one almost continuous, seamless map provided an important resource for planning discussions and the basic data for reserve selection models. This cooperative exercise demonstrates how communication among managers, stakeholders and scientists can benefit from, and promote, cooperative progress in applied conservation research and management.

Recreational and commercial values were identified as an important social and economic consideration in the planning of the marine park. Approximately 1,752,000 tourists annually create $306 million in business for the local economy (Byron Shire Council 2002, NSW Marine Parks Authority 2003). The voluntary surveys provided a useful indicator of where community concerns were focused. However, they should be used cautiously, and only as a relative index of use. Respondents returning voluntary surveys were more likely to be individuals and organisations with particular interests affected by the zoning. It was also evident that responses for some activities and areas were affected by political organizing to influence returns. However, in the absence of site specific information on recreational values, the survey maps provided reasonable data that reliably predicted those areas and issues of most concern to different sectors of the community. More objective

estimates of use can be derived from observational studies like those of Boykett (in prep.) and Wellington (2003) and from random, statistical census techniques.

Questionnaire returns from registered commercial fishers provided approximate information on the amount and type of catch landed from different areas inside the marine park. This information was used to assess the voluntary 'buy-out' of commercial fishing licenses in the marine park under different zoning scenarios and to determine the allocation of *ex gratia* payments to buy out fishers that might otherwise be displaced to surrounding areas. Voluntary descriptions of the commercial fishing catch within the marine park were of variable quality but most provided basic descriptions of the areas most frequently used. Assessments of this data in workshops and in reserve selection simulations indicated that the information was reasonably realistic. Perhaps most importantly, it provided an opportunity for commercial fishers to provide direct input into the process and for managers to understand something of how fisheries operated in the area.

Both C-Plan and Marxan provided similar maps of irreplaceability that focussed on those habitats found at a limited number of locations. Both tools indicated high irreplaceabilities for the areas between Byron Bay and Julian Rocks, in the Brunswick River estuary and for distinctive rocky shore types at Cape Byron, Broken Head and Lennox Head. Marxan was however, able to effectively aggregate planning units into larger zones and generate a range of different reserve designs that minimised impacts on different commercial fisheries. What was surprising were the major differences between reserve designs produced using cost data for different fisheries, while still meeting conservation targets. This indicates that designs that aim to accommodate different commercial and other activities need give consideration to the individual differences among patterns of use. Unfortunately, because of time constraints, Marxan was only used to a limited degree in the workshops. The results however provided useful insights into the range of zoning options available and the potential impacts for different fisheries.

The reserve selection tool C-Plan, had a useful role in planning before, during and after the workshops. The program is a powerful 'participatory GIS' tool that enables managers and community representatives to interact directly with the goals, data and the spatial boundaries of proposed reserves. The program also saves a significant amount of time for operators and technical staff, in building and analysing GIS coverages for alternative proposals. The models developed here were used throughout the Cape Byron Marine Park draft zoning with managers and community representatives to assess options within the context of the marine park and within wider bioregional and state contexts.

However, three issues arose in relation to the use of this kind of software. The first is in regard to the use of targets. Another is in regard to the use of planning units of a fixed size and shape. The third is in providing appropriate time, resources and expertise to develop, apply and assist in using the models. Targets of specified percentages of area, or the absolute areas targeted for each conservation feature are necessary for the computation of irreplaceability. While many proponents of these methods recommend that these targets should be pre-agreed among stakeholders at some fixed level, there are

few definitive guidelines for where these should be set, and having different sectors of the community agree to these would be difficult.

The required level of representation is also dependent on the context of the target. For example, is a target calculated as a proportion of the multiple use marine park, a proportion of the bioregion, or of the entire state. The required area or proportion might also differ significantly for different features and should reflect the ecology of different conservation features, their vulnerability, condition, connectivity and other goals detailed in Chapter 2. The main problem with targets, among managers and stakeholders involved in the zoning process, was a preoccupation with meeting specific, sometimes arbitrary percentages and this tended to obscure the many other criteria important for an effective MPA (listed in Chapter 2). Examples of this include neglecting issues of reserve design, monitoring and enforcement issues and altering the location of whole reserves in order to achieve incremental increases of less than 0.1% of the park's area.

A related difficulty is in presenting results as static 'snap shots' from a limited number of simulations for a few different scenarios. This can be misleading where many different parameters can be applied and where, potentially, many alternative reserve networks can satisfy these goals. Ideally, these simulations should be run interactively with input from experts in marine ecology, reserve design and the human activities undertaken in the marine park. The next best thing is to present results for several different targets and scenarios but ensure that these results are interpreted as only indicative of the kinds of solutions possible.

During the latter stages of negotiations, very precise boundaries were required to represent stakeholder suggestions. At this stage, even the fine scale 10 hectare planning units were too coarse to accurately record proposed boundaries and the advisory committee required zones to be mapped through the exact editing of vector shape files. Examples here include extending 100 metre buffer zones from a rocky shore to include an inshore rock, but exclude the outermost rocks of a group of islands used for spear fishing. This level of detail precluded the use of reserve planning software (although theoretically, even smaller planning units could be used) and required many hours of high speed editing for GIS operators to keep up with the many proposed changes. A major improvement in the reserve planning tools would be to base simulations on polygons that could be rapidly edited while simultaneously updating databases of the conservation values they include.

The draft zoning process allowed for additional staff, resources and time to collect additional data, develop reserve selection models and assist the advisory committee before, during and after the workshops. Even so, there was only sufficient time to develop and run only basic models and the use of Marxan in these circumstances was limited. The workshop demonstrated that using an information based, 'participatory GIS' is a feasible and potentially powerful tool for community based planning. However, future exercises need to ensure that adequate resources, time and trained staff are made available for this work.

While a single mutually acceptable draft zone plan was not finally agreed upon, there was significant 'give and take' among interest groups and a variety of detailed design options were examined for specific locations throughout the marine park. A simple 'for and against' model of participants and arguments did not accurately represent the viewpoints of all stakeholders or agencies. The advisory committee included not only recreational and commercial fishing interests, but also representatives for diving (including spear fishing and SCUBA interests), tourism, local councils, indigenous people, scientists and local communities.

These groups did not automatically support or condemn fishing or conservation positions but expressed a range of views depending on the particular issue and location. Even advisory committee members and agencies within fishing or conservation interests had variable positions on different options and opposing interests were often able to work together to reach some compromise. The biggest impediment to progress in workshops appeared to be the polarising of debate around fixed ideas from conflicting points of view. A major disadvantage of this was that other, less strident views were marginalised and received less weight in decision making. In particular, values for general recreation, science and indigenous values were sometimes ignored.

At several specific locations, there were direct conflicts between protecting conservation values and maintaining access for commercial and recreational fishing. Boundary options for these areas were often complex and reflected the importance of small changes to include either local conservation values or accommodate very specific patterns of use. Local experience from the advisory committee and other community members was crucial in representing these issues. Compromises were often only achievable through small changes in boundaries at spatial scales less than hundreds of metres.

Consultation with, and among community groups was contentious and a complete consensus on one mutually acceptable zone plan was never reached. However agreement did occur for several individual sites in the plan and most decisions represented a compromise between, what were initially, diametrically opposing views. The tools and information had an important role in clarifying goals, presenting objective evidence for specific sites and allowing community representatives to contribute local knowledge, draw zone boundaries and view possible effects on a range of conservation, economic and social values.

By making decisions more transparent and accountable, the techniques inspired a greater degree of community ownership and cooperation. The open exchange of information, and the ability to readily view data as maps also created support for proposals to collect new and more detailed information. Most importantly, allowing representatives to directly participate in analyses and the drafting of boundaries helped to divert arguments away from general political stances and towards specific zoning decisions.

These techniques should have an increasingly important role in other marine planning and consultation processes. However, there are a number areas in which consultation and the use of this technology could be improved. Understanding the diversity of scales, information, tools, processes and people that can assist in resolving issues can help improve decisions. It also needs to be recognised that the

information tools are there to support, not replace participatory decision making and that these tools should be used explore alternatives, rather than simply confirm preconceived ideas. Most importantly, sufficient time and resources to collect, explore and share information with communities must be allocated if it is to be done successfully. While broad scale surveys and general MPA proposals may serve to identify broad areas of interest, detailed research and direct community involvement is needed for planning at scales relevant to local ecological and human communities.

10.5 Conclusion

GIS based tools with good ecological and social data provided a very useful foundation for the draft zone plan and workshop. In particular, this approach allowed managers and community members to reach compromises through directly exploring the possible outcomes of a range of specific zoning options, rather than becoming locked in polarised debate over general issues or designs. The information systems were invaluable in integrating information from many different sources and formats and in recording and developing options among stakeholders. However the most challenging problems were not scientific or technological, but in how to coordinate balanced discussions among competing interests and develop joint management options.

11 General Discussion

"you can't depend on anything…you need a bus load of faith to get by"

Lou Reed, "New York", Sire Records 1989.

Marine protected areas have an important role in how we manage and understand marine ecosystems. However there is much uncertainty in how they should be applied and what outcomes might be expected for different species, environments and human activities. There are no automatic solutions to problems in marine conservation and MPAs are only one way to help maintain marine ecosystems. Establishing marine protected areas on their own and without careful consideration of the ecosystems and human activities will not guarantee protection and understanding how to manage our use of marine ecosystems is no simple task.

In this thesis, I demonstrated how the systematic use of ecological, social and economic information can help address these complex or so called "wicked" problems in ecosystem conservation and research. However, while the use of spatially explicit, decision support tools has received much attention in recent applications of this approach, these tools are not a completely necessary or sufficient component of a systematic conservation planning process. Knight *et al.* (2006) define systematic conservation assessment as the "technical, often computer-based, identification of priority areas" and conservation planning as these technical assessments "coupled with processes for the development of an implementation strategy and stakeholder collaboration."

Despite this, decision support tools are one way to bring many of the diverse components of conservation planning to focus on specific problems and possible solutions. The tools add value to conservation planning by applying planning principles in a structured, analytical environment. An environment where real planning problems can be confronted in a transparent and repeatable process and where alternatives can be critically assessed using the best available information.

Figure 11. 1 highlights systematic conservation planning tools as one technique to unite many different elements of conservation planning. In the overall scheme of conservation and research, decision support tools require only a portion of the total effort, resources and attention involved. However, to get to the point where these tools can be used requires the systematic organisation of all the resources in the 'pyramid' in Figure 11. 1. The greatest strength of these tools may therefore be in helping to coordinate a central, strategic approach to planning and research. Systematic conservation planning and management relies on the coordinated integration of many interdependent scientific, social and political components. The following discussion highlights the relatively small, but pivotal role of these tools, and emphasises how they are dependent on many other factors for success.

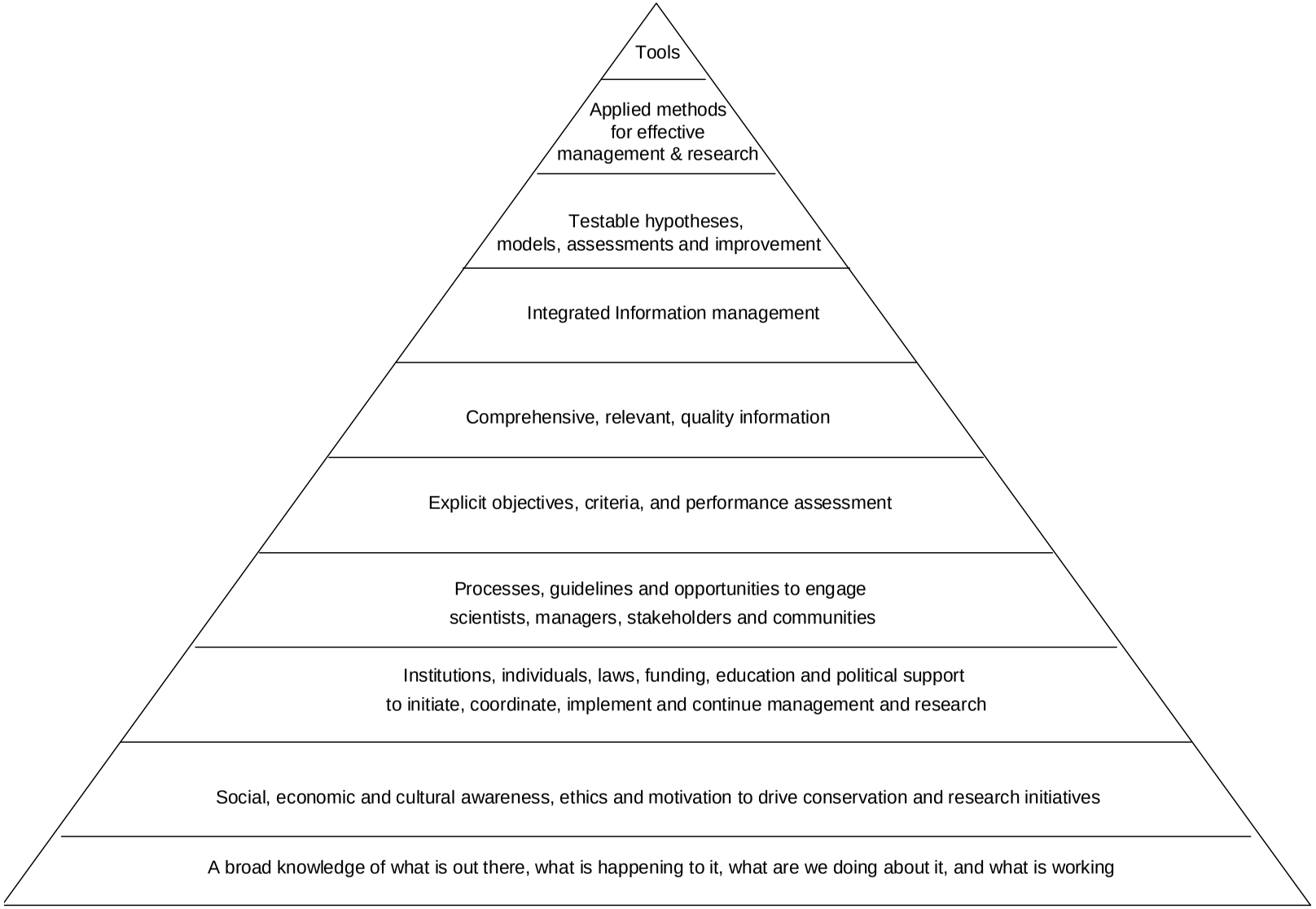

Figure 11. 1. The support required for systematic conservation tools to be effective.

11.1 What is out there? What is happening to it? What are we doing ? Is it working?

These four questions summarise the core knowledge requirements for environmental management. The questions provide the context for the assessments in this thesis and the starting point for any environmental study. If these questions are considered, it is evident that our knowledge although increasing, is limited. An initial recognition of this is a reasonable first step towards planning for a more informed basis for management. For at least some marine locations, there is a reasonable knowledge of what is 'out there' in terms of broad habitat types, some of the more obvious processes and those conspicuous species that may be of special importance to us. However, for most species, habitats and processes, relatively little is known.

Knowledge of what is happening to these systems is even less and a matter debated by many. However, there is a general consensus that for many locations, undesirable changes are occurring in marine systems and in the products and values they provide for human societies. Given that this knowledge of biodiversity is limited and that measuring change is arguably even more difficult, it is quite possible that predictions of 'what is happening?' are underestimates. MPAs are an important tool for understanding the extent and nature of these impacts. For example, comparisons inside and outside of marine reserves demonstrate that fishing can cause significant direct and indirect effects on marine environments (Langlois and Ballantine 2005).

Research associated with MPAs has also had an important role in assessing other impacts such as the effects of run off on sedimentation and water quality (Furnas and Brodie 1996, Koop *et al.* 2001), climate change (Berkelmans and Oliver 1999, Berkelmans *et al.* 2004), tourism (Harriot *et al.* 1997, Breen and Breen 1994ab, Breen *et al.*1997ab) and development (Kelleher and Kenchington 1986, Smith and Rule 2001).

MPAs are however, just one way to help understand and manage impacts. For management to be effective, a range of strategies need to be considered together. MPA management must be considered within the context of sustainable fishing practices, catchments, coastal development, aquaculture, biosecurity, climate change, human demographics, social welfare and politics. The use of different types of MPAs (IUCN 1994, 2000) and combinations of these within large multiple use MPAs, is one way in which integrated management can be achieved.

This thesis aims to integrate marine management and research by reviewing basic, regional knowledge of what marine biodiversity and ecosystems exist, how these resources might be managed in a network of MPAs and identifying where more research is needed. However, it contributes very little towards understanding what may be happening to marine environments, or towards knowing how effective management efforts are.

It does however, provide a foundation on which to design appropriate monitoring programs, and aims to establish MPAs to support this work. The goals, criteria and information presented provide a basis for future evaluation of MPAs as well as other marine conservation strategies. The biodiversity assessments should therefore be considered as only a first step in a process to identify and protect conservation values, compare the effects of this management with outcomes achieved through other strategies and then adapt management accordingly. The sites selected for MPAs in his thesis are essentially management hypotheses based on existing information. Research is now required to ground truth these predictions and to assess whether the MPAs established achieve the goals they were designed to meet (Walters 1986, Underwood 1998, Walters and Holling 1999, Hockings 1998, Creese and Breen 2003, Day *et al.* 2003).

11.2 Awareness, education and motivation

Support for conservation strategies ultimately requires a political and social awareness of the need for management and confidence in the ability of management to achieve its goals. This support is critical if options for MPAs are even to be considered, proposed or assessed and if the resulting MPAs are to be adequately resourced. An awareness of the benefits of MPAs is most important where, as is often the case, there are competing uses such as commercial, recreational or subsistence fishing.

For these reasons a community driven approach to MPA identification and establishment is often recommended (Christie *et al.* 1994, Gilman 1997, Krausse 1998). However this approach can also incorporate a systematic, information based component (Elwood and Lietner 1998, Harris and Weiner 1998, Lewis *et al.* 2003, Close and Hall 2006). MPA processes often incorporate either one or the other of these components, but the approaches complement each other well and when used together, can provide more effective solutions. An information based approach provides structure and direction for community consultation by integrating ecological and social goals and providing access to better information. Communities in return can help develop and refine goals and criteria, validate scientific surveys with their own observations and provide information of their own, particularly for areas they regularly use.

Providing reliable data directly to communities helps increase their awareness of conservation issues, bolsters their confidence in management and empowers them to make their own informed decisions. There are many ways in which consultation can be enhanced through advisory committees (Vasseur and Renaud 1997), community meetings, information sessions, displays, the media and through the availability of staff for public communication. Effective consultation encourages public confidence and a sense of ownership and contributes to the effectiveness of MPAs in adequately conserving marine biodiversity.

In NSW, information was provided through published electronic and hard copy reports and summaries, through internet based map applications and through the direct supply of GIS data to user groups. The provision of information on MPAs in NSW and elsewhere is increasing, but remains an opportunity to support marine conservation that is under-exploited. Without community awareness, motivation and political support, it will become increasingly difficult to establish MPAs and even harder to enforce, fund and maintain these areas. Providing readily understood, well researched information on the values that MPAs protect and the benefits they provide for ecosystems is one of the best ways to ensure that MPAs continue to receive support.

11.3 Institutions, individuals and political support

Promoting marine conservation issues requires dedication from individuals and institutions. Institutions require people to establish, maintain and ultimately make the decisions that create and manage MPAs. It often also individuals who lobby and work to establish MPAs in the absence, or in spite of, institutions for this purpose. In many areas, it is still local communities and individuals who bear most responsibility for establishing and maintaining MPAs.

Institutions however, organise the efforts and resources of many individuals beyond a single working lifespan and can establish the ‘law or other effective means’ (IUCN 1994) required to give MPAs a degree of permanence. Institutions can also help coordinate the development of regional networks of MPAs to meet goals for many different ecosystems, habitats, species and communities. The role of government in this area has lead to the steady, coordinated development of national networks of MPAs and increasing funding for their management. At a global level, international organisations like the IUCN help to promote, coordinate and support the development of MPAs across whole regions.

The way that institutions operate and interact is now recognised as a major factor determining the effectiveness of regional conservation strategies and this topic now has a scientific literature of its own (Imperial 1999, Kinzig 2001). The establishment, for example, of the Great Barrier Reef Marine Park Authority in 1975 was a major step for marine conservation in Queensland, but also provides a model and support for MPA management and research elsewhere. The Authority works closely with several scientific and educational institutions on coral reef studies including a cooperative research centre specifically dedicated to reef research and industry involvement. The Representative Areas program described in Chapter 3 benefited from the expertise and support of scientists and managers from many of these institutions and its success was due in no small part to their cooperation.

Similarly, the NSW Marine Parks Authority is one of the smallest government departments in the state, but it exploits the resources and expertise of the Fisheries, National Parks and Premier’s departments as well as several other departments with a role in marine and coastal

management. The latter include the NSW Department of Waterways, the NSW Department of Infrastructure and Planning, the NSW Land Information Centre, Ports Authorities and councils.

Among this many institutions, there is much potential for duplication of effort and resources, but also many opportunities to share resources and information. The assessments in this thesis made use of information and advice from many of these departments and the assessments themselves promote a wider awareness of this knowledge. The decision support tools used in this thesis were also provided freely by individuals supported by other government and educational institutions. These resources are available to agencies and communities through internet sites developed for this purpose (e.g. www.canri.nsw.gov.au). Such cooperation however depends on those individuals within institutions willing to promote data sharing and encourage informed planning and management.

Cooperation among institutions has been important factor in planning for MPAs throughout Australia. The assessments described in this thesis, for example, are just a few of the many joint projects carried out between state agencies and the Marine Protected Areas Program at Environment Australia.[1] More recently, the Commonwealth has sought support from state agencies to develop regional plans which include options for MPAs in offshore waters. The plans and the MPAs proposed will address marine ecosystems adjacent to state waters and therefore cooperation among Commonwealth and state agencies will be required for success.

11.4 Processes to engage scientists and communities

While it is important to inform communities of marine conservation issues and their management, it is also necessary to build processes that allow people, other than conservation managers, to participate in decision making. It may seem expedient to involve fewer participants, particularly where there are opposing views. However this can lead to perceptions that consultation is a pretence, that decisions have already been made and that public comment is only sought to satisfy legislative and political requirements.

Davey (1998) lists eleven reasons why MPAs fail, six of which involve stakeholder input.

- they do not address key issues
- they fail to involve stakeholders
- they rely too much on external experts and fail to involve local people
- they are weak on implementation
- they fail to raise political support for protected areas as a worthwhile concern
- they are poorly publicised.

To engage properly with communities requires that consultation begin early in the MPA planning process rather than towards the end. To do this requires consultation guidelines and

[1] Now the Commonwealth Department of Environment and Heritage.

processes to be established, preferably by law. The *NSW Marine Parks Act (1997)*, for example, requires that an advisory council of stakeholder and community representatives be established to provide recommendations on all marine parks. A local advisory committee is also required to provide specific advice to the government on each individual marine park and a minimum period of consultation is required for each draft and final zoning and operational plan.

At the start of the Manning Shelf bioregional assessment, information sessions on the assessment process were held at regional centres throughout the bioregion. Community forums were also conducted in the Port Stephens and Great Lakes area by a non-government organisation, the Marine and Coastal Community Network. These occurred six years before declaration of the Port Stephens–Great Lakes Marine Park. The report on the "Broad scale biodiversity assessment of the Manning Shelf Marine Bioregion" was made available on the internet and as hard copies, and meetings with representatives of interest groups occurred before the declaration of the park.

However, there were few other opportunities for stakeholders, communities or scientists to provide direct input into selecting boundaries for the park. It could be argued that this approach avoided political debate and further delays (after five years) in establishing the park. However, while general plans for a park were well known, this approach did not encourage trust from the community and the process may not have benefited from all the information that stakeholders could have contributed. Although a Marine Parks Scientific Advisory Committee of four scientists from NSW Fisheries and NSW National Parks oversaw the assessment process, there was little direct input from the broader marine science community. Input from the scientific sector into the zoning process for Cape Byron was also limited to letters in the public submission process and a representative on the Marine Parks Advisory Council and on the Cape Byron Advisory Committee.

This situation contrasts strongly to Great Barrier Reef Marine Parks Representative Areas Program where a multi-disciplinary Scientific Steering Committee with representatives from several scientific and tertiary education institutions provided guidance for the whole process. Interviews were also conducted with over 70 different experts in tropical marine animal and plant ecology, oceanography, geology and reserve design. Expert workshops were also held to interpret the data collected, develop bioregions, and establish reserve design guidelines to zone the marine park. This scientific input covered a broad range of marine ecosystem science on topics including fishes, invertebrates, algae, seagrasses, mammals, birds, reptiles, water quality, oceanography, geology and social science (Day *et al.* 2002). This input provided much additional information to that available from scientific literature and databases. The support of so many scientists with experience in the region also generated a high degree of confidence in the plan and a greater appreciation of the conservation values involved.

Community consultation to develop a zoning plan for the Great Barrier Reef Marine Park then collected submissions from over thirty thousand people through meetings, phone calls and surveys where individuals could map areas that were important to them for different interests (Innes 2004, Fernandes *et al.* 2005). Similar techniques were also used to analyse responses to previous plans for the Cairns, Whitsundays and Cooktown areas of the Great Barrier Marine Park and to map social and ecological values (Bollard-Breen 2006). This method was adopted in Chapter 10, for the Cape Byron Marine Park Draft Zoning process, and for the subsequent Port Stephens – Great Lakes Marine Park draft zone plan. In this way, the views and concerns of local communities could be systematically considered in zoning options and managers could make use of community information that might not otherwise have been available.

In Chapter 10, I also demonstrated how community workshops and reserve planning software could integrate this social data with ecological information to interactively design a system of MPAs using a participatory GIS approach. Similar community workshops have been conducted elsewhere with some success for terrestrial (Pressey 1998) and marine protected areas using tools such C-Plan, Marxan and multiple criteria analysis (Fernandes 1996, Villa *et al.* 2002). However, their use in MPA processes is often limited or included too late in the planning process. Adequate time and resources are required for this approach to be effective and informed workshops need to be scheduled as a mandatory component of the planning process.

An area where this approach could be of special value is in the ecological design of MPA networks. A workshop of scientists with expertise in biology, modelling, connectivity, fisheries and experimental design would be able to make the best use of the more advanced spatial features of reserve planning tools. They could also provide direct input on the likely outcomes of alternative designs and how predictions could be tested. The effects of different MPA network designs on protected and surrounding marine ecosystems is one of the most pressing issues in MPA science and management but practical attempts to address this question are few (Sale *et al.* 2005). Large, multiple use marine parks in NSW are ideal candidates for this type of study as they effectively establish whole regional networks of highly protected reserves and other MPAs simultaneously. Management is also required to monitor and review the performance of these MPAs every five years. However, so far, the direct input of scientists into MPA design in NSW has been limited and this approach needs to be carefully explored. Scientists need to be included not just as stakeholders with an interest in permitted research, but as experts that can contribute substantially to the design, management and functioning of MPAs.

11.5 Objectives, criteria and performance assessment

I used multiple criteria models to explicitly model the relationships among policy goals, criteria and the measures used to assess locations for MPAs. These presented a systematic, unified summary of the various guidelines, policies and legislation that verbally define how MPAs are to be identified by the NSW Government. In developing and prioritising the multiple criteria models, other studies have relied on input from managers, stakeholders and the community (Fernandes 1996, Villa *et al.* 2002). In this study, there was little opportunity to involve stakeholders and community directly in developing the models. However, comments from initial community meetings and documents summarising many years of consultation and experience were incorporated in many of the criteria.

The models are broadly applicable elsewhere and can be easily modified to accommodate new goals and criteria, alternative priorities and new information. In a more comprehensive consultation process, input from other sources could be used to develop alternative models.

It is important to distinguish between the conceptual (Chapter 2) and applied multiple criteria models developed (Chapters 5-9). The conceptual models were developed to represent the many potential goals portrayed in policy and legislation. The applied models were based on the conceptual models but constrained by the information available at the time. A comparison between the conceptual models and their actual application in the assessments clearly shows what information was available and where more information may be required. These goals and criteria also provide the logical basis to assess in the future, how well the MPAs perform in meeting their objectives.

11.6 Comprehensive, relevant and useful data

Models and decision support tools can assist in interpreting and summarising data from many different sources. However, support for decisions should ultimately be founded on direct observations and not just on derived indices. Models and indices are a powerful way to summarise data, but they can obscure the individual influences of many contributing factors and under-represent the weight of evidence provided by a range of independent information sources. An index may indicate that a site has high conservation value, but only the underlying data will reveal which particular value, or values are important and what is the appropriate management action. Individually identified sources of evidence are also more readily understood, evaluated and trusted by communities and scientists.

When interpreting an analysis it may be prudent to “not believe it, unless you can see it, and then, still don’t believe it” (B. McArdle pers. comm.). For this reason, the assessments in this thesis provided individual descriptions of all data sources, their limitations and features of the data likely to contribute to a site’s suitability as a MPA. A deliberate attempt was made to

represent each measure in a format that was easily understood by simply mapping and graphing data. In this way, all interested parties could assess for themselves the values that occur at a site for any given criteria, rather than relying solely on aggregate mathematical scores or subjective interpretations.

Several studies have examined the effectiveness of using a limited set of biodiversity surrogates to represent a wider range of perhaps more detailed biodiversity values (Ferrier and Watson 1997, Ward *et al.* 1999, Buxton 2005). However to assess the validity of a particular surrogate requires independent data for verification and where this data is available, it should then also be presented, particularly if it provides additional support or new interpretations.

The assessments in this thesis relied primarily on a broad scale environmental classification applied at several spatial scales with surrogate classes ranging from bioregions, ecosystems, habitats, and communities to species. The hierarchical nature of the classification, and the classes chosen in each level, significantly influenced which locations were identified as potential locations for MPAs.

The decision to establish representative MPAs, including at least one marine park, in each of five different bioregions immediately constrained choices about where MPAs should be located. Criteria also required the inclusion of each estuary type in each bioregion within MPAs. This constrained choices further, especially where only a few locations were able to meet these criteria. At the habitat surrogate level, the locations of rarer features such as islands, reefs and the larger complexes of seagrass, mangrove and saltmarsh again strongly influenced which sites were identified as MPAs. For zoning within the limited area of the Cape Byron Marine Park, these features, and finer scale classes such as boulder shores and reefs in different depth zones, were a major influence on where sanctuary zones were established.

A basic assumption here, is that the surrogate bioregion, ecosystem and habitats actually correlate with patterns in biodiversity. While general justifications for all of these categories were available from the scientific literature, there were few comprehensive data sets of species distributions throughout the state available to test the overall performance of this classification.

It was therefore considered prudent to assess whatever other information on biodiversity values was available to supplement these choices. This was reasonable given the uncertainty in many data, the approximate nature of the surrogates, the complexity of the systems studied and the range of different questions and criteria to be addressed. This approach was also consistent with a philosophy to provide information for decision making, rather than simply impose decisions through an *a priori* selection or exclusion of information. Confronting alternative decisions with different data sets provides more opportunities to compare and question alternative choices for MPAs. Although it may require more time to assess a wide range of information, the time

required to implement and consult for MPAs can be considerably longer, particularly where the justification for the MPA is questioned. The weight of evidence provided by many data sources was therefore considered a reasonable and convincing approach given the circumstantial nature of much of the information available.

Constraints on funding and time often limit applied marine biological research to short term studies at a few selected locations. Surveys are often opportunistic and information for whole regions is often fragmented into many different data sets, collected at different times by a range of different methods. It is possible to aggregate data from many similar studies. This has been done, for example, for bathymetry (Buchanan 1998) and seabed sediment data sets (Jenkins 1997, 1999ab, Roy and Boyd 1996, Boyd *et al*. 2004). However this approach requires many data points and adjustments to produce an even coverage that avoids biases in site selection, methods and units of measurement.

For most areas, biological data sets only provide a sparse and uneven distribution of species records. The Great Barrier Reef Marine Park Representative Areas project was to a degree, an exception to this. Although by no means a complete coverage, several systematic data sets were available across large regions for many species of fishes, hard and soft corals, algae, seagrasses, sponges and other benthos. This region has been the subject of extensive research programs for several decades. It includes relatively calm, warm, shallow waters, is important for tourism and fishing, includes conspicuous and attractive biodiversity and is adjacent to an affluent population with government agencies that are relatively well resourced. For these reasons, the region is relatively 'data rich' when compared to many other areas.

However, even here, very few, if any, data sets extend over the entire region of interest and all the data required at least some level of interpolation. The major issue, however, was not whether data existed, but whether it was accessible to planners, managers and scientists in an integrated form that could be used in decision making.

In NSW, marine environments have also been the subject of many years of research, but deeper, colder and more exposed conditions and a focus on the ocean as a resource (or dumping ground) have constrained research on marine biodiversity to greater degree. For inshore NSW, there were few systematic surveys of species distributions at broad spatial scales. Data collections for commercially fished species (Pease 1999) and museum specimens (Avery 2001) provided information for some areas but were biased by the intent and scope of the original research. However, other systematic surveys of intertidal organisms (Otway 1999), threatened sharks (Otway *et al*. 2003), estuarine fishes (R. Williams pers. comm.), birds (NPWS 1999abc, 2000bcd), and wetlands (NPWS 2000a) provided important data for the assessments.

Many other detailed studies were not included in the assessments because they were limited to a few locations. These could, in the future, be aggregated with other similar data, or used in planning for specific sites. A systematic process to review these data and address gaps in our knowledge of marine ecosystems is greatly needed. At a general level, the assessments in this thesis provide a starting point for this process.

Comparisons between the ideal goals and criteria defined in Chapter 2 and the actual measures used in Chapters 5-8 clearly show the approximate nature of the surrogate measures used and they highlight information gaps for many regions, habitats, taxa and other criteria. It was recognised in the assessments that more detailed information for fine scale habitats, individual species and social, economic and cultural values would be necessary to implement any options for MPAs and the assessments emphasise these information gaps.

In particular, the assessments identify the need for more detailed surveys of:

- subtidal environments, particularly offshore but also in estuarine areas
- finer scale biodiversity surrogates, especially for less well studied flora and fauna
- condition, vulnerability and changes in marine environments and populations
- ecological processes, connectivity and MPA designs to support these processes
- human activities and values and how these interact with marine ecosystems and MPAs
- comprehensive ground truthing of data and testing of assumptions and outcomes.

Vast areas of subtidal reef and offshore sediment throughout the state remain poorly mapped. Many of these areas are probably well known to fishermen and this knowledge has been used to produce detailed, scientifically verified maps of seabed and benthos for the continental shelf off the southern NSW and Victorian state border (Williams and Bax 2003). There is also the potential to aggregate existing geological seabed data (Jenkins 1997) and Boyd *et al.* (2003), for example have now developed a broad scale model of the entire NSW continental shelf. Multibeam (A. Jordan pers. comm. NSW Marine Parks), sidescan sonar (Bickers 2004) and video methods are also being used to map subtidal habitats in marine parks in NSW.

However the relationship between coarse scale surrogates and the community structure of different species assemblages is still poorly understood. As this link is a major assumption of assessments, and because biodiversity at the species level is a primary concern for conservation, it is important that research to assess these assumptions is planned and supported.

Another challenge for MPA research and management is to understand the ecological processes that link species populations, habitats and regions and how these processes respond to different management strategies. The importance of such relationships for designing a functioning MPA network is well recognised and acknowledged in the goals and criteria adopted for MPA identification and elsewhere (Sale *et al.* 2005). However, actually assessing criteria for these

process is complex, given that our knowledge on how organisms respond to different MPA network designs is mainly theoretical. These aspects of reserve design have not been adequately addressed in this thesis. However, research linking marine ecosystem dynamics and MPA performance has been developing through a steadily growing body of observations (Sale *et al.* 2005), theory, mathematical models and workshops. Empirical studies of migration, reproduction, dispersal, recruitment, growth and survival have been made for an increasing number of species. There has also been a greater recognition that larvae and juveniles are not passive particles but influence their dispersal through directed behaviours (Leis 2003).

Research of this kind can be used to inform theoretical models and simulations with biological parameters relevant to the organisms that MPAs are designed to conserve. Some studies have used geographically realistic models to simulate ecological processes for specific regions and locations. James *et al.* (1990, 1998, 1999) simulated larval dispersal on the Great Barrier Reef using mathematical models of the interaction of tides, winds and currents with complex reef structures throughout the Cairns region. Wolanski *et al.* (1996) simulated the behaviour of propagules at smaller scales using three dimensional models of individual reefs and current fields. Trophic mass balance models have been used to integrate data on biomass and energy flows among different species, trophic levels and environments which include spatially explicit models of MPAs (Mackinson *et al.* 1997, Guenette and Pitcher 1999, Watson *et al.* 2000). Parnell *et al.* (2006) used models developed for 20 species and five habitats to help select the best location for a marine reserve near La Jolla, California.

Many terrestrial studies have also investigated the role of ‘corridors,’ habitat patch size, separation and configuration in maintaining ecological processes (Rouget *et al.* 2005). The mathematics of ‘graph theory’ provides a potentially useful way to evaluate how connectivity changes as habitats are included or excluded from a network (Bunn *et al.* 2000). For habitat and species data stored in GIS, many relevant parameters such as patch size, distance, and connectivity can be easily estimated or simulated. The spatially explicit, object oriented nature of these databases also provides an environment to build individual-based models (Hinckley *et al.* 1996) with realistic habitats, populations and management interventions. Reserve selection algorithms now also incorporate spatial reserve design parameters for size, spacing and replication and organism occurrence, dispersal and persistence.

The virtual ‘seascapes’ developed in the assessments described here could now be used to explore dynamic ecosystem models that use spatially realistic data for habitats, species and systems of MPAs. The potential to model processes using mapped objects of real environments and management interventions, could be a highly effective tool for future marine planning. Specific predictions from these models could then be rigorously tested in carefully designed monitoring programs.

Among the most neglected areas of research for MPAs is an understanding of their social, economic and cultural values. These values are usually considered as part of a consultation process, but are rarely included in any preceding systematic data collection or analysis of options. Such values were recognised in the conceptual MPA goals and criteria in Chapter 2, but were not considered within the scope of the broad scale bioregional assessments. In Chapter 9 however, I showed how surrogate measures for some social and economic values could be estimated from surveys and interviews and how this data could be integrated with ecological data in reserve selection algorithms and community workshops. While social, economic and cultural issues are complex, MPA programs can still benefit from adopting a systematic approach to collecting and analysing data on these issues as part of wider selection, management and monitoring strategies.

While identifying may MPAs require research, the reciprocal contribution of MPAs in initiating, supporting and continuing research can be even greater. MPAs highlight the conservation values of particular locations, and marine ecosystems in general, to a wide political, social, economic and scientific audience. They also serve to showcase the research of scientists working within MPAs. MPAs often generate increased resources for more detailed research on biodiversity, ecological processes and human values.

The Great Barrier Reef Marine Parks Representative Areas program, for example, provided support and recognition for existing research programs, initiated additional studies and supported more detailed analyses of data collected previously. This included the mapping and statistical analysis of data for seagrasses, fishes, corals, algae, sponges, *Halimeda* bioherms and seabed morphologies.

Assessments in NSW and the Great Barrier Reef Marine Park successfully transcribed many data sets from verbal, written, paper or other media into digital GIS formats. The assessments had an important role in archiving information and expert knowledge that might otherwise be lost or forgotten.

Initial reviews of both these projects indicated that very little information for either of these regions would be available and that very simple measures or an *ad hoc* approach would be more realistic. While less data were available in NSW, both assessments were however able to collect substantial amounts of information to inform planning.

Without these assessments, the MPA identification and selection processes could have relied on *ad hoc* or subjective decisions or very coarse scale, physical predictors of biodiversity. It is therefore important, that processes and structures are in place to maintain and develop a collective knowledge of marine ecosystems. This should include not just the verbal documents which the scientific literature relies upon, but also the data that underpins this work.

11.7 Integrated data management

Figure 11.1 highlights the importance of integrated data management in systematic conservation planning. Human impacts occur at many scales for many different ecosystems, habitats, processes and species. Impacts can be complex and involve cumulative, synergistic and emergent effects that are not easily predicted or understood. For these reasons, ecosystem wide management, modelling and research must take a holistic view that is able to integrate information from many different disciplines and sources.

Once goals and criteria are identified, conservation assessments need to identify what information is available and bring this information into a common environment where different data sets can be stored, documented and analysed together. GIS have an important role here because of their ability to join and query different data sets on the basis of spatial locations common to otherwise disparate tables. GIS now combine the capabilities of relational databases with powerful tools for spatial analysis and data visualisation. These tools are readily integrated with other scientific and management databases (Fernandes *et al.* 2005), internet programs (www.spatialvision.com.au, http://chrisweb.dpi.qld.gov.au/CHRIS/), statistical packages (Day *et al.* 2002, Bollard-Breen 2006, www.splus.com) and bibliographic databases.

Data integration requires a central repository for data storage. This may be as simple as a dedicated file server or directory for a project. There are also centralised databases on the internet for many agencies, regions and fields of interest and directories that provide links to information with global repositories increasing rapidly in number and scale (Grassle 2000, www.marine.csiro.au/datacentre, www.canri.nsw.gov.au). The GBRMPA Representative Areas Program and the assessments in NSW relied heavily on initial internet searches of these sources. Community based assessments such as described in Chapter 10 for the Cape Byron Marine Park can also make use of these data. In NSW, for example, the marine environmental classification and other measures in this thesis were mapped in an internet GIS application (www.nratlas.nsw.gov.au) and community representatives were able to download shape files and metadata (www.canri.nsw.gov.au/download) to help develop independent options for zoning.

Protocols and agreements associated with centralised approaches to data management can help ensure the assumptions and limitations of data are recognised and that ownership and intellectual property is protected without necessarily excluding other users. While detailed information for many areas and subjects may not yet exist, systematic approaches to data collection, storage and documentation can help ensure that existing information is not lost, that research effort is not duplicated unnecessarily and that the best available information is readily available to all scientists, managers and community. These data collections also serve to highlight gaps in data availability and identify where further research is required.

11.8 A scientific approach to develop and test marine management hypotheses

The initial selection and much of the management of MPAs depends strongly on an integrative approach to ecology as there is often little opportunity to experiment at a scale that addresses the range of issues involved. However, research and management for MPAs can benefit greatly from adopting a rigorous, scientific approach to collecting and assessing evidence and ensuring that the results of scientific research are directly used by environmental decision makers.

Repeated assertions of the effectiveness of MPAs, without scientific support, are not in the best interests of conservation. In the long run, it is worth recognising uncertainty and aiming to reduce the role of *ad hoc* decisions by making the best use of what information is available and seeking to test and improve this knowledge.

In the assessments in Chapters 5-8, quantitative planning tools and a range of different data were used to generate alternative hypotheses about how well different MPA networks were likely to represent marine biodiversity. In the Cape Byron draft zoning process, this approach provided a flexible way for managers and community representatives to assess alternative MPA networks and how these might affect different human interests. In both these processes an iterative modelling approach was used to propose, test and then improve MPA designs while using only existing data and "local" knowledge. However, as MPA networks develop, decisions will become more complex and costs to competing activities will create more dispute. Much of the current evidence to guide and support the design of MPA networks is circumstantial. The MPAs recommended in this thesis are effectively predictions about how well different areas are likely to conserve a representative sample of marine biodiversity. Where possible, alternative options, and tools to explore other options were provided to encourage ongoing testing and refinement of MPA designs.

In NSW, initial improvements were readily apparent as many unique and previously unprotected ecosystems, habitats and species were successively included in MPAs. However, at a local level, scrutiny of available data by the Cape Byron Marine Park Advisory Committee identified significant gaps and provided the impetus for more detailed surveys including sidescan sonar and video surveys of subtidal environments, updated maps of estuarine vegetation, more detailed classifications and studies of intertidal shores and surveys of recreational and commercial activities (NSW Marine Parks Authority 2003, Bickers 2004, S. Banks and D. Scott pers. comm., D. Chapman pers. comm., G. West pers. comm.)

We can also attempt to model the uncertainty in proposed MPA models. However, with many parameters, data sets and sources of error this could become a very complex task. In most cases, there has simply not been enough data to quantify systematic or random sources of error.

However, techniques that may assist here are being explored. Halpern *et al.* (2006), for example, compare estimates of uncertainty derived from traditional statistics and modelling with techniques in probability bounds analysis, interval analysis and info-gap theory. They apply these methods to the problem of modelling optimal reserve separation based on the estimated dispersal distance of a single fish species. These approaches, even applied at such a simple level, could provide at least cursory tests of the many assumptions implied in the design of reserve systems and the spatial and ecological information provided in this thesis and related research would greatly assist in doing so.

Ultimately however, the true test of an MPAs lies in how effectively it achieves its goals for conservation and sustainable use. This can only be assessed by rigorous monitoring of predicted outcomes and at least some consideration of experimental design in designating MPAs. This is also the only reliable way in which choices about reserve size, spacing and configuration can eventually be made. Many studies have documented changes within MPAs. However, the more subtle effects of spill over, recruitment and other benefits to surrounding areas, although frequently espoused, have rarely been tested. Examining how existing and newly established MPA networks perform in these areas would provide a better foundation for future networks.

There are many design requirements common to robust MPA networks and rigorous scientific research designs (Table 11.1). Much of the work required for both these tasks is complementary and can best be carried out using MPAs as quasi-experimental units. The zoning of multiple use MPAs where different levels of management are allocated to different areas provides an ideal opportunity to test these and other hypotheses about surrogates, representativeness and the various effects of MPAs. However, this framework is rarely taken advantage of, and research and monitoring for MPAs is often applied inconsistently, even within the same network and jurisdiction (Creese and Breen 2003).

This thesis has demonstrated that it is possible to learn a lot about marine ecosystems at broad spatial scales from existing information and a relatively simple, desktop mapping and iterative modelling process. MPA management and research should however, aim to integrate the results of these types of studies with an experimental approach to network development. The assessments should be regarded as just the first step, in an ongoing cycle of adaptive management and research where conclusions from finer scale experiments are applied and tested at a broader ecosystem level.

Table 11. 1 Similarities and differences between MPA and experimental designs (based on Kingsford 1999).

Management of MPA systems	**Research methods**
Need to assess effects of reserving (or not reserving) areas against a background of natural change.	Need to assess the effects of treatments against a background of natural change.
Selectively sample MPAs from sets of candidate sites.	Randomly sample from statistical populations of interest.
Need to understand natural patterns and processes and how they interact with humans.	Need to understand natural patterns and processes and how they interact with humans.
Findings used to evaluate initial management strategies, improve management model, and reassess.	Findings used to evaluate hypotheses, improve scientific models and test new hypotheses.
Need to assess effects of reserving (or not reserving) areas against a background of natural change.	Need to assess the effects of treatments against a background of natural change.
Selectively sample MPAs from sets of candidate sites.	*Randomly* sample from statistical populations of interest.
Need to understand natural patterns and processes and how they interact with humans.	Need to understand natural patterns and processes and how they interact with humans.
Findings used to evaluate initial management strategies, improve management model, and reassess.	Findings used to evaluate hypotheses, improve scientific models and test new hypotheses.

11.9 Real world applications of systematic marine planning and decision support tools.

Systematic assessments and decision support tools can only achieve real outcomes and be fully evaluated if they are applied to real planning situations and the results are used to guide and support management and research programs (Knight *et al.* 2006a). It is critical that they are not merely academic exercises in ecological mathematics. Their application to 'real-world' problems is therefore emphasised at the ninth level in Figure 11.1. Knight *et al.* (2006b) caution that conservation assessments alone, "do not deliver the actions necessary to conserve nature, they merely generate data to support the planning and implementation of conservation interventions. They cite that "between 1980 and 2000 at least 245 published studies employ selection algorithms" but caution that the fascination of many planners with the incremental improvement of assessment techniques has drawn the focus away from the real goal – directing conservation actions – because relatively few assessments published in peer reviewed literature actually lead to nature conservation (Prendergast *et al.* 1999, Faith *et al.* 2003, Knight *et al.* 2006b).

Managers have been slow to adopt systematic methods despite steadily increasing access to sophisticated ecological research, decision support and information management tools. A number of reasons may have been responsible for this. Firstly, there are fears that numerical, and particularly computer based methods usurp human decisions with 'black box' methods that produce arbitrary or unrealistic results beyond the control of decision makers.

Secondly, decision making is politically influenced and driven by administrative expediency with strict limits on time and resources. In these situations, simple methods and answers are the most readily trusted. Methods that complicate issues, require additional skills and resources, question assumptions or generate alternative views are regarded as obstacles to progress.

Thirdly, while systematic conservation planning and decision support may be based on policy and accepted principles, advanced theories and applied methods in ecology, mathematics and computing are unfamiliar to many people. These techniques may be mistrusted by managers and communities, particularly if they must rely on specialists for interpretation.

As a result, many conservation agencies still make only limited use of ecological data and spatial information technologies and provide only minimal resources to support systematic, science based, ecological planning. With some important exceptions, the majority of this work is done by external research or educational institutions or by contractors as isolated projects rather than within strategic, mainstream, corporate priorities. Without ongoing, dedicated maintenance by employed ecological analysts, much of the work actually done in setting up ecosystem information systems is often undone, forgotten or made obsolete when short term

projects end. Effort is then duplicated by repeating these exercises from start, for each new problem. It is therefore critical, that practical applications of these methods are shown to be a realistic and cost effective part of a wider, and ongoing business strategy and not just experimental trials for isolated test cases.

To achieve this, is perhaps more challenging than the science itself. It requires planning for the development and refinement of tools that can be reliably used by, or at least with, managers and community members. It also requires: an increased awareness of these methods; an acceptance of their role in supporting and not replacing human decisions; the time, resources and opportunities for their use; and a professional capacity that includes staff familiar with these methods (Rodriguez *et al.* 2006).

The best way to do this is through practical examples that directly engage scientists, managers and communities and carefully planned and structured communication with these groups. The following sections compare the application of these methods in this thesis with previous assessments in NSW and elsewhere.

In Australia and elsewhere, systematic planning for terrestrial reserves has assisted in developing extensive systems of terrestrial protected areas and highlighted gaps where new reserves are most needed (Csuti *et al.* 1997, Margules and Pressey 2000, Cowling *et al.* 2003). This planning approach has involved extensive surveys and mapping of environments, flora and fauna (Margules and Stein 1989, McKensie *et al.* 1989, Margules *et al.* 1994), assessments of surrogates for biodiversity (Ferrier and Watson 1997) and the development of decision support tools now used around the world (Margules and Pressey 2000).

Planning for the conservation of marine environments in NSW has been less systematic. There have been many surveys of marine habitats and species, but with some exceptions (West *et al* 1985, Short 1995, Andrew *et al.* 1997, Williams *et al* 1998), most were limited to a few locations. There have also been studies of biodiversity surrogates (Ward *et al.* 1999) and trials of reserve planning tools (Pilav-Savic *et al.* 1996, Gladstone 2002). Broad scale assessments and proposals for networks of MPAs in NSW have been made previously (Pollard 1980, 1997, Pollard *et al.* 1997, Parker 1995) and finer scale assessments have been made for specific areas, habitats or species (Otway 1999, Frances 2000, Avery 2001, Gladstone 2001, Otway *et al.* 2003). The assessments in this thesis share many similar sources of information with these studies. This study however, differs in the range of criteria and locations assessed and the extent to which systematic planning tools were used to integrate, analyse and communicate information.

Pollard (1997) identified priority areas for MPAs and many of these were eventually implemented as aquatic reserves and the first marine parks in the state. The systematic analyses

in this thesis support the selection of many of these sites including the large marine parks established at the Solitary Islands and Jervis Bay. Parker (1995) also identified a comprehensive system of marine and estuarine protected areas that included large marine national parks and smaller marine nature reserves. This proposal was not included explicitly in the bioregional assessments in order to keep the more recent studies as independent as possible. However, in retrospect, there are many similarities between Parker's proposals and the recommendations of the bioregional assessments in this thesis. The assessments include many of Parker's recommended areas within options for the large marine parks described in Chapters 6, 7 and 8 and within other smaller areas recommended for protection.

Otway (1999, Otway and Morrison, in prep.) identified several sites for MPAs on rocky shores in the Manning, Hawkesbury and Batemans Shelf bioregions using fine scale habitat predictors and surveys of species richness. Again, many of these sites are included in proposals for MPAs selected using broad scale biodiversity surrogates in Chapters 6, 7 and 8. Frances (2000) employed an expert panel and similar criteria to this study to identify sites for estuarine aquatic reserves. Once more, many of these sites are included in the MPA options described in the broad scale assessments.

It would be surprising, if these studies reached markedly different conclusions. However the similar recommendations, from different sources and using different approaches, tend to confirm the suitability of these areas as MPAs. Although not entirely independent, the studies provide convincing evidence that supports conservation management at these locations.

Two of the recommended options (Port Stephens - 972 km^2 and Batemans Bay - 850 km^2) are now established as the largest MPAs in the state. Options for a third large marine park in the Hawkesbury Shelf bioregion are also proposed. Figure 11.2 shows the progressive implementation of a network of MPAs in NSW, which now includes over 35% of state waters. Less than a third of this area is closed to all fishing within highly protected 'no-take' areas. However, all of the MPA sites are to be managed for the conservation of biodiversity.

It is difficult to completely distinguish the relative influence of systematic assessments in establishing these MPAs. Other factors such as increasing levels of institutional support, and a wider political and community awareness are an essential part of the process. These, and other factors listed in Figure 11.1 have provided fundamental support for the assessments and the authority to implement these changes. Other *ad hoc* opportunities have also influenced outcomes, sometimes more than is commonly appreciated. However, systematic assessments can provide guidance and support under all of these circumstances and a basis for ongoing management.

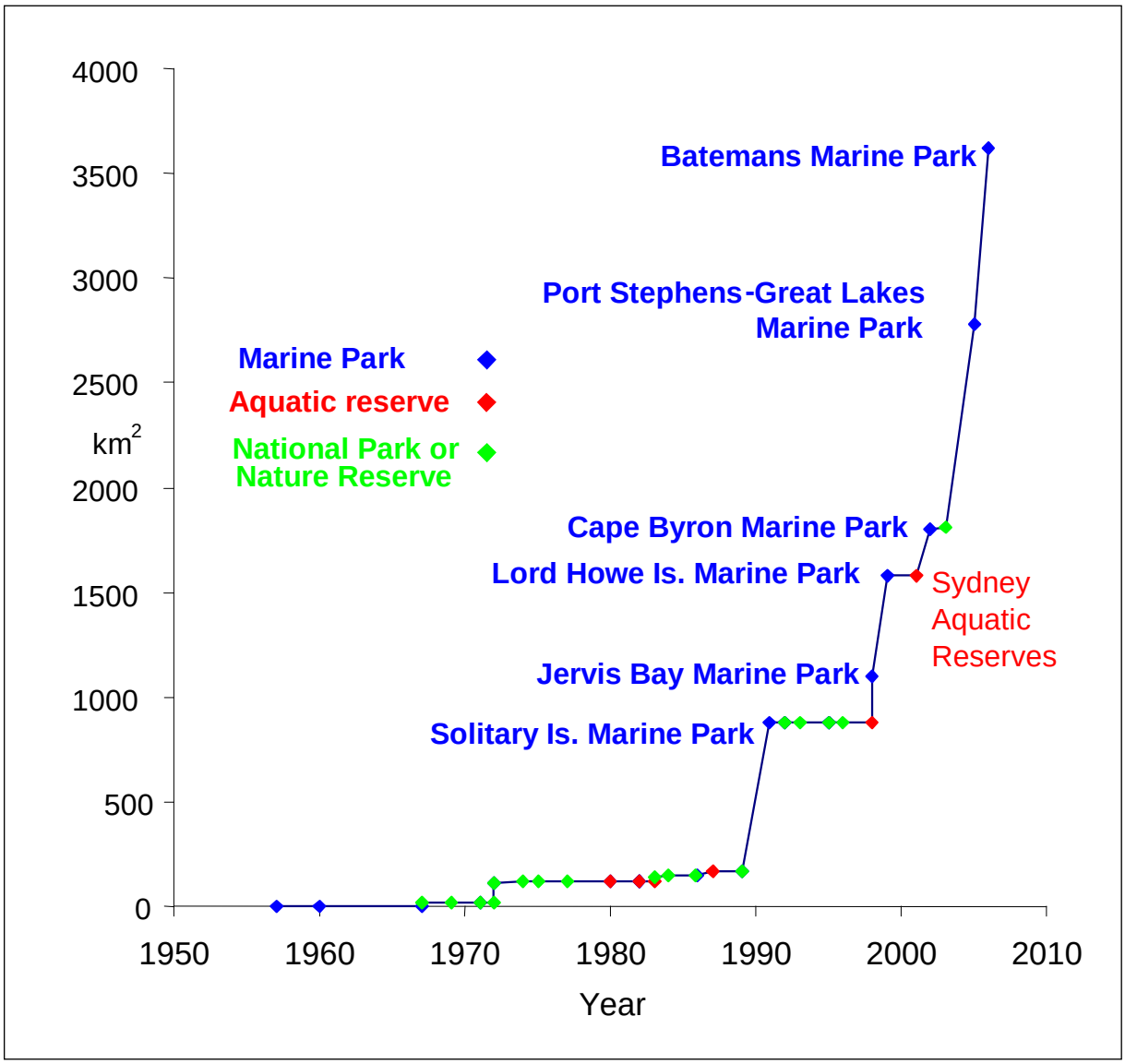

Figure 11.2. Increasing area (km^2) of MPAs in NSW.

11.10 Application of decision support tools for other MPAs

The use of a systematic approach and decision support tools has had significant outcomes for marine conservation and research elsewhere. For many years, the Great Barrier Reef Marine Park Authority maintained a GIS capability and supported extensive research and monitoring programs within the department and through associated research and educational institutions. Planning at the Authority also benefited from clearly defined objectives, comprehensive consultation processes and extensive education programs.

This work provided an important foundation for the Authority's Representative Areas program. This process incorporated a GIS based biodiversity assessment with ecological and social guidelines, decision support tools (Ball and Possingham 2000 and De'Ath 1999) and consultation with scientists, stakeholders and communities. The program also benefited from a high level of government and community support.

The resulting zoning plan increased the area of highly protected 'no-take' zones in the Great Barrier Reef Marine Park from less than 5 % to 33 % of its total area (345,000 km^2). The resulting network of fully protected areas, each at least 20-40 km in diameter, included a minimum of 20 % of the area of 70 biologically distinct regions (Fernandes *et al*. 2005).

Similar systems are being used to inform planning for marine protected areas in Queensland (Banks *et al.* 2005, Buxton 2005), South Australia (Stewart *et al.* 2002, Stewart and Possingham 2003, 2005), and at locations in Florida (Leslie *et al.* 2003, Cowie-Haskell and Delaney 2003), California (Airame *et al.* 2003), Maine and New England (Cook and Auster 2005), Wales (Richardson *et al.* 2006), and the Mediterranean (Villa *et al.* 2002). Some of these projects have been more successful than others in implementing MPAs, which suggests that assessments are not sufficient on their own to establish effective MPAs. All have however, provided critical assessments of existing networks and informed recommendations on what additional measures are required.

In New Zealand, for example, commercial fishing representatives (Deepwater Stakeholder Group 2006) proposed to close 31 % (1. 2 million km^2) of the country's Exclusive Economic Zone (EEZ) to bottom trawling. However, other forms of trawling and fishing would be allowed throughout these areas and the proposal required the repeal of regulations protecting seamounts in 18 areas currently closed to all fishing.

In addition, the proposal called for a signed accord with the government to consider the contribution of these proposed "Benthic Protection Areas" (BPAs) when assessing "the need for any marine protected areas" or "the need for, and funding of, research relating to any need for any such closed areas." The accord also sought agreement from the Minister for Fisheries to not "intend to close any further areas…to bottom trawling." However, a systematic evaluation of

the distributions of trawled fish species by Leathwick *et al.* (2006b) using the reserve planning software Zonation, revealed that the proposed areas coincided with areas of low biodiversity value and would result in only a minimal loss of fishing opportunity. The timing of this proposal coincided with a bill to amend the New Zealand Marine Reserves Act 1971 to allow fully protected marine reserves to be established in the EEZ beyond territorial waters (beyond 12 nautical miles of the coast).

Without independent, objective and systematic assessments, proposals such as the accord threaten to trade existing and future MPAs for management that may not adequately represent or protect marine biodiversity. A failure to carry out reliable assessments can therefore result in even existing levels of protection being removed and in compromising future opportunities to develop effective MPA.

11.11 Systematic marine conservation planning and decision support tools

Several different decision support tools were used in the assessments for NSW. While some differences were evident, all of the tools produced broadly similar results. Most variation appeared to be due more to the data, planning units, targets, priorities and reserve design parameters used. While studies assessing the efficiency of a range of numerical tools (Csuti *et al.* 1997, Pressey *et al.* 1997, Cabeza and Moilanen 2001) often focus on differences in performance, it is frequently the similarities in solutions that is most evident.

In Figure 11.1, the particular choice of tool used is less likely to influence final planning and conservation outcomes than any other level in the hierarchy. What is important is that at least some form of systematic approach or tool is used (Knight *et al.* 2006b). The tools used in this thesis, although similar, had slightly different, but complementary uses.

C-Plan (NPWS 2001) was particularly useful in providing an almost instant statistical assessment of irreplaceability under changing scenarios of different targets, data and the selection or exclusion of planning units. The use of relatively large plan units in the bioregional assessments overcame constraints in aggregating small units into large reserves and provided easily interpreted, multivariate measures of conservation value for whole estuaries and sections of coast. The additional use of smaller (10 hectare to 4 km^2) plan units allowed for more detailed, interactive MPA design. The ability of C-Plan to update conservation priorities makes it a useful ‘hands on’ tool for conservation planning with scientists, managers and communities. The tool was used in this way with managers for the bioregional assessments and with community representatives in the Cape Byron Marine Park draft zoning process. However, a more open planning process would permit a much wider use of this capability.

Marxan (Ball and Possingham 2000) provides a flexible and powerful tool for goal oriented reserve design with options that include spatial aggregation, replication and configuration of reserve options. The tool is flexible in that repeated use of the simulated annealing algorithm can provide a range of MPA options. Marxan was used to develop options for a range of conservation targets throughout NSW and designs to minimise impacts on commercial fishing costs in the Cape Byron Marine Park. Marxan was also recently used to assess zoning options for the newly declared Port Stephens – Great Lakes Marine Park using ecological, recreational and commercial data..

Unlike C-Plan, Marxan, Worldmap, Zonation and other similar tools, the multiple criteria models built in Criterium Decision Plus (InfoHarvest 2001) do not inherently take into account the complementarity of sites in contributing towards conservation targets. However, this tool was able to integrate previously calculated estimates of irreplaceability from C-Plan with over 60 other quantitative and qualitative measures in a hierarchically structured tree of MPA goals, priorities and scores for alternative sites. This tool also provided a way to assess alternative sites according to varying priorities provided by different individual users.

The decision support tools applied employ relatively sophisticated techniques. However, these assessments have explored only part of their full potential and new techniques continue to be developed. The C-Plan reserve planning software has been modified to link with Marxan and now incorporates spatial criteria for advanced reserve design. The Zonation algorithms developed in Finland (Moilanen and Cabeza 2002) are now being used to incorporate design criteria for population persistence, uncertainty and dispersal. Other methods that incorporate uncertainty, decision theory, risk, ecological modelling and social science in new ways are also being applied (Ferrier and Watson 1997, Faith *et al.* 2003, Wintle *et al.* 2006, Halpern *et al.* 2006, Leathwick *et al.* 2006b).

The objective framework, data and models in this thesis provide some raw materials to apply these techniques in NSW. However their success will require opportunities and support from managers, scientists and the community. Finally, almost all depend on the use of GIS to integrate information. The capabilities of these systems are summarised in the following draft from a national workshop in 2005, to develop MPAs in the United States.

“Geographic Information Systems are considered to be an ideal tool for decision makers and conservation planning due to functionalities that allow the integration of physical, biological, and socioeconomic data into a single spatial frame of reference. The GIS platform also allows for the integration of data with different spatial and temporal scales, the application of a broad suite of software tools including statistical packages, and the visual representation and manipulation of data through user interfaces. Developing a participatory approach to mapping

human activities in support of MPA planning and management is important for a number of reasons. Human dimensions of MPAs are the keys to the success of MPA design and management. Participatory methods can empower people and provide a platform for voicing diverse needs, concerns, and perspectives. Participatory research can increase the legitimacy of the planning process in which the data collection efforts are embedded, foster greater cooperation and consensus building, and increase the long-term viability of the management decisions. Methods that encourage participation can also facilitate future commitment to monitoring and evaluation, and may yield valuable local and experience-based knowledge that would otherwise remain untapped" (National Marine Protected Areas Centre 2005).

11.12 Conclusion

This thesis has adopted a holistic, ecosystem approach to planning and research that aims to provide a foundation for more detailed studies. The methods are based on explicit goals and comprehensive reviews of available information, but ultimately depend on the need to rigorously test conclusions and outcomes in an ongoing process. The spatially explicit way in which data are integrated and displayed provides an intuitive way for broad sections of the community to understand and participate in marine conservation. However, a key requirement of these approaches, is a spirit of cooperation among individuals, institutions and communities. Overcoming this segregation is a major challenge, but one that can be met by dedication to better communication. Prendergast *et al.* (1996) suggest that the main reason for a lack of success in conservation planning is that people are simply unaware of 'what science can contribute to practical conservation' and that 'low levels of funding, lack of understanding about the purpose of these tools and a general antipathy toward what is seen as a prescriptive approach to conservation all play a part.' They call for a closer dialogue between theoreticians and practitioners in conservation biology.

Science may also need to be more flexible in adapting methods to the ecological problems at hand, if the impact of research is to be felt outside the profession itself. Robinson (2006) suggests that "conservation biology must generate answers even when full knowledge is lacking and must structure scientific knowledge around policies and debates that influence what we value as conservationists, go beyond the certitude of biological sciences into the more contextual debates of the social sciences, engage scientifically with human-dominated landscapes, and address the question of how conservation can contribute to the improvement of human livelihoods and the quality of human life. "