Funded by the
Marine Protected Areas Program

Australian Department of
Environment and Heritage

and the NSW Marine Parks Authority

Broadscale Biodiversity Assessment of the Batemans Shelf and Twofold Shelf Marine Bioregions

Final Report 2005

D.A. Breen, R.P. Avery and N.M. Otway

Marine Parks Authority
NEW SOUTH WALES

Natural Heritage Trust
Helping Communities
Helping Australia
A Commonwealth Government Initiative

This document has been prepared on behalf of the NSW Marine Parks Authority as a final report for the Batemans Shelf and Twofold Shelf Bioregional Assessment Project.

Research and collation of information presented were undertaken with Natural Heritage Trust funding from Environment Australia (now the Australian Government Department of Environment and Heritage) for the Marine Protected Areas Program at NSW Department of Primary Industries (formerly NSW Fisheries) and the NSW Marine Parks Authority.

ISBN 1 920812 19 9

This report may be cited as:

Breen, D.A. Avery, R.P. and Otway N.M. (2005). Broadscale biodiversity assessment of marine protected areas in the Batemans Shelf and Twofold Shelf marine bioregions. Final report for the NSW Marine Parks Authority.

Acknowledgements

Research and collation of information presented was undertaken with funding from the Australian Government Department of Environment and Heritage (formerly Environment Australia) for the Marine Protected Areas Program and the NSW Marine Parks Authority.

For their comments, advice, assistance and guidance we gratefully acknowledge:

Andrew Read, Bob Creese, Greg West, Francis Dorman, Danielle Morrison, Natalie Morrison, Michelle Belcher, Alan Genders, Melissa Walker, Brett Louden, Natalie Taffs, Bruce Pease, Jane Frances, Rob Williams, Steve Kennelly, Paul O'Connor, Wendy Stamp and Steve Dunn from NSW Department of Primary Industries (formerly NSW Fisheries).

Helen Muldoon from the NSW Marine Parks Authority.

Rodney James, Kevin Shanahan, Simon Banks, Kelly Waples, Michael Wright, Bob Pressey and Mal Ridges from the NSW Department of Environment and Conservation (formerly NSW National Parks and Wildlife Service).

All other individuals and organisations who assisted by providing data, information and advice.

Table of Contents

List of Figures

List of Tables

Summary

This report examines broadscale patterns of biodiversity in the Batemans Shelf and Twofold Shelf marine bioregions and identifies areas that should be considered in selecting a system of marine protected areas (MPAs). The information, criteria and methods applied in the report may also assist in ongoing assessment, selection, and management of MPAs in NSW. Similar assessments have been completed for the North Coast of NSW (Manning Shelf bioregion and NSW section of the Tweed-Moreton bioregion).

The Batemans Shelf bioregion extends south from Shellharbour (34° 35' S.) to Wallagoot Lake, south of Tathra (36° 48' S.). The Twofold Shelf bioregion extends south-west from Wallagoot Lake to east of Wilsons Promontory in the State of Victoria and south into Tasmanian waters.

The bioregions are part of a classification of 65 Australian marine bioregions and provinces that together provide a national framework for consistent, ecologically based planning of marine protected areas (MPAs). The bioregions include all estuarine, coastal and offshore waters to the edge of the continental shelf at the 200 m depth contour. NSW contains 5 bioregions and 1 province. This report focuses on NSW state waters within 3 nautical miles of the coast.

Information used in this report was derived from:

- national criteria for the identification of MPAs
- a broadscale atlas of NSW marine ecosystems and habitats
- existing broadscale scientific surveys of habitats, communities and species
- existing data, maps, aerial photographs, literature and conservation assessments
- new data coverages and analyses generated for this study
- ecological guidelines for reserve design
- discussions with scientists, managers and the community.

Broadscale (10's of km^2) and fine-scale (4 km^2) planning units were used to identify areas with important biodiversity values using over 50 specific criteria derived from state and national guidelines. Assessments were assisted by mapped displays and analyses in a Geographic Information System (GIS) and irreplaceability analysis using C-Plan reserve selection software. Given the uncertainty involved in assessing biodiversity and the associated complex issues, a strong emphasis was placed on presenting information and methods to identify important areas.

Together the NSW waters of the Batemans Shelf and Twofold Shelf bioregions feature approximately 80 estuaries, including many coastal lakes, barrier estuaries and three large ocean embayments. NSW waters in these bioregions include approximately 2885 km^2 of oceanic and estuarine waters to a maximum depth of about 120 metres off Jervis Bay, Brush Island and Montague Island. The NSW waters in the Batemans Shelf bioregion are approximately 3.5 times the size of those in the Twofold Shelf bioregion.

Areas with important biodiversity values

This report identifies many areas within Batemans Shelf and Twofold Shelf bioregions with important biodiversity values. These areas typically contribute to meeting criteria for comprehensiveness and representativeness for most mapped ecosystems, habitats and species distributions. In most cases these areas: have a high degree of naturalness and catchment protection; include areas recommended from previous conservation assessments; consistently score highly in quantitative analyses for a range of criteria; and, complement existing MPAs and conservation management strategies.

In the Batemans Shelf and Twofold Shelf Bioregions there are many important areas which may be relatively unaffected by human impacts. While some criteria are quite restrictive in what areas qualify for protection (e.g. representation of drowned river valleys, ocean

embayments and offshore islands), others are more flexible in the number of areas potentially suitable (e.g. representation of intermittent lagoons and barrier estuaries).

The options for exactly where and how MPAs can be established are therefore relatively flexible for all but a few criteria. One way to effectively conserve a range of different ecosystems, habitats and species for biodiversity and sustainable use is through large, multiple-use marine parks. The exact nature of the protection provided in multiple-use marine parks will depend on subsequent zoning to protect different habitats and to address different threats, and operational plans to regulate how activities are carried out.

There are numerous important areas in the Batemans Shelf and Twofold Shelf bioregions and these cannot all be contained in reserves. Nevertheless, this report identifies many important areas that should be considered in the development of future proposals for a network of MPAs (marine parks, national parks and nature reserves, and aquatic reserves). These areas are identified and discussed in Chapter 5 of this report.

Many other offshore areas of reef and sediment on the NSW shelf have not been mapped in detail and little is known of the broadscale patterns in the distribution of many offshore biota. There may be many areas in deeper waters with significant values and these require further investigation.

Existing marine protected areas in the Batemans Shelf and Twofold Shelf bioregions are described in Chapters 2 and 6 of this report. The important areas identified in this assessment and the group of existing MPAs can now be used to develop MPA proposals for Batemans Shelf and Twofold Shelf bioregions. These MPA proposals should to aim to represent geographic variation in biodiversity throughout the bioregions, and assist in fulfilling the principles of comprehensiveness, adequacy, and representativeness. Where possible, selection of MPAs should aim to include neighbouring habitats to increase the range of biodiversity represented and accommodate the movement of organisms among these areas.

1 Introduction

The NSW Marine Parks Authority aims to establish and manage a comprehensive, adequate and representative system of marine protected areas (MPAs) to help conserve marine biodiversity and maintain marine ecosystem processes (NSW Marine Parks Authority 2001).

The Batemans Shelf and Twofold Shelf bioregional assessment is one of several projects to systematically assess broadscale patterns of biodiversity within each of the five marine bioregions in NSW and identify where additional MPAs may be required (Fig. 1 & Fig. 2).

Scientists and conservation managers have identified 65 Australian marine bioregions and provinces (IMCRA 1998) to help plan a national system of marine protected areas. Including the characteristic biodiversity of each bioregion within a system of MPAs aims to ensure that marine ecosystems are effectively managed for the conservation of biodiversity and for sustainable use.

National guidelines and criteria have been developed to identify and select MPAs within each bioregion (ANZECC TFMPA 1998ab, 1999 and Appendix 1). This report summarises the broadscale methods and information used to identify some options for new MPAs on the basis of ecological criteria alone. A separate selection process is now required for more detailed site assessment and consideration of social, economic and cultural values.

1.1 Geographic extent

The bioregions include estuaries, coast and offshore waters out to the continental shelf break (approximately the 200 m depth contour). The Batemans Shelf bioregion extends south from Shellharbour (34° 35’ S.) to Wallagoot Lake, south of Bega (36° 48’ S. - Fig. 2). The Twofold Shelf bioregion continues south from Wallagoot Lake and across the state border to near Corner Inlet in Victoria and also includes areas of Bass Strait in Victorian and Tasmanian State waters (Fig. 1).

This report focuses on NSW state waters within 3 nautical miles of the coast as defined by the Australian Maritime Boundary Information System (AMBIS) data provided by Geoscience Australia (Commonwealth of Australia 2001).

The 1:100,000 map sheets for the NSW sections of the bioregions are:

Kiama	9026	Narooma	8925
Jervis Bay	9027	Bega	8824
Ulladulla	8927	Eden	8823
Batemans Bay	8926	Green Cape	8923

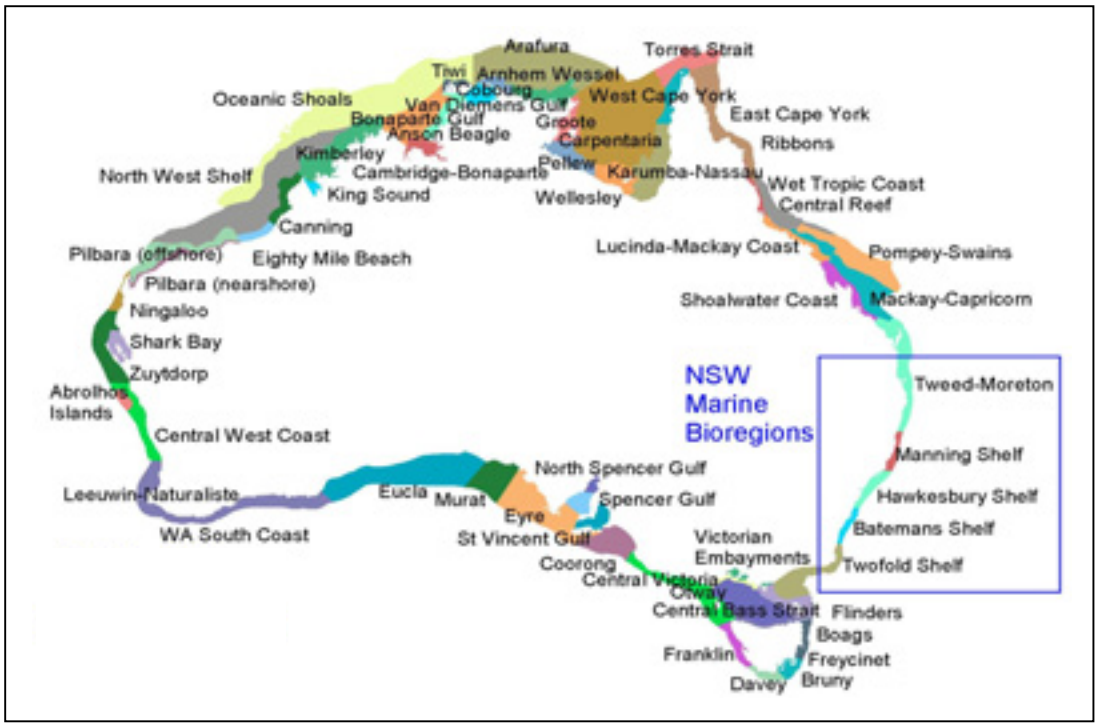


Fig. 1. Interim Marine and Coastal Regionalisation of Australia (IMCRA 1998)

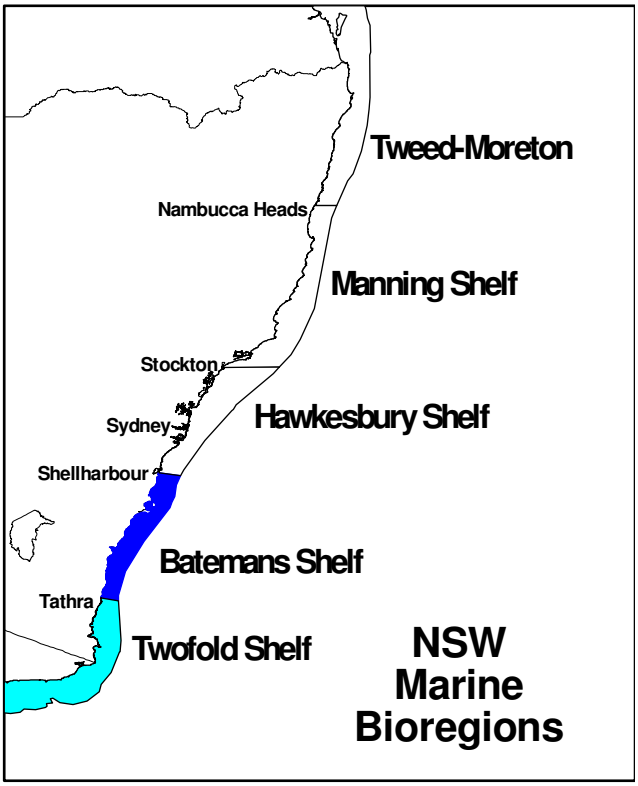


Fig. 2. IMCRA bioregions of NSW.

2 MPAs in the Batemans Shelf and Twofold Shelf bioregions

Three types of marine protected areas (IUCN 1994) are recognised in NSW:

- **marine parks** - managed under the *Marine Parks Act 1997* by the NSW Marine Parks Authority
- **aquatic reserves** - managed by NSW Department of Primary Industries (DPI - Fisheries) under the *Fisheries Management Act 1994*
- and the **marine components of national parks and nature reserves** - managed by NSW National Parks and Wildlife Service (NPWS) in the NSW Department of Environment and Conservation (DEC) under the *National Parks and Wildlife Act 1974.*

The locations of MPAS in NSW (Fig. 3) and their extent in the Batemans Shelf and Twofold Shelf bioregions (Table 1 & Fig. 4) are described below. A summary of management arrangements for these MPAs is also provided below, but described in more detail in *Developing a representative system of marine protected areas - an overview* (NSW Marine Parks Authority 2001), at the NSW Marine Parks Authority website at www.mpa.nsw.gov.au and in a review by Pollard (1997).

Table 1. Estimated extent of MPAs in coastal waters (estuaries and ocean within 3 nm of the coast) of the Batemans Shelf and Twofold Shelf marine bioregions.

MPA type	**Name**	**Area (km^2)**
Marine parks	Jervis Bay Marine Park	214.5
This area represents 9.6 % of coastal waters in the Batemans Shelf bioregion.		
Commonwealth Marine Reserve	Booderee National Park	8.3
This area represents 0.4 % of coastal waters in the Batemans Shelf bioregion.		
Aquatic Reserves	Bushrangers Bay	0.04
This area represents 0.002 % of coastal waters in the Batemans Shelf bioregion.		
National parks and nature reserves	Clyde River NP	0.08
	Comerong Island NR	2.46
	Jervis Bay NP (NSW)	6.41
	Conjola NP	0.45
	Narrawallee Creek NR	0.35
	Meroo NP	1.73
	Eurobodalla NP	7.11
	Murramarang NP	1.25
	Cullendulla Creek NR	0.81
This area of 20.65 km^2 represents 0.9 % of coastal waters in the Batemans Shelf bioregion.		
National parks and nature reserves	Bournda NP	0.71
	Ben Boyd NP	2.11
	Nadgee NR	1.32
	Mimosa Rocks NP	1.41
This area of 5.55 km^2 represents 0.8 % of coastal waters in the Twofold Shelf bioregion.		

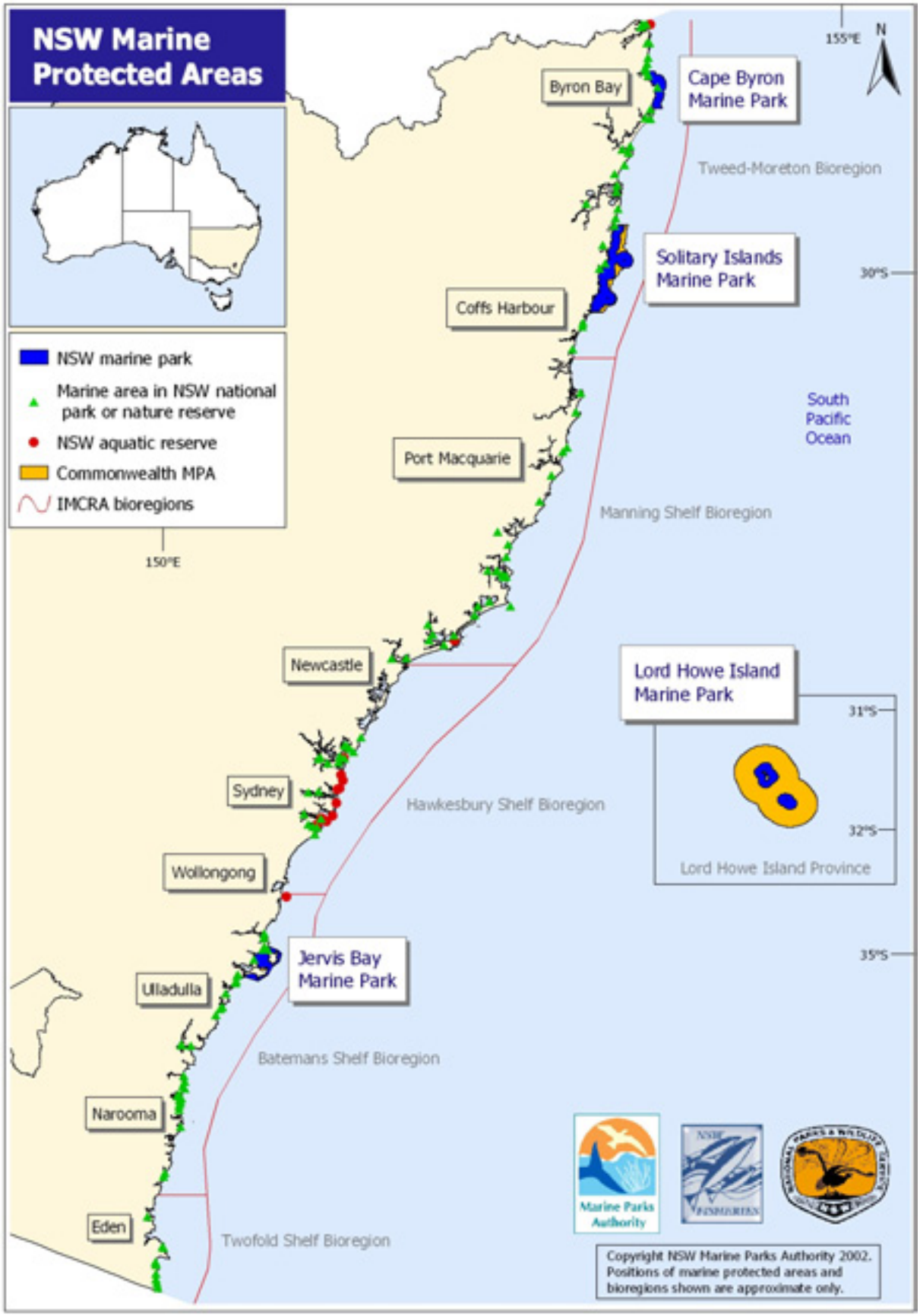


Fig. 3. Marine protected areas in NSW (map provided by Rodney James, Department of Environment and Conservation).

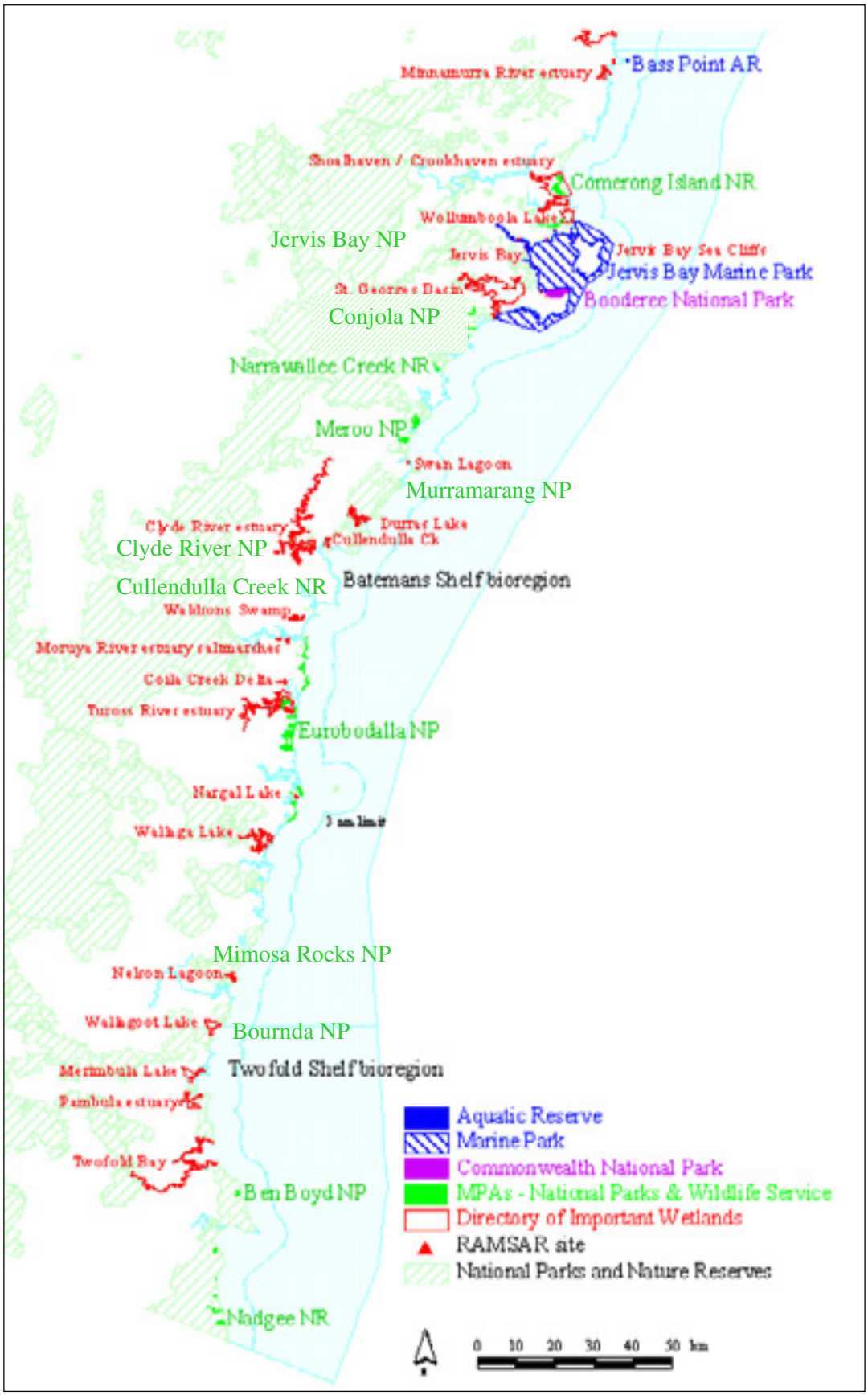


Fig. 4. Marine protected areas (marine parks, aquatic reserves, Commonwealth National Park and the marine components of NSW national parks and nature reserves), RAMSAR sites (none) and important wetlands in the Batemans Shelf and Twofold Shelf bioregions.

2.1 Marine parks

The *Marine Parks Act 1997* aims to conserve marine biological diversity, habitats and ecological processes in marine parks. Where consistent with these objectives, it also aims to provide for the ecologically sustainable use of fish and marine vegetation (including commercial and recreational fishing) and provide opportunities for public appreciation, understanding and enjoyment of marine parks. Marine parks also assist in managing pollution, visitor use, activities on adjacent lands, marine pests and a wide range of environments, species and human activities.

Four marine parks have been declared in New South Wales so far (Fig. 3). Solitary Islands, Jervis Bay, Lord Howe and Cape Byron Marine Parks are large, multiple-use MPAs, ranging from approximately 200 km^2 to 700 km^2 in area. These marine parks are zoned to allow for a range of human activities, including commercial and recreational fishing. They also include sanctuary zones where plants and animals are fully protected. For example, 12% of the Solitary Islands and 20% of the Jervis Bay Marine Parks are sanctuary zones.

As well as zoning and other forms of regulation, marine parks use education, consultation, research, monitoring and best practices to manage what activities occur and how activities can be carried out sustainably.

Large marine parks attempt to include a range of interconnected ecosystems and habitats to provide for a greater continuity in ecological processes, more insulation from external threats, increased protection for mobile and widely dispersed populations and a capacity to manage a wider range of impacts. Having many features spread over broad areas within a large marine park also provides for greater flexibility in multiple-use zoning, with more opportunities to meet community and stakeholder requirements while meeting primary conservation goals.

2.2 Aquatic reserves

Aquatic reserves aim to conserve the biodiversity of fish and marine vegetation, but may also focus specifically on the protection of fish habitat, protection of threatened species, populations and ecological communities, and on providing for education and scientific research.

There are currently 13 aquatic reserves in New South Wales. Most are relatively small (2–150 ha), and with the exception of Towra Point (which includes 1,400 ha of estuary, seagrass and wetland), they include mainly rocky intertidal shores and inshore reefs and sediments. They have an important role in complementing the range of ecosystems found in other MPAs, and in addressing specific issues and concerns for biodiversity.

2.3 National parks and nature reserves

Marine protected areas also occur where national parks and nature reserves are specifically gazetted over subtidal or intertidal areas. In New South Wales there are approximately 50 national parks and nature reserves with recognised marine components.

National parks and nature reserves differ substantially from aquatic reserves and marine parks in that there is no zoning or regulation for ‘multiple use’. However, while these areas can protect animals, vegetation and substrata, they cannot directly protect fish or aquatic invertebrates from fishing. Direct protection of fish can be achieved by arrangement with the NSW Department of Primary Industries through aquatic reserves or fishing closures.

Conservation of marine species in national parks and nature reserves can also be enhanced through the protection of habitat and the general management of use including control over moorings, motor vessel access and the construction of marinas and other structures, and by protecting adjacent terrestrial habitat. MPAs within national parks and nature reserves exist as components of a broader terrestrial reserve system. Generally they include large areas of intertidal and subtidal estuarine habitat and smaller areas of intertidal and subtidal coastal habitat. Offshore ecosystems have not been, and are unlikely to be targeted for protection.

As a part of an integrated system of MPAs, national parks and nature reserves make a complementary contribution to comprehensiveness, particularly in coastal and estuarine areas. The number and area of MPAs in national parks and nature reserves is substantial and several are large enough (e.g. Myall Lakes at 97 km^2) to include a range of marine habitats and ecosystem processes.

Because of their relationship with terrestrial reserves, these areas bridge gaps in protection for saltmarsh, mangrove, rocky shore, beach and other transitional areas of coast. The associated terrestrial reserves also provide protection for catchments and coastal ecological processes that critically affect biodiversity on land and in the sea. In particular, the protection of shoreline and catchment from habitat clearing, development and pollution sources provides an important buffer for nearshore environments. Agreements with other management agencies (e.g. NSW Department of Primary Industries) can provide direct protection for fish in MPAs and assist in integrating conservation strategies for marine and terrestrial environments.

The *National Parks and Wildlife Act 1974* requires a plan of management to be prepared for national parks and nature reserves, as soon as practicable after reservation. Common issues for these areas currently include the control of vehicle access and dogs on beaches and intertidal areas, which may threaten the conservation of seabirds, waders and other biodiversity.

2.4 Commonwealth MPAs

The NSW State jurisdiction includes only part of the Batemans Shelf and Twofold Shelf bioregions, which extend well beyond the three nautical mile state limit to the edge of the continental shelf break at the 200 m depth contour. These areas beyond state waters include ecological gradients across the shelf, shelf break and slope associated with a distinct but largely undescribed diversity of organisms and processes with widespread importance to oceanic ecosystems. Dramatic changes in depth and sea floor topography create unique habitats for benthic invertebrates and demersal fishes and produce unique oceanographic conditions. Currents and up-welling in these areas have important roles in the feeding and migration patterns of many fishes, invertebrates, birds, reptiles and mammals.

MPAs beyond the three nautical mile limit of state territorial waters are managed by the Commonwealth Government through the Department of Environment and Heritage. Currently the Solitary Islands and Lord Howe Island Marine Parks are declared out to the three nautical mile state limit with complementary Commonwealth MPAs established further offshore. Planning for the Commonwealth sections of Australia's marine bioregions is currently underway through the National Oceans Office (www.oceans.gov.au) and the Department of Environment and Heritage (www.deh.gov.au).

3 Information and methods used in the assessment

The methods used to assess broadscale patterns in marine biodiversity and identify potential sites for MPAs are summarised below with more detailed descriptions in Breen *et al* (2003, 2004), Creese and Breen (2003) and Appendix 1.

Information used to assess options for MPAs included:

- MPA goals and identification and selection criteria (see Appendix 1)
- an environmental classification of marine ecosystems, habitats and communities
- available broadscale surveys of marine communities and species
- derived measures from related conservation assessments and
- maps of existing marine protected areas.

Methods used to help identify candidate MPA locations from this information included:

- summary statistics displayed in graphs and tables
- Geographical Information System (GIS) maps and spatial analyses
- irreplaceability analysis of the potential contributions of sites towards conservation goals
- and a review of literature and previous assessments.

3.1 An environmental classification of marine biodiversity for NSW

An environmental classification developed in conjunction with the NSW Marine Parks Research Committee was used to represent progressively finer scales of biological variation in NSW marine environments. Levels in the hierarchy are:

- IMCRA bioregions (Fig. 2)
- broadscale 'ecosystem' units based on estuary type and cross-shelf depth zones (Fig. 5-8)
- small scale 'habitat' units based on substrata, tidal exposure and vegetation (Fig. 24-27)
- finer scale 'community' units from physical surrogates, dominant biota or species associations
- estimated distributions and abundances of species and populations.

The methods used to map marine ecosystems, habitats and community level attributes are summarised below, with a brief description and justification of each unit. The assessment focused on mapping variation at the ecosystem and habitat level. The area, number and size of these 'ecosystem' and 'habitat' units were then used to assess the comprehensiveness of existing and proposed networks of MPAs.

The mapping process was based largely on the modification of existing data into an appropriate GIS format. The principal constraint on the mapping was the scarcity of biological data for community and species level variation across the bioregion, and the absence of detailed maps of subtidal seabed (i.e. reef and sediments) beyond the nearshore zone.

In general, methods reflected the overall urgency for basic data and a significant by-product of this work was the identification of gaps in our knowledge of marine biodiversity in New South Wales. However, by basing its assessment on a broadscale environmental classification, this project avoids many of the biases inherent in examining only those areas where detailed research information is available. The ecological classification presented here lays foundations for future research and is general enough to incorporate new information as it becomes available.

Once options for MPAs are identified at the bioregional level, finer-scale data will be required for planning, management, research and monitoring within MPAs. The broadscale environmental classification provides a framework for these studies and will assist in applying MPA objectives to ongoing planning, zoning and management as well as reserve establishment.

3.1.1 Estuary ecosystem classes

Coastal water bodies from the NSW Waterways[5] GIS coast coverage were classified on the basis of coastal morphology, entrance type and tidal exchange according to Roy *et al.* (2001) who associate these differences with characteristic ecosystem processes and related assemblages of organisms.

The classes are:

I. Ocean embayments. These semi-enclosed bays are transitional zones between estuaries and the ocean and include communities of both environments. They generally have low turbidity, ocean tidal ranges and salinities, and include sandy areas with seagrass beds in protected locations (e.g. Jervis Bay, Batemans Bay, Botany Bay).

II. Tide dominated, drowned river valleys. These are tidal, generally deep, narrow estuaries with rocky sides, and sometimes with large, submerged, sand deltas extending up the estuary (e.g. Hawkesbury River, Clyde River estuary).

III. Wave dominated barrier estuaries. Young barrier estuaries in the early stages of infilling have large shallow lagoons with dense seagrass beds away from the main tidal channels (e.g. Lake Macquarie, St Georges Basin, Tuross Lake). Mature estuaries in the late stages of infilling form a riverine estuary with extensive flood plains and coastal wetlands. They often have narrow, elongated entrance channels and broad barrier sand flats (e.g. Shoalhaven River).

IV. Intermittent lagoons and creeks. These are intermittently open to the ocean, are usually associated with small catchments and small fluvial inputs, and are often non-tidal and brackish. Mangroves are generally absent, with sea rush (*Juncus kraussii*) often dominant. Benthic species diversity is often low, but there are sometimes extreme variations in abundance (e.g. Durras Lake, Narrabeen Lakes, Smiths Lake).

V. Brackish barrier lakes. These bodies of fresh to brackish water have only a tenuous connection to the sea and are dominated by freshwater species. They are relatively rare in NSW (e.g. Myall Lakes).

3.1.2 Ocean ecosystem classes

Oceanic ecosystem types were derived from depth contours digitised by NSW Waterways[5] from Australian Hydrographic Office nautical charts. The contours were used to divide the shelf into four broad depth zones: 0-20 m, 20-60 m, 60-200 m and waters deeper than 200 m. These zones aim to account for biotic and abiotic variation across the shelf in algae (Womersley 1981), sponges (Roberts and Davis 1996), benthic fauna (Coleman *et al.* 1997, Gray 1997), fish assemblages (Andrew *et al.* 1997), light, wave action, sediments, currents, temperature, salinity and water chemistry (Rochford 1975, Godfrey *et al.* 1980, Colwell *et al.* 1981, Chapman *et al.* 1982, Skene and Roy 1986, Short 1993).

3.1.3 Seagrass, mangrove and saltmarsh habitats

The distributions of seagrass, mangrove and saltmarsh habitats were estimated from a GIS coverage digitised by the National Parks and Wildlife Service[1] from paper maps produced by West *et al.* (1985). Mangrove and salt marsh communities contribute to estuaries through nutrient cycling, trapping of sediments and detritus and providing habitat for characteristic and highly diverse assemblages of fish, birds and invertebrates (Hutchings and Recher 1982, Saenger 1999). Seagrass beds are widely recognised for their role in providing habitat for diverse assemblages of flora and fauna (Bell and Pollard 1989, Howard and Edgar 1999, Hannan and Williams 1998).

[5] now NSW Maritime

[1] now within the NSW Department of Environment and Conservation

3.1.4 Shallow subtidal reef habitats

Areas of shallow nearshore reef systems and intervening sediment patches were estimated from coverages mapped to a depth of 10-20 m by Ron Avery (DEC) using 1:10,000 – 1:25,000 scale aerial photographs provided by the NSW Department of Infrastructure, Planning and Natural Resources (DIPNR). Shallow areas of reef and shoal further offshore were digitised from Australian Hydrographic Office nautical charts.

Subtidal rocky reef areas in NSW provide habitat for distinctive assemblages of invertebrates, algae and fishes (Andrew 1999; Underwood *et al.* 1991). However, the use of aerial photographs to map subtidal habitats is limited to nearshore areas and hydrographic charts focus only on those reefs and shoals which approach the sea surface and pose a hazard for shipping. It is recommended that a more comprehensive assessment of existing seabed data is made and that, where required, additional seabed surveys are carried out to accurately characterise these environments.

3.1.5 Island habitats

Areas of islands and emergent rocks were estimated from a GIS coverage generated for the Australian Maritime Boundary Information System (AMBIS) held by Geoscience Australia (Commonwealth of Australia 2001). Islands, emergent rocks and surrounding waters provide unique and important habitats for seabirds, marine mammals, fish, invertebrates and other species. Fronts, wakes and other oceanographic features that extend beyond rocks and islands (Cresswell *et al*. 1983) are important for the feeding ecology of many species and the transport and retention of larvae (Kingsford and Choat 1986, Kingsford 1990, Kingsford and Suthers 1994, 1996, Wolanski 2000).

3.1.6 Shallow subtidal sediment habitats

Areas of nearshore subtidal sediments were estimated from the GIS coverage described above for subtidal reef. Benthic fauna are known to vary significantly with depth and grain size (Poore *et al*. 1985 in Ward and Blaber 1994, Coleman *et al*. 1997), but there is currently little broad scale information on the distribution of sediments that can be easily accessed. While cross shelf variation in sediment distribution is at least partly represented by ocean depth zones, further research and collation of existing data is required in this area.

3.1.7 Intertidal beach habitats

The difference between high and low water marks in the Digital Cadastre Database and 1:25,000 topographic maps from the Land and Property Information Division (LPI) of the NSW Department of Lands were used to produce a GIS coverage of intertidal areas and estimate areas of intertidal beach habitat. Justification for the classification of beaches in NSW is provided by Hacking (1998a, b) and based on relationships described in Brown and McLachlan (1990).

3.1.8 Intertidal rocky shore habitats

The GIS coverage described in section 3.1.7 for beach habitats was also used to estimate the area of intertidal rocky shore habitats. Field surveys by Otway (1999) were used to score sections of rocky shore for the presence of five “community” level substrata (platform, boulder, cobble, pool, crevice) which have been correlated with the number of species present for a given shore.

3.2 Data for individual species and other conservation values

More detailed information was available for some communities and species including surveys of estuarine vegetation (West *et al.* 1985 and more recent surveys, R. Williams pers. comm.), juvenile fish biodiversity in estuaries (R. Williams pers. comm.), intertidal rocky shores (Otway 1999, Otway and Morrison, in prep.) and threatened Grey nurse shark (Otway and Parker 2000). Other, less systematic data sources for species include analyses of commercial fish catch

data (Pease 1999), and sightings databases kept by the NSW Department of Primary Industries and the NSW Department of Environment and Conservation.

3.3 Condition, vulnerability and previous assessments

There was little direct information available on condition, threat or vulnerability for marine environments across whole bioregions. However, data sets indicative of condition, potential threats and vulnerability were available for adjoining terrestrial areas. These included GIS maps of national parks and nature reserves, state forest, wetlands, wilderness, land capability, built-up areas, acid sulphate soils, and the Australian River and Catchment Condition Database (Stein *et al*. 2000). Indices of the percentage area of these attributes within immediate shoreline areas were calculated for estuaries and sections of coast.

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), and rock platforms (Short 1995, Otway 1999) were also summarised and related to MPA identification and selection criteria along with descriptive information from coastal management plans.

3.4 Systematic methods to evaluate MPA options

A systematic approach was used to help document alternatives, and interpret the many criteria and sources of information used to assess options for MPAs. The methods used included summary statistics, Geographical Information System (GIS) maps and spatial analyses, irreplaceability analyses and reviews of literature and existing conservation plans.

Two types of spatial planning units were used to help summarise information: fine-scale (4 km^2) hexagonal plan units (Fig. 34 & Fig. 35) and relatively large, broadscale units representing whole estuaries and sections of coast and shelf (Fig. 5 - Fig. 8). The small planning units were useful for summarising local patterns, and for identifying small scale planning options. The large planning units were more useful for summarising broadscale regional patterns, analysing patchy data and identifying MPA options at wider scales.

The reserve selection software “C-Plan” (NPWS 2001) was used to compute 'irreplaceability' for ecosystem and habitat classes (estuary types, ocean depth zones, seagrass, mangrove, saltmarsh, rocky intertidal shore, beach, reef, and islands); juvenile fish and invertebrate data (R.J. Williams pers. com., NSW Fisheries[2]); commercial fish catch data (NSW Fisheries[2]); bird sightings data (NSW National Parks and Wildlife[1]) and threatened species data (NSW National Parks and Wildlife[1] and NSW Fisheries[2]).

The software calculates statistical estimates of 'irreplaceability' to evaluate the likelihood that a planning unit is required to represent specified conservation values within a network of protected areas (Pressey *et al*. 1994, Ferrier *et al.* 2000). Links between C-Plan and ArcView GIS allow operators to quickly map the results of analyses and include or exclude potential sites from potential protected area networks while assessing the consequences of alternative decisions (Fig. 34 and Fig. 35).

Criteria, data and options identified in this assessment can also be used in multiple criteria analyses (Criterium Decision Plus, InfoHarvest 2000) to assess a range of options as a function of the combined scores for many criteria and priorities. These methods have been widely applied elsewhere in management, environmental impact assessment (Edwards 1977, www.expertchoice.com), fisheries (Mardle and Pascoe 1999) and in the selection and management of reserve networks (Fernandes 1996, Rothley 1997). The techniques allow for the weighting of criteria, calculation of trade offs, representation of uncertainty, sensitivity analyses

[1] now within the NSW Department of Environment and Conservation

[2] now within the NSW Department of Primary Industries

of the relative influence of criteria, and the ability to combine and assess alternative models, data and sources of opinion.

4 Assessment of identification criteria

This section describes each information source, which criteria were addressed, the measures used to assess the criteria and the degree to which different areas meet those criteria.

4.1 Assessment of comprehensiveness

4.1.1 Estuarine ecosystems

Data sources

Roy *et al*. (2001). "Structure and function of south-east Australian estuaries."
GIS coverage of estuaries from NSW Waterways[5].
Oblique aerial photos from the NSW Department of Infrastructure, Planning and Natural Resources estuaries website - www.dlwc.nsw.gov.au/care/water/estuaries/estuaries.html

Data description

A GIS coverage of estuaries from NSW Waterways[5] was classified by estuary type according to Roy *et al.* (2001).

Criterion

Comprehensiveness.

Assessment measures

Area and number of different estuary types represented in marine protected areas.

Assessment

Of the 72 major estuaries in the Batemans Shelf and Twofold Shelf bioregions classified according to Roy *et al*., there was only one tide dominated drowned river valley, but four ocean embayments, 24 wave dominated barrier estuaries and 43 intermittent coastal lagoons or creeks (Fig. 5 - Fig. 13).

The Clyde River is the only example of a tide dominated, drowned river valley in the Batemans Shelf bioregion and this estuary type is not represented in any MPA in the bioregion (Fig. 9b).

Jervis Bay, the largest ocean embayment in the Batemans Shelf bioregion is entirely included within Jervis Bay Marine Park and Booderee National Park (Fig. 9a). Booderee National Park is a Commonwealth protected area owned by the Wreck Bay Aboriginal Community Council and jointly managed by the Aboriginal Community Council and the Department of Environment and Heritage. A Management Plan for Booderee National Park includes management zoning of the marine portion of the national park.

Twofold Bay is the only ocean embayment in the Twofold Shelf bioregion. Ocean embayments are not represented within MPAs in the NSW or Victorian sections of the bioregion.

St Georges Basin and the Shoalhaven River are the largest wave dominated barrier estuaries in the Batemans Shelf bioregion and there are several other large estuaries of this type in the bioregion including Tuross Lake, Wallaga Lake, Wagonga Inlet, Lake Conjola, Moruya River, Burrill Lake and others (Fig. 9c). There are approximately 3 km^2 of wave dominated barrier estuary in Currumbene Creek within Jervis Bay Marine Park and in national parks and nature reserves in the Shoalhaven, Tuross and Narrawallee estuaries. This represents a total of 2% of this estuary type within MPAs in the bioregion.

[5] now NSW Maritime

In the Twofold Shelf bioregion there are four wave dominated barrier estuaries, the largest being Pambula Lake. However, there are currently no barrier estuaries represented in MPAs in either the NSW or Victorian sections of the bioregion.

Coila Lake, Lake Wollumboola, Swan Lake, Wallagoot Lake and Durras Lake are the largest intermittent estuaries in the Batemans Shelf bioregion and there are over twenty other estuaries of this type in the bioregion (Fig. 10). Carama Creek is within Jervis Bay Marine Park and all of Lake Wollumboola, Berrara Creek, Termeil Lake, Meringo Creek, Lake Brunderee, Lake Tarouga, Lake Brou, and Mummuga Lake, and parts of Swan Lake, Lake Tabourie, Congo Creek, Nangudga Lake and Corunna Lake are included within national parks and nature reserves representing a total of 11 km^2 or 30% of the area of intermittent estuaries in the Batemans Shelf bioregion included within MPAs.

There are at least twelve intermittent estuaries in the NSW section of the Twofold Shelf bioregion, the largest being Nadgee Lake. Five of these estuaries (Merrica River, Wirra Birra Creek, Table and Little Creek, Nadgee River and Nadgee Lake) are within the declared wilderness of Nadgee Nature Reserve representing 1.6 km^2 or 50% of the area of this estuarine ecosystem type for the NSW section of the bioregion.

In summary, for the Batemans Shelf bioregion, 76% of the bioregion's ocean embayment, 0% of drowned river valley, 2% of barrier estuary and 30% of the area of intermittent estuarine ecosystems are included within MPAs. Jervis Bay Marine Park includes areas of estuarine habitat with a significant proportion of these in sanctuary zones. However, those areas in national parks or nature reserves do not have direct protection for fish or aquatic invertebrates from fishing.

In the Twofold Shelf bioregion, there are no ocean embayments or barrier estuaries included within MPAs, but almost 50% of the area of intermittent estuaries in the NSW section of the bioregion is included within national parks or nature reserves.

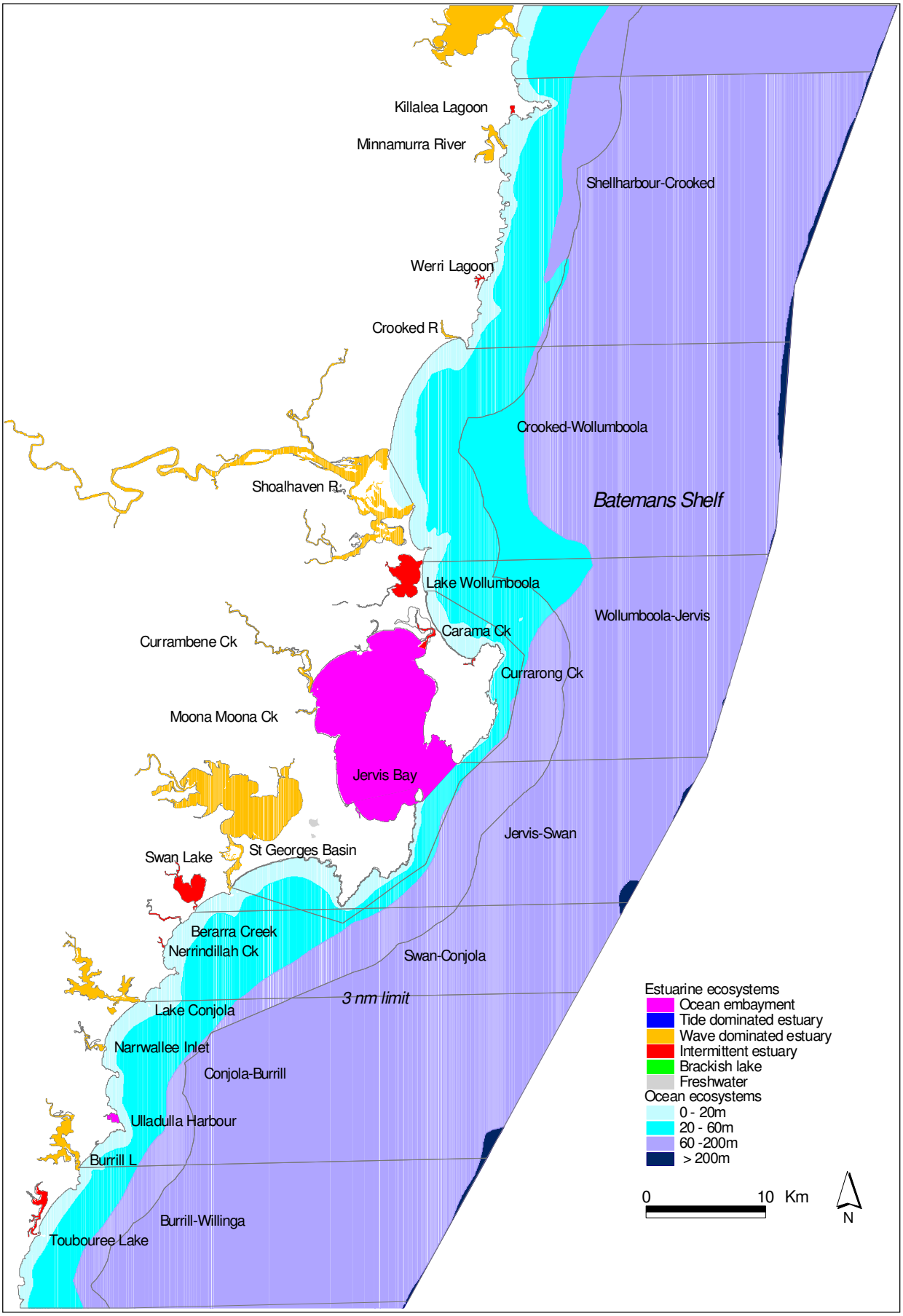


Fig. 5. Broadscale planning units of whole estuaries and sections of exposed coast with mapped estuarine and ocean ecosystem types – Shellharbour to Burrill Lake.

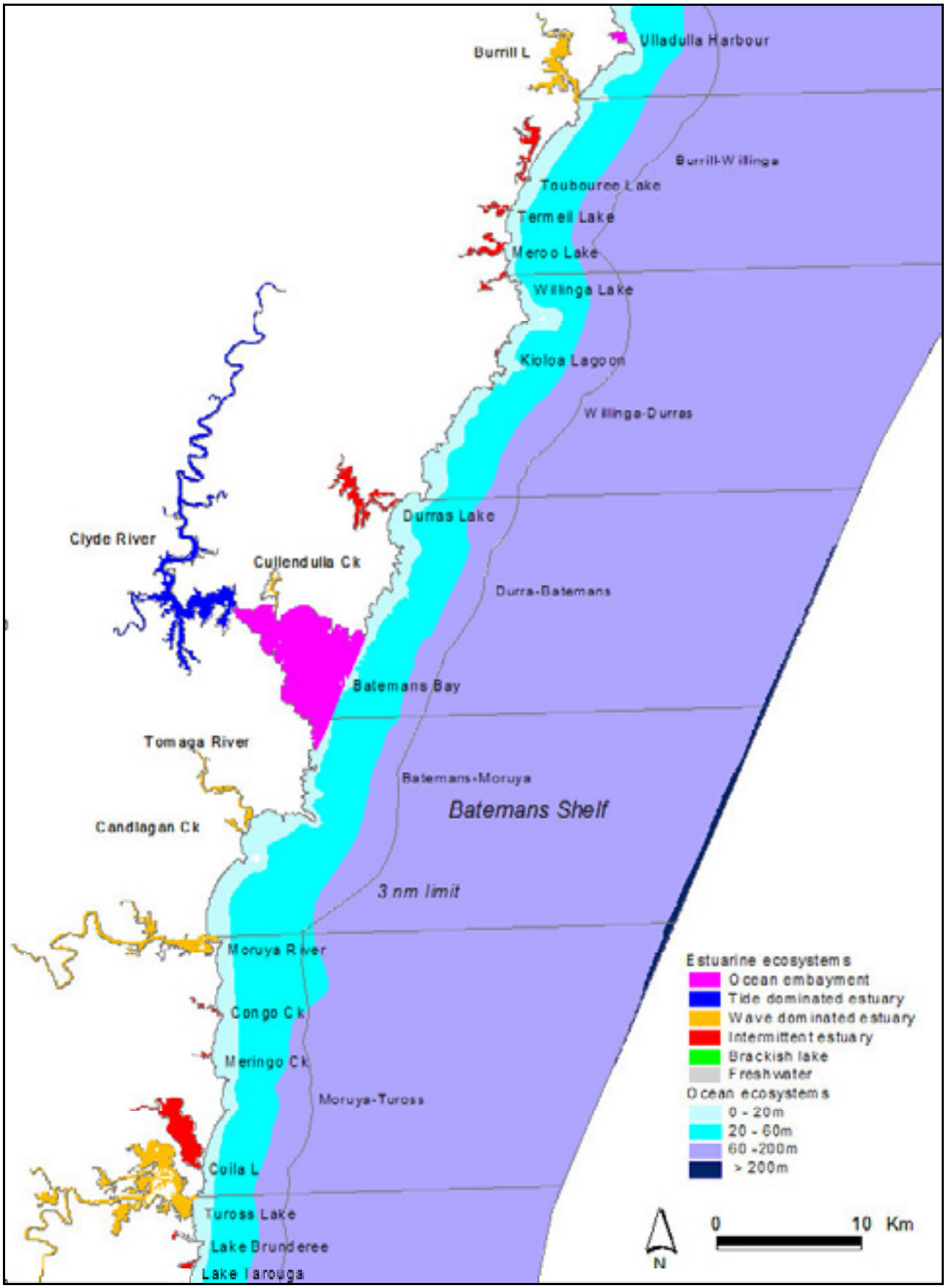


Fig. 6. Broadscale planning units of whole estuaries and sections of exposed coast with mapped estuarine and ocean ecosystem types – Burrill Lake to Tuross Lake.

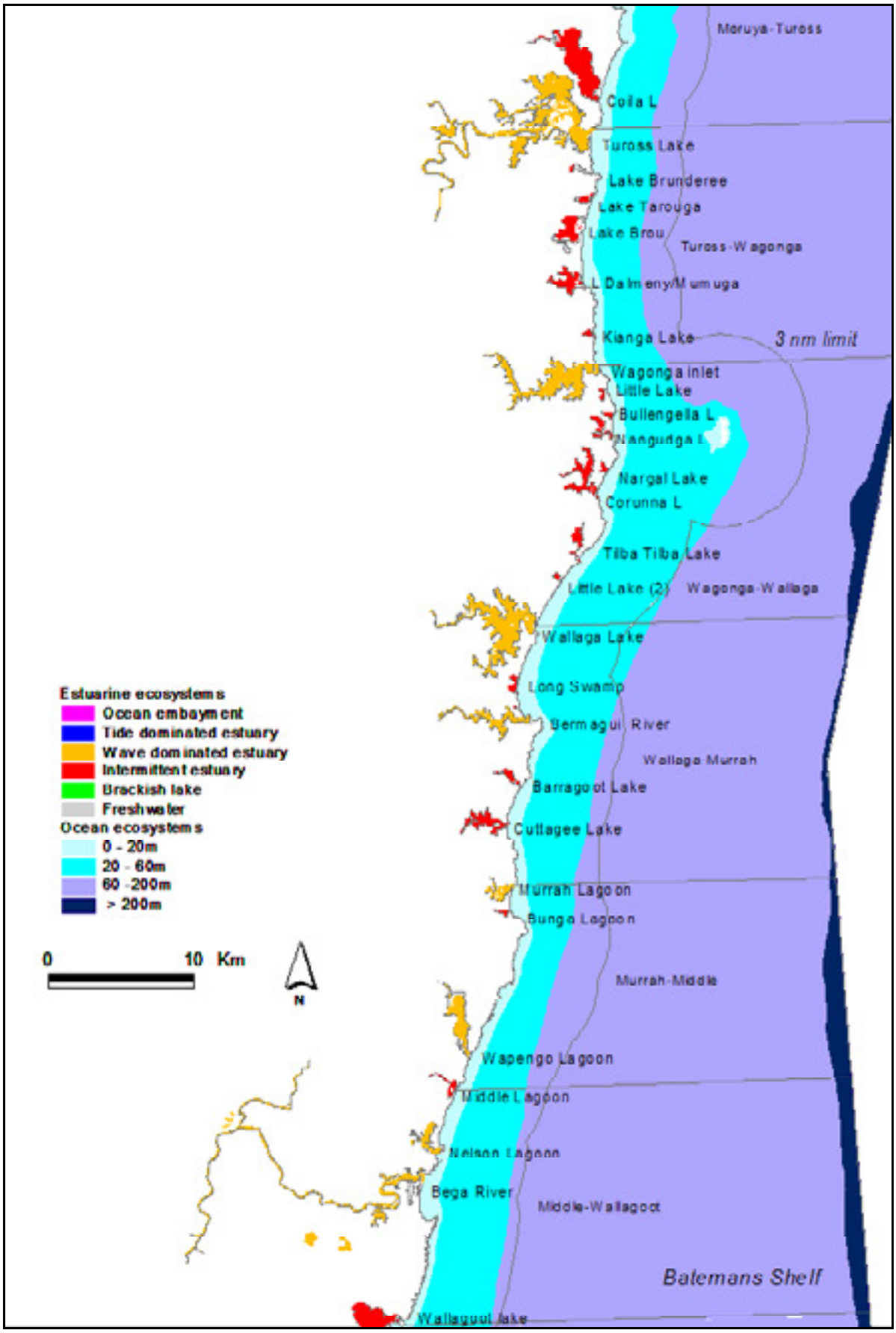


Fig. 7. Broadscale planning units of whole estuaries and sections of exposed coast with mapped estuarine and ocean ecosystem types – Tuross Lake to Wallagoot Lake.

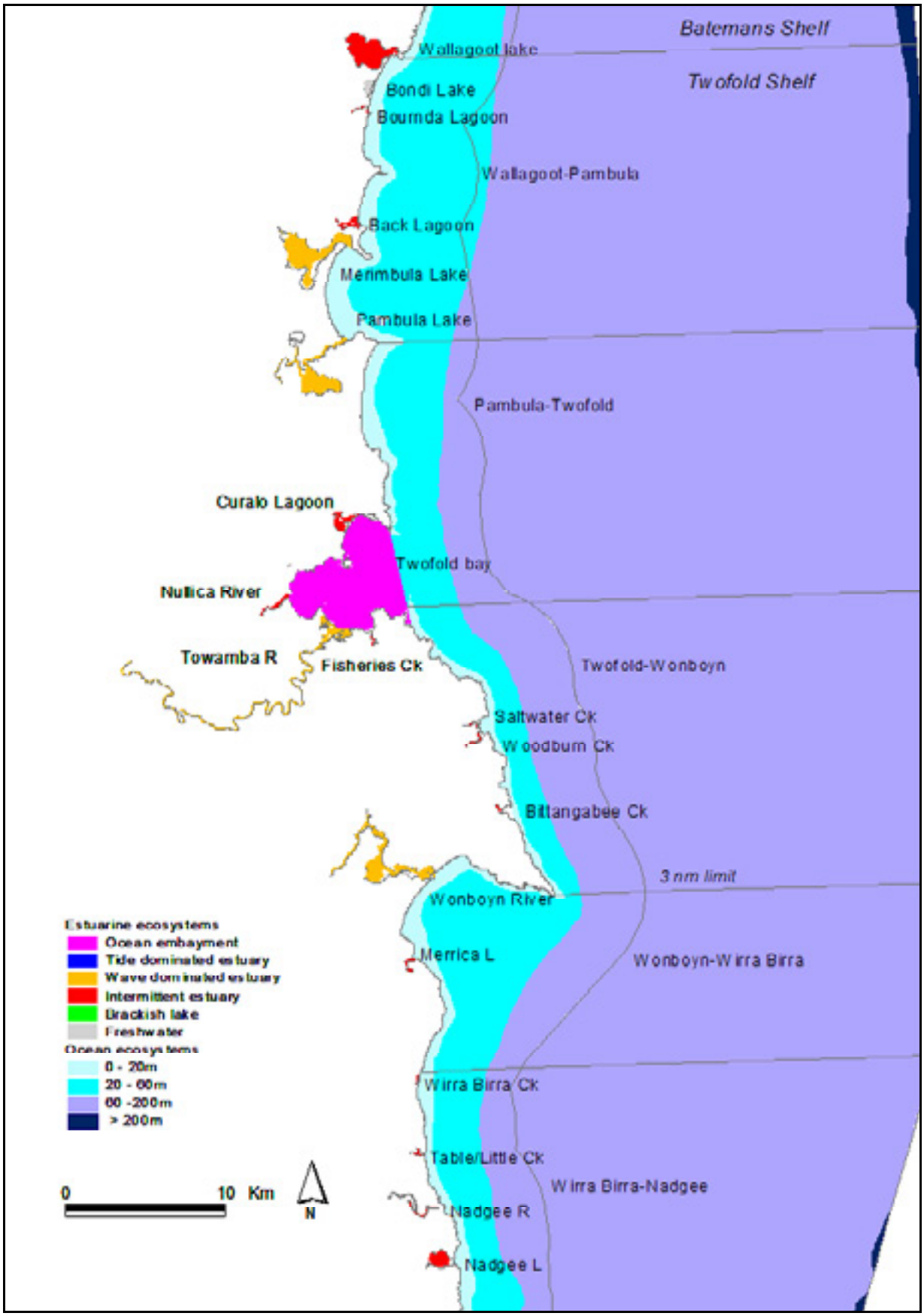


Fig. 8. Broadscale planning units of whole estuaries and sections of exposed coast with mapped estuarine and ocean ecosystem types – Wallagoot Lake to the Victorian border.

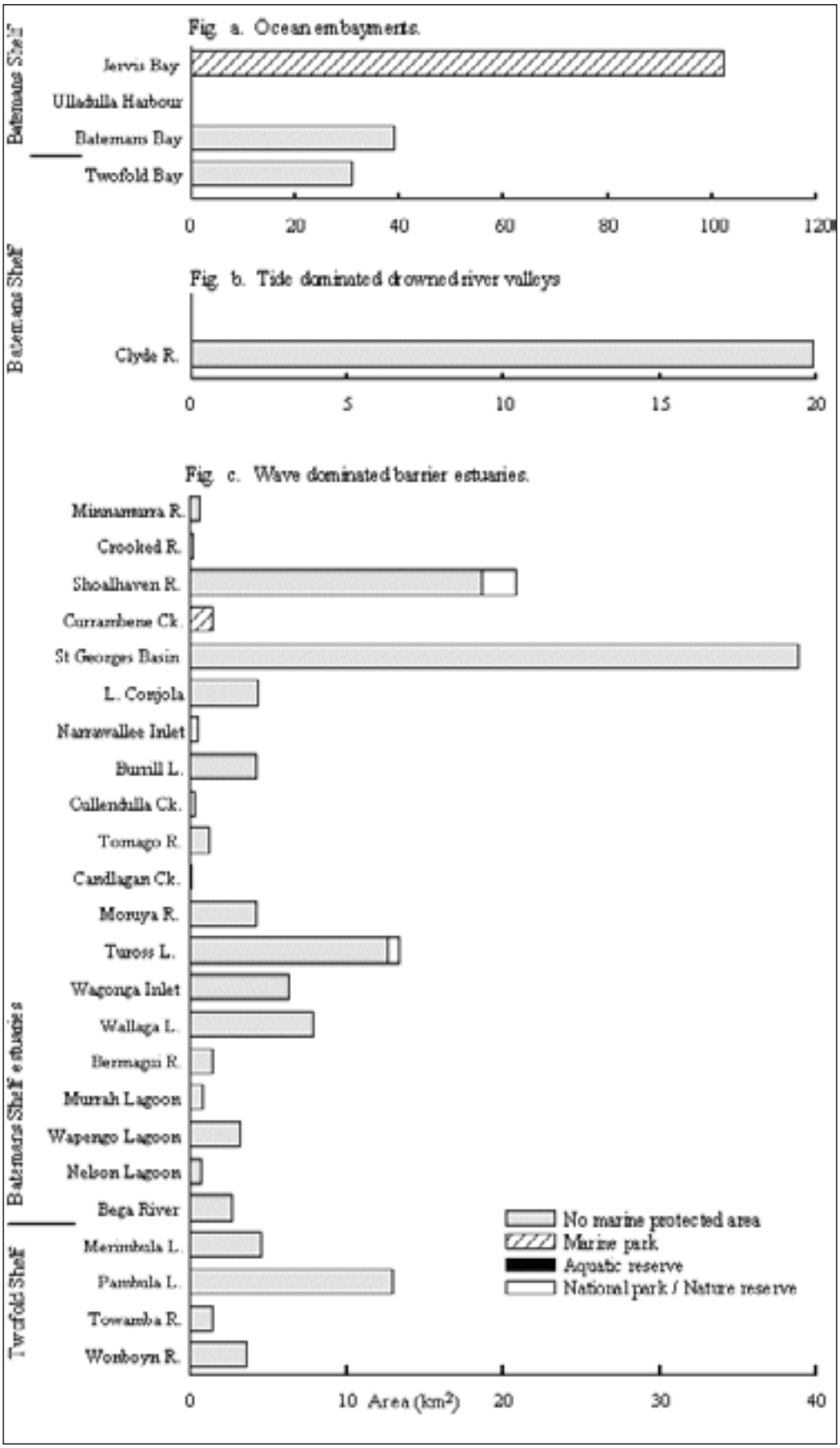


Fig. 9a-c. Area (km^2) of open water within and outside marine protected areas for different estuary ecosystem types in the Batemans Shelf and Twofold Shelf bioregions. Raw data from West *et al.* 1985, estuaries classified according to Roy *et al.* 2002.

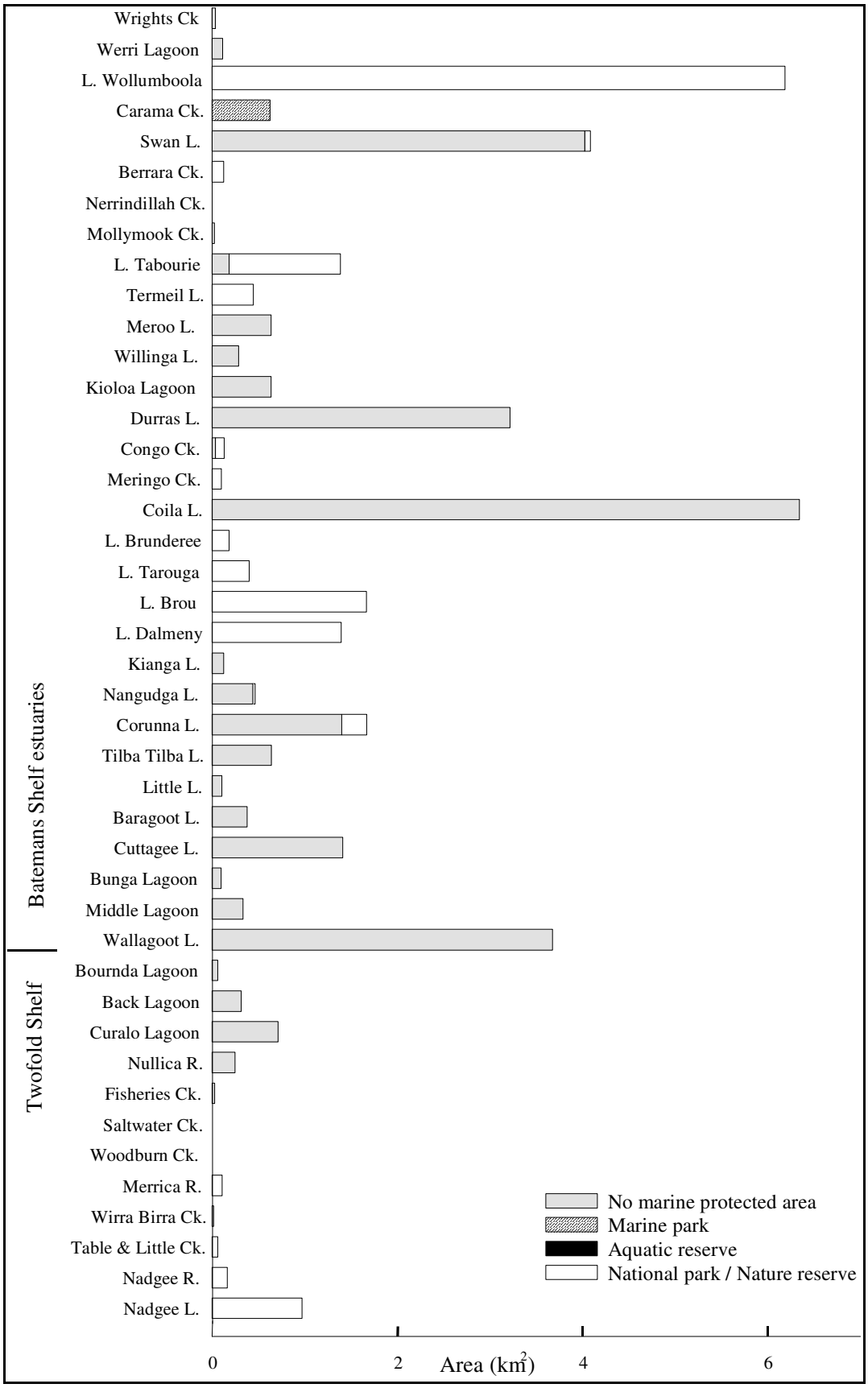


Fig. 10. Area of open water (km^2) within marine protected areas for intermittent lagoons and creeks in the Batemans Shelf and Twofold Shelf (NSW) bioregions. Raw data from West *et al.* 1985, estuaries classified according to Roy *et al.* 2002.

a. Minnamurra River b. Werri Lagoon c. Crooked River d. Shoalhaven River

e. Lake Wollumboola f. Jervis Bay g. St Georges Basin h. Swan Lake

i. Berrara Creek j. Nerrindillah k. Lake Conjola

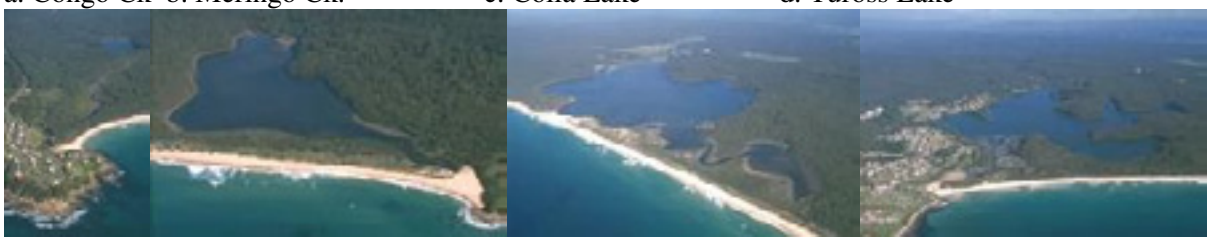
l. Narrawallee Creek m. Burrill Lake n. Tabourie Lake

o.Termiel Lake p. Meroo Lake q. Willinga Lake r. Durras Lake

s. Batemans Bay t. Tomago River u. Candalagan Ck v. Moruya River

Fig. 11a-v. Oblique aerial photographs of estuaries in the Batemans Shelf bioregion (provided by the NSW Department of Infrastructure, Planning and Natural Resources).

a. Congo Ck b. Meringo Ck. c. Coila Lake d. Tuross Lake



e. L. Brunderee f. Lake Tarouga g. Lake Brou h. Lake Mummuga

i. Kianga Lake j. Wagonga Inlet k. Nangudga Lake

l. Corunna Lake m. Tilba Tilba Lake n. Little Lake

o. Wallaga Lake p. Bermagui River q. Baragoot Lake

r. Cuttagee Lake s. Murrah Lagoon t. Bunga Lagoon

Fig. 12a-t. Oblique aerial photographs of estuaries in the Batemans Shelf bioregion (provided by the NSW Department of Infrastructure, Planning and Natural Resources).

a. Wapengo Lagoon b. Middle Lagoon c. Nelson Lagoon

d. Bega River e. Wallagoot Lake f. Back Lagoon

g. Merimbula Lake h. Pambula Lake i. Curalo Lake

j. Twofold Bay k. Towamba River l. Wonboyne River

m. Merrica R. n. Nadgee River o. Nadgee Lake

Fig. 13a-o. Oblique aerial photographs of estuaries in the Batemans Shelf bioregion (provided by the NSW Department of Infrastructure, Planning and Natural Resources).

4.1.2 NSW Fisheries[2] assessment of wave dominated and intermittent estuaries

Data source

Frances, J. (2000) "Identification of candidate sites for aquatic reserves in the Hawkesbury Shelf and Batemans Shelf bioregions".

Data description

The estuary classification of Roy *et al*. (2001) was used to assess comprehensiveness and representativeness and criteria for ecological importance, uniqueness, national and international importance, productivity, vulnerability and naturalness. An expert panel considered this collated data, provided ratings for estuaries and prioritised sites for declaration as Aquatic Reserves.

Criteria

Comprehensiveness, representativeness, ecological importance, uniqueness, national and international importance, productivity, vulnerability and naturalness.

Assessment measures

Area and number of different estuary types represented in marine protected areas.

Assessment

Tables 2, 3 and 4 display short-listed sites for each estuary type in the assessment, their ratings and their priority for declaration as MPAs. A more detailed description of these sites is given in Section 4. Wallaga Lake (Fig. 14), Nelson Lagoon (Fig. 15) and Durras Lake (Fig. 16) were selected as priority candidate aquatic reserves, but after public consultation a final decision on their declaration was deferred until after completion of this assessment. Insufficient data was available for the expert panel to nominate a mature intermittent estuary as a candidate MPA and the assessment did not include estuaries in the Twofold Shelf bioregion.

[2] now within the NSW Department of Primary Industries

Table 2. Ratings (low, medium, high) and priorities for NSW Fisheries[2] estuarine aquatic reserve candidates – youthful wave dominated and intermittent estuaries (Frances 2000). Dash equals "No data".

Type	Estuary	Ecological importance	Uniqueness	Naturalness	Vulnerability	Expert ID	Priority
Youthful Wave dominated	Burrill L.	Med	-	Med	Med	Yes	4
	Wagonga Inlet	High	-	Med	High	Yes	3
	St Georges Basin	High	High	Med	High	Yes	2
	L. Conjola	Low	-	Low	Med		
	Wallaga L	Med	-	High	Low	Yes	1
Youthful Intermittent	Swan L	High	-	High	Low	Yes	
	Werri Lagoon	-	-	Low	High		
	L. Wollumboola	High	High	Med	Low	Yes	1
	Berrara Ck	-	-	High	Low		
	Durras L	High	-	High	Low	Yes	2
	Meringo Ck	-	-	Low	Low		
	Coila L	Med	-	Low	Low	Yes	3
	Mummuga L	-	-	Med	Med		
	Corunna L	-	-	Med	Low	Yes	
	Cuttagee L	-	-	Med	Low		

[2] now within the NSW Department of Primary Industries

Table 3. Ratings (low, medium, high) and priorities for NSW Fisheries[2] estuarine aquatic reserve candidates – mature wave dominated estuaries (Frances 2000). Dash equals "No data".

Type	Estuary	Ecological importance	Uniqueness	Naturalness	Vulnerability	Expert ID	Priority
Mature Wave dominated	Minnamurra R	Med	-	Low	High		
	Crooked R	Med	-	Low	High		
	Shoalhaven R	High	High	Low	High	Yes	3
	Crookhaven R	Med	-	Low	High		
	Narrawallee Ck	High	-	Med	Med	Yes	
	Cullendulla Ck	High	High	Med	Med	Yes	
	Tomago R	-	-	Med	Med		
	Candalagan Ck	-	-	Med	Med		
	Moruya R	Med	-	Low	High		
	Tuross L	Med	High	Low	Med	Yes	
	Bermagui R	High	-	Low	Med	Yes	2
	Murrah Lagoon	-	-	Med	Low	Yes	
	Wapengo Lagoon	High	Med	Med	Low	Yes	
	Nelson Lagoon	High	Med	High	Low	Yes	1
	Bega R	Low	-	Low	Low		

[2] now within the NSW Department of Primary Industries

Table 4. Ratings (low, medium, high) and priorities for NSW Fisheries[2] estuarine aquatic reserve candidates – mature intermittent estuaries (Frances 2000). Dash equals "No data".

Type	Estuary	Ecological importance	Uniqueness	Naturalness	Vulnerablility	Expert ID	Priority
Mature Intermittent	Bensons Ck	-	-	Low	High		-
	Nerrindillah Ck	-	-	Med	Low		-
	Tabourie L	High	-	Med	Low	Yes	-
	Termeil L	-	-	Med	Low		-
	Meroo Ck	-	-	Med	Low		-
	L. Brou	-	-	Med	Med		-
	Kianga L	-	-	Med	Low		-
	Nangudga Inlet	-	-	Low	Low	Yes	-
	Tilba Tilba L	-	-	Low	Med		-
	Baragoot L	-	-	Low	Low		-
	Bunga Lagoon	-	-	Med	Low		-
	Wrights Ck	-	-	Low	High		-
	Mollymook Ck	-	-	Low	High		-
	Willinga L	-	-	Med	Med		-
	Kiola Lagoon	-	-	High	Low		-
	Congo Ck	-	-	Med	Low		-
	Little L	-	-	Low	Low		-
	Middle Lagoon	High	-	Med	Low	Yes	-

[2] now within the NSW Department of Primary Industries

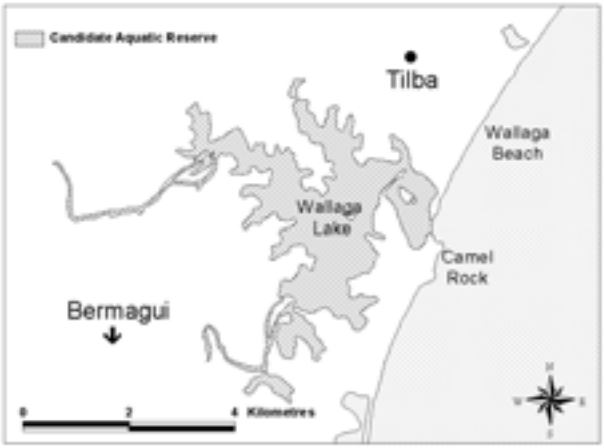


Fig. 14. Previous candidate aquatic reserve at Wallaga Lake, a young wave dominated estuary (NSW Fisheries[2] 2001).

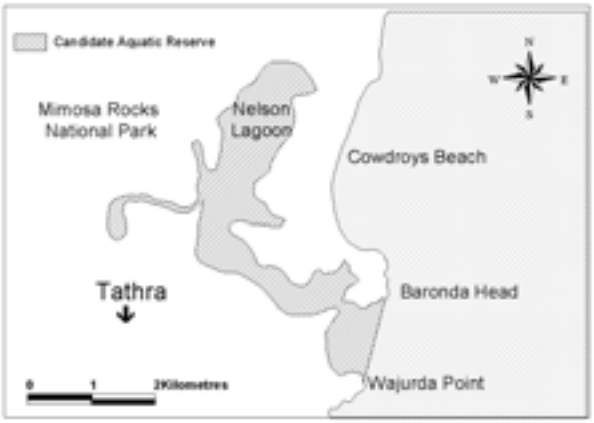


Fig. 15. Previous candidate aquatic reserve at Nelson Lagoon, a mature wave dominated estuary (NSW Fisheries[2] 2001).

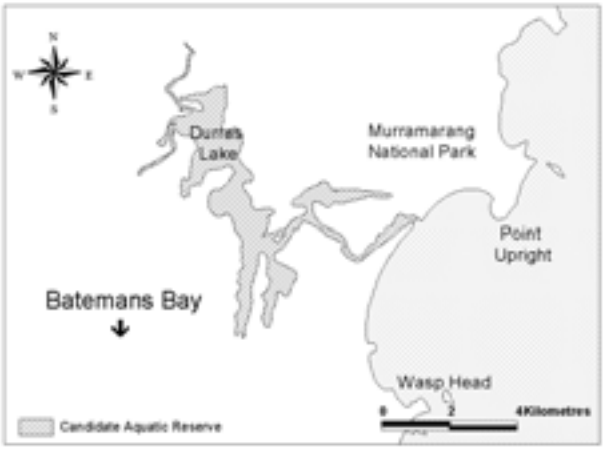


Fig. 16. Previous candidate aquatic reserve at Durras Lake, a youthful intermittent estuary (NSW Fisheries[2] 2001).

[2] now within the NSW Department of Primary Industries

4.1.3 Ocean ecosystems

Data source

Derived from NSW Waterways[5] and Australian Hydrographic Office data.

Data description

Four depth zones (0-20 m, 20-60 m, 60-200 m and > 200 m) derived from depth contours digitised by NSW Waterways[5] from AHO hydrographic charts.

Criterion

Comprehensiveness

Assessment measures

Area of depth zones within broadscale planning units (sections of exposed coast and ocean).

Assessment

Options for representation of the ocean ecosystems, as defined by major depth zones, are spread throughout the latitudinal extent of the bioregion though there tends to be more area in the 0-20 m zone at the northern end of the Batemans Shelf bioregion (Fig. 17).

Jervis Bay Marine Park includes 39 km^2 of the 0-20 m depth zone (or 13% of this depth zone for the bioregion within 3 nm of the coast) and 52 km^2 of the 20-60 m depth zone (or 5% of this zone within 3 nm). The Marine Park includes only 1.2 km^2 (0.2% of the waters within 3nm) of the 60-200 m depth zone and there are much larger areas of the deeper zones in Commonwealth waters beyond 3 nm of the coast which are not represented in MPAs (Fig. 18b & c).

In the NSW section of the Twofold Shelf bioregion there is no representation of these zones in MPAs but this does occur within Victorian and Tasmanian MPAs.

[5] now NSW Maritime

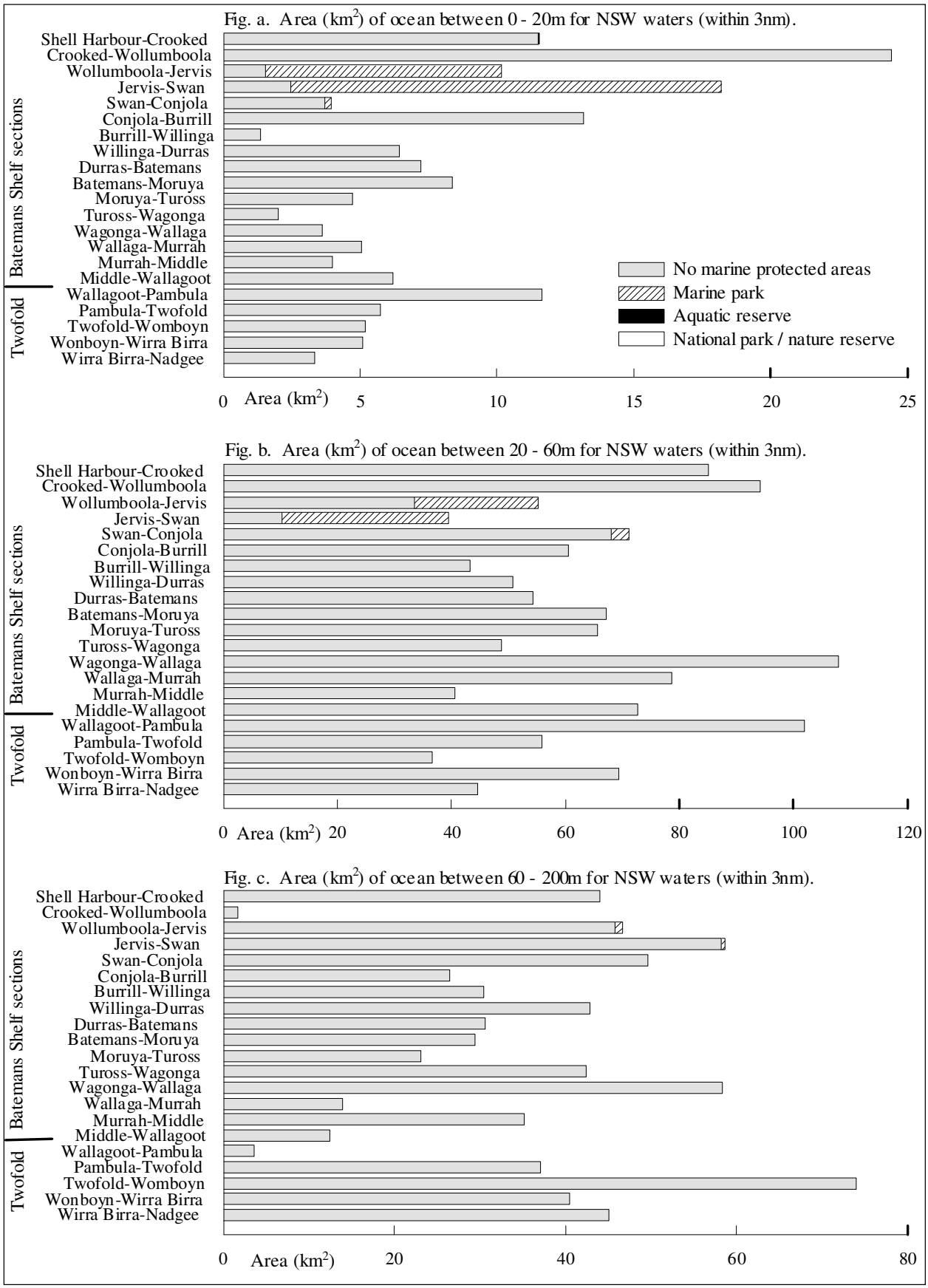


Fig. 17a-c. Area (km^2) of ocean depth zones in marine protected areas for sections of ocean coast in NSW waters (within 3nm) of the Batemans Shelf and Twofold Shelf bioregions.

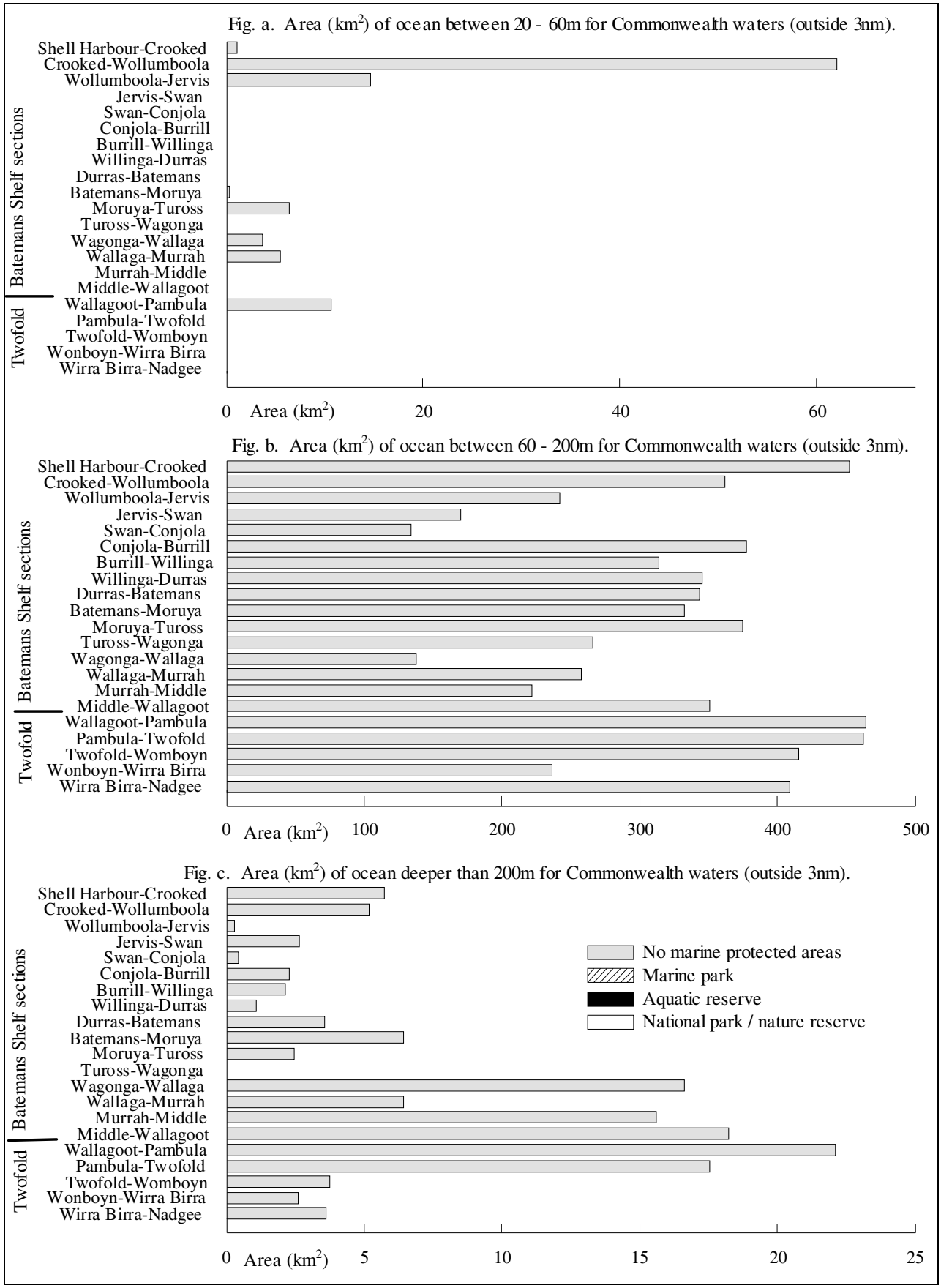


Fig. 18a-c. Area (km^2) of ocean depth zones in marine protected areas for Commonwealth waters (outside of 3nm) of the Batemans Shelf and Twofold Shelf bioregions.

4.1.4 Oceanography - East Australian Current

Data source

A summary of some key oceanographic processes in the Batemans Shelf and Twofold Shelf bioregions (Cresswell *et al*. 1983, Pollard *et al*. 1997, Cresswell 1998, CSIRO Australia 2001) and sea surface temperature satellite images provided by Cresswell (1998).

Criteria

Comprehensiveness, representativeness, ecological importance and productivity.

Data description and assessment

The East Australian Current (EAC) runs south along the east coast of Australia from the Coral Sea into the Tasman Sea and brings warm tropical and subtropical water into the cooler temperate waters of NSW (Fig. 19). It has an important influence on marine biodiversity in coastal and offshore waters throughout NSW through its influence on ocean temperature, density and chemistry, eddies, counter currents, upwellings, primary productivity, transport of larvae and food supply. The influence of the current on phytoplankton and productivity has been well studied and the movements of larger organisms such as gemfish, tuna and a range of pelagic species are also thought to be influenced by the current (CSIRO Australia 2001).

The current moves at speeds up to 5 knots, transports up to 30 million cubic metres of water per second, and can affect waters down to 500 metres in depth and 100 kilometres across. The EAC is strongest in summer, flowing up to twice the strength of the current in winter months (CSIRO Australia 2001).

The EAC often moves inshore across the continental shelf, generating northward flowing currents and small clockwise 'cold core' eddies. The current also periodically meanders south and retreats north across the Tasman Front, creating large anti-clockwise warm-core eddies up to 200 km in width and 1000 m deep, with currents up to four knots at their periphery. These eddies often continue to migrate south taking warm waters and incumbent larvae and other plankton into cold temperate waters (CSIRO Australia 2001).

The EAC moves away from the coast most frequently near South West Rocks and Seal Rocks in the Manning Shelf bioregion, yet sometimes continues inshore as far south as Ulladulla. An assessment by Pollard *et al*. (1997) estimated that the EAC influences NSW coastal waters between Tweed Heads and Seal Rocks about 90% of the time, but that this influence decreases to 50% of the time between Seal Rocks and Jervis Bay, and to 10% of the time between Jervis Bay and Cape Howe. This indicates that while the Tweed-Moreton and Manning Shelf bioregions are often influenced by subtropical waters, and the Hawkesbury Shelf alternates between two extremes, the inshore areas of the Batemans Shelf and Twofold Shelf bioregions are more often influenced by temperate conditions. The complex nature of the current and its eddies means that its influence on coastal and offshore conditions is highly variable, regardless of the seasonal averages (Fig. 20).

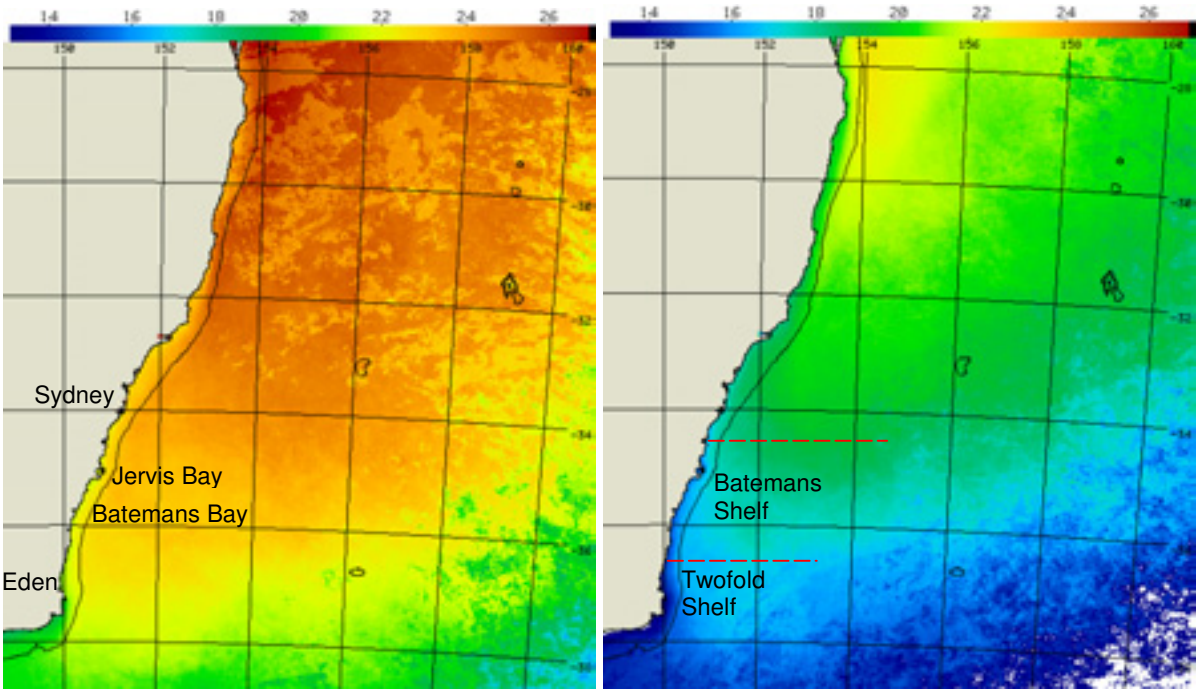
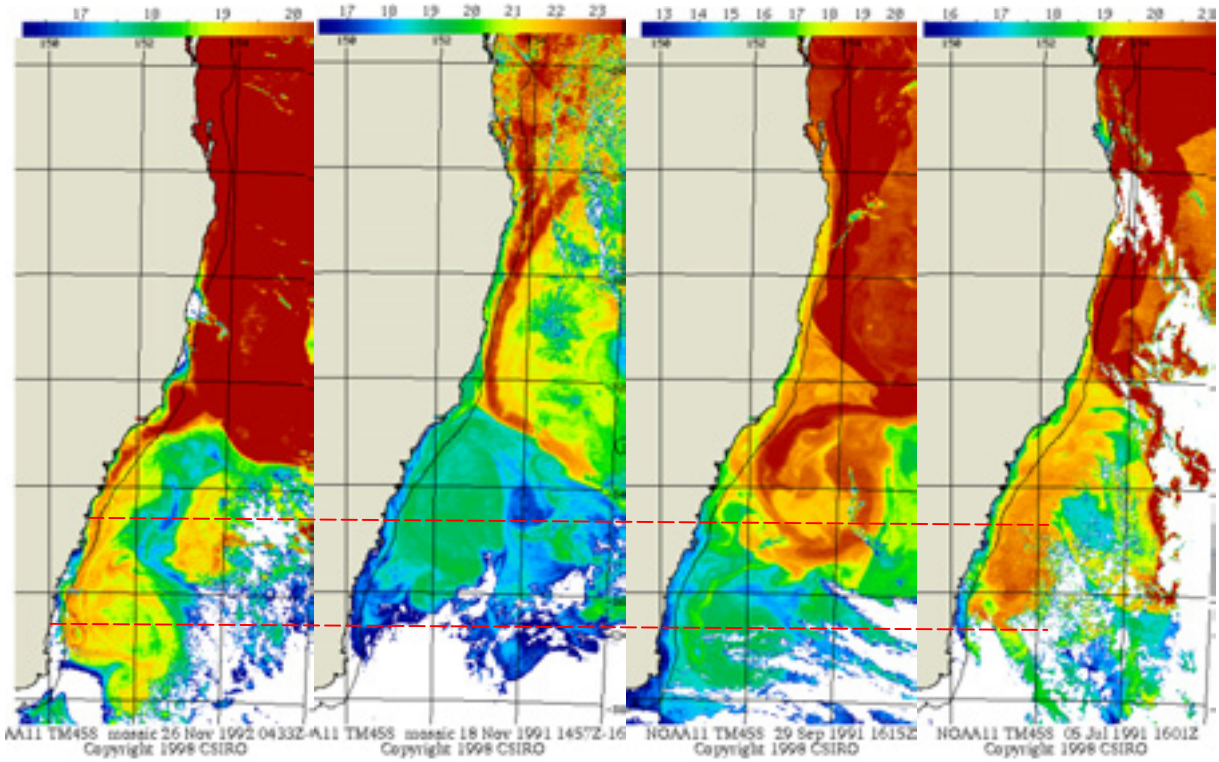


Fig. 19. Mean sea surface temperature off NSW coast averaged for summer (January-March) and winter (July-September) (Cresswell 1998).



a. b. c. d.

Fig. 20. Broadscale oceanographic processes off the NSW coast represented by sea surface temperature (SST) NOAA11 TM45S satellite images (after Cresswell 1998); a. East Australian current warming inshore waters of the Batemans Shelf and Twofold Shelf bioregions during November; b. cool inshore waters in the Batemans Shelf and Twofold Shelf during November as the EAC heads offshore from South West Rocks; c. Cool inshore waters during September; d. warm inshore waters in July. Red dashed lines = Batemans Shelf (images from Cresswell 1998).

4.1.5 Seagrass, mangrove and saltmarsh habitats

Data sources

Estuarine vegetation maps (West *et al*. 1985) digitised by National Parks and Wildlife Service[1].

Data description

Estuarine plant communities were mapped between 1981 and 1984 using 1:25,000 scale aerial photographs and a 1:25,000 scale topographic map base. Vegetation identified in the digitised GIS data coverage included saltmarshes, mangroves and seagrasses (Fig. 21 - Fig. 27). These surveys should be regarded cautiously as a general indication of broad spatial patterns. More recent surveys by Fisheries (DPI) are underway (Robert Williams pers. comm.)

Criteria

Comprehensiveness and representativeness.

Assessment

In the Batemans Shelf bioregion, large areas of seagrass habitat (9 km^2) are protected within Jervis Bay Marine Park and Booderee National Park representing 25% of the area of this habitat for the bioregion. Large areas of seagrass are also found in St Georges Basin (8.5 km^2) with smaller areas in many other estuaries including an additional 2 km^2 in the marine components of national parks and nature reserves.

In the NSW section of the Twofold Shelf bioregion, there are areas of seagrass habitat in Merimbula and Pambula Lakes and smaller areas in other estuaries. However, only 0.1 km^2 of seagrass representing 2% of this habitat in the NSW section of the bioregion occurs within MPAs. As the Victorian and Tasmanian MPAs in the Twofold Shelf bioregion do not include estuaries, seagrass habitats may not be well represented for this bioregion.

The largest areas of mangrove habitat in the bioregion are in the Shoalhaven River and the Clyde River and there are smaller areas in a number of other estuaries. Currently, about 0.7 km^2 of mangrove habitat, accounting for 5% of the area of this habitat in the bioregion is represented in Jervis Bay Marine Park, Comerong Island Nature Reserve in the Shoalhaven River and Eurobodalla National Park in Tuross Lake. Another 2.8 km^2 (21% of the habitat in the bioregion) of mangrove occurs above the mapped high tide mark in terrestrial national parks and nature reserves.

In the Twofold Shelf bioregion mangrove habitats are only recorded by West *et al*. from Pambula Lake, Merimbula Lake and the Towamba River. None of this habitat is included in MPAs but 0.3 km^2 or 34% of the mangrove in the NSW section of the bioregion occurs above the mapped high water mark in terrestrial national parks and nature reserves. The extent of mangrove habitats within MPAs in the Victorian section of the bioregion is not known but is not likely to be large given the exposed locations of the Victorian Marine National Parks.

The largest areas of saltmarsh in the Batemans Shelf bioregion occur around Carama Creek, above mapped mean high water, and therefore outside Jervis Bay Marine Park, but within Jervis Bay National Park. Large areas of saltmarsh are also found near the Shoalhaven River but only some of these are included in Comerong Nature Reserve. Smaller areas of saltmarsh (<1 km^2) are also found near almost 40 other estuaries in the bioregion including Currumbene Creek (above high tide and therefore outside Jervis Bay Marine Park), the Clyde River, Moruya River, Coila Lake, Tuross Lake, Wallaga Lake, Lake Brou, Wapengo Lagoon and the Bega River. In total, less than a square kilometre of saltmarsh habitat is included in MPAs in the Batemans Shelf bioregion, but a larger area (2.6 km^2 or 26% of the habitat in the bioregion) occurs above the mapped mean high water mark in terrestrial national parks and nature reserves.

The largest areas of saltmarsh habitat in the Twofold Shelf bioregion occur near Merimbula Lake and the Wonboyne River. None of this habitat is included in MPAs but 0.6 km^2 or 35% of

[1] now within the Department of Environment and Conservation

saltmarsh habitat in the NSW section of this bioregion is included in the terrestrial components of Ben Boyd National Park and Nadgee Nature Reserve.

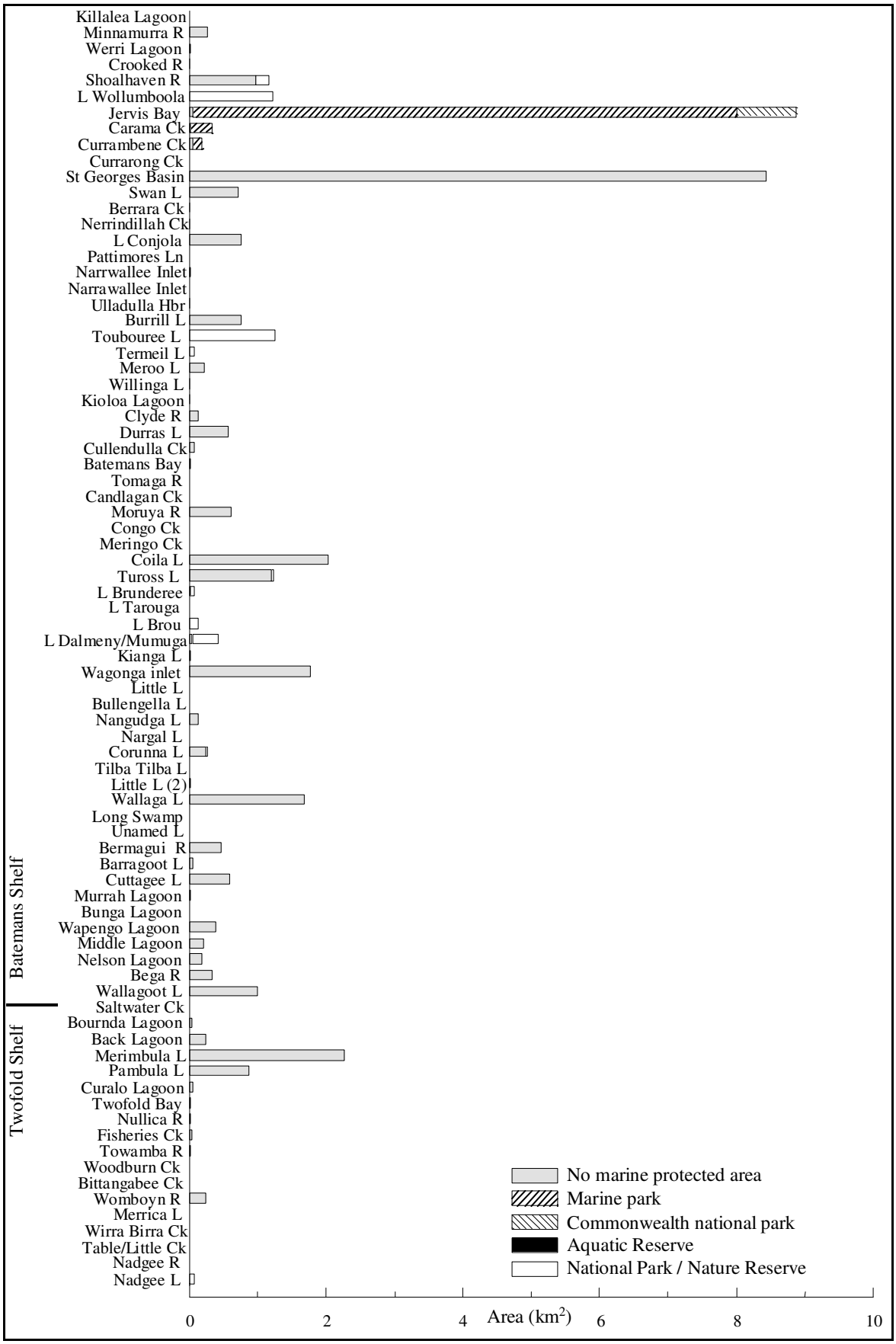


Fig. 21. Area (km^2) of seagrass habitat in marine protected areas for estuaries of the Batemans Shelf and Twofold Shelf bioregions (raw data from West *et al.* 1985).

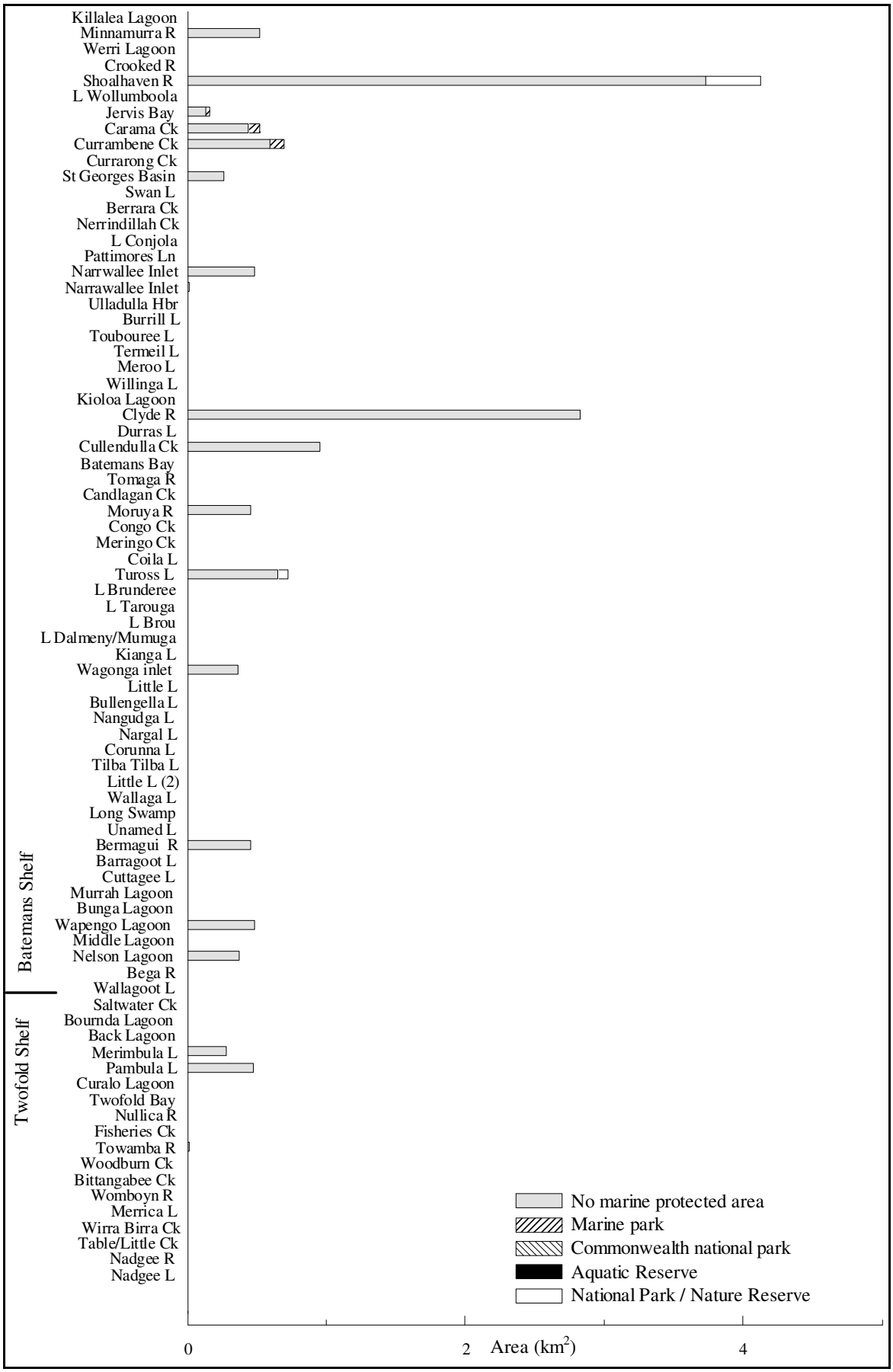


Fig. 22. Area (km^2) of mangrove habitat in marine protected areas for estuaries of the Batemans Shelf and Twofold Shelf bioregions (raw data from West *et al*. 1985).

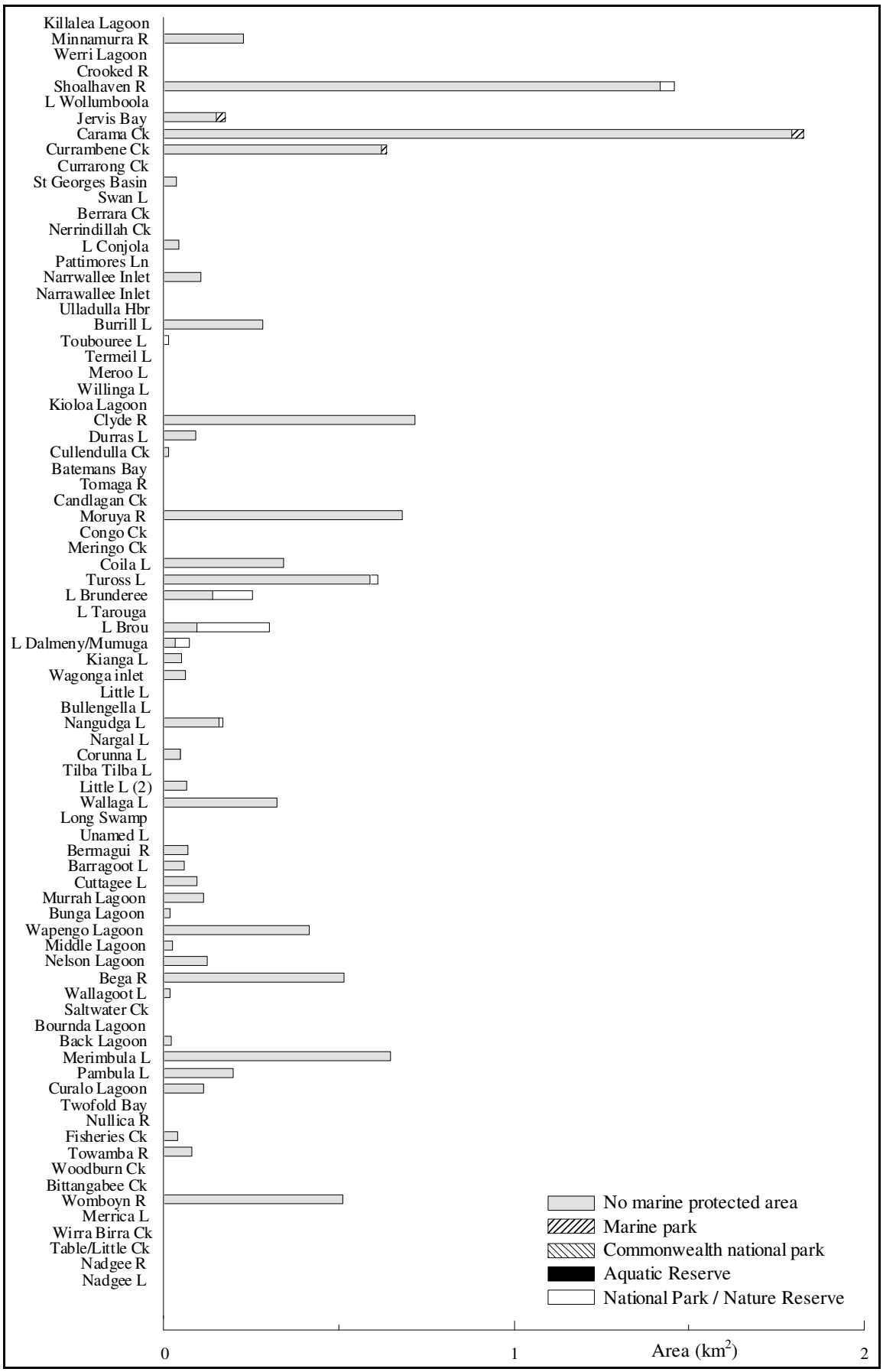


Fig. 23. Area (km^2) of saltmarsh habitat in marine protected areas for estuaries of the Batemans Shelf and Twofold Shelf bioregions (raw data from West *et al*. 1985).

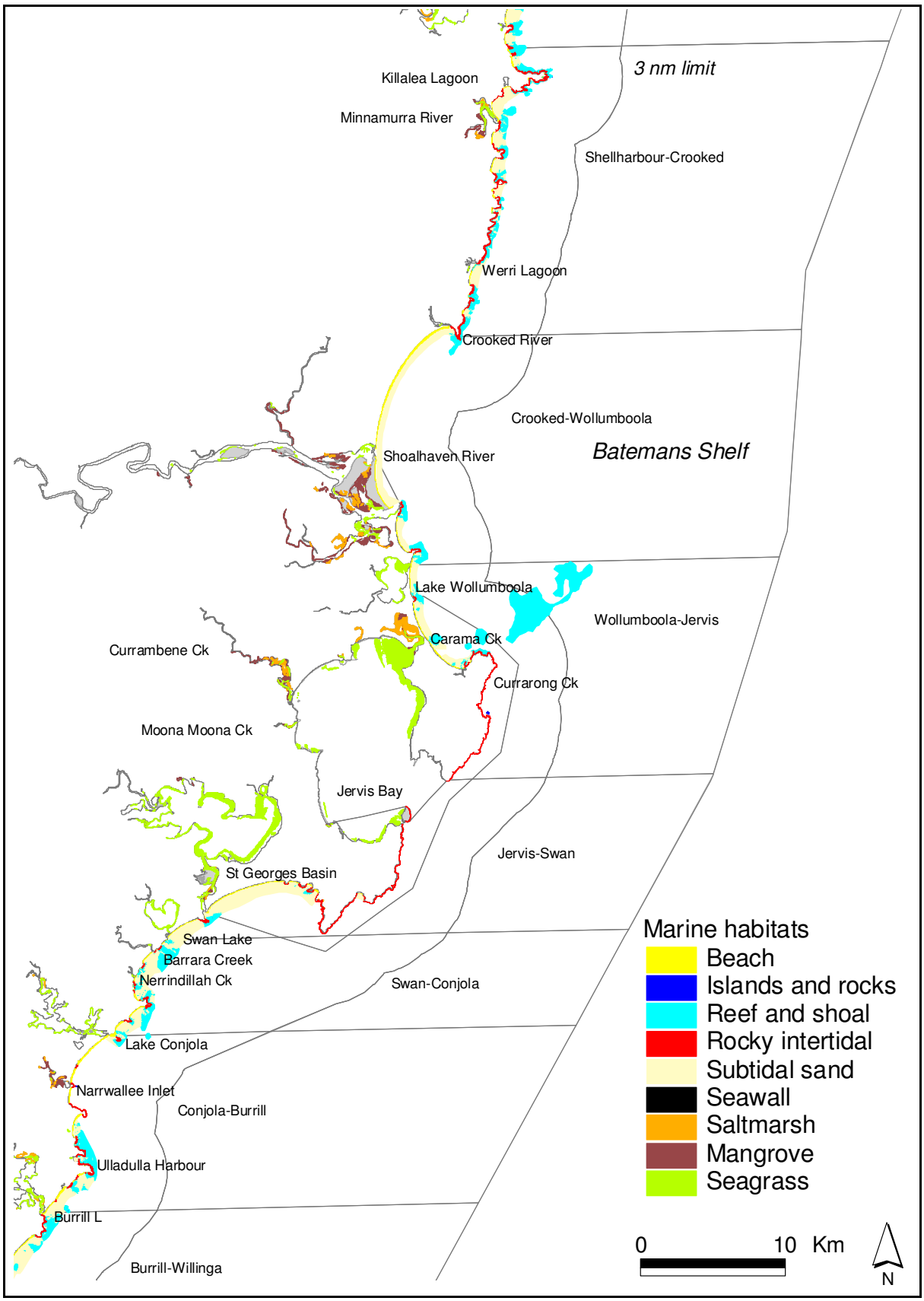


Fig. 24. Mapped marine habitat units between Shellharbour and Burrill Lake.

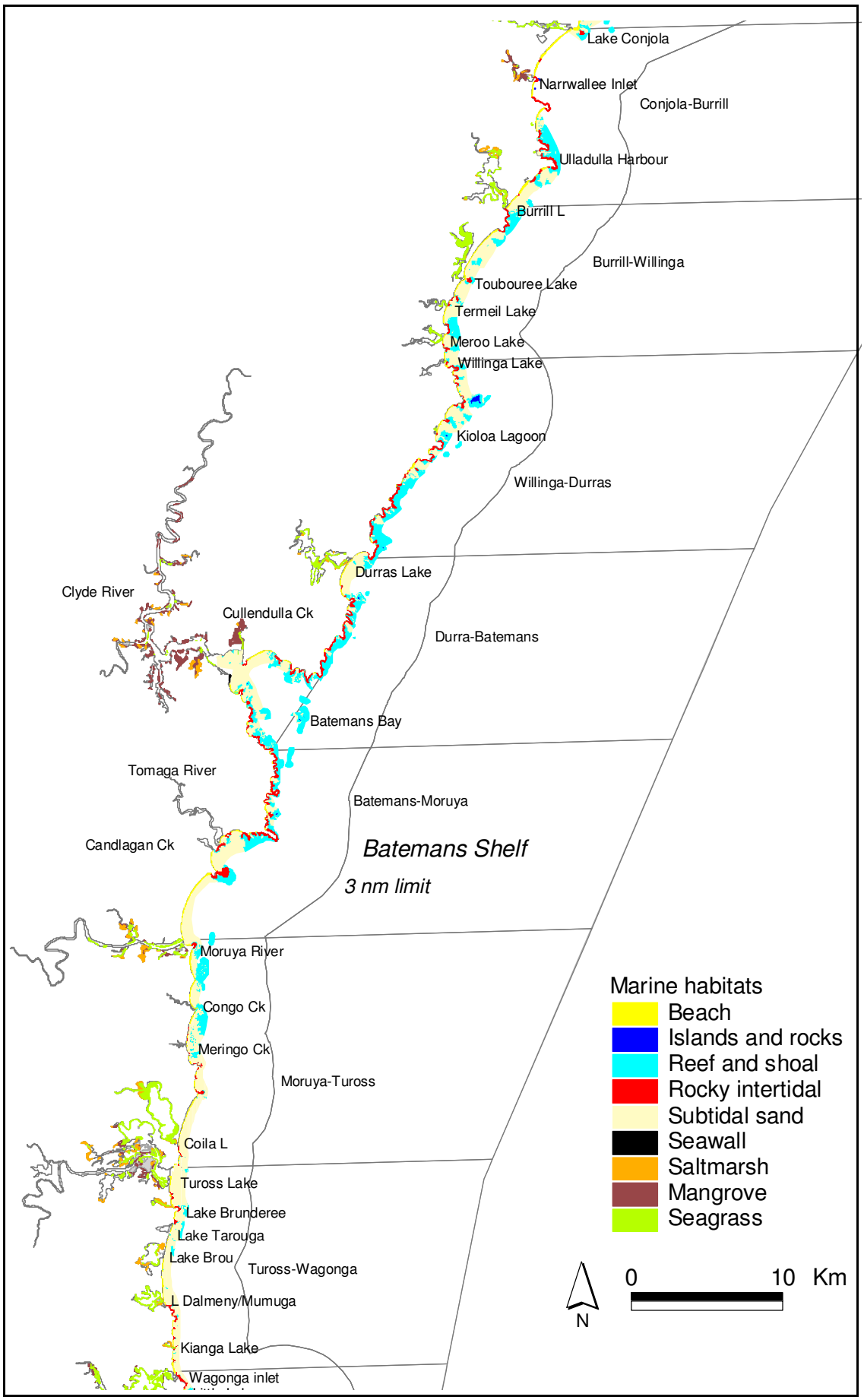


Fig. 25. Mapped marine habitat units between Burrill Lake and Tuross Lake.

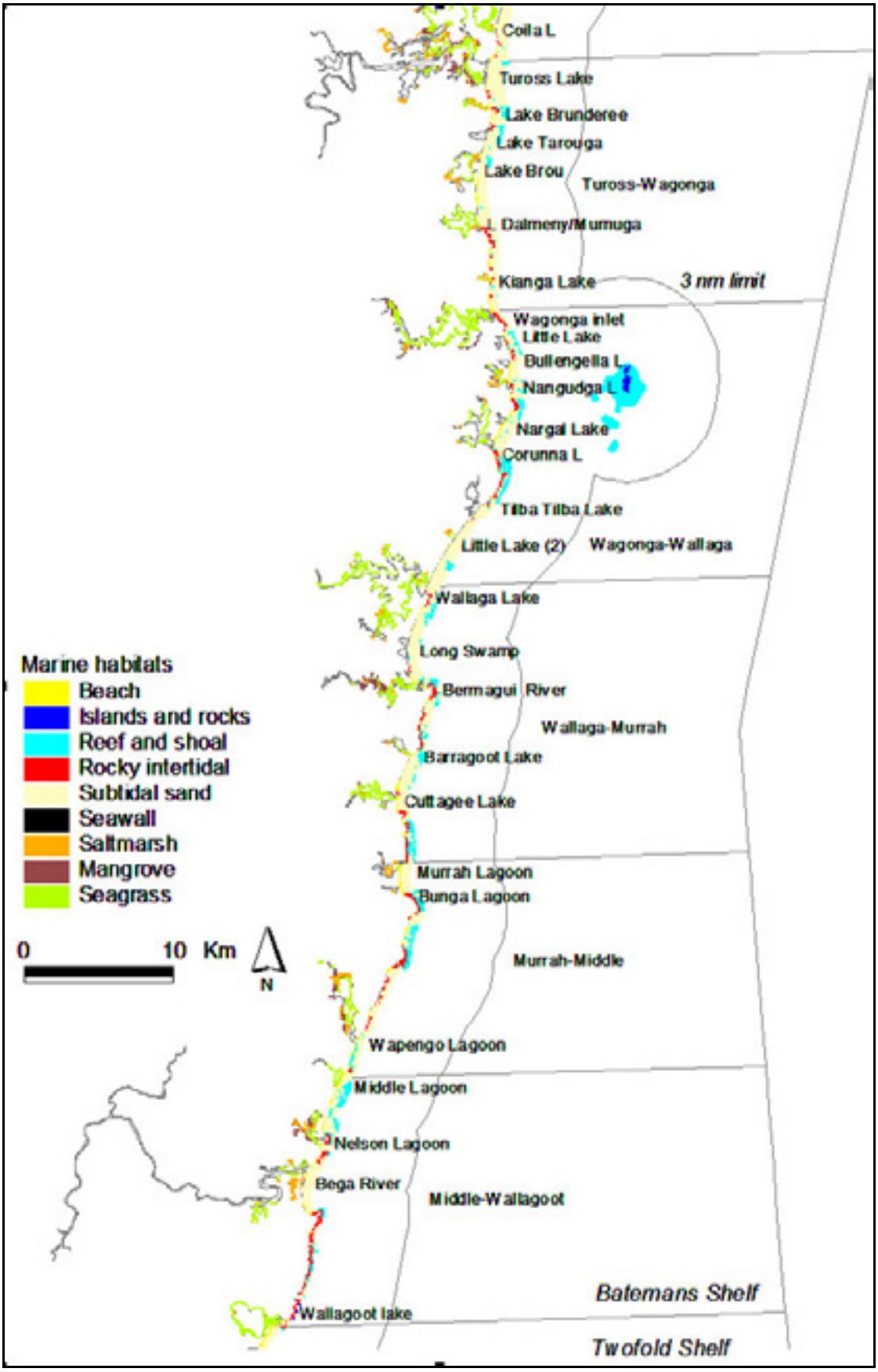


Fig. 26. Mapped marine habitat units between Tuross Lake and Wallagoot Lake.

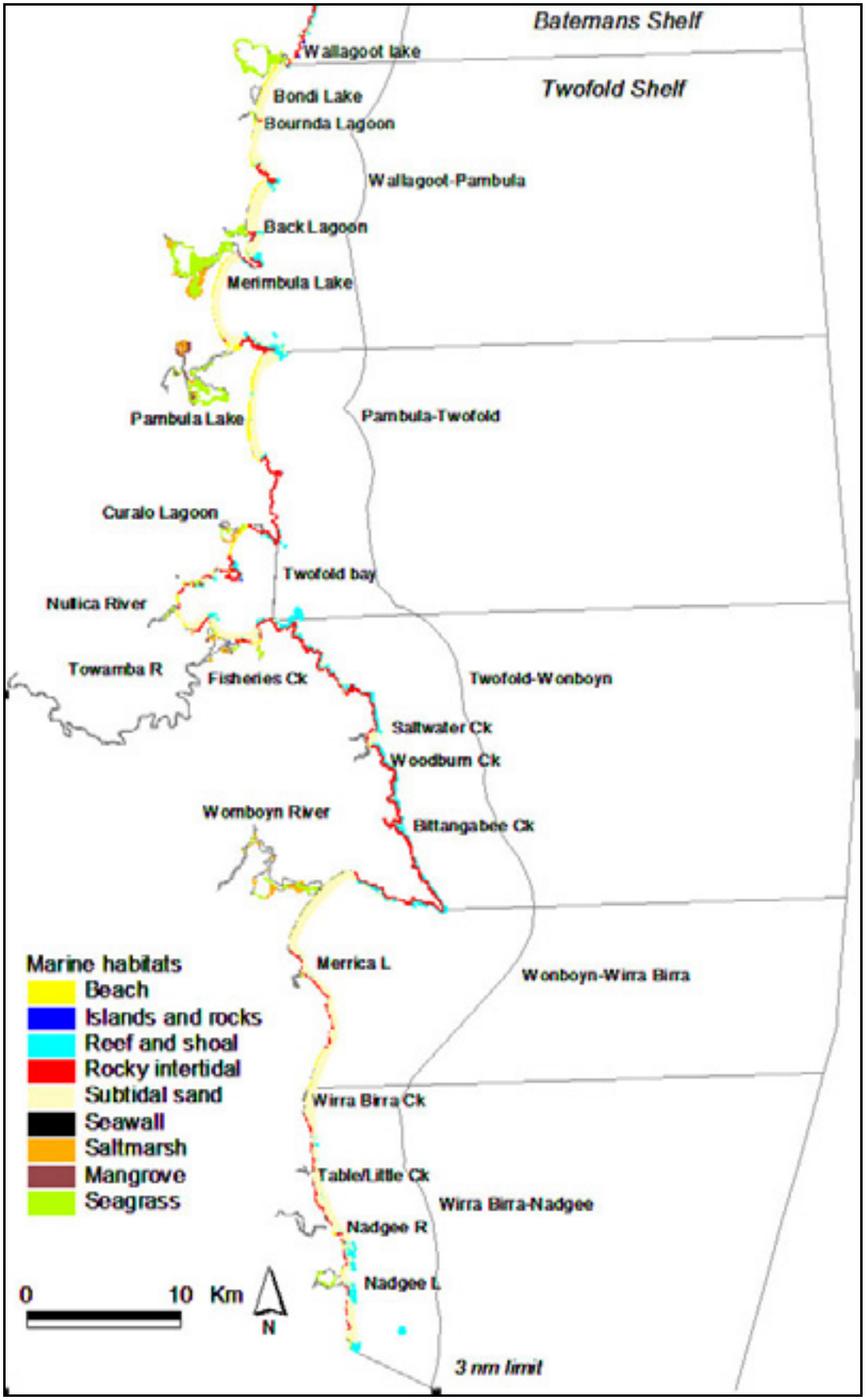


Fig. 27. Mapped marine habitat units between Wallagoot Lake and the Victorian border.

4.1.6 Shallow subtidal reef and shoal

Data source

GIS maps of shallow nearshore reef digitised by Ron Avery (DEC) from aerial photography held by the Department of Infrastructure, Planning and Natural Resources.
GIS maps of shallow offshore reefs and shoals digitised from Australian Hydrographic Survey Charts.

Data description

Reefs were digitised from high resolution (1:8,000 –1:25,000) aerial photographs but this technique is limited to depths of 10-20m. Hydrographic charts focus only on those reefs and shoals which approach the sea surface and pose a hazard for shipping and will therefore also under-represent the total area of reef present at all depths.

It is therefore recommended that for finer scale assessments, a more comprehensive assessment of existing seabed data is made and that where required, additional seabed surveys are carried out to accurately characterise these environments.

Reefs were also classified by their distance offshore (more or less than 1 km) to approximately represent major differences in surrounding depths and the relative degree of terrestrial and oceanic influences. However more detailed surveys at specific sites are likely to provide more precise descriptions of the biodiversity present.

Criteria

Comprehensiveness and representativeness.

Assessment measures

Area in broadscale (sections of exposed coast and ocean) and small-scale planning units.

Assessment

Most mapped shallow reef and shoal occurred in the Wollumboolah-Jervis (9.8 km^2), Willinga-Durras (8.4 km^2), Wagonga-Wallaga (7.3 km^2) and Shell Harbour-Crooked (7 km^2) sections of coast. Most of the Wollumboolah-Jervis (7 km^2) and Wagonga-Wallaga (5.1 km^2) reef and shoal occurred more than 1 km offshore, while in the Willinga-Durras section (8.4 km^2) most reef occurred within 1 km of the coast (Fig. 28).

A total of 2.8 km^2 of mapped reef and shoal lies within Jervis Bay Marine Park and Bushrangers Bay Aquatic Reserve representing 4% of this habitat for the Batemans Shelf bioregion. All of this reef and shoal is within 1 km of shore and there are no mapped offshore reef or shoal habitats within MPAs.

The Twofold-Wonboyn section of coast had the greatest area of mapped reef (3.8 km^2) in the NSW section of the Twofold Shelf bioregion. There are no areas of reef in MPAs in the NSW section of the Twofold Shelf bioregion, but reef habitats do occur in Point Hicks Marine National Park, Cape Howe Marine National Park and Beware Reef Marine Sanctuary in Victorian State waters and in the Kent Group Marine Reserve in Tasmanian waters.

Results for this habitat should be regarded cautiously as the use of aerial photographs to map subtidal habitats is limited to nearshore areas and hydrographic charts focus on those reefs and shoals which approach the sea surface and pose a hazard for shipping. There is little, readily available information on the distribution of deeper reefs in most offshore areas. It is recommended that a more comprehensive assessment of existing seabed data is made and that, where required, additional seabed surveys are carried out to more accurately assess these environments.

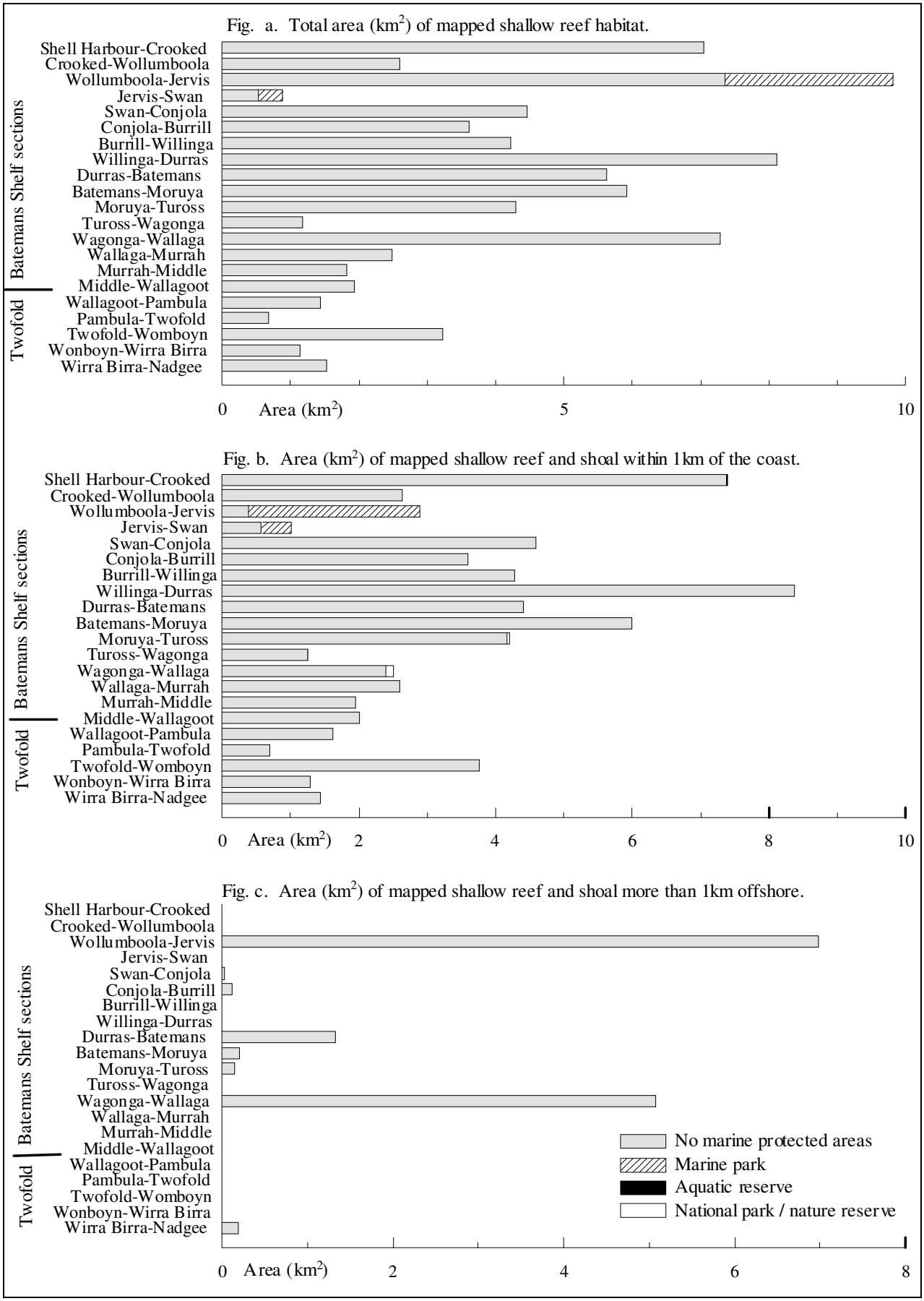


Fig. 28. Area of mapped shallow reef for sections of ocean coast.

4.1.7 Islands

Data source

GIS cover of islands and emergent rocks from the AMBIS dataset provided by Geoscience Australia (Commonwealth of Australia 2001).

Data description

Areas of islands and exposed rocks categorised by their distance offshore (greater or less than 1 km from the coast).

Criteria

Comprehensiveness and representativeness.

Assessment measures

Area of islands within broadscale plan units and 100m island buffers in fine scale plan units.

Assessment

The largest area of islands and rocks occurred in the Wagonga-Wallaga, Jervis-Swan and Willinga-Durras sections of coast. Most islands less than 1 km offshore occurred in the Jervis-Swan and Willlinga-Durras sections of coast and ocean. Most islands over 1 km from shore occurred in the Wagonga-Wallaga section of coast (Montague Island) and the Durras-Batemans section of coast (Tollgate Islands) (Fig. 29).

Islands and rocks occurred within MPAs in the Jervis Bay Marine Park in the Wollumboola-Jervis (Drum and Drumsticks) and the Jervis-Swan sections (Bowen Island) representing 24% of the total area of islands in the bioregion.

Most islands in the NSW section of the Twofold Shelf bioregion occurred in the Twofold-Wonboyne section within 1 km of the coast. There were no islands in the NSW section of the Twofold Shelf bioregion included within an MPA, but islands do occur within MPAs in the Victorian and Tasmanian sections of the bioregion.

4.1.8 Shallow subtidal sediments

Data source

GIS coverage of nearshore sediments digitised by Ron Avery (DEC) from aerial photographs provided by the NSW Department of Infrastructure, Planning and Natural Resources.

Data description

Nearshore sediment digitised from high resolution (1:8,000 –1:25,000) aerial photographs.

Criteria

Comprehensiveness and representativeness.

Assessment measures

Area in broadscale (sections of exposed coast and ocean) and small-scale planning units.

Assessment

The area of inshore sand mapped was similar for most sections of the Batemans Shelf bioregion ranging from approximately 5 km^2 up to 11 km^2 (Jervis-Swan). About 11.6 km^2 of this habitat was represented in Jervis Bay Marine Park accounting for 9% of the total area of this habitat in the bioregion (Fig. 30a).

Relatively large areas of inshore sand were mapped in the Wallagoot-Pambula and Wonboyne-Nadgee sections (5-10 km^2) of the Twofold Shelf bioregion with smaller areas in the sections of coast between Twofold Bay and Wirra Birra Creek (1-3 km^2). There were no areas of inshore sand in MPAs in the NSW section of the Twofold Shelf bioregion but this habitat is likely to be represented in the Ninety Mile Beach Marine National Park and other Victorian and Tasmanian MPAs.

Results for this habitat should be regarded cautiously as the use of aerial photos is limited to shallow areas. Further research into existing seabed data is needed and where required, additional seabed surveys should be carried out to accurately characterise offshore sediments.

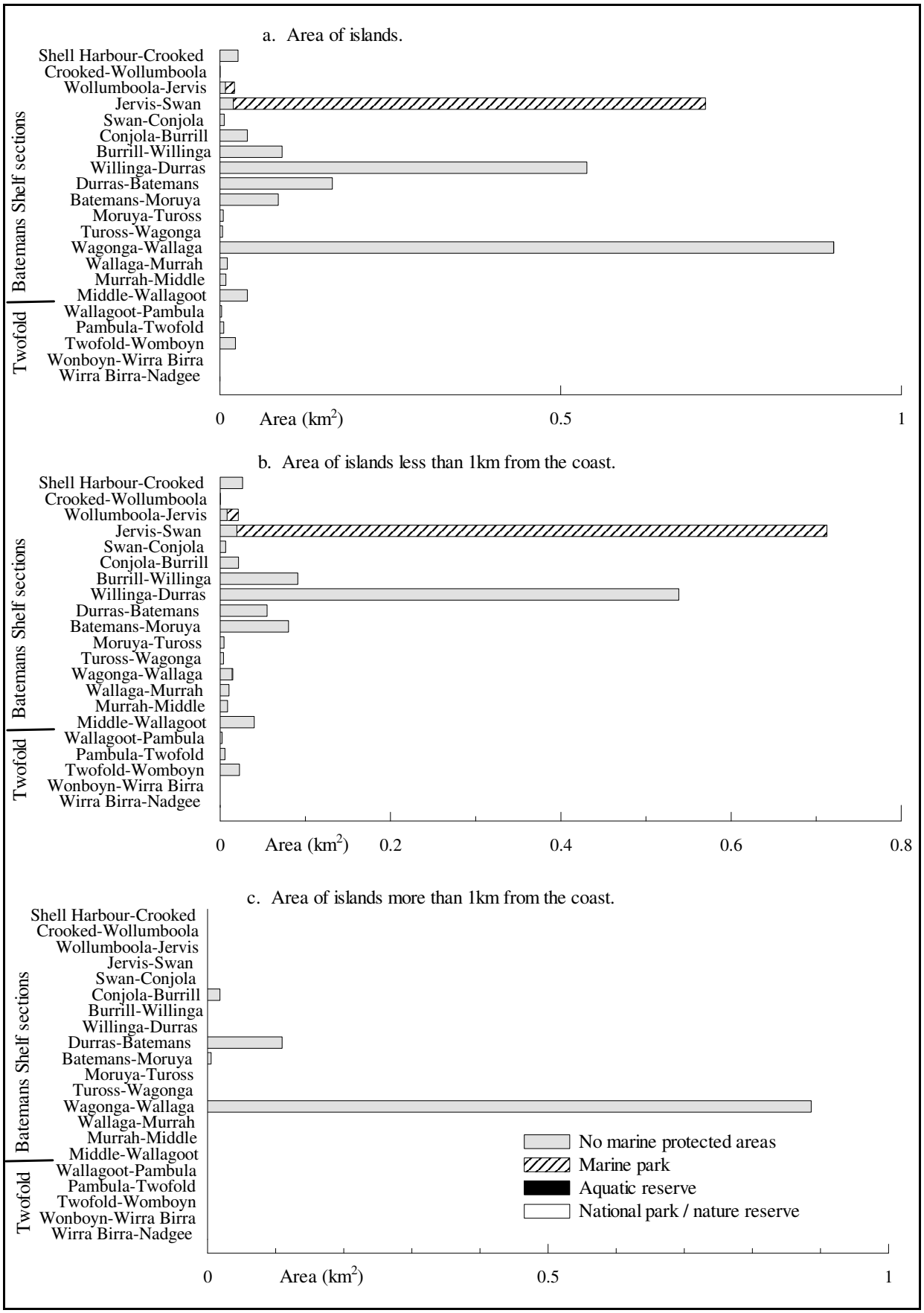


Fig. 29a-c. Area (km^2) of total, inshore and offshore islands for coastal sections (NSW waters within 3nm) of the Batemans Shelf and Twofold Shelf bioregions.

4.1.9 Exposed intertidal beach

Data sources

Digital cadastre database and 1: 25,000 topographic maps provided by the Land and Property Information Division (NSW Department of Lands).

Data description

Ocean beaches were identified from 1:25,000 topographic maps and their areas calculated from the difference between the high and low water marks in the digital cadastre.

Criteria

Comprehensiveness and representativeness.

Assessment measures

Area in broadscale (sections of exposed coast and ocean) and small-scale planning units.

Assessment

The largest area of intertidal beach occurred in the Crooked-Wollumboola section (1.3 km^2) (Fig. 30b) but most sections had similar areas of this habitat. Approximately 0.6 km^2 of exposed sandy beach occurred in Jervis Bay Marine Park and an additional 0.9 km^2 in Eurobodalla National Park together representing 16% of the total area of this habitat in the bioregion.

Most exposed intertidal beach in the Twofold Shelf section occurred in the Wallagoot-Pambula section (1.3 km^2). No areas of this habitat were included in MPAs within the NSW section of the bioregion. However, this habitat is represented in Ninety Mile Beach Marine National Park and in other Victorian and Tasmanian MPAs.

4.1.10 Intertidal rocky shore

Data sources

Digital cadastre database and 1: 25,000 topographic maps provided by the Land and Property Information Division (NSW Department of Lands).

Data description

Ocean intertidal rocky shores were identified from 1:25,000 topographic maps and their areas calculated from the difference between the high and low water marks on the digital cadastre.

Criteria

Comprehensiveness and representativeness.

Assessment measures

Area in broadscale (sections of exposed coast and ocean) and small-scale planning units.

Assessment

Most intertidal rocky shore occurred in the Shellharbour-Crooked, Willinga-Durras, Batemans-Moruya and Wagonga-Wallaga sections of coast. Approximately 1 km^2 of rocky shore occurred in Jervis Bay Marine Park and Bushrangers Bay Aquatic Reserve and another 0.4 km^2 in Eurobodalla National Park together representing 15% of the total area of this habitat in the Batemans Shelf bioregion (Fig. 30c).

Most rocky shore in the NSW section of the Twofold Shelf bioregion occurred in the Twofold-Wonboyn section (1.9 km^2, Fig. 30c). This habitat is not represented in MPAs in the NSW section of the bioregion but does occur in the Point Hicks and Cape Howe Marine National Parks in Victoria and the Kent Group Marine Reserve in the Tasmanian section of the Twofold Shelf bioregion.

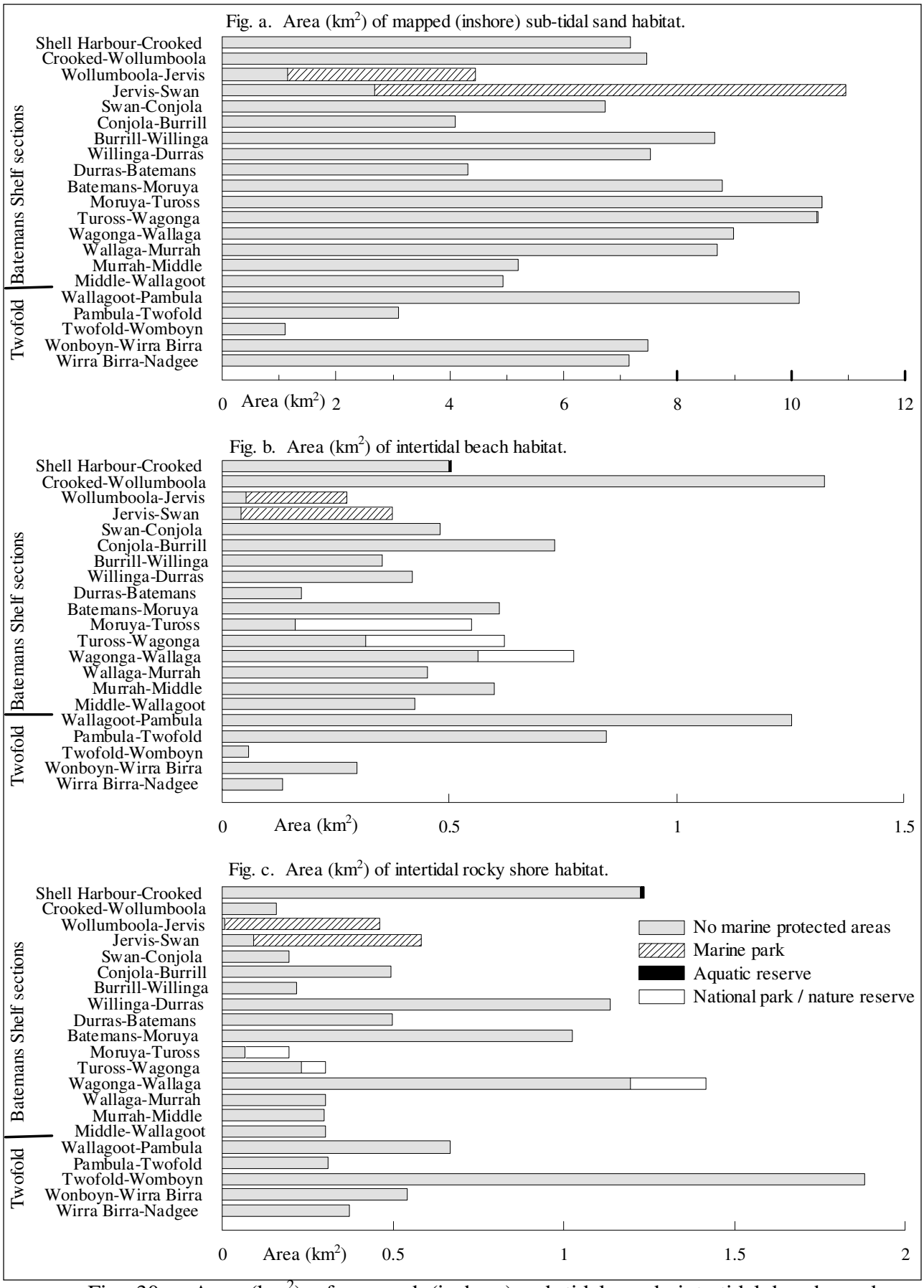


Fig. 30a-c.Area (km^2) of mapped (inshore) sub-tidal sand, intertidal beach, and intertidal rocky shore habitat in marine protected areas.

4.1.11 NSW Fisheries[2] assessment of rocky intertidal communities

Data source

Otway, N. (1999). "Identification of candidate sites for declaration as aquatic reserves for the conservation of rocky intertidal communities in the Hawkesbury Shelf and Batemans Shelf bioregions". NSW Fisheries Report, Cronulla NSW.

Data Description

Rocky shores short-listed by an advisory committee of stakeholders and community members were surveyed by Otway (1999), scored for species richness and the presence of platform, boulder, rubble, pool and crevice microhabitats with locations recommended for MPAs.

Criteria

Comprehensiveness, representativeness and adequacy.

Assessment

Seventeen locations, (Bass Point, Cathedral Rocks, Bombo Head, Conjola National Park, Inyadda Point, Preservation Point, Ulladulla Head, Warden Head, Bawley Point, Wasp Head, Observation Head, Mossy Point, Toragy Point, Tuross Head, Dalmeny Head, Wagonga Head and Cuttagee Point) were recommended as candidate sites for MPAs by the advisory committee.

Otway (1999) surveyed these areas and found 4-5 microhabitats and a higher species richness at Bombo Head (119 spp.), Inyadda Point (138 spp.), Preservation Point (123 spp.), Warden Head, (154 spp.) and Wagonga Head (134 spp.) and recommended these sites as candidate locations for marine protected areas along with Bass Point which lies adjacent to important Grey Nurse Shark habitat (Fig. 31 - Fig. 33). Three microhabitats and a lower species richness were found at the remaining locations.

The advisory committee also short-listed Tathra Head and Short Point as candidate aquatic reserves. Short Point included four habitat types but did not include boulder habitats, while extensive platform, boulder and cobble areas were absent from Tathra Head.

[2] now within the NSW Department of Primary Industries

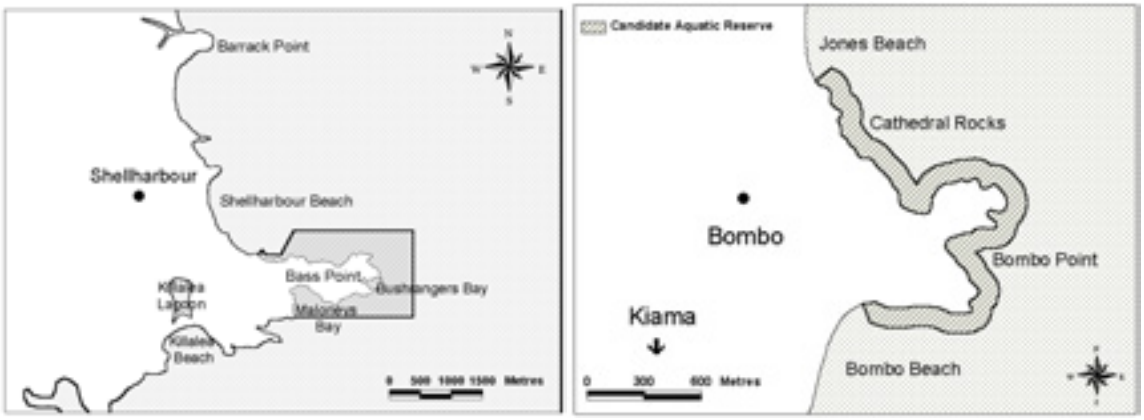


Fig. 31. Bass Point and Bombo Head, previous candidate rocky intertidal aquatic reserves (NSW Fisheries[2] 2001).

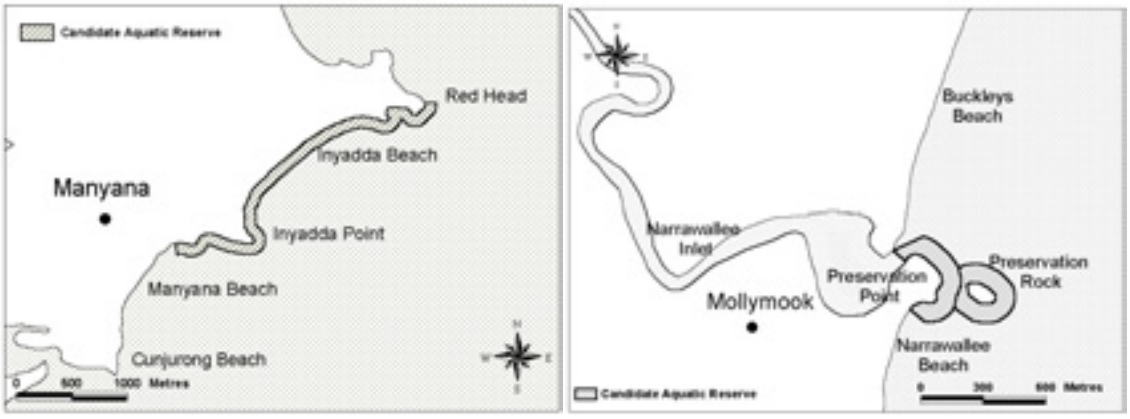


Fig. 32. Inyadda Point and Preservation Point, previous candidate rocky intertidal aquatic reserves (NSW Fisheries[2] 2001).

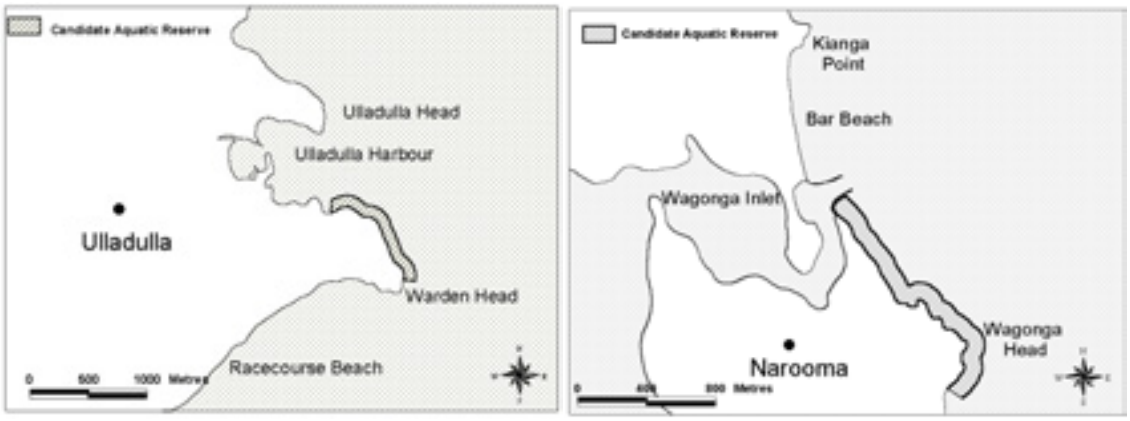


Fig. 33. Warden Head and Wagonga Head, previous candidate rocky intertidal aquatic reserves (NSW Fisheries[2] 2001).

[2] now within the NSW Department of Primary Industries

4.1.12 Coastal rock platforms (Total Environment Centre)

Data source

Short J.M. (1995). Protection of coastal rock platforms in NSW. National Estate Grant Project NEP 94-288. Total Environment Centre, Sydney.

Data description

This database of 'significant rock platforms' identifies 198 separate rock platforms in NSW, 33 of which lie in the Batemans Shelf and Twofold Shelf bioregions.

Criteria

Representativeness, uniqueness and naturalness (condition).

Assessment measures

The database includes attributes relating to location, access, platform dimensions, physical characteristics, geology, biology, impacts, existing management and recommendations.

Assessment

Based on the assessment of the characteristics described above, Short (1995) recommended 25 rock platforms in the Batemans Shelf and Twofold Shelf bioregions for protection. These were:

- Pheasant, Blowhole and Marsden Points in the Shellharbour-Crooked section
- Crookhaven Heads in the Crooked to Wollumboola section
- Beecroft Peninsula in the Wollumboola-Jervis section
- St Georges Head in the Jervis-Swan section
- Red Head (Bendalong) in the Swan-Conjola section
- North Ulladulla Harbour Head in the Conjola-Burrill section
- Murramurrang Point, O'Hara Head, Snapper Point and Point Upright in the Willinga-Durras section
- Wasp Head, Flat Rock Island and the northern head of Batemans Bay in the Durras-Batemans section
- Broulee Point and Island in the Batemans-Moruya section
- Bunga Head in the Murrah-Middle section
- Baronda Head, Wajurda, Tathra Head and Turingal Head in the Middle-Wallagoot section
- Bournda Island and Haycock Island in the Wallagoot-Pambula section
- Long Beach, Worang Point, Jews Head and Red Point in the Pambula-Twofold section
- Green Cape in the Twofold-Wonboyn section and
- Black Head and Nadgee Point in the Wirra Birra-Nadgee section.

4.2 Irreplaceability analysis for ecosystem and habitat units

Irreplaceability is a measure designed to estimate the likelihood of a site being required to meet conservation targets or, the extent to which conservation options are reduced if that site is unavailable. Conservation targets are usually defined as areas, numbers or proportions for a range of different habitats, species or other 'features'. *Summed* irreplaceability is calculated by adding the feature irreplaceabilities for all the different features in a site. High values indicate that a site is important for achieving conservation goals for many different features.

Fig. 34 shows summed irreplaceability for the fine-scale planning units in the Batemans Shelf using a hypothetical goal of 20% of the area of each ecosystem (estuary types and ocean depth zones) and habitat feature (seagrass, mangrove, saltmarsh, rocky intertidal, beach, subtidal sand, reef, and island). Higher values indicate those sites more likely to contribute to targets for more than one habitat or ecosystem thus minimising the total area required to represent those features. High values for *summed* irreplaceability do not necessarily imply that a site is required to meet a goal, only that it is likely to contribute to more than one feature target.

In Fig. 34, localised areas of high summed irreplaceability are evident at the mouths of several estuaries and at several locations along the coast where different ocean habitats occur together. Relatively high summed irreplaceabilities are also present in estuaries where different estuarine habitats occur together.

Fig. 35 shows summed irreplaceability for the fine-scale planning units in the Twofold Shelf using a hypothetical goal of 20% of the area of each ecosystem and habitat feature. Again localised areas of high summed irreplaceability are evident at the mouths of estuaries and where different ocean habitats occur together. In this case however, the display does not account correctly for the whole of the Twofold Shelf bioregion as specific data were not available for the Victorian or Tasmanian sections.

Fig. 36-Fig. 38 show summed irreplaceabilities for estuarine broadscale planning units calculated for a hypothetical representation of 20% of mapped ecosystems and habitat units.

Fig. 36 shows high summed irreplaceabilities for the Shoalhaven River, Clyde River, St Georges Basin and moderate summed irreplaceabilities for Coila Lake, Tuross Lake, Durras Lake, Swan Lake and the Moruya River. Note that while initial values for existing MPAs at Jervis Bay and Lake Wollumboola were not graphed, they were among the highest in the bioregion.

Fig. 37 shows summed irreplaceabilities adjusted for features already included in Bushrangers Bay Aquatic Reserve and Jervis Bay Marine Park. Fig. 38 shows irreplaceabilities adjusted for features represented in all MPAs, including the marine components of national parks and nature reserves. The high scores for the Shoalhaven River and the Clyde River are maintained in all three simulations as they include features such as barrier estuary, drowned river valley, mangrove and saltmarsh that are not well represented in the existing system of MPAs.

Fig. 39 a-c. shows summed irreplaceabilities for sections of ocean coast while accounting for features represented in existing aquatic reserves, marine parks and the marine components of national parks and nature reserves. The highest consistent values, after accounting for all existing MPAs occur for the Wagonga-Wallaga, Willinga-Durras and Shellharbour-Crooked sections.

Although irreplaceability provides a convenient static index to summarise general patterns it's full potential is only realised in a more iterative process where alternatives are more fully explored using experience from managers, scientists and key stakeholders. The models developed here can be easily used in such a process and be refined as more data becomes available.

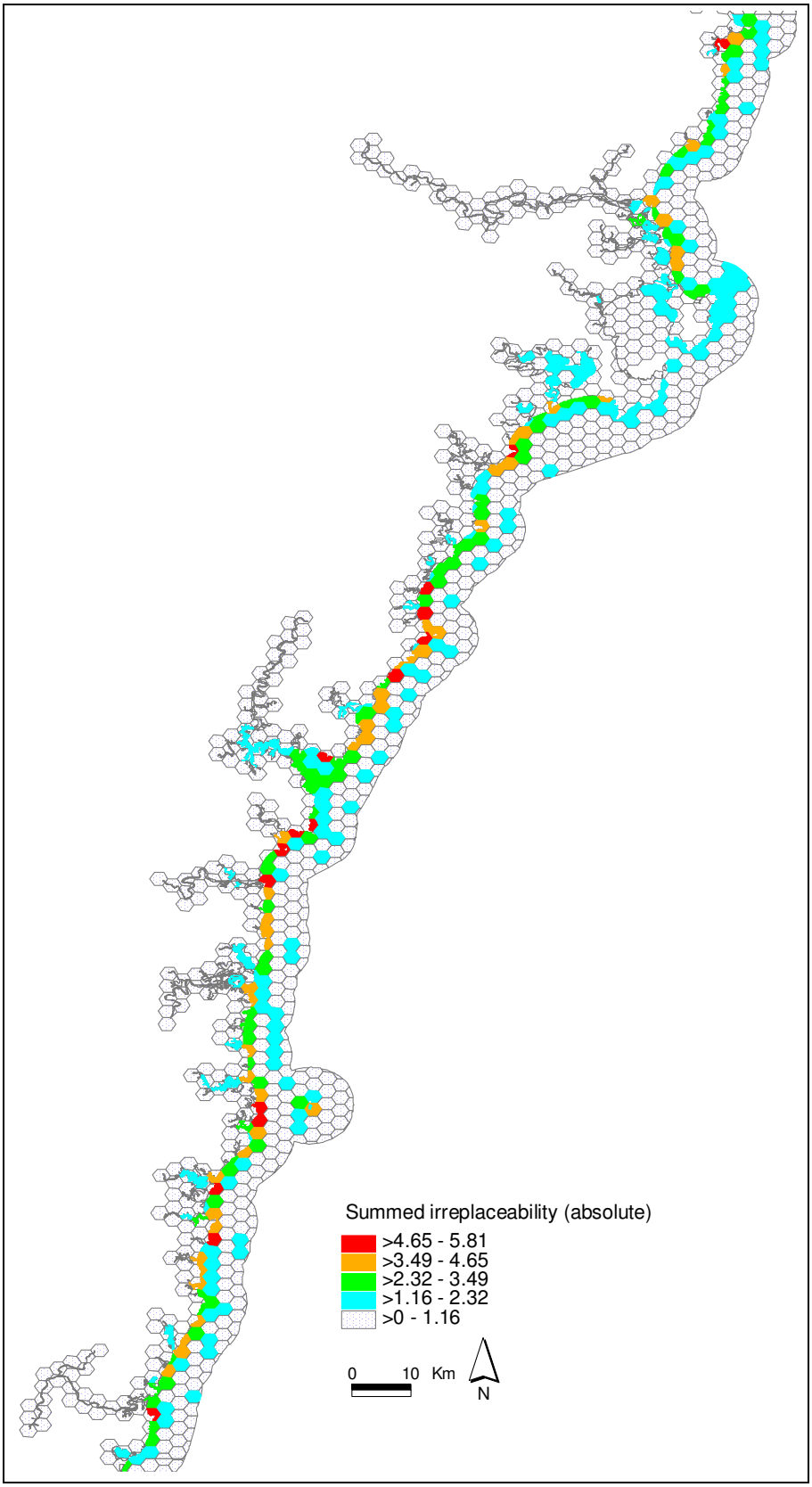


Fig. 34. Summed irreplaceability of fine-scale (4 km^2) planning units for ecosystem and habitat types within NSW waters (within 3 nm) of the Batemans Shelf bioregion. Values indicate the degree to which a unit can contribute to meeting a hypothetical 20% goal for a number of different estuarine and oceanic ecosystem and habitat types (from C-Plan reserve selection software provided by the NSW Department of Environment and Conservation).

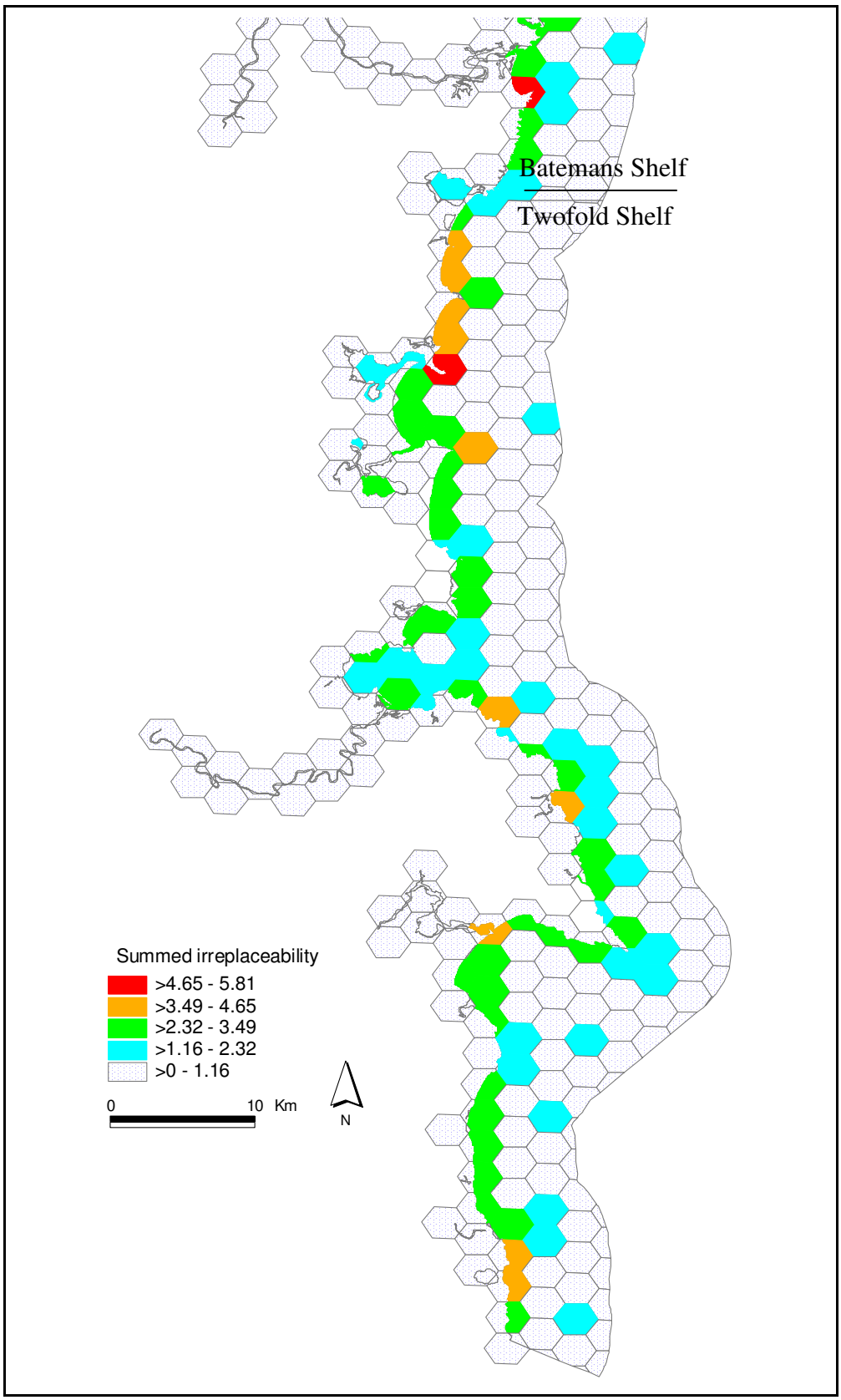


Fig. 35. Summed irreplaceability of fine-scale (4 km^2) planning units for ecosystem and habitat types in NSW waters (within 3 nm) of the Twofold Shelf bioregion. Values indicate the degree to which a unit can contribute to meeting a hypothetical 20% goal for a number of different estuarine and oceanic ecosystem and habitat types (values from C-Plan reserve selection software provided by the NSW Department of Environment and Conservation).

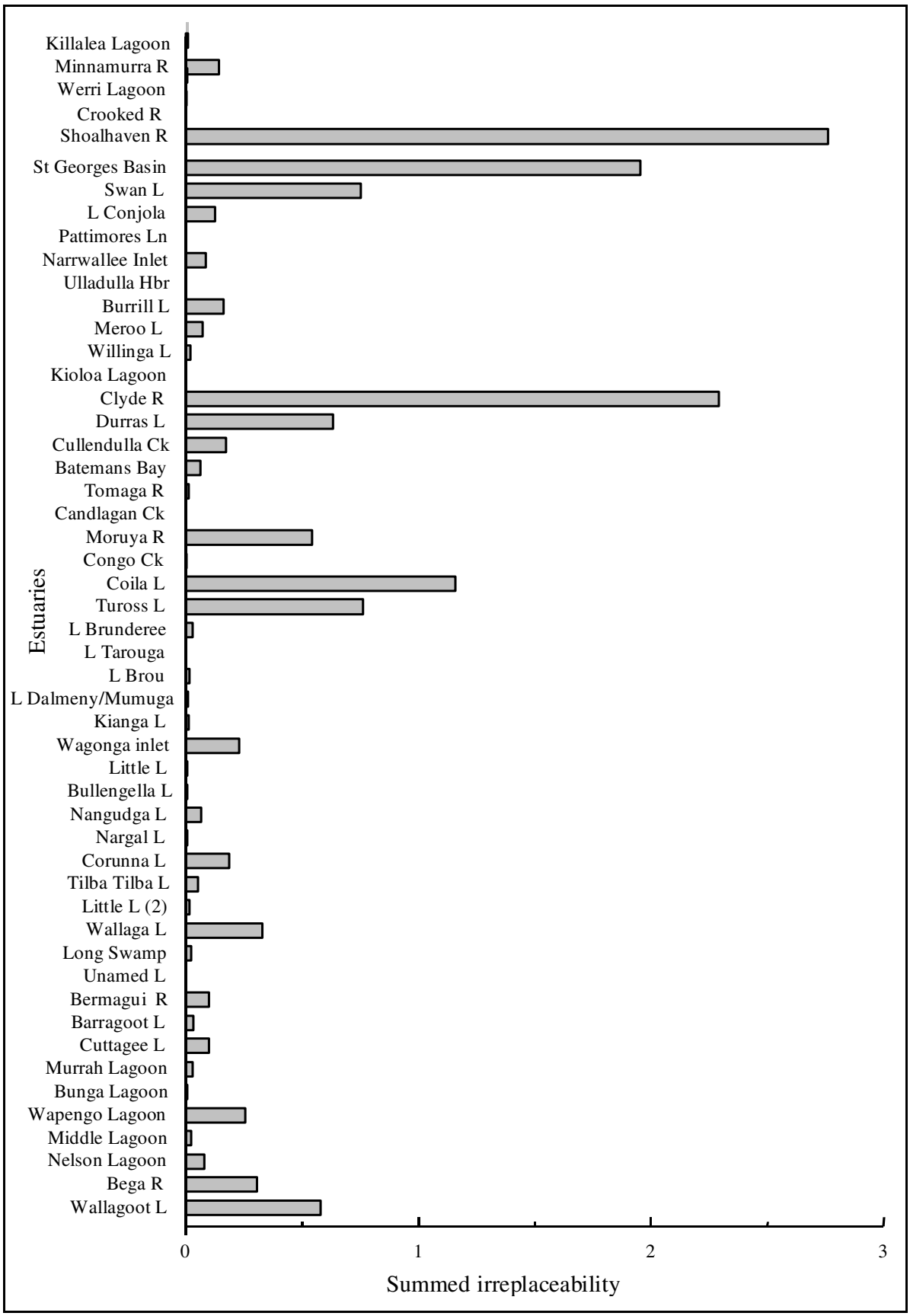


Fig. 36. Summed irreplaceability scores of areas not already in MPAs for representation of a hypothetical goal of 20% of the area of estuarine ecosystem and habitat classes in the Batemans Shelf marine bioregion - assuming there are no existing MPAs.

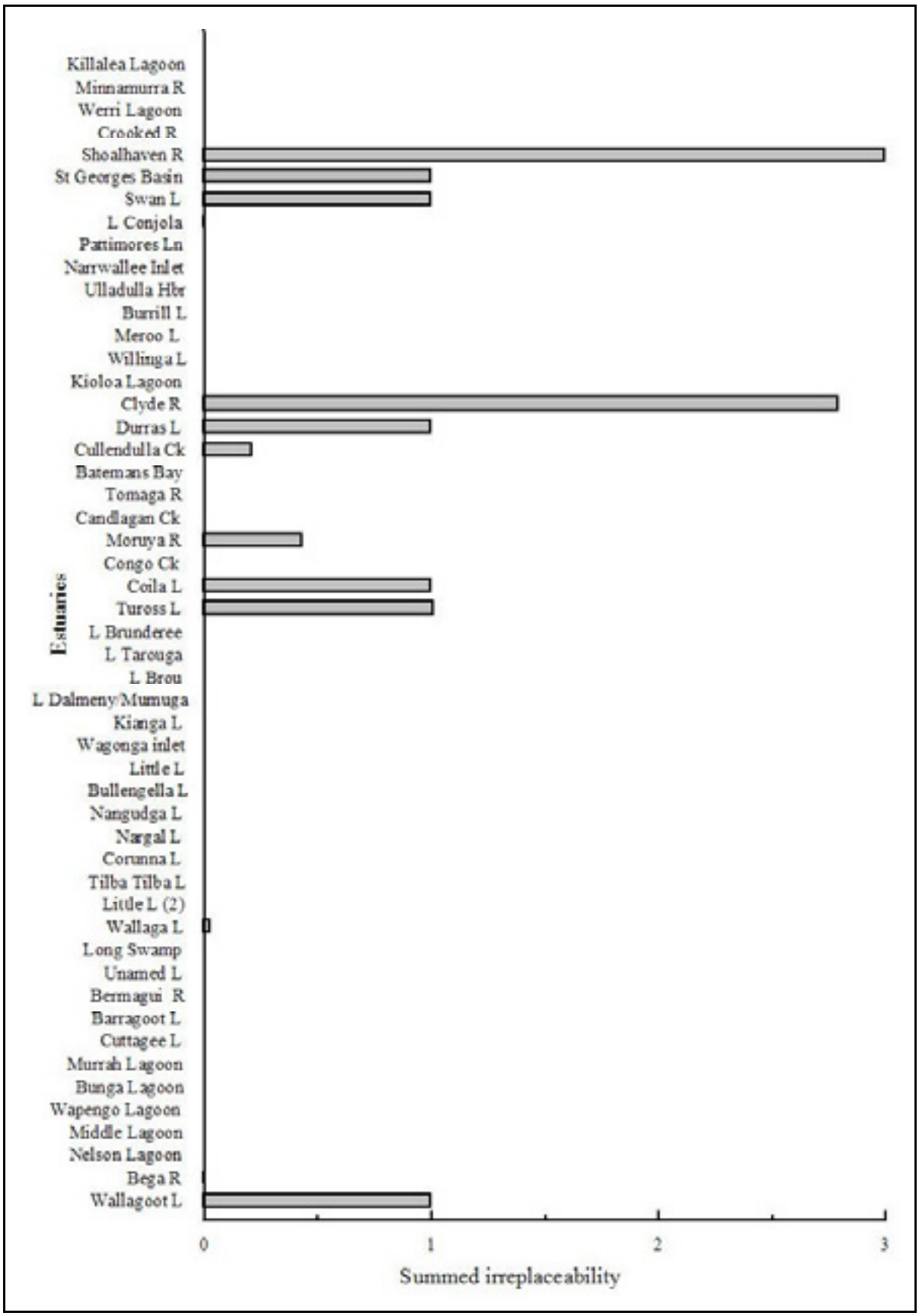


Fig. 37. Summed irreplaceability scores of areas not already in MPAs for representation of a hypothetical goal of 20% of the area of estuarine ecosystem and habitat classes in the Batemans Shelf marine bioregion - allowing for areas already included in existing marine parks and aquatic reserves.

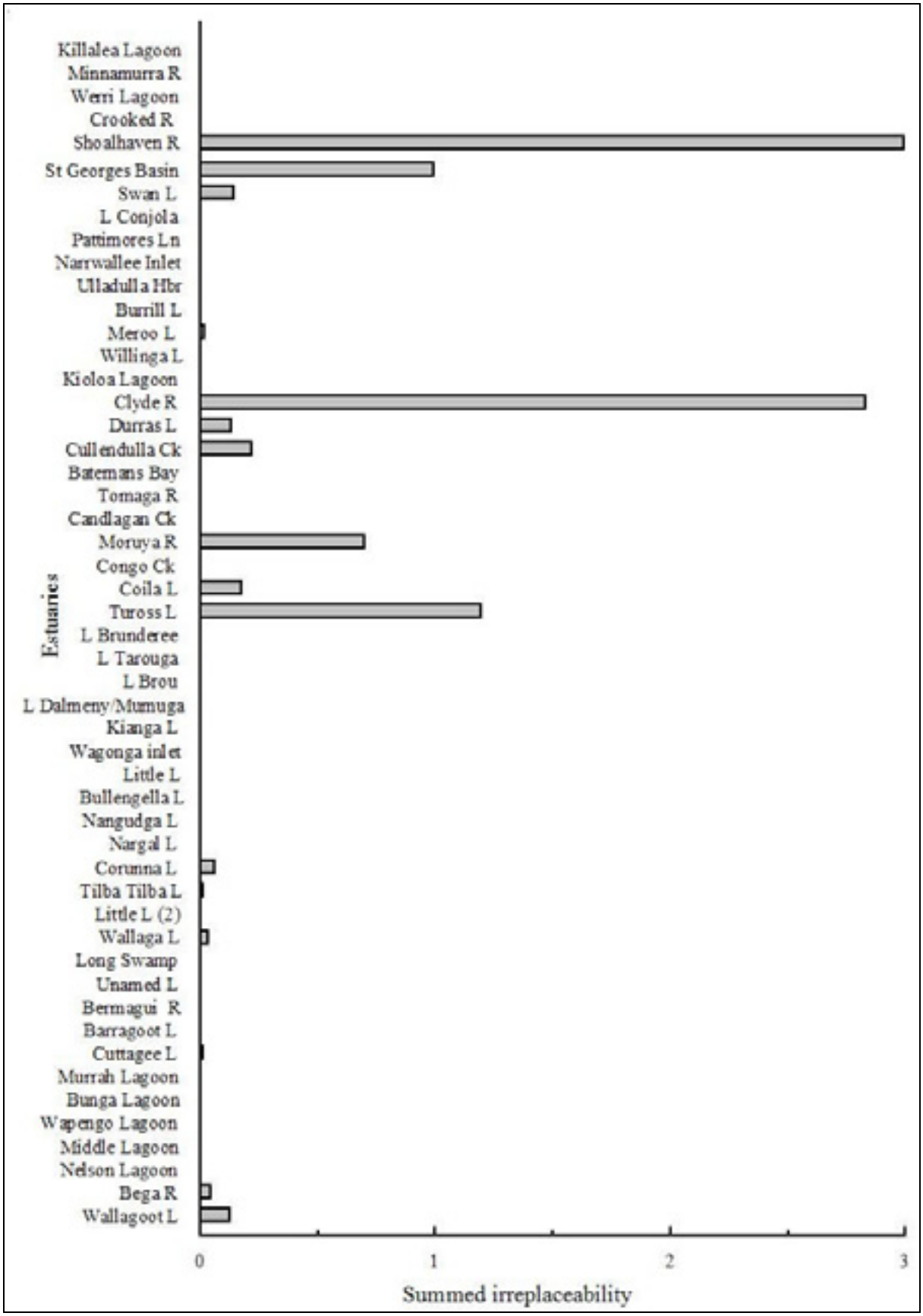


Fig. 38. Summed irreplaceability scores of areas not already in MPAs for representation of a hypothetical goal of 20% of the area of estuarine ecosystem and habitat classes in the Batemans Shelf marine bioregion - allowing for areas included in existing marine parks, aquatic reserves, national parks and nature reserves.

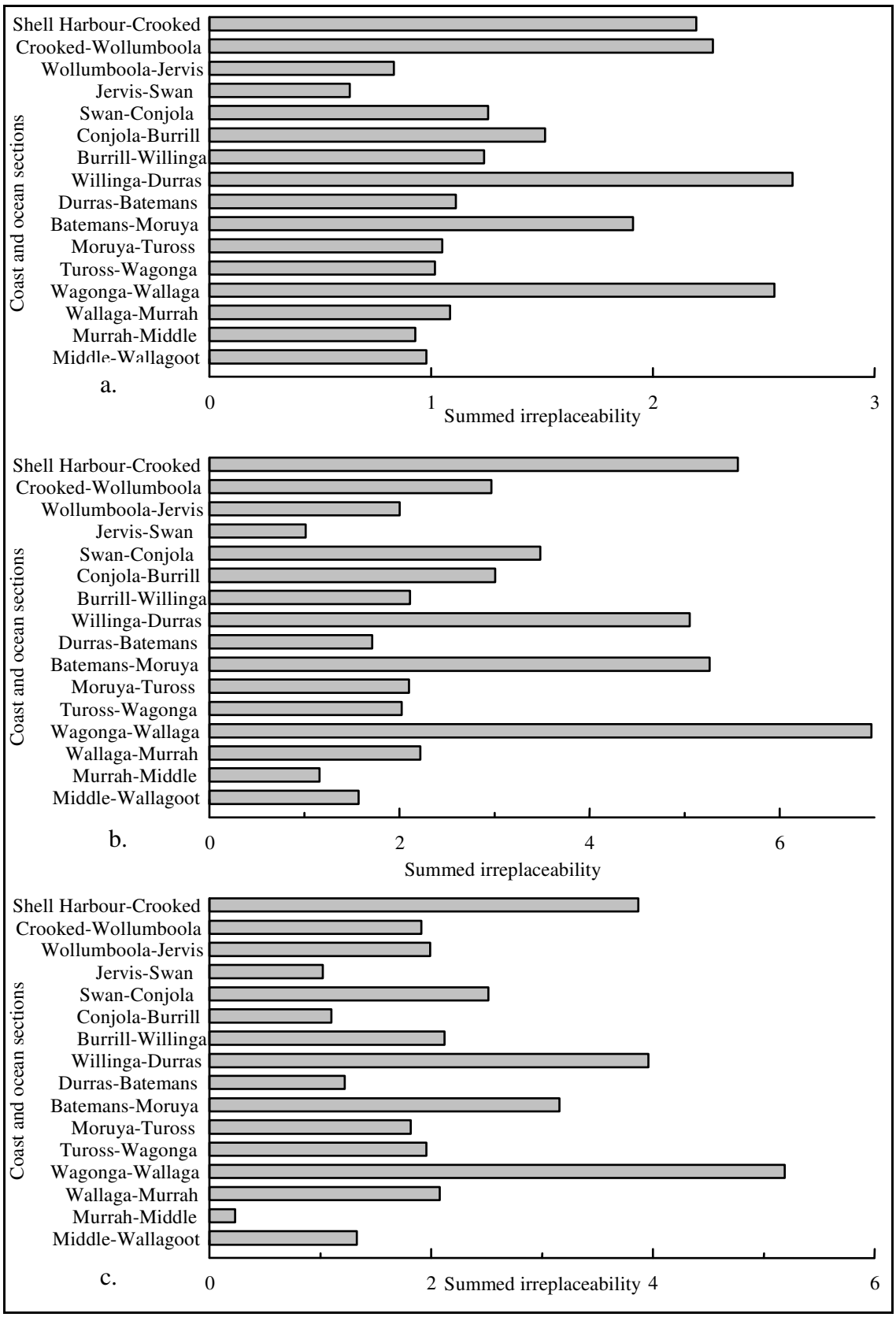


Fig. 39. Summed irreplaceability scores for 20% representation of ocean ecosystem and habitat classes in the Batemans Shelf marine bioregion a. assuming there are no existing MPAs; b. allowing for areas included in marine parks and aquatic reserves. c. allowing for areas included in marine parks, aquatic reserves, national parks and nature reserves.

4.3 Representativeness - species

4.3.1 Estuarine juvenile fish and invertebrate biodiversity

Data source

Estuarine fish biodiversity project undertaken by the NSW Fisheries[2] Office of Conservation and funded by the Natural Heritage Trust (R.J. Williams, pers. comm.)

Data description

Juvenile fishes and invertebrates were sampled by seine net along estuarine shores on vegetated and bare substrata, within 2-3 zones between the estuary mouth and riverine habitats. Currently 500,000 fish from 176 taxa have been collected throughout NSW. The survey has not yet sampled all estuaries or analysed all data (R.J. Williams, pers. comm.).

Identification criterion

Representativeness.

Assessment measures

Summed irreplaceability for representation of at least one of each species.

Assessment

Summed irreplaceability scores for sites (for representation of each species in the total catch from five seine hauls) are shown in Fig. 40a-h. For most sites, summed irreplaceability was relatively low (<4) given the high number of species overall (>100). This may be due in part to the low number of hauls per site but may also reflect the widespread occurrence of many common species.

High values occurred in St Georges Basin, Clyde River, Wagonga Inlet, Merimbula Lake and the Wonboyne River, but estuaries did not differ markedly given the amount of variation within estuaries. In addition, there were large variations among estuaries in the number of sites sampled, and these differences were strongly correlated with overall species richness and irreplaceability scores for each estuary.

These differences made it difficult to make unbiased comparisons among different estuaries. However, a more detailed analysis of this data is warranted as systematic surveys of species diversity and abundance have the potential to provide a more direct assessment of marine biodiversity than coarser scale surrogates.

[2] now within the NSW Department of Primary Industries.

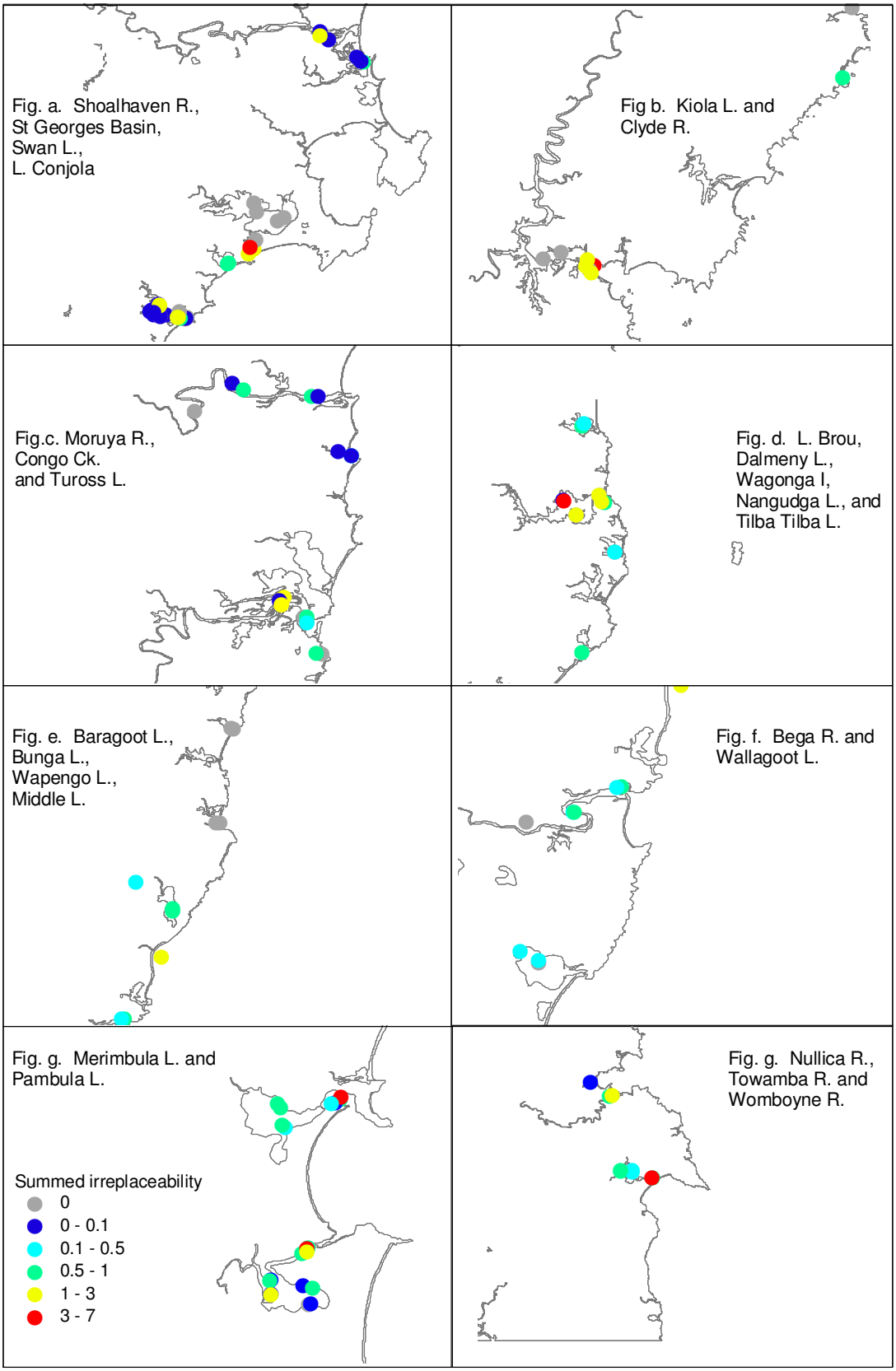


Fig. 40a-h. Summed irreplaceability for representation of at least one of each species of juvenile fish and invertebrates sampled by seine net (n=5 hauls) along estuarine shores in the Batemans Shelf and Twofold Shelf bioregions. Raw data from the Natural Heritage Trust funded NSW Fisheries[2], Office of Conservation, Estuarine Fish Biodiversity project (pers. comm. R.J.Williams).

[2] now within the NSW Department of Primary Industries

4.3.2 NSW Fisheries[2] commercial catch data

Data Source

NSW Fisheries[2] Commercial Catch Returns database.
Tanner and Liggins (1999). New South Wales Commercial Fisheries Statistics 1993/94 to 1997/98. NSW Fisheries Research Institute.

Data description

Commercial fish and invertebrate catch and effort statistics from mandatory catch return forms submitted by commercial fishers.

Criteria

Representativeness, productivity, potential threats and human use.

Assessment measures

Number of species, catch and summed irreplaceability for representation of each species.

Assessment

Summed irreplaceability and the number of species caught commercially in estuaries were highest for Jervis Bay, the Shoalhaven River, St Georges Basin and Tuross Lake. The differences however, probably reflect the high catches for these areas. Summed irreplaceability, species richness and catch in the Twofold Shelf bioregion were highest for Pambula Lake but low when compared to scores for the Batemans Shelf bioregion (Fig. 41 - Fig. 43).

Summed irreplaceability and the number of species landed at ocean ports were highest for Ulladulla, Eden, Kiama, Greenwell Point, Batemans Bay and Bermagui and again this probably reflects the size of the catch landed at these ports and potentially, catches brought in from other fishing locations (Fig. 44).

These results should be regarded cautiously given the likely bias in species richness towards areas receiving more catch, and potential biases in determining exactly where catch was caught, as opposed to landed. More detailed analyses of catch data have been made by Pease (1999).

[2] now within the NSW Department of Primary Industries.

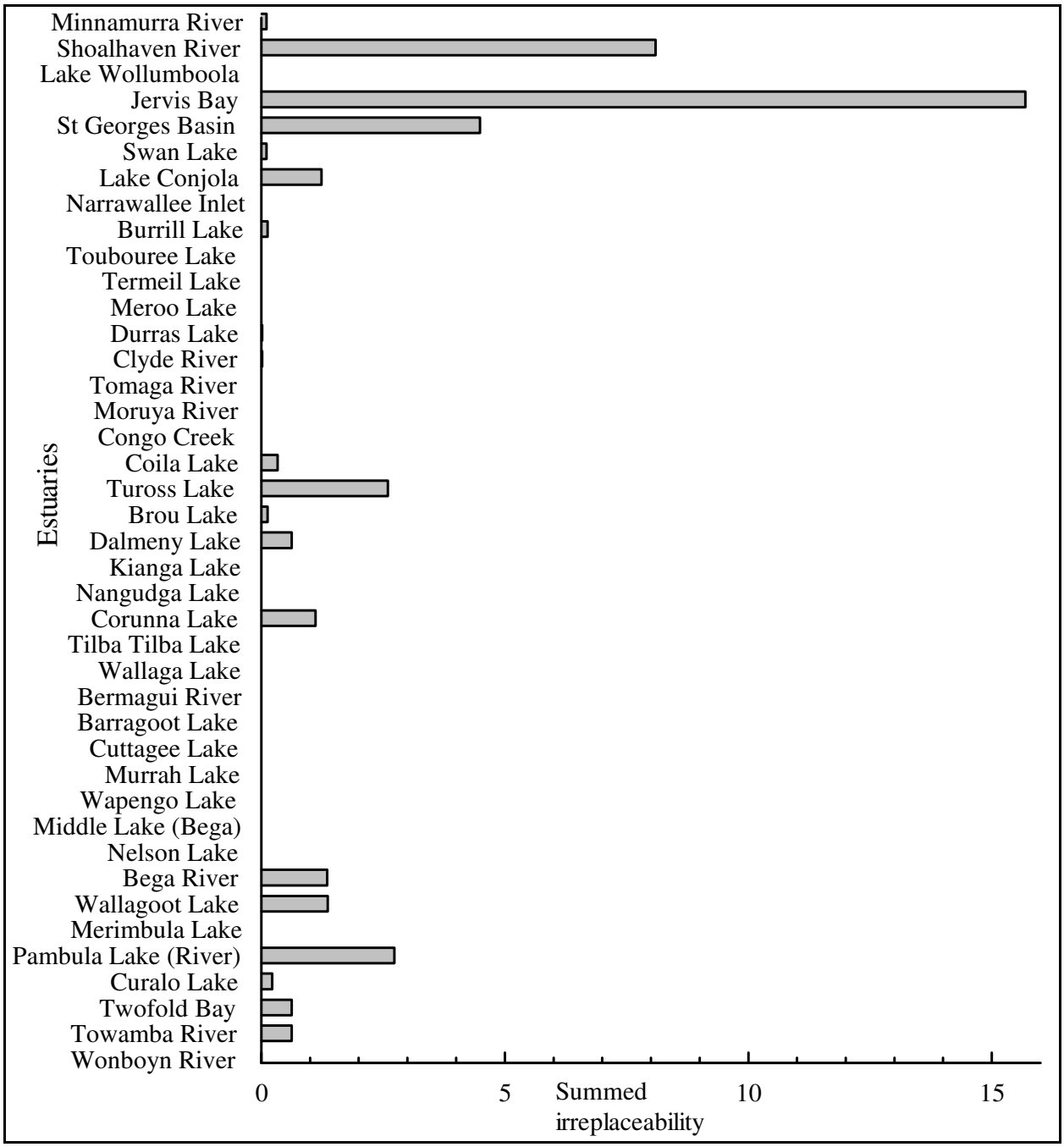


Fig. 41. Summed irreplaceability for representation of at least one of each species in the commercial catch for **estuaries** in the Batemans Shelf and Twofold Shelf bioregions in 1997/98. Raw data from NSW Fisheries[2] (pers. comm. Geoff Liggins and Marnie Tanner).

[2] now within the NSW Department of Primary Industrries.

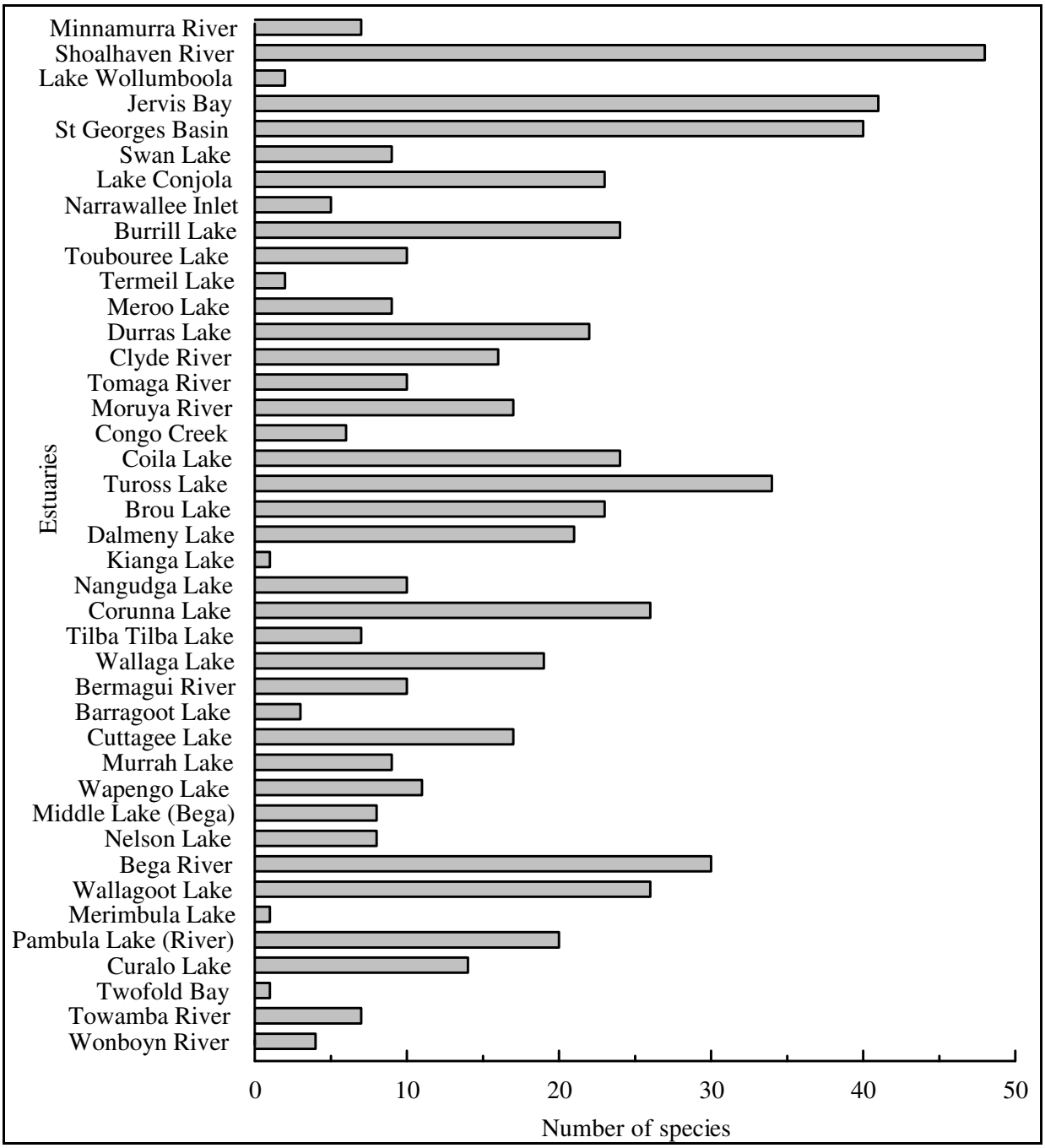


Fig. 42. Number of species in commercial catch for **estuaries** in the Batemans Shelf and Twofold Shelf bioregions in 1997/98. Raw data from NSW Fisheries[2] (pers. comm. Geoff Liggins and Marnie Tanner).

[2] now within the NSW Department of Primary Industries.

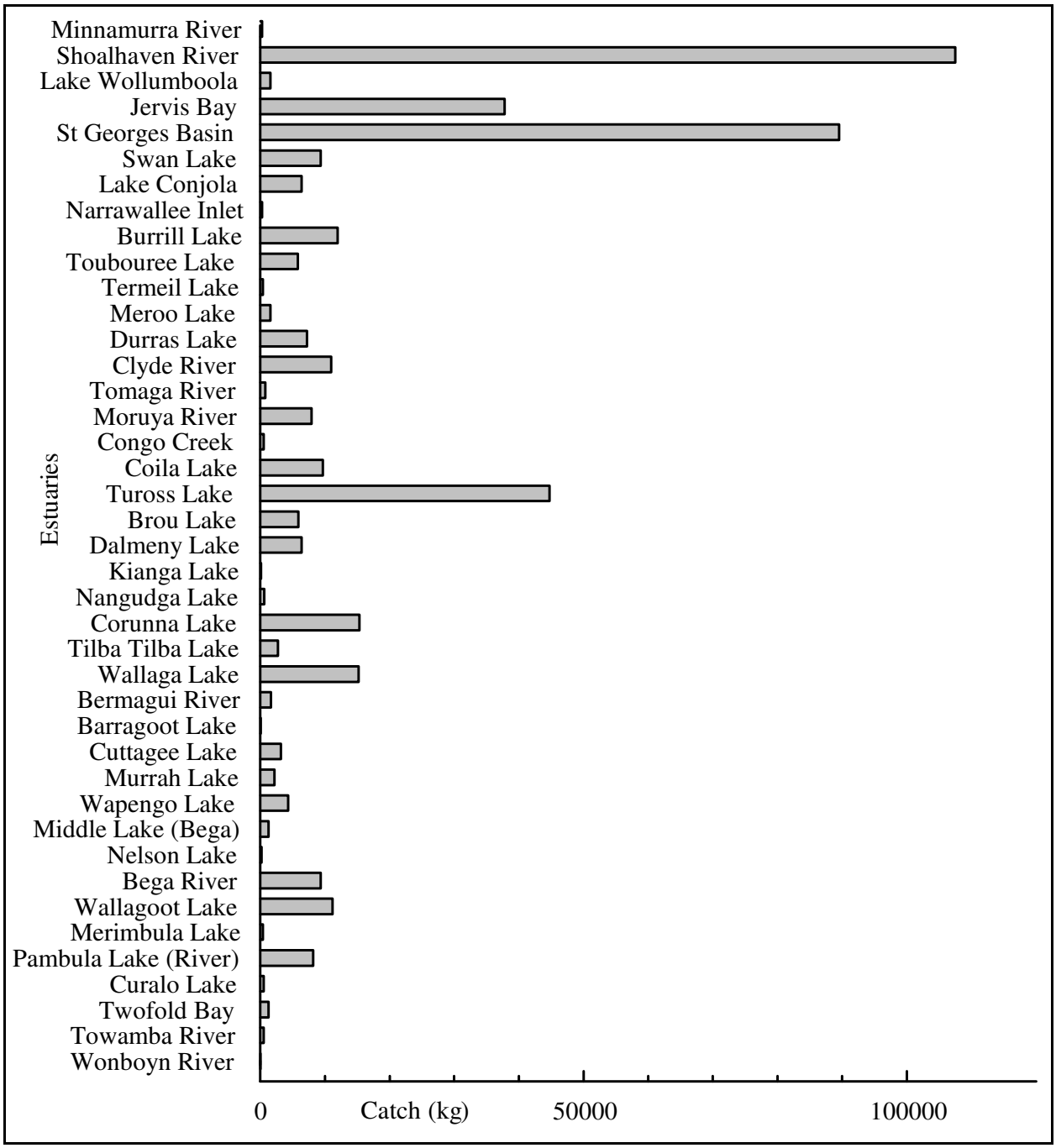


Fig. 43. Weight of commercial catch (kg) for **estuaries** in the Batemans Shelf and Twofold Shelf bioregions in 1997/98. Raw data from NSW Fisheries[2] (pers. comm. Geoff Liggins and Marnie Tanner).

[2] now within the NSW Department of Primary Industries

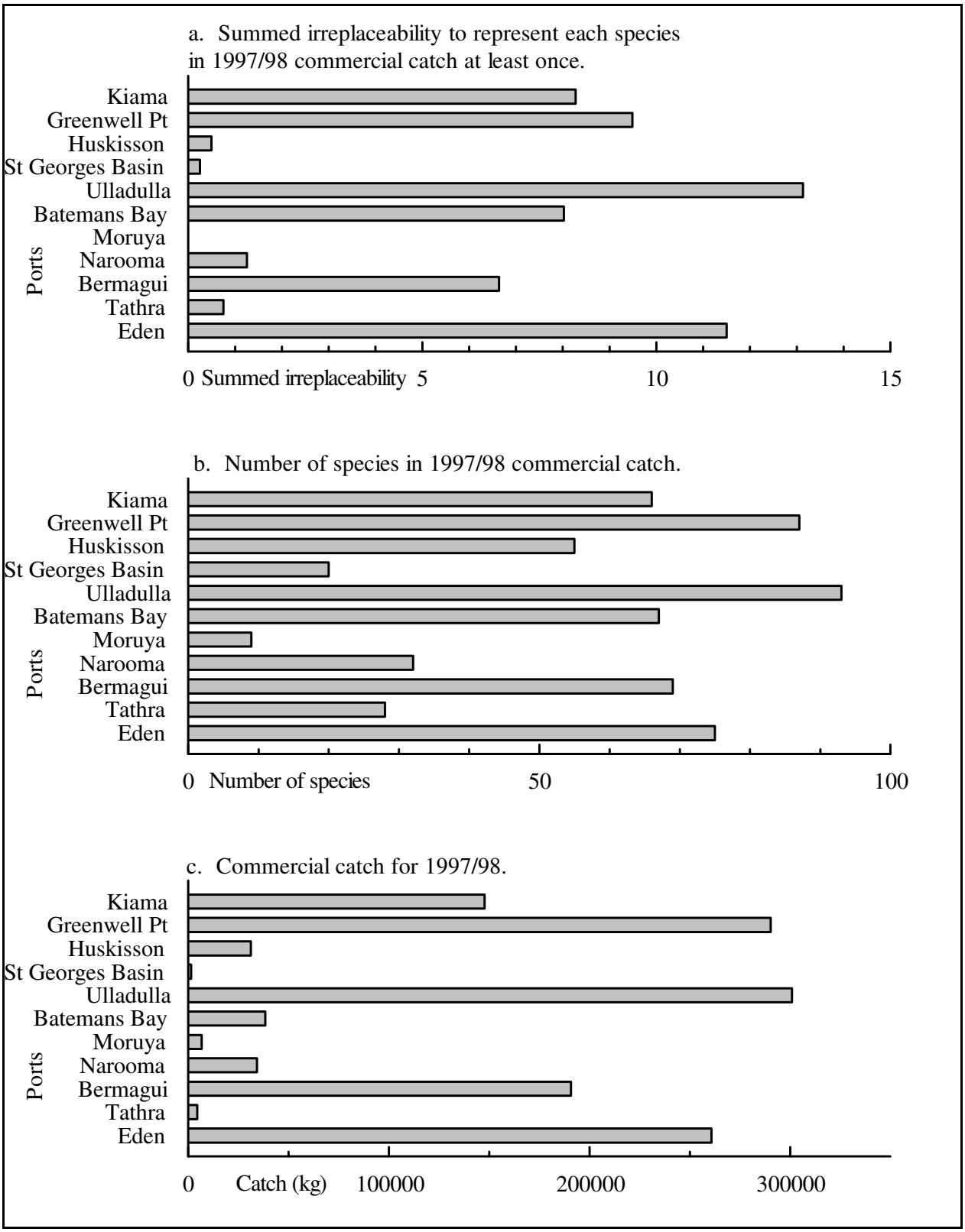


Fig. 44. Summed irreplaceability, number of species and weight of commercial catch for **ocean ports** in the Batemans Shelf and Twofold Shelf bioregions in 1997/98. Raw data from NSW Fisheries[2] (pers. comm. Geoff Liggins and Marnie Tanner).

[2] now within the NSW Department of Primary Industries

4.3.3 Threatened fish species sightings database

Data Source

Database held by NSW Department of Primary Industries (formerly NSW Fisheries) of sightings of threatened fish species reported by volunteers.

Data Description

The *NSW Fisheries Management Act 1994* includes provisions to declare threatened species of fish and marine vegetation, endangered populations and ecological communities, and key threatening processes.

Four marine species have been declared threatened:

- Great white shark (*Carcharodon carcharias*)
- Grey nurse shark (*Carcharias taurus*)
- Black cod (*Epinephelus daemelii*) and the
- Green sawfish (*Pristis zijsron*).

Seven other marine species are protected in NSW waters:

- Ballina angelfish (*Chaetodontoplus ballinae*)
- Bleekers devil fish (*Paraplesiops bleekeri*)
- Weedy sea dragon (*Phyllopteryx taeniolatus*)
- Elegant wrasse (*Anampses elegans*)
- Estuary cod (*Epinephelus coioides*)
- Herbsts nurse shark (*Odontaspis ferox*) and
- Queensland groper (*Epinephelus lanceolatus*).

Other species protected from commercial fishing include:

- Black marlin (*Makaira indica*)
- Blue marlin (*Makaira nigricans*)
- Striped marlin (*Tetrapturus audax*) and
- Blue groper (*Achoerodus viridis*).

Sightings in the threatened fish species database depend on voluntary reports and are currently limited to 129 records for the Batemans Shelf and Twofold Shelf bioregions. While the data are probably too sparse for quantitative analysis, they provide descriptive, site specific information.

Criteria

Representativeness.

Assessment measure

Descriptive summary.

Assessment

Table 5 lists sightings of threatened fish species in the Batemans Shelf and Twofold Shelf bioregions.

Table 5. Sightings of threatened fish species in the Batemans Shelf and Twofold Shelf bioregions.

Species	Nearest town	Plan unit	Bioregion
Black cod	Shellharbour	Shellharbour-Crooked	Batemans Shelf
	Gerringong	Shellharbour-Crooked	Batemans Shelf
	Crookhaven	Shellharbour-Crooked	Batemans Shelf
	Bendalong	Swan-Conjola	Batemans Shelf
	Durras	Durras-Batemans	Batemans Shelf
	Tathra	Middle-Wallagoot	Batemans Shelf
	Merimbula	Wallagoot-Pambula	Twofold Shelf
	Eden	Twofold-Wonboyn	Twofold Shelf
Great white shark	Kiola	Willinga-Durras	Batemans Shelf
Grey nurse shark	Shellharbour	Shellharbour-Crooked	Batemans Shelf
	Huskisson	Jervis-Swan	Batemans Shelf
	Cunjurong	Swan-Conjola	Batemans Shelf
	Batemans Bay	Durras-Batemans	Batemans Shelf
	Narooma	Wagonga-Wallaga	Batemans Shelf
	Merimbula	Wallagoot-Pambula	Twofold Shelf
Bleekers devil fish	Shellharbour	Shellharbour-Crooked	Batemans Shelf
	Huskisson	Jervis-Swan	Batemans Shelf
	Broulee	Bateman-Moruya	Batemans Shelf
	Merimbula	Wallagoot-Pambula	Twofold Shelf
Estuary cod	Nowra	Shoalhaven R	Batemans Shelf
	Huskisson	Jervis-Swan	Batemans Shelf
	Batemans Bay	Batemans Bay	Batemans Shelf
	Narooma	Wagonga Inlet	Batemans Shelf
Queensland groper	Batemans Bay	Batemans Bay	Batemans Shelf
Weedy sea dragon	Shellharbour	Shellharbour-Crooked	Batemans Shelf
	Huskisson	Jervis-Swan	Batemans Shelf
	Ulladulla	Conjola-Burrill	Batemans Shelf
	Merimbula	Wallagoot-Pambula	Twofold Shelf

4.3.4 Threatened Grey Nurse Shark

Data source

A GIS coverage of significant Grey nurse shark (*Carcharias taurus*) aggregation sites was prepared from data provided by Otway and Parker (2000) and Otway *et al.* (2003).

Data description

The Grey nurse shark is listed as endangered under the *Fisheries Management Act 1994*. NSW Fisheries[2] staff and volunteer scuba divers surveyed approximately 65 sites during 4 week long survey periods in each season (Summer, Autumn, Winter, Spring) between November 1998 and October 2000.

Criteria

Representativeness, ecological importance and threatened species.

Assessment measure

Maximum number of sharks observed during surveys and other sites where sharks have been observed in the past.

Assessment

Grey nurse sharks have been observed at a number of locations in the Batemans Shelf and Twofold Shelf bioregions (Fig. 45) but recent surveys have identified Bass Point, near Shellharbour, the Tollgate Islands in Batemans Bay and Montague Island as the most important aggregation sites.

At Bass Point, sharks have been observed at two sites during 10% of surveys in numbers representing approximately 1% of the observed population (NSW Fisheries 2002, NSW Draft Recovery Plan for the Grey Nurse Shark). In December 2002, NSW Fisheries[2] declared an area of critical habitat extending 200 m out from the southern point of Bushrangers Bay, with an 800 m buffer extending beyond this.

At the Tollgate Islands, sharks have been observed during 90% of surveys in numbers representing 8.9% of the observed population and 15.4% of the observed female population. This site is the most important known aggregation site for females, and it is thought that the females may be gestating at this site during summer and autumn. A 200 m critical habitat zone and 800 m buffer zone now extends seaward of the most easterly island.

At Montague Island, sharks aggregate mainly at the northern tip of the island but also at three sites on the western side of the island. Sharks were observed during 20% of surveys at this site in numbers representing 1.3% of the total observed population. Most sharks surveyed here were females and a number of these may have been pregnant. A 200 m critical habitat zone extends out from the main aggregation site north of the island and a 800 m buffer zone extends out from the entire island.

In the critical habitat and buffer zones commercial fishing by drop, drift or set line is now banned as is any fishing with wire trace from an anchored or moored vessel. In addition, any fishing with bait in the critical habitat zone from a moored or anchored vessel is prohibited but fishing with lure or fly, trolling (with or without trace), drift fishing with a weight less than 500 grams (with or without trace), or fishing without wire trace from the beach or rocks is allowed. Commercial line fishers are limited to using recreational fishing gear in each critical habitat and buffer zone.

There are also rules for scuba diving in critical habitats to limit the disturbance to Grey nurse sharks. These include prohibiting night dives, blocking of caves and gutters, feeding, touching or chasing sharks, and the use of electronic repelling devices and underwater scooters.

[2] now within the NSW Department of Primary Industries

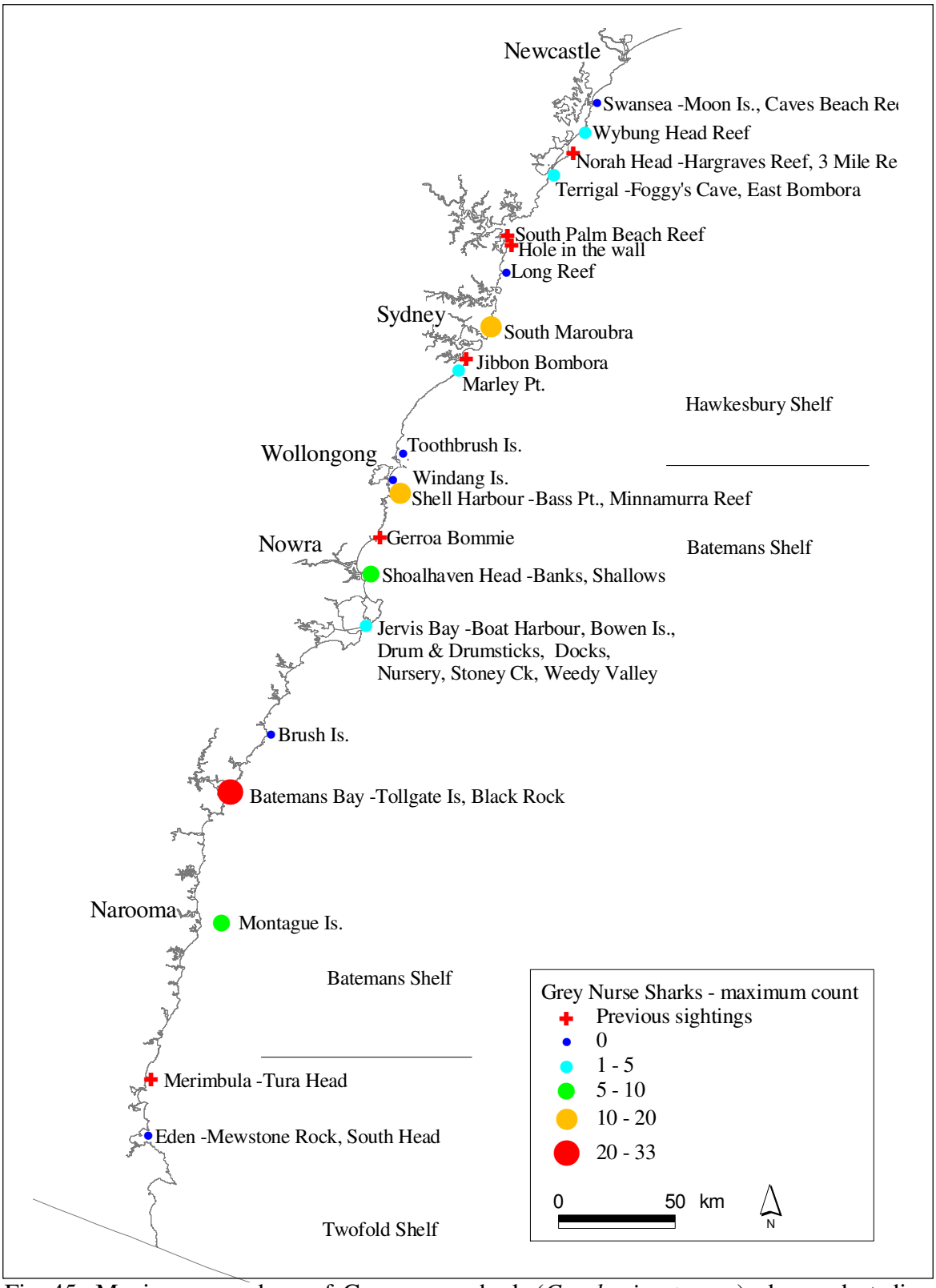


Fig. 45. Maximum numbers of Grey nurse shark (*Carcharias taurus*) observed at dive sites in the Hawkesbury Shelf, Batemans Shelf and Twofold Shelf bioregions during eight survey seasons in 1998 and 2000 and additional historical sightings (data from Otway and Parker 2000 and Otway *et al.* 2003).

4.3.5 Threatened birds

Data source

Information on threatened sea bird and wader species was derived from the NSW Wildlife Atlas, threatened species profiles and threatened species recovery plans from the NSW National Parks and Wildlife Service[1] (NPWS 1999a, b, c, 2000).

Data description

The NSW Wildlife Atlas records 32 species of seabirds and intertidal wader in NSW listed as threatened under the *NSW Threatened Species Conservation Act 1995*. Of these, 23 have been recorded from the Batemans Shelf and Twofold Shelf bioregions with four species listed as endangered (Table 6).

Table 6. Threatened intertidal waders and seabirds.

Endangered	
Beach Stone-curlew *Esacus neglectus*	Little Tern *Sterna albifrons*
Bush Stone-curlew *Burhinus grallarius*	Hooded Plover *Thinornis rubricollis*
Vulnerable	
Australasian Bittern *Botaurus poiciloptilus*	Osprey *Pandion haliaetus*
Black Bittern *Ixobrychus flavicollis*	Pied Oystercatcher *Haematopus longirostris*
Black-browed Albatross *Diomedea melanophrys*	Providence Petrel *Pterodroma solandri*
Black-tailed Godwit *Limosa limosa*	Sanderling *Calidris alba*
Broad-billed Sandpiper *Limicola falcinellus*	Shy Albatross *Diomedea cauta*
Flesh-footed Shearwater *Puffinus carneipes*	Sooty Albatross *Phoebetria fusca*
Great Knot *Calidris tenuirostris*	Sooty Oystercatcher *Haematopus fuliginosus*
Greater Sand Plover *Charadrius leschenaultii*	Sooty Tern *Sterna fuscata*
Lesser Sand Plover *Charadrius mongolus*	Terek Sandpiper *Xenus cinereus*
Little Shearwater *Puffinus assimilus*	

Assessment

Little Tern

Little Terns (*Sterna albifrons* subspecies *sinensis*) in NSW nest in spring on sand spits, sand islands and beaches near the entrances of estuaries, and feed in nearby waters. A migratory Asian population that does not breed in NSW also occurs, but does not nest and is not the focus of threatened species management in NSW.

Nests are generally located on open sand within 150 m of the water and less than 1.5 m above the high tide mark and are highly vulnerable. Threats include nest disturbance by recreational beach users, flooding, foreshore development, and predation and disturbance by silver gulls (*Larus novaehollandiae*), ravens, kestrels, falcons, whimbrels, foxes, dogs, ghost crabs and ants (NPWS 2000).

Prey species recorded from NSW include the Port jackson perchlet (*Ambassis jacksoniensis*), Striped gudgeon (*Gobiomorphus australis*), Empire gudgeon (*Hypseleotris compressa*), Sandy sprat (*Hyperlophus vittatus*), Sand mullet (*Myxus elongatus*), Sea mullet (*Mugil cephalus*), Silver sweep (*Scorpis lineolatus*), Trumpeter whiting (*Sillago maculata*), Surf fish (*Tropidostethus rhothophilus*) and juvenile Flying fish (references in NPWS 2000).

While no areas of critical habitat for Little Terns have been listed under the *Act (1995),* significant nesting sites have been identified near Comerong Island, Lake Wollumboola, Lake Conjola, Tuross Lake, Brou Lake, Tilba Lake, Wallaga Lake and the Bega River. As the

[1] now within the NSW Department of Environment and Conservation.

condition and location of nesting habitats can vary greatly over different years, areas of critical habitat will be reviewed regularly. The recovery plan for the Little Tern includes provision for exploring and implementing opportunities for the creation and enhancement of Little Tern nesting habitat (NPWS 2000). Table 7 lists historical nesting sites of Little Tern with the most recent and most successful nesting records.

Table 7. Nesting sites of Little Tern in the Batemans Shelf and Twofold Shelf bioregions with largest and most recent nesting records (NPWS 2000).

Nesting site	Last Record	Largest colony recorded
Shellharbour	1930s	No data
Minnamurra	1967/68	4 pairs 1967/68
Comerong Island	1996/97	13 pairs 1976/77
Lake Wollumboola	1996/97	30 pairs 1995/96
Lake Conjola	1996/97	10 pairs 1940's/50's
Narrawallee Creek	1984/85	2 pairs 1984/85
Burrill Lake	early 1950's	10 pairs 1940's/50's
Tabourie Lake	early 1950's	10 pairs 1940's/50's
Meroo Lake	pre 1963	no data
Mossy Point	1960/61	2-3 pairs 1960/61
Congo Creek	1994/95	1-2 pairs 1994/95
Mullimburra Point	early 1980's	3 pairs early 1980's
Coila Lake	1994/95	3 pairs 1982/83
Tuross Lake	1994/95	12 pairs 1985/86
Brou Lake	1993/94	35 pairs 1990/91
Tilba Lake	1994/95	35 pairs 1988/89
Wallaga Lake	1996/97	34 pairs 1993/94
Murrah Lagoon	1995/96	4 pairs 1989/90
Middle Lagoon	1996/97	1 pair 1996/97
Nelson lagoon	1996/97	1 pair 1996/97
Bega River	1996/97	13 pairs 1996/97
Wallagoot Lake	1994/95	12 pairs 1989/1990
Nadgee Lake	1984/85	9 pairs 1980/81

Beach Stone-curlew

The Beach Stone-curlew (*Esacus neglectus*) was known from around northern Australia as far south as the Manning River, but has largely disappeared from the south-eastern extent of its range. It has been estimated that the current Australian population may be as few as 15 breeding pairs. It occurs on open undisturbed beaches, islands, reefs, rock platforms and on intertidal sand and mud flats in estuaries and river mouths. Its diet includes crabs and other marine invertebrates. Threats to this species include loss of habitat to development, human disturbance from four wheel driving and boating, and predation by raptors, cats, dogs and pigs (NPWS 1999a).

Sightings of Beach Stone-curlew in the Batemans Shelf and Twofold Shelf bioregions are limited to the Comerong Island area of the Shoalhaven River estuary. A recovery plan has not yet been prepared for this species.

Bush Stone-curlew

The Bush Stone-curlew (*Burhinus grallarius*) is widespread throughout northern Australia and was once widespread along the east coast of NSW including much of the Cumberland Plain and in the Tweed, Brunswick, Richmond, Clarence, Macleay, Manning and Hunter Valleys. The NSW population now appears to be centred near Gosford (near Brisbane Water), Port Macquarie, Grafton, Port Stephens and Karuah. Sightings in the Batemans Shelf and Twofold Shelf bioregions are restricted to near the Shoalhaven River estuary.

This species is generally found in open woodland and feeds on insects, molluscs, centipedes, crustaceans, frogs, lizards, snakes and some vegetation. Threats include loss of habitat (including fallen woody debris), altered fire regimes, disturbance from humans, cultivation, over grazing and forestry, poisoned rabbit baits and predation by foxes, pigs, dogs and cats. A draft recovery plan has been prepared for this species (NPWS 1999b).

Hooded Plover

The Hooded Plover (*Thinornis rubricollis*) occurs throughout south eastern and south western Australia. Within NSW, it occurs south of Jervis Bay but was known previously as far north as Port Stephens and has occasionally been sighted in Wollongong and Sydney. In Australia, this species is found mostly on long stretches of sandy shore adjacent to lagoons and nesting on sparsely vegetated sand dunes. Its diet consists of marine worms, molluscs, crustaceans, insects, water plants and seeds. Threats include predation by Silver Gulls, foxes and raptors, loss of habitat to development, destruction of nests by stock and disturbance during the breeding season from humans and the use of four wheel drive vehicles in dune areas. There have been sightings of Hooded Plover at range of locations along the Batemans Shelf Shelf coast. A recovery plan has not yet been prepared for this species (NPWS 1999c).

Other threatened bird species

For estuaries, most threatened bird species were sighted around the Shoalhaven River (14 species) and at Durras Lake, Batemans Bay, Moruya River, Tuross Lake, Wagonga Inlet, Tilba Tilba Lake, Wallaga Lake, Lake Conjola and the Bega River. By far the most sightings occurred at the Shoalhaven River and the highest summed irreplaceability occurred at the Shoalhaven River, Batemans Bay, Durras Lake and the Moruya River (Fig. 46 - Fig. 48).

For sections of coast and ocean, most threatened bird species were sighted in the Moruya-Tuross, Shellharbour-Crooked and Crooked-Wollumboola sections, with most sightings in the Crooked-Wollumboola section and the highest summed irreplaceability in the Shellharbour-Crooked and Crooked-Lake Wollumboola sections (Fig. 49).

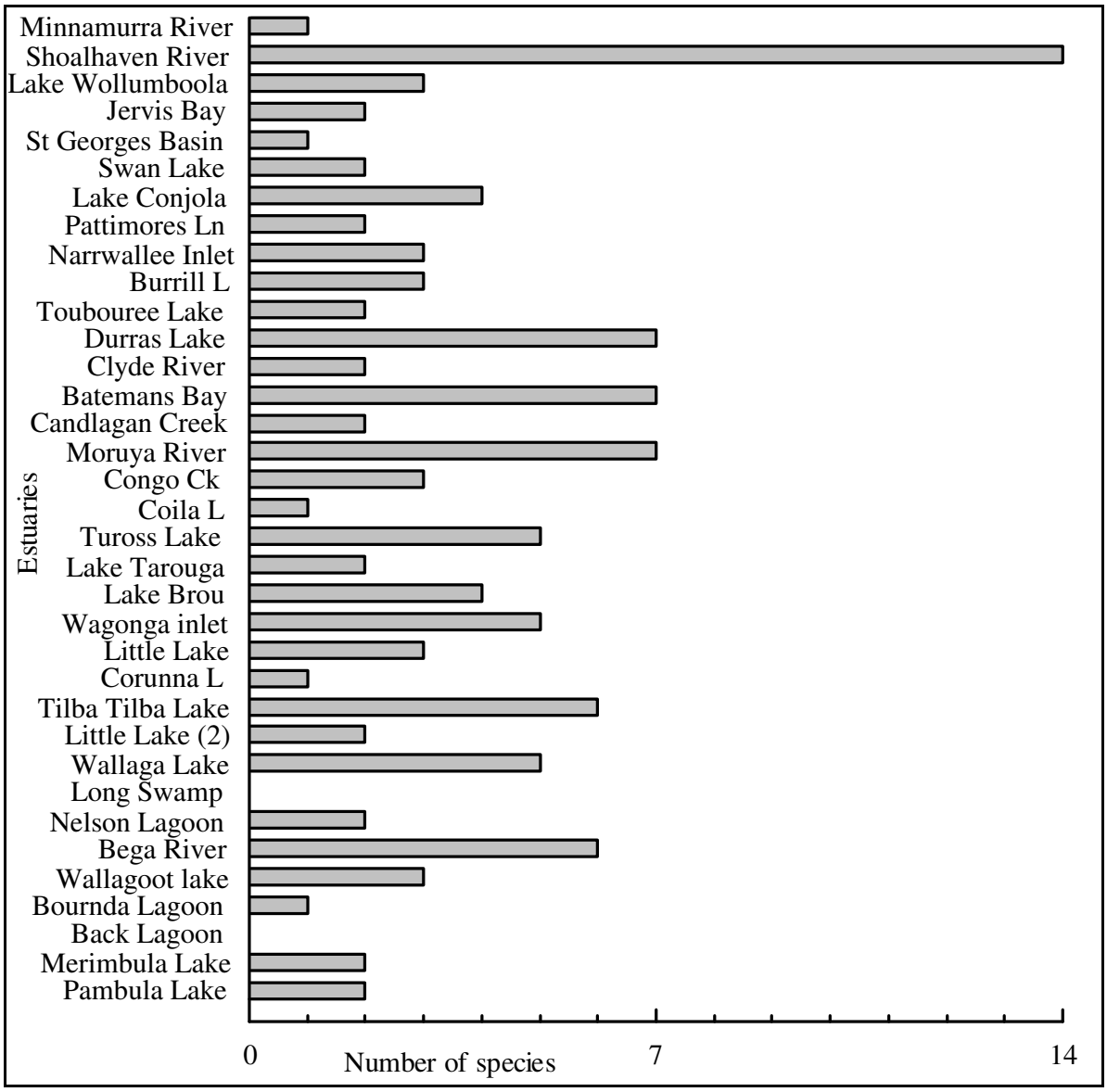


Fig. 46. Number of threatened bird species sighted near estuaries in the Batemans Shelf and Twofold Shelf bioregions (raw data from NPWS Wildlife Atlas).

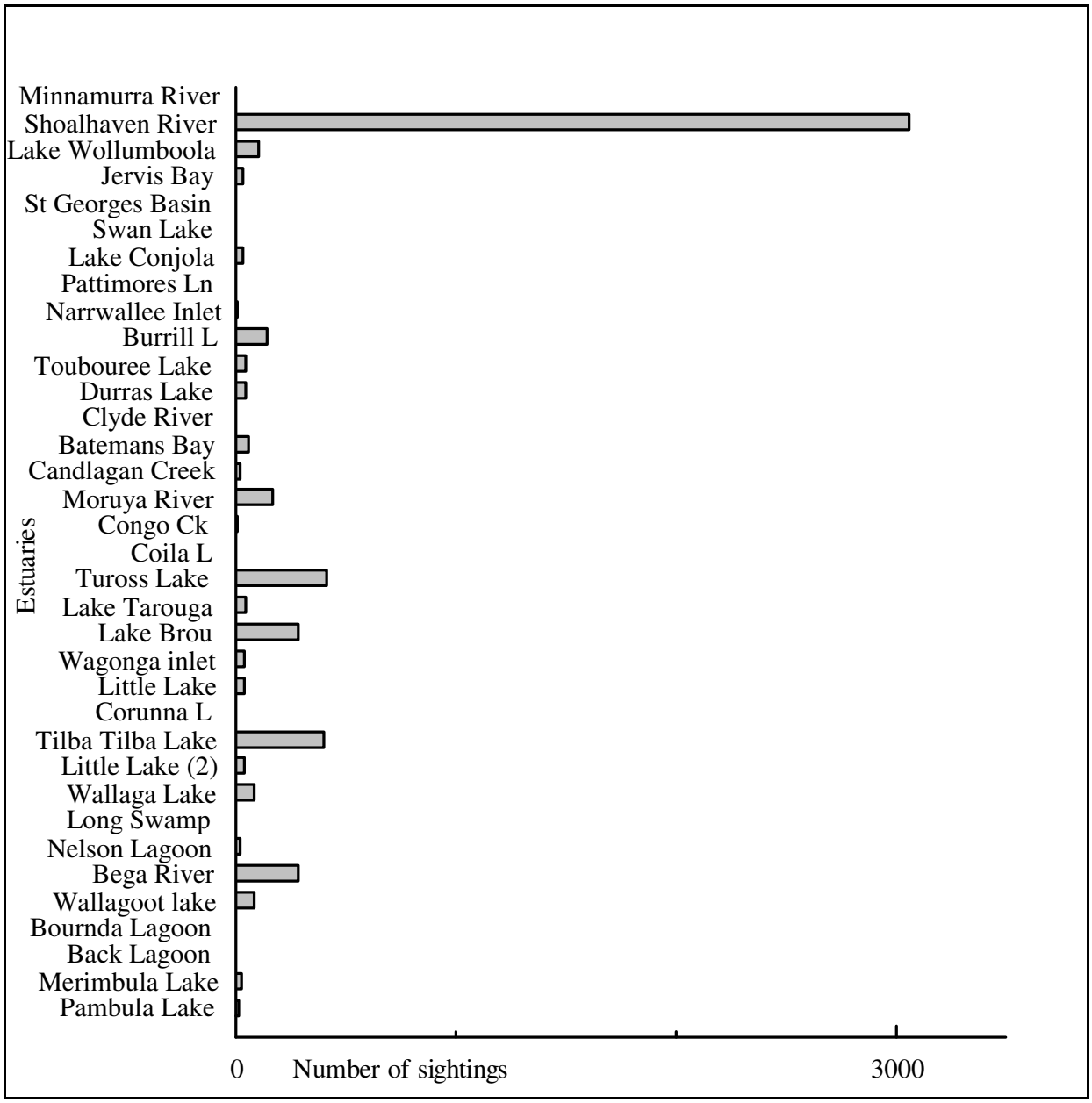


Fig. 47. Number of sightings of threatened bird species near estuaries in the Batemans Shelf and Twofold Shelf bioregions (raw data from NPWS Wildlife Atlas).

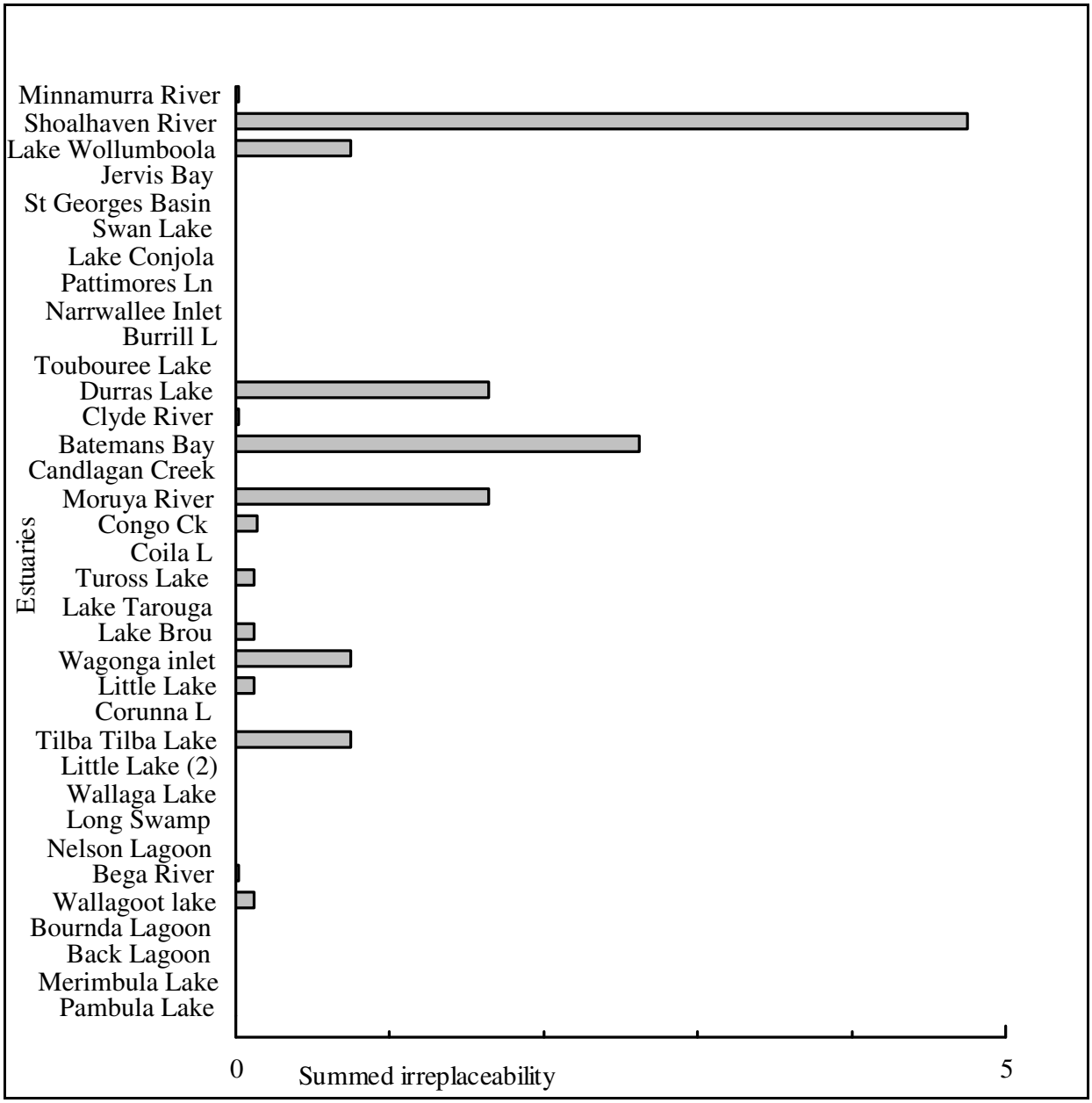


Fig. 48. Summed irreplaceability for representation of at least one sighting of each threatened bird species for estuaries in the Batemans Shelf and Twofold Shelf bioregions (raw data from NPWS Wildlife Atlas).

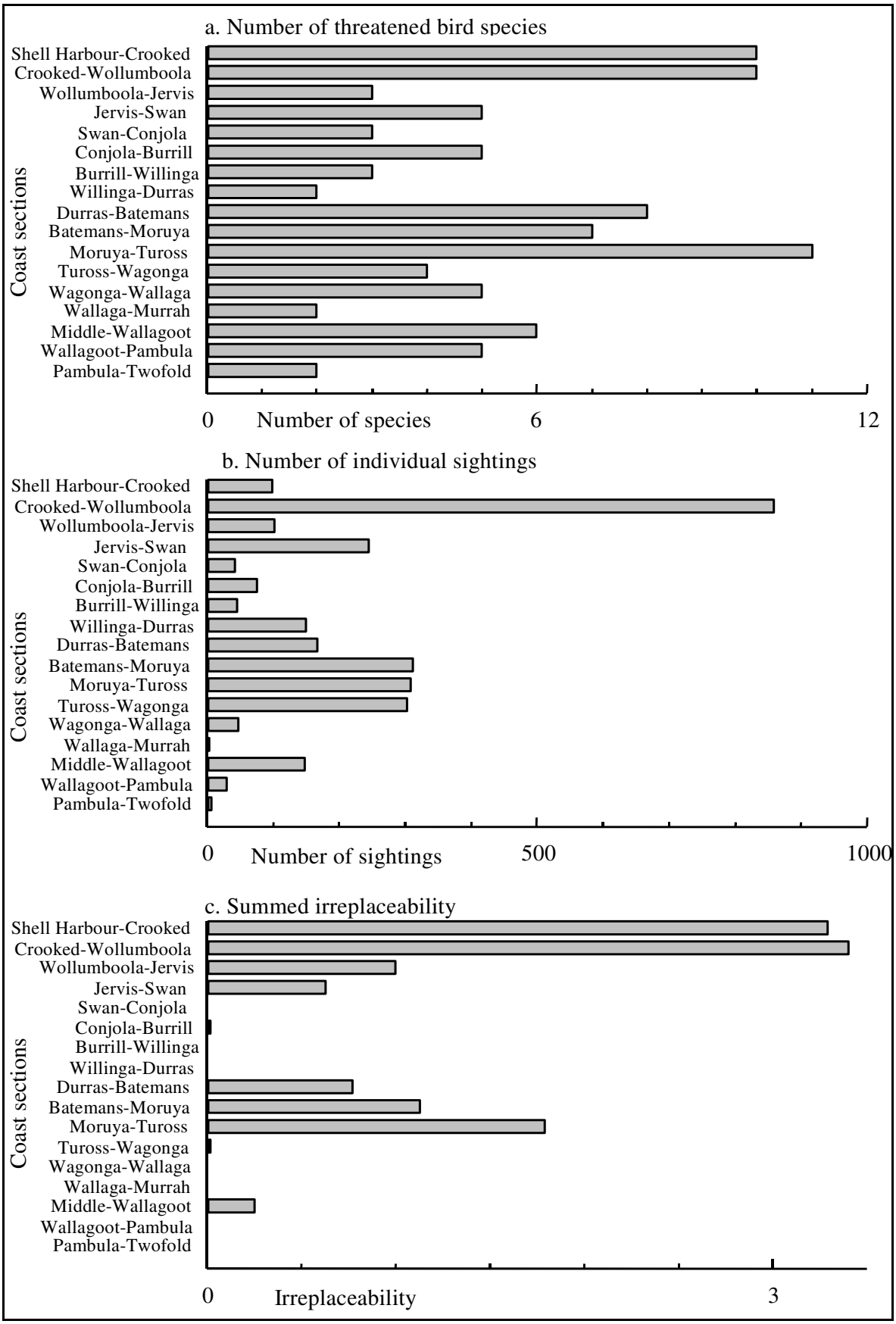


Fig. 49. Number of threatened bird species sighted, number of sightings and summed irreplaceability for representation of each species at least once for sections of ocean and coast in the Batemans Shelf and Twofold Shelf bioregions (raw data from NPWS Wildlife Atlas).

4.3.6 Significant areas for shorebirds and seabirds – Department of Environment and Heritage.

Data source

Australian Government Department of Environment and Heritage.

Data description

GIS shape files and data tables for areas considered by Wetlands International (Oceania) as significant for shorebirds (from Watkins D. 1993. A National Plan for Shorebird Conservation in Australia. RAOU Report No. 90.) and islands for which the Department of Environment and Heritage has breeding records.

Criteria

Representativeness, threatened species and ecological importance.

Assessment Measures

Area of habitat, number of species, number of birds, summed species irreplaceability.

Data assessment

The Shoalhaven River and Wagonga Inlet had large areas of significant shorebird habitat with the Shoalhaven River having a greater number of shorebird species, abundance and summed irreplaceability (Fig. 50).

The Willinga-Durras and Durras-Batemans sections included the most sea bird islands in the Batemans and Twofold Shelf bioregions, but the Durras-Batemans and Wagonga-Wallaga sections included the most nesting seabirds, seabird species, and summed irreplaceability for representation of each species at least once (Fig. 51).

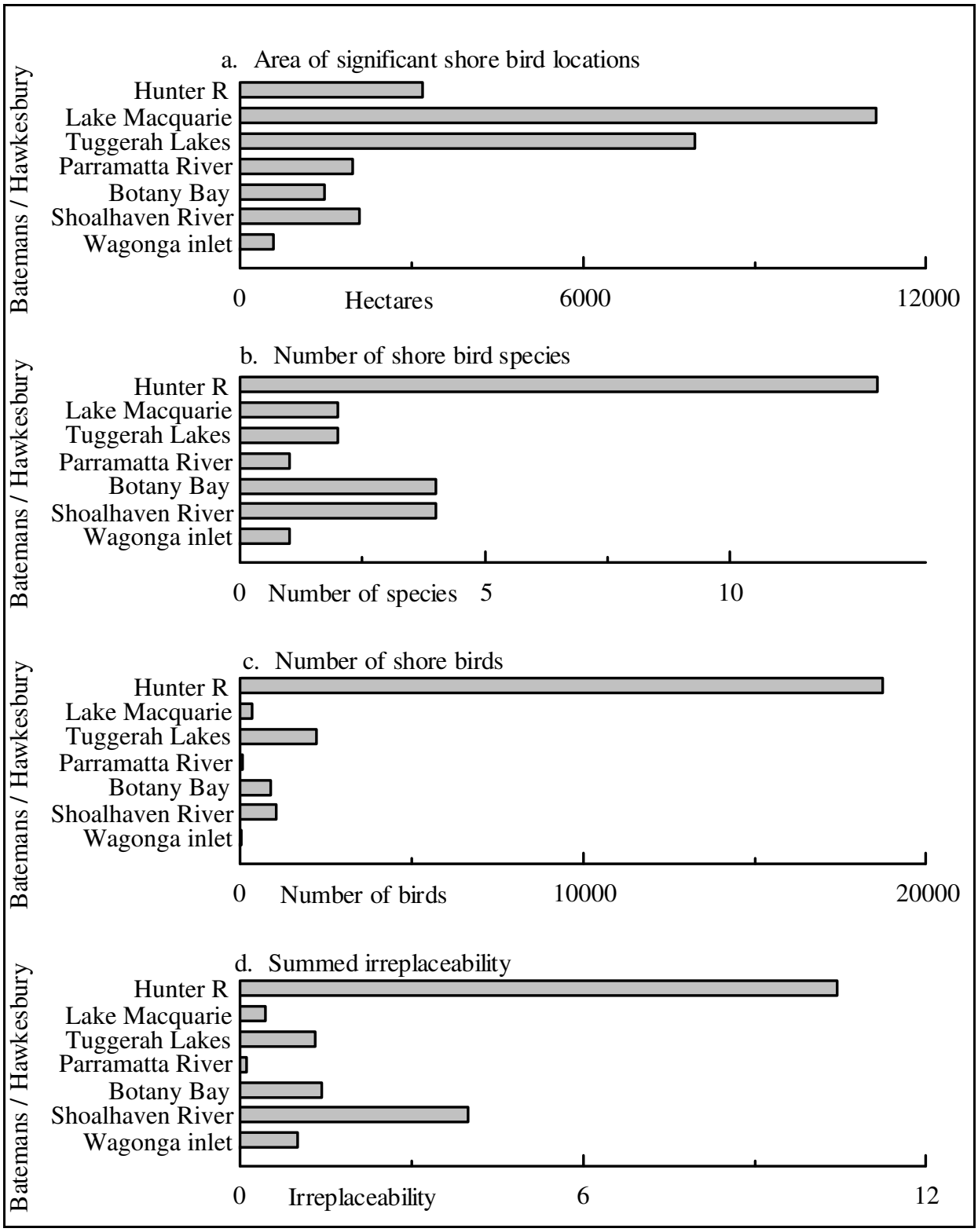


Fig. 50. Area, number of species, number of birds and summed irreplaceability for representation of each species at least once for significant shore bird locations in the Hawkesbury Shelf and Batemans Shelf bioregions (raw data from the Department of Environment and Heritage).

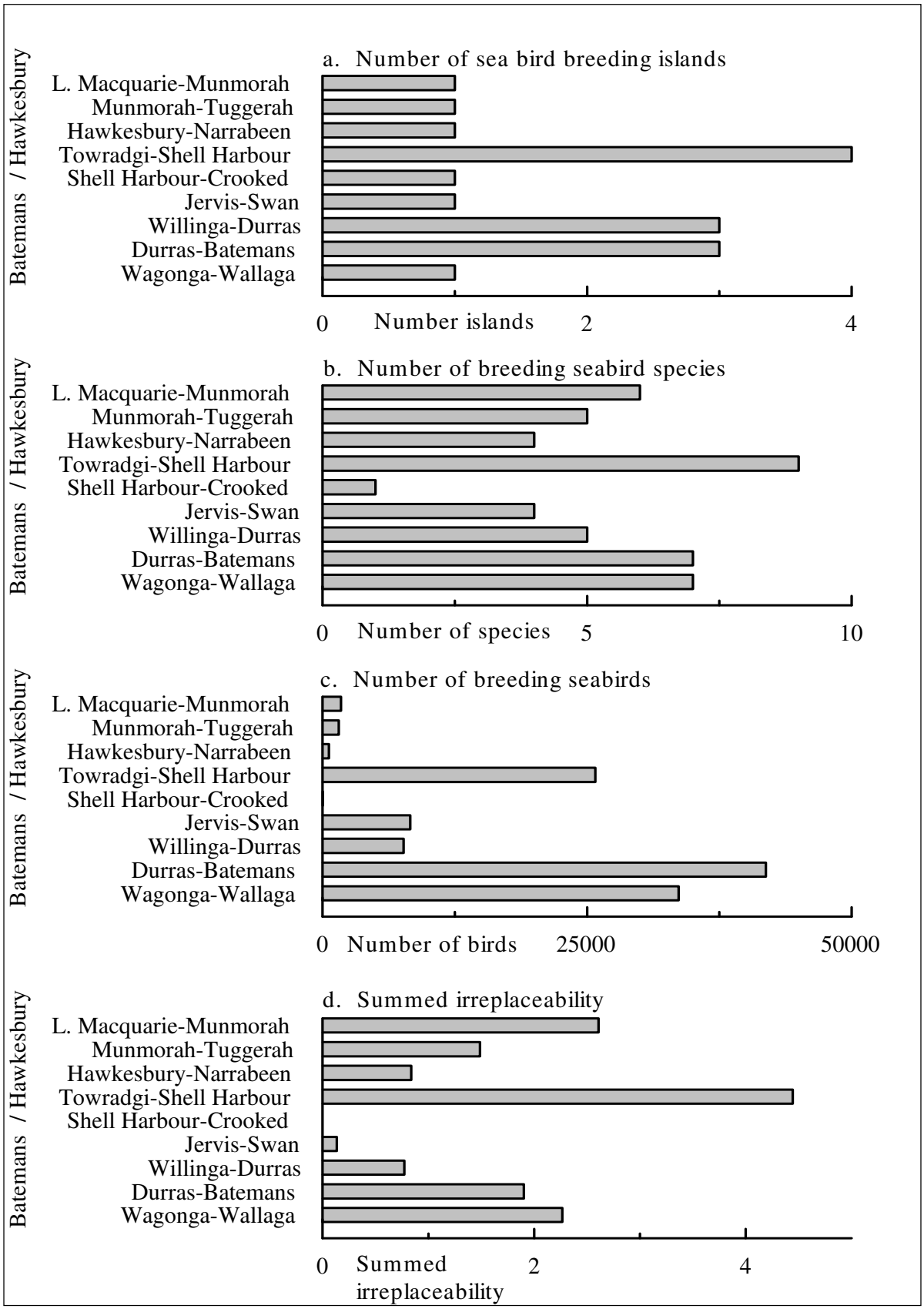


Fig. 51. Area, number of species, number of birds and summed irreplaceability for representation of each species at least once for sea bird breeding islands in the Hawkesbury Shelf and Batemans Shelf bioregions (raw data from the Department of Environment and Heritage).

4.3.7 Marine mammals and reptiles

Data sources

Australian Government Department of Environment and Heritage.
Transport Safety Bureau's NSW Oil Spill Response Atlas V 2.2 (CD-ROM June 2000).

Data Description

The database held by the Department of Environment and Heritage holds broadscale distribution maps and taxonomic, ecological and management information about Species of National Environmental Significance as listed under the *Environment Protection and Biodiversity Conservation Act 1999*. The NSW Oil Spill Response Atlas includes sightings data for marine mammals in NSW.

Criteria

Representativeness and threatened species.

Assessment measures

Descriptive summary.

Assessment

Marine mammal distributions in the bioregions include the Humpback whale (*Megaptera novaeangliae*), Southern right whale (*Eubalaena australis*), Sei whale (*Balaenoptera borealis*), Fin whale (*Balaenoptera physalus*), Blue whale (*Balaenoptera musculus*), and the Dusky dolphin (*Lagenorhynchus obscurus).* Marine reptile distributions in the Batemans Shelf bioregion include the Green turtle (*Chelonia mydas*) which extends south to Jervis Bay and the Leatherback turtle (*Dermochelys coriacea*), which extends south to Eden. These distributions extend well beyond NSW and several species are at the limit of their range.

The NSW Oil Spill Response Atlas includes 1002 sighting records of marine mammals in the bioregions including sightings of Humpback whale, Killer whale (*Orcinus orca*), Gray's beaked whale (*Mesoplodon grayii*), Dense beaked whale (*Mesoplodon densirostis*), Strap toothed beaked whale (*Mesoplodon layardi*), Gingko beaked whale (*Mesoplodon gingkodens*), Long finned pilot whale (*Globicephala melas*), Melon-head whale (*Peponocephala electra*), Minke whale (*Balaenoptera acutorostrata*), Pygmy sperm whale (*Kogia breviceps*), Dwarf sperm whale (*Kogia simus*), Sperm whale (*Physeter macrocephalus*), Short-finned pilot whale (*Globicephala macrorhynchus*), Southern right whale (*Eubalaena australis*), Pygmy right whale (*Caperea marginata*), Southern bottlenose whale (*Hyperoodon planiforms*), Bottlenose dolphin (*Tursiops truncatus*), Common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), Striped dolphin (*Stenella coeruleoalba*), Leopard seal (*Hydrurga leptonyx*), Australian fur seal (*Arctocephalus pusillus*), New Zealand fur seal (*Arctocephalus forsteri*), Australian sea-lion (*Neophoca cinerea*) and Southern elephant seal (*Mirounga leonina*). The distributions of these mammals extend well beyond the bioregion and several are at the extreme limit of their range. Most sightings (predominantly seals) occurred in the Wagonga-Wallaga section (93).

Montague Island is the most northerly and only remaining haul out site in NSW for Australian fur seals (*Arctocephalus pusillus*). The number of seals at the island ranges from around 25 for most of the year, to 700 in the breeding season and numbers appear to be increasing. It is thought that the island is not a breeding colony although there are anecdotal reports of seal pups being born there. There is only a limited knowledge of use of the island by seals and research is needed into the potential impacts of disturbance by humans (NPWS 1995).

Humpback whales are regularly observed off the NSW coast in June and July migrating to winter breeding grounds off Queensland and returning south between October and November to feed in colder waters. This east Australian population of humpbacks was estimated to have declined from 10,000 to 500 whales during the first half of the 20th century but is now increasing slowly each year (Baker 1983, Paterson and Paterson 1989, Smith 1997). These whales often pass relatively close to the coast, particularly near prominent headlands, and whale watching tourism is becoming established in several coastal ports including Jervis Bay, Batemans Bay, Narooma, Bermagui and Eden.

4.4 Ecological importance, condition and vulnerability

4.4.1 Directory of important wetlands in Australia

Data Source

The "Directory of Important Wetlands" (ANCA 1996) is a cooperative project between the Commonwealth, State and Territory Governments of Australia and is coordinated by The Department of Environment and Heritage to identify nationally important wetlands.

Data Description

The wetlands listed in the Directory are those which meet the criteria of national importance as revised by the ANZECC Wetlands Network in August 1994. All wetlands which meet the criteria have been listed, not just the best representatives of a wetland type. Criteria used to assess important wetlands include, whether the wetland is:

- a good example of a wetland type occurring in the bioregion
- important ecologically or hydrologically in the natural functioning of a major wetland
- important as habitat for animal taxa at a vulnerable stage of their life cycle, or provides refuge in adverse conditions such as drought
- supporting 1% or more of the national population of any plant or animal taxa
- supporting native plant, animal taxa or communities considered endangered or vulnerable at a national level or
- of outstanding historical or cultural significance.

Criteria

Representativeness and international or national importance.

Assessment measures

Presence of nationally important wetlands and descriptive summaries in Section 5.

Assessment

Table 8. Lists the locations of important wetlands in the Batemans Shelf and Twofold Shelf bioregions and these areas are mapped in Fig. 4 and discussed in further detail in Section 5.

Table 8. Important Wetlands in the Batemans Shelf and Twofold Shelf bioregions (ANCA 1996).

Wetland name	Area (ha)
Killalea Lagoon	20
Minnamurra River Estuary	200.
Shoalhaven / Crookhaven Estuary	2,500
Coomonderry Swamp	670
Wollumboola Lake	850
Jervis Bay	30, 000
Jervis Bay Sea Cliffs	175 ha, 25 km long
St Georges Basin	4400
Swan Lagoon	6
Durras Lake	400
Clyde River Estuary	2,900
Cullendulla Creek & Embayment	220
Waldrons Swamp	225
Moruya River Estuary Saltmarshes	50
Coila Creek Delta	40
Tuross River Estuary	1,200
Wallaga Lake	950
Nargal Lake	25
Nelson Lagoon	200
Bondi Lake	50
Wallagoot Lagoon	360
Merimbula Lake	450
Pambula Wetlands	200
Twofold Bay	850

4.4.2 Independent inquiry into coastal lakes

Data Source

"Independent public inquiry into coastal lakes: final report." Healthy Rivers Commission of New South Wales, April 2002.

Data Description

The classification assesses lakes on their "natural sensitivity, current condition of the water body and catchment, and recognised ecosystem and resource conservation values." The classification also takes into account existing settlement, resource use, government and court decisions, potential for restoration and development of other lakes in the region.

Assessments were influenced by the availability of information, but were informed by data analysed by the Department of Land and Water Conservation[3] in its "Estuaries Inventory," the Commonwealth Government's "National Land and Water Resources Audit" and additional data from universities, independent experts, state agencies, councils and submissions made to the Coastal Lakes Inquiry.

Criteria

Representativeness, uniqueness, threatened species, naturalness, vulnerability, management practicality and human use.

Assessment measures

Qualitative ranks for natural sensitivity, existing catchment and lake condition, recognised conservation value, potential for improvement and orientation for management.

Assessment

The assessment examined over fifty coastal lakes in the Batemans Shelf and Twofold Shelf bioregions. Its results are summarised in Table 9 below. The category "management orientation" identifies the suggested approach to managing each lake and its catchment according to guidelines provided in the Coastal Lakes Inquiry. These guidelines range from CP, which indicates the need for 'Comprehensive Protection' for relatively natural lakes to SP, 'Significant Protection', HMC, 'Healthy Modified Condition' and TR, 'Targeted Repair' for the most degraded lakes.

Wollumboola, Termeil, Meroo, Durras, Brunderee, Tarouga, Brou, Nargal, Nelson and Bondi Lakes and Lagoons in the Batemans Shelf bioregion were recommended for comprehensive protection by the Coastal Lakes Inquiry. In the Twofold Shelf bioregion, Bournda Lagoon and Nadgee Lake were recommended for comprehensive protection.

[3] now within the NSW Department of Infrastructure, Planning and Natural Resources.

Table 9. Classification of coastal lakes in the Batemans Shelf and Twofold Shelf bioregions

(Healthy Rivers Commission 2002).

Coastal Lake	Natural Sensitivity	Existing Condition		Conservation Value	Management Orientation
		Catchment	Lake		
Killalea	Extreme	Modified	Unknown	Moderate	HMC
Werri	Extreme	Modified	Moderately affected	Low	HMC
Wollumboola	Extreme	Largely Unmodified	affected	High	CP
St Georges Basin	High	Modified	Slightly affected	High	HMC
Swan	Extreme	Largely Unmodified	Slightly affected	High	SP
Conjola Berringer	High	Modified	Slightly affected	Moderate	SP
Narrawallee	High	Modified	Slightly affected	Moderate	HMC
Burrill	High	Modified	Moderately affected	Moderate	HMC
Tabourie	Extreme	Modified	Slightly affected	Moderate	SP
Termeil	Extreme	Near Pristine	Unknown	Moderate	CP
Meroo	Extreme	Near Pristine	Slightly affected	Moderate	CP
Willinga	High	Largely Unmodified	Slightly affected	Moderate	SP
Swan	Extreme	Modified	Unknown	Moderate	HMC
Kioloa	Extreme	Largely Unmodified	Unknown	Moderate	HMC
Durras	Very High	Near Pristine	Slightly affected	Moderate	CP
Candalagan	High	Largely Unmodified	Unknown	Low	SP
Congo	Very High	Modified	Unknown	Low	HMC
Meringo	Extreme	Largely Unmodified	Unknown	Low	SP
Mullimburra	Extreme	Modified	Unknown	Moderate	HMC
Bingie	Extreme	Modified	Unknown	Unknown	SP
Coila	Extreme	Largely Unmodified	Slightly affected	Moderate	HMC
Tuross	High	Largely Unmodified	Slightly affected	High	HMC
Brunderee	Extreme	Near Pristine	Unknown	Low	CP
Tarourga	Extreme	Near Pristine	Unknown	Low	CP
Brou	Extreme	Near Pristine	Slightly affected	Moderate	CP
Mummuga	Very High	Largely Unmodified	Slightly affected	Moderate	SP
Kianga	Extreme	Largely Unmodified	Severely affected	Moderate	HMC
Wagonga	High	Largely Unmodified	Slightly affected	High	HMC

Table 9 (continued).
Classification of coastal lakes in the Batemans Shelf and Twofold Shelf bioregions (Healthy Rivers Commission 2002).

Coastal Lake	Natural Sensitivity	Existing Condition		Conservation Value	Management Orientation
		Catchment	Lake		
Little	Extreme	Severely Modified	Moderately affected	Unknown	TR
Bullengella	Extreme	Modified	Unknown	Low	HMC
Nangudga	High	Modified	Unknown	Low	HMC
Nargal	Extreme	Near Pristine	Pristine	High	CP
Corunna	Very High	Largely Unmodified	Slightly affected	Moderate	SP
Tilba Tilba	Extreme	Modified	Moderately affected	Moderate	HMC
Little	Extreme	Modified	Unknown	Moderate	HMC
Wallaga	High	Largely Unmodified	Slightly affected	High	HMC
Long Swamp	Extreme	Modified	Moderately affected	Moderate	HMC
Baragoot	High	Largely Unmodified	Unknown	Low	SP
Cuttagee	Very High	Near Pristine	Slightly affected	Low	SP
Murrah	High	Largely Unmodified	Slightly affected	Low	HMC
Bunga	Extreme	Largely Unmodified	Unknown	Low	SP
Wapengo	High	Largely Unmodified	Slightly affected	High	SP
Middle	Extreme	Largely Unmodified	Slightly affected	Moderate	SP
Nelson	High	Near Pristine	Slightly affected	High	CP
Wallagoot	Very High	Largely Unmodified	Slightly affected	Moderate	SP
Bondi	Extreme	Near Pristine	Pristine	High	CP

Twofold Shelf bioregion

Bournda	Extreme	Near Pristine	Pristine	Moderate	CP
Back	Very High	Largely Unmodified	Moderately affected	Low	SP
Merimbula	High	Modified	Moderately affected	High	HMC
Pambula	High	Largely Unmodified	Slightly affected	High	HMC
Curalo	Very High	Largely Unmodified	Slightly affected	Moderate	HMC
Wonboyn	High	Near Pristine	Slightly affected	High	SP
Nadgee	Extreme	Near Pristine	Pristine	High	CP

4.4.3 Environmental inventory of estuaries and coastal lagoons

Data source

Bell and Edwards (1980). *An inventory of estuaries and coastal lagoons in New South Wales.* Total Environment Centre.

Data description

Bell and Edwards (1980) conducted inventories of NSW estuaries including descriptions of recreation and tourism significance, degree of disturbance, area, mean annual rainfall, mean annual runoff and conservation features. While these data may not be the most current in regards to coastal development and catchment use, they provide a relative measure of differences among estuaries and a useful check against more recent inventories.

Criteria

Naturalness and vulnerability.

Assessment measures

Qualitative score between 1-4 for shore and water disturbance and for catchment disturbance.
Verbal description of conservation and human-use values and threats.

Assessment

Table 10 lists disturbance scores for over fifty estuaries. With some exceptions most of the scores are low particularly when compared to estuaries in the Hawkesbury Shelf, Manning Shelf and Tweed-Moreton bioregions.

Table 10. Disturbance scores for estuaries in the Batemans Shelf and Twofold Shelf bioregions (0-Very Low to 5-Very High, Bell and Edwards 1980).

Estuary	Shore and water	Catchment
Batemans Shelf bioregion		
Minnamurra River	3	3
Werri Lagoon	3	3
Crooked Creek	3	4
Shoalhaven River	3	2
Lake Wollumboola	3	1
Jervis Bay	3	2
St. Georges Basin	2	1
Swan Lake	1	1
Berrara Creek	1	1
Nerrindillah Creek	0	1
Lake Conjola	2	2
Narrawallee Creek	1	3
Burrill Lake	2	3
Tabourie Lake	1	1
Termeil Lake	1	1
Meroo Lake	1	1
Willinga Lake	3	2
Durras Lake	1	1
Batemans Bay and Clyde R.	2	1
Tomaga River	3	2
Candalagan Creek	3	2
Moruya River	3	1
Congo Creek	2	3
Coila Lake	3	2
Tuross Lake	3	2
Lake Brunderee	1	1
Lake Tarouga	1	1
Lake Brou	1	1
Lake Mummuga	3	1
Kianga Lake	3	2
Wagonga Inlet & Narooma R.	3	2
Nangudga Lake	3	3

Table 10 (continued).
Disturbance scores for estuaries in the Batemans Shelf and Twofold Shelf bioregions (0-Very Low to 5-Very High, Bell and Edwards 1980).

Estuary	Shore and water	Catchment
Batemans Shelf bioregion (continued)		
Corunna Lake	3	3
Tilba Tilba Lake	4	4
Wallaga Lake	1	3
Bermagui River	3	3
Baragoot Lake	1	1
Cuttagee and Little Lakes	3	1
Murrah Lagoon	3	3
Bunga Lagoon	2	1
Wapengo Lagoon	2	2
Middle Lagoon	1	2
Nelson Lagoon	1	0
Bega River	4	3
Wallagoot Lake	3	2

Twofold Shelf bioregion	Shore and water	Catchment
Bondi Lake	0	1
Sandy Beach Creek	1	1
Back Lagoon	3	1
Merimbula Lake	4	3
Pambula R. and Lake	3	2
Curalo Lake	4	2
Nullica River	1	1
Towamba River	1	3
Bittangabee Bay	0	0
Wonboyn R. and Lake	1	2
Merrica River	0	1
Little Creek	0	1
Nadgee River	0	0
Nadgee Lake	0	0

4.4.4 Australian Estuaries Database and the OzEstuaries Database

Data source

Digby, M. J., Buchner, D., Saenger, P., Whelan, M. B., McConchie, D., Eyre, B. and Holmes, N. (1998). Australian Estuarine Database.

Heap, A., Bryce, S., Ryan, D., Radke, L., Smith, C., Smith, R., Harris, P. and Heggie, D. (2001). Australian Estuaries and Coastal Waterways: A Geoscience Perspective for Improved and Integrated Resource Management. Australian Geological Survey Organisation. Record 2001/07.

Data description

The OzEstuaries database combines data from the Australian Estuarine Database (AED) of Digby *et al.* (1998), with new data acquired for the National Land and Water Resources Audit. The new data includes geometrical measurements, facies (habitat) areas, denitrification rates and efficiencies, sedimentation rates and sediment chemistry for estuaries and other coastal waterways.

The Australian Estuarine Database is derived from Buchner and Saenger (1989) with a revision of some of the spatial data, and the inclusion of additional geographic and climatic data.

Criteria

Ecological importance, naturalness (condition), vulnerability and human use.

Assessment measures

Qualitative scores for condition, conservation value and threat, fisheries value and threat, ecological status and water quality.

Assessment

Table 11 summarises the estimated condition of Batemans Shelf and Twofold Shelf estuaries in the OzEstuaries database. Condition ranges from extensively modified for the Shoalhaven River and Curalo Lagoon to near pristine for Meroo, Willinga and Durras Lakes and the Merrica River.

Table 11. Condition of estuaries listed in the OzEstuaries Database.

Estuary	Condition
Minnamurra River	modified
Shoalhaven/Crookhaven River	extensively modified
Wollumboola Lake	largely unmodified
Jervis Bay	largely unmodified
Currambene Creek	largely unmodified
Saint Georges Basin	modified
Swan Lake	largely unmodified
Lake Conjola	modified
Narrawallee Inlet	largely unmodified
Burrill Lake	largely unmodified
Tabourie Lake	modified
Meroo Lake	near pristine
Willinga Lake	near pristine
Durras Lake	near pristine
Clyde River/Batemans Bay	largely unmodified
Tomaga River	largely unmodified
Moruya River	modified
Coila Lake	modified
Tuross Lake	modified
Lake Brou	largely unmodified
Lake Mummuga	largely unmodified
Wagonga Inlet	modified
Corunna Lake	largely unmodified
Tilba Tilba Lake	largely unmodified
Wallaga Lake	largely unmodified
Bermagui River	modified
Cuttagee Lake	largely unmodified
Murrah Lagoon	largely unmodified
Wapengo Lagoon	largely unmodified
Middle Lagoon	largely unmodified
Nelson Lagoon	largely unmodified
Bega River	modified
Wallagoot Lake	largely unmodified
Merimbula Lake	modified
Pambula Lake	largely unmodified
Curalo Lagoon	extensively modified
Nullica River	largely unmodified
Towamba River	largely unmodified
Wonboyn River	largely unmodified
Merrica River	near pristine

4.4.5 Adjacent national parks and nature reserves

Data source

GIS coverage of estate from the NSW National Parks and Wildlife Service (NPWS)[1].

Data description

These data include GIS boundaries of existing national parks, nature reserves, state recreation areas, historic sites, Aboriginal areas, and regional parks declared under the NSW National Parks and Wildlife Act 1974. National parks and nature reserves are generally declared on the basis of their high conservation values and high natural condition. Their declaration helps ensure long term protection of these values, and provides an important permanent buffer for estuaries and coastal environments against the effects of inappropriate land use.

Criteria

Ecological importance, naturalness (condition) and vulnerability.

Assessment measures

Percent of adjacent lands managed as national park or nature reserve within 1 km of each estuary and within 1 km of the high water mark for sections of exposed coast.

Assessment

For estuaries in the Batemans Shelf bioregion, the highest percentage of adjacent lands within 1 km managed as national park or nature reserve was highest for Nelson Lagoon (83%), Termeil Lake (72%), Berrara Creek (71%), Tabourie Lake (67%), Carama Creek (64%), Swan Lake (63%), Durras Lake, Meroo Lake, Middle Lagoon, Nerrindillah Creek, Lake Tarouga and Lake Brou (40-60%; Fig. 52a).

The cover of national park or nature reserve within 1 km was less than 10% for Nangudga Lake, Lake Brunderee, St Georges Basin, Tuross Lake, Bega River, Bermagui River, Candalagan Creek, Coila Lake, Moruya River, Bullengella Lake and the Crooked River. There were no adjacent national parks or nature reserves for Kianga Lake, Killalea Lagoon, Little Lake, Minnamurra River, Murrah Lagoon, Tomaga River, Ulladulla Harbour, Wagonga Inlet, Bunga Lagoon and Werri Lagoon (Fig. 52a).

For sections of ocean coast in the Batemans Shelf bioregion, the highest percentage of adjacent lands within 1km in national park or nature reserve occurred between Durras-Batemans (76%), Middle-Wallagoot (64%), Willinga-Durras (55%), Murrah-Middle (55%) and Burrill-Willinga (43%). The least area in national park or nature reserve occurred for the Shellharbour-Crooked (0%), Batemans-Moruya (1.5%), Wallaga-Middle (4%) and the Jervis-Swan sections (4%) (Fig. 53a).

For estuaries in the Twofold Shelf bioregion all of the adjacent lands within 1 km of Nadgee River, Wirra Birra Creek, Merrica Lake, Table and Little Creek were included in Nadgee Nature Reserve and Wilderness Area. All lands around Woodburn, Saltwater and Bittangabee Creeks were included in Ben Boyd National Park and all land around Bondi Lake and Bournda Lagoon were included in Bournda National Park (Fig. 52a).

Pambula Lake (42%), Wonboyn River (27%), Curalo Lagoon (20%), Twofold Bay (20%) and Towamba River (10%) also had significant areas of national park and nature reserve within 1 km of their shores (Fig. 52a).

For sections of ocean coast in the Twofold Shelf bioregion all sections except the Wallagoot-Pambula (34%) section had over 90% of adjacent land in national park or nature reserve (Fig. 53a).

[1] now within the NSW Department of Environment and Conservation

4.4.6 Wilderness

Data source

Comprehensive Regional Assessment (CRA) by the National Parks and Wildlife Service[1].

Data description

GIS coverage of areas declared as wilderness by the National Parks and Wildlife Service[1].

Identification criteria

Ecological importance, naturalness (condition) and vulnerability.

Assessment measure

Percent of adjacent lands managed as wilderness within 1 km of each estuary, and land within 1 km of high water for sections of exposed coast.

Assessment

No wilderness areas occurred within 1 km of any estuaries or coasts in the Batemans Shelf bioregion (Fig. 52b). However, in the Twofold Shelf bioregion, all adjacent lands within 1 km of Nadgee River, Wirra Birra Creek, Merrica Lake, Table and Little Creek were included in wilderness area (Fig. 52b) and all of the coast between Wirra Birra and Nadgee and 40% of the coast between Wonboyn and Wirra Birra was included in a wilderness area (Fig. 53b).

4.4.7 State forest[4]

Data Source

State Forests of NSW[4]

Data description

GIS coverage of the location and extent of state forests.

Criteria

Ecological importance, naturalness (condition) and vulnerability.

Assessment measure

Percent of adjacent lands managed as state forest within 1 km of each estuary, and within 1 km of high water for sections of exposed coast.

Assessment

In the Batemans Shelf bioregion, the Clyde River (49%), Bermagui River (40%), Nerrindillah Creek (32%) and Mummuga Lake (30%) had the most adjacent land within 1 km in State Forest. Lake Brou, Cuttagee Lake, Kianga Lake, Wagonga Inlet, Lake Brunderee and the Tomaga River had 10-20% of nearby land in State Forest and all other estuaries had less than 10% of adjacent lands in State Forest (Fig. 52c). All sections of coast in the Batemans Shelf bioregion had less than 3% of adjacent land in state forest (Fig. 53c).

In the Twofold Shelf bioregion, Fisheries Creek (62%), Nullica River (35%), the Wonboyne River (30%) and Towamba River (27%) had the highest proportion of adjacent land in State Forest. All other estuaries had less than 6% in State Forest (Fig. 52c). Coastal sections in the Twofold Shelf bioregion all had 1% or less of adjacent land in State Forest (Fig. 53c). However a large proportion of the upper catchments for rivers south of Merimbula are included in state forest.

[1] now within the NSW Department of Environment and Conservation.

[4] now trading as Forests NSW within the NSW Department of Primary Industries.

4.4.8 State Environmental Planning Policy – Wetlands (SEPP 14)

Data Source

NSW Department of Infrastructure, Planning and Natural Resources.

Data description

GIS coverage of coastal wetlands protected under State Environmental Planning Policy No. 14 (SEPP14) of the NSW *Environmental Planning and Assessment Act 1979.*

Criteria

Ecological importance, naturalness (condition) and vulnerability.

Assessment measure

Percent of adjacent lands managed under SEPP 14 within 1 km of each estuary and within 1 km of high water for sections of exposed coast.

Assessment

In the Batemans Shelf bioregion, Carama Creek (36%) and Moona Moona Creek (33%) had the most area of adjacent land within 1 km included within SEPP 14 classification. Narrawallee Creek, Candalagan Creek, Cullendulla Creek, Little Lake, Currambene Creek, Congo Creek and the Minnamurra River had between 10-20% of adjacent land in SEPP 14. All other estuaries had less than 10% of nearby areas in SEPP14 (Fig. 52d).

The Wollumboola-Jervis and Durras-Batemans section of coast had approximately 4% of adjacent land in SEPP 14 and all other sections had 1% or less of nearby land in SEPP 14 (Fig. 54a).

In the Twofold Shelf bioregion, Nadgee Lake and River had 100% of nearby land in SEPP 14 and other estuaries had less than 10% of adjacent land within 1 km in SEPP14 (Fig. 52d). All sections of coast in the Twofold Shelf bioregion had less than 1% of adjacent land in SEPP 14 (Fig. 54a).

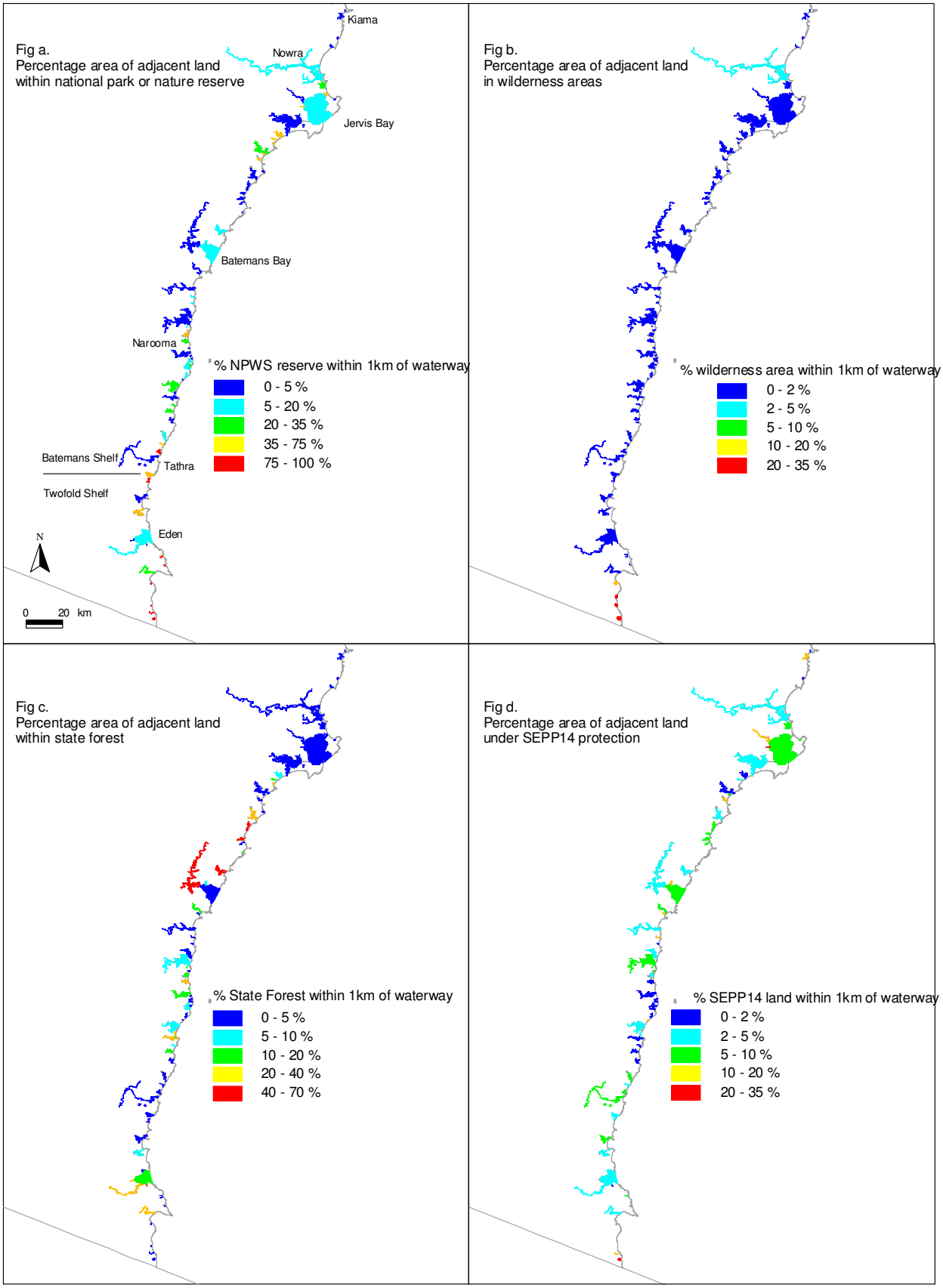


Fig. 52. Percentage area of lands within 1 km of estuaries within national parks or nature reserves, wilderness areas, state forest and State Environmental Planning Policy 14 (wetland) areas in the Batemans Shelf and Twofold Shelf bioregions.

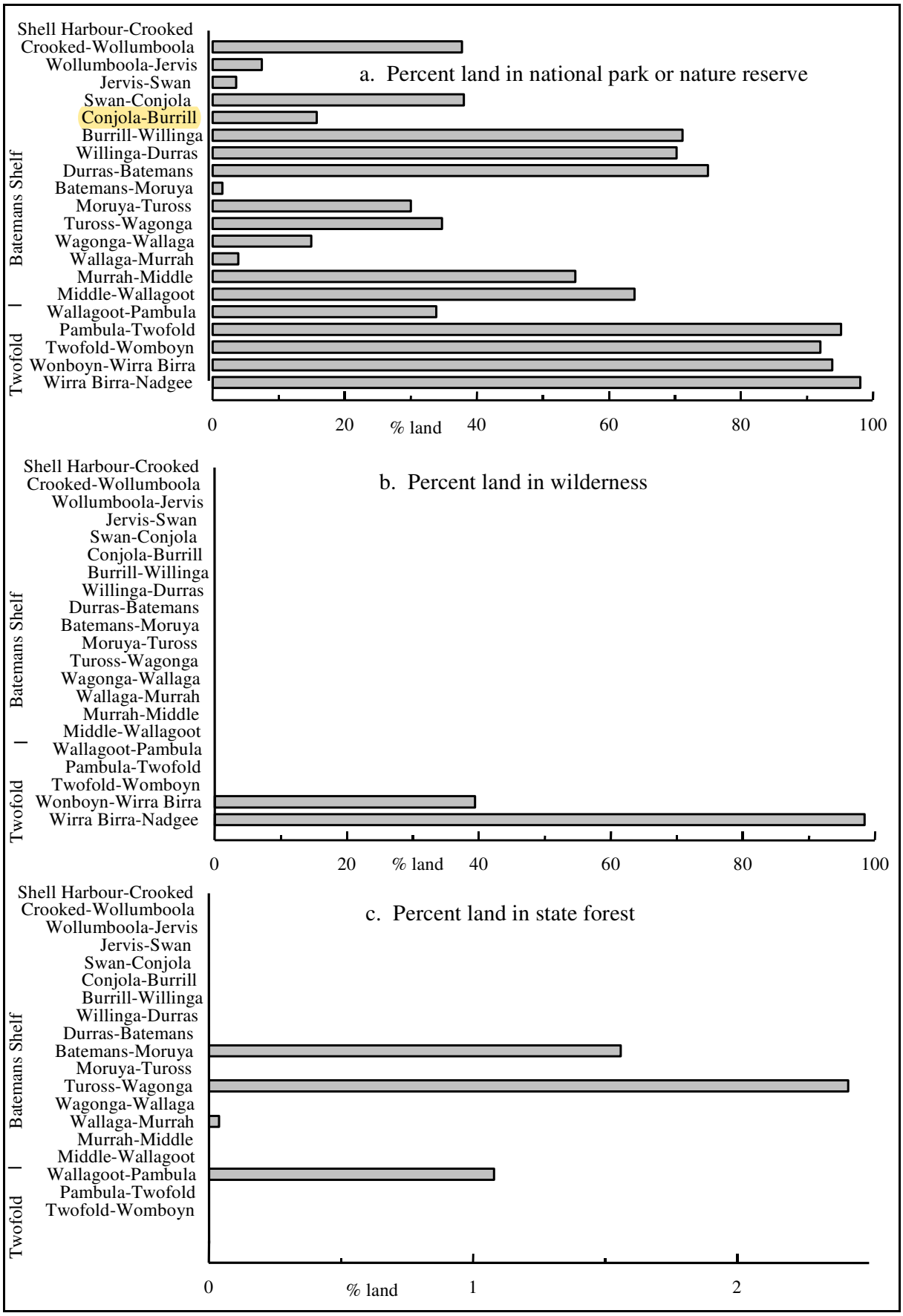


Fig. 53. Percentage area of land within 1 km of coast in national park or nature reserve, wilderness areas, or State Forest in the Batemans Shelf and Twofold Shelf bioregions.

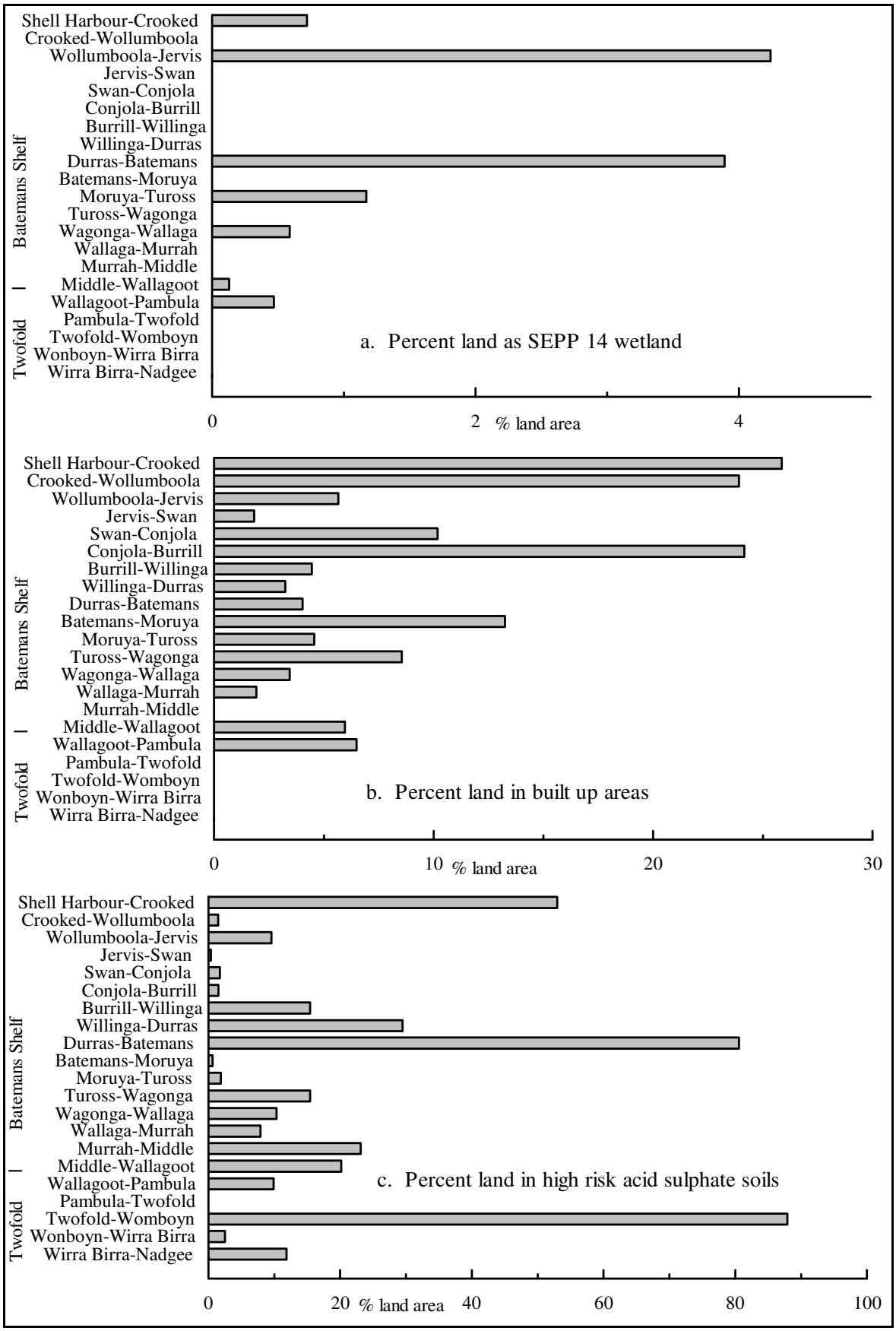


Fig. 54. Percentage area of land within 1 km of coast in SEPP 14 areas, built up areas and with high risk or disturbed acid sulphate soils.

4.4.9 Land capability

Data Source

NSW Department of Land and Water Conservation (DLWC)[3]

Data description

GIS coverage of land capability from "Land capability mapping," Soil Conservation Service, DLWC. NSW lands were classed by the capability of different soils and terrains to support 8 main categories of land use. These categories were grouped into those classes suitable for cultivation (1-3), suitable for grazing (4-6), or suitable for forest or left with natural vegetation (7-8).

Identification criteria

Vulnerability and naturalness (condition).

Assessment measures

Percentage of adjacent lands in each pooled land capability group within 1 km of each estuary and within 1 km of high water for sections of exposed coast.

Assessment

Land capability for forest or land to be left under natural vegetation.

Carama Creek (72%), Moona Moona Creek (47%) and Narrawallee Inlet (43%) had the most adjacent land within 1 km classed as suitable for forest or native vegetation (Fig. 55a).
The Burrill-Willinga (38%), Crooked-Wollumboola (33%) and Wollumboola-Jervis Bay (28%) sections of coast had the most adjacent land suitable for forest or native vegetation (Fig. 56c).

Land capability for cultivation

The Crooked River (49%), Werri Lagoon (31%), Moruya River (23%), Shoalhaven River (23%), Tuross Lake (18%) and the Bega River (12%) had the most adjacent land suitable for cultivation (Fig. 55b). All other estuaries had less than 10% of adjacent land suitable for cultivation. All sections of ocean coast had less than 4% of adjacent land suitable for cultivation (Fig. 56a).

Land capability for grazing.

Currarong Creek (0%), Ulladulla Harbour (0%), Carama Creek (3%), Nelson Lagoon (11%), Jervis Bay (11%), Lake Tabourie (16%) and Termeil lake (17%) had the least adjacent land classed as suitable for grazing. All other estuaries had between 25% and 95% of adjacent land suitable for grazing (Fig. 55c). Sections of coast between the Crooked River and Swan Lake and south of Pambula Lake had the least adjacent land suitable for grazing. All other sections had between 20 and 80% of nearby lands suitable for grazing (Fig. 56b).

[3] now within the NSW Department of Infrastructure, Planning and Natural Resources.

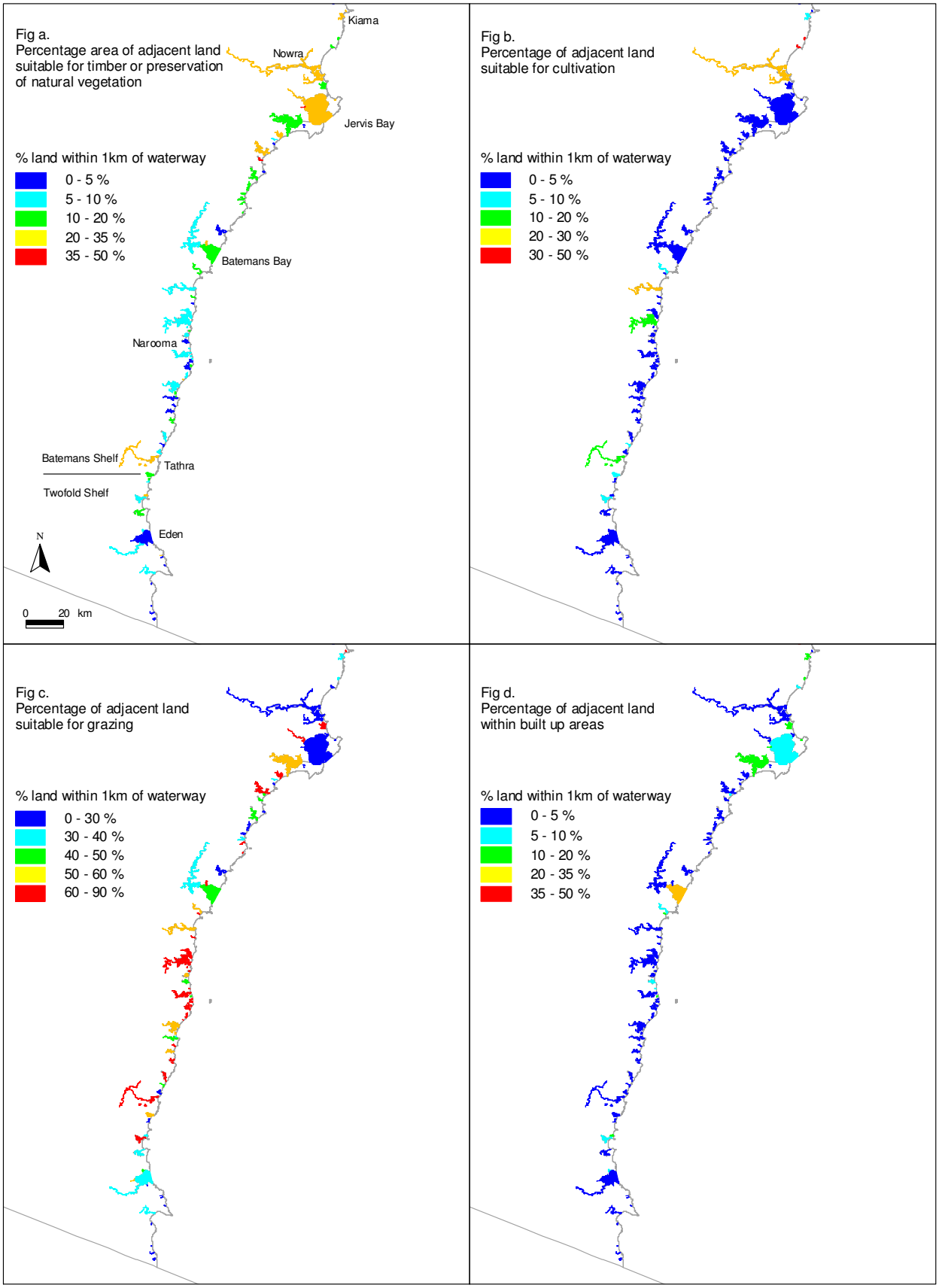


Fig. 55. Percentage area of lands within 1 km of estuaries suited to different land uses and within built up areas in the Batemans Shelf and Twofold Shelf bioregions.

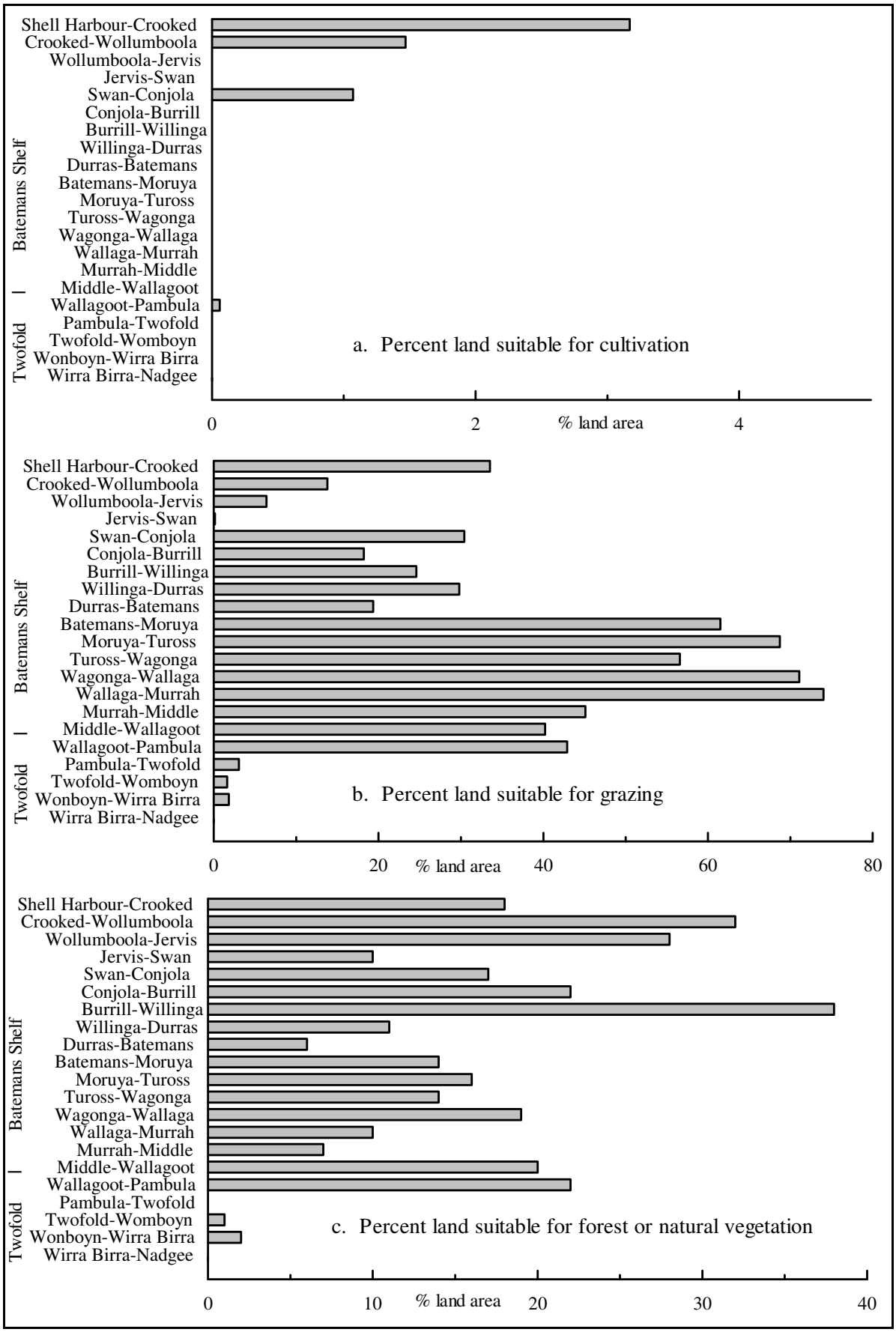


Fig. 56. Percentage area of land within 1 km of coast in areas suitable for cultivation, grazing and timber or natural vegetation for the Batemans Shelf and Twofold Shelf bioregions.

4.4.10 Built-up areas

Data Source

1:250,000 topographic database held by Geoscience Australia.

Data description

GIS layer of built up areas.

Criteria

Vulnerability, naturalness (condition) and human use.

Assessment measure

Percent of lands in built-up areas within 1 km of each estuary and each section of coast.

Assessment

In the Batemans Shelf bioregion, Ulladulla Harbour (53%), Batemans Bay (24%), Little Lake (19%), Minnamurra River (14%), Lake Wollumboola (14%), Currarong Creek, Candalagan Creek (13%), Moona Moona Creek (13%), Werri Lagoon (12%) and St Georges Basin (12%) had the greatest area within 1 km in built up areas. All other estuaries had less than 10% in built-up areas and 26 estuaries had no built-up areas within 1 km (Fig. 55d).

For sections of coast in the Batemans Shelf bioregion, the Shellharbour-Crooked (26%), Conjola-Burrill (24%) and Crooked-Wollumboola (24%), Batemans-Moruya (13%) and Swan-Conjola (10%) sections of coast had the most adjacent land in built-up areas. All other sections had less than 10% of nearby land in built-up areas (Fig. 54b).

In the Twofold Shelf bioregion, Back Lagoon (14%), Curalo Lagoon (7%), Merimbula Lake (6%), Twofold Bay (4%) and Pambula Lake (2%) were the only estuaries to have built-up areas within 1 km of their shores (Fig. 55d).

For sections of ocean coast in the Twofold Shelf bioregion, the Wallagoot-Pambula section had 6% of adjacent land in built-up areas and all other sections had virtually no built-up areas within 1 km of the ocean shore (Fig. 54b).

4.4.11 Acid Sulphate Soils

Data source

GIS maps of acid sulphate soils from the NSW Department of Land and Water Conservation[3].

Data description

Acid sulphate soil risk maps predict the distribution of acid soils based on an assessment of the geomorphic environment using 1:25 000 scale aerial photograph interpretation and field and laboratory soil analysis. Acid sulphate soils occur naturally and only become a threat when oxidised through exposure to the air. This occurs when either the water table is lowered artificially or sediments are excavated. Many estuaries in the Batemans and Twofold Shelf bioregions have acid sulphate soils present, but these sediments cause little harm while left undisturbed. The threat of acid release is related to inappropriate land use as well as the occurrence of the sediments themselves.

Criteria

Vulnerability.

Assessment measure

Percent of adjacent lands with high risk or disturbed acid sulphate soils within 1 km of each estuary.

Assessment

The Minnamurra River (47%), Werri Lagoon (41%), Crooked River (26%), Shoalhaven River (23%), Lake Brou (23%) and Currarong Creek (20%) had the most adjacent land with disturbed or high acid sulphate soils. All other estuaries had less than 20% of nearby land with disturbed or high risk acid sulphate soils (Fig. 57a).

[3] now within the NSW Department of Infrastructure, Planning and Natural Resources.

4.4.12 Australian River and Catchment Condition Database (ARCCD)

Data source

Australian Rivers and Catchment Condition Database (ARCCD). Stein *et al*. 2000. The Identification of Wild Rivers: Methodology and database development. Australian Heritage Commission.

Data description

GIS raster grids (with a cell size of 250 m) attributed with catchment and flow disturbance indices calculated from a wide range of distance weighted, topographic features (e.g. land use, roads, mines, weirs, pollution sources, vegetation etc.)

Criteria

Naturalness (condition) and vulnerability.

Assessment measures

Area weighted averages of grid values for lands within 1 km of each estuary and within 5 km of each section of exposed coast.

Assessment

Mean total river disturbance (RDI) :

- Mean RDI was highest for the Shoalhaven River (0.23), Crooked River (0.24), Killalea Lagoon (0.19), Minnamurra River (0.18), Tilba Tilba Lake (0.16) and relatively low for most other estuaries (Fig. 57b).
- For sections of ocean coast, mean RDI was highest for the Shellharbour-Crooked and Crooked-Wollumboola sections (Fig. 59a).

Mean Catchment disturbance (CDI) :

- Mean CDI was highest for the Crooked River, Killalea Lagoon, Tilba Tilba Lake, Middle Lagoon, Minnamurra River, Werri Lagoon and Ulladulla Harbour (Fig. 57b).
- For sections of ocean coast, mean CDI was highest for Shellharbour-Crooked, Crooked-Wollumboola, Conjola-Burrill, Wagonga-Wallaga, Moruya-Tuross and Wagonga-Wallaga (Fig. 59c).

Mean flow disturbance (FDI):

- Mean FDI was highest for the Shoalhaven River (0.45), Minnamurra River (0.1), Little Lake (0.10), Bega River (0.08) and Crooked River (0.07; Fig. 57c).
- Mean FDI was not reported for sections of ocean coast, as this measure was more relevant to rivers and estuaries.

Mean settlement factor (SF):

- Mean SF was highest for St Georges Basin (0.09), Ulladulla Harbour (0.07), Burrill L. (0.07), Crooked R. (0.07), Shoalhaven R. (0.06) and Killalea Lagoon (0.05) (Fig. 58a).
- For sections of ocean coast, mean SF was highest for Shellharbour-Crooked, Crooked-Wollumboola, Conjola-Burrill and Jervis-Swan (Fig. 59c).

Mean land use factor (LUF):

- Mean LUF was highest for Killalea Lagoon, Crooked River, Tilba Tilba Lake, and Werri Lagoon (Fig. 58b).
- For sections of ocean coast, mean LUF was highest for Shellharbour-Crooked, Crooked-Wollumboola, Conjola-Burrill, Moruya-Tuross and Wagonga-Wallaga (Fig. 60a).

Mean infrastructure factor (IF)

- Mean IF highest for Werri Lagoon, Crooked River and Durras Lake (Fig. 58c).
- For ocean coast, mean IF was highest for the Shellharbour-Crooked section (Fig. 60).

Mean extractive industry/pollution point source factor (EF):

- Mean EF was highest for Mummuga Lake, Kianga Lake, Lake Wollumboola and Lake Brou (Fig. 58d).
- For sections of ocean coast, mean EF was highest for Tuross-Wagonga and Crooked Wollumboola (Fig. 60).

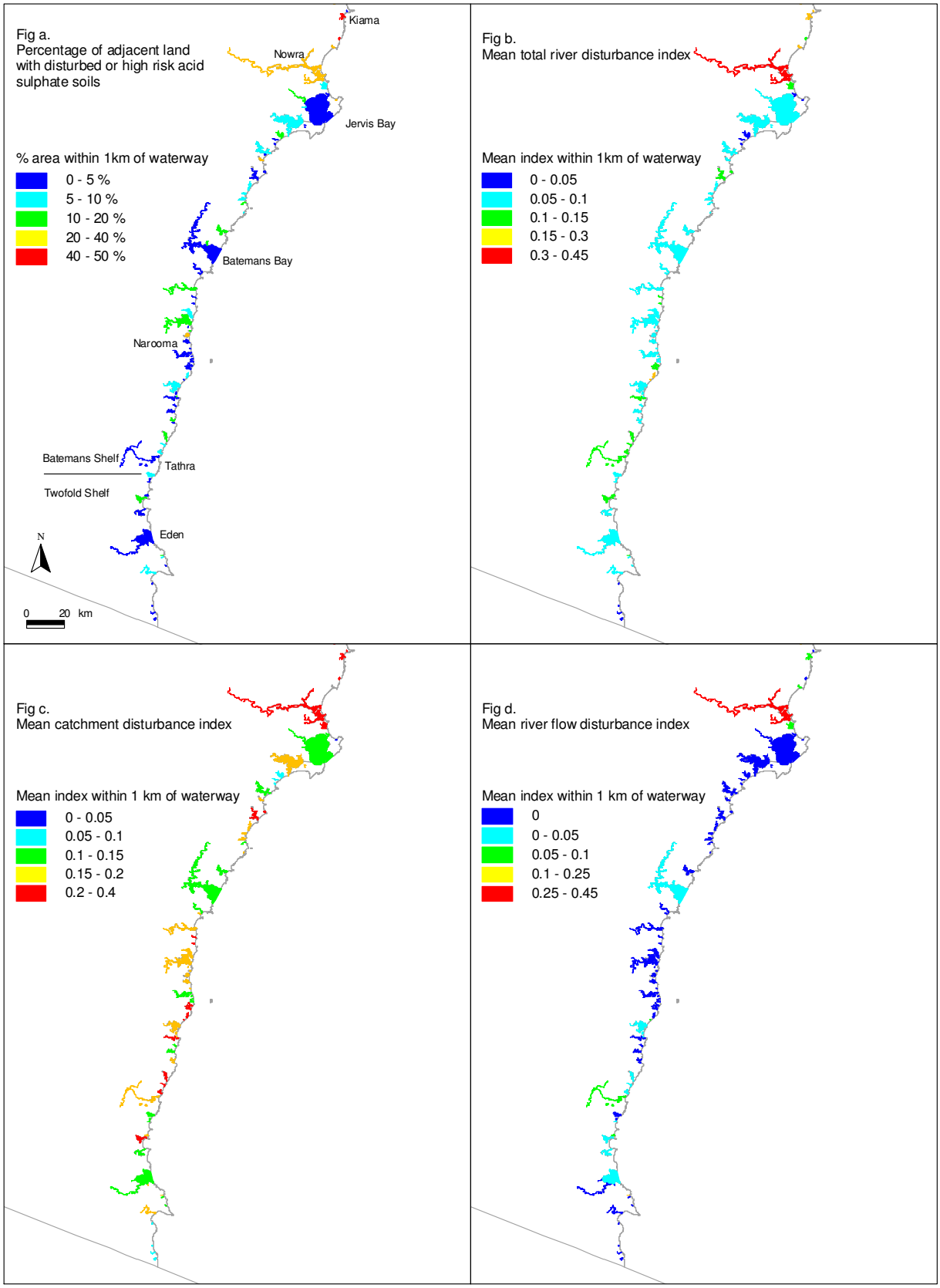


Fig. 57. Percentage area of lands within 1 km of estuaries with disturbed or high risk acid sulphate soils and mean Australian River and Catchment Condition Indices for estuaries in the Batemans Shelf and Twofold Shelf bioregions.

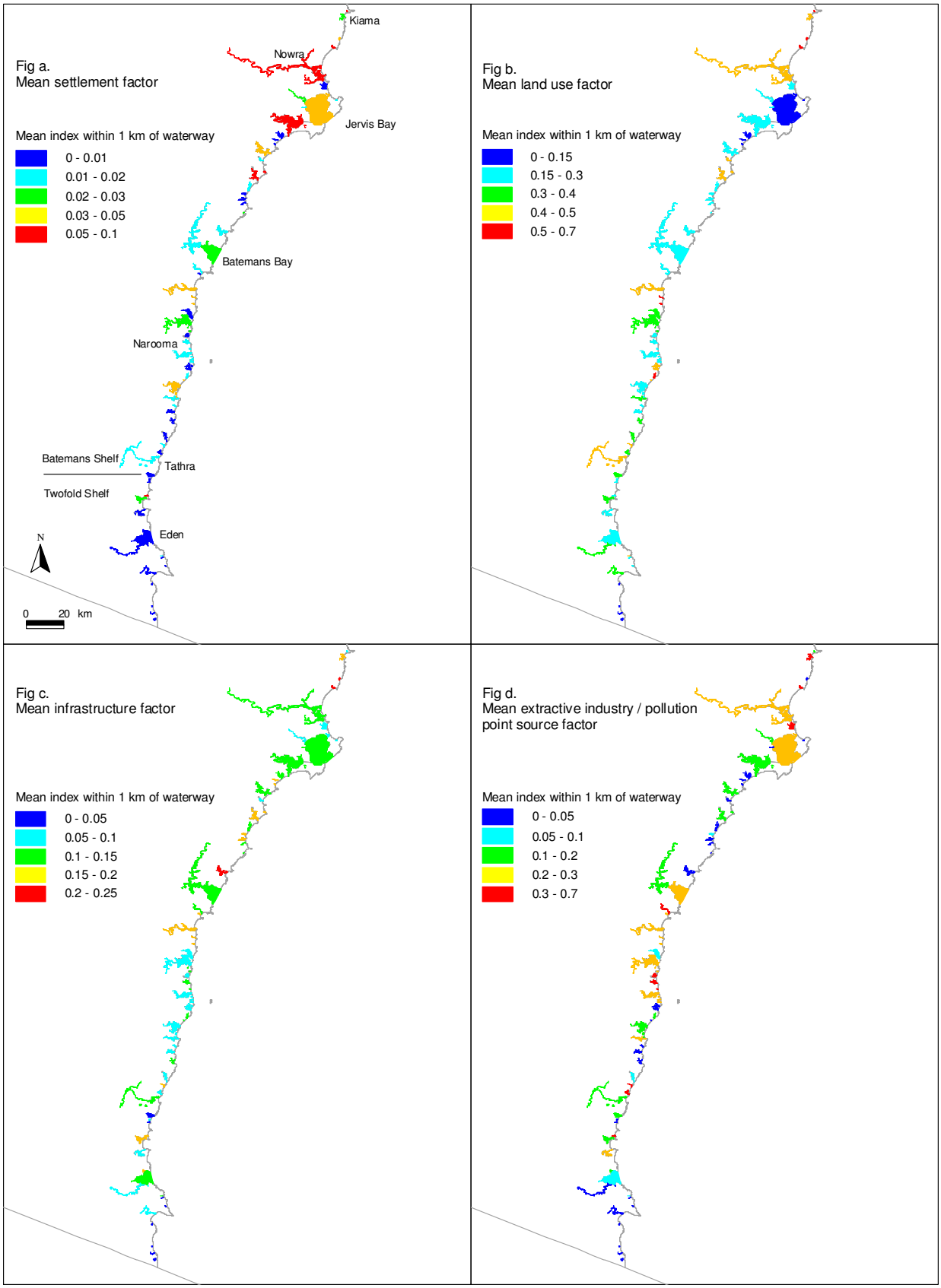


Fig. 58. Mean Australian River and Catchment Condition Indices (continued) for estuaries in the Batemans Shelf and Twofold Shelf bioregions.

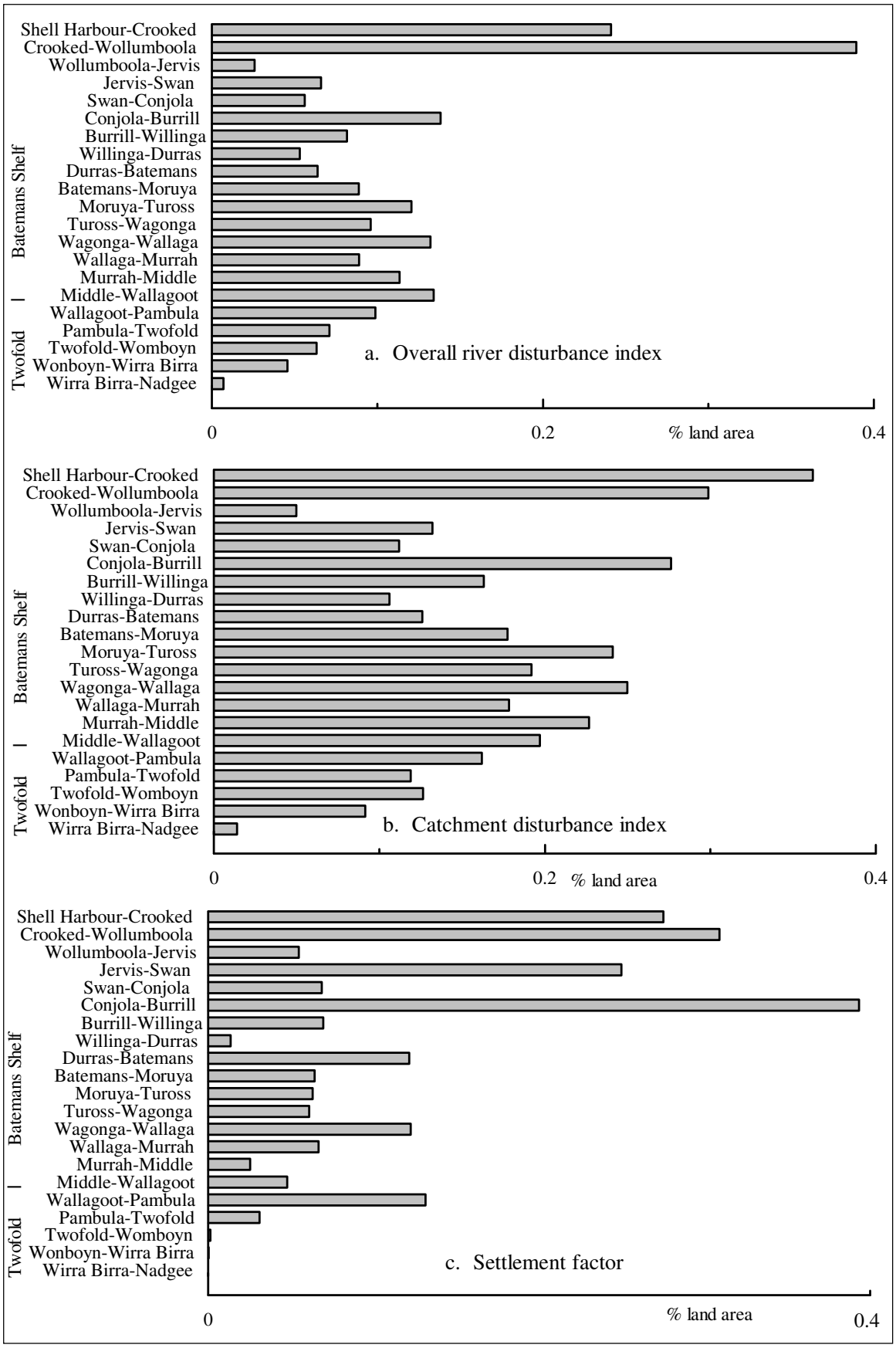


Fig. 59. Mean Australian River and Catchment Condition indices within 5 km of coast for overall river disturbance, catchment disturbance and settlement for the Batemans Shelf and Twofold Shelf bioregions.

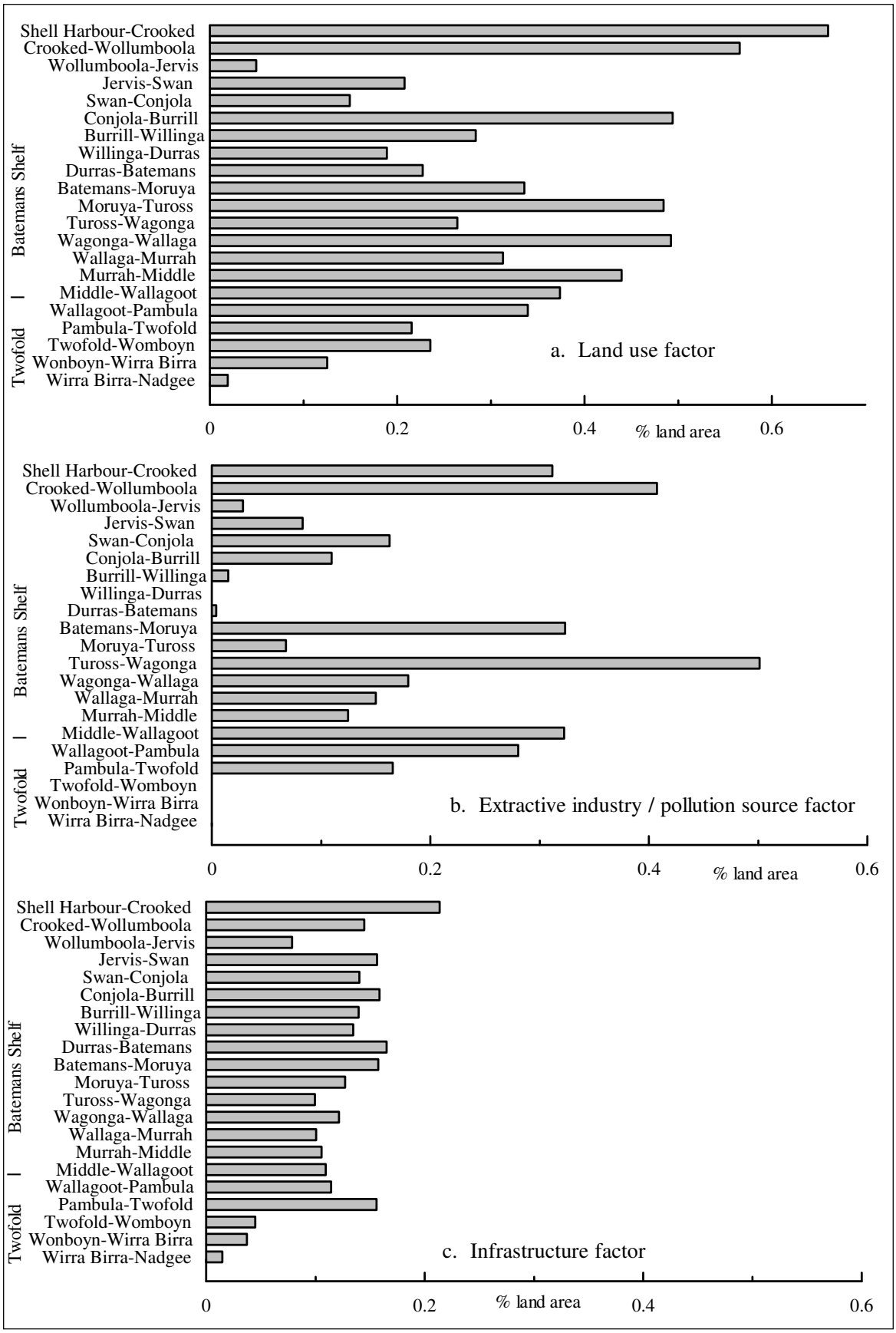


Fig. 60. Mean Australian River and Catchment Condition indices within 5 km of coast for land use, extractive industries and pollution, and infrastructure for the Batemans Shelf and Twofold Shelf bioregions.

4.5 MPAs in the Victorian and Tasmanian sections of the Twofold Shelf bioregion

Data source

Department of Sustainability and Environment, Victoria.
Tasmanian Department of Primary Industry, Water and the Environment.

Data description

The locations and extent of Marine National Parks and Marine Sanctuaries in Victoria and Marine Reserves in the Tasmanian section of the Twofold Shelf bioregion.

Assessment

In 2002, Victoria established a system of 13 marine national parks and 11 marine sanctuaries which cover approximately 540 km^2 or 5.3 per cent of Victoria's marine waters. In all of these MPAs, marine life is protected from extractive use such as fishing.

The Victorian section of the Twofold Shelf bioregion includes three marine national parks and one marine sanctuary (Fig. 61 - Fig. 65). These include sections of rocky coast, ocean beaches and offshore reef and sand but no estuarine ecosystems or habitats from the Twofold Shelf bioregion. The Cape Howe Marine National Park extends up the NSW border and out to the 3 nm limit to State waters.

Tasmania has marine reserves at Governor Island (50 ha), Maria Island (1,500 ha), Ninepin Point (60 ha), Tinderbox (45 ha) and Macquarie Island (74,715 ha). In February 2004, two new marine reserves were announced at Port Davey/Bathurst Harbour (17,000 ha) and the Kent Group of islands (29,000 ha).

The MPA in the Kent Group of islands is located in the eastern Bass Strait area of the Twofold Shelf bioregion. The reserve is a multiple-use MPA with a sanctuary (no-take) zone around the western section of the island group (Fig. 66). The islands are reported to be unusually rich in fish species having the highest diversity in Tasmania. They are subject to a range of influences including the warm East Australian Current coming from New South Wales and the westerly influence of Bass Strait.

Fig. 61. Victorian Marine National Parks – (11,12 & 13 are in Twofold Shelf bioregion).

1. Discovery Bay
2. Twelve Apostles
3. Point Addis
4. Port Phillip Heads
5,6,7. Western Port Bay
8. Bunurong
9. Wilson's Promontory
10. Corner Inlet
11. Ninety Mile Beach
12. Point Hicks
13. Cape Howe

(Victorian Department of Sustainability and Environment).

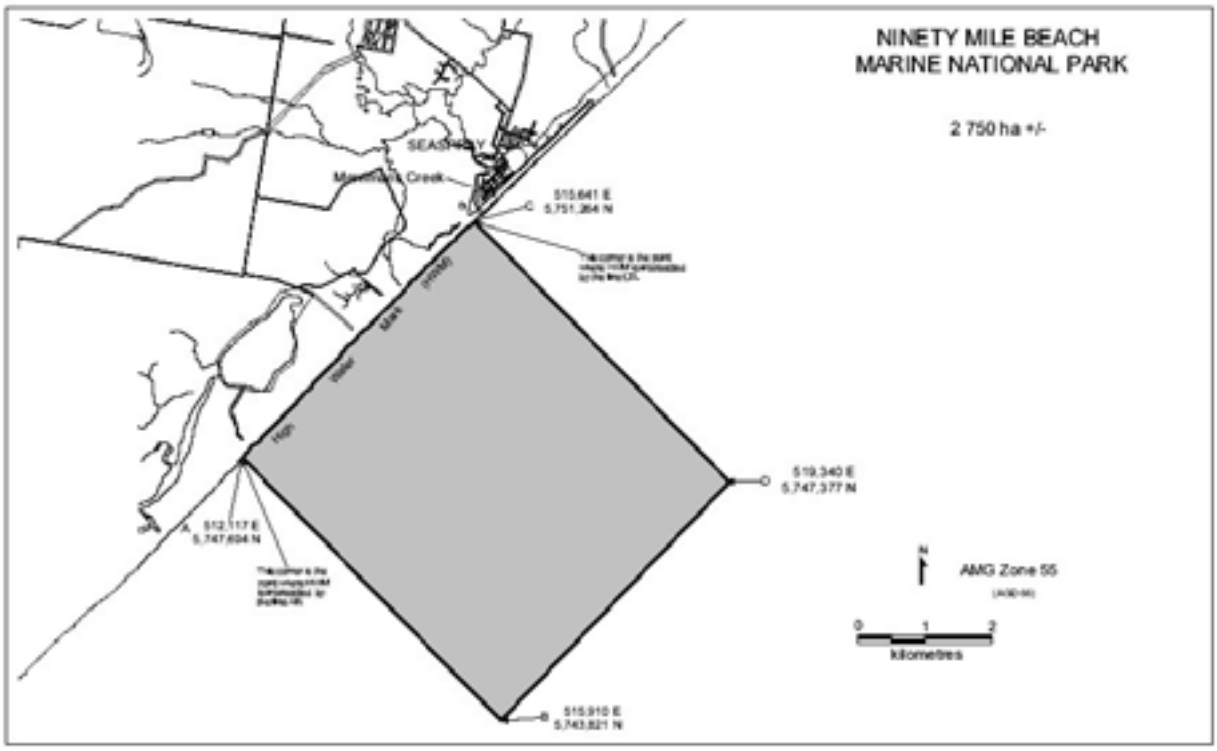


Fig. 62. The Ninety Mile Beach Marine National Park in the Twofold Shelf bioregion, Victoria (Victorian Department of Sustainability and Environment).

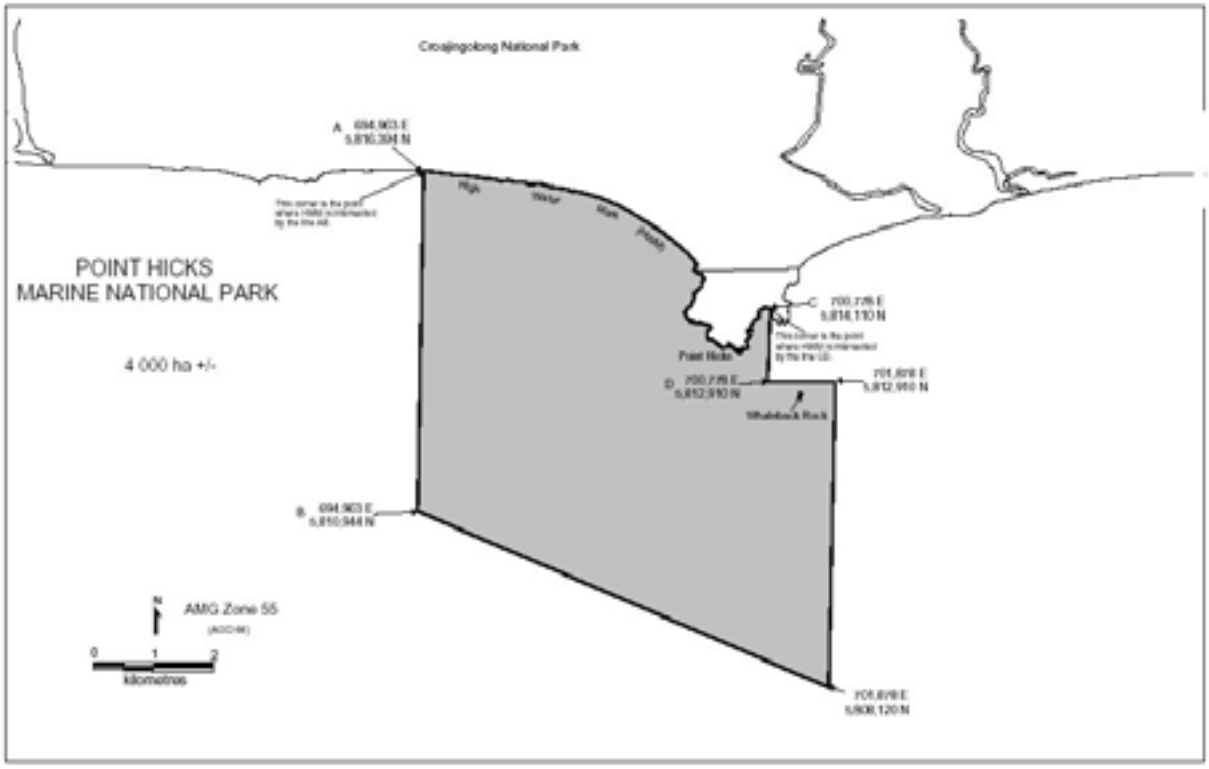


Fig. 63. The Point Hicks Marine National Park in the Twofold Shelf bioregion, Victoria (Victorian Department of Sustainability and Environment).

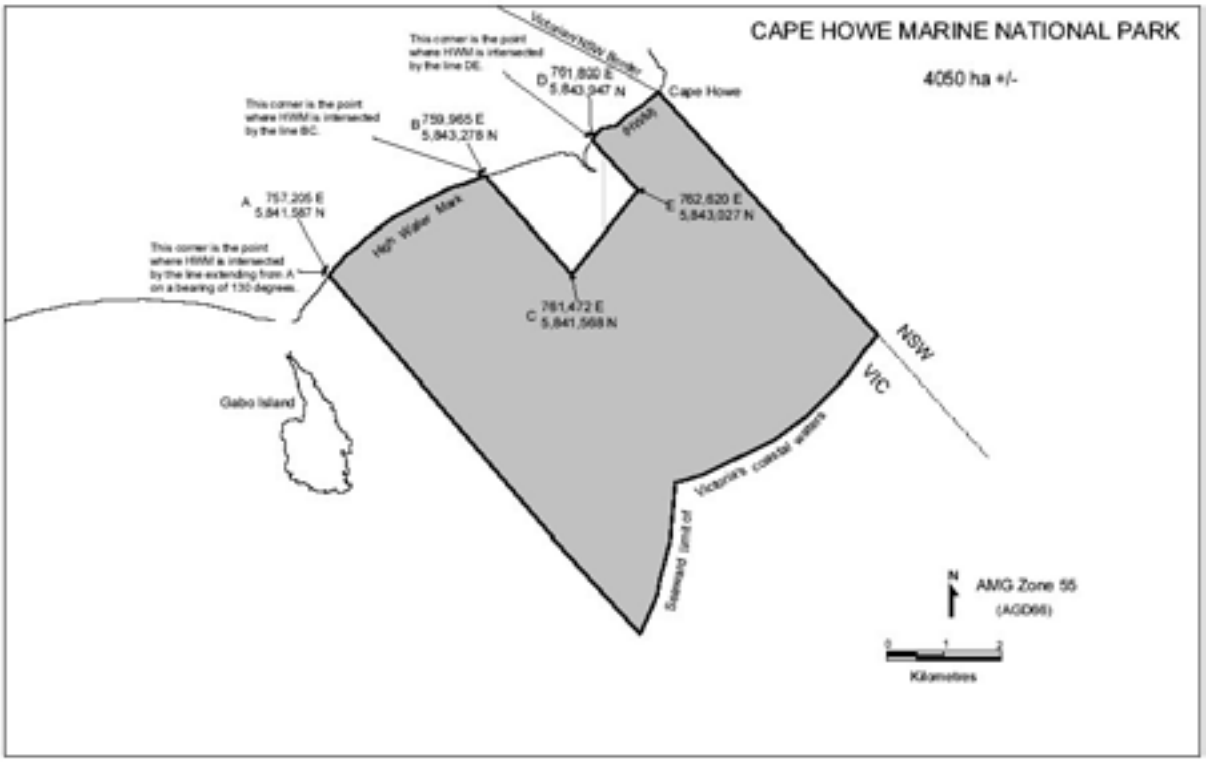


Fig. 64. The Cape Howe Marine National Park in the Twofold Shelf bioregion, Victoria (Victorian Department of Sustainability and Environment).

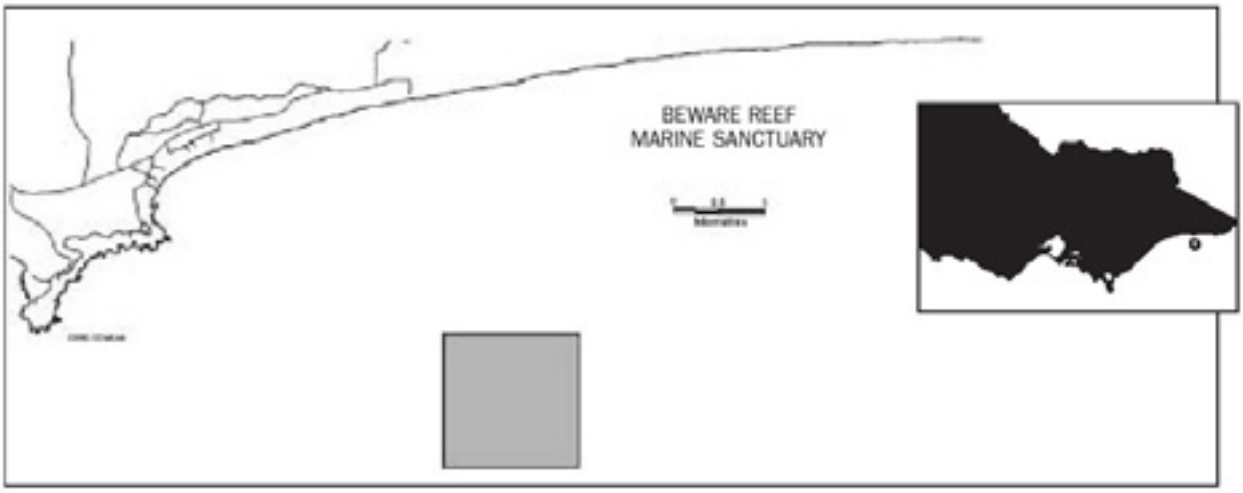


Fig. 65. The Beware Reef Marine Sanctuary in the Twofold Shelf bioregion, Victoria (Victorian Department of Sustainability and Environment).

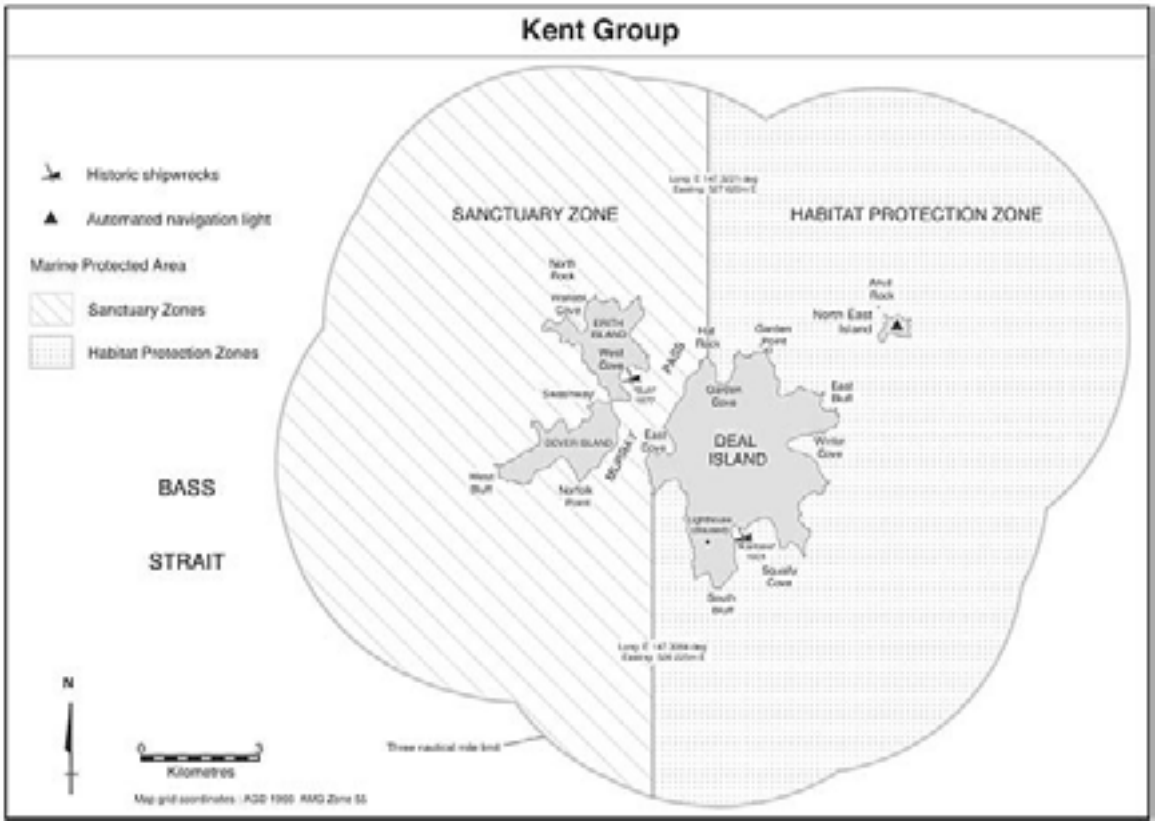


Fig. 66. The Kent Group multiple-use marine reserve in the Twofold Shelf bioregion, Tasmania (Tasmanian Department of Primary Industry, Water and the Environment 2004).

5 Areas with important biodiversity values

Analysis of available data utilising methods described in Chapter 3 has allowed the determination of areas with the potential for incorporation into a system of marine protected areas within the Batemans Shelf and Twofold Shelf marine bioregions. Specific locations and biodiversity values that might be included in a system of MPAs are described below for the northern and southern parts of the Batemans Shelf bioregion and for the Twofold Shelf bioregion. Developing a system of MPAs would allow representation of geographic variation in biodiversity throughout these bioregions.

The primary ecological identification criteria for important areas used in this study were comprehensiveness, representativeness and adequacy of management. The areas listed below contribute significantly to meeting criteria for comprehensiveness and representativeness for most mapped ecosystems, habitats and species. According to the environmental classification used, this means representation of each of the four major estuarine ecosystems, the four ocean ecosystems classified by depth, and the nine habitat surrogates (mangrove, seagrass, saltmarsh, subtidal sediment, beach, intertidal rocky shore, subtidal reef and island) within areas that can be effectively managed for the conservation of biodiversity.

Areas with important biodiversity values were identified using:

- national criteria for the identification of MPAs;
- a broadscale atlas of NSW marine ecosystems and habitats;
- existing broadscale scientific surveys of habitats, communities and species;
- existing data, maps, aerial photographs, literature and conservation assessments;
- new data coverages and analyses generated for this study;
- ecological guidelines for reserve design; and,
- discussions with scientists, managers and the community.

5.1 Batemans Shelf – Northern section

The northern section of the Batemans Shelf bioregion includes coastal waters and estuaries between Shellharbour and Ulladulla. The northern section of the Batemans Shelf bioregion does not include any tide dominated, drowned river valley, estuary ecosystems.

Some areas of coast and estuary in the northern section of the Batemans Shelf bioregion are protected in Comerong Island Nature Reserve and Jervis Bay and Seven Mile Beach National Parks. However, the aquatic components of these reserves do not have direct protection for fish or aquatic invertebrates from fishing. Some areas in the northern part of this area of coast are vulnerable to urban and industrial development.

Jervis Bay Marine Park includes some of the most important areas in the Batemans Shelf bioregion for marine biodiversity. All estuarine ecosystem types, except tide dominated drowned river valley, and extensive examples of estuarine habitats are represented in Jervis Bay Marine Park. However, the Batemans Shelf bioregion contains large areas of barrier estuary, intermittent lagoon, deeper ocean ecosystems and mangrove and saltmarsh habitats that are not well represented in Jervis Bay Marine Park.

Jervis Bay, the Shoalhaven River and the coast between Shellharbour and Lake Wollumboola scored highly in summed irreplaceability analyses (Chapter 4) as they include habitats and ecosystems not readily found elsewhere in the Batemans Shelf bioregion.

Areas with important biodiversity values identified in this section of the bioregion are listed following:

- ***Bass Point***, an aggregation site and declared critical habitat for the endangered Grey Nurse Shark. The site was previously proposed as a candidate for an Aquatic Reserve and is listed on the Register of the National Estate.

  The Bass Point area includes relatively undisturbed examples of high diversity, fringing reef, intertidal pool and boulder field communities with soft corals, gorgonian sea fans, sponge gardens and many crustacean, mollusc and cnidarian species not commonly found in the Illawarra region (Commonwealth of Australia, 2003).

  The protected Bleeker's Devilfish (*Paraplesiops bleekeri*), Black Rock Cod (*Epinephelus daemelii*) and Elegant Wrasse (*Anampses elegans*) and 151 other fish species have been recorded from this area, a higher number than found at similar sites (Commonwealth of Australia, 2003). At least seventeen rare or uncommon fish species occur in the area, as well as a rare zoanthid, two rare coral species, a rare sea pen, eight rare or uncommon molluscs, four rare crustaceans, two rare sea spiders, four rare echinoderms and two rare or uncommon ascidians. The broach shell (*Trigonia strangeii*) and the sand dollar (*Clypeaster tumidus*) are also thought to occur here (Commonwealth of Australia, 2003).

- ***Bushrangers Bay*** is an aquatic reserve listed on the Register of the National Estate. This small, rocky, semi-enclosed oceanic bay includes boulder, reef and sand habitats, an area of *Posidonia australis*, and a diverse fish and invertebrate faunal assembly including cuttlefish, sea dragons, nudibranchs, leather jackets, bream, yellowtail, bullseyes, stingrays, squid, octopus, morwongs, blue groper, starfish, feather stars, hawkfish, catfish, moray eels and nudibranchs. Beyond the entrance to the Bay there are also sponge gardens and soft corals (Commonwealth of Australia, 2003).

- ***Killalea Lagoon*** is listed in the Directory of Important Wetlands and provides breeding habitat for large numbers of Black Swans and vulnerable species including Pied Oystercatcher (*Haematopus longirostris*), Comb-crested Jacana (*Irediparra gallinacea*), Blue-billed Duck (*Oxyura australis*) and Australasian Bittern (*Botaurus poiciloptilus*) (ANCA, 1996).

  Species listed under JAMBA or CAMBA and found here include the Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), Glossy Ibis (*Plegadis falcinellus*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red-necked Stint (*Calidris ruficollis*), Latham's Snipe (*Gallinago hardwickii*), Bar-tailed Godwit (*Limosa lapponica*), Common Greenshank (*Tringa nebularia*), Marsh Sandpiper (*Tringa stagnatilis*), Wood Sandpiper (*Tringa glareola*), Common Sandpiper (*Actitis hypoleucos*), Curlew Sandpiper (*Calidris ferruginea*), Crested Tern (*Sterna bergii*) and Caspian Tern (*Sterna caspia*). Other waterbird species include Pied Cormorant (*Phalacrocorax varius*), Little Black Cormorant (*Phalacrocorax sulcirostris*), Pelicans and Black Duck (*Anas superciliousa*) (References in the ANCA 1996). The area also provides habitat for the endangered Green and Golden Bell Frog (*Litoria aurea*) (ANCA, 1996).

- The ***Minnamurra River*** is an important wetland with significant mangrove and saltmarsh communities supporting vulnerable bird species and 7 JAMBA/CAMBA species. The river has Grey Mangrove (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*) with saltmarsh, *Casuarina* forests and rushes in tidal areas. Saltmarsh species include Samphire (*Sarcocornia quinqueflora*), Salt Couch (*Sporobolus virginicus*) and pigface. The floodplain area is crossed by a number of creeks that support fringes of mangroves. Species present also include Swamp She-oak (*Casuarina glauca*), Northern Boobialla (*Myoporum acuminatum*), Salt Rush (*Juncus kraussii*), Club Rush (*Isolepis nodosa*), Seablite (*Suaeda australis*), Salt Couch (*Sporobolus virginicus*), Streaked Arrowgrass (*Triglochin striata*) and Creeping Brookweed (*Samolus repens*) (ANCA, 1996).

Bird species listed as threatened include the Australasian Bittern (*Botaurus poiciloptilus*), Comb-crested Jacana (*Irediparra gallinacea*), Sooty Oystercatcher (*Haematopus fuliginosus*) and the Black Bittern (*Ixobrychus flavicollis*) (ANCA, 1996).

Birds listed under JAMBA or CAMBA and occurring at this location include the Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), Glossy Ibis (*Plegadis falcinellus*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Whimbrel (*Numenius phaeopus*), Crested Tern (*Sterna bergii*) and Caspian Tern (*Sterna caspia*) (ANCA, 1996).

- ***Bombo Head*** has previously been proposed as an aquatic reserve (NSW Fisheries, 2001) and is listed on the Register of the National Estate for its geological significance. Penguin Head at Culburra, Black Head at Gerroa, and the Kiama Blowhole and Little Blowhole are geological sites also listed on the Register of the National Estate.
- The ***Shoalhaven River*** is the second largest wave dominated barrier estuary in the bioregion with the largest area of mangrove habitat, the second largest area of saltmarsh in the bioregion and the highest summed irreplaceability score for estuarine ecosystems and habitats.

  The river includes important habitat for Australian bass and the Australian grayling and was identified as a third priority candidate aquatic reserve in a previous assessment (NSW Fisheries, 2001).

  The lower estuary is listed in the Directory of Important Wetlands. Wetland plants include River Mangrove (*Aegiceras corniculatum*), Sea Rush (*Juncus kraussii*), *Juncus polyanthemus*, Common Reed (*Phragmites australis*), Swamp Oak (*Casuarina glauca*), Samphire (*Sarcocornia quinqueflora*), Salt couch (*Sporobolus virginicus)*, Seablite (*Suaeda australis*), Goosefoot (*Chenopodium glaucum*) and New Zealand Spinach (*Tetragonia tetragonioides*). The largest remaining area of littoral rainforest on the south coast occurs on the south- western side of Comerong Island (ANCA, 1996).

  This estuary is one of five coastal wetlands considered to be the second most important for shorebirds on the NSW coast. It supports the endangered Little Tern (*Sterna albifrons*), Beach Thick-knee (*Esacus neglectus*) and Hooded Plover (*Thinornis rubricollis*), and vulnerable species including the Mongolian Plover (*Charadrius mongolus*), Large Sand Plover (*Charadrius leschenaultii*), Sooty Oystercatcher (*Haematopus fuliginosus*), Pied Oystercatcher (*Haematopus longirostris*), Terek Sandpiper (*Xenus cinereus*), Broad-billed Sandpiper (*Limicola falcinellus*), Great Knot (*Calidris tenuirostris*), Black-tailed Godwit (*Limosa limosa*) and Osprey (*Pandion haliaetus*).

  Species found here and listed under JAMBA or CAMBA include the Wedge-tailed Shearwater (*Puffinus pacificus*), Short-tailed Shearwater (*Puffinus tenuirostris*), Cattle Egret (*Ardea ibis*), Great Egret (*Ardea alba*), Grey Plover (*Pluvialis squatarola*), Lesser Golden Plover (*Pluvialis dominica*), Ruddy Turnstone (*Arenareia interpres*), Eastern Curlew (*Numenius madagascariensis*), Whimbrel (*Numenius phaeopus*), Grey-tailed Tattler (*Tringa brevipes*), Common Sandpiper (*Tringa hypoleucos*), Greenshank (*Tringa nebularia*), Marsh Sandpiper (*Tringa stagnatilis*), Latham's Snipe (*Gallinago hardwickii*), Asian Dowitcher (*Limnodromus semipalmatus*), Bar-tailed Godwit (*Limosa lapponica*), Red Knot (*Calidris canutus*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red-necked Stint (*Calidris ruficollis*), Long-toed Stint (*Calidris subminuta*), Curlew Sandpiper (*Calidris ferruginea*), Sanderling (*Calidris alba*), White-winged Tern (*Chlidonias leucoptera*), Caspian Tern (*Sterna caspia*), Common Tern (*Sterna hirundo*) and Crested Tern (*Sterna bergii*). The endangered Green and Golden Bell Frog (*Litoria aurea*) has also been found here (ANCA, 1996).

  Many parts of the Shoalhaven River are in relatively good condition. However, Tallowa Dam obstructs 80% of the catchment and there are many other obstructions to fish passage within the catchment. Inappropriate land use and increasing urban development in the lower parts of

the river have also caused oxidation of acid sulphate soils, bank erosion and loss of wetlands (Healthy Rivers Commission, 1999).

- ***Lake Wollumboola*** is the largest intermittent estuary in the bioregion and a first priority candidate in a previous assessment for potential aquatic reserve establishment (NSW Fisheries 2001). The lake is part of Jervis Bay National Park. It is the fourth largest, and second most successful, nesting area for the endangered Little Tern in NSW. It supports 11 threatened bird species, at least 24 JAMBA/CAMBA species and is listed in the Directory of Important Wetlands.

  The lake includes beds of seagrass and the surrounding wetlands include Casuarina forest, teatree, saltmarsh and sedgelands, containing species including Common Reed (*Phragmites australis*), Salt Rush (*Juncus kraussii*), Sedge (*Baumea juncea), Wilsonia rotundifolia*, Samphire (*Sarcocornia quinqueflora*), Paperbark (*Melaleuca* sp.) and Swamp She-oak (*Casuarina glauca*) (ANCA, 1996).

  The lake is important as feeding habitat for Black Swans and Chestnut Teal and supports vulnerable bird species including the Little Shearwater (*Puffinus assimilus*), Broad-billed Sandpiper (*Limicola falcinellus*) and Lesser Sand Plover (*Charadrius mongolus*) (ANCA, 1996).

  Species listed under JAMBA or CAMBA and known to inhabit the area include the Bar-tailed Godwit (*Limosa lapponica*), Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Latham's Snipe (*Gallinago hardwickii*), Common Greenshank (*Tringa nebularia*), Grey Plover (*Pluvialis squatarola*), White-winged Black Tern (*Chlidonias leucopterus*), Crested Tern (*Sterna bergii*) and Caspian Tern (*Sterna caspia*) (ANCA, 1996). Pollard (in ANCA, 1996) recorded 41 fish species from the lake of which 26 were of commercial importance.

- ***Jervis Bay*** is the largest ocean embayment with the largest area of seagrass in the bioregion. Jervis Bay, its associated wetlands and the Jervis Bay Sea Cliffs are listed in the Directory of Important Wetlands and the Register of the National Estate. The area includes a very wide diversity of habitats including tidal, intertidal and estuarine wetlands, freshwater lagoons, swamp, saltmarsh, sedgeland, sheltered and exposed rocky shores, beaches, reef, subtidal sediments and non-tidal forested wetlands (ANCA, 1996).

  Jervis Bay has extensive beds of *Zostera* and *Halophila* seagrasses and the largest beds of *Posidonia australis* in NSW. Jervis Bay also includes areas of the seagrasses *Heterozostera tasmanica* and *Zostera muelleri*, both uncommon in NSW. Mangrove species include Grey Mangrove (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*). Saltmarsh species include *Sarcocornia quinqueflora*, *Wilsonia backhousei*, and *Sporobolus virginicus*. The saltmarsh on the cliff tops of Bowen Island is unique in that it receives its moisture from sea spray (ANCA, 1996).

  Bowen Island supports a colony of Little Penguins, three shearwater species and sea eagles. The rare Pied Oystercatcher (*Haematopus longirostris*) nests near the bay and 27 wader species, 17 of which are listed under JAMBA or CAMBA use the area. The endangered Green and Golden Bell frog (*Litoria aurea*) is found on Bowen Island and in the northern part of the Jervis Bay area (ANCA, 1996).

  The sea cliffs on the Beecroft and Bherwerre Peninsulas are some of the tallest on the NSW coast and include incised inlets such as Eves Ravine and Devils Inlet, islets like the Drum and Drum Sticks and marine caves, overhangs, tunnels and crevices.

5.2 Batemans Shelf – Southern section

The southern section of the Batemans Shelf bioregion includes coastal waters and estuaries between Ulladulla and Tathra.

This section of coast includes many seabird breeding islands and diverse and abundant breeding seabirds. The Middle-Wallagoot section of ocean coast includes the largest area of islands between Bega and Victoria. Between 40 and 75% of the ocean coast and most islands in the section of coast between Termeil Lake and Durras Lake are within national parks boundaries. Approximately 75% of the ocean coast between Durras Lake and Batemans Bay is included in national park but there has been significant development at a number of urban centres in this area. Approximately 30% of the coast between Tuross Lake and Wagonga Inlet and over 60% of the ocean coast between Middle and Wallagoot Lakes is included in national park. Most of Middle and Nelson Lagoons are surrounded by national park. However, the aquatic components of national parks and nature reserves do not have direct protection for fish or aquatic invertebrates from fishing.

The Tuross, Clyde and Moruya Rivers and the coast and ocean between Wagonga and Wallaga Lakes, and that between Willinga and Durras Lakes, score very highly in summed irreplaceability analyses (Chapter 4) as these areas include ecosystems and habitats not readily found in other parts of the bioregion.

Areas with important biodiversity values identified in this section of the bioregion are listed following:

- ***Termeil, Meroo and Durras Lakes*** are intermittent estuaries with near pristine catchments and are protected in national parks. The Coastal Lakes Inquiry recommended these lakes for comprehensive protection.
- The ***Willinga-Durras*** section of ocean coast has some of the largest areas of inshore reef and island habitat and includes significant offshore habitats and had the second highest summed irreplaceability score for ocean ecosystems and habitats.
- ***Durras Lake*** is the fifth largest intermittent estuary in the bioregion. The Lake was previously proposed as a candidate for an estuarine aquatic reserve (NSW Fisheries, 2001) and is part of Murramarang National Park. It is listed in the Directory of Important Wetlands and the adjoining swamp and forest is listed in the Register of the National Estate. The Lake has extensive seagrass beds of *Zostera capricorni*, with Swamp She-oak forest (*Casuarina glauca*), sedge, Sea Rush (*Juncus krausii*), Bare Twig-rush (*Baumea juncea*) and Spotted Gum (*Eucalyptus maculata*) forest surrounding most of the lake.

  Endangered species known to occur within this area include the Hooded Plover (*Thinornis rubricollis*) and vulnerable species include the Little Shearwater (*Puffinus assimilus*), Flesh-footed Shearwater (*Puffinus carneipes*), Shy Albatross (*Diomedea cauta*), Black-browed Albatross (*Diomedea chlororhynchos*), Osprey (*Pandion haliaetus*), Sooty Oystercatcher (*Haematopus fuliginosus*), Pied Oystercatcher (*Haematopus longirostris*), Greater Sand Plover (*Charadrius leschenaultii*), Sooty Tern (*Sterna fusca*) and Black Bittern (*Ixobrychus flavicollis*) (ANCA, 1996).

  Species listed under JAMBA or CAMBA and known to occur in the area include the Short-tailed Shearwater (*Puffinus tenuirostris*), Great Egret (*Ardea alba*), Eastern Reef Egret (*Egretta sacra*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red Knot (*Calidris canutus*), Red-necked Stint (*Calidris ruficollis*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Crested Tern (*Sterna bergii*), Caspian Tern (*Sterna caspia*) and Common Tern (*Sterna hirundo*) (ANCA, 1996).

- The ***Clyde River*** is the only tide dominated, drowned river valley in the bioregion. The estuary includes the second largest area of mangrove habitat in the bioregion and contains large areas of saltmarsh. It has the second highest summed irreplaceability score for estuarine ecosystems and habitats for the bioregion (after the Shoalhaven). Much of the river's catchment and shores are within National Park and State Forest and it is listed in the Directory of Important Wetlands and the Register of the National Estate.

  The Clyde River is "important in the evolution of Australia's fauna and flora as a complete ecosystem relatively untouched by human habitation". Approximately 95% of the catchment of the Clyde River is uncleared and it may be the "only river left on the NSW coast that flows uninterrupted from its source to the sea" (Commonwealth of Australia, 2003).

  Native fish species found in the river include gudgeons (*Hypseleotris*), Australian smelt (*Retropinna semoni*), eels, bullrouts, Australian bass (*Macquarie novemaculeata*) and Australian grayling (*Prototroctes maraena*). Three endangered fish species have been recorded from the river. The river also provides potential habitat for migratory waders, but this aspect is poorly studied. Vulnerable waterbird species found in the estuary include the Sooty Oystercatcher (*Haematopus fuliginosus*).

- ***Cullendulla Creek Embayment*,** a drowned creek gully on the Clyde River, is listed in the Directory of Important Wetlands and the Register of the National Estate and is within a Nature Reserve. The beach chenier here is uncommon in NSW and provides a record of shoreline trends during the Holocene (from 10 000 years ago). The embayment is a good example of a low energy beach ridge and mud flats in an enclosed bay (ANCA, 1996). *Limonium australe* occurs in the saltmarsh and probably the largest population of this species in NSW occurs at this site. The White-bellied Sea-Eagle (*Haliaeetus leucogaster*), listed under CAMBA, also occurs here.

- ***Batemans Bay*** is the second largest ocean embayment in the bioregion after Jervis Bay. The bay includes offshore island and reef habitats and an important aggregation site declared as critical habitat for the endangered Grey Nurse Shark (*Carcharias taurus*). At the Tollgate Islands, sharks have been observed during 90% of surveys in numbers representing 8.9% of the observed NSW population and 15.4% of the observed female population. This site is the most important known aggregation site for female Grey Nurse Shark in NSW, and it is thought that females may be gestating at this site during summer and autumn. The Tollgate Islands is a Nature Reserve also containing a diversity of marine algae.

- The ***Moruya River*** is an example of a wave dominated barrier estuary with significant areas of saltmarsh. This site is listed in the Directory of Important Wetlands and the Register of the National Estate. The estuary includes a "number of extensive, modified salt and brackish marshes…all of conservation significance, and due to their variability, of considerable floristic interest (Adam, 1992, in ANCA, 1996).

  These diverse saltmarshes include Samphire (*Sarcocornia quinqueflora*), Seablite (*Suaeda australis*), Sea Rush (*Juncus krausii*), Streaked Arrowgrass (*Triglochin striata*), Native Sea Lavender (*Limonium australe*), Creeping Monkey-flower (*Mimulus repens*), scattered Chaffy Saw-sedge (*Gahnia filum*) and Saltbush (*Atriplex australasica*). The upper marsh includes species such as *Selliera radicans*, New Zealand Spinach (*Tetragonia tetragonioides*), *Leptinella longipes,* Sea Celery (*Apium prostratum*), Creeping Brookweed (*Samolus repens*) and Swamp She-oak (*Casuarina glauca*). Grey Mangrove (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*) grow on the channels draining the saltmarsh (ANCA, 1996).

  The endangered Wandering Albatross (*Diomedea exulans*) and Hooded Plover (*Thinornis rubricollis*), and the vulnerable Shy Albatross (*Diomedea cauta*), Black-browed Albatross (*Diomedea melanophrys*), Square-tailed Kite (*Lophoictinia isura*), Sanderling (*Calidris alba*),

Great Knot (*Calidris tenuirostris*), Black-tailed Godwit (*Limosa limosa*) and Pied Oystercatcher (*Haematopus longirostris*) are recorded from the estuary. Species listed under JAMBA or CAMBA and known to occur in the estuary include the Ruddy Turnstone (*Arenaria interpres*), Red Knot (*Calidris canutus*), Latham's Snipe (*Gallinago hardwickii*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Whimbrel (*Numenius phaeopus*) and Grey Plover (*Pluvialis squatarola*).

- ***Coila Lake*** is the largest intermittent estuary in the bioregion. Brunderee, Tarourga, Brou and Nargal Lakes are also intermittent estuaries located in this zone. These intermittent estuaries exhibit near pristine catchments and have been recommended for comprehensive protection by the Coastal Lakes Inquiry.
- ***Coila Creek Delta*** is listed in the Directory of Important Wetlands and has important areas of saltmarsh and includes Samphire (*Sarcocornia quinqueflora*), *Wilsonia rotundifolia*, Sea Rush (*Juncus krausii*), *Selliera radicans,* Creeping Monkey-flower (*Mimulus repens*) and Swamp She-oak (*Casuarina glauca*) forest. The large, healthy population of *Wilsonia rotundifolia* is near its northern extent and has high conservation significance (Adam, 1992, in ANCA, 1996). Algae, Seagrass (*Zostera* sp.), Sea Tassel (*Ruppia* sp.) and Sea Wrack (*Halophila* sp.) are also present adjoining the saltmarsh (ANCA, 1996). The vulnerable Pied Oystercatcher (*Haematopus longirostris*) has been recorded within the Lake area. Species listed under JAMBA or CAMBA and known to occur at this location include the Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*) and the Crested Tern (*Sterna bergii*) (ANCA, 1996).
- ***The Tuross River Estuary*** delta is listed in the Directory of Important Wetlands and provides a diversity of habitats along its extensive shoreline. The delta islands support a variety of plant and animal communities including mangroves (*Avicennia marina*), saltmarsh (*Sarcocornia quinqueflora*)*, Casuarina glauca* swamp forest, littoral rainforest, seagrasses (*Zostera sp.* and *Halophila sp.)* and sand and mud flats.

  The endangered Little Tern (*Sterna albifrons*) and Hooded Plover (*Thiornis rubricollis*) and the vulnerable Black-tailed Godwit (*Limosa limosa*), Pied Oystercatcher (*Haematopus longirostris*) and Lesser Sandplover (*Charadrius mongolus*) have been recorded from the estuary.

  Species listed under JAMBA or CAMBA and known to occur in the area include the Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Common Sandpiper (*Actitis hypoleucos*), Ruddy Turnstone (*Arenaria interpres*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red Knot (*Calidris canutus*), Curlew Sandpiper (*Calidris ferruginea*), Red-necked Stint (*Calidris ruficollis*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Whimbrel (*Numenius phaeopus*), Marsh Sandpiper (*Tringa stagnatilis*), White-winged Black Tern (*Chlidonias leucopterus*) and Crested Tern (*Sterna bergii*). Cormorant rookeries are also found in upper parts of the area (ANCA, 1996).
- ***Tuross Lake, Wallaga Lake and Wagonga Inlet*** are the largest wave dominated barrier estuaries in the Batemans Shelf bioregion after the Shoalhaven River and St. Georges Basin.
- ***Montague Island*** is the largest offshore island in NSW with the exception of Lord Howe Island. Montague Island is a Nature Reserve, and has been classified by the National Trust as a Landscape Conservation Area for its scenic, scientific and historical values. The island is a haul out site and feeding site for Australian fur seals. It is one of the most important sea bird breeding islands in NSW and the second largest breeding area in Australia for Little Penguins. The threatened Sooty Oystercatcher (*Haematopus fuliginosus*) breeds here and the Wandering Albatross (*Diomedea exulans*) and Fleshy-footed Shearwater (*Puffinus carneipes*) have been recorded on the island or in adjacent waters (NPWS, 1995). Montague Island is also important

for the high diversity and biogeographic significance of its marine algae (Millar, National Herbarium of New South Wales, pers. comm.).

Montague Island is an important aggregation site and area of critical habitat for the Grey Nurse Shark (*Carcharias taurus*). Sharks aggregate mainly at the northern tip of the island but also at three sites on the western side of the island. Sharks were observed during 20% of surveys in numbers representing 1.3% of the total observed NSW population. Most sharks surveyed here were females and a number of these may have been pregnant.

- The ***Wagonga-Wallaga*** section of ocean coast includes the largest area of rocky intertidal shore and offshore islands in the bioregion, and the second largest area of offshore reef in the bioregion. Wagonga Head was proposed as an aquatic reserve in a previous assessment of intertidal rocky shores (NSW Fisheries, 2001). The shore is also a significant fossil site listed in the Register of the National Estate.
- ***Nargal Lake*** is listed in the Directory of Important Wetlands and is one of the few dune-swale freshwater lakes in the region (along with Bondi Lake). The shoreline includes small areas of Swamp She-oak (*Casuarina glauca*) forest and sedgelands of Spike-rush (*Eleocharis sp.*) that provide shelter for waterbirds including Musk Duck (*Biziura lobata*) and breeding areas for Black Swan (*Cygnus atratus*). A herbfield of *Selliera radicans* and other species occurs on the eastern shoreline. The CAMBA listed White-bellied Sea-Eagle (*Haliaeetus leucogaster*) has been recorded here (ANCA, 1996).
- ***Wallaga Lake*** is listed in the Directory of Important Wetlands and was proposed as an estuarine aquatic reserve in a previous assessment (NSW Fisheries, 2001). The Lake has large areas of sand flat exposed at low tide near the entrance, a number of inflowing tributaries and open forest, with Swamp She-oak (*Casuarina glauca*) and Swamp Paperbark (*Melaleuca ericifolia*) along much of the shoreline and islands within the lake. The upper tributaries have saltmarsh habitats with mangroves and seagrasses (*Zostera sp.* and *Halophila sp.*). The sand flats provide habitat for foraging and resting waterbirds and seabirds.

  The endangered Little Tern (*Sterna albifrons*) nests on the fore dunes of the beach and fledglings and adults feed in the estuary. The endangered Hooded Plover (*Thiornis rubricollis*) and vulnerable Pied Oystercatcher (*Haematopus longirostris*) and Osprey (*Pandion haliaetus*) occur in the estuary.

  Species listed under JAMBA or CAMBA and recorded at Wallaga Lake include the Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Sharp-tailed Sandpiper (*Calidris acuminata*), Curlew Sandpiper (*Calidris ferruginea*), Red-necked Stint (*Calidris ruficollis*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Lesser Golden Plover (*Pluvialis dominica*), Crested Tern (*Sterna bergii*), Caspian Tern (*Sterna caspia*) and Common Tern (*Sterna hirundo*) (ANCA, 1996).
- ***Nelson Lagoon*** is an intermittent estuary with near pristine catchments and slightly affected waters proposed in a previous assessment as an estuarine aquatic reserve (NSW Fisheries, 2001) and recommended in the Coastal Lakes Inquiry for comprehensive protection. Nelson Lagoon is listed in the Directory of Important Wetlands and the area around the lagoon includes saltmarshes of significant conservation value (Adam, 1992, in ANCA, 1996).
- ***Tathra Head*** was short listed as an aquatic reserve candidate by a community advisory panel in a previous assessment of intertidal areas (NSW Fisheries, 2001).

5.3 Twofold Shelf

The NSW section of the Twofold Shelf bioregion includes coastal waters and estuaries between Tathra (Wallagoot Lake) and the NSW-Victoria border.

Within this geographic section: approximately 30% of the coast between Wallagoot and Pambula and approximately 95% of the coast between Pambula and Twofold bay is within national park; all of Bondi lake and Bournda Lagoon are surrounded by national park; and approximately 40% of Wallagoot Lake and Pambula Lake adjoin national parks. Almost all the ocean coast between Twofold Bay and the Victorian border is included in national park or nature reserve and much of it is in the declared Wilderness area. These areas are likely to be among the least disturbed coastal areas in NSW. Saltwater, Woodburn and Bittangabee Creeks are near pristine small coastal catchments that are entirely surrounded by Ben Boyd National Park. The Nadgee Nature Reserve and Wilderness area includes Wirra Birra, Table and Little Creeks, the Merrica and Nadgee Rivers and Nadgee Lake, and their catchments. However, the aquatic components of national parks and nature reserves do not have direct protection for fish or aquatic invertebrates from fishing.

Areas with important biodiversity values identified in this section of the bioregion are listed following:

- The ***rocky shores and subtidal reefs south of Tathra*** are important for their high diversity and biogeographic significance of marine algae (Alan Millar pers. comm., National Herbarium of New South Wales).

- ***Wallagoot Lake*** is the largest intermittent lagoon in the section and occurs at the border of the Twofold and Batemans Shelf bioregions. The Lake is listed in the Directory of Important Wetlands and has extensive sand spits and sandy islets at the east end of the lagoon and extensive seagrass beds (including *Posidonia*), rushes, sedges, Saltmarsh (*Sarcocornia quinqueflora*), Streaked Arrow-grass (*Triglochin striata*), Saw-sedge (*Gahnia* sp.) and Common Reed (*Phragmites australis*).

  Endangered species sighted here include the Little Tern (*Sterna albifrons*) and the Hooded Plover (*Thinornis rubricollis*). Vulnerable species sighted here include Pied Oystercatcher (*Haematopus longirostris*), Australasian Bittern (*Botaurus poiciloptilus*) and Sanderling (*Calidris alba*).

  Species listed under JAMBA or CAMBA include the Short-tailed Shearwater (*Puffinus tenuirostris*), Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Ruddy Turnstone (*Arenaria interpres*), Sharp-tailed Sandpiper (*Calidris acuminata*), Curlew Sandpiper (*Calidris ferruginea*), Red-necked Stint (*Calidris ruficollis*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Common Greenshank (*Tringa nebularia*), Common Redshank (*Tringa totanus*), Lesser Golden Plover (*Pluvialis dominica*), Grey Plover (*Pluvialis squatarola*), Crested Tern (*Sterna bergii*), Caspian Tern (*Sterna caspia*), Common Tern (*Sterna hirundo*) and White-throated Needletail (*Hirundapus caudacutus*) (ANCA, 1996).

- ***Bondi and Bournda Lagoons*** are intermittent estuaries with near pristine catchments and slightly affected to pristine waters. Both are recommended in the Coastal Lakes Inquiry for comprehensive protection.

- ***Bondi Lake*** is listed in the Directory of Important Wetlands. Although it is generally fresh, the Lake appears to become more saline as its volume diminishes. The Lakes' 200 ha catchment is wholly within Bournda National Park. Species listed under JAMBA or CAMBA and known to occur within the area include the White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Sharp-tailed Sandpiper (*Calidris acuminata*), Curlew Sandpiper (*Calidris*

ferruginea), Red-necked Stint (*Calidris ruficollis*) and Common Greenshank (*Tringa nebularia*) (ANCA, 1996).

- ***Merimbula Lake*** is the second largest barrier estuary in the NSW section of the bioregion. The Lake includes the largest area of seagrass habitat, the second largest area of mangrove and the largest area of saltmarsh in the NSW section of the bioregion. The Lake is at the southern limit for River Mangrove (*Aegiceras corniculatum*) and includes a significant population of the Saltbush *Sclerostegia arbuscula* (Adam, 1992, in ANCA, 1996). The area provides habitat for endangered and vulnerable bird species and waders protected under JAMBA and CAMBA and is listed in the Directory of Important Wetlands.

  The endangered Hooded Plover (*Thinornis rubricollis*) and vulnerable Australasian Bittern (*Botaurus poiciloptilus*), Sooty Oystercatcher (*Haematopus fuliginosus*) and Pied Oystercatcher (*Haematopus longirostris*) have been recorded from the lake (ANCA, 1996).

  Species listed under JAMBA or CAMBA and known to occur in the area include the Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Latham's Snipe (*Gallinago hardwickii*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*) and Whimbrel (*Numenius phaeopus*) (ANCA, 1996).

- ***Pambula Lake*** is the largest wave dominated barrier estuary in the NSW section of the Twofold Shelf bioregion. The Lake has the second largest area of seagrass, the largest area of mangrove and the third largest area of saltmarsh in the NSW section of the bioregion. This type of estuary occurs in the Victorian section of the bioregion but is not represented in marine protected areas. Areas upstream of the lake include channels, sand flats, mangroves, saltmarsh, and brackish and freshwater assemblages listed in the Directory of Important Wetlands.

- ***Twofold Bay*** is the only ocean embayment in the Twofold Shelf bioregion within NSW or Victoria. The bay and the four intermittent and barrier estuaries that flow into it are listed in the Directory of Important Wetlands. The sheltered rocky shores, beaches, reefs, deep-water areas, sand flats and wetlands around the bay provide important habitat for marine life, cetaceans and threatened and migratory birds (ANCA, 1996).

  The endangered Hooded Plover (*Thiornis rubricollis*) and the vulnerable Shy Albatross (*Diomedea cauta*), Black-browed Albatross (*Diomedea melanophrys*), Sooty Albatross (*Phoebetria fusca*) and Pied Oystercatcher (*Haematopus longirostris*) have been recorded from Twofold Bay (ANCA, 1996).

  Humpback Whales (*Megaptera novaeangliae*) are regularly sighted here when migrating north and south. Southern Right Whales (*Eubalaena australis*) and the Blue Whale (*Balaenoptera musculus*) also visit the bay occasionally as well as other cetaceans including dolphins and Pilot Whales. The bay is a known resting locality for cetacean migrants (ANCA, 1996).

  Species listed under JAMBA or CAMBA and known to occur in the area include the Short-tailed Shearwater (*Puffinus tenuirostris*), Australian Reef Egret (*Egretta sacra*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*) and Grey Plover (*Pluvialis squatarola*) (ANCA, 1996).

- ***Towamba and Wonboyn Rivers*** are representative barrier estuaries in a largely unmodified condition. Wonboyn Lake has been recommended by the Coastal Lakes Inquiry for significant protection.

- The ***ocean coast between Twofold Bay and Wonboyn River*** includes the largest area of mapped inshore reef in NSW south of Tuross Heads. The section includes small areas of inshore islands and rocks and the largest area of intertidal rocky shore of all sections in the Batemans Shelf bioregion or the NSW section of the Twofold Shelf bioregion.

- ***Saltwater, Woodburn and Bittangabee Creeks*** are small, near pristine coastal catchments that are entirely surrounded by Ben Boyd National Park.

6 Conclusion

This project provides the basic information and methods to systematically identify areas with important biodiversity values and to help plan a system of marine protected areas in the Batemans Shelf and Twofold Shelf bioregions. Because of the scope of this task and the need for consistent information across areas as large as whole bioregions, approximate surrogates for biodiversity and other criteria have been used. However, even at the broad scale of this study, a number of patterns were evident.

Jervis Bay Marine Park already protects some of the most important areas for marine biodiversity in the Batemans Shelf bioregion and occupies an area of 224 km^2. However barrier and intermittent estuaries, deeper ocean ecosystems and mangrove and saltmarsh habitats are not well represented in the existing marine park.

Mangrove and saltmarsh habitats however, do occur in the marine and terrestrial components of national parks and nature reserves. These protected areas also include significant intermittent estuaries and areas of intertidal ocean beach and rocky shore. However, these areas cannot, on their own, directly protect fish or marine invertebrates from fishing.

In total, about 10% of coastal waters in the Batemans Shelf bioregion are currently included within some form of marine protected area.

In the Twofold Shelf bioregion, there are no marine parks or aquatic reserves in NSW waters and 2 km^2 of estuary in national park and nature reserve. This represents 0.3% of coastal waters in the NSW section of the bioregion.

Victorian and Tasmanian marine protected areas in the Twofold Shelf bioregion include additional areas of beach, rocky shore, subtidal reef, island and sediment habitats. However, estuarine ecosystems and habitats are not well represented within marine protected areas in the Victorian or Tasmanian sections of the Twofold Shelf bioregion.

This assessment identifies a number of areas with important biodiversity values. These are areas that best meet criteria for representing a range of ecosystems, habitats and species in locations with protected foreshores, catchments and waters relatively unaffected by human impacts. The options for exactly where and how marine protected areas can be established are therefore relatively flexible for all but a few criteria.

Reserve design including many interrelated features within larger marine protected areas means a greater likelihood of managing whole ecosystems, processes, communities and populations throughout the duration and spatial extent of entire life cycles. This may help to maintain connectivity among different ecosystems and their diverse components, and provides greater control over threatening processes operating from within and from outside marine protected areas.

There is the potential to include larger areas of most ecosystem and habitat types, and a greater number and variety of features in large multiple use marine parks. This replication is likely to include a greater diversity of life forms and provide better protection against disturbance. Having many features spread over a broader area also allows for greater flexibility in multiple-use zoning with more opportunities to provide for a range of conservation values, sustainable use and community interests.

7 References

Agardy, M.T. 2000. Information needs for marine protected areas: scientific and societal. Bulletin of Marine Science 66 875-888.

Andrew, NA. 1999. NSW. In: Under southern seas. The ecology of Australia's rocky shores. Ed. Neil Andrew. University of New South Wales Press. Sydney. pp 8-19.

Andrew N.L., Graham K.J., Hodgson K.E. and Gordon G.N.G. 1997. Changes after twenty years in relative abundance and size composition of commercial fishes caught during fishery independent surveys on SEF trawl grounds. NSW Fisheries Research Institute, Cronulla, NSW.

ANZECC / TFMPA. 1998a. Guidelines for establishing the national representative system of marine protected areas. Australian and New Zealand Environment and Conservation, Task Force on Marine Protected Areas. Canberra. Environment Australia.

ANZECC / TFMPA. 1998b. Strategic Plan of Action for the NRSMPA. Australian and New Zealand Environment and Conservation Council, Task Force on Marine Protected Areas. Environment Australia, Canberra.

ANZECC TFMPA. 1999. Understanding the principles of comprehensiveness, adequacy and representativeness for the NRSMPA. Report prepared for the Australian and New Zealand Environment and Conservation Council (ANZECC) Task Force on Marine Protected Areas (TFMPA), in satisfaction of Actions 1, 2 and 3 of the Strategic Plan of Action for the National Representative System of Marine Protected Areas. Unpublished Report.

Australian Nature Conservation Agency. 1996. A directory of important wetlands in Australia. Second edition. ANCA Australia.

Baker, A.N. 1983. Whales and dolphins of Australia and New Zealand. Victoria University Press, Wellington.

Bell, F.C. and Edwards A.R. 1980. An inventory of estuaries and coastal lagoons in New South Wales. Total Environment Centre.

Bell, J.D. and Pollard, D.A. 1989 Ecology of fish assemblages and fisheries associated with seagrasses. In: A treatise on the biology of seagrasses with special reference to the Australian region. (Eds) Larkum, A.W.D., McComb, A.J., Shepard, S. Elsevier Amsterdam.

Breen, D.A., Avery R.P. and Otway N.M. 2003. Broadscale biodiversity assessments for marine protected areas in New South Wales, Australia. Proceedings of the World Congress on Marine Protected Areas. Cairns, Queensland, 2002.

Breen, D.A., Avery R.P. and Otway N.M. 2004. Broadscale biodiversity assessment of the Manning Shelf marine bioregion. Final report for the NSW Marine Parks Authority and Environment Australia.

Brown, A.C. and A. McLachlan. 1990. Ecology of sandy shores. Elsevier.

Buchner, D. and Saenger, P. 1989. An inventory of Australian estuaries and enclosed marine waters. Prepared for the Australian Recreational Sport Fishing Confederation and Australian National Parks and Wildlife Service. Centre for Coastal Management, 7 Volumes.

Chapman, D.M. Geary, M. Roy, P.S. Thom, B.G. 1982. Coastal Evolution and Coastal Erosion in New South Wales. Sydney. Coastal Council of NSW.

Coleman, N., Gason, A.S.H. and Poore, G.C.B. 1997. High species richness in the shallow marine waters of south-east Australia. Marine Ecology Progress Series 154:17–26.

Colwell, J.B. Jones, H.A. Davies, P.J. 1981. Initial Results of the Sonne Cruise SO-15 on the East Australian Continental Shelf, September-November 1980. Bureau of Mineral Resources, Geology and Geophysics 1981.

Commonwealth of Australia 2001. AMBIS 2001 (Version 1.1), Data user guide. Vector, Maritime boundaries data for GIS. National Mapping Division, Geoscience Australia.

Commonwealth of Australia. 2003. Register of the National Estate.

Cowling R.M. 1999. Planning for persistence – systematic reserve design in southern Africa's Succulent Karoo desert. Parks 9(1):17–30.

Creese R.G. and Breen D.A. 2003. Marine Protected Areas in New South Wales, Australia: challenges for research. In: Conserving marine environments. Out of sight out of mind. Edited by Pat Hutchings and Daniel Lunney. Royal Zoological Society of New South Wales, Mossman, NSW.

Cresswell, G.R. Ellyett, C. Legeckis, R. Pearce, A.F. 1983. Nearshore features of the East Australian Current system. Australian Journal of Marine and Freshwater Research 34 105-114.

Cresswell, G.R. 1998. Satellite infrared images of the coastal and offshore waters of NSW, and review of oceanographic processes. Report for the NSW Marine Parks Authority.

Crosby, M.P., Greenen, K.S. and Bohne, R. 2000. Alternative access management strategies for marine and coastal protected areas: A reference for their development and assessment. Man and the Biosphere Program, Washington DC, USA.

CSIRO Australia 2001. The East Australian Current. Information sheet No. 37.

Davey, A.G. 1998. National system planning for protected areas. IUCN, Gland, Switzerland.

Digby, M. J., Buchner, D., Saenger, P., Whelan, M. B., McConchie, D., Eyre, B. and Holmes, N. 1998. Australian Estuarine Database. Prepared for the National River Health Program, Urban Sub Program by the Centre for Coastal Management, Southern Cross University, Lismore, NSW.

Edwards W. 1977. How to use multiattribute utility measurement for social decision making. IEEE Transactions on Systems, Man, and Cybernetics. 37-53.

Faith, D.P. and Walker, P.A. 1996. Integrating conservation and development: incorporating vulnerability into biodiversity-assessment of areas. Biodiversity and Conservation 5:417–29.

Ferrier S, Presssey RL, Barnett T.W. 2000. A new predictor of the irreplaceability of areas for achieving a conservation goal, its application to real-world planning, and a research agenda for further refinement. Biological Conservation 93 303-325.

Fernandes L. 1996. Evaluating proposed uses of coral reefs: comparison of economic and multiple criteria approaches. Ph.D. thesis, Department of Geography, University of Hawaii.

Garcia-Charton, J.A., Williams, I.D., Perex Ruzafa, A., Milazzo, M., Chemello, R., Marcos, C., Kitsos, M.S., Koukouras, A. and Riggio, S. 2000. Evaluating the ecological effects of Mediterranean marine protected areas: habitat, scale and the natural variability of ecosystems. Environmental Conservation 27:159–78.

Gray, J.S. 1997. Marine biodiversity: patterns, threats and conservation needs. Biodiversity and Conservation 6 153-175.

Godfrey, J.S., Cresswell, G.R., Golding, T.J., Pearce, A.F., Boyd, R. 1980. The separation of the East Australian Current. J. Phys. Oceanogr., 10(3), 430-440.

Griffiths, O. 1982. Intertidal Platform Survey. In Coastal Headlands Survey. Parts 4-5. National Trust of Australia, Sydney.

Hacking, N. 1998a. Sandy beach macrofauna of eastern Australia: A geographical comparison. Ph.D. Thesis. University of New England. Chapter 9.

Hacking, N. 1998b. Macrofaunal community structure of beaches in northern NSW, Australia. Marine and Freshwater Research. 49: 47-53.

Hannan, J.C. and Williams, R.J. 1998. Recruitment of juvenile marine fishes to seagrass habitat in a temperate Australian estuary. Estuaries 21 29-51.

Healthy Rivers Commission 1999. Independent Inquiry into the Shoalhaven River System.

Healthy Rivers Commission. 2002. Independent Inquiry into Coastal Lakes – Final report.

Heap, A., Bryce, S., Ryan, D., Radke, L., Smith, C., Smith, R., Harris, P. and Heggie, D. (2001). Australian Estuaries and Coastal Waterways: A Geoscience Perspective for Improved and Integrated Resource Management. Australian Geological Survey Organisation. Record 2001/07.

Howard, R.K. and Edgar, G.J. 1999. Seagrass Meadows. In, L.S. Hammond and R.N. Synnot (eds) Marine Biology. Longman. South Melbourne.

Hurlbert, S.T. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54(2):187–211.

Hutchings, P.A. and Recher, H.F. 1982. The fauna of Australian Mangroves. Proc. Linn. Soc. NSW. (106) 83-121.

InfoHarvest. 2000. Criterium decision plus. Seattle Washington USA. www.infoharvest.com.

Inglis, G. 1992. In: Battershill C., Neal, (eds) Proceedings of the second international temperate reef symposium, January 7–10 1992. Auckland, New Zealand. Wellington, New Zealand: NIWA Marine. pp. 23–8.

Interim Marine and Coastal Regionalisation for Australia (IMCRA) Technical group. 1998. Interim Marine and Coastal Regionalisation for Australia: an ecosystem-based classification for marine and coastal environments, Version 3.3. Environment Australia, Commonwealth Department of the Environment. Canberra.

IUCN. 1994. Guidelines for protected area management categories. Gland Switzerland.

Kingsford, M.J. 1990. Linear oceanographic features: A focus for research on recruitment processes. Australian Journal of Ecology 15 391-401.

Kingsford, M.J. 1999. Marine protected areas in Australia and New Zealand: decision making and current research. Proceedings of the first international workshop on marine reserves. Murcia, 1999.

Kingsford, M.J. Choat, J.H. 1986. Influence of surface slicks on the distribution and onshore movements of small fish. Marine Biology 91 161-171.

Kingsford, and M.J. Suthers, I.M. 1994. Dynamic estuarine plumes and fronts: importance to small fish and plankton in coastal waters of NSW, Australia. Continental Shelf Research 14 655-672.

Kingsford, M.J. and Suthers, I.M. 1996. The influence of tidal phase on patterns of ichthyoplankton abundance in the vicinity of an estuarine front, Botany Bay, Australia. Estuarine, Coastal and Shelf Science 43, 33-54.

Mardle S, Pascoe S. 1999. A review of applications of multiple-criteria decision making techniques to fisheries. Marine Resource Economics. 14:41-63.

NSW Fisheries. 2001. Identification of candidate aquatic reserves in the Hawkesbury and Twofold Shelf bioregions. NSW Fisheries Report, Cronulla NSW.

NSW Fisheries. 2002. NSW Recovery Plan for the threatened Grey Nurse Shark (*Carcharias taurus*). NSW Fisheries Report, Cronulla NSW.

NSW Marine Parks Authority - MPA Strategy Working Group. 2001. Developing a representative system of marine protected areas in NSW. An overview. NSW Marine Parks Authority, Sydney.

NPWS 1995. Montague Island Nature Reserve Plan of Management. NSW National Parks and Wildlife Service

NPWS 1999a. Threatened species information. Beach Stone-curlew. NSW National Parks and Wildlife Service.

NPWS 1999b. Threatened species information. Bush Stone-curlew. NSW National Parks and Wildlife Service.

NPWS 1999c. Threatened species information. Hooded Plover. NSW National Parks and Wildlife Service.

NPWS 2000. Little Tern (*Sterna albifrons*) Draft Recovery Plan. Hurstville, Sydney. NSW National Parks and Wildlife Service

NPWS 2001. C – Plan Conservation planning software, version User manual 3.06. www.ozemail.com.au/~cplan. NSW National Parks and Wildlife Service.

Otway, N.M. 1999. Identification of candidate sites for declaration as aquatic reserves for the conservation of rocky intertidal communities in the Hawkesbury Shelf and Batemans Shelf Bioregions. Report to Environment Australia by NSW Fisheries.

Otway, N.M., Burke, A.L., Morrison, N.S. and Parker, P.C. 2003. Monitoring and identification of NSW Critical Habitat Sites for conservation of Grey Nurse Sharks. Final Report to Environment Australia. Project No. 22499. NSW Fisheries Final Report Series No. 47. ISSN 1440-3544. 62pp.

Otway, N.M and Morrison N. In prep. Identification candidate shores for declaration as aquatic reserves for the conservation of rocky intertidal communities in the Manning Shelf Bioregion.

Otway, N.M. and Parker P. C. 2000. The biology, ecology, distribution, abundance and identification of marine protected areas for the conservation of threatened Grey Nurse Sharks in south east Australian waters. NSW Fisheries Final Report Series No.19. NSW Fisheries Office of Conservation.

Paterson, R.A. and Paterson, P. 1989. The status of the recovering stock of Humpback whales *Megaptera novaeanglidae* in east Australian waters. Biological Conservation 47:33-48.

Planes, S. Galzin, R. Rubies, G. Goni, R. Harmelin, J.-G. Le Direach, L. Lenfant, P. Quetglas, A. 2000. Effects of marine protected areas on recruitment processes with special reference to Mediterranean littoral ecosystems. Environmental Conservation 27 126-143.

Pease, B.C. 1999. A spatially oriented analysis of estuaries and their associated commercial fisheries in New South Wales, Australia. Fisheries Research 42 67-86.

Pollard, D.A. 1997. A review of marine and estuarine protected areas in NSW, with emphasis on research and monitoring as a basis for scientific management. Draft Report for comment.

Pollard D, Ortiz E, Pethebridge R. 1997. New South Wales marine and coastal bioregionalisation study: Towards the development of a representative system of marine and estuarine protected areas for NSW. Report to Environment Australia.

Pressey RL, Johnson IR, Wilson PD. 1994. Shades of irreplaceability: towards a measure of contribution of sites to a reservation goal. Biodiversity and Conservation. 3:242-62.

Pressey, R.L. and Taffs, K.H. 2001. Scheduling conservation action in production landscapes: priority areas in western New South Wales defined by irreplaceability and vulnerability to vegetation loss. Biological Conservation 100:355–76.

Roberts, C.M. 2000. Selecting marine reserve locations: optimality versus opportunism. Bulletin of Marine Science 66(3):581–92.

Roberts, C.M. and Hawkins, J.P. 1997. How small can a marine reserve be and still be effective? Coral Reefs 16:150.

Roberts, C.M. and Hawkins, J.P. 2000. Fully-protected marine reserves: a guide. World Wide Fund for Nature, Washington, USA.

Roberts, D.E. Davis, A.R. 1996. Patterns in sponge (Porifera) assemblages on temperate coastal reefs off Sydney, Australia. Marine and Freshwater Research 47 897-906.

Rochford, D.J. 1975. Nutrient enrichment of East Australian coastal waters. II Laurieton Upwelling. Australian Journal of Marine and Freshwater Research 26 233-43.

Rothley KD. 1997. Designing reserve networks to satisfy multiple, conflicting demands. Ecological Applications. 9:741-50.

Roy, P.S., Williams, R.J., Jones, A.R., Yassini, I., Gibbs, P.J., Coates B., West, R.J., Scanes, P.R., Hudson, J.P., Nichol, S. 2001 Structure and function of South-east Australian estuaries. Estuarine and coastal shelf science Vol. 53, No. 3. 351-384.

Saenger, P.E. 1999 Mangroves and Salt marsh. In L.S.Hammond and R.N. Synnot (eds) Marine Biology. Longman. South Melbourne.

Salm, R.V. Clark, J.R. and Siirila, E 2000. Marine and coastal protected areas: a guide for planners and managers. Third edition. Gland, Switzerland. International Union for Conservation of Nature and Natural Resources.

Short, A. 1993 Beaches of the New South Wales Coast: a guide to their nature, characteristics, surf and safety. University of Sydney.

Short JM 1995 Protection of coastal rock platforms in NSW. National Estate Grant Project NEP 94-288. Total Environment Centre, Sydney.

Skene, D.L. Roy, P.S. 1986. The quarternary geology of the coast and innershelf at Wooli, northern NSW. Dept of Mineral Resources. Sydney.

Smith, P. 1997. Management manual for marine mammals in NSW. National Parks and Wildlife Service, Hurstville.

Stein, J.L. Stein, J.A. and Nix H.A. 2000. The identification of wild rivers – methodology and database development. A report for the Australian Heritage Commission by the Centre for Resource and Environmental Studies, Australian National University.

Tanner, M. and Liggins, G.W. 1999. New South Wales commercial fisheries statistics. NSW Fisheries Research Institute.

Ward T.J. and Blaber S.J.M 1994 Continental shelves and slopes. In: Marine Biology. Eds. L. S. Hammond and R. N. Synnot. Longman Cheshire, Melbourne, Australia. pp. 333-344.

Underwood, A.J., Kingsford, M.J. and Andrew, N.L. 1991 Patterns in shallow subtidal marine assemblages along the coast of New South Wales. Australian Journal of Ecology. 6:231-249.

West, R.J., Thorogood, C.A., Walford, T.R., Williams, R.J. 1985 An estuarine inventory for New South Wales, Australia. Fisheries Bulletin 2. NSW Dept of Agriculture.

Wolanski, E. 2000 Oceanographic Processes of Coral Reefs: Physical and Biological Links in the Great Barrier Reef. CRC Press, Florida.

Womersley, H.B.S. 1984. The marine benthic flora of Southern Australia. Part I. South Australian Government Printing. Adelaide.

Appendix 1: Goals and criteria for marine protected areas

(adapted from Breen, Avery and Otway 2003, 2004)

National and NSW goals and criteria

This assessment was based on national goals and criteria adopted by the NSW Marine Parks Authority (ANZECC/TFMPA 1998ab, 1999, NSW Marine Parks Authority MPA Strategy Working Group 2001). These goals and criteria reflect over 30 years of international and national discussion, published research and practical management experience in protected areas (e.g. Kelleher and Kenchington 1991).

Table 1.1 lists national goals and Table 1.2a lists national criteria recommended for the identification of marine protected area (MPA) options on ecological grounds. Table 1.2b lists national selection criteria recommended for the selection of MPAs areas from among the ecological options identified.

For the assessment, hierarchical tree-like models of goals, criteria and performance indicators were used to interpret these goals and criteria in terms of specific information (Figs. 1.1-1.5). The models can also used to quantitatively assess goals and criteria in multiple criteria analyses using a range of specific data. These techniques provide a useful framework for the assessments and for the consistent application of goals and criteria in subsequent planning, research and review of MPA management.

Table 1.1 National goals for marine protected areas

The **primary goal** of the National Representative System of MPAs (NRSMPA) is to establish and manage a comprehensive, adequate and representative system of MPAs to contribute to the long term ecological viability of marine and estuarine systems, to maintain ecological processes and systems, and to protect Australia's biological diversity at all levels.

The secondary goals are to:

- promote development of MPAs within the framework of integrated ecosystem management
- provide a formal management framework for a broad spectrum of human activities, including recreation, tourism, shipping and the use and extraction of resources
- provide scientific reference sites
- provide for the special needs of rare threatened or depleted species and threatened ecological communities
- provide for the conservation of special groups of organisms – for example, species with complex habitat requirements or mobile or migratory species or species vulnerable to disturbance and which may depend on reservation for their conservation
- protect areas of high conservation value including those containing high species diversity, natural refugia for flora and fauna and centres of endemism
- provide for recreational, aesthetic and cultural needs of indigenous and non indigenous people.

Table 1.2a National identification criteria for marine protected areas

1. Representativeness (Figs. 1.1, 1.3)

Will the area:

- represent one or more ecosystems within an IMCRA bioregion, and to what degree
- add to the representativeness of the NRSMPA, and to what degree
- reasonably reflect the biotic diversity of the marine ecosystems from which they derive?

2. Comprehensiveness (Figs. 1.1, 1.2)

Does the area:

- add to the coverage of the full range of ecosystems recognised at an appropriate scale within and across each bioregion
- add to the comprehensiveness of the NRSMPA?

3. Ecological importance (Fig. 1.3)

Does the area:

- contribute to the maintenance of essential ecological processes or life-support systems
- contain habitat for rare or endangered species
- preserve genetic diversity
- contain areas on which species or other systems are dependant e.g. contains nursery or juvenile areas or feeding, breeding or resting areas for migratory species
- contain one or more areas which are a biologically functional, self-sustaining ecological unit?

4. International or national importance (Fig. 1.3)

Is the area rated, or have the potential to be listed on the world or a national heritage list, declared a Biosphere Reserve or subject to an international or national conservation agreement?

5. Uniqueness (Fig. 1.3)

Does the area:

- contain unique species, populations, communities or ecosystems
- contain unique or unusual geographic features?

6. Productivity (Fig. 1.3)

Do the species, populations or communities of the area have a high natural biological productivity?

7. Vulnerability assessment (Fig. 1.4)

Are the ecosystems and/or communities vulnerable to natural processes?

8. Biogeographic importance (Fig. 1.3)

Does the area capture important biogeographic qualities?

9. Naturalness (Fig. 1.4)

To what extent has the area been protected from, or not been subjected to, human induced change?

Table 1.2b National selection criteria for marine protected areas

1. Economic interests (Fig. 1.5)

Does the site:

- make an existing or potential contribution to economic value by virtue of its protection, e.g. for recreation or tourism, or as a refuge or nursery area or source of supply for economically important species
- have current or potential use for the extraction of, or exploration for, resources
- have importance for shipping and/or trade
- have importance to traditional users including commercial fishers
- make a contribution to local or regional employment and economic development?

2. Indigenous interests (Fig. 1.5)

Does the site:

- have traditional usage and/or current economic value
- contain indigenous cultural values
- have native title considerations
- have importance for maintaining indigenous ecological knowledge?

3. Social Interests (Fig. 1.5)

Does the site have existing or potential value to the local, national or international communities because of its heritage, cultural, traditional, aesthetic, educational, recreational or economic values?

4. Scientific Interests (Fig. 1.5)

Does the site have existing or potential value for research or monitoring?

5. Practicality/feasibility (Fig. 1.4)

Does the site:

- have a degree of insulation from external destructive influences
- have social and political acceptability, and a degree of community support
- have access for recreation, tourism, education
- have compatibility between an MPA declaration generally and its uses
- have relative ease of management, and compatibility with existing management regimes?

6 Vulnerability assessment (Fig. 1.4)

Is the site vulnerable and susceptible to human-induced changes and threatening processes?

7. Replication (Fig. 1.4)

Will the site provide replication of ecosystems within the bioregion?

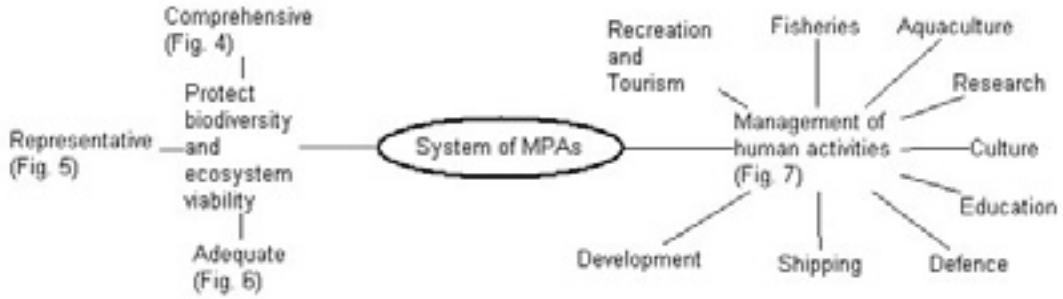


Fig. 1.1 Primary and secondary goals for a system of marine protected areas.

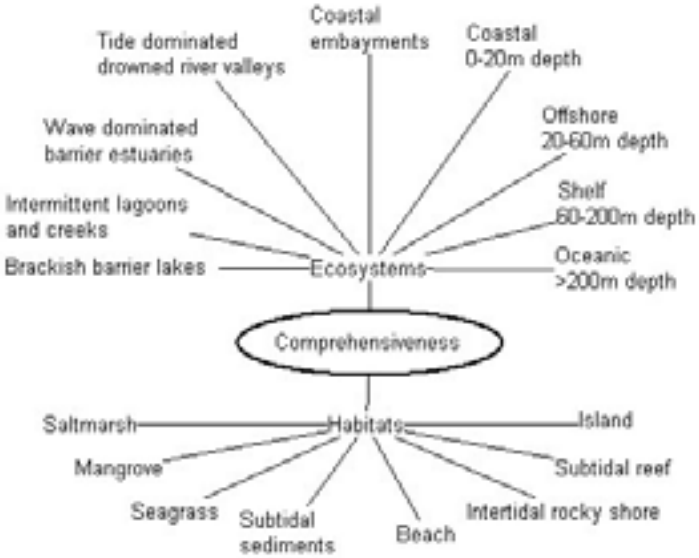


Fig. 1.2 Criteria for comprehensiveness.

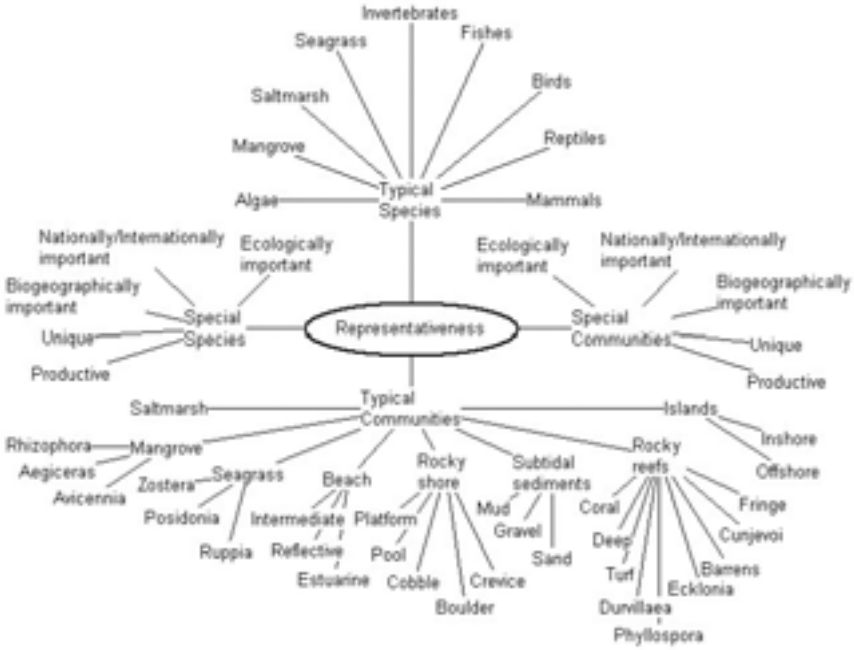


Fig. 1.3 Criteria for representativeness.

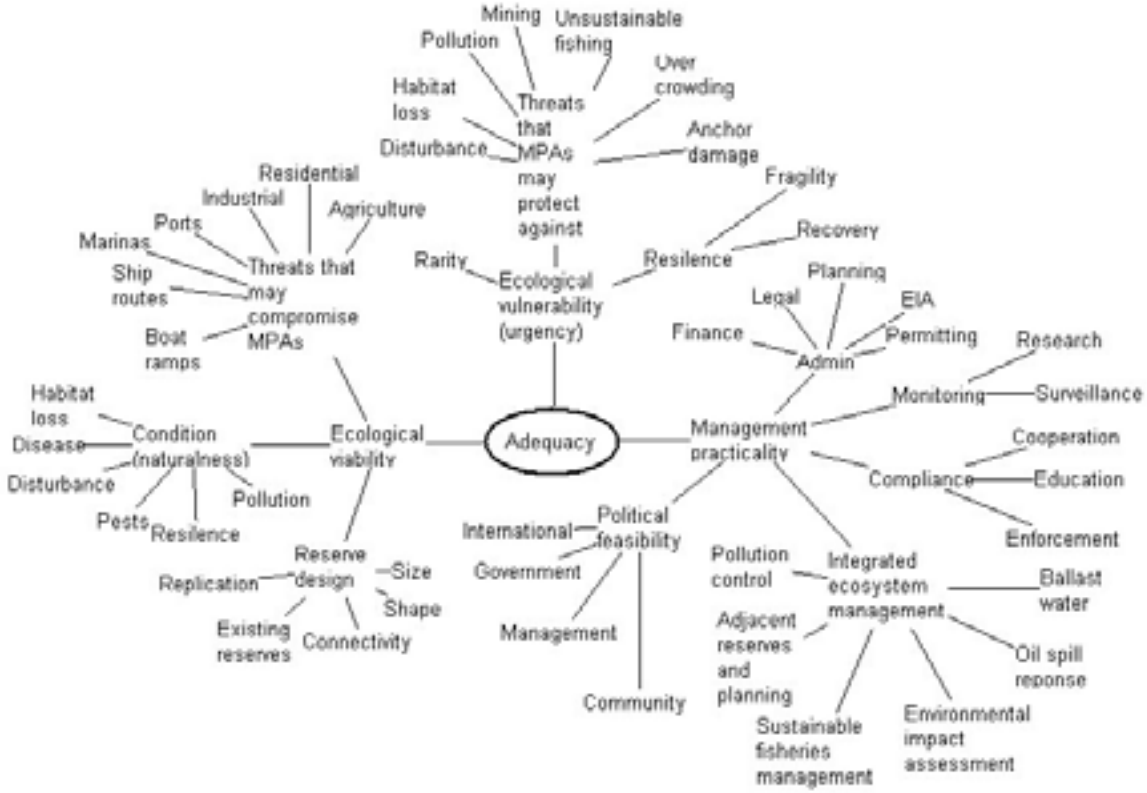


Fig. 1.4 Criteria for adequacy.

Fig. 1.5 Criteria for human activities.

Protection of biodiversity and ecosystem viability

The multiple criteria models can be used to group MPA identification and selection criteria into two main branches (Fig. 1.1): primary goals to protect biodiversity and ecosystem viability and secondary goals to provide for human use. The scope of the bioregional assessments is restricted to identifying candidate MPAs by assessing the primary goals on the basis of ecological criteria. These criteria can be organised under 3 main branches: comprehensiveness, representativeness and adequacy.

Comprehensiveness

Comprehensiveness is defined as including 'the full range of marine ecosystems and habitats' within MPAs (ANZECC/TFMPA 1998ab). Strictly speaking, ecosystems and habitats are too complex and dynamic to define and map accurately, however 'surrogate' measures or indicators can be used to approximately map generally recognised broadscale patterns in biodiversity.

For the assessment, ecosystems and habitats (Fig. 1.2) were defined in an environmental classification based on broadscale differences in geomorphology, depth, substratum and exposure. On the basis of existing ecological knowledge, these largely physical differences in environments were assumed to reflect a corresponding diversity in different habitats, species, and ecological processes.

Representativeness

Representativeness means that areas included in MPAs should 'reasonably reflect the biotic diversity of the marine ecosystems from which they derive' (ANZECC/TFMPA 1998ab). That is, while comprehensively sampling the range of biotic variation, MPAs should also include a reasonably unbiased and sufficiently large, representative proportion of the variation within this range.

An important outcome of this approach is to protect typical species, processes and areas rather than protecting only well known, charismatic, rare, threatened, scenic, recreational or convenient elements of biodiversity. Vulnerable and unique elements, however should not be ignored, and a representative system of MPAs should protect both typical and 'special' components of biodiversity (Inglis 1992, Jones *et al.* 1992, Jones and Kaly 1998).

Fig. 1.3 describes representativeness as a function of typical and special communities and species. Typical communities and species are represented through finer scale physical indicators, available broadscale surveys, incidental sightings, and descriptive records of communities and species populations.

Special species and communities in Fig. 1.3 include rare, endemic, threatened, ecologically important, unique, productive, biogeographically and internationally or nationally important communities and species. Threatened communities and species include those communities, populations and species listed as endangered and vulnerable under the NSW *Fisheries Management Act 1994* and the *Threatened Species Conservation Act 1995*.

Adequacy

Adequacy is defined as 'the required level of reservation to ensure the ecological viability and integrity of populations, species and communities' (ANZECC/TFMPA 1998ab). Adequacy includes criteria that affect the ability of MPAs to sustain the biodiversity they aim to conserve and involves consideration of vulnerability, condition, reserve design, connectivity and practical MPA management (Fig. 1.4).

Vulnerability

Vulnerability may be interpreted in two ways. Where there is a range of options available for protection of a feature it may be preferable to include areas that are least threatened to increase their probability of survival. This approach may apply when threats originate from outside the MPA and are beyond the immediate control of MPA management. An example might be in selecting marine areas with catchments protected by terrestrial protected areas.

However, where there are only a few examples of a habitat or species, there may be urgent reasons for protecting the areas most threatened, particularly where threats operate inside the MPA and are under some control of MPA management. This priority is now incorporated implicitly in terrestrial reserve selection methods (Faith and Walker 1996, Cowling 1999, Pressey and Taffs 2001). An example might be a rare habitat or species that might otherwise be lost without the protection of a MPA.

Condition

Condition or 'naturalness' reflects whether an area has already undergone some degree of impact. If an area has been affected by pollution, disturbance, pests, disease, habitat loss, or over-exploitation, the ecological viability of the area, as well as the diversity of organisms present may be affected.

Ecological reserve design

Ecological viability requires consideration of reserve design including size, shape, replication and the configuration of reserves within a network. Reserve design criteria aim to ensure that individual MPAs and the overall reserve system remain ecologically viable. Basic reserve design guidelines include the need to:

Establish clear objectives

The primary objectives of any MPA need to be stated clearly. A reserve's location, design and management should reflect its intended purpose. Reserve design for fisheries management, sedentary organisms, birds and whole ecosystems may differ considerably (Agardy 2000, Planes *et al*. 2000, Roberts and Hawkins 2000, Salm *et al*. 2000).

Select, design and manage the MPA in line with these objectives

The biology of the target organisms including their life cycles, movements, feeding, behaviour and physiology all need to be considered in reserve design. Even where a range of biodiversity is targeted, careful consideration should be given to the ecology of the organisms the MPA is designed to protect.

Conduct site assessments

Once candidate MPA sites have been identified at a regional level, more detailed site studies are required to assess the validity of broadscale predictions, collate any detailed information available and specifically assess local patterns of biodiversity, threats and issues for future management.

Use natural boundaries and where possible include whole ecosystems and habitats

Where possible, the natural limits of ecosystems or habitats should be used to help define marine protected area boundaries (Salm *et al*. 2000). Where an entire ecosystem or habitat is important for conservation, all of its area should be protected (Roberts and Hawkins 2000, Salm *et al*. 2000). Reservation of an entire system is likely to enhance protection by:

- taking advantage of the unit's natural isolation from threatening processes
- inhibiting excessive spillover of mobile organisms from the reserve
- protecting the full range of variation occurring within a unit.

Use core and buffer zones

Highly protected core conservation areas should be surrounded by an appropriate buffer zone to avoid sudden transitions from highly protected areas to areas with relatively little protection. High value conservation sites that are vulnerable to human use should be protected in core protection zones. Buffer zones may also be used to provide important corridors between areas.

Use highly protected areas

The concept of minimum or optimum MPA size should be applied to core sanctuary zones, not to the total extent of a multiple-use MPA (Salm *et al*. 2000). Most evidence of the beneficial effects of MPAs is related to core sanctuary (or 'no take') areas where extractive use is prohibited.

Ensure adequate size and number of reserves

There are few general rules for determining the best size and arrangement of MPAs as biologies and life histories vary widely among species and with season and location (Roberts and Hawkins 1997, Crosby *et al.* 2000, Roberts 2000, Salm *et al*. 2000). However, protected areas should be as large as possible and should not be smaller than the average size for a given habitat type (Salm *et al*. 2000).

Where MPAs target particular species, and where sufficient data exist, attempts can be made to estimate an appropriate MPA size and configuration. MPA size may also be determined by examining the percentage of species richness represented with increasing reserve size (Salm *et al.* 2000), or through fisheries and other modelling techniques (Crosby *et al.* 2000).

One trend however, persists: the larger the MPA, the more species that will be represented, and the more likely their populations are to survive disturbances (Salm *et al*. 2000).

Maximise habitat complexity

Representation of species and habitat diversity can be enhanced by establishing MPAs in locations with a wide range of physical environments (e.g. estuaries, islands and headlands with significant depth gradients and both protected and exposed aspects). Different organisms associate with different marine structures and high habitat complexity is often associated with high species diversity. For example, the species richness of rocky reef fish communities is greatest in areas with high habitat complexity (Garcia-Charton *et al*. 2000).

Maximise the connection between neighbouring habitats

Many species selectively use different habitats at different times, seasons or stages in their life history. Protection of organisms in one habitat may be compromised unless other locations on which they depend are also managed for conservation (Salm *et al*. 2000).

Complement existing MPAs

Reserve design should consider the role of individual MPAs in contributing to the overall complement of biodiversity represented in reserves and should also consider the role of MPAs in the ecological functioning of the reserve system (Crosby *et al.* 2000, Salm *et al*. 2000).

Coordinate management across marine and terrestrial environments

Coordinated management of marine and terrestrial systems can help conserve ecosystem function and mitigate against catchment based threats. Increasing urban development and inappropriate land use in coastal catchments are recognised as major threats to marine biodiversity in New South Wales. With the population in the non-metropolitan coastal areas of NSW increasing by 45% between 1981–1991, the terrestrial reserve system and improved integrated planning are seen as key mechanisms for conserving marine and coastal biodiversity (NSW Government 1997).

Develop a network of MPAs for all ecosystems, communities and species to:

- represent the full regional range of marine biodiversity
- insure against risk through replication
- ensure connectivity between ecosystems and populations
- provide scientific reference sites
- intersperse replicate study sites for research, monitoring and adaptive management
- promote 'spill over' effects to surrounding areas
- provide for the recovery of damaged environments
- provide opportunities for understanding, sustainable use and enjoyment
- provide opportunities for community input and stewardship.

Exercise risk management and the uncertainty principle

Information for management of marine biodiversity will never to be perfect and identification and selection criteria can only hope to approximate ideal objectives and goals. In setting and implementing criteria, the NSW Government has adopted a precautionary approach to managing MPAs i.e. 'Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation' (National Strategy for Ecologically Sustainable Development 1992).

Management practicalities

Management practicalities also affect the ability of MPAs to adequately conserve biodiversity. Criteria that need to be considered in identifying MPAs include:

- education (recognition of values, regulations and boundaries)
- cooperation (best practices, consultation, voluntary compliance, volunteer work)
- planning, regulation and enforcement considerations
- research and monitoring design for adaptive management
- benefits from integrated ecosystem management of surrounding areas
- ease of administration, planning, permitting, impact assessment and finance
- political and community support to establish and make the MPA system work.

Education

For a system of MPAs to be effective, community support is essential. Support can only be gained if people are properly informed and educated about the value of MPAs. For management processes to be seen as transparent, people need to be made aware of the reasons for MPAs and how decisions are made. The complexities of MPA management can also lead to misinterpretation of management strategies. Education can help avoid confusion and allay unjustified fears in the community.

Although education can, and should be provided to all areas, some locations are particularly suited to these activities and may already have education programs in place. Areas recognised for their high natural values are often suitable subjects for documentaries and printed articles on marine environments that can be entertaining, informative and promote marine conservation to audiences internationally. Providing information for local displays, tours, businesses, schools and other agencies provides tangible benefits to the community and opportunities for community input. In these instances, education can involve all age and community groups including children and the broader community, as well as those stakeholders most directly affected by MPAs.

Planning, regulation and enforcement

In an integrated system of MPAs, there needs to be coordination of planning and compliance among MPAs, and between management jurisdictions. With three NSW agencies responsible for MPA management, and several other regulatory agencies in New South Wales with marine responsibilities, there is much scope for cooperation in management strategies as well as the potential for confusion over jurisdiction. In addition, responsibilities for bioregions off the NSW coast are shared with the Federal Government (e.g. for part of Jervis Bay and waters more than 3 nm offshore) and with neighbouring state governments (for the sections of the Tweed-Moreton and Twofold Shelf bioregions).

MPA design also needs to take into account strategies and restrictions already in place. In this way, they may take advantage of existing regulations, programs and facilities, avoid legal complications, minimise additional impacts on existing use and generally manage for conservation in a more effective manner.

Care should also be taken to ensure that ecological objectives are not compromised by gaps in jurisdiction. For example, where MPAs are declared to the high water mark, measures should be taken to ensure that the mangrove and saltmarsh habitats inland of this boundary are also conserved.

This approach applies to management for a wide range of issues including catchment management, agriculture, development, fisheries, national parks, pollution, shipping, waste management and law enforcement. Opportunities for integrated management exist across all these areas in surveillance, research and monitoring, education, consultation, development of best practices, pest control, risk assessment and rehabilitation.

Research

MPAs have a crucial role as reference sites in understanding changing marine environments and the impact of human activities. Without reference sites where impacts are virtually absent or at least controlled, there are no baselines for distinguishing natural from human disturbances or for differentiating the causes of impacts from sources as diverse as fishing, land use, pollution, pests, development or climate change. Without this knowledge, our ability to detect problems or develop (and test) effective solutions is severely limited.

In particular, without consideration of experimental design in the identification, selection and design of MPAs it may be very difficult to assess whether the reserves are even effective in achieving their objectives. Important considerations here are the balanced replication of areas within a range of habitats and levels of protection, an interspersed allocation of replicates (Hurlbert 1984) and procedures to assess compliance with designated levels of protection.

As the design of reserve networks and research programs share similar guidelines, even small alterations at the MPA design stage may have significant effects on the validity of future research and assessment (Kingsford 1999). The partnership between research and management should be regarded as an ongoing and iterative process of adaptive management to gradually improve the design and management of MPAs.

As research in marine environments is often difficult and costly there are significant advantages in cooperative research among MPA agencies and the many other agencies, universities, industries, organisations and individuals involved with marine environments in New South Wales. Consideration of existing research programs, infrastructure and local knowledge at potential MPA sites may have important benefits for research, monitoring and biodiversity conservation.

Managing and providing for human activities

Table 1.2b and Figs. 1.1 and 1.5 list criteria under the secondary goal to: 'Manage and provide for human activities'. Criteria for human activities are scheduled by national guidelines into a separate site 'selection' process. Where consistent with ecological goals, the selection process aims to minimise restrictions on human activities, and even enhance cultural, social and economic values. Often the ecological options for MPAs are flexible enough to allow for a variety of human uses.

Fig. 1.5 lists just some of the interests potentially affected by MPAs. It is evident, even in this simplified view, that there is potential for conflict between conservation values and competing interests. Careful consideration of human activities is therefore required if MPAs are to be implemented.

Stakeholders often spend many professional and recreational hours observing marine ecosystems and can often contribute valuable information on species distributions, habitats, vulnerability, condition and threats. When used cautiously, such information may lead to more realistic MPA management that adapts more readily to local conditions, habitats and organisms (Johannes *et al*. 2000). Subject to intellectual property rights, indigenous knowledge should also be included in MPA research programs and management, and incorporated into MPA interpretation and education strategies.

Davey (1998) lists eleven reasons why plans for 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.

There are many ways in which consultation can be enhanced through advisory committees, community meetings, information sessions, displays, through all forms of the media and through the general 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.

Glossary

Adequacy	The maintenance of the ecological viability and integrity of populations, species and communities (ANZECC 1999).
Biodiversity	The variety of life forms: the different plants, animals and micro-organisms, the genes they contain, and the ecosystems they form (NSW National Parks 1999).
Bioregion	An area defined by a combination of biological, social and geographic criteria, rather than by geopolitical considerations. Generally, a system of related, interconnected ecosystems (ANZECC 1999).
Comprehensiveness	Includes the full range of ecosystems recognised at an appropriate scale within and across each bioregion (ANZECC 1999).
Ecologically sustainable use	Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future can be increased.
Ecosystem	All of the organisms in a community in a given area in interaction with their abiotic (non-living) environment and each other.
Endemism	Originating in a given area and confined to that area (NSW National Parks 1999).
Habitat	The living space of a species or community, providing a particular set of environmental conditions (NSW National Parks 1999).
Irreplaceability	Irreplaceability is a measure designed to estimate the likelihood of a site being required to meet a conservation target or the extent to which conservation options are reduced if that site is unavailable. *Summed* irreplaceability is calculated by adding the individual feature irreplaceabilities for all the features at a site.
Naturalness	The extent to which an area is free from human induced change.
NSW waters	Waters within 3 nautical miles of the NSW coast and islands, under the jurisdiction of the State of NSW.
Representativeness	Those marine areas that are selected for inclusion in reserves should reasonably reflect the biotic diversity of the marine ecosystems from which they derive (ANZECC 1999).

Abbreviations

AHO	Australian Hydrographic Office
AMBIS	Australian Marine Boundary Information System
ARCCD	Australian River and Catchment Condition Database
ANZECC	Australian and New Zealand Environment and Conservation Council
CAR	Comprehensive, adequate and representative
DEC	NSW Department of Environment and Conservation
DIPNR	NSW Department of Infrastructure, Planning and Natural Resources
DPI	NSW Department of Primary Industries
EEZ	Exclusive economic zone
EPA	NSW Environmental Protection Authority
FMA	*Fisheries Management Act 1994*
IMCRA	Interim Marine and Coastal Regionalisation for Australia
IUCN	World Conservation Union (formerly known as International Union for the Conservation of Nature and Natural Resources)
MPA	Marine protected area (includes marine and estuary areas)
MPAC	Marine Park Advisory Council
NPWS	National Parks and Wildlife Service
NPWAC	National Parks and Wildlife Advisory Council
NRSMPA	National Representative System of Marine Protected Areas
NSWMPA	NSW Marine Parks Authority
NSWSMPA	NSW System of Marine Protected Areas
SEPP	State Environmental Planning Policy