NRSMPA Strategic Plan of Action: Review of Methods for Ecosystem Component Mapping (Action 8 – Review Methods for Ecosystem Mapping)

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A report to the ANZECC Task Force on Marine Protected Areas

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1. Introduction

1.1 Background to the Project

This report is one of four reports prepared as part of a project undertaken for the ANZECC Task Force on Marine Protected Areas (TFMPA). The project brief is provided in Appendix A. TFMPA is responsible for establishing a comprehensive, adequate and representative system of marine protected areas (MPAs). In July 1999, ANZECC published the *Strategic Plan of Action for the National Representative System of Marine Protected Areas: A Guide for Australian Governments* (ANZECC TFMPA 1999a). The Strategic Plan sets out actions to achieve the goals of the NRSMPA.

This project addresses four of the 34 actions contained in the Strategic Plan. The reports produced under this project will together contribute to:

- providing a national review of methods of mapping of ecosystems / ecosystem components (Action 8) and mapping coverage by jurisdictions (Action 6) (it is useful to refer to the reports for Actions 6 and 8 together);
- promoting an assessment and mapping process for vulnerable marine ecosystems (Action 4); and
- identifying national priorities for candidate MPAs (Action 5).

The project reports make reference to the *Interim Marine and Coastal Regionalisation for Australia (IMCRA): an ecosystem-based classification for marine and coastal environments* (IMCRA Technical Group 1998). ANZECC have agreed that IMCRA provides the national and regional planning framework for developing the National Representative System of Marine Protected Areas (NRSMPA). Within the ecosystem-based regionalisation, more detailed information on ecosystem, communities and/or species distributions can be used to assist decision-making across or within a bioregion.

1.2 Background to Action 8

Action 8 is a review of methods used by the jurisdictions for describing and mapping ecosystem components for the NRSMPA. This action is a Stage 1 priority among the information requirements of the Strategic Plan of Action.

TFMPA has an adopted hierarchy for the classification of marine ecological groupings for the NRSMPA against which the principles of comprehensiveness, adequacy and representativeness (CAR) are applied:

- Bioregion (refer IMCRA meso–scale bioregionalisation, IMCRA Technical Group 1998);
- Ecosystem;
- Habitat;
- Community / population; and
- Individual / species.

The basis of the principle of comprehensiveness is to ensure that the full range of ecosystems, habitats and communities, as surrogates for marine biodiversity, are recognised at an appropriate scale for inclusion in the NRSMPA. ANZECC TFMPA (1999b) defines ecosystems in the context of CAR as mapping units encompassing a community of associated organisms and their surrounding environments. The TFMPA does not prescribe the appropriate scale of recognition of the above biodiversity surrogates, however Figure 4.1 (refer Section 4) broadly indicates the common scales at which the jurisdictions recognise these biological groupings (based on consultation). At a broad scale, Action 8 contributes to the NRSMPA Strategic Plan by indicating the jurisdiction progress towards

identifying marine ecosystem components, as mapping units for strategic planning, for inclusion of example(s) in a system of MPAs. At a finer scale, mapping provides a context for management by building a knowledge base of the range of ecosystem components within and surrounding an MPA.

Ecosystem component mapping below the habitat level also contributes to the assessment of representativeness (ie. that those marine areas selected for inclusion in MPAs should reasonably reflect the biodiversity of the marine ecosystems from which they derive). The mapping and characterisation of ecosystem components reported under Action 8 contributes to the identification of those areas regarded as 'typical' as well as those that have distinct character. Under the NRSMPA MPAs should include examples of marine biodiversity at broad ecosystem scales as well as rare and threatened and 'atypical' ecological communities, species and habitats at finer scales(refer Action 4).

Notwithstanding the TFMPA hierarchy, there are a variety of approaches and classification systems used among the jurisdictions for creating a resource base for strategic planning for MPAs. Mapping methods used vary most widely according to the strategic planning or specific management objective proposed for the output. However, among mapping projects with consistent objectives, a number of common elements are apparent. For most jurisdictions, benthic habitats are identified at a strategic level to assist in planning to achieve a comprehensive system of MPAs. In contrast, the term ecosystem is much less frequently used as a spatial mapping unit due to the less clear spatial definition of boundaries in relation to its functional attributes. However, ecosystems may be identified post hoc as aggregations of mapped component habitats or communities. This is important because the concept of ecosystem forms a key stratum for the planning and management for the NRSMPA within the IMCRA framework.

For the purposes of this action, mapping methods used in relation to any ecosystem component (above species level) relevant to the NRSMPA were included.

Action 8 is linked to several other actions in the Strategic Plan. Consultation with representatives of each jurisdiction on mapping approaches and definitions is a key input to this Action. Actions 1-3 would also provide a backdrop appreciation of the guiding principles of CAR. The output of Action 8 provides a context for measuring ecosystem component mapping coverage in Action 6.

2. Ecosystem Component Mapping Methods

2.1 Objectives, Scope and Methodology

2.1.1 Review "Ecosystem" Mapping Methods and Standards

The objective is to review the marine ecosystem component mapping methods jurisdictions and relevant scientific agencies employ for the purpose of strategic planning for a NRSMPA.

The scope of this report includes a review of mapping with application for the capture of marine biodiversity at sub-IMCRA scales, directly (using biological data) or indirectly through physical habitat surrogates (ie marine benthic habitat classes). The scope of this review is limited to collection methods of spatial data expressed as mapping. Point data is relevant only so far as it supports the spatial mapping process. The geographic scope of this review is limited to the boundaries of the IMCRA bioregions and does not extend to the Exclusive Economic Zone (EEZ).

The review was compiled by literature review and consultation with representatives of each jurisdiction and relevant scientific agency (refer below and Appendix C) following a checklist format.

The review focussed on the following:

- The purposes for which mapping was undertaken;
- The ecological units (or ecosystem components) being used as the basis for mapping;
- The ecological definitions and hierarchies used for ecosystem components;
- Mapping scales by purpose of mapping and attributes mapped;
- Resolution of baseline data for mapping and extent of field verification;
- Accuracy and tolerances used in data capture (ie digitizing boundary mapping) GIS Metadata standards employed (ie ANZLIC Guidelines); and
- Map projections and datum.

The review is presented by jurisdiction / scientific agency in Tables 2.1 – 2.13.

2.1.2 Developing a National Approach for Ecosystem Component Mapping

The objective is to identify draft suitable standards and scales for mapping with broad application to meet the information requirements of strategic planning tasks among jurisdictions for the NRSMPA. This includes the development of operational definitions of ecosystem, habitat and community for mapping purposes.

This action is achieved through a comparison of mapping methods (reported by each jurisdiction) used to progress similar strategic planning objectives as well as through the identification of methods with broad application to progress the NRSMPA in relation to inshore and offshore waters. In particular, mapping methods and definitions are endorsed and further developed that best enable the jurisdictions to assess the extent to which their MPA priorities would achieve CAR. The discussion of the development of a common approach for mapping is included in Section 3 in relation to GIS / metadata and Section 4 in relation to mapping classifications.

2.2 Ecosystem Component Mapping by Jurisdictions/Scientific Agencies

Sections 2.2.1 to 2.2.9 present summary descriptions of the ecosystem component mapping undertaken by the states, territories and GBRMPA. Sections 2.2.10 to 2.2.13 list habitat mapping undertaken by other scientific agencies including CSIRO, AIMS, AGSO and Universities.

2.2.1 New South Wales

Key Mapping Issues

NSW Marine Parks Authority (via NSW Fisheries and NPWS) has undertaken an 'ecosystem' based mapping approach for the Tweed Moreton bioregion (south of Queensland border). The mapping and attribute classification approach is described below by Avery (2000) and involves the use of existing physical datasets for the development of marine physiographic features and the development of a micro-scale regionalisation approach using available biodiversity datasets. The resulting micro-scale bioregions are regarded as being at an 'ecosystem' scale.

The hierarchy applied is consistent with a broad hierarchy intended for general application at a range of scales as a basis for future mapping for strategic planning of MPAs in other bioregions. The Manning Bioregion is the next priority for strategic mapping based on socioeconomic reasons.

A revised approach to classifying and mapping marine habitats is outlined in an early draft document titled "An Interim Marine Habitat Classification for NSW and its Proposed Application in the Manning Shelf (IMCRA) Bioregion" (MPA, in prep). This document is a product of the Manning Shelf Bioregional Assessment Project, and is currently under review by the Project's steering committee. Features of the revised approach (ie 'interim marine habitat classification' - currently under discussion) include:

- A change in terminology for mapped units from 'ecosystem' units to habitats' to provide consistency with other jurisdictions;
- Adoption of the Ferns and Hough (1999) definition of ecosystem ie holistic entity rather than discrete unit;
- Habitat is a surrogate for the diversity within the ecosystem. Consequently where possible other forms of biodiversity information should be obtained and incorporated;
- A change in terminology for 'micro-regions'. In future the term will be used in a manner more consistent with other jurisdictions. That is to refer very generally to the variety of micro-scale representative areas/units identified within a meso-scale region (eg habitat, ecosystem, biounits etc);
- The interim marine habitat classification may be applied at three hierarchical levels: 1. Regional Level (micro-scale/10s-100s of kms, approximately 1:100,000 maps, for the purpose of MPA establishment); 2. Local Level (pica-scale/<10km, approximately 1:25,000 for the purpose of MPA management); and 3. Site Level (>1:5,000, site specific, for the purpose of monitoring etc);
- At the Regional Level, marine habitats are primarily delineated in a rapid three-stage process. The revised approach has some similarities with that of Avery (2000) in that it can be applied in the absence of biological data by selectively applying physical data as biological surrogates in the absence of biological data. The use of surrogates is considered an interim step to facilitate the establishment of a representative MPA system and is regarded as a temporary substitute for systematic biological surveys. Three stages in the proposed process include:
    - Physiographic features (eg reef system, estuaries, intertidal beach, intertidal rock) are mapped using existing or modified GIS (eg delineation of offshore reefs using bathymetric relief, and nearshore reefs from existing aerial photos and potentially LandSat TM imagery);

- Physiographic features are partitioned to reflect the variation within each unit. In the absence of systematically surveyed biological data, physical data may be employed as a surrogate for natural biological variation eg subtidal reef system may be partitioned into several depth categories to reflect ecological depth gradients, estuaries may be divided into multiple types based on an accepted estuary classification system, intertidal beaches may be divided into three categories of beach state based on known relationships between beach state and the biodiversity of sandy beach macro-fauna. Other surrogates include exposed / protected shores, onshore/offshore position of islands/rocks;
- Where sufficient evidence exists physiographic features may be partitioned (generally along the coast) to reflect biogeographic variation over 10s-100s of kms; and

• Additional attributes including West et al.'s (1985) estuarine vegetation mapping will complement the habitat maps.

Mapping, Defining and Partitioning Marine Physiographic Features

Figure 2.1 and Table 2.2 demonstrate the process of identifying representative units used by Avery (2000) for mapping marine physiographic features and ultimately desegregating elements of the Tweed Moreton meso-scale bioregion into separate 'ecosystems'. This was undertaken for estuaries zoned along ecological gradients with respect to other marine environments. The Marine Parks Authority (MPA) advise that the terminology will change from "ecosystem" to "habitat" (pers. Comm. Avery, 2000).

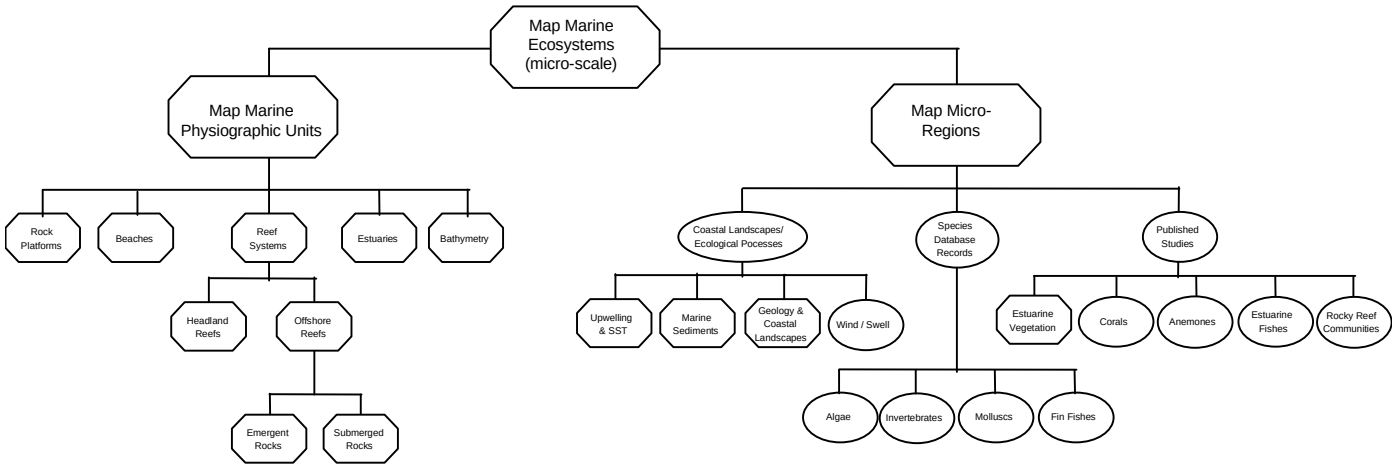

Figure 2.1: Marine Ecosystem Components used for Micro Scale Bioregionalisation of Tweed Moreton Bioregion (Avery, 2000)

Table 2.1: Summary Review of Ecosystem Component Mapping for New South Wales

New South Wales	Mapping Purpose		
	Mapping for Bioregionalisation and Sub Regions 1:100,000	Estuarine and Wetland Mapping for Resource Management	
		Estuarine Inventory for NSW (West et al 1985) 1:40,000	Coastal Wetlands of NSW (Adam et al 1985) 1:100,000 - 1:25,000
Summary / Purpose	A strategic planning and mapping process was undertaken to provide a basis for assessing the representativeness of the proposed Byron Bay MPA, and to demonstrate the potential application of habitat / ecosystem mapping for planning a representative system of MPAs in the northern NSW component of the Tweed Moreton Bioregion (Draft Byron Bay Assessment Project (Avery 2000)).	Providing a database and map of the habitat resources of estuaries in NSW as a resource inventory for managers and conservation planners	Designation of coastal wetland areas for conservation under State Environmental Planning Policy 14
Data Collection Overview	Marine 'ecosystems' were identified in a rapid three-stage process. 1. Physiographic features (eg reef system, estuaries, intertidal beach, intertidal rock) were mapped using existing or modified GIS data. 2. Physiographic features were partitioned across the continental shelf to reflect known within unit variation. In the absence of systematically surveyed biological data, physical data was employed as a surrogate for natural biological variation; eg subtidal reef systems and soft sediments were partitioned into several depth categories to reflect ecological depth gradients across the shelf. 3. Where sufficient evidence was available (eg published biological information, or oceanographic, sediment data) specific physiographic features were partitioned at points along the coast to reflect biogeographic variation over 10-100s of kms (eg micro-regionalisation.	Estuarine habitats were mapped using colour aerial photography.	Mapping based on colour aerial photography interpretation along NSW coast, with limited ground truthing.

New South Wales	Mapping Purpose		
	Mapping for Bioregionalisation and Sub Regions 1:100,000	Estuarine and Wetland Mapping for Resource Management	
		Estuarine Inventory for NSW (West et al 1985) 1:40,000	Coastal Wetlands of NSW (Adam et al 1985) 1:100,000 - 1:25,000
Data Sources	Aerial photo mapping (1:25,000), topographic maps and naval charts.	Aerial photo mapping (1:25,000) and field truthing by boat and dive survey.	Aerial photo mapping (1:25,000) and wetland definition and outline mapping for zoom transfer to topographic base.
Attributes Mapped / Hierarchies	Marine ecosystems mapped based on marine physiographic features (rock platforms, beaches, reef systems, estuaries, bathymetry) and mapping of micro regions (refer hierarchy attached)	Seagrass (species), mangroves and saltmarsh and estuarine sedgelands	Coastal wetland components grouped: mangrove, saltmarsh, Melaleuca forest, Casuarina forest, sedgeland, brackish / freshwater swamps, wet meadow
Ecosystem Component Definitions	Ecosystems were represented as discrete 'ecosystem' units delineated by physiographic features partitioned to reflect known ecological variation (at a scale of 10-100s of kms) along the coast and across the continental shelf.	Descriptions of attributes mapped only	Vegetation community inclusion and exclusion criteria provided
Level of Ground Truthing	Ground truthing – as for contributing datasets	NA	Extent not reported
Accuracy, Precision and Resolution of Data Capture	Limited to resolution of input mapping sources and photography (1:25,000)	NA	+/-50m error in boundary mapping
GIS or Other Presentation	ArcInfo	Hardcopy	Hardcopy
GIS Metadata Standards Used	ANZLIC	No	No
Coverage	NSW Portion of Tweed Moreton IMCRA Bioregion	Entire state (except small estuaries/lagoons)	Entire coastal area of state
Key References	Avery (2000) Preliminary GIS Coastal Inventory (Coastal Council, in prep.)	West et al (1985)	Adam et al (1985)
Comments	NSW is currently revising its classification and mapping approach for application on the Manning bioregion. A series of bioregional assessments along the remainder of coast are then anticipated.		Wetland types not differentiated

Table 2.2 is consistent with the broad hierarchy of scales for ecosystem component mapping presented by NSW Fisheries / MPA (Source's: NSW Marine Parks Authority, Deliberation of MPA Research Committee, Unpublished) as a general guide for future ecosystem component mapping (refer Table 2.3). This classification system only addresses ecosystems at the regional level (micro-scale). The revised 'interim marine habitat classification' system currently being developed will address the hierarchy of levels in a manner consistent with the Marine Park Authority NSW, 2000 'A Framework for Establishing a System of MPAs in NSW' Draft Discussion Paper, February 2000 (MPA, 2000a).

Table 2.2: Draft Physiographic Features and Marine Ecosystem Classification System for Tweed / Moreton Bioregion
(Including Micro-regionalisation of Estuaries) (Avery, 2000)

Physiographic Features	Micro-regions Identified	Primary data	Marine Ecosystems			
			Micro-regions		Ecosystem characteristics	Within ecosystem variation
i. Beach	no	sandy beach macro fauna	(No micro-regionalisation)	1.	Warm temperate macrofauna characterised by *Pseudolana elegans* (isopod), *Urohaustoriius gunni* (amphipod), *Scolelepis normalis* and *Nepthys australiensis* (polychaetes), and *Donax veruinus* (bivalve mollusc)	• Intermediate and reflective beach types (within and between beaches) based on both the Beach State Index and sandy beach macrofauna communities
ii. Rock platform	no	-	(No micro-regionalisation)	2.	Generally considered to be little geographic variation in rock platform communities within the bioregion	• Variation between exposed and sheltered headlands.
iii. Estuary	yes	Estuary Classification	IIIa-b Barrier Esturaies (Young)	3.	Barrier (wave dominated) estuary – relatively young / early stages of infilling. e.g. Clarence Broadwater. Large, shallow lagoons in low energy environments away from active tidal channels. Often densely covered by seagrass.	• Habitat variation within estuaries include: fringing vegetation, seagrass beds, unvegetated sediment, and channels. • Distance to estuary mouth
			IIIc-d Barrier Estuaries (mature)	4.	Barrier (wave dominated) estuary - relatively mature / late stages of infilling. e.g. Clarence River channel. Barrier estuary in-filled to form riverine estuary. Often narrow, elongated entrance channels within broad back barrier sand flats	
			IV Intermittent Estuaries	5.	Intermittent estuaries - saline coastal lagoons and small coastal creeks in coastal valleys with small catchments. Intermittently open to ocean. Small fluvial inputs. Mangroves generally absent. Often brackish but non-tidal. Waters occasionally become hyper-saline; benthic species diversity low and extreme variation in abundance.	
			V Brackish Barrier Lakes	6.	Brackish barrier lakes – bodies of fresh to slightly brackish water with a tenuous connection to the sea. Relatively rare in NSW. Vegetation dominated freshwater species. e.g. Lakes Cudgen and Arragan	

Physiographic Features	Micro-regions Identified	Primary data	Marine Ecosystems			
			Micro-regions		Ecosystem characteristics	Within ecosystem variation
iv. Reef Shallow (0-20m)	yes	algae	Reef Shallow Depth (nth of Ballina)	7.	Algal flora influenced by warm temperate waters, reflected in the absence of southern species *Schitza japonica*, *Curdiea crassa* and *Hormosira banksii*, and rare occurrence of *Ecklonia radiata*	• Potential influence of localised oceanographic up-welling, and fluvial discharge (particularly from the larger river systems).
			Reef Shallow Depth (sth of Ballina)	8.	Algal flora influenced by cool temperate waters, reflected in the presence of southern species *Schitza japonic*, *Curdiea crassa* and *Hormosira banksii*, and rare occurrence of *Ecklonia radiata*	
v. Reef medium (20-40m)	no	-	(No micro-regionalisation)	9.	This ecosystem is poorly researched. Assumed to be a depth related change in epi-benthic communities. e.g. sponge communities with less cover, high species richness and more massive form	
vi. Reef deep (40-200m)	no	-	(No micro-regionalisation)	10.	This ecosystem is poorly researched. Assumed to be depth related change in epi-benthic communities.	• Possible community variation with depth / position across the continental shelf
vii. Soft sediment shallow (0-20m)	yes	Marine sediments; Sea surface temperature	Soft Sediment Shallow Depth (nth of Ballina)	11.	Course, well sorted sands; high energy zone due to wave/swell action. Strong, nearshore East Australian Current	• Potential influence of localised oceanographic up-welling, and fluvial discharge (particularly from the larger river systems).
			Soft Sediment Shallow Depth (sth of Ballina)	12.	Course, well sorted sands; high energy zone due to wave/swell action. Weakened nearshore affect of the East Australian Current. Higher concentration of muds	
viii. Soft sediment medium (20-40m)	yes	Marine sediments; Sea surface temperature	Soft Sediment Medium Depth (nth of Ballina)	13.	Well sorted, mobile sands; high energy zone due to strong, nearshore East Australian Current	
			Soft Sediment Medium Depth (sth of Ballina)	14.	Diversity of grain sizes including muds, gravels and sands. Weakened nearshore affect of the East Australian Current. Concentration of muds. Decreasing effect of wave/swell action.	
ix. Soft sediment deep (40-200m)	no	Marine sediments; Sea surface temperature	(No micro-regionalisation)	15.	Strong East Australian Current, and sediment scouring at the continental shelf margin. Higher concentrations of carbonate in sediments, periodic intrusions of cool continental slope waters onto the continental shelf. No light at depth.	• Variation in sediment, light, temperature, water chemistry with depth and position across the shelf.

Table 2.3: Draft Interim Classification of Marine Habitats at Three Levels or Scales (NSW Fisheries)[1]

Level 1 (Meso)	Level 2 (Macro)	Level 3 (Micro or Pica)
Typical scale: 1:100,000 and greater	Typical Scale: 1:100,000 to 1:10,000 (data dependant)	Typical Scale: 1:10,000 and below
Estuaries	Types classified by Roy (1984) (tide dominated, wave dominated, and coastal lagoons)	Sand, mud, seagrass, mangrove, saltmarsh, natural rock, artificial habitats.
Beaches	Dissipative and reflective, scales of 50-100 km (biota)	Local anomalies and wave exposure
Intertidal rocky reef	Classified by dominant biota	Wave exposure, platform, rock pool, cobble, boulder, cliff, crevices, artificial
Shallow (0-25m) subtidal reefs	Classified by dominant biota (sessile, mobile and demersal)	Barrens, 'kelp', pinnacles
Shallow soft sediments	Classified by dominant biota and sediment type	Sand, mud
Deep reef	Physical structure, biota, sediment pockets	Extent, and vertical profile
Deep soft sediments	Biota and sediment type	
Sea mounts	Physical structure, biota	Extent, and vertical profile
Islands	Biota, breeding colonies, seals, birds (penguins and others)	Topography coves, beaches and cliffs.

Note 1: Table 2.3 is an early interim habitat classification put to the Manning Region Shelf Bioregional Assessment Project prior to work developing the interim marine habitat classification for NSW (MPA 2000a). The interim table is put forward only as a general guide to the mapping and classification scales and attributes under consideration.

2.2.2 Northern Territory

Key Mapping Issues

The meso-scale bioregionalisation process (Ferns 1999) pulls together much of the available relevant environmental datasets, together with a multivariate analysis of biological factors including coral, fish and mangrove distribution.

At a local scale several relevant ecosystem component mapping datasets for mangroves, corals and seagrasses have been collected including: Brocklehurst and Edmeades (1996) and Poiner et al (1987) (including CSIRO). A Coastal Resource Atlas of the major port areas is also held by the DLPE.

There is little field truthed mapping of benthic habitat types throughout the Territory other than datasets for Darwin Harbour, the Gulf of Carpentaria and Beagle Gulf. Turbidity, difficult access, marine hazards and relative lack of comprehensive baseline physiographic data hinder the application of conventional ecosystem mapping techniques.

Table 2.4: Summary Review of Ecosystem Component Mapping for the Northern Territory

Northern Territory	Mapping Purpose	
	Mapping for Bioregionalisation (IMBRENT) 1:1,000,000	Estuarine and Wetland Mapping for Resource Management
Summary/Purpose	Creation of a bioregional framework for marine conservation in the NT.	DLPE Coastal Geomorphology Atlas – linear characterisation. Brocklehurst and Edmeades (1996) – Mangrove distribution in Darwin Harbour.
Data Collection Overview	Oceanographic mapping data compiled from national sources used with local biophysical inventories to form the basis of a multivariate analysis of bioregions at a mesoscale.	DLPE linear mapping data input sources not known. Mangrove mapping by aerial photography interpretation and ground truthing.
Attributes Mapped/ Hierarchies	Currents, temperature, tectonic provinces, tidal range, cyclonic severity, drainage basins, mangrove community groups, mangrove coastal regions.	Mangrove Communities.
Ecosystem Component Definitions	IMBRENT regions	Mangrove Community Types.
Data Sources	AGSO – generalised bathometry interpolated from 5min grid (20m and 100m isobath interval). AGSO/AUSLIG – Geological maps 1:500,000 and 1:250,000. AODC and CSIRO Oceanography– oceanographic physico-chemical data (Sea surface temperature). CSIRO Wildlife and Ecology – Cyclone severity point data. Ocean Sciences Institute (Syd Uni) – sediment. Flinders Uni National Tidal Facility – tidal data (0.24 degree spacing contoured for polygons). NTPWA – hydrology.	Topographic mapping. Aerial photography.

Northern Territory	Mapping Purpose	
	Mapping for Bioregionalisation (IMBRENT) 1:1,000,000	Estuarine and Wetland Mapping for Resource Management
	NT Fisheries – fish catch/effort. NT Herbarium Wightman 1989 – mangrove distribution. NT Museum CCNT – Marine taxa point data for voucher specimens: fish, coral, sponge, starfish, polychaete, mollusc. Poiner (1987)(Biological communities of Gulf of Carpentaria). Other benthic biological communities seagrass, corals, marine algae – data restricted to selected studies in Darwin region, Beagle Gulf and Gulf of Carpentaria.	
Level of Ground Truthing	Literature review.	NA
Accuracy, Precision, and Resolution of Data Capture		NA
GIS or Other Presentation	Refer Appendix I of Ferns (1999).	Hardcopy – Letraline tape on topographic map.
GIS Metadata Standards Used	DLPE Metadatabase. Ferns (1999), Appendix 1 and 2.	NA
Coverage	Entire NT.	Entire NT. Darwin Harbour.
Key References	Ferns (1999). Brocklehurst and Edmeades (1996).	DLPE Unpublished. Beagle Gulf Benthic Survey Report (DLPE in prep). Brocklehurst and Edmeades (1996).
Comments	PWCNT commencing marine benthic mapping project involving: Beagle Gulf Benthic Survey; Cobourg Marine Mapping, Preliminary Mapping of Pellew Region.	DLPE – dataset may be digitised in future.

2.2.3 Queensland

Key Mapping Issues (excluding GBRMPA)

Considerable mapping effort coordination has occurred between DPIQ, QPWS and GBRMPA. Table 2.5 concentrates on the broad scale intertidal and nearshore habitat type mapping undertaken through DPIQ of some 70 – 80% of the mainland coastline. Mapping of offshore benthic habitats is being undertaken by Coles et al (1992b – ongoing) and GBRMPA / AIMS data sets. In particular, the long term monitoring of cross shelf transects includes surveys of seagrass and benthic epifauna.

A range of region specific mapping datasets of seagrass and mangrove mapping are held in regional DPIQ offices in relation to local investigations.

Table 2.5: Summary Review of Ecosystem Component Mapping for Queensland (excluding GBRMPA)

Queensland	Mapping purpose		
	Shoreline Mapping and Classification > 1:100,000	Strategic Mapping Coastal Wetlands Resource Mapping < 1:100,000	Strategic Mapping Seagrass/Benthos Resources Inventory < 1:100,000
Summary / Purpose	Linear map of physical coastline features of the mainland - Shoreline Mapping System (QPWS)	Coastal Wetlands Resource Mapping (DPIQ) - Strategic planning for the declaration of protected areas (including Fish Habitat Areas (FHAs), MPAs and Ramsar sites)	Seagrass (or marine plant) resource inventories for fisheries & marine park zoning and coastal zone management. Some information on algae and other benthos collected during seagrass surveys. Some macro-benthos survey information for non-reef waters of the shelf.
Data Collection Overview	Coastline type: wave exposure, tidal range, beach, rocky coast, mangrove	Mangrove communities by dominant genera present, saltpan and saline grassland. Additional information on habitat type, floristics and density collected	Seagrass area estimates; density (cover or biomass); species composition; depth, substrate, some notes on ecological value. Algae presence/absence also recorded.
Data Sources	Aerial photographs (1:12,000) and digital aerial videographic coverage Oceanographic data: 15 sec grid data	Landsat TM Bands 1-5, 7 Aerial photography- 1:12,000 and 1:50,000	Seagrass mapping & monitoring at various scales by free-dive surveys, u/w video, aerial photography, Landsat, helicopter overviews.
Level of Ground Truthing	Selected areas	Variable	Seagrasses: (refer Lee Long et al. 1993) dive and/or video surveys using transects and spot checks.
Accuracy, Precision and Resolution of Data Capture	Interpretation of aerial photographs has been accurate in the limited number of areas that have been ground truthed	Greater than 80% by comparison of ground truthing, aerial photography and satellite imagery	Between 10m and several hundred metres error on seagrass meadow boundaries, depending on survey methods and data source.
GIS or Other Presentation	GIS	ArcInfo coverage Hardcopy A3 maps	ArcInfo at GBRMPA (archive), MapInfo/ArcView at DPIQ (custodians)
GIS Metadata Standards Used	ANZLIC	ANZLIC	ANZLIC

Queensland	Mapping purpose		
	Shoreline Mapping and Classification > 1:100,000	Strategic Mapping Coastal Wetlands Resource Mapping < 1:100,000	Strategic Mapping Seagrass/Benthos Resources Inventory < 1:100,000
Coverage	Mainland coast almost complete, islands not yet mapped	70-80% of the coastline	Mainland coast almost complete (at various scales); eastern Qld deepwater (Great Barrier Reef lagoon & inter-reef) and reef platforms only sub-sampled (not mapped systematically). Torres Strait approx. 80% ?? sampled by CSIRO and DPIQ.
Key References		Bruinsma and Danaher (2000)	Lee Long et al. (1993); Coles et al (1996); Lee Long et al. (2000) ; Coles et al 2000.
Comments	Linear mapping of coastline	Burdekin Delta investigations DPIQ Danaher 1995 used as an example of the dataset. Techniques cited by Ward et al (1998a) as an appropriate model for 'mangrove area' determination for national SoE reporting. Reef not mapped. Also cross-shelf transects.	Deepwater (Great Barrier Reef lagoon & inter-reef) and reef platforms only sub-sampled (not mapped systematically). All data currently being validated for inclusion archives, as part of the CRC Reef Research Centre.

2.2.4 South Australia

Key Mapping Issues

Biounits:

Within the 8 bioregions in SA, a more detailed classification level ("biounits") has been devised during the past decade. The biounit classification was based largely upon existing biophysical information gathered as part of SA's contribution to the IMCRA planning process, complemented by (i) data and knowledge provided by an inter-agency Marine Protected Areas Working Group (Edyvane 1999a), and (ii) state-wide benthic survey data, gathered during the Benthic Surveys Program in SA.

The biounit classification reflects the variety of geological, geomorphological, oceanographic and major biological/ecological features within each bioregion. Thirty-five biounits have been classified (Edyvane 1999a), with nominated seaward boundaries at 50m for oceanic biounits, and 30m for gulfs biounits. The biounit classification was largely developed independently of the CSIRO "habitat" mapping work. In SA, the biophysical-based biounit classification is considered to be a suitable basis for developing a CAR system of MPAs, provided that mappable ecosystems information within biounits can be applied (see below)

Mappable Ecosystem Units

Within *biounits*, there are a number of mappable ecosystem types (e.g. *Posidonia* seagrass meadows, *Heterozostera*-dominated sandy/mud beds, *Scytothalia* and *Acrocarpia*-dominated boulder reef; *Macrocystis*-dominated limestone reef etc). Both dominant benthic biota and substrate type contribute to the classification. The mapping and classification of ecosystem types within biounits is currently in progress, as part of the assessment of MPA nominations using CAR principles.

Similar to workers in New South Wales, SA recognises that "ecosystems" are holistic entities, and therefore there may be physical, chemical, biological and ecological links between mappable ecosystem units (such as seagrass beds, and macro-algal dominated reefs; or between estuarine *Zostera* seagrass areas, and benthic *Posidonia* seagrass beds, to name two nearshore examples). Nevertheless, mappable ecosystem units (within and between the state's 35 biounits) provide a useful basis and scale for the development of a CAR system of MPAs in SA. The "mappable ecosystem units" are equivalent to the description of "marine habitat class" being developed in other states, and also relate to the level of "microscale" marine habitat classes, as described in Figure 4.1 (Hierarchical Classification of Marine Environments).

In SA, the development and use of marine ecosystem maps for application to the NRSMPA and a CAR system of MPAs, has recently become the responsibility of the Department of the Environment and Heritage (SA DEH), with the assistance of DTUP (Department of Transport, Urban Planning and the Arts) for data warehousing and GIS support.

The following main data sources are being used to develop a useful ecosystems/habitat classification.

- benthic survey information for SA;
- other published and unpublished survey reports and maps (biological, ecological, geological, geomorphological, oceanographic);
- 1: 10 000 - 1 40 000 coloured aerial photographs (which indicate major marine geological types and major benthic cover from 0m to approximately 20m, and are also useful for vulnerability/threats analysis, indicating coastal development, position of drainage points etc);
- state-wide bathymetry vector coverage (5m intervals).

The classification is in progress, and is being used to evaluate potential MPA nominations (there are 96 potential areas) in terms of their contribution to a CAR system of MPAs. The ecosystems/habitat classification is also being used to correct the erroneous CSIRO "habitat" map coverage (see below), so that part of that coverage will be useful for the development of a CAR system, in addition to other site-level decision-making. Additional ground-truthing, where necessary, may occur at a later stage.

Other mapped data used in SA
Other data assisting the development of the CAR system of MPAs in SA include:

- Statewide GIS bathymetry vector coverage (5m intervals);
- GIS point data of marine mammal and seabird distributions;
- GIS map of shipwreck sites;
- GIS map of coastal national parks and conservation parks;
- Mapped distributions of known major spawning, feeding, shelter, nursery areas for fish (in progress);
- Distributions of commercially and recreationally significant fish and mollusc species and other spatial fisheries information (in progress);
- GIS maps relevant to vulnerability/threats analysis (drainage and discharge points, aquaculture lease boundaries and descriptions; position of coastal national parks as buffers against some coastal threats etc)

Datums; Data Quality:
Marine GIS coverages are warehoused at DTUP, and form part of the SA Coastal Atlas and the environmental nodes of SA's Land Information System. All data sets have now been converted to the new Geocentric Datum of Australia (GDA) 1994. This also includes all coordinate information stored as attribute text. Data quality is variable, depending upon the source agency for each coverage, method of collection, and the scale at which it is mapped. Metadata are available for most coverages, and are documented systematically by DTUP.

Scales of Application:
The biounit classification is applied at the scale of hundreds of kilometres (1: 100 000+), and is being used to ensure that adequate representation of major biophysical types (biounits) occurs within IMCRA bioregions (1000's km).

The ecosystem/habitat classification described above is being applied/used at the scales of approximately:

- 1: 10 000- 1: 25 000: for (i) assessment of single potential MPAs in the proposed MPA network; (ii) for establishing zones within, and boundaries around, MPAs; (iii) for threat analysis; and (iv) to assist MPA management after establishment
- up to approximately 1: 100 000: for (i) assessing potential MPAs within and between biounits, and comparing their relative contributions to the CAR network system in SA (including bioregional representation, at larger scales); (ii) for regional threat analysis.

Single Species/Population Data:
Representing mappable ecosystem types/habitats in a CAR system is now widely considered to be a useful surrogate for protecting biodiversity, particularly for site-attached species, and those species and populations with strong habitat linkages. In SA, it is recognised that the conservation of many species, particularly highly mobile species, will require information on their distribution and abundance, in addition to the use of surrogate ecosystems measures.

Presently, there is no specific program in SA to map the distribution and relative abundance of species that are considered important in the development of a CAR system (e.g. endemic, rare, actually or potentially threatened, commercially and recreationally-significant, keystone species, and species of social importance, amongst others). However, for many of these species, sufficient information is available for their distributions and habitat linkages to be represented as point features on GIS maps, and this information is being mapped where available, and used for the development of the CAR system. Also being considered is the spatial separation of life stages of key species in the development of the MPA network, such as those species which may utilise different habitat types

(occurring in different biounits, or even different bioregions) during different stages of their life (post-larval, juvenile, adult etc).

It is also recognised that there are many species whose conservation status is currently not known (particularly many of the invertebrate groups). Sessile and habitat-linked species whose conservation status is not known, will hopefully be well served in a CAR system that represents ecosystems/habitat types. Others (mobile species) may not, and a project proposal has been prepared recently to determine the conservation status of several invertebrate and fish groups, to assist state-level conservation decision-making, as well as the development of a CAR system of MPAs.

There are many populations and species whose protection is better served by means other than (or in addition to) MPAs. Systems-wide management measures are required, that consider the needs of highly mobile species; and the spatial linkages between habitats, between separate populations of species, and between widely separated individuals of the same population. A vulnerability assessment program is underway as part of the development of a CAR system of MPAs. This will consider point source and regional pollution sources; poorly managed coastal and marine developments that degrade water quality, marine habitats and species; the introduction of exotic species (particularly in relation to port distribution); and inadequate fisheries management measures; amongst other potential and actual threats that require mitigation.

CSIRO "Habitat" Maps:
The CSIRO 1: 100 000 remotely sensed mapping of marine "habitats" is not being used by SA DEH as the main tool for developing a CAR system in SA due to a number of errors in the coverage. The CSIRO coverage will be revised.

Table 2.6: Summary Review of Ecosystem Mapping for South Australia

South Australia	Mapping Purpose		
	Mapping for Bioregionalisation and Sub-Regions 1:100,000	Strategic Inshore Mapping 1:100,000	Mapping of Specific Areas for Management Purposes (Seagrass Mapping for bays / inlets) 1:40.000
Summary / Purpose	To assist in the bioregionalisation process at a sub IMCRA scale for the identification of candidate representative MPAs (input to Edyvane 1999 a & b).	Benthic biodiversity sampling and benthic habitat mapping, to provide an information base on nearshore habitats for bioregionalisation; inter alia strategic planning for a representative system of MPAs in shallow subtidal waters of SA; and nearshore marine planning and management applications.	To map the extent of seagrass beds and monitor changes over time as indicators of environmental stress (mapping in Adelaide area only). To map location and condition of saltmarsh, mangrove, and other intertidal habitat, for management applications.
Data Collection Overview	Bioregions are not regarded as ecosystem-level in SA. Biounits are not regarded as habitat scale in SA. The SA mapping "hierarchy"* is as follows: • Bioregions (thousands of km) (8); • Biounits (hundreds of km) (35); • Mappable ecosystem units/habitats (usually tens of km to low hundreds of km) (number currently being determined and mapped); • Communities/Assemblages (from less than a kilometre, up to tens of km) (to be determined - lower priority if higher level surrogates can be used); • Patch (less than 1 km) (not being mapped). (*Note that the classification is not strictly hierarchical , because mappable ecosystem units/habitats are of variable size; some cross biounit boundaries, and others occur in several biounits.)	The SA benthic survey data, in addition to other marine data sources and 1: 10,000 - 1 – 25,000 coloured aerial photographs, are currently being used to develop an ecosystems/habitat classification. The Benthic Survey Program involved replicated sampling of marine flora (seagrass and macroalgae) and sessile invertebrates, in selected nearshore waters (usually to 20m) and offshore islands in each bioregion. CSIRO "habitat" classification and mapping utilised mainly enhanced 1: 100,000 LANDSAT images, and was ground truthed in a number of areas (coincidental with the benthic surveys), mainly using benthic grab samples of seagrass. The CSIRO geological categories in the "habitat" classification included low profile platform reef/heavy limestone or calcarenite reef/granite reef. This geological classification was largely derived from visual inspection of satellite imagery, and the method is not considered adequate for decision-making that requires habitat classification, without extensive editing, and inclusion of correct ecosystem types/habitat categories.	Mapping of seagrass beds, density/pattern/species in areas under greatest threat including Adelaide area and progressing to complete state coverage. Mapping of supratidal, intertidal and shallow subtidal habitats, including saltmarsh, mangroves, intertidal and shallow subtidal seagrasses, and other categories.

South Australia	Mapping Purpose		
	Mapping for Bioregionalisation and Sub-Regions 1:100,000	Strategic Inshore Mapping 1:100,000	Mapping of Specific Areas for Management Purposes (Seagrass Mapping for bays / inlets) 1:40.000
Attributes Mapped / Hierarchies	Refer biogeographic groupings above.	Refer Key Mapping Issues above.	65 categories of supratidal, intertidal, and shallow benthic habitat, incorporating geomorphological (e.g. shore platform; intertidal channel), biological (e.g. cyanobacterial mat, samphire, mangrove, seagrass) and condition (e.g. degraded; intact) data into the classification.
Ecosystem Component Definitions	Refer biogeographic groupings above.	Refer Key Mapping Issues above.	As above.
Data Sources	For biounit classification: navigation charts / wave exposure data / temperature / salinity / tidal data (via Flinders University)/ geological and geomorphological data, major ecological features (e.g. major seagrass and reef systems). For ecosystems/habitat classification: see Strategic Inshore Mapping section.	Landsat TM (Band 1 processed to level 9) (for creation of CSIRO "habitat" maps). 1:10,000 – 1:40,000 coloured aerial photographs (which indicate major marine geological types and major benthic cover from 0m to approximately 20m). SA benthic survey information (see Level of Ground Truthing). Statewide bathymetry vector coverage (5m intervals). Other published and unpublished survey reports and maps (biological, ecological, geological, geomorphological, oceanographic).	1: 10,000 - 1: 25,000 coloured aerial photography, supplemented by ground truthing in some areas.

South Australia	Mapping Purpose		
	Mapping for Bioregionalisation and Sub-Regions 1:100,000	Strategic Inshore Mapping 1:100,000	Mapping of Specific Areas for Management Purposes (Seagrass Mapping for bays / inlets) 1:40.000
Level of Ground Truthing	Refer Marine Biogeography dataset.	• Benthic sampling (SA Benthic Survey Program) using replicated 1m quadrats, along transects 1km - 10km apart, mainly from 5m to 20m. Not all 5m-depth intervals from 5m to 20m were sampled in each location (considered unnecessary, in many cases where habitat was similar 5m above or below the sample area). • Most ground truthing for the CSIRO habitat mapping work involved grab samples. • In some cases, the dive quadrat samples (which formed a major part of the SA Benthic Survey Program) were not considered in the creation of the CSIRO maps, resulting in discrepancies between mapped habitat types, and known habitat types from field sampling. • SARDI benthic sample data are of high quality/accuracy, but limited spatial extent (10 surveys covering parts of the nearshore marine environment in each bioregion, and offshore island groups, but many ecosystems/habitats across SA have still not been sampled/ground-truthed). • CSIRO habitat maps are of lower quality/accuracy, but useful spatial extent (i.e. state-wide coverage).	All mapping is being ground truthed for attribute accuracy.
Accuracy, Precision and Resolution of Data Capture	Refer Marine Biogeography dataset.	TBC.	Resolution 1:10,000 – 1:25,000. Accuracy of data is generally within 15 metres.
GIS or Other Presentation	ArcInfo.	ArcInfo. Vector format. Polygon feature class.	In Vector format . Polygon feature class (ArcInfo).
GIS Metadata Standards Used	ANZLIC.	ANZLIC.	ANZLIC.
Coverage	The 35 classified biounits have been given a nominal 30m boundary (in the gulf biounits), and 50m (offshore biounits), but sampling has not occurred at these depths.	Benthic sampling occurred in all bioregions, and included coastal areas and island groups across SA. Note: survey extended into western Victoria - Portland. The benthic sampling was limited to areas ranging to approximately 20m depth. Similarly with the CSIRO mapping, resolution from both satellite imagery and aerial photography does not extend beyond approximately 20m, at best.	All of the SA saltmarsh and mangrove habitats have been mapped and are currently being ground truthed.

South Australia	Mapping Purpose		
	Mapping for Bioregionalisation and Sub-Regions 1:100,000	Strategic Inshore Mapping 1:100,000	Mapping of Specific Areas for Management Purposes (Seagrass Mapping for bays / inlets) 1:40.000
Key References	Edyvane (1999 a & b)	Edyvane and Baker (1996a & b), Edyvane (1999 a & b)	EPA (1995)
Comments	This study pulls together the marine biogeographic dataset into a statewide bioregionalisation	Dataset input to Coastal Atlas	Similar coverage and techniques for mangrove and saltmarsh mapping. Saltmarsh layer will soon be on SA Coastal Atlas web site. A Coastal Resource Atlas for Oil Spills includes shoreline and estuarine and wetland features

2.2.5 Tasmania

Key Mapping Issues

Strategic mapping and survey for the purpose of establishing a CAR system of marine protected areas in Tasmania has occurred at two broad scales. Surveys of reef communities and specific habitat and community mapping of small MPAs have occurred at scales sufficient for management and monitoring (1:25,000 and below). Strategic scale mapping and sampling of nearshore benthic habitats has occurred at 1;100,000 scale. However this mapping has not yet been linked with parallel biodiversity survey (at habitats other than reefs) to provide a basis for bioregionalisation at sub-IMCRA scales. Consultation with relevant Tasmanian agencies also indicates difficulties in establishing a broad coastal resource baseline, especially due to the variable quality and coverage of coastal aerial photography. Offshore benthic habitats beyond 30m-50m have not been comprehensively mapped or field truthed.

A classification of Tasmanian estuaries and assessment of their conservation significance using ecological and physical attributes, population and landuse has been undertaken by Edgar et al (1999). This study included broad physical classification (using Landsat TM bands 1-5), biological characterisation and catchment mapping of estuaries to determine threats and conservation significance.

Table 2.7: Summary Review of Ecosystem Component Mapping for Tasmania

Tasmania	Mapping Purpose		
	Strategic Inshore Mapping 1:100,000	Mapping of Specific Areas for Candidate MPAs 1:25,000	Mapping of Specific Areas for Management Purposes (point data) *For the Open Coast*
Summary / Purpose	Regional Classification of Tasmanian Coastal Waters (Stage 3): Marine Habitat Mapping (Edyvane et al 1999).	Habitat Mapping of Potential Marine Propagation Areas on Tasmanian N / NE Coasts (Barrett and Wilcox 1999) to determine the representativeness of and suitability for inclusion as MPAs of 5 areas nominated by the Tasmanian Fishing Industry Council and the Tasmanian Amateur Sea Fishermen's Association.	Survey of 186 reef sites around Tasmania to contribute to a multivariate classification process for meso scale bioregionalisation. Program also included biological diversity surveys addressing representativeness of specific potential marine reserve locations (ie. Bass Strait: King Island, Rocky Cape, Eastern Bass Strait Islands) (Barrett and Edgar 1992).
Data Collection Overview	Remote sensing and ground truthing of broad inshore water habitat types (ie reef, sand, seagrass).	Habitat mapping by visual observation of candidate sites and dive transect survey for seagrass and macroalgae.	Dive transect biological survey of reefs at 5-10m depth sampling abundance, cover and diversity of fish, invertebrates and macroalgae (Point data only not mapping).
Attributes Mapped / Hierarchies	Seagrass, flat reef, complex reef, sand, mud and cobble.	Depth (2,5,10,+5m isobaths). Mud, sand, seagrass, flat reef, complex reef and cobble. Dominant seagrass and macroalgae also recorded Quantitative and qualitative fish and macroalgal transect survey.	Fish, invertebrates, macroalgae, abundance at reef sites.

Tasmania	Mapping Purpose		
	Strategic Inshore Mapping 1:100,000	Mapping of Specific Areas for Candidate MPAs 1:25,000	Mapping of Specific Areas for Management Purposes (point data) *For the Open Coast*
Ecosystem Component Definitions	Habitats defined by physiographic features including substrate type and geology (ie. Reef/sand) and occurrence and density of seagrass.	Habitat types (as above).	NA
Data Collection Sources and Input Mapping Scales	Landsat TM (Band 1 processed to level 9). Aerial photography 1:25,000 from Tas Land information Bureau.	Bathymetry by depth sounder corrected by tidal records and input to 3D-Mapps program (2m,5m,10m +5m contours produced). Coastline and Aerial Photography 1:25,000 from Tas Land Information Bureau.	Dive transect biological survey of sites (4 x 50m transects at 5m depth per site).
Level of Ground Truthing	NA	Grid pattern of visual observation (density of ground truthing not reported, sonar and video tow with GPS location.	4 to 6 sites (4 x 50m transects at 5m isobath for fish census, invertebrates, macroalgae) per location (Waterhouse Point, King Island, Rocky Cape).
Accuracy, Precision and Resolution of Data Capture	NA	NA	NA
GIS or Other Presentation	ArcInfo	Mapinfo	NA
GIS Metadata Standards Used	NA	NA	NA
Coverage	Entire coast – inshore waters to 20m.	Rocky Cape, Low Head, Waterhouse Bay, Binalong Bay, Lillico Beach, Three Sisters-Goat Island - to depth of 15 to 35m	14 – 17 sites at reefs at 5m depth (Waterhouse Point, King Island, Rocky Cape).
Key References	Edyvane et al (1999).	Barrett and Wilcox (1999).	Edgar et al (1994); Edgar et al (1997); Barrett and Edgar (1992).
Comments	It is noted that mapping for this dataset was not undertaken in tandem with a marine biodiversity sampling program.		Data collected for reef community characterisation and baseline for monitoring – not habitat mapping.

2.2.6 Victoria

Key Mapping Issues (Victoria)

In Victoria, marine 'ecosystem' mapping is conducted on both a strategic and management basis. The scale of mapping for both spatial and attribute detail is therefore dependent on the purpose for which it is required and resources available.

All the attributes can be represented at different spatial scales, but this is dependent on the resolution and availability of attribute information from one area to the next. Victoria considers an 'ecosystem' as a holistic entity. The 'ecosystem' is not a separate entity that is readily definable at one spatial scale, it is the attributes that form part of the 'ecosystem' that exist on various spatial scales. Below the broad meso-scale (ie. IMCRA bioregions) the following units are termed:

- Marine Habitat Classes (MHCs). At finer scales (1:100,000 – 1:10,000) Victoria has developed MHCs based on characteristic attributes. We have attempted to construct a logical approach to mapping by developing standard attribute descriptors that can be selected to represent MHCs at various spatial scales (1:10,000 – 1:100,000). The choice of attribute(s) for mapping will depend on purpose, suitability and availability at a particular scale. In general the attributes describe the dominant physical and biological structure of marine 'habitats'. MHC attributes are available for intertidal and subtidal areas.
- Communities. For 'communities', this is a relatively new area of work involving detailed quantitative assessment of constituent species within a close range of MHCs. For example, kelp-dominated MHCs may number approximately 8 in Victoria (refer Table 2.10). However, detailed quantitative analysis involving community dissimilarity and distance matrices (eg multidimensional scaling) among the 8 MHCs reveals that there are in fact 20 community types. A study has recently been completed on kelp communities of the Central Victorian Bioregion. This work is considered new and not ready for public release.

Table 2.8: Summary Review of Ecosystem Component Mapping for Victoria

Victoria	Mapping Purpose				
	Mapping for Bioregionalization 1:1,000,000	Strategic Inshore Mapping 1:100,000	Extended Mapping Of Selected Offshore Areas 1:100,000	Mapping Of Specific Areas For Management Purposes *For The Open Coast* 1:10,000 - 1:25,000	Mapping Of Specific Areas For Management Purposes *For Bays And Inlets* 1:10,000 - 1:25,000
Summary/ Purpose	Broad examination and classification of physical and biological components of Victoria's coastal waters and the Bass Strait. Work supported the development of IMCRA.	Strategic statewide area mapping of Victoria's broad substratum classes within nearshore waters (generally < 30m depth).	Extended mapping of nearshore waters to the 3nm State Territorial Boundary to assist with the identification of candidate MPAs.	Mapping at specific areas of Victoria's open coast for management and monitoring purposes.	Mapping at specific areas of Victoria's bays and inlets for management and monitoring purposes.
Data Collection Overview	Initially the list of key marine environmental datasets was identified as suitable for the development of a biophysical classification (eg bathymetry, tides, physico-chemical, waves, geology, distribution of biota etc.). Physical classification of open coastal waters via multivariate analysis using the following variables: bathymetry, coastal orientation, tidal levels, currents, wave energy and sea surface temperature. Physical classification of Bass Strait using multivariate analysis of physico-chemical properties of seawater. Spatial boundaries for bioregions submitted towards the development of IMCRA.	Initially LandSat TM imagery of open coastline nearshore waters supplemented with aerial photo interpretation to produce spatial boundaries of major substratum attributes ranging from 10-50 m depth. (Note: aerial photo interpretation used exclusively for intertidal mapping). Spatial boundaries and substratum attributes checked through series of bounce dives, video drops and grab samples. Dominant biota described from observations. (Note: Quantitative infauna community and sediment data derived from broad scale sampling of sediments across the open coast).	Refinement of spatial boundaries and substratum attributes derived from original LandSat TM using hydoacoustic devices (eg RoxAnn and Echo Listener). Spatial boundaries extended to 3nm, additional substratum attributes derived from application of hydroacoustic technology. Substratum attributes checked through series of video drops. Dominant biota described from observations.	Further refinement of spatial boundaries for open coast areas using combined side-scan sonar and EchoListener devices to achieve fine-scale spatial resolution. Quantitative data on biotic communities inhabiting rocky reefs collected by trained marine biologists. Divers swim series of stratified 200m belt transects.	Aerial photo interpretation to produce spatial boundaries, mainly depicting macrophyte beds and major substratum attributes. (Note: technique outlined for open coast can also be employed, ie side scan sonar and EchoListener) Semi quantitative data on macrophytes. Visual transects using glass bottom observation pod on base of survey vessel. Also video transects using towable camera.

Victoria	Mapping Purpose				
	Mapping for Bioregionalization 1:1,000,000	Strategic Inshore Mapping 1:100,000	Extended Mapping Of Selected Offshore Areas 1:100,000	Mapping Of Specific Areas For Management Purposes *For The Open Coast* 1:10,000 - 1:25,000	Mapping Of Specific Areas For Management Purposes *For Bays And Inlets* 1:10,000 - 1:25,000
Data Sources and Input Mapping Scales	Numerous data sources, see Key References for details.	LandSat TM Images from ACRES (Band 1, preprocessed to level 9), rectified against AUSLIG 1:100,000 topographic maps. Final processed maps incorporate 1:25,000 coastline.	Collected directly from field sampling.	Collected directly from field sampling.	Rectified colour positive aerial photos, other data collected from field sampling.
Attributes Mapped / Hierarchies	Refer Hamilton (1994) and VIMS (1994).	For Marine Habitat Class attributes, refer Tables 2.9 and 2.10. For Community attributes, refer Ferns and Hough (2000).	For Marine Habitat Class attributes, refer Tables 2.9 and 2.10. For Community attributes, refer Ferns and Hough (2000).	For Marine Habitat Class attributes, refer Tables 2.9 and 2.10. For Community attributes, refer Ferns and Hough (2000).	For Marine Habitat Class attributes, refer Tables 2.9 and 2.10. For Community attributes, refer Ferns and Hough (2000).
Ecosystem Component Definitions	Bioregion.	Marine Habitat Class, Community.	Marine Habitat Class, Community.	Marine Habitat Class, Community.	Marine Habitat Class, Community.
Level of Ground Truthing	Regions derived through modelling and expert opinion. Bioregionalisation provides an initial framework towards delineating the marine environment into broad 'homogeneous' regions.	Bounce dives and video variable, depending on heterogeneity of local area (in total 467 samples to date) Broad-scale systematic sampling of soft sediments involved 46 transects, 20 Km apart. Replicate samples taken at 10m, 20m and 40m stations (total of 136 samples).	Selected offshore areas mapped using hydroacoustic devices involve boat transects 200 – 500 m apart using RoxAnn and EchoListener acoustic devices.	Bunurong area mapped using hydroacoustic devices involve boat transects approx 200 m apart. Note: side scan sonar provides a swath area approximately 120m therefore mosaic of whole area generated.	Numerous transects and observation sites (generally <100) in each study area.
Accuracy, Precision and Resolution of Data Capture	Varies for original data. Most data point form then modelled into continuous polygon areas using spatial interpolation methods.	DGPS employed throughout surveying. Polygon boundary accuracy +/-30m. Attribute accuracy derived from remote sensing interpretation generally 80% accurate.	DGPS employed throughout surveying. Polygon boundary accuracy +/-30m Polygons generated using IDW interpolation of transect data combined with LandSat TM polygons. Attribute accuracy derived from remote sensing interpretation generally 80% accurate.	DGPS employed throughout surveying. Polygon boundary accuracy +/-20m. Attribute accuracy derived from remote sensing interpretation generally 80% accurate.	DGPS employed throughout surveying. Polygon boundaries accurate to within 5-10m. Attribute accuracy derived from remote sensing interpretation generally 80% accurate.

Victoria	Mapping Purpose				
	Mapping for Bioregionalization 1:1,000,000	Strategic Inshore Mapping 1:100,000	Extended Mapping Of Selected Offshore Areas 1:100,000	Mapping Of Specific Areas For Management Purposes *For The Open Coast* 1:10,000 - 1:25,000	Mapping Of Specific Areas For Management Purposes *For Bays And Inlets* 1:10,000 - 1:25,000
GIS or Other Presentation	Available on NRE Marine and Coastal Corporate Geospatial Data Library and Australian Coastal Atlas (see GIS references: Ferns and Catlin 1999; Mahon 1997; Roob et al 1995).	Available on NRE Marine and Coastal Corporate Geospatial Data Library and Australian Coastal Atlas (see GIS references: Ferns and Catlin 1999; Mahon 1997; Roob et al 1995).	Available on NRE Marine and Coastal Corporate Geospatial Data Library and Australian Coastal Atlas (see GIS references: Ferns and Catlin 1999; Mahon 1997; Roob et al 1995).	Not yet publicly available.	Gippsland Lakes and Corner Inlet available on NRE Marine and Coastal Corporate Geospatial Data Library and Australian Coastal Atlas (see GIS references: Ferns and Catlin 1999; Mahon 1997; Roob et al 1995). Other areas not yet publicly available.
GIS Metadata Standards Used	All data captured according to full ANZLIC metadata standards.	All data captured according to full ANZLIC metadata standards.	All data captured according to full ANZLIC metadata standards.	All data captured according to full ANZLIC metadata standards.	All data captured according to full ANZLIC metadata standards.
Coverage	Statewide (and National).	Statewide nearshore waters.	Selected areas	Bunurong Marine Park.	All major bays, inlets and estuaries across Victoria (Port Phillip Bay to be completed late 2000).
Key References	Hamilton (1994); VIMS (1994); CEE (1992)	Ferns (1999); Ferns and Hough (1999); Ferns and Hough (2000); Ferns (2000) (See Ferns and Catlin (1999); Mahon (1997) and Roob et al (1995) for work associated with GIS)	Ferns (1999); Roob and Currie (1996); Roob and O'Hara (1996); Roob, Blake and Perry (1999)	Ferns and Hough (2000) (Also see Ferns and Hough (1999) for review on side scan sonar technique)	Roob and Ball (1997); Roob Morris and Werner (1998); Blake et al (2000) (Western Port Bay and Port Phillip Bay unpublished).
Comments					

Table 2.9: Interim MHC Attributes for the Intertidal and Immediate Coastal Areas (Victoria)

Description	Intertidal MHC Attributes
Shoreline category	Dune Beach Platform Beach / Platform Reef Cliff (steep or inclined) Lagoon Flat Artificial seawall
Intertidal area / zone	Coastal / Backshore Supralittoral Littoral Infralittoral fringe
Substratum type	Bedrock Bedrock (broken) Cobble Bedrock / rock Boulder / cobble Sand Sand / Gravel Sand / Bedrock Mud Mud / Sand Artificial structure (ie Concrete/ Wood / Metal)
Lithology	Basalt Granite Sandstone Limestone Calcarenite
Wave Energy / Exposure	Low Moderate Moderate – High
Dominant structural biota	Coastal scrub Coastal heath Mangrove Salt marsh Seagrass Fleshy algae – mixed greens Fleshy algae – mixed browns Durvillaea Hormosira Turf algae Coralline algae Pyura Mussels Barnacles

Table 2.10: Interim MHCs for Subtidal Reef and Sand Substrata (Victoria)

Description	Subtidal MHC Attributes			
Substratum type	Reef		Sediment	
Substratum relief	Low profile (reef) Heavy (reef)		Flat (sand / mud) Ripples (sand) Gently undulating ridges (sand) Steeply undulating ridges (sand)	
Substratum texture	Solid Broken (boulders / slabs / bommies) Cobbles Rubble/Pebbles/Gravel	Gutters	Coarse sand Medium sand Fine sand	Muddy Sand Mud / silt Shelly rubble / grit
Substratum consistency	Continuous	Patchy		
Lithology	Basalt Granite Sandstone Limestone Calcarenite			
Dominant reef biota	Kelp – Phyllospora dominated Kelp – Macrocystis dominated Kelp – Durvillaea dominated Kelp - Ecklonia dominated Kelp – Mixed Phyllospora / Ecklonia Mixed algae - Brown algae dominated Mixed algae – other		Cystophora Amphibolis Cystophora / Amphibolis Red algae dominated Sessile invertebrates (eg sponges) Urchin barrens	
Reef understorey biota	Encrusting coralline algae Mixed red algae Sessile invertebrates		Caulerpa dominated Mixed algae Plocamium dominated	
Dominant sediment biota	Halophila Posidonia Amphibolis Zostera	Heterozostera Ruppia Mixed seagrass / algae Caulerpa dominated	Mixed Zostera /Posidonia / Halophila Mixed Posidonia / Halophila Mixed Zostera / Posidonia Mixed Zostera / Halophila	
Seagrass density	Sparse	Medium	Dense	

2.2.7 Western Australia

Key Mapping Issues

Broad habitat mapping coverage of WA waters is divided into the temperate waters mapping dataset south of Perth (following unpublished CSIRO (H Kirkman) / WA Department of Transport, Coastal resource Mapping), and a collection of datasets for specific areas elsewhere (ie Ningaloo Reef, Abrolhos Islands).

CALM report that initial broad stratification using satellite images and rectified aerial photos is conducted and, subsequently, representative areas and areas of interest are identified for field surveys. A field survey is conducted to confirm the biological content/identity of the habitat classes (refer Table 2.12) by direct observation in shallow waters/coasts, and by spot dives and/or video/jump camera in deeper waters. These sampling approaches have involved in the Ningaloo Marine Park, about 600 spot surveys over an area with about 100km coastline length. Field confirmation from field trips is broad (for the purpose of validating mapping classes and identity), primarily to confirm identity and spatial location.

Table 2.11: Summary Review of Ecosystem Component Mapping for Western Australia

Western Australia	Mapping Purpose		
	Strategic Inshore Mapping 1: 100,000	Mapping of Specific Areas for Management Purposes (1:100,000 to 1:10,000)	Specific Fisheries Project Related Mapping (Various Scales)
Summary/Purpose	Defines physical and biogeographic characteristics of ecosystems.	Purpose to clarify strategic scale mapping and identify boundaries of MPAs following Wilson report (CALM 1994). Habitats are defined by bio-geomorphological criteria including sand, algal covered reef, seagrass etc.	Maps broad biogeographic characteristics of ecosystems.
Data Collection Overview	Initial broad stratification using satellite images and rectified aerial photos. Representative areas and areas of interest are identified for field survey. A broad field survey confirmation is conducted. For temperate waters south of Perth – the dataset is derived from broadscale habitat classification (unpublished CSIRO (H Kirkman) / WA Department of Transport, Coastal resource Mapping). Data collection and field truthing standards are variable in other areas.	Combination of Landsat and aerial photo mapping with variable extent of field truthing among datasets. Ningaloo is a recent comprehensive example of this mapping.	Different survey methods including towed videos, aerial photos and spot dives.
Attributes Mapped / Hierarchies	Refer hierarchy Table 2.12.	Refer hierarchy in Table 2.12.	Sand, reef, algae, seagrass.

Western Australia	Mapping Purpose		
	Strategic Inshore Mapping 1: 100,000	Mapping of Specific Areas for Management Purposes (1:100,000 to 1:10,000)	Specific Fisheries Project Related Mapping (Various Scales)
Ecosystem Component Definitions	Ecosystems are defined on mainly physical and biogeographic criteria (above), while habitats are defined by bio-geomorphological criteria; elements include sand, algal covered reef, seagrass, platform reef.	Habitats classified according to hierarchy Table 2.12.	Ecosystems not defined, habitats are defined by bio-morphological criteria, elements include sand, reef, algal covered reef, seagrass.
Data Sources	Landsat TM (Band 1) for temperate waters and aerial photos at various scales.	Landsat TM (Band 5 – Ningaloo). Aerial Photos 1:20,000.	Aerial photos (various scales).
Level of Ground Truthing	Dive transects.	Ground truthing boat/dive inspection based on habitat heterogeneity.	NA
Accuracy, Precision and Resolution of Data Capture	Varying tolerances due to the generally fuzzy nature of boundaries.	Generally +/- 20-30m where aerial photos used as a mapping basis or +/- 100m for Landsat mapping.	Various, dGPS generates locational errors of a few meters or less.
GIS or Other Presentation	ArcInfo	ArcView (Ningaloo).	GIS
GIS Metadata Standards Used	Generally CALM which follow WALIS considered to be ANZLIC compliant.	Generally CALM which follow WALIS considered to be ANZLIC compliant.	WALIS (ANZLIC).
Coverage	Various IMCRA bioregions – part CWC, all LNE / WSC / EUC.	Various IMCRA bioregions – EUC (nil), WSC (20%), LNE (30%), CWC (20%), ABR (20%), SBY (50%), ZUY (nil), NIN (100%), PIN (10%), PIO (10% - Monte Bello), CAN (nil), KSD (nil), KIM (nil), OSS (5%), BON (nil), CAB (nil).	Various including Abrolhos Islands, Jurien, Dampier Archipelago, Shark Bay and Recherche Group.
Key References	Kirkman & Kuo (1996), CALM (1994).	CALM (2000) .	Fisheries WA (1998) Plan of Management for Abrolhos Islands.
Comments	Comparable habitat classification to temperate inshore areas mapped by Kirkman in SA, Vic and Tas.	Refer hierarchy in Table 2.12	Fisheries WA notes that WA jurisdiction is divided into 4 fisheries regions for management purposes, these do not directly overlap with IMCRA bioregions

Other Relevant WA Mapping Datasets

Linear mapping of mangrove coverage (extent and density) along WA coastline (Fisheries WA). Geomorphology of entire coastline mapped at 1:100,000 (DOTWA). Bathymetric data base (DOTWA). Coastal Resources Atlas of WA (DOTWA).

Table 2.12 : Habitat Classification Hierarchy (Western Australia)

Habitat classification	Tidal range	Substrate type	Relief	Macrobiology	Sub -categories	Comments
Rocky shore	Intertidal	Igneous Metamorphic Sedimentary	High and low	Bare		Continuous rocky shore cliff, boulders, pavement around HWM
Beach	Intertidal	Sand	Low	Bare		Continuous intertidal sand
Shoreline reef platform	Intertidal	Igneous Metamorphic Sedimentary	Low	Bare Algal turf		Continuous reef platform along the shoreline
Intertidal reef	Intertidal	Igneous Metamorphic Sedimentary	Low	Coralline algae, Macroalgae		Offshore
Mangal	Intertidal	NA	NA	Mangroves		Continuous mangrove cover (<1 ha)
Mudflat	Intertidal	Mud Silts	Low	Bare Algal mats		Continuous intertidal mudflat Includes flats behind mangals
Sand shoal	Intertidal	Sand	Low	Bare Little macroalgae		Medium to coarse sand Highly mobile sand
Salt marsh	Intertidal	Mud Silt	NA	Samphire		Continuous salt marsh cover (>1 ha) on protected or low energy coastline
Coral reef (Tropical Only)	Intertidal & subtidal	NA	High and low	Hard and soft corals	Coral area - subtidal, high live coral cover Intertidal coral reef flat - intertidal, low live coral %	Typical coral reef community >10% cover Seaward reef slope, reef crest, back reef, reef flat and individual bommies
Rubble (Tropical only)	Subtidal	Dead coral	Low	Sparse live coral Sparse vegetation		Lagoonal areas Mainly unconsolidated coral rubble
Reef platform	Subtidal	Igneous Metamorphic Sedimentary	Low	Diverse algae Sessile invertebrates (including sponges, sea-whips, sea-pens)		Includes limestone pavement or low relief reef
Macroalgae dominated limestone reef	Subtidal	Sedimentary	High and	Macroalgae		Typically covered in macroalgae (>10%) with diverse

Habitat classification	Tidal range	Substrate type	Relief	Macrobiology	Sub -categories	Comments
(Temperate only)			low			invertebrate life in overhangs & caves
Macroalgae dominated granite reef	Subtidal	Igneous Metamorphic	High and low	Macroalgae		Typically covered in macroalgae (>10%) with diverse invertebrate life in overhangs & caves
Macroalgal beds	Subtidal	Sand Pavement	Low	Macroalgae	Dense macroalgae - >30% cover Sparse macroalgae - 10-30% cover	Continuous macroalgal cover (>1 ha) Seasonal macroalgae % coverage allowance (min 10%)
Seagrass meadows	Subtidal	Sand Pavement	Low	Seagrasses	Dense seagrass - >30% cover Sparse seagrass - 10-30% cover	Continuous (>10%) seagrass coverage (>1 ha) Perennials/ephemerals
Sand	Subtidal	Sand (generally white)	Low	Bare		Little or no vegetation
Silt	Subtidal	Muds Silts	Low	Bare		Marine and/or terrigenous muds & silts Little or no vegetation

2.2.8 Commonwealth of Australia (excluding GBRMPA)

Marine protected area development and management

In Commonwealth waters no systematic and broadscale process of mapping and sampling offshore marine biodiversity has been undertaken with the aim of establishing a representative system of MPAs. Commonwealth mapping priorities have historically followed other driving factors. A large proportion of the mapping data for Commonwealth waters has been collected by CSIRO or derived from datasets of other agencies such as AGSO.

Ecosystem component (habitat) mapping has been undertaken in Commonwealth waters (at varying scales and of different attributes) in specific areas nominated as candidates for Commonwealth and Commonwealth/State MPAs. Areas mapped in the Commonwealth jurisdiction are described in Table 2.13. The objectives of these mapping and survey projects have included mapping for MPA management and monitoring, as well as strategic planning for MPA identification and zoning. In most cases, mapping results being used for the purposes of MPA planning or management have been collected by other stakeholders for other original purposes.

Historically, ecosystem mapping in Commonwealth waters has generally been undertaken for the following main purposes:

- Industrial interest in prospective grounds for commercial activities. The information derived from such mapping is often made available (under various arrangements) to environmental managers and/or the Commonwealth MPA team for the following purposes. This kind of mapping may be used for bioregionalisation or may be considered strategic mapping.

- Initial surveying of a relatively unknown area to assess the possible conservation values of a prospective MPA. This information is generally on a broad scale and is gathered to determine the general composition and complexity of an area, to get an indication of the biological diversity of an area, or to assess the potential vulnerability of an area to some specific activity. This mapping is generally for strategic purposes but may also form the basis for management.

- Subsequent surveying or ground-truthing in an area where some broad scale mapping has been done previously. This information is usually gathered for management decisions and is targeted at providing more detail on biological diversity at a finer scale, ecological linkages, and vulnerability of a habitat or species to a specific activity.

Mapping in remote Commonwealth waters is usually done on a much broader scale and generally at lower resolution than inshore mapping. The scale of mapping in these areas is not consistent within or between categories and varies according to the original purpose and methodologies of the mapping activity, and the size of the area being mapped.

The Environmental Resources Information Network (ERIN) within Environment Australia plays a major role in coordinating and facilitating access to Commonwealth and other jurisdiction GIS mapping datasets, including the internet mapping tool “Australian Coastal Atlas”. ERIN promotes the use of consistent GIS metadata standards based on ANZLIC guidelines.

National Oceans Policy and the development of Regional Marine Plans

Under *Australia’s Oceans Policy* (1998), the Commonwealth is developing an integrated and ecosystem-based approach to planning and management for Australian marine jurisdiction through the development of Regional Marine Plans, for areas based on large marine ecosystems. Development of the plans will be coordinated by the National Oceans Office, located in Hobart.

Based in part on the provincial-level categorisation developed in the IMCRA process and the preliminary large marine domain bioregionalisation used *in Australia's Oceans Policy,* some 14 large marine systems have been identified in Australian waters. In addition to identifying current and potential uses and values within the Regions, the plans will identify priorities and put in place measures to meet conservation requirements and will determine those areas that are to be assessed for marine protected area declaration through the NRSMPA processes.

Development of the first of Regional Marine Plan - for the South-east Region - commenced on 14 April 2000. The South-east Region coves some 2 million sq km and includes marine areas off Victoria, Tasmania (including Macquarie Island), southern New South Wales and eastern South Australia. Broadly, the Region includes all of the waters and seabed within the 200 nautical mile limit of the Exclusive Economic Zone (EEZ), and the extended continental shelf beyond the EEZ, to which Australia will be claiming certain rights under the United Nations Convention on the Law of the Sea.

Priority will be given to the development of methods that will allow assessment of seabed structure and patterns of biological diversity and the development and testing of habitat mapping and monitoring techniques. An important first step is the development of high resolution seabed coverage for the Region and testing of acoustic mapping techniques for seabed habitats, coupled with targeted biological and other sampling programs for the seabed and water column, and remote sensing.
Two major seabed mapping projects have been commissioned:

- Building on initial high-resolution seabed mapping in the South-east, a joint National Oceans Office/AGSO survey in 1999/2000 has provided high-resolution acoustic swath mapping coverage of some 240,000 square km of the continental slope in the Region and adjacent waters, including the deeper areas of the Great Australian Bight Marine Park and the margins of Lord Howe Island. Modern acoustic mapping techniques can provide considerable information beyond bathymetry and, while most efficient in deeper water, may provide very cost-effective means of developing testable broad-scale and high resolution mapping of seabed features and sediment types and major seabed habitat types.
- Building on the seabed mapping surveys, a joint National Oceans Office/CSIRO study will test the potential application of high resolution swath mapping acoustic techniques in assessment and mapping of seabed habitat types. An initial 45 day survey program in the South-east Region and adjacent waters was completed in April-May 2000. An important component is the use of a range of deep-water video camera and sampling techniques to ground-truth acoustic information, and a structured sampling program for areas in deeper water for which little or no information currently exists.

Table 2.13: Summary Review of Ecosystem Component Mapping for Commonwealth Marine Protected Areas

MPA Name / (IMCRA Bioregion/Province)/ MPA Size	Mapping Purpose / Description of Data Collection			
	Mapping at Bioregional Scale	Specific Mapping for Management Purposes	Raw Data Custodian	References / Comments
Cartier Island and Ashmore Reef (Oceanic Shoals Bioregion) Approx. 80,000 ha, depths of intertidal to 500m.	Broad scale bathymetric mapping. Fish stock levels and coral mapping.	Fine scale habitat mapping of main features of the reef and near shore areas. Fine scale mapping of main reefs within the area of joint Australian and Indonesian cooperation.	AGSO, CSIRO CSIRO	Various maps available, including some hand drawn maps and GIS layers. Skewes et al (1999 a & b), Milton (1999).
Coringa-Herald National Nature Reserve and Lihou Reef National Nature Reserve (Coral Sea Territory) Approx. 900,000 ha.	Broad scale bathymetric mapping for general region.	Some reef habitats broadly mapped including main reef structures in shallower waters. No benthic mapping of deeper waters in reserves.	EA, Royal Australian Navy, AUSLIG.	References in Commonwealth of Australia (in prep).
Elizabeth and Middleton Reefs Marine National Nature Reserve (Norfolk Province (c)) Approx. 200,000 ha.	Broad scale bathymetric mapping for general region.	Some fine-scale naval charts and mapping of commercial activities.	Royal Australian Navy, Commercial sources.	
Great Australian Bight Marine Park (Eucla Bioregion) Approx. 2 million ha, depths of 50-5500m.	Broad scale bathymetric mapping.	Recent benthic habitat mapping by trial rapid assessment techniques using multi-beam swath mapping and ground-truthing with trawls and benthic grabs in shallow to deep waters.	AGSO, CSIRO, National Oceans Office.	Report in preparation (CSIRO, AGSO).
		Some mapping of pelagic and migratory species distributions, using aerial surveys and incidental sightings. Benthic habitat and benthic species distributions using various techniques, including video-surveys, benthic sled and grab sampling in shallow waters. Mapping of major oceanographic characteristics using satellite imagery and current metres. Mapping of sediment composition and geological features of the bottom at various depths.	Various sources, see references.	Some findings summarised and specific references found in the bibliography of Commonwealth of Australia (1999).
Heard Island and McDonald Islands region (Kerguelen Province) Approx. depths of 200-3000m	Broad scale bathymetric mapping using various techniques.	Localised benthic habitat mapping in shallower areas using combination of commercial information and research results from various techniques.	Australian Antarctic Division, some international and domestic commercial sources.	Findings summarised and specific references included in Meyer et al. (2000).
Lord Howe Island Marine Park (Norfolk Province (b)) Approx. 300,500 ha, depths of 40-2000m	Broad scale bathymetric swath mapping within 12 nautical miles of the island. Naval navigational bathymetric maps. General commercially available bathymetric maps.		AGSO, Royal Australian Navy, AUSLIG.	Report in preparation (AGSO).

MPA Name / (IMCRA Bioregion/Province)/ MPA Size	Mapping Purpose / Description of Data Collection			
	Mapping at Bioregional Scale	Specific Mapping for Management Purposes	Raw Data Custodian	References / Comments
Monte Bello Islands (Pilbara Offshore Bioregion)	Broad scale bathymetric mapping.	Some mapping of biological data, bathymetric data and petroleum industry information.	AGSO, CSIRO and North West Shelf Study	GIS mapping pilot project
Macquarie Island Marine Park (Macquarie Province) Approx. 18 million ha, depths of 500-5500m.	Broad scale bathymetric mapping in and around the Province (eco-sounding).		NZ Oceanographic Institute.	Navigational charts at 1:1,000,000 and 1:200,000 scales (1967 and 1970, available from the NZ Oceanographic Institute).
	Broad scale bathymetric mapping in the south-east part of the Province and shallow portions of the Macquarie Ridge (swath mapping).		AGSO, CSIRO, National Oceans Office.	Reports in preparation (AGSO).
		Some localised benthic habitat mapping near Macquarie Ridge (deep-sea video system, CSIRO) and limited ground-truthing (with benthic sleds and dredges).	CSIRO, Fisheries Research and Development Corporation (FRDC), EA.	Report in press (CSIRO); further reports in preparation (CSIRO, FRDC).
		Migratory and foraging ranges mapped for some species using satellite tracking.	Various researchers.	Summarised in Scott (1994) and Robinson and Scott (1999).
Mermaid Reef Marine National Nature Reserve (Indian Ocean) Approx. 54,000 ha.	Broad scale bathymetric mapping in shallow waters only.		AGSO	
		Localised mapping of main habitat types and surveys by WA Museum. Annual monitoring of fish and coral distributions (no longer for lagoon).	AIMS	Berry et al (1986), Done et al. (1994)
Ningaloo Marine Park (Ningaloo Bioregion) Approx. 232,600 ha.	Broad scale bathymetric mapping.		AGSO	
Solitary Islands Marine Reserve (Tweed-Moreton Bioregion) Approx. 13,000 ha, depths of 20-50m.	Broad scale bathymetric mapping in the region.	Fine scale habitat mapping for the Reserve and adjacent State marine park using various methods.	AUSLIG and Royal Australian Navy (broad scale). NSW Marine Parks Authority & NSW NPWS (fine scale).	NSW Marine Parks Authority, (2000).

MPA Name / (IMCRA Bioregion/Province)/ MPA Size	Mapping Purpose / Description of Data Collection			
Tasmanian Seamounts Marine Reserve (Tasmanian Seamounts area) Approx. 40,000 ha, depths of 700-2000m.	Broad scale multi-beam sonar mapping of seamount bathymetry and recent swath mapping of general south-east seamount slope.		AGSO	Koslow and Gowlett-Holmes (1998), further reports in preparation, CSIRO.
	Broad scale hydrographic sectioning of pelagic environments (water chemistry analyses).		CSIRO	Rintoul et al. (1997), Rintoul and Bullister (1999).
		Benthic habitat mapping of seamounts and pelagic systems inside and near the Reserve, using deep-sea video system, trawling, grab sampling and benthic sled.	CSIRO, EA	Koslow (1997), Koslow and Gowlett-Holmes (1998), Koslow et al. (1998).

2.2.9 Great Barrier Reef Marine Park Authority (GBRMPA)

A large number of mapping projects have taken place within the Park. The Authority has mapping below the IMCRA meso-scale level across the entire Park in regards to the evaluation of MPAs. The Authority is looking at finer scale mapping to derive new boundaries for highly protected zones within the Park.

Ecosystem Components used as Mapping Basis

The datasets discussed below relate to the sub-IMCRA bioregionalisations of the GBR World Heritage Area.

Existing data sets used as the basis for the GBR sub-IMCRA bioregionalisations were: reef fish, soft corals, hard coral, reef biota, macroalgae, seagrass, reef geomorphology, bathymetry, mean tidal range, and broad scale currents. Numerical analysis - classification and regression tree (CART) and multiple regression tree analysis (MRT) were conducted on these datasets and formed the basis upon which the reefal and inter-reefal bioregions were drawn by workshops of experts. A summary listing of the datasets is included as Table 2.14.

Bioregions were the ecological unit mapped based upon:

- Mapped distributions of taxa, abundance and patterns of diversity;
- Distributions of physical habitat descriptors such as sediment type, grain size, bathymetry, currents, etc;
- Reef geomorphology;
- Mapped distributions of critical habitats and sites for migration, spawning, nesting;
- Mapped distributions of natural and anthropogenic threats; and
- General knowledge of the GBR marine ecosystem.

Ecological Definitions of Mapping Units

The reefal and inter-reefal bioregionalisations have 31 and 34 separate regions respectively. These 'bioregions' were defined on the basis of their biophysical characteristics. The biological characteristics found within a bioregion were considered less heterogeneous within the bioregion than compared to surrounding bioregions.

Mapping Scales

No single scale is relevant. The question of scales is inappropriate for a number of the databases including depth, sediments and regression tree models as these data were not digitised. Positional accuracy of point data would depend also on the method by which the latitude and longitude was measured.

Accuracy of Mapping and GIS Data Input

The bioregions were determined at a workshop using a GIS projection of the Great Barrier Reef environs (showing bathymetry, sedimentology, reefs etc). The respective reef and inter-reef experts agreed on the locations of the boundaries of the bioregions. From the lines drawn to overlay the projected GIS coverage, polygons defining the bioregions were digitised. The error in the geographical location of the boundary lines was of less import than the category of the bioregions. The projected boundaries took into account the amount of information available to determine the position of the line and the categories it represented. In particular, it was important to discern whether this indicated a distinct bioregion difference or a subtle one and whether the bioregions delineated were heterogenous due to geomorphological, biological or other parameters.

Furthermore, the accuracy of the base maps of the GBR environs showing reef and coastlines is questionable. These base maps have a nominal scale of 1:250 000. Therefore any bioregion boundaries drawn between reefs will be accurate relative to the reefs themselves but the derived geodetic positions of these lines will be questionable.

GIS Metadata

Many of the biophysical coverages used to help the biological experts determine the extent of bioregions were derived from Australian government sources (eg. AGSO, ERIN etc) and therefore came with metadata compliant with ANZLIC guidelines. Other data sources such as those for fish and soft corals are from individual scientists at the Australian Institute of Marine Science (AIMS) and the Barrier Reef Cooperative Research Centre (ReefCRC). As some of these individuals are the guardians of the data, some of this metadata has not been physically recorded.

Information relating to the bioregions GIS coverages was drafted in a report *Biophysical Regionalisation of the Great Barrier Reef World Heritage Area,* (Kerrigan, 1998). This document detailed the scientific process and numerical analysis underlying the determination of the bioregions.

GBRMPA is in the process of upgrading all its GIS metadata into ANZLIC format. For all datasets created in-house, this metadata format will be applied. For all datasets created externally but used in-house that do not have metadata in ANZLIC format, efforts are made to obtain sufficient information that this format can be applied.

Projection and Datum of Mapping

GBRMPA has a policy for all GIS data shown externally to be in the GDA 94 datum. However, conversion to this datum is an ongoing process and not all data is currently in GDA 94. The bioregionalisation data has been prepared in WGS 84 datum. It should be noted, however, that given the similarity between GDA 94 and WGS 84, and the scale at which most of the data is both drawn and viewed, for most of the uses of this data, two are used interchangeably.

GBRMPA Marine Ecosystem Component Mapping Datasets

GBRMPA are using the spatial datasets in Table 2.14 referenced in: Metadata Summary for Mapping Known and Predicted Environmental and Biological Diversity in the GBR World Heritage Area (GBRMPA, undated). Where the information is available, an indication of the scale, accuracy and resolution of the spatial data / mapping is provided.

Table 2.14: Summary of GBRMPA Datasets

Dataset	Mapping (M)/ Point Data (P)	Scale / Accuracy	GIS	Source/ Custodian
IMCRA (Queensland Component)	M	30 minute grid cells	ArcInfo	QLD Dept of Environment and Heritage, Tim Stevens /EA
Interim Biological Regionalisation of Australia and Bioregions and Provinces of QLD	M	1:3m scale base map	ArcInfo	QLD Dept of Environment and Heritage, AUSLIG, EA Biodiversity Group
Australian Coastal Regionalisation	M		ArcInfo	CSIRO Wildlife and Ecology/ERIN (1996)
Coastal Lands of Australia – Galloway Database CAMRIS	M		ArcInfo	CSIRO Wildlife and Ecology/ERIN
GBR Depth and Elevation Model	M		ArcInfo GRID data	Cooperative Centre for Reef Research
Seafloor Aspect and Slope 15 and 30 Second Gridded Bathymetry Model	M	0.004 degrees (cell size)	ArcInfo GRID coverages	AGSO (1998)
Benthic Irradiance (bottom/surface)	P			Walker (1980)
Turbidity (Secchi Depth)	P			AODC
Broad Sediment Size Classes	P			C Jenkins, OSI
Sedimentology (AUSEBED) (Sediment Facies)	P	0.01 degree grid	Arcview	C Jenkins, OSI
Coastline and Intertidal Zone Coverage		1:250,000	ArcInfo	AUSLIG
Sediments associated with Halimeda beds	P			Drew (1993)
Distribution of Mud, Carbonate, Mineral, and Biological Sediment Facies	M		ArcInfo	Maxwell (1968)
Coastal Wetlands Dataset	M	0.5 degree grid cells	ArcInfo	CAMRIS, CSIRO Wildlife and Ecology/ERIN (1994)
Australian Drainage Basin Dataset	M		ArcInfo	CAMRIS, CSIRO Wildlife and Ecology/ERIN (1994)
GBR GIS Coverage for Coastal Rivers	M	1:250,000	ArcInfo	GBRMPA
Australian Estuaries Dataset	P		ArcInfo	CAMRIS, CSIRO Wildlife and Ecology/ERIN (1996)
GBR GIS Coverage of Reef/Exposed Reef/Named Rocks/Islands/Cays/Island and Reef Inventory	M	1:250,000	ArcInfo	GBRMPA
GBR Classification of Islands	M	1:250,000	Oracle	Hopley (1982)
GBR Classification of Reef Morphology	M		Oracle	Hopley (1982)
GBR Regionalisation/Numberical Grid Regionalisation of Reef Morphology	M	30 minute grids	ArcInfo/ ArcView	Hopley (1982), (1989)
Representative Latitudinal and Cross Shelf Distributions of Mean Phosphate Concentration	M			Furnas and Mitchell (1997), Furnas and Brodie, (1995)
Biological Oceanography of GBR	P		ArcView	Furnas and Mitchell, Brodie
Cyclones Flood Plumes and Water Quality in the GBR Lagoon	P		ArcView	AIMS, GBRMPA

Dataset	Mapping (M)/ Point Data (P)	Scale / Accuracy	GIS	Source/ Custodian
Australian Region Oceanography Dataset – vertical profiles of physio-chemical parameters	P	(+/- 1 degree accuracy)	ArcView	CAMRIS, CSIRO Wildlife and Ecology/ERIN
Regional Seasonal Ocean Maps – vertical profiles of physio-chemical parameters	M	0.5 degree grids	ArcInfo	CSIRO (1996)
Sea Surface Temperature 1967-1976 Ten year mean, January and July	P		ArcView	CSIRO
Sea Surface temperatures and Effects on Coral Bleaching	P	1 degree grids		Berkelmans and Oliver (GBRMPA), Lough AIMS
Cooperative Centre for Reef Research Regional Hydrodynamics and Dispersal Project	P			James, Bode and Mason
Coral Reefs and Mangroves: Modelling and Management (CRAMMM) Project	P/M			Wolanski and King AIMS
Tidal Ranges for the GBR and Adjacent Waters	M		ArcView	Unknown
Australian Region GEOSAT Wave Dataset CAMRIS	M		ArcInfo	CSIRO Wildlife and Ecology/ERIN
Atlas of Tropical Cyclones in the GBR Region	M		ArcInfo	Puotinen, Done, Kelly; CRC Reef Research Centre, Dept of Tropical and Environmental Studies and Geography, AIMS
Australian Region Cyclone Dataset – CAMRIS	M	+/- one degree	ArcInfo	CSIRO Wildlife and Ecology, BOM/ERIN
Dr Ed Drew's Halimeda Surveys	P		GIS	Dr Ed Drew
AIMS Algal Survey Database			ArcView	McCook, AIMS & CRC Reef Research (1999)
GBR GIS Coverage of Mangroves	M	1:250,000	ArcInfo	GBRMPA/AUSLIG
Mangroves Species Composition for QLD estuaries	M		ArcView	Dr N Duke MERMBG Uni of QLD
Inshore and Deepwater Seagrasses of the GBR region	M		Map Info	Dept of Primary Industries QLD Northern Fisheries Centre (NFC)
AIMS Soft Coral Surveys	M		ArcInfo	Fabricius, AIMS
AIMS Hard Coral Surveys	M		ArcInfo	Devantier and Done, AIMS
AIMS Long Term Monitoring Surveys (Reef Benthos)	P		ArchInfo	Reef benthos data of the LTMP, AIMS
Classification and Regression Tree Predictions of Soft Coral/Hard Coral/Reef Benthos/Reef Fish Surveys	M		ArchInfo	AIMS
Reef Fish Surveys from the AIMS LTMP (Reef Position)	M		GIS	AIMS
Dr B McB Williams' Reef Fish Surveys	P		ArcView	AIMS
Bait Fish	M		ArcView	Glaister, Diplock and Cappo AIMS
Pelagic Fish	M		ArcView	Speare AIMS and AFMA, East Coast Tuna MAC
Mapstone, Ayling and Choat Surveys of Reef Biota in the Cairns Section of the GBR	P			Mapstone, Ayling and ChoatSea Research Dept of Marine Biology JCU, and QED Consulting
Delphic Reef Bioregionalisation	M		ArcView	Ayling, Done, Williams, Wachenfeld
Dept of Primary Industries QLD-Northern Fisheries Inter-reefal Benthos Survey (transects)	P		Mapinfo	Coles and Leelong DPIQ-NFC, Cairns
Central Section Inter-reefal Benthos Surveys (transects)	P		ArcView	Birtles and Arnold

Dataset	Mapping (M)/ Point Data (P)	Scale / Accuracy	GIS	Source/ Custodian
CSIRO Effects of Trawling Study	P			CSIRO Marine, Cleveland
Queensland Museum	P			Cannon, QLD Museum
Data from the Australian and QLD Museums Database (Echinoderms)	P			Australian and Queensland Museum databases
Descriptions of characteristic echinoderms from the Cairns Section	P			Hoggett and Vail, Lizard Is. Research Station
Australian and QLD Museums Database (Molluscs)	P			Ponder and Locke Australian Museum, Hooper QLD Museum
Northeast Australia Surveys (Sponges)	P			Hooper QLD Museum
QLD Museum Database (Urochordates)	P			Hooper QLD Museum
Cetaceans	P			QLD EPA database
Turtles	M		ArcView	Limpus, Turtle Database EPA Brisbane
Seabird Atlas	M		ArcView	Sea Bird Atlas EPA Brisbane
Cape Flattery GBRMPA Coastal Resource Atlas	M			
Multivariate Regression Tree Predictions of Williams' Reef Fish Surveys	M			B Williams
Multivariate Regression Tree Predictions from Algal Surveys	M			McCook

2.2.10 Commonwealth Scientific and Industrial Research Organisation (CSIRO)

CSIRO Major Areas Mapped

CSIRO Marine Research report generally consistent methodologies for broadscale mapping of offshore marine habitats at "regional" scales of 15km grid and "local" scales of 5km grid depending on habit heterogeneity (eg North West Shelf). The mapping approach typically involves:

- Initial stratification using available bathymetry and other oceanographic data
- Acoustic sampling / water column characterisation / video or photographic sampling / physico – chemical data acquisition / sediment sampling / trawls
- Application of habitat classification hierarchy

Marine benthic habitats have been mapped by CSIRO in the following areas:

- Gulf of Carpentaria (seagrasses and soft benthic habitats);
- Torres Strait (seagrasses, reef and soft benthic habitats);
- Jervis Bay (seagrasses, rocky reef and soft benthic habitats – fine scale);
- South East Continental Shelf / Slope (broad scale bathymetry, some high resolution bathymetry, reef and soft benthic habitats);
- North West Shelf (broad scale bathymetry and offshore benthic habitats); and
- Central WA through SA, also Tasmania (seagrasses, rock reef and soft benthic habitats – fine scale).

The Coastal and Marine Resources Information System (CAMRIS) (CSIRO Division of Wildlife and Ecology, Coastal Zone Program) contains the following national mapping datasets:

- Coastal soils;
- Marine benthic substrate;
- Seagrass;
- Australian estuaries;
- Australian temperate dune plants;
- Australian coastal wetlands; and
- Cyclone tracking / coastline crossings / eye pressures.

2.2.11 Australian Institute of Marine Science (AIMS)

The Australian Institute of Marine Science (AIMS) conducts a range of relevant Research and Development projects in tropical waters, mainly related to the Great Barrier Reef. The data captured and the methods used vary widely, but are focused on project-specific goals. Mapping of ecosystem components is conducted for project-specific purposes, often at very large scales but covering only small proportions of the ecosystems in question. The most comprehensive mapping program is the AIMS Long Term Monitoring Program, which maps fish and coral distributions in a selected set of reefs on the GBR. Other map data sets include the distribution of *Halimeda* beds and reef algae; soft corals; hard corals; reef fish; mean nutrient concentrations in GBR waters; cyclones, flood plumes and general water quality on the GBR. These map data sets are limited in focus, but provide an adequate basis for large scale maps of these components on the GBR.

The following AIMS datasets reported in the Marine and Coastal Data Directory of Australia include spatial data elements:

- AIMS Long Term Monitoring Program: Benthic Coverage Transects / Fish Census Data / Juvenile COTS Surveys / Reef Aesthetics / Sediment Analysis Data / Adult COTS Manta Tow Data / Video Transects / Water Quality Data / Crown of Thorns Feeding Preferences;
- Burdekin River Sediment Data;
- Cross Shelf Crustacean Survey in the Central Section of the GBR;
- Cross Shelf Distribution and Abundance of Larval Cephalopods in the Central Section of the GBR;
- Cross Shelf Distribution and Abundance of Larval Fishes in the Central Section of the GBR;
- Cross Shelf Fish Recruitment Survey in the Central Section of the GBR;
- Distribution and Abundance of Juvenile Starfish in the Central Section of the GBR;
- Exmouth Gulf Sediment Data;
- Fish Recruitment at Ningaloo Reef;
- Fish Recruitment on the GBR;
- Genetic Variation Related to Habitat Variation in the Coral *Pocillopora damicornis*;
- Genetic Variation in Fish Populations in the GBR;
- Gulf of Papua Sediment Data 1990-95;
- Herbert River Sediment Data 1992-95;
- Hydrodynamics and Fish Recruitment in One Tree Lagoon;
- Hydrodynamics and Larval Supply around Helix Reef;
- Larval Supply and Fish Recruitment at Bowden Reef;
- Myrmidon Reef Currents and Sealevel Data Great Barrier Reef;
- Near-reef Hydrodynamics and Larval Supply at Helix Reef;
- Papuan Shelf Margin Detritus Export Study;
- Population Genetics / Taxonomic Investigations of Various Species;
- Recruitment Surveys of Lagoonal Fish in the Capricorn Bunker Group of the GBR;
- Reef Fish Community Composition in Seven Reefs in the Capricorn Bunker Group of the GBR;
- Replenishment of Coral Trout Populations in the Cairns Section of the GBR;
- Survey of Phyto-chemical Constituent and Light Absorbing Pigments in Mangroves in the Great Barrier Reef and the Northern Territory;
- Three Reefs Project;
- Willis Island Tide Gauge Great Barrier Reef; and
- Meteorological Data (at various reefs).

2.2.12 Australian Geological Survey Organisation (AGSO)

AGSO maintain a range of oceanographic datasets (mapping and point data) with application for broadscale physical and oceanographic classification of elements of the marine environment. The following AGSO datasets are frequently used as a basis for stratification of further smaller scale mapping or data collection exercises. Particularly relevant datasets pertain to the geomorphological classification of Australia's coast, sea bed grain size classification.

AGSO (pers comm P Petkovic) offers the following descriptions of relevant datasets for bathymetric and ecosystem mapping. Of particular relevance is the AGSO Petroleum and Marine database 'Mardat' and various derived products referred to as grids.

The Petroleum and Marine Division aims in promoting petroleum exploration has led to most of their data acquisition being done in deep water areas and rarely closer than 20 nm from the coast. AGSO have a large collection of surveys from their own work as well as oil exploration company surveys and foreign institutions, containing gravity, magnetic and water depth data. AGSO also have access to the Australian Hydrographic Office digital data on the shelf, and have expanded that by digitising many of their charts. Data density on the shelf in most places is such that gridding can be done at no better than 1 km grid cell size. AGSO have sufficient data in the Timor Sea region to grid bathymetry at 250m horizontal resolution, and there are several areas in deep water (>400m) where swath bathymetry data from recent and old surveys allows grids at 100m cell size at best.

AGSO advise that the relevance of their datasets to ecological mapping is limited by the following factors:

- AGSO do not use ecological units as mapping criteria nor define maps in ecological terms;
- AGSO rarely produce traditional maps, and the trend is towards digital grids and images of those grids. Clients use these grids to incorporate into their own mapping systems using whatever scale suits their needs;
- the digital data density is such that pixel size is 100-1000m. If a pixel density of 75 dpi is required, then maps drawn from these data will typically be at scales of 1:300,000 to 1:3 million;
- because of the regional nature of AGSO's work, and with exploration and research effort focused on deeper parts of the shelf and continental slope, there is currently limited digital coverage in coastal waters within, say, 10-20 nm from the shore;
- positional accuracy of data is variable, according to the vintage and type of navigation systems used. Positions in the database do not have an accuracy attribute, but do have an attribute signifying the navigation system used. For example, surveys from the 1970's which typically used dead reckoning tied to Transit satellite fixes were accurate to 50-100m on the shelf. More recent surveys using differential GPS have positions accurate to 5m regardless of water depth. Bathymetric grids produced from these data after levelling has been applied have a depth error of 1-5%, but are sufficient to define the relative sea floor changes and province definition for geological interpretation. Swath data depths are more accurate by an order of magnitude;
- ANZLIC metadata guidelines are being implemented, and metadata have sufficient content to meet the core elements; and
- digital data are unprojected and given in geodetic coordinates on the WGS84 datum.

Specific AGSO mapping datasets recorded in the Coastal Atlas, Marine and Coastal Data Directory of Australia include:

- 50m slope analysis Australian Arc/Info Grid;
- AGSO Surveys (Various) (Seabottom structure, bathymetry, magnetics, Seismic, gravity);
- Australian Basin Form Map;
- Australian Shelf Sedimentary Environments;
- Australian coastline from DCW;
- Bathymetric depth model for Australia EEZ;
- Bathymetric depth model for Australian region;

- Bathymetric depth slope classification for the Australian EEZ;
- Bathymetric depth slope classification for the Australian region;
- Bathymetric grid for Australia;
- Bottom depth Classification of WOA 1994 Annual data for Australia;
- DEM to 200m Australian Arc/Info Grid;
- DEM to 50m Australian Arc/Info Grid;
- Fraser Island CM data;
- GEBCO bathymetric contours;
- geomorphological Classification of Australia's coast;
- Gulf R&D Co seismic survey NW Australia;
- Holocene sea levels for Australia;
- Late Quaternary sea levels for Australia;
- Moreton Bay Sediment Grain Size;
- North West Shelf Tectonic Elements Database;
- North West Shelf Tectonic Elements Map;
- Northwest Australia Gravity, Magnetic and Topography Grids;
- Northwest Australia Gravity Montage;
- Sea bed grain size classification;
- Sea bed grain size classification 18 classes;
- Shell 'Petrel' seismic survey NW and W margin;
- Shell 'Petrel' seismic survey NW and W margin;
- Surface Classification of WOA 1994 Annual data for Australia;
- Valdivia Survey VA16-1A;
- World Ocean Atlas 1994 Annual data for Australian Region; and
- Geologic mapping (with AUSLIG)(1:1,000,000 lithology, Cainozoic coverage, geo fault coverage, geo syncline coverage, geo tectonic provinces.

2.2.13 Universities / Other Agencies

University researchers hold an immense amount of data on the marine environment. Some of this is accessible as it is published in the scientific literature (but generally in summary form). A compilation is far beyond the scope of this consultancy but should be undertaken as a priority at a later stage.

Research on marine biogeography is most relevant to the IMCRA and NRSMPA programs. However, there are relatively few specialists in marine biogeographic research in Australia (often based in Museums. Most university research is undertaken by an individual researcher (sometimes with a team of postgraduates) and focuses on a particular research question or hypothesis. Funding from most research funding agencies (e.g. ARC) is available only for 'higher order' science, and not for basic mapping, inventory, monitoring or taxonomy. Spatial information may be collected during research, but as 'mapping' or 'inventory' is not the primary objective of the data and is often not in an immediately useable format for these purposes. However, this should not preclude its compilation and application.

Specific mapping and inventory projects are undertaken by university researchers through consultancies (with government agencies, or for environmental impact assessments). For example, Southern Cross University has produced an “Inventory and Classification of Australian Estuaries (Digby et al 1999) (consultancy for Environment Australia), while individual scientists’ research has included mapping of various species and communities (e.g. subtropical corals and mangroves).

Mapping and inventory is frequently undertaken by consultants for environmental impact assessment. Generally this is limited in area (to the site which may be affected by a development), but in some cases may cover a significantly large geographic area.

3. GIS / Metadata Standards

3.1 GIS / Metadata Standards

Mapping methods and standards vary considerably between the jurisdictions (refer Chapter 2 for jurisdictions current methods). This is not due to a lack of coordination but, more so to other factors, such as:

- Purpose of mapping;
- Depth of mapping; and
- Clarity of waters.

Factors such as these result in different methods and different tools being used for mapping. Typically, the jurisdictions appear to be mapping with best practice according to the resources available to them. Keeping this in mind, a standard needs to be reinforced to identify the quality and reliability of the data. Two main areas that need to be standardised are:

- data documentation (widespread use of ANZLIC Metadata guidelines / data libraries; ANZLIC 1996); and
- data reliability and quality.

Most jurisdictions have established systems in place under the Australian Coastal Atlas Program for digital marine and coastal data coordination, documentation and information systems using internet technology. Latest developments may be sought from ERIN and referenced accordingly.

3.1.1 Data Documentation

This is probably the most important area that needs to be standardised since jurisdictions are presently producing very different levels of output. Australian jurisdictions involved in marine management have broadly adopted the ANZLIC Metadata guidelines. However, where many datasets occur or funding is constrained, the jurisdictions have not documented all datasets.

The core metadata elements are described in Table 3.1 and presented graphically in Figure 3.1. The elements listed are the result of an extensive consultation and review process undertaken by the ANZLIC Working Group on Metadata during the past 18 months. Core elements which relate to similar information have been grouped into categories. The Working Group has also prepared Guidelines and Worked Examples of the core elements.

Table 3.1: Metadata Core Elements: A Summary (ANZLIC Guidelines 1999)

Category	Element	Comment
Dataset	Title	The ordinary name of the dataset.
	Custodian	The organisation responsible for the dataset.
	Jurisdiction	The state or country of the custodian.
Description	Abstract	A short description of the contents of the dataset.
	Search Word(s)	Words likely to be used by a non expert to look for the dataset.
	Geographic Extent Name(s) OR	A picklist of pre defined geographic extents such as map sheets, local government areas, catchments, that reasonably indicate the spatial coverage of the dataset.
	Geographic Extent Polygon(s)	An alternate way of describing geographic extent if no pre-defined area is satisfactory.
Data Currency	Beginning Date	Earliest date of data in the dataset.
	Ending Ddate	Last date of information in the dataset.
Dataset Status	Progress	The status of the process of creation of the dataset.
	Maintenance and Update Frequency	Frequency of changes or additions made to the dataset.
Access	Stored Data Format	The format or formats in which the dataset is stored by the custodian.
	Available Format Type	The formats in which the dataset is available, showing at least, whether the dataset is available in digital or nondigital form.
	Access Constraint	Any restrictions or legal prerequisites applying to the use of the dataset, eg. licence.
Data Quality	Lineage	A brief history of the source and processing steps used to produce the dataset.
	Positional Accuracy	A brief assessment of the closeness of the location of spatial objects in the dataset in relation to their true position on the Earth.
	Attribute Accuracy	A brief assessment of the reliability assigned to features in the dataset in relation to their real world values.
	Logical Consistency	A brief assessment of the logical relationships between items in the dataset.
	Completeness	A brief assessment of the completeness of coverage, classification and verification.
Contact Information	Contact Organisation	Ordinary name of the organisation from which the dataset may be obtained.
	Contact Position	The relevant position in the Contact Organisation.
	Mail Address 1	Postal address of the Contact Position.
	Mail Address 2	Aust and NZ: Optional extension of Mail Address 1.
	Suburb or Place or Locality	Suburb of the Mail Address.
	State or Locality 2	Aust: State of Mail Address. NZ: Optional extension for Locality.
	Country	Country of the Mail Address.
	Postcode	Aust:Postcode of the Mail Address. NZ: Optional postcode for mail sorting.
	Telephone	Telephone of the Contact Position.
	Facsimile	Facsimile of the Contact Position.
	Electronic Mail Address	Electronic Mail Address of the Contact Position.
Metadata Date	Metadata Date	Date that the metadata record for the dataset was created.
Additional Metadata	Additional Metadata	Reference to other directories or systems containing further information about the dataset.

To further clarify Table 3.1 the following information is provided:

Dataset and *Description* categories provide essential information about the content of the data, the agency responsible for its collection and maintenance, and the geographic area it covers. The *Search Word(s)* element has caused concern for data providers who generally seek to use keywords that adequately categorise the specific content of datasets. The inclusion of this

element, however, is intended to make it easier for non-specialist users to search directories for information categorised under broad, general subject headings.

Data Currency and *Dataset Status* categories establish the time frame of the data described. The *Access* category is intended to provide potential users of datasets with sufficient information to determine if the data is in a suitable format or able to be transformed for their purpose. Access to some data is restricted for a variety of reasons. However, it is important that the existence of these datasets and the constraints on their use for other purposes are clearly identified in directory systems.

The inclusion of *Data Quality* elements in the highest level directory systems has been the subject of a great deal of debate within the geographic information community. It is clear that the key elements identified — lineage, positional accuracy, attribute accuracy, logical consistency and completeness — have not always been well documented in the past. Also, the meaning of some of these elements has not been well understood and some may not be relevant to some dataset types.

It has been argued that these elements are only relevant to the more detailed levels of the directory system, however, a consensus view is that data quality information is critical to determining the usefulness of a dataset for a particular application. For this reason, the national directory system must provide some information about data quality, at least a summary or overview, at the highest level. If custodians are unable to provide information for these elements they should not leave the field blank. Statements such as “Not Relevant”, “Not Documented” or “Not Known” should be used.

Contact Information provides address details for the contact position in the contact organisation that is responsible for delivery of the dataset to other users.

Metadata Date establishes currency of the directory entry.

The Additional Metadata element provides a link to the source of more detailed information about a dataset through specific theme directory systems, such as the Marine and Coastal Data Directory of Australia (“Blue Pages”), or individual agency level directories. These more detailed directories will often supply a technical contact for listed datasets.

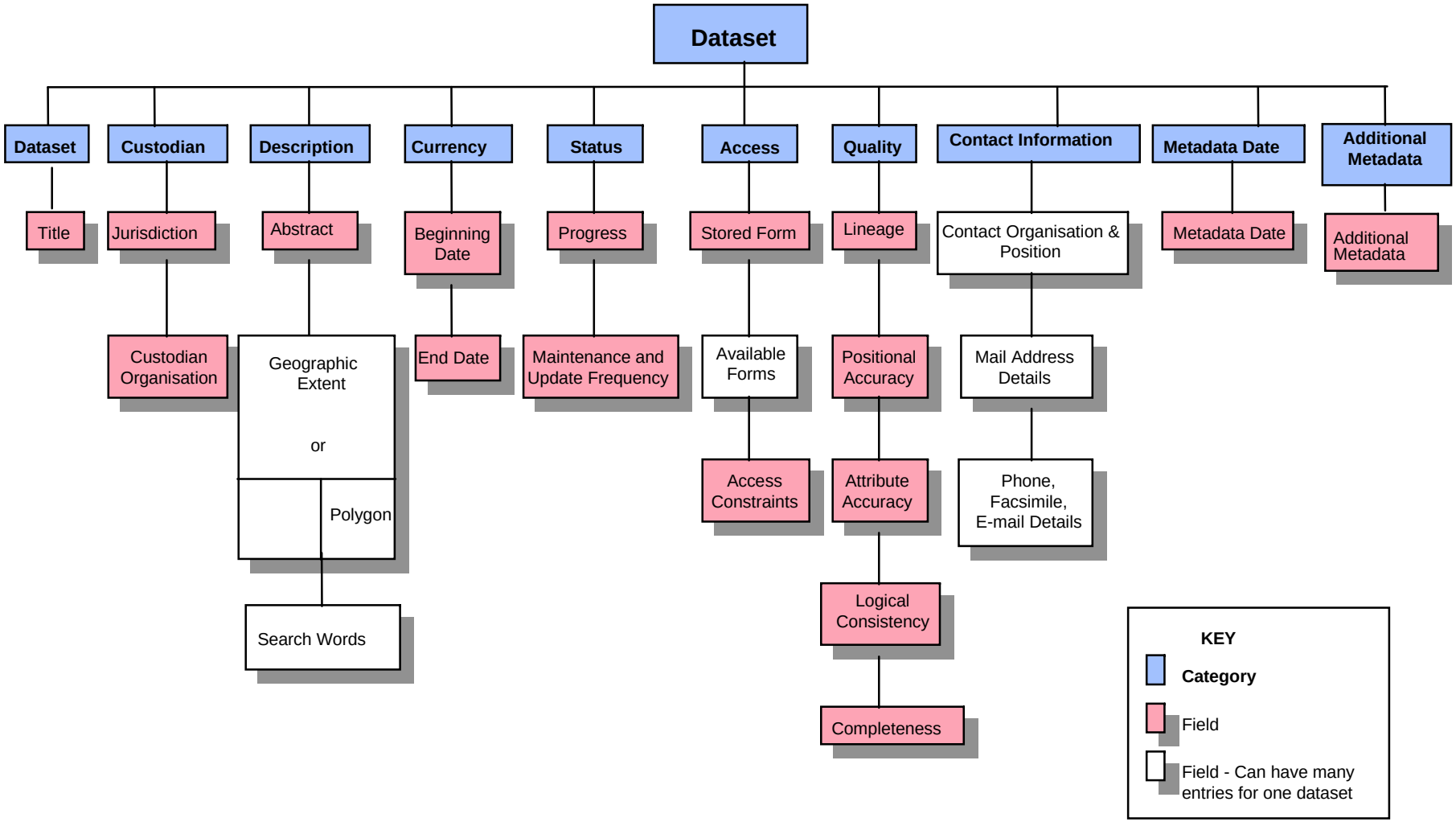

Figure 3.1: Graphical Representation of Core Metadata Elements (ANZLIC Guidelines, 1999)

3.2 Quality and Reliability of Data

Data quality relates to how well (positional accuracy, consistency and completeness, refer element descriptions in Table 3.1) and how many iterations or processes it has taken to transfer the data collected in the field to a computer based map. Data quality will certainly vary according to the precision of tools used in the field and the tolerances and precision of the tools used in converting this data into a digital map. Agencies such as AUSLIG (AUSLIG 2000) and ERIN (ERIN 1999) have documented data standards and with the introduction of ISO standards for spatial data later this year, every jurisdiction should be preparing a minimum standards document similar to that of the above mentioned agencies for implementation.

Data reliability is based on the reliability of the mapping boundaries and the attributes that are associated with them (attribute accuracy, refer element descriptions in Table 3.1). Data reliability can be defined by the density of the ground truthing, ranging from sparse to comprehensive.

As discussed, not all jurisdictions can meet the minimum or core elements set out by AUSLIG or ERIN, however, a category system could be put into place to measure reliability and quality of each data source. For example:

- quality of data (category 1 - 4 range of best practice, category 5 fully meeting standards); and
- scale of data reliability (category 1 sparse – category 5 comprehensive ground truthing).

When tabular data needs to be produced such as in Action 6 (status / coverage of ecosystem / ecosystem component mapping) then a table similar to Table 3.2 below should be produced.

Table 3.2: Ecosystem Mapping Coverage Data Quality Reliability *(Example Only)*

Bioregion	Area sq km	% Mapped	Range of ecosystem components mapped	Quality	Reliability	Comments
Example bioregion	32,198	3.4	Substrate type Bathymetry Benthic habitat type	4 5 3	3 4 3	Source A Source B Source C

4. Towards a National Mapping Approach

4.1 Summary of Jurisdiction Mapping Approaches

In planning for a comprehensive, adequate and representative system of marine protected areas there is a clear need to capture biodiversity in such a manner that representatives of distinct bioregions can be recognised within MPAs at a number of different scales (ANZECC TFMPA 1999a). Initially meso-scale bioregions have been identified and agreed around Australia that both trace broad biophysical discontinuities and which group common biophysical elements. IMCRA Technical Group (1998) report some 60 meso-scale bioregions around the continental shelf of Australia based on the synthesis of data collected by all jurisdictions and interpreted through inshore and offshore waters technical groups.

Below this level the TFMPA has adopted 'ecosystem' to describe the spatial ecological grouping with sufficient resolution to represent for biodiversity at a scale above habitat and community. However, the term "ecosystem" is defined broadly under the NRSMPA Guidelines (ANZECC TFMPA 1998 and Commonwealth of Australia 1992): as a complex of communities and the non-living environment interacting as a functional unit. The functional relationship dimension of the term has contributed to reluctance among the jurisdictions for 'ecosystem' to be used as a spatially defined mapping unit.

At scales below IMCRA bioregion, jurisdictions have identified and spatially represented a range of ecosystem components including various marine habitat classes and communities. With the benefit of information on the relationships between habitats and their communities, some jurisdictions (ie GBRMPA, SA) have constructed groupings of mapping units at a scale that is equivalent to 'ecosystem' under the TFMPA hierarchy. The mapping of marine (usually benthic) habitats is a necessary step at spatially representing groupings of ecosystem components at scales suitable for the strategic planning of a comprehensive system of MPAs. As a result this report focuses on the review of methods by jurisdictions at broad scale mapping marine benthic habitat classes. Section 4.3.2 and Figure 4.1 show the relationship of mapping units and mapping purposes at different spatial scales.

Table 4.1 presents a checklist of the usage by jurisdictions of mapping units corresponding to levels of the TFMPA hierarchy. A summary of the nature of marine benthic habitat mapping and finer scale mapping for management purposes is provided as Table 4.2.

Table 4.1: Jurisdiction Usage of Mapping Units

Jurisdiction	Mapping Units Used			
	Bioregion[1]	Ecosystem	Habitat	Community[2]
NSW	Yes	Yes[3]	Yes	-
QLD	Yes	-	Yes	(refer GBRMPA)
SA	Yes	Yes[4]	Yes	Yes
TAS	Yes	-	Yes	Yes (reefs)
VIC	Yes	-	Yes	Yes (kelp)
WA	Yes	-	Yes	-
NT	Yes	-	Yes (ltd areas)	-
Commonwealth	Yes	-	Yes (ltd areas)	-
GBRMPA	Yes	Yes	Yes	Yes

Notes:
1. Refer IMCRA bioregionalisation process (IMCRA Technical Group, 1998);
2. Seagrass mapping is included as habitat mapping;
3. Tweed Moreton Bioregion only;
4. SA uses the term 'biounit' for this scale of mapping, but it does not necessarily equate to an ecosystem.

Table 4.2: Summary Table of Jurisdiction Mapping Methods

Jurisdictions	Mapping Purpose					
	Mapping for Bioregionalisation (broader than1:100,000 scale) (P2)	Strategic Mapping of Benthic Habitats for Identification of Candidate Representative MPAs (Approx 1:100,000 scale) (P3/4)			Mapping for Management Purposes (finer than1:100,000 scale) (P4/5)	
		Estuaries / Bays / Inlets / Intertidal	Inshore (<30-50m)	Offshore Areas	Estuaries / Bays / Inlets / Intertidal	Open Coast / Islands
New South Wales	Refer IMCRA Technical Group (1998)	Tweed Moreton physical classification using Naval charts, topographic maps, oceanographic physico-chemical datasets and available species distribution data to define marine physiographic features and "ecosystems / habitats"	Tweed Moreton physical classification using Naval charts, topographic maps, oceanographic physico-chemical datasets and available species distribution data to define marine physiographic features and "ecosystems / habitats"		Aerial Photography for seagrass and mangrove communities with ground truthing along entire coast with specific investigations Jervis Bay	
Queensland	Refer IMCRA Technical Group (1998) Refer GBRMPA for sub-IMCRA bio-regionalisation	Mainland only coastal resource inventory of wetlands – data capture using Landsat TM and aerial photography – ground truthing of seagrass boundaries using transects 1 nautical mile apart. QPWS is currently finalising a project to map and undertake a preliminary assessment of the conservation values of estuaries in Queensland identified in the Physical Classification of Australian Estuaries	Mainland only linear shoreline mapping system (QPWS) using aerial photography and AGSO 15 sec grid data	Refer GBRMPA for GBR and CSIRO datasets for benthic communities of Gulf of Carpentaria	Refer DPIQ/ GBRMPA/ CRC Reef for Region-specific datasets for seagrasses and mangrove communities derived from aerial photography, satellite imagery and ground truthing. Some fine- or medium-scale monitoring at locations where management issues existed.	Refer DPIQ/CRC/GBRMPA for broad-scale study of continental shelf lagoon and inter-reef benthos. GBRMPA for long term monitoring across shelf transects?? Refer DPIQ/ GBRMPA/ CRC Reef for Region-specific datasets for seagrasses, derived from aerial photography, satellite imagery and ground truthing.

Jurisdictions	Mapping Purpose					
	Mapping for Bioregionalisation (broader than1:100,000 scale) (P2)	Strategic Mapping of Benthic Habitats for Identification of Candidate Representative MPAs (Approx 1:100,000 scale) (P3/4)			Mapping for Management Purposes (finer than1:100,000 scale) (P4/5)	
		Estuaries / Bays / Inlets / Intertidal	Inshore (<30-50m)	Offshore Areas	Estuaries / Bays / Inlets / Intertidal	Open Coast / Islands
South Australia	Refer SA Marine Biodiversity Program (SARDI / Edyvane and Baker – various), IMCRA Technical Group (1998), Edyvane (1999)	Statewide coverage of nearshore benthic habitats (e.g. seagrasses and reefs / algal beds) collected using: Landsat TM; aerial photography; and ground truthed for physiography using grab samples and video transects. Simultaneous biological sampling of sessile benthos using dive transects/replicated quadrat samples. Major parts of SA coastal marine and island groups ground-truthed, but gaps remain in large parts of some bioregions.	Statewide coverage of nearshore benthic habitats (e.g. seagrasses and reefs / algal beds) collected using: Landsat TM; aerial photography; and ground truthed for physiography using grab samples and video transects. Simultaneous biological sampling of sessile benthos using dive transects/replicated quadrat samples. Major parts of SA coastal marine and island groups ground-truthed, but gaps remain in large parts of some bioregions.		Seagrass mapping (1:40,000) for monitoring purposes in Eyre Peninsula, Northern Spencer Gulf, Adelaide area. Saltmarsh and mangrove mapping (using 1: 10 000 - 1: 140 000 aerial photos), and ground truthing.	
Tasmania	Refer IMCRA Technical Group (1998)	Landsat TM and aerial photography of nearshore benthic habitats around entire coast and ground truthing of physiographic features and seagrass distribution but not accompanied by biological sampling of reef, seagrass or benthic communities at ground truthing locations.	Landsat TM and aerial photography of nearshore benthic habitats around entire coast and ground truthing of physiographic features and seagrass distribution but not accompanied by biological sampling of reef, seagrass or benthic communities at ground truthing locations.		Mapping of candidate MPAs in seagrass and headland habitats at six locations on north coast at 1:25,000 using bathymetric survey / sonar, visual / dive survey, video tow (Barrett and Wilcox 1999).	Biological survey (fish census, invertebrates, macroalgae) of selected reef communities (Waterhouse Point, King Island and Rocky Cape) in support of MPAs and fishing closures around Tasmania by dive transect (TAFI).
Victoria	Refer IMCRA Technical Group (1998) Physical classification of open coastal waters and Bass Strait	Landsat TM and aerial photography for substratum attributes, checked using: bounce dives, video drops and grab samples. Quantitative infauna community and sediment data from sediment samples.	Landsat TM and aerial photography for substratum attributes, checked using: bounce dives, video drops and grab samples. Quantitative infauna community and sediment data from sediment samples.	Selected areas to 3nm extension and refinement of inshore data collection means using hydroacoustic devices (ie RoxAnn / Echo Listener) and Video drops and observations.	Aerial photography for macrophyte beds, seagrasses and substratum attributes. Semi-quantitative data on macrophytes. Visual transects (glass bottom pod / towable camera).	Refinement of spatial boundaries using side scan sonar and Echo Listener. Quantitative biotic surveys using 200m belt dive transects.

Jurisdictions	Mapping Purpose					
	Mapping for Bioregionalisation (broader than1:100,000 scale) (P2)	Strategic Mapping of Benthic Habitats for Identification of Candidate Representative MPAs (Approx 1:100,000 scale) (P3/4)			Mapping for Management Purposes (finer than1:100,000 scale) (P4/5)	
		Estuaries / Bays / Inlets / Intertidal	Inshore (<30-50m)	Offshore Areas	Estuaries / Bays / Inlets / Intertidal	Open Coast / Islands
Western Australia	Refer IMCRA Technical Group (1998)	For temperate waters: Landsat TM and aerial photography for seagrass, reef and substratum attributes, representative areas of interest surveyed using: dives and grab samples.	For temperate waters: Landsat TM and aerial photography for substratum attributes, representative areas of interest surveyed using: dives and grab samples Selected area coverage of sub tropical / tropical habitats (ie Ningaloo).		Specific project mapping at Shark Bay, Jurien Bay.	Specific project mapping: Abrolhos Islands, Recherche Group, Dampier Archipelago, Ningaloo.
Northern Territory	Refer IMCRA Technical Group (1998) IMBRENT mapping process using available climate, oceanographic, physico-chemical, fishery and biological distribution datasets.		Beagle Gulf (benthic habitats) Cobourg and Pellew regions (benthic habitat mapping commencing).		Darwin Harbour (seagrass, mangroves and benthic habitats).	Gulf of Carpentaria (Poiner et.al. 1987).
Commonwealth (ex GBRMPA waters) *(refer Note 1)*	Refer IMCRA Technical Group (1998), Commonwealth of Australia (1998). High-resolution acoustic swath mapping coverage of some 240,000 sq km off the continental slope in the South-east Marine Region and adjacent waters, including the deeper areas of the Great Australian Bight Marine Park and the margins of Lord Howe Island.			Great Australian Bight and Tasmanian Seamounts (associated with MPAs) bathymetry, video trawls and sediment grabs (also refer CSIRO).	Jervis Bay 1:4,000 scale estuarine resource mapping via DoD / CSIRO.	Physiographic mapping of benthic habitats of Monte Bello Islands, Cartier, Mermaid and Ashmore Reefs.
GBRMPA	Reefal and Inter-reefal bioregionalisation project using a wide variety of source material (refer Table 2.13).	Refer Table 2.13.	Refer Table 2.13.	Refer Table 2.13.	Refer Table 2.13.	Refer Table 2.13.

Note 1: In relation to the Commonwealth of Australia, the purpose of mapping and the scale of maps are not necessarily consistent with other jurisdictions, given the diversity of marine ecosystems and the size and often remote location of MPA's / candidate MPA's in Commonwealth waters (refer Table 2.13).

Table 4.2 shows the range of mapping approaches adopted by the jurisdictions around Australia. A summary of the approaches of each jurisdiction is provided below.

NSW (with a moderately long coastline with moderate complexity) is developing its mapping and inventory program, the offshore mapping is focused in the Tweed Moreton bioregion and planned and existing MPAs (including: Byron area, Solitary Is). Jervis Bay was comprehensively mapped by the CSIRO/Defence environmental baseline studies conducted in the early 1990s and the Solitary Islands Marine Park was mapped in benthic surveys drawing on GIS data prepared by NPWS from Royal Australian Navy data. Other nearshore habitat mapping, of wetlands (Adam et al 1985) and estuarine resources (West et al 1985) has occurred throughout the state.

Mapping of Queensland marine systems (with a very long coastline and complex marine environments) is relatively well advanced with respect to the GBRMP. The GBR has long been mapped (using Landsat) and there is detailed information from GBRMPA, AIMS, DPIQ and James Cook University on many aspects of the GBR. The Gulf of Carpentaria is more remote, but has been the subject of seagrass and benthic habitat mapping by CSIRO. GBRMPA has access to a wide range of habitat and community mapping at various scales and for various purposes over coral reef and soft bottom communities. Queensland Parks and Wildlife Service (QPWS) is currently finalising projects to map and classify the shoreline (intertidal zone) of the mainland coast and continental islands and estuaries throughout the state for the purposes of conservation planning. Queensland Department of Primary Industry (DPIQ) has also undertaken seagrass mapping (dive-based ground truthing, aerial photography) in the eastern Gulf of Carpentaria as well as the east coast and Torres Strait. DPIQ recently conducted broad-scale studies using underwater video to estimate seagrass distribution (and coarse-level descriptions of the benthos) in the Great Barrier Reef lagoon and inter-reef areas. Equally, DPIQ has substantially mapped marine coastline vegetation (approx 70% complete - completion by end 2001) along the entire Queensland coast.

South Australia (with a moderately long coastline, and moderately complex marine environments) appears to be well advanced in research, mapping and inventory in terms of inshore marine benthic habitats. The higher level of detail in mapping and corresponding algal community characterisation would have assisted in achieving a more comprehensive classification of ecosystem components.

Tasmania (with a moderately long coastline and moderately complex marine environments) shows progress in relation to broad nearshore benthic habitat mapping, estuarine inventory and finer scale reef habitat / community mapping (and monitoring).

Victoria (with a relatively small coastline with moderate complexity, dominated by two large bays) appears to have an ambitious, logically constructed, well developed and well advanced mapping and inventory program for its intertidal and nearshore subtidal environment. The recently published inventory of Victoria's marine ecosystems (Ferns and Hough 1999) records mapping and analysis of physical and biological relationships.

Western Australia (with a very long coastline, and very complex marine environments) is better studied and the mapping approach appears to be more logically structured (reflecting WA CSIRO inputs). However, the vast size and complexity have imposed major constraints on the detail of mapping.

The Northern Territory (with a long coastline and complex marine environment) is little studied and there appears be minimal inventory and mapping outside selected areas where benthic sampling or mangrove mapping has occurred. The turbid macrotidal waters and low scientific research base makes inventory difficult.

Until recently, mapping in offshore Commonwealth waters was restricted to broad oceanographic and sediment sampling datasets as opposed to mapped representations. In several small areas around Australia, benthic habitat mapping extends into Commonwealth waters. Specific project or MPA management related mapping projects such as Jervis Bay, Ashmore and Mermaid Reefs habitat mapping have also been undertaken at a fine scale. However, the program of surveys recently commenced by the National Oceans Office will map ecosystem components on a broad scale, initially in the South-east Marine Region, with some high resolution mapping.

4.2 Common Themes in Ecosystem / Ecosystem Component Mapping

4.2.1 Similarities and Differences among Jurisdictions

The jurisdictions have a common objective of achieving a system of MPAs that embody the principles of comprehensiveness, adequacy and representativeness. To achieve this, there is a broad appreciation of the data and mapping requirements needed to capture biodiversity at the scales necessary to ensure that MPAs can be demonstrated as comprehensive in terms of their inclusion of examples of the diversity of marine life – initially on a bioregional scale. At finer scales, the usage of benthic habitats as a mapping unit surrogate for biodiversity in mostly nearshore waters is a key element which is common among jurisdictions.

There are, however, differences in the approaches and mapping progress of the various jurisdictions. This reflects:

- the extents of the marine environments of the States (which affects the scale of mapping);
- the nature of the marine environments (eg shallow / turbid waters or high wave action coastline) which may limit the remote sensing or field survey techniques which are applicable;
- the difference in ocean uses, management issues, management agencies and responsibilities, and resources (human and financial) for marine research and management (including mapping); and
- the conceptual differences in defining mapping elements and mapping scale hierarchies of ecosystem components.

In general, the diversity of the marine realm within each jurisdiction, the spatial scale of their responsibilities, and the different capacities available in each jurisdiction has resulted in the mapping of MPAs with variable levels of definition and a focus on different aspects of ecosystem properties.

4.2.2 Marine Habitat Mapping

Benthic habitats in nearshore waters have been identified in many jurisdictions at a broad scale (eg 1:100,000) via a combined remote sensing and ground truthing approach around the temperate coastline of Australia. A common element in several jurisdictions has been the mapping of temperate seagrass and nearshore reef habitats by CSIRO. This work has been associated with further habitat characterisation in South Australia and Victoria where algal / reef community surveys were undertaken simultaneously.

Common techniques of interpretation of aerial photography and Landsat TM (Band 1) imagery as well as comparable ground truthing techniques (visual / video / dive transects) have been applied to the habitat mapping projects in temperate Western Australia, South Australia, Tasmania and Victoria. The resolution of ground truthing has varied according to habitat heterogeneity, coastline length, diving or boating conditions and depth. In deeper waters to 30-

50m or in turbid conditions alternative habitat mapping tools have been employed including the use of hydroacoustic techniques ground truthed with benthic sediment grab samples (as in Victoria).

4.2.3 Ecosystem as a Mapping Unit

The identification of mapping units at a level between IMCRA bioregion and habitat equates to the NRSMPA TFMPA 'ecosystem' level. However, the polygons mapped at this level do not equate to ecosystems as defined as functional units under the NRSMPA (refer section 4.3 definitions).

No jurisdictions derive mapping units at the ecosystem level without building upwards from available habitat mapping units as well as supporting information on interrelationships among benthic habitats and pelagic communities, usually inferred from oceanographic or physiographic data.

Those jurisdictions which have undertaken a bioregionalisation below IMCRA level (eg GBRMPA, South Australia and to a lesser extent NSW) have used existing mapping datasets of marine habitat classes which are grouped and divided based on either physiographic, oceanographic or biological relationships.

GBRMPA have used a multicriteria approach considering community / habitat relationships as well as oceanographic and physiographic mapping datasets to develop a system of sub IMCRA bioregions via a delphic workshop series (GBR Representative Areas Program (not published)).

In South Australia, 35 mostly nearshore 'biounits' representing combinations of mapped habitats have been developed based on major physiographic features and the representation and distribution of major marine habitats (Edyvane, 1999 a and b).

In New South Wales, an assessment for the proposed Byron MPA involved sub IMCRA bioregionalisations of estuaries and beaches using oceanographic data (ie temperature variation) to define the different character of northern versus southern portions of this component of the Tweed Moreton bioregion (Avery 2000).

Strategic analysis across a jurisdiction has, in general, been conducted using high level knowledge and data, while local-scale decision-making about boundaries and zones has been based on fine scale knowledge of ecosystem components, usually habitat-level mapping.

4.2.4 Use of Remote Sensing Technology

While the waters of Australia's continental shelf are vast in size and complexity there has been only moderate reliance on new remote sensing techniques. Landsat (TM) has long been available and has been used extensively in nearshore marine habitat mapping in temperate waters. At the finer scale SPOT, and the recent Landsat ETM also have application for benthic habitat mapping. Seafloor imaging has also been possible with radar satellites (eg. Radarsat, ERS, JES). Finer detail of seafloor features are available through acoustic devices, including side-scan sonar. The RAN has also fine scale bathymetry for strategic areas, some of which are available for external use. In fact, almost all of the Australian shelf, and much of the slope and plateaus have been mapped at coarse scale (and much at the fine scale) using sonar technology by AGSO, and offshore petroleum explorers, and is readily available.

A review of remote sensing applications for coral reef habitat mapping was recently published by Mumby et al (1997). They compared Landsat MSS, Landsat TM, SPOT XS, SPOT Pan and merged Landsat TM/SPOT Pan with aerial photography and CASI (compact airborne spectrophotographic imagery). Their results found that Landsat TM was most accurate and cost effective to map broad areas in coarser detail (eg strategic nearshore mapping). For maps with intermediate detail, aerial photography exhibited similar accuracy to Landsat and SPOT ; CASI was most accurate for fine detail habitat mapping. Mumby et al (1997) concluded that satellites are suitable for coarse detail and CASI is most suitable and cost effective for habitat mapping at fine detail.

The availability of a range of remote sensing oceanographic and physiographic data provides the opportunity for the initial stratification stage of any habitat survey. Ocean current and various physico-chemical properties also have an application for the recognition of relationships among pelagic communities and mapped habitats, which would in turn assist in the classification of mapping units at the ecosystem level.

4.2.5 Inshore Versus Shelf Waters

Almost all of the mapping focus appears to be on inshore waters less than 30-50m. Shelf communities are poorly known and mapped other than in terms of coarse bathymetric mapping. There is very little habitat differentiation as mapping in offshore areas, including the External Territories (Coral Sea Territory, Norfolk Island, Subantarctic Territories, Indian Ocean Territories). However, it is noted that the scope of this project is limited to the outer boundary of the IMCRA bioregions (around 200m isobath).

4.3 Ecological Definitions

4.3.1 Ecological Definitions in the Marine Environment

Nature is an interconnected continuum which makes categorisation, definition and precise mapping and inventory challenging, especially where mapping purports to depict areas with common functional relationships. This is particularly so in the marine environment where water circulation and currents preclude mapping of hard 'physical' boundaries, where most species have a larval stage which is carried some distance from the parents, and where many have juveniles which occupy a third habitat or ecological niche (eg most reef fish have larval and juvenile stages associated with inshore wetlands (seagrass, mangroves etc)). Even terrestrial catchments and related water quality changes are important influences on the marine environment. Obviously all components and influences on an ecosystem or managed area (many of which are physically external) must be considered in the planning for a national system of marine protected areas.

Ecosystem includes not only a (loosely) delineable biota and their physical and chemical environments, but also functions (energetics, trophic levels, nutrient cycling etc.), and their evolution. The concept does not readily lend itself to close definition and clear delineation. It is used variably within the context of the NRSMPA, sometimes to describe 'habitats', 'communities' or 'assemblages' or to describe the level of bioregionalisation. Victoria (L Ferns pers comm) views ecosystems as a holistic entity and not as an entity that is readily definable at one spatial scale, it is the attributes that form part of the ecosystems that exist on various spatial scales. For example GBRMPA and SA have created sub-IMCRA scale bioregions (biounits) for what SA labels a 'habitat' level. These 'biounits' are constructs that have a definition specific to the method of their creation and occupy a classification level between bioregion and habitat.

A major issue in attempting to develop a set of common 'operational' definitions for the NRSMPA is that the various jurisdictions each operate at different scales of space and taxonomic resolution, depending on their own situation and on the purpose at hand. The jurisdictions have therefore engaged in the tasks of identifying and declaring MPAs using different levels of the marine realm, and have used these levels to define their own 'ecosystem' level approach to MPA implementation.

In order to promote discussion about common mapping themes, it is proposed to aggregate the mapping systems using a hierarchical ecosystem-based classification. This classification includes the mapping approaches undertaken by the jurisdictions and organises them into a single system constructed to reflect the purposes for mapping, and the physiographic and ecological components of ecosystems in Australia's marine realm (see Section 4.4 and Figure 4.1). The following puts in context the NRSMPA classifications, and suggests ways in which these can be developed and applied.

4.3.2 Ecological Definitions for the NRSMPA Hierarchy

The levels of the NRSMPA hierarchy of biological organisms have both an ecological definition and an operational application. In some cases the formal ecological definitions are not useful in applying the concepts as classifications or mapping units - without the context provided by the scope, scale and purpose of mapping. The following ecological definitions are derived from IMCRA Technical Group (1998) and ANZECC TFMPA 1999a (Commonwealth of Australia 1992):

- *Bioregion*: an ecologically based regionalisation at a particular scale (ie IMCRA meso- to provincial scale);
- *Ecosystem*: a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit;
- *Habitat*: a specific type of environment inhabited either permanently or temporarily by organisms;
- *Community*: an assemblage of species occupying a particular habitat or area;
- *Population*: a grouping of living organisms of a species;
- *Species*: a group of organisms capable of interbreeding freely with each other but not with members of other species; and
- *Individual*: a single organism of a species.

These formal ecological definitions do not transpose to a clear set of operational criteria for classifying mapping units as surrogates for biodiversity at scales relevant for strategic planning for the NRSMPA. To achieve this, an appreciation of the purpose of mapping, scale nature of boundary delineation and data sources would be required.

Several jurisdictions have refined the hierarchical classification of mapping units within various levels of the NRSMPA or other comparable hierarchy. Some of these jurisdictions are working towards a comprehensive listing of habitat and community types (with accompanying criteria) as mapping units with application at a particular scale throughout the jurisdictions waters. This process usually includes the nomination of the scales or levels at which mapping would occur for different purposes and the nomination of the habitat and community types within which different classification/mapping units would be differentiated (and mapping criteria set).

Examples of tabulated hierarchical classifications have been included in Section 2.2 for Victoria (Tables 2.9 and 2.10), Western Australia (Table 2.12) and New South Wales (Table 2.3). Other classification examples include: GBRMPA (reef and non-reef habitats and communities), South Australia (macroalgal communities), CSIRO (seagrass communities).

It is not yet practical to achieve a nationally applicable nor complete set of habitat and community classifications for all Australian waters. However, this would be a desirable goal to aid tracking the achievement of a comprehensive and representative system of MPAs on a national basis. At this stage it would be appropriate for the jurisdictions to recognise the hierarchical context in which they classify different ecological groupings. The following section provides a discussion of the scale at which ecosystem components are recognised, while Section 4.4 recommends a framework for applying the classification of ecosystem components for the NRSMPA.

4.3.3 Scales of Classification Hierarchies

Different hierarchies have been proposed in Australia and overseas, but without precise definitions and criteria. An appreciation of the scale of application of each classification is important for encouraging consistency in the application of the NRSMPA agreed hierarchy.

Macroscale

While there is wide recognition of the existence of the wider scale, the terms are used loosely and there are no universal definitions or criteria. Some terms used for macroscale regionalisation are: biogeographic 'provinces' (broadest division) and 'regions' (subdivision); the IMCRA 'provinces' (not apparently analogous with biogeographic 'provinces), 'large marine ecosystems', 'marine domains', 'regional seas', etc. However, it should be possible to reconcile the various criteria developed by marine biogeographers (e.g. Ekman Knox, Wilson, Poore, Ortiz), and more recent CSIRO, IMCRA concepts, and produce some agreed hierarchies and operational definitions.

Mesoscale

This encompasses the NRSMPA level of 'ecosystem'. However, there appears to be a range of interpretations amongst the practitioners in NRSMPA mapping. Ortiz (1992) observes that at this scale major discontinuities in biogeography, climatology, oceanography and physiography are used to identify biophysical regions at a scale of hundreds of kilometres. The subsequent IMCRA bioregionalisation process occurred at this scale.

Microscale

The NRSMPA terms of 'community/population', and 'individual/species' lie at this level. However, the combination of 'community/population' and 'individual/species' are curious, and not consistent with accepted ecological concepts and definitions.

Other Scales

Ortiz (1992) identifies two scales below mesoscale. Firstly, a 'local' scale (tens of kilometres) at which fluvial erosion and marine abrasion processes sculpt the coast, creating structures and making possible the linkages between biological and structural units and the delineation of local scale biophysical regions (biounits). Ortiz (1992) defines these as functional ecosystem components with recognisable natural boundaries and (a degree of) internal homogeneity. Secondly at a smaller scale (tens to thousands of metres) one is concerned with the mosaic of physical (ie rocky reef) and biological habitats (algal beds) that can be found within different 'biounits'.

A literature review of alternative units and terminologies used at various spatial scales would also include consideration of: Allen and Starr (1982), Hayden et al (1984), Ray and Hayden (1992), Zacharias and Howes (1998), Zacharias et al (1998) and Zacharias and Roff (in press).

4.4 National Mapping Standards to Define Ecosystem Components for NRSMPA

4.4.1 Recommended Hierarchy of Ecosystem Mapping Processes

The objectives for mapping conducted by the jurisdictions can be classified into 5 main types, here identified as 'purposes'. The mapping scale and the mapped ecosystem component for each purpose are different, although the finer scale knowledge is capable of being aggregated upwards to also provide data for higher order purposes. As with all classification systems, to satisfy the requirements of each purpose, each class at each level has been considered to be relatively internally homogeneous. As the requirements (purposes) move to more finer scales of action (such as making a boundary declaration) the classes must be more finely resolved to meet the more detailed requirements of the finer scale of purpose. Figure 4.1 demonstrates this hierarchy.

Purpose 1 (P1): Classification of the Marine Realm

For this objective, mapping has been conducted at scales of 1:10,000,000 using oceanographic features and broad patterns in bathymetry to identify classes of Australia's EEZ known as Large Marine Domains (CSIRO, AGSO, EA; Australia's Oceans Policy).

Purpose 2 (P2): Overview of Jurisdictional Resources

For this objective, mapping has been conducted at scales of about 1:1,000,000 to develop an overview of the 'mesoscale' patterns in ocean ecosystems as the basis for strategic planning of the NRSMPA. Mapping at this level has identified the IMCRA 'meso-scale bioregions'

Purpose 3 (P3): Strategic Planning for Identifying Candidate MPAs

For this objective, mapping has been conducted within jurisdictions as part of strategic planning to identify candidate MPAs. This mapping is generally at about 1:100,000, and leads to the identification of sub-IMCRA regions (such as 'biounits').

Purpose 4 (P4): Establishing Boundaries and Zones

For this objective, mapping has been conducted at scales down to 1:10,000 to define the broad nature of marine habitats, and communities/assemblages within an intended MPA. This then becomes the basis for declaration of firm legally enforceable boundaries identified by grid coordinates.

Purpose 5 (P5): Site-specific Monitoring

For this objective, mapping has been conducted at scales finer than 1:10,000 where specific attributes of MPAs are monitored, and the broad patterns of habitats or communities/assemblages are monitored in detail to ensure that MPA goals are being met, or that threats are held in check.

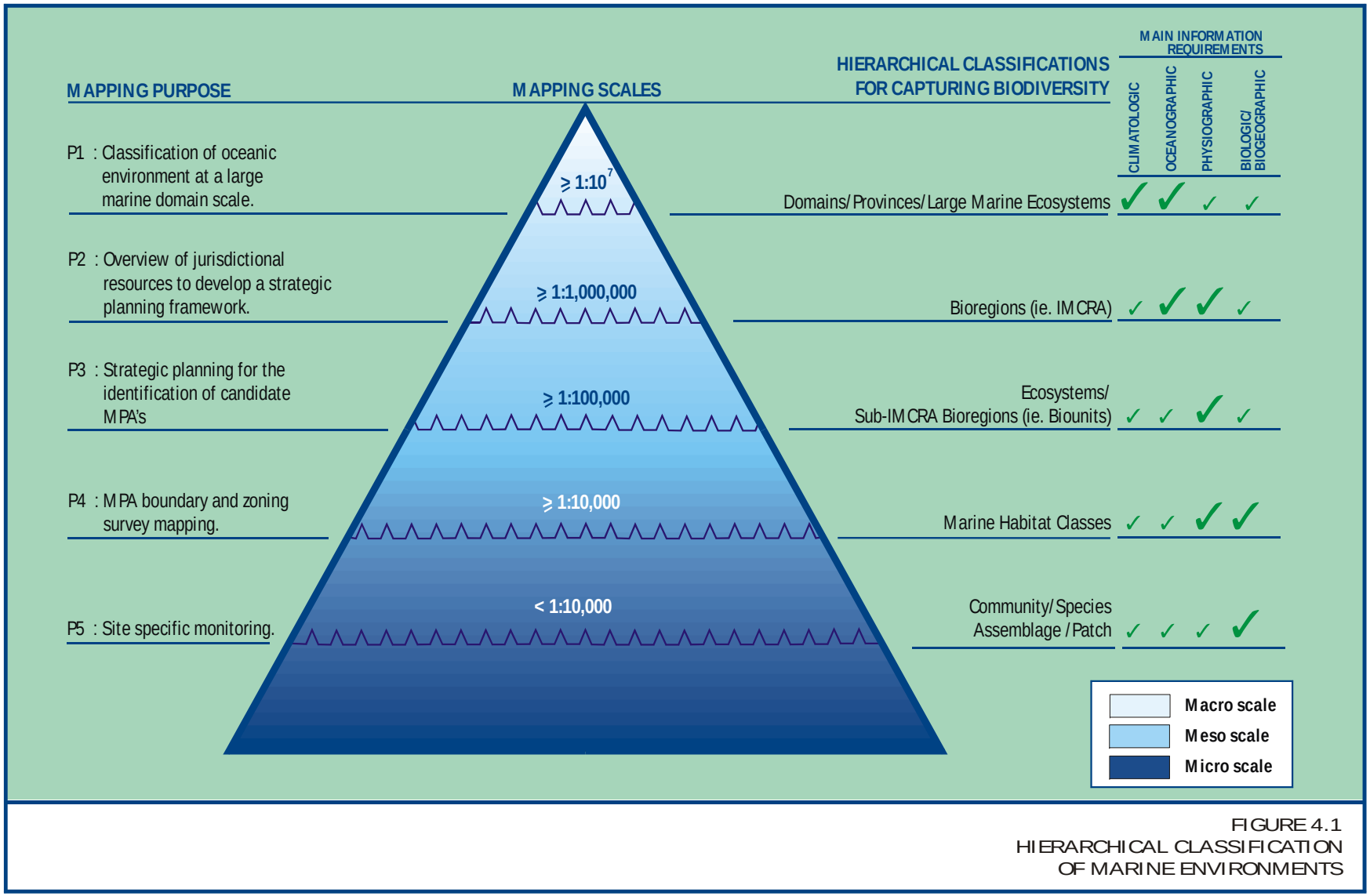

FIGURE 4.1
HIERARCHICAL CLASSIFICATION OF MARINE ENVIRONMENTS

4.4.2 Appropriate Mapping Methods and Data Sources

For the above mapping purposes and scales, the following mapping methods and data sources are applied.

P1: Classification of the Marine Realm

This classification can be conducted using global-scale data on bathymetry, remotely sensed ocean properties such as wave height, ocean colour and sea-surface temperature, and broad patterns in major ocean currents (such as the East Australian Current and the Leeuwin Current). Remotely sensed data is the dominant basis for this classification.

P2: Overview of Jurisdictional Resources

This classification can be conducted using bathymetry, ocean properties, and broad-scale biological patterns such as province-level data on marine plants or coastal fish assemblages. The data is derived from remotely sensed data and from broad comparative analyses of biological assemblages in the published literature.

P3: Strategic Planning for Identifying Candidate MPAs

This classification has been developed using mainly biological data, with physiographic and oceanographic data as surrogates where biological data are limited. Surveys of seabed conditions are used to identify the major class of habitat or community/assemblage, in sufficient detail to resolve the distinction between classes. These may be conducted using a combination of satellite images, aerial photography, diver or remote video, diving observations, or vessel-based sampling with grabs or nets. Maps from such data are derived by spatial modelling techniques and by expert opinion.

P4: Establishing Boundaries and Zones

This classification is mainly based on biological data, although substrate knowledge is also important where biological data is limited and where the topography is complex. The methods used are as in P3 above.

P5: Site-specific Monitoring

The data used for this level of classification and mapping is almost entirely biological. Where threats are present or suspected, measures of water quality are also used as the basis for monitoring.

4.4.3 Recommended Standards and Scales of Mapping

Habitat

The model provided in Figure 4.1 broadly depicts the conceptual scales at which mapping is undertaken to define ecosystem, habitat and community. In practice, a degree of consistency in mapping scales has only been adopted for mapping of habitat classes in temperate Australia where mapping occurs at 1:100,000 scale of nearshore habitats. This scale has proved useful for strategic planning purposes in clear nearshore waters (less than 30m-50m) and would be an appropriate mapping scale where resources permit sufficient resolution of data capture and ground truthing to justify the output scale.

Where remote sensing techniques are not available or depth / turbidity do not enable direct delineation of benthic habitat discontinuities, then reliance on point data (ie sediment grab samples) would reduce the resolution of any mapping to the scale of the sampling grid. In

these circumstances it is not appropriate to recommend a density of sampling and consequent mapping scale as this will be dictated by the specific mapping purpose and resources.

Likewise in offshore waters, the output mapping scale should be governed by the resolution of boundary discontinuity identification offered by the remote sensing or scanning tools used as well as the practical density of ground truthing necessary to validate the boundary definition. In offshore waters this would be expressed in terms of a grid size for point data or a broad mapping scale for continuous coverage. It is unlikely that scales finer than 1:250,000 would be achieved for mapping of offshore benthic habitats (bathymetry excepted).

Community

Mapping of nearshore benthic communities is more frequently done for management planning or monitoring purposes and is appropriate at a finer scale. In the context of the NRSMPA, community mapping would assist in depicting the biodiversity of a certain area and would contribute to determining the representativeness of MPA. Mapping scales of between 1:4,000 and 1:25,000 are typically reported among the jurisdictions, with 1:10,000 being the most consistently used. It is not appropriate to recommend any specific scale for any benthic community mapping as this would be totally dependent on the management purpose and mapping tools available. However, where common communities are targeted (eg kelp) a common scale should be adopted at least on a jurisdiction wide basis.

In offshore benthic communities and in relation to pelagic communities the resolution of community boundaries becomes problematic and much broader mapping scales would be applied.

Ecosystem

Mapping to define bioregional units at a scale between IMCRA bioregion and habitat are undertaken by two means:

- aggregation of component mapped habitats/communities based on mapping at a finer scale (from bottom up); and
- qualitative delineation of similar areas using a delphic workshop approach based on available research (from top down).

Ecosystem mapping by combining mapped habitat units has a defendable basis and is founded on the quality of the habitat mapping data which can be depicted at any scale broader than the resolution of the component mapping. The biounit identification in South Australia is an example of this approach (Edyvane, 1999a), although it is noted that one biounit does not necessarily correspond to one ecosystem.

For many jurisdictions (and for all jurisdictions in offshore waters) the component habitat mapping is not available or complete. However, the need to make an early attempt at establishing a comprehensive system of MPAs remains a high priority. In such circumstances the adoption of a delphic approach for the qualitative nomination of mapping unit boundaries at the “ecosystem” scale would be an appropriate interim measure to enable some distinction of the different areas desirable for inclusion in a comprehensive system of MPAs. Using delphic techniques the output mapping scale would be very broad and unlikely to be justifiable below 1:1,000,000.

4.4.4 Classification of Mapping Systems

All jurisdictions use a form of hierarchical classification of ecosystem components that is a mixture of physiographic and biological information, most of which can be aggregated into successively higher levels of organisation. This aggregation (or divisive resolution) is not within a single system of classes; as the scales become finer so the classification moves more towards uniquely biological data, or conversely as the scales become coarser the data becomes predominantly physiographic. This is based on the availability of data and knowledge.

For the NRSMPA as a whole it is now important that a mapping system be devised that covers both physiographic habitats and biological communities/assemblages, which are the most common target used by the jurisdictions. This mapping system would be based on concepts such as those applied by the jurisdictions (refer Section 2.2) expanded to cater for all situations ranging from mainly physiographic features at the smallest scale (domains) to mainly biological units at the largest scale (assemblages) of jurisdiction's interests. This mapping system would be based on existing work by the jurisdictions and expanded to be fully comprehensive of scales and purposes. Development of a comprehensive mapping system for the NRSMPA would follow logically from this review, and be based on the concepts presented here, but is beyond the present scope.

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Appendix A

Study Brief

INITIAL ASSESSMENTS OF ECOSYSTEM MAPPING, VULNERABLE ECOSYSTEMS AND NATIONAL PRIORITIES FOR THE NRSMPA (Incorporating Threatening Processes Analysis)

1.0 BACKGROUND

1.1 Strategic Plan of Action for the NRSMPA

In July 1999, ANZECC endorsed the *Strategic Plan of Action for the National Representative System of Marine Protected Areas*: *a guide for action by Australian governments*. The Strategic Plan was developed cooperatively by all relevant marine management agencies in each State, the Northern Territory and the Commonwealth, through the ANZECC Task Force on Marine Protected Areas (TFMPA).

The primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative system of marine protected areas (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 NRSMPA has secondary goals to: promote integrated ecosystem management; manage human activities and to provide, among other things, for the needs of species and ecological communities; and for the recreational, aesthetic, cultural and economic needs of indigenous and non-indigenous people, where these are compatible with the primary goal.

The Strategic Plan lists 34 actions to be undertaken by the Commonwealth, the States and the Northern Territory to advance marine protected area development in Australia. TFMPA have agreed to a process involving the use of small action teams, comprising representatives from each of the jurisdictions involved, to progress each of the actions in the Strategic Plan. The staged implementation of these actions will progressively inform the process of identifying candidate MPAs.

The Strategic Plan complements the *Interim Marine and Coastal Regionalisation for Australia (IMCRA)* and the *Guidelines for Establishing the National Representative System of Marine Protected Areas*, which were endorsed by ANZECC in June and December 1998, respectively.

1.2 Comprehensiveness, Adequacy and Representativeness (CAR)

The Strategic Plan defines comprehensiveness, adequacy and representativeness (or CAR) as the three principles that underpin the establishment, planning, management and performance assessment of MPAs in the NRSMPA.

- Comprehensiveness: The NRSMPA will include the full range of ecosystems recognised at an appropriate scale within and across each bioregion.
- Adequacy: The NRSMPA will have the required level of reservation to ensure the ecological viability and integrity of populations, species and communities.
- Representativeness: Those marine areas that are selected for inclusion in MPAs should reasonably reflect the biotic diversity of the marine ecosystems from which they derive. *(Source: ANZECC TFMPA 1999)*

Scale is an important consideration for the application of the CAR principles. For the NRSMPA, the agreed hierarchy of biological organisms, against which the principles are applied, is:

bioregion

ecosystem

habitat

community/population

individual/species.

For the NRSMPA comprehensiveness and adequacy are understood and applied at the scales of bioregions, ecosystems and habitats. Representativeness is applied at the finer scales of communities and individuals/species.

The CAR principles underpin the implementation of all actions under the Strategic Plan. As such, it is important that all parties understand and use the principles consistently. A draft report (in progress) entitled *Understanding and Applying the Principles of Comprehensiveness, Adequacy and Representativeness for the NRSMPA* is currently being prepared through TFMPA to facilitate national agreement to applying the principles in a consistent fashion.

2.0 PROJECT OVERVIEW

This project relates to four key Actions from the Strategic Plan of Action for the NRSMPA (pages 6-7):

Action 4: Vulnerable ecosystems

Assessments and mapping of rare, vulnerable and endangered marine ecosystems will be carried out, in association with an analysis of threatening processes.

*Action 5: Identifying priorities for candidate MPAs**

Identify national and regional candidate areas for establishing MPAs based on information from Actions 1-4 and 10-11.

Action 6: Ecosystem mapping

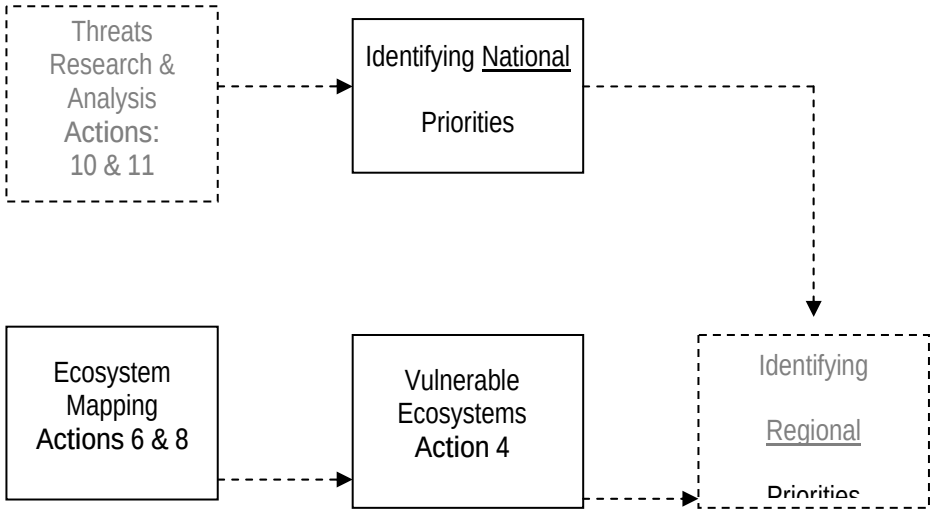
Continue ecosystem mapping and biodiversity assessment work. This data will also be used in future refinement of IMCRA.

Action 8: Review methods for ecosystem mapping

Review methods for mapping ecosystems for the NRSMPA and develop an operational definition of ecosystem.

*Action 5 will incorporate the results of the work on Threats Analysis and Research (Action 10) being undertaken separately by Environment Australia (Attachment C).

The relationship between these actions is represented in the diagram below.



3.0 PROJECT TASKS

3.1 Task 1: Review Methods for Describing and Mapping Ecosystem Components for the NRSMPA (Action 8)

There is no agreed national approach to ecosystem mapping in the Australian marine environment. Mapping methods used, and the interpretation of what constitutes an 'ecosystem' at particular mapping scales, varies quite considerably among jurisdictions. However, habitats are the most commonly used unit to map ecosystem components.

Given the differences in mapping scales and methodologies, a review of this information is vital for national understanding and comparison and for the development of an agreed approach and common standards for ecosystem mapping. It will also assist in assessing the comprehensiveness, adequacy and representativeness of the NRSMPA.

3.1.1 Objectives

Review ecosystem mapping methods employed by jurisdictions, including mapping units.

- Review relevant ecosystem mapping methods, including mapping units, employed by other scientific agencies (eg. AIMS, CSIRO, AGSO and Universities).
- Establish suitable minimum standards and scales of mapping to define 'ecosystems', 'habitats' and 'communities' for the NRSMPA.

3.1.2 Scope

In consultation with Commonwealth, State and Territory agencies:

- Review ecosystem mapping methods and standards (sub-IMCRA scale) employed by each jurisdiction.
- Review relevant ecosystem mapping methods and standards employed by other key scientific agencies (eg. AIMS, CSIRO, AGSO and Universities).
- Review mapping scales and hierarchies used by each jurisdiction to define 'ecosystem', 'habitat' and 'community'.

- Propose suitable minimum standards and scales of mapping to define 'ecosystem', 'habitat', and 'community' for the NRSMPA (inshore and offshore waters).

3.1.3 Outputs:

A consolidated report of ecosystem mapping methods and standards for each jurisdiction/key agency, including a description of:

mapping scales and hierarchies used to define 'ecosystem', 'habitat', and 'community';
the types of ecosystem components mapped;
data, attributes and descriptions;
data collection methods, including accuracy, precision and resolution measures; and
methods for analysis, interpretation and presentation of data (eg. GIS).

Recommendations to guide the development of an agreed national approach to ecosystem mapping under the NRSMPA.
Draft minimum standards and scales for mapping to define 'ecosystem', 'habitat', and 'community' for the NRSMPA.

3.2 Task 2: Status of 'Ecosystem' Mapping for the NRSMPA (Action 6)

Ecosystems form the basis of planning and management for the NRSMPA. Many jurisdictions have made considerable advances in collecting, analysing and mapping the marine environment, generally at the 1:100,000 scale. Most map habitats. In some instances (eg. South Australia), IMCRA regions are divided into sub-units (eg. biounits). A review of ecosystem mapping in each jurisdiction is required to benchmark progress for the NRSMPA.

3.2.1 Objective

Review each jurisdiction's progress towards mapping ecosystem components for the NRSMPA.

3.2.2 Scope

In consultation with Commonwealth, State and Territory agencies:

Review the progress each jurisdiction has made toward identifying and mapping marine ecosystem components at sub-IMCRA scales.
Establish quantitative measures of progress in ecosystem mapping, expressed as:
a proportion of the jurisdiction's waters mapped at a given scale; and
a proportion of each IMCRA region mapped at a given scale.

3.2.3 Outputs

A report providing an overview of the progress made by each jurisdiction on mapping ecosystem components, including examples of existing map products.

3.3 Task 3: 'Vulnerable' Ecosystems (Action 4)

The principle of representativeness implicitly requires that the MPA system also include those marine ecosystems that are rare, vulnerable or endangered.

3.3.1 Objectives

Review progress made by jurisdictions to identify rare, vulnerable and endangered marine ecosystems.
Develop and apply an interim classification system for rare, vulnerable and endangered marine ecosystems under the NRSMPA.

3.3.2 Scope

In consultation with Commonwealth, State and Territory agencies:

Review and document procedures used and progress made by jurisdictions to classify and map rare, vulnerable and endangered marine ecosystems.
Develop an interim classification system for rare, vulnerable and endangered marine ecosystems under the NRSMPA, including draft criteria for its application.
Using the above criteria, determine the conservation status of marine ecosystems in 2-3 jurisdictions yet to undertake this task.

3.3.3 Outputs

A report outlining the procedures used, and the progress made, by jurisdictions to identify rare, vulnerable and endangered marine ecosystems, including for each jurisdiction:
a list of ecosystems which have undergone conservation assessment;
GIS coverage (mapping) of rare, vulnerable and endangered ecosystems.
An interim conservation classification system for marine ecosystems under the NRSMPA, including draft criteria for its application.
For 2-3 jurisdictions, lists and GIS coverage of ecosystems which have undergone a conservation assessment using the newly developed criteria.

3.4 Task 4: Identifying Priorities for Candidate MPAs (Action 5)

This task will assist in identifying and setting comprehensive, adequate and representative priorities for MPAs. It will also contribute to the performance assessment of the NRSMPA.

3.4.1 Objective

Document current information on MPA declarations, zonings and proposals for each jurisdiction.
Identify an initial set of national priority IMCRA regions for establishing MPAs.

3.4.2 Scope

In consultation with jurisdictions, collate and document current information on MPA declarations, zonings and proposals (where available).
Establish percentage coverage of MPAs within IMCRA meso-scale regions, including an update of Map 2 of the Strategic Plan, using:
spatial data on declared MPAs; and
spatial data on declared plus proposed MPAs.

Note: The calculations of percentage coverage of MPAs within IMCRA regions will be affected by the accuracy and treatment of spatial data. Technical advice in this area can be provided by ERIN, the Environmental Resources Information Network, if required.

Identify and map an initial set of national priority IMCRA regions based on the integration of:
percentage coverage of MPAs within IMCRA meso-scale regions; and
IMCRA level threatening process information (Action 10) to be provided by Environment Australia (refer Attachment C).

Note: Identifying regional (sub-IMCRA scale) priorities for establishing MPAs under Action 5 is not part of this consultancy.

In consultation with jurisdictions, undertake a basic qualitative assessment of the contribution of existing MPAs to CAR.

3.4.3 Outputs

An overview report of available information on MPA declarations, zonings and proposals for each jurisdiction.

Tables and maps detailing percentage coverage of MPAs within IMCRA meso-scale regions for:

- declared MPAs; and
- declared plus proposed MPAs.

A list and map of national priority IMCRA regions.
An overview report providing a basic qualitative assessment of the contribution of existing MPAs to CAR.

Appendix B

Glossary and Acronyms

*Glossary

Adequacy The maintenance of the ecological viability and integrity of populations, species and Communities

ANZECC Australian and New Zealand Environment and Conservation Council, a Ministerial Council representing all jurisdictions

Baseline The territorial sea baseline is the line from which the seaward limits of Australia's maritime zones are measured

Bioregion An ecologically based regionalisation at a particular scale (ie IMCRA meso- to provincial scale)

Biodiversity The variety of life forms: the different plants, animals and micro-organisms, the genes they contain, and the ecosystems they form. It is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity

CAR Reserve System A system of protected areas that address the comprehensiveness, adequacy and representativeness (CAR) of all its component ecosystems

CAPAD Collaborative Australian Protected Areas Dataset

Community An assemblage of species occupying a particular habitat or area

Comprehensiveness Includes the full range of ecosystems recognised at an appropriate scale within and across each bioregion

Condition The current state of ecosystems compared to what would be considered pristine

Conservation The protection, maintenance, management, sustainable use, restoration and enhancement of the natural environment

Ecosystem A dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit (Convention on Biological Diversity, 1992)

Endemic Restricted to a specific region or site

Ground truthing Site investigations to validate the mapping assumptions made using remote sensing

Habitat A specific type of environment inhabited either permanently or temporarily by organisms

IMCRA The Interim Marine and Coastal Regionalisation for Australia is an ecosystem based classification for marine and coastal environments. It provides ecologically based regionalisations at the mesoscale (100-1000km) and at a provincial scale (greater than 1000s km)

Inshore The near coastal waters extending from the coastline and estuaries out to 3 n miles, which is the boundary of the State and Territory waters.

Marine Protected Area An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (IUCN 1994)

Physiographic Features Geomorphological elements of the landscape or seabed

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
Remote Sensing	Use of satellite or aerial photographic imagery as a mapping tool
Side-scan Sonar	Transmission of short regular pulses of sound and receipt of echoes by a transducer pointing sideways from a survey vessel. Resulting echoes are digitised and recorded electronically.
State waters	Australia's Offshore Constitutional Settlement established Commonwealth. State and Territory jurisdictions over marine areas. States generally have primary jurisdiction over marine areas to 3 n miles from the baseline. These waters are termed State waters for the purpose of this report
Territorial Sea	The area of sea adjacent to Australia which extends beyond its land territory and internal waters. Australia's territorial sea extends 12 n miles from the baseline
Threatening Processes	The dominant limiting factors and constraints to the ongoing conservation of biodiversity
Viability	The likelihood of long-term survival of the example / population of the particular ecosystem or species under consideration

*Acronyms

AGSO	Australian Geological Survey Organisation
AIMS	Australian Institute of Marine Science
AODC	Australian Oceanographic Data Centre
AUSLIG	Australian Surveying and Land Information Centre
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZLIC	Australia New Zealand Land Information Council
CALM	Department of Conservation and Land Management (WA)
CAPAD	Collaborative Australian Protected Areas Dataset
CAR	Comprehensiveness, Adequacy and Representativeness
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DoD	Department of Defence
DPIQ	Department of Primary Industries Queensland
DTUP	Department of Transport, Urban Planning and the Arts (SA)
EA	Environment Australia (Commonwealth Department of the Environment and Heritage)
ERIN	Environmental Resources Information Network
FHA	Fish Habitat Areas
FRDC	Fisheries Research and Development Corporation
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
IMCRA	Interim Marine and Coastal Regionalisation for Australia
MPA	Marine Protected Area
NPWS	National Parks and Wildlife Service (NSW)
NRSMPA	National Representative System of Marine Protected Areas
PWCNT	Parks and Wildlife Commission of the Northern Territory
QPWS	Queensland Parks and Wildlife Service
SA DEH	SA Department of Environment and Heritage
TAFI	Tasmanian Aquatic and Fisheries Institute
TFMPA	Task Force on Marine Protected Areas

* Largely extracted from: Australian and New Zealand Environment and Conservation Council Task Force on Marine Protected Areas 1999, *Strategic Plan of Action for the National Representative System of Marine Protected Areas: A Guide for Action by Australian Governments*. Environment Australia, Canberra.

Appendix C

List of Contacts

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