CHAPTER 1

SYNTHESIS OF STAGE 3

DESCRIBING MARINE BIODIVERSITY THROUGH MAPPING AND QUANTITATIVE ANALYSIS OF BIOLOGICAL DATA:

A CLASSIFICATION SYSTEM FOR VICTORIA'S INTERTIDAL AND SUB-TIDAL MARINE WATERS

Lawrance Ferns

Don Hough

Jason Catlin

CHAPTER 1

SYNTHESIS OF STAGE 3

DESCRIBING MARINE BIODIVERSITY THROUGH MAPPING AND QUANTITATIVE ANALYSIS OF BIOLOGICAL DATA: A CLASSIFICATION SYSTEM FOR VICTORIA'S INTERTIDAL AND SUB-TIDAL MARINE WATERS

1.1 Introduction

Describing marine biodiversity through mapping and classification of habitats and associated biological communities is considered an important tool for conservation management and ecological sustainable development (eg Southeran *et al* 1997; Zacharias and Howes 1998; Ward *et al* 1999; Edinger and Risk 2000). In recent times, these tools assisted the development of a *National Representative System of Marine Protected Areas* (NRSMPA). The aim of a NRSMPA is establish and manage a comprehensive, adequate and representative (commonly referred to as "CAR") system of marine protected areas (MPAs)[1] to protect areas which represent all of Australia's major marine bioregions and the biological communities of plants and animals they contain.

The NRSMPA is being implemented through the *Strategic Plan of Action for the National Representative System of Marine Protected Areas*[2] (ANZECC TFMPA 1999). A key component of the of the Strategic Plan is to implement CAR principles (Box 1) through ecosystem mapping, classification and biodiversity assessment at various spatial scales[3].

Marine systems can be described and classified at various hierarchical scales (eg Allen and Starr 1982; Hayden *et al* 1984; Ray and McCormick-Ray 1992; Zacharias *et al* 1998; Ferns 1999a; Zacharias 2000). It is accepted that biodiversity exists at the ecosystem, species and genetic levels (Noss 1990; Norse 1993;). For the NRSMPA, a general framework for describing the hierarchy of biodiversity includes levels termed: 'bioregions'; 'ecosystems'; 'habitats'; 'communities' / 'populations' and 'species' (Interim Marine and Coastal Regionalisation for Australia Technical Group 1998; TFMPA 1999). Consequently, the management of marine biodiversity must similarly involve the collection and understanding of physical and biological information across a range of spatial and temporal scales (Ray and McCormick-Ray 1992).

This chapter provides a synthesis of Stage 3 of the *Environmental Inventory of Victoria's Marine Ecosystems*, a multi-disciplinary project to characterise shallow water marine habitats and biological communities at various spatial scales for strategic planning purposes. The focus of Stage 3 was firstly to map and classify Victoria's marine habitats, and secondly improve knowledge of Victoria's biological communities associated with rocky reefs due to their high biodiversity, social and economic value[4].

[1] Refer to actions 1, 2 and 3 of the *Strategic Plan of Action for the NRSMPA* (ANZECC TFMPA 1999; TFMPA 1999).
[2] Refer also to *Guidelines for Establishing the Representative System of Marine Protected Areas* (ANZECC TFMPA 1998).
[3] Refer to actions 6, 8 and 9 of the *Strategic Plan of Action for the NRSMPA* (ANZECC TFMPA 1999).
[4] Studies associated with habitats and biodiveristy of Victoria's soft sediment benthos form the basis of Stage 4 of the Environmental Inventory Program (Ferns 1999b; Ferns 2000).

The primary objectives of Stage 3 were:

- to improve knowledge of the distribution of Victoria's benthic marine habitats, communities and species to assist with the progressive development of a CAR system of MPAs; and
- to improve the understanding of environmental factors influencing the distribution and structure of biological communities associated with rocky reefs.

Two approaches for describing marine biodiversity in Victoria's nearshore waters at the 'habitat' and 'community' levels of the biodiversity hierarchy are outlined. The first approach is based on classifying intertidal and sub-tidal marine 'habitats' using qualitative attributes collected from remote sensing and field survey techniques that describe their dominant physical and biological characteristics. The second approach is based on classifying biological 'communities' of macrophytes, macroinvertebrates and fish associated with rocky reefs using quantitative numerical analysis.

New understanding of biological communities associated with rocky reefs at broad and fine scales are outlined. For broader scales, biogeographic patterns in the distribution of selected taxa for southern Australia, and the distribution of macroalgae, macroinvertebrate and fish communities associated with rocky reefs across the Central Victoria and Flinders bioregions are described. For finer scales, the physical determinants influencing the distribution and structure of communities on rocky reefs; and the factors influencing association patterns of smaller sessile and slow-moving species that exist amongst the holdfasts and canopies of larger dominant vegetation are described.

The relationship of Stage 3 to other national marine habitat mapping programs[5] and data collection standards is also briefly discussed.

Box 1 Definition of CAR principles (ANZECC TFMPA 1999; TFMPA 1999)

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.

[5] The status of marine benthic habitat mapping in Australia has been recently reviewed by ANZECC TFMPA (2000).

1.2 Marine Habitat Mapping

The habitat mapping component of Stage 3 was initiated in 1995 to1996 and involved employing aerial photography, Landsat TM imagery, aeromagnetic and hydro-acoustic remote sensing techniques to develop a 1:100,000 scale substratum type map of the entire Victorian coastline for waters generally < 30 m deep (Chapter 2). The work was supplemented in places with ground truthing observations from bounce dives, video deployment and collection of substratum samples.

From 1997 to 1999, ground truthing work for substratum type mapping at 1:100,000 continued, including extending the use of hydro-acoustic sonar technology in waters generally > 30 m deep (out to the 3 nm State territorial boundary) to map specific areas under consideration as MPAs.

Data from other commissioned marine surveys along the open coast were used and also integrated to assist the application and interpretation of data obtained from the techniques applied in Stage 3 (refer also Appendix 1.1). These surveys included:

- off Portland in the 1950s (Boutakoff 1963);
- along the Victorian coast - abalone reef atlas 1986 (McShane *et al* 1986);
- off Wilsons Promontory and Bunurong in 1982 (Wilson *et al* 1990);
- off East Gippsland in 1990 (Parry *et al* 1990;
- areas under consideration as candidate MPAs (Roob and Currie, 1996; Roob and O'Hara, 1996; Roob *et al* 1999);
- data collected for the Environmental Inventory Stage 4 (Ferns 1999b; 2000); and
- seagrass mapping for Gippsland Lakes (Roob and Ball 1997), Corner Inlet / Nooramunga (Roob *et al* 1998), Western Port and Victoria's Minor Inlets (Blake *et al* 2000).

1.2.1 Mapping Scale

The size of marine habitat 'patches' can vary by orders of magnitude, from metres to thousands of metres. The nominated mapping scale for the Environmental Inventory was 1:100,000. Experience over the last five years shows that adoption of that scale (features of hundreds of metres) is ideal in nearshore waters to support strategic planning of MPAs. For strategic planning purposes, this scale represents an optimum in terms of operational practicality and cost relative to the suitability of the information gained.

While a nominal scale of 1:100,000 is sufficient to address strategic management issues in nearshore waters, the management and planning of individual MPAs or specific localities may require higher resolution mapping to better define the spatial characteristics of areas for the purpose of assessing management performance**.**

For deeper offshore waters, the strategic issues and available information suggest that a broader mapping scale (coarser than 1:100,000) may be appropriate for marine habitat data. It should be noted that existing physical data sets, that provide surrogate measures of biological variability, form a solid basis on which to map the variability of marine habitats in central Bass Strait and the areas immediately beyond its entrances. In some instances these data sets are available at nominal map scales of 1:100,000.

1.3 Classification and Nomenclature

Victoria's marine ecosystems can be characterised by using three approaches to its classification:

- Marine bioregions (scales of 100s – 1000 km, typically represented at 1:1 million);
- Marine Habitat Classes (scales of 1 m – 100 km, typically represented at 1:10, 000 - 1:100,000); and
- Marine Ecological Communities (scales of 1 m – 1 km, typically represented at ≤ 1:25,000).

1.3.1 Marine Bioregions

Bioregions are geographic areas at scales of 100s – 1000 km that have distinct broad-scale biophysical processes. Bioregions are used nationally for Australia's IMCRA regions (Interim Marine and Coastal Regionalisation for Australia Technical Group 1998). IMCRA bioregions relevant to Victoria (from west to east) are:

- Otway (Western Victoria - Cape Jaffa in SA to Apollo Bay);
- Central Victoria (Cape Otway to west of Wilsons Promontory);
- Flinders (entrance to Bass Strait, including Wilsons Promontory to Flinders Island);
- Twofold Shelf (Eastern Victoria - east of Wilsons Promontory to Tathra in NSW);
- Victorian Embayments (Victoria's bays, inlets and estuaries eg Port Phillip Bay and Western Port);
- Central Bass Strait (cental offshore region of the Bass Strait).

1.3.2 Marine Habitat Classes

Marine Habitat Classes (MHCs) are areas at scales from 1 m - 100 km that have distinct physical and / or biological 'habitat' attributes. This attribute data is based on qualitative descriptions of the seafloor substratum (eg 'reef' and 'sand') and dominant biota (eg 'seagrass' and 'kelp') (refer Chapter 2 and Appendix 1.1). The spatial scale and level of resolution possible for mapping MHCs is dependant on the detail of attribute information available for the particular area (refer 1.4 below). MHCs using attributes of substratum type descriptions such as 'reef', 'sand' and 'seagrass' are available for all Victoria's nearshore waters and major embayments. In selected areas, additional attribute information is available to map MHCs using substratum texture descriptions (eg 'reef - high profile', reef - 'boulders', 'sand - medium grain') and dominant biota (eg 'kelp - *Ecklonia* dominated', 'seagrass - *Heterozostera* dominated').

1.3.3 Marine Ecological Communities

Marine Ecological Communities (MECs) are areas at scales from 1 m to 1 km that consist of distinct biological 'communities'. MECs are derived from numerical classification of biological data derived from systematic quantitative sampling using visual census techniques (Chapter 6). Presently, MECs for macrophytes, invertebrates and fish have been delineated for a selection of rocky reefs of the Central Victoria and Flinders bioregions (refer 1.5 below).

1.4 MHC Attributes

MHC attributes have been identified for intertidal and sub-tidal areas. These attributes are mainly qualitative and are readily observed by aerial and satellite remote sensing techniques, and field surveys using underwater divers, video and benthic grabs. For convenience, the relationship between the interpretation of remotely sensed data and the results of field surveys will be discussed by considering intertidal areas and sub-tidal areas separately.

1.4.1 Intertidal Areas

The physical substratum of intertidal habitats can be unambiguously classified (eg ‘reef’, ‘sand’, ‘mud’). In most instances, the mapped distribution of the substratum classes is time invariant (1 to +10 years), temporal variations do however occur in some localised areas subject to the movement of sand masses and other unconsolidated materials.

In addition, the lithology of the intertidal reef substrata can be confidently allocated to most intertidal areas of the open coast (eg basalt, granite, limestone). This can be done from existing documentation (maps and reports) arising from field programs, many of which involved direct and continuous observation through walking along much of the coastline or observation from boats. An initial classification of Victoria’s broad intertidal substratum types at 1:25,0000 was developed by Roob *et al* (1997). Classification of intertidal habitats has also been undertaken for the Victorian Oil Spill Response Atlas (Marine and Freshwater Resources Institute 2000) at a nominal scales of 1:25,000 and provides the basis for an interim classification of Victoria’s intertidal MHCs (Table 1.1).

With regard to the biological classification of intertidal habitats[6] using remote sensing, high resolution colour aerial photography has considerable potential. Some of this photography is available for Victoria’s intertidal areas and research investigations have been conducted at the University of Melbourne (Dr M. Keough and Dr J. Leach pers. comm.). It should be noted that unlike lithology, the distribution and density of intertidal biota are potentially time-dependent.

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) Bedrock / rock Cobble	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 1.1 Interim MHC attributes for the intertidal areas adapted from the Victorian Oil Spill Response Atlas (Marine and Freshwater Resources Institute 2000).

[6] The distribution of intertidal species across Victoria has been documented by Handreck and O’Hara (1994). This work was incroporated to developing the biophysical regionalisation of Victoria’s marine environment (Victorian Institute of Marine Sciences *et al* 1994; Hamilton 1994)

1.4.2 Sub-tidal Areas

The development of sub-tidal MHCs is based on combining attributes of the substratum with dominant biota (Table 1.2). The substratum attributes were developed as part of the underwater mapping project described in Chapter 2. Biota attributes were derived from dominant species commonly described on both reef and soft sediment substrata (eg Tsernjavski 1995; Porter 1997; Roob *et al* 1998; Chapters 2 , 4, 5 and 6 this report). Additional attributes also describe co-dominant species, dominant understorey species and seagrass density.

The descriptions of dominant algae, seagrass or sessile invertebrates used for MHC mapping are largely qualitative. There is no requirement to accurately quantify the abundance of dominant attribute biota for purposes of representing marine habitats as map information products, particularly at the scale of 1:100,000. However, it is relatively easily to estimate densities of marine habitats such as seagrass from remote sensing techniques and field verification (eg Allen 1994; Pasqualini *et al* 1998; Blake *et al* 2000). At this time, the sub-tidal MHC attributes[7] outlined in Table 1.2 provide a workable classification that can be readily used by trained underwater divers or by biologists viewing video footage (eg Williams and Leach 1997; 1999 and 2000). Additional descriptive information pertaining to selected MHC attributes in Table 1.2 are summarised in Appendix 1.2.

Description	**Sub-tidal MHC Attributes**			
Substratum type	Reef		Sediment	
Substratum relief	Low profile (reef) High profile (reef)		Flat (sand / mud) Ripples (sand) Gently undulating ridges (sand) Steeply undulating ridges (sand)	
Substratum texture	Solid Broken (boulders/slabs/bommies) Gutters Outcrops		Coarse/very coarse sand Medium sand Very f ine/ 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 Acrocarpia Seirococcus Amphibolis Cystophora / Amphibolis Sessile invertebrates (eg sponges)	Red algae dominated 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	

Table 1.2 Interim MHCs for sub-tidal reef and sediment substrata across Victoria (refer to Appendix 1.2 for detailed attribute descriptions).

[7] Note: depth is important factor in the distribution of dominant biota and the MHC attributes described here are most relevant to the 2.5 m to 20 m water depth. Additional MHC attribute descriptors will be necessary for 0 m to 2.5 m water depth and water depths beyond about 20 m (see also section 1.6 below).

1.4.3 Applying MHCs

MHCs provides a basis for mapping the marine environment for variety of planning and management purposes. MHC mapping has been recently applied to the further development of Victoria's Oil Spill Response Atlas (Marine and Freshwater Resources Institute 2000). Data collated for the Environmental Inventory was used to map the distribution of kelp / macroalgal communities across central Victoria and Cape Otway (Edmunds *et al* 2000) (Figure 1.1). The availability of MHC maps in digital form will encourage the use of the data in strategic (immediate application) and day-day decision making (this potential will be realised in the longer term).

It should be noted that mapping of underwater substrata using remotely sensed data will always be subject to continued improvement. The accuracy and resolution of the data, its interpretation and its resultant mapping presentation is constantly being upgraded as technology and data becomes available. The use of satellite and airborne technology for mapping marine habitats has been reviewed in tropical waters by Mumby *et al* (1997) and (1998); hydroacoustic sonar technologies to map complex seabeds have been employed by Greenstreet *et al* (1997) using RoxAnn and Barnhardt (1998) using side scan sonar; and the use of videography as a tool for interpreting seafloor features has been undertaken in Victoria by Williams and Leach (1997, 1999 and 2000)[8].

For mapping based solely on interpretation of remotely sensed data from satellite or acoustic sonar techniques, an estimate of accuracy can be derived from comparison of the expected substratum type compared to the actual substratum type encountered from ground truthing surveys. Based on experience to date in Victoria (eg Ferns 1999b) and elsewhere in Australia (H. Kirkman, pers. comm.), the reliability of a particular area classified from a single remotely sensed technique alone is estimated to be approximately 80% accurate. For selected areas of Victoria where two remote sensing techniques have been applied together, the reliability of interpreted data increases significantly to approximately 90%.

1.5 MEC Attributes

MEC attributes are currently available for selected sub-tidal rocky reefs within the Central Victoria and Flinders bioregions. MEC attributes are derived from quantitative numerical analysis and classification of biological community data (Chapter 6) using:

- similarities measures using multivariate community data (eg dendrograms and ordinations);
- relative abundances of species (ie the number or percent cover of characteristic species)
- relative species diversity (ie numbers of species and evenness measures); and
- site specific spatial patterns in species distribution (ie characteristic mosaic patches of species at given sites).

In contrast to the collection of MHC attribute data, the collection of MEC attribute data requires scientifically-trained divers with capacity to carry out underwater visual census techniques, and identify a broad taxonomic range of marine flora and fauna. The subsequent analysis and interpretation of data also requires a high degree of statistical and ecological expertise. The classification of MECs (Chapter 6) for macroinvertebrate, macrophyte and fish communities across the Central Victoria and Flinders bioregions are presented in Tables 1.3 to 1.5 below.

[8] A report reviewing remote sensing techniques and other biodiversity assessment tools for is currently being prepared for Action 9 (and in relation to Action 8) of the *Strategic Plan of Action for the NRSMPA* (ANZECC TFMPA, 1999).

As MECs are based on location-specific quantitative data, they potentially serve as useful indicators for reporting on the long-term status of marine communities. Such indicators are useful for communicating complex information among researchers, managers, stakeholders and policy makers (Done and Reichelt 1998). MECs may also serve as an indicator for assessing the integrity of marine communities within MPAs, and larger systems such as bioregions of which they form part of [9].

MEC Code*	Description
GHIJ	*Heliocidaris erythrogramma*, *Haliotis rubra* and *Cenolia trichoptera* very abundant. High diversity of sea star species with characteristic species including *Nectria ocellata*, *Nectria macrobrachia*, *Patiriella brevispina*, and *Petricia vernicina*. Location: Wilsons Promontory.
KLM	*Haliotis rubra* and *Turbo undulatus* the most abundant species. *Dicathais orbita*, *Plagusia chabrus* and *Patiriella brevispina* also common. *Heliocidaris erythrogramma* not abundant. Locations: Lonsdale Bay, Lonsdale Back Beach, Phillip Island and Bunurong.
NOP	*Haliotis rubra*, *Haliotis laevigata*, *Heliocidaris erythrogramma* and *Patiriella brevispina* the most abundant species. Locations: Port Phillip Heads and Bunurong.
Q	All species low in abundance. *Haliotis rubra* the most abundant. Other characteristic species: *Nectria ocellata*, *Nectria macrobrachia*, *Fromia polypora* and *Tosia australis*. Location: from Gunnamatta to Cape Schanck.
R	*Cenolia trichoptera* abundant, all other species relatively low in abundance, including *Haliotis rubra*. Location: south of Warratah Bay.

*Refer to Chapter 6 for explanation of MEC Codes. Note macroinvertebrate MECs A, BC, D and E and F delineated in Chapter 6 are not yet described due to very low abundances of invertebrate species and lack of replicate sites to enable confident descriptions. Further sampling will eventually elucidate their status.

Table 1.3 Macroinvertebrate MECs of Victoria's rocky reefs (Cental Victoria and Flinders bioregions).

[9] Reporting on the performance of MPAs and the NRSMPA are key Actions of the *Strategic Plan of Action for the NRSMPA* (ANZECC TFMPA, 1999). Refer to Actions 32, 33 and 34.

MEC* Code	Description
HI	Mixed browns dominated by *Acrocarpia paniculata*, *Cystophora retorta*, *Seirococcus axillaris* and the seagrass *Amphibolis antarctica*. *Phyllospora* absent, *Ecklonia radiata* uncommon. *Macrocystis angustifolia* present in small patches. Erect coralline algae abundant. Locality: south and east Bunurong
E	Mixed browns dominated by *Cystophora moniliformis*, *Cystophora retroflexa*, *Cystophora retorta*, *Acrocarpia paniculata* and *Macrocystis angustifolia*. Erect coralline algae abundant. Fleshy red algae not abundant. Locality: east Pyramid Rock, Phillip Island.
F	*Phyllospora comosa* dominated community. *Acrocarpia paniculata*, *Macrocystis angustifolia*, *Cystophora* spp and other browns also abundant. Understorey and open turfs of erect coralline algae and fleshy red algae, including *Haliptalon*, *Amphiroa* and *Phacellocarpus*. *Ecklonia* uncommon. Locality: Phillip Island.
G	*Phyllospora-Ecklonia-Cystophora retorta* dominated community. *Acrocarpia paniculata*, *Carpoglossum confluens* and *Cystophora platylobium* abundant. Understorey of fleshy red algae including *Pterocladia lucida*, *Melanthalia obtusata*, *Plocamium* spp, *Phacelocarpus peperocarpus*. Locality: Lonsdale Back Beach.
PR	*Ecklonia* dominated community. Fleshy red algal species abundant, similar species to Category G. *Phyllospora* absent.
A	*Ecklonia* dominated community with patches dominated by *Caulerpa brownii* and *Cladophora rugulosa*. Mixture of other browns, reds and green algae in low abundance. Locality: South Channel Fort.
B	*Ecklonia* dominated community with occasional patches of *Cladophora rugulosa*, some areas dominated by *Macrcystis angustifolia*. Understorey sparse cover of thallose red algae. Other brown algae in very low abundance. Locality: Popes Eye.
C	*Ecklonia* and mixed *Cystophora* and *Sargassum* species dominate, occasional patches dominated by *Amphibolis antarctica* or mixtures of *Cladophora rugulosa, Sargassum* and red algae. Locality: Inside Port Phillip Heads (Victory Shoal, Shortland Bluff, Point Franklin).
KL	*Ecklonia-Phyllospora* dominated community. *Seirococcus axillaris*, *Carpoglossum confluens*, *Sargassum* species abundant and fleshy red algal species abundant. Locality: northwest (Shellback Is) and northeast Wilsons Promontory (from north Waterloo Bay).
MNO	*Phyllospora* dominated community. *Ecklonia* abundant. Understorey of fleshy and coralline red algae common but in low abundance. High cover of encrusting coralline algae. Other browns present but in very low abundance. *Durvillaea* may be present in the shallow sub-littoral zone. Locality: Lonsdale Bay; Nepean Bay; Cape Woolamai; midwest, south to mid-eastern Wilsons Promontory.
D	*Amphibolis antarctica* dominated community. Occasional patches of *Ecklonia* and other brown algae such as *Cystophora*. Understorey mainly *Caulerpa* species and other red algae in low abundance. Locality: Nepean Bay
Q	*Phyllospora* and *Durvillaea* community, *Durvillaea* occurring to considerable depth (>3 m). Understorey algae generally absent. High cover of encrusting coralline algae. Locality: Cape Schanck; Cape Otway.
S	Low to medium cover of large brown algal species, either mixed or monospecific (generally less than 50% cover). Sparse to patchy stands of *Phyllospora*, *Macrocystis*, *Ecklonia* and *Acrocarpia*. High cover of encrusting and erect coralline algae, including *Haliptalon*, *Metagoniolithon* and *Cheilosporum*. *Halopteris*, *Caulerpa flexilis*, *Caulerpa obscura* and *Sonderopelta* common. Locality: Flinders to Cape Schanck.

* Refer to Chapter 6 for explanation of MEC Codes.

Table 1.4 Macrophyte MECs of Victoria's rocky reefs (Cental Victoria and Flinders bioregions).

MEC Code*	Description
C	Dominant species *Trachinops caudimaculatus* in very high abundance, other species in high abundance *Scorpis aequipinnis*, *Notolabrus tetricus, Notolabrus fucicola, Meuschenia freycineti* and *Parma victoriae*. Location: Popes Eye.
D	Dominant species *Trachinops caudimaculatus* in high abundance. Other species *Notolabrus tetricus* characteristic. Location: South Channel Fort.
F	Dominant species *Notolabrus fucicola, Odax cyanomelas* and *Scorpis aequipinnis* in low abundance. Locations: Phillip Island (Red Bluff, north of Pyramid Rock).
GH	Dominant species are *Notolabrus tetricus*, *Odax cyanomelas*, *Scorpis aequipinnis*, *Notolabrus fucicola* and *Cheilodactylus nigripes*. Other characteristic species include *Parma victoriae*, *Pictilabrus laticlavius*, *Meuschenia hippocrepis* and *Aplodactylus arctidens*. Locations: Lonsdale Back Beach, Phillip Island and Bunurong.
I	Dominant species are *Notolabrus tetricus*, *Odax cyanomelas*, *Parma victoriae* and *Cheilodactylus nigripes*. *Scorpis aequipinnis* and *Notolabrus fucicola* are generally low in abundance. Other characteristic species include *Pictilabrus laticlavius*, *Upeneichthys vlamingii*, *Meuschenia hippocrepis* and *Meuschenia flavolineata*. Location: Port Phillip Heads.
J	Dominant species are *Caesioperca rasor*, *Notolabrus tetricus*, *Notolabrus fucicola*, *Dinolestes lewini* and *Odax cyanomelas*. Other characteristic species are: *Acanthaluteres vittiger*, *Enoplosus armatus*, *Cheilodactylus nigripes*, *Scorpis aequipinnis* and *Trachinops caudimaculatus*. Location: western Wilsons Promontory.
K	Dominant species are *Caesioperca rasor*, *Notolabrus tetricus* and *Dinolestes lewini*. Other characteristic species are: *Cheilodactylus nigripes*, *Scorpis aequipinnis*, *Scorpis lineolata*, *Atypichthys strigatus* and *Latridopsis forsteri*. Location: eastern Wilsons Promontory.

* Refer to Chapter 6 for explanation of MEC Codes. Note Fish MECs A, B, D and E delineated in Chapter 6 are not yet described due to very low abundances of fish species and lack of replicate sites to enable confident descriptions. Further sampling will eventually elucidate their status.

Table 1.5 Fish MECs of Victoria's rocky reefs (Cental Victoria and Flinders bioregions).

Figure 1.1 Marine Habitat Classes based on dominant biota (macroalgae) in the 2.5 – 20 m depth range in the vicinity of the Mornington Peninsula and Phillip Island (central Victoria).

1.6 Biological Communities on Victoria's Rocky Reefs

Ecological studies of reef biota have been undertaken at a number of spatial scales and provide both qualitative and quantitative information on the distribution and environmental determinants of reef communities. At the broader scale (eg Chapter 2), this work has contributed to Victoria's MHC mapping project described in 1.4 above. MHCs have provided Victoria with a basis for a 'comprehensive' NRSMPA network. For finer scale studies (eg Chapters 4 and 6) this work has increased the understanding of species and community patterns associated with rocky reefs, and the physical determinants which appear to influence them. Identifying how species / communities are structured and how they interact with the environment contributes to the on-going assessment of 'adequacy' and 'representativeness' of the NRSMPA (TFMPA 1999) (Box 1).

1.6.1 Biogeographic Patterns

Biophysical processes change over geological times scales. This is fundamental to recognising that ecosystem processes are influenced by the Earth's natural forces operating over many thousands to millions of years. The marine waters of southern Australia feature many endemic species due to long periods of oceanic isolation; periodic sea level changes; and periods of global warming which has resulted in the periodic invasion of tropical species from the Indo-Pacific (Edyvane 1999). In Chapter 3 of this report, the distribution of decapod crustacean and echinoderm species were investigated at the continental scale. This work provided an insight to biogeographic patterns across southern Australia using selected taxa, and provided a hypothesis to explain these patterns based on physical and ecological processes operating at large temporal and spatial scales. For Victoria, the selected taxa could be grouped into four biogeographic categories as follows:

- a 'common' group that occur throughout Victoria;
- a 'western' group that has a eastern limit in Victoria;
- an 'eastern' group that has a western distribution limit within Victoria; and
- a 'central' group that occurs in central Victoria but not at the eastern of western limits of the State .

The spatial patterns associated with these groups corresponds geographically with Victoria's IMCRA bioregions (Interim Marine and Coastal Regionalisation for Australia Technical Group 1998). This further supports the robustness of the meso-scale classification that was originally based on other biological data and physical processes (Victorian Institute of Marine Sciences *et al* 1994).

Chapter 3 also found that only 51% of the decapod crustaceans and echinoderm taxa selected for the study occur throughout Victoria, while the remaining 49% have some biogeographic limit to their distribution within Victoria. Of interest was the observation that the area exhibiting the most rapid turnover in species occurred between Port Phillip Bay and Wilsons Promontory. This might be a reflection of the heterogeneity of the environment within this region which coincides with the boundaries of three Victorian IMCRA bioregions, and overlapping boundaries of the Flindersian, Peronian and Maugean biogeographic provinces proposed by Bennett and Pope (1953) (refer Figure 6.1, Chapter 6).

Biogeographic patterns were examined further in Chapter 6 using quantitative data from sites across the Central Victoria and Flinders bioregions. This study has found that reef communities of macrophytes, macroinvertebrates and fish from the Central Victoria bioregion are differentiated from those in the Flinders bioregion. Furthermore, reef communities changed considerably more across sites within the Central Victoria bioregion compared to sites within the Flinders bioregion. This pattern is consistent with the findings of Chapter 3 in that the Central Victoria bioregion is an area which exhibits a rapid turnover in species.

1.6.2 Fine Scale Patterns

Chapter 4 of this study was commissioned to elucidate the influence of physical variables on biological communities associated with rocky reefs. The study measured the following variables at representative rocky reefs within the vicinity of Phillip Island to Wilsons Promontory:

- lithology
- substratum relief
- interstitial space
- substratum complexity
- depth
- exposure
- aspect
- distance from shore
- reef slope
- longitude / biogeographical region
- sediment cover

The survey design of Chapter 4 employed quantitative measures of macroalgae and macroinvertebrate abundances to allow comparisons using diversity, dominance and multivariate analysis methods. The study found that macroinvertebrate structure was closely associated with substratum structure (ie crevice complexity and slope), depth and longitude (ie a geographic influence, refer again to 1.6.1 above). For macroalgae, community structure was closely associated with variations in exposure, depth and reef slope.

For classifying marine biodiversity at the ‘habitat’ level in the biodiversity hierarchy, often larger dominant species which provide shelter and niches (ie ‘habitat’) for other species within a local area are considered important (Underwood and Petraitis 1993). For this reason Chapter 5 sought to investigate if ‘habitats’ based on dominant vegetation types are effective surrogates for determining presence/absence of associated species. The study also served to assess the benefit employing dominant vegetation attributes for MHCs as a tool for describing marine biodiversity at the ‘habitat’ scale.

Sampling was conducted across a range of sub-tidal rocky reefs dominated by the following vegetation types :

- large kelps (*Ecklonia radiata* and / or *Phyllospora comosa* dominated);
- seagrass (*Amphibolis antarctica* dominated); and
- mixed brown algae (typically *Cystophora* spp., *Sargassum* spp. dominated)

The study demonstrated that dominant vegetation types exhibit different suites of associated sessile and slow moving species. Furthermore the study suggests that dominant vegetation act as useful surrogates for representing the distribution of marine biodiversity within a regional context from 10 - 100 km.

1.7 National Data Standards

For the development of the mapping component for Stage 3, particular attention was taken to ensure that data collected contributes to national arrangements to map and describe Australia's marine biodiversity, particularly in relation to protected areas, while recognising that the skill base, priorities and marine conditions in Australian jurisdictions may vary[10].

Central to the mapping component was the involvement of Dr Hugh Kirkman (formerly CSIRO Division of Marine Research) who applied Landsat TM imagery as the initial template for Victoria's nearshore marine ecosystem mapping. Dr Kirkman's work has also been applied in South Australia, Western Australia and Tasmania.

The ground truthing and development of Victoria's MHCs is also similar to the work undertaken in South Australia which has included the mapping of broad habitat types (Edyvane and Baker 1994; Edyvane 1999), as well as multivariate statistical analysis to refine and further classify South Australia's IMCRA bioregions.

Biological sampling involving quantitative visual transect methods reported in Chapters 4 and 6 have employed techniques developed in Tasmania by Drs Graeme Edgar and Neville Barrett (Edgar and Barrett 1997) which have been applied to MPA monitoring of Tasmanian marine reserves since 1992 (see Box 2).

The data compiled as part of the Environmental Inventory are quite varied and involve the integration of physical and biological data using various technical instrumentation and professional expertise. It is noteworthy that some of the field survey technologies, statistical and data management techniques used in Stage 3 were either not available a decade ago, or were difficult to use on a routine basis. The use of such techniques highlights the increasing ease with which data about Victoria's marine waters can be obtained, processed and stored as an aid to decision making.

Box 2 Marine environmental inventory work in Tasmania

Tasmania's IMCRA bioregions were developed from a study collecting biological data over large geographic and taxonomic scales to support decisions regarding the ecologically sustainable development of coastal ecosystems (Edgar *et al*, 1997). The study surveyed the macrobenthos of rocky reefs from 156 sites around Tasmania. Conspicuous species of invertebrates, fish and macroalgae were recorded (present / absent) from 50 m transects at each location at 5 or 10 m depths. The results of this study indicated that the primary influence on biota at sites was local conditions, particularly wave exposure. However, latitude is also important with the north of Tasmania being distinguished from the east, south and west. Sea water temperature does not account for the observed geographic differences. Rather, the lack of large sheltered embayments along the east and west coasts ensures that the northern biota is readily distinguishable. As a further result seven bioregions were distinguished, three in Bass Strait and four along the eastern, southern and western coasts.

A complementary study has surveyed the sheltered embayments, estuaries and coastal lagoons around Tasmania (Moverley 1996). Cores (15 cm diameter, 10 cm deep) were taken in *Zostera*, *Heterozostera* and *Posidonia* seagrass and in unvegetated sites. The results show that there was as much variation between sites as within sites. Multivariate ordinations show that the samples from each seagrass species graded into each other, but were clearly distinguished from the unvegetated samples. A temporal study of some sites over one year found temporal variation but no consistent seasonal pattern.

Tasmania has also embarked on a long-term monitoring project within a number of marine reserves to determine whether the reserves are fulfilling their intended function as sanctuary areas (Edgar and Barrett, 1997). The specific aim of the project is to measure the effects of reserves on population abundances and size structures of reef biota, or whether other unexpected ecological effects occur following declaration.

Other work in progress is habitat mapping within existing and proposed Tasmanian marine reserves. This work will be documented in a report titled "Regional Classification Of Tasmania's Marine Waters Stage 3" (K. Edyvane pers. comm.).

[10] refer to Actions 6, 7 and 8 of the *Strategic Plan of Action for the NRSMPA* (ANZECC TFMPA, 1999).

Wherever possible, data have been collected in a standardised manner, and when national standards exist for the collection of data these have been used[11]. In addition, the sampling strategies were chosen to maximise the results per dollar expended, and to ensure statistical validity. Attention to temporal changes required that in some instances, sampling had to be completed within strict time frames. This was the case for the collection of biological data described in Chapters 4, 5 and 6. In other instances because some of the attributes are effectively time invariant, data can be accumulated from observations spaced over longer time intervals (Chapters 2 and 3). Such circumstances, for example, apply to the lithology of reef substratum types.

1.8 Discussion

Qualitative descriptions of dominant taxa combined with benthic substrata can be used to produce classes that can be mapped at nominal scales up to 1:100,000. This mapping provides the basis for Victoria to map ecosystem components for assessing 'comprehensiveness' in accordance with the NRSMPA. MHC mapping also has the potential to be used for number of functions relating to integrated coastal planning and fisheries management.

The benefit of using MHCs for planning networks of MPAs has been recently investigated by Ward *et al* (1999) in Jervis Bay, NSW. Their findings indicated that MHCs alone could account for approximately 93% of all known taxa surveyed from the Jervis Bay area. This indicates that MHCs, when used as surrogates for representing biodiversity, are potentially highly cost-effective methods for planning and management of marine biodiversity. The use of MHCs derived from biophysical units (termed 'ecounits') has been recently employed in British Columbia as a tool in the establishment of marine reserves based on a representative ecosystems approach (Zacharias and Howes 1998; Zacharias *et al* 1998). MHCs have also been employed recently for ecological assessment of the Great Barrier Reef Marine Park (DeVantier *et al* 1998) and for fisheries assessment in New South Wales (Andrew and O'Neill 2000).

The effectiveness of qualitative approaches to describe marine biodiversity increases considerably when supplemented with information on species abundances and community structure. The systematic collection of such data in Victoria and by other jurisdictions such as Tasmania and New Zealand has proved to be cost efficient, and provided invaluable information for a wide range of conservation issues (Edgar and Barrett 1997; Edgar *et al* 1997; Cole *et al* 1990; MacDiarmid and Breen 1992).

From experience gained in sampling and describing marine biodiversity in Victoria (eg Chapters 2, 4, 5 and 6), and based on informal discussions with experts in Tasmania, South Australia and New South Wales, the following ecological principles related to the distribution of marine biodiversity in Victoria can be summarised within the context of Victoria's IMCRA bioregions:

- Communities in the shallow sub-tidal (0 - 2.5 m) generally differ from those at moderate (2.5 - 20 m) and deeper depths (> 20 m);
- geographically localised conditions, governed primarily by substratum topography / complexity and exposure have the strongest influence on the composition of communities within a given depth range, as described above;

[11] refer to Actions 7, 16 and 19 of the *Strategic Plan of Action for the NRSMPA* (ANZECC TFMPA, 1999).

- dominant vegetation types within geographic areas approximately 10 - 100 km and similar environmental conditions appear to associate with similar suites of smaller, slow moving and sessile species; and
- biogeographical patterns in the distribution of marine species and communities can be distinguished across Victoria.

1.9 References

Allen, T.F.H. and Starr, T.B. (1982). *Hierarchy: perspectives for ecological complexity.* University of Chicago Press, Chicago.

Allen, M.F.M. (1994). *A methodology for mapping and monitoring seagrass in shallow waters using remotely sensed data*. Master of Applied Science Thesis, Royal Melbourne Institute of Technology, Melbourne, Australia. pp.234.

Andrew, N.L. and O'Neill, A.L. (2000). Large-scale patterns in habitat structure on subtidal rocky reefs in New South Wales. *Marine and Freshwater Research* 51: 255-263.

ANZECC TFMPA (1998). *Guidelines for establishing the National Representative System of Marine Protected Areas.* Australia and New Zealand Environment and Conservation Council, Task Force on Marine Protected Areas. Environment Australia, Canberra. pp. 80.
(Available at http://www.environment.gov.au/marine/marine_protected/nrsmpa/main.html)

ANZECC TFMPA (1999). *Strategic Plan of Action for a National Representative System of Marine Protected Areas: A guide for action by Australian Governments.* Australia and New Zealand Environment and Conservation Council, Task Force on Marine Protected Areas. Environment Australia, Canberra. pp. 15.
(Available at http://www.environment.gov.au /marine/marine_protected/nrsmpa/main.html)

ANZECC TFMPA (2000). *National Reserve System of Marine Protected Areas: Strategic Plan of Action. Action 6 – Status of benthic habitat mapping.* Australia and New Zealand Environment and Conservation Council, Task Force on Marine Protected Areas. Environment Australia, Canberra.
(Available at http://www.environment.gov.au /marine/marine_protected/nrsmpa/main.html)

Barnhardt, W.A., Kelley, J.T., Dickson, S.M. and Belknap, D.F. (1998). Mapping the Gulf of Maine with side-scan sonar: A new bottom-type classification for complex seafloor. *Journal of Coastal Research* 14: 646-659.

Bennett, I. and Pope, E.C. (1953). Intertidal zonation of the exposed rocky shore of Victoria, together with a rearrangement of the biogeographic provinces of temperate Australian shores. *Australian Journal of Marine and Freshwater Research* 4: 105-159.

Blake, S., Roob, R., Patterson, E. (2000). *Seagrass: Minor Inlets of Victoria*. Marine and Freshwater Resources Institute Report No. 10, Department of Natural Resources and Environment, Melbourne, Australia. pp. 80.

Boutakoff, N. (1963). *The Geology and Geomorphology of the Portland Area*. Geological Survey of Victoria, Memoir No 22.

Cole R. G., Ayling T. A., Creese R.G. (1990). Effects of marine reserve protection at Goat Island, northern New Zealand. *New Zealand Journal of Marine and Freshwater Research* 24: 197-210.

Coleman, N., Gason, A. and Poore, G. (1997). High species richness in the shallow marine waters of south-east Australia. *Marine Ecology Progress Series* 154: 17-26.

Commonwealth of Australia (1992). *National Strategy for Ecologically Sustainable Development*. Australian Government Publishing Service, Canberra.

Consulting Environmental Engineers, 1992. *Inventory of Victoria's Marine Ecosystems - Stage 1: Review of Information Sources*. Unpublished report to the Department of Conservation and Environment and Land Conservation Council, Melbourne, Australia.

Costello, M.J. (1994). The BioMar (LIFE) project: developing a system for the collection, storage and dissemination of marine data for coastal management. *In*: Hiscock, K. (Ed.). *Classification of benthic marine biotypes of the North-east Atlantic. Proceedings of a BioMar-LIFE Workshop held in Cambridge, 16-18 November 1994*. Joint Nature Conservation Committee, Peterborough. pp. 9-17.

DeVantier, L.M., De'arth, G., Done, T.J., and Turak, E. (1998). Ecological assessment of a complex natural system: a case study from the Great Barrier Reef. *Ecological Applications* 8: 480-496.

Done, T.J. and Reichelt, R.E. (1998). Integrated coastal zone and fisheries ecosystem management: generic goals and performance indices. *Ecological Applications* 8 (Suppl.): s110-118.

Edmunds, M., 1990. *The community ecology of fishes on Tasmanian rocky reefs.* Unpublished Honours Thesis, University of Tasmania, Australia. pp. 67.

Edmunds, M; Roob, R. and Ball, D. (2000). *Victorian Oil Spill Response Atlas – Biological Resources. Macroalgal Communities in Central Victoria*. Report to the Australian Maritime Safety Authority. Australian Marine Ecology Report No. 109, Melbourne, Australia. pp.42.

Edgar G. J. and Barrett N. S. (1997). Short term monitoring of biotic change in Tasmanian marine reserves. *Journal of Experimental Marine Biology and Ecology* 213: 261-279.

Edgar, G., Moverley, J., Barrett, N.S., Peters, D. and Reed, C. (1997). The conservation related benefits of a systematic marine biological sampling programme: The Tasmanian Reef Bioregionalisation as a Case Study. *Biological Conservation* 79: 227-240.

Edinger, E.N. and Risk, M.J. (2000). Reef classification by coral morphology predicts coral reef conservation value. *Biological Conservation* 92: 1-13.

Edyvane, K.S. (1999). *Conserving marine biodiversity in South Australia Part 2 – Identification of areas of high conservation value in South Australia*. South Australian Research and Development Institute, Adelaide. pp.281.

Edyvane, K.S. and Baker, J. (1994). The South Australian Marine Regionalisation Project. *In*: Muldoon, J. (Ed). *Towards a Marine Regionalisation for Australia*. Great Barrier Reef Marine Park Authority: Australia. pp. 121-140.

Environment Conservation Council (1999). *Marine, Coastal and Estuarine Investigation: Draft report for public comment*. Environment Conservation Council, Melbourne, Australia. pp. 140. (Available at http://www.nre.vic.gov.au/ecc/index.htm)

Ferns L.W. (1999a). *Interim marine biophysical regionalisation for the Northern Territory: A bioregional framework for marine conservation in the Northern Territory*. Parks and Wildlife Commission of the Northern Territory, Darwin, Australia.

Ferns. L.W. (Ed.). (1999b). *Environmental Inventory of Victoria's Marine Ecosystems Stage 4 (Part 1) – Physical classification of soft sediment ecosystems*. Parks, Flora and Fauna Division, Department of Natural Resources and Environment, East Melbourne, Australia.

Ferns, L.W. (Ed.). (2000). *Environmental Inventory of Victoria's Marine Ecosystems Stage 4 (Part 2) – Towards the identification of candidate soft benthic marine protected areas.* Parks, Flora and Fauna Division, Department of Natural Resources and Environment, East Melbourne, Australia

Ferns, L.W. and Catlin, J. (1999). *Australian Coastal Atlas: Victorian State Node 1998 /1999 Annual Report*. Parks, Flora and Fauna Division, Department of Natural Resources and Environment, Melbourne, Australia.

Gray, J.S., Poore, G.C.B., Ugland, K.I., Wilson, R.S., Olsgard, F. and Johannessen, Ø. (1998). Coastal and deep-sea benthic diversities compared. *Marine Ecology Progress Series* 159: 97-103.

Greenstreet, S.P.R, Tuck, I.D., Grewar, G.N., Armstrong, E., Reid, D.G. and Wright, P.J. (1997). An assessment of the acoustic survey technique, RoxAnn, as a means of mapping seabed habitat. *ICES Journal of Marine Science* 54: 939-959.

Hamilton, N.T.M. (1994). *Environmental Inventory of Victoria's Marine Ecosystems Stage 2. A physical classification of Bass Strait waters: pattern analysis of selected attributes together with a review of an existing shore-based classification*. Report to the Land Conservation Council and Department of Conservation and Natural Resources, Melbourne, Australia.

Handreck, C.P. and O'Hara, T.D. (1994). *Occurrence of selected species of intertidal and shallow subtidal invertebrates at Victorian locations*. A report by the Marine Research Group of Victoria Incorporated to the Land Conservation Council, Melbourne, Australia. pp. 68.

Harris, G., Bateley, G., Fox, D., Hall, D., Jernakoff, P., Molloy, R., Murray, A., Newell, B., Parslow, J., Skyring, G. and Walker, S. (1996*). Port Phillip Bay Environmental Study Final Report*. CSIRO, Canberra, Australia. pp. 239.

Hayden, B. P., Ray, G.C. and Dolan, R. (1984). Classification of coastal and marine environments. *Environmental Conservation* 11: 199-207.

Interim Marine and Coastal Regionalisation of Australia Technical Group. (1998). *Interim Marine and Coastal Regionalisation for Australia: an ecosystem-based classification for marine and coastal environments. Version 3.3*. Environment Australia, Commonwealth Department of the Environment, Canberra, Australia. pp. 104.
(Available at http://www.environment.gov.au/marine/marine_protected/nrsmpa/main.html)

Mahon, G. (Ed.). (1997). *Development of a Marine and Coastal Geographic Information System for Victoria Stage 2*. Parks, Flora and Fauna Division, Department of Natural Resources and Environment, Melbourne, Australia. pp. 32.

MacDiarmid A. B. and Breen P. A (1992). Spiny lobster population change in a marine reserve. *In*: Battershill, C.N. (Ed.). *Proceedings of the Second International Temperate Reef Symposium in Auckland, New Zealand*. NIWA Marine, Wellington.

Marine and Freshwater Resources Institute (2000). *Victorian Oil Spill Response Atlas*. Compact disc produced for the Victorian Marine Pollution Committee and the Australian Maritime Safety Authority. Department of Natural Resources and Environment, East Melbourne, Australia.

McShane, P.E., Beinssen, K., and Foley, S. (1986*). Abalone Reefs in Victoria - a Resource Atlas*. Marine Science Laboratories Technical Report No. 47, Melbourne, Australia.

Moverley, J. and Jordan, A. (1996). *Biological surveys of inshore soft bottomed communities in Tasmania*. OR2000 Project No OR02. Department of Primary Industries and Fisheries Tasmania, Hobart, Australia. pp. 42.

Mumby, P.J., Green, E.P., Edwards, A.J. and Clark, C.D. (1997). Coral reef habitat mapping: how much detail can remote sensing provide? *Marine Biology* 130: 193-202.

Mumby, P.J., Green, E.P., Clark, C.D. and Edwards, A.J. (1998). Digital analysis of multispectral airborne imagery of coral reefs. *Coral Reefs* 17: 59-69.

Norse, E.A. (Ed.). (1993). *Global marine biological diversity: A strategy for building conservation into decision making*. Island Press, Washing ton DC. pp. 384.

Noss, R. (1990). Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology* 4: 355-364.

Parry, G.D., Campbell, S.J. and Hobday, D.K. (1990). *Marine Resources off East Gippsland, Southeast Australia.* Marine Science Laboratories Technical Report No 72, Melbourne, Australia.

Pasqualini, V., Pergent-Martini, C., Clabaut, P., and Pergent, G. (1998). Mapping of *Posidonia oceanica* using aerial photographs and side scan sonar: application off the Island of Corsica (France). *Estuarine, Coastal and Shelf Science* 47: 359-367.

Porter, C. (1997). *Subtidal reef areas in Victoria's central marine biophysical region: Identification, assessment and documentation of significant sites for nomination to the register of the National Estate*. A report to the Victorian National Parks Association and the Australian Marine Conservation Society – Victorian Branch, Melbourne, Australia. pp. 99.

Ray, G. C., and McCormick-Ray, M. G. (1992). *Marine and estuarine protected areas: A strategy for a national representative system within Australian coastal and marine environments.* Consultancy Report for the Australian National Parks and Wildlife Service. Department of Environmental Sciences, University of Virginia.

Roob, R. and Currie, D. (1996*). Marine and Coastal Special Investigation: Offshore survey of selected areas*. Report to the Land Conservation Council by the Victorian Fisheries Research Institute. Department of Natural Resources and Environment, Melbourne, Australia. pp. 22.

Roob, R. and O'Hara, T. (1996*). Marine and Coastal Special Investigation: Additional offshore survey of selected areas*. Report to the Land Conservation Council by the Marine and Freshwater Resources Institute. Department of Natural Resources and Environment, Melbourne, Australia. pp. 16.

Roob, R. and Ball, D. (1997). *Seagrass: Gippsland Lakes*. Marine and Freshwater Resources Institute Report to Fisheries Victoria, Department of Natural Resources and Environment, Melbourne, Australia. pp. 48.

Roob, R., Lewis, A., Thurlin, S. and Pelikan, M. (1995). *Development of a Marine and Coastal Geographic Information System for Victoria Stage 1*. Department of Conservation and Natural Resources, Melbourne, Australia. pp. 32.

Roob, R, Hough, D., Mahon, G. and Dow, N. (1997). Information products. *In*: G. Mahon (Ed.). *Development of a Marine and Coastal Geographic Information System for Victoria Stage 2*. Parks, Flora and Fauna Division, Department of Natural Resources and Environment, Melbourne, Australia.

Roob, R., Morris, P. and Werner, G. (1998). *Seagrass: Corner Inlet and Nooramunga*. Marine and Freshwater Resources Institute Report No. 10, Department of Natural Resources and Environment, Melbourne, Australia. pp. 59.

Roob, R. Blake, S. and Parry, G. (1999*). Marine and Coastal Special Investigation: Additional offshore survey of selected areas*. Report to the Environment Conservation Council by the Marine and Freshwater Resources Institute. Department of Natural Resources and Environment, Melbourne, Australia.

Southeran, I.S., Foster-Smith, R.L. and Davies, J. (1997). Mapping of marine benthic habitats using image processing techniques within a raster-based geographic information system. *Estuarine, Coastal and Shelf Science* 44 (Suppl. A): 25-31.

Swan, J.M., Neff, J.M. and Young, P.C. (1994*). Environmental Implications of Offshore Oil and Gas Development in Australia*. Australian Petroleum Exploration Association.

TFMPA (1999). *Understanding and applying the principles of comprehensiveness, adequacy and representativeness for the NRSMPA, Version 3.1.* Report prepared by the Action Team for the ANZECC Task Force on Marine Protected Areas. Marine Group, Environment Australia, Canberra. (Available at http://www.environment.gov.au/marine/marine_protected/nrsmpa/main.html)

Tsernjavski, N. (1995). *Marine and coastal sites of significance in Victoria. Nomination form and guidelines for listing marine and coastal areas to the National Estate Register*. A report by the Victorian National Parks Association to the Australian Heritage Commission, Melbourne, Australia. pp. 113.

Underwood, A.J. and Petritis, P.S. (1993). Structure of intertidal assemblages in different locations: how can local processes be compared? *In*: Ricklefs, R.E. and Schluter, D. (Eds.). *Species diversity in Ecological communities: historical and geographical perspectives*. University of Chicago Press, Chicago. pp. 39-51.

Victorian Institute of Marine Sciences, Consulting Environmental Engineers, Dames and Moore, and Museum of Victoria. (1994). *Environmental Inventory of Victoria's Marine Ecosystems Stage 1: Biophysical classification*. Unpublished report to the Land Conservation Council and the Department of Natural Resources and Environment, Melbourne, Australia.

Ward, T.J., Vanderklift, M.A., Nicholls, A.O. and Kenchington, R.A. (1999). Selecting marine reserves using habitats and species assemblages as surrogates for biological diversity. *Ecological Applications* 9: 691-698.

Williams, I. M., and Leach, J. H. J. (1997). Along Track Video for Ocean Data Sampling - Problems and Possible Solutions. *Ocean Data Symposium*, Dublin, Ireland, Paper pw4a.
Williams, I. M., and Leach, J. H. J. (1999). The relationship between depth, substrate and ecology: a drop video study from the southeastern Australian coast. *Oceanologica Acta*, 22: 651-662.

Williams, I. M., and Leach, J. H. J. (2000). Video remote sensing for seafloor mapping. *10th Australasian Remote Sensing and Photogrammetry Conference*, The Remote Sensing and Photogrammetry Association, Adelaide, August 21-25. CD volume, paper 52. pp.14.

Wilson, R.S., Poore, G.C.B. and Gomon, M.F. (1990). *Marine Habitats at Wilsons Promontory and the Bunurong Coast, Victoria: Report on a Survey, 1982.* Marine Science Laboratories. Technical Report No 73, Melbourne, Australia.

Zacharias, M.A. and Howes, D.E. (1998). An analysis of marine protected areas in British Columbia, Canada, using a marine ecological classification. *Natural Areas Journal* 18: 4-13.

Zacharias, M.A. and Howes, D.E., Harper, J.R. and Wainwright, P. (1998). The British Columbia marine ecosystem classification: rationale, development and verification. *Coastal Management* 26: 105-124.

Zacharias, M.A. and Roff, J.C. (2000). A hierarchical ecological approach to conserving marine biodiversity. *Conservation Biology* 14: 1-8.

1.10 Appendix 1.1

Summary of Marine Habitat Mapping Projects in Victoria (1994 – 2000)

	MAPPING RELATED TO THE DEVELOPMENT OF BIOREGIONS FOR VICTORIA **1:1 million**	**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	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 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	Initial list of key marine environmental datasets were 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 using multivariate analysis using the 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 incorporated in 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. (NB: 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. (NB: 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 hydroacoustic 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	***For the Open Coast*** Further refinement of spatial boundaries for open coast areas using combined side-scan sonar and EcholLstener 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 transects.	***For Bays and Inlets*** Aerial photo interpretation to produce spatial boundaries, mainly depicting macrophyte beds and major substratum attributes. Semi quantitative data on macrophytes. Visual transects using glass observation pod on base of survey vessel. Also video transects using towable camera.
Scale(s)	Nominal scale of 1:1million	Nominal scale of 1:100,000	Nominal scale of 1:100,000	Nominal scale of 1:25,000	Nominal scale of 1:25,000
Data Sources	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.
Level of Ground Truthing	Regions derived through modelling and expert opinion. Bioregionalisation provides an initial framework for delineating broad 'homogeneous' marine regions.	Bounce dives and video variable, depending on heterogeneity of local area (in total 467 observations made to date) Broad-scale systematic sampling of soft sediments involved 46 transects, 20 km apart. Replicate samples taken at 10m, 20m and 40m water depths (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 boundaries accurate 30m. Attribute accuracy derived from remote sensing interpretation generally 80% accurate.	DGPS employed throughout surveying. Polygon boundary accuracy 30m Polygons generated using interpolation of transect data combined with LandSat TM polygons. Attribute accuracy derived from remote sensing interpretation generally 80% accurate.	DGPS employed throughout surveying. Polygon boundaries accuracy 20m. Attribute accuracy derived from remote sensing interpretation generally 80% accurate.	DGPS employed throughout surveying. Polygon boundaries accurate within 5-10m. Attribute accuracy derived from remote sensing interpretation generally 80% accurate.
GIS or Other data and key references	Available on NRE Marine and Coastal Corporate Geospatial Data Library and Australian Coastal Atlas. Roob *et al* (1995) Mahon (1997) Ferns and Catlin (1999)	Available on NRE Marine and Coastal Corporate Geospatial Data Library and Australian Coastal Atlas. Roob *et al* (1995) Mahon (1997) Ferns and Catlin (1999)	Available on NRE Marine and Coastal Corporate Geospatial Data Library and Australian Coastal Atlas. Roob *et al* (1995) Mahon (1997) Ferns and Catlin (1999)	Soon to be available on NRE Marine and Coastal Corporate Geospatial Data Library and Australian Coastal Atlas. Roob *et al* (1995) Mahon (1997) Ferns and Catlin (1999)	Available on NRE Marine and Coastal Corporate Geospatial Data Library and Australian Coastal Atlas. Roob *et al* (1995) Mahon (1997) Ferns and Catlin (1999)
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	Inverloch	All major bays, inlets and estuaries across Victoria (Port Phillip Bay to be completed early 2001).
Key References	Consulting Environmental Engineers (1992) Hamilton (1994) Victorian Institute of Marine Sciences *et al* 1994	Ferns (1999) Ferns (2000) Ferns and Hough (this report)	Roob and Currie (1996) Roob and O'Hara (1996) Roob *et al* (1999)	In preperation.	Roob and Ball (1997) Roob *et al* (1998) Blake *et al* (2000)

1.11 Appendix 1.2

Descriptions of Selected Attributes Used for Mapping Marine Habitat Classes

Substratum relief descriptions

- Low profile reef = flat reef (such as rock platforms) with relief predominantly < 1 m.
- High profile reef = rugose reef with relief predominantly ≥1 m.
- Flat = surface predominantly smooth without noticeable rises or depressions.
- Ripples = obvious rises up to 0.3 m in height.
- Gently undulating ridges = rises > 0.3 m in height, gradually sloping between successive troughs and rises.
- Steeply undulating ridges = rises > 0.3 m in height, steeply sloping between successive troughs and rises
- Gutters = gutter-like depressions or chutes between rock facies, often filled with sediment.

Substratum texture descriptions

- Solid = solid rock, not obviously broken into fragments.
- Broken (Boulders / Slabs / Bommies) = rock fragments >30 cm diameter or expanses of broken reef termed 'slabs' or 'bommies'.
- Gutters = gutter-like depressions or chutes in and between rock beds, often filled with sediment.
- Outcrops = protruding rock extensions, often found on edges of reef terraces.
- Larger material (Cobble/ Pebble/Granules) = 2mm – 30 cm diameter
- Coarse / very coarse sand = 0.5 mm – 2 mm diameter.
- Medium sand = 0.25 mm – 0.5 mm diameter.
- Very Fine / fine sand = 0.25 mm – 0.063 mm diameter.
- Mud / silt = < 0.063 mm diameter.
- Muddy sand = mixture of sand and mud.
- Shelly rubble / grit = sediment composed of shelly debris.

Selected dominant biota descriptions

- *Durvillaea* = *Durvillaea potatorum* forms a dense fringe just beyond the intertidal zone on exposed coasts across Victoria. *Durvillaea* can occur in lower depths (to 15 m) at very exposed locations.
- *Phyllospora*/ *Ecklonia* = The large brown algae *Phyllospora comosa* and *Ecklonia radiata* form canopies in many exposed open coast localities across Victoria (2-15 m depth). Both algae usually co-occur, however, *Phyllospora* can form single stands at shallow depths (5 m), and *Ecklonia* can dominate in slightly deeper water (10 m), particularly in far east Gippsland. Other larger algae present include *Cystophora platylobium* and *Seirococcus axillaris*. The understorey consists of red algae and sessile invertebrates.
- *Macrocystis* = *Macrocystis angustifolia* forms canopies in isolated patches across Victoria from the far west to Wilsons promontory (and possible to Cape Conran). *Macrocystis* was not covered in Part 2 of this inventory report as it occurred infrequently. Consequently there is no data to determine whether the communities in *Macrocystis* beds differ from those elsewhere. Nevertheless there is evidence from Tasmania that fish communities differ in *Macrocystis* beds (eg Edmunds, 1990).
- Mixed algae = A mixed algal community exists in shallow waters (1-5 m) on sheltered to moderately exposed coasts. This community extends sub-tidally on some coasts (eg Bunurong) to 15 m. No one algal species dominates. Species include brown algae (eg. Cys*tophora* spp, *Sargassum* spp, *Acrocarpia paniculata*, *Zonaria* spp, *Ecklonia radiata*), green algae (*Caulerpa* spp, *Codium* spp), and red algae (eg. *Sonderopelta coriacea*, *Plocamium* spp, *Phacelocarpus peperocarpos*, various coralline algae).
- Urchin "barrens" = The urchin *Centrostephanus rodgersii* forms large "barrens" in far east Gippsland. These barrens can cover several hundred square metres. Vegetation in these areas is restricted to crustose coralline algae. The common sea-urchin *Heliocidaris erythrogramma* rarely forms large barrens.
- Red algae = Red algae can dominate reefs when they are ephemeral (eg periodically covered by shifting sand) or in poor light (ie deep reefs or in turbid waters).
- *Amphibolis* = *Amphibolis antarctica* can form large beds, in sandy areas or on flat low profile reefs, in shallow water (1-7 m), on sheltered to moderately exposed coasts. It is common in small bays on the open coast or on the sheltered side of inshore reefs. *Amphibolis* beds can contain some large brown algae (eg *Cystophora*) if there are exposed patches of rock or stones. *Amphibolis* extends from western Victoria to the eastern side of Wilsons Promontory.
- *Caulerpa* = *Caulerpa* species can form large patches in shallow water (1-5 m) in sandy areas adjacent to rocky reefs or in sheltere bays (eg Westernport). Common patch-forming species include *C. brownii* and *C. cactoides*. *Caulerpa* beds often merge with adjacent seagrass beds.
- *Heterozostera* = *Heterozostera tasmanica* covers patches of sand in sheltered bays, and occasionally on the open coast, in shallow water (1 - 10 m).
- *Posidonia* = *Posidonia australis* forms large beds in Corner Inlet and in small isolated patches elsewhere (Barwon Heads and Great Glennie Island).
- Sessile invertebrates = Sessile invertebrates dominate reefs in poor light (eg in turbid or deep water). These invertebrates include sponges, bryozoans and cnidarians (gorgonians, antipatharians, hydroids) etc. Future studies may show that this habitat is heterogeneric and requires subdivision.