Victorian Subtidal Reef Monitoring Program: The Reef Biota at Beware Reef Marine Sanctuary

M. Edmunds, K. Pritchard and S. Davis

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EXECUTIVE SUMMARY

Shallow reef habitats cover extensive areas along the Victorian coast and are dominated by seaweeds, mobile invertebrates and fishes. These reefs are known for their high biological complexity, species diversity and productivity. They also have significant economic value through commercial and recreational fishing, diving and other tourism activities. To effectively manage and conserve these important and biologically rich habitats, the Victorian Government has established a long-term Subtidal Reef Monitoring Program (SRMP). Over time the SRMP will provide information on the status of Victorian reef flora and fauna and determine the nature and magnitude of trends in species populations and species diversity through time. The SRMP is established throughout Victoria. This report describes the monitoring of the Beware Reef Marine Sanctuary and reference sites, involving four surveys from 2004 to 2011.

The monitoring involves standardised underwater visual census methods to a depth of 10 m. This report aims to provide:

- a general description of the biological communities and species populations at each monitoring site and any changes over the monitoring period; and
- an identification of any unusual biological phenomena, interesting communities, strong temporal trends and/or the presence of any introduced species.

The surveys were done along a 200 m transect line. Each transect was surveyed for:

- abundance and size structure of large fishes;
- abundance of cryptic fishes and benthic invertebrates;
- percentage cover of macroalgae; and
- density of a dominant kelp *Macrocystis pyrifera*.

Beware Reef is a unique pinnacle environment and includes features such as a seal haul out, stands of bull kelp *Durvillaea potatorum* and aggregations of butterfly perch *Caesioperca lepidoptera*. The reference site at Pearl Point did not have bull kelp habitat, but had a very high density of filter feeders, which is consistent with nutrient-rich upwellings occurring in the region. Key observations during the monitoring program were:

- Small decline in common kelp *Ecklonia radiata* at both sites to 2011.
- An increase in abundance of bull kelp *Durvillaea potatorum* between 2006 and 2009.
- No significant trends in algal diversity.
- Algal species richness had an increasing trend at both sites.
• Very high abundances of filter-feeding feather stars *Comanthus trichoptera*, with much higher abundances occurring at Pearl Point – there was a peak in 2009.

• Abundances of abalone *Haliotis rubra* and sea urchins *Heliocidaris erythrogramma* and *Centrostephanus rodgersii* were moderately high at both sites – there was a decline in abundance at Beware Reef between 2006 and 2009.

• Abalone sizes were considerably larger within the Beware Reef Marine Sanctuary.

• Butterfly perch *Caesioperca rasor* were sporadically present in high abundances at Beware Reef.

• Abundances of banded morwong *Cheilodactylus spectabilis* declined at Beware Reef between 2004 and 2011 while the abundance of purple wrasse *Notolabrus fucicola* increased at both sites.

• There were no marked changes in the ecological indicators, however it is noted that the time series is still short to properly assess these yet.
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1. INTRODUCTION

1.1. Subtidal Reefs of the Twofold Shelf Bioregion

The Twofold Shelf Bioregion extends from east of Wilsons Promontory to Tathra in southern New South Wales. The western portion of the Twofold Shelf Bioregion is largely comprised of long sandy beaches (Ninety Mile Beach) with extensive areas of inshore and offshore sandy beds with some small offshore reefs. The sandy habitats of the far eastern coastline are punctuated by rocky headlands and localised outcrops of granite and metamorphic rocks, such as at Cape Conran, Point Hicks, Rame Head, Gabo Island and Iron Prince at Cape Howe. Sea temperatures are warmer in the Twofold Shelf region compared to elsewhere in Victoria because of incursions of the East Australia current bringing warmer water down the east coast of the continent. The continental slope is quite close to the far eastern Victorian shore and cold-water upwellings are frequent. These upwellings provide nutrients to the inshore ecosystems, contributing to high productivity. The biota of this region has a high component of eastern temperate species, in addition to many southern temperate and cosmopolitan species.

A prominent biological component of all Victorian shallow reefs is kelps and other seaweeds (Figure 1.1). Large species of brown algae, such as the common kelp *Ecklonia radiata* and crayweed *Phyllospora comosa*, are usually present along the open coast in dense stands. The production rates of dense seaweed beds are equivalent to the most productive habitats in the world, including seagrass beds and terrestrial grasslands, with approximately 2 kg of plant material produced per square metre per year. These stands may have 10-30 kg of plant material per square metre. The biomass of seaweeds is greater where giant species such as string kelp *Macrocystis pyrifera* and bull kelp *Durvillaea potatorum* occur.

Seaweeds provide important habitat structure for other organisms on the reef. This habitat structure varies considerably, depending on the type of seaweed species present. Tall vertical structures in the water column are formed by *Macrocystis pyrifera*, which sometimes forms a dense layer of fronds floating on the water surface. Other species with large, stalk-like stipes, such as *Ecklonia radiata*, *Phyllospora comosa* and *Durvillaea potatorum*, form a canopy 0.5-2 m above the rocky substratum. Lower layers of structure are formed by foliose macroalgae typically 10-30 cm high, such as the green *Caulerpa* and red *Plocamium* species; turfs (to 10 cm high) of red algae species, such as *Pterocladia capillacea*; and hard encrusting layers of pink coralline algae. The nature and composition of seaweed structural layers varies considerably within and between reefs, depending on the biogeographical region, depth, exposure to swell and waves, currents, temperature range, water clarity and presence of sand.
Grazing and predatory mobile invertebrates are prominent animal inhabitants of the reef (Figure 1.2). An important invertebrate of the eastern Twofold Shelf Bioregion is the long-spined sea urchin _Centrostephanus rodgersii_. _Centrostephanus rodgersii_ forms large grazing aggregations which denude the reef of erect algal species, forming ‘urchin barrens’. Removal of large seaweeds by _C. rodgersii_ causes substantial changes to subtidal reef community structure on reefs in eastern temperate Australia.

Other common invertebrate grazers found at Twofold Shelf reefs include blacklip abalone _Haliotis rubra_, the eastern temperate gastropod _Astralium tentoriformis_, warrener _Turbo undulatus_ and sea urchin _Heliocidaris erythrogramma_. Predatory invertebrates include dogwhelks _Dicathais orbita_, eastern rock lobster _Jasus verreauxi_, octopus _Octopus maorum_ and a wide variety of seastar species. Other large reef invertebrates include mobile filter feeding animals such as feather stars _Comanthus trichoptera_ and sessile (attached) species such as sponges, corals, bryozoans, hydroids and ascidians.

Fish are also a dominant component of reef ecosystems, in terms of both biomass and ecological function (Figure 1.3). Reef fish assemblages include roaming predators such as blue-throated wrasse _Notolabrus tetricus_, herbivores such as herring cale _Olisthops cyanomelas_, planktivores such as sea sweep _Scorpis aequipinnis_ and picker-feeders such as six-spined leatherjacket _Meuschenia freycineti_. The type and abundance of each fish species varies considerably, depending on exposure to swell and waves, depth, currents, reef structure, seaweed habitat structure and many other ecological variables. Many fish species play a substantial ecological role in the functioning and shaping of the ecosystem. For example, the eastern blue groper _Achoerodus viridis_ is an important predator of _C. rodgersii_ and has a role in limiting the distribution of sea urchin barrens.

Although shallow reef ecosystems in Victoria are dominated by seaweeds, mobile invertebrates and fishes, in terms of biomass and production, there are many other important biological components to the reef ecosystem. These include small species of crustaceans and molluscs from 0.1 to 10 mm in size, occupying various niches as grazers, predators or foragers. At the microscopic level, films of microalgae and bacteria on the reef surface are also very important.

Victoria’s shallow reefs are a very important component of the marine environment because of their high biological complexity, species diversity and productivity. Subtidal reef habitats also have important social and cultural values, which incorporate aesthetic, recreational, commercial and historical aspects. Shallow subtidal reefs also have significant economic value, through commercial fishing of reef species such as wrasses, morwong, rock lobster, abalone and sea urchins, as well as recreational fishing, diving and other tourism activities.
Coralline algae *Amphiroa anceps*

Peacock weed *Lobophora variegata*

Soft coral *Capnella gaboensis*

Mixed red and brown algae

Green alga *Caulerpa trifaria*

Urchin barren with coralline algae and limpets

**Figure 1.1.** Examples of macroalgae, corals and community types in the Twofold Shelf Bioregion.
Figure 1.2. Examples of reef invertebrate species present in the Twofold Shelf Bioregion.
Six-spined leatherjacket *Meuschenia freycineti*.

White-ear *Parma microlepis*.

Maori wrasse, *Ophthalmocephalus lineolatus* (front) and blue-throated wrasse, *Notolabrus tetricus* (rear).

Purple wrasse *Notolabrus fucicola* and banded morwong, *Cheilodactylus spectabilis*.

Eastern hulafish *Trachinops taeniatus*.

Trevally *Pseudocaranx georgianus*.

**Figure 1.3.** Examples of reef fish species in the Twofold Shelf Bioregion.
1.2. Subtidal Reef Monitoring Program

1.2.1. Objectives

An important aspect of the management and conservation of Victorian marine natural resources and assets is assessing the condition of the ecosystem and how this changes over time. Combined with an understanding of ecosystem processes, this information can be used to manage any threats or pressures on the environment to ensure ecosystem sustainability.

Consequently, the Victorian Government has established a long-term Subtidal Reef Monitoring Program (SRMP). The primary objective of the SRMP is to provide information on the status of Victorian reef flora and fauna (focussing on macroalgae, macroinvertebrates and fish). This includes monitoring the nature and magnitude of trends in species abundances, species diversity and community structure. This is achieved through regular surveys at locations throughout Victoria, encompassing both representative and unique habitats and communities.

Information from the SRMP allows managers to better understand and interpret long-term changes in the population and community dynamics of Victoria’s reef flora and fauna. As a longer time series of data are collected, the SRMP will allow managers to:

- compare changes in the status of species populations and biological communities between highly protected marine national parks and marine sanctuaries and other Victorian reef areas (e.g. Edgar and Barrett 1997, 1999);
- determine associations between species and between species and environmental parameters (e.g. depth, exposure, reef topography) and assess how these associations vary through space and time (e.g. Edgar et al. 1997; Dayton et al. 1998; Edmunds, Roob and Ferns 2000);
- provide benchmarks for assessing the effectiveness of management actions, in accordance with international best practice for quality environmental management systems (Holling 1978; Meredith 1997) and
- determine the responses of species and communities to unforeseen and unpredictable events such as marine pest invasions, mass mortality events, oil spills, severe storm events and climate change (e.g. Ebeling et al. 1985; Edgar 1998; Roob et al. 2000; Sweatman et al. 2003).

A monitoring survey gives an estimate of population abundance and community structure at a small window in time. Patterns seen in data from periodic surveys are unlikely to exactly match changes in the real populations over time or definitively predict the size and nature of future variation. Plots of changes over time are unlikely to match the changes in real populations because changes over shorter time periods and actual minima and maxima may
not be adequately sampled (e.g. Figure 1.2). Furthermore, because the nature and magnitude of environmental variation is different over different time scales, variation over long periods may not be adequately predicted from shorter-term data. Sources of environmental variation can operate at the scale of months (e.g. seasonal variation, harvesting), years (e.g. El Niño), decades (e.g. pollution, extreme storm events) or even centuries (e.g. tsunamis, global warming). Other studies indicate this monitoring program will begin to adequately reflect average trends and patterns as the surveys continue over longer periods (multiple years to decades). Results of this monitoring need to be interpreted within the context of the monitoring frequency and duration.

**Figure 1.4.** An example plot depicting change in an environmental, population or community variable over time (days, months or years) and potential patterns from isolated observations.
1.2.2. Monitoring Protocols and Locations

The SRMP uses standardised underwater visual census methods based on an approach developed and applied in Tasmania by Edgar and Barrett (1997). Details of standard operational procedures and quality control protocols for Victoria’s SRMP are described in Edmunds and Hart (2003).

The SRMP was initiated in May 1998 with 15 sites established on subtidal reef habitats in the vicinity of Port Phillip Heads Marine National Park. In 1999 the SRMP was expanded to reefs in the vicinity of the Bunurong Marine National Park, Phillip Island and Wilsons Promontory Marine National Park.

In 2003 and 2004, the SRMP was expanded to include Marine National Parks and Marine Sanctuaries throughout Victoria.

1.3. Monitoring at Beware Reef

This report provides a description of the monitoring program at Beware Reef Marine Sanctuary and the reference site at Pearl Point. The objectives of this report were to:

1. provide an overview of the methods used for SRMP;
2. provide general descriptions of the biological communities and species populations at each monitoring site up to October 2011;
3. describe changes and trends that have occurred over the monitoring period;
4. identify any unusual biological phenomena such as interesting or unique communities or species;
5. identify any introduced species at the monitoring locations; and
6. report on trends in selected ecosystem status indicators.
2. METHODS

2.1. Sites and Survey Times

One site was located inside the Beware Reef Marine Sanctuary and one site outside the marine sanctuary at Pearl Point (Figure 2.1; Table 2.1). Beware Reef Marine Sanctuary is a small isolated reef located approximately 4 km offshore from Cape Conran. The central position of the Beware Reef monitoring site (Site 23) is located on the eastern side of an emergent rock, with two transects along the northern side of the island and two transects along the southern side (forming a ‘v’). The transects are positioned along the 8 m isobath over small gullies and flats. The reef profile in the shallower water consists of small gullies, slopes and flats down to the ten meter isobath, where the reef generally drops off steeply into deeper water.

A reference monitoring site was located at Pearl Point (Figure 2.1). The habitat structure at Pearl Point was similar to Müller’s Reef and Petrel Point, consisting of ridges of reef 1-2 m high with gullies in between. The Pearl Point monitoring site is at 7-8 m depth.

Survey times are provided in Table 2.2.

Figure 2.1. Location of monitoring sites in the Beware Reef region. The Beware Reef Marine Sanctuary is highlighted in blue.
**Table 2.1.** Subtidal reef monitoring sites at Beware Reef.

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Site Name</th>
<th>MPA/Reference</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>Beware Reef</td>
<td>MPA</td>
<td>10</td>
</tr>
<tr>
<td>24</td>
<td>Pearl Point</td>
<td>Reference</td>
<td>8</td>
</tr>
</tbody>
</table>

**Table 2.2.** Survey times for monitoring at Beware Reef.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Season</th>
<th>Survey Period</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Autumn</td>
<td>March 2004</td>
</tr>
<tr>
<td>2</td>
<td>Summer</td>
<td>February 2006</td>
</tr>
<tr>
<td>3</td>
<td>Autumn</td>
<td>March 2009</td>
</tr>
<tr>
<td>4</td>
<td>Spring</td>
<td>October 2011</td>
</tr>
</tbody>
</table>
2.2. Census Method

2.2.1. Underwater Visual Census Approach

The visual census methods of Edgar and Barrett (1997, 1999; Edgar et al. 1997) are used for this monitoring program. These are non-destructive and provide quantitative data on a large number of species and the structure of the reef communities. The Edgar-Barrett method is also used in Tasmania, New South Wales, South Australia and Western Australia. The adoption of this method in Victoria provides a systematic and comparable approach to monitoring reefs in southern Australia. The survey methods include practical and safety considerations for scientific divers and are designed to maximise the data returns per diver time underwater. The surveys in Victoria are in accordance with a standard operational procedure to ensure long-term integrity and quality of the data (Edmunds and Hart 2003).

At most monitoring locations in Victoria, surveying along the 5 m depth contour is considered optimal because diving times are not limited by decompression schedules and these reefs are of interest to natural resource managers. However the actual area that can be surveyed varies with reef extent, geomorphology and exposure. The monitoring sites in the Beware Reef region are positioned on the 8-10 metre isobath.

2.2.2. Transect Layout

Each site was located using differential GPS and marked with a buoy or the boat anchor. A 100 m numbered and weighted transect line was run along the appropriate depth contour either side of the central marker (Figure 2.2). The 200 m transect line was divided into four contiguous 50 m sections (T1 to T4). The orientation of transect was the same for each survey, with T1 generally toward the north or east (i.e. anticlockwise along the open coast).

For each transect line, four different census methods were used to obtain adequate descriptive information on reef communities at different spatial scales. These involved the census of: (1) the abundance and size structure of large fishes; (2) the abundance of cryptic fishes and benthic invertebrates; (3) the percent cover of macrophytes; and (4) the density of string-kelp *Macrocystis pyrifera* plants (where present). In 2010, a new diver-operated stereo video method (Method 5) was implemented as a trial to assess its efficacy for monitoring fish diversity, abundances and sizes. The stereo video system enables precise measurements of fish lengths and sample volume or area for density estimates (Harvey et al. 2001a, 2001b, 2002a, 2002b; Harmen et al. 2003; Westera et al. 2003; Watson et al. 2010).

The depth, horizontal visibility, sea state and cloud cover were recorded for each site. Horizontal visibility was gauged by the distance along the transect line to detect a 100 mm long female blue-throated wrasse. All field observations were recorded on underwater paper.
2.2.3. Method 1 – Mobile Fishes and Cephalopods
The densities of mobile large fishes and cephalopods were estimated by a diver swimming up one side of each of a 50 m section of the transect, and then back along the other side. The dominant fish species observed are listed in Table 2.3. The diver recorded the number and estimated size-class of fish, within 5 m of each side of the line (50 x 10 m area). The following size-classes of fish were used: 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 375, 400, 500, 625, 750, 875 and 1000+ mm. Each diver had size-marks on an underwater slate to enable calibration of their size estimates. Four 10 x 50 m sections of the 200 m transect were censused for mobile fish at each site. The data for easily sexed species were recorded separately for males and female/juveniles. Such species include the blue-throated wrasse *Notolabrus tetricus*, herring cale *Olisthops cyanomelas*, barber perch *Caesioperca rasor*, rosy wrasse *Pseudolabrus rubicundus* and some leatherjackets. The dominant observed species are listed in Table 2.3.

2.2.4. Method 2 – Invertebrates and Cryptic Fishes
Cryptic fishes and large mobile invertebrates (e.g. large molluscs, echinoderms, crustaceans) were counted along the transect lines used for the fish survey. A diver counted animals within 1 m of one side of the line (a total of four 1 x 50 m sections of the 200 m transect). A known arm span of the diver was used to standardise the 1 m distance. The dominant observed species are listed in Table 2.4. Where possible, the maximum length of abalone and the carapace length of rock lobsters were measured in situ using Vernier
callipers and the sex of rock lobsters was recorded. Selected specimens were photographed or collected for identification and preservation in a reference collection.

2.2.5. Method 3 – Macrophytes
The area covered by macrophyte species was quantified by placing a 0.25 m$^2$ quadrat at 10 m intervals along the transect line and determining the percent cover of all macrophyte species (Figure 2.3). The quadrat was divided into a grid of 7 x 7 perpendicular wires, with 49 wire intersections and one quadrat corner making up 50 points. Cover is estimated by counting the number of points covering a species (1.25 m$^2$ every 10 m along a 200 m transect line). The dominant observed seaweed species are listed in Table 2.5. Selected specimens were photographed or collected for identification and preservation in a reference collection.

2.2.6. Method 4 – Macrocystis
Where present, the density of string kelp *Macrocystis pyrifera* was estimated. While swimming along the transect line between quadrat positions for Method 3, a diver counted all observable *M. pyrifera* 5 m either side of the transect. Counts are recorded for each 10 m section of the transect, giving counts for 100 m$^2$ sections of the transect.

![Figure 2.3. The cover of macrophytes is measured by the number of points intersecting each species on the quadrat grid.](image-url)
2.2.7. Method 5 – Fish Stereo Video

A diver operated stereo video system (DOVS; SeaGIS design) was used to supplement the diver UVC fish surveys. The videos were Canon HG21 handycams recording to SD card in 1080p format. The cameras were calibrated in a pool before and after the excursion using a SeaGIS calibration cube and SeaGIS CAL software for calibration of internal and external camera parameters. The cameras were mounted permanently to a diver frame. A flashing LED mounted on a pole in front of both frames was used for synchronisation of paired images from each camera.

The stereo camera system was operated by the diver who did the UVC fish survey at the same time (Method 1). The stereo camera frame had the underwater UVC slate mounted on it for the simultaneous observations. The camera system was pointed parallel with the transect line with the diver swimming 2.5 m to one side of the transect and then returning on the other side of the transect, 2.5 m from the transect line. The camera unit was tilted vertically (up or down) according to the fish seen to ensure adequate footage for size measurements. Lateral movement of the unit was minimised. The survey speed was 10 m per minute (0.16 m s\(^{-1}\)).

In the laboratory, the stereo video footage was converted from MTS to AVI format. The SeaGIS EventMeasure and PhotoMeasure software were then used for extracting and recording fish density and fish length estimates from the stereo video footage. Measured fish were those without body flexure and orientated transverse to the camera, as well as with the measurement points visible. Standard lengths (SL) were measured (tip of snout to end of caudal fin ray). The original video footage and frames used for fish length measurements were archived. The results of this method were archived for future analysis and were not reported here.
Table 2.3. Mobile fish (Method 1) taxa censused in the Twofold Shelf Bioregion.

<table>
<thead>
<tr>
<th>Method 1</th>
<th>Mobile Bony Fishes</th>
<th>Mobile Bony Fishes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cephalopoda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Octopus maorum</td>
<td>Upeneichthys lineatus</td>
<td>Dotalabrus aurantiacus</td>
</tr>
<tr>
<td></td>
<td>Upeneichthys vlaminghii</td>
<td>Eupetrichthys angustipes</td>
</tr>
<tr>
<td>Sharks and Rays</td>
<td>Pempheris multiradiata</td>
<td>Notolabrus gymnogenis</td>
</tr>
<tr>
<td>Heterodontus portusjacksoni</td>
<td>Kyphosus sydneyanus</td>
<td>Notolabrus tetricus</td>
</tr>
<tr>
<td>Parascyllium ferrugineum</td>
<td>Girella tricuspidata</td>
<td>Notolabrus fucicola</td>
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<td>Cephaloscyllium laticeps</td>
<td>Girella elevata</td>
<td>Pseudolabrus rubicundus</td>
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<td>Orectolobus maculatus</td>
<td>Girella zebra</td>
<td>Pseudolabrus luculentus</td>
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<td>Dasyatis brevicaudata</td>
<td>Scorpius aequipes</td>
<td>Pictilabrus laticlavius</td>
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<td>Myliobatis australis</td>
<td>Scorpius lineolata</td>
<td>Olisthops acropitus</td>
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<tr>
<td>Urolophus cruciatus</td>
<td>Atypichthys strigatus</td>
<td>Odax cyanomelas</td>
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<td>Urolophus paucimaculatus</td>
<td>Enoplosus armatus</td>
<td>Neodax balteatus</td>
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<td>Trygonoptera testacea</td>
<td>Pentaceropsis recurvirostris</td>
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</tr>
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<td></td>
<td>Parma victoriae</td>
<td>Cristiceps australis</td>
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<td>Mobile Bony Fishes</td>
<td>Parma microlepis</td>
<td>Acantholuteres vittiger</td>
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<td>Scorpaena papillosa</td>
<td>Chromis hypsilepis</td>
<td>Meuschenia australis</td>
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<td>Caesioperca lepidoptera</td>
<td>Chironemus marmoratus</td>
<td>Meuschenia flavolineata</td>
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<td>Caesioperca rason</td>
<td>Aplodactylus lophodon</td>
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<td>Meuschenia hippocrepis</td>
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<td>Trachinops taeniatus</td>
<td>Cheilodactylus nigripes</td>
<td>Eubalichthys bucephalus</td>
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<td>Dinolestes lewini</td>
<td>Cheilodactylus spectabilis</td>
<td>Eubalichthys mosaicus</td>
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<td>Pseudocaranx georgianus</td>
<td>Nemadactylus douglasii</td>
<td>Contusus brevicaudus</td>
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<td>Trachurus novaezelandiae</td>
<td>Dactylophora nigricans</td>
<td>Tectactenos glaber</td>
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<td>Trachurus declivis</td>
<td>Latridopsis forsteri</td>
<td>Diodon nichthermerus</td>
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<tr>
<td>Arripis georgianus</td>
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<tr>
<td>Arripis spp.</td>
<td>Achoerodus viridis</td>
<td>Mammals</td>
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<tr>
<td>Parequula melbournensis</td>
<td>Ophthalmolepis lineolata</td>
<td>Arctocephalus pusillus</td>
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<td>Pagrus auratus</td>
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15
Table 2.4. Invertebrate and cryptic fish (Method 2) taxa censused in Twofold Shelf Bioregion.

<table>
<thead>
<tr>
<th>Method 2</th>
<th>Crustacea</th>
<th>Cryptic Fishes</th>
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<tbody>
<tr>
<td><strong>Polychaete Worms</strong></td>
<td><strong>Crustacea</strong></td>
<td><strong>Cryptic Fishes</strong></td>
</tr>
<tr>
<td>Sabellastarte australiensis</td>
<td>Jasus edwardsii</td>
<td>Cephaloscyllium laticeps</td>
</tr>
<tr>
<td></td>
<td>Jasus verreauxi</td>
<td>Orectolobus maculatus</td>
</tr>
<tr>
<td><strong>Molluscs</strong></td>
<td>Paguristes frontalis</td>
<td>Uropholobus cruciatiss</td>
</tr>
<tr>
<td>Haliotis rubra</td>
<td>Strigopagurus strigimanus</td>
<td>Heterodontus portusjacksoni</td>
</tr>
<tr>
<td>Scutus antipodes</td>
<td>Nectocarcinus tuberculatus</td>
<td>Lotella rhacina</td>
</tr>
<tr>
<td>Phasianotrochex eximius</td>
<td>Plagusia chabrus</td>
<td>Pseudophycis bachus</td>
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<tr>
<td>Phasianella australis</td>
<td>Pagurid spp</td>
<td>Pseudophycis barbata</td>
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<tr>
<td>Phasianella ventricosa</td>
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<td>Scorpaena papillosa</td>
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<tr>
<td><strong>Turbo undulatus</strong></td>
<td>Echinoderms</td>
<td>Centropogon australis</td>
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<tr>
<td><strong>Turbo jourdani</strong></td>
<td>Comanthus trichoptera</td>
<td>Helicolenus percoide</td>
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<td>Astralium tentoriformis</td>
<td>Comanthus tasmaniae</td>
<td>Hypoplectrodes macullochi</td>
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<td>Charonia lampas rubicunda</td>
<td>Tosia magnifica</td>
<td>Pempheris multiradiata</td>
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<td>Cabestana spengleri</td>
<td>Tosia australis</td>
<td>Pempheris compressa</td>
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<td>Cabestana tabulata</td>
<td>Nectria ocellata</td>
<td>Parma victoria</td>
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<td>Argo Buccinium vexillum</td>
<td>Nectria multispina</td>
<td>Parma microlepis</td>
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<td>Ranella australasia</td>
<td>Meridiastra calcar</td>
<td>Gymnothorax prasinus</td>
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<td>Dicathais orbita</td>
<td>Coscinasterias muricata</td>
<td>Chromis hypsilepis</td>
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<td>Penion maxima</td>
<td>Astrostole scabra</td>
<td>Chironemus marmoratus</td>
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<td>Cominella lineolata</td>
<td>Goniocidaris tubaria</td>
<td>Eupetriothys angustipes</td>
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<td>Tambja verconis</td>
<td>Phyllacanthus parvispinus</td>
<td>Bovichtus angustifrons</td>
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<td>Neodoris chrysoderma</td>
<td>Heliocidaris erythrogramma</td>
<td>Trinorfolkia clarkei</td>
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<td>Hypselodoris bennetti</td>
<td>Centrostephanus rodgersii</td>
<td>Heteroclinus perspicillatus</td>
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<td>Octopus berrima</td>
<td>Amblypneustes spp.</td>
<td>Contusus brevicaudus</td>
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<td>Octopus tetricus</td>
<td>Holopneustes inflatus</td>
<td>Diodon nichthemerus</td>
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<tr>
<td>Octopus spp.</td>
<td>Holopneustes purpurascens</td>
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### Table 2.5. Macroalgae (Method 3) taxa censused in the Twofold Shelf Bioregion.

<table>
<thead>
<tr>
<th>Method 3</th>
<th>Chlorophyta (green algae)</th>
<th>Phaeophyta (brown algae)</th>
<th>Rhodophyta (red algae)</th>
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<tbody>
<tr>
<td><strong>Chlorophyta (green algae)</strong></td>
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<td></td>
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<tr>
<td><em>Ulva spp</em></td>
<td>Phyllospora comosa</td>
<td>Plocamium dilatatum</td>
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<tr>
<td><em>Chaetomorpha sp</em></td>
<td>Cystophora moniliformis</td>
<td>Plocamium leptophyllum</td>
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<tr>
<td><em>Chaetomorpha coliformis</em></td>
<td>Cystophora monilifera</td>
<td>Plocamium costatum</td>
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<tr>
<td><em>Codium duthieae</em></td>
<td>Cystophora retorta</td>
<td>Mychodea acanthymenia</td>
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<td><em>Codium galeatum</em></td>
<td>Cystophora siliquosa</td>
<td>Asparagopsis armata</td>
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<tr>
<td><em>Caulerpa scalpelliformis</em></td>
<td>Acrocarpia paniculata</td>
<td>Delisea pulchra</td>
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<td><em>Caulerpa trifaria</em></td>
<td>Sargassum spp</td>
<td>Gracilaria secundata</td>
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<td><em>Caulerpa hodkinsoniae</em></td>
<td>Sargassum verruculosum</td>
<td>Curdiea angustata</td>
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<tr>
<td><em>Caulerpa hodkinsoniae</em></td>
<td>Sargassum vestitum</td>
<td>Amphiroa anceps</td>
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<tr>
<td><strong>Phaeophyta (brown algae)</strong></td>
<td>Brown algal turf</td>
<td>Arthrocardia wardii</td>
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<td><em>Halopteris spp</em></td>
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<td>Haliptilon roseum</td>
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<tr>
<td><em>Cladostephus spongiosus</em></td>
<td><strong>Rhodophyta (red algae)</strong></td>
<td>Rhodymenia australis</td>
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<tr>
<td><em>Dictyothea dichotoma</em></td>
<td>Galaxaura marginata</td>
<td>Rhodymenia leptophylla</td>
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<td><em>Dictyothea diemensis</em></td>
<td>Pterocladia lucida</td>
<td>Rhodymenia linearis</td>
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<td><em>Dilophus spp</em></td>
<td>Gelidium austral</td>
<td>Rhodymenia obtusa</td>
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<td><em>Dilophus marginatus</em></td>
<td>Gelidium spp</td>
<td>Rhodymenia stenoglossa</td>
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<td><em>Dictyothea acrostichoides</em></td>
<td>Pterocladia capillacea</td>
<td>Rhodymenia wilsonii</td>
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<td><em>Dictyothea muelleri</em></td>
<td>Pterocladia capillacea</td>
<td>Cordylecladia furcellata</td>
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<td><em>Padina sp.</em></td>
<td>Nizymenia australis</td>
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<td><em>Homeostrichus sinclairii</em></td>
<td>Peyssonelia novaehollandiae</td>
<td>Ballia callitricha</td>
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<td><em>Zonaria angustata</em></td>
<td>Halymenia plana</td>
<td>Ceramium spp</td>
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<td><em>Zonaria crenata</em></td>
<td>Grateloupa filicina</td>
<td>Griffithia sp</td>
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<td><em>Zonaria ssp</em></td>
<td>Polyopes constrictus</td>
<td>Hemineura frondosa</td>
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<td><em>Zonaria turneriana</em></td>
<td>Polyopes tasmanicus</td>
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<td><em>(S. tasmanica)</em></td>
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<td><em>Distromium spp</em></td>
<td>Callophyllis lambertii</td>
<td>Dictymenia tridens</td>
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<td><em>Exallosorus olsenii</em></td>
<td>Callophyllis rangiferina</td>
<td>Lenormandia marginata</td>
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<tr>
<td><em>Lobophora variegata</em></td>
<td>Plocamium angustum</td>
<td>Other thallose red alga</td>
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<tr>
<td><em>Carposistrea costata</em></td>
<td>Plocamium mertensii</td>
<td>Red turfing algae</td>
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<tr>
<td><em>Sporochrus sp</em></td>
<td>Plocamium patagiutum</td>
<td>Encrusting corallines</td>
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<td><em>Colpomenia peregrina</em></td>
<td>Plocamium cartilageum</td>
<td>Filamentous red algae</td>
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<td>Phacelocarpus complanatus</td>
<td>Lophurella periclados</td>
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<td><em>Ecklonia radiosa</em></td>
<td>Phacelocarpus peperocarpos</td>
<td>Nemastoma feredayae</td>
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<td><em>Macroystis pyriform</em></td>
<td>Acrottylus australis</td>
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<tr>
<td><strong>Durvillaea potatorum</strong></td>
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</table>
2.3. Data Analysis – Condition indicators

2.3.1. Approach

Reef quality indicators were developed to encompass key features of the performance of each marine protected area in Victoria. The selection of indicators for reef ecosystem management were reviewed by Turner et al. (2006) and further theoretical and field considerations are provided by Thrush et al. (2009). Both reviews suggest a variety of indicators of both ecosystem structure and function, should be used. Rapport (1992) noted that stressors causing adverse changes in an ecosystem stand out beyond the natural range of variability observed in a system in ‘good health’. Adverse changes to an ecosystem include:

- a shift to smaller organisms;
- reduced diversity with loss of sensitive species;
- increased dominance by weedy and exotic species;
- shortened food chain lengths;
- altered energy flows and nutrient cycling;
- increased disease prevalence; and
- reduced stability/increased variability.

A suite of indicators was developed for the Tasmanian reef monitoring program, which uses the same Edgar-Barrett underwater visual census methods (Stuart-Smith et al. 2008). The indicators are grouped into the general categories: biodiversity; ecosystem functions; introduced pests, climate change and fishing. The Stuart-Smith indicators were followed and adapted for the Victorian SRMP. These indices are consistent with the reviews mentioned above. Key adaptations were the use of absolute values rather than proportions, as the Victorian data had considerable concurrent variation in the numerator and denominator of many indices, making proportional indices difficult to interpret. The Stuart-Smith approach for examining community changes was extended by using the multivariate control charting method of Anderson and Thompson (2004).

The indicators were calculated separately for the three survey components - fishes, invertebrates and algae.

The indicators presented in this report provide a basis for assessment and further refinement of indicators for marine protected area performance assessment and management.
2.3.2. Biodiversity

Community Structure

Community structure is a multivariate function of both the type of species present and the abundance of each species. The community structure between pairs of samples was compared using the Bray-Curtis dissimilarity coefficient. This index compares the abundance of each species between two samples to give a single value of the difference between the samples, expressed as a percentage (Faith et al. 1987; Clarke 1993).

Following Sweatman et al. (2003), the count data were log transformed and percent cover values were transformed using the empirical logit transformation (McCullagh and Nelder 1989).

The hyper-dimensional information in the dissimilarity matrix was simplified and depicted using non-metric multidimensional scaling (MDS; Clarke 1993). This ordination method finds the representation in fewer dimensions that best depicts the actual patterns in the hyper-dimensional data (i.e. reduces the number of dimensions while depicting the salient relationships between the samples). The MDS results were then depicted graphically to show differences between the replicates at each location. The distance between points on the MDS plot is representative of the relative difference in community structure.

Kruskal stress is an indicator statistic calculated during the ordination process and indicates the degree of disparity between the reduced dimensional data set and the original hyper-dimensional data set. A guide to interpreting the Kruskal stress indicator is given by Clarke (1993): (< 0.1) a good ordination with no real risk of drawing false inferences; (< 0.2) can lead to a usable picture, although for values at the upper end of this range there is potential to mislead; and (> 0.2) likely to yield plots which can be dangerous to interpret. These guidelines are simplistic and increasing stress is correlated with increasing numbers of samples. Where high stress was encountered with a two-dimensional data set, three-dimensional solutions were used to provide better representation of the higher-dimensional patterns.

Trends in Community Structure

Multivariate control charting was used to examine the degree of changes in community structure over time. The criterion assessed was the deviation in community structure at time \( t \) to the centroid of all previous times. This criterion is used to detect abrupt or pulse changes. When longer term data are available, comparisons with baseline conditions will be made. Control charts were prepared for the two sites. The analysis used the methods of Anderson and Thompson (2004) and calculations were done using the software ControlChart.exe (Anderson 2008). The analysis used the Bray-Curtis dissimilarity coefficient and the same data transformations described above. Bootstrapping was used to provide control-chart limits.
for identifying changes that are ‘out of the ordinary’. In this case, a 90th percentile statistic was calculated from 10,000 bootstrap samples as a provisional indicator of unusual deviations. The 50th percentile was also presented to assist in interpreting the control charts.

**Species Diversity**

The total number of individuals, $N$, was calculated as the sum of the abundance of all individuals across species.

Species richness, $S$, was given as the number of species observed at each site. Cryptic, pelagic and non-resident reef fishes were not included.

Species diversity, as a measure of the distribution of individuals among the species, was indicated using Hill’s $N_2$ statistic (which is equivalent to the reciprocal of Simpson’s index). In general, Hills $N_2$ gives an indication of the number of dominant species within a community. Hills $N_2$ provides more weighting for common species, in contrast to indices such as the Shannon-Weiner Index (Krebs 1999), which weights the rarer species.

The diversity statistics were averaged across sites for the marine protected area and reference regions.

**Abundances of Selected Species**

Mean abundance of selected species were plotted over time for the marine sanctuary and reference site. The species presented included abundant or common species as well as any with unusual changes over time.
2.3.3. Ecosystem Functional Components

Plant Habitat and Production
Biogenic habitat and standing stocks of primary producers was indicated by the pooled
abundances of macrophyte groups:

- crustose coralline algae;
- canopy browns – defined here as *Ecklonia radiata, Undaria pinnatifida, Lessonia
corrugata, Macrocystis pyrifera, Durvillaea potatorum, Phyllospora comosa, Seirococcus
axillaris, Acrocarpia paniculata, Cystophora platylobium, C. moniliformis, C. pectinata, C. monilifera, C. retorta and C. retroflexa;
- smaller browns (all other brown species except Order Ectocarpales);
- erect coralline algae;
- thallose red algae (except filamentous species);
- green algae; and
- seagrass *Amphibolis antarctica*.

Invertebrate Groups
The abundances of invertebrates were pooled into the functional groups:

- grazers and habitat modifiers, including gastropods and sea urchins;
- filter feeders, including fanworms and feather stars;
- predators, including gastropods, crabs and lobsters but excluding seastars; and
- seastars, which are mostly predators, although *Meridiastra gunnii* may also be a
detritus feeder.

Fish Groups
The abundance of fishes was also pooled into trophic groups:

- herbivores and omnivorous grazers;
- foraging predators, including pickers and foragers of stationary, benthic prey such as
amphipods, crabs and gastropods;
- hunter predators, including fishes that hunt mobile prey, particularly other fishes, as
chasers and ambushers; and
- planktivores, including feeders of zooplankton and small fish in the water column.

Sediment Cover
The percentage cover of sand and sediment on the survey transect (using Method 3) is the
only relevant abiotic parameter measured for the SRMP.
2.3.4. Introduced Species

The status of introduced species was initially reported as presence-absence of species. Where a species is established and the SRMP measures the abundance of that species, indicators of status are:

- number of introduced species;
- total abundance of introduced species; and
- where the data are suitable, time series of abundance of selected introduced species – noting the timing of surveys may influence the time series.

2.3.5. Climate Change

Species Composition

Climate change is likely to cause changes to current strengths and circulation patterns which affect both the ambient temperature regime and the dispersion and recruitment of propagules or larvae. In Victoria, there may be increased incursions of the East Australia Current into eastern Victoria and the South Australia Current into western Victoria and Bass Strait. Biological responses to such changes are potentially indicated by biogeographical changes in the species composition, toward that of adjacent, warmer bioregions. For this analysis, each species was assigned a nominal geographical range:

- coldwater species, reflecting the ‘Maugean’ province, from approximately Kangaroo Island in South Australia, around Tasmania and into southern New South Wales;
- western species, reflecting the ‘Flindersian’ province, from southern Western Australia, along the Great Australian Bight and South Australia to western Victoria;
- eastern species, reflecting the ‘Peronian’ province, encompassing New South Wales and into eastern Victoria;
- southern species, including species ranging widely along the southern Australian coast; and
- northern species, including warm temperate and tropical species in Western Australia and New South Wales and northward.

The number of species and total number of individuals was calculated for the coldwater, western and eastern groups.

*Macrocystis pyrifera*

The string kelp *Macrocystis pyrifera*, which includes the former species *M. angustifolia* (Macaya and Zuccarello 2010), is considered potentially vulnerable to climate change through reduced nutrient supply from drought and nutrient poorer warmer waters (Edyvane
2003). The mean abundance of *M. pyrifera* was plotted using densities from Method 4, or cover estimates from Method 4 where density data were unavailable. *M. pyrifera* provides considerable vertical structure to reef habitats and can also attenuate water currents and wave motion. The loss of *M. pyrifera* habitats may reflect ecosystem functional changes.

**Centrostephanus rodgersii**

The range of the long-spined sea urchin, *Centrostephanus rodgersii*, has increased conspicuously over the past decades (Johnson *et al.* 2005). This grazing species can cause considerable habitat modification, decreasing seaweed canopy cover and increasing the area of ‘urchin barrens’. Abundances are determined using Method 2 and average abundances are plotted through time. The abundance of *C. rodgersii* is also influenced by interactions with abalone through competition for crevice space, Abalone divers may periodically ‘cull’ urchins within a reef patch and the species is also of interest to urchin harvesters.

**Durvillaea potatorum**

The bull kelp *Durvillaea potatorum* is a coldwater species that is likely to be vulnerable to increased ambient temperatures. There is anecdotal evidence of a retraction of the northern distribution down the New South Wales coast by approximately 80 km. Most of the SRMP sites specifically avoid *D. potatorum* habitats as these occur on highly wave-affected and turbulent reefs. Some sites contain *D. potatorum* stands, providing limited data on population status. *Durvillaea potatorum* is potentially two species, having genetically and morphologically distinct eastern and western forms (Fraser *et al.* 2009).

### 2.3.6. Fishing

**Abalone**

Indicators of altered population structure from harvesting pressure on abalone were mean density and the proportion of legal sized individuals. The size-frequency histograms were also examined. The indicators were calculated for the blacklip abalone, *Haliotis rubra*, in most regions and for the greenlip abalone, *H. laevigata*, where present in suitable densities (in central and western Victoria).

**Rock Lobster**

The southern rock lobster, *Jasus edwardsii*, is present throughout Victoria and the eastern rock lobster, *Jasus verreauxi*, is present in the Twofold Shelf region. The SRMP transects generally did not traverse rock lobster microhabitats, however abundances and sizes are reported for suitable data.
Fishes
Potential fishing impacts or recovery of fishing impacts within marine protected areas were indicated by:

- abundances of selected fished species;
- mean size and size-frequency histograms of selected fished species;
- total abundance of fishes > 200 mm length, this being the approximate legal minimum size for most fished species;
- biomass of fishes > 200 mm length, calculated using length-weight relationships; and
- parameters of the size-spectra of all fishes.

The size spectrum of all fishes at a site was first centred and linearised. Size frequencies for each field size class were aggregated into classes centred on 87.5 mm (classes 1-6), 200 mm (class 7); 275 mm (classes 8-9); 356.25 mm (classes 10-11); 400 mm (class 12); 500 mm (class 13); 625 mm (class 14); and 750+ mm (class 15). The frequencies and size classes were log\(_e\)(x +1) and the size classes centred by subtracting the mean. Linear regression was used to estimate the slope and intercept (which is also the half-height of the slope) of the log-transformed spectrum.

Biomass was calculated for selected species \(\geq 300\) mm. Lengths were converted to weights using published conversion factors for the power relationship: weight(grams) = \(a \times \text{Length(cm)}^b\). The weight estimations used the coefficients compiled by Lyle and Campbell (1999). The selected species were the most common species under heaviest fishing pressure (where present):

- banded morwong *Cheilodactylus spectabilis* (\(a = 0.0629, b = 2.881\));
- bastard trumpeter *Latridopsis forsteri* (\(a = 0.0487, b = 3.14\));
- blue throated wrasse *Notolabrus tetricus* (\(a = 0.0539, b = 2.17\));
- purple wrasse *Notolabrus fucicola* (\(a = 0.0539, b = 2.17\));
- crimson banded wrasse *Notolabrus gymnogenis* (\(a = 0.0539, b = 2.17\)); and
- eastern blue groper *Achoerodus viridis* (\(a = 0.0539, b = 2.17\)).
3. RESULTS

3.1. Macroalgae

The algal composition of Beware Reef reflects the submaximally exposed conditions. The major canopy species are bull kelp *Durvillaea potatorum*, crayweed *Phyllospora comosa* and common kelp *Ecklonia radiata*. The relative abundances differ between transects, with *E. radiata* dominant on the landward side, *D. potatorum* in the central region and *P. comosa* on the seaward side. The algae beneath the canopy consisted predominantly of encrusting corallines and thallose red species such as *Rhodymenia wilsonii*, *R. linearis* and *Plocamium dilatatum*. The reference site at Pearl Point did not have bull kelp *D. potatorum* present. This difference was reflected in the MDS analysis of community structure, with the two sites separated between surveys in accordance with changes in *D. potatorum* abundance (Figure 3.1, c.f. Figure 3.4c). There was a general trend of change in community structure away from the first survey condition (Figure 3.1). This was in accordance with a general declining trend in *Ecklonia radiata* cover (Figure 3.4a), increase in cover of *D. potatorum* at Beware Reef (Figure 3.4c) and increase in cover of crustose coralline algae (Figure 3.4d). Notable changes in algal abundances included: lower abundances of *E. radiata* at both sites during the latest, 2011 survey; a dip in *P. comosa* abundance at Pearl Point in 2009 with subsequent increase to 2012 and a spike in crustose coralline algal abundance at Beware Reef in 2006 (Figure 3.4).

The control chart comparing the most recent survey with the centroid of prior times indicate the algal assemblages had changed from previous surveys in 2009 and 2011. These changes occurred at both Beware Reef and Pearl Point (Figure 3.2).

There is was little change in the overall seaweed abundance at either site during the monitoring program (Figure 3.3a). Algal species richness increased at both sites from 2004 to 2009, from 10 to 15 species per site, with a minor decline to 2011 (Figure 3.3b). Algal diversity was consistently higher at Beware Reef than Pearl Point and there was a slight increase at Pearl Point from 2009 to 2011 (Figure 3.3c).
**Figure 3.1.** Three-dimensional MDS plot of algal assemblage structure for Beware Reef monitoring sites. Black symbols indicate the first survey. Kruskal Stress = 0.05.

**Figure 3.2.** Control chart of algal assemblage structure inside and outside Beware Reef Marine Sanctuary. Grey lines indicate 50th and 90th percentiles.
Figure 3.3. Algal species diversity indicators inside and outside Beware Reef Marine Sanctuary.
Figure 3.4. Percent cover of dominant algal species inside and outside the Beware Reef Marine Sanctuary.
Figure 3.4 (continued). Percent cover of dominant algal species inside and outside the Beware Reef Marine Sanctuary.
3.2. Invertebrates

The invertebrate assemblage structure consisted of predominantly blacklip abalone *Haliotis rubra*, common sea urchin *Heliocidaris erythrogramma* and the feather star *Comanthus trichoptera*. There was a high abundance of *C. trichoptera* at both sites, with abundances at Pearl Point being in the order of ten times higher than Beware Reef (Figure 3.8d). This difference persisted through time and was reflected in the MDS plot (Figure 3.5). The MDS plot indicated there was a shift in assemblage structure away from conditions at the start of monitoring in 2004, with a trend back towards original conditions for the last survey in 2011 (Figure 3.5). The shift away from original conditions was largely driven by a spike in abundance of *C. trichoptera* and was more pronounced at Pearl Point. Abundances during this peak were 1153 and 7812 per 200 m² at Beware Reef and Pearl Point respectively (Figure 3.8d). The control chart also indicated a considerable shift at Pearl Point away from usual conditions in 2009 (Figure 3.6).

The invertebrate species richness was generally higher at Pearl Point, however the diversity was low because of the high dominance of *C. trichoptera*. Variations in diversity at Beware Point were also driven by abundances of this species (Figures 3.7c and 3.8d).

There was an apparent increase in abundance of abalone *Haliotis rubra* at Beware Reef in 2009 with a subsequent increase at Pearl Point in 2011 (Figure 3.8a). There was an apparent declining trend in the abundance of *Heliocidaris erythrogramma* at both sites (Figure 3.8b). There was a substantial drop on *C. rodgersii* abundance between 2006 and 2009 at Beware Reef, with relatively smaller changes at Pearl Point (Figure 3.8c).
Figure 3.5. Three-dimensional MDS plot of mobile invertebrate assemblage structure for the Beware Reef region. Black symbols indicate the first survey. Kruskal stress = 0.01.

Figure 3.6. Control charts of mobile invertebrate assemblage structure inside and outside Beware Reef Marine Sanctuary. Grey lines indicate 50th and 90th percentiles.
Figure 3.7. Mobile invertebrate diversity indicators inside and outside Beware Reef Marine Sanctuary.
Figure 3.8. Abundance of dominant mobile invertebrate species inside and outside Beware Reef Marine Sanctuary.
**Figure 3.8** (continued). Abundance of dominant mobile invertebrate species inside and outside the Beware Reef Marine Sanctuary.
3.3. Fishes

3.3.1. Fish Community Structure

A distinctive feature of the fish assemblage at Beware Reef is the high abundance of butterfly perch *Caesioperca lepidoptera*. This reflects the presence of their preferred habitat: steep, high profile reef that extends up from deeper water. *Caesioperca lepidoptera* was variable in abundance at the Beware Reef site over time however it was not a major contributor to changes in fish assemblage structure. The two sites were relatively different at the start of the monitoring program and both sites had shifts over time to converge to similar structures in 2011 (Figure 3.9). The greatest shift was between 2009 and 2011 and this was reflected in the control chart for both sites (Figure 3.10). These shifts were associated with declining trends in both species richness and species diversity (Figure 3.11).

There was an apparent declining trend in the abundance of banded morwong *Cheilodactylus spectabilis* at Beware Reef over the monitoring period (Figure 3.12b). There was a clear increasing trend in abundance of purple wrasse *Notolabrus fucicola* at both sites (Figure 3.12d). This coincided with decreased observations of sweep *Scorpis lineolata*, white-ear *Parma microlepis* and herring cale *Odax cyanomelas*.
Figure 3.9. Three-dimensional MDS plot of fish assemblage structure for the Beware Reef region. Black symbols indicate the first survey. Kruskal stress = 0.03.

Figure 3.10. Control chart of fish assemblage structure inside and outside Beware Reef Marine Sanctuary. Grey lines indicate 50th and 90th percentiles.
Figure 3.11. Fish species diversity indicators inside and outside Beware Reef Marine Sanctuary.
Figure 3.12. Abundance of dominant fish species inside and outside the Beware Reef Marine Sanctuary.
Figure 3.12 (continued). Abundance of dominant fish species inside and outside the Beware Reef Marine Sanctuary.
3.4. Ecosystem Components

3.4.1. Habitat and Primary Production

Thallose red algae were low in abundance at both sites but there was an apparent slight increasing trend over the duration of the monitoring period. The total cover of canopy brown algae varied little over the monitoring period and was similar at both sites (Figure 3.13).

3.4.2. Invertebrate Groups

There was a general declining trend in the abundance of invertebrate grazers at both sites (Figure 3.14). The total abundance of invertebrate filter feeders was driven by the high abundance of feather stars *C. trichoptera*. There was an apparent increasing trend in invertebrate predators, such as whelks, within the Beware Reef Marine Sanctuary (Figure 3.14).

3.4.3. Fish Groups

Fish grazer abundance was relatively high at both sites during 2004. Fish forager abundance had a dip in abundance during 2006 (Figure 3.15). Fish hunter densities were higher in the reference areas during the baseline period however there were no apparent trends inside the MNP (Figure 3.15 and Figure 3.d).

3.4.4. Sediment Cover

The coverage of sediments was negligible at both sites.

3.5. Introduced Species

No introduced algae, invertebrate or fish taxa have been recorded at the Beware Reef and Pearl Point sites.
Figure 3.13. Seaweed functional groups inside and outside the Beware Reef Marine Sanctuary.
Figure 3.14. Invertebrate functional groups inside and outside the Beware Reef Marine Sanctuary.
Figure 3.15. Fish functional groups inside and outside the Beware Reef Marine Sanctuary.
3.6. Climate Change

3.6.1. Species Composition

The biogeographical affinities of species at Beware Reef and Peal Point did not change appreciably during the monitoring period, with the exception of the long-spined sea urchin *Centrostephanus rodgersii* (Figures 3.16 to 3.19). This species is an eastern, warmer water species and abundances had approximately halved at the Beware Reef site from 2006 to 2011 (Figures 3.8 and 3.17).

3.6.2. *Macrocystis pyrifera*

The string kelp *Macrocystis pyrifera* was not observed at the Beware Reef and Pearl Point sites.

3.6.3. *Centrostephanus rodgersii*

As noted above, the long-spined sea urchin *Centrostephanus rodgersii* declined in abundance at the Beware Reef site from 2006 to 2011.

3.6.4. *Durvillaea potatorum*

The bull kelp *Durvillaea potatorum* was only present at the Beware Reef site. Its abundance increased by approximately a third from 2006 to 2009 (Figure 3.4c).

3.7. Fishing

3.7.1. Abalone

Abalone average sizes were considerably larger within the Beware Reef Marine Sanctuary than at the Pearl Point Reference site (Figure 3.20).

3.7.2. Southern Rock Lobster

The densities of southern rock lobster *Jasus edwardsii* were negligible at the monitoring sites.
3.7.3. Fishes

The fish indicators, including size spectrum indicators, mean sizes and abundances of larger fishes with respect to total abundances, all indicated variability in size structures, but with no identifiable trends over the four surveys to date (Figures 3.21 to 3.26).

![Maugean Algal Species](image)

![Maugean Algal Abundance](image)

Figure 3.16. Species richness and abundance of Maugean seaweeds inside and outside the Beware Reef Marine Sanctuary.
Figure 3.17. Richness and abundance of eastern invertebrate species inside and outside the Beware Reef Marine Sanctuary.
Figure 3.18. Richness and abundance of Maugean fish species inside and outside the Beware Reef Marine Sanctuary.
Figure 3.19. Richness and abundance of Eastern fish species inside and outside the Beware Reef Marine Sanctuary.
Figure 3.20. Size structure of blacklip abalone *Haliotis rubra* at Beware Reef and Pearl Point. The size-frequency plots are for the latest survey in 2011.
Figure 3.21. Fish size spectrum statistics inside and outside the Beware Reef Marine Sanctuary.
Figure 3.22. Density of all harvested fishes and larger harvested fishes in the Beware Reef region.
Figure 3.23. Abundance of all fishes and larger fishes in the Beware Reef region.
Figure 3.24. Size structure of blue throat wrasse *Notolabrus tetricus* in the Beware Reef region.
Figure 3.25. Size structure of purple wrasse *Notolabrus fucicola* in the Beware Reef region.
Figure 3.26. Size structure of all fishes in the Beware Reef region.
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5. REFERENCES


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