NUMBER 84

Victorian Subtidal Reef Monitoring Program:
The Reef Biota at Bunurong Marine National Park

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May 2011
Victorian Subtidal Reef Monitoring Program:
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EXECUTIVE SUMMARY

Shallow reef habitats cover extensive areas along the Victorian coast and are dominated by seaweeds, motile 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. In order 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 monitoring program in and around the Bunurong Marine National Park (MNP) began in 1999. Since that time, 12 census events have occurred surveying between 4 and 12 sites each time. The monitoring involves standardised underwater visual census methods to a depth of 8 m. This report aims to provide:

- a general description of the biological communities and species populations at each monitoring site; 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:

1. abundance and size structure of large fishes;
2. abundance of cryptic fishes and benthic invertebrates;
3. percentage cover of macroalgae; and
4. density of a dominant kelp species (*Macrocystis pyrifera*).

To date over 300 different species have been observed during the monitoring program in and around Bunurong Marine National Park. The algal community structure at Bunurong is one of the most diverse of the Victorian coast. This is partly due to the predominance of large brown algal species including *Seirococcus axillaris*, *Cystophora* species, *Sargassum* species and *Acrocarpia paniculata*. The invertebrate community was largely composed of the blacklip abalone *Haliotis rubra*, the gastropod *Turbo undulatus* and a variety of sea stars, particularly *Meridiastra gunnii* and *Tosia australis*. The common fish species included blue-throated wrasse *Notolabrus tetricus*, purple wrasse *Notolabrus fucicola*, senator wrasse *Pictilabrus laticlavius*, silver sweep *Scorpis aequipinnis* and scalyfin *Parma victoriae*.
Key observations from the monitoring program were:

- seaweed species richness remained relatively high and was consistently higher within the MNP, seaweed diversity during 2011 was the lowest since the MNP introduction;
- the seagrass *Amphibolis antarctica* was at maximum cover in 2011;
- little change in the cover of canopy algal species occurred inside and outside the MNP since its introduction. In 2011 however, there was a reduction in the cover of *C. platylobium* and an increase in the cover of *A. paniculata* in both reference and MNP sites;
- invertebrate abundance in both the MNP and reference sites peaked during the baseline period in 2001 to 2002 surveys. Since this time the abundance of the most dominant invertebrates *H. rubra, T. undulatus, D. orbita* and *H. erythrogramma* have declined;
- invertebrate control charts indicate a shift in the assemblage structure of invertebrates in the eastern reference sites, attributed to major declines in the abundance of *T. undulatus* and *M. gunnii*;
- the close-interval baseline monitoring identified intra and inter-annual fluctuations in density of reef fishes, particularly blue throated wrasse *N. tetricus*, purple wrasse *N. fucicola* and senator wrasse *P. laticlavius*;
- the densities of blue throated wrasse *N. tetricus* were similar inside and outside the MNP, with densities after MNP declaration varying within a similar range;
- the densities of purple wrasse *N. fucicola* were higher inside the MNP before declaration, but have since dropped to densities similar to the reference areas. No *N. fucicola* were observed in MNP sites in the 2011 survey;
- the density of senator wrasse *P. laticlavius* was generally low inside the MNP following declaration. In reference areas a spike in abundance in 2006, has not been repeated in subsequent surveys;
- exceptionally low densities were observed for zebra fish *Girella zebra* in 2005, 2006 and 2010 and for magpie morwong *Cheilodactylus nigripes* in 2010, inside and outside the MNP. *Girella zebra* abundances increased in reference areas in 2011, associated with a large number of individuals at Cape Patterson (Site 1);
- no introduced species were sighted in any of the 12 censuses at Bunurong;
- very low abundances of the coldwater string kelp *M. pyrifera* were recorded from 2003 onwards. In 2011 *M. pyrifera* was sighted at three sites in low abundances;
- there was a substantial decline in sizes of blacklip abalone *H. rubra* in MNP sites and a drastic decline at reference sites; and
• a distinct decline occurred in fish abundances over 200 mm length, with densities in 2010 and 2011 being at or below previously recorded levels. This decline was more marked inside the Bunurong MNP.
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1 INTRODUCTION

1.1 Subtidal Reef Ecosystems on the Victorian Coast

Shallow reef habitats cover extensive areas along the Victorian coast. The majority of reefs in this area are exposed to strong winds, currents and large swell. A prominent biological component of Victorian shallow reefs is kelp and other seaweeds (Figure 1.1). Large species, 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 grasslands and seagrass beds, with approximately 2 kg of plant material produced per square metre of seafloor per year. These stands typically have 10-30 kg of plant material per square metre. The biomass of seaweeds is substantially 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 *M. pyrifera*, which sometimes forms a dense layer of fronds floating on the water surface. Other species with large, stalk-like stipes, such as *E. radiata*, *P. comosa* and *D. 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 the 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 these structural layers varies considerably within and between reefs, depending on the biogeographic region, depth, exposure to swell and waves, currents, temperature range, water clarity and the presence or absence of deposited sand.

Grazing and predatory motile invertebrates are prominent animal inhabitants of the reef (Figure 1.2). Common grazers include blacklip and greenlip abalone *Haliotis rubra* and *Haliotis laevigata*, warrener *Turbo undulatus* and sea urchins *Heliocidaris erythrogramma*, *Holopneustes* spp. and *Amblypneustes* spp.. These species can influence the growth and survival of habitat forming organisms. For example, sponges and foliose seaweeds are often prevented from growing on encrusting coralline algae surfaces through the grazing actions of abalone and sea urchins. Predatory invertebrates include dogwhelks *Dicathais orbita*, southern rock lobster *Jasus edwardsii*, octopus *Octopus maorum* and a wide variety of sea star species. Other large reef invertebrates include motile filter feeding animals such as feather stars *Comanthus trichoptera* and sessile (attached) species such as sponges, corals, bryozoans, hydroids and ascidians.
Fishes are also a prominent component of reef ecosystems, in terms of both biomass and ecological function (Figure 1.3). Reef fish assemblages include roaming predators such as blue throat wrasse *Notolabrus tetricus*, herbivores such as herring cale *Odax 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 feeding activities of fishes such as scalyfin *Parma victoriae* and magpie morwong *Cheilodactylus nigripes* promote the formation of open algal turf areas, free of larger canopy-forming seaweeds.

Although the biomass and the primary and secondary productivity of shallow reef ecosystems in Victoria are dominated by seaweeds, motile invertebrates and fishes, 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 (mesoinvertebrates), occupying various niches as grazers, predators or foragers. At the microscopic level, films of microalgae and bacteria on the reef surface are also 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.
Crayweed *Phyllospora comosa* canopy

Common kelp *Ecklonia radiata* canopy

Red coralline algae *Haliptilon roseum*

Thallose red algae *Ballia callitricha*

Green algae *Caulerpa flexilis*

Encrusting coralline algae around crayweed *P. comosa* holdfast

**Figure 1.1.** Examples of macroalgae found on subtidal reefs on the Victorian coast.
Figure 1.2. Examples of species of invertebrates and cryptic fish found on Victorian subtidal reefs.
Figure 1.3. Examples of fish species found on Victorian subtidal reef.
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; Edmunds 2000);
- 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. Dayton et al. 1998; Edgar et al. 1997; Edmunds et al. 2000);
- provide benchmarks for assessing the effectiveness of management actions, in accordance with international best practice for quality environmental management systems (e.g. 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. 2008).

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 1.4). 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 Subtidal Reef Monitoring Program was expanded to include Marine National Parks and Marine Sanctuaries throughout Victoria.
1.3 Subtidal Reef Monitoring at Bunurong

This report describes the Subtidal Reef Monitoring Program in the Bunurong region and results from twelve surveys, incorporating Bunurong Marine National Park (Figure 1.5) and the adjacent conservation areas of the Bunurong Marine and Coastal Park. 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 May 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; and
5. identify any introduced species at the monitoring locations.

Figure 1.5. The Eagles Nest stack rising above intertidal platforms, eastern end of Shack Bay.
2 METHODS

2.1 Site Selection and Survey Times

Eight long-term monitoring sites were established along the Bunurong coast in June 1999 (Sites 1 to 8; Table 2.1, Figure 2.1) The sites were located in 4 - 7m depth in three zones: Western Zone (2 sites); the Central Zone (4 sites); and the Eastern Zone (2 sites). Three deep-water reconnaissance sites were surveyed in 16 m depth, with one site in each of the Western, Central and Eastern zones (Sites 9 to 11; Table 2.1, Figure 1.1).

A further four sites were established at 4-7 m depth during the second survey in January/March 2000 (Sites 12 to 15; Figure 2.1). The second Bunurong survey was over three periods because of persistent poor visibility conditions throughout the summer period (Table 2.2).

The third survey commenced in winter 2000. However, persistently bad weather and heavy rainfalls affected diving conditions and underwater visibility for much of winter and spring. Only four sites could be surveyed: Sites 6, 12, 7 and 8.

An analysis of wind and rainfall data indicated the best periods for monitoring at Bunurong were in January/February and in June.

All sites were surveyed in summer 2000/2001 (Survey 4), winter 2001 (Survey 5), summer 2001/2002 (Survey 6), winter 2002 (Survey 7), spring 2003 (Survey 8), summer 2004/2005 (Survey 9), autumn 2006 (Survey 10), summer 2009/2010 (Survey 11) and autumn 2011 (Survey 12; Table 2.2).
Table 2.1. Subtidal reef monitoring sites within zones of the Bunurong Marine and Coastal Park and Bunurong Marine National Park.

<table>
<thead>
<tr>
<th>Region</th>
<th>No.</th>
<th>Description</th>
<th>Status</th>
<th>Depth</th>
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<tr>
<td>Western Zone</td>
<td>3001</td>
<td>Cape Patterson</td>
<td>Reference</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3002</td>
<td>C. Pat. Boat Ramp</td>
<td>Reference</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>3015</td>
<td>Boat Ramp East</td>
<td>Reference</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>3009</td>
<td>Patterson West Deep</td>
<td>Reference</td>
<td>15</td>
</tr>
<tr>
<td>Marine National</td>
<td>3014</td>
<td>The Oaks Beach</td>
<td>MPA</td>
<td>7</td>
</tr>
<tr>
<td>Park</td>
<td>3003</td>
<td>Oaks East</td>
<td>MPA</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>3004</td>
<td>Twin Reefs</td>
<td>MPA</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>3005</td>
<td>Shack Bay West</td>
<td>MPA</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>3012</td>
<td>Shack Bay beach</td>
<td>MPA</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>3006</td>
<td>Shack Bay Middle</td>
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<tr>
<td></td>
<td>3010</td>
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<td>MPA</td>
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<td>The Caves</td>
<td>Reference</td>
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<td></td>
<td>3011</td>
<td>The Caves Deep</td>
<td>Reference</td>
<td>16</td>
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Table 2.2. Survey times for monitoring at Bunurong.

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<th>Survey Number</th>
<th>Season</th>
<th>Survey Period</th>
</tr>
</thead>
<tbody>
<tr>
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<td>8-26 June 1999</td>
</tr>
<tr>
<td>3</td>
<td>Winter 2000</td>
<td>30-31 August 2000</td>
</tr>
<tr>
<td>4</td>
<td>Summer 2000/2001</td>
<td>18 Dec 2000 to 3 Jan 2001</td>
</tr>
<tr>
<td>5</td>
<td>Winter 2001</td>
<td>11-12 May, 4-6 June 2001</td>
</tr>
<tr>
<td>6</td>
<td>Summer 2001/2002</td>
<td>14-16 February, 5-7 March 2002</td>
</tr>
<tr>
<td>7</td>
<td>Winter 2002</td>
<td>1-3 August, 10-11 August 2002</td>
</tr>
<tr>
<td>8</td>
<td>Autumn 2003</td>
<td>28-29 April, 13-15 May 2003</td>
</tr>
<tr>
<td>10</td>
<td>Autumn 2006</td>
<td>2-23 March 2006</td>
</tr>
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<td>12</td>
<td>Autumn 2011</td>
<td>10-31 May 2011</td>
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</table>
Figure 2.1. Location of survey sites associated with the Bunurong Marine National Park and Eastern and Western Conservation Zones of the Bunurong Marine and Coastal Park.
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. Monitoring sites along the central coast of Victoria are between 4 and 7 m deep.

2.2.2 Survey Design

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 resulting 200 m of 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 macroalgae and sessile invertebrates; and (4) the density of string-kelp *Macrocystis pynifera* 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 fish. All field observations were recorded on underwater paper.

Figure 2.2. Biologist-diver with transect line.

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 *Odax cyanomelas*, barber perch *Caesioperca rasor*, rosy wrasse *Pseudolabrus rubicundus* and some leatherjackets.

2.2.4 Method 2 – Invertebrates and Cryptic Fishes

Cryptic fishes and motile megafaunal 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 – Macroalgae

The area covered by macroalgal, seagrass and sessile invertebrate species was quantified by placing a 0.25 m² quadrat at 10 m intervals along the transect line and determining the percent cover of all sessile 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 m² 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 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 m² 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.

### 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 used by a single diver who did the UVC fish survey at the same time (Method 1). 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 Fishes (Method 1) species censused at Bunurong.

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<thead>
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<td><strong>Fishes (cont.)</strong></td>
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Table 2.4. Invertebrate and cryptic fishes (Method 2) species censused at Bunurong.

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Table 2.5. Macroalgae (Method 3) species censused at Bunurong.

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<td>Distromium spp.</td>
<td><strong>Rhodophyta (red algae)</strong></td>
<td>Erythrymenia minuta</td>
<td><strong>Magnoliophyta</strong></td>
</tr>
<tr>
<td>Homeostrichus sinclairii</td>
<td>Gelidium asperum</td>
<td>Epigossum smithiae</td>
<td>Amphibolis antarctica</td>
</tr>
<tr>
<td>Homeostrichus olsenii</td>
<td>Gelidium australe</td>
<td>Lenormandia spectabilis</td>
<td></td>
</tr>
<tr>
<td>Zonaria angustata</td>
<td>Gelidium spp.</td>
<td>Carpothamnion sp.</td>
<td>Other</td>
</tr>
<tr>
<td>Zonaria crenata</td>
<td>Pterocladia lucida</td>
<td>Polyopes constrictus</td>
<td>Algal turf</td>
</tr>
<tr>
<td>Zonaria spiralis</td>
<td>Pterocladia capillacea</td>
<td>Halymentia sp. nov.</td>
<td></td>
</tr>
<tr>
<td>Zonaria turneriana</td>
<td>Asparagopsis armata</td>
<td>Halymentia sp.</td>
<td></td>
</tr>
</tbody>
</table>
2.3 Data Analysis - Condition indicators

2.3.1 Approach

Reef quality indicators were developed to encompass key features of MPA performance assessment and management interest. 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 function, 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 (2008), 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 sought to ensure adequate 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. Two criteria were assessed, the first being the deviation in community structure at a time, \( t \), from the centroid of baseline community structures. This criterion is more sensitive to the detection of gradual changes over time away from the baseline conditions. In this case, the first 5 surveys were used for the baseline centroid (recognising there were 6 baseline surveys for 8 sites and 5 baseline surveys for 4 sites). The second criterion was the deviation in community structure at time, \( t \), to the centroid of all previous times, \((t-1)\). This criterion is more sensitive at detecting abrupt or pulse changes.

Control charts were prepared for each site as well as on a regional basis for combined sites inside the marine protected area and for reference sites. The regional analysis used average species abundances across sites within each region. 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 10000 bootstrap samples as a provisional limit or trigger line. 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. This index is used to show any simultaneous depression of abundances across all species.

Species richness, \( S \), is 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). The value varies between 1 and \( S \) (i.e. the total number of species in the sample) with higher values indicating higher diversity. 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 protected area and reference regions. 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 Ectocarpales);
- erect coralline algae;
- thallose red algae (except filamentous species);
- green algae; and
- seagrass *Amphibolis antarctica*.

The index of summed species points-cover does not equate to a total cover estimate in some cases as using species cover can be overlapping with other species at different heights.

Invertebrate Groups
The abundance 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 were 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. This index may indicate changes in hydrodynamic or coastal processes.

2.3.4 Introduced species
The status of introduced species is 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 *M. pyrifera*, which includes the former species *Macrocystis angustifolia* (Macaya and Zuccarello 2010) is considered potentially vulnerable to climate change through reduced nutrient supply from drought and nutrient poor warm 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 are likely to 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* are also influenced by interactions with abalone as competitors 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 decline in range 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*(x +1) and the size classes are 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 ≥ 300 mm. Lengths were converted to weights using published conversion factors for the power relationship: weight(g)=a x 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 Biodiversity

3.1.1 Community Structure

Macroalgae

The canopy algal assemblages at Bunurong were characterised by a diverse range of medium-sized brown algal species. The predominant brown algal species included *S. axillaris*, *C. platylobium*, *C. moniliformis*, *C. retorta*, *C. retroflexa*, *A. paniculata* and *Sargassum fallax*. Other larger brown species such as *E. radiata* and *P. comosa* were generally absent or in very low abundances. Other dominant components of the algal assemblages included the seagrass *A. antarctica*, coralline algae such as *Haliptilon roseum* and *Metagoniolithon radiatum*, as well as the red algae *Phacelocarpus peperocarpos*, *Areschougia congesta* and *Plocamium angustum*. The dominant green algae were; *Caulerpa brownii*, *Caulerpa scalpelliformis* and *Caulerpa flexilis*, however were relatively low in abundance.

The MDS plots indicated there was an overall east-west gradient in changes in algal assemblage structure (Figure 3.1a - b). This change in site algal assemblage can be largely attributed to an increasing predominance of the seagrass *A. antarctica*, as well as the brown algae *S. axillaris* and *C. pectinata* in the far eastern sites. The eastern sites also had much lower abundances of *A. paniculata* and *P. peperocarpos* than the western sites.

The sites within the Bunurong Marine National Park (MNP) were relatively similar in structure, however a distinction between Shack Bay sites (Sites 5, 6 and 12) and other sites was evident (Figure 3.1a). *Amphibolis antarctica* was absent or in very low percentage cover at Twin Reefs (Site 4), Oaks East (Site 3) and The Oaks Beach (Site 12), with prevalence much higher at Shack Bay sites.

Amongst the western reference sites, Cape Paterson (site 1) was quite different in assemblage structure and was reasonably isolated at the top of the MDS plot (Figure 3.1b). This can be explained by a higher abundance of *A. antarctica*, *C. retorta* and *C. retroflexa*, lower abundance of *P. peperocarpos* and an absence of *S. axillaris*. This algal assemblage is more similar to the far eastern sites (Sites 7, 8 and 13) and this is reflected in its relative position in the MDS plot. There was considerable overlap in assemblage structure for the three eastern reference sites (Figure 3.1b).

The algal assemblage control charts indicated an increase in deviation from both the prior times and baseline centroids for all sites except Boat Ramp East (Site 15) and Petrel Rock West (Site 13; Figure 3.2a - d). Sites at Shack Bay (Site 5, 6 and 12) showed significant
deviation from the centroids outside the 90th percentile, attributed to an increase in A. *antarctica* cover at Shack Bay West (Site 5) and Shack Bay East (Site 6) and an increase in A. *paniculata* and Shack Bay Beach (Site 12). A similar deviation was also evident in reference sites, Cape Patterson (Site 1) and Cape Paterson Boat Ramp (Site 2; Figure 3.2a - d), also a result of increased A. *antarctica* cover. Region control charts reflected an increase in deviation within the MNP, however was below the 90th percentile for both the baseline and prior times centroid, no change was evident in reference sites as a region (Figure 3.2e and f).

**Invertebrates**

The invertebrate fauna composed of the blacklip and greenlip abalone *H. rubra* and *H. laevigata*, the gastropod *T. undulatus* and a variety of sea stars, particularly *M. gunnii* and *Tosia australis*. Other commonly encountered species included the dogwhelk *D. orbita* and seastar *Nectria ocellata*.

The MDS analysis showed Twin Reefs (Site 4) varied the most from other MNP sites (Figure 3.3). Invertebrate assemblages at remaining MNP sites were divided into two groups consisting of sites at the Oaks (Sites 3 and 14) and Shack Bay (Sites 5, 6 and 12); this difference can be attributed to the higher abundance of blacklip abalone at Shack Bay sites. Variation throughout time for most reference sites showed considerable overlap in structure between sites (Figure 3.3a and b). Petrel Rock East (Site 8) was the most different from other sites, having relatively low abundances of *H. rubra* and *T. undulatus* and relatively high abundances of the seastar *M. gunnii* and sea urchin *H. erythrogramma*.

The control charts detected significant departures in invertebrate assemblage structure from both the baseline centroid and prior times centroid. Within the MNP, these occurred most notably in the 2006 and 2010 surveys, at Twin Reefs (Site 4) and Shack Bay West (Site 12; Figure 3.4a and b). The eastern reference sites, The Caves (Site 7), Petrel Rock East (Site 8) and Petrel Rock West (Site 13) were outside the 90th percentile limit for the reference sites during 2011 for both the baseline and prior times centroid and have shown a major increase in deviation since the parks introduction in 2002. This change represents a major decline in the abundance of *M. gunnii* and *T. undulatus* at these sites of (Figure 3.4c and d). This was reflected in the regional plot for the prior times centroid, with the reference region deviating outside the limit, and a decrease in deviation in MNP sites (Figure 3.4e and f).
Fishes
The fish assemblages primarily consisted of blue throated wrasse *N. tetricus*, purple wrasse *N. fucicola*, senator wrasse *Pictilabrus laticlavius* and sea sweep *S. aequipinnis*. Other common species included the scaly fin *P. victoriae*, magpie morwong *C. nigripes*, herring cale *O. cyanomelas*, zebra fish *Girella zebra* and a variety of monacanthids (leatherjackets).

The MDS analysis indicated considerable overlap of trajectories through time and limited differences between sites (Figure 3.5a and b). Shack Bay West (Site 5) varied somewhat from the remaining MNP sites with comparably lower abundances of *P. victoriae* and *C. nigripes*. Similarly Cape Patterson (Site 1) showed some deviation from other references site assemblages, perhaps due to slightly lower abundances of *N. tetricus* and at infrequently high abundances of *G. zebra*. At many of the sites, the trajectories of shift in community structure oscillated in similarity between summer and winter surveys, indicating seasonal processes may be occurring (Figure 3.5).

The control charts signal substantial departure from average conditions at Shack Bay Beach (Site 12) and The Oaks Beach (Site 14) from both baseline and prior times centroids in 2010. In 2011 Shack Bay beach deviation decreased, however was still above the 90th percentile, (Figure 3.6a and b). Regional control charts for both baseline and prior times centroids reflected the changes evident at Shack Bay Beach, with the MNP average increasing in 2010 and decreasing in 2011 (Figure 3.6e and f). For the reference sites, Boat Ramp East (Site 15), Petrel Rock West (Site 13) and Cape Patterson Boat Ramp (Site 2) were outside the 90th percentile distance from both baseline and prior times centroids (Figure 3.6c and d), which was also reflected with an increase within normal limits for the regional prior times centroid (Figure 3.6f).
Figure 3.1. Three-dimensional MDS plot of algal assemblage structure at Bunurong for each site: (a) MNP sites (b) reference sites. Kruskal stress value = 0.16
Figure 3.2. Control charts of algal assemblage structure inside and outside Bunurong Marine National Park.
Figure 3.3. Three-dimensional MDS plot of invertebrate assemblage structure at Bunurong for each site: (a) MNP sites; and (b) reference sites. Kruskal Stress value= 0.17
Figure 3.4. Control chart of invertebrate assemblage structure inside and outside Bunurong Marine National Park.
Figure 3.5. Three-dimensional MDS plot of fish assemblage structure at Bunurong for each site: (a) MNP sites; and (b) reference sites. Kruskal Stress value = 0.20
Figure 3.6. Control chart of fish assemblage structure inside and outside Bunurong Marine National Park.
3.1.2 Species richness and Diversity

Macrolgae
The total algal abundance remained at complete substratum coverage throughout the survey period (Figure 3.7a). Macrophyte species richness was relatively high (30-40 species per site) and stable at most sites over time (Figure 3.7b). Algal species diversity was consistently greater within the MNP than in the reference areas (Figure 3.7c). In 2011, species diversity inside and outside the MNP was the lowest since the MNP was established in 2002 (Figure 3.7c).

Invertebrates
Total invertebrate abundance peaked in 2001, both inside and outside the MNP area, before decreasing to below baseline surveys in 2005 and 2006, with little subsequent change to 2011 (Figure 3.8a). Invertebrate species richness had a similar decline between 2002 and 2005 surveys, and remained at a similar level in following surveys (Figure 3.8b).

Species diversity in terms of Hill’s $N_2$, was generally confined to between 2 and 3 in both regions, with no discernable trends over time (Figure 3.8c).

Fishes
Total fish abundance fluctuated over time both inside and outside the Bunurong MNP (Figure 3.9). Total abundances inside the MNP largely followed the reference area variations, except for low total abundances in 2006 (Figure 3.9a).

Both species richness and species diversity in the MNP and reference areas were at similar levels and showed similar temporal patterns prior to the establishment of the park. This pattern has generally continued except for significantly higher species richness and diversity in reference sites in the 2006 survey (Figure 3.9b and c).
Figure 3.7. Algal species diversity indicators (± standard error) inside and outside Bunurong Marine National Park.
Figure 3.8. Invertebrate species diversity indicators (± standard error) inside and outside Bunurong Marine National Park.
Figure 3.9. Fish species diversity indicators (± standard error) inside and outside Bunurong Marine National Park.
3.1.3 Abundances of Selected Species

Macroalgae

The seagrass *A. antarctica* was found in high percent cover at Cape Patterson (Site 1) and in the eastern zone reference sites, Petrel Rock West (Site 13), Petrel Rock East (Site 8) and The Caves (Site 7) in all surveys. Eastern reference sites has shown increases in 2006, 2010 and 2011 surveys, which is reflected in the reference area average (Figure 3.10a). Although average cover was much lower inside the MNP, there was a concurrent increase in *A. antarctica* coverage to 2011.

Average cover of the dominant brown algae *A. paniculata* was consistently higher within the MNP sites compared to reference sites (Figure 3.10b). There was an increase in *A. paniculata* cover in 2011 at MNP sites, Twin Reefs (Site 4), Shack Bay East (Site 6) and The Oaks Beach (Site 14). Similarly there was an increase in cover at western reference sites, Cape Patterson (Site 1), Cape Patterson Boat Ramp (Site 2) and Boat Ramp East (Site 15).

*Cystophora platylobium* abundance has remained relatively constant throughout the monitoring period, with a slight decrease evident in the latest survey in MNP sites (Figure 3.10c). There were no marked changes in abundances of the other dominant brown algae, *S. axillaris* and *C. retorta* over the monitoring period inside or outside the MNP (Figure 3.10d and e). Similarly, there were no major changes in abundances of the red algae *Plocamium angustum* and *P. peperocarpos* and the red coralline alga *H. roseum* inside or outside the MNP (Figure 3.10f - h). No discernable trends in average regional abundances were obvious, though moderate fluctuations in abundance within sites occurred.

Invertebrates

The average abundance of blacklip abalone, *H. rubra*, increased considerably from 1999 to peak abundances in 2001, both inside and outside the MNP (Figure 3.11a). There was a subsequent, gradual decline to 2005 for the reference area and 2006 for the MNP, with no appreciable increase by 2011 (Figure 3.11a). A similar pattern was observed for the warrener, *T. undulatus*, with peak abundances in 2001 and minima in 2006, (Figure 3.11b). The dogwhelk, *D. orbita*, also had a distinct peak in abundance in 2002, with low abundances in 2003 to 2011 in MNP sites and a gradual decline in abundance in reference sites since 2005 (Figure 3.11c).

Average abundances of the common sea urchin, *H. erythrogramma*, were relatively high during the baseline period compared to the recent survey periods, although low abundances were observed during 2000 (Figure 3.11d). Abundances in 2010 and 2011 were among the lowest observed levels in MPA and reference areas.
**Fishes**

The frequent baseline surveys detected considerable intra- and interannual fluctuations in blue throated wrasse, *N. tetricus*, with subsequent surveys having abundances within the range of baseline variations. The abundances of *N. tetricus* were very similar inside and outside the MNP over time (Figure 3.12a).

The abundances of purple wrasse, *N. fucicola*, fluctuated considerably during the baseline monitoring, with abundances higher inside the MNP area. Post establishment of the MNP, abundances inside the MNP were lower than baseline levels, with densities similar to the reference areas (Figure 3.12b). No *N. fucicola* were observed in MNP sites in the 2011 survey (Figure 3.12b).

A weaker decline in abundances inside the MNP was apparent for senator wrasse, *P. laticlavius*, but populations increased slightly during the 2011 survey (Figure 3.12c).

Zebrafish *G. zebra* were largely absent from both inside and outside the MNP in 2005, 2006 and 2010, which is inconsistent with baseline observations (Figure 3.12d). Higher abundances in reference sites in 2011, can largely be attributed to large abundances at Cape Patterson (Site 1).

Density of sea sweep *S. aequipinnis* varied over the monitoring period, but with no obvious trend (Figure 3.12e).

The densities of magpie morwong *C. nigripes* were similar inside and outside the MNP at all times and similar temporal fluctuations occurred in both areas. The densities in 2010 and 2011 were relatively low, Low densities were also observed in 1999 and early 2000 (Figure 3.12f).

The density of herring cale *O. cyanomelas* was consistently higher inside the MNP during the baseline period, to 2002, after which average densities were slightly lower and similar to the reference areas (Figure 3.12g). In 2011 *O. cyanomelas* was observed in low abundances in MPA and reference sites (Figure 3.12g).

The densities of scalyfin *P. victoriae* were similar inside and outside the MNP, with similar fluctuations up to 2005. Densities were notably higher than previously observed in the reference areas in 2006, and remained high comparative to the MNP sites in 2010, however were much lower and equivalent with MNP sites in the 2011 survey (Figure 3.12h).
**Amphibolis antarctica Cover**

![Graph showing the cover of Amphibolis antarctica with error bars for MPA and reference areas from 2000 to 2012.]

**Acrocarpia paniculata Cover**

![Graph showing the cover of Acrocarpia paniculata with error bars for MPA and reference areas from 2000 to 2012.]

**Cystophora platylobium Cover**

![Graph showing the cover of Cystophora platylobium with error bars for MPA and reference areas from 2000 to 2012.]

**Figure 3.10.** Percent cover (± standard error) of dominant seagrass and algal species inside and outside the Bunurong Marine National Park.
Figure 3.10 (continued). Percent cover (± standard error) of dominant seagrass and algal species inside and outside the Bunurong Marine National Park.
Figure 3.10 (continued). Percent cover (± standard error) of dominant seagrass and algal species inside and outside the Bunurong Marine National Park.
Figure 3.11. Mean abundance (± standard error) of dominant invertebrate species inside and outside the Bunurong Marine National Park.
Figure 3.11. (continued). Mean abundance (± standard error) of dominant invertebrate species inside and outside the Bunurong Marine National Park.
Figure 3.12. Mean abundance (± standard error) of dominant fish species inside and outside the Bunurong Marine National Park.
Figure 3.12 (continued). Mean abundance (± standard error) of dominant fish species inside and outside the Bunurong Marine National Park.
Figure 3.12 (continued). Mean abundance (± standard error) of dominant fish species inside and outside the Bunurong Marine National Park.
3.2 Ecosystem Components

Habitat and Production
Canopy browns are the dominant functional algae group in the Bunurong area, with average percent cover of between 40 and 80 percent (Figure 3.13a). Since the previous survey in 2010 a slight increase in the cover of crustose coralline algae cover in both MNP and reference areas (Figure 3.13b), a decrease in erect coralline algae in MNP sites, and a decrease in smaller browns in reference sites were recorded (Figure 3.13c and d). Over a larger time scale, percent cover of canopy browns, smaller browns and green algae have remained relatively similar throughout the monitoring period (Figure 3.13a, d and e). Crustose coralline algae has varied considerably between surveys with a significant decrease in both MPA and reference sites in 2006 and subsequent increases in 2010 and 2011 (Figure 3.13b). Since declaration of the park in 2002 there has been a steady increase in the cover of thallose red algae and a corresponding decrease in erect coralline algae cover in MNP sites (Figure 3.13f and c).

Invertebrate Groups
Grazers were the most abundant of the invertebrate functional groups in all surveys (Figure 3.14a). Peaks in the densities of invertebrate grazers and predators occurred prior to the MNP introduction. Densities have since declined and remained relatively constant through several surveys in both reference and MNP sites (Figure 3.14a and b). No trends were detected in the density of invertebrate filter feeders, with low abundances in most surveys (Figure 3.14c). Abundances did increase in the first survey after the MNP declaration, however this was a single occurrence and does not represent an overall trend (Figure 3.14c). Seastar densities in the MNP have been in decline since the 2002 surveys. Seastar densities at reference sites have shown considerably more variability, but an overall decline is evident (Figure 3.14d).

Fish Groups
Fish hunter and fish forager functional groups showed similar interannual variability, being consistent inside and outside the MNP, (Figure 3.15a and b). Fish grazer abundance inside the MNP was consistently lower densities than references sites in surveys after 2005 (Figure 3.15a). Fish planktivores occurred in low abundances in both the MNP and reference sites, spikes in abundance were attributed to large numbers of bullseyes, *Pempheris multiradiata*, at a small number of sites (Figure 3.15d).
Sediment Cover
Sediment cover was not a survey parameter during the first two surveys. No marked changes from baseline surveys occurred until a peak in 2005. In subsequent surveys sediment cover has been similar to those prior to 2005 (Figure 3.16).
Figure 3.13. Seaweed functional groups (± standard error) inside and outside the Bunurong Marine National Park.
Figure 3.13 (continued). Seaweed functional groups (± standard error) inside and outside the Bunurong Marine National Park.
Figure 3.14. Mean abundance (± standard error) of invertebrate functional groups inside and outside the Bunurong Marine National Park.
Figure 3.14 (continued). Mean abundance (± standard error) of invertebrate functional groups inside and outside the Bunurong Marine National Park.
Figure 3.15. Mean abundance (± standard error) of fish functional groups inside and outside the Bunurong Marine National Park.
Figure 3.15 (continued). Mean abundance (± standard error) of fish functional groups inside and outside the Bunurong Marine National Park.

Figure 3.16. Mean cover (± standard error) of sediment inside and outside the Bunurong Marine National Park.

3.3 Introduced Species

No introduced species were observed at the Bunurong monitoring sites during any of the 12 surveys to date.
3.4 Climate Change

Species composition
Cold water, Maugean algal species richness and total abundance is consistently higher in the MNP sites throughout the monitoring period. In the 2011 survey Maugean algal species richness at reference sites was the lowest of the entire monitoring period (Figure 3.17). The Maugean fish species richness and total abundance also decreased in the 2011 survey (Figure 3.18). The occurrence of Maugean invertebrate species was low or absent in all surveys.

The western algal species richness was relatively low, with abundance only varying occasionally throughout the monitoring period, (Figure 3.19). Western invertebrate species richness increased slightly over the previous three surveys, following a decline in the 2003 survey. Abundance of western invertebrates has been consistently low, with the exception of reference sites in 2000 and 2002. Species richness of western invertebrates has been similar in MPA and reference sites following a similar pattern (Figure 3.20). Western fish species richness and abundance were low on all survey occasions, with no discernible trends evident.

The eastern algal species in the Bunurong region were not well represented at any time. Eastern invertebrate species were recorded intermittently in very low densities over the monitoring period. Eastern fish species were observed in low to medium abundances in surveys prior to the park declaration, however have been absent or in very low abundances in subsequent surveys (Figure 3.21).

Macrocystis pyrifera
The string kelp *M. pyrifera* can grow up to 10 m in height and form dense forests with a thick canopy floating on the surface. Consequently, *M. pyrifera* is a significant habitat forming species. Anecdotal evidence suggests *M. pyrifera* was once present in relatively high abundance along the Victorian coast, forming large forests in some locations. Abundances of *M. pyrifera* were reduced for much of this decade. Possible causes of this decline include a rapid succession of El Niño events in the late 1980s and early 1990s (affecting water temperature and nutrient levels), a long-term increase in average sea temperature (1 °C over the last 40 years) and changes to coastal nutrient inputs.

The quadrat-cover measurements detected substantial changes in *M. pyrifera* cover between the first two surveys. During June 1999, coverage was greatest at Cape Patterson (Site 1), Oaks East (Site 3), Twin Reefs (Site 4) and Shack Bay West (Site 5) with coverage of 2.5, 1.6, 0.8 and 1.5 percent respectively. By January 2000, this had increased to 15 % at sites Oaks East and Twin Reefs, with minor increases or decreases detected at other sites. A
general decline in abundance marked the fourth survey, December 2000, with quadrat coverage of 2.2 and 0.5 % detected only at Cape Patterson (Site 1) and Shack Bay Beach (Site 12). *Macrocystis pyrifera* cover has remained low at most sites during subsequent surveys. Exceptions include Oaks East (Site 3), where cover increased to 5.4% at Survey 6 before decreasing to 0.7 % in Survey 7. No *M. pyrifera* was recorded in the quadrat-cover measurements during Surveys 8 and 9. Low percentage cover was recorded during Survey 11 in 2010 at Cape Patterson (Site 1), Shack Bay Beach (Site 12), The Oaks Beach (Site 14) and Boat Ramp East (Site 15), with 0.9, 0.2, 0.3 and 1.4 % cover respectively (Figure 3.23a). Low percentage cover was also recorded during Survey 12 in 2011 at Twin Reefs (Site 4) and Shack Bay Beach (Site 12) with 0.3 and 0.2% cover respectively (Figure 3.22a).

The quadrat-cover method is generally insensitive in detecting small changes in abundances of sparsely distributed species, such as *M. Pyrifera* plants. Therefore, given the importance of this species, a new census technique was introduced during the second survey, summer 2000. As described in Section 2.2.6, this method quantified the number of plants within 10 m sections of the transects.

The quadrat results were also reflected in the plant density measurements. Densities were highest during the first survey using this method, January 2000 (Figure 3.22b). Abundances have tended to decline or remain low during all subsequent surveys (Figure 3.22b). During Survey 7, only 25 plants were observed, all being at The Oaks Beach (Site 14). This decline continued with few plants observed during the eighth survey (Autumn 2003) and no plants observed during the ninth survey (Summer 2004/2005). During the tenth survey (Autumn 2006), four to five plants were observed at Cape Patterson (Site 1), Cape Patterson Boat Ramp (Site 2), Twin Reefs (Site 4) and Shack Bay West (Site 5) during quadrat-cover measurements, however these plants were juveniles and undetectable during plant density measurements. During the eleventh survey plants were recorded at only three sites. One plant was recorded at Oaks East (Site 3) and eleven at both Cape Patterson (Site 1) and The Oaks Beach (Site 14). In the twelfth survey, juvenile plants were also recorded at three sites. Fourteen plants were recorded at Twin Reefs (Site 4), eight plants at Shack Bay Beach (Site 12), and nine plants at The Oaks Beach (Site 14). Over the twelve years surveyed, this represents a major decrease in *M. pyrifera* at the Bunurong Marine National Park and surrounding area, a trend reflected in many other subtidal reefs along the south east Australian coast (Figure 3.22b).

*Centrostephanus rodgersii*

*Centrostephanus rodgersii* was not recorded in any of the 12 Bunurong surveys.
**Durvillaea potatorum**

*Durvillaea potatorum* was not recorded in any of the 12 Bunurong surveys.
Figure 3.17. Abundance (± standard error) of Maugean algae species inside and outside the Bunurong Marine National Park.
Figure 3.18. Abundance (± standard error) of Maugean fish species inside and outside the Bunurong Marine National Park.
Figure 3.19. Abundance (± standard error) of western algae species inside and outside the Bunurong Marine National Park.
Figure 3.20. Abundance (± standard error) of western invertebrate species inside and outside the Bunurong Marine National Park.
Figure 3.21. Abundance (± standard error) of eastern fish species inside and outside the Bunurong Marine National Park.
Figure 3.22. Abundance (± standard error) of string kelp *Macrocystis pyrifera* inside and outside the Bunurong Marine National Park.
3.5 Fishing

Abalone
The average size of blacklip abalone, *H. rubra*, was similar between the Bunurong MNP and the reference areas during most surveys prior to 2006, with variations in mean size generally less than 5 mm length (Figure 3.23a). A marked decrease in mean size of *H. rubra* was measured both inside and outside the MNP between 2006 and 2011, with mean size falling to well below previously observed sizes (Figure 3.23a). The proportion of legal sized abalone has also declined during this period to lowest observed levels, both inside and outside the MNP (Figure 3.24). Although a decline was also evident in MNP sites the scale of decline, and low abundances (Figure 3.23b), suggests an increased in fishing pressure in Western reference sites, which may extend into the MNP, to a lesser extent.

Rock Lobster
The southern rock lobster *J. edwardsii* is common inside the MNP, however the survey sites do not encompass their preferred microhabitat and do therefore do not adequately survey their abundances (Figure 3.25).

Fishess
The size spectrum analysis indicates that in reference sites the abundance of larger fishes in 2006 and 2010 were amongst the lowest of all surveys, 2010 was also the lowest for sites within the MNP (Figure 3.26). The biomass and density of fishes above 200 mm length in 2006, 2010 and 2011 is also the lowest of recorded observations inside the MNP. Similarly observations of biomass and density of fishes above 200 mm length at reference sites were low in 2010 and 2011 (Figure 3.27 and Figure 3.28). A decline in size of the larger, fished species, including blue throated wrasse *N. tetricus*, senator wrasse *P. laticlavius* and magpie morwong *C. nigripes* was apparent (Figure 3.29 to Figure 3.31). Mean size of purple wrasse *N. fucicola* was relatively consistent across all surveys, however no *N. fucicola* were observed within MNP sites in 2011 (Figure 3.32).
Figure 3.23. Abundance (± standard error) of different size classes of the blacklip abalone *Haliotis rubra* at Bunurong Marine National Park and reference sites.
Figure 3.24. Proportion of legal sized blacklip abalone, *Haliotis rubra*, inside and outside the Bunurong Marine National Park.

Figure 3.25. Density (± standard error) of southern rock lobster, *Jasus edwardsii*, inside and outside the Bunurong Marine National Park.
Figure 3.26. Fish size spectra inside and outside the Bunurong Marine National Park.
Figure 3.27. Biomass (± standard error) of fished species inside and outside the Bunurong Marine National Park.
Figure 3.28. Density (± standard error) of larger, fished fish species inside and outside the Bunurong Marine National Park.
Figure 3.29. Abundance (± standard error) of different size classes of the blue throat wrasse, *Notolabrus tetricus*, at Bunurong Marine National Park and reference sites.
Figure 3.30. Abundance (± standard error) of different size classes of the senator wrasse, *Pictilabrus laticlavius*, at Bunurong Marine National Park and reference sites.
Figure 3.31. Abundance (± standard error) of different size classes of the magpie morwong, *Cheilodactylus nigripes*, at Bunurong Marine National Park and reference sites.

Figure 3.32. Abundance (± standard error) of different size classes of the purple wrasse, *Notolabrus fucicola*, at Bunurong Marine National Park and reference sites. No *N. fucicola* were found within the MPA in 2011.
4 REFERENCES


5 ACKNOWLEDGEMENTS

This project was initially funded by the Department of Sustainability and Environment and subsequently by Parks Victoria. Supervision was by Dr Steffan Howe. Scientific divers for the last survey included Mr David Donnelly, Mr Shaun Davis, Mr Alistair Smith and Mr Hugh Brown. Field support for the last survey was kindly provided by Mr Pete Walton of T-Cat charters.
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