NUMBER 103

M. Edmunds
March 2017
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First published 2017
Published by Parks Victoria
Level 10, 535 Bourke Street, Melbourne Victoria 3000

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National Library of Australia
Cataloguing-in-publication data
Includes bibliography.
ISSN 1448-4935

Citation
Victorian Subtidal Reef Monitoring Program:
Popes Eye – Port Phillip Heads, January 2015

Matt Edmunds

Australian Marine Ecology Pty. Ltd.
January 2015
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.

This report describes the monitoring of the Popes Eye component of the Port Phillip Heads Marine National Park (MNP). There were 16 surveys, from 1998 to 2015, involving two site, Popes Eye and South Channel Fort.

This report aims to provide:

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

The ongoing monitoring surveys used a standardised procedure along a 200 m line divided into four transects. Each transect was surveyed for:

- abundance and size structure of large fishes;
- abundance of cryptic fishes and benthic invertebrates;
- percentage cover of macroalgae;
- abundance of a string kelp, *Macrocystis pyrifera*, when present; and
- abundance of manufactured debris.

Key observations during the monitoring program were:

- The seaweed community at Popes Eye was stable over time. The community at South Channel fort was comparatively variable and changed significantly over time from the initial monitoring period.
- There was a gradual decline in the abundance of the tufting alga *Cladophora prolifera* at both sites.
There was a decline in the abundance and habitat formation by giant kelp *Macrocystis pyrifera* from the start of the program in 1998 to 2002, after which it was largely absent. This change is attributable to climate change.

Invertebrate abundances were generally low and variable, with the two most abundant species being the feather star *Comanthus trichoptera* and sea urchin *Heliocidaris erythrogramma*.

*Comanthus trichoptera* was generally stable in abundance at both sites.

*Heliocidaris erythrogramma* was consistently low in abundance at Popes Eye and abundances at South Channel Fort declined from 1998 to 2003 and have not been higher since.

Popes Eye is unique in having very high fish abundances and much larger sizes, compared with most monitoring sites throughout Victoria. South Channel Fort is characterised by low abundances of fishes.

There was a marked reduction in abundance of the southern hulafish *Trachinops caudimaculatus* at both sites from 2009 onwards.

The fish assemblage at Popes Eye was highly stable and did not change from the initial monitoring period. The assemblage at South Channel Fort changed considerably from the initial monitoring period, from 2009 onwards, largely attributable to the change in *T. caudimaculatus*.

The scalyfin *Parma victoriae* and magpie morwong *Cheilodactylus nigripes* were stable in abundance over time.

There was a consistent decline in abundance of purple wrasse *Notolabrus fucicola* at Popes Eye from 2006.

There were some unusual fish sightings at South Channel Fort in 2015, including a higher abundance of senator wrasse *Pictilabrus laticlavius* and scalyfin *Parma victoriae*, presence of larger mature little rock whiting *Neoodax balteatus* and a female eastern blue groper *Achoerodus viridis*.

The disappearance of the habitat forming giant kelp *Macrocystis pyrifera* at Popes Eye is attributable to climate change.

There were no other major shifts in community structure attributable to climate change or shifts in species biogeography since the disappearance of the giant kelp *Macrocystis pyrifera*.

There were no marine pest species observed at Popes Eye MPA. The Mediterranean fanworm was observed at South Channel Fort on two occasions.
- There was no manufactured debris observed on the transects at the monitoring sites.
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1 Introduction

1.1 Subtidal Reef Ecosystems of Victoria

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*, Maori 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 *Olisthopscyanomelas*, planktivores such as sea sweep *Scorpi 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.
Common kelp *Ecklonia radiata* canopy

Crayweed *Phyllospora comosa* canopy

Thallose red algae *Ballia callitricha*

Red coralline algae *Jania rosea*

Green alga *Caulerpa flexilis*

Crayweed *P. comosa* holdfast

**Figure 1.1.** Examples of common macroalgae in the Central Victoria bioregion.
Figure 1.2. Examples of reef invertebrate species and cryptic fish in the Central Victoria bioregion.
Sea sweep *Scorpis aequipinnis* and butterfly perch *Caesioperca lepidoptera*

Old wife *Enoplosus armatus*

Scalyfin *Parma victoriae*

Magpie morwong *Cheilodactylus nigripes*

Blue-throat wrasse *Notolabrus tetricus* (male)

Six-spined leatherjacket *Meuschenia freycineti* (male)

**Figure 1.3.** Examples of reef fishes in the Central Victoria 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 among highly protected marine national parks and marine sanctuaries and other Victorian reef areas (e.g. Edgar and Barrett 1997, 1999);
- determine associations among species and among 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 will not exactly 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, recruitment and harvesting), years (e.g. El Niño), decades (e.g. pollution, extreme storm events) or even centuries (e.g. tsunamis, global warming). The 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 procedures have been added to since that publication.

The SRMP was initiated in May 1998 in the vicinity Port Phillip Heads Marine National Park. In 1999 the SRMP was expanded to reefs in the vicinity of the Popes Eye Marine National Park, Phillip Island, Wilsons Promontory Marine National Park and Point Addis Marine National Park.

In 2003 and 2004, the Subtidal Reef Monitoring Program was further extended to include Marine National Parks and Marine Sanctuaries throughout Victoria.

In 2013, the monitoring at the Popes Eye component of the Port Phillip Heads Marine National Park was separated from the Point Nepean and Point Lonsdale monitoring components.

1.3 The Marine Protected Area at Popes Eye

1.3.1 Previous marine protected areas

The Annulus (Popes Eye) was declared a sanctuary in 1979 as part of the Harold Holt Marine Reserves in the Port Phillip Heads region. Under section 79A of the Fisheries Act 1968, on 7 February 1979, all forms of commercial and amateur fishing, and removal of any living or non-living material was prohibited.

In 1998, the Environment Conservation Council provided recommendations on the location of marine protected areas for the Port Phillip Heads Region (ECC 1998). This proposal was based on the existing Harold Holt Marine Reserves and recommended higher levels of protection in all areas. The ECC final proposal (ECC 2000) was subsequently adapted to form the Port Phillip Heads Marine National Park, declared under the National Parks (Amendment) Act 2002, on 16 November 2002. The Marine National Park incorporates the five locations previously protected as the Harold Holt Marine Reserves – Point Lonsdale, Point Nepean, The Annulus (Popes Eye), Mud Islands, Swan Bay and also includes a new location – Portsea Hole.

The Annulus (Popes Eye)

The Annulus is an artificial reef, originally constructed in the 1880s as a breakwater for a semi-submerged ship-fortress, to protect the entrance of Port Phillip Bay. The artificial reef consists of a semi-circular ring of large basalt blocks, near the Popes Eye Beacon. The reef
is approximately 200 m long by 15 m wide, dropping steeply to sand bottom approximately 10 m deep. It acts as a seal haul-out and supports a significant breeding colony of Australasian gannets *Morus serrator*.

**South Channel Fort**

South Channel Fort is also an artificial structure established in the 1880s to protect the entrance of Port Phillip Bay. The reef consists of basalt boulders on an existing sandy shoal. The island structure is 120 m long by 76 m wide, dropping to a sand bottom of between 2 and 13 m deep. The fort is home to a breeding colony of white-faced storm petrels *Pelagodroma marina*, as well as little penguins *Eudyptula minor*, silver gulls *Larus novaehollandiae* and the short-tailed shearwater *Puffinus tenuirostris*. A jetty on the western side of the island was demolished and replaced in the late 1990s, with reconstruction and rock revetment work completed by summer 2000. The jetty construction did not appear to affect the average abundance of most common plant and animal species at this site (Gilmour *et al.*, 2007). The above water area is protected as part of the Mornington Peninsula National Park and is listed on the Register of the National Estate for its environmental values.

### 1.4 Monitoring at Popes Eye

This report describes the subtidal reef monitoring program in Popes Eye and the results of the 13 surveys, incorporating Popes Eye Marine National Park and the adjacent Eastern and Western Conservation Zones. The objectives of this report were to:

1. provide an overview of the methods used for the SRMP;
2. provide general descriptions of the biological communities and species populations at each monitoring site over the monitoring period;
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.
2 Methods

2.1 Site Selection and Survey Times

Monitoring sites were established on the southern side of the reef at Popes Eye (Site 12; Figure 2.1) and at South Channel Fort (Site 4; Figure 2.1). The sites were located on representative subtidal reef habitat in each area.

Sixteen surveys were completed at Popes Eye and South Channel Fort since the SRMP began in 1998 (Table 2.2). The first fourteen surveys were completed as part of the Port Phillip Heads component of the SRMP. This was done because of the unique nature of the habitat and communities present at Popes Eye and the increased conservational significance of the site due to its high visitation and marine life abundance.
Figure 2.1. Port Phillip Heads Marine National Park (shaded areas) and the positions of long-term monitoring sites (red dots). Site numbers are also indicated.
### Table 2.1. Subtidal reef monitoring sites for the Popes Eye component of Port Phillip Heads Marine National Park.

<table>
<thead>
<tr>
<th>Region</th>
<th>No.</th>
<th>Description</th>
<th>Status</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Popes Eye</td>
<td>2812</td>
<td>Annulus (Popes Eye)</td>
<td>MPA</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>2804</td>
<td>South Channel Fort</td>
<td>Reference</td>
<td>2</td>
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### Table 2.2. Subtidal reef monitoring survey times in Port Phillip Heads.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Date</th>
<th>Sites</th>
</tr>
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</tr>
<tr>
<td>2</td>
<td>September - October 1998</td>
<td>2801; 2802; 2803; 2804; 2805; 2806; 2807; 2808; 2809; 2810; 2811; 2812; 2813; 2814; 2815.</td>
</tr>
<tr>
<td>3</td>
<td>May - July 1999</td>
<td>2801; 2802; 2803; 2804; 2805; 2806; 2807; 2808; 2809; 2810; 2811; 2812; 2813; 2814; 2815.</td>
</tr>
<tr>
<td>4</td>
<td>October - November 1999</td>
<td>2801; 2802; 2803; 2804; 2805; 2806; 2807; 2808; 2809; 2810; 2811; 2812; 2813; 2814; 2815.</td>
</tr>
<tr>
<td>5</td>
<td>May - August 2000</td>
<td>2801; 2802; 2803; 2804; 2805; 2806; 2807; 2808; 2809; 2810; 2811; 2812; 2813; 2814; 2815.</td>
</tr>
<tr>
<td>6</td>
<td>November 2000 - January 2001</td>
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</tr>
<tr>
<td>7</td>
<td>June - July 2001</td>
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</tr>
<tr>
<td>8</td>
<td>January 2002</td>
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</tr>
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<td>9</td>
<td>January 2003</td>
<td>2801; 2802; 2803; 2804; 2805; 2806; 2807; 2808; 2809; 2810; 2811; 2812; 2813; 2814; 2815.</td>
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<tr>
<td>10</td>
<td>July 2004</td>
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<tr>
<td>11</td>
<td>December 2004</td>
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<td>12</td>
<td>May - June 2006</td>
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<tr>
<td>13</td>
<td>May - June 2009</td>
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<tr>
<td>14</td>
<td>July 2011</td>
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<tr>
<td>15</td>
<td>May 2013</td>
<td>2804; 2812</td>
</tr>
<tr>
<td>16</td>
<td>February 2015</td>
<td>2804; 2812</td>
</tr>
</tbody>
</table>
2.2 Census Method

2.2.1 General Description

The Edgar-Barrett methods (Edgar and Barrett 1997, 1999; Edgar et al. 1997) are used for the repeated visual census of a set of sites within locations (usually within 10s km of the coastline). The position of each site is fixed, as with the position of transects surveyed within each site. Two hundred metres of four contiguous 50 m transects are surveys at each site. In accordance with the new Reef Life Survey methods data are now recorded for each side of the transect, termed ‘blocks’.

Where possible, sampling was along the 5 m (± 1 m) depth contour, to minimise spatial variability between sites. The depth of 5 m was considered optimal for monitoring because diving times are not limited by decompression schedules and these reefs are subjected to heavy fishing pressure from wrasse fishers, rock lobster fishers and divers. Sampling at some sites had to be deeper or shallower, depending on the available habitat and exposure to wave action (with sites ranging from 2 to 12 m deep).

Each site was located using GPS and numbered and weighted transect lines were run along the appropriate depth contour. The resulting 200 m of line was divided into four contiguous 50 m transects (T1 to T4). The orientation of the transects was the same for every survey, with T1 toward the north or east along the coast (i.e. anticlockwise along the open coast: T1 is in the direction of “land-to-the-left”).

For each transect, five different census methods were used to obtain adequate descriptive information on reef communities at different spatial scales. These involved the census of:

- the abundance and size structure of large fishes (Method 1);
- the abundance of cryptic fishes and benthic invertebrates (Method 2);
- the percent cover of macro algae (Method 3);
- the density of string-kelp *Macrocystis* plants (Method 4); and
- the abundance and size structure of mobile fishes using a diver-operated stereo video system, DOVS (Method 5).

The depth, horizontal visibility, sea state and cloud cover are recorded for each site. Horizontal visibility was gauged by the distance along the transect line to detect a 100 mm long fish (female wrasse). All field observations are recorded on underwater paper. The DOVS method records observations to a calibrated stereo video pairs.

2.2.2 Method 1 – Mobile Fishes and Cephalopods

The densities of mobile large fishes and cephalopods were estimated by a diver swimming up one side of the 50 m transect (5 m wide x 5 m high x 50 m long block). The observer recorded the number and estimated size-class of fish, within 5 m of each side of the line (50 x 10 m area). The size-classes for fish are 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 375, 400, 500, 625, 750, 875 and 1000+ mm. 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 monacanths. A total of four 50 m transects (two blocks per transect) were censused for mobile fish at each site. Dominant fish species observed in the Central Victorian Bioregion are listed in Table 2.3.

### 2.2.3 Method 2 – Invertebrates and Cryptic Fishes

Cryptic fishes and mega faunal invertebrates (non-sessile: 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 transects). The diver had a known arm-length to chest measurement to standardise the 1 m distance. The maximum length of abalone and the carapace length and sex of rock lobsters were measured *in situ* using Vernier calliper, where possible. Some sites were designated abalone size monitoring sites (‘Ab100’ sites) and a minimum of 100 abalone were measured at these sites (where possible within diving limits). Sessile animals were not counted with the exception of any marine pest species of pre-determined ecological interest (such as the introduced feather worm *Sabella spallanzanii* and the native feather worm at Point Hicks *Sabellastarte australis*).

Selected specimens were collected for identification and preservation in a reference collection. Dominant cryptic fish and invertebrate species in the Central Victorian Bioregion are listed in Table 2.4.

### 2.2.4 Method 2b – Manufactured Debris

Manufactured debris items were counted along the invertebrate transect. The debris were classified into categories: fishing gear; plastic; cloth; metal; glass; wood; other and none (to indicate it was looked for but none seen). It was also recorded whether the debris was left or removed.

### 2.2.5 Method 3 – Macroalgae

The abundance of macrophytes (kelp, seaweeds, and seagrass) was quantified using a points-cover method. A quadrat, 0.5 m x 0.5 m, was placed at 10 m intervals along the transect line (5 quadrats per transect). The quadrat was divided into a grid of 7 x 7 perpendicular lines, giving 50 points (including one corner). Cover was estimated by counting the number of points intersecting with a species (Figure 2.2). The points-cover was determined independently for each species. Where there was a canopy or layers, the total number of points-counts from all species may be greater than 50. Selected specimens were collected for identification and preservation in a reference collection. Dominant macrophyte species in the Central Victorian Bioregion are listed in Table 2.6.
2.2.6 Method 4 – Macrocystis

Where present, the density of string kelp *Macrocystis pyrifera* was estimated at the same time by the seaweed (Method 3) observer. While swimming between quadrat positions, the diver counted all observable *Macrocystis* plants within 5 m either side of the transect for each 10 m section of the transect (10 x 10 m sections). This survey component commenced in spring 1999.

*Figure 2.2.* 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 alongside the diver UVC fish surveys. The videos were Canon HG21 handycams recording in 1080p format. The cameras were calibrated before and after each 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 simultaneously by the diver who did the UVC fish and done at the same time. 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 and downward 30° with the diver swimming 2.5 m to one side of the transect and 1.3 m above the canopy, as with the UVC method. The camera unit was tilted vertically (up or down) according to the fish seen to ensure adequate video for size measurements, but was generally tilted down at an angle of 30°. Lateral movement of the unit was minimised. The survey speed was 10 m per minute (0.17 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.
2.2.8 Method 0 – Off-Transect Sightings

Any species of interest sighted off-transect, or on transect but not during the formal survey, was recorded with the designation of Method 0 and Transect 0. Note that additional off transect abalone measurements were recorded as Method 2, Transect 0.

Table 2.3. Mobile fishes and cephalopods (Method 1) taxa commonly censused in the Central Victoria 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 vlamlinghii</td>
<td>Odax acroptilus</td>
</tr>
<tr>
<td>Sepia apama</td>
<td>Girella tricuspidata</td>
<td>Olisthops cyanomelas</td>
</tr>
<tr>
<td>Sepioteuthis australis</td>
<td>Girella elevata</td>
<td>Siphonognathus attenuatus</td>
</tr>
<tr>
<td>Sharks and Rays</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterodontus portusjacksoni</td>
<td>Scorpis aequipinnis</td>
<td>Siphonognathus radiatus</td>
</tr>
<tr>
<td>Parascyllium variolatum</td>
<td>Scorpis lineolata</td>
<td>Neodax balteatus</td>
</tr>
<tr>
<td>Cephaloscyllium laticeps</td>
<td>Atychthys strigatus</td>
<td>Acanthaleurbes vittiger</td>
</tr>
<tr>
<td>Trygonorrhina fasciata</td>
<td>Tilodon sexfasciatus</td>
<td>Brachaleurbes jacksonianus</td>
</tr>
<tr>
<td>Trygonorrhina guaniera</td>
<td>Enoplosus armatus</td>
<td>Monacanthus chinesis</td>
</tr>
<tr>
<td>Dasyatis brevicaudata</td>
<td>Pentaceropsis recurvirostris</td>
<td>Scobinichthys granulatus</td>
</tr>
<tr>
<td>Myliobatis australis</td>
<td>Parma victoriae</td>
<td>Meuschenia flavolineata</td>
</tr>
<tr>
<td>Urolophus cruciatris</td>
<td>Parma microlepis</td>
<td>Meuschenia freycineti</td>
</tr>
<tr>
<td>Urolophus paucimaculatus</td>
<td>Chromis hypsilepis</td>
<td>Meuschenia gali</td>
</tr>
<tr>
<td>Urolophus gigas</td>
<td>Aplodactylus arctidens</td>
<td>Meuschenia hippocrepis</td>
</tr>
<tr>
<td>Trygonoptera testacea</td>
<td>Cheilodactylus nigripes</td>
<td>Meuschenia scaber</td>
</tr>
<tr>
<td>Mobile Bony Fishes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phyllopteryx taeniolatus</td>
<td>Nemadactylus douglasii</td>
<td>Eubalichthys gunni</td>
</tr>
<tr>
<td>Caesioperca lepidoptera</td>
<td>Dactylophora nigricans</td>
<td>Eubalichthys mosaicus</td>
</tr>
<tr>
<td>Caesioperca rasor</td>
<td>Latridopsis forsteri</td>
<td>Aracana aurita</td>
</tr>
<tr>
<td>Hypopectrodes maccullochi</td>
<td>Scorpaeana papillosa</td>
<td>Aracana ornata</td>
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<tr>
<td>Trachinops caudimaculatus</td>
<td>Sphyraena novaehollandiae</td>
<td>Tetractenos glaber</td>
</tr>
<tr>
<td>Dinolestes lewini</td>
<td>Achoerodus gouldii</td>
<td>Diodon nichthemerus</td>
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<tr>
<td>Sillaginodes punctata</td>
<td>Ophthalmotrichina lineolata</td>
<td>Contusus brevicaudus</td>
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<tr>
<td>Pseudocaranx wrighti</td>
<td>Dotalabrus aurantiacus</td>
<td></td>
</tr>
<tr>
<td>Trachurus novaezelandiae</td>
<td>Notolabrus tetricus</td>
<td></td>
</tr>
<tr>
<td>Trachurus declivis</td>
<td>Notolabrus fucicola</td>
<td></td>
</tr>
<tr>
<td>Arripis spp</td>
<td>Pseudolabrus rubicundus</td>
<td></td>
</tr>
<tr>
<td>Arripis georgianus</td>
<td>Pictilabrus laticlavius</td>
<td>Mammals and Reptiles</td>
</tr>
<tr>
<td>Pagrus auratus</td>
<td>Arctocephalus pusillus</td>
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</tr>
</tbody>
</table>
### Table 2.4. Invertebrate and cryptic fish (Method 2) taxa commonly censused in the Central Victoria Bioregion.

<table>
<thead>
<tr>
<th>Molluscs</th>
<th>Crustacea</th>
<th>Echinoderms</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Haliotis rubra</em></td>
<td><em>Jasus edwardsii</em></td>
<td><em>Comanthus trichoptera</em></td>
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<tr>
<td><em>Haliotis laevigata</em></td>
<td><em>Guinnesia chabrus</em></td>
<td><em>Comanthus tasmaniae</em></td>
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<tr>
<td><em>Haliotis scalaris</em></td>
<td><em>Nectocarcinus tuberculosus</em></td>
<td><em>Heliocidaris erythrogramma</em></td>
</tr>
<tr>
<td><em>Scutus antipodes</em></td>
<td><em>Pagonistes frontalis</em></td>
<td><em>Goniocidaris tubaria</em></td>
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<tr>
<td><em>Turbo undulatus</em></td>
<td><em>Strigopagrus strigimanus</em></td>
<td><em>Amblypneustes spp</em></td>
</tr>
<tr>
<td><em>Phasianella australis</em></td>
<td><em>Paguridae spp (other)</em></td>
<td><em>Holopneustes inflatus</em></td>
</tr>
<tr>
<td><em>Phasianella ventricosa</em></td>
<td><strong>Cryptic Fishes</strong></td>
<td><em>Holopneustes porosissimus</em></td>
</tr>
<tr>
<td><em>Phasianella ventricosa</em></td>
<td><em>Gymnothorax prasinus</em></td>
<td><em>Holopneustes purpurascens</em></td>
</tr>
<tr>
<td><em>Phasinotrochus eximius</em></td>
<td><em>Pempheris multiradiata</em></td>
<td><em>Tosia magnifica</em></td>
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<tr>
<td><em>Dicathais orbita</em></td>
<td><em>Gnathanacanthus goetzeei</em></td>
<td><em>Tosia australis</em></td>
</tr>
<tr>
<td><em>Australaria australasia</em></td>
<td><em>Aetapclus maculatus</em></td>
<td><em>Pentagonaster dubeni</em></td>
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<tr>
<td><em>Penion mandarinus</em></td>
<td><em>Parascyllium variolatum</em></td>
<td><em>Petricia vernicina</em></td>
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<tr>
<td><em>Cabestana spengleri</em></td>
<td><em>Bovichtus angustifrons</em></td>
<td><em>Fromia polypora</em></td>
</tr>
<tr>
<td><em>Charonia lampas</em></td>
<td><em>Crusticeps australis</em></td>
<td><em>Echinaster arctystatus</em></td>
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<td><em>Conus anemone</em></td>
<td><em>Heteroclinus johnstoni</em></td>
<td><em>Plectaster decanus</em></td>
</tr>
<tr>
<td><em>Neodoris chrysoderma</em></td>
<td><em>Clinid spp</em></td>
<td><em>Nectria macrobrachia</em></td>
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<td><em>Ceratosoma brevicaudatum</em></td>
<td><em>Norfolkia clarkei</em></td>
<td><em>Nectria ocellata</em></td>
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<tr>
<td><em>Mimachlamys asperrima</em></td>
<td><em>Forsterygion varium</em></td>
<td><em>Nectria multispina</em></td>
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<tr>
<td><em>Octopus maorum</em></td>
<td><em>Paraplesiops meleagris</em></td>
<td><em>Pseudonepanthia troughtoni</em></td>
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<tr>
<td><strong>Cnidaria</strong></td>
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<td></td>
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<tr>
<td><em>Phylactenactis tuberculosa</em></td>
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<td><em>Meridiastra gunnii</em></td>
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<tr>
<td><strong>Annelida</strong></td>
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<td><em>Uniophora granifera</em></td>
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<tr>
<td><em>Sabella spallanzanii</em></td>
<td></td>
<td><em>Coscinasterias murecata</em></td>
</tr>
<tr>
<td>****</td>
<td></td>
<td><em>Asterias amurensis</em></td>
</tr>
</tbody>
</table>

### Table 2.5. Manufactured debris (Method 2b) censused in the Central Victoria Bioregion.

<table>
<thead>
<tr>
<th>Method 2</th>
<th>Fishing gear</th>
<th>Metal</th>
<th>Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>Cloth</td>
<td>Wood</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.6. Common macroalgae and seagrass (Method 3) taxa censused in the Central Victoria Bioregion.

<table>
<thead>
<tr>
<th>Chlorophyta (green algae)</th>
<th>Chromista (brown algae)</th>
<th>Chromista (brown algae)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulva spp</td>
<td>Homeostrichus sinclairii</td>
<td>Sargassum spinuligerum</td>
</tr>
<tr>
<td>Cladophora prolifera</td>
<td>Exallosorus olsenii</td>
<td>Sargassum varians</td>
</tr>
<tr>
<td>Apjohnia lativaerens</td>
<td>Chlanidophora microphylla</td>
<td>Sargassum verruculosum</td>
</tr>
<tr>
<td>Caulerpa longifolia</td>
<td>Cladostephus spongiosus</td>
<td>Sargassum vestitum</td>
</tr>
<tr>
<td>Caulerpa trifaria</td>
<td>Carpomitra costata</td>
<td>Ectocarpus spp</td>
</tr>
<tr>
<td>Caulerpa scalpelliformis</td>
<td>Perithalia cordata</td>
<td>Rhodophyta (red algae)</td>
</tr>
<tr>
<td>Caulerpa remotifolia</td>
<td>Bellotia eriophorum</td>
<td>Pterocladilalia capillacea</td>
</tr>
<tr>
<td>Caulerpa brownii</td>
<td>Macroystis pyrfera</td>
<td>Pterocladia lucida</td>
</tr>
<tr>
<td>Caulerpa flexilis var muelleri</td>
<td>Undaria pinnatifida</td>
<td>Gelidium australis</td>
</tr>
<tr>
<td>Caulerpa obscura</td>
<td>Durvillaea potatorum</td>
<td>Sonderophyce coriaceus</td>
</tr>
<tr>
<td>Caulerpa sedioides f. 1. geminata</td>
<td>Xiphophora chondrophylla</td>
<td>Peyssonnelia sp</td>
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<tr>
<td>Caulerpa cactoides</td>
<td>Phyllospora comosa</td>
<td>Areschougia congesta</td>
</tr>
<tr>
<td>Caulerpa hodgkinsoniae</td>
<td>Seirococcus axilares</td>
<td>Acrotylus australis</td>
</tr>
<tr>
<td>Caulerpa vesiculifera</td>
<td>Scaberia agardhii</td>
<td>Nizymenia australis</td>
</tr>
<tr>
<td>Caulerpa simpliciuscula</td>
<td>Carpoglossum confluens</td>
<td>Polyopes constrictus</td>
</tr>
<tr>
<td>Codium pomoides</td>
<td>Cystophora brownii</td>
<td>Erythroclonium spp</td>
</tr>
<tr>
<td>Codium spongiosum</td>
<td>Cystophora expansa</td>
<td>Solieria robusta</td>
</tr>
<tr>
<td>Codium australicum</td>
<td>Cystophora grevillei</td>
<td>Thamnoclonium dichotomum</td>
</tr>
<tr>
<td>Codium duthieae</td>
<td>Cystophora monilifera</td>
<td>Callophyllis rangiferina</td>
</tr>
<tr>
<td>Codium galeatum</td>
<td>Cystophora moniliformis</td>
<td>Stenogramme interrupta</td>
</tr>
<tr>
<td>Codium harveyi</td>
<td>Cystophora pectinata</td>
<td>Callophyllus laxus</td>
</tr>
<tr>
<td>Codium lucasii</td>
<td>Cystophora platylodium</td>
<td>Plocamium angustum</td>
</tr>
</tbody>
</table>

**Chromista (brown algae)**

Cystophora retorta | P. cirrhosum
Halloptera spp | Cystophora siliquosa | P. mertensis

**Dictyota**

Dictyota dichotoma | Cystophora retroflexa | P. dilatatum
Dictyota fastigiata | Cystophora subfarcinata | P. preissianum
Dictyota fenestrata | Cystophora xiphocarpa | P. cartilageum
Dictyota gunniana | Caulocystis cephalornithos | P. leptophyllum

**Dictyopteris**

Dictyopteris Muelleri | Acrocarpia paniculata | P. patagiatum

**Dictyopteris acrostichoides**

Sargassum decipiens | Phacelocarpus alatus

**Zonaria**

Zonaria angustata | Sargassum fallax | Phacelocarpus complanatus
Zonaria crenata | Sargassum heteromorphum | Phacelocarpus peperocarpus
Zonaria spiralis | Sargassum sonderi | Asparagopsis armata
Zonaria turneriana | Sargassum decipiens | Delisea pulchra
### Table 2.6 (continued). Common macroalgae and seagrass (Method 3) taxa censused in the Central Victoria Bioregion.

<table>
<thead>
<tr>
<th>Method 3</th>
<th>Rhodophyta (red algae)</th>
<th>Rhodophyta (red algae)</th>
<th>Rhodophyta (red algae)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ptilonia australis</em></td>
<td><em>Halopeltis australis</em></td>
<td><em>Gelania ulvoidea</em></td>
<td></td>
</tr>
<tr>
<td><em>Gracilaria cliftonii</em></td>
<td><em>Tylotus obtusatus</em></td>
<td><em>Echinothamnion hystrix</em></td>
<td></td>
</tr>
<tr>
<td><em>Curdiea angustata</em></td>
<td><em>Champia spp</em></td>
<td><em>Hypnea ramentacea</em></td>
<td></td>
</tr>
<tr>
<td><em>Melanthalia obtusata</em></td>
<td><em>Champia viridis</em></td>
<td><em>Thuretia quercifolia</em></td>
<td></td>
</tr>
<tr>
<td><em>Melanthalia abscissa</em></td>
<td><em>Ceramium spp</em></td>
<td>Other thallose red algae</td>
<td></td>
</tr>
<tr>
<td><em>Melanthalia fastigiata</em></td>
<td><em>Euptilota articulata</em></td>
<td>Filamentous red algae</td>
<td></td>
</tr>
<tr>
<td><em>Amphiroa anceps</em></td>
<td><em>Griffithsia monilis</em></td>
<td><strong>Tracheophyta (seagrass)</strong></td>
<td></td>
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2.3 Data Analysis – Condition indicators

2.3.1 Approach

Reef quality indicators were developed to encompass key features of MNP 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 (Rapport et al. 1995).

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).

Count data were log transformed and points-cover values were not transformed prior to multivariate analyses.

For fishes, only site-attached species were included in the analyses.

The multi-dimensional information in the dissimilarity matrix was simplified and depicted using non-metric multidimensional scaling (nMDS; Clarke 1993). This ordination method finds the representation in fewer dimensions that best depicts the actual patterns in the hyper-dimensional data (reduces the number of dimensions while depicting the salient relationships between the samples). The nMDS results were then depicted graphically to show differences between the sample periods at each location. The distance between points on the nMDS 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 little 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 are applied for the SRMP, the first being the deviation in community structure at a time $t$ from the centroid of baseline community structures (1998 to 2002). This criterion is more sensitive to the detection of gradual changes over time away from the baseline conditions. In this case, there was no before-period because the no-take zone was already established. The first five surveys were used as a baseline period to detect longer term deviations. The second criterion was the deviation in community structure at time
to the centroid of all previous times. This criterion is more sensitive at detecting abrupt or pulse changes.

Control charts were prepared for each site. The control chart 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 and 95th percentile statistic was calculated from 1000 bootstrap samples as provisional limits. 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 densities 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*.

**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 abundances 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:

• cold water 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 cold water,
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* were plotted using densities from Method 4, or
cover estimates from Method 4 where density data were unavailable. *Macrocystis 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 geographical 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 extent of urchin barrens, of any sea urchin species, will be monitored using data from Method 6, as time series data become available. 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 cold water 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 harvesting pressure on abalone were mean density, mean size and the size frequency structure. The size structure indicators were the intercept and slope of the size spectrum. Size frequencies were first compiled for 10 mm size classes centred at 105, 115, 125, 135, 145, 155 and 165 mm and the spectrum slope and intercept was determined by a linear regression of ln(count + 1) versus ln(size + 1). 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. The monitoring transects generally did not traverse rock lobster microhabitats. Abundances and sizes were reported where data were available.

**Fish**

Potential fishing impacts or recovery of fishing impacts within marine protected areas were indicated by:
- abundances of selected fished species;
- mean size of selected fished species;
- total biomass of fished fish species and the portion of biomass > 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-spectrum of fished species.

The size structure indicators were the intercept and slope of the size spectrum. Size frequencies were first compiled for 50 mm size classes centred at 100, 150, 200, 250, 300, 350, 400, 450, 500 and 550 mm and the spectrum slope and intercept was determined by a linear regression of \( \ln(\text{count} + 1) \) versus \( \ln(\text{size} + 1) \).

Biomass was calculated for the predominantly fished species, excluding incidentally caught or by-catch species. Lengths were converted to weights using published conversion factors for the power relationship:

\[
\text{weight (grams)} = a \times \text{Length (cm)}^b
\]

The weight estimations used the coefficients compiled by FishBase (www.fishbase.org). The length-weight parameters used are provided in Table 2.7.
Table 2.7. Fish length-weight conversion parameters used to calculate the biomass of fished species. Where parameters were unavailable, parameters for a similar species were applied.

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<th>b</th>
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3 Results

3.1 Macroalgae

3.1.1 Macroalgal Community Structure

The canopy at Popes Eye was predominantly composed of the common kelp *Ecklonia radiata*. The understorey consisted of low abundances of small browns such as *Halopteris* spp and thallose red algae such as *Plocamium angustum* and *Pterocladiella capillacea*. The green algae *Cladophora prolifera* and *Caulerpa brownii* were a prevalent component of the algal assemblage in most surveys. The assemblage at Popes Eye includes small (≈ 0.5 m) patches of turfing algae, including finer thallose red algae, at the entrance to crevices occupied by scalyfin *Parma victoriae*. These fish maintain the assemblage structure of these patches by weeding out undesired algae. These patches are also maintained by the foraging of other fishes such as magpie morwong *Cheilodactylus nigripes*.

At South Channel Fort, the algal canopy consisted of a mix of *Sargassum* species (most notably *S. spinuligerum* and *S. decipiens*), *Caulocystis cephalornithos* and *E. radiata*. The green algae *Cladophora prolifera*, *Caulerpa brownii* and *Caulerpa flexilis* were also important components of the algal assemblage at this site.

Although the Popes Eye and South Channel Fort sites have similar dominant algal species, including *Ecklonia radiata* and *Cladophora prolifera*, the MDS indicated the composition was non-overlapping in time and South Channel Fort had much greater variation between surveys (Figure 3.1).

The multivariate control charts indicated that the community composition at Popes Eye varied little over time from the baseline period (set arbitrarily as the first five surveys (Figure 3.2a) and that there were rapid changes from survey-to-survey (Figure 3.2b). Conversely, the South Channel Fort assemblage varied considerably from survey-to-survey, but was not significantly different from the baseline period in 2015 (Figure 3.2).

3.1.2 Macroalgal Species Richness and Diversity

The total algal abundance index did not change markedly during the survey period for both sites. For South Channel Fort, there was a spike in cover in October 1998 and a dip in cover in 2015 (Figure 3.3a). Algal species richness was relatively high at both sites from 2003 to 2015 (Figure 3.3b). Algal diversity varied considerably over time at South Channel Fort and was low and stable throughout the monitoring at Popes Eye (Figure 3.3c).
3.1.3 Common Algal Species

The giant kelp *Macrocystis pyrifera* was present in low abundances in isolated stands at Popes Eye at the start of the monitoring program, but structural habitat provided by this species had essentially disappeared by 2002. Occasional isolated plants were observed since then.

The common kelp *Ecklonia radiata* was the predominant canopy species since 2002, and has changed little since 2002: 50-60 % cover at Popes Eye and 10-30 % cover at South Channel Fort (Figure 3.4a).

There were no trends apparent in other smaller brown algae, including *Sargassum decipiens*, *Sargassum spinuligerum* and *Caulocystis cephalornithos* (Figures 3.4b, 3.4c and 3.4d).

Red algae provided low contributions to the community structure. There slightly higher abundances of the erect coralline alga *Jania rosea* at Popes Eye during 2011, 2013 and 2015 (Figure 3.4f).

The green tufting alga *Cladophora prolifera* is an introduced but low risk species (Hayes *et al.* 2005). It occurred in abundances of 15-30 % during the initial monitoring period to 2001, but has since declined markedly with an abundance of 0-10 % since 2006 (Figure 3.4i).
Figure 3.1. Three-dimensional nMDS plot of algal assemblage structure at Popes Eye. Black filled shapes denote the first survey time. Kruskal stress = 0.08.
Figure 3.2. Control charts of algal assemblage structure in the Popes Eye region.
Figure 3.3. Algal species diversity indicators for MNP and reference sites at Popes Eye MPA.
Figure 3.4. Percent cover of dominant algal species inside and outside the Popes Eye MPA.
Figure 3.4 (continued). Percent cover of dominant algal species inside and outside the Popes Eye MPA.
Figure 3.4 (continued). Percent cover of dominant algal species inside and outside the Popes Eye MPA.
Figure 3.5. Example seaweed assemblage at Popes Eye: *Ecklonia radiata* (right) with *Cystophora monilifera* (left). Popes Eye (Site 2812), 3 February 2015.

Figure 3.6. Example grazed turf patch, maintained by scalyfin *Parma victoriae*. A magpie morwong *Cheilodactylus nigripes* is foraging on the turf patch. Popes Eye (Site 2812), 3 February 2015.
3.2 Invertebrates

3.2.1 Invertebrate Community Structure

The abundances of megafaunal invertebrates were very low at both sites at all times. The assemblage at Popes Eye largely of the sea urchin *Heliocidaris erythrogramma*, the feather star *Comanthus trichoptera*, and the sea star *Tosia australis*. The blacklip abalone *Haliotis rubra* were also present in low abundances. Echinoderms were also the dominant taxa at South Channel Fort, but with a higher abundance of *H. erythrogramma*, and a lower abundance of the feather star *C. trichoptera*. Seastars *Uniophora granifera*, *Coscinasterias muricata* were occasionally present at South Channel Fort but largely absent from Popes Eye.

The invertebrate communities present at Popes Eye and South Channel Fort were distinct from each other, with little overlap over time (Figure 3.7). The relative temporal variation was similar at both sites.

The multivariate control chart indicated both sites did not significantly change from the baseline period for most surveys (Figure 3.8a). Both sites had frequent significant changes from prior-times centroids (Figure 3.8b), however this is largely an artefact of low survey abundances of most species.

3.2.2 Invertebrate Species Richness and Diversity

Although highly variable, the total invertebrate abundance was in the lower range of observed values from 2009 to 2015 (Figure 3.9a).

Invertebrate species richness and diversity had a slight downward trend at Popes Eye from 2011 to 2014 (Figures 3.9b and 3.9c).

3.2.3 Common Invertebrate Species

The abundance of the common feather star had a spike in abundance in 2006, but was otherwise stable in abundance at both sites (Figure 3.10b).

There was a gradual decrease in abundance of the common sea urchin *Heliocidaris erythrogramma* at South Channel Fort from 1998 to 2006, followed by a slight increase to relatively constant abundance, of 15-25 per 50 m², between 2009 and 2015 (Figure 3.10c).
Figure 3.7. Three-dimensional nMDS plot of invertebrate assemblage structure at Popes Eye. Black, filled shapes denote the first survey time. Kruskal stress = 0.09.
Figure 3.8. Control charts of invertebrate assemblage structure at Popes Eye MPA.
**Figure 3.9.** Invertebrate species diversity indicators for MNP and reference sites at Popes Eye.
Figure 3.10. Density of invertebrate species inside and outside the Popes Eye MPA.
Figure 3.10 (continued). Density of invertebrate species inside and outside the Popes Eye MPA.
Figure 3.11. Orange seastar *Nectria ocellata*. Popes Eye (Site 2812), 3 February 2015.

Figure 3.12. Stingaree – a cryptic fish observed during Method 2: probably the sparsely spotted stingaree *Urolophus paucimaculatus*. Popes Eye (Site 2812), 3 February 2015.
3.3 Fishes

3.3.1 Fish Community Structure

The community structure at Popes Eye is unique in having very high fish abundances, species richness and fish sizes. The most common fish species at Popes Eye were the wrasses *Notolabrus tetricus* and *Notolabrus fucicola*, leatherjackets *Meuschenia freycineti, Meuschenia hippocrepis, Meuschenia flavolineata* and *Acanthaluteres vittiger*, sea sweep *Scorps aequipinnis*, southern hulafish *Trachinops caudimaculatus*, herring cale *Olisthops cyanomelas*, magpie morwong *Cheilodactylus nigripes*, old wife *Enoplosus armatus* and scalyfin *Parma victoriae*.

The fish assemblage at South Channel Fort had many of the same species observed at Popes Eye, but in much lower abundances and infrequent occurrences. There were also low abundances of the smooth toadfish *Tetractenos glaber* and the globefish *Diodon nichthemerus* at South Channel Fort.

The nMDS plot indicated substantially greater variation in fish communities over time at South Channel Fort than at Popes Eye (Figure 3.13). This pattern was largely an artefact of the low fish abundance at South Channel Fort, increasing sensitivity to small abundance changes.

The multivariate control charts indicated no major shifts from the baseline period for Popes Eye, with no significant pulse-changes from survey-to-survey (Figure 3.14). At South Channel Fort, there was a progressive shift away from the baseline assemblage, from 2009 to 2015 (Figure 3.14).

3.3.2 Fish Species Richness and Diversity

Total fish abundance was relatively variable at both sites and this was largely because of variations in the abundance of southern hulafish *Trachinops caudimaculatus* (Figure 3.15a).

Species richness was high at Popes Eye, but at the lower range of observed values from 2011 to 2015 (Figure 3.15b).

Fish diversity was relatively stable at both sites from 1998 to 2013, followed by a considerable increase to higher than previously observed in 2015 (Figure 3.15c).

3.3.3 Common Fish Species

There were pulses of barber perch *Caesioperca rasor* present at both sites during the monitoring period, with a pulse appearing to commence in 2013-2015 (Figure 3.16a).

The southern hula fish *Trachinops caudimaculatus* was a distinctive and highly abundant component of the fishes at both sites from 1998 to 2006, however abundances have been very low at both sites from 2011 (Figure 3.16b).
The abundances of scalyfin *Parma victoriae* and magpie morwong *Cheilodactylus nigripes* have been relatively constant at both sites over the monitoring period. One exception was a notable increase in *P. victoriae* abundance at South Channel Fort in 2015 (Figures 3.16d and 3.16e).

There were other unusual observations at South Channel Fort in 2015: large mature little rock whiting *Neodax balteatus*, a female eastern blue Groper *Achoerodus viridis* and much higher abundance of senator wrasse *Pictilabrus laticlavius*.

The abundances of blue throated wrasse *Notolabrus tetricus*, rosy wrasse *Pseudolabrus rubicundus* and horseshoe leatherjacket *Meuschenia hippocrepis* were at the lower end of the observed ranges of abundances in 2013 and 2014 (Figures 3.16f, 3.16g and 3.16k).
**Figure 3.13.** Three-dimensional nMDS plot of fish assemblage structure at Popes Eye. Black, filled shapes denote the first survey time. Kruskal stress = 0.06.
**Figure 3.14.** Control charts of fish assemblage structure at Popes Eye MPA.
Figure 3.15. Fish species diversity indicators for MNP and reference areas at Popes Eye.
Figure 3.16. Density of fish species inside and outside the Popes Eye MPA.
Figure 3.16 (continued). Density of fish species inside and outside the Popes Eye MPA.
Figure 3.16 (continued). Density of fish species inside and outside the Popes Eye MPA.
Figure 3.16 (continued). Density of fish species inside and outside the Popes Eye MPA.
Figure 3.17. Giant cuttlefish *Sepia apama*. Popes Eye (Site 2812), 3 February 2015.
3.4 Ecosystem Functional Components

3.4.1 Habitat and Production

The macrophyte functional groups were predominantly canopy formers, smaller brown algae thallose red algae and green algae. The canopy component was largely stable at both sites from 2002 (Figure 3.18a). The smaller brown algae were at relatively low levels at South Channel Fort in 2013 and 2015 (Figure 3.18b). Thallose red algae was relatively low at both sites in 2015 (Figure 3.18c). Green algae, primarily *Cladophora prolifera* was relatively low in abundance since 20009.

3.4.2 Sediment Cover

Sediment cover is relatively variable at both sites. Sediment cover was relatively high at south Channel fort in 2015 (Figure 3.19).

3.4.3 Invertebrate Groups

The predominant invertebrate groups are grazers and filter feeders, reflecting the abundances of common sea urchin *Heliocidaris erythrogramma* and feather star *Comanthus trichoptera* respectively. As noted above, there has been a considerable decline in grazers at South Channel Fort (Figure 3.20a).

The abundance of seastars was comparatively low in 2015 (3.20d).

3.4.4 Fish Groups

The abundance of fish foragers and fish grazers did not have any notable trends or patterns of change over the monitoring period long term trends over the monitoring period (Figures 3.21a and 3.21b).

There was a notable reduction in planktivores, reflecting abundance changes in the southern hulafish *Trachinops caudimaculatus* (Figure 3.21c).
Figure 3.18. Percent cover of macrophyte functional groups inside and outside the Popes Eye MPA.
Figure 3.18 (continued). Percent cover of macrophyte functional groups inside and outside the Popes Eye MPA.
Figure 3.19. Sediment functional group percent cover inside and outside the Popes Eye MPA.
Figure 3.20. Invertebrate functional group densities inside and outside the Popes Eye MPA
Figure 3.20 (continued). Invertebrate functional group densities inside and outside the Popes Eye MPA.
Figure 3.21. Fish functional group density inside and outside the Popes Eye MPA.
Figure 3.21 (continued). Fish functional group density (± Standard Error) inside and outside the Popes Eye MPA.

Figure 3.22. Density of the introduced Mediterranean fan worm *Sabella spallanzanii* at Popes Eye MPA.
3.5 Introduced Species

The introduced pest Mediterranean fanworm *Sabella spallanzanii* was observed in very low abundance at South Channel Fort in 2000 and 2004, and has not been observed since (Figure 3.22). There were no observations of the Japanese kelp *Undaria pinnatifida*.

3.6 Climate Change

3.6.1 Species composition

There were no distinct changes in species composition of seaweeds or invertebrates reflecting a shift towards warmer water species. There was a reduction in two cold water, Maugan species: giant kelp *Macrocystis pyrifera* and southern hulafish *Trachinops caudimaculatus*.

3.6.2 *Macrocystis pyrifera*

The giant string kelp *Macrocystis pyrifera* once formed small patches of vertical forest structure at Popes Eye. There was a decline in frequency of observation and measured abundance of *M. pyrifera* between 1998 and 2002, with few plants observed subsequently using both the quadrat method (Method 3) and the belt transect method (Method 4; Figure 3.25). This decline occurred concurrently with declines throughout Victoria and Tasmania and is consistent with climate change influences on nutrient supply via cold water influxes.

3.6.3 *Durvillaea potatorum*

The bull kelp *Durvillaea potatorum* is not present at the monitoring sites, being moderately sheltered in exposure.

3.6.4 *Centrostephanus rodgersii*

The long-spined sea urchin *Centrostephanus rodgersii* is an eastern, warmer-water species. Its incursion westward not only indicates changes in climate, but also presents threats in terms of grazing and creating urchin-barren habitat. No *C. rodgersii* was observed during any of the Popes Eye surveys.
Figure 3.23. Abundance and species richness of cold water, Maugean algal species inside and outside the Popes Eye MPA.
Figure 3.24. Abundance and species richness of cold water, Maugean fish species inside and outside the Popes Eye MPA.
Figure 3.25. Abundance of giant kelp *Macrocystis pyrifera* inside and outside Popes Eye MPA using two methods: (a) Method 3 – quadrat points-cover; and (b) Method 4 – density per 10 x 10 m transect section.
3.7 Fishing

3.7.1 Abalone

The abundance of blacklip abalone *H. rubra* was very low at both sites during all surveys.

3.7.2 Rock Lobster

The transects at each monitoring site were largely placed on habitats with few crevices suitable for lobster habitats. One southern rock lobster *Jasus edwardsii* was observed at South Channel Fort in 2002.

3.7.3 Fishes

The biomass of commonly fished fishes was largely represented by the larger size classes, over 200 mm in length, *i.e.* of legal minimum length (Figure 3.26). The biomass of fished species was consistently very high at Popes Eye throughout the monitoring period, however there was a dip in 2011 (Figure 3.26), but this was within normal ranges in 2014 (Figure 3.26).

The fish size spectrum slope indicator (Figure 3.27a) indicated a general decreasing trend of large fish in the size spectrum at Popes Eye, from 1998 to 2011. There was an abrupt reversal of this decline in 2013 and 2014 (Figure 3.27a).

The mean size of blue throated wrasse *Notolabrus tetricus* and six-spined leatherjacket *Meuschenia freycineti* was generally much higher at Popes Eye throughout the monitoring program (Figures 3.28 and 3.29).

The much greater biomass and size of fished species at Popes Eye is strongly indicative there are minimal harvesting pressures in this no-take zone.
Figure 3.26. Total estimated biomass of fished species and estimated biomass of fished species over 200 mm inside and outside the Popes Eye MPA.
Figure 3.27. Size spectrum parameters for fished fish species inside and outside the Popes Eye MPA.
Figure 3.28. Mean size of blue-throat wrasse *Notolabrus tetricus* inside and outside the Popes Eye MPA.

Figure 3.29. Mean size of six-spined leatherjacket *Meuschenia freycineti* inside and outside the Popes Eye MPA.
3.8 Manufactured Debris

The 2015 survey was the first year to include manufactured debris at the Popes Eye monitoring sites. No debris observed at either site.
4 Acknowledgements

This project was initially funded by the Department of Sustainability and Environment (formerly Department of Natural Resources and Environment) and subsequently by Parks Victoria. Supervision was by Dr Steffan Howe.

5 References


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