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Victorian Subtidal Reef Monitoring Program:
The Reef Biota at Point Cooke Marine Sanctuary
May 2013

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Executive Summary

Shallow reef habitat covers extensive areas along the Victorian coast and is 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) on reefs located throughout Victoria. 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 Point Cooke Marine Sanctuary and reference site RAAF Base, involving six surveys from 2004 to 2013. The monitoring uses standardised underwater visual census methods to a depth of 4m.

This report aims to provide:

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

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

- abundance and size structure of large fishes;
- abundance of cryptic fishes and benthic invertebrates;
- sea urchin barren coverage (if present);
- density of sea urchins within any barrens; and
- percentage cover of macroalgae.
Key observations during the monitoring program were as follows.

- There was a fundamental shift from a kelp/green algal dominated community to a sea urchin barrens community by 2009/2011. It is suspected this shift was partly driven by the establishment of the Japanese kelp *Undaria pinnatifida*.

- The macroalgal community shifted, from a dominant cover of *Ecklonia radiata* and various carpeting green algae *Caulerpa* spp, to a dominance of crustose coralline algae and filamentous brown algae.

- The invertebrate community structure shifted from a dominance of blacklip abalone *Haliotis rubra* to the sea urchin *Heliocidaris erythrogramma*, which increased sharply in abundance to form grazing barrens.

- The fish community structure was dominated by the southern hulafish *Trachinops caudimaculatus* and the little weed whiting *Neoodax balteatus*.

- The observed introduced species were the northern Pacific seastar *Asterias amurensis*, Mediterranean featherworm *Sabella spallanzanii* and Japanese kelp *Undaria pinnatifida*.

- The Japanese kelp *Undaria pinnatifida* has seasonal growth and it is suspected that the monitoring sites are dominated by this seaweed during winter to mid summer, with the seasonal biomass stimulating and sustaining the large sea urchin aggregations. The monitoring surveys occur in autumn, when *Undaria* is senescent.

- There were no indicators of climate change responses with respect to the biogeographic affinities of the species present.
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1 Introduction

1.1 Subtidal Reefs of Point Cook Marine Sanctuary

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. Reefs in the north of Port Phillip Bay are highly accessible components of the marine environment because of their proximity to the large population centres of Melbourne and surrounding suburbs. Consequently, these reef ecosystems are subject to particular pressures arising from urban human activities.

Rocky reefs in Port Phillip Bay are generally restricted to the near-shore regions of headlands and points. Reefs in the northwest of the bay, along the Geelong Arm, are predominantly near Point Lillias, Point Wilson and Kirk Point. These reefs occupy short coastal strips from the intertidal zone to 2-4 m depth, bounded by bare sediment and seagrass habitats a short distance from shore. Occasional small patches of reef, 10-50 m across, are present further offshore, particularly between Point Wilson and Kirk Point. These patch reefs are mostly 1-3 m deep.

Along the northern shore of the bay, small patches of shallow reef, interspersed by silty sands, are also present in the vicinity of Point Cooke, Western Beach (north of Point Cooke), Altona, Jawbone (Williamstown Rifle Range), Point Gellibrand and Point Ormond. These reefs are generally no deeper than 4 m. More extensive reef habitat is present from Sandringham to Ricketts Point, extending 50-100 m from the shore and to a depth of approximately 6 m.

In general, the reefs on the north shore of the bay are quite sheltered from the prevailing north westerly to southwesterly weather and are not subject to large waves, strong currents or swell. Reefs on the northeastern side of the bay, particularly between Half Moon Bay and Ricketts Point, are exposed to the prevailing westerly weather across a relatively long fetch of water. Consequently, these reefs are occasionally subject to turbulent wind-driven waves. These northeastern reefs are also influenced, to some extent, by the Yarra River plume and east-coast drainages.

Reef habitats in the north of Port Phillip Bay are different from the predominant reef habitats in Victoria, which occur on exposed open coasts. The northern bay reefs are in estuarine...
conditions and are subject, at times, to lower salinities from coastal run-off, rivers and drains, as well as considerable temperature ranges (as low as 8° C in winter and as high as 23° C in summer). These reefs are also frequently subject to turbid conditions from phytoplankton blooms and disturbance of moderate to fine sediments. While there are similar species inhabiting both sheltered reefs in the north of the bay and reefs on more exposed coasts, there are substantial and important differences in community structure between the bay and open coast reef environments. Seaweeds are the predominant biological habitat providers in both locations however the cover of large canopy forming species such as the crayweed *Phyllospora comosa* and the common kelp *Ecklonia radiata* is much reduced on reefs in the bay. Smaller species of brown algae (10–30 cm high), such as *Sargassum spp., Dictyota dichotoma* and *Caulerpa* green algae are often the dominant habitat forming species on reefs in the bay (Figure 1.1). Species of *Caulerpa* can form large patches of mixed-species assemblages, creating meadow-like habitat in some locations. Grazed algal turfs and hard encrusting layers of coralline algae are also important species growing directly over the rocky substratum. The introduced Japanese wakame seaweed *Undaria pinnatifida* has been present in northern Port Phillip Bay since the early 1990’s and has been spreading ever since.

Mobile invertebrates are prominent animal inhabitants of the reef (Figure 1.2). Large grazing species such as the urchin *Heliocidaris erythrogramma* and blacklip abalone *Haliotis rubra* can occur in very high densities and represent a large percentage of the biomass of the bay’s reef communities. These species can significantly influence the growth and survival of habitat forming algal species and so are important habitat modifiers of reef communities. Important predatory invertebrates include octopus such as *Octopus berrima* and seastars including *Coscinasterias muriicata* and *Uniophora granifera*. Predatory gastropod molluscs (shellfish) include the dogwhelk *Dicathais orbita* and *Pleurolopa australasia*.

Filter feeding species feed on phytoplankton and detritus and can be important for transferring nutrients and energy from the water column to other species directly inhabiting reefs. Filter feeding species on reefs in the north of the bay include aggregations of mussels *Mytilus galloprovincialis*, ascidians such as *Herdmania grandis*, sponges and the introduced European fanworm *Sabella spallanzanii*. Other filter feeders are colonial species including sponges, bryozoans, the soft corals *Erythropodium hicksoni* and the stony coral *Plesiastrea versipora*.

Fish are usually dominant components of reef ecosystems both in terms of biomass and ecological function (Figure 1.3). Reef fish assemblages include predators such as snapper *Pagrus auratus*, omnivores including zebrafish *Girella zebra*, planktivores such as the southern hulafish *Trachinops caudimaculatus* and picker-feeders such as horseshoe
leatherjacket *Meuschenia hippocrepis*. Schools of small baitfish, particularly tommy ruff, sardines, pilchards and sprats are common over reef habitats in the north of the bay. The reef communities in the north and east of the bay provide important habitat for juveniles of many fish species including snapper *Pagrus auratus*. Many fish species play a substantial ecological role in the functioning and structuring of reef ecosystems.
Figure 1.1. Examples of macroalgae present in northern Port Phillip Bay.
Figure 1.2. Examples of reef invertebrate species present in northern Port Phillip Bay.

Sea urchin *Heliocidaris erythrogramma*

Eleven-armed seastar *Coscinasterias muricata* on yellow hyphae sponge

Nudibranch *Ceratosoma brevicaudatum*

Biscuit star *Tosia australis* with sea urchin *Heliocidaris erythrogramma*

Black-lipped abalone *Haliotis rubra*

Feather worm *Sabellastarte australiensis*
Southern hulafish *Trachinops caudimaculatus*

Globefish *Diodon nicthemerus*

Banjo ray *Trygonorrhina fasciata*

Smooth toadfish *Tetractenos glaber*

Scalyfin *Parma victoriae*

Old-wife *Enoplosus armatus*

**Figure 1.3.** Examples of reef fish species present in northern Port Phillip Bay.
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 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 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, 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 SRMP was initiated in May 1998 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 Point Addis 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 Point Cooke Marine Sanctuary

This report provides a description of the monitoring program at Point Cooke Marine Sanctuary and the reference site, RAAF Base, located south-west of the sanctuary. 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 2013;
3. describe changes and trends that have occurred over the monitoring period;
4. identify any unusual biological phenomena such as interesting or unique communities or species;
5. identify any introduced species at the monitoring locations; and
6. report on trends in selected ecosystem status indicators.
2 Methods

2.1 Site Selection and Survey Times

Point Cooke Marine Sanctuary is on the northwestern shore of the bay. The subtidal reef at Point Cooke consists of low-relief, textured basalt reef interspersed with patches of sand. The Point Cooke monitoring site (Site 1) was positioned along the 3-4 m isobath over the reef and patches of sand (Figure 2.1).

A reference monitoring site was located offshore from the RAAF Base at Laverton (RAAF Base; Site 2), approximately 3 km southwest of Point Cooke Marine Sanctuary. The reef at RAAF Base is similar in structure to Point Cooke but initially differed substantially in the vegetation present. The RAAF Base monitoring site is at 3-4 m depth (Figure 2.1).

The sites were first surveyed in March 2003 and have since been surveyed six times. Survey times are provided in Table 2.2.

Figure 2.1. Location of monitoring sites in northern Port Phillip Bay. Marine sanctuaries are shaded blue. The Point Cooke MS sites are Sites 1 and 2.
### Table 2.1. Subtidal reef monitoring sites at the Point Cooke Marine Sanctuary.

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Site Name</th>
<th>MPA/Reference</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4101</td>
<td>Point Cooke MS</td>
<td>MPA</td>
<td>3</td>
</tr>
<tr>
<td>4102</td>
<td>RAAF Base</td>
<td>Reference</td>
<td>3</td>
</tr>
</tbody>
</table>

### Table 2.2. Survey times for monitoring at the Point Cooke Marine Sanctuary.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Season</th>
<th>Survey Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Autumn</td>
<td>March 2003</td>
</tr>
<tr>
<td>2</td>
<td>Autumn</td>
<td>April 2004</td>
</tr>
<tr>
<td>3</td>
<td>Autumn</td>
<td>April 2005</td>
</tr>
<tr>
<td>4</td>
<td>Autumn</td>
<td>April 2009</td>
</tr>
<tr>
<td>5</td>
<td>Winter</td>
<td>June 2011</td>
</tr>
<tr>
<td>6</td>
<td>Autumn</td>
<td>May 2013</td>
</tr>
</tbody>
</table>
2.2 Census Method

2.2.1 Underwater Visual Census Approach

The visual census methods of Edgar and Barrett (1997, 1999) and 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 in the Point Cooke Marine Sanctuary area are positioned on the 3 metre contour.

2.2.2 Survey Design

Each site was located using a 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, six 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 giant kelp Macrocystis pyrifera plants (where present). In 2010, a new diver-operated stereo video method (Method 5) was implemented to assess its measure 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). In 2013, a new method (Method 6) was introduced to map the spatial extent of urchin barrens (where present) along the transect and measure the density of sea urchins within any barrens.
The depth, horizontal visibility, sea state and cloud cover were recorded for each site. Horizontal visibility was gauged by the distance along the transect line to detect a 100 mm long female blue-throated wrasse *Notolabrus tetricus*. All field observations were recorded on underwater paper.

![Figure 2.2. Biologist-diver with transect line.](image)

### 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 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. Four 10 x 50 m sections of the 200 m transect were censused for mobile fish at each site. The data for easily sexed species were recorded separately for males and female/juveniles. Such species include the blue-throated wrasse *Notolabrus tetricus*, herring cale *Olisthops cyanomelas*, barber perch *Caesioperca rasor*, rosy wrasse *Pseudolabrus rubicundus* and some leatherjackets.

### 2.2.4 Method 2 – Invertebrates and Cryptic Fishes

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

2.2.6 Method 4 – Macrocystis

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

![Figure 2.3.](image_url) 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 swimming pool before the fieldtrip using a SeaGIS calibration cube and SeaGIS CAL software for calibration of internal and external camera parameters. The cameras were mounted permanently to a frame. A flashing LED mounted on a pole in front of both cameras was used for synchronisation of paired images from each camera.

The stereo camera system was operated by the diver doing the UVC fish survey at the same time (Method 1). The stereo camera frame had the underwater UVC slate mounted on it for the simultaneous observations. The camera system was generally directed parallel with the transect line, with the diver swimming 2.5 m to one side of the transect, as with the UVC method. 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, but used to capture imagery for fish sizing and recognition where appropriate. 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 6 – Urchin Barrens

A sea urchin barren is an identifiable area of destructive macroalgal grazing by sea urchins, characterised by dominance of encrusting coralline algae and large numbers of sea urchins (Fletcher 1987). Where a sea urchin barren was encountered, the start and end positions of each patch on the transect line were recorded. The numbers of the dominant sea urchin species were counted within each barrens patch, as per Method 3. The number of sea urchins within the patch was also recorded independently for Method 3. Patch boundaries and numbers were restricted to within each transect. Where a barren crossed a transect boundary the counts and distribution were recorded up to the end of the transect only.
Table 2.3. Mobile fish and cephalopod species (Method 1) censused in northern Port Phillip Bay.

<table>
<thead>
<tr>
<th>Method 1</th>
<th>Cephalopoda</th>
<th>Mobile Bony Fishes</th>
<th>Mobile Bony Fishes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Octopus maorum</td>
<td>Girella zebra</td>
<td>Neodax balteatus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Girella tricuspidata</td>
<td>Neosebastes scorpaenoides</td>
</tr>
<tr>
<td></td>
<td>Sharks and Rays</td>
<td>Enoplosus armata</td>
<td>Nesogobius sp.</td>
</tr>
<tr>
<td></td>
<td>Trygonorrhina fasciata</td>
<td>Scorpis aequippinis</td>
<td>Acanthaluteres spilomelanurus</td>
</tr>
<tr>
<td></td>
<td>Urolophus cruciatus</td>
<td>Tilodon sexfasciatus</td>
<td>Acanthaluteres vittiger</td>
</tr>
<tr>
<td></td>
<td>Urolophus paucimaculatus</td>
<td>Parma victoriae</td>
<td>Scobinichthys granulatus</td>
</tr>
<tr>
<td></td>
<td>Mobile Bony Fishes</td>
<td>Chelodactylus nigripes</td>
<td>Meuschenia flavolineata</td>
</tr>
<tr>
<td></td>
<td>Arripis trutta</td>
<td>Dactylophora nigricans</td>
<td>Meuschenia freycineti</td>
</tr>
<tr>
<td></td>
<td>Atherinason hepsetoides</td>
<td>Notolabrus tetricus</td>
<td>Meuschenia hippocrepis</td>
</tr>
<tr>
<td></td>
<td>Atherinid sp.</td>
<td>Acanthopagrus australis</td>
<td>Aracana ornata</td>
</tr>
<tr>
<td></td>
<td>Pempheris multiradiata</td>
<td>Bovichtus angustifrons</td>
<td>Diodon nichthemerus</td>
</tr>
<tr>
<td></td>
<td>Caesioperca rasor</td>
<td>Heteroclinus perspicillatus</td>
<td>Tectactenos glaber</td>
</tr>
<tr>
<td></td>
<td>Pagrus auratus</td>
<td>Siphamia cephalotes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Platycephalus bassensis</td>
<td>Upeinichthys vlamingii</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.4. Invertebrate and cryptic fish (Method 2) taxa censused in northern Port Phillip Bay.

<table>
<thead>
<tr>
<th>Method 2</th>
<th>Molluscs</th>
<th>Echinoderms</th>
<th>Cryptic Fishes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Haliotis rubra</td>
<td>Comanthus trichoptera</td>
<td>Nesogobius sp.</td>
</tr>
<tr>
<td></td>
<td>Haliotis laevigata</td>
<td>Heliocidaris erythrogramma</td>
<td>Bovichtus angustifrons</td>
</tr>
<tr>
<td></td>
<td>Dicathais orbita</td>
<td>Amblypneustes spp.</td>
<td>Pempheris multiradiata</td>
</tr>
<tr>
<td></td>
<td>Pleuroloca australasia</td>
<td>Tosia australis</td>
<td>Heteroclinus perspicillatus</td>
</tr>
<tr>
<td></td>
<td>Pteryonotus triformis</td>
<td>Tosia magnifica</td>
<td>Diodon nichthemerus</td>
</tr>
<tr>
<td></td>
<td>Noumea sp.</td>
<td>Meridiastra gunnii</td>
<td>Brachaluteres jacksonianus</td>
</tr>
<tr>
<td></td>
<td>Ceratosoma brevicaudatum</td>
<td>Meridiastra calcar</td>
<td>Aetapcus maculatus</td>
</tr>
<tr>
<td></td>
<td>Elysia sp.</td>
<td>Parvulastra exigua</td>
<td>Parablennius tasmanianus</td>
</tr>
<tr>
<td></td>
<td>Hoplodoris nodulosa</td>
<td>Plectaster decanus</td>
<td>Heteroclinus whiteleggei</td>
</tr>
<tr>
<td></td>
<td>Ostrea angasi</td>
<td>Petricia vernicina</td>
<td>Trinorfolkia clarkei</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asterias amurensis</td>
<td>Vincentia conspersa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uniophora granifera</td>
<td>Urolophus paucimaculatus</td>
</tr>
<tr>
<td></td>
<td>Polychaetes</td>
<td>Coscinasterias muricata</td>
<td>Parma victoriae</td>
</tr>
<tr>
<td></td>
<td>Sabella spallanzani</td>
<td>Australostichopus mollis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sabellastarte australiensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crustacea</td>
<td>Crustacea</td>
<td>Crustacea</td>
</tr>
<tr>
<td></td>
<td>Nectocarcinus integrifrons</td>
<td>Naxia aurita</td>
<td>Strigopagurus strigimanus</td>
</tr>
<tr>
<td></td>
<td>Guinasia chabrus</td>
<td>Austrodromidia octodentata</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Petrocheles australiensis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2.5. Macroalgae and seagrass species (Method 3) censused in northern Port Phillip Bay.

**Method 3**

<table>
<thead>
<tr>
<th>Chlorophyta (green algae)</th>
<th>Phaeophyta (brown algae)</th>
<th>Rhodophyta (red algae)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ulva</em> spp.</td>
<td><em>Dictyota dichotoma</em></td>
<td><em>Ceramium</em> spp.</td>
</tr>
<tr>
<td><em>Enteromorpha</em> sp.</td>
<td><em>Dictyota diemensis</em></td>
<td><em>Champia viridis</em></td>
</tr>
<tr>
<td><em>Caulerpa brownii</em></td>
<td><em>Dilophus marginatus</em></td>
<td><em>Gracilaria cliftoni</em></td>
</tr>
<tr>
<td><em>Caulerpa flexilis</em></td>
<td><em>Zonaria turneriana</em></td>
<td><em>Gracilaria</em> spp.</td>
</tr>
<tr>
<td><em>Caulerpa flexilis var. muelleri</em></td>
<td><em>Distromium flabellatum</em></td>
<td><em>Griffithsia monilis</em></td>
</tr>
<tr>
<td><em>Caulerpa simpliciuscula</em></td>
<td><em>Leathesia difformis</em></td>
<td><em>Pterocladia capillacea</em></td>
</tr>
<tr>
<td><em>Caulerpa remotifolia</em></td>
<td><em>Lobophora variegata</em></td>
<td><em>Solieria robusta</em></td>
</tr>
<tr>
<td><em>Caulerpa scalpelliformis</em></td>
<td><em>Padina</em> sp.</td>
<td><em>Cheilosporum sagittatum</em></td>
</tr>
<tr>
<td><em>Caulerpa tritaria</em></td>
<td><em>Splanchnidium rugosum</em></td>
<td><em>Arthrocardia wardii</em></td>
</tr>
<tr>
<td><em>Caulerpa longifolia</em></td>
<td><em>Undaria pinnatifida</em></td>
<td><em>Jania rosea</em></td>
</tr>
<tr>
<td><em>Caulerpa obscura</em></td>
<td><em>Ecklonia radiata</em></td>
<td>Encrusting corallines</td>
</tr>
<tr>
<td><em>Caulerpa geminata</em></td>
<td><em>Acrocarpia paniculata</em></td>
<td><em>Callophyllis rangiferina</em></td>
</tr>
<tr>
<td><em>Caulerpa Hodgkinsonia</em></td>
<td><em>Caulocystis cephalornithos</em></td>
<td><em>Plocamium angustum</em></td>
</tr>
<tr>
<td><em>Cladophora prolifera</em></td>
<td><em>Cystophora brownii</em></td>
<td><em>Plocamium cartilagineum</em></td>
</tr>
<tr>
<td><em>Cladophora</em> spp.</td>
<td><em>Cystophora monilifera</em></td>
<td><em>Plocamium leptophyllum</em></td>
</tr>
<tr>
<td><em>Codium duttieae</em></td>
<td><em>Cystophora moniliformis</em></td>
<td><em>Rhodymenia australis</em></td>
</tr>
<tr>
<td><em>Codium fragile</em></td>
<td><em>Cystophora retroflexa</em></td>
<td><em>Rhodymenia obtusa</em></td>
</tr>
<tr>
<td><em>Codium harveyi</em></td>
<td><em>Cystophora siliquosa</em></td>
<td><em>Ballia callitricha</em></td>
</tr>
<tr>
<td><em>Codium lucasi</em></td>
<td><em>Cystophora subfarcinata</em></td>
<td><em>Peyssonelia</em> sp.</td>
</tr>
<tr>
<td><em>Codium</em> spp.</td>
<td><em>Phyllotricha decipiens</em></td>
<td><em>Echinothamnion hystrix</em></td>
</tr>
<tr>
<td>Filamentous green algae</td>
<td><em>Sargassum fallax</em></td>
<td><em>Gigartina</em> sp.</td>
</tr>
<tr>
<td></td>
<td><em>Sargassum linearifolium</em></td>
<td><em>Hypnea ramentacea</em></td>
</tr>
<tr>
<td></td>
<td><em>Sargassum spinuligerum</em></td>
<td><em>Laurencia botryoides</em></td>
</tr>
<tr>
<td><strong>Phaeophyta (brown algae)</strong></td>
<td><strong>Phyllotricha varians</strong></td>
<td><em>Laurencia filiformis</em></td>
</tr>
<tr>
<td><em>Colpomenia peregrina</em></td>
<td><em>Phyllotricha verruculosum</em></td>
<td><em>Laurencia tumida</em></td>
</tr>
<tr>
<td><em>Colpomenia sinuosa</em></td>
<td><em>Sargassum</em> spp.</td>
<td><em>Laurencia</em> spp.</td>
</tr>
<tr>
<td><em>Colpomenia</em> spp.</td>
<td>Filamentous browns</td>
<td><em>Dictymeria harveyana</em></td>
</tr>
<tr>
<td><em>Cladostephus spongiosus</em></td>
<td></td>
<td>Filamentous red algae</td>
</tr>
<tr>
<td><em>Halopteris</em> spp.</td>
<td><strong>Rhodophyta (red algae)</strong></td>
<td>Red turfing algae</td>
</tr>
<tr>
<td><em>Lobospira bicuspidata</em></td>
<td></td>
<td>Thallose red algae</td>
</tr>
</tbody>
</table>
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).

Following Sweatman (2000), 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 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 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 are applied for the SRMP, 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, there have only been six surveys and the baseline criterion will be applied when a longer time series is available. The second criterion was the deviation in community structure at time $t$ to the centroid of all previous times. This criterion is more sensitive at detecting abrupt or pulse changes, but less suitable at detecting departures from baseline conditions.
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 percentile statistic was calculated from 10 000 bootstrap samples as a provisional guide for systems heading out of range. 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:

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

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

Macrocystis pyrifera

The string kelp *Macrocystis pyrifera*, which includes the former species *M. angustifolia* (Macaya and Zuccarello 2010), is considered potentially vulnerable to climate change through reduced nutrient supply from drought and nutrient poorer warmer waters (Edyvane 2003). *Macrocystis pyrifera* only occurs on moderate to high exposure reefs and this indicator is not relevant to Point Cooke MS.

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 extent of urchin barrens, of any 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 coldwater species that is likely to be vulnerable to increased ambient temperatures. *Durvillaea potatorum* only occurs on highly exposed reefs and this indicator is not relevant to Point Cooke MS.

### 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 along the open coast but is not present in the more sheltered and estuarine embayment habitats of Port Phillip Bay. This indicator was not relevant to the Point Cooke MS.

**Fishes**

Potential fishing impacts or recovery of fishing impacts within marine protected areas were indicated by:

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

The size spectrum of all fishes at a site was first centred and linearised. Size frequencies for each field size class were aggregated into classes centred on 87.5 mm (classes 1-6), 200 mm (class 7); 275 mm (classes 8-9); 356.25 mm (classes 10-11); 400 mm (class 12); 500 mm (class 13); 625 mm (class 14); and 750+ mm (class 15). The frequencies and size classes were $\log_e(x + 1)$ and the size classes centered 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:

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

The weight estimations used the coefficients compiled by Lyle and Campbell (1999). The selected species were the most common species under heaviest fishing pressure (where present):

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

3.1 General

Images of general conditions, flora and fauna for the 2011 survey are provided in Figures 3.1 and 3.2.

3.2 Macroalgae

3.2.1 Macroalgal Community Structure

The algal community at Point Cooke Sanctuary was initially dominated by the canopy brown *Ecklonia radiata* and various *Caulerpa* species, prior to 2009. There was a subsequent disappearance of these species, coinciding with a sharp increase in the population of the sea urchin *Heliocidaris erythrogramma*. The algal community at Point Cooke is now composed mostly of crustose coralline algae and filamentous brown algae, along with blooms of the introduced alga *Undaria pinnatifida*. It is suspected that the establishment of *Undaria pinnatifida* contributed to the significant natural seaweed and sea urchin changes.

The nMDS analysis indicated the algal communities at Point Cooke and the reference site occupy non-overlapping multivariate space. Both the nMDS and control charts clearly showed the shift from *Ecklonia-Caulerpa* assemblages to barrens-*Undaria* communities. This first happened at the reference site in 2009 followed by the Point Cooke MS in 2011 (Figures 3.3 and 3.4). Both of these analyses indicated that assemblages stabilised as alternative states following these times.

3.2.2 Macroalgal Species Richness and Diversity

The total algal cover decreased markedly with the shift from predominantly algal cover to the urchins-*Undaria* community state. As described above, the shift was by 2009 for the reference site and by 2011 for the Point Cooke MS (Figure 3.5a). Algal species richness and diversity also reduced substantially at the same times (Figures 3.5b and 3.5c).

3.2.3 Common Macroalgal Species

The cover of common kelp *Ecklonia radiata* sharply decreased at both sites prior to the shift to the urchin-barrens state. The declines were from 2003 and 2004 for the reference and Point Cooke sites respectively (Figure 3.6a). *Ecklonia radiata* was not observed at either site since 2005 (Figure 3.6a).

Green algae *Ulva* spp cover has been highly variable throughout monitoring at Point Cooke and in 2013 was observed in low coverage at both sites (Figure 3.6b).
Crustose coralline algae cover increased markedly at both sites with the sea urchin barrens formation in recent years (Figure 3.6c). Filamentous brown algal coverage became common but low in coverage within the urchin barrens in 20011 and 2013 (Figure 3.6d). The green carpet-forming algae *Caulerpa remotifolia*, *C. brownii* and *C. flexilis* var *muelleri* were originally the dominant habitat formers but disappeared with the shift to sea urchin barrens habitat (Figures 3.8e and 3.8f).

There have been sporadic observations of the introduced Japanese kelp *Undaria pinnatifida*, however most surveys have been in autumn, prior to the typical seasonal winter growth of this species.
Common kelp *Ecklonia radiata*.

Sessile invertebrates on boulder reef.

Sponge and brown alga *Dictyota dichotoma*.

Southern golf ball sponge *Tethya bergquista*.

Green alga *Codium* sp and stony coral *Plesiastrea versipora*.

Japanese kelp *Undaria pinnatifida*.

**Figure 3.1.** General site conditions, flora and fauna observed at Point Cooke MS (Site 4101) over the monitoring period.
Figure 3.2. General site conditions, flora and fauna observed at the RAAF Base reference site (Site 4102) over the monitoring period.
Figure 3.3. Three-dimensional nMDS plot of algal assemblage structure for Point Cooke Marine Sanctuary. Kruskal stress value = 0.04. Filled black marks indicate the first survey in 2003.

Figure 3.4. Control chart of algal assemblage structure inside and outside Point Cooke Marine Sanctuary for 2013. Dotted lines indicate 90th percentile (upper) and 50th percentile (lower).
Figure 3.5. Algal species diversity indicators over time inside and outside Point Cooke Marine Sanctuary.
Figure 3.6 Percent cover of the most abundant algal species over time at Point Cooke Sanctuary and corresponding reference site. (a) *Ecklonia radiata*, (b) *Ulva* spp, (c) Crustose coralline algae.
Figure 3.6 (continued). Percent cover of the most abundant algal species over time at Point Cooke Sanctuary and corresponding reference site. (d) Filamentous Brown Algae, (e) Caulerpa remotifolia, (f) Caulerpa brownii.
3.3 Invertebrates

3.3.1 Invertebrate Community Structure

The three dimensional nMDS plot indicated the invertebrate community at Point Cooke MS and the RAAF Base reference site had similar trajectories over time. Significantly, both sites had changed substantially by 2009, which was also reflected in the control chart (Figures 3.7 and 3.8). These changes were largely driven by decreases in black lipped abalone *Haliotis rubra* and increases in common sea urchin *Heliocidaris erythrogramma*.

![nMDS plot](image)

**Figure 3.7.** Three-dimensional nMDS plot of invertebrate assemblage structure inside and outside Point Cooke Marine Sanctuary. *Kruskal* stress value = 0.07. Filled black marks indicate 2003 data.

![Control chart](image)

**Figure 3.8.** Control chart of invertebrate assemblage structure inside and outside Point Cooke Marine Sanctuary. Dotted lines indicate 90th percentile (upper) and 50th percentile (lower).
3.3.2 Invertebrate Species Richness and Diversity

The total abundance of observed mobile invertebrates first declined in the first three surveys, being largely influenced by a decline in black lipped abalone *Haliotis rubra*, followed by an increase driven by common sea urchins *Heliocidaris erythrogramma*. The switch to sea urchin barrens habitat was accompanied by reductions in species richness and diversity, however the reduction was tempered by pulses in abundance of other seastars *Tosia australis* and *Coscinasterias muricata*.

3.3.3 Common Invertebrate Species

As noted above, the invertebrate assemblage was initially dominated by the blacklip abalone *Haliotis rubra*, which declined in correlation with the kelp *Ecklonia radiata* (Figure 3.10a). This decrease was from 100s to 10s of abalone per 200 m$^2$ by 2009. The common sea urchin *Heliocidaris erythrogramma* also declined in density over this initial period, with subsequent increases to record levels from 2009 onwards (Figure 3.10b). The seastars *Tosia australis* and *Coscinasterias muricata* were also highly abundant compared with reefs elsewhere and had considerable spikes in density over the monitoring period (Figures 3.10c and 3.10d).

The introduced Mediterranean fan worm *Sabella spallanzanii* was observed at both sites throughout the monitoring program.

3.3.4 Sea Urchin Barrens

As stated above, there was a community shift at both sites from *Ecklonia-Caulerpa* habitats to sea urchin barrens. In 2013, all reef habitat was classified as sea urchin barrens.
Figure 3.9. Invertebrate species diversity indicators over time inside and outside Point Cooke Marine Sanctuary.
Figure 3.10. Density of dominant invertebrate species over time inside and outside Point Cooke Marine Sanctuary: (a) *Haliotis rubra*; (b) *Heliocidaris erythrogramma*; (c) *Tosia australis*; and (d) *Coscinasterias muricata*. 
Figure 3.10 (continued). Density of dominant invertebrate species over time inside and outside Point Cooke Marine Sanctuary: (a) *Haliotis rubra*; (b) *Heliocidaris erythrogramma*; (c) *Tosia australis*; and (d) *Coscinasterias muricata*. 
3.4 Fishes

3.4.1 Fish Community Structure

Fish communities at Point Cooke MS and the reference site had similar levels of relative variation between sites and times with no obvious trends or patterns (Figure 3.11). The multivariate control chart indicates that fish communities at both sites were generally within the 90th percentile of previous observations over the monitoring period. Both sites deviated above the 90th percentile during the 2009 survey, when increased numbers of *Trachinops caudimaculatus* were observed (Figure 3.12).

![Figure 3.11](image-url)

**Figure 3.11.** Three-dimensional MDS plot of fish assemblage structure inside and outside Point Cooke Marine Sanctuary. Kruskal stress value = 0.06. Filled black marks indicate 2003 data.
3.4.2 Fish Species Richness and Diversity

Fish abundance and diversity at Point Cooke and the reference site was largely driven by the abundances of southern hula fish *Trachinops caudimaculatus* and little rock whiting *Neoodax balteatus*. Fish diversity was generally low during recent surveys (Figure 3.13).

3.4.3 Common Fish Species

Southern hulafish *Trachinops caudimaculatus* was recorded in high density at both sites, particularly in 2009 at the reference site (Figure 3.14a). The density of the little rock whiting *Neoodax balteatus* at both sites declined steadily from 2005 to 2009 and was absent since 2011 (Figure 3.14b).
Figure 3.13. Fish species diversity indicators over time inside and outside Point Cooke Marine Sanctuary.
Figure 3.14. Density of dominant fish species over time inside and outside Point Cooke Marine Sanctuary: (a) *Trachinops caudimaculatus*; and (b) *Neodax balteatus*. 
3.5 Ecosystem Components

3.5.1 Habitat and Primary Production

The habitat and primary production indicators clearly describe the shift from the *Ecklonia-Caulerpa* habitat to sea urchin barrens habitat with crustose coralline algae as the dominant algal coverage (Figures 3.15a to 3.15c). There was also an accompanying decrease in smaller brown and red algae (Figures 3.15d and 3.15d). This change represented a significant reduction in biogenic habitat volume, however there was a substantial increase in sponge biogenic structure within the urchin barrens.

3.5.2 Invertebrate Groups

Invertebrate grazer density was high at Point Cooke and very high at the reference site, with densities of the urchin *Heliocidaris erythrogramma* driving the observed patterns in later years (Figure 3.16a). The density of invertebrate filter feeders consisted of the introduced Mediterranean fan worm *Sabella spallanzani* and generally remained low over time with the exception of a peak in 2005 (Figure 3.16b). Sea stars declined in abundance inside the Point Cooke MS and were highly variable at the reference site (Figure 3.16c).

3.5.3 Fish Groups

Most fishes at both sites were planktivores, with equal numbers of these taxa both inside and outside the MPA (Figure 3.17a). There was a peak in abundance in the reference site driven by aggregations of the southern hulafish *Trachinops caudimaculatus* during the 2009 survey. Fish forager abundance was low and variable both inside and outside the sanctuary (Figure 3.17b).

No predatory fish were observed in either area at any time, although they are known to occur in the region.
Figure 3.15. Seaweed functional groups over time inside and outside Point Cooke Marine Sanctuary.
Figure 3.15 (continued). Seaweed functional groups over time inside and outside Point Cooke Marine Sanctuary.
Figure 3.16. Abundance of invertebrate functional groups over time inside and outside Point Cooke Marine Sanctuary.
Figure 3.17. Abundance of fish functional groups over time inside and outside Point Cooke Marine Sanctuary.
3.6 Sediment Cover

Sediment coverage ranged between 10 and 40% over the monitoring period (Figure 3.18).

Figure 3.18. Sediment coverage over time inside and outside Point Cooke Marine Sanctuary.
3.7 Introduced Species

Japanese kelp *Undaria pinnatifida* was first observed in the Point Cooke region in 2009, although it should be noted that most surveys were at a time where *Undaria pinnatifida* is usually in senescence. *Undaria pinnatifida* was the only introduced algal species detected in either site to date. It is suspected that there is a high biomass of *Undaria pinnatifida* occurring at the monitoring sites during winter and spring to sustain the sea urchin aggregations.

Low densities of the introduced Mediterranean fanworm *Sabella spallanzanii* were observed at both sites over the monitoring period with a notable peak in abundance at the reference site in 2005 (Figure 3.19).

The northern Pacific seastar *Asterias amurensis* was observed in the region up to 2004, but have not been observed on the transects since.

No introduced fish taxa were observed at either site at any time.

![Graph showing observed abundances of introduced invertebrate species *Sabella spallanzanii* over time inside and outside Point Cooke Marine Sanctuary.](image)

*Figure 3.19. Observed abundances of introduced invertebrate species *Sabella spallanzanii* over time inside and outside Point Cooke Marine Sanctuary.*
3.8 Climate Change

The majority of species observed in the Point Cooke area were of cosmopolitan and Maugean species. There were no apparent shifts toward a higher proportion of western or eastern species indicative of a different climate regime.

3.9 Fishing

3.9.1 Abalone

The abundance of black lip abalone *Haliotis rubra* was initially high at both sites, with subsequent declines corresponding with the loss of thallose seaweeds (prior to barrens formation).

The mean sizes at both sites were generally similar over time with the exception of a decrease observed during the 2009 survey (Figure 3.20). A size class analysis indicated a greater proportion of abalone above the minimum legal length limit (100mm) inside the MPA during 2013 (Figure 3.21)

3.9.2 Fish

No species of commercial or recreational fisheries interest were recorded in the MPA or the reference area in 2013.

![Figure 3.20](image_url) Mean size and proportion over time of legal sized blacklip Abalone *Haliotis rubra* inside and outside Point Cooke Marine Sanctuary.
Figure 3.21 Abundance of different size classes of the blacklip Abalone *Haliotis rubra* inside and outside Point Cooke Marine Sanctuary in 2013.
4 Acknowledgements

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5 References


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