NUMBER 105

Victorian Subtidal Reef Monitoring Program: The Reef biota at Jawbone Marine Sanctuary
May 2015

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March 2017
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). The SRMP is implemented throughout Victoria and has been operating for over 16 years. It provides 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 Jawbone Marine Sanctuary and reference sites, involving seven surveys from 2004 to 2015. The monitoring uses standardised underwater visual census methods on reefs 2-3 m deep. There are two sites, one inside the marine sanctuary at Jawbone and one reference site, at Williamstown.

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 mobile invertebrates;
- percentage cover of macroalgae;
- abundance of a string kelp, *Macrocystis pyrifera*, if present; and
- abundance of manufactured debris.
Key observations during the monitoring program were:

- The seaweed community at both of the Jawbone sites was similar at both sites, but highly variable in structure. There was a departure in similarity from 2011, with Caulerpa mats and Sargassum spinuligerum becoming established at the Williamstown reference site.
- There was very little seaweed cover at Jawbone in May 2015.
- The dominant invertebrate species was the common sea urchin *Heliocidaris erythrogramma*, which tripled in abundance at both sites between 2005 and 2009.
- The abundance of blacklip abalone *Haliotis rubra* recently increased at the Williamstown reference site but remained low at the Jawbone MS site.
- Seastar abundances were highly variable over time. The abundance of the velvet star *Petricia vernicina* was at highest recorded levels in 2015.
- The fish community at both sites is dominated by high abundances of southern hulafish *Trachinops caudimaculatus*. The abundances of other species was generally very low and variable.
- Sediment cover was the highest recorded in 2015 and was approximately double prior observed coverages.
- There were no other major shifts in community structure directly attributable to climate change.
- The introduced Mediterranean fanworm *Sabella spallanzanii* and Japanese kelp *Undaria pinnatifida* is established at both sites, but only observed in low abundances during the April-May surveys. The April-May surveys are outside the main growth season of late winter to early summer for *U. pinnatifida*.
- There was no manufactured debris observed at the Jawbone MS and Williamstown monitoring sites in 2015.
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1 Introduction

1.1 Subtidal Reefs of Northern Port Phillip Bay

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 Kirks Point. These reefs occur in 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 Kirks 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 Jawbone, extending 50-200 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 south-westerly weather and are not subject to large waves, strong currents or swell. Reefs on the north-eastern side of the bay, particularly between Half Moon Bay and Jawbone, 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 north-eastern 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 open coast reef habitats in Victoria. The northern bay reefs are in semi-estuarine conditions and are subject, at times, to
lower salinities from coastal runoff, 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 crayweed *Phyllospora comosa* and 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., red thallose algae 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 muricata* and *Uniophora granifera*. Predatory gastropod molluscs (shellfish) include the dogwhelk *Dicathais orbita* and *Australaria 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 momus* and *Pyura stolonifera*, sponges and the introduced European fanworm *Sabellaria spallanzanii*. Other filter feeders are colonial species including sponges, bryozoans, the soft corals *Erythropodium hicksoni* and the stony coral *Plesiastrea versipora*.

Fish on open coast reefs are usually dominant components of reef ecosystems both in terms of biomass and ecological function, however the fish component is not a major component of northern Port Phillip Bay reefs (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 rough, 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 common macroalgae in northern Port Phillip Bay.
Native feather worm *Sabellastarte australiensis*

Black-lipped abalone *Haliotis rubra*

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

Two colour morphs of the biscuit star *Tosia australis*.

Sea urchin *Heliocidaris erythrogramma*

Nudibranch *Ceratosoma brevicaudatum*

**Figure 1.2.** Examples of common invertebrate species in northern Port Phillip Bay.
Figure 1.3. Examples of common reef fishes in the Central Victoria bioregion.

Globefish *Diodon nixthemerus*

Old wife *Enoplosus armatus*

Scalyfin *Parma victoriae*

Southern hulafish *Trachinops caudimaculatus*

Smooth toadfish *Tetractenos glaber*

Banjo ray *Trygonorrhina fasciata*
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 Bunurong 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.

1.3 Monitoring at Jawbone Marine Sanctuary

This report describes the subtidal reef monitoring program at Jawbone Marine Sanctuary and the reference site at Williamstown. 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 at Jawbone (Site 4103) inside the Marine Sanctuary and at Williamstown (Site 4104; Figure 2.1; Table 2.1).

Seven surveys were completed between March 2003 and May 2015. The survey times are in Table 2.2.

Figure 2.1. Location of marine sanctuary monitoring sites in northern Port Phillip Bay.
Table 2.1. Subtidal reef monitoring sites for Jawbone Marine Sanctuary.

<table>
<thead>
<tr>
<th>Region</th>
<th>No.</th>
<th>Description</th>
<th>Status</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Phillip Bay</td>
<td>4103</td>
<td>Jawbone</td>
<td>MS</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4104</td>
<td>Williamstown</td>
<td>Reference</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2.2. Subtidal reef monitoring survey times at Jawbone.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Time</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>March 2003</td>
<td>4103; 4104</td>
</tr>
<tr>
<td>2</td>
<td>April 2004</td>
<td>4103; 4104</td>
</tr>
<tr>
<td>3</td>
<td>April 2005</td>
<td>4103; 4104</td>
</tr>
<tr>
<td>4</td>
<td>April 2009</td>
<td>4103; 4104.</td>
</tr>
<tr>
<td>5</td>
<td>June 2011</td>
<td>4103; 4104</td>
</tr>
<tr>
<td>6</td>
<td>April-May 2013</td>
<td>4103; 4104</td>
</tr>
<tr>
<td>7</td>
<td>May 2015</td>
<td>4103; 4104</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 monocanths. A total of four 50 m transects (two blocks per transect) were censused for mobile fish at each site. Common fish species observed in Port Phillip Bay 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. Common cryptic fish and invertebrate species in Port Phillip Bay 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. Common macrophyte species in Port Phillip Bay 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 Port Phillip Bay.

<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>Septops maorum</td>
<td>Neodax balteatus</td>
</tr>
<tr>
<td></td>
<td>Pempheris multiradiata</td>
<td>Neosebastes scorpaenoides</td>
</tr>
<tr>
<td></td>
<td>Platycephalus bassensis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acanthopagrus australis</td>
<td></td>
</tr>
<tr>
<td>Sharks and Rays</td>
<td>Siphamia cephalotes</td>
<td>Acantholateres spilomelanurus</td>
</tr>
<tr>
<td>Trygonorrhina fasciata</td>
<td>Upeneichthys vlaminghii</td>
<td>Acantholateres vittiger</td>
</tr>
<tr>
<td>Dasyatis brevicaudata</td>
<td>Girella tricuspidata</td>
<td>Brachalateres jacksonianus</td>
</tr>
<tr>
<td>Urolophus cruciatus</td>
<td>Girella zebra</td>
<td>Scobinichthys granulatus</td>
</tr>
<tr>
<td>Urolophus paucimaculatus</td>
<td>Scorps aequipinnis</td>
<td>Meuschenia freycineti</td>
</tr>
<tr>
<td>Trygonoptera testacea</td>
<td>Scorps lineolata</td>
<td>Meuschenia hippocrepis</td>
</tr>
<tr>
<td></td>
<td>Tilodon sexfasciatius</td>
<td>Aracana ornata</td>
</tr>
<tr>
<td>Mobile Bony Fishes</td>
<td>Enoplosus armatus</td>
<td>Tetractenos glaber</td>
</tr>
<tr>
<td>Caesioperca rasor</td>
<td>Parma victoriae</td>
<td>Diodon nichthemerus</td>
</tr>
<tr>
<td>Trachinops caudimaculatus</td>
<td>Cheilodactylus nigripes</td>
<td></td>
</tr>
<tr>
<td>Arripis spp</td>
<td>Dactylophora nigricans</td>
<td>Mammals and Reptiles</td>
</tr>
<tr>
<td>Arripis georgianus</td>
<td>Notolabrus tetricus</td>
<td>Arctocephalus pusillus</td>
</tr>
<tr>
<td>Pagrus auratus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atherinidae spp</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2.4. Invertebrate and cryptic fish (Method 2) taxa commonly censused in Port Phillip Bay.

<table>
<thead>
<tr>
<th>Method 2</th>
<th>Crustacea</th>
<th>Echinoderms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Molluscs</strong></td>
<td><strong>Crustacea</strong></td>
<td><strong>Echinoderms</strong></td>
</tr>
<tr>
<td><em>Haliotis rubra</em></td>
<td><em>Strigopagurus strigimanus</em></td>
<td><em>Comanthus trichoptera</em></td>
</tr>
<tr>
<td><em>Dictathais orbita</em></td>
<td><em>Paguridae spp</em> (other)</td>
<td><em>Heliocidaris erythrogramma</em></td>
</tr>
<tr>
<td><strong>Australaria australasia</strong></td>
<td><strong>Pterygotus triformis</strong></td>
<td><strong>Amblypneustes spp</strong></td>
</tr>
<tr>
<td><strong>Noumea sp</strong></td>
<td><strong>Tosia magnifica</strong></td>
<td><strong>Tosia australis</strong></td>
</tr>
<tr>
<td><strong>Ceratosa brevicaudatum</strong></td>
<td></td>
<td><strong>Petricia vernicinna</strong></td>
</tr>
<tr>
<td><strong>Elysia sp</strong></td>
<td><strong>Cryptic Fishes</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Pempheris multiradiata</em></td>
<td><strong>Meridiastra calcar</strong></td>
</tr>
<tr>
<td><strong>Hoplodoris nodulosa</strong></td>
<td><em>Gnathancanthus goetzeei</em></td>
<td><em>Parvulastra exigua</em></td>
</tr>
<tr>
<td><strong>Ostrea angasi</strong></td>
<td><em>Aetapcus maculatus</em></td>
<td><strong>Uniophora granifera</strong></td>
</tr>
<tr>
<td><strong>Octopus berrima</strong></td>
<td><em>Bovichtus angustifrons</em></td>
<td><strong>Coscinasterias muricata</strong></td>
</tr>
<tr>
<td><strong>Octopus maorum</strong></td>
<td><em>Heteroclinus johnstoni</em></td>
<td><em>Asterias amurensis</em></td>
</tr>
<tr>
<td><strong>Annelida</strong></td>
<td><strong>Heteroclinus perspicillatus</strong></td>
<td><strong>Australostichopus mollis</strong></td>
</tr>
<tr>
<td><strong>Sabella spallanzanii</strong></td>
<td><em>Cristiceps australis</em></td>
<td></td>
</tr>
<tr>
<td><strong>Sabellastarte australiensis</strong></td>
<td><em>Cliniids spp</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Trinorfolkia clarkei</em></td>
<td></td>
</tr>
<tr>
<td><strong>Crustacea</strong></td>
<td><strong>Vincentia conspersa</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Guinna chabrus</strong></td>
<td><em>Nesogobius spp</em></td>
<td></td>
</tr>
<tr>
<td><strong>Nectocarcinus integrifrons</strong></td>
<td><em>Diodon nichthemerus</em></td>
<td></td>
</tr>
<tr>
<td><strong>Petrocheles australiensis</strong></td>
<td><em>Brachaluteres jacksonianus</em></td>
<td></td>
</tr>
<tr>
<td><strong>Naxia aurita</strong></td>
<td><em>Urolophus paucimaculatus</em></td>
<td></td>
</tr>
<tr>
<td><strong>Austrodromidia octodentata</strong></td>
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</tr>
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</table>

### Table 2.5. Manufactured debris (Method 2b) categories.

<table>
<thead>
<tr>
<th>Method 2</th>
<th>Metal</th>
<th>Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fishing gear</strong></td>
<td>Metal</td>
<td>Glass</td>
</tr>
<tr>
<td><strong>Plastic</strong></td>
<td>Cloth</td>
<td>Wood</td>
</tr>
</tbody>
</table>
Table 2.6. Common macroalgae and seagrass (Method 3) taxa censused in Port Phillip Bay.

<table>
<thead>
<tr>
<th>Chlorophyta (green algae)</th>
<th>Chromista (brown algae)</th>
<th>Rhodophyta (red algae)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulva spp</td>
<td>Cystophora siliquosa</td>
<td>Peyssonnelia spp</td>
</tr>
<tr>
<td>Ulva compressa</td>
<td>Cystophora retroflexa</td>
<td>Dictymenia harveyana</td>
</tr>
<tr>
<td>Caulerpa longifolia</td>
<td>Cystophora subfarcinata</td>
<td>Echinothamnion hystrix</td>
</tr>
<tr>
<td>Caulerpa trifaria</td>
<td>Caulocystis cephalornithos</td>
<td>Gigartina spp</td>
</tr>
<tr>
<td>Caulerpa scalpelliformis</td>
<td>Acrocarpia paniculata</td>
<td>Hypnea ramentacea</td>
</tr>
<tr>
<td>Caulerpa remotifolia</td>
<td>Phyllotricha decipiens</td>
<td>Laurencia filiformis</td>
</tr>
<tr>
<td>Caulerpa brownii</td>
<td>Phyllotricha sonderi</td>
<td>Laurencia tumida</td>
</tr>
<tr>
<td>Caulerpa flexilis</td>
<td>Phyllotricha varians</td>
<td>Laurencia botryoides</td>
</tr>
<tr>
<td>Caulerpa flexilis var muelleri</td>
<td>Phyllotricha verruculosum</td>
<td>Rhodymenia australis</td>
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<tr>
<td>Caulerpa obscura</td>
<td>Sargassum fallax</td>
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</tr>
<tr>
<td>Caulerpa sedoides f. geminata</td>
<td>Sargassum spinuligerum</td>
<td></td>
</tr>
<tr>
<td>Caulerpa hodgkinsoniae</td>
<td>Sargassum spp</td>
<td></td>
</tr>
<tr>
<td>Caulerpa simpliciuscula</td>
<td>Ectocarpus spp (filamentous)</td>
<td></td>
</tr>
<tr>
<td>Codium fragile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Codium harveyi</td>
<td>Rhodophyta (red algae)</td>
<td></td>
</tr>
<tr>
<td>Codium lucasi</td>
<td>Thallose red algae</td>
<td></td>
</tr>
<tr>
<td>Codium duthieae</td>
<td>Red turfing algae</td>
<td></td>
</tr>
<tr>
<td>Codium galeatum</td>
<td>Filamentous red algae</td>
<td></td>
</tr>
<tr>
<td>Codium spp</td>
<td>Encrusting coralline algae</td>
<td></td>
</tr>
<tr>
<td>Cladophora spp</td>
<td>Plocamium angustum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P. cirrhosum</td>
<td></td>
</tr>
<tr>
<td>Chromista (brown algae)</td>
<td>P. cartilagineum</td>
<td></td>
</tr>
<tr>
<td>Dicrerythra dixotoma</td>
<td>P. leptophyllum</td>
<td></td>
</tr>
<tr>
<td>Dicrerythra marginatus</td>
<td>Callithamnionis rangiferina</td>
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</tr>
<tr>
<td>Dicrerythra gunniana</td>
<td>Gracinaria cliftoni</td>
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</tr>
<tr>
<td>Zonaria turneriana</td>
<td>Champia spp</td>
<td></td>
</tr>
<tr>
<td>Distromium flabellatum</td>
<td>Champia viridis</td>
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</tr>
<tr>
<td>Leathisia diffusis</td>
<td>Ceramium spp</td>
<td></td>
</tr>
<tr>
<td>Lobophora variegata</td>
<td>Griffithsia monilis</td>
<td></td>
</tr>
<tr>
<td>Splachnium rugosum</td>
<td>Solieria robusta</td>
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</tr>
<tr>
<td>Ecklonia radiata</td>
<td>Pterocladiella capillace</td>
<td></td>
</tr>
<tr>
<td>Undaria pinnatifida</td>
<td>Jania sagittata</td>
<td></td>
</tr>
<tr>
<td>Cystophora brownii</td>
<td>Jania rosea</td>
<td></td>
</tr>
<tr>
<td>Cystophora monilifera</td>
<td>Arthrocardia wardii</td>
<td></td>
</tr>
<tr>
<td>Cystophora moniliformis</td>
<td>Ballia callitricha</td>
<td></td>
</tr>
</tbody>
</table>
2.3 Data Analysis – Condition indicators

2.3.1 Approach

Reef quality indicators were developed to encompass key features of 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 two 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(count + 1) versus ln(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:

weight (grams) = a × 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.

<table>
<thead>
<tr>
<th>Species</th>
<th>a</th>
<th>b</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheilodactylus spectabilis</td>
<td>0.01660</td>
<td>3.00</td>
<td>Fishbase</td>
</tr>
<tr>
<td>Cheilodactylus nigripes</td>
<td>0.01202</td>
<td>3.02</td>
<td>Fishbase</td>
</tr>
<tr>
<td>Cheilodactylus fuscus</td>
<td>0.01202</td>
<td>3.02</td>
<td>Fishbase</td>
</tr>
<tr>
<td>Latridopsis forsteri</td>
<td>0.01660</td>
<td>3.00</td>
<td>Fishbase: C. spectabilis</td>
</tr>
<tr>
<td>Notolabrus tetricus</td>
<td>0.00977</td>
<td>3.07</td>
<td>Fishbase: N. fucicola</td>
</tr>
<tr>
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<td>0.00977</td>
<td>3.07</td>
<td>Fishbase</td>
</tr>
<tr>
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<td>0.0977</td>
<td>3.07</td>
<td>Fishbase: N. fucicola</td>
</tr>
<tr>
<td>Achoerodus viridis</td>
<td>0.01800</td>
<td>3.044</td>
<td>Fishbase: A. gouldii</td>
</tr>
<tr>
<td>Achoerodus gouldii</td>
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<td>3.044</td>
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</tr>
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<td>Sphyraena novaehollandiae</td>
<td>0.00813</td>
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<td>Sphyraena obtusata</td>
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</tr>
<tr>
<td>Sillago flindersi</td>
<td>0.00851</td>
<td>3.09</td>
<td>Fishbase</td>
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3 Results

3.1 Macroalgae

The seaweed assemblages at the Jawbone and Williamstown sites were generally comprised of low abundances of common kelp *Ecklonia radiata*, crustose coralline algae, filamentous brown algae (Ectocarpales), small thallose browns such as *Dictyota dichotoma* and the green algae *Ulva*, *Caulerpa* and *Codium* species. The introduced kelp *Undaria pinnatifida* is present, however the surveys are usually in April-May, which is outside the seasonally abundant period of July to December.

There was considerable variability in assemblage composition over time at both sites, with both sites being reasonably similar until 2013, when the Williamstown reference site diverged in composition from the Jawbone MS site (Figure 3.1). This divergence was largely because of the establishment of *Caulerpa* mats at Williamstown, particularly *Caulerpa remotifolia* and *Caulerpa sedoides f. geminata* (Figures 3.4c and 3.4d). The density of the brown alga *Sargassum spinuligerum* also increased considerably at Williamstown and slightly at Jawbone. These increases at Williamstown were concurrent with similar increases at Ricketts Point MS and Halfmoon Bay.

The control charts indicated the most significant temporal changes was to 2015 at Jawbone MS, with the lowest recorded total algal abundance recorded over the monitoring period (Figures 3.2 and 3.3).
Figure 3.1. Three-dimensional nMDS plot of algal assemblage structure at Jawbone MS. Black filled shapes denote the first survey time. Kruskal stress = 0.07.
Figure 3.2. Control charts of algal assemblage structure at Jawbone MS.
Figure 3.3. Algal species diversity indicators inside and outside Jawbone MS.
Figure 3.4. Percent cover of common algal species inside and outside the Jawbone MS.
Figure 3.4 (continued). Percent cover of common algal species inside and outside the Jawbone MS.
3.2 Invertebrates

The megafaunal invertebrates at the two Jawbone sites were characterised by relatively high densities of sea urchins *Heliocidaris erythrogramma*, presence of blacklip abalone *Haliotis rubra* and relatively high abundances of seastars, particularly the eleven armed seastar *Coscinasterias muricata*, biscuit star *Tosia australis*, velvet star *Petricia vernicina* and Gunn’s star *Meridiastra gunnii*.

The multivariate control charts indicated there was significant variation in assemblage structure from survey to survey at the Jawbone MS site, with a significant departure from the initial survey period in 2013 and 2015 (Figures 3.5 and 3.6). This later change was also associated with reduced species richness and diversity (Figure 3.7).

The density of blacklip abalone *Haliotis rubra* was initially low at both sites in 2003, with a small increase to 2004 and subsequent gradual decline to 2011 (Figure 3.8a). Following 2011, abundances increased sequentially at Williamstown to 2013 and 2015, with little change at Jawbone MS (Figure 3.8a).

The common sea urchin *Heliocidaris erythrogramma* densities tripled at both sites between 2005 and 2009, remaining relatively high at both sites since then (Figure 3.8b).

Peaks in seastar abundances were evident in 2004, and 2009 to 2011, particularly for *Tosia australis*, *Petricia vernicina* and *Uniophora granifera* (Figures 3.8d to 3.8f). In 2013 and 2015, abundances of *Tosia australis* and *Uniophora granifera* were relatively low. The abundances of *Petricia vernicina* were the highest recorded in 2015, at both Jawbone MS and Williamstown (Figure 3.8e).
Figure 3.5. Three-dimensional nMDS plot of invertebrate assemblage structure at Jawbone MS. Black, filled shapes denote the first survey time. Kruskal stress = 0.01.
Figure 3.6. Control charts of invertebrate assemblage structure at Jawbone MS.
Figure 3.7. Invertebrate species diversity indicators inside and outside the Jawbone MS.
Figure 3.8. Density of invertebrate species inside and outside the Jawbone MS.
Figure 3.8 (continued). Density of invertebrate species inside and outside the Jawbone MS.
3.3 Fishes

The fish community at the Jawbone sites were dominated by shoals of the southern hulafish *Trachinops caudimaculatus*, which was present in highly variable abundances over time. Other species present included the little rock whiting *Neodax balleatus*, goatfish *Upeneichthys vlaminghii* and occasional aggregations of zebrafish *Girella zebra*. The highly variable presence of fish shoals and very low abundance of most species meant the multivariate analyses were generally uninformative and unreliable in identifying any trends or patterns of change (Figures 3.9 and 3.10).

The abundance of *Trachinops caudimaculatus* was the highest recorded at Jawbone MS in 2003 and moderately high abundances were also observed in 2013 and 2015 (Figure 3.12a).

![nMDS - Fishes](image)

**Figure 3.9.** Three-dimensional nMDS plot of fish assemblage structure at Jawbone MS. Black, filled shapes denote the first survey time. Kruskal stress = 0.01.
Figure 3.10. Control charts of fish assemblage structure at Jawbone MS.
Figure 3.11. Fish species diversity indicators inside and outside the Jawbone MS.
Figure 3.12. Density of fish species inside and outside the Jawbone MS.
3.4 Ecosystem Functional Components

3.4.1 Habitat and Production

The general biogenic habitat structure varied considerably during the monitoring with similarities at both sites during each survey until 2011, after which there was a divergence in biogenic structure of the flora. Smaller brown algae and green algae increased at Williamstown in more recent surveys with a concurrent reduction of most species at Jawbone MS (Figure 3.13). There may be corresponding changes in *Undaria pinnatifida* abundance, however the monitoring surveys are outside the main season of growth for *U. pinnatifida*.

3.4.2 Sediment Cover

Sediment cover in 2015 was the highest recorded at both sites, with an approximate doubling of cover (Figure 3.14).

3.4.3 Invertebrate Groups

The predominant invertebrate groups were grazers, reflecting the abundances of common sea urchin *Heliocidaris erythrogramma* and blacklip abalone *Haliotis rubra* (Figure 3.15). Total seastar abundance was relatively low in 2013 and 2015 (Figure 3.15d).

3.4.4 Fish Groups

The abundances of all fish functional groups were highly variable between surveys (Figure 3.16).
Figure 3.13. Percent cover of macrophyte functional groups inside and outside the Jawbone MS.
Figure 3.13 (continued). Percent cover of macrophyte functional groups inside and outside the Jawbone MS.
Figure 3.14. Sediment functional group percent cover inside and outside Jawbone MS.
Figure 3.15. Invertebrate functional group densities inside and outside the Jawbone MS.
Figure 3.15. (continued). Invertebrate functional group densities inside and outside the Jawbone MS.
Figure 3.16. Fish functional group density inside and outside Jawbone MS.
Figure 3.16 (continued). Fish functional group density at Jawbone MS.

Figure 3.17. Density of the introduced Mediterranean fan worm *Sabella spallanzanii* at Jawbone MS.
3.5 Introduced Species

The introduced pest Mediterranean fanworm *Sabella spallanzanii* was frequently observed in very low abundance at Jawbone MS, but was uncommon on the transect (Figure 3.17). There were occasional observations of the Japanese kelp *Undaria pinnatifida* at the Jawbone sites during the April-May surveys, however it should be noted that this species has a seasonal growth form with the larger sporophyte form usually predominant from late winter to early summer.

3.6 Climate Change

3.6.1 Species composition

There were no distinct changes in species composition reflecting a shift towards warmer water species (*e.g.* Figures 3.18 and 3.19). There was a recent slight increase in the abundance of the cold water, Maugean fish species *Trachinops caudimaculatus*.

3.6.2 *Macrocystis pyrifera*

The giant string kelp *Macrocystis pyrifera* did not occur at Jawbone.

3.6.3 *Durvillaea potatorum*

The bull kelp *Durvillaea potatorum* is not present at the monitoring sites, being 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 Jawbone surveys.
Figure 3.18. Abundance and species richness of cold water, Maugean algal species at Jawbone MS.
Figure 3.19. Abundance and species richness of cold water, Maugean fish species at Jawbone MS.
3.7 Fishing

3.7.1 Abalone

There was a recent increase in abundance of blacklip abalone *Haliotis rubra* at the Williamstown reference site from 2011 to 2015 and with relatively low abundances during the same period at Jawbone MS. The mean size of measured abalone was relatively variable between surveys, however the sample size was very low (Figure 3.20).

3.7.2 Fishes

The biomass of commonly fished fishes, resident on the reefs, was extremely low at both sites (Figure 3.21). The high dominance of small *Trachinops caudimaculatus* meant the size spectrum analysis was not a useful monitoring indicator at these sites.

3.8 Manufactured Debris

The 2015 survey was the first year to include manufactured debris at the Jawbone monitoring sites. No debris was observed on the transects.
Figure 3.20. Mean size of Blacklip abalone *Haliotis rubra* at Jawbone MS.

Figure 3.21. Total estimated biomass of fished species at Jawbone MS.
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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