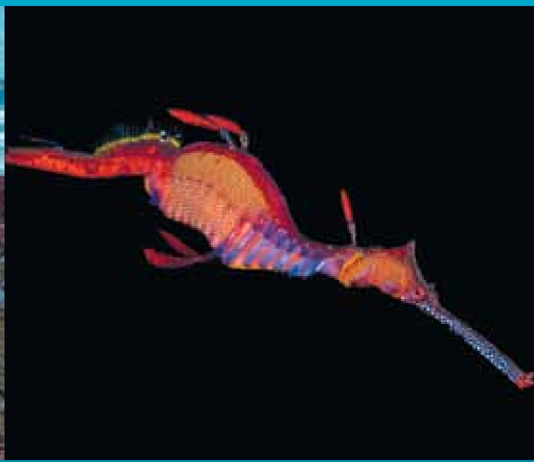

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Victorian Subtidal Reef Monitoring Program: The Reef Biota at Jawbone Marine Sanctuary April 2013

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Victorian Subtidal Reef Monitoring Program:

The Reef Biota at Jawbone Marine Sanctuary, April 2013

Matt Edmunds

Australian Marine Ecology Pty. Ltd.

April 2013

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 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 Jawbone Marine Sanctuary and associated reference site, involving six surveys from 2004 to 2013. The monitoring uses standardised underwater visual census methods.

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
- identification of any unusual biological phenomena, interesting communities, strong temporal trends and the presence of any introduced species.

The ongoing monitoring surveys were 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;
- percentage cover of macroalgae; and
- abundance of string kelp *Macrocystis pyrifera* (if present).

Key observations during the monitoring program were:

- There was a very large increase in the sea urchin *Heliocidaris erythrogramma* at both sites in 2009, persisting to 2013. The densities in 2013 were in the order of 1000 per 200 m^2;
- Seaweed community structure and species abundances were generally variable over time and there was no marked shift in association with the increase in sea urchins
- There is presently decreased cover of kelp *Ecklonia radiata* and crustose coralline algae and a moderately increased cover of filamentous brown algae;
- There was a decline and virtual disappearance of the seastar *Meridiastra calcar* from both sites during 2003 to 2005;
- Since 2005 there was an increase and subsequent decline in the abundances of the seastars *Tosia australis* and *Meridiastra gunnii*;
- Low numbers of fish species and abundances were generally observed, with occasional influxes of non-resident species to cause high variability in the time series;
- The introduced species observed at Jawbone were the Japanese kelp *Undaria pinnatifida*, Mediterranean fanworm *Sabella spallanzanii* and northern Pacific seastar *Asterias amurensis*;
- There were no indicators of climate change responses with respect to the biogeographic affinities of the species present; and
- The abundance and size of black-lipped abalone *Haliotis rubra* remained similar inside and outside the sanctuary and there was no evidence of changed fishing pressures.

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1 Introduction

1.1 Subtidal Reefs of Jawbone 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 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 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 south westerly 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 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.*, *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 muricata* and *Uniophora granifera*. Predatory gastropod molluscs (shellfish) include the dogwhelk *Dicathais orbita* and *Pleuroploca 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*, 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 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.

Ulva sp.

Caulerpa remotifolia

Juvenile introduced Japanese wakame seaweed *Undaria pinnatifida*

Common kelp *Ecklonia radiata*

Green alga *Caulerpa longifolia*

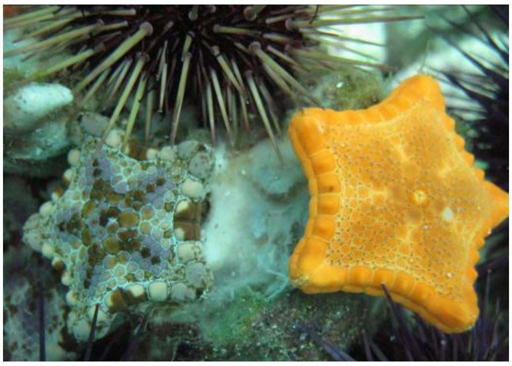
Sargassum sp.

Figure 1.1. Examples of macroalgae present in northern Port Phillip Bay.


Sea urchin *Heliocidaris erythrogramma*


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

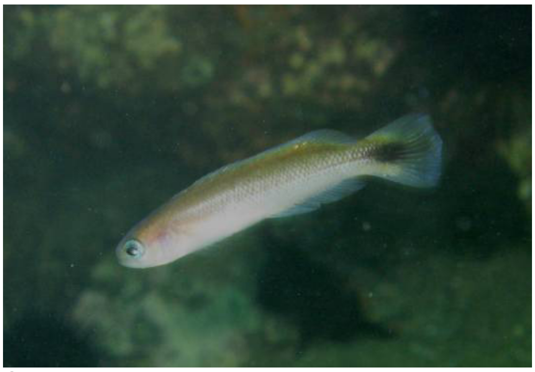

Nudibranch *Ceratosoma brevicaudatum*


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


Black-lipped abalone *Haliotis rubra*


Feather worm *Sabellastarte australiensis*

Figure 1.2. Examples of reef invertebrate species present in northern Port Phillip Bay.



Southern hulafish *Trachinops caudimaculatus*

Globefish *Diodon nichthemerus*

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 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 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.

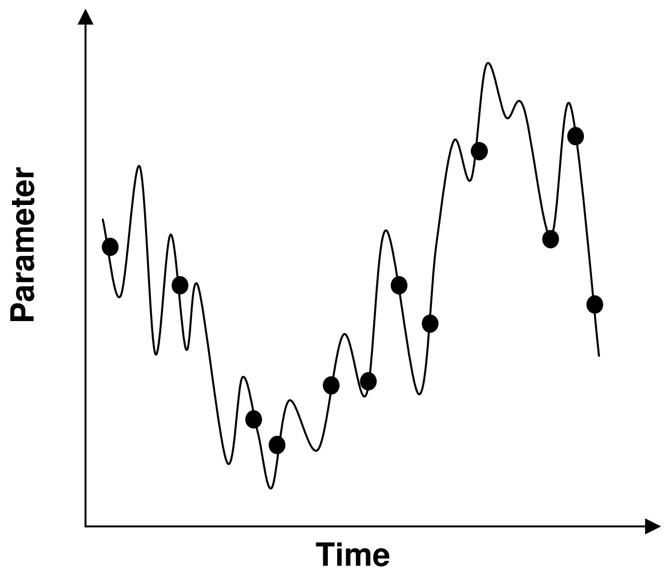


Figure 1.4. An example plot depicting change in an environmental, population or community variable over time (days, months or years) and potential patterns from isolated observations.

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 Jawbone Marine Sanctuary

This report provides a description of the monitoring program at Jawbone Marine Sanctuary and the reference site, Point Gellibrand, located south east 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 April 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 Sites and Survey Times

Jawbone Marine Sanctuary is situated between Altona and Williamstown in the north of Port Phillip Bay (Figure 2.1). The subtidal reef at Jawbone Marine Sanctuary is in shallow water (< 4 m) and consists of large basalt boulders and bedrock sloping steeply to sand at the toe of the reef. The Jawbone monitoring site (Site 4103) was very close to shore on the 2-3 m isobath.

A reference monitoring site (Site 4104) was located approximately 2 km east of Jawbone Marine Sanctuary at Point Gellibrand, Williamstown. The reef structure at this site was similar to the Jawbone reef, consisting predominantly of large basalt boulders and bedrock, but was generally flatter with more sand among reef patches. The monitoring site at Point Gellibrand was at 2 m depth.

The sites were first surveyed in March 2003 and were surveyed six times to 2013. Survey times are provided in Table 2.2.

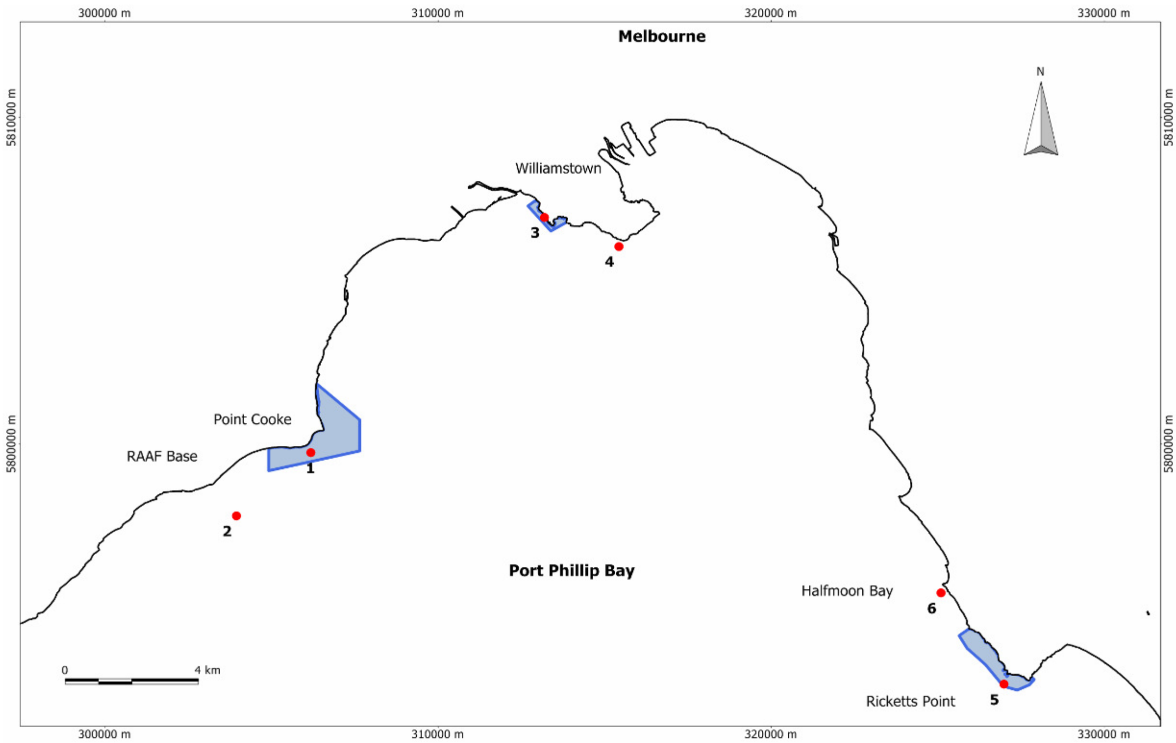


Figure 2.1. Location of monitoring sites in northern Port Phillip Bay. Marine sanctuaries are shaded blue. The Jawbone MS sites are Sites 3 and 4.

Table 2.1. Subtidal reef monitoring sites at the Jawbone Marine Sanctuary.

Site No.	Site Name	MPA/Reference	Depth (m)
4103	Jawbone MS	MPA	3
4104	Point Gellibrand	Reference	3

Table 2.2. Survey times for monitoring at the Jawbone Marine Sanctuary.

Survey	Season	Survey Period
1	Autumn	March 2003
2	Autumn	April 2004
3	Autumn	April 2005
4	Autumn	April 2009
5	Winter	June 2011
6	Autumn	April 2013

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 Jawbone 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.

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. Each diver had size-marks on an underwater slate to enable calibration of their size estimates. Four 10 x 50 m sections of the 200 m transect were censused for mobile fish at each site. The data for easily sexed species were recorded separately for males and female/juveniles. Such species include the blue-throated wrasse *Notolabrus tetricus*, herring cale *Olisthops cyanomelas*, barber perch *Caesioperca rasor*, rosy wrasse *Pseudolabrus rubicundus* and some leatherjackets.

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.

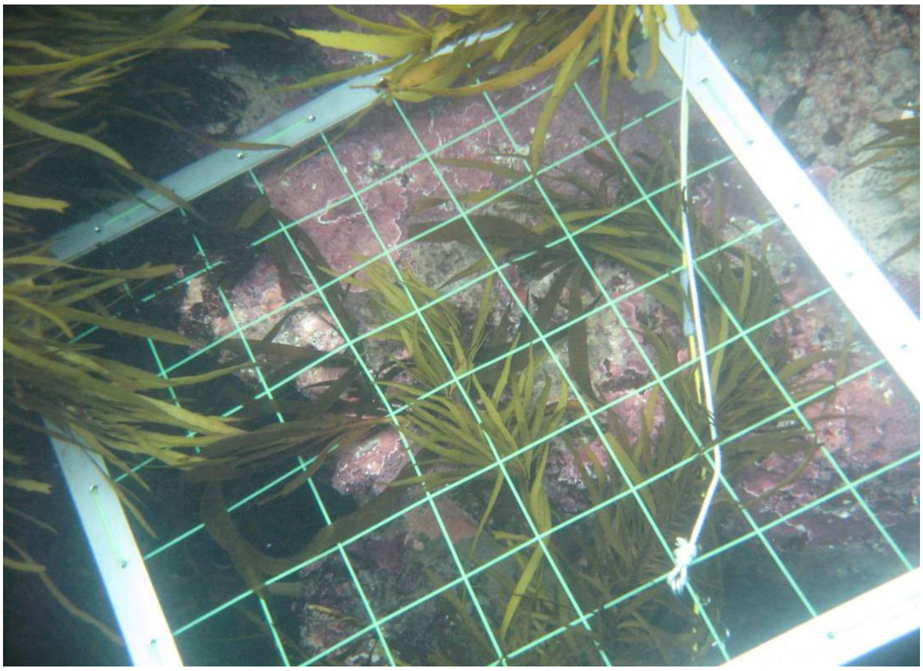


Figure 2.3. The cover of macrophytes is measured by the number of points intersecting each species on the quadrat grid.

2.2.7 Method 5 – Fish Stereo Video

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

The stereo camera system was operated by the diver who did the UVC fish survey at the (Method 1). The stereo camera frame had the underwater UVC slate mounted on it for the simultaneous observations. The camera system was pointed parallel with the transect line with the diver swimming 2.5 m to one side of the transect and then returning on the other side of the transect, 2.5 m from the transect line. The camera unit was tilted vertically (up or down) according to the fish seen to ensure adequate footage for size measurements. Lateral movement of the unit was minimised. The survey speed was 10 m per minute (0.17 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 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 (Method 1) taxa censused in northern Port Phillip Bay.

Method 1		
Cephalopoda	**Mobile Bony Fishes**	**Mobile Bony Fishes**
Octopus maorum	*Girella zebra*	*Neoodax balteatus*
	Girella tricuspidata	*Neosebastes scorpaenoides*
Sharks and Rays	*Enoplosus armata*	*Nesogobius* sp.
Trygonorrhina fasciata	*Scorpis aequipinnis*	*Acanthaluteres spilomelanurus*
Urolophus cruciatus	*Tilodon sexfasciatus*	*Acanthaluteres vittiger*
Urolophus paucimaculatus	*Parma victoriae*	*Scobinichthys granulatus*
	Cheilodactylus nigripes	*Meuschenia flavolineata*
Mobile Bony Fishes	*Dactylophora nigricans*	*Meuschenia freycineti*
Arripis trutta	*Notolabrus tetricus*	*Meuschenia hippocrepis*
Atherinason hepsetoides	*Trachinops caudimaculatus*	*Brachaluteres jacksonianus*
Atherinid sp.	*Acanthopagrus australis*	*Aracana ornata*
Pempheris multiradiata	*Bovichtus angustifrons*	*Diodon nichthemerus*
Caesioperca rasor	*Heteroclinus perspicillatus*	*Tetractenos glaber*
Pagrus auratus	*Siphamia cephalotes*	
Platycephalus bassensis	*Upeinichthys vlamingii*	

Table 2.4. Invertebrate and cryptic fish (Method 2) taxa censused in northern Port Phillip Bay.

Method 2		
Molluscs	**Echinoderms**	**Cryptic Fishes**
Haliotis rubra	*Comanthus trichoptera*	*Nesogobius* sp.
Haliotis laevigata	*Heliocidaris erythrogramma*	*Bovichtus angustifrons*
Dicathais orbita	*Amblypneustes* spp.	*Pempheris multiradiata*
Pleuroploca australasia	*Tosia australis*	*Heteroclinus perspicillatus*
Pterynotus triformis	*Tosia magnifica*	*Diodon nichthemerus*
Noumea sp.	*Meridiastra gunnii*	*Brachaluteres jacksonianus*
Ceratosoma brevicaudatum	*Meridiastra calcar*	*Aetapcus maculatus*
Elysia sp	*Parvulastra exigua*	*Parablennius tasmanianus*
Hoplodoris nodulosa	*Plectaster decanus*	*Heteroclinus whiteleggei*
Ostrea angasi	*Petricia vernicina*	*Trinorfolkia clarkei*
	Asterias amurensis	*Vincentia conspersa*
	Uniophora granifera	*Urolophus paucimaculatus*
Polychaetes	*Coscinasterias muricata*	*Parma victoriae*
Sabella spallanzani	*Australostichopus mollis*	
Sabellastarte australiensis		
Crustacea	**Crustacea**	**Crustacea**
Nectocarcinus integrifrons	*Naxia aurita*	*Strigopagurus strigimanus*
Guinusia chabrus	*Austrodromidia octodentata*	
Petrocheles australiensis		

Table 2.5. Macroalgae and seagrass (Method 3) taxa censused in northern Port Phillip Bay.

Method 3		
Chlorophyta (green algae)	**Phaeophyta (brown algae)**	**Rhodophyta (red algae)**
Ulva spp.	*Dictyota dichotoma*	*Ceramium* spp.
Enteromorpha sp.	*Dictyota diemensis*	*Champia viridis*
Caulerpa brownii	*Dilophus marginatus*	*Gracilaria cliftoni*
Caulerpa flexilis	*Zonaria turneriana*	*Gracilaria* spp.
Caulerpa flexilis var. *muelleri*	*Distromium flabellatum*	*Griffithsia monilis*
Caulerpa simpliciuscula	*Leathesia difformis*	*Pterocladia capillacea*
Caulerpa remotifolia	*Lobophora variegata*	*Solieria robusta*
Caulerpa scalpelliformis	*Padina* sp.	*Cheilosporum sagittatum*
Caulerpa trifaria	*Splanchnidium rugosum*	*Arthrocardia wardii*
Caulerpa longifolia	*Undaria pinnatifida*	*Jania rosea*
Caulerpa obscura	*Ecklonia radiata*	Encrusting corallines
Caulerpa geminata	*Acrocarpia paniculata*	*Callophyllis rangiferina*
Caulerpa hodgkinsoniae	*Caulocystis cephalornithos*	*Plocamium angustum*
Cladophora prolifera	*Cystophora brownii*	*Plocamium cartilagineum*
Cladophora spp.	*Cystophora monilifera*	*Plocamium leptophyllum*
Codium duthieae	*Cystophora moniliformis*	*Rhodymenia australis*
Codium fragile	*Cystophora retroflexa*	*Rhodymenia obtusa*
Codium harveyi	*Cystophora siliquosa*	*Ballia callitricha*
Codium lucasi	*Cystophora subfarcinata*	*Peyssonelia* sp.
Codium spp.	*Phyllotricha decipiens*	*Laurencia filiformis*
Filamentous green algae	*Sargassum fallax*	*Echinothamnion hystrix*
Unidentified green algae	*Sargassum linearifolium*	*Gigartina* sp.
	Sargassum spinuligerum	*Hypnea ramentacea*
Phaeophyta (brown algae)	*Phyllotricha varians*	*Laurencia botryoides*
Colpomenia peregrina	*Phyllotricha verruculosum*	*Laurencia filiformis*
Colpomenia sinuosa	*Sargassum* spp.	*Laurencia tumida*
Colpomenia spp.	Filamentous browns	*Laurencia* spp.
Cladostephus spongiosus	Brown algae unidentified	*Dictymenia harveyana*
Halopteris spp.	**Rhodophyta (red algae)**	Filamentous red algae
Lobospira bicuspidata	Thallose red algae	Red turfing algae

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 (nMDS; Clarke 1993). This ordination method finds the representation in fewer dimensions that best depicts the actual patterns in the hyper-dimensional data (i.e. reduces the number of dimensions while depicting the salient relationships between the samples). The MDS results were then depicted graphically to show differences between the sample periods at each location. The distance between points on the MDS plot is representative of the relative difference in community structure.

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

Trends in Community Structure

Multivariate control charting was used to examine the degree of changes in community structure over time. Two criteria 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.

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 1000 bootstrap samples as a provisional limit or trigger line. The 50th percentile was also presented to assist in interpreting the control charts. Only the comparison against the prior-times centroid was calculated here until the number of survey times increases to enable comparison against a ‘baseline’ in initial period.

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). The mean abundance of *M. pyrifera* were plotted using densities from Method 4, or cover estimates from Method 4 where density data were unavailable. *M. pyrifera* provides considerable vertical structure to reef habitats and can also attenuate water currents and wave motion. The loss of *M. pyrifera* habitats may reflect ecosystem functional changes.

Centrostephanus rodgersii

The range of the long-spined sea urchin, *Centrostephanus rodgersii,* has increased conspicuously over the past decades (Johnson *et al.* 2005). This grazing species can cause considerable habitat modification, decreasing seaweed canopy cover and increasing the area of 'urchin barrens'. Abundances are determined using Method 2 and average abundances are plotted through time. The 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. 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. *D. potatorum* is potentially two species, having genetically and morphologically distinct eastern and western forms (Fraser *et al.* 2009).

2.3.6 Fishing

Abalone

Indicators of altered population structure from harvesting pressure on abalone were mean density and the proportion of legal sized individuals. The size-frequency histograms were also examined. The indicators were calculated for the blacklip abalone, *Haliotis rubra,* in most regions and for the greenlip abalone, *H. laevigata,* where present in suitable densities (in central and western Victoria). Comparison of the maximum width between sites was done using a two-tail unpaired t-test assuming unequal variance.

Rock Lobster

The southern rock lobster, *Jasus edwardsii,* is present throughout Victoria. SRMP transects generally did not traverse rock lobster microhabitats, however abundances and sizes are reported for suitable data. In 2013, the abundance of rock lobster was specifically measured during a separate pilot survey detailed elsewhere in this report.

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 *e* centred by subtracting the mean. Linear regression was used to estimate the slope and intercept (which is also the half-height of the slope) of the log-transformed spectrum.

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

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

3 Results

3.1 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 seaweed assemblages at the Jawbone/Williamstown sites were largely depauperate of larger algal species such as patches of the common kelp *Ecklonia radiata* and seasonal (winter-spring) growth of Japanese kelp *Undaria pinnatifida*. The alga cover was generally a mixture of crustose coralline algae, filamentous brown algae (Ectocarpales), small thallose browns such as *Dictyota dichotoma* and the green *Caulerpa* and *Codium* species.

The nMDS analysis indicated the community structure was distinctly different between the two sites at all times, but the relative changes in structure followed a very similar pattern over time (Figure 3.3).

The control plot comparing deviations from prior times indicated both sites fluctuating above and below the 90th percentile deviation level (Figure 3.4).

3.2.2 Macroalgal Species Richness and Diversity

There were no obvious trends of patterns in macroalgal total abundance, species richness or diversity over the monitoring period (Figure 3.5). Total algal abundance is presently at a lower level at both sites (Figure 3.5a). Conversely, algal species richness is presently at a higher level at both sites (Figure 3.5b).

3.2.3 Common Algal Species

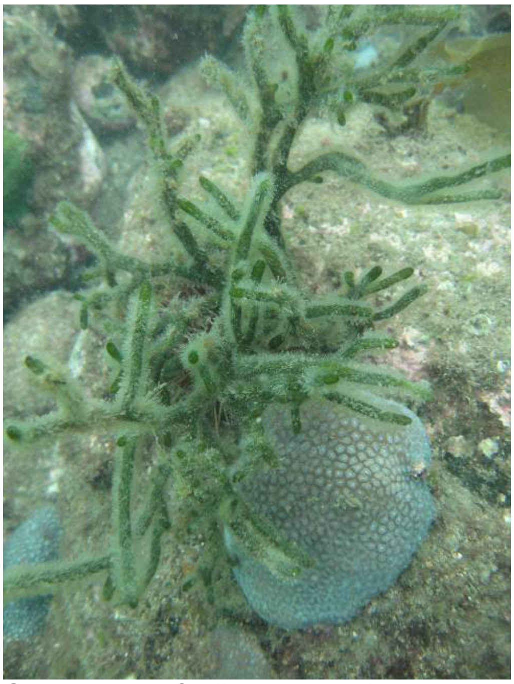
All common macroalgal species had considerable variation over the monitoring period. The most dominant group at both sites were filamentous browns (Ectocarpales), with pulsed changes in cover (Figure 3.6a). Crustose coralline algal cover was generally inversely proportional to the filamentous browns cover, with lower abundances at the beginning and more recent survey times (Figure 3.6b). A similar pattern was evident for common kelp *Ecklonia radiata*: cover was initially low, increasing to peaks of 15% at both sites, with declines back to low coverage by 2011 (Figure 3.6c). Other changes included a decrease in *Ulva* spp coverage at the reference site from 14 % to 2 % cover by 2009 and increased coverage of *Caulerpa geminata* at the reference site from 2009 to 5 % cover in 2013.

Common kelp *Ecklonia radiata*

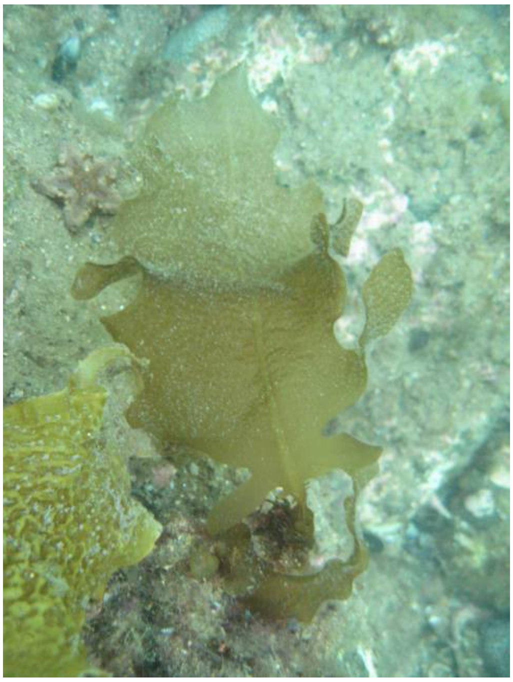
Sessile invertebrates on boulder reef

Sponge and brown alga *Dictyota dichotoma*

Southern golf ball sponge *Tethya bergquistae*



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



Japanese kelp *Undaria pinnatifida*

Figure 3.1. General site conditions, flora and fauna observed at Jawbone MS (Site 4203) in 2011.


Common sea urchin *Heliocidaris erythrogramma*


Green bubble algae *Caulerpa geminata* with red algae


Yellow massive sponge


Yellow repent hyphae sponge


Smooth grey massive sponge


Eleven armed seastar *Coscinasterias muricata*

Figure 3.2. General site conditions, flora and fauna observed at the Jawbone reference site (Site 4204) in 2011.

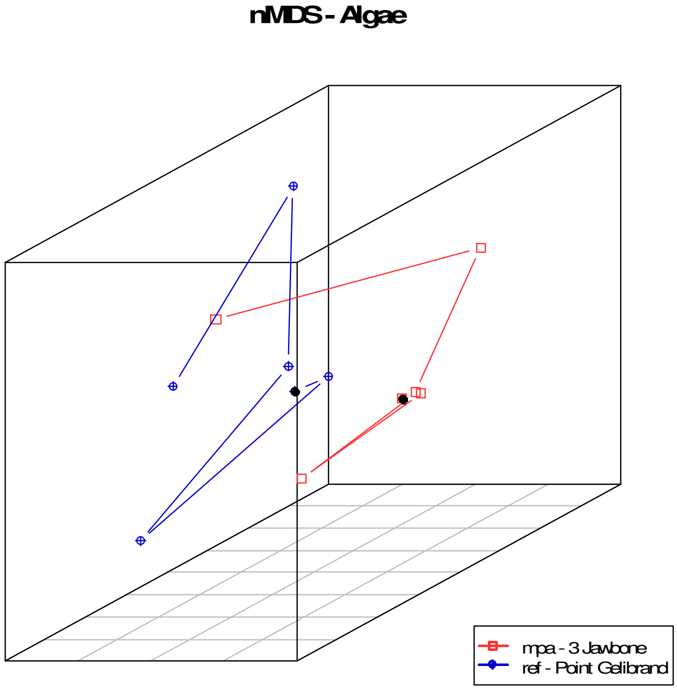


Figure 3.3. Three-dimensional nMDS plot of algal assemblage structure for Jawbone Marine Sanctuary. Kruskal stress value = 0.06. Filled black marks indicate the first survey in 2003.

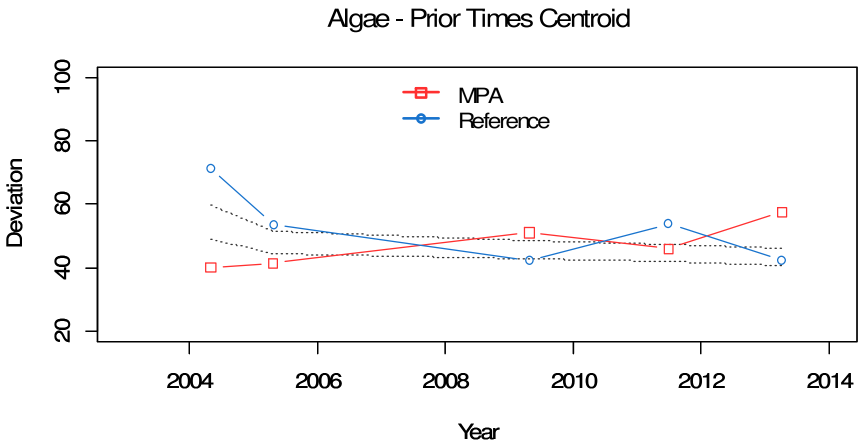


Figure 3.4. Control chart of algal assemblage structure inside and outside Jawbone Marine Sanctuary. Grey lines indicate 50th percentile (lower) and 90th percentile (upper).

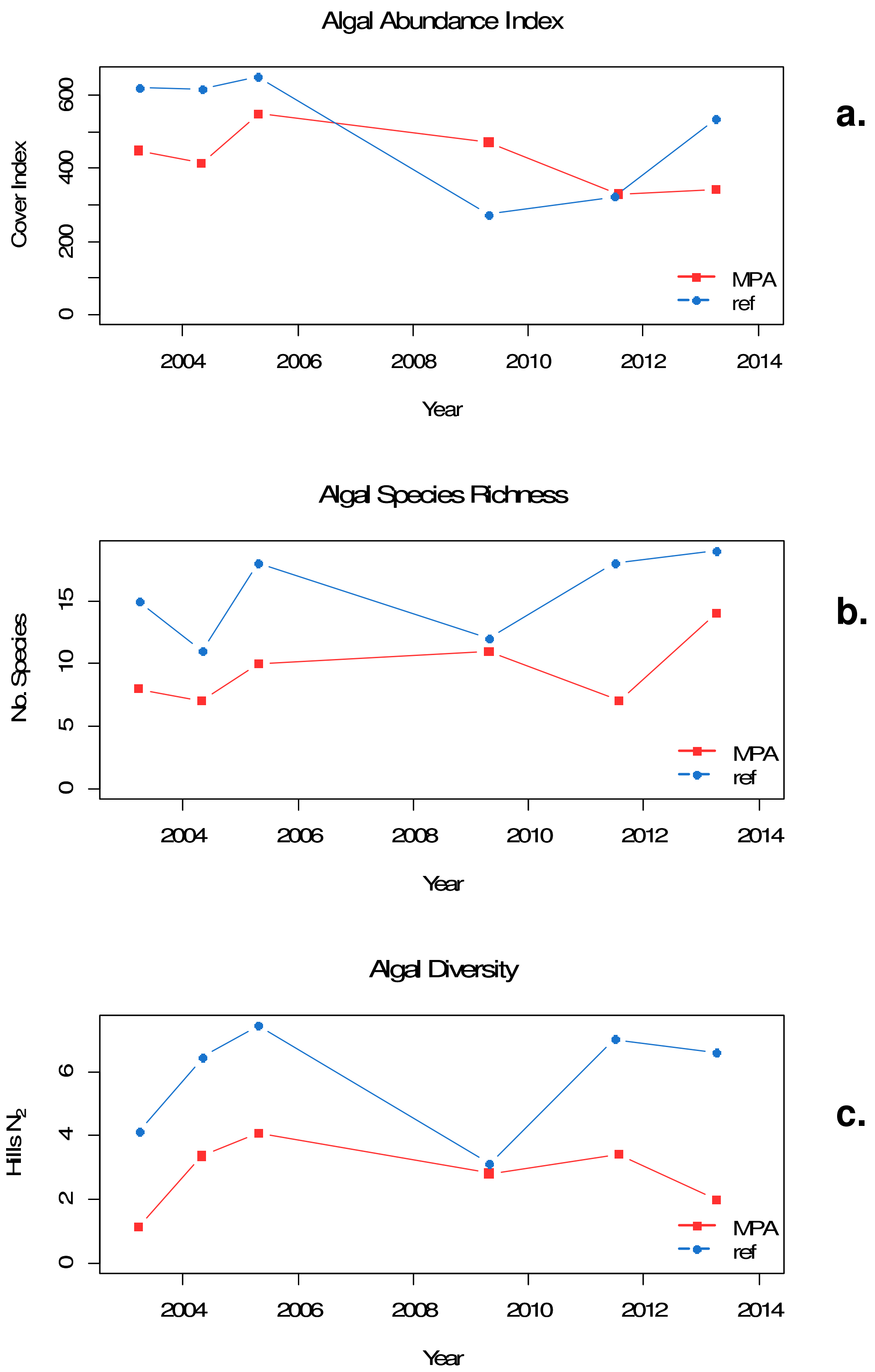


Figure 3.5. Algal species diversity indicators over time inside and outside Jawbone Marine Sanctuary.

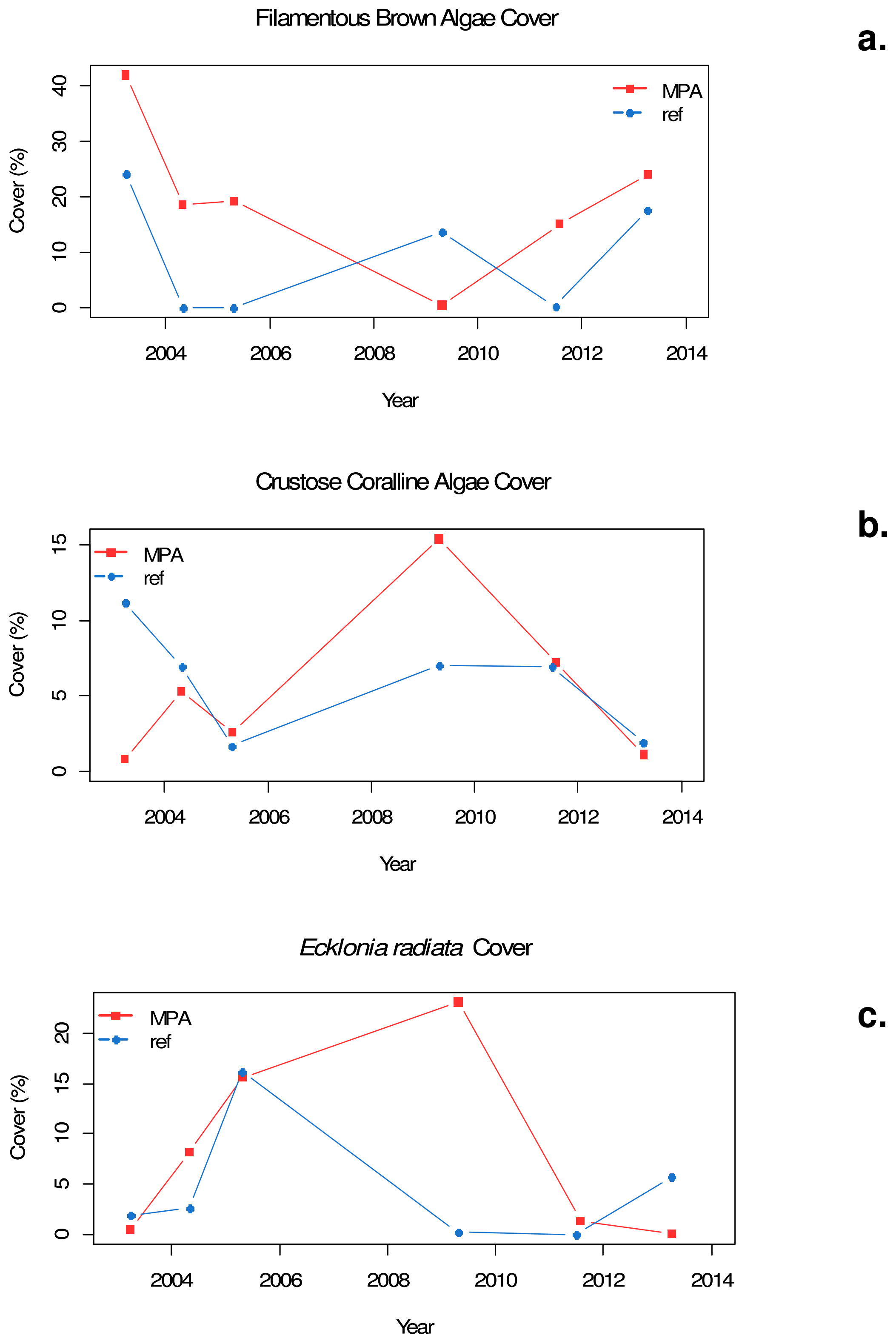


Figure 3.6. Percent cover of the most abundant algal species over time at Jawbone Sanctuary and corresponding reference site.

3.3 Invertebrates

3.3.1 Invertebrate Community Structure

Invertebrate community structure at Jawbone and reference sites appeared to co-vary in the relative trajectories of change over time, with some distinction maintained between the sites (Figure 3.7). The control chart indicated that the invertebrate assemblage was continually shifting over time away from prior-times conditions (Figure 3.8). Conversely, there were shifts at the reference site back towards prior-times conditions (Figure 3.8).

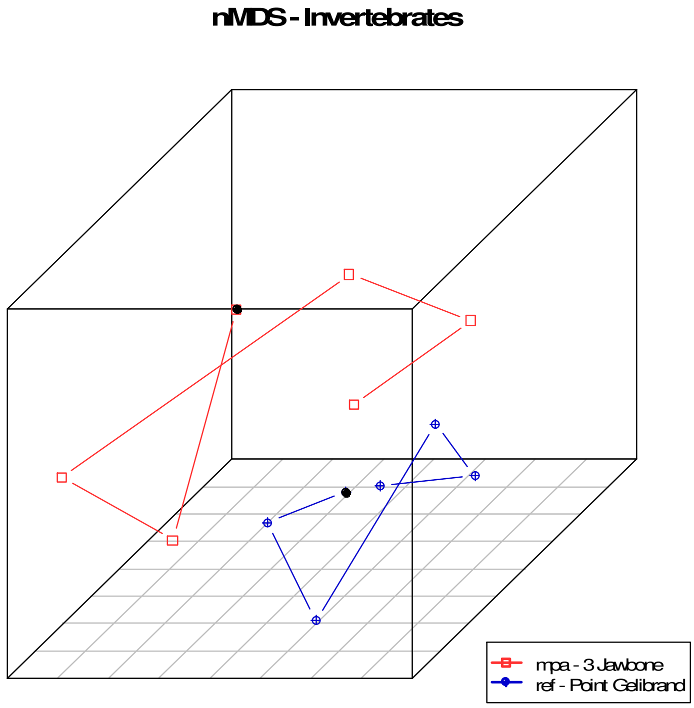


Figure 3.7. Three-dimensional nMDS plot of invertebrate assemblage structure inside and outside Jawbone Marine Sanctuary. Kruskal stress value = 0.05. Filled black symbols indicate the first survey in 2003.

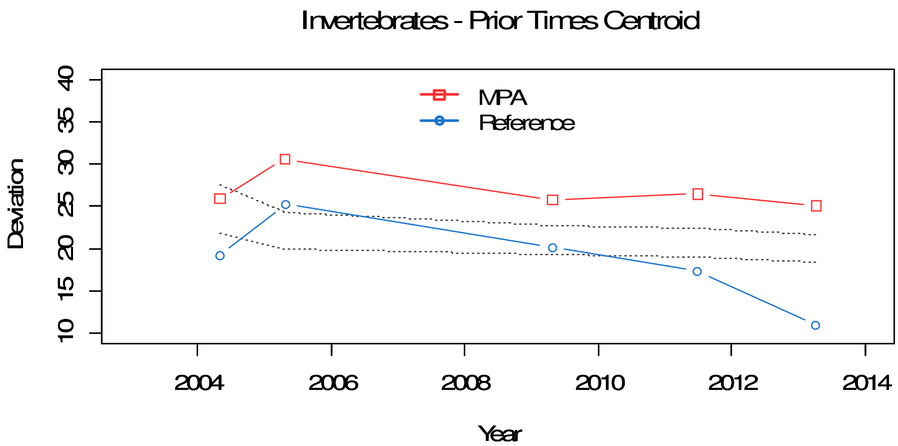


Figure 3.8. Control chart of invertebrate assemblage structure inside and outside Jawbone Marine Sanctuary. Grey lines indicate 50th percentile (lower) and 90th percentile (upper).

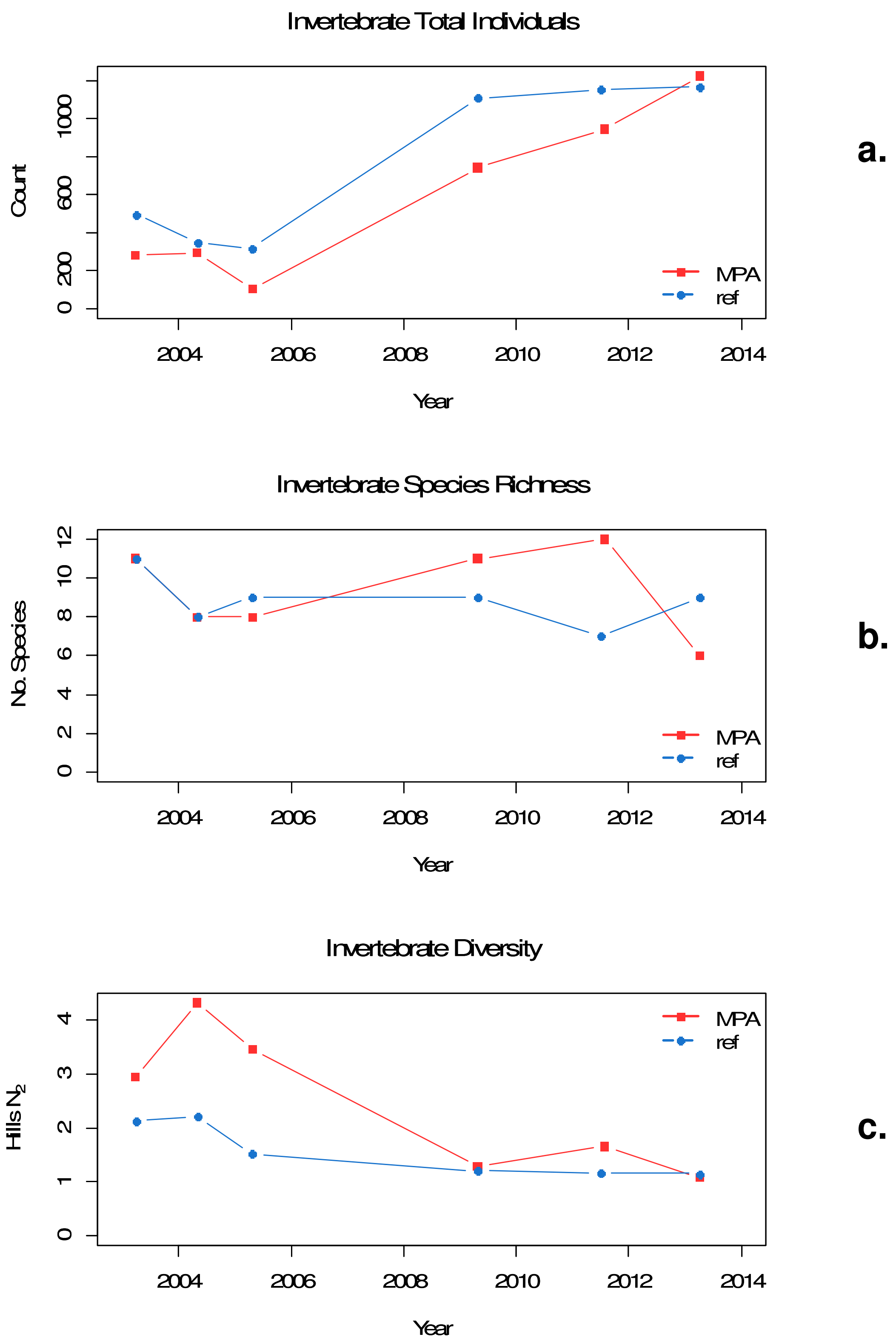


Figure 3.9. Invertebrate species diversity indicators over time inside and outside Jawbone Marine Sanctuary.

3.3.2 Invertebrate Species Richness and Diversity

There was a marked step in the total abundance of mobile invertebrates between 2005 and 2009 (Figure 3.9a). This increase was by a factor of four and was driven by an increase in the sea urchin *Heliocidaris erythrogramma*. There were no obvious trends in species richness, however there was a decline in diversity corresponding with the increased dominance of sea urchins at both sites from 2009 (Figures 3.9b and 3.9c).

3.3.3 Common Invertebrate Species

The abundance of the sea urchin *Heliocidaris erythrogramma* quadrupled between 2005 and 2009 with densities at both sites in the order of 1000 per 200 m^2 during the 2013 survey (Figure 3.10a). Relatively high abundances of the biscuit star *Tosia australis* were present at both sites during 2009 and 2011, with a subsequent decrease to previously observed levels by 2013 (Figure 3.10b). The abundances of blacklip abalone *Haliotis rubra* were similar at both sites with moderate variations over time (Figure 3.10c). The seastar *Meridiastra calcar* had abundances above 40 per 200 m^2 in 2003 and 2004, with a notable decline by 2005 (Figure 3.10d). No *Meridiastra calcar* were recorded in the reference transects since 2004 and abundances were low at the sanctuary site until 2011, with none observed in 2013 (Figure 3.10d). A similar initial pattern of decline was observed for *Meridiastra gunnii*, however abundances subsequently increased at both sites, including a spike in abundance in the sanctuary during 2011 (Figure 3.10e).

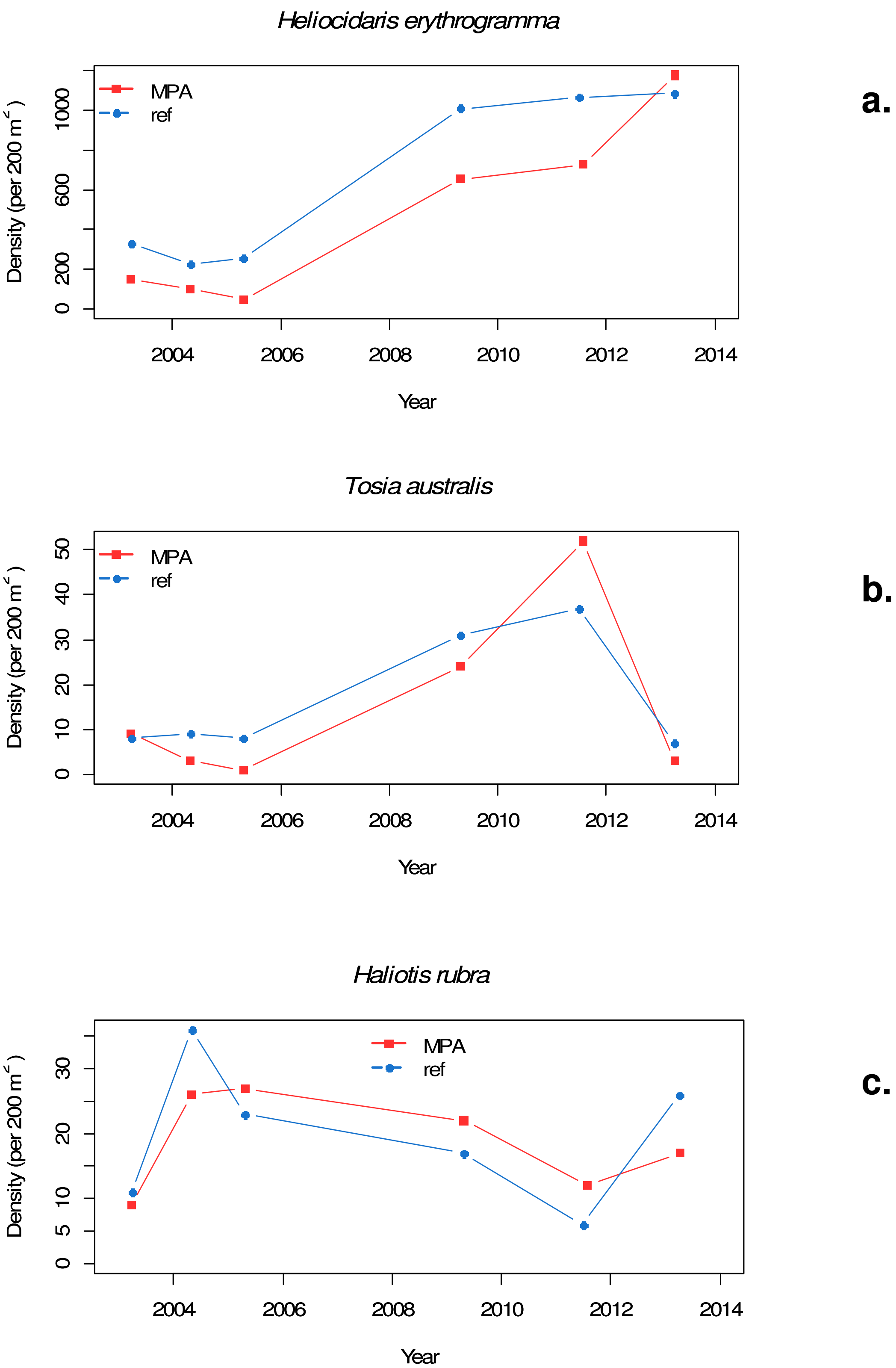
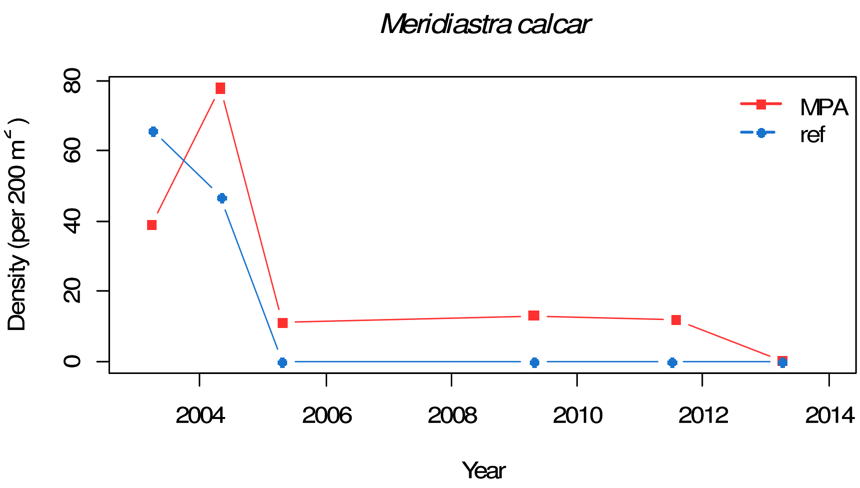
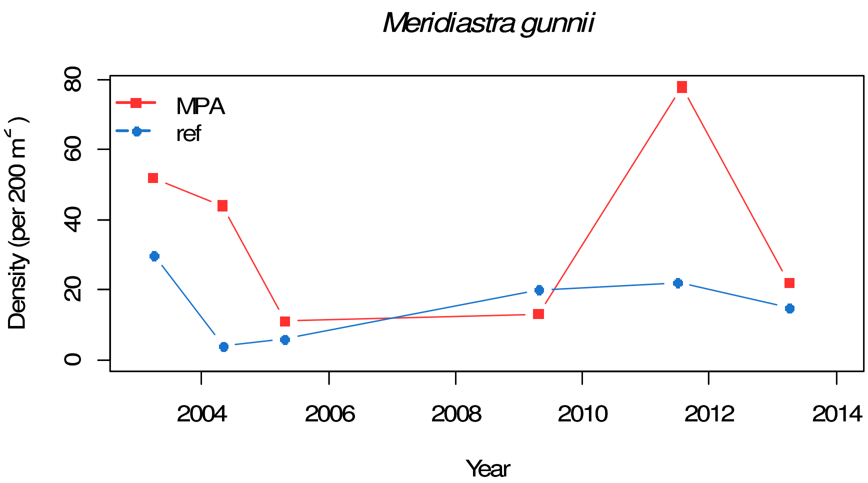


Figure 3.10. Density of dominant invertebrate species over time inside and outside Jawbone Marine Sanctuary.



d.



e.

Figure 3.10 (continued). Density of dominant invertebrate species over time inside and outside Jawbone Marine Sanctuary.

3.3.4 Urchin Barrens

The low cover of algae and high density of sea urchins observed during the last three surveys are indicative of both sites being heavily grazed by sea urchins. There was no obvious partition of the sites into non- barren areas.

3.4 Fishes

3.4.1 Fish Community Structure

The fish communities at both sites were similar at both sites and between most surveys. The greatest temporal changes were observed at both sites in 2011 (Figure 3.11). This was evident in the control chart, with deviations from prior-times being below the 90th percentile at all times with the exception of a shift in 2011 and subsequent return in 2013 (Figure 3.12). The 2011 anomaly was associated with very low fish sightings rather than a community shift.

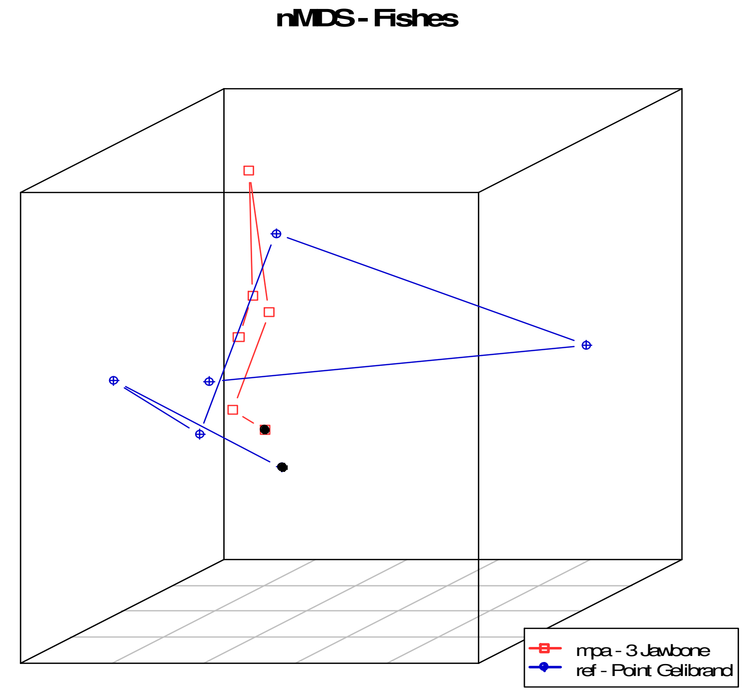


Figure 3.11. Three-dimensional nMDS plot of fish assemblage structure inside and outside Jawbone Marine Sanctuary. Kruskal stress value = 0.002. Filled black symbols indicate the first survey in 2003.

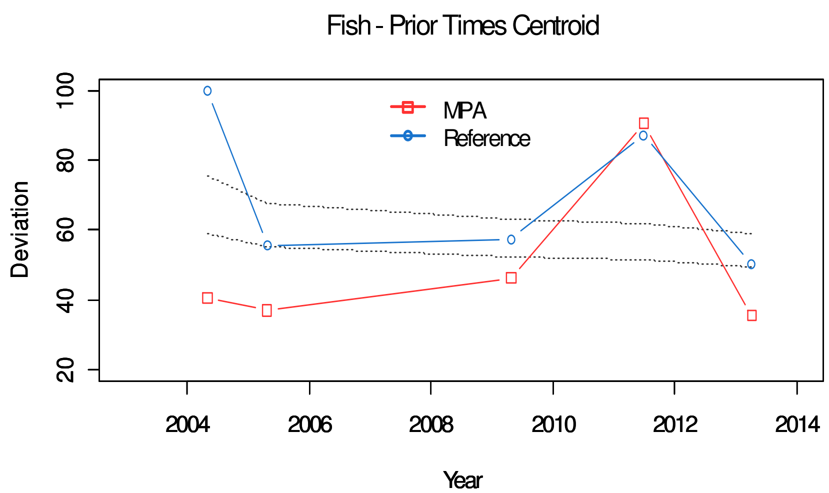


Figure 3.12. Control chart of fish assemblage structure inside and outside Jawbone Marine Sanctuary. Grey lines indicate 50th percentile (lower) and 90th percentile (upper).

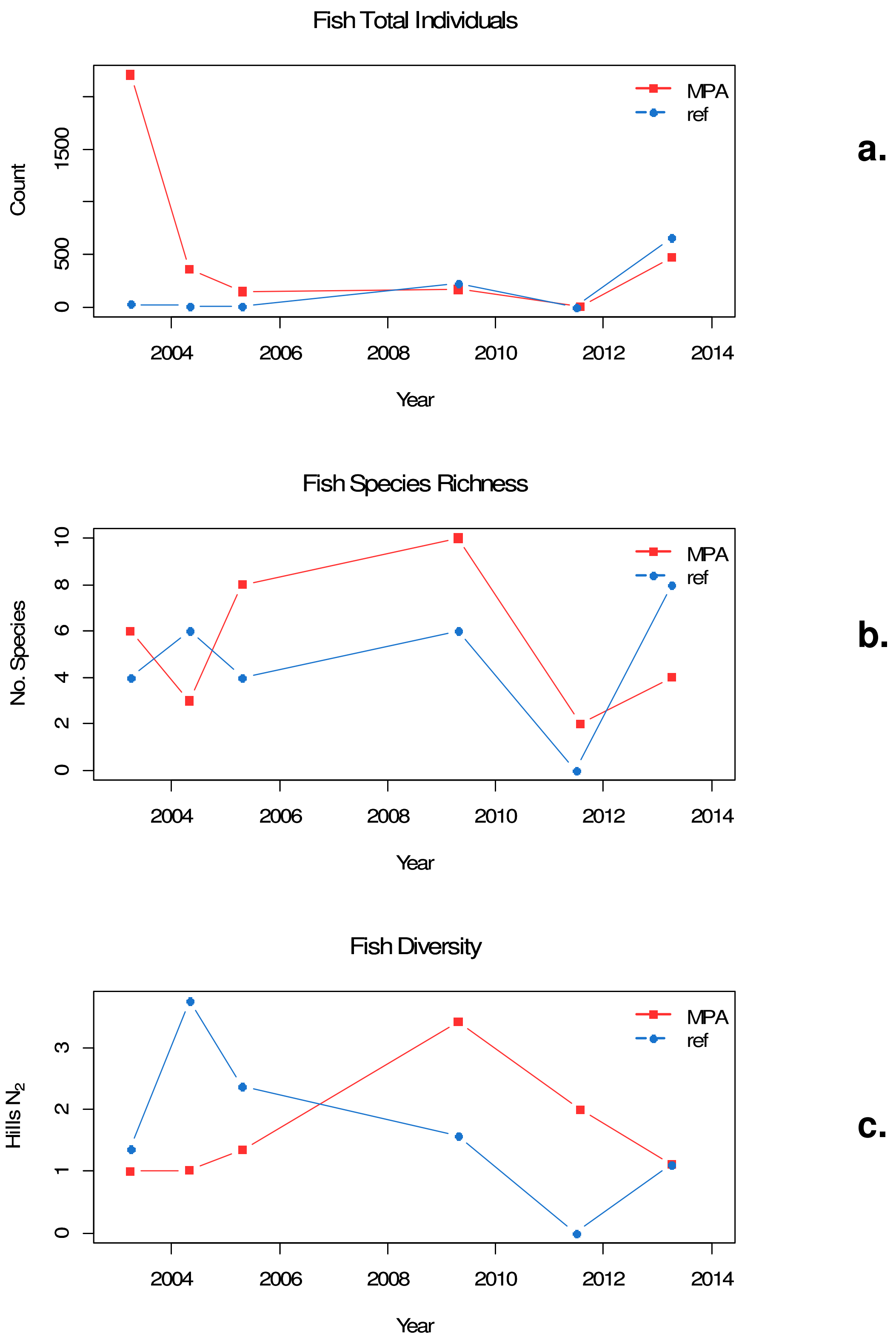


Figure 3.13. Fish species diversity indicators over time inside and outside Jawbone Marine Sanctuary.

3.4.2 Fish Species Richness and Diversity

The observed total fish numbers, species richness and diversity fluctuated markedly between surveys at both sites. The fish observations were highly influenced by occasional presence of schooling juvenile and small estuarine species (baitfish) and variable water quality conditions, including low visibility and freshwater mixing. There were no discernable trends or patterns in these fluctuations (Figure 3.13).

3.4.3 Common Fish Species

The southern hulafish, *Trachinops caudimaculatus* was the most abundant reef-associated species both inside and outside the sanctuary, with similar numbers at both sites (Figure 3.14a). The zebra fish *Girella zebra* were sporadically present in relatively high abundance (Figure 3.14b), and to a lesser extent dusky morwong *Dactylophora nigricans*. Only small numbers of the little weed whiting *Neoodax balteatus* were observed at both sites throughout the monitoring program (Figure 3.14c).

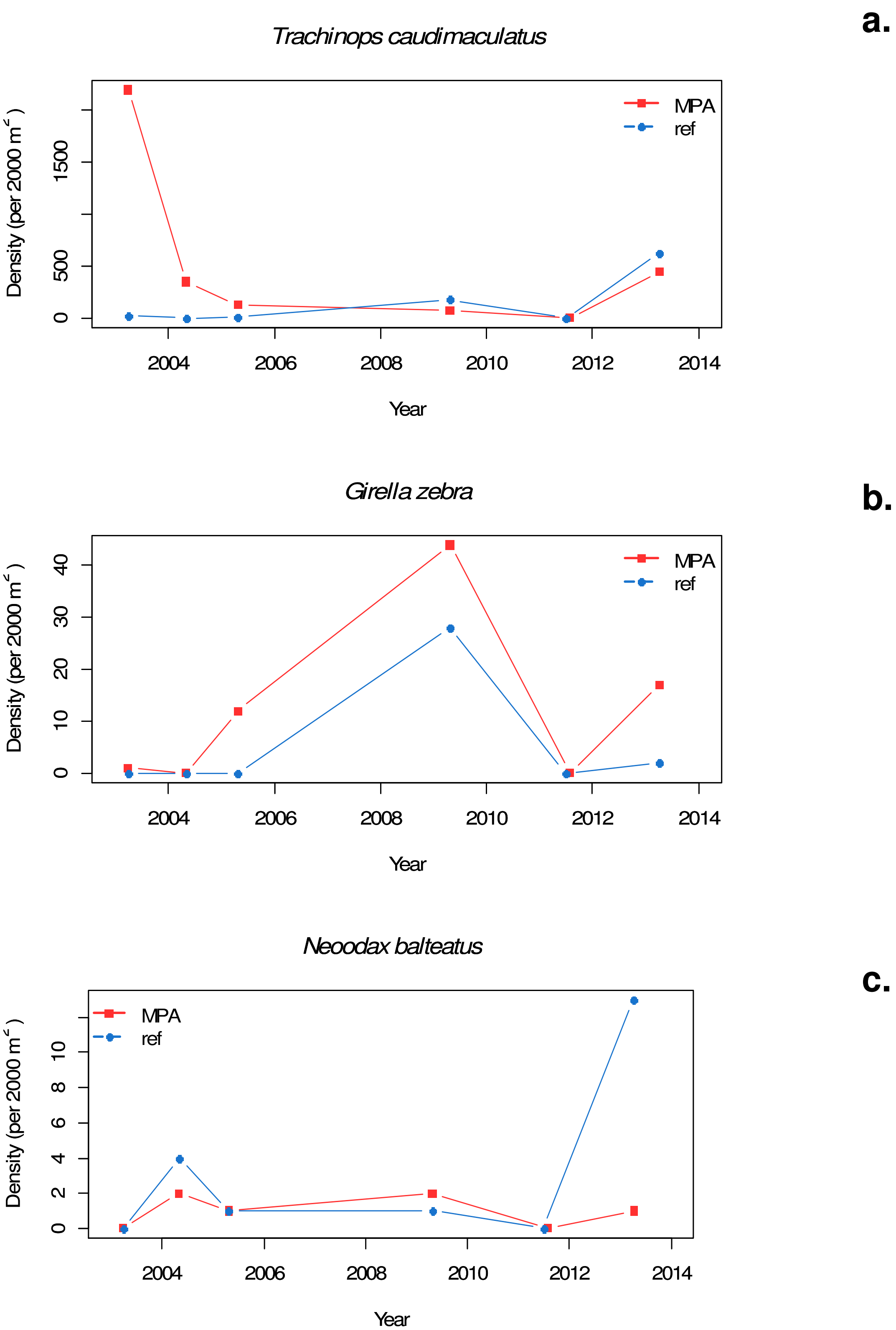


Figure 3.14. Density of dominant fish species over time inside and outside Jawbone Marine Sanctuary.

3.5 Ecosystem Components

3.5.1 Habitat and Primary Production

The ecosystem indicators for plant production and habitat provision were highly varied over time; however most components, including crustose coralline algae, were lower in abundance during the most recent surveys (Figure 3.15).

3.5.2 Invertebrate Functional Groups

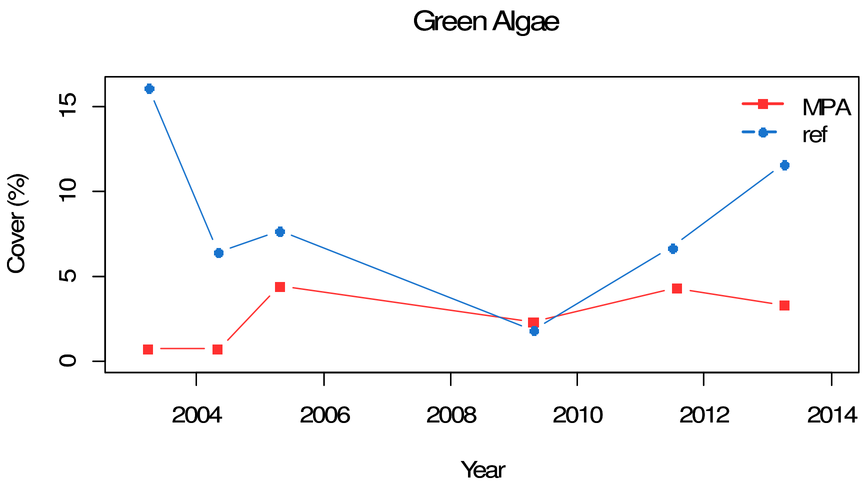
There was a distinct shift in the state of invertebrate grazers, with a marked increase in sea urchins between 2005 and 2009 (Figure 3.16a).

There was an increase in the number of filter feeding invertebrates at Jawbone in 2011 because of large numbers of the Mediterranean fan worm *Sabella spallanzanii* (Figure 3.16b). Only a few individuals of *S. spallanzanii* were observed in 2013.

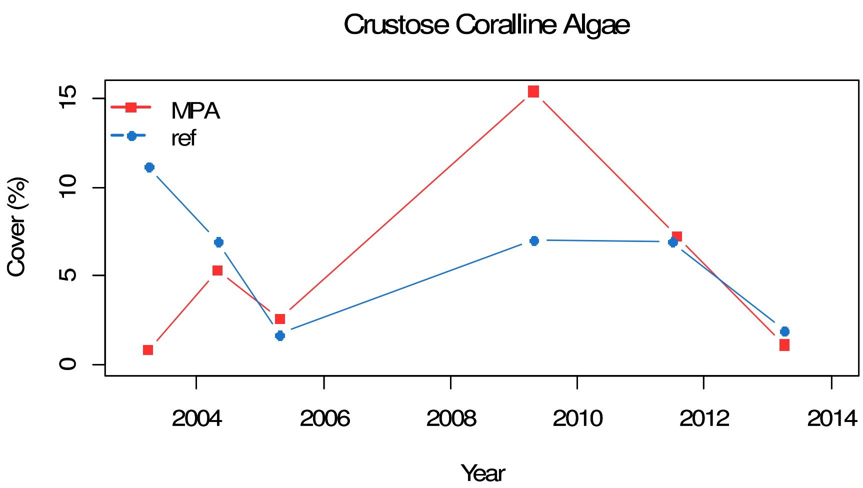
There were considerable fluctuations in seastar abundance, largely driven by the virtual disappearance of *Meridiastra calcar* by 2005 and pulses in *Tosia australis* and *M. gunnii* since that time (Figure 3.16c).

3.5.3 Fish Functional Groups

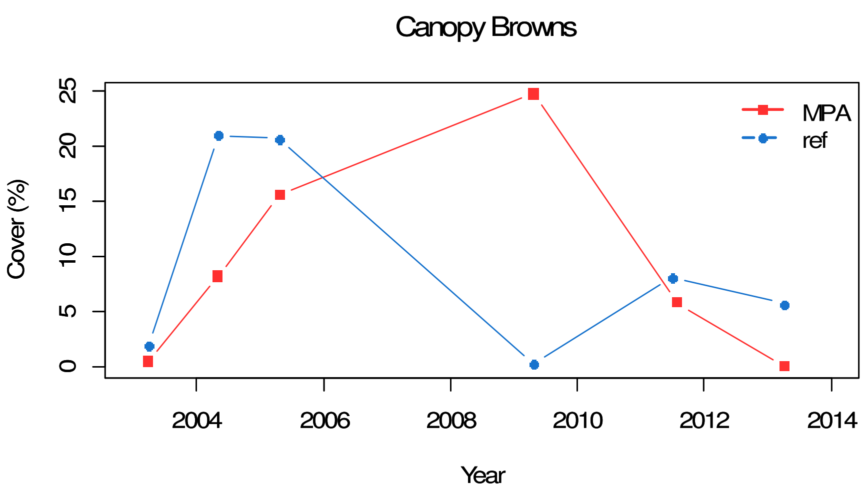
There were large fluctuations of different fish functional groups. This was likely to be more reflective of the fluctuations of the small number of species observed than fluctuations in ecosystem function (Figure 3.17).



a.

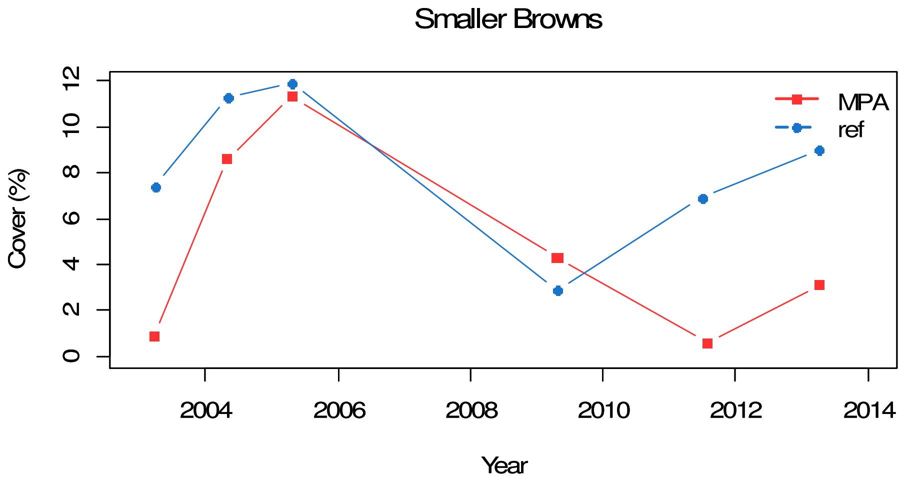


b.

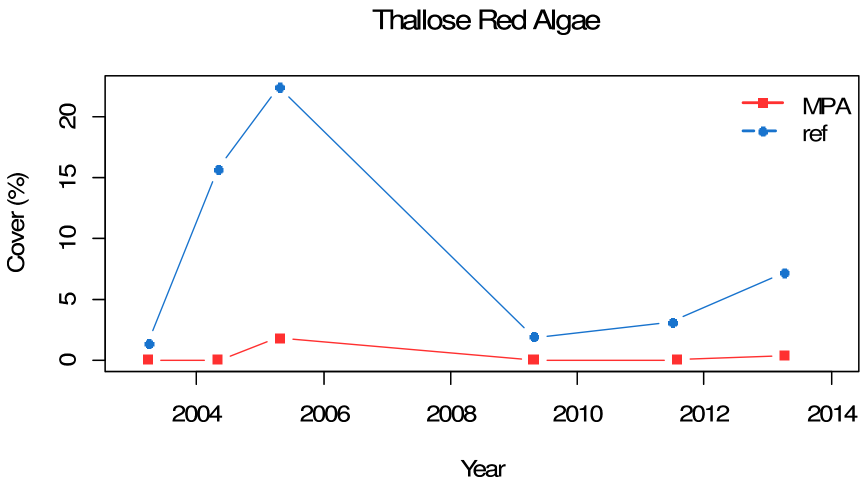


c.

Figure 3.15. Seaweed functional groups over time inside and outside Jawbone Marine Sanctuary.



d.



e.

Figure 3.15 (continued). Seaweed functional groups over time inside and outside Jawbone Marine Sanctuary.

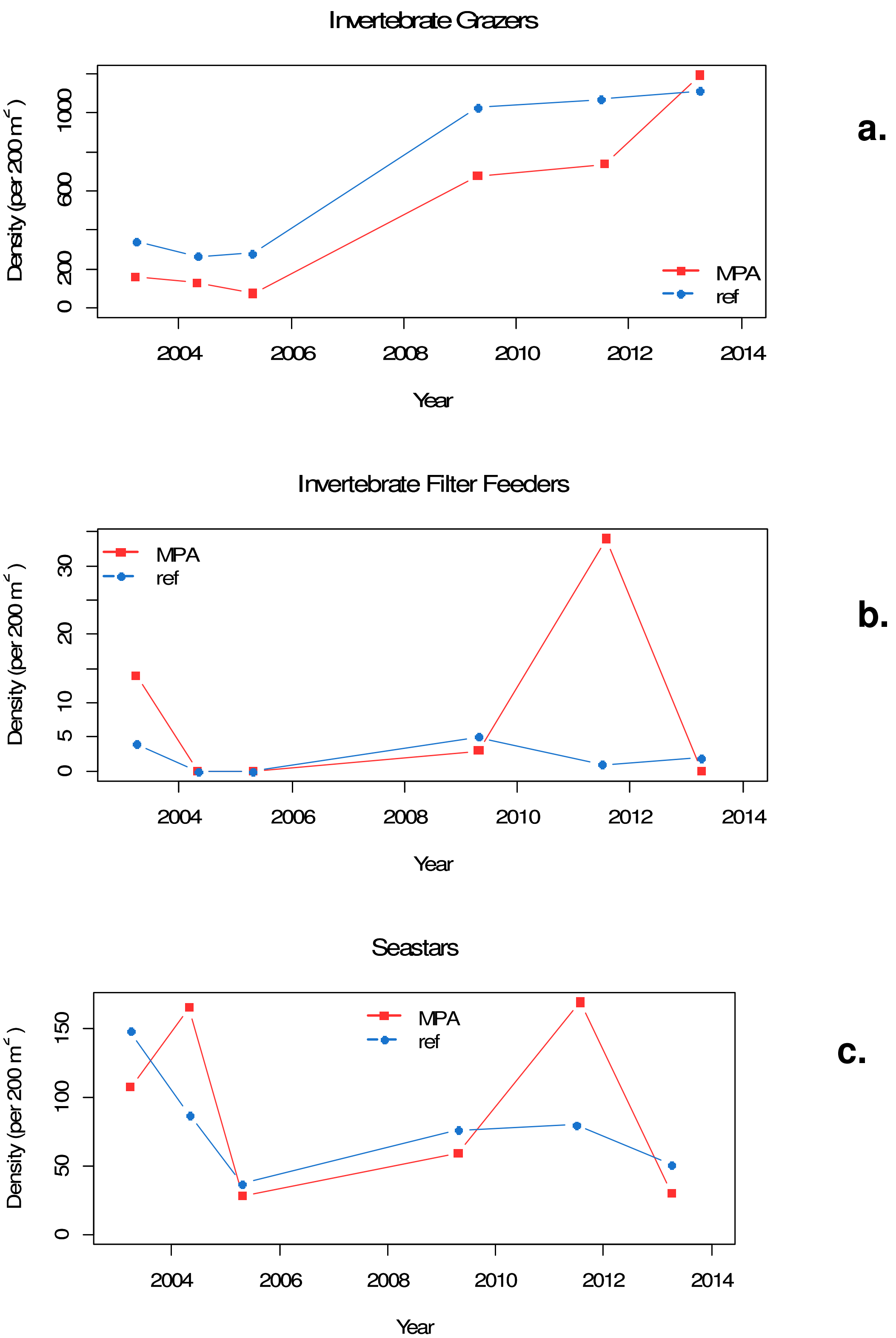


Figure 3.16. Abundance of invertebrate functional groups over time inside and outside Jawbone Marine Sanctuary.

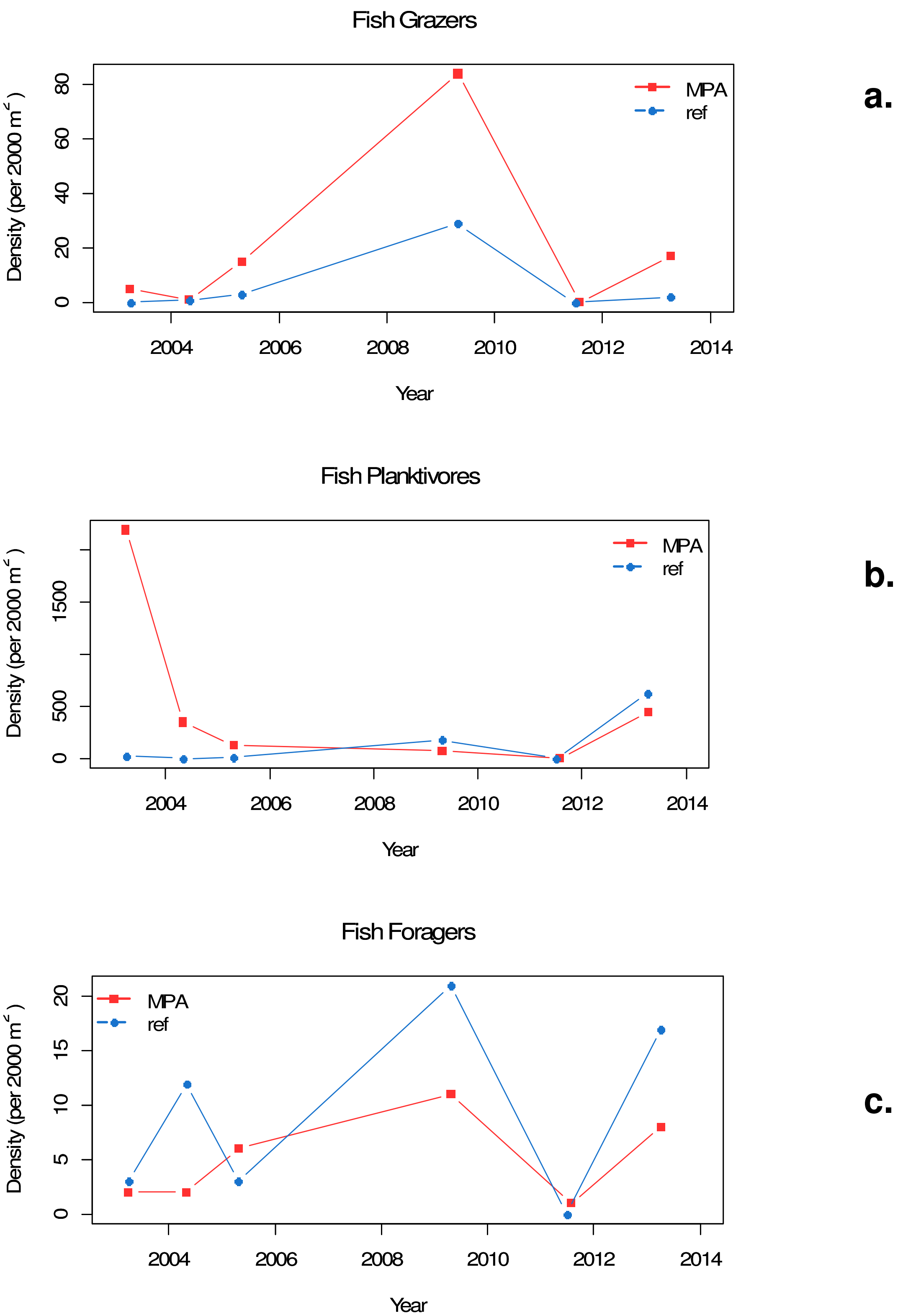


Figure 3.17. Abundance of fish functional groups over time inside and outside Jawbone Marine Sanctuary.

3.6 Introduced Species

In 2009, the Japanese kelp *Undaria pinnatifida* was found inside the MPA in low quantities, and was then observed at both sites in higher densities in 2011. In 2013 there was no *U. pinnatifida* observed at either of the sites. These observations confirm the presence of *U. pinnatifida* but not necessarily the abundance. This is because this species is a seasonal plant with maximum biomass occurring in late spring/early summer. The observed increases in sea urchins may be reflective of a greater availability of food provided by *U. pinnatifida*.

The Mediterranean fan worm *Sabella spallanzanii*, was present in high numbers in the MPA in 2011, but was only observed in the reference area in low numbers in 2013. The northern Pacific seastar *Asterias amurensis* has not been recorded on the transects at either site since 2005, although was visible on sand flats off the transects in 2011 and 2013.

3.7 Climate Change

3.7.1 Species composition

The majority of species observed in the Jawbone area were cosmopolitan and Maugean species. There were no shifts evident toward a high proportion of western or eastern species. There was an apparent, but very slight, increase in proportion of the Maugean algal component in the most recent surveys (Figure 3.18).

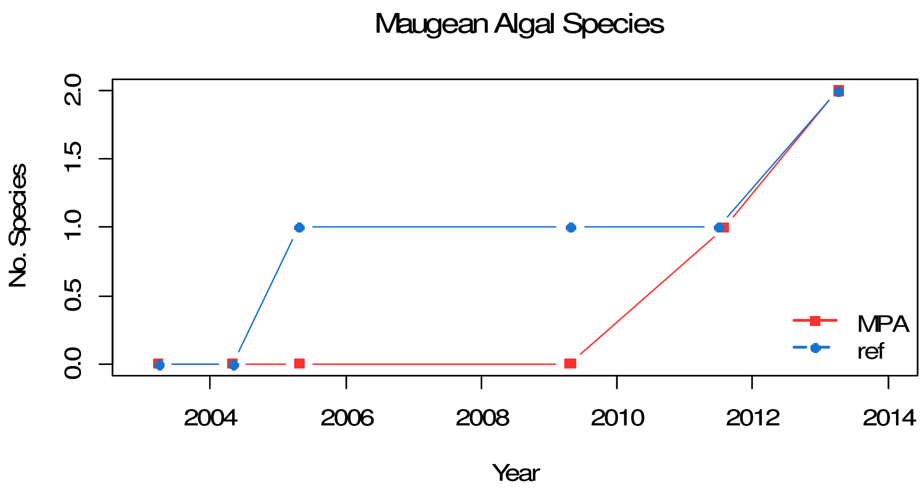
3.8 Fishing

3.8.1 Abalone

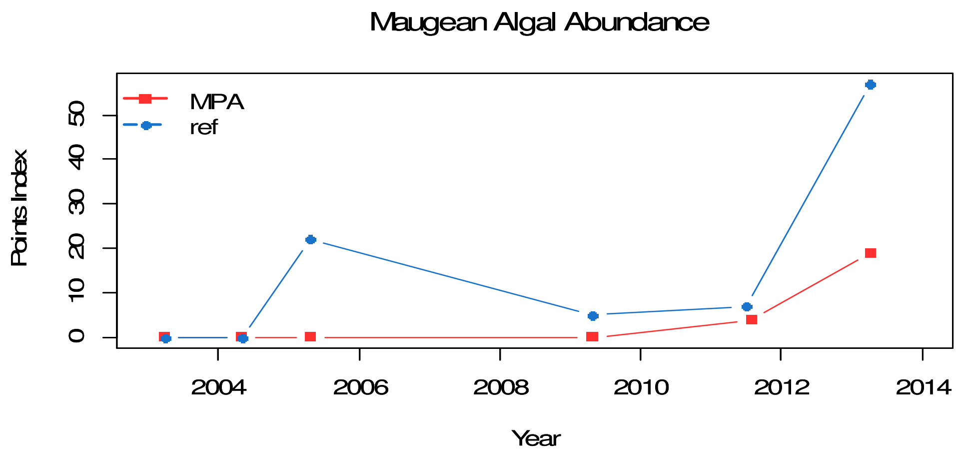
The abundance of abalone *Haliotis rubra* does not appear to have shifted with the shift to increased sea urchin grazers and abundances have been similar inside and outside the sanctuary during each survey. Present abundances are at moderate levels compared with prior observations (Figure 3.10c). The mean length of abalone has not changed markedly over the survey period, although there was a slight reduction at the sanctuary site in 2013 (Figure 3.19a). These populations are well known to be stunted in growth and there has historically been a predominance of smaller abalone at these sites, which has continued throughout the monitoring period (Figure 3.19b).

3.8.2 Fishes

Species of known value to commercial and recreational fishers occur in the area, including snapper *Pagrus auratus*, southern black bream *Acanthopagrus butcheri*, Australian salmon *Arripis* spp and gummy shark *Mustelus antarcticus*. These species are known to be transient to the area and were not recorded in appreciable abundances at the MPA or the reference sites. There were no resident fishes observed on the transects that are known to be harvested.



a.



b.

Figure 3.18. Abundance of Maugean algae species over time inside and outside Jawbone Marine Sanctuary.

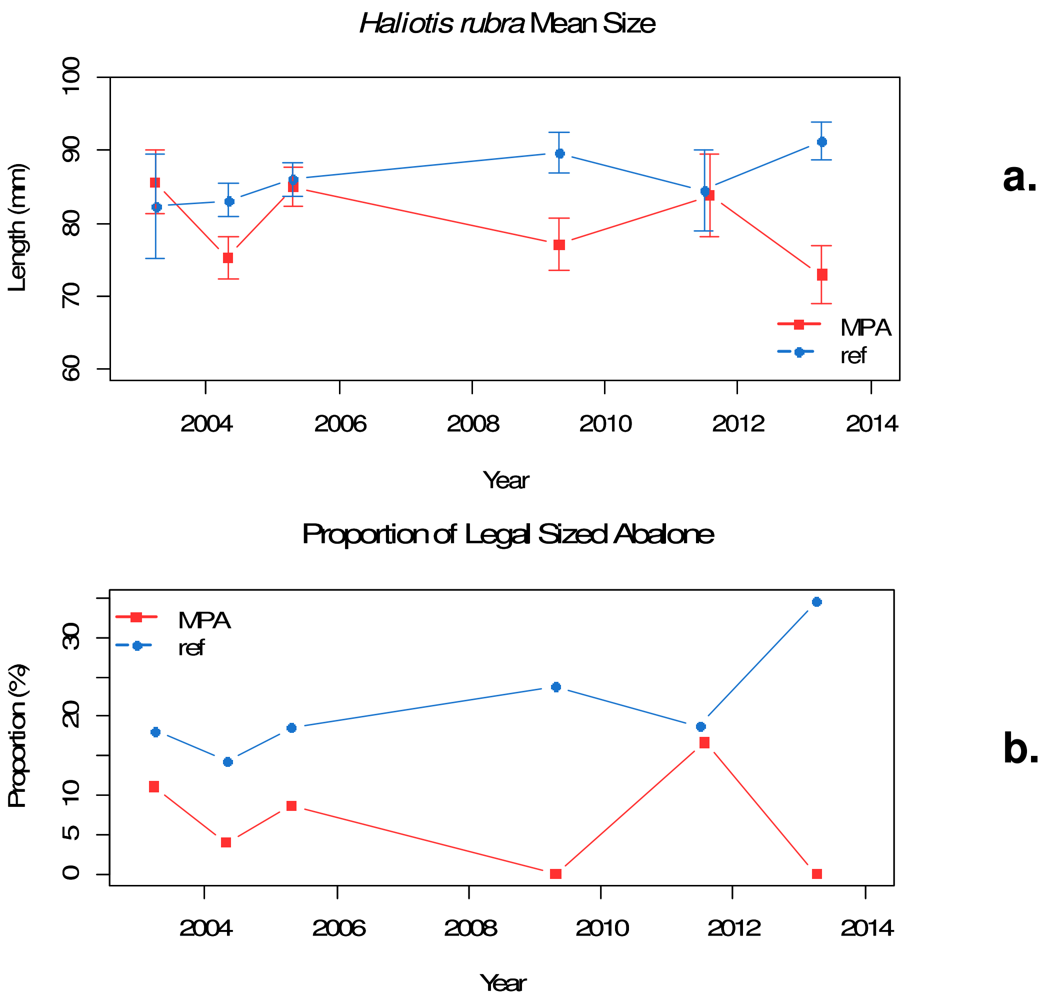


Figure 3.19. Mean size and proportion over time of legal sized blacklip Abalone *Haliotis rubra* inside and outside Jawbone Marine Sanctuary.

4 Acknowledgements

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