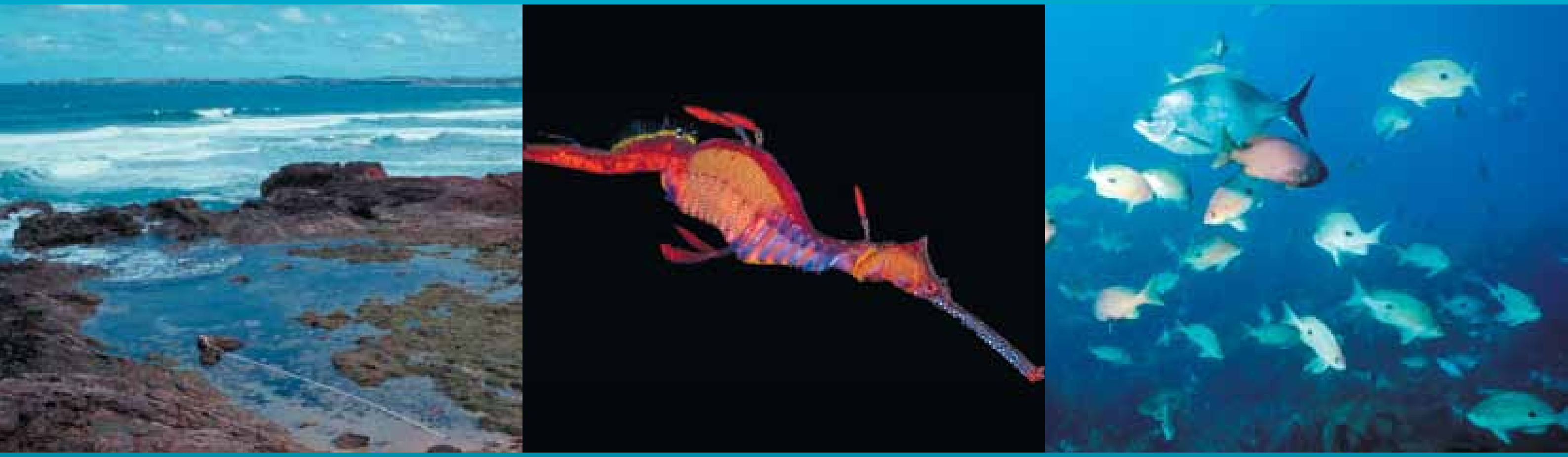

PARKS VICTORIA TECHNICAL SERIES

NUMBER 73

Victorian Subtidal Reef Monitoring Program: The Reef Biota at Merri Marine Sanctuary, April 2011

M. McArthur, T. Tan, S. Davis, and M. Edmunds

August 2012

State Government Victoria
Parks Victoria
Healthy Parks Healthy People®

First published 2012

Published by Parks Victoria
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National Library of Australia
Cataloguing-in-publication data

Includes bibliography
ISSN 1448-4935

Citation

McArthur M, Tan T, Davis S, Edmunds M (2012) Victorian Subtidal Reef Monitoring Program: the reef biota at Merri Marine Sanctuary, April 2011. Parks Victoria Technical Series No. 73. Parks Victoria, Melbourne.

The Victorian Subtidal Reef Monitoring Program was initiated and funded by the then Department of Natural Resources and Environment until 2002, when Parks Victoria assumed responsibility.

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Victorian Subtidal Reef Monitoring Program:

The reef biota at Merri Marine Sanctuary, April 2011

Matt McArthur

Tim Tan

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Australian Marine Ecology Pty. Ltd.

June 2012

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. In order to effectively manage and conserve these important and biologically rich habitats, the Victorian government has established a long-term Subtidal Reef Monitoring Program (SRMP). Over time the SRMP will provide information on the status of Victorian reef flora and fauna and determine the nature and magnitude of trends in species populations and species diversity through time.

The monitoring program in, and around, the Merri Marine Sanctuary began in 2004. Since that time two sites have been surveyed, both within the Central Victorian Marine Bioregion. The monitoring involves standardised underwater visual census methods to a depth of 7 m. This report aims to provide:

- a general description of the biological communities and species populations at each monitoring site;
- an identification of any unusual biological phenomena, interesting communities, strong temporal trends and/or the presence of any introduced species.
- The 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;
- percentage cover of macroalgae; and
- density of a string kelp *Macrocystis pyrifera*.

To date, over 150 different species have been observed during the monitoring program in and around the marine protected areas along the western Victorian coast. At both sites, algal assemblages were dominated by a canopy of large brown algal species, majority of which being *Phyllospora comosa*. Understorey assemblages were typical of other exposed southern Victorian locations and consisted largely of various species of fleshy and coralline red algae. Community structure of algae species was simular between the two sites.

The Invertebrate species richness was higher than Merri inside the outside. The species diversity followed similar trends to the species richness. The invertebrate community largely

consisted of the blacklip abalone *Haliotis rubra*, the warrener *Turbo undulatus* and a variety of sea stars. The most common seastar was *Nectria macrobrachia*.

Fish species richness varied between 7 and 19 species per site. The common fish species included blue throat wrasse *Notolabrus tetricus*, purple wrasse *N. fucicola* and herring cale *Odax cyanomelas*. Common leatherjackets were yellow tailed leatherjacket *Meuschenia flavolineata* and horseshoe leatherjacket *M. hippocrepis*.

Some notable observations following the 2011 survey were:

- seaweed, invertebrate and fish assemblage structures in 2011 deviated significantly from the prior times average (centroid);
- invertebrate species richness was relatively low from 2006 to 2011;
- fish species richness and diversity was at lowest levels in 2011;
- the dominant seaweed canopy cover of crayweed *Phyllospora comosa*, wireweed *Acrocarpia paniculata* and common kelp *Ecklonia radiata* was relatively stable over the monitoring period;
- the warrener or periwinkle *Turbo undulatus* were at high levels at the Merri MS site from 2005 and 2009, but had returned to low, 2004 levels, in 2011;
- the abundance of abalone *Haliotis rubra* at its lowest at the marine sanctuary site in 2011 and similar to abundances at the start of monitoring in 2004;
- the mean size of abalone *H. rubra* was maintained;
- the abundances of larger fishes, > 200 mm length, was at its lowest in 2011, with abundances being relatively low since 2006; and
- the mean size of blue-throated wrasse *Notolabrus tetricus* was maintained over the monitoring period.

The results in this report present a snapshot in time for community structures and species population trends, which operate over long time scales. As monitoring continues and longer-term datasets are accumulated (over multiple years to decades) the program will be able to more adequately reflect the average trends and ecological patterns occurring in the system.

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1. INTRODUCTION

1.1. Subtidal Reef Ecosystems on the Victoria Coast

Shallow reef habitats cover extensive areas along the Victorian coast. The majority of reefs in this area are exposed to strong winds, currents and large swell. A prominent biological component of Victorian shallow reefs is kelp and other seaweeds (Figure 1.1). Large species, such as the common kelp *Ecklonia radiata* and crayweed *Phyllospora comosa*, are usually present along the open coast in dense stands. The production rates of dense seaweed beds are equivalent to the most productive habitats in the world, including grasslands and seagrass beds, with approximately 2 kg of plant material produced per square metre of seafloor per year. These stands typically have 10-30 kg of plant material per square metre. The biomass of seaweeds is substantially greater where giant species such as string kelp *Macrocystis pyrifera* and bull kelp *Durvillaea potatorum* occur.

Seaweeds provide important habitat structure for other organisms on the reef. This habitat structure varies considerably, depending on the type of seaweed species present. Tall vertical structures in the water column are formed by *M. pyrifera*, which sometimes forms a dense layer of fronds floating on the water surface. Other species with large, stalk-like stipes, such as *E. radiata*, *P. comosa* and *D. potatorum*, form a canopy 0.5-2 m above the rocky substratum. Lower layers of structure are formed by: foliose macroalgae typically 10-30 cm high, such as the green *Caulerpa* and the red *Plocamium* species; turfs (to 10 cm high) of red algae species, such as *Pterocladia capillacea*; and hard encrusting layers of pink coralline algae. The nature and composition of these structural layers varies considerably within and between reefs, depending on the biogeographic region, depth, exposure to swell and waves, currents, temperature range, water clarity and the presence or absence of deposited sand.

Grazing and predatory motile invertebrates are prominent animal inhabitants of the reef (Figure 1.2). Common grazers include blacklip and greenlip abalone *Haliotis rubra* and *Haliotis laevigata*, warrener *Turbo undulatus* and sea urchins *Heliocidaris erythrogramma, Holopneustes* spp. and *Amblypneustes* spp. These species can influence the growth and survival of habitat forming organisms. For example, sponges and foliose seaweeds are often prevented from growing on encrusting coralline algae surfaces through the grazing actions of abalone and sea urchins. Predatory invertebrates include dogwhelks *Dicathais orbita*, southern rock lobster *Jasus edwardsii*, octopus *Octopus maorum* and a wide variety of sea star species. Other large reef invertebrates include motile filter feeding animals such as feather stars *Comanthus trichoptera* and sessile (attached) species such as sponges, corals, bryozoans, hydroids and ascidians.

Fishes are also a prominent component of reef ecosystems, in terms of both biomass and ecological function (Figure 1.3). Reef fish assemblages include roaming predators such as blue throat wrasse *Notolabrus tetricus*, herbivores such as herring cale *Odax cyanomelas*, planktivores such as sea sweep *Scorpis aequipinnis* and picker-feeders such as six-spined leatherjacket *Meuschenia freycineti*. The type and abundance of each fish species varies considerably depending on exposure to swell and waves, depth, currents, reef structure, seaweed habitat structure and many other ecological variables. Many fish species play a substantial ecological role in the functioning and shaping of the ecosystem. For example, the feeding activities of fishes such as scalyfin *Parma victoriae* and magpie morwong *Cheilodactylus nigripes* promote the formation of open algal turf areas, free of larger canopy-forming seaweeds.

Although the biomass and the primary and secondary productivity of shallow reef ecosystems in Victoria are dominated by seaweeds, motile invertebrates and fishes, there are many other important biological components to the reef ecosystem. These include small species of crustaceans and molluscs from 0.1 to 10 mm in size (mesoinvertebrates), occupying various niches as grazers, predators or foragers. At the microscopic level, films of microalgae and bacteria on the reef surface are also important.

Victoria’s shallow reefs are a very important component of the marine environment because of their high biological complexity, species diversity and productivity. Subtidal reef habitats also have important social and cultural values, which incorporate aesthetic, recreational, commercial and historical aspects. Shallow subtidal reefs also have significant economic value, through commercial fishing of reef species such as wrasses, morwong, rock lobster, abalone and sea urchins, as well as recreational fishing, diving and other tourism activities.

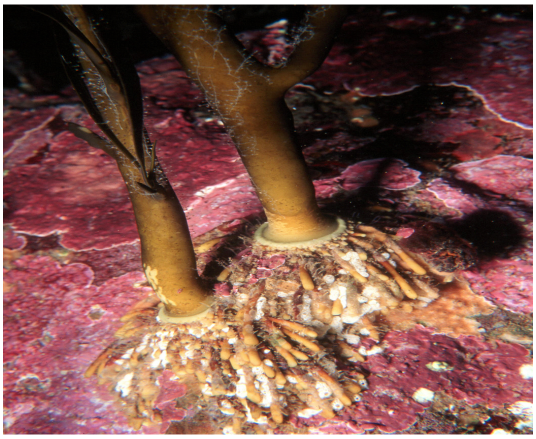
Crayweed *Phyllospora comosa* canopy

Common kelp *Ecklonia radiata* canopy

Thallose red algae *Ballia callitricha*

Red coralline algae *Haliptilon roseum*

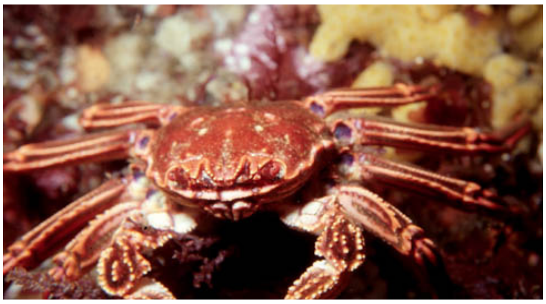
Green algae *Caulerpa flexilis*



Encrusting coralline algae around crayweed *Phyllospora comosa* holdfast

Figure 1.1 Examples of macroalgae found on subtidal reefs on the Victorian coast.

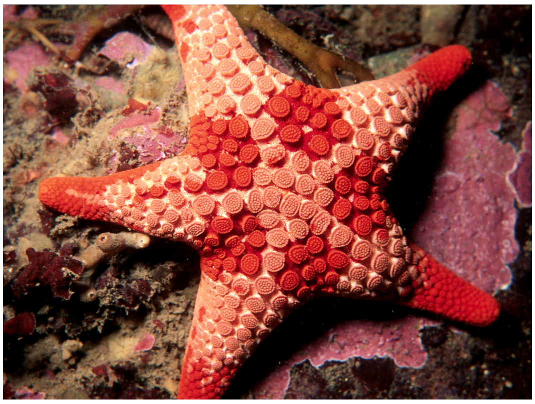
Southern rock-lobster *Jasus edwardsii*



Red bait crab *Plagusia chabrus*

Blacklip abalone *Haliotis rubra*

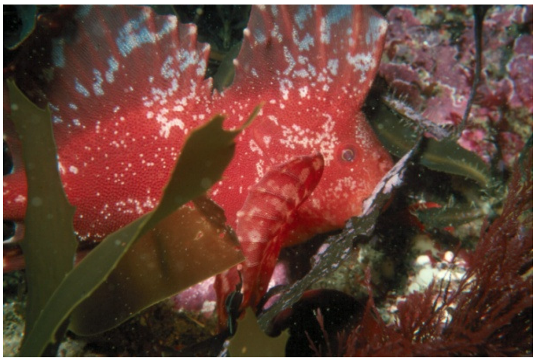
Feather star *Comanthus trichoptera*



Nectria ocellata

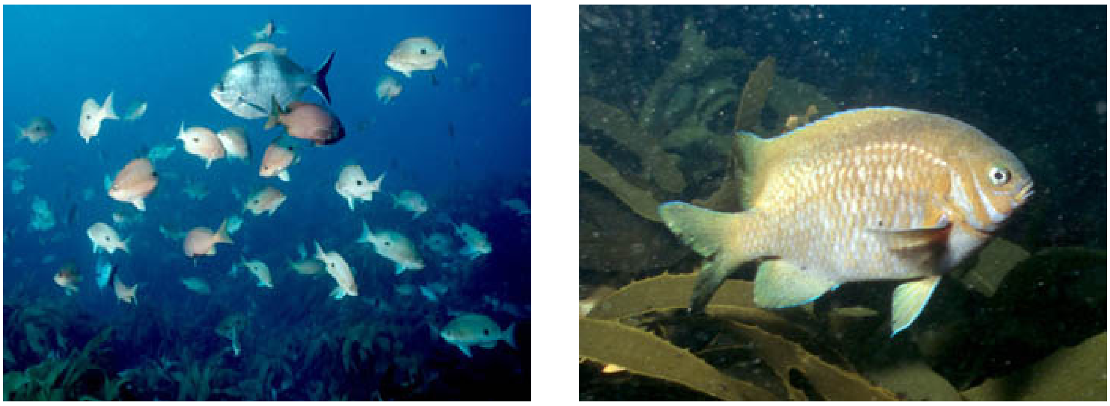
Heliocidaris erythrogramma

Fromia polypore



Red velvet fish
Gnathanocanthus goetzeei

Figure 1.2. Examples of species of invertebrates and cryptic fish found on Victorian subtidal reefs.

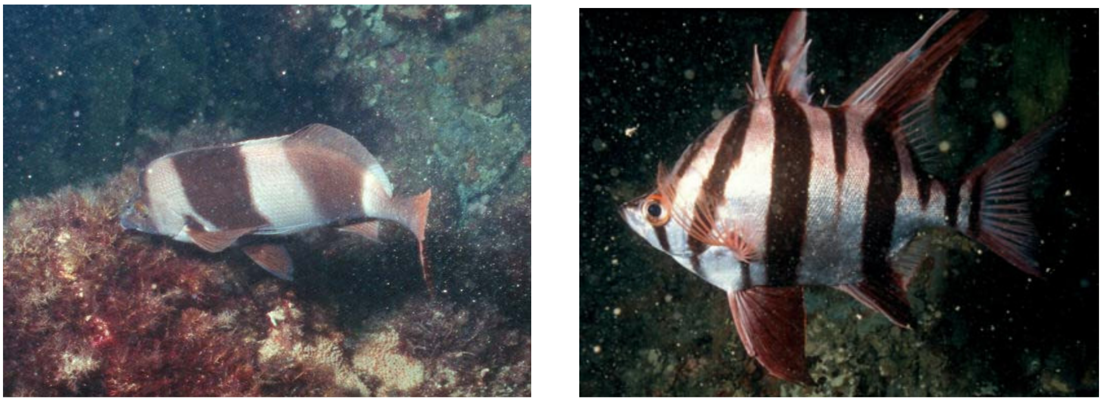


Sea sweep *Scorpis aequipinnis* and Butterfly perch *Caesioperca lepidoptera*

Scalyfin *Parma victoriae*

Blue-throated wrasse *Notolabrus tetricus*

Six-spined leatherjacket *Meuschenia freycineti* (male)



Magpie morwong *Cheilodactylus nigripes*

Old-wife *Enoplosus armatus*

Figure 1.3. Examples of fish species found on Victorian subtidal reefs.

1.2. Subtidal Reef Monitoring Program

1.2.1. Objectives

An important aspect of the management and conservation of Victorian marine natural resources and assets is assessing the condition of the ecosystem and how this changes over time. Combined with an understanding of ecosystem processes, this information can be used to manage any threats or pressures on the environment to ensure ecosystem sustainability.

Consequently, the Victorian Government has established a long-term Subtidal Reef Monitoring Program (SRMP). The primary objective of the SRMP is to provide information on the status of Victorian reef flora and fauna (focussing on macroalgae, macroinvertebrates and fish). This includes monitoring the nature and magnitude of trends in species abundances, species diversity and community structure. This is achieved through regular surveys at locations throughout Victoria, encompassing both representative and unique habitats and communities.

Information from the SRMP allows managers to better understand and interpret long-term changes in the population and community dynamics of Victoria's reef flora and fauna. As a longer time series of data are collected, the SRMP will allow managers to:

- compare changes in the status of species populations and biological communities between highly protected marine national parks and marine sanctuaries and other Victorian reef areas (*e.g.* Edgar and Barrett 1997; Edgar and Barrett 1999);
- determine associations between species and between species and environmental parameters (*e.g.* depth, exposure, reef topography) and assess how these associations vary through space and time (*e.g.* Dayton *et al*. 1998; Edgar *et al*. 1997; Edmunds, Roob and Ferns 2000);
- provide benchmarks for assessing the effectiveness of management actions, in accordance with international best practice for quality environmental management systems (*e.g.* Holling 1978; Meredith 1997); and
- determine the responses of species and communities to unforeseen and unpredictable events such as marine pest invasions, mass mortality events, oil spills, severe storm events and climate change (*e.g.* Ebeling *et al*. 1985; Edgar 1998; Roob *et al*. 2000; Sweatman *et al*. 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, harvesting), years (*e.g.* El Niño), decades (*e.g.* pollution, extreme storm events) or even centuries (*e.g.* tsunamis, global warming). Other studies indicate this monitoring program will begin to adequately reflect average trends and patterns as the surveys continue over longer periods (multiple years to decades). Results of this monitoring need to be interpreted within the context of the monitoring frequency and duration.

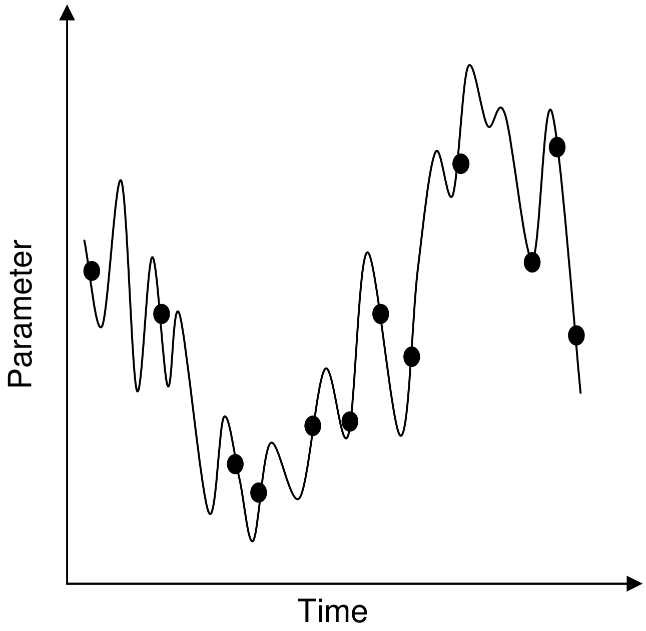


Figure 1.4. An example plot depicting change in an environmental population or community variable over time (days, months or years) and potential patterns from isolated observations.

1.2.2. Monitoring Protocols and Locations

The SRMP uses standardised underwater visual census methods based on an approach developed and applied in Tasmania by Edgar and Barrett (1997). Details of standard operational procedures and quality control protocols for Victoria's SRMP are described in Edmunds and Hart (2003).

The SRMP was initiated in May 1998 with 15 sites established on subtidal reef habitats in the vicinity of Port Phillip Heads Marine National Park. In 1999 the SRMP was expanded to reefs in the vicinity of the Bunurong Marine National Park, Phillip Island and Wilsons Promontory Marine National Park.

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

1.3. Subtidal Reef Monitoring at Merri Marine Sanctuary

This report describes the subtidal reef monitoring program in the Merri region and results from five surveys, incorporating Merri Marine Sanctuary and a reference area. The objectives of this report were to:

1. provide an overview of the methods used for SRMP;
2. provide general descriptions of the biological communities and species populations at each monitoring site up to May 2011;
3. describe changes and trends that have occurred over the monitoring period;
4. identify any unusual biological phenomena such as interesting or unique communities or species; and
5. identify any introduced species at the monitoring locations.

1.4. Site Selection and Survey Times

Merri Marine Sanctuary is in the Otway Bioregion on the west coast of Victoria near Warrnambool (Figure 1.5). Coastal reefs at Merri are either patchy and interspersed with areas of sand, or more consolidated hard reef cut by deeper depressions and large crevices (to 15 m). When establishing the Merri sites incorrect park boundary coordinates were given. Consequently, the Merri site (Site 3701) was located outside the marine sanctuary, close to Middle Island along the 8 m isobath. The site covers areas of patchy reef and sand, as well as more continuous reef with deep sections. A reference monitoring site, Breakwater (Site

3702), was located at the southeast of the sanctuary near Breakwater Rock along the 5 m isobath. The reef here is continuous and slightly undulating. The sites were first surveyed in January 2004 and have since been surveyed four times in; March 2005, December 2005, June to August 2009 and April 2011.

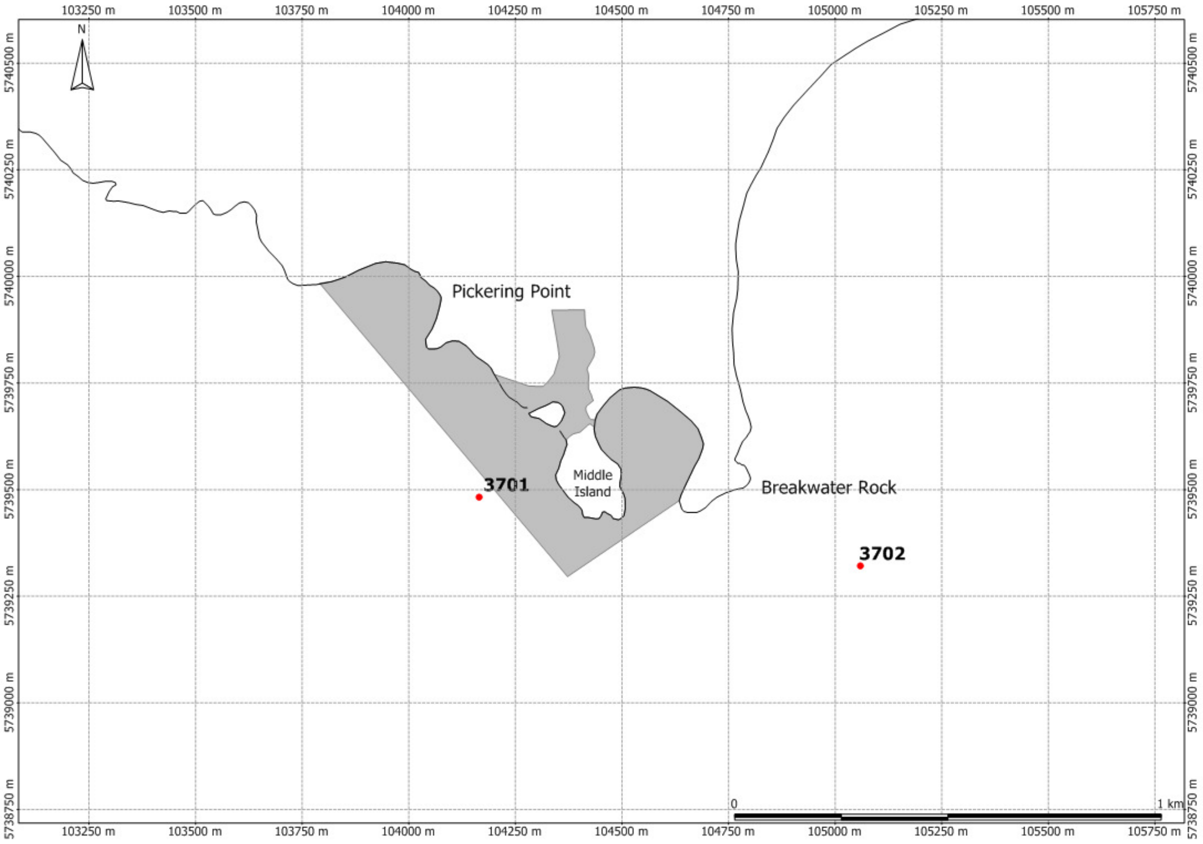


Figure 1.5. Location of monitoring sites inside and outside the Merri Marine Sanctuary. The park area is shaded grey and the monitoring sites are shown in red.

Table 1.1. Subtidal reef monitoring sites at the Merri Marine Sanctuary and Reference site.

Marine Protected Area	Site No.	Site Name	MPA/Reference	Depth (m)
Merri	3701	Merri	MPA	8
Merri	3702	Breakwater	Reference	5

Table 1.2. Survey times for subtidal reef monitoring at the Merri Marine Sanctuary and Reference site.

Survey Number	Season	Survey Date
1	Summer 2003/2004	20 January 2004
2	Autumn 2005	30 March 2005
3	Summer 2005/2006	24 February 2006
4	Winter 2009	25 June 2009 and 10 August 2009
5	Autumn 2011	8 April 2011

2. METHODS

2.1. Census Methods

2.1.1. Underwater Visual Census Approach

The visual census methods of Edgar and Barrett (1997), Edgar and Barrett (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 along the central coast of Victoria are between 4 and 7 m deep.

2.1.2. Survey Design

Each site was located using differential GPS and marked with a buoy or the boat anchor. A 100 m numbered and weighted transect line was run along the appropriate depth contour either side of the central marker (Figure 2.1). The resulting 200 m of line was divided into four contiguous 50 m sections (T1 to T4). The orientation of transects was the same for each survey and all sites, with T1 generally toward the north or east (*i.e.* anticlockwise along the open coast).

For each transect line, four different census methods were used to obtain adequate descriptive information on reef communities at different spatial scales. These involved the census of: (1) the abundance and size structure of large fishes; (2) the abundance of cryptic fishes and benthic invertebrates; (3) the percent cover of macroalgae and sessile invertebrates; and (4) the density of string-kelp *Macrocystis pyrifera* plants (where present). In 2010, a new diver-operated stereo video method (Method 5) was implemented as a trial to assess its efficacy for monitoring fish diversity, abundances and sizes. The stereo video system enables precise measurements of fish lengths and sample volume or area for density estimates (Harvey *et al*. 2001a, 2001b, 2002a, 2002b; Harmen *et al*. 2003; Watson *et al*. 2010; Westera *et al*. 2003).

The depth, horizontal visibility, sea state and cloud cover were recorded for each site. Horizontal visibility was gauged by the distance along the transect line to detect a 100 mm long fish. All field observations were recorded on underwater paper.

Figure 2.1. Biologist-diver with transect line.

2.1.3. Method 1 – Mobile Fishes and Cephalopods

The densities of mobile large fishes and cephalopods were estimated by a diver swimming up one side of each of a 50 m section of the transect, and then back along the other side. The dominant fish species observed are listed in Table 2.1. The diver recorded the number and estimated size-class of fish, within 5 m of each side of the line (50 x 10 m area). The following size-classes of fish were used: 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 375, 400, 500, 625, 750, 875 and 1000+ mm. Each diver had size-marks on an underwater slate to enable calibration of their size estimates. Four 10 x 50 m sections of the 200 m transect were censused for mobile fish at each site. The data for easily sexed species were recorded separately for males and female/juveniles. Such species include the blue-throated wrasse *Notolabrus tetricus*, herring cale *Odax cyanomelas*, barber perch *Caesioperca rasor*, rosy wrasse *Pseudolabrus rubicundus* and some leatherjackets.

2.1.4. Method 2 – Invertebrates and Cryptic Fishes

Cryptic fishes and motile megafaunal invertebrates (*e.g.* large molluscs, echinoderms, crustaceans) were counted along the transect lines used for the fish survey. A diver counted animals within 1 m of one side of the line (a total of four 1 x 50 m sections of the 200 m transect). A known arm span of the diver was used to standardise the 1 m distance. The dominant observed species are listed in Table 2.3. 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.

2.1.5. Method 3 – Macroalgae

The area covered by macroalgal and sessile invertebrate 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 sessile species (Figure 2.3). The quadrat was divided into a grid of 7 x 7 perpendicular wires, with 49 wire intersections and one quadrat corner making up 50 points. Cover is estimated by counting the number of points covering a species (1.25 m^2 every 10 m along a 200 m transect line). The dominant observed seaweed species are listed in (Table 2.2). Selected specimens were photographed or collected for identification and preservation in a reference collection.

2.1.6. Method 4 – Macrocystis

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

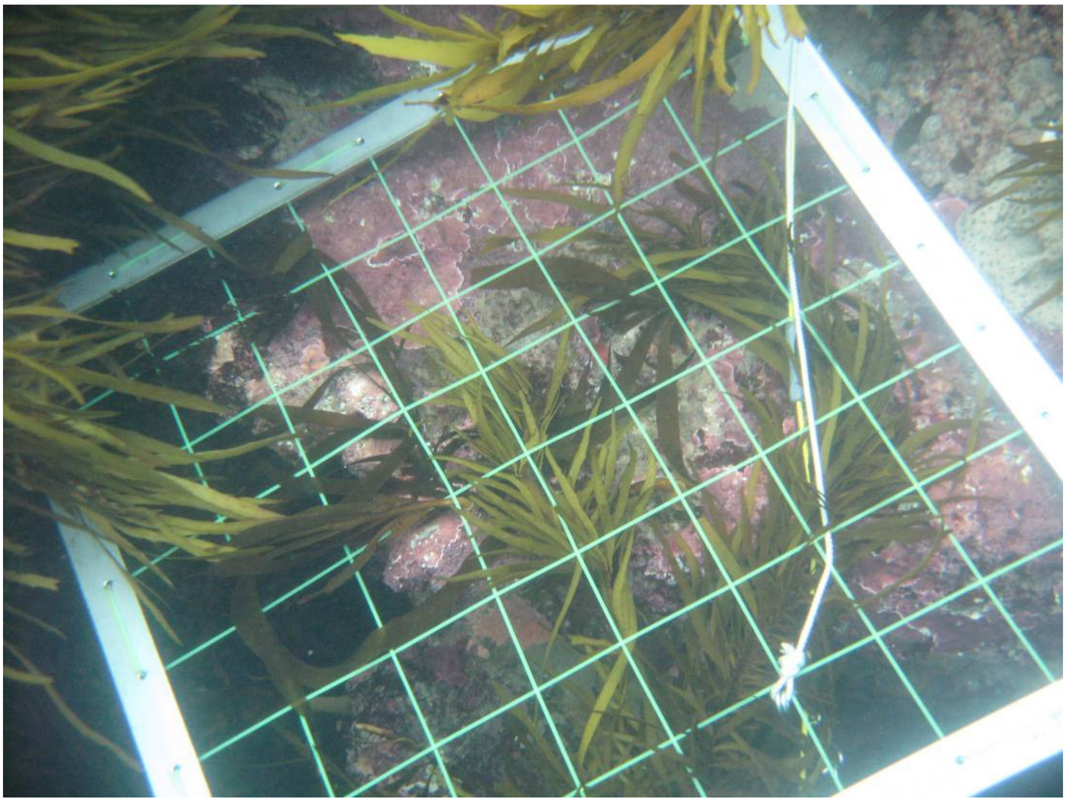


Figure 2.2. The cover of macrophytes is measured by the number of points intersecting each species on the quadrat grid.

2.1.7. Method 5 – Fish Stereo Video

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

The stereo camera system was used by a single diver who did the UVC fish survey at the same time (Method 1). The camera system was pointed parallel with the transect line with the diver swimming 2.5 m to one side of the transect and then returning on the other side of the transect, 2.5 m from the transect line. The camera unit was tilted vertically (up or down) according to the fish seen to ensure adequate footage for size measurements. Lateral movement of the unit was minimised. The survey speed was 10 m per minute (0.16 m s^{-1}).

In the laboratory, the stereo video footage was converted from MTS to AVI format. The SeaGIS EventMeasure and PhotoMeasure software were then used for extracting and recording fish density and fish length estimates from the stereo video footage. Measured fish were those without body flexure and orientated transverse to the camera, as well as with the measurement points visible. Standard lengths (SL) were measured (tip of snout to end of caudal fin ray). The original video footage and frames used for fish length measurements were archived. The results of this method were archived for future analysis and were not reported here.

Table 2.1. Mobile fishes, including sharks and rays, surveyed using Method 1 and macroinvertebrates and cryptic fishes surveyed using Method 2 in Merri Marine Sanctuary.

Method 1	**Method 2**	**Method 2**
Mobile Fishes	**Crustacea**	**Echinodermata**
Pempheris multiradiata	*Plagusia chabrus*	*Comanthus trichoptera*
Girella zebra	*Jasus edwardsii*	*Heliocidaris erythrogramma*
Scorpis aequipinnis	*Nectocarcinus tuberculatus*	*Tosia australis*
Tilodon sexfasciatus	*Paguristes frontalis*	*Pentagonaster dubeni*
Parma victoriae		*Fromia polypora*
Aplodactylus arctidens	**Mollusca**	*Plectaster decanus*
Cheilodactylus nigripes	*Haliotis rubra*	*Echinaster arcystatus*
Notolabrus tetricus	*Haliotis laevigata*	*Holopneustes porosissimus*
Notolabrus fucicola	*Scutus antipodes*	*Holopneustes*
Pictilabrus laticlavius	*Turbo undulatus*	*Pseudonepanthia troughtoni*
Odax cyanomelas	*Dicathais orbita*	
Diodon nichthemerus	*Pleuroploca australasia*	**Cryptic Fishes**
Dinolestes lewini	*Penion mandarinus*	*Parascyllium variolatum*
Dotalabrus aurantiacus	*Conus anemone*	*Parma victoriae*
Pseudolabrus rubicundus	*Chromodoris.*	UnID Heteroclinidae
Parma victoriae	*Octopus maorum*	
Parascyllium variolatum	*Astralium tentoriformis*	

Table 2.2. Macroalgae (Method 3) surveyed in Merri Marine Sanctuary.

Method 3	**Method 3**	**Method 3**
Chlorophyta (green algae)	**Rhodophyta (red algae)**	**Rhodophyta (red algae, continued)**
Ulva spp.	*Botryocladia obovata*	*Melanthalia obtusata*
Caulerpa longifolia	*Ceramium* spp.	*Melanthalia abscissa*
Caulerpa scalpelliformis	*Champia* sp.	*Plocamium angustum*
Caulerpa brownii	*Champia viridis*	*Plocamium costatum*
Caulerpa obscura	Erect corallines	*Plocamium mertensii*
Caulerpa flexilis	*Erythroclonium* spp.	*Plocamium dilatatum*
Caulerpa flexilis var. muelleri	Filamentous red algae	*Plocamium preissianum*
Caulerpa trifaria	*Gelinaria ulvoidea*	*Plocamium cartilagineum*
Codium pomoides	*Mastophoropsis canaliculata*	*Plocamium leptophyllum*
Codium spp.	Thallose red algae	*Erythrymenia minuta*
	Phacelocarpus alatus	*Rhodymenia australis*
Phaeophyta (brown)	*Polyopes constrictus*	*Cordylecladia furcellata*
Halopteris spp.	*Pterocladia capillacea*	*Ballia callitricha*
Brown algae UnID	*Ptilonia australasica*	*Euptilota articulata*
Carpoglossum confluens	*Solieria robusta*	*Areschougia congesta*
Dictyota dichotoma	*Gelidium asperum*	*Rhodymenia obtusa*
Lobospira bicuspidata	*Gelidium australe*	*Nizymenia australis*
Chlanidophora	*Pterocladia lucida*	*Sonderopelta coriacea*
Homeostrichus sinclairii	*Asparagopsis armata*	*Phacelocarpus*
Homeostrichus olsenii	*Delisea pulchra*	*Hemineura frondosa*
Zonaria turneriana	*Cheilosporum sagittatum*	*Lenormandia marginata*
Zonaria spp.	*Amphiroa anceps*	*Laurencia elata*
Carpomitra costata	*Arthrocardia wardii*	*Laurencia filiformis*
Perithalia cordata	*Haliptilon roseum*	*Echinothamnion hystrix*
Ecklonia radiata	*Metamastophora flabellata*	
Macrocystis pyrifera	*Metagoniolithon radiatum*	
Phyllospora comosa	Encrusting corallines	
Acrocarpia paniculata	*Gigartina* sp.	
Cystophora platylobium	*Hypnea ramentacea*	
	Callophyllis rangiferina	

2.2. Data Analysis - Condition indicators

2.2.1. Approach

Reef quality indicators were developed to encompass key features of MPA performance assessment and management interest. The selection of indicators for reef ecosystem management were reviewed by (Turner *et al.* 2006) and further theoretical and field considerations are provided by Thrush *et al.* (2009). Both reviews suggest a variety of indicators, of both ecosystem structure and function, should be used. Rapport (1992) noted that stressors causing adverse changes in an ecosystem stand out beyond the natural range of variability observed in a system in 'good health'. Adverse changes to an ecosystem include:

- a shift to smaller organisms;
- reduced diversity with loss of sensitive species;
- increased dominance by weedy and exotic species;
- shortened food chain lengths;
- altered energy flows and nutrient cycling;
- increased disease prevalence; and
- reduced stability/increased variability

A suite of indicators was developed for the Tasmanian Reef Monitoring Program, which uses the same Edgar-Barrett underwater visual census methods (Stuart-Smith *et al*. 2008). The indicators are grouped into the general categories: biodiversity; ecosystem function; introduced pests, climate change and fishing. The Stuart-Smith indicators were followed and adapted for the Victorian SRMP. These indices are consistent with the reviews mentioned above. Key adaptations were the use of absolute values rather than proportions, as the Victorian data had considerable concurrent variation in the numerator and denominator of many indices, making proportional indices difficult to interpret. The Stewart-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.

2.2.2. 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 (Clarke 1993; Faith *et al*. 1987).

Following Sweatman *et al.* (2003), the count data were log transformed and percent cover values were transformed using the empirical logit transformation (McCullagh and Nelder 1989).

The hyper-dimensional information in the dissimilarity matrix was simplified and depicted using non-metric multidimensional scaling (MDS; Clarke 1993). This ordination method finds the representation in fewer dimensions that best depicts the actual patterns in the hyper-dimensional data (*i.e.* reduces the number of dimensions while depicting the salient relationships between the samples). The MDS results were then depicted graphically to show differences between the replicates at each location. The distance between points on the MDS plot is representative of the relative difference in community structure.

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

Trends in Community Structure

Multivariate control charting was used to examine the degree of changes in community structure over time. Two criteria were assessed, the first being the deviation in community structure at a time, *t*, from the centroid of baseline community structures. This criterion is more sensitive to the detection of gradual changes over time away from the baseline conditions. In this case, the first 5 surveys were used for the baseline centroid (recognising there were 6 baseline surveys for 8 sites and 5 baseline surveys for 4 sites). The second criterion was the deviation in community structure at time, *t*, to the centroid of all previous times, *(t-1)*. This criterion is more sensitive at detecting abrupt or pulse changes.

Control charts were prepared for each site as well as on a regional basis for combined sites inside the marine protected area and for reference sites. The regional analysis used average species abundances across sites within each region. The analysis used the methods of Anderson and Thompson (2004) and calculations were done using the software ControlChart.exe (Anderson 2008). The analysis used the Bray-Curtis dissimilarity coefficient and the same data transformations described above. Bootstrapping was used to provide control-chart limits for identifying changes that are ‘out of the ordinary’. In this case, a 90th percentile statistic was calculated from 10 000 bootstrap samples as a provisional limit or trigger line. The 50th percentile was also presented to assist in interpreting the control charts.

Species Diversity

The total number of individuals, N, was calculated as the sum of the abundance of all individuals across species. This index is used to show any simultaneous depression of abundances across all species.

Species richness, S, is given as the number of species observed at each site. Cryptic, pelagic and non-resident reef fishes were not included.

Species diversity, as a measure of the distribution of individuals among the species, was indicated using Hill’s N_2 statistic (which is equivalent to the reciprocal of Simpson’s index). The value varies between 1 and S (*i.e.* the total number of species in the sample) with higher values indicating higher diversity. In general, Hills N_2 gives an indication of the number of dominant species within a community. Hills N_2 provides more weighting for common species, in contrast to indices such as the Shannon-Weiner Index (Krebs 1999), which weights the rarer species.

The diversity statistics were averaged across sites for the marine protected area and reference regions.

Abundances of Selected Species

Mean abundance of selected species were plotted over time for the marine protected area and reference regions. The species presented included abundant or common species as well as any with unusual changes over time.

2.2.3. 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, Cystophora moniliformis, Cystophora pectinata, Cystophora monilifera, Cystophora retorta* and *Cystophora retroflexa*;
- smaller browns (all other brown species except *Ectocarpales*);
- erect coralline algae;
- thallose red algae (except filamentous species);
- green algae; and
- seagrass *Amphibolis antarctica*.

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

Invertebrate Groups

The abundance of invertebrates were pooled into the functional groups:

- grazers and habitat modifiers, including gastropods and sea urchins;
- filter feeders, including fanworms and feather stars;
- predators, including gastropods, crabs and lobsters but excluding seastars; and
- seastars, which are mostly predators, although *Meridiastra gunnii* may also be a detritus feeder.

Fish Groups

The abundance of fishes were also pooled into trophic groups:

- herbivores and omnivorous grazers;
- foraging predators, including pickers and foragers of stationary, benthic prey such as amphipods, crabs and gastropods;
- hunter predators, including fishes that hunt mobile prey, particularly other fishes, as chasers and ambushers; and

- planktivores, including feeders of zooplankton and small fish in the water column.

Sediment Cover

The percentage cover of sand and sediment on the survey transect (using Method 3) is the only relevant abiotic parameter measured for the SRMP. This index may indicate changes in hydrodynamic or coastal processes.

2.2.4. 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.

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

Durvillaea potatorum

The bull kelp *Durvillaea potatorum* is a coldwater species that is likely to be vulnerable to increased ambient temperatures. There is anecdotal evidence of a decline in range down the New South Wales coast by approximately 80 km. Most of the SRMP sites specifically avoid *D. potatorum* habitats as these occur on highly wave-affected and turbulent reefs. Some sites contain *D. potatorum* stands, providing limited data on population status. *Durvillaea potatorum* is potentially two species, having genetically and morphologically distinct eastern and western forms (Fraser *et al.* 2009).

2.2.6. Fishing

Abalone

Indicators of altered population structure from harvesting pressure on abalone were mean density and the proportion of legal sized individuals. The size-frequency histograms were also examined. The indicators were calculated for the blacklip abalone, *Haliotis rubra,* in most regions and for the greenlip abalone, *H. laevigata,* where present in suitable densities (in central and western Victoria).

Rock Lobster

The southern rock lobster, *Jasus edwardsii,* is present throughout Victoria and the eastern rock lobster, *J. verreauxi,* is present in the Twofold Shelf bioregion. The SRMP transects generally did not traverse rock lobster microhabitats, however abundances and sizes are reported for suitable data.

Fishes

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

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

The size spectrum of all fishes at a site was first centred and linearised. Size frequencies for each field size class were aggregated into classes centred on 87.5 mm (classes 1-6), 200 mm (class 7), 275 mm (classes 8-9), 356.25 mm (classes 10-11), 400 mm (class 12), 500 mm (class 13), 625 mm (class 14) and 750+ mm (class 15). The frequencies and size classes were $\log_e(x+1)$ and the size classes are centred by subtracting the mean. Linear regression was used to estimate the slope and intercept (which is also the half-height of the slope) of the log-transformed spectrum.

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

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

3. RESULTS

3.1. Biodiversity

3.1.1. Community Structure

Macroalgae

The algal communities surveyed at and around Merri Marine Sanctuary were similar in species composition and community structure to those sites surveyed in other exposed coastal locations along the Victorian coast (*e.g.* Edmunds *et al.* 2000). Sites had an algal canopy dominated by *Phyllospora comosa*, with a smaller quantity of *Ecklonia radiata* cover. Understorey species at the reference site included the red algal species *Phacelocarpus peperocarpus*, *Melanthalia obtusata* and *Ballia callitricha*. Other species present included *Cystophora platylobium*, *Pterocladia lucida* and encrusting corallines. Merri Inside (Site 3909) had a relatively diverse assemblage of smaller brown algal species including *Haliptilon roseum* and *Cystophora moniliformis*.

The two sites had similar degrees of change relative to previous algal community structure through time in the three-dimensional MDS plot, and both sites occupy the same relative hyperspace within the plot over time (Figure 3.1). The differences in algal assemblage can be largely attributed to understorey species at each site.

The 2011 survey data for both sites fall outside the 95 % confidence limit for the prior-times centroid in the control chart (Figure 3.2). This indicated a shift to an assemblage structure different to prior times.

Invertebrates

The invertebrate fauna was largely composed of the gastropod *Turbo undulata*, the dogwhelk *Dicathais orbita*, and to a lesser extent the black lip abalone *Haliotis rubra*. Other commonly encountered species included seastars *Nectria ocellata* and *Nectria macrobranchia*.

The three-dimensional MDS plot indicated marked difference in invertebrate assemblage structure between the two sites (Figure 3.3). The MDS plot also indicated that the reference site underwent less community structure change over time than occurred inside the MPA.

The control chart indicated the MPA site deviated away from the prior times centroid in 2011, with a sequential trend from since 2006, indicating the MPA invertebrate community is changing over time when compared with all previous communities at that site (Figure 3.4). The reference site remained similar to the prior-times centroid over time – indicating little shift in community structure over time – as was also apparent in the MDS analysis.

Fish

The most abundant fish species at the Merri sites included the blue throat wrasse *Notolabrus tetricus*, herring cale *Odax cyanomelas*, scalyfin *Parma victoriae* and the horse shoe leatherjacket *Meuschenia hippocrepis*. Other species present included the purple wrasse *Notolabrus fucicola* and the magpie perch *Cheilodactylus nigripes*.

After commencing with very different community structures in 2004, the MPA and reference site fish faunas became more similar over time (Figure 3.5). The degree of variation outside the MPA was greater than that inside it. The three-dimensional MDS plot overlapped indicating similar fish assemblages are present at both sites inside and outside the marine sanctuary (Figure 3.5). There were consistent changes at each site over the survey period (Figure 3.5). Both sites had a low abundance of fish compared to other sites around the west coast of Victoria. Sites were characterised by abundance of the blue throat wrasse *Notolabrus tetricus*.

The control chart indicated both sites deviated from the prior times centroid in 2011 (Figure 3.6), reflecting community level changes in the system.

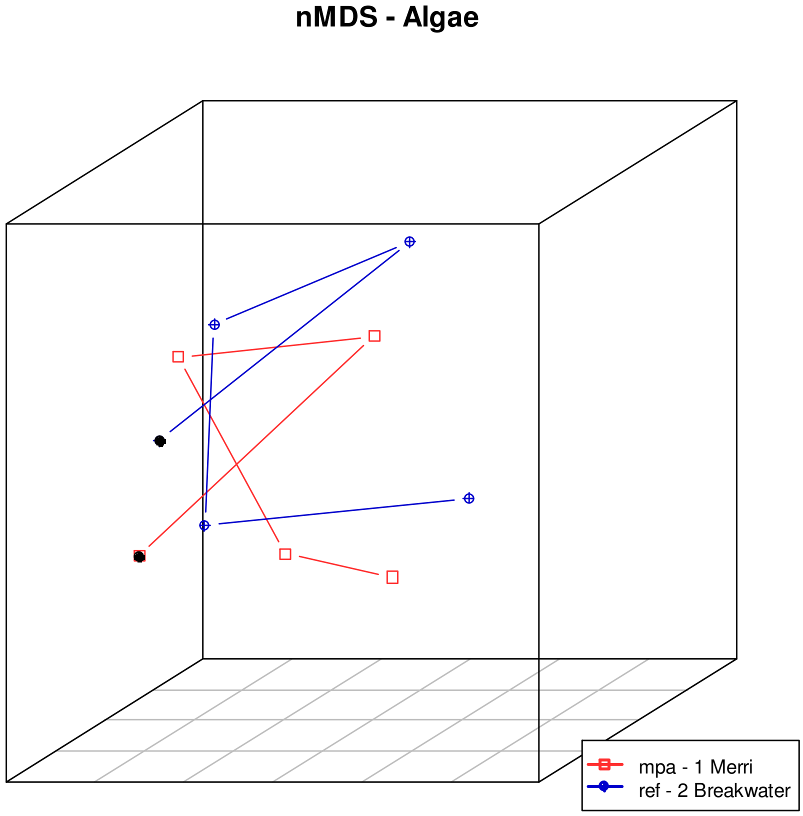


Figure 3.1. Three-dimensional MDS plot of algal assemblage structure for Merri sites. Kruskal stress value = 0.04. Filled black marks indicate 2004 data.

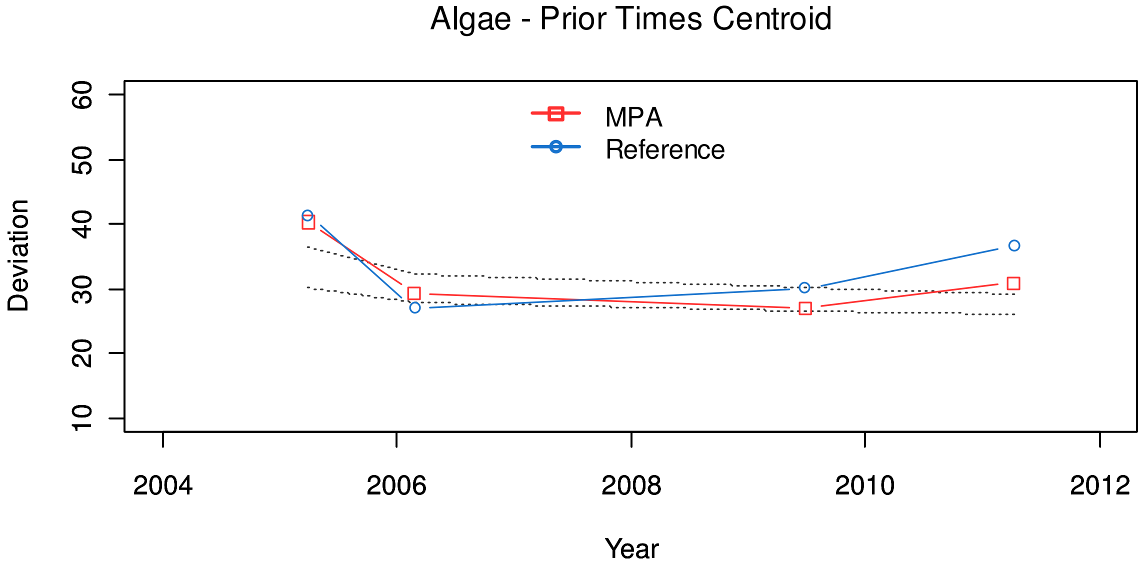


Figure 3.2. Control chart of algal assemblage structure inside and outside Merri Marine Sanctuary.

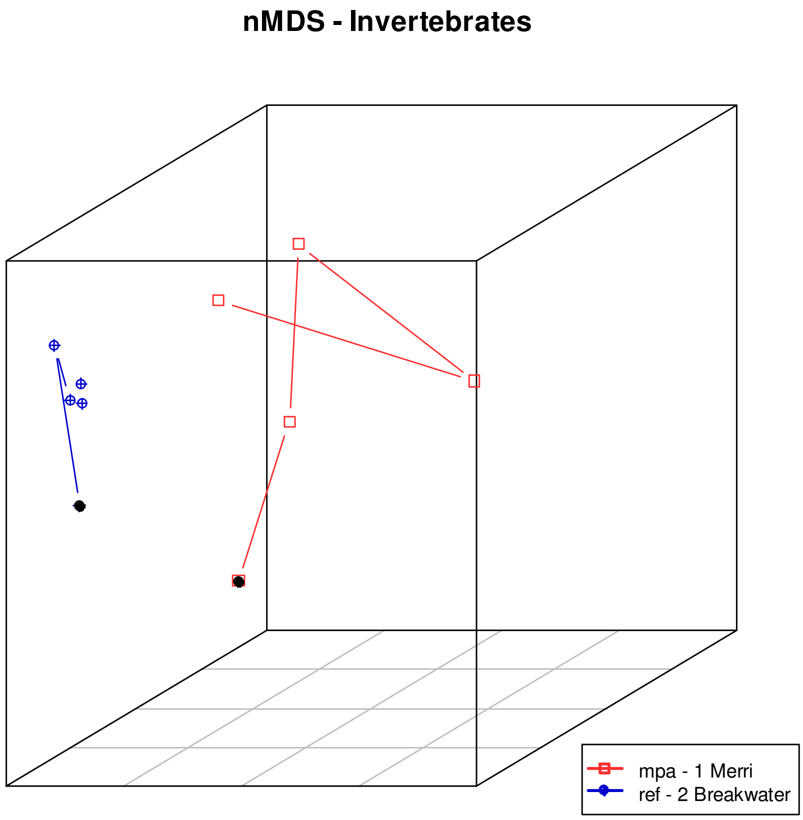


Figure 3.3. Three-dimensional MDS plot of invertebrate assemblage structure for Merri sites. *Kruskal* stress value = 0.01. Filled black marks indicate 2004 data.

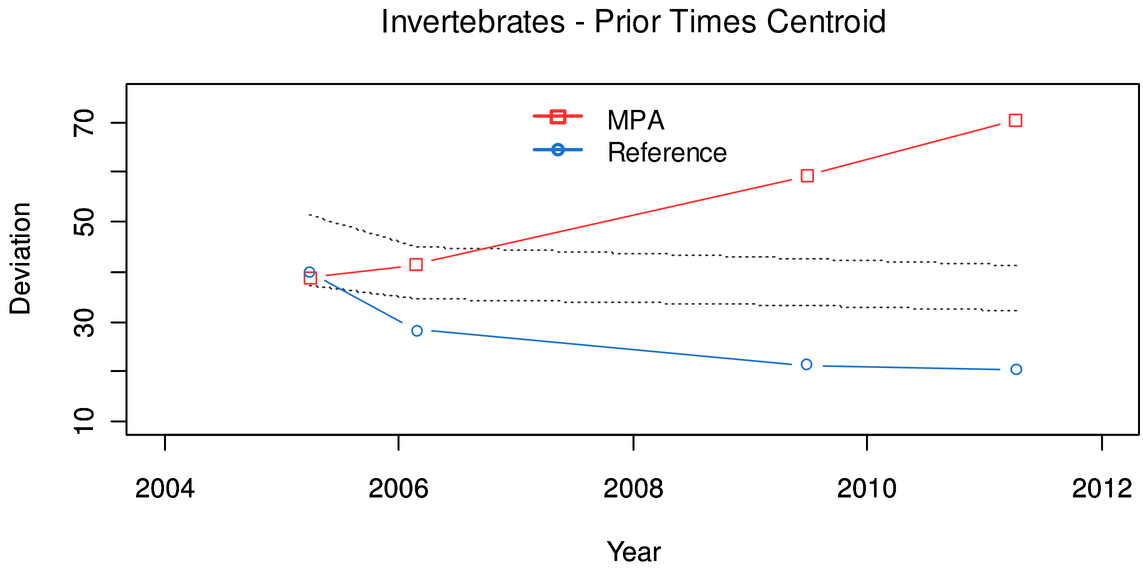


Figure 3.4. Control chart of invertebrate assemblage structure inside and outside Merri Marine Sanctuary.

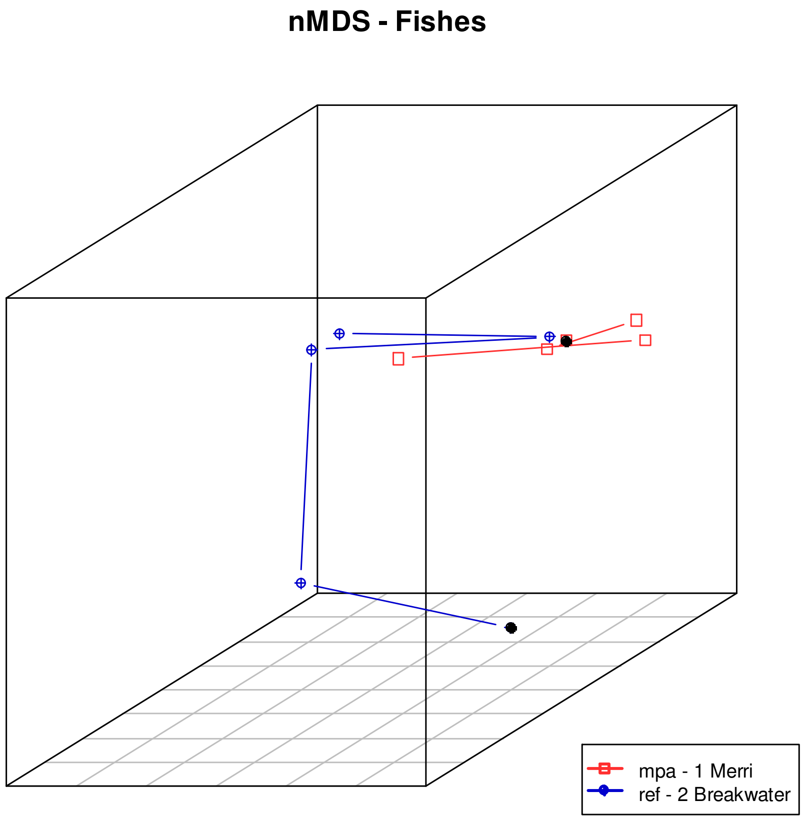


Figure 3.5. Three-dimensional MDS plot of fish assemblage structure for Merri sites. *Kruskal* stress value = 0.05. Filled black marks indicate 2004 data.

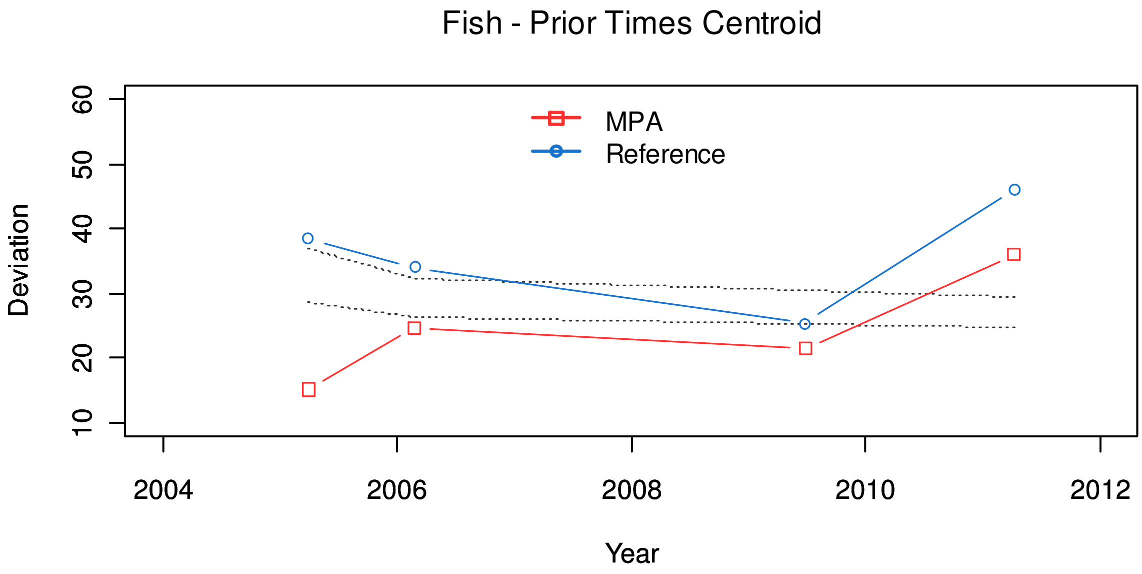


Figure 3.6. Control chart of fish assemblage structure inside and outside Merri Marine Sanctuary.

3.1.2. Species Richness and Diversity

Macroalgae

No obvious trends were observed in total algal abundance over time inside and outside the MPA (Figure 3.7a). With the exception of the first survey results, algal richness has remained closely matched inside and outside the MPA, and with a gradual decrease from initial conditions over the span of the monitoring (Figure 3.7b).

An overall decrease in algal diversity was also apparent over the span of the monitoring, through interannual variation in this measure has been greater than that in richness values and the 2011 results are not dramatically outside the range of that variation (Figure 3.7c).

Invertebrates

Total invertebrate abundance inside the marine sanctuary remained low and stable throughout the survey period. Total invertebrate abundance varied more widely in the reference area but was consistently higher than that inside the marine sanctuary (Figure 3.8a).

Invertebrate species richness and species diversity were similar inside and outside the MPA until 2006. A decrease in species richness both inside and outside the MPA is evident over the entire survey period, though the 2011 record low is not far outside the range of variation the system experienced in that time (Figure 3.8b). The decrease in species richness that occurred between 2009 and 2011 co-occurred with an increase in diversity values at both sites, reflecting a decrease in dominance as individuals in the remaining species were more homogenously distributed among species (Figure 3.8c).

Fishes

Fish abundance and species richness have followed similar patterns of increase and decrease inside and outside the MPA over time (Figure 3.9a-b). Fish species diversity inside and outside the MPA has been less synchronous, with opposite trends over time until the 2009 to 2011 period (Figure 3.9c). Fish abundance, richness and diversity decreased for both areas between 2009 and 2011, resulting in the lowest values recorded since surveying began.

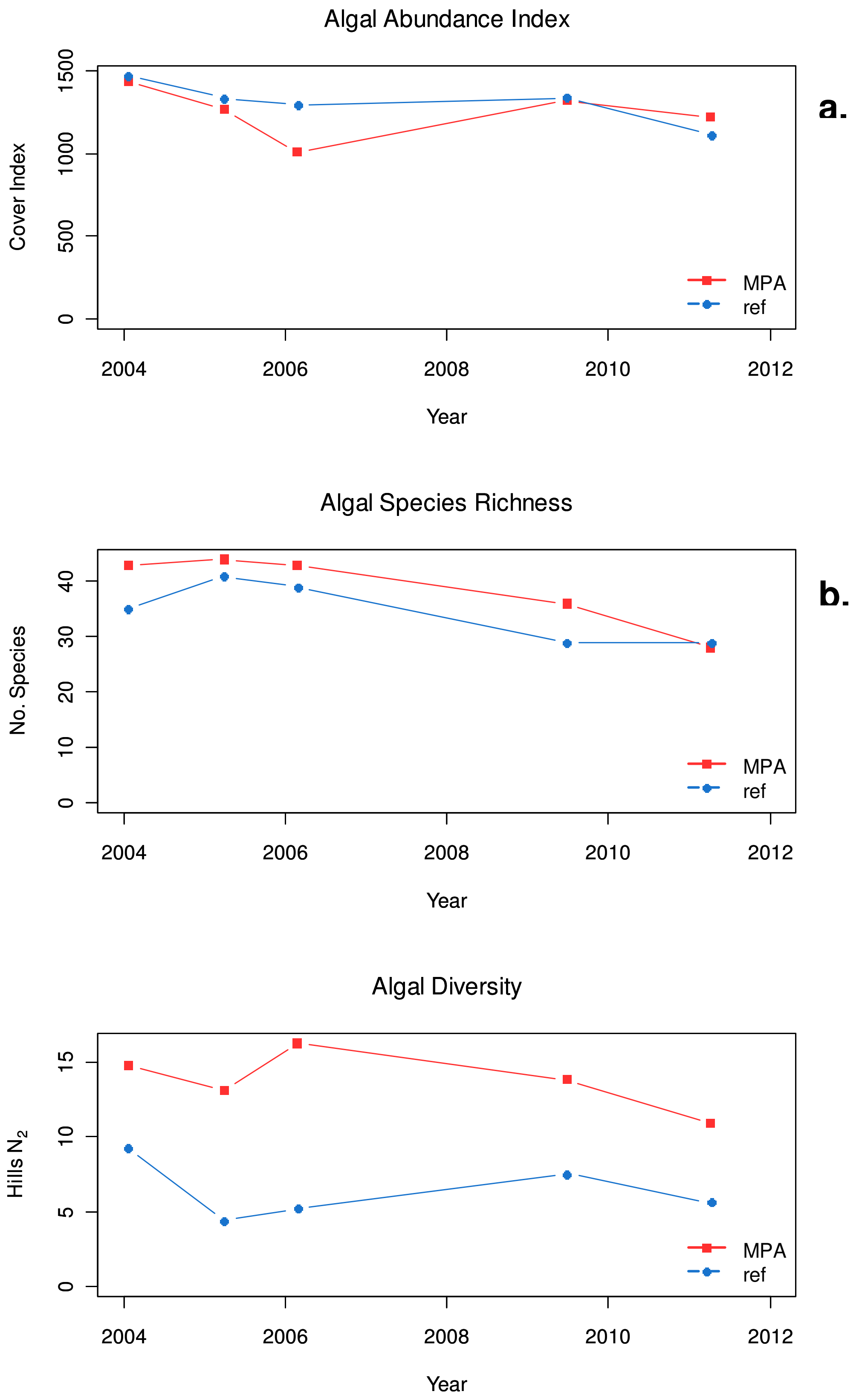
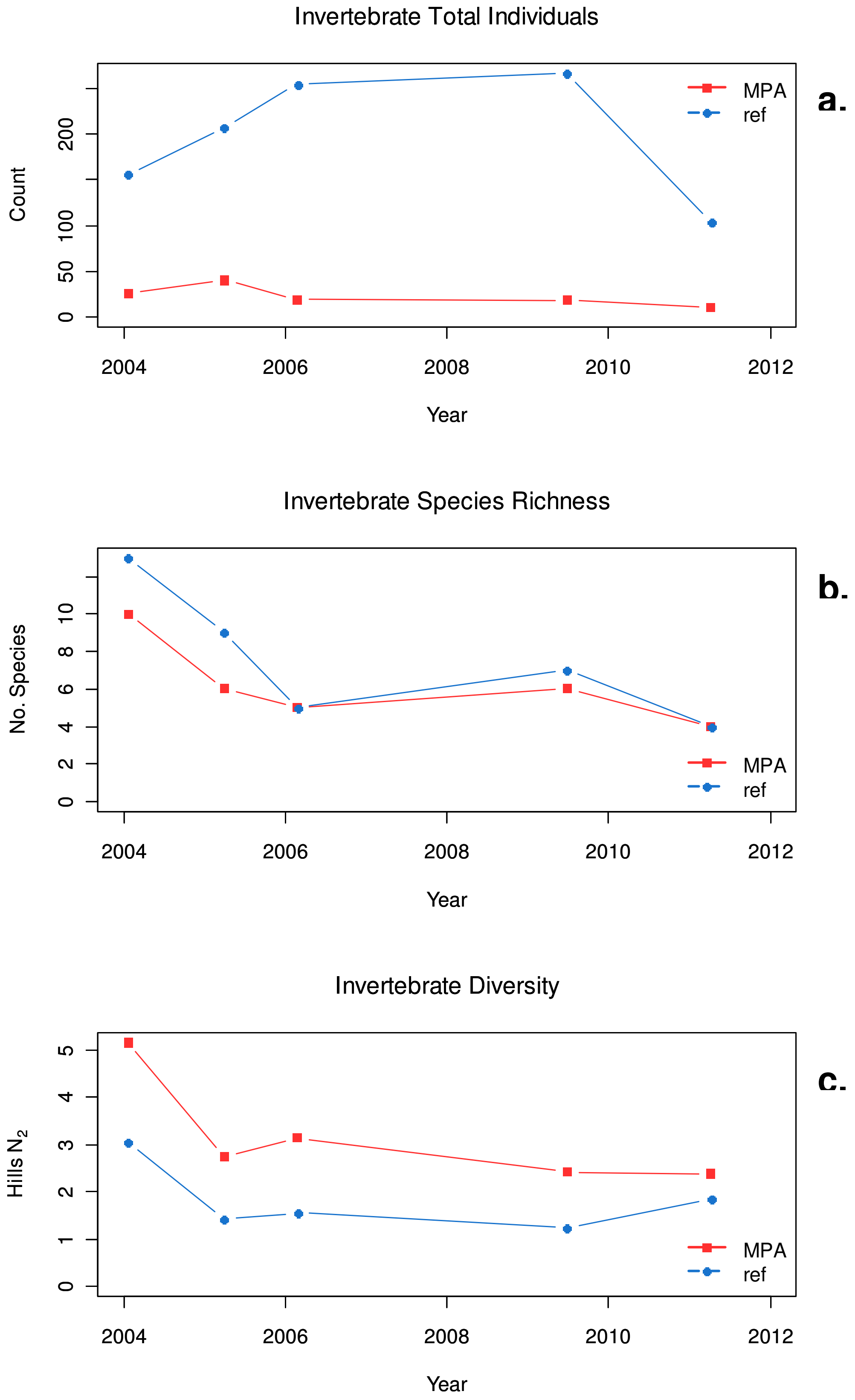


Figure 3.7. Algal species diversity indicators inside and outside Merri Marine Sanctuary.


Invertebrate Total Individuals

Invertebrate Species Richness

Invertebrate Diversity

Figure 3.8. Invertebrate species diversity indicators inside and outside Merri Marine Sanctuary.

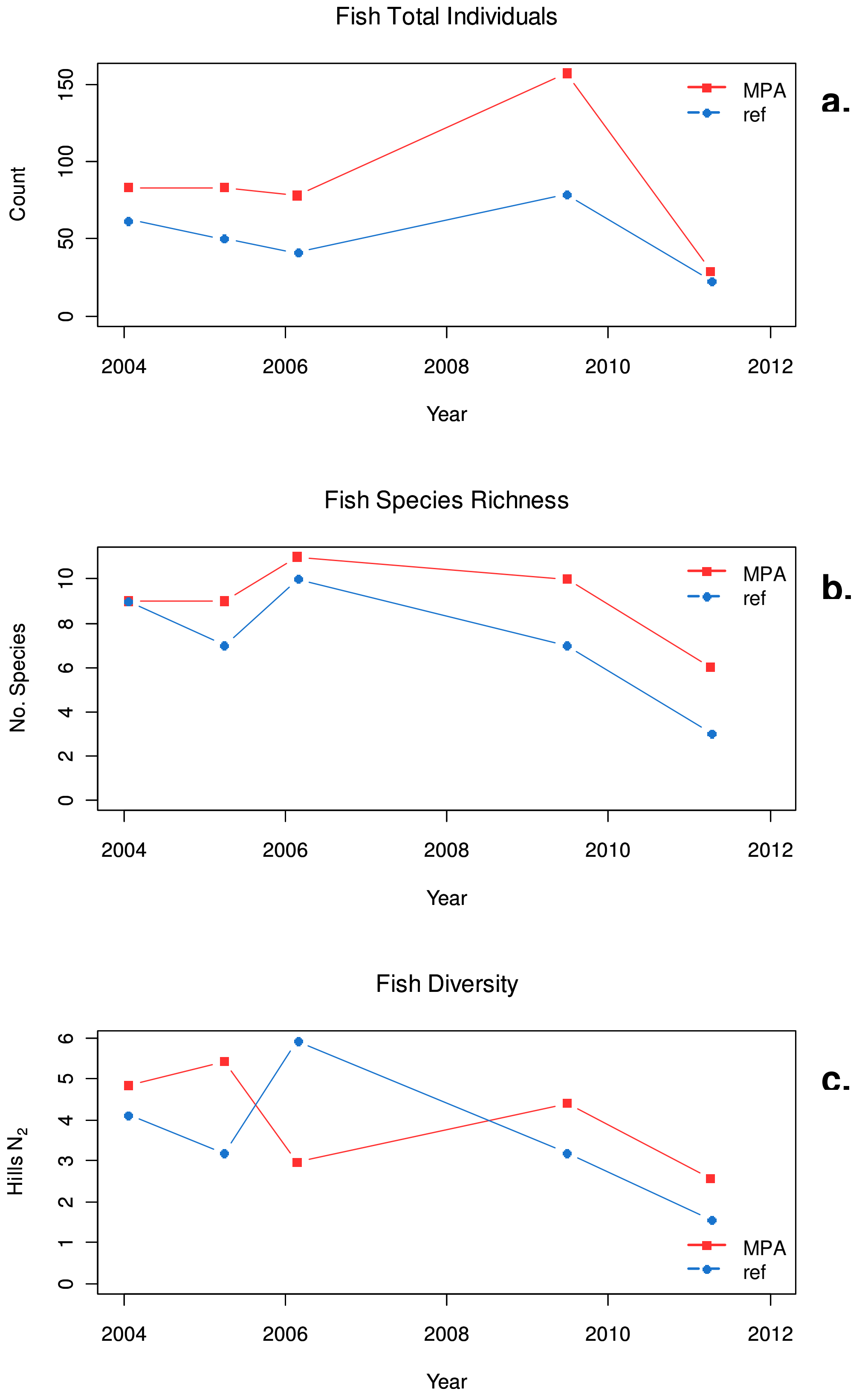


Figure 3.9. Fish species diversity indicators inside and outside Merri Marine Sanctuary.

3.1.3. Abundances of Selected Species

Macroalgae

The dominant algal canopy species sampled were *P. comosa*, *A. paniculata* and *E. radiata*. *Phyllospora comosa* cover appeared stable at both sites during the survey period, with a higher percent cover observed at the reference site (Figure 3.10a). Conversely, greater coverage of *A. paniculata* and *E. radiata* were observed at the MPA than in the reference area (Figure 3.10b, c). Cover of *A. paniculata* increased by about 10 % from 2009 to 2011 (Figure 3.10b).

The dominant understorey species was crustose coralline algae. Cover of these taxa were consistently higher at the reference site (Figure 3.11a). Other, less dominant understorey red algal species included *P. lucida, H. roseum*, *B. callitricha* and *P. peperocarpos* (Figure 3.11b-e). Cover of *P. lucida* were consistent within sites through the survey, though higher at the MPA compared to the reference site (Figure 3.11b), while abundances of *B. callitricha* at both sites appear to be correlated (Figure 3.11d). Through the survey period, the most common understorey green algae was *Caulerpa flexilis* var. *muelleri*, though this was largely due to a spike in cover at the reference site observed in 2009 survey (Figure 3.11f). The taxon was not observed in 2011. Cover of the remaining algae species surveyed were below 5 %.

Invertebrates

The abundance of *Turbo undulatus* varied markedly over the survey period outside the MPA, changing by more than threefold at times. Abundance inside the MPA remained low and stable (Figure 3.12a).

Marked changes occurred in the abundance of blacklip abalone *Haliotis rubra* inside the marine sanctuary. Abundances recorded in the first 2004 survey were low. The population increased to 40 individuals in the 2009 survey, and decreased to only one individual abalone recorded in the 2011 survey. Densities at the reference area remained consistently low over the survey period (Figure 3.12b). Signs of Abalone Viral Ganglioneuritis, such as excessive dead shell, weak animals with necrotic flesh, were observed by divers during the most recent survey.

Heliocidaris erythrogramma was not observed inside the MPA in 2011. Though never abundant, this is the first time it was absent in the MPA, whereas it was not observed in the reference area after 2004 (Figure 3.12c).

Dicathais orbita was not observed inside the MPA after 2004. No clear trends were evident in the abundance of *Dicathais orbita* outside the MPA. Densities in the reference area peaked in 2006 before returning to original observations during the latest survey (Figure 3.12d).

Fishes

Trends in abundance of blue throat wrasse *Notolabrus tetricus* were similar both inside and outside the marine sanctuary. Abundances remained consistent over time inside the MPA (Figure 3.14a) Mostly synchronous increases and decreases over time saw the populations reach parity in 2011, the final value being low for the MPA but within the range of values observed, over time, outside the MPA.

Densities of herring cale *Odax cyanomelas* continued to gradually increase in both areas over time. While abundances inside the sanctuary underwent less dramatic changes than those outside, both populations were at low values relative to those recorded in past surveys (Figure 3.14b).

Populations of *N. fucicola*, as those of *N. tetricus*, followed similar trends over time both inside and outside the MPA, often having similar densities in a given survey. This continued in 2011, with the species being absent from both areas (Figure 3.14b). This is only a slight variation outside the values recorded in 2006, but could have ecological significance if the species continues absent in the future, as it has been a consistent contributor to fish assemblages in the past.

The sea sweep *Scorpis aequipinnis*, formerly common in the MPA and present outside the MPA, declined to a single observation in the reference area in 2011 (Figure 3.14a).

The abundance of scalyfin *Parma victoriae* remained relatively low and stable inside the MPA over the survey period, but decreased to absence in the reference area (Figure 3.14b).

The magpie morwong *Cheilodactylus nigripes* was present in low but stable numbers in both the MPA and the reference areas in past surveys, but in 2011 fell to its lowest abundance inside the MPA and was absent outside (Figure 3.14c).

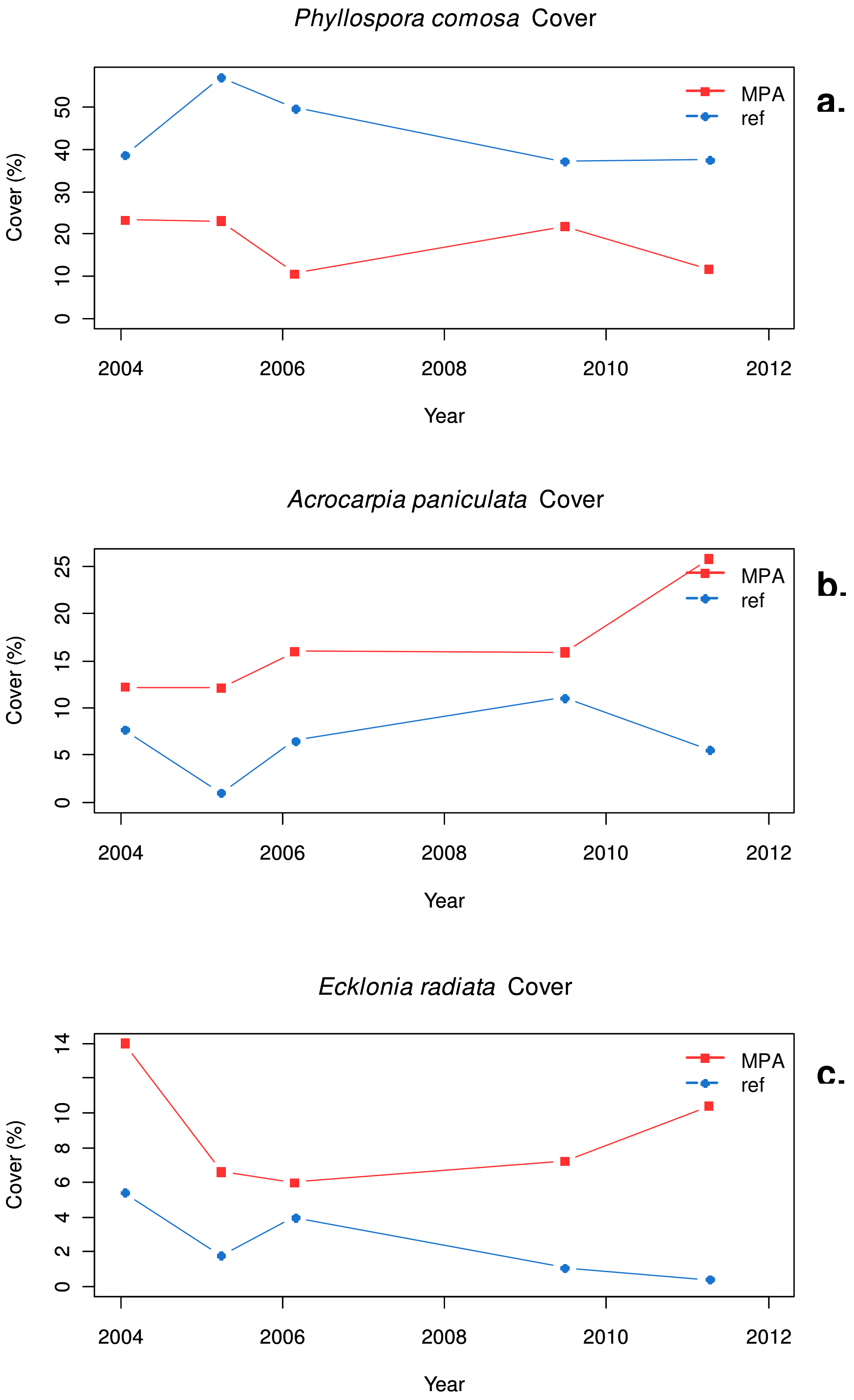


Figure 3.10. Percent cover of the most abundant algal canopy species at Merri Marine Sanctuary and corresponding reference site. (a) *Phyllospora comosa*; (b) *Acrocarpia paniculata*; (c) *Ecklonia radiata*.

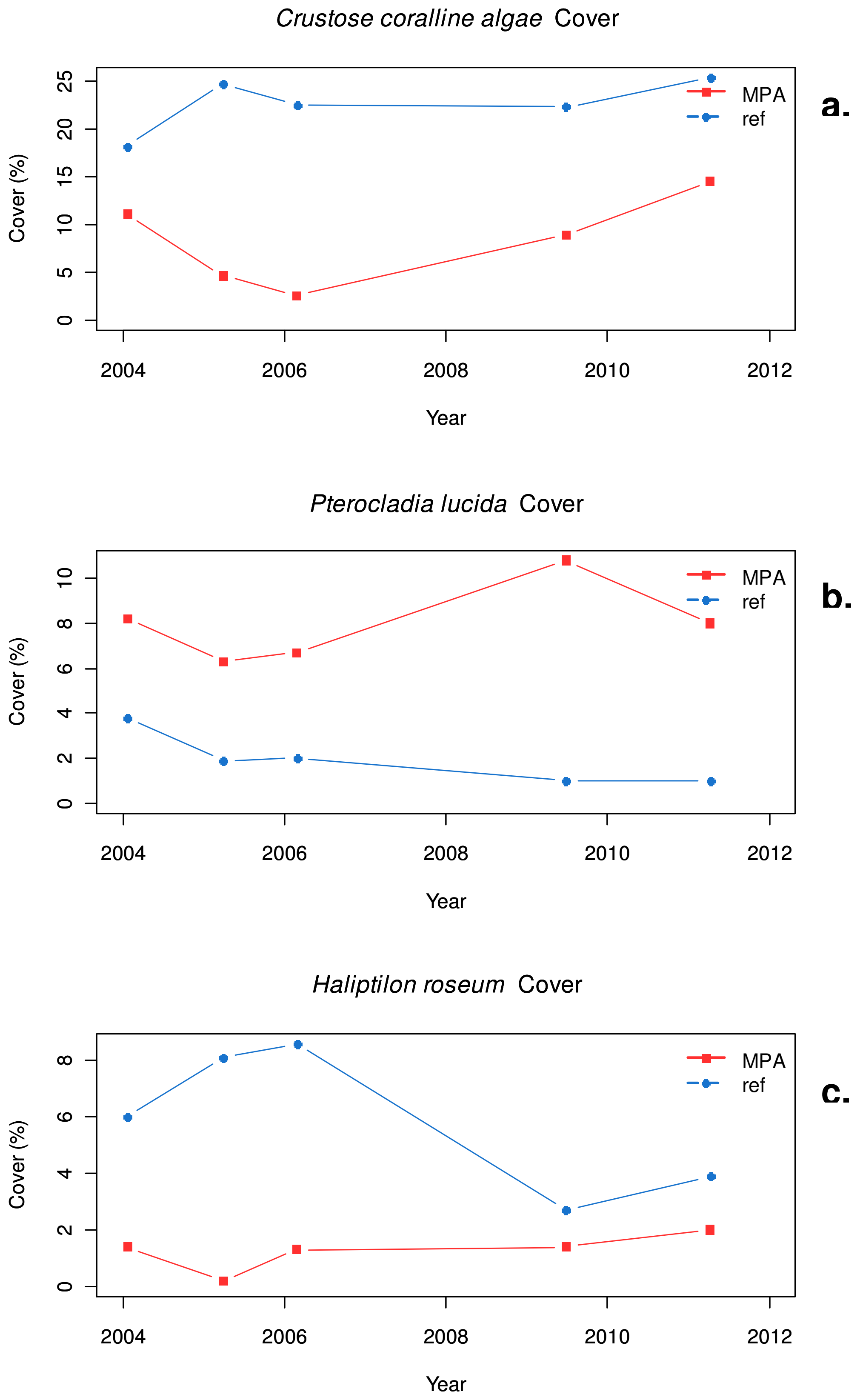


Figure 3.11. Percent cover of the most abundant understorey algal species at Merri Marine Sanctuary and corresponding reference site. (a) Crustose coralline algae; (b) *Pterocladia lucida*; (c) *Haliptilon roseum.*

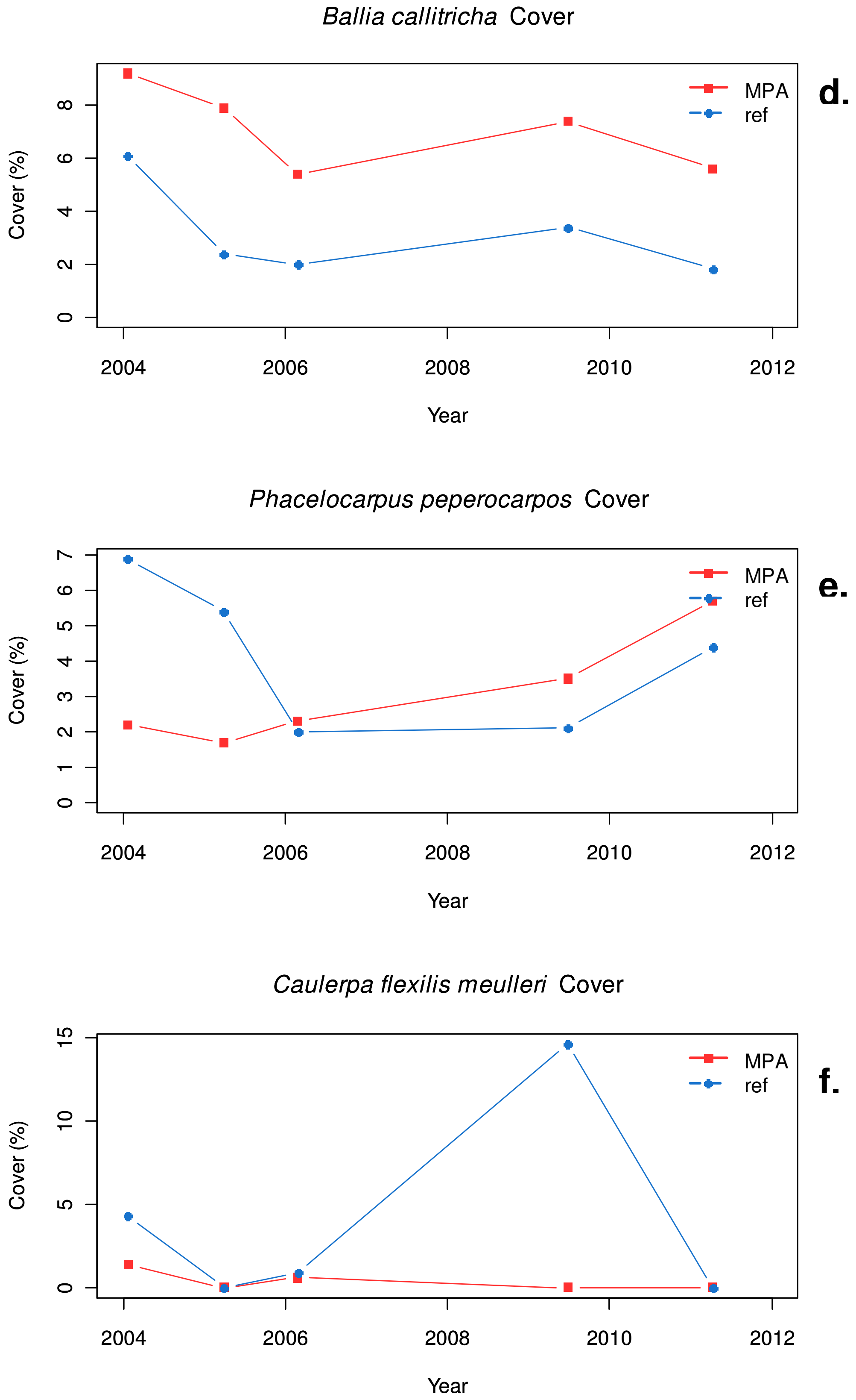


Figure 3.11 (continued). Percent cover of the most abundant understorey algal species at Merri Marine Sanctuary and corresponding reference site. (d) *Ballia callitricha*; (e) *Phacelocarpus peperocarpos*; (f) *Caulerpa flexilis* var. *muelleri*.

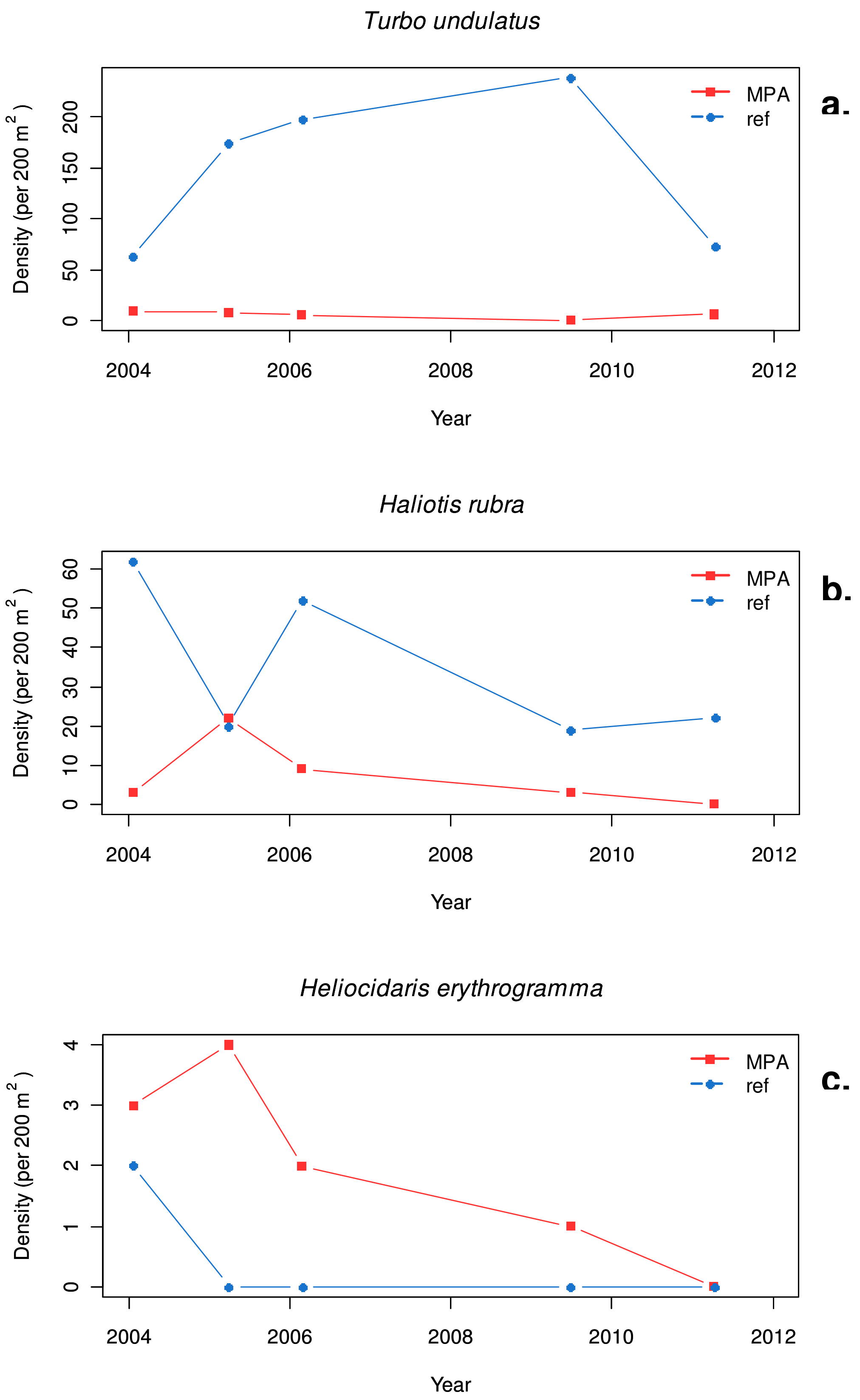


Figure 3.12 Abundance of dominant invertebrate species inside and outside Merri Marine Sanctuary. (a) *Turbo undulates;* (b) *Haliotis rubra;* (c) *Heliocidaris erythrogramma.*

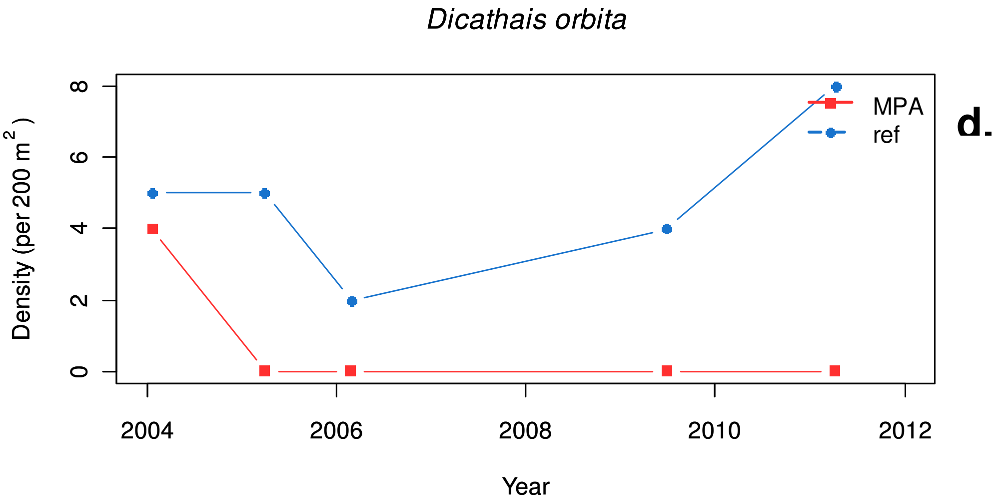


Figure 3.12 (continued) Abundance of dominant invertebrate species inside and outside Merri Marine Sanctuary. (d) Dicathais orbita.

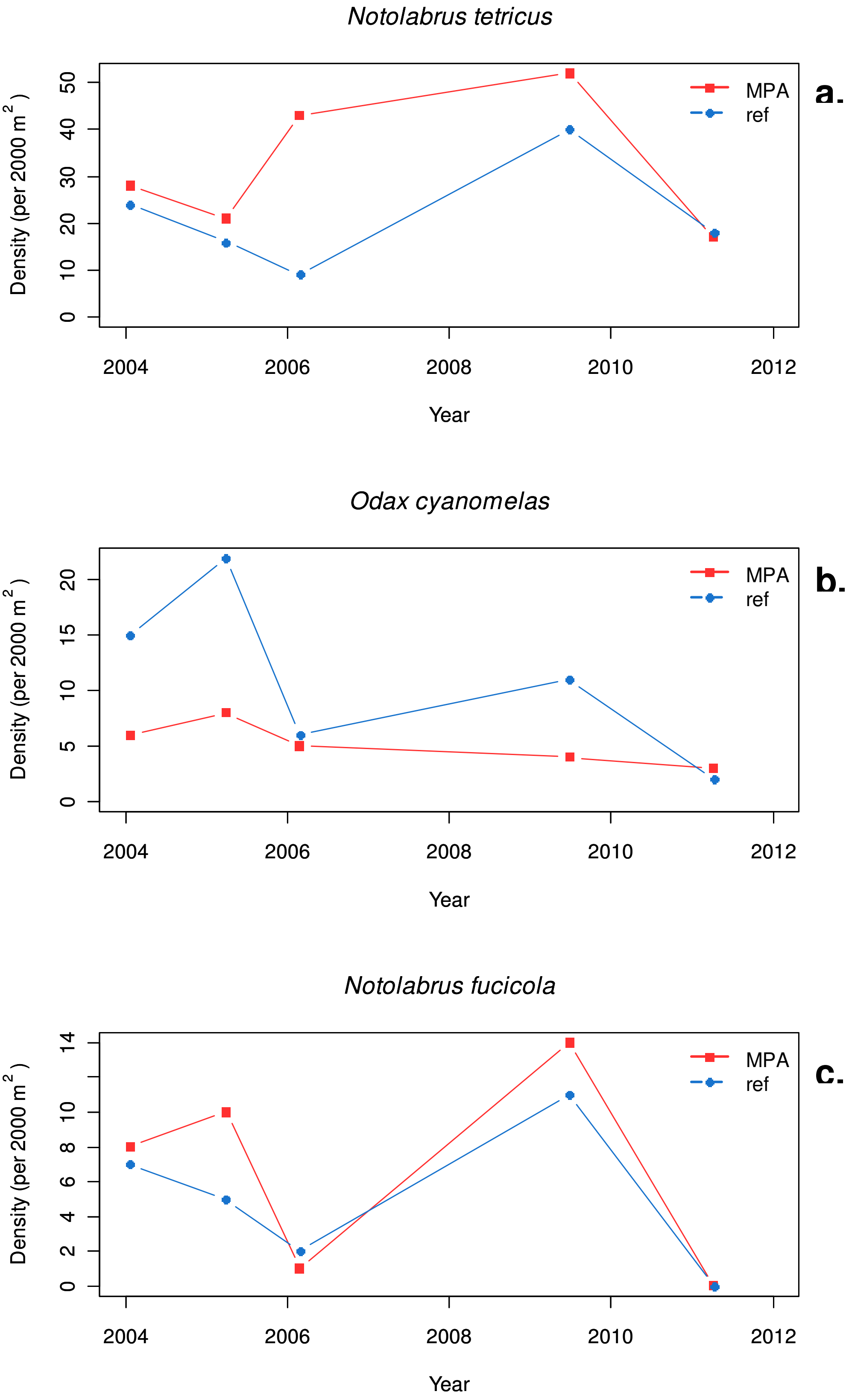


Figure 3.13. Abundance of dominant fish species inside and outside Merri Marine Sanctuary.

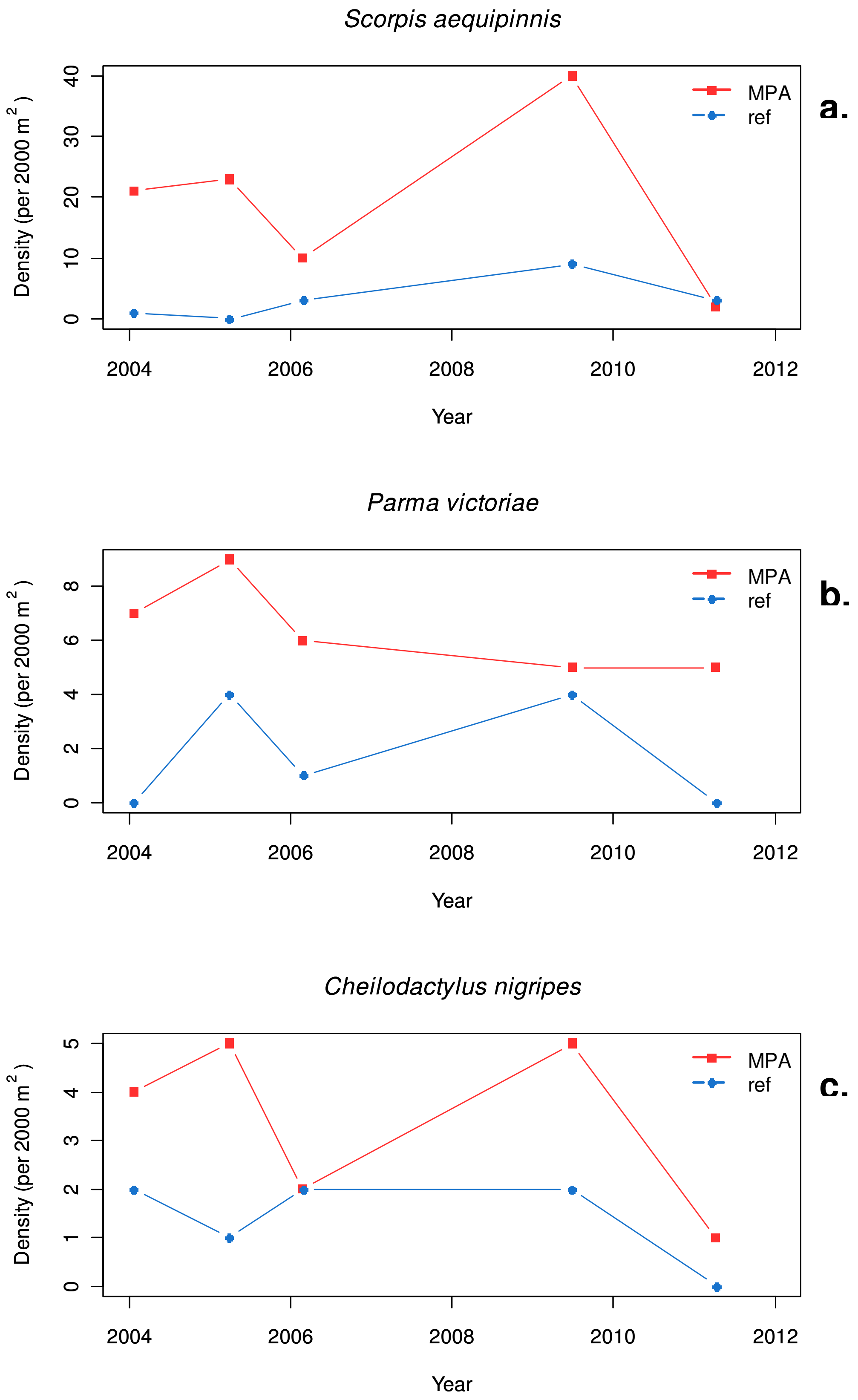


Figure 3.14. Abundance of dominant fish species inside and outside Merri Marine Sanctuary.

3.2. Condition Indicators

3.2.1. Ecosystem Components

No clear trend in the cover of different algae functional groups was evident over the survey period. Canopy browns have consistently been the dominant group (Figure 3.15a). Crustose coralline algae, consistently showing greater coverage at the reference site than within the MPA, increased their coverage at both sites between 2009 and 2011 to reach the highest values recorded for that group since monitoring began (Figure 3.15b). Green algae, also more prevalent at the reference site than within the MPA throughout the monitoring programme, underwent decreases at both sites to reach record low values in 2011 (Figure 3.15c). Thallose red algae have varied within a small range of cover values at both sites, with higher coverage consistently within the MPA that at the reference site (Figure 3.15d). Erect coralline algae have varied over a small range of coverage values at both sites, with the reserve having consistently higher percent cover than the MPA until 2011, when the values approached parity (Figure 3.15e). Smaller browns have undergone a gradual decrease in cover over the course of the surveys (Figure 3.15f).

Invertebrate Groups

Densities of invertebrate predators at both sites increased between 2009 and 2011 after several years of low abundance (Figure 3.16a). Filter feeding taxa have never been recorded in high densities at either site, but undergo periodic spikes in abundance both in the MPA and the reference area (Figure 3.16b). Densities of invertebrate grazers were markedly higher outside the marine sanctuary (Figure 3.16c). Seastars have occurred in consistently low numbers in the reference area but have undergone periodic spikes in abundance within the MPA, with 2011 figures returning to the low end of the range of values recorded for the area over time (Figure 3.16d).

Fish Groups

Similar patterns in the fish functional group indicators were observed inside and outside the MPA over the survey period. Fish grazer densities have followed similar trends through time, with low abundances in 2011 (Figure 3.17a). Planktivore density spiked within the MPA in 2007 but these species have been absent in subsequent surveys (Figure 3.17b). Fish hunters were absent at both sites since 2009 (Figure 3.17c). Fish forager densities were low at both sites in 2011 after decreases from record high values recorded in 2009 (Figure 3.17d).

Sediment Cover

Sediment cover remained low in the MPA in 2011 but rose to 16 % in the reference area (Figure 3.18). While sediment cover has fluctuated in the reference area over the survey period, the increase between 2009 and 2011 took the value well beyond previously measured variation.

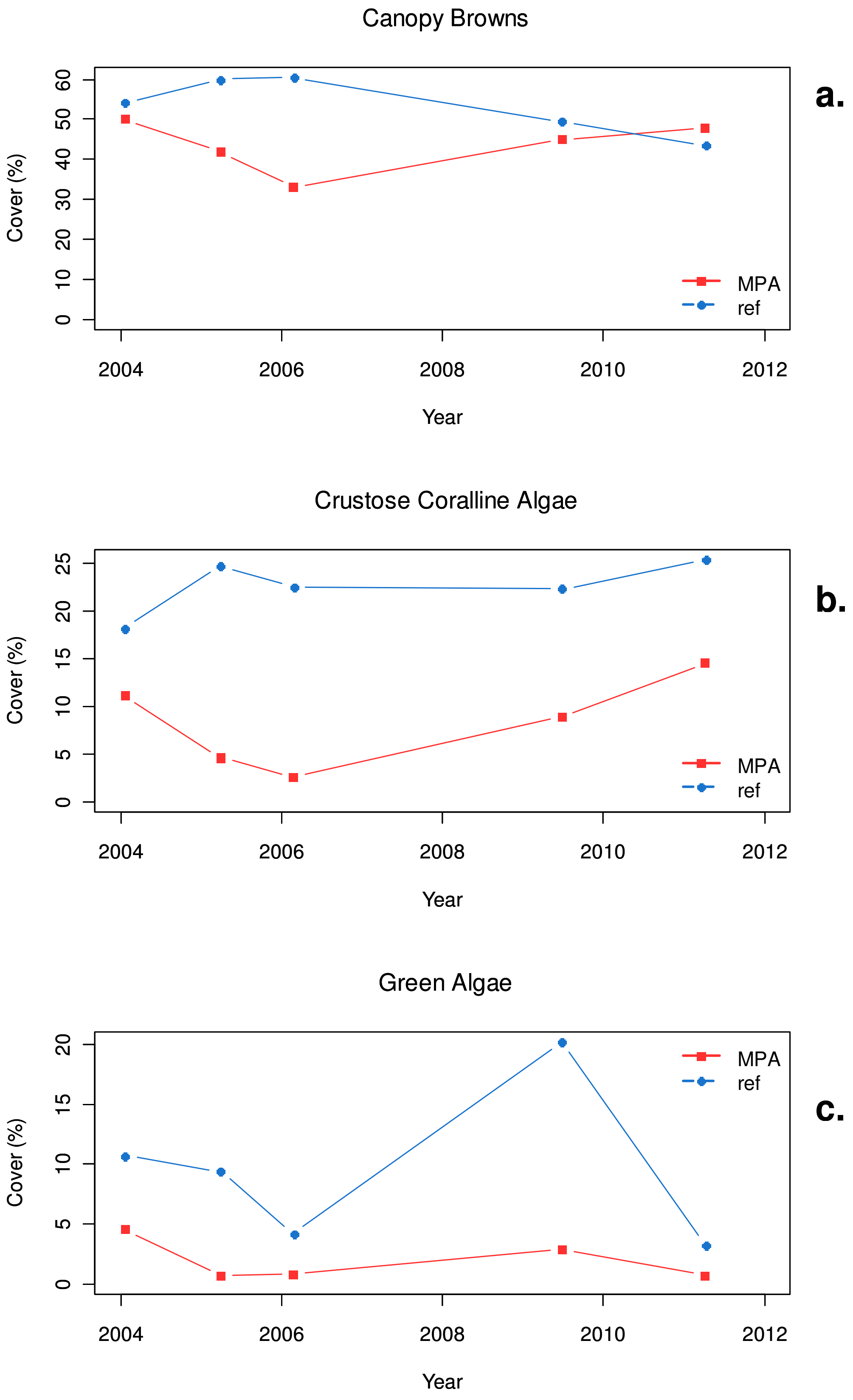


Figure 3.15. Seaweed functional groups inside and outside Merri Marine Sanctuary.

Figure 3.15. (continued) Seaweed functional groups inside and outside Merri Marine Sanctuary.

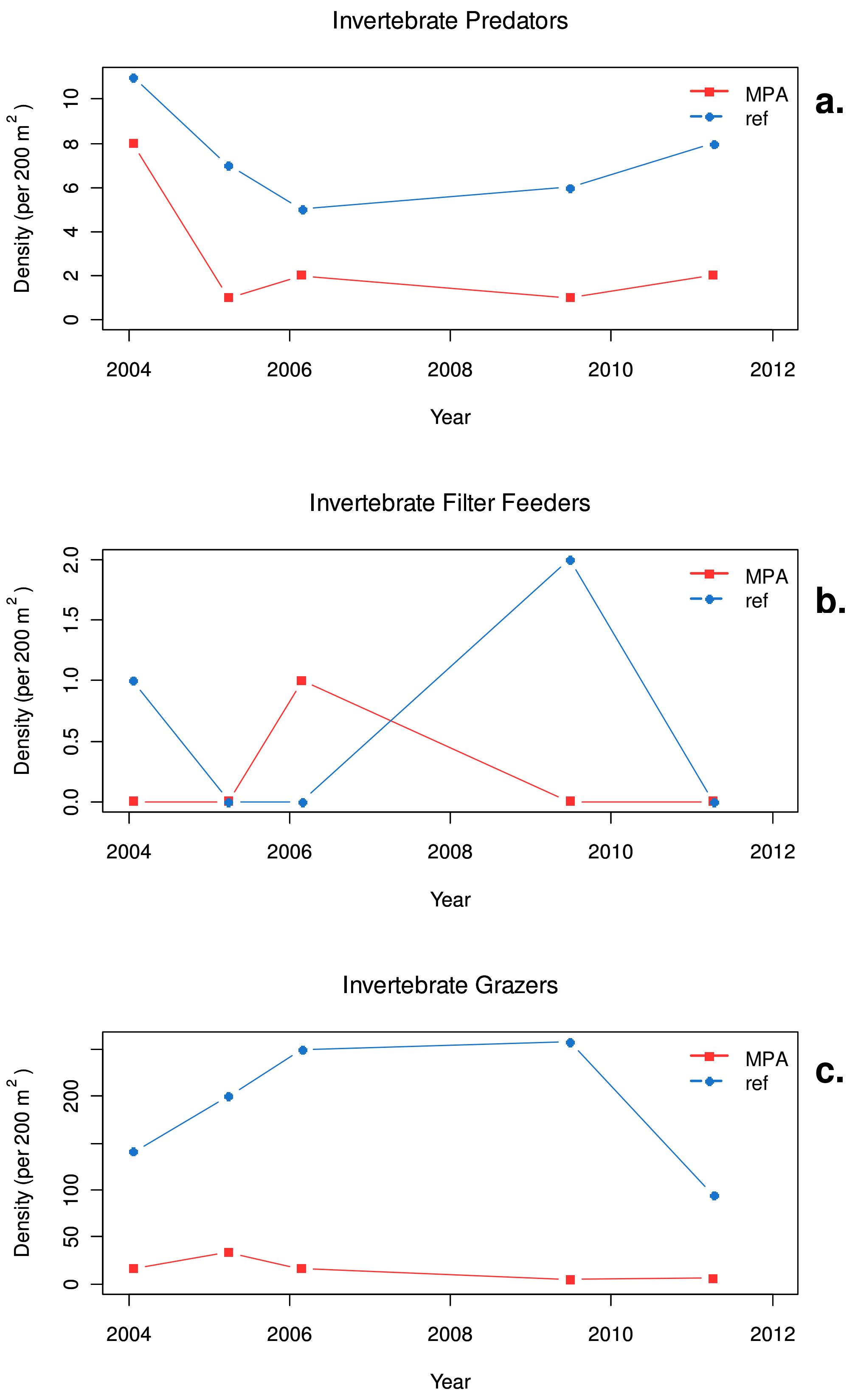


Figure 3.16. Abundance of invertebrate functional groups inside and outside Merri Marine Sanctuary.

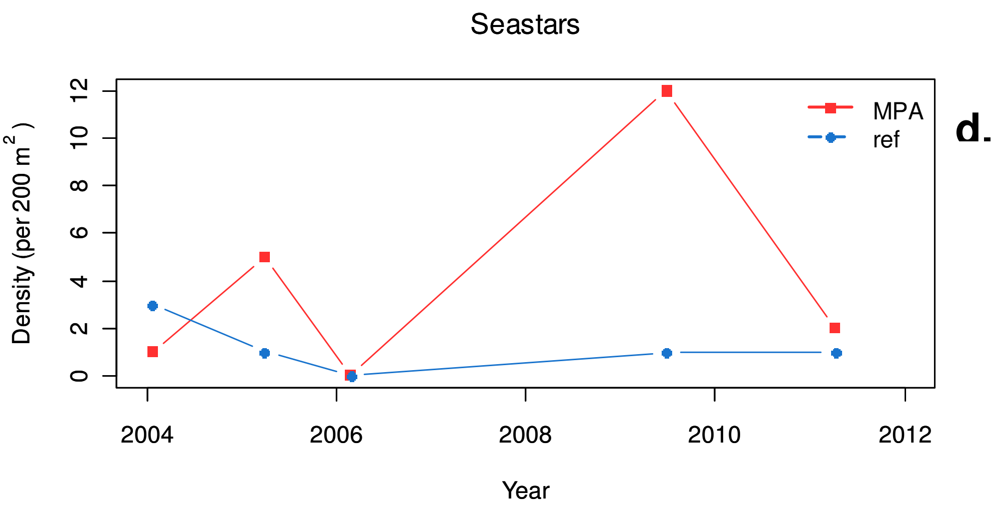


Figure 3.16. (continued) Abundance of invertebrate functional groups inside and outside Merri Marine Sanctuary

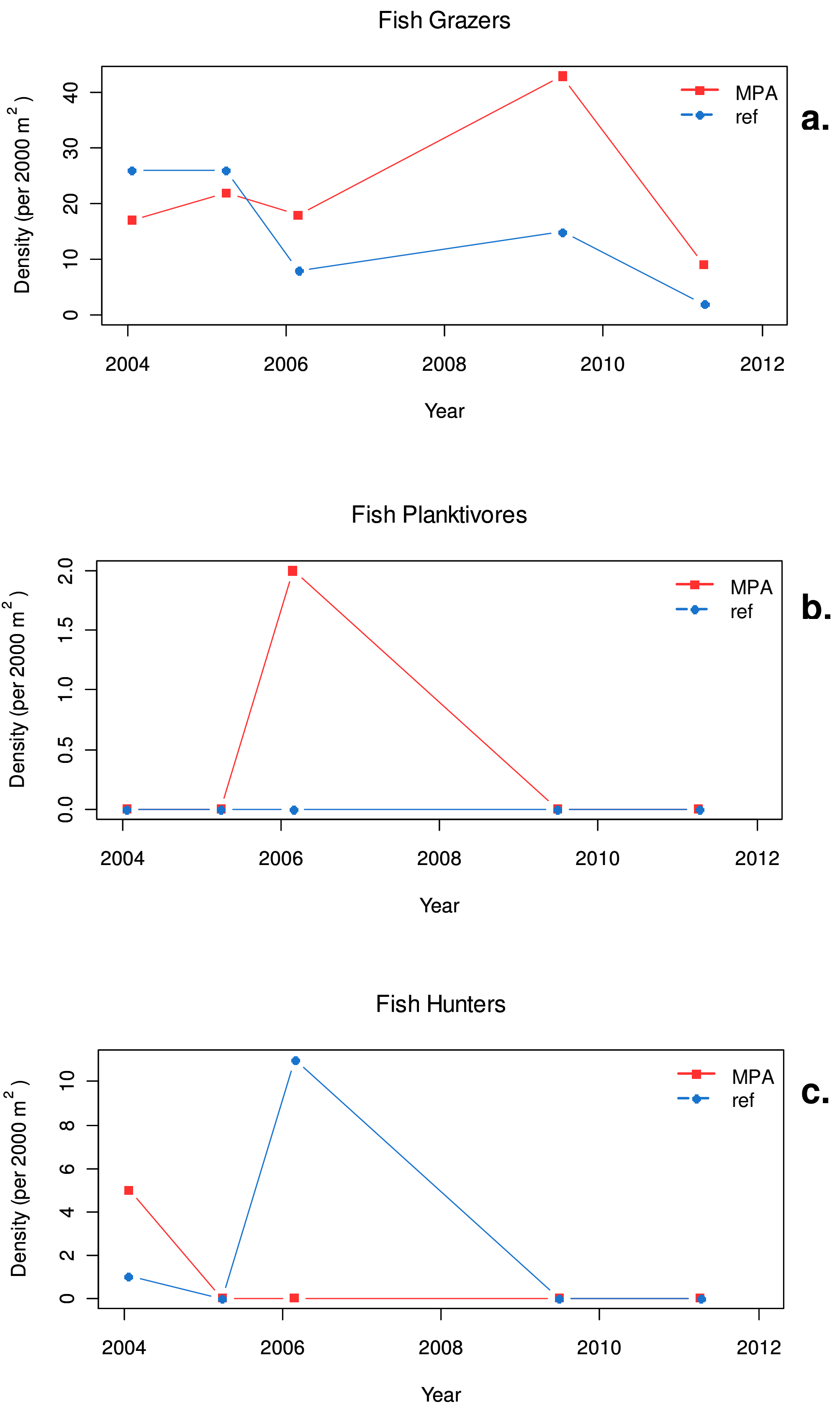


Figure 3.17. Abundance of fish functional groups inside and outside Merri Marine Sanctuary.

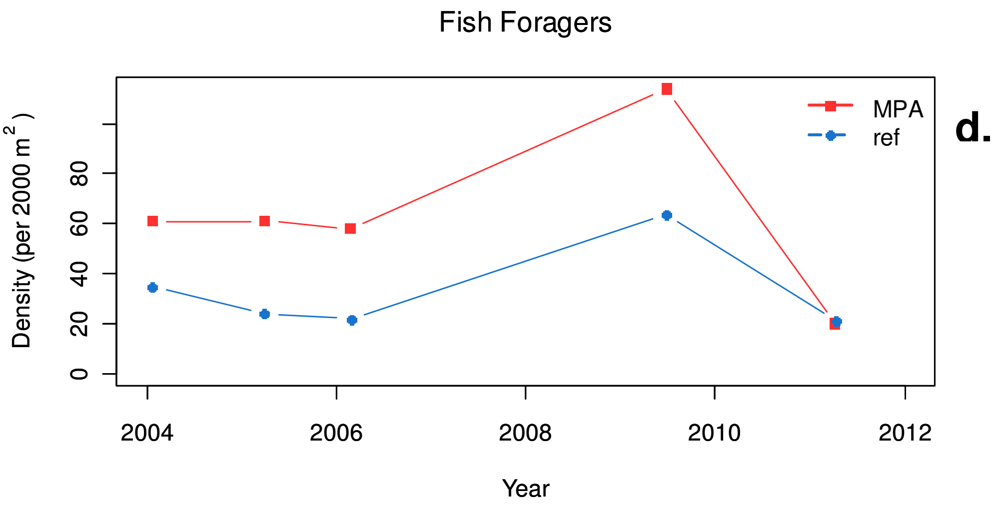


Figure 3.17. (continued) Abundance of fish functional groups inside and outside Merri Marine Sanctuary.

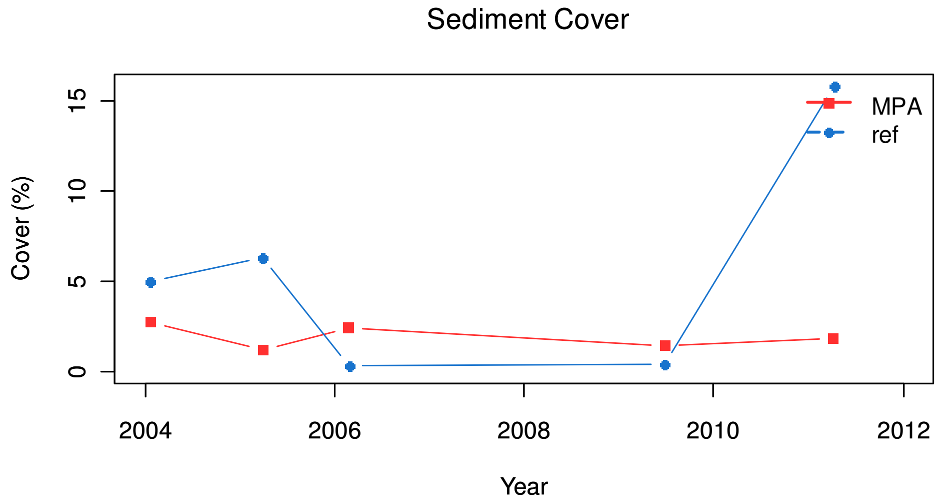


Figure 3.18. Cover of sediment inside and outside Merri Marine Sanctuary.

3.2.2. Introduced Species

No introduced species were observed at the Merri monitoring sites during any of the survey times.

3.2.3. Climate Change

Species composition

There have not been any major declines in cold water, Maugean seaweed and fish species richness or total abundance over the monitoring period. Similar patterns were observed inside and outside the MPA for Maugean algal (Figure 3.19) and fish (Figure 3.20) species.

The occurrence of western algal species was relatively low and sporadic throughout the monitoring period and only observed in the reference area. The eastern species in the Merri region were not well represented at any time.

Macrocystis pyrifera

The string kelp *Macrocystis pyrifera* has not been observed at the Merri sites since 2004 (Figure 3.22).

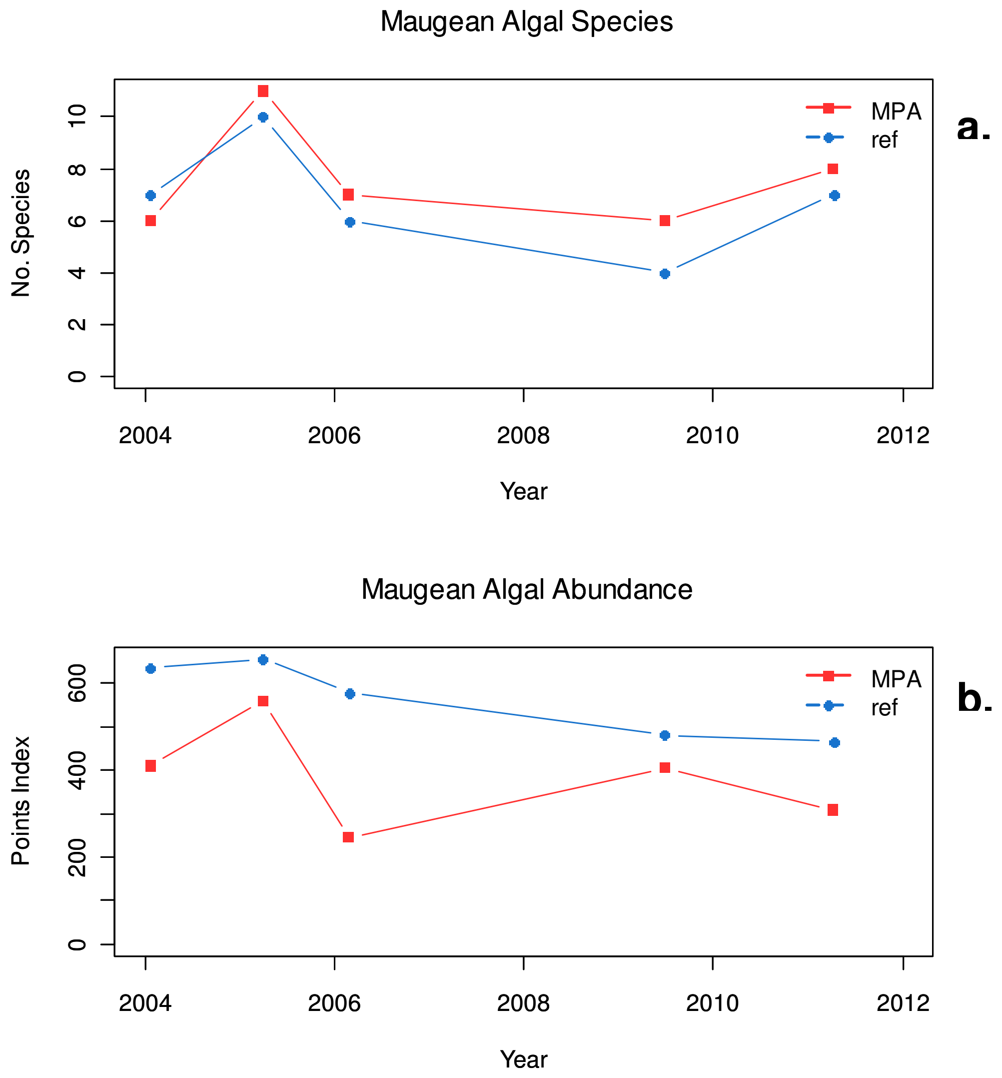


Figure 3.19. Abundance of Maugean algae species inside and outside Merri Marine Sanctuary.

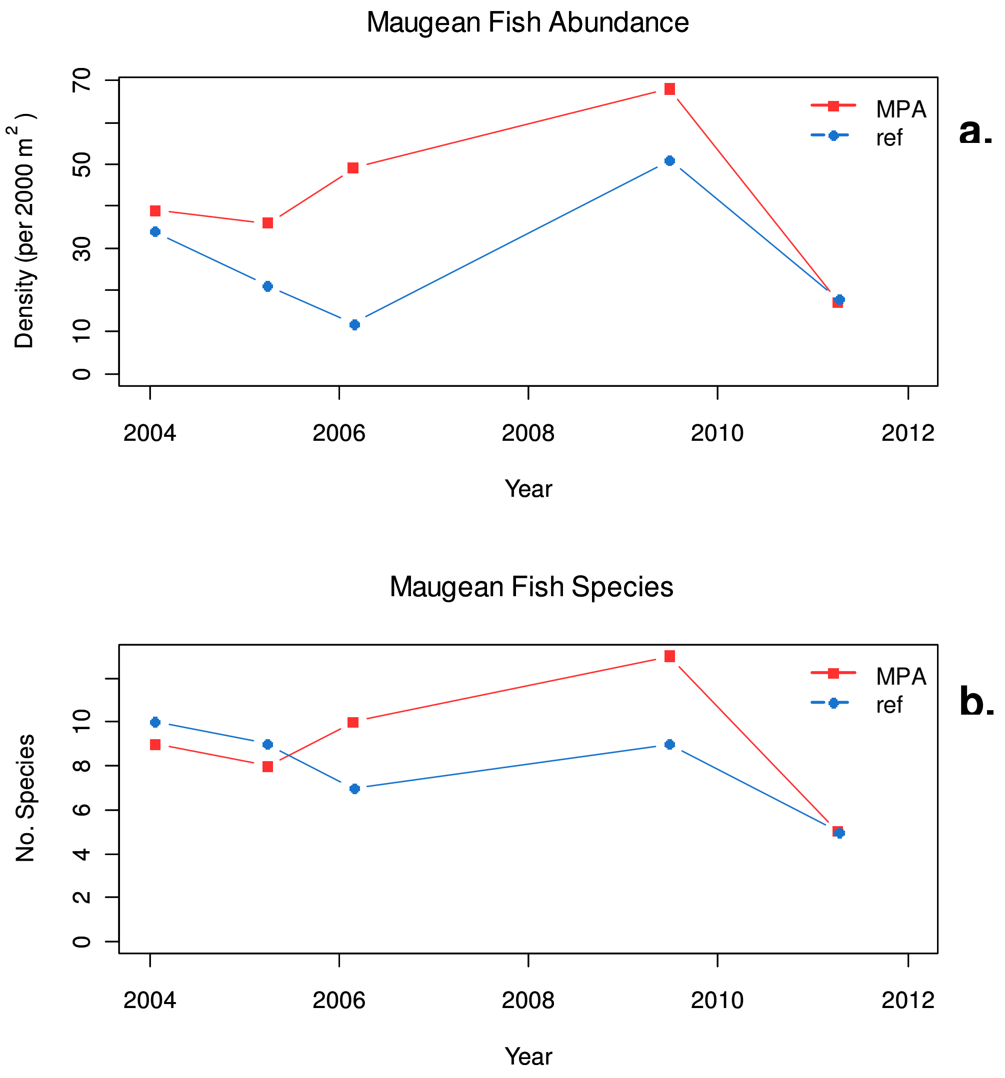


Figure 3.20. Abundance of Maugean fish species inside and outside Merri Marine Sanctuary.

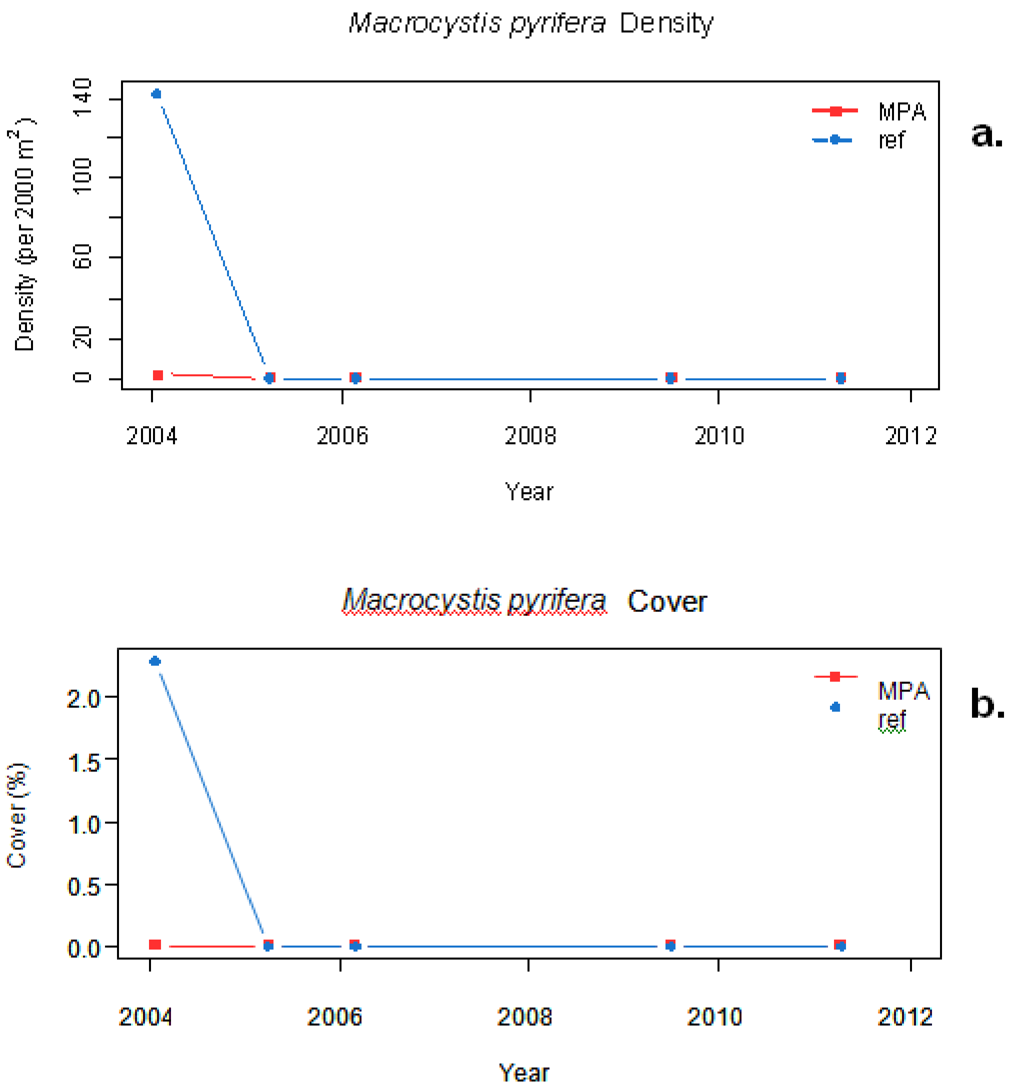
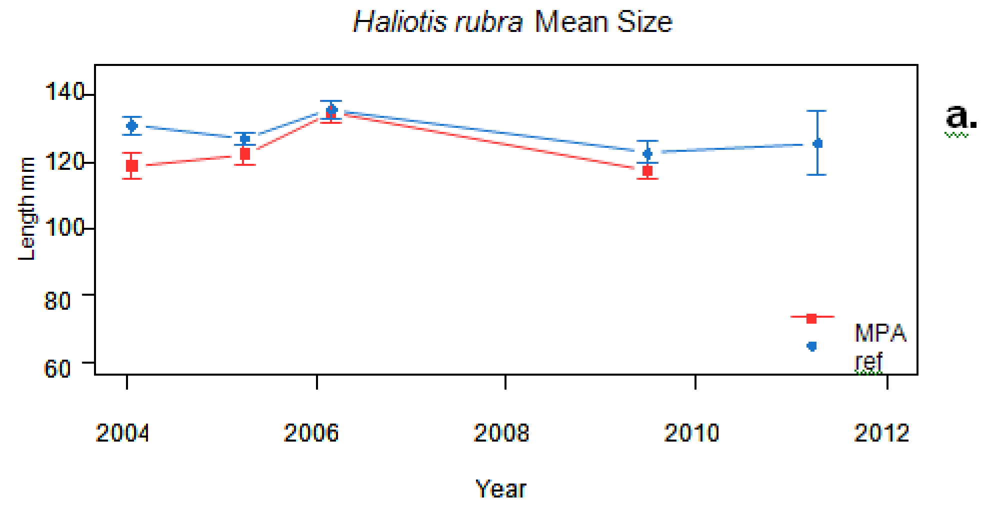


Figure 3.21 Abundance of string kelp *Macrocystis pyrifera* inside and outside Merri Marine Sanctuary.

3.2.4. Fishing

Abalone

The average size of blacklip abalone *Haliotis rubra* was similar between the Merri Marine Sanctuary and the reference areas during most surveys to 2009 (



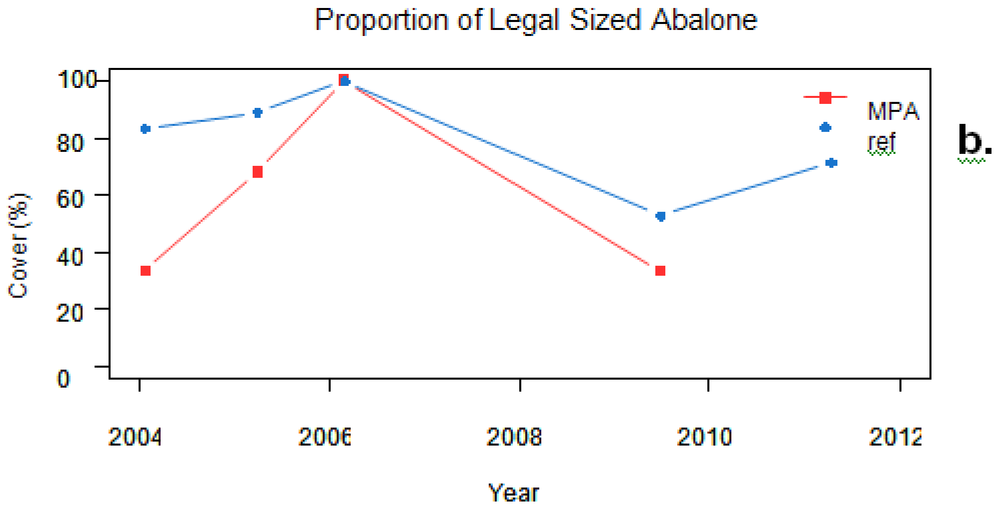
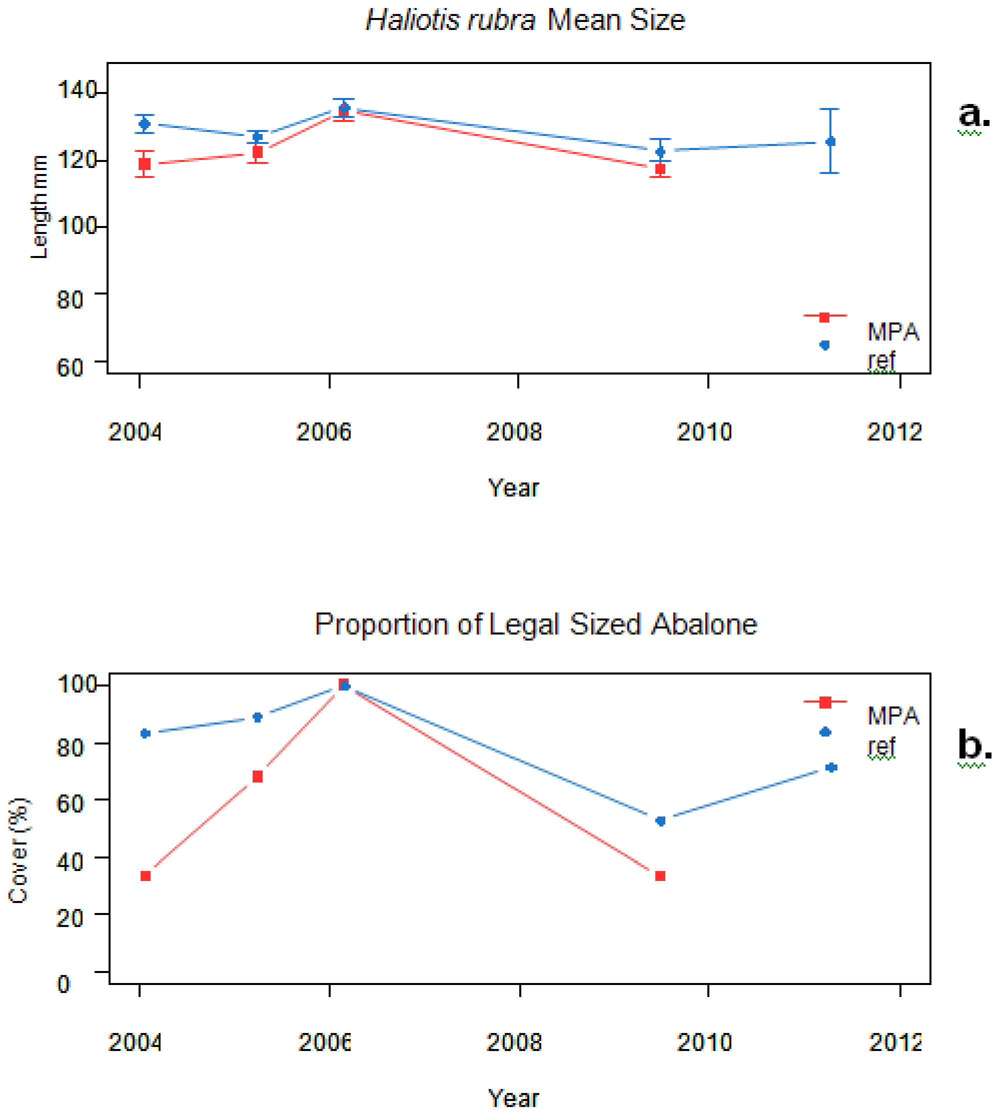


Figure **3.**22a). No *H. rubra* were found inside the MPA in 2011. While mean size of *H. rubra* in the reference area remained low in comparison to previous values, the proportion of legal size abalone there increased between 2009 and 2011 (Figure **3.**22b).



Rock Lobster

The southern rock lobster *Jasus edwardsii* was not well represented with low and sporadic observations made over the survey period, and being absent from both sites in 2011 (Figure 3.23).

Fishes

The size spectrum analysis showed a gradual reduction in the abundance of larger fishes outside the MPA over time, as indicated by the negative spectrum slope in 2011 (Figure 3.24a). The equivalent measure for inside the MPA has been relatively stable throughout the monitoring programme. The biomass and density of fishes above 200 mm length in both areas decreased from an equal median value in 2009 to an equal record low value in 2011

(Figure 3.25a-b). The density of larger fished species decreased both inside and outside the MPA between 2009 and 2011 to equal low values, a record low for the MPA and a value near equal to that in 2006 for the reference area (Figure 3.27). Similar patterns were observed inside and outside the MPA for the length of the blue throat wrasse *Notolabrus tetricus*, remaining stable over time, with heavily right skewed histograms for both areas (Figure 3.27). Densities of all fish taxa were very low in both areas, with the record high values of 2009 being followed record low values in 2011 (Figure 3.28).

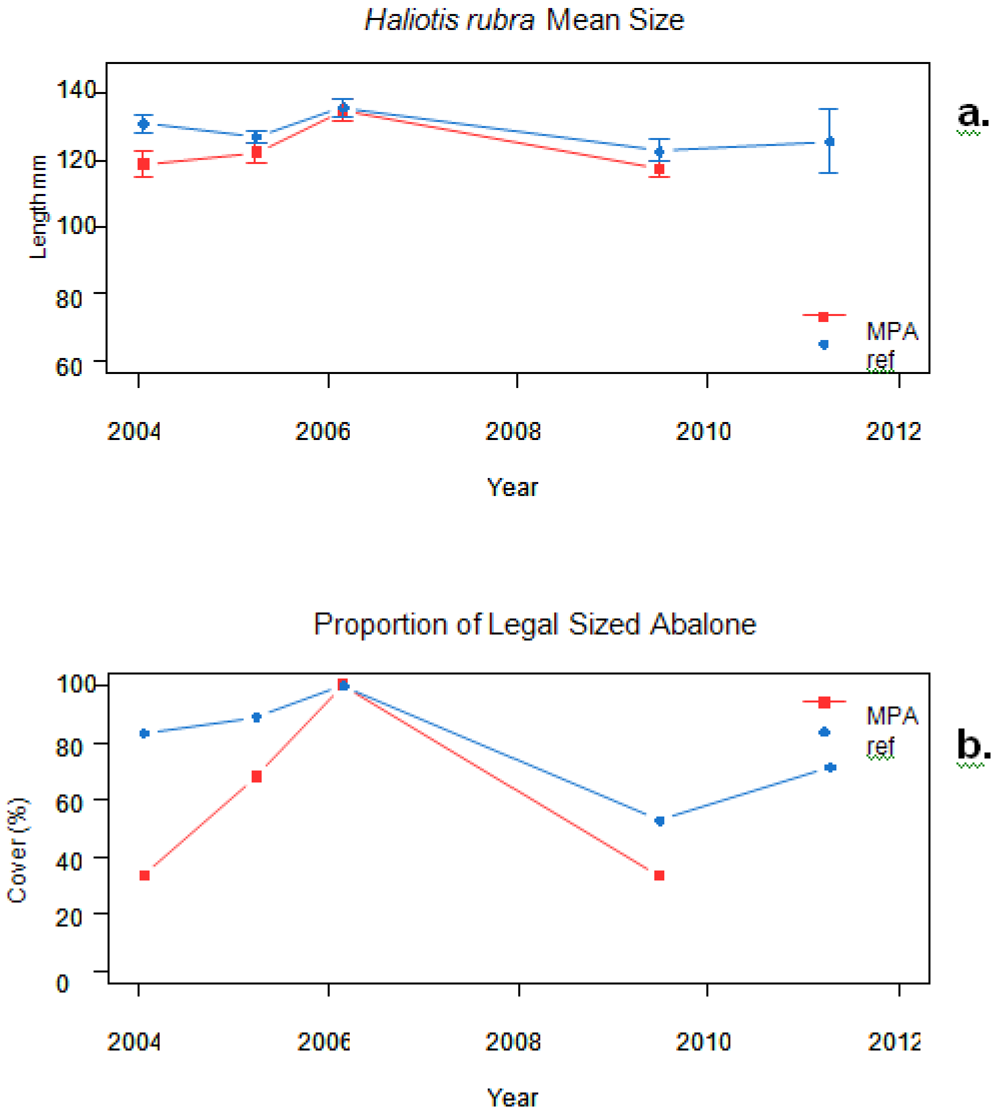


Figure 3.22. Blacklip abalone *Haliotis rubra* sizes at Merri Marine Sanctuary and the reference site: (a) mean size (± standard error); and (b) proportion of legal size.

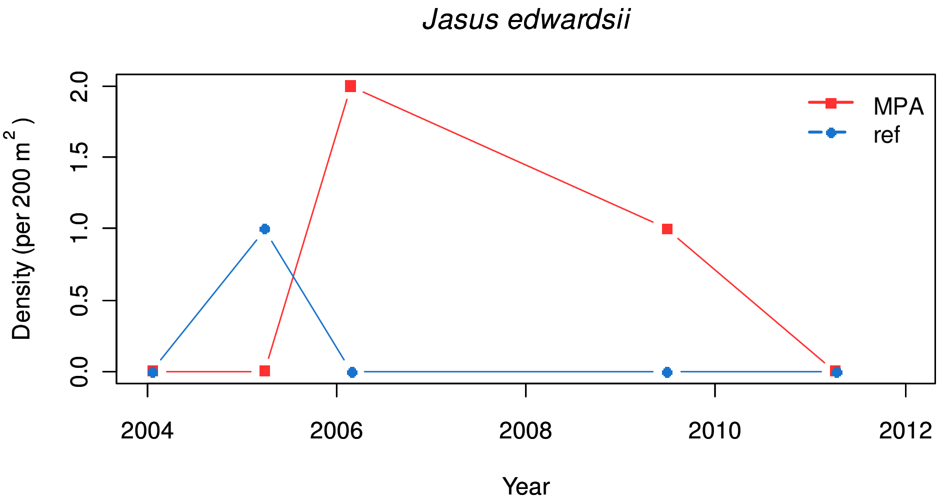


Figure 3.23. Density of southern rock lobster *Jasus edwardsii* inside and outside Merri Marine Sanctuary.

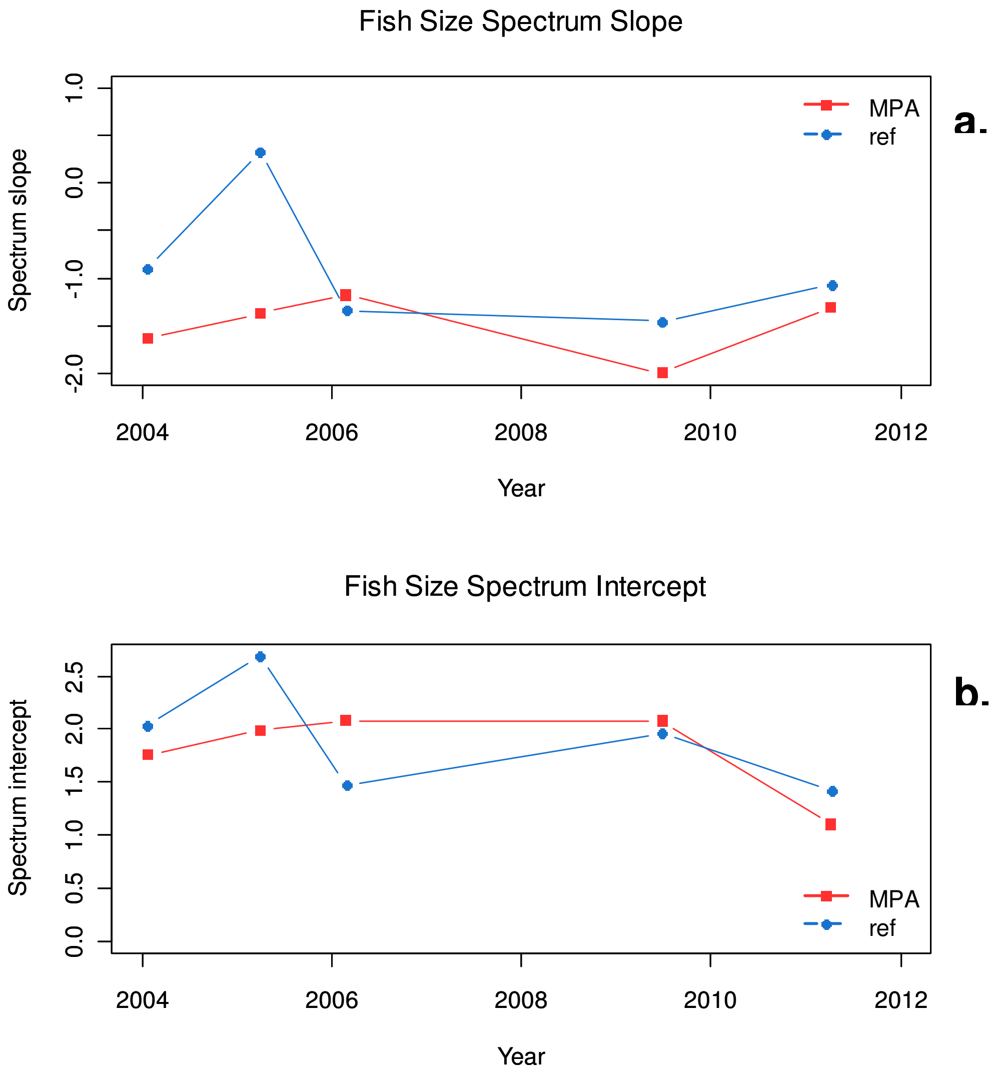


Figure 3.24. Fish size spectra inside and outside Merri Marine Sanctuary.

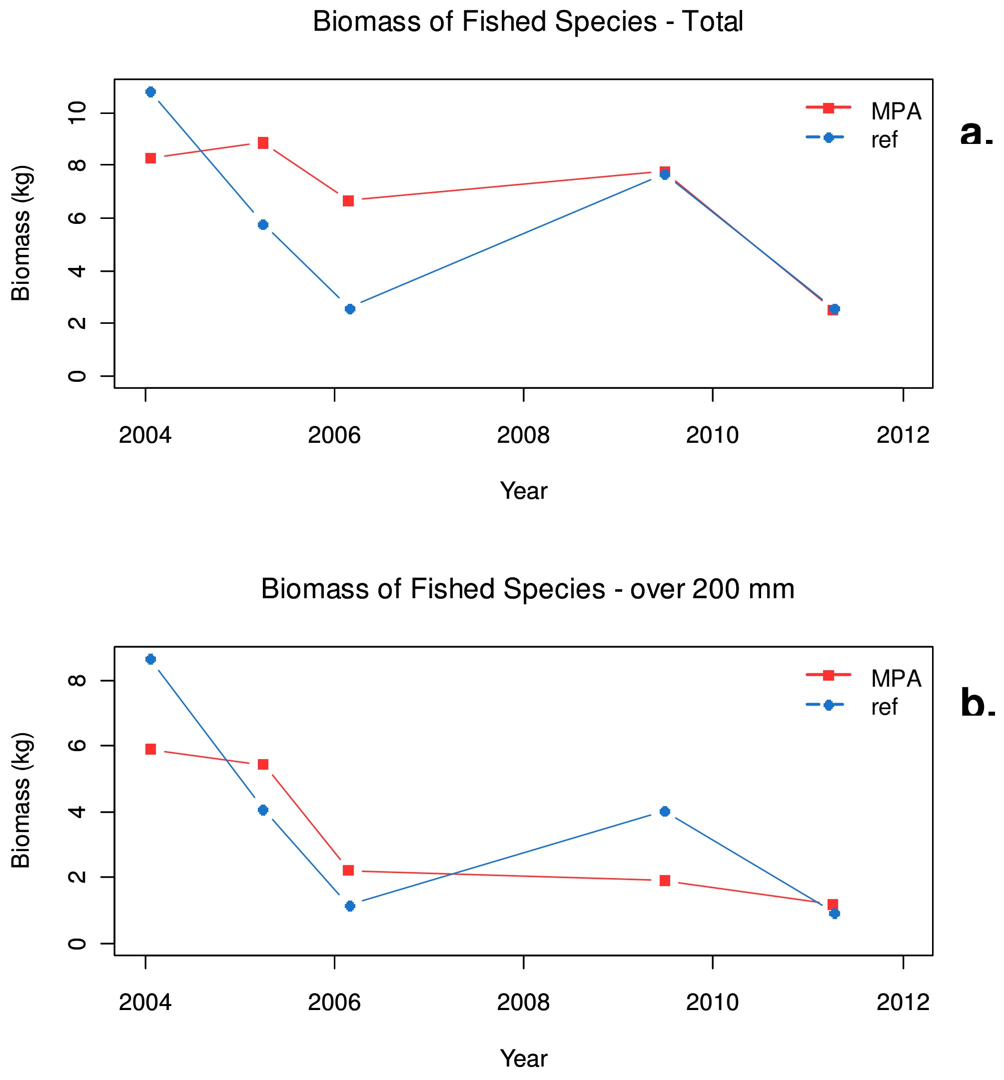


Figure 3.25. Biomass of fished species inside and outside Merri Marine Sanctuary.

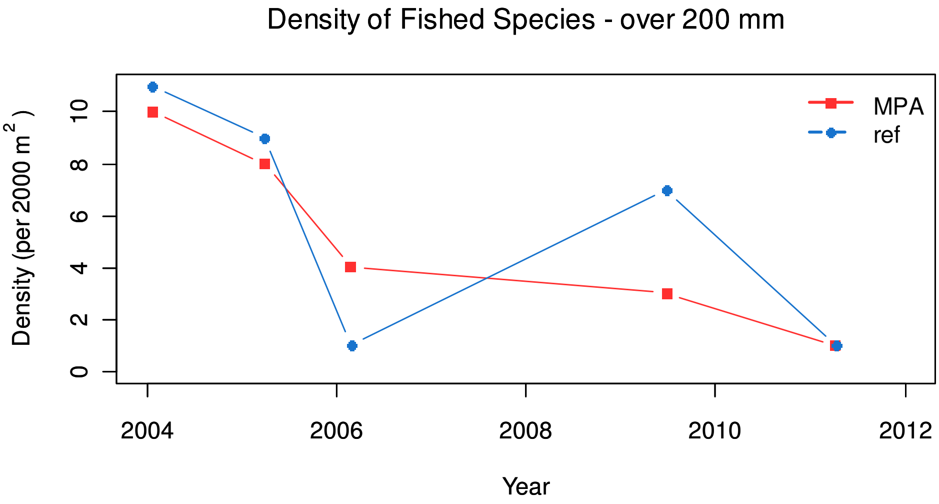


Figure 3.26. Density of larger fished fish species inside and outside Merri Marine Sanctuary.

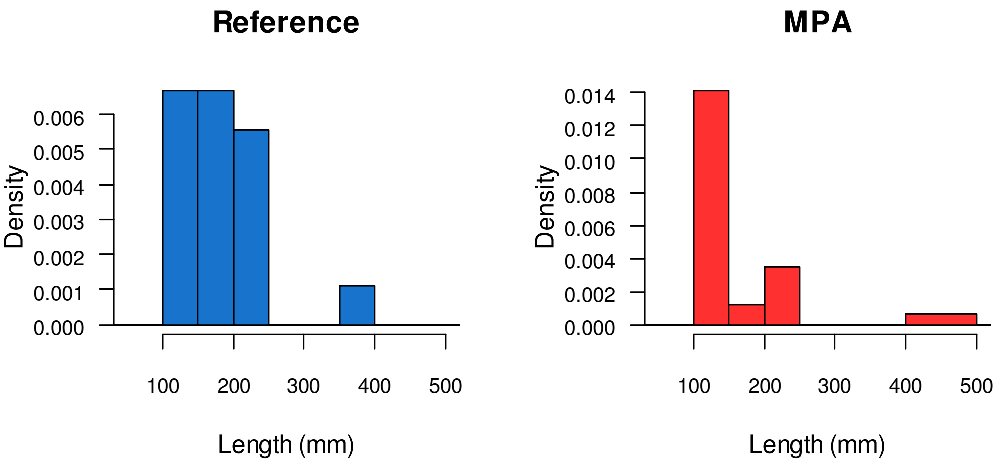


Figure 3.27. Abundance of different size classes of the blue throat wrasse *Notolabrus tetricus* at Merri Marine Sanctuary and the reference site.

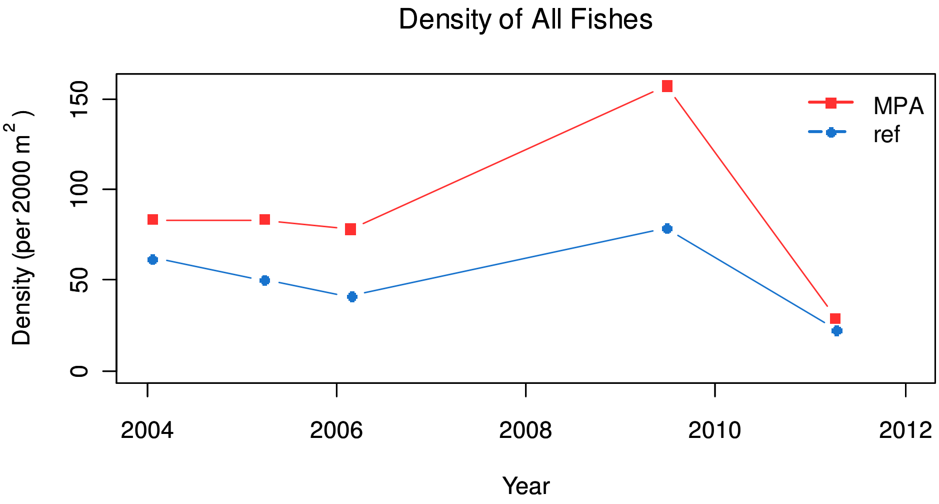


Figure 3.28. Density of all fish taxa inside and outside the Merri Marine Sanctuary.

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5. ACKNOWLEDGEMENTS

This project was initially funded by the Department of Sustainability and Environment and subsequently by Parks Victoria. Supervision was by Dr Steffan Howe. Field support for the last survey was kindly provided by Mr Jeff Giddins of Scuttlebutt Scuba charters.

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