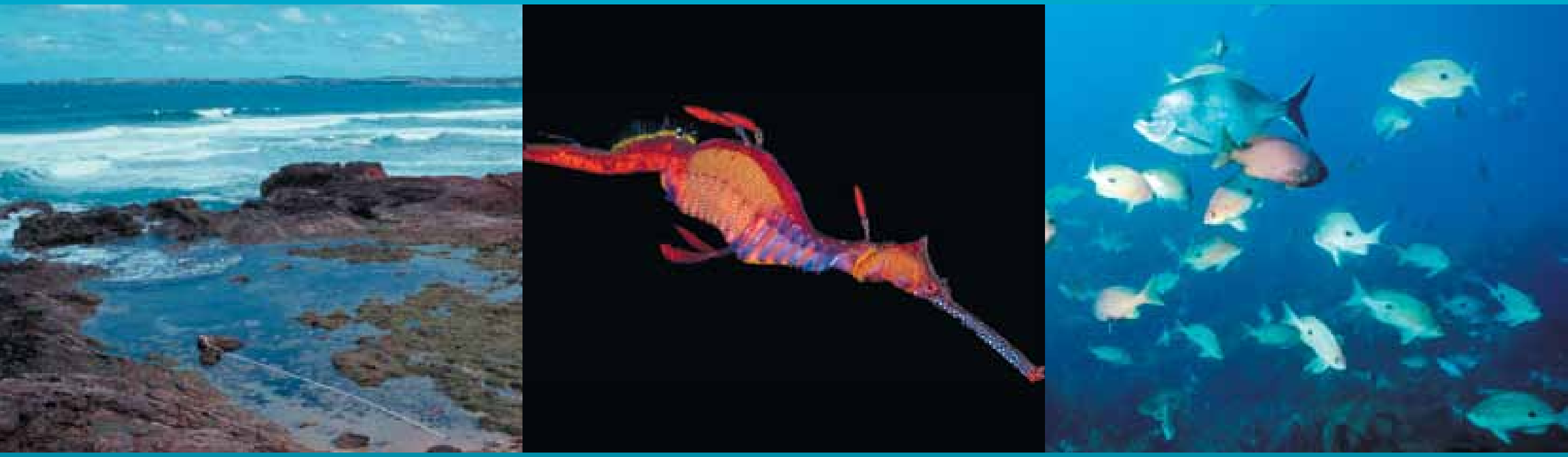

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Victorian Subtidal Reef Monitoring Program: The Reef Biota at Wilsons Promontory Marine National Park, December 2011

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Victorian Subtidal Reef Monitoring Program:

The Reef Biota at Wilsons Promontory Marine National Park, December 2011

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February 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 Wilsons Promontory Marine National Park began in November 1999. Since that time between 20 and 28 sites have been surveyed over 12 census events. The baseline monitoring period consisted of seven biannual surveys up to November 2002.

The monitoring involves standardised underwater visual census methods to a depth of 10 m. This report aims to provide:

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

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

- abundance and size structure of large fishes;
- abundance of cryptic fishes and benthic invertebrates;
- percentage cover of macroalgae; and
- density of a dominant kelp species (*Macrocystis pyrifera*).

To date, over 380 different species have been observed during the monitoring program in the region of the Wilsons Promontory Marine National Park. The observations in 2011 were very similar to those in 2010. Major findings include:

- three algal assemblages were identified: a Phyllospora dominated assemblage, an *Ecklonia-Seirococcus* dominated assemblage; and a mixed brown algal assemblage. Algal communities changed little and algal species richness and diversity appears to be stable over time at most sites;

- the common invertebrate assemblages appear to differ according to the exposure at the different sites. The invertebrate species richness typically ranged from 10 – 20 species while species diversity had a gradual decline over time as some species disappeared from the sites and others became increasingly dominant. Control charts for invertebrate assemblages indicate significant change over time both inside and outside the MNP;
- abalone *Haliotis rubra* populations and the proportion of legal size abalone follow similar patterns inside and outside the MNP and were at moderate densities inside the Marine National Park compared to baseline surveys. Abundances were increasing at Norman Point while were relatively low at Roaring Meg;
- the abundances of the other common invertebrates, including the common sea urchin *Heliocidaris erythrogramma*, feather star *Comanthus trichoptera* and common seastars had a substantial decline in abundance during the baseline period, with abundances remaining relatively low since.
- the black-spined urchin *Centrostephanus rodgersii* was observed at East Landing in 2002, Great Glennie Island in 2004 and in Waterloo Bay in 2011. No *C. rodgersii* were found at any site in December 2011;
- no urchin barren habitat of any sea urchin species were observed during the monitoring program;
- the common fish species included blue-throated wrasse, purple wrasse, herring cale, magpie perch, barber perch, silver sweep and old wife. Species richness of fishes has been stable over time.
- the abundances of purple wrasse *Notolabrus fucicola* has declined over the monitoring period and were relatively low in 2010 and 2011. Conversely, the abundances of barber perch *Caesioperca rasor* and butterfly perch *C. lepidoptera* increased markedly from 2005, with high abundances since.
- the total abundance and biomass of all fishes declined substantially during the baseline period. There was a subsequent peak in abundance of smaller fishes in 2005 and 2006, however this increase was not evident in fishes > 200 mm. The biomass of harvested species has increased slightly in the most recent surveys. Fish size frequency distributions are similar inside and outside the MNP sites during all surveys;
- the number of seals and seal pups at Shellback Island was very high compared with previous surveys, indicating the haulout area is now a breeding colony.

CONTENTS

INDEX OF FIGURES AND TABLES

FIGURES

INDEX OF TABLES

1. INTRODUCTION

1.1. Subtidal Reef Ecosystems of Victoria

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

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

Grazing and predatory motile invertebrates are prominent animal inhabitants of the reef (Figure 1.2). Common grazers include blacklip and greenlip abalone *Haliotis rubra* and *Haliotis laevigata*, warrener *Turbo undulatus* and sea urchins *Heliocidaris erythrogramma, Holopneustes* spp. and *Amblypneustes* spp.. These species can influence the growth and survival of habitat forming organisms. For example, sponges and foliose seaweeds are often prevented from growing on encrusting coralline algae surfaces through the grazing actions of abalone and sea urchins. Predatory invertebrates include dogwhelks *Dicathais orbita*, southern rock lobster *Jasus edwardsii*, 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.

Green algae *Caulerpa flexilis*

Encrusting coralline algae at the base of crayweed *Phyllospora comosa* holdfast

Red coralline algae *Ballia callitricha*

Thallose red algae *Haliptilon roseum*

Crayweed *Phyllospora comosa* canopy

Common kelp *Ecklonia radiata* canopy

Figure 1.1. Examples of species of macroalgae found on Victorian subtidal reefs.

Southern rock-lobster *Jasus edwardsii*

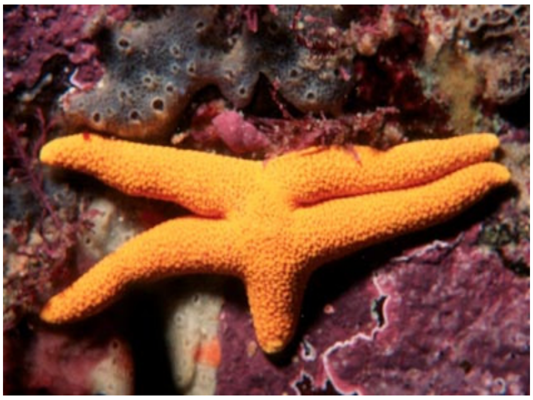
Red bait crab *Plagusia chabrus*

Blacklip abalone *Haliotis rubra*

Feather star *Comanthus trichoptera*

Nectria ocellata

Common sea urchin
Heliocidaris erythrogramma



Fromia polypora

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 (male)

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, 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.* 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, 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.

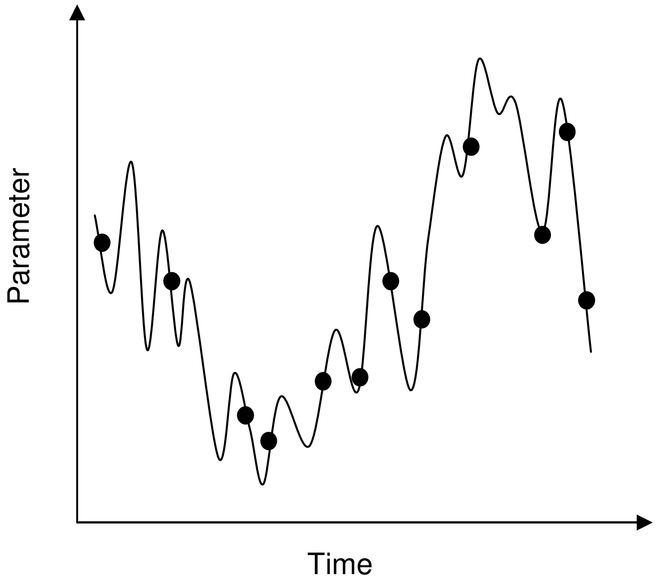


Figure 1.4. An example plot depicting change in an environmental, population or community variable over time (days, months or years) and potential patterns from isolated observations.

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. Monitoring at Wilsons Promontory

1.3.1. Marine Parks and Marine Reserves

Prior to the declaration of the Wilsons Promontory Marine National Park, the coast of Wilsons Promontory formed part of the South Gippsland Marine and Coastal Parks, declared in 1986. There were three types of conservation zone: Wilsons Promontory Marine Park along the northwest and north east coasts; Western and Eastern Protection Zones at Norman Bay and Refuge Cove; and Wilsons Promontory Marine Reserve along the southern coast (CFL 1989; O'Toole and Turner 1990; Figure 1.5). The western boundary of the Marine Park extended from Shallow Inlet out to Shellback Island, and then in a line joining the headlands to just before Norman Point.

The Marine Reserve encompassed a 300 m wide band along the southern shore, from Norman Point to Refuge Cove. The eastern part of the Marine Park continued northward from Refuge Cove, also with the boundary 300 m from the shore (Figure 1.5).

Recreational fishing was allowed in the Marine Park zone, however spearfishing, and the collection of abalone were not allowed on scuba and there was a rock lobster bag limit of one per day. Recreational fishers could only line fish in the Protection Zones and no fishing was allowed in the Marine Reserve. Commercial fishing was allowed throughout the Wilsons Promontory conservation areas, with the principal reef fisheries being for rock lobster, abalone and live wrasse/morwong.

The intertidal zone of the Wilsons Promontory coast was wholly protected as part of the Wilsons Promontory National Park. The National Park was declared in 1898, with the intertidal zone being added to the Park in 1965 (Ivanovici 1984).

1.3.2. Wilsons Promontory Marine National Park

Following proposals from the Environment Conservation Council (ECC 1999; 2000), the Wilsons Promontory Marine National Park was declared on 16 November 2002 (Figure 1.6). The Marine National Park overlays the pre-existing Wilsons Promontory Marine Reserve (except for the islands of the Glennie Group, and coasts north of Cape Wellington). The boundaries of the Marine National Park extend further offshore to fully encompass the islands of the Anser Group and Wattle Island. Reef habitats within the Marine National Park include sheltered and exposed granite habitats with a variety of smooth bedrock, rubble, boulder, bombie and pinnacle type structures.

The level of protection for marine environments within the Marine National Park has been extended to restrict all forms of recreational and commercial fishing. Recreational line fishing, and commercial fishing is only permitted in the Marine and Coastal Park or Marine Reserve areas.

1.4. Subtidal Reef Monitoring at Wilsons Promontory

This report provides a description of the monitoring program at Wilsons Promontory and results from eleven surveys, incorporating Wilsons Promontory Marine National Park and the adjacent conservation areas. The objectives of this report were to:

- provide an overview of the methods used for SRMP;
- provide general descriptions of the biological communities and species populations at each monitoring site up to December 2011;
- describe changes and trends that have occurred over the monitoring period;
- identify any unusual biological phenomena such as interesting or unique communities or species;
- identify any introduced species at the monitoring locations; and
- report on trends in selected ecosystem status indicators.

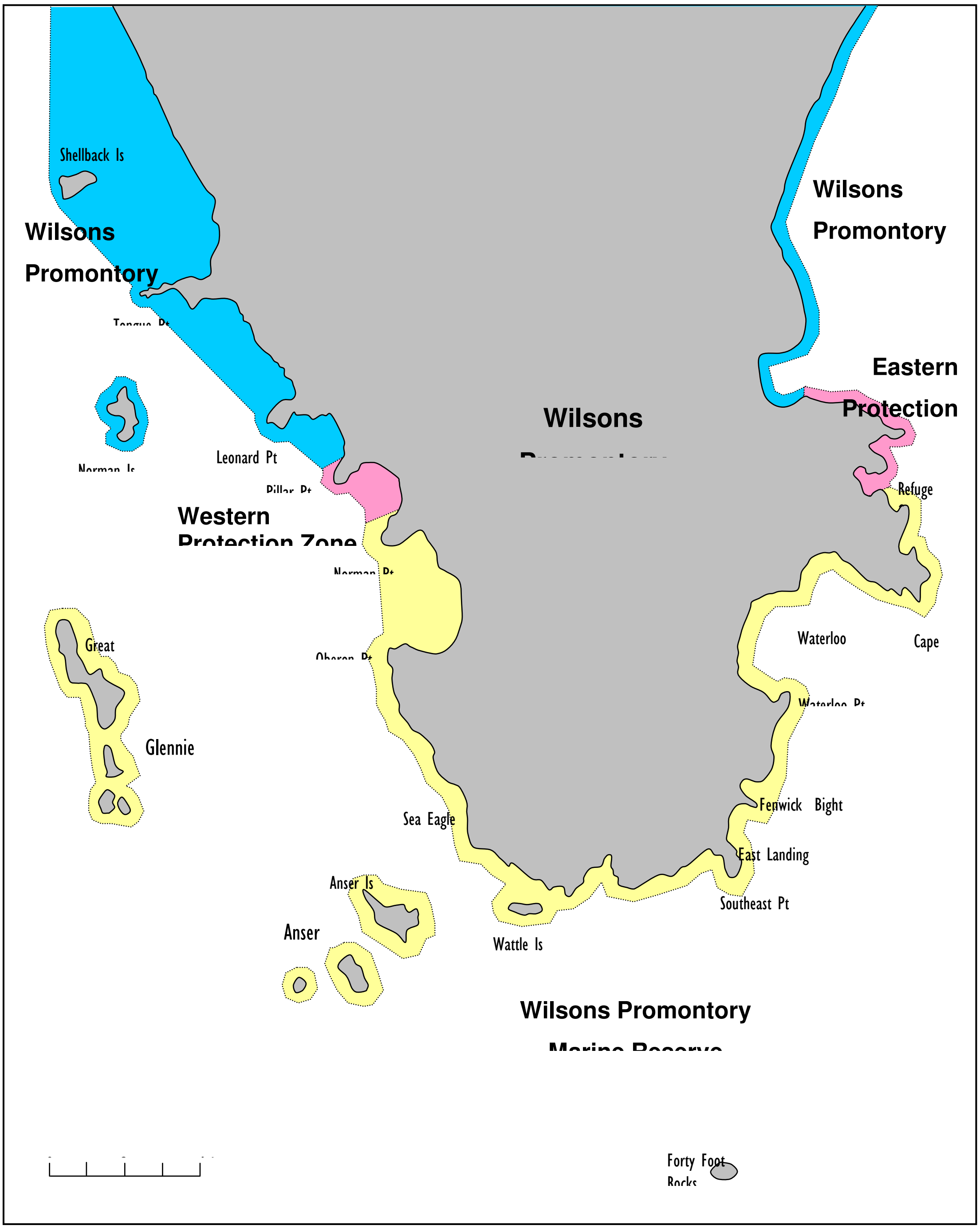


Figure 1.5. Previous marine protected areas at Wilsons Promontory (1986 - 2002): (blue) Wilsons Promontory Marine Park; (pink) Western and Eastern Protection Zones; and (yellow) Wilsons Promontory Marine Reserve. The southern, eastern and island boundaries are not to scale, being only 300 m from the shore (exaggerated here for clarity).

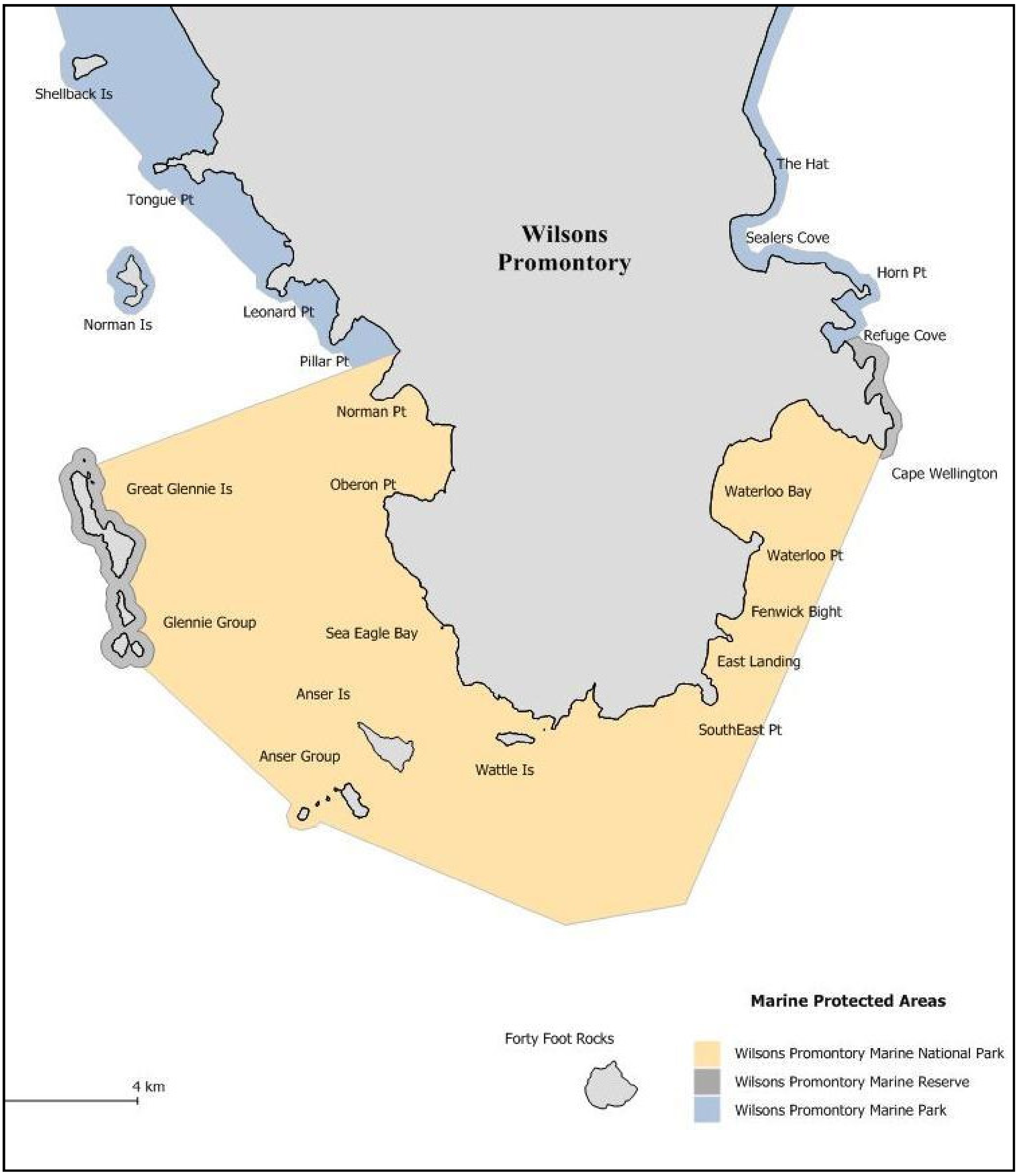


Figure 1.6. Wilsons Promontory marine protected areas: Wilsons Promontory Marine National Park; Wilsons Promontory Marine Park and Wilsons Promontory Marine Reserve.

2. METHODS

2.1. Site Selection and Survey Times

During the first survey at Wilsons Promontory, every effort was made to survey as many sites as possible, with the intention of sampling a surplus of sites. The benefits of this were to: provide the most comprehensive description of the marine flora and fauna around the Promontory; enable selection of the most appropriate sites for the long-term monitoring program; and safeguard the monitoring design against possible boundary changes before the sanctuary zone was declared. Additional field assistance was provided by Dr Neville Barrett and Alistair Morton from the Tasmanian Aquaculture and Fisheries Institute, and the sea conditions enabled the census of three sites a day, for much of the excursion. Consequently, twenty-eight sites were sampled between 30 November and 9 December 1999.

The sites were located in four general regions around the Promontory: northwest reference area, north of the Marine National Park; western Marine National Park; eastern Marine National Park; and northeast reference area (Figure 2.3; Table 2.1). Three island sites were sampled outside the proposed sanctuary, on Shellback and Norman Islands, and three inside the proposed sanctuary, on Great Glennie and Anser Islands. The sites encompassed the full range of reef habitats present at the Promontory, including sub-maximally exposed sites at Norman Island, Great Glennie Island and Sea Eagle Bay, to relatively sheltered habitats at north Shellback Island, Great Glennie Island, Waterloo Bay and The Hat north of Sealers Cove; Figure 2.1). The reef structures varied from steep plunging or stepped reefs, to more gently sloping (but high relief) boulder and bombie fields, to relatively flat bedrock and rubble reefs. A brief description of each site is provided in Table 2.1.

A set of 20 core monitoring sites were selected as a subset the initial monitoring sites (Figure 2.1; Appendix A).

Figure 2.1. Location of monitoring sites at Wilsons Promontory. The Wilsons Promontory Marine National Park boundary is outlined in grey. Core monitoring sites are marked in red.

Table 2.1. Physical descriptions of sites at Wilsons Promontory: (A) aspect; (Exp) exposure ranking; and (CI) complexity index. The exposure and reef complexity indices follow those used by Edgar (1981; see Table footnotes). Legend: (RZ) Reference zone; (MNP) Marine National Park.

Site	A (° T)	Exp*	CI†	Depth (m)	Substratum Description
Northwest RZ					
1 North Shellback Is	350	6	1.5	10	Bedrock with small boulder clusters and rubble.
2 North Tongue Pt	340	5	1.5	10	Bedrock and boulder fields 0.5-2 m.
3 North Norman Is	285	3	1.5	10	Steep bedrock with deep gullies and 5-10 m drop-offs, boulders to west.
4 West Norman Is	270	3	3	10	Medium to large boulders 1-4 m, interspersed by slab reef.
5 Leonard Pt	240	4	3.5	10	Large boulders 1-4 m, bombies, slab reef.
6 Pillar Pt	195	4	4	10	Large boulders 1-3 m, occasional tall bombies.
Southwest MNP					
7 South Norman Pt	145	5	2.5	10	Boulder field 1-3 m.
8 Oberon Pt	330	5	2	10	Boulder field 1-2 m and irregular bedrock
9 East Glennie Is	45	5	1.5	10	Steeply sloping slab with occasional bombies.
10 West Glennie Is	250	3	4	10	Boulders 5-10 m across, deep crevices between, smaller boulders to north.
11 North of Sea Eagle	240	3	3	10	Boulders 1 m, some larger outcrops, moderately high relief.
12 Sea Eagle Bay	24	4	3	10	Boulder field 1-2 m, occasional 3-5 m bombies.
13 North Anser Is	15	4	1.5	10	Steeply sloping bedrock with occasional bombies.
Southeast MNP					
14 South Pt	180	3	3	10	Boulder field 1-3 m with 3-5 m bombies.
15 Roaring Meg Bight	120	3	3	10	Steeply sloping fractured bedrock with some large boulders.
16 West Landing	150	3	3	10	Large boulders 2-4 m, large interstitial space, occasional bombies.
17 East landing	55	4	2.5	10	Rock slab stepping and sloping steeply, some bombies.
18 Fenwick Pt	35	5	3.5	10	Boulders 2-4 m interspersed by bombies 3-4 m, smaller boulders to west
19 Waterloo Pt	90	5	3	10	Slab reef, some boulder fields 2-3 m
20 Central Waterloo	130	5	2.5	10	Low boulders interspersed with bombies 3-5 m.
21 North Waterloo	180	4	3.5	10	Reef slabs, stepping 3-4 m, large bombies.
Northeast RZ					
22 Cape Wellington	65	5	2.5	10	Sloping smooth bedrock with ledges, interspersed with boulder fields 2-4 m.
23 Bareback Bay	100	5	2	10	Flat bedrock, occasional bombies, to boulder field in west.
24 South Refuge	180	5	3	10	Boulders 2-3 m, bombies 3-5 m, flat bedrock.
25 North Refuge	135	5	2	10	Sloping bedrock with occasional cracks and overhangs.
26 Horn Bay	150	5	2.5	10	Flat bedrock, small boulders 1-3 m interspersed by bombies

Table 2.1 (continued). Physical descriptions of sites at Wilsons Promontory: (A) aspect; (Exp) exposure ranking; and (CI) complexity index. The exposure and reef complexity indices follow those used by Edgar (1981; see Table footnotes). Legend: (RZ) Reference zone; (MNP) Marine National Park.

Site	A (°T)	Exp	CI[†]	Depth (m)	Substratum Description
27 North Horn Pt	20	6	2.5	10	Mostly boulder field 0.5-2 m, some slab reef.
28 The Hat	90	6	2	10	Boulder field 1-2 m.

* Exp = Exposure Index:

1 maximal

3 submaximal

5 moderate

7 sheltered open coast

9 sheltered bays

† CI = Complexity Index

1 flat rock substratum with low relief, broken occasionally by crevices and ledges

2 boulders or bedrock of moderate relief (0.5 m), ledges and crevices common

3 moderately high relief (1-2 m) substratum with ledges and crevices common

4 highly structured, high relief (> 2 m) with high interstitial volume

Figure 2.2. School of butterfly perch *Caesioperca lepidoptera* at East Landing, Wilsons Promontory.

2.1.1. Survey Times

The survey periods are outlined in Table 2.2. The survey frequency was biannual for the first seven surveys, from November 2001 to November 2002. The eighth survey, August 2004, had persistent large swell from the south west which prevented Site 4 from being surveyed. All 20 core sites were surveyed during the ninth survey in early March 2005 and tenth survey in late June 2006. There was a delay in completing the eleventh survey in December 2010, with bad visibility restricting diving at the eastern reference sites until March and April 2011.

Table 2.2. Survey times for monitoring at Wilsons Promontory.

Survey	Season	Survey Period
1	Early summer 1999	30 Nov to 9 Dec 1999
2	Early winter 2000	16-20 May and 11-15 Jun 2000
3	Early summer 2000	13-17 Nov and 25-29 Nov 2000
4	Early winter 2001	30 Apr to 4 May and 25-27 May 2001
5	Early summer 2001	30 Nov to 3 Dec and 14-16 Dec 2001
6	Early winter 2002	26-30 May and 4-6 June 2002
7	Early summer 2002	5-15 November 2002
8	Winter 2004	21-28 August 2004
9	Late Summer 2005	2-10 March 2005
10	Winter 2006	19-28 June 2006
11	Early summer 2010	4-9 Dec 2010, 9 Mar 2011 and 24 Apr 2011
12	Early summer 2011	29 Nov - 5 Dec 2011

2.2. Census method

2.2.1. Transect layout

The visual census methods of Edgar and Barrett (1997, 1999; 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. All Monitoring sites in the Wilsons Promontory region are positioned on the 10 metre contour.

2.2.2. 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 2.3). 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, 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; Westera *et al*. 2003; Watson *et al*. 2010).

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 2.3. 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 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 2.3. 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 *Odax cyanomelas*, barber perch *Caesioperca rasor*, rosy wrasse *Pseudolabrus rubicundus* and some leatherjackets.

2.2.4. 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 2.4. 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 2.4). 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 2.5. Macroalgae and seagrass (Method 3) taxa censused in central Victoria.

Selected specimens were photographed or collected for identification and preservation in a reference collection.

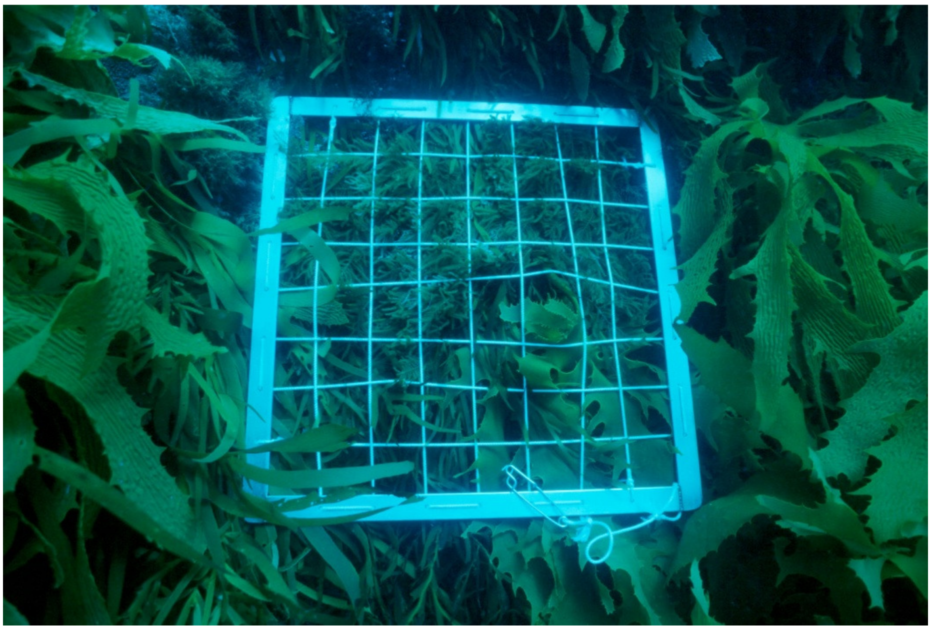


Figure 2.4. The cover of macrophytes is measured by the number of points intersecting each species on the quadrat grid.

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, 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.

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 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 operated by the diver who did the UVC fish survey at the same time (Method 1). The stereo camera frame had the underwater UVC slate mounted on it for the simultaneous observations. The camera system was 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 2.3. Mobile fish (Method 1) taxa censused in central Victoria.

Method 1	Method 1	Method 1	Method 1
Cephalopoda	**Mobile Fishes (cont.)**	**Mobile Fishes (cont.)**	**Mobile Fishes (cont.)**
Sepia apama	*Trachinops caudimaculatus*	*Aplodactylus arctidens*	*Siphonognathus beddomei*
Sepioteuthis australis	*Vincentia conspersa*	*Cheilodactylus nigripes*	*Neoodax balteatus*
Mobile Sharks and Rays	*Dinolestes lewini*	*Cheilodactylus spectabilis*	*Haletta semifasciata*
Heterodontus portusjacksoni	*Trachurus declivis*	*Nemadactylus macropterus*	*Cristiceps aurantiacus*
Cephaloscyllium laticeps	*Pseudocaranx georgianus*	*Nemadactylus douglasi*	*Thyristes atun*
Myliobatis australis	*Pseudocaranx wrightii*	*Dactylophora nigricans*	*Acanthaluteres vittiger*
Urolophus paucimaculatus	*Arripis georgiana*	*Latridopsis forsteri*	*Brachaluteres jacksonianus*
Mobile Bony Fishes	*Upeneichthys vlaminghii*	*Ophthalmolepis lineolata*	*Scobinichthys granulatus*
Engraulis australis	*Pempheris multiradiata*	*Dotalabrus aurantiacus*	*Meuschenia australis*
Aulopus purpurissatus	*Girella tricuspidata*	*Eupetrichthys angustipes*	*Meuschenia flavolineata*
Synodus variegatus	*Girella elevata*	*Notolabrus tetricus*	*Meuschenia freycineti*
Lotella rhacina	*Girella zebra*	*Notolabrus fucicola*	*Meuschenia galii*
Pseudophycis bachus	*Kyphosus sydneyanus*	*Pseudolabrus rubicundus*	*Meuschenia hippocrepis*
Pseudophycis barbata	*Scorpis aequipinnis*	*Pictilabrus laticlavius*	*Meuschenia scaber*
Genypterus tigerinus	*Scorpis lineolata*	*Odax acroptilus*	*Eubalichthys gunnii*
Phyllopteryx taeniolatus	*Atypichthys strigatus*	*Odax cyanomelas*	*Aracana aurita*
Helicolenus percoides	*Tilodon sexfasciatus*	*Siphonognathus caninus*	*Aracana ornata*
Aetapcus maculatus	*Enoplosus armatus*	*Siphonognathus attenuatus*	*Tetractenos glaber*
Platycephalus bassensis	*Pentaceropsis recurvirostris*	*Siphonognathus radiatus*	*Diodon nichthemerus*
Caesioperca lepidoptera	*Parma victoriae*	*Siphonognathus tanyourus*	*Arctocephalus pusillus*
Caesioperca rasor	*Parma microlepis*		
Sphyraena novaehollandiae	*Chromis hypsilepis*		

Table 2.4. Invertebrate and cryptic fish (Method 2) taxa censused in central Victoria.

Method 2	Method 2	Method 2	Method 2
Crustacea	**Mollusca (cont.)**	**Cephalopoda**	**Echinodermata (cont.)**
Jasus edwardsii	*Cabestana spengleri*	*Octopus sp.*	*Holopneustes inflatus*
Paguristes frontalis	*Cymatium parthenopeum*	**Echinodermata**	*Holopneustes purpurascens*
Strigopagurus strigimanus	*Dicathais orbita*	*Comanthus trichoptera*	*Heliocidaris erythrogramma*
Pagurid unidentified	*Pleuroploca australasia*	*Comanthus tasmaniae*	*Neothyonidium spp*
Nectocarcinus tuberculosus	*Penion mandarinus*	*Tosia australis*	*Australostichopus mollis*
Plagusia chabrus	*Penion maxima*	*Tosia magnifica*	
Petrocheles australiensis	*Conus anemone*	*Pentagonaster dubeni*	**Cryptic Fishes**
Mollusca	*Amoria undulata*	*Nectria ocellata*	*Parascyllium variolatum*
Haliotis rubra	*Cymbiola magnifica*	*Nectria macrobrachia*	*Conger verreauxi*
Haliotis laevigata	*Sagaminopteron ornatum*	*Nectria multispina*	*Pseudophycis barbata*
Haliotis scalaris	Nudibranch un ID	*Nectria wilsoni*	*Paratrachichthys trailli*
Scutus antipodes	*Tambja verconis*	*Petricia vernicina*	*Helicolenus percoides*
Clanculus undatus	*Neodoris chrysoderma*	*Fromia polypora*	*Scorpaena papillosa*
Calliostoma armillata	*Ceratosoma brevicaudatum*	*Plectaster decanus*	*Aetapcus maculatus*
Calliostoma ciliaris	*Chromodoris tinctoria*	*Echinaster arcystatus*	*Gnathanacanthus goetzeei*
Phasianotrochus eximius	*Chromodoris tasmaniensis*	*Pseudonepanthia troughtoni*	*Bovichtus angustifrons*
Phasianella australis	*Chromodoris splendida*	*Meridiastra gunnii*	*Parablennius tasmanianus*
Phasianella ventricosa	*Digidentis perplexa*	*Coscinasterias muricata*	*Trinorfolkia clarkei*
Turbo undulatus	*Hypselodoris bennetti*	*Uniophora granifera*	*Forsterygion varium*
Astralium tentoriformis	*Mesopeplum tasmanicum*	*Goniocidaris tubaria*	*Heteroclinus perspicillatus*
Notocypraea angustata	*Mimachlamys asperrimus*	*Centrostephanus rodgersii*	*Heteroclinus tristis*
Charonia lampas rubicunda	*Ostrea angasi*	*Amblypneustes* spp	*Heteroclinus johnstoni*
Cabestana tabulata		*Holopneustes porosissimus*	

Table 2.5. Macroalgae and seagrass (Method 3) taxa censused in central Victoria.

Method 3	**Method 3**	**Method 3**	**Method 3**
Chlorophyta (green algae)	**Phaeophyta (cont.)**	**Rhodophyta (red algae)**	**Rhodophyta (cont.)**
Chaetomorpha sp.	*Zonaria turneriana*	*Gelidium asperum*	*Melanthalia obtusata*
Abjohnia laetevirens	*Lobophora variegata*	*Gelidium australe*	*Melanthalia abscissa*
Cladophora spp	*Glossophora nigricans*	*Gelidium* spp	*Melanthalia concinna*
Caulerpa scalpelliformis	*Carpomitra costata*	*Pterocladia lucida*	*Polyopes constrictus*
Caulerpa trifaria	*Perithalia cordata*	*Pterocladia capillacea*	*Halymenia plana*
Caulerpa brownii	*Bellotia eriophorum*	*Pterocladiella capillacea*	*Thamnoclonium dichotomum*
Caulerpa obscura	*Ecklonia radiata*	*Asparagopsis armata*	*Plocamium angustum*
Caulerpa flexilis	*Macrocystis angustifolia*	*Delisea pulchra*	*Plocamium costatum*
C. flexilis var. muelleri	*Durvillaea potatorum*	*Ptilonia australasica*	*Plocamium patagiatum*
Caulerpa geminata	*Xiphophora chondrophylla*	*Asparagopsis* spp	*Plocamium mertensii*
Caulerpa annulata	*Phyllospora comosa*	*Metamastophora flabellata*	*Plocamium dilatatum*
Caulerpa cactoides	*Seirococcus axillaris*	*Amphiroa anceps*	*Plocamium preissianum*
Caulerpa vesiculifera	*Scaberia agardhii*	*Corallina officinalis*	*Plocamium cartilagineum*
Caulerpa simpliciuscula	*Caulocystis cephalornithos*	*Arthrocardia wardii*	*Plocamium leptophyllum*
Codium lucasi	*Acrocarpia paniculata*	*Haliptilon roseum*	*Rhodymenia australis*
Codium pomoides	*Cystophora platylobium*	*Cheilosporum sagittatum*	*Rhodymenia obtusa*
Codium spp	*Cystophora moniliformis*	*Metagoniolithon radiatum*	*Rhodymenia prolificans*
Phaeophyta (brown algae)	*Cystophora monilifera*	*Encrusting corallines*	*Rhodymenia* spp
Halopteris spp	*Cystophora expansa*	*Callophyllis lambertii*	*Cordylecladia furcellata*
Dictyota spp	*Cystophora siliquosa*	*Callophyllis rangiferina*	*Ballia callitricha*
Dictyota diemensis	*Cystophora retroflexa*	*Nizymenia australis*	*Euptilota articulata*
Dictyota dichotoma	*Cystophora subfarcinata*	*Sonderopelta coriacea*	*Hemineura frondosa*
Dilophus marginatus	*Carpoglossum confluens*	*Peyssonelia novaehollandiae*	*Dictymenia harveyana*
Pachydictyon paniculatum	*Sargassum decipiens*	*Sonderopelta/ Peyssonelia*	*Laurencia filiformis*
Lobospira bicuspidata	*Sargassum sonderi*	*Phacelocarpus alatus*	*Laurencia* spp
Dictyopteris acrostichoides	*Sargassum varians*	*Phacelocarpus peperocarpus*	*Echinothamnion* sp.
Chlanidophora microphylla	*Sargassum verruculosum*	*Callophycus laxus*	*Echinothamnion hystrix*
Distromium flabellatum	*Sargassum fallax*	*Areschougia congesta*	Filamentous red algae
Distromium spp	*Sargassum vestitum*	*Areschougia* spp	Other thallose red alga
Homeostrichus sinclairii	*Sargassum lacerifolium*	*Acrotylus australis*	**Magnoliophyta**
Homeostrichus olsenii	*Sargassum spinuligerum*	*Curdiea angustata*	*Halophila australis*
Zonaria angustata	*Sargassum* spp		*Amphibolis antarctica*
Zonaria spiralis	Brown algae unidentified		

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 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.

2.3.2. Biodiversity

Community Structure

Community structure is a multivariate function of both the type of species present and the abundance of each species. The community structure between pairs of samples was compared using the Bray-Curtis dissimilarity coefficient. This index compares the abundance of each species between two samples to give a single value of the difference between the samples, expressed as a percentage (Faith *et al.* 1987; Clarke 1993).

Following Sweatman (2000), the count data were log transformed and percent cover values were transformed using the empirical logit transformation (McCullagh and Nelder 1989).

The hyper-dimensional information in the dissimilarity matrix was simplified and depicted using non-metric multidimensional scaling (MDS; Clarke 1993). This ordination method finds the representation in fewer dimensions that best depicts the actual patterns in the hyper-dimensional data (i.e. reduces the number of dimensions while depicting the salient relationships between the samples). The 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 sort 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 seven baseline surveys were used for the baseline centroid. 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 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.

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 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.

2.3.3. 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* 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 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 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. *Durvillaea potatorum* is potentially two species, having genetically and morphologically distinct eastern and western forms (Fraser *et al.* 2009).

2.3.6. Fishing

Abalone

Indicators of 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, *Jasus verreauxi,* is present in the Twofold Shelf region. 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 *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. Macroalgae

3.1.1. Macroalgal Community Structure

The majority of algal assemblages at Wilsons Promontory are dominated by *Phyllospora comosa* (> 30 % cover), with assemblages at a few sites dominated by a combination of *Ecklonia radiata* and *Seirococcus axillaris.* The understorey associated with this canopy was sparse cover of thallose red algae, with much of the underlying rock covered by encrusting corallines. Common understorey species included *Phacelocarpus peperocarpus*, *Plocamium angustum*, *Plocamium dilatatum*, *Pterocladia lucida*, *Ballia callitricha*, *Haliptilon roseum* and *Melanthalia obtusata*.

Phyllospora assemblages were present at the most exposed sites, particularly on the western and southern coasts of the Promontory. *Ecklonia radiata* was the dominant canopy species in less exposed sites.

Pillar Point (3106) had a canopy almost exclusively composed of *Phyllospora*, but was notably different from other *Phyllospora* assemblages in having very low percentage cover algal understorey and high numbers of sessile invertebrates. This reef community is possibly influenced by freshwater flows from Tidal River, on the south side of Pillar Point.

Ecklonia radiata and *Seirococcus axillaris* were the dominant canopy cover species at moderately exposed to sheltered sites. *Phyllospora comosa* was sometimes present at these sites, but contributed less than 20 % to canopy cover. Thallose understorey algae were a greater component of the *Ecklonia-Seirococcus* assemblages, with 50-70 % cover compared with less than 30 % cover in the *Phyllospora* assemblages. As with the *Phyllospora* assemblages, *Phacelocarpus peperocarpus*, *Melanthalia obtusata*, *Plocamium angustum* and *Pterocladia lucida* were common understorey species. However, *Ballia callitricha* and the erect coralline *Haliptilon roseum* were generally reduced in abundance in the *Ecklonia-Seirococcus* assemblages, with smaller brown species more prevalent. These brown species included *Sargassum verruculosum*, *Sargassum sonderi*, *Perithalia cordata* and *Acrocarpia paniculata*.

Algal community structure appeared largely stable over time, with differences in between sites generally being preserved through time (Figure 3.1a-d). The greatest variation over time was in the northwestern reference zone, particularly at Pillar Point and East Glennie Island (Figure 3.1c). The crayweed *Phyllospora* dominated assemblages in the southwest and southeast tended to have smaller temporal variation than the other assemblages.

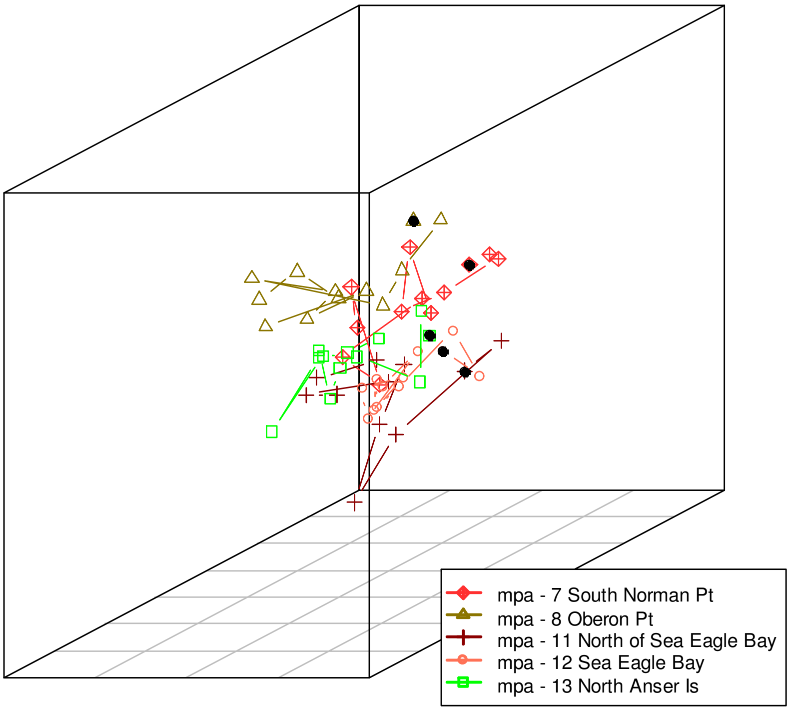
The multivariate control charts indicated there were some sites that trended in community structure away from the baseline period conditions. These sites were predominantly reference areas sites: Pillar Point, North Tongue Point, North Refuge and North Horn Point (Figure 3.2a). The combined site data also indicated a shift in community structure in the reference areas by the 2011 survey.

The control charts comparing each survey with the centroid of all prior times suggested there were some pulses in community structure change in the periods 2001-2002, 2005 and 2011, within both the reference and protected areas (Figure 3.2a).

3.1.2. Macroalgal Species Richness and Diversity

Abundance of macroalgae and algal species richness remained high throughout the monitoring period at all reference and MNP sites (Figure 3.3a-b). Algal diversity followed similar patterns of change over time in both protected and reference areas. The reference areas had consistently higher species richness and diversity (Figure 3.3c). Species richness was lowest at the exposed western and south-western sites such as Pillar Point (site 6), Norman Point (site 7) and Sea Eagle Bay (Site 12), all of which are dominated by a *Phyllospora comosa* canopy, with a reduced cover of understorey species. In contrast, the species richness and diversity was markedly higher at the more sheltered sites such as Shellback Island (Site 1), Fenwick Bight (Site 18), Bareback Bay (Site 23) and North Horn Point (Site 27) with canopies having a greater predominance of *Ecklonia radiata* and *Seirococcus axillaris* (Sites 1, 18, 23, and 27).

a. Algae - MPA West



b. Algae - MPA East

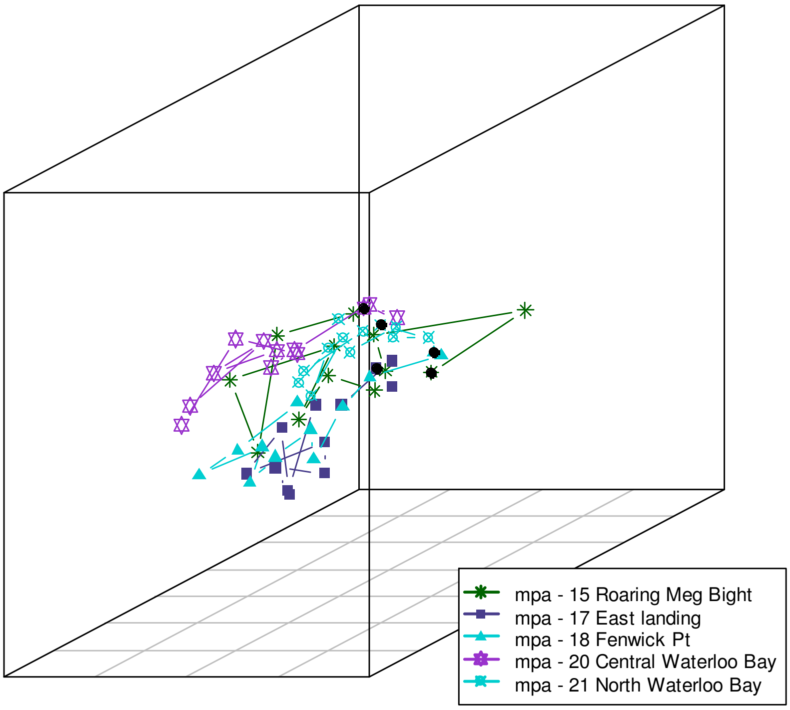
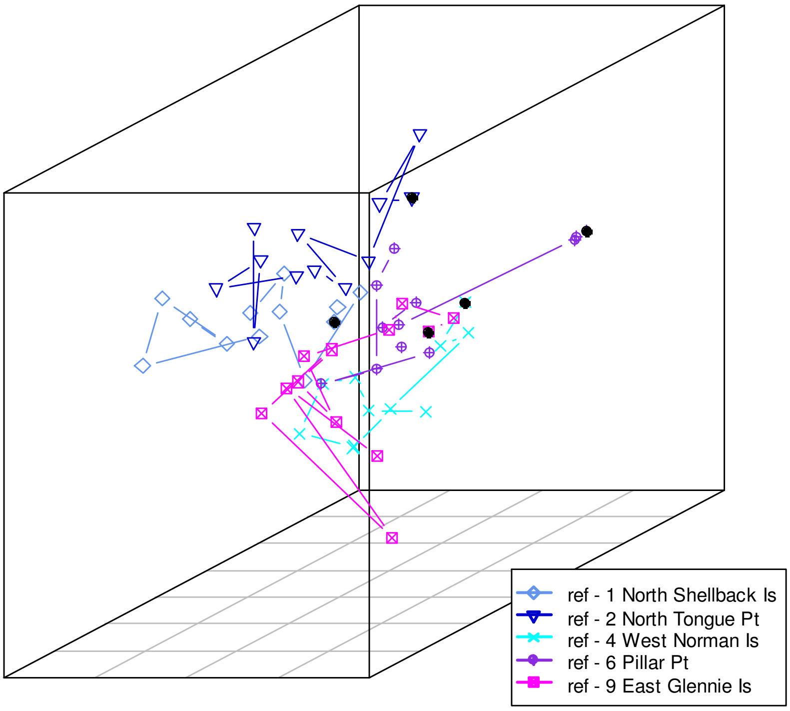


Figure 3.1. Three-dimensional MDS plot of algal assemblage structure for sites at Wilsons Promontory. Black symbols indicate the first survey. Kruskal stress = 0.16.

c. Algae - Reference West



d. Algae - Reference East

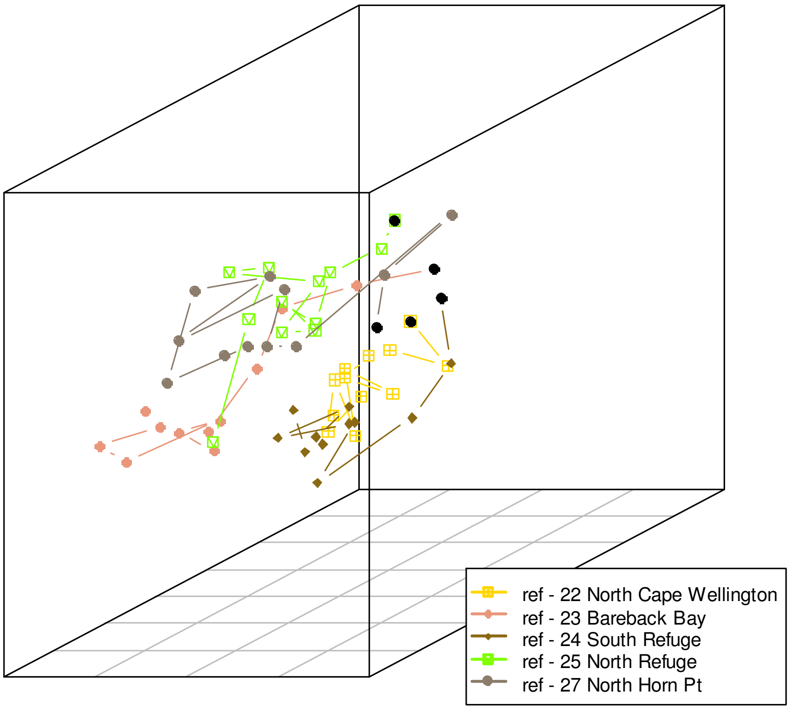


Figure 3.1 (continued). Three-dimensional MDS plot of algal assemblage structure for sites at Wilsons Promontory. Black symbols indicate the first survey. Kruskal stress = 0.16.

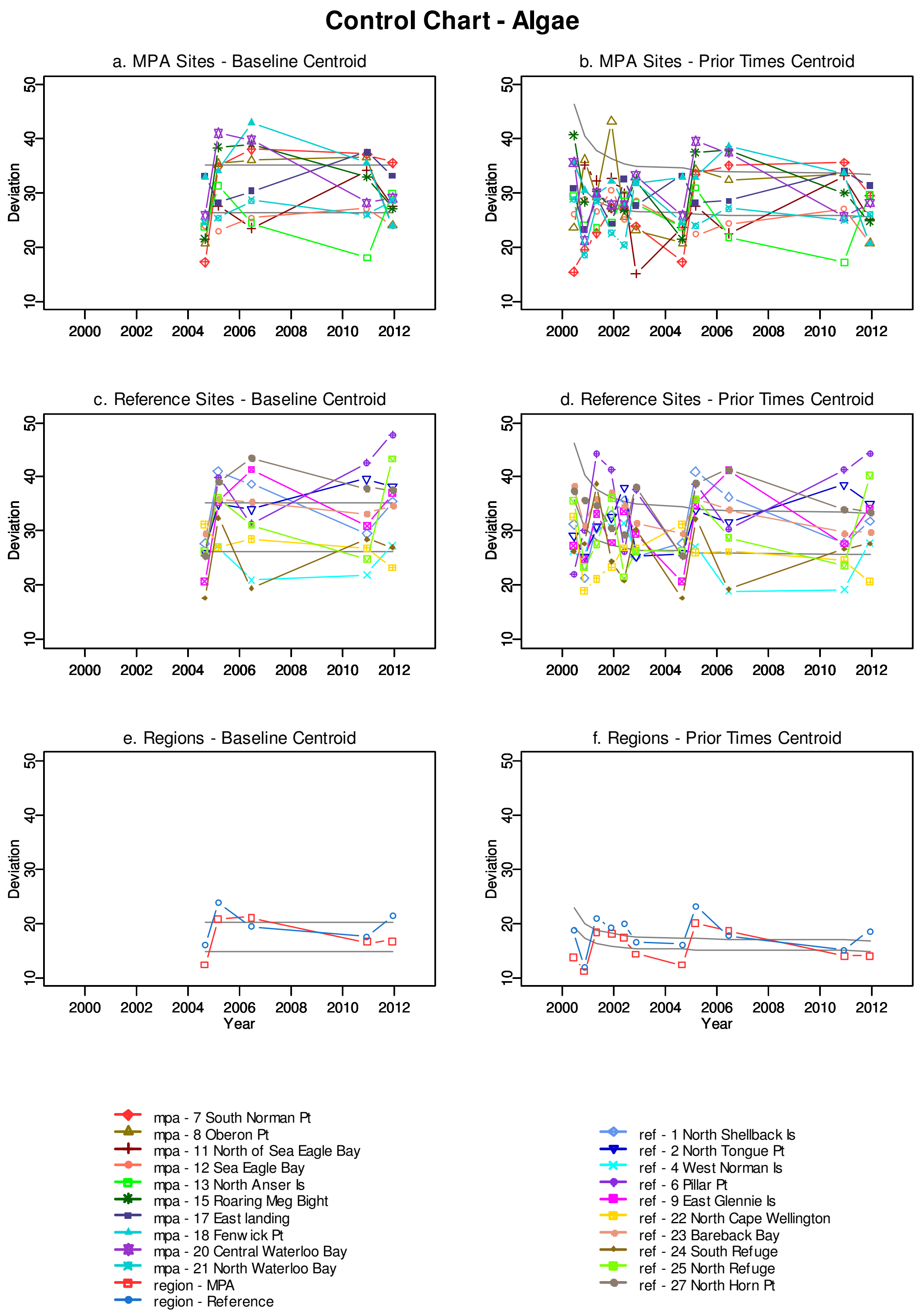


Figure 3.2. Control charts of algal assemblage structure inside and outside Wilsons Promontory Marine National Park. Grey lines indicate 50th and 90th percentiles.

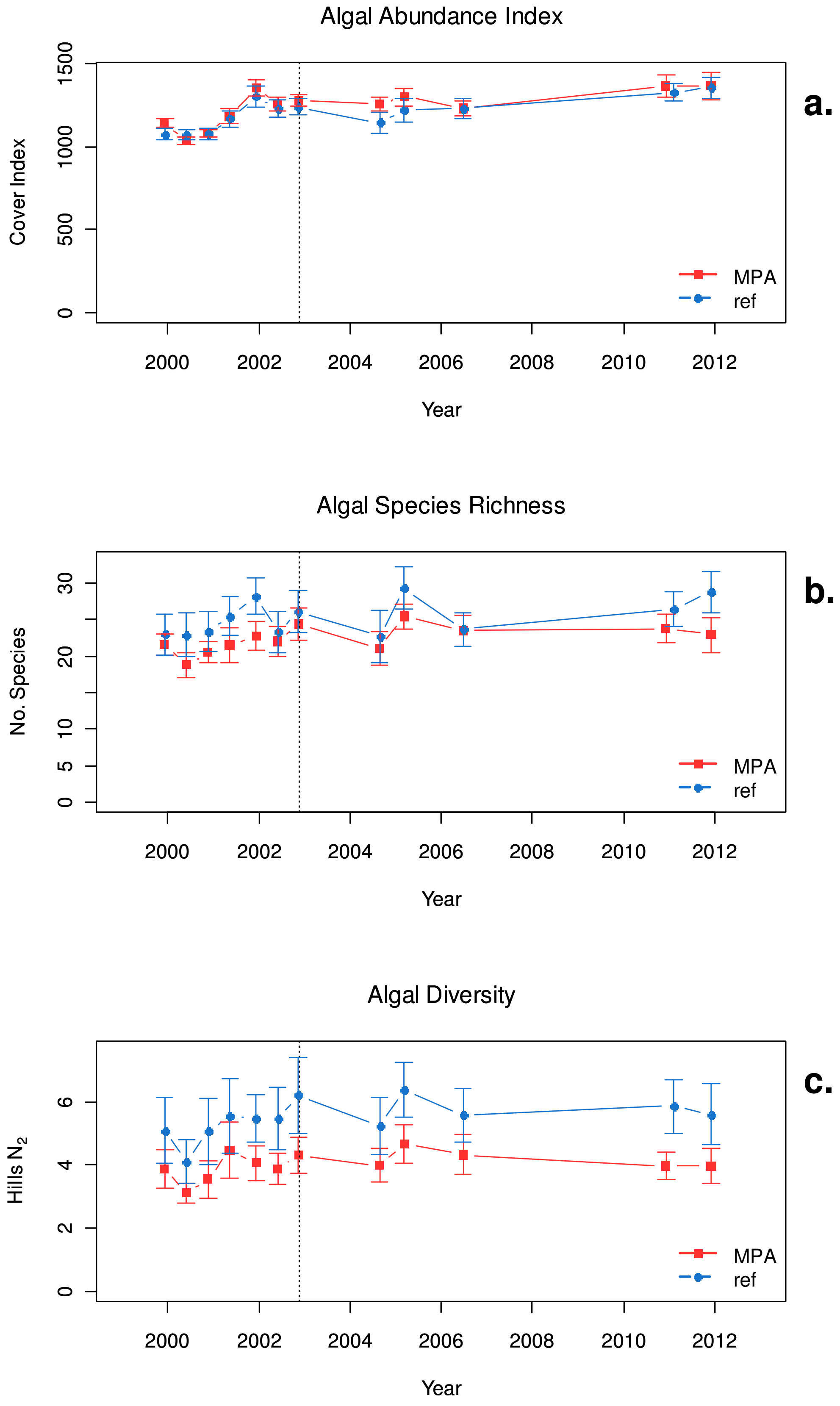


Figure 3.3. Algal species diversity indicators (mean ± standard error) inside and outside Wilson Promontory Marine National Park.

3.1.3. Common Algal Species

The mean percentage cover of *Ecklonia radiata* and *Phyllospora comosa* changed relatively little between surveys to 2011 (Figure 3.4a-b). The mean cover of *P. comosa* was consistently higher at the more exposed MNP sites. The cover of *Haliptilon roseum* was relatively low at all sites at Wilsons Promontory, however there was a notable increasing trend from 2004 to 2010, with a subsequent abrupt decline to 2011 (Figure 3.4c). *Phacelocarpus peperocarpos* cover remained relatively stable throughout the monitoring period (Figure 3.4d). *Plocamium angustum* abundance was relatively stable within the marine protected area and more variable in the reference area (Figure 3.4e). *Seirococcus axillaris* cover was relatively stable during the baseline survey period and more variable between times from 2004 to 2011 (Figure 3.4f).

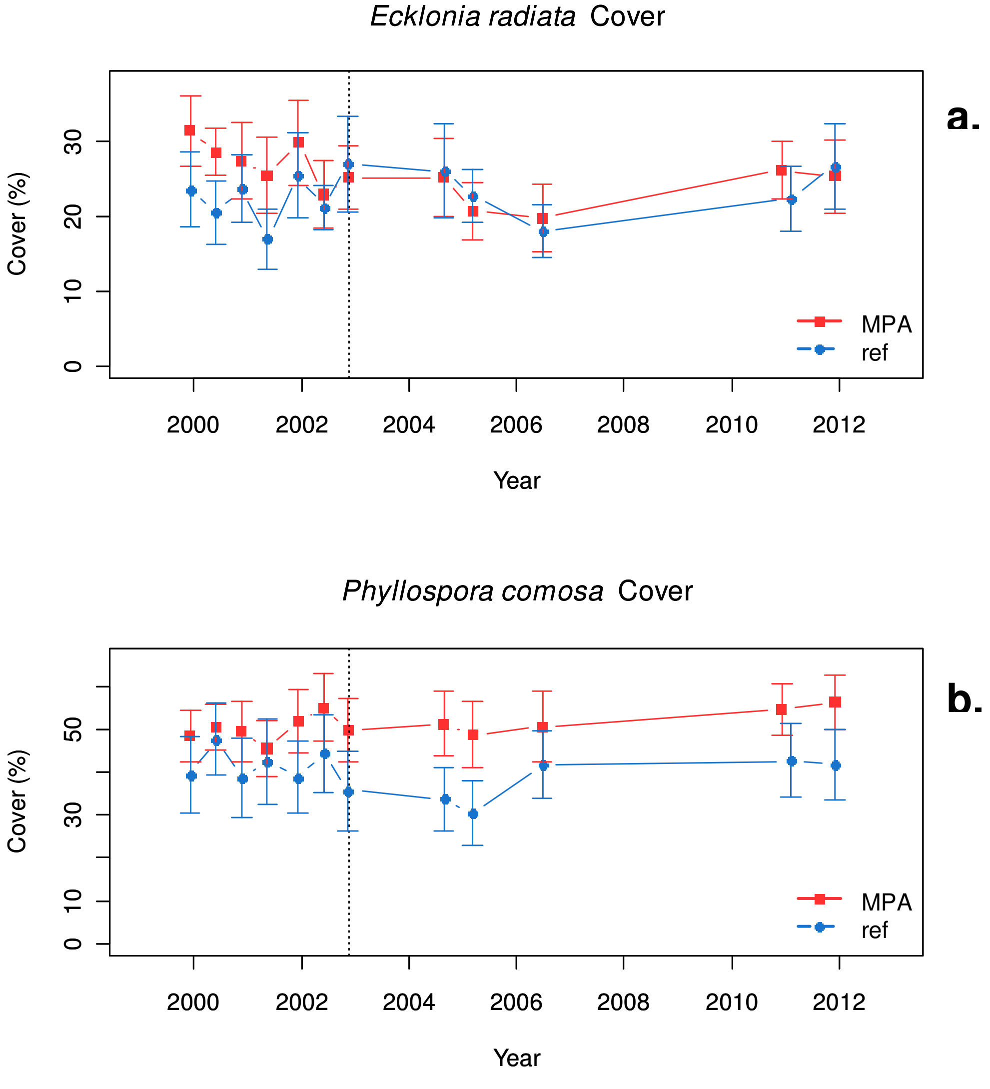
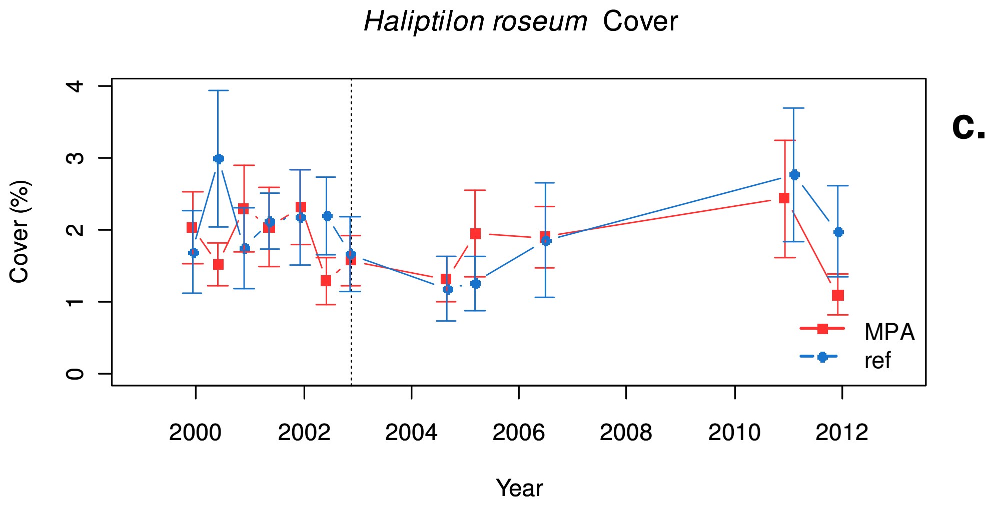


Figure 3.4. Percent cover (mean ± standard error) of dominant algal species inside and outside the Wilsons Promontory Marine National Park.



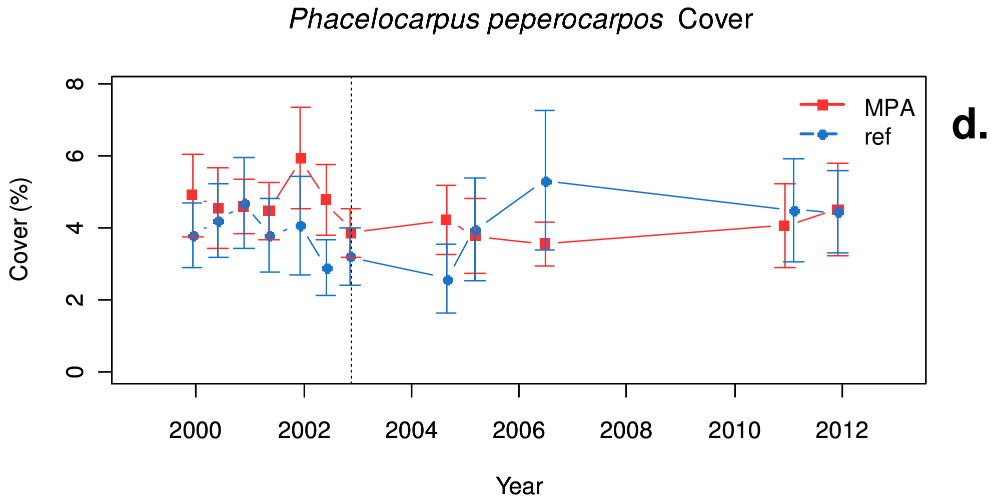


Figure 3.4 (continued). Percent cover (mean ± standard error) of dominant algal species inside and outside the Wilsons Promontory Marine National Park.

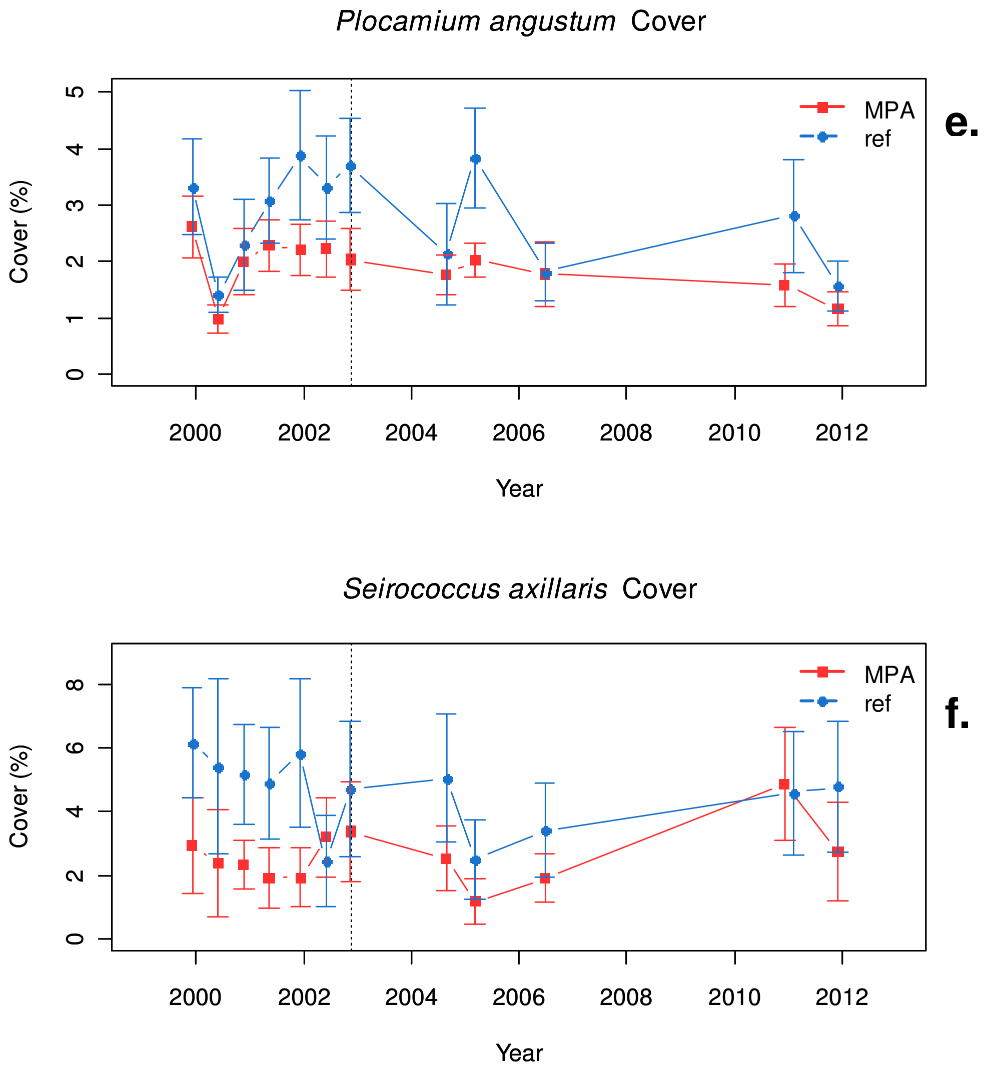


Figure 3.4 (continued) Percent cover (mean ± standard error) of dominant algal species inside and outside the Wilsons Promontory Marine National Park.

3.2. Invertebrates

3.2.1. Invertebrate Community Structure

The invertebrate assemblages at Wilsons Promontory had both north/south and east/west differences in community structure. The north/south differences correlate with exposure differences, the southern region of the Promontory being more exposed than the northern regions. Assemblage structure at the more sheltered sites consisted of a high abundance of the sea urchin *Heliocidaris erythrogramma* and moderate abundances of blacklip abalone *Haliotis rubra* and the featherstar *Cenolia trichoptera*. The sea stars *Nectria ocellata*, *Nectria macrobrachia* and *Plectaster decanus* were also common.

At more exposed sites, *Haliotis rubra* were more abundant and *Heliocidaris erythrogramma* were less abundant than at less exposed sites. *Cenolia trichoptera* and *Nectria ocellata* were generally in similar abundances between exposed and moderately sheltered sites, but Nectria macrobrachia and Plectaster decanus were less abundant than at the less exposed sites. The warrener *Turbo undulatus* tended to be more abundant at the exposed sites.

The southern, marine protected area sites were relatively similar to each other and overlapped in community structure with variations over time. The eastern and western reference sites tended to be distinct from each other over time, with little overlap between times compared with the southern sites (Figure 3.5a-d).

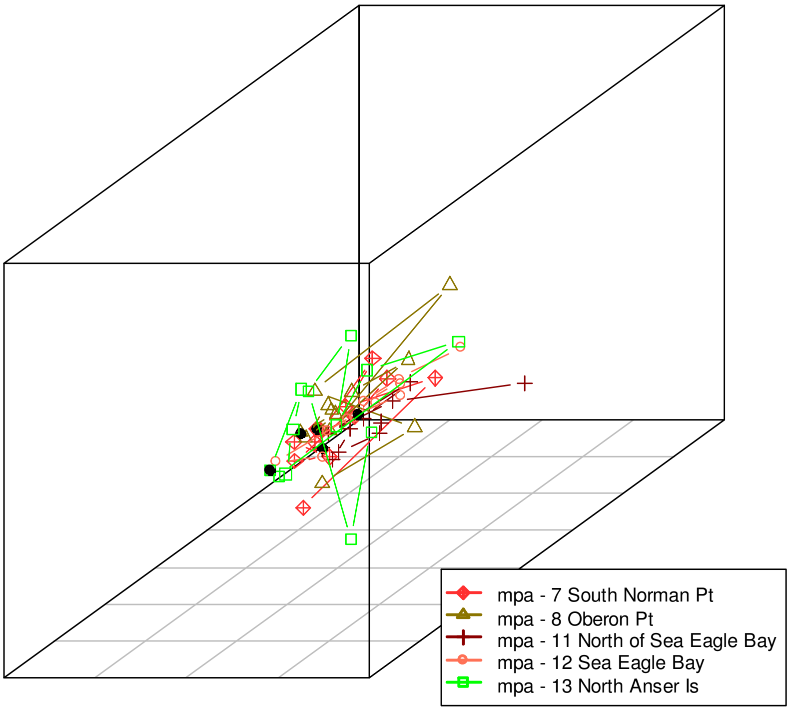
The multivariate control charts indicated there were differences in invertebrate community structure between the baseline period and the recent 2010 and 2011 surveys (Figure 3.6a, c, e). The control charts comparing each survey with the centroid of all previous surveys indicated there were more rapid or spikes of community change in 2002, 2005, 2010 and 2011 (Figure 3.6b, d, f).

3.2.2. Invertebrate Species Richness and Diversity

The mean number of invertebrate individuals per site was relatively high in all areas during the baseline period. There was also a notable seasonal fluctuation between the summer and winter surveys (Figure 3.7a). The number of total individuals declined markedly in both protected and reference areas in 2002. Although there have been fluctuations since then, numbers have remained on average half that of the initial baseline period (Figure 3.7a). This decline was driven by a variety of common species (described in the following section).

Species richness was very similar between the protected and reference areas at all times. There was some variation over time with no marked trends or changes (Figure 3.7b). There were no marked changes in species diversity over time for either the protected or reference areas, with a slight elevation occurring within the MNP during 2010 (Figure 3.7c).

a. Invertebrates - MPA West



b. Invertebrates - MPA East

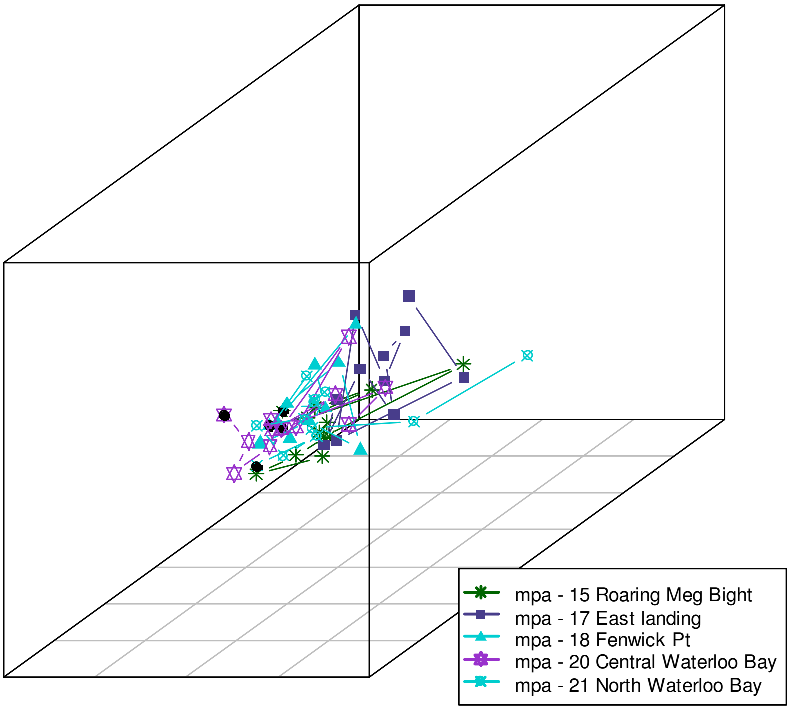
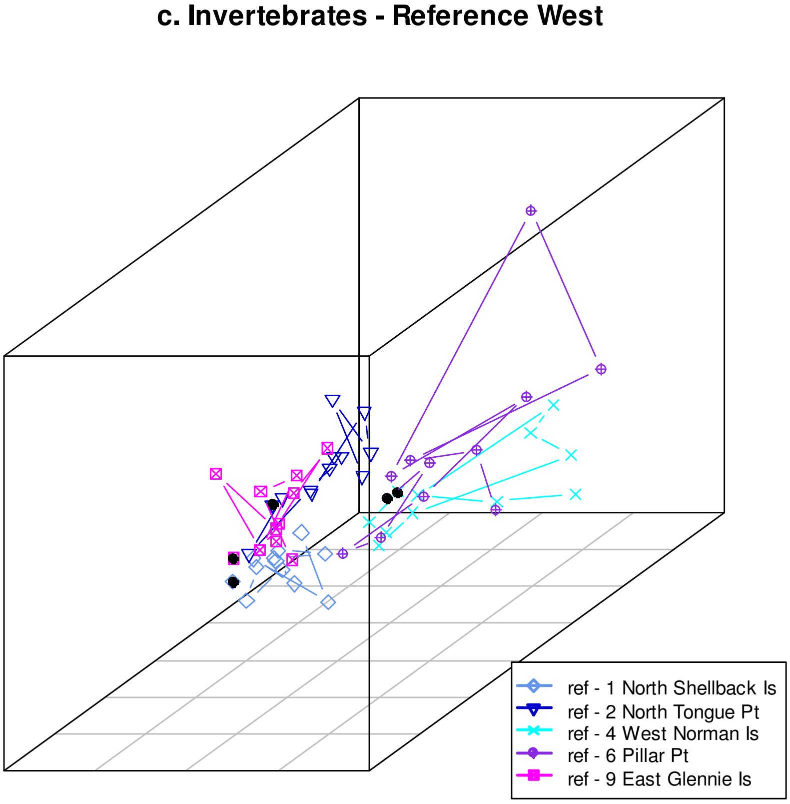


Figure 3.5. Three-dimensional MDS plot of motile invertebrate assemblage structure for sites at Wilsons Promontory. Black symbols indicate the first survey. Kruskal stress = 0.17.



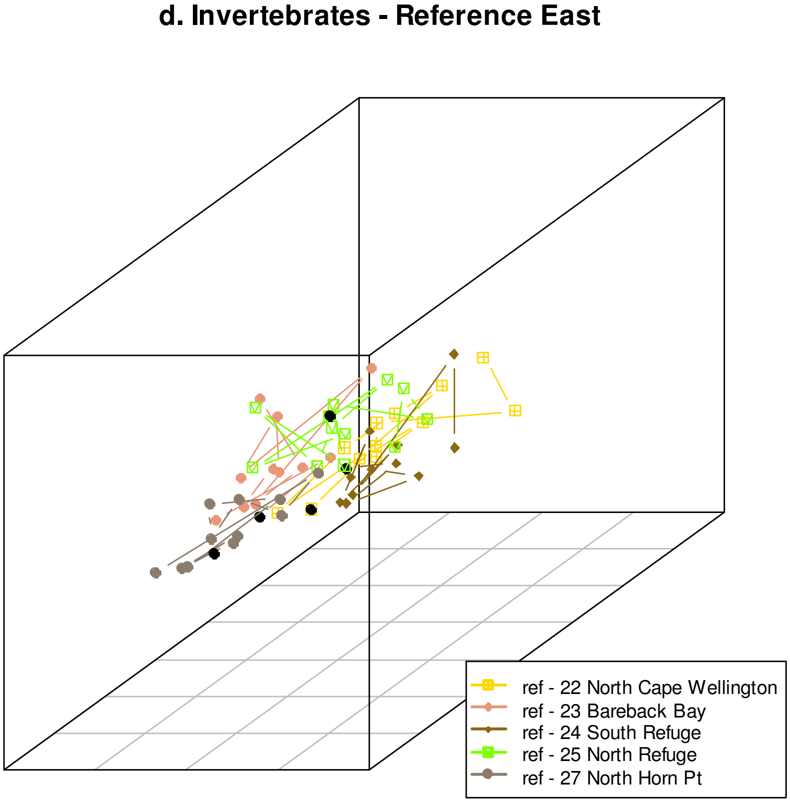


Figure 3.5 (continued) Three-dimensional MDS plot of motile invertebrate assemblage structure for sites at Wilsons Promontory. Black symbols indicate the first survey. Kruskal stress = 0.17.

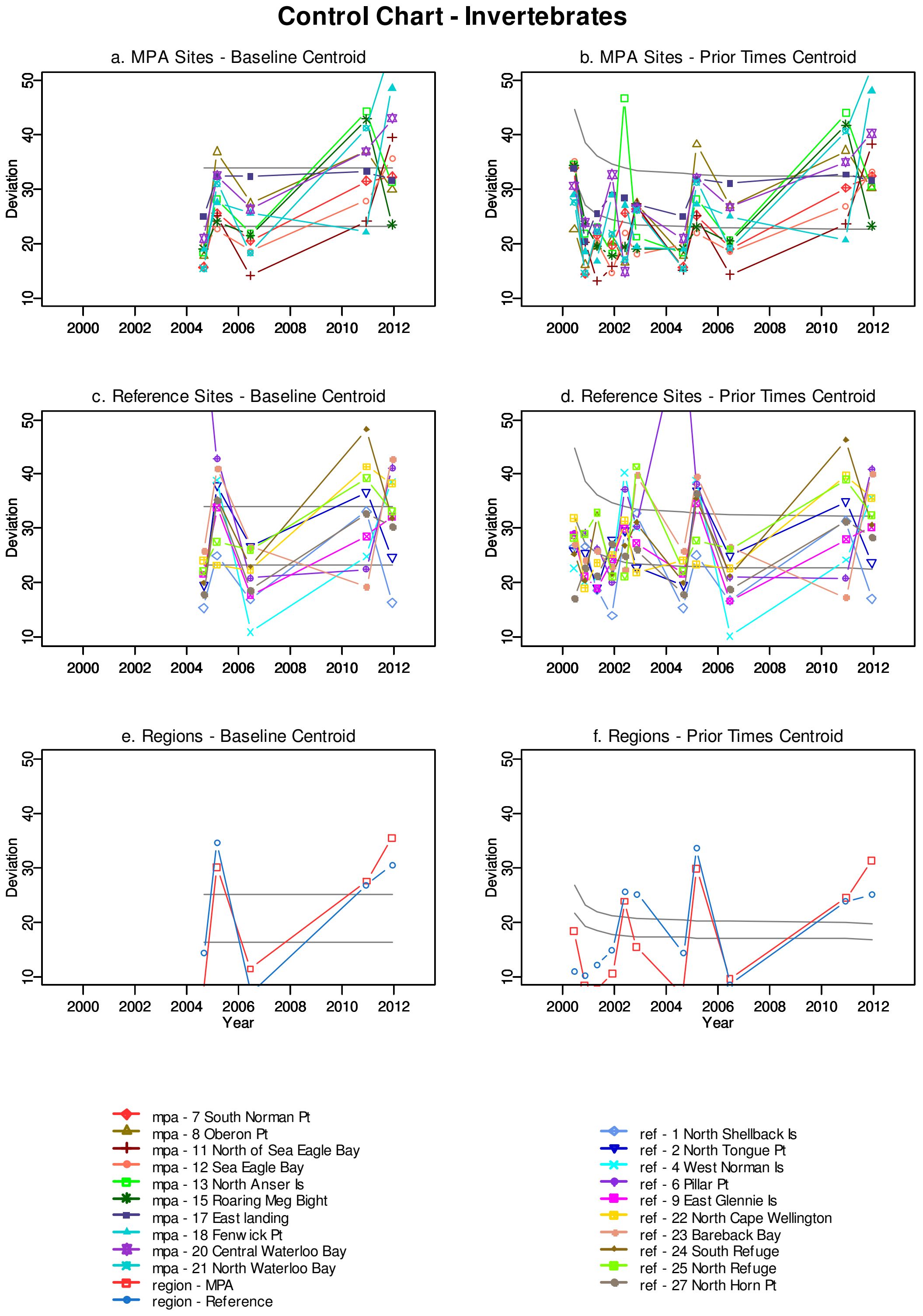


Figure 3.6. Control charts of motile invertebrate assemblage structure inside and outside Wilsons Promontory Marine National Park. Grey lines indicate 50th and 90th percentiles.

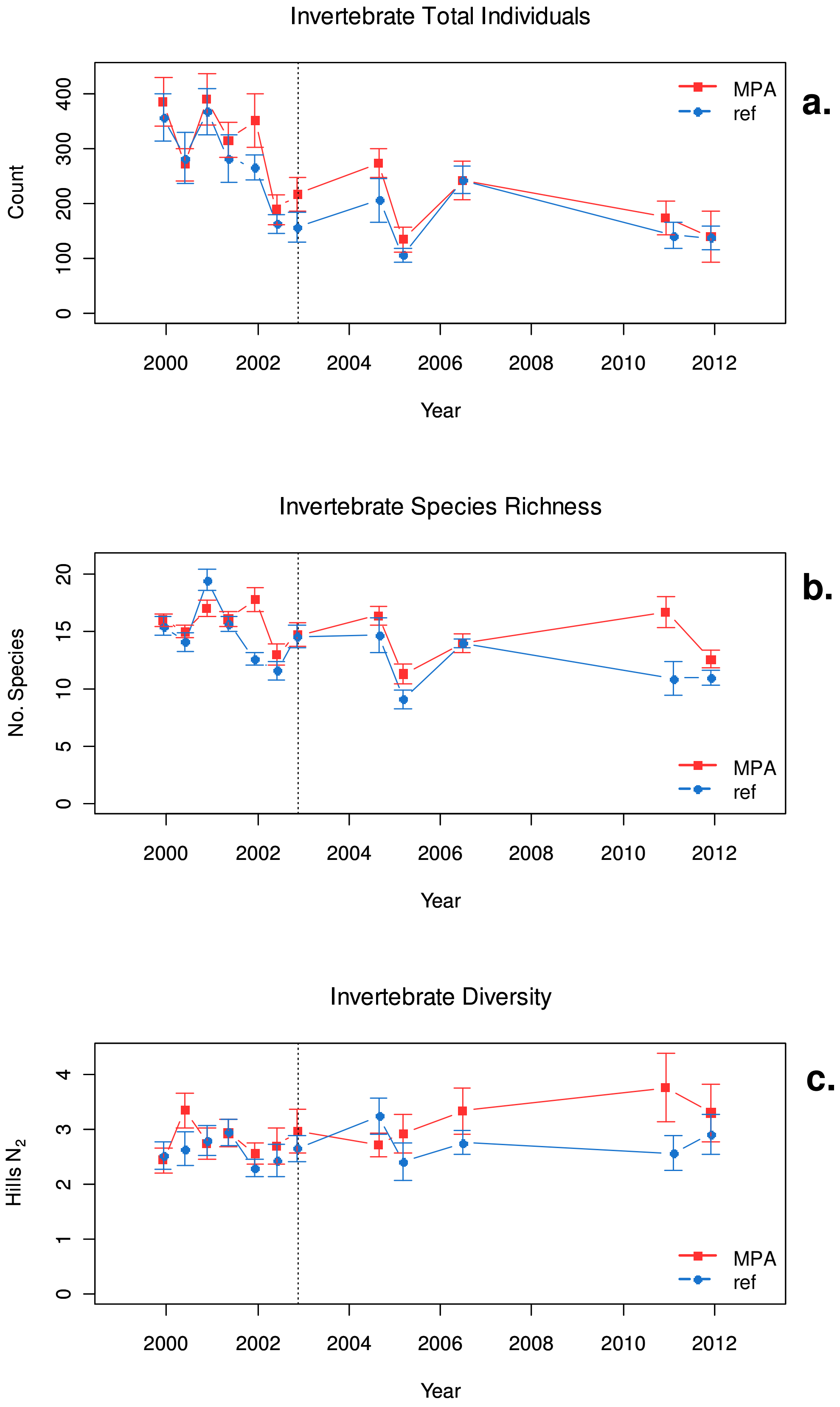


Figure 3.7. Motile invertebrate species diversity indicators (mean ± standard error) inside and outside Wilson Promontory Marine National Park.

3.2.3. Common Invertebrate Species

Density of blacklip abalone *Haliotis rubra* was generally higher inside the MNP than at reference sites throughout the monitoring period (Figure 3.8a). Conversely, the density of the featherstar Comanthus trichoptera was consistently higher within the reference areas compared with the MNP (Figure 3.8c).

The abundances of the three most common species, black lip abalone *Haliotis rubra*, sea urchin *Heliocidaris erythrogramma* and feather star *Comanthus trichoptera*, had remarkably similar trends and changes over the monitoring period. Densities of these three species were relatively high between 2000 and 2002, followed by a relatively rapid decline in late 2002. Simultaneous fluctuations followed, with peaks in 2004 and 2006 (Figure 3.8a, b, c). Similar changes in abundance were apparent for the seastars *Meridiastra gunnii*, *Nectria macrobrachia* and *Nectria ocellata*. The density of *Meridiastra gunnii* was not markedly higher during the baseline period, as it was for the other invertebrate species (Figure 3.8 e, f).

Haliotis rubra were highly abundant at Norman Point inside the park, including aggregations on open rock faces outside crevices. The densities at Norman Point in 2011 were not as high as those previously recorded there during the baseline period. No scars that would indicate poaching were apparent. Abalone abundances remained low at Roaring Meg from 2005 to 2011, where they were once moderately abundant.

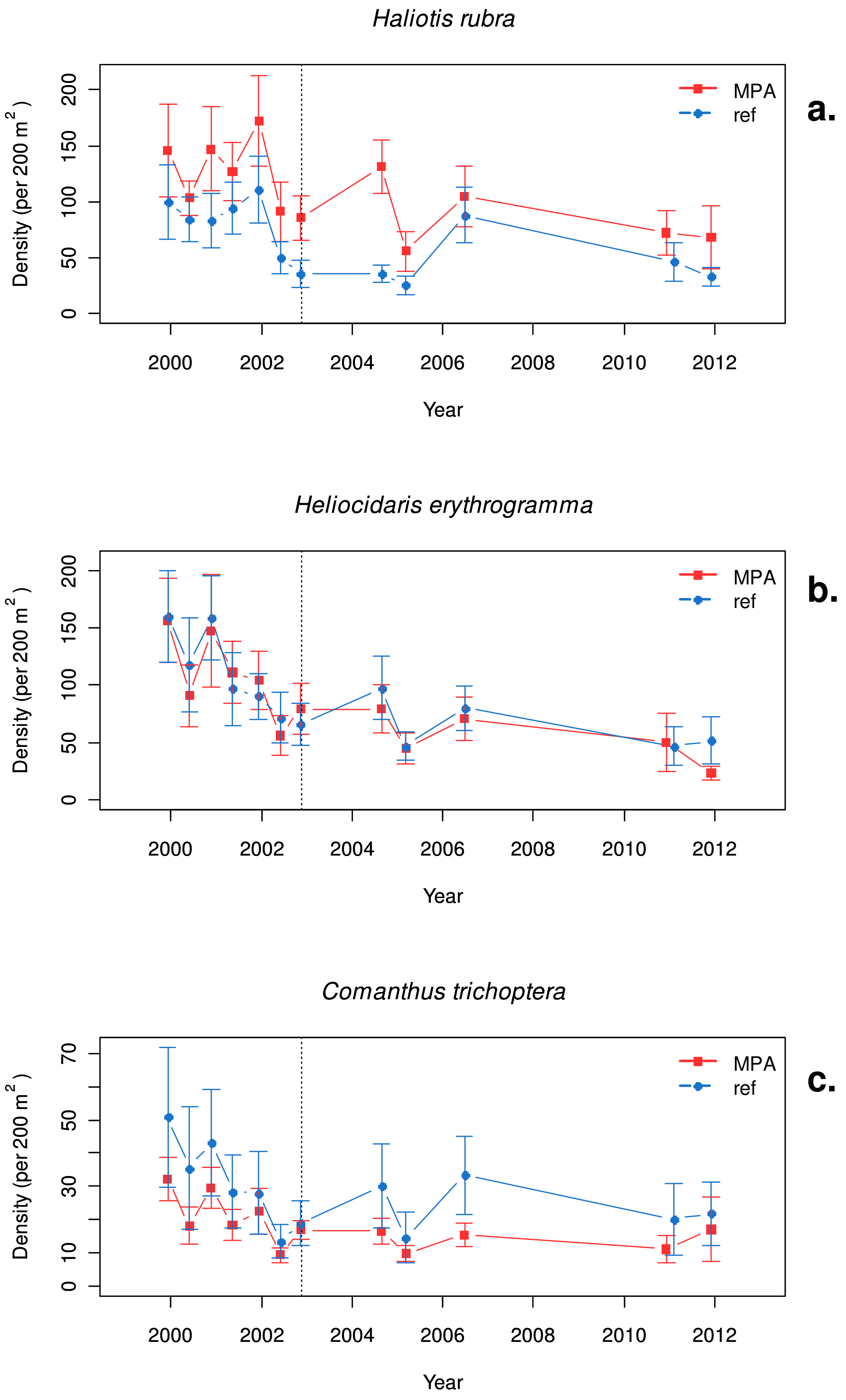
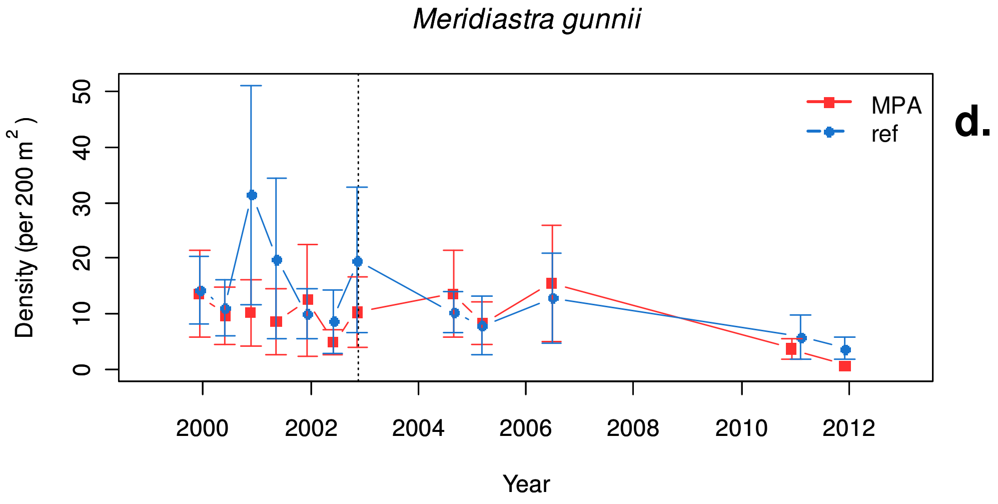


Figure 3.8 Abundance (mean ± standard error) of dominant motile invertebrate species inside and outside the Wilsons Promontory Marine National Park.



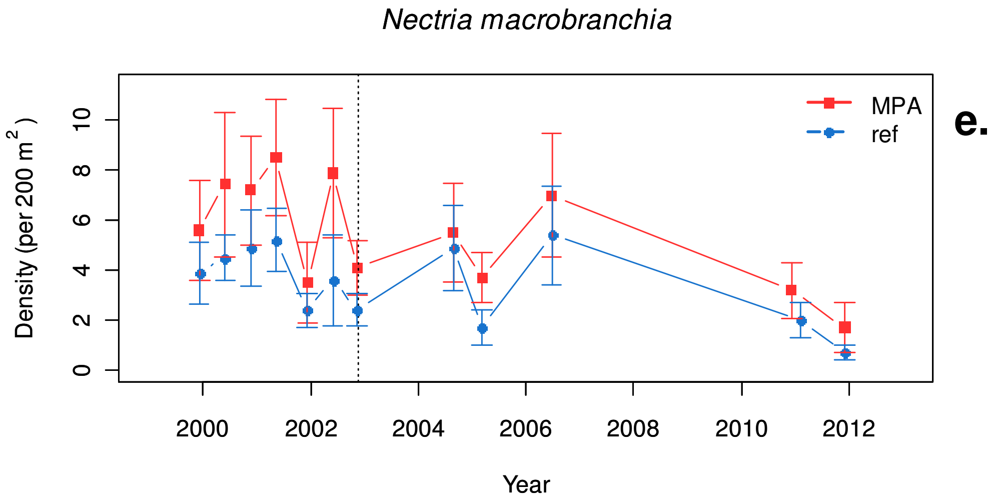


Figure 3.8 (continued). Abundance (mean ± standard error) of dominant motile invertebrate species inside and outside the Wilsons Promontory Marine National Park**.**

3.3. Fishes

3.3.1. Fish Community Structure

The predominant fish species at Wilsons Promontory were: barber perch *Caesioperca rasor*; blue-throated wrasse *Notolabrus tetricus;* purple wrasse *Notolabrus fucicola;* southern hulafish *Trachinops caudimaculatus;* silver sweep *Scorpis lineolata;* and magpie perch *Cheilodactylus nigripes*. Other common species included: toothbrush leatherjacket *Acanthaluteres vittiger*; herring cale *Odax* cyanomelas; butterfly perch *Caesioperca lepidoptera*; sea sweep *Scorpis aequipinnis*; and mado *Atypichthys strigatus*.

The MDS ordination for fishes indicated regional differences in fish assemblages with both north-south (sheltered/exposed) and east/west affinities in assemblage structure (

Figure **3.9**a-d). Differences between the western and eastern sites were largely because of higher abundances of *Odax cyanomelas*, *Trachinops caudimaculatus*, *Notolabrus fucicola*, *Dinolestes lewini*, *Scorpis aequipinnis*, *Pictilabrus laticlavius*, *Meuschenia freycineti* and *Girella zebra* in the west and higher abundances of *Scorpis lineolata* and *Atypichthys strigatus* in the east. *Notolabrus fucicola* and *Caesioperca rasor* also tended to be higher in abundance at the southern, more exposed sites. As with algal and invertebrate communities, the greatest dissimilarity between sites was measured in the western reference zone (Figure 3.9c).

The multivariate control charts for comparing trends over time relative to baseline conditions indicated considerable differences at many sites during 2010, both inside and outside the MNP, with a subsequent return to baseline conditions during 2011 (

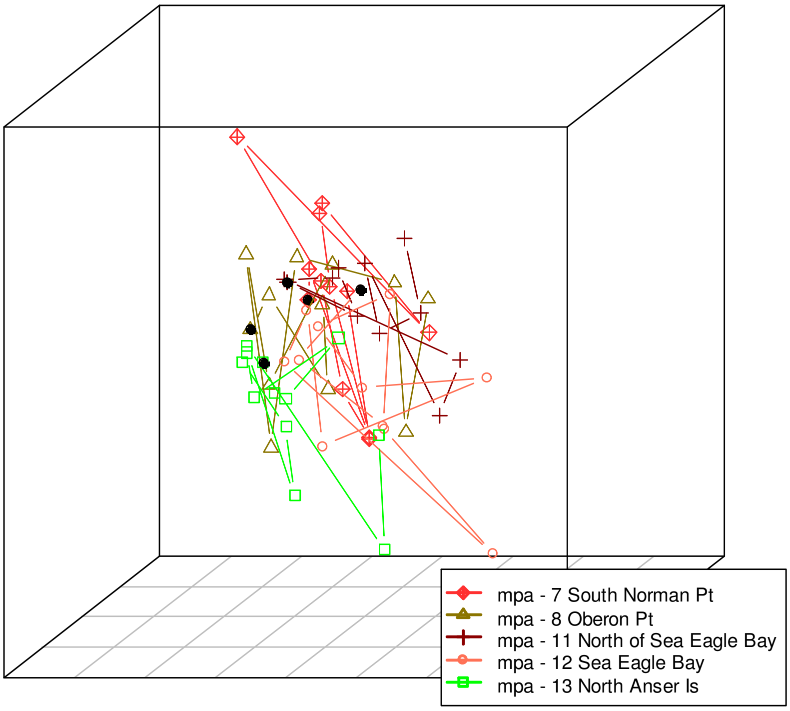
Figure **3.9**a, c, e). This change was also reflected in the comparison of each survey with all prior times, which also indicated pulse changes 2010. There was also a strong pulse-change inside and outside the MNP in 2004 (

Figure **3.9**b, d, f).

3.3.2. Fish Species Richness and Diversity

The fish community changes in 2004 and 2010 were also reflected in the total number of fish individuals and species richness statistics. For both of these statistics, there was a steady decline from the start of monitoring in 2000 to a minimum in 2004, followed by a strong peak in 2005 with another steady decline to 2010 (Figure 3.11a and b). Fish species diversity remained relatively similar at both the reference and protected areas from 2000 to 2006, with a subsequent decline inside the MNP in 2010 and 2011 (Figure 3.11c). The decline in diversity without a decline in species richness indicates an increased dominance of some species, however this was not clearly evident in the more common species abundances.

a. Fishes - MPA West



b. Fishes - MPA East

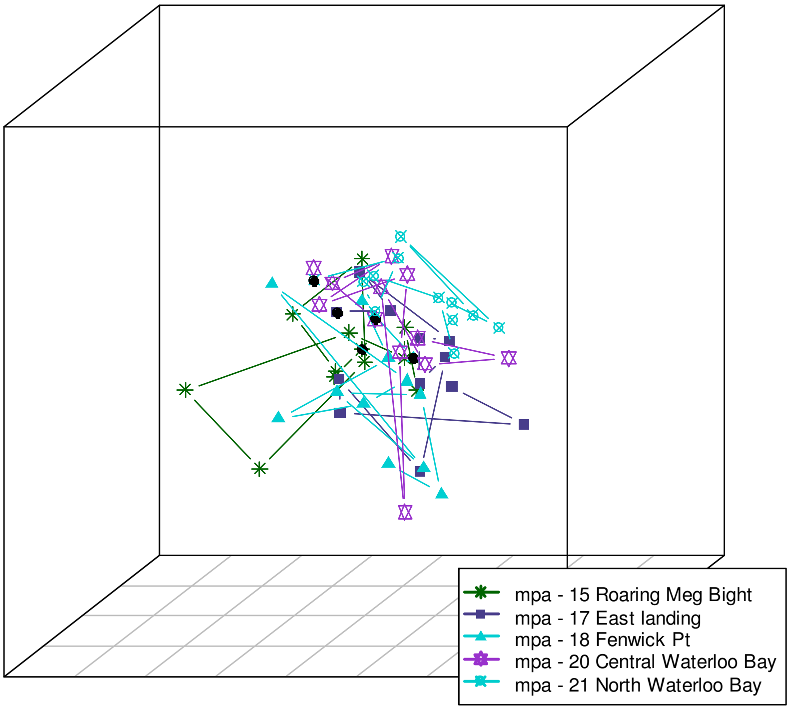
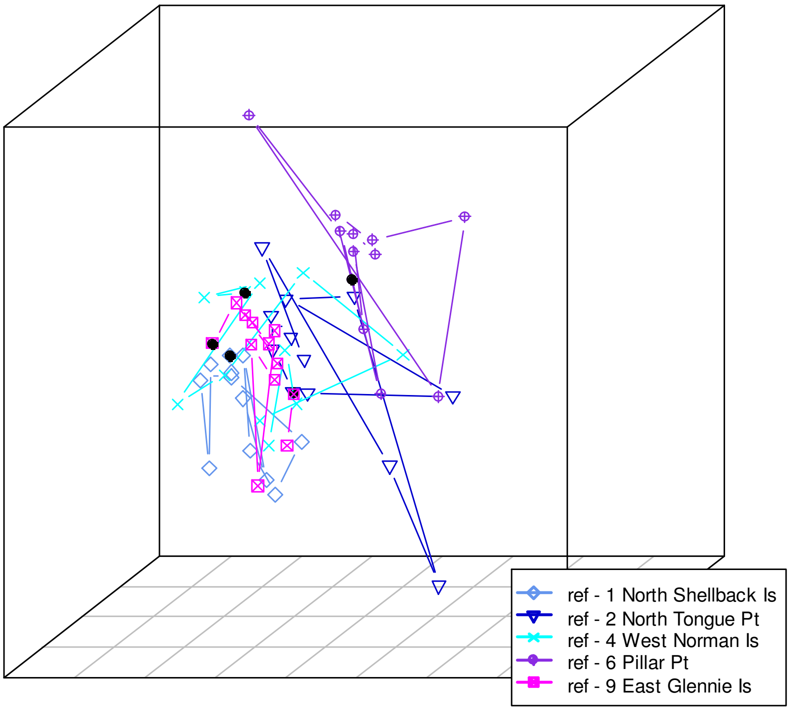


Figure 3.9. Three-dimensional MDS plot of fish assemblage structure for sites at Wilsons Promontory. Black symbols indicate the first survey. Kruskal stress = 0.19.

c. Fishes - Reference West



d. Fishes - Reference East

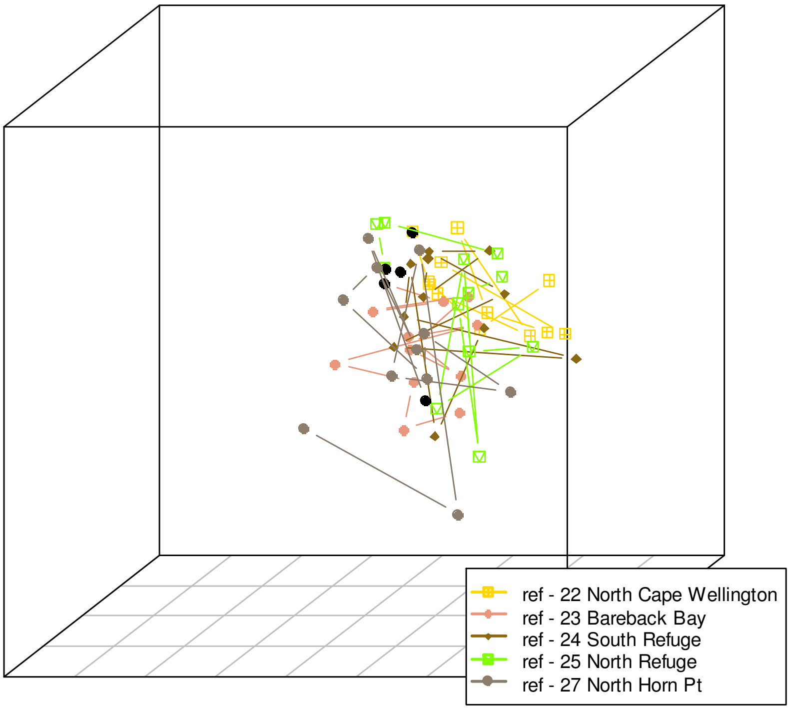


Figure 3.9 (continued). Three-dimensional MDS plot of fish assemblage structure for sites at Wilsons Promontory. Black symbols indicate the first survey. Kruskal stress = 0.19.

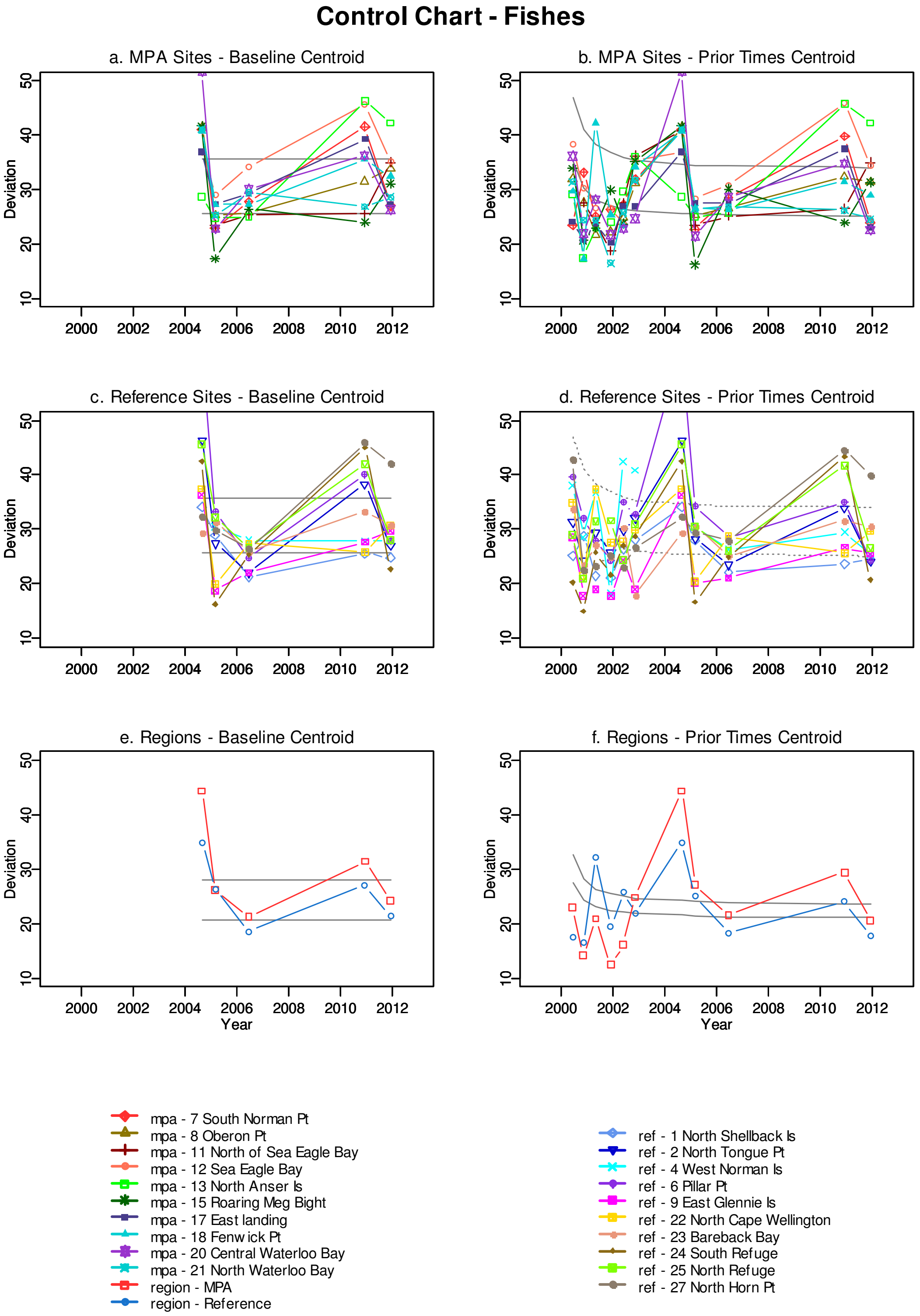


Figure 3.10. Control charts of fish assemblage structure inside and outside Wilsons Promontory Marine National Park. Grey lines indicate 50th and 90th percentiles.

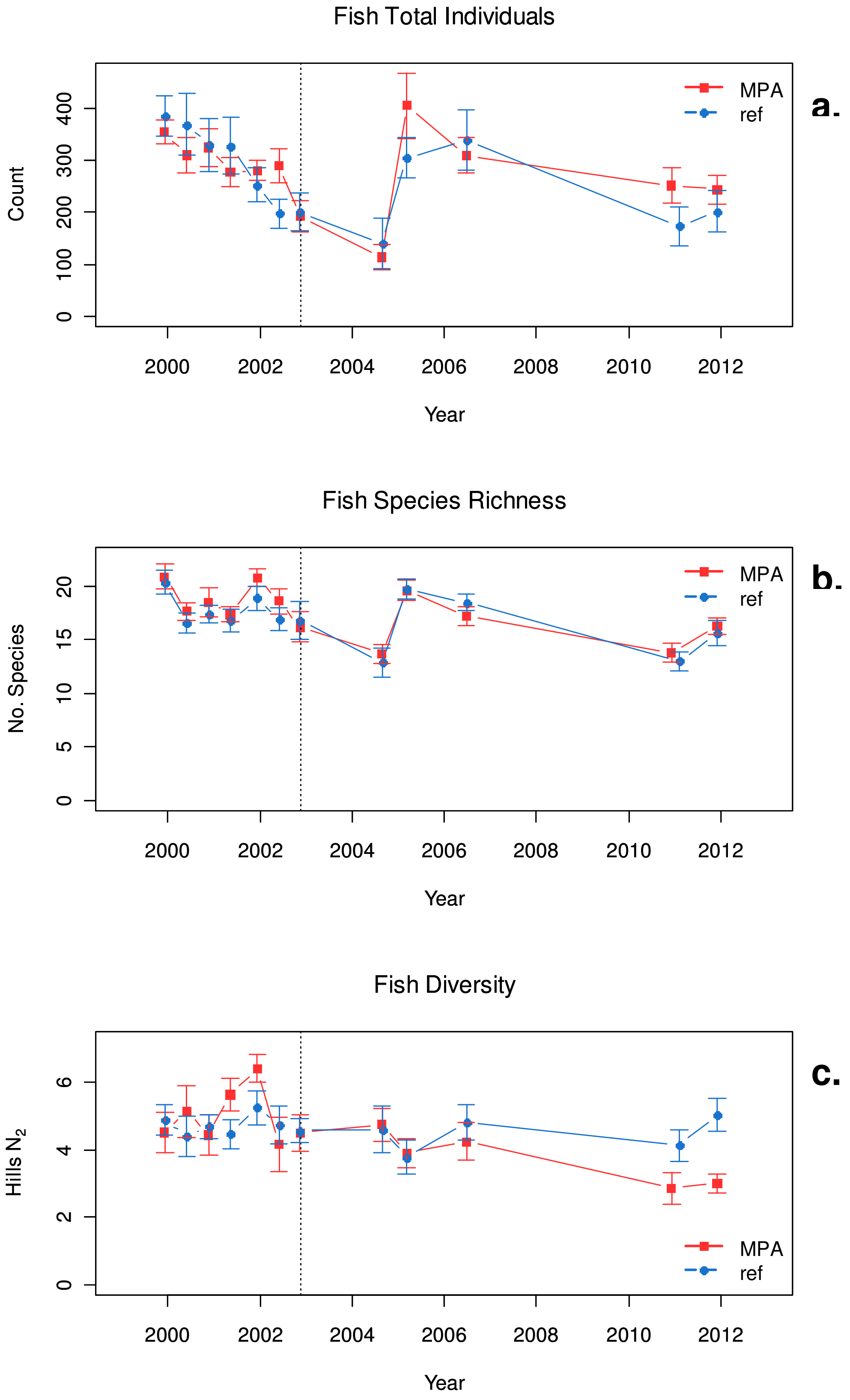


Figure 3.11. Fish species diversity indicators (mean ± standard error) inside and outside Wilson Promontory Marine National Park.

3.3.3. Common Fish Species

The mean density of blue throat wrasse *Notolabrus tetricus* and purple wrasse *Notolabrus fucicola* followed similar patterns of variation over time. The *N. tetricus* population was generally at least twice that of the *N. fucicola* (Figure 3.12a-b). Both populations had a seasonal fluctuations and an overall decrease in abundance to a minimum in 2005 and a subsequent peak in 2006. The abundances of N. fucicola were very low during the 2010 and 2011 surveys, both inside and outside the MNP (Figure 3.12a-b).

The butterfly perch *Caesioperca lepidoptera* was relatively low in abundance until 2004, although there were dense aggregations at some sites. From 2005, there was a large, sustained increase in density within the MNP (Figure 3.12c). The barber perch *Caesioperca rasor* densities were similar inside and outside the MNP during all surveys. There was a steep declining trend from 2000 to 2004, followed by a sharp increase in 2005 and more gradual declines thereafter (Figure 3.12d).

Other fish species also had a distinct minimum abundance in 2004 followed by a rapid increase in 2005 or 2006. These included sea sweep *Scorpis aequipinnis*, magpie morwong *Cheilodactylus nigripes* and old wives *Enoplosus armatus* (Figure 3.12e, f, g).

An aggregation of old wife *Enoplosus armatus* was consistently observed on transects 1 and 2 at Oberon Point, for all 12 surveys.

A historically heavily fished species, the long snout boarfish *Pentaceropsis recurvirostris*, was more noticeably present by divers in 2011 than in previous years, although most observations occurred off transect. Seadragons *Phyllopteryx taeniolatus* were observed at Tongue Point in 2000 and 2011.

The site at Shellback Island was established near a small seal haulout, initially occupied by only several seals at a time. In December 2011, there were a substantial number of pups and adult seals, indicating the haulout is now a breeding colony.

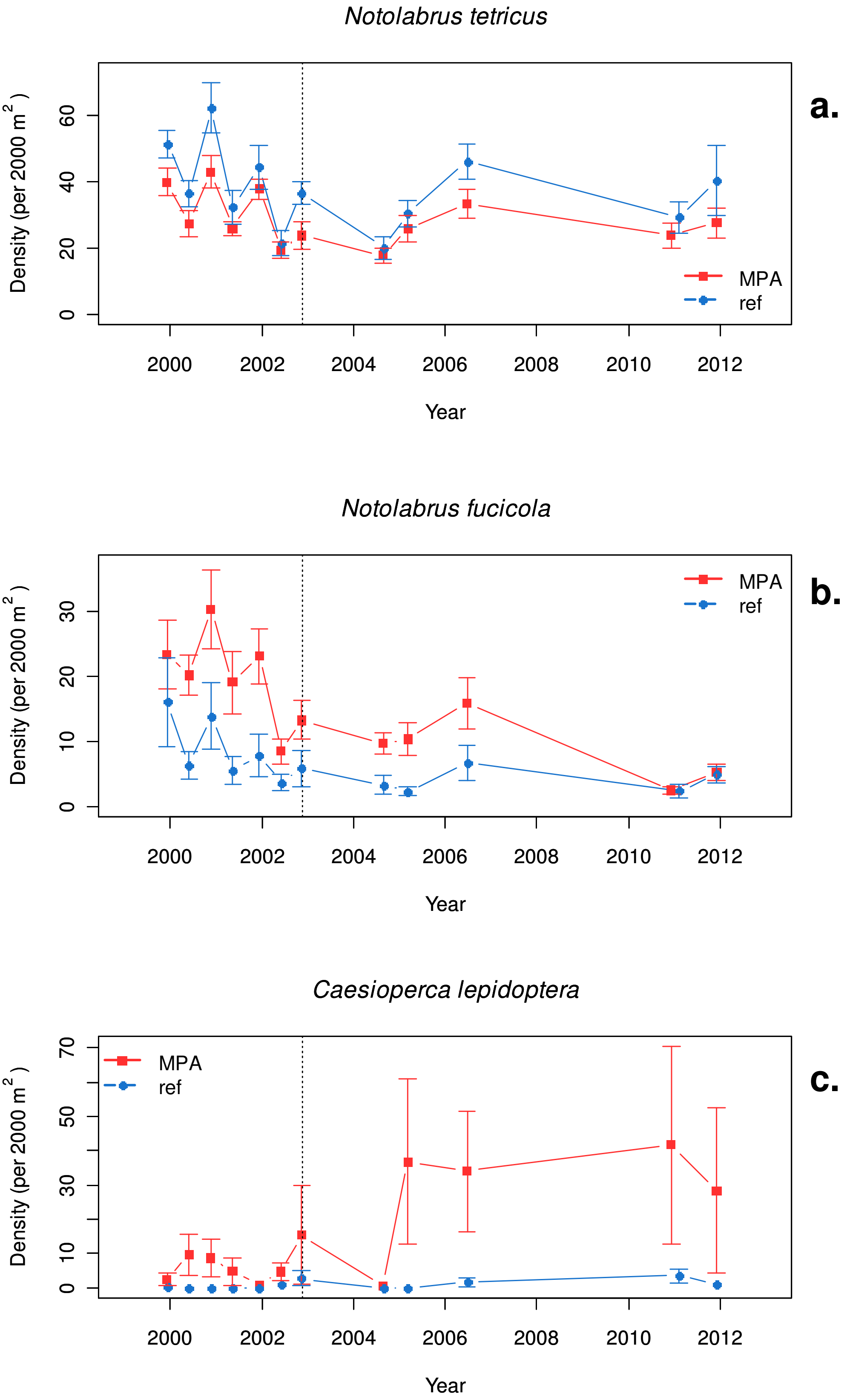
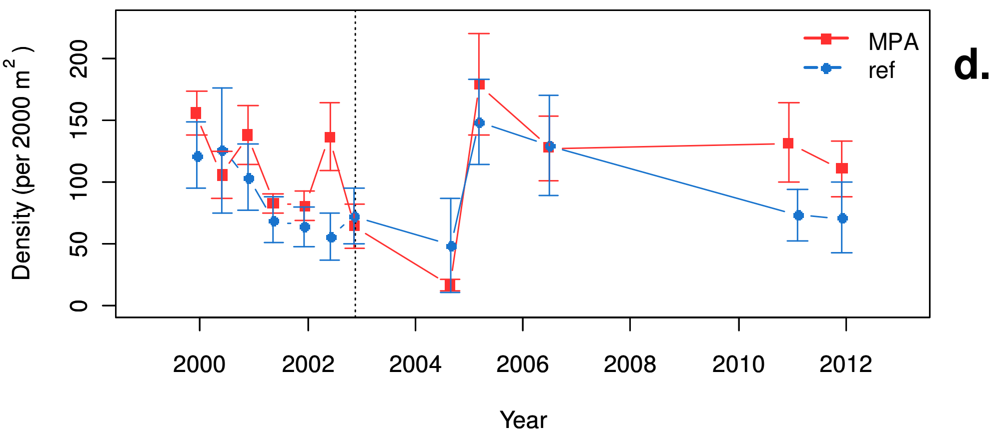
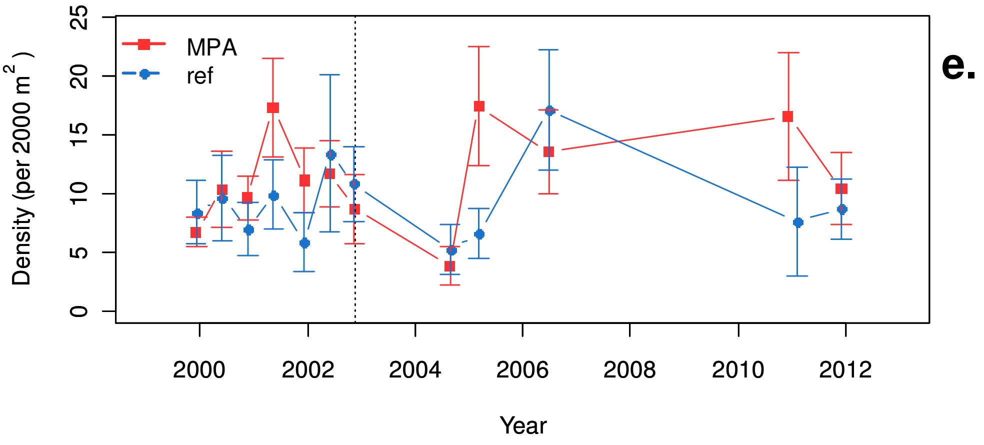


Figure 3.12. Abundance (mean ± standard error) of dominant fish species inside and outside the Wilsons Promontory Marine National Park.

Caesioperca rasor



Scorpis aequipinnis



Cheilodactylus nigripes

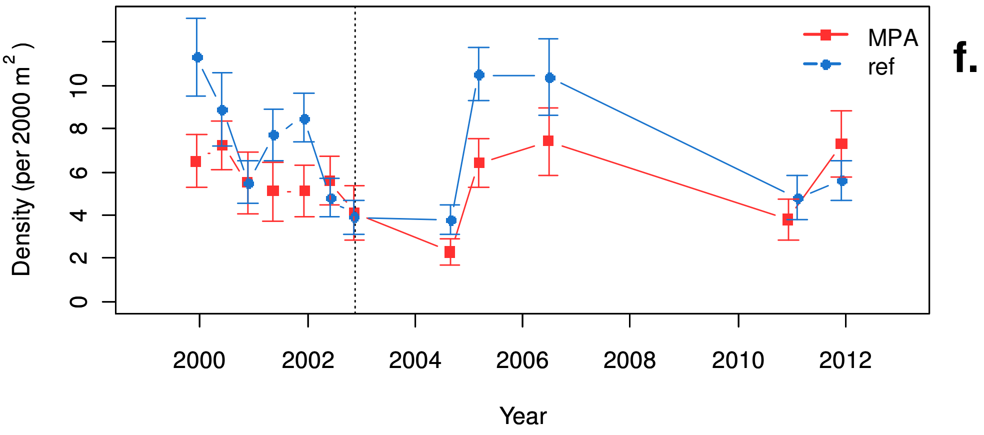


Figure 3.12 (continued). Abundance (mean ± standard error) of dominant fish species inside and outside the Wilsons Promontory Marine National Park.

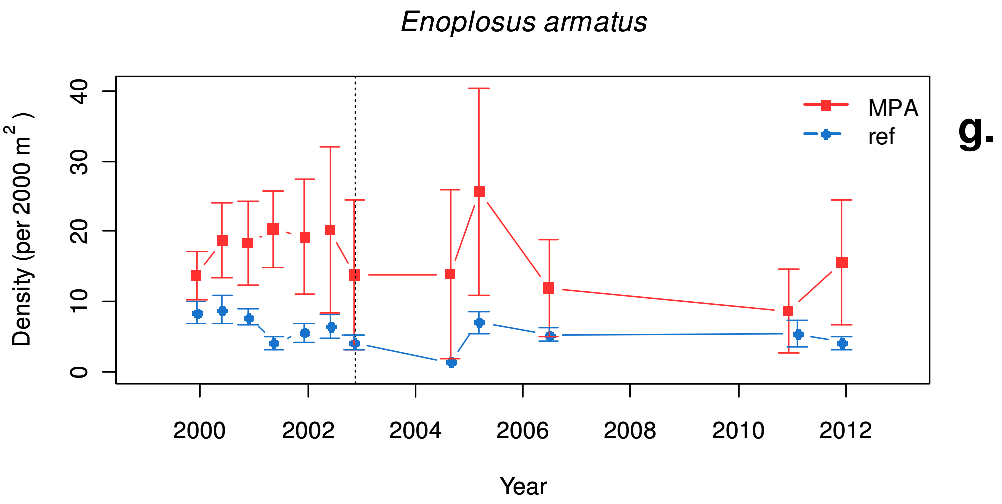


Figure 3.12 (continued). Abundance (mean ± standard error) of dominant fish species inside and outside the Wilsons Promontory Marine National Park.

Figure 3.13. Old wife *Enoplosus armatus* above canopy of *Ecklonia radiata*, North Anser Island (Site 3113), Wilsons Promontory.

3.4. Ecosystem Components

3.4.1. Habitat and Production

The cover of crustose coralline algae and canopy brown algae varied little over the monitoring period and were more dominant inside the MNP (Figure 3.14a, b). Smaller brown seaweeds were consistently more abundant in the more sheltered reference areas, with changes over time mirrored inside and outside the MNP (Figure 3.14c).

Thallose red algae had a very strong seasonal signal during the initial six-monthly sampling frequency. The range over the monitoring period was generally between 15-20 % cover, Trends were similar inside and outside the MNP (Figure 3.14d).

The erect coralline and green algae have generally remained between 2-4 % cover for the monitoring period (Figure 3.14e-f).

3.4.2. Invertebrate Groups

Density of invertebrate grazing taxa were generally higher inside the MNP than in the reference area during all surveys (Figure 3.15a). As noted above for abalone and sea urchins, the densities of invertebrate grazers declined rapidly at the end of the baseline monitoring period, with a gradual decline thereafter.

Invertebrate filter feeders were more abundant in the reference areas, consistent with a greater prevalence of suitable crevice habitat. Filter feeders also declined during the baseline monitoring period, followed by relatively unchanging abundances (Figure 3.15b). Invertebrate predator density increased to a peak in the baseline period then remained relatively low since 2003 (Figure 3.15c). This pattern was somewhat reflected in total seastar density (Figure 3.15d).

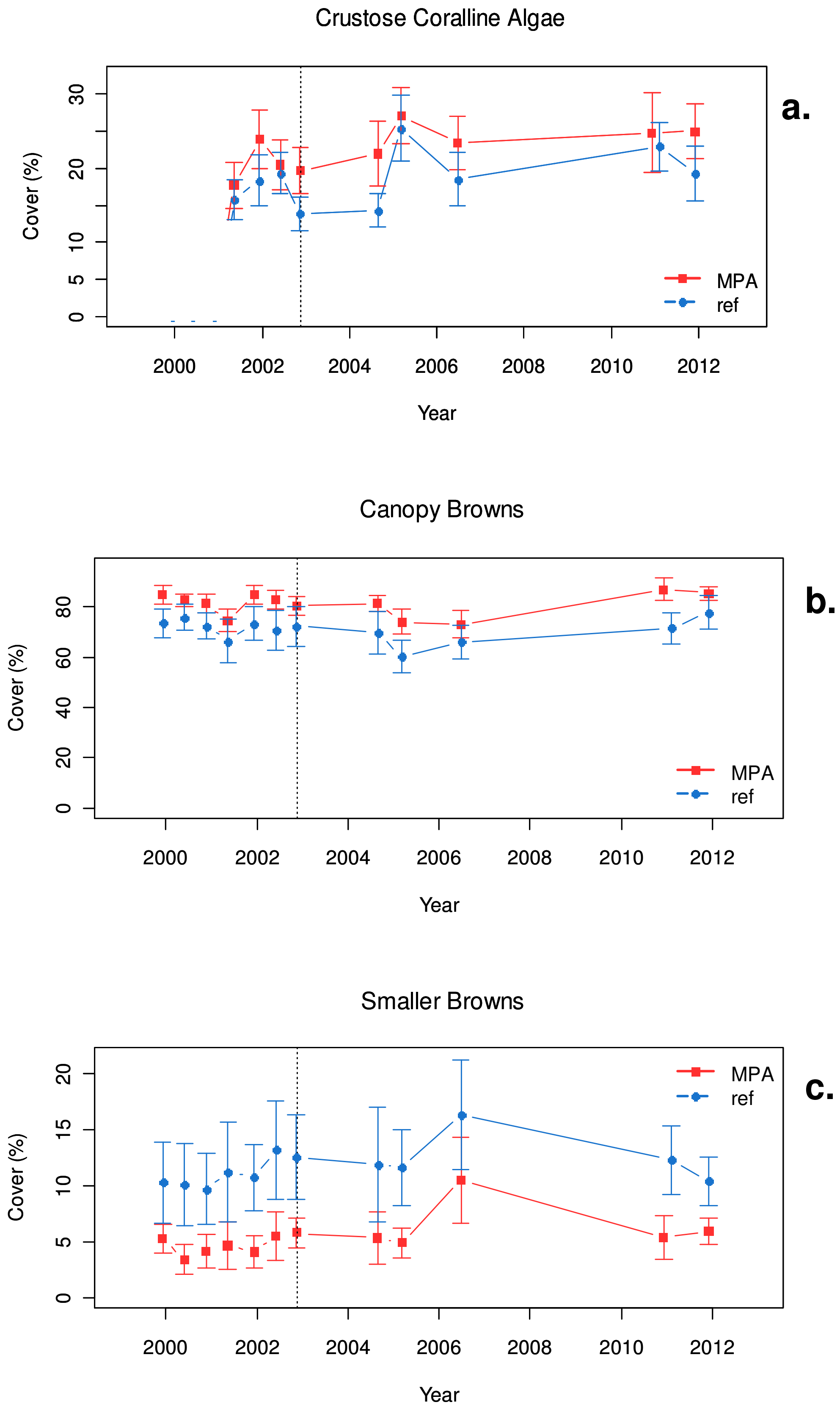


Figure 3.14. Seaweed functional groups (mean ± standard error) inside and outside the Wilsons Promontory Marine National Park.

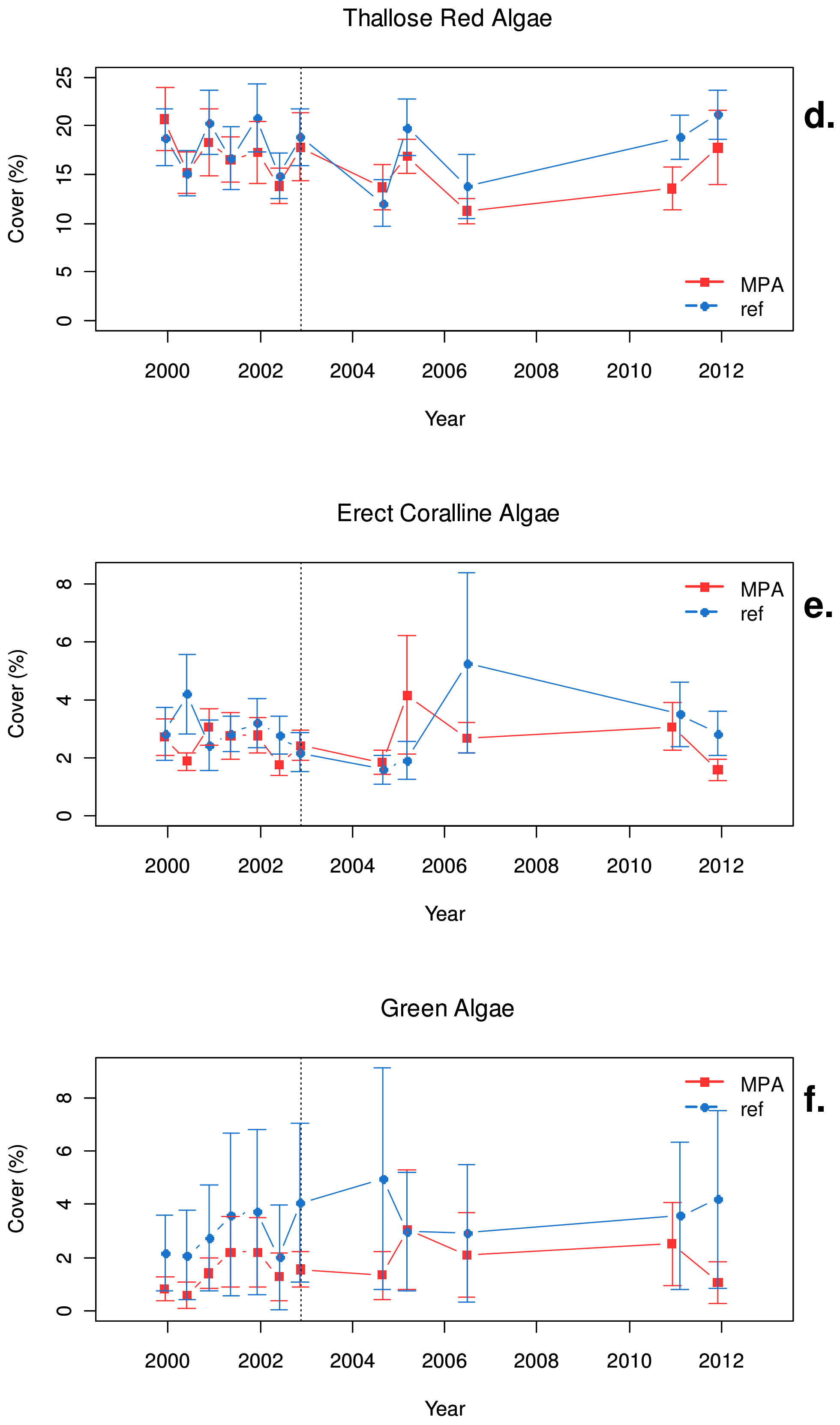


Figure 3.14 (continued). Seaweed functional groups (mean ± standard error) inside and outside the Wilsons Promontory Marine National Park.

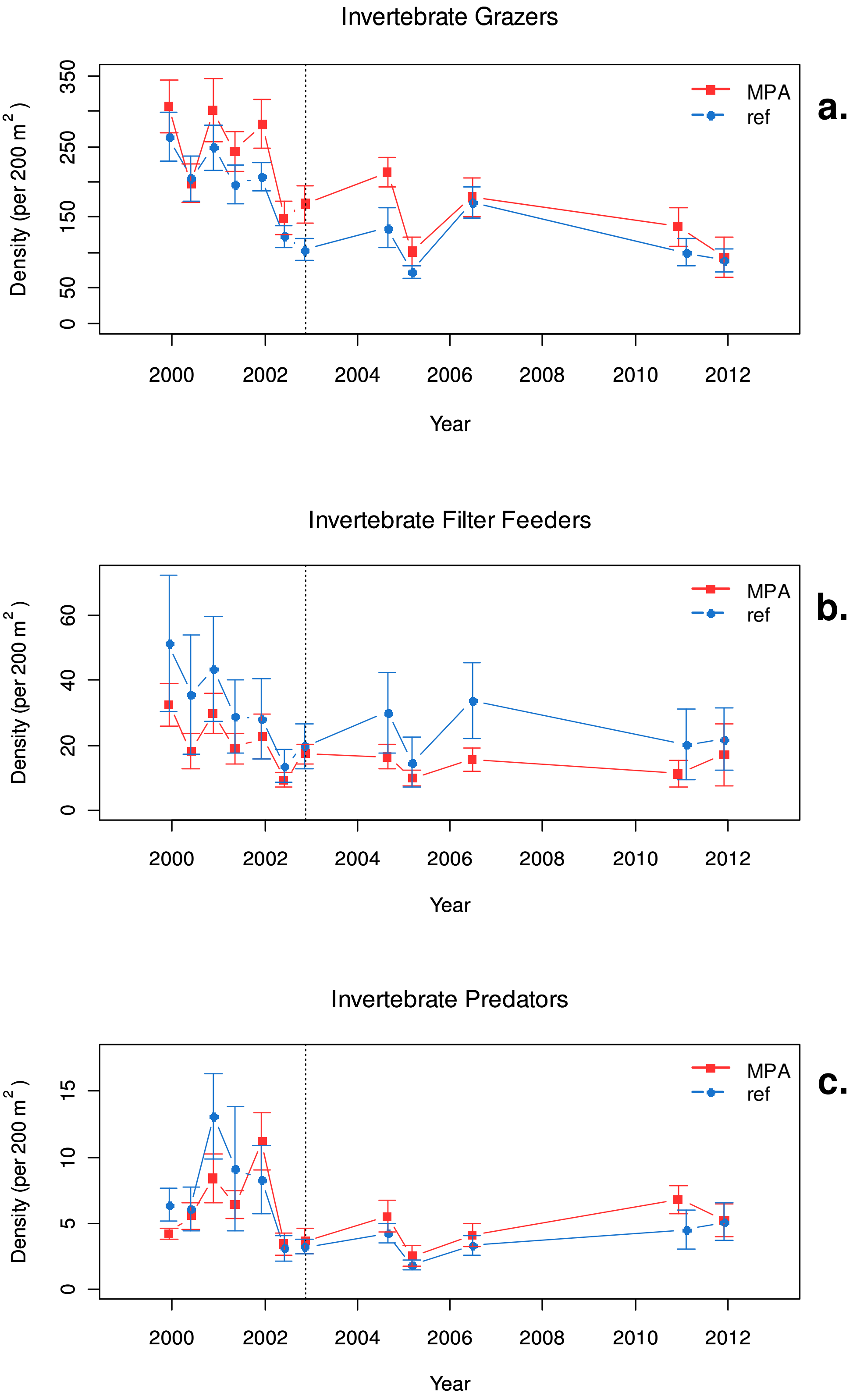


Figure 3.15. Invertebrate functional groups (mean ± standard error) inside and outside the Wilsons Promontory Marine National Park.

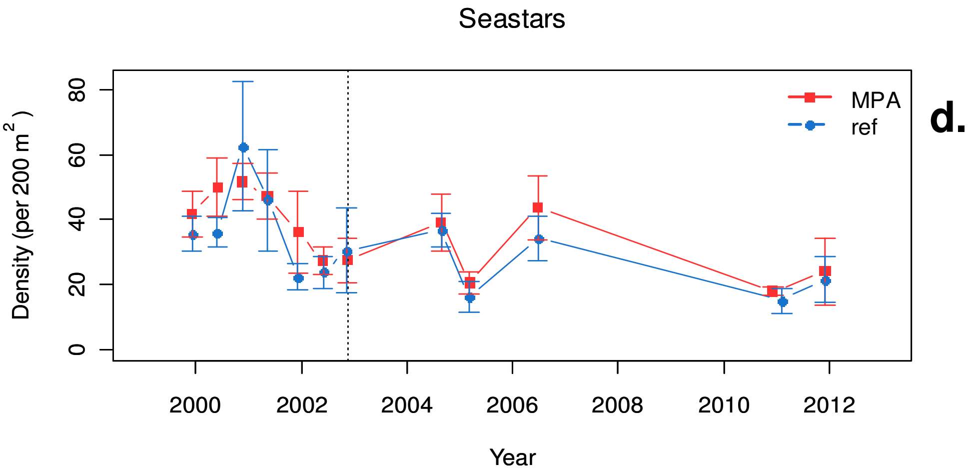


Figure 3.15 (continued). Invertebrate functional groups (mean ± standard error) inside and outside the Wilsons Promontory Marine National Park.

3.4.3. Fish Groups

Fish grazer, forager and planktivore densities followed similar patterns over time, with all three groups having a general decreasing trend during the baseline period, a peak in 2004 or 2005 and subsequent decline to relatively low abundances in 2010 and 2011 (Figure 3.16a-c). Fish hunter densities were higher in the reference areas during the baseline period however there were no apparent trends inside the MNP (Figure 3.16d).

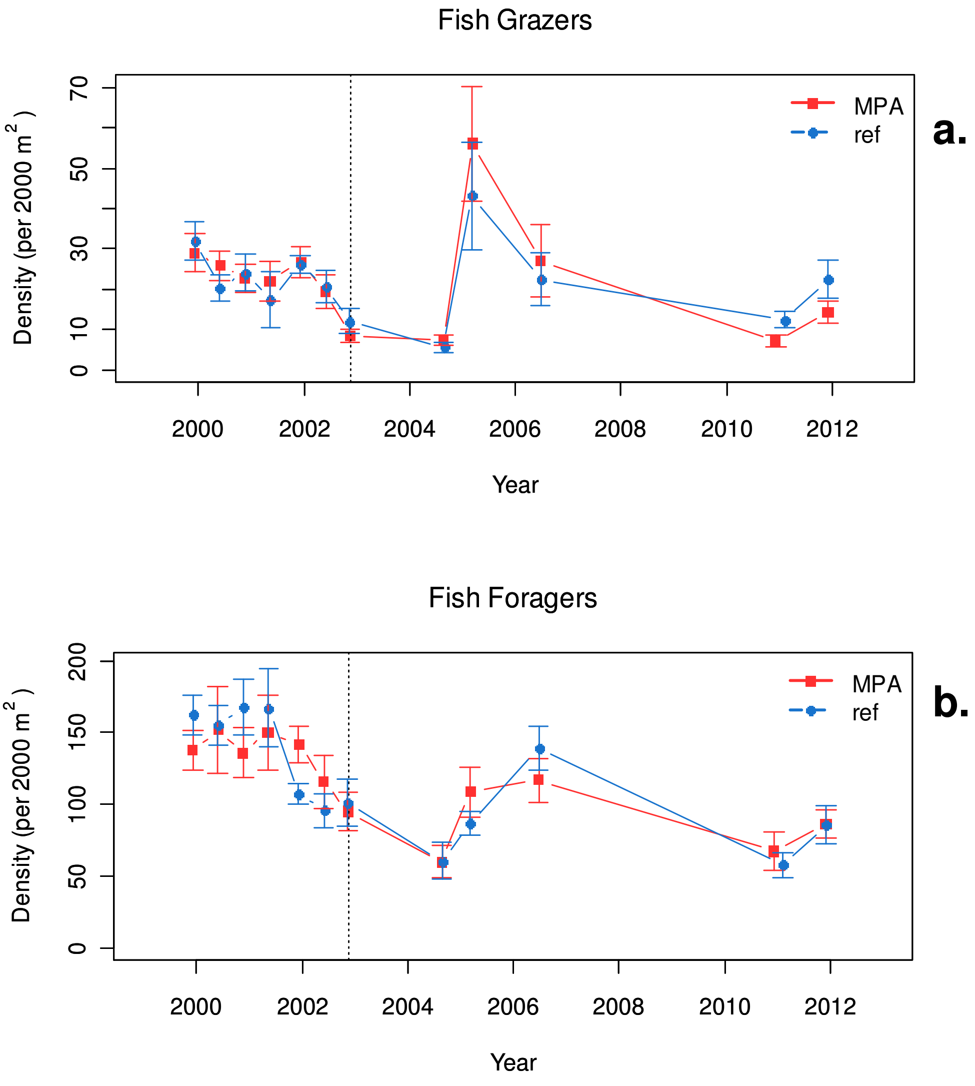


Figure 3.16. Fish functional groups (mean ± standard error) inside and outside the Wilsons Promontory Marine National Park.

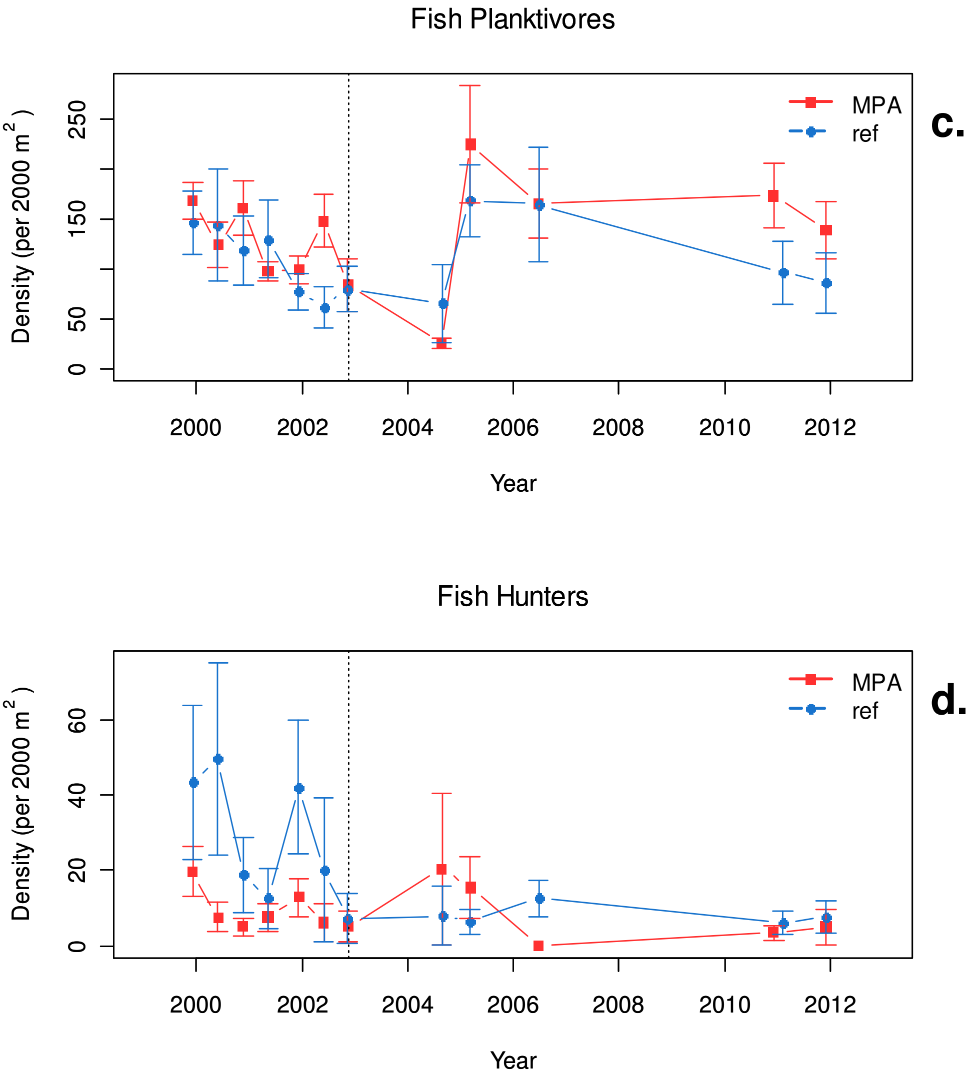


Figure 3.16 (continued). Fish functional groups (mean ± standard error) inside and outside the Wilsons Promontory Marine National Park.

3.4.4. Sediment Cover

The percent cover of sediment was very low both in the MNP and reference areas at all times (Figure 3.17).

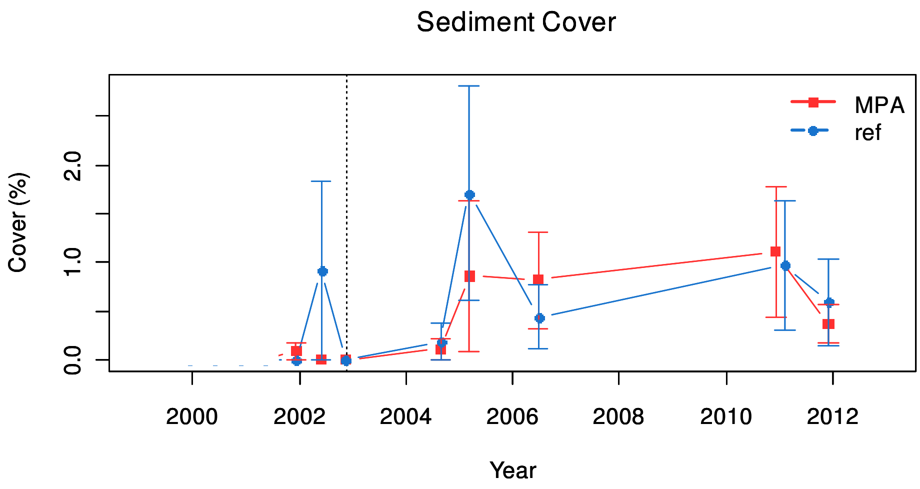


Figure 3.17 Percent cover (mean ± standard error) of sand inside and outside the Wilsons Promontory Marine National Park.

3.5. Introduced Species

No introduced algae, invertebrate or fish taxa have been recorded at Wilsons Promontory at the SRMP monitoring sites.

3.6. Climate Change

3.6.1. Algal Bioregional Affinities

The majority of Wilsons Promontory algal richness and abundance was composed of Flindersian, *i.e.* western and southern, species (Figure 3.18). The species specific to the eastern region have not been observed at any Wilsons Promontory sites since 2002.

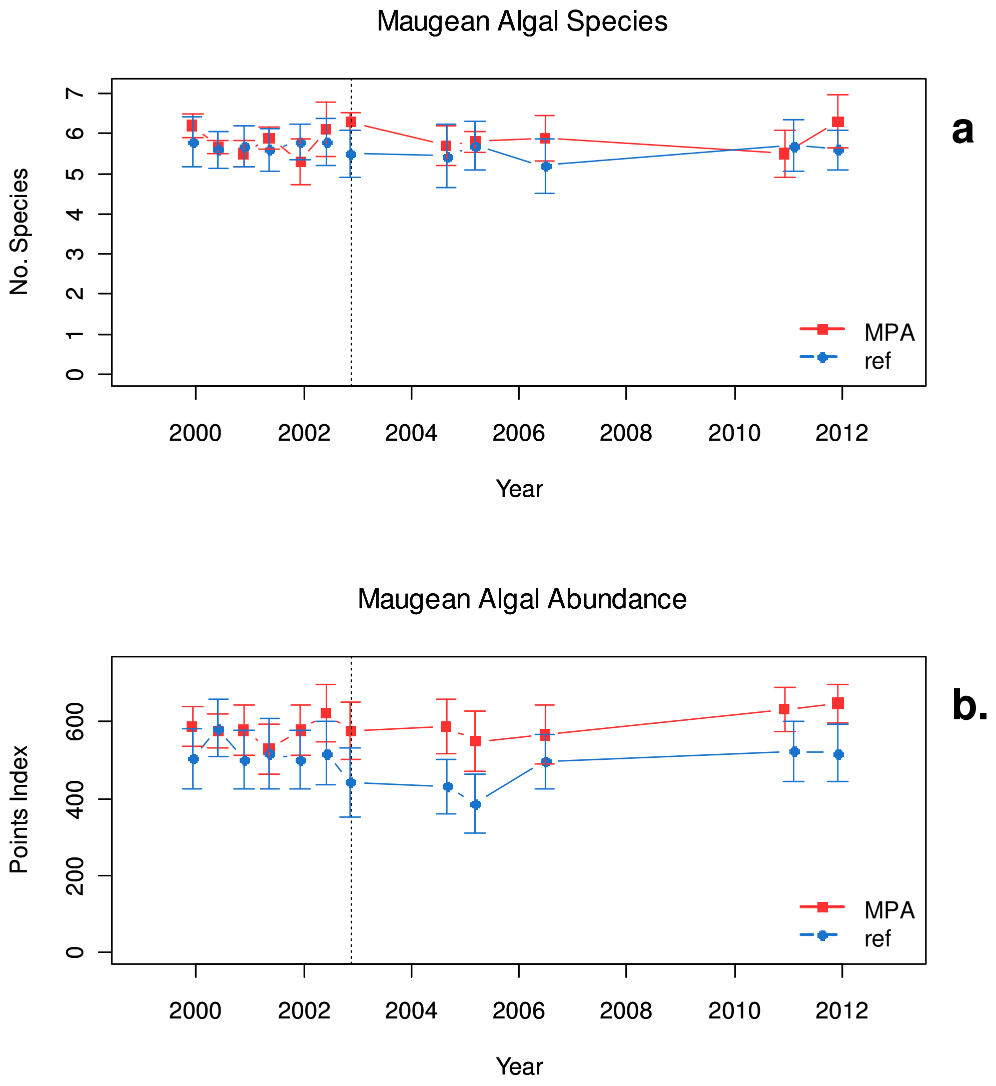


Figure 3.18. Richness and abundance (mean ± standard error) of Maugean algae species inside and outside the Wilsons Promontory Marine National Park.

3.6.2. Invertebrate Bioregional Affinities

Invertebrate faunas at all sites were composed primarily of a mixture of Maugean and western bioregion species (Figure 3.19 and 3.21). Smaller contributions to invertebrate richness and abundance values were made by eastern bioregion species (Figure 3.20a-b).

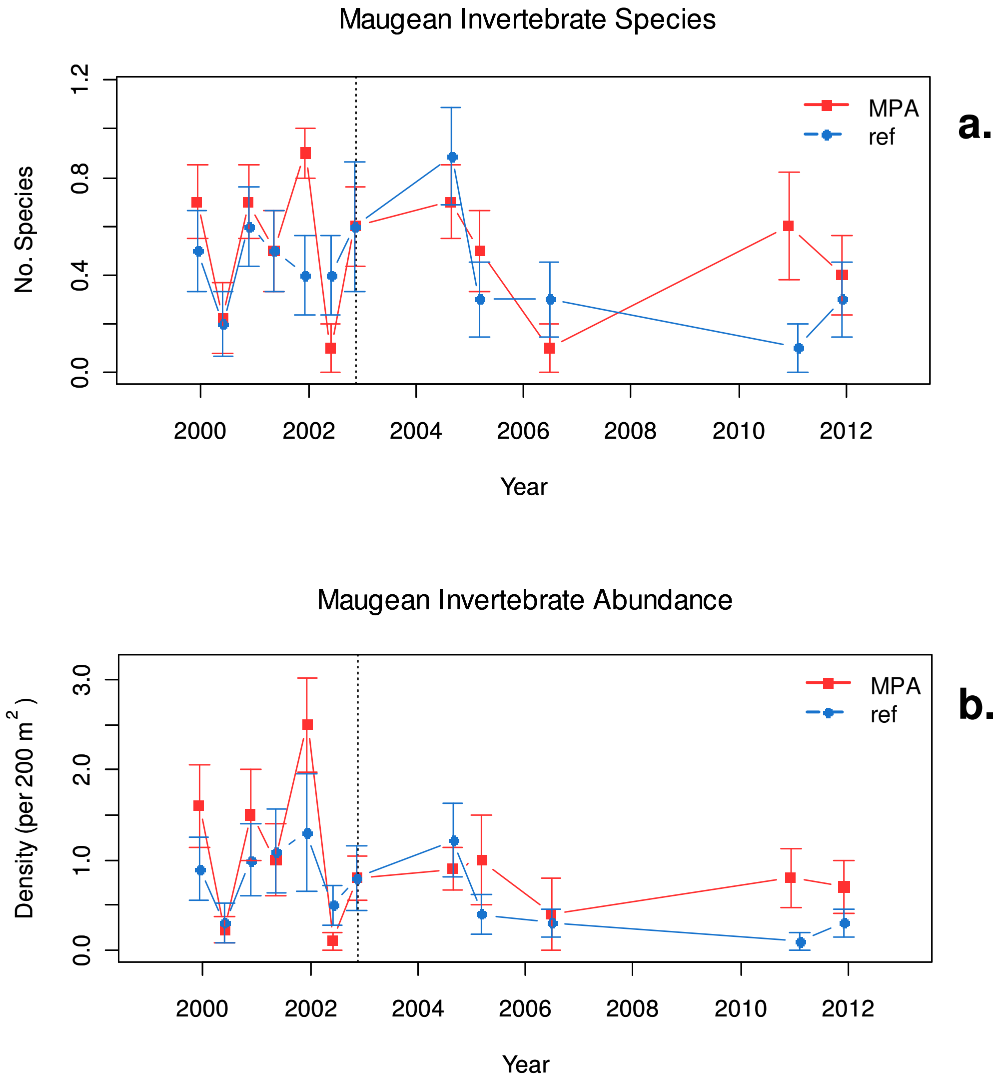


Figure 3.19. Richness and abundance (mean ± standard error) of Maugean invertebrate species inside and outside the Wilsons Promontory Marine National Park.

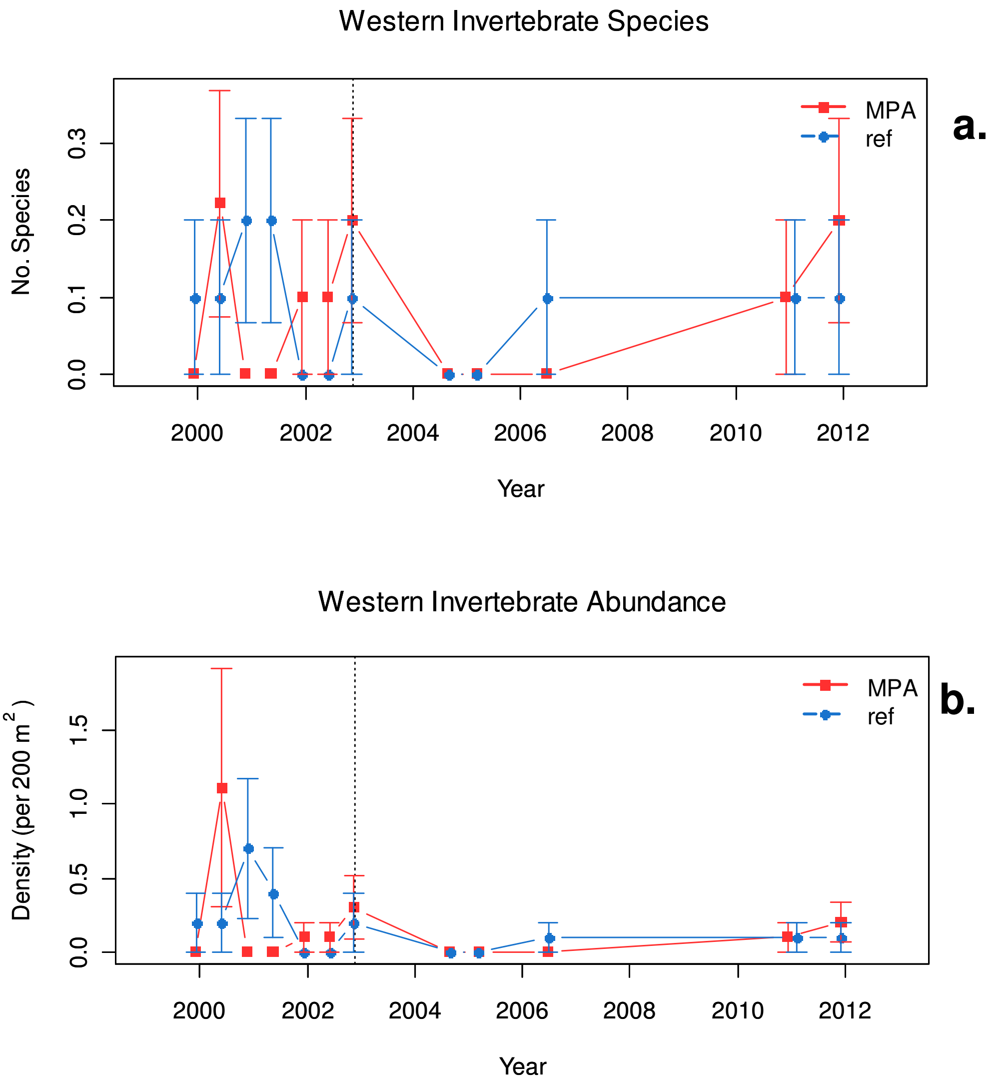


Figure 3.20. Richness and abundance (mean ± standard error) of Western invertebrate species inside and outside the Wilsons Promontory Marine National Park.

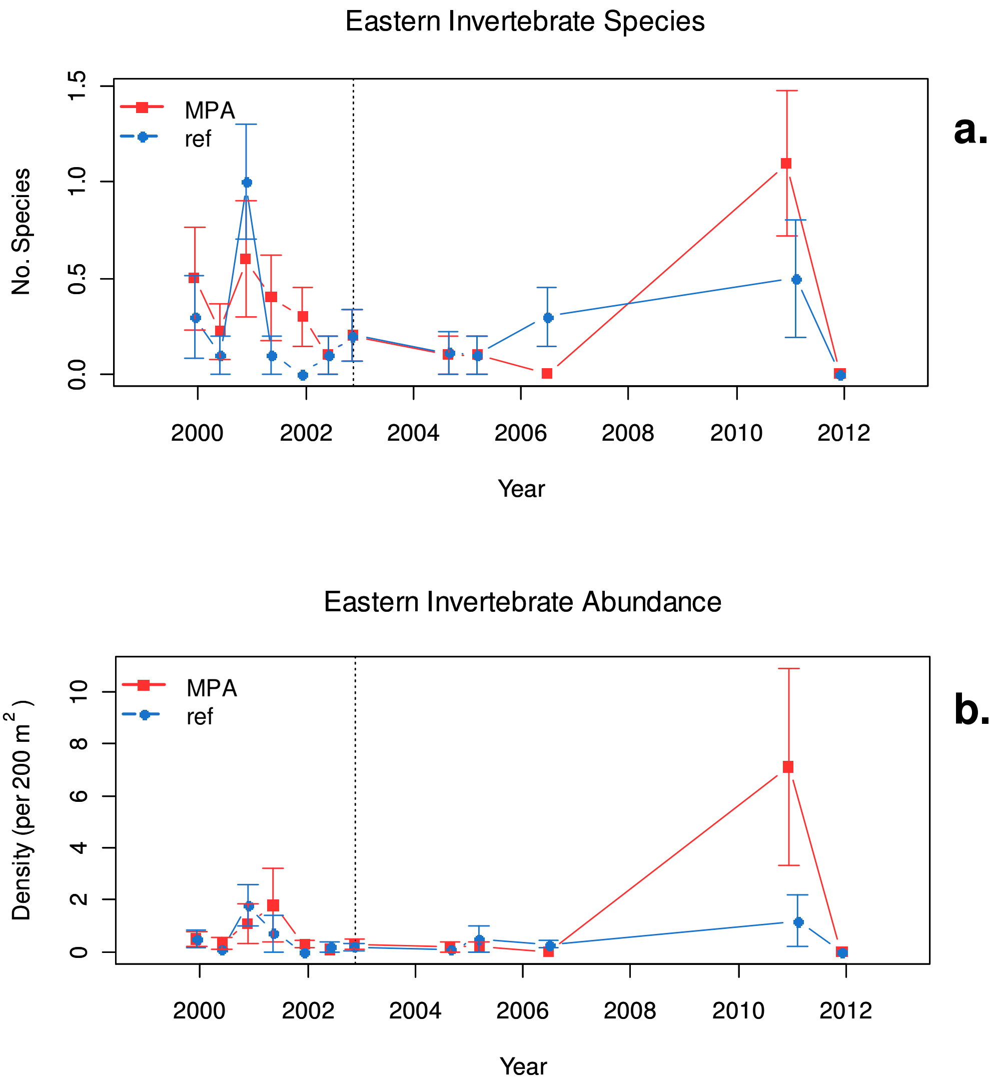


Figure 3.21. Richness and abundance (mean ± Standard error) of Eastern invertebrate species inside and outside the Wilsons Promontory Marine National Park.

3.6.3. Fish Bioregional Affinities

Fish communities around Wilsons Promontory were dominated by Flindersian and Maugean species (Figure 3.21 and 3.22). Eastern bioregion species were represented in low numbers and abundances (Figure 3.23). There were no marked changes of fish bioregional affinities.

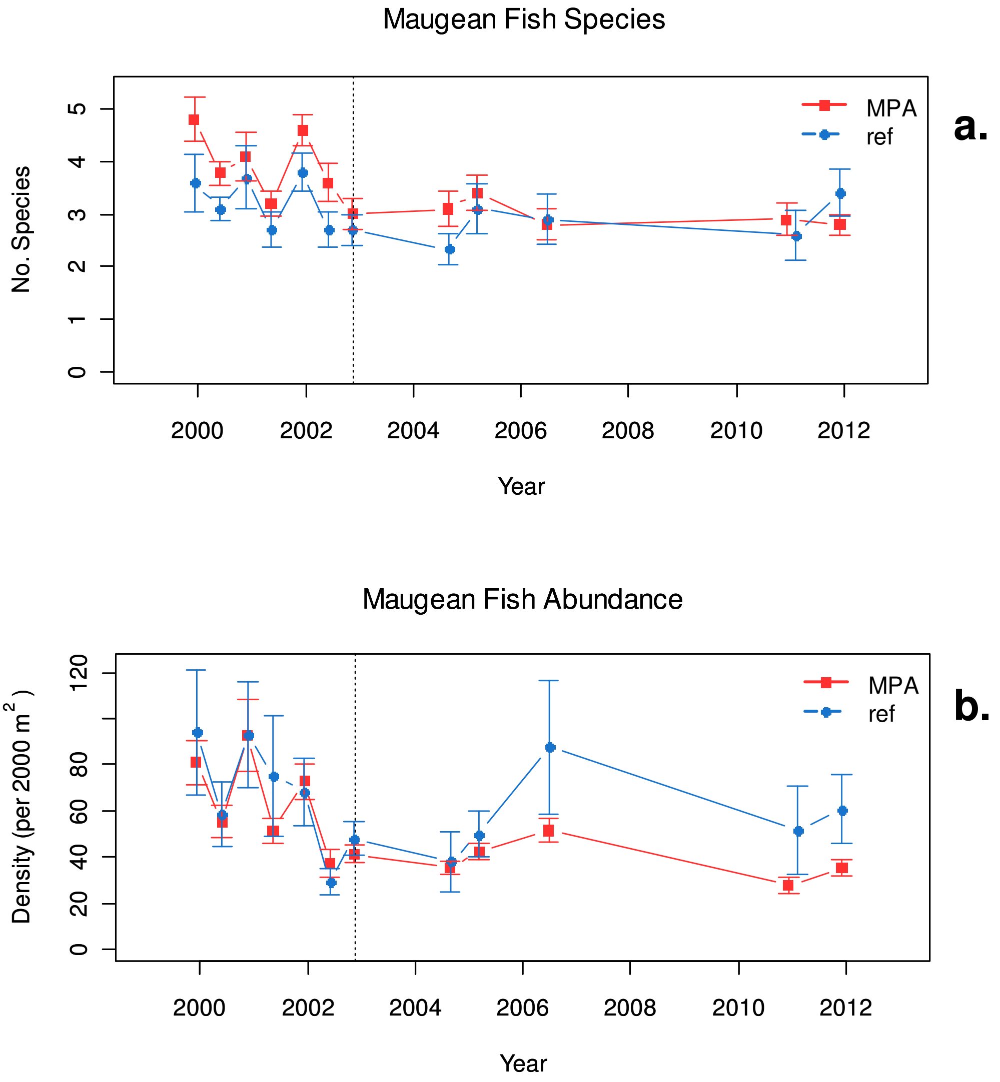
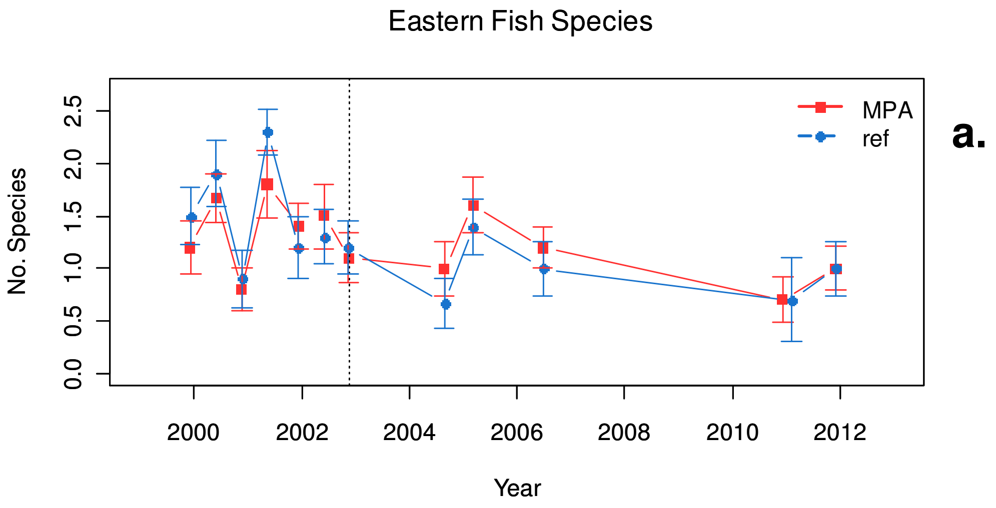


Figure 3.22. Richness and abundance (mean ± Standard error) of Maugean fish species inside and outside the Wilsons Promontory Marine National Park.



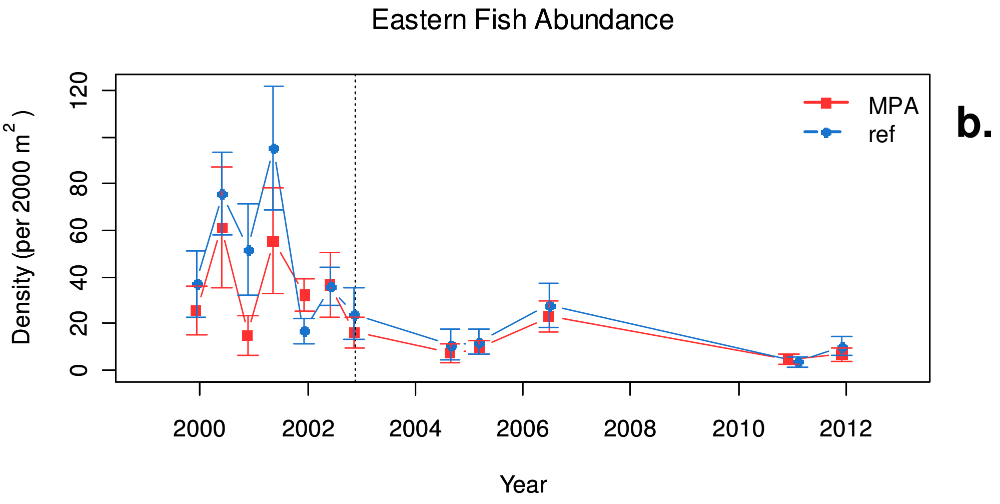


Figure 3.23. Richness and abundance (mean ± standard error) of Eastern fish species inside and outside the Wilsons Promontory Marine National Park.

3.6.4. *Macrocystis pyrifera*

The string kelp *Macrocystis pyrifera* was only present on one occasion in the baseline period, in very low densities at Waterloo Bay, inside the MNP. *Macrocystis pyrifera* has not been observed in subsequent surveys.

3.6.5. *Centrostephanus rodgersii*

At high densities, *C. rodgersii* causes community shifts from macrophyte dominated reefs to urchin barrens (Andrew and Underwood 1993). This species is of particular interest as it has increased its range down the east coast of Australia to Tasmania in recent years, causing major changes in macrophyte reef communities.

Centrostephanus rodgersii was observed at East Landing (Site 3017) in 2002. It was observed at Glennie Island (Site 3009) in 2004. During the 2010 survey, it was observed at two sites in Waterloo Bay (Site 3020 and Site 3021) in densities of 5 individuals 200 m^{-2} transect. No *Centrostephanus rodgersii* was observed during the survey.

3.6.6. *Durvillaea potatorum*

The bull kelp *Durvillaea potatorum* was only present at one reference site, Pillar Point, during the first survey and has not been observed in subsequent surveys.

3.7. Fishing

3.7.1. Abalone

During the 2010 survey, the mean size of blacklip abalone *Haliotis rubra* was in the low end of the historical range, but had increased in both the MNP and reference areas by the December 2011 survey (Figure 3.24a). The proportion of legal size abalone in both areas was at record low values for both the MNP and the reference areas in 2010, but had increased by 2011 (Figure 3.24b). The size class structure was slightly different between inside and outside the MNP, with higher abundances of 80-90 and 120-130 mm size classes inside the MNP (Figure 3.24c).

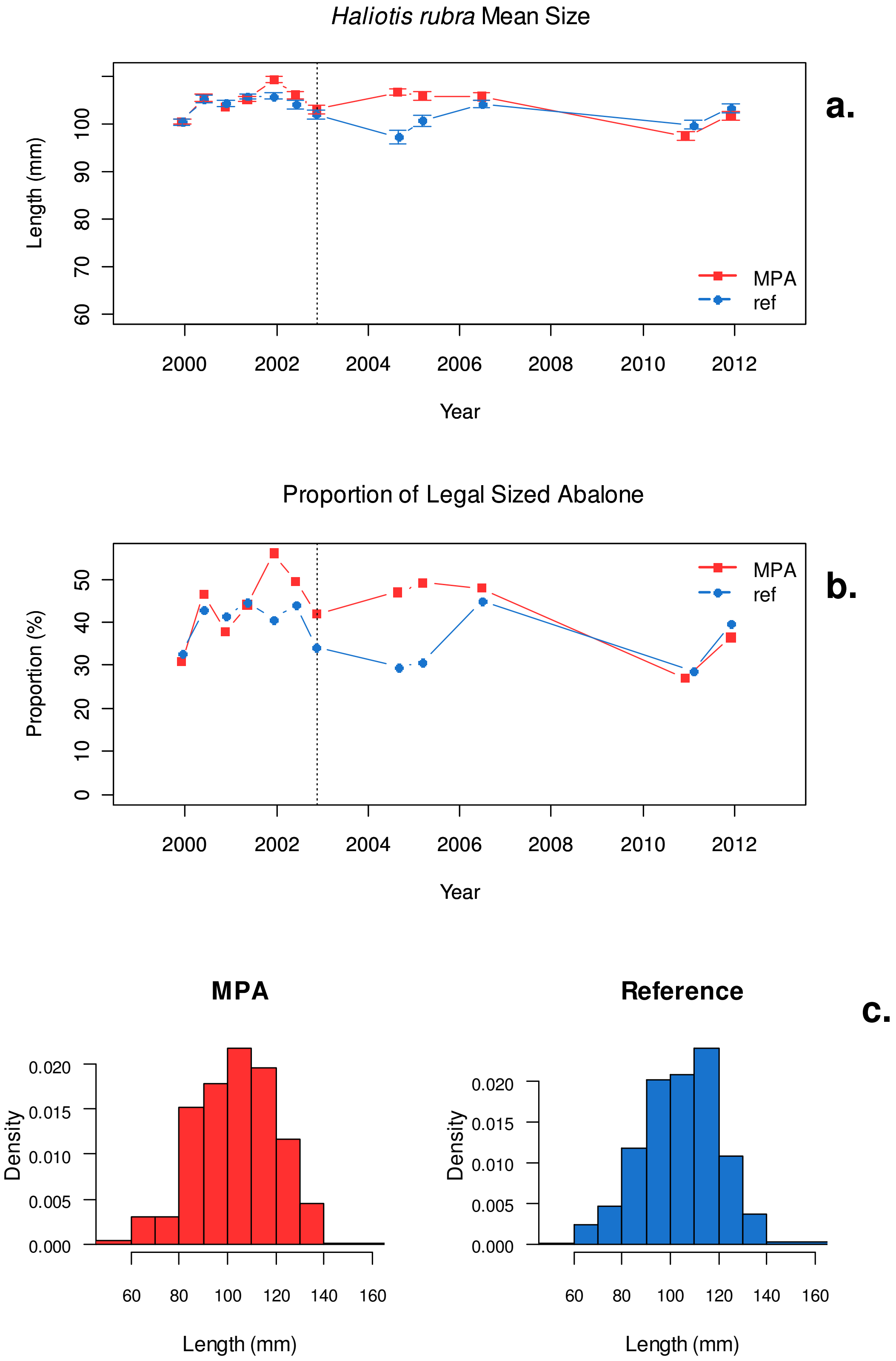


Figure 3.24. Size structure of blacklip abalone *Haliotis rubra* at Wilsons Promontory Marine National Park and reference sites.

3.7.2. Rock Lobster

The densities of southern rock lobster *Jasus edwardsii* was low at all sites throughout the monitoring program (Figure 3.25).

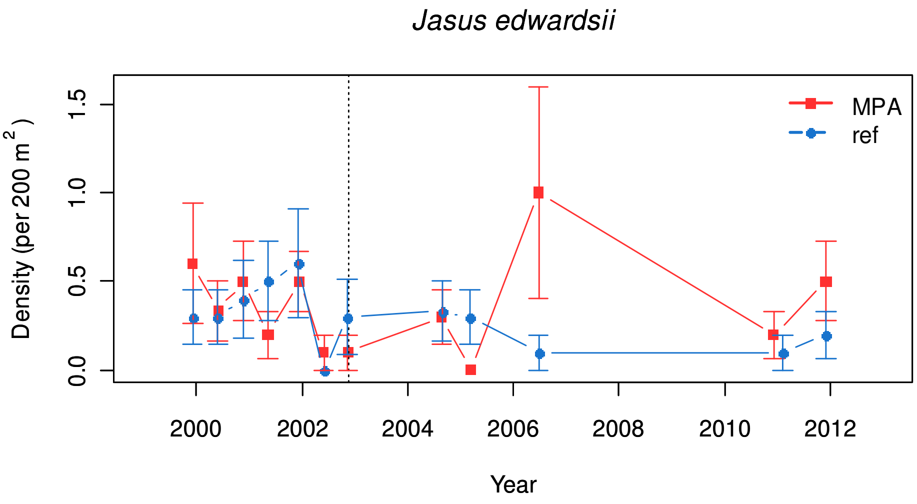


Figure 3.25. Density (mean ± standard error) of southern rock lobster, *Jasus edwardsii*, inside and outside the Wilsons Promontory Marine National Park.

3.7.3. Fishes

The fish size spectrum slope and intercept for the MNP and reference sites have been relatively consistent throughout the monitoring period. There was peak in the intercept in 2005, reflecting the peaks in abundances of different species (Figure 3.26).

The density and biomass of all fished species and fishes over 200 mm decreased during the baseline period, with densities remaining low thereafter. There was a peak in abundance of smaller fished species in 2006 (Figure 3.27 and Figure 3.28).

The density and biomass and fished species > 200 mm, and the density of all fishes remained low in both areas between the two most recent surveys (Figure 3.27b, Figure 3.28b and Figure 3.29b). The density of all fish species had a marked decline during the baseline period with a sharp increase in 2005 and 2006 with a more gradual decline to 2011 (Figure 3.29a). The density of larger fishes did not have a prominent 2005-2006 peak as with the total fish density.

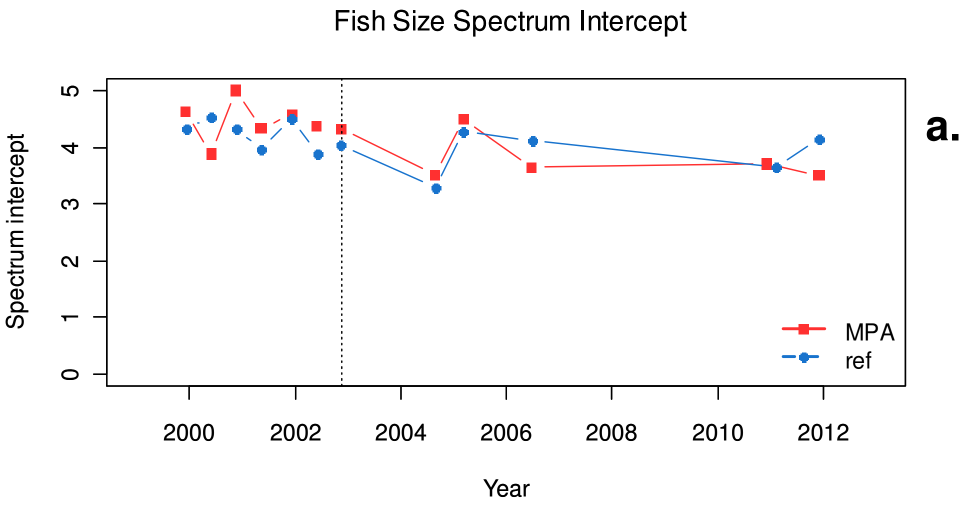
The mean size of the blue throat wrasse *Notolabrus tetricus* has decreased over time, in the order of 30-50 mm. The MNP population was consistently larger in size than that for the reference areas (Figure 3.30). *Notolabrus tetricus* Size frequency histograms are very similar for both the MNP and the reference area.

The purple wrasse *Notolabrus fucicola* populations were similar in size inside and outside the MNP, with only slight changes since 2002 (Figure **3.31**).

In December 2011, the size class structure of all fish inside the MNP had a greater dominance of fishes in 100-110 mm size class than in the reference areas (Figure 3.32).

Mean sizes of senator wrasse *Pictilabrus laticlavius* and magpie morwong *Cheilodactylus nigripes* did not change substantially over the monitoring period, with both inside and outside the MNP remaining within the same size class (Figure 3.33a, b).

Mean size of six spine leatherjackets *Meuschenia freycineti* was quite variable (200-400 mm), however densities for mean size estimation also varied considerably between surveys (Figure 3.33c).



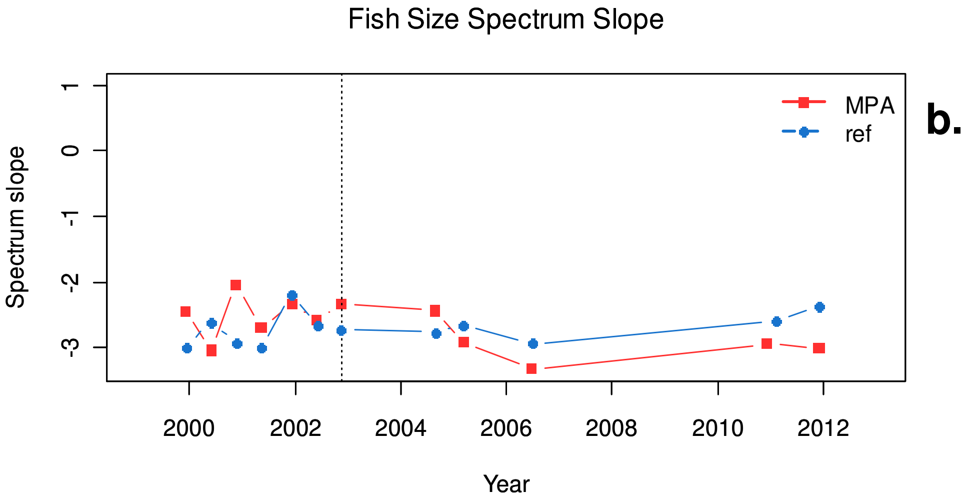


Figure 3.26. Fish size (mean ± standard error) spectra inside and outside the Wilsons Promontory Marine National Park.

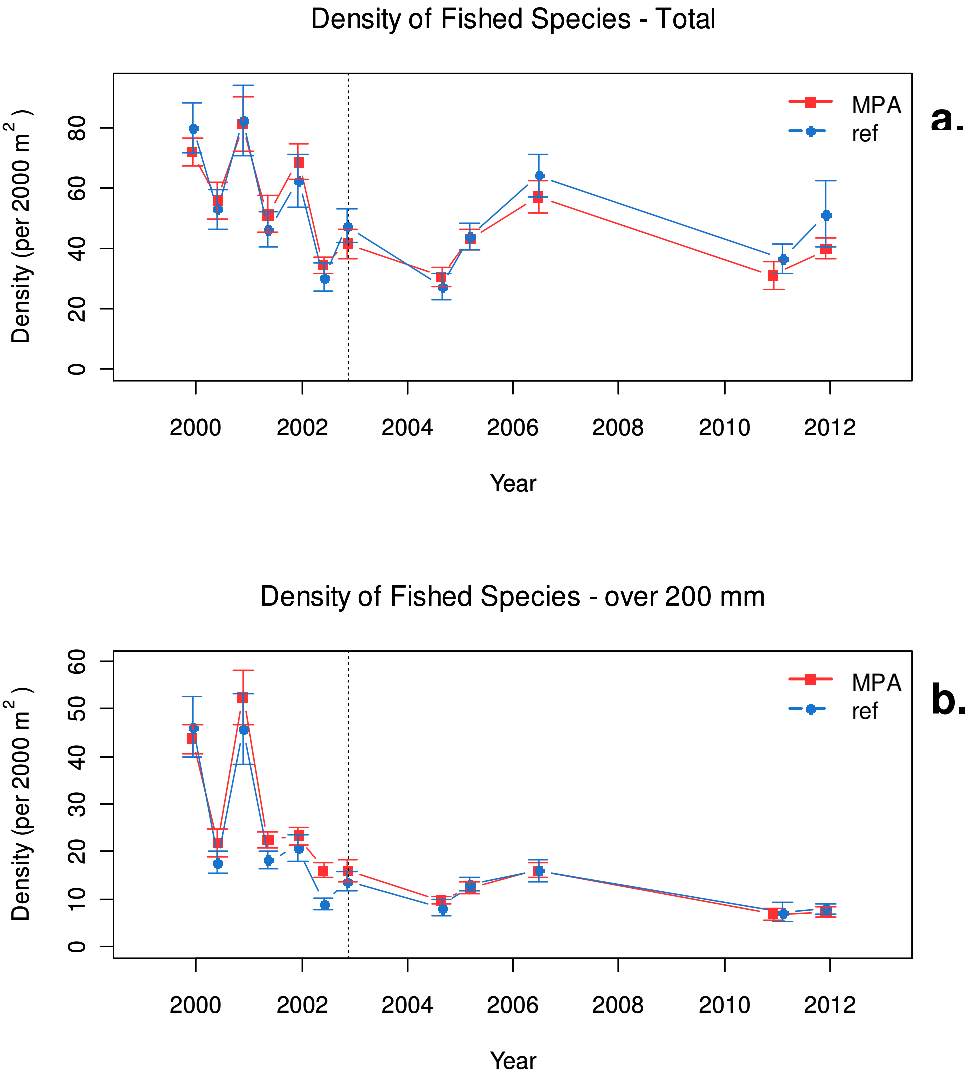
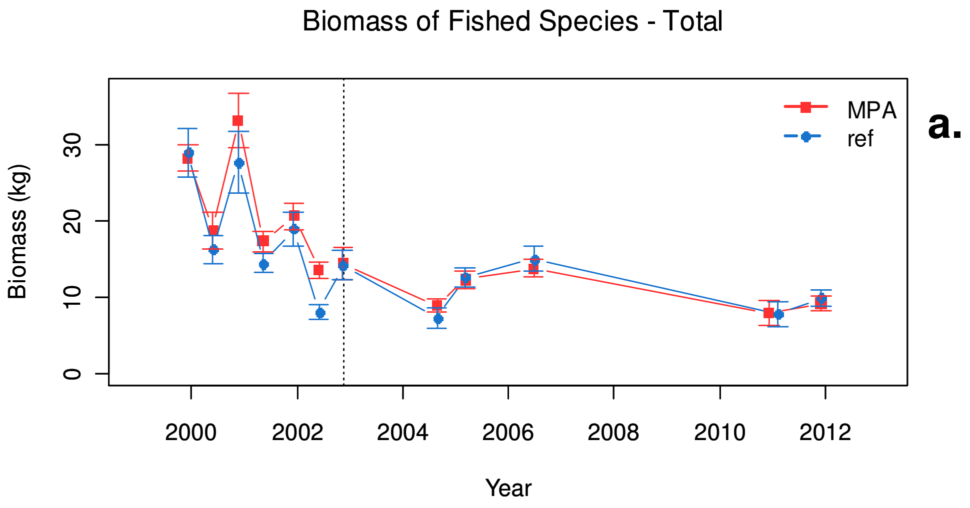


Figure 3.27. Density (mean ± standard error) of fished fish species inside and outside the Wilsons Promontory Marine National Park.



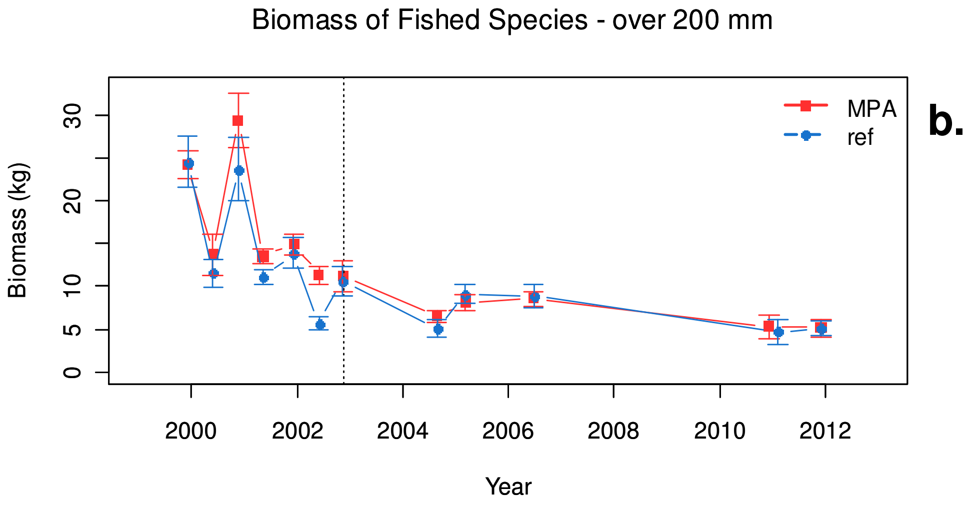


Figure 3.28. Biomass (mean ± standard error) of fished species inside and outside the Wilsons Promontory Marine National Park.

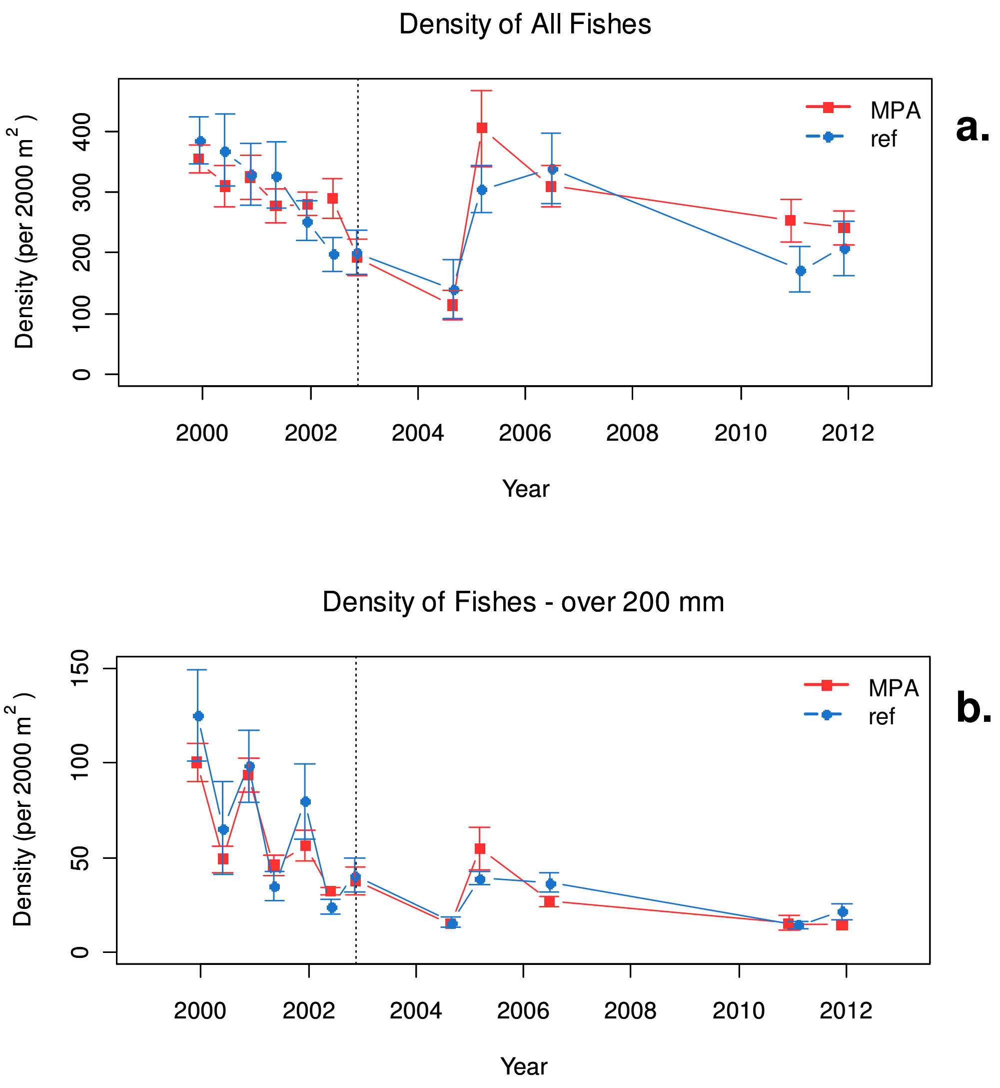


Figure 3.29. Abundance (mean ± standard error) of different size classes of fishes at Wilsons Promontory Marine National Park and reference sites.

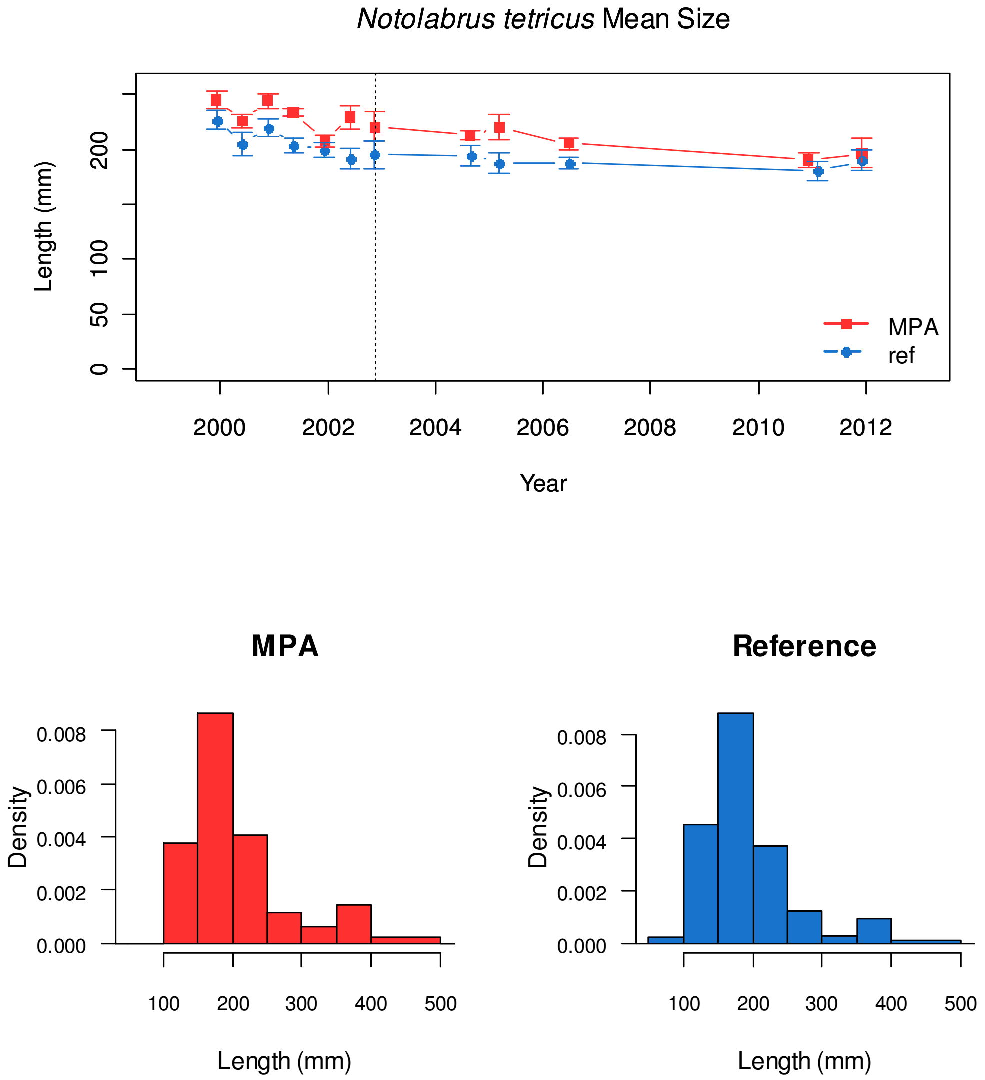


Figure 3.30. Size structure of blue throat wrasse, *Notolabrus tetricus* at Wilsons Promontory Marine National Park and reference sites.

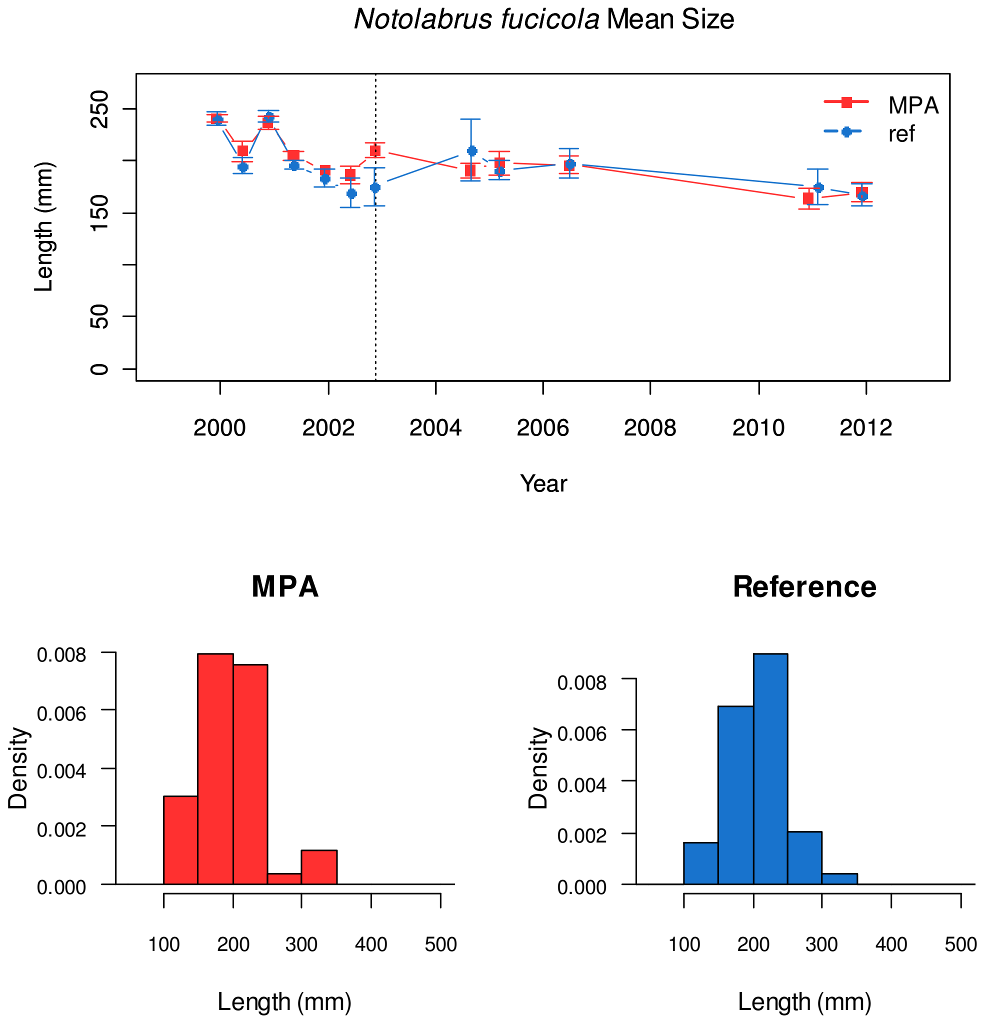


Figure 3.31. Size structure of purple wrasse, *Notolabrus fucicola* at Wilsons Promontory Marine National Park and reference sites.

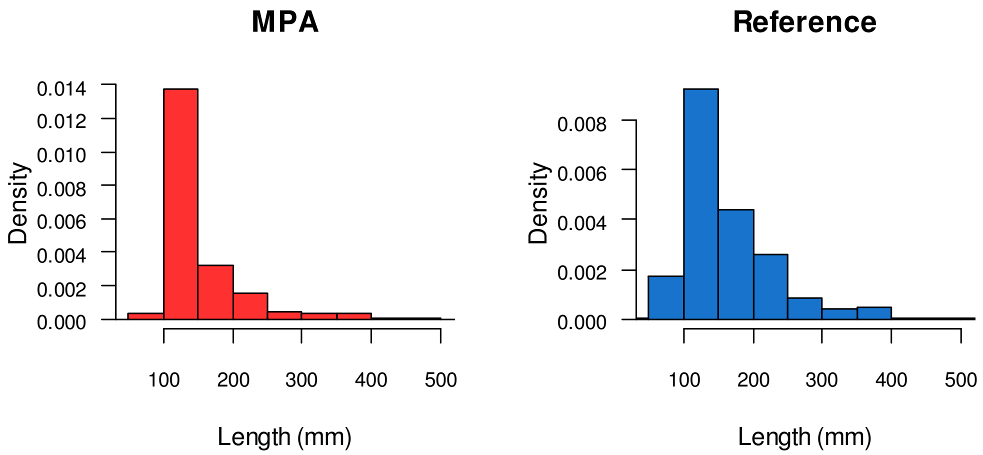


Figure 3.32. Size structure of all fishes at Wilsons Promontory Marine National Park and reference sites.

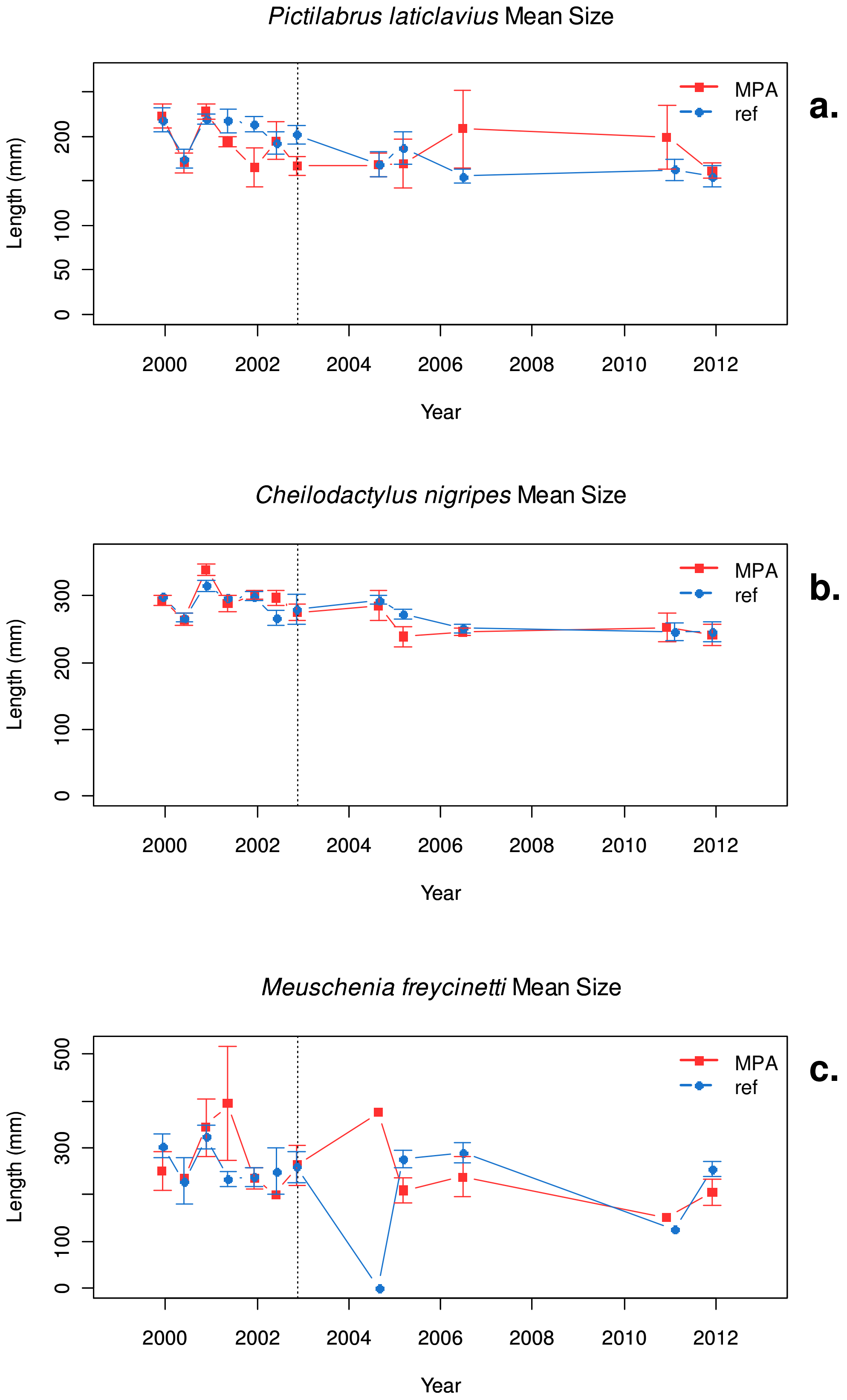


Figure 3.33. Sizes (mean ± standard error) of common fishes, at Wilsons Promontory Marine National Park and reference sites.

4. ACKNOWLEDGEMENTS

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6. APPENDIX – SITE SELECTION

The monitoring program uses repeated measurements of sites fixed in space. A statistical consequence of this design is that all sites must be sampled during each survey period. The 28 sites established in November 1999 were too numerous to reliably sample during each survey, especially in winter when the weather and shorter daylight period is less suitable for diving. Therefore, it was necessary to select a sub-set of core monitoring sites that are targeted for sampling during each excursion (with as many other sites as possible also being sampled).

Analyses from the first survey in November 1999 identified floral and faunal assemblages had both north-south and east-west differences (Edmunds *et al*. 1999). Consequently, the original sites were divided into four groups:

1. western reference, northwest coast;
2. western Marine National Park, southwest coast;
3. eastern Marine National Park, southeast coast; and
4. eastern reference, northeast coast.

A total sample of twenty sites was considered a logistically achievable minimum number of sites to be sampled during each excursion. This would provide five sites within each of the four quadrants.

Prior to the second survey in winter 2000, a sub-set of the 28 sites were selected as core monitoring sites. This selection process was based on sanctuary boundaries proposed by the Environment Conservation Council in 1999. However, these boundaries were altered for the final proposals released in 2000, which excluded the Glennie Group from the sanctuary zone (ECC 2000). The selection of core monitoring sites were revised, as described below.

The sub-set of sites were selected according the criteria:

- sites are accessible for diving under average or usual weather conditions over a ten day excursion period;
- biota at each site are representative of the sub-region; and
- biota are as similar as possible between sites inside and outside the proposed protected area.

Three sites (3103, 3116 and 3128) were excluded as core-monitoring sites based on their suitability for diving. North Norman Point (Site 3103) is near vertical and swell prone, making it very difficult for divers to work at in even low swell and sea conditions. West of West Landing (Site 3116) is highly exposed to the prevailing north-westerly to southerly weather and seas, and is particularly prone to high winds funnelling down the hills above the bay (note: strong north-westerly winds funnel around the southern tip of the Promontory, affecting southern sites as well). These presumptions were confirmed during the second survey, when none of these sites could be surveyed. The Hat (Site 3128) was excluded as it is prone to bad visibility from sediment-laden water moving down the coast from Corner Inlet.

Six sites (3101, 3106, 3107, 3121, 3122, 3127) were included as core monitoring sites to enable an examination of boundary effects, and biological trends with distance from the boundary. Sites 3106, 3107, 3121 and 3122 are located either side of the western and eastern boundaries respectively and sites 3101 and 3127 are the further-most reference sites from the sanctuary area. Site 3101 (Shellback Island) was also included because it has a relatively high algal and fish species richness, making it an interesting site to monitor in its own right.

With the above exclusion/inclusion limitations, there were 400 possible combinations of 20 sites (with five in each quadrant) that could be selected for core monitoring. An optimal combination of sites was selected based on differences in algal, fish and invertebrate assemblage structure. Matrices of differences in community composition between each site were calculated using the Bray-Curtis dissimilarity coefficient (with the matrices for fish, invertebrates and algae combined using the average B-C value for each site-comparison).

Using the Bray-Curtis coefficient, statistics calculated for each possible site combination were:

- average difference between sites within proposed reference zones (*i.e.* within reference zone variation, $BC_{within\ reference}$);
- comparison of within-zone variations ($|BC_{within\ sanctuary} - BC_{within\ reference}|$);
- average difference between sites within all groups (*i.e.* total within variation, BC_{within});
- average difference between sites from different zones (*i.e.* total between variation, $BC_{between}$); and
- difference in community structure between sanctuary and reference zones ($|BC_{between} - BC_{within}|$).

The comparison of within-zone variations, |BCwithin sanctuary - BCwithin| reference is akin to a measure of heterogeneity of variance (in community structure) between the sanctuary and reference sites. Heterogeneity of variation between the two groups being compared (sanctuary and reference sites) can confound the ability to detect changes, and should therefore be minimised where possible. The statistic |BCbetween - BCwithin| is a measure of the relative difference in community structure between sanctuary and reference zones. Changes related to the implementation of sanctuaries are easier to detect if baseline (before) differences between the sanctuary and reference zones are small. Consequently, the optimal combination of sites was selected whereby both $|BC_{within\ sanctuary} - BC_{within\ reference}|$ and $|BC_{between} - BC_{within}|$ were minimised.

The heterogeneity of variance in community structure within the park and reference zones ($|BC_{within\ park} - BC_{within\ reference}|$), and difference in community structure ($|BC_{between} - BC_{within}|$) were somewhat correlated, with a higher degree of heterogenity of variances associated in increased apparent differences in community structure (Figure 6.1). The different site combinations had a greater affect on heterogeneity of variances (range of 7 %) than between zone differences in community structure (range of 2.1 %; Figure 6.1; Table 6.1). A reasonable degree of heterogeneity of community variation was detected, with the reference zone having greater between-site variation than the park (Table 6.1). This will have to be examined carefully during statistical analysis, as such spatial confounding increasing the chance of incorrectly detecting a change (false positive or Type I error). The selected optimal site combination excluded Sites 10, 19 and 26, in addition to the sites excluded before the analysis (Sites 3, 16 and 28).

In summary, the sites selected for core monitoring were:

- Sites 3101, 3102, 3104, 3106 and 3109, western reference;
- Sites 3107, 3108, 3111, 3112 and 3113, western park;
- Sites 3115, 3117, 3118, 3120 and 3121, eastern park; and
- Sites 3122, 3123, 3124, 3125 and 3127, eastern reference.

This represents a slight change from the core monitoring sites selected prior to the Environment Conservation Council 2000 proposals. This change will have to be taken into account during analysis of the long-term, fixed site monitoring data (probably necessitating the inclusion of surrogate data).

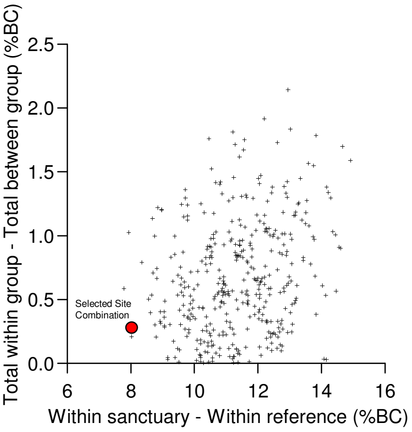

Figure 6.1. Plot for selecting an optimal set of core monitoring sites at Wilsons Promontory. Indices of within-area and between-area differences in community structure were plotted for each of 400 possible site combinations (see text and Table 2.2 for further details of calculations). Optimal combinations have similar variations between sites within the park and reference areas (Within park – Within reference is minimised) and similar community structure between park and reference areas (Within – Between is minimised). The site combination for the point circled on the graph was selected as for the Wilsons Promontory monitoring program.

Table 6.1. Indices for selecting an optimal set of core monitoring sites at Wilsons Promontory. Values given are average Bray-Curtis coefficients of difference in community structure for: (BCS) between sites within the park; (BCR) between sites within the reference area; (BCW) all within-area differences between sites; (BCB) all between-zone differences between sites (see text for further explanation of calculations). Optimal combinations have similar variations between sites within the park and reference areas (|BCR-BCS| is minimised) and similar community structure between park and reference areas (|BCB-BCW| is minimised). The first ten of 400 possible combinations with lowest values for |BCR-BCS| are listed, along with minimum, mean and maximum values. The combination shown in bold was selected as for the Wilsons Promontory monitoring program.

Site excluded								BC_S	BC_R	$\lvert BC_R - BC_S \rvert$	BC_W	BC_B	$\lvert BC_B - BC_W \rvert$
3	5	10	14	16	19	23	28	37.82	45.61	7.78	41.71	42.30	0.59
3	5	10	14	16	19	24	28	37.82	45.75	7.93	41.79	42.81	1.03
3	5	10	14	16	19	25	28	37.82	45.84	8.02	41.83	42.12	0.29
3	5	10	14	16	19	26	28	37.82	45.84	8.02	41.83	42.04	0.21
3	9	10	14	16	19	23	28	37.82	46.17	8.35	42.00	42.79	0.79
3	9	10	14	16	19	25	28	37.82	46.38	8.56	42.10	42.61	0.50
3	9	10	14	16	19	26	28	37.82	46.44	8.62	42.13	42.53	0.40
3	4	10	14	16	19	23	28	37.82	46.48	8.65	42.15	42.68	0.53
3	9	10	14	16	19	24	28	37.82	46.51	8.68	42.16	43.30	1.13
3	5	10	14	16	17	23	28	36.91	45.61	8.70	41.26	41.97	0.71
Statistics for All Combinations													
Minimum								33.56	45.61	7.78	39.58	40.73	0.01
Average								35.81	47.15	11.34	41.54	42.15	0.67
Maximum								37.82	48.47	14.91	43.43	43.74	2.14

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