
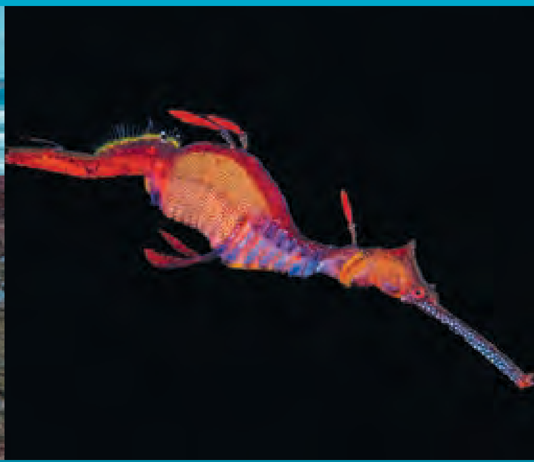


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M. Edmunds

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Author(s):
Matt Edmunds – Senior Marine Ecologist, Australian Marine Ecology Pty. Ltd.

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Victorian Subtidal Reef Monitoring Program:

Marengo Reefs Marine Sanctuary, August 2015

Matt Edmunds

Australian Marine Ecology Pty. Ltd.

August 2015

Executive summary

Shallow reef habitats cover extensive areas along the Victorian coast and are dominated by seaweeds, mobile invertebrates and fishes. These reefs are known for their high biological complexity, species diversity and productivity. They also have significant economic value through commercial and recreational fishing, diving and other tourism activities. To effectively manage and conserve these important and biologically rich habitats, the Victorian Government has established a long-term Subtidal Reef Monitoring Program (SRMP). Over time the SRMP will provide information on the status of Victorian reef flora and fauna and determine the nature and magnitude of trends in species populations and species diversity through time.

This report describes the monitoring of the Marengo Reefs Marine Sanctuary (MS). There were seven surveys, from 2003 to 2015, involving two sites at Marengo Reefs and Barnham Black.

This report aims to provide:

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

The ongoing monitoring surveys used a standardised procedure along a 200 m line divided into four transects. Each transect was surveyed for:

- abundance and size structure of large fishes;
- abundance of cryptic fishes and benthic invertebrates;
- percentage cover of macroalgae;
- abundance of a string kelp, *Macrocystis pyrifera*, when present; and
- abundance of manufactured debris.

Key observations during the monitoring program were:

- There was a relatively high cover of crayweed *Phyllospora comosa* at both sites and particularly during the most recent surveys. There were dips in abundance in 2011 and 2013 at Marengo Reefs and Barnham Black respectively.
- Crustose and erect coralline algae were predominant understorey components at Marengo Reefs.
- Fleshy red algae were more abundant at Barnham Black, with higher abundances from 2004 to 2006.

- Blacklip abalone *Haliotis rubra* abundances were very similar at both sites with very similar temporal changes, suggesting both populations are subject to the same environmental and fishing pressures.
- There has been an increasing trend in periwinkle *Turbo undulatus* abundance since 2006.
- The fish abundance and diversity was generally low and variable at all monitoring sites. There were no distinctive changes or trends in abundances or sizes over time.
- There were no major shifts in community structure attributable to climate change.
- There were no marine pest species observed at either site.
- There was no manufactured debris observed on the transects at the monitoring sites.

Contents

Index of 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*, Maori 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 *Olisthops 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.

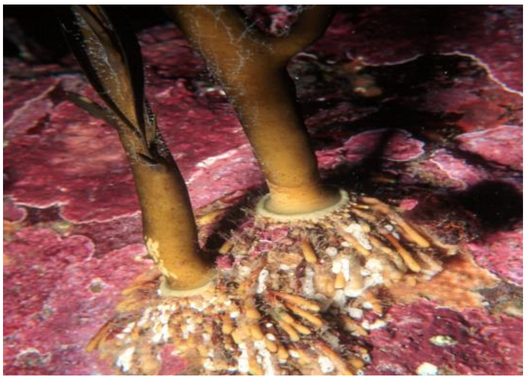
Common kelp *Ecklonia radiata* canopy

Crayweed *Phyllospora comosa* canopy

Thallose red algae *Ballia callitricha*

Red coralline algae *Jania rosea*

Green alga *Caulerpa flexilis*



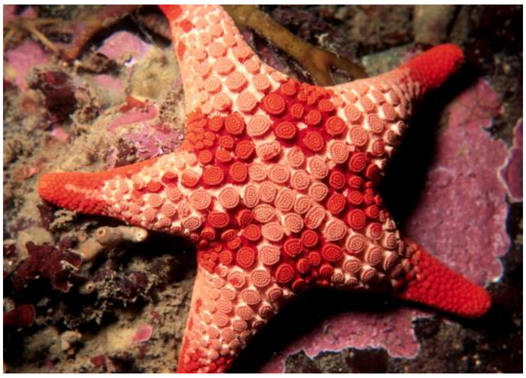
Encrusting coralline algae around crayweed *P. comosa* holdfast

Figure 1.1. Examples of common macroalgae in the Central Victoria bioregion.

Southern rock lobster
Jasus edwardsii

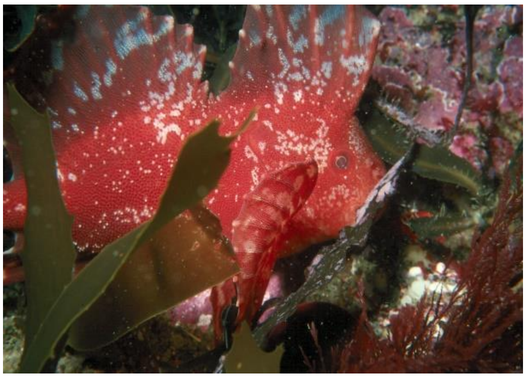
Black-lipped abalone *Haliotis rubra*

Feather star *Comanthus trichoptera*



Nectria ocellata

Sea urchin
Heliocidaris erythrogramma



Red velvet fish
Gnathanacanthus goetzeei

Figure 1.2. Examples of reef invertebrate species and cryptic fish in the Central Victoria bioregion.

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

Old wife *Enoplosus armatus*

Scalyfin *Parma victoriae*

Magpie morwong *Cheilodactylus nigripes*

Blue-throat wrasse *Notolabrus tetricus* (male)

Six-spined leatherjacket *Meuschenia freycineti* (male)

Figure 1.3. Examples of reef fishes in the Central Victoria bioregion.

1.2 Subtidal Reef Monitoring Program

1.2.1 Objectives

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

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

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

- compare changes in the status of species populations and biological communities among highly protected marine national parks and marine sanctuaries and other Victorian reef areas (*e.g.* Edgar and Barrett 1997, 1999);
- determine associations among species and among species and environmental parameters (*e.g.* depth, exposure, reef topography) and assess how these associations vary through space and time (*e.g.* Edgar *et al.* 1997; Dayton *et al.* 1998; Edmunds, Roob and Ferns 2000);
- provide benchmarks for assessing the effectiveness of management actions, in accordance with international best practice for quality environmental management systems (Holling 1978; Meredith 1997); and
- determine the responses of species and communities to unforeseen and unpredictable events such as marine pest invasions, mass mortality events, oil spills, severe storm events and climate change (*e.g.* Ebeling *et al.* 1985; Edgar 1998; Roob *et al.* 2000; Sweatman *et al.* 2003).

A monitoring survey gives an estimate of population abundance and community structure at a small window in time. Patterns seen in data from periodic surveys are unlikely to exactly match changes in the real populations over time or definitively predict the size and nature of future variation. Plots of changes over time will not exactly match the changes in real populations because changes over shorter time periods and actual minima and maxima may not be adequately sampled (*e.g.* Figure 1.4). Furthermore, because the nature and magnitude of environmental variation is different over different time scales, variation over long periods may not be adequately predicted from shorter-term data. Sources of environmental variation can operate at the scale of months (*e.g.* seasonal variation, recruitment and harvesting), years (*e.g.* El Niño), decades (*e.g.* pollution, extreme storm events) or even centuries (*e.g.* tsunamis, global warming). The monitoring program will begin to adequately reflect average trends and patterns as the surveys continue over longer periods (multiple years to decades). Results of this monitoring need to be interpreted within the context of the monitoring frequency and duration.

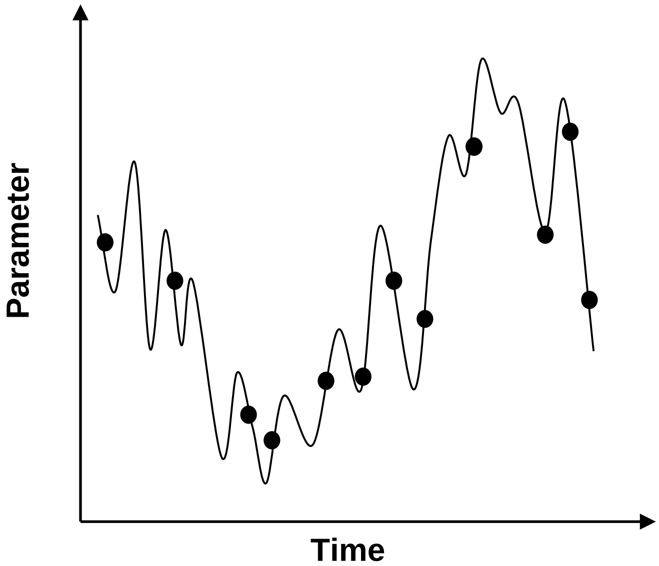


Figure 1.4. An example plot depicting change in an environmental, population or community variable over time (days, months or years) and potential patterns from isolated observations.

1.2.2 Monitoring Protocols and Locations

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

The SRMP was initiated in May 1998 in the vicinity Port Phillip Heads Marine National Park. In 1999 the SRMP was expanded to reefs in the vicinity of the Bunurong Marine National Park, Phillip Island, Wilsons Promontory Marine National Park and Point Addis Marine National Park.

In 2003 and 2004, the Subtidal Reef Monitoring Program was further extended to include Marine National Parks and Marine Sanctuaries throughout Victoria, including the Marengo Reefs Marine Sanctuary at Apollo Bay.

1.3 Monitoring Objectives at Marengo

This report describes the subtidal reef monitoring program at Marengo Reefs MS and the results of the seven surveys. The objectives of this report were to:

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

2 Methods

2.1 Site Selection and Survey Times

The Marengo Reefs Marine Sanctuary is located a short distance south of Apollo Bay, near the western boundary of the Central Victorian Bioregion (Figure 2.1). The reefs within the sanctuary consist of two rocky intertidal platforms separated by a small gutter. There is only a small area of subtidal reef habitat within the sanctuary. A monitoring site, Marengo Reef (Site 3911), was established along the 3 m depth contour on the northern (sheltered) side of the Marengo Reefs. The site consists of relatively flat slabs of reef. A reference monitoring site, Barnham Black (Site 3912), was established approximately 1.5 km north of the Marengo Reef site in 6 m depth. This site was on more complex reef with gullies and ridges.

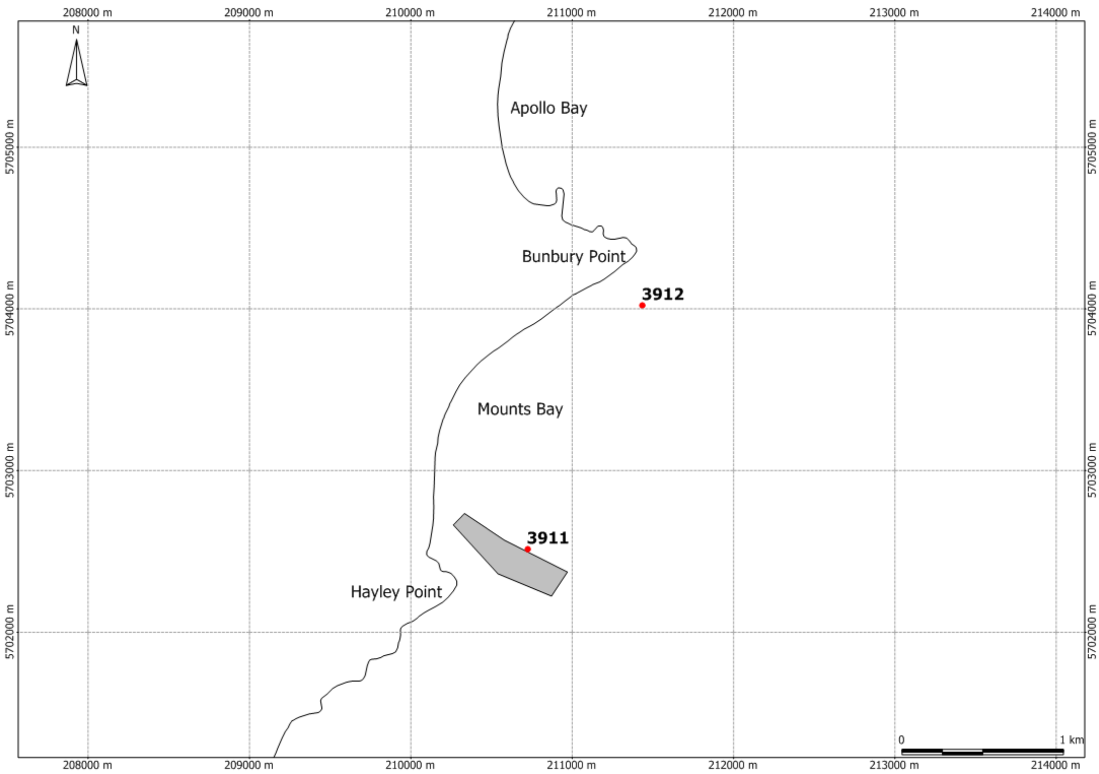


Figure 2.1. Location of monitoring sites inside and outside the Marengo Reefs Marine Sanctuary. The sanctuary is shaded in grey and the monitoring sites are shown in red (MGA coordinates).

In 2013, additional effort was invested to determine if a site could be established fully within the MS. During calm weather, the reefs and hazardous bombies inside and on the approaches to the MS were mapped and the location and nature of breaking waves were studied during heavy seas. An attempt was made to establish a transect in an east-west direction in the eastern section (Site 3703), however there were too many bombies for the vessel and divers to navigate around. There was limited available habitat to establish transects fully within the two central gulches and these areas were deemed generally unsafe because of breaking waves regularly occurring across the full width of the gulches.

A new site (Site 3704) was established in the enclosed western section where there are barrier reefs providing a modicum or protection from directly breaking waves. This site required calmer conditions to survey than the original sanctuary site (3701).

During 2015, it was observed the eastern end of the reference site was vulnerable to breaking waves and the transect at that end was angled approximately 25 m to the north.

Seven surveys were completed at Marengo Reefs MS between 2003 and 2015 (Table 2.2).

Table 2.1. Subtidal reef monitoring sites at Marengo Reefs Marine Sanctuary.

Region	No.	Description	Status	Depth (m)
Marengo	3911	Marengo Reefs	MPA	4
	3912	Barnham Black	Reference	6

Table 2.2. Subtidal reef monitoring survey times in Port Phillip Heads.

Survey	Time	Sites
1	January 2004	3911; 3912
2	March 2005	3911; 3912
3	December 2005	3911; 3912
4	June/August 2009	3911; 3912
5	April 2011	3911; 3912
6	November 2013	3911; 3912
7	August 2015	3911; 3912

2.2 Census Method

2.2.1 General Description

The Edgar-Barrett methods (Edgar and Barrett 1997, 1999; Edgar *et al*. 1997) are used for the repeated visual census of a set of sites within locations (usually within 10s km of the coastline). The position of each site is fixed, as with the position of transects surveyed within each site. Two hundred metres of four contiguous 50 m transects are surveys at each site. In accordance with the new Reef Life Survey methods data are now recorded for each side of the transect, termed ‘blocks’.

Where possible, sampling was along the 5 m (± 1 m) depth contour, to minimise spatial variability between sites. The depth of 5 m was considered optimal for monitoring because diving times are not limited by decompression schedules and these reefs are subjected to heavy fishing pressure from wrasse fishers, rock lobster fishers and divers. Sampling at some sites had to be deeper or shallower, depending on the available habitat and exposure to wave action (with sites ranging from 2 to 12 m deep).

Each site was located using GPS and numbered and weighted transect lines were run along the appropriate depth contour. The resulting 200 m of line was divided into four contiguous 50 m transects (T1 to T4). The orientation of the transects was the same for every survey, with T1 toward the north or east along the coast (i.e. anticlockwise along the open coast: T1 is in the direction of “land-to-the-left”).

For each transect, five different census methods were used to obtain adequate descriptive information on reef communities at difference spatial scales. These involved the census of: the abundance and size structure of large fishes (Method 1); the abundance of cryptic fishes and benthic invertebrates (Method 2); the percent cover of macro algae (Method 3); the density of string-kelp *Macrocystis* plants (Method 4); and the abundance and size structure of mobile fishes using a diver-operated stereo video system, DOVS (Method 5). The depth, horizontal visibility, sea state and cloud cover are recorded for each site. Horizontal visibility was gauged by the distance along the transect line to detect a 100 mm long fish (female wrasse). All field observations are recorded on underwater paper. The DOVS method records observations to a calibrated stereo video pairs.

2.2.2 Method 1 – Mobile Fishes and Cephalopods

The densities of mobile large fishes and cephalopods were estimated by a diver swimming up one side of the 50 m transect (5 m wide x 5 m high x 50 m long block). The observer recorded the number and estimated size-class of fish, within 5 m of each side of the line (50 x 10 m area). The size-classes for fish are 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 375, 400, 500, 625, 750, 875 and 1000+ mm. The data for easily sexed species were recorded separately for males and female/juveniles. Such species include the blue-throated wrasse *Notolabrus tetricus*, herring cale *Olisthops cyanomelas*, barber perch *Caesioperca rasor*, rosy wrasse *Pseudolabrus rubicundus* and some monacanthids. A total of four 50 m transects (two blocks per transect) were censused for mobile fish at each site. Dominant fish species observed in the Central Victorian Bioregion are listed in Table 2.3.

2.2.3 Method 2 – Invertebrates and Cryptic Fishes

Cryptic fishes and mega faunal invertebrates (non-sessile: *e.g.* large molluscs, echinoderms, crustaceans) were counted along the transect lines used for the fish survey. A diver counted animals within 1 m of one side of the line (a total of four 1 x 50 m transects). The diver had a known arm-length to chest measurement to standardise the 1 m distance. The maximum length of abalone and the carapace length and sex of rock lobsters were measured *in situ* using Vernier calliper, where possible. Some sites were designated abalone size monitoring sites ('Ab100' sites) and a minimum of 100 abalone were measured at these sites (where possible within diving limits). Sessile animals were not counted with the exception of any marine pest species of pre-determined ecological interest (such as the introduced feather worm *Sabella spallanzanii* and the native feather worm at Point Hicks *Sabellastarte australis*).

Selected specimens were collected for identification and preservation in a reference collection. Dominant cryptic fish and invertebrate species in the Central Victorian Bioregion are listed in Table 2.4.

2.2.4 Method 2b – Manufactured Debris

Manufactured debris items were counted along the invertebrate transect. The debris were classified into categories: fishing gear; plastic; cloth; metal; glass; wood; other and none (to indicate it was looked for but none seen). It was also recorded whether the debris was left or removed.

2.2.5 Method 3 – Macroalgae

The abundance of macrophytes (kelp, seaweeds, and seagrass) was quantified using a points-cover method. A quadrat, 0.5 m x 0.5 m, was placed at 10 m intervals along the transect line (5 quadrats per transect). The quadrat was divided into a grid of 7 x 7 perpendicular lines, giving 50 points (including one corner). Cover was estimated by counting the number of points intersecting with a species (Figure 2.2). The points-cover was determined independently for each species. Where there was a canopy or layers, the total number of points-counts from all species may be greater than 50. Selected specimens were collected for identification and preservation in a reference collection. Dominant macrophyte species in the Central Victorian Bioregion are listed in Table 2.6.

2.2.6 Method 4 – Macrocystis

Where present, the density of string kelp *Macrocystis pyrifera* was estimated at the same time by the seaweed (Method 3) observer. While swimming between quadrat positions, the diver counted all observable *Macrocystis* plants within 5 m either side of the transect for each 10 m section of the transect (10 x 10 m sections). This survey component commenced in spring 1999.

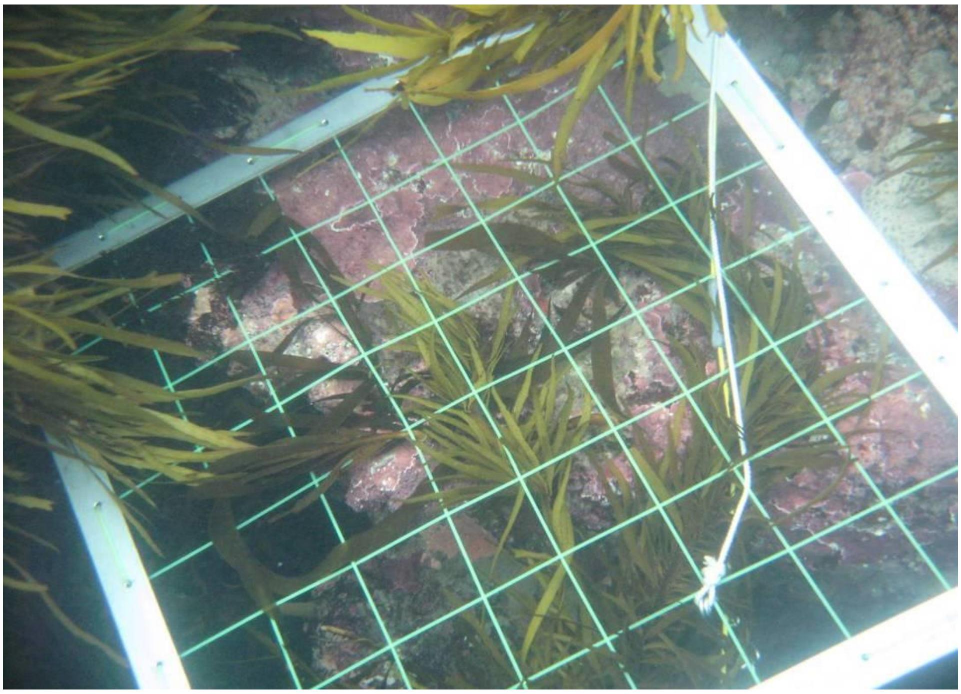


Figure 2.2. The cover of macrophytes is measured by the number of points intersecting each species on the quadrat grid.

2.2.7 Method 5 – Fish Stereo Video

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

The stereo camera system was operated simultaneously by the diver who did the UVC fish and done at the same time. The stereo camera frame had the underwater UVC slate mounted on it for the simultaneous observations. The camera system was pointed parallel with the transect line and downward 30º with the diver swimming 2.5 m to one side of the transect and 1.3 m above the canopy, as with the UVC method. The camera unit was tilted vertically (up or down) according to the fish seen to ensure adequate video for size measurements, but was generally tilted down at an angle of 30º. Lateral movement of the unit was minimised. The survey speed was 10 m per minute (0.17 m s^{-1}).

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

2.2.8 Method 0 – Off-Transect Sightings

Any species of interest sighted off-transect, or on transect but not during the formal survey, was recorded with the designation of Method 0 and Transect 0. Note that additional off transect abalone measurements were recorded as Method 2, Transect 0.

Table 2.3. Mobile fishes and cephalopods (Method 1) taxa commonly censused along the coast of Victoria.

Method 1		
Cephalopoda	**Mobile Bony Fishes**	**Mobile Bony Fishes**
Octopus maorum	*Upeneichthys vlaminghii*	*Odax acroptilus*
Sepia apama	*Girella tricuspidata*	*Olisthops cyanomelas*
Sepioteuthis australis	*Girella elevata*	*Siphonognathus attenuatus*
Sharks and Rays	*Girella zebra*	*Siphonognathus beddomei*
Heterodontus portusjacksoni	*Scorpis aequipinnis*	*Siphonognathus radiatus*
Parascyllium variolatum	*Scorpis lineolata*	*Neoodax balteatus*
Cephaloscyllium laticeps	*Atypichthys strigatus*	*Acanthaluteres vittiger*
Trygonorrhina fasciata	*Tilodon sexfasciatus*	*Brachaluteres jacksonianus*
Trygonorrhina guaneria	*Enoplosus armatus*	*Monacanthus chinensis*
Dasyatis brevicaudata	*Pentaceropsis recurvirostris*	*Scobinichthys granulatus*
Myliobatis australis	*Parma victoriae*	*Meuschenia flavolineata*
Urolophus cruciatus	*Parma microlepis*	*Meuschenia freycineti*
Urolophus paucimaculatus	*Chromis hypsilepis*	*Meuschenia galii*
Urolophus gigas	*Aplodactylus arctidens*	*Meuschenia hippocrepis*
Trygonoptera testacea	*Cheilodactylus nigripes*	*Meuschenia scaber*
Mobile Bony Fishes	*Cheilodactylus spectabilis*	*Meuschenia venusta*
Phyllopteryx taeniolatus	*Nemadactylus douglasii*	*Eubalichthys gunnii*
Caesioperca lepidoptera	*Dactylophora nigricans*	*Eubalichthys mosaicus*
Caesioperca rasor	*Latridopsis forsteri*	*Aracana aurita*
Hypoplectrodes maccullochi	*Scorpaena papillosa*	*Aracana ornata*
Trachinops caudimaculatus	*Sphyraena novaehollandiae*	*Tetractenos glaber*
Dinolestes lewini	*Achoerodus gouldii*	*Diodon nichthemerus*
Sillaginodes punctata	*Ophthalmolepis lineolata*	*Contusus brevicaudus*
Pseudocaranx wrighti	*Dotalabrus aurantiacus*	
Trachurus novaezelandiae	*Notolabrus tetricus*	
Trachurus declivis	*Notolabrus fucicola*	
Arripis spp	*Pseudolabrus rubicundus*	
Arripis georgianus	*Pictilabrus laticlavius*	**Mammals and Reptiles**
Pagrus auratus		*Arctocephalus pusillus*

Table 2.4. Invertebrate and cryptic fish (Method 2) taxa commonly censused along the coast of Victoria.

Method 2		
Molluscs	**Crustacea**	**Echinoderms**
Haliotis rubra	*Jasus edwardsii*	*Comanthus trichoptera*
Haliotis laevigata	*Guinusia chabrus*	*Comanthus tasmaniae*
Haliotis scalaris	*Nectocarcinus tuberculosus*	*Heliocidaris erythrogramma*
Scutus antipodes	*Paguristes frontalis*	*Goniocidaris tubaria*
Turbo undulatus	*Strigopagurus strigimanus*	*Amblypneustes* spp
Phasianella australis	Paguridae spp (other)	*Holopneustes inflatus*
Phasianella ventricosa	**Cryptic Fishes**	*Holopneustes porosissimus*
Phasianella ventricosa	*Gymnothorax prasinus*	*Holopneustes purpurascens*
Phasianotrochus eximius	*Pempheris multiradiata*	*Tosia magnifica*
Dicathais orbita	*Gnathanacanthus goetzeei*	*Tosia australis*
Australaria australasia	*Aetapcus maculatus*	*Pentagonaster dubeni*
Penion mandarinus	*Parascyllium variolatum*	*Petricia vernicina*
Cabestana spengleri	*Bovichtus angustifrons*	*Fromia polypora*
Charonia lampas	*Cristiceps australis*	*Echinaster arcystatus*
Conus anemone	*Heteroclinus johnstoni*	*Plectaster decanus*
Neodoris chrysoderma	*Cliniid* spp	*Nectria macrobrachia*
Ceratosoma brevicaudatum	*Norfolkia clarkei*	*Nectria ocellata*
Mimachlamys asperrima	*Forsterygion varium*	*Nectria multispina*
Octopus maorum	*Paraplesiops meleagris*	*Pseudonepanthia troughtoni*
Cnidaria		*Meridiastra gunnii*
Phlyctenactis tuberculosa		*Uniophora granifera*
Annelida		*Coscinasterias muricata*
Sabella spallanzanii		*Asterias amurensis*

Table 2.5. Manufactured debris (Method 2b) censused in Victoria.

Method 2		
Fishing gear	Metal	Glass
Plastic	Cloth	Wood

Table 2.6. Common macroalgae and seagrass (Method 3) taxa censused along the coast of Victoria.

Method 3		
Chlorophyta (green algae)	**Chromista (brown algae)**	**Chromista (brown algae)**
Ulva spp	*Homeostrichus sinclairii*	*Sargassum spinuligerum*
Cladophora prolifera	*Exallosorus olsenii*	*Sargassum varians*
Apjohnia lativaerens	*Chlanidophora microphylla*	*Sargassum verruculosum*
Caulerpa longifolia	*Cladostephus spongiosus*	*Sargassum vestitum*
Caulerpa trifaria	*Carpomitra costata*	*Ectocarpus spp*
Caulerpa scalpelliformis	*Perithalia cordata*	**Rhodophyta (red algae)**
Caulerpa remotifolia	*Bellotia eriophorum*	*Pterocladiella capillacea*
Caulerpa brownii	*Macrocystis pyrifera*	*Pterocladia lucida*
Caulerpa flexilis	*Ecklonia radiata*	*Gelidium asperum*
Caulerpa flexilis var *muelleri*	*Undaria pinnatifida*	*Gelidium australe*
Caulerpa obscura	*Durvillaea potatorum*	*Sonderophycus coriaceus*
Caulerpa sedioides f. *geminata*	*Xiphophora chondrophylla*	*Peyssonnelia* sp
Caulerpa cactoides	*Phyllospora comosa*	*Areschougia congesta*
Caulerpa hodgkinsoniae	*Seirococcus axillaris*	*Acrotylus australis*
Caulerpa vesiculifera	*Scaberia agardhii*	*Nizymenia australis*
Caulerpa simpliciuscula	*Carpoglossum confluens*	*Polyopes constrictus*
Codium pomoides	*Cystophora brownii*	*Erythroclonium* spp
Codium spongiosum	*Cystophora expansa*	*Solieria robusta*
Codium australicum	*Cystophora grevillei*	*Thamnoclonium dichotomum*
Codium duthieae	*Cystophora monilifera*	*Callophyllis rangiferina*
Codium galeatum	*Cystophora moniliformis*	*Stenogramme interrupta*
Codium harveyi	*Cystophora pectinata*	*Callophycus laxus*
Codium lucasii	*Cystophora platylobium*	*Plocamium angustum*
Chromista (brown algae)	*Cystophora retorta*	*P. cirrhosum*
Halopteris spp	*Cystophora siliquosa*	*P. mertensii*
Dictyota dichotoma	*Cystophora retroflexa*	*P. dilatatum*
Dictyota fastigiata	*Cystophora subfarcinata*	*P. preissianum*
Dictyota fenestrata	*Cystophora xiphocarpa*	*P. cartilagineum*
Dictyota gunniana	*Caulocystis cephalornithos*	*P. leptophyllum*
Dictyopteris muelleri	*Acrocarpia paniculata*	*P. patagiatum*
Dictyopteris acrostichoides	*Sargassum decipiens*	*Phacelocarpus alatus*
Zonaria angustata	*Sargassum fallax*	*Phacelocarpus complanatus*
Zonaria crenata	*Sargassum heteromorphum*	*Phacelocarpus peperocarpos*
Zonaria spiralis	*Sargassum sonderi*	*Asparagopsis armata*
Zonaria turneriana	*Sargassum decipiens*	*Delisea pulchra*

Table 2.6 (continued). Common macroalgae and seagrass (Method 3) taxa censused along the coast of Victoria.

Method 3		
Rhodophyta (red algae)	**Rhodophyta (red algae)**	**Rhodophyta (red algae)**
Ptilonia australasica	*Halopeltis australis*	*Gelinaria ulvoidea*
Gracilaria cliftoni	*Tylotus obtusatus*	*Echinothamnion hystrix*
Curdiea angustata	*Champia* spp	*Hypnea ramentacea*
Melanthalia obtusata	*Champia viridis*	Thuretia quercifolia
Melanthalia abscissa	*Ceramium* spp	Other thallose red algae
Melanthalia fastigiata	*Euptilota articulata*	Filamentous red algae
Amphiroa anceps	Griffithsia monilis	**Tracheophyta (seagrass)**
Jania sagittata	Griffithsia teges	*Zostera nigricaulis*
Jania rosea	*Ballia callitricha*	*Halophila australis*
Arthrocardia wardii	*Euptilota articulata*	*Amphibolis antarctica*
Metagoniolithon radiatum	*Dictyomenia harveyana*	**Abiotic**
Mastophoropsis canaliculata	*Dictyomenia tridens*	Sand
Metamastophora flabellata	*Jeannerettia lobata*	
Crustose coralline algae	*Hemineura frondosa*	
Botryocladia obovata	*Lenormandia marginata*	
Gloiosaccion brownii	*Epiglossum smithiae*	
Erythrymenia minuta	*Laurencia clavata*	
Cephalocystis furcellata	*Laurencia elata*	
	Laurencia filiformis	

2.3 Data Analysis – Condition indicators

2.3.1 Approach

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

- a shift to smaller organisms;
- reduced diversity with loss of sensitive species;
- increased dominance by weedy and exotic species;
- shortened food chain lengths;
- altered energy flows and nutrient cycling;
- increased disease prevalence; and
- reduced stability/increased variability (Rapport *et al.* 1995).

A suite of indicators was developed for the Tasmanian reef monitoring program, which uses the same Edgar-Barrett underwater visual census methods (Stuart-Smith *et al.* 2008). The indicators are grouped into the general categories: biodiversity; ecosystem functions; introduced pests; climate change and fishing. The Stuart-Smith indicators were followed and adapted for the Victorian SRMP. These indices are consistent with the reviews mentioned above. Key adaptations were the use of absolute values rather than proportions, as the Victorian data had considerable concurrent variation in the numerator and denominator of many indices, making proportional indices difficult to interpret. The Stuart-Smith approach for examining community changes was extended by using the multivariate control charting method of Anderson and Thompson (2004).

The indicators were calculated separately for the three survey components, fishes, invertebrates and algae.

The indicators presented in this report provide a basis for assessment and further refinement of indicators for marine protected area performance assessment and management.

2.3.2 Biodiversity

Community Structure

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

Count data were log transformed and points-cover values were not transformed prior to multivariate analyses.

For fishes, only site-attached species were included in the analyses.

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

Kruskal stress is an indicator statistic calculated during the ordination process and indicates the degree of disparity between the reduced dimensional data set and the original hyper-dimensional data set. A guide to interpreting the Kruskal stress indicator is given by Clarke (1993): (< 0.1) a good ordination with little real risk of drawing false inferences; (< 0.2) can lead to a usable picture, although for values at the upper end of this range there is potential to mislead; and (> 0.2) likely to yield plots which can be dangerous to interpret. These guidelines are simplistic and increasing stress is correlated with increasing numbers of samples. Where high stress was encountered with a two-dimensional data set, three-dimensional solutions were sought to ensure adequate representation of the higher-dimensional patterns.

Trends in Community Structure

Multivariate control charting was used to examine the degree of changes in community structure over time. Two criteria are applied for the SRMP, the first being the deviation in community structure at a time *t* from the centroid of baseline community structures (1998 to 2002). This criterion is more sensitive to the detection of gradual changes over time away from the baseline conditions. In this case, there was no before-period because the no-take zone was already established. The first two surveys were used as a baseline period to detect longer term deviations. The second criterion was the deviation in community structure at time *t* to the centroid of all previous times. This criterion is more sensitive at detecting abrupt or pulse changes.

Control charts were prepared for each site. The control chart analysis used the methods of Anderson and Thompson (2004) and calculations were done using the software ControlChart.exe (Anderson 2008). The analysis used the Bray-Curtis dissimilarity coefficient and the same data transformations described above. Bootstrapping was used to provide control-chart limits for identifying changes that are 'out of the ordinary'. In this case, a 90th and 95th percentile statistic was calculated from 10000 bootstrap samples as provisional limits. The 50th percentile was also presented to assist in interpreting the control charts.

Species Diversity

The total number of individuals, N, was calculated as the sum of the abundance of all individuals across species.

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

Species diversity, as a measure of the distribution of individuals among the species, was indicated using Hill's N_2 statistic (which is equivalent to the reciprocal of Simpson's index). In general, Hills N_2 gives an indication of the number of dominant species within a community. Hills N_2 provides more weighting for common species, in contrast to indices such as the Shannon-Weiner Index (Krebs 1999), which weights the rarer species.

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

Abundances of Selected Species

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

2.3.3 Ecosystem Functional Components

Plant Habitat and Production

Biogenic habitat and standing stocks of primary producers was indicated by the pooled abundances of macrophyte groups:

- crustose coralline algae;
- canopy browns – defined here as *Ecklonia radiata, Undaria pinnatifida, Lessonia corrugata, Macrocystis pyrifera*, *Durvillaea potatorum, Phyllospora comosa, Seirococcus axillaris, Acrocarpia paniculata, Cystophora platylobium, C. moniliformis, C. pectinata, C. monilifera, C. retorta* and *C. retroflexa;*

- smaller browns (all other brown species except Ectocarpales);
- erect coralline algae;
- thallose red algae (except filamentous species);
- green algae; and
- seagrass *Amphibolis antarctica*.

Invertebrate Groups

The abundances of invertebrates were pooled into the functional groups:

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

Fish Groups

The abundances of fishes were also pooled into trophic groups:

- herbivores and omnivorous grazers;
- foraging predators, including pickers and foragers of stationary, benthic prey such as amphipods, crabs and gastropods;
- hunter predators, including fishes that hunt mobile prey, particularly other fishes, as chasers and ambushers; and
- planktivores, including feeders of zooplankton and small fish in the water column.

Sediment Cover

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

2.3.4 Introduced Species

The status of introduced species is initially reported as presence-absence of species. Where a species is established and the SRMP measures the abundance of that species, indicators of status are:

- number of introduced species;
- total abundance of introduced species; and

- where the data are suitable, time series of abundance of selected introduced species – noting the timing of surveys may influence the time series.

2.3.5 Climate Change

Species Composition

Climate change is likely to cause changes to current strengths and circulation patterns which affect both the ambient temperature regime and the dispersion and recruitment of propagules or larvae. In Victoria, there may be increased incursions of the East Australia Current into eastern Victoria and the South Australia Current into western Victoria and Bass Strait. Biological responses to such changes are potentially indicated by biogeographical changes in the species composition, toward that of adjacent, warmer bioregions. For this analysis, each species was assigned a nominal geographical range:

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

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

Macrocystis pyrifera

The string kelp *Macrocystis pyrifera*, which includes the former species *M. angustifolia* (Macaya and Zuccarello 2010), is considered potentially vulnerable to climate change through reduced nutrient supply from drought and nutrient poorer warmer waters (Edyvane 2003). The mean abundance of *M. pyrifera* were plotted using densities from Method 4, or cover estimates from Method 4 where density data were unavailable. *Macrocystis pyrifera* provides considerable vertical structure to reef habitats and can also attenuate water currents and wave motion. The loss of *M. pyrifera* habitats may reflect ecosystem functional changes.

Centrostephanus rodgersii

The geographical range of the long-spined sea urchin, *Centrostephanus rodgersii,* has increased conspicuously over the past decades (Johnson *et al.* 2005). This grazing species can cause considerable habitat modification, decreasing seaweed canopy cover and increasing the area of urchin barrens. Abundances are determined using Method 2 and average abundances are plotted through time. The extent of urchin barrens, of any sea urchin species, will be monitored using data from Method 6, as time series data become available. The abundance of *C. rodgersii* are also influenced by interactions with abalone as competitors for crevice space, Abalone divers may periodically 'cull' urchins within a reef patch and the species is also of interest to urchin harvesters.

Durvillaea potatorum

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

2.3.6 Fishing

Abalone

Indicators of harvesting pressure on abalone were mean density, mean size and the size frequency structure. The size structure indicators were the intercept and slope of the size spectrum. Size frequencies were first compiled for 10 mm size classes centred at 105, 115, 125, 135, 145, 155 and 165 mm and the spectrum slope and intercept was determined by a linear regression of ln(count + 1) versus ln(size + 1). The indicators were calculated for the blacklip abalone, *Haliotis rubra,* in most regions and for the greenlip abalone, *H. laevigata,* where present in suitable densities (in central and western Victoria).

Rock Lobster

The southern rock lobster, *Jasus edwardsii,* is present throughout Victoria. The monitoring transects generally did not traverse rock lobster microhabitats. Abundances and sizes were reported where data were available.

Fish

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

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

The size structure indicators were the intercept and slope of the size spectrum. Size frequencies were first compiled for 50 mm size classes centred at 100, 150, 200, 250, 300, 350, 400, 450, 500 and 550 mm and the spectrum slope and intercept was determined by a linear regression of ln(count + 1) versus ln(size + 1).

Biomass was calculated for the predominantly fished species, excluding incidentally caught or by-catch species. Lengths were converted to weights using published conversion factors for the power relationship:

$$weight(grams) = a \times Length(cm)^b$$

The weight estimations used the coefficients compiled by FishBase (www.fishbase.org). The length-weight parameters used are provided in Table 2.7.

Table 2.7. Fish length-weight conversion parameters used to calculate the biomass of fished species. Where parameters were unavailable, parameters for a similar species were applied.

Species	a	b	Source
Cheilodactylus spectabilis	0.01660	3.00	Fishbase
Cheilodactylus nigripes	0.01202	3.02	Fishbase
Cheilodactylus fuscus	0.01202	3.02	Fishbase
Latridopsis forsteri	0.01660	3.00	Fishbase: *C. spectabilis*
Notolabrus tetricus	0.00977	3.07	Fishbase: *N. fucicola*
Notolabrus fucicola	0.00977	3.07	Fishbase
Notolabrus gymnogenis	0.0977	3.07	Fishbase: *N. fucicola*
Achoerodus viridis	0.01800	3.044	Fishbase: *A. gouldii*
Achoerodus gouldii	0.01800	3.044	Fishbase
Sphyraena novaehollandiae	0.00813	2.80	Fishbase
Sphyraena obtusata	0.00776	2.91	Fishbase
Sillago flindersi	0.00851	3.09	Fishbase
Sillaginodes punctata	0.00389	3.15	Fishbase
Seriola lalandii	0.01820	2.944	Fishbase
Seriola hippos	0.01820	2.944	Fishbase: *S. lalandii*
Scorpis aequipinnis	0.01000	3.04	Fishbase: generic parameters
Pentaceropsis recurvirostris	0.01000	3.04	Fishbase: generic parameters
Pagrus auratus	0.02399	2.94	Fishbase
Meuschenia scaber	0.02884	2.96	Fishbase
Meuschenia hippocrepis	0.02884	2.96	Fishbase: *M. scaber*
Meuschenia freycineti	0.02884	2.96	Fishbase: *M. scaber*
Acanthaluteres vittiger	0.02089	2.92	Fishbase: *M. scaber*

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3 Results

3.1 Macroalgae

The algae community structure at both sites was dominated by coverage of the crayweed *Phyllospora comosa*. Understory assemblages at Marengo Reefs were composed of crustose coralline algae, erect corallines such as *Jania rosea*, and a low coverage of smaller browns. The Barnham Black understory was primarily composed of invertebrate communities and a low coverage of fleshy red algae such as *Plocamium angustum*.

The three-dimensional nMDS plot indicated both sites differed in community structure with little overlap most of the time (Figure 3.1). The differences were largely because of a higher cover of crustose coralline algae and understorey red and brown species at Marengo Reefs. Despite the difference in community structure, the two sites exhibited similar rates of change over time.

The control charts indicated there were gradual shifts in community structure at both sites over time. The greatest difference from the baseline conditions was in 2011, after which there was a shift back towards initial conditions (Figure 3.2).

Total algal abundance at both sites at a slight declining trend from 2004 to 2013, followed by a rapid increase to highest recorded levels in 2015 (Figure 3.3a). There were no clear trends in time for species richness and algal diversity (Figures 3.3b and 3.3c).

There were dips in the cover of crayweed *Phyllospora comosa* in 2011 and 2013 at Marengo Reefs and Barnham Black respectively. This was followed by a relatively rapid recovery at both sites (Figure 3.4a).

The common kelp *Ecklonia radiata* was only a very minor component of the canopy, of less than 1 % cover for most surveys at both sites. There was an increased component of 6 % cover at Barnham Black in 2013 and 2015 (Figure 3.4b).

The brown alga *Acrocarpia paniculata* appeared to have periodic increases in cover at Barnham black, being higher in 2004-2005 and 2013-2015 (Figure 3.4c).

The brown algae *Cystophora retorta* and *Cystophora moniliformis* were variable and low in abundance at Marengo Reefs and largely absent at Barnham Black.

Crustose coralline algae followed similar temporal trends at both sites, with peaks in 2011 and 2015. The abundance was generally much higher at Marengo Reefs, along with the erect coralline alga *Jania rosea* (Figures 3.4f and 3.4g).

The fleshy thallose red algae *Plocamium angustum* and *Plocamium dilatatum* were both higher in abundance at Barnham Black from 2004 to 2006. An increase in abundance of *P. dilatatum* was apparent in 2015 (Figures 3.4h and 3.4i)..

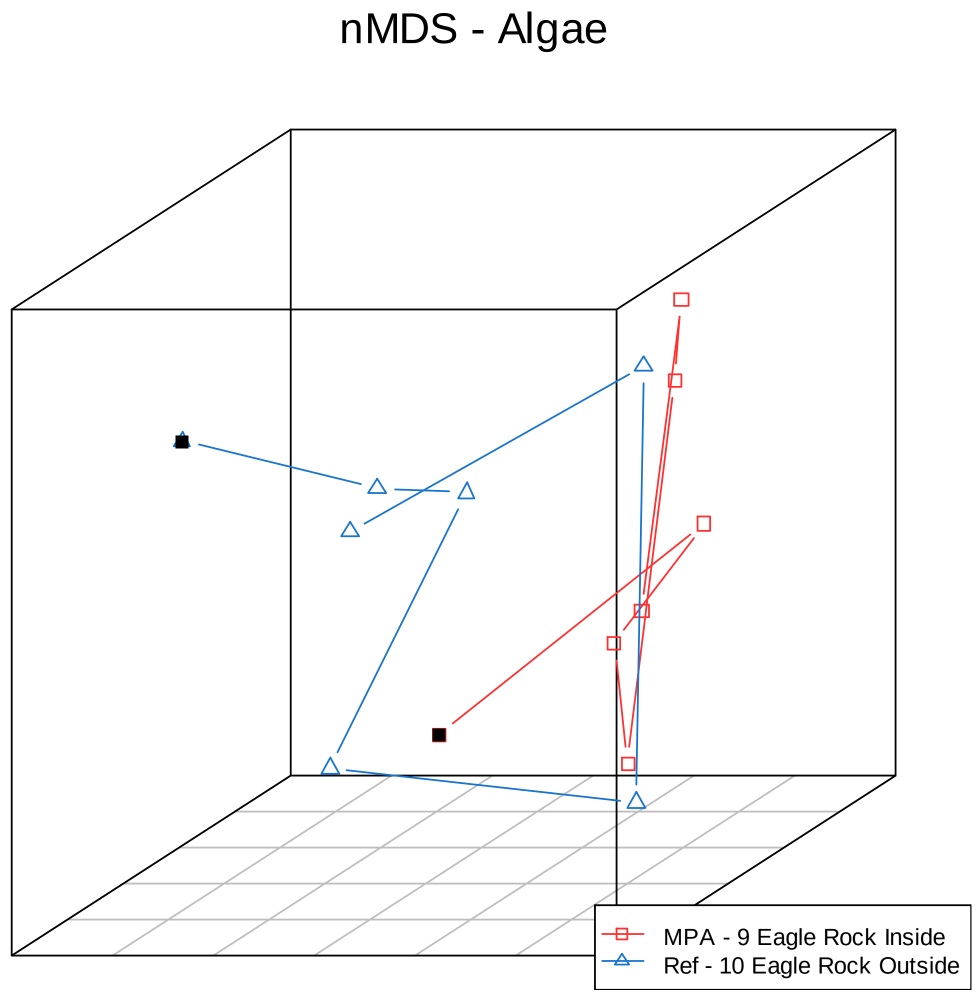


Figure 3.1. Three-dimensional nMDS plot of algal assemblage structure at Marengo Reefs MS. Black filled shapes denote the first survey time. Kruskal stress = 0.06.

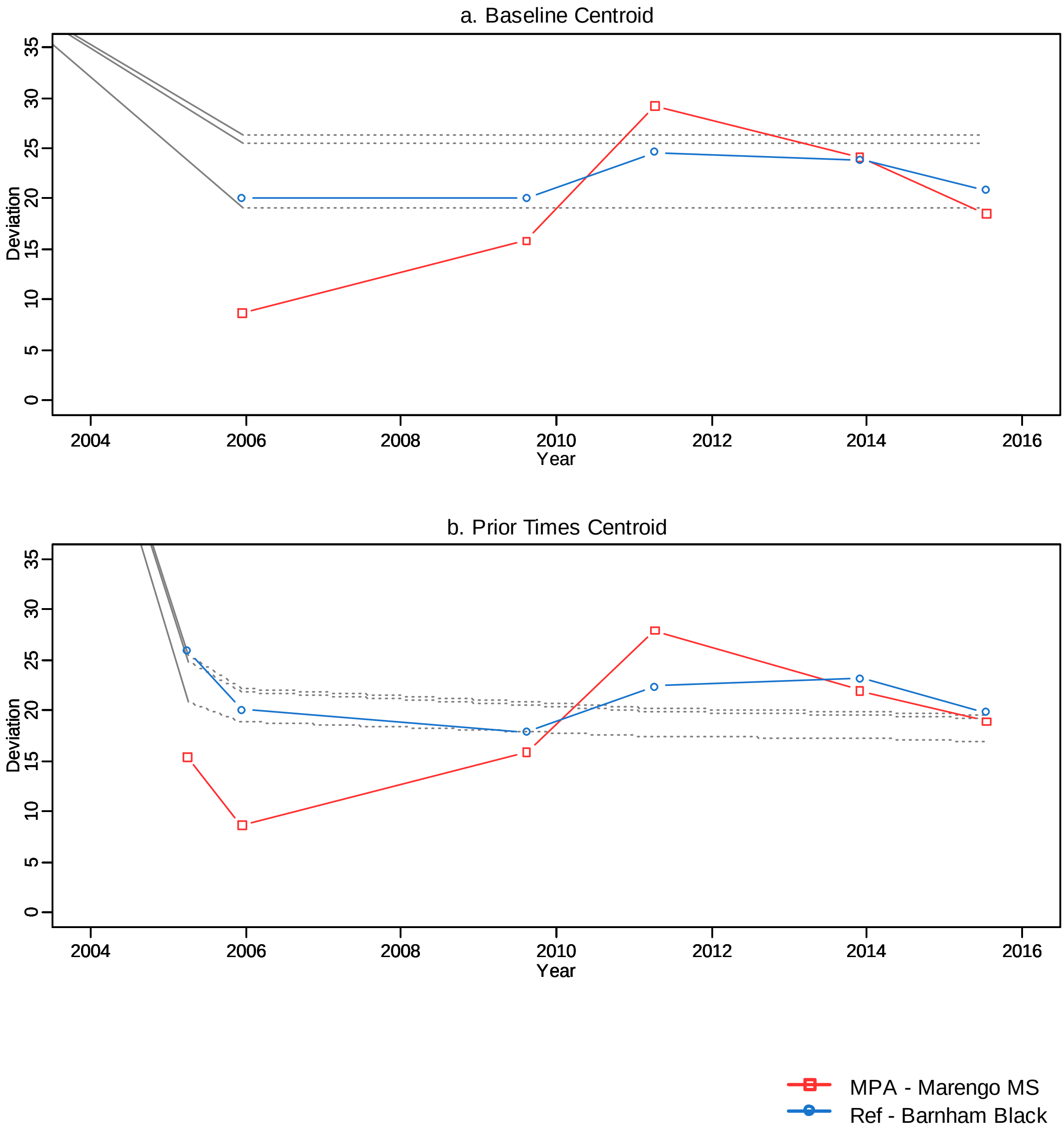


Figure 3.2. Control charts of algal assemblage structure inside and outside the Marengo Reefs MS.

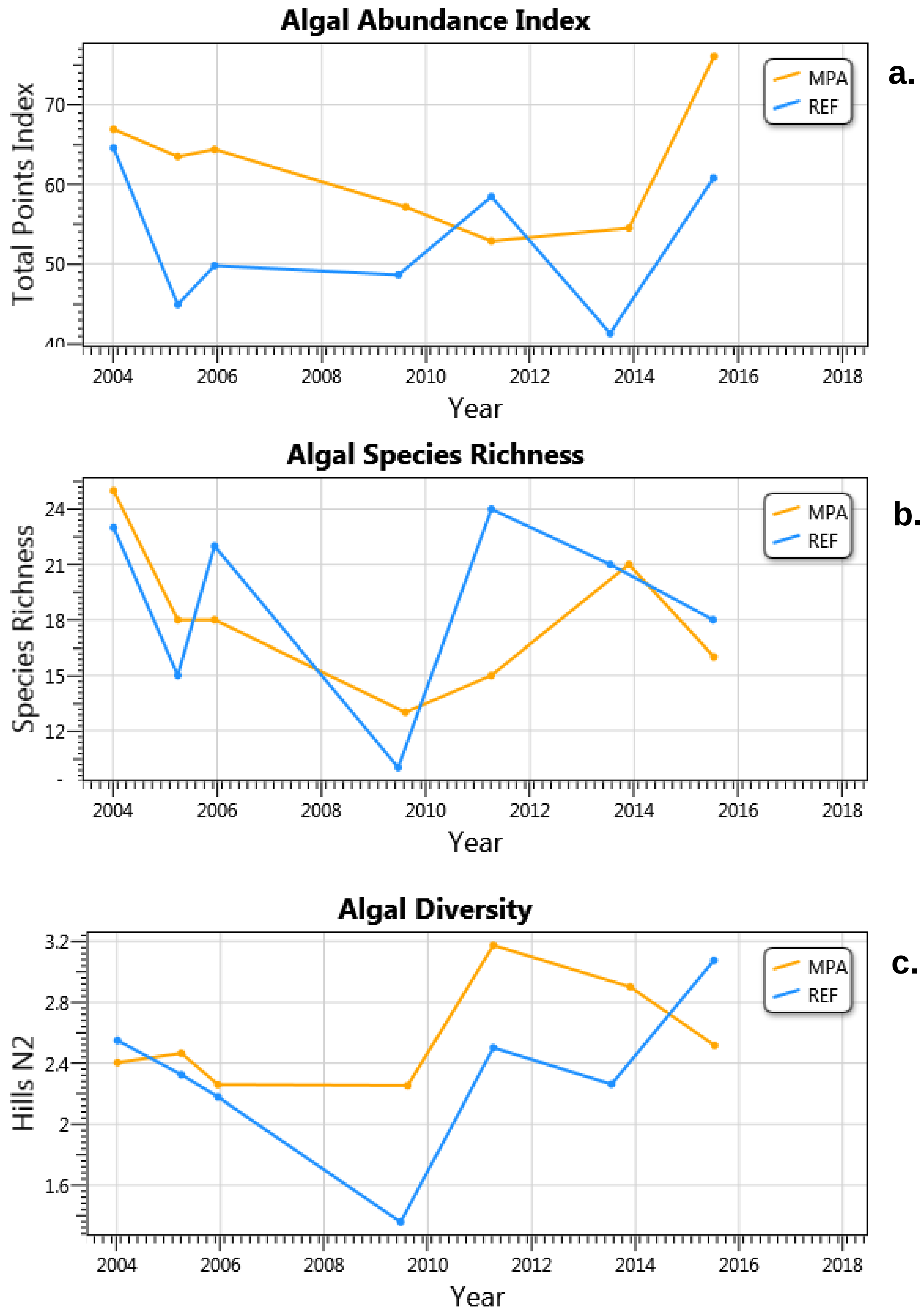


Figure 3.3. Algal species diversity indicators for MNP and reference sites at Marengo Reefs MS.

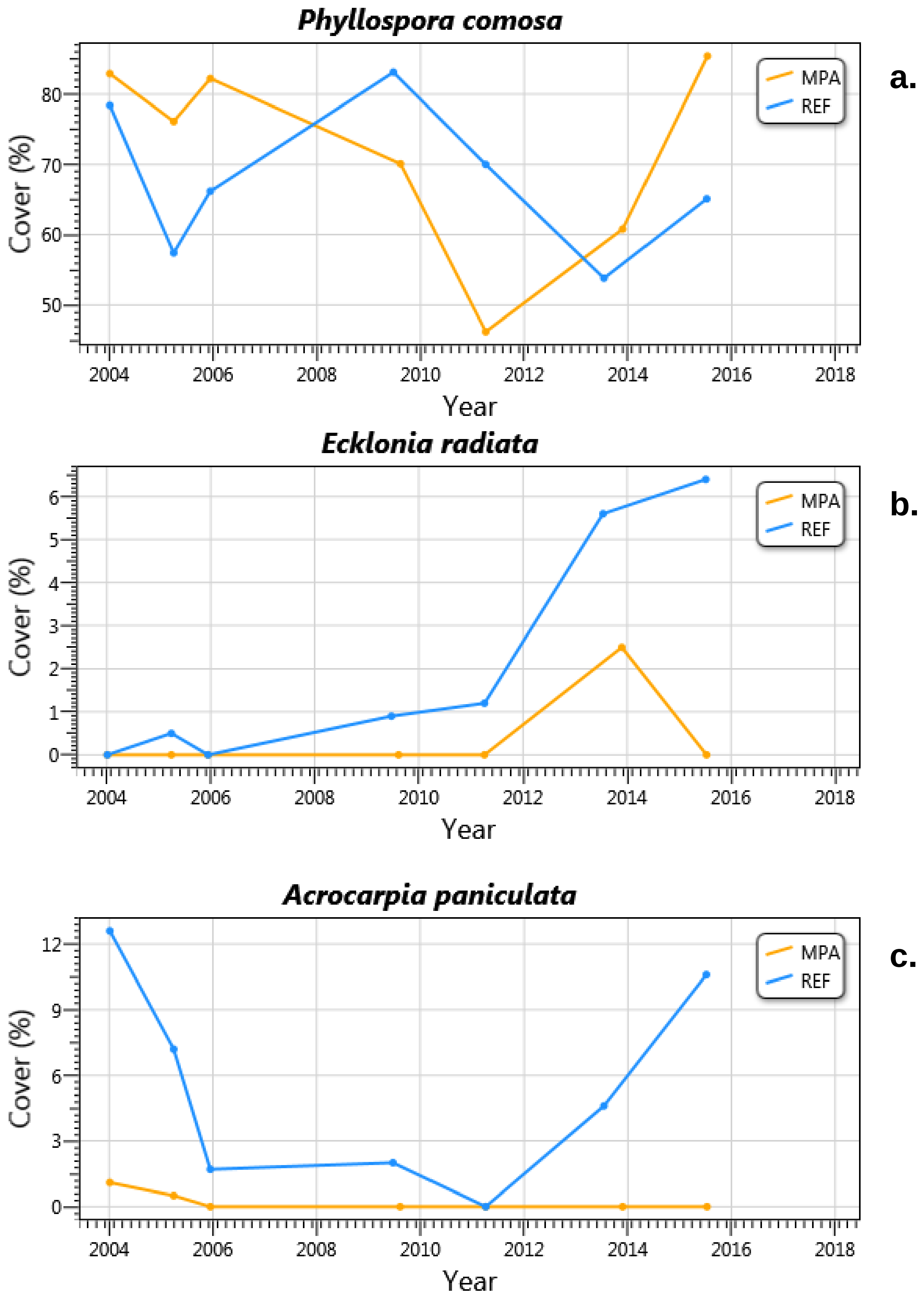


Figure 3.4. Percent cover of dominant algal species inside and outside the Marengo Reefs MS.

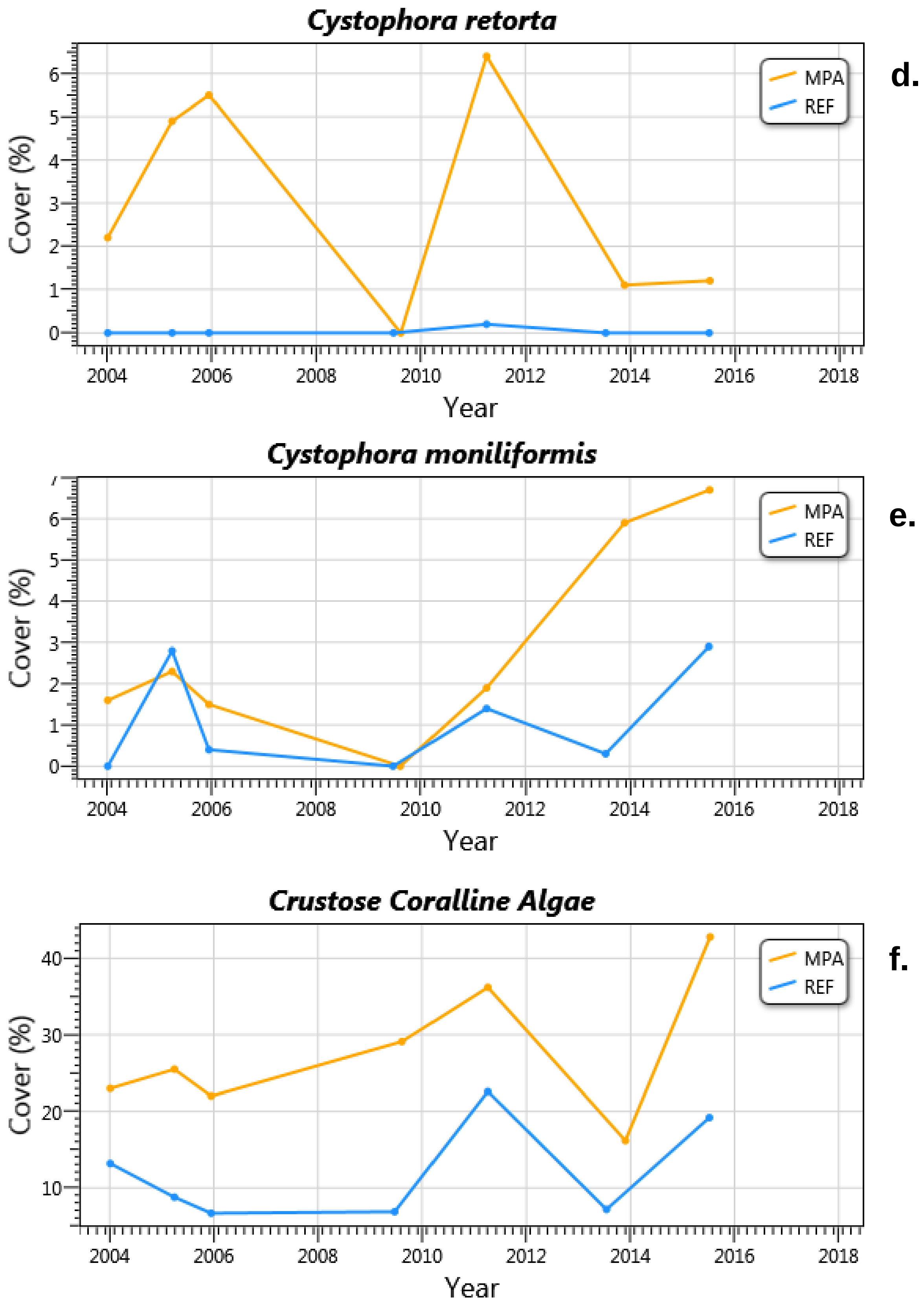
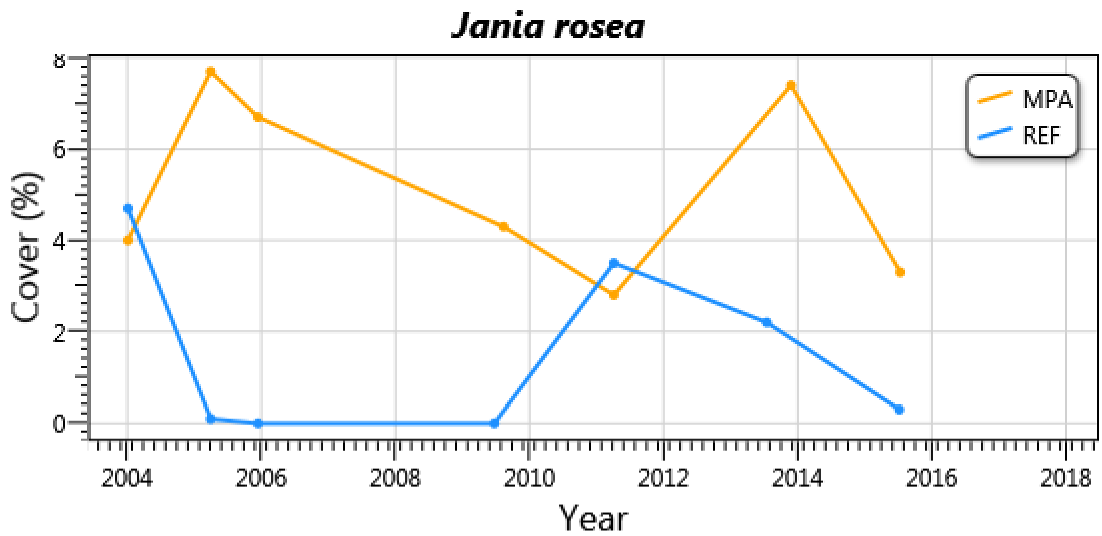
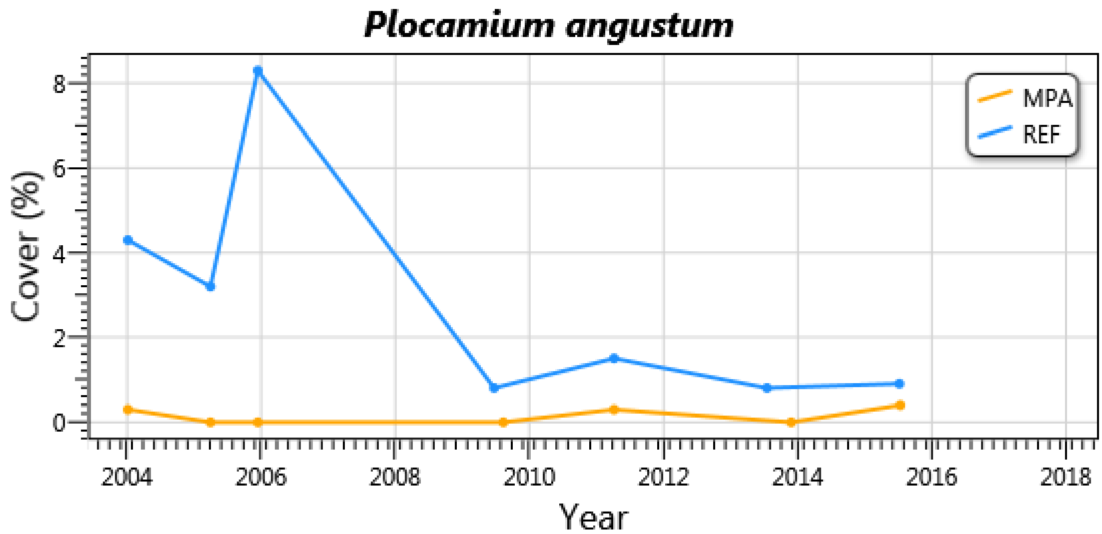


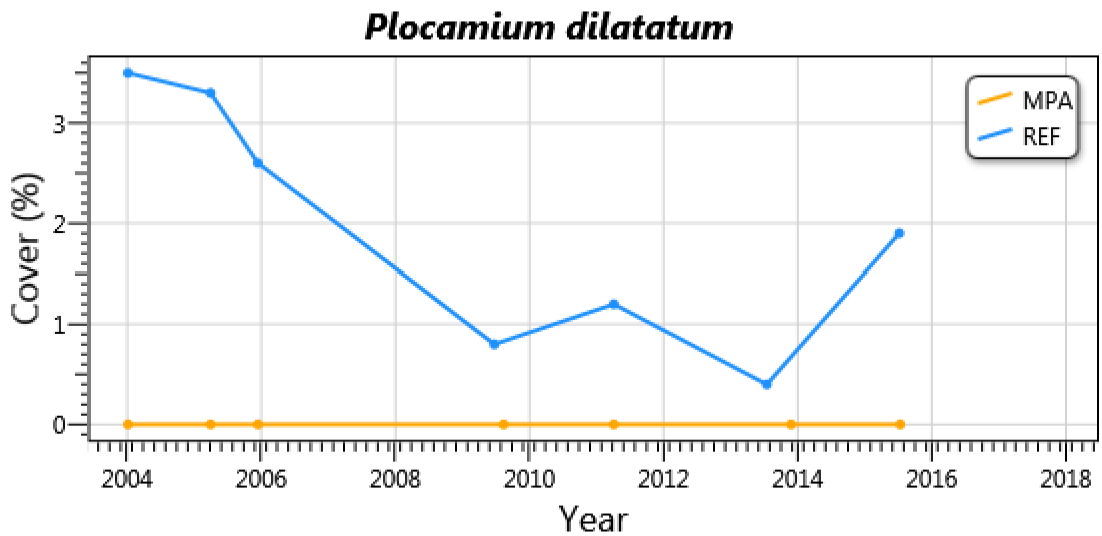
Figure 3.4 (continued). Percent cover of dominant algal species inside and outside the Marengo Reefs MS.



g.



h.



i.

Figure 3.4 (continued). Percent cover of dominant algal species inside and outside the Marengo Reefs MS.

3.2 Invertebrates

The invertebrate fauna was largely composed of the gastropod *Turbo undulatus* and the black lipped abalone *Haliotis rubra*. Other commonly encountered species included the sea stars *Tosia australis*, the feather star *Comanthus trichoptera* and the dog whelk *Dicathais orbita*.

The three dimensional nMDS analysis indicated similar invertebrate communities were present at both sites, however the trajectories of change over time were somewhat different (Figure 3.5). The control chart indicated a deviation in invertebrate assemblage structure from baseline conditions at Barnham Black in 2011 and 2013 (Figure 3.6).

Invertebrate total abundance, species richness and diversity fluctuated considerably over the monitoring period, with changes generally correlated between the two sites (Figure 3.7). Although the diversity changes were similar at both sites, they were driven by different species.

The abundance of blacklip abalone *Haliotis rubra* had very similar trends and abundances at both sites. There were notable dips in abundance at Marengo Reefs in 2004 and 2011 with relatively higher abundances present in 2013 and 2015 (Figure 3.8a).

The periwinkle *Turbo undulatus* (Figure 3.8b) was also abundant at both sites with an apparent increasing trend from 2006. There was a spike in abundance at Marengo Reefs in 2013 (Figure 3.8b).

The abundances of most other invertebrate species was relatively low and variable with no discernible temporal trends.

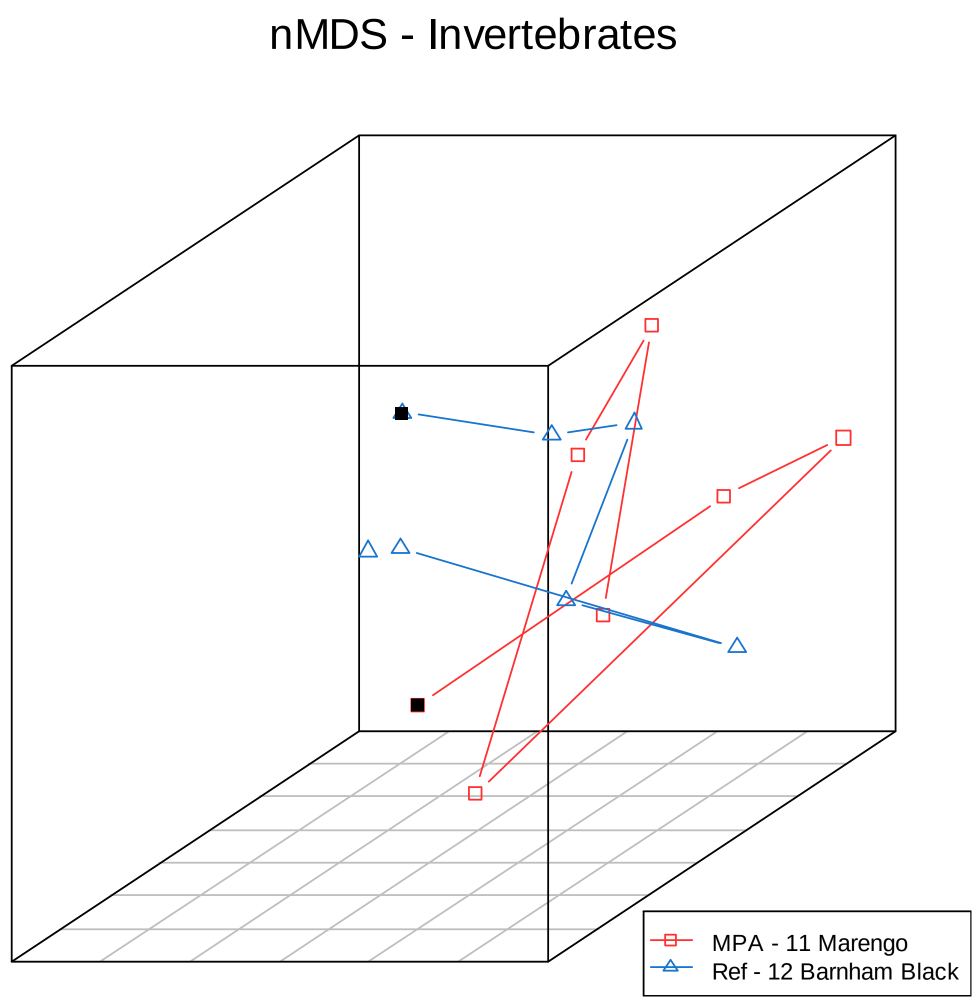


Figure 3.5. Three-dimensional nMDS plot of invertebrate assemblage structure at Marengo Reefs MS. Black, filled shapes denote the first survey time. Kruskal stress = 0.09.

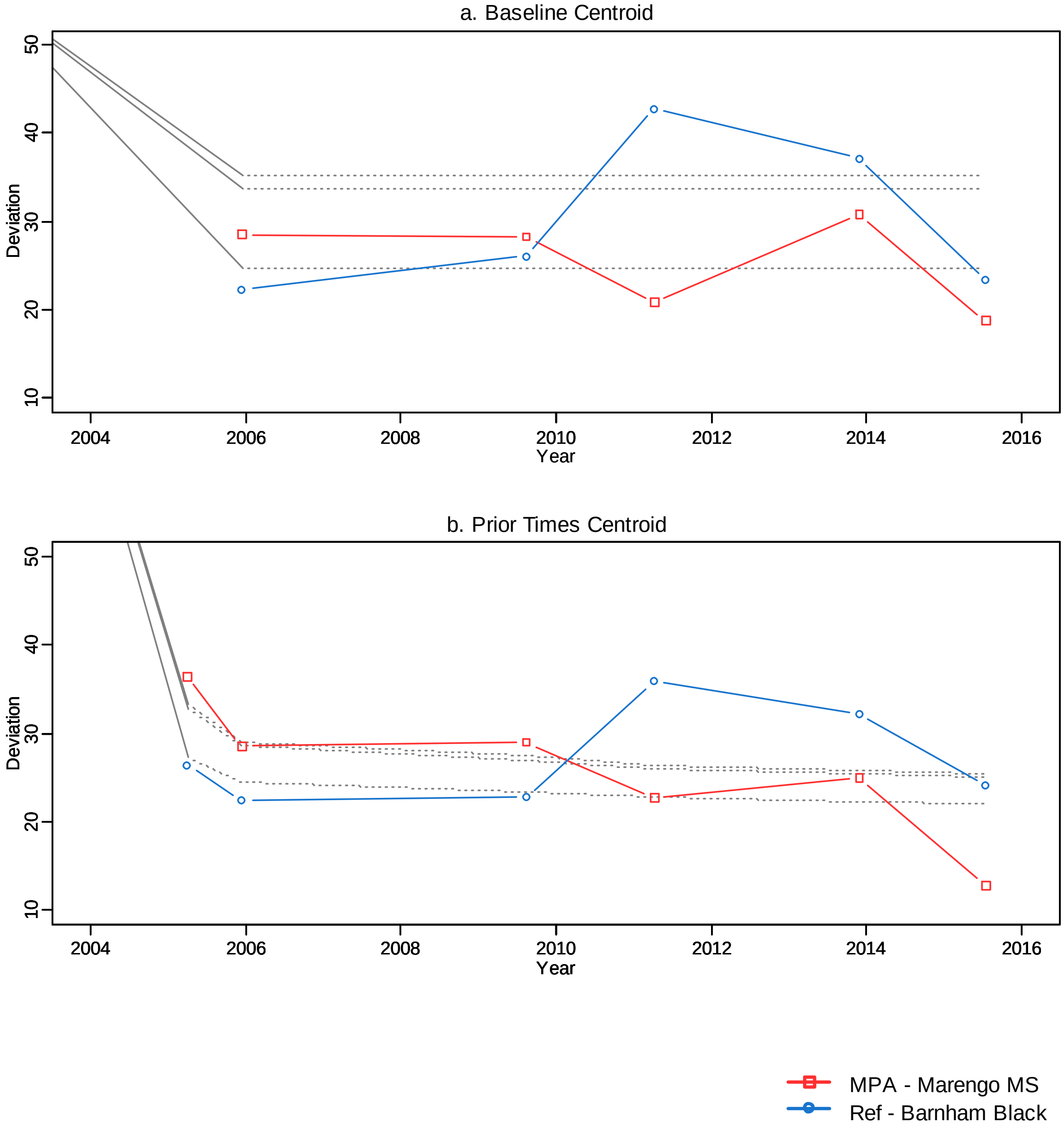


Figure 3.6. Control charts of invertebrate assemblage structure inside and outside the Marengo Reefs MS.

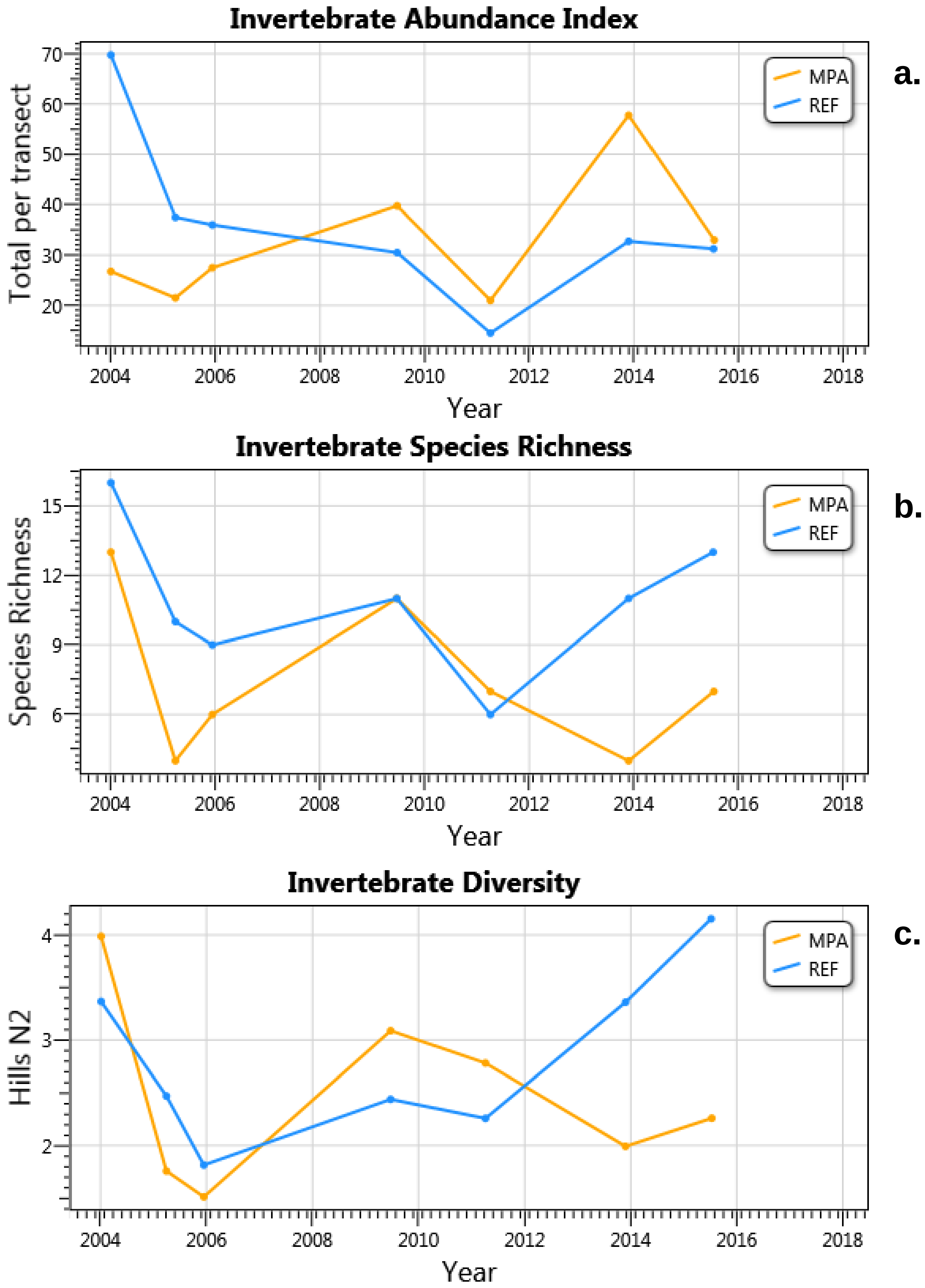


Figure 3.7. Invertebrate species diversity indicators inside and outside the Marengo Reefs MS.

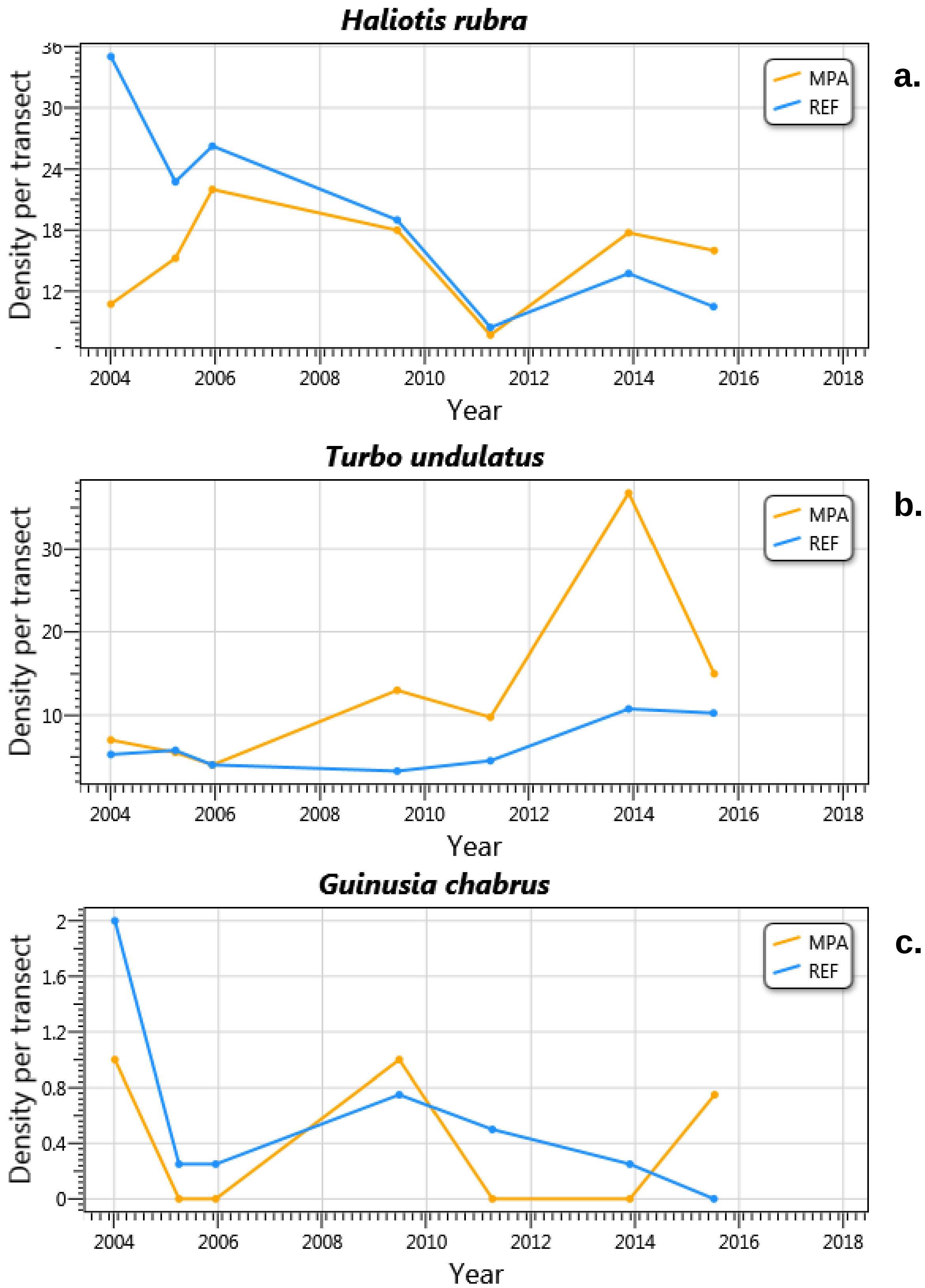


Figure 3.8. Density of invertebrate species inside and outside the Marengo Reefs MS.

3.3 Fishes

Blue throated wrasse *Notolabrus tetricus*, purple wrasse *Notolabrus fucicola*, herring cale *Olisthops cyanomelas* and sea sweep *Scorpis aequipinnis* were the most common species at Marengo Reefs and Barnham Black. The abundances were low and varied considerably over time (Figure 3.9). Because there were few dominant species without stable abundances (especially the wrasses), the control charts and diversity indices were susceptible to small changes abundances of less dominant species, leading to considerable fluctuations in the control charts and diversity indices that may be more reflective of sampling noise than community shifts (Figures 3.10 and 3.11).

The temporal trends were very similar at Barnham Black and Marengo Reefs for the species *Notolabrus fucicola*, *N. tetricus*, *Olisthops cyanomelas* and *Cheilodactylus nigripes*, with a notable peak in abundance in 2013 (Figure 3.12).

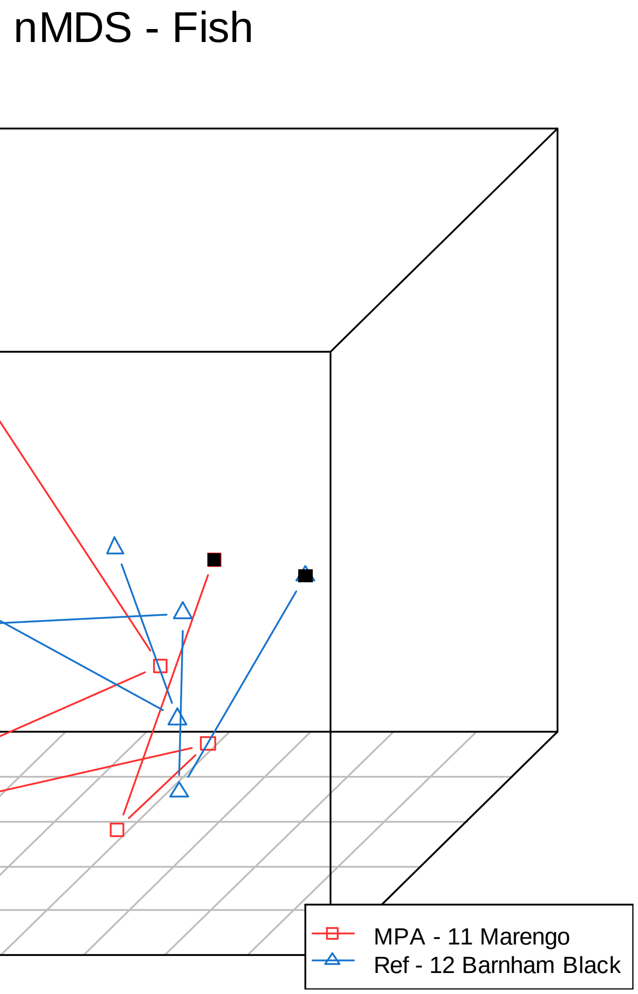


Figure 3.9. Three-dimensional nMDS plot of fish assemblage structure at Marengo Reefs MS. Black, filled shapes denote the first survey time. Kruskal stress = 0.08.

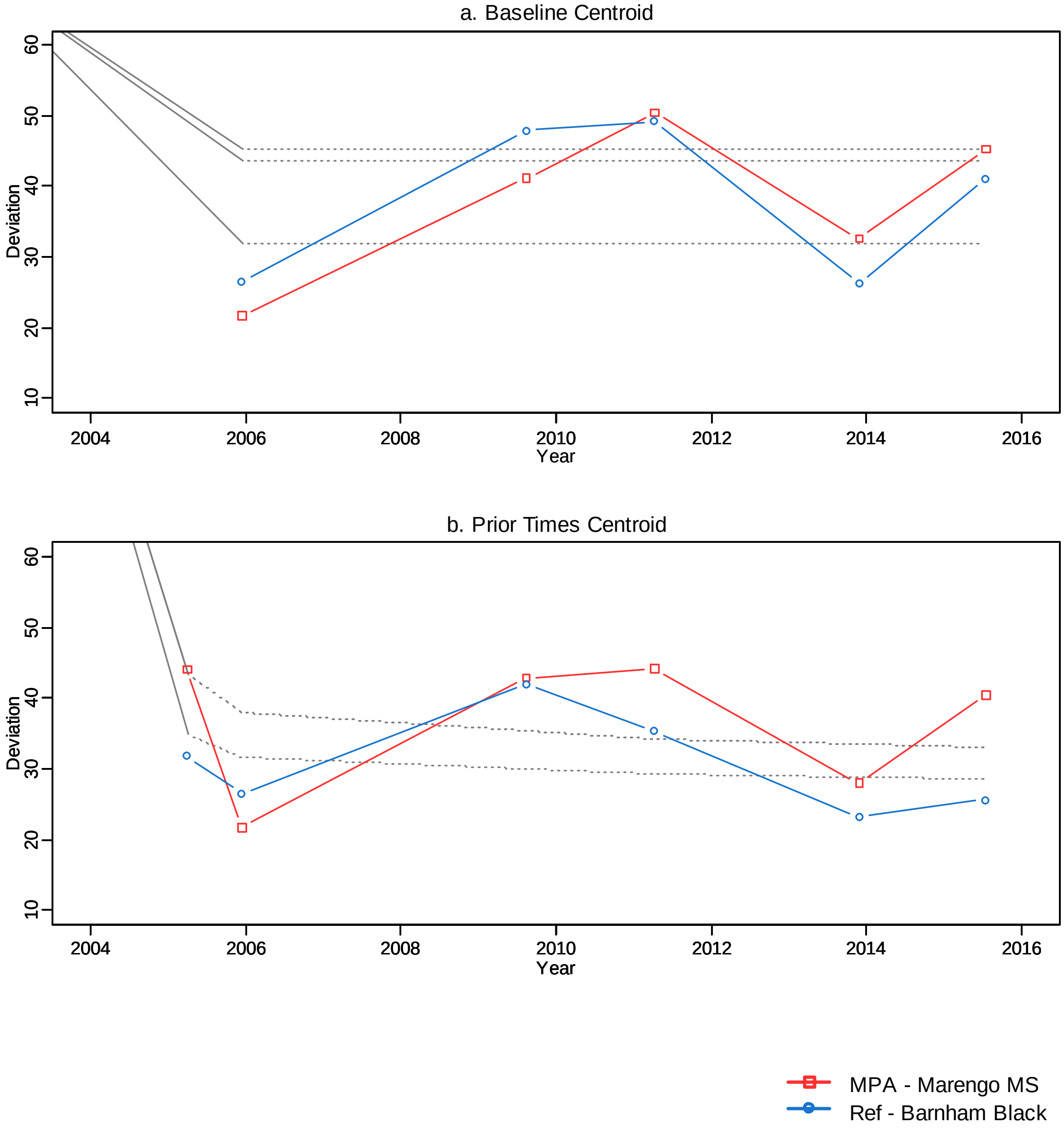


Figure 3.10. Control charts of fish assemblage structure inside and outside the Marengo Reefs MS.

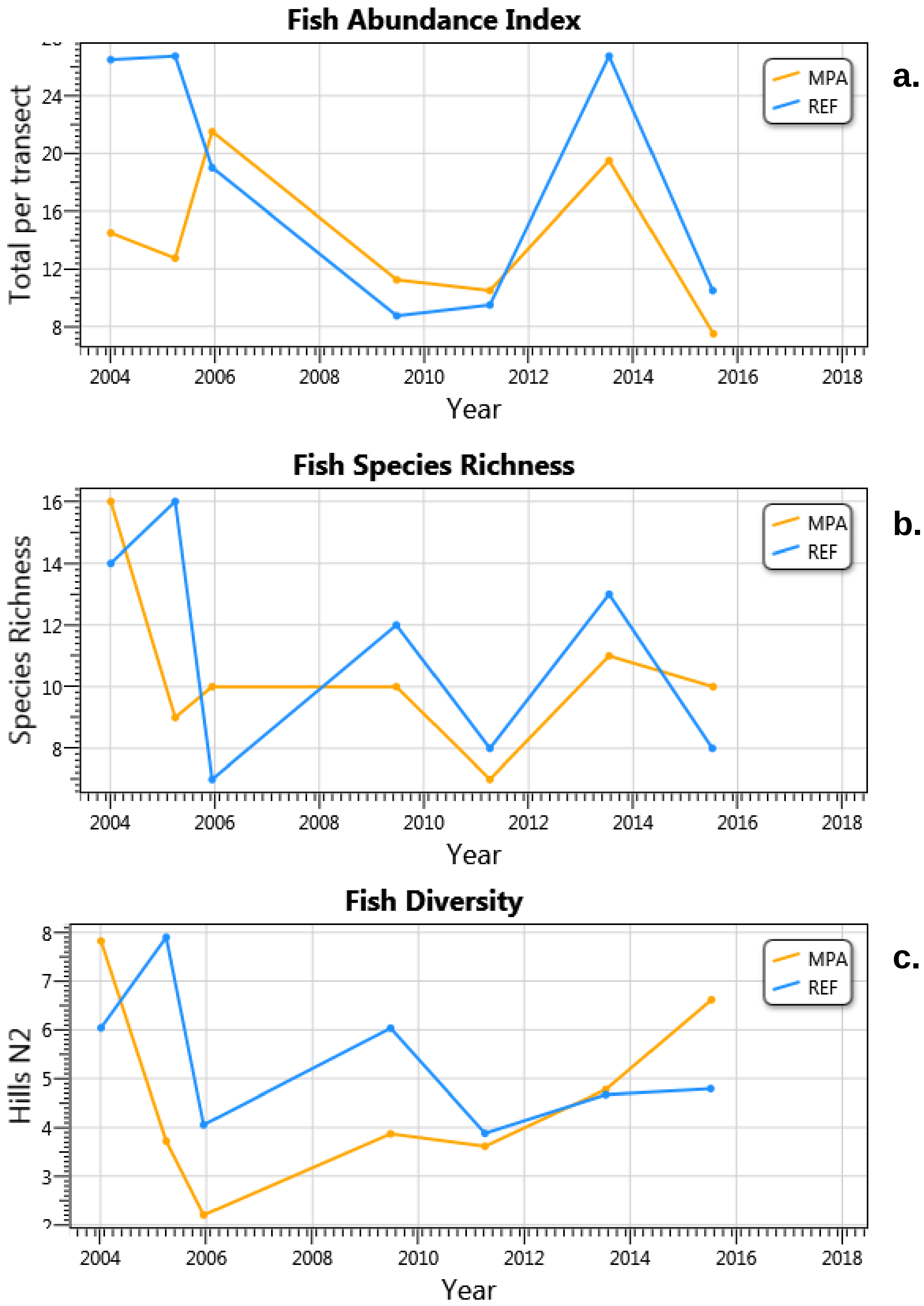


Figure 3.11. Fish species diversity indicators for MNP and reference areas at Marengo Reefs MS.

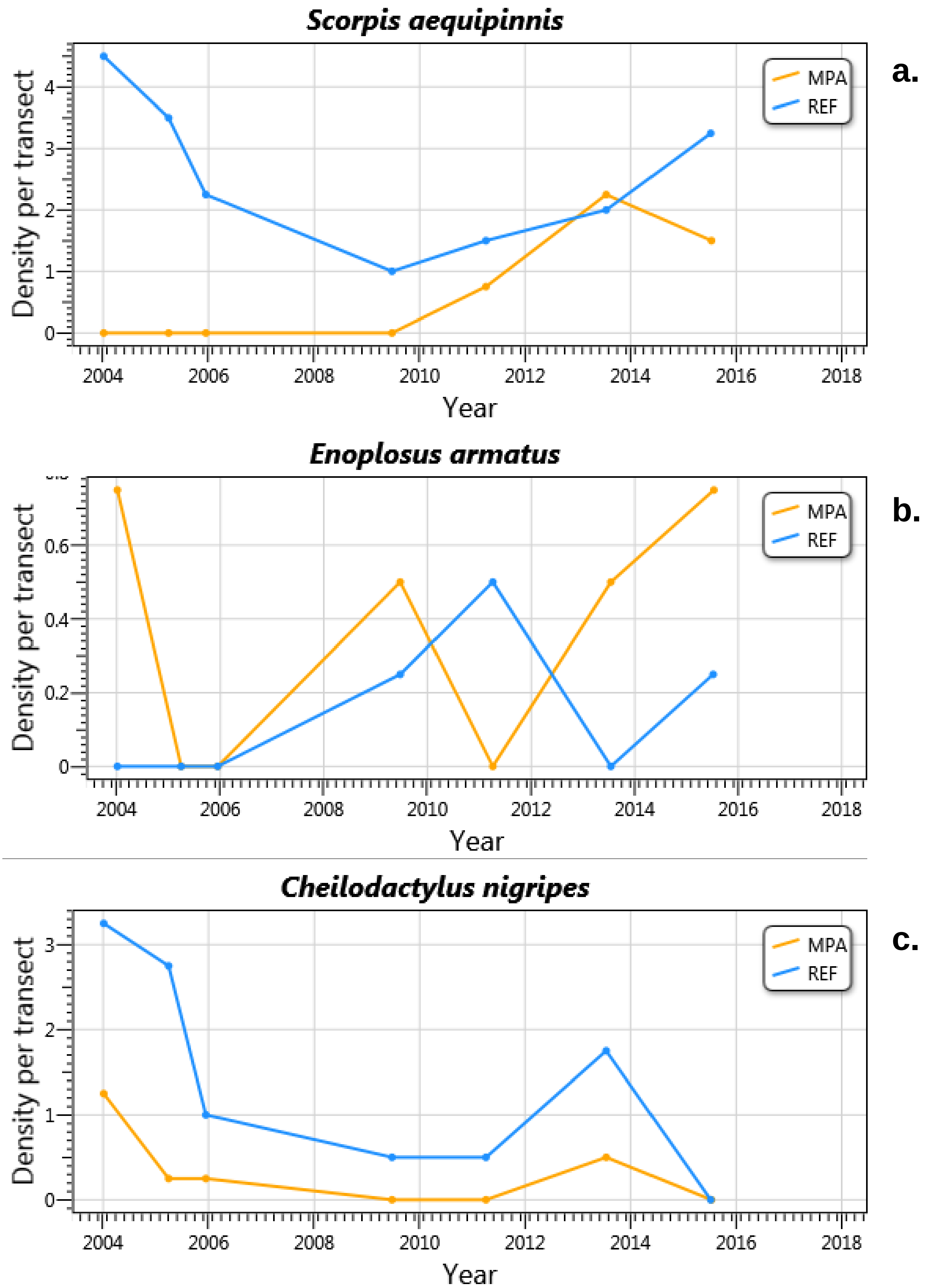


Figure 3.12. Density of fish species inside and outside the Marengo Reefs MS.

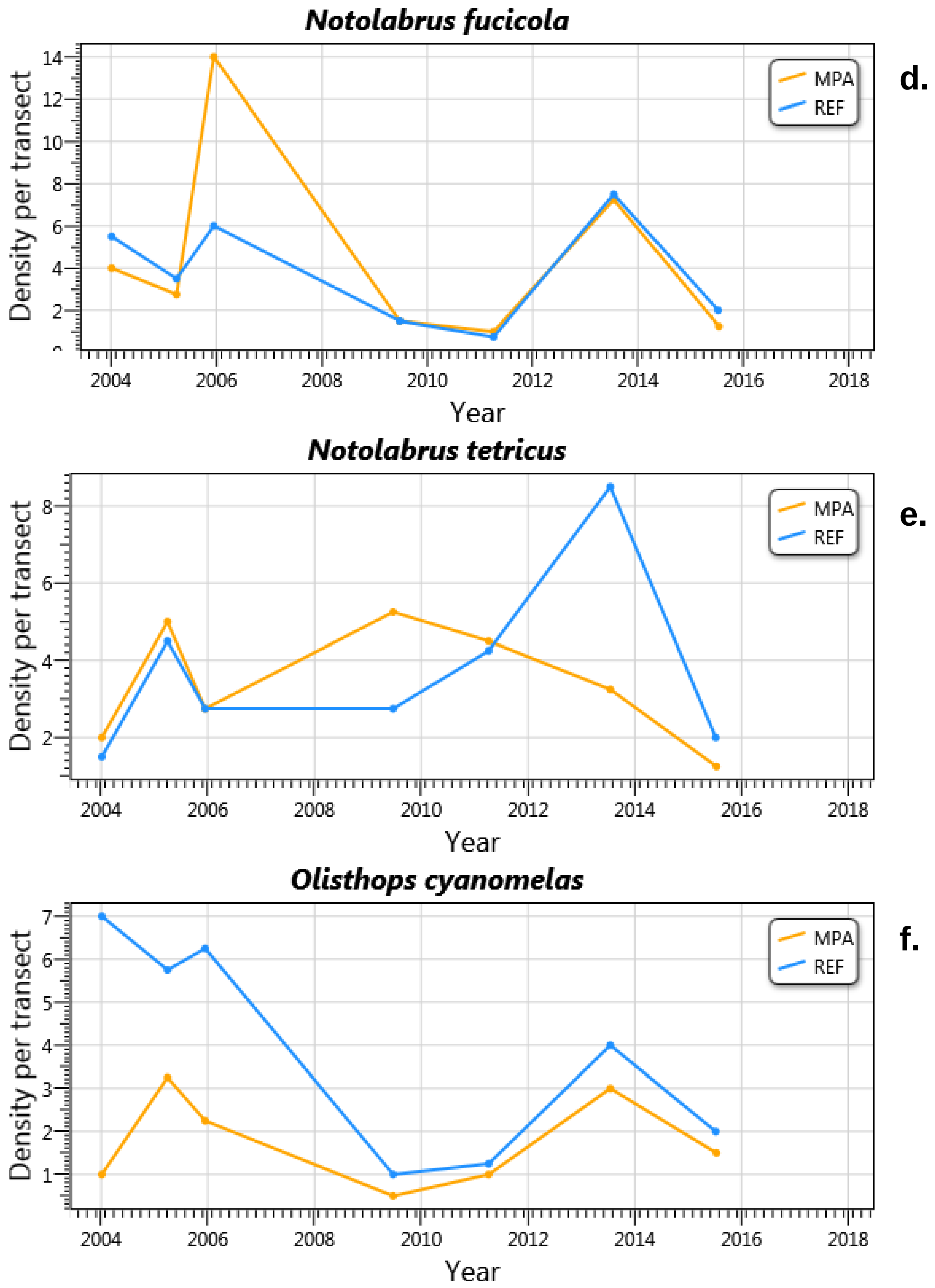


Figure 3.12 (continued). Density of fish species inside and outside the Marengo Reefs MS.

3.4 Ecosystem Functional Components

3.4.1 Habitat and Production

The canopy cover was relatively high at both sites during most surveys, with dips apparent in 2011 and 2013, following the abundance of the dominant crayweed *Phyllospora comosa*. The cover of small brown, thallose red and green algae was relatively low and variable over the monitoring period. Crustose and erect coralline algae remained relatively high in cover at Marengo Reefs over the monitoring period (Figure 3.13).

3.4.2 Sediment Cover

Sediment cover was more prevalent at the Marengo Reefs site, but was relatively low in 2013 and 2015 (Figure 3.14).

3.4.3 Invertebrate Groups

The abundance of grazers, dominated by *Turbo undulatus* and *Haliotis rubra*, was variable but with no apparent temporal trend or pattern. There was a relatively fast recovery after a dip in 2011 (Figure 3.15). Other invertebrate functional groups were in low and variable abundance.

3.4.4 Fish Groups

There were no distinctive patterns or trends in abundances of the fish functional groups (Figure 3.16).

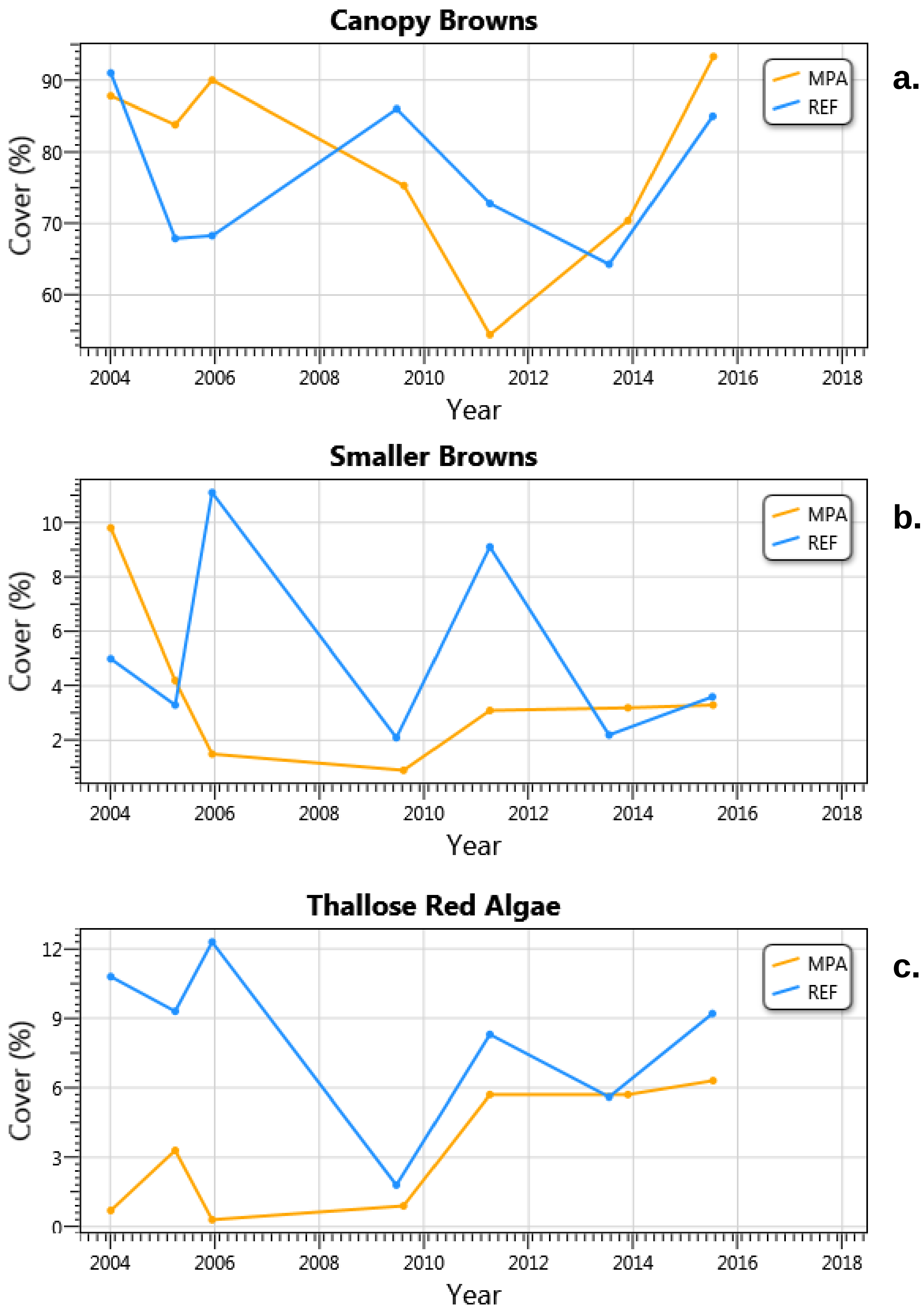


Figure 3.13. Percent cover of macrophyte functional groups inside and outside the Marengo Reefs MS.

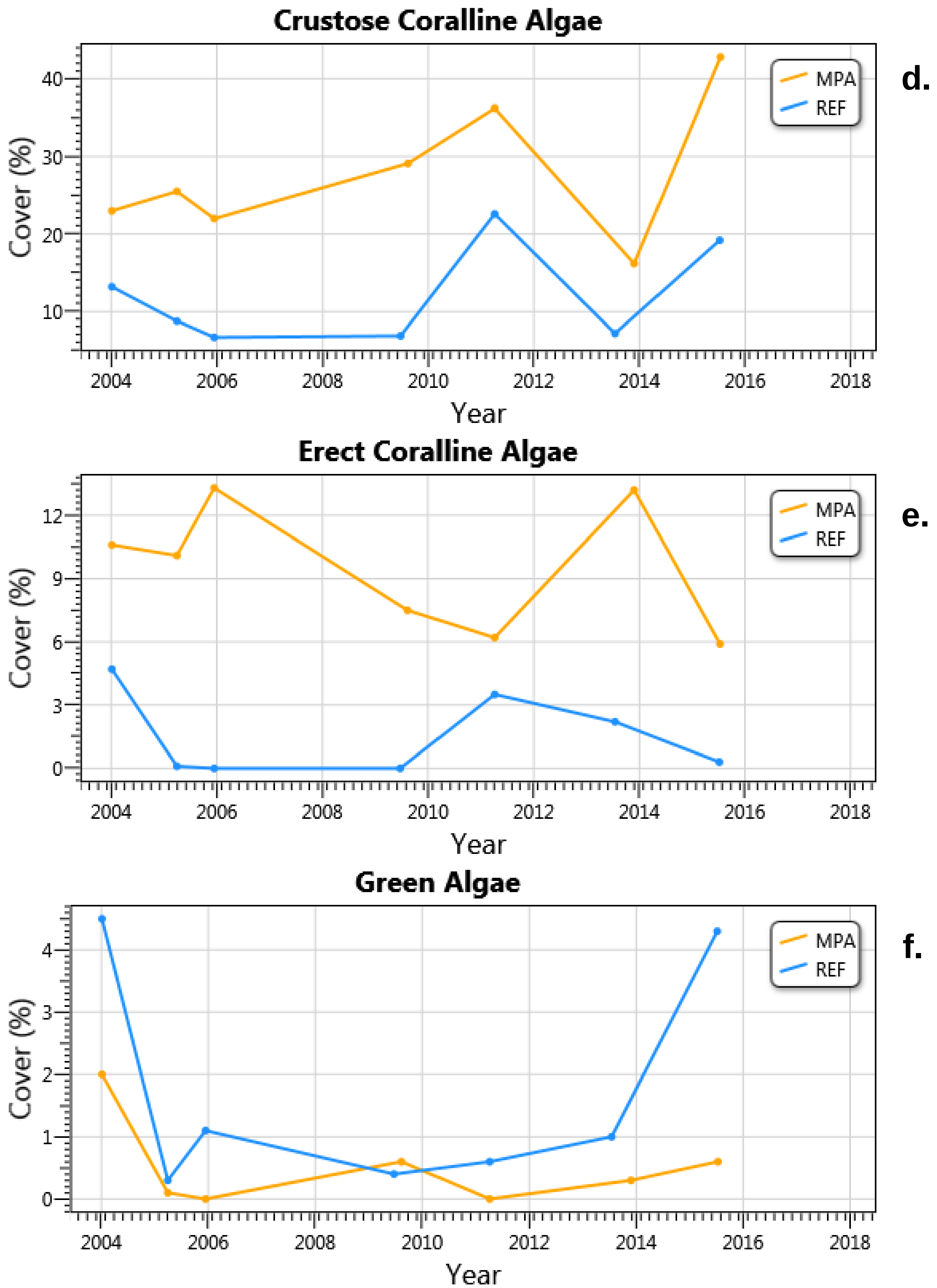


Figure 3.13 (continued). Percent cover of macrophyte functional groups inside and outside the Marengo Reefs MS.

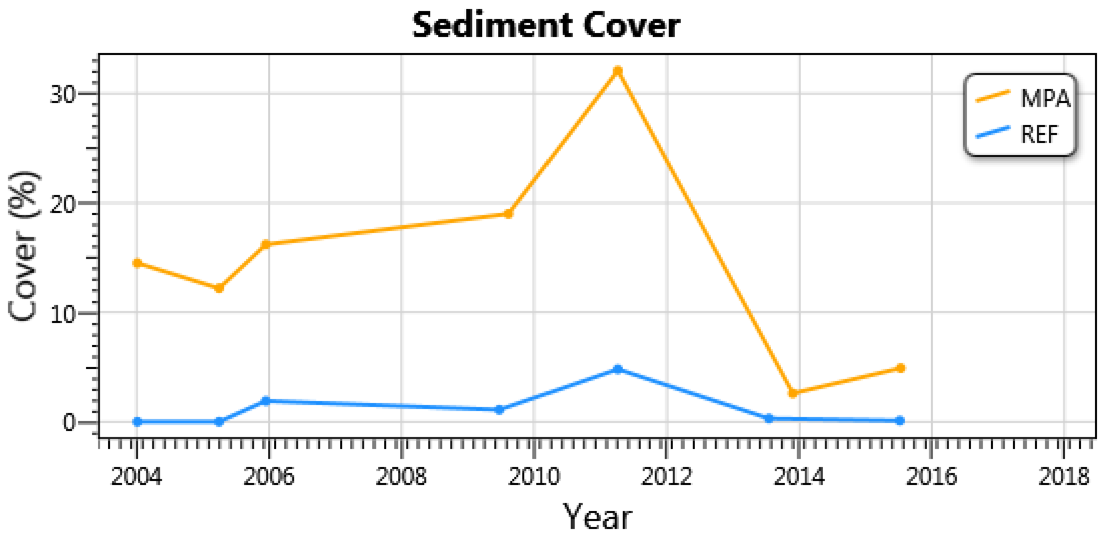


Figure 3.14. Sediment functional group percent cover inside and outside the Marengo Reefs MS.

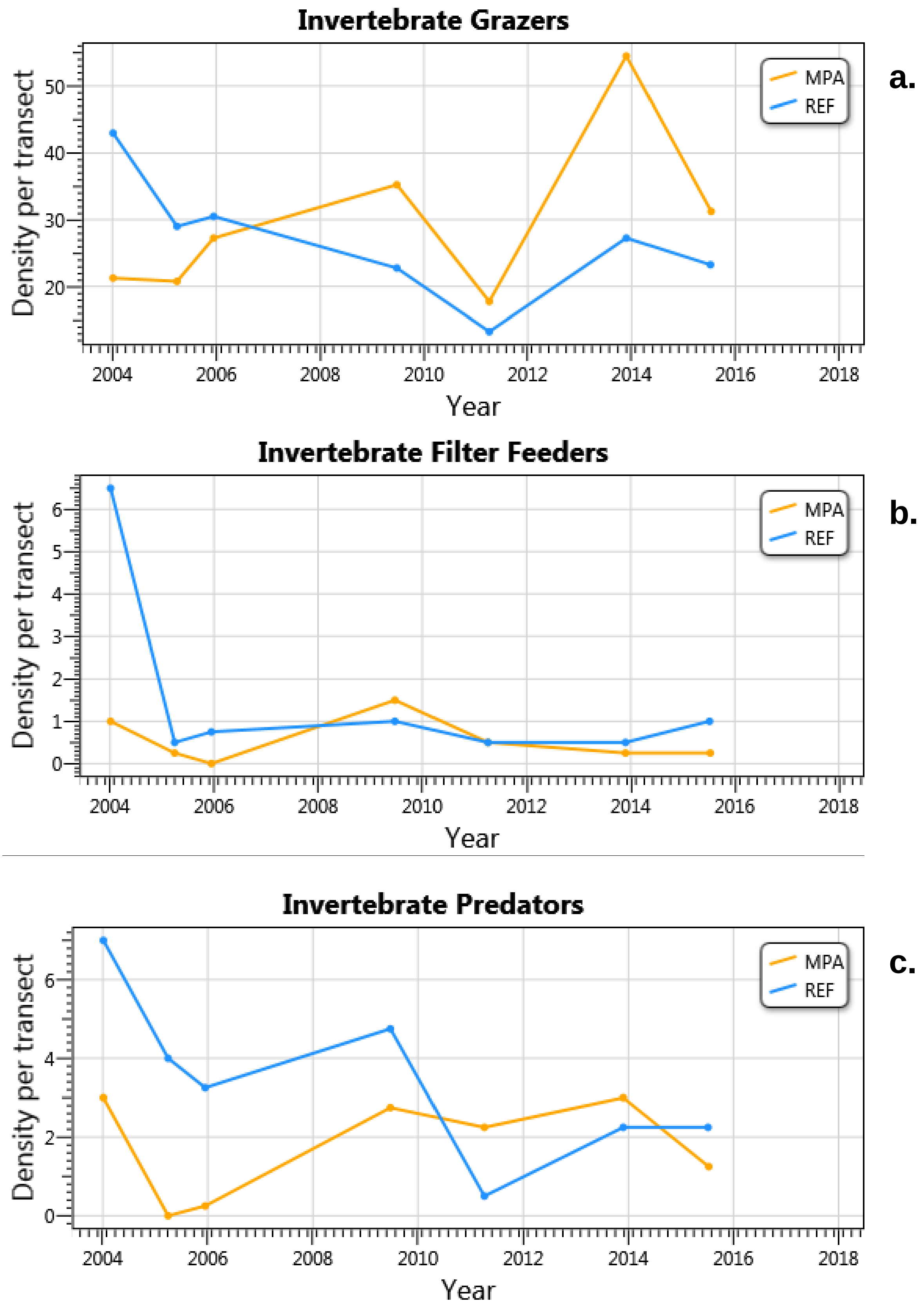


Figure 3.15. Invertebrate functional group densities inside and outside the Marengo Reefs MS

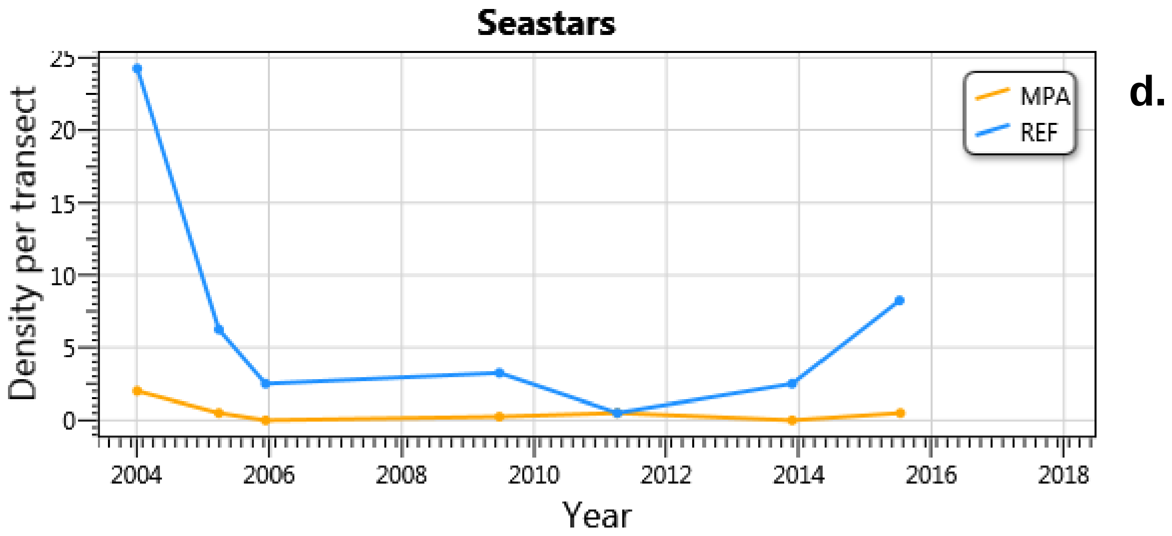


Figure 3.15 (continued). Invertebrate functional group densities inside and outside the Marengo Reefs MS.

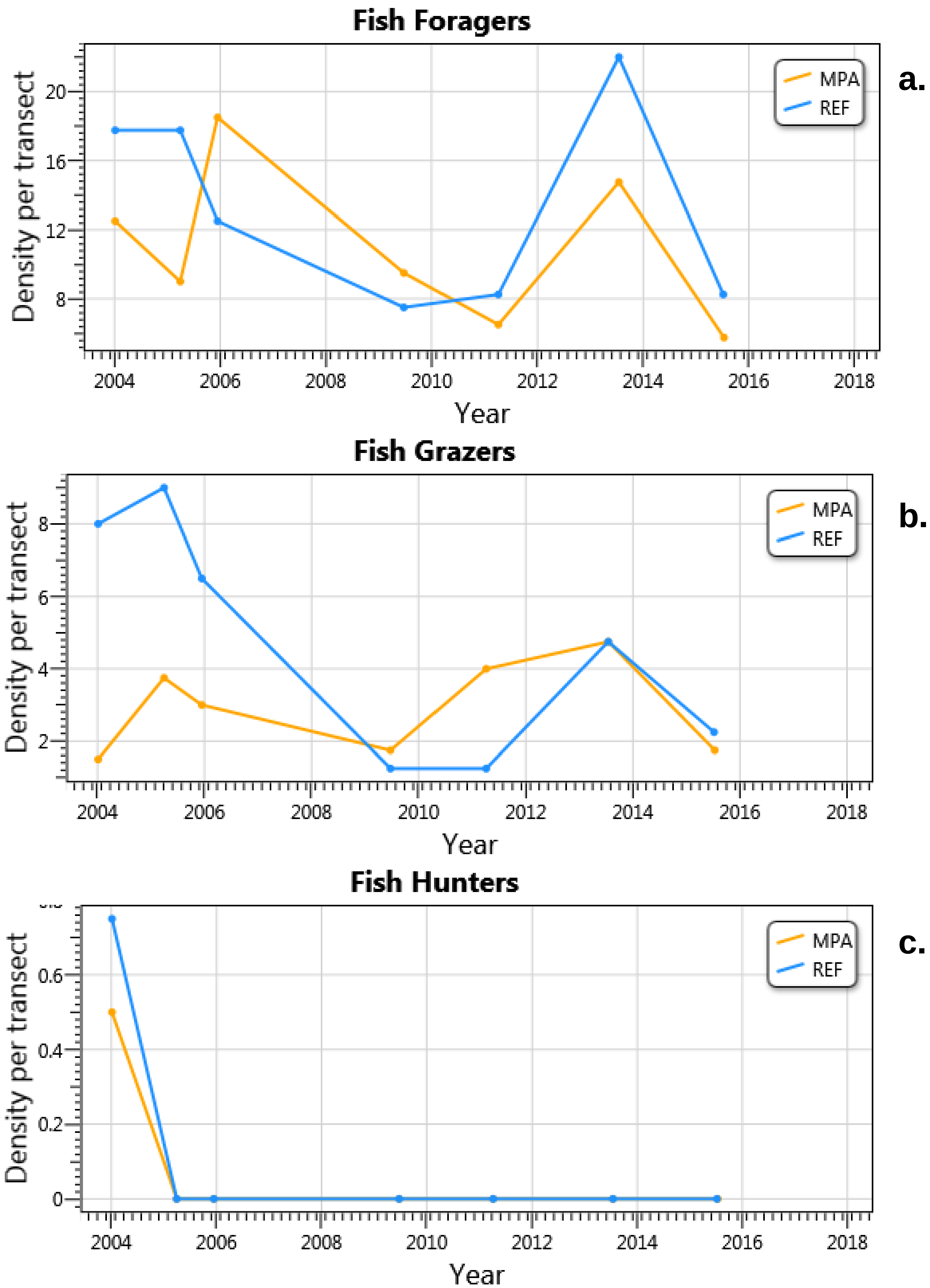


Figure 3.16. Fish functional group density inside and outside the Marengo Reefs MS.

3.5 Introduced Species

No introduced species were observed at the Marengo Reefs or Barnham Black sites during the monitoring period.

3.6 Climate Change

3.6.1 Species composition

There was no indication of species changes with affinities for different biogeographical (and climate) regions. Maugean algal and fish species abundances followed the same trajectory as the overall species abundances since 2004 (Figures 3.17 and 3.18). The occurrence of western and eastern species was low and sporadic with only a few individuals observed.

3.6.2 Macrocystis pyrifera

The giant string kelp *Macrocystis pyrifera* was not observed at either site during the monitoring period.

3.6.3 Durvillaea potatorum

The bull kelp *Durvillaea potatorum* is present vicinity of the monitoring sites, but not on the transect locations.

3.6.4 Centrostephanus rodgersii

The long-spined sea urchin *Centrostephanus rodgersii* is an eastern, warmer-water species. No *C. rodgersii* was observed during any of the surveys.

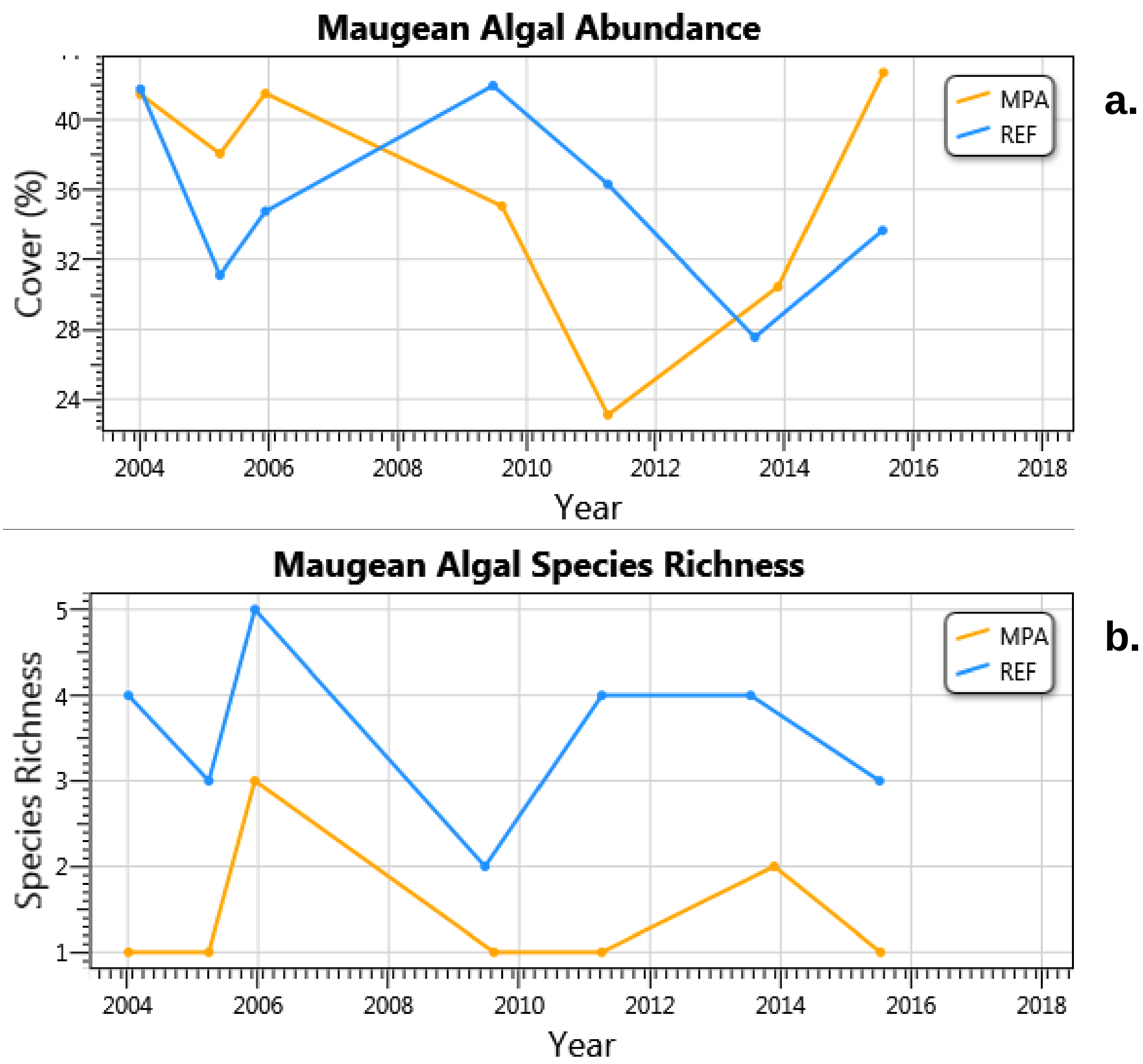
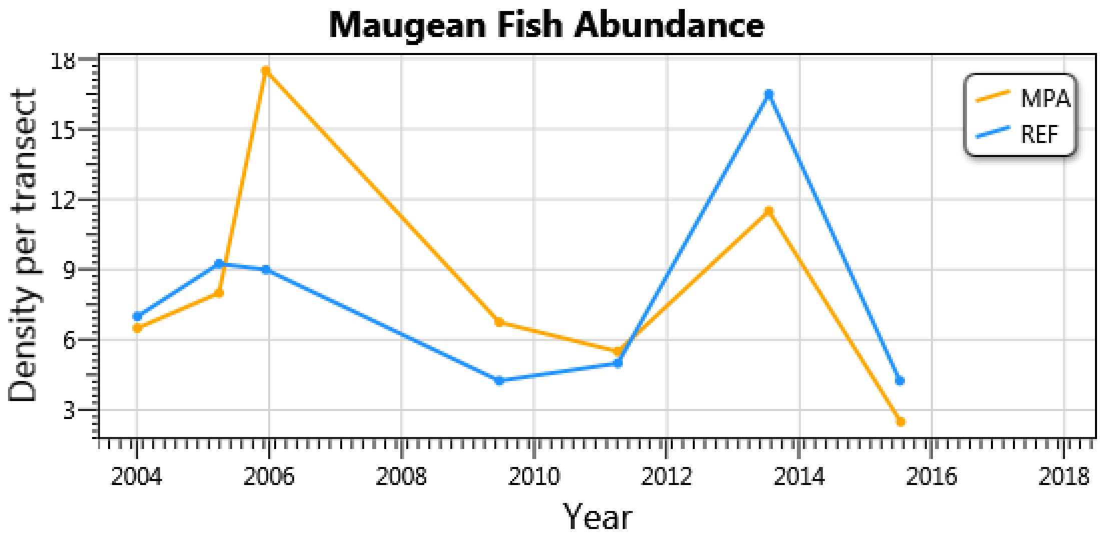
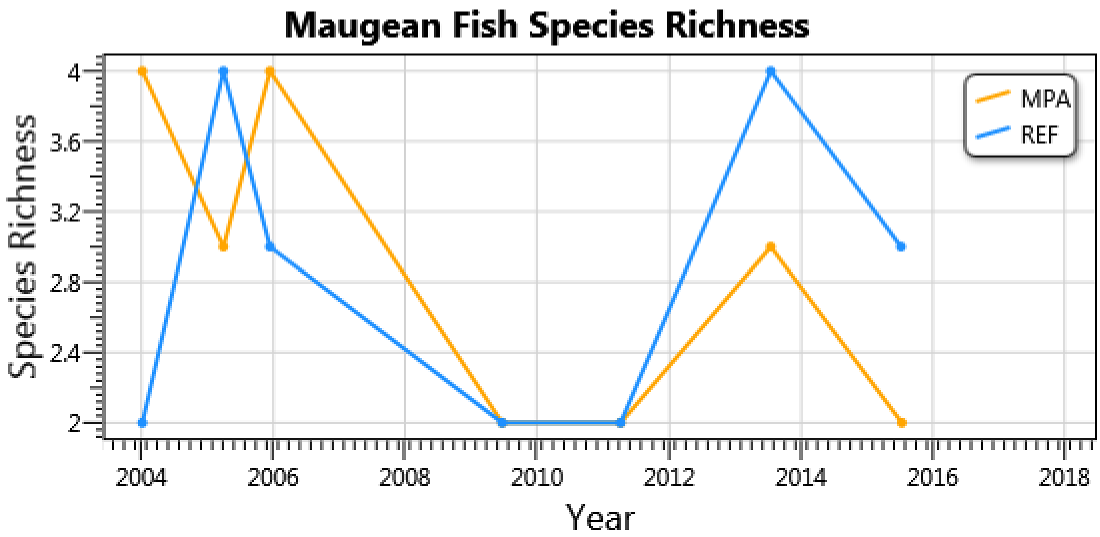


Figure 3.17. Abundance and species richness of cold water, Maugean algal species inside and outside the Marengo Reefs MS.



a.



b.

Figure 3.18. Abundance and species richness of cold water, Maugean fish species inside and outside the Marengo Reefs MS.

3.7 Fishing

3.7.1 Abalone

The abundance of blacklip abalone *H. rubra* was very similar at both sites with very similar temporal changes, including a very low dip in 2011. These similarities suggest both sites are subject to similar environmental and fishing pressures. The eastern end of the Marengo site includes fished habitat, where the boundary of the MS is at the edge of the intertidal habitat.

3.7.2 Rock Lobster

The transects at each monitoring site were largely placed on habitats with few crevices suitable for lobster habitats. Occasional individuals of southern rock lobster *Jasus edwardsii* were observed at Barnham Black.

3.7.3 Fishes

The biomass of commonly fished fishes was generally low and variable at both sites (Figure 3.20). There were no patterns or trends evident in the size structure over time (Figures 3.21).

3.8 Manufactured Debris

The 2015 survey was the first year to include manufactured debris at the Marengo monitoring sites. No manufactured debris was observed at either site.

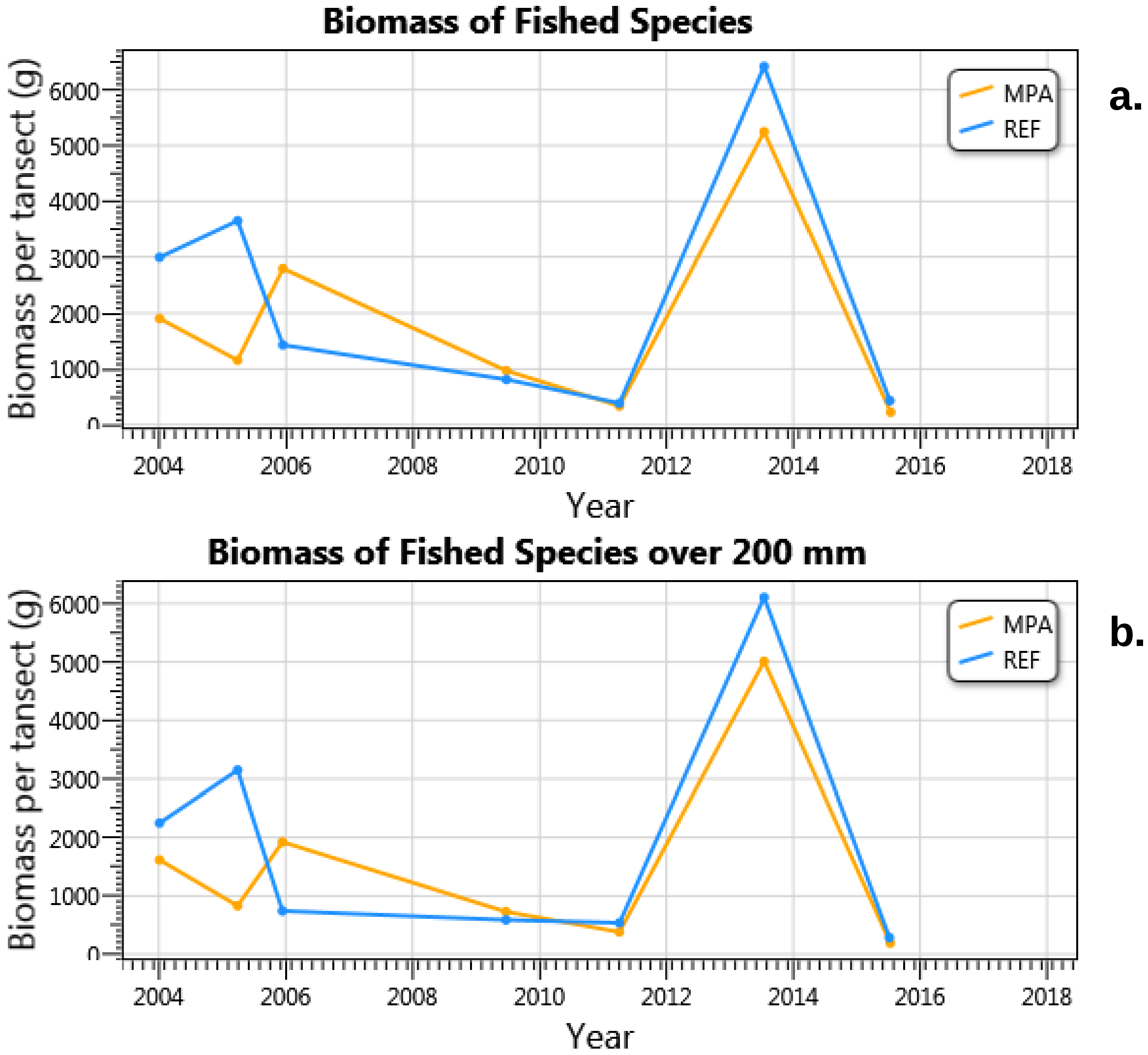


Figure 3.20. Total estimated biomass of fished species and estimated biomass of fished species over 200 mm inside and outside Marengo Reefs MS.

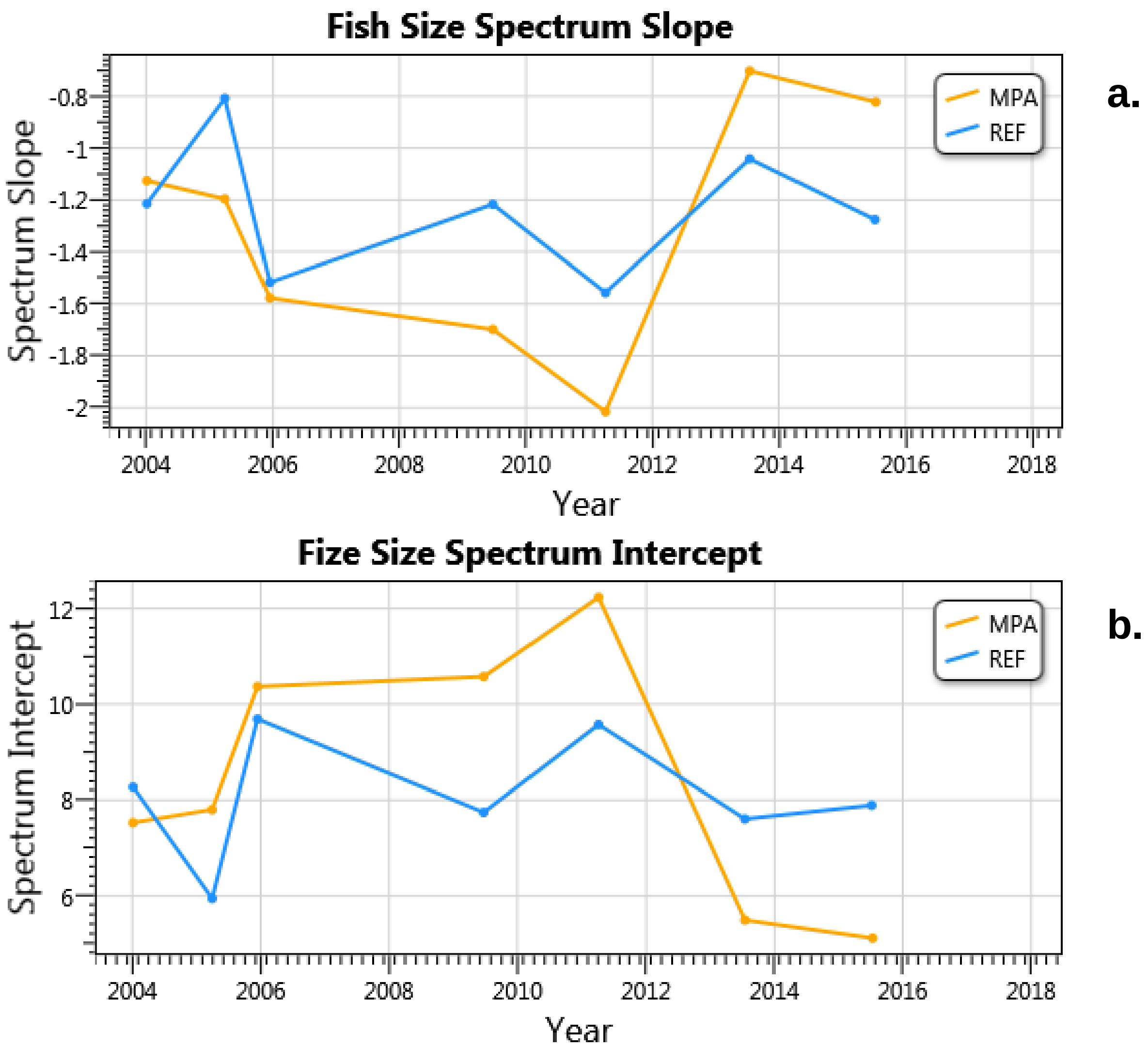


Figure 3.21. Size spectrum parameters for fished fish species inside and outside Marengo Reefs MS.

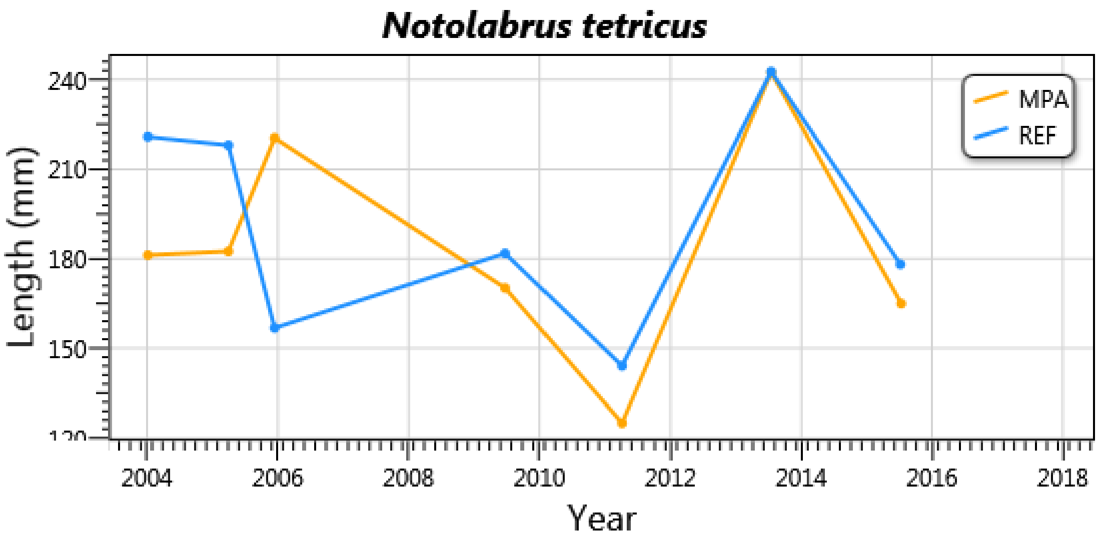


Figure 3.22. Mean size of blue-throat wrasse *Notolabrus tetricus* inside and outside the Marengo Reefs MS.

4 Acknowledgements

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