
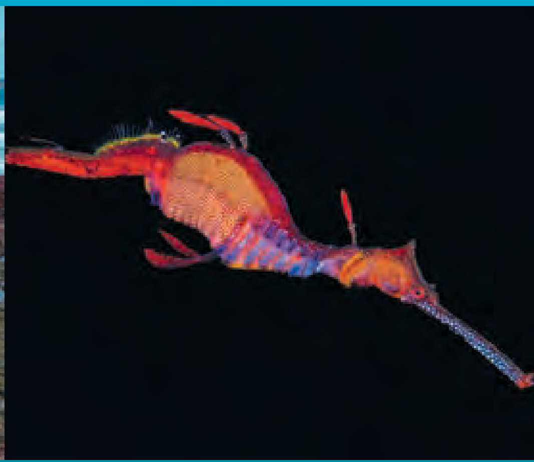


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Victorian Subtidal Reef Monitoring Program: The Reef Biota at Cape Howe Marine National Park December 2014

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Parks Victoria Technical Paper Series No. 99

Victorian Subtidal Reef Monitoring Program:

The Reef Biota at Cape Howe Marine National Park, December 2014

Matt Edmunds
Bryan Woods

Australian Marine Ecology Pty. Ltd.

December 2014

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 Cape Howe Marine National Park and the associated reference sites, involving six surveys from 2001 to 2014.

This report aims to provide:

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

The ongoing monitoring surveys were done along a 200 m line divided into four transects and two blocks on either side of the line. Each transect was surveyed for:

- abundance and size structure of large fishes;
- abundance of cryptic fishes and benthic invertebrates;
- sea urchin barren coverage and density of urchins within the barrens, when present;
- percentage cover of macroalgae; and
- abundance of a string kelp, *Macrocystis pyrifera*, when present.

Key observations during the monitoring program were:

- There was some confounding of interpretation of temporal trends in the reference areas through changes in the site locations in 2009.
- The macroalgal community composition has changed inside the MNP, particularly at Howe Border and Howe Central. This included a substantial decrease in the cover of crayweed *Phyllospora comosa* and an increase in smaller, understorey species abundances.
- There was increasing trend in algal species richness and species diversity within the Cape Howe MNP, in association with the increased understorey species abundance.
- For invertebrate community composition, there have been significant deviations from initial conditions outside the MPA, particularly at Iron Prince reef, but not within the MPA.
- Black lip abalone *Haliotis rubra* abundances have increased substantially both inside and outside the MPA since its declaration, with abundances inside the MPA being the highest recorded in 2014.
- The mean size of *H. rubra* has increased within the MPA and the size spectrum includes a greater relative abundance of larger individuals.
- The long-spined sea urchin *Centrostephanus rodgersii* did not change substantially in abundance.
- For fish community composition, there have been ongoing shifts in community structure both inside and outside the MPA on average, however there were no distinct changes on a site-by-site basis.
- There was an increase in fish species richness and diversity inside Cape Howe MNP.
- The abundances of wrasse species has generally increased inside the MPA, but particularly for the eastern blue groper *Achoerodus viridis*.
- Morwongs and trumpeter abundances also increased within the MPA, including banded morwong *Cheilodactylus spectabilis* and bastard trumpeter *Latridopsis forsteri*.
- The abundance of leather jackets generally declined, particularly six-spined leatherjackets *Meuschenia freycineti*.
- For seaweed functional groups there was a halving of canopy formers over the monitoring period, with a coincident increase in smaller browns, coralline algae and thallose red algae. There were no trends in crustose coralline algae cover.
- There were no apparent temporal trends for invertebrate functional groups.

- Similarly, there were no apparent temporal trends for fish functional groups.
- No introduced species were observed during the monitoring program.
- The reduction in the abundance of the cold water canopy seaweed *Phyllospora comosa* is an indicator consistent with climate change, however there may be other causes for the decline of this species.
- There was a substantial increase in biomass of fished fish species both inside and outside the MPA between 2010 and 2014, with this increase being greater within the MPA.
- There has been a change in the size spectrum of fished fishes within the MPA, with a greater relative abundance of smaller individuals of fished species.
- Manufactured debris was largely confined to the wreck of the Iron Prince at the Iron Prince Wreck site.

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1 Introduction

1.1 Subtidal Reef Ecosystems of the Twofold Bioregion

The Twofold Shelf bioregion extends from east of Wilsons Promontory to Tathra in southern New South Wales. The western portion of the Twofold Shelf bioregion is largely comprised of long sandy beaches (Ninety Mile Beach) with extensive areas of inshore and offshore sandy beds with some small offshore reefs. The sandy habitats of the far eastern coastline are punctuated by rocky headlands and localised outcrops of granite and metamorphic rocks, such as at Cape Conran, Point Hicks, Rame Head, Gabo Island and Iron Prince at Cape Howe. Sea temperatures are warmer in the Twofold Shelf region compared to elsewhere in Victoria because of incursions of the East Australia current bringing warmer water down the east coast of the continent. The continental slope is quite close to the far eastern Victorian shore and cold-water upwellings are frequent. These upwellings provide nutrients to the inshore ecosystems, contributing to high productivity. The biota of this region has a high component of eastern temperate species, in addition to many southern temperate and cosmopolitan species.

A prominent biological component of all Victorian shallow reefs is kelps and other seaweeds (Figure 1.1). Large species of brown algae, 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 seagrass beds and terrestrial grasslands, with approximately 2 kg of plant material produced per square metre per year. These stands may have 10-30 kg of plant material per square metre. The biomass of seaweeds is greater where giant species such as string kelp *Macrocystis angustifolia* 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 *Macrocystis angustifolia*, which sometimes forms a dense layer of fronds floating on the water surface. Other species with large, stalk-like stipes, such as *Ecklonia radiata*, *Phyllospora comosa* and *Durvillaea 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 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 biogeographical region, depth, exposure to swell and waves, currents, temperature range, water clarity and presence of sand.

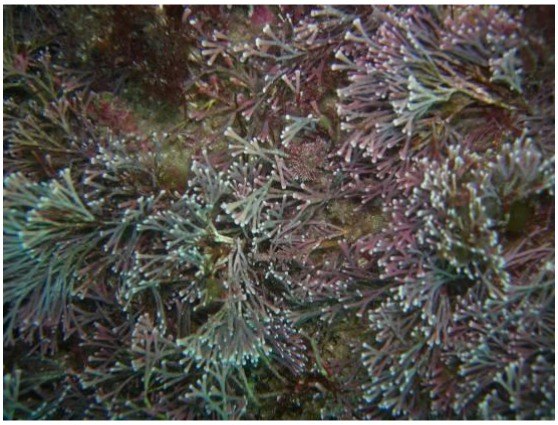
Grazing and predatory mobile invertebrates are prominent animal inhabitants of the reef (Figure 1.2). An important invertebrate of the eastern Twofold Shelf bioregion is the long-spined sea urchin *Centrostephanus rodgersii*. *Centrostephanus* forms large grazing aggregations which denude the reef of erect algal species, forming ‘sea urchin barrens’. Removal of large seaweeds by *Centrostephanus* causes substantial changes to subtidal reef community structure on reefs in eastern temperate Australia.

Other common invertebrate grazers found at Twofold Shelf reefs include blacklip abalone *Haliotis rubra*, the eastern temperate gastropod *Astralium tentoriiforme*, warrener *Turbo undulatus* and sea urchin *Heliocidaris erythrogramma*. Predatory invertebrates include dogwhelks *Dicathais orbita*, eastern rock lobster *Sagmariasus verreauxi*, octopus *Octopus maorum* and a wide variety of seastar species. Other large reef invertebrates include mobile filter feeding animals such as feather stars *Comanthus trichoptera* and sessile (attached) species such as sponges, corals, bryozoans, hydroids and ascidians.

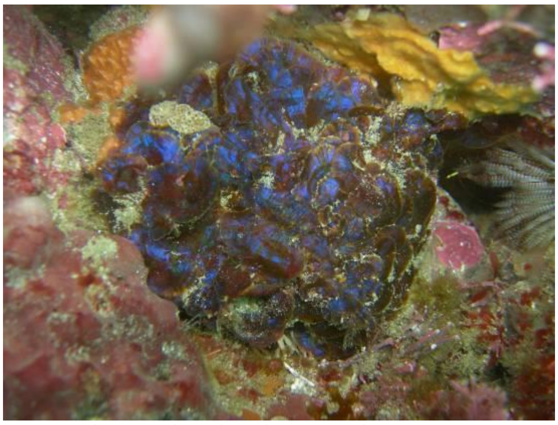
Fish are also a dominant component of reef ecosystems, in terms of both biomass and ecological function (Figure 1.3). Reef fish assemblages include roaming predators such as blue-throated wrasse *Notolabrus tetricus*, herbivores such as herring cale *Odax cyanomelas*, planktivores such as sea sweep *Scorpis 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, breeding aggregations of herring cale *Odax cyanomelas* at certain times of the year can increase patchiness in algal assemblages by concentrating herbivory on kelps in small areas for short periods of time.

Although shallow reef ecosystems in Victoria are dominated by seaweeds, mobile invertebrates and fishes, in terms of biomass and production, 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, occupying various niches as grazers, predators or foragers. At the microscopic level, films of microalgae and bacteria on the reef surface are also very 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.



Coralline alga *Amphiroa anceps*



Peacock-weed *Lobophora variegata*

Soft coral *Capnella gaboensis*

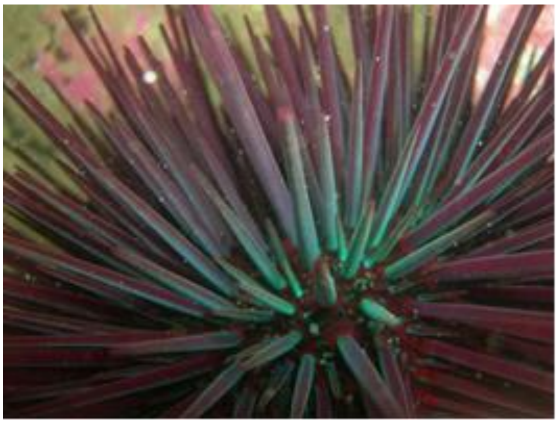
Mixed red and brown algae

Green alga *Caulerpa trifaria*

Sea urchin barren

Figure 1.1. Examples of macroalgae, sessile invertebrates and substratum types present on subtidal reefs in the Twofold Shelf bioregion.

Common sea urchin *Heliocidaris erythrogramma*



Sea urchin *Centrostephanus rodgersii*

Pencil sea urchin *Phyllacanthus parvispinus*

Nudibranch *Hypselodoris bennetti*

Black-lip abalone *Haliotis rubra*

Feather stars *Comanthus trichoptera*

Figure 1.2. Examples of invertebrate species present on subtidal reefs in the Twofold Shelf bioregion.

Leatherjacket *Meuschenia freycineti*

White ear *Parma microlepis*

Maori wrasse *Ophthalmolepis lineolatus*

Banded morwong *Cheilodactylus spectabilis* (right) and purple wrasse *Notolabrus fucicola* (left)

Eastern hulafish *Trachinops taeniatus*

Trevally *Pseudocaranx georgianus*

Figure 1.3. Examples of fish species present on subtidal reefs in the Twofold Shelf 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.

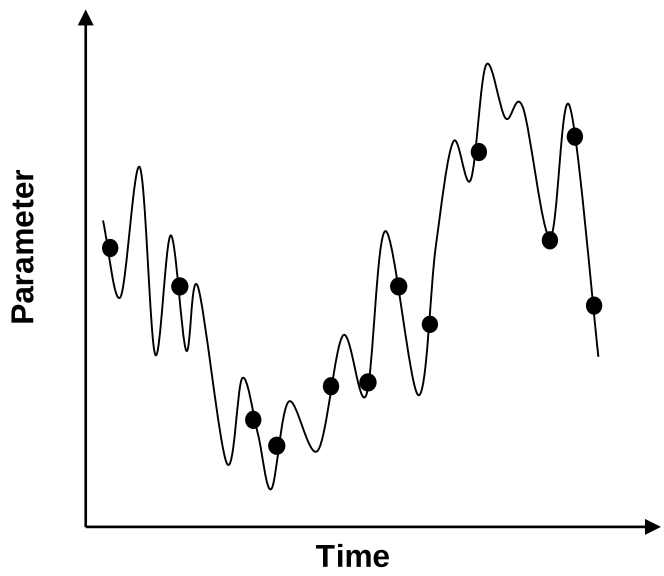


Figure 1.4. An example plot depicting change in an environmental, population or community variable over time (days, months or years) and potential patterns from isolated observations.

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

The SRMP was initiated in May 1998 in the vicinity of Port Phillip Heads Marine National Park. In 1999 the SRMP was expanded to reefs in the vicinity of the Bunurong Marine National Park, Phillip Island and Point Addis Marine National Park. In 2003 and 2004, the Subtidal Reef Monitoring Program was expanded again to include Marine National Parks and Marine Sanctuaries throughout Victoria.

1.2.2 Monitoring at the Twofold Shelf Bioregion

This report describes the subtidal reef monitoring program and the results from six surveys at Cape Howe Marine National Park. 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 up to May 2014;
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

Subtidal reefs were quantitatively surveyed in the Cape Howe region in 2001, before the current marine protected areas were gazetted (Edmunds *et al*. 2001). These sites were located on available subtidal reefs inside and outside the current marine protected area boundaries. Consequently, it was considered appropriate to incorporate some of these surveyed sites into the formal subtidal reef monitoring program that commenced in 2004 (data courtesy of Australian Marine Ecology).

In 2001, eight sites were surveyed in the Cape Howe region (Edmunds *et al*. 2001). Although the objectives of the earlier study were different to this one, the same survey method was used and many of these sites were appropriate for the Parks Victoria long-term monitoring program. Some of the sites were unsuitable for the SRMP because of their depth or representativeness. Since the commencement of the SRMP, at least eight sites at Cape Howe Marine National Park have been surveyed on six occasions (Table 2.2).

At Cape Howe, four sites inside and four sites outside the marine national park were surveyed in 2004 and 2006. In 2009, three of these sites were discontinued and three new sites were established. Under the direction of Parks Victoria, two reference sites dominated by sea urchin barrens were substituted for two sites with seaweeds. One site in the MNP, Site 3220, was deemed too close to the others so this was replaced by a more distant, but deeper site, Site 3227. A non-SRMP site, Site 11 Gabo Harbour, was resurveyed opportunistically during the 2009 survey, being previously surveyed in 2001.

The changes in monitoring sites, particularly the shift from reference sites with urchin barrens to ones dominated by seaweeds, must be considered when interpreting the time-series data, especially changes in average reference conditions.

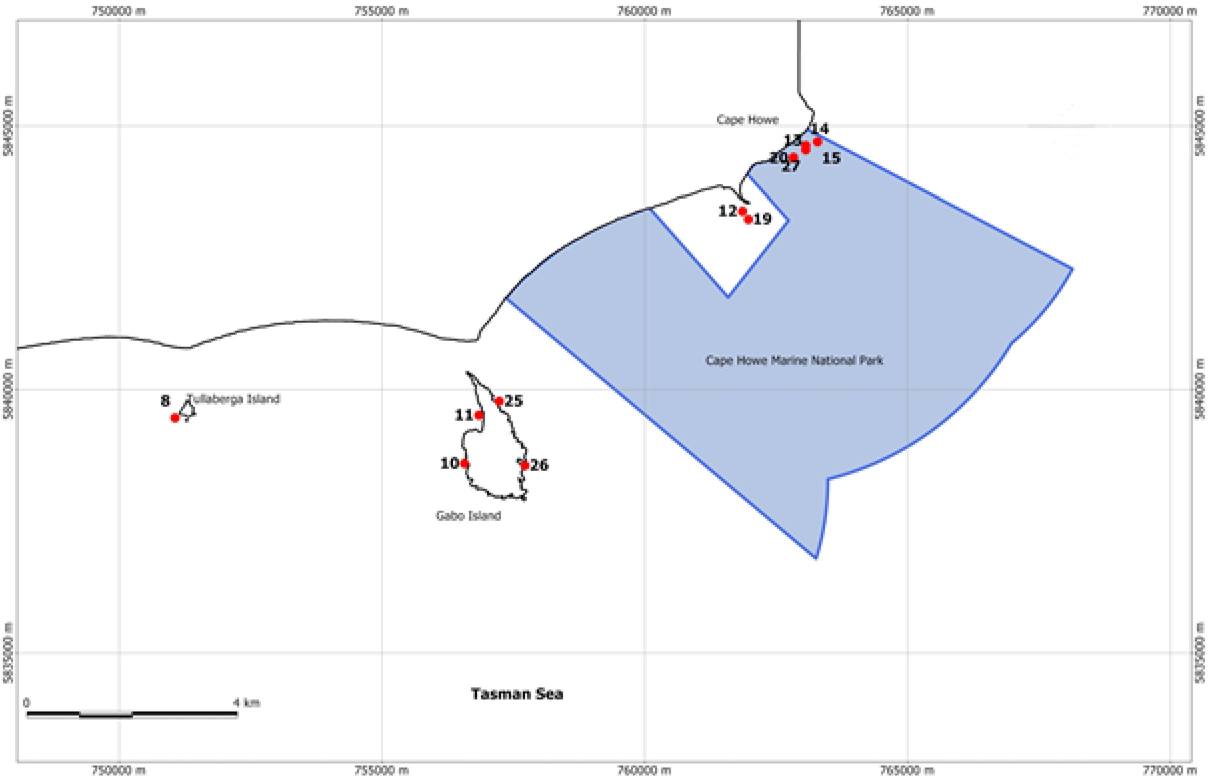


Figure 2.1. Location of sites for the Subtidal Reef Monitoring Program in the Cape Howe region. Coordinate system is Map Grid of Australia 1996 (MGA).

Table 2.1. Subtidal reef monitoring sites in the Cape Howe region.

No.	Description	Status	Depth (m)
3220	Howe Perpendicular	MPA - discontinued	10
3227	Howe Outer	MPA	14
3213	Howe West	MPA	7
3214	Howe Central	MPA	8
3215	Howe Border	MPA	10
3208	Tullaberga Deep	Reference - discontinued	7
3210	Gabo Monument	Reference - discontinued	6
3211	Gabo Harbour	Reference - discontinued	5
3225	Gabo NE Gulch	Reference	7
3226	Gabo Boulder Bay	Reference	9
3212	Iron Prince West	Reference	5
3219	Prince Wreck	Reference	6

Table 2.2. Subtidal reef monitoring survey dates in Cape Howe region.

Survey	Date	Sites
1	February 2001	3213; 3214; 3215; 3208; 3210; 3211; 3212.
2	March 2004	3220; 3213; 3214; 3215; 3208; 3210; 3212; 3219.
3	February 2006	3220; 3213; 3214; 3215; 3208; 3210; 3212; 3219.
4	March 2009	3227; 3213; 3214; 3215; 3211; 3225; 3226; 3212; 3219.
5	March 2010	3227; 3213; 3214; 3215; 3225; 3226; 3212; 3219.
6	May 2014	3227; 3213; 3214; 3215; 3225; 3226; 3212; 3219.

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, six 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); the abundance and size structure of mobile fishes using a diver-operated stereo video system, DOVS (Method 5); and the density of manufactured debris (Method 2b). 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), and then back along the other side. 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 Twofold Shelf Bioregion are listed in Table 2.3.

2.2.3 Method 2 – Invertebrates and Cryptic Fishes

Cryptic fishes and megafaunal 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 callipers, 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 or 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 Twofold Shelf 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, 20 quadrats per site). 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 each 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 Twofold Shelf Bioregion are listed in Table 2.5.

2.2.6 Method 4 – Macrocystis

Where present, the density of string kelp *Macrocystis pyrifera* was estimated by the Method 3 seaweed 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.

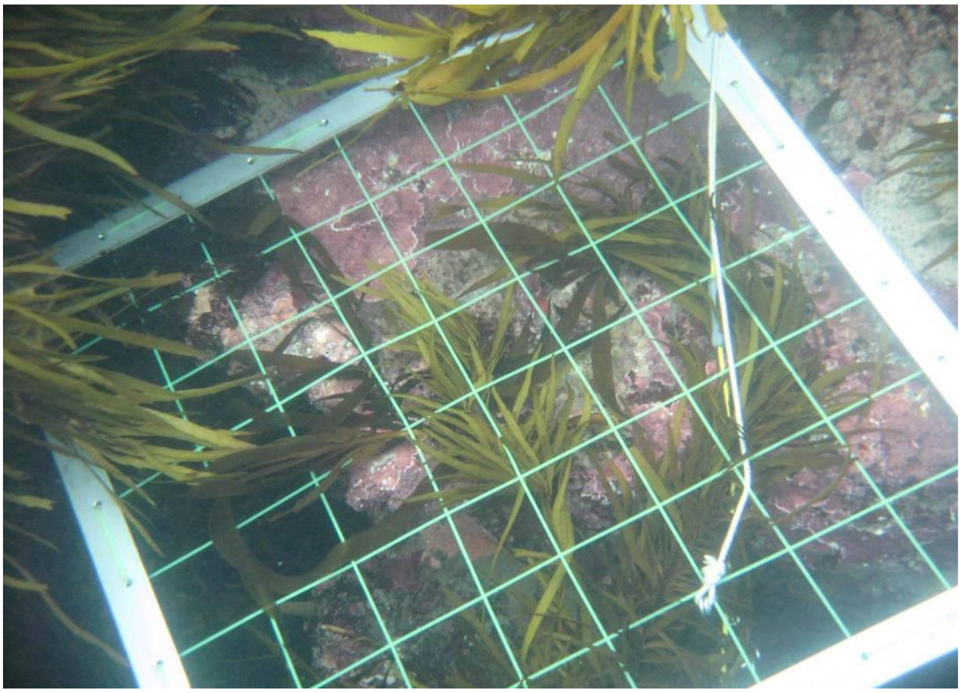


Figure 2.2. The cover of macrophytes is measured by the number of points intersecting each species on the quadrat grid.

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 fish and cephalopods (Method 1) taxa censused in the Twofold Shelf Bioregion.

Method 1		
Cephalopoda	**Mobile Bony Fishes**	**Mobile Bony Fishes**
Octopus maorum	*Upeneichthys lineatus*	*Dotalabrus aurantiacus*
	Upeneichthys vlaminghii	*Eupetrichthys angustipes*
Sharks and Rays	*Pempheris multiradiata*	*Notolabrus gymnogenis*
Heterodontus portusjacksoni	*Kyphosus sydneyanus*	*Notolabrus tetricus*
Parascyllium ferrugineum	*Girella tricuspidata*	*Notolabrus fucicola*
Cephaloscyllium laticeps	*Girella elevata*	*Pseudolabrus rubicundus*
Orectolobus maculatus	*Girella zebra*	*Pseudolabrus luculentus*
Dasyatis brevicaudata	*Scorpis aequipinnis*	*Pictilabrus laticlavius*
Myliobatis australis	*Scorpis lineolata*	*Odax acroptilus*
Urolophus cruciatus	*Atypichthys strigatus*	*Olisthops cyanomelas*
Urolophus paucimaculatus	*Enoplosus armatus*	*Neoodax balteatus*
Trygonoptera testacea	*Pentaceropsis recurvirostris*	*Bovichtus angustifrons*
	Parma victoriae	*Cristiceps australis*
Mobile Bony Fishes	*Parma microlepis*	*Acanthaluteres vittiger*
Scorpaena papillosa	*Chromis hypsilepis*	*Meuschenia australis*
Caesioperca lepidoptera	*Chironemus marmoratus*	*Meuschenia flavolineata*
Caesioperca rasor	*Aplodactylus arctidens*	*Meuschenia freycineti*
Hypoplectrodes maccullochi	*Aplodactylus lophodon*	*Meuschenia hippocrepis*
Trachinops taeniatus	*Cheilodactylus fuscus*	*Eubalichthys bucephalus*
Dinolestes lewini	*Cheilodactylus nigripes*	*Eubalichthys mosaicus*
Pseudocaranx georgianus	*Cheilodactylus spectabilis*	*Contusus brevicaudus*
Trachurus novaezelandiae	*Nemadactylus douglasii*	*Tetractenos glaber*
Trachurus declivis	*Dactylophora nigricans*	*Diodon nichthemerus*
Arripis georgianus	*Latridopsis forsteri*	
Arripis spp.	*Sphyraena novaehollandiae*	**Mammals**
Parequula melbournensis	*Achoerodus viridis*	*Arctocephalus pusillus*
Pagrus auratus	*Ophthalmolepis lineolata*	

Table 2.4. Invertebrate and cryptic fish (Method 2) taxa censused in the Twofold Shelf Bioregion.

Method 2		
Polychaete Worms	**Crustacea**	**Cryptic Fishes**
Sabellastarte australiensis	*Jasus edwardsii*	*Cephaloscyllium laticeps*
	Jasus verreauxi	*Orectolobus maculatus*
Molluscs	*Paguristes frontalis*	*Urolophus cruciatus*
Chitons	*Strigopagurus strigimanus*	*Heterodontus portusjacksoni*
Haliotis rubra	*Nectocarcinus tuberculatus*	*Lotella rhacina*
Scutus antipodes	*Guinusia chabrus*	*Pseudophycis bachus*
Phasianotrochus eximius	*Pagurid* spp	*Pseudophycis barbata*
Phasianella australis		*Scorpaena papillosa*
Phasianella ventricosa	**Echinoderms**	*Centropogon australis*
Turbo undulatus	*Comanthus trichoptera*	*Helicolenus percoides*
Turbo jourdani	*Comanthus tasmaniae*	*Hypoplectrodes maccullochi*
Astralium tentoriiforme	*Tosia magnifica*	*Pempheris multiradiata*
Charonia lampas rubicunda	*Tosia australis*	*Pempheris compressa*
Cabestana spengleri	*Nectria ocellata*	*Parma victoriae*
Cabestana tabulata	*Nectria multispina*	*Parma microlepis*
Argobuccinium vexillum	*Meridiastra calcar*	*Gymnothorax prasinus*
Ranella australasia	*Coscinasterias muricata*	*Chromis hypsilepis*
Dicathais orbita	*Astrostole scabra*	*Chironemus marmoratus*
Penion maxima	*Goniocidaris tubaria*	*Eupetrichthys angustipes*
Cominella lineolata	*Phyllacanthus parvispinus*	*Bovichtus angustifrons*
Tambja verconis	*Heliocidaris erythrogramma*	*Trinorfolkia clarkei*
Neodoris chrysoderma	*Centrostephanus rodgersii*	*Heteroclinus perspicillatus*
Hypselodoris bennetti	*Amblypneustes* spp	*Contusus brevicaudus*
Octopus berrima	*Holopneustes inflatus*	*Diodon nichthemerus*
Octopus tetricus	*Holopneustes purpurascens*	
Octopus spp		

Table 2.5. Macroalgae taxa (Method 3) censused in the in the Twofold Shelf bioregion.

Method 3		
Chlorophyta (green algae)	**Phaeophyta (brown algae)**	**Rhodophyta (red algae)**
Ulva spp	*Phyllospora comosa*	*Plocamium dilatatum*
Ulva compressa	*Cystophora moniliformis*	*Plocamium leptophyllum*
Chaetomorpha coliformis	*Cystophora monilifera*	*Plocamium cirrhosum*
Codium duthieae	*Cystophora retorta*	*Mychodea acanthymenia*
Codium galeatum	*Cystophora siliquosa*	*Asparagopsis armata*
Caulerpa scalpelliformis	*Acrocarpia paniculata*	*Delisea pulchra*
Caulerpa trifaria	*Sargassum* spp	*Gracilaria secundata*
Caulerpa hodgkinsoniae	*Sargassum verruculosum*	*Curdiea angustata*
	Sargassum vestitum	*Amphiroa anceps*
Phaeophyta (brown algae)		*Arthrocardia wardii*
Halopteris spp	**Rhodophyta (red algae)**	*Jania rosea*
Cladostephus spongiosus	*Galaxaura marginata*	*Halopeltis australis*
Dictyota dichotoma	*Pterocladia lucida*	*Rhodymenia leptophylla*
Dictyota diemensis	*Gelidium australe*	*Rhodymenia linearis*
Dilophus spp	*Gelidium* spp	*Rhodymenia obtusa*
Dilophus marginatus	*Pterocladia capillacea*	*Rhodymenia stenoglossa*
Dictyopteris acrostichoides	*Pterocladiella capillacea*	*Rhodymenia wilsoni*
Dictyopteris muelleri	*Nizymenia australis*	*Cordylecladia furcellata*
Padina sp	*Peyssonelia novaehollandiae*	*Champia viridis*
Homeostrichus sinclairii	*Halymenia plana*	*Ballia callitricha*
Zonaria angustata	*Grateloupia filicina*	*Ceramium* spp
Zonaria crenata	*Polyopes constrictus*	*Griffithsia* sp
Zonaria spp	*Polyopes tasmanicus*	*Hemineura frondosa*
Zonaria turneriana	*Callophyllis lambertii*	*Dictymenia harveyana*
Distromium spp	*Callophyllis rangiferina*	*Dictymenia tridens*
Exallosorus olsenii	*Plocamium angustum*	*Lenormandia marginata*
Lobophora variegata	*Plocamium mertensii*	*Lophurella periclados*
Carpomitra costata	*Plocamium patagiatum*	*Nemastoma feredayae*
Sporochnus sp	*Phacelocarpus complanatus*	
Colpomenia peregrina	*Phacelocarpus peperocarpos*	
Colpomenia sinuosa	*Acrotylus australis*	
Ecklonia radiata	*Plocamium cartilagineum*	
Macrocystis angustifolia		
Durvillaea potatorum		

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. This criterion is more sensitive to the detection of gradual changes over time away from the baseline conditions. In this case, there have only been six surveys and the baseline criterion will be applied when a longer time series is available. The second criterion was the deviation in community structure at time *t* to the centroid of all previous times. This criterion is more sensitive at detecting abrupt or pulse changes.

Control charts were prepared for each site. The control chart analysis used the methods of Anderson and Thompson (2004) and calculations were done using the software ControlChart.exe (Anderson 2008). The analysis used the Bray-Curtis dissimilarity coefficient and the same data transformations described above. Bootstrapping was used to provide control-chart limits for identifying changes that are 'out of the ordinary'. In this case, a 90th percentile statistic was calculated from 1000 bootstrap samples as a provisional limit or trigger line. The 50th percentile was also presented to assist in interpreting the control charts. Until there is a longer time series of monitoring to distinguish from a starting time, only the criterion for deviation from all prior times was assessed here.

Species Diversity

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

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

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

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

Abundances of Selected Species

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

2.3.3 Ecosystem Functional Components

Plant Habitat and Production

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

- crustose coralline algae;
- canopy browns – defined here as *Ecklonia radiata, Undaria pinnatifida, Lessonia corrugata, Macrocystis pyrifera*, *Durvillaea potatorum, Phyllospora comosa,*

Seirococcus axillaris, Acrocarpia paniculata, Cystophora platylobium, C. moniliformis, C. pectinata, C. monilifera, C. retorta and *C. retroflexa;*

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

Invertebrate Groups

The abundances of invertebrates were pooled into the functional groups:

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

Fish Groups

The abundances of fishes were also pooled into trophic groups:

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

Sediment Cover

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

2.3.4 Introduced Species

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

- number of introduced species;

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

2.3.5 Climate Change

Species Composition

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

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

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

Macrocystis pyrifera

The string kelp *Macrocystis pyrifera*, which includes the former species *M. angustifolia* (Macaya and Zuccarello 2010), is considered potentially vulnerable to climate change through reduced nutrient supply from drought and nutrient poorer warmer waters (Edyvane 2003). The mean abundance of *M. pyrifera* were plotted using densities from Method 4, or cover estimates from Method 4 where density data were unavailable. *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 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 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. SRMP transects generally did not traverse rock lobster microhabitats. Abundances and sizes were reported where adequate 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).

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 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 2.6.

Table 2.6. 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*

3 Results

3.1 Macroalgae

3.1.1 Macroalgal Community Structure

The algal composition at Cape Howe was dominated by monospecific stands of crayweed *Phyllospora comosa*. Other dominant species were small brown algae *Halopteris* spp, crustose coralline algae, and the coralline red alga *Jania rosea*.

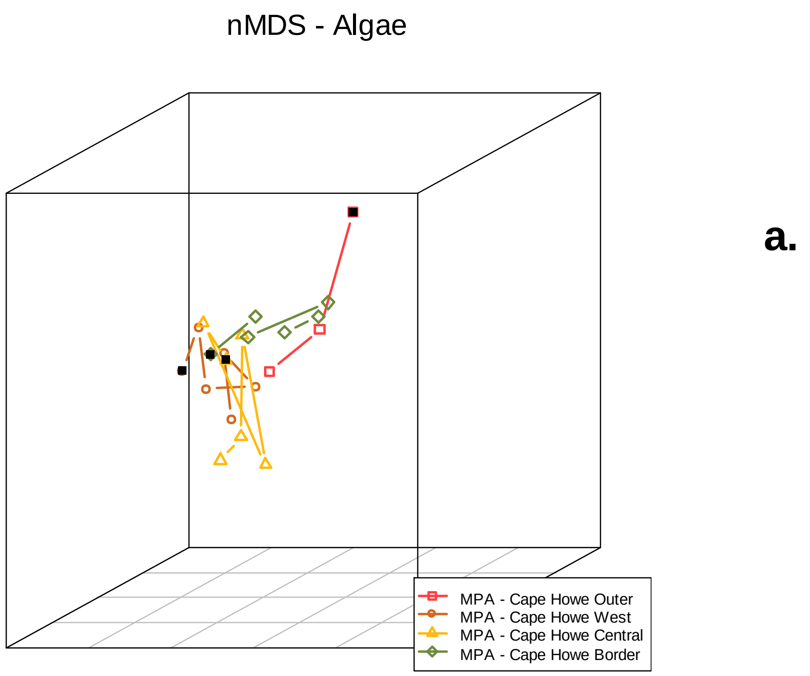
The non-metric MDS and multivariate control chart analyses indicated the algal assemblage structures have shifted in structure over time at most sites, both inside and outside the MPA (Figures 3.1 and 3.2). The shifts have tended to be incremental, although there was a relatively greater shift between 2006 and 2009 (Figures 3.2b and 3.2d).

3.1.2 Macroalgal Species Abundance, Richness and Diversity

The total algal abundance declined between 2010 and 2014 to lowest observed levels, both inside and outside the MPA (Figure 3.3a). Both algal species richness and Hill's N2 diversity remained relatively high and stable in recent years (Figures 3.3b and 3.3c). It should be noted that lower values in earlier years in the reference area are largely an artefact of site changes during the monitoring program.

3.1.3 Common Algal Species

Within the Cape Howe Marine National Park, the abundance of crayweed *Phyllospora comosa* declined by approximately 25 % cover between 2004 and 2009, with little change thereafter (Figure 3.4a). Over the same period, there was an apparent increase in the abundances of the small brown algae *Halopteris* spp and the erect coralline alga *Jania rosea* (Figure 3.4b and 3.4d). There was no apparent trend inside the MPA in the abundance of crustose coralline algae (Figure 3.4c; note this group was not measured during the first survey).



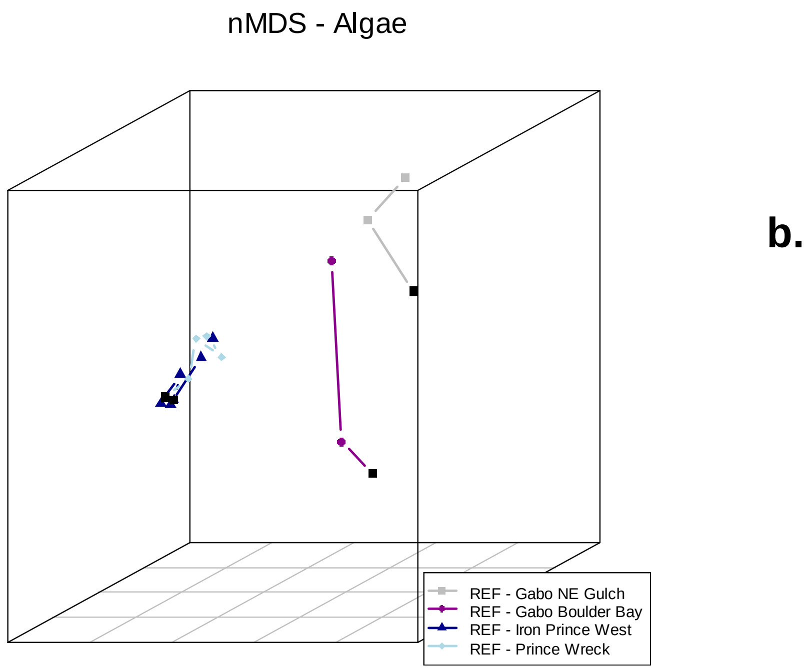


Figure 3.1. Three-dimensional nMDS plot of algal assemblage structure at Cape Howe Marine National Park. Kruskal stress = 0.07. Filled black marks indicate the start in 2001.

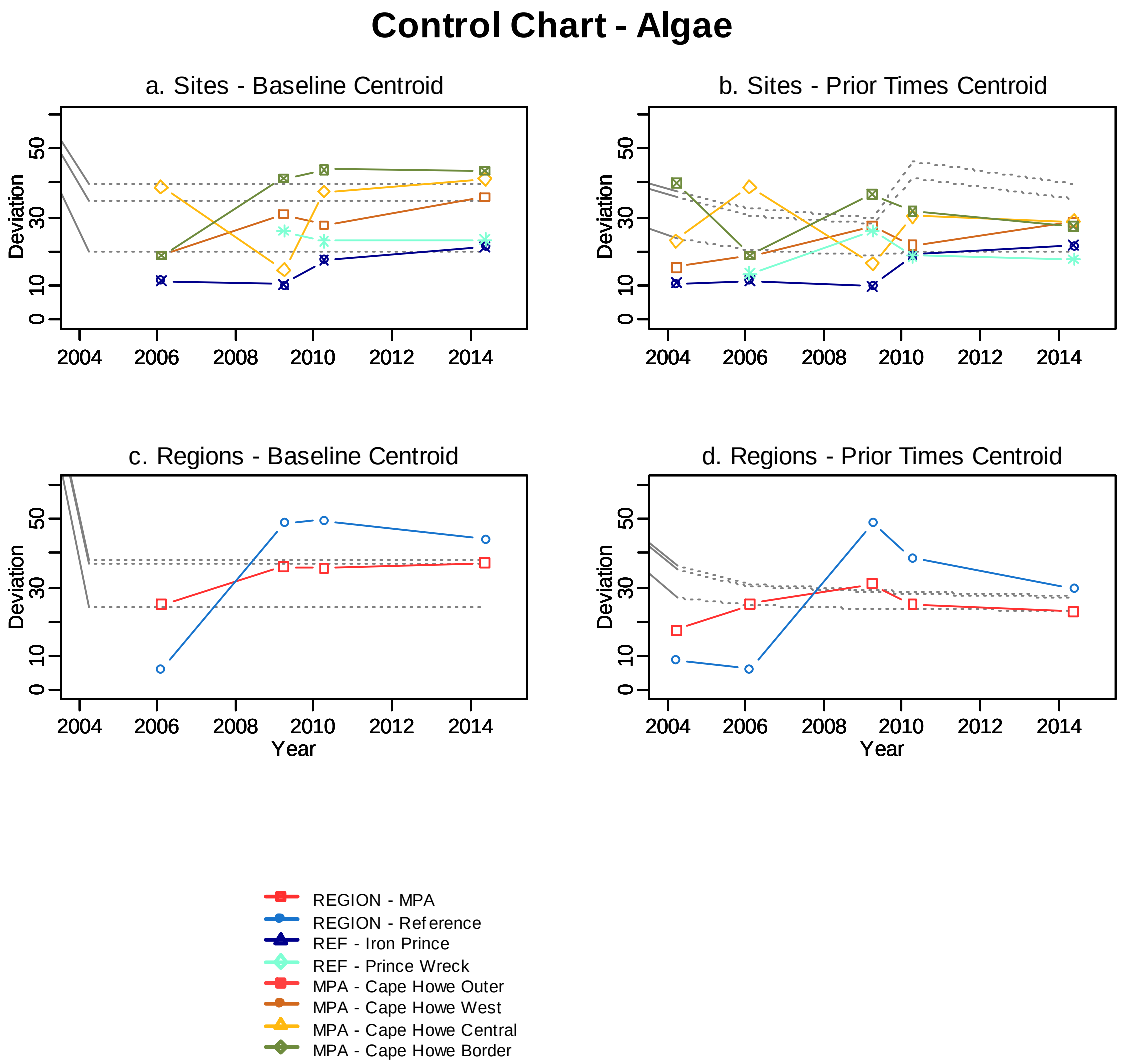


Figure 3.2. Control charts of algal assemblage structure inside and outside the Cape Howe MPA.

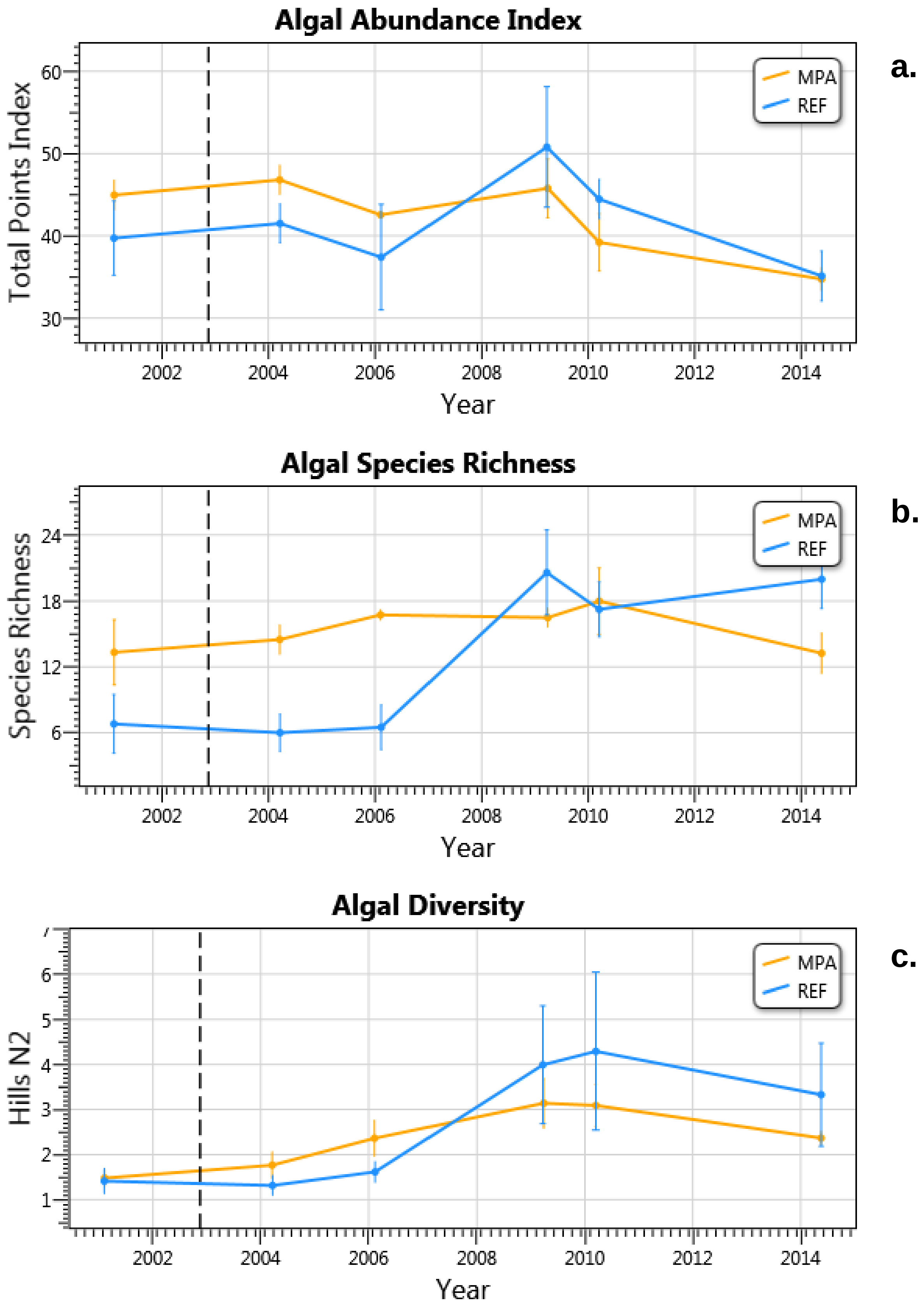


Figure 3.3. Algal species diversity indicators (± Standard Error) for MPA and reference areas at Cape Howe MPA.

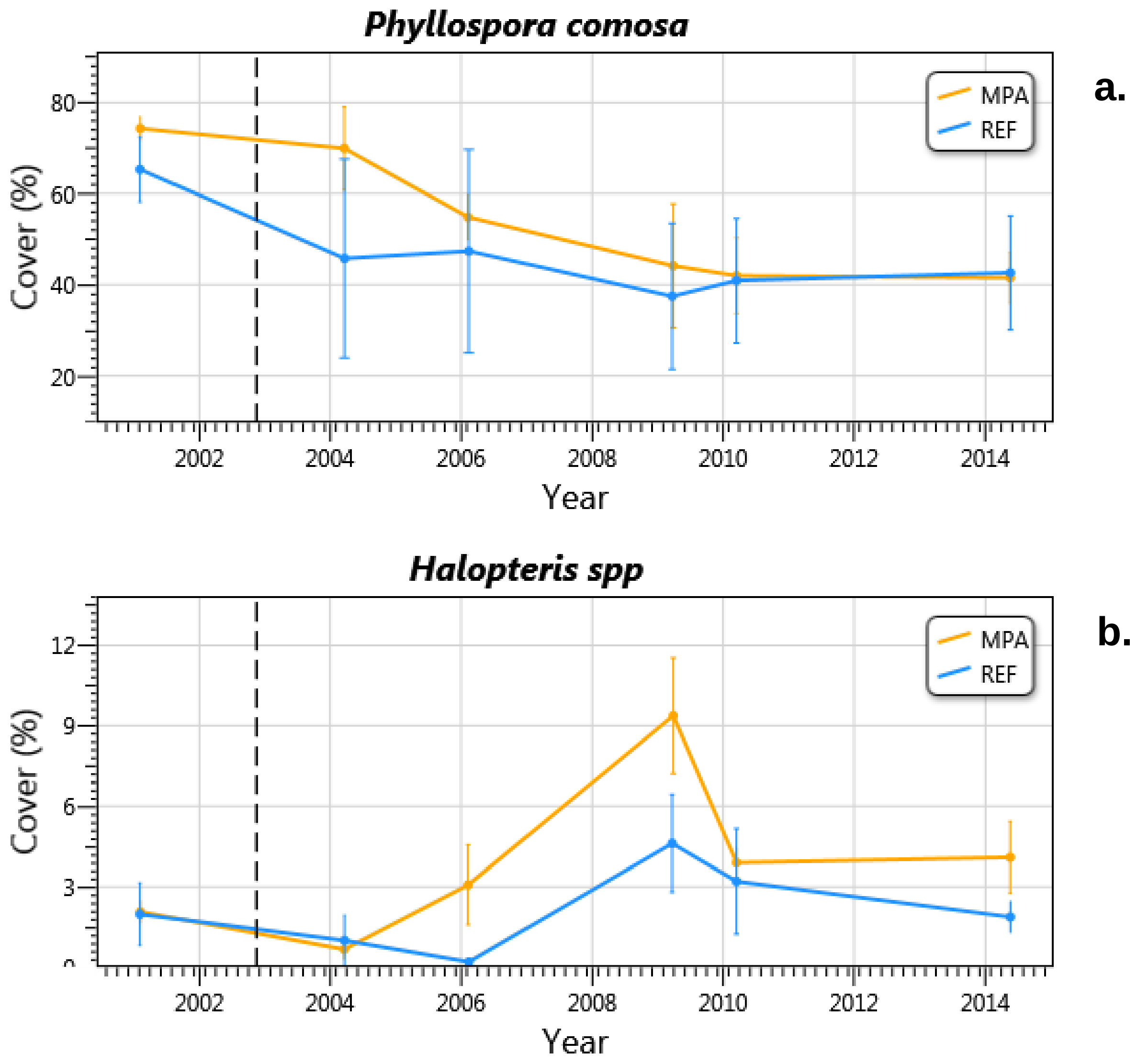
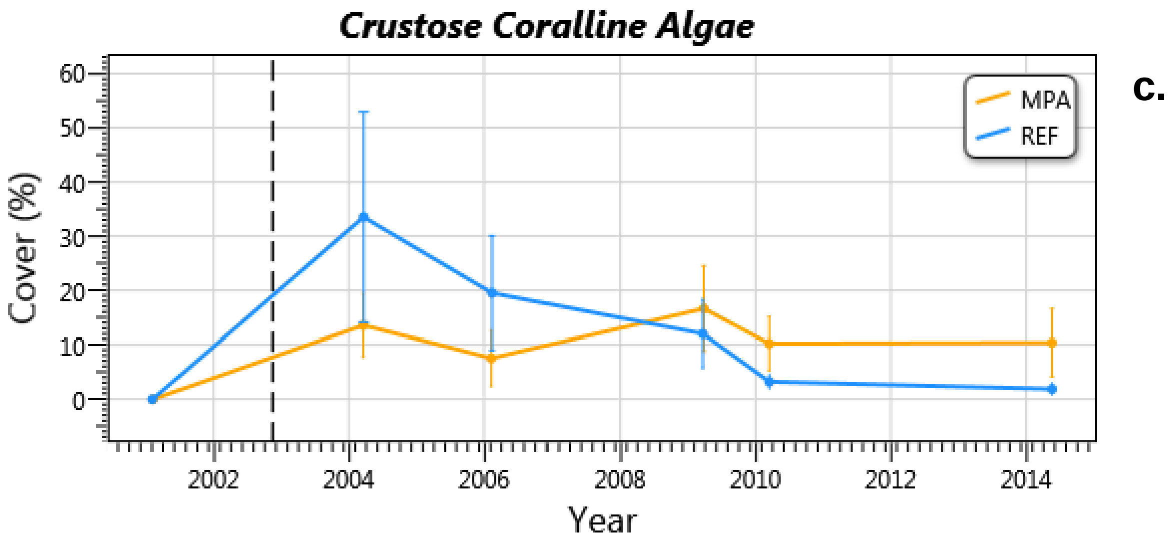


Figure 3.4. Percent cover of predominant algal species inside and outside the Cape Howe Marine National Park. Note: crustose coralline algae were not surveyed in 2001.



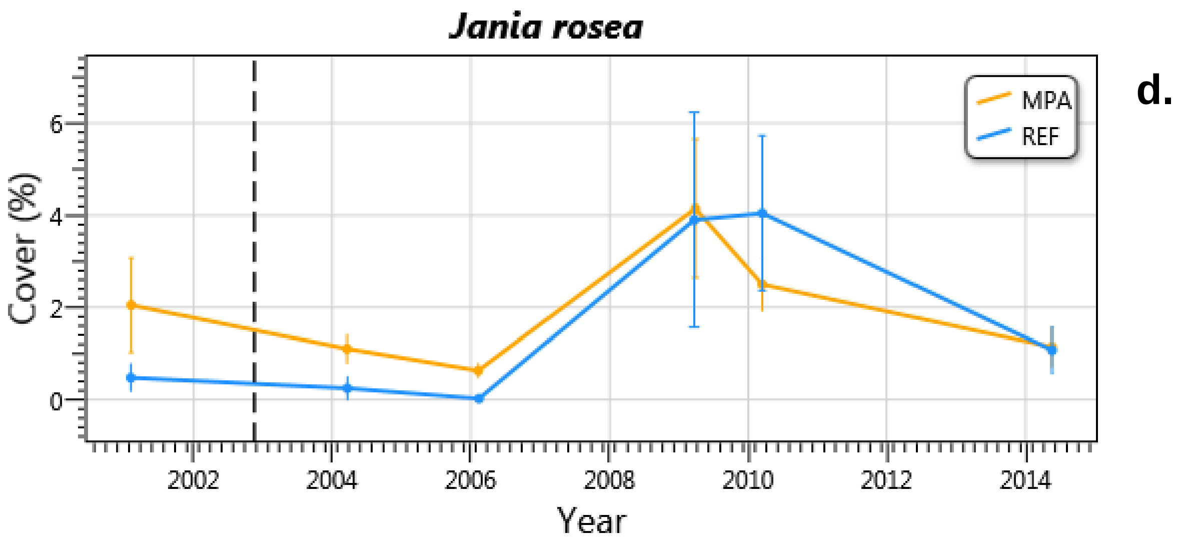


Figure 3.4 (continued). Percent cover of predominant algal species inside and outside the Cape Howe Marine National Park. Note: crustose coralline algae were not surveyed in 2001.

3.2 Invertebrates

3.2.1 Invertebrate Community Structure

There were typically higher abundances of large herbivorous invertebrates at Cape Howe. These included the sea urchin *Centrostephanus rodgersii*, blacklip abalone *Haliotis rubra*, and the periwinkle *Turbo undulatus.*

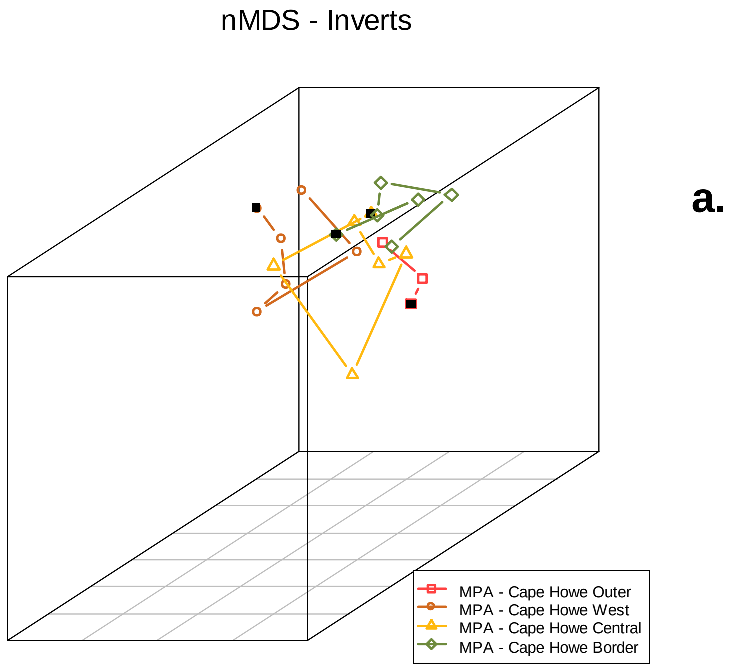
The nMDS plot indicated the invertebrate assemblages were relatively similar at each of the MPA sites, but different between reference sites (Figure 3.5). Both the nMDS and multivariate control chart analyses indicated there were shifts in assemblage structure in the reference area, largely driven by changes at the Iron Prince reference site in 2009 and 2010 (Figures 3.5 and 3.6). There was a shift back toward initial (‘baseline’) conditions in 2014, however the deviation from baseline conditions still above the 99th percentile in 2014 (Figure 3.6c). Such shifts were not apparent within the MPA.

3.2.2 Invertebrate Species Abundance, Richness and Diversity

During the monitoring program, there was a dip in total abundance of invertebrates within the MPA, with abundance halving by 2006 and a subsequent return to initial levels by 2014 (Figure 3.7a). There was a substantial decline apparent in the reference area between 2006 and 2009, however this is partly because of changes to the monitoring sites. Invertebrate species richness and diversity have not changed markedly during the monitoring program (Figures 7.7b and 3.7c).

3.2.3 Common Invertebrate Species

The abundance of blacklip abalone *Haliotis rubra* increased substantially inside the MPA since declaration of the MPA. There were corresponding increases outside the MPA in 2009 and 2010, however they were not sustained to 2014 as they were inside the MPA (Figure 3.8a). Abalone abundance within the MPA was at highest recorded levels in 2014. There was a marked decline in abundance of the warrener *Turbo undulatus* inside the MPA from 2001 to 2006, with a gradual rise thereafter (Figure 3.8b). Other invertebrate abundances within the MPA have been relatively stable over time, particularly the abundance of the long-spined sea urchin *Centrostephanus rodgersii* (Figures 3.8c to 3.8g).



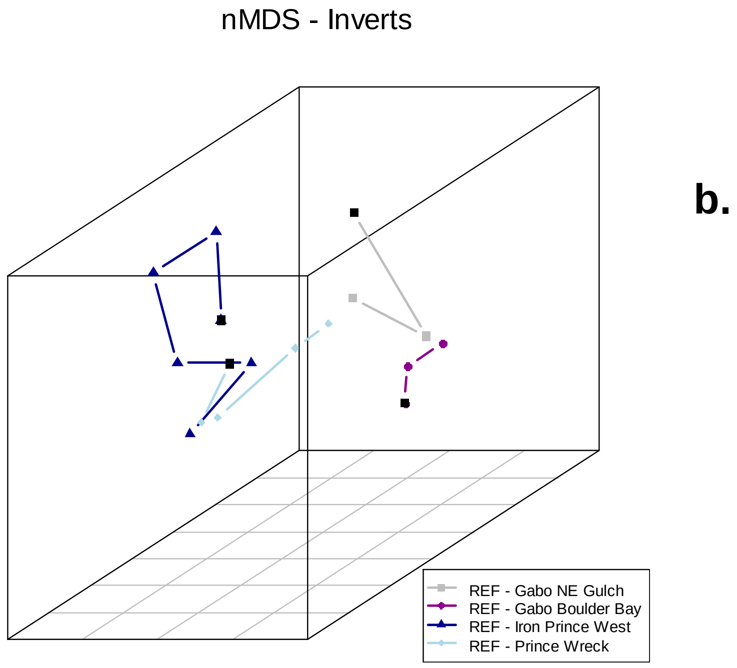


Figure 3.5. Three-dimensional nMDS plot of invertebrate assemblage structure at the Cape Howe Marine National Park. Kruskal stress = 0.09. Filled black marks indicate the start in 2001.

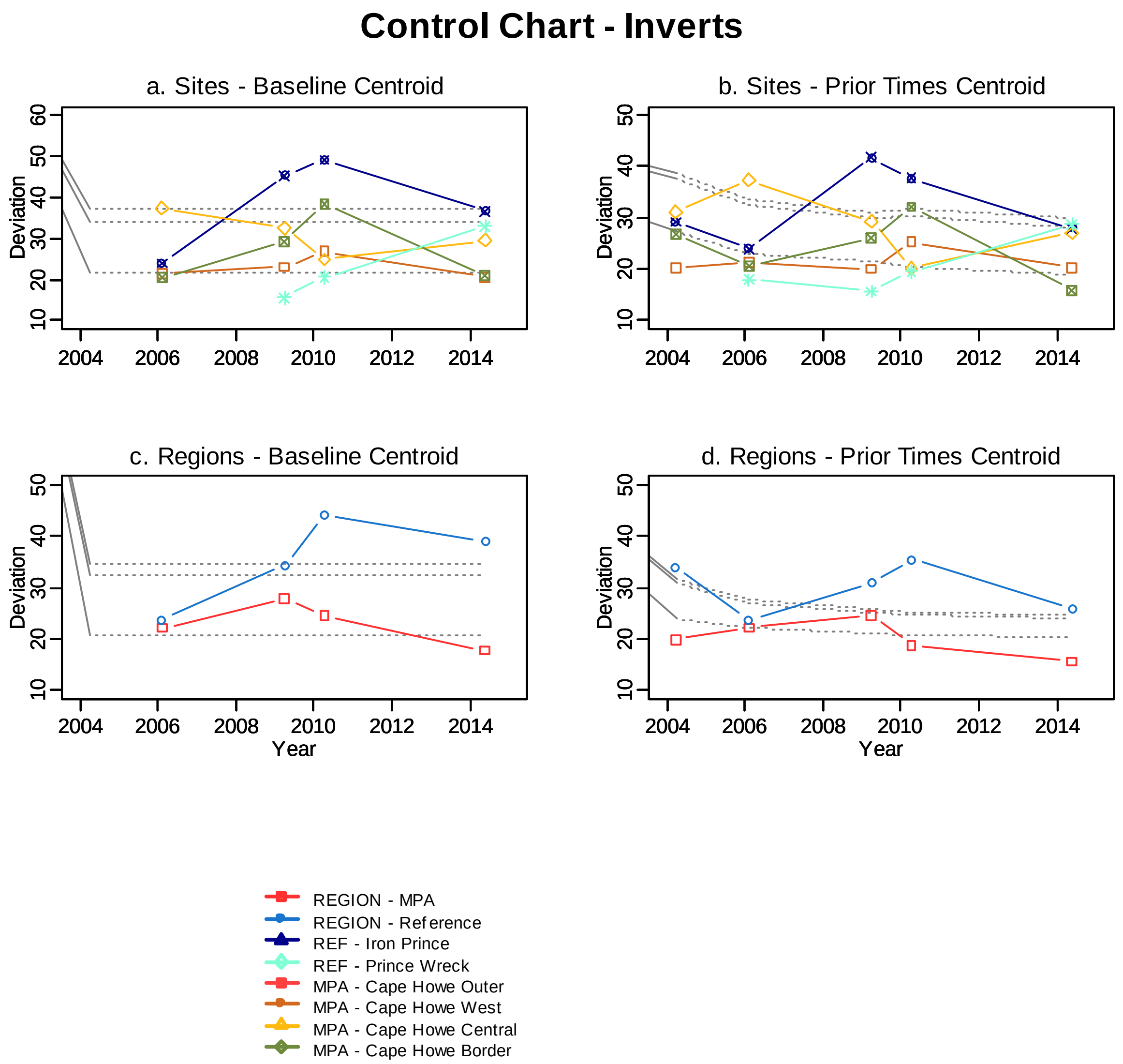


Figure 3.6. Control chart of invertebrate assemblage structure inside and outside the Cape Howe Marine National Park.

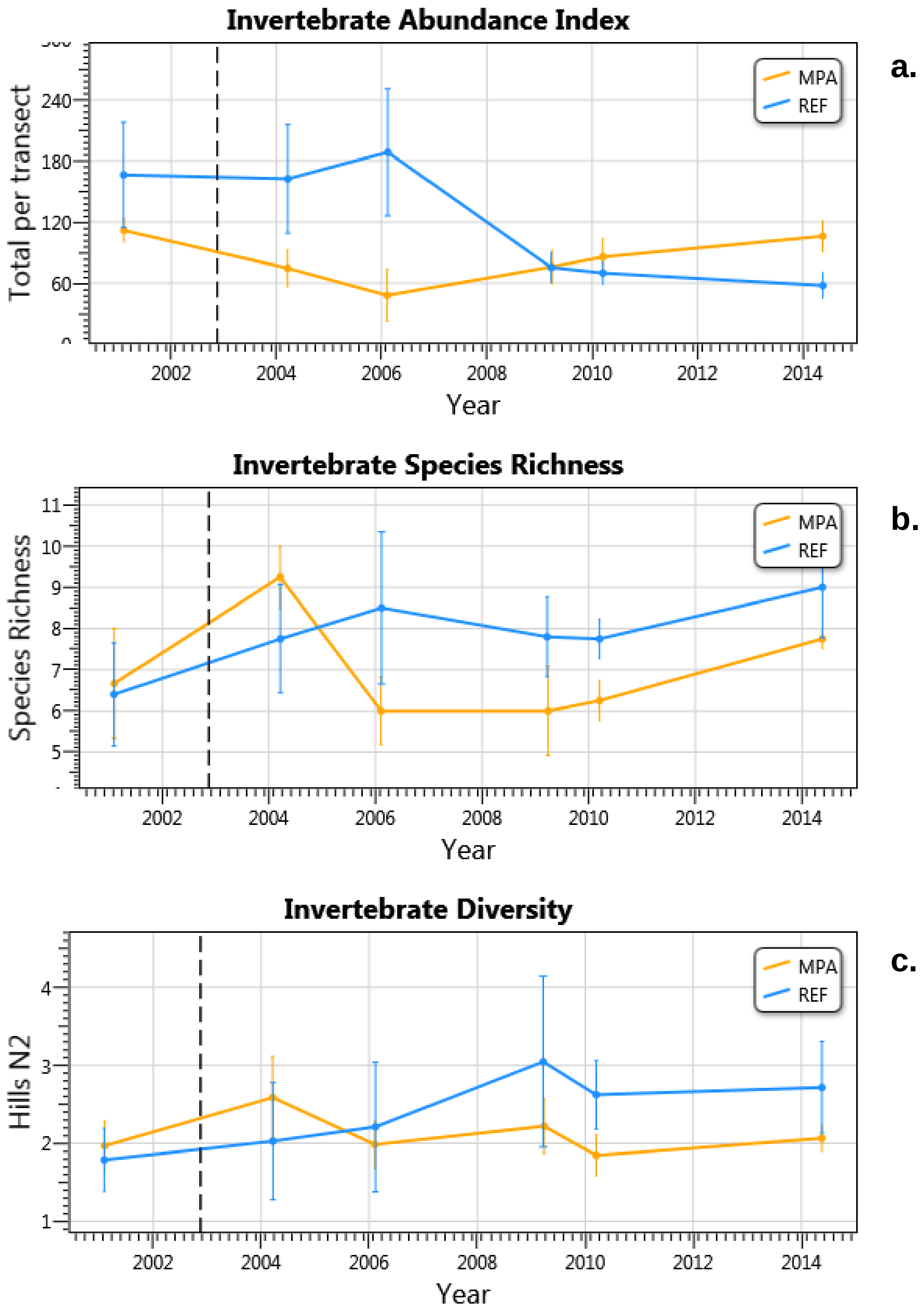


Figure 3.7. Invertebrate species diversity inside and outside the Cape Howe Marine National Park.

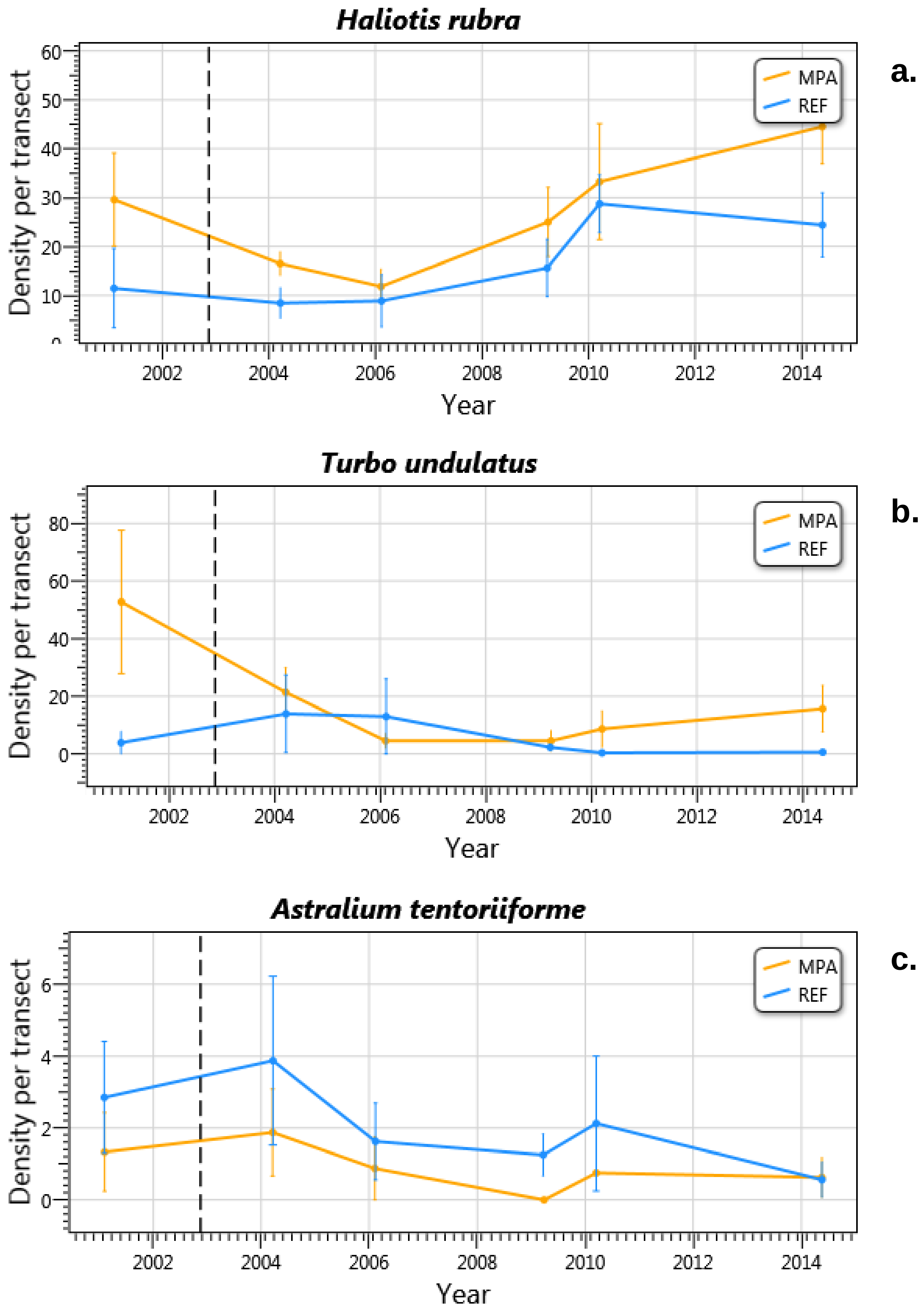


Figure 3.8. Predominant invertebrate species abundance inside and outside the Cape Howe Marine National Park.

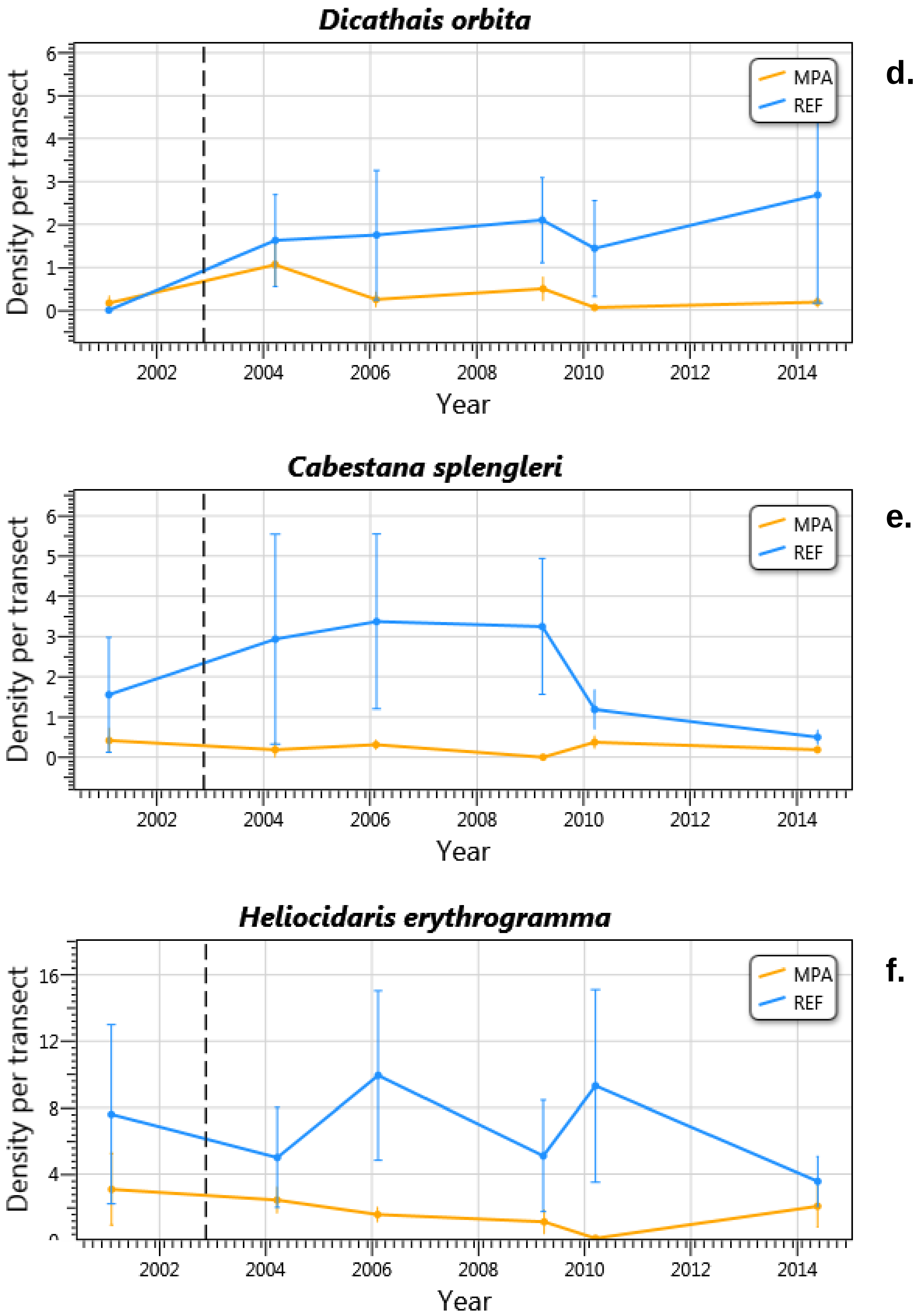


Figure 3.8 (continued). Predominant invertebrate species abundance inside and outside the Cape Howe Marine National Park.

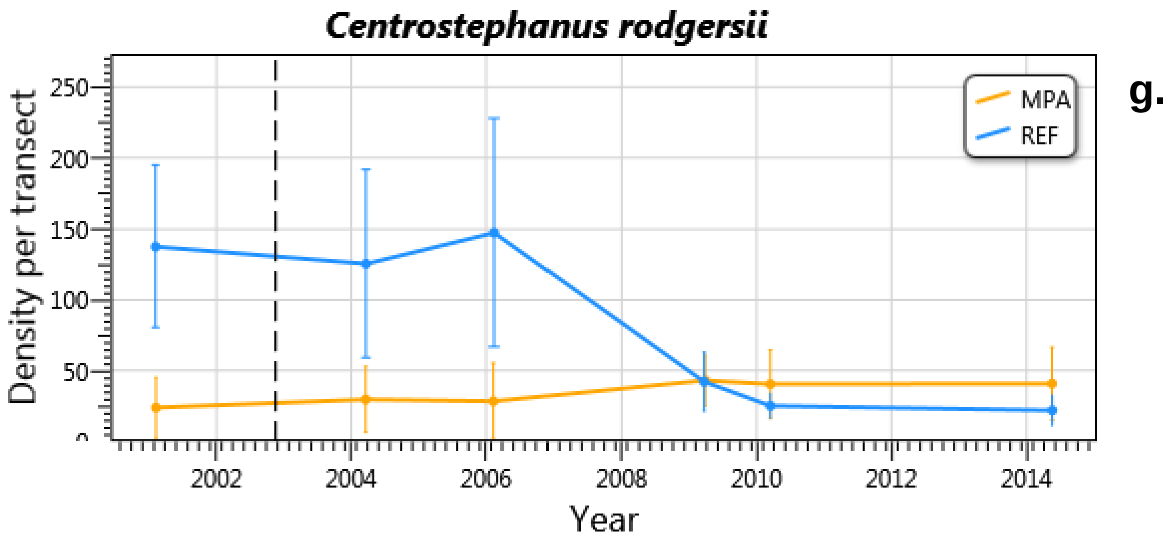


Figure 3.8 (continued). Predominant invertebrate species abundance inside and outside the Cape Howe Marine National Park.

3.3 Fishes

3.3.1 Fish community structure

Wrasses comprised the predominant fish species at Cape Howe, including the blue throat wrasse *Notolabrus tetricus*, purple wrasse *N. fucicola*, crimson wrasse *N. gymnogenis*, Maori wrasse *Ophthalmolepis lineolata* and eastern blue grouper *Achoerodus viridis*. Other distinctive fishes in the Cape Howe region included herring cale *Olisthops cyanomelas*, banded morwong *Cheilodactylus spectabilis*, kelpfish *Aplodactylus lophodon*, striped mado *Atypichthys strigatus* and the damselfishes *Parma microlepis* and *Chromis hypsilepis*.

The fish assemblage structures were relatively distinct between sites and the magnitude of changes between times within each site varied markedly between sites. The Cape Howe Central site had the greatest level of temporal variability (Figure 3.9).

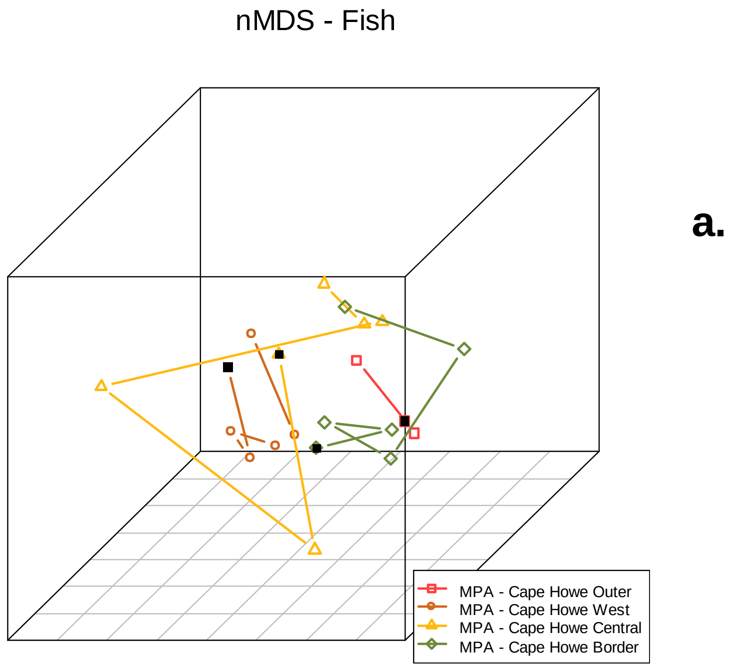
The multivariate control chart analyses indicted there have been ongoing shifts in assemblage structure both inside and outside the MPA since 2006. This includes a shift away from baseline conditions and substantial shifts from the prior times centroids with each subsequent survey (Figures 3.10c and 3.10 d).

3.3.2 Fish Species Abundance, Richness and Diversity

Total fish abundance and fish species richness followed the same pattern over the monitoring period, with peaks in 2004 and 2008 (Figures 3.11a and 3.11b). Fish diversity has increased slightly within the MPA since 2006 (Figure 3.11c).

3.3.3 Common Fish Species

The abundances of common fish species tended to follow similar temporal trajectories inside and outside the MPA (Figures 3.12a to 3.12k). Notable recent increases in abundance were observed for banded morwong *C. spectabilis* and bastard trumpeter *Latridopsis forsteri* (Figures 3.12e and 3.12f). Slight increases were observed in abundances of crimson wrasse *Notolabrus gymnogenis* and blue grouper *Achoerodus viridis* (Figures 3.12h and 3.12i).



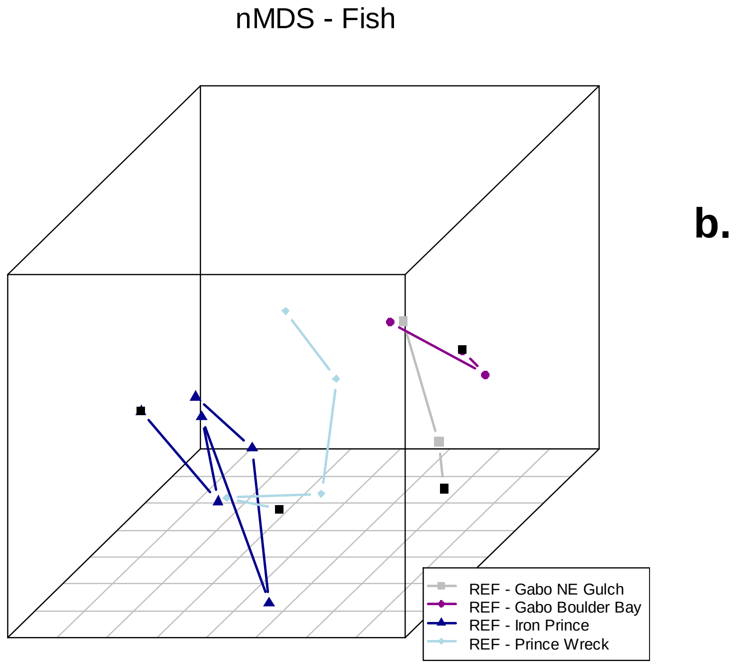


Figure 3.9. Three-dimensional nMDS plot of fish assemblage structure at the Cape Howe Marine National Park. Kruskal stress = 0.13. Filled black marks indicate 2001 data.

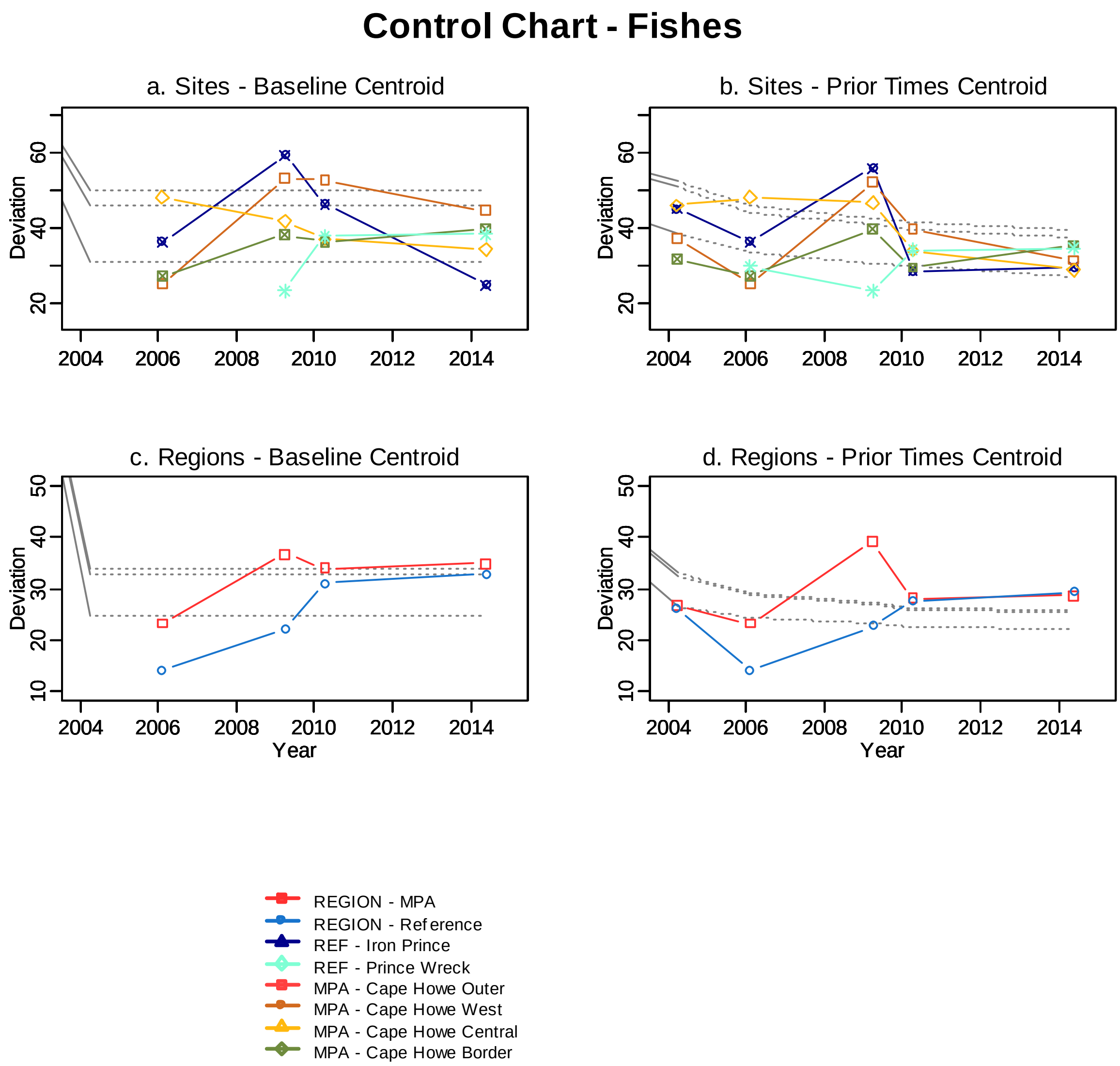


Figure 3.10. Control charts of fish assemblage structure inside and outside the Cape Howe MPA.

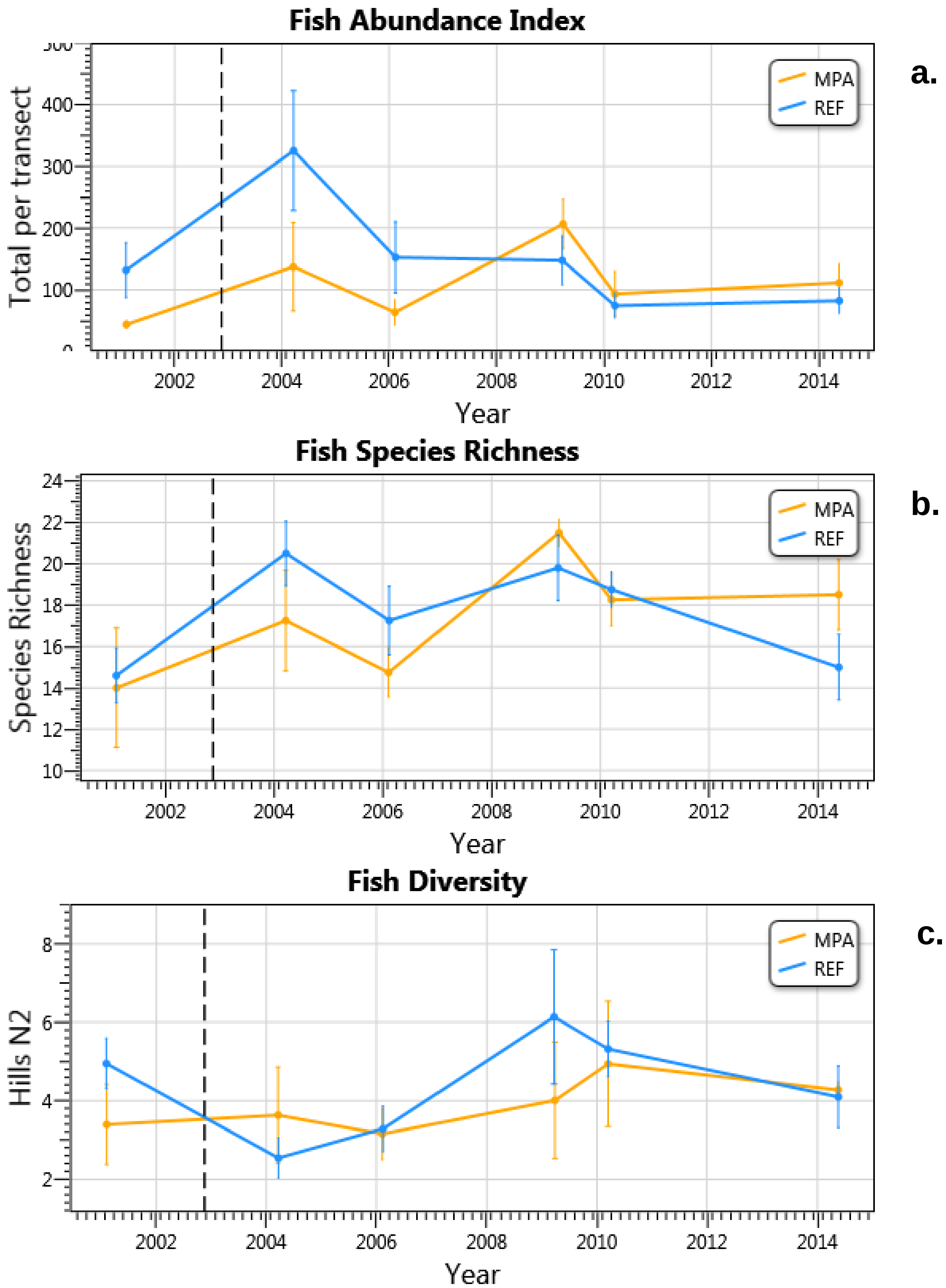


Figure 3.11. Fish species diversity indicators (± Standard Error) for MPA and reference areas at Cape Howe MPA.

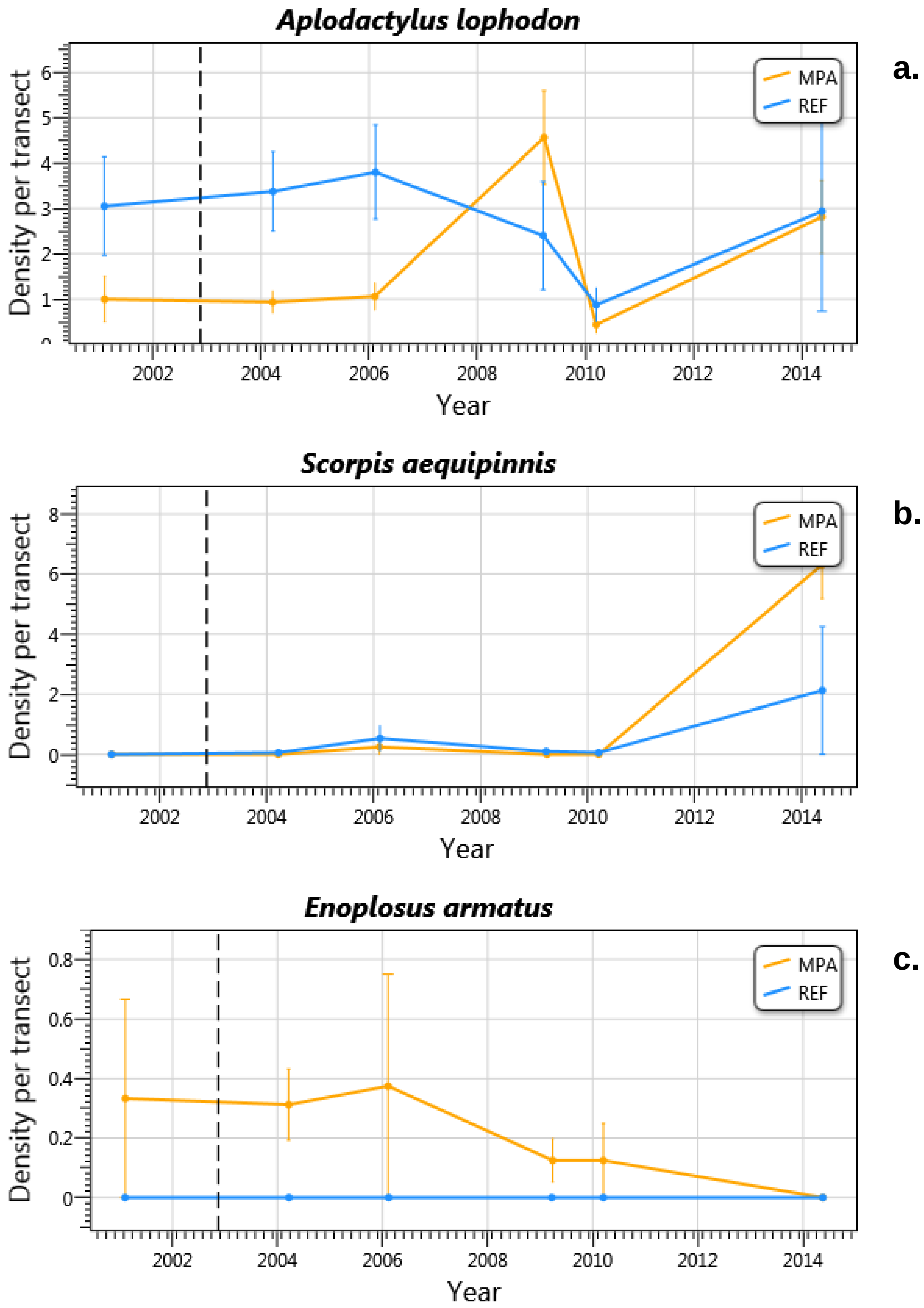
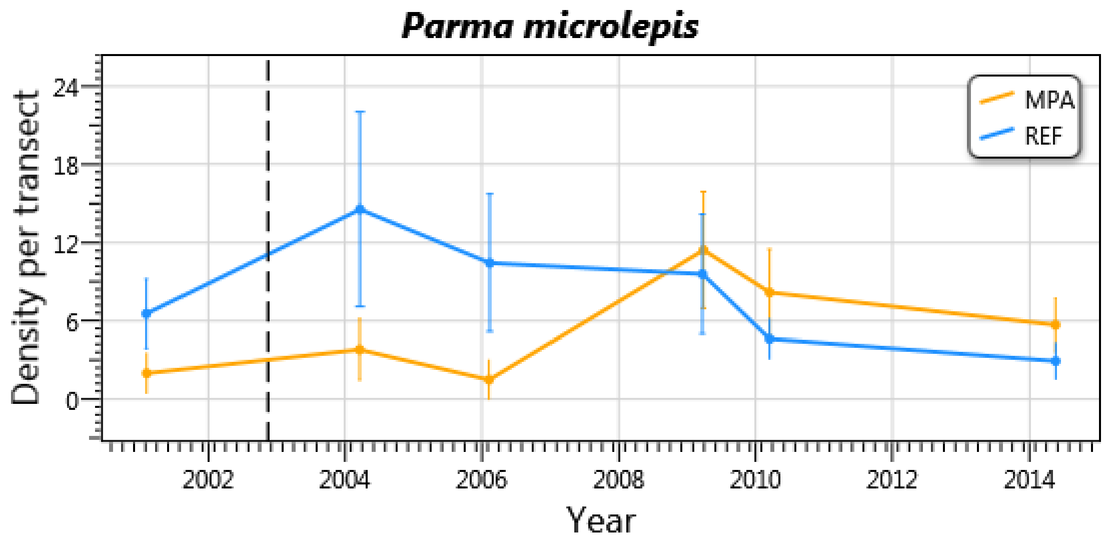
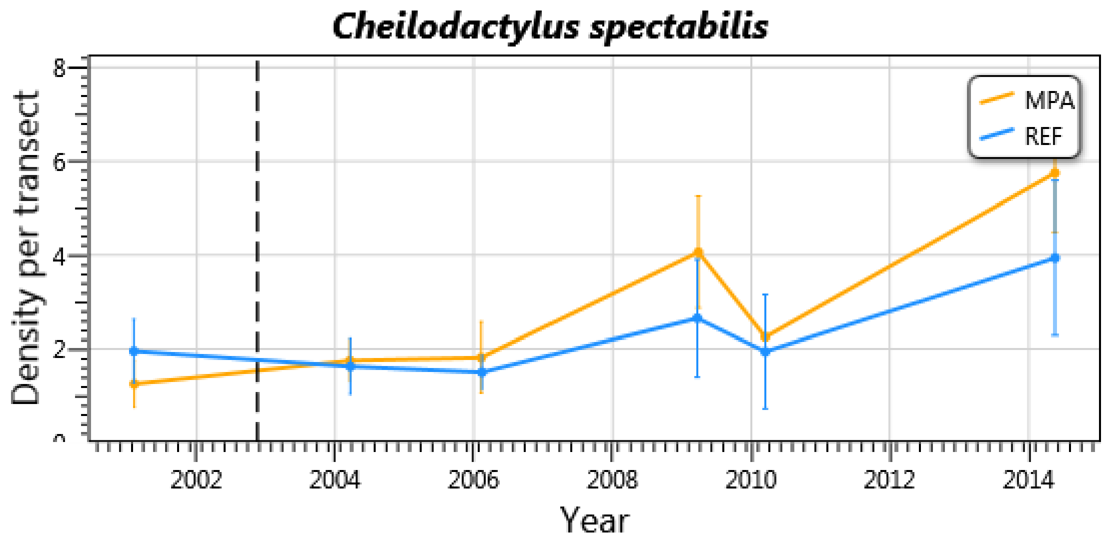


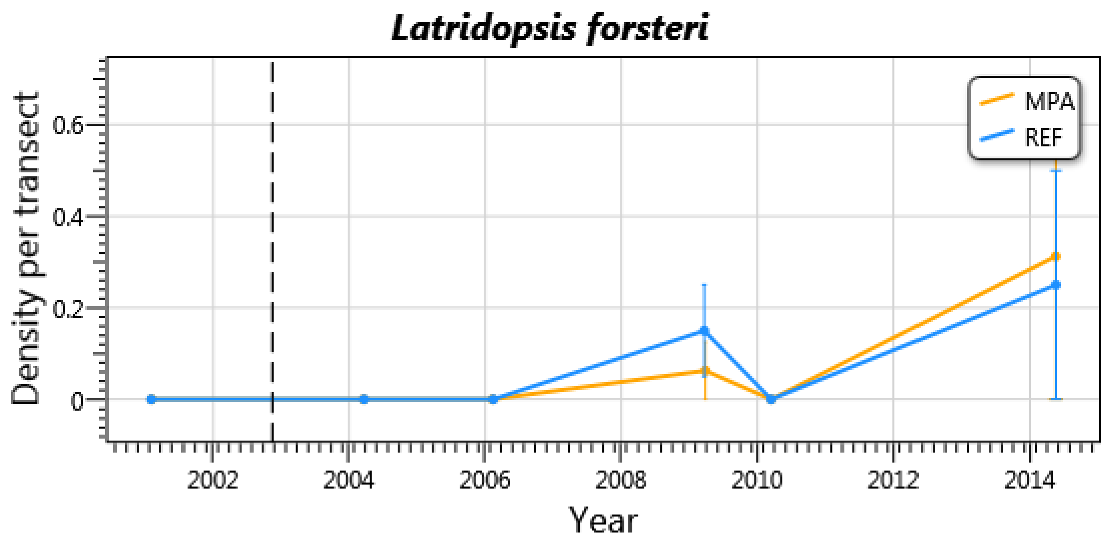
Figure 3.12. Density of fish species (± Standard Error) inside and outside the Cape Howe MPA.



d.



e.



f.

Figure 3.12 (continued). Density of fish species (± Standard Error) inside and outside the Cape Howe MPA.

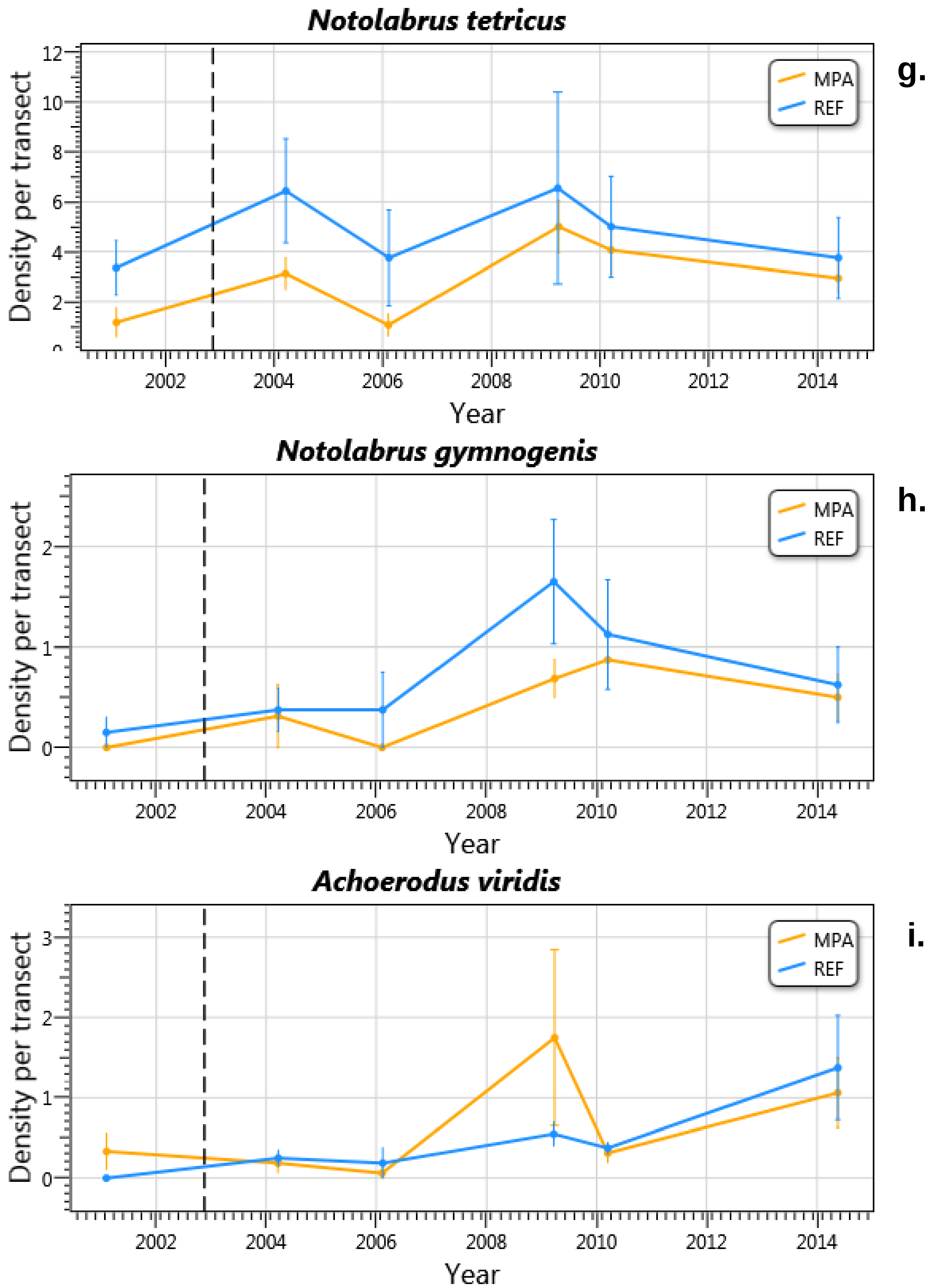


Figure 3.12 (continued). Density of fish species (± Standard Error) inside and outside the Cape Howe MPA.

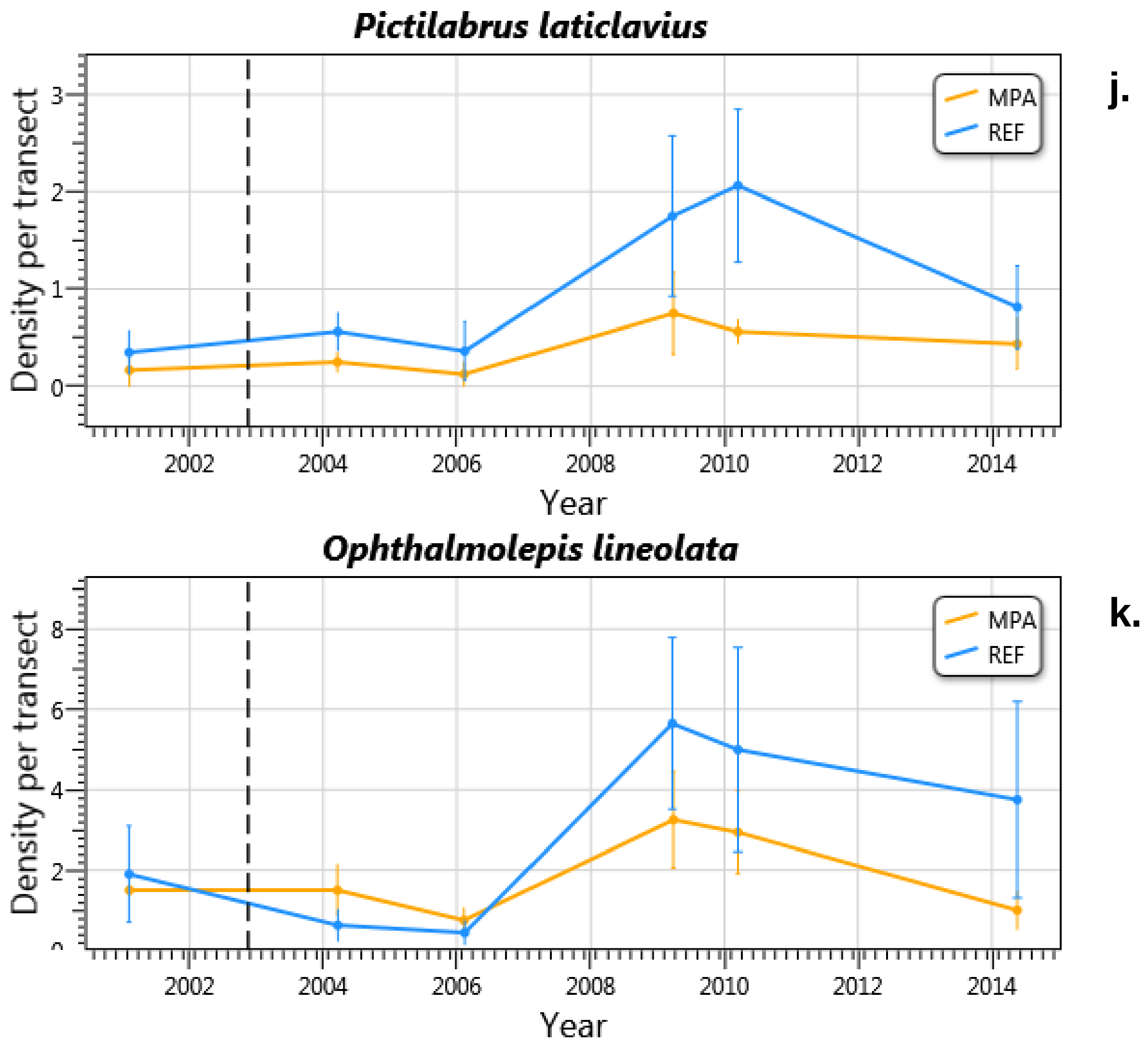


Figure 3.12 (continued). Density of fish species (± Standard Error) inside and outside the Cape Howe MPA.

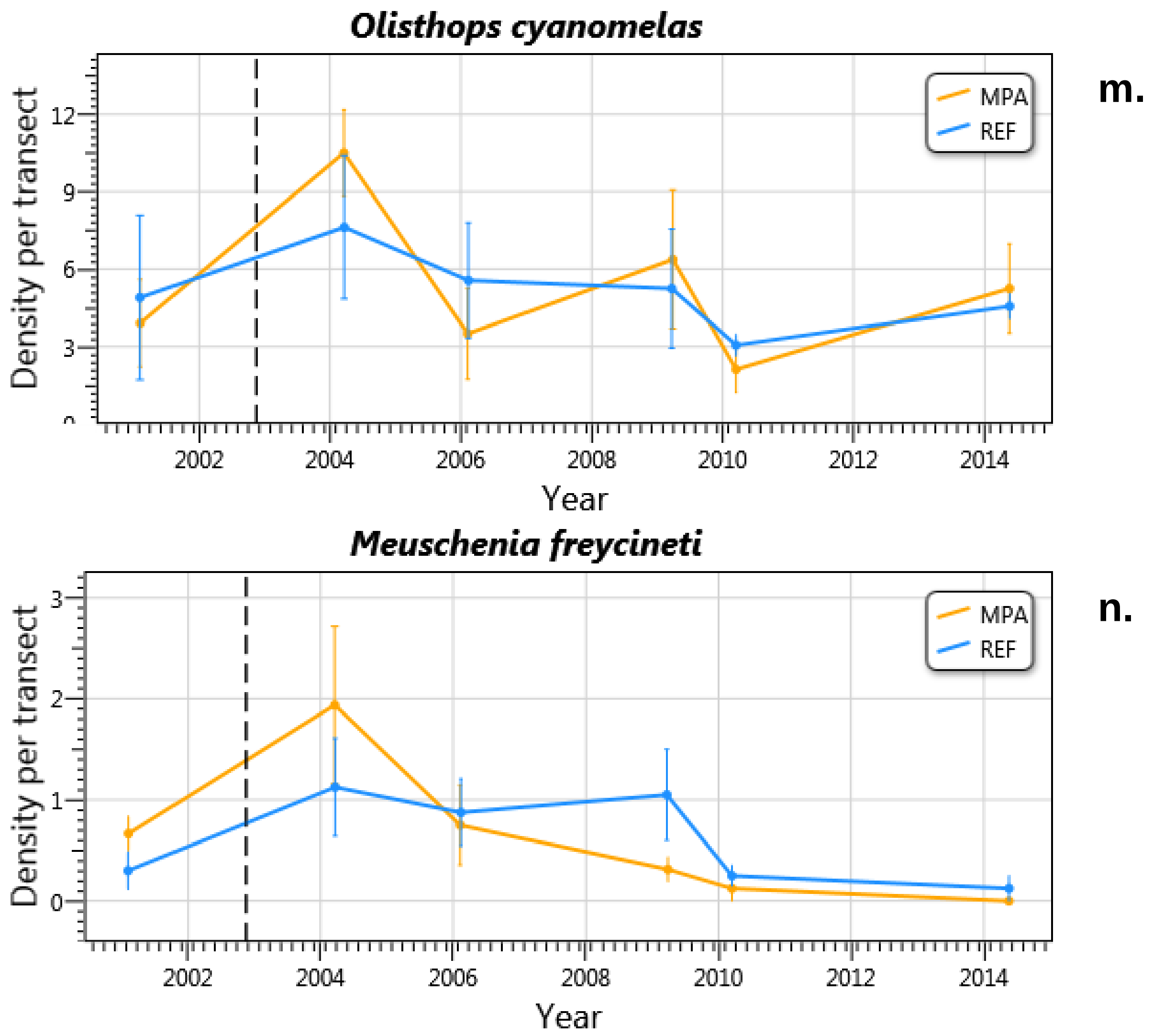


Figure 3.12 (continued). Density of fish species (± Standard Error) inside and outside the Cape Howe MPA.

3.4 Ecosystem Functional Components

3.4.1 Macrophyte Groups

There was a notable decline in the seaweed canopy cover inside the MPA, particularly between 2004 and 2009, with cover remaining low from 2009 to 2014 (Figure 3.13a). There was a corresponding increase in the cover of smaller brown algae, erect coralline algae and thallose red algae (Figures 3.13b, 3.13e and 3.13f). The cover of crustose coralline algae was relatively stable over time within the MPA (Figure 3.13d).

3.4.2 Invertebrate Groups

There as a dip in the total abundance of invertebrate grazers in 2006, being largely driven by warrener *Turbo undulatus* and blacklip abalone *Haliotis rubra* abundances (Figure 3.14a). No other trends were evident in the invertebrate functional groups.

3.4.3 Fish Groups

The fish grazers and planktivores were quite variable in abundance over time inside the MPA, with peaks in 2004 and 2009 (Figures 3.15a and 3.15d). No other trends or patterns were evident inside the MPA.

3.4.4 Sediment Cover

Sediment cover was not recorded during the first survey in 2001. Sediment cover remained relatively low at all sites at Cape Howe over the monitoring period (Figure 3.16).

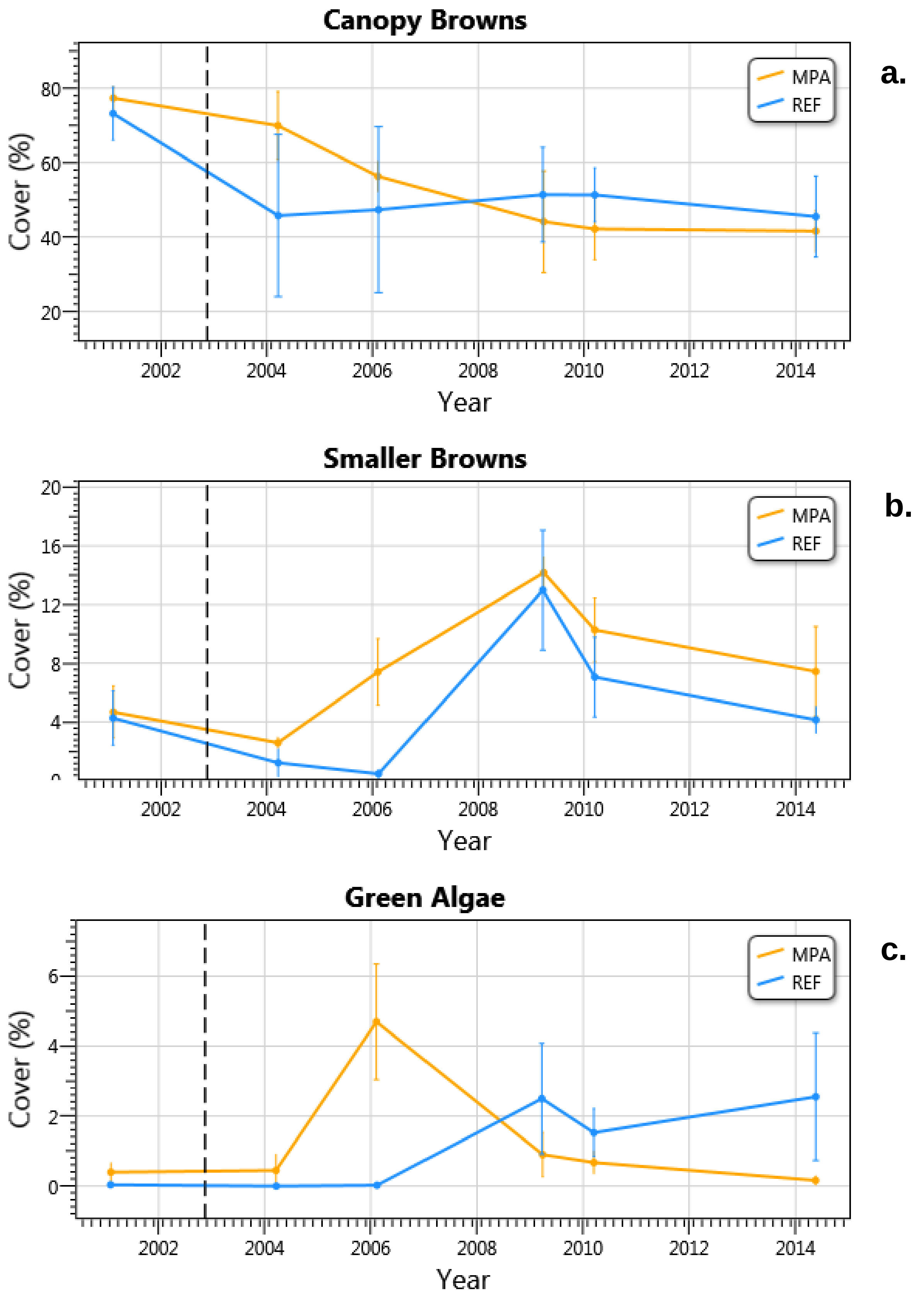


Figure 3.13. Percent cover of habitat structures (± Standard Error) inside and outside the Cape Howe MPA.

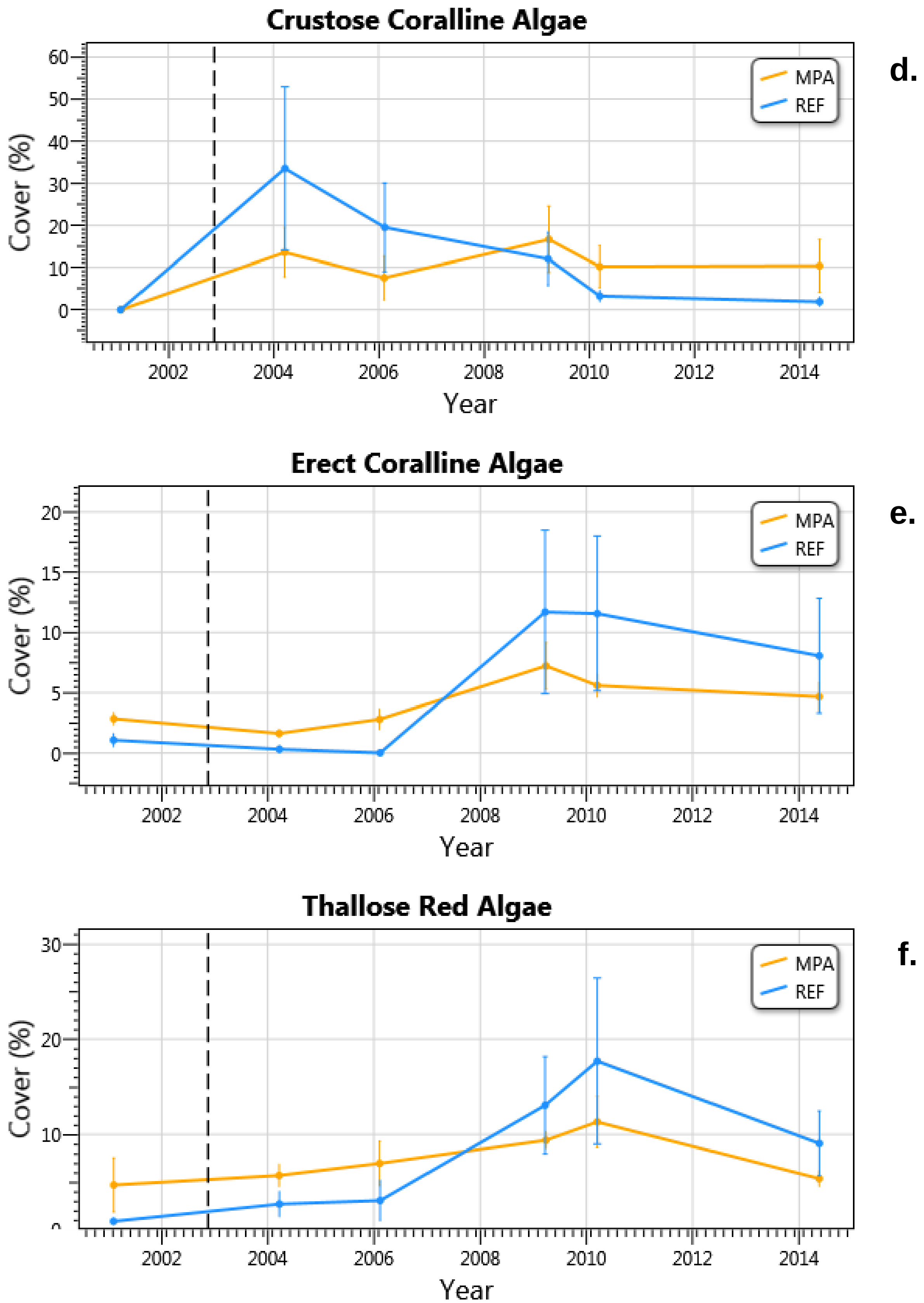


Figure 3.13 (continued). Percent cover of habitat structures (± Standard Error) inside and outside the Cape Howe MPA.

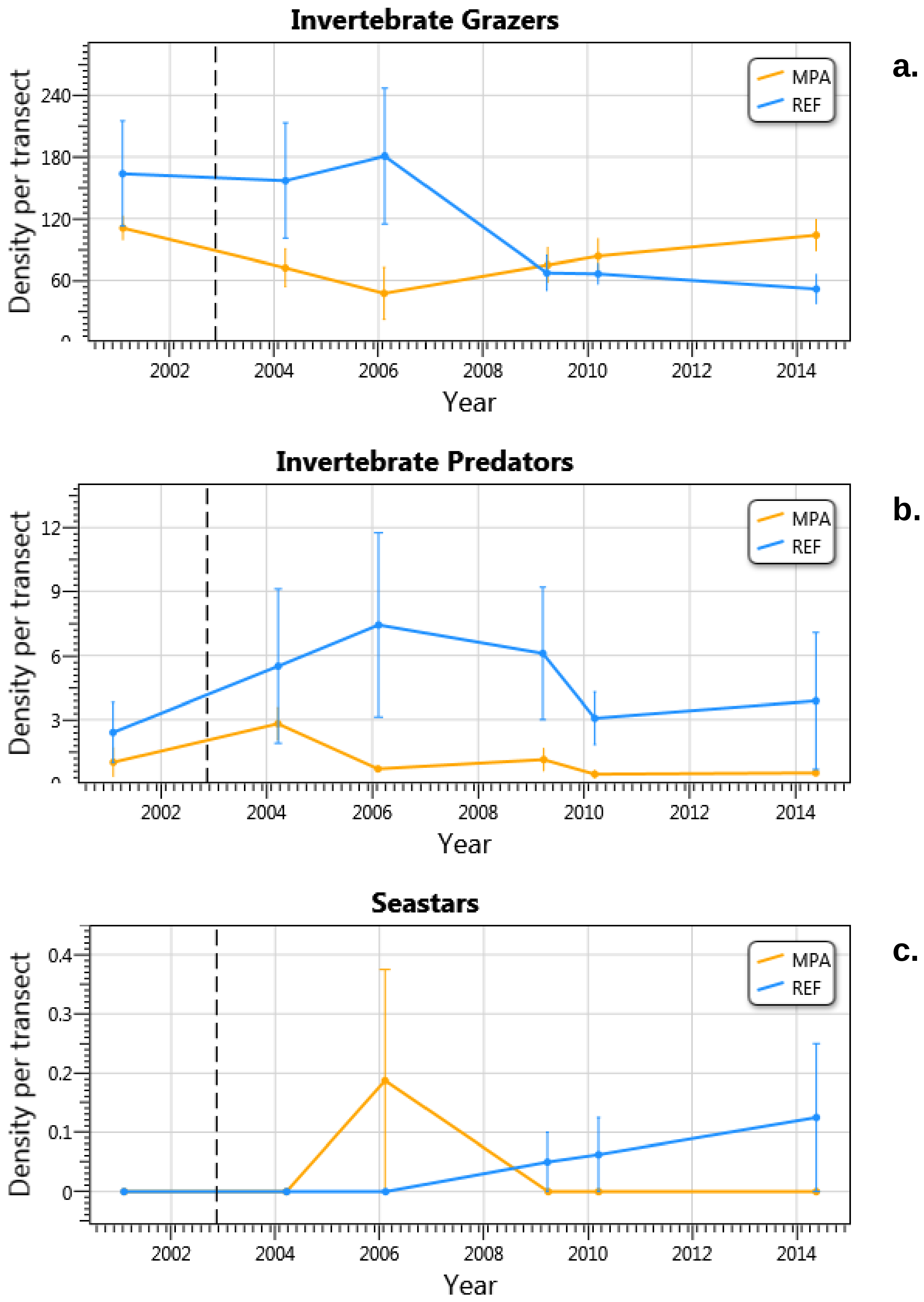


Figure 3.14. Invertebrate functional group densities (± Standard Error) inside and outside the Cape Howe MPA.

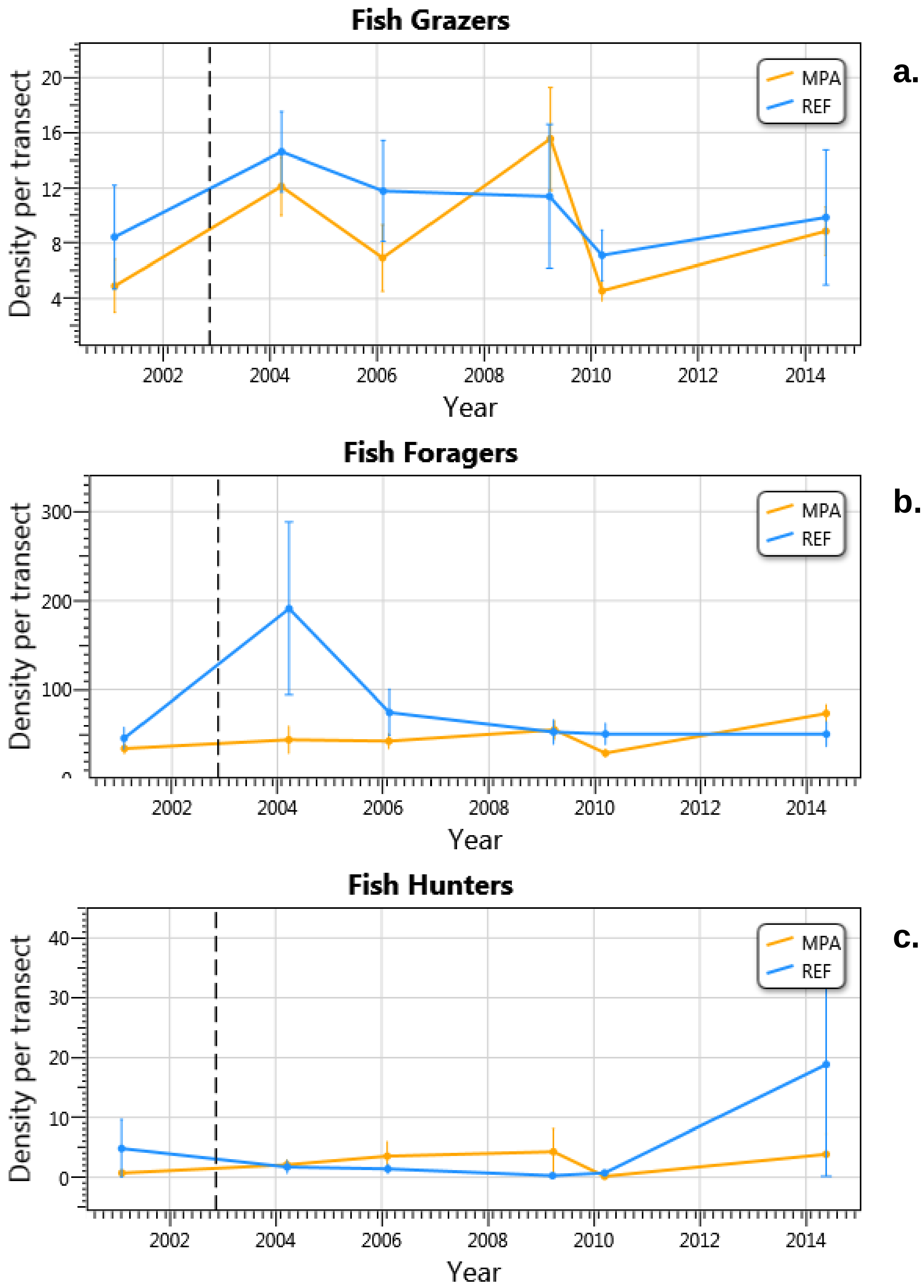


Figure 3.15. Fish functional group density (± Standard Error) inside and outside the Cape Howe MPA.

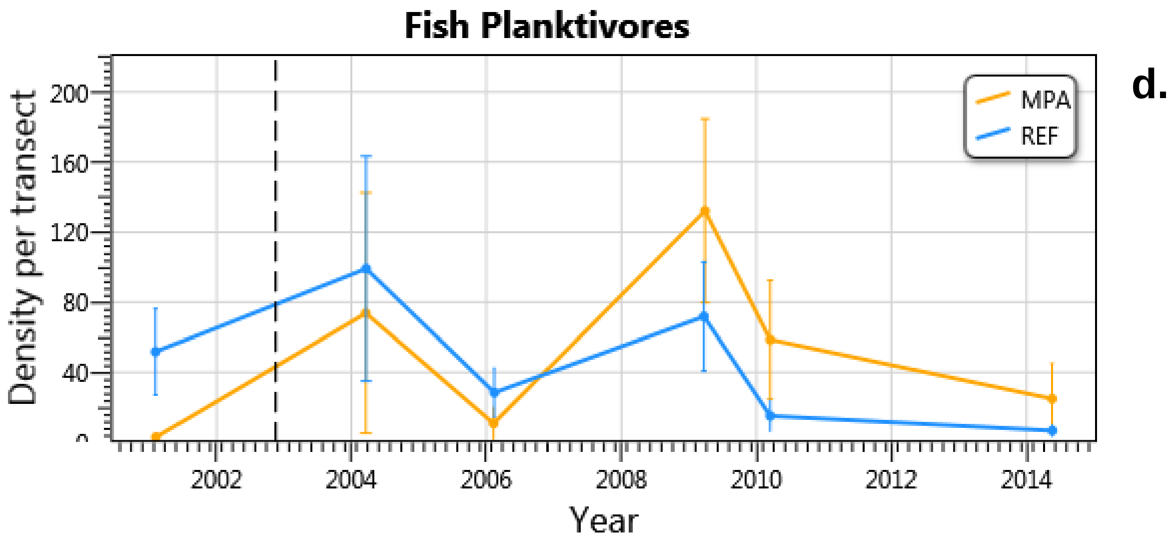


Figure 3.15 (continued). Fish functional group density (± Standard Error) inside and outside the Cape Howe MPA.

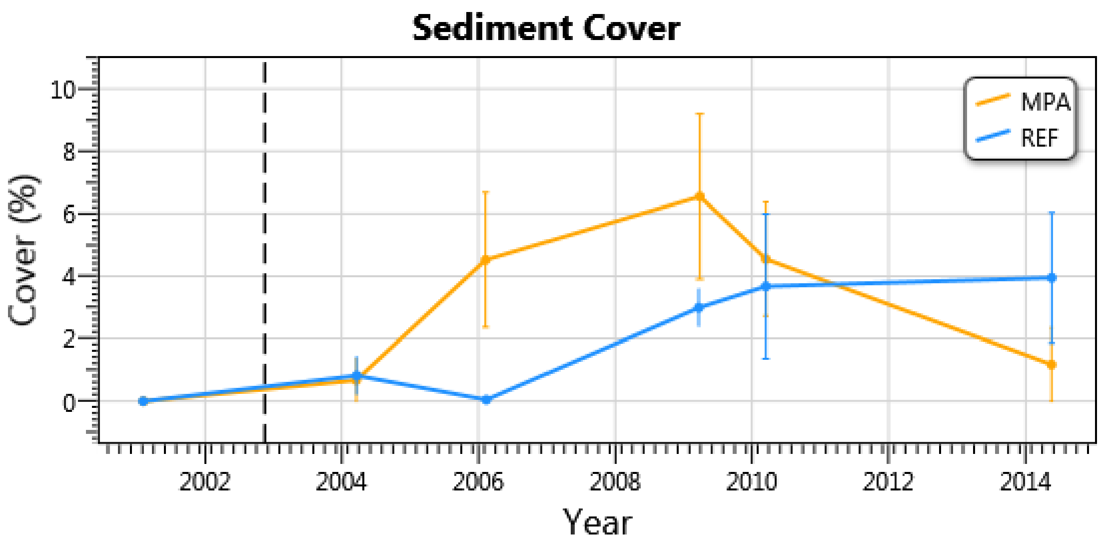


Figure 3.16. Mean cover (± Standard Error) of sediment inside and outside the Cape Howe Marine National Park.

3.5 Introduced Species

There were no introduced species detected during the monitoring program.

3.6 Climate Change

3.6.1 Species composition

There was only a low number of colder water, Maugean algal species within the Cape Howe region, the most conspicuous of these being crayweed *Phyllospora comosa*. There were no marked trends in species richness over the monitoring period, however there was a marked decline in abundance, as driven by the dominant species *P. comosa* (Figure 3.17). Eastern algal species were not well represented at the Cape Howe monitoring sites.

The Maugean invertebrate species in the Cape Howe region were not well represented at any one time. There were no apparent trends in eastern invertebrate species abundance and richness within the MPA (Figure 3.19).

There was a slight increasing trend Maugean-classified fish species and abundance within the MPA (Figure 3.20).

The eastern fish species richness was relatively stable from 2001 to 2006, after which there was a marked increase to 2009, persisting to 2010 (Figure 3.20a). There was also an increase in eastern fish abundances to 2009, however there was a subsequent dip in abundance in 2010 (Figure 3.20b).

3.6.2 Indicator Species

The monitoring sites at Cape Howe did not measure the abundance of potential indicator species such as bull kelp *Durvillaea potatorum* and string kelp *Macrocystis pyrifera*.

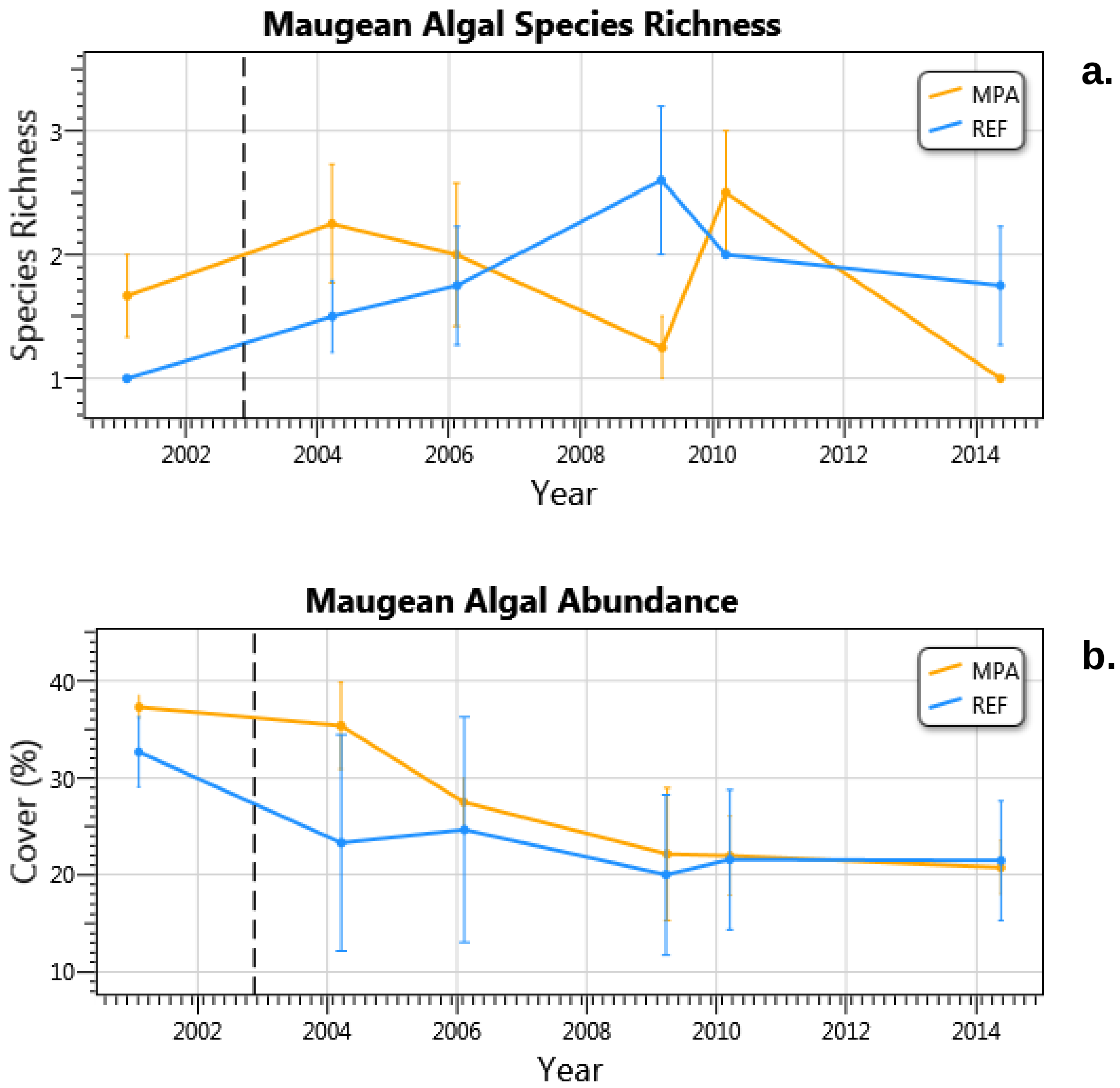


Figure 3.17. Richness and abundance of Maugean algal species (± Standard Error) inside and outside the Cape Howe MPA.

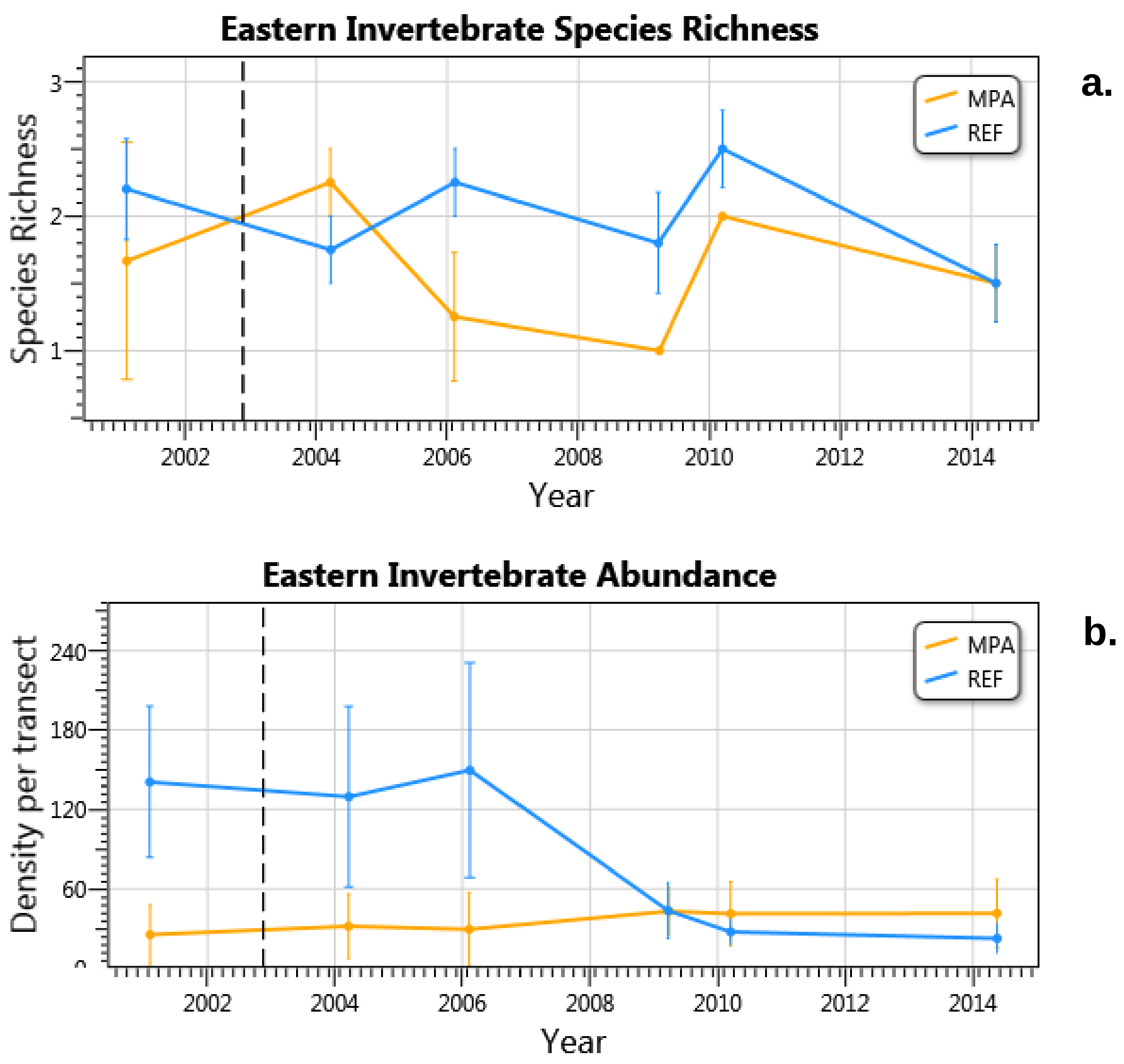


Figure 3.18. Richness and abundance of eastern algal species (± Standard Error) inside and outside the Cape Howe MPA.

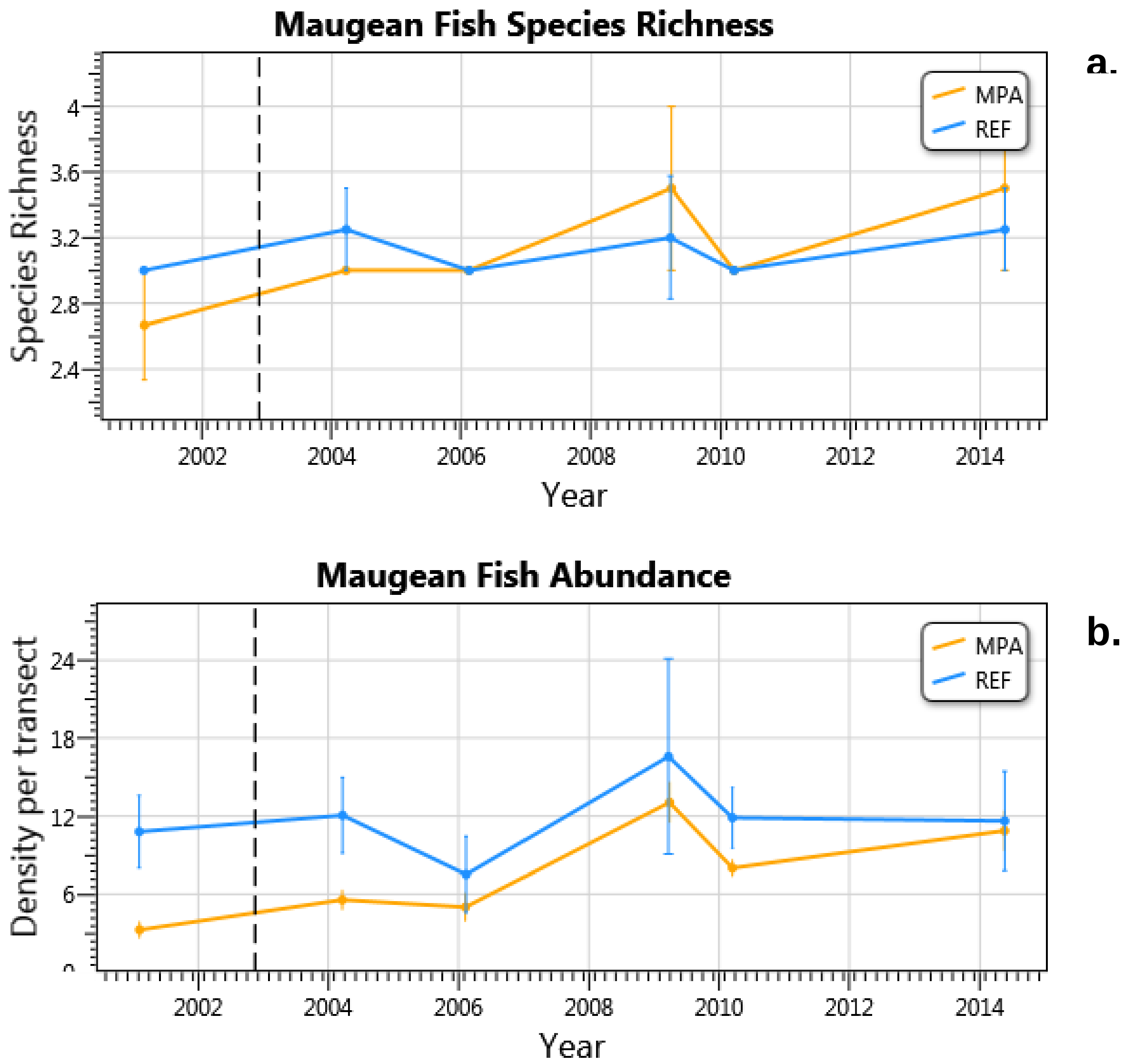


Figure 3.19. Richness and density of Maugean fish species (± Standard Error) inside and outside the Cape Howe MPA.

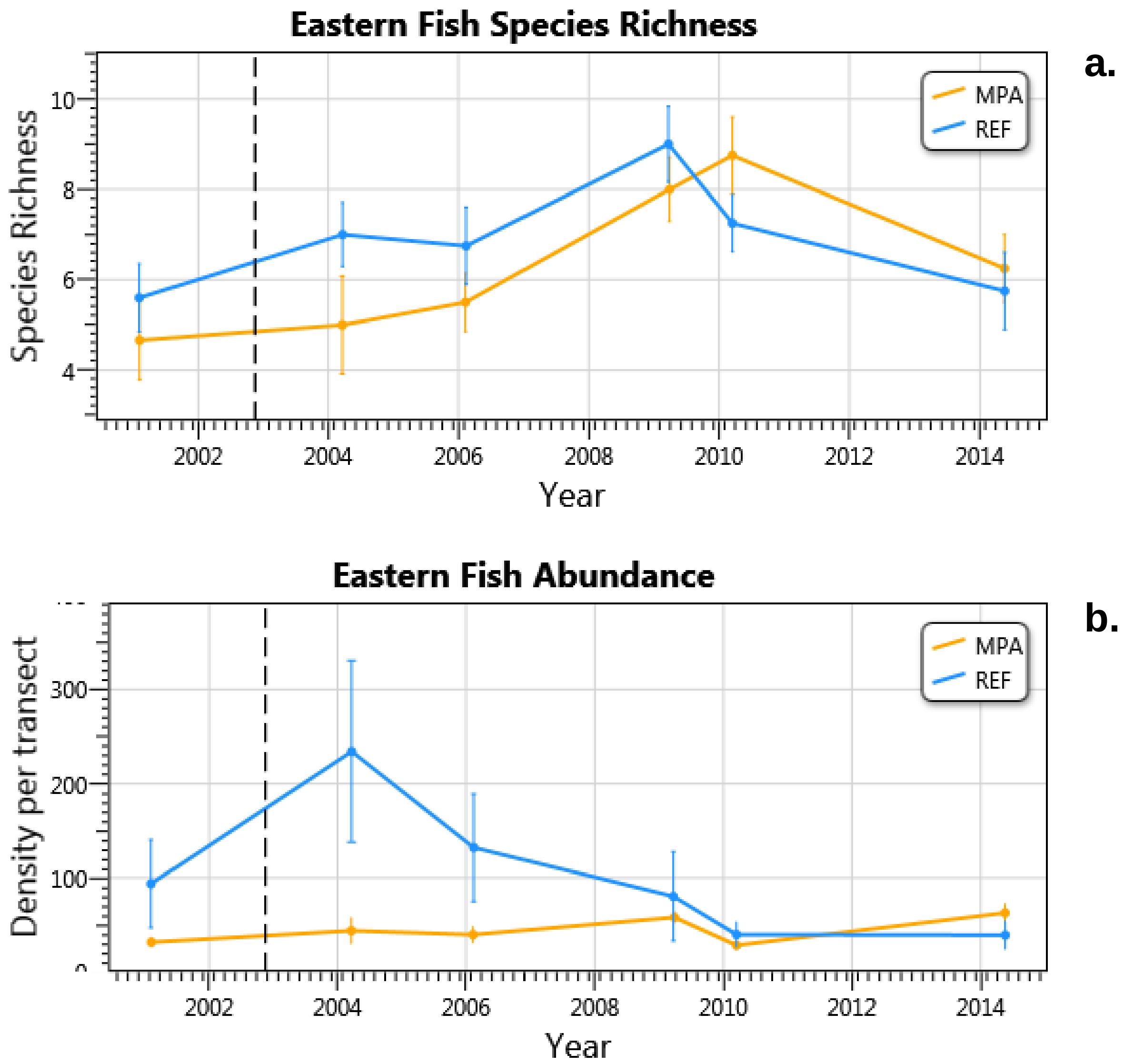


Figure 3.20. Richness and density of eastern fish species (± Standard Error) inside and outside the Cape Howe MPA.

3.7 Fishing

3.7.1 Abalone

The abundance of abalone *Haliotis rubra* has increased considerably since 2006, both inside and outside the MPA, with highest abundances inside the MPA in in 2014 (Figure 3.8a). Sizes have also increased both inside and outside the MPA (Figure 3.21). There was a weak shift to increased proportion of larger abalone inside the park (reduced size spectrum slope; Figure 3.22b).

3.7.2 Rock Lobster

Two species of lobster were observed during the monitoring: southern rock lobster *Jasus edwardsii* and packhorse lobster *Sagmariasus verreauxi*. Their abundances at the monitoring sites were too low to assess any changes in density or size structure as indicators for fishing pressure.

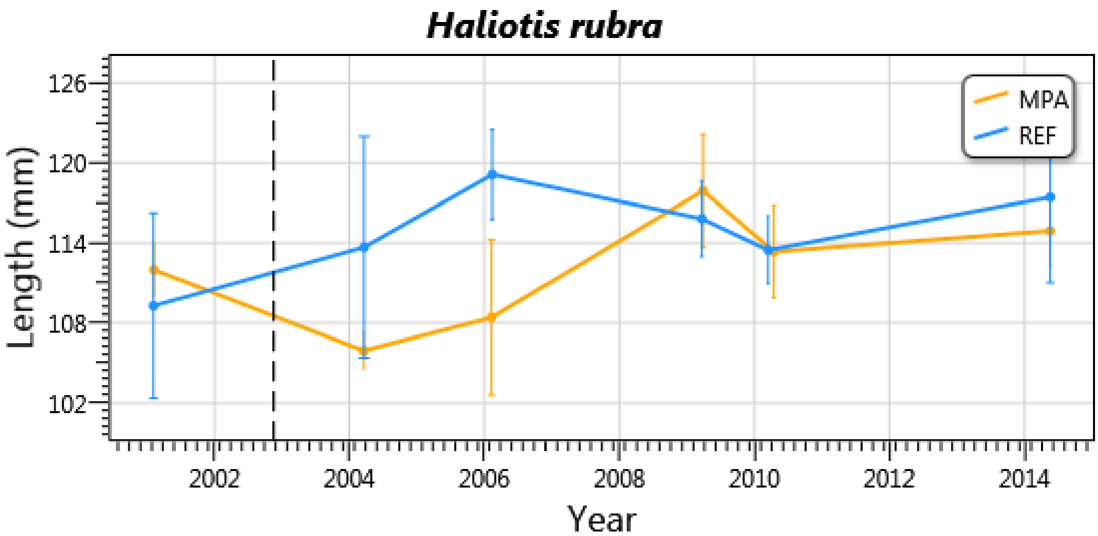


Figure 3.21. Mean size of abalone *Haliotis rubra* and proportion of legal sized *H. rubra* (± Standard Error) inside and outside the Cape Howe MPA.

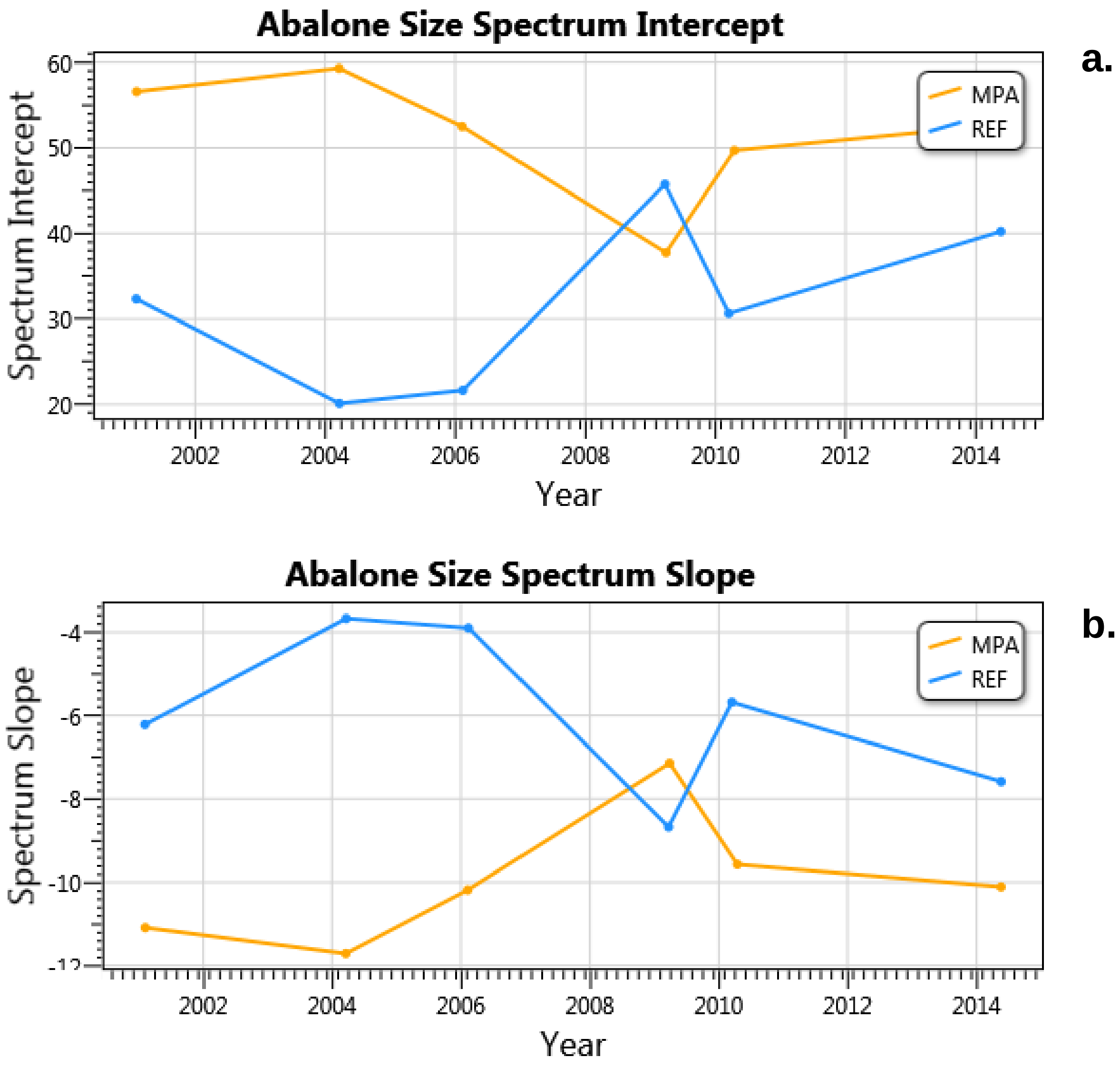


Figure 3.22. Size spectrum parameters of blacklip abalone *Haliotis rubra* inside and outside the Cape Howe MPA.

3.7.3 Fishes

The biomass of commonly fished fishes increased markedly between 2010 and 2014, with the biomass being higher within the MPA (Figure 3.23a). Much of this biomass was in fishes greater than 200 mm length, *i.e.* generally greater than legal minimum length (Figure 3.23b).

The fish size spectrum analysis indicated that, while biomass increased, the size structure of fished fish species changed to include a high density of smaller fish (Figure 3.24). The mean size of blue throated wrasse *Notolabrus tetricus* and banded morwong *Cheilodactylus spectabilis* changed little over the monitoring period, varying by approximately 50 mm for both inside and outside the MPA (Figures 3.25 and 3.26).

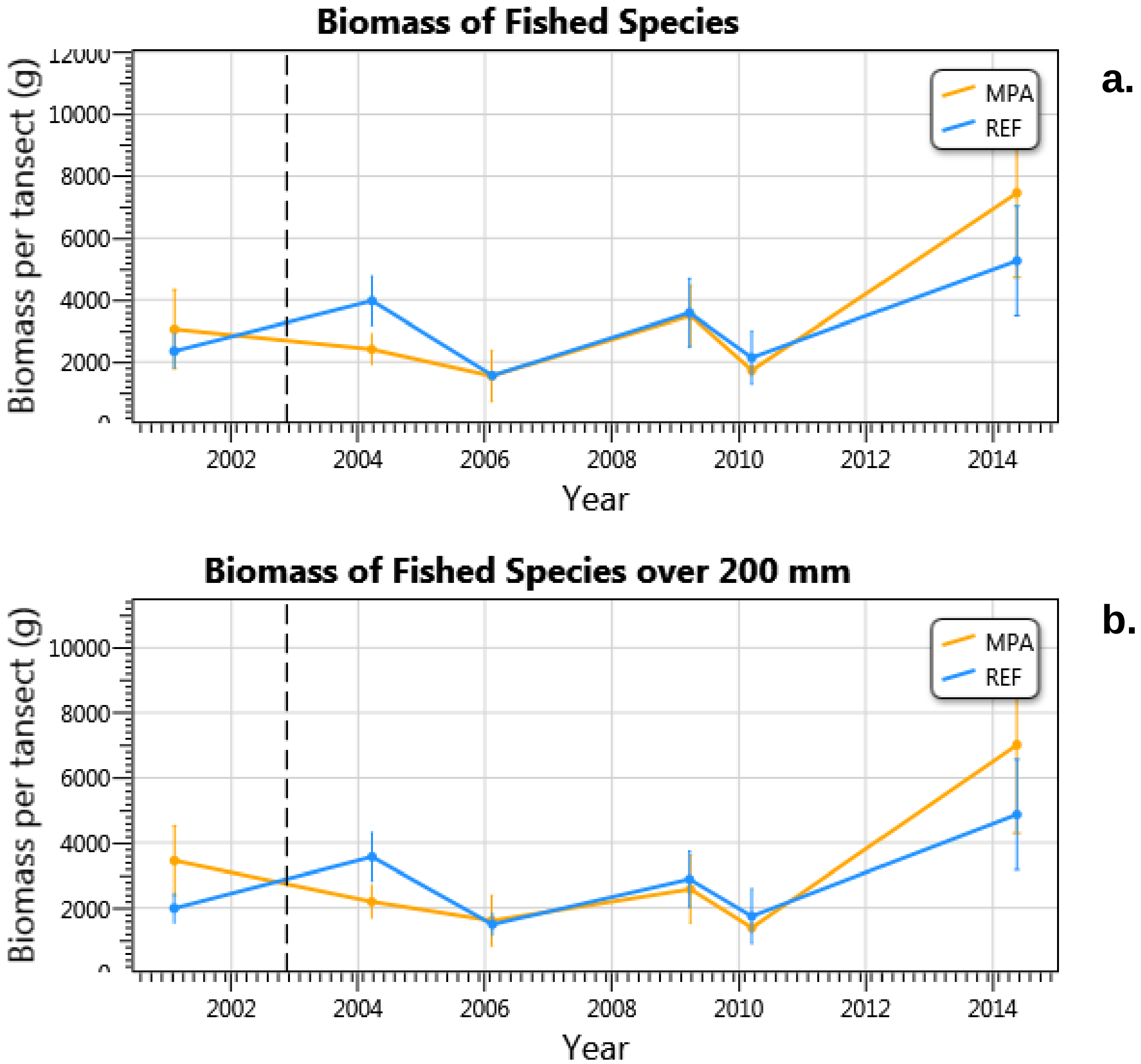
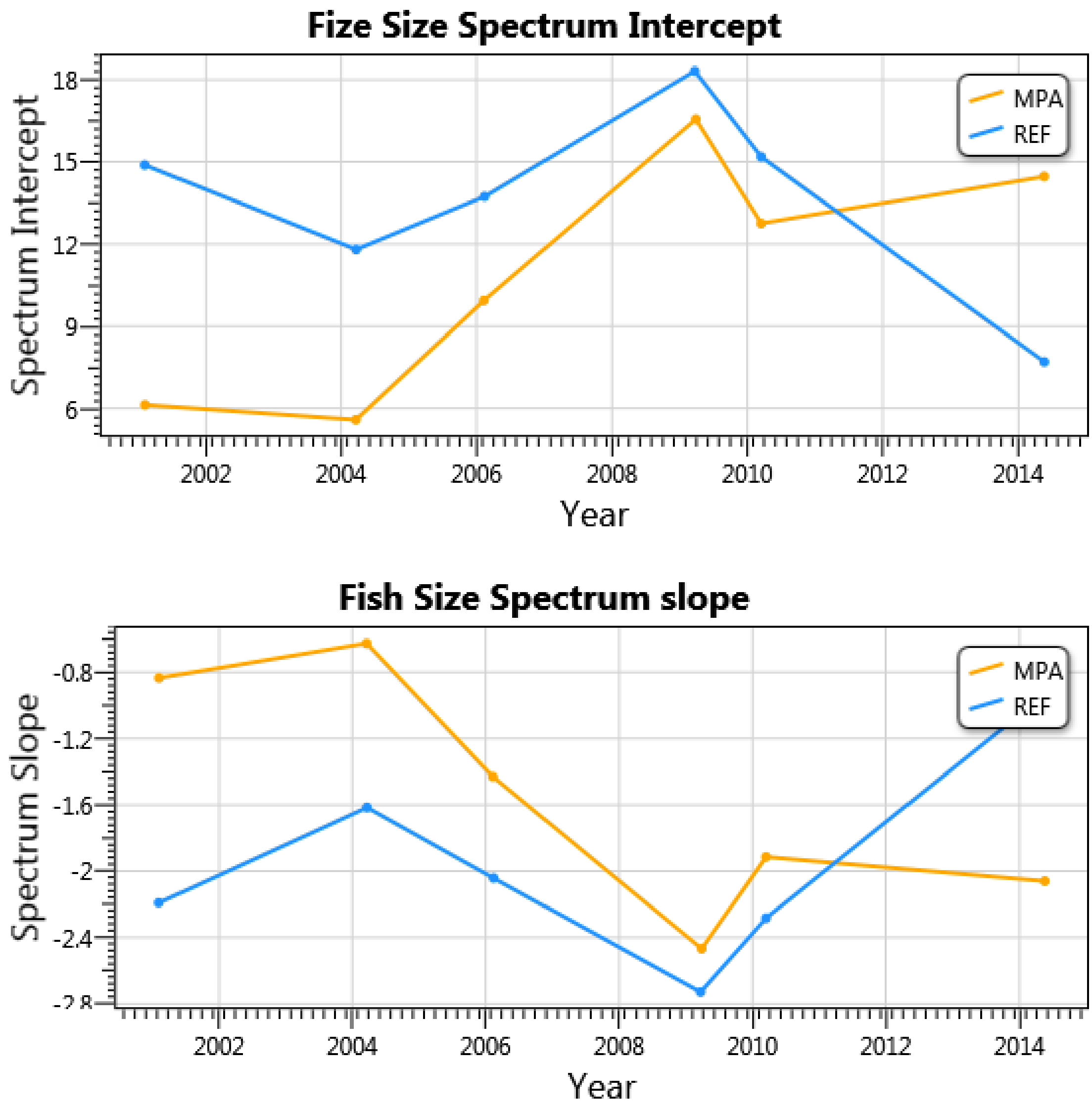


Figure 3.23. Total estimated biomass of fished species and estimated biomass of fished species over 200 mm (± Standard Error) inside and outside the Cape Howe MPA.



a.

b.

Figure 3.24. Size spectrum parameters of fished species inside and outside the Cape Howe MPA.

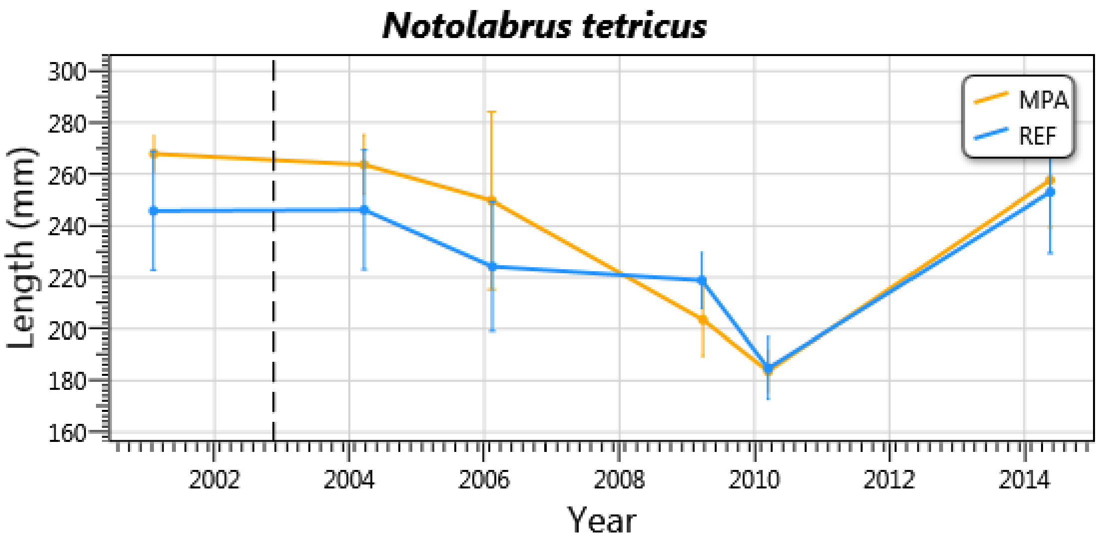


Figure 3.25. Mean size of blue throat wrasse *Notolabrus tetricus* inside and outside the Cape Howe MPA.

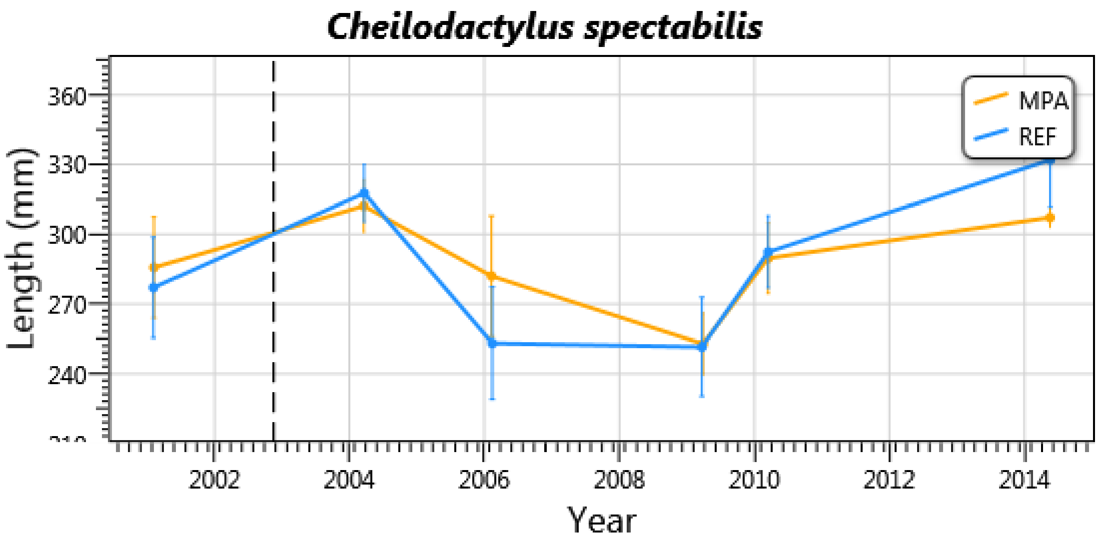


Figure 3.26. Mean size of banded morwong *Cheilodactylus spectabilis* inside and outside the Cape Howe MPA.

3.8 Manufactured Debris

The predominant manufactured debris observed were metal portions of the Iron Prince wreck at the Iron Prince Wreck site.

4 Acknowledgements

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