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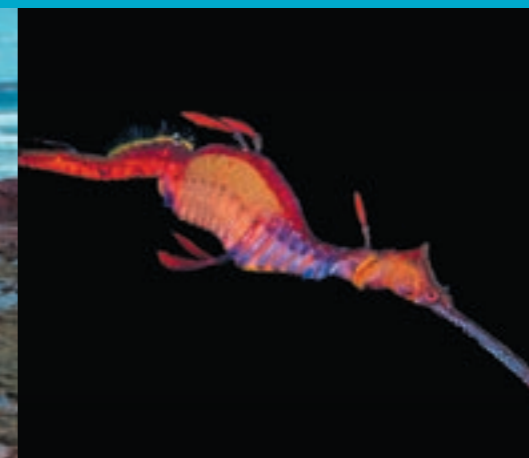
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PARKS VICTORIA TECHNICAL SERIES • NUMBER 30 Victorian Subtidal Reef Monitoring Program – The Reef Biota at Phillip Island



PARKS VICTORIA TECHNICAL SERIES

NUMBER 30

Victorian Subtidal Reef Monitoring Program

The Reef Biota at Phillip Island

*Authors: Patrick Gilmour, Matt Edmunds,
Malcolm Lindsay and Jac Monk
February 2006*

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**Victorian Subtidal Reef Monitoring
Program:
The Reef Biota at Phillip Island**

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Australian Marine Ecology Pty Ltd

February 2006



EXECUTIVE SUMMARY

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

The monitoring program along the southern coastline of Phillip Island began in 1999. Since that time 6 sites have been surveyed over 7 census events. The monitoring involves standardised underwater visual census methods to a depth of between 4 and 7 m. This report aims to provide:

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

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

1. Abundance and size structure of large fishes;
2. Abundance of cryptic fishes and benthic invertebrates;
3. Percentage cover of macroalgae; and
4. Density of dominant kelp species.

To date over 185 different species have been observed during the monitoring program at Phillip Island. The exposed sites were dominated by canopy-forming algae while the more sheltered sites were dominated by small turf-like species. The algal species richness was between 15 and 35 species per site across the survey period. Common invertebrates included blacklip abalone, warrener and southern rock lobster. The species richness for invertebrates showed an increasing trend over the survey period while the species diversity appears stable over time. The common fish species included blue-throated wrasse, purple wrasse, herring cale, and sea sweep. Species richness of fishes tended to increase over the survey period at most sites while no strong trends were apparent in species diversity.

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

CONTENTS

EXECUTIVE SUMMARY	II
CONTENTS	III
INDEX OF FIGURES AND TABLES	V
1.0 INTRODUCTION	1
1.1 Subtidal Reef Ecosystems of Victoria	1
1.2 Subtidal Reef Monitoring Program	2
1.2.1 Objectives.....	2
1.2.2 Monitoring Protocols and Locations	7
1.3 Subtidal Reef Monitoring at Phillip Island.....	7
2.0 METHODS	8
2.1 Site Selection and Survey Times	8
2.2 Census method	8
2.2.1 Transect Layout.....	8
2.2.2 Method 1 – Mobile Fishes and Cephalopods.....	11
2.2.3 Method 2 – Invertebrates and Cryptic Fishes	11
2.2.4 Method 3 – Macroalgae.....	11
2.2.5 Method 4 – <i>Macrocystis</i>	11
2.3 Data Analysis	13
2.3.1 Community Structure.....	13
2.3.2 Depiction of Community Differences.....	13
2.3.3 Trends in Community Structure.....	13
2.3.4 Species Diversity.....	14
2.3.5 Species Populations.....	14
3.0 MACROALGAE	19
3.1 Community Structure.....	19
3.2 Diversity.....	21
3.3 Population Abundances	22
3.4 <i>Macrocystis angustifolia</i>	24
4.0 INVERTEBRATES	26
4.1 Community Structure.....	26
4.2 Diversity.....	27
4.3 Population Abundances	28
5.0 FISH	31
5.1 Community Structure.....	31
5.2 Diversity.....	32
5.3 Population Abundances	32
6.0 REFERENCES	39

7.0 ACKNOWLEDGEMENTS 40

INDEX OF FIGURES AND TABLES

FIGURES

Figure 1.1	Examples of species of macroalgae found on Victorian subtidal reefs	2
Figure 1.2.	Examples of species of invertebrates and cryptic fish found on Victorian subtidal reefs	3
Figure 1.3.	Examples of fish species found on Victorian subtidal reef	5
Figure 1.4	An example plot depicting change in an environmental, population or community variable over time (days, months or years).	6
Figure 2.1.	Location of monitoring sites at Phillip Island.	9
Figure 2.2.	Biologist-diver with transect reel, Lonsdale Back Beach.....	15
Figure 2.3.	The cover of macrophytes is measured by the number of points intersecting each species on the quadrat grid.	15
Figure 2.4.	Approximate location of transects at Nobbies North, Site 1, Phillip Island.....	16
Figure 2.5.	Approximate location of transect at Red Bluff, Site 2, Phillip Island.....	16
Figure 2.6.	Approximate location of transect at Pyramid North, Site 3, Phillip Island.	17
Figure 2.7.	Approximate location of transect at Woolamai West, Site 4, Phillip Island.	18
Figure 2.8.	Approximate location of transects at Cape Woolamai Mid (Site 5) and East (Site 6), at Phillip Island.	18
Figure 3.1.	MDS plot of algal assemblage structure at Phillip Island.	20
Figure 3.2.	Trends in macrophyte species richness at Phillip Island.....	21
Figure 3.3.	Trends in macrophyte species diversity at Phillip Island.....	21
Figure 3.4.	Trends in abundance of the brown algae <i>Phyllospora comosa</i> at Phillip Island.	22
Figure 3.5.	Trends in abundance of the brown alga <i>Acrocarpia paniculata</i> at Phillip Island.	22
Figure 3.6.	Trends in abundance of the erect coralline alga <i>Halimtilon roseum</i> at Phillip Island.....	23
Figure 3.7.	Trends in abundance of the erect coralline alga <i>Amphiroa anceps</i> at Phillip Island.....	23
Figure 3.8.	Trends in abundance of the erect coralline alga <i>Metagoniolithon radiatum</i> at Phillip Island.	24
Figure 3.9.	Trends in abundance of the string kelp <i>Macrocystis angustifolia</i> at The Nobbies (Site 1), Phillip Island.....	25
Figure 4.1.	MDS plot of invertebrate assemblage structure at Phillip Island.	26
Figure 4.2.	Trends in invertebrate species richness at Phillip Island.	27
Figure 4.3.	Trends in invertebrate species diversity at Phillip Island.....	28
Figure 4.4.	Trends in abundance of the warrener <i>Turbo undulatus</i> at Phillip Island.	29

Figure 4.5. Trends in abundance of the black lip abalone <i>Haliotis rubra</i> at Phillip Island.	29
Figure 4.6. Trends in mean size (\pm 95% CI) of the black lip abalone <i>Haliotis rubra</i> at Phillip Island. Note that insufficient data were available for the sixth survey of Site 5.	30
Figure 4.7. Size frequency distributions of <i>Haliotis rubra</i> lengths at Phillip Island for the last four surveys (all data from all sites combined).	30
Figure 5.1. MDS plot of fish assemblage structure at Phillip Island. T	31
Figure 5.2. Trends in fish species richness at Phillip Island.	33
Figure 5.3. Trends in fish species diversity at Phillip Island.	34
Figure 5.4. Trends in abundance of blue-throated wrasse <i>Notolabrus tetricus</i> at Phillip Island.	34
Figure 5.5. Trends in abundance of purple wrasse <i>Notolabrus fucicola</i> at Phillip Island.	35
Figure 5.6. Trends in abundance of herring cale <i>Odax cyanomelas</i> at Phillip Island.	35
Figure 5.7. Trends in abundance of magpie morwong <i>Cheilodactylus nigripes</i> at Phillip Island.	36
Figure 5.8 Horseshoe leatherjacket <i>Meuschenia hippocrepis</i> above canopy of <i>Phyllospora comosa</i> , Red Bluff (Site 2), Phillip Island.	38

TABLES

Table 2.2. Survey times for monitoring at Phillip Island.	10
Table 2.3. Macroalgae (method 3), invertebrate and cryptic fish (Method 2) and mobile cephalopods and fish (Method 1) taxa censused along the Central Victorian coast.	12
Table 3.1. Tests of change in macrophyte communities at Phillip Island. The Mantel rM statistic is a measure of the correlation between dissimilarity in species composition (Bray-Curtis coefficient) and difference in times. The significance of the rM value was tested using a permutation test with 1000 permutations.	20
Table 4.1. Tests of change in invertebrate communities at Phillip Island. The Mantel rM statistic is a measure of the correlation between dissimilarity in species composition (Bray-Curtis coefficient) and difference in times. The significance of the rM value was tested using a permutation test with 1000 permutations.	27
Table 5.1. Tests of change in fish communities at Phillip Island. The Mantel rM statistic is a measure of the correlation between dissimilarity in species composition (Bray-Curtis coefficient) and difference in times. The significance of the rM value was tested using a permutation test with 1000 permutations.	33
Table 5.2. Population structure of blue-throated wrasse <i>Notolabrus tetricus</i> at Phillip Island (last three surveys).	36
Table 5.3. Population structure of purple wrasse <i>Notolabrus fucicola</i> at Phillip Island (last three surveys).	37
Table 5.4. Population structure of herring cale <i>Odax cyanomelas</i> at Phillip Island (last three surveys).	38

1.0 INTRODUCTION

1.1 Subtidal Reef Ecosystems of Victoria

Shallow reef habitats cover extensive areas along the Victorian coast. A prominent biological component of Victorian shallow reefs are 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 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 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). Common grazers include blacklip and greenlip abalone *Haliotis rubra* and *H. laevigata*, the warrener *Turbo undulatus* and sea urchins *Heliocidaris erythrogramma*, *Holopneustes* species and *Amblypneustes* species. These species can influence the growth and survival of habitat forming species. For example, sponges and foliose seaweeds are often prevented from growing on encrusting coralline algae surfaces through the grazing actions of abalone and sea urchins. Predatory invertebrates include dogwhelks *Dicathais orbita*, southern rock lobster *Jasus edwardsii*, octopus *Octopus moarum* and a wide variety of seastar species. Other large reef invertebrates include mobile filter feeding animals such as feather stars *Cenolia trichoptera* and sessile (attached) species such as sponges, corals, bryozoans, hydroids and ascidians.

Fishes 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 *Scorpius 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 shallow reef ecosystems in Victoria are dominated, in terms of biomass and production, by seaweeds, mobile 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, variously grazers, predators and scavengers. 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.

1.2 Subtidal Reef Monitoring Program

1.2.1 Objectives

An important aspect in 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 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.

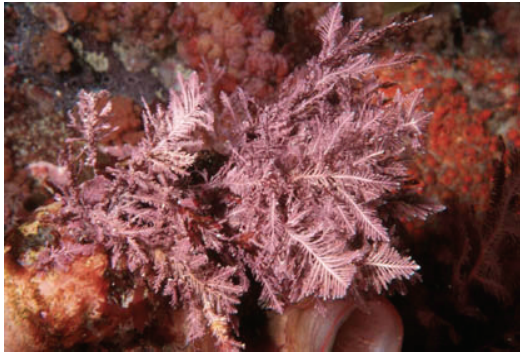


Green algae *Caulerpa flexilis*



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

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



Red coralline algae *Haliptilon roseum*



Thallose red algae *Ballia callitricha*



Crayweed *Phyllospora comosa* canopy



Common kelp *Ecklonia radiata* canopy

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



Southern rock-lobster *Jasus edwardsii*



Red bait crab *Plagusia chabrus*

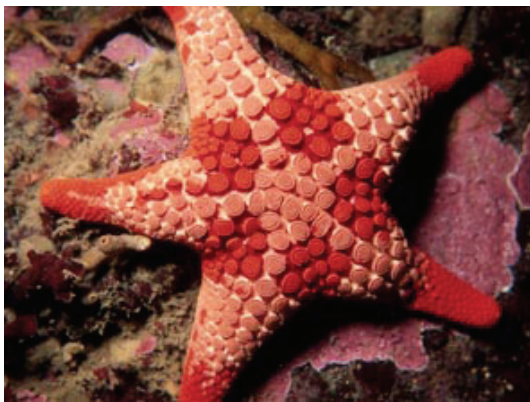
Figure 1.2. Examples of species of invertebrates and cryptic fish found on Victorian subtidal reefs



Blacklip abalone *Haliotis rubra*



Feather star *Cenolia trichoptera*



Nectria ocellata



Common sea urchin *Heliocidaris erythrogramma*



Fromia polypora



Red velvet fish *Gnathanocanthus goetzei*

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



Sea sweep *Scorpius aequipinnis*, and butterfly perch *Caesioperca lepidoptera*



Scalyfin *Parma victoriae*



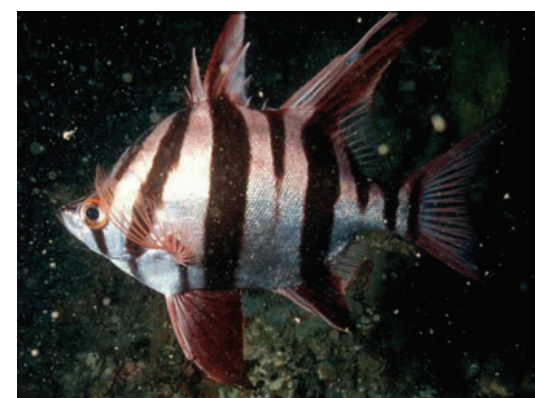
Blue-throated wrasse *Notolabrus tetricus* (male)



Six-spined leatherjacket *Meuscheni freycineti* (male)



Magpie morwong *Cheilodactylus nigripes*



Old-wife *Enoplosus armatus*

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

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

- compare changes in the status of species populations and biological communities between highly protected marine national parks and marine sanctuaries and other Victorian reef areas (e.g. Edgar and Barrett 1997, 1999);
- determine associations between species and between species and environmental parameters (e.g. depth, exposure, reef topography) and assess how these associations vary through space and time (e.g. Edgar *et al.* 1997; Dayton *et al.* 1998; Edmunds, Roob & 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. Graphs of changes over time are unlikely to match the changes in real populations because changes over shorter time periods and actual minima and maxima may not be adequately sampled (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), years (e.g. el Niño), decades (e.g. extreme storm events) or even centuries (e.g. global warming). Other studies indicate this monitoring program will begin to adequately reflect average trends and patterns as the surveys continue over longer periods (multiple years to decades). Results always need to be interpreted within the context of the time scale over which they have been measured.

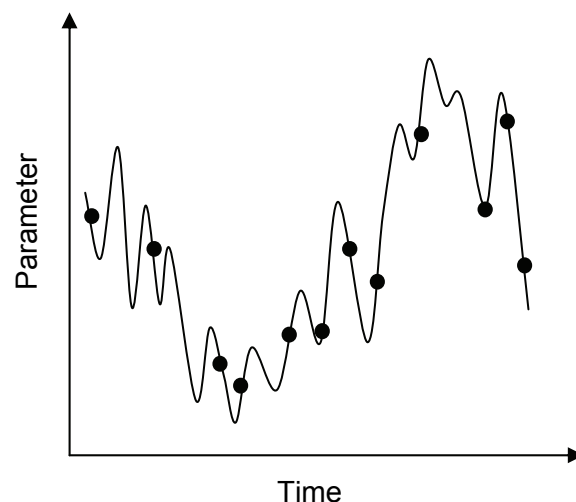


Figure 1.4 An example plot depicting change in an environmental, population or community variable over time (days, months or years). The black circles denote examples of monitoring times. Note how data from these times may not necessarily reflect patterns over shorter time periods, or true maxima or minima over longer time periods. Note further how data from any window of 2 or 3 consecutive monitoring times fails to adequately estimate the patterns or variation over the longer time period.

1.2.2 Monitoring Protocols and Locations

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

The SRMP was initiated in May 1998 with 15 sites established on subtidal reef habitats in the vicinity of Port Phillip Heads Marine National Park. In 1999 the SRMP was expanded to reefs in the vicinity of the Bunurong Marine National Park (12 sites), Phillip Island (6 sites), and Wilsons Promontory Marine National Park (20 sites).

In 2003, the Subtidal Reef Monitoring Program was expanded to include a further seven Marine National Parks and Marine Sanctuaries: Point Cooke (2 sites) , Jawbone (2 sites), Ricketts Point (2 sites), Merri (2 sites), Marengo Reef (2 sites) and Eagle Rock (2 sites) Marine Sanctuaries and Point Addis Marine National Park (4 sites). In 2004, Cape Howe (8 sites) and Point Hicks (8 sites) Marine National Parks and Beware Reef Marine Sanctuary (2 sites), all in the Twofolds shelf bioregion, were added to the Subtidal Reef Monitoring Program.

1.3 Subtidal Reef Monitoring at Phillip Island

The marine environment at Phillip Island has many ecological and conservation values. It offers a reference site in central Victoria to other locations sampled as a part of the Subtidal Reef Monitoring Program. The western end of the island (particularly The Nobbies) is recognised as an important Australian fur seal *Arctocephalus pusillus* and sea bird breeding area. Substantial bird rookeries are also present on Cape Woolamai, at the eastern end of the island. The Phillip Island region is also an important area for the threatened great white shark *Carcharodon carcharias*. The reefs along the southern coast of Phillip Island are significant areas for fish, abalone and rock lobster fisheries, both commercial and recreational. These reefs are also frequented by recreational divers and spearfishers, particularly at Cape Woolamai and Pyramid Rock.

This report describes the monitoring program and its status at Phillip Island up to June 2005. The objectives of this report are 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 June 2005; and
3. Identify any unusual biological phenomena such as interesting communities, strong temporal trends and/or the presence of any introduced species .

2.0 METHODS

2.1 Site Selection and Survey Times

Six monitoring sites were established along the southern coast of Phillip Island in September 1999 (Figure 2.1; Table 2.1). The sites were located in three general regions: The Nobbies at the western end (1 site); Pyramid Rock in the central region (2 sites); and Cape Woolamai at the eastern end of the island (3 sites). The sites were selected to represent the general range of shallow reef habitats along the southern coast of the island. The western sites (Sites 1 to 3) are on basalt reefs while the eastern sites (Sites 4 to 6) are on granite reefs. The sites range from moderate to submaximal exposure. Site 2 (Red Bluff) and Site 4 (Woolamai Washing Machine) have an aspect toward the prevailing southwesterly swells and are therefore the most exposed sites. Site 1 (Nobbies North), Site 3 (Pyramid North) and Site 6 (Woolamai East) have a northerly or easterly aspect and are more protected. Site 5 (Woolamai Central) is intermediate in exposure between Site 4 and Site 6, with rocks on the southwestern side of the bay providing some degree of shelter.

Two of the sites (Sites 2 & 4) were established on the same reefs surveyed for an Environment Conservation Council study in 1988 (Sites C & D, Table 2.1; Edmunds, Chidgey and Willcox 1998). This study used similar techniques for quantifying the abundance of invertebrates and algae, enabling the data to be integrated into the performance assessment database. Sites 1, 2 and 4 are also at or close to sites monitored annually by Primary Industry Research Victoria (PIRVIC) for abalone and seastar abundance.

There have been seven SRMP surveys at Phillip Island, as listed in Table 2.2.

2.2 Census method

2.2.1 Transect Layout

The visual census methods of Edgar and Barrett (Edgar & Barrett 1997, 1999; Edgar *et al.* 1997) are used for this monitoring program as they are non-destructive and provide quantitative data on a large number of species, and the structure of the reef communities. The Edgar-Barrett method is also used in Tasmania, New South Wales and Western Australia, and the adoption of this method in Victoria provides a systematic and comparable approach to monitoring reefs in southern Australia. The surveys in Victoria are in accordance with a standardised operational procedure (Edmunds and Hart 2003), to ensure long-term integrity and quality of the data.

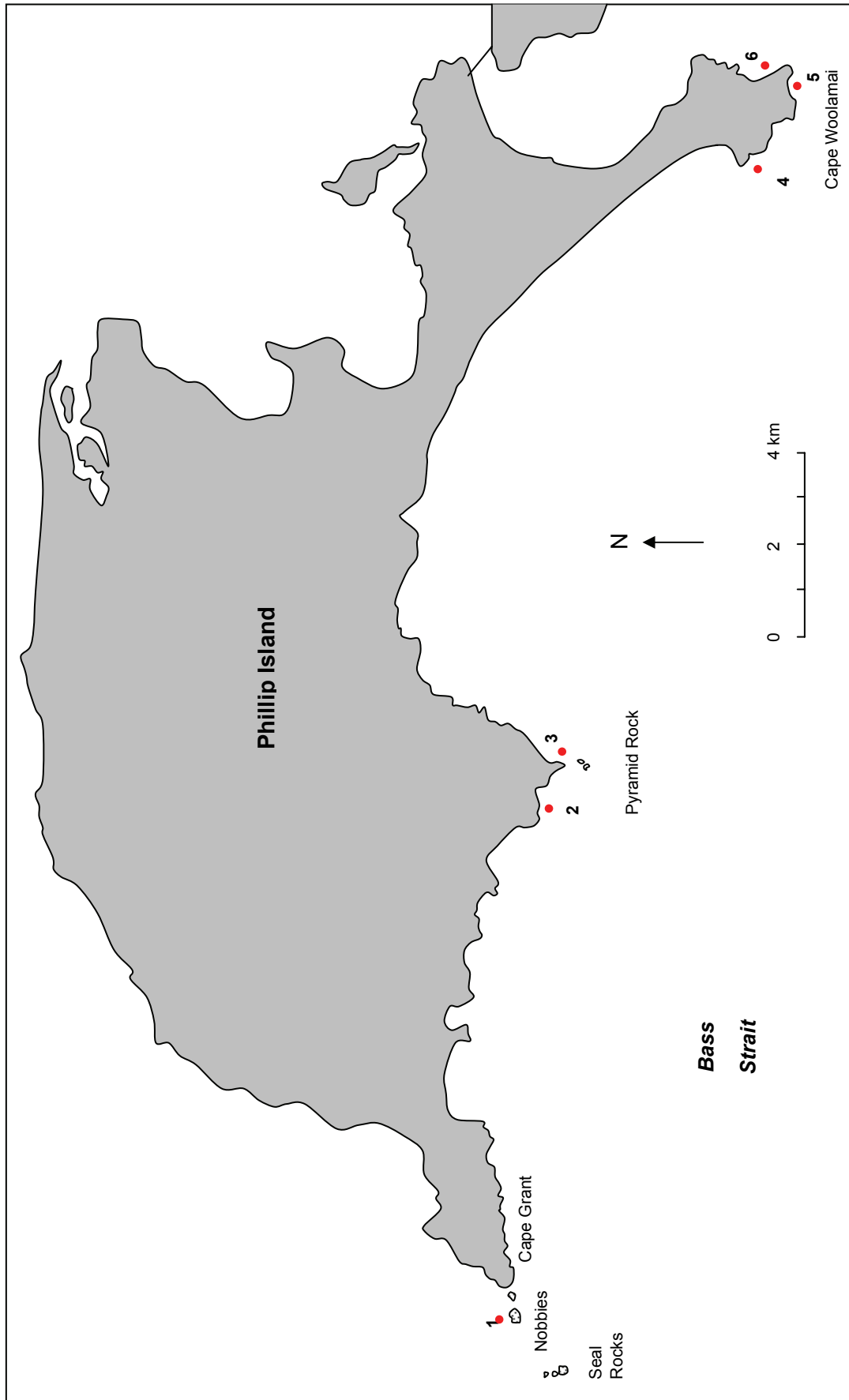


Figure 2.1. Location of monitoring sites at Phillip Island.

Table 2.1. Subtidal reef monitoring program sites at Phillip Island.

Region	No.	Description	Depth
West	1	Nobbies North	6
Central	C	Red Bluff, C	6-10
	2	Red Bluff	6
	3	Pyramid Rock North	4
East	D	Cape Woolamai, D	6-10
	4	Woolamai Washing Machine	6
	5	Woolamai Central	6
	6	Woolamai East	4

Table 2.2. Survey times for monitoring at Phillip Island.

Survey	Season	Survey Period
1	Spring 1999	9-12 September 1999
2	Summer 1999	15-17 February 2000
3	Autumn 2000	8-10 March 2001
4	Spring 2001	15-17 November 2001
5	Autumn 2002	8 March, 8-9 April 2002
6	Summer-Autumn 2003	6 January, 10 February, 6 March
7	Winter 2005	19-20 June 2005

At most monitoring locations in Victoria, surveying along the 5 m depth contour is considered optimal because diving times are not limited by decompression schedules and these reefs are of interest to natural resource managers. However, the actual depth that can be surveyed varies in accordance with reef extent, geomorphology and exposure, with some sites slightly shallower where the reef is close to sand and deeper where reefs are more exposed (to make it safe for diving). Monitoring sites at Phillip Island were between 4-7 m depth (Table 2.1).

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

For each transect, four different census methods were used to obtain adequate descriptive information on reef communities at different spatial scales. These involved the census of: (1) the abundance and size structure of large fishes; (2) the abundance of cryptic fishes and benthic invertebrates; (3) the percent cover of macroalgae; and (4) the density of string-kelp *Macrocystis* plants. Over 185 species were observed during the monitoring program at Phillip Island (Table 2.3). The depth, horizontal visibility, sea state and cloud cover are recorded for each site. Horizontal visibility is gauged by the distance along the transect line to detect a 100 mm long fish. All field observations are recorded on underwater paper.

2.2.2 Method 1 – Mobile Fishes and Cephalopods

The densities of mobile large fishes and cephalopods are estimated by a diver swimming up one side of the 50 m sections of the transect, and then back along the other. The diver records the number and estimated size-class of fish, within 5 m of each side of the line. 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. Each diver has size-marks on their underwater slate to enable calibration of their size estimates. The data for easily sexed species are recorded separately for males and female/juveniles. Such species include the blue-throated wrasse *Notolabrus tetricus*, herring cale *Odax cyanomelas*, barber perch *Caesioperca rasor*, rosy wrasse *Pseudolabrus psittaculus* and some monacanthids. A total of four 10 x 50 m sections of the transect are censused for mobile fish at each site.

2.2.3 Method 2 – Invertebrates and Cryptic Fishes

Cryptic fishes and megafaunal invertebrates (non-sessile: e.g. large molluscs, echinoderms, crustaceans) are counted along the transect line used for the fish survey. A diver counts animals within 1 m of one side of the line (a total of four 1 x 50 m sections of the transect). A pole carried by the diver is used to standardise the 1 m distance. The maximum length of abalone and the carapace length and sex of rock lobsters are measured *in situ* using vernier callipers whenever possible. Selected specimens are collected for identification and preservation in a reference collection.

2.2.4 Method 3 – Macroalgae

The area covered by macroalgal species is quantified by placing a 0.25 m² quadrat at 10 m intervals along the transect line and determining the percent cover of the all plant species. The quadrat is divided into a grid of 7 x 7 perpendicular wires, giving 50 points (including one corner). Cover is estimated by counting the number of times each species occurs directly under the 50 positions on the quadrat (1.25 m² for each of the 50 m sections of the transect line). Selected specimens are collected for identification and preservation in a reference collection.

2.2.5 Method 4 – *Macrocystis*

In addition to macroalgal cover, the density of *Macrocystis angustifolia* plants is estimated. While swimming along the 200 m transect line, a diver counts all observable plants within 5 m either side of the line, for each 10 m section of the transect (giving counts for 100 m² sections of the transect). This survey component commenced from spring 1999.

Table 2.3. Macroalgae (method 3), invertebrate and cryptic fish (Method 2) and mobile cephalopods and fish (Method 1) taxa censused along the Central Victorian coast.

Method 3		Method 2	Method 1
Chlorophyta (green algae)	Filamentous browns	Crustacea	Cephalopoda
<i>Ulva</i> spp	Brown algae unidentified	<i>Jasus edwardsii</i>	<i>Sepioteuthis australis</i>
<i>Chaetomorpha</i> sp	Rhodophyta (red algae)	<i>Strigopagurus strigimanus</i>	<i>Sepia apama</i>
<i>Chaetomorpha coliformis</i>	<i>Gelidium australe</i>	<i>Pagurid</i> unidentified	Mobile Sharks and Rays
<i>Abjohnia laetevirens</i>	<i>Asparagopsis armata</i>	<i>Nectocarcinus tuberculatus</i>	<i>Heterodontus portusjacksoni</i>
<i>Caulerpa scalpelliformis</i>	<i>Delisea pulchra</i>	<i>Plagusia chabrus</i>	<i>Parascyllium variolatum</i>
<i>Caulerpa longifolia</i>	<i>Ptilonia australasica</i>	Mollusca	<i>Cephaloscyllium laticeps</i>
<i>Caulerpa brownii</i>	<i>Amphiroa anceps</i>	<i>Haliotis rubra</i>	<i>Dasyatis brevicaudata</i>
<i>Caulerpa flexilis</i>	<i>Corallina officinalis</i>	<i>Haliotis laevigata</i>	Mobile Bony Fishes
<i>Caulerpa flexilis</i> var. <i>muelleri</i>	<i>Arthrocardia wardii</i>	<i>Haliotis scalaris</i>	<i>Trachinops caudimaculatus</i>
<i>Caulerpa geminata</i>	<i>Haliptilon roseum</i>	<i>Scutus antipodes</i>	<i>Dinolestes lewini</i>
<i>Caulerpa annulata</i>	<i>Cheilosporum sagittatum</i>	<i>Phasianella ventricosa</i>	<i>Parequula melbournensis</i>
<i>Caulerpa simpliciuscula</i>	Encrusting corallines	<i>Turbo undulatus</i>	<i>Upeneichthys vlaminghii</i>
<i>Codium pomoides</i>	<i>Callophyllis rangiferina</i>	<i>Cypraea angustata</i>	<i>Girella tricuspidata</i>
Phaeophyta (brown algae)	<i>Nizymania australis</i>	<i>Cabestana spengleri</i>	<i>Girella zebra</i>
<i>Halopteris</i> spp	<i>Sonderopelta coriacea</i>	<i>Cymatium parthenopeum</i>	<i>Scorpius aequipinnis</i>
<i>Cladostephus spongiosus</i>	<i>Sonderopelta/Peyssonelia</i>	<i>Dicathais orbita</i>	<i>Scorpius lineolata</i>
<i>Dictyota dichotoma</i>	<i>Phacelocarpus alatus</i>	<i>Pleuroploca australasia</i>	<i>Atypichthys strigatus</i>
<i>Dilophus marginatus</i>	<i>Phacelocarpus peperocarpus</i>	<i>Conus anemone</i>	<i>Tilodon sexfasciatus</i>
<i>Lobospora bicuspidata</i>	<i>Callophycus laxus</i>	<i>Sagaminopteron ornatum</i>	<i>Enoplosus armatus</i>
<i>Dictyopteris muelleri</i>	<i>Areschougia congesta</i>	Echinodermata	<i>Parma victoriae</i>
<i>Chlanidophora microphylla</i>	<i>Areschougia</i> sp	<i>Cenolia trichoptera</i>	<i>Parma microlepis</i>
<i>Homeostichus sinclairii</i>	<i>Acrotylus australis</i>	<i>Cenolia tasmaniae</i>	<i>Aplodactylus arctidens</i>
<i>Homeostichus olsenii</i>	<i>Curdiea angustata</i>	<i>Tosia australis</i>	<i>Cheilodactylus nigripes</i>
<i>Zonaria angustata</i>	<i>Melanthalia obtusata</i>	<i>Tosia magnifica</i>	<i>Cheilodactylus spectabilis</i>
<i>Zonaria spiralis</i>	<i>Melanthalia concinna</i>	<i>Pentagonaster dubeni</i>	<i>Dactylophora nigricans</i>
<i>Zonaria turneriana</i>	<i>Polyopes constrictus</i>	<i>Nectria ocellata</i>	<i>Latridopsis forsteri</i>
<i>Carpomitra costata</i>	<i>Plocamium angustum</i>	<i>Nectria macrobrachia</i>	<i>Ophthalmolepis lineolata</i>
<i>Perithalia cordata</i>	<i>Plocamium potagiatum</i>	<i>Nectria multispina</i>	<i>Dotalabrus aurantiacus</i>
<i>Ecklonia radiata</i>	<i>Plocamium mertensii</i>	<i>Petricia vernicina</i>	<i>Notolabrus tetricus</i>
<i>Macrocystis angustifolia</i>	<i>Plocamium dilatatum</i>	<i>Fromia polypora</i>	<i>Notolabrus fucicola</i>
<i>Durvillaea potatorum</i>	<i>Plocamium preissianum</i>	<i>Plectaster decanus</i>	<i>Pseudolabrus psittaculus</i>
<i>Xiphophora chondrophylla</i>	<i>Plocamium cartilagineum</i>	<i>Echinaster arcystatus</i>	<i>Pictilabrus laticlavus</i>
<i>Phyllospora comosa</i>	<i>Plocamium leptophyllum</i>	<i>Nepanthiaroughtoni</i>	<i>Odax acroptilus</i>
<i>Seirococcus axillaris</i>	<i>Rhodymenia australis</i>	<i>Pateriella calcar</i>	<i>Odax cyanomelas</i>
<i>Caulocystis cephalornithos</i>	<i>Rhodymenia</i> sp	<i>Patiriella brevispina</i>	<i>Siphonognathus beddomei</i>
<i>Acrocarpia paniculata</i>	<i>Cordylecladia furcellata</i>	<i>Coscinasterias muricata</i>	<i>Neodax balteatus</i>
<i>Cystophora platylobium</i>	<i>Ballia callitricha</i>	<i>Uniophora granifera</i>	<i>Bovichtus angustifrons</i>
<i>Cystophora moniliformis</i>	<i>Ballia scoparia</i>	<i>Holopneustes porosissimus</i>	<i>Acanthaluteres vittiger</i>
<i>Cystophora monilifera</i>	<i>Euptilota articulata</i>	<i>Holopneustes inflatus</i>	<i>Scobinichthys granulatus</i>
<i>Cystophora retorta</i>	<i>Hemineura frondosa</i>	<i>Heliocidaris erythrogramma</i>	<i>Meuschenia flavolineata</i>
<i>Cystophora siliquosa</i>	<i>Laurencia elata</i>	Cryptic Fishes	<i>Meuschenia freycineti</i>
<i>Cystophora retroflexa</i>	<i>Laurencia filiformis</i>	<i>Parascyllium variolatum</i>	<i>Meuschenia galii</i>
<i>Cystophora subfarcinata</i>	<i>Laurencia</i> spp	<i>Aetapcus maculatus</i>	<i>Meuschenia hippocrepis</i>
<i>Carpoglossum confluens</i>	Other thallose red alga	<i>Hypoplectrodes maccullochi</i>	<i>Aracana aurita</i>
<i>Sargassum decipiens</i>	Magnoliophyta (seagrass)	<i>Bovichtus angustifrons</i>	<i>Aracana ornata</i>
<i>Sargassum verruculosum</i>	<i>Amphibolis antarctica</i>	<i>Forsterygion varium</i>	<i>Tetractenos glaber</i>
<i>Sargassum fallax</i>		<i>Heteroclinus perspicillatus</i>	<i>Diodon nichthemerus</i>
<i>Sargassum vestitum</i>		<i>Heteroclinus johnstoni</i>	Unidentified fish
<i>Sargassum spinuligerum</i>		Unidentified fish	
<i>Sargassum</i> spp			
Brown algal turf			

2.3 Data Analysis

2.3.1 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).

Prior to analysis, the data were log transformed to weight down the influence of highly abundant species in describing community structure, giving a more even weighting between abundant and rarer species (following abundance transformations by Sweatman *et al.* 2000).

The Bray-Curtis dissimilarity index was calculated for all possible combinations of sites and surveys. This resulted in a matrix of pair-wise comparisons known as a dissimilarity matrix. The dissimilarity matrix is also termed a distance matrix as it effectively represents distances between samples in hyper-dimensional space. The dissimilarity matrix was used for all analyses of community structure in this study.

2.3.2 Depiction of Community Differences

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

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

2.3.3 Trends in Community Structure

Trends in community structure were examined statistically for each site using the Bray-Curtis matrix of dissimilarities. This was done by calculating the correlation between dissimilarity in species composition (Bray-Curtis coefficient) and the difference in times using all pairs of samples between times at each site (following Philippi *et al.* 1998). The Mantel r_M statistic was used as a measure of this correlation (ranging from 0 to 1). The significance of the r_M statistic was tested using a matrix permutation test with 1000 permutations (Upton & Fingleton 1985; Legendre & Legendre 1998).

2.3.4 Species Diversity

Species diversity involves the consideration of two components: species richness and evenness. Species richness is the number of species present in the community while evenness is the degree of similarity of abundances between species. If all species in a community have similar abundances, then the community has a high degree of evenness. If a community has most of the individuals belonging to one species, it has low evenness. Species diversity is a combination of species richness and the relative abundance of each species, and is often referred to as species heterogeneity. Measures of diversity give an indication of the likelihood that two individuals selected at random from a community are different species.

Species richness (S) was enumerated by the total species count per site. This value was used for calculation of evenness and heterogeneity statistics. Species diversity (*i.e.* heterogeneity among species) was described using the reciprocal of Simpson's index ($1/D_{\text{Simpson}} = \text{Hill's } N_2$). This index provides more weighting for common species, as opposed to the weighting of rarer species such as by the Shannon-Weiner Index (Krebs 1999). The weighting of common species was considered more appropriate for this study, the sampling being directed more towards the enumeration of common species rather than rarer ones.

2.3.5 Species Populations

The abundances of each species were summarised by calculating total counts of fish and invertebrates, and total percentage cover of macroalgae, for each site. These site totals were calculated for each survey time and visually examined, but not reported here. The abundances of selected species were also plotted to examine the nature of temporal variations. Trend lines were fitted to the data using linear regressions of log-transformed abundances and plotting back-transformed curves (following Sweatman *et al.* 2003 except linear not quadratic functions were fitted). Trend lines were also fitted for diversity and species richness values (using untransformed data).

The population size structure for blacklip abalone *Haliotis rubra* was assessed by calculating mean lengths and size frequency curves. The size structure of common fishes, particularly blue-throated wrasse *Notolabrus tetricus* and herring cale *Odax cyanomelas*, was examined using mean lengths and frequency tables. The sex ratio of sexually dimorphic species was also compared between sites.



Figure 2.2. Biologist-diver with transect reel, Lonsdale Back Beach.

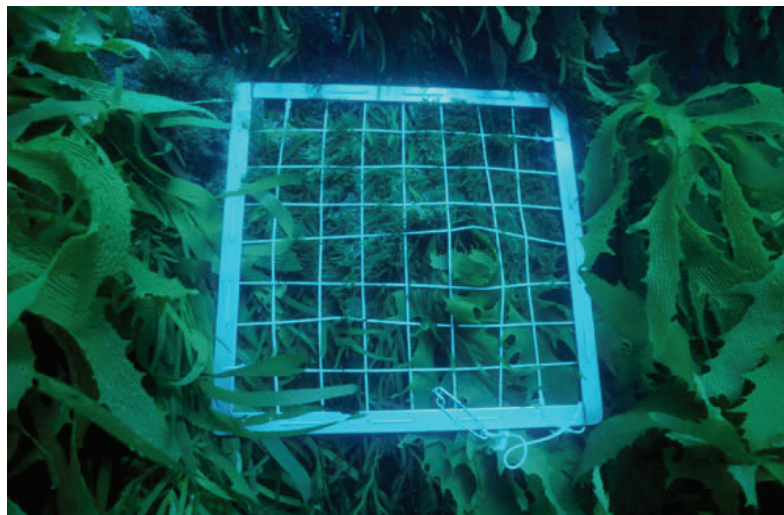


Figure 2.3. The cover of macrophytes is measured by the number of points intersecting each species on the quadrat grid.

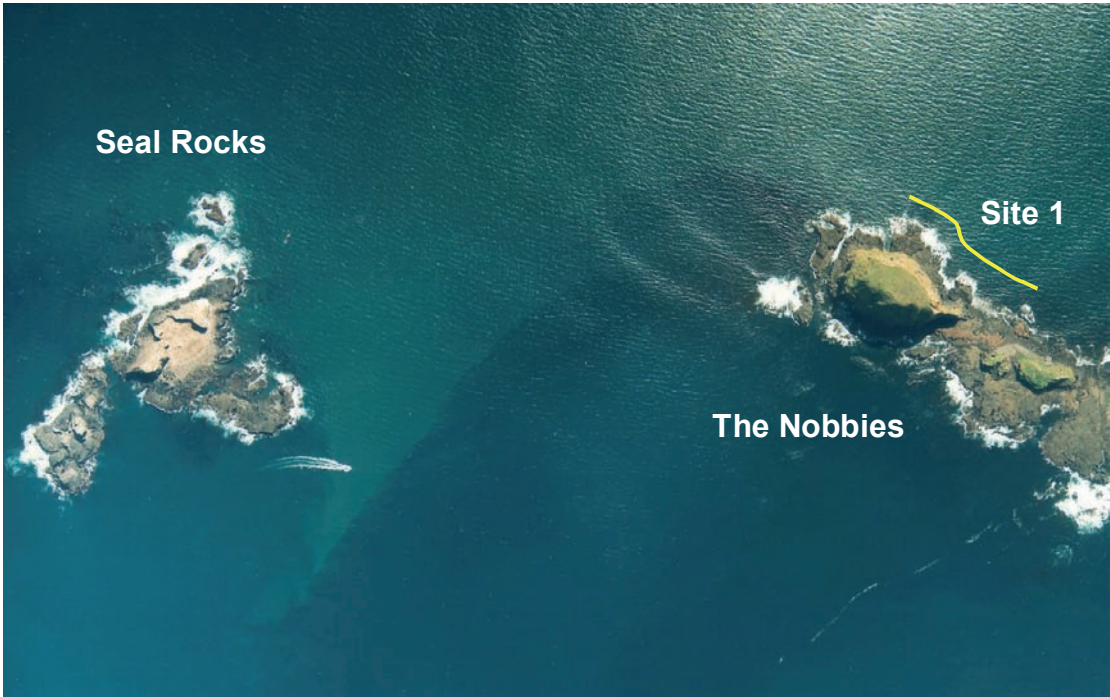


Figure 2.4. Approximate location of transects at Nobbies North, Site 1, Phillip Island.



Figure 2.5. Approximate location of transect at Red Bluff, Site 2, Phillip Island.



Figure 2.6. Approximate location of transect at Pyramid North, Site 3, Phillip Island.



Figure 2.7. Approximate location of transect at Woolamai West, Site 4, Phillip Island.

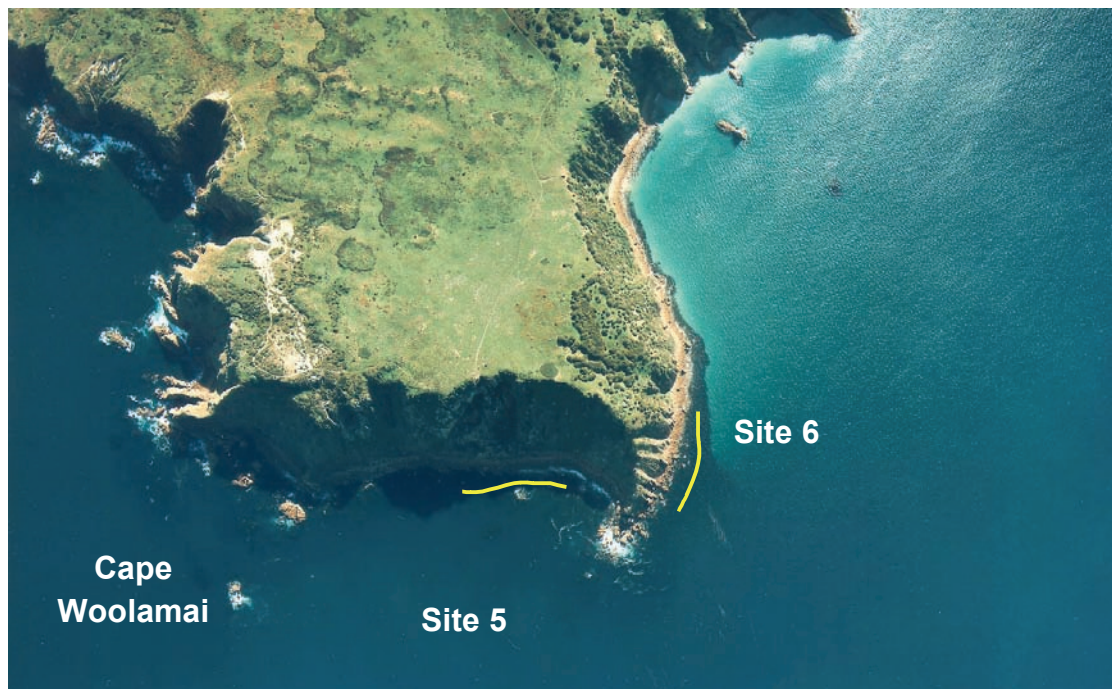


Figure 2.8. Approximate location of transects at Cape Woolamai Mid (Site 5) and East (Site 6), at Phillip Island.

3.0 MACROALGAE

3.1 Community Structure

The algal assemblage at Nobbies North (Site 1) consisted of a variety of large brown algal species, including *Phyllospora comosa*, *Macrocystis angustifolia*, *Acrocarpia paniculata*, *Cystophora retorta* and *C. retroflexa*. Smaller, turfing-like species such as the green algae *Caulerpa brownii* and *C. flexilis*, the brown alga *Halopteris* sp and the pink coralline species *Haliptilon roseum* and *Cheilosporum sagittatum* were also common in the quadrats.

Red Bluff (Site 2) and Woolamai Washing Machine (Site 4), the most exposed sites, were similar in having a high cover of the canopy-forming alga *Phyllospora comosa* (> 60% cover). The brown alga *Acrocarpia paniculata* was often present in open patches between stands of *Phyllospora comosa*. However, the smaller brown algal species were generally depauperate at these sites. The understory at Red Bluff was predominantly composed of erect coralline algae, such as *Haliptilon roseum*, *Cheilosporum sagittatum* and *Metagoniolithon radiatum*. The understory at Woolamai West was composed of fleshy red algae such as *Ballia callitricha*, *Plocamium* species and the small browns *Zonaria turneriana* and *Homoeostrichus sinclarii*.

The Pyramid North site (Site 3) was dominated by smaller brown species such as *Cystophora moniliformis*, *C. retroflexa*, *C. retorta*, *Acrocarpia paniculata* and *Xiphophora chondrophylla*. *Phyllospora comosa* was absent from much of this site. This site also had substantial patches of coralline algal turf, including *Haliptilon roseum*, *Cheilosporum sagittatum*, *Amphiroa anceps* and *Metagoniolithon radiatum*.

The Woolamai Central (Site 5) and East (Site 6) sites were reasonably similar in algal structure, having mosaics of patches dominated by *Phyllospora comosa*, *Acrocarpia paniculata* and erect coralline species. The overall cover of these three patch types was generally similar, with approximately 30% cover for each type. Other smaller algae, such as *Halopteris* sp, *Caulerpa flexilis* and *Caulerpa brownii*, were also common.

The MDS plot of similarities in algal assemblage structure generally ranked the sites in order of exposure (Figure 3.1). The most exposed sites (1, 2, 4 & 5) were located toward the front of the plot while the less exposed sites (3 & 6) were positioned more to the rear-right of the plot. These relative similarities between sites reflect the general observations described above: the most exposed site, Site 4 (Woolamai Washing Machine), was distinct in having a high coverage of *Phyllospora* and low abundances of other brown algal species (although fleshy and coralline red algae were abundant); Sites 1, 2, 5 and 6 also had a dominance of *Phyllospora*, however *Acrocarpia* was also an abundant contributor to the canopy cover; Site 1 was slightly different in having higher abundances of *Ecklonia radiata*, *Carpoglossum confluens*, *Macrocystis angustifolia* and *Cystophora platylobium*; and Site 3, the most sheltered site, was distinct in having little cover of *Phyllospora* and a predominance of other brown algae and erect corallines.

Most of the sites appeared to be relatively stable in community structure with either little variation between surveys or the time trajectories appearing to oscillate about a centroid state (Figure 3.1). Tests for progressive changes in species composition detected no significant trends (Table 3.1).

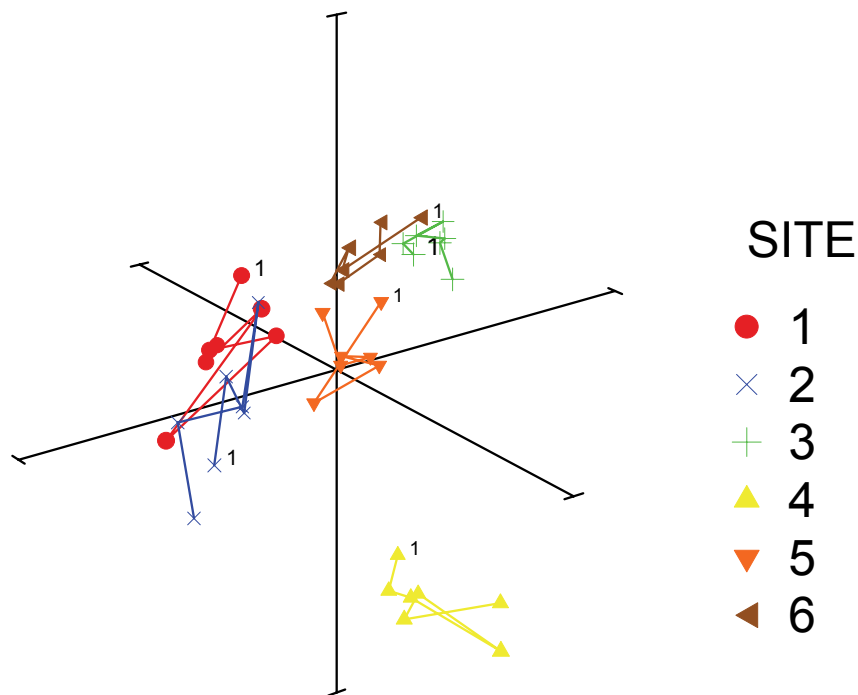


Figure 3.1. MDS plot of algal assemblage structure at Phillip Island. The numbers on the plot denote the first survey for each site (site details are given in Tables 2.1 & 2.2). Stress = 0.14.

Table 3.1. Tests of change in macrophyte communities at Phillip Island. The Mantel r_M statistic is a measure of the correlation between dissimilarity in species composition (Bray-Curtis coefficient) and difference in times. The significance of the r_M value was tested using a permutation test with 1000 permutations.

Site	Mantel r_M	Probability	% B-C Dissimilarity (first to last)
1	0.41	0.119	44.08
2	0.44	0.102	43.75
3	0.34	0.084	39.47
4	0.36	0.158	38.28
5	0.31	0.157	34.26
6	0.27	0.156	35.32

3.2 Diversity

Macroalgal species richness was higher at the western sites (Sites 1, 2 and 3) at the start of the monitoring program, with 20-25 species per site compared to the eastern sites (Sites 3, 4 and 5) with 15-20 species per site. Species richness appears to have increased at all sites since then with the exception of Red Bluff (Site 2) and Washing Machine (Site 4) which appear to have been more stable (Figure 3.2).

Macroalgal species diversity was considerably higher at Pyramid North (Site 3), and appeared to increase through time. Conversely, diversity at the Nobbies (Site 1) appears to have decreased over the survey period. Species diversity at all other sites seemed to remain more consistent through time (Figure 3.3).

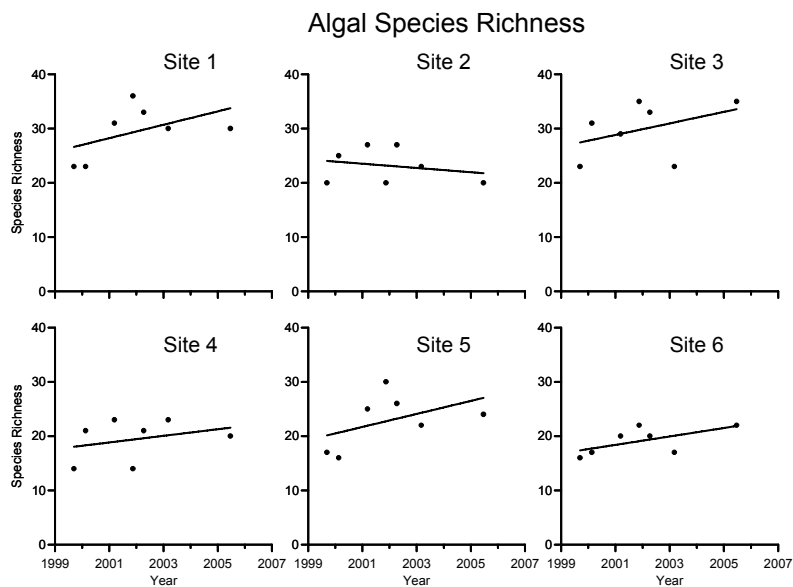


Figure 3.2. Trends in macrophyte species richness at Phillip Island.

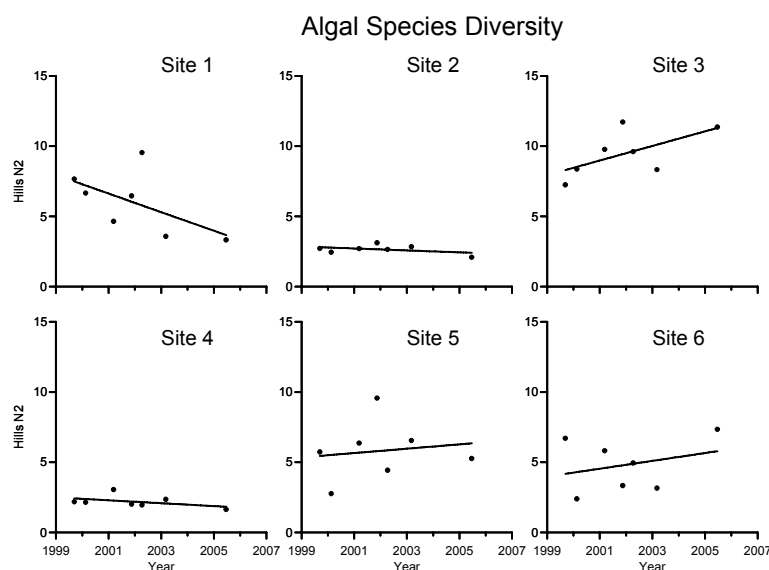


Figure 3.3. Trends in macrophyte species diversity at Phillip Island.

3.3 Population Abundances

Examples of time trends in abundances of selected species are given for each site in Figures 3.4 to 3.8. Points of interest include an apparently increasing trend in abundance of *Phyllospora comosa* at the Nobbies (Site 1) mirrored by a decrease in abundance at Woolamai East (Site 6; Figure 3.4). *Acrocarpia paniculata* appears to be showing a similar decline in abundance at Woolamai East (Site 6) (Figure 3.5). The coralline algae *Haliptilon roseum* is showing an increasing trend in abundance at the Nobbies and Pyramid North sites (Sites 1 and 3; Figure 3.6). A decreasing trend in abundance of the coralline algae *Amphiroa anceps* is indicated at Pyramid North and Woolamai East (Sites 3 and 6) while *Metagoniolithon radiatum* appears more stable through time (Figures 3.7 and 3.8).

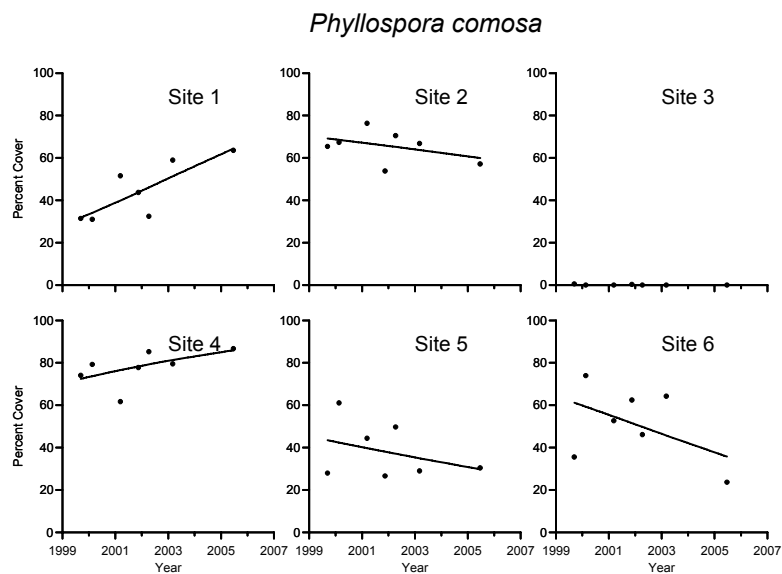


Figure 3.4. Trends in abundance of the brown algae *Phyllospora comosa* at Phillip Island.

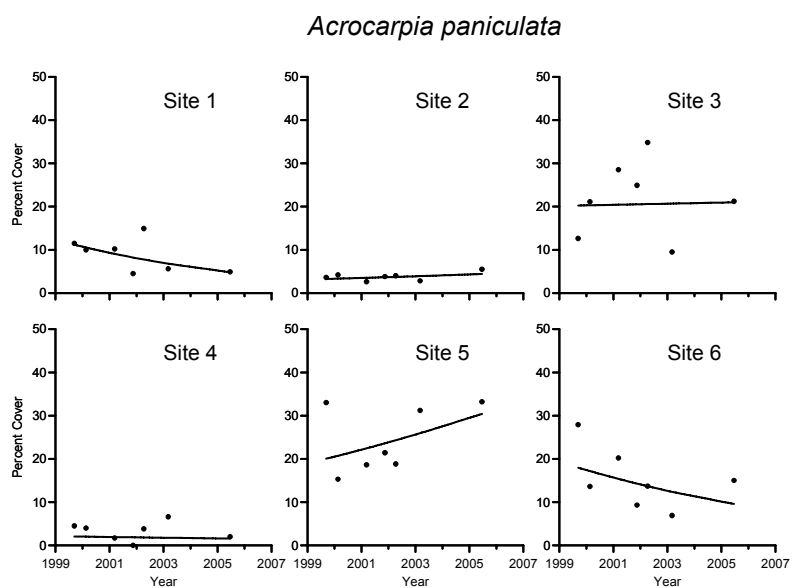


Figure 3.5. Trends in abundance of the brown alga *Acrocarpia paniculata* at Phillip Island.

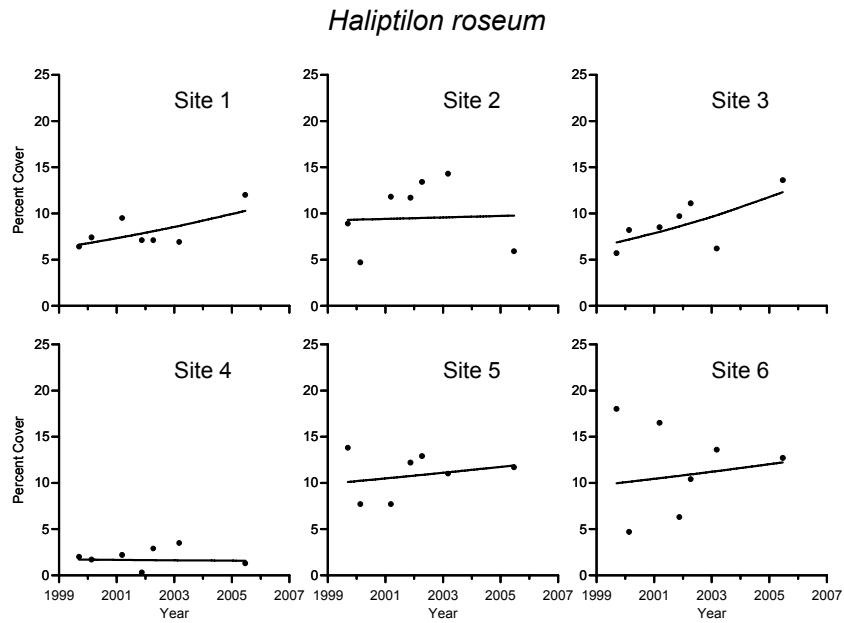


Figure 3.6. Trends in abundance of the erect coralline alga *Haliptilon roseum* at Phillip Island.

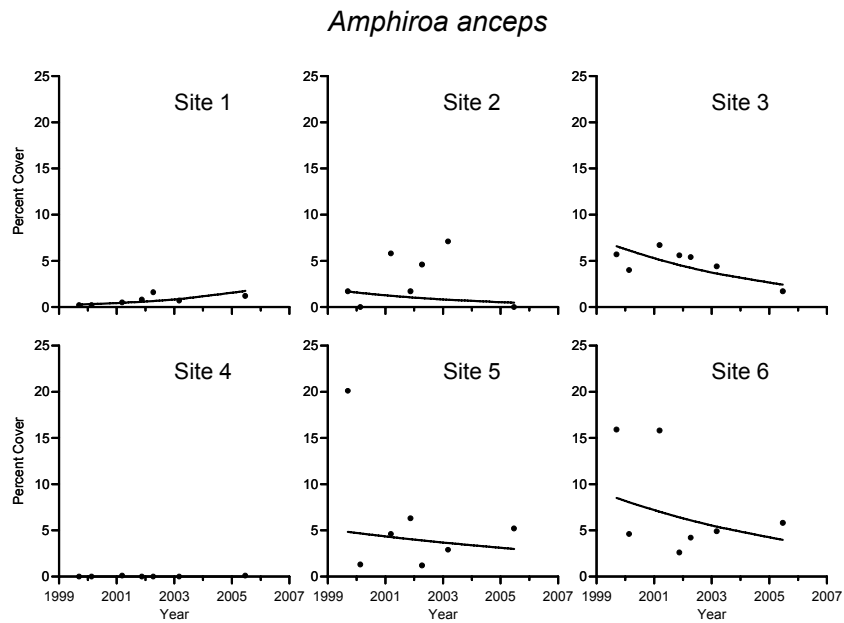


Figure 3.7. Trends in abundance of the erect coralline alga *Amphiroa anceps* at Phillip Island.

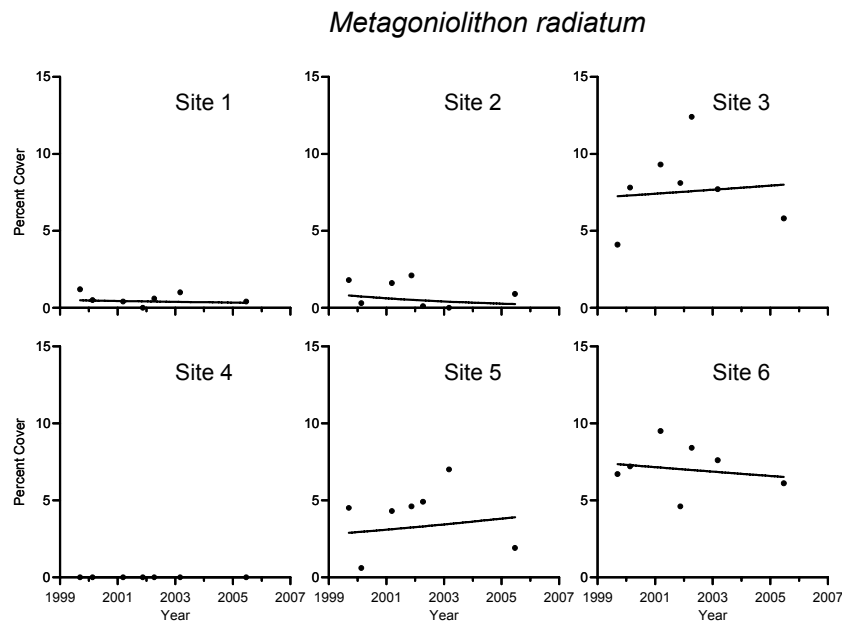


Figure 3.8. Trends in abundance of the erect coralline alga *Metagoniolithon radiatum* at Phillip Island.

3.4 *Macrocystis angustifolia*

The string kelp *Macrocystis angustifolia* can grow up to 10 m in height and form dense forests with a thick canopy floating on the surface. Consequently, *M. angustifolia* is a significant habitat forming species. Anecdotal evidence suggests *M. angustifolia* was once present in relatively high abundance along the Victorian coast, forming large forests in some locations. Abundances of *M. angustifolia* have been reduced considerably for much of this decade. Possible causes of this decline include a rapid succession of El Niño events in the late 1980s and early 1990s (affecting water temperature and nutrient levels), a long-term increase in average sea temperature (1° C over the last 40 years) and changes to coastal nutrient inputs.

Since monitoring began, *Macrocystis angustifolia* was generally only present at The Nobbies and North Pyramid Rock (Sites 1 & 3). The density of *M. angustifolia* was particularly high at The Nobbies during survey two, with 618 plants per 2000 m² (Figure 3.9). North Pyramid (Site 3) had a density of 143 plants per 2000 m² during the second survey, but none have been observed at this site during subsequent surveys. There was also a strong decreasing trend in abundance at The Nobbies (Site 1), with only 10 plants per 2000 m² observed during the last survey (Figure 3.9). This decline in abundance of *M. angustifolia* reflects trends observed at other SRMP locations in central and western Victoria.

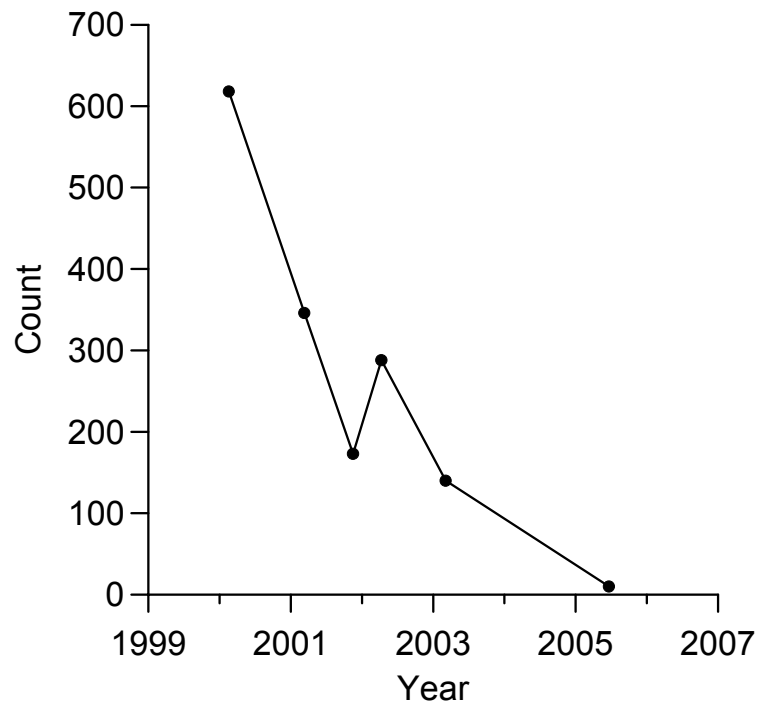


Figure 3.9. Trends in abundance of the string kelp *Macrocystis angustifolia* at The Nobbies (Site 1), Phillip Island

4.0 INVERTEBRATES

4.1 Community Structure

The invertebrate fauna was dominated at all sites by the blacklip abalone *Haliotis rubra*, the warrener *Turbo undulatus* and the dog-whelk *Dicathais orbita*. Other common species included the red bait crab *Plagusia chabrus*, sea stars *Nectria ocellata*, *N. macrobrachia*, *Echinaster arcystatus* and *Patiriella brevispina* and the sea urchin *Heliocidaris erythrogramma*. The commercially and recreationally valuable southern rock lobster *Jasus edwardsii* was also relatively common though low in abundance.

The MDS plot of invertebrate assemblage similarities tended to separate the sites according to exposure, with the most exposed sites (Sites 2 & 4) toward the rear of the plot and the most sheltered (Site 3) to the front of the plot (Figure 4.1). The Nobbies (Site 1) was generally distinct in having relatively high abundances of *Haliotis rubra*, *Turbo undulatus*, *Dicathais orbita* and *Patiriella brevispina*. Pyramid North (Site 3) also tended to be distinct from other sites, having relatively low abundances of all species.



Figure 4.1. MDS plot of invertebrate assemblage structure at Phillip Island. The numbers on the plot denote the location of the first survey for each site. See Tables 2.1 and 2.2 for site details. Stress = 0.18.

A high abundance of *Haliotis rubra* was observed at Site 3 during the first survey but not in following surveys, contributing to the large shift in community structure shown in Figure 4.1 (green line). Sites 4 and 5 had intermediate variations in community structure between surveys. Tests for progressive changes in species composition detected significant trends at Sites 2 and 4, having r_M correlation values of 0.55 and 0.56 respectively (Table 4.1).

Table 4.1. Tests of change in invertebrate communities at Phillip Island. The Mantel r_M statistic is a measure of the correlation between dissimilarity in species composition (Bray-Curtis coefficient) and difference in times. The significance of the r_M value was tested using a permutation test with 1000 permutations.

Site	Mantel r_M	Probability	% B-C Dissimilarity (first to last)
1	0.26	0.193	19.85
2	0.55	0.008	33.25
3	0.19	0.216	53.63
4	0.56	0.028	41.11
5	0.21	0.272	37.31
6	0.02	0.395	28.73

4.2 Diversity

There was an apparent increasing trend in invertebrate species richness over the survey period at Red Bluff (Site 2), Washing Machine (Site 4) and Woolamai East (Site 6) (Figure 4.2). Washing Machine and Woolamai East (Sites 4 and 6) also had relatively higher levels of invertebrate richness with 15-20 species at each site compared to 10-15 for all other sites.

Invertebrate species diversity was similar at most sites with little change over time, except for a higher diversity observed at Pyramid North during the fourth and fifth surveys (Figure 4.3). This increased diversity at Site 3 appears to be the result of a decreased dominance in abundance of *Haliotis* and *Turbo*. A gradual increasing trend in diversity is apparent at Woolamai East (Site 6; Figure 4.3).

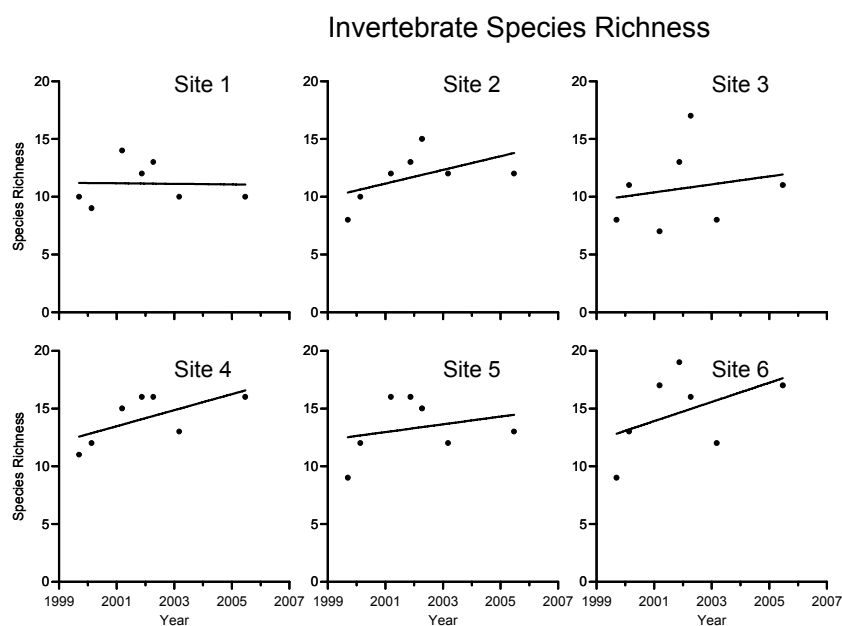


Figure 4.2. Trends in invertebrate species richness at Phillip Island.

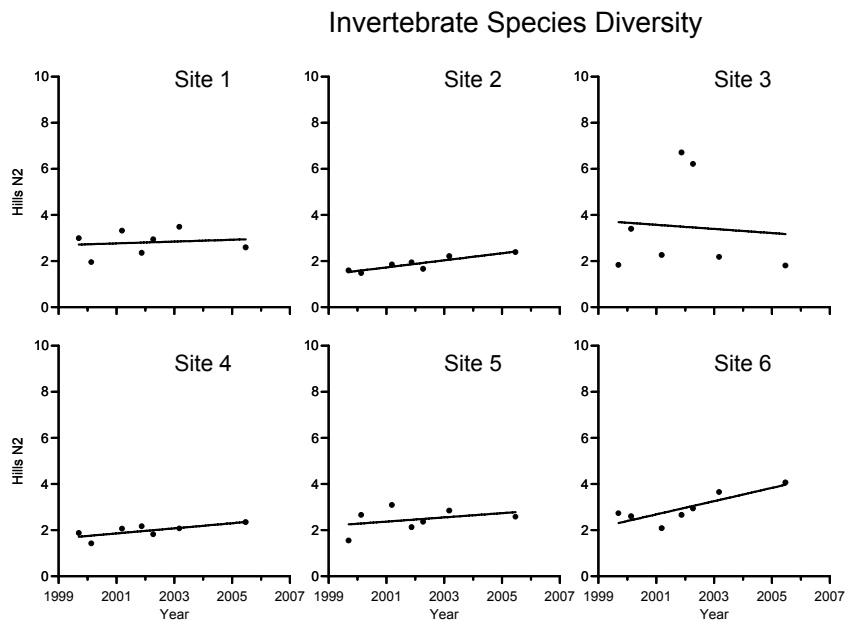


Figure 4.3. Trends in invertebrate species diversity at Phillip Island.

4.3 Population Abundances

Time trends of abundances for *Turbo undulatus* and *Haliotis rubra* are given for each site in Figures 4.4 and 4.5. The mean sizes of *Haliotis* are shown in Figure 4.6 with size frequency distributions illustrated in Figure 4.7.

The abundance of *Turbo undulatus* was comparatively high at The Nobbies and Woolamai Central (Sites 1 & 5; Figure 4.4). *Turbo undulatus* was exceptionally abundant at Red Bluff (Site 2) where a very strong increasing trend in abundance was recorded. There has been an increase of 3-4 times the initial abundance over the survey period (Figure 4.4).

The abundance of *Haliotis rubra* were also very high at Red Bluff (Site 2), with abundances higher than 1.5 m⁻². *Haliotis rubra* abundances were also relatively high at all other sites except Site 3, where moderate abundances were only observed during the first survey (Figure 4.5).

The mean size of *Haliotis rubra* was reasonably constant over time at most sites (Figure 4.6). The average sizes tended to be greater at the more exposed Red Bluff and Woolamai Washing Machine sites (Sites 2 & 4), with the average size at or above the legal minimum fishing length of 110 mm (Figure 4.6). A sharp drop in the mean length at Red Bluff (Site 2) was observed between the fourth and fifth surveys, possibly indicating this site was recently harvested by commercial fishers.

Figure 4.6 indicates that the population size structure of *Haliotis rubra* over all sites has been relatively stable over time. The population size-class density during survey 6 appears to have a slightly negatively skewed distribution, with a higher proportion of smaller individuals than at other times (Figure 4.6).

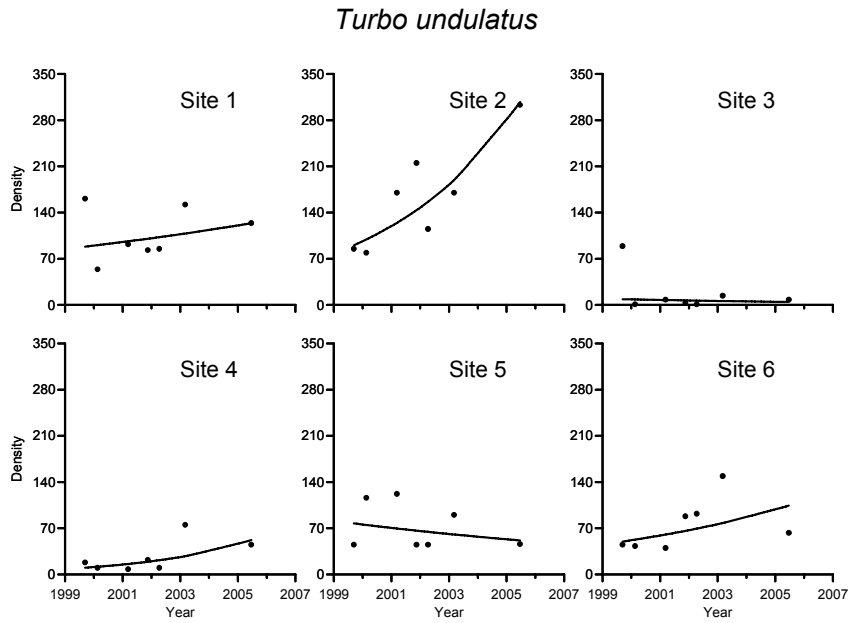


Figure 4.4. Trends in abundance of the warrener *Turbo undulatus* at Phillip Island.

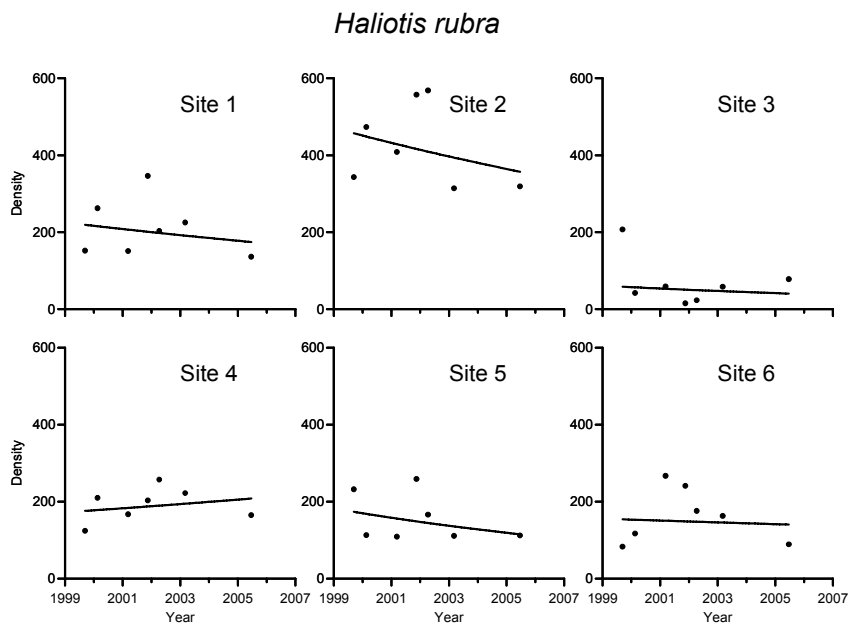


Figure 4.5. Trends in abundance of the black lip abalone *Haliotis rubra* at Phillip Island.

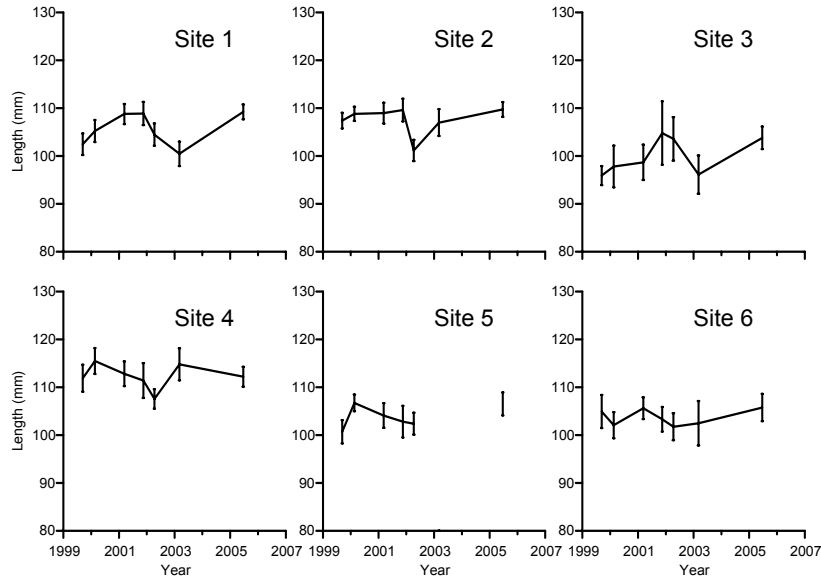


Figure 4.6. Trends in mean size (\pm 95% CI) of the black lip abalone *Haliotis rubra* at Phillip Island. Note that insufficient data were available for the sixth survey of Site 5.

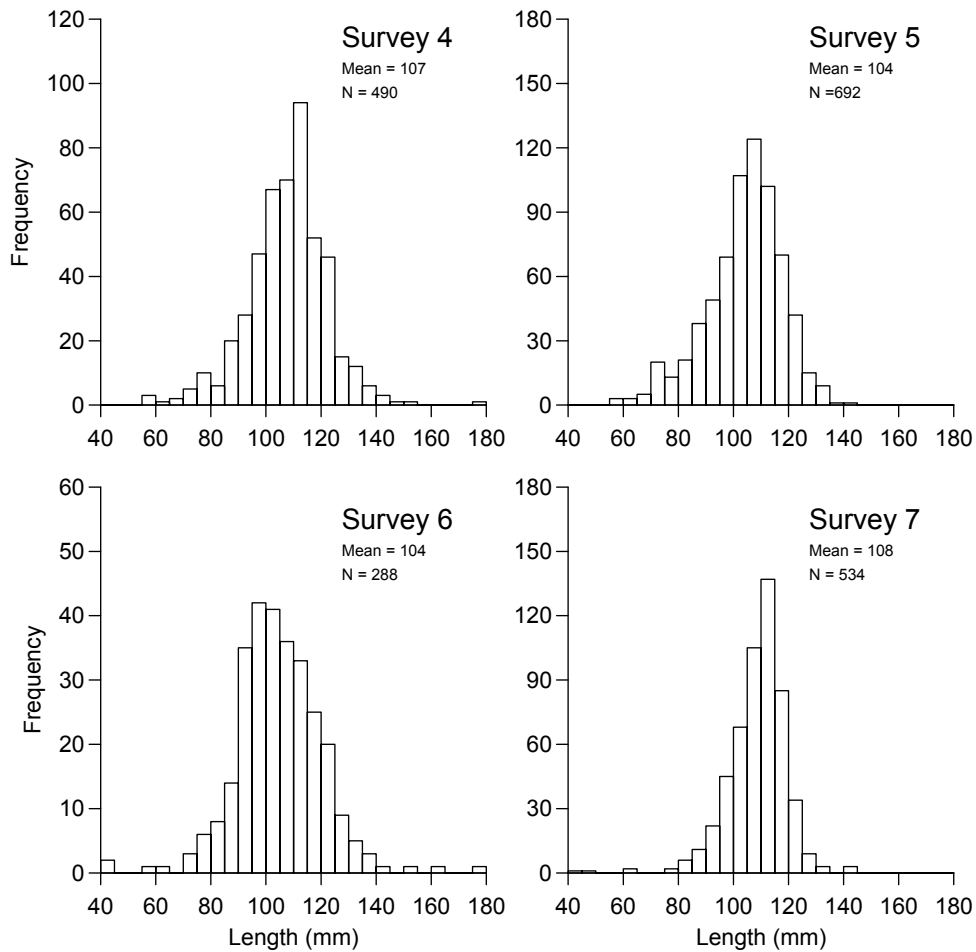


Figure 4.7. Size frequency distributions of *Haliotis rubra* lengths at Phillip Island for the last four surveys (all data from all sites combined).

5.0 FISH

5.1 Community Structure

The fish assemblages primarily consisted of blue-throated wrasse *Notolabrus tetricus*, purple wrasse *Notolabrus fucicola*, herring cale *Odax cyanomelas* and sea sweep *Scorpius aequipinnis*. Other common species included the scalyfin *Parma victoriae*, long-finned pike *Dinolestes lewini*, zebra fish *Girella zebra* and magpie perch *Cheilodactylus nigripes*. Low abundances of leatherjackets and other wrasses were also observed at all sites.

The MDS plot indicated the fish assemblages of Red Bluff and Pyramid North (Sites 2 & 3) were slightly different to the other sites (Figure 5.1). These two sites were originally differentiated by a relatively moderate to high abundance of *Notolabrus tetricus* and low abundances of *N. fucicola* and *Odax cyanomelas*. Declines in the abundance of these species at most other sites however, have resulted in more similar fish assemblages between all sites. There was substantial overlap in community trajectories over time and relatively similar levels of variation between times (Figure 5.1). The Nobbies (Site 1) has remained the most stable assemblage over time with the abundance of common species changing relatively little during the survey period.

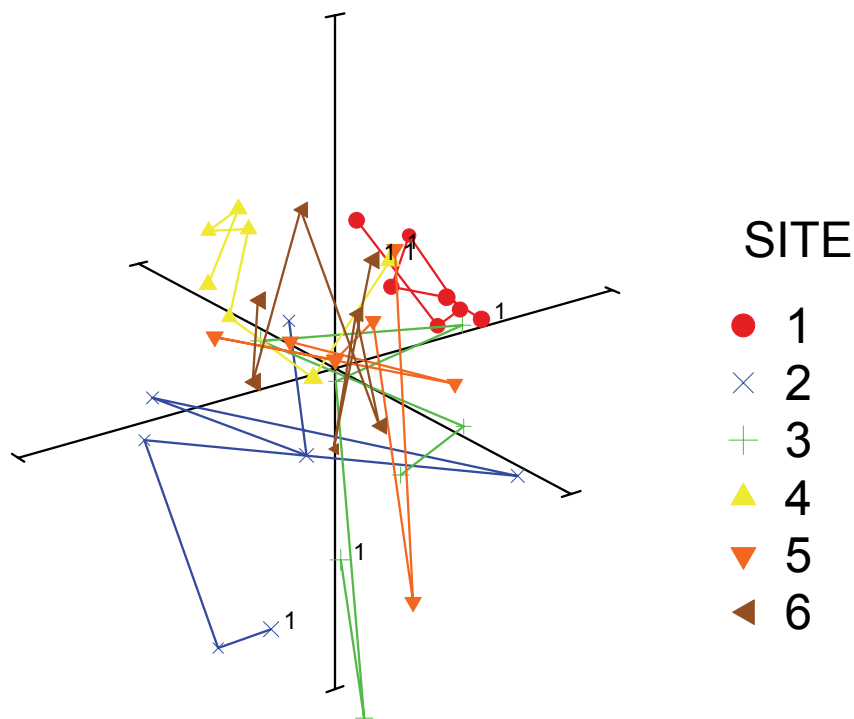


Figure 5.1. MDS plot of fish assemblage structure at Phillip Island. The numbers on the plot denote the location of the first survey for each site. See Tables 2.1 & 2.2 for site details. Stress = 0.14.

The MDS plot indicated relatively large shifts in community structure during Survey 2 for Sites 2, 3, 5 and 6 (to the left of the MDS plot; Figure 5.1). This shift appears to have been caused by lower abundances of *Notolabrus fucicola* and *Odax cyanomelas* during Survey 2. Tests for progressive changes in species composition did not detect any significant trends at any of the sites (Table 5.1).

5.2 Diversity

All sites had similar species richness with an apparent gradual increasing trend over the monitoring period (Figure 5.2). No clear trends were evident for diversity with most sites displaying little overall change (Figure 5.3). Both fish species richness and diversity were generally similar between sites (Figures 5.2 & 5.3).

5.3 Population Abundances

Examples of time trends in abundances of selected species are given for each site in Figures 5.4 to 5.7.

Abundances of *Notolabrus tetricus* appear to have increased at all sites over the monitoring period except for Woolamai Washing Machine (Site 4) where there appears to have been little change in abundance (Figure 5.4). This trend was very strong at Pyramid North and Woolamai Central (Sites 3 & 5) where large numbers of small females were recorded during Survey 7. The abundance of *Notolabrus fucicola* appears to have decreased at Woolamai Washing Machine (Site 4) but remained relatively stable at all other sites (Figure 5.5).

There was a decreasing trend in abundance apparent for *Odax cyanomelas* at The Nobbies and Woolamai Washing Machine (Sites 1 & 4) between survey 1 and 6, however this was reversed during Survey 7 by a substantial increase in abundance (Figure 5.6). An increase in abundance of *O. cyanomelas* was also observed at Woolamai Central (Site 5) during the last survey.

As with *Odax cyanomelas*, the between-survey variation for *Cheilodactylus nigripes* was quite high (Figure 5.7). No consistent trends were evident for any of the sites.

Examples of size-frequencies are also given for selected species in Tables 5.2 to 5.4. *Notolabrus tetricus* tended to be larger at The Nobbies (Site 1) and Woolamai Washing Machine (Site 4). These sites were also where the greatest proportion of males were recorded (Table 5.2). While the mean size of *N. fucicola* was similar between sites, there appears to have been a general decrease in mean size over the last three surveys (Table 5.3). There also appears to have been a similar trend for decreased mean lengths of *Odax cyanomelas* (Table 5.4).

Table 5.1. Tests of change in fish communities at Phillip Island. The Mantel r_M statistic is a measure of the correlation between dissimilarity in species composition (Bray-Curtis coefficient) and difference in times. The significance of the r_M value was tested using a permutation test with 1000 permutations.

Site	Mantel r_M	Probability	% B-C Dissimilarity (first to last)
1	0.18	0.284	37.05
2	0.29	0.115	62.66
3	-0.24	0.731	50.07
4	0.31	0.162	45.00
5	-0.21	0.725	31.96
6	0.04	0.320	35.73

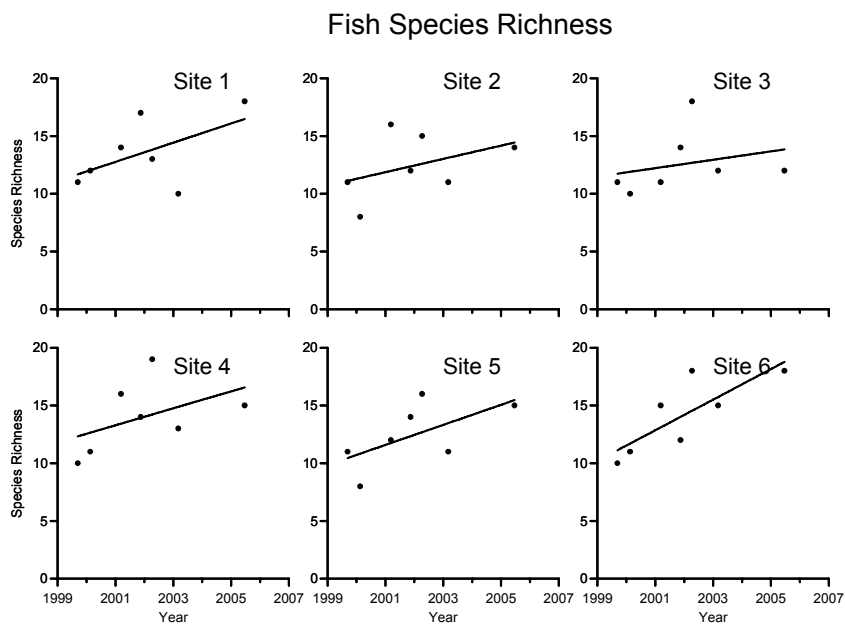


Figure 5.2. Trends in fish species richness at Phillip Island.

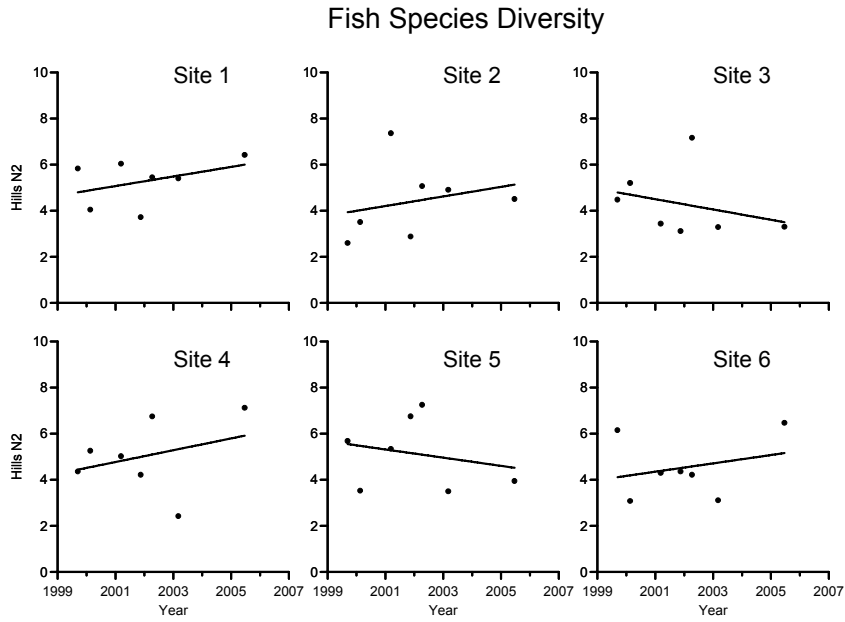


Figure 5.3. Trends in fish species diversity at Phillip Island.

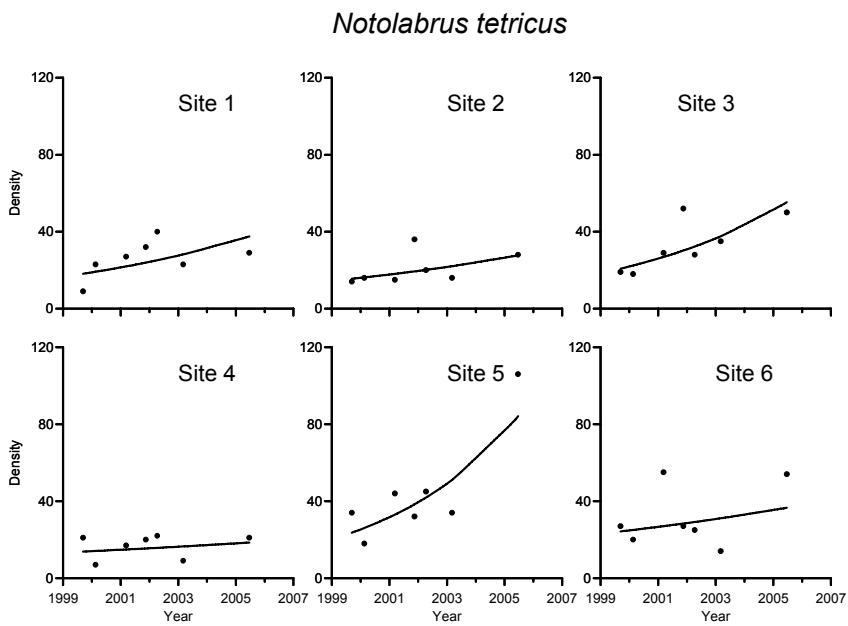


Figure 5.4. Trends in abundance of blue-throated wrasse *Notolabrus tetricus* at Phillip Island.

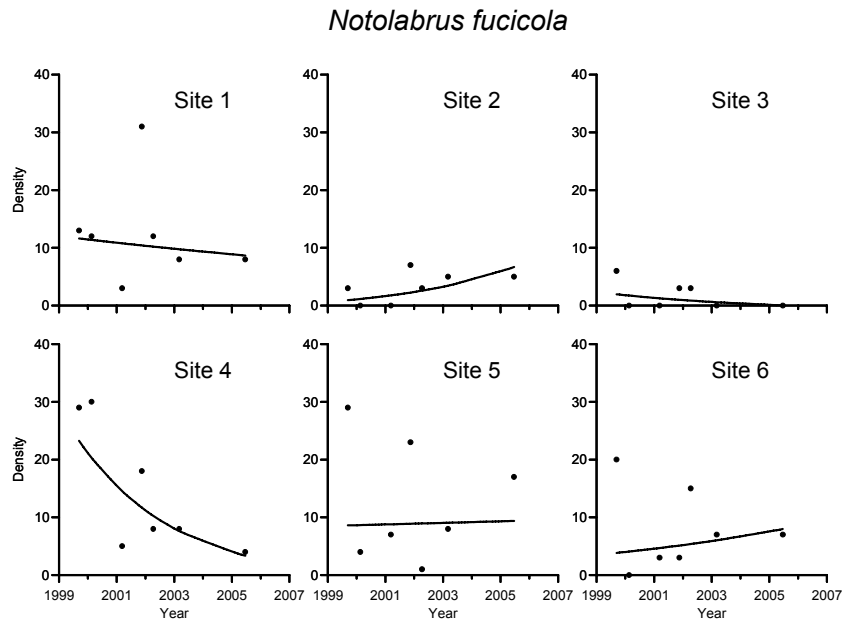


Figure 5.5. Trends in abundance of purple wrasse *Notolabrus fucicola* at Phillip Island.

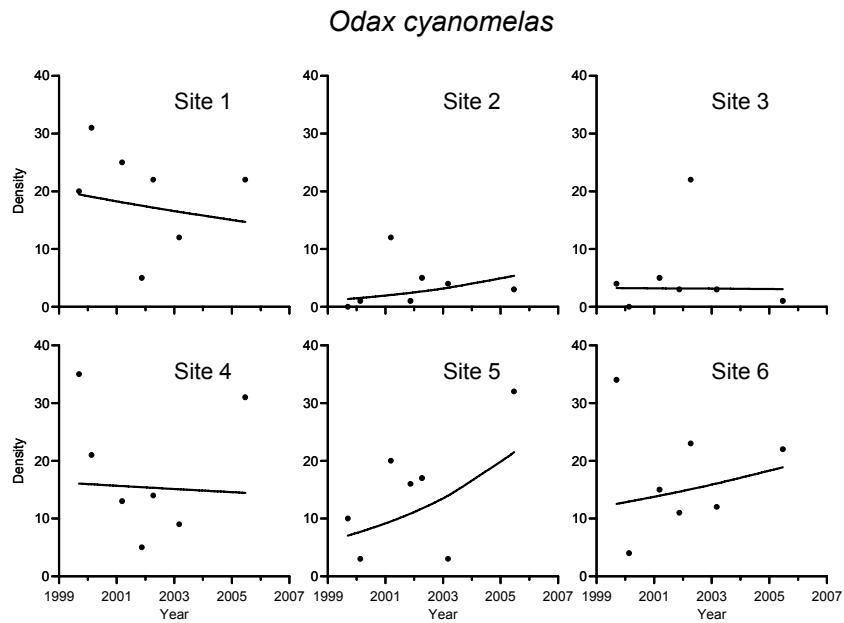


Figure 5.6. Trends in abundance of herring cale *Odax cyanomelas* at Phillip Island.

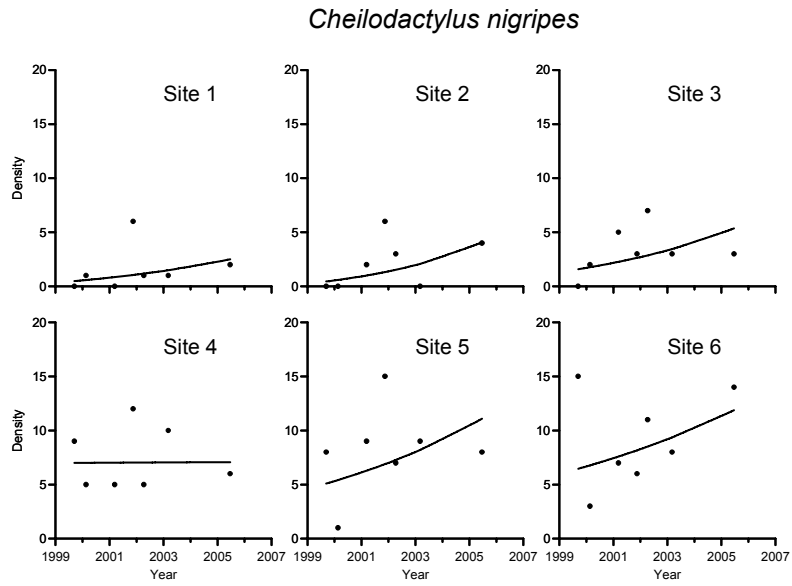


Figure 5.7. Trends in abundance of magpie morwong *Cheilodactylus nigripes* at Phillip Island.

Table 5.2. Population structure of blue-throated wrasse *Notolabrus tetricus* at Phillip Island (last three surveys).

Site	% male	Length (mm)			Length Class (mm)										
		n	mean	sd	75	100	125	150	200	250	300	350	375	400	500
Survey 5, Autumn 2002															
2901	10	40	211	92	3	1	2	11	7	6	4	4	1	1	
2902	10	20	190	85	2		3	5	4	4		1		1	
2903	0	28	157	49		3	6	12	6			1			
2904	18	22	213	77			3	5	6	5		2		1	
2905	24	45	216	90	1	2	4	12	10	3	6	4		3	
2906	8	25	181	72	1	2		12	6	2		1		1	
Survey 6, Summer 2003															
2901	22	23	189	100	1	4	1	6	4	1	2	1		2	
2902	19	16	195	105	1	2	4	2	2	1	2			2	
2903	0	35	130	45	3	13	5	10	3		1				
2904	33	9	236	108			1	3	1	1	1			2	
2905	15	34	209	92	1	1	7	3	9	4	3	3		2	
2906	14	14	223	87			1	4	3	4				2	
Survey 7, Winter 2005															
2901	34	29	226	94	1	2	3	3	9	1	3	6		1	
2902	7	28	165	81	3	4	7	5	3	3	1	1	1		
2903	0	50	125	34	7	9	19	12	2	1					
2904	57	21	244	96		1	2	3	6		1	7	1		
2905	6	106	158	57	4	12	23	32	22	5	5	1			
2906	11	54	162	71	3	5	15	18	6	1	3	1	2		

Table 5.3. Population structure of purple wrasse *Notolabrus fucicola* at Phillip Island (last three surveys).

Site	% male	Length (mm)			Length Class (mm)										
		n	mean	sd	75	100	125	150	200	250	300	350	375	400	500
Survey 5, Autumn 2002															
2901		12	204	40				3	5	4					
2902		3	217	29					2	1					
2903		3	167	29				2	1						
2904		8	163	53	1		1	3	2	1					
2905		1	200	0					1						
2906		15	200	19				1	13	1					
Survey 6, Summer 2003															
2901		8	225	65				1	5		1	1			
2902		5	155	27			1	3	1						
2904		8	175	64		1	2	1	3		1				
2905		8	209	63			1	2	1	3	1				
2906		7	186	48		1		1	4	1					
Survey 7, Winter 2005															
2901		8	166	30			1	4	3						
2902		5	175	50			1	2	1	1					
2903		4	150	0				4							
2904		17	179	39			2	6	7	2					
2905		7	157	43		1	2	1	3						
2906		8	166	30			1	4	3						

Table 5.4. Population structure of herring cale *Odax cyanomelas* at Phillip Island (last three surveys).

Site	% male	Length (mm)			Length Class (mm)										
		n	mean	sd	75	100	125	150	200	250	300	350	375	400	500
Survey 5, Autumn 2002															
2901	0	22	339	56					2	1	2	9	6	2	
2902	20	5	320	45						1	1	3			
2903	27	22	306	33						3	14	4	1		
2904	29	14	305	65					2	2	5	2	1	2	
2905	59	17	315	65					2	3	3	5	2	2	
2906	48	23	332	45						2	9	7	1	4	
Survey 6, Summer 2003															
2901	0	12	208	82		2		1	6	1	1			1	
2902	25	4	288	48						2	1	1			
2903	0	3	258	138			1			1				1	
2904	22	9	269	86				2		3	2		1	1	
2905	0	3	217	29					2	1					
2906	25	12	258	67				2	1	4	3	2			
Survey 7, Winter 2005															
2901	18	22	213	57			3	2	8	7	1	1			
2902	33	3	217	29					2	1					
2903	0	1	300	0							1				
2904	35	31	163	48			8	13	4	5					
2905	41	32	208	56				11	11	4	6				
2906	45	22	210	48			1	4	9	6	2	0			

**Figure 5.8** Horseshoe leatherjacket *Meuschenia hippocrepis* above canopy of *Phyllospora comosa*, Red Bluff (Site 2), Phillip Island.

6.0 REFERENCES

- Clarke K. R. (1993) Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* **18**: 117-143.
- Cole R. G., Ayling T. M. and Creese R. G. (1990) Effects of marine reserve protection at Goat Island, northern New Zealand. *New Zealand Journal of Marine and Freshwater Research* **24**: 197-210.
- Dayton P. K., Tegner M. J., Edwards P. B. and Riser K. L. (1998) Sliding baselines, ghosts, and reduced expectations in kelp forest communities. *Ecological Applications* **8**: 309-322.
- Ebeling A. W., Laur D. R. and Rowley R. J. (1985) Severe storm disturbances and reversal of community structure in a southern California kelp forest. *Marine Biology* **84**: 287-294.
- Edgar G. J. (1998) Impact on and recovery of subtidal reefs. In: *Iron Barron Oil Spill, July 1995: Long Term Environmental Impact and Recovery*. Tasmanian Department of Primary Industries and Environment, Hobart, pp273-293.
- Edgar G. J., Barrett N. S. (1997) Short term monitoring of biotic change in Tasmanian marine reserves. *Journal of Experimental Marine Biology and Ecology* **213**: 261-279.
- Edgar G. J. and Barrett N. S. (1999) Effects of the declaration of marine reserves on Tasmanian reef fishes, invertebrates and plants. *Journal of Experimental Marine Biology and Ecology* **242**: 107-144.
- Edgar G. J., Moverly J., Barrett N. S., Peters D., and Reed C. (1997) The conservation-related benefits of a systematic marine biological sampling program: the Tasmanian reef bioregionalisation as a case study. *Biological Conservation* **79**: 227-240.
- Edmunds M., Chidgey S. S. and Willcox S. T. (2000) Association between Biological Communities and Physical Variables on Victorian Rocky Reefs. In: L. W. Ferns and D. Hough (eds). *Environmental Inventory of Victoria's Marine Ecosystems Stage 3 (Volume 2)*. Parks, Flora and Fauna Division, Department of Natural Resources and Environment, East Melbourne. Australia.
- Edmunds M. and Hart S. (2003) *Parks Victoria Standard Operating Procedure: Biological Monitoring of Subtidal Reefs*. Parks Victoria Technical Series No. 9, Parks Victoria, Melbourne.
- Edmunds E, Roob R. and Ferns L. (2000) Marine Biogeography of the Central Victoria and Flinders Bioregions – a Preliminary Analysis of Reef Flora and Fauna. In: L. W. Ferns and D. Hough (eds). *Environmental Inventory of Victoria's Marine Ecosystems Stage 3 (Volume 2)*. Parks, Flora and Fauna Division, Department of Natural Resources and Environment, East Melbourne. Australia.
- Faith D., Minchin P. and Belbin L. (1987) Compositional dissimilarity as a robust measure of ecological distance. *Vegetatio* **69**: 57-68.
- Holling C. S. (1978) *Adaptive Environmental Assessment and Management*. Wiley, Chichester.
- Krebs C. J. (1999) *Ecological Methods, Second Edition*. Benjamin/Cummings, Menlo Park.
- Legendre P. and Legendre L. (1998) *Numerical Ecology, 2nd English Edition*. Elsevier Science, Amsterdam.
- Meredith C. (1997) *Best Practice in Performance Reporting in Natural Resource Management*. Department of Natural Resources and Environment, Melbourne.

Phillipi T. E., Dixon P. M. and Taylor B. E. (1998) Detecting trends in species composition. *Ecological Applications* **8**: 300-308.

Roob R., Edmunds M. and Ball D. (2000) *Victorian Oil Spill Response Atlas: Biological resources. Macroalgal Communities in Central Victoria*. Report to Australian Marine Safety Authority, Australian Marine Ecology Report No. 109, Melbourne.

Sweatman H., Abdo D., Burgess S., Cheal A., Coleman G., Delean S., Emslie M., Miller I., Osborne K., Oxley W., Page C., Thompson A. (2003) *Long-term Monitoring of the Great Barrier Reef. Status Report Number 6*. Australian Institute of Marine Science, Townsville.

Upton G. and Fingleton B. (1985) *Spatial Data Analysis by Example*. John Wiley and Sons, Chichester.

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