Reef Watch South Australia: The first decade of community reef monitoring

Reef Watch Intertidal Monitoring Program
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Conservation Council
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- Adelaide and Mount Lofty Ranges Natural Resources Management Board
- South Australian Research and Development Institute, Aquatic Sciences
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- Environment Protection Authority

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1 Introduction

1.1 What is Reef Watch?

Reef Watch was the first community-based marine monitoring program in Australia. Marine scientists were able to adapt their ecological survey methods for use by recreational divers to monitor marine ecosystems, as lack of resources meant that full ecological surveys could not be conducted everywhere they were needed. At the same time there was a recognised need in the community for some kind of community marine monitoring. The idea developed that community volunteers would be able to monitor marine ecosystems using carefully designed scientifically valid surveys. The data gathered by volunteers could then be provided to environmental managers and marine scientists to support management of those marine ecosystems. This idea was formalised into what is today's successful Reef Watch program.

Reef Watch began by training recreational divers to survey subtidal reefs, and has now expanded to include intertidal reef monitoring and the 'Feral or In Peril' program. The Feral or In Peril program invites reports from users of the marine environment, such as divers, fishers and boaters, of both introduced marine species and native marine species of conservation concern.

By interacting with volunteers, Reef Watch also engages and educates the public about marine environments. At the time of writing, Reef Watch has been operating for 12 years. It has endured difficult periods with little funding, but has also had great successes, and has received several awards including the 2008 Premier's NRM Award for Outstanding Integrated Volunteer Program.

Reef Watch is managed by the Conservation Council of South Australia (CCSA), who are proud to have hosted and managed Reef Watch since its inception. CCSA has a diverse marine program, of which Reef Watch is the flagship. In South Australia, it is the only long-term volunteer program that engages people in natural resource management underwater. Reef Watch is a significant community engagement program and it is also a significant natural resource management program, providing scientifically valid data, as shown in Collings *et al.* (2008), making it an interesting case study in 'citizen science'. CCSA looks forward to supporting Reef Watch for many more years.

1.2 Mission Statement and objectives

Reef Watch contributes to the health of the marine environment by training community volunteers to monitor temperate marine environments using non-destructive, internationally recognised techniques. Volunteers generate valuable scientific data that informs adaptive management for conservation of the marine environment. Reef Watch engages and empowers the community through education, which raises awareness about the marine environment and fosters a sense of stewardship that is vital to the long-term health of marine environments.

The objectives of the Reef Watch program, as specified in the Advisory Committee's Terms of Reference are:

- To contribute to adaptive management of temperate reefs through ongoing condition monitoring.
- To raise awareness about the marine environment through educating and engaging the public.

1.3 Purpose of this report

Being the first community-based marine monitoring program of its kind in Australia, it is important that the history, development, achievements and learnings of the Reef Watch program are archived. This document is an attempt to both document all of the above and to provide a detailed look at the results of the data from 1998-2007. This report can be used by government agencies and by other community groups wishing to undertake similar marine monitoring in other states.

1.4 Importance of temperate reefs

The temperate zone is generally defined as lying between the latitudes of 23° 27' and 66°33' north or south. There are fundamental differences in the structure and dynamics of temperate and tropical reef ecosystems. Temperate reefs exist where consolidated sediments or rocky sea beds provide a site for settlement and attachment of algae and sessile (fixed) invertebrates. In contrast, coral reefs are largely built up by the constituent corals and algae and once established they can develop and expand upon this substratum. Coral reefs are temperature-dependent and are generally restricted to a belt within 30° N and S latitudes. Furthermore, the physical and chemical environments are distinctly different. Temperate waters are cooler and nutrient levels tend to be higher compared to reefs in tropical waters. Together, these factors have had a profound effect on the evolution of the biota in these regions.

The Southern Australian coastline has often been referred to as ‘the unique south’. Reef communities found along this coastline are indeed unique, particularly when considered at a global scale, with a high diversity and proportion of endemic species. The proportion of endemic species (up to 85% in some groups) is substantially greater than adjacent tropical systems in which only some 15% of the species found are endemic to Australia. For example, there are more species of macroalgae (seaweed) growing along the southern coast than there are species of corals on the Great Barrier Reef. (For more detail see Appendix 2.)

1.5 Threats to temperate reefs

There are a number of anthropogenic inputs into the marine environment that directly influence or threaten near-shore subtidal reef ecosystems, particularly the habitat-forming species such as *Ecklonia radiata* and sponges. The most obvious human impacts threatening reefs include turbidity and sedimentation, nutrient enrichment, opportunistic and exotic species, climate change, toxicants and extractive resource use (e.g. fishing). These are discussed in greater detail in Appendix 1.

2 Identified gaps and needs

2.1 Ecosystem management

Evidence-based management is a relatively new form of ecosystem management that comes from the logic that you cannot manage what you do not know. To manage ecosystems information is needed about how the system works, baseline data on abundance, diversity, community structures, etc. There is also an ongoing need for other information such as what happens when organisms are removed, when pollutants are added, when populations are reduced, etc. Research contributes to finding baseline data and potentially the thresholds of ecosystems.

Monitoring contributes to ecosystem management by collecting data on changes over time. Data collected from monitoring activities contribute in making suggestions for management options. This data provides the evidence upon which management decisions can be based. Monitoring can also gather information on the changes that may occur as a result of management decisions and programs such as marine parks and seagrass rehabilitation. In some cases monitoring is built in to research programs.

2.2 Long-term data and volunteers

There are numerous reasons to gather long-term data and to use community volunteers to do so. Marine research is expensive and resource-heavy, being limited by time and funds. Non-commercial marine species are often not funded for research because they produce no reciprocal value to offset the cost of the research. If monitoring is funded, it is usually only for specific issues (e.g. port surveys for marine pests) and short-term, which produces little long-term data and little spatial coverage, although these short-term projects still produce valuable information.

The need for long-term data is essential for forward planning and management of ecosystems, and to monitor the progress of programs such as marine parks, or seagrass restoration.

Monitoring programs act as early warning systems. Volunteers can pick up long-term changes, such as a shift from robust brown algae to turfing algae, which can indicate water quality or warming effects. Where this is most valuable is volunteers looking out for introduced species that are deleterious to temperate marine ecosystems, in particular species such as Aquarium Caulerpa (*Caulerpa taxifolia*) and Northern Pacific Seastar (*Asterias amurensis*), which could be devastating to the South Australian marine environment.

3 Creation of Reef Watch

3.1 Baseline data and the Reef Health research program

In 1996 the University of Adelaide and Flinders University were commissioned by the Environment Protection Authority (EPA) to 'provide detailed information on appropriate approaches to the assessment of reef systems in Gulf St. Vincent' (Cheshire *et al.*, 1998a). This was the first quantitative account of the composition of these communities in Gulf St. Vincent. Specific objectives of this assessment included:

- Provision of a literature review which details what is known about the nature of South Australian temperate reef ecosystems and how this relates to our ability to define the 'health' or the 'status' or these systems
- Provision of the details of the methodologies which can be used to assess the physical condition and the status of the biota on temperate reefs (this included a critical assessment of these methods as they relate to the ongoing monitoring of reefs in South Australia)
- Provision of the details of the survey methodology used to develop an initial assessment of the status of selected reefs in Gulf St. Vincent

Initial findings included (Cheshire *et al.*, 1998a):

- Species level assessments are difficult to make and, in general, are not considered either necessary or appropriate for surveys of the kind undertaken.
- Insufficient information to accurately define health but it is possible to define what would be considered the preferred states for reef systems.
- Assessments of the age and life-cycle distribution of benthic (bottom-dwelling) organisms are not possible and could not be generally applied by, for example, community groups.

These initial surveys led to the development of the Reef Health research program, led by SARDI Aquatic Sciences and separate from Reef Watch.

The methodologies that were developed through the Reef Health research program were three non-destructive sampling techniques:

- A Line Intercept Transect (LIT) method - used to survey the sessile macro-benthos (bottom-dwelling species) that forms the major structural components of temperate reef systems.
- A non-destructive quadrat method - used for the non-algal sessile and sedentary biota.
- A visual census method - used to assess mobile biota.

Recommendations regarding these techniques included that 'efforts should be concentrated on the development of the LIT method for use in the long-term monitoring of … reef systems. This method is particularly suitable for implementation by community groups.' (Miller *et al.*, 1998). The quadrat method was recommended for investigations of a 'more specific nature' and the fish visual census for the 'assessment of changes in fish populations of particular interest' (Miller *et al.*, 1998).

The results (Cheshire *et al.*, 1998b) of surveying six major Adelaide metropolitan reefs (Aldinga, Noarlunga, Hallett Cove, Broken Bottom, Dredge/Barge and Semaphore) demonstrated a pattern of changing macroalgal community structure along a north-south gradient down the metropolitan coast. Southern sites (Aldinga, Noarlunga, Hallett Cove) were generally dominated by robust brown algae, whereas the remaining northern sites were dominated by red foliaceous algae with very few larger brown algae. In all cases the sessile invertebrate taxa contributed very little to the characterisation of either the sites or the differences between sites and there were no clear differences in the structure of the resident fish communities.

Following this initial study, the survey was repeated in 1999 (Cheshire and Westphalen, 2000) with additional sites in the south, central and north metropolitan area. The pattern of change demonstrated in the 1996 study was found again in this second study with brown macroalgae proliferating in the south and central reefs giving over to foliaceous reds at the northern sites. On health reefs (south and central) there had been large increases in the cover of robust brown macroalgae between 1996 and 1999. There was also evidence suggesting that there has been a considerable increase in the cover of mussels (*Xenostrobus pulex*) at Noarlunga and Horseshoe reefs, which appeared to be restricting the recruitment of robust brown macroalgae. These mussels were considered a potential threat and it was recommended that further research into the dynamics of the communities of these reefs be undertaken.

At the time that the 1996 study was being written and published (1997-1998) the three methodologies developed via this study were also being modified and further developed for use with the Reef Watch program. Since that time the methodologies have been refined as outlined in Chapter 4.

3.2 Development of Reef Watch

In 1996 two consecutive processes were happening. The CCSA Coastal Working Group had proposed a Jetty Watch project to address divers' concerns that the Department of Transport was clearing jetty marine life whilst surveying jetty structures. This proposal turned into the Reef Watch project through discussions between the Scuba Diver's Federation and SARDI Aquatic Sciences.

At the same time, the work described above in section 3.1 was being carried out and it was decided to use the University of Adelaide methodology.

The Reef Watch Community Environmental Monitoring Program was officially established in 1997 as a joint initiative with organisations sharing a common interest in community-based reef monitoring (Table 1). The first media release is shown on the next page.

Table 1. Organisations involved in the initial establishment of the Reef Watch program in 1997.

Conservation Council of South Australia (CCSA)
South Australian Environment Protection Agency (EPA)
South Australian Research and Development Institute – Aquatic Sciences (SARDI)
Marine Life Society of South Australia (MLSSA)
Marine and Coastal Community Network (MCCN)
Scuba Divers Federation of South Australia (SDF)
Threatened Species Network (TSN)
University of Adelaide (UofA)

THE MARINE & COASTAL COMMUNITY NETWORK

MEDIA RELEASE

Reef watchers Get Ready for Action

One of the exciting projects being supported by Coastcare, and launched on Ocean Care Day is the ***Reefwatch*** program being prepared for the ***International Year of the Reef in 1997.***

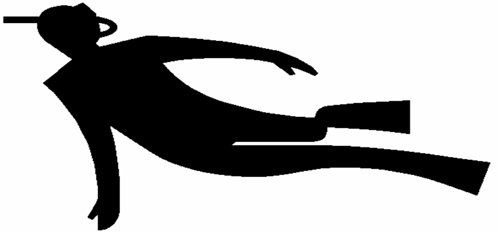
In initiating this community-based reef monitoring survey, the **South Australian Conservation Council** and the **Marine & Coastal Community Network**, are taking the lead in highlighting the intense pressure facing our unique temperate reefs. information gathered by volunteer recreational divers will be used to develop management tools and to increase community education about South Australia's unique reef environments.

The Reefwatch program is being developed by the Conservation Council and the Marine & Coastal Community Network in association with the Environmental Protection Authority, Coastcare, The Threatened Species Network, Adelaide University, Marine Life Society and the Scuba Divers Federation.

*"**Our reefs are the forgotten fringe, suffering the impact of over-collection and fishing, trampling, anchor damage and pollution**,"* said Tony Flaherty of the Marine Network., ***the Reefwatch dive monitoring program being developed will enable local dive groups to act as watchdogs and guardians of our offshore reefs. All too often research, funding and publicity is focused on coral reefs, partly because its so much warmer for scientists to dive in the tropics, but this has lead to a real lack of knowledge about our unique southern rocky reefs."***

Over the next year, the project, funded by the EPA and Coastcare will produce survey kits and training programs for local dive clubs to monitor metropolitan reefs, with the program later extending to other areas. Each dive group would undertake to "*adopt a reef*", carrying out monitoring and help with community awareness of our unique marine environments.

Reefwatch Contacts: Tony Flaherty Tel: (08) 200 2455 . Mobile 019 678869
Margi Prideaux 0414 555 398 or
Michelle Grady, Conservation Council of SA Tel. 8223 5155



OceanRescue 2000

Initial funding was provided by the EPA in 1997, as well as through an Australian Federal Government initiative called Coastcare. This allowed for the employment of a part-time project officer to coordinate the establishment of the program and support volunteer involvement.

Reef Watch was established as a long-term program with the following key objectives:

- to monitor temperate reef environments in South Australia with the support of recreational divers;
- to establish an information database to house data collected by the program;
- to provide community education and increase awareness of the issues affecting temperate reefs systems; and
- to increase community involvement in coast and marine management.

Further funding was obtained from the EPA in 1998, and from Coastcare in 1999 and 2000 (Table 2). The program expanded through several 'Dive with Reef Watch' days, which were held in conjunction with community events including National Science Week and National Threatened Species Day. A Reef Watch website was established towards the end of 1999.

By the year 2000, the program had developed considerable momentum and a number of new initiatives were launched including:

- the inaugural 'Marathon Dive' at Noarlunga Reef, which involved about 50 divers and snorkelers, participating in fish surveys at different locations along the reef;
- a public lecture at which Prof Anthony Cheshire (at the time a lecturer at the University of Adelaide) spoke about the importance of local reef environments, and specifically on the results of scientific reef health surveys undertaken by the University of Adelaide (see Cheshire *et al.* 1998, Cheshire and Westphalen 2000);
- a marine invertebrate identification workshop with 12 guest tutors and speakers from various government and educational institutions, attracting over 65 participants. This was open to both Reef Watch volunteers and the general public. The format allowed participants to work in small groups and obtain hands-on experience identifying marine invertebrates and macroalgae.

Table 2. Summary of activity associated with the Reef Watch program, 1997 to 2007.

Year	No. of surveys (dives)	Events	Funding (approximate years)	Milestones/Major Events
1997	7 (3)		$10,000 - Environment Protection Authority (EPA) Marine Environment Protection Fund; $4,000 - Coastcare (Marine Group Environment Australia 1999)	Basic training kits developed; manuals developed; training commenced.
1998	77 (26)		$5,000 - EPA Marine Environment Protection Fund; $22,000 - Coastcare	Ongoing training; newsletters
1999	105 (39)		$45,000 - Coastcare	Website launched
2000	124 (29)	Marathon Dive; public lecture; identification workshop		1st Marathon Dive; 1st public lecture; 1st marine life identification workshop
2001	76 (18)	Marathon Dive		2nd Marathon Dive
2002	88 (25)	Marathon Dive; scientific expedition; identification workshop	$40,000 - Natural Heritage Trust Fisheries Action Program (FAP)	First scientific expedition; 3rd Marathon Dive
2003	57 (25)	Scientific expedition	$32,000 - SA Department for Environment and Heritage (DEH); $7,000 - World Wildlife Fund Threatened Species Network	Website upgrades including on-line data entry: manuals revised; PADI Reef Watch Survey Diver course developed; Feral/In Peril kit developed
2004	99 (27)	Marathon Dive; scientific expedition; slide night	$50,000 - Mt Lofty and Greater Adelaide Interim Integrated Natural Resources Management Board (NRM)	First slide night; 4th Marathon Dive
2005	126 (29)	Marathon Dive; public lecture; quiz night' identification workshop; intertidal workshop; scientific expedition;	$70,000 - Adelaide and Mt Lofty NRM Board	1st quiz night; won Civic Trust Award; on-line identification tutorials and quizzes developed; intertidal program development; 5th Marathon Dive
2006	96	Marathon Dive; scientific expedition; quiz night	$80,000 - Adelaide and Mt Lofty NRM Board; $10,000 - Kangaroo Island NRM Board; $10,000 - Northern & Yorke NRM Board	6th Marathon Dive; 2nd quiz night;
2007		Marathon Dive; quiz night; identification workshop; National Science Week display; 10th Anniversary celebration	$100,000 - Adelaide and Mt Lofty NRM Board; $10,000 - Northern & Yorke NRM Board; $13,000 - Eyre Peninsula NRM Board	7th Marathon Dive; 3rd quiz night; won 3 awards: Unsung Hero of SA Science Award; Coastcare Award; Premier's NRM Award for Outstanding Integrated Volunteer Project

Marathon dives, public lectures and marine identification workshops are now held on an annual basis.

The program suffered considerable setbacks in 2001, due to the loss of funding and consequent loss of the project officer. In response, a new steering committee was formed, which rebuilt the program with the help of a one-day per week in-kind staff contribution provided by the South Australian Department for Environment and Heritage (DEH), to act as a program coordinator.

Funding problems were addressed in 2002 and a new part-time project officer was appointed using funding through the Natural Heritage Trust (NHT) Fisheries Action Program (Anon 2003b).

As the Reef Watch program again gained momentum, it became apparent that a number of significant issues were threatening the monitoring aspect of the program. The two main problems were:

- dramatic increases in the cost of liability insurance resulting from an increasingly litigious culture, increased canvassing by lawyers for class action suits, a trend towards courts upholding strict liability, and the collapse of HIH Insurance (Anon 2002);
- legal advice that the program would fall under the realm of the newly developed scientific diving standard in Australia (AS/NZS2299-2 2002). This implied that recreational divers involved in the program would need to obtain expensive occupational training.

Following extensive negotiations, these liability issues were overcome by the development of an accredited specialty course through the Professional Association of Diving Instructors (PADI). This course effectively defined the survey methods as being a recreational rather than scientific activity.

In 2003, a gap between the NHT1 and the regionally based NHT2 funding programs was bridged by a $32,000 grant from DEH. A grant from the World Wildlife Fund's Threatened Species Network for $30,000 was also given specifically to set up a subprogram to monitor introduced marine pests and marine species of conservation concern ('Feral or in Peril').

The advent of NHT2 and NRM funding processes led to an increased and eventually more secure funding base with forecasts of indicative funding for two years in advance. This allowed the Reef Watch program to bring to fruition many initiatives previously developed in an *ad hoc* manner, and resulted in an increase in the overall level of community participation.

New developments include:

- development of on-line data entry pages;
- some simple, automatically-generated reports on the information gathered;
- a number of scientific expeditions around SA to survey reef fish populations;
- development of a benthic identification manual supported by on-line tutorials and quizzes;
- development of a 'Feral or in Peril' kit to involve volunteers in looking for introduced pests as well as for species of conservation concern;
- further educational events including slide nights and quiz nights; and
- an intertidal monitoring program.

Reef Watch is based at the Conservation Council of SA (CCSA), an umbrella organisation for more than 50 environmental groups. A proportion of all grant money goes to CCSA in exchange for the following facilities and services:

- office space;
- receptionist;
- banking and financial administration;
- broadband internet and IT support;
- office equipment including printing (b/w and colour), laminating and photocopying facilities;
- volunteer management;
- general administrative support;
- human resources support;
- meeting space; and
- access to community and conservation networks.

Over the history of the SA Reef Watch program, approximately 850 surveys have been completed at various locations around the state, excluding surveys carried out during training courses.

4 Development of monitoring methodologies

The Reef Watch survey methods are designed to be:

- non-destructive (no removal of flora or fauna);
- scientifically valid;
- comparable with other data sets;
- teachable to recreational divers with no scientific background;
- supported only by simple, cheap and light equipment
- safe (performed by a buddy pair within normal bottom times); and
- enjoyable and educational.

The original methods, designed with input from Dr Anthony Cheshire, then of Adelaide University, and Dr Karen Edyvane, of SARDI Aquatic Sciences, were:

- a 50m belt transect, whereby divers recorded all fish observed within 1.5m of each side of the line (Emmett 1998);
- a quadrat – divers recorded the benthic flora and fauna within a 1m x 1m quadrat, as percentage cover and/or species counts (Emmett 1998); and
- a line intercept transect (LIT). Divers progressively moved a 1m steel rule along a 20m guideline and recorded the transition points (in cm) between different benthic flora and fauna under the edge of the ruler. This was promoted as an advanced method (Emmett 1997).

Two benthic habitat survey methods were adopted as they each complemented different research programs and each had their own strengths. The quadrat method, which was easier for divers, quicker to complete, and required less equipment, was promoted as the standard method. The LIT method provided more detailed information that was of interest to a key funding body. This method was promoted as an advanced method to be adopted by divers who had mastered the quadrat method.

Identification was on the basis of particular species for the fish (Figure 2) and lifeform codes based on appearance for the algae and invertebrates (Figure 3).

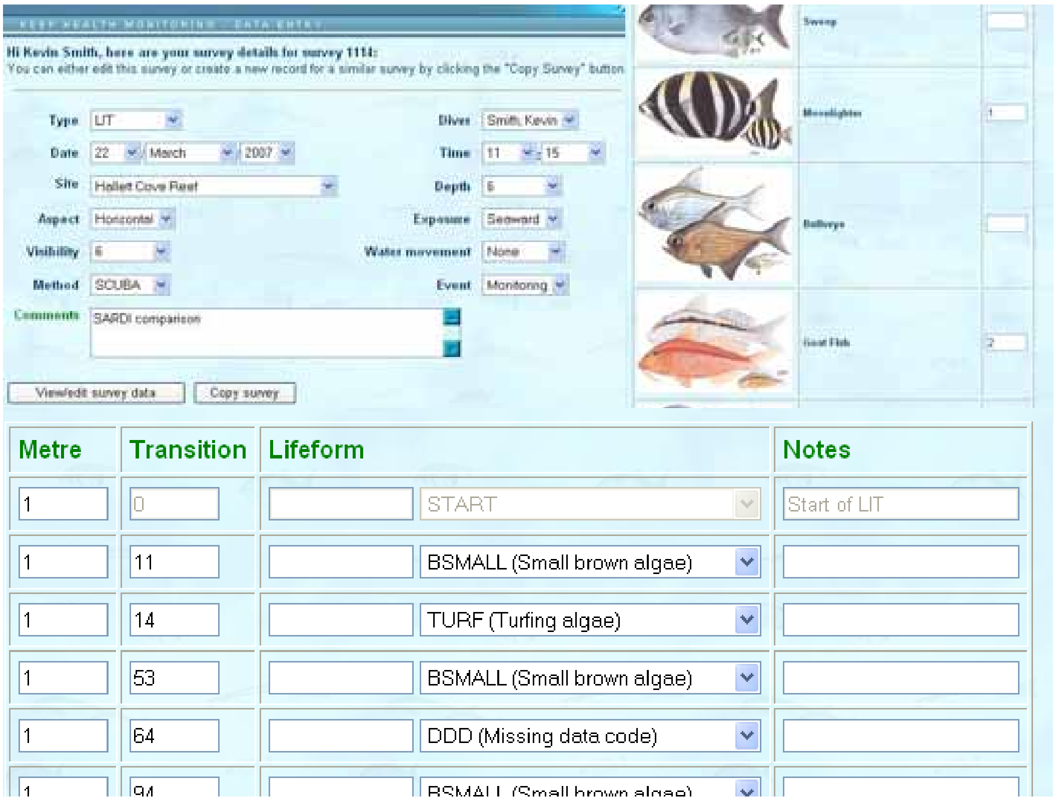
Particular reefs were selected as a focus for the surveys, which were to be located randomly at specific depths (multiples of 5 m) on the reef substrate. The intention was that dive clubs with multiple divers would perform sufficient surveys to be able to characterise the overall reef. Divers were encouraged to complete two quadrat surveys and a fish survey during their dive, and then repeat that effort at the same depth during a second dive where possible.

These methods evolved over time, in order to:

- increase compatibility with methods undertaken by researchers;
- simplify them or make them more amenable to divers; and/or
- capture information on different components of reef flora and fauna.

An additional method, a 50m x 1m belt transect recording mobile invertebrates (crabs, echinoderms, molluscs) and cryptic (hidden) fish, was introduced in 2006. The changes to the methods from 1998 - 2007 are described in Table 3. The methods are now described by online manuals and the associated slates and datasheets are also available online.

Prior to 2004, data was recorded on waterproof datasheets, then entered into spreadsheets by Reef Watch staff or volunteers. After that time, online data entry was available (see Figure 1), and divers were able to personally enter the data recorded on their waterproof LIT datasheets or directly onto their fish slate. The data underwent extensive checking in both 2002 and 2007, and any anomalies or inconsistencies were clarified with the participants or in some cases resulted in the survey being discarded.



REEF HEALTH MONITORING - DATA ENTRY

Hi Kevin Smith, here are your survey details for survey 1114:

You can either edit this survey or create a new record for a similar survey by clicking the "Copy Survey" button

Type: LIT
Date: 22 March 2007
Site: Hallett Cove Reef
Aspect: Horizontal
Visibility: 6
Method: SCUBA
Comments: SARDI comparison
Diver: Smith, Kevin
Time: 11 : 15
Depth: 6
Exposure: Seaward
Water movement: None
Event: Monitoring

Sweep	
Moonlighter	1
Bullseye	
Goat Fish	2

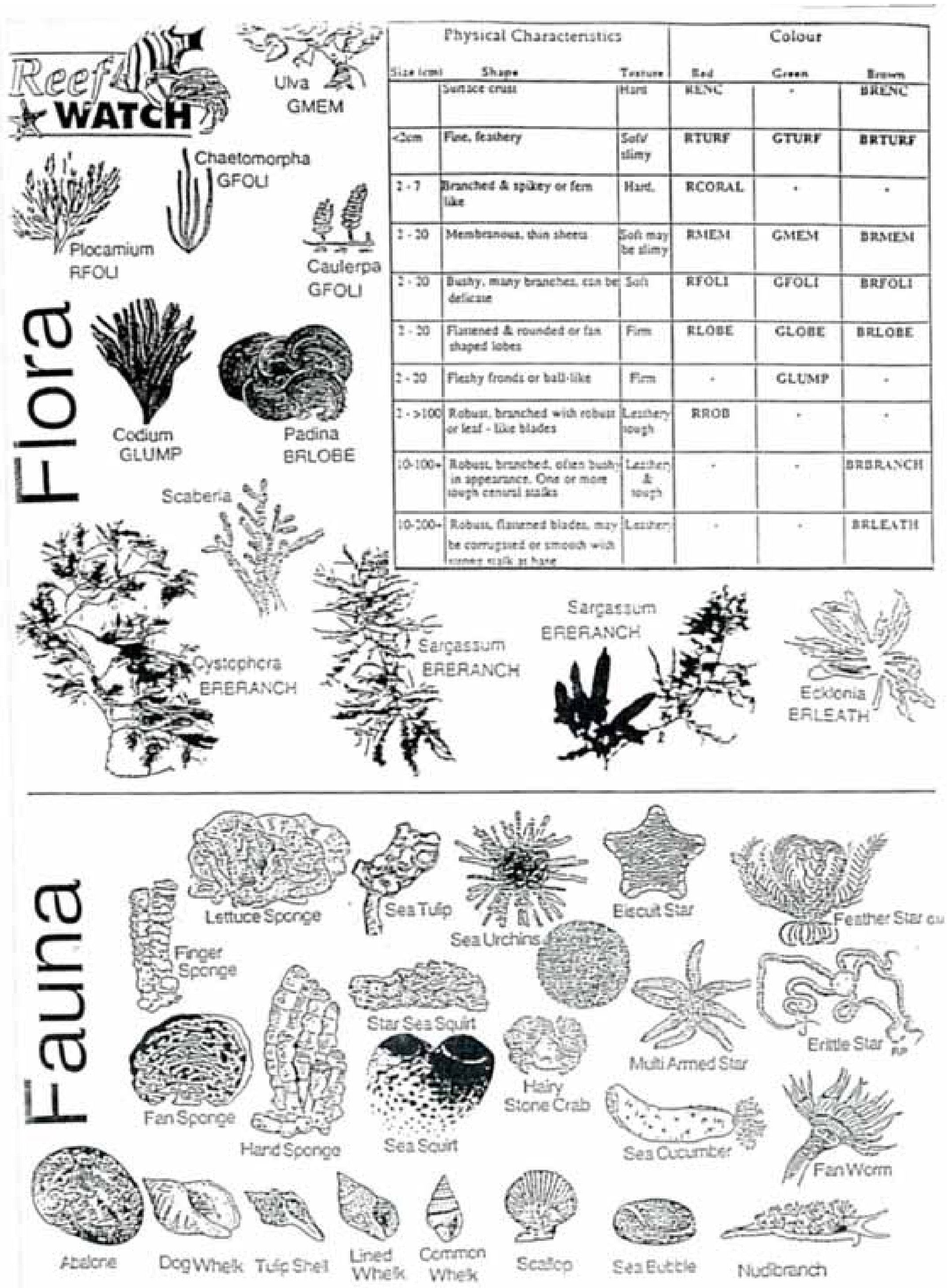
Metre	Transition	Lifeform		Notes
1	0		START	Start of LIT
1	11		BSMALL (Small brown algae)	
1	14		TURF (Turfing algae)	
1	53		BSMALL (Small brown algae)	
1	64		DDD (Missing data code)	
1	94		BSMALL (Small brown algae)	

Figure 1. Online data entry for the fish

Table 3. Modifications to the Reef Watch methods, 1998-2007.

	Fish	Quadrat	LIT	Invertebrate	Survey location/design
1998-2001	50m x 3m belt transect. Species level identification using initial version of slate as guide (Figure 2). Data recorded on waterproof paper.	1m x 1m quadrat, percentage area totaling 100%, counts of discrete fauna. Used lifeform codes from initial version of slate (Figure 3)	20m length, used lifeform codes from initial version of slate		A survey classified as 1 fish, 2 quadrat. Replication of 2 surveys desirable. Placement random. Some emphasis on fixed transects for LIT in 2000.
2002-2003	Return, cryptic fish pass included in survey.				
2004-2005	New identification slate with genus level identification for many species and direct recording of sightings on slate.	Counts of canopy only (totaling 100%) and all species (totaling > 100%) both recorded.	Minimum required length of LIT relaxed to 8m		
2006	Belt width changed to 5m for outward pass and 1m for return pass.				
2007	Return, cryptic fish pass discarded (now undertaken as part of invertebrate survey). Significant reduction in the number of target species	Significant simplification of lifeform codes	Significant simplification of lifeform codes	Invertebrate survey added, with direct recording onto slate of 30 target species	A shift in emphasis to more precisely defined transect locations with the fish invertebrate and line intercept transects integrated where possible.

Figure 2: Original fish slate



Physical Characteristics			Colour		
Size (cm)	Shape	Texture	Red	Green	Brown
	Surface crust	Hard	RENC	-	BRENC
<2cm	Fine, feathery	Soft/ slimy	RTURF	GTURF	BRTURF
2 - 7	Branched & spikey or fern like	Hard.	RCORAL	-	-
2 - 20	Membranous, thin sheets	Soft may be slimy	RMEM	GMEM	BRMEM
2 - 20	Bushy, many branches, can be delicate	Soft	RFOLI	GFOLI	BRFOLI
2 - 20	Flattened & rounded or fan shaped lobes	Firm	RLOBE	GLOBE	BRLOBE
2 - 20	Fleshy fronds or ball-like	Firm	-	GLUMP	-
2 - >100	Robust, branched with robust or leaf - like blades	Leathery tough	RROB	-	-
10-100+	Robust, branched, often bushy in appearance. One or more tough central stalks	Leathery & tough	-	-	BRBRANCH
10-200+	Robust, flattened blades, may be corrugated or smooth with [illegible] stalk at base	Leathery	-	-	BRLEATH

Figure 3: Original invertebrate slate

5 Community engagement

5.1 Training

The Reef Watch training methods and associated identification skills were taught in a number of ways, including:

- supervised training dives
- identification workshops and slide shows
- social events with an informal educational component
- training manuals, identification guides and online tutorials and quizzes

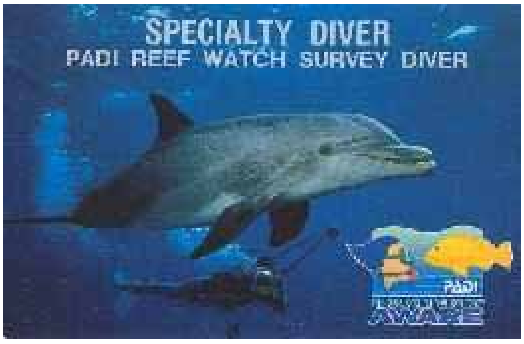
5.1.1 Supervised training dives

The provision of supervised, in-water ("hands-on") training has been recognised as a crucial component of the Reef Watch training program. It was initially undertaken in a voluntary capacity by the Project Officer, until appropriate insurance could be arranged.

The in-water training component faced similar challenges from changes to the insurance market after 2001 and advice that emerging scientific diving standards in Australia may be applicable to the program. The increased costs associated with these developments meant the program was unable to provide in-water training during 2002.

The issues were addressed in 2003 by designing a formal, recreational diving continuing education course (for divers already with Open Water qualification), and getting it accredited by the Professional Association of Diving Instructors (PADI). This course effectively defined the

Reef Watch activities as "recreational" rather than "scientific" and allowed the instructors to gain very affordable public liability and professional indemnity insurance. Reef Watch employed professional dive instructors with suitable experience to provide this training (free of charge) to the dive community.



5.1.2 Identification workshops and slide shows

Identification workshops provided further "hands-on" training opportunities. These were generally held on an annual basis from 2000 until 2005 as all day events involving more than 50 participants from the general public. Considerable in-kind support was offered by SARDI Aquatic Sciences, who provided their facilities at West Beach, and a pool of twenty of the State's leading marine biologists and educators were demonstrators. The demonstrator to student ratio was typically about 1:6. The workshops generally included a keynote speaker, and other particularly popular features of the workshops were touch tanks, museum specimens and microscopes attached to large screen displays.

Although further larger scale workshops remain on the agenda, in 2006 there was a shift to smaller scale workshops. The aim was to better engage those most likely to participate in surveys, namely divers. Two or three demonstrators with museum specimens, touch tanks and microscopes attended dive club meetings (generally weekday evenings). Four such workshops were held in 2006/07 and in all cases the dive clubs requested a follow-up session.

Slide shows focused on identification have also been held on a regular basis during club meetings, and have not only proved to be popular but also an essential supplement to the in-water training.

Volunteer Reef Watch instructors engage members of the public at identification workshops. *(Left, Dr Kirsten Benkendorff, Flinders University; right, Dr Grant Westphalen (back to camera), formerly SARDI Aquatic Sciences)*

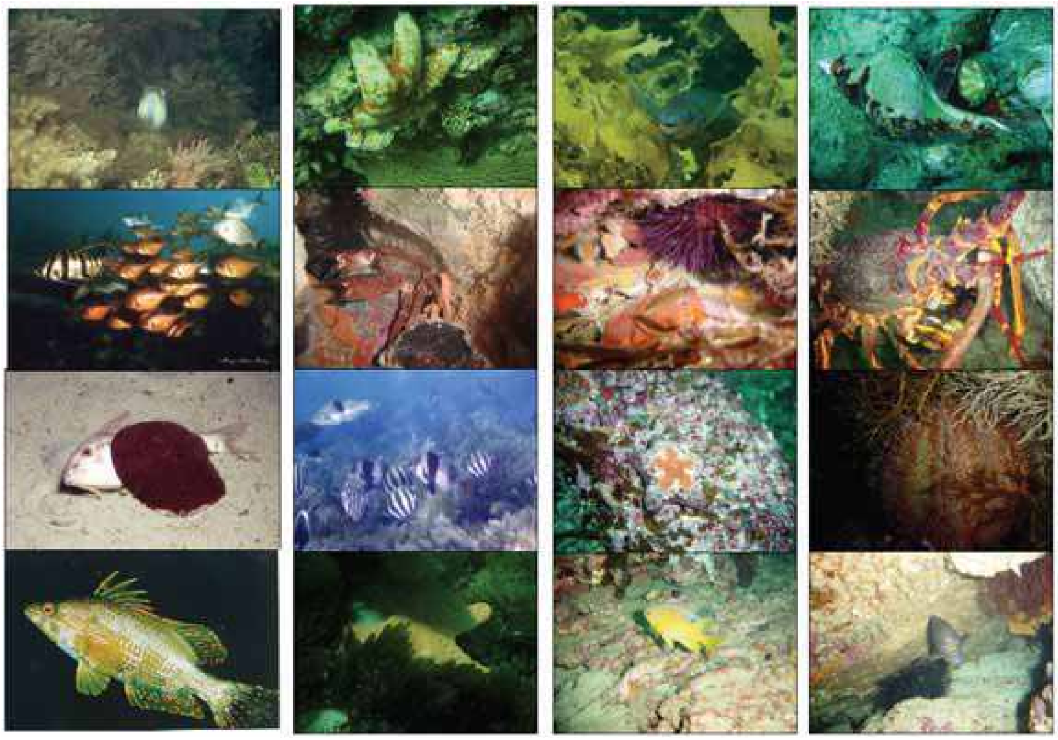
5.1.3 Social events

A less formal educational event was held in 2004. The first such event was a slide night with audience contributions and an panel of expert identifiers and commentators. There were 70 participants.

For the next three years, the event took the form of a quiz night, and attracted 150-200 people on each occasion. The core questions were designed to be informative about species targeted by Reef Watch surveys, but were presented in such a way that participants did not require any prior knowledge of the program, nor of marine biology.

An additional activity performed by each quiz team was to identify species from a montage of photos, with the assistance of the Reef Watch identification slates. The answers were reviewed with a commentated PowerPoint presentation.

Quiz Night underway.



Example of a quiz night image sheet, participants identify the species for extra prizes.

5.1.4 Manuals and on-line resources

Manuals and identification guides are available as PDFs downloadable from the Reef Watch website, and were available as hard copies for participants without internet access. Identification manuals make reference to popular text books generally owned by at least one club member, e.g. *Australian Marine Life* by Graham Edgar (2000).

Illustrations of fish[1] and photos of invertebrates and algae are also available in the form of an online quiz (see Figures 4 and 5).

Horseshoe Leatherjacket (*Meuschenia hippocrepis*)

Other common names

Identification notes

Distinguishable from other leatherjackets by the horseshoe-shaped marking on the sides of the body. The base colour is variable from yellowish green to darkish green and they have many other markings of varying colours on the head, although males usually have a black band.

Length

Maximum length 64cm

Habitat

They are common on coastal reefs, rocky outcrops and broken bottom substrates.

Diet

Omnivore

Figure 4. Example of online fish information.

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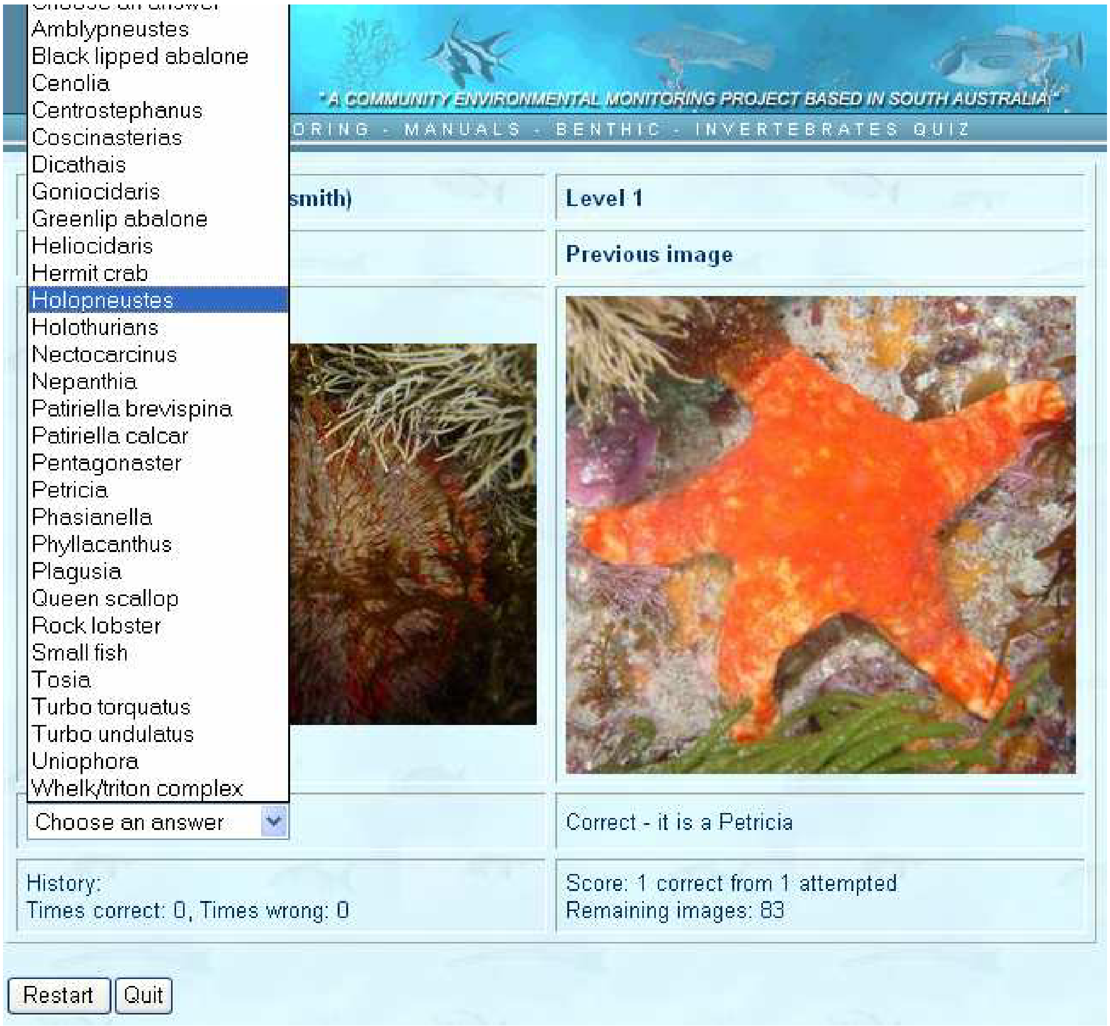
[1] Illustrations are from "Sea Fishes of Southern Australia" by Hutchins, B and Swainston, R. (used with permission from Swainston Publishing, Perth).



Correct - it is a Petricia

History:
Times correct: 0, Times wrong: 0

Score: 1 correct from 1 attempted
Remaining images: 83

Figure 5. Online identification quiz.

5.2 Community education

5.2.1 Public lectures

Reef Watch has been fortunate to have the support of some significant South Australian marine scientists who have agreed to participate in community education via public lectures and participation in workshops. The public lecture format is ideal for an evening event, and introduces the public to images and information about the local marine environment to which they may not previously have been exposed.

The first Reef Watch public lecture was held in 2000 with Professor Anthony Cheshire becoming involved in the program. Prof. Cheshire volunteered his time to give public lectures and to talk at identification workshops. These public events were extremely successful.

Other notable speakers who have kindly donated their time and expertise include Dr Scoresby Shepherd, Dr David Turner, Associate Professor Sean Connell and Dr Sue Murray-Jones. All of these scientists have worked on different aspects of reefs and reef health and have contributed significant time to Reef Watch. Their educational talks and passionate approach to educating the public about South Australian marine life, make their presentations accessible and interesting.

5.2.2 Social events

The social aspect of community monitoring is extremely important. Reef Watch has recognised this and has, therefore, developed a number of events that happen throughout the year to keep the interest of volunteers while developing their skills and knowledge.

A Marathon Dive has become a major social event. It is held on an annual basis (except for 2003) at Port Noarlunga, with the objective of using as many recreational divers and snorkelers as possible to monitor Noarlunga Reef in one day (usually in March each year). Many non-divers attend this day as volunteers. Tasks undertaken include cooking a barbecue, assisting divers with their gear, registration and administration of divers, and acting as a public information service for bystanders.

Quiz Nights are now into their third year. These grew out of successful slide nights, which were held at a pub. These evenings are a huge social occasion where all are welcome, not just Reef Watch volunteers. They are a very successful way of providing a fun but educational event with general knowledge questions and some specific Reef Watch questions. Participants can bring their own food and drink and form teams to play with friends or colleagues. Many prizes are generously made available by the local dive industry and other supporters of Reef Watch.

During winter there is a long period of time when Reef Watch is unable to access the marine environment due to poor weather conditions. During this time an effort is made to have at least one social event to keep contact with volunteers. This is often done via an 'AGM' or public lecture type event. This winter event is extremely important in keeping volunteers interested and furthering their education regarding the local marine environment. Whilst Reef Watch is not the kind of organisation that is required to hold an AGM, this event takes the format of a public lecture but for Reef Watch volunteers. A marine scientist is usually secured to provide the main bulk of the information for the evening via a presentation of recent research.

5.2.3 Public displays

Reef Watch has developed a range of display materials including a large banner, laminated posters and information sheets for use as needed. For example, in 2007 Reef Watch was given the opportunity to display at an event called 'Science Alive!'. This free, 2-day, public science event showcases businesses, organisations, government departments, universities, and more, that are involved with science in some way. Over the 2 days in 2007, an estimated 20,000 people attended the event. Other events at which Reef Watch has had the opportunity to provide a display in 2007 are the Conservation Council of South Australia's 'Connect 07' conference, at a State NRM Forum and at community field days and festivals.

These opportunities are useful mechanisms for interaction with members of the public face-to-face. People can ask questions, sometimes handle specimens or equipment and the simple information on the laminated posters provides just enough to read very quickly.

5.2.4 Written publications

In the last ten years, Reef Watch has had a number of different project officers, all of whom have brought their own style to Reef Watch publications.

A newsletter was established in 1998, the second year of Reef Watch. The 'Reef Watcher' has been going ever since, usually on a quarterly basis. It has undergone a transformation with each project officer. Currently it has a print distribution of 600 and an electronic distribution of over 400. The Reef Watcher is an essential source of information for those who are not yet 'online' and can be sent to retail outlets and organisations such as dive clubs, where it can be shared with members. The newsletter provides information about upcoming events such as training and monitoring, Marathon Dive and Quiz Nights. It also provides more general information about the marine environment as well as suggestions for behaviour change that can lead to positive outcomes for the marine environment.

A number of information brochures and posters have been created over the last decade and this is an ongoing process. Currently Reef Watch has four brochures in print: general information about the whole program; Subtidal Program; Intertidal Program; and Feral or In Peril. These are distributed at displays, conferences, workshops, meetings and to other organisations who wish to promote Reef Watch. Posters have not been utilised as much as brochures but there is currently a poster for the 'Feral or In Peril' program, as its importance as an early warning system is significant, so kits are made available through dive shops and clubs, as well as through the Reef Watch program.

The use of oral and written communication is essential not only for training and education about the marine environment but it is becoming increasingly clear that Reef Watch must engage the community in ongoing encouragement for positive behaviour changes in terrestrial catchments. This is the full circle for environmental monitoring. It is not enough simply to ask people to engage in this activity, there must also be reciprocal outcomes such as providing volunteers with analysis and interpretation of their data, and ongoing education and training. However, an organisation such as Reef Watch must also be seen to be a community role model - it provides a model of ways in which we try to be 'environmentally friendly' (such as using recycled paper, car pooling and electronic communication) and we also provide the community with information about ways in which, through their home and working lives, they can improve environmental outcomes for the marine environment, and hence for the environment at large.

6 Summary of results from 1998-2007

By Grant Westphalen, independent consultant who undertook the full analysis in Appendix 5.

The following comprises a brief summary of a critical analysis of the first ten years of Reef Watch data using indices developed for Reef Health surveys in 2007 (see Turner *et al.* 2007) as well as independent analyses to examine the potential for spatiotemporal gradients in LIT and fish data. The full report of these analyses and interpretation is contained in Appendix 5.

The objectives of this analysis were to:

- Consider the Reef Watch data with respect to the indices employed for the Turner *et al.* (2007) and Collings *et al.* (2008) Reef Health investigations.
- Analyse Reef Watch data with the aim of identifying site specific and seasonal changes as evidence of the effectiveness of the survey approach.
- Assess the effectiveness of the Feral or in Peril data with respect to its capacity to contribute to analyses of the above.
- Identify areas where approaches to reef status sampling can be improved or simplified.

6.1 Reef Watch data

The available data from Reef Watch comprise a diverse suite of observations for reef community cover (LIT) as well as fish and invertebrate species and abundances based on the methods employed in Turner *et al.* (2007). However data from the Feral or in Peril Program have been included (Table 4).

Table 4. Number of observations at each reef site surveyed by Reef Watch since 1998 relative to each survey type, including Line Intercept Transects (LIT), fish, invertebrates and Feral or in Peril (F/P). Those sites in red indicate locations close to those used in Reef Health surveys. Those sites with a grey background were considered in terms of reef status indices within this report.

Region	Site	Code	Number of observations			
			LIT	Fish	Invert.	F/P
Eyre Peninsula	Coffin Bay	COF				1
	Hopkins Island	HOP				4
	Tumby Bay Jetty	TBJ				1
	Whyalla Old Jetty	WHO				1
Fleurieu Peninsula	Aldinga	ALD				4
	Blacks Reef	BLA				3
	Bluff (Rosetta Head)	BLU	2	2	1	3
	Broken Bottom	BB				1
	Carrackalinga	CAR	1			13
	Hallett Cove	HAL	10	12	2	
	Horseshoe Outside	HSO		1		
	Noarlunga North Inside	NNI	8	22	3	1
	Noarlunga North Outside	NNO	11	12	2	8
	Noarlunga South Inside	NSI	4	10	1	

	Noarlunga South Outside	NSO	4	10	1	
	Seacliff	SCF	1	4	1	1
	Second Valley	SVA	3	2	1	1
	Lassiters Reef - Second Valley	LAS				4
	Semaphore	SEM		1		
	Mac's Ground	MACS				1
	Milkies Reef	MIL				2
	Moana South Inside	MSI				1
	Onkaparinga Estuary	ONK				2
	Rapid Bay Jetty	RBJ				1
	Rapid Head	RPHD				1
	Star of Greece Wreck - Port Willunga	SGW				5
	West Lakes/Port River	WLPR				1
Kangaroo Island	Kinscote Jetty	KGJ				2
	Penneshaw	PEN				1
	Stokes Bay	STK				2
Noyts Archipelago	Masillon Island	MAS				1
Wedge Island	Wedge Island North	WEJN				9
Yorke Peninsula	Cape Elizabeth	CEL				5
	Edithburg Jetty	EDBJ				10
	Edithburg Pool	EDP	1			13
	Hougomont Wreck - Stenhouse Bay	HOU				1
	Klein Point	KLP				1
	Port Giles Jetty	PGJ				1
	Port Hughes Jetty	PHJ				1
	Port Vincent	PTV				1
	Royston Head	ROY				1
	Songvaar Wreck – Port Victoria	SON				1
	Stansbury Jetty	STJ				5
	The Gap - Innes National Park	GAP				1
	Willyama Wreck – Marion Bay	WIW				1

6.2 Reef status indices - application and results

Reef Health reporting (Turner *et al.* 2007) was developed around 11 indices of reef status based on a number of factors that can be derived from reef surveys (Table 5). However, not all of these indices could be employed in the analysis of Reef Watch surveys as appropriate data were not collected. Therefore, deriving an overall measure of reef status was conducted using a reduced number of indices (up to 7) targeted at each group of Reef Watch observations summarised in terms of location, year and season.

Table 5. Eleven indices developed by Turner *et al.* (2007) to describe the environmental status (or "health") of reef systems on the South Australian coast. Note that those in red text were considered in this analysis.

Index type	Index
Areal cover	Areal cover of canopy-forming macroalgae Areal cover of turfing macroalgae Areal cover of mussel mats Areal cover of bare substrate
Abundance	Size and abundance of blue-throated wrasse Abundance of site-attached fish Abundance of mobile invertebrate predators
Presence	Presence of invasive taxa Presence of high sedimentation
Species richness	Richness of macroalgae Richness of mobile invertebrates

An indication of the reliability of the results can be determined based on the LIT distance covered on each observation. LIT data from Reef Health surveys each have a total minimum transect length (including the "no data" group) of 80 m (or four x 20 m transects; Cheshire *et al.* 1998a, b, Miller *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008). Over half (24) of the Reef Watch location-year-season combinations have less than 20 m of total LIT transect considered (Table 6 - grey shaded rows). Only eight of the 45 location-year-season combinations from Reef Watch (Table 6 - green shaded rows) were greater than 40 m long. The representativeness of Reef Watch observations in many (even most) instances based on the available LIT data is therefore open to question.

In terms of the overall index, 16 location-year-season combinations were rated as Good, with 14 combinations rated as Caution and 15 as Poor (Table 6). The large number of Caution and Poor rated combinations should not be considered as cause for concern. In part some ratings should be discounted on the basis of limited LIT cover data (i.e. there is not enough data to allocate a reef to Good, Caution or Poor). It is also important to realise that these indices are not without issues with respect to definition, calculation or interpretation and both their validity and ease of application is open to debate. While Collings *et al.* (2008) used these indices, they noted that alternative methods are required for the assessment of mobile fauna (fish and invertebrates) and that appropriateness of "null" scores needs to be reconsidered. None of the indices employed in reef status assessment should be viewed as either comprehensive or infallible, but should be used as a basis for further investigation (Turner *et al.* 2007).

In addition, there are seasonal factors related to macroalgal community composition and cover that can place these ratings within context. Many of the macroalgal species that are included in the canopy index incur substantial seasonal changes in biomass (and therefore cover) due to seasonal reproduction, most notably amongst *Cystophora* and *Sargassum* species (Edgar 1983, Edgar *et al.* 2004, Collings 1996, Collings *et al.* 2008) that are normally included in the BrFoli functional group. Major changes in macroalgal biomass occur in late summer and autumn when many species shed their redundant reproductive tissues and may substantially alter the nature of a reef's macroalgal community. Seasonal loss of biomass from reefs dominated by these species will have flow-on effects relative to reef status indicators including:

- Loss of percentage canopy cover
- Likely increase in percent cover of bare substrate (if present)
- Likely increase in percent cover of mussels (if present)
- Likely increase in percent cover of turf (if present)
- Changes in site-attached fish due to loss of cover (see Edgar *et al.* 2004)

- Changes in mobile invertebrates again due to a loss of cover (see Edgar *et al.* 2004).

There was substantial seasonal variability in reef status relative to location and year, although there was relatively little data collected as a progression across seasons within specific locations and years (e.g. only for NNO 2001 were data collected for four seasons within a single year; Table 6). Hence any inferences about seasonal differences are likely to be confounded with changes between years. The observed differences in index values highlight both the need to consider reef health in context with potential seasonal and probably interannual changes as well as the fact that in spite of the increase in the number of reef status measures, many (even most) are not independent of each other.

Areal cover indices derived from LIT data provide the most cohesive measure of reef status in terms of both the information with respect to reef status as well as the most prolonged capacity to provide longer term (since 1996) trends. The Reef Watch LIT data quite readily lend themselves to the development of these indices, although as noted by Collings *et al.* (2008), transects vary substantially in length from 1.5 - 40 m (averaging ~ 11 m). While it may be argued that short transects are less likely to be representative, many of these were collected as components of replicated sampling within a site (mostly Noarlunga North and Hallett Cove, possibly from the "Marathon Dives" in early autumn; see Tanner *et al.* 2008) and can therefore be very informative.

However, application of a statistically appropriate level of sampling is critical to the validity of any survey regime. If the aim of Reef Watch surveys is to support Reef Health observations and indices, attention should focus on an increased level of sampling such that each observation (location-year- season combination) is characterised by at least 40 m of LIT. In addition, any single sampling event for LIT should not be less than 5 m.

Table 6. Reef index results based on Reef Watch data (see Turner *et al.* 2007 for a description of the assumptions and calculations). Green shading indicates LIT transects > 40 m in length whereas grey shading indicates where available LIT cover data is limited (< 20 m).

Location	Year	Season	Status	Overall	Canopy	Turf	Mussel	Bare	Fish	Wrasse	Invasive
BLU	2003	Summer	Caution	65	100				30		
BLU	2005	Spring	Good	100	100						
CAR	2003	Summer	Good	100	100						
EDP	2004	Autumn	Good	87	87						
HAL	1998	Autumn	Good	93	93						
HAL	1998	Winter	Poor	22	38			6			
HAL	1999	Winter	Good	96	96						
HAL	2001	Autumn	Poor	6	11	0					
HAL	2002	Autumn	Good	71	100			46	66		
HAL	2002	Summer	Caution	48	12				83		
HAL	2004	Autumn	Caution	60	100				19		
HAL	2005	Autumn	Caution	64	100				23	68	
HAL	2006	Spring	Caution	49	32			27	36	100	
HAL	2007	Autumn	Good	77	32				100	100	
NNI	2001	Autumn	Caution	42	6			21	100		
NNI	2003	Summer	Poor	34	41		26				
NNI	2004	Autumn	Caution	56	100				54	13	
NNI	2005	Autumn	Caution	40	41		36		62	22	
NNI	2005	Summer	Poor	25	0		0		43	56	
NNI	2006	Spring	Caution	50	93				22	34	
NNI	2007	Autumn	Poor	31	0			0	100	22	
NNI	2007	Spring	Poor	0	0						
NNO	2001	Autumn	Good	74	47				100		
NNO	2001	Spring	Poor	21	16				25		
NNO	2001	Summer	Poor	28	49	6.67					
NNO	2001	Winter	Good	100	100						
NNO	2002	Autumn	Good	77	100				53		
NNO	2002	Summer	Good	100	100				100		
NNO	2004	Autumn	Caution	62	100				65	22	
NNO	2005	Autumn	Poor	22	0	24.96			41	22	
NNO	2005	Summer	Caution	57	57						
NNO	2006	Autumn	Good	68	100				35		
NNO	2007	Autumn	Poor	34	21				47		
NSI	2004	Autumn	Caution	50	39				60		
NSI	2005	Summer	Good	76	76						
NSI	2006	Autumn	Poor	19	2			12	43		
NSI	2007	Autumn	Good	69	69			38	100		
NSO	2004	Autumn	Poor	34	26				41		
NSO	2005	Autumn	Poor	26	0		0		77		
NSO	2006	Autumn	Caution	46	25				67		
NSO	2007	Autumn	Poor	15	0			0	27	34	
SCF	2007	Autumn	Poor	18	0				31	22	
SVA	2004	Spring	Good	100	100						
SVA	2005	Summer	Good	82	100				47	100	
SVA	2006	Summer	Caution	65	99			31			

As a way forward, Reef Watch should perhaps focus on sampling within a more proscribed spatiotemporal framework that might sample more sites, but with substantially reduced temporal variability such that comparisons between locations are less confounded. This approach would be in line with the recommendations of Collings *et al.* (2008).

6.3 General analyses

In addition to the consideration of Reef Watch data with respect to status indices, a more general analysis was undertaken of LIT, fish and Feral or in Peril data with the aim of determining what, if any, environmental gradients could be observed. Data from all Reef Watch observations was included, encompassing a broad range of potential gradients including:

- Larger scale spatial (differences between reefs)
- Smaller scale spatial (differences within reefs)
- Larger scale temporal (interannual)
- Smaller scale temporal (seasonal)

However, with Reef Watch sampling largely restricted to nearshore locations outside the zone of degraded reefs on the central Adelaide coast, analyses of the data is actually limited to looking at gradients within and between what are generally considered to be "healthy" reefs (see Turner *et al.* 2007, Collings *et al.* 2008). Differences may therefore be subtle and difficult to interpret, particularly given the observed lack of structure to the data.

The influence of location, year, season and depth was investigated through ordination analyses of LIT and fish transects using simplified datasets through modification of the taxonomic resolution. Ordinations, like graphs, are a means of examining relationships in data and can be used to develop an understanding of physical environmental gradients relative to community composition (see Appendix 5 for a full explanation of taxonomic resolution and analytical approaches; see Appendix 6 for an explanation of ordinations).

Ordination results found little, if anything by way of patterns with respect to location, year, season or depth within either LIT or fish observations. Reef Watch surveys are mostly from shallow water (38 out of 45 combinations were less than 6 m depth), with far more observations from autumn relative to other seasons (Table 6). Part of the challenge in interpreting any analysis of the Reef Watch data is the lack of balance in sampling across sites, seasons, depths and years. Inclusion of the Marathon Dive observations from Noarlunga substantially increases the available information, but this data can potentially overwhelm gradients relative to other seasons, depths or locations, although interannual differences for these observations would be strengthened.

Greater representation of alternative sites outside the metropolitan area (i.e. The Bluff, Second Valley, Aldinga, etc.), with a focus on collecting either seasonal or interannual data and sampling from fixed points within locations (if not depths) would assist in balancing the sampling such that environmental gradients would be more readily apparent. Similarly, the inclusion of degraded reefs from further north on the Adelaide coast within the analysis might serve to galvanise these groupings, as these reefs are starkly different in composition and structure (e.g. Turner *et al.* 2007, Collings *et al.* 2008).

However, ordination results relative to reef status indices found that LIT appeared to produce a contiguous relationship, meaning that the pattern of community cover tended to correlate with reef status indices. Conversely ordination of fish ordination results relative to status revealed little by way of any observed pattern. In general terms this suggests that LIT data provide a better contribution to reef status relative to fish data. However, it needs to be noted that the fish data were summarised at the genus level and included all taxa, not just those that were site attached.

There are substantial additional factors identified within the Reef Watch data that have been identified as a result of these and further analyses (see Appendix 5 for further information). Feral or in Peril was able to contribute to index analysis, but the suite of species considered within the program is perhaps due for review. Importantly, there was a lack of reporting when none of the target species was observed, for the period under analysis (i.e. 1998-2007). However, this is now included as 'negative' reporting.

6.4 Recommendations

In addition to the above recommendations from Collings *et al.* (2008), some additional improvements to the sampling regime are recommended:

- Development of a discrete set of questions to be considered by Reef Watch with respect to its sampling program (see Appendix 5). This might focus on southern Adelaide areas, where reefs may be at risk.
- Within the framework of fixed sampling points:
  - Individual LIT transects must be at least 5 m in length.
  - There must be at least 20 m (preferably 40 m) of total LIT transect within any single observation for it be representative of a site at any single point in time.
- A need to acknowledge that LIT data provide the best approach to understanding reef status.
- The Marathon Dive at Noarlunga could be given a greater degree of structure in the sampling wherein participants are directed to collect from within specific depth ranges (i.e. less than 5 m versus greater than 8 m observations).
- Data sheets and data entry should require data on:
  - Total transect length.

    - Presence/absence of invasive species based of the Feral or in Peril list. Note that recording the absence of invasive species is extremely important.
- Greater alignment between Reef Watch and Reef Health in terms of species used in index calculation.
- More focus given to ensuring that fish and LIT surveys are spatiotemporally more aligned.
- The Feral or in Peril list might be revised in terms of the species of conservation concern ('in Peril').

7 Discussion

The independent report commissioned by Reef Watch to analyse the data collected during the past 10 years, and to critically review the collection of those data (included in its entirety as Chapter 6, by Grant Westphalen), makes a number of recommendations, some of which are further discussed below. There is a fairly comprehensive discussion attached to that report (Section 6.6), which will not be repeated here. Hence this section will be relatively short.

A review of the potential for community monitoring in South Australia, carried out as part of the Reef Health project, concluded that there was considerable support for community-based monitoring programs, both from management agencies and from the community itself (Turner *et al.*, 2006). Community monitoring programs such as Reef Watch have the ability to meet a number of objectives, in particular to raise community awareness, and to provide data that can be linked back into the management of marine ecosystems.

The fourth report of the Reef Health project was an assessment of community based-monitoring and the status of reefs (Collings et al. 2008). The project included a direct comparison between the surveys done by the trained marine ecologists that made up the Reef Health team, and the data collected from the same sites by Reef Watch divers (although note that one of the strengths of Reef Watch is that many trained scientific divers are on the steering committee and do conduct Reef Watch surveys; indeed some of the Reef Heath team are also Reef Watch divers - however, to avoid bias in the results, non-professional divers were used for the comparative surveys). The two sets of surveys showed similar results. The report concluded that the use of community divers showed great promise for the monitoring of the status of South Australian reefs, and that overall the data collected by Reef Watch divers was in close agreement to the Reef Health data.

Collings et al (2008) suggested some improvements to the Reef Watch methodology that Westphalen reiterated in Chapter 6. These were mostly based around the need for permanently marked transects, using photopoints, improvements to mobile fauna counts, and the need to include a wider range of reefs. Westphalen suggested a number of improvements as well, such as an increase in the amount of LIT needed per site, and the need for spatio-temporal replication to be carefully considered. Most of these are self-explanatory and well covered in Chapter 6, and the Reef Watch Steering Committee has already begun discussions around implementing them.

Westphalen was in agreement with Collings et al. (2008) that the quality of Reef Watch LIT data is good. The difficulties raised by Westphalen centre around the lack of balance in the data (i.e. observations are not evenly spread across locations with respect to season, year and depth), which makes spatiotemporal comparisons problematic. This is an ongoing problem with a volunteer program. Divers tend to pick locations that are easily accessible and of interest to them. Divers often do not plan dives during winter. In the beginning of the program, the Reef Watch project officer would organise monitoring dives and inform volunteers, who would then dive under the project officer's direction. After trialing an unsuccessful 'adopt-a-reef' approach, Reef Watch has returned to the strategy of organising dives via individual dive shops and clubs. One of the problems with the change to the type of insurance cover mentioned in Chapter 3 is that Reef Watch can no longer tell people where to dive and when.

Reef Watch is debating various strategies to improve spatio-temporal replication. As of June 2008, Reef Watch is only surveying six sites in the Adelaide and Mount Lofty Ranges Natural Resource Management Region: the Bluff at Victor Harbor, Second Valley, Noarlunga inside north and south, Hallett Cove and Broken Bottom. The aim is to complete a minimum of two survey sets at each site per season. Reef Watch is also discussing the technical aspects of providing permanent transect markers on these sites, as recommended by Collings *et al.* (2008).

In addition, Westphalen notes the lack of a boat has limited the ability of Reef Watch divers to extend the range of reefs surveyed. Money to charter a boat could be requested as part of each future grant application and funding request where applicable, to enable access to specific reefs. Reef Watch currently has the support of a major Adelaide diving retail outlet that have offered reduced boat fees to Reef Watch divers and free boat trip for Reef Watch instructors.

It is clear from Chapter 5 that Reef Watch has had considerable success in terms of community engagement and participation, hence fulfils a vital role in terms of education and stewardship, both important components of Reef Watch's objectives. However, it is less clear the degree to which the actual data has been provided to management agencies, and taken up and used to guide management of South Australia's reefs.

The data collected are of good quality, and Reef Watch divers are competent. When compared, the information collected by volunteers showed the same picture as the data collected by a trained marine survey team. While not collected at fine taxonomic resolution, the methodology used by Reef Watch is entirely capable of detecting habitat change, such a switch from large robust brown macroalgae to a turfing algal cover or predominantly smaller red algae, which appear to be common changes noted in reefs with declining health. It also fulfils a role as baseline data, to detect future changes and hence monitor for impact. The Reef Health project (Collings et al. 2008), and the independent report by Grant Westphalen commissioned by Reef Watch made a number of recommendations (see Chapter 6), but these are relatively minor. At present, the lack of spatial and temporal replication in the data collection precludes full Reef Health assessments, but gaps in the data could be augmented by the new Reef Life project. Reef Life and Reef Watch have developed a Memorandum of Understanding to share data, which will avoid duplication of effort and increase power to answer questions.

The main problem seems to be the lack of provision of Reef Watch data to management agencies. This is in the process of being improved. Our current arrangement with the Adelaide and Mount Lofty Natural Resources Management Board, our major funding body, is that we will provide a reef status report at the end of every financial year. Thus a budget amount has been set aside each year from 2008-09 for this purpose.

The Reef Watch website does offer automatically generated summaries of fish surveys. There should also be online summaries of the reef monitoring surveys on the Reef Watch website. The Reef Watch Steering Committee has decided to trial photographic monitoring. Photopoint (permanent spots that are photographed regularly) could be placed on the website, providing a visual record of change (or the lack thereof) over time.

With the Marine Parks network of South Australia rolling out, there is potential for Reef Watch to become actively involved in monitoring the performance of the parks. DEH is very interested in exploring this avenue. Similarly, the EPA is exploring the option to develop report cards for various areas, and the Reef Watch data could substantially add to that process.

There is no doubt that Reef Watch forms an effective stewardship and educational role for the South Australian diving community. There are high participation rates in educational events such as public lectures, slide nights, identification workshops and quiz nights. However, Reef Watch data are not currently being fed back to management agencies, or taken up and used to guide management. The data collected are repeatable and capable of detecting change. More analysis, summary and reporting are required.

8 Recommendations

- That the Steering Committee closely consider the recommendations made by Collings et al. (2008) and Westphalen (Chapter 6), and adopt them where practicable
- that the Steering Committee include a component for chartering boats into all future grant applications, where suitable
- that Reef Watch undertakes regular data interrogation, analysis and reporting, and that the reports are provided to management agencies (particularly funding bodies) and placed on the Reef Watch website
- that Reef Watch works with the EPA to incorporate Reef Watch data into report cards
- that Reef Watch investigates all opportunities to be involved in Marine Parks monitoring and performance assessment
- that Reef Life Survey data be incorporated into the Reef Watch data to cover spatial and temporal gaps in data and augment the existing data set.

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Appendix 1: Threats to temperate reefs (detail)

Turbidity and sedimentation

Increases in turbidity and sedimentation commonly result from dredging, sewage and industrial discharges, stormwater, land reclamation and erosion. In the South Australian gulfs, coastal development, effluent discharge, catchment modification, and seagrass loss have all contributed to elevated levels of sediment within the near-shore marine environment (Turner 2004). Along with pollution, sedimentation is considered to pose a major threat to marine ecosystems in South Australia (Steffensen *et al.* 1989, Cheshire *et al.* 1998b, Gorgula and Connell 2004).

Increased turbidity and sedimentation reduces the amount of light reaching algal communities, reducing photosynthesis. Deposition of sediment is not uniform but dependent on hydrodynamic conditions and the nature of the sediment. As an example, in high wave-energy environments finer sediments are quickly resuspended and only persist where entrapment occurs (e.g. in crevices or through biotic accretion, Airoldi 2003). Over prolonged periods, this can adversely affect the health of the algae. As sediment loads increase, some will begin to settle out. Sediment deposition affects reef biota through a combination of smothering, scour, and by changing the physical characteristics of the substratum. Through these mechanisms, small-scale fluctuations in sedimentation rates have been shown to influence macroalgal community structure. High sedimentation loads can also clog the gills of sessile invertebrates, as previously discussed.

In a recent review of the effects of sediments on rocky reefs, Airoldi (2003) identified a number of common changes to community structure. Generally, organisms that rely upon sexual reproduction are more vulnerable than those using vegetative means, probably due to the lack of substratum stability and the likelihood of smothering of new recruits. In contrast, organisms with sediment-trapping morphologies, or opportunistic species and those with physical adaptations to sediment tend to do well in sediment-affected environments (Airoldi 2003).

Areas impacted by elevated levels of sediment often lose the larger canopy-forming taxa, and tend to have lower diversity, often dominated instead by turf and opportunistic foliose red algae or species with vegetative or migratory life histories (Airoldi 2003). Increases in sedimentation along the Adelaide metropolitan coastline are thought to have contributed to the transformation on many reefs from canopy to turf-dominated macroalgal assemblages (Turner and Cheshire 2002, Connell 2003, Gorgula and Connell 2004, Turner 2004, Connell 2005).

Salinity

Decreases in diversity have been reported under conditions where salinity is less than (Middelboe et al. 1998), or greater than (Kendrick et al. 1990) the average for open marine systems. Linked with fluctuations in salinity is the presence of fresh water or marine inflows that can also contribute nutrients, suspended matter and pollutants to the near-shore environment.

Nutrient enrichment

Low nutrient concentrations are a major factor limiting plant (and algal) growth (Cosser 1997). Conversely, algal blooms and excessive epiphyte growth are often observed in eutrophic waters. Nutrient availability also stimulates phytoplankton growth that in turn promotes an increase in filter-feeding organisms such as sponges, tubeworms and mussels (Brodie 1997). Increased phytoplankton growth may lead to blooms, which are capable of increasing turbidity and may result in toxic water conditions, although toxin production is limited to only a few phytoplankton and cyanobacteria species.

We are only recently beginning to understand the effects of increased nutrient loads on subtidal reef assemblages in temperate waters. Declines in abundances of some species of fish and invertebrates, and a decline in the species richness of fish assemblages have been demonstrated around a subtidal outfall (Smith and Witman 1999). A recent study at West Island, South Australia, showed that an increase in nutrients had interactive effects with grazers and canopy cover. The loss of canopy-forming algae can be a precursor to nutrient-driven changes of benthic assemblages (Russell and Connell 2005). In the presence of kelp, no effect was detected on macroalgal assemblages when ambient nutrients were increased; however, when nutrients were increased in the absence of kelp and when grazers (mostly molluscs) were present, foliose algae dominated the community. In the absence of kelp and grazers however, and with increased nutrients, filamentous-forming algae dominated space. Steneck *et al.* (2002) believe herbivory is the greatest threat to kelp forests and, although they were principally referring to urchins, the results from South Australia (Russell and Connell 2005) show that combined herbivory and nutrients have the potential to change macroalgal assemblages and reef structure.

In general, turf-forming algae are known to form more extensive habitat on subtidal rock adjacent to urban than non-urban coasts of South Australia (Gorgula and Connell 2004). In experimental trials, the addition of nutrients to the water column had the largest influence on the growth of turf-forming algae, while increased nutrients plus increased sedimentation together were sufficient to explain variation in turf formation between urban and non-urban habitats in South Australia (Gorgula and Connell 2004).

Urchin barrens are common in New South Wales and Tasmania but are rare and not extensive in South Australia except in parts of mid to upper Spencer Gulf (S.A. Shepherd, pers. com.). Russell and Connell (2005) postulate that this may be due to Southern Australian waters having typically low nutrients and therefore ecosystems are more strongly influenced by bottom-up inputs instead of top-down interactions. It is possible that increases in nutrients so that they are no longer limiting may allow top-down interactions to play a more important role in structuring the reef, allowing trophic cascades to begin. Alternatively lower urchin numbers may be due to lower larval supply and or increased predation.

Toxicants

The substances in the marine environment that are of most concern are those that are persistent and toxic even at low concentrations. Many inhibit growth or recruitment and are often associated with urban and stormwater runoff, and industrial discharges. Some chemicals may also bind to fats leading to bioaccumulation in organisms. The degree to which any chemical accumulates in an organism depends on the chemical and the organism itself; however, it may be as high as 500,000 times greater within the organism than in the surrounding seawater (Bryan 1979, Edgar 2001).

Suspension feeders are at the greatest risk of having high concentrations of toxicants as they filter large quantities of water and so accumulate the toxicant. Algae are also likely to have high concentrations of toxic substances due to their large surface-area-to-mass ratio. Bioaccumulation up the food chain is of particular concern. Both carnivorous animals and particularly filter feeders eat many times their own body weight in prey, all potentially containing the toxic substance. Heavy metals, for instance, can cause cancer, behavioural disorders and other problems in a broad range of mammals, including marine mammals (Irwin *et al.* 1997), and can adversely affect human heath if built up in the tissues of fished species (Olsen 1983). The toxicants that are of most concern are heavy metals, tributyltin, organochlorine pesticides, dioxins and polychlorinated biphenyls. While South Australian waters are not polluted by world standards, high metal levels have been found in water, sediments (Anon 1996, 2000), fish (Edwards *et al.* 2001) and dolphins (Butterfield 2003) in the Port River system in Gulf St Vincent, and from upper Spencer Gulf in sediments, seagrasses (e.g. Ward 1987), and fish and molluscs (Edwards *et al.* 2001).

Extractive resource use

Extractive resource use is capable of instigating change in subtidal reefs, with the most common use being fishing. Fishing is known to have numerous effects on the species targeted, including reducing average size, fecundity, and behavioural changes (Tegner and Dayton 1999, 2000, Shepherd and Baker in prep.). In cases where levels of exploitation are high, effects can be severe, with fisheries being in decline worldwide (Tegner and Dayton 1999), and nearly one in four collapsing between 1950 and 2000 (Mullon *et al.* 2005). Worldwide it is estimated that up to 90% of large predatory fish have been lost (Myers and Worm 2003).

Current figures for fish stocks managed by the Australian Government indicate that fourteen (19%) species are considered 'overfished' with the status of a further 40 species (54%) being uncertain (Caton and McLoughlin 2004). It is disturbing to note that this represents an increasing trend towards 'overfishing' in the past decade in spite of changes to management (O'Brien 2004). In South Australia, most species of commercial interest are considered to be 'fully exploited' with a further two classified as 'overfished' (Nicolson *et al.* 2003). For coastal reef fish species in Gulf St Vincent, the greatest impact appears to be through recreational fishing activity and primarily through rock fishing (Shepherd and Baker in prep.).

In addition to affecting the targeted species, fishing also has cascading effects onto other marine biota. Probably the best documented of these is the formation of urchin barrens as a result of the removal of predators of urchins, such as sea otters in California (Fanshawe *et al.* 2003) and lobsters in New Zealand (Shears and Babcock 2003).

Closures of reefs to extractive industries such as fishing can have widespread ecosystem effects, and result in dramatic changes in the abundances of both macroalgal and fish species (Edgar and Barrett 1997, Shears and Babcock 2002).

Research at Leigh Marine Station, New Zealand, where a Marine Protected Area was declared 25 years ago, showed major community changes after fishing was banned (Shears and Babcock 2003, Parsons *et al.* 2004). Between 1978 and 1996 benthic communities shifted from being dominated by sea urchins to being dominated by macroalgae. This was a result of a trophic cascade thought to be an indirect effect of increased predator abundance. Densities of sea urchins have continued to decline in shallow areas of the reserve and after 25 years of protection, all sites classified as urchin barrens in 1978 were dominated by large brown algae. Lower densities of grazing molluscs were also found at reserve sites, and are thought to be responses to changes in habitat structure, representing additional indirect effects of increased predators (Shears and Babcock 2002, 2003).

Other extractive industries such as sand or mineral extraction can also impact on reefs. As an example, a study into the impact of sediment plumes, associated with near-shore sand mining on Adelaide's southern metropolitan coastline, demonstrated a considerable level of degradation on Noarlunga and Horseshoe Reefs (Turner 2004).

Coastal development

The majority of Australians live near the sea. In coastal cities such as Adelaide, seaside suburbs are almost entirely developed with little of the natural coastal system remaining. From an ecological point of view, coastal development such as housing, marinas, aquaculture operations, industry, boat ramps and wharves, and dredging for various purposes has caused widespread vegetation clearance and habitat loss, both above and below water, as well as a host of other impacts related to human population expansion, such as stormwater run-off and increased nutrient loads. Although the problems associated with inappropriate coastal development are now recognised, development continues particularly with the increasing preference in Australia for coastal living (Nicolson *et al.* 2003).

Opportunistic and exotic taxa

The establishment of opportunistic and exotic taxa can change habitats and reduce biodiversity completely, by smothering or shading, or reducing the recruitment success of other species (e.g. Guidetti and Boero 2004), as such, the impacts of introduced species can be severe (see review in Grosholz 2002). Introduced species also have the potential to introduce pathogens, which can be more devastating than the organism itself (Grosholz 2002). Some introduced species recognised as potential threats to reefs due to their invasive nature include: *Caulerpa taxifolia, C. racemosa varcylindracea, Undaria pinnatifida, Carcinus maenas, Ciona intestinalis, Asterias amurensis, Sabella spallanzanii,* and *Musculista senhousia* (Furlani 1996, Reef Watch 2003). All of these have been found in Southern Australian waters.

Resistance to invasion appears to be connected to community composition and or structure. As an example, Ceccherelli *et al.* (2002) found that the spread of *Caulerpa taxifolia* and *Caulerpa racemosa* was faster in turfing communities than more structurally complex assemblages. *Undaria pinnatifida* has also been observed to recruit more readily into disturbed areas (Edgar *et al.* 2004b). Similar results have been reported in other studies and it has been widely argued that human impacts, like overfishing, can make an ecosystem more prone to invasion by opportunistic species (e.g. Levine 2000, Harris and Tyrrell 2001).

Appendix 2: Importance of temperate reefs (detail)

In contrast to the domination by corals and sponges seen on tropical reefs, the dominant biota on temperate reefs (at least in the photic zone) is generally macroalgae. In temperate systems, the majority of carbon fixed is via these large algae. This is in contrast to tropical systems in which the majority of carbon fixed is by the symbiotic relationship of microscopic algae living in the tissue of sponges and corals. Hence there is a greater distinction between the producers and consumers on temperate reefs and consequently there are fundamental differences in many of the dynamic processes.

South Australian waters typically have low nutrient levels as a consequence of a number of factors. The nearshore coastal ecosystems are effectively isolated from any significant additional nutrient inputs due to the slow weathering and low rainfall of the southern regions of the Australian continent. Combined with the flow of nutrient-poor water from the northern tropical regions, the result is that South Australian species have evolved or adapted to an oligotrophic environment. This process of evolution and adaptation may perhaps have been facilitated by climatic stability over the past 65 million years. However, recent research has indicated the existence of a large wind-driven coastal upwelling system that forms during summer along the southern continental shelves, spanning a distance of ~800 km. Coastal upwellings occur simultaneously in three welling centres: off southern Eyre Peninsula, off southwestern Kangaroo Island, and along the Bonney Coast. It is hypothesized that this upwelling system provides substantial nutrient input into the near shore coastal ecosystem, evidence of which is shown by the rapid growth of phytoplankton in the region during upwelling events.

On most continents, long coastlines generally traverse several latitudes rather than longitudes. As a result, their habitats are strongly influenced by changes in water temperature, which occur with changes in latitude. The most extreme example is the more-or-less continuous north-south coastline of the Americas, crossing from the Arctic through the tropics and to the sub-Antarctic.

In contrast, the Southern Australian coastline lies within a narrow latitudinal range, with an approximate length of 5,500 km, making it the longest stretch of southern-facing coastline in the world. As such, the coastline provides a large area with similar physico-chemical attributes (such as temperature), but also comprises different habitats including exposed rocky shores, gulfs and bays.

The unique character with respect to both the physical/oceanographic environment and the biota in this region, has significant consequences to the understanding and management of our reefs. The fundamental differences in character of Southern Australian temperate reefs, and the implications this has for the underlying processes operating in these systems, make it imperative that management decisions are based upon relevant data that have been obtained from local ecosystems.

Southern Australian temperate reefs have significant economic and social value in terms of their importance for many activities, both recreational and commercial, as well as significant environmental value for biodiversity and by providing important ecosystem services.

All of these values can be couched in terms of the ecosystem services provided by temperate reefs, which fall into four major categories:

- Provisioning services: food, pharmaceuticals, fibres (e.g. seagrass)
- Regulating services: regulation of climate, mitigation of natural hazards such as floods, disease, wastes and water quality
- Cultural services: recreational, aesthetic and spiritual benefits
- Supporting services: photosynthesis, nutrient cycling, nursery areas for juvenile animals

Cultural services provided by temperate reefs and embodied under the above scheme include recreational activities focused largely around fishing, snorkeling, diving and underwater photography. The economic, social and aesthetic values embodied in these activities is significant for all South Australians. The economic benefits associated with these recreational activities is most strongly felt in the immediate coastal area in dive and tackle shops. Value-added economic benefits roll on into the community through restaurants, cafes, pubs and other supporting retail outlets in the coastal region. Many recreational fishing species inhabit temperate reefs such as cuttlefish, abalone, black cowry and rock lobster.

In the category of 'provisioning services' the commercial activities regarding temperate reefs largely focus on fishing. Two major commercial species most closely associated with reefs are southern rock lobster (*Jasus edwardii*) and abalone (*Haliotis* spp.). These are extremely valuable fisheries: in the 2005-06 financial year these two fisheries combined were worth over $115,000,000.

Other services on which it is difficult to place a value include the regulating and supporting services. A State Government report attempted to estimate the value of these services provided by marine communities in South Australia. They estimated these services are worth $24,500,000,000 per year. A large proportion of these services are carried out by seagrass and reef ecosystems, free of charge and often without our knowledge.

Appendix 3: Analysis of Reef Watch subtidal data

Reef Watch South Australia
Analysis of Reef Watch subtidal data

Grant Westphalen

A report to the Conservation Council of South Australia and Reef Watch

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Reef Watch data analysis – Westphalen Consulting

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1 Overview

The purpose of this report is to present a critical analysis and interpretation of the rocky reef biotic data collected by Reef Watch from 1998 to 2007, mostly along the southern Adelaide metropolitan coast. Data include information on macroalgal, fish and invertebrate communities, largely based on the sampling regime defined by the Reef Health program. In addition, distributions related to a select group of species of conservation concern and marine pests are included from the Feral or in Peril program.

Data for each reef location were amalgamated with respect to year and season at around from 3 – 7 m depth. Data were then considered with respect to:

- Reef status indices as developed by Turner *et al.* (2007)
- Line Intercept Transect (LIT) data at each site within seasons and years
- Fish transect data at each site within seasons and years and
- A summary of the Feral or in Peril program.

Seven of the twelve reef status indices developed during the 2005 Reef Health program (see Turner *et al.* 2007) were employed as a means of investigating the existing Reef Watch data. Sedimentation, species richness and invertebrate related indices could not be calculated owing to either the absence or inadequacy of the available data. In addition, owing to the need to consider a different suite of fish taxa and differences in the taxonomy employed in macroalgal data, the resulting indices from Reef Watch could not be directly compared to Reef Health values.

Based on index results, reef status varied substantially within sites relative to season and year. This variability is a partly a reflection of the somewhat *ad hoc* nature of the sampling with many results comprised of more than one set of observations, often having LIT and fish surveys undertaken on separate occasions. The results thus entail a relatively higher level of small scale (within reef) spatial variability. However, there was also a lack of representative data in many instances, with most cover indices (derived from LIT) based on less than 20 m of information within a particular location, year, season and depth (this is less than a quarter of the amount used in the Reef Health project, see Turner *et al.* 2007). While there is an abundance of fish data in the Reef Watch database in many instances, the species suite considered is not the same as that employed in Reef Health (covering only 38 of the 60 species used to calculate the site-attached fish index).

None of the Feral species from the Feral or in Peril program were reported from any survey, although this lack has been assumed as the “null” observation is not documented (i.e. that none of the “Feral” species on the list were observed in a particular survey). With respect to the “in Peril” component of the Feral or in Peril program, observations are dominated by western blue groper and western blue devils that cover well over half the observations. Alternative rare/endangered species might be worth considering.

Index analysis highlights the need for Reef Watch to undertake surveys within a more structured context (see below). However, index results also suggest that reef status measures are themselves in need of further investigation and development, particularly for those related to fish. Note that the latter is not considered to be the responsibility for Reef Watch, but should be considered within any future Reef Health project.

Ordination analysis of LIT and fish abundance data (considered at the Reef Health taxa and genus levels respectively) reflected differing degrees of variability with respect to location, year, season, depth and probably include interactions of these factors. Within LIT data, differences between reefs were readily apparent but the lack of balance in the data (i.e. observations are not evenly spread across locations with respect to season, year and depth) makes spatiotemporal comparisons problematic. Species changes that act as drivers for differences between sites, seasons, years or depths could therefore not be identified. However, despite the lack of orthogonality, analysis results suggest that Reef Watch data acquisition for LIT and fish are both consistent and of reasonable (if not high) quality. Reef Watch observations are therefore reliable, but require a greater level of structure such that there are consistent and representative observations from each location.

Ordination results for fish data may were less informative, which would be in line with results of other reef surveys (Turner *et al.* 2007, DEH 2009). However, while fish transect data may not be as useful as LIT data within the current analytical context, they might yet prove to be a valuable resource for alternative investigations/analysis. In particular, these data may be an important component in consideration of larger scale/longer term factors such as the issues related to global warming (sea level rise, sea temperatures, water chemistry, etc). Note also that refinement of fish observations to a more discrete set of indicators does not necessarily preclude the use of the current data (or at least a portion thereof) in a historical context.

In a comparison of Reef Watch and Reef Health data Collings *et al.* (2008) recommended with respect to community surveys:

- Professional guidance for Reef Watch surveys
- More reefs should be surveyed accepting there will be a reduction in sampling frequency
- Fixed transects at each reef
- Photographic assessments
- Assessment methods for mobile fauna need to be improved and
- Improvements to indices.

Note that the first three relate directly to the Reef Watch program, whereas the remainder require a level of professional input (at least in terms of methodology for photographic assessments) that is arguably more within the scope of Reef Health. In particular the approaches to mobile fauna (both fish and invertebrates) need to be significantly reassessed, perhaps with greater emphasis on identification of indicator species and/or lifeforms.

In addition to the above, results of this investigation into Reef Watch data suggest a need for:

- Development of a discrete set of questions to be considered by Reef Watch with respect to its sampling program (see general discussion). This might focus on southern Adelaide areas, where reefs may be at risk.
- Within the framework of fixed sampling points;
    - Individual LIT transects must be at least 5 m in length.
    - There must be at least 20 m (preferably 40 m) of total LIT transect within any single observation for it be representative of a site at any single point in time.

- A need to acknowledge that LIT data provide the best approach to understanding reef status.
- The Marathon Dive at Noarlunga could be given a greater degree of structure in the sampling wherein participants are directed to collect from within specific depth ranges (i.e. less than 5 m versus greater then 8 m observations).
- Data sheets and data entry should require data on:
  - Total transect length
  - Presence/absence of invasive species based of the Feral or in Peril list. Note that recording the absence of invasive species is extremely important.
- Greater alignment between Reef Watch and Reef Health in terms of species used in index calculation.
- More focus given to ensuring that fish and LIT surveys are spatiotemporally more aligned.
- The Feral or in Peril list might be revised in terms of the species of conservation concern (‘in Peril’).

2 Background

The environmental status of reef systems on the Adelaide metropolitan coast has been an increasing cause for concern. Scientific investigations of rocky reefs in 1996, 1999 funded by the EPA, and in 2005 and 2007 as part of the Reef Health project have all found a gradient of decline from the urbanised northern to the less modified southern Adelaide coast (Cheshire *et al.* 1998a, b, Cheshire and Westphalen 1999, Turner *et al.* 2007, Collings *et al.* 2008). Reefs in the northern metropolitan area are dominated by filamentous red and green macroalgae as well as large areas of turf-forming species. In contrast, reefs in the south are dominated by larger canopy-forming brown macroalgal complexes similar to those observed elsewhere around the Fleurieu Peninsula and the southern Australian coast. The area of reef status decline broadly correlates with the zone of well documented seagrass loss on the Adelaide coast (Turner *et al.* 2007, Westphalen *et al.* 2004).

Increased sediment and nutrient loads have been suggested as the primary cause for ecosystem decline for both reefs and seagrass beds (e.g. Turner and Cheshire 2002, Westphalen *et al.* 2004, Turner *et al.* 2007, Collings *et al.* 2008). In particular, sedimentation has been implicated as being important to reefs while nutrients are considered to have greater implications for seagrass beds.

Early Reef Health investigations derived an indication of reef status based on the composition and coverage of larger macroalgae from Line Intercept Transect observations (see Miller *et al.* 1998, Cheshire and Westphalen 2000 for a comprehensive description of this survey method). However, in an effort to broaden the basis of reef status assessment, Turner *et al.* (2007) developed eleven indicators of reef environmental status (Table 1) as well as an overall index value based on the average of the others (where they are not null values). This overall status was then interpreted using a “traffic light” approach that related reefs to one of “Good”, “Caution” and “Poor” environmental health categories. A full description of each of the indices, including the approaches to calculation and interpretation can be found in Turner *et al.* (2007). The indices developed by Turner *et al.* (2007) were reemployed for the 2007 Reef Health surveys conducted by Collings *et al.* (2008).

Table 1. Eleven indices developed by Turner *et al.* (2007) to describe the environmental status (or “health”) of reef systems on the South Australian coast. Note that those in red text were considered in this report.

Index type	Index
Areal cover	Areal cover of canopy-forming macroalgae
	Areal cover of turfing macroalgae
	Areal cover of mussel mats
	Areal cover of bare substrate
Abundance	Size and abundance of blue-throated wrasse
	Abundance of site-attached fish
	Abundance of mobile invertebrate predators
Presence	Presence of invasive taxa
	Presence of high sedimentation
Species richness	Richness of macroalgae
	Richness of mobile invertebrates

The community based monitoring program, Reef Watch, has been actively engaged in reef surveys on the South Australian coast since 1997 (Turner *et al.* 2006). These surveys have a number of important aspects (Turner *et al.* 2006, Tanner *et al.* 2008) including:

- assisting in reef monitoring and management
- community education, communication, participation and empowerment
- assisting with the need for longer term datasets
- assisting with the need for establishing baselines as well as exploring spatiotemporal variability in reef systems

In addition, Reef Watch members are on the alert for a number of species of conservation concern as well as a select group of marine pests as part of a program called Feral or in Peril.

The survey methodologies employed by Reef Watch have evolved in line with the formal Reef Health surveys (see Turner *et al.* 2007, Collings *et al.* 2008). These methods have the advantage over traditional approaches for surveying temperate reef systems in that the sampling is non-destructive and the taxonomic rigour required (particularly with respect to the daunting diversity of macroalgal species in southern Australia) has been highly simplified. Full descriptions of the survey methodologies available to Reef Watch can be found in Turner *et al.* (2007), although not all aspects of this sampling regime are employed.

The data obtained from Reef Watch surveys can be summarised in terms of four basic elements:

- Reef community composition and cover based on Line Intercept Transects (LITs)
- Fish community composition based on visual transects
- Invertebrate community composition based on transects and
- Observations of marine pests (largely based on the Feral or in Peril program).

The objectives of this report are to:

- Consider the Reef Watch data with respect to the indices employed for the Turner *et al.* (2007) and Collings *et al.* (2008) Reef Health investigations
- Analyse Reef Watch data with the aim of identifying site specific and seasonal changes as evidence of the effectiveness of the survey approach
- Assess the effectiveness of the Feral or in Peril data with respect to its capacity to contribute to analyses of the above
- Identify areas where approaches to reef status sampling can be improved or simplified.

Against the backdrop of these aims it must also be noted that the approaches employed by Reef Watch in training, awareness and information form an invaluable public education and awareness mechanism that encompasses a much broader audience than the people engaged in surveys. A range of important issues are covered through the educational aspect of the program, including (amongst others):

- Generating awareness of the high diversity and endemism in southern Australian marine systems
- Awareness of the threats and pressures imposed on these systems

- Awareness of the difficulties and limitations confronted in managing these systems and
- Understanding of where the community can be of assistance.

The overall point to consider is that the value of the Reef Watch surveys is not constrained to the data obtained or indeed the interpretations offered in this report (see Tanner *et al.* 2008 for an in-depth assessment of other aspects of the Reef Watch program).

3 Reef Watch surveys and data

Reef Watch surveys employ the same methods as used in the Reef Health observations, although the application of different aspects of the survey protocols (LIT, fish, invertebrates and marine pests) is rather varied (Table 1). A Reef Watch survey generally comprises one of these aspects but rarely all of them as would be the case in Reef Health assessments. Some aspects (notably the presence of high levels of sedimentation) are not considered at all. Consequently, although many of the locations align with Reef Health sites, the surveys are very differentially applied in terms of the number of observations (Table 1).

Table 1. Number of observations at each reef site surveyed by Reef Watch for each data type, including Line Intercept Transects (LIT), Fish, Invertebrates and Feral or in Peril (F/P). Those sites in red indicate locations close to those used in Reef Health surveys (although only in 2005 in some instances – see Turner *et al.* 2007). Those sites with a grey background were considered in terms of reef status indices.

Region	Site	Code	Number of observations			
			LIT	Fish	Invert.	F/P
Eyre Peninsula	Coffin Bay	COF				1
	Hopkins Island	HOP				4
	Tumby Bay Jetty	TBJ				1
	Whyalla Old Jetty	WHO				1
Fleurieu Peninsula	Aldinga	ALD				4
	Blacks Reef	BLA				3
	Bluff (Rosetta Head)	BLU	2	2	1	3
	Broken Bottom	BB				1
	Carrackalinga	CAR	1			13
	Hallett Cove	HAL	10	12	2	
	Horseshoe Outside	HSO		1		
	Noarlunga North Inside	NNI	8	22	3	1
	Noarlunga North Outside	NNO	11	12	2	8
	Noarlunga South Inside	NSI	4	10	1	
	Noarlunga South Outside	NSO	4	10	1	
	Seacliff	SCF	1	4	1	1
	Second Valley	SVA	3	2	1	1
	Lassiters Reef - Second Valley	LAS				4
	Semaphore	SEM		1		
	Mac's Ground	MACS				1
	Milkies Reef	MIL				2
	Moana South Inside	MSI				1
	Onkaparinga Estuary	ONK				2
	Rapid Bay Jetty	RBJ				1
	Rapid Head	RPHD				1
	Star of Greece Wreck - Port Willunga	SGW				5
	West Lakes/Port River	WLPR				1
Kangaroo Island	Kinscote Jetty	KGJ				2
	Penneshaw	PEN				1
	Stokes Bay	STK				2
Noyts Archipelago	Masillon Island	MAS				1
Wedge Island	Wedge Island North	WEJN				9
Yorke Peninsula	Cape Elizabeth	CEL				5
	Edithburg Jetty	EDBJ				10
	Edithburg Pool	EDP	1			13
	Hougomont Wreck - Stenhouse Bay	HOU				1
	Klein Point	KLP				1
	Port Giles Jetty	PGJ				1
	Port Hughes Jetty	PHJ				1
	Port Vincent	PTV				1
	Royston Head	ROY				1
	Songvaar Wreck – Port Victoria	SON				1
	Stansbury Jetty	STJ				5
	The Gap - Innes National Park	GAP				1

Willyama Wreck – Marion Bay	WIW				1
Total number of locations	45	10	10	8	40
Total number of observations		45	76	12	117

The Feral or in Peril (F/P) surveys are by far the most abundant in terms of the number of sites (41) and observations (117) mostly across Fleurieu, Yorke and Eyre Peninsulas (Table 1), reflecting both the width of the audience that this program covers as well as the relative ease of the observations. Fish surveys comprise 76 observations at 10 sites, with 45 reef community observations (from Line Intercept Transects) at 10 sites (Table 1). Invertebrate sampling is somewhat restricted to 12 observations at eight locations.

Line Intercept Transect (LIT), fish and invertebrate surveys almost exclusively occurred on the Fleurieu Peninsula and in particular the southern Adelaide coast (Table 1) as these observations are restricted to sites that can be accessed from land, notably those at Noarlunga and Hallett Cove. It is critical to interpretation of the data generated by the Reef Watch surveys to understand that these areas are not amongst the impacted reefs further north (notably Glenelg Blocks, Semaphore Reef and the Dredge and Barge wrecks; Cheshire *et al.* 1998a b, Cheshire and Westphalen 1999, Turner *et al.* 2007, Collings *et al.* 2008). Reef Watch surveys cannot therefore be used to verify the larger scale Reef Health observations along the Adelaide metropolitan coast. Rather, analyses must consider the relationships between sites, years, seasons and depths within the southern metropolitan reefs.

In addition, there are more Reef Watch observations in autumn relative to other seasons (Table 2). This is in part because of the “Marathon Dive” (Tanner *et al.* 2008) at Noarlunga Reef, when there is a major survey effort. This bias has important implications for the interpretation of the resulting indices.

Table 2. Number of surveys in each season for each data type (not including Feral or in Peril).

Season	LIT	Fish	Invertebrates
Summer	11	24	2
Autumn	25	37	6
Winter	3	5	
Spring	6	10	4

3.1 Indices of reef status

Reef index calculation is based on the approach used in Turner *et al.* (2007) for the Reef health project, and repeated in Collings *et al.* (2008). The indices were assessed with respect to the Reef Watch data, although not all of the measures developed by Turner *et al.* (2007) could be considered using Reef Watch data (see Table 1). Indices considered in this summary include those related to areal cover (based on the LIT data), the size and abundance of blue-throated wrasse, abundance of site-attached fish and the presence of invasive taxa (Table 1).

Note that this report is not intended as a critical review of the indices developed for reef health assessment by Turner *et al.* (2007) and used by Collings *et al.* (2008). Rather, this report seeks to examine the use of these indices as a mechanism for examining the Reef Watch data. Conversely, it is also important to realise that these measures are not without issues with respect to definition, calculation or interpretation and both their validity and ease of application is open to debate. While Collings *et al.* (2008) used these indices, they noted that alternative methods are required for the assessment of mobile fauna (fish and invertebrates) and that appropriateness of “null” scores needs to be considered. None of the indices employed in reef status assessment should be viewed as either comprehensive or infallible, but should be used as a basis for further investigation (Turner *et al.* 2007). See Turner *et al.* (2007) and Collings *et al.* (2008) for more discussion of some of the issues related to these indices.

3.1.1 Indices employed and calculation

Forty-five location-year-season combinations were considered in terms of status indices, based on the availability of cover data from LITs (Table 1). These combinations formed the core of the index calculation relative to other parameters (site-attached fish, blue-throated wrasse and invasive species). Unfortunately, this approach precluded examination of some 31 observations for which there was only data available on fish as well as the bulk of the locations covered by Feral or in Peril (35 out of 45 sites; Table 1). However, an examination of the fish related indices (site-attached fish and blue throated wrasse), independent of other indices, was considered likely to prove meaningless, particularly given that the species employed in Reef Watch are not the same as those in Reef Health (see below).

Areal cover indices are derived from LIT data. Areal cover indices provide the most cohesive measure of reef status in terms of both the usefulness of the information with respect to reef status as well as the most prolonged capacity to provide longer term (since 1996) trends. The Reef Watch LIT data quite readily lend themselves to the development of these indices, although as noted by Collings *et al.* (2008), transects vary substantially in length from 1.5 - 40 m (averaging ~ 11 m). While it may be argued that short transects are less likely to be representative, many of these were collected as components of replicated sampling within a site (mostly Noarlunga North and Hallett Cove, possibly from the “Marathon Dives” in early autumn; see Tanner *et al.* 2008). Note that the lifeform code for foliose brown macroalgae, BRFOLI, was used as a component of the canopy rather than as part of the understorey (BrUnd), as is the case in Reef Health surveys, owing to some ambiguity in application of this lifeform within Reef Watch.

Fish observations covered 33 of the 45 location-year-season combinations with LIT data (Table 1). The site-attached fish index calculation differed substantially from Reef Health in that it was based on a subset of 38 out of the 60 species employed in the latter (93 species were identified across all Reef Watch observations; see Appendix B). This difference in species assemblage meant that the median fish abundance value used to calculate the site-attached fish index in Reef Health (see Turner *et al.* 2007) could not be validly applied to Reef Watch data. Instead, the median fish abundance based on Reef Watch data was used to calculate this index. The upshot of this approach is that direct comparison of this index as well as the overall reef status index with the results of Reef Health surveys (Turner *et al.* 2007, Collings *et al.* 2008) is confounded.

Blue-throated wrasse abundance data were available from 13 of the 45 location-year-season combinations and there were no length data available as required for calculation of this index (Turner *et al.* 2007). To cover this lack, the average length of fish from 2005 and 2007 Reef Health surveys was employed as a proxy (data not shown). The sensitivity of this approach was tested by examining the effect of changing the average length (± 10 cm) on the wrasse index as well as the overall index and found to be inconsequential (results not shown).

The presence of invasive species could in theory be based on the Feral or in Peril data. However, the dataset comprises only ten records related to invasive (Feral) species, with the remainder (100 records) related to rare (in Peril) taxa. None of the invasive observations related to Reef Watch surveys. The major problem in this instance is that both Feral or in Peril observations and Reef Watch surveys failed to report a negative (no invasive species observed) result. Given that the Feral or in Peril program is well understood by Reef Watch participants (and note that 'in Peril' species have been observed at some of the reef sites considered for this analysis), it is considered likely that any of the readily identifiable invasive species on this list would have been reported had they been observed. The inclusion of marine pest data thus presents very little by way of impact, as it has been assumed (although arguably) that none occurred at any of the sites examined. Reporting of the negative result within Feral or in Peril is now being encouraged.

No data were collected on sedimentation levels and this index was not employed.

The indices for abundance of mobile invertebrate predators and richness of mobile invertebrates (Table 1) could not be calculated owing to the lack of available data. There were only 12 invertebrate surveys at eight locations (Table 1), which resulted in relatively few records (less than 200 compared to the number of LIT data (~4,800) and fish (~2,100) records), although it is worth noting that four of the species (and 39 of the records) were actually fish (meaning only 158 records actually relate to invertebrates). Further only three of the 26 invertebrate species identified by Reef Watch align with the 32 invertebrate predators employed in the Reef Health index (Turner *et al.* 2007).

The index for richness of macroalgal species was also not employed. Given that the aim of using lifeforms in gathering field data is to subsume species level complexity, the related macroalgal richness index has questionable validity. Lifeform codes as used in Reef Watch comprise ~ 27 macroalgal groups with from zero to 22 taxa occurring across all LIT observations (although more than 90% of observations were in the range from 10-22 taxa). With species level observations, Reef Health uses ~ 95 taxa with between 10 and 50 species across observations (data not shown – note that the values presented in Reef Health reports are scaled to maximum of 100; Turner *et al.* 2007). Consequently, while one could calculate macroalgal "taxa" richness (rather than species richness), the result would have a relatively restricted sensitivity.

Data supporting each index was averaged within each location-year-season combination (i.e. across transects) before being used in index calculation.

4 Reef Watch index results

Because not all location-year-season combinations had data on fish species (see Appendix A), the overall reef status index in terms of resulting "Good", "Caution" and "Poor" status was assessed with respect to the inclusion or exclusion of the site-attached fish and blue-throated wrasse indices. The result of this comparison (Table 3) suggested some differences with removal of both indices, with 29 combinations remaining unchanged in terms of overall status, while five were improved and ten reduced. Despite these differences it was considered that the best (and indeed simplest) approach comprised a single analysis of overall reef status that included all indices.

Table 3. Results of comparison of overall reef status index results depending on the exclusion of site-attached fish and blue-throated wrasse parameters.

Overall index status	Number of location-year-season combinations
No Change	29
Improved	5
Reduced	10
Total	44

Data in support of the overall index were variously available across location-year-season combinations (Appendix A). However, it needs to be realised that a blank cell (or null value) within the results (Table 5) may in fact be required as an artefact of index calculation. For example, it has been assumed that there are no (meaning zero rather than no data) invasive species observed across all location-year-season combinations (see above and Appendix A) but the index calculation requires that this is reported as a null. This approach can make interpretation of the indices very confusing as it is impossible from the results alone to determine whether a null means "no data" (which is normally the case) *or* that the null is in fact the result. Collings *et al.* (2008) suggested that the use of null scores as components of the index development should be reviewed.

The indices calculated for this report are not comparable to those used in either the Collings *et al.* (2008) or Turner *et al.* (2007) reports, owing to the differences in species composition (particularly within fish and invertebrate data). In addition, not all of the indices could be employed, including sedimentation, macroalgal and invertebrate species richness (Table 1).

As direct comparison with Reef Health status indices is not possible with the current data, some level of reliability of the results can be based on the area or distance of reef covered. In each observation LIT data from Reef Health surveys each have a total minimum transect length (including the "no data" or "DDD" group) of 80 m (four 20 m transects; Cheshire *et al.* 1998a, Miller *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008). Over half (24) of the Reef Watch location-year-season combinations have less than 20 m of total LIT transect considered (Table 5- grey shaded rows). Only eight of the 45 location-year-season combinations from Reef Watch (Table 5- green shaded rows) were greater than 40 m long. In contrast, Reef Health observations as conducted by Turner *et al.* (2007) and Collings *et al.* (2008) were 80 m long. The representativeness of Reef Watch observations in many (even most) instances is therefore open to question.

Table 4. Reef index results based on Reef Watch data (see Turner *et al.* 2007 for a description of the assumptions and calculations). Green shading indicates LIT transects > 40 m in length whereas grey shading indicates where available LIT cover data is limited (< 20 m).

Location	Year	Season	Status	Overall	Canopy	Turf	Mussel	Bare	Fish	Wrasse	Invasive
BLU	2003	Summer	Caution	65	100				30		
BLU	2005	Spring	Good	100	100						
CAR	2003	Summer	Good	100	100						
EDP	2004	Autumn	Good	87	87						
HAL	1998	Autumn	Good	93	93						
HAL	1998	Winter	Poor	22	38			6			
HAL	1999	Winter	Good	96	96						
HAL	2001	Autumn	Poor	6	11	0					
HAL	2002	Autumn	Good	71	100			46	66		
HAL	2002	Summer	Caution	48	12				83		
HAL	2004	Autumn	Caution	60	100				19		
HAL	2005	Autumn	Caution	64	100				23	68	
HAL	2006	Spring	Caution	49	32			27	36	100	
HAL	2007	Autumn	Good	77	32				100	100	
NNI	2001	Autumn	Caution	42	6			21	100		
NNI	2003	Summer	Poor	34	41		26				
NNI	2004	Autumn	Caution	56	100				54	13	
NNI	2005	Autumn	Caution	40	41		36		62	22	
NNI	2005	Summer	Poor	25	0		0		43	56	
NNI	2006	Spring	Caution	50	93				22	34	
NNI	2007	Autumn	Poor	31	0			0	100	22	
NNI	2007	Spring	Poor	0	0						
NNO	2001	Autumn	Good	74	47				100		
NNO	2001	Spring	Poor	21	16				25		
NNO	2001	Summer	Poor	28	49	6.67					
NNO	2001	Winter	Good	100	100						
NNO	2002	Autumn	Good	77	100				53		
NNO	2002	Summer	Good	100	100				100		
NNO	2004	Autumn	Caution	62	100				65	22	
NNO	2005	Autumn	Poor	22	0	24.96			41	22	
NNO	2005	Summer	Caution	57	57						
NNO	2006	Autumn	Good	68	100				35		
NNO	2007	Autumn	Poor	34	21				47		
NSI	2004	Autumn	Caution	50	39				60		
NSI	2005	Summer	Good	76	76						
NSI	2006	Autumn	Poor	19	2			12	43		
NSI	2007	Autumn	Good	69	69			38	100		
NSO	2004	Autumn	Poor	34	26				41		
NSO	2005	Autumn	Poor	26	0		0		77		
NSO	2006	Autumn	Caution	46	25				67		
NSO	2007	Autumn	Poor	15	0			0	27	34	
SCF	2007	Autumn	Poor	18	0				31	22	
SVA	2004	Spring	Good	100	100						
SVA	2005	Summer	Good	82	100				47	100	
SVA	2006	Summer	Caution	65	99			31			

Identification of a statistically appropriate level of sampling is critical to the validity of any survey regime. If the aim of Reef Watch surveys is to support Reef Health observations and indices, attention should focus on an increased level of sampling such that each observation (location-year-season) is characterised by at least 40 m of LIT. In addition, any single sampling event for LIT should not be less than 5 m.

In terms of the overall index, 16 location-year-season combinations were rated as Good, with 14 combinations rated as Caution and 15 as Poor (Table 5). The large number of Caution and Poor rated combinations should not be considered as cause for concern. In part some ratings should be discounted on the basis of limited LIT cover data (i.e. there is not enough data to allocate a reef to Good, Caution or Poor). In addition, there are seasonal factors related to macroalgal community composition and cover that can place these ratings within context. Many of the species that are included in the canopy index incur substantial seasonal changes in biomass (and therefore cover) relative to seasonal reproduction, most notably amongst species of *Cystophora* and *Sargassum* (Edgar 1983, Edgar *et al.* 2004, Collings 1996, Collings *et al.* 2008) that are normally included in the BrFoli functional group. Major changes in macroalgal biomass occur in late summer and autumn when many species shed their redundant reproductive tissues, which may substantially alter the nature of a reef's macroalgal community. The seasonal loss of biomass from reefs dominated by these species will have flow-on effects relative to reef status indicators including:

- Loss of percentage canopy cover
- Likely increase in percent cover of bare substrate (if present)
- Likely increase in percent cover of mussels (if present)
- Likely increase in percent cover of turf (if present)
- Changes in site-attached fish due to loss of cover (see Edgar *et al.* 2004)
- Changes in mobile invertebrates again due to a loss of cover (see Edgar *et al.* 2004)

While a loss of fauna due to a lack of cover from predators is considered possible, during the actual period of macroalgal biomass shedding there may actually be an increase in herbivore and detritivore activity (Personal Observation). Note that while a loss of canopy macroalgal cover can be seen to potentially influence other indices, changes in other indices need not necessarily translate the other way (i.e. a low macroalgal canopy cover might creditably suggest an expectation for fewer site-attached fish, but a low number of site-attached fish does not infer low macroalgal cover). Low numbers of mobile species, especially fish, may relate to a number of factors independently of the associated reef status, in particular the water clarity and movement at the time of observation. Any data that may be influenced by animal behaviour (i.e. curiosity, timidity, territoriality, etc.) should be viewed with a level of caution, particularly given a short period of each observation.

Reef status was closely related to the canopy index value, with twelve out of 16 combinations with a Good rating having a canopy index value greater than 75, whereas all combinations with a Poor rating had a Canopy index of 49 or less (Table 5). Conversely, only six Good ratings rated above 50 for the site-attached fish (Table 5). Other indices are therefore less informative, but nonetheless serve to support the results from canopy data.

There was substantial seasonal variability in reef status relative to location and year, although there was relatively little data collected as a progression across seasons within locations and years (e.g. only for NNO 2001 were data collected for four seasons within a single year; Table 6). Hence any seasonal differences are likely to be confounded with interannual changes.

Table 5. Reef status for each location-year-season combination based on the overall index.

Location	Year	Autumn	Spring	Summer	Winter
BLU	2003			Caution	
BLU	2005		Good		
CAR	2003			Good	
EDP	2004	Good			
HAL	1998	Good			Poor
HAL	1999				Good
HAL	2001	Poor			
HAL	2002	Good		Caution	
HAL	2004	Caution			
HAL	2005	Caution			
HAL	2006		Caution		
HAL	2007	Good			
NNI	2001	Caution			
NNI	2003			Poor	
NNI	2004	Caution			
NNI	2005	Caution		Poor	
NNI	2006		Caution		
NNI	2007	Poor	Poor		
NNO	2001	Good	Poor	Poor	Good
NNO	2002	Good		Good	
NNO	2004	Caution			
NNO	2005	Poor		Caution	
NNO	2006	Good			
NNO	2007	Poor			
NSI	2004	Caution			
NSI	2005			Good	
NSI	2006	Poor			
NSI	2007	Good			
NSO	2004	Poor			
NSO	2005	Poor			
NSO	2006	Caution			
NSO	2007	Poor			
SCF	2007	Poor			
SVA	2004		Good		
SVA	2005			Good	
SVA	2006			Caution	

In spite of the high level of agreement between Reef Health and Reef Watch surveys observed by Collings *et al.* (2008) for LIT data from 2007, a comparison of status indices across LIT, fish, invertebrate and invasive species as well as the overall value differed considerably with substantially more variability within Reef Watch data compared to Reef Health. Differences between indices were in part due to the spatiotemporal differences observed in the LIT comparison (some observations from the same reef were more than 300 m apart; Collings *et al.* 2008) with probably similar differences for the fish and invertebrate observations. However, there are also differences in the suite of fish and invertebrate species covered by the different surveys.

When considered along with the above, the LIT data would appear to provide the best measure of reef status.

The observed differences in index values highlight both the need to consider reef health in context with potential seasonal (and probably interannual) changes as well as the fact that in spite of the increase in the number of reef status measures, many (even most) are not independent of each other.

As a way forward, Reef Watch should perhaps focus on sampling within a more proscribed spatiotemporal framework that might sample more sites, but with substantially reduced temporal variability such that comparisons between locations are less confounded. This approach would be in line with the recommendations of Collings *et al.* (2008).

5 General analysis

A key aspect to understanding reef status is determining the range of what might constitute a "healthy" reef, acknowledging that there is substantial natural variability in biotic composition and structure of reef systems in southern Australia. Turner *et al.* (2007) found that reefs at Point Souttar and Point Riley on Yorke Peninsula rated as being in "poor" health based on the index results. However, these sites were somewhat different to other Yorke Peninsula locations, being relatively sheltered and having low relief making them potentially more prone to sedimentation, which may be natural or anthropogenic in origin. The key point is that both these locations may reflect natural gradients and pressures, rather than any lack of health, meaning that what might comprise an unhealthy reef in one location may not be the case elsewhere. A fixed, single notion of a healthy reef is therefore inappropriate. Rather, reef status must be determined against both an understanding of spatiotemporal differences and natural gradients that may impact at a range of spatial and temporal scales. Finally, these differences point to a critical need to increase our understanding of the range of what might comprise "healthy" reefs. This is where Reef Watch data can serve an important role.

In addition to the consideration of Reef Watch data with respect to status indices, a more general analysis was undertaken of LIT, fish and Feral or in Peril data with the aim of determining what, if any, environmental gradients could be observed. While a comparison of Reef Watch and Reef Health LIT data was undertaken by Collings *et al.* (2008), this analysis aimed to determine how well the two surveys aligned and focussed on sites represented in both surveys in 2007. In this instance, data from all Reef Watch observations was included, encompassing a broad range of potential gradients including:

- Larger scale spatial (differences between reefs)
- Smaller scale spatial (differences within reefs)
- Larger scale temporal (interannual)
- Smaller scale temporal (seasonal)

With sampling largely restricted to nearshore locations outside the zone of degraded reefs on the central Adelaide coast, analyses of the Reef Watch data is limited to looking at gradients within and between what are generally considered to be "healthy" reefs (see Turner *et al.* 2007, Collings *et al.* 2008).

5.1 Taxonomic resolution

The classification and naming of organisms (or "taxonomy") is based around seven levels of naming starting at kingdom at the highest level, then phylum, class, order, family, genus and then species (although there are often variants and subgroups within these). An analysis does not necessarily need to occur at the species level. Indeed, as accurate identification to species level may require microscopic or genetic analyses, there are good reasons not to attempt to identify everything to species level. Instead the data may be variously summarised within higher taxonomic classes (genus, family or even mixtures of levels), or within functional groupings. Establishing the appropriate taxonomic resolution in analysing ecological data can be challenging because different summaries may serve to highlight different environmental gradients.

Reef Health and Reef Watch both employ a functional form approach to LIT observations, in which the daunting complexity of reef systems in southern Australia is subsumed to a readily applied set of around 53 groups. This approach is critical to enabling both Reef Health and Reef Watch observations because identification to species is not required. The analysis of the LIT data is further simplified to only six or seven groups (see Turner *et al.* 2007, Collings *et al.* 2008). The same summary has been employed for the Reef Watch LIT data, although note that this level is targeted to show large scale differences in reef status, largely on the basis of canopy-forming macroalgal cover. Using a coarse resolution for the functional groups is therefore useful in highlighting differences between sites. However, more finely resolved environmental gradients may be lost using this level of summation.

Within the fish data, apart from the Syngnathidae and Gobiidae family groups, Reef Watch fish data were analysed at the genus level. This substantially simplified the dataset (reduced from 93 to 58 groups; Appendix B) and meant that composite groups (i.e. "Other leatherjackets" and similar) that might confound a species level analysis, remained relevant. However, there were eight fish groups identified by only a common name for which a genus could not be allocated and these records (perhaps 13 fish in total) had to be ignored as the common name encompassed more than one genus. Comparisons of ecological data at levels other than species can be achieved with a limited loss of information (e.g. Warwick 1988a, b, Ferraro and Cole 1995). Note also that while Southern calamari (*Sepioteuthis australis*) is technically a mollusc, in terms of ecological function this species operates as a fish and has been included as such (Appendix B).

5.2 LIT Transect data

Line Intercept Transect (LIT) data were reconfigured such that transects were split into 5 m segments, effectively increasing the number of samples from 106 to 289, although this reduced the amount of information in individual sampling units. This balanced the information content in each observation relative to each other and enabled a better representation of the "average" situation at each location-year-season combination to be obtained, particularly where samples were limited to few (or one) larger transects (one cannot create a mean from a sample of one).

Each Reef Watch LIT observation can be identified according to a range of factors including:

- Location
- Year
- Season
- Depth

Differences between location-year-season combinations were investigated through an analysis technique called ordination. Ordinations, like graphs, are a means of examining relationships in data and can be used to develop an understanding of ecological gradients (such as location, year, season, depth, etc. in the Reef Watch data). However, rather than examining the effect of an environmental factor (such as depth) relative to a single species spread across all sites, ordinations look at factors relative to the integrated information from *all* species within each observation. Ordination has frequently been used to interpret differences in Reef Health data (Cheshire *et al.* 1998a, b, Cheshire and Westphalen 1999, Turner *et al.* 2007, Collings *et al.* 2008), most commonly using an approach called Multidimensional Scaling (MDS; see Appendix C for a more in depth description of ordinations and how to interpret them).

MDS ordination of the LIT data averaged within each location-year-season and depth combination produced a plot in two dimensions with an associated stress of 0.15, suggesting that the result is a fair representation of the multidimensional space. However, interpretation of the plot relative to depth, sampling year, season and location revealed a complex dispersion with no dominant pattern relative to any one of these factors (Figure 1).

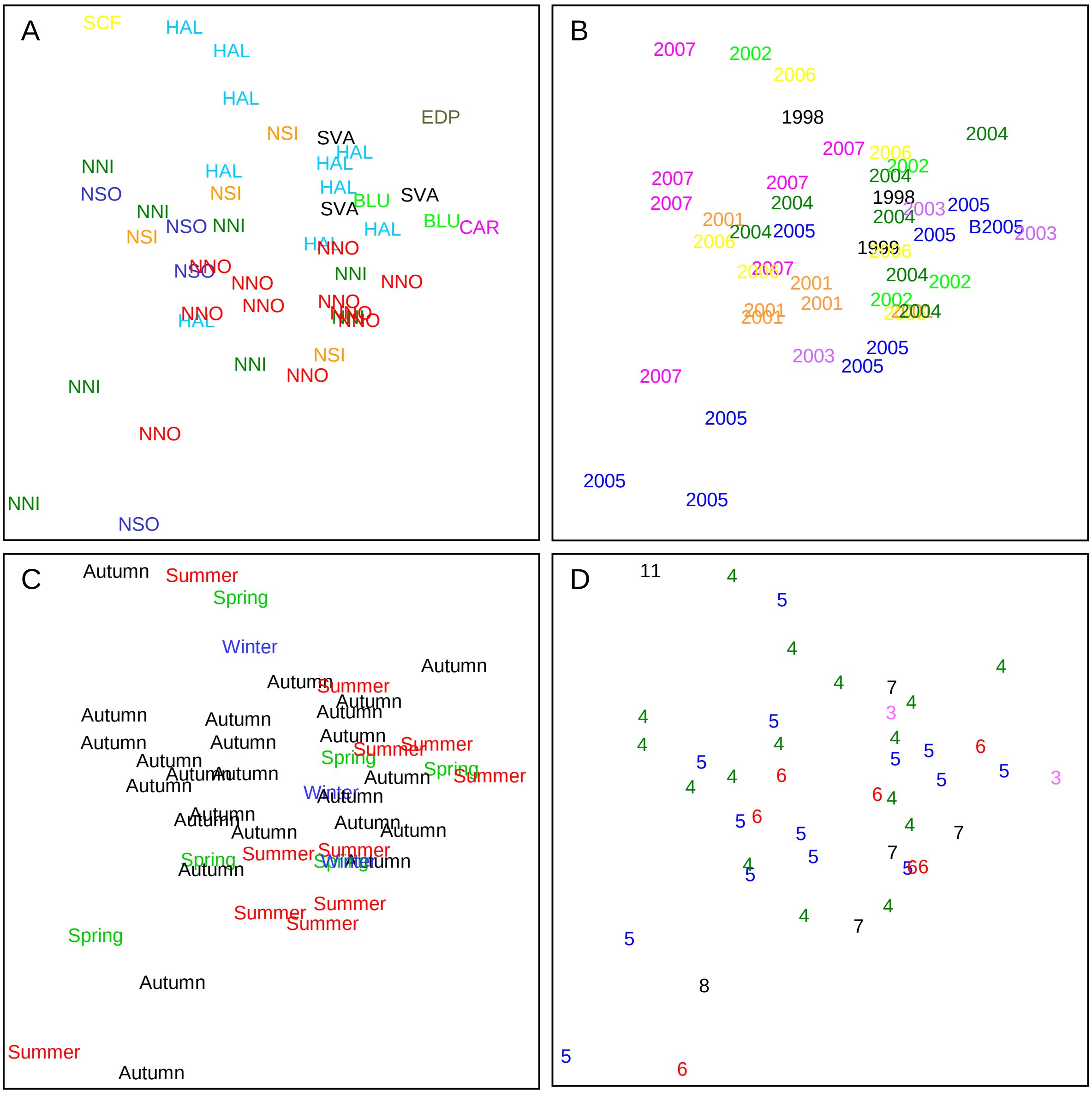

Figure 1. MDS ordination of the average percent cover for each analysis taxon from LIT data within each location-year-season and depth combination (two dimensional result with stress = 0.1513). Note that the same analysis is presented four times with different labelling of the points for easier interpretation (A. Location; B. Year; C. Season; D. Depth).

The Noarlunga Reef location-year combinations (NNI, NNO, NSI and NSO) dominate the centre of the plot, with a diffuse Hallett Cove (HAL) group toward the upper right, although all groups overlapped each other to some extent (Figure 1). Less frequently sampled sites, including The Bluff, Second Valley, Edithburg Pool, Seacliff and Carackalinga (BLU, SVA, EDP, SCF and CAR respectively) occur amongst or at the fringes of the Hallett Cove cluster, suggesting a broader similarity between these locations relative to Noarlunga (Figure 1). Four outlier points, two from NNI and one each from NSO and NNO occurred to the lower right of the plot, which represent two different years (2005 and 2007), three seasons (autumn, spring and summer and a range of depths (5 – 8 m; Figure 1). All four observations rated as being Poor in terms of health

(Table 5; Figure 2) being dominated by either or both high turf (31 – 71%) and/or animal cover (64 – 70%; Figure 3). Similarly, the Seacliff and Hallett Cove sites at the top of the plot (SCF and HAL) also rated poorly (Table 5; Figure 2), probably owing to low canopy cover (9 and 25 % respectively; Figure 3). In fact if the above MDS ordination analysis is reconsidered with respect to overall health index (Figure 2) it can be seen that location-year-season combinations with Poor ratings are far more varied than those rated as Caution or Good and that there is little overlap between rating groups.

Only one site that rated as Good had a canopy cover less than 50% (Hallett Cove 2005 Autumn with around 32%), with all other Good rated combinations having from 50 – 98% canopy cover (Figure 3). All combinations with high canopy cover occurred to the centre and right of the plot (Figure 2; Figure 3). Otherwise combinations with high cover of understorey brown macroalgae (BrUnd) tended toward the top of the plot, while turf and animal covers increased from the centre to lower left (Figure 2; Figure 3). Other groups of taxa (RUnd, GUnd) were diffusely allocated and probably not overly influential.

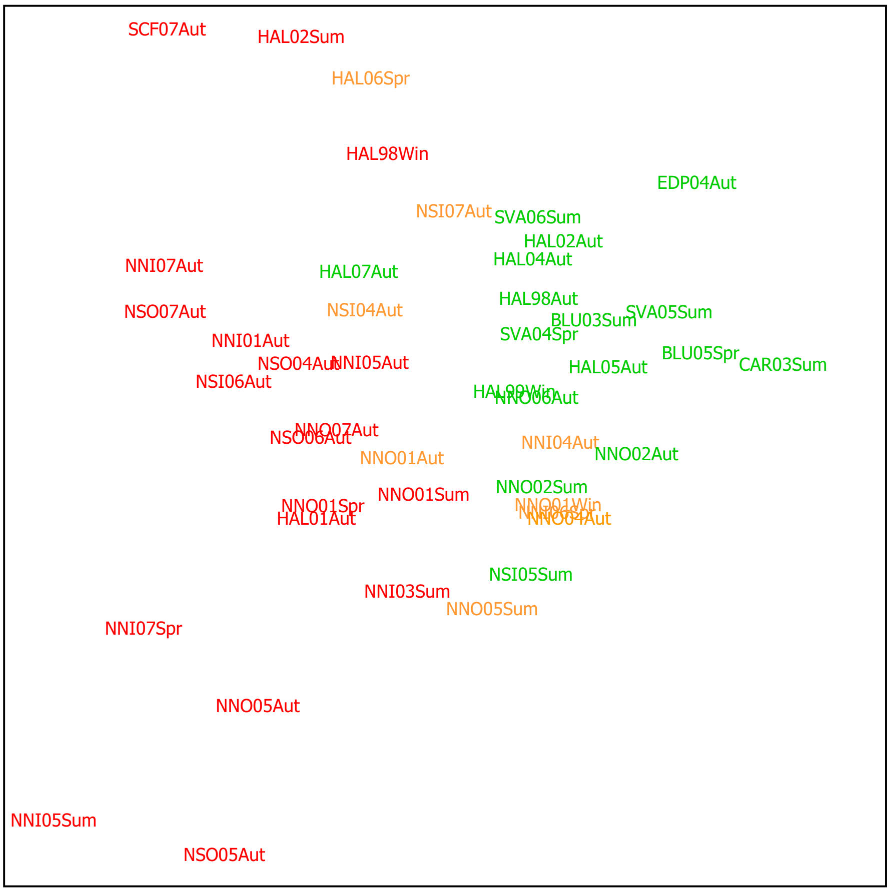

Figure 2. Repeat of the first LIT MDS ordination of the average percent cover for each analysis taxon within each location-year-season and depth combination (two dimensional result with stress = 0.1513). Labels coloured according to overall stress rating with Red = Poor, Orange = Caution and Green = Good.

Surveys are mostly from shallow water (38 out of 45 combinations were less than 6 m depth), with far more observations from autumn relative to other seasons (Table 2). Part of the challenge in interpreting any analysis of the Reef Watch data is the lack of balance in sampling across sites, seasons, depths and years. Inclusion of the Marathon Dive observations from Noarlunga substantially increases the available information, but this data can potentially overwhelm gradients relative to other seasons, depths or locations, although interannual differences for these observations would be strengthened.

Greater representation of alternative sites (i.e. The Bluff, Second Valley, Aldinga, etc.), a focus on collecting either seasonal or interannual data and sampling from fixed points within locations (if not depths) would assist in balancing the sampling such that environmental gradients would be more readily apparent. Similarly, the inclusion of degraded reefs from further north on the Adelaide coast within the analysis might serve to galvanise these groupings, as these reefs are starkly different in composition and structure (e.g. Turner *et al.* 2007, Collings *et al.* 2008).

Collings *et al.* (2008) compared 2007 Reef Health and Reef Watch LIT data, finding a high degree of confluence with differences thought to relate to spatiotemporal variation within and between reefs as well as some issues in taxonomic interpretation. However, the Collings *et al.* (2008) comparison did not include observations from across other years as these would have confounded that interpretation.

In general terms, results of this analysis suggest a degree of spatiotemporal variability between observations related to location, year, season and depth and, most probably, uneven mixtures of these factors. Further analysis within the LIT data (for example considering the Noarlunga location-year-season combinations alone) or averaging across factors (i.e. season or depth) would most likely serve to confirm the results observed by Collings *et al.* (2008). However, given the gradient of reef status within the LIT ordination as well as a lack of marked outliers, results suggest that data acquisition has been consistent across observations and that differences between locations are readily apparent.

Note that this interpretation is based on a very coarse taxonomic summation with 53 Reef Watch LIT lifeforms shoehorned into only seven analysis groups (Figure 3). These groups are targeted to the needs of Reef Health, meaning the analysis is aimed at identifying gross differences between degraded and healthy reefs. Analyses using a different taxonomic interpretation might indicate more subtleties about the relationships between observations, although this poses the question as to what Reef Watch seeks to achieve in its reef sampling program.

5.3 Fish transects

MDS ordination of the fish transects from all location-year-season and depth combinations was also appropriate in two dimensions, although with stress level of 0.18, this representation of multivariate differences is therefore somewhat marginal (see Appendix C for more information on interpretation of stress values in MDS). The plot reveals a substantial level of variability with no dominant gradient (Figure 4). As before, Noarlunga and Hallett Cove combinations (NNI, NNO, NSI, NSO and HAL) occur in the centre of the plot, although the latter are more diverse across years, suggesting either a high rate of change within the site and/or substantial spatial variability.

Twenty-eight of the 76 combinations are described by less than ten genera (Figure 5 – green shaded bars), which includes Semaphore (SEM), most of the Seacliff sites (SCF), the Second Valley (SVA) outlier at the top of the plot and eight of the twelve observations from Hallett Cove as well as the only Horseshoe reef (HSO) observation (Figure 4). However, not all outliers are described by few numbers of genera. For example the lower SVA outlier comprised 14 different fish genera, which is above the average (mean ± standard error: 12.72 ± 0.74).

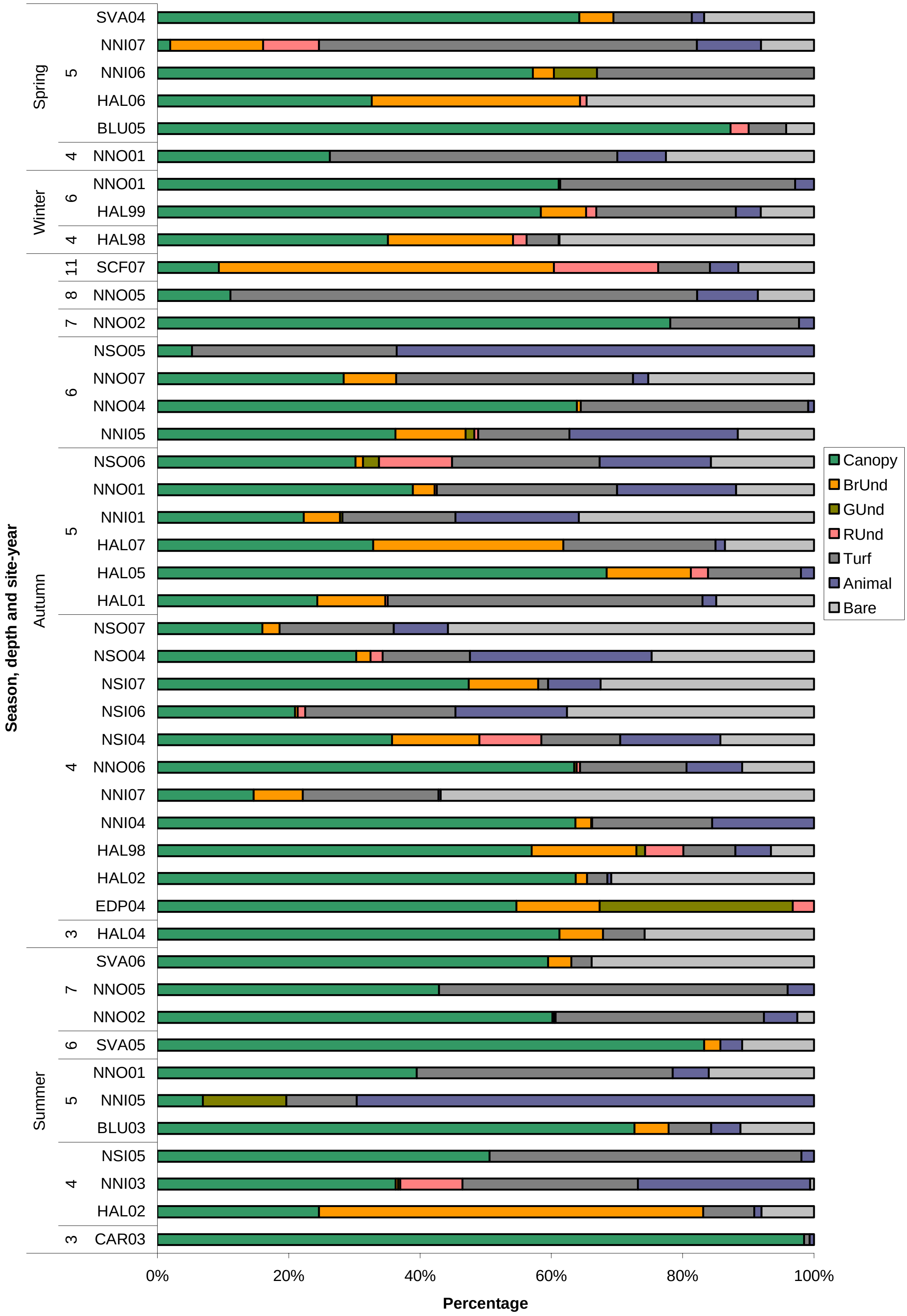

Figure 3. Stacked percent cover of LIT analysis groups averaged within location, year, season and depth.

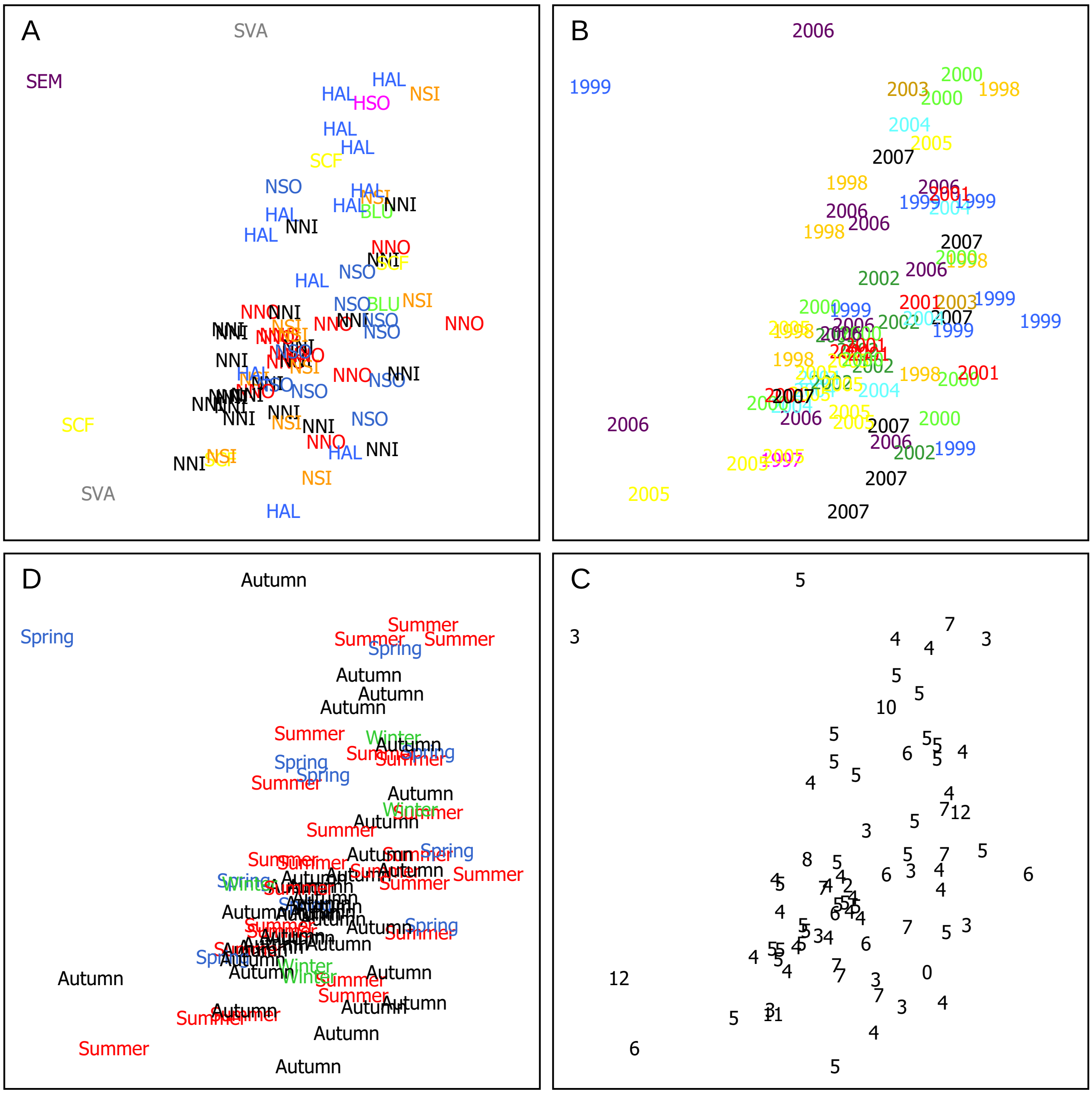

Figure 4. MDS ordination of the average abundance of fish genera within each location-year-season and depth combination (two dimensional result with stress = 0.1825). Note that the same analysis is presented four times with different labelling of the points (A. Location; B. Year; C. Season; D. Depth) for easier interpretation.

As the ability to identify and count fish taxa is related to conditions at the time of observation (notably the visibility), the number of fish genera observed was plotted against the average visibility (Figure 6). Regression based on a linear fit visibility indicated very little if anything by way of a relationship (Figure 6), which suggests that fish observations are actually independent of visibility. However, information on sea conditions, visibility, bottom time and water temperature should be recorded for all Reef Watch observations. Even while this information might have no direct relationship to the biological data, it can suggest how much effort is expended in survey operations.

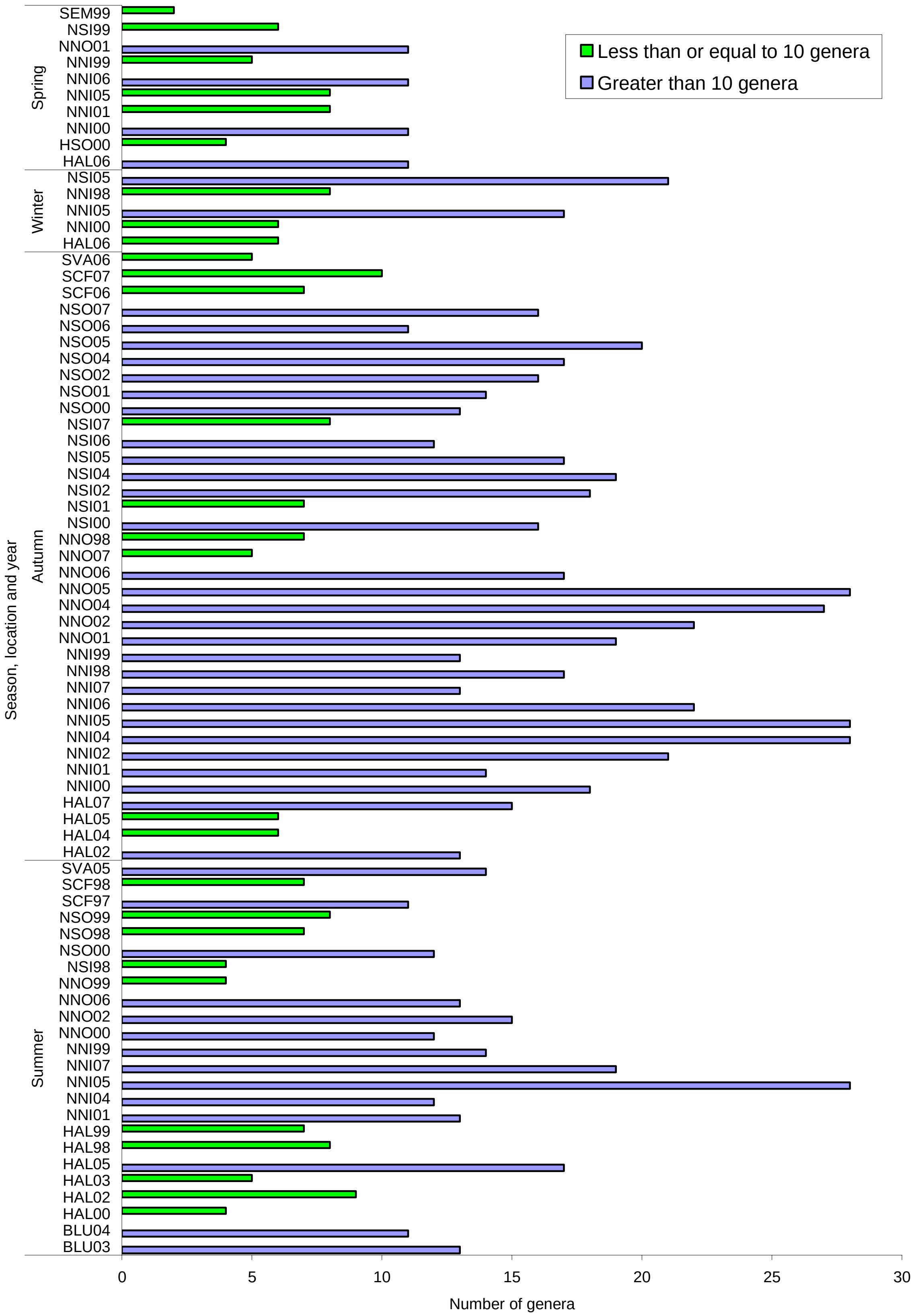

Figure 5. Number of fish genera within each combination.

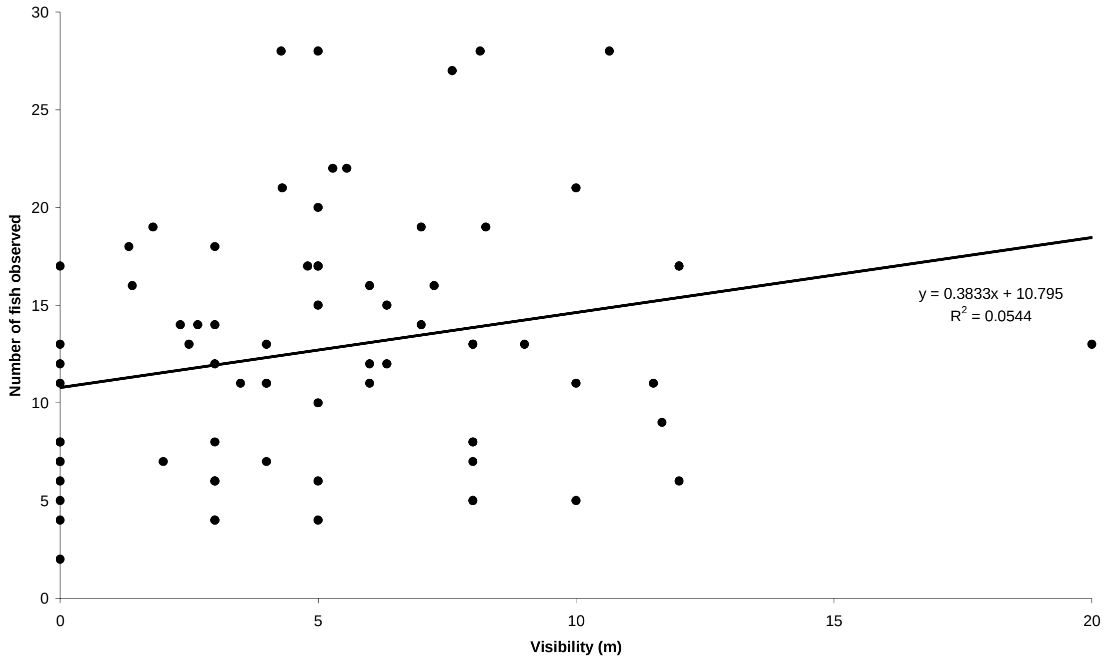

Figure 6. Scatterplot of number of fish observed against visibility for each observation. Regression based on a linear best fit produced a R^2 = 0.0544 indicating basically no relationship between these factors.

Consideration of the fish transect ordination with respect to reef health status shows no pattern (Figure 7). This might suggest that fish data are not as good an indicator of reef status as LIT, which would tend to support the views of Reef Health surveys (Turner *et al.* 2007, Collings *et al.* 2008). However, it must be remembered that less than half (30 out of 76; Table 1; Table 3) of the fish location-year-season combinations for which there was concomitant LIT data were included in reef status assessment. For this reason, the search for patterns of reef status with respect to location-year-season combinations must be considered as inconclusive.

As with LIT surveys, a balanced, more structured approach to surveys would greatly assist in analysis and interpretation of the data. However, this dataset, along with Reef Health fish and DEH surveys (see DEH 2009) may offer an important benchmark for future comparisons, particularly in light of large scale, long term threats such as climate change. Future development of fish-oriented indicators of reef status (i.e. species, genera, lifeforms, etc.) may not preclude the use of the related subset of these datasets in an historical context.

Shepherd and Baker (2008) summarised a fish survey from 57 reef sites in the southern Fleurieu and Yorke Peninsulas as well as Kangaroo Island. These observations concerned a group of 46 fish species that occurred at most sites, with 18 considered to be common. This compares to the 93 identified across all surveys conducted by Reef Watch, 36 species of which co-occurred with Shepherd and Baker (2008; Appendix B). Similarly, 38 of the species identified by Reef Watch were considered to be "Site-attached" by Turner *et al.* (2007). Twenty-two species were common to all three species lists (Appendix B). However, the overall impression is that the composition of reef fish communities is open to substantial debate. While more than 600 species of fish may be found in coastal shelf waters in southern Australia, assemblage compositions (i.e. specific community compositions and structures) are relatively unknown (Shepherd and Baker 2008).

It is worth noting that the Shepherd and Baker (2008) observations are based on four 100 m long transects at each location, substantially longer than Reef Health (Turner *et al.* 2007) or Reef Watch transects.

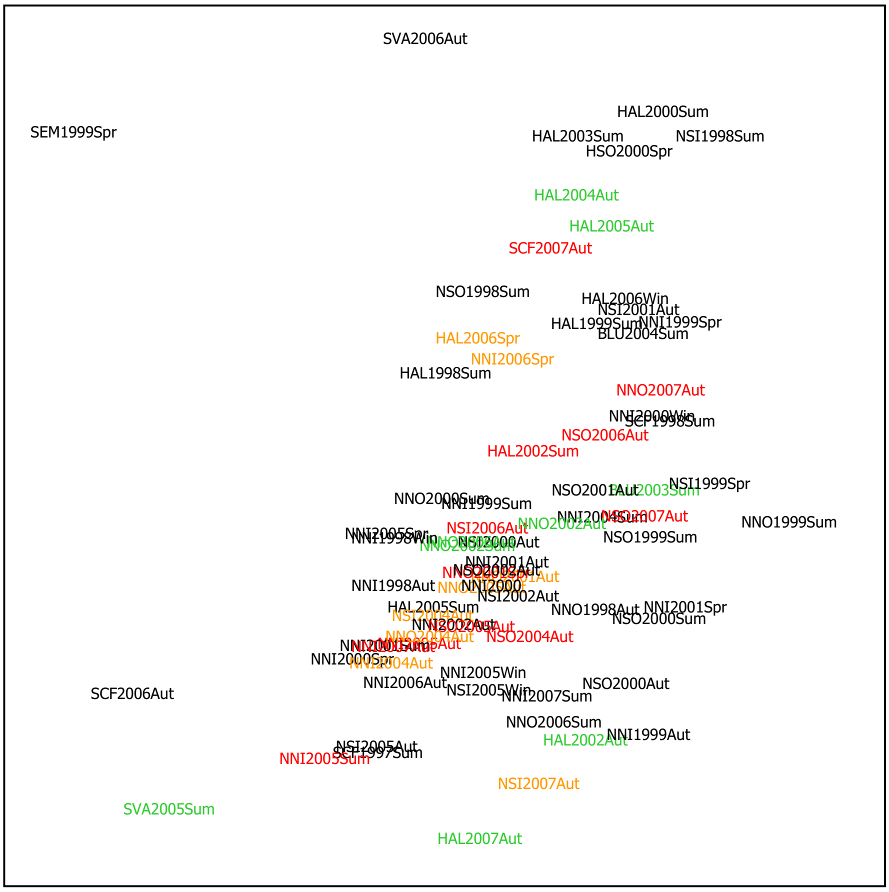

Figure 7. Repeat of the first MDS ordination of the average abundance of fish genera within each location-year-season and depth combination (two dimensional result with stress = 0.1825). Labels coloured according to overall stress rating with Red = Poor, Orange = Caution, Green = Good and Black = Not Assessed.

5.4 Feral or in Peril

The Feral or in Peril program has a far wider geographic reach than other observations (Table 1), at least in part because the observations can be undertaken as part of other activities that do not necessarily involve Reef Watch. In addition, the Feral or in Peril program is targeted well outside the Reef Watch frame of reference, including recreational fishers, dive clubs, surfers and other beach users. Feral or in Peril targets eight marine species of conservation concern and seven pest species in South Australia (Table 6). A critical point to the Feral or in Peril program is the acknowledgement that there are relatively few scientifically trained divers operating on our coasts such that observations of rare/endangered or exotic species are far more likely to come from members of the public rather than those from research institutions.

However, of the 110 individual reports from the Feral or in Peril program, only 10 relate to marine pests (Table 7). The current Feral or in Peril data are dominated by the “in Peril” species, some of which have been observed at many locations (Western Blue Groper and Western Blue Devil with 35 and 33 recordings respectively), such that the composition of the in Peril species group should perhaps be revised. However, there is little information at present regarding the status of marine species in SA.

Importantly, observations of important marine pests are not recorded in the data. For example, *Caulerpa taxifolia* is widely counted as being amongst the world's worst marine pests (ISSG Global Invasive Species Database; http.www.issg.org/database; Accessed September 2008) and observations of its spread around the Adelaide coast are extremely important to marine managers (Westphalen and Rowling 2005). While sightings of this pest on a North Haven beach were appropriately reported to authorities by a member of Reef Watch in June 2005 (Westphalen and Rowling 2005), there is no related record in the Feral or in Peril database (the single record for *Caulerpa* in the data related to the population in West Lakes and Port River; Table 7). The current approach to the marine pests within the Feral or in Peril program maintains a group of three "Red Alert" species that should be reported to authorities (Table 6). While the reporting of Red Alert taxa is critical and Reef Watch has already been shown to play a significant role, it is important that Reef Watch maintain a focus on ensuring completeness within its datasets, particularly for reporting related to marine pests.

An important problem for the Feral or in Peril program is that currently data are only recorded when a species is observed. For feral or pest species, the recording of information on survey or even casual dives for which none where observed needs to be recorded. The "not found" category (see Table 6) serves to help determine modes of spread and infestation as well as possibly point the way to potential management options. It is both heartening and disturbing that the marine pests reported within the Feral or in Peril program comprise only a small portion of records. While the number of positive observations suggest that the target pest species are still relatively rare, the lack of reporting on sites where feral species were not observed (even though the 'in Peril' observations suggest extensive spatial coverage; Table 2) raises some question as to data quality. The assumption undertaken in development of reef status indices that there were no feral species at any of the sites considered is open to justifiable criticism in that it is not based on solid information. However, these data match data collected during the Reef Health surveys, which found few feral species.

Table 6. List of species used in the Feral (F) or in Peril (P) observations. Those pests shaded red are considered to be "Red Alert" species that should be reported to appropriate authorities.

Common name	**Species name**	**F/P**	**Description**
European sea squirt	*Ciona intestinalis*	F	Almost colourless ascidian that forms dense colonies
European shore crab	*Carcinus maenas*	F	Hardy greenish brown crab found in shallow locations
Asian date mussel	*Musculista senhousia*	F	Small fast growing mussel - prefers intertidal and shallow subtidal
Mediterranean fan worm	*Sabella spallanzanii*	F	Large tube (fan) worm colonising a range of habitats
Aquarium Caulerpa	*Caulerpa taxifolia*	F	Bright green foliaceous algae - highly invasive
Northern Pacific sea star	*Asterias amurensis*	F	Five armed star that can colonise a variety of habitats
Japanese kelp	*Undaria pinnatifida*	F	Large kelp with greenish foliage and unusual base
Western blue groper	*Achoerous gouldii*	P	Large friendly easily recognised fish
Leafy seadragon	*Phycodurus eques*	P	Delicate leaf-like appendages - SA marine emblem
Weedy seadragon	*Phyllopteryx taeniolatus*	P	More colourful but less leafy than the Leafy Seadragon above
Western blue devil	*Paraplesiops meleagris*	P	Dark blue with iridescent lighter blue spots
Reef coral	*Plesiastrea versipora*	P	One of only a few stony corals in southern Australia
Striped pyjama squid	*Sepioloidea lineolata*	P	White squid with black / brown stripes - nocturnal
Black cowry	*Cypraea friendii thersites*	P	Large cowry with mottled dark blotches on its shell
Harlequin fish	*Othos dentex*	P	Large colourful fish
No Feral/Peril species found	N/A		Used to record surveys where no Feral or In Peril species were found

Table 7. Summary of Feral or in Peril observations.

Species Name	Common Name	F or P	Count
Sepioloidea lineolata	Striped Pajama Squid	P	6
Plesiastrea versipora	Reef Coral	P	10
Phycodurus eques	Leafy Sea Dragon	P	1
Paraplesiops meleagris	Western Blue Devil	P	35
Othos dentex	Harlequin Fish	P	6
Cypraea friendii thersites	Black Cowry	P	9
Achoerodus gouldii	Western Blue Groper	P	33
Sabella spallanzanii	Mediterranean Fan Worm	F	5
Ciona intestinalis	European Sea Squirt	F	1
Caulerpa taxifolia	Aquarium Caulerpa	F	1
Carcinus maenas	European Shore Crab	F	3
Total in Peril			**100**
Total Feral			**10**

6 General Discussion

Collings *et al.* (2008) stated that, when combined with professional guidance, Reef Watch can provide an excellent monitoring tool. Results of this analysis would entirely support this view in that data acquisition within observations appears to be consistent and reliable. However, analyses of the data also suggest that there is more that can be done with respect to the structure of the observations to make them more readily comparable.

From an analytical perspective, the analyses considered within this report are by no means comprehensive. Differences in taxonomic resolution in terms of ordination analyses could be explored as well as related investigations into indicator taxa; however, the role of this report was to consider Reef Watch data in a similar context to Reef Health, chiefly through application of status indices.

The Collings *et al.* (2008) Reef Health report provides the most recent comprehensive assessment of the status of Adelaide's metropolitan reefs. Reef Health and Reef Watch macroalgal data were reasonably well aligned, with discrepancies considered to be the result of medium scale (10s - 100s of metres) spatial heterogeneity as well as some taxonomic inconsistencies (Collings *et al.* 2008). There may also be some temporal factors if sites are included from the beginning and end of the season as a lot of changes can occur within a macroalgal community in three months (Edgar 1983, Collings 1996). Importantly many results comprise more than one set of observations, often having LIT and fish surveys undertaken on separate occasions. The resulting observations thus entail a relatively higher level of small scale spatial (within reef) variability.

With respect to community surveys Collings *et al.* (2008) recommended:

- Professional guidance for Reef Watch surveys
- More reefs should be surveyed accepting there will be a reduction in sampling frequency
- Fixed transects at each reef
- Photographic assessments
- Assessment methods for mobile fauna need to be improved and
- Improvements to indices.

Note that the first three relate directly to the Reef Watch program, whereas the remainder require a level of professional input (at least in terms of methodology for photographic assessments) that is arguably more within the scope of further Reef Health assessments. In particular the approaches to mobile fauna (both fish and invertebrates) need to be significantly reassessed, perhaps with greater emphasis on identification of indicator species and/or lifeforms.

As with previous Reef Health surveys, the LIT data, particularly with respect to macroalgal cover provides probably the best indicators of reef status. A survey of 25 reefs along the Fleurieu Peninsula conducted by DEH found that both similarities within as well as differences between reefs were largely determined by the macroalgal component, in particular the canopy forming species (DEH 2009). Note that the DEH survey did not include the impacted reefs along the Adelaide metropolitan coast (i.e. the survey comprised "healthy" reefs, much the same as Reef Watch observations).

Notwithstanding the deficiencies within the current approaches to reef status indices, LIT data contributes to four of the eleven parameters. In addition, LIT data comprises community composition and structure of the primary producers (macroalgae) within the system and therefore provides a strong linkage to ecosystem processes and energy flows and is probably more sensitive to environmental stress factors identified from the Adelaide metropolitan coast (specifically sedimentation and nutrients - Turner and Cheshire 2002, Fox *et al.* 2007). From the first Reef Health surveys in 1996, Miller *et al.* (1998) recommended that the LIT method should be promoted as the mechanism for long-term monitoring. None of the reef status surveys conducted since that time, nor any of the results of Reef Watch surveys would contradict this suggestion.

In one of the initial assessments of the LIT methodology in temperate reef systems Turner (1995) concluded that around 5 m of LIT was equivalent to a single 1 × 1 m quadrat in terms of information content. Applying this relationship to subsequent Reef Health assessments suggests that LIT data collected were equivalent to up to 16 quadrats (i.e. 80 m) worth of information for each site. In an extensive examination of spatiotemporal variability in macroalgal systems through much of the early 1990s, Collings (1996) considered that a minimum of eight 1 × 1 m quadrats was required to represent a patch of reef at a point in time. This would arguably suggest that 40 m of LIT is required to match this level of sampling intensity, although there may be substantial issues regarding the independence of samples from a continuous 40 m transect. The bulk (over half) of Reef Watch LIT observations are less than 20 m long within a particular location-season-year combination, which raises questions as to the adequacy of sampling with respect to both index calculation as well as identification of taxa/lifeforms relative to spatiotemporal differences. Hence while there is little question related to the quality of Reef Watch LIT data, there is both lack of balance in terms of sampling *across* locations, seasons, years and depths as well as the representativeness of sampling *within* observations in many instances.

Fish observations appear to be limited in terms of their capacity to identify reef status or indeed gradients related to location, year, season or depth. In part, this may be due to a lack of alignment with the suite of species employed in the Reef Health surveys, but also because these indices are themselves not particularly informative in their current format (at least relative LIT data). However, it is important to realise that the Reef Watch fish data do not include any of the degraded reefs from the northern and central Adelaide metropolitan coast and therefore the large scale driver for reef differences (i.e. location/health) is not represented in the data. Refinement of the fish related indices used in Reef Health is required, possibly with the identification of a small subset of indicator species (or families or lifeforms), although this process should occur within the Reef Health program (assuming this is continued); however, current fish observations will remain useful in terms of larger scale/longer term monitoring of factors such as climate change. They may also be reinterpreted with respect to indices developed in the future (possibly as part of Reef Health).

Expanding our understanding of the status of reef systems as well as the processes that lead to spatial and temporal variability requires an appropriate sampling strategy. The methodology employed within the framework of Reef Health observations from 2005 and 2007 serves as a basis for that used by Reef Watch, but should not be seen as the only approach. Whatever sampling is employed needs to be sensitive to environmental change. However, there are severe restrictions on what Reef Watch can achieve, in particular the lack of access to an appropriate dive vessel, which means that degraded reefs on the northern and central Adelaide metropolitan coast are currently inaccessible. The current Reef Watch data is thus restricted to observations of spatiotemporal differences across what are generally considered to be “healthy” reefs (see Turner *et al.* 2007, Collings *et al.* 2008).

Putting this restriction to one side, if Reef Watch is to contribute to large scale ecosystem monitoring on the South Australian coast, focus should be given to the identification of a discrete set of questions for which sampling should be targeted. Examples of questions might include:

1) How do reefs on the northern and central Adelaide metropolitan coast compare to those further south?

This question could form the basis of a comparison of 3 – 4 impacted versus 3 – 4 relatively pristine reefs at a single time of year (preferably summer and autumn in alignment with later Reef Health surveys). Reef Health monitoring has varied in intensity from 3 – 6 year intervals. Assessment of interannual differences within degraded and “healthy” reefs would greatly assist in placing Reef Health surveys in an appropriate context. For example, Collings *et al.* (2008) noted an improvement in the status of some degraded reefs, but with only a single observation it cannot be established from Reef Health whether this is part of a definite trend. With improvements to water quality on the Adelaide coast (see Fox *et al.* 2007) as well as new and ongoing issues such as the construction of a desalination plant at Port Stanvac and climate change, the need to establish longer term trends is increasingly important. Note that this question makes the assumption that Reef Watch has access to an appropriate vessel to extend the range of reefs accessible to volunteers.

2) What seasonal changes occur on reefs within the southern Adelaide metropolitan zone?

This could focus on Hallett Cove and Noarlunga Reef with regular surveys within each season. This would encompass much of the sampling that is currently being undertaken as well as encourage more balance in the observations, such that gradients relative to site, season, perhaps depth, etc., are more readily identified. This approach would also place a “watching brief” on those reefs on the fringe of the metropolitan area, that are probably more at risk than those further south. Notwithstanding this approach, observations based on sound sampling methods from outside this framework should not be discouraged. Rather, the former should be seen as a “core” dataset.

Following on from Collings *et al.* (2008) Reef Watch surveys should be conducted at fixed locations (within 5 m) such that temporal differences are not confounded with spatial heterogeneity. Photographic/video transects might also be considered as these offer a rapid means of collecting observations as well as a capacity to reanalyse images in a variety of means. However, this approach is not without costs, and there is significant time required in interpreting the images.

In addition to the above recommendations from Collings *et al.* (2008), some additional improvements to the sampling regime are recommended:

- Development of a discrete set of questions to be considered by Reef Watch with respect to its sampling program (see general discussion). This might focus on southern Adelaide areas, where reefs may be at risk.
- Within the framework of fixed sampling points;

  - Individual LIT transects must be at least 5 m in length.
  - There must be at least 20 m (preferably 40 m) of total LIT transect within any single observation for it be representative of a site at any single point in time.
- A need to acknowledge that LIT data provide the best approach to understanding reef status.
- The Marathon Dive at Noarlunga could be given a greater degree of structure in the sampling wherein participants are directed to collect from within specific depth ranges (i.e. less than 5 m versus greater then 8 m observations).
- Data sheets and data entry should require data on:
  - Total transect length.
  - Presence/absence of invasive species based of the Feral or in Peril list. Note that recording the <u>absence</u> of invasive species is extremely important.
- Greater alignment between Reef Watch and Reef Health in terms of species used in index calculation.
- More focus given to ensuring that fish and LIT surveys are spatiotemporally more aligned.
- The Feral or in Peril list might be revised in terms of the species of conservation concern (‘in Peril’).

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Appendix A - Reef health index calculation

Data for index calculations were obtained from LIT and fish surveys as well as the Feral or in Peril surveys (Table 9). See Table 2 for location codes.

Table 8. Reef Watch data employed in index calculation. Note that the average size of Blue-throated wrasse (*) is based on the Reef Health data.

Location, year & season	LIT percent cover data				Site-attached fish			Blue throated wrasse				Invasive species
	Bare	Turf	Mussel	Canopy	Number	Transects	Area	Number	Avg_Size*	Transects	Area	
BLU 2003 Summer	11.2	2.08	0	72.66	18	1	1750					0
BLU 2005 Spring	4.24	1.6	0	87.28								0
CAR 2003 Summer	0	0.80	0	98.54								0
EDP 2004 Autumn	0	0	0	54.66								0
HAL 1998 Autumn	6.54	1.79	1.16	57.02								0
HAL 1998 Winter	38.74	0.69	0	35.14								0
HAL 1999 Winter	8.09	2.18	0	58.38								0
HAL 2001 Autumn	14.89	44.62	0.23	24.37								0
HAL 2002 Autumn	30.89	1.35	0.58	63.71	31	1	1250					0
HAL 2002 Summer	7.98	7.76	0	24.61	50	1	1750					0
HAL 2004 Autumn	25.8	6.31	0	61.24	5	1	750					0
HAL 2005 Autumn	0	5.43	0	68.42	6	1	750	3	20.75	1	250	0
HAL 2006 Spring	34.62	0	0	32.63	28	1	2250	9	20.75	1	500	0
HAL 2007 Autumn	13.53	18.28	0	32.87	555	1	4000	5	20.75	1	250	0
NNI 2001 Autumn	35.78	0	17.33	22.27	87	1	2000					0
NNI 2003 Summer	0.57	8.92	26.13	36.31								0
NNI 2004 Autumn	0	5.58	13.96	63.66	561	1	29250	3	20.75	1	1250	0
NNI 2005 Autumn	11.58	4.53	24.59	36.24	302	1	14000	2	20.75	1	500	0
NNI 2005 Summer	0	1.29	68.65	6.94	208	1	13900	4	20.75	1	400	0
NNI 2006 Spring	0	0	0	57.21	19	1	2500	3	20.75	1	500	0
NNI 2007 Autumn	56.85	16.4	0	14.65	422	1	3500	2	20.75	1	500	0
NNI 2007 Spring	8.05	12.68	0	1.95								0
NNO 2001 Autumn	11.84	3.95	11.02	38.92	240	1	6500					0
NNO 2001 Spring	22.54	11.90	0	26.29	22	1	2500					0
NNO 2001 Summer	16	39	0	39.5								0
NNO 2001 Winter	0	1.71	0	61.15								0
NNO 2002 Autumn	0	7.94	0	78.11	211	1	11500					0
NNO 2002 Summer	2.54	8.54	0.69	60.16	155	1	4000					0
NNO 2004 Autumn	0	18.29	0	63.92	505.5	1	22500	1	20.75	1	250	0
NNO 2005 Autumn	8.53	36.26	0	11.14	206	1	14500	1	20.75	1	250	0
NNO 2005 Summer	0	6.43	0	42.9								0
NNO 2006 Autumn	10.95	5.49	0	63.5	61	1	5000					0
NNO 2007 Autumn	25.2	16.54	0	28.4	12	1	750					0
NSI 2004 Autumn	14.24	3.91	12.07	35.75	150.5	1	7250					0
NSI 2005 Summer	0	0	0	50.58								0
NSI 2006 Autumn	37.59	22.08	16.3	20.97	55	1	3750					0
NSI 2007 Autumn	32.5	0	7.5	47.4	84	1	1250					0
NSO 2004 Autumn	24.7	5.57	17.86	30.3	21	1	1500					0
NSO 2005 Autumn	0	31.16	48.77	5.28	265	1	10000					0
NSO 2006 Autumn	15.67	19.81	1.18	30.18	40	1	1750					0
NSO 2007 Autumn	55.71	16.9	3.37	15.99	59	1	6250	3	20.75	1	500	0
SCF 2007 Autumn	11.51	7.89	0	9.35	24	1	2250	1	20.75	1	250	0
SVA 2004 Spring	16.73	0	0	64.29								0
SVA 2005 Summer	10.96	0	0	83.29	44	1	2750	5	20.75	1	250	0
SVA 2006 Summer	33.83	2.89	0	59.51								0

Appendix B - Reef Watch fish taxa

The fish taxa identified across all Reef Watch surveys was aligned with the species identified from Reef Health (Table 10). This subset was employed in the derivation of the site-attached fish index (Appendix A).

Table 9 - List of fish taxa observed across Reef Watch surveys. Green shaded rows indicate the taxa employed in the calculation of site-attached fish. Those species listed in red text were also observed in the Shepherd and Baker (2008) survey. Note that Southern calamari (*Sepioteuthis australis)* although technically a mollusc is functionally a fish and treated as such. Analysis was undertaken at the genus level.

Common Name	Species Name	Genus
Australian salmon	*Arripes truttaceus*	*Arripes*
Banded sweep	*Scorpis georgiana*	*Scorpis*
Black bream		*Acanthopagrus*
Black-spotted wrasse	*Austrolabrus maculatus*	*Austrolabrus*
Blennie		
Blue groper	*Achoerodus gouldii*	*Achoerodus*
Blue-lined leatherjacket	*Meuschenia galii*	*Meuschenia*
Blue-throated wrasse	*Notolabrus tetricus*	*Notolabrus*
Bridled leatherjacket	*Acanthaluteres spilomelanrus*	*Acanthaluteres*
Brown striped leatherjacket	*Meuschenia australis*	*Meuschenia*
Brown-spotted wrasse	*Notolabrus parilus*	*Notolabrus*
Bullseye	*Pempheris*	*Pempheris*
Castlenose or Pretty polly wrasse	*Dotolabrus aurantiacus*	*Dotolabrus*
Clingfish		
Common bullseye	*Pempheris multiradiata*	*Pempheris*
Common stinkfish	*Foetorepus calauropomus*	*Foetorepus*
Common weedfish	*Heteroclinus perspicillatus*	*Heteroclinus*
Cowfish	*Aracana*	*Aracana*
Cuttlefish	*Sepia apama*	*Sepia*
Dragonet	*Bovichtus angustifrons*	*Bovichtus*
Drummer	*Kyphosus sydneyanus*	*Kyphosus*
Dusky morwong	*Dactylophora nigricans*	*Dactylophora*
Eagle Ray	*Myliobatus australis*	*Myliobatus*
Estuary catfish	*Cnidoglanis macrocephalus*	*Cnidoglanis*
Flathead		*Platycephalus*
Flathead (not sand)		*Platycephalus*
Globe fish	*Diodon nicthemerus*	*Diodon*
Goat fish	*Upeneichthys vlamingii*	*Upeneichthys*
Goby	Gobiidae	Gobiidae
Grub fish		*Parapercis*
Gurnard		
Harlequin fish	*Othos dentex*	*Othos*
Herring cale	*Odax cyanomelas*	*Odax*
Horseshoe leatherjacket	*Meuschenia hippocrepis*	*Meuschenia*
Hulafish	*Trachinops*	*Trachinops*
Johnston's weedfish	*Heteroclinus johnstoni*	*Heteroclinus*
King George whiting	*Sillaginodes punctata*	*Sillaginodes*
Little weedy whiting	*Neoodax balteatus*	*Neoodax*
Long-finned pike	*Dinolestes lewini*	*Dinolestes*
Long-rayed weed whiting	*Siphonognathus radiatus*	*Siphonognathus*
Long-snouted boarfish	*Pentaceropsis recurvirostris*	*Pentaceropsis*

Common Name	**Species Name**	**Genus**
Luderick	*Girella tricuspidata*	*Girella*
Magpie perch	*Cheilodactylus nigripes*	*Cheilodactylus*
Moonlighter	*Tilodon sexfasciatus*	*Tilodon*
Mulloway	*Argyrosomus japonicus*	*Argyrosomus*
Old wife	*Enoplosus armatus*	*Enoplosus*
Ornate cowfish	*Aracana ornata*	*Aracana*
other Cale	*Odax*	*Odax*
other Leatherjacket		*Meuschenia*
other Wrasse	*Wrasse spp.*	*Wrasse*
Parrot fish		
Pencil weed whiting	*Siphonognathus beddomei*	*Siphonognathus*
Pipe fish	Syngnathidae	Syngnathidae
Port Jackson shark	*Heterodontus portusjacksoni*	*Heterodontus*
Rainbow cale	*Odax acroptilus*	*Odax*
Sand flathead	*Platycephalus bassensis*	*Platycephalus*
Scalyfin	*Parma victoriae*	*Parma*
Sea sweep	*Scorpis aequippinis*	*Scorpis*
Senator wrasse	*Pictilabrus laticlavius*	*Pictilabrus*
Shaw’s cowfish	*Aracana aurita*	*Aracana*
Silver trevally	*Pseudocaranx dentex*	*Pseudocaranx*
Six-spined leatherjacket	*Meuschenia freycineti*	*Meuschenia*
Smooth stingray	*Dasyatis brevicaudata*	*Dasyatis*
Smooth toadfish	*Tetractenos glaber*	*Tetractenos*
Snapper	*Pagrus auratus*	*Pagrus*
Southern calamary	*Sepioteuthis australis*	*Sepioteuthis*
Southern hulafish	*Trachinops caudimaculatus*	*Trachinops*
Southern sea carp	*Dactylosargus arctidens*	*Dactylosargus*
Southern silverbelly	*Parequula melbournensis*	*Parequula*
Spiney-tailed leatherjacket	*Acanthaluteres brownii*	*Acanthaluteres*
Sprats		
Squid		
Stingray		
Striped perch	*Pelates octolineatus*	*Pelates*
Sweep	*Scorpis*	*Scorpis*
Threefin spp.		
Toadfish	*Omegophora armilla*	*Omegophora*
Tommy ruff	*Arripis georgianus*	*Arripis*
Toothbrush leatherjacket	*Acanthaluteres vittiger*	*Acanthaluteres*
Trevally	*Pseudocaranx*	*Pseudocaranx*
Velvet leatherjacket	*Meuschenia scaber*	*Meuschenia*
Wavy grubfish	*Parapercis haackei*	*Parapercis*
Weed whiting	*Siphonognathus*	*Siphonognathus*
Weedfish	*Heteroclinus*	*Heteroclinus*
Weedy seadragon	*Phyllopteryx taeniolatus*	*Phyllopteryx*
Western bluedevil	*Paraplesiops meleagris*	*Paraplesiops*
Western cleaner clingfish	*Cochleoceps bicolor*	*Cochleoceps*
Western stingaree	*Trygonoptera mucosa*	*Trygonoptera*
Western talma	*Chelmonops curiosus*	*Chelmonops*
Wobbegong	*Orectolobus*	*Orectolobus*
Yellow-headed hulafish	*Trachinops noarlungae*	*Trachinops*
Yellow-striped leatherjacket	*Meuschenia flaviolineata*	*Meuschenia*
Zebra fish	*Girella zebra*	*Girella*

Appendix C - Understanding ordinations

An important feature of the analysis of the reef status data (and indeed to understanding many of the results of the extant Reef Health reports) is the use of a multivariate analysis technique called ordination. There are a large number of different ordination approaches that are often confusing and/or intimidating for the uninitiated. However, the key point to remember is that like any graph or chart, all ordinations are essentially a means of observing relationships within the data. Ecological data are inherently complex and difficult to interpret in raw form. Ordination provides a means of simplifying this complexity and displaying the data in a format that maintains important relationships between observations.

The best approach to understanding what an ordination does is to consider an imaginary set of quadrats (A-H), each of which may have varying numbers of two species (Table 11).

Table 10 - An imaginary set of data describing a number of quadrats in terms of two species.

Quadrat	Species 1	Species 2
A	12	11
B	1	6
C	12	14
D	4	0
E	11	10
F	5	5
G	15	9
H	4	2

The degree to which these quadrats resemble each other can be presented graphically by plotting each quadrat according to the abundance of each species (Figure 8). It is readily apparent that there are two broad groups of observations (A, C, E and G versus B, D, F and H).

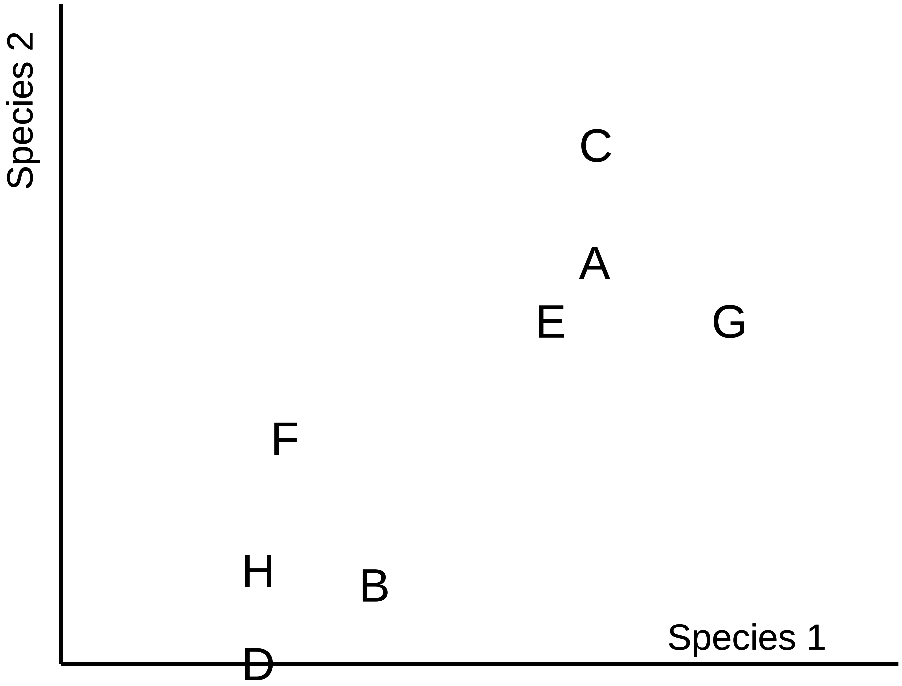

Figure 8 - Representation of the above imaginary dataset comprising two species in two orthogonal axes.

If we add an additional species to the dataset (Table 11), the data can still be represented in terms of three axes (Figure 9). The same broader groups can still be observed, although there is now some dispersion of the A, C, E and G group.

Table 11 - The same imaginary set of data as before but with an additional species.

Quadrat	Species 1	Species 2	Species 3
A	12	11	3
B	1	6	6
C	12	14	2
D	4	0	6
E	11	10	4
F	5	5	0
G	15	9	2
H	4	2	4

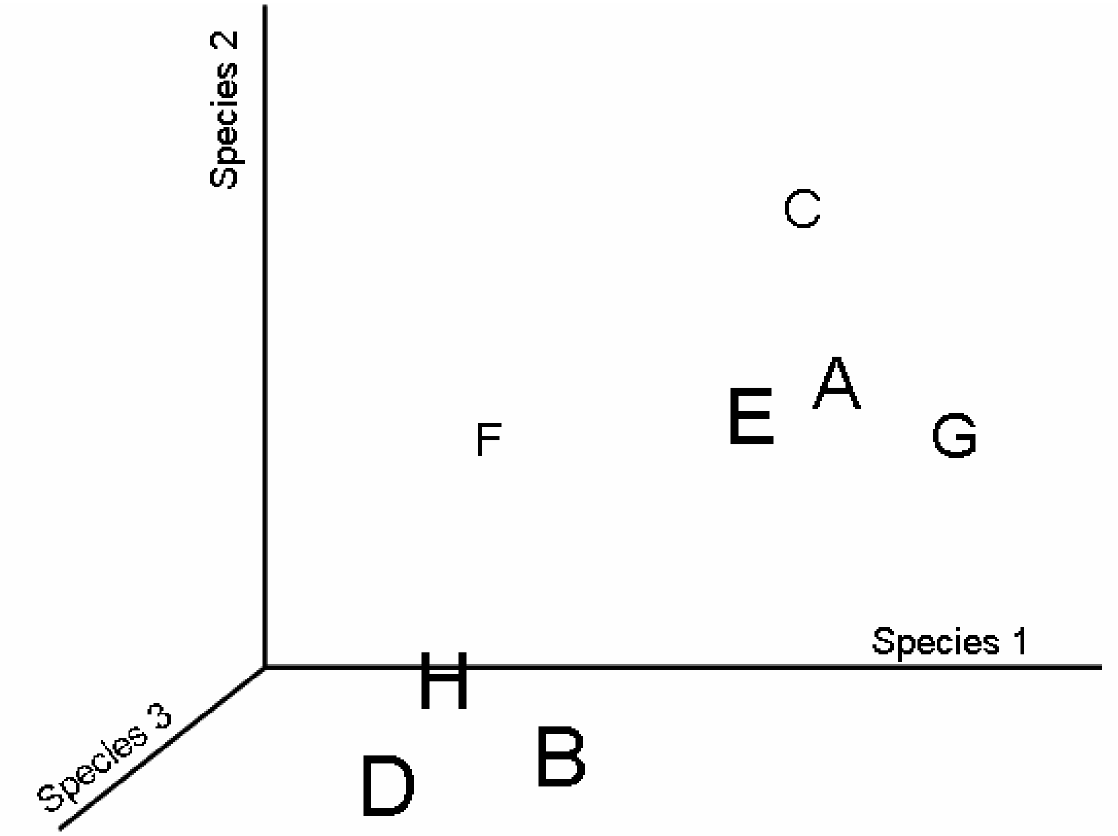

Figure 9 - Three dimensional representation of the imaginary dataset across three orthogonal axes.

While the pattern in this simplified example is relatively apparent, if we were to include additional species to the above dataset, the quadrats can no longer be represented in a three dimensional space without a substantial loss of information. However, an ordination analysis is capable of calculating the relationships between objects (in this case quadrats) across a large number of attributes (species), each represented by its own dimension at right angles to all others. The problem is therefore how to represent the multidimensional species space in an interpretable framework (i.e. three or two dimensions).

Using the above example we can reduce the number of dimensions from three to two by projecting each point onto a two dimensional plane (Figure 10) albeit with a loss of some information. Through a broad range of different methods, ordinations undertake much the same process with positioning of this projection plane such that the loss of information from higher dimensions is minimised.

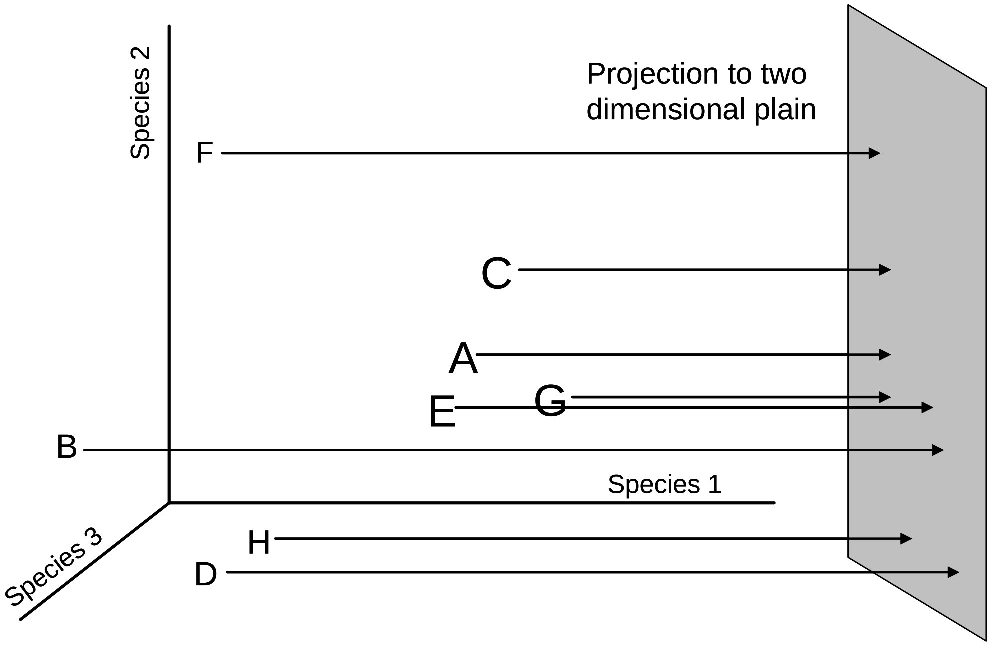

Figure 10 - Projection of three dimensional space onto a two dimensional plane.

It must be kept in mind that at least some information will be lost in reducing the dimensionality and the observed groups of points will be varyingly artificial. Another point to remember is that within each multivariate analysis the information from one quadrat (to use this example) will to some extent influence all others within the species space, meaning that removal of a quadrat for some reason will require a reanalysis of the remainder and may have a very different result. Finally, it is important to note that ordinations, like graphs, say nothing as to the significance of any observed relationships between points. However, they often form the basis for generating questions (hypotheses) that may be tested statistically.

The ordination method employed in this report is called Non-Metric Multidimensional Scaling (MDS; Clarke 1993). The MDS approach has relatively few assumptions about the input data and is commonly used in biological/ecological analyses. Further, the resulting two or three dimensional outputs can be considered relative to an indicator of how much information has been lost in reducing the dimensionality. The so called “stress” value will inform the user as to how well the resultant graphic represents the multidimensional species space with typically values of less than 0.15 are recommended (Clarke 1993).