Development and evaluation of community-based monitoring programs for coastal ecosystems and fisheries habitats

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Development and evaluation of community-based monitoring programs for coastal ecosystems and fisheries habitats

by

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More information:
Further information about the Reef Health Program along with copies of reports and technical documents may be obtained from the Reef Watch website at http://www.reefwatch.asn.au, or by contacting SARDI Aquatic Sciences.

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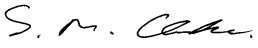

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OBJECTIVES:

1. To develop a better knowledge and understanding of coastal reef ecosystems through:
   - Identification of appropriate indices for assessment and development of survey methodologies; and
   - Application of these methodologies to obtain baseline and time scale data for coastal reef ecosystems which is relevant to the needs of key management agencies including SA Water, SA Environmental Protection Authority, and SA Department for Environment and Heritage.
2. To foster community ownership and participation in monitoring and assessment:
   - Through the development of training and education packages; and
   - By encouraging and mobilising community participation.
3. To develop a credible assessment program:
   - Through the process of training, testing and accreditation of all participants; and
   - By undertaking scientifically rigorous evaluation of the community-monitoring program.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

This project provides a comprehensive baseline on the health of shallow (mostly 4-5 m) subtidal reefs from metropolitan Adelaide and the Fleurieu and Yorke Peninsula in 2005, along with data from metropolitan reefs in 2007. The data show a clear geographic gradient in reef health along the metropolitan Adelaide coast, with the healthiest reefs in the south. Importantly, by surveying a previously unsurveyed reef to the north of the Adelaide metropolitan region, it is shown that this is not a natural south-north gradient, as the northern reef was healthier than some further south. Thus the project has provided strong evidence that the gradient in reef health is partly driven by impacts from the city of Adelaide. However, for those reefs for which we have a time series of data since 1996, we can see a gradual improvement in health, suggesting that recent initiatives to improve water quality are in fact having a positive effect. In addition, the project has helped to make important advances in community monitoring and understanding of reefs. Substantial effort was put into promoting the importance of reef habitats to the public through the development of brochures, short videos and a schools training package. The community Reef Watch program was also closely involved in the project, and refined its training protocols based on some of the recommendations coming out of this project. There was also a quantitative comparison between community collected and scientific data, which should provide managers with confidence as to what extent the community collected data can be relied upon.

Concern over the degradation of Adelaide's metropolitan reefs (from Aldinga to Semaphore) led to the development of a number of environmental monitoring and research initiatives. The first Reef Health survey was initiated in 1996 and expanded in 1999, with follow-up surveys completed in 2005 and 2007. The 2005 survey program was considerably extended compared to previous surveys.

Generally, the decreasing south to north gradient in reef health observed across metropolitan reefs in 1996 and 1999 was also observed in 2005 and 2007. Based on macroalgal functional group composition and cover, northern metropolitan reefs (sites from Semaphore to Broken Bottom) appear to be in poor condition, with red foliaceous and turfing macroalgae dominating. There are signs of further declines in 2005 (compared to previous surveys) on central metropolitan reefs (from Seacliff to Southport), in particular those at Horseshoe Reef and some sites on Noarlunga Reef, with a loss of robust brown macroalgae, establishment of mussel mats, and in some instances, the development of large areas of bare substrate. Southern reefs (Moana to Aldinga) have remained much the same and appear healthy, retaining most of their robust macroalgal canopy.

Similar analyses of macroalgal cover and composition at sites surveyed during 2005 on Yorke Peninsula (11 sites) and Fleurieu Peninsula (8 sites) found reefs were generally healthy, particularly when compared to metropolitan reefs. However, there was a high level of variability within regions. Some sites (notably Point Souttar and Point Riley on Yorke Peninsula) had a relatively low cover of canopy macroalgal species, but as the natural environment at these sites is different to other sites, this cannot be interpreted as poor condition without further information.

In order to obtain a more robust indication of reef status, we developed ten additional health indices in addition to macroalgal cover. To get an overall value for any particular reef, the set of indices are averaged to obtain an overall score. The reef was then scored, and grouped into one of three categories (Poor Condition, Caution Recommended and Good Condition).

This 'stoplight' approach indicated a more complex picture than simply scoring on macroalgal functional group cover. A large number of sites across the metropolitan region fell into the Caution Recommended category, even within the generally healthier southern zone. Similarly, a few sites on the Fleurieu Peninsula coast (Granite Island and Port Elliot) rated Caution Recommended status, while four sites on Yorke Peninsula rated either Caution Recommended (Troubridge Point and Cable Hut Bay) or Poor Condition (Point Souttar and Point Riley). None of the non-metropolitan sites scored as low as northern sites on the Adelaide metropolitan coast. This is a very preliminary approach and the 'stoplight' method has drawbacks. For example, Point Souttar is in an area of naturally low current flow and high sedimentation, and may never have supported large canopy macroalgal species. Invertebrate diversity was moderate at this site; however, the nature of the indices used has meant that this reef has ranked low. It is important to remember, for all sites, particularly those sampled for the first time, that the data provide a snapshot of the system. The real value of this type of survey is that it will act as a baseline and enable comparisons over time.

The inclusion of a reef in Gulf St Vincent to the north of the previously surveyed reefs in 2007 (and yet away from the influence of metropolitan Adelaide) allowed us to demonstrate that the poor condition of these reefs did not simply represent the northern extent of a natural north-south geographic trend. Rather, some other influence, probably associated with urban Adelaide, was evident.

Long-term trends from 1996-2007 seem to indicate a general improvement in the status of reefs along the Adelaide metropolitan coast. This may be a biotic reflection of the cessation of some dredging operations or of a decrease in the nutrient loading from wastewater treatment plants, and provides circumstantial evidence that such an improvement in practices has the potential to allow regeneration of impacted reefs. Nevertheless, the poor condition of the reefs closest to metropolitan Adelaide indicates that further improvements are required.

Comparison was made between the dataset of the Reef Health program and that collected by Reef Watch, a community-based monitoring initiative. A very similar picture emerged from both sets of data when employing multivariate analysis to study the line intercept transect data. To a large extent, where discrepancies arose, it is likely to be the result of medium scale spatial variation (i.e. sampling different areas) rather than a real difference between the data collectors. Having said this, there were some minor taxonomic issues which need to be assessed in more detail to determine if they will improve the Reef Watch monitoring.

Assessment of the reefs based on the Reef Health Index demonstrated greater disparity between comparable datasets than was the case for the Line Intercept Transect (LIT) analysis – i.e. the 2005 v 2007 datasets, and the Reef Health v Reef

Watch datasets. It is proposed that this is due to inadequate methodology for the assessment of mobile fauna (in particular, greater temporal and/or spatial replication is required) and the fact that the mathematical model used to calculate the index is in early stages and will develop greater utility and accuracy with continuing use and development. As an example, fish surveys conducted during periods of low visibility currently reduce the score a reef receives on the Reef Health Index, whereas it may be more appropriate to give these a null score (as opposed to scoring them as 0), as conditions don't allow the full suite of fish present to be surveyed.

KEYWORDS: Rocky reef, temperate reef, macroalgae, community monitoring, reef health, reef health index

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This project was made possible through the generous financial and in-kind support of the following agencies: Fisheries Research and Development Corporation (FRDC Project Number 2004/078), South Australian Water Corporation, South Australian Department for Environment and Heritage (DEH), South Australian Environment Protection Authority (EPA), Adelaide and Mount Lofty Natural Resources Management Board, Flinders University of South Australia, Conservation Council of South Australia (CCSA), South Australian Fishing Industry Council, South Australian Recreational Fishing Advisory Council, and Seanet.

Professor Anthony Cheshire was the original Principal Investigator (PI), Dr David Turner was the PI for most of the project, and Dr Simon Bryars was PI during the 2007 surveys. Thanks to all others involved in the project, many of who are listed in Appendix 2. Thanks to the project reference group, including Anthony Cheshire, Chris Ball, Claire van der Geest, David Duncan, Sam Gaylard, Grant Ebert, Jackie Griggs, James Brook, Karen Rouse, Kirsten Benkendorff, Bryan McDonald, Sue Murray-Jones, Neil MacDonald, Peter Fairweather, Tim Kildea, Tony Flaherty, and Trevor Watts.

Thanks to Steve Leske and the volunteers from the Reef Watch community-monitoring program for conducting surveys and supplying data for comparison. Bob Baldock and James Brook assisted in training of staff (taxonomy and field methodologies). Bryan Womersley, Bob Baldock and Carolyn Ricci (State Herbarium of South Australia) undertook macroalgal identification and cataloguing. Alex Gaut provided information on Reef Watch activities to include in this report.

Background

This project aims to increase knowledge about Southern Australian temperate reefs and in particular aspects of ecosystem health, so as to enable more informed management of these environments. This will occur through synthesis of current knowledge plus the development and implementation of a standardised monitoring framework to facilitate data collection. The project will engage community groups in the application of this framework and thereby obtain critical baseline information about the status of these coastal systems.

The key research and development (R&D) innovations involved in this project will be in the synthesis of existing knowledge relating to the assessment and evaluation of the health of temperate reef ecosystems, the development of a robust framework for monitoring and assessment of coastal reefs and the quantitative analysis of the data, obtained through community based assessments, in comparison with the assessments made by professional science based organisations.

Collectively this will provide managers, users of the marine environment and the community with a credible and mutually accepted system for the assessment of

coastal reefal environments, which can be referenced by all stakeholders, providing greater levels of certainty and acceptance of management decisions and strategies.

Nationally the general public is developing a greater awareness about matters that relate to natural resource management and particularly the accelerating rate of degradation of coastal marine environments. However, concomitant knowledge and information that would enable the community to take a more overt role in supporting the management of these resources does not match this awareness.

There is therefore, a growing need to equip the community with relevant skills and knowledge about coastal ecosystems. The development of these skills will empower local communities and enable them to take an active role both in community based monitoring and advocacy leading in turn to improved management outcomes at local, state and national levels.

Coastal reefs provide an ideal vehicle for the development of such community based programs. These reefs are important in the provision of both food and habitat for many fisheries species and are also sites that receive high visitation rates for recreational fishing, diving and related activities. They also have a high, and distinct, biodiversity. Importantly, reef systems close to metropolitan areas around Australia (and particularly the metropolitan coast of Adelaide) are degraded due to a combination of factors including waste water disposal, storm water runoff, over-fishing, invasive species and increased sediment mobility (particularly due to associated seagrass losses).

Effective mitigation and rehabilitation strategies can only be developed if managers are informed about the causal linkages between putative impacts and habitat degradation. By developing community-based programs to monitor and evaluate the status of reefs, we can make substantial progress in addressing this need.

Whereas monitoring activities need to be ongoing to provide the best opportunity for early problem detection, marine research is profoundly expensive. The use of well-trained community volunteers will provide an effective way to augment the efforts of other agencies and thus increase overall coverage of coastal ecosystems.

Historical perspective

Surveys of reefs along the metropolitan coast of Adelaide were conducted from 1996 to 1999, and culminated in a report to the South Australian (SA) Environment Protection Authority (EPA) on the status of their ecological health (Cheshire et al. 1998a, 1998b, Miller et al. 1998, Cheshire & Westphalen 2000). The northern metropolitan reefs were highlighted as being in particularly poor condition, gradually improving south of Port Noarlunga. The poor condition of the northern reefs was considered to be due to the high number of anthropogenic inputs (storm water drains, coastal runoff and wastewater discharge) to the area.

These initial surveys stimulated a program to monitor reef health utilising divers from the South Australian Reef Watch program. Reef Watch began as a joint project

between the South Australian Research and Development Institute (SARDI) Aquatic Sciences, the Conservation Council of South Australia, the Marine and Coastal Community Network, University of Adelaide, the Scuba Divers Federation of SA, and other non-government organisations, with support from the Environmental Protection Authority (Marine Protection Fund) and later Coastcare. In particular the University of Adelaide worked closely with the CCSA to trial a series of methods for community-based monitoring of coastal reefs.

The program has moved along in a somewhat ad-hoc manner due to limitations in funding and the inability to adequately resource the development and delivery of appropriate training programs. Regardless, Reef Watch has generated significant community interest for reef monitoring. To date a number of training courses have been run with the support of staff from SARDI Aquatic Sciences, SA Department for Environment and Heritage (DEH), the SA Museum, Flinders University, University of South Australia and the University of Adelaide. These courses have trained divers to recognise the common macroalgae and macroinvertebrates found on SA costal reefs, including invasive and endangered species. Several hundred community divers have undertaken some level of training through the Reef Watch program, and well over 100 have contributed survey data to an on-line database. As part of the current program, the database has been expanded to provide web access to information about coastal reefs and as such it is expected (over time) to expand our knowledge about the status of these reefs in SA. The Reef Watch website (http://www.reefwatch.asn.au) is an exceptional site, which illustrates the scope of what can be achieved by community groups in this sort of program.

Need

Nationally the general public is developing a greater awareness about matters that relate to natural resource management and particularly the accelerating rate of degradation of coastal marine environments. However, concomitant knowledge and information that would enable the community to take a more overt role in supporting the management of these resources does not match this awareness.

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Objectives

1. To develop a better knowledge and understanding of coastal reef ecosystems through:

- Identification of appropriate indices for assessment and development of survey methodologies; and

- Application of these methodologies to obtain baseline and time scale data for coastal reef ecosystems which is relevant to the needs of key management agencies including SA Water, SA Environment Protection Authority, and SA Department for Environment and Heritage.

2. To foster community ownership and participation in monitoring and assessment:

- Through the development of training and education packages; and

- By encouraging and mobilising community participation.

3. To develop a credible assessment program:

- Through the process of training, testing and accreditation of all participants; and

- By undertaking scientifically rigorous evaluation of the community monitoring program.

Objective 1.
A series of three reports was published that directly addressed Objective 1 (hereafter Reports Part 1, 2 & 4):

Turner DJ, Kildea TN and Murray-Jones S (2006) Examing the health of subtidal reef environments in South Australia, Part 1: Background review and rationale for the development of the monitoring program. SARDI Publication Number RD03/0252-3. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Turner DJ, Kildea TN and Westphalen G (2007) Examining the health of subtidal reef environments in South Australia, Part 2: Status of selected South Australian reefs based on the results of the 2005 surveys. SARDI Publication Number RD03/0252-6. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Collings G, Bryars S, Turner D, Brook J and Theil M (2008) Examining the health of subtidal reef environments in South Australia, Part 4: Assessment of community reef monitoring and status of selected South Australian reefs based on the results of the 2007 surveys. SARDI Publication Number F2008/000511-1. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Two scientific papers were also submitted to journals as part of Objective 1, and are reproduced on the accompanying CD:

Connell SD, Russell BD, Turner DJ, Shepherd SA, Kildea T, Miller D, Airoldi L and Cheshire A (2008) Recovering a lost baseline: missing kelp forests from a metropolitan coast. Marine Ecology Progress Series. 360: 63-72.

Turner DJ and Collings GJ (2008) Subtidal macroalgal communities of Gulf St Vincent. In: Natural History of Gulf St Vincent (Eds Shepherd SA, Bryars S, Kirkegaard I, Harbison P & Jennings J) pp. 264-278. (Royal Soc. S. Aust., Adelaide).

Objective 2.
This objective was addressed through a number of activities including:

- Supporting the community Reef Watch program wherever possible;
- Conducting a series of community identification workshops;
- Production of training manuals;
- Production of two DVDs on temperate reefs, containing a total of seven short (5-8 min) documentaries;
- Supporting an upgrade of the Reef Watch website; and
- Production of a schools education package.

In addition, a report has been published on the potential for community representatives to undertake environmental monitoring (hereafter Report Part 3):

Turner DJ, Brook J and Murray-Jones S (2006) Examining the health of subtidal reef environments in South Australia, Part 3: An evaluation of the potential for the community to undertake environmental monitoring of temperate reef habitats: A review of the South Australian Reef Watch Program. SARDI Publication Number

RD03/0252-7. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Reef Watch itself has been the driving force behind much of the community participation aspects of the project, and has done a lot over many years to foster community involvement and understanding of reefs. Their success in this has been acknowledged in recent years by a number of awards:

2005	Civic Trust (Natural Category)
2007	National Science Week: Unsung Hero of South Australian Science (Highly Commended)
2007	Premier's NRM Award for Outstanding Integrated Volunteer Project (Winner)
2007/08	Coastcare (State Winner, going to National Coastcare finals in October 2008)

Objective 3.
This objective was addressed through a number of activities including:

- Training of community divers;
- A thorough evaluation of the potential for community divers to undertake reef surveys (Report Part 3); and
- A quantitative comparison of data collected from the same reefs by community and scientific divers (Report Part 4).

The present report provides a synopsis of Reports Parts 1-4 and the various other activities as they pertain to Objectives 1-3.

Objective 1: Developing a better knowledge and understanding of coastal reef systems

1.1 Introduction

While coastal reef systems are intensively studied worldwide, there are still substantial gaps in our understanding of how they function. In particular, South Australia has a number of unique features that mean an understanding of reef functioning in other biogeographic regions, such as the east coast of Australia, cannot simply be transferred to the local context. While intrinsically interesting in its own right, understanding how coastal reefs function also has important management implications. Much of Australia's population lives on or near the coast, and most of our major population centres are on the coast. In South Australia, the capital Adelaide (population ~1.2 million) lies on the coast of Gulf St Vincent, and as a consequence coastal water quality has declined substantially in the period since European settlement. This deterioration is caused by a combination of domestic wastewater disposal, industrial effluents, and stormwater runoff, all of which increase pollutant and sediment loads in the gulf. As a consequence, coastal habitats have declined in quality over the last 50 or so years for which adequate records have been kept. As an example, there has been in excess of 5000 ha of seagrass lost along the Adelaide metropolitan coast (Hart 1997), which has substantial social and economic implications in relation to such ecosystem services as beach protection and recreational fishing (e.g. Fonseca & Fisher 1986, Connolly et al. 1999). Concomitantly, the health of coastal reefs has also declined along the Adelaide coast, with a clear trend in community structure being detected from north to south in earlier surveys (Cheshire et al. 1998a, 1998b, Miller et al. 1998, Cheshire & Westphalen 2000).

As a consequence of this documented decline in reef health along the coast, and over time, a key objective of this project was to develop a better knowledge and understanding of coastal reef ecosystems through:

1. Identification of appropriate indices for assessment and development of survey methodologies

2. Application of these methodologies to obtain baseline and time scale data for coastal reef ecosystems which is relevant to the needs of key management agencies including SA Water, EPA, and DEH

The first step in this process was to review the existing knowledge with respect to the functioning and status of reefs in South Australia, as well as the potential methods for assessing reef health. This was then followed by the development of a suite of relevant indices, and an extensive series of surveys of reefs along the Adelaide metropolitan coast, as well as from the Yorke and Fleurieu Peninsula's, in 2005 (see Figure 1.1). A follow-up survey of Adelaide metropolitan reefs was then conducted in 2007, to assess how their status had changed over the two-year period. Each of these components has been reported in detail in a series of separate reports produced

as a part of the project. In addition, two scientific papers have been submitted for publication (reproduced in the CD that accompanies this report). These reports are summarised below, and are reproduced in their entirety on the accompanying CD.

1.2 Review of existing information and rationale for development of the monitoring program

The following is extracted from Turner, Kildea & Murray-Jones (2006).

> This is the first report of a series focussing on improving the capacity for monitoring and assessing the health of temperate reef ecosystems. The main objective of this report is to provide a summary of our current understanding of reef environments, and how to measure their 'health'.
>
> Temperate reefs occur across the southern half of the Australian continent, where consolidated sediments or rocky seabeds provide a site for settlement and attachment of algae and sessile invertebrates. In South Australia, most shallow reefs are dominated by macroalgae, which often form dense multilayered assemblages. These environments are important in providing a number of ecosystem services including: primary production; carbon storage and flow; nutrient cycling; disturbance regulation; climate regulation; erosion control; remineralisation; biological control; recreation; tourism; education; indicators of global change; coastal protection; habitat and refuge; food; raw materials; genetic resources; and natural heritage.
>
> A range of biotic and abiotic process shape the structure of the reef community, and some of these occur as a direct consequence of, or are modified by, anthropogenic activity. Generally accepted threats that have the potential to negatively affect reef function include: elevated sedimentation; nutrient enrichment; increased abundance of opportunistic species and invasion by exotic taxa; climate change; toxicants; and extractive resource use. It is the consequence of these anthropogenic inputs on near-shore marine ecosystems that often lead marine researchers and the public to question whether a particular ecosystem is "healthy" or not.
>
> The term "ecosystem health" is increasingly being used in public and scientific forums, and maintaining the health of an ecosystem is an active goal for many environmental managers. Defining the key elements of a healthy ecosystem is often subjective, particularly when considering the enormous complexity of marine ecosystems. A simplistic definition is perhaps to describe ecosystem health as a function of the key processes that operate to maintain a stable and sustainable ecosystem.
>
> There are a number of approaches that can be utilised to assess ecosystem health. One method of determining the health of an ecosystem is to use biological indicators, which are able to integrate, characterise and simplify complex ecological information. This report discusses the applicability of utilising a variety of different indicators to assess reef health.
>
> Once indicators have been chosen, sampling programs are used to collect data. An important aspect of the sampling program is the design. As a general rule sampling programs need to be replicated in both time and space, and should include control sites, which are sites that are not impacted by anthropogenic influences. Programs should also focus on a range of trophic levels within the system and be backed by a solid understanding of the types of processes that structure the community.

This report provides the following recommendations for establishing a monitoring program to assess reef health:

- Indicators should be chosen to represent important facets of the ecosystem including structural components and integral processes;
- Trigger values need to be set for the various indicators;
- Protocols must be established that outline what actions are to be taken when a trigger value is crossed, and these must have the support and backing of the relevant management agencies;
- Sampling programs should be non-destructive wherever possible to minimise the impact of repeated surveys;
- Consideration needs to be given to methodological protocols that can be adopted by volunteer divers. Alternatively compatible methods should be developed that will serve broader community use; and
- Effort should be placed into fostering greater community involvement in reef monitoring initiatives through program development and education initiatives.

1.3 2005 Surveys

The following is extracted from Turner, Kildea & Westphalen (2007).

Concern over the degradation of Adelaide's metropolitan reefs led to the development of a number of environmental monitoring and research initiatives. The first Reef Health survey was initiated in 1996 and expanded in 1999, with a follow-up survey completed in 2005. The 2005 survey program was considerably extended compared to previous surveys and aimed to achieve a number of objectives including:

1. An up-to-date assessment of the condition of reefs along Adelaide's metropolitan coast;
2. A comparison of the condition of reefs in 2005 with past observations (1996 and 1999) to determine whether there was any shift in the structure of the biological communities associated with the metropolitan reefs;
3. The development and interpretation of a number of indices to assist in determining the status of reef health;
4. The establishment of baseline information for reefs in non-metropolitan areas (specifically Fleurieu and Yorke Peninsulas); and
5. A comparison of metropolitan with non-metropolitan reefs.

Generally, the north to south gradient in reef health observed across metropolitan reefs in 1996 and 1999 was also observed in 2005. Based on macroalgal functional group composition and cover, northern metropolitan reefs (sites from Semaphore to Broken Bottom) appear to be in poor condition, with red foliaceous and turfing macroalgae

dominating. There are signs of further declines (compared to previous surveys) on central metropolitan reefs (from Seacliff to Southport), in particular those at Horseshoe Reef and some sites on Noarlunga Reef, with a loss of robust brown macroalgae, establishment of mussel mats, and in some instances, the development of large areas of bare substrate. Southern reefs (Moana to Aldinga) have remained much the same and appear healthy, retaining most of their robust macroalgal canopy.

Similar analyses of macroalgal cover and composition at sites surveyed during 2005 on Yorke Peninsula (11 sites) and Fleurieu Peninsula (8 sites) found reefs were generally healthy, particularly when compared to metropolitan reefs. However, there was a high level of variability within regions. Some sites (notably Point Souttar and Point Riley on Yorke Peninsula) had a relatively low cover of canopy macroalgal species, but this cannot necessarily be interpreted as poor condition without further information.

In order to obtain a more robust indication of reef status, we developed ten additional health indices. To get an overall value for any particular reef, the set of indices are averaged to obtain an overall score. The reef was then scored, and grouped into one of three categories (Poor Condition, Caution Recommended and Good Condition).

This 'stoplight' approach indicated a more complex picture than simply scoring on macroalgal functional group cover. A large number of sites across the metropolitan region fell into the Caution Recommended category, even within the generally healthier southern zone (see Figure 1.1). Similarly, a few sites on the Fleurieu Peninsula coast (Granite Island and Port Elliot) rated Caution Recommended status, while four sites on Yorke Peninsula rated either Caution Recommended (Troubridge Point and Cable Hut Bay) or Poor Condition (Point Souttar and Point Riley). None of the non-metropolitan sites scored as low as northern sites on the Adelaide metropolitan coast. This is a very preliminary approach and the 'stoplight' method has drawbacks. For example, Point Souttar is in an area of naturally low current flow and high sedimentation, and may never have supported large canopy macroalgal species. Invertebrate diversity was high at this site; however, the nature of the indices used has meant that this reef has ranked low. It is important to remember, for all sites, particularly those sampled for the first time, that the data provide a snapshot of the system. The real value of this type of survey is that it will act as a baseline and enable comparisons over time.

The indices employed are not perfect; however, they are informative, with the summary average probably being the most useful. The use of a range of indices targeting different ecological aspects of reef ecosystems has led to a better understanding of the nature and complexity of these communities. Furthermore, the results and interpretations presented in this report highlight the difficulty associated with producing a robust but practical approach to assessing reef health.

To really understand the overall health of reef systems, a greater understanding of the interactions between the biological assemblages and their environment is needed. This would allow predictions to be made about the types of communities that could be expected in different environments. This would also assist in assessing impacts from anthropogenic sources. The development of indices employed in the interpretation of reef health is an evolving process that will be refined in tandem with increasing knowledge of the dynamics of southern temperate reef systems.

Additionally, different types of putative impact should be targeted, such as industrial areas; reefs in proximity to coastal developments; and reefs subject to different fishing intensities or other extractive industries. Such data will further expand our knowledge

of what constitutes a 'healthy' reef, and assist in the development of management and remediation strategies for reef systems.

The following recommendations are made:

- Baseline data needs to be collected from other reefs across South Australia (Eyre Peninsula, West and South-east coasts). A range of sites including near pristine and potentially impacted areas should be included;

- Data should also be collected from areas of high conservation value as well as those areas likely to be subject to human impact;

- Further (and more focused) monitoring should be carried out for sites which are rated Poor Condition or Caution Recommended by the stoplight approach;

- The link between abiotic factors (e.g. substrata composition, wave exposure) and the biotic assemblages present on a reef requires further investigation. This would allow biologists to make predictions (which can then be tested) about the types of biotic assemblages that should be expected under various conditions;

- The reef health indices need to be further refined, and preferably augmented with data on keystone species. The concept of indicator species should be further investigated;

- The potential influence of climate change on reef ecosystems needs investigation;

- The potential impact of seagrass loss off Adelaide on reef health should be investigated;

- Community-based reef-monitoring initiatives (e.g. Reef Watch) are a cost effective method for increasing the volume of information that can be collected, and should be supported.

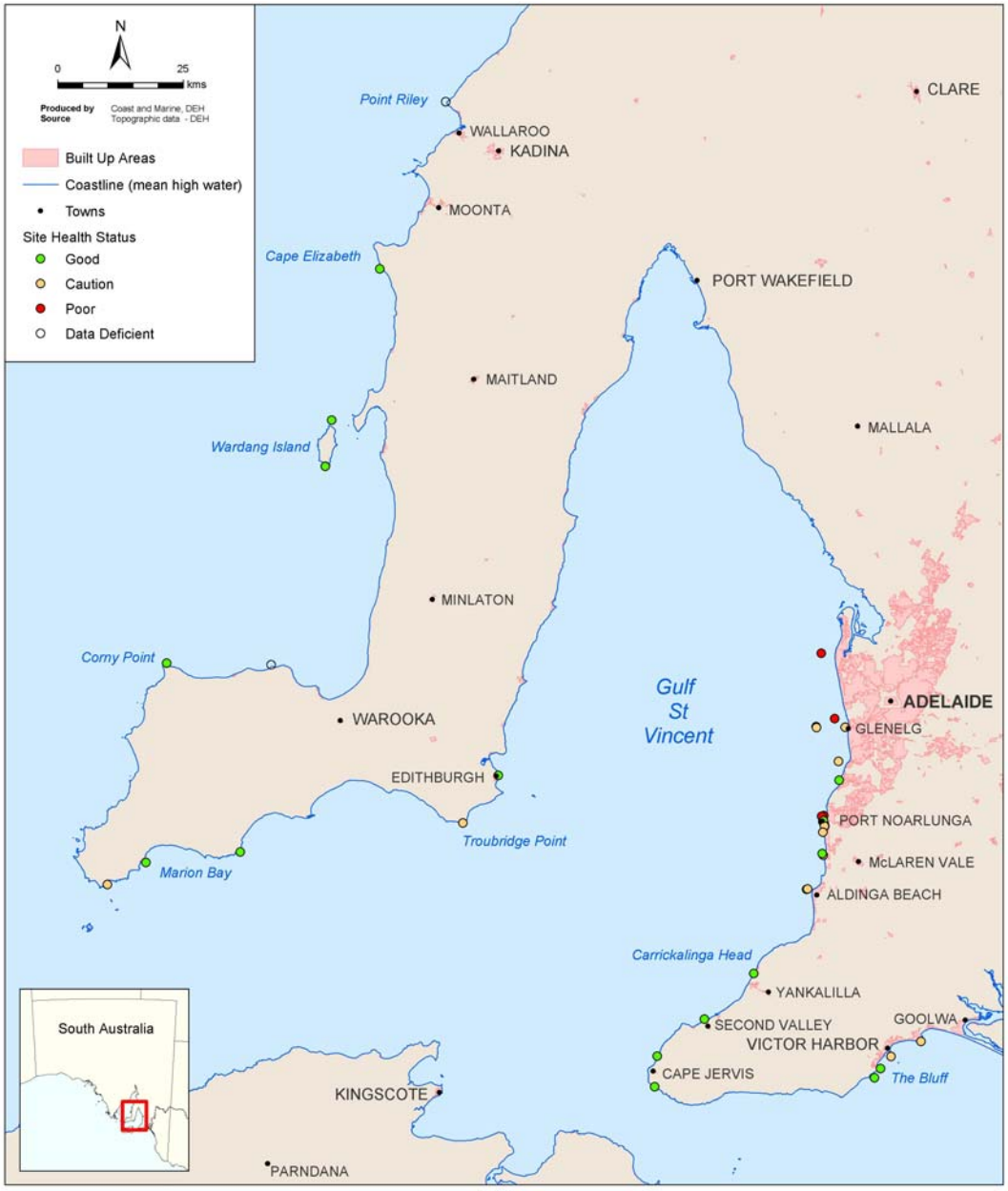

Figure 1.1: Map showing location of reefs surveyed in 2005, along with their status.

1.4 2007 Surveys

The following is extracted from Collings et al. (2008).

> Concern over the degradation of Adelaide's metropolitan reefs has led to several Reef Health scientific surveys since 1996 and the ongoing community Reef Watch monitoring program. The last survey was conducted in 2005, and the subsequent report provided a health ranking for a number of reefs adjacent to Adelaide. The present report extends the 2005 survey report by:
>
> 1. Providing an up-to-date assessment of the condition of Adelaide's reefs;

2. Comparing the condition of Adelaide's reefs in 2007 with the 2005 survey to determine whether there has been any change in reef health rankings; and

3. Comparing the 2007 scientific and community data for monitoring reef health to assess the efficacy of community monitoring.

The reefs of Adelaide and Fleurieu Peninsula showed the same broad pattern in 2007 as when they were previously surveyed two years earlier as part of the same project. Based on the line-intercept transect data, there were two major groups of sites, representing the northern and the southern reefs and, quite separate to these two groups, the two apparently impacted reefs -- Broken Bottom and Semaphore. The inclusion this year of a reef to the north of these (and yet away from the influence of metropolitan Adelaide) allowed us to demonstrate that the poor condition of these reefs did not simply represent the northern extent of a natural north-south geographic trend. Rather, some other influence, probably associated with urban Adelaide, was evident.

Long-term trends since 1996 seem to indicate a general improvement in the status of reefs along this coast. This may be a biotic reflection of the cessation of some dredging operations or of a decrease in the nutrient loading from wastewater treatment plants, and provides circumstantial evidence that such an improvement in practices has the potential to allow recovery of impacted reefs. Nevertheless, the poor condition of the reefs closest to metropolitan Adelaide indicates that further improvements are required.

A comparison between the dataset of the Reef Health program and that collected by Reef Watch, a community-based monitoring initiative, showed a very similar picture when employing multivariate analysis to study the line-intercept transect data. To a large extent, where discrepancies arose, it is likely to be the result of medium-scale spatial variation (i.e. sampling different areas) rather than a real difference between the data collectors. Having said this, there were some minor taxonomic issues, which, once addressed, will improve the Reef Watch monitoring.

Assessment of the reefs based on the Reef Health Index (Turner et al. 2007) demonstrated greater disparity between comparable datasets than was the case for the LIT analysis – i.e. the 2005 v 2007 datasets, and the Reef Health v Reef Watch datasets. This is probably due to inadequate methodology for the assessment of mobile fauna (in particular, greater temporal replication is required), and the fact that the mathematical model used to calculate the index is in its early stages and will develop greater utility and accuracy with continuing use and development.

The following recommendations are made:

- Reef monitoring should continue;

- In combination with some professional guidance, community-based monitoring programs (in particular Reef Watch) offer an excellent vehicle for this work which should be encouraged and resourced appropriately;

- A broader range of reefs should be surveyed, possibly at the expense of the frequency of re-survey;

- The protocols utilised by the Reef Health program should be continued with the following modifications:
    - Transects should be marked with permanent endpoints;
    - Photographic transects should be adopted where possible;
    - Alternative methods of assessing mobile fauna for the reef health index are required; and
    - Attention needs to be paid to calculation of individual indices, particularly the appropriateness of a “null” score.
- Improvement to water quality since the mid-1990s should be lauded and continued improvement should be encouraged if we are to see recovery of the most impacted reefs.

Objective 2: Fostering community ownership and participation in monitoring and assessment

2.1 Introduction

There is a lack of appreciation and understanding of the threats marine habitats face in comparison with terrestrial habitats. To many people, subtidal marine habitats are out of sight, out of mind, and the general public is simply not aware of what is even present, let alone how it is threatened. This lack of awareness is changing, however, and it is becoming more common for people to consider the implications for the marine environment. This change is being brought about by the activities of committed individuals and groups, as well as governments, in promoting an awareness of the marine environment. In South Australia, one of these groups is Reef Watch, which has been training divers to undertake reef surveys for over ten years, and educating them about the threats to reefs of South Australia.

To further public knowledge of the status of reefs off Adelaide, and to assist Reef Watch with their activities, one of the project's objectives was to foster community ownership and participation in monitoring and assessment:

- Through the development of training and education packages; and
- By encouraging and mobilising community participation.

To meet the above objective, this project has involved considerable extension activities, particularly in association with Reef Watch, to continue to increase public awareness of the marine environment in general, and specifically the status, and indeed presence, of reefs off the Adelaide coast. Project staff have been integrally involved in a number of Reef Watch activities, and a variety of extension products have been provided to the general public and South Australian schools. Many of the extension activities undertaken have focussed specifically on encouraging community members to become directly involved in the monitoring and assessment of reefs off Adelaide, while others have been targeted more broadly at raising awareness.

2.2 Extension activities

2.2.1 Marathon Dive(s)

The Marathon Dive is an annual event organised by Reef Watch to survey marine life at Port Noarlunga Reef. Community divers participate throughout the day, and survey algae, macroinvertebrates and fish. The aims of this activity are twofold. Firstly, gathering a large number of divers together generates substantial publicity for Reef Watch, improving community understanding of the group's aims and the threats faced by our metropolitan reefs, and attracting new members. Secondly, the dive is conducted at the same time every year, using broadly the same protocols, and thus it has generated a time series of data that can be used to look for trends during the past 8 years since its inception. In 2005, the marathon dive was conducted on 13th March,

and 80 divers/snorkellers participated. In 2006 and 2007, dives were conducted on the 19th & 18th March respectively, although the numbers of divers were not recorded.

2.2.2 Reef Watch training

Over 200 divers have completed training for the Reef Watch program. This training is conducted by qualified scuba instructors, and leads to a PADI specialty certification (PADI Reef Watch Survey Diver). Students are trained how to utilise standard survey techniques, including line intercept transects for surveying macroalgae, and belt transects for macroinvertebrates and fish. They are also trained in identification. Training materials are available via the Reef Watch web site (http://reefwatch.asn.au). Reef Watch training was extended away from Adelaide to the regional centers of south-east SA, Victor Harbor, Kangaroo Island, Yorke Peninsula, Whyalla and Port Lincoln for the first time. In addition, there has been active engagement with the Narrunga aboriginal community at Point Pearce, on Yorke Peninsula, who are keen to undertake training and participate in monitoring. The engagement of the Narrunga community has been so successful that funding has been offered to pay for some of them to train for their scuba diving certification. All training is co-ordinated by Reef Watch, with the active participation of a number of marine scientists from the agencies involved in the Reef Health program.

2.2.3 Quiz nights

A number of Reef Watch quiz nights were held with a focus on marine information relevant to undertaking reef monitoring and related activities. These nights were well attended with up to 150 people from dive clubs, agency staff, scientists, conservation groups and naturalists. These quiz nights were held on Friday 29th July 2005, Friday 20th October 2006, and Friday 12th October 2007.

2.2.4 Community education workshops

A number of community education workshops were held during the project (17th October 2004, 13th November 2005), as well as four workshops for individual dive clubs. These workshops are well attended by community members, and are a good vehicle for increasing community understanding of our reefs, as well as for training divers involved in Reef Watch monitoring to improve their taxonomic capabilities. The community Reef Watch program, with technical support and intellectual input from staff from a range of agencies involved in the Reef Health program, coordinates the workshops. The workshops are expected to be an ongoing feature of the Reef Watch program after the completion of the current project (FRDC 2004/078).

2.2.5 Brochures

Two thousand five hundred copies of a full-colour brochure (Figure 2.1) were printed and distributed through appropriate outlets (e.g. dive shops, fishing tackle shops). The brochures contained information on southern Australian reefs, threats to reefs, the existing FRDC project and 2005 survey outcomes, and what people can do to help (e.g. join Reef Watch, reduce litter/pollution etc).

Figure 2.1: Reef health brochure distributed to public.

2.2.6 Newsletter

Reef Watch established a quarterly newsletter, the 'Reef Watcher' in 1998. Currently it has a print distribution of 600 and an electronic distribution of over 450. 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 Dives 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.

2.2.7 Website

The Reef Watch website was updated with a summary of the current FRDC project and outcomes, and links to completed project documents (Parts 1-4) and reef identification guides. Online information, quizzes, slates, manuals and an interactive database are available on the Reef Watch website: http://reefwatch.asn.au. Members are able to submit their survey data after which a number of automated checks are made on the data. All surveys are individually tagged making it relatively easy for a moderator to screen data for quality control. As well as providing a vehicle for Reef Watch divers to enter their data and obtain updated training materials, the web site also has a community education focus. As such, a number of relevant reports and other information are available to the general public.

2.2.8 Open Day

An educational stall was staffed by members of the Reef Health program during a SARDI Aquatic Sciences Open Day (26th February 2006), which was attended by about 3,500 people. This stall included a variety of static materials, but revolved around an interactive touch tank, which proved to be extremely popular with people of all ages (Figure 2.2). For many, this was one of their first opportunities to actually see and interact with local marine life.

2.2.9 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 two 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 are the Conservation Council of South Australia's 'Connect 07' conference, at the State Natural Resources Management Forum, and at community group events such as field days. These opportunities are an effective way to interact 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 quickly.

Figure 2.2: Members of the public enjoying the touch tank organised by the Reef Health program at the SARDI open day.

2.2.10 Intertidal monitoring

Reef Watch also began an intertidal monitoring program with support from the Reef Health program, the Conservation Council of South Australia, and particularly Flinders University (see Figure 2.3). This program now has four groups doing regular surveys, and is also set to be expanded to regional areas. There has been particular interest in this activity from a number of schools, as it is an activity that students of a range of ages can participate in, unlike the subtidal monitoring.

Figure 2.3: Brochure created to advertise the advent of the new intertidal reef monitoring program run by Reef Watch.

2.2.11 Reef Health documentaries

A series of seven 5-9 min documentaries were commissioned for the project (see Figure 2.4). Masters students in the Department of Screen Studies (Natural History Film Making) at Flinders University produced these documentaries as part of their studies, with funding and footage provided by the Reef Health project, as well as input into the scripts. These documentaries are reproduced on the DVD accompanying this report.

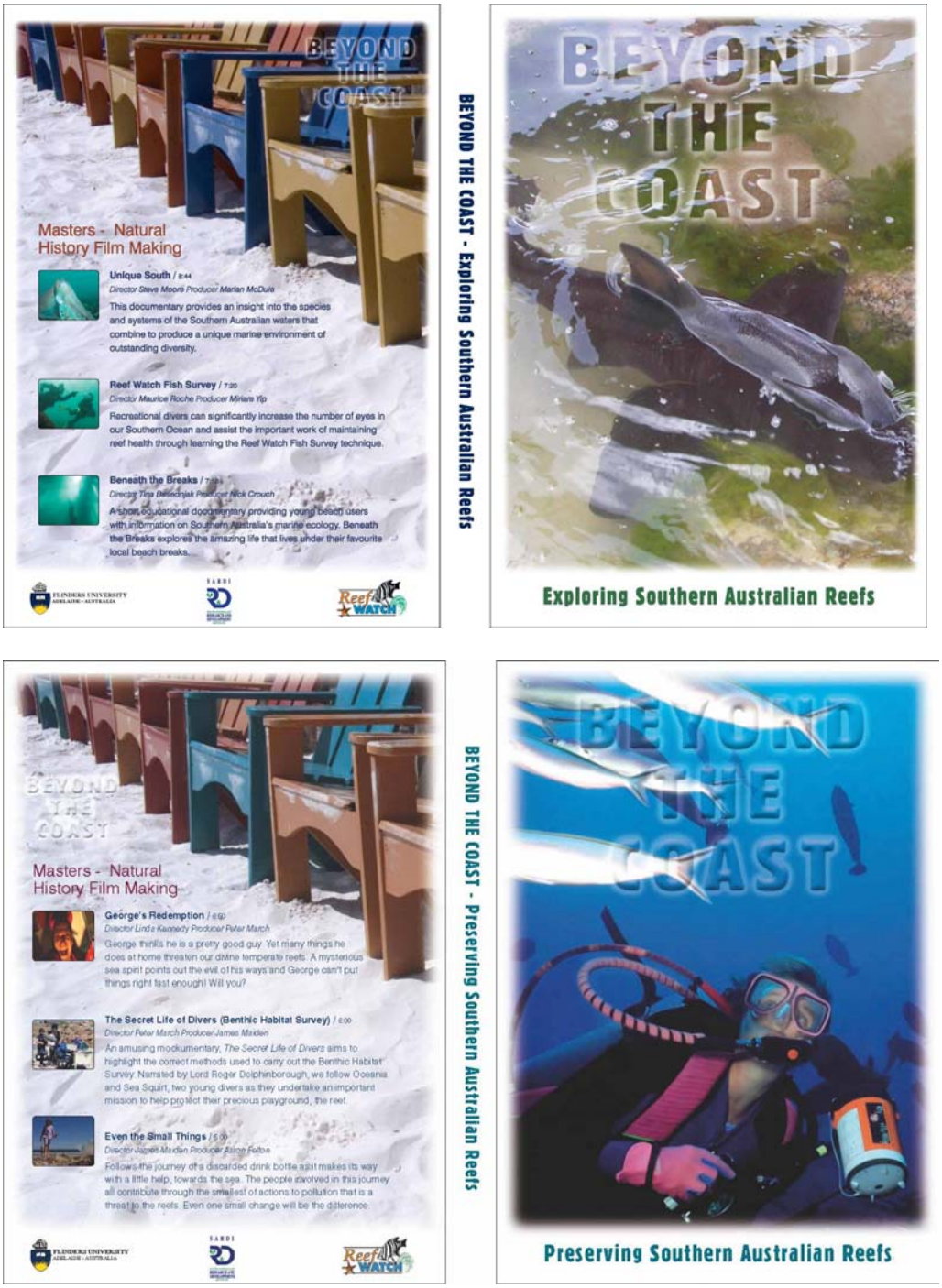

Figure 2.4: Covers for the two DVDs produced containg the seven short documentaries for the project.

2.2.12 School education

Alexandra Gaut (Octopus Education) was contracted to develop an education package for schools. This package was based in part on the outcomes of the 2005 reef health surveys, as well as the documentaries produced by Flinders University. The major issues surrounding reefs and reef health are discussed in the package, along with their ecology, threats to reefs, and what can be done to help preserve and improve them. The following is a summary of what she undertook and her views of how it was received.

> From November 2006 - June 2007, Octopus Education was contracted to produce an educational resource for schools, focused around the topic of temperate reefs as part of the Reef Health Program.
>
> As a final part of the delivery of this resource, Octopus Education provided South Australian teachers with opportunities for professional development using the new educational package. Four workshops were provided at:
>
> 1. Hallett Cove R-12 School;
> 2. Victor Harbor High School;
> 3. Ocean View P-12 College, Taperoo; and
> 4. Tenison Woods College, Mount Gambier.
>
> The teacher workshops consisted of a PowerPoint presentation about temperate reefs, one of the movies from the 'Beyond the Coast' DVDs, an opportunity to use the CD-ROM, the opportunity to view preserved specimens of South Australian marine organisms, and opportunities to view marine education resources such as books, posters and other CD- ROM s and DVDs. Each workshop participant got to take away a copy of the CD- ROM, the pair of 'Beyond the Coast' DVDs and an information sheet about temperate reefs produced by DEH and SARDI Aquatic Sciences.
>
> Octopus Education also serviced all three campuses of Kangaroo Island Community Education - providing students of all ages with workshops about temperate reefs, including a presentation and preserved specimens.
>
> A total of 45 teachers attended the workshops, with very positive initial responses with the following themes:
>
> - Teachers appreciated having time to use the CD- ROM ;
> - Teachers appreciated having other marine education resources to look through;
> - Interesting and clear information, presented in an enthusiastic and knowledgeable way;
> - Great images and great to see movie footage of local marine habitats;
> - Teachers appreciated that the CD- ROM was based around South Australian habitats and species;

- Teachers appreciated getting 'freebies' to take away and use immediately in class and to share with other teachers; and

- Many teachers already started getting ideas for teaching activities whilst in the workshop.

Samples of feedback statements:

- 'amazing amount of info. - so expertly passed on';

- 'It was well presented. There was a wealth of new knowledge that was willingly shared. There was a variety of resources. There were things for us to use straight away at school';

- 'Fascinating, well-presented approach using powerpoint with explanations of slides';

- 'very interesting, relevant and helpful information';

- 'lots of good ideas'; and

- 'very clear explanations';

Many teachers suggested that a follow-up workshop be conducted on a weekend, when they could go on a field trip to some coastal and/or marine habitats to learn *in situ* about the habitats and species, as well as activities to do with students outdoors.

The CD- ROM was even requested by, and sent to, interstate teachers who had heard about the workshops but could not attend and felt that such a resource was missing in their state. A few South Australian rural teachers also requested the CD- ROM and the feedback from one teacher stated 'What a rich resource. It is PERFECT for our R-12 Area School. Thank you.'

I believe the resource will be extremely valuable for teachers across a range of year levels and across the State. I look forward to being able to help publicise the final version and having a relevant, curriculum-linked, state-based marine education resource enter schools by the end of 2007.

Figure 2.5: Picture from Kingscote and Parndana schools showing the education package being trialled (photo credit: Judith Wingate).

Objective 3: Developing a credible assessment program

3.1 Introduction

To adequately protect our coastal reefs from continued development activity and other stressors, it is first necessary to understand how they are changing over time. Without being able to rigorously document a decline in health, it is unlikely that management agencies will expend substantial resources on fixing a problem that may not exist. To this end, there have now been four scientifically conducted reef health monitoring exercises since 1996 along the Adelaide metropolitan coast (and further afield in 2005). While each of these has covered a different number of reefs, it seems clear that there is a trend of declining health from south to north along the metropolitan Adelaide coast, and over time (Turner et al. 2007, Collings et al. 2008). However, these surveys are expensive, and thus cannot be conducted on an annual basis, nor on a large number of reefs at each survey. It is thus important to explore alternative mechanisms for obtaining data on reef health over time, which can be used both to document long-term trends and to provide an early warning of major rapid changes. One way of doing this is to engage community members in a monitoring program. For this approach to work in the long-term, it requires that volunteers be adequately trained, and that the data they collect can stand up to scientific scrutiny. In particular, it is important that the data collected by volunteers is shown to show comparable trends to that collected by scientific divers, although they do not necessarily have to be as detailed as those collected by trained scientists.

A key objective of this project is thus to use the existing Reef Watch program to develop a credible assessment program:

- Through the process of training, testing and accreditation of all participants; and
- By undertaking scientifically rigorous evaluation of the community monitoring program.

The first step in meeting this objective was to review the Reef Watch program, and evaluate the potential of trained community divers to undertake environmental monitoring (Turner, Brook & Murray-Jones 2006). The results of this review, and the increased understanding developed from the 2005 surveys, were then used to refine the Reef Watch protocols, and to help enhance the training program provided to volunteers. Finally, the data collected by volunteer divers were rigorously compared to those collected during the 2007 surveys by trained scientific divers.

3.2 Review of the Reef Watch program

The Reef Watch program was reviewed early in the project to assess its strengths and weaknesses, and to evaluate the potential for volunteer divers to undertake environmental monitoring of reefs in a sufficiently rigorous way. The results of this

review are presented as a separate report (Turner, Brook & Murray-Jones 2006), which is summarized here.

Community involvement in monitoring is becoming widespread and numerous examples are available from disciplines including meteorology, sociological, as well as a range of terrestrial and marine biological surveys. Successful community monitoring programs generally have strong linkages between community organisations and professional scientists. Community monitoring initiatives generally aim to gather, process and disseminate data of sufficient quality to facilitate management.

This report aims to provide an assessment of the potential use of volunteer recreational divers as part of a structured reef-monitoring program. Key factors such as diver aptitude, professionalism, and physical ability are identified and addressed. Assessments are made of the available resources and support structures necessary to operate such a program. The report examines the framework for a community-managed program and whether there is sufficient long-term interest to sustain it. This report does not provide an examination of the quality and reliability of data collected by such a program, as this is the subject of a future report.

In South Australia, a community run monitoring program known as Reef Watch has been operating since 1997, with joint aims: monitoring reefs using recreational divers; and educating the community to facilitate involvement in coast and marine management. Most of the examination of recreational diver potential in this report is based on experience in South Australia from the Reef Watch program.

Divers involved in the Reef Watch program generally approach training and the survey program with enthusiasm. Not all divers are able to immediately grasp the underlying principles of the survey methods, and many have trouble with certain aspects of identification; however, those that continue with the program generally improve with experience. Ongoing training and the need for a process of accreditation are particularly important.

Availability of divers (at least in the metropolitan area) is not a limiting factor for the program. Diver numbers have been strengthened through the involvement of a dozen recreational dive clubs (with memberships ranging from 20 to 500). Increased stewardship is also gained through an ‘Adopt a Reef’ program, which encourages clubs to regularly monitor a specific site.

Funding support for the program has allowed Reef Watch to subsidise monitoring activities by providing free training and monitoring kits. Current funding arrangements for the program are sufficient to maintain the employment of two part-time staff, one of whom is also a dive instructor, to oversee and coordinate the program, and provide training. A second instructor is also employed to cover additional training during peak periods.

Strong support is provided to the program in terms of expert assistance. Technical support is provided primarily through the program’s steering committee, which comprises a range of expertise including science, operations, and education. A number of government departments, research agencies and community organisations are represented on the steering committee.

Conclusions and recommendations

There is considerable support for community-based monitoring programs, both from management agencies and from the community itself. In general, community monitoring programs 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.

A number of issues have been raised in this report as being critical to the future of any such program. These include the following points:

- the program needs adequate support, both in terms of money and resources, and people's time. Support is needed from local agencies, experts, as well as from volunteers and community groups;
- the survey methods should be within the capability of divers to master and physically manage;
- participation needs to be kept affordable for volunteers, both in terms of costs and the time commitment expected;
- information should be disseminated appropriately and frequently;
- training should be continuously assessed and adjusted;
- appropriate training resources are needed and should be continually updated;
- in-water training is essential; and
- continuity of funding and hence the provision of a paid coordinator greatly facilitates progress and prevents loss of momentum.

Reef Watch provides a useful working model of a successful community reef-monitoring program. A number of shortfalls in the program have been addressed, and the program is generally regarded as successful. In South Australia, to build on the success of the existing Reef Watch program, this report makes the following recommendations:

- a communications strategy should be developed and updated regularly;
- efforts should be made to secure long-term funding. Looking forward and developing alternative funding strategies should be kept as a high priority;
- quality control and quality assurance are critical. At some point, validation of the methods, as well as the precision and accuracy of data collected by Reef Watch volunteers, is required to deflect criticism and maintain credibility; and
- there is scope for additional technical input into the program and additional research into indicators that could provide a focus for monitoring and facilitate reporting.

3.3 Refinement of Reef Watch protocols and training

As a consequence of the review of Reef Watch discussed in section 3.2, and reported in detail in Turner, Brook & Murray-Jones. (2006), it was decided to only make a few minor changes to the Reef Watch protocols and training. In particular, the original methodology required that benthic taxa be allocated to 1 of 38 classes, and the review identified that many participants struggled with this large number. As a consequence, the lifeforms have now been stream lined into 18 groups, which are much easier to remember and to identify (Table 3.1).

Table 3.1: Life-form codes used by Reef Watch for benthic surveys

PLANTS	*brown*	*red*	*green*
The leathery kelp *Ecklonia*	**BKelp**		
Other canopy forming plants (>20cm)	**BBig**	**RBig**	**GBig**
Smaller plants (<20cm)	**BSmall**	**RSmall**	**GSmall**
Corraline algae		**RCoral**	
Sea lettuce			**GLettuce**
All seagrass			**GRass**

Animals	Mobile animals	**MOban**
	Mussel beds	**MUssels**
	Other attached animals e.g. sponges	**ATtan**
COVER	Turfing – “moss” (<2cm)	**TUrf**
	Encrusting - "paint"	**ENc**
	Rock or rubble	**ROck**
	Sand, mud or deep silt (>5cm thick)	**SAnd**
	Missing data	**DDd**

3.4 Comparison of volunteer and scientific data

Testing of the ability for community divers to collect useful monitoring data has been undertaken on several levels. Initially, this testing is through a training process whereby divers are taught and then assessed on their ability to identify life forms and correctly use the survey protocols. This process occurs through a combination of interactive self study resources available on the Reef Watch website, community workshops, and in-water activities involving instructors. Divers receive accreditation for this training through a specialty diver qualification (Reef Watch Survey Diver) which is administered through the Professional Association of Diving Instructors (PADI). Further details and a list of current activities are available here: http://www.reefwatch.asn.au/inwater.shtml. At the time of writing, 66 divers had received certificates of competence, and a further 90 were partially trained. A second level of testing was undertaken following the review of Reef Watch (section 3.2, and reported in detail in Turner, Brook & Murray-Jones 2006) whereby data collected by

community volunteers was analysed using the same method as used in the reef health surveys, and the calculated index values compared. Results from this trial were promising. Table 3.2 shows overall index results for sites where sufficient Reef Watch data were available for comparison. RH-Actual is the reported Reef Health score based on surveys using trained professionals. RH-Modified is a modified score, necessary because not all indices could be computed from the Reef Watch database. The third column shows the scores calculated using Reef Watch volunteer data.

Table 3.2: Preliminary comparison of Reef Health (scientific) and Reef Watch (community) data using the Reef Health index. Letters represent G = good, C = caution and P = poor.

Site	RH-Actual	RH-Modified	Reef Watch
Site A	76 **G**	74 **G**	78 **G**
Site B	45 **C**	54 **C**	46 **C**
Site C	76 **G**	100 **G**	81 **G**
Site D	34 **P**	25 **P**	22 **P**
Site E	38 **C**	27 **P**	28 **P**
Site F	72 **G**	100 **G**	85 **G**
Site G	72 **G**	69 **G**	75 **G**

As can be seen, there is a good degree of concordance between the scientific and volunteer sampling programs. Some variation (other than natural) should be expected given that data for the two methods were collected over different time periods and involved different levels of resolution. Based in part on these results, the refinement of the Reef Watch protocols described in section 3.3 was confined to streamlining the lifeform codes used.

Finally, Collings et al. (2008) undertook a more comprehensive analysis of the community collected Reef Watch data, and quantitatively compared it to data collected by scientists from the same reefs. In general, this analysis showed what was considered to be a reasonable degree of concordance between the two data sets, although the results were by no means identical. This comparison was made at two different levels. Firstly, a detailed analysis of the line-intercept transect data of benthic cover was undertaken. It was considered that the discrepancies in the results between the two data sets in this analysis were primarily related to small-scale spatial variability, although this was not examined in detail. While the data collected by scientists was at a finer taxonomic resolution than that collected by the community, the former was aggregated to the same level as the latter prior to analysis. Secondly, the Reef Health Index described above was compared in greater detail. This comparison showed greater discrepancies, which probably reflect the inadequacy of some of the component indices more than anything else, and further work needs to be done to refine and validate these before the overall Reef Health index can be used reliably.

While it now appears that volunteer divers are capable of learning and undertaking reef monitoring activities (based on descriptions above), a major concern remains the ongoing interest of divers to stay with the program. Training divers to an appropriate level to allow for the collection of meaningful data is a resource-consuming process,

as such it will be important for the long term future of the program that once trained, diver enthusiasm and participation in reef monitoring is maintained. As such, Reef Watch are in the process of examining a range of possible ways to improve volunteer longevity within the program.

Conclusions

4.1 Benefits and adoption

Information generated from the Reef Health project is playing an important role in informing management decisions affecting the marine environment, in particular off the Adelaide metropolitan coast. The strong buy-on to the project is indicated by the number of agencies that have either provided funding, or who had representation on the reference group that met regularly throughout the projects life to guide its direction. A number of agencies also provided support in the way of field staff or assistance in report writing. These contributions are documented in the acknowledgements section.

The management decisions being taken based at least in part on the results of this project, are aimed at improving environmental conditions in coastal waters, and thereby the health of the reefs. As a flow-on from this, these reefs are likely to become better habitat for commercially and recreationally fished species, potentially improving fishing opportunities over the long term. This is particularly important for the Adelaide metropolitan coast, where recreational fishing pressure is intense, and opportunities are declining due to a range of reasons.

The Adelaide and Mount Lofty Ranges Natural Resource Management Board has already used information from the Reef Health project to inform a number of decisions, and has also provided funding for follow-up work to look at sedimentation on reefs (Tony Flaherty pers. comm.):

> The Adelaide and Mount Lofty Ranges Natural Resource Management Board has utilised the Reef Health study in development of the regional Natural Resource Management Plan. Reef health information has been used in reporting on marine habitat condition in the NRM Plan's State of the Region Report.
>
> Importantly the data has been used in prioritizing allocation of resources to mitigate land-based impacts on reef systems. In its draft NRM Plan, the Board has indicatively allocated up to $1,063,000 over three years to mitigate impacts to reef and seagrass communities, as well as further monitoring of reef health with partner agencies and the community.
>
> The Reef Health information has been used as a basis for further Board funded investigations into sedimentation on metropolitan reefs (Fernandes, M., Theil, M., and Bryars, S. (in press) Sedimentation surveys of Adelaide's coastal reefs. Report for the Adelaide and Mount Lofty Ranges Natural Resource Management Board, South Australian Research & Development Institute (Aquatic Sciences), Adelaide). This study has highlighted potential impacts of coastal erosion and catchments on reef sedimentation, and will assist in prioritization of coastal and catchment on ground works to assist in mitigation. The Board has indicatively allocated up to$1,410,000 over three years to target coastal on-ground works as well as a range of other NRM investments within

> the Plan to improve catchment health and water quality improvement programs in the region.

The South Australian Environmental Protection Authority also makes use of the data collected by the Reef Health program (Sam Gaylard pers. comm.):

> The EPA has utilised the Reef Health program results to include in the State of the Environment Reporting for 2002 (the 1999 surveys) and 2008 (recent surveys). The reef health results have formed a time series for many reefs which have been used in understanding impacts of poor water quality on macroalgal reefs and change over time in response to management actions. In areas previously unsurveyed, this information has formed an important baseline for future surveys to establish trends and provides information about site and habitat specific differences between regions. This information has also strengthened views about the role of water quality in reef condition and in conjunction with EPA water chemistry data from nearby locations has given us information about the relative sensitivity of reefs to declines in water quality.
>
> The EPA also uses trends in reef health identified in the Reef Health program in its negotiations with licensees such as the Christies Beach WWTP upgrade and in development applications where there are possible water quality impacts.

SA Water are also using information generated by the Reef Health project to make management decisions related to waste water discharges (T. Kildea pers. comm.):

- Knowledge acquired about reef habitats and species present has influenced the design of wastewater treatment plant upgrades, particularly in the region of Christies Beach
- Species lists and habitat descriptions of individual reefs along metropolitan coasts, developed through the reef health program, have provided important data in assessing the suitability of site locations for a desalination plant as part of the Adelaide Desalination Program
- The Reef Heath project developed a corporate awareness of the fragile state of reefs along the metropolitan coast
- Through the Reef Health program, a synergistic relationship has started to develop between SA Water and Reef Watch

In addition, the Reef Health survey protocols are now being used to conduct baseline monitoring for the proposed desalination plant at Port Stanvac. Using these protocols means that data are being collected on an additional reef that can be compared to the existing comprehensive data set. Also, these baseline surveys are being conducted on a quarterly basis, and thus the data can be used to examine shorter-term fluctuations in reef assemblage composition.

4.2 Further development

Turner et al. (2007) made a number of recommendations for future work following the analysis of the 2005 survey data:

- Baseline data needs to be extended to other reefs across South Australia (Eyre Peninsula, west and south-east coasts). A range of sites including near pristine and putatively impacted areas should be included;

- Monitoring attention should be given to areas of high conservation value (including marine protected areas) as well as those areas likely to be subject to human impact;

- Further (and more focused) monitoring should be conducted of sites with 'Caution Recommended' ratings;

- Future investigations should collect data that are more comprehensive with respect to physical parameters, which will allow for greater predictability of the types of biotic assemblages that may well be expected under natural conditions;

- The indices need to be further refined, and preferably augmented with data on keystone species. 'Indicator' invertebrate species are worthy of further investigation in this respect;

- The potential influence of climate change on reef ecosystems needs investigation;

- The role of seagrass loss off Adelaide as an agent in reef health should also be considered;

- The development of a model linking biotic and physical data from reefs needs to be developed. Such a model would increase our understanding of what constitutes a healthy reef, and allow predictions (which can be tested) about likely impacts from disturbance. For example, a granite substrate in an exposed position should support a predictable macroalgal community that will differ from a sheltered sandstone substrate. The response of these reefs are likely to differ greatly to disturbances such as local dredging creating a sediment plume.

- Finally, more resources need to be allocated to increasing the capacity for community based reef-monitoring initiatives (e.g. Reef Watch) as a cost effective method for increasing the volume of information that can be collected. Testing the validity of data collected by community-based programs forms an important component of the surveys being carried out in late summer/autumn of 2007, as part of the Reef Health program.

Following analysis of the 2007 survey data, the analysis of trends since 1996, and the quantitative comparison of scientific and community data collected in 2007, Collings et al. (2008) made the following recommendations for further work:

- Reef monitoring should continue;

- In combination with some professional guidance, community-based monitoring programs (in particular Reef Watch) offer an excellent vehicle for this work which should be encouraged and resourced appropriately;

- A broader range of reefs should be surveyed, possibly at the expense of the frequency of re-survey;

- The protocols utilised by the Reef Health program should be continued with the following modifications:

  - Transects should be marked with permanent endpoints;
  - Photographic transects should be adopted where possible;
  - Alternative methods of assessing mobile fauna for the reef health index are required; and
  - Attention needs to be paid to calculation of individual indices, particularly the appropriateness of a "null" score.

- Improvement to water quality since the mid-1990s should be lauded and continued improvement should be encouraged if we are to see recovery of the most impacted reefs.

The data set provided by this project has been analysed primarily to examine reef health, and there are numerous other analyses that could be undertaken to maximise its use if the resources are made available. For example, as data were collected on the physical environment as well as the biological assemblages, it could be used to relate these two, to help determine what reefs should be like under a given set of conditions. This would not only provide fundamental information about the processes that determine reef structure, but it would also aid in refining future assessments of reef health.

4.3 Planned outcomes

1. More efficient management based on a better understanding of key ecological and biophysical processes.

The project has provided strong evidence that the decline in reef health that has been documented from south to north along the metropolitan Adelaide coast is actually a response to the presence of the city of Adelaide, and not a natural gradient in response to environmental features such as wave exposure (see in particular Connell et al. in press). In addition, there is evidence from the 2007 surveys that the situation has improved slightly since the surveys in the 1990s. These two outcomes provide a good basis for management, in that they show that coastal inputs from Adelaide are causing a problem, and that recent efforts to reduce these inputs are actually having a positive effect, suggesting that the situation is still reversible.

2. Increased knowledge and understanding about the current status of reefs and future prognosis resulting from comprehensive baseline surveys.

The surveys conducted in 2005 and 2007 provide a comprehensive baseline against which future changes in reef health can be assessed. In 2005, a total of 39 sites from 31 different reefs were surveyed, covering the Adelaide metropolitan coast, Yorke Peninsula and Fleurieu Peninsula (Turner et al. 2007). The Adelaide sites included 8 that were surveyed in 1996, and 17 that were surveyed in 1999 (Cheshire et al. 1998a, 1998b, Cheshire & Westphalen 2000). Thus in addition to a baseline, we now have some limited ability to look at trends over time on a limited set of reefs (Collings et

al. 2008). At each site, several different survey methodologies were utilized to ensure a broad coverage of the taxa present. Macroalgae and sessile invertebrates were predominantly assessed using line intercept transects, mobile invertebrates were counted in belt transects, and fish were also counted in belt transects. The same methodology is now being utilized for other projects in the area, to both maximize the benefits of having a baseline, and to extend the temporal coverage of surveys. For example, it is being utilized in the baseline surveys for the proposed Adelaide desalination plant. As these surveys will be conducted quarterly, they also have the potential to give us an understanding of seasonal variation, something that was not examined in the current project.

3. Community ownership and commitment to environmental management and protection through a more informed and educated community.

As discussed previously, particularly under Objective 2, there have been a number of initiatives to improve community understanding and engagement with Adelaide's reefs. Reef Watch delivered much of the community education aspect of the project as part of their ongoing operations. The project allowed the Reef Watch survey protocols to be refined, to reduce the difficulty experienced by some volunteers with utilizing a large number of life form codes, and to make participation in surveys more rewarding. In addition, a brochure was delivered to Adelaide dive shops, fishing tackle shops etc, documenting the results of the 2005 surveys, and providing information on Reef Watch and how individuals could help the marine environment and/or participate in Reef Watch. A schools education package was also developed, and will soon be made available via the Reef Watch web site.

4. Training programs will lead to ongoing cost effective monitoring using skilled community divers in partnership with institutional effort.

The project contributed to a range of training opportunities for Reef Watch divers and the general community, including several community education workshops that gave participants a hands-on opportunity to learn about marine life. There was also a comprehensive evaluation of the performance of community divers in comparison to scientific divers in 2007. This evaluation involved asking Reef Watch volunteers to survey a number of reefs that were also surveyed by scientific divers working on the project at a similar time of year. While scientists were involved in some of the initial training of the volunteer divers, they did not get involved with the Reef Watch surveys in any way other than to nominate the reefs involved. This ensured that the volunteer divers were acting independently, and that their results truly reflected what would happen in a community monitoring program. The results of this comparison show that community monitoring does have some utility, although there is a requirement for trained scientific personnel to be actively assessing the data and looking for patterns in it, as this is beyond the ability of community divers.

5. More eyes in the water also mean more highly resolved data and a more effective early warning system for potential problems.

By encouraging community participation in Reef Watch surveys, and making the survey protocols simpler, the project should lead to an increase in the number of surveys being conducted, as well as in improvement in the quality of the data collected. In combination with the encouraging results obtained from the comparison between community and scientific data, this means that there will be data available from a number of key sites along the metropolitan Adelaide coast and in regional areas on a much finer temporal scale than it would be financially possible to obtain from surveys by trained scientists. While the community data will not give us as good an understanding as that obtained by scientists, the much greater frequency means that we can get a better feel of trends, and also get an early warning of any major problems. This early warning then allows scientific divers to conduct a follow-up survey in more detail if warranted. These surveys also target the presence of key marine invasive species, and as such will help provide an early warning of any incursions into South Australia, or of expansions of existing populations in the state.

6. Quantitative evaluation of the efficacy of community-based programs will lead to confidence amongst government, industry and the wider community in the use of such data and the development of a standardised monitoring framework.

It is likely that the formal quantitative evaluation of the performance of community divers in comparison to scientific divers will improve the confidence of management agencies and others in community data. For the first time in a temperate marine setting, Collings et al. (2008) have shown the strengths and weaknesses of community data, which will give managers a feel for how far it can be interpreted. As this component of the project has only just been completed, it is not yet possible to determine how positively managers will respond to the information that is being delivered by the project in this regard.

4.4 Conclusions

A summary of how the key outcomes in relation to the objectives of the project is provided below.

1. To develop a better knowledge and understanding of coastal reef ecosystems through:

- Identification of appropriate indices for assessment and development of survey methodologies; and

- Application of these methodologies to obtain baseline and time scale data for coastal reef ecosystems which is relevant to the needs of key management agencies including SA Water, SA Environment Protection Authority, and SA Department for Environment and Heritage.

This project has substantially increased our knowledge of shallow coastal reef ecosystems in South Australia through the collection of extensive data on benthic and pelagic assemblages across both spatial and temporal gradients. Surveys in 2005 extended from near the Murray Mouth in the east, to western Yorke Peninsula. While the geographic scope of the 2007 surveys was narrower, they focussed on reefs that had been surveyed with similar methodologies prior to this project, and now give us four points on a 12-year time series for these reefs. Based on these surveys, and historical reconstructions of reef assemblages (Connell et al. 2008), we have been able to demonstrate that the south to north decline in apparent health of reefs along the Adelaide metropolitan coast is not a natural geographic gradient. Instead, this decline is directly related to anthropogenic disturbances, probably due to wastewater and stormwater inputs to Gulf St Vincent. The 2007 surveys also suggest that this decline may be starting to reverse, with some indication of an improvement in the health of some reefs over the period 2005-2007. During this survey program, the methodology used in previous surveys was refined, in order to maximise the cost-effectiveness of the surveys without sacrificing their scientific rigour. To make communication of the results easier, we also developed a preliminary Reef Health Index, that can be used to present the health of a reef using a traffic light approach. This index gave reasonable results for the Adelaide metropolitan reefs, although some of its components do need to be refined further. The index did not work as well outside the metropolitan area, however, primarily because it did not take into account the different physical settings of some of the reefs further afield.

2. To foster community ownership and participation in monitoring and assessment:

- Through the development of training and education packages; and

- By encouraging and mobilising community participation.

Community participation and education were an important component of this project. There was a close linkage with the community-based Reef Watch program throughout, with many of the scientific staff involved participating in Reef Watch activities such as the annual Marathon Dive at Port Noarlunga, Reef Watch training, quiz nights and community education workshops. In addition, the project produced a number of outputs directly targeted at community education. These outputs included a full-colour brochure documenting the outcomes of the 2005 surveys, and providing information on how members of the public can contribute towards maintaing and improving the health of reefs, a series of 5-9 min documentaries on reefs and activities that impact detrimentally on them that have been distributed primarily to schools, and a school education package.

3. To develop a credible assessment program:

- Through the process of training, testing and accreditation of all participants; and

- By undertaking scientifically rigorous evaluation of the community monitoring program.

Eary on in the project, a comprehensive review of the volunteer Reef Watch program was undertaken. As a consequence of this review, a few minor changes to the Reef Watch protocol were made. In particular, the number of life-form codes was reduced from 38 to 18, to make them easier to identify and remember. The utility of data collected by Reef Watch volunteers was also carefully evaluated by comparing data collected by Reef Watch and as part of the Reef Health project from the same reefs at approximately the same time. While this comparison showed that there were some differences in the details, the broad picture of change was the same between both scientifically trained and volunteer data collectors. The main issue identified in the comparison was that small-scale spatial variability made it difficult to compare, as the volunteer divers did not survey exactly the same part of the reef as the scientific divers. There were also a number of discrepancies when the outcomes of the Reef Health Index were compared between the two groups, and it is thought that this probably reflects some inadequacies in the methods used to calculate the index.

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Appendix 1: Intellectual property

This report will be made freely available to the public via FRDC, Reef Watch, and SARDI.

Appendix 2: Staff

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