SURVEYS ACROSS REEFS IN THE ADELAIDE AND MT LOFTY RANGES NATURAL RESOURCE MANAGEMENT REGION 2010 - 2011

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

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OVERVIEW

This report summarises Reef Watch monitoring data for the period from (and including) June 2010 to May 2011 across six coastal reef sites in the Adelaide and Mt Lofty Ranges Natural Resource Management Region. Reef cover, fish and invertebrate community data from each site were summarised within continuous seasons and interpreted using the reef status index calculations defined by Turner *et al.* (2007).

Overall, the Reef Watch dataset in terms of seasonal coverage across sites for this reporting period is similar to 2009-2010, but otherwise more comprehensive than previous years (see CCSA 2009, Westphalen 2009, 2010a).

Hallett Cove remained largely unchanged relative to the 2009-2010 reporting period, with "Caution" status, although the seasonal coverage was poor. Noarlunga sites (both north and south) seemed to have improved, and there was substantial variability at Second Valley with a "Poor" status in spring that improved to "Good" by the following autumn.

Results are broadly similar to the previous year in terms of coverage, quality and overall results. Improvements to the monitoring program have been maintained, but not extended, in part because of the limitations entrained within use of the indices but also perhaps because survey effort is over-stretched in an attempt to cover six sites in each season (i.e. 24 observations).

Based on the available data it would seem that there is still cause for concern about Hallett Cove. Analysis of additional data from this site (see Westphalen 2010b) would suggest that change in status may be localised, but there is a need for a specifically targeted survey of both the Reef Watch site as well as more broadly across this reef. The apparent decline in status at Second Valley is less concerning, in part because the site has been shown to undergo substantial seasonal changes in previous surveys, but mostly because it also recovered.

RESULTS OF SURVEYS

Recommendations for further action that are not the responsibility of Reef Watch include:

- A scientific survey of Adelaide metropolitan reefs along the lines of Turner *et al.* (2007), and Collings *et al.* (2008) aimed at establishing the nature of the decline at Hallett Cove and verifying if there is any degradation in the area south of Noarlunga to Second Valley.

- A specifically targeted professional survey should be undertaken of the Reef Watch Hallett Cove site, preferably in conjunction with the sites employed by Russell and Connell (2010) for surveys on this reef.

- More research is required into the causal link between sediment loads and reef decline and there is a need for more data on sedimentation and turbidity levels along the Adelaide metropolitan coast as well as less urbanised areas to the south.

Recommendations for Reef Watch to consider:

- Seasonal comparisons of the Reef Watch data are hampered by a lack of coverage, particularly (but not surprisingly) in autumn and winter. In moving forward, a better approach may be to consider a summer-winter (or hot-cold) comparison of each site. This would add a degree of flexibility to the organisation of surveys, allow for a

degree of spillage outside the official summer and winter periods as well as encourage a more orthogonal dataset. Note that the minimal LIT length of 20 m should be maintained, but the overall amount of LIT would not be diminished under a simplified approach.

- Feral or in Peril observations should be encouraged, particularly at man-made structures (jetties, breakwaters, boat ramps, etc.) on the southern AMLR coast.

INDICES

Recommendations for the indices remain largely unaltered from previous years (see CCSA 2009, Westphalen 2009, 2010a). Broadly, it is strongly recommended that further use of these indices be considered in light of the need for further research and development.

Recommendations for index review and development include:

- Better use of Reef Watch data through simplification of the field requirements and/or adjustment to index calculation/interpretation.
- Removal of indices that are not employed or only make sporadic contributions to index calculation:
    - Sedimentation index – not used,
    - Richness of macroalgae – not used,
    - Richness of mobile invertebrates – not used,
    - Blue-throated wrasse – does not occur across all sites.
- Simplification and/or targeting of the taxonomy used in deriving fish and invertebrate indices to specific species/genera/lifeforms.
- Simplification of the estimation of numbers, particularly as relates to fish surveys such as the use of Braun-Blanquet style categories.
- An expanded interpretation of reef status (or “health”) to include:
    - Consideration of marine debris,
    - Consideration of EPBC/NP&WS listed species.

INTRODUCTION - REEF OBSERVATIONS AND REEF WATCH

Community-based monitoring of reef systems on the Adelaide metropolitan coast has been undertaken since the late 1990s, building on the results of more formal and comprehensive surveys conducted in 1996, 1999, 2005 and 2007 (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008). The initial emphasis of the Reef Watch program was to develop a broader awareness and education of reef health issues (Turner *et al.* 2006). However, as the skill base amongst members has evolved, coupled with a more appropriate sampling protocol, a more rigorous analysis and reporting of Reef Watch data has been possible (see CCSA 2009, Westphalen 2009, Westphalen 2010a). Reef Watch monitoring now has a substantial level of sampling rigor and data integrity such that it can be readily employed against environmental decision-making objectives, most appropriately as a "standing watch" on a number of reefs within the Adelaide and Mt Lofty Ranges NRM region.

The effectiveness of the Reef Watch program was well demonstrated in the 2009-2010 analysis that indicated a potentially disturbing decline in reef health at Hallett Cove (see Westphalen 2010a), which instigated a broader discussion across a range of stakeholders (including government, non-government and Adelaide University). Analyses of additional data provided by Adelaide University (see Russell and Connell 2010) indicated that this observation appeared to be isolated to a relatively small area and therefore likely to relate to a localised event (see Westphalen 2010b).

It is thus well demonstrated that data collected by Reef Watch retain the capacity to undertake comparisons of specific reef patches through time (both seasonally and inter-annually), which greatly enhances the likelihood of observing changes.

This report summarises Reef Watch monitoring data for the period from (and including) June 2010 to May 2011 across six coastal reef sites in the Adelaide and Mt Lofty Ranges Natural Resource Management region. Reef cover, fish and invertebrate community data from each site are summarised within continuous seasons and interpreted using the reef status index calculations defined by Turner *et al.* (2007).

AIMS

The aims of the 2010-2011 Reef Watch report are to:

1. Describe Reef Watch data obtained in the 2010-2011 period in light of recommendations from previous analyses.
2. Consider the status of each Reef Watch observation site through the approach provided by the Turner *et al.* (2007) indices.
3. Propose areas where sampling might be further improved.

REEFS CONSIDERED

Formal reef surveys conducted by Adelaide University and the South Australian Research and Development Institute (SARDI), Aquatic Sciences, have established a zone of degraded reefs corresponding to the most urbanised stretch of the Adelaide coast, possibly extending as far south as Seacliff (i.e. from Semaphore to Brighton; Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008). Disturbingly, there have been indications of a possible decline of reefs further south, in particular Horseshoe Reef and Noarlunga Reef, where there has been substantial urban and industrial development

(Cheshire and Westphalen 2000, Turner *et al.* 2007). Expansion of the zone of degradation to the extensive reef systems on the Fleurieu Peninsula coast has been raised as a key area of concern (Cheshire and Westphalen 2000, Turner *et al.* 2007), although note that Collings *et al.* (2008) indicated that there were signs of improvement in the status of some sites.

Reefs in the transitional area between urbanised and rural coasts to the south of the Adelaide metropolitan area require focussed scrutiny, particularly in light of the desalination plant development at Pt Stanvac, as well as growing "sea-change" urban expansion within satellite townships along the coast (e.g. Moana, Aldinga, Sellicks, etc.). Data obtained by Reef Watch for this area, notably for Noarlunga Reef to the south and Hallett Cove to the north, can form a critical baseline against which impacts can be assessed.

Reef Watch surveys for 2010-2011 (June –May inclusive) include the same six reefs from the AMLR coast used in previous surveys (2008-9009 and 2009-2010; Figure 1):

- Broken Bottom, a degraded reef off Glenelg
- Hallett Cove, an exposed reef that previous surveys had confirmed as being healthy, although the 2009-2010 observations raised some concerns about this site
- Noarlunga North Inside and Noarlunga South Inside, which might be considered to be "at risk" sites that have shown signs of decline
- Second Valley on the Fleurieu Peninsula, considered to be a healthy reef
- The Bluff (Rosetta Head) at Victor Harbour, also considered a healthy reef

Reef Watch observations therefore encompass reefs that may be cause for concern in the Noarlunga area and now possibly Hallett Cove, a reef previously ranked as degraded (i.e. Broken Bottom) and sites considered as healthy (Second Valley and The Bluff). Changes in reef status at any of these sites can thus be placed in an appropriate context.

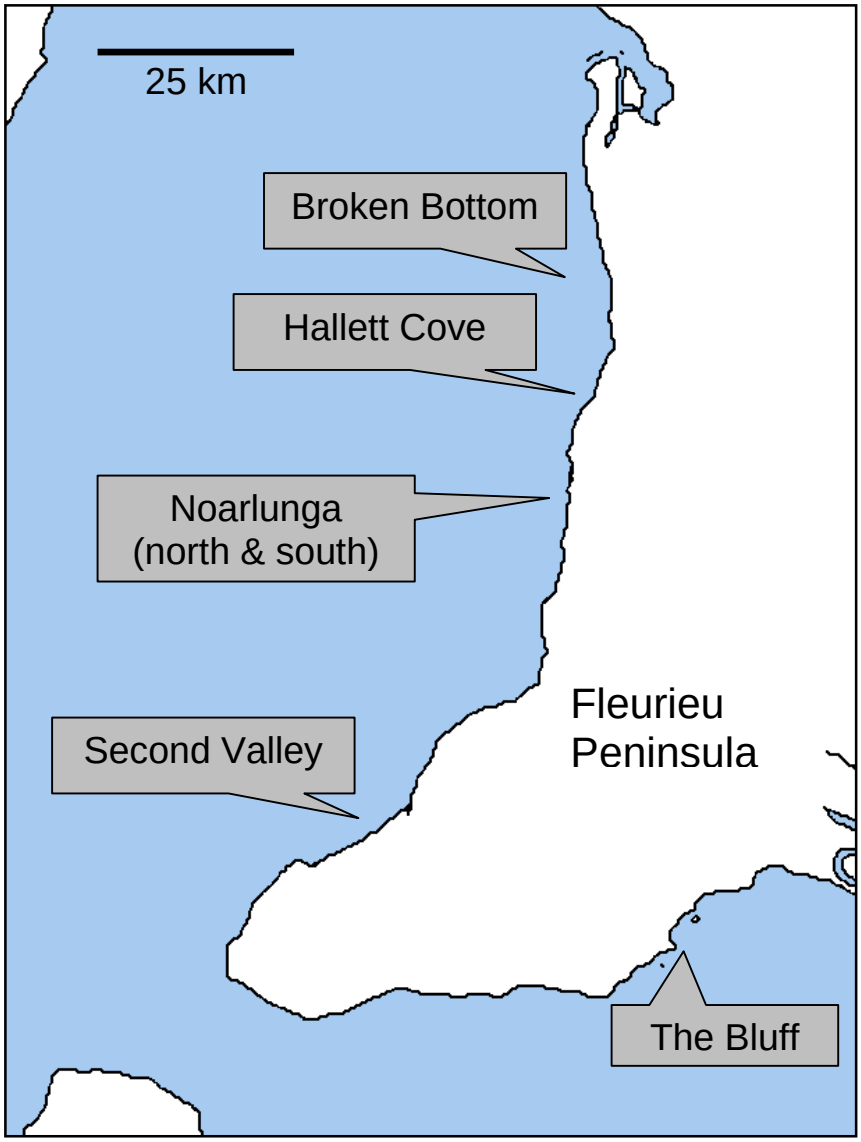

Figure 1 - Map of Fleurieu Peninsula within the AMLR NRM region showing the locations of the reefs considered.

METHODS AND INDICES

Reef status (or "health") in the context of Reef Watch observations is based on data obtained from four reef community strata:

- Sessile reef community composition
- Fish community composition
- Invertebrate community composition
- Invasive species observations

The methods employed in obtaining reef data are based on those used in Reef Health investigations, a full summary of which may be found in Turner *et al.* (2007), although note that the taxonomy employed within each strata, including Line Intercept Transects (LITs), Fish and Invertebrate surveys have been substantially simplified (see Appendix A).

Feral or in Peril observations are not based on a structured sampling approach, but nonetheless form a useful additional data resource in this context (see Reef Watch; http://www.reefwatch.asn.au/fpreport.html, accessed September 2011).

The primary tool for analysing Reef Watch data are the 11 indices of reef status developed by Turner *et al.* (2007), although not all could be employed (Table 1). A full description of each index including their calculation as well as some of their limitations is found in Turner *et al.* (2007). Further interpretation and critiquing of the indices can be found in Collings *et al.* (2008), CCSA (2009) and Westphalen (2009, 2010a). Additional interpretations of the Reef Watch data are based on the findings and recommendations from previous reporting for Reef Watch (see CCSA 2009, Westphalen 2009, 2010a).

Table 1 - Eleven indices developed by Turner *et al.* (2007) to describe reef "health" on the South Australian coast. Note that only those in red text were employed in this report.

Index type	Index	Data source
Areal cover	Areal cover of canopy-forming macroalgae	LIT
	Areal cover of turfing macroalgae	LIT
	Areal cover of mussel mats	LIT
	Areal cover of bare substrate	LIT
Abundance	Size and abundance of blue-throated wrasse	Fish
	Abundance of site-attached fish	Fish
	Abundance of mobile invertebrate predators	Invertebrate
Presence	Presence of invasive taxa	A general part of surveys and/or Feral or in Peril
	Presence of high sedimentation	No Data
Species richness	Richness of macroalgae	Not Used
	Richness of mobile invertebrates	Not Used

Index scores from the above were averaged to develop an overall indicator of reef health for each site-season observation (see below).

Given the substantial differences in the species considered between different reef surveys (Turner *et al.* 2007, Collings *et al.* 2008, CCSA 2009, Westphalen 2009, 2010a), the species richness indices were not employed in this analysis.

The sedimentation index was also not used as Reef Watch does not collect these data.

SURVEY DATA, INDEX RESULTS AND DISCUSSION

Reporting of Reef Watch data for 2010-2011 includes summaries of the index calculations based on formal surveys as well as the "Feral" aspect of Feral or in Peril reporting.

Note that the *actual* reporting period for Reef Watch data includes fish, invertebrates and LIT summaries across continuous months within each season, meaning that analyses include observations undertaken from June 2010 through to the end of May 2011. Otherwise the summary data would use data that are actually split across two winters (i.e. June 2011 along with July and August 2010), which would likely add an uninformative level of variability within the results.

INDEX DATA AVAILABILITY AND QUALITY

The Reef Watch surveys for the reporting period included all six sites (Figure 1, Table 2). The total of 36 transects included 15 site-season observations out of a maximum of 24 (Table 2), with, not surprisingly, spring and summer having most (five out of six sites for each) and autumn having the least (two sites). All sites were considered at least twice, but no site was examined in all four seasons. There is general alignment of observations across line intercept, fish and invertebrate transects (data not shown), meaning that reef status was based on the same potential number of indices in each instance. This continuity forms a substantial improvement over previous surveys, building on the achievements of the 2008-2009 and 2009-2010 surveys (see Westphalen 2009, 2010a). Overall, the Reef Watch dataset in terms of seasonal coverage across sites for this reporting period is similar to 2009-2010, but otherwise more comprehensive than previous years (see CCSA 2009, Westphalen 2009, 2010a).

Table 2 – Reef Watch surveys on the AMLR NRM coast from June 2010 to May 2011 in terms of the total length of LIT within each site-season in metres with the corresponding number of transects in parentheses (total of 36). Red number indicates where there was not enough LIT data for a summary to be considered (see CCSA 2009).

	Season			
Site	Winter	Spring	Summer	Autumn
Broken Bottom	34 (3)		40 (4)	
Hallett Cove		14 (2)	112 (7)	
Noarlunga North Inside		36 (2)	34 (2)	40 (2)
Noarlunga South Inside	7 (1)	41 (2)	18 (1)	
Second Valley		25 (1)	49 (4)	39 (3)
The Bluff	16 (1)	20 (1)		

Fish and invertebrate surveys use fixed length transects (50 m – see Turner *et al.* 2007), whereas LITs can vary substantially in length (e.g. Table 2). However, LIT data forms the basis for four of the eight indices (Table 1), and a minimal total length of 20 m of LIT is required at each site-season combination for it to be included in the analysis (see CCSA 2009, Westphalen 2009, 2010a), which is half that employed in more formal surveys (e.g. Turner *et al.* 2007, Collings *et al.* 2008). This approach is based on previous Reef Watch analyses (notably CCSA 2009) that found, while LIT data are accurately collected, transects have often been very short even when summed across a season such that the representativeness of the observation is suspect (see CCSA 2009).

Eleven out of the 15 site-season combinations had a total of 20 m or more (Table 2), although the average length of transects across all sites was around 14.5 m.

In winter Noarlunga South Inside had a total transect length of only 7 m (Table 2). Based on the approach used in an earlier analysis (CCSA 2009, Westphalen 2009, 2010a) this site-season was not included in the results. A further three site-seasons including Hallett Cove in spring, Noarlunga South Inside in Summer and The Bluff in winter included total LIT lengths from 14 – 18 m (Table 2) and are considered marginal in terms of inclusion. Otherwise LIT coverage ranged from 20 m at The Bluff in spring to 112 m for Hallett Cove in summer (Table 2).

Reef Watch field operations should attempt collecting a minimum of 20 m worth of LIT from each of the six core sites in each season. However, given the current level of coverage is similar to previous years, it may be preferable to consider a summer-winter (or hot-cold) comparison rather than attempt comparisons of seasonal nuances with a non-orthogonal dataset. This would simplify data collection to 12 observations as well as offer greater flexibility in data acquisition in that some spillage of sampling into spring and autumn can be tolerated.

INDEX DATA

As with previous reporting of Reef Watch data using the Turner *et al.* (2007) indices, only a subset of the collected data is employed (see Westphalen 2009, 2010a), including six of the 19 LIT lifeforms, 16 of the 27 fish species and only five of the 31 observed invertebrate species (Appendix A). Simplification of the taxa considered within each of the strata should be considered, particularly with regards to LITs.

There were only five blue-throated wrasse recorded across the entire fish dataset (36 transects worth; Table 3) and it was considered that this index was uninformative at this level. Blue-throated wrasse data were thus excluded from the results, reducing the total number of indices to seven.

High numbers of site attached fish at Noarlunga North in spring and summer as well as Hallett Cove in summer were due to large numbers of yellow-headed hulafish (*Trachiniops norlungae*) and bullseye (*Pempheris* spp.) respectively (Table 3). These included values of 500 or more on some transects and are based on estimates rather than actual counts. For abundance data, both the field observations and the ensuing index calculation may benefit from the use of a Braun-Blanquet like approach with abundances estimated according to categories (i.e. 1 = species present, ranging up to 5 = more than 500 individuals). This approach is likely to be quicker and probably more consistently applied across different observers, although the reconfiguration of the index may not be a trivial issue and it may limit comparisons with previous reporting.

Table 3 - Summary of the Reef Watch data used as input to index calculation.

Site	Season	LIT data (% cover)				Invertebrates		Fish			Invasives
		Bare rock	Canopy	Mussels	Turf	Number predators	Number transects	Number site attached	Blue-throated wrasse number	Number transects	
Broken Bottom	Summer	42.85	0	0	18.58	4	2	18	0	2	0
Broken Bottom	Winter	56.03	0	0	7.03	2	1	59	0	4	0
Hallett Cove	Summer	11.32	34.37	0	2.04	12	6	597	0	6	0
Noarlunga North Inside	Autumn	13.70	61.77	8.53	2.60	17	1	14	0	1	0
Noarlunga North Inside	Spring	30.26	34.96	2.08	3.43	45	4	1076	0	4	0
Noarlunga North Inside	Summer	6.61	61.96	20.72	0	33	2	410	0	2	0
Noarlunga South Inside	Spring	20.09	25.10	40.82	1.24	95	2	11	0	2	0
Noarlunga South Inside	Summer	10.11	22.94	56.11	1.94	16	1	31	1	1	0
Noarlunga South Inside	Winter	7.71	39.29	21.14	8.86	52	2	9	0	1	0
Second Valley	Autumn	9.30	64.51	0	2.64	5	3	44	1	3	0
Second Valley	Spring	18.4	38.12	0	0.56	0	1	5	0	1	0
Second Valley	Summer	14.98	32.10	0	20.00	8	4	30	1	3	0
The Bluff	Spring	0	81.79	0	0	5	4	53	2	4	0
The Bluff	Winter	0	88.06	0	0	3	1	1	0	1	0

FERAL OR IN PERIL - FERAL OBSERVATIONS 2009-2010

Feral or in Peril data collected by Reef Watch for the period June 2009 to May 2010 were investigated for supporting information related to invasive species within the AMLR region (see Appendix B). Note that, given that Feral or in Peril observations are not based on a fixed sampling strategy, it is impossible to determine whether multiple observations within a site cover either the same ground or include similar observational intensity (i.e. number of divers x time spent searching).

Observation of a feral species does not necessarily mean that the pest has become permanently established at particular location. Conversely, not seeing a pest at a particular site cannot be construed to indicate its absence, particularly if it has been previously observed. It also needs to be noted that the list of feral species employed in the program comprises species that are readily recognisable by non-experts and these surveys are therefore not a substitute for formal marine pest investigations.

Feral data for the reporting period comprises 16 observations across 10 locations around the AMLR NRM coast (Figure 2; Appendix B). Importantly, the Feral or in Peril data now includes data on surveys where no feral species were observed, a key deficiency in earlier surveys (CCSA 2009). The number of observations is relatively low compared to previous years (42 in 2009-2010; Westphalen 2010a), possibly related to apparent problems with the online database.

Two invasive species from the "Feral" list were reported. The most common was the Mediterranean fanworm (*Sabella spallanzanii*), which was found at North Haven Boat Ramp, Glenelg and Brighton Jetties (Figure 2) reflecting a possible preference for artificial substrates in sheltered areas (Boxall and Westphalen 2003). However, *S. spallanzanii* was also reported as sporadic and/or dead individuals at Noarlunga Reef. Formal surveys of the spread of *S. spallanzanii* indicate that, as of 2002, this pest was as far south as Brighton (Boxall and Westphalen 2003).

In 2008 Reef Watch reported an incursion at Kingscote, which was the first observation of this pest for Kangaroo Island. Follow up investigations by the Kangaroo Island NRM Board found a number of vessels with *S. spallanzanii* as hull fouling at American River and Bay of Shoals along with another pest (*Ciona intestinalis*; see Kinloch *et al.* 2010). The likely sources for marine pest incursions are the port and mooring facilities on the Fleurieu Coast, notably Wirrina, which a collaborative investigation with the AMLR NRM Board, Biosecurity SA and Reef Watch found to be heavily infested with *S. spallanzanii*. Wirrina is a popular mooring area for vessels, sometimes for protracted periods (see Kinloch *et al.* 2010), and a potential source for incursions further south.

More recent observations by Kangaroo Island NRM officers found an infestation at Bay of Shoals (Pers. Comm. Danny Brock, Scientific Officer, DENR Coast and Marine Program).

Further spread of *S. spallanzanii* is inevitable, either naturally through distribution of its spores or through artificial vectors, most probably as hull fouling. Most of the locations where *S. spallanzanii* has been found comprise artificial substrates in relatively sheltered locations (Boxall and Westphalen 2003), which would appear to be supported by the current data. However, only three jetty/boat ramp locations were documented in the current reporting period, whereas the 2009-2010 observations for the AMLR NRM region included seven jetties versus four in 2008-2009 (Westphalen 2009, 2010a). Given that man-made structures would appear to be the primary points of establishment of this pest, a focus on

reporting from jetty dives and boat ramps should be encouraged, particularly on the coast south of Brighton.

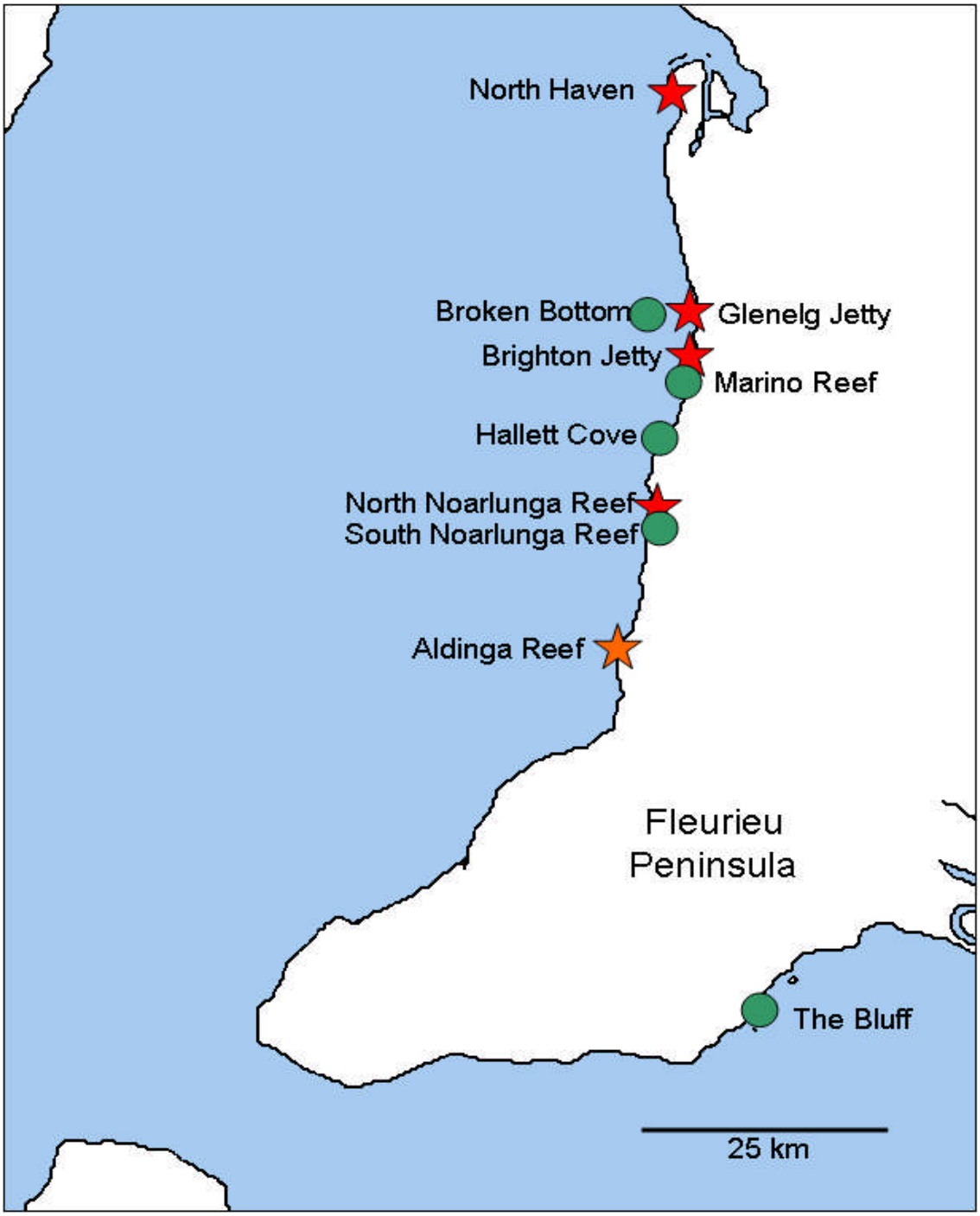

Figure 2 - Map of the Fleurieu Coast showing the location of Feral observations from the Feral or in Peril dataset from June 2010 to May 2011. Green circles indicate where nothing was found, Red stars show where *Sabella spallanzanii* was observed at any stage during the reporting period, Orange star indicates where Northern Pacific Seastar *(Asterias amurensis)* was reported but later discounted as a local species.

The other invasive species reported in Feral or in Peril observations was the northern Pacific seastar (*Asterias amurensis*) at Aldinga Reef (Figure 2; Appendix B). This species, along with *Caulerpa taxifolia* and *Undaria pinnatifida* is amongst the "red alert" taxa that are to be reported to Fish Watch. Subsequent follow up of the Aldinga observation confirmed that it was a local species (*Uniophora granifera*) that is easily confused with the invasive (see Reef

Watch; http://www.reefwatch.asn.au/fpreport.html, Accessed September 2011). Note that this result should by no means be considered a failing.

The above results highlight the potential importance of Feral or in Peril observations as a tool for monitoring the spread of marine pests.

INDEX RESULTS

Previous reporting of Reef Watch data (notably the CCSA 2009 summary report) states that numbers of site attached fish, blue-throated wrasse and the mobile invertebrate predators are not as strong as the LIT-based indices as determinants of reef status. In part this inference is based on the difference in species suites considered for fish and invertebrates between Reef Watch and those used in Turner *et al.* (2007) but also because blue-throated wrasse were not widespread enough to be consistently applied (CCSA 2009, Westphalen 2009, 2010a).

The number of blue-throated wrasse observed in the 2010-2011 reporting period was considered too few to make this index useful (see above).

Note that health status indices were not employed until the Turner *et al.* (2007) observations and hence comparisons with earlier surveys in the 1990s (i.e. Cheshire *et al.* 1998, Cheshire and Westphalen 2000) are arguably subjective, particularly given seasonal differences (summer-autumn for Cheshire *et al.* 1998, Cheshire and Westphalen 2000 and Turner *et al.* 2007 while Collings *et al.* 2008 surveyed from autumn-winter).

It has been previously recommended that the reef status indices as they currently stand are in need of reconsideration and review (CCSA 2009, Westphalen 2009, 2010a).

Conversely, the improvement to Reef Watch data collection and management means that, regardless of the various above caveats, comparisons can be undertaken and theories/ hypothesis regarding both seasonal and inter-annual differences in reef status can be developed.

COMPARISON BETWEEN REEF STATUS SURVEYS

Broken Bottom retained a consistent “Caution” status noted in previous years (Table 4, Appendix C). Similarly, “Good” reefs are still predominantly in the south and non-metropolitan areas (Noarlunga, Second Valley and The Bluff). However, the north-south gradient of reef health observed in previous surveys (i.e. Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008, CCSA 2009, Westphalen 2009) was not readily apparent. “Caution” and even “Poor” status were recorded at Second Valley in summer and spring respectively (Table 4). It should be noted that “Poor” status has not been observed south of Noarlunga in previous Reef Watch reporting periods (see Appendix C).

Concerns about the status of Hallett Cove were not allayed by the available data, which indicated “Caution” status (Table 4). However, there is also a lack of coverage across seasons (only the summer was sufficiently surveyed). Given the concerns about this site in 2009-2010 (Westphalen 2010a, 2010b), more data from this site would have been appropriate.

The Noarlunga Inside sites (both north and south) appear to have improved with “Good” status recorded at both sites (notably across spring, summer and autumn in the north) relative to 2009 and 2010 reporting periods wherein “Caution” and even “Poor” health were

observed (Table 4, Appendix C). Previous formal health observations at Noarlunga Inside have generally showed a status of "Good" or "Caution" (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008).

Results of the 2010-2011 reporting period generally serve to highlight the spatiotemporal variability in reef composition and structure, but based on the available data, there nonetheless remain concerns about the status of reefs in the Hallett Cove region as well as the occurrence of "Poor" status at Second Valley.

Table 4 - Overall reef status index results (see Turner *et al.* 2007) for the 2010-2011 reporting period. Note that a summary table of results of Reef Watch 2008-2009 and 2009-2010 surveys (Westphalen 2009, 2010a) is included in Appendix C.

Site	Season			
	Winter	Spring	Summer	Autumn
Broken Bottom	Caution		Caution	
Hallett Cove			Caution	
Noarlunga North Inside		Good	Good	Good
Noarlunga South Inside	Good	Caution	Caution	
Second Valley		Poor	Caution	Good
The Bluff	Caution	Good		

All site-season combinations with "Caution" or "Poor" health status are characterised by relatively low canopy cover (Table 5), except The Bluff in winter, where there would appear to be relatively few site attached fish (Table 5). Second Valley in spring ("Poor" status) also had low canopy cover, but also had fewer fish and no mobile invertebrate predators (Table 3, Table 5).

Table 5 - Reef status indices for each site-season considered by Reef Watch in the 2010-2011. See Turner *et al.* (2007) for the details of each index. Note that the blank cells in the results (notably the columns for turf, mussels and invasive species) are "Null" values for the index score that are not the same as zeros or "no data".

Site	Season	Status	Overall Score	Canopy	Turfing algae	Mussels	Bare rock	Site attached fish	Invertebrate predators	Invasives
Broken Bottom	Summer	Caution	39	0			0	100	57	
Broken Bottom	Winter	Caution	39	0			0	100	57	
Hallett Cove	Summer	Caution	64	36				100	57	
Noarlunga North Inside	Spring	Good	72	37			49	100	100	
Noarlunga North Inside	Summer	Good	100	100				100	100	
Noarlunga North Inside	Autumn	Good	100	100				100	100	
Noarlunga South Inside	Winter	Good	83	48				100	100	
Noarlunga South Inside	Spring	Caution	44	13		0		64	100	
Noarlunga South Inside	Summer	Caution	52	7		0		100	100	
Second Valley	Spring	Poor	34	45				58	0	
Second Valley	Summer	Caution	62	30				100	57	
Second Valley	Autumn	Good	82	100				100	47	
The Bluff	Spring	Good	78	100				100	35	
The Bluff	Winter	Caution	65	100				11	85	

A lack of robust canopy-forming algae has long been considered typical of degraded reefs on the Adelaide coast (e.g. Cheshire and Westphalen 2000, Turner *et al.* 2007). Otherwise these sites tend to be dominated by bare substrate and/or turfing/filamentous red macroalgal species (Cheshire and Westphalen 2000, Turner *et al.* 2007) with increased mussel cover as has been observed at Horseshoe Reef, which has been speculated to be either a cause or response to reef decline (Smith 2000). However, turfing algae, mussel and bare substrate did not appear to be influential in reef status. Mussels were only noted at the Noarlunga sites (Table 3) and triggered the index only in the south (spring and summer). High mussel cover that was observed at Hallett Cove in 2009-2010 (Westphalen 2010a) were not reported in the current period (Table 3), suggesting either a high level of turnover or that the observations may be from slightly different locations. Given that there is a marker buoy at this site to direct surveys, there is greater certainty that the same patch of reef is being monitored. However, with only one robust set of observations at Hallett Cove, there is no chance of tracking any change at finer temporal scales.

The highest bare substrate index score was at Noarlunga North Inside in spring (Table 5), a site that actually reported "Good" overall status. Turfs were highest at Broken Bottom and Second Valley in summer (Table 3), but did trigger the index (Table 5).

It remains an open question as to the appropriateness of the reef status indices in terms of their definition, calculation (including cut-offs) and interpretation.

POTENTIAL FACTORS FOR INTER-ANNUAL DIFFERENCES

There are substantial inter-annual differences within sites with improvements observed at Noarlunga Reef and a decline in status at Second Valley. In addition, while Hallett Cove would appear largely unchanged in terms of overall status, the total lack of mussel cover in 2010-2011 relative to 2009-2010 suggests very high turnover within this strata.

Sedimentation is increasingly considered to be a cause for reef decline (Cheshire and Westphalen 2000, Greig 2000, Smith 2000, Airoldi 2003, Turner 2004). After a relatively mild summer and wet winter in 2010-2011, changes in status between years may be related to increased sediment run-off from higher stormwater inputs as well as greater influxes from rivers and streams. This model may explain the changes observed at Second Valley, which is probably the most rural site in the survey, although it's exposure to terrestrial inputs relative to the other locations is unknown. However, the period of "Poor" status at Second Valley was in spring rather than autumn (there were no winter data for this site).

It is perhaps time to undertake formal surveys of Adelaide metropolitan reefs along the lines of Turner *et al.* (2007), Collings *et al.* (2008). Importantly, there is a substantial distance (and quite a lot of reef) between Noarlunga Reef and Second Valley (~ 22 km straight line distance) and it would be prudent to determine the status of intervening reefs (Southport, Aldinga and Moana) with the view to establishing if reef decline has encroached south of Noarlunga, although note that this should not be the responsibility of Reef Watch, but may be a component of formal (professional) surveys. While The Bluff is a good example of a healthy reef within the AMLR NRM region, its location makes it a poor indicator of processes within Gulf St Vincent.

More research is required into the causal link between sediment loads and reef decline and there is a need for more data on sedimentation and turbidity levels along the Adelaide metropolitan coast as well as less urbanised areas to the south.

SEASONAL DIFFERENCES

There is some capacity to observe the effect of season on reef status, although an in-depth consideration of differences between sites and/or seasons would be best achieved via a multivariate analytical approach that makes comprehensive use of the available data rather than via the index scores and related summary data.

Seasonal differences are readily apparent within sites (where there is enough coverage), notably Second Valley across spring, summer and autumn with "Poor" improving to "Caution" and then "Good" (Table 4). Similar changes were observed at Second Valley in 2008-2009 (Westphalen 2009) and 2009-2010 along with The Bluff (Westphalen 2010a) suggesting that these sites are highly dynamic. Certainly The Buff site has a reputation for being relatively higher energy to that of the other sites (personal observation).

The occurrence of "Poor" status at Second Valley in spring is therefore less concerning than the possible decline at Hallett Cove. It is readily apparent from past and present data that this site is quite dynamic in seasonal terms but, more importantly, the site recovered to "Good" by the following autumn.

Some of these changes may be due to seasonal differences in macroalgal cover, particularly amongst canopy-forming species of *Cystophora* and *Sargassum* (Edgar 1983, Edgar *et al.* 2004, Collings 1996, Collings *et al.* 2008), which would be supported by the observed differences of canopy cover at Second Valley (Table 3, Table 5). However, there would also seem to be concomitant changes in the site attached fish and mobile invertebrate predators (Table 3, Table 5).

While site attached fish implies a notion of a fixed "home" site, the degree of fidelity may change according to life cycle imperatives and/or external factors, both natural (e.g. predators, competitors and/or storm events) or anthropogenic (e.g. fishing, boating and/or diving disturbance). Similarly, mobile invertebrate predators may undergo changes due to species-specific or external influences.

It is an arguable point that Reef Watch effort might be better allocated to collecting summer and winter data only (or a hot-cold comparison dataset), particularly given the lack of complete coverage across seasons.

IMPROVEMENTS TO INDICES

The status indices developed by Turner *et al.* (2007) were never intended to be the definitive approach to reef health assessment. There is a need for critical assessment of the validity, parameterisation and calculation of each index, responding to the criticisms raised in both Reef Health (Collings *et al.* 2008) and Reef Watch reporting (CCSA 2009, Westphalen 2009, 2010a). However, it needs to be pointed out that reassessment/improvement to reef status indices is not a job for Reef Watch, although it may provide an excellent forum within which modified approaches can be tested.

CONCLUSIONS AND RECOMMENDATIONS

Overall, the Reef Watch dataset in terms of seasonal coverage across sites for this reporting period is similar to 2009-2010, but otherwise more comprehensive than previous years (see CCSA 2009, Westphalen 2009, 2010a).

Hallett Cove remained largely unchanged relative to the 2009-2010 reporting period, with "Caution" status, although the seasonal coverage was poor. Noarlunga sites (both north and

south) seemed to have improved, and there was substantial variability at Second Valley with a "Poor" status in spring that improved to "Good" by the following autumn.

Results are broadly similar to the previous year in terms of coverage, quality and overall results. Improvements to the monitoring program have been maintained, but not extended, in part because of the limitations entrained within use of the indices but also perhaps because survey effort is over-stretched in an attempt to cover six sites in each season (i.e. 24 observations).

Based on the available data it would seem that there is still cause for concern about Hallett Cove. Analysis of additional data from this site (see Westphalen 2010b) would suggest that change in status may be localised, but there is a need for a specifically targeted survey of both the Reef Watch site as well as more broadly across this reef. The apparent decline in status at Second Valley is less concerning, in part because the site has been shown to undergo substantial seasonal changes in previous surveys, but mostly because it also recovered.

RESULTS OF SURVEYS

Recommendations for further action that are not the responsibility of Reef Watch include:

- A scientific survey of Adelaide metropolitan reefs along the lines of Turner *et al.* (2007), and Collings *et al.* (2008) aimed at establishing the nature of the decline at Hallett Cove and verifying if there is any degradation in the area south of Noarlunga to Second Valley.
- A specifically targeted professional survey should be undertaken of the Reef Watch Hallett Cove site, preferably in conjunction with the sites employed by Russell and Connell (2010) for surveys on this reef.
- More research is required into the causal link between sediment loads and reef decline and there is a need for more data on sedimentation and turbidity levels along the Adelaide metropolitan coast as well as less urbanised areas to the south.

Recommendations for Reef Watch to consider:

- Seasonal comparisons of the Reef Watch data are hampered by a lack of coverage, particularly (but not surprisingly) in autumn and winter. In moving forward, a better approach may be to consider a summer-winter (or hot-cold) comparison of each site. This would add a degree of flexibility to the organisation of surveys, allow for a degree of spillage outside the official summer and winter periods as well as encourage a more orthogonal dataset. Note that the minimal LIT length of 20 m should be maintained, but the overall amount of LIT would not be diminished under a simplified approach.
- Feral or in Peril observations should be encouraged, particularly at man-made structures (jetties, breakwaters, boat ramps, etc.) on the southern AMLR coast.

INDICES

Recommendations for the indices remain largely unaltered from previous years (see CCSA 2009, Westphalen 2009, 2010a). Broadly, it is strongly recommended that ongoing use of these indices needs to be considered in light of the need for further research and development.

Recommendations for index review and development include:

- Better use of Reef Watch data through simplification of the field requirements and/or adjustment to index calculation/interpretation.
- Removal of indices that are not employed or only make sporadic contributions to index calculation:
    - Sedimentation index – not used,
    - Richness of macroalgae – not used,
    - Richness of mobile invertebrates – not used,
    - Blue-throated wrasse – does not occur across all sites.
- Simplification and/or targeting of the taxonomy used in deriving fish and invertebrate indices to specific species/genera/lifeforms.
- Simplification of the estimation of numbers, particularly as relates to fish surveys such as the use of Braun-Blanquet style categories.
- An expanded interpretation of reef status (or “health”) to include:
    - Consideration of marine debris,
    - Consideration of EPBC/NP&WS listed species.

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APPENDIX A – TAXA USED IN REEF WATCH ANALYSES

LINE INTERCEPT TRANSECTS

Lifeform	Description	Index
ATTAN	Attached animal	NA
BBIG	Brown big	Canopy
BKELP	Brown kelp	Canopy
BSMALL	Brown small	NA
DDD	No data	NOT USED
ENC	Encrusting	NA
GSMALL	Green small	NA
MOBAN	Mobile animal	NA
MUSSELS	Mussels	Mussels
RBIG	Red big	NA
RCORAL	Red coralline	NA
ROCK	Bare rock	Bare
RSMALL	Red small	NA
SAND	Bare sand (on rock)	Bare
START	Transect start	NA
TURF	Turf	Turf

NA = Not Applicable

FISH SPECIES OBSERVED ACROSS REEF WATCH SURVEYS

Common	Species	Site Attached	Blue-Throated Wrasse
Blue-throated wrasse	*Notolabrus tetricus*	YES	YES
Bullseye	*Pempheris* spp.	YES	NO
Cuttlefish	*Sepia apama*	NO	NO
Drummer	*Kyphosus sydneyanus*	NO	NO
Dusky morwong	*Dactylophora nigricans*	NO	NO
Goat fish	*Upeneichthys vlamingii*	NO	NO
Herring cale	*Odax cyanomelas*	YES	NO
Horseshoe Leatherjacket	*Meuschenia hippocrepis*	YES	NO
Hulafish	*Trachinops* spp.	NO	NO
Leafy seadragon	*Phycodurus eques*	YES	NO
Long-finned pike	*Dinolestes lewini*	NO	NO
Magpie perch	*Cheilodactylus nigripes*	YES	NO
Moonlighter	*Tilodon sexfasciatus*	YES	NO
Old wife	*Enoplosus armatus*	YES	NO
Other leatherjacket		NO	NO
Other wrasse		YES	NO
pipe fish		YES	NO
Rainbow cale	*Odax acroptilus*	YES	NO
Scalyfin	*Parma victoriae*	YES	NO
Senator wrasse	*Pictilabrus laticlavius*	YES	NO
Small fish		NO	NO
Sweep	*Scorpis* spp.	NO	NO
Weed whiting	*Siphonognathus*	NO	NO
Western talma	*Chelmonops curiosus*	YES	NO
Yellow-headed hulafish	*Trachinops noarlungae*	YES	NO
Yellow-striped leatherjacket	*Meuschenia flaviolineata*	YES	NO
Zebra fish	*Girella zebra*	NO	NO

INVERTEBRATE SPECIES OBSERVED IN REEF WATCH SURVEYS

Common	Species	Index
Amblypneustes	*Amblypneustes* spp.	NO
Blacklipped abalone	*Haliotis* spp.	NO
Bullseye	*Pempheris* spp.	FISH
Cenolia (feather star)	*Cenolia* spp.	NO
Centrostephanus	*Centrostephanus tenuispinus*	NO
Coscinasterias (11 arm star)	*Coscinasterias muricata*	YES
Dicathais	*Dicathais orbita*	YES
Greenlip abalone	*Haliotis laevigata*	NO
Heliocidaris	*Heliocidaris erythrogramma*	NO
Hermit crab		NO
Holopneustes	*Holopneustes* spp.	NO
Holothurian (sea cucumber)	*Stichopus* spp.	NO
Moonlighter	*Tilodon sexfasciatus*	FISH
Nepanthia	*Nepanthia troughtoni*	NO
Patiriella brevispina	*Patiriella brevispina*	NO
Patiriella calcar	*Patiriella calcar*	NO
Pentagonaster (firebrick star)	*Pentagonaster dubeni*	NO
Petricia	*Petricia vernicina*	NO
Phasianella	*Phasianella* spp.	NO
Phyllacanthus	*Phyllacanthus irregularis*	NO
Plagusia (red bait crab)	*Plagusia chabrus*	NO
Queen scallop	*Equichlamys bifrons*	NO
Rock lobster	*Jasus edwardsii*	YES
Small fish		FISH
Tosia	*Tosia* spp.	NO
Turbo torquatus	*Turbo torquatus*	NO
Turbo undulatus	*Turbo undulatus*	NO
Uniophora	*Uniophora granifera*	YES
Western Bluedevil	*Paraplesiops meleagris*	FISH
Western Talma	*Chelmonops curiosus*	FISH
Whelk/triton complex		YES

APPENDIX B – FERAL OR IN PERIL – FERAL OBSERVATIONS

Location	Date	Observation	Depth (m)
South Noarlunga Reef	18/9/2010	No feral species observed	4
Hallett Cove	26/9/2010	No feral species observed	4
The Bluff	24/10/2010	No feral species observed	3
The Bluff	24/10/2010	No feral species observed	6
North Noarlunga Inside	7/11/2010	No feral species observed	5
Marino Reef	25/11/2010	No feral species observed	2
North Noarlunga Reef	26/11/2010	No feral species observed	3
Hallett Cove	8/12/2010	No feral species observed	5
North Haven Boat Ramp	30/12/2010	European fanworm (*Sabella spallanzanii*)	3
Broken Bottom	30/1/2011	No feral species observed	10
South Noarlunga Reef	5/2/2011	No feral species observed	7
Hallett Cove	22/2/2011	No feral species observed	7
Brighton Jetty	6/3/2011	European fanworm (*Sabella spallanzanii*)	3
Glenelg Jetty	6/3/2011	European fanworm (*Sabella spallanzanii*)	2
North Noarlunga Reef	12/3/2011	European fanworm (*Sabella spallanzanii*)	5
Aldinga Reef Aquatic Reserve	31/12/2011	Northern Pacific seastar (*Asterias amurensis*)	5

APPENDIX C – REEF WATCH SUMMARY TABLES FROM 2008-2010

Overall reef status index results for Reef Watch observations for surveys conducted in 2008-2009 and 2009-2010.

Site	Survey	Season			
		Spring	Summer	Autumn	Winter
Broken Bottom	2008-2009			Caution	
	2009-2010	Poor		Caution	
Hallett Cove	2008-2009	Good	Good	Good	
	2009-2010	Caution	Poor	Caution	
Noarlunga North Inside	2008-2009	Caution			
	2009-2010	Caution		Caution	Caution
Noarlunga South Inside	2008-2009	Caution			
	2009-2010	Caution	Poor		
Second Valley	2008-2009	Good	Caution	Good	
	2009-2010	Good	Caution	Good	
The Bluff	2008-2009	Good	Caution		
	2009-2010		Good		