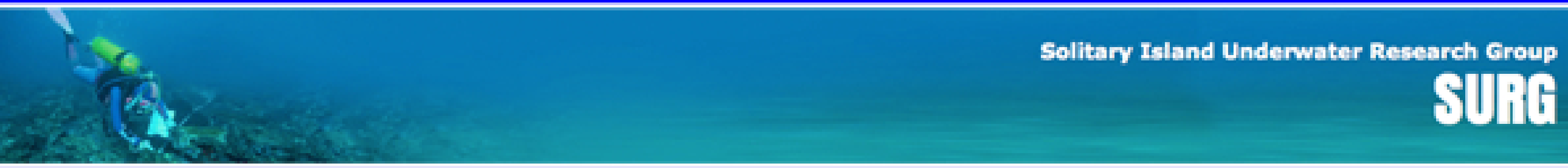

An assessment of the 'health' of corals in the Solitary Islands Marine Park, northern NSW

Robert J Edgar

Solitary Islands Underwater Research Group

NSW GOVERNMENT | NSW Environmental TRUST

Report prepared for the NSW Environmental Trust, May 2015

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Front Cover Image: Ian Shaw

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Introduction

The intention of this report is to provide the NSW Environmental Trust, as the funding agency, with a preliminary analysis of the assessment and monitoring of corals that were the subject of the study. A thorough analysis of the data collected during the study will be undertaken at a later date and a paper published in a peer-reviewed journal.

The Solitary Islands Underwater Research Group (SURG)

The Solitary Islands Underwater Research Group (SURG), founded in 1985, comprises community members with an interest in the marine environment and in particular, the waters of the Solitary Islands Marine Park (SIMP). Members are drawn from all walks-of-life, are active scuba divers, and include tertiary-trained biologists, talented underwater photographers (both stills and video), and keen naturalists. Since 1992, SURG has conducted a number of research and monitoring activities with funding provided by various government agencies and programs, such as NSW Fisheries, Coastcare, Envirofund, Caring for Our Country and the NSW Environmental Trust.

Papers have been written describing local mollusc and pycnogonid communities; 'Identification Cards' of common local marine fauna have been produced and sold in Australia and overseas; papers have been presented at various symposia; public displays using photographic material and 'touch tanks' have been conducted and, SURG is a regular participant in national 'Clean Up Australia' days.

Importantly, SURG actively lobbied for the formation of Solitary Islands Marine Reserve through detailed submissions based on an extensive local knowledge of the marine biota and different habitat types. The Solitary Islands Marine Park was eventually established in 1991. During the public consultation process leading to the development of zoning and operational plans for SIMP, SURG took every opportunity to provide input and provided support for the NSW Marine Parks Authority staff.

Over the last 20 years, SURG has been actively engaged in scientific research and monitoring within SIMP. The research has entailed a commitment of several thousand person hours, in field data collection and data analyses. Projects have included:

- habitat mapping at the cardinal points of the five largest islands
- an assessment of threatening processes
- monitoring coral disease and coral bleaching
- monitoring targeted fish species and threatened and endangered fish species
- assessing sub-tidal marine debris loads
- developing a web-based *Solitary Islands Marine Park Marine Species Photo Inventory* and,
- the installation of an underwater 'Education Trail' at North Solitary island.

Rationale for the study

The East Australian Current (EAC) comprises the southward movement of waters from the Queensland tropics, south along the east coast of Australia. The current is responsible for transporting tropical larvae of many taxa to NSW coastal waters (Booth et al, 2007). In the last 60 years the EAC has become stronger, with warmer, saltier water now found 350 km further south (Ridgeway, 2007). As a result of climate change and the consequent strengthening of the EAC, water temperatures in southeast of Australia are warming faster than other regions – it is a global warming hotspot. Southward range extensions have been documented for seaweeds, phytoplankton, zooplankton and demersal and pelagic fishes (E.S. Poloczanska et al, 2012).

Coral bleaching is the dissociation of the symbiotic relationship between zooxanthellae and their cnidarian host, and/or a reduction in photosynthetic pigment concentration as a result of stress. Stress may result from a number of factors including changes in salinity, solar radiation (including ultraviolet radiation), pollution, change in seawater temperature, or diseases (Dalton and Carroll 2011).

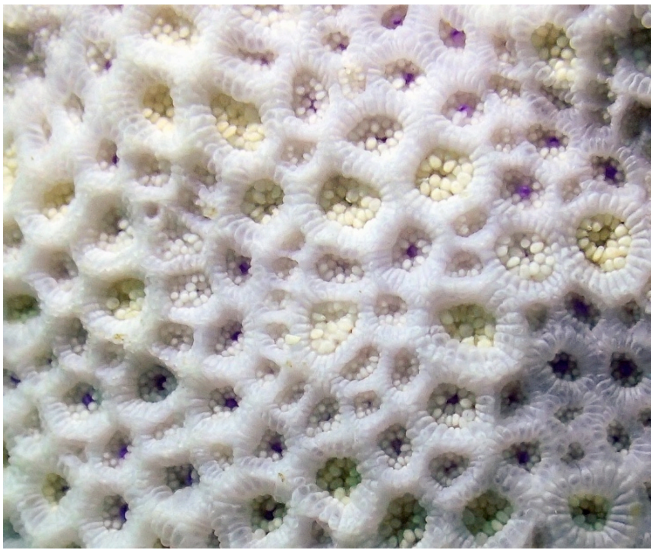


Figure 1 - Bleached Faviidae coral. Summer 2015. North West Solitary Island. (Image: Matt Nimbs)

Overwhelming scientific studies indicate that climate change will have negative and potentially catastrophic impacts on the structure and function of coral reef ecosystems. Understandably, the focus of most research has been on tropical systems, but there is a need for greater recognition of subtropical reefs in the broader climate change picture. For example, many members of the Coffs Harbour community would be unaware that corals dominate many reefs in the SIMP and that these reefal communities provide habitat for a range of threatened and protected endemic species, as well as potential refugia for tropical taxa forced southward by increasing seawater temperatures.

A recent model for subtropical reefs in NSW predicts that many corals will bleach when seawater temperatures exceed 26.5°C (Dalton and Carroll 2011). Subsequent mortality will depend on the intensity of insolation at the location and the duration of the thermal anomaly. The model predicts that repeated bleaching events would lead to a decline in dominant coral species and thus a change in the structure of reefal communities.

Coral health, as indicated by the incidence of bleaching and disease, can be readily observed and monitored using well established protocols currently being deployed in tropical ecosystems. The project will promote 'education through participation' in the assessment of coral health in an important subtropical region, using citizen scientists from SURG. A key outcome of the project is to communicate the importance of subtropical coral ecosystems and the role the community has in fostering their resilience to future change.

There is an urgent need to engage with regional communities to educate them about important marine systems; the threats the systems are facing and, steps that can be taken to improve their resilience. The project will accomplish this through active participation in monitoring; the preparation of educational materials on regional coral communities and, the promotion of measures that will reduce impacts on reefal communities.

Objectives

1. To engage with underwater volunteers and members of the wider community to collect baseline data on the health of corals in northern NSW waters using a standardised protocol developed by researchers from the University of Queensland (UQ).
2. To build capacity in local community-based underwater volunteers to utilise a rigorous scientific method that has utility for government agencies charged with managing marine resources in NSW.
3. To contribute to an international database on coral health using a standardised scientifically credible protocol.
4. To educate the general public about subtropical coral communities, coral health and measures that can be taken to promote resilience of these communities into the future.
5. To provide an opportunity for local community members to participate in a global reef-monitoring project thus mitigating the sense of hopelessness felt by many in the face of outcomes predicted from climate change models.

The Solitary Islands Marine Park

The Solitary Islands Marine Park (SIMP) is composed of a number of estuaries, headlands, beaches, small, rocky islands and marine waters in the vicinity of Coffs Harbour on the mid-north coast of NSW, Australia (Lat. 30^{o}S, Long. 153^{o}20'E). It covers approximately 100,000 hectares of aquatic environment stretching along 75 kilometres of coastline (Figure 2).

Within this area, two opposite flowing ocean currents interact; one a nutrient poor, relatively warm current flowing southwards, and the other derived from cooler temperate waters flowing northwards. "This interaction has resulted in biological communities having affinities with both the subtropical/tropical and temperate biotas of Australia" (Zann, 1997).

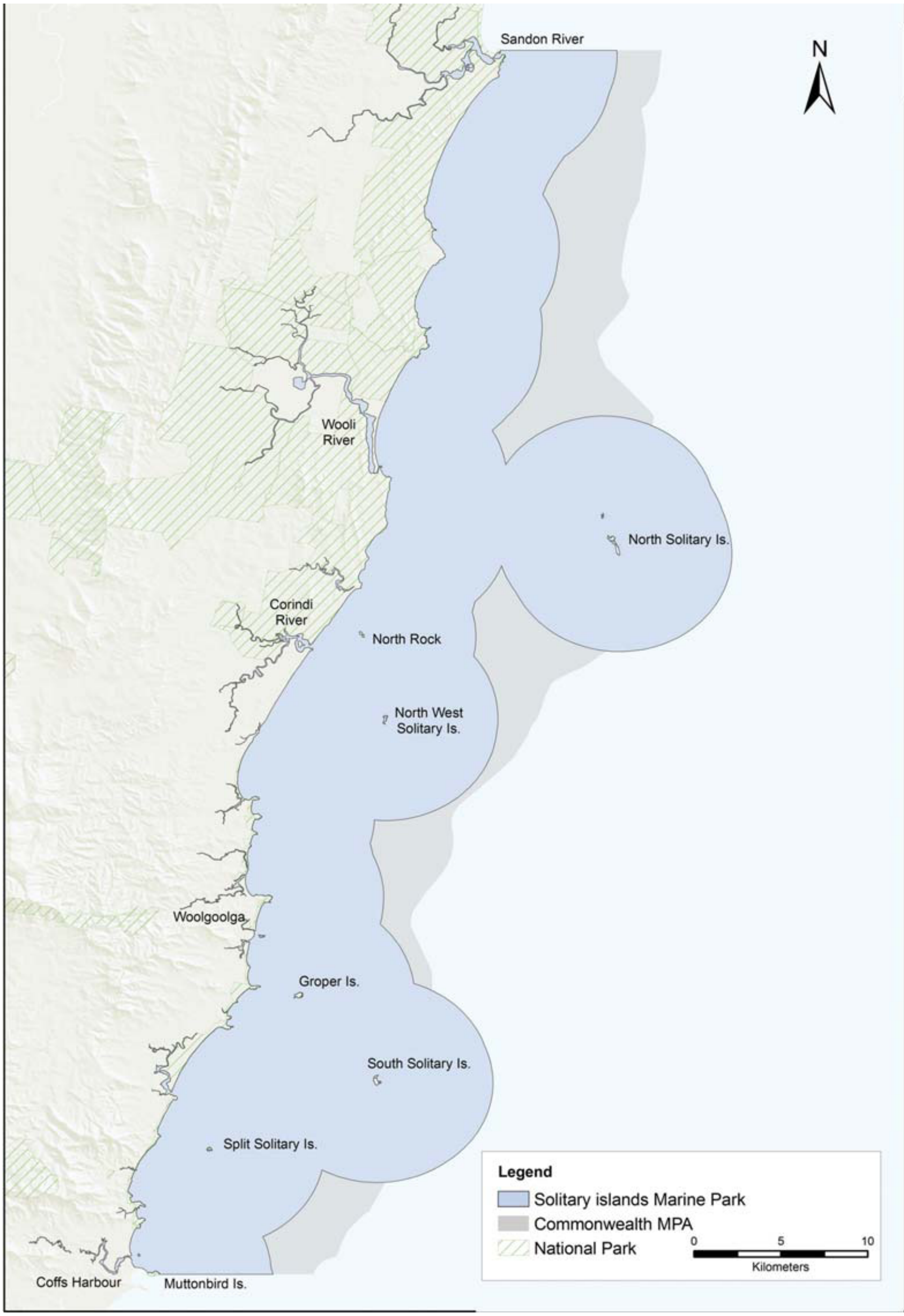


Figure 2 - Location of Solitary Islands Marine Park (New South Wales, Australia) including study locations of North Solitary Islands and North-West Solitary Island. From: Marine Parks Authority, 2008.

CoralWatch

CoralWatch is a non-profit organisation built on a research project at the University of Queensland (http://www.coralwatch.org). Its aim is to provide hands-on monitoring and education tools to increase awareness of reef threats and encourage behavioural change towards a sustainable, low-carbon future.

The main research tool utilised by CoralWatch is the Coral Health Chart. The chart is comprised of a series of sample colours, with variation in brightness representing different stages of bleaching and recovery, based on controlled experiments. It is an inexpensive, simple, non-invasive method for monitoring coral bleaching and assessment of coral health. To date, approximately 4,000 surveys have been conducted under the CoralWatch banner, with corals assessed in the tropical waters of Australia, the Indo-Pacific and Caribbean regions.

In the field, users compare colours of corals with colours on the chart and record matching codes. For example, a coral colony might be assessed with codes of B5 and B1. The average of the two values is the colour score. In this instance 5 + 1 = a colour score of 3. The colour score indicates the 'health' of the colony.

Method

Site selection

Coral assemblages in the SIMP are formed as a veneer over rock. Ninety-one hard coral species have been recorded in the marine park with some locations having a high percentage of cover (e.g. at Chopper Rocks the mean coral cover is ~ 45%) (Marine Parks Authority 2008).

North Solitary Island, North West Solitary Island, South West Solitary Island, Split Solitary Island and South Solitary Island were included in the study. One islet, North West Rock, and Surgeon's Reef were also surveyed. Survey data collected from North West Rock, lying approximately 1 km to the north of North Solitary Island, were included with data from North Solitary Island for analysis. Surgeon's Reef, lying approximately 0.9 km to the north of North West Solitary Island, was included with this island.

At each island a number of sites were surveyed. The locations of sites are indicated in Table 1 and Figures 3, 4, 5, 6 and 7.

Island	Location/Site	Latitude	Longitude
North Solitary	North Solitary Anemone Bay	-29.9235	153.3878
North Solitary	North Solitary Bubble Cave	-29.9305	153.3893
North Solitary	North Solitary Elbow Cave	-29.9305	153.3910
North Solitary	North Solitary Monterey	-29.9282	153.3900
North West Rock	North West Rock Mooring	-29.9126	153.3833
North West Solitary	North West Solitary 'E' Gutters	-30.0199	153.2702
North West Solitary	North West Solitary Manta Mooring	-30.0168	153.2695
North West Solitary	North West Solitary Midway Mooring	-30.0183	153.2699
North West Solitary	North West Solitary Lion's Den	-30.0169	153.2672
North West Solitary	North West Solitary Snorkellers Mooring	-30.0177	153.2698
North West Solitary	Surgeons Reef	-30.0077	153.2700
South Solitary	South Solitary Cleaner Station	-30.2019	153.2680
South Solitary	South Solitary Gantry	-30.2049	153.2665
South Solitary	South Solitary Manta Arch	-30.2031	153.2677
South Solitary	South Solitary North Boulder Wall	-30.2014	153.2662
South Solitary	South Solitary Shark Gutters	-30.2021	153.2667
South Solitary	South Solitary Buchanan's Wall	-30.2078	153.2665
South West Solitary	South West Solitary Coral Gardens	-30.1602	153.2297
South West Solitary	South West Solitary Coral Surprise	-30.1598	153.2273
South West Solitary	South West Solitary Western Mooring	-30.1601	153.2248
South West Solitary	South West Solitary North East	-30.1590	153.2286
Split Solitary	Split Solitary Mike's Mooring	-30.2419	153.1798
Split Solitary	Split Solitary North Mooring	-30.2388	153.1800
Split Solitary	Split Solitary Turtle Cove	-30.2420	153.1808
Split Solitary	Split Solitary Western Mooring	-30.2407	153.1781

Table 1 - Islands and sites surveyed at each island

Criteria used to select the islands and survey sites included:

- An inshore/offshore transition with South West Solitary and Split Solitary Islands being closer inshore, and North Solitary, North West Solitary and South Solitary Islands located further offshore.
- The extensive coral cover at the six survey locations.
- The proximity to fixed moorings and safe diving depths in relation to the logistics and constraints required to conduct surveys.
- The prevailing weather and oceanic conditions at the time the surveys were conducted.

Figure 3 - North Solitary Island and North West Rock. Locations of survey sites indicated.

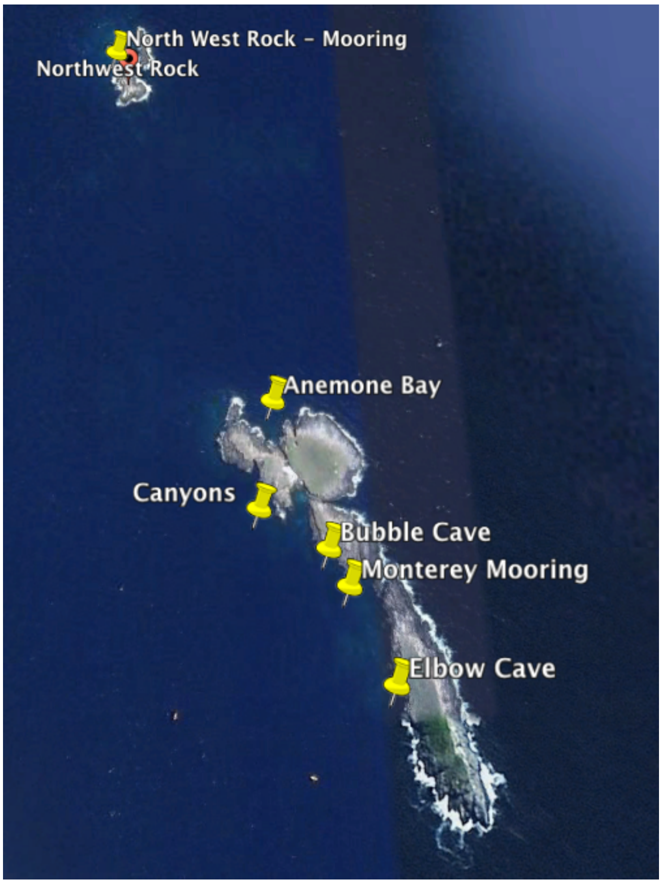


Figure 4 - North West Solitary Island. Locations of survey sites indicated.

Figure 5 - South Solitary Island. Locations of survey sites indicated.

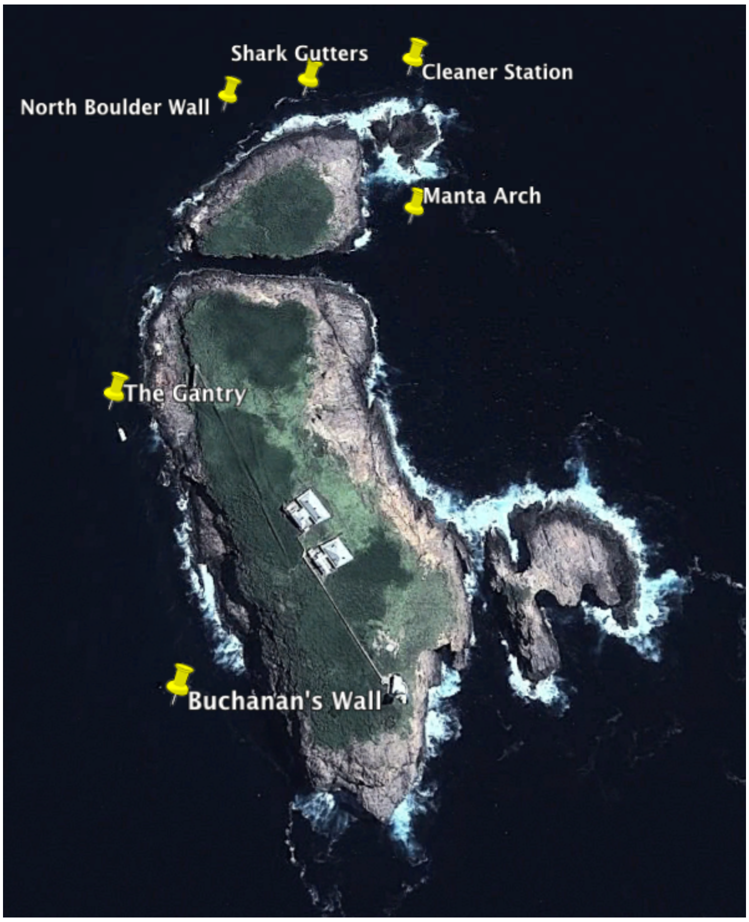
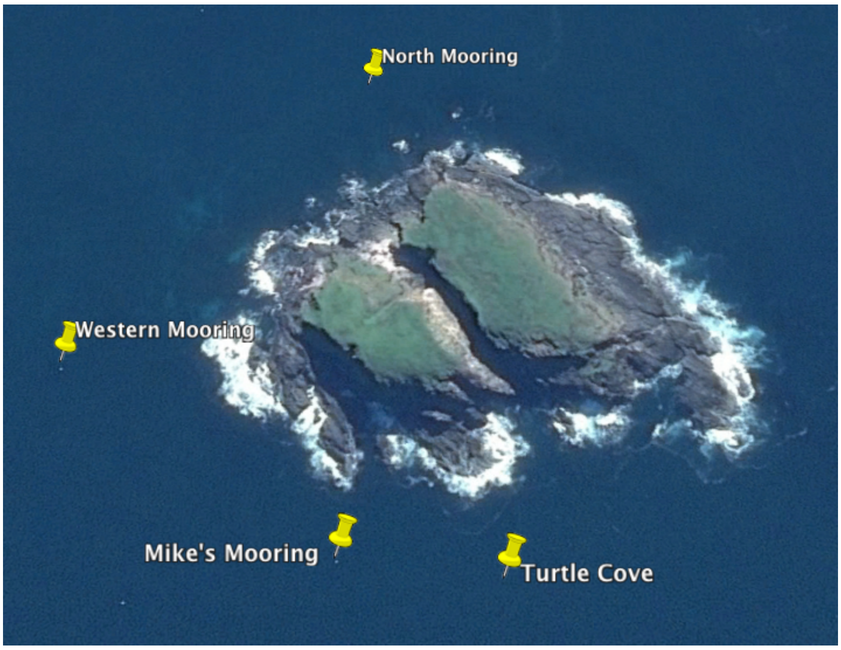


Figure 6 - South West Solitary Island. Locations of survey sites indicated.

Figure 7 - Split Solitary Island. Locations of survey sites indicated.



Data Collected

Metadata

Participants in a site survey recorded the following metadata: Location/Site Name; Date; Time; Water Temperature (^{o}C); Depth; Latitude/longitude; Weather Conditions; Name of person conducting survey, and Compass Bearing along tape measure from start point.

Coral types

Coral types are determined from the characteristic basic growth forms or shapes of coral colonies. The four main types surveyed as mandated in the CoralWatch program determined the types of corals recorded. Types include branching, plate, boulder and soft coral 'types', images of which are provided in Figure 8.

'Branching' refers to any branching coral such as *Acropora* and *Pocilloporid* species. 'Boulder' refers to any massive or rounded corals, or those that have an encrusting habit (conforming to the shape of the substrate) such as some *Favid, Dendrophyllid* and *Porites* species. 'Plate' refers to any coral that forms a plate-like or foliose formation such as tabular *Acropora or Turbinaria* species, and the 'Soft' category refers to octocorals lacking a hard skeleton, such as the *Sarcophyton* species.

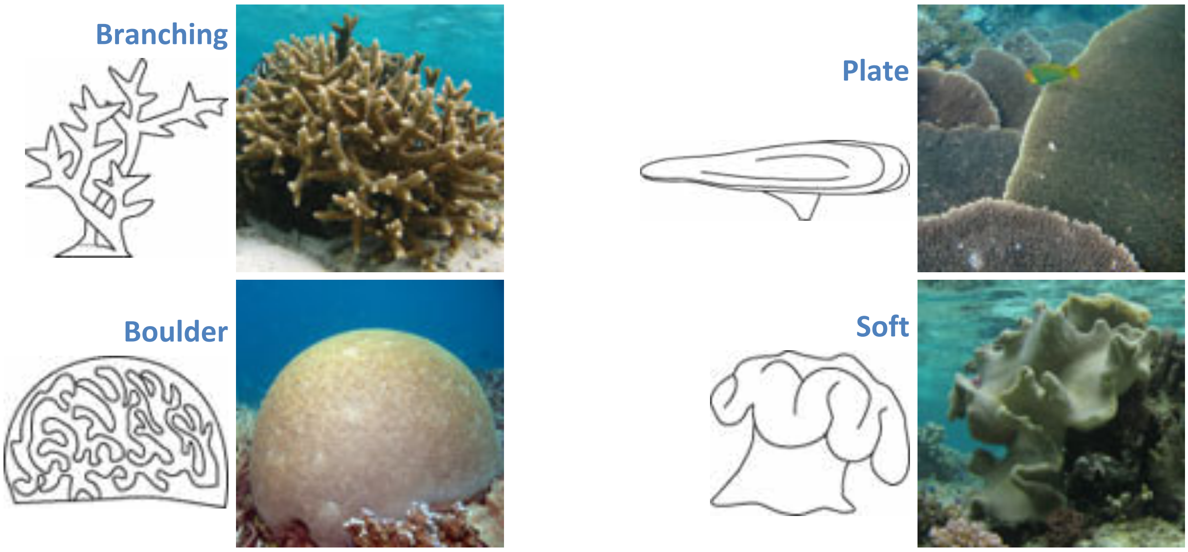


Figure 8 - Corals types (from www.coralwatch.org)

Coral families

"The project focussed on five coral families that modelling predicts are most prone to bleaching in the SIMP" (Dalton and Carroll, 2011). The families included the Poritidae (*Porites* and *Goniopora spp.)* with boulder growth habits; Pocilloporidae (*Pocillopora damicornis, Stylophora pistillata*) with branching growth habits; Acroporidae (*Acropora spp.*) with plate and branching growth habits; Dendrophylliidae (*Turbinaria spp.*) with plate and boulder growth habits, and Faviidae (*Plesiastrea, Goniastrea, Platygyra, Montastrea* and *Favites* spp.) with boulder growth habits.

Coral Health Chart

The Coral Health Chart (Figure 9) is based on the actual colours of bleached and healthy corals. Each colour square corresponds to a concentration of symbionts contained in the coral tissue. The concentration of symbionts is directly linked to the health of the coral. The hues on the chart represent the most common coloured corals, and assist our eyes to make an accurate match. The brightness of the colours, ranging from 1 to 6, is the same on every side of the chart.

Using the coral health chart

1. Choose a coral colony.
2. Observing the coral, select the lightest coloured area avoiding the tips of branching corals.
3. Hold the colour chart next to the selected area and rotate chart until you find the closest colour match.
4. Record the matching colour code on the data sheet.
5. Repeat steps 2 to 5 for the darkest area of the coral.
6. Continue survey, repeating steps 1 to 5.

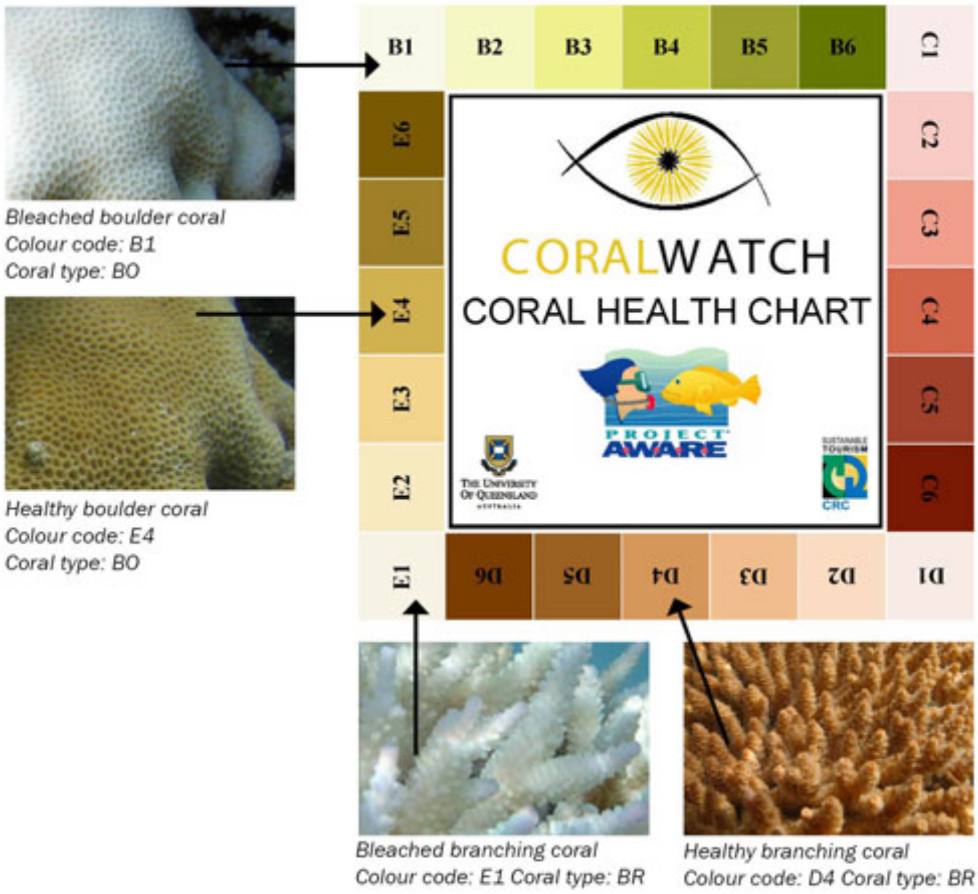


Figure 9 - Coral Health Chart

Data sheet

Each diver was provided with a polyester plastic data sheet (Figure 10) for recording metadata and assessments of the health of individual corals. Sheets could be written on using graphite pencils in an underwater context.

Location/Site: ______________________________ Date: __________

Time (0000hrs): ________ Water Temp. (C) ________ Depth (m): ____________

Lat/Long: ____________________________ Sunny/Cloudy/Raining (Please Circle)

Name: ______________________________ Bearing: __________

Number	Coral Type	Family	Dark	Light	Number	Coral Type	Family	Dark	Light
1					16				
2					17				
3					18				
4					19				
5					20				
6					21				
7					22				
8					23				
9					24				
10					25				
11					26				
12					27				
13					28				
14					29				
15					30				

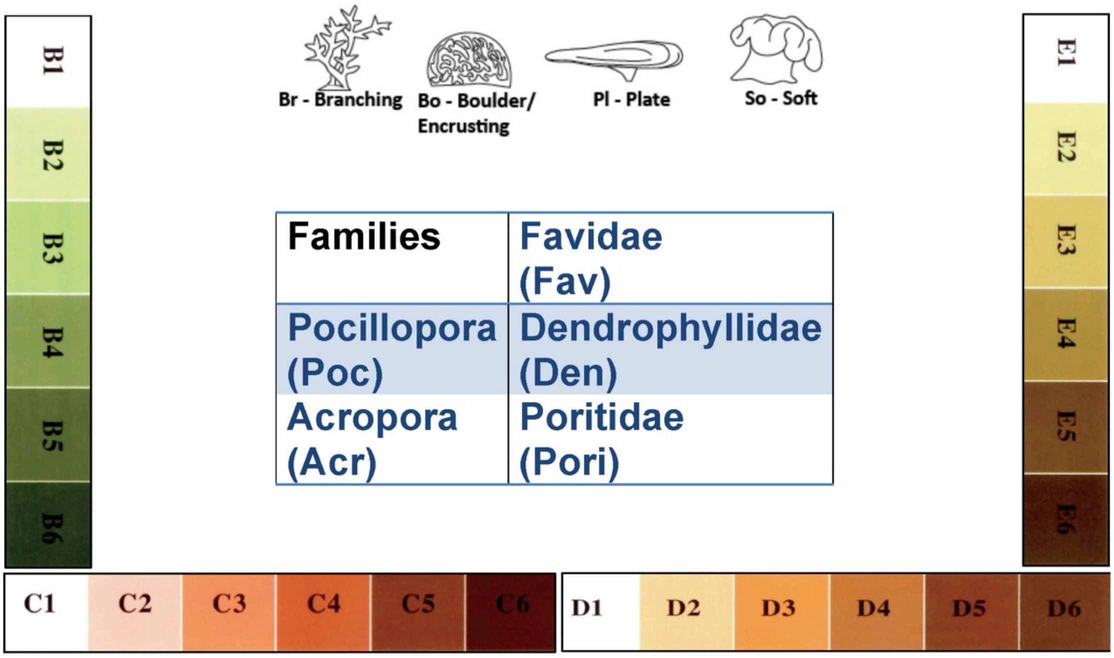


Figure 10 - Data sheet for recording metadata, assessments of individual coral colonies, the Coral Health Chart, families of corals and growth types of corals

Supplementary material

Divers were provided with supplementary identification images and family specific information, printed on polyester sheets that could be used underwater to aid in the recognition of families and growth forms of corals (Figures 11, 12, 13 and 14).

SURG - Targeted Coral Families

Acroporidae - Acropora

Acropora can form plate and table shaped colonies from clusters of tiny branchlets
An axial corallite at branch tips is surrounded by radial corallites

Poritidae - Porites & Goniopora

Porites - Thin or encrusting plates with ridges or bumps of skeleton on colony surface. Colonies often appear fragmented. Corallites very small (<1.5mm) with well-defined walls

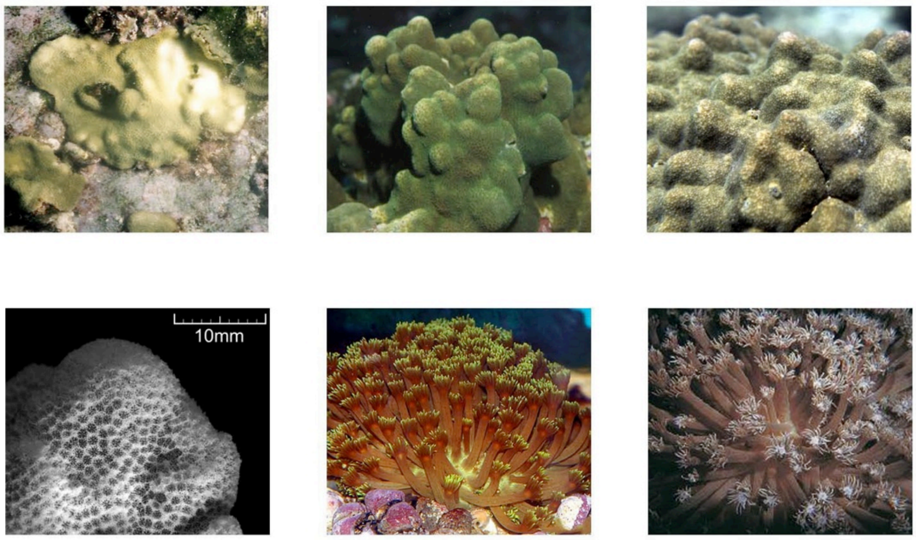


Figure 11 - Identification sheet showing images and distinguishing characteristics of the Acroporidae and Poritidae families of corals.

SURG - Targeted Coral Families

Faviidae - Goniastrea, Favites & Favia

Colonies can typically form mounds, encrusting, thick plates & domes. Some species can form short or long meandering valleys from 4-20mm wide. Others have corallites forming cones or tubes in which corallites may be rounded to sub-angular.

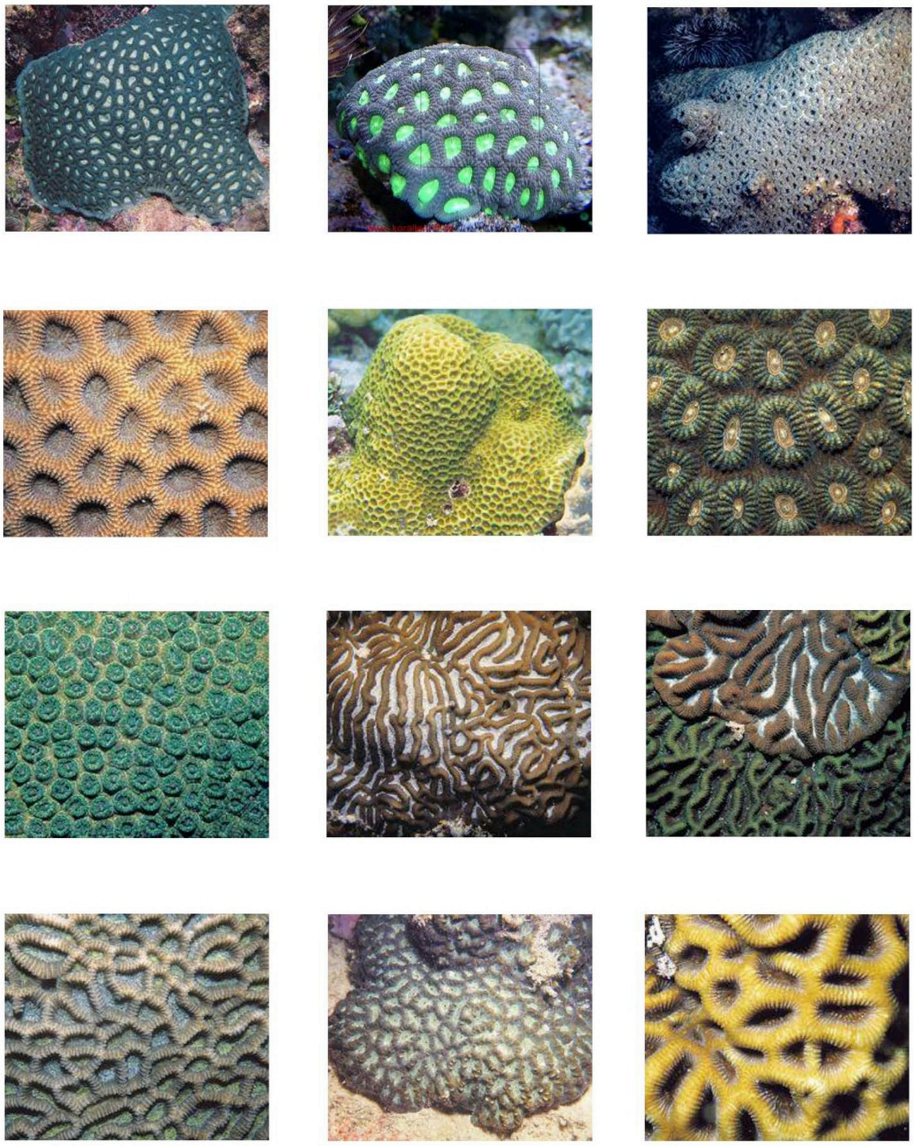


Figure 12 - Identification sheet showing images and distinguishing characteristics of the Faviidae family of corals.

SURG - Targeted Coral Families

Pocilloporidae - Pocillopora & Stylophora

Colonies variable; branches have blunt or slightly flattened ends as if squeezed slightly at the tips.

Corallites small and usually with hoods

Colonies made of knobby branches covered in skeltal bumps called verrucae. Corallites immersed or among the verrucae. A fine 'fuzz' of tentacles is often present.

Dendrophylliidae - Turbinaria

Thin, contorted plates, often tiered, corallites round (2.5-6mm), tubular or level with the colony surface. Surface texture smooth between corallites.

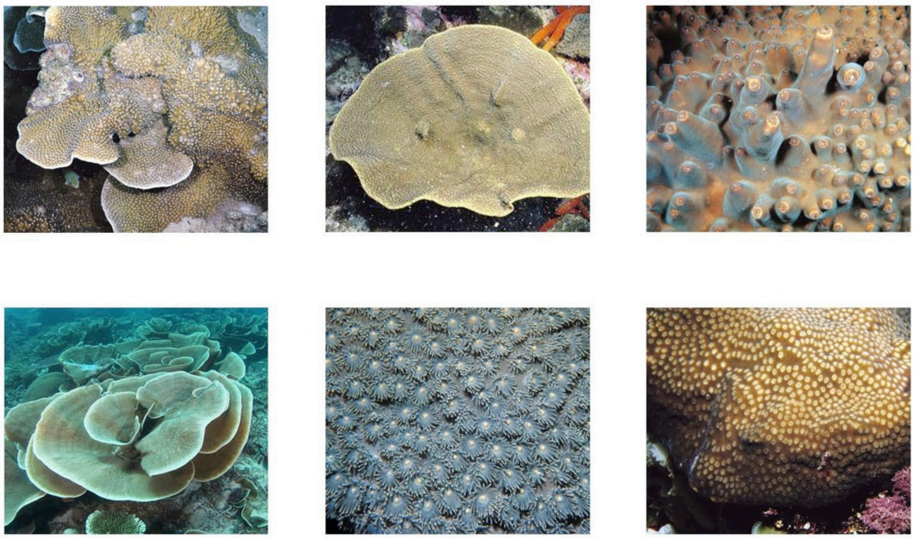


Figure 13 - Identification sheet showing images and distinguishing characteristics of the Pocilloporidae and Dendrophylliidae families of corals.

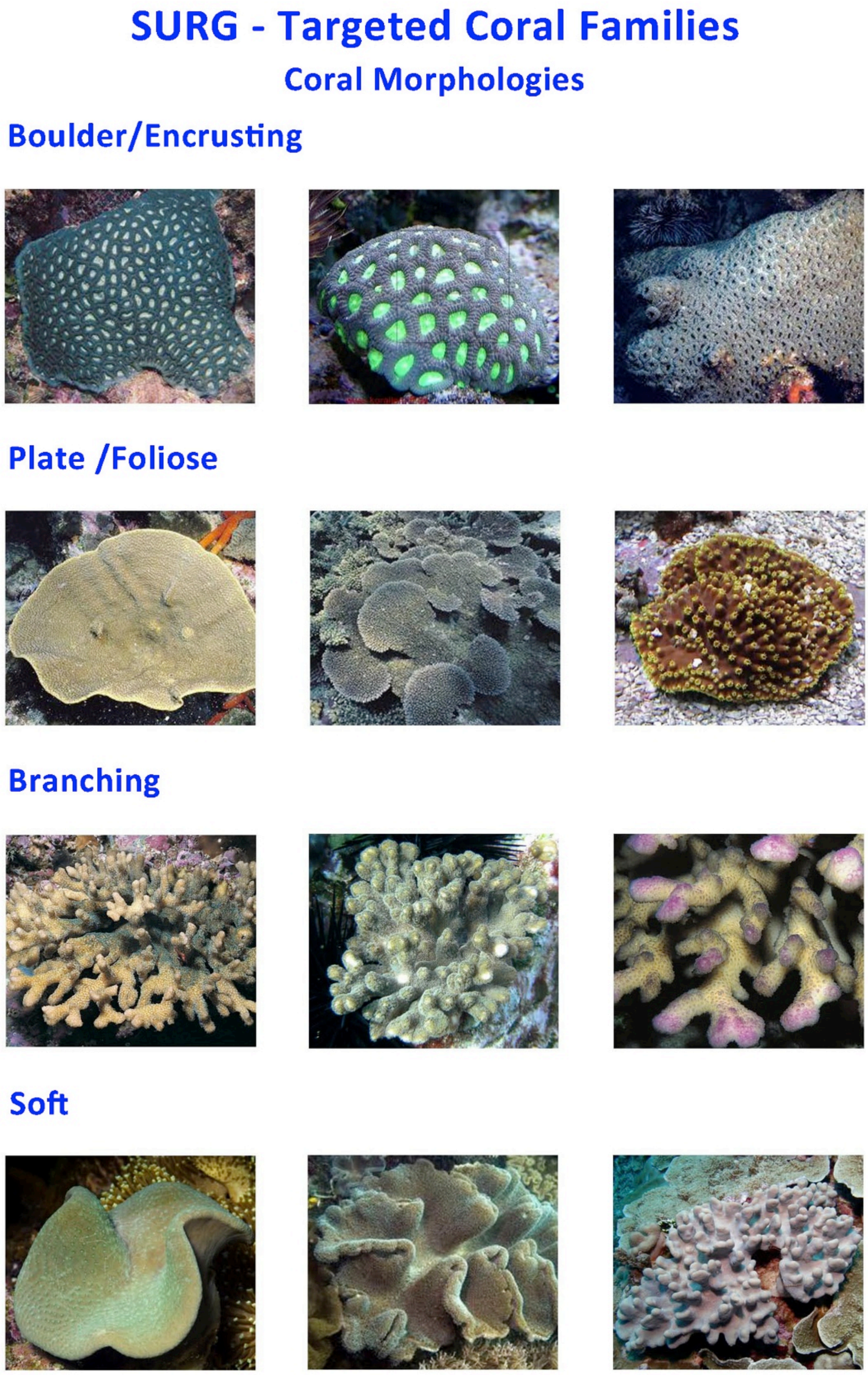


Figure 14 - Identification sheet showing images of types of corals recording during surveys.

Training

Prior to data being collected, all participants were required to undertake formal training in both classroom and field (in-water) contexts. Training was conducted by SURG members with expertise in the fields of coral taxonomy and the recognition of coral bleaching and disease. Programs were developed to ensure participants were able to conduct surveys in the prescribed manner.

The classroom program included the aims of the program; a synopsis of the CoralWatch program; the phenomenon of coral bleaching and its recognition; identification of coral growth forms; recognition of the five targeted families of corals; survey methodology; data recording; roles and responsibilities, and safe diving practices. The classroom program was conducted at the beginning of each summer sampling period, and at opportunistic times such as when new SURG members were recruited to the program.

A number of web-based, downloadable, interactive tests were developed to aid in the recognition of growth types and targeted families of corals, http://www.surg.org.au/content/training. This enabled members to 'sit' the tests at a time of their choosing. The tests scored the number of correct responses to identifications made by a member and provided them with the correct response to questions answered incorrectly. Each test could be attempted as often as a member chose.

In–water training was conducted prior to each summer sampling period and also at opportunistic times. During each training session, inexperienced participants were buddy-paired with SURG members who had conducted coral surveys in the past and who thus played a mentoring role. For example, if an inexperienced member encountered a coral colony and was unsure which family it belonged to, they could simply query the more experienced member as to its identification. If a member encountered a coral colony and neither they nor their dive buddy was certain of its identification, then that coral was not included in the survey.

Surveys

Dive Leaders allocated buddy pairs on the basis of the skill level of the members. Each buddy pair comprised an experienced and a less experienced surveyor, or two experienced surveyors. This depended on the makeup of the participants on any survey trip.

Each participant was provided with an underwater slate with data record sheet attached. One member also carried a 30m tape measure. Divers were provided with a torch to illuminate both the coral and the chart when making a colour 'match'.

Upon descending to the seafloor, the tape measure was laid haphazardly on the seafloor in an area dominated by corals (Figure 15). Members would then complete the metadata on their data sheet. Generally four buddy pairs would 'work' at a site. The tape measures were laid in such a fashion so that no two tape measures intersected; thereby ensuring no coral colony was assessed twice on any one survey. Buddy pairs would swim along the tape measure; one on each side of it. Whenever a coral belonging to one of the targeted families of corals was encountered within a 2m wide strip as measured from the tape measure, the coral health chart was used to determine its 'health'. This process was continued until 30 individual colonies were assessed, or a diver terminated the survey due to having 50atm of air remaining in their scuba tank. This was a safety strategy to enable divers to return to a moored vessel with adequate air remaining.

Figure 15 – SURG member laying a tape measure across a coral dominated community at North Solitary Island. Summer 2015. (Image: Matt Harrison)

When all divers had returned to the vessel, the dive leader would ensure all data on each individual's data sheet was complete and legible. At the conclusion of each survey trip the dive leader would collect all the record sheets and pass these on to the SURG member responsible for transposing the data into an Excel Spreadsheet.

Results

Seven survey periods loosely corresponding to summer and winter seasons were undertaken between March 2012 and April 2015. A total of 12,805 assessments of coral colonies were undertaken. Table 2 presents the breakdown of colonies assessed by coral type and family. Corals with boulder or branching growth habits comprised 75% of colonies assessed, with relatively few (3%) soft coral colonies recorded.

Coral Type	Family	No. of Colonies	Percentage (%)
Boulder		**3978**	**31**
	Poritidae	956	7
	Faviidae	2589	20
	Dendrophylliidae	433	3
Branching		**5670**	**44**
	Acroporidae	1734	14
	Pocilloporidae	3936	31
Plate		**2818**	**22**
	Acroporidae	678	5
	Dendrophylliidae	2140	17
Soft		**339**	**3**
	Soft	339	3
Total		**12805**	**100**

Table 2 - The number of assessments made of colonies and percentage of each coral type and family assessed.

The most abundant coral family was the Pocilloporidae (31%) with similar numbers of colonies of the Acroporidae, Dendrophylliidae and Faviidae (~20% each) recorded. The sample size of the Poritidae (7%) reflects the lower abundance of this family in coral communities within SIMP, as does the low number of soft corals. 83% of the Dendrophylliidae had a boulder growth habit, with the remainder characterised by a plate-like, or foliose, growth habit. A branching growth habit was recorded for 72% of the Acroporidae, with the remainder characterised by a plate-like growth habit.

The average colour score (Av.CS) for each survey period, regardless of coral family or water temperature, is presented in Figure 16. The data indicate the scores for each summer survey period were lower than those in the preceding winter survey period, with the lowest score (4.34) being recorded for the summer 2013 survey period. Av.CSs in summer 2013 and summer 2014 were significantly lower than scores recorded for any of the three winter survey periods and the summer 2015 survey period.

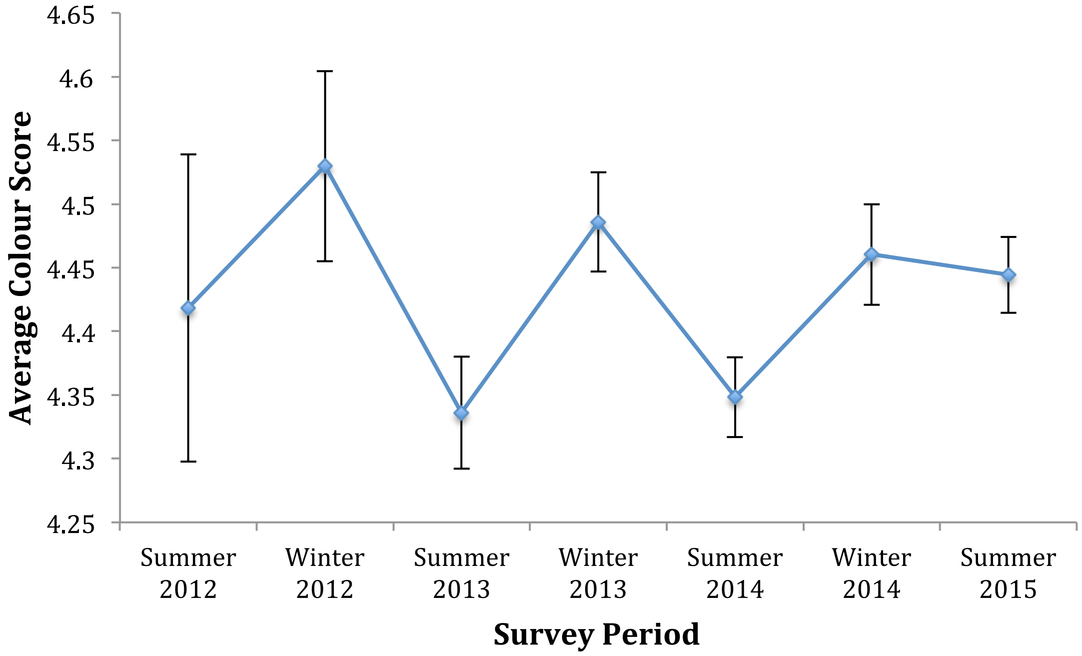


Figure 16 - Average Colour Score (+/- 95% CIs) for all coral colonies assessed during each survey period.

The frequency of each colour score (CS) for all colonies during summer sampling periods is presented in Figure 17. A low CS equates with less healthy colonies. When the lower colour scores are examined (CS of 3 and below) summer 2015 had the highest frequency (17%), followed by summer 2013 (12%) then summer 2014 (9.5%). The data indicate that the majority of corals were classed as 'healthy'.

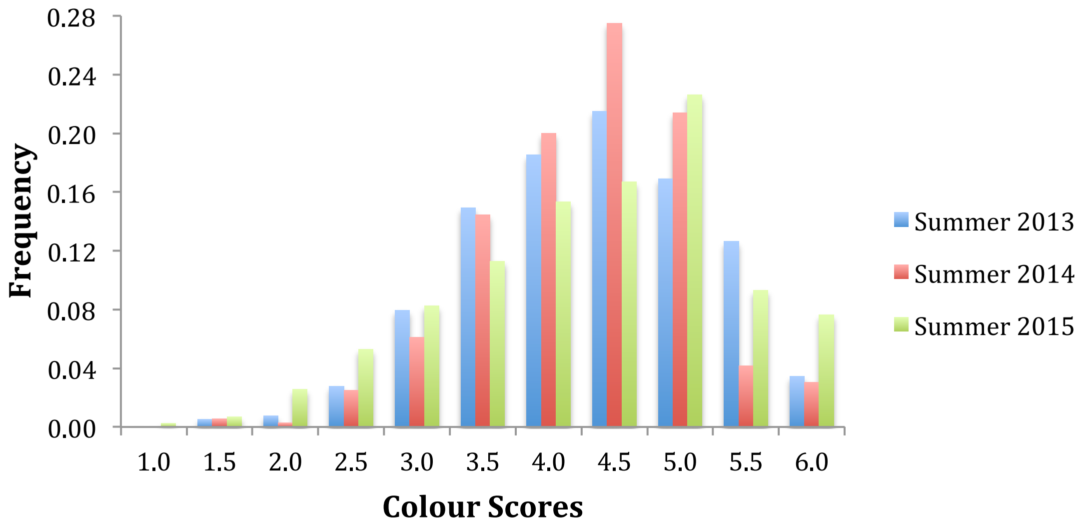


Figure 17 - Frequency of colour scores for all coral colonies assessed during each summer survey period.

Figure 18 indicates the proportion of colonies having a specific colour score with the data filtered based on temperature, i.e. colour scores based on colonies assessed at temperatures of 23°C and below and temperatures at 24°C and above. Only 9% of colonies assessed at 23°C and below had colour scores equal to or below 3, compared to 19% for colonies assessed at 24°C and above. At temperatures of 24°C and above, a higher proportion of colonies were assessed as being less 'healthy'.

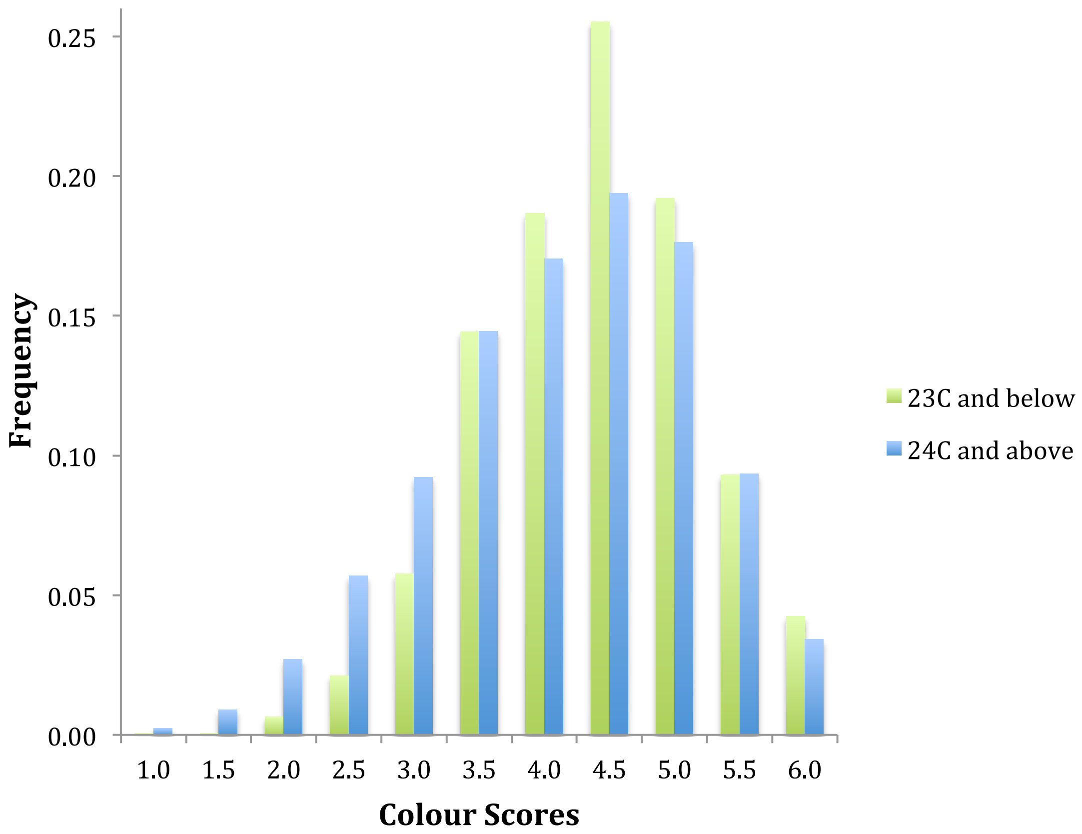


Figure 18 - Frequency of colour scores of all colonies. Colour scores are grouped for colonies surveyed at temperatures of 23°C and below or 24°C and above.

A comparison of the Av. CSs for each family assessed at inshore sites against offshore sites at temperatures of 24°C and above is presented in Figure 19. The data indicate two families, the Pocilloporidae and Poritidae, had lower Av. CSs than the Acroporidae, Dendrophylliidae or Faviidae. Three families; the Acroporidae, Pocilloporidae and Poritidae, had significantly lower Av. CSs at offshore sites compared with inshore sites. At offshore sites the Pocilloporidae and Poritidae had significantly lower Av. CSs than the Acroporidae and Dendrophylliidae, with the Faviidae having a significantly higher Av. CS compared with the other four families.

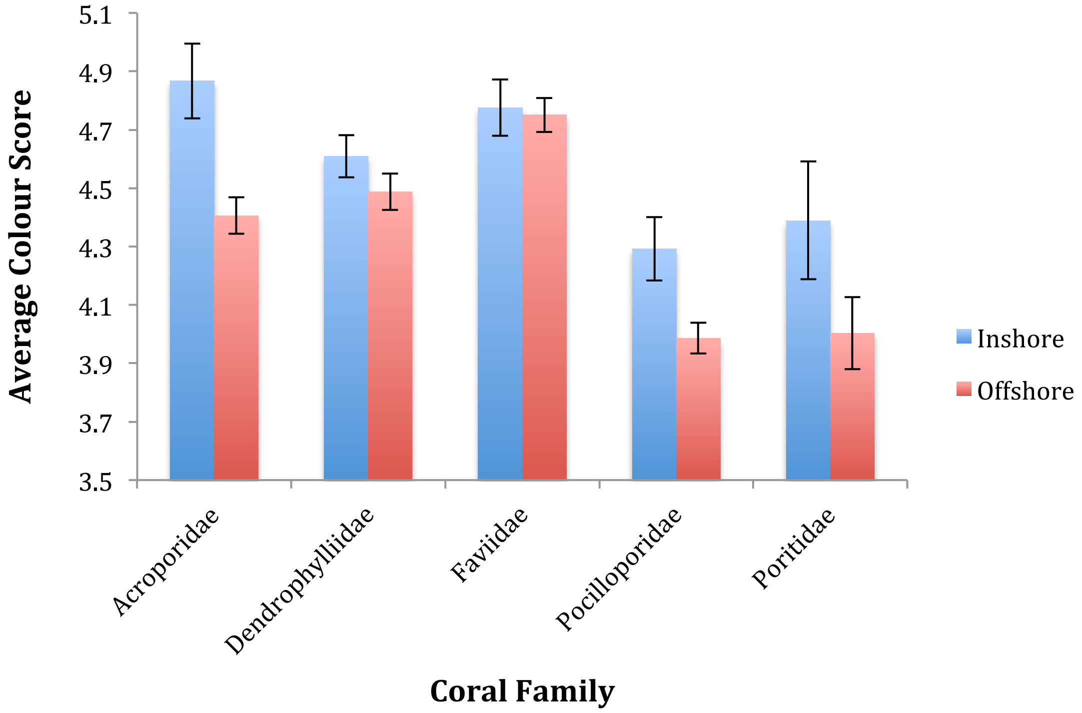


Figure 19 - Inshore versus offshore comparison. Average colour score (+/- 95% CIs) for colonies assessed at temperatures of 24°C and above during summer 2013, 2014 and 2015.

The Av. CS for all colonies assessed at each offshore island, when temperatures were 24°C and above, are indicated in Figure 20. North Solitary Island had a significantly lower Av. CS than did North West Solitary, which itself had a lower score than South Solitary.

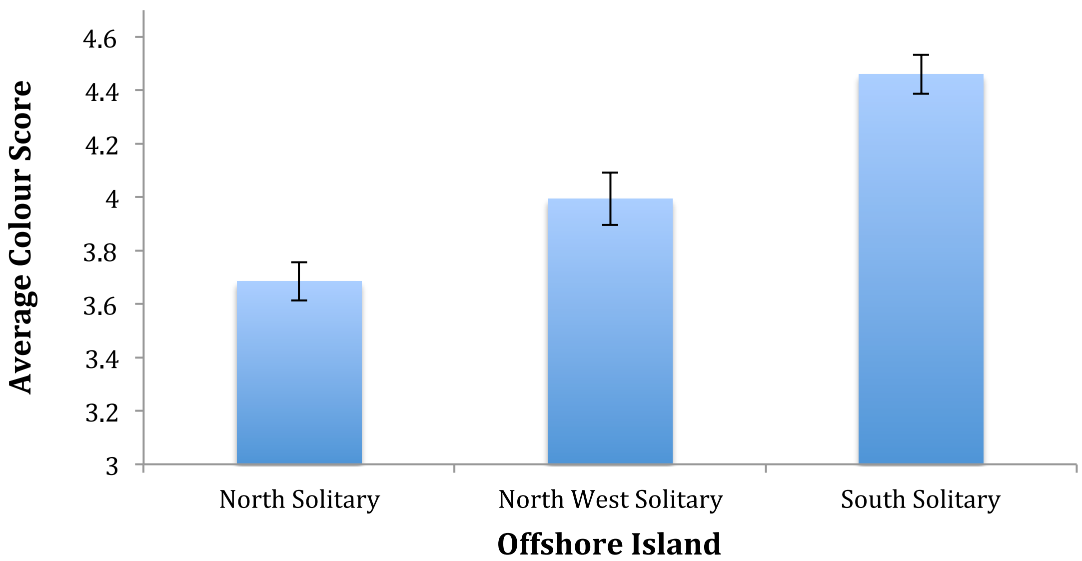


Figure 20 – Average colour score (+/- 95% CIs) for colonies assessed at temperatures of 24°C and above at each offshore island. Av. CSs were calculated for combined Pocilloporidae and Poritidae colonies.

A comparison of the Av. CSs for the five families assessed at offshore islands indicated that the Pocilloporidae and Poritidae had the lowest scores (Fig. 19). Av. CSs are presented for these two families at each of the offshore islands in Figure 21. The data indicate that the Av. CSs for the Pocilloporidae at North Solitary and North West Solitary Islands were significantly lower than the Av. CS at South Solitary Island. With regard to the Poritidae, the Av. CS at North Solitary Island was significantly lower than at North West Solitary Island. Furthermore, at North West Solitary Island, the Av. CS for the Pocilloporidae was significantly lower than that of the Poritidae.

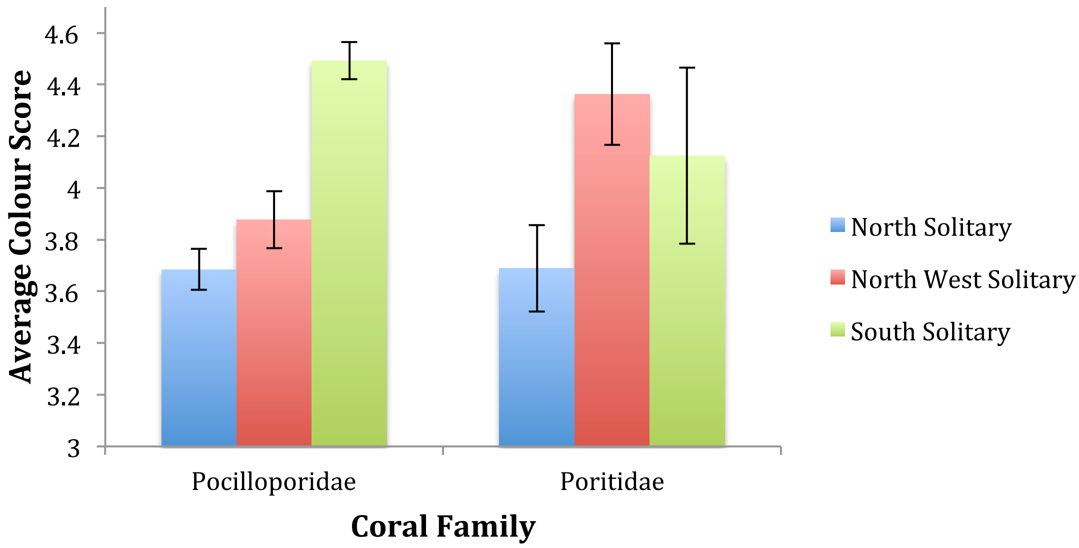


Figure 21 – Average colour score (+/- 95% CIs) for Pocilloporidae and Poritidae colonies assessed at temperatures of 24°C and above at each offshore island.

The Av. CS for coral types over the three summer survey periods when water temperatures were 24°C and above are indicated in Figure 22. Both branching and soft coral types had lower Av. CSs in each survey period compared to those with boulder and plate growth habits. The Pocilloporid corals are a family of branching corals. Of the branching colonies recorded, 71% (Table 2) were members of the Pocilloporidae, the remainder belonging to the Acroporidae.

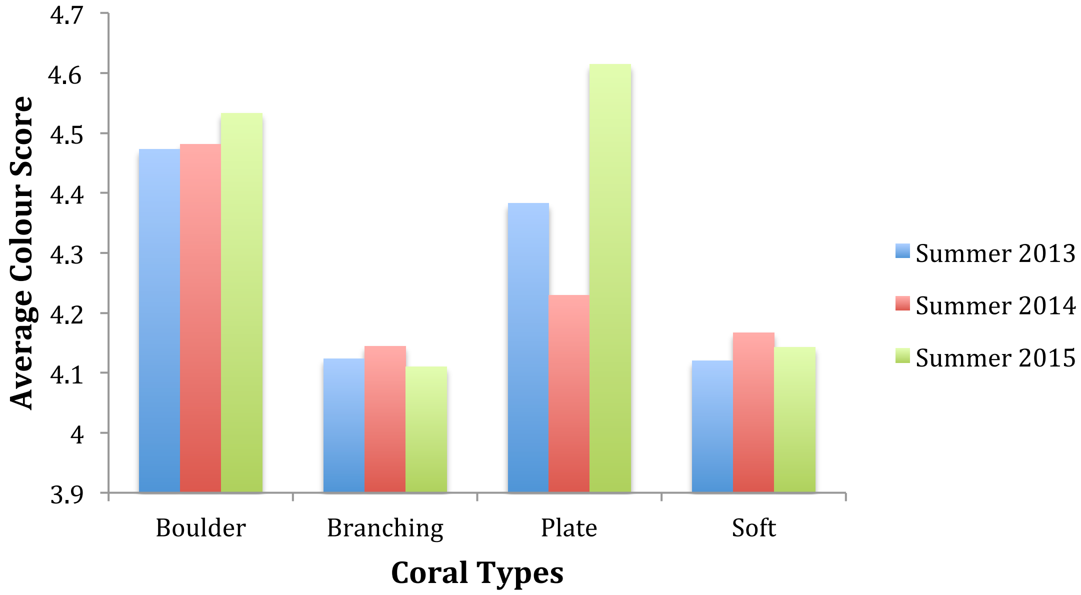


Figure 22 - Average colour scores for coral types surveyed at temperatures 24°C and above during summer 2013, 2014 and 2015.

Discussion

The most abundant coral type recorded during the study was the 'Branching' that included the Acroporidae and Pocilloporidae families and made up 44% of all colonies assessed. The 'Boulder', 'Plate' and 'Soft' coral types, with the 'Soft' type contributing only 3% of assessments made, followed it in descending order. Other coral families found within SIMP were not the target of this project, but can be broadly categorised into one of these four coral types.

Av. CSs, regardless of family or coral type, have a cyclical pattern with lower Av. CSs evident each summer compared to the preceding winter period. Given that modelling predicts a rise in coral bleaching, and thus a lower colour score, during periods of warmer water, i.e. during summer, then this observation supports the model.

The summer 2015 survey period recorded the highest frequency of low colour scores, with scores for 1, 1.5, 2, 2.5 and 3 more common than for summer 2013 and 2104 equivalent colour scores. SURG members were questioned on their perceptions of the number of 'unhealthy' corals observed over each of the three summer survey periods. They unanimously agreed that the 2015 summer survey period had a higher number of bleached/partially-bleached corals than other survey periods, thus supporting the data collected. Even so, the majority of corals surveyed would be deemed to be moderately healthy. In a survey of a 'healthy' (unaffected) reef you would expect a higher frequency of scores of 4 and above compared to those surveyed in this study, i.e. the curves in Fig. 17 would be skewed towards the higher colour scores.

The data indicate that for all colonies surveyed at temperatures of 24°C and above the frequency of lower colour scores (3 and below) were higher compared with colonies surveyed at temperatures of 23°C and below (Fig.18). If the data for the Pocilloporidae and Poritidae are used in this comparison then the difference is even more obvious. Inshore sites (South West and Split Solitary Islands) had higher Av. CSs than offshore islands (North, North West and South Solitary Islands) for three of the families, the Acroporidae, Pocilloporidae and Poritidae. Corals belonging to these families tended to be less 'healthy in offshore locations. Thus, even though the data presented in Fig. 19 are for colonies assessed at temperatures of 24°C and above it seems likely there was another factor coming into play resulting in lower Av. CSs for these three families in an offshore context.

Figure 22 – A bleached colony of Pocillopora damicornis *(F. Pocilloporidae). Summer 2015. South Solitary Island. Partially bleached polyps can be seen on the basal portions of each branch. (Image: Matt Nimbs)*

Of the five families, the Pocilloporidae and Poritidae had the lowest Av. CSs. When the combined data from these families are examined for each offshore island a clinal gradation is evident. North Solitary, the northernmost, furthest offshore and tropically influenced island, had a significantly lower Av.CS (3.7) than either of the other two islands. North West Solitary Island, lying latitudinally between North and South Solitary, had a significantly lower Av.CS (4.0) than the southernmost island, South Solitary (4.5). It was primarily the Pocilloporidae, a branching growth-habit family and the most commonly surveyed coral family, which contributed to this pattern, with Av. CSs increasing significantly from north to south. This is consistent with a finding by Dalton and Carroll (2011) in which total bleaching response (moderate and severe combined) was highest in the Pocilloporidae compared to the other four families during 2005 summer surveys. The analysis of the Av. CSs for each of the coral 'types' indicates that the 'Branching' type had a low score, which is to be expected given that the Pocilloporidae comprised the majority records for this 'type'. The low Av. CS for the 'Soft' coral type is not so much an indication of health of these colonies, but rather a typical light colour hue possessed by the species observed.

There was no evidence of widespread bleaching events in the Solitary Islands Marine Park during the study and all common coral families are generally in good condition, with the exception of the Pocilloporidae and a member of the Poritidae (*Goniopora sp*.) during the summer 2015 survey period. However, the recent prediction of a prolonged and intense El Nino event for later this year (http://www.bom.gov.au/climate/enso/) does not bode well for our local coral communities, with high water temperatures for lengthy periods potentially leading to a severe and widespread bleaching event. SURG has resolved to seek a funding source that will enable the Group to undertake surveys over summer 2016 and to assess recovery of corals in winter 2016 should the El Nino event prove to have a major impact on coral communities.

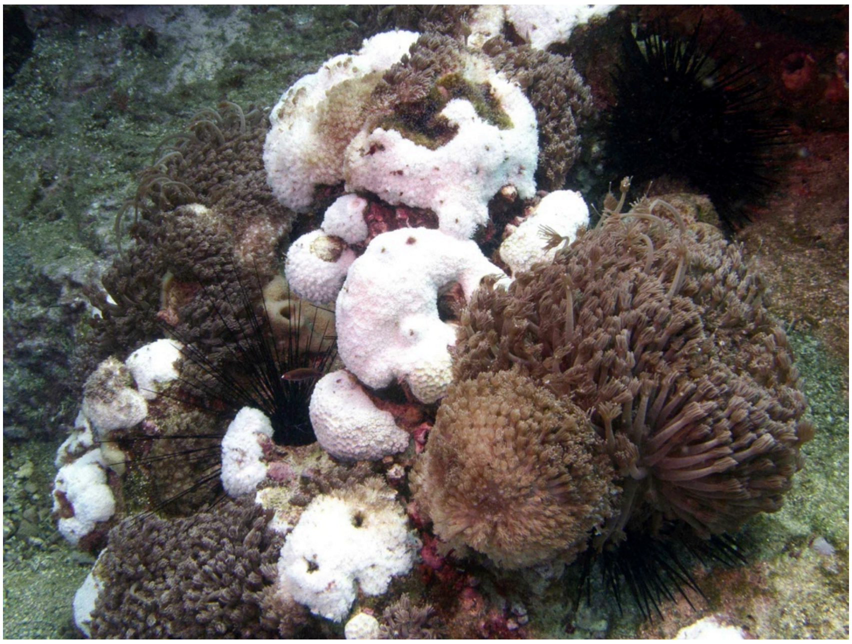


Figure 23 – Several colonies of Goniopora sp*. (F. Poritidae). Some colonies are fully bleached whist adjacent colonies are 'healthy'. Summer 2015. North West Solitary Island. (Image: Bob Edgar)*

The data generated in this study provide important information on the natural and seasonal variation in coral pigmentation. Generally, coral pigmentation tends to be more variable within individual colonies during summer.

Increasingly, scuba divers view SIMP as an incredibly diverse seascape and biologically rich marine park in which to conduct their activities. Visitations by scuba divers from other areas of Australia, as well as an increasing number of divers from overseas, are witness to its natural amenity. Additionally, the diving community in the local area is increasing in size. Most scuba divers today support the principles of ecologically sustainable development and are all too well aware of the predictions derived from models of the likely consequences of human-induced climate change, particularly the potential to impact on marine communities.

The project provided a vehicle for resident citizen scientists to be involved in monitoring a locally important marine ecosystem, i.e. the coral dominated reefs. To this end, it can be viewed as being highly successful. Through publicising the objectives of the project in local/online media and dive charter shops SURG was able to attract new members to the group and develop a pool of volunteers who have been trained in collecting scientific data.

The number of community members directly participating in the project stands at 59, contributing 2,948 person-hours to shed light on the impact of a changing biophysical environment on local coral communities. Members come from a variety of backgrounds, but importantly a number are school students or are involved in tertiary courses, some of whom are actively pursuing careers in management and research in the marine environment. SURG sees it as vital to attract enthusiastic volunteers from the 'younger generation' as the long-term viability of the organisation will be in their hands.

Importantly this project has provided a mechanism for the strengthening of ties between SURG and a number of institutions with interests in the marine environment in SIMP, including the NSW Marine Parks Authority (NSW DPI), the National Marine Science Centre (Southern Cross University) and CoralWatch (University of Queensland).

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