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CoralWatch – a flexible coral bleaching monitoring tool for you and your group

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Abstract. The CoralWatch Coral Health Chart, a standardised colour reference card, is an inexpensive, flexible tool that anyone can use for rapid, wide-area assessment of changing coral condition. The charts are used in a growing number of scientific studies as well as by a large number of non-expert visitors to reefs world-wide. Here we describe and analyse two general ways in which the methodology can be used to provide useful data on coral reef condition over time, 'fingerprinting' and long term monitoring of selected colonies. Data stemming from trained and untrained observers, collected via the CoralWatch online database is analysed and compared to data collected by trained observers. Detection of bleaching events and evaluation of recovery rates of corals against temporal and geographic variation in coral colour requires more data collected regularly and frequently by anyone using this globally applicable method.

Key words: colour, coral bleaching, recovery, reef fingerprint, volunteer

Introduction

The CoralWatch Coral Health Chart, a standardised colour reference card, is an inexpensive, flexible tool that anyone can use for rapid, wide-area assessment of changing coral condition (Siebeck et al. 2006). Long-term trends in bleaching and recovery are not well understood at present due to the limited data available. What has been lacking is an objective method that can be used over large spatial scales by volunteers with limited or no training. Various other observer-based methods exist, however, they often require rigorous training and are thus restricted to a relatively small number of scientific volunteers (Miller and Müller 1999).

Measurements with the Coral Health Chart rely on observers finding the closest match between a coral and a colour on the chart. Even with limited training observers are able to do this accurately (Siebeck et al. 2006). Any visitor to a reef can contribute valuable information by simply following the instructions on the card and adding their data to the CoralWatch online database. On the other hand, the chart has been accepted as a useful tool for scientists and is regularly used to assess coral colour or condition (Fabricius 2006; Anthony and Kerswell 2007; Cox 2007; Frisch et al. 2007; McClanahan et al. 2007; Cooper et al. 2008; Spalding 2008).

Here, two general ways of using the charts are discussed, 'reef fingerprinting' and long-term monitoring of individual colonies. We also present a preliminary analysis of the dataset collected through the CoralWatch website.

Material and Methods

Colour measurements

Coral colour was determined as described in Siebeck et al. (2006). Briefly, the Coral Health Chart was held near the selected coral colony. The chart was rotated until the closest match between the overall colour of the colony and a colour on the chart was found. In all cases, the colour score (1-6) of the matching colour was used for the analysis. In previous work a controlled bleaching experiment was used to calibrate the chart with respect to symbiont density and chlorophyll a (Siebeck et al. 2006). It was found that a colour score difference larger than 2 indicates a significant change in symbiont density and chlorophyll a content, and thus bleaching state.

Long-term monitoring of tagged colonies

Twenty randomly selected colonies (10 bleached colonies with colour score < 2, and 10 non-bleached colonies with colour score of > 3 of various species) were marked on the Heron Island Reef flat, Great Barrier Reef, Australia with plastic tags during the 2002 bleaching event. Colour chart measurements were made once every two weeks for 24 months. In each case the observer (Heron Island Research Station Staff) recorded the lightest area excluding the tips.

Fingerprinting

Two independent trained observers collected colour data for 100 randomly selected corals on the Heron Island Reef. Their instructions were to randomly select a coral in the inner reef flat, measure its colour, then take three steps towards the reef rim, identify the coral closest to them and record the colour of that coral. The observers were instructed to repeat this selection process until 100 corals were measured. For each coral, the observers noted both the lightest and darkest area excluding the tips of branching corals. Data were collected in this way during the 2002 bleaching event (Heron Island, March) and during the winter after the bleaching event (Lizard Island, Green Island and Heron Island, July).

Volunteers using the Coral Health Chart followed the instructions on the chart (as above) and entered their data via the CoralWatch website. Any suspected mistakes in the dataset were removed before analysis. The following information in the dataset was used to detect mistakes: entries labeled with the words "test" or "practise", exact replicates of nearby entries, entries of corals with exactly the same colour score, or entries missing critical data fields, such as 'location', 'date' and 'colour scores'. The data of all volunteers that entered at least 10 datapoints were included. The cut-off was set arbitrarily to ensure that the volunteer had reasonable experience with the method and shown some enthusiasm for it.

Long-term datasets for sites in Australia (Heron Island) and Netherlands Antilles (Barracuda Reef and Mushroom Gardens, St. Eustatius) were examined for changes in coral condition over time. A comparison was also made between coral colour data from a site with reported bleached corals (Christmas Island, April 2005) and data from the same site monitored on different dates. Colour scores from different sites (Heron Island, North Keppel Island, Australia and Richelieu Rock, Thailand March 2005) monitored around the same time as the bleaching occurrence were also examined.

Results

Long-term monitoring of 20 coral colonies

Repeated colour measurements of the 20 marked colonies on the Heron Island Reef flat document the recovery process the corals went through following the 2002 bleaching (Fig. 1a). Pair-wise comparisons show that until May there is a significant difference between the group of corals that appeared healthy (group 1) and the group that was visibly affected by the bleaching (group2) (March & early April $F_{1,18} > 56$, $p < 0.0001$; late April $F_{1,18} > 16.0$, $p = 0.001$; 8-May: $F_{1,18} = 3.1$, $p > 0.05$). As the corals recover this difference disappears and the colours of both groups are similar – although there is a trend for bleached corals to maintain a lower colour score.

In early September, a second sampling period was initiated as the observers noticed minor bleaching after a severe rainstorm. Results show that both groups of corals suddenly bleached again and further recordings document their recovery from that bleaching event. During the event the colours of both groups are similar. The colour before and after the rainstorm is significantly different for group 1 (ANOVA, $F_{1,6} = 21.1$, $p < 0.01$) but not for group 2 (ANOVA, $F_{1,12} = 3.3$, $p > 0.05$). During the winter months slight fluctuations of the colours of both groups can be observed.

Examples for the variability in recovery rates and timing are shown in Fig. 1b. Colonies 1-3 start to recover at different times within the first month of sampling, while colony 4 does not recover within this first observation phase. At the beginning of the second observation phase colony 4 and 1 show some recovery (colour change of 2-3 scores) until November followed by colony 3 in early December. Interestingly, colony 2 which showed fast recovery in observation phase 1 does not seem to recover from the rain bleaching. This is an example of how the fate of individual corals can be mapped.

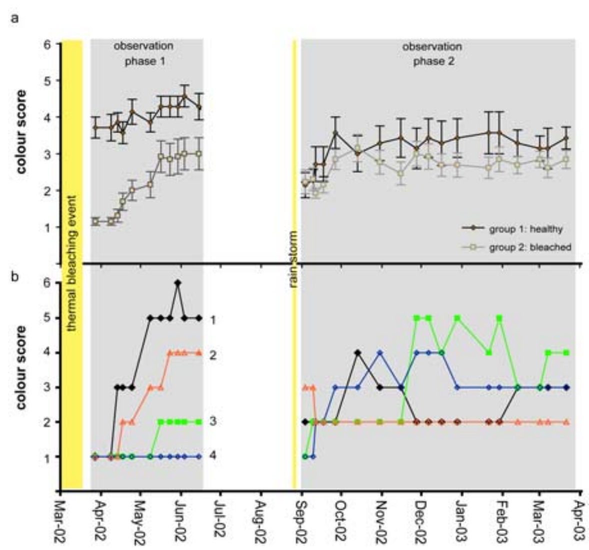

Figure 1: Results for the repeated colour measurements of the 20 corals on the Heron Island Reef Flat following the bleaching event in early 2002 and a second bleaching event caused by a rainstorm at a low tide. a) The average colour scores (mean ± se) are given for healthy corals (group1) and bleached corals (group2). b) Colour change of 4 example colonies showing variability of responses during the observation phases following the two bleaching events.

'Fingerprinting' the reef

Trained observers

The distribution of coral colour on the Heron Island Reef flat during the 2002 bleaching is significantly different from the distribution measured in July (ANOVA, $F_{1,237} = 339$, $p < 0.0001$; Fig. 2a). In March, the distribution is skewed and most corals have a colour code of 1, which represents white coloration. In July, the frequency distribution appears more normal and very few corals have a colour code of less than 3.

A comparison of the colour of 438 corals around the Heron, Green and Lizard Island Reefs in July 2002 shows that the colours on the three reefs have a similar distribution (Fig. 2b). There is no significant difference between the colour scores of corals from Lizard Island and Green Island during July 2002 (ANOVA, $F_{1,259} = 0.098$, $p >> 0.1$) while the colours of the Heron Island Reef in the same month are significantly darker than those of the other two reefs (ANOVA, $F_{2,435} = 5.4$, $p < 0.01$).

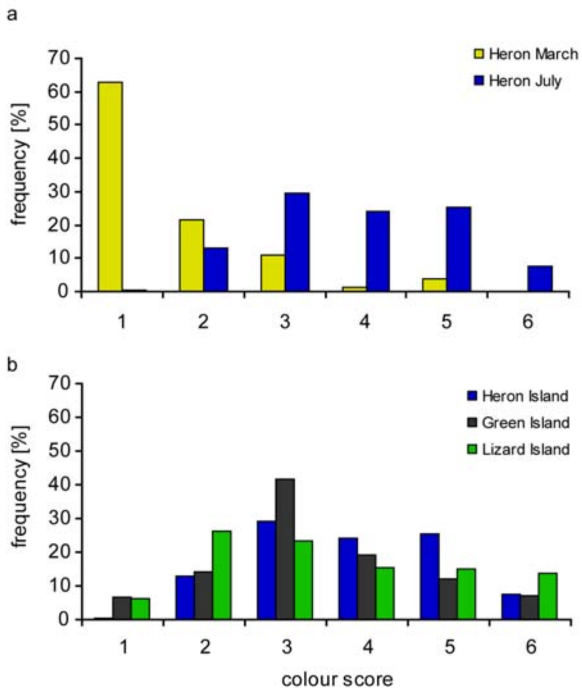

Figure 2: Results of the 'fingerprinting' survey. Distribution of coral colour a) on the Heron Island Reef flat during (March) and after (July) the 2002 bleaching event and b) for a total of 438 corals on the Heron, Green and Lizard Island Reefs in July 2002.

Untrained observers (online database)

Data from 246 sites in 44 countries have been collected and reported by 440 different volunteers (CoralWatch 2008). A bleaching event was reported anecdotally in April 2005 at Christmas Island. Average colour scores were found to be measurably lower (~2 scores) than those observed in October 2005 and October 2006 at the same site (Fig. 3a). Scores were also lower than those from Heron and North Keppel Islands (Australia) and Richelieu Rock (Thailand) measured one month before (Fig. 3b).

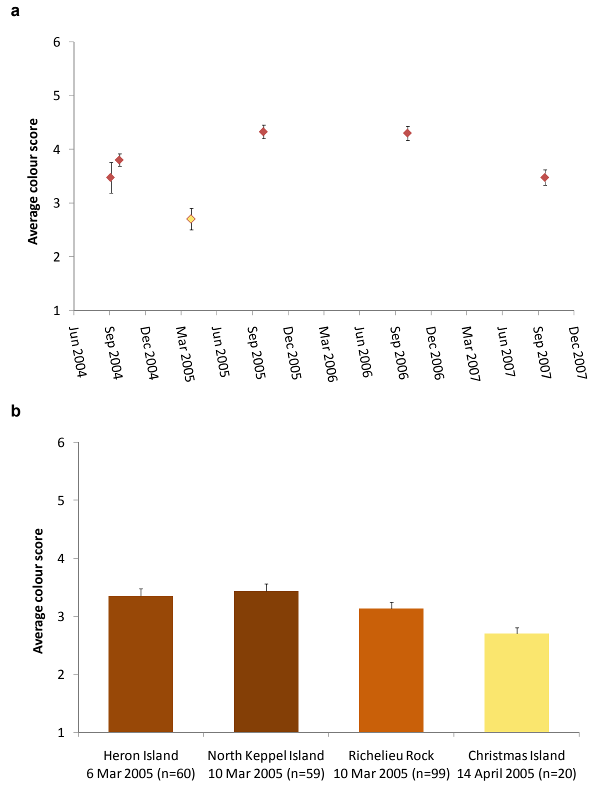

Figure 3: Results of volunteer 'fingerprinting' surveys. Average daily coral colour scores for a) all days that monitoring occurred at Christmas Island sites and b) Heron Island, North Keppel Island (Australia) and Richelieu Rock (Thailand) in March 2005 and Christmas Island in April 2005. Note: Brightness of colours shown using a brown hue in these two graphs provide a rough approximation of the actual average coral colour scores measured.

The largest datasets stem from 3 reef sites, Heron Island (Australia) as well as Barracuda Reef and Mushroom Gardens at St Eustacias, (Netherlands Antilles). Corals at Heron Island Reef observed between 2003 and 2008 show a slight trend of lighter coral colours in spring (Sep to Nov) and darker colours in autumn (March to May) (Fig. 4a). Irregular monitoring occurred in some years, with frequency of data collection varying throughout the year. Data that has been collected more frequently and regularly at both Heron Island (May to Oct 2003) and the Netherlands Antilles show less fluctuation in coral colour over time (Fig. 4b and 4c).

Some slight variation between sites is seen in regard to overall average colour scores, with the coral colour at Heron Island Reef being darker than both Barracuda Reef and Mushroom Gardens (Fig. 4d).

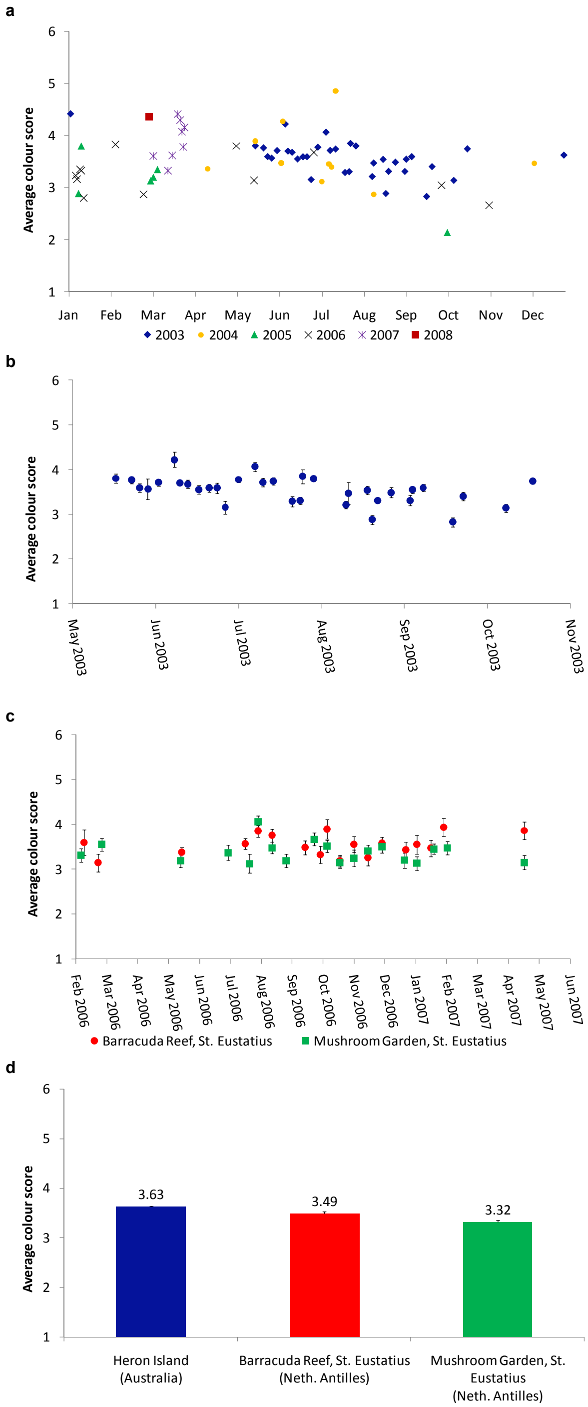

Figure 4: Long term data sets of volunteer 'fingerprinting' surveys. Average daily colour scores (mean ± se) are shown for a) all days that monitoring occurred at Heron Island, displayed over an entire year from 2003 to 2008, b) Heron Island from May to October 2003 and c) Barracuda Reef and Mushroom Gardens (St. Eustatius, Netherlands Antilles) from February 2006 to April 2007. d) Overall average colour scores for long term data at Heron Island, and St. Eustatius.

Discussion

The CoralWatch Coral Health Chart provides a six point scale with which changes in coral colouration, as an indicator of symbiont density, can be measured. This scale can be incorporated in any existing monitoring methodology. Here, an example of two methods proposed to be useful for the wider community are presented: 'fingerprinting' of randomly selected corals and long-term monitoring of specific colonies. The former method leads to large-scale information about the general condition of a reef while the latter method can be used to detect condition changes of individual colonies. At present, the fingerprinting method is better suited to untrained volunteers, such as tourists as even a single visit to the reef can yield useful data when added to the general database. In the future, marked coral colonies, along permanent transects, will provide the opportunity for anyone to participate in long-term monitoring of specific coral colonies. Benefits gained by involving non-scientists are not only due to large amounts of data gathered but also include education and an increase in general awareness of environmental problems, such as global warming and its consequences (Pfeffer and Wagenet 2007).

Repeated measurements of 20 colonies on the Heron Island Reef flat allow the documentation of the condition change of a group of corals, some of which were affected by the 2002 bleaching event. Within six weeks of the first measurement, most bleached corals had recovered and their colours were similar to those of the healthy corals. Two corals had not recovered at that time, which is why the average colour score of the bleached groups is lower than that of the healthy group. It is interesting to note that even the corals that appeared healthy during the bleaching event show a slight darkening in the months following the bleaching, and it is possible that they were also affected by the bleaching event. On the other hand, the possibility exists that the darkening is due to annual changes in symbiont density (Fitt et al. 2000).

The data for individual corals indicate that different recovery timeframes exist. Indeed, there is evidence that coral species have different temperature and time thresholds at which they bleach (Berkelmans and Oliver 1999; Marshall and Baird 2000; Berkelmans 2002) and that this may be true for recovery as well (Hueerkamp et al. 2001). However, more data are needed to detect species-specific patterns.

The first survey period ended in winter, when it appeared that the coloration of the corals would remain relatively constant. However, the same observers noticed that the reef appeared bleached after a severe rainstorm and initiated the second survey period. Both original coral groups were affected, and it appeared that the corals belonging to the group classified healthy during the March bleaching was actually affected more than the previously bleached group. On average, recovery of both groups was faster after the rain bleaching compared to the bleaching in March, presumably because the salinity returned to normal within just a few hours. This is a good example of how non-expert observers can use the charts to quantify changes in coral health.

Unlike the long-term monitoring of specific coral colonies the 'fingerprinting' protocol is not dependent on the presence of permanent transects and is thus suitable for any interested visitor on any reef worldwide. The 'fingerprinting' method is able to pick up differences between as well as within bleached and recovered reefs. It appears that corals on southern reefs (Heron Island) are relatively darker than corals on northern reefs (Green Island and Lizard Island), and that corals on the Heron Reef flat had made a significant step towards recovery by July.

Untrained volunteer observers collecting CoralWatch data provide a measure of coral condition over time, increasing the chance that a bleaching event will be detected while supplying baseline data that highlights temporal or geographic variation in coral colour. Bleaching events, such as those at Heron Island and Christmas Island, are evident as lower average colour scores when compared against this baseline data.

These data are publicly available and can be reported and used by anyone to make general comparisons of coral condition. Correlations can be made with recorded time of day, weather conditions, coral types, sampling activity and water temperature (CoralWatch 2008), as well as with information from other complimentary datasets on reef condition, such as Reefbase, Coral Reef Watch or Reef Check.

A measure of long-term fluctuation in coral condition is provided in better resolution by following individual colonies over time and could include volunteers observing permanent transects at select sites. Schools and tourism operators returning regularly to the same sites are well suited to monitoring long term trends in coral colour change. Hundreds of recreational divers have registered through Project AWARE and are including CoralWatch monitoring in their dive training and regular dive trips. Other uses of the CoralWatch method include impact assessments, as are being performed by OceanWay in Hong Kong to measure the potential effects of dredging on corals.

More data collected on a regular basis are needed to better detect trends and identify variables influencing changes in coral colour relating to coral bleaching and recovery and potential natural cycles (for example, see Fabricius 2006). Involving more people in consistent observations or targeted reef monitoring in response to predicted or detected bleaching events is expected to improve the current sporadic or non-existent nature of volunteer and scientific monitoring at many reefs sites.

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