***Monitoring:***

*How Far Should We Push Precision in Monitoring Coral Reefs?*

James Stoddart, MScience Pty Ltd, 239 Beaufort St, Northbridge, Western Australia 6003, Australia. Email: jim@mscience.net.au

## Abstract:

Projects approved on the basis of 'no effect on adjacent coral communities' are required to implement reactive management based on coral condition monitored during construction. Management triggers have been driven increasingly to the detection of ever smaller changes in coral cover or coral mortality – sometimes less than a few percent. While monitoring techniques are available to detect such changes, the ability to interpret the results is often limited by inadequate understanding of the 'normal' dynamics of these populations. As a consequence, projects may spend a large amount of money establishing extensive and precise monitoring programs that can reveal such small changes in coral populations that there is no historical basis to interpret them as natural or anthropogenic.

Monitoring for several recent large dredging projects in north-western Australia is discussed here as an example of these challenges.

## Introduction

That the world's coral reefs have declined substantially over the past 50 years and are continuing to decline with no clear endpoint is abundantly documented in the scientific literature (Pandolfi et al. 2003) and the popular press. It is a clear signal in the minds of most people and the conservation of coral reefs is given clear prominence in both the process and outcome of environmental impact assessment (EIA) in many countries and certainly in Western Australia (WAEPA 2007).

Within EIA in Western Australia, the Environmental Protection Authority's guidance note on the protection of benthic habitat (WAEPA 2004) is an attempt to change the emphasis from individuals to habitats. Sadly, the practical application of this guidance often results in criteria judged on the protection of individual corals rather than a broader view of habitat.

Legal conditions derived from the EIA process for several recent dredging projects in the Dampier Harbour, Mermaid Sound, Western Australia include:

- Net loss of coral cover at any 'at risk' coral communities to be no greater than 10% above that of reference sites;
- Net loss of coral cover averaged across a range of 'at risk' coral communities to be no greater than 10% above that of reference sites;

- Net loss of coral cover at any “at risk” coral community to be no greater than that at a reference site(s).

Management plans required to be approved by EPA have been required to set levels of impact on corals at less than 5%.

In the above cases, monitoring is required to be at high frequency to allow as early as possible detection of impacts which then require reactive management. For reactive management of projects such as dredging, which can result in rapid changes to large areas of seabed, to be effective it is critical that the period between collection of coral health information and its input to management decision-making is minimised.

What I would like to address in this presentation is the degree to which the desire of EIA outcomes that there is ‘no net loss’ of coral or maintenance of the status quo of ecological processes can be, or should be, realised in reactive management. I do this through two questions:

- Do practical monitoring techniques exist which can provide rapid, precise and powerful tests of change in coral health for programs with a spatially extensive impact risk? (see Methods & Results)
- If so, can the output of these programs separate dredging-related change from normal fluctuations in population numbers or processes? (See Discussion)

## Methods

<u>Monitoring Techniques</u>

As in impact assessment, there is a clear distinction between monitoring undertaken to assess the status of coral ecosystems or large parts thereof and that undertaken to answer questions as to local levels of coral mortality. A comparison of the form and utility of monitoring methods used for the former has been published recently (Jokiel et al. 2005) but there is no similar compendium discussing the relative merits of methods for impact monitoring on corals. Many of the methods currently used for impact monitoring are derivations of those developed for system monitoring and are not suited to the levels of precision or statistical power required.

Multiple Repeated Individual Images (MRII)

Coral mortality may be recorded as the death of entire colonies, however partial mortality, where a part of the coral colony has died, is more common and probably more relevant to monitoring impacts on a colonial organsism. MRII uses digital still images of entire individual coral colonies (or heads) captured during a series of surveys repeated over time. It establishes a permanent set of coral colonies and records each from as similar aspect as possible during each survey event.

Images are then scored using Coral Point Count with Excel Extensions (CPCE (Kohler and Gill 2006) using a square grid of 64 points. Only points lying within the borders of a coral colony, established from a baseline image, are counted in the scoring. Scoring categories may be varied but routinely include either a measure of live or dead coral. As coral tissue may be obscured by things like sediment, algae or fauna, it is safest to score live coral and define ‘partial mortality’ as 1-‘live coral”.

Exact questions addressed in monitoring may be varied by selection of a subset of the coral present (ie sensitive species only, no small corals, only small corals, random mix). In instances discussed below where monitoring has been required to address general tests of coral mortality, coral selection has targeted a species mix similar to that found at each site, but avoided very small corals (as these tend to bias results) and corals which are difficult to photograph from a consistent view or which have obscure edges.

Statistical Treatment

Each coral image is assigned a percent partial mortality (for coral i – $PM_i$) where

$$PM_i = (1 - \text{points scored as live coral/number of points within the coral boundary})$$

where $PM_{ix}$ is the partial mortality of coral i at survey *x*.

The Partial Mortality estimate for a site is the average of that for the corals scored at that site for that survey – eg for Site TEST in Survey 2:

$$PM(TEST_2) = \Sigma\, PM_{i2}/N$$

where i goes from 1 to N corals.

The Gross Mortality at a site is calculated as (e.g. for site TEST at Survey 2)

$$GM(TEST_2) = \Sigma(PM_{i2} - PM_{iB})/N$$

where i goes from 1 to N corals with N corals being the corals measured at time 2 and iB those same corals from the baseline survey. Equally, if there are sufficient surveys conducted prior to the commencement of the impact in question it may be possible to develop a trend estimate for mortality and use this rather than a simple point value for the baseline. Gross Mortality may be negative where Partial Mortality decreases to a level below the baseline – such as can occur when sediment cover on top of a live coral is reduced between monitoring events.

In many repeated measures analyses, the power of the analysis comes from evaluating the aggregation of all repeated measures performed during the course of the experiment. Reactive monitoring does not have the luxury of making a decision at the end of the program: it must be prepared to make a determination of significant loss at the end of each survey.

Significance tests used here are based primarily around the concept that sample means of GM at a site or group are estimates of the true mean at that site and thus have confidence intervals calculated using between-coral variance in GM. Statistical tests are conducted as t-tests between the means of 2 independent samples. Strictly these are multiple tests (both with many surveys and many sites each survey) and should be subject to BonFerroni type corrections of significance. Tests of 'no net mortality' are conducted simply as a 1-tail test of whether GM at the impact site is significantly higher than that of the pooled reference sites. Tests of specific levels of mortality may be conducted with the 'effect size' between impact and reference sites set to that level.

Comparison of MRII to transect methods

MRII only measures mortality at a site. It does not measure the increase in coral cover that may accrue from coral growth or the settlement of new corals. Thus it is not a measure of whether populations are sustaining themselves at a site, only whether they are dying at diffierent rates to other sites. However, in measuring that parameter, it does have some advantages over the use of belt transects or line intercepts.

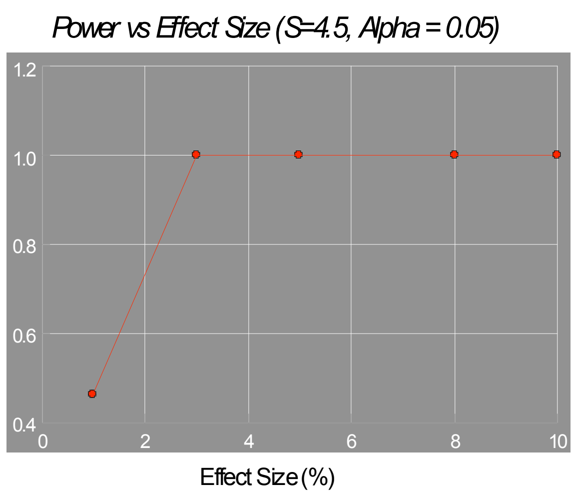
Measures of coral loss are normally set as a percentage of the coral present pre-impact. That means a 10% loss from a community with 30% coral cover must detect a 3% change in absolute cover, or 1% in a community with 10% cover. Belt or line transects which measure absolute coral cover show rapid drops in statistical power in communities below 30% cover (Stoddart et al. 2005) which can be a problem if the communities closest to the impacts have low coral cover. As MRII targets individual corals it is not constrained by the background coral cover.

Coral communities are renowned for their spatially patchy nature (Hughes 1989) and it is essential that repeated measures monitoring records the exact piece of substrate each survey (Ryan and Heyward 2003). Belt transects and line transects struggle to do so.

## Results

Practicality: MRII requires no more resources than standard methods of belt transects or other surveys. With an experienced team, survey times can be cost effective. Surveys conducted for the dredging programs within Dampier Harbour were able to record 100 corals per site for 16 sites spread over 30km of Harbour within 4 diving days.

Power: The following data are from a program conducted within the Pilbara nearshore where eight sites were surveyed using MRII with a set of 60 corals at each site and a fortnightly survey interval and show that for changes greater than 3% of partial mortality, the MRII Method is very robust.




Interpretation: In yielding sequential images of individual corals MRII provides the capacity to assign mortality directly to individuals and to allow visual investigation of the causes of that mortality (providing the survey frequency is sufficiently intensive).

## Discussion

MRII is one method which can provide a practical and powerful test of change in coral mortality of less than 5%. However detection of change is not the same as assigning cause. In reviewing methods which look at measuring change in a broader coral ecosystem, Wilkinson (2004) points to a need to use methods which cope with the levels of change seen routinely in healthy (in the sense of long term persistence) coral communities. Long term studies of reef areas show clearly that these are not normally areas of stasis either in coral cover or demographic processes (Connell et al. 1997).

Connell (1997) points to a level of above 30% decline in cover as a being significant impact on a reef. While it would be inappropriate to set that as an action trigger, compliance monitoring systems should consider that interpretation of changes below that magnitude risk being part of the normal cycle of a 'healthy' reef. In practice local events and characteristics of specific communities deny the notion that changes of a few percent in coral cover between sites declared at risk from impact and those used as references can definitively indicate a dredging-related impact. When we deal with change at this level, cause will normally be equivocal.

To conclude, the EIA process should be wary of outcomes which attempt to deny the constant nature of change in coral communities and mandate a 'no net change' condition. Where EIA outcomes wish to give coral communities a high degree of protection they should not focus primarily on the survival of adult corals.

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