

# JCU ePrints

This file is part of the following reference:

**Dinsdale, Elizabeth (2004) *Coral reef health indicators: integrating ecological and perceptual assessments of anchor damage*. PhD thesis, James Cook University.**

Access to this file is available from:

<http://eprints.jcu.edu.au/67>

**Coral reef health indicators: integrating ecological and perceptual  
assessments of anchor damage**

**Thesis Submitted by**

**Elizabeth Dinsdale B.Sc. (JCU)**

**in December 2004**

**For the degree of Doctor of Philosophy  
In the School of Tropical Environment Studies and Geography  
James Cook University**

## STATEMENT OF ACCESS

I, Elizabeth Dinsdale, author of this work, understand that James Cook University will make this thesis available for use within the University Library and via the Australian Digital Theses network, for use elsewhere.

I understand that, as an unpublished work, a thesis has significant protection under the Copyright Act and;

I do not wish to place any further restriction on access to this work.

---

Elizabeth Dinsdale

---

Date

## STATEMENT OF SOURCES

### DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

---

Elizabeth Dinsdale

---

Date

## DECLARATION ON ETHICS

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the *National Statement on Ethics Conduct in Research Involving Human* (1999), the *Joint NHMRC/AVCC Statement and Guidelines on Research Practice* (1997), the *James Cook University Policy on Experimentation Ethics. Standard Practices and Guidelines* (2001), and the *James Cook University Statement and Guidelines on Research Practice* (2001). The proposed research methodology received clearance from the James Cook University Experimentation Ethics Review Committee (approval number H1359).

---

Elizabeth Dinsdale

---

Date

## **Acknowledgements**

I wish to thank the commitment of my family, particularly my husband, Brett, who encouraged me and had faith in my ability to complete a Ph.D. His understanding and patience never faltered. I would like to thank my girls, who in a reversal of roles told me how proud they were of their mother. Thanks to my own parents, brothers and their families for their support, encouragement and for forgiving me when I forgot special dates.

I would like to acknowledge my appreciation for the contribution of my supervisors, Vicki Harriott, Mark Fenton and Peter Valentine. They provided guidance and encouragement throughout the Ph.D. process. The breadth of this Ph.D. I believe was a challenge to all of us. Special thanks is given to Vicki Harriott, for her commitment to producing good students, but sadly died of cancer before the examiner's comments on this thesis were known.

I wish to acknowledge the financial contributions made by the CRC Reef Research Centre, School of Tropical Environment Studies and Geography, Great Barrier Reef Marine Park Authority, and Queensland Smart State Funding. The funding from these institutions provided both scholarship and research support.

Even with funding support from these bodies, the research would not have been possible without the support of the Airlie Beach branch of the Queensland Park and Wildlife Service, who provided me with safe passage around the Whitsundays and allowed me to use their cabin and camping facilities. The field trips were made more hospitable when they dropped in for a chat. Logistical support was also provided by Hayman Island Resort.

Thanks also to the people who participated in the perceptual study, your time made the research possible. Thanks to the people who joined me on field trips. While sometime we enjoyed the spectacular scenery and conditions that the Whitsundays has to offer, we also froze and terrified ourselves when the weather was not what they advertised in the brochures.

## **PAPERS ARISING FROM THE PhD THESIS**

**Dinsdale E.A.** 2003 Indicators of coral reef condition: integrating views of society. Proceedings of the World Congress on Aquatic Protected Areas, Cairns. 1:415-420. Presented in chapter 2

**Dinsdale E.A.** and Harriott V.J. 2004 Assessing anchor damage on coral reefs: a case study in the selection of environmental indicators. *Environmental Management* 33(1):126-139. Presented in chapter 3

**Dinsdale E.A.** and Fenton D.M. 2004 Assessing coral reef condition: eliciting community meanings. *Society and Natural Resources*, in review. Presented in chapter 4

**Dinsdale E.A.** 2004 Coral Reef Health Indicators: ecological and perceptual assessments of anchor damage. In prep *Society and Natural Resources*. Presented in Chapter 5.

**Dinsdale E.A.** 2004 Evaluating management: ecological and perceptual assessments of a program to protect coral reefs from anchor damage. In Prep *Environmental Conservation*. Presented in Chapter 6

Other publications arising during my candidature, which are presented in Appendix 2.

**Dinsdale E.A.**, 2002 Abundance of Black-band disease on corals from one location on the Great Barrier Reef: a comparison with abundance in the Caribbean region. Proceedings of the Ninth International Coral Reef Symposium, Bali. 2:1239-1243.

Hughes T.P, A.H. Baird, **E.A. Dinsdale**, V. J. Harriott, N.A. Moltschaniwskyj, M.S. Pratchett, J.E. Tanner and B.L. Willis 2002 Latitudinal patterns in larval recruitment: Detecting regional variation using meta-analysis and large-scale sampling. *Ecology* 83: 436-541.

Hughes T.P, A.H. Baird, **E.A. Dinsdale**, N.A. Moltschaniwskyj, M.S. Pratchett, J.E. Tanner and B.L. Willis 2000 Supply side ecology in reverse: the link between adults, fecundity and larval recruits. *Ecology* 81:2241-2249.

Willis B.L., C. Page and **E.A. Dinsdale** 2004 Chapter 3. Coral disease in the Indo-Pacific. pp 69-104. Loya Y. and R. Rosenberg (eds) *Coral health and disease*. Springer, Berlin.

## **ABSTRACT**

The ecosystem health concept is an integrative approach to environmental management and while conceptually logical, it is difficult to implement. The false dichotomy of nature and culture, and the way in which knowledge is constructed has led to many of these problems. To understand the relationship between knowledge systems, the ecosystem health concept is explored here by assessing the condition of coral reefs associated with different intensities of anchoring, using both an ecological and a social perspective. Specifically, the research aims to: 1) identify environmental indicators to evaluate management strategies; 2) identify perceptual meanings ascribed to coral reefs; 3) evaluate the relationship between perceptual meanings, health judgments and environmental indicators; and 4) use the ecosystem health indicators developed to assess a coral reef management strategy.

Because environmental conservation can alienate scarce natural resources from competing uses, it is important to gain support for conservation programs by demonstrating that management actions have been effective in achieving their goals. One way to do this is to show that selected significant environmental variables (indicators) vary between managed and unmanaged areas, or change over time following implementation of a management regime. However, identifying indicators that reflect environmental conditions relevant to management practices has proven difficult. Initially this thesis focuses on developing a framework for choosing indicators in a coral reef habitat. To identify indicators suitable to measure the success of a management strategy to reduce anchor damage to a coral reef, twenty-four candidate variables were identified and evaluated at sites with different intensities of anchoring. In this study, measures which reflected injuries to coral colonies were generally more efficient than traditional measures of coral cover in describing the effects of anchoring. The number of overturned colonies was identified as the single most useful indicator of coral reef condition associated with anchoring intensities. The indicator selection framework developed has the advantages of being transparent, cost efficient, and is readily transferable to other types of human activities and management strategies.

To further the development of collaborative management, an understanding of the meanings people hold for the environment is required. Therefore, community meanings for coral reefs were elicited by asking participants, with a range of experiences, to describe photographs of the coral reefs surveyed to identify the environmental indicators. Three important meanings ascribed to coral reefs were elicited. The most important meaning was “evaluation”, whether the scenes were perceived positively or negatively. The second meaning was “activity”, whether the scene depicted movement through the variation in numbers of fish and types of coral. The third meaning was “diversity”, describing highly diverse scenes compared to monocultures of coral. Participants with and without a working association with coral reefs all ascribed these meanings and had a remarkably consistent conceptualisation of coral reefs. Coral reefs with high levels of anchoring were associated with the constructs “unhealthy”, “boring”, “lacklustre” and “dead”, suggesting they had lost much of their value.

A health judgement was added to the ecological and perceptual meanings of the coral reefs to identify the usefulness of the ecosystem health concept. The three assessments described changes to coral reef condition associated with anchoring. The ecological measures identified an increase in the number of overturned corals and a reduction in soft and branching corals, the perceptual meanings identified a loss of visual quality and the health judgements identified a reduction in health of the coral reef sites associated with high levels of anchoring. Comparing the three perceptual meanings with the health judgement showed that the evaluation dimension was highly correlated with coral reef health judgements, suggesting that when people enter an environment, the first and most important feature they identify is whether the environment is healthy. Health judgements were related to key ecological measures or environmental cues, the most important being the amount of damaged coral followed by amount of branching coral and perceived activity.

The three ecological measures and normative health judgement were used as indicators to evaluate the effectiveness of the Reef Protection Program implemented to protect coral reefs from the effects of anchoring. To conduct the evaluation, three coral reef sites with high levels of boating, but a reduced number of anchor drops, because of the management

strategy, were surveyed in addition to the six coral reef sites associated with low and high levels of anchoring intensity. The Reef Protection Program would be effective if the level of each of the indicators at the protected sites resembled that of the sites associated with low levels of anchoring. Two of the indicators, the number of overturned coral colonies and the judgement of health, showed that the condition of the protected coral reef sites were proceeding towards that of the coral reef sites with low levels of anchoring. However, the condition of the other two indicators, cover of soft corals and corals in the family *Acroporidae*, showed that the protected coral reefs sites were similar to the coral reef sites with high levels of anchoring intensity. Therefore, the Reef Protection Program is effective in reducing damage and improving the health of the coral reefs, but the reef condition had not yet returned fully to the condition described for the reefs associated with low levels of anchoring intensity.

The coral reef case study showed that the ecosystem health concept, although contentious, is an appropriate concept for incorporating community and scientific information into environmental management decisions. People's first assessment of coral reefs is a judgement of its health. The similarity in health judgements provided by the two groups of participants shows that health judgements are understood by a wide range of people and could be used to discuss concepts between various stakeholders. The health judgements were related to ecological measures and were useful in describing changes in condition associated with anchoring and a management strategy designed to protect coral reefs from the effects of anchoring. The evaluation of the Reef Protection Program showed that if the environment is managed to promote ecosystem health, humans can in some circumstances, change the way they are using the environment, to increase their use without causing detrimental effects to the environment.

## Table of contents

<b>CHAPTER 1</b> .....	1
<b>GENERAL INTRODUCTION: EXPLORING THE ECOSYSTEM HEALTH CONCEPT</b> .....	1
1.1 Introduction.....	1
1.2 General aims and significance.....	8
1.3 Thesis Outline.....	9
<b>CHAPTER 2</b> .....	11
<b>INDICATORS TO ASSESS CORAL REEF CONDITION: INTEGRATING VIEWS OF SOCIETY</b> .....	11
2.1 Introduction.....	11
2.2 Ecological indicators for coral reefs.....	14
2.3 Community indicators of coral reefs.....	16
2.4 Application of the indicators.....	19
<b>CHAPTER 3</b> .....	20
<b>ASSESSING ANCHOR DAMAGE ON CORAL REEFS: A CASE STUDY IN SELECTION OF ENVIRONMENTAL INDICATORS</b> .....	20
3.1 Introduction.....	20
Management of anchoring - a case study from the Great Barrier Reef.....	25
3.2 Methods.....	26
Phase 1: Generation of candidate variables.....	26
Phase 2: Field testing of candidate variables.....	28
Phase 3: Evaluation against selection criteria.....	34
3.3 Results.....	35
Evaluation of Potential Indicators against Feasibility Criteria.....	43
3.4 Discussion.....	45
<b>CHAPTER 4</b> .....	49
<b>ASSESSING CORAL REEF CONDITION: ELICITING COMMUNITY MEANINGS</b> .....	49
4.1 Introduction.....	49
Personal construct theory.....	52
Damage to coral reefs associated with anchoring and boat use.....	53
4.2 Methods.....	54
Underwater photography.....	54
Selection of photographs and questionnaire construction.....	55
Study procedure.....	57
Participants.....	59
Statistical analysis.....	59
4.3 Results.....	60
Characteristics of participants.....	60
Meanings ascribed to coral reefs.....	61
Relationship of the photographs with the ascribed meanings.....	67
4.4 Discussion.....	68

4.4 Discussion.....	69
<b>CHAPTER 5.....</b>	<b>74</b>
<b>CORAL REEF HEALTH INDICATORS: ECOLOGICAL AND PERCEPTUAL ASSESSMENTS OF ANCHOR DAMAGE .....</b>	<b>74</b>
5.1 Introduction.....	74
5.2 Methods .....	79
Assessments of coral reefs using the three individual measures.....	79
Analysis of the relationship between local knowledge and health judgements .....	83
Analysis to identify environmental cues .....	83
5.3 Results.....	84
Assessments of coral reefs using three measures.....	84
Relationship between local knowledge and health judgements .....	88
Environmental cues that are important in describing coral reef health.....	89
5.4 Discussion.....	95
<b>CHAPTER 6.....</b>	<b>101</b>
<b>EVALUATION OF THE REEF PROTECTION PROGRAM USING ECOSYSTEM HEALTH INDICATORS.....</b>	<b>101</b>
6.1 Introduction.....	101
6.2 Methods .....	104
6.3 Results.....	107
6.4 Discussion.....	111
<b>CHAPTER 7.....</b>	<b>114</b>
<b>GENERAL CONCLUSIONS .....</b>	<b>114</b>
<b>REFERENCES.....</b>	<b>122</b>
<b>APPENDIX 1.....</b>	<b>143</b>
<b>APPENDIX 2.....</b>	<b>161</b>

## Table of figures

<b>Figure 1.1</b> The ecosystem health concept describes the condition of the environment using two dimensions, biological condition and human disturbance (from Karr 2000).....	2
<b>Figure 3.1.</b> Framework for selecting indicators. Steps for choosing indicators are described in plain text and examples particular to the case study are in italics.....	24
<b>Figure 3.2.</b> Location of survey sites (*) on the Whitsunday Islands. Low levels of anchoring occurred at sites 1 - 3 and high levels of anchoring occurred at sites 4 - 6.....	30
<b>Figure 3.3.</b> Mean number ( $\pm 1$ standard error) of injuries to corals on the crest and lower slope of coral reefs influenced by high (clear bars) and low (shaded bars) intensities of anchoring.....	36
<b>Figure 3.4.</b> Mean percent coral cover ( $\pm 1$ standard error) on the crest and lower slope of coral reefs influenced by high (clear bars) and low (shaded bars) intensities of anchoring.....	38
<b>Figure 3.5.</b> Mean percent cover of substrate type including total reef biota ( $\pm 1$ standard error) on the crest and lower slope of coral reefs influenced by high (clear bars) and low (shaded bars) intensities of anchoring.....	39
<b>Figure 3.6.</b> Mean colony area ( $\pm 1$ standard error) for four coral species on reefs influenced by high (clear bars) and low (shaded bars) intensities of anchoring.....	40
<b>Figure 3.7.</b> Results of CDA using five injury variables on reef sites influenced by low (dark grey) and high (light grey) intensities of anchoring. ....	42
<b>Figure 3.8.</b> Results of CDA using eight coral cover variables on reef sites influenced by low (dark grey, sites) and high (light grey) intensities of anchoring.....	42
<b>Figure 4.1</b> An example of a typical coral reef photograph used in the perceptual study...	56
<b>Figure 4.2.</b> The distribution of the 26 photographs on the three important dimensions used to describe coral reefs by the two participant groups .....	68
<b>Figure 5.1</b> Types of damaged to corals caused by anchoring and associated chain.....	81
<b>Figure 5.2.</b> The separation of coral reef sites associated with high and low anchoring intensity by the objective measures of mean cover ( $\pm 1$ standard error) of each coral community component.....	85
<b>Figure 5.3.</b> The separation of coral reef sites associated with high and low anchoring intensity by perceptual meanings provided by the two participant groups. ....	86

<b>Figure 5.4.</b> The separation of coral reef sites associated with high and low anchoring intensity by the mean health ratings ( $\pm 1$ standard error) provided by the two participant groups.....	87
<b>Figure 5.5.</b> The relationship of coral health ratings and the evaluation dimension of the subjective descriptions provided by A) group 1 and B) group 2 participants respectively.	89
<b>Figure 5.6.</b> The relationship of evaluation dimension to the five objective measures and two perceptual meanings provided by the regression tree analysis for (A) group 1 and (B) group 2 participants.....	91-92
<b>Figure 5.7.</b> A representative photograph for each health group identified by the regression tree analysis.....	94
<b>Figure 6.1.</b> Location of survey sites in the Whitsunday Islands. Survey sites are indicated by an asterisks and low levels of boating activity occurred at sites 1-3, high levels of boating activity occurred at sites 4-6 and high levels of boating activity with protection occurred at sites 7-9.....	105
<b>Figure 6.2.</b> Mean measure ( $\pm 1$ standard error) of coral reef condition on the crest and lower slope of coral reefs associated with the three treatments.....	108
<b>Figure 6.3</b> Results of CDA using the four indicators of coral reef health indicators to separate the low levels of boating activity, high levels of boating activity and protected coral reef sites.....	110
<b>Figure 7.1</b> The ecosystem health concept, redrawn to show that the environment should be managed to increase use, but not change the biological condition (curved line).....	121

## Table of Tables

<b>Table 3.1.</b> Comparison of ability and time required for combinations of variables to describe the changes in coral reef condition associated with different intensities of anchoring.....	43
<b>Table 3.2.</b> The potential indicators were evaluated against nine feasibility criteria.....	45
<b>Table 4.1</b> A comparison of the coral reef experience and personal characteristics of participants.....	61
<b>Table 4.2</b> Comparison of the amount of variation explained on the five principal components derived from the principal component analysis of the two grids.....	62
<b>Table 4.3</b> The twelve highest and lowest constructs provided by the participants on principal component 1. Reviewing the constructs provided the meanings ascribed to coral reef scenes, the first being evaluation.....	64
<b>Table 4.4</b> The twelve highest and lowest constructs provided by the participants on principal component 2. Reviewing the constructs provided the meanings ascribed to coral reef scenes, the second being activity.....	65
<b>Table 4.5</b> The twelve highest and lowest constructs provided by the participants on principal component 3. Reviewing the constructs provided the meanings ascribed to coral reef scenes, the third being diversity.....	66
<b>Table 5.1.</b> The number of photographs distributed into each “Health group” as defined by the two participant groups in the regression tree analysis.....	94