GEOMORPHOLOGICAL SEPARABILITY, LANDSAT MSS AND AERIAL PHOTOGRAPHIC DATA: HERON ISLAND, GREAT BARRIER REEF

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Great Barrier Reef Marine Park Authority

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SUMMARY

This paper is a summary report of the research conducted under the title, "Geomorphological Separability, Landsat MSS and Aerial Photographic Data: Heron Island Reef, Great Barrier Reef, Australia". Only the major research findings are given here. A complete documentation of the research is available in a doctorate thesis by Kuchler (1984), and in published papers. Details of these manuscripts and other relevant publications are given in the references section of this memorandum.

KEYWORDS: coral reef, geomorphology, Landsat MSS, aerial photography, Heron Island, GBR.

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EXECUTIVE SUMMARY

Introduction

This memorandum is one of a series of four GBRMPA Technical Memoranda dealing with the terminology, recognition and classification of coral reef cover and zonation features in the analysis of remotely sensed data of the Great Barrier Reef.

Objective

The memorandum presents the findings of a study to determine whether remote sensing can be used effectively to detect various coral reef resources and provide information of significant value to planning and management.

Summary

The study consisted of a cross comparison of results obtained from the interpretation of numerical (digital) Landsat multispectral scanner (MSS) data, enhanced Landsat MSS images and aerial photography and known ground data. Details of these comparisons are given and presented in tabular format.

The results indicated that groups of surface features or classes can be separated in the imagery and consistently interpreted. This record of consistency shows that the results are of informational value to planning and management programs. It is clear from the discussion that interpretation improves with the greater use and availability of ancillary data. Interpretive skill also increases if the interpreter is familiar with the subject conditions in the field.

The study identifies a number of factors which influence the separability, and therefore the interpretability, of features in the imagery. These both vary within Landsat images and air photos as well as from feature class to feature class.

It is concluded that class uniqueness, water depth, feature contrast, spatial resolution, class location (adjacency) and transient boundaries all affect separability and recognition and tend to operate as a suite with the position of a variable factor within the suite changing through time, operative technique and between classes.

Conclusion

It is clear that significant information can be obtained from remotely sensed data to permit a reliable, 70% accuracy, reconnaisance inventory of the coral reef resources of the Great Barrier Reef. The data has great potential utility for monitoring because it is obtained at regular intervals and can be analysed spectrally and spatially at a number of scales.

Further research and improvements in the technology can only improve the utility of remotely sensed data if it is obtained within an appropriate, integrated multi-stage inventory and monitoring framework. In additions to the spectrographic studies such a framework must be developed.

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1. INTRODUCTION

Standard nomenclature and classification systems have been specifically developed as tools for the formal identification and codification of remotely sensed and ground observed coral reef features.

Employment of these tools indicates that classes separable within Landsat MSS and aerial photograph remotely sensed data translate to surrogate reef cover classes. For statistically defined Landsat spectral classes, a separability accuracy of 85 percent was found for reef zones; 82 percent for geomorphological reef features; and 64 percent for components of geomorphological reef features. The results for spatially defined Landsat image classes were a separability accuracy of 78 percent for reef zones; 63 percent for geomorphological reef features; and 52 percent for components of geomorphological reef features. Spatially defined aerial photo image classes have a separability accuracy of 92 percent for reef zones; 77 percent for geomorphological reef features; and 65 percent for components of geomorphological reef features.

These results allow remotely sensed coral reef data to be used confidently and consistently as a surrogate source of ground information.

2. RESEARCH OUTLINE

2.1 Research objective

To determine the separability of coral reef resources within remotely sensed coral reef data.

2.2 Management objective

To determine if remotely sensed coral reef resources are sufficiently separable to be used as surrogates for ground data.

2.3 Research method

Numerical Landsat MSS data, Landsat MSS image data and colour aerial photographic image data were cross-compared with ground data. The Barrier Reef Image ANalysis (BRIAN) software package, developed by D.L.B. Jupp of CSIRO, Division of Water and Land Resources in Canberra, was used to analyse the data and conduct the cross-comparison (Jupp, et al., 1985).

Systems of nomenclature and classification for the Great Barrier Reef were developed to assist the research method. These have been published by the Great Barrier Reef Marine Park Authority as Technical Memorandums, Numbers 7, 8 and 9 (Kuchler, 1986a, 1986b, 1986c).

3. MAJOR RESEARCH FINDINGS

The remotely sensed data were found to be separable into three groups of classes. Each class group was determined from a trade-off between separability accuracy and the scale of class separability.

Coral reef resources contained within the class groupings, could be separated within remotely sensed data with greater than 70 percent accuracy. The class groupings of coral reef resources are listed in Table 1.

Table 1. Separability of coral reef resource classes.

	CLASS	LANDSAT IMAGERY		AIR PHOTOS
		Numeric	Interpreted	
GROUP I	cay	100	100	100
	reef flat	96-90	LT70	87
	reef rim	LT70	80-75	95
	lagoon	87-68	95-89	97
	reef slope	LT70	100	93
	ocean (shallow)	95-83	75-65	85
GROUP II	beach	100	100	100
	reef flat	96-90	LT70	87
	reef rim	LT70	85-77	89
	spur and groove	LT70	83-50	100
	reef slope	LT70	82-55	83
	shallow lagoon*	LT70	LT70	35
	deep lagoon*	LT70	LT70	72
	ocean (shallow)	95-84	LT70	85
	coral	LT70	100	86
	bank	LT70	71	100
GROUP III	beachrock	100-0	LT70	100
	sand beach	75	100	100
	algae coated coral	LT70	100	86
	coral covered reef slope	LT70	LT70	73
	sanded reef slope	LT70	LT70	LT70
	coral rubble	LT70	LT70	LT70
	sand	86-69	LT70	86
	coral covered spur and groove	LT70	LT70	LT70
	sanded shoals	LT70	LT70	LT70
	ocean	73-66	LT70	LT70
	rubble covered spur and groove	LT70	LT70	LT70
	shingle	LT70	71	100
	shallow lagoon with sand floor*	LT70	LT70	LT70
	shallow lagoon with coral floor*	LT70	LT70	LT70
	deep lagoon with sand floor*	LT70	LT70	LT70
	deep lagoon with coral floor*	LT70	LT70	81

Notes: Figures are measures of percentage.
LT70 indicates a separability Less Than 70 percent.
* indicates that the analyses did not completely satisfy the research objective.

Coral reef resource classes were also consistently separable within the remotely sensed data. Consistently separable classes are those which can be separated using both Landsat (image or numerical) data and aerial photographic data.

The consistently separable classes are given below:

Group I :
- cay
- reef flat
- reef rim
- lagoon
- reef slope
- ocean

Significantly, this means that the total Heron Island reef surface can be consistently classified at greater than 70 percent accuracy using six Group I information classes and either Landsat or aerial photographic data.

Group II :
- beach
- reef flat
- reef rim
- spur and groove
- reef slope
- ocean
- coral
- bank

Significantly, this means that the Heron Island reef surface can be consistently classified at greater than 70 percent accuracy using eight Group II information classes and either Landsat or aerial photographic data.

Group III:
- sand beach
- algae coated
- coral
- sand
- shingle

Significantly, this means that the Heron Island reef surface can be consistently classified at greater than 70 percent accuracy using five Group III information classes and either Landsat or aerial photographic data.

An additional 11 Group III classes can be separated with between 60 and 70 percent accuracy. These are listed in Table 2.

Table 2. Group III classes with between 60 and 70 percent separability accuracy, calculated using 17 class separations.

CLASS	LANDSAT IMAGERY		AIR PHOTOS
	Numeric	Interpreted	
coral covered reef slope	NSS	80-40	S
coral rubble	70-55	NSS	NSS
sanded reef slope	NSS	67-50	67
coral	NSS	S	59
beachrock	100-0	NSS	S
sanded shoals	NSS	NSS	59
coral covered spur and groove	NSS	67	67
ocean	S	67-63	62
algae coated	NSS	67-63	63
deep lagoon with coral floor*	NSS	67-59	S

Note: Figures are measures of percentage
NSS indicates Not Sufficiently Separable
S indicates data Separable at greater than 70 percent
* indicates that the analyses did not completely satisfy the research objective

The results from when the spectral classes were cross-compared with the interpreted Landsat image classes have not been included in the findings on data separability. This is because only the same type of data in two different formats were cross-compared, and the objective was not to verify the data, but to test how well an interpreter could label a screen image.

There is sufficient evidence to conclude that an interpreter can effectively and accurately attribute informational value to spectral classes displayed on a screen image. The evidence is contained in the cross-comparison of the interpreted Landsat image data against ground data and the aerial photographic data.

The quality of the interpreter's knowledge and image analysis skills are obviously the critical determinants. Extensive ancillary support was also given to the interpretation of the Landsat image by aerial photographic data.

A number of factors have been identified as influencing remotely sensed data separability. The importance of these factors varies both within the Landsat and aerial photo data and from class to class. These factors represent significant research findings, since they consistently operate independently of the separability technique, and the class being separated. Thus, they operate as a suite of factors which directly control class separability within remotely sensed data. The suite of factors is outlined below:

- **Uniqueness of class**
  Irrespective of many of the criteria or analyses used to identify and delineate a reef cover class within remotely sensed data, some classes are characterised by one or more unique attributes. These attributes make them easily identifiable and delineable. For example, the cay, beach and bank classes all have three unique attributes - reflectivity, geographical association and shape.

- **Water depth**
  The reflectivity, and therefore separability of a submerged coral reef surface is affected by a water depth factor. Water depth has the effect of decreasing the data contrast and thereby decreasing separability precision.

- **Low contrast data**
  It appears that the contrast within remotely sensed coral reef data is too low for separating some coral reef covers. Thus, sampling of spectral variability, and the suitability of current classifiers for low contrast data, are important issues which require further research. These are discussed in Kuchler, 1984a and 1984b. It is possible that the classes displaying low separability are not spectrally distinct even when they are exposed. This question also needs to be researched.

The opposite of low contrast features are those features which are spectrally distinct, for example the reef rim. Due to the spatial resolution of the MSS instrument however, they appear as 'mixels' within Landsat data and therefore become spatially indistinct. This problem nevertheless, will be resolved with the new generation of satellites, for example the French SPOT satellite.

- **Spatial resolution, class adjacency and transient boundaries**
  Spatial resolution, class adjacency and transient boundaries were three factors which operate together to result in a combined and significant effect on class separability levels. Since their effect is one of lowering data separability, the mapping error which is determined by these factors can be minimised, by maximizing the scale at which the data is separated. These factors will not significantly influence the separability of coral reef covers when higher resolution data (such as SPOT and Landsat TM) is available.

Two major knowledge components have contributed towards solving the research problem. The research has;

- identified the variables which directly control separability - the variables which currently restrict the amount of information which can be extracted from the data - data utility;

- and, identified that these controlling variables consistently operate as a suite; and, that the position of a variable within this suite changes through time, with separability techniques, and from class to class.

4. MANAGEMENT IMPLICATIONS OF RESEARCH FINDINGS

The research findings have five implications for management. These are listed below:

- There is a consistent information-based relationship between management needs and remotely sensed coral reef data.

- This information-based relationship has value for users because it allows coral reef resources on the Great Barrier Reef to be inventoried with greater than 70 percent accuracy.

- Such resource information is operationally collected; is available in computer compatible tape form; and, at present is theoretically available every 18 days for the entire extent of the Great Barrier Reef.

- The separability of coral reef resources within remotely sensed data has proved usable here. The precision, quality and scale at which coral reef resources can be separated can only improve in the future.

- Resource information from remotely sensed data can be obtained at many scales.

5. REQUIREMENTS FOR FUTURE KNOWLEDGE

Future research efforts are required in the following areas and are listed in descending order of priority:

Short-term immediate

Establishment of the spectral characteristics of coral reef features; and the storage of this information in a nationally accessed computer-based spectral signature data bank.

This information is urgently needed:

- so that variables controlling data utility can be effectively eliminated or controlled in an operational situation;

- since many more spectral wavelengths are becoming available within remotely sensed satellite data; and,

- since in the future, users will be able to purchase usable wavelengths individually. To take advantage of this reduced-expenses and higher resolution offer however, spectral information is required.

Establishment of the separability and utility of digitalised aerial photographic data.

Such research is required because only the separability of aerial photograph image data has been assessed thus far (Kuchler, 1984). Furthermore, initial research attempts by Maniere et al., (1984) have outlined the applicability of digital image analysis techniques to aerial photographic coral reef image data.

Longer-term operational

Develop appropriate strategies for the realisation of a multistage coral reef resource inventory concept.

This research is necessary to maximise on all operationally available remotely sensed data.

6. CONCLUSION

It has been established that the amount of useful information which can be extracted from or separated within Landsat MSS and aerial photographic data is considerable. It has been possible to combine a number of surface ground categories into classes, associate these with individual resolvable elements as 'seen' by the remote sensors, and consequently recover resource information.

Identification of multispectral signatures for particular reef covers submerged in particular marine environments will contribute to the understanding of the nature of remotely sensed reef covers and consequently improve on the separability results presented here.

Obviously, because only two technologies were tested here (Landsat MSS and aerial photography), a general claim to the separability of remotely sensed coral reef covers cannot be made. It is encouraging however, that ground, aircraft and satellite based instrumentation now available, has the capability to resolve many of the questions raised by this research.

Separability of reef covers is controlled principally by three physically interrelated variables: water depth, spatial extent and spectral resolution. The influence of the last two variables will decrease with the availability of new remote sensing instruments. With the major separability variables identified, it is encouraging to know that control over these major variables is highly possible in an operational situation.

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