Report to

Great Barrier Reef Marine Park Authority

Use of Infra-Red Aerial Photography for Monitoring Effects of *Acanthaster planci* Outbreaks

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This Report summarises progress in relation to each of the stated objectives. During the period July 1987 - September 1988 a number of conference papers have been and will be presented relating to work on both this project and a James Cook University funded project to examine cyclic and long term change in algal cover on reefs. Copies of these papers (and abstracts where no published paper is involved) are provided in the Appendix.

OBJECTIVES

Three objectives were addressed during the year July 1987 - July 1988:

1 Assessment of optimum scale for aerial monitoring of *Acanthaster planci* outbreaks.

2 Analysis of digitised aerial photography.

3 Collection of Ground Truth data.

DATA COLLECTION: Photographic data

Two photographic flights have been undertaken since the previous Report. As in the past, opportunities for photographic data collection are limited by the availability of negative tides during daylight hours.

Date	Reefs covered	Flying Heights (feet)
06.09.87	Pandora Reef	7,000
"	" "	500
"	Iris Point	7,000
"	John Brewer Reef (transect)	7,000
"	Helix Reef	7,000
"	" " (transect)	1,000
"	Grub Reef (transect)	7,000
"	Wheeler Reef	7,000
"	" " (transect)	1,000
30.06.88	Helix Reef (transect)	1,000
"	Grub Reef (transect)	1,800
"	" " "	500
"	Wheeler Reef	2,000
"	" " (transect)	500

DATA COLLECTION: Ground Truth Data

A 4 day Ground Truth data collection trip was undertaken from 31st March - 3rd June 1988 using the Research Vessel 'James Kirby'. Data collection was planned for Helix, Wheeler, and Grub Reefs to coincide with photographic transects. Unfortunately, poor weather conditions during this period (Fantasy Island sank during this time) precluded visiting Helix Reef, but data were collected along transects on Grub and Wheeler Reefs.

REPORT ON OBJECTIVES

1 ASSESSMENT OF OPTIMUM SCALE

Photography of target reefs is now available at 1,000', 3,000', 7,000' and in some cases 500' flying heights. The two problems to be addressed are firstly relative information content at the various photo scales produced, and secondly, the cost of obtaining the information. For the main objective of this project, the necessity is to detect small area, short term changes in ecological communities rather than macroscale changes in reef ecology and/or morphology. A summary of the relative information content of photography at each flying height, based on the use of standard 23 cm x 23 cm IR prints, is given below.

7,000'

Photoscale: 1:8132.
Allows clear discrimination of limits of coral/algal communities on exposed areas of reefs, but only provides information on large area changes. For example, on Pandora Reef the boundaries of major features such as the moated pool and the extent of live coral/algae on the reef fringes are clearly visible, but only the larger microatolls in the pool can be detected, and changes in area and/or composition of the biotic communities would have to be fairly extensive to be detectable. It seems unlikely that coral and algal growth can be separated. However, this scale does give good overall information on the distribution of biotic communities in relation to reef morphology, and changes over a longer time should be detectable if large areas are involved.

4,000', 3,500', 3,000'

Photoscales: 1:4649, 1:4066, 1:3483.
These three flying heights have been grouped together as they produce similar levels of information.

Several frames are needed to cover even small reefs such as Pandora, hence cost is considerably higher and an overall impression is not given. However, this scale range appears to have great potential for monitoring purposes and when digitised (see later section) produces a pixel size of approximately 50 cm on the ground. Using Helix Reef as an example, a range of spectral signature variations produced by the communities on the reef fringes is clearly discernible, and the same number of spectral classes are detectable at this scale as appear on larger scale (1:1162) photography flown at 1,000'. The relevant pair of photographs appear as Plates 1 and 2 in the July 1987 Report. This scale appears feasible for use in detecting change, providing there is no water over the area. Mapping of Helix Reef over the period June 1986 - June 1988 is proceeding to further examine detectability of change. This scale range of photography has so far produced excellent results when digitised.

1,000'

Photoscale 1:1162.
This scale is useful for the delimiting of coral/algal communities but the considerably lower flying height results in large numbers of photographs being required for a small area. This scale would be most useful for collecting information on reef fringes where starfish are more likely to be active than on the reef flats. Studies currently in progress using the Helix Reef 1:1162 photography suggest this scale is very useful for mapping changes in community composition and/or vigour over small areas. Extensive photography of reef flats at this scale appears less useful.

500'

Photoscale 1:580.
Individual coral heads are visible, with a minimum detectable size of about 10 cm. An expensive form of data for other than small areas. Stereo coverage is not easy to obtain as the minimum possible flying speed does not usually permit full 60% overlap. Little work has so far been carried out using this photography owing to the relatively high cost, and photographs taken in June 1988 have not yet been closely examined.

2 ANALYSIS OF DIGITISED PHOTOGRAPHY

In April 1988 James Cook University purchased a MicroBRIAN digital image processing system which has greatly facilitated analysis of the digitised images received in July 1987. Previously the system at GBRMPA was used, which involved logistical problems in terms of travelling and availability of time on the GBRMPA MicroBRIAN.

Subsets of four images have so far been examined in order to assess:

a) the detectability and spectral separability of coral and algal communities;

b) the potential advantages of digitised imagery over conventional hard-copy prints;

c) the usefulness of digital image processing for mapping and measuring *Acanthaster planci* outbreaks.

In addition to the above objectives, consideration of optimum photo scale (as per major objective 1) has also received attention.

Each photograph sent to ASO was scanned as a series of 9 subsets, each 512 pixels x 512 lines. The ground resolution of the digitised images is a function of the scale of photography and the size of the actual print scanned. Scenes examined to date are:

Area	Flying Height	Approx. pixel size
Helix Reef	3,000'	50 cm
Helix Reef	1,000'	17 cm
Cape Tribulation (IR)	3,500'	55 cm
Cape Tribulation (True Colour)	3,500'	55 cm

Digital image analysis is still in the preliminary stages and so far has involved examination of enhanced data. Digital data processing involving band ratios, band subtraction, and image classification is currently being undertaken in order to evaluate this form of image data in relation to the stated objectives. Initial visual comparison of data in channels 1, 2, and 3 suggests that inter-band processing may assist discrimination of coral communities.

The pixel sizes produced allow detailed mapping of coral/algal cover and produce very detailed data compared with hardcopy prints. Plate 1 is an inkjet plot of a subset of a 1:1162 photograph of Helix Reef showing the boundaries of the biotic communities. The original photograph appeared as Plate 2 in the 1987 Report. A ground truth trip will be undertaken to identify the nature of the communities producing the different spectral signatures. The blue tones comprise areas covered by water, the white areas are carbonate and the red, yellow, orange, and pink tones are areas of coral/algal cover. Ground truth data collection in a similar environment on Wheeler Reef suggests that the main reef surface classes are hard coral, coralline algae, macroalgae, and carbonate. The dataset in Plate 1 will be further processed following ground truth data collection. Plate 2 shows a subset of Plate 1 displayed as 4 individual bands. Inter-band processing of channels 2 and 3 shows potential for improving discrimination of surface types.

The scale of photography most suitable for digitising is still being assessed. The only 1:1162 photograph digitised has poor colour reconstitution on the screen although the boundaries between spectral signatures are accurately reproduced. This may be a function of the actual colours involved (pinks and mauves). The 1:3483 and 1:4066 photography has so far produced excellent results when digitised. Plate 3 shows a subset of the 1:4066 photography of Cape Tribulation fringing reefs, and Plate 4 shows an enlargement of a spur on which algal/coral communities are clearly visible.

3 GROUND TRUTH DATA COLLECTION

Ground Truth data collected in June 1988 await further detailed analysis in conjunction with recent low-level photography of the same sites. Prints have not yet been received. Preliminary examination of transect data collected on Grub and Wheeler Reefs suggests that the main surface types producing the observed spectral signatures are hard coral, coralline algae, macroalgae, and bare carbonate surfaces.

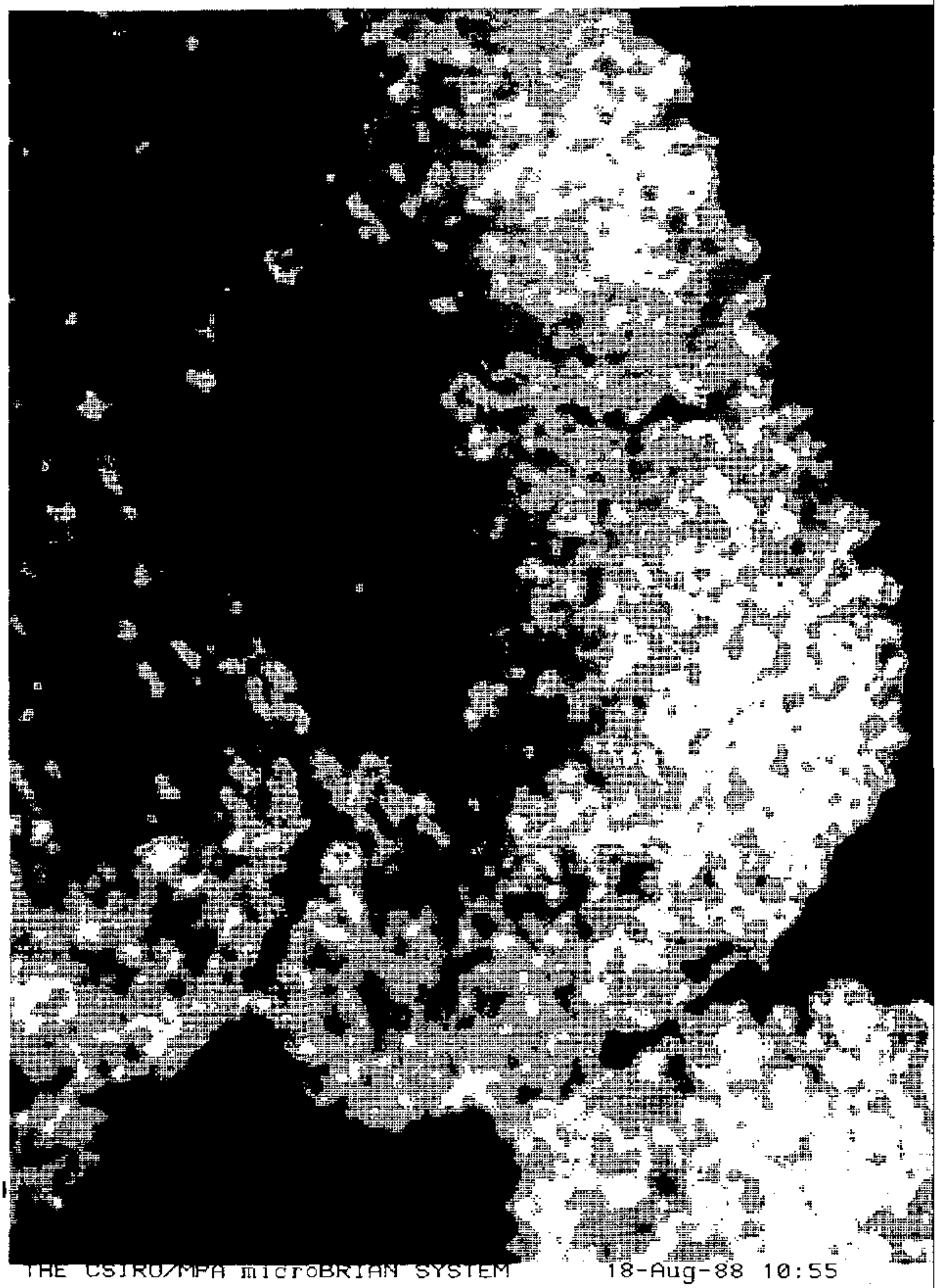

PLATE 1.

MicroBRIAN inkjet plot of a subset of a 1:1162 I.R. print showing a section of Helix Reef. Areas covered by water appear as blue tones, carbonate dominated surfaces appear white, and biotic communities appear as red, orange, yellow, and pink tones.

Channel 1
Blue Filter

Channel 2
Green Filter

Channel 3
Red Filter

Channel 4
Clear Filter

PLATE 2.
Digitised IR photography of Helix Reef. Plots showing spatial distribution of brightness values in each of the 4 channels for a subset of the photograph. Light tones correspond to bright reds on the original photograph while the darkest tones represent water.

PLATE 3.

MicroBRIAN inkjet plot showing fringing reefs near Cape Tribulation. Subset digitised from 1:4066 I.R. print. Density of blue tones indicates increasing depth of water. Coral/algal cover appears red.

PLATE 4.

MicroBRIAN inkjet plot showing enlargement of single spur from Plate 3. Distribution of biotic communities is shown by red tones.

APPENDIX

RELEVANT CONFERENCE PAPERS AND ABSTRACTS 1987-1988.

Symposium on Remote Sensing of the Coastal Zone, Queensland 1988

ASSESSMENT OF LARGE SCALE PHOTOGRAPHIC IMAGERY FOR MANAGEMENT AND MONITORING OF THE GREAT BARRIER REEF

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ABSTRACT

The management and monitoring of the diverse resources of the Great Barrier Reef involves continuous assessment and planning to accommodate reef dynamics and human activity.

This pilot project commenced in 1986 to assess the potential for using low level air photography as a monitoring tool, particularly to provide information in relation to attack by Crown-of-Thorns Starfish (Acanthaster planci), seasonal and longer term changes in algal cover, and changes in reef morphology. Both true and false colour photography have been assessed. The optimum photo scale for information content in relation to cost is being investigated using a range of flying heights between 7000' and 500'.

Flights are timed to coincide with the lowest possible daytime tides. Both fringing and offshore reefs have been included, and a range of Crown-of-Thorns infestation levels have been investigated.

Data interpretation involves the use of both hardcopy and digitised photography, the latter being processed via the MicroBRIAN digital image processing system.

Results to date suggest there is potential for using this relatively low cost method of reef monitoring as a data source for both mapping change and devising planning strategies, and also for monitoring specific projects such as the floating hotel on John Brewer Reef.

INTRODUCTION

The efficient management of a diverse, dynamic natural resource such as the Great Barrier Reef is dependent upon the availability of both up-to-date information for the development of management strategies and the ability to monitor the effectiveness of those strategies. Remote sensing techniques offer a broad range of data collection methods to fulfil both these requirements. Since the launch of ERTS-1 (LANDSAT 1) in 1972 a number of researchers have utilised remotely sensed data to investigate reef morphology, dynamics, ecology, and bathymetry. Work by Hopley (1978), Hopley and Van Steveninck (1977), Van Steveninck (1976), Jupp et al (1981, 1984, 1985) Jupp (1983), Kuchler (1984), Reichelt and Bainbridge (1988) serve to illustrate progress to date. The application of currently available sensors to studies on the Great Barrier Reef is summarised in the recent publication Marine and Coastal Remote Sensing in the Australian Tropics (eds McCracken and Kingwell, 1988). Increasing human pressure on the fragile resources of the Reef emphasises the need to devise efficient management and monitoring strategies to minimise the impact of developments such as the Four Seasons Floating Hotel on John Brewer Reef.

Two basic problems emerge from attempts to utilise remote sensing techniques to monitor the Reef. Firstly, while satellite data provide a convenient form of digital or hard copy imager which has proved valuable for morphological mapping purposes the ground resolution is too coarse to be of value for mapping and monitoring the biotic communities of the reef. Secondly, while data collected from airborne non-photographic sensors offers improved resolution this is only available at high cost as commissioned surveys. A monitoring programme requires a regular return period for data collection at a reasonable cost. Vertical air photographs have been used in studies of the Great Barrier Reef since 1925 and the major applications are summarised in Hopley (1978), Kuchler (1984) and Catt (1988). The present study aims to re-evaluate the potential of this remotely sensed data source to obtain the high resolution imagery and digital data handling capacity required to supplement satellite imagery for efficient reef monitoring and management.

Following from the work of Van Steveninck (1976) and Hopley and Van Steveninck (1977), true colour and false colour IR film is currently being re-evaluated for a range of applications in response to the growing need to monitor both cyclic and long term changes in reef ecology and morphology. Changes in seawater chemistry, particularly in respect of increasing phosphate levels, together with increasing turbidity resulting from soil erosion have been related to decreasing vigour and calcification rates in coral growth (Rasmussen, 1986) and with changes in the nature and composition of the algal cover. Infestation by Crown-of-Thorns Starfish (*Acanthaster planci*) is also causing changes in the ecology of reefs which are as yet poorly understood. In addition to these biotic changes, changes in reef morphology and ecology as a result of tourist activities require investigation and monitoring to prevent the onset of irreversible degradation of the Reef. None of these phenomena are easily detectable on satellite imagery or existing commercial air photography, but under present constraints specialised air photography over selected monitoring transects and the subsequent digitising of images offers the most cost effective solution.

OBJECTIVES

The present project comprises a number of objectives which are the subject of ongoing research:

a) Evaluation of the feasibility of using of large scale aerial photography along selected transects for monitoring Reef dynamics and establishing a data base for management purposes.

b) Assessment of the relative information content of true and false colour IR film for Reef mapping and monitoring.

c) Determination of optimum flying height and hence photo scale for cost effective monitoring flights.

d) Evaluation of digitised aerial photography for obtaining high resolution digital imagery.

A number of sites in the Townsville section of the Great Barrier Reef have been chosen to cover a range of reef environments including both fringing and offshore reefs as listed in Table 1.

Table 1 Reefs selected for Survey

Reef	Type	Comments
Cape Tribulation	Fringing	Increasing turbidity affecting coral growth
Iris Point	Fringing	Algal cover to be monitored
Pioneer Bay	Fringing	Algal cover to be monitored
John Brewer	Offshore	Recreational impact, starfish outbreak 1983-4
Grub Reef	Offshore	Some starfish present 1988: population treated with copper sulphate 1986
Wheeler Reef	Offshore	Not subject to starfish infestation until about 1986
Helix Reef	Offshore	Extensively damaged by starfish
Bramble Reef	Offshore	Infested by starfish
Pandora Reef	Offshore	Selected for algal mapping and geomorphological information

METHODOLOGY

Acquisition of Photography

Photographic flights commenced in June 1986 and are timed to coincide with the lowest possible daytime tides. Photography using infrared colour film is only worthwhile when reefs are exposed owing to poor water penetration. The majority of flights to date have taken place during the period June - September as negative tides at other times of the year are generally at night.

A Hasselblad 70 mm format camera with an 80 mm focal length lens is mounted in a light aircraft hired for the purpose. Both true colour and false colour IR film is used to evaluate the relative information content for a range of applications. A range of flying heights between 7000' (2134 m) and 500' (174 m) is utilised to determine the most cost effective scale of photography for monitoring purposes.

Data Analysis

Photographs are examined using both visual interpretation and, for selected scenes, digital image analysis. A number of scenes have been digitised by the Australian Survey Office using an Eikonix camera and are analysed using the MicroBRIAN digital image processing system. Hardcopy output is obtained via a Tektronix colour plotter.

Ground Truth Data Collection

To date, one series of ground truth transects have been examined on Grub and Wheeler Reefs in an attempt to correlate image tone/texture with type of surface and biotic community. The planned field programme was curtailed owing to gale conditions and further data will be collected in late 1988. Ground truth data collection was also undertaken on the Cape Tribulation fringing reefs in June 1988.

DISCUSSION OF RESULTS TO DATE

Results to date will be discussed under sub-headings corresponding to the relevant objectives. This is an on-going project and much data still awaits analysis.

a) Monitoring Potential

The pilot survey to date comprises a series of 7 flights each of which covers most of the target reefs. Visual interpretation of prints for a transect across Helix Reef show a change over a 12 month period in the distribution of areas with high reflectivity in the infra-red. This is curently being mapped and awaits the inclusion of the 1988 data. By using digitised images, a digital data base of such changes can be established. In addition to evidence of short term change, the time series photography also provides a 'then' database for current and future developments such as the Floating Hotel and increased tourist access to outer reefs.

The most efficient scale for such monitoring flights, which are envisaged as an annual event, is currently under investigation and is discussed further in a later section. Cost effectiveness has to take into account the costs of flying time, film, processing, prints, digitising, and interpreter time.

b) Information Content of True Colour and False Colour Photography

Visual comparisons suggest that both have merits and any decision as to film suitability will inevitably be influenced by the objective sought. Work by Hopley and Van Steveninck (1977) presents findings from a study of reef feature discrimination using 4 types of film based on comparison of densitometer traces of 35 mm positive transparencies over a range of reefs and reef features. The findings are summarised in Table 2.

Table 2

Matrix of film type best differentiating between reef zones. Figures refer to the zones listed in the key. The bottom left section of the matrix indicates largest mean values for density differences between pairs of zones while the top right section indicates smallest standard deviations over the range of images used. The largest mean with the smallest standard deviation is underlined.

SMALLEST STANDARD DEVIATION

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LARGEST MEAN DIFFERENCE

FILM TYPE:

P - Panchromatic
C - Colour
M - I-R monochrome
I - I-R colour

KEY - List of Coral Reef Zones and Features

1 Living corals
2 Algal rim
3 Shingle and boulder rubble
4 Basset edges (cemented basal portion of ramparts)
5 Shingle ramparts
6 Moats
7 Sanded reef flat
8 Reef flat with seagrasses
9 Reef flat with abundant small living corals
10 Reef flat with algal covered rubble
11 Deeper lagoons (>5 m)
12 Mangroves
13 Cay beach or unvegetated cay
14 Beachrock
15 Herbaceous vegetation (colonizing species)
16 Woodland vegetation

Source: Hopley and Van Steveninck (1977)

The current study has only considered the use of colour emulsions and a matrix of results based on initial visual interpretation is given in Table 3.

Table 3

Reef feature	Film Type IR	TC
Living coral	X	
Algal cover	X	
Carbonate	O	O
Sand cay	O	O
Reef edge bathymetry		X
Delimitation of pools	X	
Shingle features	O	O

X - indicates better discrimination of feature type
O - easily discriminated on either

Similar comparisons using the digitised imagery are still in progress.

c) Most Cost Efficient Scale of Photography

Photographic flights have been carried out at a range of flying heights, giving a range of photo scales as indicated in Table 4.

Table 4

Flying Height	Nominal scale of conventional 23 cm x 23 cm print
7000' (2134 m)	1:8132
4000' (1220 m)	1:4649
3500' (1067 m)	1:4066
3000' (914 m)	1:3483
1000' (305 m)	1:1162
500' (152 m)	1:580

All photography taken so far has contributed some information on reef dynamics, but one object of the project is to determine a suitable scale for collecting data not already available from other sources such as LANDSAT or SPOT. Flying height experiments were carried out over Pandora Reef (7000', 3000', 1000') to compare geomorphological and biogeographical information content, and over Helix Reef and Wheeler Reef (7000', 3000', 1000', 500') to determine ecological information content.

In each case, the 7000' image gives a good overview of the whole reef, and in the case of IR film permits delimitation of the area(s) of active coral and/or algal growth. Major morphological features such as the sand cay on Wheeler Reef and microatoll pool on Pandora Reef are clearly visible, as are dynamic features such as shingle encroachment over the reef flat on Pandora Reef.

The flying heights in the range 3-4000' enable visual discrimination of geomorphological features and reef surface types on the true colour photos, but it is difficult to clearly delimit areas of algal/coral growth on the basis of texture and colour tone. In the case of IR photos, discrimination of algal/coral growth is possible even on individual bommies although individual coral heads cannot be detected. The digitised photography at this scale examined so far appears to be very useful for delimiting and quantifying areas of coral/algae. This aspect will be discussed further in a later section.

A flying height of 1000' gives a wealth of reef surface information on both types of film. Individual microatolls having a diameter of less than 1 m can be identified in the microatoll pool on Pandora Reef. Water depth variations and the extent of algal growth in the same pool is clearly visible on the IR photograph. This scale has great potential for time series monitoring of selected short transects, but represents a high cost in terms of the number of photographs required to cover even a small reef at this scale. Pandora Reef, which is approximately 1050 m long and 400 m wide, requires 9 photographs at this scale to give stereo coverage of the long axis of the reef, and would require another 10 frames to cover the remaining width.

The photographs taken from 500' show a wealth of detail including individual coral heads and patches of algal cover but require large numbers of photographs to cover a small area. Coverage of whole reefs is not feasible at this scale, but occasional photography over target monitoring sites such as the vicinity of the Floating Hotel would be valuable.

The cost effectiveness of this form of monitoring is a pressing consideration, and low level photography provides data not easily available from other sources. A flying height of 3000' (914 m) utilising an 80 mm focal length camera gives good indication of change over time, with small target areas or transects surveyed at a larger scale.

d) Evaluation of Digitised Photography

A limited number of photographs have been digitised to date, and digital analysis is still in progress. Preliminary findings only are presented here. The data are being analysed using the MicroBRIAN image processing system with standard MicroBRIAN software. It is envisaged that subsequently additional software will need to be developed to establish an image database for monitoring.

The only digitised images examined so far were scanned by the Australian Survey Office, Canberra, and supplied on floppy disks for use with MicroBRIAN. Several problems have been encountered in using this data, and other sources of digitised data are being sought for comparative purposes.

The ASO personnel reported problems in digitising associated with reflection from the surface of prints which would probably be overcome by using negatives or transparencies. The colours reconstituted via MicroBRIAN are somewhat variable - areas of high reflectance in the infra red prints tend to be reproduced as white, yellow, and orange rather than in shades of red, pink, and purple. The range of colours present in the original image appears to affect the representation of colours on the screen - for example the true colour scene of the Cape Tribulation reefs is poorly reproduced compared with a true colour image of Helix Reef. The main difference in the original images is the presence of a large area of green vegetation in the Cape Tribulation scene which appears to have affected the overall colour balance of the scan. These problems are not insurmountable, and a careful comparison with the original prints shows that only the colours have changed - boundaries between tones and textures are faithfully reproduced.

Apart from the initial problems encountered in reconciling the digitised images to the originals, the additional data handling facility offered by digital image processing greatly enhances the usefulness of the surveys. Each image was scanned to give 4 channels of data according to filters used:

Channel 1:	blue filter
Channel 2:	green filter
Channel 3:	red filter
Channel 4:	clear filter

The examination of individual channels and combinations of channels is currently being undertaken in order to correlate reef surface phenomena with observed reflectance patterns. Reconnaisance ground truth transects indicate that discrimination between hard coral, coralline algae, turf algae, and macroalgae is not always possible from hardcopy - on Wheeler Reef the brightest spectral signatures on IR prints appear to be produced by coralline algae while on the Cape Tribulation fringing reefs macroalgae frequently produce the brightest signatures. Inter-channel comparisons are being investigated to improve discrimination efficiency. The distribution of brightness values for a colour IR subscene of Helix Reef is shown in Figure 1, while Figure 2 shows the data content of each channel for a small subset of the image. The peaks at lower histrogram values in Figure 1 represent water while high reflectance in channel 3 corresponds to coralline algae, hard corals, and turf algae on the reef edge and offshore bommies. In Figure 2, darker areas in channels 2 and 3 away from the water are reef flat coverd by shallow water. The surface of this reef flat mainly consists of carbonate with scattered coral heads and coralline algae but the spectral signatures are suppressed by the water. Band ratios and subtractive processing have yet to be applied to this data. Further evaluation of single channel data is in progress.

Digitised true colour photography demonstrates excellent potential for mapping local bathymetry in the vicinity of both offshore and fringing reefs.

The work carried out on the digitised imagery to date shows the great potential of this form of digital data, providing the initial digitising problems can be overcome and the scanning process standardised. The merging of digital data sets derived from different film emulsions offers a resource which has not yet been explored but forms an objective for the next phase of this project.

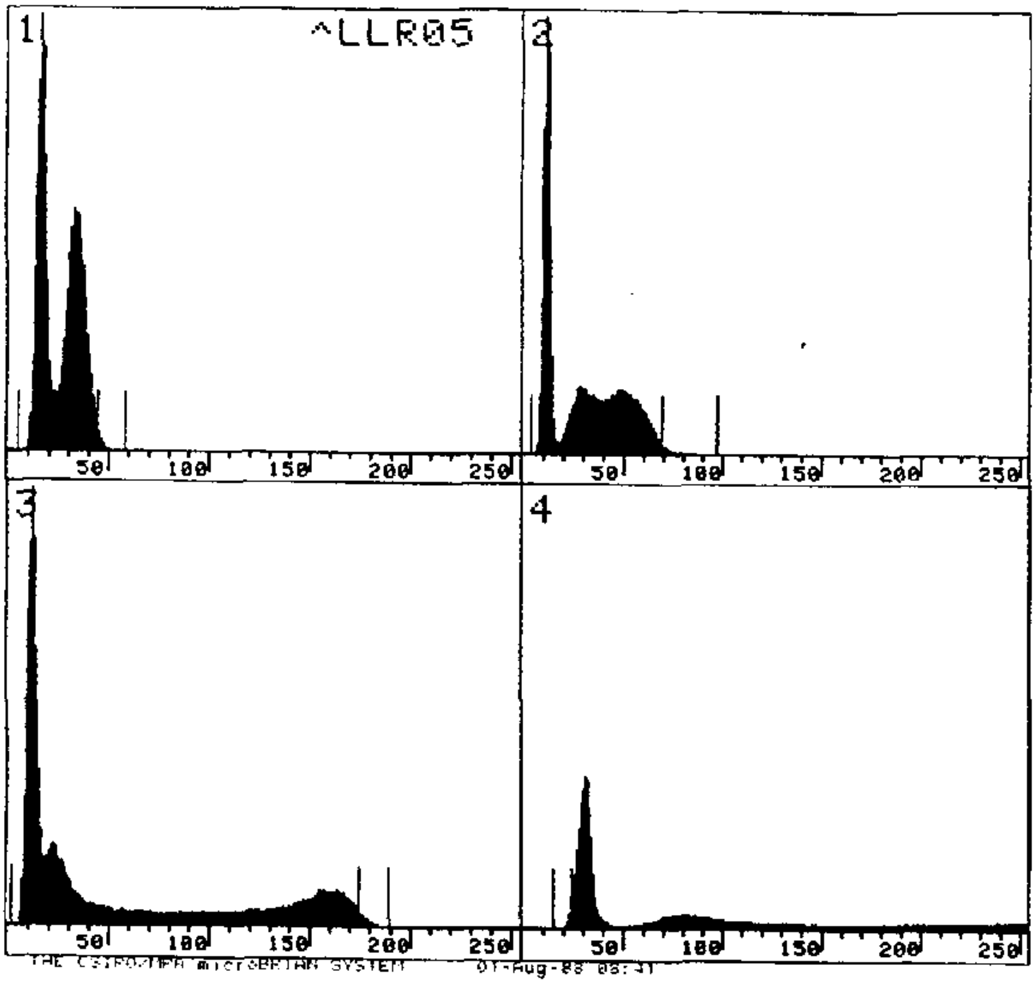
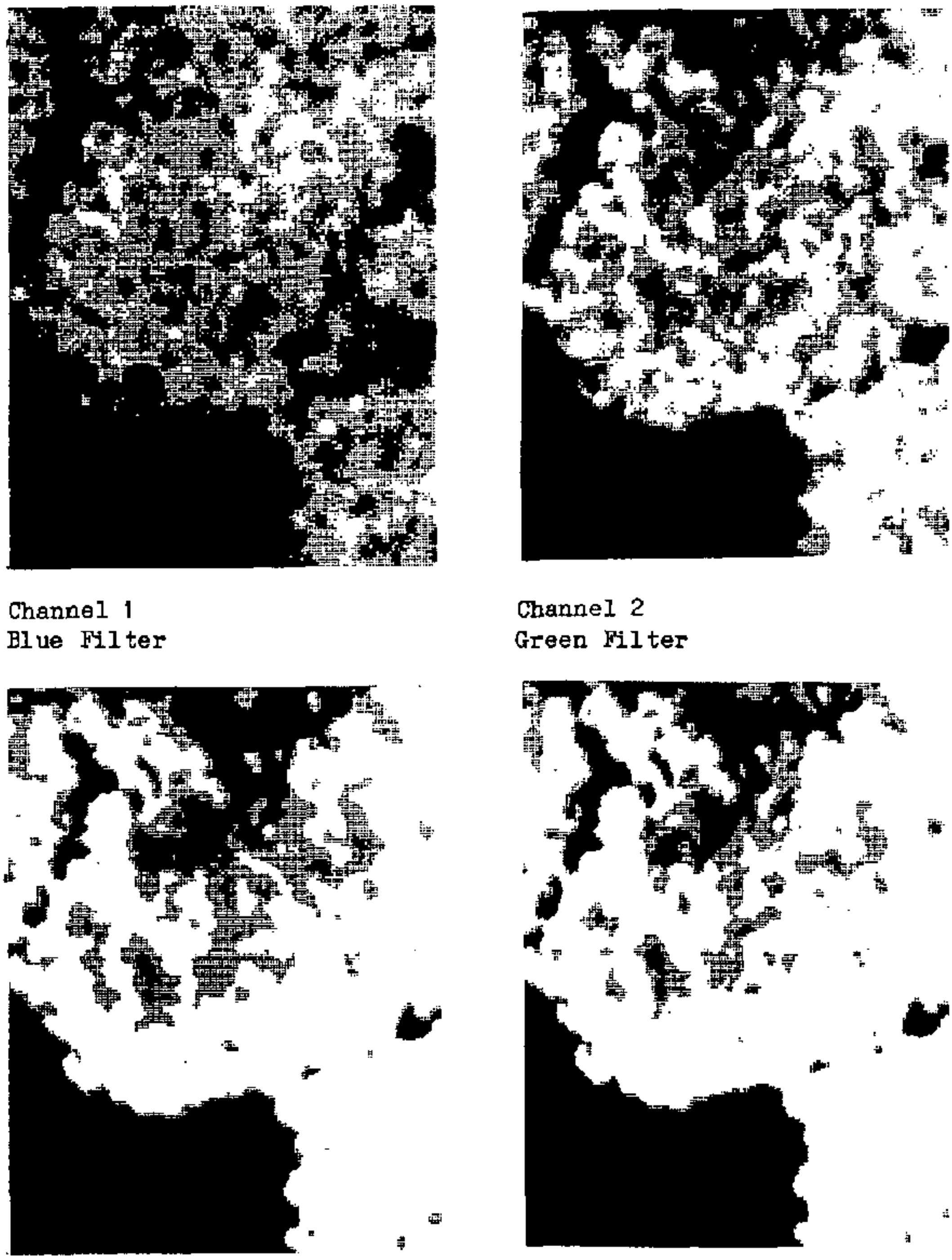


Figure 1

Histograms showing brightness values in the 4 channels digitised from a subset of a Helix Reef IR colour print
1 = blue, 2 = green, 3 = red, 4 = clear filter.



Channel 1
Blue Filter

Channel 2
Green Filter

Channel 3
Red Filter

Channel 4
Clear Filter

Figure 2

Digitised IR photography of Helix Reef. Plots showing spatial distribution of brightness values in each of the 4 channels for a subset of the photograph. Light tones correspond to bright reds on the original photograph while the darkest tones represent water.

CONCLUSIONS

This paper represents an overview of an ongoing project which is attempting to overcome the ground resolution problems of existing commercially available remotely sensed data for reef monitoring. Of available satellite data sources, LANDSAT Thematic Mapper offers high spectral resolution but relatively poor ground resolution while SPOT panchromatic mode offers 10 m ground resolution with poor spectral resolution. Both offer the possibility of short return period (16 days LANDSAT, 26 days SPOT) but are expensive. LANDSAT Multispectral Scanner data is less expensive but has poor ground resolution (80 m) and no visible blue channel. The present project is designed to evaluate an additional remotely sensed data resource to complement the existing satellite resources.

The ground scale of the major problems facing the Great Barrier Reef is relatively small: a very large Crown-of-Thorns Starfish is only about 50 cm in diameter and the Floating Hotel occupies only a few pixels on a satellite image. The study of these problems and the detection of change requires a data source with higher spatial resolution. The photography used in the study has not succeeded in locating actual starfish to date, but is intended to detect the extent of reef damage by starfish as reflected in changes in coral vigour and algal cover, thus monitoring the progress of infestation and reef recovery over time. Changes in coral growth and algal cover related to change in seawater chemistry and change in hard coral distribution resulting from turbidity are phenomena which are initially small scale and will only become apparent over time. The establishment of an inventory type of data base utilising time series air photography offers the possibility of detecting the onset of such changes and the opportunity for management decisions to be made before such problems become sufficiently extensive to be detected on satellite imagery.

Results to date indicate excellent potential for the use of large scale air photography as a management tool. The photographic archive compiled so far during the present project extends over a period of 3 years and already variations in reef ecology are visually detectable. These changes are now being quantified and interpreted with the assistance of ground truth data and ground photography. The initial investigations of digitised photography analysed via the MicroBRIAN system have produced far more information than was originally anticipated, and inter-band processing is now in progress with the aim of improving discrimination of ecological phenomena. The project is continuing with 1988 photography currently in progress, and change over time is being mapped on an annual basis. The success of the early stages of the investigation has resulted in a wide range of applications for this photography in mapping, planning and monitoring for reef management purposes.

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Abstract of Paper to be presented at the International Geographical Congress, Sydney, August 1988.

APPLICATION OF LARGE SCALE PHOTOGRAPHIC IMAGERY FOR MONITORING THE GREAT BARRIER REEF

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Aims

Low level, large scale infra-red and true colour aerial photography is currently being acquired on a repetitive basis for selected reefs. This is a pilot programme to evaluate the potential of such imagery for long term reef monitoring. The major objectives of the current programme are:

a) the study of seasonal, cyclic, and long-term changes in the nature and density of algal cover;
b) monitoring the decline in areas of living coral on reefs affected by the Crown of Thorns Starfish (Acanthaster planci);
c) the evaluation of the potential for use of digitised air photography for image analysis and to develop a digital image data base.

Methodology

Photographic flights are timed to coincide with the lowest possible tides over a variety of seasons. In order to determine the optimum scale of imagery, photography has been carried out at three flying heights: 7000' (2153 m), 3000' (923 m), and 1000' (307 m). Initial visual interpretation is carried out using hard copy imagery. Selected images are digitised for analysis using the MicroBRIAN image processing system, with the longer term objective of establishing a digital image database for monitoring purposes. The relative usefulness of high and low resolution scanning is also being evaluated. Ground truth data is to be collected along selected transects in May 1988.

Results

This is an ongoing project therefore only preliminary findings can be presented here:

a) Infra-red imagery has proved far superior to true colour for the identification and mapping of live coral, damaged coral, and algal cover.
b) Lower flying heights show a considerable increase in information content, but bring the accompanying problem of high volume and cost of imagery. The 3000' flying height (approximately 1:11,5000) is useful for the discrimination of geomorphological features but provides little detail on the corals and algae. The 1000' flying height (1:3800) allows discrimination between living corals and the dead tops of corals in microatoll pools. Microatolls as small as 20 cm in diameter, and the decrease in area of living coral under attack by Acanthaster planci on Helix Reef between June 1986 and July 1987 can clearly be detected at this scale.
c) A selection of images has been digitised. Initial processing of the digitised imagery suggests that this method of obtaining repetitive high resolution digital imagery has great potential. The problems of image rectification and registration are currently being addressed.

USE OF NEAR INFRA-RED AERIAL PHOTOGRAPHY FOR MONITORING

ECOLOGICAL CHANGES TO CORAL REEF FLATS ON THE GREAT BARRIER REEF

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If a sealevel rise of approximately one metre takes place during the next half century as a result of the Greenhouse Effect, the area of coral reefs which will first react to this rise are going to be the reef flats. Although mapping of reef flat ecology can be carried out by normal ground methods and true colour aerial photography can greatly aid in this mapping process, previous experimentation has indicated that the differentiation of living corals and other organisms such as algae is greatly enhanced by using near infra-red aerial photography. A program is already underway using this methodology for two purposes, 1) to indicate the seasonality of zonation on many coral reefs produced by algal variation; and 2) to indicate the effect and recovery of reef flats damaged by Acanthaster planci populations. A number of reefs have been photographed over a two year period in the Townsville region of the Great Barrier Reef, and it is suggested that a continued program of monitoring on these particular reefs will pick up the effect of any sealevel rise if the program is continued over the next fifty years. Discussion of the technique and results will be given and illustrated by the images already to hand. Processing of the results includes scanning and computer analysis.

Preferred presentation format: Poster

Abstract of Oral and Poster Papers presented at 6th International Coral Reef Symposium, Townsville, August 1988.

Text of Poster Paper presented at the 4th Australasian Remote Sensing Conference, Adelaide, September 1987.

APPLICATION OF LARGE SCALE INFRA-RED AND TRUE COLOUR AERIAL PHOTOGRAPHY TO MAP AND MONITOR ALGAL GROWTH AND INFESTATION OF CROWN-OF-THORNS STARFISH (ACANTHASTER PLANCI) ON THE GREAT BARRIER REEF

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Introduction

Management of the physical and biotic resources of the Great Barrier Reef poses a wide range of problems, including the need to obtain information on changing conditions. The projects outlined in this display are aimed to assist in data collection for mapping and monitoring two important aspects of Great Barrier Reef ecology which have long-term implications for the future of the Reef, namely infestation by Crown-of-Thorns Starfish and changes in algal cover related to seasonal and cyclic changes in environmental conditions.

The infestation of reefs by the Crown-of-Thorns Starfish (Acanthaster planci) is resulting in the destruction of live corals and consequent degradation of reefs where coral regeneration is slow. Not all reefs are affected at the present time, but new infestations periodically occur. In order to derive maximum effect from control programmes it is necessary to determine which reefs are infested and how quickly and extensively the reefs are being damaged. Following infestation the recovery of coral also requires monitoring. Remotely sensed data offer the possibility for periodic monitoring, but commercially available forms of imagery have neither the ground resolution required to detect starfish outbreaks nor the choice of timing of the data collection. Work by a range of researchers (eg Jupp 1983, Kuchler 1984) and the authors suggests that the most useful form of imagery for this purpose is low level air photography. While it is not possible to discriminate actual starfish on the imagery so far obtained, the change in areas of live coral over time can be detected and is considered to be related to the level of infestation.

Seasonal and cyclic changes in algal growth on coral reefs is a little studied area of reef ecology although such changes have been noted by many workers. Algae are agents of both reef construction and reef destruction, and while these roles have been tentatively identified in respect of individual genera and species the implications of changes in algal cover have not been adequately considered. In the case of the Great Barrier Reef, changes in seawater chemistry, particularly in respect of increasing phosphate levels, together with increasing turbidity have been related to decreasing vigour and calcification rates in coral growth (Rasmussen 1986). These changes are thought to be largely due to increasing usage of phosphate fertiliser coupled with increasing soil erosion in the sugar cane growing areas of the adjoining mainland. Such changes in seawater quality are also likely to be reflected in long term change in algal cover, which would provide a useful indicator of this form of pollution. Algal cover may also change following infestation by starfish. This is a pilot project to establish a basis for monitoring both seasonal and longer term changes in algal cover to facilitate further research into this aspect of reef ecology. Low level near infra-red air photographs are being used for this purpose.

These are pilot projects to evaluate the techniques employed, and are still in the early stages.

Data Collection and Analysis

Air photographs have been taken on a total of 5 flights to date. Flights are timed to coincide with the lowest possible tides and hence tend to be concentrated during the winter months. This allows maximum reef exposure thus facilitating the use of infra-red film which has poor water penetration capability. True colour and infra-red photographs are taken using a standard aerial camera. A range of reefs (including both fringing and offshore reefs) has been selected for study, including reefs which are heavily infested (eg Helix Reef) and currently unaffected (eg Wheeler Reef) by starfish. The photography is being analysed visually as well as digitised for use with the MicroBRIAN image analysis system. Ground truth data is to be collected on a seasonal basis.

Three specific objectives have been addressed during 1987, and data collection and analysis continue.

Objectives 1987

1. Comparison of suitability of true colour and near infra-red photography for the projects.

2. Determination of optimum flying height and hence photo scale.

3. Digitising of photography for use with MicroBRIAN system, and evaluation of MicroBRIAN software for analysis of this imagery.

Discussion of Results to date

Objective 1

Infra-red photography is far superior to true colour for detection of coral damage and algal presence. Attention to date has concentrated on detection of starfish damage, using the change in IR spectral signature from red to pink representing the change from live to dead or damaged coral. The superior water penetration of true colour film may, however, prove useful and both types of film will continue to be used.

Objective 2

Flying heights of 1,000', 3,000' and 7,000' have been used to evaluate the level of information obtained in relation to cost. Comparisons were made using a) Pandora Reef and b) a section of Helix Reef. Figure 1 shows the locations of these reefs. Unfortunately the 7,000' IR photography of Pandora Reef was unsuccessful and is to be repeated. The true colour photographs at all three flying heights are presented here for visual comparison of information content and scale (Plates 1, 2 and 3). Future work will concentrate on the use of IR photography. Visual comparison of the 1,000' and 3,000' IR photographs of Pandora Reef shows a considerable increase in information content in the 1,000' photograph. The 3,000' photo (Plate 4) is useful for the discrimination of geomorphological features, but provides little detail on the algae and corals. (It should be noted that the original photographs are of better quality than the enlarged reprints displayed here.) The 1,000' photo (Plate 5) includes a wealth of detail in terms of tones and textures, and allows discrimination between living corals and the dead tops of corals in the microatoll pool. Microatolls as small as 20 cm in diameter can be detected. This is not possible with the poorer ground resolution of the 3,000' photo. A ground map of Pandora Reef is presented in Figure 2 for comparison.

A comparison of 3,000' and 1,000' flying heights has also been used in the examination of a transect on Helix Reef to monitor the spread of starfish. The 'baseline' photographs taken on 22/6/1986 at both scales are presented here for visual comparison (Plates 6 and 7) and are currently being analysed in digital form using MicroBRIAN. Subsequent photography of the same area has shown a decrease in the area producing the red spectral signature.

Objective 3

A selection of images has been digitised using an Eikonix scanning camera. The digital data were not received in time for discussion here, but work is currently proceeding. The digitising of hardcopy prints presented some problems due to reflection, and in future the original negatives will be digitised.

Conclusions

This paper presents only the early stages of a continuing programme. Results to date suggest that the methodology employed has great potential. Cost effectiveness of such a monitoring system needs careful consideration as findings suggest that reducing costs by increasing flying height (hence reducing aircraft time and number of images) greatly reduces the information content of the imagery. The use of fixed transects rather than covering whole reefs may be a suitable strategy.

Digitising of data shows good results in the initial stages, and problems encountered in relation to reflection from prints should be overcome by using negatives. The use of digital data via an image processing system will facilitate the establishment of an image database for monitoring purposes.

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