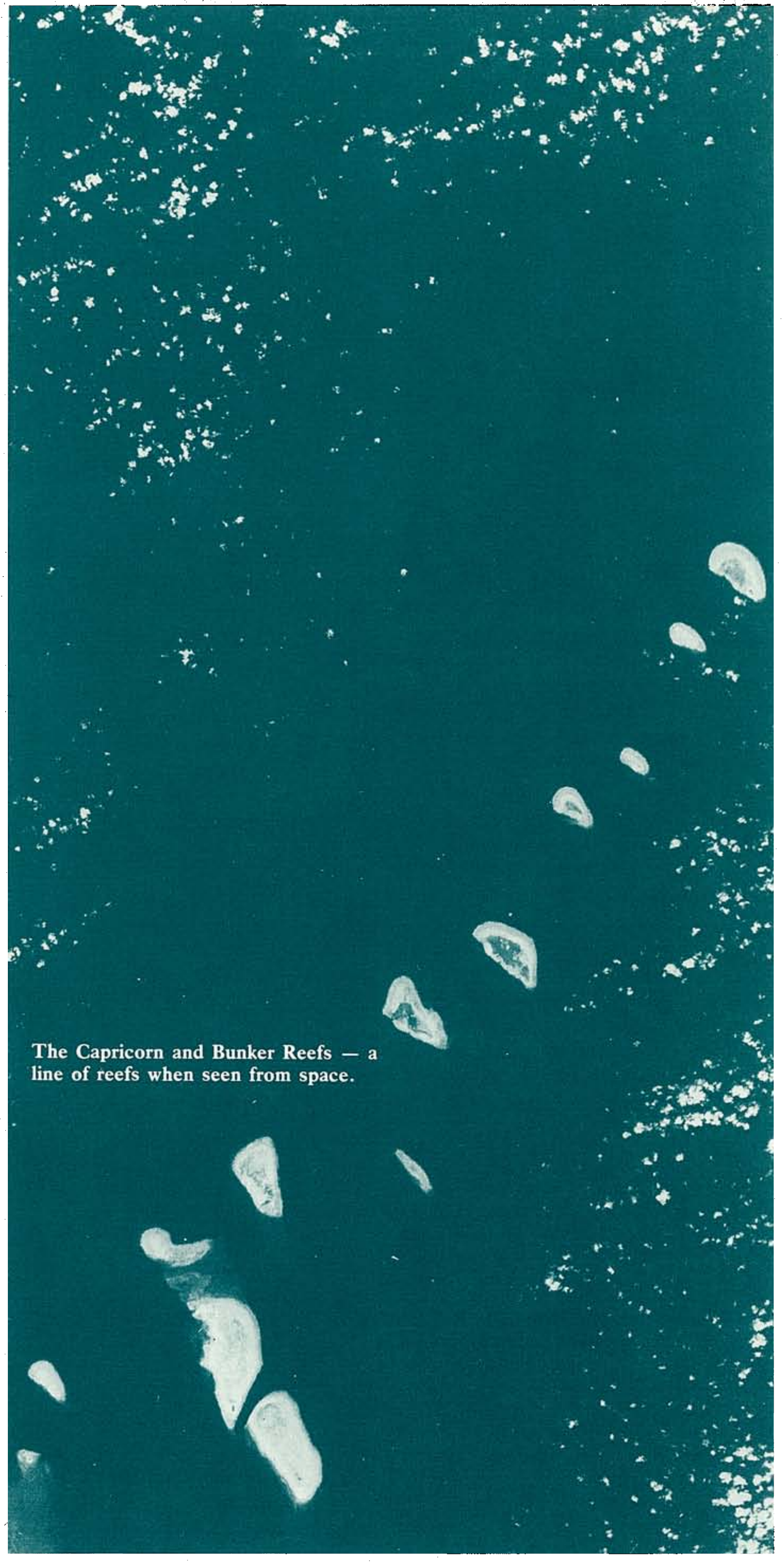
Landsat looks at the Great Barrier Reef

The Great Barrier Reef is the world's largest and most complex aggregation of living coral. Some 400 species of coral, over thousands of years, have given rise to 2000 kilometres of reefs, from the coastal waters of Papua New Guinea to just south of the Tropic of Capricorn.



The Capricorn and Bunker Reefs — a line of reefs when seen from space.

It is not a continuous barrier, but a broken maze of reefs and more than 70 coral islands (called cays). In places, it comprises a series of narrow 'ribbon' reefs, while in the south it broadens into a vast wilderness of 'patch' reefs separated by winding channels.

Some 2500 individual reefs — ranging in size from less than a hectare to more than 100 square kilometres — have been mapped. Most of them are submerged, although low tide brings large numbers into view. All are the accumulated skeletal remains (largely calcium carbonate) of simple plants and animals and support a veneer of living organisms, including more than 1500 species of fish.

The reef ecosystem is liable to damage from many quarters. Phenomena such as cyclones and infestations of crown-of-thorns starfish recur from time to time. Human influence, constantly increasing, poses threats too. Fishing, removal of shells and coral as souvenirs, and pollution from a number of sources can upset the balance. Careful management of the Reef is needed, but there is a basic lack of knowledge about its structure and life processes, not to mention uncertainties about the effects of environmental changes.

In 1975 the Great Barrier Reef Marine Park Authority was created. The intention is that the Authority should work towards having sections of the Reef progressively declared part of the Great Barrier Reef Marine Park. The Capricornia section of the Park was proclaimed two years ago, and the Cairns section last November. These two areas take in the most heavily used parts of the Reef. The Capricornia section, especially, is subject to great pressures because it is highly accessible and close to major centres of population.

Research to help

A number of research bodies are presently furthering our understanding of the Reef. For example, the Australian Institute of Marine Science in Townsville is studying many of its environmental and physical processes, and the Bureau of Mineral Resources carries out research into its geological evolution.

The University of Queensland, James Cook University, Townsville, and the Australian Museum are undertaking basic research on the Reef, and the CSIRO Division of Oceanography studies the physical oceanography of the adjoining waters.

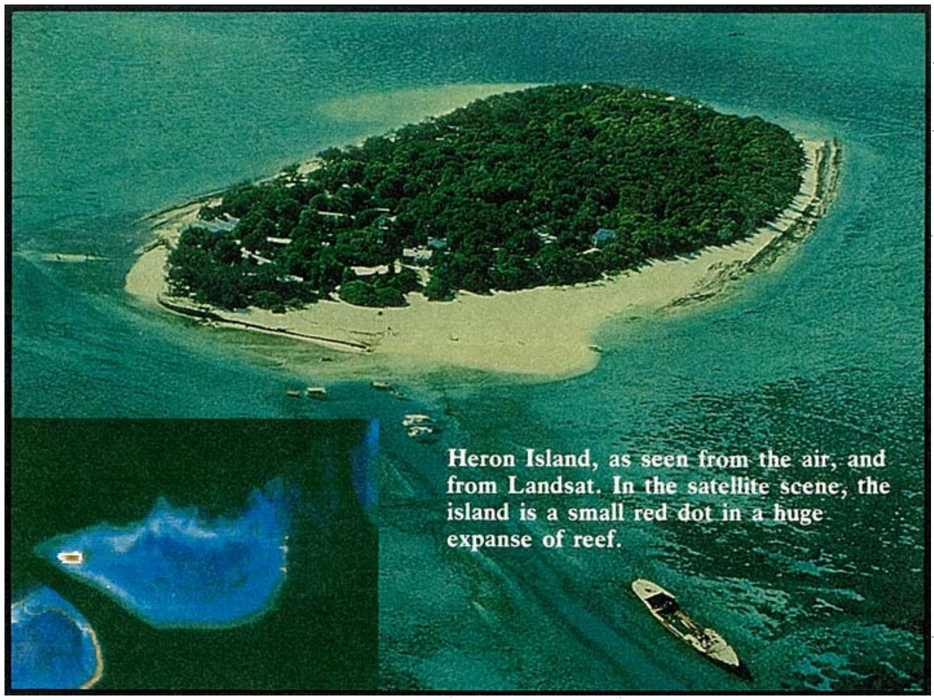
Careful management of the Reef is needed, but there is a basic lack of knowledge.

The Great Barrier Reef Marine Park Authority (GBRMPA) doesn't generally carry out research itself, but it does commission others to do so. One such research project that shows exciting possibilities occupies scientists at the CSIRO Division of Land Use Research. The Australian Marine Sciences and Technologies Advisory Council is contributing funds.

Dr David Jupp and colleagues Mr Kevin Mayo, Mrs Sandra Heggen, and Mr Stuart Kendall are employing computer methods to investigate how Landsat satellite photographs can be used to identify characteristics of the Reef and to show up any long-term changes in its appearance.

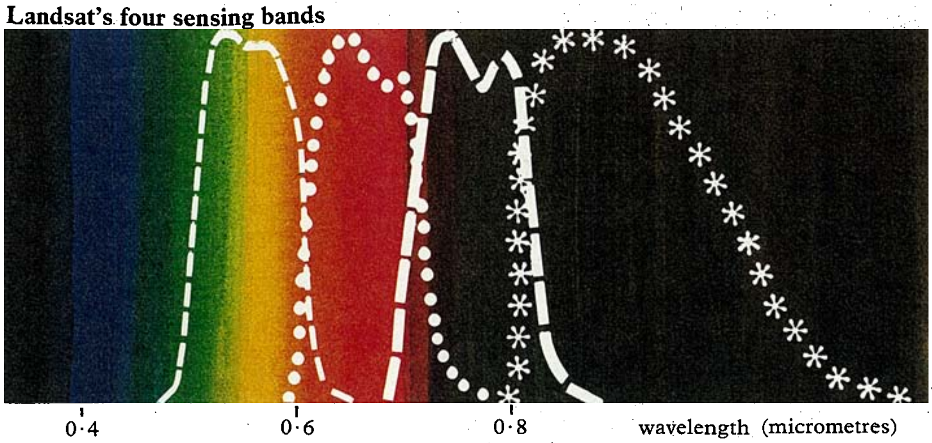
For example, Dr Jupp wants to know whether Landsat can distinguish various elements within areas of lagoon, sand, shingle bank, shoal, cay, coral, and reef flat. Nobody knows how much of this type of information can be extracted from Landsat pictures. Each one is actually a summation of four pictures taken at different wavelengths (two bands in the visible region and two in the infra-red). Computer techniques can be used to enhance features in one or more of the bands to reveal previously hidden detail.

One of the disadvantages of Landsat is that its resolution is limited to the size of the smallest picture element (or 'pixel'), corresponding to an area on the ground

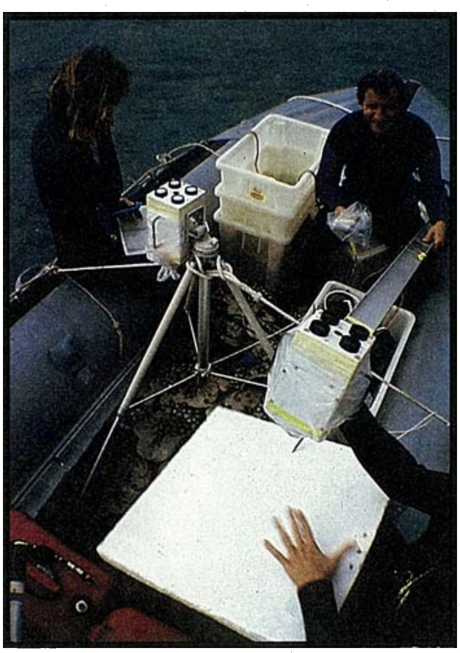


Heron Island, as seen from the air, and from Landsat. In the satellite scene, the island is a small red dot in a huge expanse of reef.

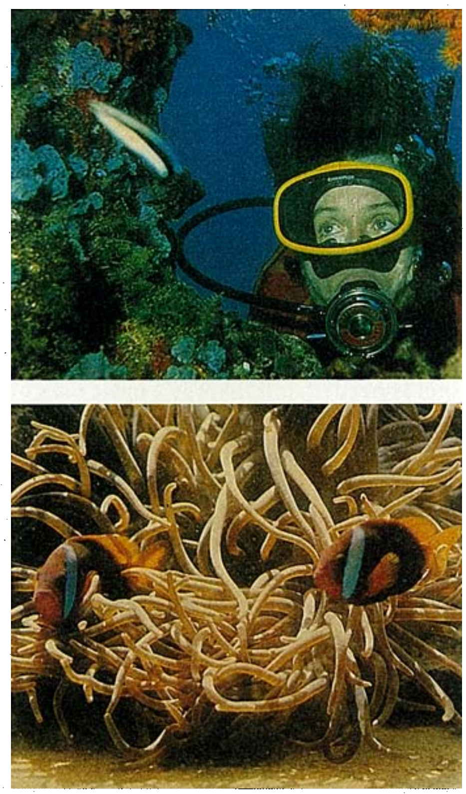
Landsat's four sensing bands



The detectors aboard Landsat look at the earth in four bands ranging from the visible to the infra-red.



Equipment used to measure and cross-check the brightness of features seen by Landsat.



Without coral there'd be no Reef.

Landsat satellite photographs can be used to identify characteristics of the Reef.

about 80 metres square. Against this must be put the large area (185 kilometres square) its cameras survey and the low cost of obtaining this imagery. An Australian Landsat receiving station has been operating since November 1979, and a library of Landsat scenes covering the Barrier Reef area is being built up at the Division of Land Use Research from this source.

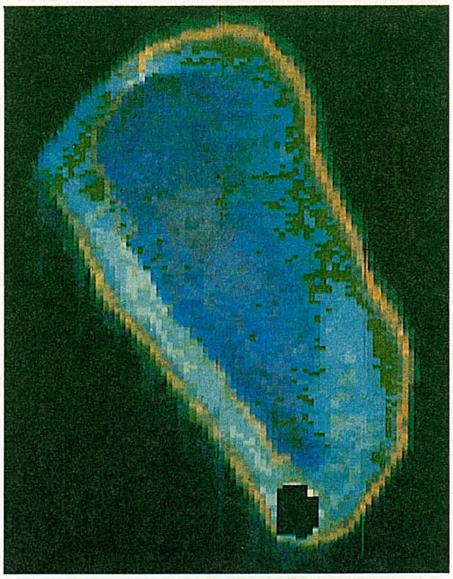
Compared with the cost of Landsat tapes, photography from specially equipped aircraft is very expensive. Nevertheless, Ms Debbie Kuchler of James Cook University is working with Dr Jupp and his team comparing Landsat scenes with aerial photographs taken at 1500, 4500, or 9000 metres. In this way it will be possible to work out what particular features show up as resolution improves. It may be that Landsat photographs as tl main source, and a smaller quantity of aircraft shots, will prove to be the best means of providing the information GBRMPA needs for management of the Reef. The researchers are trying to find the best trade-off between resolution and cost.

Extending knowledge

Vast areas of the Reef remain largely unknown. Access to them is by small boat only, and only for brief periods during the year can such craft venture forth. The monsoon season presents dangers of cyclones, and big seas and strong southeasterly winds normally affect the area during much of the remainder of the year. Remote sensing by satellite is therefore very attractive.

The hope is that computer methods can be used to transfer an experienced reef scientist's knowledge of a small area of the Reef to other unknown areas that have the same Landsat 'signature'. For example, a person with an intimate knowledge of one reef can label particular colours in an enhanced Landsat image of it as corresponding to live coral, sand, vegetation, and so on. Then, when the same colours (or signatures) show up on areas of unknown reefs, the computer can apply the same labelling.

Dr Jupp, Mr Mayo, Mrs Heggen, and Mr Kendall have been working with Mr Richard Kenchington of GBRMPA and a number of reef scientists, including Mr



Wistari Reef as seen by Landsat and enhanced by Dr Jupp's group.

Reefs the scientists know

One of the first steps Dr Jupp and his colleagues had to take was to decide which of the hundreds of reefs they should pick to study. The chosen reefs had to be fairly well known, so that, without much difficulty, any feature showing up on a Landsat analysis of it could, with a fair degree of certainty, be attributed to known existing features or recognized as an artefact of the Landsat imagery. (Artefacts can, for example, be produced by small cloud patches or even by haze.)

Also, cases where different types of land cover produced very similar Landsat signatures needed to be readily recognized. Image-enhancement techniques could then be used to make it easier to pick out the different land covers.

The scientists chose the reefs listed here, as representative of the southern, central, and northern zones of the Great Barrier Reef.

Heron Island Reef, within the southern zone, was chosen because people use it extensively, and relatively abundant scientific data have been collected at the University of Queensland's research station there. The most significant human disturbance has been the dredging of a boat channel through the reef.

The reefs studied

southern region — Capricorn–Bunker area
- Heron Island
- Wistari Reef
- One Tree Reef

central region — Townsville area
- Wheeler Reef
- Davies Reef

northern region — Cairns–Cape Melville area
- Green Island
- Arlington Reef
- Lizard Island
- Carter Reef
- Yonge Reef

Wistari Reef was chosen for comparison with Heron Island Reef, as it is relatively undamaged by man.

A research station run by the University of New South Wales operates at One Tree Reef, which the Bureau of Mineral Resources has also studied extensively, so this reef became a subject for study too.

Heron Island Reef, One Tree Reef, and Wistari Reef all lie within the proclaimed Capricornia section of the Great Barrier Reef Marine Park.

Within the central zone of the Great Barrier Reef, Wheeler Reef and Davies Reef are accessible and are being studied by scientists at the Australian Institute of Marine Science at Townsville and James Cook University.

Bordering the division between the central and northern zones is Green Island Reef. This was selected for study because use of the reef flat has given rise to environmental problems. Human influence on Green Island Reef will be compared with that on Heron Island Reef.

In the northern zone, Carter and Yonge Reefs were adopted as examples of ribbon reefs. Also, they form part of the outer barrier, in contrast with the others chosen for study, which are examples of inner platform reefs. Marine scientists know Carter Reef well, it is easily accessible, and it is serviced by the Australian Museum's research station at Lizard Island. In addition, there is a small research platform on the reef itself.

Arlington Reef was chosen because of its large area compared with the others. A large reef is easier to map by satellite than a smaller one because relatively fewer picture elements take in a mixture of different (bordering) land covers.

How the computer analyses Landsat images

Dr Jupp and Mr Mayo have devised a Barrier Reef Image Analysis System (BRIAN) to take the Landsat images and convert them to maps of reef zones. The maps show each type of land cover as a different colour. This is how it's done.

The starting point — the Landsat image — is made up from superimposed images, each in a different wavelength band (two in the visible band and two in the infra-red).

The image in each wavelength band comprises numerous picture elements or pixels (a pixel corresponds to a patch on the ground about 80 metres square). Each pixel appears as one of 64 shades of grey, according to its brightness in the particular wavelength band.

A colour Landsat image can be produced on a video screen by assigning different colours to any three of the four wavelength bands, and superimposing all three colours. The result can be made to resemble how the scene would look to our eye; but, more often, a false-colour image is produced.

In the latter case, the infra-red band, for example, may be combined with the others to give a strong purple colour to certain chosen land covers. The aim is to enhance the features of significance.

Living vegetation shows up most clearly when the infra-red band is emphasized. Algae-covered pavement areas on reef rims (which have been compacted by waves) are also picked out well with this treatment. In other words, the 'signature' for an algae-covered pavement has a strong infra-red component.

A major aim of the scientists is to identify the signature of each of the biologically significant zones on the Reef so that, using the images produced, the computer can map these zones clearly.

One prerequisite for success in this enterprise is the 'reconciliation' of Landsat images taken at different times. The computer is programmed to compare images and eliminate variations due to angle of the sun, cloud, tide height, wind, and other ephemeral influences. When this has been done, mapping can begin.

For this purpose, a person who has good knowledge of a reef looks at the Landsat scene on a video screen and labels the different areas presented to him by the computer. The computer picks out those with distinctive signatures. After comparing a number of different colour enhancements (each wavelength band is, in turn, given a strong colour), the scientists select one that seems to best pick out the area in question.

Pixels at boundaries between land types need to be processed carefully, as they contain mixed signatures. They are not a strange third land type; rather, as Dr Jupp notes, they are 'mixels', and the analysts have to decide to which type each should be assigned.

The result of carving up the image on the screen into a small number of types is a computer listing or colour map of similar, although not identical, signatures for each type.

The computer has the task of working out an average signature for each type, and the amount of variation from the average that can be encountered. It works out what overlapping can exist, and how frequently this is likely to happen in practice.

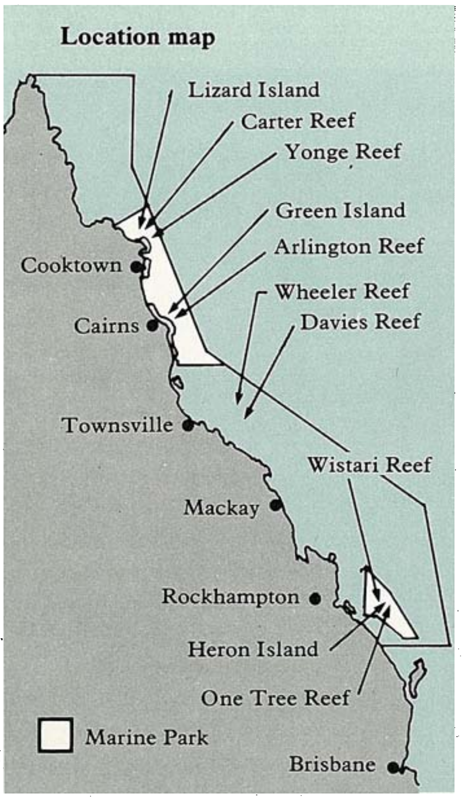
It also estimates how best to specify the boundaries between zones of different signatures — that is, the best threshold signature (where one zone's signature changes to another zone's) — so that a minimum of reef is wrongly labelled. The person familiar with an area may make fresh visits there to see what is causing overlap of signatures in particular cases.

In September 1980 and May 1981, during Landsat overpasses coinciding with low tides, members of the research group visited Heron Island Reef and carried out field measurements of atmospheric conditions and water properties using radiometers and infra-red photography of exposed and slightly submerged coral. They also made on-the-spot checks of land cover at 162 sites. This information was used to adjust the labelling signatures to achieve the sharpest differentiation possible between adjoining reef zones.

Unlike previous Landsat-image-analysis methods, the BRIAN system has the computer learning to label areas itself and even giving itself a score for accuracy.

The BRIAN method for large-area inventory and monitoring. D. L. B. Jupp, K. K. Mayo, D. Kuchler, S. J. Heggen, and S. W. Kendall. *Proceedings of the Second Australian Remote Sensing Conference, Canberra, September 1981.*

Tourism may damage the Reef.



Len Zell of GBRMPA, Ms Anne Bothwell of the University of Queensland, and Ms Vicky Harriott of the Australian Museum. The scientists are becoming increasingly confident that the computer can correctly label unknown areas of Landsat images (see the box on page 6).

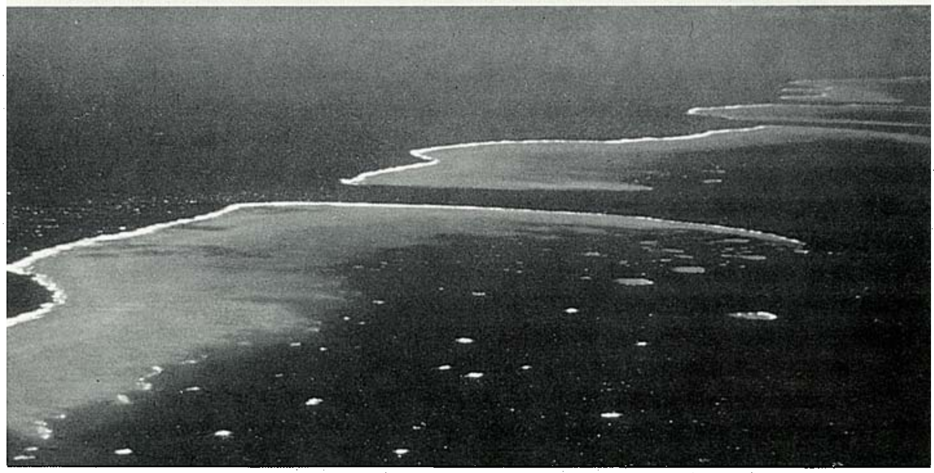
Checking it out

A cross-check has been done in which Landsat-labelled areas of Heron Island Reef were compared with the results of an expedition by boat (and occasionally on foot) to the Reef. At the moment the scientists have reason to believe the labelling is at least 93% accurate for major land-cover categories — such as cay, lagoon, reef flat, reef rim, and reef front — and 76% accurate for finer categories within these — such as areas of algae-covered coral, and shallow, medium, and deep lagoons that have various combinations of sand and coral patches.

They have found that, for Landsat to provide useful information about the finer categories, the tide must be low (less than 1·5 metres above its lowest point) and the atmosphere reasonably clear (less than three-eighths cloud cover). Under these conditions, they have found Landsat's infra-red bands very useful in discriminating areas of living coral and zones covered by algae. Sand, shingle banks, and vegetation on cays are also easily distinguished using these bands. Unfortunately, infra-red rays are rapidly absorbed by water, so low tides are a necessity.

Computer techniques can be used to reveal previously hidden detail.

Carter Reef's edge.



Carter and Yonge Reefs — northern outer-barrier reefs.

Weather patterns make the necessary combination of low tide and low cloud cover fairly rare. Also needed for clear images are gentle winds (so that the water surface is still) and the sun reasonably high in the sky. As with satellite images of land, the direct light from the sun and the scattered light from the sky contribute differently to the Landsat signal, and the effects of the two must be separated in the computer analysis.

Although Landsat passes over any one point every 18 days, in some years only two or three of the possible 20 overpasses may have the necessary low tide and good weather. Nevertheless, a couple of good images usually provide sufficient data to resolve ambiguous signals (such as may arise from an episode of turbid water).

Numerous images, when available, allow the scientists to track the movement of sediments and follow the growth, or contraction, of areas of dead or damaged coral.

The scientists intend to produce an inventory of features of the unknown parts of the Reef. They also hope to pin-point places on the Reef where changes appear to be occurring. In this way GBRMPA could be alerted to untoward happenings in the Reef ecosystem.

Andrew Bell

More about the topic

Remote sensing by Landsat as support for management of the Great Barrier Reef. D. L. Jupp, K. K. Mayo, D. Kuchler, S. J. Heggen, and S. W. Kendall. *Proceedings of the Second Australian Remote Sensing Conference, Canberra, September 1981.*

'A Coral Reef Handbook: a Guide to the Fauna, Flora, and Geology of Heron Island and Adjacent Reefs and Cays.' Ed. Patricia Mather and Isobell Bennett. (Great Barrier Reef Committee: Brisbane 1978.)