Remote Sensing and the Management of Caribbean Coral Reefs

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What can we map?

Satellite investigations of coral reef structure date back to 1975, shortly after the launch of Landsat MSS). Since then, the search for applications of satellite imagery to reef science and management has been almost exhaustive. Satellite imagery has been used for cartographic base mapping, detecting change in coastal areas, environmental sensitivity mapping, charting bathymetry, fisheries management and even stock assessment of commercial gastropods. The most widespread use of satellite imagery has been the mapping and inventory of coastal resources.

Remote sensing provides information on several parameters which are of importance to reef science and management (see Figure below). From a remote sensing point of view, the easiest of these to map are coral reef boundaries. The next level of sophistication is to distinguish principal geomorphological zones of the reef (e.g. reef flat, reef crest, spur and groove zone). For management purposes, such information may be used to provide a background for planning, but these maps may also have more sophisticated ecological uses which include the stratification of field sampling regimes. Mapping the ecological components of coral reefs (usually named "habitat mapping") appears to be considerably more difficult for remote sensing. Ecological components may be defined in various ways including assemblages of coral species, assemblages of coral and non-coral species, or assemblages of species and substrata. The choice depends on the ecological objective and physiognomy of the area. For example, coral species assemblages would be appropriate in places where coral cover was high, but perhaps less appropriate where coral cover rarely exceeded 20%. Maps of reef habitat are a useful planning tool which, among other uses, allow management boundaries to be located and the identification of representative reef habitats. Aerial photography and multispectral imagery have been used successfully to map tropical marine habitats whereas satellite-borne sensors seem to be unable to map habitats in detail.

Moving beyond mapping reef habitats to the status of individual coral colonies, it seems likely that only high resolution (low altitude) airborne methods will be successful. To date, there is limited evidence that coral cover and algal cover can be mapped routinely using remote sensing. Infrared aerial photographs have been used to detect living coral colonies in very shallow water (<< 1m) in Thailand but the dependence on shallow water deems the method unsuitable for the majority of Caribbean reefs. Recent work in French Polynesia set a precedent for distinguishing living and recently-dead coral to a depth of 7m using airborne imagery but the representativeness of these results are still being evaluated. Coral or algal species discrimination does not appear to be possible.

Future challenges in coral reef remote sensing

1) *Progress in mapping:*
   Most deleterious processes on coral reefs such as nutrification and overfishing result in reduced coral cover and increased algal cover. Detecting changes in coral and algal cover is therefore a key goal of remote sensing. Although coral and algal cover can be mapped using remote sensing where conditions are optimal (i.e. clear, shallow water), the limitations of the methods have yet to be evaluated. Radiative transfer models are required to test the overall limitations of remote sensing for measuring the health of coral reefs. This is particularly pertinent for the generation of new high-resolution satellite sensors such as IKONOS with 4 m pixels. New methods are also required to mitigate the continuing problems of variable water depth and pixels containing mixtures of substrata.

2) *Mapping the locations of reefs:*
A surprising additional challenge for the remote sensing community is the basic mapping of the World's coral reefs. Despite 30 years of reef remote sensing, many reefs have never been mapped although such maps are needed to understand the connectivity between reef systems and develop transboundary coastal management initiatives.

3) *Applications of remote sensing for biodiversity assessment:*
Remote sensing can provide an overview of the distribution and abundance of marine habitats. The use of such information for managing benthic diversity and reef fisheries has barely been explored. For example, can habitat maps be used as a surrogate for other levels of diversity? In a related vein, recent studies have used the long time series of Landsat imagery to detect general increases in macroalgal abundance resulting from the loss of *Diadema antillarum*.

Recent bibliography

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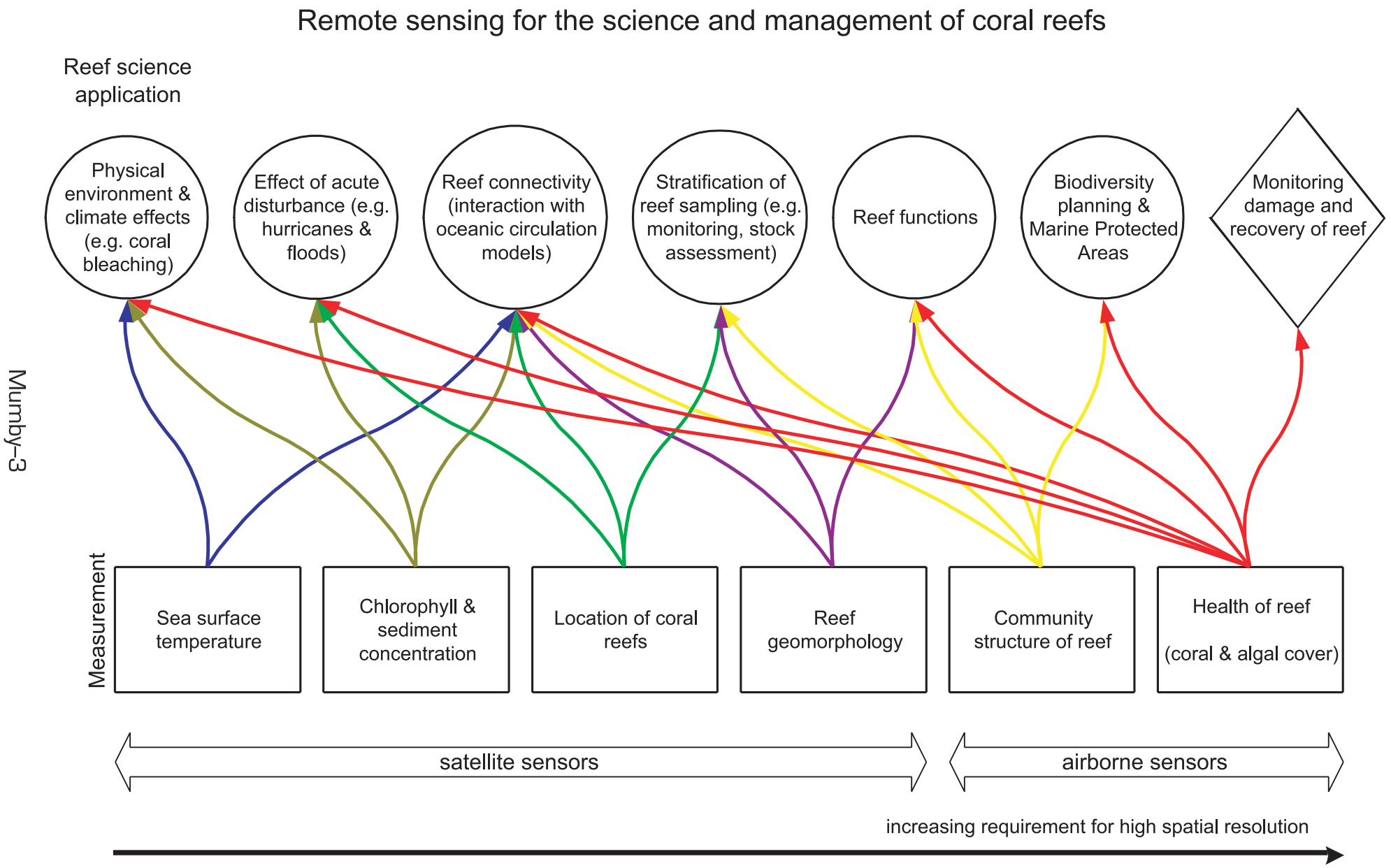
Remote sensing for the science and management of coral reefs
Reef science application
Physical environment & climate effects (e.g. coral bleaching)
Effect of acute disturbance (e.g. hurricanes & floods)
Reef connectivity (interaction with oceanic circulation models)
Stratification of reef sampling (e.g. monitoring, stock assessment)
Reef functions
Biodiversity planning & Marine Protected Areas
Monitoring damage and recovery of reef
Measurement
Sea surface temperature
Chlorophyll & sediment concentration
Location of coral reefs
Reef geomorphology
Community structure of reef
Health of reef (coral & algal cover)
satellite sensors
airborne sensors
increasing requirement for high spatial resolution
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