OceanObs'09
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Session 2C: Biogeochemistry and ecosystems

HABITATS AND CORALS

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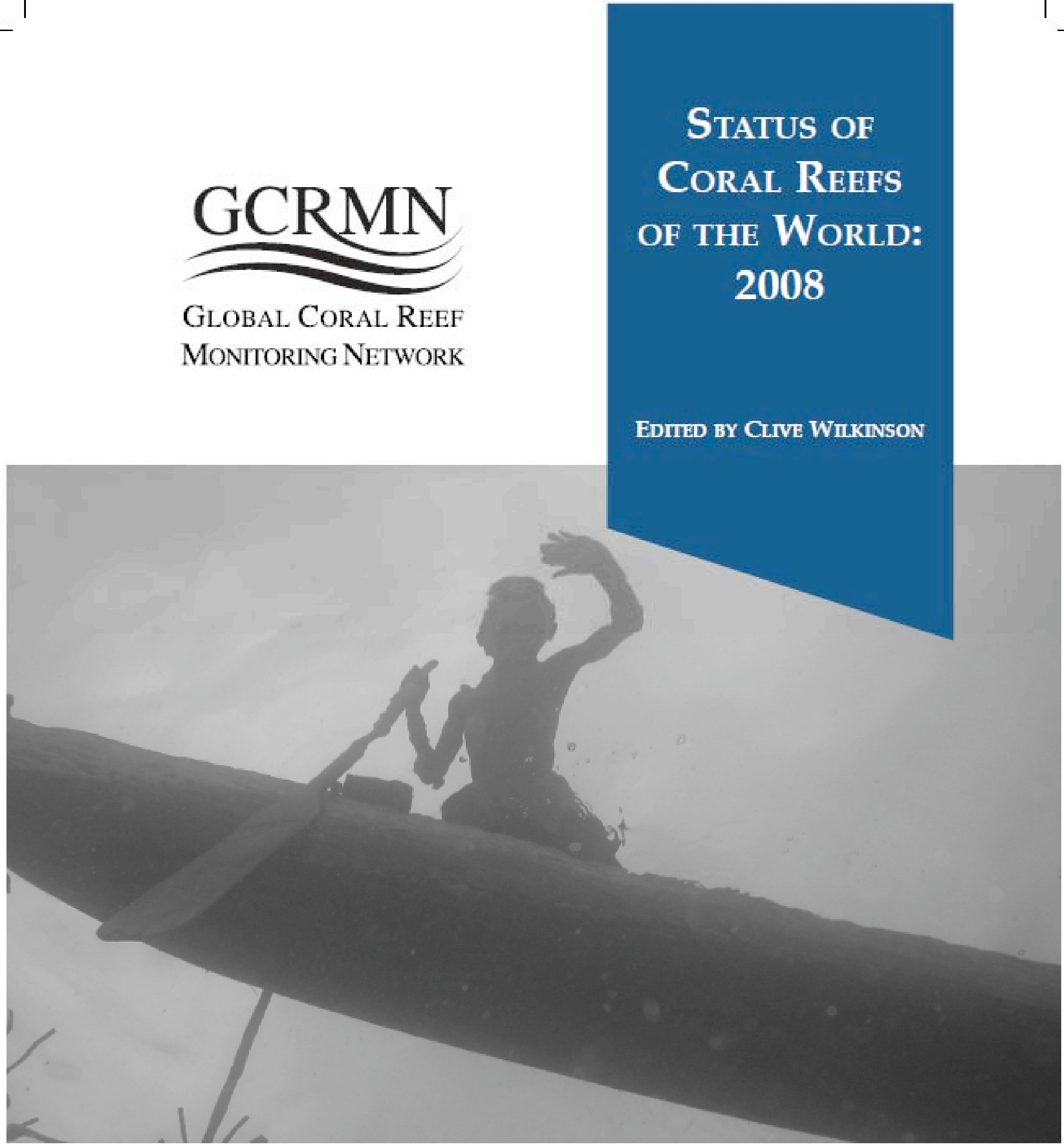
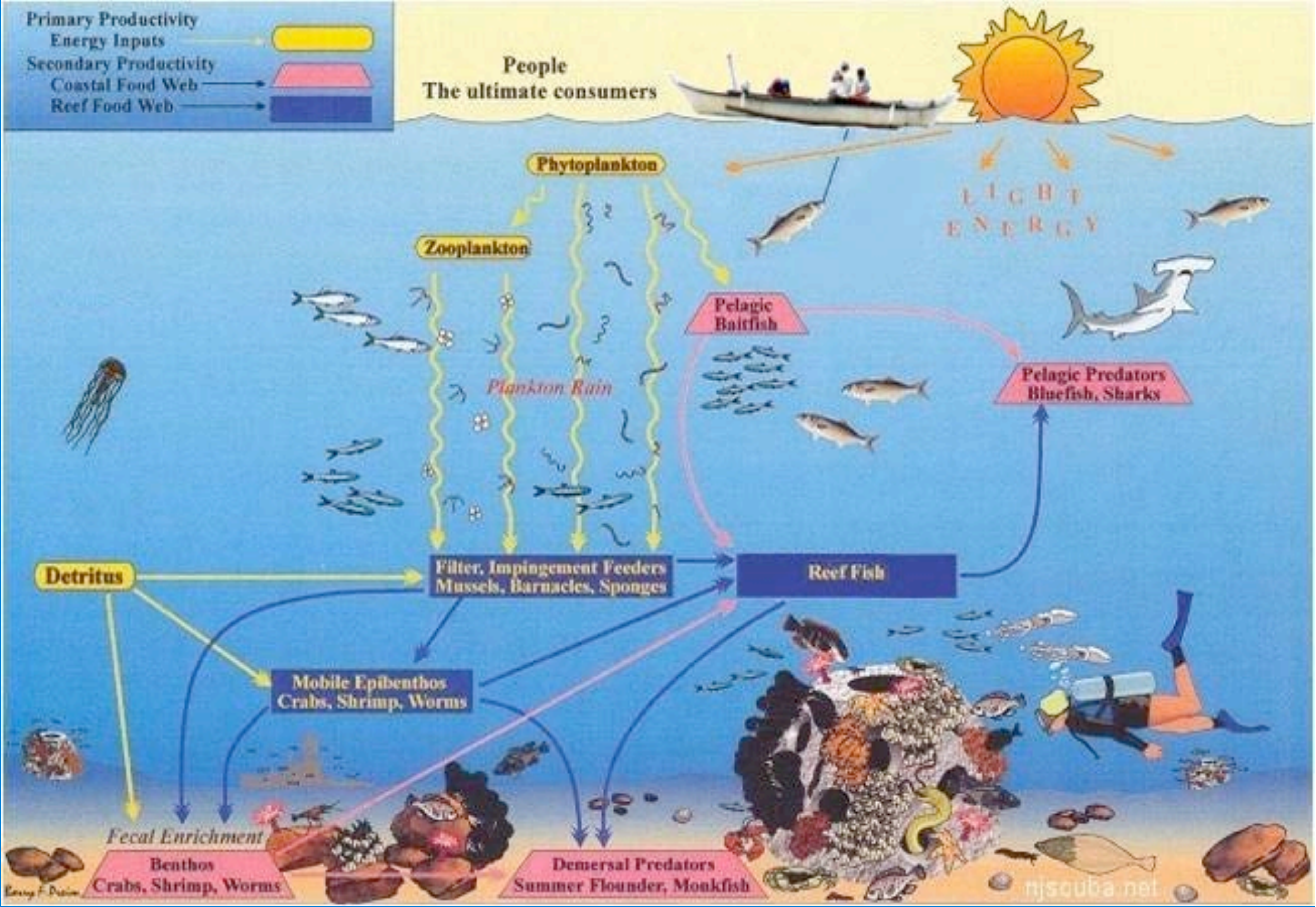


WHAT IS THE CURRENT STATUS OF KNOWLEDGE?



MODIFIED FROM http://njscuba.net/reefs/misc_ecology.html

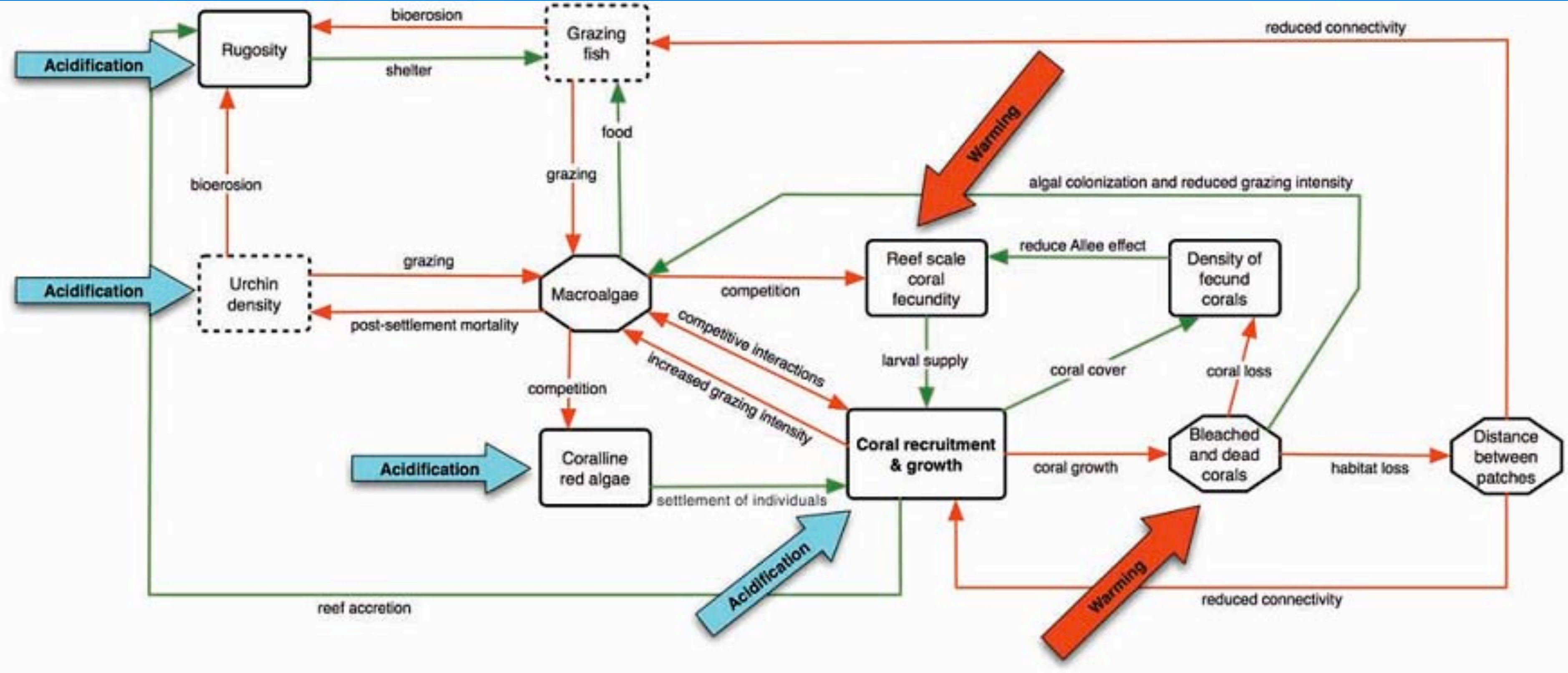
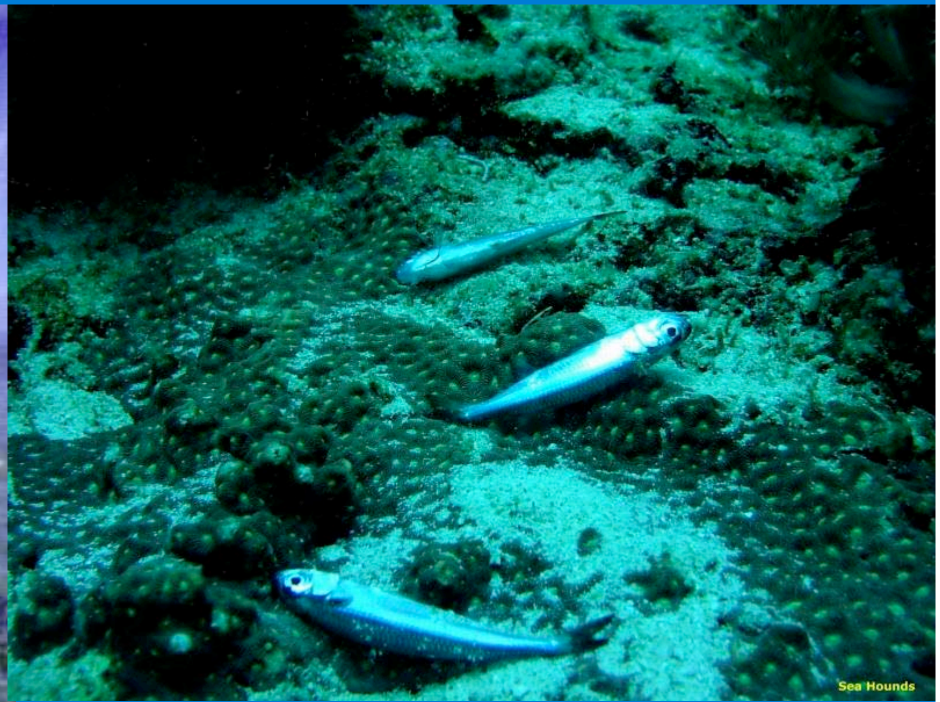


Fig. 3. Ecological feedback processes on a coral reef showing pathways of disturbance caused by climate change. Impact points associated with ocean acidification (e.g., reduced reef rugosity, coralline algae) are indicated by the blue arrows, and impact points from global warming (e.g., bleached and dead corals) by the red arrows. Boxes joined by red arrows denote that the first factor has a negative (decreasing) influence on the box indicated. Green arrows denote positive (increasing) relationships. Over time, the levels of factors in hexagonal boxes will increase, whereas those in rectangular boxes will decline. Boxes with dashed lines are amenable to local management intervention.

Hoegh-Guldberg et al. 2007

WELL-DOCUMENTED ANTHROPOGENIC IMPACTS ON CORAL REEFS

http://www.xray-mag.com/files/DynamiteFishing.jpg



http://image22.webshots.com/23/5/35/34/221453534qdYXul_ph.jpg

Blast fishing

Sedimentation

http://www.aims.gov.au/ibm/pages/news/images-200211/3-ngerikiil-230.jpg

Pollution

Guimaras oil spill

http://www.dmcii.com/news_images/oil372.jpg

http://www.oceanwideimages.com/images/11013/large/24M1910-01-marine-pollution.jpg

Coral diseases

Common coral diseases in the Caribbean. (A) *Diploria strigosa* with black band disease, (B) *Dichocoenia stokesi* with white plague, (C) *Acropora cervicornis* with white band and (D) *Montastrea faveolata* with yellow blotch syndrome – Photos E. Weil

http://ccma.nos.noaa.gov/products/biogeography/cres/OnePagers/coral_disease.html

THEME: ECOSYSTEM APPROACHES TO MANAGEMENT

Developing a global monitoring system for coral reefs requires understanding the fundamental nature of ecosystems

STRUCTURE

Influenced by topographic complexity

Species diversity

Abundance (density), size frequency, distribution

(focus is on major groups, usually chosen on the basis of their function as "indicators"

e.g., hard corals; selected invertebrates such as crown-of-thorns starfish, black-spined sea-urchin *Diadema;* algae such as *Halimeda;* fish such as chaetodontids)

Nature of ecosystems (continued)

FUNCTION

Physiological processes

(photosynthesis; growth; mortality; reproduction)

Biogeochemical cycles

(nutrients)

SIGNIFICANT NEW THREATS

Global warming, ocean acidification, changes in storm patterns

(in addition to well-documented direct human impacts)

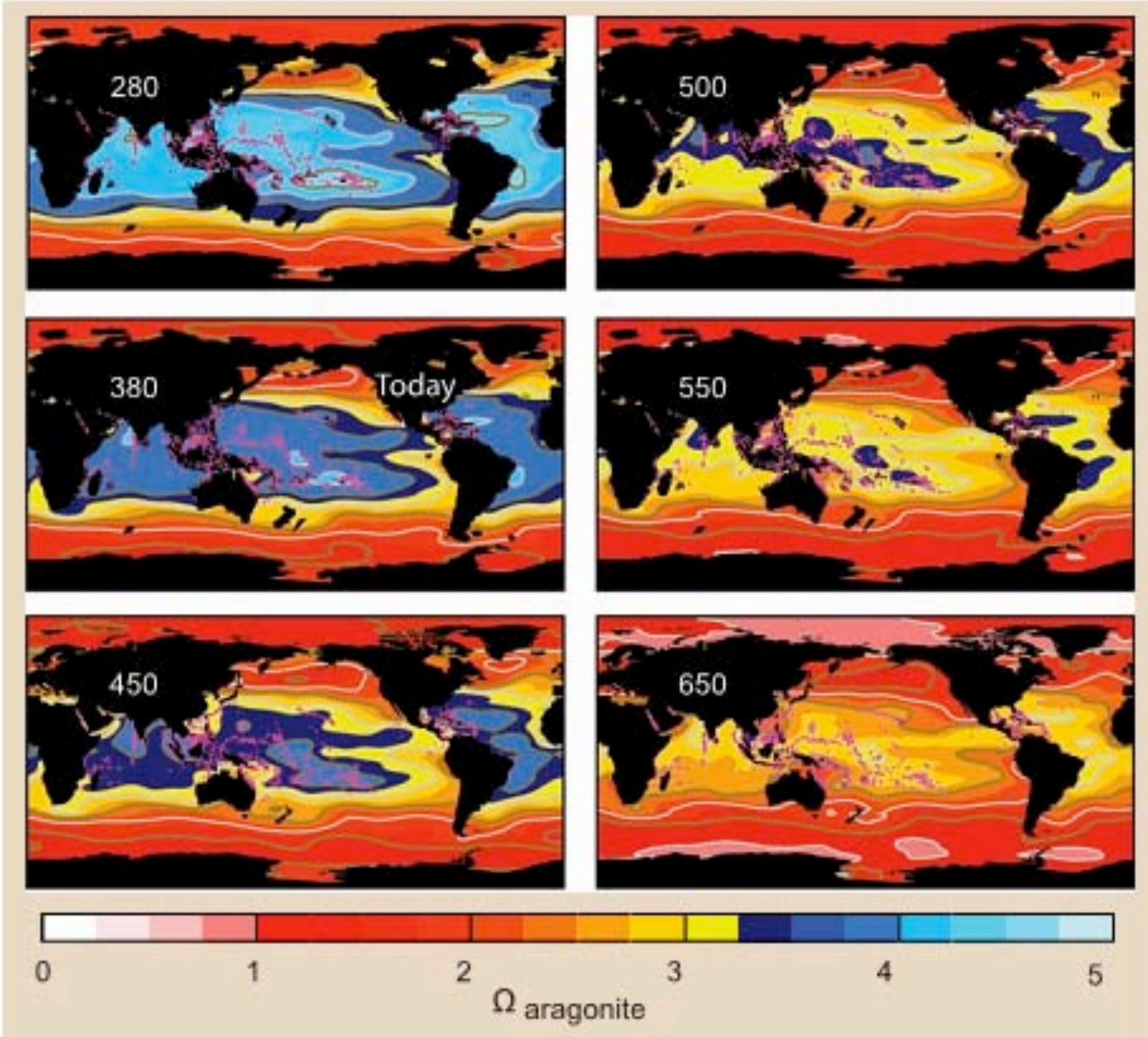


Fig. 4. Changes in aragonite saturation $(\Omega_{aragonite} = ([Ca^{2+}][CO_3^{2-}])/K_{sp\ aragonite})$ predicted to occur as atmospheric CO_2 concentrations (ppm) increase (number at top left of each panel) plotted over shallow-water coral reef locations shown as pink dots (for details of calculations, see the SOM). Before the Industrial Revolution (280 ppm), nearly all shallow-water coral reefs had $\Omega_{aragonite} > 3.25$ (blue regions in the figure), which is the minimum $\Omega_{aragonite}$ that coral reefs are associated with today; the number of existing coral reefs with this minimum aragonite saturation decreases rapidly as $[CO_2]_{atm}$ increases. Noticeably, some regions (such as the Great Barrier Reef) attain low and risky levels of $\Omega_{aragonite}$ much more rapidly than others (e.g., Central Pacific).

Hoegh-Guldberg et al. 2007

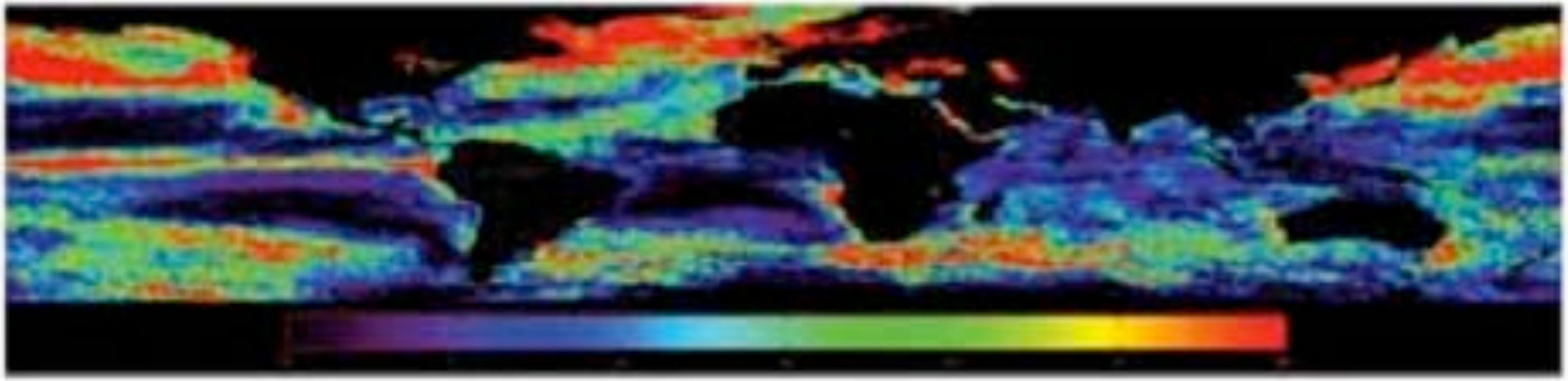


Figure 12: Global map of number of years with DHW greater than 4 from weekly 4km gap-filled AVHRR Pathfinder satellite data, over the period 1985-2005.

Hoegh-Guldberg et al. 2009

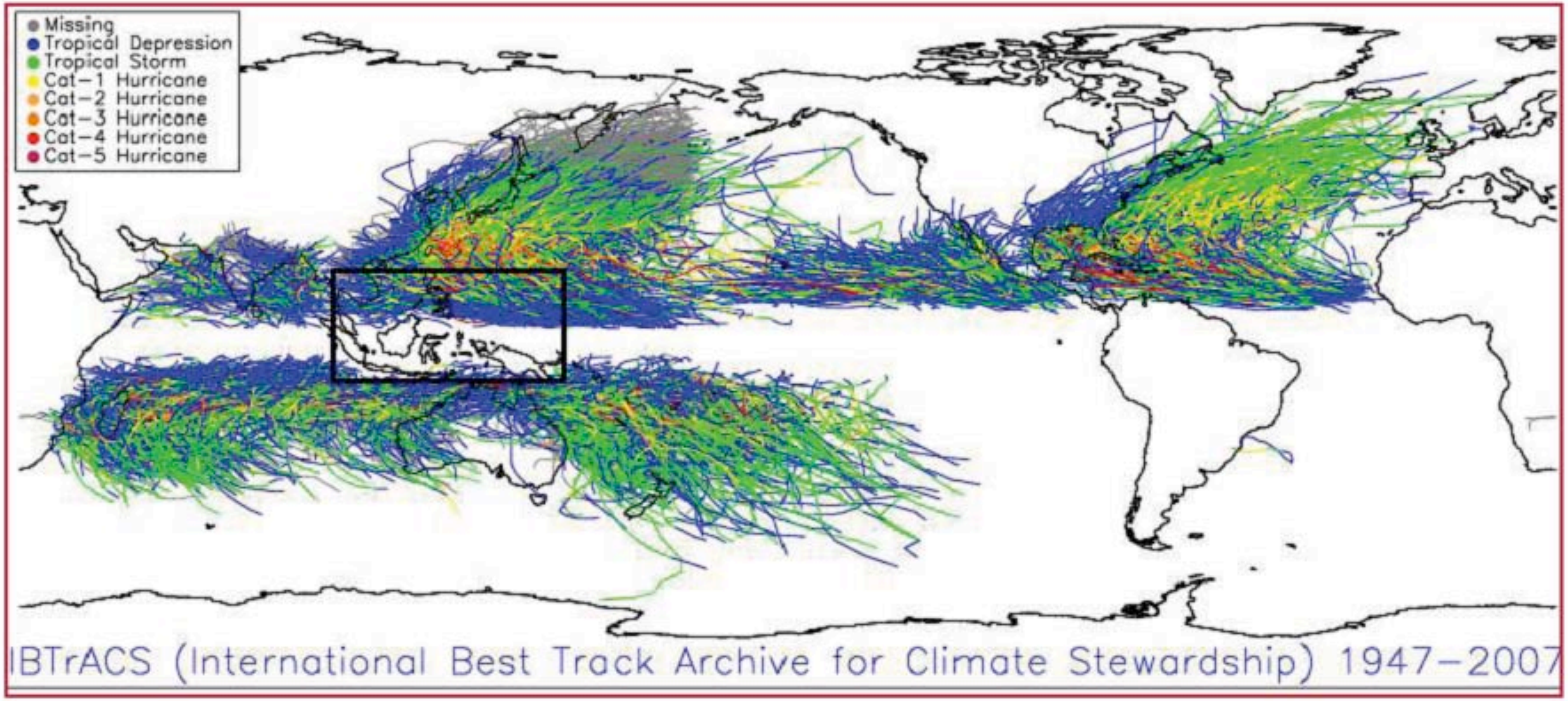


Figure 6: Map of all tropical storm and tropical cyclones tracks, 1947-2007

Hoegh-Guldberg et al. 2009

An International Network of Coral Reef Ecosystem Observing Systems (I-CREOS)

- Visual surveys
- Moored instrument arrays
- Spatial hydrographic and water quality surveys
- Satellite remote sensing
- Hydrodynamic and ecosystem modelling

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***NOAA* CREIOS**

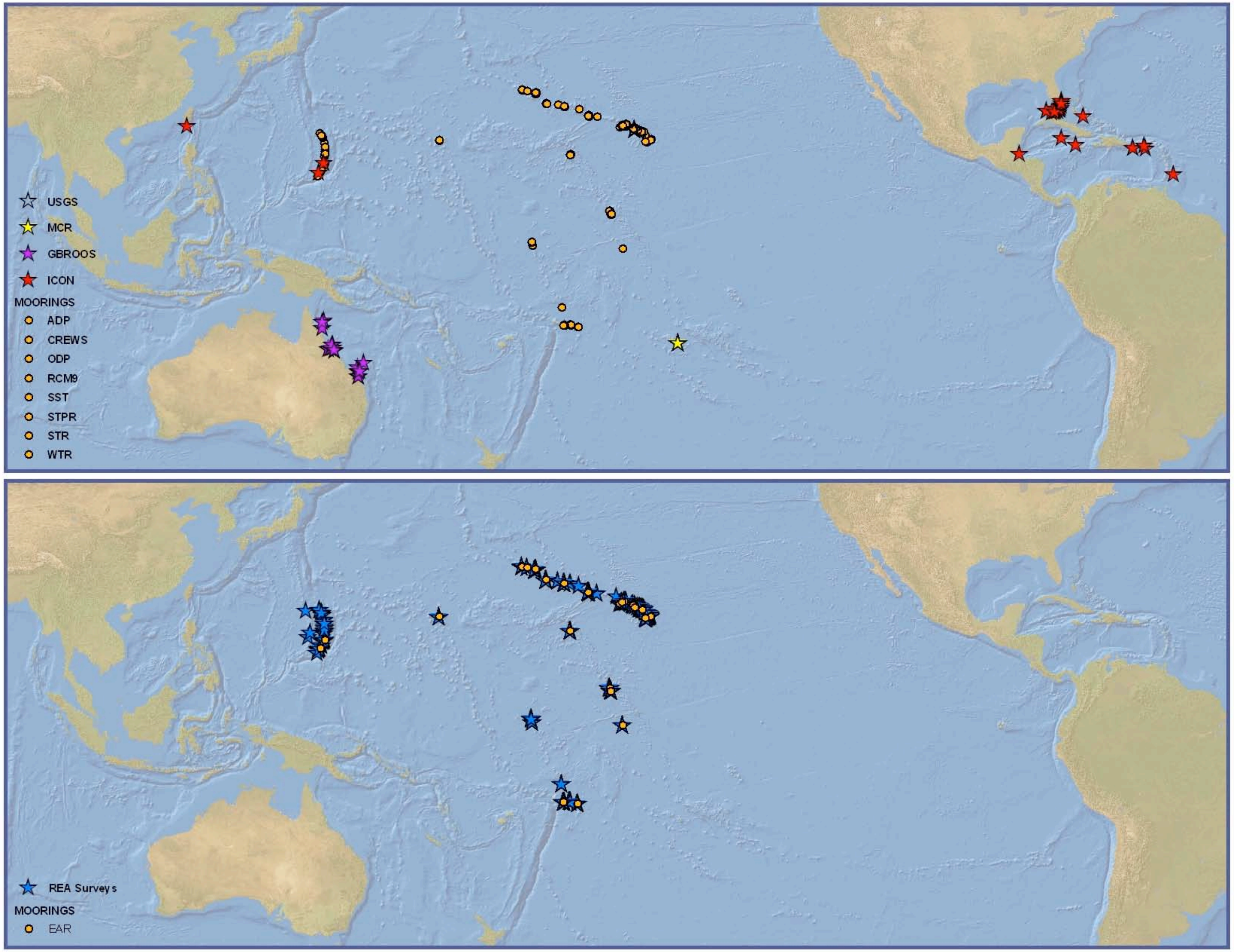
***Great Barrier Reef* Ocean Observing System (GBROOS)**

***Moorea* Coral Reef (MCR) Long-Term Ecological Research (LTER)**

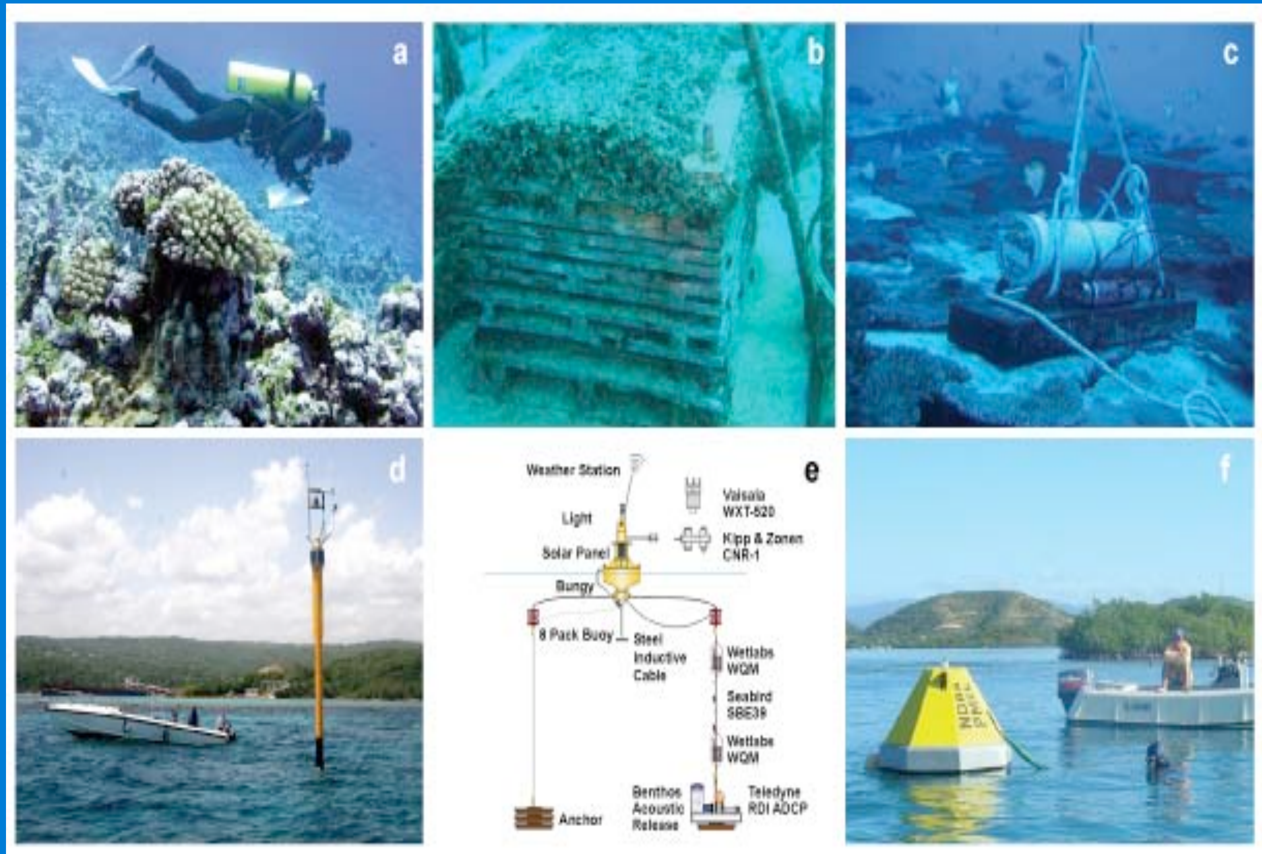
***French Polynesia* CRIOBE**

Coral Reef Environmental Observatory Network (CREON)

Indian Ocean



A) Locations of moored instrumentation from USGS, Moorea LTER MCR, GBROOS, ICON, and NOAA CREIOS moorings. B) Locations of biological monitoring in the Pacific Islands (needs to be expanded to include other biological monitoring sites and biological instrumentation (e.g. ARMS, etc.).



Examples of key biological (a-c) and physical (d-f) observing system components of I-CREOS. a). Visual surveys of reef fish, corals, invertebrates, and algae (Photo NOAA-CRED); b) Autonomous Reef Monitoring Structure (ARMS) at a forereef site in Hawaii (Photo NOAA-CRED); c). Ecological Acoustic Recorder (EAR) deployed at French Frigate Shoals, Northwestern Hawaiian Islands (Photo NOAA-CRED); d). ICON/CREWS station at Media Luna Reef, Puerto Rico (Photo J. Hendee); e). GBROOS Shelf mooring design; and f). MAP-CO2 Buoy near Cayo Enrique Reef, La Parguera, Puerto Rico (Photo J. Hendee).

ECOSYSTEM STRUCTURE

Visual surveys (standard, “old reliable” method)

-- on-site, by humans

New: genetic pyrosequencing techniques

ECOSYSTEM FUNCTION

Standard parameters:

- SST, Salinity → Physiological processes, growth
- PAR, UV-B → Photosynthesis
- Turbidity, Ocean color → Biomass (chlorophyll-*a*)
- Sediments, Nutrients → Primary production

ECOSYSTEM FUNCTION (continued)

New: Pulse-amplitude-modulating (PAM) fluorometry

Standard oceanographic parameters:

- Air temperature, barometric pressure, wind velocity
- Currents, waves, tides
- Bottom topography (depth)
- Coastal inundation, erosion

New: Sound

To elucidate DOMINANT PHYSICAL FORCING MECHANISMS AND LIKELY WATER MASS SOURCES; LARVAL TRANSPORT

ECOSYSTEM FUNCTION (continued)

Recent interests:

Aspects of ocean carbonate chemistry

(surface aragonite saturation state Ω_{arg})

Parameters: $pCO_{2\ sw}$, total alkalinity, carbonate and bicarbonate ion concentrations

For all of the above, need to measure on a range of SPATIAL and TEMPORAL SCALES

RECENT SCIENTIFIC ADVANCES

Remote sensing

Benthic structure in shallow-water ecosystems being resolved at finer scales,

e.g., differentiate between vegetation and hard cover; between live and dead coral cover

Implications:

SPECIES DIVERSITY: it is possible to associate species diversity with topographic complexity of the bottom substratum, or with the proportion of live to dead corals;

Low habitat complexity is associated with fewer species;

A dominant cover by one species has fewer associated species.

Coral reef classification of remotely sensed data

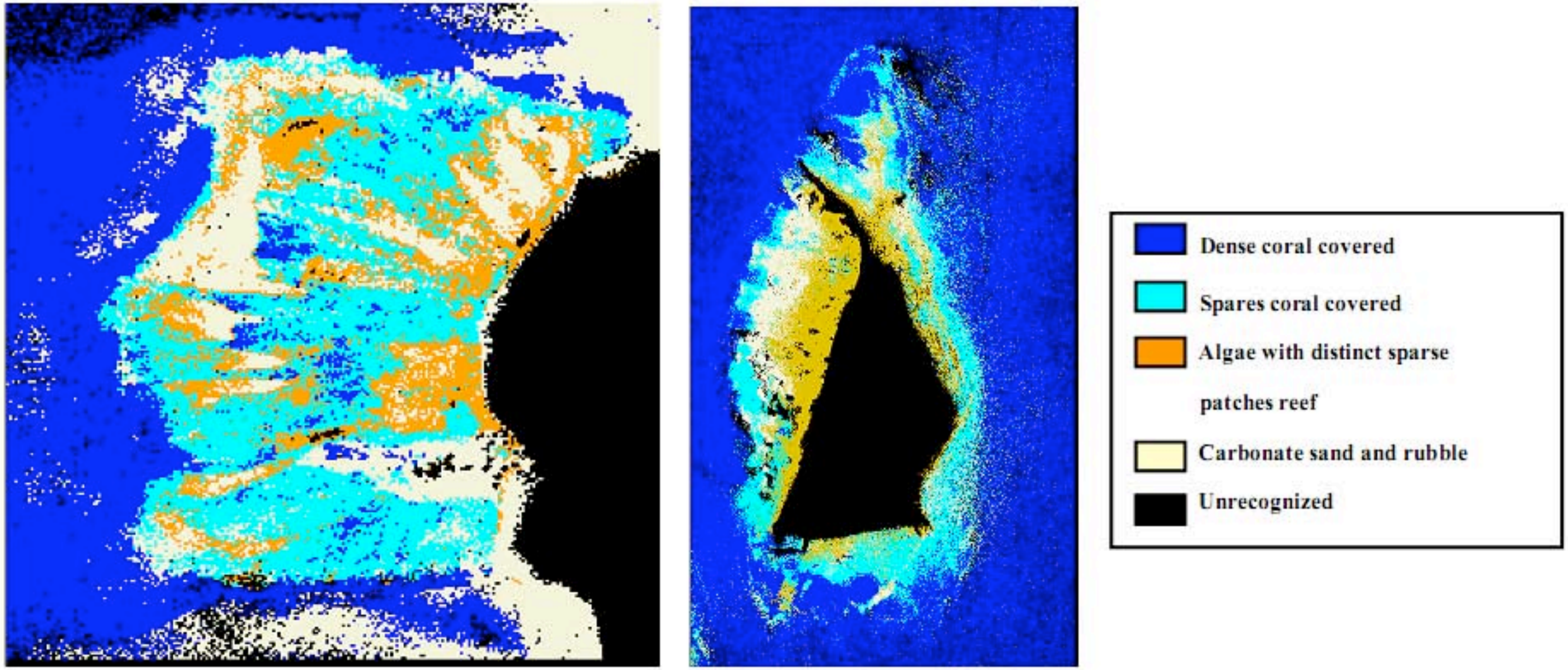


Figure 3 Thematic Images generated using the Maximum Likelihood decision rule for: a) Phuket and b) Kradat.

Wongprayoon et al. 2006

Examples:

Mass coral mortality after bleaching caused by elevated sea water temperatures

-- was followed by a take-over by algae in terms of dominance of benthic cover; this was associated with a shift in composition of associated fish species plus a decline in their diversity

Increase in proportion of dead over live coral

-- associated with a decrease in diversity of associated species (especially fish and invertebrates)

Parameters with physiological effects

TEMPERATURE

pH (ACIDIFICATION, ALKALINITY)

Coral bleaching at Inner Talim Point, Batangas, Philippines, July 2007
Photo: Mark Vergara, University of the Philippines

GAPS IN KNOWLEDGE

Differences in responses of different species to acidification

e.g., surprising finding: calcification *increases* in some species under conditions of lowered pH, but this has implications for growth and reproduction

Synergistic effects between pH and temperature

-- cause different responses in different biotic groups

Much more research needed on other species besides corals, e.g., the algae, other invertebrates, vertebrates (fish, whales…)

Effects on critical components of food webs

-- Changes in competition regimes

-- Alterations in trophic pathways, with implications for abundance of harvested organisms

http://coralreef.noaa.gov/images/iyor_foodweb.jpg

OUTSTANDING QUESTIONS

How are the various regional programmes funded?

Is this funding sustained?

Counterparts from: GOVERNMENT
PRIVATE SECTOR

e.g., partnership with oil-gas industry?

Need more examples of:

Specific scientific outputs of various programmes (publications)

Their direct input into decision-making (management, policy)

(Have they made significant impact?)

OUTSTANDING NEEDS

Automated, "smart" observation systems*

-- producing data streams with direct user interface

LOW MAINTENANCE

REASONABLE COST

"Versatility, accessibility, robustness"

Standardized sampling regimes

*Link with instrument manufacturers

Some notes on the **PANEL FOR INTEGRATED COASTAL OBSERVATIONS (PICO)** (***Malone et al.*, this symposium**)

- Managing and mitigating the impacts of coastal inundation on marine ecosystems and coastal communities (natural hazards, ecosystem health and living marine resources benefit areas);
- Preventing human exposure to waterborne pathogens (public health benefit area);
- Monitoring ocean acidification and its effects (ecosystem health benefit area);
- Monitoring habitat modification and loss (natural hazards, ecosystem health and living marine resources benefit areas);
- Forecasting coastal eutrophication and hypoxic events (ecosystem health and living marine resources benefit areas); and
- Predicting changes in the abundance of exploitable living marine resources (ecosystem health and living marine resources benefit areas).

SUMMARY POINTS

- Existing store of knowledge about coral reef structure and function, and effects of natural and human perturbations over historic time

- Recently understood perturbations include ocean warming, ocean acidification and changes in storm patterns

- The effects of these on ecosystem structure and function are not clear, and are probably complex

  Possible significant impacts on food webs, affecting human harvest of resources

- Over time, developed nations have improved the techniques of global monitoring of various oceanic and reef parameters

- The biggest challenge is how to engage the broader community of nations, particularly in the developing world (issues of AFFORDABILITY and COMMITMENT)