

## Cross-Node Ecological Synthesis: First Light From an Ecological Observatory

Les Kaufman  
Principal Investigator  
Marine Management Area Science Program  
Conservation International

A core goal of the MMAS Program was to launch a networked global observatory for human-natural coupled system dynamics in the tropical nearshore, over a period of five years. The MMAS network of nodes can be thought of as an observational instrument whose task is to reveal processes underlying the generation and use of marine ecosystem services. At the end of five years, the business end of the instrument is complete, with data streams primed from four widely distributed study nodes, and two reference areas:

<b>Location</b>	<b>Region Represented</b>	<b>CI Seascape</b>
<b>NODES</b>		
Belize	NW tropical Atlantic	W. Caribbean (embryonic)
Brazil	SW tropical Atlantic	Abrolhos (new)
Panama	tropical eastern Pacific	ETPS (established)
Fiji	central Pacific	Pacific Oceanscape
<b>REFERENCE AREAS</b>		
PIPA	central Pacific	Pacific Oceanscape
Galapagos	tropical eastern Pacific	ETPS

The purpose of the reference areas was (1) to provide a baseline for a nearshore system minimally affected by local human population impacts (PIPA), and (2) to indicate how interactions between global climate change and local human impacts might be manifested under different management scenarios (Galapagos).

The goal after five years was to achieve proof-of-concept for the network of nodes, by demonstrating that each could produce an ecological data stream, and that examination of these simultaneous streams could yield emergent insights for marine conservation in addition to achieving the local objective of providing science support to adaptive management. Ideally, in the next step, the global nearshore observatory would encompass standardized observations of social, cultural and economic parameters tied to marine management. Studies in these disciplines carried out as part of MMAS at these same locations provide the basis for modifying the observatory so that it is fully capable of monitoring the entire picture of human activities embedded in their ecosystem context.

Networked observatories are an effective means of studying complex systems distributed in a spatial and temporal hierarchy. This approach is used to great effect in astronomy, meteorology, and geology, but its application as a central tool in ecology is still at an early stage. NEON (national ecological observatory network), the first formal attempt to construct a facility of this sort in the US, has recently gotten off the ground.

As the observatories in an astronomical network are brought on line, each is said to have experienced “first light”, with first light for the array produced when all components are operating and the first interference, or composite picture has been produced. For MMAS, system first light consists of integrated analysis of the ecological data stream from all four nodes and two reference areas.

A workshop was held in Boston recently at the Pardee Center for the Study of the Longer Term Future. The meeting brought together the lead ecologists from each of the six MMAS study areas (4 nodes plus 2 reference areas), to work on making their ecological monitoring data comparable in terms of target variables, format, and analytical framework. The work of that meeting is not yet complete, but we do have the recent data from all study areas now in a form that permits initial comparisons. From this exercise we have some idea how ecosystem behavior in response to management varies in the different areas, as well as how to make the network work better in the future. Here we summarize a few of the findings that have emerged from work within and across the nodes.

### 1) Methodologies

Although all the nodes share a set of basic parameters that are being measured, local adaptation was necessary to generate data in the slightly disparate environments of the different nodes. Coral reef morphometry can vary considerably among the eastern and western Pacific, and the north and south Atlantic, making it unwise to try and apply the same linear transect methods to all four. In Abrolhos, Brazil, the reef is largely composed of mushroom-shaped structures called chapeiroes. Special methods were developed to wrap transects around the chapeiroes and also to separately sample the flattened tops; the data from these methods so far appear comparable to what’s obtained from more traditional linear transects. The Brazilian team also developed a new nested cylinder visual census method for quantifying fish species and biomass and it compared it to conventional strip transects. The new method works well in the topographically complex habitats of the Abrolhos reefs but also compares well in terms of data quality to strip transects, and probably produces data from Brazil that is more comparable to other localities than would be the case if the strip transect method were forced upon Brazil’s often inappropriate habitat.

In Fiji, reef morphometry varied so much between island shelf-edge and platform or inner shelf reefs that this introduced a significant confound, while in Belize, cross-shelf variation was a major concern. Stratification of study areas across the full range of habitats, with comparisons among management regimes nested within site, is able to address this problem to some extent.

In Belize, we developed and tested a new method for estimating commercial fish biomass at low levels, where floor effects compromise data quality (and unfortunately where much of the world is today). Non-commercial fish biomass provides a good proxy for commercial fish biomass, a relationship that was also tested for and revealed in Fiji.

## 2) Diagnostics

Several new diagnostics were developed for MMAS ecological monitoring that are transportable to other sites. These include the Coral Resilience Assay, the use of induced visible-light fluorescence to facilitate quantification of young coral colonies, and CHI, the Coral Health Index. CHI is based on MMAS-funded studies of some of the world's most pristine reefs, located in Kiribati. Here, the Northern Line Islands offered a gradient from low to high local human impact, the Southern Line Islands remained a relatively pristine baseline for comparison, and the Phoenix Islands afforded us a look at resilience following catastrophic bleaching (due to global climate flux) in an otherwise robust system. We drew from field data in these three island groups to create a universally applicable index of coral reef health and resilience based upon three simple types of measurements: benthic, fish, and microbial. CRA and CHI are already being used in the field; reliable fluorescence methods for counting coral spat are still being developed.

We also began work on a field-ready assay to fill in the required microbial data for the CHI index. The assay is based upon total *Vibrio* titres in seawater. This is an important assay to hammer out the details on, but it is going to take more work.

## 3) Early Results

- A. Well-enforced no-take areas quickly accumulate higher fish biomass than exploited areas, no matter where you are in the world. This is well-supported by examples from all six areas. However, the benefits are ephemeral if fishing resumes or enforcement flags. Since enforcement inevitably waxes and wanes, the ecology under different management regimes is a reflection of an enforcement and environmental time-series, including a variety of accidental and contingency effects. This complexity is compounded by the usually very small size of each regime (such as a no-take or controlled extraction area).
- B. MMAs are at the mercy not only of both global climate and local human impacts. Surprising to us was the magnitude of the downstream effects of deforestation in the Nadi Basin, Fiji, where severe flooding generated turbid plumes that bathed the offshore Mamanuca Islands, including the Malolo study site. Similar situations were observed in Belize and Brazil, where the human waste stream was concentrated and high incidences of coral disease were observed.
- C. Whether herbivorous fishes are positively or negatively correlated to fleshy algal biomass can be used as an indicator of ecosystem state and resilience. The inspiration for this came from the observation that the classical expectation of a negative correlation between herbivore and fleshy algal biomass is often flipped when algal biomass rises in the wake of a major disturbance, such as a hurricane, bleaching event, or outbreak of coral or even herbivore disease.
- D. While a rapid rise in fish biomass may be observed following the implementation

of a no-take area, conclusions should not be drawn until several years of data are in hand. The initial rise can trigger elevated poaching and crowding of fishers to the edges of no-take areas, with undesirable knock-on effects.

- E. If the regulation of fisheries extraction has an indirect effect on the health of corals and other benthic organisms, it was not apparent during the brief duration of this study. Here as well, a long-term period of observation is required because the process itself takes decades to unfold. In terms of information useful for decision makers in the short term, we can only observe initial stages of a stochastic process, and there is high uncertainty unless the management horizon is extended into a period of decades, as for forest conservation and forestry.
- F. In the crucial task of sorting out the effects of local versus global impacts, replication is a serious obstacle. As we know from the literature, some of the most important questions about MMA function could, in the past, be answered only through a metaanalysis of a great many initially unrelated studies. Our results so far, while preliminary, do indicate that a systematic approach to this problem through the establishment of comparable MMA experiments around the world is of value. It can greatly improve our efficiency and confidence in determining whether politically challenging policy initiatives will in fact yield the desired benefits provided that sufficient time and effort are allotted. Certainly, it is apparent that viewing MMA effects at multiple spatial scales, and over decadal time scales, are prerequisites for the casting and testing of theory about the workings of human-natural coupled systems.

The tropical nearshore is the most important human-natural coupled system in the world: it encompasses most of humanity, hosts the highest biological diversity in the known universe, and a large fraction of these people who live here face daily challenges of hunger, poverty, and disease. The results of MMAS indicate that local action can make a big enough difference to bring significant benefits despite the looming immensity of climate impacts. Our results also suggest tantalizingly- though this is not yet certain- that local action can also weaken the punches of climate change. This effect may be large enough to allow nearshore tropical ecosystems like coral reefs, mangrove forests and seagrass meadows, to adapt, to survive, and to restore themselves, with perhaps a little help from some friends.