Towards a scientific mediation of man induced environmental impacts, from novel approaches to legal action

The example of tropical coral reefs

“Ocean changes and its ecological impacts”
PART ONE: OBSERVING

Where?  Who?  How?
PRACTICAL DEFINITIONS

BIOSPHERE
is the set of all life forms and of their metabolic products within the spatial confines necessary for their sustenance, development and evolution.

ECOSYSTEM
is a distinct community of living organisms (eukaryotes and prokaryotes) in dynamic interaction between them and with the geochemical environment they are sharing.

BIODIVERSITY
is the variation of life forms expressed in a given locality. Hotspots localities combine high levels of endemism and diversity/area.
THE BIOSPHERE: land/air/sea interfaces with the right life-supporting chemistry

**ATMOSPHERE**
- Oxygenated
- Very thin (8 kms max.)
- Constantly changing
- Movements of air masses
- Evaporation-precipitation

**HYDROSPHERE**
- Very large surface/volume ratio
- Fast surface movements
- Currents and flows
- Seasonal freezing/thawing at poles

**LITHOSPHERE**
- Interface between oxidized atmosphere and reduced transition zone
- Tectonic movements
- Chemical transformation
PART TWO

CORAL REEFS

IN A CHANGING WORLD
**HUMAN IMPACTS IN A GLOBALIZED ECONOMY**

Carbon volatilized in the atmosphere (indirect)
- Warming, acidification

Selective overexploitation of live resources
- Destruction of natural cycles

Urbanization
- Landscape remodelling, habitat destruction
- Misuse of « common goods » (sand, freshwater...)

Creation of new genomes and of artificial molecules
- Chemical pollution
- and displacement of wildtypes

Nitrogen enrichment (direct)
- Pollutions and necrotic diseases, local, reversible

Global commerce
- Introduction of alien species
- Widening gap between deciders/consumers and between producers/recyclers
20% of all coral reefs are definitely destroyed, 25% are at risk and 25% are « evolving ». The remaining 30% might not survive in year 2100.

The ecological crisis on coral reefs is unprecedented since man appeared (anthropocene).

Biogeochemical imbalance and direct human forcings are held responsible for the observed acceleration of impacts.

In 2014, biodiversity census, delineation of protected areas and educational programs exist, but no-one is acting at the source of the problem.
Changing societal attitudes requires coordinated actions between developers, end users of natural resources, and politicians – with scientists and eco-engineers having a central role as consultants.

Using experimental data, the researcher creates new tool to measure and even to predict the health status of biota under evaluation, by combining different approaches.

Calibrated responses obtained using these approaches lead to a precise diagnosis, and to recommendations to deciders, much like DNA tests are used in forensic science.

We must hurry up.
PART THREE

NEW TOOLS,
NEW APPROACHES
The 3-scale dimension applied to coral reefs

**GLOBAL SCALE:** ENVIRONMENTAL SATELLITES

Cooperation at international level

**ECOSYSTEM SCALE: MACRO et MESOCOSMS**

Statewide and Regional level

**MICROCOSM LEVEL: AQUARIA AND BENCHTOP SCIENCE**

Laboratory scale

La Barre, 2011
Choose your holobiont

- CORALLINE ALGAE: CEMENTATION
- SPONGES: BIOACCUMULATION
- CORALS: PHOTOSYSTEMS

- Useful concept to study the dynamics of stress,
- Allows assessing loss of functions of host, and biodiversity loss of macro and micro associates
- Can be studied in aquarium or in meso or microcosms
- The sentinel species can be used as a proxy for its environment
Healthy holobiont: the coral model

1. Autotrophic regime

2. Functions optimally

3. Active interactions

Microbiome is diversified

Rich chemosphere and fluid mucus

Zooxanthellae pigmentations

Host 1/10

5000x

100x
Evolving holobiont: the coral model

1 – HETEROTROPHIC REGIME

2 – EMERGING DISEASES

3 – BIODIVERSITY LOSS

MICROBIOME POOR
PATHOGENS

TOXIC CHEMOSPHERE AND THICK MUCUS

WHITENING

DEATH

EXPULSION
GENE NORMAL TRANSCRIPTOME
NORMAL PROTEOME
NORMAL METABOLOME

Oligotrophic regime, connectivity
Resilience and adaptive capacity

Under anthropic forcings
Under geoclimatic evolution

-OMICS

GENE STRESS TRANSCRIPTOME DIFFERENCIATED EXPRESSION ALTERED PROFILE
CLIMATIC AND BIOTIC STRESSES CAUSE BIODIVERSITY LOSS IN CORALS

GLOBAL METABOLOME

NORMAL METABOLOME

GRADIENT OF STRESS

EXPRESSION

CRITICAL POINTS

STRESS METABOLOME

TEMPERATURE

HEAVY METALS

UV RADIATIONS

OSMOTIC STRESS

ORGANIC POLLUTANTS, ALLELOTOXINS

REGULATION BY ENZYMES

STRESS PROTEINS

SPECTRAL PROFILES

STRESS CHEMOMARKERS
TOTAL TRANSCRIPTOME, PROCARYOTIC & EUKARYOT

Bacterial DNA → mRNA → Protein

Genomic DNA → pre-mRNA → Poly(A)mRNA → maturation → mRNA → Protein

Stéphane La Barre, 2012
Scaling responses to an experimental thermal stress

- **Optimal Conditions**
- **Stress but Resilience**
- **Loss of Functions**
- **Cell Death**

**Physiological Approach**
- Onset of stress symptoms
- No-return point
- Destruction of cells

**Metagenomic Approach**
- Autotroph dominated functional microflora
- Microflora progressively less diverse
- Heterotroph dominated pathogenic microflora
- Septic conditions
- Whitening
- Degeneration
- Necrosis

**Transcriptomic Approach**
- Heat shock proteins
- MBL lectins lost
- Loss of antibiotic defences
- ROS activation
- Ca++ binding lost
- PO activation
Towards environmental tools

STRESS INDICATORS

MICROBIAL BARCODING

METABOLISM

SENTINEL SPECIES

Healthy coral

Sick coral

ECOSYSTEM

Pristine

Endangered

POLLUTANTS CHECK

MICROSCOPE

SATELLITE
RADAR GRID ON STRESS RESPONSES OF SENTINEL HOLOBIONT

**Function loss**

- **Imaging**
- **Metabolomics**
- **Transcriptomics**
- **Proteomics**

- **Control 0-2**
- **Initial 2-4**
- **Light 4-6**
- **Severe 6-8**
- **Lethal 8-10**

**Categories:**
- **Mandatory**
- **Complementary**
- **Optional**
SENTINEL CORAL HOLOBIONT UNDER LASTING HEAT STRESS

- **Imaging**
- **Function loss**
- **Metabolomics**
- **Transcriptomics**
- **Proteomics**

- **MANDATORY**
- **COMPLEMENTARY**
- **OPTIONAL**

Heat Stress Levels:
- **CONTROL 0-2**
- **INITIAL 2-4**
- **LIGHT 4-6**
- **SEVERE 6-8**
- **LETHAL 8-10**
PROPOSED STEPS TOWARDS A MULTI-APPROACH ENVIRONMENTAL TOOL

1. IDENTIFYING THE ISSUE
   - Select the major stressor/ describe biome

2. SELECT A SENTINEL SPECIES
   - Must be common and displaying gradual stress responses

3. SELECT ANALYTICAL APPROACHES
   - Omics, imaging (visual), toxicology (metabolism)...

4. ESTABLISH DATABASE IN PRISTINE CONDITIONS
   - Robustess (n> 30), define acceptable limits

5. COMPARE STRESSES AGAINST CONTROL PROFILES
   - Calibrate responses and define threshold levels

6. COMBINE INDIVIDUAL PROFILES ON A RADAR CHART
   - Test and validate tool

7. IMPLEMENTATION
   - Following up an environment evolving under stress
ANALYSIS

Use genetic algorithms coupled with neural networks to extract meaningful information from clouds of complex data. Bioinformatics specialists can develop software specifically adapted to a given analysis.

PREDICTION

The study of a complex system, such as the overall fitness of a model organism, is worth studying if novel global properties are emerging from the multitude of local interactions that are monitored.
PART FOUR

CONCLUSION

Ainslie Roberts – The Dreamtime Heritage
Chemodiversity exploration of biodiversity hotspots is essential for the discovery of new drug candidates and for bio-inspired technologies. But sourcing is often subjected to extremely complex procedures at all levels, from international to local. Besides being of general interest, it links to biodiversity conservation.

At the same time, abusive or illegal exploitation protected biodiversity hotspots and poaching of endangered species have a devastating effect on short-range endemic species already at risk.

Science-mediated solutions should address conflicting biodiversity exploitation and conservation issues.
I have a dream...

Ask not whether your environment can make you rich, but question what you can do to keep it clean...

We do not inherit the ocean from our ancestors, we borrow it from our children...

Yes, we can!

The proper use of science is not to conquer Nature, but to live in it

Super Polyp thanks you for your attention!

Super Polyp « borrowed » quotes, 2014