

## **UNDERSTANDING CORAL BLEACHING ACROSS FOUR OCEANS - addressing CBD's Specific Workplan on Coral Bleaching**

Ole Vestergaard<sup>1</sup>, Ove Hoegh-Guldberg<sup>2</sup>, Umit Unluata<sup>1</sup>

1) The Intergovernmental Oceanographic Commission of UNESCO, 1 rue Miollis, 75005 Paris, France  
2) Centre of Marine Studies, University of Queensland, St Lucia QLD 4072, Australia

*Keywords: coral bleaching, targeted research, capacity building, mitigating responses*

[Download CBD's workplan on Coral Bleaching](#)

### **Introduction**

Coral bleaching is rapidly developing as a major problem for the health of coral reefs worldwide. Unfortunately, the level of understanding of this phenomenon is limited. Developing a good understanding of the phenomenon is important if management practices are to be effective in minimising the detrimental impacts of coral bleaching as projected to occur over the next 50 years.

In response to this situation an expert group, the *IOC/UNESCO Working Group on Coral Bleaching*, has been established with the purpose to 1) integrate, synthesize and develop global research on coral bleaching and related impacts of climate change on coral ecosystems; 2) generate tools and techniques to detect early stress responses and longer-term impacts of climate change with a wide applicability in both developed and developing nations; and 3) strengthen the capacity for research and management of coral bleaching impacts in developing countries affected by coral bleaching, through the transfer of expertise and technologies. The effort has become an important implementer of **CBD's Specific Workplan on Coral Bleaching** (COP 6 VI/3, 2002).

### **Background**

Coral reefs play a key role for the functioning of tropical coastal ecosystems and for the large coastal populations that depend on reef resources for their daily livelihoods. Unfortunately, coral reefs are now experiencing unparalleled levels of human related stress. Furthermore, recent evidence suggests that coral reefs also appear to be very sensitive to environmental changes like climate change related temperature stress (Hoegh-Guldberg 1999). Coral bleaching and mortality have steadily increased over the past 20 years. Coral bleaching occurs when the critical symbionts of corals become stressed and the symbiosis breaks down. Mass coral bleaching (global episodes) has not been reported prior to 1979. In 1998, the world experienced the largest and most widespread example of mass bleaching with an estimated 16% of the world's living corals were eliminated in a single warming event (Wilkinson 2000).

Our current understanding of the potential impacts of global climate change is still relatively limited. As a global society, we have a minimal understanding of the mechanisms, ecological outcomes and economic ramifications. Improving this understanding is critical if we are to understand the changes that have occurred in the past and if we are to accurately project how the

health of our coastal oceans will change as the earth experiences one of the most rapid periods of climate change in recent history. The latter is important if humans are to adapt to or mitigate the impacts of these changes over the next 50 to 100 years. Our understanding will also be critical in assessing the pros and cons of different strategies as regards energy use and the adoption of new forms of energy.

### **Expert group on coral bleaching and local ecological responses**

The IOC/UNESCO Working Group on Coral Bleaching and Local Ecological Responses was established in fall 2000 by the *Intergovernmental Oceanographic Commission (IOC)* of the *United Nations Educational, Scientific and Cultural Organization (UNESCO)* with the specific mandate to fill critical knowledge gaps relating to 1) tolerance limits and potential mechanisms of corals for adaptation/acclimatization to global environmental change; 2) long-term responses of coral reefs to large-scale changes in environmental variables and 3) development of possible molecular, cellular, physiological or community indicator tools that are reliable in their ability to detect environmental stress responses.

### **Membership and correlative research**

The Bleaching Working Group includes scientists from developing as well as developed countries bringing together expertise in different fields of coral physiology and ecology. The members are: Barbara Brown (UK); John Bythell (UK); Bill Fitt (USA); Ruth Gates (USA); Ove Hoegh-Guldberg, *Chairperson* (Australia); Roberto Iglesias-Prieto (Mexico); Ron Johnstone (Australia); Michael Lesser (USA); Yossi Loya (Israel); Nyawira Muthiga (Kenya); David Obura (Kenya); Rob van Woesik (USA); Helen T. Yap (Philippines). Associated with the group is a long list of young researchers and students at participating research institutions.

The IOC/UNESCO Bleaching Working Group has joined forces with five additional targeted working groups within the framework of a developing *GEF/World Bank Targeted Research program on Coral Reef Sustainability and Capacity Building* (see separate SBSTTA 8 abstract, CBD Technical Series).

### **Implementing CBD's Specific Workplan on Coral Bleaching**

The CBD Specific Workplan on Coral Bleaching was developed under the programme of work on marine and coastal biological diversity in consultation with an international liaison group of experts. It was recommended for implementation by SBSTTA 6 (Recommendation VI/2, Annex 2, March 2001) and adopted by COP 6 (Decision VI/3, April 2002).

The overall goal of this plan is to: *“Support efforts to gather and assimilate information on, build capacity to mitigate the effects of, and to promote policy development and implementation strategies to address the impacts of coral bleaching and related mortality on coral-reef ecosystems and the human communities which depend upon coral reef services, including through financial and technical assistance.”*

The IOC/UNESCO Coral Bleaching Working Group has become an important implementer of the Workplan, addressing specific items in the areas of *information gathering; capacity building and mitigating responses*, as follows:

## **I. CBD Bleaching workplan: Information gathering**

### ***Critical questions***

From its first meeting in April 2001 the group has engaged in research discussions and collaborative experiments addressing key questions regarding the future status of reefs under predicted climate change. The group has discussed different aspects of molecular and cellular responses to heat stress and other stressors disrupting the algal-coral symbiotic relationship leading to bleaching, the subsequent ecological impacts, and the potential for developing indicators and tools to assess changes and predict longer-term impacts of coral bleaching.

An overarching theme to be investigated is the issue of adaptation/acclimatization to increased sea surface temperature and the ability of corals to recover from bleaching; and the possible new state of coral reefs at increasing frequency of mass bleaching events, as summarised in the following broader questions:

*Are coral reefs resilient in the face of projected climate change over the next 100 years?*

*How is the primary factor temperature affected by other secondary factors?*

*Why are some corals more immune than others?*

*How fast will change occur within coral reefs' ecosystems?*

*Can coral reefs recover and if so, how fast?*

*What factors influence the ability of reefs to recover?*

*Is a phase shift permanent?*

*What will the final state of the ecosystem be like if coral abundance decreases dramatically?*

To address these and related questions a set of specific work hypotheses have been developed addressing fundamental physiological mechanisms leading to bleaching and longer-term ecological impacts of thermal stress, which will be tested through joint physiological experiments, ecological studies, reviews and discussions.

### ***Main research themes***

The project activities span from investigations at the molecular to ecological level and will generate tools and techniques applicable to a wide range of problems facing both developed and developing nations. The specific components within the major project for the next five years are as follows:

1. To develop a more complete understanding of the molecular to cellular mechanisms underpinning coral bleaching and mortality of reef-building corals.
2. To establish and test bioindicators of climate impacts and reef health and to develop appropriate bioindicator technologies at molecular, physiological and ecological scales.
3. To pursue a greater understanding of the ecological mechanisms and outcomes of climate impacts on coral reefs.
4. To provide the basis for firmer estimates of the direction and rate of ecological changes to coral reef ecosystems under progressive climate change. Inherent in this last objective is to

integrate the knowledge gained to create a sturdy knowledge basis for developing strategies for human societies to adapt to or mitigate climate driven changes.

Within these major objectives, there are specific questions that will be undertaken around five principle research areas: (A) Mechanisms of thermal stress; (B) Bioindicators of coral stress; (C) Coral susceptibility, tolerance and associated factors of thermal stress; (D) Ecological consequences of reduced coral abundance; and (E) Projections of future change.

## **II. CBD Bleaching workplan: Mitigating responses**

### ***Indicator tools***

A major output of the experimental program will be a series of indicator tools such as:

*Molecular markers* that will rapidly and easily distinguish heat stress from other types of stresses (e.g. sedimentation, metal contamination, nutrient stress) on coral reefs.

*Cellular markers* that will enable users to accurately anticipate and monitor the advent of coral bleaching or recovery.

*Genetic markers* that will enable insight into the tolerance and resilience of communities of reef-building corals.

*Ecological markers* that will enable users to monitor impacts of coral bleaching and to project how the changes are likely to impact on local ecosystem function.

### ***Predictive models and scenario building***

A more complete *model* of the mechanisms that trigger mass coral bleaching will be developed that will enable better projections of the potential impact of climate change on coral reefs, and enable better prediction of the potential impacts on those human communities relying upon them as sustainable resources.

Scenario planning will be used to develop an in-depth understanding of the changes that are likely to occur on reefs as reefs warm, starting with the four key IPCC scenarios (B1, B2, A1 and A2 scenarios) and developing a series scenarios based on biological responses in the context of economic and sociological scenarios. This project component will integrate the information derived from the other programs and will develop a series of tools by which managers can assess the impact of the changes they (or the society that they live in) are making to ameliorate the negative impacts of climate change.

### ***Rapid response capability***

Standard Operating Procedures and protocols will be developed and applied at all the field sites to collect and investigate coherent information on bleaching and its impacts on reefs, allowing comparisons at regional and global scales. Ultimately the network, the new tools and the standard procedures will provide a rapid response capability to document coral bleaching and mortality in developing countries and remote areas, as well as an infrastructure to follow longer-term effects.

## **III. CBD Bleaching workplan: Capacity building**

### ***Collaborative research through global network***

The GEF/World Bank Coral Reef Targeted Research project will engage researchers and students from developing and developed countries in collaborative experiments, seminars, training workshops and discussions.

Teams will engage in series of regional research workshops at selected pilot sites, bringing together all associated scientists and students in a global network. The activities will include lab experiments and fieldwork spanning molecular, cellular to ecological research, as well as seminars and discussions. Grants will be provided to local researchers and students for longer-term studies at selected sites.

Training-through-research and grants for developing country scientists to visit foreign laboratories and to attend seminars and training courses will spread new knowledge and techniques and provide career opportunities for young researchers in coral physiology, taxonomy, ecology and related disciplines.

By implementing the activities at developing country institutions the program will strengthen national research capacities with new expertise, technologies and management skills. Field sites are being established with universities and research laboratories at four representative ocean areas covering sites in Mexican Caribbean, East Africa, Philippines and Southern Great Barrier Reef.

To maximise cross-fertilisation, mutual exchanges and cost sharing, the activities will be coordinated closely among the six GEF Coral Reef Targeted Research working groups, covering 1. Coral Diseases, 2. Connectivity, 3. Remote Sensing, 4. Modelling & decision Support; and 5. Remediation and Restoration. The total number of scientist in this global network will be well over 100, with wide representation of institutions and research communities.

### **Dissemination of new knowledge**

Syntheses of new findings and results will be presented in scientific papers, reviews, technical guidelines and disseminated via seminars and training workshops. New knowledge generated through this effort will be integrated and continuously made available from the working group's website: <http://www.ioc.unesco.org/coralbleaching>.

### **Pilot research workshops**

During 2002 two field workshops were held to test the concept of collaborative research, investing specific work-hypotheses and pilot future work. Both workshops included joint thermal simulation experiments, ecological surveys and scientific seminars given by attending scientists and students.

The first workshop took place from 25 February to 18 March 2002 at Heron Island Research Station, Southern Great Barrier Reef, hosted by the Centre of Marine Studies, University of Queensland, Australia. It involved 32 scientists and 18 postgraduate students. The hypotheses tested ranged through a series that was developed during the April 2001 discussions. The coincidence of a major bleaching event across the Great Barrier Reef taking place during the workshop led to some unusual opportunities for the targeted working group to pursue questions associated with a "natural" bleaching event. Among the highlights of this successful workshop were a major audit of symbiotic *dinoflagellate* strains, the discovery of new coral diseases for the

GBR region, new insights into the role of cell suicide and *apoptosis* in bleaching and the important role of clonal variability in coral stress tolerance.

The second step in testing the concept of targeted research took place from 9 to 22 September 2002 in Puerto Morelos, Mexican Caribbean, hosted by Universidad Nacional Autónoma de México. The workshop was attended by 25 local and international students and scientist. It led to the development of draft ecological survey protocols, and wide-ranging discussions illuminated the critical chain of physiological mechanisms leading to bleaching, ecological responses and implications for society.

Near-future efforts will focus on finalising review papers, further refine and consolidate the concept of targeted research and initiate the development of specific tools and biomarkers, which will provide new insight in the complex area of coral bleaching and climate change.

### **Further information**

The IOC/WB Coral Bleaching Group is online: <http://www.ioc.unesco.org/coralbleaching> with information on contacts, workshop reports, seminar proceedings, workplans, publications and information sheets on recent progress and future activities.

The CBD Specific workplan on coral Bleaching is available online from at CBD's website: <http://www.biodiv.org/recommendations/>.

For additional information please contact IOC/UNESCO at [o.vestergaard@unesco.org](mailto:o.vestergaard@unesco.org) or [u.unluata@unesco.org](mailto:u.unluata@unesco.org), or Working Group chairman Professor Ove Hoegh-Guldberg at [oveh@uq.edu.au](mailto:oveh@uq.edu.au).

### **References**

Hoegh-Guldberg, O. (1999) "Coral bleaching, Climate Change and the future of the world's Coral Reefs." *Review, Marine and Freshwater Research*. 50:839-866.

Wilkinson, C. (2000) The Status of the Worlds Coral Reef 2000 (IOC/UNESCO-UNEP-IUCN-World Bank)