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UA Biosphere 2 Ocean

**Racing Up the Slippery Slope to Super Corals: Biosphere 2 & Beyond**

*Summary*

The UA Biosphere 2 Ocean (B2O) is well into the first phase of an exciting new three-phase project that will investigate key processes and novel solutions for restoring resilient coral reefs from a degraded state. These resilient reefs can maintain critical reef structure, function, and diversity in the face of continuing climate change. The controlled environment of the B2O is a perfect test bed for novel, even radical, techniques of reef restoration, selective breeding, and assisted evolution that are too difficult or risky to test in the wild. The algae-dominated reef state of the current B2O — similar to that of a degraded reef after disturbance(s) — also presents a unique opportunity to investigate recovery processes and explore solutions for rebuilding resilient coral reefs.

During this critical first phase, we are closely monitoring the physical, chemical, and biological conditions of the B2O to document the transition from algae to coral reef as we re-engineer the system to support a “super reef” of the future. In the coming months, we will populate the ocean with key species (coral, symbionts, herbivores, etc.) expected to contribute to a functional and resilient coral reef, and test recent advances in materials and techniques for coral restoration. Capitalizing on the range of controlled environments in the B2O and adjacent experimental raceways, we will also conduct experiments to explore novel ways to increase corals’ resilience to stress (e.g. by selective breeding and/or by manipulating depth, feeding, symbionts, or stress exposure). In the final phase of this project, this “super reef” will be exposed to environmental conditions of future reefs (i.e., high temperature, low pH, frequent extreme events) to examine the adaptive potential of coral reef ecosystems to projected climate change.
PHASE ONE PROGRESS

I. Engineering

LIFE SUPPORT FOR THE SUPER REEFS OF THE FUTURE

Re-engineering plans for the Biosphere 2 ocean reef were finalized in November 2018. The planned renovations will allow us to build and improve upon the infrastructure of the original B2O reef experiment in a number of key ways. For example, the quantity and wavelength of light reaching the B2O reef, lower and more selective than typically found in nature, provided a continuous source of stress to the original B2O coral reef. When the ocean was initially populated, coral depths were tediously manipulated to reduce stress (Abigail Alling, pers. communication). The re-engineered B2O will have a series of trusses supporting up to 288 halogen and LED lights to supplement lighting over the reef. We are optimizing the location of the lighting grid relative to the underlying bathymetry to ensure proper lighting over all planned experimental regions (from the shallow water lagoon to the reef crest to the deep fore-reef environment, Figure 1).

In addition to new lighting structures, we are also upgrading the life support systems to improve heating/cooling, filtration, circulation, and water quality of the B2O. In Fall 2019, the newly upgraded heat exchanger will facilitate realistic stress-hardening and thermal-stress experiments. These new systems will permit the background temperature of the B2O to be manipulated across a broad range of temperatures (from 25 to 35 degrees Celsius) and at a rate of up to 2 degrees Celsius per day – rates that are commonly observed in nature during extreme bleaching events and across many reefs on a diurnal or even tidal cycle. The ability to simulate high background temperature variability will be essential for stress-hardening and future-resilience experiments in phases 2 & 3, as a number of studies have demonstrated that reefs are less likely to severely bleach if they are frequently exposed to temperature extremes.
Figure 1: Schematic of the new B2O lighting system (top) and the underlying ocean bathymetry (bottom).

II. Baseline Studies

MEASURING, DOCUMENTING, AND UNDERSTANDING THE B2O “DEGRADED STATE”

Since August 2018, we have closely monitored all physical, chemical, and biological conditions of the B2O in its current “degraded state” to establish a baseline for the system and determine the timescales across which key parameters change (or cycle) on the reef. The physical conditions (light, temperature, salinity, pH, chlorophyll, blue-green algae, and dissolved oxygen) of the B2O are monitored continuously; these data will be transmitted to public displays in the “Ocean Gallery” at Biosphere 2 and to our new B2O website (to be released in 2020). Twice weekly, we also collect water and sediment samples from the B2O to measure the key chemical (e.g., nutrients, alkalinity / acid buffering capacity, cations, anions) and microbial (bacterial, viral) constituents of the B2O. Molecular sequencing will be performed for taxonomic and functional classification of microbial communities. Collaborator Ty Roach— an expert in the role of bacteria
and viruses in biogeochemical cycling, energy flow, and community structuring in coral reef ecosystems – is currently leading the microbial surveying and sequencing of the B2O (manuscript in preparation, to be submitted in 2020). In parallel, the macro-biome (e.g., algae, invertebrates, fish) are monitored ~monthly using conventional reef survey techniques and state-of-the-art 3D photo mosaic technology (in collaboration with Stuart Sandin at Scripps Institution of Oceanography). Finally, and critically, we will leverage this sampling routine to expand both our citizen science and undergraduate programs at the Biosphere 2.

III. Bold Experiments

LESS ALGAE, MORE REEF -- BIOREMEDIATION & REEF RESTORATION

After establishing baseline dynamics of the Biosphere 2 ocean system in its current algae-dominated state, we began testing novel solutions for bioremediation and reef restoration. In Spring 2019, we introduced a number of herbivorous invertebrates and fish to assess the role of herbivory in biogeochemical cycling of this degraded reef system. In the next stage, herbivore-exclusion experiments will investigate algae—herbivore dynamics on the degraded reef and assess the impact of the herbivore community on the reef composition and function (on macro- and micro- scales). These experiments will provide critical constraints on the capacity for ecological approaches to remediating degraded reefs following disturbance(s). Depending on the success of the ecological remediation, we will then manually remove the algae and track the algal biomass removed from the system (Fall 2019-Spring 2020). These ecological and manual remediation efforts will facilitate the introduction of corals into the B2O to test novel methods and materials for reef restoration during Phase Two. In particular, we will capitalize on the controlled environment of the B2O to test the role of microbes (e.g., “probiotics”) in enhancing the resilience of corals transplanted during reef restoration.

In preparation for phase two, we have made significant progress in identifying grazing fish species that will fill key functional niches on the B2O reef. Furthermore, thanks to a network of colleagues in the aquaculture industry, we have developed connections for ethically-raised reef fishes (reared entirely in captivity). Two new species of herbivores were released during Earth Month April 2019 “Ribbon Cutting & Release” events for the public at the Biosphere 2 Ocean—the first fish introductions since the late 1990's! Over the coming months, we will continue to build infrastructure and protocols for future fish introductions.
Vision and Leadership for the Biosphere 2 Ocean project

As the new director Marine Research at B2O, I’m thrilled by the opportunity to be a part of transformative reef science over the coming months and years! Recognizing the international scope and impact of this project, I will be working over the coming year to develop and implement a growth model and organizational plan for the B2O project as it continues to flourish. Looking to successful analogues as an example (e.g. long-term ecological research programs), and working closely with the other Biosphere 2 biomes and education & outreach programs, I will develop a structure to support collaborative proposal submissions and review, data management, publications, dive and laboratory safety, undergraduate and graduate student research, public engagement, diversity & inclusion, and scientific excellence. In the first stage of this process, we have officially established a scientific advisory committee, and invited Dr. Julia Cole to be chair of this important committee. The Biosphere 2 Advisory Board will continue to play a seminal role in the vision and growth of the B2O project, and I look forward to working with you all to address the grand-challenge facing our world’s coral reefs.

Dr. Diane Thompson
Director of Marine Research, Biosphere 2

Throughout each of these phases, we will also continue to actively apply for federal and foundation grants to achieve our research goals and continue to expand the B2O collaborative team (e.g., additional postdoctoral and graduate student fellowships). For example, we applied for two major grants in the 2018-2019 academic year to support the B2O Research and Education Initiatives: (1) NSF “Mid-scale RI-1 (M1:IP): Building resilient coral reefs: Biosphere 2 & Beyond”, PI Thompson and co-PI Bonine ($19,663,955), and (2) Keck Undergraduate Education Program, "Biosphere 2 Ocean: Equipping NextGen Systems Scientists to Tackle the Coral Reef Crisis," PI Thompson ($300,000). With the generous support from donors and funding agencies, our goal is to achieve the following milestones for phases 1-3 over the coming year:
**Phase One: Life Support for the Super Reefs of the Future**

1. Acquisition of key equipment and personnel for “baseline” B2O monitoring: **October 2018**
2. Finalized engineering plans for the revitalized B2O: **November 2018**
5. Photomosaic survey of the “baseline” B2O: **January 2019**
6. Reef ecology workshop: **January 2019**
7. Heat exchanger installation: **August-October 2019**
8. Installation of other critical life support equipment: **TBD, funding dependent**
10. Acquisition of new key functional herbivores: **February-March 2019**
11. Introduction of herbivores (new invertebrates & grazing fish): **April 2019 (Earth Month)**
12. Biosphere 2 Ocean: Equipping NextGen Systems Scientists to Tackle the Coral Reef Crisis (New Undergraduate Course): **TBD**
13. Bioremediation & grazing experiments: **February – December 2019**

**Phase Two: Racing Up the Slippery Slope**

1. Initial raceway experiments & initial B2O coral implantation: **Winter 2019-2020**
2. Hire marine biogeochemistry postdoctoral scholar ASAP
3. Hire coral ecology postdoctoral scholar ASAP
4. Begin phase 2 experiments: **~Winter 2020**
   a. Assessment of recent advancements in materials & techniques for coral restoration
   b. Impact of probiotics & microbial communities on restoration success
   c. Photomosaic survey of the B2O reef community & comparison to “baseline”: **TBD**
   d. Identification of novel species interactions and their impacts on the structure and function of restored reefs
   e. Additional Phase 2 experiments, outlined at Jan 2019 Reef Ecology Workshop

**Phase Three: Building “Super” Reefs of the Future**

In the final phase of this project, the Biosphere 2 “super reef” will be exposed to environmental conditions projected for the future (i.e., high temperature, low pH, frequent extreme events). The goal of these experiments is to determine the adaptive potential of coral reef ecosystems to projected climate change. Preparation for phase three experiments will continue in parallel with phases one & two over coming months. Timeline for major phase 3 milestones will be shared with the Biosphere 2 Advisory Board in November 2019. Experiments for phase three will tentatively begin in 2020 (pending support for remaining critical life support systems).
CRITICAL NEXT STEPS FOR FUNDING:

1. Support for corals and shipping of corals (Hawaii and Mote Marine) for raceways and main ocean tank
2. Lighting structure and lights (1000W metal halides & 500W LEDs) over main tank
3. DIC & pCO₂ monitoring system for main ocean tank
4. YSI Exo3 sonde to replace failing instrumentation in main ocean tank
5. Additional coral raceways (4+ replicates for existing raceway system)
6. Full time life support and water quality/chemistry staff support
7. Development personnel to assist with above
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