MAKE FOR THE PLANET BORNEO

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RESTORING REEFS EVERYWHERE: SCALABLE DESIGN INNOVATIONS TO RESTORE CORAL REEFS

Presented by: Tom Moore, Coral Reef Restoration Team Lead, NOAA Restoration Center

The Problem

Saving the world's coral reefs will require a multi-pronged approach that ranges from actions at the local to the global level. Globally, we need solutions that dramatically and rapidly reduce energy consumption and reverse the effects of global climate change. Locally, we need to manage threats to coral reefs such as overfishing and pollution. In addition, we need to create and deploy scalable and cost-effective systems to repopulate coral reefs with resilient, genetically diverse, and reproductively viable coral populations through restoration and novel ecological interventions.

This particular challenge is focused on sourcing scalable and cost-effective solutions to repopulate coral reefs with resilient, genetically diverse, and reproductively viable coral populations through restoration efforts. The problem is that coral reef restoration methods are currently too slow and not scalable. The solutions need to operationalize the coral restoration methods to be faster and most efficient.

While in the long term the coral restoration community needs to increase efficiency at least 10-20x, (likely utilizing robotics or other automated deployment methods), there is a critical need to increase the efficiency ~5x of the "diver based" deployment methods used commonly today in coral gardening projects. That is the constraint this challenge will seek to address.

Challenge Statement

This challenge seeks solutions that operationalize coral restoration efforts so that the outplanting process becomes more efficient (maximize productivity with minimum wasted effort), and scalable so that we can achieve coral restoration over large areas (kilometers vs. meters, and millions of corals vs. thousands of corals).

Core Constraints to Scaling Up

While some biological questions remain as obstacles to achieving coral reef restoration at a 10-20x scale, the only challenges that exist to achieve a 5x increase in scale are engineering and efficiency problems. In order to solve those problems teams will need to work backward from outplanting on the reef (the least efficient process currently) to the nursery phase (currently the most efficient phase). While constraints and efficiency can certainly be improved at all levels, failure to solve the least efficient phase first will just result in bottlenecks at other phases. However it is recognized that solutions to improve outplanting efficiency may require changes in other phases as well. Below is an outline of the core constraints at each phase, working in order in importance to address:

Outplanting (Primary Bottleneck)

- Outplanting involves the act of physically securing the nursery grown coral to the reef using either puddy type 2-part epoxy, zip/cable ties, nails, and/or cement. Pictures of different methods are here.

- Corals ready for outplanting are generally 10-15cm in length (models will be available at IMCC5).
- The most commonly used practice is outlined in this presentation.
- This process is time consuming taking a skilled diver ~3min to clear the substrate, form the two-part epoxy balls, place them on the reef, and then secure the coral. When using nails (masonry) a diver has to hammer a nail into the reef and then secure the coral with a zip/cable tie. Because there is some movement using a zip/cable tie 2-3 attachment points are necessary.
- Ideally the time is reduced to less than 30 seconds, allowing a diver to retrieve a coral from pouch or basket and secure it to the reef with limited movements.
- Potential solutions considered, but not currently in use are:
    - A negatively buoyant epoxy/adhesive that is tube deployed/mixed that is tacky/sticky and able to adhere to a non-cleaned/roughed-up surface. Most also not be toxic to coral.
    - A “plug” that the coral is grown on in nursery already that can be quickly placed/secured in a drilled hole.
    - A “plug” that placed into a drilled hole on the reef and then receive a coral branch into a “female” receptacle that allows the branch to push in but not come back out.
- Outplant attachment solutions need to tightly secure the coral to reef immediately as wave energy can quickly dislodge or break colonies.
- Outplant solutions can be biodegradable if they will last long enough for the coral to over grow the solution and onto the reef (6 months).
- Ideal solutions can be fully deployed with one diver, however a solution that requires two divers doing different tasks is fine if it can operate is a systematic manner.

Transport from Nursery to Reef

- Transport involves removing the coral from the grow-out structure, taking it to the surface, placing it on a boat, transporting to outplanting site, and deploying the corals into the water for diver retrieval and outplanting. Pictures of different methods are here.
- The primary constraints are outlined below:
    - Getting the coral quickly off the grow out structure and to the boat without breaking it.
    - Placing the maximum amount of odd shaped coral in bins/containers on the deck of the boat.
    - Keeping the corals wet without overloading the boat or causing stability loss as a result of water in the bins.
    - Quickly deploying the corals from the boat to the outplant site in a manner that allows divers to quickly pick them up and work with them once on the bottom.
- Within this phase the issue that presents the most challenge is the boat transport.

Currently corals are placed into seawater filled bins. Because of the odd shape of the corals the bins can only take a limited number even when piled on top of each other, resulting in an effort that transports more water then coral. This takes up valuable deck space and adds significant weight to the boat.

- The corals need to be wet, but not submerged during transport. As a result a potential solution could involve stackable bins that connect to a misting or irrigation system. To be most efficient the "bins" should be the same ones used to collect the coral from the nursery and then deploy them to the reef. The irrigation system would need to plug into the bins or be otherwise connected to it. The bins would also need to be open on the top and slotted on the sides/bottom to allow a diver to swim with them in the water during the collection and outplanting phase.

Coral Nursery Growout and Structures

- Coral nurseries can exist both in-situ (ocean based) and ex-situ (land-based). In-situ nursery have found to work best when corals are suspended in the water column on floating structures. Ex-situ nurseries involve shallow tanks where corals are grown-out. Pictures of different types are here.
- While there are differences between coral species the process generally works by taking advantage of asexual reproduction and pruning vigor. Once larger corals are broken up into many smaller corals, those smaller corals exhibit much faster growth then their cousins on the reef and over the course of a year may grow 10x their original size.
- The nursery phase represents the least limiting step in the process, however there are improvements that can be made, particularly if the two subsequent phases are sped up and therefore a greater supply of corals is needed. This is particularly true for in-situ nurseries that require the use of divers.
- The primary constraints currently affecting in-situ nurseries are described below:
  - Traditionally used materials (pvc pipe, monofilament, sand anchors, duckbill anchors etc.) are subject to breakage in storm events. Improving the storm tolerance of nurseries would be beneficial.
  - Individually removing and refitting corals on nursery structures suspended in the water column by divers is time consuming. Monofilament fishing line and metal crimps are the most common method for attachment but require extreme dexterity to rig quickly underwater. The ability to quickly remove a coral for outplanting and replace it with a new coral fragment would increase production.
  - Biofouling of floating nurseries by marine organisms presents an ongoing maintenance issue for divers. The ability to switch to materials that limit bio-fouling or simply coat materials with a non-toxic anti-foulent that can work for multiple years would reduce diver time and increase efficiency.
- One consideration is that nursery structures may need to be modified to accommodate more efficient outplanting and/or transport.

Background Information
Immediate and aggressive action to address climate change, while absolutely critical, is only part of the larger equation to ensuring a future for coral reefs and the ecological and economic services they provide. Carbon already released into the atmosphere will continue to warm ocean waters to a level inhospitable to corals for decades to come. Increased bleaching combined with reproductive failures, resulting from various factors including continually decreasing population size and density, sets the stage for complete ecological collapse. If the critical ecologic and economic functions that coral reefs provide the world today are to be preserved, it is necessary to buy time and increase ecosystem resilience in the shorter term by dramatically improving the coral reef restoration methods.

Coral Reef Restoration is part of the solution. Although a number of organizations have active coral restoration programs, there is much room for innovation and improvement to deploy coral reef restoration on a large enough scale to provide ecosystem benefits. The current tools and techniques used for the "demonstration" and "proof-of-concept" projects currently underway are not suitable or efficient enough to move from restoring tens of thousands of corals annually to the scale of millions that are needed globally.

Prizes/Opportunities Specific to the Coral Restoration Challenge

- 2 scholarships for attendance and an opportunity to present to coral restoration practitioners at the conference ***Reef Futures 2018: A Coral Restoration and Intervention-Science Symposium*** to be held December 10-14, 2018 in Key Largo, Florida.
- Availability of funds to pay for manufacture of proof of concept items deemed to be viable for rapid deployment.
- Match making with existing coral restoration practitioners to test and deploy proof of concept.
- Widespread exposure within the global coral restoration community and opportunity for ongoing collaborations, partnerships, and potentially funding.

Further reading & examples of potential solutions

Photos and Background Material
https://drive.google.com/drive/u/0/folders/1hThRY1Pxm9B0WnXmdem1J9-bhK5MoS0o

Step by Step Restoration Video using current techniques:
https://www.youtube.com/watch?v=1tvfmWdZHR4&t=197s

Florida Keys Coral Nursery
https://www.youtube.com/watch?v=1t-Byj5JtKs

Reef Resilience Network
http://www.reefresilience.org/
in particular, look at the resources under "Restoration"

Watch webinar by Tom Moore, NOAA
https://youtu.be/nZ-4iYeTnww

Recovering after Typhoon Haiyan in the Philippines:
https://concernworldwide.exposure.co/rebuilding-the-philippines-reefs

NOAA Coral Nurseries in Puerto Rico with Elkhorn Coral:
https://response.restoration.noaa.gov/about/media/how-noaa-uses-coral-nurseries-restore-damaged-reefs.html

CCMI Coral Nurseries in the Cayman Islands:
https://reefresearch.org/what-we-do/conservation/coral-nursery/

NOAA coral nurseries:
https://response.restoration.noaa.gov/about/media/how-noaa-uses-coral-nurseries-restore-damaged-reefs.html

Coral Restoration Foundation outplanting methods
https://coralrestoration.org/outplanting-methods/

SECORE international coral restoration methods
http://www.secore.org/site/home.html