The First Hawai‘i Workshop For Coral Restoration & Nurseries

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Abstract

Coral nurseries and active restoration efforts are becoming widespread throughout the world as coral reef ecosystems collapse from local and global threats. This workshop brought ~45 local and national participants together at the Hawai‘i Institute of Marine Biology (HIMB) in July 2017 to form a working group and discuss past, present, and future coral restoration efforts in Hawai'i. Although restoration efforts in Hawai‘i are in the formative stages, there are currently several large projects including: (1) an *ex-situ* (land based) Coral Restoration Nursery facility recently constructed by the State of Hawai‘i Division of Aquatic Resources (DAR); (2) *in-situ* restoration activities by NOAA, and HIMB; (3) cultivation and transplantation work by the Maui Ocean Center (MOC), and; (4) ongoing experimental work at UH Mānoa. This workshop focused on Hawai‘i specific challenges, and developing new capacity and tools such as coral nurseries, transplantation methods, micro-fragmentation, assisted evolution, cryopreservation, conservation genetics, genomics, transcriptomics, and proteomics. The goal of the workshop was to provide an overview of current efforts and highlight the array of tools available to provide a foundation to fuel future coordination and collaboration efforts.

1. Introduction

The rapid decline of coral reef ecosystems worldwide requires not only immediate action to ameliorate local and global threats but to also implement active measures that can slow or reverse their decline. Although not without controversy (Jokiel & Naughton 2001; Precht et al. 2005; Hein et al. 2017), coral restoration ecology is emerging as a field with the goals of studying the rehabilitation of coral reefs, preventing the loss of endangered species, and providing insights into these complex reef ecosystems (Rinkevich 2005; Baums 2008; Drury & Lirman 2017). The history of coral restoration has

progressed through distinct phases with early pilot scale projects in the 1980's and 90's resulting in limited success and heavy skepticism (e.g., Guzmán 1991; Edwards & Clark 1999; Jokiel & Naughton 2001), followed by projects in the 2000's beginning to focus on increasing densities of endangered Caribbean corals to maintain sexual reproduction (e.g., Nedimyer et al. 2011; Rinkevich 2014; Leal et al. 2016). Current efforts are increasingly focused on methods to 'scale-up' coral restoration efforts and make them more efficient (Spurgeon 2001; Shafir et al. 2006; Griffin et al. 2012; Young et al. 2012; Chamberland et al. 2017). Reef restoration efforts in Hawai'i are only now beginning to gain widespread interest, and prior efforts have primarily focused on transplantation, removal of invasive algae, and reducing local anthropogenic threats. Hawaiian reefs are among the most isolated in the world, facing many unique challenges such as high wave action, slow coral growth due to cooler waters, a high proportion of endemics, as well as introduced and invasive species (Friedlander et al. 2008; Fautin et al. 2010). Currently there are no ESA listed corals in the main Hawaiian Islands, yet corals are protected under State law, and Federally protected as a NOAA trust resource under mandates including Essential Fish Habitat (under the Magnuson Stevens Fishery Conservation and Management Act), the Oil Pollution Act, and Executive Order 13089 to protect coral reefs under the US Coral Reef Task Force. Within this context, this workshop brought reef restoration practitioners together for the first time to discuss current activities that are rapidly proliferating in Hawai'i.

2. Overview of Current Major Efforts and Capacity

Several large-scale reef restoration projects have recently been initiated in Hawai'i. One of the largest single efforts is led by the State of Hawai'i Division of Aquatic Resources (DAR) Coral Restoration Nursery (CRN), a large capacity *ex-situ* (land based) nursery, established to develop improved methods of coral transplantation using corals that would have otherwise been lost as source material. The facility has focused on the micro- fragmentation and fusion method (Forsman et al. 2015) to cover large (eg. 40 cm diameter) modules with coral tissue at rates orders of magnitude higher than previously observed (Minton 2013). The CRN has also partnered with the Maui Ocean Center (MOC) to cultivate rare and endemic Hawaiian coral species through jointly-managed coral "arks". The MOC also has a large *ex-situ* capacity focused on mitigation, restoration and transplantation activity in Maui in coordination with the CRN. These efforts coincide with parallel efforts at NOAA and a variety of entities within the University of Hawai'i at Mānoa, including the Hawai'i Institute of Marine Biology (HIMB), the Kewalo Marine Laboratory, the Department of Biology, and the Hawai'i Coral Reef Initiative (HCRI).

HIMB has a long legacy of coral restoration, transplantation, and experimental studies on reef building corals. Currently there are several active research groups at HIMB with work pertaining to restoration and coral nurseries, including the Point Lab, the Gates Lab, the Hagedorn lab and the Toonen/Bowen lab. The Point Lab has the longest history of coral research, focusing on the

identification and reduction of threats to coral reefs. In response to widespread coral bleaching events and future ocean acidification threats, the Gates lab is spearheading 'assisted evolution' research with the goal of accelerating natural selection to enhance stress tolerance by developing a biological toolkit that can identify more resilient corals to be used in future coral nursery and restoration efforts. This initiative is in collaboration with the Australian Institute of Marine Science (AIMS), where both teams are attempting to increase coral resilience through 1) selective breeding, 2) inducing acclimatization, and 3) modifying symbioses (van Oppen et al. 2015, van Oppen et al. 2017). The Gates Lab uses both *ex-situ* and *in-situ* experimentation to investigate these questions. The Hagedorn lab works with the Smithsonian Institute on cryopreservation methods as a way of preserving biodiversity and potentially improving work with coral sexual reproduction for restoration. The Toonen/Bowen ("ToBo") Lab focuses primarily on molecular ecology and evolution which has resulted in discoveries of cryptic coral species and genetic structure, which has informed ESA listing decisions and restoration work. In addition, the ToBo lab built a floating midwater coral nursery platform using recycled materials from decommissioned floating net pens that were covered with >1,000 corals that might otherwise have been lost. This HIMB Coral Nursery platform aims to use these corals as source material for numerous experiments to improve cultivation efficiency and encourage reef recovery and resilience. The ToBo lab is also collaborating with NOAA, DAR, and HCRI to study mitigation using 'corals of opportunity' from boat strikes in Kāneʻohe Bay. The project is examining survival and growth rates with and without intervention to explore whether corals of opportunity could be used as non-extractive material for future restoration activities.

In addition to work at HIMB, the UH Mānoa Kewalo Marine lab and Department of Biology have a variety of projects that are relevant to reef restoration activities. Work in the Richmond Lab focuses on biomarkers for stress, using genomic, transcriptomic, and proteomic tools while the Hixon Lab has an ongoing 'Coral Resilience Module Experiment' (CReME). This work tests whether cubic-meter, concrete, artificial coral heads ("modules") providing many physical shelters can attract enough herbivores to keep nearby hard substrata sufficiently clean to foster coral settlement and survival. After just one year modules deployed near relatively healthy reefs in the Hanauma Bay Nature Preserve were colonized by multiple species of sea urchins, which prevented virtually any benthic algal cover. In contrast, modules deployed at the same time near relatively degraded reefs off Waikīkī attracted virtually no herbivores (fishes or urchins) and became covered by dense algal and invertebrate turf.

3. Future Efforts

The DAR-CRN is embarking on a large-scale effort to restore reef substrate with large (40 – 80 cm) coral colonies derived primarily from small harbor corals fragmented and rapidly grown at the CRN. It is also interested in collaborative efforts with HIMB on re-establishing extremely rare, endemic coral species populations in Kāneʻohe Bay. Additionally, the CRN has initiated projects aimed at 'Seeding the

Reef' with sexual or asexually derived larvae and colonies. Currently NOAA is in the process of designing, building, and deploying several in-water coral nurseries around the island of O'ahu that will attempt to take advantage of naturally detached, but otherwise healthy, 'corals of opportunity'. These nurseries will need to house relatively large (20-40 cm) coral colonies, since corals in Hawai'i have relatively slow growth rates, and larger colonies may have a higher success/survival rate during outplanting activities. Robust structural design would be required to house larger colonies and withstand forces associated with currents and water motion from open ocean waves, therefore NOAA partnered with the University of Hawai'i's Mechanical Engineering Program to develop structural designs. Moving forward with these efforts requires collaboration among larger groups of coral researchers, federal and state agencies, non-profit organizations, the community, and other important stakeholders, therefore the formation of this working group is an important first step. In order to continue the momentum generated from this workshop, we recommend the formation of a working group with annual stakeholder meetings. We further recommend that future efforts increase the focus on economic feasibility and scalability.

4. Conclusions

Compared to regions like the Caribbean, coral restoration efforts in Hawai'i are not as abundant due to unique ecological and geographic characteristics, yet these efforts are rapidly proliferating and in need of coordination. This workshop leveraged the individual momentum that has recently been building in multiple agencies and organizations across the state. The partnering of key natural resource trustee agencies with academic and husbandry experts has resulted in a variety of reef restoration tools and capacity for the unique conditions in Hawai'i. The workshop was the first step towards increasing collaboration between the groups and the future hope is that additional workshops could improve communication on key shared priorities and challenges. This type of collaboration will be critical in coordinating the capacity of the Hawai'i coral restoration community of scientists and managers. Although restoration projects have been improving in design and implementation it is important that the focus remain on the underlying impacts to coral reefs. Management strategies must also address pollution, sedimentation, and climate change. Continued bleaching events or poor land management practices that impact reefs can quickly overshadow restoration efforts. Restoration efforts therefore must be coupled with management strategies and political impetus to understand and reduce the threats to these vital, yet fragile ecosystems.

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