Coral Restoration Consortium
Priorities for 2020-2025
Outcomes from March 2020 Leadership Team Meeting

The Coral Restoration Consortium Leadership Team met from March 3-6, 2020 in Playa Hermosa, Costa Rica. The primary objective of the meeting was to review the Coral Restoration Consortium's priorities which were last reviewed three years prior. Before the in-person meeting, over e-mail (i.e. blindly) we solicited ideas from all team members on the biggest challenges in coral restoration. The executive team then binned those challenges into the categories presented below for discussion by the attendees. These are the CRC's Priorities for 2020-2025. During the in-person meeting, each Leadership Team member selected the challenge they wanted to work on, forming small groups for each of the five challenges. Over the course of several sessions spanning one and a half days, these small groups listed the tasks necessary to solve each of these challenges.

The groups created exhaustive lists of tasks and the high-impact, short-term tasks are highlighted in this document. When a particular working group or individual is the clear owner of a task, the name of that working group or individual is explicated. Each Priority has its own color to aid navigation in the document. (Like the mall parking garage.) Tasks that were deemed outside the scope of the CRC, low impact, or not achievable within five years are listed at the end of each priority.

Coral Restoration Consortium Priorities for 2020-2025:

1. Develop and promote the use of standardized terms and metrics for coral reef restoration.
2. Increase restoration efficiency, focusing on scale and cost-effectiveness of deployment.
3. Scale-up larval propagation for its effective integration in coral restoration efforts, with an emphasis on recruit health, growth and survival.
4. Develop guidance that promotes a holistic approach to coral reef ecosystem restoration.
5. Develop guidance to ensure restoration of threatened coral species takes place within a comprehensive population genetics management context.
6. Develop new and synthesize existing resources to guide and support coral reef restoration practitioners working in diverse geographic locations.

Priority #1: Develop and promote the use of standardized terms and metrics for coral reef restoration

Need: Although ecological restoration has been around for decades, coral restoration is a relatively new sub-field. Research has shown that lack of common definitions slows the transmission of ideas and the adoption of new techniques. In order to increase the scale and efficiency of restoration, we must be able to communicate effectively. This entails identifying and defining commonly used terms, cross-walking among terms, establishing standard definitions when needed, and developing standard metrics with which to evaluate the success of coral restoration.

Tasks:

A. Define common terms for coral restoration and cross-walk among commonly used terms, keeping in mind that terms can be specific to restoration methods or geographies.
    1. Develop a group and choose a leader
    2. Coordinate with other groups / organizations / authors who have worked on similar topics (e.g. SER (Society for Ecological Restoration), Reef Resilience Network, Lisa Bostrom Einarrson's paper, National Academies of Sciences Reports, RRAP, Monitoring Guidelines, NESP report)
    3. List terms to define (e.g. best practice, Micro fragging, emergency restoration, units of management)
    4. Define terms and build glossary
    5. Conduct review with glossary using several lenses / angles (region, developing v developed nations, non-technical language, target audience)
    6. Add terms to CRC resource documents
    7. Determine best tactics for socializing (e.g. newsletter, webinar, reef futures packet) and format for publication
    8. Share, socialize, communicate with target audiences (scientist, managers, public)
    9. Develop plan for keeping the document up-to-date and relevant

Responsible Parties: This will be a sub-group of the Management WG. Several members of the Leadership Team that elected to work on this challenge at the meeting in Costa Rica, volunteered for the ad hoc group.

Timeline:

- Whitney will submit a written prospectus about forming the group prior to the 4/16 CRC Leadership meeting. The group will meet monthly and divide tasks.
- Planned completion date: May 2021.

Appendix: None.

B. Develop a menu of standard metrics to help evaluate the progress of coral restoration projects. Socialize the universal metrics already developed in the CRC's Monitoring Guidelines with various audiences (e.g. managers, CRTF, GCRMN, ACRC, AGRRA, Reef Check, Reef Life Survey) and determine if additional standardized metrics are appropriate.
    1. *By Fall 2020*: Make a summary version / 1 pager / infographic of the universal metrics. Host a webinar on the topic.
    2. *By Spring 2021:* Update RRN's online course module. Present at conferences, post on website, add to RF welcome packet
    3. Set an "extinguish by" date on the monitoring guidelines to ensure that there is a plan to update them on a regular basis. If it's a "living document" then, develop a plan to keep the document updated.

Responsible Parties: These tasks fall primarily under the Monitoring Working Group, but require assistance from others (e.g.communications experts)

Timeline: Completed before Reef Futures.

Appendix: Longer-term actions

4. *High priority*: Develop standard metrics for artificial reef structures
5. *Low priority*:
    - Build local capacity in analyzing coral restoration monitoring data according to standard metrics (e.g. host a datathon at RF)
    - Find a partner (e.g. MERMAID, AGRRA) and funding to build a data system built on standard metrics that can paint regional pictures
    - Determine if metrics are being used

Priority #2: Increase restoration efficiency, focusing on scale and cost-effectiveness of deployment.

Need: Currently, coral restoration is a labor intensive process. To restore reefs at a meaningful ecological scale, we must experiment with methods to increase the efficiency of restoration. Three primary ways we can do this (A) Increase the number of groups doing restoration, (B) Grow corals faster, and (C) Get corals to the reef faster. The primary bottle-neck is the time it takes to outplant a coral. No matter how a coral is grown, propagated, or gathered - the act of restoration means it is being placed in a new environment. Thus increasing the efficiency of outplanting is paramount to increasing the overall efficiency and geographic scale of coral restoration.

Tasks:

A. Optimize coral growth rate in nursery - evaluate the optimum size of stock for different species to ensure that growth is sufficient to replace outplanted stock in <1 year.
B. Deploy corals to the reef faster
    1. Experiment with methods to increase transplantation time until transplantation is 10x faster (need baseline)
    2. “Paloozafy” planting - get lots of volunteers on a particular day or weekend to do a massive outplanting.
    3. Improve coral adhesion (e.g. without having to clear substrate). IN PROGRESS Many researchers currently working on this via NOAA’s SBIR .
    4. Create a list of novel techniques to try in multiple places - for a controlled study.
C. Develop faster methods of attachment
    1. Re-skinnable substrates (e.g. biofilm)
    2. New substrates [Engineering Ad Hoc Group]
    3. Optimize attachment methods using a 6- sigma approach.
D. Enhance survivorship in nursery and post-transplantation
E. Enhance sexual reproduction in nursery-bred colonies while in nursery and following transplantation

Responsible Parties: Field-based, Land-based, and Larval Propagation Working Groups, Engineering Ad Hoc Group as noted above.

Appendix:
Lower priority items that fall under existing Working Groups:

- Field-Based WG:
    - Develop tangible exit plans in the event a restoration project fails and or money is lossed.

        - Improve division of labor in restoration operations
        - Build in production efficiencies and complementary efforts though the combination of land and field-based programs (e.g. larval corals, reared in a land-facility can be transferred as adults to a nursery program for production then outplanted to increase genetic diversity of field based programs).
    - Larval WG:
        - Develop a metapopulation design for reef restoration
        - Use larval pools to collect from outplant sites
        - Develop “recruitment” surfaces (e.g. paint, film, cleaned natural surfaces) to promote settlement and early growth stages.

Longer-term Actions:

Dedicated mentor program and continued education (e.g. such as that of Corales de Paz)
Use our networks to socialize coral restoration (use social institutions, work w/spiritual organiza
Understand local incentives for involvement
Foster watershed associations
Sustainable restoration financing that kicks-in when goodwill has reached its limit.
Increase efficiencies in how to transport corals
Create more nurseries
Start with initial large population to increase numbers over time.
Stakeholder driven, practitioners give needs list. Restoration should be stakeholder driven.
Robotics.
Low tech, highly scalable
Metapopulation design
Higher survivorship for smaller outplants
Use larval pools to collect from outplant sites.
Grow corals faster and at a larger scale.
Develop high tech options and low tech deployable.
Drop billions of corals out of helicopters.

Franchise approach (McDonalds)
Work with profit companies

Priority #3: Scale-up larval propagation for its effective integration in coral restoration efforts, with an emphasis on recruit health, growth and survival.

Need: To upscale larval propagation, we first need to increase the effectiveness of outplanting recruits, by increasing their health, growth, and survival. To upscale these activities, we then need to work with more coral species, at more locations, with more people and at larger spatial scales. Most of the work on larval propagation to date has focused on broadcast spawning species; however there is a strong need to develop methods for both brooding and broadcast spawning species.

Tasks: The tasks below apply to brooders and broadcast spawners. For this priority action the high impact, tasks that could be accomplished over the next 1-2 years divided easily among existing CRC Groups. There are an additional ~30 tasks that were identified as lower priority, not appropriate for the CRC, or longer than 1-2y. Those are listed in the appendix below.

Responsible Party: Larval Working Group

A. Develop list of research priorities
B. Upscale accessibility to training and improve coordination of methods/technology to diversity of skills/access
C. Develop site selection criteria for spawning hubs, larval outplanting (for broadcast spawners)
D. Create appendix to Monitoring BMPs for larval recruitment [with Monitoring WG]
E. Identify criteria for broodstock selection and creation
F. Develop plan for larval to asexual propagation lifecycle (allowing natural selections)
G. Develop protocol for stress testing progeny (land-based or on reef)

Responsible Party: Land-based Working Group

H. Develop live bank criteria/guidance
I. Increase capacity for land-based spawning
J. Develop guidance/protocols for off-cycle spawning

Responsible Party: Cryopreservation Ad-hoc Group

K. Develop criteria to use cryopreserved material (which species/who gets to use)
L. Use cryopreservation to assist AGF
M. Use cryopreservation for genetic preservation (sperm/tissue)

Responsible Party: Genetics Working Group

N. Issue guidance that every coral used in propagation should be genotyped based on a standardized methodology
O. Identify site selection criteria for collection of AGF sourcing

Appendix: Longer-term Actions

Upscale methods/technology mobile for use in remote locations
Training (larval propagation/cryopreservation)
Develop LOTS of sites (in situ/ex situ) working on larval propagation (R2O)
Develop genetic registry database
Identify site selection criteria for larval outplanting - Prepare & maintain reef substrate to enhance survival and health
Identify locations and create spawning hubs for research, assisted fertilization, and natural reproductions (e.g Plant a Million corals lab containers)
Research Priorities:
Determine genet age influence on reproduction and early life history of offspring (multiple species/locations)
Quantify maternal effects on fitness (eg. egg quality) to develop recommendations for selection of moms
Develop advanced technologies for collection of gametes (esp for gonochores)
Track larvae oceanographically after spawning (eDNA)
Develop methods to cryopreserve new species & make available
Use model organisms (non-coral) to rapidly develop and practice cryopreservation protocols
Characterize cryptic species (tools to differentiate)
Develop direct seeding to reef methods
Investigate fitness and appropriate use of hybrids
Conduct larval recruitment/health treatments (food, temperature, symbiont/microbiome infection)
Optimize methods for infection of larvae with beneficial symbionts (algae, bacteria, etc)
Identify locations of natural sexual reproduction (spawning) for target species at a regional scale
Characterize locations with natural recruitment
Conduct life history research and observations for unstudied species to develop resource for larval propagation
Identify why X species in not naturally recruiting even in places with appropriate substrate
Conduct experiment for get larvae to settlement stage through multiple treatments: clean substrate, hydrodynamics, etc...to help answer where do the larvae go?
Develop "surfaces/structures" (including green/gray) that enhance survival and prohibit detrimental growth
Develop methods/technologies for deployment at multiple scales

Priority #4: Develop guidance that promotes a holistic approach to coral reef ecosystem restoration.

The need: Coral reef restoration has focused on the growing and planting of coral animals. This is logical as corals are the foundational builders of the coral reef ecosystem. However, the coral reef ecosystem is complex and rebuilding a functioning ecosystem can involve more than replacing the corals themselves. Furthermore, future reefs will be subject to different circumstances than historic reefs or current reefs. There is a need for guidance on how to restore a functioning coral reef ecosystem that will be resilient to current and future biophysical challenges.

The tasks:

A. Facilitate community recovery

1. Develop a road map for how to do coral restoration with an eye towards full coral reef ecosystem recovery through time.
2. Provide guidance on herbivore restoration (e.g. urchin, crab)

B. Preserve biodiversity

1. Develop guidance for possible coral species extinction. Prioritizing species for preservation versus possible extinction may become necessary soon in the Pacific. Ensure taxonomic diversity and functional redundancy in places where prioritizing.
2. Develop triage plans.
3. Genetics & Larval WGs - Promote AGF, Assisted Migration, Focused Breeding and Propagation
4. Cryopreservation, Genetics, Land-based WGs - Preserve species in cryo-, gene-, and live-banks (aquaria)

Responsible Parties: Cryopreservation, Genetics, Land-based WGs have been identified for two tasks. No responsible parties have been identified for providing guidance on herbivore restoration, prioritization processes to manage extinction, or triage plans. The whole priority may nest under the Field-based WG.

Appendix:

Lower priority and outside the scope of CRC: Improve existing criteria for site selection (e.g. for large scale restorations - consider source-sink dynamics and climate refugia (or ID this as a research need))

Outside the scope of the CRC:

- Measure biodiversity
- ID cryptic species (complicated by IDing sps and genera using molecular tools and the ever shifting classification of corals)
- Develop guidelines for protecting sites, and intervening in the environment if necessary

Priority #5: Develop guidance to ensure restoration of threatened coral species takes place within a comprehensive population genetics management context.

The Need: Unfortunately, many of the world's coral reef ecosystems were built by species that are now at low abundances and in need of strategic and thoughtful population management in order to use them in restoration going forward. Consideration must be taken to maximize the remaining genetic diversity to allow for successful sexal reproduction, adaptation, and recovery of these populations so they may once again be the foundation of the coral reef ecosystem. Sound guidance is necessary to ensure that population management plans are developed with appropriate genetic (including epigenetic), propagation, husbandry, and environmental considerations.

The Tasks: Create a Population Management Planning WG that will do the following:

A. Develop Population Management Planning guidance (who, what, when, where, why)
B. Develop fast pipeline to translate research to operations - "Six Sigma"
C. Develop easy pipeline for genotyping and getting results
D. Develop framework for coordinate data structure (either a giant database or integration plan to access multiple databases)
    1. Track ancestry of broodstock and outplant stock, phenotypes of known genets
    2. Leverage/develop bridges to tech community to provide analytics for this massive data
E. Develop cheap tools for monitoring environmental parameters
F. Develop a customer support line (phone a pop geneticist, practitioner)
G. Advertise research needs
    1. Develop high resolution/fine scale hydrodynamic models across the world to assist in site selection
    2. Conduct monitoring of genetic and genotypic diversity of small populations
    3. Develop diagnostic tool for distribution of expression of important traits
    4. Understand functional redundancy

Responsible Parties: New Working Group
Appendix: None

Priority #6: Develop new and synthesize existing resources to guide and support coral reef restoration practitioners working in diverse geographic locations.

The need: In addition to the effort of producing guidelines and best practices for restoration, there also exists a challenge to get those restoration tools into the hands and use of practitioners for application. As a way to expand the geographic scope (and scale) of restoration, this priority creates a process to formalize methods for knowledge exchange, which is already a core part of the CRC mission, but until now, has not had a specific group/priority assigned to take action.

The tasks:

A. Target communications at the community level, coupled with national and international levels in terms that are relevant to those groups.
    1. Create communication packages for different audiences (various levels of government and practitioners)
    2. Provide resources for effective stakeholder engagement
    3. Engage with stakeholders to create a “license to operate”

B. Increase access to in-person training
    1. Compile list of existing trainings
    2. Convene, organize, and support regular (e.g. every 6 months) in-person trainings, including post-training mentorship and follow-up
    3. Standardize training protocols

C. Identify what tools and resources exist and how they are being used.

D. Host Reef Futures Symposium.

E. Increase the number and capacity of groups around the world who do restoration
    1. Work with dive community (e.g. Alert Diver, Green Fins) to recruit responsible divers
    2. Create a certification for a travelling diver - restoration passport (e.g. Corales de Paz’s reef restoration continuing education for divers)
    3. Provide basic tool sets (e.g. BMPs) to guide and encourage practitioners.
    4. Identify and develop tools that allow existing organizations to scale-up their restoration capacity.

Responsible Parties: Needs a standard or Ad hoc WG. At some scale, Corales de Paz is already working on this with training and programs. Phanor may be interested in Chairing/Co-Chairing. Key people here are Nathan Cook, Andrew Taylor and others already providing training on reef restoration.ICRI (Ian McLeod), UNEP (Margaux Hein) and RRAP Stakeholder Engagement subproject, (Bruce Taylor) would be useful contacts for this work. RRN is a given.

Appendix: None.