



K. Nedimyer

Workshop Report

Planning for Coral Reef Restoration Research, Best Practices, and Implementation of Aquarius Coral Restoration/Resilience Experiments (ACRRE)

Coordinated and Hosted by:

- NOAA Fisheries- Southeast Fisheries Science Center
- NOAA Coral Reef Conservation Program
- NOAA Florida Keys National Marine Sanctuary (FKNMS)
- NOAA’s National Undersea Research Center at University of North Carolina - Wilmington (NURC/UNCW)

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EXECUTIVE SUMMARY

Coral reefs around the world are declining, including in the Caribbean and Florida Keys where cover has decreased dramatically starting in the late 1970s. Marine Protected areas (MPAs) have been established within the Florida Keys to manage multiple uses and set aside specific sites for special use and enhanced protection. Restoration techniques utilizing coral culture and transplantation have been applied to a limited extent in the Florida Keys and elsewhere around the region to repair acute damage done by incidents such as vessel groundings. It is hoped that restoration practices can ameliorate site specific coral damage within the context of wider-scale ecosystem restoration and protection. The Aquarius Reef Base program (ARB), located in an MPA off Key Largo, FL, and NOAA Fisheries received funding to support a dedicated saturation mission (the Aquarius Coral Restoration and Resilience Experiments, or ACRRE) to address restoration management needs through scientific research. A workshop was held in August 2007 to address the following questions identified by the Florida Keys National Marine Sanctuary as priorities for managers:

- *What are management needs and priorities related to coral restoration via culturing and transplantation?*

- *What are required studies and related technical needs required to address these management priorities?*
- *How can the ACRRE mission best fulfill some of these study needs and complement existing programs?*

Priority recommended objectives and related actions included:

- Establish standards and best practices for culturing and transplantation (ACTION: Create ongoing working group to pursue continued discussion of genetics and health guidelines)
- Improve communication, coordination and integration of on-going and new restoration efforts (ACTION: Develop template to go into database for regional projects and techniques; piggyback onto summary of coral reattachment techniques developed by the NOAA restoration center)
- Support a number of research and management efforts including:
 - A synthesis of techniques being used, their cost, and success rate;
 - Studies that build on previous data, fill gaps and provide information on biological and ecological controls/processes in coral reef ecosystems as it pertains to restoration practices, recruitment success and limitations, and how restoration success or failure is related to physical and chemical ocean conditions.
 - Studies that seek to understand genetic population structure including the possible existence of ‘ecotypes’, resilience and restoration success.
 - Genetic surveys of target species, such as *Acropora cervicornis*, throughout south Florida region, which is spatially explicit, to create a catalog of genetic diversity and describe geneflow patterns
 - Development of established experimental approaches related to, e.g., recruitment, disease, husbandry, and ecotype resilience.
 - Studies to acquire information on performance differences between wild versus lab cultured transplants.
- ACRRE project should focus on assessing performance of differently sourced-corals (ACTION: Establish working group to further refine experimental design and integrate with other active restoration efforts in Keys).

BACKGROUND:

Coral reefs around the world are declining, including in the Caribbean and Florida Keys where cover has decreased dramatically starting in the 1970s (Gardner et al. 2003¹). There is also concern that natural populations have lost their resilience and natural ability to recover from disturbances, such as storms or human impacts (Jackson et al. 2001²). The decline has been accompanied by an increase in sponge and algal cover, further hindering recovery by making it difficult for new coral recruits to find suitable substrate (Hughes, 1989³).

NOAA's Coral Reef Conservation Program (CRCP) identified the most important restoration objectives for the next decade in a 2005 report to Congress (http://www.coris.noaa.gov/activities/reportcongress2005/chap9_restoration.pdf), including:

- Review and evaluate existing reef restoration projects to quantify the benefits gained by the restoration effort and expenditure of the restoration compared to scenarios in which no restoration efforts were undertaken and make recommendations for improvements.
- Develop and test innovative methods and techniques to expedite reef restoration for all major categories of coral reef injury using a hypothesis-driven approach that involves rigorous, quantitative evaluation.
- Develop regional restoration plans that identify significant restoration alternatives and weigh the costs and benefits of natural recovery compared with restoration alternatives.
- Promote cost-effective pilot restoration of selected degraded U.S. reefs, focusing on habitats of high ecological, economic, and social or conservation value.
- Rehabilitate degraded fish habitat through the deployment of artificial structures and rapid, inexpensive transplant methods.
- Transfer proven restoration tools, techniques, and lessons learned to domestic and international partners.

NOAA's *Coral Reef Ecosystem Research Plan* for 2007-2011 (http://coris.noaa.gov/activities/coral_research_plan/) includes management objectives and research needs related to coral restoration in the Florida Keys. These priorities target key species, including acroporids, and encourage pilot efforts to restore degraded reef habitat through a variety of techniques, including vigilance regarding protocols and possible negative consequences of restoration efforts.

¹ Gardner TA, Cote IM, Gill JA, Grant A, Watkinson AR (2003) Long-term region-wide declines in Caribbean corals. *Science* 301:958–960.

² Jackson JBC (2001) What was natural in the coastal oceans? *Proc. Natl. Acad. Sci. USA* 98:5411–5418.

³ Hughes TP (1989) Community structure and diversity of coral reefs: the role of history. *Ecology* 70:275–279.

The FKNMS and other regional coral management interests have immediate concerns and questions regarding the application of coral restoration approaches and possible consequences. The improved capacity in fragmentation and culture of important reef building corals and the implementation of coral ‘rescue’ as a mitigation measure for various projects by a wide range of institutions and individuals (including FKNMS, Biscayne National Park, Mote Marine Lab, K. Nedimyer, NCRI in Broward County among others) have greatly increased the potential supply of coral transplant material in the Florida Keys region. With greater availability of transplant material via these rescue efforts and greater success in the active culturing of corals, also comes additional questions regarding the appropriate use and fate of coral stocks in field- or land-based holdings. Two high priority questions for managers include:

- 1) What are the ‘best practices’ for husbandry and attachment (e.g., maximizing growth, productivity, and recruitment success in the nursery and transplant setting)?; and
- 2) What are appropriate and best uses for these corals?
 - Is it appropriate and beneficial to transplant them, and over what scales? That is, what is the appropriate ‘propagule transfer zone’ (a largely genetic question).
 - Does the transplant of lab culture/nursery colonies to field populations pose health risks associated with changes in the associated microbial communities in these different environments?

Many management and science stakeholders have also expressed the dire need for long-term evaluation of coral performance (transplants or ‘natives’) through cycles of ecosystem disturbance, such as bleaching or disease events, along with simultaneous monitoring of environmental parameters to better understand cause and effect. To be of most benefit, however, long term observations need to be of sufficient temporal resolution to accurately assess causes of change.

FKNMS and state managers now face decisions regarding appropriate transplant strategies. Meanwhile, the NOAA Fisheries Service is also currently focused on developing a “Recovery Plan” for the Atlantic *Acropora* spp. corals recently listed as Threatened under the Endangered Species Act. Related questions regarding these specific species are also relevant under NOAA’s ESA legal mandates, for example: what are the best ‘rescue’ and husbandry techniques, and what scales/sources of transplantation are most appropriate and effective, and are there ways to enhance husbandry efforts?

AQUARIUS CORAL RESTORATION AND RESILIENCE EXPERIMENTS (ACRRE):

NURC/UNCW obtained limited funding from the CRCP to design and pursue an intended long term Aquarius Coral Restoration/Resilience Experiments (ACRRE) program based at the Aquarius Reef Base (ARB), Carpenter Basin/Conch Reef off Key Largo, FL (Figure 1). Based on discussions

with FKNMS managers (and confirmed by the outcome of the workshop discussions), ACRRE will seek to address aspects of the above culture/transplant questions. In addition to its location in an MPA (FKNMS “Research Only Area”) on the outer reef tract, ARB is well equipped to serve many of these objectives. In addition to the Aquarius undersea lab (Figure 2), the world's only seafloor lab where scientists live and work for weeks per mission, the ARB includes:

- Aquarius Coral Reef Observatory (ACRO) that measures physical, chemical and optical properties (real-time data stream at <http://www.conchreefdata.net>);
- Telecommunications system (Figure 2) capable of sending up to 155 Mbps of real-time data to the Web, including a variety of in situ Webcams (live video at <http://www.uncw.edu/aquarius>);
- Dive support team on site for over 280 days per year; and
- Shore base with dorms, labs, boats, and dive locker 20 min. from Conch Reef.

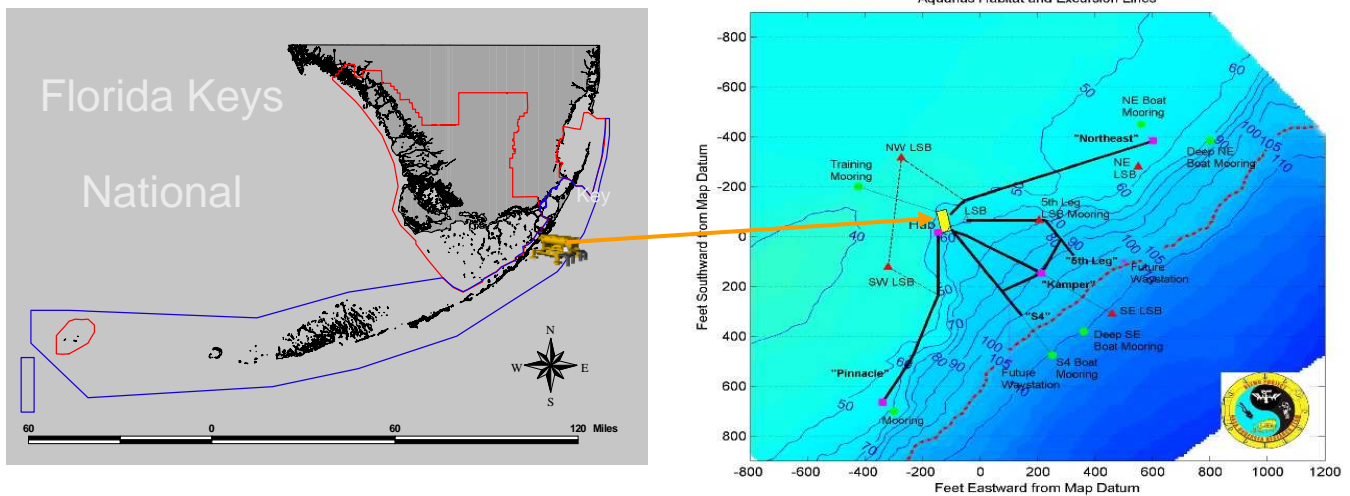


Figure 1. ARB is located in the Florida Keys National Marine Sanctuary at the base of Conch Reef.

Although the ARB is situated at a deeper depth (20 m) than most traditional reef restoration projects (e.g., former Keys grounding sites), applicable results can be obtained by designing and executing the major, long-term experiments with ARB support (aquanaut excursions, shore support, dive access, real-time observing and monitoring) at depths of greater than 14 m, while running complementary experiments at adjacent shallower depths, where *Acropora* were once abundant and to ‘calibrate’ deeper results. ARB is also well suited to establish a long-term experimental testbed for restoration practices and related research projects, especially in terms of having ongoing ocean observations, year-round access to the site, and periodic intense operational access via saturation missions.

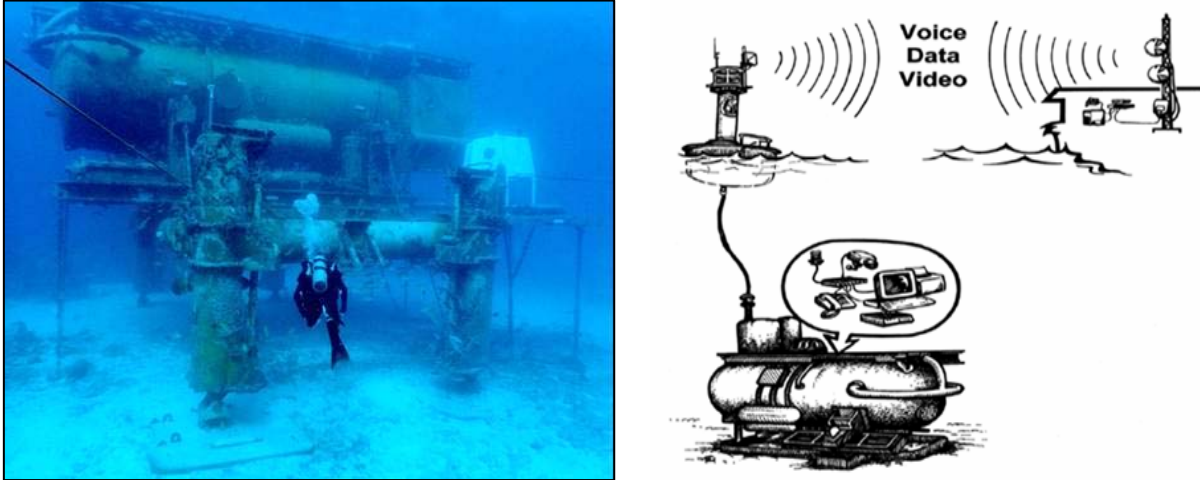


Figure 2. Left—Aquarius undersea lab on bottom at Conch Reef. Right—schematic of real-time telecommunications via the Aquarius Reef Base Life Support Buoy.

Based on workshop consensus, a common garden approach to determine the performance of differently sourced corals was recommended as a focus for the ACRRE mission, keeping the following in mind:

- Conduct continuous, fine-scale observations of coral status, associated reef assemblage, and environmental parameters using ARB observatory capabilities
- Use ecologically meaningful units (colony sized) and wide variety of genotypes
- Make use of day boat operations up front and follow on
- Strengthen statistical design, e.g., by using randomization to account for variability and appropriate controls, and using standard transplant unit size
- Utilize depth gradient

It was also deemed a high priority to set up a working group to design the experimental approach to be used and to examine what other research questions could be addressed during the mission and in continued efforts.

RESTORATION WORKSHOP:

Based on the current and immediate challenges facing Keys managers regarding the possible use of coral transplants, a planning workshop was held with scientists and managers in Homestead, FL, on August 22-23, 2007, to address the following questions:

- *What are management needs and priorities related to coral restoration via culturing and transplantation?*
- *What are required studies and related technical needs required to address these management priorities?*
- *How can ACRREs mission best fulfill some of these study needs and complement existing programs?*

Thirty-two invited participants included scientists and managers from various agencies and institutions within the south Florida region with specific restoration responsibilities and/or on-going restoration projects in the Keys (**Appendix A**). The agenda (**Appendix B**) included plenary talks that featured some of these projects, and breakout group discussions designed to answer the above key questions.

Priorities and Proposed Actions:

Recommended priorities and proposed actions were proposed related to the three meeting questions listed above (**Table 1**). Complete notes from the working groups and final plenary discussion that led to Table 1 are included in **Appendix C**. Although Table 1 attempts to summarize the key findings, it is important to look at the notes in Appendix C to get the full scope of concerns, priorities and recommendations discussed.

Discussions repeatedly returned to the important distinction between smaller scale, site-specific restoration versus ecosystem restoration. Managers and scientists do not want to suggest to the public that restoration as now practiced is the answer to reversing the decline of corals throughout the Florida Keys, especially given the current state of understanding of the causes of this decline (i.e., complex and to some degree global in scale) and restoration science. Thus, the workshop focused on recommendations related to the more tractable applications of coral transplantation and culture methods for dealing with acutely damaged, degraded or injured sites, while recognizing the connectivity and complexity of the coral reef ecosystem and emphasizing the overarching need for ecosystem-wide approaches and solutions. However, consensus of the workshop participants was that restoration activities using culturing and transplant techniques should be cautiously pursued within a context of larger, ecosystem-wide restoration efforts.

RESTORATION WORKSHOP REPORT, August 2007, Homestead, FL

Table 1. Priorities and related proposed action items. * = identified as high priority action.

Q#	Priority Need	Proposed actions
1	Standards and best practices for culturing and transplantation including: <ul style="list-style-type: none"> Genetic and Health Guidelines – species specific Define “Propagule transfer zone” – species specific Experimental framework for site specific restoration within damaged as well as degraded sites What is the best use of corals of opportunity? Legal issues? Performance measures of success – project specific Effective tagging and tracking of coral in situ and ex situ (International workshop in February 2008) 	<ul style="list-style-type: none"> Literature review and survey, synthesis and translation (e.g. MS thesis) Look at IUCN guidelines *Create ongoing working group to pursue continued discussion of genetics and health guidelines.
	Improved communication, coordination and integration: <ul style="list-style-type: none"> Of information for managers and regulators (e.g. standard formatting, criteria for applying, and science based criteria for permitting) Of previous results and ongoing projects Careful tracking of genetic material and where transplants take place Possible clearinghouse or database Information linked with permitting Zoos and aquaria creating Genetic Banks 	<ul style="list-style-type: none"> *Develop template to go into clearinghouse, project database and techniques (piggyback onto summary of coral reattachment techniques – NOAA restoration center) Coral list serve specifically on restoration Make use of ICRS Mini Symposium on Restoration Encourage publication in peer-reviewed literature *Create an ongoing working group for adaptive strategies, FWC lead *Make this a priority for funding
	Additional funding and resources	
	Cost-benefit analysis for research and techniques	<ul style="list-style-type: none"> Include query in project template sent to investigators
	More information on biological and ecological controls/processes on coral reef function, recruitment success, relationship to environmental parameters (for both site specific and wider-scale, in addition to what is already known)	<ul style="list-style-type: none"> Emphasize in ongoing research
	Need to understand genetic populations, resilience, and ecotypes	
2	Genetic survey of specific target species throughout south Florida region, which is spatially explicit, creating a catalog of genetic diversity	<ul style="list-style-type: none"> Leverage Florida Reef Resilience Project, SECREMP, SCREAM, CREMP, and other ongoing survey projects Sampling protocol needs to be designed, could also use for disease
	Develop experimental approaches, including: <ul style="list-style-type: none"> to investigate scale and distance issues to enhance recruitment (larval supply and survival) to study and screening of disease/syndromes to advance husbandry to accelerate biological recovery to determine ecotypes that do well in certain conditions to assess effects of coral density, size and timing of translocation to define optimal assemblage of species to determine species succession to describe microbial community dynamics to determine zooxanthellae clades 	<ul style="list-style-type: none"> Foster opportunities to investigate these issues experimentally (e.g. ACRRES) Look into World Bank coral program, Disney World Wildlife Fund, UNEP Apply to NOAA Coral Reef Program

RESTORATION WORKSHOP REPORT, August 2007, Homestead, FL

	Additional information on performance and differences of using wild versus lab cultured transplants, including microbial communities	<ul style="list-style-type: none"> • Incorporate into ACRRES program • Use current coral caches to investigate microbial populations (e.g MS thesis)
	Study of ecological and biological drivers of the system	<ul style="list-style-type: none"> • ACRRES and other projects
	Need to closely monitor environmental variables in close conjunction with transplantation and restoration monitoring related to success or failure	<ul style="list-style-type: none"> • Integrate with FL COOS as a client or user, other project collecting plankton/DNA (USF) • Develop an <i>in situ</i> sensor package for use in restoration sites (temperature, salinity, turbidity, nutrients, chlorophyll, ADCP, oxygen, UV, pH, PCO₂, surge intensity)
3	<p>Priority ACRRE objective is to determine performance of differently sourced corals; recommendations include:</p> <ul style="list-style-type: none"> • Conduct continuous, fine-scale observations of coral status, associated reef assemblage, and environmental parameters using ARB observatory capabilities • Use ecologically meaningful units (colony sized) and wide variety of genotypes • Make use of day boat operations up front and follow on • Strengthen statistical design, e.g., by using randomization to account for variability and appropriate controls, and using standard transplant unit size • Utilize depth gradient • Study microhabitat differences using mini-restoration modules • Determine influence of density, assemblage, herbivores • Determine how size and density attracts fauna • Monitor disease • Look at how genetic composition influences structure of communities associated with experimental plots 	<ul style="list-style-type: none"> • *Establish Working Group on experimental design • Integrate with TNC project, and work of Dana Williams (include them on WG).
	Integrate previous research activities and results into plan	<ul style="list-style-type: none"> • Review historic change at Conch Reef; create related publication
	Develop phased approach and flexible enough to integrate emerging issues	<ul style="list-style-type: none"> • Develop plan for long-term restoration test bed • Look towards having a parallel effort in Puerto Rico
	Incorporate active outreach and education, e.g., Web-camera on plots, interactive involvement of students and teachers	<ul style="list-style-type: none"> • Have education specialist on working group, also TNC/Ken N representative • Highlight restoration heroes and successes • Link up with ICRS meeting and International Year of the Reef, FL Oceans Day

APPENDIX A: WORKSHOP PARTICIPANTS

Workshop Participants, 8/22-23/07:

WG: # = group 1, 2, or 3; F = facilitator, R=recorder

WG	Last	First	Affiliation	email	Phone
1	Baums	Iliana	Penn State Univ.	ibb3@psu.edu	814-867-0491
1	Bergh	Chris	The Nature Conservancy (TNC)	cbergh@TNC.ORG	305-745-8403
	Bourque	Amanda	National Park Service-Biscayne NP	Amanda_bourque@nps.gov	305-230-1144 x3081
2	Brooke	Sandra	Ocean Research & conservation Assoc.	sbrooke@oceanrecon.org	727-415-0032
3	Callahan	Michael	FL Fish & Wildlife Conservation Commission (FWC)	Michael.Callahan@MyFWC.com	727-896-8626
1	Capo	Tom	Univ. Miami	tcapo@rsmas.miami.edu	305-421-4941
3	Curry	Richard	Biscayne National Park	Richard_curry@nps.gov	305-230-1144 x3006
3	Donahue	Scott	FL Keys National Marine Sanctuary (FKNMS)	Scott.donahue@noaa.gov	305-809-4689
2	Gregg	Lisa	FWC, Div. of Marine Fisheries Management	lisa.gregg@fwc.state.fl.us	850-487-0554
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3F	Miller	Margaret	NOAA/NMFS/SEFSC	Margaret.miller@noaa.gov	305-361-4561
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3	Moore	Tom	NOAA/NMFS/Restoration	Tom.moore@noaa.gov	727-551-5716
3	Moulding	Alison	NCRI/Nova SE Univ.	moulding@nova.edu	954-262-3677
3	Nedimyer	Ken	SeaLife Inc.	sealife@bellsouth.net	305-942-3250
	Patton	Glenn	Sanctuary Friends	glenn@sanctuaryfriends.org	305-451-4891
All	Prager	Ellen	NURC/UNCW	pragere@earthlink.net	305-720-7070
1R	Puglise	Kimberly	NOAA Undersea Research Program	Kimberly.puglise@noaa.gov	301-734-1007
1	Ritchie	Kim	Mote ML	Ritchie@mote.org	941-388-4441
3R	Rutten	Otto	NURC/UNCW	rutteno@juno.com	305-451-0233 x202
2	Schittone	Joe	NOAA/NMSP	Joe.Schittone@noaa.gov	301-713-7265
2R	Schull	Jen	NOAA/NMFS/SEFSC	Jennifer.schull@noaa.gov	305-361-4204
1F	Score	Dave	Florida Keys NMS	David.a.score@noaa.gov	305-809-4696
2F	Shepard	Andy	National Undersea Research Center - UNCW	sheparda@uncw.edu	910-962-2446
3	Vaughan	Dave	Mote Marine Lab	dvaughan@mote.org	305-745-2729
1	Walczak	Joanna	FDEP Coral Reef Conservation Program	Joanna.Walczak@dep.state.fl.us	305-795-2111
1	Yanong	Roy	UFL/FL Aquarium	rpy@ufl.edu	813-671-5230 x104

APPENDIX B: WORKSHOP AGENDA

August 22-23, 2007, National Park Service Krome Training Center, 950 N. Krome Ave., Homestead, FL

August 22:

- 0900: Andy Shepard-- Welcome
- 0905: Margaret Miller-- Meeting Purpose
- 0915: David Score-- Sanctuary Nursery/Transplant Efforts and Plans
- 0930: Ken Nedimyer/Chris Bergh-- *A.cervicornis* nursery and transplant project
- 1000: Richard Curry AND Amanda Bourque-- Biscayne NPS field nursery efforts
- 1020: Tom Capo-- Coral Lab Culture (especially *A. cervicornis*)
- 1040: Break
- 1100: Dave Vaughn-- Mote Marine Lab team, Coral culture, transplants and restoration efforts
- 1120: Alison Moulding-- NCRI/Broward County nursery/transplant
- 1140: Tom Moore-- Puerto Rico restoration efforts
- 1200: Iliana Baums-- 'State of the Science' of coral restoration genetics
- 1220: Lunch; Ellen Prager-- Aquarius Reef Base
- 1330: Margaret Miller-- 2008 ACRREs mission
- 1350: Ellen Prager-- Breakout Group process
- 1420: Breakout group discussions
- 1630: break:
- 1700: Breakout group reports
- 1745: Adjourn

August 23:

- 0900: Summary of breakout group reports and open forum discussion
- 1045: Roy Yanong, U. of FL-- FL Aquarium health, genetics and restoration program
- 1100: Action Items
- 1200: Adjourn

APPENDIX C: DISCUSSION NOTES

Blue team notes.....12
Red team notes.....14
Yellow team notes16
Final plenary notes.....18

BLUE TEAM:

Facilitator- D. Score, Recorder- K. Puglise

Management Needs:

- Must consider scale:
 - Do we know enough to consider large scale restoration?
 - Are small scale efforts worth cost?
- Need to define measures of success (performance metrics):
 - Accelerated recovery towards full ecosystem function
 - Look to marsh and terrestrial system efforts, how differ from marine systems?
- Species specific approaches including genetics and habitat considerations.
- Determine limitations to reef injury recovery using biological restoration.
- Priority need to determine methods which accelerate recovery of both injured and naturally degraded reefs.
- Tracking (history) of coral colonies used for restoration, culture, and transplantation.
- Best practices for use of corals of opportunity, cached and cultured corals; Species specific.
- Need cost documentation for genetic typing.
- Need sampling design to validly type a reef and deal with genetic variability.
- Use of in situ cultured corals:
 - Microbial concerns
 - Bottlenecks
 - Disease introductions to wild.
- Best practices for handling corals that may improve or hinder restoration success.
- Must determine what efforts can be approved and permitted now—conditions for approval:
 - Require rigorous experimental designs
 - Species specific
 - Limits on use of artificial substrata that litter or have potential toxic effects.

ACRRE:

- Integrate project with TNC program, e.g., use same genotypes.

- Enhanced observing and monitoring for episodic disease events.
- Use day boat operations prior to sat missions to acclimate specimens.
- Use variety of genotypes, including from wild, lab and nursery sources.
- Integrate with D. Williams work in Upper Keys.
- Use and monitor un-manipulated controls.
- Consider microhabitat factors including T, S, turbidity, DO.
- Regarding genotype success experiment, plot composition will influence community structure; consult Peter Glynn and Nancy Knowlton.
- Use ecologically functional units.
- Add size class component to experimental design.
- Focus on depth gradient as important factor in design; maximizes benefit of ARB.
- Be sure to randomize design to strengthen statistical power of experiments; important considering environmental variability that will be encountered.

SUMMARY OF PRIORITIES:

Management Needs:

- Lack of information and understanding:
 - Experimental designs to accelerate community recovery
 - Review NURC 1993 report and recommendations.
- Species specific approaches:
 - Prioritize species for restoration, including genetics, habitat considerations, reproductive biology.
- Tracking of corals used in transplantation and related experimentation:
 - Create standards and protocol
 - Initiate clearinghouse and database.
- Best management practices for use of corals and project designs:
 - Species specific
 - Target use of lab corals in wild
 - Document costs for genetic typing, mitigation and restoration work
 - Monitoring and research activities.

Research Needs:

- Disease screening techniques.
- Advanced experimental husbandry and gardening techniques:
 - Substrate preference studies
 - Methods to accelerate and enhance recruitment success.
- Controlled studies on transition from lab stock to wild, e.g., microbial associates, disease susceptibility.

RED TEAM:

Andy Shepard (facilitator), Jennifer Schull (recorder), Kiho Kim (reporter), Sandra Brooke, Joe Schittone, Lisa Gregg, Jennifer Moore

<i>What are management needs and priorities related to restoration via culture and transplantation</i>	<i>What are the required studies and related technical needs to address management priorities?</i>	<i>How can ACRREs mission address knowledge gaps and compliment existing programs</i>
need for synthesized document with best practices for culture & transplantation techniques	poll researchers and compile data/literature (gray and peer reviewed) as to what works and what doesn't and why	ACRRE contract could require a literature review of best practices that will be used as part of this project
		Attachment techniques are not a high priority for aquarius - use something that is tried and true and that works
Permits: Information to facilitate permitting process for local, state, and Federal AND need for standardized permitting process for all managers to adopt... Genetics and Health (disease considerations, disease transport from relocation and culture, associated microbial community).	Develop coral genetic and health policies. Collect data necessary to delineate transfer zones (and increasing specifics of genetics/health policy) by species and provided to permitters, we could streamline permitting process for these types of activities	N/A
	create database for researchers/managers to track restoration/transplantation activities across the region	N/A
	Formulate genetics tracking/gene-banking protocol for restoration activities	N/A
understanding whether environmental and/or genetic factors are contributing to the "resilience" of corals		Take "resilient" corals from several different areas and put them together in the same area and see how they do under controlled environments (probably non-fragmenting, non brooding deeper water corals for experiment)
Most groundings, hundreds per year, are in very shallow water 1-2 meters	What is the best way to do restoration in 1-2 meter water?	N/A
Why do some coral reefs and some species appear to be more resilient than others? Is it location, water quality, or genetics? What are the environmental conditions that contribute to successful restoration outcomes	Determine a suite of environmental parameters that may contribute to restoration success and deploy at various restoration sites and monitor coral success over time	Aquarius could be one site for monitoring; add nitrate/nitrite; phosphorus, UV, DOC, PCO2, pH
Does ecosystem restoration (including transplantation) have a greater effect on function and value of reef MORE THAN typical bandaid "structure" restoration activities without transplants; ie. Is transplantation a value added activity?	Density dependent ecosystem function - does density of transplants effect ecosystem function and community response? (measure fish, invertebrates, algal cover, disease etc)	transplant different densities of coral fragments and monitor reef health over time

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Can we experimentally manipulate the natural environment to make it a more attractive environment for natural settlement and growth and survival? Benefits natural settlement and growth and short term and long term survival.		Develop an array to prepare for coral spawning period- spawning plates, UV, electrical charges, etc...
Is it a good idea to transplant healthy corals into an unhealthy system?	Use healthy transplants to test whether the system is healthy and can support coral growth/survival	transplant coral fragments and put them up off the substrate in historical Acropora areas
Active Outreach and Education		Add teacher to aquarius mission
		Weblogs/livecams
		have students vote on how to structure a small portion of the experiment
		monitor your own coral in your coral garden (classroom can log in and check on progress of your corals)

Other management and science issues and questions identified included:

- Sanctuary Act has decided that restoration should occur for acute anthropogenic impacts (i.e. ship groundings)
- Sanctuary does not use appropriated funds for any restoration activities - they only use recovered funds to recover that specific site; CRCA reauthorization states you can use recovered funds for research
- FWC main concern is that statute and rules in place don't allow us to go into court to prosecute cases - lack of legal authority to recover damages/no monetary support for restoration activities
- Management goal is to restore damaged reef to original function and value - what is the best way to get there?
- Can we standardize metrics for coral restoration success?
- Are transplanted corals self sustaining at some point without maintenance (scrubbing and picking off predators)?
When?

YELLOW TEAM:

Facilitator- M. Miller

PRIORITY ISSUES:

- Now have increased culture capacity.
- Organisms change in lab setting.
- Keys ecosystem is severely degraded; are we ready to try things that we would not in pristine environment?
- We need best practices, e.g., use of concrete must be replaced.
- We need to understand why system is degraded.
- Research needs to be operationalized/translated for management.
- Need improved communication and coordination between programs.
- Need to take parallel strategies of 1) solve problems of why system is degraded and 2) develop methods for triage and repair (coral banking and culture).
- Solutions are long-term and have to commence.
- Can we promote recovery of natural system? Perhaps must focus on short-term, small scale projects (injury events) to best address the large scale ecosystem problem.
- Analysis paralysis/"build it and they will come."

MANAGEMENT NEEDS:

- Need best available science and translation for managers.
- Need best practices:
 - What are they and how do we determine?
 - Formal plan developed by multi-agency group
 - Guidelines for health and genetics
 - Review and build on work in other model systems.
- Outplanting-- Transplantation outside of injury areas; need controls/comparison in and outside event.
- "Do no harm" policy.

RESEARCH NEEDS:

- Genetic surveys for target spp.
- Can transplants be self-sustaining?
- Enhance natural recruitment—bottleneck of recruitment limitation versus adult mortality.
- Do cultured corals spawn?

ACRRE:

- Rigorous sampling design so treatments are equal.

- Cut coral specimens to standard equal size.
- Include size as treatment.
- Split genotypes between deep and shallow depths.
- Use PIT tags to track samples
- Are small pieces relevant for restoration projects?
- Keep experiment as simple as possible by reducing number of variables and taking phased approach.
- Emphasize outreach and education; use volunteers; target specific audience.
- Diadema “clean-up” crew.
- Measuring small growth increments and measure environmental variables at fine scale.
- Program must be longer than one-year to provide answers relevant to management.

FINAL PLENARY:

Facilitator- E. Prager, Recorder- A. Shepard

Discussion was driven by summary of breakout group reports prepared by Dr. Prager. Essential issues and actions are included in body of report.

MANAGEMENT NEEDS:

- Replace “distance for transplants” with “delineate propagule transfer zone.”
- All projects are species specific.
- Scale issue is a critical issue—event/injury versus ecosystem restoration; managers need to be honest brokers and not lead public on into thinking we can restore coral reef ecosystem in Keys at this time
- There was strong recommendation to focus on event restoration projects at this stage; continue research on applications for ecosystem restoration
- There is urgency in how do we use growing caches of corals available for restoration—there is likely more now available than is needed for just injury restoration projects.
- So, we should pursue both tracks—site-specific (injured, damaged, degraded) and experimental restoration projects that apply to ecosystem restoration
- Sole focus on site-specific projects overlooks complexity of problem we must deal with if we wish to scale up to ecosystem; clearly, all feel that this is ultimate goal, but we are not there yet
- Urgent question is whether study of degraded areas is waste of time and funds? Requires rigorous and robust experimental design.
- Final report needs to recognize both tracks.
- Improving communications and collaboration:
 - Standards for permitting
 - Database applications, e.g., tracking genetic materials (translocation and genotypes)
- Need more funding for restoration efforts:
 - USFWS Wildlife Foundation Fund
 - Census of Marine Life
 - Sanctuary Friends
- More scientific information is required:
 - Environmental conditions
 - Genetic populations and ecotypes
- Ex-situ banking; collaborate with Assoc. of Zoos and Aquaria; may be collaborator for working group to develop certified in situ culture methods.

RESEARCH NEEDS:

- Genetic surveys; establish genetic landscape; species specific and spatially constrained
- Collaborate with FRRP to conduct Keys-wide survey
- Required experimental approaches:
 - Diseases and syndromes—etiology and extent
 - Ecology of community assemblages in restoration projects
 - Larval studies and sampling program
 - Density, size and timing of transplants
 - Studies of community succession
 - Microbial community, including zooxanthellae clades

ACRRE:

- Transplant survival studies:
 - Add density and assemblage observations
 - Conduct herbivore studies
 - Monitor attraction of fauna
 - Determine diseases vectors, timing, and correlations
- Conduct review of historical change at Conch Reef as background for restoration.
- Sponges are key component of current ecosystem—key interaction to observe.
- Look for ways to coordinate various ARB studies with restoration work.
- Use phased experimental approach—keep variables to minimum.

ACTIONS:

- Assign working group or graduate thesis to conduct synthesis of on-going efforts and best practices.
- Work with National Center for Ecological Analysis (NCEAS) which specializes in working group exercises to develop proposed syntheses.
- Conduct literature review related to health, similar to Baums review of genetics.
- Managers review of existing guidelines.
- Develop template of existing projects that can be used to solicit best practices and improve coordination.
- NOAA Restoration Program has techniques synthesis document in development.
- Establish user group for Restoration on Coral List Serve; perhaps expand Injury group.
- Conduct dedicated session at ICRS (July 2008), Alison Moulding is co-chair.
- Society for Conservation Genetics has meeting in NYC in Sep 2007—partner for developing guidelines for restoration working group.
- Should have separate health and genetics working groups; include geneticists, aquarists, managers and ecologists.
- Partners for synthesis working group—FWC lead, EPA, NMS, MPS, SAFMC.
- Research studies should coordinate with active groups, e.g., FRRP, SECREMP, CREMP, SCREAM.

- Pursue for experimental studies from: World Bank, Disney World Wild Life Fund, UNEP Coral Reef Unit, NOAA CRCP.
- Pursue funding for Observing System support from SECOORA.
- USF has strong sensor development program for plankton and DNA microarrays.
- Restoration observing package should include: T, S, Chla, nutrients, pH, PCO₂, D.O. U.V., currents/surge, waves (ADCP), turbidity, sedimentation.

ACRRE actions:

- Set up working group with Ken Nedimyer to develop experimental design and define fine scale observations to be measured.
- Review ARB projects for background.
- Develop phased approach.
- Hire Outreach Coordinator (approach CRCP or SEFSC).
- Develop comparative pristine study site, e.g., PR/NOAA Restoration site.

FINAL THOUGHTS:

- We need a better way of tagging to facilitate tracking; related workshop in NZ.
- We need economic valuation of value of restoration to show benefits.
- Take advantage of International Year of Reef to feature ACRRE and other restoration efforts; develop Web site of heroes who are leading restoration efforts.
- Live link events at NF EcoDiscovery Center in Key West.
- Use Web to post meeting report, working group notes, and ppts.
- Other research concerns mentioned included: sponge mortality, disappearance of crinoids, lack of recovery of *Diadema*, and effects of invasive species (e.g., lionfish).