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STRATEGIC PLAN





For more information about Guam NSF EPSCoR
and the
Guam Ecosystems Collaboratorium for Corals and Oceans (GECCO)
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EXECUTIVE SUMMARY

The University of Guam (UOG) is strategically located in a U.S. jurisdiction in the tropical western Pacific. Guam harbors corals and coral-associated taxa, the diversity of which far exceeds those of the heavily studied Caribbean and Hawaiian Islands. These reefs are under threat from climate change, specifically ocean warming, that promotes coral bleaching, and land-based threats, including sedimentation and other stressors. Knowledge generated by understanding and tracking responses of reef-building organisms to climatic disturbances and other anthropogenic stressors enables predictions of both taxonomic composition and ecosystem services for reefs and associated systems. Changes to these systems will affect patterns of local and regional biodiversity, which impacts natural ecosystems and the services they provide to the people and economy of Guam.

This NSF EPSCoR RII Track-1 project, the Guam Ecosystems Collaboratorium for Corals and Oceans (GECCO), will implement a systematic research agenda incorporating new knowledge of biodiversity, population genetics, genomics, phylogenetics, ecology, microbiology, oceanography, and mathematical modeling to document and predict the taxonomic and functional diversity of reef-builders and associated taxa in a changing environment. GECCO will enhance UOG cyberinfrastructure as a nexus for high-speed networks in the Pacific Rim and build high throughput computing capabilities for processing the big data sets generated by genomic and oceanographic components of this project. GECCO will also develop programs that promote STEM education and training, sustainability, and collaborative science.

The vision of the GECCO project is to promote our understanding of the Micronesian region's biodiversity and identify solutions that promote the sustainability of coral reefs in rapidly changing environment across the tropical Pacific. GECCO's mission is to employ

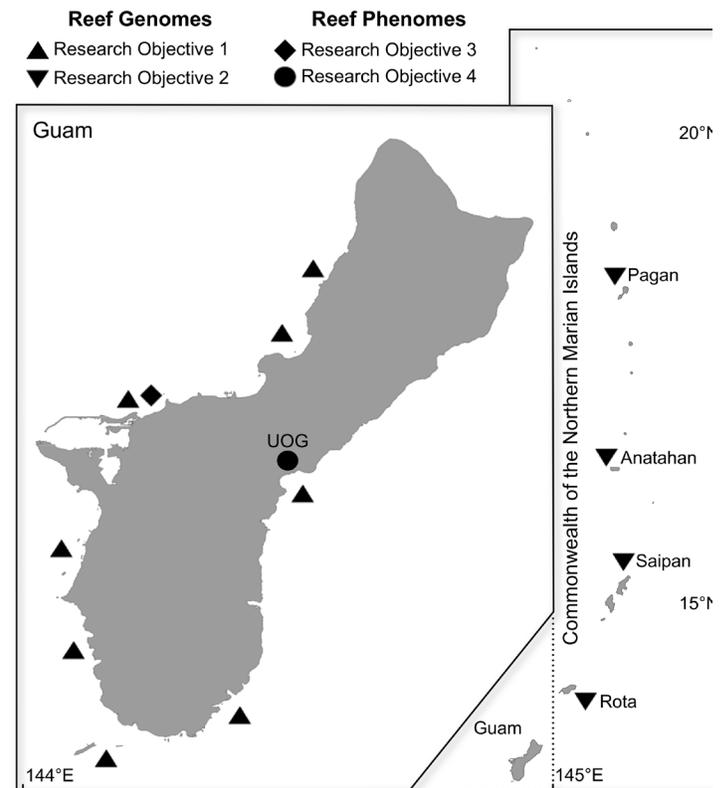


Figure 1: Research activities in the region

modern, cutting-edge methods to determine solutions that address the challenges imposed by climate change on coral reefs and associated ecosystems. Crucial to achieve this goal are documentation of local and regional marine and aquatic biodiversity, the promotion of high-quality STEM education to grow a skilled workforce, and improving sustainability of island communities.

Research. GECCO employs an integrative framework for investigating reef ecosystem resilience with a multidisciplinary team with expertise in genomics, ecology, oceanography, and mathematical modeling. Guam and the broader region host a diverse biota that provide coastal protection, economic stability in a tourism-based economy, and ensure food security in the region by supporting local fisheries. The economic

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value of Guam’s reefs is mostly derived from tourism-related activities, the largest industry on island that generates roughly 12% of Guam’s total GDP and provides one third of non-federal jobs. Climate change is predicted to have severe impacts on coral reefs and will have lasting effects on the ecosystem services provided by these reefs. In particular, globally increasing sea surface temperatures cause coral bleaching (the break-down of the association between corals and their photosynthetic endosymbionts) that is predicted to occur annually by 2050, likely leading to wide-spread and persistent reef declines. In Guam, reefs have suffered unprecedented bleaching events in four of the past six years, leading to a loss of coral cover and likely declines in reef-associated taxa. In addition, coastal development exerts additional pressure on near-shore reef ecosystems. For example, poor land management practices have led to increasing coastal run-off, exerting additional pressures on coral reef ecosystems locally and regionally. GECCO’s research agenda is carried out by two teams with complementary expertise and goals to examine the drivers of reef resilience in a changing climate. The **Reef Genomes** research team will investigate the environmental drivers of genetic connectivity and diversity of reef taxa. The **Reef Phenomes** research team will use common-garden experiments to determine phenotypic responses of corals to environmental change, with the goal of developing a compartmental model of coral population dynamics to predict coral reef resilience and change.

Reef Genomes. The reef genomes team will document the genetic diversity of reef taxa locally in Guam and in the broader Micronesian region. The team will use a combination of reef monitoring, oceanographic modeling, DNA barcoding, and population genomics to characterize reef communities and assess population diversity and connectivity, with the end-goal of identifying the environmental drivers shaping the diversity of Guam’s reefs. By combining population genetics with ocean circulation models, the team will provide mechanistic insights into processes of reef connectivity and provide sound scientific models to inform reef management

locally and regionally. Further, the team will employ and develop automated reef community monitoring systems using hyperspectral imaging techniques. This work will require developing image databases to train image-recognition software. Once developed and vetted, this technology will afford higher-resolution and more rapid assessments of reef communities than feasible with current techniques that rely on expert observers in the field. In a changing climate, expedient assessments of ecosystem changes will be vital to make informed decisions for management and mitigation efforts. The reef genomes research team consists of six core faculty members with organismal expertise in reef-building and reef-associated taxa as well as near-shore oceanographic processes. An expert in crustacean biology will be hired through the project and contribute to the team’s mission.

Reef Phenomes. The mission of the reef phenomes team is to identify the functional phenotypic traits that drive coral resilience to increasing sea surface temperatures. Using common-garden field experiments, the phenotypic responses of corals to environmental change will be documented for the duration of the project. This will yield a long-term time-series of quantitative phenotypic traits and covarying environmental parameters that will be made available to the global community for the study of coral reef change. This time-series will also form the foundation for the development of a compartmental model that will allow modeling and predicting the response of different coral species to predicted climate change scenarios. This model will allow predictions of reef community composition in Guam and the region to facilitate planning by local stakeholders for the changing ecosystem services provided by coral reefs in the coming decades. To gain fine-grained mechanistic understanding of the coral response to rising sea surface temperatures and local micro-habitat variations, manipulative experiments in the field and the lab will be used to investigate the physiological response of corals to environmental change. Development of two additional coral model systems will be a central effort in this endeavor, including whole genome sequencing to allow for in-depth gene



expression experiments. The reef phenomes team consists of five current UOG faculty researchers with expertise in coral ecology, genomics, bioinformatics, and mathematical modeling. GECCO will provide the means to expand the team's capabilities to include ecophysiology and microbiology with the addition of two new faculty positions in these areas. Through GECCO, dedicated facilities for controlled laboratory experiments will be established at the University of Guam Marine Laboratory (UOGML). This will put the UOGML into an ideal position to become a premier institution for resident and visiting scientists to combine field and laboratory-based studies to gain in-depth understanding of the cellular-level processes driving the response of reef organisms to environmental change.

Biorepository. GECCO will facilitate the consolidation and expansion of Guam's natural history collections and provide state-of-the-art digitization, imaging and mapping of local and regional taxa. The Biorepository encompasses existing UOG online databases for a variety of marine, aquatic and terrestrial taxa with data that includes both existing and new collections on Guam. The project will improve curatorial infrastructure and research capabilities and provide broad-based documentation and understanding of biodiversity on Guam and throughout the Pacific. The Biorepository will provide specimens, curatorial services, specimen storage, bar code analyses, biodiversity analyses, and global access to its databases. GECCO will be able to expand the Biorepository's ability to examine patterns of

biodiversity within the region with addition of two research faculty positions in vertebrate morphology (ichthyology) and crustacean biology.

Cyberinfrastructure. To increase data analysis capacity in the jurisdiction, high throughput computing (HTC) resources will be implemented locally in Guam and partnerships established to broaden access to off-campus HTC resources. Local and remote data storage arrays will improve data access, security, and long-term archival. A dedicated research computing facilitator will provide assistance and training to users of these resources to maximize the impact of infrastructure developments.

Education and Workforce Development. *GECCO Education and Workforce Development (EWD)* will advance the jurisdiction's STEM capacity needs and contribute to improved island sustainability through expanded place-based and culturally relevant activities. GECCO contributes to the local workforce, stimulating Guam's competitive research capabilities and encouraging a green economy. GECCO will meet four NICE (Natural Resources, Information Technology, Circular Economy, Engagement) objectives.

- 1. Natural Resources (N):** GECCO will expand training and education in natural resources-related research. Student research experiences, professional development trainings, connections to national opportunities, and natural resources curricula will be expanded, impacting 20-36 students and 19-25 faculty/

researchers/postdocs each year.

- 2. Information Technology (I):** GECCO will build IT capacity for the jurisdiction while supporting research activities. GECCO will support professional development, coursework, and certifications for UOG Office of Information Technology (OIT) team members, coding camps for students and community members, and coordination for gatherings of Silicon Village.
- 3. Circular Economy (C):** GECCO will catalyze the Guam Green Growth (G3) Initiative to spark a new green economy in the jurisdiction and improve island sustainability through the cultivation of a circular economy. GECCO will support a business incubator and makerspace and redesign a business capstone course to accelerate a circular economy in Guam.
- 4. Engagement (E):** The communities of Guam and Micronesia are underrepresented and underserved in STEM on the national landscape. GECCO will add considerably to the work accomplished under Guam's previous NSF-EPSCoR award, the Guam Ecosystems Collaboratorium (GEC). GECCO will greatly increase STEM awareness and engagement through a variety of educational outreach activities through special courses, conferences, science fairs, and the coordination of environmentally sustainable campus operations.

Collaboratorium. The Collaboratorium has three principal activities that will contribute to the success of the GECCO project:

- 1. Partnerships and Collaborations:** The Collaboratorium will establish partnerships with various entities to promote sustainable economic growth in island communities. This will promote institutional and individual research collaborations for GECCO and support two visiting faculty members annually to conduct research and teach specialized courses or workshops.
- 2. Seed-funding Grants:** The Collaboratorium will provide grants in support of risky but innovative research and instruction relevant to the project's goals and objectives. This will allow GECCO to support high-risk, high-reward research that support the GECCO

vision

- 3. Mentoring of Junior Faculty and Post-doctoral Fellows:** The Collaboratorium will support mentoring of junior faculty members and post-doctoral fellows hired to the project are described. This will allow GECCO to develop competitive faculty researchers and enhance skill sets of post-doctoral fellows towards advancing their careers.

Data Management Plan. Data will be entered, stored, and managed in a globally accessible database. Specimen, environmental, oceanographic, and functional trait data will be integrated into the Biorepository database and distributed after an initial embargo period to allow project researchers priority access for data analysis and publication. Integrating these different types of data in a single portal will create a one-stop-shop for biological and environmental data from Guam, increasing visibility and discovery of Guam's research enterprise.

Communication and Dissemination Plan. The GECCO communication and dissemination will inform researchers, natural resource managers and stakeholders, decision makers, government agencies, non-governmental organizations, the private sector, and the general public about Guam and NSF EPSCoR, GECCO research, education, outreach and workforce development activities, and project accomplishments. There will be two forms of communication and dissemination: internal and external.

- **Internal Communication:** Internal communication and its methods of dissemination will be designed to inform and coordinate team members of project schedules, requirements, procurement researcher, graduate student and undergraduate student assignments, deadlines, developments and progress, and other activities that allow the team to meet the goals of the project. Objectives and activities include maintenance of internal communications within the project through regular meetings (weekly, biweekly, or monthly depending upon task focus and content), email messages to team members, Dropbox and G-Suite data file access, and social media announcements on WhatsApp or FaceTime.
- **External Communication:** External communication and its methods of dissemination

will be designed to inform the scientific community, funders, government entities, and the general public of what GECCO is doing, why, how, and how significant the outcomes of the project are.

Sustainability Plan. GECCO will contribute to the sustainability of research capacity at UOG by hiring four tenure-track faculty members and seven post-doctoral fellows, and four research technicians. Support, in the form of research stipends and tuition waivers, for 12 graduate students will be provided annually. Faculty members working on the project will be strongly encouraged to seek external funding from NSF, NOAA, NASA, NIH, and various foundations to advance their research interests.

Project Management. GECCO will be led by a five-person leadership team consisting of the principal investigator and three co-principal investigators, plus the project administrator. Terry Donaldson serves as the Project Director and Janet Dirige serves as the Project Administrator. Bastian Bentlage serves as the Research Coordinator, Austin Shelton serves as the Education and Workforce Development Coordinator. Rachael Leon Guerrero serves as the Collaboratorium Coordinator. The Management Team consists of the Project Director, Project Administrator, and a support staff. The Research Team management consists of science leads David Combosch (Objective 1), Sarah Lemer (Objective 2), Laurie Raymundo (Objective 3), Bastian Bentlage (Objective 4) and Terry Donaldson (Biorepository). Manny Hechanova serves as the Cyberinfrastructure Lead. Austin Shelton leads EWD activities. Rachael Leon Guerrero leads the Collaboratorium and is responsible for promoting collaborations with other institutions and researchers, and oversight of seed funding projects conducted at UOG. Sara Bolduc (Sara Bolduc Planning and Evaluation, LLC) serves as the External Evaluator and will collect quantitative data for tracking activities and output, and qualitative data for describing the processes of project work. The evaluator will also provide annual reports with recommendations that may be used to improve practices and enhance project success. Oversight will be provided by the Guam Science and Technology Steering Committee, with membership drawn from government, business and academic communities. GECCO leadership will be advised by the External Advisory Board (EAB).



Evaluation and Assessment Plan. External Evaluator Sara Bolduc will annually collect data for quantitatively tracking activities and outputs of the project, provide analyses, and make recommendations for improving efficiency in the conduct of project activities.

Risk Management Plan. The GECCO Risk Mitigation Plan addresses the most likely risks to the success of the project, with major emphasis given to COVID pandemic restrictions, and describes ways to mitigate their effects.

Succession Plan. The Succession Plan provides a roadmap for replacing members of the Leadership and Management Teams should vacancies occur in their respective positions.



INTRODUCTION

Guam has the nation’s most diverse and complex coral reefs. They are at threat from the effects of climate change and other stressors, such as sedimentation from poor land use practices. Coral bleaching, increased turbidity and sediment loads, algal blooms, and other impacts contribute to habitat loss and also to declines in the biodiversity of reefs and associated habitats. The urgency for bringing cutting-edge tools to understanding how reef organisms respond to climate change has grown as we seek solutions for resilience and sustainability.

Organizational Partners. All research and outreach activities of GECCO will be performed by members of the faculty, staff, and students of the University of Guam. Collaborations with researchers, and STEM and outreach personnel from other institutions, agencies, and the private sector, will also occur on Guam and elsewhere.

Alignment with the Guam Science and Technology Plan. GECCO aligns with four goals of the Guam Science and Technology (S&T) Strategic Plan by: 1) serving as a state-of-the-art regional research hub and global facilitator of sustainability and knowledge of Guam and the region; 2) producing a STEM-competent and Micronesian-centric workforce through a holistic, place-based education pipeline that sustainably meets the needs of government and the private sector; 3) providing facilities and equipment infrastructure necessary for Guam to conduct needed cutting-edge research relevant to the sustainability of Guam and the region’s island communities, and enhance connectivity between academic, educational and government institutions; and 4) promoting increased communication throughout Micronesia and the region for informed decision making, knowledge-sharing, and continuing education to develop a regional community of STEM learners.

Benefits to Guam’s academic research and education infrastructure. GECCO will build research capacity at the University of Guam in support of the growing needs of Guam and the region. The project will hire four tenure track faculty members,

Table 1 – GECCO faculty hires

Year	Position
1	Marine microbiologist
2	Vertebrate morphologist (Ichthyologist)
2	Crustacean biologist
2	Marine ecophysiologicalist

seven post-doctoral fellows, and four technicians, and provide research support for 12 graduate students annually. GECCO will also provide the means to invite two visiting faculty researchers annually to conduct GECCO-aligned research and provide seminars in specialized areas for the benefit of students and faculty. Research collaborations at UOG and with other institutions and researchers, will also be provided.

The project will provide data and analyses that will broadly impact the development of management plans by local and federal agencies that will lead to greater protection of reefs and associated habitats on Guam and within the region. GECCO will enhance UOG research capacity in genetics, genomics and mathematical modeling of coral reef systems experiencing environmental changes, build a Guam Coastal Oceanographic Sensing Array that will provide long-term data sets of oceanographic conditions, expand the existing Biorepository as a means for describing the region’s biodiversity, and establish high-throughput computing resources to allow for processing of very large data sets. GECCO research capacity will attract visiting scientists, increase the quantity and quality of students, including underrepresented minorities (URMs), in UOG’s STEM programs, and will eventually lead to the creation of a new Ph.D. program in Biology at UOG. The project will also promote increased communication on Guam and throughout Micronesia and the region for informed decision making, knowledge-sharing, and continuing education to develop a regional community of STEM learners. GECCO will also make possible the promotion of sustainability initiatives that support island communities.

Project Implementation

Strategic Plan Development Process: Preparations for the development of the GECCO Strategic plan began with a meeting between members of the Management Team and the NSF-designated facilitator, John Riordan, to discuss logistics. This was followed by another meeting with him with members of the Leadership, Management and Research Leads teams to begin an analysis of Strengths, Weaknesses, Opportunities and Threats (SWOT). Each section of the project was subsequently examined with a SWOT analysis and tables were prepared (Appendix A) for use in the preparation of a Risk Management Plan to be included in the Strategic Plan document. Then, members of the Leadership Team, in consultation with the Research Leads, prepared two drafts of the Strategic Plan prior to consideration of the revised plan during the Strategic Planning Meeting held virtually with representatives of NSF EPSCoR, John Riordan, and various team members on 16-18 September 2020. Leadership and Management Team members completed the final draft of the Strategic Plan after this meeting was held.

Strategic Plan Elements: The GECCO project is comprised of research activities, the Biorepository in support of research, Cyberinfrastructure, Education-Workforce Development, and the Collaboratorium (Seed Funding and Emerging Areas, Partnerships and Collaborations, and Mentoring). In addition, the plan addresses Communications and Dissemination, Sustainability, Project Management, Project Evaluation, Risk Management and Succession. Each are described in the text with goals, objectives, tasks, outputs, and outcomes summarized in tables. Outputs and outcomes reflect benefits resulting from GECCO's various activities.

The Project Management Plan describes the different levels of leadership necessary to ensure project success and delineates responsibilities within the project. Research activities describe the four main objectives of the project plus those of the Biorepository. Cyberinfrastructure activities will create high-throughput computing capabilities to handle large data sets. Education and Workforce Development activities address educational and training at different levels, and the promotion of sustainable island economies. Collaboratorium

activities include programs for Seed Funding and Emerging Areas of Research that will support high-risk / high-reward research and instruction methods relevant to the main areas of the GECCO's research. The Collaboratorium will promote institutional and individual collaborations, partnerships for sustainable economic development, and mentoring of junior faculty researchers and post-doctoral fellows. The Data Management Plan provides a means for integrating, storing, and managing different datasets that include specimen, environmental, oceanographic and functional trait data in a single database with global access. The Communications and Dissemination Plan describes information sharing strategies to be used internally within the project and externally with the general public. The Sustainability Plan describes how new faculty hires, post-doctoral and student recruitment, student support, the Visiting Scientist Program, and efforts by new and current junior faculty members to secure external research funding all further GECCO's impacts well after the project has concluded. The Evaluation and Assessment Plan provides the tools for measuring whether GECCO is on course and how to keep it on course. Finally, a Risk Management Plan describes both

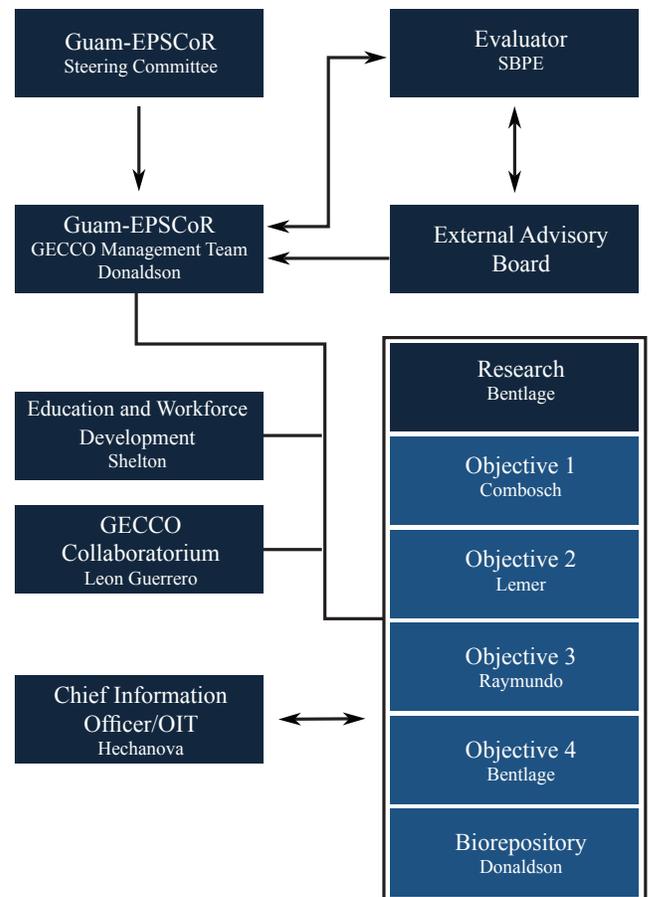


Figure 2: GECCO management structure

Table 2 – Leadership and Management Teams

Team	Name	Role
Leadership	Terry Donaldson	Principal Investigator and Project Director
	Janet Dirige	Project Administrator
	Bastian Bentlage	Co-Principal Investigator - Research
	Austin Shelton	Co-Principal Investigator - EWD
	Rachael Leon Guerrero	Co-Principal Investigator - Collaboratorium
Management	Terry Donaldson	Principal Investigator and Project Director
	Janet Dirige	Project Administrator
	Jordan Jugo	Project Associate - Tracking
	Annalyn Baslin	Financial Analyst
	Glenn Meno	Grant Budget Specialist
	Amanda Dedicatoria	Science Communicator
	Corey Santos	Science Communicator
	Colin Kirk	Assistant Science Communicator
Research Team Leads	Manny Hechanova	Cyberinfrastructure
	David Combosch	Science Lead-Objective 1
	Sarah Lemer	Science Lead-Objective 2
	Laurie Raymundo	Science Lead-Objective 3
	Bastian Bentlage	Science Lead-Objective 4
	Terry Donaldson	Biorepository Lead
	David Burdick	Biorepository Collections Manager

the likelihood and magnitude of risks to the project, with a recognition of restrictions imposed by COVID-19, and how these risks can be managed. The project’s Succession Plan is included in this section.

Project Management Plan

Leadership, Administration Management, and Project Teams. GECCO will be led by Leadership, Administration Management, and Project teams that are responsible for activities that lead to the success of the project (Figure 2). Leadership will receive feedback annually from the External Evaluator that will help improve project performance. The External Advisory Board (EAB) and the Guam Science and Technology Steering Committee (GSTSC) will provide guidance.

Leadership of GECCO (Table 2) will be provided by the Principal Investigator/Project Director (PI/PD), the Project Administrator (PA), and three co-Principal Investigators (co-PI), each of whom are responsible for management of specific sections within the project. Management of the project (Table 2) will be provided by the PI/PD and PA, with support from a Financial Analyst, a Project Associate, and a Grants Budget Specialist. A Science Communicator and Assistant Science Communicator will also provide support

and will have shared duties with the Education and Workforce Development sections of the project and provide information on project activities and outputs to a broad audience. Team Leads (Table 2) have been appointed for specific sections of the project, including Cyberinfrastructure, Research (four objectives), and the Biorepository (including the Collections Manager). The GSTSC will provide oversight and input to the Leadership Team. This committee includes members from the local and federal government agencies, academia, and the private sector. Guam NSF-EPSCoR’s PI/PD and Project Administrator serve as ex officio members of this committee. The GSTSC will provide annual reviews of GECCO’s progress and provide guidance towards meeting the Guam Science and Technology Plan’s goals.

The Leadership Team will receive recommendations from the External Advisory Board (EAB) that consists of various experts who will measure progress towards meeting project milestones and provide advice on recognizing and correcting problems that impede progress. The EAB membership includes the following: Charles Birkeland (University of Hawai’i at Manoa), William Gerwick (University of California, San Diego) Monica Medina (Pennsylvania State University), Gustav Paulay (University of Florida) and Maggie Werner-Washburne (NSF PAESMEM awardee, emerita University of New Mexico).



RESEARCH PROGRAM

The reliance of humans on reef ecosystems that are at risk of collapse requires understanding the mechanisms of reef resilience. GECCO addresses fundamental questions of how the response of coral-reef organisms to disturbance is regulated, how resilience is affected by local and regional demography, and how reef communities change over time. Tracking and understanding responses of reef-building organisms to disturbances allows predicting both the taxonomic composition and ecosystem services that reefs may provide in coming decades, and to develop mitigation solutions to address the loss of ecological functions and stability. Objectives and tasks are given in Tables 3a and 3b (following pages).

Research Themes and Goals

1: Reef Genomes – How do genetic diversity and connectivity confer reef resilience?

1.1: Characterize local reef environments and communities

1.2: Assess local population diversity/structure and uncover signatures of selection

1.3: Identify regional patterns of genetic connectivity

1.4: Develop local and regional ocean circulation models

2: Reef Phenomes – Which traits confer resilience to key reef builders?

2.1: Identify functional traits that drive coral resilience

2.2: Develop dynamic coral reef ecosystem model

2.3: Quantify local habitat effects on coral health and resilience

2.4: Characterize the role of the coral microbiome in reef resilience

1. Reef Genomes – How do genetic diversity and connectivity confer reef resilience?

GECCO will characterize population genetic connectivity and diversity across reef-building and reef-associated taxa to provide foundational knowledge of coral reef demography. Guam and the islands of the Micronesian region represent a unique opportunity to study reef connectivity and resilience in a changing climate. Species and population resilience in a changing environment depend on genetic diversity and connectivity. Without sufficient genetic diversity, isolated populations are at risk of decline due to combined effects of inbreeding and genetic drift. Regional connectivity via larval dispersal is a widely recognized process of reef recovery following disturbances. In addition to connectivity, ecological processes affect recovery and community composition. For example, recruitment of scleractinian corals after broad-scale bleaching events depends on healthy CCRA communities that serve as settlement substrates for coral larvae. GECCO researchers will use seascape genomics, oceanographic modeling, and develop automated reef monitoring systems to uncover regional patterns of coral reef connectivity and

determine local patterns of community composition and environmental adaptation. Table 4 lists core researchers for the reef genomes team.

Objective 1.1: Characterize local reef environments and communities

At 544km², Guam is the largest island in Micronesia, comprising approximately 20% of the land mass in the entire region. Guam possesses a complex geological foundation with an elevated fossil limestone reef in the north and past volcanic activity in the south. The size of the island combined with its geological diversity have generated a multitude of marine habitats in Guam's coastal waters. The abundance of different habitats provides habitat heterogeneity, including possible climate change refugia, and opportunities for local adaptation of marine fauna and flora. To facilitate efficient assessments of habitats and reef communities, hyperspectral imaging will be used. The focus of reef assessments will be locally and regionally dominant reef-building corals and crustose coralline algae (CCRA). Surveys typically rely on observers in the field and manual annotation of field photographs, both time consuming tasks that rely on expert personnel.

Table 3a - Research Question 1: Reef Genomes — How do genetic diversity and connectivity confer reef resilience?

Goal 1.1: Characterize local reef environments and communities							
Objective 1.1a: Characterize sampling sites							
Objective 1.1a	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Site selection	Combosch, Lemer, Schils	Primary sampling sites selected	Secondary sampling sites selected				Training database of coral and CCRA hyppectral signatures for automated reef community characterization
Identification and abundance estimation of coral and CCRA communities	Schils	Hyperspectral imaging of field sites complete	Hyperspectral image analysis complete	Reef community composition analysis complete			
Goal 1.2: Assess local population diversity/structure and uncover signatures of selection							
Objective 1.2a: Specimens collections							
Objective 1.2b: DNA Barcoding and Population Genetics							
Objective 1.2a	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Coral and other invertebrate collections at sites identified in 1.1a	Combosch, Lemer, Schils	25% of samples for population genomics of 2 coral species and one reef-associated invertebrate collected	2 additional coral species and reef-associated invertebrates collected; sampling efforts around Guam 75% complete	Collections 100% complete			Collection of tissue and voucher specimens from key reef-building and reef-associated taxa.
CCRA barcoding and population diversity at sites identified in 1.1a	Schils	50% of collections for 3 CCRA species-groups complete	CCRA species sampling 100% complete				
Timely hires	Combosch, Schils	2 postdocs hired with expertise in coral genomics and phycology	new faculty crustacean biologist	end of initial postdoc appointments; 2 new postdocs hired			
Objective 1.2b	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Conduct coral barcoding	Combosch & postdoc	75% coral samples barcoded for identification, focusing on difficult-to-identify species complexes	75% of coral samples barcoded for identification, focusing on difficult-to-identify species complexes; 75% of 4 target coral species genotyped using RAD sequencing	remaining coral samples barcoded			DNA barcoding and population genomics datasets. Analyses of species diversity and population structure.
Coral population genomic analysis	Combosch & postdoc		75% of 4 target coral species genotyped using RAD sequencing	RAD genotyping complete; dataset of at least 1 species fully analyzed	RAD genotype data analyzed for all target corals		
CCRA barcoding and population diversity analysis	Schils & postdoc	DNA barcoding of CCRA species for identification and diversity estimates 50% complete; Genotyping by sequencing (GBS) pilot study for 1 CCRA species initiated and 25% of specimens genotyped	DNA barcoding of CCRA species 100% complete; DNA barcoding for species delimitation and diversity analysis complete; all specimens of one species genotyped using GBS sequencing	Phylogenetic analyses of DNA barcode data; population genetics of select CCRA species; GBS genotyping of additional species 50% complete	GBS genotyping 100% complete		
Reef-associated invertebrate barcoding and population genomic analysis	Lemer, new faculty hire crustaceans & postdoc		genotyping 30% complete	DNA barcoding and RAD genotyping complete; data analyzed for at least one species			
Goal 1.3: Identify regional patterns of genetic connectivity							
Objective 1.3a Collect reef-building and reef-associated taxa regionally							
Objective 1.3b Identify patterns of reef connectivity and migration in the region							
Objective 1.3c Phylogeography of diadromous taxa							
Objective 1.3a	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Regional Coral, CCRA and 5 additional invertebrate collections	Combosch, Schils & Lemer	50% Sites and species identified; number of specimens targeted determined; permit applications filed	Field work in the CNMI completed by end of year 2	Applications for permits and field work in Palau and FSM			Regional collection of tissue and voucher specimens
Timely hires	Lemer	postdoc with expertise in invertebrate biology hired		end of appointment invertebrate postdoc			
Objective 1.3b	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Coral genotyping and analyses	Combosch		RAD sequencing of 5 coral taxa begins, with 2 taxa 50% complete by end of year 2	Coral genotyping 100% complete for 2 species and 50% complete for 3 species	Genotyping 100% complete; data analysis of 2 taxa complete	Data analysis completed for all taxa	DNA barcoding and population genomics datasets for reef-building and reef-associated taxa
CCRA genotyping and analyses	Schils		Expand geographical sampling of target taxa into neighboring islands of the CNMI and FSM; sampling 50% complete	100% of sampling effort complete; 50% of samples barcoded for species identification and diversity analyses	GBS genotyping of samples for 1 species 50% complete	GBS genotyping 100% complete	
5 Invertebrate (non coral) taxa genotyping and analyses	Lemer & postdoc		genotyping of 2 taxa 50% complete	genotyping of 2 taxa 100% complete; 3 additional taxa 50% complete	Genotyping of all taxa 100% complete; data analysis of 2 taxa completed	All genotyping data analyzed	
Timely hires	Lemer & Fujimura				Postdoc with expertise to integrate genetic and oceanographic data hired	End of postdoc appointment	

Objective 1.3c	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Diadromous species collections from regions targeted in 1.3a	Combosch	Collection sites and target species identified	Application for permits submitted; field work completed				DNA barcoding dataset of diadromous taxa
Diadromous species diversity analyses	Schils	DNA barcoding for 2 species 50% completed using samples previously collected	DNA barcoding 100% complete; species descriptions drafted	DNA barcoding of 2 additional taxa 50% complete	DNA barcoding 100% complete; necessary species descriptions drafted		
Goal 1.4: Develop local and regional ocean circulation models							
Objective 1.4a Collect local ocean current circulation data							
Objective 1.4b Develop ocean circulation model and correlate with genetic data							
Objective 1.4a	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Release microstar drifters in Guam (sites identified in 1.1a)	Fujimura	15 drifters deployed around Guam	15 drifters deployed around Guam	15 drifters deployed around Guam			Dataset of sea-surface drifter tracks
Release microstar drifters in the CNMI (sites identified in 1.3a)	Fujimura		Deployment of 5 drifters in the CNMI				
Collect ocean circulation data	Fujimura		GPS tracks for year 1 drifters collected and archived	GPS tracks from year 2 drifters collected and archived	GPS tracks from year 3 drifters collected and archived		
Objective 1.4b	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Model ocean circulation	Fujimura & postdoc		Bathymetric data for modeling collected and computational grid for modeling established	Local ocean current model developed and validated	Regional ocean currents modeled and validated		Regional and locally nested ocean current model

Table 3b - Research Question 2: Reef Phenomes — Which traits confer resilience to key reef builders?

Goal 2.1: Identify functional traits that drive coral resilience							
Objective 2.1a: Establish coral common garden experimental plots							
Objective 2.1b: Develop database and data curation protocol							
Objective 2.1c: Identify traits that covary with resilience							
Objective 2.1a	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Literature and previous bleaching survey data review	Raymundo & Bentlage	coral species and field sites for common garden experiments identified (fall 2020); application for permits submitted (fall/spring 2021); experimental design finalized					Coral functional trait and environmental data collection
Coral collection and genotyping	postdoc	Samples from parent source colonies samples and preserved for later DNA barcoding or genotyping if necessary; source colonies fragmented for outplanting and parent colonies tagged for monitoring (April-May, prior to bleaching season, 2021)					
Environmental data collection	Fujimura & postdoc	Multi-parameter probes procured and deployed	Data downloaded and curated				
Trait data collection	Raymundo, Bentlage, postdoc & ecophysiology hire	Common gardens established at 1 reef-flat and 1 fore-reef site (April-May, prior to bleaching season, 2021); monitoring schedule established and traits/parameters to monitor identified (Jan-May 2021); monitoring commences by May 2021	biweekly to monthly monitoring of phenotypic traits during bleaching season; monthly to quarterly for other seasons and traits	biweekly to monthly monitoring of phenotypic traits during bleaching season; monthly to quarterly for other seasons and traits	biweekly to monthly monitoring of phenotypic traits during bleaching season; monthly to quarterly for other seasons and traits	biweekly to monthly monitoring of phenotypic traits during bleaching season; monthly to quarterly for other seasons and traits	
Timely hires	Raymundo, Bentlage	postdoc with coral ecology expertise hired		end of first postdoc appointment; postdoc with coral ecology expertise and strong data science skills hired		end of second postdoc appointment	
Objective 2.1b	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
database: traits, environment, genotypes	Aquino, Bentlage, research computing facilitator, Carlson	Database designed and implement in MySQL	trait data for years 1 and 2 incorporated into database	trait data for year 3 incorporated into database	trait data for year 4 incorporated into database	trait data for year 5 incorporated into database	Trait database
Objective 2.1c	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Phenotypic and molecular genetic coral trait data collection (eg, bleaching, growth rates, symbiont abundances, symbiont clade)	postdoc, Aquino, Raymundo, Bentlage	Format and content of parameter/trait dataset finalized in coordination with modeling team	Summary and QC of year 1 of common garden experiment complete and data provided to modeling team	Summary and QC of year 2 of common garden experiment complete and data provided to modeling team	Summary and QC of year 3 of common garden experiment complete and data provided to modeling team	QC of year data complete	Identification of key functional traits driving coral resilience to

diversity, microbiomes)							environmental disturbance
Trait data analysis	Combosch & postdoc			Year 1 and 2 data analyzed	Year 1-3 data analyzed	cumulative four-year data set analyzed	
Goal 2.2: Develop dynamic coral reef ecosystem model							
Objective 2.2a Identify reef resilience modeling approach and relevant data to parameterize model							
Objective 2.2b Develop ordinary differential equations to model population responses							
Objective 2.2a	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Literature and previous bleaching survey data review	Raymundo, Bentlage	Background literature reviewed and modeling approach finalized					Student training in databasing and mathematical modeling
Examine parameters for model development	Aquino, Oh, Choi, student researchers	Simulations using basic parameters to experiment with model behavior completed	Find values of parameters using traits database (update quarterly)	Find values of parameters using traits database (update quarterly)	Find values of parameters using traits database (update quarterly)	Parameters for Math Model finalized	
Objective 2.2b	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Set up mathematical model	Oh, Aquino, Choi, student researchers	SIR model set up using parameters from literature, Summer and Fall 2021	SIR model set up using parameters determined under 2.1a	SIR model revised/updated with updated parameters	SIR model revised/updated with updated parameters	Mathematical model completed and interpreted	Predictive model of coral responses to environmental change
Goal 2.3: Quantify local habitat effects on coral health and resilience							
Objective 2.3a Expand capacity for coral physiological experiments at UOGML							
Objective 2.3b Identify cellular-level physiological processes in coral stress response							
Objective 2.3a	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Install flume tank	Fujimura, Bentlage, Raymundo	Space for flume tank secured and flume tank procured	Additional tank systems (light, temperature control, plumbing, etc.) procured and installed; system tested and operational				New wetlab facilities for experimental work and genomic resources for coral research.
Establishment two of coral model systems selected from eight coral species in 2.1a	ecophysiologicalist, Bentlage & Lemer		2 coral models identified and 25% of whole genome shotgun sequencing complete	75% of genome sequencing complete; first draft assembly complete	100% of genome sequencing completed; second draft of assembly	gene prediction and genome annotation completed	
Timely hires	Bentlage		new faculty in ecophysiology hired				
Objective 2.3b	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Coral physiology experiments targeting species (or their close relatives) from 2.1a	Fujimura, Lemer, new hire ecophysiology & postdoc	Coral physiological experiment at Okinawa Institute for Science and Technology completed	Data analysis for year 1 experiment completed	Coral photophysiology, ROS, and transcriptomic experiments conducted for 2 coral species that were identified as potential models in 2.3a	Transcriptome sequencing and physiological data analysis of year 3 experiments 100% done	Transcriptome analyses complete	Comprehensive datasets of coral gene expression and physiological response to stressor
Timely hires	Fujimura & new hire ecophysiology			Postdoc with expertise in coral physiology and genomics hired		Postdoc contract ends	
Goal 2.4: Characterize the role of the coral							
Objective 2.4a Identify the role of the coral microbiome in reef resilience							
Objective 2.4a	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Additional field sites identified to compare to common gardens from 2.1a	Bentlage, new faculty marine microbiology & postdoc	Field sites identified; multi-parameter probes deployed at field sites	Tissue samples for microbiome metabarcoding collected	reciprocal transplant experiments initiated	Transplant tissue samples collected		Coral microbiome barcoding and metagenome datasets.
Field collections and lab work	Bentlage, new faculty marine microbiology & postdoc		DNA extracted and metabarcoded for 75% of specimens	DNA extraction and metabarcoding 100% complete	DNA extraction and metabarcoding 100% complete; metagenome sequencing for microbiome functional characterization 75% complete	metagenome sequencing 100% complete	
instrument procurement	Bentlage, new faculty marine microbiology & postdoc	procurement of flow-cytometer and multi-parameter sondes for environmental monitoring	new faculty in ecophysiology hired				
Timely hires	Bentlage, new faculty marine microbiology & postdoc	faculty in marine microbiology hired	Postdoc with marine microbiology expertise hired			Postdoc contract ends	

GECCO researchers will develop training sets for image recognition software to automate reef surveys based on hyperspectral imaging. Hyperspectral imaging provides fine wavelength resolution across the electromagnetic spectrum, allowing discrimination between reef-organisms from these high-resolution images. Developing this approach for reef monitoring will facilitate rapid reef assessments to monitor reef-responses to changing environments.

Objective 1.2: Assess local population diversity/structure and uncover signatures of selection

To date, limited genetic data for marine taxa around Guam indicate significant small-scale population genetic differences and taxonomic diversity. Given the possible retention of propagules in Guam’s near-shore waters, local adaptation to different environments may lead to strong population genetic structure across small spatial scales (km²) and increased genetic diversity in habitat generalists. Several species of coral and CCRA that are abundant and ecologically important reef-builders on fore-reefs and reef-flats in Guam and the broader region will be targeted for study. Population genetic studies of corals will comprise a range of habitat specialists and generalists that occur in healthy and altered reef environments. CCRA to be studied include taxa that are associated with or indicative of healthy or altered reefs. Using genome-scale population genetic data, levels of genetic diversity and population structure will be examined, investigating these data for signatures of selection due to local adaptation. Heterogenous environments are likely to select for different alleles to allow a species to persist across microhabitats, a potentially important driver of genetic diversity and reef resilience. This work will provide a framework of how habitat heterogeneity affects the genetic diversity of key reef-builders.

Objective 1.3: Identify regional patterns of genetic connectivity

Larval dispersal is one of the most important predictors of population connectivity and species resilience to changing environmental conditions. Oceanic larval transport is almost entirely passive for many corals and reef invertebrates because of their small size and limited swimming capabilities. Ultimately, connectivity through larval dispersal between islands and archipelagos can facilitate population recovery following severe or catastrophic disturbances. Understanding propagule-mediated gene

Table 4. Reef Genomes Faculty Researchers

Name	Expertise	Goal
David Combosch (co-lead)	Population Genetics	1.2, 1.3
Atsushi Fujimura	Oceanography	1.4
Sarah Lemer (co-lead)	Genomics	1.2, 1.3
Daniel Lindstrom	Genetics	1.3
Laurie Raymundo	Reef Ecology	1.1
Tom Schils	Phycology	1.1, 1.2
new faculty	Crustacea	1.2, 1.3

flow will be essential to allow inferences on the effects of climate change and habitat degradation. Using a comparative approach across multiple taxa, representative of different taxonomic groups, GECCO researchers will use a seascape genomics approach to study regional patterns of connectivity that may promote resilience of coral reefs to perturbations. Population genomic analyses of reef-building and reef-associated taxa possessing different life histories, pelagic larval or spore/gamete durations (and consequently differing dispersal potential), and habitat preferences will be undertaken in a comparative framework. Genetic connectivity and diversity will be estimated within and between islands, correlating these genome-based estimates of connectivity to with ocean current data to derive a spatially explicit model of migration patterns and connectivity. Combining oceanographic data and molecular genetic tools will enable identification of populations that serve as sources of recovery.

Objective 1.4: Develop local and regional ocean circulation models

During their pelagic phase larvae are transport by oceanic currents, traveling distances ranging from meters to hundreds of kilometers. Data on ocean currents and water mass transport are limited for Guam and the Marianas archipelago but previous studies suggest that Guam’s marine fauna and flora may be primarily self-seeding. The Federated States of Micronesia (FSM), Marshall Islands, and the Northern Mariana Islands may serve as additional sources of larval recruitment for Guam. Understanding ocean currents and connectivity has important implications for predicting and managing resilience of reef ecosystems across the region. Mechanistic models

of dispersal patterns and distributions over regional spatial scales will provide vital insights into past and present dynamics of reef demography, connectivity and limitations to dispersal. GECCO researchers will simulate coastal and open ocean currents. Initial and boundary conditions for the coastal ocean model will be based on local environmental data (waves, wind, temperature) measured around Guam. For the open ocean model, a global ocean model and publicly available sea surface temperature data will be used as input. Additionally, sea surface drifters will be released around Guam and in the CNMI to validate the ocean circulation models. Drifter experiments simulate larval transport. The simulated water currents will be coupled with an individual-based (larval tracking) model to simulate larval transport and connectivity. Modeling results will then be compared with the genetic data to further understand source-sink dynamics and local adaptation.

2. Reef Phenomes – Which traits confer resilience to key reef builders?

Understanding species-specific responses to environmental change is central to predicting composition and function of reefs in future decades. Quantifying the contributions of functional phenotypic traits on species persistence can elucidate processes that are responsible for community change and allow predictive modeling of reef dynamics. Recurring severe increases in sea surface temperature are expected to trigger fundamental changes in the structure of coral reef communities globally, including Guam and the broader Micronesian region. This will likely affect the ecosystem services provided by coral reefs that coastal communities and economies depend upon. We will use a combination of field and laboratory studies to identify functional traits that confer resilience to reef-building corals. Common gardens will be used in the field to test the response of corals to different environmental conditions. In the lab, environmental stressors will be simulated under controlled conditions to identify the drivers of coral resilience. Core researchers are listed in Table 5.

Objective 2.1: Identify functional traits that drive coral resilience

Understanding coral responses to bleaching and other stressors requires understanding which traits contribute to resistance and recovery. Conceptually, coral bleaching may be understood as symbiont loss

Table 5. Reef Phenomes Faculty Researchers

Name	Expertise	Goal
Leslie Aquino	Modeling	2.2
Bastian Bentlage (co-lead)	Bioinformatics	2.1, 2.4
Jaeyong Choi	Statistics	2.2
Hyunju Oh	Modeling	2.2
Sarah Lemer	Genomics	2.3
Laurie Raymundo (co-lead)	Reef Ecology	2.1, 2.3
Atsushi Fujimura	Oceanography	2.1, 2.3
new faculty hire	Ecophysiology	2.1, 2.3
new faculty hire	Microbiology	2.4

due to heat stress followed by starvation and/or infection with secondary agents (e.g., pathogens), a cascade of physiological stress that results in partial or complete mortality of coral colonies. GECCO researchers will use common garden experiments to track bleaching susceptibility of different corals and their post-bleaching recovery. Functional traits associated with the three major components of the coral holobiont (host, photo-symbiont, and microbiome) will be tracked over a 4-year period to assess correlations between coral traits and resilience to bleaching. GECCO's goal is to enable explaining the resilience dynamics in diverse coral communities using a multi-dimensional dataset of phenotypic and ecophysiological traits. Time series of trait data from multiple taxa will enable understanding differences in the stress responses between different coral species, enabling predictions on how different corals will respond to changing environments regionally and globally.

Objective 2.2: Develop dynamic coral reef ecosystem model

While correlation analyses can identify traits strongly associated with resilience, dynamic modeling allows quantification of trait contributions to coral resilience and reef responses to environmental drivers. Ordinary differential equations (ODE) are commonly used to model coral population responses to events such as bleaching, disease, or overfishing of grazing species. Leveraging the coral trait data collected under Objective 2.1, GECCO researchers will develop a dynamic bleaching resilience model to describe interactions between the environment,



bleaching and tissue loss, and secondary infections/disease. Additional physiological traits will be incorporated into the model in consultation with the new ecophysiology hire to quantify the effect of these traits on population responses to disturbance.

Objective 2.3: Quantify local habitat effects on coral health and resilience

Local environmental conditions may exacerbate impacts of climate change and managing these local effects may reduce the impact of climate change. The complexity of the interplay between local environments and global climate change begs further investigation and is essential to understanding the nature of reef resilience. GECCO researcher Fujimura examined intra- and intercolonial variability of bleaching in zoanthids under different water currents, indicating that bleaching is less severe upstream, and that smaller colony size is advantageous during bleaching events. Coral mortality during bleaching events differs dramatically between reef sites and corals exposed to different water flow regimes. Previous gene expression studies conducted by the GECCO team found that these differences may be explained by gene frontloading, which allows corals to quickly respond to increasing water temperatures. The second major environmental factor that determines coral community composition and health on Guam are gradients of turbidity and sedimentation, as a result of terrestrial runoff. Building on past and emerging research at the UOGML that is establishing dominant reef-building coral species of staghorn *Acropora* and massive *Porites* as emerging model systems, the GECCO team will investigate the effects of water flow and turbidity caused by suspended sediments on coral physiology and gene expression. We will examine the response of functional physiological traits in controlled lab experiments using existing flow-through tanks at the UOGML and a flume tank

that will be procured through this award. In particular, the modulating effects of water flow on coral gene expression, symbiont photophysiology, and harmful reactive oxygen species (ROS) production and build-up in coral tissues will be studied to quantify the effect of local habitat variation on the coral physiological response to bleaching stress. Our aim is to clarify how differences in water flow and turbidity affect cellular-level processes that modulate differences in coral host and symbiont resilience to elevated water temperatures. A new faculty hire in marine ecophysiology will support the objectives of this goal.

Objective 2.4: Characterize the role of the coral microbiome in reef resilience

Coral microbiome communities of the emerging model systems established at the UOGML, *Acropora pulchra* and *Porites cf. lobata*, will be characterized along environmental gradients of water flow and turbidity using a metabarcoding approach. To infer microbiome function, metagenome sequencing will be used to identify the metabolic capabilities of coral-associated bacteria. To establish the role of the environment in driving microbiome composition, a combination of water quality measures will be taken along these gradients, including dissolved organic matter and carbon (DOM and DOC) measurements as well as abundance estimates of bacterial groups using flow-cytometry. Reciprocal transplant experiments will be used to test how flexible the microbiomes are in adapting to local conditions. Combining detailed environmental characterizations of micro-habitats with metabarcoding of coral microbiome communities will allow insights into the role of the environment in shaping microbiome communities. To support this objective of the GECCO research agenda and build UOG's capacity in coral reef research, a marine microbiologist will be recruited.



The goal of the Biorepository is to support GECCO research on the biodiversity of the region. The Biorepository provides curatorial, digitization and imaging, and specimen storage services to the project, and allows for the use of various databases to facilitate research into the biodiversity of Guam and the region worldwide. Tasks are listed in Table 7. While its main emphasis is upon marine and amphidromous aquatic organisms, the project will also unite different natural history collections present at UOG and provide a common ground for all to disseminate data and information globally through online database services that the Biorepository provides. There are two objectives:

Objective 1: Provide specimens, curation, digitization, imaging, mapping, specimen storage, and database services to GECCO.

All collections and data sets will be digitized, imaged, and mapped. Global access to these databases will be provided online. We will provide whole and tissue specimens for and incorporate data from analyses of corals and mollusks described above. We will add to the whole and tissues specimen collections of fishes and crustaceans for biodiversity comparisons. We will also fully incorporate the newly acquired R.H. Randall Coral Collection, consisting of over 31,000 partial or whole specimens collected from the region. We will incorporate all UOG natural history collections into the Biorepository. We will also conduct BIOBLITZ surveys of marine and aquatic organisms from Guam to measure local biodiversity in different coral reef

habitats on Guam. We will then conduct Bar Code analyses from specimens collected in BIOBLITZ and additional collecting to define species limits. We will also map species distributions in relation to habitat types locally. investigate morphological relationships between fish species using a micro-CT scanning and provide imagery for research and instruction. This scanning will be augmented with 2-D and 3-D scanning for research on external morphology and body shape. We will establish a life-history database for fishes that will incorporate data from existing sources and new data collected by GECCO. We will consolidate and incorporate existing and new UOG microscope slide collections into an online database. We will conduct or contribute to biodiversity and biogeographic analyses using the Biorepository databases. These databases will be linked to global biodiversity networks.

Objective 2: Incorporate or facilitate access to UOG natural history collections into the Biorepository and its databases.

We will incorporate existing natural history collections at UOG into the Biorepository, and provide linkages to databases, curatorial support and infrastructural support. These efforts will contribute to the sustainability of these marine, aquatic and terrestrial collections. Global access to these databases will be provided. Core UOG researchers are listed in Table 8. These will be augmented by visiting researchers, undergraduate interns, and project researchers.

Goal 1: Provide high-throughput computing capabilities and provide data redundancy and security.

Previous NSF investments and partnerships with the University of Hawai’i and national and international research and education networking organizations laid the foundation for high-speed network connectivity across UOG’s campus and to the global research community. In particular, the Guam Open Research and Education eXchange (GOREX) was created to serve as a hub for the Pacific Islands Research and Education Network (PIREN), providing 100G high-speed connectivity between Guam, Hawaii, the US mainland, Australia, New Zealand, Japan, Hong Kong, and Singapore. Maintaining this connectivity plays a vital role for GECCO. The next step in supporting Guam’s research through cyberinfrastructure development is the advancement of local high-throughput computing (HTC) capabilities and access to off-campus HTC services. The GECCO project will rely on access to HTC resources for genomic data analyses, image recognition algorithms and simulations of mathematical models. In addition to HTC capacity, on-site and off-site data storage systems will be improved to ensure data redundancy and security. Core personnel are given in Table 6 and activities in Table 9.

Objective 1.1: Provide access to high-throughput computing (HTC)

Building on established partnerships, GECCO will seek to develop a memorandum of understanding between UOG and the University of Hawai’i to provide access to project researchers to the UH computer cluster. In addition, the Open Science Grid (OSG) will provide access to its distributed computing network to facilitate parallel computing, supporting GECCO research. Locally, a small but

capable compute cluster will be implemented on the UOG campus. A research computing facilitator will be recruited to provide system support, identify and respond to the computing needs of the UOG research community. Leveraging existing partnerships to enable remote access to HTC resources, implementation of local HTC hardware and effective user support will accelerate UOG’s capacity for data-intensive research, moving UOG closer to its goal of becoming a research-intensive university.

Table 6. Cyberinfrastructure team

Name	Expertise	Goal
Leslie Aquino	Mathematics	1.2
Bastian Bentlage	Bioinformatics	1.1, 1.2
Manuel Hechanova	Interim CIO	1.1, 1.2
Research Computing Facilitator	Technical support	1.1

Objective 1.2: Improve Research data Redundancy and Security

Accessibility, backup, and archival of data are of paramount importance to protect the investments made in data collection, curation, and analysis. GECCO will address this issue by installing high-capacity data storage arrays on campus and off-site, increasing data availability to facilitate analysis by team members and to insure against data loss through backups. To preserve data and resulting products generated as part of the project long-term archival will be provided by participation in the NSF-funded OU & Regional Research Store (OURRstore) digital tape archive (OAC-1828567). Datasets generated by Guam’s research community that are in need of long-term preservation will be solicited for inclusion in the long-term data archive.



Table 7 - Biorepository Milestones

Table 7 - Biorepository Milestones							
Goal 1: Support GECCO research on biodiversity of the region.							
Objective 1: Hire new faculty, post-doc, and technicians; assign Graduate Research Assistants; procure equipment and supplies.							
Objective 2: Provide specimens, curation, digitization, imaging, mapping, specimen storage, and database services to GECCO.							
Objective 3: Incorporate or facilitate access to UOG natural history collections into the Biorepository and its databases.							
Objective 1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Activity 1: Hire faculty members/curators	Donaldson		Vertebrate morphologist (ichthyologist) and Crustacean Biologist hired				Two faculty member hires
Activity 2: Hire post-doctoral fellow	Donaldson			Post-doctoral fellow hired			One post-doctoral fellow hire
Activity 3: Hire technicians	Donaldson	Curatorial technician hired	Microscope/SEM technician hired				Two technicians join existing database technician; 1-2 GRAs per year assigned over five years; equipment for curation, imaging, scanning, and analyses; well-curated specimens and datasets in collections.
Activity 4: Assign GRAs	Donaldson	One GRA assigned	Two GRAs assigned	Two GRAs assigned	Two GRAs assigned	Two GRAs assigned	
Activity 5: Procure equipment	Donaldson, Burdick, Dirige,	SEM, microscope slide scanner, computer equipment, photography and imaging equipment, dive equipment, collecting equipment	m-CT Scanner, compactor shelves, computer equipment,	Complete procurement of equipment if delays from COVID in Years 1-2 experienced	Complete procurement of compactor shelves if delayed by COVID and space acquisition problems	Compactor shelves installed and utilized; incorporation of other collections into Biorepository, either physically or in the database	
Activity 6: Procure curatorial supplies	Donaldson, Burdick, Dirige,	Curatorial supplies acquired and used	Curatorial supplies acquired and used	Curatorial supplies acquired and used	Curatorial supplies acquired and used	Curatorial supplies acquired and used	
Objective 2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Activity 1: Fully incorporate Randall Coral Collection	Burdick, GECCO staff and graduate students	Digitization and imaging of 10% of specimens, fieldnotes; online access	Digitization and imaging of 25% of specimens, fieldnotes; online access	Digitization and imaging of 25% of specimens, fieldnotes; online access	Digitization and imaging of 20% of specimens, fieldnotes; online access	Complete digitization and imaging of specimens, fieldnotes; online access	Globally-accessible database to further knowledge of regional biodiversity that generates collaborative papers on various taxonomic groups. Detection of cryptic and new species generating additional publications. Visualization of internal anatomy of fishes for papers on comparative morphology and imagery for use in dynamic instruction.
Activity 2: Make collections of coastal marine and aquatic species	Donaldson, Burdick	Collect specimens and tissue, image, digitize, database	Collect specimens and tissue, image, digitize, database	Collect specimens and tissue, image, digitize, database	Collect specimens and tissue, image, digitize, database	Collect specimens and tissue, image, digitize, database	
Activity 3: Conduct four BIOBLITZ surveys	Donaldson, Burdick	Prepare for first BIOBLITZ (fishes); equipment, supplies, schedule travel arrangements	Collect fish specimens and tissues, image, digitize, database, arrange for Y3 BIOBLITZ, prepare manuscript	Collect mollusk specimens and tissue, image, digitize, database; arrange for Y4 BIOBLITZ; prepare manuscript	Collect crustacean specimens and tissue, image, digitize, database; arrange for Y5 BIOBLITZ, prepare manuscript	Collect coral, cnidarian specimens and tissue, image, digitize, database; complete BIOBLITZ collections, prepare manuscript	
Activity 4: Conduct bar code analyses of BIOBLITZ and other collections	Donaldson, Lindstrom, new hire	Begin bar coding fishes and corals in current collections; complete 30%	Bar code marine/freshwater fishes, mollusks, corals in new collections; complete 20%; complete 30% of existing collections	Bar code marine/freshwater fishes, mollusks, corals in new collections; complete 20%; complete 30% of existing collections	Bar code marine/freshwater fishes, mollusks, corals in new collections; complete 20%; complete 30% of existing collections	Complete barcode marine/freshwater fishes, mollusks, corals, and crustaceans in new collections and existing collections; prepare 3 papers	
Activity 5: Digitize and image microscope slide collections	Donaldson, Burdick, new technician, GRAs	Assemble microscope slide collections at UOGML and Biology; scan, digitize; store images and metadata in Biorepository database (20% of collections)	Obtain new microscope slide collections at UOGML and Biology; scan, digitize, store images and metadata in Biorepository database (20% of collections)	Obtain new microscope slide collections at UOGML and Biology; scan, digitize, store images and metadata in Biorepository database (20% of collections)	Obtain new microscope slide collections at UOGML and Biology; scan, digitize, store images and metadata in Biorepository database (20% of collections)	Complete microscope slide scanning, digitization, and database activities (20% of remaining collections)	
Activity 6: Conduct m-CT, 2-D and 3-D scans of fishes and other taxa for comparative research and education; database; develop dynamic imagery	Donaldson, new hire, Burdick		Scan fishes in new collections, database, analysis	Scan fishes in new collections, database, analysis; develop teaching tools	Scan fishes in new collections, scan other taxa, database, analysis; develop teaching tools	Scan fishes in new collections, scan other taxa, database, analysis; develop teaching tools	
Activity 7: Incorporate Biorepository data into global biodiversity networks	Donaldson, Burdick, two new faculty hires	Join biodiversity networks, share data on regional biodiversity; learn and incorporate new curatorial, analytical, and database methods	Maintain networks; learn and incorporate new methods; prepare and deliver 1-2 papers	Maintain networks; learn and incorporate new methods; prepare and deliver 1-2 papers	Maintain networks; learn and incorporate new methods; prepare and deliver 1-2 papers	Maintain networks; learn and incorporate new methods; prepare and deliver 1-2 papers	
Activity 8: Biodiversity analyses	Donaldson, Burdick, two new faculty hires	Compile checklists of fishes and produce new records paper; database; examine diversity patterns, map distributions	Compile checklists of fishes and produce new records paper; database; examine diversity patterns, map distributions; prepare one paper	Update checklists of mollusks and crustaceans; database; map distributions	Update checklists of mollusks and crustaceans; database; map distributions;	Update checklists of mollusks and crustaceans; database; map distributions; prepare 2 papers	
Activity 9: Establish and maintain life history database; workshop	Donaldson, Burdick, new hire (fish), technicians, GRAs	Create fish life history database; extract data from FishBase, literature, student research; Marianas focus	Update fish life history database; extract data from FishBase, literature, student research; Marianas focus; workshop	Update fish life history database; extract data from FishBase, literature, student research; Marianas focus	Update fish life history database; extract data from FishBase, literature, student research; Marianas focus	Update fish life history database; extract data from FishBase, literature, student research; Marianas focus	
Outcomes	Online accessible databases of taxonomic diversity, Randall Coral Collection, microscope slide collections (otoliths, gonads, etc.), patterns of diversity, habitat association and life history for select groups.						
Objective 3	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Activity 1: Incorporate collection holdings in Biorepository (diatoms, terrestrial plants, marine/aquatic plants, insects, nudibranchs; digitize, image, database, place data online	Donaldson, Burdick, curators	Begin incorporation of UOG natural history collections; digitization, imaging, database entries (10% of holdings)	Digitization, imaging, database entries, online (20% of holdings)	Digitization, imaging, database entries, online access (25% of holdings)	Digitization, imaging, database entries, online access; storage of collections in new or improved facilities (25% of holdings)	Digitization, imaging, database entries, online access; storage of collections in new or improved facilities (20% of holdings)	One-stop source for biodiversity specimens and data
Outcomes	Increased infrastructure and curatorial management capabilities for UOG natural history collections, global access to databases; increased collections that document regional biodiversity.						

Table 8 – Biorepository faculty, staff, and external collaborators

Name	Affiliation	Expertise	Goal/Tasks
Bastian Bentlage	UOGML	Bioinformatics, cnidarians	G1/T2,3,8
David Burdick	UOGML	Collections Manager, corals	G1/T1, 2, 3,5,6,7,8,9; 2/1
Terry Donaldson	UOGML/Guam EPSCoR	Science Lead, Curator of Fishes	G1/T2,3,4,5,6,7,8,9; 2/1
Sarah Lemer	UOGML	Assistant Curator of Mollusks	G1/T2,3,8
Daniel Lindstrom	UOG Biology	Genetics, aquatic species	G1/T2,3,4
Chris Lobban	UOG Biology	Curator of Diatoms	G2/T1
Aubrey Moore	UOG CNAS-Agriculture	Curator of Insects	G2/T1
Tom Schils	UOGML	Curator of Marine Plants	G2/T1
Wei Xiao	UOG Biology	Assistant Curator of Terrestrial Plants	G2/T1
Biorepository Data Technician	Guam-EPSCoR	Programming and databases	G1, G2/all tasks
New hire	UOGML	Assistant Curator of Fishes, vertebrate morphology	G1/T2,3,6
New hire	UOGML	Assistant Curator of Crustaceans	G1/T2,3,8
New hire post-doc	UOGML	Taxonomy, systematics, bioinformatics	G1/T2, 3, 4, 8
Hank Bart	Tulane University	Ichthyology, bioinformatics	G1/T3,7,8
Michael Crosby	Mote Marine Laboratory	Biodiversity, coral reefs	G1/T3,7,8
Erik Franklin	Hawaii Institute of Marine Biology	Fishes, life histories	G1/T3,7,8,9
Michelle Gaither	University of Central Florida	Genetics, genomics, biodiversity	G1/T3,7,8
Carol Stepien	NOAA Pacific Environmental Research Lab	e-DNA	G1/3,4
Jonathan Whitney	NOAA Pacific Islands Fisheries Center	Fishes, biodiversity, life histories	G1/T3,7,8,9





Table 9 – Cyberinfrastructure in Support of Research: Establish High-throughput Computing Resources

Goal 1: Provide high-throughput computing capabilities, data redundancy and security							
Objective 1.1a: Implement local HTC compute pool							
Objective 1.1b: Improve HTC research computing support							
Objective 1.1c: Enable access to national HTC resources							
Objective 1.2a: Local data storage and backup							
Objective 1.2b: Remote data archival							
Objective 1.1a	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Establish HTC compute-pool at UOG	Hechanova, Bentlage	procurement and installation of servers; set up of job scheduling system for shared use	onboarding of users; identify additional software to be installed to serve users; develop online documentation for HTC resource	survey to identify issues with user experience	survey to identify issues with user experience	survey to identify issues with user experience	Local HTC compute cluster
Objective 1.1b	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Timely hires	Hechanova, Bentlage	Recruit research computing facilitator					User support and training for HTC resources
HTC user support	Research Computing Facilitator		training for research computing facilitator at UW-Madison (potentially virtual training if COVID-19 pandemic continues)	training and workshops for UOG HTC users	training and workshops for UOG HTC users	training and workshops for UOG HTC users	
Objective 1.1c	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Assess capabilities and needs for research computing	Bentlage	assess UOG's research computing capabilities; conduct survey among UOG faculty to identify specific needs	Annual survey to assess research computing user experience	Annual survey to assess research computing user experience	Annual survey to assess research computing user experience	Annual survey to assess research computing user experience	Assessment of research computing capabilities and needs. Access to off-campus computing resources to improve capabilities.
Open Science Grid (OSG)	Research Computing Facilitator		identify potential users of OSG through survey; workshop on OSG usage	provide support for UOG OSG users; evaluate feasibility of local OSG submit node and implement node	provide support for UOG OSG users	provide support for UOG OSG users	
University of Hawaii compute cluster	Bentlage, Research Computing Facilitator	Develop MOU with UH to provide UOG researchers access to UH compute cluster	onboarding of users to UH compute cluster	interview users and UH collaborators to identify potential issues			
Objective 1.2a	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Data storage and backup	Hechanova, Bentlage	procure network attached storage arrays (NAS); install one NAS locally to serve as data drives to local HTC pool; identify mission critical directories and files to be backed up to the Google cloud using existing UOG contract for cloud-storage	install second NAS off-campus at local telecommunications provider; implement daily backup routines to push data from campus servers to off-campus NAS	procure additional hard drives for NAS as necessary			Redundant data storage, providing accessibility and security
Objective 1.2b	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Remote data archival	Bentlage, Research Computing Facilitator	File participation application with NSF-funded OARRstore data archive; estimate initial size of archival data and procure tape-space at OARRstore archive	provide workshops to UOG researchers to raise awareness and provide training on scope and usage of data archive	Annual solicitation of proposals across campus for datasets to be included in archive; selected datasets uploaded to archive	Annual solicitation of proposals across campus for datasets to be included in archive; selected datasets uploaded to archive	Annual solicitation of proposals across campus for datasets to be included in archive; selected datasets uploaded to archive	Long-term data archive



EDUCATION AND WORKFORCE DEVELOPMENT

The GECCO Education and Workforce Development (EWD) Program will advance the jurisdiction's STEM capacity needs and contribute to improved island sustainability through expanded place-based and culturally relevant activities. GECCO will accomplish this by meeting four (4) NICE (Natural Resources, Information Technology, Circular Economy, Engagement) objectives. GECCO contribute to the local workforce, further stimulating Guam's competitive research capabilities and encouraging a local green economy. Objectives and tasks are summarized in Table 10.

1. Natural Resources: GECCO will expand training and education in natural resources-related research. Student research experiences, professional development trainings, connections to national opportunities, and natural resources curricula will be expanded. GECCO will maximize opportunities to broaden participation in island communities in alignment with the NSF INCLUDES SEAS Island Alliance (HRD-1930857) together with hubs in the U.S. Virgin Islands and Puerto Rico.

- **Activity 1. Student Research Experiences:** Undergraduate and graduate student research assistants will work with faculty/researchers on GECCO-related research.
- **Activity 2: Near-Peer Mentorship Program:** A near-peer mentor is close-in age/experience to a mentee who seeks advice in overcoming obstacles the mentor recently surmounted. Post-docs, graduate students, and undergraduates will participate in a near-peer mentoring program to promote matriculation upward along the STEM pathway. UOG programs will be leveraged to assist with academic support and services for undergraduate research assistants.
- **Activity 3. Island Sustainability Certificate Program:** Island sustainability is a common research thread across the university that ensures critical island needs are met. An interdisciplinary committee of faculty will establish an Island Sustainability Certificate Program for undergraduate and graduate education. As UOG moves toward the goal of a Carnegie R3 designation and creating a Ph.D. program in

biology, this certificate program will serve as a unique offering to attract students.

- **Activity 4. SACNAS National Conference:** Due to distance from the U.S. mainland, Guam's students are at a disadvantage for accessing national STEM opportunities. GECCO will support travel for student research assistants, mentors, and program staff to attend the SACNAS National Conference, the nation's largest multicultural and multidisciplinary STEM diversity conference. Students will have the opportunity to present their research and access a national network of mentors, graduate school, and career opportunities.
- **Activity 5. Professional development for post-docs and early-career faculty:** GECCO will host annual workshops for postdocs, faculty, and researchers. Topics may include promotion and tenure, publishing, building effective collaborations, science communication, and student mentoring. Relevant experts on the topics will be recruited from collaborating institutions and the national SACNAS network to conduct the workshops. To promote retention and career development, opportunities for individual discipline-specific training will be provided through seed funding, and post-docs and early-career faculty will be paired with a senior faculty mentor and complete an individual development plan.
- **Activity 6. Professional development (PD) for STEM students:** GECCO student research assistants and members of UOG and Guam Community College STEM-related student organizations will be invited to participate in professional development activities, such as leadership retreats and STEM symposia each year. Content will include pathway strategies to matriculate from undergraduate to graduate programs, including the proposed UOG Ph.D. program in biology.

2. Information Technology: GECCO will build IT capacity for the jurisdiction while supporting research activities. GECCO will support professional development, coursework, and certifications for

UOG Office of Information Technology (OIT) team members, coding camps for students and community members, and coordination for gatherings of Silicon Village.

- Activity 1. Professional Development in IT: To increase capacity and retention of staff in OIT, the team will receive training and continuing education opportunities.
- Activity 2. Coding Camps: To increase IT capacity and workforce development in the jurisdiction, coding camps will be conducted in cooperation with the non-profit Code Fountain for students and community members.
- Activity 3. Silicon Village: Silicon Village is an organization of telecommunications professionals working together to address IT capacity needs for the jurisdiction necessary for continued cyberinfrastructure improvements. Guam EPSCoR will assist in coordinating the network and aligning efforts with the Guam Science & Technology Committee.

3. Circular Economy: GECCO will catalyze the Guam Green Growth (G3) Initiative to spark a new green economy in the jurisdiction and improve island sustainability through the cultivation of a circular economy.

- Activity 1. Circular Economy Business Incubation: Support trainings, workshops, and seed funding to stimulate new circular economy industries and improve island sustainability.
- Activity 2. Guam Green Growth (G3) Maker Space: Establish a makerspace in the jurisdiction to facilitate the development of new 'circular' local products and innovations. A G3 coordinator will recruit 'Green Growth Makers' to work in the G3 Maker Space and connect them with developmental resources to create business plans and bring products to market.
- Activity 3. Redesign business capstone course: A faculty committee will redesign the School of Business and Public Administration (SBPA) Business Strategy and Policy Capstone Course (BA480) to incorporate an island sustainability and circularity focus. The redesigned course will be interdisciplinary and inclusive of STEM

students. Capstone teams will be taught to use systems-thinking to find leverage points in economic supply chains, close leakages, and develop profitable business plans for the private sector or zero-net-loss strategies for government investment into solutions for island challenges.

4. Engagement: The communities of Guam and Micronesia are underrepresented and underserved in STEM on the national landscape. GECCO will increase STEM awareness and engagement through a variety of educational outreach activities through special courses, conferences, a science learning center, science fairs, and the coordination of environmentally sustainable campus operations.

- Activity 1. Educational Outreach and Community Engagement: Communicate and disseminate GECCO science to public through educational outreach and community engagement activities, such as outreach tabling, classroom presentations, and STEM and Sustainability Expos.
- Activity 2. GECCO Conferences and Special Courses: Coordinate conferences, workshops, and special courses to increase STEM awareness and build capacity for local informed decision making.
- Activity 3. Science Learning Center: Collaborate with UOG Sea Grant and the Center for Island Sustainability to run the STEM and Marine Science Learning Center.
- Activity 4. Island Wide Science Fair: Support the annual Guam Island-Wide Science Fair. Science fair participation has been shown to increase the likelihood that participants will major in a STEM discipline in college.
- Activity 5. Sustainable operations and campus community: Ensure that GECCO themes of climate change, resiliency, and island sustainability will permeate throughout the university campus through the creation of a sustainable operations strategy.

Table 10 : Education Workforce Development Goals and Milestones

EWD GOAL: Increase the jurisdiction's STEM and workforce capacity while contributing to improved island sustainability through place-based and culturally relevant activities							
Objective EWD 1: Natural Resources- Increase capacity to support the understanding and management of natural resources amid global environmental changes by expanding training and education							
Objective EWD 1.1: Provide Research Opportunities to Undergraduate and Graduate Students (SRE/GRA)							
Objective EWD 1.2: Promote matriculation upward along the STEM pathway							
Objective EWD 1.3: Support UOG's goal of a Carnegie R3 designation and creating a Ph.D. program in biology by establishing a pathway that focuses on the islands sustainability needs							
Objective EWD 1.4: Increase local student opportunities to access national STEM Opportunities							
Objective EWD 1.5: Promote retention and career development for Post-Docs, Faculty, and Researchers							
Objective EWD 1.1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 1.1a Facilitate in-school programs established by GEC - Graduate Research Assistantship (GRA) - 3 Year Program.	Shelton, Sanguenza, Bentlage, Hammond	EWD Program Associate hired. Guam EPSCoR Student Committee formed and protocols established. Virtual student management platform created. Six (6) GRAs supported in Guam EPSCoR research.	Sixteen (16) GRAs supported in GECCO research.	Twenty-four (24) GRAs supported in GECCO research. Six (6) GRAs conclude EPSCoR research and transition for graduation at end of Year 3.	Eighteen (18) GRAs supported in GECCO research. Ten (10) GRAs conclude GECCO research and transition for graduation at end of Year 4.	Eight (8) GRAs supported in GECCO research. Eight (8) GRAs conclude GECCO research and transition for graduation at end of Year 5.	24 total GRAs and 60 undergraduates/postgraduates trained in Guam EPSCoR research and outreach, of which 50% are URM and/or women.
Task EWD 1.1b Facilitate in-school programs established by GEC - Student Research Experience (SRE) - One (1) Year Program in GECCO Research.	Shelton, Sanguenza, Hammond	Student Research Experiences (SRE) programming developed. Twelve (12) undergraduates or postgraduates supported in GECCO SREs, with option to defer some positions to Years 2-5 as a COVID-19 pandemic mitigation measure.	Twelve (12) undergraduates or postgraduates supported in GECCO SREs.	Twelve (12) undergraduates or postgraduates supported in GECCO SREs.	Twelve (12) undergraduates or postgraduates supported in GECCO SREs.	Twelve (12) undergraduates or postgraduates supported in GECCO SREs.	
Task EWD 1.1c Targeted recruiting and tailored promotion of student research assistantships and experiences. (Broadening Participation)	Shelton, Sanguenza, Hammond	Strategy developed to recruit underrepresented minority (URM) and women student participants for Guam EPSCoR research (including SE Asian/Filipino students traditionally underrepresented in STEM in Guam).	Increase in URM student participants since Year 1. On track to reach 50% URM and/or women student participation in Year 3.	50% of student participants are URM and/or women.	50% of student participants are URM and/or women.	50% of student participants are URM and/or women.	
Outcomes EWD1.1	Broadened participation of URM and/or women students in scientific research who are prepared for next steps in STEM careers.						
Objective EWD 1.2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 1.2a Implement Near- Peer Mentorship Program to include post-docs, graduate students, and undergraduates led by a UOG School of Education faculty member. UOG TRIO programs will assist with providing academic support and services for undergraduate research assistants.	Sanguenza, Hammond	UOG School of Education faculty member hired to GECCO team. Near-peer Mentorship Program Developed. All Guam EPSCoR undergraduates, GRAs, and Post-docs participated in Near-Peer Mentorship Program activities.	All Guam EPSCoR undergraduates, GRAs, and Post-docs participated in Near-Peer Mentorship Program activities.	All Guam EPSCoR undergraduates, GRAs, and Post-docs participated in Near-Peer Mentorship Program activities.	All Guam EPSCoR undergraduates, GRAs, and Post-docs participated in Near-Peer Mentorship Program activities.	All Guam EPSCoR undergraduates, GRAs, and Post-docs participated in Near-Peer Mentorship Program activities.	All Guam EPSCoR undergraduates, GRAs, and Post-docs benefit from a Near-Peer Mentorship Program and PD workshops.
Task EWD 1.2a Annual Professional Development Workshops for GECCO Student Researchers and STEM-related Student Organizations from UOG and GCC.	Shelton, Sanguenza, Hammond	One (1) PD workshop for STEM students held with 20-50 participants.	One (1) PD workshop for STEM students held with 20-50 participants.	One (1) PD workshop for STEM students held with 20-50 participants.	One (1) PD workshop for STEM students held with 20-50 participants.	One (1) PD workshop for STEM students held with 20-50 participants.	
Outcomes EWD 1.2	Opportunities expanded for URM islander students to succeed in STEM and matriculate through programs, increasing the number of students who secure competitive STEM Careers within the region and globally.						
Objective EWD 1.3	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 1.3a Facilitate and convene an interdisciplinary committee of faculty to establish an academic Island Sustainability Certificate Program.	Shelton, Enriquez, Hammond	Interdisciplinary faculty committee formed and chair appointed. A report of recommendations for implementing an Island Sustainability Certificate Program is created.	Program requirements, core competencies, and program learning outcomes are determined, a course map is developed, and courses are added or adapted across programs to create interdisciplinary Island Sustainability offerings.	Island Sustainability Certificate Program piloted and assessed.	Certificate program implemented, assessed, and adjusted.	Certificate program implemented, assessed, and adjusted. At least ten (10) students enrolled in program or completed.	A new Islands Sustainability Certificate Program created at UOG and ten (10) students enrolled or completed before end of project.
Outcomes EWD1.3	An unique STEM and interdisciplinary certificate offering is created at UOG, contributing to the institution's goal of creating a Ph.D. program in biology and achieving a Carnegie R3 designation.						
Objective EWD 1.4	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 1.4a Support travel for students, research mentors, and program staff to attend the SACNAS National Diversity in STEM Conference.	Shelton, Sanguenza, Hammond	A delegation of thirty (30) Guam EPSCoR students, faculty, and staff participate in virtual conference in lieu of travel.	A delegation of ten (10) Guam EPSCoR students, faculty, and staff participated in the SACNAS National Diversity in STEM Conference.	A delegation of ten (10) Guam EPSCoR students, faculty, and staff participated in the SACNAS National Diversity in STEM Conference.	A delegation of ten (10) Guam EPSCoR students, faculty, and staff participated in the SACNAS National Diversity in STEM Conference.	A delegation of ten (10) Guam EPSCoR students, faculty, and staff participated in the SACNAS National Diversity in STEM Conference.	Seventy (70) Guam EPSCoR students, research mentors, and staff participate in SACNAS conferences.

Outcomes EWD 1.4	Islander students, research mentors, and program staff, who are normally separated by distance from national opportunities, will have the opportunity to present their research and access a national network of mentors, graduate schools, and career opportunities at the nation's largest multicultural and multidisciplinary STEM diversity conference.						
Objective EWD 1.5	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 1.5a Host an annual professional development workshop for postdocs and early-career faculty.	Shelton, Sanguenza, Donaldson, Leon Guerrero, Hammond	One (1) annual professional development workshop is held for 10-20 post-docs and early-career faculty participants.	One (1) annual professional development workshop is held for 10-20 post-docs and early-career faculty participants.	One (1) annual professional development workshop is held for 10-20 post-docs and early-career faculty participants.	One (1) annual professional development workshop is held for 10-20 post-docs and early-career faculty participants.	One (1) annual professional development workshop is held for 10-20 post-docs and early-career faculty participants.	5 professional development workshops for post-docs and early-career faculty are held.
Outcomes EWD 1.5	Retention and career development of postdocs and early-career faculty supported through professional development opportunities.						

Table 10 : Education Workforce Development Goals and Milestones Continued...

Objective EWD 2: Information Technology- Build IT capacity for the jurisdiction while supporting research activities							
Objective EWD 2.1: Increase IT capacity and retention of staff in UOG Office of Information and Technology							
Objective EWD 2.2: Increase IT/Cyberinfrastructure capacity and workforce development in the jurisdiction							
Objective EWD 2.1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 2.1a Professional development awards given to OIT staff to support workshop travel and participation, coursework fees, or certifications.	Shelton, Bentlage, Hechanova, Hammond	One (1) professional development award, maintaining option to defer to Years 2-5 as a COVID-19 pandemic mitigation measure.	One (1) professional development award.	N/A	One (1) professional development award.	One (1) professional development award.	Four (4) professional development awards provided to OIT staff.
Outcomes EWD 2.1	The jurisdiction benefits from increased OIT staff capacity in areas such as high throughput computing for network engineers to improve long-term computing power, volume of tasks, and improvement of user workflow efficiency.						
Objective EWD 2.2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 2.2a Conduct coding camps for students and community members	Shelton, Bentlage, Hechanova, Hammond	Development of Coding Camp curriculum and instruction partners to host events annually	Two (2) Coding Camps events held targeting 20 participants	Two (2) Coding Camps events held targeting 20 participants	Two (2) Coding Camps events held targeting 20 participants	Two (2) Coding Camps events held targeting 20 participants	Eight (8) Coding Camps events held targeting 80 participants and 5 Silicon Village Meetings held.
Task EWD 2.2b Coordinate "Silicon Village" meetings and align efforts with the Guam Science & Technology Committee.	Shelton, Moore-Linn, Hammond	Silicon Village meeting held.	Silicon Village meeting held.	Silicon Village meeting held.	Silicon Village meeting held.	Silicon Village meeting held.	
Outcomes EWD 2.2	Increased awareness and capacity in IT careers and improved jurisdictional IT/Cyberinfrastructure coordination.						

Table 10 : Education Workforce Development Goals and Milestones Continued...

Objective EWD 3: Circular Economy- Spark a new green economy in the jurisdiction and improve island sustainability through the cultivation of a circular economy							
Objective EWD 3.1: Place-based and culturally relevant activities to catalyze island sustainability and circular economy initiatives relative to GECCO							
Objective EWD 3.2: Incorporate an island sustainability and circularity focus into University offerings							
Objective EWD 3.1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 3.1a Partner with a local business incubator to incubate circular economy businesses.	Shelton, Mugol	Partnership with Guam Unique Merchandise & Art (GUMA) business incubator to stimulate new or expanded local circular economy industries. One (1) cohort completes business incubator with circular economy focus. At least one (1) circular economy practice adopted or expanded by a local business.	One (1) cohort completes business incubator with circular economy focus. At least one (1) circular economy practice adopted or expanded by a local business.	One (1) cohort completes business incubator with circular economy focus. At least one (1) circular economy practice adopted or expanded by a local business.	One (1) cohort completes business incubator with circular economy focus. At least one (1) circular economy practice adopted or expanded by a local business.	One (1) cohort completes business incubator with circular economy focus. At least one (1) circular economy practice adopted or expanded by a local business.	Circular economy makerspace, innovation hub, and business incubator are established to promote and expand island circular economy industries.
Task EWD 3.1b Coordinate with Pacific Islands Small Business Development Center (PI-SBDC), UOG School of Business and Public Administration C4E1, and Guam Economic Development Authority to create an Innovation Hub that stimulates the creation and expansion of island circular economy industries.	Shelton, Mugol	Partnerships are formed and a G3 Circular Economy Innovation Hub is created, serving as a business ecosystem to support circular economy industries.	Innovation hub resources developed and curated to promote the creation and expansion of island circular economy industries. Directory of experts maintained and connections facilitated between hub members. Circular economy workshops offered, recorded, and curated. Educational resources maintained for entrepreneurs to create business plans and bring products to market.	Innovation hub resources developed and curated to promote the creation and expansion of island circular economy industries. Directory of experts maintained and connections facilitated between hub members. Circular economy workshops offered, recorded, and curated. Educational resources maintained for entrepreneurs to create business plans and bring products to market.	Innovation hub resources developed and curated to promote the creation and expansion of island circular economy industries. Directory of experts maintained and connections facilitated between hub members. Circular economy workshops offered, recorded, and curated. Educational resources maintained for entrepreneurs to create business plans and bring products to market.	Innovation hub resources developed and curated to promote the creation and expansion of island circular economy industries. Directory of experts maintained and connections facilitated between hub members. Circular economy workshops offered, recorded, and curated. Educational resources maintained for entrepreneurs to create business plans and bring products to market.	
Task EWD 3.1c Integrate GECCO Research into G3 Innovation Hub through researcher-led "Science Cafes".	Shelton, Mugol, Hammond, Research Team	Partnerships are formed and a G3 Circular Economy Innovation Hub is created, serving as a business ecosystem to support circular economy industries.	GECCO Researchers will contribute to the G3 Innovation Hub through 'Science Cafe' meetings with the general community, entrepreneurs and the	GECCO Researchers will contribute to the G3 Innovation Hub through 'Science Cafe' meetings with the general community, entrepreneurs and the	GECCO Researchers will contribute to the G3 Innovation Hub through 'Science Cafe' meetings with the general community, entrepreneurs and the	GECCO Researchers will contribute to the G3 Innovation Hub through 'Science Cafe' meetings with the general community, entrepreneurs and the	

			emerging green workforce to offer scientific background on natural resources and environmental issues. Participants will learn circular economy principles (designing out waste and pollution, regenerating natural systems, keeping materials in use) and how to adopt environmentally-conscious business models.	emerging green workforce to offer scientific background on natural resources and environmental issues. Participants will learn circular economy principles (designing out waste and pollution, regenerating natural systems, keeping materials in use) and how to adopt environmentally-conscious business models.	emerging green workforce to offer scientific background on natural resources and environmental issues. Participants will learn circular economy principles (designing out waste and pollution, regenerating natural systems, keeping materials in use) and how to adopt environmentally-conscious business models.	emerging green workforce to offer scientific background on natural resources and environmental issues. Participants will learn circular economy principles (designing out waste and pollution, regenerating natural systems, keeping materials in use) and how to adopt environmentally-conscious business models.	
Task EWD 3.1 d Establish the G3 Circular Economy Makerspace in the jurisdiction to facilitate the development of new 'circular' local products and innovations.	Shelton, Mugol	Guam Green Growth (G3) Circular Economy Coordinator hired. Makerspace established and opened in central Guam location.	G3 Makerspace operations maintained. Community of Green Growth Makers recruited and cultivated. Circular economy prototypes and products created in G3 Makerspace.	G3 Makerspace operations maintained. Community of Green Growth Makers recruited and cultivated. Circular economy prototypes and products created in G3 Makerspace.	G3 Makerspace operations maintained. Community of Green Growth Makers recruited and cultivated. Circular economy prototypes and products created in G3 Makerspace.	G3 Makerspace operations maintained. Community of Green Growth Makers recruited and cultivated. Circular economy prototypes and products created in G3 Makerspace.	
Outcomes EWD 3.1	GECCO EWD and Research catalyzed the Guam Green Growth (G3) initiative and contributed to a new green economy in the jurisdiction, improving island sustainability.						
Objective EWD 3.2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 3.2a Faculty committee will redesign the School of Business and Public Administration (SBPA) Business Strategy and Policy Capstone Course (BA480) to incorporate an island sustainability and circularity focus.	Shelton, Schumann, Rivera, Hammond	A faculty committee convenes and integrates circular economy focus into the SBPA Business Strategy and Policy Capstone Course (BA480).	New capstone course is piloted and assessed.	Capstone course implemented and assessed.	Capstone course implemented and assessed.	Capstone course implemented and assessed.	New capstone course with a circular economy focus is implemented and assessed. PMBA program updated with UN SDG sustainability focus.
Task EWD 3.2b Guam Green Commitment	Shelton, Schumann,	A faculty committee convenes and integrates Guam Green	Pilot program and assessment.	Guam Green Commitment formally integrated into PMBA	Continued implementation and assessment.	Continued implementation and assessment.	
Outcomes EWD 3.2	Business and circular economy solutions to critical island challenges are developed using systems-thinking to find leverage points in economic supply chains, close leakages, and develop profitable business plans for the private sector or zero-net-loss strategies for government investment.						
Table 10 : Education Workforce Development Goals and Milestones Continued...							
Objective EWD 4: Engagement- Increase STEM/Sustainability awareness and engagement in underrepresented and underserved communities in the region							
Objective EWD 4.1: Communicate and disseminate GECCO science to public							
Objective EWD 4.2 Broaden STEM participation and awareness and build capacity for informed local decision making							
Objective EWD 4.3 Permeate GECCO themes of climate change, resiliency, and island sustainability throughout the university campus							
Objective EWD 4.1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 4.1 a Educational outreach and community engagement activities, such as outreach tabling, classroom presentations, and STEM and Sustainability Expos.	Shelton, Dedicataria, Kirk, Santos, Hammond	EWD Program Associate and Science Communicators hired. Develop outreach and community engagement strategy.	5,000 community members reached through direct contact and/or social and virtual media. Student/Graduate research assistants conducted a minimum of 20 hours of community outreach hours.	5,000 community members reached through direct contact and/or social and virtual media. Student/Graduate research assistants conducted a minimum of 20 hours of community outreach hours.	5,000 community members reached through direct contact and/or social and virtual media. Student/Graduate research assistants conducted a minimum of 20 hours of community outreach hours.	5,000 community members reached through direct contact and/or social and virtual media. Student/Graduate research assistants conducted a minimum of 20 hours of community outreach hours.	10-15K community members reached through direct contact and social media. Science Learning Center updated with GECCO Research. UOG Conference on Island Sustainability coordinated. Seed funding projects incorporate EWD elements.
Task EWD 4.1 b Collaborate with UOG Sea Grant and the Center for Island Sustainability to run the STEM and Marine Science Learning Center.	Shelton, Dedicataria, Kirk, Santos, Hammond, Research Team	Science Learning Center incorporates GECCO research focus areas.	Continual exhibit improvements made with input from EPSCoR Researchers. Educational tours coordinated.	Continual exhibit improvements made with input from EPSCoR Researchers. Educational tours coordinated.	Continual exhibit improvements made with input from EPSCoR Researchers. Educational tours coordinated.	Continual exhibit improvements made with input from EPSCoR Researchers. Educational tours coordinated.	
Task EWD 4.1 c Coordinate conferences to highlight and share GECCO topics of interest.	Shelton, Hammond	The UOG Conference on Island Sustainability is coordinated, showcasing GECCO research and reaching 200-300 attendees.	The UOG Conference on Island Sustainability is coordinated, showcasing GECCO research and reaching 200-300 attendees.	The UOG Conference on Island Sustainability is coordinated, showcasing GECCO research and reaching 200-300 attendees.	The UOG Conference on Island Sustainability is coordinated, showcasing GECCO research and reaching 200-300 attendees.	The UOG Conference on Island Sustainability is coordinated, showcasing GECCO research and reaching 200-300 attendees.	
Task EWD 4.1 d Incorporate educational outreach and sustainability components to Seed Funding and Emerging Areas (Table 12).	Donaldson, Leon Guerrero, Shelton	Collaborate with PIs of GECCO Seed Funding Research and Education Projects to develop and implement a STEM educational outreach component.	Collaborate with PIs of GECCO Seed Funding Research and Education Projects to develop and implement a STEM educational outreach component.	Collaborate with PIs of GECCO Seed Funding Research and Education Projects to develop and implement a STEM educational outreach component.	Collaborate with PIs of GECCO Seed Funding Research and Education Projects to develop and implement a STEM educational outreach component.	Collaborate with PIs of GECCO Seed Funding Research and Education Projects to develop and implement a STEM educational outreach component.	
Outcomes EWD 4.1	The underrepresented and underserved islander community is connected and aware of local, regional, and national STEM/Sustainability research and resources and opportunities.						
Objective EWD 4.2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task EWD 4.2a Coordinating workshops and special courses on science fair teacher training, traditional navigation, climate change, and/or other place-based and	Shelton, Hammond	Special courses and/or workshops are coordinated reaching 20-100 participants.	Special courses and/or workshops are coordinated reaching 20-100 participants.	Special courses and/or workshops are coordinated reaching 20-100 participants.	Special courses and/or workshops are coordinated reaching 20-100 participants.	Special courses and/or workshops are coordinated reaching 20-100 participants.	Special courses and/or workshops are coordinated

culturally relevant topics.								reaching 200-500 participants.
Task EWD 4.2b Support the annual Guam Island-Wide Science Fair.	Shelton, Hammond	The annual Guam Island Wide Science Fair conducts an educational training activity as a COVID-19 mitigation measure.	The Guam Island Wide Science Fair is co-coordinated, engaging 400 to 600 K-12 student participants.	The Guam Island Wide Science Fair is co-coordinated, engaging 400 to 600 K-12 student participants.	The Guam Island Wide Science Fair is co-coordinated, engaging 400 to 600 K-12 student participants.	The Guam Island Wide Science Fair is co-coordinated, engaging 400 to 600 K-12 student participants.	The Guam Island Wide Science Fair is co-coordinated, engaging 400 to 600 K-12 student participants.	The Guam Island Wide Science Fair is held annually, reaching 1600 to 2400 K-12 student participants.
Outcomes EWD 4.2	STEM engagement opportunities increased in the jurisdiction.							
Objective EWD 4.3	Responsible Parties	Milestones					Outputs	
		Year 1	Year 2	Year 3	Year 4	Year 5		
Task EWD 4.3a Promote Sustainable Operations on Campus through UOG Green.	Shelton, Hammond	A UOG Sustainable Operations Committee established, providing strategies for incorporating sustainable systems-thinking into campus operations.	Regular committee meetings facilitated. Sustainable activities implemented and assessed.	Regular committee meetings facilitated. Sustainable activities implemented and assessed.	Regular committee meetings facilitated. Sustainable activities implemented and assessed.	Regular committee meetings facilitated. Sustainable activities implemented and assessed.	Regular UOG Sustainable Operations are held and sustainable activities implemented. Campus community engaged each year through sustainable outreach events.	
Task EWD 4.3b Engage the student body in marine and environmental science issues.	Shelton, Hammond	1-2 campus sustainability outreach events coordinated, reaching 250-500 students.	1-2 campus sustainability outreach events coordinated, reaching 250-500 students.	1-2 campus sustainability outreach events coordinated, reaching 250-500 students.	1-2 campus sustainability outreach events coordinated, reaching 250-500 students.	1-2 campus sustainability outreach events coordinated, reaching 250-500 students.		
Outcomes EWD 4.3	University of Guam becomes a regional leader in Sustainable Operations, setting examples for local business and communities to follow. The campus community is educated on sustainability issues, leading to positive changes in life practices and increased engagement in these issues.							

Partnerships and Collaborations

The Collaboratorium is to establish a network of collaborating researchers and partnerships to work on various aspects of research problems and to increase competitive research and STEM capacity. Partnerships leading to economic development are discussed in the section on Education and Workforce Development. Research collaborations and science outreach activities are summarized in Table 11. These include formal Memoranda of Understanding (MOU) with institutions, agencies, telecoms, individual external collaborations, competitive seed funding awards for junior UOG faculty members (see below) pursuing collaborative research on remote sensing and coral reefs with the Guam NASA-EPSCoR program, a workshop with researchers from the Hawaii Institute of Marine Biology, promotion of curatorial digitization and high-speed connectivity with the UOG Archaeology Repository funded by the U.S. Department of Defense, and linkages with telecoms to provide for data management and training at UOG and in the community.

Seed Funding and Emerging Areas

GECCO will provide seed funding annually to UOG junior faculty researchers in Biology, Environmental Science, Mathematics and Engineering programs to catalyze research in high-risk, transformative, and emergent areas relevant to the GECCO project. Research support (\$10,000 to \$50,000 per award) to engage in the development and implementation of innovative research projects that would also support and provide training for 1-2 graduate or undergraduate students per project. Awardees will be required to develop a research proposal to be funded externally based upon their research supported with GECCO seed funding.

Additionally, GECCO will provide seed funding (\$10,000) annually for up to two UOG researchers in the form of innovative education and outreach grants to promote interest in STEM among women and underrepresented minorities in K-12, community college, or university levels, or to generate GECCO products for use by the STEM community.

Seed-funding grants will be awarded through open

competitions in Years 2-5 of the project (Table 12). Applications will be evaluated by a review team consisting of external experts not associated with the project.

Mentoring of Junior Faculty and Post-Doctoral Fellows

A plan to mentor junior faculty members and post-doctoral fellows will be developed and implemented beginning in Year 1 of the project in accordance with the programmatic terms and conditions specified by NSF (Table 13). Specifically, all Assistant Professors with research responsibilities in the project will identify an external (to UOG) scientific mentor in their field of research whose function will be to help the Assistant Professor plan and balance research strategies and develop timelines for their research. The mentor will be a mid-career or senior scientist with a proven track record of success in the field of research of the mentee. The mentor will be approved by the project management team as well as the EAB. The mentor/mentee will be expected to complete at least one reciprocal visit (one where the mentor visits the mentee's laboratory and one where the mentee visits the mentor's laboratory) during the project. The Assistant Professor and mentor will produce a report that demonstrates this mentor/mentee relationship by discussing developed plans and strategies that will help ensure scientific success for the Assistant Professor. The Assistant Professor's Department Chairperson, the project's PD, and the EAB will approve this report and a short commentary on each of these reports will be provided to NSF through an additional section of the annual report.

For Post-Doctoral Fellows, the sponsoring research faculty member will provide mentoring in research methodology. This mentoring will be supplemented with workshops or instruction on student supervision, grant writing, and job application strategies provided by the projects EWD, UOG's ORSP and the UOG Global Learning and Engagement Program.

Data Management Plan

Physical voucher specimens for morphological identification (e.g., whole specimens, dry skeletons, etc.) and genetic work (cryo-preserved tissue samples)

will be collected and deposited in the Biorepository. Specimens records will be digitized, and images will be stored in the database and shared using the Specify 6 web-portal, relying on an underlying relational database to manage records and images hosted on UOG's servers. Relevant literature and field notes will also be organized and shared using the Biorepository's database and web portal. Environmental, oceanographic, and functional trait data will be integrated into the Biorepository database and distributed after an initial embargo period to allow project researchers priority access for data analysis and publication. Integrating these different types of data in a single portal will create a one-stop-shop for biological and environmental data from Guam, increasing visibility and discovery of Guam's research enterprise. In addition, the project will generate large amounts of DNA sequencing data for animal and algal specimens for population genetics, DNA barcoding, metabarcoding, and genomics. These data will be backed up across on- and off-site data arrays, as well as the cloud to ensure data security and redundancy. Once results of analyses are disseminated to the broader scientific community, all sequencing data generated by the project will be archived in NCBI's GenBank. The NSF-funded long-term data archive OURRStore will provide long-term archival of images, videos, environmental and oceanographic data generated by GECCO and other projects at UOG. Tasks will be performed by collection curators and researchers, visiting researchers, the Collections Manager, two research technicians (curatorial and cyber), and graduate research assistants (typically two per year in the Biorepository; these may be augmented by a single undergraduate intern per year).

Communication and Dissemination Plan

The GECCO communication and dissemination plan (Table 14) will inform researchers, natural resource managers and stakeholders, decision makers, government agencies, non-governmental organizations, the private sector, and the general public about Guam and NSF EPSCoR, GECCO

research, education, outreach and workforce development activities, and project accomplishments. There are two objectives in the plan: 1) provide regular project updates and announcements through internal communications; and 2) provide information on project activities, developments, and outputs through external communications to external audiences. Internal communication and its methods of dissemination will be designed to inform and coordinate team members of project schedules, requirements, procurement tasks, as well as researcher, graduate student and undergraduate student assignments, deadlines, developments and progress, and other activities that allow the team to meet the goals of the project. Objectives and activities include maintenance of internal communications within the project through regular physical or virtual meetings (weekly, biweekly, or monthly depending upon task focus and content), email messages to team members, Dropbox and G-Suite data file access, and social media announcements on WhatsApp or FaceTime. External communications and its methods of dissemination will be designed to inform the scientific community, funders, government entities, and the general public of what GECCO is doing, why, how, and also of the significance of the outcomes of the project are. These communications will utilize the Guam EPSCoR website, various social media platforms, press releases and other means. Researchers, including faculty members, post-doctoral fellows, and graduate students will present results at scientific conferences annually, as well as in local and regional conferences such as the Island Sustainability Conference held annually on Guam that attracts hundreds of participants from around the world, either in person or through virtual means. Graduate students will relate the results of their research at thesis defense presentations. On campus seminars given by project researchers and collaborators will also describe the project's work. GECCO's science communication team, supervised by co-PI Austin Shelton, will be responsible for promoting the project's activities and outcomes.

Table 11: Partnerships and Collaborations Goals and Milestones

Goal PC 1: Build collaborations to increase GECCO research and outreach.							
Objective PC 1.1: Build and sustain collaborations and exchanges that enhance GECCO's research capabilities.							
Objective PC 1.2: Build and sustain collaborations and exchanges that enhance GECCO's outreach capabilities.							
Objective PC 1.1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1.1a Secure MOUs and collaborate with agencies, institutions, and telecoms.	Donaldson, Leon Guerrero	Collaborate with Mote, Marine Laboratory, Guam-NASA EPSCoR, HIMB, DOD, GTA, DOCOMO, etc.	Conduct exchanges, collaborative research; enhanced data management.	Collaborative research leading to publications, grant proposals, training opportunities; workshops; recruitment of graduate students; enhanced digital and cyber capabilities.			
Task 1.1b Establish and maintain collaborations with external researchers.	Donaldson, Bentlage, GECCO Researchers	Collaborate with individuals from external institutions and agencies in research related to GECCO.	Conduct research at UOG and elsewhere; individual exchange visits; produce papers.	Conduct research at UOG and elsewhere; individual exchange visits; produce papers.	Conduct research at UOG and elsewhere; individual exchange visits; produce papers.	Conduct research at UOG and elsewhere; individual exchange visits; produce papers.	
Outcomes PC 1.1	Research experiences and data contribute towards broadening GECCO research capabilities at the institutional level. One-to-one research experiences, data generation, and paper writing contribute towards broadening GECCO research capabilities.						
Objective PC 1.2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1.2a Collaborate with other institutions to communicate and disseminate GECCO science to public through educational outreach and community engagement activities, such as outreach tabling, classroom presentations, and STEM and Sustainability Expos.	ALL	Collaborate with Department of Education, NSF Investments, Sea Grant, and other institutional and community organizations.	Collaborate with Department of Education, NSF Investments, Sea Grant, and other institutional and community organizations.	Collaborate with Department of Education, NSF Investments, Sea Grant, and other institutional and community organizations.	Collaborate with Department of Education, NSF Investments, Sea Grant, and other institutional and community organizations.	Collaborate with Department of Education, NSF Investments, Sea Grant, and other institutional and community organizations.	At least 3 EWD External Partners.
Outcomes PC 1.1	The communities of Guam and Micronesia are underrepresented and underserved in STEM on the national landscape. GECCO will continue GEC efforts to increase STEM awareness and engagement through a variety of educational outreach activities.						
Goal PC 2: Increase STEM, Workforce Development, and sustainability partnerships in Guam and within the region (Micronesia)							
Objective PC 2.1: Establish EWD Synergies/Collaborations to broaden participation and student capacity building in STEM							
Objective PC 2.2: Develop and sustain collaborations with institutions, networks, and business for workforce development and capacity building							
Objective PC 2.3 Nurture partnerships for place based and culturally relevant activities to catalyze island sustainability and circular economy initiatives							
Objective PC 2.1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task PC 2.1a Align with NSF INCLUDES Island Alliance and foster synergies with other NSF investments, i.e. NSF CC* (OAC-1659182)	Shelton, Sanguenza, Bentlage, Hammond	Establish synergy with NSF INCLUDES: SEAS Island Alliance (HRD#1930857).	Maintain synergy with NSF Includes and look for other investments partnerships.	Maintain synergy with NSF Includes and look for other investments partnerships.	Maintain synergy with NSF Includes and look for other investments partnerships.	Maintain synergy with NSF Includes and look for other investments partnerships.	Maintain synergy with NSF Includes and look for other investments partnerships. Partnerships with Global Networks, Local Networks, and Local Education Organizations.
Task 2.1b Coordinate and collaborate on conferences, workshops, special courses, and fairs to increase STEM Participation. I.E. SACNAS Conference, UOG Regional Conference on Sustainability, Science Learning Center, Island Wide Science Fair, etc.	Shelton, Hammond, All GECCO Participants	Partnerships with Global Network (SACNAS), Local Network (Guam Green Growth), and Local Education Organizations (Guam Science and Discovery Society).	Maintain partnerships. Expand and enhance as needed. Pursue other opportunistic ventures.	Maintain partnerships. Expand and enhance as needed. Pursue other opportunistic ventures.	Maintain partnerships. Expand and enhance as needed. Pursue other opportunistic ventures.	Maintain partnerships. Expand and enhance as needed. Pursue other opportunistic ventures.	
Outcomes PC 2.1	Increase Matriculation in STEM Programs within the University. Recruitment of prospective students into STEM pathways. Develop Career Pathways for participants and develop them to be competitive in global markets. By leveraging financial support from other initiatives and programs GECCO will increase URM and women participation to 50% by 2025.						
Objective PC 2.2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 2.2a Recruit and collaborate with experts from institutions and SACNAS Network to facilitate Professional Development opportunities for Post Docs, Faculty, and Researchers.	Shelton, Hammond, All GECCO Participants	Recruit regionally or nationally recognized leaders to solidify reputation of Professional Development offerings.	Recruit regionally or nationally recognized leaders to solidify reputation of Professional Development offerings.	Recruit regionally or nationally recognized leaders to solidify reputation of Professional Development offerings.	Recruit regionally or nationally recognized leaders to solidify reputation of Professional Development offerings.	Recruit regionally or nationally recognized leaders to solidify reputation of Professional Development offerings.	Recruit and collaborate with regionally or globally recognized leaders to solidify reputation of Professional Development offerings
Task 2.2b Partnerships with Global IT Experts, and local IT Professionals/Businesses to enhance professional development, networking, and capacity building.	Shelton, Hechanova, Hammond	Recruit regional or global recognized leaders to solidify reputation of Professional Development offerings. Seek new partnerships for Silicon Village network.	Recruit regional or global recognized leaders to solidify reputation of Professional Development offerings. Seek new partnerships for Silicon Village network.	Recruit regional or global recognized leaders to solidify reputation of Professional Development offerings. Seek new partnerships for Silicon Village network.	Recruit regional or global recognized leaders to solidify reputation of Professional Development offerings. Seek new partnerships for Silicon Village network.	Recruit regional or global recognized leaders to solidify reputation of Professional Development offerings. Seek new partnerships for Silicon Village network.	
Outcomes PC 2.2	Improve local IT and workforce capacity through personnel and infrastructure developments providing STEM programs with improved human resources and efficiency tools to fulfill GECCO research and EWD Objectives.						
Objective PC 2.3	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 2.3a Create partnerships with government agencies to stimulate new circular economy initiatives and improve island sustainability	Shelton, Mugol, Hammond	Partnership with Guam Economic Development Authority for matching funds and Office of the Governor of Guam for Guam Green Growth political support.	Maintain partnerships. Develop as needed.				

Task 2.3b Create partnerships with local organizations to stimulate new circular economy industries and improve island sustainability.	Shelton, Mugol, Hammond	Establish partnerships with Guam Unique Merchandise and Art (GUMA) (a local business incubator). Have regular meetings to align objectives across programs. Collaborate on education and workshops.	Maintain partnerships. Expand and enhance as needed. Pursue other opportunistic ventures.	Maintain partnerships. Expand and enhance as needed. Pursue other opportunistic ventures.	Maintain partnerships. Expand and enhance as needed. Pursue other opportunistic ventures.	Maintain partnerships. Expand and enhance as needed. Pursue other opportunistic ventures.	GUMA business incubator cohort courses and support of small grants to create or expand circular economy businesses. Recruit Green Growth Makers to create products in the maker space and bring to the local and online market. Establish a Island Sustainability Certificate Program and drive Circular Economy principles into UOG Course offerings. Development of local, regional, and global partnerships laying the foundation for the islands sustainable future.
Task 2.3c Establish partnership with University organizations to stimulate new circular economy industries and improve island sustainability.	Shelton, Mugol, Hammond	Establish partnership and align Circular Economy objectives with School of Education, College of Natural and Applied Sciences, School of Business and Public Administration, the Pacific Islands Small Business Development Center (PI-SBDC), and Center for Innovation and Entrepreneurship. Collaborate on education and outreach. Create partnerships with UOG Plant and Facilities and UOG Student Government to Align sustainability objectives to support sustainable operations goals.	Maintain and develop new partnerships as needed.				
Task PC 2.3d Seek partnerships with educational institutions that offer Sustainability Programs to model Island Sustainability Certificate Program.	Shelton, Mugol, Hammond	Develop partnership with Arizona State University Julie Ann Wrigley Global Futures Laboratory	Continue partnership	Continue partnership	Continue partnership	Continue partnership	
Task PC 2.3e Establish partnerships with global organizations to further sustainability initiatives in the region	Shelton, Mugol, Hammond	Establish and maintain mutually beneficial relationships with the Global Island Partnership, Hawaii Green Growth, Local2030 Islands Network, and Global Consortium for Sustainability Outcomes.	Maintain partnerships and advance sustainability goals.				
Outcomes PC 2.3	GECCO will catalyze the Guam Green Growth (G3) Initiative to spark a new green economy in the jurisdiction and improve island sustainability through the cultivation of a circular economy. Mission to diversify industries and adapt practices to build economic resilience.						

Table 12 – Seed Funding and Emerging Areas

Goal 1: Provide funding for high-risk and potentially transformative research and outreach for GECCO.							
Objective 1: Support UOG junior faculty to pursue potentially transformative research linked to GECCO.							
Objective 2: Support UOG junior faculty to develop and implement innovative education and outreach projects that promote interest in STEM and GECCO research.							
Objective 1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Award research grants	Donaldson, Bentlage, Committee		Award	Award	Award	Award	Seed grants of \$10,000 to \$50,000 each awarded to UOG junior faculty.
Outcomes	Researchers pursue research questions important to the GECCO project and spur new external proposals for funding.						
Objective 2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Award education grants	Donaldson, Shelton		Award	Award	Award	Award	Seed grants of \$10,000 each awarded to UOG junior faculty.
Outcomes	Development of new and use of innovative methods to promote interest in STEM education and GECCO research within the community.						

Table 13 – Mentoring of Junior Faculty and Post-doctoral Fellows

Goal 1: Provide professional skills in research and management to new faculty and post-docs.							
Objective 1: Mentor junior faculty members							
Objective 2: Mentor post-doctoral fellows							
Objective 1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1: Provide UOG mentoring	Leon Guerrero, ORSP	Mentoring of new microbiologist begins	Mentoring of new microbiologist complete; three new hires begin mentoring program	Mentoring of new hires complete	New opportunities	New opportunities	New faculty hires proficient in UOG, GECCO research, and course development and instruction methods.
Outcomes	New faculty hires acquire skills necessary to understand UOG policies, GECCO research tasks, and graduate course instruction methods.						
Task 2: Match junior faculty member with senior external researcher	Donaldson, Bentlage, GECCO researchers		New microbiologist partnered with senior researcher; meetings via Zoom or other medium	Three new faculty researchers partnered with senior researcher; meetings via Zoom or other medium			New faculty hires apply methods learned towards research and instruction task.
Outcomes	New faculty hires learn procedures for running an effective and successful research project and the development of an innovative graduate course.						
Task 3: Junior faculty member-mentor exchanges	Donaldson, Bentlage, Leon Guerrero		New microbiologist visits mentor's lab.	Mentor visits microbiologist's lab.	Three new faculty researchers visit mentor's lab.	Mentors visit three researchers' labs.	Mentee/mentor reports provide details of mentoring relationships and skills acquired
Outcomes	New hires acquire additional knowledge of research and instruction methods from visit to mentor's lab; mentors see results of mentee's visit as applied to the mentee's lab and course development.						
Objective 2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1: Mentoring of post-doc by sponsor.	Donaldson, Bentlage, GECCO sponsors	Post-docs assigned to GECCO sponsors	Sponsors mentor post-docs in research, management methods	Sponsors mentor post-docs in research, management methods	Sponsors mentor post-docs in research, management methods	Sponsors mentor post-docs in research, management methods	Post-doctoral fellows apply methods learned and experience towards advancing their careers.
Outcomes	Post-doctoral fellows gain experience on laboratory management, research methods, and mentoring students.						
Task 2: Mentoring on UOG procedures and job applications	Leon Guerrero, ORSP	Post-docs assigned to UOG mentoring programs	Programs instruct post-docs in UOG procedures and in creating successful job applications	Programs instruct post-docs in UOG procedures and in creating successful job applications	Programs instruct post-docs in UOG procedures and in creating successful job applications	Programs instruct post-docs in UOG procedures and in creating successful job applications	Post-doctoral fellows apply methods learned and experience towards advancing their careers.
Outcomes	Post-doctoral fellows gain experience on university procedures and applying for research positions.						

Table 14 – Communication and Dissemination Plan

Objective 1: Provide regular internal announcements and updates about GECCO.							
Objective 2: Provide regular announcements about GECCO, Guam EPSCoR and NSF to external audiences.							
Objective 1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1: Provide GECCO participants with immediate updates	Donaldson, Dirige	GECCO listserv updated; shared as needed	Updates shared as needed	Updates shared as needed	Updates shared as needed	Updates shared as needed	Updates shared with participants and collaborators; monthly meetings bring together all Guam participants
Task 2: Provide GECCO participants with periodic updates	Donaldson, Dirige	PI/PD and PA provide monthly updates on progress	PI/PD and PA provide monthly updates on progress	PI/PD and PA provide monthly updates on progress	PI/PD and PA provide monthly updates on progress	PI/PD and PA provide monthly updates on progress	
Task 3: Hold GECCO team meetings monthly	Donaldson, Dirige	Monthly meetings held in Guam EPSCoR office	Monthly meetings held in Guam EPSCoR office	Monthly meetings held in Guam EPSCoR office	Monthly meetings held in Guam EPSCoR office	Monthly meetings held in Guam EPSCoR office	
Outcomes	GECCO participants inform on progress of project, report on developments, and increase understanding of project goals, objectives and scope.						
Objective 2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1: Maintain and update Guam-EPSCoR website	Shelton, science communicators	Revamp Guam EPSCoR website; solicit new information for posts	Update Guam EPSCoR website; solicit new information for posts	Update Guam EPSCoR website; solicit new information for posts	Update Guam EPSCoR website; solicit new information for posts	Update Guam EPSCoR website; solicit new information for posts	Website continuously updated; social media provides rapid dissemination of project news; monthly online newsletter distributed to wide audience; between 10-20 videos or interactive digital events presented; 5-10 featured seminars on GECCO results; project promoted at annual Island Sustainability Conference and other events; public informed about graduate student thesis research results.
Task 2: Promote progress through social media	Shelton, science communicators	Update social media 1-3 times a week; solicit new information for posts	Update social media 1-3 times a week; solicit new information for posts	Update social media 1-3 times a week; solicit new information for posts	Update social media 1-3 times a week; solicit new information for posts	Update social media 1-3 times a week; solicit new information for posts	
Task 3: Promote progress through monthly online press release to NSF and EPSCoR jurisdictions	Shelton, science communicators	Create and update mailing list; solicit and post new information via listserv	Update mailing list; solicit and post new information via listserv	Update mailing list; solicit and post new information via listserv	Update mailing list; solicit and post new information via listserv	Update mailing list; solicit and post new information via listserv	
Task 4: Share GECCO progress in public events	Shelton, science communicators	Create and share 2-4 videos or other content online	Create and share 2-4 videos or other content online	Create and share 2-4 videos or other content online	Create and share 2-4 videos or other content online	Create and share 2-4 videos or other content online	
Task 5: Promote GECCO progress in public events	Shelton, science communicators	Seminars, events to promote GECCO work	Seminars, events to promote GECCO work	Seminars, events to promote GECCO work	Seminars, events to promote GECCO work	Seminars, events to promote GECCO work	
Task 6: Thesis research presentations by students	Graduate students	Public thesis defense presentations	Public thesis defense presentations	Public thesis defense presentations	Public thesis defense presentations	Public thesis defense presentations	
Outcomes	Local and global audiences informed about GECCO progress and findings; promote science and project understanding; promote public relations.						



SUSTAINABILITY PLAN

UOG has committed to recruit four tenure-track research scientists from diverse backgrounds and experiences to work with GECCO research faculty members and their labs to address specific objectives in the project. UOG has committed to supporting these salaries after the conclusion of the project. GECCO will also recruit seven post-doctoral fellows (funded by the project) to provide integration between the research of existing and visiting research faculty and all graduate and undergraduate students working on various parts of the proposed project. UOG will provide tuition waivers to graduate research assistants recruited to the project and GECCO will provide additional support in the form of research stipends. Beginning in Year 2, two visiting researchers per year

will be recruited to conduct research in specific areas or teach specialized courses or workshops that will further benefit UOG students. Research technicians will be hired to provide full-time technical assistance for research (genetics/genomics/bioinformatics, 1), the Biorepository (curatorial and microscopy, 2), and for data management (1). A cyber program coordinator would be hired by the project to improve cyber operations relevant to the grant, and to ensure sustainability of improvements made to UOG's IT capabilities. The proposed project would also provide a vehicle for UOG to develop a Ph.D. program in Biology at before 2025 and provide a pipeline for students to be trained in it. The plan is summarized in Table 15.

Table 15 – Sustainability Plan

Table 15 – Sustainability Plan							
Goal: Increase sustainability of GECCO research with new hires and applications for external funding.							
Objective 1: Hire four new tenure track faculty researchers and seven new post-doctoral fellows							
Objective 2: Hire new research technicians							
Objective 3: Recruit visiting faculty							
Objective 4: Recruit and fund graduate students							
Objective 5: Apply for several levels of external funding							
Objective 1	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1	Donaldson, Bentlage, Leon Guerrero	Hire coral microbiologist	Hire vertebrate morphologist, crustacean biologist, ecophysiologicalist				Four new faculty members; seven new post-doctoral fellows.
Task 2	Donaldson, Bentlage	Hire and assign up to five post-docs to research tasks	Complete hiring and assigning five post-docs to research tasks	Hire and assign two post-docs to research tasks			
Outcomes		New faculty hires contribute to GECCO and UOG fields of research					
Objective 2	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1	Donaldson, Bentlage	Hire technicians for Biorepository, data management, genetics lab	Hire technician for SEM/microscopy lab				Dedicated technicians available to support research.
Outcomes		Qualified research technicians contribute to success of project by managing laboratories, maintaining equipment and building research infrastructure.					
Objective 3	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1	Donaldson, Bentlage, Leon Guerrero	Begin searches for visiting scientists	Recruit visiting scientists (2) for research or instruction	Recruit visiting scientists (2) for research or instruction	Recruit visiting scientists (2) for research or instruction	Recruit visiting scientists (2) for research or instruction	Eight visiting scientists contribute to project through research or specialized instruction.
Outcomes		Conduct research in specific areas relevant to project or teach specialized courses or workshops					
Objective 4	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1	Donaldson, Bentlage, Shelton, GECCO faculty	Recruit new students	Recruit new students	Recruit new students	Recruit new students	Recruit new students	Trained and experienced graduate students ready for Ph.D programs or workforce.
Task 2	Donaldson, Bentlage, Shelton GECCO faculty	Provide stipends and tuition waivers for 12 graduate students	Provide stipends and tuition waivers for 12 graduate students	Provide stipends and tuition waivers for 12 graduate students	Provide stipends and tuition waivers for 12 graduate students	Provide stipends and tuition waivers for 12 graduate students	
Outcomes		Steady stream of graduate students to receive training and conduct research; students supported by research stipends and tuition waivers.					
Objective 5	Responsible Parties	Milestones					Outputs
		Year 1	Year 2	Year 3	Year 4	Year 5	
Task 1	GECCO faculty	Up to five GECCO-related proposals submitted	Up to five GECCO-related proposals submitted	Up to nine GECCO-related proposals submitted	Up to nine GECCO-related proposals submitted	Up to 10 GECCO-related proposals submitted	Up to 38 proposal submissions
Outcomes		External funding procured to continue and expand GECCO research and outreach.					



EVALUATION AND ASSESSMENT PLAN

The external evaluation of the University of Guam (UOG)'s NSF EPSCoR RII-Track 1 Award "Guam Ecosystems Collaboratorium for Corals and Oceans" (GECCO) will be conducted by Sara Bolduc Planning and Evaluation, LLC (SBPE), a Honolulu-based consultancy firm with more than ten years' experience in Program Evaluation. SBPE led the evaluation and assessment effort for the previous NSF EPSCoR RII-Track I Award to the UOG, as well as other federal research grants to the University of Hawaii (NSF, USAID) and is well positioned to systematically track and assess the progress of all GECCO activities over the next five years. The evaluation team will consist of SBPE Principal Researcher and President Sara Bolduc, PhD; Dr. John M. Knox, who has more than 35 years of experience conducting evaluation and socio-economic research in Hawaii and the Pacific region; and Barrett E. Ristroph, PhD, J.D, a social scientist and planner with extensive experience working in rural and culturally diverse settings.

The External Evaluation will evolve around these five main evaluative questions:

1. To what extent has the GECCO Program led to researchers in Guam increasingly conducting premier research to generate new knowledge related to reef community composition and function?
2. To what extent have curatorial, digitization, imaging, and specimen storage services been developed for the project and shared with the larger research community?
3. To what extent have place-based and culturally relevant activities expanded to contribute to island sustainability and meet local island needs?
4. To what extent has a foundation been established for high throughput computing, data storage and archiving at the institutional and jurisdictional levels?
5. To what degree has a linked network of collaborating researchers been enabled to work on various aspects of research problems expanded, if at all?

The evaluation will consist of a formative and summative assessment of all project components

(including Research; Biorepository; Education and Workforce Development; Cyberinfrastructure; and Collaboratorium). The formative assessment will monitor program processes and emergent properties, and also track any new developments. External evaluators will gather data to assess developmental progress of the program through (1) periodic participation of team leadership discussions (via teleconference and/or email and phone communications); (2) bi-annual participant interviews about perceptions of process quality; and (3) an annual Team Survey to assess team dynamics. The summative assessment will track observable program outputs and outcomes as evidence of progress toward short- and long-term goals (for all program elements) that can be attributed to program activities (also see Summary Table 16):

- **Research capacity** will be evaluated based on the degree to which the Program has progressed toward its envisioned long-term goal of better predicting future changes in marine and coastal aquatic ecosystems in response to environmental changes. Anticipated outcomes of research will include evidence that researchers in Guam are conducting premier research and generating new knowledge in reef community composition and function. Tracking progress toward these outcomes will include: 1) Increasing number and impact of researcher publications; 2) Increasing number of proposals submitted; 3) Increasing numbers (#) and amount (\$) of funding awards; 4) Timely hires; and 5) Post docs coming on board in a timely fashion.
- **Biorepository Activities** will be evaluated based on the degree to which the Program has progressed toward its envisioned long-term goal of increased services to biodiversity research. Anticipated outcomes of Biorepository activities will include evidence that GECCO has promoted curatorial, digitization and imaging, and specimen storage services for the project. Tracking progress toward these outcomes will include: 1) increasing digitization and imaging for corals, mollusks, fish, and BIOBLITZ; 2) increasing number of BIOBLITZ Manuscripts; 3) implementation of bar code analysis; 4) timely



implementation of microscope slide scanning and digitization; and 5) Increasing number of specimens uploaded to the Database.

- ***Education and Workforce Development***

activities will be evaluated based on the degree to which the Program has progressed toward its envisioned long-term goal of promoting STEM Education and Workforce Development while emphasizing sustainability locally and regionally. Anticipated outcomes of Education and Workforce development activities will include evidence that these expanded place-based and culturally relevant activities will contribute to island sustainability and meet local island workforce needs. Tracking progress toward these outcomes will include: 1) Evidence of the matriculation of EPSCoR students; 2) Increasing the diversity capacity of EPSCoR students; 3) The quality of mentoring offered to students, and post-docs; 4) Increasing Sustainability Certificate Program enrollment; and 5) Increasing community outreach.

- ***Cyberinfrastructure Advancements*** will be evaluated based on the degree to which the Program has progressed toward its envisioned long-term goal of creating Cyberinfrastructure capacity that supports and enhances UOG's research capabilities. Anticipated outcomes of Cyber activities will include evidence that a foundation has been established for high throughput computing access and data storage and archiving at UOG. Tracking progress toward these outcomes will include: 1) The timely hire of a Research Computing Associate; 2) Increasing use of local high throughput computing; 3) Providing professional development activities for IT staff; and 4) Increasing remote archival of program data .

- ***The Collaboratorium*** will be evaluated based on the degree to which the Program has progressed toward its envisioned long-term goal of growing

collaborative network of researchers. Anticipated outcomes of Collaboratorium activities will include evidence that it has linked a network of collaborating researchers working on various aspects of research problems. Tracking progress toward these outcomes will include Social Network analysis of: 1) Overall network growth: Formal collaborations; 2) Network of collaborators for publications and proposal writing; 3) Timely assignment of mentors and mentees; and 4) Quality mentoring for junior researchers.

Through the implementation of its activities, GECCO will: Catalyze research capability across and among jurisdictions; Establish STEM professional development pathways; Broaden participation of diverse groups/institutions in STEM; Effect engagement in STEM at national and global levels; and Impact jurisdictional economic development.

Evaluation feedback and communication will involve strategic transfers of evaluation findings to program leadership and participants each year. A semi-annual evaluation report (Mid-Year Check-in) as well as a formal Annual Evaluation Report will be shared with Program Participants each year. GECCO response to evaluation reports will be expected to be shared with the evaluator as well. The evaluators will participate in the review of the program's strategic plan, participate in monthly team meetings, and attend (remotely for now) the Guam EPSCoR/ Center for Island Sustainability Conference each year to observe program progress, communicate findings, and suggest ways to address potential challenges.

A complete evaluation plan (with target and metrics for each output/outcome) will be submitted to GECCO Leadership and NSF EPSCoR as part of SBPE's Year 1 Evaluation Report.

Table 16 – Summary of Measurable GECCO Outcomes and Outputs

Program Element Goal	Outputs (metrics)	Outcomes
<p>RESEARCH To examine the processes that shape and connect the genomes and phenomes of reef-builders within reef systems</p>	Increasing number of researcher publications	<p>Researchers in Guam are conducting premier research and generating new knowledge in reef community composition and function</p>
	Increasing impact of researcher publications	
	Increasing number of researcher proposals submitted	
	Increasing numbers (#) and amount (\$) of funding awards	
	Timely hires (Faculty Researchers) (4 total)	
	Timely Hires (Post docs 7 positions total)	
	Timely Hires (Research Techs. including Biorepository)	
<p>BIOREPOSITORY Increased services to biodiversity research</p>	Digitization/ imaging: Crustaceans, mollusk, fish, BIOBLITZ	<p>Curatorial, digitization and imaging, and specimen storage services is provided for the project</p>
	BIOBLITZ Manuscripts	
	Bar code analysis	
	Microscope slide scanning and digitization	
	Increasing number of specimens uploaded to Database	
<p>COLLABORATORIUM A growing collaborative network of researchers</p>	Overall network growth (Social Network Analysis)	<p>A linked network of collaborating researchers working on various aspects of research problems</p>
	Formal collaborations (increasing MOUs/MOAs)	
	Network of collaborators for publications	
	Network of collaborators for proposal writing	
	Timely assignment of mentors and mentees	
	Quality mentoring for junior researchers	
<p>CYBERINFRASTRUCTURE capacity that supports and enhances UOG’s research capabilities</p>	Timely hire (Research Computing)	<p>A foundation has been established for high performance computing access, data storage and archiving</p>
	Increasing use of local high throughput computing	
	Professional development opportunities for IT Staff	
	Increasing remote archival of data	
<p>EDUCATION AND WORKFORCE DEVELOPMENT Promote STEM Education and Workforce Development while emphasizing sustainability locally and, regionally</p>	Timely graduation for GRAs/UREs (cohort continuous)	<p>Expanded place-based and culturally relevant activities that contribute to island sustainability and meet local island workforce needs</p>
	GRAs continuing on to PhD	
	Increasing diversity of GRAs and UREs	
	UG STEM Research Experience impact (pre-post survey)	
	Quality of mentoring (Post-doc, GRAs and UREs)	
	Establishment of a Sustainability Certificate Program	
	Increasing community outreach	
<p>PROCESS: Team Dynamics</p>	Team is increasingly working effectively	<p>An effective science team</p>



RISK MANAGEMENT

GECCO’s complexity and scale over the next five years has the potential to encounter various degrees of risk that could pose difficulties in meeting project goals. The GECCO Risk Mitigation Plan (Table 17), derived from a SWOT analysis (Appendix A), addresses likely risks faced by the project and provides steps towards mitigating problems caused by these risks. A succession plan is provided also that addresses steps necessary to deal with vacancies in key leadership and other positions should they arise.

Table 17 — GECCO Risk Mitigation Plan				
Component	Condition	Result	Impact Likelihood	Mitigation
Research	In-person communication is severely limited due to COVID-19 pandemic, posing challenges for effective communication of large research team	All research objectives and all personnel may suffer delays in work	Medium High	Develop schedule for regular meetings early on; seek IT support to facilitate digital meetings if necessary
	New team members and organizational structures; new roles/functions will take time to learn	All research objectives and all personnel may suffer delays in work	Medium Medium	Define roles and responsibilities clearly and early
	Supply chains for materials and supplies long and slow; COVID restrictions and deliberate postal delivery delays cause further problems	All research objectives compromised	Low High	Previous project identified suitable vendors; requires planning ahead
	Talent pool for recruitment of research technicians and support personnel limited	Mostly genetics-related research objectives affected; delays in on-boarding support personnel	Medium Medium	Actively recruit qualified applicants (e.g., reach out to alumni)
	Some research participants with heavy teaching or administrative loads during semester	Research Objectives 2 and 3 compromised	Medium High	Coordinate activities with affected team members
	COVID-19 pandemic affects key areas: outside collaborations, travel, fieldwork, faculty and student exchanges, supply chains	All research objectives delayed and all personnel affected	Medium High	Travel restrictions beyond team’s control; if travel remains challenging, establish regular virtual work sessions with outside collaborators; new vendors must be sought; previous identified vendors may not be able to supply required equipment and supplies
	COVID-19 pandemic affects field activities beyond the jurisdiction	Research Objective 2 compromised	High High	Collections and population genetics research can begin locally on Guam; reach out to collaborators for help with collections; leverage existing collections of material
	Key collaborator left position in the CNMI thus limiting ability to collect specimens	Research Objective 2 compromised	Medium High	Identify and recruit alternate collaborator
	Typhoon cuts power, renders boat operations untenable, damages equipment	Field and laboratory field operations stalled	High Medium	Laboratory tasks not affected at Marine Laboratory which has a redundant generator system but may be elsewhere; transfer to Laboratory or delay work. Reschedule boat operations for when seas are calm. Utilize backup equipment
Biorepository	Multi-location collaborators separated by large physical distances and time zones can make informal interaction difficult	Communication and dissemination of information delayed or strained	Medium Low	Adoption of a unified communication and collaboration platform for on- and off-island collaborators; utilize existing protocols
	Team is large and diverse with many complex collaborative tasks to complete in a limited timeframe	Biorepository operations may be delayed	Medium Low	Develop plan that assigns tasks and timelines to researchers or groups of researchers; utilize post-doc to guide GRAs and SREs
	COVID social distance requirements limit the number of researchers in Biorepository lab spaces	Biorepository operations will be delayed	High High	Develop plan for scheduling use of spaces and resources

Cyberinfrastructure	Lack of a dedicated building for specimen storage, curation, and laboratories	Biorepository operations will be delayed	High	Medium	Identify campus resources that can be used temporarily until purpose-built structure is ready
	Obstacles inevitable in collecting, curating and digitizing specimens/data from COVID restrictions will require the team to be very adaptable	Biorepository operations will be delayed	Medium	Medium	Develop collections and curatorial plans; schedule boats and vehicles; assign specific tasks to meet current needs; have alternative plans that are adaptable
	For the first 6-10 months of grant the Collections Manager will only be available on a half-time basis	Biorepository operations won't be supervised entirely by the Collections Manager	Low	High	Account for this temporary capacity shortage when developing task implementation plan
	Interruptions in collection, curatorial, imaging, digitization and travel activities due to COVID	Biorepository operations will be delayed	Medium	Medium	Develop plan that schedules use of resources and tasks among personnel; defer travel until COVID restrictions are relaxed
	Financial implications that may result due to COVID	Biorepository operations affected if local salary employees furloughed	High	High	Create plan to reassign tasks of locally-funded personnel or arrange for compensation for work; prioritize equipment and supply procurement; ensure GRA and SRE stipends from grant
	Inability to recruit new faculty hires because of COVID restrictions	Biorepository operations will be delayed	Low	Low	Postpone faculty recruitment and focus effort on existing levels of expertise
	A researcher becomes unable to contribute to project due to illness or departs university	Biorepository operations will be delayed	Low	Medium	Assign post-doc to lead researcher's work; recruit new researcher if current one has departed
	Inability to recruit qualified students because of COVID restrictions	Biorepository operations will be delayed	Low	Low	Identify local undergraduate students with promise, provide SRE, recruit to graduate program with financial support
	Potential inability to keep data secure because of typhoons	Biorepository operations will be delayed	Low	Medium	Utilize existing and new backup servers, including the Cloud, and provide regular uploads to increase redundancy; utilize generator systems for local storage
	Typhoons interrupt work, power supplies, ability for personnel to perform duties	Biorepository operations will be delayed	High	High	Prepare for typhoon using standard UOGML protocols; utilize existing generator systems to restore power if lost; prioritize tasks to protect loss of specimens, servers and data; delay other tasks until conditions return to normal
EWD	OIT currently short-staffed	Support for equipment installation and maintenance low	Low	High	Careful planning of activities; search for vacant position planned for fall 2020
	Local IT talent pool low	Affects ability to hire a research computing facilitator	Medium	Medium	Provide on-the-job training for new hire, including funded opportunities for professional development
	COVID-19 pandemic restricts ability for travel of research computing facilitator for training	Ability of the research computing facilitator to provide training and support for research personnel is affected	Medium	High	Seek out virtual training opportunities
	Limited direct cross-pollination between research component and EWD	Education and Workforce Development and research components not communicating	Medium	Low	Encourage participation of research teams in EWD activities. Creatively integrate research topics into EWD outreach
	Few opportunities to expand diversity activities beyond Pacific Islanders and women	Education and Workforce Development and research components lack diversity	Medium	High	Enhance global partnerships with institutions from other URM areas.
	Limited leadership and investment from regional governments and communities in research and sustainability.	Education and Workforce Development and research components lack support	Medium	Medium	Communicate short and long term benefits from research projects and capacity building efforts. EPSCoR team pursue funding sources for long-term sustainability.
	Social media accounts have low audience engagement/content	Project lacks community support	Low	Low	Create engaging content related to breakthrough research conducted by students and faculty. Make content relateable to general public and "everyday" issues.

Collaboratorium	Interruptions in GECCO activities due to COVID-19	Operations delayed	High	High	Creatively continue meeting the goals of the program while adhering to federal and local government, public health, and local institutional guidance.	
	Fear rooted in COVID-19 increases reluctance for participation.	Operations delayed	Medium	Medium	Continue and evolve risk management strategies as well as implementation of digital processes.	
	A project participant becomes unable to contribute to project due to illness or departs university	Operations delayed	High	Medium	Create redundancies in students or faculty assigned to or capable of specific projects.	
	Inability to recruit enough qualified students to fill graduate and undergraduate positions	Operations delayed	High	Medium	Establish relationships with STEM student organizations and regional colleges to stimulate interest from local students	
	Implementation failures by program partners	Objectives compromised	Medium	Low	Pursue redundant or multiple program partners.	
	Conduct of collaborative research with off-island scientists compromised by COVID restrictions	Research collaborations stalled	Medium	Medium	In lieu of travel, utilize online tools for collaboration. If face-to-face contact required, follow established COVID protocols for research and travel	
	Conduct of seed funding research requiring face-to-face interactions may violate COVID restrictions	Seed funding research and instruction projects stall	Medium	Medium	Utilize COVID Face-to-Face protocols; utilize online tools whenever possible	
	Inability to conduct seminars by collaborating researchers because of COVID restrictions	Seminars cancelled	High	Low	Conduct seminars online using appropriate tools or delay implementation until after restrictions lifted	
	Collaborating researcher becomes unable to contribute to project due to illness or departs university	Research collaborations stalled	Medium	Medium	Delay implementation of work for assigned task; train post-doctoral fellow to assume role if collaborating researcher leaves the project, and have senior researcher provide oversight	
	Communications	Poor communications during COVID restrictions; website functions poorly	Inability to communicate internally or provide information to the general public, thus compromising our message	High	Medium	Utilize virtual meetings, email, telephone communications, social media, and website in management of personnel, procurement, and other tasks.
Management		Loss of senior personnel	Disruption in project management			Activate succession plan
	COVID restrictions create obstacles to execution of administrative plans	Project administration is ineffective	High	Medium	Follow UOG and RCUOG protocols for COVID; prioritize tasks, use remote communications for meetings; use appropriate software for signing documents; devise multiple scenarios for executing work	
	Official travel restricted	Collaborative science more difficult; official travel disrupted	Medium	High	Delay implementation of travel until restrictions lifted. Utilize online virtual methods for meetings, etc.	
	Financial implications that may result due to COVID-19 restrictions	Personnel with locally funded salaries furloughed	Medium	Low	Key personnel work without pay until locally-funded salary and back salary are restored	
	Inability to recruit new and qualified staff hires	Tasks go undone because of lack of expertise	Medium	Medium	Prioritize tasks and reassign to qualified personnel; recruit temporary hires	
	Staff member becomes unable to contribute to project due to COVID or other illness or departs university	Disruption in completion of tasks	Medium	Low	Prioritize tasks and reassign to qualified personnel until staff member recovers or is replaced; hire temporary staff if necessary	
	Typhoon disrupts power supply	Inability to complete many tasks	High	Medium	Transfer administration staff to Marine Laboratory, which has a redundant generator system, until power is restored.	
	Potential inability to keep data secure	Project administration	High	Low	Utilization of Cloud services and large stand-alone backup hard drives	
	Evaluation and Assessment	Inability to conduct in-person interviews might impact the quality of information received	Formative evaluation may not be accurate	Medium	Medium	Keep frequent communication remotely with all project participants
		Interruptions in research might impact evaluation activities	Breaks in data collection	Medium	Medium	Utilize a broader variety of indicators for annual reporting



SUCCESSION PLAN

Principal Investigator/Project Director: Should this position become vacant the co-Principal Investigators will determine a successor who will be confirmed by the president of the University of Guam pending approval by NSF in accordance with the programmatic terms and conditions.

Project Administrator: Should this position become vacant the PI/PD will conduct a search for a successor in consultation with the co-Principal Investigators. The NSF program officer will be notified in accordance with the programmatic terms and conditions.

Co-Principal Investigator for Research: Should this position become vacant the PI/PD will determine a successor in consultation with the remaining co-PIs. NSF will be notified in accordance with the programmatic terms and conditions.

Co-Principal Investigator for Education and Workforce Development: Should this position become vacant the PI/PD will determine a successor in consultation with the remaining co-PIs. NSF will be notified in accordance with the programmatic terms and conditions.

Co-Principal Investigator for the Collaboratorium: Should this position become vacant the PI/PD will determine a successor in consultation with the remaining co-PIs. NSF will be notified in accordance with the programmatic terms and conditions.

Replacements for other vacancies will be chosen by the PI/PD from a pool of qualified candidates, with preference given to UOG collaborators already working on the project. This will be in consultation with the co-PIs. NSF will be notified in accordance with the programmatic terms and conditions.

Evaluator: Should Sara Bolduc Planning and Evaluation, LLC no longer act as the GECCO Evaluator, the PI/PD will determine a successor in consultation with the co-PIs. NSF will be notified.



APPENDIX A

Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis

During August 2020, members of the research and leadership teams developed the basis for a SWOT analysis of various components of the GECCO project. On August 14, 2020, the teams met virtually with the NSF-appointed facilitator, John Riordan, to discuss SWOT analysis logistics prior to conducting the analysis for their respective project components. These were discussed by the science leads and project leadership, who produced a draft of the project SWOT analysis document that was discussed again at the Strategic Planning meeting held virtually on September 16-18 2020.

Strengths identified by the teams included:

Project Management

- Experienced EPSCoR office.
- Experienced EPSCoR upper management team.
- A single unified center to direct resources and guide sustainability efforts.
- RCUOG expertise.
- ER-Core participation for tracking.
- Office of Research and Sponsored Programs experience with large grants.

Research

- Reorganization of facilities management at UOG improved facilities maintenance and improvement.
- Majority of collaborators from outside UOG have established experience working with at least one of the PIs and/or research leads.
- Majority of research team has worked on projects collaboratively previously.
- Research builds on long history of reef monitoring in Guam.

Biorepository

- Team Science approach.
- Solid research plan building on expertise and resources of team.
- Strong team with diverse and relevant expertise, an established track record of collaborative efforts, and confidence in and belief of the importance of the project.
- Access to expert technical resources.

- Collaborators from institutions involved in project have good reputation in research community/among stakeholders.
- Access to competent student pool.
- Increased opportunities for student participants.

Education and Workforce Development

- Institutions and programs involved in project have good reputation in community/among stakeholders.
- Project elements built from successful models or from previous activities with proven success.
- Integration into established programs and systems.
- One Guam EPSCoR university recipient will help to direct resources and guide research.

Cyberinfrastructure

- Recent EPSCoR and NSF CC* investments created high speed internet connectivity across campus and connectivity to the national research and education network.

Collaboratorium

- Faculty mentoring capabilities.
- Seed funding grants.
- Research faculty for collaborations.

Weaknesses identified by the teams included:

Program Management

COVID restrictions create obstacles to execution of administrative plans and will require the staff to be very adaptable.

Potential loss of senior personnel from COVID or related illness.

Website functions poorly under adverse conditions.

Research

In-person communication is severely limited due to COVID-19 pandemic, posing challenges for effective communication of large research team.

New team members and organizational structures; new roles/functions will take time to learn.

Talent pool for recruitment of research technicians and support personnel limited.

Supply chains for materials and supplies long and slow.

Some research participants with heavy teaching or administrative loads during semester.

Biorepository

Social distancing COVID requirements limit the number of researchers in Biorepository lab spaces. Immediate lack of a dedicated building for specimen storage, curation, and laboratories.

Obstacles inevitable in collecting, curating and digitizing specimens/data under COVID restrictions will require the team to be very adaptable.

For the first 6-10 months of grant the Collections Manager will only be available on a half-time basis. Multi-location collaborators separated by large physical distances and time zones can make informal interaction difficult.

Education and Workforce Development

Limited direct cross-pollination between research component and EWD.

Few opportunities to expand diversity activities beyond Pacific Islanders and women.

Limited leadership and investment from regional governments and communities in research and sustainability.

Social media accounts have low audience engagement/content.

Cyberinfrastructure

OIT currently short-staffed.

Local IT talent pool low.

WiFi bandwidth variability if participants are working from home because of COVID restrictions.

Collaboratorium

Conduct of collaborative research with off-island scientists compromised by COVID restrictions.

Conduct of seed funding research requiring face-to-face interactions may violate COVID restrictions.

Obstacles inevitable in research plans that will require collaborators to be very adaptable because of COVID restrictions.

Opportunities identified by the teams included:

Program Management

New ways to accomplish administrative tasks under COVID restrictions.

Build research capacity, expand workforce, and stimulate industry growth in Guam.

Leverage grant to acquire new facilities to advance the project.

External advisory board poised to assist the team in their ultimate goal of sustainability.

Research

Project has the potential for truly cross-disciplinary research, establishing research collaborations between departments at the UOG.

Start of GECCO project coincides with large NFWF-funded coral restoration project.

Faculty and postdoc hires likely to have lasting impact on research capacity of UOG Marine Laboratory.

Increased support of research activities through postdocs and technicians.

Biorepository

Discovery of new ways to conduct research and outreach due to COVID.

Potential to build Biorepository research capacity and workforce development.

Enhanced student, post-doc, and early career faculty opportunities.

Potential to address today's research questions in this area.

New research tools provide incentives to expand research focus while providing training.

Education and Workforce Development

COVID-19 may spark innovations for new research, teaching, and outreach methods.

Potential of GECCO to build research capacity, expand workforce, and stimulate industry growth in Guam.

Enhanced student and early career faculty opportunities.

Significantly increase opportunities for Pacific Islander students to engage and succeed in STEM.

Become a global leader for advancing island sustainability.

COVID pandemic has accelerated priorities of sustainability and conservation.

Cyberinfrastructure

Award will provide resources to install high-throughput computing resources on campus.

Development of an MOU with the University of Hawai'i for increased collaboration in research

computing.

Collaboratorium

Virtual meetings for mentoring in case of COVID restrictions.

Seed funding grant project design to incorporate social distancing.

Collaboration online using multiple tools to allow for social distancing.

Threats identified by the teams included:

Program Management

Interruptions in activities due to COVID.

Financial implications that may result due to COVID.

Inability to recruit new and qualified staff hires.

Staff member(s) becomes unable to contribute to project due to COVID or other illness or departs university.

Typhoon or tropical storm causes extended power outages and interrupts activities.

Potential inability to keep data secure.

PI, PA, co-PIs, or researchers leave the project.

Research

COVID-19 pandemic affects key areas: outside collaborations, travel, fieldwork, faculty and student exchanges, supply chains.

COVID-19 pandemic affects field activities beyond the jurisdiction.

Key collaborator left position in the CNMI.

Biorepository

Interruptions in collection, curatorial, imaging, digitization and travel activities due to COVID.

Typhoons and tropical storms disrupt activities, damage facilities and specimens, interrupt work

Inability to recruit new faculty and post-doc hires.

Inability to recruit qualified students.

A researcher becomes unable to contribute to the project due to illness or departs university.

Education and Workforce Development

Interruptions in GECCO activities due to COVID-19.

Fear rooted in COVID-19 increases reluctance for participation.

A researcher becomes unable to contribute to project due to illness or departs university.

Inability to recruit enough qualified students to fill graduate and undergraduate positions.

Implementation failures by program partners.

Cyberinfrastructure

COVID-19 pandemic restricts ability for travel of research computing facilitator for training.

Collaboratorium

Interruptions in research collaboration activities due to COVID.

Inability to conduct seminars by collaborating researchers because of COVID restrictions.

Collaborating researcher becomes unable to contribute to project due to illness or departs university.



APPENDIX B

CI – Cyberinfrastructure
CNAS – College of Natural and Applied Sciences
EPSCoR – Established Program to Stimulate Competitive Research
EWD – Education and Workforce Development
GEC – Guam Ecosystems Collaboratorium
GECCO – Guam Ecosystems Collaboratorium for Corals and Oceans
GIS – Geographic Information System
GRA – Graduate Research Assistantships
GSTP – Guam Science and Technology Plan
GSTSC – Guam Science and Technology Steering Committee
HIMB – Hawai'i Institute of Marine Biology, University of Hawai'i
HTC – High Throughput Computing
NASA – National Aeronautics and Space Administration
NGS – Next Generation Sequencing
NIH – National Institutes of Health
NSF – National Science Foundation
OIT – UOG Office of Information Technology
RCUOG – Research Corporation of the University of Guam
SBPE- Sara Bolduc Planning and Evaluation, LLC
SNA – Social Network Analysis
SRE – Student Research Experience for Undergraduates
STEM – Science, Technology, Engineering, Math
SWOT – Strengths, Weaknesses, Opportunities, and Threats analysis
UOG – University of Guam
UOGML – University of Guam Marine Laboratory
UH – University of Hawai'i
URM – Under-Represented Minorities

