GUAM NSF EPSCoR

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ADVANCING SUSTAINABLE DEVELOPMENT OPPORTUNITIES
FOR THE GUAM RESEARCH ECOSYSTEM

2025 - 2029
STRATEGIC PLAN

PROJECT DIRECTOR: Dr. Bastian Bentlage
JURISDICTION: Guam   **AWARD NUMBER:** 2445825
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VISION STATEMENT

Advance research development and integration in Guam through interdisciplinary initiatives and collaboration across research teams and institutions.

MISSION STATEMENT

Assess ecosystem services of Guam's natural resources and train a skilled workforce capable of engaging with economic development opportunities.

PREFACE

The vision of this E-RISE RII incubator is to advance research integration and development in Guam through interdisciplinary initiatives that foster collaboration across research teams and institutions to develop a skilled workforce capable of addressing local and regional challenges. This incubator facilitates interdisciplinary research, enhances STEM capacity, and promotes workforce development in four thematic areas: (1) Biodiversity and Ecosystem Services (BES); (2) Data Science and Modeling (DSM); (3) Integrative Biological Collections (IBC); and (4) Research and Knowledge Translation (RKT). These themes (Fig. 1) and their goals are strategically aligned with jurisdictional priorities outlined in Guam's Science and Technology Economic Diversity Plan (S&T Plan). The incubator will build collaborative networks and partnerships between researchers, professionals, and stakeholders to drive innovation in Guam. The incubator aims to support teams of faculty researchers and postdoctoral scholars, and provide training opportunities for undergraduate and graduate students from Guam's two institutions of higher education, the University of Guam (UOG) and Guam Community College (GCC).

The incubator's mission is to assess the ecosystem services provisioned by Guam's biodiversity and to train a skilled workforce capable of engaging with economic opportunity areas outlined in Guam's Science & Technology (S&T) Plan, in particular sustainable natural resources and information technology.
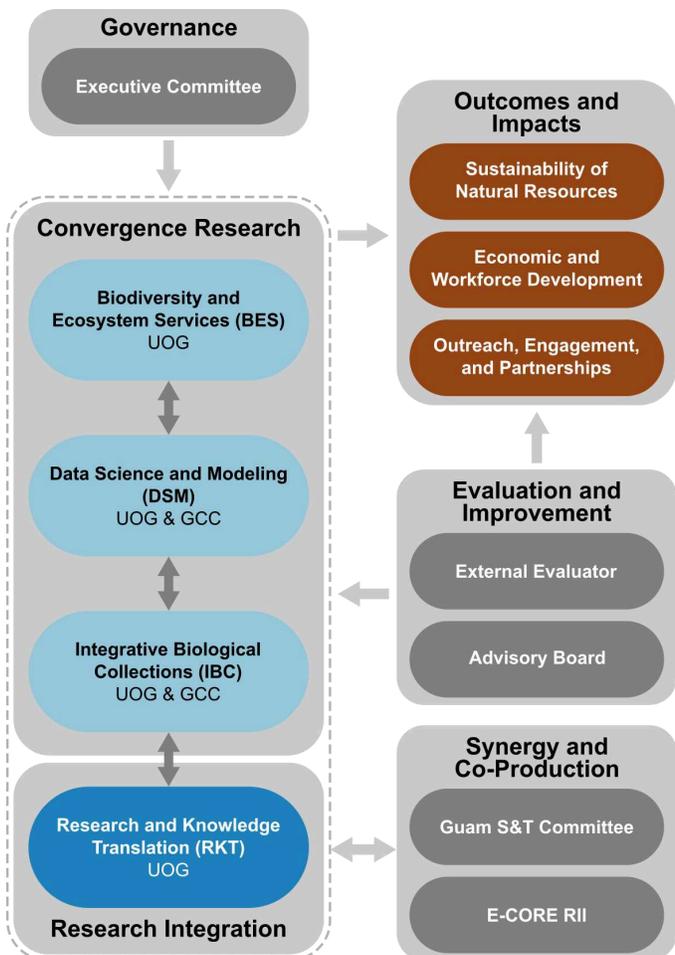

Fig. 1 Overview of the E-RISE RII incubator and its components.

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Theme One (BES) and Theme Two (DSM) support interdisciplinary science by conducting field-based research on Guam's marine ecosystems, developing and implementing innovative approaches to biodiversity data analysis using machine learning and statistical modeling. Theme Three (IBC) serves as a cross-cutting element, expanding the collaborative network of researchers capable of evaluating complex ecosystem processes by leveraging Guam's growing biological collections. A central theme is the Integration of collections across disciplines that will require a unified organizational structure to form the foundation for the Guam Center for Biodiversity Research (GCBR). The organizational structure (Fig. 1) will rest on an executive committee comprising curators and biodiversity researchers on Guam and an advisory board, including university administrators and curators from US institutions that have a track-record in building and supporting biological collections. Theme Four (RKT) will lead workforce development activities to translate project outcomes for jurisdictional agencies and policymakers, including workshops to facilitate continuing education to increase workforce readiness for economic development initiatives aligned with Guam's S&T Plan.

PROJECT IMPLEMENTATION

Project Description And Purpose

BES and DSM research focuses on marine environments, investigating ecosystem services provided by Guam's natural resources. The team aims at quantifying differences in ecosystem services across spatial and temporal scales to contribute to informed and data-driven decision-making processes for sustainable development opportunities in the jurisdiction that relies heavily on its marine natural resources, for example, to provide coastal protection from severe storms (typhoons) and attract visitors that support the local tourism industry. IBC and RKT build collaborative networks within the jurisdiction across UOG and GCC campuses and with Guam's agencies. Establishing the GCBR, led by the IBC theme, anchors this E-RISE RII incubator to ensure the sustainability of networks and partnerships that will be established within the jurisdiction and beyond its boundaries to engage with the scientific community across the nation. These networks will promote policy and natural resource management aligned with jurisdictional and regional economic opportunities.

Jurisdictional Science And Technology Plan Alignment

Guam holds significant potential for sustainable economic development and diversification through university-led research and workforce development programs. The island's natural resources, including its coral reefs and terrestrial habitats, play a critical role for Guam's economy, including tourism industry and fisheries. In addition, these natural assets help safeguard infrastructure and coastal communities while supporting industries central to Guam's economy. Invasive species, degradation of marine and terrestrial ecosystems, and poor land development practices threaten these resources. Addressing these challenges requires integrating scientific research with education and workforce development. Partnerships between UOG and GCC are key to developing a workforce for addressing these challenges to sustainable economic development. UOG is leading local and regional efforts to link natural resource management with innovation and workforce readiness. Through the NSF EPSCoR

investments in the jurisdiction, the Western Pacific Tropical Research Center, Center for Island Sustainability and Sea Grant, and Marine Laboratory, UOG advances research in biodiversity, aquaculture, and sustainable resource use. This E-RISE RII incubator and the development of the GCBR will strengthen these efforts, providing critical baseline data through biological collections and supporting monitoring of biodiversity trends. Expanding training in data science, artificial intelligence, and computer science through this incubator will enable analysis of complex environmental datasets to predict ecosystem trends, and inform policy and business development. These activities will aid in positioning Guam as a regional leader in applying science and technology to protect coastal resources, sustain economic growth, and build a resilient, knowledge-driven economy.

As a US territory located in the Micronesian region of the western Pacific, Guam occupies a pivotal strategic role in US foreign policy. Defense spending and relocation of military personnel and assets to Guam contribute significantly to Guam's economy. Guam is at the center of international rivalry and a workforce capable of addressing cybersecurity concerns will be vital in this competition. Interest in establishing data centers in Guam that leverage the island's geographic location to connect digital assets between Asia and the US has the potential to play a significant role in diversifying Guam's economy. This regional focus provides opportunities that will benefit from collaboration between government, private sector, and researchers. A strong information and communications infrastructure is essential to advancing Guam's STEM capacity and economic resilience. With expanding broadband access and the growing integration of AI and other emerging technologies, there is increasing demand for skilled IT and cybersecurity professionals to support both public and private sector innovation. Opportunities abound for local entrepreneurs and businesses to develop tech-based services, including data management and cybersecurity solutions. This E-RISE RII incubator engages with these economic opportunities by providing training in data and computer science in a collaboration between GCC and UOG. Providing students with opportunities to develop technical skills that are transferable across sectors of the digital economy will strengthen Guam's IT workforce to position the island as a regional technology hub.

Expected Benefits For The Jurisdiction

This E-RISE RII project will establish an incubator that provides capacity for addressing key areas of opportunity identified in Guam's S&T Plan. In particular, establishing the GCBR's structure and mechanisms for its oversight through an executive committee and external advisory board will provide capacity for documenting and understanding Guam's natural resources to contribute to their sustainable use for the benefit of Guam's residents and visitors. Communicating the outcomes of project research activities and developing training workshops for Guam's stakeholder community will fill gaps in STEM education opportunities that are envisioned to provide support for continuing education of professionals working in the jurisdiction. The project will further train students in mathematics and data science, contributing to the further development of a STEM-enabled workforce that is ready to engage with the expanding IT, cybersecurity, and data science industry in the jurisdiction. Targeted recruitment of students from GCC to participate in these training opportunities at UOG will strengthen existing articulation agreements between the two institutions that form the backbone of higher education

in Guam. It is anticipated that connecting GCC students to educational programming and mentors at UOG will increase transfer rates of students between the two institutions, further increasing Guam's STEM educated workforce.

Primary Partners

UOG is a Land, Sea, and Space Grant institution accredited by the Western Association of Schools and Colleges (WASC) and serves as Guam's premier center for research and higher education, offering 34 undergraduate and 11 master's programs to serve students in the jurisdiction. UOG has been supported through NSF EPSCoR since 2015 and secured funding from other NSF programs, in addition to NASA, NOAA, NIH, USDA, and other agencies. Since 2022, UOG ranked 284 out of 890 US universities in R&D expenditures, a significant achievement for an institution of its size. For this incubator, UOG partnered with GCC, the jurisdiction's sole community college which has been accredited by the Accrediting Commission for Community and Junior Colleges (ACCJC), Western Association of Schools and Colleges (WASC) since 1979. GCC provides vital technical training to support workforce development aligned with Guam's priorities for economic growth and diversification. UOG and GCC have established seamless 2+2 pathways, including in computer science, to strengthen STEM education and research opportunities. Collaboration between UOG and GCC in this E-RISE RII incubator enhances student access to hands-on research opportunities to support STEM training pathways that support Guam's growing research and innovation ecosystem.

Project Leadership And Management

Each project team has a lead who is tasked with organizing implementation of activities that are designed to achieve objectives that contribute to the overall goals of the project. All team members meet monthly to discuss project progress. Themes will hold their own meetings to discuss progress and implementation strategies. Some activities will rely on contributions by personnel across themes (e.g., data sharing between DSM and BES themes for summer research experiences). To facilitate the sharing of data and ideas, theme leads and members are encouraged to communicate frequently across the boundaries of their themes. Research translation and stakeholder engagement will rely on coordination between researchers and RKT theme members. The project supports a science communicator and extension associate. In addition, the project will be able to leverage the science communication team of Guam's E-CORE RII project, UOG Sea Grant and the Center for Island Sustainability for the co-production of outreach events and workshops for our stakeholder community. The E-CORE RII Science and Technology Committee Coordinator will provide linkages between this E-RISE RII project and Guam's S&T Steering Committee.

Project Oversight, Coordination, And Theme Leads

The team providing oversight of different aspects of the project is listed below. Requests and inquiries should be directed to the appropriate individual listed below.

Project Oversight: **Bastian Bentlage** (PI / PD), Associate Professor of Bioinformatics, Marine Laboratory, University of Guam – bentlageb@triton.uog.edu

BES: **Tom Schils** (Research Lead), Professor of Marine Biology / Associate Curator of Marine Algae, Marine Laboratory, University of Guam – tschils@triton.uog.edu

DSM: **Hyunju Oh** (co-PI), Professor of Mathematics, College of Natural & Applied Sciences, University of Guam – ohh@triton.uog.edu

IBC: **Robert Lasley** (co-PI), Assistant Professor / Curator of Crustacea, Marine Laboratory, University of Guam – lasleyr@triton.uog.edu

RKT: **Austin Shelton** (co-PI), Director, Center for Island Sustainability and Sea Grant, University of Guam – shelton@triton.uog.edu

Coordination with Guam Community College: **Michael Chan** (co-PI), Dean, School of Technology & Student Services, Guam Community College – michael.chan@guamcc.edu

Inquiries, procurement requests, or other related issues: **Kikue Roberto**, Project Associate, Guam NSF E-RISE RII – robertokm@triton.uog.edu

Extension And Outreach

Extension and outreach activities will be coordinated by the RKT theme but supported by leveraging Guam's NSF E-CORE RII project, UOG Sea Grant and the Center for Island Sustainability. Requests for support to organize outreach events, press releases, or assist with the dissemination of project activities and outcomes through the Guam NSF EPSCoR website or social media pages should be directed to the following.

Kyle Mandapat, Assistant Director for Communications, Center for Island Sustainability / UOG Sea Grant / Guam NSF EPSCoR / Guam Green Growth – mandapatk@triton.uog.edu

Christian Sumalpong, Science Communicator, Guam NSF E-CORE RII – sumalpongc6474@triton.uog.edu

Matt Zapata, Website Specialist, Guam NSF E-CORE RII – zapatam@triton.uog.edu

Science And Technology Steering Committee

The Guam NSF E-CORE RII S&T Project Associate provides a conduit for interacting with the Guam S&T Committee. Project progress updates will be provided to the Guam S&T Committee through its coordinator on a regular basis to inform the committee on project outcomes and solicit feedback from the committee to facilitate a cycle of continual project improvement. This will ensure that the goals and objectives of this E-RISE RII project remain in alignment with evolving priorities of the jurisdiction

Axel Defngin, Science & Technology (S&T) Project Associate, Guam NSF E-CORE RII – defngina@uog.edu

Evaluation Plan

Project Goals, Objectives, Outcomes And Milestones, Impacts

A full External Evaluation Plan (EEP) document will be delivered to the cognizant NSF Program Officer not later than 9 months after the beginning of the Award. An abbreviated EEP can be found in the Guam EPSCoR E-RISE Evaluation Plan Table below that outlines project goals, objectives, outcomes and milestones, and longer term impacts.

Themes (Goals)	Objectives	Outcomes and Milestones
BES – Identify ecosystem services	1. Characterize abundance of reef calcifiers 2. Develop framework for a reef carbonate budget model 3. Assess biodiversity across spatio-temporal scales	-12 cross-disciplinary collaborative manuscripts by Yr 4 -8 (2/Yr) funding proposals submitted (individual & collaborative) -50% of proposals submitted by early career faculty as PI/co-PI
DSM – Develop ecosystem models	1. Integrate natural resource assessments with advanced data analytics 2. Expand training opportunities for students in computer and data science programs at the University of Guam (UOG) and Guam Community College (GCC)	-Social Network Analysis to track collaborative networks Years 2 & 4 -32 (8/Yr) UG students trained -50% graduation rate – UG students by Yr 4 -80% graduation rate – Grad students by Yr 4 -50% transfer rate of GCC SRE to UOG by Yr 4 -20% of students who graduate continue in MS/PhD by Yr 4
IBC – Document species diversity	1. Integrate Guam Center for Biodiversity Research (GCBR) collections 2. Conduct and support biodiversity research 3. Form administrative structure for GCBR oversight and outreach 4. Grow existing collections 5. Achieve sustainability	-8 students (2/Yr) enter MS Data Science program -3 models/analysis pipelines developed (reef accretion, community dynamics, AI) by Yr 3 -30% growth of biological collections by Yr 3 -80% data digitization completed by Yr 3
RKT – Employ ADOPT, CONNECT, TRAIN (ACT) framework to facilitate adoption of knowledge	1. Engage stakeholders to ADOPT new knowledge that informs natural resource management policy and practice 2. CONNECT stakeholders with GCBR to facilitate collaboration 3. TRAIN jurisdictional natural resource management workforce	-4 (2/Yr) Natural Resources organizations engaged -5 prof. dev. opportunities (workshops) offered in Yr 2–4 -100 attendants of prof. dev. opportunities -2 faculty/Yr engaged in res. translation activities -3 booklets/reports for stakeholders; 12 newsletters produced
Impacts		
● Diversified funding portfolio to sustain the research incubator and ensure lasting impacts ● Growing, locally trained STEM-trained workforce capable of engaging with emerging economic opportunity areas ● Locally driven solutions for natural resource sustainability informed by science ● Increasing collaboration between Guam's academic and natural resource management institutions		

External Evaluator

Sara Bolduc Planning and Evaluation, LLC (SBPE) has been retained as an independent evaluator for the Guam E-RISE RII project. Sara Bolduc, Ph.D., president of SBPE, is a Professional Evaluation Specialist with over 15 years of experience leading program evaluations in the United States, Territories and US-Affiliated Pacific Islands. Dr. Bolduc and her team have

worked as research and evaluation consultants on a range of projects throughout the Pacific region since 2009 including external evaluation services for the two RII Track-1 awards in Guam, two active EPSCoR Awards in Hawaiʻi (Track 2 RII-FEC program, and RII BEC), an NSF RISE~ Collaborative Implementation Grant, an NSF INCLUDES Design and Development Launch Pilot, a National Cancer Institute U54 CPACHE Award, and several other federally-funded research awards (CDC, USAID). Dr. Bolduc also serves on the American Evaluation Association STEM Topical Interest Group (TIG) Leadership Committee and is currently Vice President of the Hawaiʻi-Pacific Evaluation Association (H-PEA). She and her team have expertise in program and policy evaluation, STEM evaluation, survey design and implementation, qualitative and quantitative methods, facilitation, community outreach, and strategic and environmental planning.

The external evaluation of this E-RISE project will consist of a formative (process) component, examining the project's development to suggest adjustments towards improvement. The formative assessment will include regular remote and in-person participant interviews and listening sessions. The evaluation will also include a summative component, tracking quantifiable output/outcome data to assess the degree to which the project is meeting its stated goals over the entire 4-year award period. Together, the formative and summative evaluation components will ensure an unbiased, rigorous, expert assessment of progress towards expected long-term goals, namely, the extent to which this E-RISE project has successfully endeavored toward advancing research integration and development in Guam through interdisciplinary and collaborative initiatives. SBPE will share the findings that emerge from the formative and summative assessments and provide recommendations to project leadership via in-person and remote meetings, frequent emails and phone conversations, and the delivery of an Annual External Evaluation Report. Recommendations from the report will inform updates to the objectives and activities outlined under Research Themes and Interdisciplinary Integration below. The Evaluation team will also work closely with project leadership to compile and report program data in the EPSCoR Data Outcomes Collection System (EDOCS).

SBPE will assess each of the project goals and evolve around these evaluation questions:

- How has the project developed a network of collaborative, jurisdictionally aligned and pertinent research?
- To what extent has the project contributed to the development of a skilled workforce through its activities?
- How has the project incorporated use-inspired perspectives and potentially impacted innovation and policy that may benefit society?
- To what extent do project activities have the potential to have lasting impacts into the future?

Project Themes And Cross-Disciplinary Integration

This integrated E-RISE RII research and capacity-building project employs a cohesive framework for generating, curating, modeling, and sharing biodiversity and ecosystem knowledge to support scientific discovery, workforce development, and community engagement.

The BES theme provides the foundational empirical data needed to characterize ecosystem processes and services, informing the development of robust ecological baselines. The DSM theme builds interdisciplinary analytical capacity that enhances our understanding of ecosystem processes and supports data-driven decision-making. The IBC theme ensures long-term preservation, accessibility, and educational value of specimen-based data, linking research, training, and public engagement through modern collections infrastructure. The RKT theme amplifies the program's broader impacts by translating research outcomes into actionable knowledge, fostering cross-sector partnerships, and contributing to the development of a skilled workforce. Together, these four themes establish a synergistic model for aligning research, workforce development, and science communication to advance jurisdictional priorities.

<u>Theme 1: Biodiversity And Ecosystem Services (BES)</u>

Observations of shifts in Guam's reef community composition over the last decade point to the changing and dynamic nature of these ecosystems and their sensitivity to local environmental impacts and biological interactions. Notably, some reefs have shifted from dominance of complex, branching reef-building corals to encrusting and stress-tolerant species, leading to reduced habitat complexity and potential negative impacts on reef-associated biodiversity. In addition, on some reefs where coral cover was reduced, calcifying algae have gained prominence, altering the structure of Guam's reef. In tropical reef ecosystems, corals are the primary calcifiers contributing to reef carbonate budgets and accretion of substrate. Encrusting algae, such as crustose calcifying red algae (CCRA), represent secondary calcifiers and a shift to these taxa may impact carbonate budgets. However, some CCRA species may deposit carbonate at rates comparable to corals, potentially maintaining carbonate budgets on these altered reefs. Building on this foundational research in Guam, this E-RISE RII incubator aims to accurately measure growth and calcification rates of dominant reef organisms through field experiments and advanced imaging, leveraging prior investments by NSF EPSCoR in the jurisdiction that facilitated procurement of 3D and computed tomography (CT) scanning equipment at UOG. Cutting-edge tools such as AI-based image recognition and structure-from-motion surveys will be used to characterize the composition of Guam's reefs. A continued effort will focus on accurate identification of calcifying taxa, including prominent secondary calcifiers (mostly CCRA) using DNA barcoding for accurate taxonomic identification. Information on growth and calcification rates will be integrated with the benthic surveys to develop a reef accretion and carbonate budget model for Guam. This model will serve as an analytical tool to support effective management of Guam's marine resources and the ecosystem services they provide.

Goal: Identify ecosystem services

BES aims to characterize the foundations of reef ecosystem services by integrating structural, biological, and functional data across multiple spatial and temporal scales. Through a coordinated set of objectives, the project links reef structure, carbonate budgets, and biodiversity patterns to the ecosystem services provided by Guam's reef habitats. Reefs play central roles in the economy of Guam and the Micronesian region. By comparing ecosystem

metrics collected by the project to existing data from other tropical reef systems, the project will provide an assessment of Guam's reef biodiversity, health, and resilience.

Objective 1.1: Characterize abundance of reef calcifiers and benthic structure

This objective quantifies the composition and three-dimensional structure of reef-building communities to evaluate their role in supporting habitat complexity and ecological function of reef habitats.

Key Activities (Years 1–4):

- **Site selection and baseline surveys (Year 1):** Identify and characterize field sites across reef systems to represent gradients in reef morphology and environmental conditions.

- **Structure-from-Motion (SfM) surveys and mapping (Years 1–2):** Generate high-resolution orthomosaics and digital elevation maps to quantify reef topography and benthic cover.

- **Genetic identification of reef calcifiers (Years 1–3):** Conduct DNA barcoding and morphological verification to verify species identities and resolve taxonomic uncertainties.

- **Automation and computational analysis (Years 2–3):** Develop and test automated segmentation algorithms to accelerate image processing.

- **Quantification and synthesis (Years 3–4):** Derive structural metrics (rugosity, surface area, relief) from SfM products to evaluate spatial variability in habitat complexity and integrate experimentally determined growth rates to quantify carbonate production and reef accretion.

Objective 1.2: Develop framework for a reef carbonate budget

This objective uses growth experiments to determine empirical growth and calcification rates of calcifiers and establishes a modeling framework to quantify carbonate production rates to assess the accretion potential of reef ecosystems.

Key Activities (Years 1–4):

- **Experimental quantification of calcification (Years 1–2):** Implement *in situ* growth experiments to measure rates of skeletal deposition among primary and secondary calcifiers.

- **Morphometric and density analyses (Years 1–3):** Utilize computed-tomography (CT) scanning to characterize skeletal density and morphology of calcifiers to inform carbonate production estimates.

- **Modeling and tool development (Years 2–4):** Build a carbonate-budget toolkit capable of integrating field and laboratory to estimate net production.

- **Model validation and application (Year 4):** Finalize carbonate-budget model, taking stakeholder feedback into account.

Objective 1.3: Assess biodiversity across spatial and temporal scales

This objective examines biodiversity patterns through time and space to evaluate community turnover and differences in community composition across study sites.

Key Activities (Years 1–4):

- **Survey design and baseline inventories (Year 1):** Establish standardized protocols (e.g., Automated Reef Monitoring System - ARMS) for biodiversity assessment across representative reef habitats.

- **Field surveys and specimen collection (Years 1–3):** Deploy settlement structures and conduct repeated sampling to document benthic species richness, abundance, and functional composition of reef sites.

- **Genetic and molecular analyses (Years 2–3):** Employ DNA-barcoding approaches to aid in identification of species and documentation of diversity, including cryptic taxa.

- **Temporal analyses of community change (Years 2–4):** Quantify differences in community structure and composition to detect transitions through time and between sampling sites.

- **Cross-scale integration (Years 3–4):** Combine biodiversity metrics with environmental (e.g., temperature) and structural data (e.g., reef complexity) to infer patterns of resilience and ecosystem function.

Synthesis

Together, the objectives above form a comprehensive framework linking reef structure, carbonate dynamics, and biodiversity to the quantification of ecosystem services. The integrative approach outlined here supports mechanistic understanding of reef productivity and biodiversity, providing a scientific basis for ecosystem service valuation and management.

A detailed summary of BES activities is provided in the table below.

Theme 1: Biodiversity and Ecosystem Services (BES)					
Goal: Identify Ecosystem Services					
Objective 1.1: Characterize abundance of reef calcifiers					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible Parties**
1.1.1: Identify field sites for comparative study across themes	Sites identified based on existing data from prior and ongoing field surveys				Schils; Bentlage; Lasley; Mihalitsis

	Activities	Year 1	Year 2	Year 3	Year 4	Responsible parties
1.1.2: Produce orthomosaics and digital elevation models of study sites	Conduct Structure-from-Motion (SfM) surveys for half of the study sites and initiate development of the SfM field acquisition and 3D reconstruction workflow	Development of an automated image segmentation and classification pipeline in collaboration with DSM theme Completion of SfM imaging for the remaining study sites	Extract benthic structural metrics from SfM-derived digital elevation models (DEMs) to quantify reef surface complexity and calcifier cover of study sites	Combine SfM-derived structural metrics with CT-measured skeletal densities and experimentally determined growth rates to construct and calibrate models that quantify carbonate production and reef accretion	Schils	
1.1.3: DNA barcoding to ensure accurate species identification of secondary reef calcifiers	Conduct DNA barcoding of common secondary calcifier taxa from forereef habitats, including those used in the *in situ* growth experiments	Expand DNA barcoding to include secondary calcifier taxa from reef flat sites, including those used in the growth experiments	Continue DNA barcoding and identify key ecological taxa that warrant more detailed taxonomic and systematic study	Prepare manuscripts on the taxonomy and systematics of important secondary reef calcifiers	Schils; Bentlage	
1.1.4: Graduate student training	Recruit and mentor 2 GRAs in molecular laboratory procedures, underwater field surveys and experimental techniques, Structure-from-Motion (SfM) data processing	GRAs conduct fieldwork and data analysis for MS thesis research within the carbonate budget theme	GRA 1 defends MS thesis focused on reef carbonate budget objective	GRA 2 defends MS thesis focused on reef carbonate budget objective Disseminate results from MS thesis though publications in peer-reviewed journals	Schils; Bentlage	

Objective 1.2: Develop framework for a reef carbonate budget model					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible parties**
1.2.1: In situ growth experiments	Establish and initiate *in situ* growth experiments targeting key primary and secondary calcifiers on forereefs to quantify species-specific calcification and growth rates	Expand growth experiments to include key primary and secondary calcifiers from reef flats in addition to forereefs	Complete growth experiments and conduct quantitative analyses of growth and calcification rates across key primary and secondary calcifiers	Compile a comprehensive dataset of growth and calcification rates for important reef calcifiers from Guam, supplemented with literature data	Schils; Bentlage

1.2.2: CT-scanning of primary and secondary calcifiers	Conduct CT-scanning of primary and secondary calcifier skeletons deposited in IBC collections; develop workflow (taxon selection, scan protocol, calibration using phantoms) to calculate skeletal density	Continue the CT-scanning effort to broaden taxonomic coverage and refine skeletal density estimates of primary and secondary calcifiers	CT-scan samples from *in situ* growth experiments to obtain skeletal density data	Produce a curated dataset of skeletal density values, ready for integration into carbonate budget models and analyses	Schils; Bentlage
1.2.3: Toolkit for carbonate budget modeling	Evaluate existing carbonate budget modeling tools in collaboration with DSM theme to identify strengths, limitations, and opportunities for improvement	Start developing a carbonate budget modeling framework for Guam's reefs, capable of integrating growth rate and skeletal density data for key calcifiers	Continue development of the carbonate budget modeling framework and convene a stakeholder forum (RKT theme integration) with local partners to guide its refinement and adoption	Finalize, validate, and launch the carbonate budget modeling tool, and submit a corresponding manuscript to an open-access journal	Schils; Bentlage
1.2.4: Postdoc hires	Recruit and onboard 1 postdoc	Active participation in all components of the carbonate research program	Prioritize research outputs and peer-reviewed publications of project findings	Preparation of peer-reviewed publications; postdoc appointment ends	Schils
Objective 1.3: Assess biodiversity across spatio-temporal scales					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible parties**
1.3.1: Characterize reef communities through time using standardized settlement structures across sites	Deploy settlement structures (tiles or ARMS) across study sites after securing permits	Retrieve first set of settlement structures after 12 month deployment	Retrieve second set of settlement structures after 24 month deployment		Bentlage; Lasley
1.3.2: Identification of reef communities captured by standardized settlement structures		Process organisms collected from settlement structures (images, identification of motile and sessile	Process organisms collected from settlement structures (images, identification of motile and sessile		Bentlage; Postdoc

		fraction, DNA metabarcoding of bulk samples)	fraction, DNA metabarcoding of bulk samples)		
1.3.3: Characterization of reef communities from settlement structures			Data analysis in collaboration with DSM theme of Yr 2 settlement structures; share data with DSM team	Data analysis in collaboration with DSM theme of Yr 3 settlement structures and manuscript preparation	Bentlage; Postdoc
1.3.4: Assess the relationship between reef habitats and cryptobenthic fish communities	Procurement of equipment and materials required Secure collection permit and clearance by Institutional Animal Care and Use Committee	Collect data for 50% of sites Initiate data collection for remaining sites	Finalise data collection Data analysis and interpretation Identify causal links between fish communities (morphological analysis on fish) and biodiversity drivers (e.g., water velocity) across habitats	Preparation of manuscript for peer-reviewed journal Data analysis and interpretation	Mihalitsis
1.3.5: Postdoc hire	Recruit and onboard 1 postdoc	Postdoc takes lead role in settlement structure surveys	Postdoc continues role in settlement structure surveys	Postdoc appointment ends	Bentlage
1.3.6: Graduate student training	Onboard and train 1 GRA in lab and field-based techniques	Active GRA involvement in research program Onboard and train second GRA	GRA 1 graduates	GRA 2 graduates Publications in collaboration with students	Mihalitsis; Bentlage

Theme 2: Data Science And Modeling (DSM)

The Data Science and Modeling (DSM) program strengthens Guam's STEM workforce by integrating training of students in data science, mathematical modeling, and artificial intelligence into the biodiversity and ecosystem research themes (BES and IBC). Partnering with the BES and IBC teams, DSM uses project-based learning (PBL) to immerse students in real-world research using complex environmental datasets. This hands-on approach enhances quantitative reasoning, computational proficiency, and interdisciplinary problem-solving – skills vital for a STEM-enabled workforce that will be able to engage in economic opportunity areas identified in Guam's S&T Plan. Building on a successful track-record of undergraduate mentoring, the DSM theme provides cohort-based experiences that foster peer support and academic achievement. In addition to faculty mentors, the research experiences in the DSM theme will be supported by graduate students pursuing graduate-level coursework in UOG's recently established MS in Data Science.

DSM's workforce development model establishes clear educational pathways from associate to graduate-level STEM degrees in Guam. Through collaboration between UOG and GCC, each year six undergraduate students will gain research experience in data science and modeling, with opportunities to continue the pathway into UOG's new MS Data Science program. Students are trained in foundational and applied skills such as machine learning, mathematical biology, and computational analysis using tools like R, Python, and MATLAB. Each research experience culminates in public presentations and technical reports, reinforcing communication and professional readiness. By linking education, mentorship, and research, DSM equips students with the expertise and confidence needed to enter and lead in Guam's growing data-driven STEM workforce.

Goal: Develop Ecosystem Models

This goal aims to advance understanding of ecosystem dynamics, employing mathematical modeling and artificial intelligence (AI) for data analysis. The effort emphasizes capacity building through student training and collaboration across research teams to strengthen expertise and applied data science skills in the jurisdictional workforce.

Objective 2.1: Integrate natural resource assessments with advanced data analytics

This objective focuses on developing interdisciplinary collaborations and data-sharing frameworks to integrate ecological data with advanced analytical tools to allow for in-depth assessment of natural resources.

Key Activities (Years 1–4):

- **Collaborative framework development (Year 1):** Conduct workshops and meetings to align data collection efforts and data-sharing protocols among BES, IBC, and DSM themes.

- **Cross-team integration (Years 1–4):** Maintain regular interdisciplinary meetings to ensure alignment and exchange of data and ongoing engagement between teams.

- **Data sharing and model harmonization (Years 2–4):** Receive and process datasets from BES and IBC themes, establishing workflows for data-sharing and collaborative data analysis and model development protocols.

- **Iterative refinement (Years 2–4):** Integrate expanding datasets annually to refine models of ecosystem structure and function.

- **Collaborative capacity building (Years 1–4):** Involve research personnel, including faculty, postdocs, and students, in data analysis and analytical model development to strengthen expertise across project participants and teams.

Objective 2.2: Expand training opportunities for students in computer and data science programs at UOG and GCC

This objective supports the development of capacity and technical expertise by offering structured research experiences in data analysis, ecosystem modeling, and interdisciplinary science for graduate students and undergraduates.

Key Activities (Years 1–4):

- **Undergraduate research experience (Years 1–4):** Implement annual Summer Research Experience (SRE) program for undergraduates from GCC and UOG to gain applied research skills in data analysis and modeling.

- **STEM pathway development (Years 1–4):** Create clear research and academic pathways connecting undergraduate programs at GCC and UOG with graduate training opportunities at UOG.

- **Graduate student mentorship (Years 1–4):** Support Graduate Research Assistants (GRAs) in the MS Data Science program to gain advanced training in computational and analytical methods.

- **Professional development and dissemination (Years 2–4):** Support students to present research results at conferences and publication in peer-reviewed journals.

- **Collaborative program coordination (Years 1–4):** Partner with the RKT and BES teams to provide comprehensive student mentorship and integrate training and research activities across project themes.

Synthesis

Together, these objectives contribute to the project's broader ecosystem model development goal and provide a pathway for students transitioning from GCC to UOG and undergraduates to graduate programs for further training in sought-after skills to support workforce development in the jurisdiction. The approach of the DSM theme enhances both the technical capacity and the collaborative approach needed to analyze ecosystem processes that will inform resource management and support assessments of ecosystem services.

A detailed summary of DSM activities is provided in the table below.

Theme 2: Data Science and Modeling (DSM)					
Goal: Develop Ecosystem Models					
Objective 2.1: Integrate natural resource assessments with advanced data analytics					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible Parties**
2.1.1: Workshop/ Meeting: Understanding differences in disciplinary languages and datasets	Develop data sharing plans and timelines across themes Hold data sharing workshop each semester	Receive data from BES and/or IBC Hold data sharing workshop each semester	Receive data from BES and/or IBC Hold data sharing workshop each semester	Receive data from BES and/or IBC Hold data sharing workshop each semester	Oh; Aquino; Yoon

2.1.2: Develop interdisciplinary research program on Guam's coral reef ecosystems	Engage in regular cross-team meetings with BES and IBC researchers	Engage in regular cross-team meetings with researchers	Engage in regular cross-team meetings with researchers	Engage in regular cross-team meetings with researchers	Oh; Aquino; Yoon; Schils; Lasley; Bentlage

Objective 2.2: Expand training opportunities for students in computer and data science programs at the University of Guam (UOG) and Guam Community College (GCC)

Activities	Year 1	Year 2	Year 3	Year 4	Responsible parties
2.2.1: Conduct Summer research experience (SRE)	Recruit 6 undergraduates (2 from GCC, 4 from UOG)	1st year SRE cohort conducts data analysis project Recruit 6 undergraduates for 2nd year SRE	2nd year SRE cohort conducts data analysis project Recruit 6 undergraduates for 3rd year SRE	3rd year SRE cohort conducts data analysis project	Oh; Aquino; Yoon; Chan
2.2.2: Develop research pathways and formalize internship agreement between GCC and UOG	Recruit 2 GCC students for summer SRE program at UOG	Recruit 2 GCC students for summer SRE program at UOG	Recruit 2 GCC students for summer SRE program at UOG		Oh; Aquino; Yoon; Chan
2.2.3: Conduct training to enhance GRA theoretical foundations and technical skills to perform data science research	Train 2 GRAs enrolled in MS Data Science	Train 2 GRAs from MS Data Science; GRAs mentor SREs	Train 2 GRAs from MS Data Science; GRAs mentor SREs	Train 2 GRAs from MS Data Science; GRAs mentor SREs	Oh; Aquino; Yoon
2.2.4: Share results via peer-reviewed publications or presentations at regional, national, and/or international conferences/ symposia		Present the results from SRE at conference and prepare publication	Present the results from SRE at conference and prepare publication	Present the results from SRE at conference and prepare publication	Oh; Aquino; Yoon
2.2.5: Collaborate with RKT to manage student participants as part of workforce development	Conduct student recruitment for SREs and GRAs	Conduct student recruitment for SREs and GRAs Conduct pre-survey and post-survey for SRE and GRA programs	Conduct student recruitment for SREs and GRAs Conduct pre-survey and post-survey for SRE and GRA programs	Conduct student recruitment for SREs and GRAs Conduct pre-survey and post-survey for SRE and GRA programs	Oh; Aquino; Yoon, RKT team

The IBC theme strengthens Guam's capacity for biodiversity research by modernizing and expanding biological collections that serve as important repositories for understanding the island's natural resources. Through the IBC theme this E-RISE-RII incubator will establish the Guam Center for Biodiversity Research (GCBR) at UOG, uniting six biological collections in a unified collection management system under a shared digital roof (Invertebrate Zoology including the Coral Collection, Ichthyology, Diatoms, Macroalgae, Herbarium, and Tissue Collection). IBC will catalog, curate, and digitize specimens, expand tissue collections for genomic-level research, and build a shared cyberinfrastructure for data access among researchers in the jurisdiction and across the nation. These collections will provide the foundation for interdisciplinary research and inform natural resource management through standardized datasets, identification tools, and a DNA barcode library. By consolidating six major collections and establishing an organizational structure with executive committee and external advisory board, the IBC theme ensures long-term sustainability of a vital asset of Guam's research infrastructure. Collections-based research will further promote collaboration among researchers working on marine and terrestrial biodiversity at UOG and other institutions.

IBC emphasizes hands-on research and training for students and professionals to develop skills in taxonomy, curation, and data management. Participants in training exercises will gain experience in specimen collection, taxonomy, molecular genetic analysis, digital imaging, and database development, strengthening Guam's scientific workforce and technical capacity in biodiversity monitoring and resource management. Intensive biological surveys, including "bioblitz" events, will further enhance workforce training by involving students and researchers in large-scale field collections and species identification workshops. A growing DNA barcode library and tissue repository will facilitate future research on Guam's marine and terrestrial ecosystems while supporting biosecurity initiatives, such as the detection and monitoring of invasive species through advanced molecular methods.

Goal: Document Species Diversity

This goal establishes the institutional infrastructure and protocols necessary to preserve, digitize, and disseminate biodiversity knowledge. By integrating collections, research, training, and outreach, the IBC theme strengthens the empirical basis for biodiversity and ecological studies, including assessments of ecosystem services, while developing a platform for collaboration between researchers within and beyond the jurisdiction.

Objective 3.1: Integrate Guam Center for Biodiversity Research (GCBR) collections

This objective consolidates and modernizes biodiversity collections to improve data integrity, discoverability, and usability.

Key Activities (Years 1–4):

- **Unify data in a single digital platform (Specify) (Years 1–3):** Consolidate specimen records across participating collections into a single database.

- **Serve data globally (Years 2–3):** port IBC data to other digital platforms (e.g., InvertEBase and GBIF).

- **Expand database coverage across taxa (Year 3):** Develop strategic plan to incorporate additional collections (e.g., entomology, nematology and other underrepresented groups).

- **Facilities planning for collections growth (Years 1–3):** Assess space, storage, and environmental requirements; prepare renovation plans and associated grant proposals to support long-term curation.

Objective 3.2: Conduct and support biodiversity research

This objective develops an integrated research program that leverages the collections for hypothesis-driven studies and supports training of graduate students.

Key Activities (Years 1–4):

- **Establish an IBC research program (Years 1):** Develop and coordinate cross-theme projects (collections, biodiversity, ecosystem science) that use vouchered specimens for research in systematics, biogeography, ecology, and other biodiversity related fields.

- **Collaborative project development (Years 2–4):** Align faculty and student projects with priority taxonomic groups and questions of regional relevance; integrate specimen acquisition with research design.

- **Graduate and undergraduate training (Years 1–4):** Mentor GRAs in project design and analytical methods; recruit and supervise undergraduate interns for collections, data capture, and basic analyses.

- **Specimen loans (Years 1-4):** Support collaborative research through specimen loans.

- **Scholarly dissemination (Years 2–4):** Target presentations and peer-reviewed publications derived from collections-based studies and cross-team syntheses.

Objective 3.3: Form administrative structure for GCBR oversight and outreach

This objective establishes governance, academic programming, and public-facing activities that anchor GCBR as a resource for biodiversity information in Guam and the broader Micronesian region.

Key Activities (Years 1–4):

- **Oversight committees and governance (Years 1–4):** Establish an executive board and advisory committee which meet regularly.

- **Curricular development (Years 2–4):** Design and deliver summer courses that integrate and leverage biological collections.

- **Public engagement and exhibits (Years 1–4):** Develop a permanent or rotating exhibit space showcasing regional biodiversity and host annual outreach events to broaden community engagement.

Objective 3.4: Grow and enhance existing collections

This objective increases the scientific value and representativeness of the collections through targeted surveys, back-cataloging existing collections, and increasing the breadth of utility of new material by expanding the tissue collections.

Key Activities (Years 1–4):

- **Integrate BES material and backlogs (Years 1–4):** Collect, catalog, and digitize materials produced under IBC and BES theme research, ensuring consistent metadata standards.

- **Bioblitz surveys and targeted sampling (Years 1–2):** Conduct rapid biodiversity assessments to address spatial, temporal, and taxonomic gaps, prioritizing groups critical for regional baselines.

- **Catalog ongoing and historical collections (Years 2–3):** Systematically clear cataloging backlogs and reconcile legacy records; track collection growth targets.

- **Expand and enhance tissue collection (Years 1–4):** Curate tissue samples of new collections and expand utility for genomics.

Objective 3.5: Achieve sustainability

This objective secures long-term viability of the GCBR beyond the end of the project through funding, staffing, and institutional integration.

Key Activities (Years 1–4):

- **Diversified funding portfolio (Years 1–2):** Identify and pursue grants and contracts aligned with collections support.

- **Core staffing and roles (Years 1–3):** Establish and fill a permanent collections manager position and define, train, and fund technical staff roles to maintain continuity of operations.

- **Institutional alignment (Year 3):** Embed GCBR collections within university policies through a memorandum of understanding (MOU) between participating academic units

Synthesis

The IBC theme links curated specimens, digitized data, and active research with education and public engagement. By strengthening data standards, digitization, and governance structures, the theme provides the foundation to establish a durable, institutionally supported center for biodiversity research.

A detailed summary of IBC activities is provided in the table below.

Theme 3: Integrative Biological Collections (IBC)					
Goal: Document Species Diversity					
Objective 3.1: Integrate Guam Center for Biodiversity Research (GCBR) collections					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible Parties**
3.1.1: Combine collections data in one digital platform (Specify)	Fully functional online portal (invertebrates, fish collections on portal) Develop cross collection integration plan	Macroalgae, diatoms, and herbarium data integrated Develop tissue collections plan	Tissue collections data in Specify		Lasley; Burdick; Schils; Wei; Lobban; Bentlage
3.1.2: Serve data online		Develop plan with OIT to port data to GBIF and InvertEBase	Port data to GBIF and InvertEBase		Lasley; Burdick
3.1.3: Expand database to include additional collections		Develop strategic plan for integration of additional collections (e.g., entomology, nematology) during 3-year project renewal phase			Lasley; Burdick
3.1.4: Planning and implementing collections space needs	Assess space needs across facilities and collections	Develop strategy for funding space needs	Planning meeting for space allocation and associated grant proposals		Lasley; Schils; Bentlage
Objective 3.2: Conduct and support biodiversity research					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible Parties**
3.2.1: Develop and establish IBC research program	Cross theme meetings to identify research priorities and collaborations	Submit collections-based publications (2)	Submit collections-based publications (3)	Submit collections-based publications (4)	Lasley; Schils; Lobban; Bentlage
3.2.2: Graduate student training	Recruit 1-2 GRAs Recruit 1-2 undergraduate interns to work in collections	Onboard 1-2 GRAs Recruit 1-2 undergraduate interns to work in collections	Recruit 1-2 undergraduate interns to work in collections	GRAs graduate Recruit 1-2 undergraduate interns to work in collections	Lasley; Wei
3.2.3: Postdoc hire	Recruit and onboard 1 postdoc	Postdoc takes lead role in settlement structure surveys	Postdoc continues role in settlement structure surveys	Postdoc appointment ends	Lasley
Objective 3.3: Form administrative structure for GCBR oversight and outreach					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible Parties**

3.3.1: Form oversight committees	Meet quarterly with executive board and semi-annually with advisory board	Meet quarterly with executive board and semi-annually with advisory board	Meet quarterly with executive board and semi-annually with advisory board	Meet quarterly with executive board and semi-annually with advisory board	Lasley
3.3.2: Develop summer course		Develop strategy: course content and funding sources	Apply for funding	Offer summer course	Lasley; Burdick
3.3.3: Develop outreach events and exhibits	Host outreach event (1)	Develop strategy: funding and exhibit space Host outreach event (1)	Apply for funding Host outreach event (1)	Complete small exhibit space Host outreach event (2)	Lasley; Burdick; IBC and RKT team

Objective 3.4: Grow and enhance existing collections					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible Parties**
3.4.1: Integrate BES material into collections	Fully catalog BES collections	Fully catalog BES collections	Fully catalog BES collections	Fully catalog BES collections	Lasley; Burdick; Schils; Mihalitsis; Bentlage
3.4.2: Conduct Bioblitz	Host Bioblitz 1	Host Bioblitz 2	Publish Bioblitz species checklists		Lasley; Burdick
3.4.3: Catalog ongoing and historical collections		Catalog specimens to reach 10% growth across collections (from year 1)	Catalog specimens to reach 20% growth across collections (from year 1)	Catalog specimens to reach 30% growth (from year 1)	Lasley; Burdick
3.4.4: Expand and enhance tissue collection	Curate tissue samples of new collections	Curate tissue samples of new collections	Curate tissue samples of new collections Consult with external board to develop plan for expanding/ modernizing tissue collection	Curate tissue samples of new collections Implement modern tissue collection strategy	Lasley; Bentlage

Objective 3.5: Achieve sustainability					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible Parties**
3.5.1: Identify and apply for funding	Develop portfolio for funding streams	Submit two proposals (e.g., NSF Capacity, Inspire!)			Lasley
3.5.2: Create and fill GCBR positions	Create position and hire fulltime collections manager	Hire collections technician and database specialist	Transition collections manager to UOG paid position		Lasley; Bentlage

3.5.3 Institutional alignment			Develop MOU for GCBR to provide collections support across academic units		Lasley; Bentlage

Theme 4: Research And Knowledge Translation (RKT)

The RKT theme strengthens Guam's capacity for effective natural resource management by ensuring that research outcomes from BES, DSM, and IBC are translated into actionable strategies for local and regional decision-makers. By linking researchers with management agencies, RKT helps develop science-based approaches to sustain vital ecosystems, such as coral reefs, which directly support Guam's economy and livelihoods through tourism, fisheries, and coastal protection. Recognizing the need for a skilled workforce, RKT focuses on building technical and communication expertise among students and professionals in resource management. Through targeted training programs and public outreach, RKT supports developing qualified personnel capable of applying scientific knowledge to maintain and enhance Guam's natural capital — the foundation for long-term economic resilience.

To ensure that new knowledge leads to tangible benefits, RKT facilitates workshops, symposia, and outreach efforts that promote collaboration between scientists, industry, and government agencies. Training activities emphasize practical skills relevant to resource monitoring, restoration, and sustainable use, aligning with workforce needs identified by local and regional organizations and Guam's S&T Plan. Regular workshops and symposia hosted by RKT provide venues for sharing innovations and best practices that can inform both policy and business development related to Guam's natural resources. Communication tools such as newsletters and impact reports further extend the reach of research findings, highlighting opportunities to leverage biodiversity and ecosystem services and their linkages to economic opportunity areas. Through this integrated approach, RKT positions the Guam Center for Biodiversity Research as a hub for innovation that supports both environmental stewardship and sustainable economic development.

Goal: Employ ADOPT, CONNECT, TRAIN (ACT) Framework to Facilitate Transfer of Knowledge

This goal advances research translation, outreach, and workforce development by implementing the ADOPT–CONNECT–TRAIN (ACT) framework to connect scientific research with community outreach and stakeholder engagement. The theme integrates communication, strategic partnerships, and training workshops to expand the reach, relevance, and application of project research outputs. Through the ADOPT, CONNECT, and TRAIN pillars, the theme builds capacity to share knowledge effectively across multiple audiences.

Objective 4.1: ADOPT – Facilitate uptake and application of research outputs

This objective advances adoption of project research outputs by developing mechanisms that accelerate the transfer of scientific knowledge into practice through communication that is responsive to stakeholder needs and interests.

Key Activities (Years 1–4):

- **Stakeholder consultations and testing (Year 1):** Conduct focus groups with community partners to identify needs for scientific information and continuing training and education opportunities.

- **Iterative improvement of outreach materials (Years 2–4):** Apply feedback loops through surveys to outreach event participants to refine content and delivery methods based on participant evaluation.

- **Disseminate project outcomes (Years 2–4):** Convey key research findings to the research community and stakeholders (managers, educators, and the public) through presentations and symposia.

Objective 4.2: CONNECT – Strengthen partnerships and outreach networks

Activities under this objective create messaging and materials that convey key research findings to managers, educators, and the public in accessible and context-relevant formats.

Key Activities (Years 1–4):

- **Develop multi-platform communication channels (Years 1–2):** Create web and media interfaces that link ongoing research efforts with community awareness and policy dialogue.

- **Community engagement and events (Years 3–4):** Host outreach events (science cafés or open houses) to disseminate project results and solicit stakeholder input.

- **Synthesize project impacts (Years 2–4):** Booklets will be produced to communicate project impacts to key stakeholders.

Objective 4.3: TRAIN — Build capacity and workforce readiness

This objective develops training workshops to offer continuing education opportunities to personnel at Guam's natural resource management agencies and other interested parties.

Key Activities (Years 1–4):

- **Understand requirements for offering continuing education units (Year 1):** UOG's Global Learning and Engagement department will be engaged to identify pathways for the project to offer formal training opportunities to project partners.

- **Identify workshop topics (Year 1):** Survey project research team to identify potential topics for co-production of workshop content and curriculum.

- **Offer training workshops (Years 2–4):** Training for natural resource agency staff and other stakeholders will be provided through workshops.

Synthesis

Through the ACT framework, the RKT theme transforms research results into meaningful knowledge exchange and workforce development outcomes. The structured approach ensures

that new scientific information is not only communicated effectively but also embedded within communities of practice. RKT establishes a model for knowledge transfer that enhances the societal impact and visibility of the broader research program.

A detailed summary of RKT activities is provided in the table below.

Theme 4: Research and Knowledge Translation (RTK)					
Goal: Employ ADOPT, CONNECT, TRAIN (ACT) Framework to Facilitate Transfer of Knowledge					
Objective 4.1: ADOPT – Facilitate uptake and application of research outputs					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible parties**
4.1.1: Survey stakeholders, assess needs for training and WFD, and gauge effectiveness of engagement activities	Initial meeting with DSM, BES, IBC to identify potential stakeholders Introduce project and GCBR to a focus group of natural resource managers and policy makers and solicit feedback of needs for scientific information and products Electronic surveys distributed	Data Collected from surveys and reported	Electronic surveys distributed	Data Collected from surveys and reported	Shelton; Science Communicator
4.1.2: Host annual symposium at the UOG Conference on Island Sustainability to disseminate research results to local and regional stakeholders to provide a forum for discussion	Poster session for students (~10 students)	Poster session for students (~10 students) Breakout session for project researchers to present project progress	Poster session for students (~10 students) Breakout session for project researchers to present project progress	Poster session for students (~10 students) Breakout session for project researchers to present project progress	Shelton; Extension Associate; Project Associate
Objective 4.2: CONNECT – Strengthen partnerships and outreach networks					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible parties**

Activities	Year 1	Year 2	Year 3	Year 4	Responsible parties
4.2.1: Disseminate project outcomes through newsletters	3-4 newsletter will be produced by the RKT science communicator to disseminate research updates from the project to jurisdictional stakeholders	3-4 newsletter will be produced by the RKT science communicator to disseminate research updates from the project to jurisdictional stakeholders	3-4 newsletter will be produced by the RKT science communicator to disseminate research updates from the project to jurisdictional stakeholders	3-4 newsletter will be produced by the RKT science communicator to disseminate research updates from the project to jurisdictional stakeholders	Science communicator
4.2.2: Publication of annual impact booklet		1 impact booklet will be produced to synthesize research results and their relevance for natural resource management and their intersection with economic opportunities to inform jurisdictional agencies/ organizations and the Guam S&T Committee	1 impact booklet will be produced to synthesize research results and their relevance for natural resource management and their intersection with economic opportunities to inform jurisdictional agencies/ organizations and the Guam S&T Committee	1 impact booklet will be produced to synthesize research results and their relevance for natural resource management and their intersection with economic opportunities to inform jurisdictional agencies/ organizations and the Guam S&T Committee	Science Communicator
4.2.3: Public outreach			Science Cafe to communicate project to community	Science Cafe to communicate project to community	Science Communicator

Objective 4.3: TRAIN – Build capacity and workforce readiness					
Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Responsible parties**
4.3.1: Provide training opportunities for jurisdictional natural resource management workforce	UOG Global Learning and Engagement (GLE) contacted to identity requirements for continuing education units or certificates Research teams (DSM, IBC, BES) surveyed and potential work-shops identified	1 week (3-5 days) long workshop	2, week (3-5 day) long workshops	2 week (3-5 day) long workshops	Extension Associate

RISK MANAGEMENT PLAN

Overview

This risk mitigation plan provides a comprehensive strategy for addressing internal weaknesses and external threats identified across all four thematic areas of the project – BES, DSM, IBC, RKT. The risk mitigation approach emphasizes resilience, operational continuity, and institutional adaptability to environmental, logistical, and capacity-related challenges. Mitigation strategies have been drawn directly from the SWOT analysis that identified the likelihood and severity of weaknesses and threats to the project. Particular attention was paid to risks rated as high or medium in likelihood and impact.

Risk Mitigation – Theme 1: Biodiversity And Ecosystem Services (BES)

The BES theme faces environmental and logistical risks due to Guam's geographic isolation and exposure to extreme weather events such as typhoons. These high-impact threats could disrupt fieldwork, delay data collection, and damage critical research infrastructure. To mitigate these risks, the BES team leverages a robust network of established vendor relationships to enable timely procurement and maintenance of field and laboratory equipment, while prior experience with typhoon preparedness strengthens the team's capacity to maintain operations during adverse conditions. In particular, critical laboratory spaces and equipment, such as freezers, are connected to generator backup power to ensure that samples remain intact in the wake of typhoons when grid power may not be available for days or weeks. The use of existing infrastructure from previous EPSCoR investments in the jurisdiction allows the team to conduct research activities efficiently, minimizing downtime that could be caused by lengthy procurement processes of new equipment. Through coordinated scheduling and contingency planning, the BES team will maintain momentum and safeguard core project deliverables.

Risk Mitigation – Theme 2: Data Science And Modeling (DSM)

The DSM theme encounters institutional risks associated with limited personnel capacity, including high faculty teaching loads and dependence on timely data access provided by members of the BES and IBC themes. These challenges, if unmitigated, could constrain analytical output and delay project milestones. The mitigation strategy centers on redundancy and workflow stabilization. The team is utilizing legacy datasets to ensure continuity when new data acquisition is delayed, while strengthening communication pathways between DSM and other project teams to synchronize research priorities. Recruitment of dedicated graduate students from UOG's MS Data Science program provides critical analytical support to the DSM team, distributing workload and ensuring consistent progress during the semester when faculty are constrained by teaching duties. Collaboration with GCC reinforces jurisdictional STEM pathways and contributes to a student body involved in project research activities. Student involvement and cross-theme communication and data sharing fortify DSM team capacity to manage high and medium risk factors through structural redundancy and proactive coordination.

Risk Mitigation – Theme 3: Integrative Biological Collections (IBC)

Risks under the IBC theme are primarily structural and operational, encompassing staffing limitations, some fragmentation of digitization systems used for biological collections, and limited physical space to accommodate collection growth. These weaknesses present high and medium likelihood threats to research activities and long-term data integrity. To address these weaknesses, the IBC team is pursuing a multifaceted mitigation plan. Key strategies include the establishment of a full-time curatorial position, cross-training of existing personnel, and harmonization of collection management software across collections to ensure consistent data standards. Planned expansion of the Marine Laboratory into the Water and Environmental Research Institute (WERI) building in 2026 will alleviate spatial constraints. Similar to the BES theme, natural disasters, such as typhoons, present threats to IBC theme activities and deliverables. Existing generators supplying collections spaces with power to in the event of grid failure play a key role in mitigating these environmental risks. Complementary measures, including maintaining organized inventories of supplies, proactive procurement, and plans to secure additional infrastructure funding, further strengthen the theme's ability to prevent and respond to logistical disruptions and concerns about the growing need for space.

Risk Mitigation – Theme 4: Research And Knowledge Transfer (RKT)

The RKT theme presents institutional and engagement-related risks, including potentially inconsistent stakeholder participation considering the small size of Guam's ecosystem and a limited pool of researchers that may be recruited to participate in workshop delivery and instruction. These risks could undermine the program's broader objectives of translating project outcomes for jurisdictional stakeholders, including policy makers. To mitigate this risk, the RKT team is relying on structured and established communication pathways among researchers, policymakers, and community partners. Regular outreach activities, including symposia and digital platforms for knowledge sharing, ensure that project outcomes are effectively disseminated and that stakeholder engagement remains active to maximize impact. Embedding outreach into core research workflows will strengthen efforts to translate research into policy and community benefit. The strategies employed by the RKT team mitigate medium and high-impact risks by sustaining visibility, continuity, and relevance of project activities for Guam's stakeholder community across the program's lifespan.

Cross-Theme Strategic Integration

Across all themes, the program's risk mitigation framework emphasizes integration, coordination, and resource optimization. By embedding risk reduction into staffing, infrastructure, and communication strategies, the institution project ensures that vulnerabilities are addressed holistically rather than in isolation. Investments in data digitization, shared facilities, and personnel development provide flexibility and redundancy, while strategic collaborations and partnerships amplify capacity beyond local constraints. This cohesive approach not only reduces the likelihood and impact of identified risks but also strengthens resilience, positioning the project to adapt effectively to changing conditions.

APPENDIX 1 – Advisory Board

The advisory board for the Guam Center for Biodiversity Research (GCBR) consists of five (5) members with experience in developing and sustaining biological collections and/or leadership positions at academic institutions. Two (2) board members (Leon Guerrero, Raymundo) were recruited from the University of Guam to establish channels of communication with the administration of the institution housing the GCBR. Three (3) board members (Paulay, Paul, Kocot) were recruited from US institutions based on their experience in collection development and research in tropical ecosystems, including Guam.

Advisory board members and their institutional affiliations:

- Rachael T. Leon Guerrero

  Dean, College of Natural and Applied Sciences, University of Guam

- Laurie J. Raymundo

  Director, Marine Laboratory, University of Guam

- Gustav Paulay

  Curator, Florida Museum of Natural History

- Valerie Paul

  Director, Smithsonian Marine Station at Fort Pierce, Smithsonian Institution

- Kevin Kocot

  Curator of Invertebrate Zoology, Alabama Museum of Natural History

APPENDIX 2 – SWOT ANALYSIS

SWOT Analysis – Theme 1: Biodiversity and Ecosystem Services (BES)		
Internal Strengths	Significance (Hi / Med / Lo)	Leveraging Strategy
The proposed research builds on previous and ongoing projects conducted by members of the team	Hi	The BES team is building on a foundation on prior and ongoing research projects funded in a variety of ways; BES research builds on a foundation on published regionally specific knowledge and the broader knowledge base of changing reef ecosystems
The team possesses experience working in the environments in which experiments will be conducted	Hi	The BES team has met regularly to discuss field work implementation
The team has a network of collaborators that may advise on implementation of certain project aspects (eg, ARMS deployment)	Med	IBC team hosts visitors for workshops / BioBlitz surveys that can be leveraged to foster collaboration
Prior NSF EPSCoR projects made investments in equipment and facilities that the project will be able to leverage	Hi	Equipment is on campus; project will have to pay for supplies and possible maintenance/repairs when they become necessary
UOG is uniquely positioned to address reef resiliency questions through research facilities located in close proximity to field sites	Hi	
Recent and upcoming hires/searches increased faculty with whom the project can engage	Med	Research team will engage with new faculty to develop collaborations where possible and mutually beneficial
Internal Weaknesses	**Risk** (Likelihood / Impact)	**Mitigation Strategy** (for all Hi & Med risks)
STEM ecosystem in Guam is limited (only one university and one community college in the jurisdiction)	Med / Lo	Collaboration beyond the borders of the jurisdiction
Guam is comparatively remote, posing challenges to research (supply chains, service	High / Med	Reliance on procedures and network of vendors established and maintained by Admin Core of E-CORE

and support for equipment)		
Faculty is relatively small and departures of project participants may impact deliverables	Lo / Med	The project supports graduate students and postdocs that will be central to ensuring timely completion of deliverables. Their participation will buffer potential departures of faculty. Project leadership has experienced departure of faculty in previous EPSCoR-funded projects in Guam and is prepared to mitigate impact of personnel departure
External Opportunities	Significance *(Hi / Med / Lo)*	Leveraging Strategy
Annual Island Sustainability Conference on Guam provides opportunities for engaging with local research ecosystem and stakeholders	Hi	Project will organize annual symposia to highlight research and its relevance / importance for Guam / alignment with jurisdictional development goals
E-CORE project aims at organizing workshops/symposia annually and support collaborative grant writing activities across Guam's research ecosystem	Hi	Project can leverage E-CORE RII project and its personnel/staff to facilitate engagement with Guam stakeholders and potential collaborators
External Threats	**Risk** (Likelihood / Impact)	**Mitigation Strategy** (for all Hi & Med risks)
Severe weather events (typhoons) may impact field instruments and lab spaces	Med / Med	The team has experience in typhoon preparation and recovery from previous events; lab spaces are equipped with generator backup power; typhoon forecasting provides advance warning

SWOT Analysis – Theme 2: Data Science and Modeling (DSM)		
Internal Strengths	Significance *(Hi / Med / Lo)*	Leveraging Strategy
DSM activities rely on a model for STEM student training that has been used successfully by project participants	Hi	Team builds on the experiences and lessons learned
DSM goal of recruiting GCC students to UOG research experiences aligns with existing priorities and articulation agreements between the two institutions	Hi	coPI Chan is in leadership position at GCC directly associated with computer sciecne programming alignment between GCC and UOG
Internal Weaknesses	**Risk** (Likelihood / Impact)	**Mitigation Strategy** (for all Hi & Med risks)
DSM activities rely on timely delivery of data by BES team for student training activities	Med / Hi	DSM team can work with old existing datasets initially while BES team collects new data
Priorities of BES researchers and DSM participants may not always align, creating discrepancies in expectations	Med / Med	Establish and maintain regular lines of communication between BES and DSM to co-develop summer research agenda for students and faculty
External Opportunities	Significance *(Hi / Med / Lo)*	Leveraging Strategy
DSM team has external collaborators that contributed to the success of prior iterations of summer math research experiences	Med	These collaborators are in a non-EPSCoR jurisdiction which creates challenges for providing support with EPSCoR funds for collaborative work; collaborators should be engaged early to potentially develop additional funding proposals
External Threats	**Risk** (Likelihood / Impact)	**Mitigation Strategy** (for all Hi & Med risks)
DSM leads have high teaching loads that impose challenges for publishing results of summer research activities once the semester starts again	Med / Med	DSM will have dedicated MS students in Data Science; collaboration with BES faculty can be strengthened to support publication efforts

SWOT Analysis – Theme 3: Integrative Biological Collections (IBC)		
Internal Strengths	Significance (Hi / Med / Lo)	Leveraging Strategy
Previous projects laid foundation for collections-based work by establishing biorepository	Hi	Project will rely on established collections on support team to lay foundation for Guam Center for Biodiversity Research
Many of the digitization issues have been sorted out--e.g., software, online portal, allocation of resources/staff	Med	Resources can be used across collections
Collections lend themselves to outreach--events, workshops, exhibits	Hi	Work across project to develop outreach activities across collections
Well trained, knowledgeable, motivated staff	Hi	Train across collections
Internal Weaknesses	**Risk** (Likelihood / Impact)	**Mitigation Strategy** (for all Hi & Med risks)
Number of dedicated curators for collections is limited	Med / Med	Work with existing faculty to develop a model for shared responsibilities for curation of collections
The collections manager is currently half time	Hi / Hi	Solve hiring issues and work with admin to create fully funded position
Outsized focus on one collection – invertebrate zoology	Med / Med	Allocate resources, staff to increase output of other collections
Collections use different software and digitization is at various levels	Med / Hi	Communicate across collections and provide training and staff
Publication record is low	Med / Med	Work across collections, global collaborations, and with other themes
External Opportunities	Significance (Hi / Med / Lo)	Leveraging Strategy
Biodiversity research and collections provide opportunity for engaging broader community through education workshops and outreach	Hi	Coordination with RKT team and E-CORE activities to develop effective engagement/extension activities and workforce development
Other important collections (e.g,, entomology) on island can be integrated once cyberinfrastructure and collaboration in place	Hi	Coordination with heads of other collections
Guam is strategically located to conduct new collections with global importance	Hi	Work across collections and OIT is increase field collections and data
Collection materials stimulate global collaboration	Med	Use online portal and bioblitzes to engage scientific community

External Threats	Risk (Likelihood / Impact)	Mitigation Strategy (for all Hi & Med risks)
Lack of space for growing collections and staff is a concern	Med / Hi	Marine Lab will expand into WERI bldg in 2026; need to ensure that collections will be considered in space usage of new facilities
Difficult to obtain needed infrastructure (e.g., shelving), equipment, and supplies	Hi / Med	Stay organized, plan ahead, order in bulk
Adverse weather and natural disasters - collections require stability (e.g., humidity, earthquakes)	Med / Med	Secure additional funding for infrastructure, equipment

SWOT Analysis – Theme 4: Research and Knowledge Translation (RKT)		
Internal Strengths	Significance (Hi / Med / Lo)	Leveraging Strategy
RKT team has track record in community engagement and workforce development activities	Hi	Coordination with ongoing and new efforts through UOG Sea Grant / Center for Island Sustainability
Internal Weaknesses	**Risk** (Likelihood / Impact)	**Mitigation Strategy** (for all Hi & Med risks)
Guam's STEM ecosystem is small and there are limited faculty / researchers to engage for workshop delivery	Hi / Med	Identify suitable faculty / researchers early and involve them in curriculum development' cultivate network of external faculty/researcher participants
External Opportunities	Significance (Hi / Med / Lo)	Leveraging Strategy
Annual Conference on Island Sustainability provides avenue for engaging Guam's stakeholder community / broader STEM ecosystem	Med	Project works with conference organizers to develop relevant symposia/workshops annually to disseminate project outcomes
External Threats	**Risk** (Likelihood / Impact)	**Mitigation Strategy** (for all Hi & Med risks)
Recruitment of personnel to support curriculum development and implementation of outreach / training workshops may be delayed	Med / Med	Guam Green Growth conservation corps provides pipeline to recruit talent