The following projects were funded by the Western Pacific Coral Reef Institute (WPCRI), a collaborative regional partnership whose mission is to protect and preserve Micronesia's reefs through scientific research that is directly applicable to coral reef management, as well as training and education activities. The research focuses on climate change, land-based sources of pollution, fisheries, and traditional practices of local communities.

"Integrating reef resilience and climate change vulnerability into protected area design and management in Palau and greater Micronesia" by Yimnang Golbuu et al.

This project identified thermal variability and the average frequency of thermal stress events severe enough to cause bleaching over the last two decades, and projected rates of temperature increase across Micronesia using climate models. Historical remote sensing data suggests that the average frequency of thermal stress events per decade ranges from 2-5 events. Based on climate model outputs, a >3°C change in temperature is projected for reefs across Micronesia by 2100, bleaching conditions are projected to occur annually by 2050, and bleaching conditions are projected to occur 2x per decade by 2025.

To complement the remote sensing and modeling outputs, resilience assessments were completed for reef sites across Palau within existing and proposed MPAs by using established resilience protocols and historical SST data and bleaching records. Variables assessed included: coral diversity (using growth form as a proxy), recruitment, bleaching resistance, thermal variability, macroalgae cover, coral disease, nutrient input, sedimentation, fishing pressure, and anthropogenic physical impacts (i.e., anchor and fin damage). Each site was ranked based on resilience indicators and anthropogenic stressors to produce a relative resilience ranking. The results of the rankings will be used to inform the design of the Protected Area Network in Palau and associated management strategies. Tools were developed and shared with partners to help build the capacity of local resource managers to address the threat of climate change in the region. Specifically, a "How-to-guide" to conduct resilience assessments was developed and a suite of GIS data layers were produced for each indicator independently and combined indicators for resilience and anthropogenic stress.

Finally, based on the results of the analysis, a number of management recommendations and next steps were identified to support coral reef and coastal managers working in Palau. The ability to identify potentially resilient sites and human impacts will be critical to inform management decisions that provide reefs with the best chance of coping with climate change and other human impacts. The results of this work provide essential case studies to help coral reefs managers around the world operationalize reef resilience to inform management decisions.

This project successfully achieved the following outcomes to support coral reef management in Palau and Micronesia more broadly: (1) improved ability to design existing and future marine protected areas through the incorporation of climate projections, historical thermal stress patterns, and resilience indicators; (2) improved ability to manage existing marine protected areas through assessment of impacts (e.g., land-based pollution, fishing impacts, and climate change) to inform management plans and the Protected Area Network; (3) strong partnerships established and reinforced among climate researchers, conservation NGOs, and local research institutions to support marine conservation in the region; (4) key gaps filled in regional MC database through the inclusion of historical SSTs, bleaching thresholds, climate projections, and bleaching and resilience indicators for Palau; (5) resilience tools and trainings

developed to build the capacity of local institutions to integrate vulnerability to climate change and resilience into their protected area network, and (6) project outputs provided to local governments to improve the Protected Area Network and to local agencies and communities so recommendations can be incorporated into their management plans.

"Comparative Multi-Species Assessment of Temporal and Spatial Movement and Residency of Apex Predators for MPA Design and Effectiveness" by Eugene Joseph et al.

Using acoustic telemetry at two known semi-protected grouper (fish) spawning aggregation sites (FSA), this project provided the following information: (1) documentation of grouper reproductive seasonality at Ant Atoll; (2) verification of overlapping reproductive seasonality for groupers between Ant Atoll and Pohnpei (Kehpara Marine Sanctuary); (3) identification of spatial habitat use and patterns of movement of grey reef (*Carcharhinus amblyrhynchos*) and blacktip reef sharks (*Carcharhinus melanopterus*) at Ant and Pohnpei; (4) documentation of long-distance, inter-island movement of grey reef sharks; (5) determination of the effectiveness of existing FSA-based marine protected areas (MPAs) in Pohnpei for conserving coastal reef sharks, and (6) verification that trophic opportunism by non-resident sharks is less likely than previously assumed at the FSA.

From these findings, management decision-makers are now more informed in developing area and temporal protection measures for groupers and have better information on the development of management for coastal sharks. This project showed that marine protected areas focused at grouper FSA sites are partially effective in protecting sharks, a finding previously shown for groupers. Specifically, effective protection of coastal sharks and reproductively active groupers require moderately sized marine protected areas that incorporate areas of core usage (i.e. the actual spawning site) and adjacent areas used as migratory corridors by groupers, as well as all outer reef areas used by coastal reef sharks. Based on findings from this and past research, such an MPA would need to include the FSA and outer reef areas from the FSA core 5-km north and south of the FSA, including adjacent reef channels (i.e. 10-20 km2) of outer reef. The size and area of the MPA would likely increase substantially when inner lagoon habitat area included. Based on past research for groupers, such and area would increase to 100-200 km2.

The study also concluded that grouper reproductive seasonality was common between Ant and Kehpara (Pohnpei). Recommendations include temporal bans on catch and sale for the three co-aggregating species be implemented, with bans on camouflage (*Epinephelus polyphekadion*) and brown-marbled grouper (*Epinephelus fuscoguttatus*) from February to April and for squaretail coral grouper (*Plectropomus areolatus*) from January through May. Area protection, such as that recommended previously, should also include previously identified migratory pathways, as well as the core FSA area, and some home range habitat. Based on catchment area estimates for the aforementioned co-aggregating species, an MPA of 100-200 km2 is recommended.

"Improving local capacity for coral monitoring programs in the Federated States of Micronesia and the Republic of the Marshall Islands" by Dr. Peter Houk

This project, built upon existing efforts, provided one-on-one collaborations between the Pacific Marine Resources Institute (PMRI) and the respective programs to help re-design coral-reef monitoring programs and begin standardized data collection across Micronesia. The first activities associated with the present award were to bring key staff from the jurisdictional monitoring programs together and agree upon a standard set of regional and local questions that drive survey designs and protocol selection. These efforts resulted in a standardized monitoring-to-management framework developed for regional programs that will address the needs of the Micronesian Challenge and beyond. After refining monitoring-to-management frameworks and associated survey designs, PMRI began conducted monitoring alongside the local programs. This intensive effort has yielded a consistent set of monitoring data across the region that encompasses 10 sites on each main island of the Federated States of Micronesia and the Republic of the Marshall Islands, sampled along gradients of human influence.

Key outcomes include: (1) summary power points that describe the current state of the reefs for numerous jurisdictions, and Micronesia as a whole; (2) step-by-step guides that compare and contrast expert fish observer datasets with datasets collected by local programs across Micronesia. Guidance documents aim to isolate upon common problems and limitations that local programs face in order to improve the capacity for the future generation of high-quality data; (3) standardized datasets pertaining to benthic assemblages, coral communities, and fish abundances across Micronesia; (4) localized analyses that summarize the efficacy of key management actions such as marine protected areas, and (5) regional analyses that summarize key linkages between fish, benthic and coral assemblages in the form of trophic cascades across Micronesia. Such analyses highlight that apex predators and humans have opposite roles in structuring Micronesia's coral-reef food webs.

Through the combined grants from WPCRI and the Micronesian Conservation Trust (MCT), PMRI was able to facilitate direct collaborations between expert fish (WPCRI-funded) and coral (MCT-funded) scientists and the local monitoring programs. Outcomes, furthered below, have been improved program structure, regional standardization, regional database generation, and insightful data summaries and reporting that are directly applied to pressing management needs.

This project has facilitated the expansion and standardization of coral-reef monitoring programs across Micronesia through expert collaborations and tangible products. Through continued efforts such as these, the overall goals of PMRI are to maintain dedicated relationships that ensure the development of high-quality, standardized monitoring datasets, and begin to translating their meaning. Clearly there is a strong need to translate the ensuing data assessments into compelling products that will aid decision making and improve management effectiveness. As this process develops through efforts such as the Micronesian Challenge, standardized, high-quality monitoring data will continue to provide the knowledge-base for decision making and reporting progress.

"Integrating reef resilience and climate change vulnerability into protected area design and management in the Commonwealth of the Northern Mariana Islands (CNMI) and greater Micronesia" by Steven Johnson et al.

Severe thermal stress events have already caused coral mortality in Micronesia, and climate models suggest the reefs of Micronesia, including CNMI, will suffer increased thermal stress. This project identified thermal variability and the average frequency of thermal stress events likely to induce a bleaching response over the last two decades, and projected rates of temperature increase across Micronesia using climate models.

Historical remote sensing data suggests that the average frequency of thermal stress events per decade ranges from 2-5 events. Based on climate model outputs, a >3°C change in temperature is projected for reefs across Micronesia by 2100, bleaching conditions are projected to occur annually by 2050, and bleaching conditions are projected to occur 2x per decade by 2025.

To complement the remote sensing and modeling outputs, resilience assessments were completed for reef sites across Saipan by using established resilience protocols and historical SST data and bleaching records. Variables assessed included: coral diversity, recruitment, bleaching resistance, thermal variability, herbivore biomass and macroalgae cover, coral disease, nutrient input, sedimentation, fishing access (proxy for fishing pressure), and anthropogenic physical impacts (i.e., anchor and fin damage). Each site was ranked based on resilience indicators and anthropogenic stressors to produce a relative resilience ranking.

The results of the rankings will be used to inform management decisions in Saipan and associated management strategies. Tools were developed and shared with partners to help build the capacity of local resource managers to address the threat of climate change in the region. Specifically, a "How-to-guide" to conduct resilience assessments was developed and a suite of GIS data layers were produced for each indicator independently and combined indicators for resilience and anthropogenic stress.

Finally, based on the results of the analysis, a number of management recommendations and next steps were identified to support coral reef and coastal managers working in Saipan. The ability to identify potentially resilient sites and human impacts will be critical to inform management decisions that provide reefs with the best chance of coping with climate change and other human impacts. The results of this work provide essential case studies to help coral reefs managers around the world operationalize reef resilience to inform management decisions.