GLOBAL REEF EXPEDITION

Scientific Research Plan

Khaled bin Sultan
Living Oceans Foundation

SCIENCE WITHOUT BORDERS®

The Coral Reef Imperative

1

HUMAN CIVILIZATION IS WITNESSING, AND PARTICIPATING IN, A HISTORICALLY SIGNIFICANT GLOBAL CORAL REEF CRISIS. CORAL REEFS ARE NOW CONSIDERED TO BE THE MOST ENDANGERED MARINE ECOSYSTEM ON EARTH. NEARLY 500 MILLION PEOPLE DEPEND UPON CORAL REEFS FOR FOOD, COASTAL PROTECTION, MAINTENANCE OF CULTURAL HERITAGE, AS WELL AS REVENUE FROM TOURISM AND REEF PRODUCTS.

Coral reefs provide critical habitat for fish, crustaceans, mollusks and other marine creatures, and approximately 30 million of the world's poorest people depend entirely on coral reefs for food and income. It is estimated that the annual value of products and services provided by coral reefs worldwide is US$375 billion – an impressive figure considering that coral reefs occupy only a fraction of one percent of the marine environment. Coral reefs are typically situated along coastal shelf edges and serve to buffer wave action, thus acting as natural coastline protectors. Beyond the tangible products and services that coral reefs provide, these beautiful ecosystems harbor an invaluable array of natural biodiversity, the loss of which will be tragic to our descendants and jeopardize the overall health of our planet.

Coral reefs worldwide are experiencing a rapid decline in health and vitality. The coral reef crisis has arisen from chronic stressors attributed to human practices and acute impacts from climate change, both of which are increasing in severity and frequency. One of the most dramatic changes coral reef scientists are observing in some tropical regions is a shift from high-diversity, high-productivity ecosystems with 50-80% living coral cover, to low-diversity, algae-dominated, hard-ground communities with less than 10% live coral cover; often this has been associated with losses of entire assemblages of important reef building corals. As the skeletons of these corals progressively break down, important high-relief habitat that provides nursery, shelter, and feeding areas is lost, being replaced by low-relief limestone platforms that no longer support commercially and ecologically valuable fishes and invertebrate species. Without a reverse of this trajectory, coral reefs may be the first major ecosystem in the modern era to become ecologically extinct (Sheppard et al. 2009)[1].

NEARLY 20% OF THE WORLD'S CORAL REEFS HAVE EFFECTIVELY BEEN LOST AND ANOTHER 15% ARE SERIOUSLY THREATENED AND MAY BE LOST WITHIN THE NEXT 10-20 YEARS. AN ADDITIONAL 20% ARE UNDER THREAT OF LOSS WITHIN 20-40 YEARS (Wilkinson 2008)[2].

Providing a sense of hope and urgency, the remaining 45% of reefs world-wide are considered to be relatively healthy and not under an immediate threat of destruction. However, actions must be taken now to minimize present and future stressors, so resilience of these remaining reefs can be enhanced, thereby affording an opportunity for coral reefs to adapt to future stressors predicted to occur with climate change (e.g., warming oceans and ocean acidification).

The coral reef crisis must be countered with strategic, direct, and rapid management interventions, underpinned by comprehensive scientific research. The biggest obstacle standing in the way of this conservation strategy is the significant gap in scientific knowledge. Many remote reefs have never been described or have very limited baseline scientific information, and the ecological roles and interactions of coral reef species are not fully understood.

The Khaled bin Sultan Living Oceans Foundation's *Global Reef Expedition* (2011-2015) will close these critical gaps in scientific knowledge. This outcome-driven expedition will engage in a systematic, two-pronged approach: 1) conduct habitat mapping, assess coral reef community structure and characterize the health and resilience of remote coral reef ecosystems, and 2) compare and contrast remote coral reefs with near-shore reefs that are affected by local and regional human stressors through comprehensive SCUBA assessments of coral and fish population dynamics, reef health, human and natural threats, and resilience indicators.

The *Global Reef Expedition* will: 1) identify and characterize remote, unique, high-value coral reefs that should be included in a global network of Marine Protected Areas (MPAs); 2) complete the first global assessment of the health of coral reefs; 3) recommend critical conservation targets for certain functional species that indicate and regulate reef health; 4) produce decision-aids and tools designed to facilitate management and conservation actions aimed at improving the health and resilience of coral reefs; 5) yield one of the largest, integrated shallow-water habitat mapping efforts to date; and 6) conduct a unique and valuable educational and outreach program throughout the Expedition to raise awareness and understanding of reef ecosystems and to encourage informed conservation actions at all levels of decision-making, from individuals to international organizations.

[1]Sheppard, CRC, SK Davy and GM Pilling. 2009. The biology of coral reefs. Oxford University Press, 339 pp.

[2]Wilkinson, C. 2008. Status of Coral Reefs of the World: 2008. Global Coral Reef Monitoring Network and Reef and Rainforest Research Center, Townsville, Australia. 296pp.

2 Unique Scientific Research Capabilities

THE KHALED BIN SULTAN LIVING OCEANS FOUNDATION'S UNIQUE AND PRIMARY RESEARCH PLATFORM FOR THE *GLOBAL REEF EXPEDITION* IS THE MOTOR YACHT *GOLDEN SHADOW*. THE *GOLDEN SHADOW* PROVIDES THE CAPABILITY TO EXPLORE REMOTE CORAL REEF ECOSYSTEMS AND COMPARE THESE ACROSS GRADIENTS OF BIOLOGICAL DIVERSITY, PHYSICAL AND OCEANOGRAPHIC PARAMETERS, AND ANTHROPOGENIC (HUMAN-CAUSED) STRESSORS.

The *Golden Shadow* is a fully equipped 67 m (219 ft) research ship. The ship carries multiple surface support vehicles including two large catamaran dive boats, two rigid hull inflatable dive boats, and the *Golden Eye*, a Cessna Caravan float plane. The *Golden Shadow* has a stern elevator platform used to launch and recover both the *Golden Eye* float plane and the largest dive boat. The platform also facilitates diver access and recovery in rough sea conditions and can be used to deploy a small submersible. The *Golden Shadow* has a fully functional dive locker with a two-person recompression chamber in the event of a diving medical emergency. The ship also has a scientific laboratory outfitted with a suite of scientific research equipment, including a flow-through sea water system and multiple aquaria. The *Golden Shadow* supports up to 24 researchers in a dedicated section of the ship. Fully qualified medical staff members are present on all research missions, along with a dive master, crew, and officers to operate support vessels, as well as full staffing for meals and logistical support. Additionally, the vessel is outfitted with a SeaKeepers 1000™ system, which is an automated data logging ocean and weather monitoring system. The research platform will provide coral reef researchers with the opportunity to explore, map, and characterize remote reefs that have not been sufficiently surveyed. All research will involve collaborative partnerships with world-renowned scientists and local management agencies, with an emphasis on the identification and training of local scientists and resource managers in collection and interpretation of coral reef data through the Foundation's *Science Without Borders*® program.

3 Core Scientific Research Team

THE CORE SCIENTIFIC RESEARCH TEAM FOR THE *GLOBAL REEF EXPEDITION* WILL INCLUDE LIVING OCEANS FOUNDATION STAFF MEMBERS CAPT PHILIP RENAUD, USN (RET.) (EXECUTIVE DIRECTOR), DR. ANDREW BRUCKNER (CHIEF SCIENTIST), AND AMANDA WILLIAMS (MARINE SCIENCE GIS ANALYST), ALONG WITH PARTNERS FROM THE NATIONAL CORAL REEF INSTITUTE (NCRI), THE UNIVERSITY OF QUEENSLAND AND THE FOUNDATION'S PH.D. FELLOWS.

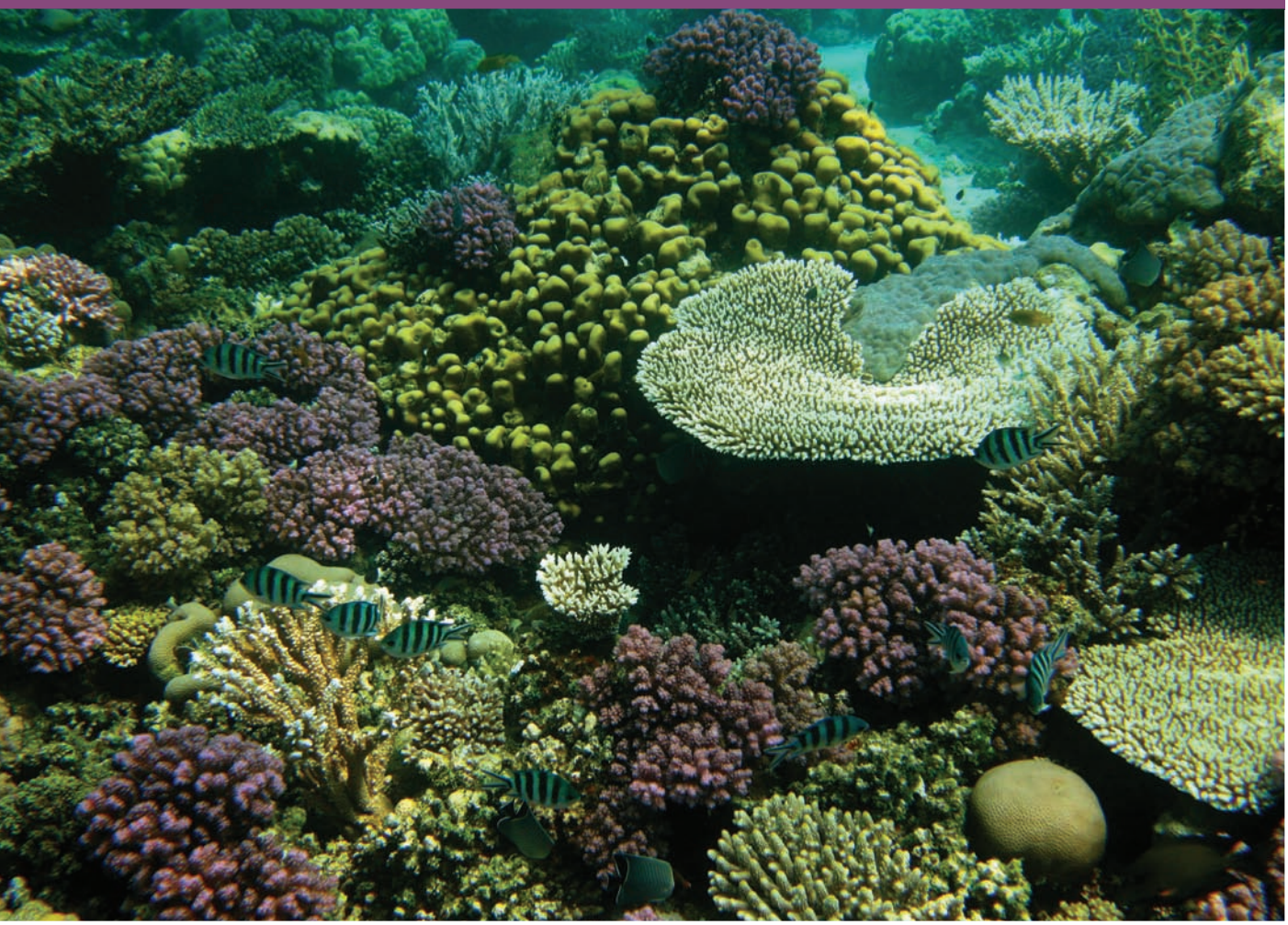
The National Coral Reef Institute has been a principal collaborator with the Foundation on remote sensing and ground-truthing field operations and production of high-resolution coral reef habitat maps since 2006. Dr. Samuel Purkis (Assistant Professor, NSU), a member of the core research team, will be leading the remote sensing and ground-truthing operations. Living Oceans Foundation Fellow Jeremy Kerr, a Ph.D. student at NSU under the supervision of Dr. Purkis, will create high-resolution habitat maps and perform ground-truthing field work throughout the *Global Reef Expedition*. Prof. Peter Mumby, University of Queensland, has collaborated with the Foundation since its inception, and is supervising another Living Oceans Foundation Fellow, Sonia Bejarano. Both Prof. Mumby and Sonia will be core members of the scientific research team, concentrating on herbivory functions and coral reef fisheries.

4 Scientific Research Differentiation

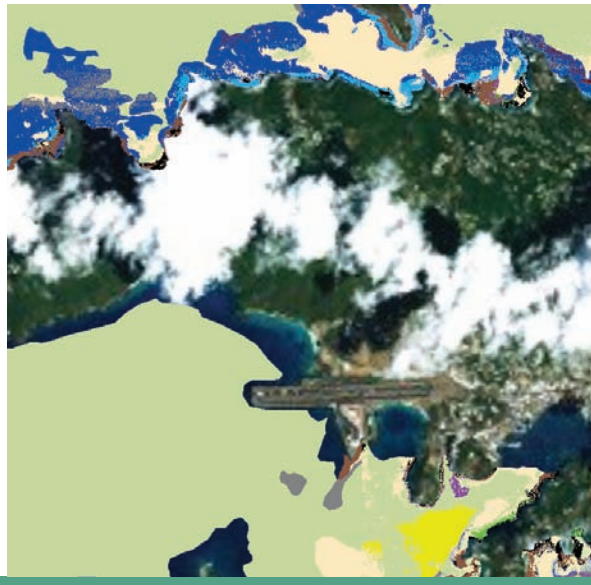
THE *GLOBAL REEF EXPEDITION* SCIENTIFIC RESEARCH PLAN DIFFERS FROM PREVIOUS CORAL REEF STUDIES IN THAT AN INTEGRATED, SYSTEMATIC, SCIENTIFIC RESEARCH APPROACH WILL BE EMPLOYED, WHICH PROVIDES THE INFORMATION NEEDED TO BRIDGE ON-THE-GROUND CONSERVATION ACTIONS WHILE CLOSING CRITICAL SCIENTIFIC KNOWLEDGE GAPS.

Over the past two decades, impressive advancements in coral reef ecology have been achieved, advancing scientific understanding of the distribution and spatial extent of reefs, biodiversity supported by reef ecosystems, the importance of reefs to human health, and the negative impacts of human activities. Numerous studies have been conducted on well-known and easily accessible coral reef sites, such as the Great Barrier Reef in Australia, the Florida Keys and some Caribbean coral reefs, but these studies have predominantly focused on specific scientific interests. Very few surveys have been conducted on remote reefs where direct human stressors are minimal, partially because they are difficult and costly to access. Therefore, gaps in scientific knowledge exist relating to the understanding of processes that support natural, healthy reef systems. One of the challenges in conserving these remote reefs, which are likely to be the healthiest coral reefs remaining on the planet, is that resource managers don't know the relative standing of these reefs in relation to associated habitats, linkages with other sites, or the importance of the communities within these sites from a biodiversity standpoint. Recommendations for coral reef management action have been identified, but there are critical knowledge gaps and management challenges remaining. For example, climate change impacts are thought to pose the greatest threat to reefs

on a long-term, global scale and it is critical that the current rate of greenhouse gas emissions is reduced. While reducing greenhouse gas emissions is largely outside the scope of local coral reef resource managers, it is critical that governments and resource managers consider implications of climate change in their conservation strategies and implement actions that will maximize coral reef resilience. The most urgent and plausible direct, on-the-ground conservation actions fall into three general categories: 1) minimizing direct and indirect human-caused stressors that affect the health of reefs, 2) scaling up networks of MPAs and improving the management and enforcement of MPAs, and 3) implementing new ecological research and monitoring approaches to facilitate adaptive management. The *Global Reef Expedition* Scientific Research Plan differs from previous coral reef studies in that an integrated, systematic, scientific research approach will be employed on a global scale. These studies will provide the information needed to bridge the three categories above while closing critical scientific knowledge gaps. This approach will yield scientific knowledge that will assist in the development of management decision-aids and tools urgently needed by stake-holders to achieve globally-effective coral reef conservation.

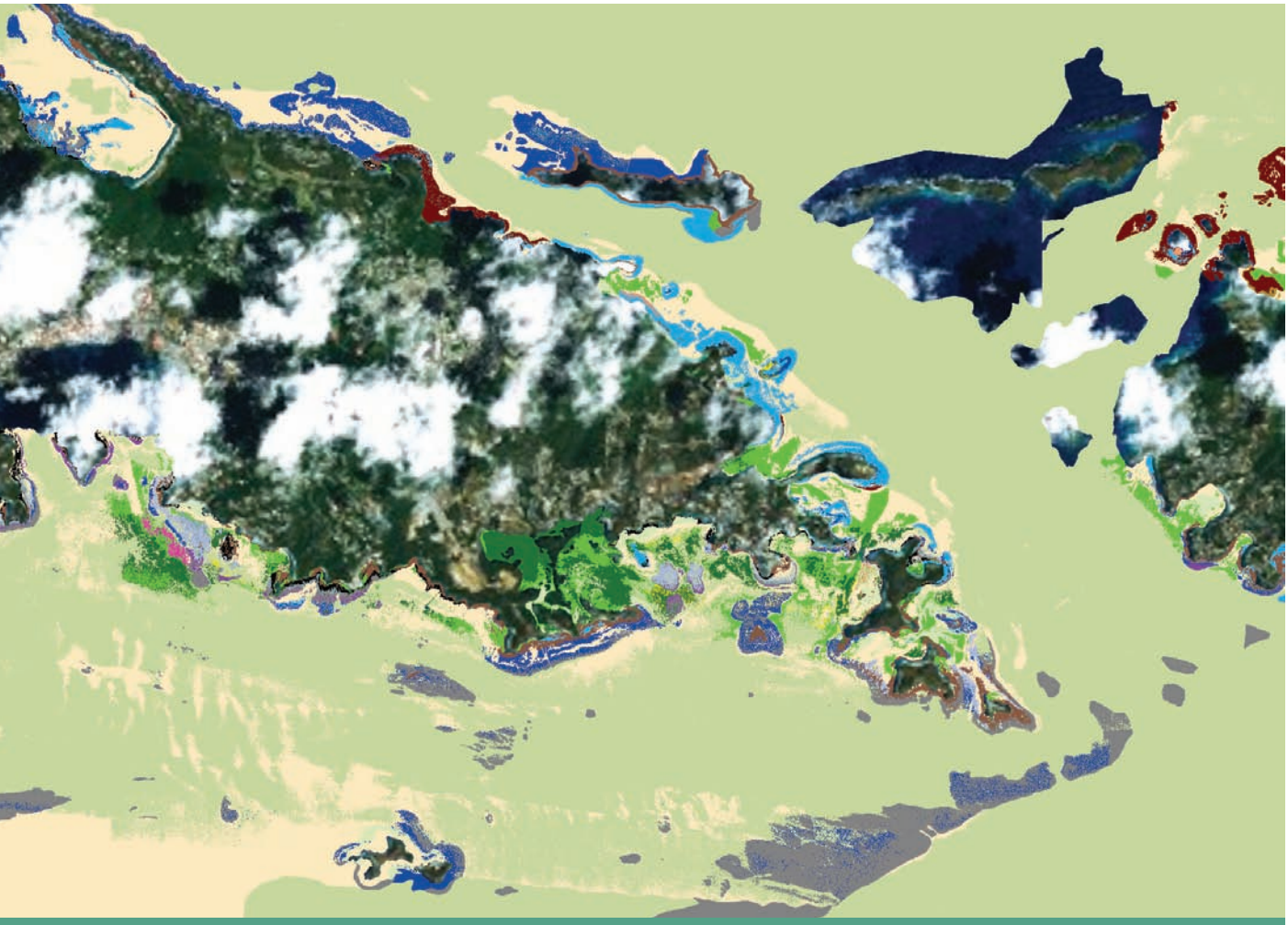


5 Research Goals and Objectives



THE RESEARCH GOALS OF THE *GLOBAL REEF EXPEDITION* ARE TO:

- Map and characterize the extent and spatial distribution of different habitats within poorly studied, remote coral reef ecosystems,
- Characterize the community structure and functional role of reef fishes, stony corals, algae and other ecologically and economically important organisms from coral reef ecosystems around the globe,
- Increase scientific understanding of fundamental processes of coral reef ecosystems in the context of linkages and interactions at a "landscape" scale,
- Vastly improve understanding of the current status of coral reefs at a global scale, differences between ocean basins and across human and environmental gradients,
- Identify the major threats to coral reef health, their severity and potential impacts,
- Produce usable knowledge that can enhance coral reef health and resilience, and
- Deliver scientifically-valid management and decision support tools, including one of the largest, integrated shallow-water habitat mapping efforts to date, necessary to advance on-the-ground coral reef conservation.



THE *GLOBAL REEF EXPEDITION* SCIENTIFIC RESEARCH PLAN HAS FIVE PRIMARY OBJECTIVES:

1. Produce high–resolution, shallow-water habitat maps and characterize coral reef ecosystems, utilizing remote-sensing technologies, ground-truthing methods, and SCUBA surveys,
2. Identify primary drivers of coral reef community structure, composition and health,
3. Measure and assess the most important indicators of coral reef resilience,
4. Determine impacts of global climate change on coral reef health and linkages with tractable human stressors, and
5. Produce global coral reef health and resilience assessment reports.

6 Methodologies and Outputs

CHARACTERIZE

Objective 1: Characterize coral reef ecosystems and produce high resolution habitat maps. The Living Oceans Foundation and National Coral Reef Institute (NCRI) have partnered to implement novel satellite and ground-truthing technologies for improving the accuracy and resolution of marine habitat maps and to develop habitat classification schemes at appropriate scales for local management. High-quality mapping and habitat characterization underpins the *Global Reef Expedition*, while taking advantage of modern survey and processing technologies. Existing relevant regional data (e.g., side-scan sonar, multibeam bathymetry and backscatter) will be integrated with expedition data using Geographic Information System (GIS) software. Unmapped, remote coral reef areas will be imaged by satellite, surveyed at sea, and ground-truthed in the field using validated visual and electronic sampling techniques. The Expedition will yield one of the largest, integrated shallow-water habitat mapping efforts to date. The map products generated by the Foundation will provide a framework for the spatial organization of research data, a mechanism to communicate results, and a starting point for spatially-based management interventions, including identification of management zones and MPAs.

IDENTIFY

Objective 2: Identify primary drivers of coral reef community structure and function. Key ecological processes that shape coral reef ecosystems (e.g., recruitment, herbivory, bioerosion) will be compared and contrasted across biophysical gradients and between geographic localities. Specific biological, physical and oceanographic parameters, such as diversity, productivity, habitat structure, specific anthropogenic stressors (e.g., fishing pressure), will be evaluated to determine how they influence ecological states of the reefs. For example, through surveys of species assemblages and feeding behavior of major herbivorous fishes, predictions will be made of relative patterns of algal production and functions necessary to avoid shifts from coral to macroalgal domination. The results of this work will determine the role of different species of fishes and invertebrates in supporting fully functional reef ecosystems and the environmental, biological, and physiological conditions that allow particular species to survive under suboptimal conditions. It will also facilitate in modeling and forecasting the key drivers and components that can promote ecosystem recovery from periodic disturbance.

MEASURE

Objective 3: Measure and assess the most important indicators of coral reef resilience. SCUBA surveys will be conducted to determine how species assemblages and major local and global threats vary across gradients of human and environmental stressors. Standardized survey methodologies will be used to assess coral reef resilience by characterizing key processes that drive ecosystem health and determining how ecological, biological and environmental attributes influence various ecological states (e.g., coral vs. algae reefs). In each region, rapid assessments will be conducted to characterize the population structure and health of important reef building corals, ecologically relevant fish species, major functional groups of algae, and other keystone species, as well as physical and biological attributes that are indicative of resilience. Surveys will provide a regional understanding of the status of coral reef communities and trajectories of reef health and will allow for categorization of areas according to their level of threat and resilience. Understanding resilience, which is the ability of coral reef ecosystems to recover from a major disturbance (e.g., hurricane, bleaching event) and/or adapt to long term changes (e.g., increased temperatures and acidification associated with global climate change) while maintaining its functions and services, will provide empowering knowledge to resource managers. Research across a gradient of environmental stressors will test critical questions, such as why and how some taxa or ecosystems appear to rebound well from stress and others do not, and will also help identify the most critical species that regulate the health of the reef and their optimal abundance. This will enable resource managers to better understand pathways to resilience, project ecosystem reactions through modeling, and focus management actions on the highest priority components of the ecosystem.

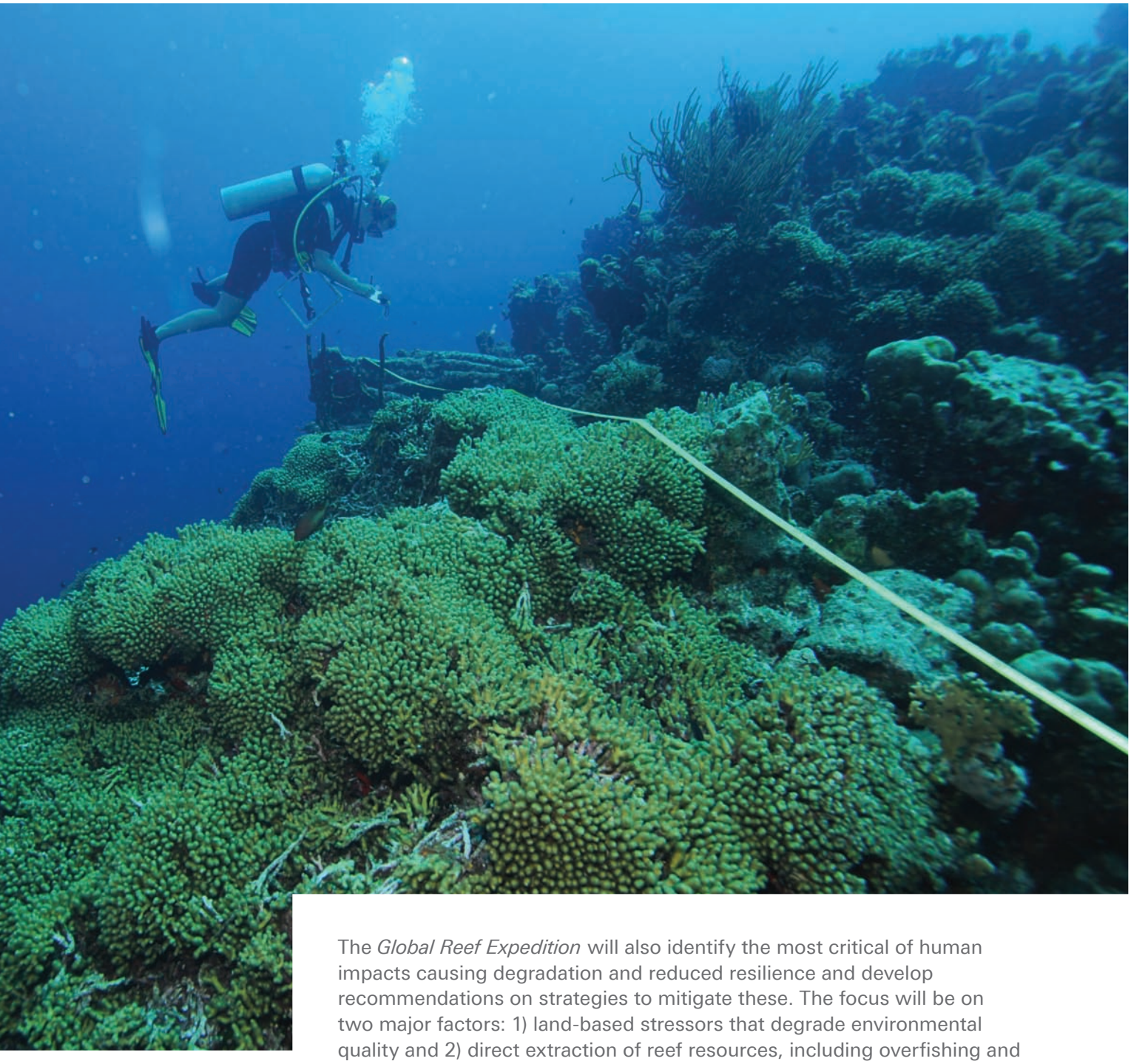
DETERMINE & ASSESS

Objectives 4 and 5: Determine impacts of global climate change on coral reef health and linkages with tractable human stressors (Objective 4). Large scale climate-related events (e.g., unusual sea-surface temperature anomalies) are occurring and have increased in frequency and severity over the last decade. These have been associated with regional and global scale coral reef bleaching events often followed by catastrophic losses of corals. In some cases, reefs have demonstrated the ability to recover from such acute events and others have failed to recover. While some of the overarching factors that may control the rate and extent of recovery are known, others include biological and environmental factors that vary spatially and are integrally linked (e.g., damaged reefs need a source of coral larvae and good habitat quality for settlement and growth). Furthermore, major stressors affecting reef health (e.g. overfishing, sedimentation, pollution) vary in severity and their impacts may be worsened when combined with other local stressors and global climate change. Because of the complex nature of coral reef ecosystems, it has been difficult to separate out the specific stressors that play the most significant role. Understanding the sources, types, and magnitude of human impacts is essential in developing suitable responses. By surveying remote coral reefs throughout the *Global Reef Expedition*, natural processes will be differentiated from confounding impacts of human stressors. This will allow for evaluation of relationships between community structure and natural processes that control reef function, as well as ecological, physical and chemical parameters (e.g., temperature, salinity, alkalinity, current patterns, wave action, and sedimentation) that either mitigate or exacerbate deterioration in reef health. Historical data analysis, SCUBA surveys, and oceanographic sensor data will provide detailed information on the effects of coral bleaching, disease, hurricanes, and ocean acidification on reef-building corals, and patterns of recovery from major disturbances (e.g., bleaching events) in areas exposed to various types of human pressure (e.g., fishing, land-based pollution). By understanding patterns of coral mortality and recruitment following previous climate change events, their response to future ocean warming events and changes in ocean chemistry may be predicted. Upon completion of data processing and synthesis, regional and global health assessments on the condition of reefs will be produced and will provide options to mitigate stressors and improve their ability to cope with climate change (Objective 5).

7 Anticipated Outcomes

THE FOUNDATION'S STRATEGY IS TO PROVIDE APPLIED SCIENTIFIC KNOWLEDGE TO LOCAL RESOURCE MANAGERS AND RELEVANT GOVERNMENT ENVIRONMENTAL AGENCIES, BUILDING A BRIDGE BETWEEN SCIENCE AND MANAGEMENT IN ORDER TO ACHIEVE THE LONG-TERM GOAL OF ENSURING HEALTHY AND SUSTAINABLE CORAL REEF ECOSYSTEMS AROUND THE GLOBE.

Establishment of MPAs and networks of MPAs offers one of the most promising solutions to the coral reef crisis. MPAs can serve as refuge for biodiversity and may assist in replenishing degraded reefs due to the movement of adults and larvae from protected areas into adjacent areas. The results of the *Global Reef Expedition* will assist local managers in designing and implementing large-scale networks of marine protected areas, whereby, 1) risks of global climate change are minimized by protecting representative and replicated areas of major habitat types, 2) key sources of larvae are safeguarded, and 3) ecological connectivity between habitats is maintained.



The *Global Reef Expedition* will also identify the most critical of human impacts causing degradation and reduced resilience and develop recommendations on strategies to mitigate these. The focus will be on two major factors: 1) land-based stressors that degrade environmental quality and 2) direct extraction of reef resources, including overfishing and destructive fishing techniques. The distribution, severity and impacts of natural stressors (e.g. coral predators, disease, bleaching, and storm damage) will be evaluated in context of the distribution and severity of human impacts to identify possible causal relationships and mitigation strategies. By implementing recommendations on relevant spatial scales, using the high-resolution habitat maps as a framework, knowledge and tools will be provided to effectively manage these stressors, ensuring reefs endure as healthy, sustainable, and productive ecosystems.

8

Summary

THE *GLOBAL REEF EXPEDITION* INITIATIVE IS FULFILLING AN URGENT PRIORITY AT THE CROSSROADS OF AN OCEAN HEALTH CRISIS. TIME IS RUNNING OUT, KNOWLEDGE GAPS MUST BE CLOSED, AND PROACTIVE STEPS MUST BE QUICKLY IMPLEMENTED TO REVERSE THE DECLINE OF THE WORLD'S INVALUABLE CORAL REEF RESOURCES. THIS IMPERATIVE IS NOT JUST ABOUT PROTECTING THE HEALTH OF CORAL REEF ANIMALS; IT IS AN IMPERATIVE TO SAFEGUARD THE HEALTH OF THE OCEANS, WHICH REGULATES AND SUSTAINS ALL LIFE ON THIS PLANET, INCLUDING OUR OWN.

The *Global Reef Expedition* is the first known global coral reef scientific expedition designed to directly impact the world's collective responsibility to confront the coral reef crisis. The scientific research plan is unique in its systematic and integrated approach with a key focus on applied research. The *Global Reef Expedition* will bring together a strong network of interdisciplinary marine scientists with the ability to reach local researchers, managers, students, and teachers under the Foundation's existing *Science Without Borders*® program. The Expedition will yield one of the largest, shallow-water habitat mapping efforts to date and the information and tools developed will empower local resource and reef managers worldwide. The *Global Reef Expedition* will result in an integrated set of deliverables, including a comprehensive GIS database for each country surveyed, containing detailed habitat maps, habitat characterization, and geo-referenced data on coral reef community structure, health and threats. Recommendations on establishing high-value, ecologically-linked MPAs will be developed, based on cultural, biological, and environmental attributes of the Expedition research sites.

The *Global Reef Expedition* will also develop strategies for restoring the health and biological diversity of coral reefs that have deteriorated from human-caused disturbances, using available information about pre-disturbance condition and rapid ecological assessments conducted throughout the Expedition. The research program will build a strong bridge between science and management that will promote proactive management and intervention approaches with the objective to sustain healthy and productive reefs for future generations. The knowledge resulting from the *Global Reef Expedition* on factors and processes which enhance the resilience of coral reef ecosystems will be invaluable to coral reef resource managers, empowering them to focus on managing the priority components of the ecosystem.

Khaled bin Sultan
Living Oceans Foundation

8181 Professional Place, Suite 215
Landover, Maryland 20785 USA
(301) 577-1288
www.livingoceansfoundation.org
prenaud@livingoceansfoundation.org