Caribbean Region

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For report contact information, please see Appendix 4.

Workshop Summary

The United States of America and New Zealand, in partnership with the Secretariat of the Pacific Regional Environment Programme, hosted a two-day International Workshop on Ocean Acidification: State-of-the-Science Considerations for Small Island Developing States (SIDS) on August 28–29, 2014, in Apia, Samoa. The workshop was an official parallel event to the Third United Nations Conference on SIDS. Workshop participants included technical experts on ocean acidification and policy experts on ocean issues, in addition to SIDS delegates from three SIDS regions – the Pacific, the Caribbean and the Atlantic, Indian Ocean, Mediterranean and South China Sea (AIMS). The overarching goals of the workshop were to:

- Provide workshop participants with an in-depth overview of the state-of-the-science with regards to ocean acidification on a global level focusing on sharing monitoring and research best practices;

- Initiate discussions on OA monitoring and capability requirements, with an aim of regional representation as part of the Global Ocean Acidification Observing Network (GOA-ON); and

- Provide a forum to initiate the formation of regional SIDS ocean acidification stakeholder networks to facilitate conversations about the state of ocean acidification science and to further catalyze partnerships among scientists, user groups including civil society organizations, policymakers, donor partners, academia, business and industry as follow-ons to the Third United Nations Conference on SIDS.

Ocean acidification (OA) is a direct result of the increasing CO_2 level in the atmosphere. The concentration of CO_2 in the ocean is controlled by air-sea gas exchange and by biological processes (production and respiration). As atmospheric CO_2 is absorbed by seawater, it undergoes a series of reactions which lower the pH and decrease the carbonate ion concentration in the seawater.

Ocean acidification is multidimensional and directly threatens islands and island communities. Participants jointly recognised the nature of the OA threat to marine ecosystems surrounding SIDS, which provide their communities with food security, livelihoods and economic stability, resilience to extreme weather events, and cultural identity. Some of the marine species specifically important to SIDS and potentially vulnerable to OA include corals; molluscs such as conchs, clams, and oysters; crustaceans such as lobsters and crabs; and reef and pelagic fish, including tuna. OA could indirectly affect sustainable development for SIDS through multiple and cumulative impacts on these species and the broader marine ecosystems on which they depend.

Ocean acidification is a present and escalating threat. Some impacts are evident today, and others will increasingly be felt over coming decades. Participants recognised the need to establish standardised, affordable, long-term research and monitoring capacity, including consideration of traditional knowledge, while also taking advantage of

international communities-of-practice, such as the Global Ocean Acidification Observing Network and the Ocean Acidification International Coordination Centre, by leveraging and mobilising existing scientific and technological resources and organisations within individual SIDS countries, across SIDS regions, and through international partnerships and cooperation. The importance of raising awareness, building capacity, transferring technology, and mobilising resources was emphasised, including potential development of regional centres of excellence as an efficient way to develop capacity within SIDS.

Several key thematic issues emerged during the workshop:

1. Scientific capacity-building is clearly a challenge for SIDS, and to be fully engaged in understanding and managing OA, meaningful and durable capacity-building opportunities are needed—both at individual and institutional levels.
2. Financing is a key challenge and requires working closely with development partners.
3. There is a present need for more effective national and regional coordination, as well as the strengthening of existing mechanisms for response to OA.
4. Meaningful and sustainable partnerships are an important part of SIDS development, and participants welcome partnerships and collaboration between and among SIDS, developed nations, and developing nations.
5. Bridging the gap among scientists, communities, and policy makers is critical for the awareness and understanding of OA issues as well as for developing adaptation response(s).
6. Informing and educating the wider public about OA and its impacts to social, environmental, and economic security is a vital next step.
7. A key goal is integrated monitoring linked to livelihoods that connect SIDS, is focused on SIDS, and driven by SIDS.

The workshop fostered the creation of OA networks for the Caribbean, Pacific Islands, and AIMS SIDS regions, which will continue to develop next steps in their regions, including engaging participants from countries not present at the workshop, and to generate SIDS-driven, SIDS-connected, and SIDS-focused ‘Joint SIDS Recommendations on Ocean Acidification’.

Participants recognised that monitoring, resilience-building strategies and practical adaptation actions, where feasible, must be simultaneously explored and developed given the serious implications of OA impacts. Actions and partnerships must be sustainable and must include SIDS-SIDS interactions and interactions between developing nations in addition to partnerships with developed nations. Strategies and actions should include, but not be limited to, efforts that enhance functioning of local marine ecosystems (for example, management of nutrient run-off, overfishing, land-use change, cultivation and management of sea grass beds, and use of marine protected areas) and that strengthen resilience of local communities through open sharing of scientific findings and capacity building to develop local awareness, expertise, and knowledge. Participants

recommended that any efforts to combat OA must rely on understanding linkages between ecosystems and must support ecosystems health.

The group emphasised that all efforts involve people: community awareness is an important component for adaptive responses. Learning about and incorporating new management strategies will enable communities to more effectively respond and adapt to OA.

The workshop consisted of a series of Sessions in which there were presentations focused on the science of ocean acidification (OA), monitoring efforts, impacts and adaptation strategies, and building networks and partnerships in SIDS regions. All workshop participants attended these Sessions as a whole group and the presentations were followed by large group discussions. Participants also broke into smaller regional SIDS Breakout Groups for more in-depth regional-based discussions focused on Session presentations topics. This document represents the initial documentation of findings from the Caribbean Breakout Group's working sessions.

The Honourable Faamoetauloa Lealaiauloto Taito Dr. Faale Tumaalii, Minister of Natural Resources and Environment (Samoa), officially opened the workshop and welcomed workshop participants to Samoa. The workshop was co-chaired by Dr. Libby Jewett, Director, NOAA Ocean Acidification Program, National Oceanic and Atmospheric Administration (United States of America) and Melchior Mataki, Permanent Secretary of the Ministry of the Environment, Climate Change & Disaster Management, Solomon Islands). The Workshop Agenda can be found in Appendix 1.

Workshop Sessions and Caribbean Breakout Session Summaries

Session 1: Identifying the Problem and Its Impacts

Objective

To identify the nature and extent of OA in Small Island Developing States.

Session 1 Presentations

Andreas Andersson, Assistant Professor at Scripps Institute of Oceanography (USA), "Ocean acidification and SIDS: the basics" (OA).

Simon Nicol, Principal Fisheries Scientist at the Secretariat of the Pacific Community (New Caledonia), "Potential impact of OA on pelagic ecosystems in the Pacific Ocean"

Rachel Allen, Ministry of Water, Land, Environment and Climate Change (Jamaica), "The reality of ocean acidification in the Caribbean"

Philip Munday, Professor at James Cook University (Australia), "Ocean acidification and coral reef communities"

Session 1 Discussion

> "Research and monitoring will not solve the problem of OA. Alongside this additional research, we need to take action to increase the resilience of the reef to respond to OA. […] We need to take direct actions to prepare the reefs and the communities". *Andreas Andersson, OA SIDS Workshop, 2014*

Session 1 opened with a general overview of the chemistry of ocean acidification (OA). The concept of net ecosystem calcification was introduced, defined as coral reef growth minus coral dissolution. Reef growth varies seasonally, but Andersson reported that scientists have been observing periods of net dissolution, when reefs are breaking down faster than they are growing. There are examples of a reef exhibiting net dissolution over seasonal periods when it has historically demonstrated active coral growth. Andersson anticipated that this trend will continue.

Ocean acidification interacts with increasing water temperatures to cause losses of coral cover, habitat complexity, biodiversity, and species abundance on reefs. OA has direct effects, long-term physiological/energetic costs, and recently discovered behavioural effects.

The effects of localised impacts, such as runoff from agricultural sources, were discussed. It was noted that these impacts are more of a concern for reefs on shorter time scales than the long term, persistent stressors like OA. By reducing these stressors, which are human-induced, the reef might be able to more effectively handle longer-term, globally-driven changes caused by rising CO_2.

Optimal frequency of experimental sampling on reefs was also discussed. Some criteria to consider are the reef system in question, the target questions, funding, and availability of other program/project resources. Monthly time series measurements (water sampling from boats or shore taken at the same place, every month) can provide sufficient information at the ecosystem scale as part of longer-term studies. High-frequency temporal surveys, which are usually conducted by moored, autonomous buoys outfitted with sensors, can provide higher resolution information about changes happening over a day and through seasons but does not provide information about the spatial variability of the system. Intermittent sampling, while worthwhile, produces a single snapshot. A detailed spatial survey, conducted over a compressed time period, can indicate what is occurring at a reef at one time and can augment a high-frequency temporal survey for complete system characterisation.

Participants also discussed research designed to understand the impacts of OA on reef organisms. Both direct (on the organism) and indirect (through habitat availability) effects of OA could alter ecological processes and abundance, distribution, and community structure. In addition, these are factors that are affected by interaction with other environmental stressors. How organisms respond when exposed to OA and other environmental stressors is an active field of study. The discussion noted that pH and carbonate availability are not the only concerns with OA. Increases in dissolved CO_2 alter the gradient between the environment and the tissues of animals, and 'water breathers' are particularly vulnerable. If seawater pCO_2 increases, blood pCO_2 also increases, and so tissues may also acidify.

It was noted that some fish species are more sensitive to pH than others and that sensitivity varies among life-cycle stages. Broadcast spawners with small, poorly developed larvae are particularly susceptible. Parental exposure can ameliorate the impact of increased CO_2, i.e. adults exposed to low pH produce juveniles that appear to be more tolerant, but there are metabolic costs to survival at lower pH.

Detrimental behavioural effects were seen in juvenile coral trout (a commercially-valuable species) from 600 to 850 µatm pCO_2, i.e. realistic near-future levels. The same effects are also seen at CO_2 seeps, and there is no physiological ability to adapt within the lifetime of an individual to avoid the behavioural effects. Looking across generations, offspring display similar behavioural affects even if the parents lived under high CO_2 conditions.

Pelagic species can also be influenced by OA, including those important to commercial fisheries, presenting a source of vulnerability for SIDS. The effects of OA have been detected in yellow fin tuna brood stock within the plausible ranges of OA forecast over

the next 100 years. Adaptation to OA in tuna species has not been documented, and both direct and indirect effects of OA on tuna are likely.

With on-going anthropogenic pressures on the ocean, OA is likely to exacerbate issues of species' food availability as well. Early research on the effects of OA on certain species of micronekton has suggested that there will be an impact, ultimately affecting commercially-important predators, like tuna. Changes in marine pH will vary spatially, and coastal OA could affect nursery areas of commercially-important species.

Fishing pressure is another consideration. Any stock that is fished is under evolutionary selection, regardless of the extent of the fishing pressure. Within heavily fished stocks, there is stronger selection for faster growth and smaller size. The evolution of growth rates, size, and other characteristics can be related to fishing pressure (at any intensity) in addition to pressures like OA. Clearly, the issues are complex, and the solutions will also be complex in the context of ecosystem change. It was also noted that the Achotines Laboratory in Panama, established by the Inter-American Tropical Tuna Commission, is the only facility of its kind near a coast and is that provides a unique location/facility for testing the effects of stressors such as OA on pelagic fish. Funding issues in support of research on tuna were also discussed.

It is also critical to consider the human aspect of OA through cohesive science monitoring/research and sustainable ocean governance. Coordination among SIDS is an on-going challenge. As was pointed out by Rachel Allen, "We may be oceans apart, but we are under a common threat". Allen identified a need to respect and record traditional knowledge and to include the communities in decision making from the outset. The discussion considered a survey recently conducted in the Cook Islands to collect knowledge from elders regarding the impact of climate change. The findings included many indicators of climate change, increasing brittleness of reefs, and sea level rise. It was noted that it is very important to collect this kind of traditional knowledge as it can guide research in the region.

Aquaculture was discussed as an adaptation strategy, with examples in Jamaica including farming conch and supplementing natural populations. Although the United States has shifted to aquaculture for clam fisheries, there appears to be limited 'adaptation' capacity for conch fishers. Trinidad and Tobago shared similar concerns. In addition to the conch, oysters on mangrove roots are also affected; the oyster shells are thinner and more brittle, and the compactness of the calcium carbonate structure has changed and led to more disease. To export conch to the European Union, certain health standards must be met; it is important that susceptibility to any disease does not increase as disease will devastate both the conch populations and the industry. Conch is considered a best-practice stock in terms of management, with stock measured and new catch limits set every year. However, present resource management provides no control over the external threat of OA.

Participants acknowledged there were common concerns about OA among SIDS regions, but regional concerns were focused on different species. Few ocean measurements are

being made in the SIDS regions represented in the workshop. There is a need for a moored monitored buoy system (such as that of NOAA Pacific Marine Environmental Laboratory) to collect data, integrating all oceanic data on which SIDS rely. The University of the West Indies has five monitoring stations throughout the region, which would need to be upgraded to measure CO_2. It was suggested that NOAA should establish a monitoring station in the Pacific. One participant noted, "We should consider an integration of all sectors that affect the quality of the ocean. There is an historical pattern of looking at environmental areas separately from other effects. It is timely that we islands talk about OA, but also consider other variables that act together with OA and climate change."

Session 1 Caribbean Region Breakout:

How is the region defined?

- The participants agreed to define the region in broad terms and to focus on the geographical boundaries of the Caribbean Sea, given that other ways to define the region can be controversial.

What is/are the regional assessments of the issue(s)?

- There are some existing monitoring systems in place, but many require alteration to measure CO_2, and on-going maintenance is a challenge
- The discussion considered the access, ownership, and use of data from monitoring systems, with participants noting the present vast differences among nations' in-country capacity to effectively use such data.
- In addition to long-term trends, the group discussed ways to identify short-term effects using alternative studies, such as isotope analysis of the conch shells that were said to have become more brittle.
- Participants suggested an assessment of past and present work on OA in the region and the consideration of an information coordination mechanism at the regional level.

What are the region's unique considerations/experiences (environmental/biodiversity/socioeconomic)?

- It was noted that the Caribbean States do not have a strong sense of collective 'identity'. in terms of regional platforms for discussions. These platforms are stronger at the sub-regional level of close proximity. Another challenge is the lack of buy-in/ownership by fisher folk to regionally developed policies.
- Resource limitation and lack of funding for in-country capacity were identified as key issues regarding OA research and response.

How does OA compare with other environmental pressures? (Is this known?)

- A general lack of awareness of OA among policy makers as well as at the grassroots level (fisher folk) was noted.
- Challenges to raising awareness of OA include the relatively long time horizons associated with OA and the lack of information materials available for dissemination.

Session 2: Understanding the Problem and its Impacts

Objective

Workshop participants have an enhanced understanding of existing ocean acidification monitoring methodologies as well as monitoring impacts of ocean acidification and how Small Island Developing States (SIDS) can leverage capabilities and resources to better understand the problem and its impacts.

Session 2 Presentations

Rusty Brainard, National Oceanic and Atmospheric Administration (United States), "Monitoring ecological impacts of ocean acidification on coral reefs"

Kim Currie, National Institute of Water and Atmospheric Research (New Zealand), "Ocean acidification monitoring in New Zealand"

Bronte Tilbrook, Commonwealth Scientific and Industrial Research Organisation (Australia), "Ocean acidification observing systems"

Jan Newton, University of Washington (United States), The Global Ocean Acidification Observing Network (GOA-ON).

Peter Houk, University of Guam Marine Laboratory (Guam), "Collaborative coral reef monitoring for local jurisdictions with limited resources across Micronesia: Maximizing local benefits and regional knowledge"

Elizabeth Jewett, Director, NOAA Ocean Acidification Program, National Oceanic and Atmospheric Administration (United States), Sharing Ocean Acidification Data

Session 2 Discussion

Discussions in Session 2 noted that SIDS cannot solve the OA issue alone and it is important to focus on needs, including monitoring and raising awareness to inform decision-makers.

OA is occurring in a context of biodiversity loss. However, the discussion noted that in some areas (near upwelling), coral reefs are doing well despite low carbonate saturation.

Whether there is a genetic adaptation by coral reefs is yet to be fully assessed, but present understanding points toward the availability of food sources for coral reef resilience in these areas rather than genetic adaptation.

There are natural pH variations between regions and related coral cover patterns. There is a need to understand the variability and define areas of vulnerability or resilience. Monitoring can identify areas of high resilience to environmental stressors, like OA. SIDS need simple, consistent, cost-effective time-series observations of physical/chemical and key ecological parameters to inform policy and management. Most of what is currently known about biological/ecosystem effects of OA is from laboratory studies. Long-term, global observations are needed to determine if what is observed in the laboratory will occur in nature.

On-going monitoring work in Hawai'i and Australia was discussed, with this research primarily linked to biological models. Sampling for OA-related components via the NOAA Ocean Acidification Program was built into the existing Pacific Coral Reef Assessment & Monitoring Programme in 2005. Rusty Brainard encouraged the use of strategies employed in NOAA's National Coral Reef Ecosystem Monitoring Program.

A New Zealand OA monitoring network has been developed through a partnership with aquaculture and fishing industries, councils, governmental departments, coastal marine guardians, and Kiwi. It was noted that the knowledge gap among scientists, policy groups, and communities is an important challenge, and measures to engage wider communities were also discussed. It is critical to engage with regional leaders and inform them about OA issues and the impacts in their environments. Partnerships are essential in this process.

Observation programmes can be developed using extant capacity, such as established fisheries observer networks for the collection of and ocean chemical sampling, although sample storage can be a challenge. Metered sampling might be a possibility, perhaps via fish aggregating devices FADs. However, sensors vary in quality, and users must ensure that boat crews know how to use the equipment.

It was discussed that SIDS should begin participating in monitoring and needed to consider scale, affordability, and available technology and expertise. Monthly sampling was recommended, with bottle samples collected locally in a variety of areas and sent to an analysis centre for processing, as in done in many developed regions, since the required analytical equipment demands continual use and maintenance. Not every region/country needs to build expensive, under-used laboratories; collaboration is driven by the economy of scale. Global collaboration is a priority.

Building in-country capacity is also a priority, and technology is becoming easier to access and transfer. SIDS might benefit from offshore measurement capacity, such as profiling floats. Regular monitoring is not labour-intensive. Regardless of the approach taken, the entire process should be fully assessed since the protocols used must be uniform to enable data comparisons/analyses. Data sharing helps communities at all

scales by identifying needs and times for action and providing context for experimentation. The International Coordination Center for OA (OA-ICC) and the European Project on Ocean Acidification (EPOCA), with data available through the PANGAEA data publisher, were noted.

There is a need for standardisation of high-quality scientific methodologies across SIDS, with benefits including shared learning and outreach and the effective use of existing institutions. Long-term temporal and spatial monitoring is critical for understanding environmental processes and the level at which to manage and/or adapt to stressors. Monitoring can be cumbersome for each region to sustain. The design of a monitoring system depends on the questions to be answered and the needs affecting policy and decision-making in the region.

The Global Ocean Acidification Observing Network (GOA-ON) was introduced. A global approach is needed to create information and data products to inform policy makers and the public about OA and its implications for the health of the planet. These processes are occurring at global scales, demanding coordinated local- to global-scale observations. Input from SIDS is critical for better data on OA, to enable forecasting/prediction of OA, and to communicate the status of OA.

Discussion considered membership and actions of GOA-ON since its formation in 2012. Participants were invited to the initial GOA-ON meeting based on scientific expertise and globally representation; there are no membership dues or restrictions. GOA-ON is a concept of the best practice observing network that member nations can implement. GOA-ON is not an inter-governmental entity at present and is not a funding source. GOA-ON members are following the structural example of the GOOS platform from Intergovernmental Oceanographic Commission and are working together on a volunteer basis to integrate current and planned observations and activities into one system.

There is value in being able to present a network such as GOA-ON. An internationally-supported monitoring network is more likely to be supported by other governments. The goal of contributing to the GOA-ON network provides guidance on the type of measurements to take and the quality required.

The inclusion of SIDS in GOA-ON was discussed, and participants suggested that GOA-ON add another goal – mobilising monitoring information on the ground. There is a need to use understanding of OA to make effective policies at national, regional, and global levels. There is a need for building capacity in the region, and using ships of opportunity (to deploy sampling gear or collect samples on non-OA cruises) requires funding. For GOA-ON to grow its capacity, large national and international entities must engage with regional organisations in SIDS. The existence of the GOA-ON plan will help to identify these needs for capacity-building and requirements for additional funding.

There is a scarcity of infrastructure to fund science in the region and opportunities for young scientists in SIDS are lacking. Regional organisations often cannot find opportunities within in academic institutions. As such, many students move to

universities out of the SIDS region. It was noted that there are strong inter-linkages between science and policy within SIDS and as such, science can readily be informed by policy. All citizens, including scientists, can talk to ministers and policy-makers and this linkage should be used as a resource.

It was noted that SIDS can take actions and provide global benefits even with limited resources. The participants encouraged creativity in accessing funding and noted the benefit of engaging across governments, non-governmental organisations, and industry.

The discussion emphasised that the people who live in SIDS are in their environment every day. These communities have a type of knowledge gained from this interaction with their environment, although that knowledge is less measurable. A participant stated, "We must find ways to incorporate that knowledge to find different paths forward for this planet".

Session 2 Caribbean Region Breakout

What monitoring efforts are currently underway in the region?

- It was suggested that regional centres should take the lead on OA because there is already work toward a regional monitoring programme under the EU Global Climate Change Alliance and EDF 11. Such regional centres have the capacity to source funds and do policy work.
- The present monitoring system via CREWS/ICON was noted. Previous monitoring efforts have occurred but are resource-limited and relied on different sampling approaches. A Coastal Zone Management Unit in Barbados is setting up a CREW station and has been monitoring for a long time. Some OA-relevant data are available. The Institute of Marine Affairs in Trinidad has the capacity for water quality analysis.
- Capacity exists on many islands; funding is the constraint.
- The discussion considered other kinds of OA-relevant monitoring, such as socio-economic impacts.

How are data managed?

- Participants noted that although data were being collected in places throughout the region, there was no central repository, and there are issues of restricted access due to competition between institutions and government vs. private sector complications, compounded by a lack of trust and insufficient communication.

What does an ideal monitoring network look like when taking into account current resource availability?

- The ideal system identified by the group would include regional monitoring with widespread coverage, complementary systems, and monitoring stations tailored to local and regional needs. Participants agreed upon the need to better capture the 'human element' of OA regarding socio-economic systems.

What kind of regional capacity-building is needed?

- Considering the human context, the region needs to explore options and resources for adaptation/response measures, by combining time, resources, and expertise to find effective solutions for the region. The Caribbean region needs to have vertically and horizontally integrated systems in place to facilitate good governance on OA. However, each island has its own responsibilities, concerns, interests, funding, priorities, and vulnerabilities. A single approach is insufficient to establish a regional forum/platform to address OA.
- Participants noted a strong need for regional cooperation and coordination of OA-relevant monitoring and data as part of capacity building. At present, there are differing levels of capacity, awareness, and infrastructure, in part because development has come from outside with no permanence and limited local ownership. In-region program sustainability requires funding, long-term commitment, human resources, regional governmental support, and international collaborations.
- The group agreed that the region should target monitoring stations, ideally one for every island to identify the effects of OA locally and regionally. A station in Pedro-Bank would be of benefit because it is a more central location in the region. Using existing infrastructure (such as CREW stations) and upgrading resources to measure CO_2 would be a good entry point.
- Geopolitical positions need to be considered so that each island can determine who measures what and where to contribute the most information on currents, OA, and other related concerns. Moreover, a geopolitical analysis would determine the existing systems in the region, and these systems should be used as a reference for extant knowledge on OA. Historical/empirical information (if any) is an important entry point so that newly acquired information can be added to existing information.
- Participants recommended a regional analysis that considers the needs of the region and of each island to assist in establishing areas of interest, potentially guided by GOA-ON parameters.

What can SIDS do with limited resources?

- Ways to address resource limitation included training on how to access funding and greater collaboration among academic institutions.

- A proposal was made that richer developed countries should bear the burden of funding poorer countries' monitoring activities because the majority of greenhouse gases originated from developed countries. Others were of the opinion that SIDS should take responsibility and invest in their own research because OA impacts SIDS economies directly.
- The substantial funding available to the region for climate change mitigation was identified as a resource. It was suggested that project-funding proposal evaluation criteria by organisations and national permitting agencies include criteria regarding how research projects will contribute to strengthening of capacity in SIDS.

How might GOA-ON be relevant for SIDS?

- Participants were interested to know how they could contribute to GOA-ON and to know the minimum sampling criteria (identified as temperature, salinity, and either pH or two other variables to constrain the carbonate system). The use of bottled samples is substantially cheaper than buoys, likely within the reach of poorer nations, and the results are considered more reliable.

Emerging Commonalities from Day 1 Breakout Discussions

The workshop participants agreed that each of the regions requires organisation and coordination due to the extensiveness of the regions, considering political, geographical, cultural, and biological diversity. There is need for an institutional arrangement to facilitate communication and coordination. The CROP agencies were established within the Pacific region to meet those needs for communication and organisation. Organisations within SIDS need to be strengthened so they can understand issues like OA and understand how they can address such issues.

All regions are seeking clarity regarding needs within the regions. There is a need, at the regional and international levels, to specifically define organisational targets, desires and requirements regarding OA and broader issues/needs. Scientists and policy makers must work together to bring OA into the forefront in discussions of resource management, fisheries, and other groups at the national level.

To address the common problem of sustainability in programmes, clearly defined sample and date collection, storage, and analyses protocols must be established. The network of scientists conducting research on coral reef bleaching can be considered an asset. The discussion noted that when considering a regional centre, we must be cognisant of the risk of diluting effort among many scattered centres rather than streamlining. It is important to disseminate information into specific areas, and it is also important to acknowledge and use existing centres. In addition to discussing the importance of regional groups of databases, direction/coordination by international agencies was

identified as important. A combination of the entities is essential, providing regional power and using best practices to maintain data quality and be able to compare/use data across different regions.

Participants described a past challenge in the Pacific, with multiple databases relying on national and regional information and with various sectors collecting their own data. A coordinating agency (SPREP) was inaccurately seen by users as a supposed source of funding for fieldwork. Historically, there has been confusion regarding sources of resources and/or funding, or a lack of recognition of the need for organisation/collation. Future efforts must identify the need for communication and collaboration, as distinct from funds or technologies but equally necessary for growth.

Participants expressed the need to extend the functions and scale of existing infrastructures, and the need for funding to do so. The region faces staff limitations. There is some potential conflict within existing structures over who needs to take the lead on marine issues. The human resource issue must be addressed before it will be possible to assimilate OA into programmes. The use of specific task forces was suggested within a region that would utilise a region's capacity but also use expertise and support among regions, to ensure added benefits of continuity and data quality. Task forces can move between regions to ensure similar research is of similar quality.

Capacity-building is very important. Some of the regions have human resources in terms of trained researchers and other support, but must build OA-specific capacity to incorporate OA into work plans, projects, and institutions and to sustain in-country expertise. The past example of international partners coming in to do research, using locals only to collect samples but not process/analyse data, is not desirable in future efforts. It is no longer good enough to observe or facilitate research; SIDS need to build capacity to *do* (design and conduct) that research. The SIDS regions need true sustainability. Participants expressed desire for SIDS nationals to travel to host institutions. Participants unanimously urged involvement by mainland nations in technology and capacity transfer/building to support SIDS.

Many islands, particularly remote ones, do not have established long-term institutions and processes for monitoring. There are, for example, meteorological services, but monitoring in general has not been emphasised by governments. Monitoring is left to academics and conservation groups. The data in a regional centre will only be as good as the ground-level data. SPREP noted that monitoring the ocean, in general, is a potential area of growth for the region.

The technical experts stated the value of basic, practical sampling, such as water samples shipped to analysis centres, as an effective monitoring method that is commonly used in developed nations and will be equally applicable for SIDS. An OA assessment (of the present oceanographic status and of the knowledge/capacity demand) was agreed upon as a vital first step toward a strategy, implementation, and resource mobilisation plan.

Participants urged grassroots involvement, reaching the people who rely on these resources in their daily lives, by giving communities simple information, in local languages, to let them know of OA, as a way of providing information and knowledge to those who are most affected. Considering the human element, participants stated that it must be globally and regionally recognised that by helping ourselves, we will help our environment.

Emphasis was given to the need to identify and work with partner(s) inside a country and to use that information to contribute to management, combining science and policy in practical ways. Participants noted the need for the issues, terms, and goals to be used/known within the countries. Partnering with local agencies and bringing the information throughout the government and communities is vital.

The participants identified the goal of integrated monitoring that is linked to livelihoods and that is SIDS connected, SIDS driven, and SIDS focused. Such integration includes integration across geographic scales as well as integration of ecological and social goals. Partnerships are necessary, but local agencies need to be involved *throughout* the process, not handed a plan at the end. That integration is what capacity-building is about. We need to have meaningful and durable capacity-building opportunities for SIDS.

Session 3: Responding to the Problem and its Impacts: Priorities for Small Island Developing States

Objectives

To begin to prioritise actions within regions for addressing current and projected/potential regional problems/impacts related to OA, to look across regions for common issues for SIDS in adapting to OA, and to identify existing common knowledge gaps.

Session 3 Presentations

Len McKenzie, James Cook University (Australia), "Tropical seagrass ecosystems: Are seagrasses the saviours of coral reefs?"

Todd Capson, Sustainable Fisheries Partnership (United States)**,** "The US West Coast Oyster Story and Future Proofing New Zealand's Shellfish Aquaculture: Monitoring and Adaptation to Ocean Acidification"

Session 3 Discussion

The effects of OA on seagrass beds and shellfish production were discussed, linking ecosystem value, commercial value, and livelihoods. Examples of major shellfish fishery losses in the US due to OA were highlighted. Sensitivity of shellfish, particularly larvae, to aragonite (carbonate) saturation state was noted and monitoring, mitigation and adaptation approaches for shellfish hatcheries were presented. Partnerships between

industry, research institutions, and government are key to mitigation and leaders of the US and NZ shellfish industry have become spokesman for action on OA. The partnership approach adopted by the US and NZ in delivering the Workshop was viewed as a potentially useful platform to help build capacity in other Pacific nations.

There are some suggestions that seagrass beds can locally offset OA, depending on many factors, such as the endemic sea grass species, rate of water mixing, light conditions, and other factors. At Green Island, GBR, where dense sea grass meadows grow high on the reef platform and around the reefs, research has documented differentiation between upstream and downstream reefs. The daytime pH was ~8.1, and increased to ~9 as the water came off the seagrass during low tide (aragonite saturation was not measured).

Seagrass beds serve important biological roles, including subsistence fisheries, production of oxygen, contributions to nutrient cycling, and sequestering carbon. Globally, seagrass beds are as important as forests and can store carbon 35 times faster than rainforests. The value of the carbon stored in seagrass is ~USD 12,000 ha^{-1}.

We lack sufficient information about seagrass resources to identify if OA threats can be effectively managed. It is likely that 4 to 5% of shallow water areas contain seagrass, but this is not definitive, and the status of the beds is not known. Present seagrass beds can be enhanced by protecting the system and potentially by transplantation. Transplantation success rates, however, are poor due to several key issues: site suitability (existing pressures preventing seagrass from presently growing there), availability (avoiding damage to existing beds to harvest propagules), limited experience, and scale. Transplantation of sea grass to new areas without historical records of sea grass must take into consideration the appropriateness of transfer of genetic material, as well as the reason(s) for the absence of seagrass in a seemingly appropriate site.

Coral reefs do not exist in isolation: ecosystems are connected. Following a consistent theme of the workshop, optimal protection of a reef will also protect the ecosystems around it—just as strategies to support healthy environments will support OA resilience. The workshop participants recommended that any efforts to combat OA must rely on understanding linkages between ecosystems and must support ecosystem health.

Participants expressed deep concern over the environmental losses occurring without consideration by responsible parties or adequate expression of local community needs. The message of a region's value (in terms of biodiversity and carbon value, etc.) should be conveyed to the people making the decisions. Participants agreed that the best way to make a change is to build the constituency, by teaching voters and ensuring that local users understand what is at risk and the value of what they presently have. A loud constituency is considered more effective than the voices of researchers.

Concern was expressed that without quantification, management is limited or impossible. The costs of developing a monitoring network were discussed. The cost of designing a survey is distinct from the cost of monitoring once sites have been established. Development of local capacity helps reduce costs and maximise sources of information.

To begin successful monitoring, bottle sampling was suggested; large, expensive instrumentation is not necessary to start. There was discussion of training opportunities for SIDS students, perhaps via study abroad programmes, although there were concerns of trained experts not returning to their home regions.

Participants discussed the applicability of existing scientific instruments to tropical systems and the potential for linking US-AID interest in oceans and other disciplines to OA in SIDS. Participants considered potential responses to a worst-case scenario, e.g., loss of a fishery, suggesting responses such as a compensation program and training opportunities. The required actions to avoid crossing environmental thresholds will vary by region. Managers may be able to create adaptive responses to mitigate OA by managing systems as a whole.

Acidification in the coastal zone is the result of multiple drivers, not just climate change. Ecosystem change is rarely the result of a single factor, and several forms of stress typically act in concert to cause change. Organism health is a complex indicator of multiple forcing mechanisms, and that complexity must be considered in responses.

Session 3 Caribbean Region Breakout

What are existing common knowledge gaps?

- The group defined areas of concern: a lack of a baseline of ocean chemistry, current ecosystem condition, rates of change, and critical habitats, relevant at local/sub-regional levels; impacts on molluscs, coral, and larvae; and cultural and socioeconomic shifts.

- The participants stressed the loss of coastal protection provided by reefs. In the absence of baseline data, the future health of *all* marine and coastal ecosystems is of concern. The participants considered that human effects were driven by the impact of OA on tourism and fisheries, but information is required regarding effects of OA on various economic sectors, regional differences, and the scope of human impact. The state of knowledge among stakeholders and their capacity to change should be identified to guide educational initiatives. A global reduction of CO_2 emissions was mentioned as a way to address OA.

- The group discussed the limitation that monitoring is often linked to short-term, localised projects. The lack of a regional coordination mechanism for OA was identified as one of the main challenges. The quality of water-testing labs was also raised as a constraint.

- The participants proposed a pilot study(s) to (1) establish the baseline chemistry of coastal waters in with respect to OA, (2) establish the rate of change, and (3) determine impacts on coral reefs. It was felt that expert advice would be needed to determine a geographically appropriate sampling strategy amongst the countries (due to heterogeneity of reef types and conditions), using sites that are representative and influential. The point was also made that OA research should be added to existing research projects. Integration and coordination were seen as key needs, as was a timeline for action. Potential resources were discussed**.** (Appendix 2).

What adaptation approaches are most applicable/have the most potential?

- Suggested potential response measures included minimisation of other stressors; creation of an insurance policy for affected regions/stakeholders; genuine consideration of a future without corals and a relevant strategic plan; incorporation of monitoring into response plans; aquaculture; alternate livelihoods; identification of more resilient/resistant species; and protection of resilient/resistant habitat(s) by way of e.g. MPAs.

What resources/capabilities/actions are required for these?

- The group noted it is important for OA studies to include a focus on social and economic impacts to gain the attention of policy makers. The need for greater integration between fisheries research and management and for research and management approaches focusing on ecosystems was noted. It would be important to tie OA research to existing regional and national government priorities and action plans.

- The establishment of a 'regional task force' was suggested as an effective mechanism for action. Other suggestions included an investment in education and outreach for stakeholders (coordinated with extension programmes) and the implementation of a comprehensive capacity assessment/gap analysis (regarding quality of labs, levels of awareness, etc.). Education and awareness initiatives must reach all levels.

Session 4: Bringing it all together

Objective

Explore options for local, regional and international follow-on actions from the Workshop within and among the three represented regions to address OA, culminating in (1) an International Workshop on Ocean Acidification: State-of-the Science Considerations for Small Island Developing States Declaration Statement to

the United Nations Third International Conference on Small Islands and Developing States, (2) draft steps for planning a SIDS-wide Ocean Acidification Framework for Action, and (3) a draft International OA SIDS Workshop Report.

Session 4 Presentations

Marc Metian, International Atomic Energy Agency (Monaco), "Ocean Acidification Engagement Strategies"

Session 4 Discussion

The presentation raised awareness of the Ocean Acidification International Coordination Centre (OA-ICC) of the IAEA, with efforts on science (focused on research partnerships and linking the human dimensions of environmental studies), communication, and capacity building. OA-ICC has key resources residing on their website, news-stream, data compilation, and bibliographic database to learn about OA and related developments and opportunities. Capacity-building is not only important for developing countries; capacity-building must be increased everywhere to respond to OA and other issues.

Several challenges regarding public engagement about OA were noted:
(1) The scale and pace of impacts are poorly-defined and not well quantified.
(2) Impacts of OA are 'invisible' and difficult to isolate from other effects or stressors.
(3) OA is a global concern, and will have asymmetrical effects.
(4) OA has a low public profile; limited awareness impedes individual action.

In identifying solutions for OA, it was noted that involving multiple sectors leads to more effective engagement. We must advance the scientific understanding of OA, enhance data collection/monitoring, strengthen cooperation (technical and political), explore legal/economic instruments to directly address OA (i.e. through reduction of CO_2 emissions), and, perhaps most importantly, improve public education and awareness about OA.

Session 4 Caribbean Region Breakout

What are the thoughts on a SIDS Ocean Acidification Network?

- The participants were in support of a SIDS Ocean Acidification Network.

What are next steps in preparations for a SIDS-wide Ocean Acidification Framework for Action?

- Generate a working group/task force.
- Conduct a baseline assessment of marine chemistry, human capacity, data gaps, and response options.
- Develop a communications strategy for education from children up to the governmental/United Nations level.
- Turn commitments into actions.

SIDS and OA: The Path Forward

Present Needs

The scale of OA is challenging. Knowledge gaps include the present conditions and rate of change. Obtaining a strong baseline is a major priority. Education and outreach for stakeholders is vital, as is ensuring that the entire community is involved and aware of the issues, needs, and actions. Maintaining international communication is important for educating partners about the needs and desires of SIDS.

The Caribbean region stated a need to assess the capacity to effectively respond to OA and to assess the scope of human impacts. Participants suggested potential effective response measures might include environment, social, and economic factors as well as the linkages among these factors. They wanted a realistic plan that they can address with present capacity and grow into further. Locally accessible data management and sharing were considered vital, including raw data available in a local centre and data products given to local stakeholders at a level that they can directly use.

The participants noted the need for greater integration and coordination to prevent redundancy. Because resources are limited, the best way forward is to integrate the OA agenda into existing research and to link OA to existing action plans within a timeline to help hold people accountable. OA does not have to be a new burden. Participants urged linkage of OA with other issues to support responses to both, to provide more initiative for sound environmental management, and to drive sustainable use of resources. The development of a regional task force was seen as an effective way to drive progress on OA with accountability. Participants stated the need to identify key partners at every level and to form new connections to maximise efforts and facilitate funding.

The participants identified the need to create a set of recommendations, including definitive actions and timelines that can be applied across all regions. Each nation needs its own OA response, but a single SIDS voice is powerful. Progress can be driven from the national level, while maintaining a regional identity. All efforts are coupled with a continued call for global reduction of CO_2 emissions.

A SIDS Ocean Acidification Network

The participants were generally in favour of a SIDS OA network that encompasses expertise, actions and frameworks, with the following anticipated results:

- Production of information regarding OA (impact cost, worth, risks) and specific actions for stakeholders
- Multiple actions through the network:
  - Identification and statement of recommendations
  - Identification of key entities within nations
  - Development of communications in and at each scale
  - Maintenance of overall and regional SIDS perspectives
  - Use and development of SIDS expertise and capacity

- Development of partnerships

A SIDS-wide Ocean Acidification Framework for Action (2015-2016)

Participants stated the need to communicate formally to the external countries already involved and other potential supporters. There is a need for a solid coordination effort. In all actions and programmes, effective communication is mandatory, as is the maintenance of a SIDS perspective and the use and development of SIDS expertise, not limited outside expertise. As the issue of OA is important to people in SIDS, addressing it should not be driven from outside. The response to OA should reflect SIDS ownership and leadership.

Appendices

Appendix 1. List of Participants from Caribbean Region

Region / Breakout Group	Participant	Position/Affiliation	Nation represented	Email
Caribbean	Andreas Andersson	Assistant Professor, Scripps Institution of Oceanography	United States of America	aandersson@ucsd.edu
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Caribbean	Kenrick Leslie	Executive Director, Caribbean Community Climate Change Centre	Belize	oed@caribbeanclimate.bz
Caribbean	Tommy Moore	SPREP Pacific Islands Global Ocean Observing System (PI-GOOS) Officer		tommym@sprep.org
Caribbean	Herman Timmerman	Climate Change Adviser, GIZ CCCPIR Regional Project, SPREP		hermant@sprep.org

Appendix 2: Suggested Resources for Caribbean OA Efforts

The group identified some potential resources. This list is not comprehensive.

Identified sources of expertise and funding included the following:

- Public-private-academia partnerships
- UNFCCC
- World Bank Caribbean Programmes
- Intergovernmental Panel on Climate Change (IPCC)
- Intergovernmental Oceanographic Commission (IOC)
- World Meteorological Organisation (WMO)
- International Coral Reef Institute (ICRI)
- United Nations World Ocean Assessment
- Economic Commission for Latin America and the Caribbean (ECLAC/CEPAL)
- Caribbean Community Secretariat (CARICOM)
- World Ocean Council

Appendix 3. Co-chairs Report

An International Workshop on Ocean Acidification: State-of-the-Science Considerations for Small Island Developing States (SIDS)
August 28–29, 2014
Pacific Jewel, Apia, Samoa

Co-Chairs Report

Elizabeth **Jewett** (United States of America)
Melchior **Mataki** (Solomon Islands)
Co-Chairs

The United States of America and New Zealand, in partnership with the Secretariat of the Pacific Regional Environment Programme, hosted a two-day International Workshop on Ocean Acidification: **State-of-the-Science Considerations for Small Island Developing States (SIDS) on August 28–29, 2014, in Apia, Samoa**. The workshop was an official parallel event to the Third United Nations Conference on SIDS. Workshop participants included technical experts on ocean acidification and policy experts on ocean issues, some of whom were SIDS delegates from the three SIDS regions.

Participants jointly recognised **the nature of the ocean acidification threat to marine ecosystems surrounding SIDS, which provide their communities with food security, livelihoods and economic stability, resilience to extreme weather events, and cultural identity.** Some of the important marine species that are potentially vulnerable to ocean acidification include corals, molluscs such as conchs, clams, and oysters, crustaceans such as lobsters and crabs, and reef and pelagic fish.

Ocean acidification is a current and escalating threat. Although some impacts are already occurring, others will increasingly be felt over coming decades. Participants recognised the need to establish standardised, affordable, long-term research and monitoring capacity, including consideration of traditional knowledge, while also taking advantage of international communities-of-practice, such as the Global Ocean Acidification Observing Network and the Ocean Acidification International Coordination Centre, by leveraging and mobilising existing scientific and technological resources and organisations within individual SIDS countries and across SIDS regions and through international partnership and cooperation. The importance of awareness raising, capacity building, technology transfer, and resource mobilisation was emphasised, including the

potential development of regional centres of excellence, as an efficient way to develop capacity within SIDS.

The workshop **fostered the creation of ocean acidification networks for the Caribbean, Pacific Islands, and AIMS SIDS regions**, which will continue to develop next steps in their regions, including engaging participants from countries not present at the workshop, and generate SIDS-driven, SIDS-connected and SIDS-focused "Joint SIDS Recommendations on Ocean Acidification".

Participants recognised that **resilience-building strategies** and practical adaptation actions, where feasible, must be simultaneously explored and developed given the serious nature of ocean acidification impacts. Strategies and action should include, but not be limited to, efforts that **enhance functioning of local marine ecosystems** (for example, management of nutrient run-off, overfishing, land-use change, seagrass beds, and use of marine protected areas) and **strengthen resilience of local communities** through open sharing of scientific findings and capacity building to develop local awareness, expertise and knowledge.

Participants encouraged countries taking part in the Oceans, Seas and Biodiversity Partnership Dialogue and side events during the UN SIDS conference to seriously consider this report and its recommendations and conclusions.

Appendix 4. Contact Information

Regarding this document:

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