Commonwealth Ocean Acidification Action Group
Proceedings of the Workshop

17-19 February 2019

Dunedin, New Zealand

October 2019, Dunedin, Otago, New Zealand. R., Zitoun; W., Dillon, N.E., Espinel-Velasco; C., McGraw, C., Law, K., Currie, N., Glassey, G., Chin (eds).

NEW ZEALAND FOREIGN AFFAIRS & TRADE

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The Commonwealth

Executive Summary

45 workshop participants and observers including leading scientific experts on ocean acidification and 23 government officials participated in the Commonwealth Ocean Acidification Action Group technical workshop hosted by New Zealand from 17 to 19 February 2019, in Dunedin, New Zealand. 17 Commonwealth countries were represented (Antigua and Barbuda, Australia, Cook Islands, Fiji, Ghana, Kenya, Mauritius, Mozambique, New Zealand, Samoa, Seychelles, Solomon Islands, South Africa, Tonga, Tuvalu, United Kingdom and Vanuatu).

The workshop's objective was to enhance Commonwealth members' ability to address the impacts of ocean acidification by:

- Communicating the scientific bases of ocean acidification and deepening participants' understanding of its environmental, economic, social, and cultural impacts;

- Identifying options for effective regional monitoring, regional capabilities and research requirements, as well as opportunities to develop/improve regional monitoring and technical capacities;

- Assessing potential mitigation, adaptation and resilience measures; and

- Identifying potential actions and governance strategies, including improving links between science, policy and the public and building cross-Commonwealth networks.

There were two desired outcomes:

- Development of ideas for National Strategies to address ocean acidification: Participants were encouraged to assess the current status of ocean acidification within their country, identify gaps and areas for improvement, next steps and long-term goals and record contacts from the workshop to follow up on their return.

- Identification of next steps for the Commonwealth Ocean Acidification Action Group: Participants explored ways in which the Commonwealth Ocean Acidification Action Group and Commonwealth Blue Charter could add value, and identified actions that the Action Group could undertake.

Ocean acidification is a global problem manifesting local effects, which requires a unified community to raise awareness and drive change. Participants also noted that with the accelerating pace of ocean acidification, scientists, resource managers, and policymakers must move forward as a community and act now, taking advantage of the impetus delivered by the work already carried out to bring ocean acidification to the forefront of the global agenda.

Participants identified an opportunity for the Action Group to act as a facilitator to support member nations to deliver on their national commitments, particularly SDG 14, including to:

- Bring stakeholders, businesses, institutions, policymakers, government, and communities together to collectively deliver on SDG 14 commitments.

- Facilitate capacity building in the form of access to funding, technical support, monitoring and research infrastructure, data repositories, and communication pathways.

- Link and facilitate connections across Commonwealth initiatives, strategies, innovation hubs and actions.

- Help to promote action on ocean acidification in the wider community.

The problem

Since the beginning of the industrial era, anthropogenic emissions of carbon dioxide (CO_2) have climbed rapidly, increasing the levels of CO_2 in the atmosphere and the ocean. The increased oceanic uptake of CO_2 is resulting in a shift in the chemical equilibrium, which is causing the seawater to become more acidic (lower pH), a process known as *ocean acidification.* The total acidity (hydrogen ion concentration) is expected to increase 100 to 150% over preindustrial levels by the end of this century.

The decreased seawater pH can decrease the stability of calcium carbonate structures of many calcifying organisms, including shellfish (e.g. oysters, clams and mussels), sea urchins, shallow water corals, deep sea corals and calcareous plankton. In addition, these changes in seawater pH can increase the amount of energy required by calcifying organisms to build and maintain their shells and skeletons.

Ocean acidification may also be a problem for non-calcifying organisms, as changes in water chemistry can have adverse effects upon their behaviour and physiology (e.g. olfactory system, predator detection and identification of suitable habitat in some fish species). However, the increase in CO_2 in seawater may benefit other groups, such as some algae and seagrasses, which use this as a substrate for photosynthesis.

Ocean acidification is expected to impact marine species to varying degrees with cascading effects throughout a broad range of marine ecosystems. Although, potential consequences of ocean acidification to marine life, aquacultures, fisheries, tourism, and other economic activities dependent on a healthy marine ecosystem are difficult to assess and predict, preliminary research suggests they are potentially devastating.

Addressing key challenges

Participants in the workshop identified ways to address key challenges in tackling the impacts of ocean acidification:

- Advance the Scientific Understanding of Ocean Acidification – Develop national vulnerability assessments to identify the potential impact of ocean acidification (amongst other environmental stressors) on key ecological, cultural, and economic marine resources and species, as well as the communities that depend on them. Advancements in the development of modelling and forecasts are key to help identify priorities and potential actions to improve societal adaptive capacities.

- Prioritise Local Impacts – Emphasise local and regional short- and long-term issues including ecosystem health, food security, livelihoods and economic stability, resilience, as well as cultural identity.

- Establish Baseline Measurements – Establish monitoring programs or engage with existing monitoring programs to detect changes in water chemistry (e.g. pH, aragonite saturation state, calcite saturation state, deoxygenation, temperature, and other indicators) and ecosystem health due to anthropogenic carbon dioxide input.

- Build Capacity – Develop relevant and durable scientific capacity-building to understand and manage ocean acidification. This is needed at both individual and institutional levels, especially in the African and Pacific Island nations.

- Take Meaningful Actions – Reduce the causes of ocean acidification by supporting the testing and implementation of long-term local and regional ocean acidification mitigation, resilience and adaptation strategies. This includes shell recycling, water aeration, water chemistry amendment, co-culture of shellfish and aquatic vegetation, coral farming, cultivation of sea-grass beds, mangrove restoration, creation of marine protected areas, fishing closures, land-use-change, and alternative livelihood options).

- Create Data Reporting Networks – Establish data products, reporting networks, and mechanisms to share scientific findings and lessons.

- Raise Public Awareness – Inform and educate the wider public about ocean acidification and its impacts on social, environmental, and economic security to develop local awareness, expertise, knowledge, and thereby drive action.

- Enhance collaboration and coordination – Bridge the gap between scientists, communities, and policy makers to increase awareness and understanding of ocean acidification risks, as well as for developing mitigation and adaptation responses and resource management strategies. Further, there is a need for more sustainable and effective international partnerships and collaborations between and among developed and developing nations in the Commonwealth to build capacity, transfer technology, link initiatives, share networks, and mobilise resources.

- Increase Sustained Financial Support – Develop coordinated funding strategies and identify existing or potential funding sources that will help complement regional long-term ocean acidification-focused actions such as research, monitoring, and outreach activities.

Potential actions

Participants identified the following steps, Action Plans and solutions as priorities to address the impacts of ocean acidification on ocean health:

- Take advantage of knowledge-exchange networks, science hubs focused on ocean acidification, and international ocean and climate initiatives (e.g., Global Ocean Acidification Observing Network, International Alliance to Combat Ocean Acidification and the Ocean Foundation) to build capacity and mobilise scientific, technological, and policy resources.

- Turn scientific knowledge into social and political action by sharing stories about local challenges and successes.

- Leverage existing education and outreach networks to propagate key information and build support for priority actions both within national government and local communities.

- Coordinate monitoring developments to assess and enhance existing adaptation strategies.

- Encourage stakeholders and indigenous communities to assess and manage local marine environments with respect to local priorities.

- Move from more complex scientific jargon towards simple and familiar language.

- Drive change by leveraging relationships with local businesses, academic institutions, stakeholders, indigenous communities, and government institutions to provide a platform and collaborative approach to learning more about the impacts of ocean acidification on regional water bodies.

- Elevate ocean acidification into national policy by engaging stakeholders and ministries with compelling narratives, not metrics. Engage political leadership at a high-level to drive ocean acidification-related change and action.

- Identify key priorities and talking points for use by officials who will act as ambassadors on ocean acidification. Recruit relevant stakeholders, government and affiliate members to incorporate action on ocean acidification as part of their personal brand.

- Incorporate ocean acidification into existing Climate Action Plans or national adaptation, mitigation, and resiliency strategies.

- Incorporate ocean acidification into existing ocean ecosystem management plans, resource management plans, or fisheries management plans.

- Create long-term national strategies and regional policy (e.g. Action Plans) through an existing intergovernmental coordinating body with sustained funding. Action Plans should include solutions and tools that are tractable and tangible for each respective nation.

- Develop actions that will meet existing national commitments and targets (e.g. SDG 14.3).

Contents

Workshop Design

As part of its support for the Commonwealth Blue Charter, an agreement by 53 Commonwealth countries to collaborate to mitigate and solve global ocean-related problems, New Zealand volunteered to champion the Commonwealth Ocean Acidification Action Group. Information about the Commonwealth Blue Charter is located at Appendix 1.

Workshop

New Zealand hosted the Commonwealth Ocean Acidification Action Group workshop from 17 to 19 February 2019 in Dunedin, New Zealand, bringing Commonwealth policy makers and technical experts together to explore ways to minimise and address the impacts of ocean acidification. The workshop was the first activity of the Commonwealth Ocean Acidification Action Group, which aims to drive collaboration to help improve Commonwealth capability to address the impacts of ocean acidification by sharing knowledge, experience and best practice.

Participants

45 workshop participants and observers included leading local and international scientific experts on ocean acidification and 23 government officials from 17 Commonwealth countries – Antigua and Barbuda, Australia, Cook Islands, Fiji, Ghana, Kenya, Mauritius, Mozambique, New Zealand, Samoa, Seychelles, Solomon Islands, South Africa, Tonga, Tuvalu, United Kingdom and Vanuatu. The full list of participants can be found in Appendix 2.

Programme

The full programme of the workshop can be found at Appendix 3. The workshop was co-chaired by two New Zealand ocean acidification experts, Prof Cliff Law from National Institute of Water and Atmospheric Research and Dr Christina McGraw from the New Zealand Ocean Acidification Community Council, who introduced and summarised each day's events.

The workshop was divided into four half-day sessions focusing on:

- The science and impacts of ocean acidification;
- Monitoring and research;
- Adaptation; and
- Governance and action.

Each session included expert presentations followed by an interactive panel discussion. Biographies of the co-chairs and presenters can be found in Appendix 4.

Participants self-selected into two or three break-out discussion groups, each with a different theme (see Appendix 5 for guiding questions). This break-out format provided an opportunity for each participant to contribute to the session themes by sharing their regional perspectives and recommendations on the subject. A rapporteur from each group summarised their group's discussion to the rest of the workshop.

Steering Committee

The workshop was organised and led by a Steering Committee comprised of New Zealand Government officials and representatives from New Zealand science community (listed in Appendix 6).

Objectives and Outcomes

The workshop's objective and desired outcomes were informed by a pre-workshop survey of participants on what they hoped to achieve from the workshop (Appendix 7).

The workshop's objective was to enhance Commonwealth ability to address the impacts of ocean acidification by:

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- Identifying options to develop and improve regional monitoring, research and technical capabilities;
- Assessing potential mitigation, adaptation and resilience measures; and
- Identifying potential actions and governance strategies, including building cross-Commonwealth networks and improving links between science, policy and the public.

There were two desired outcomes:

- Development of ideas for National Strategies to address ocean acidification: Participants were encouraged to assess the current status of ocean acidification within their country, identify gaps and areas for improvement, next steps and long-term goals and record contacts from the workshop to follow up on their return.

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Workshop Opening

"The workshop should act as a glue to bring existing ideas, national strategies, groups, networks, and initiatives together in order to move ahead as a collective"

Prof Cliff Law, National Institute of Water and Atmospheric Research (New Zealand)

Official welcome

The workshop was officially opened by Mr Hoani Langsbury from local *iwi* (people) Te Rūnaka o Ōtākou. His *mihi whakatau* (welcome speech) explained the Māori interwoven concept of *tana* (land) and *Tangaroa* (sea) and that we as people must protect and look after both environments, as part of our *kaitiakitanga* (stewardship or guardianship).

Mr Langsbury acknowledged the challenge that lies in front of the Commonwealth member nations regarding their commitment to ocean health, stressing the importance of passing on knowledge to the next generation. He urged the ocean acidification community to preserve and value the environment, inspire others to take responsibility and apply *kaitiakitanga*.

Introduction to Commonwealth Blue Charter

The Commonwealth Secretariat was represented at the workshop by Dr Nicholas Hardman-Mountford, Head of the Oceans and Natural Resources Division. He introduced participants to the Commonwealth and its 53 members which all share common laws, principals, values, and goals as outlined in The Commonwealth Charter. He emphasised that all members of the Commonwealth have an equal say, regardless of size or economic stature, meaning that Small Island and Developing States have a strong voice in shaping the Commonwealth.

46 Commonwealth nations have marine coastlines, comprising a third of the world's marine waters within national jurisdictions. 32 Commonwealth nations contain 42% of the world's coral reefs and eight of 20 of the world's largest marine protected areas. These figures highlight the importance of the Commonwealth Blue Charter adopted in April 2018 by all 53 Commonwealth countries to actively co-operate to mitigate and solve ocean-related problems.

Since ocean issues cannot be considered in isolation, Dr Hardman-Mountford encouraged Commonwealth countries to collaborate across the country-driven Commonwealth Blue Charter Action Groups to meet international and national commitments, including Sustainable Development Goal (SDG) 14.

Commonwealth Ocean Acidification Action Group

Mr Nathan Glassey, Lead Adviser on Ocean, Biodiversity and Conservation at the New Zealand Ministry of Foreign Affairs and Trade, introduced New Zealand's Commonwealth Ocean Acidification Action Group.

Ocean acidification is especially pertinent to New Zealand as a small maritime nation where the economy has significant dependence upon aquaculture, fisheries and tourism. He noted that it is important to collaborate and share science, lessons, and wisdom to make the Action Group more effective, and to improve capability as well as capacity building among Commonwealth member nations.

Through this workshop, the Action Group could identify the opportunities for Commonwealth countries to act effectively as a collective through the Action Groups in order to meet the common goal of ocean

and ecosystem health. Mr Glassey also urged participants to encourage their own government to become a member of the Commonwealth Ocean Acidification Action Group to move forward and help lead the actions to mitigate global, regional, and local ocean acidification issues.

Session 1: The Science of Ocean Acidification

"Ocean acidification isn't happening in a vacuum … We need to move from the single stressor, single species approach towards what policy-makers need. This is a challenge"

Dr Christina McGraw, University of Otago (New Zealand)

Presentations and panel discussion

Session 1 of the workshop focused on the science of ocean acidification and aimed to deepen participants' understanding of ocean acidification and its impacts, particularly around:

- Projected future impacts on coastal and marine ecosystems;
- Associated stressors and cumulative impacts;
- Unique considerations and experiences of different regions;
- Economic and social impacts; and
- Knowledge gaps.

Presentations included a scene-setter from Dr Christina McGraw (New Zealand) on the nature and extent of ocean acidification and regional perspectives from Mr Mutshutshu Tsanwani (South Africa), Mr Kushaal K Raj (Fiji), Dr Will Howard (Australia) and Mr Ruleo Camacho (Antigua and Barbuda). Presentations are listed in Appendix 8.

The subsequent panel Q&A session discussed the following themes:

Importance of measuring chemical parameters

- Measuring chemical parameters alongside biological monitoring networks is important to evaluate the effectiveness of pre-existing adaptation strategies and increase current knowledge of ocean acidification baselines in the natural environment.

- Different carbonate chemistry parameters (i.e. pH, partial pressure of carbon dioxide, dissolved inorganic carbon, total alkalinity) are interlinked and thus should always be measured together to obtain relevant scientific information regarding the carbonate system in the ecosystem of interest.

- Standard protocols to collect, measure, analyse, and present pH and other carbonate chemistry parameters in the marine environment are already in place. These protocols and should be followed to obtain good quality data to facilitate inter-comparison of data and data exchange.

The science/policy interface

- Translation between science and policy should be bi-directional, ensuring policy targets are aligned with monitoring targets.

- Identification of meaningful scientific indices for ecosystem health and the definition of ocean acidification thresholds would facilitate faster decision-making with regard to management strategies on a legislative level.

Communicating ocean acidification

- Raising awareness of ocean acidification-related issues, and especially their socioeconomic impacts, will help to increase the willingness of stakeholders, government agencies, and the wider community to engage in ocean acidification.

- Simple ocean acidification terminology should be used with narratives and anecdotes to effectively inform a broader audience on the issue of ocean acidification.

- For consistency and simplicity, existing terminology that is used by international programmes, such as "acidity" instead of "pH" in SDG 14.3, is preferable.

Breakout session

Following the presentations, participants split into three breakout groups:

- Group 1 – Coral Reefs and Other Ecosystems
    - Facilitator: Dr Linn Hoffman, New Zealand Ocean Acidification Community Council (New Zealand)
    - Rapporteur: Mr Ruleo Camacho, Department of Environment (Antigua and Barbuda)

- Group 2 – Shellfish and Aquaculture
    - Facilitator: Dr Norman Ragg, Cawthron Institute and New Zealand Ocean Acidification Community Council (New Zealand)
    - Rapporteur: Ms Alexis Valauri-Orton, The Ocean Foundation (USA)

- Group 3 – Fisheries
    - Facilitator and Rapporteur: Dr Will Howard, Department of the Environment and Energy (Australia)

What is known about the ecological, societal and economic impacts of ocean acidification in your region?

- Known ecological impacts of ocean acidification included the degradation of coral reefs and other fish habitats, including mangroves and seagrass beds, and a decrease in ecosystem services and biodiversity. For coral reefs, knowledge is limited as there are no specific valuations in place for ocean acidification and there is a lack of high resolution monitoring data in reef environments.

- Monitoring of sea surface temperature (SST) is already in place in most small Island nations and African countries, but no funding or information is available for ocean acidification monitoring, especially in sensitive habitats such as coral reef ecosystems. In some regions, while there are no national ocean acidification monitoring programmes within states, regional monitoring efforts and mitigation measures are getting started. However, in many regions, there are no regional directives to monitor ocean acidification as national strategies and regional collaboration are concentrated on the general impacts of climate change on ecosystem health. There is no or limited knowledge or capacity available for ocean acidification research, monitoring and adaptation strategies.

- Information on the vulnerability of fish is lacking, although laboratory studies suggest significant impacts on fish physiology, olfactory system, reproduction, fertility and larvae development. The effect of ocean acidification on wild fish is difficult to study and obtain meaningful results, especially when ocean acidification changes fish behaviour. Ocean acidification also affects the

food source of fish such as krill and pteropods, but the cascading effects and impacts on the food web are unknown. This lack of knowledge inhibits government action.

- The aquaculture industry has studied the effect of ocean acidification on the metabolic costs of organisms in different life stages through studies carried through several reproduction cycles to understand transgenerational affects. Combined studies such as these allow the development of dynamic energy budget models to make population scale assessments. There is also existing data in the aquaculture sector regarding food quality, water conditions, growth, and reproduction output for brood stock in operational data records.

- Societal impacts include the loss of heritage sites.

- The economic impacts on fisheries and aquaculture are being studied. Generally, there has been a decrease in fish stocks and fish size in both high-sea and inshore fisheries. The status of some fisheries, especially deep-water and open-water fisheries such as offshore tuna and deep-water snapper, is still unknown. However, the link to ocean acidification is still unclear as the fishing industry and local fishermen are generally only interested in the catch and stock numbers rather than ocean acidification as a potential cause. Some information on the effect of ocean acidification is available, particularly on coastal fish, but this has not yet been translated into national policy and mitigation strategies. Participants noted the general challenges in management and quantification of both commercial hatchery and naturally occurring shellfish populations. Spat survival and shellfish stock management is particularly difficult during under-saturation events and heat waves as seen in Washington (USA) and New Zealand.

What other stressors (e.g. temperature, erosion) are expected to exacerbate the impact of ocean acidification in your region?

- The effect of ocean acidification on fish is a complex problem that is aggravated by multiple stressors, especially in coastal fisheries. Participants agreed that the following stressors are considered potential threats to future ocean and ecosystem health in addition to ocean acidification: increase in temperature, nutrient runoff, erosion, eutrophication, low oxygen events, sargassum assemblages (creates dead zones), natural events (tropical storms, tsunami), human activity including tourism development, as well as sea level rise and overfishing. They noted that stressors interlinked with climate change have a higher priority for government actions than ocean acidification.

- For fisheries, the long-term threat of ocean acidification means that it is overshadowed by a multitude of short-term problems, especially in coastal areas. These short-term stressors include anthropogenic pollution, piracy, invasive plant species, and the difficulty in monitoring and sharing of resources across coastlines and freshwater bodies.

What are the most pressing knowledge gaps?

- Participants noted a general difficulty assessing specific gaps of knowledge due to the lack of research, monitoring, and adaptation strategies and capacities.

- There are gaps around the ecological impacts of multi-stressors, including ocean acidification, on ecosystems response and health as well as fisheries. More knowledge is needed on the interactions of coral reefs with other ecosystems (e.g., seagrass, mangroves) regarding adaptation and mitigation strategies. Further, the high variability and unique conditions in the natural environments inhibits generalisation of such strategies. Existing models may simplify studies, but do not have the resolution needed to address local issues.

- For fisheries, there is no knowledge available regarding the state of fish stocks, especially in deep-waters and in the open-ocean as well as solutions and management strategies for their sustainability. There is only limited knowledge on the effect of ocean acidification on fish behaviour, demography, physiology, as well as on thresholds, and biological tipping points. Uncertainties regarding the impact of ocean acidification on fish limit effective input to policy and management strategies. Biological responses to ocean acidification between and among fish species are highly variable, which complicates the development of reliable models.

- Participants also saw a gap in engagement with policy makers and other stakeholders to drive change and political action. Insufficient communication between scientists, government agencies and the public contributes to a lack of general awareness of ocean acidification. Further, data relating to ocean acidification held by the aquaculture industry and is not readily shared with researchers. These intellectual property considerations inhibit modelling and the development of management strategies. This is changing in the US and New Zealand as industry is driven to collaborate to address the crisis.

What information do you need to address those gaps?

- Participants emphasised the need for more data, including an urgent need for long-term regional monitoring and increasing current monitoring efforts to more basic and relevant parameters in order to define a common proxy for coral reef and/or ecosystem health. Establishing monitoring protocols and standards could facilitate the comparison of data as well as production of high quality data. Establishing long-range monitoring systems that extend beyond national boundaries could improve climate change models. These efforts could be streamlined by identification of priority species, priority areas for monitoring, and adding ocean acidification monitoring to existing monitoring networks (e.g. of SST) to reduce cost. Making data publicly available would be beneficial, as would holistic national adaptation and mitigation strategies including fishery management, species management, and ecosystem based management: mangrove restoration, coral farming, seagrass planting, usage of non-destructive fishing methods, seasonal or permanent closure of certain fisheries and areas, raising awareness, and alternative livelihoods.

- For fisheries, this data should be differentiated across deep-water, open-ocean and coastal-ocean fisheries as they will all need different management strategies and policies.

- Including more environmental parameters in models would to improve model predictions for sustainable fishing quotas and for localised scenarios. Participants also proposed running models under different scenarios get an idea of potential biological responses and associated effective and relevant management strategies. For aquaculture, assessment of organism energy budgets could help to quantify the impacts of environmental stressors on shellfish stock management.

- Smaller countries could benefit from capacity development to build smaller and more relevant models for their respective region to facilitate decision making and to share information and data with partners. Increased data capacities such as data products and network to share knowledge, lessons, and experiences could inform policymakers and support better decision making. Participants noted the role of regional and international cooperation. Such collaborations could assist to analyse and interpret data appropriately and effectively and build and improve regional expertise to define national needs.

- Participants identified that there could be better communication of information and strengthened relationships between stakeholders. For example, basic statistics and a common

language would improve the communication between scientists, industry, government agencies, and the community. Further work could be done to engage, inform, and educate the community to drive action from the ground up at a local level, including through gathering local knowledge from indigenous peoples and local communities. Raising awareness among stakeholders that both ocean acidification and climate change impact fish stocks and catches could start the dialogue regarding sustainable monitoring efforts, the need for commitment, and the incorporation of ocean acidification into policy. The need for longevity of programs with initial and ongoing commitment from government agencies was noted.

What countries are facing similar challenges to yours? Can their knowledge inform the knowledge gaps in your region?

- Many Commonwealth countries have similar needs and face common problems. Thus,closer collaborations between countries in similar conditions are needed to increase current capacities and take advantage of knowledge already present in other countries and through existing networks (such as GOA-ON).

- Improving infrastructure and communication networks will help nations to meet their national commitments, as well as inform and help each other.

How can the Commonwealth Ocean Acidification Action Group add value?

- Participants identified the facilitator role that the Action Group could play in linking local and regional efforts and facilitating regional and international collaborations and partnerships. It could support national ocean acidification workshops to bring relevant stakeholders together in order to help establish national activities and strategies.

- The Commonwealth Blue Charter and Action Groups could consider playing a role in access to finance for member nations (particularly developing countries) to build capacity and facilitate access to resources such as training, courses, funding initiatives, networks, and data products. A joint statement could be issued regarding exploring financial options.

- There is an opportunity for the Action Group to deliver centralised and coordinated integration of information from scientific, commercial, and non-scientific (anecdotal, cultural) sources and encourage teamwork between stakeholders, including by sharing data. It was noted that the messenger matters, stressing that scientific communicators do not always deliver messages relevant for policy-makers.

Session 2: Monitoring and Research

"Monitoring tools and models are imperative for understanding ocean acidification's effects on ecology, economy, and culture"

Dr Bronte Tilbrook, UN Community of Ocean Action (Australia)

Presentations and panel discussion

Session 2 of the workshop aimed to identify options for effective monitoring and research and developing monitoring and technical capacity and consider:

- Best practice monitoring;
- Existing regional and global monitoring networks;
- Data management frameworks;
- Resource and capacity constraints;
- Capacity-building priorities; and
- Research priorities.

Presentations included a scene-setter from Dr Bronte Tilbrook (Australia) on the tools for monitoring ocean acidification, a presentation on engaging local communities and stakeholders by Dr Kim Currie (New Zealand) and overviews of the Global Ocean Acidification Observing Network (GOA-ON) from Dr Libby Jewett (USA), the Western Indian Ocean Marine Science Association (WIOMSA) from Dr Julius Francis (Tanzania) and the GOA-ON North East Atlantic hub from Prof Steve Widdicombe (UK). Presentations are listed in Appendix 8.

The subsequent panel Q&A session discussed the following themes:

Importance of multi-stakeholder support

- Current and future monitoring efforts need to be supported by governments and other stakeholders, such as industry, to sustainably address potential socioeconomic impacts of ocean acidification, e.g. food security, fisheries, and ecosystem health.

- The main challenge was considered to be the lack of centralisation in governments, inhibiting communication, discussion, coordination, and fast decision-making.

- Citizen science projects and regional science hubs can also play a role in monitoring efforts.

Need for capacity building

- Stakeholders need to be educated and supported. For example, citizen science projects and regional science hubs require specialised training, including on how to conduct proper sampling, develop efficient monitoring programs, assure good data quality, and align outcomes with relevant management strategies.

- Such training, as well as outreach, often depends on budgets and may be difficult to access in developing countries. Participants saw a role for the Action Group to facilitate capacity building opportunities to support these countries in creating regional science hubs to address their regional needs and priorities.

- Other opportunities for regional ocean acidification support are also available. For instance, GOA-ON is funded by the US government and The Ocean Foundation, but is also assisted by national private funders (e.g., shellfish industry).

Accessibility of data

- Making data available and accessible to the wider community using pre-existing networks such as GOA-ON is especially key for countries without their own data products and networks.

- The GOA-ON data portal is an important platform for linking global data systems. The portal includes all climate change and ocean acidification-relevant monitoring data, including Argo floats, from GOA-ON partners and external entities.

Breakout session

Following the presentations, participants split into three breakout groups:

- Group 1 – Initiating and Expanding National Monitoring Networks
    - Facilitators: Prof Steve Widdicombe, Plymouth Marine Laboratory (UK) / Dr Libby Jewett, Global Ocean Acidification Observing Network (USA)
    - Rapporteur: Ms Gabrielle Chin, Ministry of Foreign Affairs and Trade (New Zealand)

- Group 2 – Shellfish and Aquaculture
    - Facilitator: Dr Julius Francis, Western Indian Ocean Marine Science Association (Tanzania)
    - Rapporteur: Dr Norman Ragg, Cawthron Institute and New Zealand Ocean Acidification Community Council (New Zealand)

What sort of framework is required in your country to monitor your important ecosystems?

- There is a general need to measure chemical parameters for ocean acidification. While many of the participants' countries already have some form of monitoring networks in place, most do not measure chemical parameters related to ocean acidification, especially in the Pacific, African and Caribbean regions.

- Some participants considered it simple to add ocean acidification to what is already being measured. However, others considered that monitoring efforts, strategies and networks might need to be downscaled to prioritised local needs. This need for downscaling is due limited capacity for some countries to measure carbonate parameters, such as dissolved inorganic carbon and total alkalinity.

- Further, there is a lack of expertise and funding in developing countries to establish analysis centres required to analyse chemical parameters. There is also a need to quantify baselines and thresholds to evaluate ecosystem health.

- Defining and measuring biological indicators: In order to engage multi-stakeholders such as government, donors, funding agencies and the public, biological proxies and indices for ecosystem health need to be defined and measured. Participants discussed how the impacts of ocean acidification on ecology are easier for stakeholders to understand as compared to the impacts on chemistry.

- Possible biological indicators identified by participants included larvae development, shell dissolution, changes in community structure, increase in autotrophic biomass, molecular responses, carbon to inorganic carbon ratio, DNA, metabolic coding, transcriptomes, gene expressions, and enzymes.

- However, scientists might need to look at a broad range of different indicators to reduce uncertainties for environmental risk assessments. Ultimately, it is necessary to align scientific efforts and data reporting with government and community priorities.

What existing capacity does your country have? Do you have blue carbon initiatives? Do you have ocean acidification research programmes?

- Most Commonwealth countries have monitoring networks for Sea Surface Temperature (SST) already in place. Ocean acidification monitoring is limited to certain countries, and Pacific, African, and Caribbean Commonwealth members currently have no ocean acidification monitoring networks. New Zealand, Australia, and the United States have chemical and/or biological monitoring networks in place. In New Zealand, the Environmental Protection Agency is considering including Megalopa larvae into current water quality monitoring efforts.

- Local modelling projections (past and future) could be improved to facilitate the implementation of management strategies.

- In terms of monitoring impact, most Commonwealth countries have existing shellfish hatcheries, which can be used as experimental research facilities for ocean acidification. The United States, United Kingdom, and New Zealand have existing ocean acidification research programs, and others in the Pacific, Africa, and the Caribbean are at the initial stages of expanding their capacities.

- On reporting, New Zealand is required to report on ecosystem changes, but without focus on ocean acidification impacts. Australia must report on the state of the Great Barrier Reef, including pH and its impacts, every 5 years.

What additional resources does your country need?

- Monitoring efforts need to be increased to define risks, stressors, thresholds, and baselines. Historical data (e.g. fish catches) can be quite resourceful towards understanding the rate of ecosystem changes over times.

- However, long-term monitoring efforts are resource-limited (lack of sensors, buoys, analytical systems), especially in small Island states and African countries. There is lower cost instrumentation currently being developed, but some are concerned about quality. Alternative methods and equipment are possible.

- Better infrastructure and logistics are needed to minimise cost and time lag between sample (bottle) collection and analysis. Secondary standards can be created to reduce costs, as well as identifying site specific sampling regimes (spatial and temporal sampling resolution dependent on local variability). There is a trade-off between continuous monitoring, which requires special instrumentation and sporadic sample collection.

- Participants recognised the need for monitoring stations and regional monitoring with widespread coverage and high temporal resolution. This should be tailored to local and regional needs and priorities. Each respective region needs to explore options and resources for

adaptation measures, by combining time, resources, and local knowledge and expertise to find relevant monitoring sites.

- Regional cooperation and coordination of monitoring can assist with faster analysis, increased laboratory access, training of technicians and sharing of knowledge, assets, data products, reporting networks, and mechanisms. Generic processes and fixed protocols including carbonate chemistry for laboratory based bioassay experiments would be required to guarantee interoperability of results.

- Connected to this is the need for long-term, sustained funding for the set-up and maintenance of these monitoring and analysis networks (e.g. maintenance, staffing, quality control standard solutions, and consumables). The link between ocean acidification and climate change could be leveraged to lobby governments to support ocean acidification monitoring systems as high quality baseline measurements could improve climate change model predictions.

- Some participants suggested there be a focus on the need to reduce or mitigate economic and societal loss and damage rather than trying to advocate for monitoring as the economic and societal impacts of ocean acidification will attract more attention and funding.

- Engaging legislators and policy-makers could also be done by using interesting narratives with interesting species (e.g., whales, clownfish), not metrics.

- There is a general need to understand the effect of ocean acidification on the whole ecosystem, stressing the need to track ocean acidification impacts through the entire food web to understand cascading effects. While identifying ocean acidification-specific indicators could increase knowledge and encourage policy-makers and governments to act specifically on ocean acidification (for example, monitoring hydrothermal seeps to identify ecological effects of only ocean acidification), a more holistic approach might be needed as no ecosystem can be fixed by just addressing ocean acidification.

- Further, by the time biological responses manifest, organisms and ecosystems might already be over the tipping point. On the other hand, while it is widely accepted that a decrease in pH will have massive ecological impacts, there may be different ecological, economic, and societal values of a changing ecosystem.

What partnerships need to be developed?

- Regional hubs need to be developed to share knowledge, experience, assets, and resources, possibly in the form of centres of excellence, which could give countries in need access to training, human resources, laboratories, and analytical instruments.

- It is important to link national strategies of countries with limited resources to already existing long-term initiatives and programs (e.g. GOA-ON) to strengthen capacities. Australia's climate change project could also be used as an asset for Pacific island nations.

- Partnerships on funding, and between different stakeholders are also required.

How can the Commonwealth Ocean Acidification Action Group add value?

- The Action Group could assist with facilitating communication and dialogue between Commonwealth governments, or create a common framework to enable Commonwealth

members to meet and deliver on existing commitments under the Sustainable Development Goals.

- There would be benefit in the Action Group advocating the importance of carbonate chemistry in order to pressure policy-makers to include OA in pre-existing monitoring efforts and national management strategies.

- The Action Group could play a role with capacity-building, by linking regional and international training centres, workshops, infrastructures, technical support, data repositories, and communication pathways and Commonwealth countries. Alliances with other initiatives/programmes could leverage or maximise existing funding.

- The Action Group could help identify finance strategies and funding opportunities for Commonwealth members in need (e.g. Green Climate Fund), and be a repository of available resources.

- The Action Group could align with other Commonwealth Blue Charter Action Groups to demonstrate unity and maximise funding allocations and opportunities.

Participants also discussed how in most countries, it is unclear where responsibility lies within the government for ocean acidification research, monitoring, and other adaptation and mitigation strategies. There is an urgent need to clearly define the responsibilities and duties within the central governing body (centralise all departments responsible for ocean issues) to allow for faster decision-making.

Co-chair's Summary – Day 1

"Moving from words to action"

Prof. Cliff Law, National Institute of Water and Atmospheric Research (New Zealand)

Workshop co-chair Prof Cliff Law reviewed the first day of the Action Group workshop by stressing that the scale of ocean acidification-related issues is challenging. He acknowledged that steps have been made during the first day of the workshop in addressing the overall aims of the Commonwealth Blue Charter initiative regarding the development of national strategies and the establishment of the relevant science and communication in order to support Commonwealth nations to address and meet their national SDG commitments.

Each region has its own economic, ecological, cultural, and societal priorities, which require custom-tailored local coordination, capacity building, and strategy management, given regional priorities and concerns. Nonetheless, several commonalities were identified:

Integration of monitoring efforts

- Establish long-term and high-resolution monitoring programs, which integrate pre-existing biological indicators and adaptation strategies with chemical monitoring networks in order to increase current knowledge, improve management strategies, develop local modelling projections, and support the creation of ocean acidification risk maps.

Need for meaningful and durable capacity-building opportunities

- Relevant and sustainable scientific-capacity-building opportunities are needed to effectively respond to ocean acidification, both at individual and institutional levels.

- Capacity-building requirements include regional science hubs, human resources, expertise, scientific tools, data products, reporting networks, and mechanisms to share scientific findings and lessons.

Raising awareness

- Inform and educate stakeholders, policymakers, and the public with interesting narratives using common language to escalate ocean acidification and bring it into the forefront in discussions of resource management, fisheries, industries, governments, and other groups at the national level.

Prof Cliff Law emphasised that all participants recognised the need for prompt action, stressing that communication and coordination between international and interregional stakeholders, science hubs, ocean initiatives (e.g. GOA-ON), governments, and the wider community are urgently needed to build capacity and start driving necessary change and action. He further stressed that there is a common understanding between participants that Commonwealth Blue Charter members need to tackle ocean issues together to deliver on the SDG14 as a collective.

Lastly, Prof Cliff Law acknowledged the importance of acting now and setting the pace on as a community, taking advantage of the impetus delivered by the Commonwealth Blue Charter campaign to bring ocean acidification into the forefront of the global climate change initiative.

Session 3: Adapting to Ocean Acidification

"We need to focus on solution-based management to mitigate the problems, and these solutions need to be applicable and trackable for each region"

Prof. Cliff Law, National Institute of Water and Atmospheric Research (New Zealand)

Presentations and panel discussion

The objectives of session 3 of the workshop were to assess potential mitigation, adaptation and resilience measures, drawing on existing local, national, regional, and international activities. This included discussions on:

- Potential adaptation approaches;
- Resources and capabilities required to support adaptation;
- Barriers to pursuing adaptation measures (e.g. knowledge, policy); and
- Managing ocean acidification with multiple stressors.

Presentations included a scene-setter from Dr Jan Newton (USA) on lessons learned from Washington State Blue Ribbon Panel on Ocean Acidification and presentations on how ocean acidification is addressed in New Zealand from Prof Cliff Law (New Zealand), the New Zealand-Pacific Partnership on Ocean Acidification from Dr Duncan McIntosh (Samoa) and the role of science/policy/industry in management and adaptation plans from Ms Alexis-Valauri-Orton (USA). Presentations are listed in Appendix 8.

The subsequent panel Q&A session discussed the following themes:

Blue carbon strategies

- Blue carbon strategies such as coral farming, mangrove protection, and seagrass restoration actions have the potential to offset ocean acidification.

- The United States and some Pacific Island states are already implementing mitigation strategies, e.g. planting kelp and seagrass next to coral reef and mussel-farms, to offset ocean acidification conditions but the success and the effectiveness of these local management strategies are still not well-characterised.

Genetic engineering and selective breeding

- The use of genetic engineering and selective breeding could increase the resilience of organisms to ocean acidification.

- The shellfish industry in New Zealand is supporting research into selective breeding of genetic resilient Greenshell mussel families, following high losses of the industry as a result of seed failure two years in a row, potentially due to ocean acidification and regional heatwaves.

- Approximately 40% of organisms' resilience is explained by genetics, so including selective breeding programs into management strategies might be an effective and meaningful mitigation strategy for stakeholders.

Preservation of natural habitats

- While there are benefits of blue carbon strategies, such as creating new habitats, geo-engineered adaptation and mitigation strategies are not effective on large scales and do not help address other stressors such as excessive nutrient input, sea level rise, and coastal erosion.

- It may be more effective to preserve natural habitats (e.g. seagrass beds, mangroves, coral reefs, kelp forests, and marine sediments, which are known to be huge carbon stores) instead of relying on geo-engineering to combat ocean acidification-related ocean issues.

Breakout session

Following the presentations, participants split into three breakout groups:

- Group 1 – Coral Reefs and Other Ecosystems
    - Facilitator: Dr Duncan McIntosh, Secretariat of the Pacific Regional Environment Programme (Samoa)
    - Rapporteur: Mr Joe McCarter, Ministry of Foreign Affairs and Trade (New Zealand)

- Group 2 – Shellfish and Aquaculture
    - Facilitator: Dr Jan Newton, Washington Blue Ribbon Panel on Ocean Acidification (USA)
    - Rapporteur: Dr Norman Ragg, New Zealand Ocean Acidification Community Council (New Zealand)

- Group 3 – Fisheries
    - Facilitator: Ms Constance Nutsford, Ministry for the Environment (New Zealand)
    - Rapporteur: Dr Mary Livingston, Ministry for Primary Industries (New Zealand)

Which adaptation and mitigation options are most appropriate?

- In general, resilience and adaptation strategies should respond to local needs and have immediate effects. Therefore, multi-stakeholder buy-in is required.

- Human intervention could play a role, including reducing larvae dispersal to increase local recruitment, use of engineered substrates to protect corals from bleaching, harvesting of macro algae to use as fish food, and rearing of larvae through their most sensitive life stages in aquacultures before releasing them back into their natural environment.

- Participants in the coral reefs breakout group discussed adaptation and mitigation strategies including coral restoration, coral farming, mangrove restoration, seaweed farming, and spatial planning. Specific management strategies and risk assessments could be informed by the selection of resilient key species e.g. coral farming with species resistant to coral bleaching.

- Adaptation strategies which reduce ecosystem stressors should be prioritised e.g. filtering water discharges to decrease nutrient and contaminant input and culturing fast-growing algae to sequester carbon dioxide.

- For shellfish and aquaculture, implementation of a green approach through green technology and sustainable operations is important. Prioritisation of key stocks is important, and should include species of economic, ecological and cultural value. Existing technologies such as the Burke-o-lator, could be used to obtain data for effective strategies.

- Spatial management strategies should be increased or developed for fisheries. In South Africa 20 marine protected areas have recently been approved.

- Stakeholder engagement is important for effective fishing management strategies, and benefits such as "edge effects" of marine protected areas can help to convince local communities of the value of marine protected areas. Community-based management and restoration strategies ensure that these meet local needs and priorities.

- Industry should shift from destructive fishing methods (e.g., benthic trawling) to less damaging fishing gear to protect fish habitats. Where industry already has infrastructure in place, environmental outcomes could be leveraged.

- Profitability of the fishing industry and small-scale community fisheries can also be increased through diversification, e.g. the Fish 2.0 platform.

- Participants discussed rearing wild species in aquacultures to create alternative livelihoods, assure food security, as well as alleviate the fishing pressure in the natural environment. These options which will help give nature time to recover.

What are the roadblocks to uptake?

- Implementation of adaptation strategies is hampered by the lack of research on the strategies themselves, e.g. on carbonate buffering, sequestering and storage or mangrove restoration, and into their effectiveness when dealing with variable ecosystems and additional stressors such as sargassum algae, invasive species, natural disasters (e.g., volcano eruption, earthquake, tsunamis), storm events (e.g., cyclone), and anthropogenic pollution (e.g., plastic, nutrients, metals).

- Biological monitoring also lacks integration with physical parameters which inhibits scientists from drawing relevant conclusions.

- Particularly for fisheries, there is limited knowledge on the effects of ocean acidification on wild fish stocks, especially in the deep-ocean, at seamounts, and in the open-water. The effect of ocean acidification on fisheries becomes "guess territory" the deeper and further one goes from the coast.

- The difficulty in incorporating climate change and ocean acidification parameters into stock calculations also inhibits the implementation of appropriate management strategies. There are many uncertainties regarding the reasons and drivers behind globally declining fish stocks and catches: Overfishing? Natural effects owing to highly variable environments? Did the fish die or disperse or relocate? If ocean acidification is the driver, are fish able to adapt?

- Fisheries face additional problems due to synergistic effects of viruses, algae blooms which drive hypoxic events leading to high fish mortalities (e.g., South Africa), as well as El Niño and La Niña years.

- There are also policy challenges, for example lack of government buy-in. The lack of centralisation in governmental systems makes it difficult for scientists to communicate issues to the right person and engage in decision making.

- Government agendas and local community priorities also do not always overlap with conservation agendas and so there are limited political opportunities related to ocean

acidification. Participants noted the challenge engaging legislators and policy-makers in ocean acidification-related ocean issues, querying whether ocean acidification and climate change needs to be separated when it comes to lobbying for political action.

- There is a need for policy to evaluate and monitor the success of adaptation strategies, e.g., marine protected areas, coral farming, and habitat restoration. Without the metrics to support scientific recommendations and suggestions it is hard to engage government to drive action. Gor fisheries, metrics are needed to obtain economic, social and ecological vulnerability assessments for key species in order to develop fishing management strategies and adjust catch levels. Ocean acidification also needs to be incorporated in fishing management and adaptation strategies, such as marine protected areas.

- The lack of sustained and long-term funding, limited industry communication and capacity to implement strategies are also challenges.

What are the co-benefits & opportunities?

- Most adaptation and mitigation strategies capture and sequester carbon. Ecosystem health benefits are already being observed for some adaptation strategies. Mauritius identified positive results of mangrove propagation for coral protection.
- There are opportunities for non-governmental organizations (NGOs) to take the lead on national management strategies, Commonwealth countries to share data, resources, and building capacities and national governments to partner with industry to meet national commitments, including the Sustainable Development Goals. Local indigenous knowledge and historical data can be leveraged to obtain baselines for appropriate management strategies.

Are there opportunities for international cooperation?

- There are opportunities for international cooperation to share data, knowledge, lessons, and experience, including on the success of pre-existing adaptation strategies and socioeconomic impacts of ocean acidification.

- International cooperation is needed to build upon existing networks, research and monitoring efforts, as well as to drive legislative change.

- Industry should take advantage of international commercial fishery workshops and conferences and share data with each other.

How can the Commonwealth Ocean Acidification Action Group add value?

- The Action Group could help to establish a common framework on science, innovation, indicators and strategies to facilitate data comparison and exchange and identify best practice. It could act as a repository for knowledge and data exchange, especially for evaluations of monitoring and adaptation strategies and support linkages to other scientific initiatives or opportunities for capacity building. It could identify international funding opportunities and coordinate funding proposals of Commonwealth nations.

- Increase community, industry and government engagement, by creating opportunities for the Action Group to raise awareness with multi-stakeholders. The Action Group could encourage politicians and governments to address intergovernmental issues for faster and more effective decision making.

- Coordination within the Commonwealth Blue Charter and its Action Groups could leverage common goals, including through monitoring stations.

Session 4: Governance and Action

"We need a clear goal of action to push the action"

Prof Karen Scott, University of Canterbury (New Zealand)

Presentations and panel discussion

Session 4 of the workshop revolved around potential actions and governance strategies for addressing the impacts of ocean acidification, including:

- International policy landscape and action on ocean acidification;
- Developing national policy frameworks to support adaptation action;
- National Action Plans – best practice examples;
- Prioritising ocean acidification in development assistance partnerships; and
- Science/policy interface.

Presentations covered a scene-setter from Professor Karen Scott (New Zealand) on the international legal and policy ocean acidification landscape, Sustainable Development Goal 14.3 and the 2030 Sustainability Agenda from Dr Bronte Tilbrook (focal point for the UN Community of Ocean Action for Ocean Acidification), mobilising global leadership to advance ocean acidification Action Plans from Ms Jessie Turner (USA), and how governments can respond to ocean acidification, Ms Alexis Valauri-Orton (USA). Presentations are listed in Appendix 8.

The subsequent panel Q&A session discussed the following themes:

Importance of elevating ocean acidification into national policy

- Elevating ocean acidification into national policy is crucial to provide a legislative basis to develop sustained monitoring and adaptation strategies.

- Regional-specific Action Plans which include clear thresholds, targets, priorities and goals need to be developed in order to build effective national focused policy, but cautioned against pressing resource-limited Commonwealth nations to commit to timelines.

- Instead of being required to develop complete and independent Action Plans, resource-limited Commonwealth countries could have access to framework options and templates, so they can more easily identify and adopt relevant Action Plans strategies based on available resources and individual needs.

- Strategies should be country-driven, including decisions on relevant monitoring locations. Countries should be encouraged to periodically review and revise strategies in light of emerging scientific findings and increased capacities.

Integrating ocean acidification into existing frameworks

- A first step in achieving the common aim of national ocean acidification strategies is to integrate ocean acidification into existing environmental frameworks and policies, especially in Commonwealth nations which already struggle to adopt and implement ocean policies. This

could be followed by ocean acidification-specific and legislation in order to move from regional to national frameworks.

Breakout session

Following the presentations, participants split into three breakout groups:

- Group 1 – Raising Awareness of Need to Take Action on Ocean Acidification
    - Facilitator and Rapporteur: Ms Jessie Turner, International Alliance to Combat Ocean Acidification (USA)

- Group 2 – Development or Implementation of Relevant Legal or Policy Frameworks
    - Facilitator: Prof Karen Scott, University of Canterbury (New Zealand)
    - Rapporteur: Ms Constance Nutsford, Ministry for the Environment (New Zealand)

- Group 3 – Prioritising Ocean Acidification in Development Assistance Partnership
    - Facilitator: Ms Alexis Valauri-Orton, The Ocean Foundation (USA)
    - Rapporteur: Dr Linn Hoffman, New Zealand Ocean Acidification Community Council (New Zealand)

What are some immediate steps that can be taken after this workshop?

- In general, prioritisation and goal-setting was considered to be an important initial step for participants. These should seek to address local needs, whether done at a national or regional level. To facilitate this, socioeconomic studies and identification of key species could be undertaken.

- To raise awareness, participants could report on outcomes of this workshop back to their governments and other stakeholders, advocating for an awareness of the importance of ocean acidification. Community awareness could be increased by implementing national workshops, community outreach programmes and engaging the media. Existing initiatives and programs (e.g. ocean education programs, universities) should be used. There are many international resources (e.g., flyers, booklets, information sheets, protocols) that could be translated into other languages and circulated.

- Raise stakeholder and community awareness on ocean acidification to prioritise ocean acidification in development assistance partnerships. Existing partnerships and projects could incorporate ocean acidification-related biological and chemical monitoring and include comprise global citizen science projects to engage the community.

- Identify existing funding initiatives and instruments for the regions to leverage support for ocean acidification projects, identify capacities of national governments to support science and develop management strategies.

- Non-binding ocean acidification soft targets could be more easily implemented into pre-existing frameworks and also used to build policies as an immediate step in the development and implementation of legal and policy frameworks. There are questions around on how to phrase the targets (tied to CO_2 or pH) and what targets to set.

What are some long-term goals to plan towards (i.e. within the next five years)?

- Create ocean acidification Action Plans and strategies at a national level, which are aligned with political agendas. Action Plans should implement long-term and sustained ocean acidification initiatives with a focus on solutions-based science to improve ecosystem health.

- Long-term monitoring strategies and networks should be developed to collect more baseline data, which can be used to create regional baselines. This information can inform pH targets which can be tied in with temperature targets in existing climate change legislation to drive policy and management strategies. Coordinated mechanisms should be developed for reporting data to ensure interoperability.

- Sustained financing is needed for research, monitoring and implementing adaptation strategies. Entities that profit from healthy ecosystems and habit restoration (e.g. tourism industry) should be part of the investment model.

- Engage stakeholders, including policy-makers, to encourage more funding and policy responses to address ocean acidification. Engage with indigenous peoples and local communities to ensure decision-making and management strategies are locally driven and responsive to their needs. This may require increasing support for food security and alternative livelihoods, if the management strategies involve restricting activities.

What are the barriers to achieving this priority?

- Challenges in obtaining useful data and information are a barrier to understanding the impacts of ocean acidification and articulating this to policy-makers. This includes the lack of interoperability, e.g. different measurements and indicators of ecosystem health inhibit the implementation of a common framework to facilitate inter-comparison of data and data exchange, or general uncertainty regarding how much data and monitoring is necessary before a reliable risk assessment can be made and strategies implemented. Ocean acidification data products and management networks are currently not streamlined, and are difficult to use.

- Practical barriers, such as the lack of affordable instruments and technology to initiate monitoring efforts and limited capacity, especially in Pacific, African, and Caribbean Commonwealth countries, also prevent effective monitoring. There is a lack of knowledge regarding currently available technologies when it comes to adaptation and mitigation strategies. The lack of funding is also a practical barrier: funding opportunities for ocean acidification issues are very limited in many regions. Most funding is allocated for resolving the major problems of climate change and ocean acidification is generally seen as an issue of low priority.

- There are also governance challenges, where structural hurdles in national government systems (lack of centralisation) prevent the development of ocean acidification research and implementation of ocean acidification in ocean-related policy frameworks. Legislation in most countries is mostly outdated and in many countries, policies are currently only in place for climate change, pollution, and plastic related ocean issues. There is generally no overarching ocean policy, and as a result, ocean acidification is overlooked. Participants suggested that ocean acidification is a grey area that nobody feels responsible for.

- This is linked to the challenges posed by competing priorities, particularly in resource-strapped countries, where the concern is that ocean acidification projects might divert money away from other urgent risk assessments and management strategies, such as hurricane warning systems.

How can the Commonwealth Ocean Acidification Action Group add value?

- The Action Group could advocate for incorporating ocean acidification into existing monitoring efforts and management strategies, by highlighting the importance of measuring pH, carbonate chemistry as well as biological parameters as proxies of general ecosystem health. Monitoring is crucial to evaluate effectiveness of management strategies.

- The Action Group could play a facilitative role linking Commonwealth countries to existing networks, initiatives, and resources (e.g. GOA-ON in a box), and develop a contact registry for the various networks and a platform for countries to continue to share data, knowledge, lessons and experiences. The Partnership for Observation of the Global Ocean's IODE Associate Data Unit could be useful to assist countries which do not have their own data centres. The economic, ecological and cultural diversity of Commonwealth countries would make the exchange of such information especially valuable. The Action Group could facilitate common frameworks for capacity-building, ocean acidification policies, interventions, funding strategies and processes for reporting back on SDG14.

- The Action Group could also provide direct support to countries to increase data, inform stakeholders and pressure policy-makers to take action on ocean acidification through efficacy and socioeconomic impact studies across different environments. There was a suggestion to give Commonwealth countries access to satellite observation data in order to create better models at locally relevant scales. The Action Group could also fund training workshops for existing initiatives such as GOA-ON.

Co-chair's Summary – Day 2

"Global problem with local consequences"

Dr. Jan Newton, Washington Blue Ribbon Panel on Ocean Acidification (USA)

Workshop co-chair Dr Christina McGraw reviewed the second day of the Action Group workshop and identified the key themes emerging from the second day:

Importance of language

- There is a trend to move away from more complex scientific jargon towards simple and familiar language (e.g., acidity). The use of narratives, instead of metrics, can be a more effective approach to raise awareness and engage stakeholders, government agencies and the wider community.

Need to mobilise resources

- Resources are limited, especially in Pacific, African, and Caribbean Commonwealth nations, hindering the national development of ocean acidification relevant science and monitoring networks and the implementation of much needed adaption strategies.

- Participants considered it imperative to mobilise Commonwealth resources and make use of already existing networks, programs, and initiatives (e.g., Marine Resources Advisory Council, International Alliance to Combat Ocean Acidification, The Ocean Foundation, Northwest Association of Networked Ocean Observing Systems) in order to respond to ocean acidification-related ocean issues and national commitments.

Engaging legislators and policy-makers

- There is a clear interest in global ocean acidification action, demonstrated by the number of countries currently engaging in ocean acidification networks (e.g. the International Alliance to Combat Ocean Acidification has more than 70 members).

- However, there is a lack of concrete international and national policy action focused on mitigation to develop much-needed national ocean acidification Action Plans.

- Ocean acidification has begun to appear on the global agenda (SDG 14.3) but few policy targets are mainstreamed with necessary mitigation and adaptation strategies.

- Thus, there is a need to elevate ocean acidification into national policy, using the SDGs as a framework, by engaging specific political leaders to act as ambassadors on ocean acidification.

Lastly, Dr McGraw acknowledged that while ocean acidification is a global issue with local consequences, it also has local solutions. Commonwealth nations need to share positive and compelling local success stories in order increase awareness in the political and broader community. Examples of local success stories highlighted in this workshop included Ghana's improved fishery management and South Africa's recent approval of 20 marine protected areas.

Way forward

"We do this not for ourselves, but for those that come after us. We might not see an immediate effect of our actions, but our children's children might."

Mr Hoani Langsbury, Te Rūnaka o Ōtākou (New Zealand)

At the conclusion of the workshop, Mr Nathan Glassey from the New Zealand Ministry of Foreign Affairs and Trade noted that the workshop represented the first step for the Action Group, and that we must find a path forward that provides a strong basis for identifying future needs and priorities for understanding and responding to ocean acidification.

He highlighted some of the many excellent ideas and examples of coordination and integration to move towards meeting the Action Group's aim to drive collaboration to help improve Commonwealth capability to address the impacts of ocean acidification via sharing knowledge, experience and best practice.

One of the main challenges facing the scientific community that was identified at the workshop is how to elevate ocean acidification into national policy in order to set objectives and drive action. Mr Glassey noted that participants had emphasised the importance of increasing awareness and boosting engagement of communities, industry, businesses, governmental agencies and NGOs through the use of compelling narratives about the impacts of ocean acidification as well as management success stories to help facilitate the development of ocean acidification-focused national and international policy.

He also noted that participants had emphasised the importance of creating enduring cross-Commonwealth connections on ocean acidification, as well as linkages with other international and interregional networks, in order to facilitate creation of regional science hubs and to develop capacity (e.g., technical support, expertise, funding, training, outreach, education), which support and nurture national actions.

Ocean issues will become more manageable when the resources of the Commonwealth nations can be leveraged together. Mr Glassey underlined the significance of Commonwealth nations working together as a collective to understand the changing ocean and create relevant National Strategies in order to move closer to meeting the common goal of delivering on SDG commitments.

Next steps for Action Group

Mr Glassey ended his remarks by explaining the next steps of the Commonwealth Ocean Acidification Action Group. New Zealand, as the champion of the Action Group, would assimilate the outcomes of the workshop into a useable set of proceedings and update the Action Group concept note to reflect the needs and priorities of Commonwealth members, as expressed at the workshop. Participants were encouraged to use this workshop as a first practical step to develop national strategies and to become formal members of the Action Group.

Mr Hoani Langsbury officially closed the workshop, highlighting the importance of leading by example. He emphasised the role of every nation, and the young Commonwealth community as a whole, to act as *kaitiaki* (guardians) and take care of *Tangaroa* (ocean). He further advocated the importance of collaborating to address future ocean problems for younger generation and "support the ones that cannot speak for themselves".

Appendix 1: Overview of the Commonwealth Blue Charter

The Commonwealth Blue Charter is an agreement by all 53 Commonwealth countries, adopted at the Commonwealth Heads of Government Meeting (CHOGM) in London, April 2018. The Charter of the Commonwealth provides the underlying principles for the Blue Charter, ensuring that the Commonwealth takes a fair, equitable, inclusive and sustainable approach to ocean economic development and protection. In the Blue Charter, Commonwealth countries agree to actively cooperate to solve ocean-related problems and meet commitments for sustainable ocean development, with particular emphasis on the UN Sustainable Development Goals (SDGs), especially SDG 14 (Life Below Water).

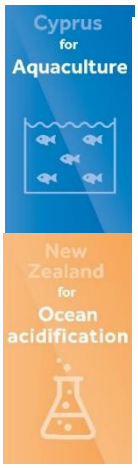
Implementation of the Commonwealth Blue Charter is through 'Action Groups. These are member-driven, led by 'Champion' countries. To date, 12 countries have stepped forward to be Champions on nine topics identified as priorities. Action Groups will unlock the power of 53 nations and guide the development of tools and training, they are: Aquaculture, Blue Economy, Coral Reef Protection and Restoration, Mangrove Restoration, Ocean Acidification, Ocean and Climate Change, Ocean Observations, Marine Plastic Pollution and Marine Protected Areas.

Comments and questions:

Jeff Ardron, Adviser Ocean Governance and project lead, j.ardron@commonwealth.int

Alison Swaddling, Adviser Ocean Governance, a.swaddling@commonwealth.int

Nick Hardman-Mountford, Head of Oceans and Natural Resources, n.hardman-mountford@commonwealth.int



1. Action Group on Aquaculture
Cyprus has stepped forward as a Champion for the action group on aquaculture. This action group aims to promote environmentally sustainable, financially viable and socially acceptable aquaculture. Aquaculture is ocean farming, including the breeding, rearing, and harvesting of fish, shellfish, plants, algae and other organisms in all types of water environments.

2. Action Group on Ocean Acidification
New Zealand will Champion an action group to address the impacts of ocean acidification. Ocean acidification affects many marine creatures, especially those with external shells and skeletal structures, such as shellfish and corals. Ocean acidification is predicted to impact communities economically dependent on fish and increase the vulnerability of coastal areas dependent on coral reefs for protection.

3. Action Group on Marine Plastic Pollution

To push for a global change, the United Kingdom and Vanuatu have taken the lead as co-Champions on marine plastic pollution. They are bringing together a group of member states to form the Commonwealth Clean Oceans Alliance (CCOA). With around 12.2 million tonnes of plastic making its way into oceans each year, pollution has become one of the biggest threats facing the marine environment, accumulating in food chains to eventually make its way to our dinner plates.

4. Action Group on the Ocean Change and Climate Change

The action group, championed by Fiji, will focus on significant actions that can deliver a sustainable ocean and contribute to positive climate outcomes. The reality of ocean change and climate change is evident for those whose livelihood depends on the sea. While ambitious targets on reducing emissions are essential, decreasing other negative human-induced stress on the ocean and restoring natural marine eco-systems is critical for building resilience.

5. Action Group on Restoration of Mangroves

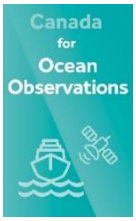
Sri Lanka has stepped forward to Champion the action group on mangrove restoration to share best practices and expand mutual cooperation in conservation and the sustainable use of mangroves. Mangroves are vital species in blue carbon ecosystems. Their benefits include: highly-efficient capture and storage of CO_2 from the atmosphere; provide habitats for many species of plants and animals; important fish nurseries; prevent coastal erosion by protecting shorelines from storms and waves; and, help maintain water quality.

6. Action Group on Coral Reef Restoration

Australia, Belize and Mauritius have teamed up to co-Champion this action group. 42% of reefs are in Commonwealth waters. Reefs have the highest biodiversity of all ecosystems on the planet and are home to ¼ of all known marine species, they support 250 million people directly through fish, tourism and coastal protection, and many more indirectly. However, 20% of the world's coral reefs have been effectively destroyed and show no immediate prospects of recovery. Some 24% are under imminent risk of collapse through human pressures and a further 26% are under a longer term threat of collapse.

7. Action Group on Blue Economy

Kenya will Champion an action group on developing an integrated approach to the blue economy, encouraging better stewardship of our ocean or 'blue' resources for economic growth, improved livelihoods, and ocean ecosystem health. The value of ocean assets (natural capital) has been estimated at US$24 trillion.



8. Action Group on Ocean Observations

This action group, championed by Canada, will explore the power of harnessing recent advances in ocean observation techniques and technology, coupled with practical approaches to provide the environmental intelligence needed to support decision making for the sustainable management of the ocean. Understanding ocean processes is vital for sustainably managing our ocean and the services it supplies, developing blue economies, and predicting extreme weather events.

9. Action Group on Marine Protected Areas

This action group, championed by Seychelles, will establish a network for exchange of experiences, expertise and information amongst Commonwealth Countries and partners in order to promote the need for establishment of new Marine Protected Areas (MPAs) and expansion of existing ones, together with the need for effective management of MPAs.

Appendix 2: List of Participants

Name	Affiliation	Country
Mr Ruleo Camacho	Department of Environment	Antigua and Barbuda
Dr Bronte Tilbrook	UN Community of Ocean Action	Australia
Dr Cate McElroy	Department of the Environment and Energy	Australia
Dr Will Howard	Department of the Environment and Energy	Australia
Dr Teina Rongo	Office of the Prime Minister	Cook Islands
Mr Kushaal Raj	Climate Change and International Cooperation Division, Ministry of Economy	Fiji
Ms Cecilia Nyadia	Ministry of Environment, Science, Technology and Innovation	Ghana
Mr Kipkosgei Toroitich	Ministry of Foreign Affairs	Kenya
Mr Pradeep Neermul	Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping	Mauritius
Mr Francisco Zivane	National Institute of Fisheries Research	Mozambique
Prof Karen Scott	University of Canterbury	New Zealand
Mr Nathan Glassey	Ministry of Foreign Affairs and Trade	New Zealand
Mr Joe McCarter	Ministry of Foreign Affairs and Trade	New Zealand
Ms Gabrielle Chin	Ministry of Foreign Affairs and Trade	New Zealand
Mr Danny Eyre	Ministry of Foreign Affairs and Trade	New Zealand
Prof Cliff Law	National Institute of Water and Atmospheric Research and University of Otago	New Zealand
Dr Christina McGraw	University of Otago and New Zealand Ocean Acidification Community Council	New Zealand
Dr Mary Livingston	Ministry for Primary Industries	New Zealand
Dr Norman Ragg	Cawthron Institute	New Zealand
Dr Kim Currie	National Institute of Water and Atmospheric Research	New Zealand
Ms Constance Nutsford	Ministry for the Environment	New Zealand
Dr Linn Hoffman	University of Otago and New Zealand Ocean Acidification Community Council	New Zealand
Mr Hoani Langsbury	Te Rūnaka o Ōtākou	New Zealand
Dr Duncan McIntosh	Secretariat of the Pacific Regional Environment Programme	Samoa
Mr Mulipola Ausetalia Titimaea	Ministry of Natural Resources and Environment	Samoa
Ms Ashley Dias	Ministry of Environment Energy and Climate Change	Seychelles
Mr David Hiba Hiriasia	Solomon Islands Meteorological Service	Solomon Islands
Mr Mutshutshu Tsanwani	Department of Environmental Affairs	South Africa
Dr Julius Francis	Western Indian Ocean Marine Science Association	Tanzania
Dr Siola'a Malimali	Ministry of Fisheries	Tonga
Mr Faoliu Teakau	Department of Environment	Tuvalu
Prof Steve Widdicombe	Plymouth Marine Laboratory	UK

Dr Nicholas Hardman-Mountford	Commonwealth Secretariat	UK
Dr Tarquin Dorrington	Department of Environment Food and Rural Affairs	UK
Ms Jessie Turner	International Alliance to Combat Ocean Acidification	USA
Dr Jan Newton	Washington Blue Ribbon Panel on Ocean Acidification	USA
Dr Libby Jewett	Global Ocean Acidification Observing Network	USA
Ms Alexis Valauri-Orton	The Ocean Foundation	USA
Mr McKenzie Kalotiti	Consul-General of Republic of Vanuatu	Vanuatu

Observers:

Ms Rebecca Zitoun	University of Otago	New Zealand
Mr Wayne Dillon	University of Otago	New Zealand
Ms Nadjejda Espinel Velasco	University of Otago	New Zealand
Ms Alexia Saint-Macary	University of Otago	New Zealand

Appendix 3: Programme

Sunday 17 February

3:00pm	Guided tour of the albatross colony
5:00pm	Orientation Dinner

Monday 18 February

8:30am	**Workshop opening** • Welcome and housekeeping • Commonwealth Blue Charter overview • Workshop objectives – national strategies and Commonwealth collaboration • Workshop programme overview
Session 1 The Science of Ocean Acidification Deepen understanding of ocean acidification and its impacts *Issues covered:* • Projected future impacts on coastal and marine ecosystems • Associated stressors and cumulative impacts • Unique considerations and experiences of different regions • Economic and social impacts • Knowledge gaps	
9:00am	**Presentations** • Scene setter: nature and extent of the ocean acidification problem • Regional perspectives: Pacific Islands • Regional perspectives: Australia • Regional perspectives: Caribbean • Regional perspectives: Africa
10:40am	**Break-out session with morning tea** • Group 1 – Coral Reefs and Other Ecosystems • Group 2 – Shellfish and Aquaculture • Group 3 – Fisheries
11:40am	**Report back**
12:10pm	**Lunch**

Session 2 Monitoring and Research

Identify options for effective monitoring and research and developing monitoring and technical capacity

Issues covered:

- Best practice monitoring
- Existing regional and global monitoring networks
- Data management frameworks
- Resource and capacity constraints
- Capacity-building priorities
- Research priorities

1:10pm	**Presentations:** • Scene setter: methods and tools used to conduct chemical and biological monitoring • Global Ocean Acidification Observing Network (GOA-ON) • Western Indian Ocean Science Association • Engaging local communities in monitoring efforts • GOA-ON's North East Atlantic hub
2:50pm	**Break-out session with afternoon tea** • Group 1 – Initiating National Monitoring Networks • Group 2 – Expanding Existing Networks • Group 3 – Monitoring The Impacts of Ocean Acidification
4:10pm	**Report back**
4.40pm	**Review of Day 1 and preview of Day 2**
7:00pm	Dinner

Tuesday 19 February

Session 3 Adapting to Ocean Acidification Assess potential mitigation, adaptation and resilience measures, drawing on existing local, national, regional and international activities *Issues covered:* • Potential adaptation approaches • Resources and capabilities required to support adaptation • Barriers to pursuing adaptation measures (e.g. knowledge, policy) • Managing ocean acidification with multiple stressors	
8:45am	**Presentations** • Scene setter: Washington State Blue Ribbon Panel • Coastal Acidification: Rate, Impacts and Management • New Zealand Pacific Partnership on Ocean Acidification • Development of adaptation strategies and plans
10:25am	**Break-out session with morning tea** • Group 1 – Coral Reefs and Other Ecosystems • Group 2 – Shellfish and Aquaculture • Group 3 – Fisheries
11:35am	**Report back**
12:05pm	**Lunch**

Session 4 Governance and Action

Identify potential actions and governance strategies for addressing the impacts of ocean acidification

Issues covered:

- International policy landscape and action on ocean acidification
- Developing national policy frameworks to support adaptation action
- National Action Plans and best practice examples
- Prioritising ocean acidification in development assistance partnerships
- Science/policy interface

1:00pm	**Presentations** • Overview of the international policy landscape and action on ocean acidification • Sustainable Development Goal framework including SDG 14.3.1 methodology • Ocean Acidification Action Plans • Putting policy frameworks into practice
2.40pm (60 minutes)	**Break-out session with afternoon tea** Identifying issues to prioritise and pursue in national strategies
3.40pm (30 minutes)	**Report back**
4:10pm (50 minutes)	**Discussion** • Sharing ideas for National strategies • Commonwealth Ocean Acidification Action Group – next steps • What will success of the Action Group look like? • Wrap-up

Appendix 4: Biographies of Co-Chairs and Presenters

Co-Chairs

Dr Christina McGraw

Christina is the Chair of the New Zealand Ocean Acidification Community Council, co-leader of the New Zealand Ocean Acidification Action Plan Working Group, and a Senior Lecturer in the Department of Chemistry at the University of Otago. Christina has broad interests in analytical and marine chemistry. Her research revolves around the design of field-deployable instrumentation for Marine research, including automated culture systems to study the impact of global climate change on marine ecosystems, miniature sensors to monitor fluctuations in marine carbonate, and deployable devices to study real-time dissolution and precipitation of calcium carbonate. Christina is also a Full Member of SCOR Working Group 149: Changing Ocean Biological Systems (COBS): How will biota respond to a changing ocean?

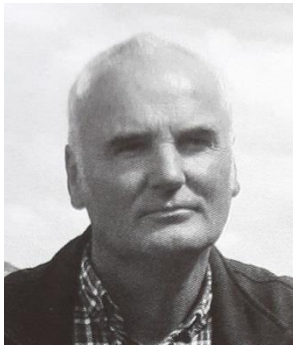
Contact: cmcgraw@chemistry.otago.ac.nz

Prof Cliff Law

Cliff coordinates the Ocean-Climate Interaction programme research at the National Institute of Water and Atmospheric Research in Wellington, and is a Professor in the Department of Chemistry at the University of Otago. He contributes to international policy development on ocean fertilisation via the London Convention, and ocean acidification via NZ input to COP24. He is a member of the Scientific Steering Committee for the IGBP program SOLAS (Surface Ocean Lower Atmosphere Study). His current research interests include trace gas cycling and sources in coastal and open ocean regions, nutrient limitation of phytoplankton and impacts of ocean acidification.

Contact: cliff.law@niwa.co.nz

Presenters



Mr Hoani Langsbury

Ko Aoraki te Mauka, Ko Waitaki te awa, Ko Takitimu te waka, Ko Kai Tahu, Kati Mamoe, Waitahi, Rapuwai, Kati Hawea nga Iwi, Ko Otakou te Whenua, Ko Otakou te Marae.

Hoani is an Ecologist, recognised and respected Conservationist, and Community Leader with over 2 decades of experience working with senior teams, communities, and other indigenous leaders to achieve successful outcomes for the environment. He is experienced in governance, strategic planning, change management, and providing holistic solutions for modern challenges. Hoani is an active Kaitiaki at both grassroots and governance levels, and is also involved in many conservation organisations, including as former Chair of the Otago

Conservation Board, current Chair of the Otago Peninsula Biodiversity Trust, and trustee for the Yellow Eyed Penguin and Predator Free Dunedin Trusts.

Contact: hoani.langsbury@xtra.co.nz

Dr Nick Hardman-Mountford

Nick is Head of Oceans and Natural Resources at the Commonwealth Secretariat, where he leads a technical advisory team working on ocean governance and sustainable natural resource development projects. Prior to joining the Commonwealth, Nick was Principal Scientist at Australia's national research agency, the Commonwealth Scientific and Industrial Research Organisation, where he led the Indian Ocean Ecology and Oceanography group. His research on ocean observations and modelling has taken him to the Atlantic, Indian, Pacific and Southern Oceans and has found application in addressing a diverse range of societal drivers such as sustainable blue economies, carbon storage, food security, energy and climate change.

Contact: n.hardman-mountford@commonwealth.int

Mr Mutshutshu Tsanwani

Mutshutshu is a Marine Scientist in the branch Oceans and Coasts of the South African Department of Environmental Affairs. He is responsible for monitoring of pCO_2, pH, DIC, TA, nutrients, dissolved oxygen and Chl-a. His research interest is in ocean acidification and CO_2 dynamics of the Benguela Upwelling System. He has an MSc degree in Analytical Chemistry from the University of Pretoria and he is currently a PhD student at the University of Cape Town studying the combined effects of ocean acidification, hypoxia and temperature changes on marine coastal ecosystems.

Contact: MTsanwani@environment.gov.za

Mr Kushaal Raj

Kushaal is the Ocean Specialist for the Climate Change and International Cooperation Division at the Ministry of Economy, Fiji. He coordinates the Ocean and Climate activities in communicating Fiji's climate change and ocean change response needs and for communicating the nation's progress towards the role of the ocean in climate change frameworks, in particular the United Nations Framework Convention on Climate Change and the Paris Agreement.

Contact: kushaal.raj@economy.gov.fj

Dr Will Howard

Will works on Mitigation and Climate Science Policy at Australian Government Department of the Environment and Energy. Dr Howard has a PhD in Geological Sciences from Brown University in the US. He was Postdoctoral Fellow at Lamont-Doherty Earth Observatory of Columbia University, a lecturer in oceanography at the Sea Education Association in Woods Hole USA, a researcher at the Antarctic Climate & Ecosystems Cooperative Research Centre in Hobart, and Assistant Director, Science, at the Office of the Chief Scientist in Canberra.

Contact: Will.Howard@environment.gov.au

Mr Ruleo Camacho

Ruleo is a Natural Resource Officer in the Antigua and Barbuda Department of Environment. He is a Marine Ecologist with a demonstrated history of working in the higher education and environmental industry and has a Master's degree in Marine Biology and Marine Policy from University of Maine.

Contact: rcam.doe@gmail.com or Ruleo.Camacho@ab.gov.ag

Dr Bronte Tilbrook

Dr. Bronte Tilbrook is a senior principal research scientist with the CSIRO Oceans and Atmosphere and the Antarctic Climate and Ecosystems Co-operative Research Centre, based in Hobart, Tasmania. He has a PhD in chemical oceanography from the University of Hawaii. Tilbrook leads a team that has established Australia's ocean observing system for ocean acidification and of ocean carbon dioxide uptake and storage, with projects extending from the tropics to the Antarctic shelf. He has been involved in a number of international programs to build sustained observing systems to determine changing environmental conditions in the ocean. His current roles include co-chair of the Global Ocean Acidification Observing Network and acting as one of two focal points for the United Nations Community of Ocean Action for ocean acidification.

Contact: Bronte.Tilbrook@csiro.au

Dr Kim Currie

Kim is a marine Chemist with the National Institute of Water and Atmospheric Research (NIWA). Her main research interest is in Carbon dioxide chemistry in seawater. As part of the Ocean-Atmosphere Interactions group, she is responsible for surface ocean carbon programmes including the Munida Time Series, a long-running transect of ocean carbon measurements off the coast of New Zealand, and the open ocean carbon sink quantification project, using the RV Tangaroa.

She is a part of a multi-disciplinary team working on coastal ocean acidification in New Zealand, and has recently set up a coastal ocean acidification observing network.

Contact: kim.currie@niwa.co.nz

Dr Libby Jewett

Libby became the first Director of the NOAA Ocean Acidification Program in May 2011, and has been busy ever since crafting the shape of this important, new NOAA science enterprise. A founding member of NOAA's Ocean Acidification Steering Committee, Libby led NOAA-wide meetings of scientists and policymakers to conceive and develop NOAA's first comprehensive ocean acidification research plan. She continues to represent NOAA on the ocean acidification interagency working group (under Subcommittee on Ocean Science and Technology) where she helped develop an ocean acidification strategic research plan for the nation. Libby earned a Ph.D. in Biology with a focus on Marine Ecology at the University of Maryland, a Master of Public Policy at Harvard University's Kennedy School of Government, and a B.A. at Yale University.

Contact: libbyjewett@aol.com

Dr Julius Francis

Julius currently works for the Western Indian Ocean Marine Science Association (WIOMSA), which is a regional professional, non-governmental, membership organization, based and registered in Zanzibar, Tanzania. The organization is dedicated to promoting the educational, scientific and technological development of all aspects of marine sciences particularly in the 10 countries of the region (Somalia, Kenya, Tanzania, Mozambique, South Africa, Comoros, Madagascar, Mauritius, Seychelles, and Reunion [France]) and he has been involved in different aspects of conservation, research and management of coastal and marine environments in the western Indian Ocean (WIO) region for a number of years working with many collaborators and partners including decision makers, local communities, managers, scientists and students. Also, been involved in coastal and marine resource management programs, community based natural resources management, capacity building for MPA management, ICM, and Marine Spatial Planning. His particular interest is in linking the knowledge that emerges from research to the management and governance issues that affect marine and coastal ecosystems in the region. Recently, he has been playing a key role in setting up a regional platform for interactions between scientists and decision-makers under the auspices of the Nairobi Convention. He coordinated the production of the first comprehensive Regional State of the Coast Report for the WIO region.

Contact: julius@wiomsa.org

Professor Steve Widdicombe

Steve leads the Plymouth Marine Laboratory strategic science area Marine ecology and biodiversity. He is a marine ecologist with 25 years of experience in using field observations and manipulative experiments to address issues relating to benthic ecology, biodiversity and ecosystem function. Much of his recent research has concentrated on the ecological impacts of increasing seawater CO_2 levels, rising temperatures and expanding areas of hypoxia. Through this interest in CO_2 research, Steve has developed an expertise in Ocean Acidification and in the potential biological impacts of leakage from CO_2 Capture and Storage (CCS).

Contact: swi@pml.ac.uk

Dr Jan Newton

Jan is a principal oceanographer with the Applied Physics Laboratory of the University of Washington, and an affiliate assistant professor in both the UW School of Oceanography and the School of Marine and Environmental Affairs. Jan serves as co-director of the recently established Washington Ocean Acidification Center, which operates from the College of the Environment and fosters connections among researchers, policymakers, industry, and others to address key priorities established by the state legislature concerning ocean acidification. She also is the executive director of the Northwest Association of Networked Ocean Observing Systems (NANOOS), which is part of a broader program of Integrated Ocean Observing Systems throughout the United States. Jan's expertise is in biological oceanography, and her work focuses on the physical, chemical, and biological dynamics of Puget Sound and coastal Washington, including understanding effects from climate and humans on water properties.

Contact: janewton@uw.edu

Dr Duncan McIntosh

Duncan is the Oceanography Officer at the Secretariat of the Pacific Regional Environment Programme (SPREP). He provides advice and support to SPREP and its Members on all issues relating to oceanography, ocean observing, ocean acidification and climate change impacts on the marine environment and supporting the regional National Meteorological Services (NMS) in developing oceanography and marine weather service programmes.

Contact: robertmc@sprep.org

Ms Alexis Valauri-Orton

Alexis serves as Program Manager at The Ocean Foundation where she manages the International Ocean Acidification Initiative. In 2012 she completed a Thomas J. Watson Fellowship studying how ocean acidification might affect marine communities in Norway, Hong Kong, Thailand, New Zealand, The Cook Islands, and Peru. Her research during this fellowship was highlighted at the Inaugural Our Ocean Conference in Washington, DC. At The Ocean Foundation she delivers training workshops for scientists and policy makers around the world to build their capacity to monitor, understand, and respond to ocean acidification. To date, Alexis has managed the delivery of seven training workshops in Africa, the Pacific Islands, and Latin America and the Caribbean.

Contact: avalauriorton@oceanfdn.org

Prof Karen Scott

Karen is a Professor at the University of Canterbury in New Zealand having previously taught at the University of Nottingham in the UK. She was the Head of the School of Law between 2015 and 2018, Vice-President of the Australian and New Zealand Society of International Law (ANZSIL) from 2011 – 2016 and the General Editor of the New Zealand Yearbook of International Law from 2009 to 2012. She researches and teaches in the areas of public international law, law of the sea and international environmental law. Karen has published over 60 journal articles and book chapters in these areas and is the co-editor of Donald R. Rothwell, Alex Oude Elferink, Karen N. Scott and Tim Stephens (eds), Oxford Handbook on the Law of the Sea (Oxford, OUP, 2015, paperback edition, 2017) and of Alan D. Hemmings, Donald R. Rothwell, Karen N. Scott (eds), Antarctic Security in the Twenty-First Century: Legal and Policy Perspectives (London/ New York, Routledge, 2012). Karen's recent work has focused on oceans and climate and selected recent publications include: Karen N. Scott, 'Ocean Acidification and Sustainable Development Goal 14: A Goal but No Target?' in Myron H. Nordquist, John Norton Moore, and Ronan Long (eds), The Marine Environment and United Nations Sustainable Development Goal 14: Life below Water ((Koninklijke Brill, Leiden) (2018) 323 – 341; Karen N. Scott, "Mind the Gap: Marine Geoengineering and the Law of the Sea" in Robert C. Beckman, Millicent McCreath, J. Ashley Roach, Zhen Sun (eds).

Contact: karen.scott@canterbury.ac.nz

Ms Jessie Turner

Jessie leads advocacy and facilitation projects at the local, state, regional and international level and has 10 years of experience working in public policy development, advocacy and stakeholder engagement. She is a facilitator to the Pacific Coast Collaborative (PCC), a collaboration between the states of California, Oregon, Washington and the Province of British Columbia in Canada working together on climate and energy issues that impact the North American West Coast region. In that role, Jessie led the PCC ocean acidification working group between 2013-2016 and assisted in the creation of the International Alliance to Combat Ocean Acidification (OA Alliance). The OA Alliance is now an initiative of more than 70 governments and non-government members dedicated to taking action to protect coastal communities and livelihoods from the threat of ocean acidification. Through her position at Cascadia Law Group, Jessie is now the Secretariat for the OA Alliance, helping to set its strategic direction, establish partnerships across a wide variety of disciplines and coalitions, and support members in the development of practicable and implementable adaptation and resiliency strategies.

Contact: jturner@cascadialaw.com

Appendix 5: Questions to Guide Discussions

These questions were developed as suggestions to guide discussions during the break-out sessions. Participants were encouraged to consider them in the context of their country and/or region.

Session 1: The Science of Ocean Acidification

Group 1 – Coral reefs and Other Ecosystems Group 2 – Shellfish and Aquaculture Group 3 – Fisheries

- What is known about the ecological, societal and economic impacts of ocean acidification in your region?
- What are the most pressing knowledge gaps?
- What information do you need to address those gaps?
- What countries are facing similar challenges to yours? Can their knowledge inform the knowledge gaps in your region?
- What other stressors (e.g. temperature, erosion) are expected to exacerbate the impact of OA in your region?
- How can the Commonwealth Ocean Acidification Action Group add value?

Session 2: Monitoring and Research

Group 1 – Initiating National Monitoring Networks Group 2 – Expanding Existing Networks Group 3 – Monitoring the Impacts of Ocean Acidification

- What sort of framework is required in your country to monitor your important ecosystems?
- What existing capacity does your country have?
- What additional resources does your country need?
- Monitoring impact – what experimental facilities do you have? Do you have blue carbon initiatives? Do you have OA research programmes?
- What partnerships need to be developed?
- How can the Commonwealth Ocean Acidification Action Group add value?

Session 3: Adapting to Ocean Acidification

Group 1 – Coral Reefs and Other Ecosystems Group 2 – Shellfish and Aquaculture Group 3 – Fisheries

- Which options are most appropriate?
- What are the roadblocks to uptake?
- What are the co-benefits & opportunities?
- Are there opportunities for international cooperation?
- How do we monitor and determine effectiveness?

- How can the Commonwealth Ocean Acidification Action Group add value?

Session 4: Governance and Action

Group 1 – Raising Awareness of Need to Take Action on Ocean Acidification Group 2 – Development or Implementation of Relevant Legal or Policy Frameworks Group 3 – Prioritising Ocean Acidification in Development Assistance Partnerships

- What are some immediate steps that can be taken to achieve this priority (i.e. when you return home)?
- What are some long-term goals to plan towards (i.e. within the next five years)?
- What are the barriers to achieving this priority?
- What is the current international status of resources to achieve this priority, and what are the gaps?
- How can the Commonwealth Ocean Acidification Action Group add value in relation to this priority?

Appendix 6: Contact Information

Regarding these proceedings:

- Ms Gabrielle Chin, Policy Officer, New Zealand Ministry of Foreign Affairs and Trade: gabrielle.chin@mfat.govt.nz

Regarding the workshop:

- Ms Gabrielle Chin, Policy Officer – Ocean, New Zealand Ministry of Foreign Affairs and Trade: gabrielle.chin@mfat.govt.nz
- Dr Kim Currie, Marine Chemist, National Institute of Water and Atmospheric Research (New Zealand): kim.currie@niwa.co.nz
- Prof Cliff Law, Principal Scientist – Marine Biogeochemistry, National Institute of Water and Atmospheric Research/University of Otago (New Zealand): cliff.law@niwa.co.nz
- Mr Nathan Glassey, Lead Adviser – Ocean, Biodiversity and Conservation, New Zealand Ministry of Foreign Affairs and Trade: nathan.glassey@mfat.govt.nz
- Dr Mary Livingston, Principal Scientist, New Zealand Ministry for Primary Industries: mary.livingston@mpi.govt.nz
- Mr Joe McCarter, Development Manager, New Zealand Ministry of Foreign Affairs and Trade: joe.mccarter@mfat.govt.nz
- Dr Christina McGraw, Senior Lecturer, University of Otago; New Zealand Ocean Acidification Community Council (New Zealand): christina.mcgraw@chemistry.otago.ac.nz
- Ms Constance Nutsford, Senior Analyst, New Zealand Ministry for Environment: constance.nutsford@mfe.govt.nz

Appendix 7: Survey Responses

Specific issues or topics participants would like covered:

1. The Science of Ocean Acidification

- What are the latest findings related to locally buffering ocean acidification near coral reefs?
- Causes: from a climate and variability perspective – studies in the South Pacific
- Solutions, mitigation, management and adaptation
- Water chemistry (changes)
- Coral reef bleaching
- Impacts on phytoplanktons
- Issue of coastal variability vs open ocean
- Latest field studies on biological responses to key species in the region, particularly fin fish
- Chemical reactions that triggers ocean acidification
- How does warming affect chemistry?

2. Monitoring and Research

- What are monitoring best practices for reporting data to SDG Indicator 14.3.1?
- Discussion around the multiple types of technologies that can be used to monitor and respond to ocean acidification and the various cost levels and accessibilities.
- Discussions include mention of collaboration between industry and scientists and in particular how industry needs and science needs can be quite different, so different technology is needed to meet the respective needs.
- Case studies already done in the Pacific (network of monitoring stations in the Pacific and ocean acidification)
- Coordinating activities for a regional and global perspective
- Local, coastal variability
- Best local toolkits to use/methodologies
- Long term time series
- Sensor development
- ARGO floats
- Issue of remote areas for monitoring
- International quality standards
- Archiving of data
- What is the status of data management and future needs?
- Opportunities for countries to cooperate on regional monitoring
- Description and location of GOA-ON sites
- Monitoring/Research methodologies on associated impacts of ocean acidification on marine species i.e. corals etc.
- Case studies, lessons learnt from other countries, key research outcomes, encouraging signs
- Most affected or likely to be affected species
- Where and how – costs and information sharing

3. Adapting to Ocean Acidification

- What adaptation actions for fisheries/coral reefs and their dependent communities have been tried so far?
- What adaptation actions are recommended?

- How can we increase coral reef resilience to ocean acidification?
- Adaptation measures addressing ocean acidification
- Management and conservation of biodiversity and resources
- Managing multiple stresses in the marine environment
- Tolerant gene pools
- Mapping areas of risk
- Marine Protected Area benefits
- Example projects of how governments have made adaptation and resilience plans – how they are funded and how long they take to implement
- How well different groups of organisms can adapt to ocean acidification
- Adaptive capacity and recovery from ocean acidification
- Priority what can be done, case examples with costs and benefits explained

4. Governance and Action

- What should the priority be when addressing ocean acidification governance?
- The emphasis of ocean acidification in the UN negotiations (does loss and damage address OA as a key issue)
- "Long"-term planning and monitoring
- Solutions
- Country inputs/voluntary commitments
- Outcomes of the IPCC Special Report into the Oceans and Cryosphere
- International quality standards
- Archiving of data
- How can the Action Group add value through engagement with the UN SDG 14.3 on ocean acidification?
- Management responses and addressing policy gaps i.e. energy etc.
- Ocean governance
- Awareness and Education
- Research
- Examples of legislation and policy
- Possibility of action through UNFCCC to include pH as a target (would this help?)

What do you hope to achieve from the workshop?

- Increased understanding of the science of ocean acidification, and of best practices for managing coral reefs in the face of ocean acidification
- Knowledge and understanding, existing ocean acidification monitoring networks, assessment of the situation feasibility, scientific methodologies
- Make contacts and increase network
- Help build capacities and activities
- Information on more local hands-on training/technology needs
- A better understanding of how we can integrate the ocean acidification work carried out across the Commonwealth (and further afield) and how this joint action by NZ can be used to integrate oceans into the UNFCCC process.
- A thorough understanding of what capacity building needs of countries and how the international community can help in monitoring and data management.

- An agreement developed (or initiated) that the countries will work on the OA issue to highlight the problem within our own governments and that the plan will engage with the UN SDG14.
- Exciting to meet many decision makers who are seeking to better understand their role in investing in this work, convening the right set of actors.
- Options for effective ocean acidification monitoring and opportunities for capacity building in our region
- Learn from others on actions that they have taken to address the impacts of ocean acidification
- What I hope to gain from the workshop is increased knowledge on present and future social, economic and most importantly environmental impacts of ocean acidification.
- A way forwards for policy makers to address issues related to ocean governance
- Inform the development of an Action Plan to assist countries to adapt.

Appendix 8: List of Presentations

For a copy of a presentation, please contact:

- Ms Gabrielle Chin, Policy Officer, New Zealand Ministry of Foreign Affairs and Trade: gabrielle.chin@mfat.govt.nz

Session 1: The Science of Ocean Acidification

	Presenter	Title
1.1	**Dr Christina McGraw** University of Otago and New Zealand Ocean Acidification Community Council (New Zealand)	Scene setter: The nature and extent of ocean acidification
1.2	**Mr Mutshutshu Tsanwani** Department of Environmental Affairs (South Africa)	Ocean Acidification in South Africa
1.3	**Mr Kushaal K. Raj** Ministry of Economy (Fiji)	Ocean acidification: a Fijian overview
1.4	**Dr Will Howard** Department of the Environment and Energy (Australia)	Science and policy challenges of ocean acidification for Australia
1.5	**Mr Ruleo Camacho** Department of Environment (Antigua and Barbuda)	Ocean Acidification: Perspectives from the Caribbean

Session 2: Monitoring and Research

	Presenter	Title
2.1	**Dr Bronte Tilbrook** CSIRO Oceans and Atmosphere (Australia)	Scene setter: Tools for ocean acidification monitoring
2.2	**Dr Libby Jewett** Global Ocean Acidification Observing Network (USA)	Global Ocean Acidification Observing Network: Past, Purpose, Projects and Plans
2.3	**Dr Julius Francis** Western Indian Ocean Marine Science Association (Tanzania)	Monitoring and research in the West Indian Ocean
2.4	**Dr Kim Currie** National Institute of Water and Atmospheric Research (New Zealand)	Engaging local communities and stakeholders in monitoring efforts
2.5	**Dr Steve Widdicombe** United Kingdom Ocean Acidification Regional Hub (UK)	The GOA-ON North East Atlantic hub: aspirations, process and plans

Session 3: Adapting to Ocean Acidification

	Presenter	Title
3.1	**Dr Jan Newton** Blue Ribbon Panel (USA)	Lessons learned from Washington State's Blue Ribbon Panel on Ocean Acidification
3.2	**Prof Cliff Law** National Institute of Water and Atmospheric Research and University of Otago (New Zealand)	Addressing Ocean Acidification in New Zealand
3.3	**Dr Duncan McIntosh** Secretariat of the Pacific Regional Environment Programme (Samoa)	New Zealand Pacific Partnership on Ocean Acidification
3.4	**Ms Alexis Valauri-Orton** The Ocean Foundation (USA)	The Role of Science/Policy/ Industry in Management and Adaptation Plans

Session 4: Governance and Action

	Presenter	Title
4.1	**Professor Karen Scott** University of Canterbury (New Zealand)	Scene-setter: The Ocean Acidification Regime Complex: An overview of the international legal and policy landscape
4.2	**Dr Bronte Tilbrook** UN Community of Ocean Action – Ocean Acidification (Australia)	SDG 14.3 and the 2030 Sustainability Agenda
4.3	**Ms Jessie Turner** International Alliance to Combat Ocean Acidification (USA)	Mobilizing Global Leadership to Advance OA Action Plans that Protect Coastal Communities and Livelihoods from a Changing Ocean
4.4	**Ms Alexis Valauri-Orton** The Ocean Foundation (USA)	Solutions and Strategies to Monitor, Understand, and Respond to Ocean Acidification: How Governments can Respond to Ocean Acidification, Protecting their Marine Resources and the Jobs that Depend Upon Them