Intergovernmental Oceanographic Commission

Workshop Report No. 271

WESTPAC Workshop on Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems

Phuket, Thailand
19–21 January 2015

UNESCO

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EXECUTIVE SUMMARY

The WESTPAC Workshop on Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems took place in Phuket, Thailand, 19–21 January 2015 at the Phuket Marine Biological Centre, Thailand. A total of 42 participants from Bangladesh, Cambodia, China, Indonesia, Japan, Korea, Malaysia, Philippines, Thailand, United States of America and Vietnam attended the workshop.

The workshop exchanged information on existing and proposed ocean acidification monitoring and research approaches, methods, and techniques at global, regional, and national levels; established an ocean acidification research and observing network in the Western Pacific and its adjacent region by bringing together regional experts who have been making efforts on the research and monitoring of ocean acidification.

In view of the pressing need to draw the attention of high-level policy-makers and relevant stakeholders in the region to ocean acidification, the workshop established a task force to start formulating, with technical assistance of the NOAA Ocean Acidification Program, an outreach flyer on ocean acidification and its social-economic impacts in the region.

With the case study on the US NOAA National Coral Reef Monitoring Program, particularly its Pacific Reef Assessment and Monitoring Program, the workshop recognized great challenges and gaps in monitoring the ecological impacts of ocean acidification on coral reef ecosystems in the region. Given the limited understanding on the ecosystem responses to ocean acidification against a critical need to develop meaningful projections on future impacts of ocean acidification on marine ecosystem, especially on coral reefs in the region to enable resource and fisheries managers, and policy-makers to develop effective long-term mitigation and adaptation strategies for the people of the region, the workshop stressed the need, building on existing coral reef monitoring initiatives, to develop a joint long-term monitoring programme/network on the impacts of ocean acidification on coral reefs in the region.

To this end, the workshop selected several pilot sites as a starting point for developing the regional monitoring program/network. A table for monitoring capacity analysis was developed and will be distributed to participants willing to join the programme development, with a view to analysing the current monitoring capacity, identifying common monitoring methods, and further considering developing a consistent, comparable and cost-effective “Standard Operating Procedure (SOP)” for all pilot sites.

All participants expressed their great appreciation to NOAA for the technical assistance provided in the organization of this event. The second workshop was tentatively scheduled for late August or early September of 2015.

1. Opening and self-introduction

WESTPAC Workshop on Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems was convened at 09:00 a.m. on Monday, 19 January 2015 at the Cape Panwa Hotel, Phuket, Thailand. The workshop was organized by the IOC Sub-Commission for the Western Pacific (WESTPAC), and was hosted by the Phuket Marine Biological Center (PMBC), Thailand.

Mr Wenxi Zhu, Head of the IOC Regional Office for the Western Pacific (WESTPAC Office), opened the workshop by introducing the Workshop Organizing Committee consisting of Dr Rusty Brainard from the National Oceanic and Atmospheric Administration (NOAA), Dr Somkiat Khokiattiwong from the Phuket Marine Biological Center (PMBC), Dr Suchana Chavanich from the Chulalongkorn University of Thailand and himself. He expressed his appreciation to all other members of the Committee for their great efforts in the planning and organization of this workshop, and further encouraged any interested participants to join this open-ended Committee.

In the opening, Mr Ukkrit Satapoomin, Director of the Phuket Marine Biological Center (PMBC), Thailand was invited to deliver his welcome remarks. He welcomed all participants to the workshop. While expressing his concerns over the predicted impacts of ocean acidification on the distribution and abundance of marine organisms, he emphasized the importance of more understanding on ocean acidification and its impacts on marine organisms and coral reef ecosystems. He highlighted the unique role of WESTPAC in bringing together marine scientific communities, and catalysing multi-disciplinary cooperation among its Member States in the research and monitoring of the ecological impacts of ocean acidification on ocean ecosystems. He wished the workshop a great success.

Dr Dwight Gledhill of NOAA's Ocean Acidification Program, speaking on behalf of the Global Ocean Acidification Observing Network (GOA-ON), congratulated WESTPAC and all organizers for their great efforts in making the event possible. He stressed the need for WESTPAC to develop this initiative of a regional research and monitoring network on ocean acidification, through a series of regional workshops and transfer of technology, with a view to filling the knowledge gap on global distribution of and changes in ocean chemistry. He expected that this workshop would generate a clear roadmap towards the development of the regional ocean acidification monitoring network.

Dr Somkiat Khokiattiwong, Chair of the IOC Sub-Commission for the Western Pacific (WESTPAC) delivered his remarks by recalling the recommendation from the 9th WESTPAC International Scientific Symposium (Nha Trang, Vietnam, 22–25 April 2014) which called upon WESTPAC to conduct relevant research and monitoring of ocean acidification. He stressed the importance of WESTPAC, serving as the IOC's regional subsidiary body for the Western Pacific and its adjacent regions, to advance international cooperation on marine science, and further expected new programme(s) on ocean acidification could be initiated under the framework of WESTPAC.

All participants were invited to give self-introduction on themselves and briefly describe their research focus. The list of participants is attached as Annex II to this report.

2. Setting the scene

2.1 Brief on the workshop objectives, layout and expected outputs and outcomes

Mr Wenxi Zhu briefed on the workshop objectives, which aim to: (i) share existing and proposed ocean acidification monitoring and research approaches, methods, and techniques; (ii) improve the understanding, and develop regional capability of research and

long-term monitoring on ocean acidification in the Western Pacific and its adjacent regions; and (iii) identify challenges, gaps and explore the possibility, building on existing coral reef monitoring initiatives, of a joint long-term monitoring and associated research programme on the impacts of ocean acidification on coral reefs in the region.

To achieve the objectives, he explained that a total of six sessions were designed: Session 1 to set the scene; Session 2 to exchange information on research and monitoring efforts on ocean acidification in the region; Session 3 to provide a case study on the ocean acidification monitoring within NOAA's Coral Reef Monitoring Program (NCRMP); Session 4 to brainstorm feasible ideas on future collaborative research and/or monitoring efforts on ocean acidification in the region; Session 5 to define physical/chemical and biological measurements required in a monitoring programme; and Session 6 for recommendations and conclusions on the next steps.

In order to achieve the goal of the development of a regional long-term programme on the monitoring of the ecological impacts of ocean acidification on coral reefs, he announced that so far three regional workshops were planned including the present one. In this regard, he further encouraged all the participants to actively engage in discussions and fully demonstrate their expertise in the planning and development of future regional initiative(s) on ocean acidification. The agenda of the workshop is attached as Annex I to this report.

2.2 Overview on ocean acidification: what is OA and why do we care?

Dr Adrienne Sutton, NOAA Pacific Marine Environmental Laboratory and University of Washington Joint Institute for the Study of the Atmosphere and Ocean, USA illustrated the importance of multi-disciplinary approach and essential linkage between science and actions with a story from the U.S. west coast where ocean acidification research and monitoring is helping restore commercial oyster hatcheries.

While briefly reviewing the main causes of ocean acidification and its potential impacts on ocean ecosystems, she pointed out the challenges for ocean acidification research, including lack of knowledge on near-shore conditions, marine organism's response to the changing ocean acidification, and socioeconomic implications.

This presentation prompted wide interests. One inquiry was made concerning the response of local governments in U.S. west coast to ocean acidification. Dr Sutton clarified that it was the oyster hatchery communities that started to push the U.S. Congress to engage in broader discussions of ocean acidification in considerations of the significant economic impacts of ocean acidification on their industries.

2.3 Global Ocean Acidification Observing Network (GOA-ON)

Dr Dwight Gledhill from NOAA's Ocean Acidification Program provided an overview on the Global Ocean Acidification Observing Network (GOA-ON) with an emphasis on the strategy being employed for coral reef ecosystems.

He introduced that the GOA-ON is a newly established collaborative and international approach to documenting ocean acidification across a range of marine environments, designed to improve understanding of the global impacts to marine ecosystems. The GOA-ON builds upon and extends an existing global oceanic carbon observatory network and promotes integration into existing marine ecosystem monitoring efforts. He explained that the monitoring strategy prescribed by the GOA-ON adopts monitoring metrics to track direct chemical changes, organism response, biodiversity impacts, dissolution/bioerosion, and community-scale feedbacks. Despite significant challenges in standardizing biological monitoring methodologies and interpreting long-term changes amidst multiple factors driving ecosystem change, the changing status of these metrics over time should aid in ascribing

specific attribution to ocean acidification. He finally invited participants to refer to more detailed information on GOA-ON at http://www.goa-on.org.

2.4 Need to intensify research and monitoring efforts in the Western Pacific and adjacent regions

In view of predicted impacts of ocean acidification on ocean ecosystems, Dr Somkiat Khokiattiwong from the Phuket Marine Biological Center, pointed out that the effects of ocean acidification on organisms and ecosystems remain poorly understood with most of our knowledge based on simplified laboratory experiments. Given that the region is the epicentre of marine biodiversity and endemism of the world, more research and long-term monitoring are critically needed to develop meaningful projections on future impacts of ocean acidification on marine ecosystems, especially on coral reefs, in the region. Only then can resource and fisheries managers as well as policy-makers develop effective long-term mitigation and adaptation strategies for the region. To this end, he urged all countries in the region to intensify their research and monitoring efforts on ocean acidification, and further encouraged all to develop a joint WESTPAC programme to monitor the ecologic impacts of ocean acidification on ocean ecosystems, particularly coral reefs. He finally expressed his thanks to the NOAA expert team for their technical assistance provided in the planning and organization of this workshop.

3 Research and monitoring efforts on ocean acidification in the region

3.1 Ocean acidification threatens marine ecosystems and livelihood security in Bangladesh

Dr Shahadat Hossain from the University of Chittagong, Bangladesh presented that the recent analysis of time-series datasets on seawater pH and Sea Surface Temperature (SST) clearly indicated a declining trend of pH and showed a rising trend of SST in the northern Bay of Bengal, Bangladesh. Therefore, ocean acidification coupled with elevated levels of SST may threaten 66 coral species and 317 marine molluscs biodiversity of Bangladesh by hampering the process of reef/shell formation, i.e. calcification. In consequence, numerous reef-based organisms, including valuable fisheries and their habitats (i.e. spawning, feeding and nursery grounds), may shifts and thus affect species diversity, abundance and distribution, which may have significant implications for food security, nutrition and the livelihoods of millions of coastal poor.

He expressed with regret that no much research on ocean acidification was conducted so far in Bangladesh. Therefore, adequate research and continuous monitoring programme is required to determine the current and future socio-economic impacts of ocean acidification, and the development and implementation of specific national action plans and adaptation strategies on ocean acidification shall be accorded priority in Bangladesh.

Responding to questions on the average low pH 7.4 observed in the northern Bay of Bengal during 1990–1999 and how to distinguish whether it resulted from ocean acidification or from other anthropogenic inputs, Dr Hossain explained relevant studies need to be further conducted and standard observations methodologies need to be applied in Bangladesh. In addition, Dr Hossain's humble note is to consider coral reefs as global assets instead of any countries/regions and develop plan for the planet.

3.2 Coastal zone conservation and management in Cambodia

Dr Ratanak Ou, Ministry of Environment, Cambodia, briefed on the current status of Cambodia on marine biodiversity and its significant economic benefit provided for Cambodian. Despite plenty of conservation efforts provided in the National Biodiversity

Strategic and Action Plan, Cambodia's marine biodiversity and ecosystems have been severely affected mainly by human activities. Due to limited technical and human resources, research and monitoring of ocean acidification have not yet been well conducted. Nevertheless, he reported that his government has recognized the importance of marine scientific research and observations underpinning the management of marine biodiversity in Cambodia with ocean observations and ocean acidification listed as one priority area by the National Committee on Management and Development of Cambodian's Coastal Areas.

3.3 Acidification induced by the individual ocean conditions

Dr Qinsheng Wei from the First Institute of Oceanography, State Oceanic Administration of China, presented his research results on ocean acidification respectively in the large estuary of the Changjiang River and subtropical upwelling area off the coast of Vietnam in the South China Sea. He highlighted that these studies provided insight on the mechanisms responsible for acidification in different sea areas, which is essential for understanding and predicting acidification.

He introduced that escalating human activities had since the 1980s been resulting in excess nutrient enrichment and severe environmental problems such as harmful algae blooms (HABs) and hypoxia at the bottom off the Changjiang River estuary. The result from the survey in May and August of 2011 showed that the bottom hypoxia and acidification occurred off the estuary from the spring to summer, and the extensive area of low pH coincided with the hypoxic zone. Furthermore, the analysis of data collected off the Changjiang River estuary revealed a significant positive correlation between bottom water pH and dissolved oxygen (DO) concentration, which provided a link of acidification to oxygen consumption via the remineralization of local organic matters. In the case of upwelling systems, Dr Wei introduced that the cross-shelf transects conducted in June of 2009 revealed the upwelling off the coast of Vietnam. The results showed that the sea surface pH was lower in the upwelling area than in the nearby non-upwelling area. Meanwhile, large amounts of nutrients brought to shallower depths by the upwelling could also promote the reproduction of phytoplankton in the upper layer waters, which would thereby increase buffering capacity to the further decreasing of pH. However, compared with the biological production associated with the upwelling, the physical transport of CO_2 rich waters from subsurface layers was predominant, leading to a decrease in pH value. In the end, he concluded that those signals of acidification in river estuary and open upwelling systems suggested that the intense acidification may be closely related to the typical/special ocean conditions.

3.4 Efforts and case studies of NMEMC in the research and monitoring of the ecological impacts of ocean acidification on coral reef ecosystems

Dr Zhendong Zhang, National Marine Environmental Monitoring Center (NMEMC), China briefly reported on the efforts of his institute on the research and monitoring of the impacts of ocean acidification on coral reefs. He provided a case study on Xisha Islands (Paracel islands) with monitoring results from 2005 to 2009 showing high seawater acidity. Among all 74 bottom-monitoring stations, 19 stations' pH value were lower than 8, and 29 stations' pH value ranged between 8 and 8.1. This may provide some clues for the severe degradation of coral reefs in that area.

He also introduced some other ocean acidification related research and monitoring programmes his institute conducted, including the identification of coastal ecological monitoring and control zones, sensitivity assessment of marine ecoregion to climate change, use of *Emiliania huxleyi* as proxy in monitoring ocean acidification, experimental studies on the effects of ocean acidification on sensitive marine organism, and capacity assessment of CO_2 sequestration and pre-study of risk control technology. Given limited knowledge, he

finally stressed the need for cooperation among all in the research and monitoring the impacts of ocean acidification.

3.5 Experimental effects of climate change and ocean acidification on coral reefs: synergic impacts and management implication

Dr Jamaluddin Jompa, Hasanuddin, University of Indonesia, pointed out that, despite predicted greater risks of ocean acidification to the Coral Triangle than any other areas, the ocean acidification has not drawn high attention from policy-makers and the general public in the Coral Triangle Initiative (CTI) and Indonesia yet. He illustrated the risks with the experimental effects of the increased temperature (at three levels: 30, 32, and 34^{o}C) and CO_2 concentration (at three levels: 385, 750, and 1000 ppm) on the growth and zooxanthella density of *Acropora formosa.* The results indicated that both temperature and CO_2 have significant impacts on coral conditions.

Given that some 85% of Indonesian reefs are under integrated local threats, he expressed his concerns over the potential synergistic effects of ocean acidification. He shared his opinion that ocean acidification may offer a "blessing in disguise", impelling managers at all levels to apply effective conservation efforts, i.e., ICM, MPA and EAFM, to build the resilience of ocean ecosystems to ocean acidification and other global threats. In this regard, Dr Jompa further suggested that ocean acidification be strategically addressed through the inclusion into the CTI Regional and National Plans of Action and other high-level political commitments.

Further to several inquiries from the floor, Dr Jompa expressed that, despite limited research and experiments conducted in Indonesia as a result of financial and facilities constraints, he would consider selecting one site to join the regional collective efforts. In addition, the importance of engaging local communities was also stressed concerning how to draw the attention of policy-makers in Indonesia to ocean acidification.

3.6 Ocean acidification in Indonesia: present and future

Mr Suratno, Indonesian Institute of Sciences (LIPI), Indonesia presented the research status on ocean acidification in Indonesia. He informed that there were lack of knowledge on biological and chemical parameters to be measured and ecosystem responses to the increasing ocean acidification in Indonesia. Limited efforts include chemical measurement conducted in Pari Island, Cirebon Estuarine, Banten Bay, Donan Estuarine, Nasik Strait, Java Sea to Nutuna Sea, Probolinggo Estuarine, Lombok (West Nusa Tenggara), Maluku Area, North Sulawesi, and Bintan; and laboratory experimental study on the impacts of ocean acidification on several species. Research and publication on ocean acidification in Indonesia still remain rare due to high cost in conducting the research and lack of ocean acidification research plan. Therefore, he suggested that monitoring the impacts of ocean acidification on coral reef ecosystems requires plenty of considerations including research approach, and collaboration nationally and regionally.

3.7 Projecting the combined effects of rising seawater temperatures and ocean acidification on coral habitats around Japan under multiple climate change scenarios

Dr Shintaro Takao from Hokkaido University, Japan presented his study on the potential combined effects of rising seawater temperatures and ocean acidification on tropical/subtropical and temperate coral communities in the seas around Japan. He explained that Japan is uniquely suited for assessing the effects of rising seawater temperatures and ocean acidification on corals as it extends across a wide latitudinal range, covering subtropical to temperate areas.

He introduced that sea surface temperature (SST) and aragonite saturation state (Ω_{ar}) were used as a simplified index for global warming and ocean acidification, respectively. Based on the estimation form four coupled global carbon cycle-climate models ((MIROC-ESM(Japan), HadGEM2-ES (UK), IPSL-CM5A-LR (France), and GFDL-ESM2G (USA)) under the four IPCC AR5 CO_2 emission scenarios, he reported that continued warming may drive a northward shift in coral habitats with large differences depending on the climate scenario. For the highest emission scenario, coral habitats are projected to suffer coral bleaching and low Ω_{ar}. As a result, the suitable habitat for tropical/subtropical coral communities around Japan may be reduced by half by the 2020s to 2030s, and is projected to disappear by the 2030s to 2040s. Previously suitable habitat for the temperate communities is also projected to become untenable by the 2070s, although they are thought to have the higher tolerance for low Ω_{ar}. For the lowest emission scenario, most existing tropical/subtropical communities would be affected by severe bleaching. However, temperate communities would not be impacted by both bleaching and low Ω_{ar} until the 2090s. Dr Takao suggested that Japanese corals may be endangered in the high CO_2 world. He concluded that CO_2 reduction is needed to minimize influences of rising water temperatures and ocean acidification to corals.

3.8 Variability of the inorganic carbon system in the Mid-East Coast of Korea

Dr Geun-Ha Park, Korea Institute of Ocean Science & Technology (KIOST), Republic of Korea reported on her investigation on the seawater carbonate system and the effect of upwelling on Ocean Acidification in Hupo, a central part of the east coast of South Korea. The estimated mean net sea-air CO_2 flux was −1.99 ± 1.18 mol C m−2 yr−1, indicating that this region was a sink for atmospheric CO_2. Monthly data revealed that temporal changes in surface CO_2 concentrations and $CaCO_3$ saturation states (Ω) were mainly governed by physical and biological processes. In particular, the wind-driven upwelling observed in July 2013 brought waters with high nutrients/CO_2 and low pH/Ω to the surface, thus resulting in enhanced biological production in surface waters.

She concluded that, given that ocean acidification in this coastal ecosystem is expected to be exacerbated by anthropogenic CO_2 uptake and upwelling, long-term monitoring, along with comprehensive measurements of carbon and other parameters is critically needed.

3.9 Transcriptional changes in coral responding to the marine acidification and rising seawater temperature

Dr Seonock Woo, Korea Institute of Ocean Science & Technology (KIOST), Republic of Korea pointed out that the biological and physiological processes of many organisms will be challenged by increasingly acidic conditions and temperatures. Experiments have been carried out on the physiological aspect, and transcriptional responses of the soft coral (*Scleronephthya gracillimum*) in Korea against the various combinations with or without increased heat and carbon dioxide (CO_2).

She presented that morphological changes were induced after corals were exposed 24 hrs to the pH stress (pH 7.0, pH 7.5), heat stress (28 ^{0}C) and pH combined with heat stress (28 ^{0}C + pH 7.0, 28 ^{0}C + pH 7.5) respectively. The microarray experiment indicated the shared genes in corals responded to various stresses. Eight common genes expressions were induced and 9 common genes were reduced by greater than two fold by 28 ^{0}C, pH 7.0, pH 7.5, 28 ^{0}C + pH 7.0 and 28 ^{0}C + pH 7.5. These genes had the significant changes in expression, particularly when temperature stress was combined with pH stress. She further suggested that these isolated gene candidates were differentially expressed and might be used as molecular biomarkers for the identification of environmental stressors.

The presentation aroused wide interests from participants. As to how to observe the different gene expressions induced in hard corals, Dr Woo responded that the different gene expression in hard corals could be observed by their colour and tissue. In terms of whether coral could recover if the environment would be reversed back to normal, she explained from her experiment that it was likely for corals to recover if they were exposed to those stressors shorter than three days.

3.10 Growth rate comparison of Pacific Oyster, Crassostrea Gigas, reared in a high-CO_2 environment

Dr Jeong Hee Shim, National Fisheries Research and Development Institute, Republic of Korea introduced that, given the mass Pacific oyster production and its economic benefits in Korea, she carried out a study both in the laboratory and an *in situ* experiment to discover effects of ocean acidification on the growth rate of the Pacific oyster *Crassostrea gigas*. She explained that artificial mesocosm facilities were established at the most important oyster spawning area of Korea on Nulcha Island with mean pH_{NBS} values (±SD) of controlled environment (M1, M2) established respectively at 7.71±0.28 and 7.72±0.28, and that of reference at 8.20±0.12. Juvenile oysters with mean (±SD) shell length at 29.21±6.30 mm and weight at 4.08±2.36 g (n=90), were detached from shells of scallop (a device for settling spat), and exposed to three mesocosm treatments.

Dr Shim presented the result that the mean growth rates of oyster weight and shell length were significantly different. The weight and length growth rate of reference were higher than those of low pH controlled. These results indicated that ocean acidification can seriously affect shell and weight growth of juvenile oysters, resulting in significant loss of oyster aquaculture industry.

3.11 Diurnal changes of pH and alkalinity on the coral reefs of the straits of Malacca, and the South China Sea

Dr Zulfigar Yasin, Universiti Malaysia Terengganu, Malaysia emphasized the need to study the effects of ocean acidification on coral reefs, as they are believed to be particularly vulnerable to ocean acidification. In view of knowledge on the diurnal fluctuation in seawater pH and total alkalinity (A_T) providing information on the range of natural variability that coral reef organisms are exposed to, his research team documented 3-day diurnal variability in pH and total alkalinity (A_T) on shallow water coral reefs at three different islands in the Straits of Malacca and the South China Sea during the wet season.

He explained that the result showed distinct diurnal fluctuation throughout the observation period at all three locations. It is suggested that the diurnal variability can occur as a result of biological processes, such as respiration and photosynthesis. In terms of future studies, he further suggested: (i) studies on calcification rates and reef integrity in the region taking into consideration local stressors; (ii) development of a common methodology for the monitoring of ocean acidification on coral reefs; (iii) increase of the number and spread of long-term monitoring sites; (iv) development of baseline carbonate chemistry information and data sharing for the Southeast Asia region at selected sites; (v) study on the depth of certain reefs and the effect of ocean acidification on these and associated biota; (vi) integrated research with other physical and chemical approaches of ocean acidification and beyond, and socio-economics of reef use and especially to fisheries.

The presentation was well received with a wide range of inquiries made from participants. Responding to the inquiry on whether the success in conducting the monitoring could be replicated at national level on ocean acidification, Dr Yasin informed that the National Professors' Council, Malaysia had agreed to incorporate ocean acidification and climate change into the curriculum of primary school in Malaysia. Recognizing the need to

demonstrate the value of ocean acidification research and monitoring for economic benefits, he also briefed the meeting on another project studying the effects of ocean acidification on molluscs given a big portion molluscs amounting to the whole aquaculture in Malaysia.

3.12 Changes on a coral reef at a thermal vent along a pH gradient – community characteristics of corals and molluscs

Dr Aileen Tan Shau Hwai from the Universiti Sains Malaysia, Malaysia presented her study on a coral reef in the vicinity of an underwater thermal vent in Pulau Weh, Indonesia as a "window" to future survival of corals exposed to ocean acidification. Three parameters were measured, including pH of seawater during wet and dry season, live coral coverage and coral genus composition. In this study, the pH at the site at Pulau Weh ranged from 6.89-7.89 in dry season and 6.99-8.01 in wet season. Locations of sampling points along the pH gradient were established. She pointed out that the result shows that live coral at the sampling points far away from the thermal vent (pH 7.83) are healthier than the ones at the source of thermal vent (pH 7.21).

Dr Aileen further studied shell characteristics of bivalves collected from the areas with different pH environment namely three sites in Pulau Weh, Indonesia: jetty, hotspring station and bubble station. These stations are located along a pH gradient. The control site was in Penang, Malaysia (control site). The shell characteristics of the bivalves from different locations were studied using X-ray diffraction, X-ray Fluorescene and Scanning Electron Microscopy. Results showed that the degree of crystallinity decreased in shells exposed to lower pH environment. The microstructure of the shells changed from large irregular shapes to flat as the pH in the environment decreased. The findings from this study described the changes in the shell characteristics of bivalves with respect to the changing of the pH of seawater along a gradient.

Dr Aileen also pointed out that larvae, produced by broodstock from different pH environments, exhibited different responses to different pH environments. Larvae produced by broodstock harvested from low pH environment were able to tolerate lower pH levels compared to those produced by broodstock harvested from a higher pH environment. In addition, she concluded that the settlement response of oyster larvae was influenced more by the salinity than by the pH level of the environment. This information may be useful in the selection of oysters to sustain the oyster/fishery industry in the region.

3.13 Impacts of ocean acidification on marine biodiversity: gaps and potential research collaboration

Dr Emienour Muzalina Mustafa, University of Malaya, Malaysia provided an overview of a variety of research activities on ocean acidification at the University of Malaya, which included the understanding of long-term pCO_2 trends in Malaysian Waters, large scale mesocosm experiments: investigating bacterial respiration in high CO_2 waters, effects of acidification on bacterial process rates, carbon flux through bacteria in coastal waters of Peninsular Malaysia, effects of acidification on marine microbial diversity and proteases, and effects of ocean acidification and temperature change on seaweed halocarbon emissions.

She informed that great research opportunity was offered by her university to develop joint research on response of coastal and marine habitats in the South China Sea region to ocean acidification and potential adaptation strategies, which aims to cover the following topics: variability in habitat responses to ocean acidification; pH and seawater chemistry changes in habitats in response to elevated CO_2 levels; response and tolerance of commercially & ecologically important marine species to pH/CO_2 changes; to identify the tipping points and adaptation: innovative technology to ensure sustainable benefits and

habitat protection under future climate (e.g. ecosystem-based fisheries management; coastal protection; renewable energy).

3.14 A concerted monitoring and research framework on coral reefs conservation by Malaysian Universities

Dr Hii Yii Siang from the University Malaysia Terengganu expressed his concern over monitoring and research on coral reef conservation in the region. He reported that coral reefs monitoring presents a great challenge to researchers due to the fluctuating baseline observation as a result of lack of standardized methodologies including monitoring devices. Coral reef monitoring programs in Malaysia were mainly conducted respectively by three groups, researchers, government agencies, and NGO/public, which could generate different reports and interpretation on the same study area of coral reef ecosystems.

To address the problem, he highlighted the need for a concerted monitoring and research framework on coral reefs conservation. He informed that the coral reef conservation and restoration framework was moulded at the Institute of Oceanography and Environment, a High Institution Centre of Excellence (HICOE) under the Ministry of Education, Malaysia with four stakeholders identified under the framework: university researchers, government administrators, non-governmental organizations and communities. He pointed out that the current challenge was to establish a standard monitoring protocol and platform for data sharing in the region.

3.15 Status of ocean acidification research in the Philippines

Dr Maria Lourdes San Diego-McGlone, University of the Philippines reported on the status of the Philippines reefs, as well as on related and on-going work on ocean acidification in the Philippines. Dr McGlone mentioned that ocean acidification research in the Philippines is relatively new. Initial efforts include collaborative work with NOAA to deploy instrumentation to establish baseline observations, and individual studies by foreign research partners and student theses to examine carbonate chemistry. Current research on ocean acidification in the Philippines focuses on studies to determine coral species that are resilient to stressors such as pH, temperature, and nutrients. These studies are part of coral restoration efforts. She emphasized that only less than 5% of Philippine reefs are in excellent condition.

According to Dr McGlone, there are facilities to conduct ocean acidification research at the Bolinao Marine Laboratory (BML), the marine station of the Marine Science Institute, University of the Philippines. Research on the threats to coral reef including global warming and ocean acidification is needed for the Philippines coral ecosystems.

3.16 Coral reef monitoring in the Philippines

Dr Hazel Arceo from the University of the Philippines presented the trends in coral reef assessment and monitoring in the Philippines. The Philippines was one of the first countries to undertake a systematic inventory of its coral reefs in the 1970's. Technical capabilities to carry out scientific reef assessment were enhanced starting in the mid- 1980's through an ASEAN-Australian collaborative project. Monitoring (or repeated assessments) was initially conducted in a few sites, particularly to determine the effects of two marine protected areas (MPAs) in Central Philippines, but has since been done in many other MPAs in the country over the years.

She further reported that community-based or participatory reef monitoring methods were developed in the 1990s, with the recognition that the capacity to monitor reefs need not

be limited to the academic and government institutions. Dr Arceo also presented that a national programme for the nationwide assessment of coral reefs was initiated in 2014 to determine the state of coral reef environments in the Philippines and to present possible projections of their future state based on their vulnerability and resilience to human and climate-related threats. The programme aims to lay the groundwork towards the development of a more systematically designed national coral reef monitoring programme by establishing monitoring sites in appropriate locations. A crucial component of this monitoring programme is regular feedback of information to facilitate timely management responses and actions.

3.17 Influence of pH on coral larvae and the monitoring of carbonate system in a Thai reef

Dr Suchana Chavanich from Chulalongkorn University introduced that only limited studies have been done related to ocean acidification monitoring and its impacts on coral reefs in Thailand. However, a monitoring site has been established at Sameasan Island, Chonburi Province In the upper Gulf of Thailand to monitor total alkalinity, dissolved inorganic carbon and pH since December 2013 with assistance of the Phuket Marine Biological Center in some chemical analysis. In addition, laboratory experiments were conducted to investigate the influence of pH on the larval development and settlement of the corals, *Pocillopora damicornis and Acropora millepora.*

She detailed her study on the effect of pH on the larval development and settlement of the corals, *Pocillopora damicornis and Acropora millepora*. The results showed that pH had a potential effect on the settlement and development of coral larvae of *Pocillopora damicornis*: when pH decreased, the settlement rates decreased, and larval development delayed and was not able to complete in low pH such as at 7.6. In addition, pH also affected the fertilization and settlement rates of *Acropora millepora*. She finally informed that, in partnership with the Phuket Marine Biological Center, ocean acidification monitoring in Thailand would be carried on at Sameasan Island in the Gulf of Thailand and other locations in the Andaman Sea.

3.18 Ocean acidification monitoring program of the Department of Marine and Coastal Resources

Dr Somkiat Khokiattiwong from the Phuket Marine Biological Center, Thailand briefed on the Ocean Acidification Monitoring Program of the Department of Marine and Coastal Resources. He informed that Phuket Marine Biological Center is one of the five research centers of the Department conducting research related to the ocean acidification. From 2007 to 2012, PMBC had implemented three projects, namely ORCAS project, Bioassay project and Calcification on Marine Organisms projects focusing on internal wave and ocean acidification-related parameters. Dr Somkiat informed that in 2014 stations along the Andaman coast were designed and water samplings of SST and chemical properties has been carried out. In 2015 the centre planned to expand study area along the Gulf of Thailand.

He expected that the research being conducted since 2014 in the Andaman Sea and the Gulf of Thailand will address its objectives to: (i) understand the status of acidity of seawater in Thai waters; (ii) understand the chemical property of seawater (especially the acidity) around vicinity of coral reefs; (iii) develop and increase research capability on the ocean acidification in Thai waters; and (iv) develop long-term monitoring and studies on ocean acidification and its impacts on marine ecosystem in the future.

3.19 Overview of NOAA ocean acidification research and monitoring programme

Dr Dwight Gledhill, NOAA, USA outlined the NOAA Ocean Acidification Program (OAP), which was established to oversee and coordinate research, monitoring, and other activities consistent with the Strategic Plan for Federal Research and Monitoring of Ocean Acidification developed by the US Interagency Working Group on Ocean Acidification (IWGOA). The programme aims to foster, direct and coordinate: (i) interdisciplinary research to improve understanding of ocean acidification; (ii) the establishment of a long-term monitoring programme of ocean acidification; (iii) research to identify and develop adaptation strategies and techniques for effectively conserving marine ecosystems; (iv) educational opportunities exploring the impacts of ocean acidification; (v) national public outreach; and (vi) coordination of ocean acidification monitoring and impacts research with other appropriate international ocean science bodies. The OAP supports a variety of research projects.

Dr Gledhill highlighted the cross-disciplinary approach of OAP to the development of its ocean acidification monitoring network, which involves various monitoring platforms and technologies, and a variety of research projects around U.S in various ecosystems to better understand ocean acidification and its impacts.

3.20 Overview of academic research and monitoring on ocean acidification on coral reefs

Dr Anne Cohen, Woods Hole Oceanographic Institution (WHOI), USA elaborated on the research of the US academic community on the impact of ocean acidification on reef structure in view of valuable and vital ecosystem services that coral reefs provide. The ability of the reef to provide the ecosystem services depends on the ability of corals and other reef calcifying organisms to grow and produce calcium carbonate (calcification) faster than the reef is eroded away (bioerosion).

Given the projected pH decline by the end of this century (up to 0.35 units across global tropics), Dr Cohen briefed that existing laboratory experiments and field studies at naturally low pH reef sites showed that the projected pH decline will negatively impact calcium carbonate production and increase rates of bioerosion.

She further illustrated that the rates of calcification and bioerosion are modulated by multiple physical, bio-geochemical and biological factors, not only pH. The impact of ocean acidification would occur faster and be felt sooner on some reefs than on others. She explained that the reef benthic community plays a major role in how the pH of seawater within the reef system responds to the progressive acidification of the open ocean that surrounds it, as photosynthesis, respiration, and calcification change the chemistry of ocean water as it moves over the reef.

As to quantifying whether/how and how rapidly the reef community is responding to ocean acidification and climate change, Dr Cohen stressed the importance of establishing baseline observations now so that variations in reef chemistry on diurnal, seasonal and inter-annual timescales, as well as the community responses to those changes on the same time-scales could be compared with data collected in the same way several decades from now.

3.21 Monitoring activities of coral reefs in Vietnam

Dr Van Long Nguyen, Institute of Oceanography, Vietnam reported on coral reef monitoring activities conducted in Vietnam since 1998. Despite the lack of a national integrated coral reef monitoring programme in Vietnam, the number of monitoring sites

gradually increased from 8 in 1998 to 33 in 2012 with the support from several provincial, national and international projects.

He explained that parameters monitored were mainly focused on biological aspects (benthic cover, reef fishes and macro-invertebrates), and physical impacts to coral reefs (dynamite, anchoring, coral bleaching, COTS, *Drupella snails*). Overall status of coral reef benthos surveyed from 1994 to 2012 showed a notable decline. Over the last several years, coral reefs in many areas of Vietnam have severely suffered from coral bleaching, coral damage from natural events (storms), fishing methods and coastal development (ports, airports, dredging) and invasive organisms (COTS, *Drupella, Diadema*).

Dr Long informed that Vietnam would keep maintaining the monitoring of biophysical factors with the additional parameters (pH and CO_2) at key locations of coral reefs and three sites in the national environmental monitoring system, and develop new projects for research and monitoring of impacts from ocean acidification on coral reefs.

3.22 Trend of coastal water quality of Nha Trang Bay, Viet Nam

Ms Vinh Le Thi, Institute of Oceanography, Vietnam reported that water quality monitoring in the whole Nha Trang bay was carried out from 2007 to 2014. The results of the surveys in the dry (from April to June) and rainy season (October to November) showed that the value of the common parameters (pH, TSS, DO, BOD_5), nutrient concentrations ($NH_{3,4}$, NO_2, NO_3 and PO_4, SiO_3), heavy metals (Fe, Zn, Cu and Pb), hydrocarbon changed over location with higher nutrient concentrations and Fe and lower pH in mouths, and over time with higher values of DO, BOD_5, SiO_3, NO_2 and Fe and lower values of pH and ammonia in the rainy season. From 2007 to 2014, water quality did not change clearly despite the obvious decrease in TSS and hydrocarbon and increase in BOD_5 and Cu in both seasons.

She further reported on the water quality at the coral reef in Nha Trang Bay. The results of surveys in August 2010 and 2013 showed that there was no obvious change in water quality. According to the criteria for coral reef conservation, coastal water quality in the entire bay was quite good in general, although there were some sporadic contaminations at some locations over time.

4. Approaches and challenges

This session is intended, with case study provided on the US NOAA National Coral Reef Monitoring Program (NCRMP), particularly its Pacific Reef Assessment and Monitoring Program (Pacific RAMP), to elaborate on the comprehensive interdisciplinary approach to monitoring ecological impacts of ocean acidification on coral reefs and possible components of an ocean acidification monitoring network.

Dr Rusty Brainard, Pacific Islands Fisheries Science Center of NOAA, started his presentation by pointing out the predicted significant impacts of ocean acidification on coral reefs and the associated ecosystem services they provide to human societies. He stressed the importance for long-term monitoring of ecological impacts of ocean acidification on coral reefs in order to inform, validate, and improve laboratory studies and modelling predictions of future conditions and impacts. He further elaborated on US NOAA's collaborative and integrated efforts to monitor the ecological impacts of ocean acidification on coral reef ecosystems mainly through its Pacific Reef Assessment and Monitoring Program, which aims to assess spatial patterns and monitor long-term temporal trends of seawater carbonate chemistry, benthic community structure and biodiversity, and calcification and bioerosion rates of corals and calcareous algae spanning gradients of biogeography, oceanography, and anthropogenic stressors across the central and western Pacific.

Dr Rusty detailed the technical and technological requirements for carbonate chemistry measurements and biological surveys, with focus on autonomous reef monitoring structures (ARMS), calcification accretion units (CAUs) and bioerosion monitoring units (BMUs). Recognizing the need for simple, consistent/systematic, cost-effective time series observations of physical, chemical, ecological, and biological conditions and processes to inform policy & resource management decisions in WESTPAC countries and region, he further urged WESTPAC countries to collaborate internally, regionally, and globally to monitor/observe and model ecological impacts of ocean acidification.

4.1 Approaches/challenges to monitoring carbonate chemistry of coral reef ecosystems

Following Dr Rusty's overview, Dr Gwight Gledhill from the NOAA Ocean Acidification Program, briefed on approaches to monitoring carbonate chemistry of coral reef ecosystems by drawing the attention of all participants to several available resources and publications online, which include the Guide to Best Practices for Ocean CO_2 Measurements; Guide to Best Practices for Ocean Acidification Research and Data Reporting.

He introduced that at present four parameters can be reliably measured for the seawater carbon dioxide system (A_T, DIC, pH, pCO_2), and one of these, pH, has multiple possible definitions which in turn can result in multiple values for acid-dissociation constants. *Handbook of methods for the analysis of the various parameters of the carbon dioxide system in seawater* (DOE, 1994) and of the more recent *Guide to Best Practices for Ocean CO_2 Measurements* (Dickson et al., 2007) and recommend use of the so-called total hydrogen ion concentration scale to define pH in seawater media. At this time, the analytical methods described in the *Guide to Best Practices for Ocean CO_2 Measurements* (Dickson et al., 2007) are presently the best understood and have the lowest uncertainty. For studies on natural seawater, he recommended to measure A_T and DIC as samples for these can be preserved easily and the measurements could be made with low uncertainty.

Dr Adrienne Sutton, NOAA/UW Joint Institute for the Study of the Atmosphere and Ocean, shared her experience on challenges to using autonomous sensors, including pCO_2/pH pair, depth, accuracy, biofouling and shipping/customs issues for factory recalibrations. To address those challenges, she further recommended that sensors be chosen based on what research question shall be addressed for cost effectiveness, collaboration be established with existing observation programs, sensor uncertainly be verified with information provided in literatures, and future technologies be anticipated.

4.2 Approaches/challenges to monitoring biological impacts of OA on coral reef ecosystems

Dr Rusty emphasized the importance of leveraging existing coral reef monitoring programmes when considering developing the monitoring programme on the biological impacts of ocean acidification on coral reefs. It is essential to bring together scientists from different disciplines to develop integrated and collaborative research for informed decisions.

Intensive and extensive discussions were prompted on various technical and financial challenges to the development of an integrated ocean acidification monitoring program/network, ranging from the minimum measurement requirement to the criteria for selection of pilot sites, from uniformity in methodology to inter-laboratory comparison and analysis.

4.3 Integrating the use of ocean models into observing system design

Dr Tom Oliver from the Pacific Islands Fisheries Science Center, NOAA highlighted the needed balance between good temporal resolution/coverage and good spatial resolution/coverage. Therefore, ocean models could be used as one of cost-effective tools in ocean acidification monitoring system/network design.

He explained that, while data with good quality and coverage could help build more robust and stable models, models could guide data collection to achieve good representation with samples at oceanographically distinct areas. He further illustrated with the NOAA NCRMP, the combination of “Deep Anchor” approach, i.e., deploy automated instrument, to document temporal variability in a few places, and “Wide Net” approach, i.e., to spread water-sampling efforts, to minimize temporal variability across samples in many places. He further underscored the importance to share sampling protocols among institutions in order to ensure collected data is comparable for a regional and global perspective.

5. Brainstorming on the way forward, particularly bearing in mind the objective to develop a regional program to monitor the impacts of ocean acidification on coral reef ecosystems

The purpose of this session is to enable all experts to brainstorm any feasible ideas on future collaborative research and/or monitoring efforts on ocean acidification in the region.

In the light of limited research and monitoring capacity for ocean acidification in the region, all participants stressed the need for cooperation and collaboration among scientists, institutions, and countries in the region. The participants recognized that the present ocean acidification related research and monitoring efforts in most of countries are in rudimentary stage. In this connection, several pertinent points were raised on future collaboration that WESTPAC could facilitate and develop, which, inter alia, include:

- Preparation of course curricula for university education incorporating ocean acidification and related challenges (causes, effects, goods and services, adaptation, mitigation, biodiversity conservation, societal impacts) to metamorphose today’s readers as tomorrow’s leaders in this discipline;
- Development of outreach materials on ocean acidification and its social-economic impacts to convince high-level policy makers, fishery communities of the importance of research and monitoring on ocean acidification and its impacts on ocean ecosystems;
- Joint study on ocean acidification related scientific hypothesis, building on monitoring network to test hypothesis;
- Comparative observations on ocean acidification and its ecological impacts among countries with similar methodology and measurements adopted.

6. Breakout sessions

Following the brainstorming session, all participants broke out into two groups, one focusing on monitoring the biological aspects of ocean acidification and another focusing on monitoring the physical/chemical aspects of ocean acidification. The two groups discussed what measurements and parameters need to be accounted for in the program design, from a physical/chemical perspective, from a biological perspective, and most importantly, from an integrated perspective.

To facilitate breakout discussions, the following inexhaustible list of questions was proposed to the session participants:

- What minimum physical, chemical and biological parameters should be measured? Where? At what depths?
- What is the desired spatial (where? what depths? how many?) and temporal resolution (frequency) of these measurements?
- What (parameters) and where are the gaps in present observing systems? Where and what new measurements do we need?
- Where could be suggested as pilot sites with interests received for the development of a monitoring programme on the impacts of ocean acidification on coral reefs, and of joint research on ocean acidification and its related changes/process?

The Physical/Chemical Group breakout session

The Physical/Chemical Group, facilitated by Drs Adrienne Sutton and Dwight Gledhill and rapporteured by Dr Somkiat Khokiattiwong, started its session with mapping existing capacity for carbonate chemistry analysis in the region, followed by the identification of capacity building requirements for carbonate measurement and sample processing. With reference to the NOAA National Coral Reef Monitoring Plan (NCRMP), the Group briefly developed a draft outline for carbonate monitoring in the region's ocean acidification observing network, including proposed discreet physical/chemical parameters, and their temporal and spatial resolution for measurement. Before reporting to the plenary session, the Group proposed several criteria for the selection of pilot sites.

It was noted that many countries are already measuring standard parameters, such as Temperature (T), Salinity (S), Oxygen (O_2), Dissolved Inorganic Carbon (DIC), and Total Alkalinity (A_T). However, some modifications in methods to measure ocean acidification may be necessary. Meanwhile, to facilitate building regional capacity for carbonate measurement, Dr Sutton further came up with the following list of resource information, with which WESTPAC can help plan trainings for some labs to gain experience on measurement of the carbonate system and other methods.

- Online OA short course:
  http://www.whoi.edu/page.do?pid=33598
- *Guide to Best Practices for Ocean CO_2 Measurements* (standard methods for OA water sampling and analysis):
  http://cdiac.ornl.gov/oceans/Handbook_2007.html
- *Guide to best practices for ocean acidification research and data reporting*:
  http://www.epoca-project.eu/index.php/guide-to-best-practices-for-ocean-acidification-research-and-data-reporting.html
- Certified Reference Material:
  http://scrippsscholars.ucsd.edu/adickson/biocv
- CO_2 sys for calculating the carbon system:
  http://cdiac.ornl.gov/ftp/co2sys/
- Existing OA observational programmes for ideas and potential collaborations:
  http://www.goa-on.org/;
  http://docs.lib.noaa.gov/noaa_documents/NOS/CRCP/noaa_crcp_national_coral_reef_monitoring_plan_2014.pdf

Moreover, it was suggested that some labs might be able to serve as “Centres of Excellence” for carbon measurements and process samples from other groups that do not have access to a full carbon analytical laboratory.

The Biological Group breakout session

The Biological Group, facilitated by Drs Rusty Brainard, Apple Chavanich and Anne Cohen and rapporteured by Dr Aileen Tan Shau Hwai, initially focused on identifying the most appropriate biological parameters to observe and monitor to enable the ability to attribute ecological and biological changes of coral reef ecosystems to ocean acidification as part of the regional ocean acidification observing network. The Biological Group promptly reached consensus that the regional ocean acidification observing network for coral reefs should, wherever possible, build upon and augment existing coral reef monitoring programmes in each of the countries. There was also agreement on the need to outline a hierarchical approach with different levels or classes of observations ranging from a basic minimum set of parameters with minimum spatial and temporal resolution sampling to increasingly more comprehensive sets of parameters with higher spatial and temporal resolutions, similar to the approach outlined and implemented by NOAA. A hierarchical approach would enable institutions in each of the WESTPAC countries to be active and engaged members of the regional ocean acidification network by initiating their efforts and the class most appropriate to their existing resources and capacity. Over time, additional resources and capacity could be provided to enhance their capacity and observing capability.

The Biological Group discussed and agreed on the following key biological/ecological parameters to monitor, which they then prioritized into 4 different hierarchical classes from class 0 to class 3 as follows:

Class 0: (in many cases these are already a component of existing coral reef monitoring programs)

1. Water samples for carbonate chemistry (surface and benthic) stratified random sites to characterize area
2. Benthic cover, basic functional community composition including live coral cover (preferably to functional type, e.g. branching, massive, encrusting), macroalgae, sediments/sand, etc.
3. Biodiversity (species richness, abundance) with a primary focus on fisheries resources, including invertebrates (crustaceans, molluscs, sea urchins, sea cucumber, etc.)
4. Uses of the reefs
5. Levels of protection (e.g. marine parks, no-take zones, etc.)

Class 1: includes and builds upon Class 0 observations

1. Reef-mounted subsurface temperature recorders
2. Biodiversity (species richness, abundance) of fish and invertebrates important for fisheries (crustaceans, molluscs, sea urchins, sea cucumber, etc.)
3. Calcium carbonate accretion rates or production rates using Calcification Accretion Units (CAU) or equivalent standard
4. Photographic transect (techniques for archive)

Class 2: includes and builds upon Classes 0 and 1 observations

1. Diurnal cycle of carbonate chemistry by collecting water samples every ~4 hours (for a few days) or short-term deployments of pH sensors
2. Cryptobiota diversity measurements (the other 99%) using Autonomous Reef Monitoring Structures (9-12 per location)

3. Rates of bioerosion using Bioerosion Measurement Units (BMUs) (~4 sets of 5)
4. Coral recruitment using short-term settlement plates
5. Coral growth/calcification rates using shallow coral cores for massive corals and markers for branching corals
6. Calcium carbonate accretion or production rates using Calcification Accretion Units (CAU) or equivalent standard
7. Photographic transect (techniques for archive)
8. Vertical thermal structure using an array of reef-mounted temperature recorders at depths of ~1m, 5m, 15m, and 25 m.

Class 3: includes and builds upon Classes 0,1, and 2 observations

1. High temporal frequency measurements of carbonate chemistry using Moored Autonomous pCO_2 ($MApCO_2$) buoys or similar replacements capable of observing carbonate chemistry parameters on time scales from diurnal (every 3 hours) to seasonal (annual)
2. Bi-weekly water sampling for carbonate chemistry (TA, DIC)
3. Health, condition, disease, and abnormality of corals
4. Microbial community of water samples immediately adjacent to coral reefs

7. Reports of Breakout Groups, followed by Recommendations, Conclusions and the next steps

Following the results respectively generated from the two Groups, a plenary session was convened with extensive discussions made mainly on the most feasible approach to the development, building on existing coral reef monitoring initiatives, of a joint long-term monitoring programme or network on the impacts of ocean acidification on coral reefs in the region.

Given major challenges that vary from one country to another, including research and observing capacity disparity, and non-uniformity of measurement and sample analysis, the workshop decided that it would be more feasible to start the development of the monitoring program or network with pilot site demonstration sites.

To this end, the workshop selected several pilot sites, as a starting point for developing the regional monitoring program (or network), upon the strong interests and recommendations received from participants. These pilot sites preliminarily selected at the meeting include:

- Bangladesh:

Saint Martin’s Island	(20° 37' 38.12" N, 92° 19' 21.28” E)

- China:

Weizhou Island	(21° 1' 19.20" N, 109° 4' 37.20" E)
East coast, Hainan Island	(19° 16' 23.88" - 19° 58' 59.88" N, 110° 39' 24.12" - 110° 59' 26.52" E)

- Malaysia:

Bidong Island	(5° 37' 18.36" N, 103° 4' 19.55" E)
Cape Racardo	(2° 27' 31.10" N, 101° 50' 48.08" E)

- Indonesia:

Pari island	(5° 51' 40.21" S, 106° 35' 48.59" E)
Mataram site in Kodek Bay	(8° 23' 19.06" S, 116° 6' 13.96" E)

- Philippines:

Bolinao, Pangasinan	(16° 26' 16.39" N, 119° 56' 46.13" E)
Lian, Batangas	(13° 59' 46.40" N, 120° 37' 23.23" E)
Sablayan, Occidental Mindoro	(12° 51' 2.3826" N, 120° 46' 31.3572" E)
Taytay, Rizal	(10° 54' 42.86" N, 119° 31' 51.86" E)
Mactan, Cebu	(10° 17' 6.8028" N, 124° 0' 4.4568" E)
Samal Is., off Davao City	(07° 09' 47.40" N, 125° 40' 54.68" E)
San Juan, Siquijor	(9° 10' 31.2342" N, 123° 27' 42.1416" E)
Bongao, Tawi-Tawi	(5° 2' 46.536" N, 119° 44' 21.534" E)

- Thailand:

Ko Racha Yai (Island)	(07º 35' 40.4" N, 98º 22' 7.5" E)
Ko Miang (Island)	(08º 33' 41" N, 97º 38' 26" E)
Sameasan (Island)	(07° 11' 83.7" N, 13° 93' 46.9" E)

- Vietnam:

Nha Trang Bay	(12° 00’ - 12° 45’ N, 109° 15' - 109° 30' E)
Phu Quoc Island	(09° 45’ - 10° 30’ N, 103° 55' - 104° 05' E)

The workshop further requested Dr Rusty to revise the Table for Monitoring Capacity Analysis, initially developed by the Biological Group, by adding necessary physical/chemical parameters. Once done, it will be distributed to participants willing to join the program development, with a view to analysing the current monitoring capacity, identifying common monitoring methods, and further considering to develop a consistent, comparable and cost-effective “Standard Operating Procedure (SOP)” for all pilot sites.

In view of the pressing need to draw the attention of high-level policy makers and relevant stakeholders in the region to ocean acidification, the workshop decided to establish a Task Team led by Dr Aileen from Malaysia. The workshop further requested the Task Team start formulating, with technical assistance of the NOAA Ocean Acidification Program and other volunteers, an outreach flyer on ocean acidification and its social-economic impacts in the region.

Finally, all participants expressed their great appreciation to the IOC Sub-Commission for the Western Pacific for taking this initiative to develop regional partnership and observing network on ocean acidification, to the National Oceanic and Atmospheric Administration for its technical assistance, and the Phuket Marine Biological Center for logistics support it provided throughout the organization of this event. According to the timeframe specified in the attached Concept Paper, the second workshop was tentatively scheduled for late August or early September of 2015.

ANNEX I

AGENDA

OBJECTIVES OF THE WORKSHOP

- Improve the understanding, and develop regional capability of research and long-term monitoring on ocean acidification in the Western Pacific and its adjacent regions;
- share existing and proposed ocean acidification monitoring and research approaches, methods, and techniques;
- establish an ocean acidification monitoring and research network among scientists, institutions, and agencies in the region;
- identify challenges, gaps and explore the possibility, building on existing coral reef monitoring initiatives, of a joint long-term monitoring program on the impacts of ocean acidification on coral reefs, and of joint research on ocean acidification and its related changes/processes in seawater chemistry in the region.

1. Opening and self introduction
(*Facilitator: Mr Wenxi Zhu*)

- Welcome Remarks by Director of the Phuket Marine Biological Center (PMBC)
- Opening Remarks by Dr Somkiat Khokiattiwong, Chair of the IOC Sub-Commission for the Western Pacific (WESTPAC)
- Congratulatory Remarks by Dr Dwight Gledhill, Global Ocean Acidification Observing Network (GOA-ON), NOAA Ocean Acidification Program
- Participants' brief self-introduction

2. Setting the scene
(Facilitator: Dr Suchana Chavanich)

- Brief on the workshop objectives, layout and expected outputs and outcomes – Mr Wenxi Zhu, UNESCO/IOC Regional Office for the Western Pacific (WESTPAC)
- Overview on ocean acidification: what is OA and why do we care? – Dr Adrienne Sutton, NOAA/UW Joint Institute for the Study of the Atmosphere and Ocean
- Global Ocean Acidification Observing Network (GOA-ON) – Dr Dwight Gledhill, NOAA Ocean Acidification Program
- Need to intensify research and monitoring efforts in the Western Pacific and adjacent regions – Dr Somkiat Khokiattiwong

3. Research and monitoring efforts on ocean acidification in the region
(Facilitator: Prof Dr Jamaluddin Jompa, Dr Zulfigar Yasin, Dr Jeong Hee Shim, and Dr Maria Lourdes San Diego-McGlone)

- Ocean acidification threatens marine ecosystems and livelihood security in Bangladesh, Prof M. Shahadat Hossain, University of Chittagong, Bangladesh
- Coastal zone conservation and management in Cambodia, Dr Ratnak Ou, International Conventions and Biodiversity Department, Cambodia

- Acidification induced by the individual ocean conditions, Dr Qinsheng Wei, First Institute of Oceanography, China
- Efforts and case studies of NMEMC in the research and monitoring of the ecological impacts of ocean acidification on coral reef ecosystems, Dr Zhendong Zhang, National Marine Environmental Monitoring Center (NMEMC), China
- Experimental effects of climate change and ocean acidification on coral reefs: synergic impacts and management implication, Prof. Dr Jamaluddin Jompa, Hasanuddin University, Indonesia
- Ocean acidification in Indonesia: present and future, Mr Suratno, Indonesian Institute of Sciences (LIPI), Indonesia
- Projecting the combined effects of rising seawater temperatures and ocean acidification on coral habitats around Japan under multiple climate change scenarios, Dr Shintaro Takao, Hokkaido University, Japan
- Variability of the inorganic carbon system in the Mid-East Coast of Korea, Dr Geun-Ha Park, Korea Institute of Ocean Science & Technology (KIOST), Republic of Korea
- Transcriptional changes in coral responding to the marine acidification and rising seawater temperature, Dr Seonock Woo, Korea Institute of Ocean Science & Technology (KIOST), Republic of Korea
- Growth rate comparison of Pacific Oyster, Crassostrea Gigas, reared in a high-CO_2 Environment, Dr Jeong Hee Shim, National Fisheries Research and Development Institute, Republic of Korea
- Diurnal changes of pH and alkalinity on the coral reefs of the straits of Malacca, and the South China Sea, Dr Zulfigar Yasin, Universiti Malaysia Terengganu, Malaysia
- Changes on a coral reef at a thermal vent along a pH gradient – community characteristics of corals and molluscs, Dr Aileen Tan Shau Hwai, Universiti Sains Malaysia, Malaysia
- Impacts of ocean acidification on marine biodiversity: gaps and potential research collaboration, Dr Emienour Muzalina Mustafa, University of Malaya, Malaysia
- A concerted monitoring and research framework on coral reefs conservation by Malaysian Universities, Dr Hii Yii Siang, University Malaysia Terengganu
- Status of ocean acidification research in the Philippines, Dr Maria Lourdes San Diego-McGlone, University of the Philippines
- Coral reef monitoring in the Philippines, Dr Hazel Arceo, University of the Philippines
- Influence of pH on coral larvae and the monitoring of carbonate system in a Thai reef, Dr Suchana Chavanich, Chulalongkorn University
- Ocean acidification monitoring program of the Department of Marine and Coastal Resources, Dr Somkiat Khokiattiwong, Phuket Marine Biological Center, Thailand
- Overview of NOAA ocean acidification research and monitoring program, Dr Dwight Gledhill, NOAA Ocean Acidification Program, USA

- Overview of academic research and monitoring on ocean acidification on coral reefs, Dr Anne Cohen, Woods Hole Oceanographic Institution (WHOI), USA
- Monitoring activities of coral reefs in Vietnam, Dr Van Long Nguyen, Institute of Oceanography, Vietnam
- Trend of coastal water quality of Nha Trang Bay, Viet Nam, Ms Vinh Le Thi, Institute of Oceanography, Vietnam

4. Approaches and challenges
(Facilitator: Dr Somkiat Khokiattiwong)

- Monitoring ecological impacts of ocean acidification on Indo-Pacific coral reefs and what are the possible components of an ocean acidification monitoring network based on existing resources – Dr Rusty Brainard
- Approaches/challenges to monitoring carbonate chemistry of coral reef ecosystems – Dr Dwight Gledhill / Dr Adrienne Sutton
- Approaches/challenges to monitoring biological impacts of OA on coral reef ecosystems – Dr Rusty Brainard
- Integrating the use of ocean models into observing system design – Dr Tom Oliver

5. Brainstorming on the way forward, particularly bearing in mind the objective to develop a regional programme to monitor the impacts of ocean acidification on coral reef ecosystems
(Facilitator: Dr Rusty Brainard, Dr Somkiat Khokiattiwong, Dr Suchana Chavanich and Mr Wenxi Zhu)

6. Breakout sessions
(Facilitator:

Biological Group – Dr Rusty Brainard and Dr Suchana Chavanich;

Physical/chemical Group - Dr Dwight Gledhill, Dr Adrienne Sutton, and Dr Somkiat Khokiattiwong)

The purpose of this session is to define the measurements of the monitoring programme.

All participants will be divided into two groups, respectively on biological aspect and physical/chemical aspect. The two groups will focus on what measurements need to be accounted for in the programme design, from a physical/chemical perspective, a biological perspective, and most importantly, from an integrated perspective.

To facilitate breakout discussions, the following list of questions was proposed as below. However, please be assured that any other questions raised from prior sessions could be added at any time.

1. What minimum physical, chemical and biological parameters should be measured? where? at what depths?
2. What is the desired spatial (where? what depths? how many?) and temporal resolution (frequency) of these measurements?
3. What (parameters) and where are the gaps in present observing systems? Where and what new measurements do we need?
4. Where could be suggested as pilot sites with interests received for the development of a monitoring programme on the impacts of ocean acidification

on coral reefs, and of joint research on ocean acidification and its related changes/process?

7. Reports of breakout groups, followed by recommendations, conclusions, and next steps

(*Facilitator: Mr Wenxi Zhu*)

ANNEX II

LIST OF PARTICIPANTS

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ANNEX III

CONCEPT PAPER

Towards the Development of a Regional Programme to Monitor the Impacts of Ocean Acidification on Coral Reef Ecosystems

(v.4, 8 October 2014)

Justification

The ocean has absorbed about one third of the anthropogenic carbon dioxide (CO_2) emissions since the industrial revolution, greatly reducing the impact of this greenhouse gas on the climate. However, this massive input of CO_2 is generating global changes in the chemistry of seawater, especially on the carbonate system. These changes are collectively referred to as "ocean acidification" because increased CO_2 lowers seawater pH (i.e., increases its acidity). Quantitatively, ocean acidity has increased by 30% (0.1 decrease in pH) since the beginning of the Industrial Revolution. It is predicted that the future CO_2 absorption into the ocean will result in a decrease of pH of 0.3-0.4 and a 16% decrease in carbonate ion concentrations by 2100. According to geological records, this acidification is happening at rates not seen for at least 50 million years.

Recent studies have shown that the resulting decrease in ocean pH will make it more difficult for marine calcifying organisms, such as corals, molluscs, and calcareous plankton, to form biogenic calcium carbonate, and existing calcium carbonate structures will become vulnerable to dissolution. Thus, ongoing acidification of the oceans poses a threat to ocean-based security. Since this ocean acidification may be occurring more rapidly than prior ocean acidification events that are thought to have coincided with mass extinction events, there are concerns that marine ecosystems will change, that biodiversity will be lost, and that important ecosystem services that human societies depend upon for food security, livelihoods, and coastal protection could be significantly impacted. Unfortunately, the effects of ocean acidification on organisms and ecosystems remain poorly understood, with most of our knowledge based on simplified laboratory experiments.

The Western Pacific and its adjacent regions are among the richest and most productive in the world as a home to more than 600 coral species (more than 75% of all known coral species) and ~53% of the world's coral reefs. Most Southeast Asian coastal communities are socially and economically dependent upon coral reef ecosystems and an estimated 70-90% of fish caught in Southeast Asia are dependent on coral reefs. Globally, it has been estimated that coral reefs support greater than 25% of all known marine species.

Despite the recognition that ocean acidification from increasing levels of atmospheric CO_2 represents a major global threats to coral reefs and other calcifying marine organisms, awareness of the impacts of this 'other CO_2 problem' has emerged only over the last decade. The ecosystem responses to ocean acidification are poorly understood in the region and more research and long-term monitoring are critically needed to develop meaningful projections on future impacts of ocean acidification on marine ecosystem, especially on coral reefs, in the region to enable resource and fisheries managers, and policy-makers to develop effective long-term mitigation and adaptation strategies for the people of the region.

In this context, the IOC Sub-Commission for the Western Pacific (WESTPAC) aims to establish regional research and monitoring network on ocean acidification in the Western Pacific and its adjacent regions, and develop a regional programme, as one regional component of the Global Ocean Acidification Observing Network (GOA-ON), to monitor the impacts of ocean acidification on coral reef ecosystems, mainly through a series of regional

workshops & trainings, selection of pilot areas, and transfer of knowledge and technology among experts, institutions within and outside the region.

Workshop Objectives

To this end, upon the generous support of the National Commission of Thailand for UNESCO, the first Regional Workshop was scheduled for 19–21 January 2015 with the host of the Phuket Marine Biological Center.

The first regional workshop aims to:

- Improve the understanding, and develop regional capability of research and monitoring on ocean acidification in the Western Pacific and its adjacent regions;
- establish an ocean acidification monitoring and research network among scientists, institutions, and agencies in the region;
- share existing and proposed ocean acidification monitoring and research approaches, methods, and techniques;
- recommend efficient, robust, and cost-effective monitoring approaches;
- identify challenges and gaps in the development of a regional program to monitor the impacts of ocean acidification on coral reef ecosystems;
- explore the possibility, building on existing coral reef monitoring initiatives, of a joint long-term monitoring program on the impacts of ocean acidification on coral reefs, and of joint research on ocean acidification and its related changes/process in seawater chemistry in the region.

Based on outputs of the first workshop, the second regional workshop, supposed to be organized about six months after the first one, will focus on defining and agreeing upon a suite of metrics, which could discern, to the extent possible, attribution of changes to coral reef ecosystems in response to ocean acidification; recommend the most efficient, robust, and cost-effective monitoring approaches for these defined metrics; map gaps in current capabilities; and select pilot study areas for the application of the identified monitoring approaches.

The third workshop, one year after the second one, will be convened to evaluate and refine monitoring approaches, provide solutions to any technical problems incurred, and come up with a roadmap for the future.

Tentative Program for the first workshop

The first workshop will take place in Phuket, Thailand, 19–21 January 2015. The workshop would comprise plenary and breakout sessions.

During plenary sessions, invited keynote presentations will be given about ocean acidification, including changes in seawater chemistry, known and projected impacts on marine organisms and ecosystems at global and regional levels; global programmes on ocean acidification research and monitoring efforts; and present practices of monitoring the ecological impacts of ocean acidification on coral reef ecosystems. National experts nominated and/or identified from each country will be invited to provide reports on research and monitoring efforts on the effects of ocean acidification on coral reefs, or related activities, in their respective countries.

The participants will break into several groups (probably by sub-regions) to have detailed discussions about gaps, challenges, and opportunities to initiate a cooperative

regional network to monitor and conduct research on the impacts of ocean acidification on coral reef ecosystems.

Qualification of invited experts

Preferably two scientists will be invited from each country with one on marine biology with focus on coral reefs and coastal ecosystems, and the other on marine chemistry specialized in carbonate chemistry. Ideally, *they should have experience conducting ocean acidification related research and monitoring, and are able to lead and carry out ocean acidification research and monitoring in their countries moving forward.*

IOC Workshop Reports

The Scientific Workshops of the Intergovernmental Oceanographic Commission are sometimes jointly sponsored with other intergovernmental or non-governmental bodies. In most cases, IOC assures responsibility for printing, and copies may be requested from:

Intergovernmental Oceanographic Commission – UNESCO
1, rue Miollis, 75732 Paris Cedex 15, France

No.	Title	Languages
1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand, 24-29 September 1973 UNDP (CCOP),	E (out of stock)
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (UNESCO Technical Paper in Marine Sciences, No. 20).	E (out of stock) S (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean; Monte Carlo, 9-14 September 1974.	E,F E (out of stock)
4	Report of the Workshop on the Phenomenon known as 'El Niño'; Guayaquil, Ecuador, 4-12 December 1974.	E (out of stock) S (out of stock)
5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources; Kingston, Jamaica, 17-22 February 1975	E (out of stock) S
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Suva, Fiji, 1-6 September 1975.	E
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/UNESCO/ EAC; Nairobi, Kenya, 25 March-2 April 1976.	E, F,S, R
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters; Penang, 7-13 April 1976	E (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience; Mauritius 9-13 August 1976.	E, F, S, R
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring; Monaco, 14-18 June 1976	E, F E (out of stock) R
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976.	E, S (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions; Port of Spain, Trinidad, 13-17 December 1976	E (out of stock), S
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects; Fort-de-France, Martinique, 28 November-2 December 1977.	E, F, S
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area; Port of Spain, Trinidad, 16-18 January 1978.	E, S
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas; Abidjan, Côte d'Ivoire, 2-9 May 1978	E, F
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific; Santiago de Chile, 6-10 November 1978.	E (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	E, F, R
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS); Moscow, 9-11 April 1979.	E
17 suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceano-graphic Products and the IGOSS Data Processing and Services System; Moscow, 2-6 April 1979.	E
18	IOC/UNESCO Workshop on Syllabus for Training Marine Technicians; Miami, U.S.A., 22-26 May 1978 (UNESCO reports in marine sciences, No. 4 published by the Division of Marine Sciences, UNESCO).	E (out of stock), F, S (out of tock), R
19	IOC Workshop on Marine Science Syllabus for Secondary Schools; Llantwit Major, Wales, U.K., 5-9 June 1978 (UNESCO reports in marine sciences, No. 5, published by the Division of Marine Sciences, UNESCO).	E (out of stock), S, R, Ar
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources; Bandung, Indonesia, 17-21 October 1978	E
21	Second IDOE Symposium on Turbulence in the Ocean; Liège, Belgium, 7-18 May 1979.	E, F, S, R
22	Third IOC/WMO Workshop on Marine Pollution Monitoring; New Delhi, 11-15 February 1980.	E, F, S, R
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific; Tokyo, 27-31 March 1980.	E, R
24	WESTPAC Workshop on Coastal Transport of Pollutants; Tokyo, Japan, 27-31 March 1980.	E (out of stock)
25	Workshop on the Inter-calibration of Sampling Procedures of the IOC/ WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters; Bermuda, 11-26 January 1980.	E (Superseded by IOC Technical Series No.22)
26	IOC Workshop on Coastal Area Management in the Caribbean Region; Mexico City, 24 September- 5 October 1979.	E, S
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific; Nouméa, New Caledonia, 9-15 October 1980.	E
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes. Lima, 20 April-5 May 1980.	E
29	WESTPAC Workshop on Marine Biological Methodology; Tokyo, 9-14 February 1981.	E
30	International Workshop on Marine Pollution in the South-West Atlantic; Montevideo, 10-14 November 1980.	E (out of stock) S
31	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E, F, S
32 Suppl.	Papers submitted to the UNU/IOC/ UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime; Paris, France, 27 September-1 October 1982.	E
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR); Halifax, 26-30 September 1963.	E
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa); Tenerife, 12-17 December 1963.	E, F, S
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific; Suva, Fiji, 3-7 October 1983.	E
36	IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, Portugal, 28 May-2 June 1984.	E
36 Suppl.	Papers submitted to the IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, 28 May-2 June 1984	E
37	IOC/UNESCO Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs; Colombo, 8-13 July 1985.	E
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region; Basrah, Iraq, 8-12 January 1984.	E
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific; Suva, Fiji, 24-29 September 1985.	E
40	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications; Sidney, B.C., Canada, 29-31 July 1985.	E
40 Suppl.	First International Tsunami Workshop on Tsunami Analysis, Prediction and Communications, Submitted Papers; Sidney, B.C., Canada, 29 July-1 August 1985.	E
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2); Dakar, Senegal, 28 October- 1 November 1985.	E
43	IOC Workshop on the Results of MEDALPEX and Future Oceano-graphic Programmes in the Western Mediterranean; Venice, Italy, 23-25 October 1985.	E
44	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E (out of stock) S
44 Suppl.	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities, Submitted Papers; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E
45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
46	Reunión de Trabajo para Desarrollo del Programa "Ciencia Oceánica en Relación a los Recursos No Vivos en la Región del Atlántico Sud-occidental"; Porto Alegre, Brasil, 7-11 de abril de 1986.	S
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
50	CCALR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR); Paris, France, 2-6 June 1987.	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E
52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere; Paris, France, 6-10 May 1985.	E
53	IOC Workshop on the Biological Effects of Pollutants; Oslo, 11-29 August 1986.	E
54	Workshop on Sea-Level Measurements in Hostile Conditions; Bidston, UK, 28-31 March 1988.	E
55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 1988.	E
56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 July 1988.	E
57	IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms; Takamatsu, Japan, 16-17 November 1987.	E
58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E
58 Suppl.	Second International Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness,	E

No.	Title	Languages
	Observation and Instrumentation. Submitted Papers; Novosibirsk, USSR, 4-5 August 1989.	
59	IOC-UNEP Regional Workshop to Review Priorities for Marine Pollution Monitoring Research, Control and Abatement in the Wider Caribbean; San José, Costa Rica, 24-30 August 1989.	E, F, S
60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E
61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	E
62	Second Workshop of Participants in the Joint FAO-IOC-WHO-IAEA-UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region; Accra, Ghana, 13-17 June 1988.	E
63	IOC/WESTPAC Workshop on Co-operative Study of the Continental Shelf Circulation in the Western Pacific; Bangkok, Thailand, 31 October-3 November 1989.	E
64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, Thailand, 25-31 September 1989.	E
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) in the Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E
66	IOC ad hoc Expert Consultation on Sardine/ Anchovy Recruitment Programme; La Jolla, California, U.S.A., 1989	E
67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)
68	International Workshop on Marine Acoustics; Beijing, China, 26-30 March 1990.	E
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Submitted Papers; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur; Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, U.S.A., 29 April-2 May 1991.	E
76	IOC/WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas of the Western Pacific; Penang, Malaysia, 2-6 December 1991.	E
77	IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands; Mombasa, Kenya, 24-28 June 1991.	E
78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, U.S.A., 18-21 February 1992.	E
79	IOC/WESTPAC Workshop on River Inputs of Nutrients to the Marine Environment in the WESTPAC Region; Penang, Malaysia, 26-29 November 1991.	E
80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, U.S.A. 2-3 November 1991.	E
81	Joint IAPSO-IOC Workshop on Sea Level Measurements and Quality Control; Paris, France, 12-13 October 1992.	E
82	BORDOMER 92: International Convention on Rational Use of Coastal Zones. A Preparatory Meeting for the Organization of an International Conference on Coastal Change; Bordeaux, France, 30 September-2 October 1992.	E
83	IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 12-13 October 1992.	E
84	Workshop on Atlantic Ocean Climate Variability; Moscow, Russian Federation, 13-17 July 1992	E
85	IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management; Kona, Hawaii, 1-5 June 1992.	E
86	International Workshop on the Black Sea; Varna, Bulgaria, 30 September – 4 October 1991	E
87	Taller de trabajo sobre efectos biológicos del fenómeno «El Niño» en ecosistemas costeros del Pacífico Sudeste; Santa Cruz, Galápagos, Ecuador, 5-14 de octubre de 1989.	S only (summary in E, F, S)
88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	E
89	IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990.	E
90	IOC Seminar on Integrated Coastal Management; New Orleans, U.S.A., 17-18 July 1993.	E
91	Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, U.S.A., 1-10 December 1991.	E
92	Réunion de travail IOCEA-OSNLR sur le Projet « Budgets sédimentaires le long de la côte occidentale d'Afrique » Abidjan, côte d'Ivoire, 26-28 juin 1991.	E
93	IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992.	E
94	BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-enclosed Seas and Harmful Algal Blooms, Bremerhaven, Germany, 29 September-3 October 1992.	E
95	SAREC-IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 23-25 November 1993.	E
96	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Zanzibar, United Republic of Tanzania, 17-21 January 1994.	E
96 Suppl.	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
96 Suppl	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Submitted Papers 2. Sea Level; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
97	IOC Workshop on Small Island Oceanography in Relation to Sustainable Economic Development and Coastal Area Management of Small Island Development States; Fort-de-France, Martinique, 8-10 November, 1993.	E
98	CoMSBlack '92A Physical and Chemical Intercalibration Workshop; Erdemli, Turkey, 15-29 January 1993.	E
99	IOC-SAREC Field Study Exercise on Nutrients in Tropical Marine Waters; Mombasa, Kenya, 5-15 April 1994.	E
100	IOC-SOA-NOAA Regional Workshop for Member States of the Western Pacific - GODAR-II (Global Oceanographic Data Archeology and Rescue Project); Tianjin, China, 8-11 March 1994.	E
101	IOC Regional Science Planning Workshop on Harmful Algal Blooms; Montevideo, Uruguay, 15-17 June 1994.	E
102	First IOC Workshop on Coastal Ocean Advanced Science and Technology Study (COASTS); Liège, Belgium, 5-9 May 1994.	E
103	IOC Workshop on GIS Applications in the Coastal Zone Management of Small Island Developing States; Barbados, 20-22 April 1994.	E
104	Workshop on Integrated Coastal Management; Dartmouth, Canada, 19-20 September 1994.	E
105	BORDOMER 95: Conference on Coastal Change; Bordeaux, France, 6-10 February 1995.	E
105 Suppl.	Conference on Coastal Change: Proceedings; Bordeaux, France, 6-10 February 1995	E
106	IOC/WESTPAC Workshop on the Paleographic Map; Bali, Indonesia, 20-21 October 1994.	E
107	IOC-ICSU-NIO-NOAA Regional Workshop for Member States of the Indian Ocean - GODAR-III; Dona Paula, Goa, India, 6-9 December 1994.	E
108	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Paris, France, 9-12 May 1995.	E
108 Suppl.	UNESCO-IHP-IOC-IAEA Workshop on Sea-Level Rise and the Multidisciplinary Studies of Environmental Processes in the Caspian Sea Region; Submitted Papers; Paris, France, 9-12 May 1995.	E
109	First IOC-UNEP CEPPOL Symposium; San José, Costa Rica, 14-15 April 1993.	E
110	IOC-ICSU-CEC regional Workshop for Member States of the Mediterranean - GODAR-IV (Global Oceanographic Data Archeology and Rescue Project) Foundation for International Studies, University of Malta, Valletta, Malta, 25-28 April 1995.	E
111	Chapman Conference on the Circulation of the Intra-Americas Sea; La Parguera, Puerto Rico, 22-26 January 1995.	E
112	IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials (GESREM) Workshop; Miami, U.S.A., 7-8 December 1993.	E
113	IOC Regional Workshop on Marine Debris and Waste Management in the Gulf of Guinea; Lagos, Nigeria, 14-16 December 1994.	E
114	International Workshop on Integrated Coastal Zone Management (ICZM) Karachi, Pakistan; 10-14 October 1994.	E
115	IOC/GLOSS-IAPSO Workshop on Sea Level Variability and Southern Ocean Dynamics; Bordeaux, France, 31 January 1995	E
116	IOC/WESTPAC International Scientific Symposium on Sustainability of Marine Environment: Review of the WESTPAC Programme, with Particular Reference to ICAM, Bali, Indonesia, 22-26 November 1994.	E
117	Joint IOC-CIDA-Sida (SAREC) Workshop on the Benefits of Improved Relationships between International Development Agencies, the IOC and other Multilateral Inter-governmental Organizations in the Delivery of Ocean, Marine Affairs and Fisheries Programmes; Sidney B.C., Canada, 26-28 September 1995.	E
118	IOC-UNEP-NOAA-Sea Grant Fourth Caribbean Marine Debris Workshop; La Romana, Santo Domingo, 21-24 August 1995.	E
119	IOC Workshop on Ocean Colour Data Requirements and Utilization; Sydney B.C., Canada, 21-22 September 1995.	E
120	International Training Workshop on Integrated Coastal Management; Tampa, Florida, U.S.A., 15-17 July 1995.	E
121	Atelier régional IOC-CERESCOR sur la gestion intégrée des zones littorales (ICAM), Conakry, Guinée, 18–22 décembre 1995	F
122	IOC-EU-BSH-NOAA-(WDC-A) International Workshop on Oceanographic Biological and Chemical Data Management, Hamburg, Germany, 20-23 May 1996	E
123	Second IOC Regional Science Planning Workshop on Harmful Algal Blooms in South America; Mar del Plata, Argentina, 30 October–1 November 1995.	E, S
124	GLOBEC-IOC-SAHFOS-MBA Workshop on the Analysis of Time Series with Particular Reference to the Continuous Plankton Recorder Survey; Plymouth, U.K.,4-7 May 1993.	E
125	Atelier sous-régional de la COI sur les ressources marines vivantes du Golfe de Guinée ; Cotonou, Bénin, 1-4 juillet 1996.	E

No.	Title	Languages
126	IOC-UNEP-PERSGA-ACOPS-IUCN Workshop on Oceanographic Input to Integrated Coastal Zone Management in the Red Sea and Gulf of Aden. Jeddah, Saudi Arabia, 8 October 1995.	E
127	IOC Regional Workshop for Member States of the Caribbean and South America GODAR-V (Global Oceanographic Data Archeology and Rescue Project); Cartagena de Indias, Colombia, 8-11 October 1996.	E
128	Atelier IOC-Banque Mondiale-Sida/SAREC-ONE sur la Gestion Intégrée des Zones Côtières ; Nosy Bé, Madagascar, 14-18 octobre 1996.	E
129	Gas and Fluids in Marine Sediments, Amsterdam, the Netherlands; 27-29 January 1997.	E
130	Atelier régional de la COI sur l'océanographie côtière et la gestion de la zone côtière ;Moroni, RFI des Comores, 16-19 décembre 1996.	E
131	GOOS Coastal Module Planning Workshop; Miami, USA, 24-28 February 1997	E
132	Third IOC-FANSA Workshop; Punta-Arenas, Chile, 28-30 July 1997	S/E
133	Joint IOC-CIESM Training Workshop on Sea-level Observations and Analysis for the Countries of the Mediterranean and Black Seas; Birkenhead, U.K., 16-27 June 1997.	E
134	IOC/WESTPAC-CCOP Workshop on Paleogeographic Mapping (Holocene Optimum); Shanghai, China, 27-29 May 1997.	E
135	Regional Workshop on Integrated Coastal Zone Management; Chabahar, Iran; February 1996.	E
136	IOC Regional Workshop for Member States of Western Africa (GODAR-VI); Accra, Ghana, 22-25 April 1997.	E
137	GOOS Planning Workshop for Living Marine Resources, Dartmouth, USA; 1-5 March 1996.	E
138	Gestión de Sistemas Oceanográficos del Pacífico Oriental; Concepción, Chile, 9-16 de abril de 1996.	S
139	Sistemas Oceanográficos del Atlántico Sudoccidental, Taller, TEMA;Furg, Rio Grande, Brasil, 3-11 de noviembre de 1997	S
140	IOC Workshop on GOOS Capacity Building for the Mediterranean Region; Valletta, Malta, 26-29 November 1997.	E
141	IOC/WESTPAC Workshop on Co-operative Study in the Gulf of Thailand: A Science Plan; Bangkok, Thailand, 25-28 February 1997.	E
142	Pelagic Biogeography ICoPB II. Proceedings of the 2nd International Conference. Final Report of SCOR/IOC Working Group 93; Noordwijkerhout, The Netherlands, 9-14 July 1995.	E
143	Geosphere-biosphere coupling: Carbonate Mud Mounds and Cold Water Reefs; Gent, Belgium, 7–11 February 1998.	E
144	IOC-SOPAC Workshop Report on Pacific Regional Global Ocean Observing Systems; Suva, Fiji, 13-17 February 1998.	E
145	IOC-Black Sea Regional Committee Workshop: 'Black Sea Fluxes' Istanbul, Turkey, 10-12 June 1997.	E
146	Taller Internacional sobre Formacíon de Capacidades para el Manejo de las Costas y los Oéanos en le Gran Caribe, La Habana, – Cuba, 7–10 de Julio de 1998 / International Workshop on Management Capacity-Building for Coasts and Oceans in the Wider Caribbean, Havana, Cuba, 7–10 July 1998	S/E
147	IOC-SOA International Training Workshop on the Intregration of Marine Sciences into the Process of Integrated Coastal Management, Dalian, China, 19-24 May 1997.	E
148	IOC/WESTPAC International Scientific Symposium – Role of Ocean Sciences for Sustainable Development Okinawa, Japan, 2-7 February 1998.	E
149	Workshops on Marine Debris & Waste Management in the Gulf of Guinea, 1995-97.	E
150	Primera Sesión del Grupo de Trabajo COI sobre Algas Nocivas en el Caribe y Regiones Adyacentes (IOCARIBE-ANCA)/First Meeting of the IOC Working Group on Harmful Algae in the Caribbean and Adjacent Region (IOCARIBE-ANCA), 29 June – 1 July 1998, Havana, Cuba.	S/E ***(electronic copy only)***
151	Taller Pluridisciplinario TEMA sobre Redes del Gran Caribe en Gestión Integrada de Areas Costeras Cartagena de Indias, Colombia, 7-12 de septiembre de 1998.	S
152	Workshop on Data for Sustainable Integrated Coastal Management (SICOM) Maputo, Mozambique, 18-22 July 1998	E
153	IOC/WESTPAC-Sida (SAREC) Workshop on Atmospheric Inputs of Pollutants to the Marine Environment Qingdao, China, 24-26 June 1998	E
154	IOC-Sida-Flanders-SFRI Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA project) Capetown, South Africa, 30 November-11 December 1998.	E
155	Science of the Mediterranean Sea and its applications UNESCO, Paris 29-31 July 1997	E
156	IOC-LUC-KMFRI Workshop on RECOSCIX-WIO in the Year 2000 and Beyond, Mombasa, Kenya, 12-16 April 1999	E
157	'98 IOC-KMI International Workshop on Integrated Coastal Management (ICM), Seoul, Republic of Korea 16-18 April 1998	E
158	The IOCARIBE Users and the Global Ocean Observing System (GOOS) Capacity Building Workshop, San José, Costa Rica, 22-24 April 1999	E
159	Oceanic Fronts and Related Phenomena (Konstantin Fedorov Memorial Symposium) – Proceedings, Pushkin, Russian Federation, 18-22 May 1998	E
160	Under preparation	
161	Under preparation	
162	Workshop report on the Transports and Linkages of the Intra-americas Sea (IAS), Cozumel, Mexico, 1-5 November 1997	E
163	Under preparation	
164	IOC-Sida-Flanders-MCM Third Workshop on Ocean Data Management in the IOCINCWIO Region (ODINEA Project), Cape Town, South Africa, 29 November – 11 December 1999	E
165	An African Conference on Sustainable Integrated Management; Proceedings of the Workshops. An Integrated Approach, (PACSICOM), Maputo, Mozambique, 18 –25 July 1998	E, F
166	IOC-SOA International Workshop on Coastal Megacities: Challenges of Growing Urbanization of the World's Coastal Areas; Hangzhou, P.R. China, 27 –30 September 1999	E
167	IOC-Flanders First ODINAFRICA-II Planning Workshop, Dakar, Senegal, 2-4 May 2000	E
168	Geological Processes on European Continental Margins; International Conference and Eight Post-cruise Meeting of the Training-Through-Research Programme, Granada, Spain, 31 January – 3 February 2000	E
169	International Conference on the International Oceanographic Data & Information Exchange in the Western Pacific (IODE-WESTPAC) 1999, ICIWP '99, Langkawi, Malaysia, 1-4 November 1999	E ***(electronic copy only)***
170	IOCARIBE-GODAR-I Cartagenas, Colombia, February 2000	***under preparation***
171	Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks, Toulouse, France, 10-11 May 1999	E
172	(*Under preparation*)	
173	The Benefits of the Implementation of the GOOS in the Mediterranean Region, Rabat, Morocco, 1-3 November 1999	E, F
174	IOC-SOPAC Regional Workshop on Coastal Global Ocean Observing System (GOOS) for the Pacific Region, Apia, Samoa, 16-17 August 2000	E
175	Geological Processes on Deep-water European Margins, Moscow-Mozhenka, 28 Jan.-2 Feb. 2001	E
176	MedGLOSS Workshop and Coordination Meeting for the Pilot Monitoring Network System of Systematic Sea Level Measurements in the Mediterranean and Black Seas, Haifa, Israel, 15-17 May 2000	E
177	*(Under preparation)*	
178	*(Under preparation)*	
179	*(Under preparation)*	
180	Abstracts of Presentations at Workshops during the 7th session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Honolulu, USA, 23-27 April 2001	E
181	*(Under preparation)*	
182	*(Under preparation)*	
183	Geosphere/Biosphere/Hydrosphere Coupling Process, Fluid Escape Structures and Tectonics at Continental Margins and Ocean Ridges, International Conference & Tenth Post-cruise Meeting of the Training-through-Research Programme, Aveiro, Portugal, 30 January-2 February 2002	E
184	*(Under preparation)*	
185	*(Under preparation)*	
186	*(Under preparation)*	
186	*(Under preparation)*	
187	Geological and Biological Processes at deep-sea European Margins and Oceanic Basins, Bologna, Italy, 2–6 February 2003	E
188	Proceedings of 'The Ocean Colour Data' Symposium, Brussels, Belgium, 25-27 November 2002	E
189	Workshop for the Formulation of a Draft Project on Integrated Coastal Management (ICM) in Latin America and the Caribbean (LAC), Cartagena, Colombia, 23–25 October 2003	E F ***(electronic copy only)***
	Taller de Formulación de un Anteproyecto de Manejo Costero Integrado (MCI) en América Latina y el Caribe (ALC), Cartagena, Colombia, 23–25 de Octubre de 2003	
190	First ODINCARSA Planning Workshop for Caribbean Islands, Christchurch, Barbados, 15–18 December 2003	E ***(electronic copy only)***
191	North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes — International Conference and Twelfth Post-cruise Meeting of the Training-through-research Programme, Copenhagen, Denmark, 29–31 January 2004	E
192	Regional Workshop on Coral Reefs Monitoring and Management in the ROPME Sea Area, Iran I.R., 14–17 December 2003	E ***(under preparation)***
193	Workshop on New Technical Developments in Sea and Land Level Observing Systems, Paris, France, 14–16 October 2003	E ***(electronic copy only)***
194	IOC/ROPME Planning Meeting for the Ocean Data and Information Network for the Central Indian Ocean Region	***(under preparation)***
195	Workshop on Indicators of Stress in the Marine Benthos, Torregrande-Oristano, Italy, 8–9 October 2004	E
196	International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean within a Global Framework, Paris, France, 3–8 March 2005	E
197	Geosphere-Biosphere Coupling Processes: The TTR Interdisciplinary Approach Towards Studies of the European and North African Margins; International Conference and Post-cruise Meeting of the Training-Through-Research Programme, Morocco, 2-5 February 2005	E
198	Second International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean, Grand Baie, Mauritius, 14–16 April 2005	E
199	International Conference for the Establishment of a Tsunami and Coastal Hazards Warning System for the Caribbean and Adjacent Regions, Mexico, 1–3 June 2005	E
200	Lagoons and Coastal Wetlands in the Global Change Context: Impacts and Management Issues — Proceedings of the International Conference, Venice, 26–28 April 2004 (*ICAM Dossier N° 3)*	E
201	Geological processes on deep-water European margins - International Conference and 15th Anniversary Post-cruise Meeting of the Training-Through-Research Programme, Moscow/Zvenigorod, Russian Federation, 29 January–4 February 2006	E
202	Proceedings of 'Ocean Biodiversity Informatics': an international conference on marine biodiversity data management Hamburg, Germany, 29 November–1 December 2004	E
203	IOC-Flanders Planning Workshop for the formulation of a regional Pilot Project on Integrated Coastal Area Management in Latin America, Cartagena de Indias, Colombia, 16–18 January 2007	*E* ***(electronic copy only)***
204	Geo-marine Research along European Continental Margins, International Conference and Post-cruise Meeting of the Training-through-research Programme, Bremen, Germany, 29 January–1 February 2007	E
205	IODE/ICAM Workshop on the development of the Caribbean marine atlas (CMA), United Nations House, Bridgetown, Barbados, 8–10 October 2007	E ***(electronic copy only)***
206	IODE/JCOMM Forum on Oceanographic Data Management and Exchange Standards, Ostend, Belgium, 21–25 January 2008	*(Under preparation)*
207	SCOR/IODE Workshop on Data Publishing, Ostend, Belgium, 17–18 June 2008	*(Under preparation)*

No.	Title	Languages
208	JCOMM Technical Workshop on Wave Measurements from Buoys, New York, USA, 2–3 October 2008 (IOC-WMO publication)	*(Under preparation)*
209	Collaboration between IOC and OBIS towards the Long-term Management Archival and Accessibility of Ocean Biogeographic Data, Ostend, Belgium, 24–26 November 2008	*(Under preparation)*
210	Ocean Carbon Observations from Ships of Opportunity and Repeat Hydrographic Sections (IOCCP Reports, 1), Paris, France, 13–15 January 2003	E ***(electronic copy only)***
211	Ocean Surface pCO_2 Data Integration and Database Development (IOCCP Reports, 2), Tsukuba, Japan, 14–17 January 2004	E ***(electronic copy only)***
212	International Ocean Carbon Stakeholders' Meeting, Paris, France, 6–7 December 2004	E ***(electronic copy only)***
213	International Repeat Hydrography and Carbon Workshop (IOCCP Reports, 4), Shonan Village, Japan, 14–16 November 2005	E ***(electronic copy only)***
214	Initial Atlantic Ocean Carbon Synthesis Meeting (IOCCP Reports, 5), Laugavatn, Iceland, 28–30 June 2006	E ***(electronic copy only)***
215	Surface Ocean Variability and Vulnerability Workshop (IOCCP Reports, 7), Paris, France, 11–14 April 2007	E ***(electronic copy only)***
216	Surface Ocean CO2 Atlas Project (SOCAT) 2nd Technical Meeting Report (IOCCP Reports, 9), Paris, France, 16–17 June 2008	E ***(electronic copy only)***
217	Changing Times: An International Ocean Biogeochemical Time-Series Workshop (IOCCP Reports, 11), La Jolla, California, USA, 5–7 November 2008	E ***(electronic copy only)***
218	Second Joint GOSUD/SAMOS Workshop, Seattle, Washington, USA, 10–12 June 2008	E ***(electronic copy only)***
219	International Conference on Marine Data management and Information Systems (IMDIS), Athens, Greece, 31 March–2 April 2008	E
220	Geo-marine Research on the Mediterranean and European-Atlantic Margins. International Conference and TTR-17 Post-cruise Meeting of the Training-through-research Programme, Granada, Spain, 2–5 February 2009	E ***(electronic copy only)***
221	Surface Ocean CO_2 Atlas Project Pacific Regional Workshop, Tsukuba, Japan, 18-20 March, 2009 (IOCCP Report Number 12)	E ***(electronic copy only)***
222	Surface Ocean CO_2 Atlas Project Atlantic and Southern Oceans Regional Meeting, Norwich, UK, 25-26 June, 2009 (IOCCP Report Number 13)	E ***(electronic copy only)***
223	Advisory Workshop on enhancing forecasting capabilities for North Indian Ocean Storm Surges, Indian Institute of Technology (IIT), New Delhi, India, 14–17 July 2009	E ***(electronic copy only)***
224	2009 International Nutrients Scale System (INSS) Workshop Report, Paris, France, 10–12 February 2009	E ***(electronic copy only)***
225	Reunión subregional de planificación de ODINCARSA (Red de Datos e Información Oceanográficos para las Regiones del Caribe y América del Sur)/ ODINCARSA (Ocean Data and Information Network for the Caribbean and South America region) Latin America sub-regional Planning Meeting, Universidad Autónoma de Baja California (UABC), Ensenada (México), 7-10 December 2009. 2010	E/S ***(electronic copy only)***
226	OBIS (Ocean Biogeographic Information System) Strategy and Work plan Meeting, IOC Project Office for IODE, Oostende, Belgium, 18–20 November 2009	E ***(electronic copy only)***
227	ODINAFRICA-IV Project Steering Committee, First Session, Ostend, Belgium, 20–22 January 2010. 2010	E ***(electronic copy only)***
228	First IODE Workshop on Quality Control of Chemical Oceanographic Data Collections, Ostend, Belgium, 8–11 February 2010. 2010	E ***(electronic copy only)***
229	Surface Ocean CO_2 Atlas Project Equatorial Pacific, North Pacific, and Indian Ocean Regional Workshop, Tokyo, Japan, 8–11 February 2010. 2010 (IOCCP Report Number 18)	E ***(electronic copy only)***
230	SCOR/IODE/MBLWHOI Library Workshop on Data Publication, Paris, France, 2 April 2010	E ***(electronic copy only)***
231	First ODINAFRICA Coastal and Marine Atlases Planning Meeting, Ostend, Belgium, 12–14 October 2009	E ***(electronic copy only)***
232	Eleventh International Workshop on Wave Hindcasting and Forecasting and Second Coastal Hazard Symposium, Halifax, Canada, 18–23 October 2009	E ***(electronic copy only)***
233	2010 Meeting of the Joint IODE-JCOMM Steering Group on the Global Temperature-Salinity Profile Programme Ostend, Belgium, 5–7 May 2010	E ***(electronic copy only)***
234	Southern and Indian Surface Ocean CO_2 Atlas (SOCAT) Workshop, CSIRO Marine Laboratories, Hobart, Tasmania 16-18 June 2010	E ***(electronic copy only)***
235	The Caribbean Marine Atlas (CMA) Review and Planning Workshop and Saint Lucia National Coastal Atlas Stakeholder Event, Bay Gardens Inn, Rodney Bay, Saint Lucia, 2–6 August 2010	E ***(electronic copy only)***
236	First Session of the IODE Steering Group for the IODE OceanDataPortal (SG-ODP-I), 20–22 September 2010, Ostend, Belgium	E ***(electronic copy only)***
237.	Ad hoc meeting of the IODE Steering Group for OBIS, Ostend, Belgium 18-19 November 2010	E ***(electronic copy only)***
238.	Implementing Adaptation to Climate Change in Western and Eastern Africa, Nairobi, Kenya, 3-5 November 2010	E ***(electronic copy only)***
239.	2nd Advisory Workshop on enhancing forecasting capabilities for North Indian Ocean Storm Surges, 11-15 February 2011, New Delhi, India	E ***(electronic copy only)***
240.	Ocean Biogeographic Information System (OBIS) Infrastructure Meeting, INCOIS, Hyderabad, India, 2–4 March 2011.	E ***(electronic copy only)***
241.	Best Practice on Tsunami and Coastal Hazards Community Preparedness and Readiness in Central America and the Caribbean, 11–13 August 2008, Panama City, Panama	E ***(electronic copy only)***
242.	Integrated Coastal Area Management (ICAM) Training Workshop for the English Speaking Caribbean States, 16–18 March 2011, Bridgetown, Barbados	E ***(electronic copy only)***
243.	*Cancelled*	
244.	SCOR/IODE/MBLWHOI Library Workshop on Data Publication, 4th Session, British Oceanographic Data Centre, Liverpool, United Kingdom, 3-4 November 2011	E ***(electronic copy only)***
245.	*Cancelled*	
246.	NEAMTIC/ICAM Workshop on Coastal Management Approaches for Sea-Level Related Hazards, Paris, UNESCO, 5–7 December 2011	E ***(electronic copy only)***
247.	Technical Workshop on the IODE OceanDataPortal, IOC Project Office for IODE, Ostend, Belgium, 27-29 February 2012	E ***(electronic copy only)***
248.	Inter-sessional working group for updating the IOC Strategic Plan for Oceanographic Data and Information Exchange (2012-2015), Ostend, Belgium, 1-2 March 2012	E ***(electronic copy only)***
249.	Operational Oceanography of IOC (for Group II Member States), 20–22 March 2012 Paris, UNESCO (Advisory Workshop)	E ***(electronic copy only)***
250.	Advisory Workshop on The Future of IOC towards next ten years and its Implications for Member States, Varna, Bulgaria, 19 March 2012	E ***(electronic copy only)***
251	Second Technical Meeting of Ocean Biogeographic Information System (OBIS), Ostend, Belgium, 21–22 June 2012	E ***(electronic copy only)***
252.	SCOR/IODE/MBLWHOI Library Workshop on Data Publication, 5th Session, Woods Hole Oceanographic Institution, Woods Hole, USA, 9-10 October 2012	E ***(electronic copy only)***
253.	Second IODE Workshop on Quality Control of Chemical and Biological Oceanographic Data Collections, 22-24 October 2012, IOC Project Office for IODE, Ostend, Belgium	E ***(electronic copy only)***
254.	Consultation on Scientific and Technical Aspects of Sustained Ocean Observations and Services, 5th March, 2013, Rio de Janeiro, Brazil	E ***(electronic copy only)***
255.	Earthquake and tsunami hazard in Northern Haiti: Historical events and potential sources (Meeting of experts)	E ***(electronic copy only)***
256	Sexto Taller Regional de Planificación Científica sobre Floraciones de Algas Nocivas en Sudamérica, Guayaquil, Ecuador, 22-24 Octubre 2003	S ***(electronic copy only)***
257	*(Under preparation)*	
258	*(Under preparation)*	
259	Noveno Taller Regional-COI de Planificación Científica sobre Florecimientos de Algas Nocivas en Sudamérica, 11-13 enero 2011, Puerto Varas, Chile	S ***(electronic copy only)*** *(Summary in E)*
260	*Caribbean Marine Atlas Review and Planning Meeting, Miami, USA, 10-13 December 2013*	
261	Indo-Pacific Ocean Forum on "Charting the Future of Sustained Ocean Observations and Services", Bangkok, Thailand, 25-28 Nov. 2013	E ***(electronic copy only)***
262	*First Planning Workshop For The Ocean Data And Information Network For The Westpac Region (ODINWESTPAC), Tianjin, China, 4-7 March 2014*	
263	*International Coastal Atlas Network Workshop 6: Expanding Participation in Coastal Web Atlas Development and Use, 16–17 June 2013, University of Victoria, British Columbia, Canada*	
264	9th WESTPAC International Scientific Symposium, Research Directors' Forum: A Healthy and Safe Ocean for Prosperity in the Indo-Pacific region, Nha Trang, Viet Nam, 22 April 2014	E ***(electronic copy only)***
265	Electoral Group 1 Consultation on the Future of the IOC, Utrecht, The Netherlands, 26–27 May 2014	E ***(electronic copy only)***
266	IOC-UNESCO-ISESCO workshop on Improving Tsunami Warning and Emergency Response in the North-Eastern Atlantic, Mediterranean and connected seas Rabat, 23-24 September 2014	A/E/F ***(electronic copy only)***
267	Proceedings of the First IOCAFRICA Ocean Forecasting workshop for the Western Indian Ocean region, Nairobi, Kenya, 11–15 August 2014	E ***(electronic copy only)***
268	Proceedings of the African Summer School on Application of Ocean Data and Modelling Products, Ghana, Kenya, April–September 2014	E ***(electronic copy only)***
269.	*Forum on Sustained Ocean Observations and Services in IOC Group V (Africa and Arab countries)*	*Under preparation*
270.	*Second China-Africa Forum on Marine Science and Technology, 9-10 April 2015, Nairobi, Kenya*	*Under preparation*
271.	WESTPAC Workshop on Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems. Phuket, Thailand, 19–21 January 2015	E ***(electronic copy only)***