IAEA INT7019 Task Force Meeting on the Development and Standardization of Methodology for Ocean Acidification Research

12-14 October 2016

IAEA Environment Laboratories, Monaco

Summary

The International Atomic Energy Agency (IAEA) convened an expert meeting on ocean acidification methodology from 12-14 October 2016 at the IAEA Environment Laboratories in Monaco. The meeting was organized in the framework of the IAEA Technical Cooperation project "*Supporting a Global Ocean Acidification Observing Network - towards Increased Involvement of Developing States*" (INT7019).

The overall goal of the meeting was to advance discussions on the development of simplified methodology and ocean acidification research "kits," in particular for research institutes entering the ocean acidification research field and with limited technical infrastructure and capacities.

More specifically meeting discussions centered on the following topics:

- Development of a questionnaire to assess capacities and needs in participating Member States of INT7019 and other nations/institutes concerned by ocean acidification and interested in initiating research in this field.
- Acceptable uncertainties in oceanic carbonate chemistry parameters, and how to estimate them.
- Development of simplified, less costly, methodology to measure total alkalinity and pH.
- Development of "tool kits" for ocean acidification research (for both field and laboratory studies).
- Data quality, data sharing, and training needs and possibilities.
- Opportunities for collaboration and coordination with other international efforts.

Meeting report

1. Introduction

One of the overall goals of the *Global Ocean Acidification Observing Network* (GOA-ON; www.goa-on.org), created in 2012, is to work together internationally to expand coverage of ocean acidification (OA) measurements to areas where there is currently little or no data. The IAEA Technical Cooperation project "*Supporting a Global Ocean Acidification Observing Network – toward increased involvement of developing states* (INT7019)" aims to help equip IAEA Member States concerned by and interested in ocean acidification research to participate in international efforts such as GOA-ON in a scientifically meaningful way (i.e. to provide data of sufficient quality to be scientifically useful). The INT7019 project is an inter-regional project with 40 Member States participating to date, from all IAEA Technical Cooperation regions (Africa, Asia & the Pacific, Europe and Latin America). The participating countries have very different levels of OA knowledge, from complete beginners to more advanced laboratories, and many do not have access to sophisticated equipment, infrastructure and the technical expertise required to make the high-quality measurements needed to meet the most stringent requirements in uncertainty defined by GOA-ON's "climate-level" goal.[1] Instead, the goal is to use the limited project funds as efficiently as possible to help provide adequate methodology, training, and collaboration opportunities for the least resourceful countries to be able to measure ocean acidification with GOA-ON "weather-level" quality, and/or to set up pertinent laboratory biological experiments.

In the context of the above, the IAEA convened a small expert meeting (12-14 October 2016, Monaco) to discuss the development of simplified, less expensive, methodology and ocean acidification starting "kits" (both observing and experimental), particularly for research institutes entering the ocean acidification field, and with limited infrastructure and capacities. Another goal was to discuss possibilities of coordination and collaboration with members of key organizations and international projects to ensure long term sustainability of efforts and contribution to international activities.

[1] http://www.goa-on.org/docs/GOA-ON_2nd_edition_final.pdf

2. Participating experts and organization representatives, and current ocean acidification-related work

The following organizations and scientific experts participated in the meeting (see also Annex I). Current OA-relevant efforts and initiatives are briefly mentioned below for each.

International Atomic Energy Agency (IAEA; Lina Hansson and Marc Metian)

- ***IAEA Technical Cooperation Projects:*** The INT7019 project is a 4-year (2016-2019) Technical Cooperation project with a total budget of 400k EUR and the overall goal to help build and enhance capacity to measure and study ocean acidification, and connect countries and regions with a concern about and interest in this issue. IAEA Member States can join the project at any time (40 Member States are participating to date). The project will promote capacity building, regional and inter-regional networking and collaboration, data sharing, and outreach to key stakeholders (through data synthesis projects, white papers and a stakeholder meeting). In addition to the inter-regional INT7019 project, the IAEA currently implements two regional Technical Cooperation projects with ocean acidification components:
    - Africa: "*Applying nuclear analytical techniques to support harmful algal bloom management in the context of climate and environmental change, Phase II (RAF7014)"*
    - Latin America: "*Establishing the Caribbean Observing Network for Ocean Acidification and its Impact on Harmful Algal Blooms, using Nuclear and Isotopic Techniques (RLA7020)"*

- ***IAEA Peaceful Uses Initiative Project:*** The *IAEA Ocean Acidification International Coordination Centre* (OA-ICC; www.iaea.org/ocean-acidification) launched in 2012 facilitates a series of international activities of benefit to the wider ocean acidification research community and other stakeholders, including strengthening scientific capability (particularly in developing Member States), helping to establish GOA-ON, supporting international ocean acidification data management, promoting the use of best practices, providing online resources and data bases, and communicating the science to non-scientists. The OA-ICC has organized several training courses on ocean acidification around the globe (e.g. Xiamen and Cape Town courses in 2015, Ensenada in 2016) and supports the establishment of regional OA networks such as LAOCA (Latin American network), OA-AFRICA and OA networking initiatives in Asia.

Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO; Kirsten Isensee)

IOC-UNESCO (http://ioc-unesco.org/) is actively supporting the establishment of GOA-ON (Represented on the GOA-ON Executive Council) and the IOC-UNESCO Representative co-chairs the GOA-ON Biology Working Group. As the lead UN Agency for matters relating to marine science, IOC is the responsible UN organization for the reporting towards Target 14.3 of the Sustainable Development Goals (Ocean acidification target). The IOC Sub-Commission for the Western Pacific (IOC-WESTPAC) is leading an ocean acidification monitoring project focused on coral reefs and have organized several workshops on this topic, as well as the development of Standard Operating Procedures for OA measurements within the project. Similar subcommittees exist for Africa (IOC-AFRICA) and the Caribbean region (IOCARIBE). IOC-UNESCO is collaborating closely with the IAEA on SDG14.3 implementation and other ocean acidification related initiatives and is represented on the

OA-ICC Advisory Board. Several IOC-UNESCO-supported initiatives are relevant for the global ocean acidification research community such as the Global Ocean Observing System (GOOS), the International Oceanographic Data and Information Exchange (OBIS), Ocean Teacher (e-learning platform) etc.

International Ocean Carbon Coordination Project (IOCCP; Maciej Telszewski)

Co-sponsored by the Scientific Committee on Oceanic Research and IOC-UNESCO, the IOCCP (http://www.ioccp.org/) promotes the development of a global network of ocean carbon observations for research through technical coordination and communication services, international agreements on standards and methods, and advocacy and links to the global observing systems. Ocean acidification is one of 9 key activities of the IOCCP and the project is supporting the development of GOA-ON in close collaboration with NOAA OAP, GOOS, IOC-UNESCO, OA-ICC and other organizations represented on the GOA-ON Executive Board, and is coordinating closely with the GOOS Biology Panel and other OA-relevant initiatives.

The Ocean Foundation (Mark Spalding and Alexis Valauri-Orton)

The Ocean Foundation (TOF; https://www.oceanfdn.org/) works both on building capacity to monitor and understand ocean acidification and with stakeholders and legislators to enact legislation and implement mitigation strategies. TOF supports the GOA-ON, both in terms of capacity building efforts (two training courses in Africa to date; in Mozambique and Mauritius in 2016) and administration of the *Friends of GOA-ON Fund.* Over the next years TOF has resources to support the distribution of ocean acidification equipment (kits), initially to four countries trained at the Mauritius workshop (Mauritius, Mozambique, Seychelles and South Africa), develop e-learning material such as video courses, facilitate the establishment of regional networks, and has pledged to organize four more training workshops. The first two of these, Pacific Islands in 2017 and Latin America and the Caribbean in 2018, are funded through a public private partnership with the U.S. Department of State. The Ocean Foundation is actively seeking funding for the second two courses, for the Caribbean and the Arctic. In addition, these courses and distribution of kits are nested in TOF's current development of a proposal to attract funding for an international OA Secretariat. This proposed Secretariat would include international stakeholder engagement and policy work, building on TOF's work replicating Washington State's ocean acidification legislation throughout the U.S. and internationally. TOF is collaborating closely with the U.S. Department of State and NOAA's Ocean Acidification Program on many of the above activities, and TOF and IAEA/OA-ICC have initiated collaboration to leverage their respective activities as much as possible.

US NOAA Ocean Acidification Program (NOAA OAP; Alex Harper)

The mission of the NOAA Ocean Acidification Program (OAP; http://oceanacidification.noaa.gov/) is to better prepare society to respond to changing ocean conditions and resources by expanding understanding of ocean acidification, through interdisciplinary partnerships, nationally and internationally. The NOAA OAP is actively participating in the establishment and facilitation of GOA-ON and is leading the recently launched GOA-ON Pier2Peer mentoring program. The NOAA OAP is also involved in the Ocean Acidification Mitigation and Monitoring (OAMM) and regional OA networks in the US (CANs) for which there is a need for capacity and tools to study OA, e.g. in native communities, as well as the Ocean Acidification and Hypoxia Monitoring Taskforce (through which a monitoring/asset inventory is currently in progress).

Doug Connelly, NERC, National Oceanography Centre, Southampton, UK

Doug Connelly is professor in marine chemistry with part of his research interests focusing on the development of *in situ* sensor technologies for the marine environment. He coordinates the EC funded SenseOCEAN project and is the NOC lead on the AtlantOS project developing an integrated Atlantic observing system. Prof Connelly is a member of the Scientific Steering Group of IOCCP, in which he serves as the responsible SSG member for "Instruments and Sensors." He is also involved in projects with ocean acidification components in the UK overseas territories through the CME (Commonwealth Marine Economies) Programme.

Andrew Dickson, Scripps Institution of Oceanography, University of California, San Diego, USA

Andrew Dickson is professor of marine chemistry with research interests focusing on improving our understanding of the chemistry of carbon dioxide in seawater, with a current emphasis on the effects of ocean acidification. He has played a key role in developing quality control standards for oceanic carbon dioxide measurements and leads a program to prepare, certify, and distribute CO_2 reference materials to the international marine science community. He has been involved as a lecturer in several IAEA-supported training courses on ocean acidification in different regions of the world. Dr. Dickson is currently working on a project to develop simplified and less costly methodology for total alkalinity and pH, with co-support from the INT7019 project.

Sam Dupont, University of Gothenburg, Sweden

Sam Dupont is a researcher in marine ecophysiology with main research topics centered on the impact of increased CO_2 and related changes on marine species and ecosystems. His work aims at revealing the mechanisms behind species and ecosystem responses and at developing the needed unifying theory for large scale predictions. He is a member of the Advisory Board of OA-ICC, the Executive Council of GOA-ON, and is co-chairing the GOA-ON Biology Working Group. Dr. Dupont has been involved as a lecturer in several IAEA or IAEA-sponsored training courses on ocean acidification in different regions of the world. Current activities include developing a questionnaire to assess the capacities of participating institutes in the framework of the INT7019 project.

Steve Widdicombe, Plymouth Marine Laboratory, UK

Steve Widdicombe is a marine ecologist using field observations and manipulative experiments to address issues relating to benthic ecology, biodiversity and ecosystem function, including ocean acidification. He leads the Plymouth Marine Laboratory strategic science area “Marine ecology and biodiversity,” with much of his recent research concentrated on the ecological impacts of increasing seawater CO_2 levels, rising temperatures and expanding areas of hypoxia. Mr. Widdicombe is a Member of the GOA-ON Biology panel.

A 2-hour videoconference slot on 13 October with presentation of main discussion outcomes allowed input from additional experts (see Annex I for full List of Participants).

3. Summary of discussions (main points)

See also Annex IV for summary Powerpoint presentation of the meeting outcomes.

3.1. Development of a questionnaire to assess OA capacities and needs (lead: S.Dupont)

In the framework of the INT7019 project, Dr. Sam Dupont has agreed to take the lead on developing a questionnaire to be used to assess existing capacities and priorities of the participating Member States. The questionnaire will solicit information such as available infrastructure, equipment, staff and their level of expertise, planned projects on OA, networking opportunities, and local key scientific and socio-economic questions and challenges. The information collected will be used to identify the priorities of each participating institute/Member State, opportunities for collaboration with other project partners and institutes around the globe, as well as appropriate equipment and training that may be required. It will also allow identifying potential lecturers and locations for training courses and networking meetings. The questionnaire will be of value also to other ocean acidification projects and initiatives (e.g. other current and upcoming IAEA TC projects, TOF efforts, regional networks such as the Latin American OA Network (LAOCA), the emerging OA-AFRICA network, and Asian networking initiatives, as well as the Pier2Peer program) and will be designed to be as complete as possible and respond to multiple goals to maximize efforts and results.

During the meeting, the group developed a first draft of the questionnaire. Substantial time and effort were devoted to define the kind of questions and level of detail to be included. It seemed important that the questionnaire be sufficiently comprehensive to be able to get an as complete picture as possible about the needs and resources available, while relatively straightforward to complete (e.g. it should not take longer than 30 minutes). The group came up with the following main categories of questions:

- Expertise and motivation
- Existing infrastructure, equipment, human resources and knowledge/know-how
- Regional strengths and important marine resources, concerns
- Potential challenges and barriers
- Other resources and existing contacts/collaborations (e.g. possible funding opportunities)

The full draft questionnaire is available in Annex III. It will be available as a Google document/survey, as well as Word document or similar to make sure that a wide audience can access it.

Time line and actions: The first version of the questionnaire was developed during the workshop, finalized by Dr. Dupont and will be tested and fine-tuned by mid-December 2016. It is proposed to test the questionnaire among the meeting participants and, in a second step, through some of the participants of the OA-AFRICA network currently in development and led by Doctors Warren Joubert (CSIR, South Africa) and Chibo Chikwililwa (University of Namibia). A PowerPoint slide introducing the philosophy of the questionnaire will be produced for use by the wider community during scientific conferences.

3.2. *Acceptable uncertainties for seawater carbonate chemistry measurements and simplified methodology for total alkalinity and pH (lead: A Dickson)*

This discussion was led by Dr. Dickson who started with a presentation on acceptable uncertainties in carbonate chemistry parameters, including results from a recent inter-laboratory comparison exercise[2].

For *in situ* measurements, the "weather" quality goal outlined in the GOA-ON Plan[3] is defined as *"measurements of quality sufficient to identify relative spatial patterns and short-term variation. With respect to ocean acidification, this is to support mechanistic interpretation of the ecosystem response to and impact on local, immediate OA dynamics. The weather objective requires the carbonate ion concentration to have a relative standard uncertainty of 10%. This implies an uncertainty of approximately 0.02 in pH; of 10 µmol kg^{-1} in measurements of total alkalinity (TA) and total dissolved inorganic carbon (DIC); and a relative uncertainty of about 2.5% in the partial pressure of carbon dioxide (pCO_2)."* The GOA-ON Goal 1, Level 1 ("understanding global OA conditions") required suite of measurements include temperature, salinity, pressure (water depth at which measurement is made), oxygen concentration and carbon-system constraint (2 parameters needed), as well as fluorescence and irradiance when possible.

Dr. Dickson introduced ongoing work, with partial support through the INT7019 project, on the development of simplified methodology for measurement of total alkalinity and pH, using cheaper and simpler components, yet fit for purpose (i.e. able to achieve the uncertainties required to reach the GOA-ON weather objective). The following techniques are currently being tested:

- A manual technique for alkalinity using an open-cell potentiometric titration procedure with a Gilmont syringe burette, together with a pH meter. This includes testing e.g. whether temperature control is needed or not.
- A simple manual approach to measure seawater pH colorimetrically using 1cm cells and calibrated m-cresol purple. This exercise includes testing of impure versus pure m-cresol purple dye and if an empirical adjustment can be used as a correction rather than purchasing the pure dye.[4]

The semi-automated computer driven systems of the Dickson laboratory at SCRIPPS will be used to understand the likely increases in uncertainty resulting from each modification to the methods (i.e., using simpler/less costly components). Approximate costs for TA equipment would be around 1,500 USD and 500 USD for pH if the laboratory already has a spectrophotometer (otherwise: 3,000-4,000 USD).

The above methodology development focuses on TA and pH since those are considered the easiest to measure and still obtain good results. Spectrophotometric pH determination was chosen since the precision is better and the calibration less complicated than other options. Also, there is a value in measuring pH for the biological community, and there are new pH sensors and optodes coming up (e.g. the iSAMI from Sunburst, pH sensor by Bob Byrne, Lisa Robbins et al., and optodes in

[2] Bockmon & Dickson, 2015 (http://dx.doi.org/10.1016/j.marchem.2015.02.002)

[3] http://www.goa-on.org/docs/GOA-ON_2nd_edition_final.pdf

[4] Alternatively, the US National Institute of Standards and Technology (NIST) is looking to offer m-cresol purple as a certified reference material for pH. This may ultimately make purified dye more available for users.

development by Connelly et al.). For TA, calibration is also potentially straightforward and the method is like the experience of titration well-known by many labs.

The merit of trying to support a laboratory to act as regional node for centralized carbonate chemistry measurements was also discussed. The idea would be that laboratories take water samples, preserve them, and ship the bottles to the central lab for analysis. Although there are clear advantages of such a set-up (it would allow the participation of many countries which do not have the resources and know-how to do the sample analysis in their labs), it would probably need substantial efforts, time and resources to set up such an approach. One of the challenges discussed included the potential lag time for sample analysis. It was proposed to draft a concept note detailing the capacity that such a centre would need to have, the kind of support required (training, equipment etc.), and perhaps to create a small working group/advisory committee to further discuss this issue. A test with one pilot project could be one initial action. (Lead: A. Dickson).

The discussions concluded that it should be possible for participants of INT7019 and similar initiatives to achieve, ***with the appropriate equipment, methodology, and training***, the GOA-ON Goal 1, Level 1 objectives with weather quality (see Annex III). Ultimately, the acceptable uncertainty of a measurement should be adapted to the research question, and it is critical to be aware of the accuracy/uncertainty of what is measured (importance of quality control of results). This is closely connected to the training and resources component of the proposed OA kits (see below).

Time line and actions: The testing of the methods is expected to be completed and the new protocols available by March 2017 (A. Dickson). It is envisaged to have a few labs test the new methodologies. Short concept note on central laboratories for carbonate chemistry analysis to be available by 1 February 2017 (Lead: A. Dickson).

3.3. Development of OA "kits" (observing and experimental)

The goal is to provide a list of resources and equipment/material needed to start ocean acidification research, referred to as "software" and "hardware," respectively. Three types of kits were imagined by the group (Figure 3.3.1):

- *Carbonate chemistry* (essential to all ocean acidification work, both observing and experimental studies)
- *Monitoring biological impacts* (as discussed in Task 2 of the GOA-ON Biology Working Group[5]), and
- *Experimental* (with the goal to explore OA responses in marine organisms).

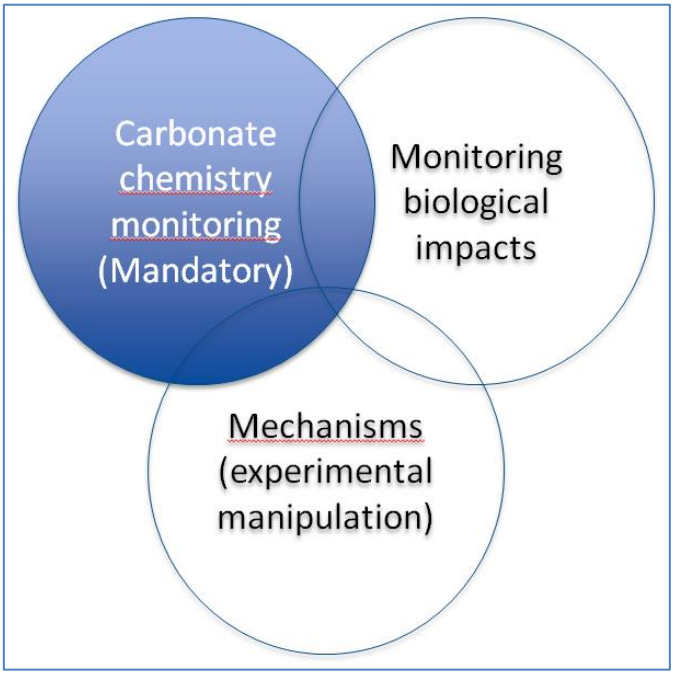

Figure 3.3.1: *Starter OA kits to respond to three separate sets of questions: (i) basic chemistry monitoring (ii) basic biological monitoring, and (iii) study of the underlying mechanisms of how the chemistry is affecting the biology. Courtesy Steve Widdicombe and Sam Dupont.*

The software and hardware proposed for the different kits are summarized in Table 3.3.1., with lead contributors.

[5] See https://news-oceanacidification-icc.org/2016/10/21/meeting-of-the-biology-working-group-of-the-global-ocean-acidification-observing-network-goa-on-10-11-october-2016-monaco/#more-26283

	Software	Hardware
Chemistry	**Documents, E-learning:** - Suggested protocols (Standard Operating Procedures) for: • Sampling and preservation of seawater (Andrew) • Measurement of T, S, oxygen, and recommended CO_2 system parameters (TA and pH), including quality control (Andrew). • "What chemical data are needed for biologists"? (Sam) - Data analysis and data submission guidelines/template (could build on existing templates developed by the ocean carbon community, but may need to be adapted since currently for open ocean measurements). (Maciej, Libby, Benjamin) - Training videos (TOF) and e-lectures (Andrew's and Lisa Robbins' lectures). Build on existing material, e.g. OA-ICC/USGS e-modules and Andrew's videos on water sampling. - Forum, FAQ, "Contact an expert" (Alex)	**Water sampling and preservation:** - Suitable sample containers - Mercury(II) chloride -System for safely dispensing mercury(II) chloride into samples **Spectro pH:** - spectrophotometer - 1 cm cells - thermometer probe for 1 cm cells - calibrated meta-cresol purple ***In situ* pH:** - iSAMi or equivalent sensor **TA:** - Calibrated syringe burette - Digital voltmeter / pH preamplifier / pH cell - Thermometer / Titration vessel **Quality control:** Certified Reference Materials (CRMs)
Impacts	**Documents, E-learning:** - General information on long term biological monitoring: importance, methodology (e.g. plankton nets, nutrients, etc.) (e-lecture; Maciej) - OA-specific biological endpoints (GOA-ON Biology WG – task 2; Kirsten) - How to deploy and analyze accretion plates (e-lecture; GOA-ON Biological Working Group Task 2 - Kirsten) - Data analysis and data submission guidelines/template (Benjamin Pfiel, Yan Yang, TBC) - Training videos (TOF) and e-lectures (build on existing material, e.g. IOC-WESTPAC) - Forum, FAQ, "Contact an expert" (Alex)	Accretion plates Other?
Mechanisms	**Documents, E-learning:** - OA big picture + how to identify a key question (e-lecture; Sam)* - Experimental design check list (generalities, scenarios, etc.) (e-lecture; Sam)* - Recommended methodology for carbonate chemistry manipulation (decision tree; Sam) - Considerations on characterization of the carbonate chemistry in biological experiments (e-lecture; Andrew)* - How to manipulate seawater with CO_2 and pHstat (e-lectures; Sam) - Data analysis and data submission guidelines/template (Benjamin, Yan) - Forum, FAQ, (e.g. biological endpoints), "Contact an	A set of 6 pH stat systems (e.g. Aquamedic pH computer + pH probe + manometer + electric valve).

	expert" (Alex) - Training videos (TOF) * = Build on existing/upcoming OA-ICC/USGS e-modules.	

Table 3.3.1: *Suggested content for the three types of OA kits.*

The approximate cost of a starter kit should be less than 15,000 USD (assuming that the laboratory already has access to basic infrastructure and small material, some equipment (e.g. a spectrophotometer) and equipment and resources to measure T, S, and oxygen for OA observing measurements:

- TA: 1500
- pH: 500
- iSAMI: 3000 USD
- Accretion plates (approx. 5 units): 400 USD
- pHstat: 6*300 = 1800 USD
- Reference material: 4 bottles (minimum shipping) = 212 USD plus shipping and customs
- Possible travel stipend for expert/mentor to install/deliver kit: 4000 USD (TOF)

For the biology kits, the group does not recommend to suggest sentinel species to detect OA effects (see also discussions of Biology WG of GOA-ON), but to focus on the local research questions/interests. The "Mechanisms" kit will build on Sam Dupont's recent experience from the training course in Mozambique (February 2016) where a basic OA laboratory was set up from scratch and some first data on biological impacts collected. The basic experimental kit should be possible to be moved around easily (e.g. for set up in a laboratory but also e.g. an aquaculture setting).

The kits should be seen as a help to start OA research, with the hope that these initial activities can help leverage national interest and funding so as to ensure the sustainability of the research (e.g. human resources, incorporating OA into longer-term research plans etc.). It is also important to note that the INT7019 project only has limited project funds to procure the actual hardware of the kits at this point in time. TOF will have some funds during the coming years to provide kits to selected laboratories in the regions where they will be conducting workshops (including hardware).

Time line and actions: The OA-ICC and USGS have been supporting the development of e-learning modules based on the lectures from previous OA-ICC training courses coordinated by Lisa Robbins. These are currently in review by the lecturers (Andrew, Sam, Lisa, Helen Findlay, Patrizia Ziveri) and could be made available as soon as the lecturers are comfortable with the content. TOF has a dedicated budget for e-learning material and will take the lead on the production of the other e-lectures mentioned in the table above, as well as the proposed video lectures (how to use the kits), together with the experts. The SOPs for TA and pH are expected to be available by the end of the year. It is hoped that (most of) the software part of the kits could be available by July 2017, recognizing that it will be an iterative process and that the content of the kits may evolve over time. The software part of the kits (resources, documents, e-lectures) will be made available for the community via several outlets and web sites (OA-ICC, GOA-ON, IOCCP, NOAA OAP, IOC-UNESCO etc.).

3.4. Training needs and possibilities

One of the main messages from the discussions was that providing the hardware alone will not be sufficient to ensure sustainable results. The training component is essential, and is also the most challenging aspect, requiring substantial effort and resources. For example, for *in situ* sensors such as the iSAMI it is not sufficient just to deploy the sensor, but there will be a need for substantial post-processing of the data collected and appropriate training to learn how to do so.

It is recognized that different levels of training will be needed, and the ideal would be to use a layered capacity building approach. The resources and e-learning tools included in the software parts of the kits are a key first step and will allow informing a large number of individuals. Basic OA courses such as the ones organized in the past by the OA-ICC, TOF and others are very useful to introduce the topic and to get started, but more advanced or targeted training will be needed for many labs. The goal is to be able to identify and propose tailored training based on the information collected from the questionnaire, with entry level being the basic OA course format (chemistry and biology with some hands-on exercises) and intermediate level being more targeted (e.g. a course specifically on how to measure TA and pH, with substantial hands-on and quality control elements; a 1-week fellowship with an advanced OA laboratory; a course dedicated to biological aspects such as experimental design; or the visit of an expert to help set up equipment and provide on-site training). For more advanced research groups, appropriate training courses could deal with data analysis, QC and management, or workshops/activities on specific topics (e.g. networking, data sharing, data synthesis products, proposal writing, inter-comparison exercises etc.). The Pier2Peer mentorship program is a very valuable scheme which will complement the training at all levels. Additional useful resources would be the creation of an online forum where people could post questions and exchange experiences, as well as a Frequently Asked Questions document. These resources will be crucial to make training effective since a training course can only accommodate so many people. It is also recommended to produce high-quality training videos, working with a professional filmmaker on a suitable script, with material from training courses which could be used to reach a wider audience (e.g. filming the set-up of a biology kit, or hands-on training on carbonate chemistry parameters).

Pros and cons of different formats, lengths, number of students, and focus of training activities were discussed, e.g. extending courses to two weeks, more targeted courses (focus on chemistry vs. biology aspects), focusing on only two carbonate chemistry parameters, building training around the kits, benefit of training courses versus fellowships, practical duration of fellowships etc.[6] Hopefully the information gathered from the questionnaire will help to adapt courses and other capacity building actions to meet the need, and this will be largely on a case-by-case basis.

The follow-up of training courses and other capacity building actions is also critical. In addition to Pier2Peer, the discussion forum and FAQs mentioned above, and networking activities such as OA-AFRICA, it would for example be valuable to support or at least inform about e.g. international funding opportunities for research projects (both through the software part of the kits and as an integral part of the training activities). One such opportunity could be the new Future Earth – Belmont Forum "Collaborative Research Action" (http://futureearth.org/sites/default/files/oceans_1.pdf).

[6] See also reports from IAEA courses in Xiamen and Cape Town, where different types of formats were briefly discussed: https://www.iaea.org/ocean-acidification/page.php?page=2246.

Time line and actions: The distribution of and assessment of the results from the questionnaire is the first step to analyse training needs. In terms of INT7019 implementation a meeting of all project partners is planned for 10-12 April 2017, where training needs will be assessed.

3.5. Implementation and possibilities for collaboration

A main goal of the meeting was to bring together different organizations working on ocean acidification capacity building projects and identify opportunities for collaboration and coordination of efforts to make the most of the available resources and avoid duplication. Section 2 above briefly described OA-related activities of the participants and partnerships already in place. The discussions also identified new possibilities for collaboration, such as ongoing and planned projects in the UK overseas development areas through the CME (Commonwealth Marine Economies) Programme.[7] Table 3.5.1 lists upcoming and planned meetings, courses and activities by the organizations represented at the meeting and other known events with potential for collaboration.

Dates and venue	Meeting	Lead organizers/supporters
3-10 December 2016, Ensenada, Mexico	Technical Workshop on Carbonate System Measurements for Latin-American Ocean Acidification Network	IOCCP, LAOCA, OA-ICC
12-20 February 2017, Dakar, Senegal	Training + networking for African countries (tbc)	Future Earth Coasts, SOLAS, IMBER, SMART, OA-ICC
TBD January, 2017	OA-AFRICA Second Networking Call	Chibo Chikwililwa (University of Namibia), Warren Joubert (CSIR, South Africa), TOF, NOAA OAP
20-24 February 2017, Accra, Ghana	IAEA RAF7014 regional training course on OA carbonate chemistry (basic)	IAEA TC
10-12 April 2017, Vienna, Austria (IAEA HQ)	INT7019 Coordination meeting (with all project Counterparts)	IAEA TC
17-20 April 2017, Qingdao, China	10th WESTPAC International Scientific Conference	IOC-WESTPAC
April/May 2017, UNESCO HQ, Paris, France, TBD	GOA-ON Executive Council meeting	GOA-ON, IOC-UNESCO
TBD April, 2017	OA-AFRICA Third Networking Call	Chibo Chikwililwa (University of Namibia), Warren Joubert (CSIR, South Africa), TOF, NOAA OAP
Spring/summer 2017, Scripps	Inter-laboratory comparison exercise	Scripps, NOAA OAP
16-18 May 2017, Buenos Aires, Argentina	LAOCA Science Symposium	LAOCA
5-9 June 2017, New York, USA	SDG14 conference	Fiji, Sweden, IOC-UNESCO…
5-6 October 2017, Malta	2017 Our Ocean Conference	
5-7 December 2017, Cape Town, South Africa (tbc)	OA-AFRICA in-person networking workshop	OA-ICC, CSIR, University of Cape Town and other partners
2017, TBD	Training courses/workshops of INT7019 (level and location to be determined, per questionnaire results)	IAEA TC/OA-ICC
Second semester 2017, TBD	IAEA RAF7014 regional training course on OA carbonate chemistry (advanced)	IAEA TC
2017, Latin America TBC	Reference User Group regional stakeholder meeting (aquaculture focus?)	RUG/OA-ICC (LAOCA?)
End 2017, Fiji	Training course (with kits provided)	TOF/GOA-ON
2018, Caribbean/Latin America	Training course (with kits provided)	TOF/GOA-ON
2018, Kristineberg (Sweden)	Training course on sensors and carbonate chemistry similar to the 2015 course (see	IOCCP

[7] For example, in the Seychelles pH, nitrate and phosphate sensors have been deployed in conjunction with a CTD (Conductivity, Temperature, Depth) sensor that will enable changes in marine nutrients and ocean acidification to be monitored around the Saint Anne Marine National Park. Training activities are also planned.

	http://www.ioccp.org/sensorscourse)	
2018, Indonesia	2018 Our Ocean Conference	
2018, tbd	Training courses/workshops of INT7019 (level and location to be determined, per questionnaire results)	IAEA TC/OA-ICC
2018, Caribbean TBC	Reference User Group regional stakeholder meeting (focus on coral reefs?)	RUG/OA-ICC
2019, Arctic countries, TBC	Training course (with kits provided)	TOF/GOA-ON
2019, TBD	INT7019 Stakeholder meeting	IAEA TC
2018, South Africa, India? TBC	Reference User Group regional stakeholder meeting (focus on fisheries?)	RUG/OA-ICC

Table 3:5.1 *Upcoming or tentative meetings, training courses and events with potential for collaboration or good to be aware of.*

Different actors are complementary in terms of coverage/priorities of countries and types of actions possible to support (courses, fellowships, e-learning, networking meeting, kits/material), with many possibilities for collaboration and leveraging efforts. For example, support through the IAEA INT7019 project could be explored to cover participation from the four IAEA Members States in the Pacific SIDS (Marshall Islands, Palau, Fiji and Papua New Guinea) to attend the planned TOF training course in Fiji at the end of 2017 (TOF funds will be used toward Fiji, Vanuatu, Papua New Guinea, and Palau). Similar arrangements were put into place for the TOF course in Mauritius in July 2016 where 5 IAEA participants were able to participate.

Time line and actions: A list of countries (and potentially individuals) involved in various projects/ efforts will be shared in a Google spreadsheet (Lina, Alex, Alexis, Doug). Regular coordination calls organized by TOF will continue (Alexis, Sam, Andrew, Alex, Lina etc.). Check on the possibility for Pier2Peer/INT/OA-ICC collaboration (e.g. jointly funded calls for proposals; Lina and Alex).

3.6. <u>INT7019 implementation and next steps</u>

In addition to the matters discussed above, advice from participants on the implementation of INT7019 (but relevant also to other efforts) included the importance of data sharing and thinking about data management aspects from the beginning (e.g. submission to national Data Centres and participation in international data portal or data compilation initiatives such as GOA-ON and OA-ICC activities). Another advice was to try to ensure an active and effective data quality control program. In terms of quality control for carbonate chemistry measurements, one interesting activity would be to organize an inter-laboratory comparison like the one described in Bockmon & Dickson, 2015. Scripps/NOAA will do another one in the second quarter of 2017 and it may be possible for IAEA to sponsor additional labs (approximate cost to participate is 400 USD).

Tentative INT7019 time line:

- December 2016: Questionnaire distributed and simplified methodology and protocols available.
- February 2017: Capacity assessment/analysis completed.
- 10-13 April 2017, Vienna (IAEA HQ): Coordination meeting involving all INT7019 Counterparts. Presentation of the new methodologies, kits and results from questionnaire, planning of capacity building and other project activities according to needs and priorities (levels, locations etc.), discussing opportunities for collaboration (presentation of planned

work in MS), data sharing and outreach aspects (e.g. white papers). Inform about international efforts and opportunities.

- 2017-2018: Implementation of different levels of training and capability enhancement to enable MS to reach the level required to produce adequate data and start collaborations with other countries. Data collection and analysis, coordination activities, with in-person meetings of the participating MSs and representation in international meetings.
- 2019: Data synthesis activities, continued networking, and communication to stakeholders.

Annexes

Annex I: List of participants

Annex II: Agenda

Annex III: Draft questionnaire

Annex IV: Summary Powerpoint presentation

ANNEX I – LIST OF PARTICIPANTS

Expert meeting on development and standardization of methodology (IAEA INT/7/019)
12 - 14 October 2016
IAEA Environment Laboratories
Monaco

1	**IOC-UNESCO**	**Ms Kirsten Isensee** Intergovernmental Oceanographic Commission - Ocean Science Section UNESCO 7, Place de Fontenoy 75732 PARIS cedex 7 FRANCE	Email : k.isensee@unesco.org
2	**POLAND**	**Mr Maciej Telszewski** International Ocean Carbon Coordination Project Institute of Oceanology of Polish Academy of Sciences Ul. Powstancow Warszawy 55 81-712 SOPOT	Email : m.telszewski@ioccp.org
3	**SWEDEN**	**Mr Sam Dupont** Department of Biological and Environmental Sciences - Kristineberg University of Gothenburg Kristineberg 566 SE-451 78 FISKEBÄCKSKIL	Email : sam.dupont@bioenv.gu.se
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5	**UK**	**Mr Steve Widdicombe** Plymouth Marine Laboratory Prospect Place The Hoe PLYMOUTH PL1 3DH	Email: swi@pml.ac.uk
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8	**USA**	**Mr Mark J. Spalding** The Ocean Foundation 1320 19th Street NW 20036 WASHINGTON DC	Email: mspalding@oceanfdn.org
9	**USA**	**Ms Alexis Valauri-Orton** The Ocean Foundation 1320 19th Street NW 20036 WASHINGTON DC	Email: avalaurioton@oceanfdn.org
10	**IAEA**	**Ms Lina Hansson** OA-ICC / Radioecology Laboratory IAEA Environment Laboratories 4a Quai Antoine 1er 98000 MONACO	Email: L.Hansson@iaea.org
11	**IAEA**	**Mr Marc Metian** Radioecology Laboratory IAEA Environment Laboratories 4a Quai Antoine 1er 98000 MONACO	Email : M.Metian@iaea.org
		PARTICIPATING VIA VIDEOCONFERENCE ON 13 OCTOBER	
12	**AUSTRALIA**	**Mr Bronte Tilbrook** CSIRO Oceans and Atmosphere & Antarctic Climate and Ecosystems CRC Hobart	Email: Bronte.Tilbrook@csiro.au
13	**CHINA**	**Mr Minhan Dai** State Key Lab of Marine Environmental science College of Ocean & Earth Sciences Xiamen University Xiamen	Email: minhandai@qq.com

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15	**EGYPT**	**Ms Nayrah Shaltout** National Institute of Oceanography and Fisheries Cairo	Email: nshaltout@gmail.com
16	**FRANCE**	**Mr Jim Orr** LSCE/IPSL, Laboratoire des Sciences du Climat et de l'Environnement CEA-CNRS-UVSQ Gif-sur-Yvette	Email: James.Orr@lsce.ipsl.fr
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19	**USA**	**Ms Jan Newton** University of Washington Seattle	Email: janewton@uw.edu
19	**USA**	**Ms Adrienne Sutton** NOAA Pacific Marine Environmental Laboratory Seattle	Email: Adrienne.Sutton@noaa.gov

Group picture. From left to right: Andrew Dickson, Maciej Telszewski, Lina Hansson, Alex Harper, Doug Connelly, Kirsten Isensee, Sam Dupont and Alexis Valauri-Orton.

ANNEX II - AGENDA

Expert meeting on development and standardization of methodology (IAEA INT/7/019)
12 - 14 October 2016
IAEA Environment Laboratories
Monaco

Wed 12 Oct ***Technical discussions on OA kits and simplified protocol development***

9:00 Welcome address (Mr David Osborn, Director, IAEA NAEL)

9:05-9:20 Presentation of IAEA INT7019 and goals of the meeting, logistics (Ms Lina Hansson, IAEA)

9:20-10:30 **Capacity assessment:** Presentation of questionnaire to assess capacities of Member States, and preliminary results (input from a few countries) (Mr Sam Dupont, Univ. of Gothenburg).

Feedback from meeting participants.

10:30-11:00 *Coffee and tea*

11:00-12:30 **OA kits and simplified protocols** (Leads: S. Dupont and A. Dickson).

Requirements for: infrastructure, equipment, smaller material, protocols, training modules, human resources, maintenance aspects, and associated costs (start with biology)

12:30-14:00 *Lunch*

14:00-16:00 OA kits discussion cont. (Leads: S. Dupont and A. Dickson)

16:00-16:30 *Coffee and tea*

16:30-17:15 **Acceptable uncertainties in carbonate chemistry parameters, and how to estimate them** (Mr Andrew Dickson, Scripps Institution of Oceanography). Data management (QA/QC of obtained data, data archiving and sharing).

17:15-18:00 Discussion: acceptable uncertainties in carbonate chemistry parameters, and how to estimate them (Lead: A. Dickson)

19:00 *Reception*

AGENDA

Thursday 13 Oct	***Technical discussions on the development of OA kits cont., implementation of kits and capacity building***
8:30-10:30	Uncertainties discussion cont. (Lead: A. Dickson)
10:30-11:00	*Coffee and tea*
11:30-12:30	**Implementation:** possibilities of coordinating, funding and implementing the kits to ensure long term sustainability and contribution to international efforts (Lead: L. Hansson)
12:30-14:00	*Lunch*
14:00-16:30	Implementation discussion cont. (Lead: L. Hansson)
16:30-17:00	*Coffee and tea*
17:00-19:00	Discussion slot on uncertainties and kits with participants by VC
Friday 14 Oct	***Workshop products. INT7019 implementation.***
8:30-10:30	OA kits and uncertainties discussion cont. as needed (Leads: S. Dupont and A. Dickson)
10:30-11:00	*Coffee and tea*
11:30-12:30	**INT7019 schedule and implementation:** Input from participants on INT7019 implementation plan and appropriate training for INT7019 participants (e.g. merit of regional carbonate chemistry centres, potential hosts for fellowships and lecturers for training courses, in order to tailor capacity building to the specific needs of the Member State).
12:30-14:00	*Lunch*
14:00-16:00	Implementation INT7019 discussion cont.
16:00-16:30	*Coffee and tea*
16:30-18:00	Work on protocols, kits, meeting report, as needed
18:00	Wrap up and end of meeting

ANNEX III - QUESTIONNAIRE

The online questionnaire is available here:

https://docs.google.com/a/noaa.gov/forms/d/e/1FAIpQLSeeRlrb9HE2dqTeOMychPCz5xAXUWx2ke9tz82DAXL5a2S0lA/viewform

Below is the questionnaire in Word format:

Evaluating Capacity

Your name:
Your institution:
Your email address:
Your position (e.g. minister, researcher, student, etc.):

Expertise & Motivation

- What is your expertise? (e.g. marine biology, biogeochemistry, etc.)
Type of answer: OPEN ANSWER

- Are you already working on OA?
Type of answer: YES / NO

If yes

- Since when?
  Type of answer: (YEAR)

- What aspect of OA are you currently covering?
  Type of answer: Chemical monitoring, Biological monitoring, Experimental work, Social, Political, Communication, other (OPEN)

- Are you planning to expand your work to other aspect(s)?
  Type of answer: Chemical monitoring, Biological monitoring, Experimental work, Social, Political, Communication, other (OPEN)

If no

- What is your motivation to start OA research?
  Type of answer: Collect data, networking, education, policy, other (OPEN)

- What aspect of OA are you intending to cover?
  Type of answer: Chemical monitoring, Biological monitoring, Experimental work, Social, Political, Communication, other (OPEN)

Equipment & Human resources

- Describe the electric system at your institution:
  - What is the voltage?
    Type of answer: 220/230V, 110/120V, other (OPEN)
  - What is the frequency?
    Type of answer: 50Hz, 60Hz, other (OPEN)
  - What is the type of socket?
    Type of answer: OPEN? (or list form https://en.wikipedia.org/wiki/AC_power_plugs_and_sockets)
  - Do you have electricity supply 24h per day?
    Type of answer: YES/NO
  - Is the electric system stable?

Type of answer: YES/NO
If no, is there any back-up system (e.g. generator)?
Type of answer: YES/NO

- Is there access to stable internet network?

Type of answer: YES/NO

- Do you have access to a fully equipped chemical laboratory?

Type of answer: YES/NO

If yes

- do you have access to:
  - ✓ Laboratory balance (±1mg)
  - ✓ Assorted laboratory glassware
  - ✓ Purified water source
  - ✓ Temperature bath, or temperature controlled lab (±1°C)
  - ✓ Pipettes
  - ✓ Magnetic stirrer

Type of answer: Tick box

- Do you have access to a fully equipped biology laboratory?

Type of answer: YES/NO

If yes

- do you have access to:
  - ✓ Assorted laboratory glassware
  - ✓ Assorted laboratory plastic ware
  - ✓ Micropipettes and tips
  - ✓ Binocular microscopes
    - With camera
  - ✓ Microscopes
    - With camera
  - ✓ Dissection kits

Type of answer: Tick box

- Do you have access to thermoconstant lab facilities?

Type of answer: YES/NO

If yes

- What is the temperature range?

Type of answer: from (temp) to (temp)

- Do you have access to marine infrastructures?

Type of answer: YES/NO

If yes

- do you have access to:
  - ✓ Flowing seawater
    - Natural
    - Artificial
  - ✓ Climate room controlling for
    - Temperature
    - Photoperiod
    - Other (OPEN)

Type of answer: Tick box

- What field sampling method do you have access to?
  - ✓ Diving
  - ✓ Boat

- ✓ Plankton nets
- ✓ Dredging
- ✓ Manual
- ✓ Box cores
- ✓ ROV

Type of answer: Tick box

- What equipment/human resources are available to measure the following parameters:

- Temperature **If yes**
  - ✓ Functional and calibrated equipment (precise: OPEN)
  - ✓ Trained technician

  Type of answer: Tick box
- Salinity **If yes**
  - ✓ Functional and calibrated equipment (precise: OPEN)
  - ✓ Trained technician
  - ✓ Standards

  Type of answer: Tick box
- pH **If yes**
  - ✓ Functional and calibrated equipment
    - Glass electrode
    - Spectrophotometer
  - ✓ Trained technician
  - ✓ Standards

  Type of answer: Tick box
- Alkalinity **If yes**
  - ✓ Functional and calibrated equipment (precise: OPEN)
  - ✓ Trained technician
  - ✓ Standards

  Type of answer: Tick box
- DIC **If yes**
  - ✓ Functional and calibrated equipment (precise: OPEN)
  - ✓ Trained technician
  - ✓ Standards

  Type of answer: Tick box
- pCO_2 **If yes**
  - ✓ Functional and calibrated equipment (precise: OPEN)
  - ✓ Trained technician
  - ✓ Standards

  Type of answer: Tick box

- Do you have some equipment to manipulate the carbonate chemistry?

Type of answer: YES/NO

If yes

- Acid/carbonate
- Pure CO_2 gas
- Pre-mixed CO_2 gas
- pH stat
- Gas mixer

Type of answer: Tick box

Training needs

- Did you/your staff or colleagues already receive training on ocean acidification? (OPEN)

- What kind of training do you think you and/or your colleagues would need to be able to monitor OA or set up OA experiments at your institute / in your country? (OPEN)

National strength and marine resources

- What are the key marine ecosystems in your country/area?

- Coastal
  - ✓ Intertidal
  - ✓ Sandy shores
  - ✓ Rocky shores
  - ✓ Mudflats
  - ✓ Mangrove and salt marshes
  - ✓ Estuaries
  - ✓ Kelp forests
  - ✓ Seagrass meadows
  - ✓ Coral reefs
- Open ocean
  - ✓ Surface waters
  - ✓ Deep sea
- Sea floor
  - ✓ Vents and seeps
  - ✓ Trenches
  - ✓ Seamounts

Type of answer: Tick box

- What are the key marine economical resources in your country/area?

- Food
  - Traditional fishery (if clicked, OPEN for taxa)
  - Industrial fishery (if clicked, OPEN for taxa)
  - Aquaculture (if clicked, OPEN for taxa)
- Tourism
- Blue technology
- Shipping
- Mining
- Non-economic resources (if clicked, OPEN)

- What are the key marine related questions in your country/area (scientific, societal, etc.)?

Type of answer: OPEN ANSWER

Networking, Challenges & Barriers

Are you or have you been involved in an IAEA project?

Type of answer: YES/NO

If Yes, could you provide project number or describe activity

Type of answer: OPEN ANSWER

- Are you a member of the Global OA Observing Network (GOA-ON)

Type of answer: Tick box

- Yes, I am a GOA-ON member
- No, I am not a member but would like to become one
- No, I am not interested in becoming a GOA-ON member

- Do you belong to any OA regional network?

Type of answer: YES/NO
If yes

- Which organization?

  Type of answer: Tick box
  - ✓ Latin American OCean Acidification (LAOCA) Network
  - ✓ IOC-WESTPAC
  - ✓ OA-Africa Network
  - ✓ Arctic Monitoring and Assessment Programme (AMAP)
  - ✓ Other

- Are you involved in the Pier2Peer mentorship program?

Type of answer: Tick box

- Yes, I am involved.
- No, but I would like to sign-up.
- No, I am not interested in participating in the Pier2Peer program.

- Are you aware of any barriers for e.g. data sharing, equipment sharing, equipment/sensor safety, networking, in your institution or country?

Type of answer: YES/NO
If yes, OPEN for more information

Other resources & contacts

- Are you aware of existing OA-related work in your country?

If yes,

- Chemical monitoring (if clicked, provide contact information)
- Biological monitoring (if clicked, provide contact information)
- Experimental work (if clicked, provide contact information)
- Outreach/Communication (if clicked, provide contact information)
- Social/Political Science (if clicked, provide contact information)

Type of answer: Tick box

- Are you aware of other relevant marine monitoring work in your country?

If yes,

- Chemical monitoring, e.g. cruises, buoys, time series (if clicked, provide contact information)
- Biological monitoring (if clicked, provide contact information)

Type of answer: Tick box

- Can you provide contact for 2-3 key marine science / marine infrastructure in your country (name, affiliation, email address)?

Type of answer: OPEN

- Is there anything else you would like to share with us?

Type of answer: OPEN