Interim Program Evaluation 3/23/23 (updated Dec. 2023)

International Quiet Ocean Experiment

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Foreword: The leaders of the International Quiet Ocean Experiment (IQOE), when they formally initiated the program in 2015, considered it a "decadal" program that should achieve its goals by 2025, when the program would be fully evaluated and then deliberately and purposefully concluded, continued, or re-invented. This document is an interim self-evaluation of IQOE's life to date intended both to improve strategy for the next two years and to establish the framework for the 2025 evaluation.

1. IDEA and/or GOAL

a) What was the original idea or goal of the IQOE? Did the Program fulfill the original idea? What were the major ways in which the concept or goals changed or evolved?

The original goal of the IQOE was to learn about the effects of sound on marine life by subtracting rather than adding noise, both through "natural experiments" (periods when human and other sources of noise greatly diminish, as after a major storm) and through an organized week or day during which human sources might be minimized. First raised by Jesse Ausubel in 2009 in a talk at Dalhousie University on "Broadening the scope of global change to include illumination and noise" and then at a 2008 meeting of the Scientific Committee on Oceanic Research (SCOR), the vision was to enhance widely the system for observing ocean sound with passive acoustics and then to have periods of intense recording of both the soundscapes and behaviors of marine life. Ausubel, based on his experience with the Census of Marine Life and the International Geosphere-Biosphere Programme, believed that ocean sound, as an element of global change, had not been properly addressed and that decreasing human sound in the ocean could help us learn more about the effects of sound on marine organisms and benefit both the organisms and sustainability of stakeholders who add sound to the ocean. In the background was a question of capacity building, as early career scientists did not seem to be choosing marine acoustics and bioacoustics in sufficient numbers to meet upcoming challenges, either in developed or less-developed nations.

An exploratory meeting (U of Rhode Island, 2010) and an 150-person open science meeting at the Intergovernmental Oceanographic Commission (Paris, 2011) led to publication of an IQOE Science Plan (2015), describing a program of research, observations, and modeling to document the levels of sound in the ocean and its impacts on marine organisms.

The Program has partly fulfilled the original idea but has not led to the expected level of development of passive acoustic monitoring for marine ecology on a global scale.

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The Program shifted away from large-scale monitoring demonstrations and development to narrower experiments, standardization, calibration, software development, and digital libraries.

COVID changed the program, helpfully providing a "Year of the Quiet Ocean" but also slowing developments in several dimensions.

b) What about idea proved new?

IQOE is the first fully global project on ocean acoustics and bioacoustics. Also novel is the focus on passive acoustics, studies on natural and anthropogenic sound in the ocean, but not by adding sound to the ocean. The possibilities of low-cost hydrophones and low-cost acoustic observing systems are also new, though not unforeseen. Taking advantage of passive acoustics to assess marine biodiversity on large scales is new. Taking advantage of the natural experiment of the COVID pause obviously was new, and unexpected. The progress of machine learning created unanticipated opportunities for automated analyses of ocean sound.

c) What about the idea proved most important?

IQOE has drawn attention to the absence of publicly available time series of sound on ecologically important frequencies throughout the global ocean and to the difficulty of accessing the time series that do exist.

It has provided a platform for the international passive marine acoustics community to grow stronger and advocate for inclusion of acoustic measurements in national, regional, and global ocean observing systems and encouraged a next generation of leaders.

It successfully developed and won acceptance for Ocean Sound as an Essential Ocean Variable in the Global Ocean Observing System.

It capitalized on the COVID pause, declaring 2020 the "Year of the Quiet Ocean".

It established the possibility of new sources of data for marine biodiversity assessments (such as the World Ocean Assessment and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)) and to inform policy (e.g., for the Convention of Biodiversity (CBD) and the Intergovernmental Oceanographic Commission (IOC)).

d) How did the leadership shape the opportunity?

The leadership operated mainly in three ways. First, an International Science Committee formed and provided overall leadership on content and priorities. The SC provided the overall shape of the program. Ian Boyd, Peter Tyack, and George Frisk played the largest roles in the early years, and Tyack, Steve Simpson, and Miles Parsons more recently. Tyack formally bridged IQOE and the Global Ocean Observing System (GOOS) through his membership in its BioEco Panel. Second, professional staff members of SCOR (Ed Urban and Patricia Miloslavich) and POGO (Sophie Seeyave) provided consistent, reliable, and constructive operations (including the IQOE website) and effective liaisons with the main international sponsors and with stakeholders such as the IMO and CTBTO. Third, an informal, largely American group, including Jesse Ausubel, Paul Gaffney, and Jennifer Miksis-Olds played leading roles in arranging funding, providing feedback on strategy, and assuring substantial U.S. participation. The scientific leaders maintained control of the program. One issue was whether to ally with the active

acoustics community; the leadership consistently opted to keep the IQOE purely focused on passive acoustics.

e) Was there timeliness in pursuing the idea? Was it too early or too late?

IQOE development was timely in that it coincided with the increasing deployment of non-military hydrophones, and IQOE may have stimulated this process. IQOE has documented and mapped this increase. IQOE has also been timely because it has taken place as the Global Ocean Observing System's Essential Ocean Variables (EOVs) were developed. The original list of EOVs did not include ocean sound, an important variable for understanding many ocean processes including distribution and abundance of marine organisms and human impacts on these organisms.

IQOE may also have been too early, in that the ocean acoustics and bioacoustics community had no experience in working together globally. IQOE provided a catalyst to help these communities work together globally, but there is still progress to be made, both in networking and expanding hydrophone deployment. Coverage is still far from global and includes many gaps.

While the geopolitical climate around 2010 was quite favorable for international cooperation, the steep increase since then in "Great Power Competition" has made international cooperation harder in general, and for ocean sciences in particular. In 2020 the United Nations proclaimed a Decade of Ocean Science for Sustainable Development (UNDOS, 2021-2030) to gather ocean stakeholders worldwide behind a common ocean science framework to support countries in improving ocean health and conditions for sustainable development of the ocean. However, this program has also suffered from the difficult geopolitical context, as well as from the inevitable priority of responding to COVID.

The "COVID Pause" in global economic activity during 2020 was fortuitous for the IQOE, as it caused substantial quieting in much of the ocean.

The IQOE may have been a little early in that machine learning/AI may be extremely helpful for digestion of enormous datasets, and these capabilities are just now coming online, as demonstrated by the March 2023 paper by the Chakraborty group (Goa, India).

Important aspects of the ocean acoustics field remain bound by constraints of military and government control. This has not changed appreciably over the lifetime of the IQOE.

2. PROCESS

a) How did the leadership pursue the idea?

A systematic approach was used to develop the IQOE idea, starting with an exploratory meeting, followed by a large open science meeting, and then formation of several working groups to involve a greater cross-section of the community and address particular needs such as standardization and calibration or regions such as the Arctic and areas with high biodiversity. Until COVID, the leadership met in person once or twice each year. During 2020-2022 most meetings were by Zoom, and one in-person meeting (in Berlin) was complicated by COVID. A blended meeting including about 50 researchers in person in April 2023 re-energized the program.

Rather than design a set of field programs from the bottom up, the field strategy adopted was to support relevant applications and endorse programs that meshed with IQOE objectives and standards.

The main endorsed efforts have been

- ADEON: Atlantic Deepwater Ecosystem Observatory Network (2016-2021)
- JOMOPANS: Joint Monitoring Programme for Ambient Noise North Sea (2018-2022)
- JONAS: A Joint program for Ocean Noise in the Atlantic Seas (2019-2022)
- NOAA/NPS Ocean Noise Reference Station Network (NRS)
- PHYSIC: Ports, Humpbacks, Y Soundscapes In Colombia
- QUIETSEAS: Assisting (sub) regional cooperation for the practical implementation of the MSFD second cycle by providing methods and tools for D11 (underwater noise) (2021-2023)
- SanctSound: NOAA Navy Sanctuary Soundscape Monitoring Project (ended 2021)
- Solutions @ Underwater Radiated Noise (SATURN) (2021-2025)
- TANGO: Rerouting shipping lanes in the Kattegat – effects on soundscape and ecosystem

The first World Passive Acoustic Monitoring Day (8 June 2023) created a dataset of globally synchronized aquatic soundscape recordings from over 100 partners in 34 nations at about 300 sites from tropical islands to ice-covered seas (and included some freshwater ponds and rivers). The Lounsbery Foundation recently awarded a grant for a post-doctoral fellow to help analysis and published the results of the 2023 WOPAM Day.

b) Did the eventual expenditure correspond to initial rough budgets?

Neither a detailed financial plan nor budget was ever developed. In general terms, the expectation was that most funding (probably $100-$300 million over a decade) would go for field experiments. Lesser amounts would support technical developments and data science/management, while a Secretariat or Project Office would coordinate the program and assist with outreach/engagement (perhaps $500k-700k/yr). While the leadership made a few applications to the EU and in the United States for core funding, the efforts were not aggressive and most proposals were declined.

In 2016-17 the Partnership for Observation of the Global Ocean (POGO) encouraged its members to step up and fund/host a Project Office, by writing to them individually soliciting proposals. Substantial interest from the Alfred Wegener Institute (AWI, Bremerhaven) led to a meeting with the AWI Director during a Science Committee meeting hosted by AWI in 2018. Although a broad Project Office was never formally established at AWI, AWI hired data managers to support IQOE work, which ultimately enabled the development of the OPUS data portal.

An important result of the overall funding shortfall was the inability to hire a full-time IQOE project manager.

Several affiliated field programs succeeded at raising funds on their own, and the expenditure on these probably totaled about $50 million.

c) Did the effort prove financially sustainable? How?

The very frugal model implemented, including much volunteer effort, has been sustainable. In terms of products in relation to expenditure the IQOE probably looks very good. Funding and important in-kind support have included:

- Targeted funding from the Alfred P. Sloan Foundation, Monmouth University/Rockefeller

University joint marine initiative, Richard Lounsbery Foundation, and POGO:

- Sloan provided seed funding for IQOE development.
- Monmouth University/Rockefeller University Consortium provided support for central functions of IQOE and development of U.S. contributions to IQOE.
- Lounsbery provided support for development of MANTA, development of the Aquatic Acoustic Library, support of central IQOE functions including some interactions with industries and with UNDOS, the on-line literature library on noise impacts on aquatic life, open access for *Exploring Animal Behavior Through Sound: Volume 1*, support to help IQOE access to data from the Comprehensive Test Ban Treaty Organization, and WOPAM. Lounsbury has also supported post-doctoral fellows to support the GLUBS and WOPAM efforts and growth of the African Bioacoustics Community.
- POGO provided support to develop the hydrophone database (from Appendix II of the IQOE Science Plan) and make it available on the IQOE website, development of the application of the Ocean Sound EOV, and development of the Ocean Sound EOV Implementation Plan.

- Annual funding from SCOR since 2015 to maintain basic functions, such as the IQOE Website and newsletter, and partial support for four meetings of the IQOE Science Committee.
- In-kind support from SCOR of part of Ed Urban's time as IQOE Project Manager. After Feb. 2020, Urban has continued staffing the project as a volunteer (except for time paid by POGO for EOV-related work).
- As mentioned, field projects such as ADEON and JOMOPANS secured substantial funding independently. IQOE provided letters of support for several programs, but it is unknown whether such letters made a difference.

d) What was the program management concept? What proved to be strengths and weaknesses?

The essence was voluntary coordination and harmonization of efforts, and adoption of roles by diverse institutions, including the Univ. of New Hampshire (USA), Woods Hole Oceanographic Institution (USA), Alfred Wegener Institute (Germany), Curtin University (Australia), U. of Perpignan (France), and other institutions. While the approved plan described above included timelines for various activities, the IQOE was not in a position to buy or enforce compliance. In the United States, NOAA generated an Acoustics Roadmap stimulated in large part by the IQOE but has implemented it only weakly.

COVID both weakened and inspired the IQOE. Momentum toward a tighter leadership group, proposal writing, and outreach to more partners was lost, but the existence of the IQOE network helped researchers to grasp the opportunity to measure and analyze the COVID pause.

IQOE created a website intended both for the broad public and participants (with a login option). The site has served mainly archival purposes. Potentially exciting features, such as the literature library, were not made user friendly or widely known.

e) How long did it take to make substantial progress?

POGO funded an IQOE Working Group in 2016, which quickly identified the lack of ocean sound as a variable measured by the Global Ocean Observing System (GOOS) and its national components. This group developed the specification sheet for an Ocean Sound Essential Ocean Variable (EOV) by 2018,

which was approved by the GOOS in 2021. IQOE has developed an implementation plan which was reviewed in 2022 and is now publicly available in 2023.

It took until about 2019 for field projects to begin to achieve results, and longer for software development and other digital resources to emerge.

The COVID pause peaked in March-April of 2020.

The concept of the Global Library of Underwater Sounds (GLUBS) emerged in 2022.

The first peer-reviewed article from IQOE activities was published in 2020, and the Erbe book in 2023. The program did not try to keep track of all technical publications that might be considered contributions to the IQOE.

In 2023, IQOE initiated the World Oceans Passive Acoustic Monitoring Day (WOPAM Day, 8 June 2023). It remains to be seen how useful WOPAM will become, but the first WOPAM Day generated a large set of observations worldwide that might generate a useful snapshot of ambient ocean sound.

In retrospect, the field was less well-formed and less prepared to move forward than the founders appreciated. More informatics infrastructure (such as MANTA, OPUS, and GLUBS) as well as the development and acceptance of the EOV were needed before an aggressive, widespread field program could be usefully implemented. While the project ramped up slowly due to lack of funding and lack of a full-time project manager, additional early funding and staffing might still have encountered problems that would have resulted in the same delays.

f) What were roadblocks? (E.g., Intellectual property issues, data management) What proved to be the highest or most dangerous risks?

Experts in passive ocean acoustics around the world did not have strong pre-existing networks and did not see themselves as a global interdisciplinary community nor know how to operate as one. This was a motivation for the program, but also a problem. One reason for the lack of community or fragmentation is that passive acoustics is of course also important for national security, so tends to be organized around national networks, and working around the security issues takes time and wisdom. Similarly, offshore energy and shipping companies, and other maritime industries have an interest in the mission of the IQOE but can be reluctant partners in research that may affect their operations. Some initial successes in relations with the International Maritime Organization and with industries were set back by COVID; during COVID most organizations retreated into themselves and focused simply on survival. While NOAA and some other national ocean agencies followed the program with interest, no national agency became its champion in the intergovernmental arena. As mentioned, the modest funding and lack of staffing were challenging. Happily, the IQOE did not run into difficulties with either environmental activist groups or militaries.

g) What did progress look like? How did the leadership know progress was being made? What were the most useful metrics?

The eleven IQOE newsletters (to date) chronicle the progress of the program. Its contributions are seen through a combination of peer-reviewed publications, tools to help the acoustic community (MANTA and OPUS), workshops convened to stimulate international cooperation, and knowledge of IQOE in the ocean acoustics community through various press releases and articles in *Oceanography*

magazine and *ECO* magazine. Modest efforts at "branding" were quite successful. Mass media coverage of the program has been excellent in relation to the investment made, and entirely favorable and friendly. Science and environment reporter Alice Hutton wrote a long, lively and informative article for the UK *Guardian* newspaper about IQOE in May 2023**.**

h) What partners emerged?

Probably the single most important international partner has turned out to be the Global Ocean Observing System, housed at the Intergovernmental Oceanographic Commission. While the imprimatur of GOOS can be widely influential in coming years in encouraging national ocean agencies to implement passive acoustic observing systems as defined by IQOE in the EOV, it is important to appreciate that GOOS itself has no resources (no money, no platforms). Another valuable international partner is the Comprehensive Test Ban Treaty Organization, which does have an excellent, enduring deep sea hydrophone network, which can grow in importance for environmental monitoring and as an operational model. Numerous national universities and institutes, such as those already mentioned, as well as the National Institute of Oceanography (Goa, India) and the U. of Exeter (UK) and National Physical Laboratory (UK) have partnered in IQOE-related activities.

h) If the group had not pursued this, would other organizations have stepped up?

On the contrary, what is striking is the absence of alternatives or competitors. The IQOE has encouraged creation of new and complementary acoustic programs, such as the Maritime Acoustic Environment program endorsed by UNDOS.

i) Within the program, what internal processes/procedures proved most significant or difficult?

The process of sharing the IQOE logo with field programs proved mutually useful. The IQOE network learned about diverse initiatives, and the concerns of IQOE (as for data management with MANTA and OPUS) may well have helped nascent programs to improve their designs.

Zoom workshops also proved fruitful, particularly with regard to low-cost hydrophones and passive acoustics in the Arctic region.

Working Groups varied in their levels of activity and effectiveness. The Biodiversity Hot Spot group generated GLUBS. The Working Groups concerned with standardization and calibration developed valuable workflows in relation to the standards organizations, ISO and ANSI.

The Newsletters and annual reporting to POGO and SCOR were very helpful in developing understanding of progress and shortcomings.

The periodic meetings (usually in Woods Hole) of the U.S. strategy group often surfaced issues in a timely way for the SC and also helped with fund-raising.

3. OUTCOMES

a) What were the main outputs?

Selected peer-reviewed publications related to IQOE

- Mooney, T.A., L.Di Iorio, M. Lammers, T-H. Lin, S. Nedelec, M. Parsons, C. Radford, E. Urban, and J. Stanley. 2020 Listening forward: approaching marine biodiversity assessments using acoustic methods. R. Soc. Open Sci. 7:201287.
- Tyack, P.L., J. Miksis-Olds, J. Ausubel, and E.R. Urban Jr. 2021. Measuring ambient ocean sound during the COVID-19 pandemic. Eos 102, https://doi.org/10.1029/2021EO155447. Published on 04 March 2021.
- Parsons, M.J., T.-H. Lin, T.A. Mooney, C. Erbe, F. Juanes, M. Lammers, S. Li, S. Linke, A. Looby, S.L Nedelec, I.C. Van Opzeeland, C.A. Radford, A.N. Rice, L. Sayigh, J. Stanley, E. Urban, and L. Di Iorio. 2022. Sounding the call for a global library of biological underwater sounds. Frontiers in Ecology and Evolution 10:810156. doi: 10.3389/fevo.2022.810156
- Robinson, S., P Harris S-H Cheong, L Wang, V Livina, G Haralabus M Zampolli & P Nielsen, The extraordinary circumstances of the COVID-19 pandemic led to, Impact of the COVID-19 pandemic on levels of deep-ocean acoustic noise, doi:10.1038/s41598-023-31376-3
- VP Mahale, K Chanda, B Chakraborty, T Salkar, GB Sreekanth, Biodiversity assessment using passive acoustic recordings from off-reef location—Unsupervised learning to classify fish vocalization, Journal of the Acoustical Society of America 153 (3), 1534-1553, https://doi.org/10.1121/10.0017248
- Seger, K.D., R. Sousa-Lima, J.J. Schmitter-Soto, and E.R. Urban Jr. 2021. Editorial: Before-After Control-Impact (BACI) Studies in the Ocean. Front. Mar. Sci. 8:787959. doi: 10.3389/fmars.2021.787959

Other Publications

- Boyd, I.L., G. Frisk, E. Urban, P. Tyack, J. Ausubel, S. Seeyave, D. Cato, B. Southall, M. Weise, R. Andrew, T. Akamatsu, R. Dekeling, C. Erbe, D. Farmer, R. Gentry, T. Gross, A. Hawkins, F. Li, K. Metcalf, J.H. Miller, D. Moretti, C. Rodrigo, and T. Shinke. 2011. An International Quiet Ocean Experiment. Oceanography 24(2):174–181.
- JOINT WORKSHOP REPORT: PREDICTING SOUND FIELDS—GLOBAL SOUNDSCAPE MODELLING TO INFORM MANAGEMENT OF CETACEANS AND ANTHROPOGENIC NOISE. 15-16 April 2014, TNO-Gorter Building, Wassenaarseweg 56, Leiden, Netherlands
- Tyack. P., G. Frisk, I. Boyd, E. Urban, and S. Seeyave (eds.). 2015. International Quiet Ocean Experiment Science Plan
- Workshop Report. 2019. Guidelines for Observation of Ocean Sound
- Studying Marine Life's Brief Break from Human Noise
- IQOE Inventory of existing standards and guidelines relevant to marine bioacoustics
- Compiled list of papers related to the effects of the COVID-19 pandemic on ocean sound
- IQOE Newsletters and Website

Workshops

- 2010: Workshop on An International Quiet Ocean Experiment
- 2011: International Quiet Ocean Experiment: Open Science Meeting
- 2014: Predicting Sound Fields: Global Soundscape Modelling to Inform Management of Cetaceans and Anthropogenic Noise
- 2018: IQOE/ASA Forum on Approaches for Studying Effects of Sound on Marine Organisms and Ecosystems
- 2019: Virtual Conference on Acoustics in the Arctic Ocean
- 2021: IQOE On-line Workshop on Low-Cost, Self-contained Underwater Acoustic Recording Systems
- 2022 and 2023: Global Underwater Library of Underwater Sounds (GLUBS) workshops

Software and Data

- MANTA
- OPUS
- Hydrophone Metadatabase

b) What were the main outcomes? What might be longer term outcomes?

In a tangible sense, the main outcomes are the EOV and the map of locations of hydrophones and associated database. In the longer run, GLUBS, WOPAM and other incipient efforts could prove very important, also the stimulus to develop low-cost systems.

A very important longer-term outcome may be a passive acoustics community ready to move to a full-scale field program for global soundscapes, and to participate coherently in assessment activities such as WOA, IPBES, and those related to climate change.

A key outcome would be integration of passive acoustics into additional observing platforms such as Argo floats and the OceanSITES deepwater reference stations.

With regard to capacity building, GLUBS in particular has surfaced a new generation of dynamic researchers and organizers. IQOE has helped boost the African Bioacoustics Community, networked from Sea Search Research and Conservation (Tess Gridley, South Africa).

c) How are the outcomes best measured or otherwise evaluated?

For the Ocean Sound EOV, having won acceptance by GOOS, the next step is development of a team for long-term implementation of Ocean Sound in GOOS. For GLUBS, the keys will be sustainable growth and use of the library. The growing literature on the COVID pause documents the outcomes of approaches to measure quieting and its effects on marine ecosystems.

d) What have been and could be impacts of these outcomes?

A couple of examples: As a recent paper from India shows, GLUBS together with AI/Machine Learning could lead to dramatically new and better ways to monitor marine life of reefs. The COVID pause literature could help identify areas where reduction of ambient noise improves the status of cetacean species.

Some success appears to have been achieved with public understanding and engagement. With Terry Collins (Toronto), three news releases chronicled the work of the IQOE and each received wide and accurate coverage:
News Release 3: Do Fish Bay at the Moon? Can Their Odd Songs Identify Hawaiian Mystery Fish? Eavesdropping Scientists Progress in Recording Understanding Ocean Soundscapes 26 April 2023
News Release 2, Global Library of Underwater Biological Sounds, "GLUBS," will help monitor changing marine life (here) 17 Feb 2022
Release 1: Year of the quiet ocean: Emerging ocean listening network will study seas uniquely quieted by COVID (in full here) 8 April 2021

e) Who are the outcomes benefitting? Are there equity issues?

A main beneficiary is likely to be marine life. Offshore industries, including the wind industry, could implement monitoring programs that will offer timely information on possible harm or benefits. A multi-user monitoring program would be more cost-effective, technically better and fairer in terms of comparing potential impacts of all activities.

The Erbe-Thomas book *Exploring Animal Behavior Through Sound: Volume 1* published in 2022 has been accessed over 146,000 times as of 7 December 2023, which suggests an enormous reach for a textbook costing $60 in hardcover. Open access tends to be especially precious for researchers in less privileged settings.

f) Did any ethical issues arise? Did the community/performers conduct itself/themselves well?

No issues that we know of.

g) Is it possible to offer some cost/benefit estimate, or some kind of benchmarking against comparable efforts?

We have not done so, but we could look at costs of establishing global observing vs one-off systems for each application and also compare costs of independent national systems with regionally and globally integrated ones. Acoustics ideally will be integrated with other observing approaches, including genomic and visual surveys. It might be possible to compare costs/benefits of the individual approaches with the joint approaches.

4. DOCUMENTATION AND OTHER DIMENSIONS

a) What are the main publications, websites or other enduring products? Are these properly archived?

The website www.iqoe.org has most key documents such as the IQOE Science Plan. A long-term strategy needs to be developed for the various documents and materials. AWI and NCEI may handle much of the data for the long run. The question of the Literature Library needs to be revisited. IQOE was slow in becoming a Wikipedia entry but now has a useful site, owing largely to teenage Canadian acoustics prodigy Artash Nath.

b) Who proved to be the most valuable and productive Program members? Which institutions (organizations, partners) proved especially valuable – or disappointing?

Mentioned above – IOC/GOOS, IMO, CTBTO at the international level. National ocean agencies have been somewhat disappointing, reflecting the ambiguity within nations for responsibility for ocean noise. The UN Decade of Ocean Science for Sustainable Development looked like it might become a valuable partner, but is itself struggling to grow.

5. MAJOR LESSONS LEARNED: What are major lessons learned? What actions or events or developments or results especially stand out?

IQOE proves that passive acoustic monitoring can be used to assess biodiversity and ecosystem health much more widely, effectively, and affordably than most other methods.

Understanding the effects of sound on marine life requires experiments to study the effect of reducing exposure as well as adding exposure.

The ocean acoustics community is highly motivated to coordinate and collaborate but needs institutional structures to maintain and curate an international data network.

GOOS offers a potential framework for coordinating funding and operations of a network of ocean acoustic observations.

Ocean acoustics is a powerful way to capture the attention and imagination of the general public.

6. PLANS FOR PROJECT LEGACY: What activities might continue beyond the life of the project?

IQOE as a coordinated international project is scheduled to run through the end of 2025. IQOE will attempt to transition several of its activities into stand-alone status as the project concludes:

- The Ocean Sound EOV is currently the responsibility of IQOE and GOOS has not agreed to assume responsibility for this EOV after 2025. It will be necessary to develop a group of experts to oversee the evolution of the EOV. This might be done by the Global Hydrophone Network group (see next point).
- Most global observing systems are overseen by either an international organization (IOC or WMO) or by a community-led group (e.g., the Argo network). IQOE is developing a Working Group on the Global Hydrophone Network that will attempt to coordinate hydrophone observations worldwide, including tracking locations and metadata, and identifying how the network needs to evolve to meet the needs of the Ocean Sound EOV. The IQOE Hydrophone

Metadatabase will provide a starting point for the network. Whatever community-led group is developed to oversee the network will be most successful if hosted by POGO, SCOR, or some other international organization that can provide logistical support.

- GLUBS envisions a platform that will evolve beyond the life of IQOE to provide tools to expand the use of passive sound observations for both science and management.