IIOE-2 2nd International Indian Ocean Expedition 2015-2025

Seventh meeting of the International Steering Committee of the Second International Indian Ocean Expedition 2015-25

IIOE-2 SC7

REPORT

By

IIOE-2 Project Office, India (INCOIS, Hyderabad)

4th and 5th March 2024

Kawasan Sains Kurnaen Sumadiharga, Badan Riset dan Inovasi Nasional (BRIN), Lombok, Indonesia

Contents

1. Preamble

The Second International Indian Ocean Expedition (IIOE-2) is a major global scientific program that engages the international scientific community in collaborative oceanographic and atmospheric research from coastal environments to the deep sea revealing new information on the Indian Ocean (e.g. its currents, its influence upon the climate, its marine ecosystems) which is fundamental for future sustainable development and expansion of the Indian Ocean's blue economy. The program was initially formulated for a period of five years (2015-2020) which was subsequently extended for another five years (till 2025) considering its importance. A large number of scientists from research institutions from around the Indian Ocean and beyond planned their involvement in IIOE-2 in accordance with the IIOE-2 Science Plan and its overarching six scientific themes of the program. IIOE-2 activities also include a significant focus on the capacity building of nations around the Indian Ocean to understand and apply observational data or research outputs for their own socio-economic requirements and decisions. In addition, an Early Career Scientists Network (ECSN) was also formed to facilitate the exchange of knowledge, translation of the science and information outputs for societal benefit, and the training of early career constituents from surrounding nations in these areas. Details on the IIOE-2's program, including its the governance structure, Steering Committee (SC), National committees, working groups and science themes are available at https://iioe-2.incois.gov.in/IIOE-2/index.jsp.

The seventh meeting of the IIOE-2 International Steering Committee (IIOE-2 SC7) was held at the Kawasan Sains Kurnaen Sumadiharga, Badan Riset dan Inovasi Nasional (BRIN), Lombok, Indonesia during 4th to 6th March 2024. As customary since 2015, IIOE-2 meeting was held under the over-arching banner of the International Indian Ocean Science Conference (IIOSC 2024) as part of an integrated set of meetings (spanning 4th to 8th March at the same venue) including - Sustained Indian Ocean Biogeochemistry and Ecosystem Research of IMBeR and IOGOOS (SIBER: 15th major meeting), Indian Ocean Region Panel of CLIVAR/IOC-GOOS (IORP: 20th major meeting), Indian Ocean Observing System Resources Forum of IOGOOS (IRF: 18th major meeting) and Indian Ocean Global Ocean Observing System (IOGOOS: 19th major meeting) along with the Korea-US Indian Ocean Science (KUDOS) Workshop as part of International Indian Ocean Science Conference (IIOSC 2024). The Kawasan Sains Kurnaen Sumadiharga, Badan Riset dan Inovasi Nasional (BRIN) provided the venue and logistical support.

The IIOSC 2024 Conference Information Booklet is available at https://iioe-2.incois.gov.in/documents/IIOE-2/IIOSC2024/IIOSC-2024-INFORMATION%20BOOKLET%20V2.pdf

The agenda of the Seventh meeting of the International Steering Committee of Second International Indian Ocean Expedition (IIOE-2 SC7) is available at https://iioe-2.incois.gov.in/documents/IIOE-2/IIOSC2024/Agenda_Seventh%20meeting_IIOE-2.pdf

This report acts as the minutes meeting in the form of a report style record to the meeting's agenda items and related actions thereof.

2. Proceedings of the meeting

2.1. Introductory Remarks

The seventh meeting of the IIOE-2 International Steering Committee (IIOE-2 SC7) was hosted by Kawasan Sains Kurnaen Sumadiharga, Badan Riset dan Inovasi Nasional (BRIN) at Lombok, Indonesia. The local host, Prof. Dr. Ocky Karna Rajasa, Head of the Earth and Maritime Research Organisation, thanked the IOGOOS secretariat for providing the opportunity to host the event at BRIN, Lombok, Indonesia. He briefed on the activities focusing on the Indian Ocean in which BRIN is involved and how it can contribute to various Indian Ocean forums.

Dr Marie-Alexandrine Sicre, Co-Chair of IIOE and representative of the Scientific Committee on Oceanic Research (SCOR) welcomed the co-chairs and members of IOGOOS and its allied programs. Dr Sicre expressed her sincere gratitude for being part of IIOE-2 on behalf of SCOR. Dr Sicre mention that IIOE-2 is a major global scientific program executed with the engagement of the international scientific community in collaborative oceanographic and atmospheric research in the Indian Ocean. Dr Sicre also appreciated the efforts by the leads of the IIOE-2 working group and science theme is preparing addendum to science plan and revised implementation plan for extension of IIOE-2 till 2030. She also ensured support from SCOR for IIOE-2.

Dr T Srinivasa Kumar, Chair of IOGOOS and Co-Chair of IIOE-2 Steering Committee, joined the session virtually and expressed his sincere gratitude to be part of IOGOOS and other Indian Ocean Forums. He briefed on how IOGOOS has significantly contributed to the Indian Ocean Observing System, and the Secretariat has also played a key role in coordinating the activities. Dr Kumar also mentioned that IIOE-2 has been a successful project and must continue aligning with the themes of the UN Decade of Ocean Science for Sustainable Development. He also mentioned the brainstorming meeting held at INCOIS in November 2023 to finalise the future roadmap IIOE-2.

2.2. Plenary keynote talks by invitation.

- **Ocean Dynamics in the Southeastern Tropical Indian Ocean under the Warning Earth" – by Prof. Iskhaq Iskandar, Sriwijaya University, Indonesia**.

Prof Iskhaq Iskandar presented "Ocean Dynamics in the Southeastern Tropical Indian Ocean," focusing on Indonesian seas. He discussed significant warming trends and sprint freshening in the Banda Sea, highlighting the vital role of Indonesian waters in global climate regulation. The study traced warming trends since 1900, emphasizing impacts on monsoon circulation and rainfall, affecting the region's food web. Rising sea surface temperature enhances ocean stratification, reducing nutrient mixing and primary productivity. Iskandar's research revealed Indonesian sea warming trends surpass global averages. He explored drivers and implications on precipitation and mixed layer depth. Additionally, Iskandar analyzed freshwater fluxes in the Southern Makassar Strait, detailing their correlation with temperature and salinity variability in Indonesian seas. Overall, Prof. Iskandar's work provides crucial insights into the intricate ocean dynamics

of the Southeastern Tropical Indian Ocean and their implications for regional climate variability.

- **Biodiversity of Indian Ocean – by Prof. Dr. Dwi Listyo Rahayu, National Research and Innovation. Agency (BRIN), Indonesia"**.

  Prof Dwi Listyo Rahayu's presentation on "Marine Biodiversity in the Indonesian Area of the Indian Ocean" highlighted the extensive variety of flora and fauna found in Indonesian waters. She emphasized the diverse coastal morphology, ranging from sandy beaches to estuaries, and the presence of ecosystems such as mangroves, seagrasses, and coral reefs. Rahayu discussed findings from recent deep-sea expeditions, noting a decline in marine species between depths of 300 to 4700 meters. She showcased the use of four types of instruments across 63 sampling stations during exploration, revealing discoveries of new species and subsequent publication of study findings. Overall, Prof. Rahayu underscored the importance of understanding and preserving marine biodiversity in the Indonesian area of the Indian Ocean, calling for continued research and conservation efforts to protect these vital ecosystems.

- **Navigating the Depths: Advancements and Challenges in the Second International Indian Ocean Expedition (IIOE-2) 2025-2030 – by Prof. Juliet Hermes, Department of Oceanography, University of Cape Town.**

  Prof Juliet Hermes presented on "Navigating the Depths: Advancements and Challenges in the Second International Indian Ocean Expedition (IIOE-2) 2025-2030," tracing its evolution from its predecessor (2015-2000 and 2000-2025) and its transformative impact on exploration and understanding of the Indian Ocean. She advocated for its continuation beyond its tenure, emphasizing a sustained push for progress. Hermes presented a SWOT analysis, identifying strengths like global collaboration and opportunities such as policy impacts. She also noted weaknesses including resource constraints and threats like climate change. Prof Hermes highlighted the importance of visibility through blue economy initiatives and platforms like GOOS and SCOR, while stressing capacity building and coastal research as crucial areas of focus.

2.3. IIOE-2 National Committee reports

In this session, representatives from 11 countries (India, Australia, France, Japan, South Africa, Germany, United States of America, United Kingdom, Indonesia and Korea) presented the national activities under IIOE-2. Dr Aneesh Lotliker presented the National Committee Report for India on behalf of Dr T Srinivasa Kumar. Dr(s)/Prof(s) Jean-François Ternon (France), Jenny Huggett (South Africa), Hermann Bange (Germany) provided pre-recorded presentation. There was no presentation from China and hence not included in the report. The reports highlights are as follows:

- **India: Aneesh Lotliker (on behalf of T Srinivasa Kumar)**

  Dr Aneesh Lotliker presented the national committee report for India on behalf of Dr T Srinivas Kumar. Dr Lotliker introduced India's advancements in Indian Ocean observation under MoES institutions like CMLRE, NCCR, INCOIS, and NIOT which actively

contribute to research and maintain observational platforms. INCOIS reached milestones with its 500th Argo float deployment and 15 satellite-tracked surface drifters. New initiatives include coastal seawater quality monitoring at 50 locations, while the Deep Ocean Mission deployed Slocum gliders and wave drifters. Dr Lotliker emphasized the significance of observational networks for climate services and concluded with future collaboration prospects and outcomes of the IORDC conference.

- **Australia: Lynnath Beckley**

  Dr. Lynnath Beckley outlined Australia's contributions to the Second International Indian Ocean Expedition (IIOE-2), highlighting seven endorsed projects. The Australian IIOE-2 committee comprises about 20 representatives from diverse institutions around the country. Notable recent endeavours include EP47, quantifying ocean transport dynamics on the NW Shelf, and EP48, assessing marine life in the Gascoyne Marine Park off Ningaloo. Dr. Beckley referenced conference talks and publications resulting from these expeditions, showcasing Australia's significant involvement in IIOE-2. She also noted the support from the Integrated Marine Observing System, Bureau of Meteorology and the Marine National Facility

- **France: Jean-François Ternon**

  The IIOE-2 National Committee report from France, presented by Jean Francois Ternon, outlined recent French projects and cruises in the southwest Indian Ocean. Projects like IRP VOKCE focus on continental SST variability and plastic inventories under ST-01 (Human benefits and impacts), while ST-02 (Boundary current dynamics) includes the RESILIENCE project. ST-04 (Circulation and climate variability) featured the OBS Austral cruise and ongoing projects such as OISO and THEMISTO. ST-05 (Extreme events) monitored seismic activity in Mayotte. In ST-6, research on megabenthic assemblages in the Mozambique channel was highlighted. The Indian Ocean Mission 2022 and R/V AGHULAS II cruise supported diverse research efforts, including ecosystem studies using biologging devices. The future plans include SPACIBA and EXPAND cruises, along with a 10-year, 23 M Euro project named BRIDGES.

- **Japan: Yukio Masumoto**

  The IIOE-2 National Committee in Japan, chaired by Yukio Masumoto, has been actively involved in promoting Indian Ocean research since its establishment in 2017. With members representing various scientific disciplines, the committee aims to advance IIOE-2 within Japan, facilitate outreach activities, and discuss future research directions. Recent activities include servicing buoys for the RAMA array, organizing research cruises, and studying oceanic biophysical responses. Notable research highlights include investigations into iron distribution in the Bay of Bengal and the impact of wind forcing on nutrient fluxes. The committee also collaborates internationally, conducting expeditions in the Central Indian Ridge and other regions. Future endeavors include a new research cruise in 2024 focusing on upwelling off Java Island and continued exploration of oceanic crustal characteristics through projects like MOWALL. Overall, the committee plays a crucial role in advancing Indian Ocean research and fostering international collaboration in oceanography.

- **South Africa: Jenny Huggett**

  The South African Initiatives in support of IIOE-2, presented by Jenny Huggett, encompass a range of impactful projects and collaborations. Project EP-26 conducted two regional research cruises in the Western Indian Ocean (WIO) aboard R/V SA Agulhas II, with a focus on training of WIO students. Various efforts delve into the Agulhas current's effects on coastal environments and contribute to the GOOS ocean observing co-design program. Additionally, the African Coastal Ecosystem Program represents a significant multi-disciplinary endeavour to map and understand the marine ecosystem along South Africa's east coast. Zooplankton metabarcoding initiatives in the Indian Ocean region have yielded significant progress and high-quality research outcomes. Capacity building efforts, such as the Mozambique zooplankton project (ReMo Turb), focus on developing taxonomic skills. The MetaZooGene project, endorsed as a new UN Ocean Decade Action, aims to explore zooplankton diversity. MaRIP (Marine Remote Imagery Platform) facilitates numerous field trips and collaborations, while benthic habitat mapping and microplastic monitoring projects contribute to a comprehensive understanding of the region's marine environment.

- **Germany: Hermann Bange**

  The National Committee Report for Germany outlines research initiatives and cruises conducted by leading scientists in the field. Established in 2016, the committee comprises distinguished members from various institutions. Notable projects include EASI, focusing on East Antarctic Ice Sheet Instabilities, and BIOGIN-IIOE2, investigating biochemistry in the equatorial Indian Ocean. Despite some challenges, such as awaiting permission for the Bengal shelf cruise, research efforts remain robust. Funded projects like INDOCRISIS and SAMOVAR aim to understand oceanic responses to climate change and monsoon variability. Additionally, collaborations between institutions, such as the International Research Training Group at Kiel University, demonstrate concerted efforts towards comprehensive oceanic studies. Recent and forthcoming publications, including the IO Book and articles by prominent researchers, contribute valuable insights into Indian Ocean dynamics, addressing critical gaps in understanding climate systems and biogeochemistry.

- **United States of America: Raleigh Hood**

  Raleigh Hood provided an update on US IIOE-2 Steering Committee activities, emphasizing key initiatives. The US IIOE-2 website serves as a central platform for communication and updates. A network of over 300 Principal Investigators facilitates collaboration and proposal submissions. The completion of the Science Plan in 2018 guides research themes and priorities. Recent and upcoming projects, such as MINTIE and TRIUMPH, highlight US involvement in Indian Ocean research. Emphasis is placed on tracking research activities and encouraging proposal submissions to funding agencies. Despite challenges posed by COVID-19, efforts continue to restore RAMA-2.0 buoy functionality in the Indian Ocean.

- **United Kingdom: Greg Cowie**

  The University of Plymouth is actively engaged in Indian Ocean research, with projects funded by the Bertarelli Foundation focusing on oceanographic drivers of ecosystem

response, cetacean ecology, and manta ecology. Additionally, a collaboration between SAEON and the University of Cape Town is investigating multiscale drivers of manta movement and behavior, marine heatwaves, and the impact of the Indonesian Throughflow on Indian Ocean circulation. Mesophotic Coral Ecosystem (MCE) research, supported by the Garfield Weston Foundation, has recorded the deepest bleaching at 90 m due to the Indian Ocean Dipole (IOD) and internal waves. Recent surveys aim to assess the impact of the 2023 IOD on deep bleaching, with a proposal submitted to WIOMSA for coordinating MCE research across the region. Nekton's Indian Ocean activities from 2022 to 2024, led by Chief Executive Oliver Steeds, further contribute to ocean exploration and understanding.

- **Indonesia: Ocky Karna Radjasa**

  Indonesia's report on the International Indian Ocean Expedition-2 (IIOE-2) covered various research initiatives and collaborations in the region. Key highlights include BRIN's management of research vessels, IDSSE CAS's exploration of deep-sea ecosystems, and the University of Tokyo's study on Eastern Indian Ocean dynamics. Collaborative efforts with Ocean X and MINTIE focus on understanding oceanic processes like the Indonesian Throughflow. TRIUMPH and EWIN 2024 delve into ocean physics and marine geosciences, respectively. Additionally, INATEWS plays a crucial role as a tsunami warning provider for Indian Ocean countries. These efforts showcase Indonesia's commitment to advancing ocean science and enhancing regional cooperation for disaster risk reduction and marine conservation.

- **Korea – Dong-Jin Kang**

  The Korean Institute of Ocean Science & Technology (KIOST) leads the KIOS project, funded by the Ministry of Oceans & Fisheries, focusing on Indian Ocean research. Their endeavours encompass water mass, current, and marine ecosystem studies facilitated by satellites, underwater robots, and time series data collection tools. Publications highlight diverse topics, including dissolved oxygen sensors and phytoplankton characterization. Capacity plans include a 2024 research cruise, financial support until 2026, and continued international cooperation, including hosting workshops.

2.4. Upwelling research initiatives

- **WIOURI: Western Indian Ocean Upwelling Research Initiative**

  Dr Mike Roberts did not participate in the meeting and hence there is no report.

- **EIOURI: Eastern Indian Ocean Upwelling Research Initiative**

  Dr Yukio Masumoto presented on EIOURI which was initiated in 2016 as one of the core initiatives under IIOE-2. The Eastern Indian Ocean Upwelling Research Initiative (EIOURI) began in 2016 under IIOE-2, conducting observational cruises until 2019. However, due to the COVID-19 pandemic, international activities paused in 2020. Despite this, individual research efforts continued. EIOURI aims to revive its activities by 2025, updating its Science Plan with recent findings and observing system advances. The focus areas include upwelling processes, bio-physical relationships, biogeochemistry, and human

impacts like sustainable fisheries and marine conservation. To facilitate discussions and collaborations, EIOURI plans sessions at international conferences such as JpGU 2024 and AOGS 2024. Additionally, a new R/V Hakuho-Maru cruise is scheduled for August/September 2024, focusing on coastal upwelling structures off Java Islands. This cruise, a "re-try" from a cancelled 2020 expedition, aims to contribute to IIOE-2/EIOURI objectives, aligning with the initiative's goal of advancing understanding in the Indian Ocean.

2.5. IIOE-2 Working group reports.

In this session, the co-chairs of the three working groups (WG) presented the latest updates. The co-chair of WG-2, E. Pattabhi Rama Rao gave an online presentation, and the WG-3 was represented by the Associate member N Kiran Kumar. The significant updates are highted below.

- **WG-1: Science and Research – Raleigh Hood**

  The IIOE-2 Working Group I Report presented progress in international participation and research initiatives like EIOURI, WIOURI, YMC, and KUDOS. With 52 endorsed projects involving 20 countries. Research focused on Indian Ocean upwelling, maritime continents, and Seychelles-Chagos. Active working groups cover diverse themes, and despite COVID interruptions, 16 IIOE-2 cruises and many others are ongoing. Efforts are ongoing to restore RAMA. Notable publications include EGU synthesis papers and DSR II issues, totalling 70+ papers.

- **WG-2: Data and Information Management – E. Pattabhi Rama Rao**

  The Co-Chair of IIOE-2 Working Group II, Pattabhi Ramarao, presented Terms of Reference on Data and Information Management, detailing procedures for data collected in IIOE-2 endorsed projects and emphasizing long-term data preservation. The IIOE-2 Data and Information Management Policy promotes data sharing, aligning with national policies and open data principles. Guidelines for data submission, access, citation, and metadata were developed, along with a metadata catalogue for cruises and publications. Coordination with the IIOE-2 Project Office ensures PI data submission, and a web interface facilitates data sharing with provided login credentials. Various search methods, including spatial and keyword searches, are available through the master directory and WebGIS. Efforts are underway to establish core measurements and data types for IIOE-2 activities, alongside organized training programs with support from multiple agencies.

- **WG-3: Operational Coordination – N. Kiran Kumar on behalf of Rajan Sivaramakrishnan**

  The International Indian Ocean Expedition-2 (IIOE-2) aims to enhance understanding of the Indian Ocean's role in the Earth System for sustainable development. At the recent meeting, operational coordination progress was presented, focusing on establishing web-based planning tools and databases, facilitating access to training, and enhancing outreach efforts. Despite challenges such as non-submission of project plans and data, recommendations were made to encourage timely sharing of project details and results.

Additionally, new and continuing members were nominated to ensure effective coordination. Overall, the initiative seeks to foster collaboration and advance knowledge of the Indian Ocean's significance.

2.6. Invited talks by the Principal Investigators of the endorsed project (existing & new)

- **Existing: A coupled bio-physical, ecosystem-scale, examination of Australia's IIOE 110°E line: mesopelagic fishes & krill – by Lynnath Beckley, Murdoch University, Australia**

  Prof Lynnath Beckley presented one aspect of a comprehensive study conducted along Australia's 110°E line in the Southeast Indian Ocean, revisiting the region initially explored during the International Indian Ocean Expedition (IIOE-1) in the 1960s. Led by a team of principal investigators, the overall study aimed to understand the coupling of physical, biogeochemical, and ecological processes in the area. The research presented involved multiple sampling techniques and covered various fish diversity and abundance, krill assemblages, and oceanography. Findings highlighted the influence of oceanographic variables on assemblages and provided valuable insights into the region's biodiversity and ecosystem dynamics.

- **New: will nitrogEn fiXaTion offset nitrogen dePletion in expAnding oceaN Deserts (EXPAND)? – Mar Benavides, Institut de Recherche pour le Développement, France**

  Dr Mar Benavides presented on the topic of will nitrogEn fiXaTion offset nitrogen dePletion in expAnding oceaN Deserts? widely referred as **Expand**. The presentation delved into the question of whether nitrogen fixation can counterbalance nitrogen depletion in expanding ocean deserts, with a focus on a project proposal submitted to ERC by Mar Benavides from IRD, France. It began by discussing the concept of ocean deserts, highlighting their significance in marine ecosystems. The presentation provided an overview of nitrogen fixation in the ocean, discussed its role in the euphotic zone, sub-euphotic zone, and deep regeneration and nitrification processes. The objectives of the proposed project include tracking seasonal changes in Indian Ocean gyre expansion, understanding the impact of gyre expansion on diazotrophic nitrogen inputs, and extending in situ measurements for predicting nitrogen availability in the future Ocean. The collaborations and support from various institutions across France, the USA, India, Spain, South Africa, and the UK were acknowledged. The presentation concluded with acknowledgments and a reference to the project website.

- **New: Enhancing knowledge of the Arabian Sea Marine environment through Science and Advanced Training [Indian Component] (EKAMSAT) – M S Girish Kumar, Indian National Centre for Ocean Information Services (INCOIS), India**

  The presentation outlined the climatology and trends of various environmental parameters in the Arabian Sea, focusing on July-September. It highlighted significant changes driven by global warming, including reductions in marine phytoplankton and expansions of oxygen minimum zones. Trends in sea surface temperature (SST) and precipitation were discussed, indicating notable shifts over the years. The impact of SST biases in climate models on monsoon simulations was emphasized, underlining the necessity for accurate

representations. Furthermore, the presentation addressed biases in temperature/salinity structure and the role of turbulence processes in the Arabian Sea. It also explores sub-mesoscale processes, thermohaline interleaving structures, and diurnal variability in the atmosphere boundary layer, aiming to deepen understanding and improve model simulations. Specific science questions were posed to guide the implementation plan of the EKAMSAT program, which aims to advance knowledge of the Arabian Sea marine environment through science and advanced training. The presentation concluded with a timeline for program execution and listed the observation tools to be utilized, underscoring the importance of precise data collection for effective research outcomes.

2.7. Early Career Scientists Network

IIOE-2 Early Career Scientists Network was formed 2nd December 2015 at the National Institute of Oceanography (NIO) in Goa. The idea of the network emerged in a session on "Recent Results from Early-Career Scientists in Indian Ocean Research" during the conference that celebrated the 50th Anniversary of the completion of the first International Indian Ocean Expedition (IIOE). The motivation of the ECSN of IIOE-2 was to bring together the young scientists working on the Indian Ocean, to encourage exchange and participation, with overall all aim to enhance the understanding of the under-explored Indian Ocean. Subsequent to an initial, informal, and self-driven phase, the network was formally adopted on 24th August 2018. More details can be viewed at https://iioe-2.incois.gov.in/ecsn/index.html.

- **ECSN overview of science during past year – Fehmi Dilmahamod (Chair)**

  Fehmi Dilmahamod, Chair of the Early Career Scientist Network (ECSN) of IIOE-2, outlined the network's objectives and ongoing activities. Established in 2015 at NIO Goa, ECSN aims to foster collaboration, connect researchers, and organize events like meetings, workshops, and trainings. The committee utilizes social media platforms, including Twitter (X) and a newly launched YouTube channel, for outreach. The ECSN website provides information on joining and collaborating with other early career scientists, continually updated and maintained. Notable achievements include 7 IIOE-2 papers, led by two ECSN members, and organized IIOE-2 sponsored cruises. Initiatives like the Ocean Insights Seminar Series and creating a nested network with institutional leads aim to boost visibility. ECSN collaborates with other early career groups for meaningful scientific engagement. They are involved in projects like the IPCC and Ocean Decade review, Indo-French collaborations, and an online course on Fishery Oceanography. Their contributions to the IIOE-2 implementation strategy for 2025-2030 and the DECCaD-IO capacity development event at INCOIS ITCO centre highlight their commitment. Challenges ahead include addressing visibility, inclusivity, funding, and impact assessment systematically.

- **Flash Talk 1: Increasing importance of anammox process for aquaculture wastewater treatment – by Muhammad Naufal, BRIN**

  The study investigates the osmoadaptation capabilities of freshwater Anammox (Anaerobic Ammonium Oxidation) sludge in saline environments, addressing a critical knowledge gap in ecological stability. Oxygen Minimum Zones (OMZs) in marine environments are

crucial for nitrogen loss, with diverse anaerobic microorganisms dominating these zones. Anammox bacteria play a significant role in sustainable biological nitrogen removal processes. The study classifies Anammox bacteria into freshwater and marine species, highlighting their different adaptation strategies to salinity levels. Through genomic analysis, distinct clustering between freshwater and marine species is observed, indicating specific adaptation mechanisms, such as osmoadaptation marker genes. Glutamate supplementation is found to enhance gas production and reactor performance in saline conditions, offering valuable insights for wastewater treatment applications. Overall, the study provides crucial insights into enhancing the stability of freshwater Anammox sludge in saline environments, with implications for broader applications in environmental biotechnology.

- **Flash Talk 2: Spatio-temporal variation of blue mackerel (*Scomber australasicus*) spawning in Northern Taiwan – by Sunarti Sinaga, BRIN**

  The study focuses on the reproductive biology of blue mackerel (*Scomber australasicus*) in northeast Taiwan, spanning from 2017 to 2020. Biological data collection involved body measurement, gonad dissection, and histological observation, while environmental and fishing data from 2015 to 2021 were also analyzed. Various reproductive parameters such as length at 50% maturity, gonadosomatic index (GSI), fecundity, and spawning frequency were assessed. Results showed inter-annual variations in spawning behavior, with spawning peaks occurring in different months each year. Spatial-temporal analysis revealed differences in spawning ground and period compared to neighboring regions like Japan and Korea. The influence of environmental factors, particularly the dynamic Kuroshio Current, on spawning habitat suitability was explored. Overall, the study provides insights into the reproductive biology of blue mackerel and highlights the importance of understanding environmental influences on spawning behavior for fisheries management and conservation efforts in the region. Further research aims to update stock and ocean condition information to support sustainability initiatives and guide future studies.

2.8. IIOE-2 Science Theme reports

In this session, the co-chairs of the six science themes (ST) presented the latest updates. There was no representation for ST-3 and hence there is no report. The details of the endorsed projects under various science themes are available at https://iioe-2.incois.gov.in/IIOE-2/Endorsed_Projects.jsp. The significant updates are highted below.

- **Theme-1: Human Impacts and Benefits – by Halina Kobryn**

  The endorsed projects under Theme 1 of the IIOE-2 initiative encompass a diverse array of research endeavours aimed at understanding and mitigating human impacts on the Indian Ocean. These projects include initiatives such as the International Buoy Programme and marine biodiversity exploration expeditions like NEKTON Indian Ocean Mission. They involve comprehensive data collection, habitat mapping, and biodiversity assessment, fostering collaboration among international partners from various countries. Despite facing challenges such as delays due to COVID-19 and funding issues for some projects, significant progress has been made. Completed projects have yielded valuable insights into

marine ecosystems, while ongoing projects continue to expand our understanding and support conservation efforts. Looking ahead, additional research questions on the socio-economic consequences of altered biodiversity and changing food webs in the Indian Ocean, as well as the impact of coastal urbanization, will further guide efforts to ensure the sustainability of this vital marine environment.

- **Theme-2: Boundary current dynamics, upwelling variability and ecosystem impacts – by Prof P. N. Vinayachandran**

  The ST-2 presentation highlighted recent and planned cruises focused on boundary current dynamics, upwelling variability, and ecosystem impacts in the Indian Ocean. One project, BIOCAT, aimed to study biogeochemistry-atmosphere processes in the Bay of Bengal to contribute to IIOE2. The Equatorial current system and oxygen minimum zones (OMZ) in the Bay of Bengal were investigated using moored profiler and single point current meters. The replacement of RAMA mooring at 5S 95E by R/V Hakuho-maru and a new cruise in Aug./Sep. 2024 were discussed. Research highlights included studies on intra seasonal oscillations of the Andaman Sea thermocline, the role of salinity in strengthening the Indonesian Throughflow (ITF), and vertical structures of marine heatwaves. The BOBBLE Project analyzed turbulent dissipation rates and salt fluxes across the Summer Monsoon Current. Additionally, investigations into external supply of dissolved iron (dFe) into NICW in the Bay of Bengal were conducted. Frictional effects on Rossby waves were compared, with Laplacian friction found more efficient at eliminating short-wavelength waves and Rayleigh friction more effective at dissipating long-wavelength waves.

- **Theme-3: Monsoon variability and ecosystem response – by Adrian Matthews**

  No Report

- **Theme-4: Circulation, climate variability and change – by Helen Phillips**

  The presentation highlighted the endeavours of ST-4, co-chaired by Dr Helen Phillips and Prof. Amit Tandon. The membership includes representatives from various countries. Achievements encompass contributions to the Indian Ocean Book and successful projects like the Deep Madagascar Basin (DMB) Voyage and Antarctic Bottom Water study. Project updates feature ongoing investigations such as the examination of the East Madagascar Current (EMC) and the KIOST Indian Ocean Study. Noteworthy is the EKAMSAT Pilot and EKAMSAT–Roger Revelle Cruise, focusing on monitoring oceanic and atmospheric boundary layers. New endorsed projects include studies on the Eastern Gyral Current and water mass change in the Agulhas Current region. Scientific updates delve into topics like land heating in the Middle East and coastal signals near Australia. The outlook emphasizes rejuvenating the committee, fostering early career scientists, and enhancing the dissemination of research findings through diverse communication channels. These efforts aim to advance understanding of Indian Ocean circulation, variability, and change.

- **Theme-5: Extreme events and their impacts on ecosystems and human populations – by Roxy Mathew Koll**

The presentation by Roxy Mathew Koll from the Indian Institute of Tropical Meteorology, in collaboration with Charitha Pattiaratchi, addressed critical issues related to extreme events in the Atlantic, Pacific, and Indian Ocean regions. It highlighted the profound impact of these events, including terrestrial heatwaves, cyclones, storm surges, monsoon floods, droughts, and marine heatwaves, on both natural ecosystems and human populations. The key findings underscored the Indian Ocean's status as the fastest-warming tropical ocean, with observed warming rates of 1.2°C per century and projections indicating a substantial increase to 3.8°C per century. This warming trend has significant implications, notably the exacerbation of locust swarms, posing serious threats to food security in the region. Moreover, the presentation delved into the phenomenon of marine heatwaves, characterized by periods of exceptionally high ocean temperatures, and their detrimental effects on marine habitats, including coral bleaching and seagrass destruction. Of particular concern was the intensification of cyclones due to marine heatwaves, as exemplified by Cyclone Amphan. The presentation underscored the critical importance of sustained ocean observations and regional partnerships in understanding and mitigating the impacts of extreme events. Case studies from the Western Indian Ocean, Bay of Bengal, Australian Seas, and East China Sea provided empirical evidence of the linkages between ocean warming and the intensification of extreme weather phenomena.

- **Theme-6: Unique geological, physical, biogeochemical and ecological characteristics of the Indian Ocean – by Lynnath Beckley**

  This umbrella theme encompasses 28 endorsed projects, each contributing distinct insights. Despite challenges in project reporting, diligent efforts resulted in communication with 25 principal investigators. Notable projects include EP01, the first scientific cruise under IIOE-2, which mapped water masses and conducted comprehensive biophysical surveys. EP06 examined ecosystem-scale changes along the 110^{o} E line beyond Australia's waters, yielding significant publications. EP07 investigates biogeochemistry-atmosphere processes in the Bay of Bengal, while EP08 utilized gliders to study ocean dynamics. EP12 explored dust-induced nitrogen fixation in the Arabian Sea, while EP13 focused on upwelling research. However, EP14 on geology and geophysics ceased due to COVID-related constraints. EP19 successfully completed GO-SHIP observations, while ongoing projects like EP22 continue to explore deep reefs. EP33 examined marine biodiversity in submarine canyons, and EP38 investigates trace element biogeochemistry. Overall, these projects contribute crucial insights into the complex dynamics and biodiversity of the Indian Ocean, addressing key scientific and environmental challenges.

2.9. IIOE-2 Steering Committee Business Meeting

2.9.1. IIOE-2 PO Report & endorsement for new projects

Dr Aneesh Lotliker presented the report from IIOE-2 Project Office (PO), India hosted by Indian National centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences (MoES), Hyderabad, India. Dr Lotliker presented the roles and responsibility of the IIOE-2 PO followed by action taken report from the previous SC6 meeting. The report highlights are as follows:

- All the actions from the previous SC6 meeting were completed except for "Financial and in-kind resources needed to run IIOE-2" which was passed to IOGOOS Secretariat. The IIOE-2 SC6 Action Taken Report is available at https://iioe-2.incois.gov.in/documents/IIOE-2/IIOSC2024/IIOE-2_SC-6_ActionTakenReport.pdf
- Organized a meeting to discuss the future road map for IIOE-2 at INCOIS, Hyderabad during November 28 – 30, 2023 with the leads from various Indian Ocean forums such as IIOE-2, IOGOOS, IORP, IRF, SIBER, IOCINDIO and SCOR.
- Maintained the IIOE-2 website (https://iioe-2.incois.gov.in/IIOE-2/index.jsp) with the latest updates including metadata portal (https://iioe-2.incois.gov.in/IIOE-2/data.jsp), endorsed scientific projects (https://iioe-2.incois.gov.in/IIOE-2/Endorsed_Projects.jsp) and dedicated web page for Early Career Scientist Network (ECSN) (https://iioe-2.incois.gov.in/ecsn/index.html).
- The monthly newsletters were continued to update the Indian Ocean community on the recent IIOE-2 activities and upcoming events, meetings, conferences etc. Total 85 newsletters have been published and are available online (https://iioe-2.incois.gov.in/IIOE-2/Publications.jsp?mode_pub_id=NL). The bi-annual IIOE-2 Bubble has been continued and 17 issues have been published (https://iioe-2.incois.gov.in/IIOE-2/Bubble.jsp).
- The PO received two projects for endorsement from Dr Mar Benavides (France) and Dr M S Girish Kumar (India).
- A new draft Prototype for Website design has been developed for Early Career Scientist Network (ECSN) and shared with all the members of ECSN. The webpage also includes a form to join the IIOE-2 ECSN Network.

  The IIOE-2 SC-7 recommended that the ECSN website should be given wide publicity through IIOE-2 newsletter and other possible modes.

2.9.2. Endorsement of Scientific Projects

The IIOE-2 PO received the following two projects for endorsement

- will nitrog**E**n fi**X**ation offset nitrogen de**P**letion in exp**A**nding ocea**N** **D**eserts (EXPAND)? – by Mar Benavides, Institut de Recherche pour le Développement, France.
- **E**nhancing **K**nowledge of the **A**rabian sea **M**arine environment through **S**cience and **A**dvanced **T**raining [Indian Component] (EKAMSAT) – by M S Girish Kumar, Indian National Centre for Ocean Informaiton Services (INCOIS), India

The principal investigators of the projects presented the proposal to IIO-2 International Steering Committee. The projects fall within the acceptable criteria.

The IIOE-2 SC-7 recommended endorsement of both the projects i.e. EXPAND and EKAMSAT

2.9.3. IIOE-2 newsletters and Indian Ocean Bubble

The SC appreciated the efforts from the IIOE PO for regular publishing the newsletters and Indian Ocean Bubble. However, it is also noted that the contribution from authors from outside India is sparse. The Science Theme leads should put effort into getting the articles from the PIs of the endorsed project sand explore more contribution from other countries.

The IIOE-2 SC-7 recommended that the Working Group and Science Themes leads should put effort into getting articles for the newsletter and Indian Ocean Bubble.

2.9.4. Update on chairing and membership of existing STs and WGs

The SC noted that several members of the Working Group and Science Theme are not active. In this regard, IIOE-2 PO had communicated with the co-chairs and members of the working group and science theme. Prof. Raden Dwi Susanto requested to change his membership from ST-3 to ST-2 due to change in his nature of the research.

Prof. Adrian Matthews is not willing to continue as a co-chair of ST-3 (Monsoon variability and ecosystem response) as his research directions are heading to slightly different directions. In case of replacement Prof. Matthews suggested Dr Ben Webber who is a faculty member in the School of Environmental Sciences, University of East Anglia, UK and an active researcher in Indian Ocean oceanography.

The IIOE-2 SC-7 recommended the following.

- ✓ ***Change the membership of Prof. Raden Dwi Susanto from ST-3 to ST-2.***
- ✓ ***Getting bio-sketch of Dr Ben Webber and obtain his willingness to co-chair ST-3.***
- ✓ ***The co-chairs of the respective working groups and science themes to nominate the members along with their bio-sketch.***

2.9.5. Future roadmap for IIOE-2 (Nick D'Adamo on behalf of Raleigh Hood)

The IIOE-2 SC-7 noted that the tenure of the IIOE-2 is until 2025. For the last seven years, the IIOE-2 community has contributed significantly to understanding the Indian Ocean in terms of observation, research and capacity development. Also, there have been many international collaborations in which scientific ideas have been exchanged. In addition, the ECSN has gained momentum, and discontinuing the programme may impact it. Therefore, it is imperative that efforts should be put to extend the tenure of IIOE-2 till 2030 by aligning with the UN Decade of Ocean Science for Sustainable Development.
In this regard, a meeting was convened at INCOIS, Hyderabad, during November 28 – 30, 2023, with the leads of the various forums in the Indian Ocean, such as IOGOOS, IORP, IRF, SIBER, IOCINDIO and SCOR. The discussion resulted in agreement to prepare an addendum to the IIOE-2 science plan and revised implementation strategy.

Nick D'Adamo presented the addendum to the IIOE-2 science plan (on behalf of Raleigh Hood) and revised implementation strategy. In the proposed extended IIOE-2 tenure (2025 – 2030), the emphasis will be on the ST-1 (Human benefits and impacts). In addition, a new WG for ECSN is proposed in the revised implementation strategy. The

draft outline of the addendum to the science plan, along with the execution timeline, is available at https://iioe-2.incois.gov.in/documents/IIOE-2/IIOSC2024/IIOE-2_2025-2030_DiscussionOutline&Background.pdf. The draft revised implementation strategy for the IIOE-2 is available at https://iioe-2.incois.gov.in/documents/IIOE-2/IIOSC2024/IOCIIO_1.pdf.

The IIOE-2 SC-7 recommended that the addendum to the IIOE-2 science plan and the revised strategy should be finalized and circulated to the IIOE-2 WG & ST cochairs and members for review.

The IIOE-2 SC-7 recommended ECSN to prepare Terms-of-Reference for newly proposed WG.

2.9.6. Major Indian Ocean Science Conference

The SC-7 discussed that the IIOE-2 is completing 10 years in 2025 and hence it is time to bring the Indian Ocean research community together for a major science conference. The Director, Indian National Centre for Ocean Information Services (INCOIS), India has kindly agreed to host the conference at Hyderabad, India.
There was also discussion on preferred time of the conference either in later 2025 or early 2026. However, there was no consensus among the group due to other major events scheduled during later 2025 and early 2026.

The IIOE-2 SC-7 recommended to circulate a poll to find an appropriate date for the major Indian Ocean Science Conference.

2.9.7. Financial Resources

The IIOE-2 project office in India is supported in-kind by INCOIS with human resource, capacity building and business meeting. It was brought to the notice of the SC-7 that the IOC allocated budget for IOGOOS, there is one line item for IIOE-2. However, it is to be further explored with the modus operandi for funding IIOE-2.

The IIOE-2 SC-7 recommended communicating with IOC through IOGOOS secretariat to obtain modus operandi for funding IIOE-2.

2.9.8. IIOE-2 SC 8: Host, Location/venue & date

The SC 7 discussed that the IIOE-2 was partly planned in Mauritius and also the first expedition of IIOE-2 was from Goa to Mauritius. Hence the Mauritius could be a good venue to host the SC8 meeting of IIOE-2..
Explore the possibility of organizing IIOE-2 SC 8 at Mauritius in consultation with IOGOOS secretariat.

3. Summary of the Recommendations and actions

Recommendations	**Action**
The IIOE-2 SC-7 recommended that the ECSN website should be given a wide publicity	PO to give wide publicity to ECSN website and communicate with ECSN

through IIOE-2 newsletter and other possible modes	core committee to update the website content.
The IIOE-2 SC-7 recommended endorsement of both the projects i.e. EXPAND and EKAMSAT	PO to complete the necessary formalities and communicate to the principal investigators.
The IIOE-2 SC-7 recommended that the Working Group and Science Themes leads should put efforts in getting articles for newsletter and India Ocean Bubble	PO to communicate with the leads of the WG and ST to get articles in newsletter and Indian Ocean Bubble
Change the membership of Prof. Raden Dwi Susanto from ST-3 to ST-2	PO to complete the necessary formalities and communicate to Prof. Raden Dwi Susanto.
Getting bio-sketch of Dr Ben Webber and obtain his willingness to co-chair ST-3	PO to obtain the necessary details and send to the SC for consideration.
The co-chairs of the respective working groups and science themes to nominate the members along with their bio-sketch	PO to communicate with the leads of the WG and ST to get necessary details and send to SC for consideration.
The IIOE-2 SC-7 recommended that the addendum to the IIOE-2 science plan and the revised implementation strategy should be finalized and circulated to the IIOE-2 WG & ST cochairs and members for review	PO to obtain and circulate the addendum to the IIOE-2 science plan and the revised implementation strategy
The IIOE-2 SC-7 recommended ECSN to prepare Terms-of-Reference for newly proposed WG	PO to communicate with ECSN core committee and obtain Terms-of-Reference and send to SC for consideration.
The IIOE-2 SC-7 recommended to circulate a poll to find an appropriate date for the major Indian Ocean Science Conference	PO to circulate the poll
The IIOE-2 SC-7 recommended communicating with IOC through IOGOOS secretariat to obtain modus operandi for funding IIOE-2	PO to communicate with IOC through IOGOOS secretariat to obtain modus operandi for funding IIOE-2
Explore the possibility of organizing IIOE-2 SC 8 at Mauritius in consultation with IOGOOS secretariat.	PO to liaise with IOGOOS secretariat

4. Group Photo

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Enroll yourself with IIOE-2 Community

https://iioe-2.incois.gov.in/IIOE-2/Signup.jsp