SCOR/IOC/IOGOOS Second International Indian Ocean Expedition (IIOE-2)

Report to SCOR 2019/20

Peter Burkill (SCOR Executive Reporter)

GOAL
The goal of IIOE-2 remains as to advance our understanding of the Indian Ocean and its role in the Earth System in order to enable informed decisions in support of sustainable development and the well-being of humankind.

MANAGEMENT
While delivery of IIOE-2 occurs through national activities¹ these are coordinated by a Core Group comprising the following key personnel:

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Chair IIOE-2</td>
<td>Peter Burkill⁴</td>
<td>SCOR</td>
</tr>
<tr>
<td></td>
<td>Vladimir Ryabinin</td>
<td>IOC</td>
</tr>
<tr>
<td></td>
<td>Sateesh Shenoi</td>
<td>IOGOOS</td>
</tr>
<tr>
<td>Co-Chair WG 1 (Science &amp; Research)</td>
<td>Raleigh Hood</td>
<td>USA</td>
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<tr>
<td></td>
<td>Hermann Bange</td>
<td>Germany</td>
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<tr>
<td>Co-Chairs WG 2 (Data &amp; Information Management)</td>
<td>Cyndy Chandler⁵</td>
<td>USA</td>
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<tr>
<td></td>
<td>Harrison Ong’Anda</td>
<td>Kenya</td>
</tr>
<tr>
<td>Chair WG 3 (Operational Coordination)</td>
<td>Shailesh Nayak</td>
<td>India</td>
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<tr>
<td>Supported by</td>
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<tr>
<td>International Project Office (Perth)</td>
<td>Nick d’Adamo</td>
<td>IOC</td>
</tr>
<tr>
<td>International Project Office (Hyderabad)</td>
<td>Satya Prakash</td>
<td>IOGOOS</td>
</tr>
<tr>
<td>SCOR Office</td>
<td>Patricia Miloslavich³</td>
<td>SCOR</td>
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¹ Nations with IIOE-2 committees (chair) are: Australia (Lynnath Beckley), France (Francis Marsac), Germany (Birgir Gaye & Hermann Bange), India (Madhavan Nair Rajeevan), Japan (Yukio Masumoto), UK (Greg Cowie), USA (Raleigh Hood).

b) Resigned in 2020.
c) Patricia Miloslavich took over from Ed Urban in January 2020.

The Core Group comprises 3 Working Groups (WG1 Science & Research; WG2 Data & Information Management & WG3 Operational Coordination). Each of these interact with each other, the Joint Project Offices’s in Perth and Hyderabad and the Co-Chairs who represent the sponsors and oversee the Core Group.
The Core Group has met electronically 5 times: in Nov 2019, February, April, July and October 2020 over the last year to deal with strategic issues. The International Project Offices in Perth, Australia and Hyderabad, India have dealt with a day-to-day issues within IIOE-2.

**DEVELOPMENTS AS A RESULT OF COVID-19**

a) The Indian Ocean community was to have met from 16th to 20th March 2020 in Goa, India for the *International Indian Ocean Science Conference 2020*. This open science conference was set up to debate and consider the new understandings gained in first four years of results of IIOE-2; this conference was organized by an International Board. The 2020 IIOE-2 SSC meeting was also scheduled to take place to discuss development and evolution of IIOE-2. One of the main focus of this was how IIOE-2 might best contribute to the development of the *UN Decade of Ocean Science for Sustainable Development*. Sadly, both these key meetings have had to be postponed to a future, and as yet, unknown date because of the Covid problem. It was hoped that the meeting could be rescheduled for later in 2020 but this depends on Indian Government approval and it looks possible that we might meet in person in October 2021.

b) IIOE-2 cruises have had to be postponed by many countries such as India and Germany. How and when these may be re-planned remains to be determined.

c) However, it is not all doom-and-gloom as this enforced ‘breather’ has given an opportunity to push ahead with other matters reported below.

**WG1: SCIENCE & RESEARCH.**

This is lead by Raleigh Hood (USA) and Hermann Bange (Germany) who are charged with working with the IO research community to develop better understanding of the natural processes occurring in the Indian Ocean. This occurs largely through research.

**PEER-REVIEWED RESEARCH OUTPUTS**

Two excellent summaries of the current state of understanding of the Indian Ocean have been produced by Hermes *et al* (2019)² and Anon (2020)³. Both these publications underpin the importance of observational procedures, the summaries touch on almost all aspects of the surface and midwaters of the Indian Ocean. They are particularly relevant to future requirements for research in the IO. Arguably, the biggest single issue they raise is the large quantity of heat taken up by the Indian Ocean and its consequences for global processes. It is noteworthy that the world’s smallest ocean has taken up >25% of global ocean heat gain over the last 20 years and perhaps as much as 45% in surface waters in the last 10 years. As a result, since 1950, the Indian Ocean has warmed about 1°C at the surface, compared to a global ocean’s average of 0.6°C. The reasons for this remain to be resolved and are crucial for if mankind is to understand and manage climate, sea-level rise, ecosystems and fisheries.

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³ Anon (2020). The Recent Decadal Review (2020-2030) of the Indian Ocean Observing System (IndOOS-2) and its Outcomes **CLIVAR Special Issue Exchanges 78**: Doi: https://doi.org/10.36071/clivar.78.2020
Sea surface temperature change in the past 66 years (reported by Anon 2020 based on Cheng et al 2017).

While the IIOE-2 community publishes its findings anywhere in the open literature, many key publications are to be found in co-ordinated Special Issues of Deep-Sea Research II Volumes 161 and 166. These are coordinated by Raleigh Hood who makes appoint of acknowledging SCOR and IIOE-2 in his introductory MS in each volume. The DSR MSS are summarized below:

**Deep-Sea Research II Volume 161:**


White et al. (2019) Resilience of benthic ecosystem C-cycling to future changes in dissolved oxygen availability. DSR2 Special Issue on IIOE2, 161: 29-37.

Saalim et al. (2019) Assessing the ecological preferences of agglutinated benthic foraminiferal morphogroups from the western Bay of Bengal. DSR2 Special Issue on IIOE2, 161: 38-51.

Mao et al. (2019) Mesoscale eddy characteristics in the interior subtropical southeast Indian Ocean, tracked from the Leeuwin Current system. DSR2 Special Issue on IIOE2, 161: 52-62.


Baer et al. (2019) Carbon and nitrogen productivity during spring in the oligotrophic Indian Ocean along the GOSHIP IO9N transect. DSR2 Special Issue on IIOE2, 161: 81-91.
Vinayachandran et al. (2020) Maintenance of the southern Bay of Bengal cold pool. DSR2 Special Issue on IIOE2, in press.

Amol et al. (2020) Effect of freshwater advection and winds on the vertical structure of chlorophyll in the northern Bay of Bengal. DSR2 Special Issue on IIOE2, in press.

Sreeush et al. (2020) Biological production in the Indian Ocean upwelling zones - Part 2: Data based estimates of variable compensation depth for ocean carbon models via cyclo-stationary Bayesian Inversion. DSR2 Special Issue on IIOE2, in press.

Sarma et al. (2020) Physical forcing controls spatial variability in primary production in the Indian Ocean. DSR2 Special Issue on IIOE2, in review.

Bernal et al. (2020) Diet composition of myctophid larvae off western Australia. DSR2 Special Issue on IIOE2, in review.

Liu et al. (2020) Eddy–current interaction in the Leeuwin Current off the lower west coast of Australia. DSR2 Special Issue on IIOE2, in review.

Vinayachandran et al. (2020) Processes governing the seasonality of vertical chlorophyll-a distribution in the central Arabian Sea: Bio-Argo observations and ecosystem model simulation. DSR2 Special Issue on IIOE2, in review.

Huang et al. (2020) MJO induced diurnal sea surface temperature variations off the Northwest Shelf of Australia observed from Himawari geostationary satellite. DSR2 Special Issue on IIOE2, in review.


Sprintall et al. (2020) Seasonality of the Somali Current/Undercurrent System. DSR2 Special Issue on IIOE2, in review.

Harms et al. (2020) Particulate matter fluxes reveal no coherence between primary production and organic carbon export in the Indian Ocean subtropical gyre. DSR2 Special Issue on IIOE2, in review.

Ningish et al. (2020) Zonal Current Characteristics in the Southeastern Tropical Indian Ocean (SETIO). DSR2 Special Issue on IIOE2, in review.

A further volume in the DSR II series is planned based on the 2019 IIO degree East cruise on the R.V. Investigator. It current has 23 MSS planned.

There is also a further series of MSS arising from this Australian lead cruise. These are at various stages of development as follows:

<table>
<thead>
<tr>
<th>Authors</th>
<th>Title/content</th>
<th>Comments</th>
<th>Date expected</th>
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<tbody>
<tr>
<td>Landry et al.</td>
<td>Mesozooplankton biomass and temperature-enhanced grazing along a 110°E transect in the eastern Indian Ocean</td>
<td>Submitted MEPS</td>
<td>Feb 2020</td>
</tr>
<tr>
<td>Beckley et al.</td>
<td>Data report overview paper on the 110E voyage</td>
<td>Something similar to Jovane et al. (2019) South Atlantic multidisciplinary voyage paper – still awaiting response from Editor of Frontiers</td>
<td></td>
</tr>
<tr>
<td>Phillips et al.</td>
<td>Variability/change of water mass properties near 20S</td>
<td>GRL</td>
<td>Dec 2020</td>
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<tr>
<td>Phillips</td>
<td>Long term variability 1960s to 2019</td>
<td></td>
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<tr>
<td>O’Brien, Seymour et al.</td>
<td>Sulphur cycling (concentrations and qPCRs)</td>
<td>Progress has been made with biogeochemistry &amp; extraction of DNA for qPCR. Hoping to publish the 110E line with not just biogeochemistry &amp; qPCR but incorporation of some community data (amplicons) and metagenomics. This has become a thesis chapter</td>
<td>2021</td>
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As well as good progress with peer-reviewed publications, the IIOE-2 community also uses informal publications to maintain momentum, to pose ideas and to ensure the community remains informed and cohesive. The IIOE-2 website (see below) is an important repository for this.

**INFORMAL PUBLICATIONS**

IIOE-2 communications about the project through a monthly newsletter, quarterly publication (Indian Ocean Bubble-2), and its website (see below) remains important.

**KEYNOTE TALKS**

Keynotes have been given at the International Conference on Earth and Environmental Sciences & Technology for Sustainable Development, ICEEST 2020 held at the InterContinental, Dhaka on 25-27 January. A second was given at the SOLAS Indian Ocean meeting held on-line on 30th September.

**WG 2: DATA AND INFORMATION MANAGEMENT WORKING GROUP**

This Working Group is charged with early sharing of data using internationally agreed rules of data exchange. It is central to IIOE-2 and was ably led by Cyndy Chandler who sadly resigned on her retirement in 2019. The D&MI Plan she ably led is almost complete and the Core Group is in the process of appointing an interim successor to finish the Plan. The Group will then begin its Implementation. This is an important aspect of developing IIOE-2 in the future.

**WG 3: OPERATIONAL COORDINATION**

This WG is charged with develop and integrate web-based tools, databases and partnerships to enable a sufficient level of cooperation, resource-sharing, scientific collaboration and capacity alignment. The WG is lead by Dr Shailesh Nayak.
IIIOE-2 WEBSITE
This can be found at www.iioe-2.incois.gov.in and is IIOE-2’s main interface with the world.

Links within SCOR
It is marvellous to note that SOLAS now has initiated studies in the IO group. In this, SOLAS Core Themes are integrated to understand key environments such as the IO. This is lead by Anoop Mahajan (India), aided by Parvadha Suntharalingam (United Kingdom) and Hermann Bange (Germany). Their first meeting of SOLAS IO was held on-line on 30th September with ~360 scientists registered. Details can be found at https://www.solas-int.org/science/implementation-strategy/integrated-studies-of-high-sensitivity-systems.html

Other Issues: Now and the Future

UN DECADE OF OCEAN SCIENCE FOR SUSTAINABLE DEVELOPMENT
The relationship between IIOE-2 and the DECADE programme is still evolving and is likely to be a fruitful 2-way street with IIOE-2 projects contributing to the DECADE while aspects of IIOE-2 delivery (e.g. Role of IO in Global Processes) will undoubtedly gain from the DECADE. We are fortunate to have Vladimir Ryabinin, the architect of the DECADE programme, as one of the IIOE-2 Co-Chairs and he will be crucial to the integration of IIOE-2 into the DECADE program. A position paper is being produced by the Core Group (R Hood and N d’Adamo as leads) on Mapping the high-order IIOE-2 science opportunities onto the DECADE’s high-level opportunities. This should be produced soon as the call by the DECADE for Expressions of Interest is due on 15th October.

EVOLUTION OF IIOE-2
1) IIOE-2 is now at a turning point in its evolution. There are a myriad of unanswered research questions that remain to be addressed. The biggest, arguably, is what causes the rapid heating of the Indian Ocean? This heating has major knock-on effects including those the directly influence society (sea-level rise). At the same time as addressing these largely research-led questions, IIOE_2 is poised to join up with the DECADE program and this will need some careful thought. The DECADE program will incorporate a closer-to-society focus and this will require some new skills (and probably people). We were due to discuss this at the Goa Meeting in March but that process has been put on hold.

2) There are also some programmatics issues for IIOE-2 that will need to be addressed in the near future. While the structure of IIOE-2 was simplified in 2019, each of the components remains crucial for the successful delivery of IIOE-2. The component that needs nurturing is the Data and Information Management Working Group. A new leader is being sought and once that person is in place, the community should have more faith in using the IIOE-2 database. As IIOE-2 data will remain as an enduring legacy of the program, that currently remains an important challenge for the near future. We are aware that Data Management issues are evolving fast and WG2 needs to be integrated into recent developments such as those lead by IODE.

### Future Timetable

<table>
<thead>
<tr>
<th>When? Year, month</th>
<th>What?</th>
<th>Who?</th>
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<tbody>
<tr>
<td>2020, Nov-Dec</td>
<td>Core Group 18</td>
<td>Members</td>
</tr>
<tr>
<td>2021, Feb</td>
<td>IIOE-2 SSC 4</td>
<td>Members</td>
</tr>
<tr>
<td>2021, Feb</td>
<td>IIOE-2 Science Talks</td>
<td>Open</td>
</tr>
<tr>
<td>2021, Oct</td>
<td>IIOSC 2020</td>
<td>Open</td>
</tr>
<tr>
<td>2021, Oct</td>
<td>IIOE-2 SSC 5</td>
<td>Members</td>
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### Request to SCOR

We request that SCOR agrees that the already allocated $15k is used to underpin T&S for SCOR participants at the postponed Goa meeting. This assumes that the meeting will take place.