Working group proposal submitted to SCOR

DeepSeaDecade

Roadmap for a Standardised Global Approach to Deep-Sea Biology for the Decade of Ocean Science for Sustainable Development

April 2019

1. Summary

The deep-sea remains one of the least known parts of our planet, yet our basic ecological knowledge of this region is limited because of an historical piecemeal approach to research, and significant spatial bias in the data collected (northern hemisphere, developed nations exclusive economic zones). Fundamental ecological data forms the input parameters to all ecosystem models. Our lack of knowledge of the deep sea means it remains the 'black box' in global model simulations. The road map for the UN Decade of Ocean Science for Sustainable Development (UN DOSSD) recognises the deficit of deep-sea data and the impact of this on sustainable management of the oceans. It calls on the deep-sea science community to address this deficit under the UN DOSSD. The community have responded by identifying the key questions to be answered and the potential role of new technology in addressing those questions. What is now required is an unprecedented level of global coordination to effect a giant leap in understanding by the end of the UN DOSSD. This working group will 1) develop a global survey and sampling modular design, 2) agree methods and standards for the acquisition of biological data, including potential use of novel technologies, 3) build on the global design with habitat-specific approaches, 4) integrate developed plans with other global initiatives and 5) build global capacity for conducting deep-sea research. We will produce a series of multi-author peer reviewed papers that will form the reference point for deep-sea research for the next decade and beyond.

2. Scientific Background and Rationale

The composition and functioning of the deep sea, comprising the largest living space on Earth, is still poorly understood, with a minimal proportion of the deep seafloor sampled and investigated to date (Ramirez-Llodra et al., 2010). To most of society, the deep sea is thought of as a remote, featureless, and inaccessible space. However the combination of particular geological, physical and geochemical attributes of the deep seafloor and water column, create a set of complex habitats with unique characteristics. Each of these habitats supports faunal communities with specific physiological and behavioural adaptations to high pressure, darkness, low temperatures (or steep temperature gradients in the case of hydrothermal vents), food limitation (particularly at abyssal plains) and in some cases geographic isolation (e.g. seamounts, vents, trenches, and seeps). Deep-sea biodiversity at bathyal and abyssal depths is amongst the highest on the planet (Grassle and Maciolek, 1992; Mora et al. 2011), and in poorly sampled regions, such as the abyssal Pacific, up to 90% of species collected may be new to science (Glover et al. 2002). Our limited knowledge of very basic baseline information is the major challenge when addressing issues of biodiversity, ecosystem function, and the potential impacts of - and resilience to - human activities in the deep sea (Mengerink et al. 2014).

The United Nations Decade of Ocean Science for Sustainable Development (DOSSD) is due to commence in 2021, and we are currently in the preparation phase. The stated motivation for the decade is to reverse the cycle of decline in ocean health and create improved conditions for sustainable development of the ocean. The roadmap developed for the DOSSD recognises the deficit of biological data for the deep-sea ecosystem, and specifically calls on the scientific community to use the Decade to conduct research to understand better the deep-sea ecosystem and its functions. Deep-sea scientists have responded to this call by holding a series of international meetings. Firstly to agree to science priorities and knowledge gaps for the DOSSD (1-day meeting, Sept 2018, Monterey, USA, and follow-up meeting October 2018, Aveiro, Portugal), and secondly to explore the potential for new technology to address them (Royal Society funded meeting – Beyond Challenger Nov 2018). We now

have community-level agreement on the key research questions in deep-sea science, and have identified new technologies on the horizon that may help us to address these questions.

2.1 The questions

i. What is the diversity of life in the deep ocean?

We lack fundamental ecological data for much of the deep sea. Poor knowledge of what lives there, how it is distributed from global to local 'patch' scales, as well as over environmental gradients, prevents us from establishing a baseline and knowing what is common and what is rare. Critically, fundamental ecological data form the input to **all** biological ecosystem models. Our ability to forecast how marine biodiversity will respond to environmental change and other anthropogenic pressures, depends on good base knowledge such as species distributions, physical and chemical drivers of distribution, abundance, biomass, growth rates, etc. Efforts to model species distributions to fill data gaps are currently severely limited by a lack of fundamental ecological data. Existing models are simplistic, and of questionable accuracy due to limited, and / or poor quality input data (Davies and Guinotte, 2011; Howell et al., 2016).

ii. How are populations & habitats connected?

At present, we do not know the linkages between habitats and populations, including migration routes, ontogenetic or seasonal movement between habitats, larval dispersal pathways and genetic connectivity, or energy flow pathways in the form of trophic links and food webs. Understanding these linkages, collectively termed connectivity, is critical to effective ocean management and sustainable use. Connectivity promotes healthy and resilient populations; disruptions to the connections, for example through changes in ocean circulation patterns, can impact their persistence and population recovery after disturbance, as well as the effectiveness of Marine Protected Area networks. Understanding population connectivity is also important for our mechanistic understanding of species divergence and ultimately speciation in the ocean, and the role that physical mechanisms play in this (Cowen et al, 2000).

iii. What is the role of living organisms in ecosystem function & service provision?

We are at an early stage in understanding the role of the deep sea in provision of goods and services (for example food provision or nutrient cycling), and detail on mechanisms of delivery are scant. What are the key species/habitats involved in carbon sequestration? Are some groups more important than others? For example, we know sponges may play an important role in global Si cycling (Maldonado et al. 2005), as well as having a key role as a sink for inorganic nitrogen, surpassing that of marine sediments at equivalent depths (Hoffmann et al. 2009). To ensure the ongoing provision of those services, and to understand better marine system processes such as biogeochemical cycling, we need to identify the functional groups present, their role in ecosystem function, and how that function relates to delivery of goods and services. Again, fundamental ecological data are critical to this understanding and to our ability to bring biology into wider ecosystem models.

iv. How do species, communities and ecosystems respond to disturbance?

Understanding how the interactions and synergies play out between climate stressors and direct disturbance is essential to effective management of the deep ocean. This is an understanding that can only be gained through use of modelling approaches, and fundamental ecological data provide the input terms to such models.

2.2 The challenge

Although deep-sea science has a history of successful, international collaborative research programmes, none to date have provided the level of integration and standardisation required in order to deliver answers to the above questions. The Census of Marine Life programme made significant advances in joining-up international efforts around a common goal to understand marine ecosystems, including various deep-sea systems (e.g. seamounts, abyssal plains, continental slopes, etc.). However, the lack of an agreed common survey / sampling design and standardized methodologies among contributing projects meant that datasets could not be combined to address larger questions. Recently, there have been efforts within the deep-sea community to develop frameworks for globally consistent datasets (Woodall et al., 2018). Still, these efforts need to go further in generating a globally coherent underpinning design, and standardised methods. Only then can we hope to make the leaps in knowledge required to effectively manage the deep sea going forward, and deliver the societal outcomes identified by the DOSSD roadmap.

2.3 The need for a SCOR working group

The deep-sea science community has identified the need for a new international programme of research for the UN DOSSD that is global and inclusive. They have also identified the questions that such a programme would address. However, before any further progress can be made there needs to be a concerted effort for dialogue within the community to agree on standards and methods used to address the questions identified, and ensure future research efforts are integrated and inclusive. This requires bringing together a diverse group of researchers including deep-sea habitat specialists (seamount, vent, abyssal plain, continental slope, etc.), macro-ecologists, and process specialists (connectivity, diversity, ecosystem function, etc.). This working group will assemble a team of scientists to work jointly towards delivering an overarching plan that will form the basis of deep-sea biological research for the next decade. It will provide essential data to move towards the targets of the UN Sustainable Development Goals (in particular SD13 on Climate Action and SDG14 on Life Below Water), and it will also help inform the UN World Ocean Assessment II.

3. Terms of Reference

1. To develop a global plan for survey / sampling deep-sea ecosystems to underpin deep-sea research for the UN Decade of Ocean Science.
2. To agree on methods and standards for the acquisition of biological data, including the role of existing and novel technologies.
3. To develop habitat-specific approaches for survey / sampling the deep-sea ecosystem (following the Census of Marine Life model), that integrate the global approaches developed under ToRS 1 and 2, but allow greater specialisation.
4. To integrate ToRs 1-3 with wider efforts under the Global Ocean Observing System (GOOS) via the Deep Ocean Observing Strategy (DOOS).
5. To actively facilitate efforts to build capacity in developing nations for deep-sea science.

4. Working plan

Please see the Gantt chart provided in Appendix 1 for timing of key events associated with the UN Decade of Ocean Science for Sustainable Development, and proposed timings of SCOR working group

meetings (both physical and virtual) and deliverables (draft and final). While each physical meeting will have a key focus outlined below, multiple ToRS will be discussed at each to ensure good integration of ideas both within the working group and with other UN DOSSD initiatives. The Challenger Society's Deep Sea Special Interest Group will provide funding to support an initial meeting in September 2019, and a funding application for support will be submitted to the Deep Sea Biology Society.

To address ToR 1 we will develop a coherent well-designed global survey and sampling plan, but one that is modular. The underlying principle will be that each survey / sampling module can be placed within a local, regional and / or habitat-specific context and thus be readily integrated with local, regional, research team interests. However, results from all modules can ultimately be combined to answer global scale questions, and provide 'one giant leap' for human understanding of the ocean. This plan will be developed using two in-person workshops, beginning with the Challenger Deep-Sea Special Interest Group, followed by the first SCOR working group meeting (SCOR-WG workshop 1). A virtual meeting will also be scheduled between the two workshops to develop further our ideas. The rapid timing of this ToR is important in order to interface with the UN Decade of Ocean Science's preparation phase and the finalisation of the Decade implementation plan in mid-2020.

ToR 2 is the next logical progression from ToR 1. Having agreed on a modular framework, combining data in the future will only be possible if methods are standardised. SCOR-WG workshop 2 will focus on standardisation of methods of data acquisition and processing. Building on published outputs from the Census of Marine Life (Clark et al., BLAH), a more recent workshop (Woodall et al., 2018), and a Royal Society (UK) funded meeting in Nov 2018, we will identify those measurements / samples best acquired using novel technology, and those that may be acquired using more traditional, cheaper, or more accessible technologies. Consideration of methods is important in democratising deep-sea research and enabling participation of all nations, many of whom lack access to expensive novel technologies. The outcomes of ToRs 1 and 2 will be written up as an open-access peer reviewed publication that will provide a key reference text for deep-sea science for the next 10 years and beyond, underpinning future research efforts.

ToR 3 will be developed in parallel to ToRs 1,2 and 4. We will look at habitat-specific considerations not covered by the global plan alongside the development of that plan. A sampling / survey design that works globally may not fully consider habitat-specific issues. For example, a global programme may require depth-stratified sampling of seamounts; however, a single series of depth-stratified transects on a seamount will not enable us to address seamount specific questions that may require replication on different sides of seamounts. For this ToR we will hold virtual workshops, following each of the first two SCOR workshops, for habitat-specific working groups chaired by appropriate members of the SCOR-WG to engage the wider deep-sea science community fully in the formulation of sampling plans. These virtual groupings will be advertised via the DOSI, INDEEP, Deep-Sea Biology Society and Challenger Society networks in order to reach a wide audience.

At outset, the SCOR working group will work with DOOS (via overlapping participants) to identify ways the SCOR activities advance the DOOS goals (ToR4) and develop a plan to integrate these into DOOS actions and communications. With DOOS we will focus in particular on the integration of biology with the existing deep ocean physical and biogeochemical measurement programs (e.g. ARGO, deep ARGO, BGC Argo, GoSHIP, Ocean Sites, Observatories). Specifically, once we have established both global and habitat-specific plans, ToR 4 will review the plans against existing wider community efforts under the Global Ocean Observing System (GOOS) via the DOOS in SCOR-WG workshop 3. We will identify synergies between our plans and DOOS, ensure there is no duplication of effort, and that these different global strategies are integrated. Specifically, we anticipate key collaboration with the DOOS

Essential Ocean Variable Biology and Ecosystem panel (which itself is working with the GOOS Biology and Ecosystem panel), the DOOS demonstrations projects, and with the DOSI/INDEEP/DOOS SDG 14 voluntary commitments. Critical links to the existing deep-ocean physical and biogeochemical measurement programs (e.g. ARGO, deep ARGO, BGC Argo, GoSHIP, Ocean Sites, Observatories) can also be achieved through DOOS.

ToR 5 will be partially addressed throughout the development of ToRs 1-4. The proposed working group membership draws scientists from developing nations. In addition, we will seek input from other scientists from developing nations, including early-career scientists through DOSI (in particular the DOSI working group on capacity building), INDEEP, Deep-Sea Biology Society and Challenger Society networks. We intend to consult as widely as possible on the development of deliverables to ensure broad uptake in the future. Our aim is for a truly inclusive working group. We will also hold a specific virtual workshop to develop an action plan to provide sea-going training opportunities for students from developing nations. We anticipate the action plan will consist of a statement of commitment that members of the deep-sea research community can sign-up to; a mechanism through which to advertise opportunities for students; a transparent application, assessment, and selection process; and a requirement for a short post-cruise reflection report. We will ensure engagement with similar initiatives developed under other programmes e.g. POGO.

5. Deliverables

1. An open-access peer-reviewed publication detailing a global plan for survey / sampling the deep-sea ecosystem, including use of standardised methodologies to underpin deep-sea research for the UN Decade of Ocean Science. (ToRs 1 and 2)
2. A series of open-access peer reviewed publications consisting of habitat-specific plans (following the Census of Marine Life model, and similar to German et al., 2011) to advance the global plan developed under ToRs 1 and 2 ensuring no duplication of effort with wider initiatives. (ToRS 3 and 4)
3. A research community-endorsed action plan to provide training opportunities and peer support for students from developing nations in order to broaden the research base and nurture talent (ToR 5).

6. Capacity Building

Deep-sea research, exploration and exploitation has historically been led by a small number of developed nations. This is also reflected in availability of samples, bias in available data (Fig. 6.1), and overall understanding of deep-sea ecosystems, which is currently severely limited. The least-studied parts of the deep sea are often within developing nations' EEZs and / or on the High Seas / the Area, away from the continental slopes. In addition, deep-sea research is currently conducted in a very piecemeal and poorly coordinated fashion. Individual projects tackle aspects of larger questions. The projects are often constrained by available budgets, time, and the logistics of sampling in the deep sea. There are often trade-offs made in experimental design or resolution of data against greater temporal / spatial coverage, or to provide data to satisfy multiple competing aims. While this approach has helped us continue to advance our knowledge of the deep-sea ecosystem, it has failed to make the great leaps needed to manage our ocean more effectively.

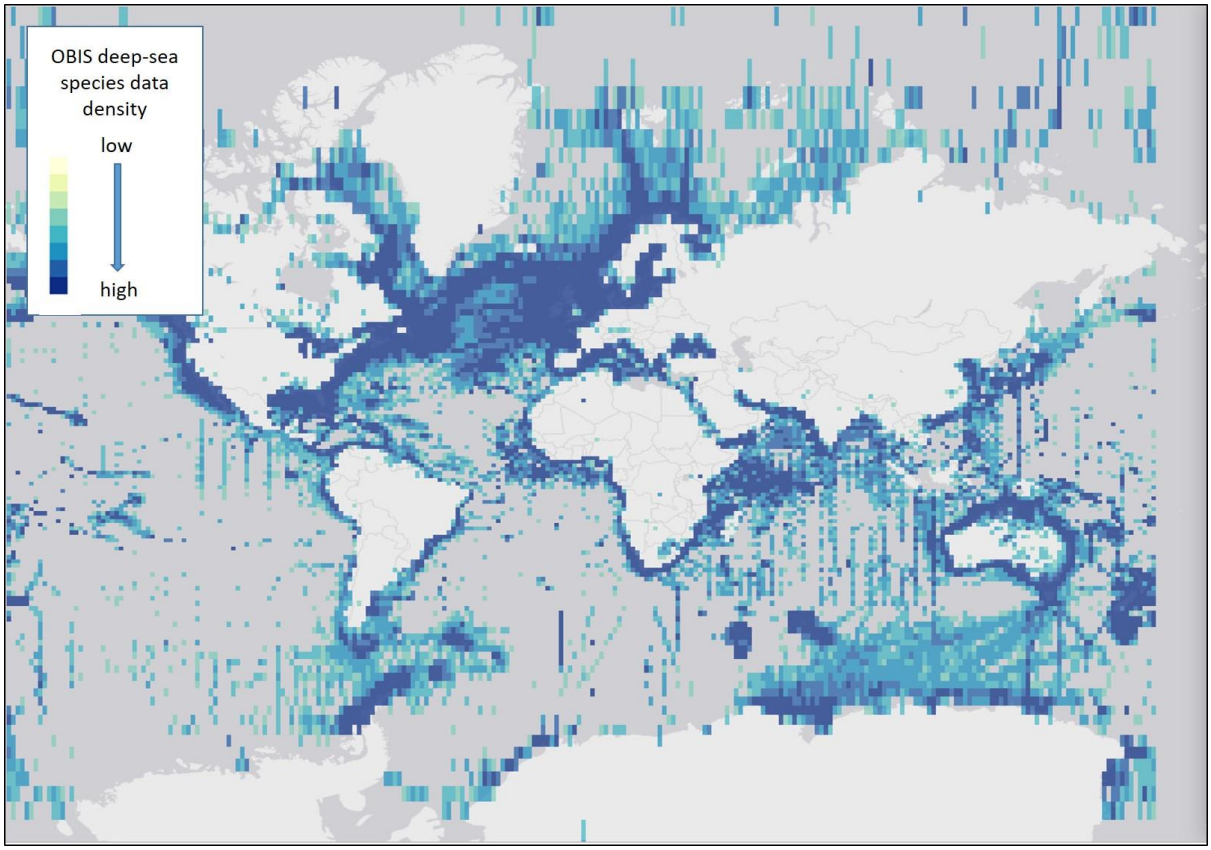

Figure 6.1 Density of deep-sea species records currently held by the Ocean Biogeographic Information System, showing clear bias in sampling effort.

International collaboration is the key to both broadening our knowledge of the deep-sea, and to make deep-sea research more accessible to scientists from all nations. This working group, through developing agreed global habitat-specific plans, will build long-lasting capacity for the research community to tackle the long-held, and unanswered, questions outlined above. The published plans will enable the global deep-sea research community to contribute to answering these long-standing questions through regional and local research programmes, in a targeted or opportunistic fashion. The modular design and standardised methodologies will enable separate programmes to adopt a particular module where it fits in with, or contributes to their project-specific research aims. Scientists working at regional scales will generate data for their own programmes, but also for the global research effort. Over the next decade, this globally coherent dataset will grow, and by the end of the decade, we will finally be able to answer the questions posed with confidence.

This working group will also significantly advance efforts to build capacity for deep-sea research in the next generation of scientists, and in developing nations. ToR 5 will specifically address the lack of opportunity for students and researchers from nations lacking in deep-sea science infrastructure to gain experience in sea-going deep-sea research. The development of an action plan to support students, early-career scientists, and researchers from developing nations to gain access to research vessel opportunities will help broaden and diversify the deep-sea research community. It will also help fulfil the aspirations of the Decade of Ocean Science. The Decade Roadmap clearly states that the Implementation Plan, to be developed by 2020, will include a plan for capacity development, training and education (R&D priority 7).

7. Working Group composition

7.1 Full Members

Name	Gender	Place of work	Expertise relevant to the proposal
Kerry Howell (co-chair)	Female	Plymouth University, UK	Deep-sea ecologist, ecological modeller, use of AI, links to DOSI, INDEEP, Challenger Society. Seamount & canyon ecology.
Elva Escobar	Female	Universidad Nacional Autónoma de Mexico, Mexico.	Biological oceanography, biodiversity, macroecology. Link to UN DOSSD executive planning group. Abyssal ecology. Regional capacity needs.
Alex Rogers	Male	REV Ocean, Norway	Marine molecular ecology, biodiversity. Links to UN and philanthropic funded programmes. Seamount Ecology
Malcom Clark	Male	National Institute for Water and Atmospheric Research, New Zealand	Deep-sea fish, fisheries. CoML lead, link to ISA. Seamounts, oceanic ridges.
Ana Hilario (co-chair)	Female	University of Aviero, Portugal	Reproductive ecology, connectivity and biogeography of deep-sea ecosystems. Vent ecology.
Paul Snelgrove	Male	Memorial University of Newfoundland, Canada.	Deep-sea benthos, biodiversity drivers and roles in sediments, links to UN BBNJ process.
Lisa Levin	Female	Scripps Institution of Oceanography, USA.	Deep-sea benthos and climate change, links to DOOS, DOSI, and IPCC
Christopher German	Male	Woods Hole Oceanographic Institution, USA	Deep-sea exploration, including innovative use of robotic vehicles and telepresence.
Kerry Sink	Female	South African National Biodiversity Institute, South Africa.	Deep-water ecology, South Atlantic, SW Indian Ocean, regional capacity needs
Roberto Danovaro	Male	Stazione Zoologica Anton Dohrn, Naples & Polytechnic University of Marche, Italy.	Deep-Sea benthos, biodiversity loss, ecosystem functions, climate change.

7.2 Associate Members

Name	Gender	Place of work	Expertise relevant to the proposal
Bhavani Narayanaswamy	Female	Scottish Association for Marine Science, UK	Deep-sea ecologist, biodiversity, effects of biological/anthropogenic inputs, continental margins, seamounts NE Atlantic, SW Indian and Arctic Oceans
Paulo Sumida	Male	University of São Paulo, Brazil.	Deep-sea ecology. South Atlantic regional capacity needs
Anna Metaxas	Female	Dalhousie University, Canada.	Biological oceanography, evolutionary ecology.
Lenaick Menot	Male	Ifremer, France.	Deep-sea ecologist. Vents, Abyss.
Nick Higgs	Male	Cape Eleuthera Institute, Bahamas.	Deep-sea biodiversity, marine observatories, whale fall. Caribbean regional capacity needs.
Eva Ramirez-Llodra	Female	Norwegian Institute for Water Research, Norway.	Deep-sea ecologist, biodiversity, connectivity. Links with DOSI, INDEEP, IUCN-CEM Deep-sea ecosystems and mining.
Hiromi Watanabe	Female	Japan Agency for Marine-Earth Science and Technology, Japan	Deep-sea benthos, larval dispersal, population connectivity, hydrothermal vents.
Awantha Dissanayake	Male	University of New South Wales, Sydney, Australia	Ecological physiology, Experimental Biology, Climate Change.
Craig McClain	Male	Louisiana Universities Marine Consortium, USA.	Macroecology, macroeveolution, biodiversity, body size, energy flow.
Javier Sellanes	Male	Catholic University of the North, Chile.	Deep-sea benthos ecology and taxonomy. SE Pacific, regional capacity needs

8. Working Group contributions

Kerry Howell (co-chair) is a deep-sea ecologist and modeller, co-proposer of the SCOR working group, co-chair of the DOSI DOSSD working group, and chair of the Challenger Deep-Sea Special Interest Group. She brings expertise in rugged terrain deep-sea habitats (seamounts, canyons,

continental slopes) and various types of ecological modelling including food web, connectivity and habitat suitability modelling.

Elva Escobar contributes with knowledge in biological oceanography studying the marine biodiversity and macroecology of the seabed ecosystems in the Mexican EEZ. She is co-lead of DOSI, and a member of the IOC's Executive Planning Group for the UN DOSSD. She will ensure the working group's activities are communicated to the IOC and UN.

Alex Rogers brings expertise in biodiversity of marine ecosystems, including environmental drivers, interspecies interactions, connectivity, longer term-evolutionary processes and human impacts. He has undertaken numerous UN projects and is currently science director for REV Ocean. He will communicate the working group's plans to REV Ocean and looks for areas of shared interest.

Malcom Clark brings expertise in deep-water fish and fisheries, deep-sea ecosystems including seamount and oceanic ridges, and sampling techniques. He headed the Census of Marine Life on Seamounts, and currently sits on the Legal and Technical Commission of the International Seabed Authority.

Ana Hilario (co-chair) is a deep-sea ecologist and co-chair of the DOSI DOSSD working group and INDEEP Population Connectivity working group. She contributes with expertise on reproductive ecology, larval dispersal, population connectivity and its implications for biogeography and spatial management; as well as experience on capacity building activities in developing countries.

Paul Snelgrove brings expertise on biodiversity and ecosystem functioning in deep-sea ecosystems, and particularly seafloor environments. He has been actively involved in discussions on Biodiversity Beyond National Jurisdiction.

Lisa Levin contributes expertise on continental margin benthic ecosystems, their ecosystem services, exposure and response to climate change, and to other forms of human disturbance in the deep ocean. Through her involvement in IPCC (AR5, AR6 and Special Report on Oceans and Cryosphere), DOOS and DOSI she will identify for SCOR the major deep-ocean ecological function and service information that can contribute to ongoing climate assessment and create direct SCOR linkages to DOOS and DOSI planning and activities.

Christopher German contributes expertise in Deep Ocean exploration and, in particular, the innovative use of advances technologies to conduct that work including autonomous underwater vehicles, collaborative robotic systems and telepresence. He has experience in national and international project leadership including as Co-Chair of InterRidge, the Census of Marine Life ChEss Project, SCOR WG135 and NASA's new Network for Ocean Worlds.

Kerry Sink contributes expertise in marine ecosystem classification and assessment for the Southwest Indian, Southeast Atlantic and Southern Ocean. Kerry will provide developing country context, identify regional capacity needs and help align efforts across projects and programs.

Roberto Danovaro is a deep-sea biologist and ecologist, specialist in the assessment of the interactions between biodiversity loss and impairment of ecosystem functions and on evaluation of the impact of climate change on deep-sea habitats and ecosystems.

9. Relationship to other international programs and SCOR Working groups

There are a number of current SCOR WGs focused on standardization of methods and developing global approaches to studying marine systems (WG147 & WG143). Some current WGs are considering biology specifically (WG149), including the role of novel technologies in global efforts (WG156 & WG 157) and integrations with global programmes (WG154). While these current WGs have aspects in common with our proposed WG, none are considering the wider biological component of marine systems or the deep sea. This demonstrates the opportunity offered by our proposal.

Perhaps the most comparable SCOR WGs are historical. SCOR WG 76, approved in 1983, was focused on the ecology of the deep sea floor. As with our proposal, this WG recognized the great technical and statistical difficulties of obtaining adequate information on the deep-sea benthic ecosystem. They proposed a critical review of the then state-of-the-art, clearly identifying what would be desirable, but at the time impracticable to do. Our proposed WG is a natural progression from where this WG concluded 36 years ago. We understand information needs, how new technology may help gather that information, and have recognised that an international programme of collaborative research is required.

SCOR WG5, the International Indian Ocean Expedition, had a single ToR: to plan and organize international co-operative exploration of the Indian Ocean. This resulted in a large-scale multinational hydrographic survey of the Indian Ocean, which took place from 1959 to 1965. It involved over 45 research vessels from 14 countries. Our proposed WG has a series of ToRs that are analogous to the single ToR of SCOR WG5. Our aim is to produce a road map for international co-operative biological research on the global ocean under the Decade of Ocean Science.

Our proposed WG has very clear links to the UN DOSSD that have been identified throughout, as well as the GOOS and DOOS initiatives. Our proposed membership includes a representative of the IOC's DOSSD Executive Planning Group, and a Co-Chair of the DOOS initiative. Their participation will ensure good communication and integration with these international programmes. The DOSSD roadmap outlines six critical societal outcomes (SO), and a further seven priority areas for research and development (R&D), which the Decade seeks to address by 2030 (Fig. 9.1). The questions that the deep-sea science community have identified (section 2.1) have direct relevance to the DOSSD SOs and R&D priority areas. Deliverables 1 and 2 of our proposed working group will specifically identify how the scientific plans developed will also address the decades SOs and R&D priorities (Table 9.1, Fig. 9.1). In addition, deliverable 3 will directly contribute to R&D priority area 7 (Fig. 9.1).

Table 9.1 How the questions identified by the deep-sea science community contribute to societal outcomes and research and development priority areas identified by the DOSSD road map.

Questions	Societal Outcomes (SO) of the Decade of Ocean Science for Sustainable Development						Research & Development (R&D) Priority Areas						
	1	2	3	4	5	6	1	2	3	4	5	6	7
i													
ii													
iii													
iv													

The six Societal Outcomes (SO) of the Decade of Ocean Science for Sustainable Development

1. A clean Ocean whereby sources of pollution are identified, quantified and reduced, and pollutants removed from the Ocean
2. A healthy and resilient Ocean whereby marine ecosystems are mapped and protected, multiple impacts (including climate change) are measured and reduced, and provision of ocean ecosystem services is maintained
3. A predicted Ocean whereby society has the capacity to understand current and future ocean conditions, forecast their change and impact on human wellbeing and livelihoods
4. A safe Ocean whereby human communities are protected from ocean hazards and where safety of operations at sea and on the coast is ensured
5. A sustainably harvested and productive Ocean ensuring the provision of food supply and alternative livelihoods
6. A transparent and accessible Ocean whereby all nations, stakeholders and citizens have access to Ocean data and information, technologies, and have the capacities to inform their decisions.

The seven Research & Development (R&D) Priority Areas

1. Comprehensive map (digital atlas) of the oceans
2. A comprehensive ocean observing system
3. A quantitative understanding of ocean ecosystems and their functioning as the basis for their management and adaptation
4. Data and information portal
5. Ocean dimension in an integrated multihazard warning system
6. Ocean in earth-system observation, research and prediction, with engagement of social and human sciences and economic valuation
7. Capacity building and accelerated technology transfer, training and education, ocean literacy.

From the *Revised Roadmap for the UN Decade of Ocean Science for Sustainable Development*

Figure 9.1 Societal outcomes and research and development priority areas identified in the Decade of Ocean Science for Sustainable Development roadmap.

10. References

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Appendix

Gantt chart: Timing of key points in the road map for the UN Decade of Ocean Science for Sustainable Development (light blue), and proposed timings for SCOR working group meetings (SCOR funded – black, externally funded – dark blue), virtual meetings (dark grey), ToRs (light grey), and deliverables (draft – light green, final – dark green).

Action	May-19	Sep-Nov 19	Dec-Feb 19/20	Mar-May 20	Jun-Aug 20	Sep-Nov 20	Dec-Feb 20/21	Mar-May 21	Jun-Aug 21	Sep-Nov 21	Dec-Feb 21/22	Mar-May 22	Jun-Aug 22
Decade global meeting #1													
Second Exective Planning Group meeting													
Decade global meeting #2													
Endorsment of Decade plan by IOC													
Official start of Decade													
SCOR working group meetings													
TOR 1: global plan for survey / sampling deep-sea ecosystems													
TOR 2: agree methods and standards													
TOR 3: develop habitat-specific approaches													
TOR 4: integrate with wider marine observation efforts													
TOR 5: capacity building													
Deliverable 1: Publication of global plan for decade of ocean science													
Deliverable 2: Publication of habitat specific plan for decade of ocean science													
Deliverable 3: Community-endorsed action plan for capacity building													
SCOR-WG close													

Full member selected relevant publications

Kerry Howell (co-chair)

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