Working group proposal submitted to SCOR 2020

Respiration in the **M**esopelagic **O**cean (**ReMO**): Reconciling ecological, biogeochemical and model estimates

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1. Summary

Together with organic matter export from the surface ocean, microbial respiration in the mesopelagic realm (~200m – 1000m) determines the long-term storage of carbon in the ocean, the extent of mesopelagic deoxygenation and, ultimately, the levels of carbon dioxide in the atmosphere. Yet, microbial respiration remains one of the least constrained metabolic rates in the Earth System, with mismatches between inverse model predictions, in situ budgets and in vitro observations of an order of magnitude. These mismatches stem from the difficulties in quantifying microbial respiration rates in the dark ocean. However, with the dawn of novel in situ technologies such as optodes, in situ incubators, gliders, and floats, we are now able to determine mesopelagic microbial respiration with unprecedented spatial and temporal coverage. However, whilst technologies have advanced substantially, efforts to bring all the data together across depth-, size-, and time-scales are still lacking.

This working group will bring together experts in observation, experimentation, data analyses, and modelling to systematically compile and compare data sets of mesopelagic microbial respiration in order to constrain respiration uncertainties and improve quantifications of organic matter flux and remineralisation rates. A final outcome will be to improve projections of the effects of global change on the decline of oxygen in the world's oceans, with implications for fisheries and food security. The outputs of ReMO will have a high impact on future ocean research as they will enable efficient use of the wealth of data currently collected by autonomous instruments in the oceans.

2. Scientific background and rationale

2.1 The relevance of mesopelagic respiration

Microbial respiration in the mesopelagic ocean is a major contributor to the vital ecosystem service of climate mitigation, determining the balance between the storage of organic carbon in the sea or its remineralisation to, and ultimately evasion of, carbon dioxide to the atmosphere. Yet it is one of the least constrained metabolic processes in the marine system, with large mismatches between predictions and observations. This severely compromises our ability to predict future decreases in oxygen and resultant changes to fisheries and global food supply. It is vital to fully understand the functioning of the mesopelagic ocean as soon as possible, prior to the imminent risk of commercial exploitation for fisheries and mineral extraction (Martin et al., 2020).

2.2 The challenge

Reasons for the paucity of mesopelagic data and the mismatch between ecological and biogeochemical measurements include the relative inaccessibility of the deep sea, and that despite being such a vast region of the ocean, through which all sinking material must pass, remineralisation rates are sufficiently slow that many direct methods struggle to make reliable measurements. A range of exciting new techniques means that the time is right to compare estimates made through a combination of ecological, biogeochemical and modelling approaches which integrate across different temporal and spatial scales.

Mesopelagic microbial respiration rates can be estimated from the consumption of oxygen or production of carbon dioxide in an incubated water sample; from the maximum activity of the enzymes associated with the electron transport system (ETS) of the plankton in a filtered water sample; from the time resolved estimate of the amount of oxygen consumed or carbon dioxide produced in a defined water body (transient tracer models), or from budgets of oxygen, nutrients or carbon in a given volume (box) of the ocean. In the case of transient tracer models, the oxygen utilisation rate (OUR) is based on the apparent age of the water estimated from tracers such as sulphur hexafluoride, while in box models, the time scale is the renewal time of water in the box. Microbial respiration can also be estimated from prokaryotic production (assuming a growth efficiency); determined from oxygen consumption rates estimated from quasi-Lagrangian autonomous platforms; inferred from the depth distribution of particle flux; or reconstructed from microbial metaproteomics.

Some recent developments of these approaches include :

i) the ability to incubate samples, including suspended and sinking particles, in situ, thereby avoiding pressure and sample manipulation effects,
ii) the use of pyridine nucleotide concentrations and an enzyme kinetic model alongside the ETS technique to measure actual rather than maximum activity,
iii) the use of a proxy for respiration derived from the in vivo reduction of the 2-para (iodophenyl)-3(nitrophenyl)-5(phenyl) tetrazolium (INT) salt by the cellular ETS,
iv) the increase in in situ oxygen measurements from autonomous instrumentation such as gliders and Biogeochemical (BGC) Argo floats,
v) the development of fluorescent redox probes enabling the linkage between respiratory activity and microbial community structure,
vi) the improved spatial and temporal coverage of estimates of particle flux attenuation derived from optical instruments on ship-deployed or autonomous platforms, and
vii) the improved representation of particle sinking and decay in global models based on size spectra and age-dependency of remineralisation.

Before widespread use in the mesopelagic, each new technique requires comparison and intercalibration with traditional methods, and may have particular advantages, limitations or even be unfeasible in certain contexts. An ideal approach would be one which derived respiration from a combination of measurements covering the range of temporal and spatial scales from cellular metabolism to water column oxygen and nutrient budgets. Unfortunately, up until now, the small number of such comparative studies which have taken place, are only loosely constrained.

Calibrations of marine biogeochemical models with observed distributions of dissolved nutrients and oxygen are most sensitive to the parameters describing export and remineralisation of organic matter. Different models apply different parameterisations of particle flux attenuation in the mesopelagic ocean, with consequences for the simulation of oxygen minimum zones and atmospheric carbon dioxide. Observational constraints available so far have been insufficient to converge on appropriate parameterisations that are globally applicable and can be reliably used in climate change projections. Hence, coupled physical-biogeochemical models can currently only account for 50% of the observed decline in mesopelagic dissolved oxygen.

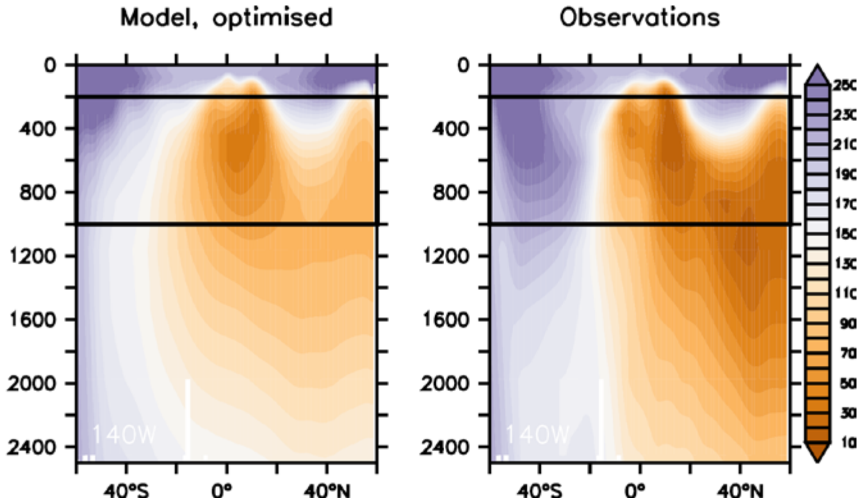

Figure 1. Dissolved oxygen (mmol m[-3]) along 140°W in a global biogeochemical model optimised against observed nutrients and oxygen after simulation over 3000 years (left: Kriest et al., 2020) and climatological observations (right: Garcia et al., 2006). Horizontal lines denote the mesopelagic between 200 and 1000m.

There is therefore a clear need to include the recently developed techniques in a comparative approach across the breadth of temporal and spatial scales, in order to constrain estimates of mesopelagic microbial respiration, and identify and parameterise factors which control variability in mesopelagic respiration, allowing accurate implementation into global models.

Such reconciliation requires progress through the following steps:

a) A need to review and improve methodologies for more accurate and precise ecological measurements of respiration considering the effects of pressure, temperature, in situ oxygen and carbon dioxide concentrations, and the formation, transformation and mineralisation of particles
b) A need to understand what is required to build better, more reliable models and how these can be validated
c) A need to constrain the variability in the conversion factors used to estimate respiration from indirect ecological measurements, for example I) the ratio between dissolved oxygen consumption, single cell proxies of respiration and the ETS activity of cells in the water column, II) the respiratory quotient used to convert between oxygen consumption and carbon dioxide production, and III) prokaryotic growth efficiencies used to convert prokaryotic heterotrophic production into prokaryotic respiration
d) A need to reconcile ecological and biogeochemical estimates measured over a range of scales, for example oxygen utilization rates (OUR) derived from profiling sensors on buoys and gliders with oxygen consumption rates and rates of ETS activity
e) A need to compare and confront coupled physical-biogeochemical models, ranging from regional to increasingly high-resolution global climate models, with data, and undertake model sensitivity studies informed by observations and their uncertainties to understand processes and help constrain drivers of change

2.3 Why a SCOR working group ?

The work that we propose requires a multidisciplinary team involving ecologists, biogeochemists, physical oceanographers and ecosystem modellers who work across scales from cells to ocean basins. The expertise in these fields does not reside within a single nation, and national research funding rarely covers the type of method intercomparison and data collation exercises that are required to move the field forward. As new methods and approaches are being developed and tested, there is a need for an internationally recognised best practice manual and a network of experienced scientists able to increase the global extent of research groups studying mesopelagic respiration through training and mentorship. The scientific breadth, reputation and international perspective of SCOR, along with a key focus on capacity building, provides the ideal framework in which to undertake the activities proposed here.

In the 10 years since the last review of mesopelagic respiration (Arístegui et al. 2009), there have been significant developments in technologies, including enzyme kinetics, sensors on moorings, floats and gliders and in situ incubators. This has enabled greatly increased temporal and spatial data coverage alongside the growing consensus that the open ocean is losing oxygen overall, with the volume of the ocean's oxygen minimum zones projected to grow by 7.0 $\pm$ 5.6 % by 2100. There is therefore an urgent requirement to derive reliable estimates of respiration to resolve the dissolved oxygen consumption in the contemporary world ocean and to support and validate Earth System Models predicting the impacts of climate change.

3. Terms of Reference (ToR)

This working group will focus on quantification of mesopelagic microbial respiration in order to constrain mismatches between predictions and observations. It aims to:

ToR# 1 Identify, quantify and prioritise gaps in our knowledge, and prepare an action plan to reduce these gaps by reviewing available information on mesopelagic respiration

ToR# 2 Develop a global dataset of mesopelagic respiration estimates, derived from the range of ecological and biogeochemical techniques available, in order to create a resource for validation of biogeochemical models including Earth System Models used for climate projection

ToR# 3 Produce a new synthesis of open ocean mesopelagic respiration

ToR# 4 Produce a best practice manual of techniques and approaches to determine mesopelagic respiration, and make recommendations as to which is the most appropriate method or combination of methods for a particular application, including best practice on how to reconcile approaches across time and space scales

ToR# 5 Build capacity, share knowledge and transfer technical skills, particularly to scientists in developing nations

4. Work Plan

To deliver ToR# 1

We will collate publications on mesopelagic respiration, quantify the differences between estimates, and identify the gaps in our knowledge which are hindering progress. We will then prepare an action plan proposing how to address these gaps (Deliverable #1).

We will design studies to compare ecological, biogeochemical and model approaches, and to intercompare models, to address the identified uncertainties. The action plan and designs for comparative studies will form the basis of a position paper (Deliverable #2) on the importance of mesopelagic respiration, the identified knowledge gaps and the way forward. We will initiate the designed model intercomparison study, focussed on organic matter supply and mesopelagic respiration, and produce an open access publication (Deliverable #3).

To deliver ToR# 2

We will create a dataset of global mesopelagic respiration estimates, and, using a simple spreadsheet format on an open access platform such as Google docs encourage international colleagues to contribute. We will register this dataset for a Digital Object Identifier (DOI) through the British Oceanographic Data Centre (BODC) Published Data Library https://www.bodc.ac.uk/submit_data/data_citations/ thus ensuring that it remains accessible and useable as a long term product (Deliverable #4). We will launch the dataset at an international conference, and submit a data paper to the journal *Earth System Science Data* https://www.earth-system-science-data.net/ (Deliverable #5).

To deliver ToR# 3

We will undertake a case study comparing approaches for determining mesopelagic respiration using published and our own unpublished data. We will identify suitable regions, such as the North Atlantic and Eastern Equatorial Pacific, where mesopelagic respiration can be derived from available data such as OUR, ETS activity, and particle flux attenuation from sediment trap data and in situ optics profiling. We will also review the literature and interrogate the collated database from ToR#2 to assess the controls on mesopelagic respiration including organic matter input, microbial community composition, temperature, decreasing oxygen and increasing carbon dioxide. This case study will form the basis of a synthesis paper which we will present at a major international conference (Deliverable #6).

To deliver ToR# 4

We will collate information on the ecological, biogeochemical and modelling techniques used to determine mesopelagic respiration, identify the advantages and limitations, and wherever possible, quantify the errors, of each technique in order to recommend the ideal combination of approaches for a particular context. We will use this information to write a best practice manual linked to the Ocean Best Practices (OBP) https://www.oceanbestpractices.net/platform platform (Deliverable #7), and launch it at a suitable international conference.

We will organise a method intercomparison workshop at the University of Las Palmas de Gran Canaria in order to compare and contrast a range of ecological and biogeochemical methods. The data and interpretations obtained during the workshop will be submitted as a comparative paper and dataset (Deliverable #8).

To deliver ToR# 5

We will create and deliver a training course on mesopelagic respiration to be held immediately after the method intercomparison workshop (Deliverable #9). We will also create a series of online lectures and practical demonstrations of respiration techniques and modelling exercises (Deliverable #10). These materials will maximise the accessibility of the training while reducing the carbon footprint of the working group. We will submit a manuscript on mesopelagic respiration aimed at children to *Frontiers for Young Minds* (Deliverable #11).

Timeline

Year 1 - 2021

An initial workshop will be held during Spring/Summer 2021, possibly associated with the Gordon Research Conference on Biogeochemistry. The activities undertaken during the workshop will be to discuss, compare and evaluate approaches to determine respiration in order to begin to structure the action plan and design an observational and modelling intercomparison exercise, to discuss and design the format of the dataset and the best practice manual, and to plan the method intercomparison workshop and training course. We will allocate tasks amongst ReMO members to create a subgroup and lead members for each ToR, and hold virtual meetings every 2 months during the year in order to ensure timely progress of these.

By the end of year 1 we expect to have completed the action plan (Deliverable #1) and position paper (Deliverable #2) and have made progress with the dataset and best practice manual.

Year 2 - 2022

During year 2 we will continue with bimonthly virtual meetings in order to progress several of our deliverables. In particular, we will focus on planning and preparation for the intercomparison workshop and training course, undertaking the model intercomparison and drafting the respiration synthesis paper and the paper for school children.

By the end of year 2 we aim to have completed a first version of the dataset and the model intercomparison paper (Deliverable #3), and to have progressed with the best practice manual and data paper.

Year 3 - 2023

We will hold a second working group meeting alongside the method intercomparison workshop and training course (Deliverable #9). Due to the logistics, cost and associated airmiles, we feel these two activities are best achieved consecutively. The University of Las Palmas is the preferred venue for these activities based on easy access to deep water, suitable laboratory facilities, in-kind support and access for students from developing nations. During the workshops we will create the series of training podcasts.

By the end of year 3 we aim to have completed the best practice manual (Deliverable #7), the dataset (Deliverable #4) and data paper (Deliverable #5) and progressed with the synthesis paper.

Year 4 - 2024

We will hold a final working group meeting alongside an appropriate international conference such as Ocean Sciences to progress the remaining ToRs. We will launch the best practice manual and the dataset at a Town Hall meeting at the conference, chair a special session on mesopelagic respiration and present the synthesis paper.

By the end of year 4 we will have published the data and interpretations arising from the method intercomparison workshop (Deliverable #8), the synthesis paper (Deliverable #6), the paper for children (Deliverable #11) and made the training podcasts available online (Deliverable #10).

5. Deliverables

From ToR# 1 :

1. An action plan to identify gaps in knowledge and propose ways to address those gaps
2. A position paper, based on the plan, highlighting the importance of reliable estimates of mesopelagic respiration, and suggesting priority research questions
3. A model intercomparison / data sensitivity paper

From ToR# 2 :

4. A global dataset, linked to international marine data hubs, for use by modellers, launched at a Town Hall meeting at an international conference such as Ocean Sciences
5. A data paper in *Earth System Science Data* https://www.earth-system-science-data.net/

From ToR# 3 :

6. A synthesis paper on a model/observational case study, and presentations at appropriate international conferences

From ToR# 4 :

7. A best practice manual for ecological and biogeochemical methods used to derive mesopelagic respiration
8. A method intercomparison paper and dataset

From ToR# 5 :

9. A training course on model and observational approaches to derive mesopelagic respiration for early career and experienced researchers, particularly aimed at scientists from developing nations
10. Online training materials such as lectures and practical demonstrations of analytical techniques, budgeting exercises and modelling approaches
11. A manuscript for children on mesopelagic microbial respiration in *Frontiers for Young Minds* https://kids.frontiersin.org/

6. Capacity Building

Deep-sea biogeochemistry, microbiology and numerical modelling have historically been led by a small number of developed nations, yet marine ecosystem services such as climate mitigation and the potential for climate change effects such as ocean deoxygenation and acidification are worldwide challenges, potentially disproportionately affecting developing regions dependent on coastal fisheries. Therefore, one of the key aims of this working group is to provide materials, training and mentorship to extend access to the measurement, interpretation and understanding of mesopelagic microbial respiration, including how it affects climate and is itself influenced by climate change.

In order to do this, we will first interact with the SCOR Committee on Capacity Building, in order to benefit from their expertise in developing and implementing capacity building activities, including contacting their existing networks and mentoring programmes.

We have developed the deliverables of this working group specifically to contribute to this key capacity building aim. The action plan and position paper within ToR#1 aim to motivate the international community to incorporate studies on mesopelagic respiration into ecological and biogeochemical investigations of the deep ocean. This will require training and mentorship of experienced and early career scientists from developing nations. To this end, we will produce a best practice manual available through the Ocean Best Practices (OBP) https://www.oceanbestpractices.net/platform platform, an open access, permanent digital repository of community best practices in ocean-related sciences maintained by the International Oceanographic Data and Information Exchange (IODE) of the UNESCO-IOC.

We will also organise a dedicated training course for scientists from around the world, with priority given to scientists from developing nations, focussed on gaining experience in a range of ecological, biogeochemical and modelling approaches used to estimate mesopelagic respiration. We will take advantage of video streaming and recording technology to broaden participation in this training course, and we will produce a series of online lectures and practical demonstration podcasts detailing the relevant analytical techniques and modelling approaches. These will be posted online, through the Integrated Marine Biosphere Research (IMBeR) project's YouTube and YouKu channels https://www.youtube.com/channel/UCinzjRz7_TKHESn6uggCKlw/featured and http://i.youku.com/imberipo. We will also create a teaching 'module' on measuring and modelling respiration which can be used to contribute to the schedule of already established international summer schools, for example the IMBeR project's Climate and Ecosystems (ClimEco) series (http://www.imber.info/en/events/climeco-imber-summer-schools).

We will create a dataset of mesopelagic respiration which can be used in undergraduate and postgraduate teaching to understand the variability in respiration, in addition to being used to validate Earth System Models. The dataset will be hosted at the British Oceanographic Data Centre (BODC), assigned a Digital Object Identifier (DOI) linked to DataCite https://datacite.org/mission.html, thus ensuring adherence to FAIR Guiding Principles for scientific data management and stewardship (i.e. the capacity to **F**ind, **A**ccess, **I**nteroperate and **R**euse data with none or minimal human intervention), and it will also be linked to relevant international data hubs such as IMBeR's Marine Data Hub https://ccdatahub.ipsl.fr/, the Joint Exploration of the Twilight Zone Ocean Network (JETZON) data sharing and method intercomparison site http://jetzon.org/ and the Simons Foundation's Collaborative Marine Atlas Project (CMAP) https://cmap.readthedocs.io/en/latest/index.html. The dataset and metadata will also be preserved through an open access publication in a specialist journal such as *Earth System Science Data*. We will aim to release a first version DOI of the dataset during year two so it can be used for case studies during the training course and within the model intercomparison paper, with the final DOI version launched in year four with the best practice manual.

Where possible, ReMO meetings will be held alongside conferences such as IMBeR's Western Pacific Symposia so associate members, early career researchers and scientists from developing nations can attend the sessions, and we will work with the scientific community to leverage additional funding for such participation. Progress towards ReMO Terms of Reference will be monitored and achieved through virtual meetings held at two monthly intervals. We envisage that some of these meetings will be open to the scientific community and targeted to scientists from developing nations to include webinar presentations and discussions of data.

We aim to initiate a mentoring scheme, whereby each ReMO member is paired with and subsequently mentors an early career scientist from a developing nation. This mechanism has been used successfully by organisations such as IMBeR, the American Geophysical Union (AGU) and the Association for the Sciences of Limnology and Oceanography (ASLO), over short time periods (i.e. a few months) leading up to major international conferences. We would hope to extend such a scheme to cover the full time period of ReMO. The opportunity to be a mentee on such a scheme would be advertised through the network afforded by the SCOR sponsored global projects, the SCOR capacity building committee and early career researcher networks such as the Young Earth System Scientists (YESS) community, the Interdisciplinary Marine Early Career Network (IMECaN), the IOC-UNESCO Ocean Decade's network of Early Career Ocean Professionals, and the Association of Polar Early Career Scientists (APECS). We would evaluate the success of the scheme in order to know whether this could be a useful capacity building tool for future groups.

The action plan, position paper and design of comparative studies, undertaken within ToR#1, would also be the basis for a number of research proposals to be submitted to our national funding agencies in order to gain research ship time to undertake a more extensive biogeochemical, ecological and modelling intercomparison exercise at an established oceanographic time series station. Within these research proposals, berths will be made available and funding requested for early career scientists from developing nations to take part as shipboard trainees in mesopelagic respiration measurements. We would also apply to the Nippon Foundation - Partnership for Observation of the Global Ocean (NF-POGO) fellowship scheme to increase the number of early career scientists from developing nations able to take part, following the successful model used on the Atlantic Meridional Transect (AMT; https://www.amt-uk.org/) programme.

We will set up a webpage within the SCOR and our institutional websites linked to a twitter account, in order to advertise the plans, activities and achievements of the working group.

The activities of ReMO will contribute to two of the United Nation's sustainable development goals : SDG14 (Life below water) and SDG13 (Climate Action), and to three of the societal goals outlined in the Implementation Plan for the UN Decade of Ocean Science for Sustainable Development to define the '**ocean we want**' including a *healthy and resilient ocean* that will ensure continuing delivery of marine ecosystem services to society, a *predicted ocean* allowing confident predictions of the future state of the ocean to support business and policy decisions, and a *transparent and accessible ocean* whereby all nations, stakeholders and citizens have access to ocean data and information.

7. Composition of the Working Group

ReMO includes 10 Full Members with the range of expertise needed to address the Terms of Reference, including biochemistry, analytical chemistry, microbial ecology, biogeochemistry, particle flux and coupled ocean-atmosphere modelling, and experience in data collation, method development, public engagement and capacity building. They represent a broad geographic spread including from Europe, Australasia, South America and Asia. The gender balance is 4:6 female:male and the members include 3 early career researchers who gained their PhD within the last 10 years. The early career members are each recognised as expert in a particular new technique or approach, and will contribute this expertise in particular to the evaluation and comparison of mesopelagic respiration techniques using new datasets. ReMO will be co-ordinated by 3 co-chairs (Robinson, Arístegui and Kriest) who have substantial experience in the ecological, biogeochemical and modelling approaches to be used here.

7.1 Full members

Name	Gender	Place of Work	Expertise relevant to proposal
Carol Robinson (co-chair)	F	University of East Anglia, **UK**	Microbial oxygen consumption and carbon dioxide production
Iris Kriest (co-chair)	F	GEOMAR Helmholtz Centre for Ocean Research, **Germany**	Global biogeochemical models
Gerhard Herndl	M	University of Vienna, **Austria** & Netherlands Institute for Sea Research (NIOZ) **The Netherlands**	Single cell respiration measurements using fluorescing redox dyes linking to phylogeny, in situ microbial activity, pressure effects, metaproteomics and metagenomics
Natalia Osma (early career)	F	University of Concepcion, **Chile**	Electron transport system activity and enzyme kinetic models
Javier Arístegui (co-chair)	M	University of Las Palmas de Gran Canaria, **Spain**	Microbial oxygen consumption and growth efficiency, ETS activity, box models
Matthieu Bressac (early career)	M	University of Tasmania, **Australia**	Oxygen consumption of particle attached bacteria
Ying Wu	F	East China Normal University, **China**	Geochemical cycles, oxygen consumption and dissolved organic matter degradation
Hyung Jeek Kim (early career)	M	Korea Institute of Ocean Science and Technology (KIOST) **Korea**	Sinking particle flux derived from sediment traps
Morten Iversen	M	Alfred Wegener Institute, **Germany**	Aggregate-associated microbial respiration, organic matter export and turnover using traps and in situ optics in profiles and on moorings
Jack Middelburg	M	Utrecht University, **The Netherlands**	Biogeochemistry, organic geochemistry, stable isotopes, modelling, degradation kinetics

The Associate Members provide additional expertise and experience, including in modelling, microbial ecology, oxygen optodes within in situ respirometers, use of BGC Argo data to derive oxygen and carbon fluxes, and the effects of pressure on microbial metabolic rates.

7.2 Associate members

Name	Gender	Place of Work	Expertise relevant to proposal
Christian Tamburini	M	Mediterranean Institute of Oceanography (MIO), **France**	Pressure effects, particle degradation, sinking particles simulation, prokaryotic diversity
Sara Ferrón	F	University of Hawaii, **USA**	Oxygen and carbon dioxide fluxes, in situ optodes, in vivo ETS, gliders, membrane inlet mass spectrometry
Yao Zhang	F	University of Xiamen, **China**	Mesopelagic microbial community structure and activity, budgets of carbon flux
Giorgio Dall'Olmo	M	Plymouth Marine Laboratory, **UK**	Estimates of particle fluxes and oxygen consumption from BGC Argo data
Toshi Nagata	M	University of Tokyo, **Japan**	Microbial control of particle coagulation and disintegration
Dominique Lefevre	M	Mediterranean Institute of Oceanography (MIO), **France**	Optode calibration, in situ oxygen dynamic auto-sampler (IODA), CO_2, ETS
Katja Fennel	F	Dalhousie University, **Canada**	BGC Argo, regional biogeochemical models
Xose Antón Álvarez-Salgado	M	CSIC Institute of Marine Research, **Spain**	Geochemical determination of OUR and stoichiometric ratios, water mass mixing and mass balance
Haimanti Biswas	F	National Institute of Oceanography, **India**	Microbial oxygen consumption and degradation of dissolved organic carbon

8. Working group contributions

Carol Robinson studies the role of marine bacteria, phytoplankton and zooplankton in the global cycling of carbon and oxygen, with a particular focus on determining the magnitude and variability of microbial respiration using a combination of ecological and enzymatic techniques. She has extensive experience in leading international multidisciplinary research programmes including the Atlantic Meridional Transect (https://www.amt-uk.org/Home) and IMBeR, and a passion for outreach, mentoring and engagement.

Iris Kriest's research foci are the description of biogeochemical processes in large-scale ocean models, assessment of model skill, and calibration of biogeochemical model parameters (constants) on a global scale. This also involves analysis and synthesis of observations, as well as development and tests of metrics for global model optimisation.

Gerhard Herndl is working on mesopelagic microbial activity at the bulk and single-cell level as well as on the effects of hydrostatic pressure on microbial activity in meso- and bathypelagic waters. His group also uses metaproteomics and metagenomics to characterize the microbial activity of distinct microbial populations in mesopelagic waters.

Natalia Osma contributes her experience in measuring ETS activity in a wide range of ecosystems. She developed the methodology to measure pyridine nucleotides and applied an enzyme kinetic model to estimate respiration rates in marine organisms for the first time, and recently adapted this to water column work.

Javier Arístegui has extensive experience working on mesopelagic respiration, combining ecological (microbial oxygen consumption and growth efficiency), enzymatic (microbial ETS activity) and biogeochemical (particulate and dissolved organic carbon box model) approaches. He led the first published review on respiration in the dark ocean.

Matthieu Bressac (co-)developed the novel *in situ* incubators, RESPIRE and TM-RESPIRE, which allow the non-intrusive interception and incubation of settling particles at in situ pressure and temperature. RESPIRE determines oxygen consumption of particle-attached bacteria, while TM-RESPIRE allows the quantification of bacterial regeneration of nutrients and trace elements.

Ying Wu uses organic geochemical proxies to study the depth-dependence of remineralization of dissolved organic material and its interaction with microbial community structure and functioning. Building on her capacity building experience, she will identify regional capacity needs and help align activities across regional projects and programs.

Hyung Jeek Kim contributes his experience in using time-series sediment traps to determine particulate organic carbon flux and variability in the efficiency of the biological carbon pump, including seasonal variability and the influence on fluxes of the El Niňo-Southern Oscillation (ENSO).

Morten Iversen is working on how upper ocean food web composition spanning from prokaryotes to zooplankton impacts on particle export dynamics, specifically how particle size and composition determine sinking velocity and remineralization. His group is developing several novel methods and instrumentations to measure in situ rates of settling, turnover, and export as well as collecting intact marine aggregates for detailed composition and rate measurements at high temporal resolution during year-long deployments in different regions.

Jack Middelburg contributes his extensive experience in organic matter degradation and how it links to the identity of the organisms involved. He pioneered the use of reactive continuum modelling and integrates organic geochemical, biogeochemical and ecological approaches.

9. Relationship to other international programmes and SCOR working groups

9.1 IMBeR, SOLAS, GO2NE, JETZON, BioGeoSCAPES

The ToRs of ReMO will strongly enhance the Integrated Marine Biosphere Research (**IMBeR**) project's science goal, contributing specifically to Grand Challenge 1 (*Understanding and quantifying the state and variability of marine ecosystems*) and 2 (*Improving scenarios, predictions and projections of future ocean-human systems at multiple scales*) of the IMBeR Science Plan. However, the topic lies outside IMBeR's interdisciplinary focus and so IMBeR funds are not available to progress this endeavour. The working group membership includes several current and previous members of IMBeR's scientific steering committee (i.e. Robinson [SSC Chair 2016-2021], Arístegui, Wu and Herndl) which will ensure effective interaction between ReMO and IMBeR. The importance of mesopelagic respiration to deoxygenation, acidification and the production of carbon dioxide, means that the work within ReMO will also be of relevance to Core Theme 1: *Greenhouse gases and the oceans* of the Surface Ocean Lower Atmosphere Study (**SOLAS**) which aims to understand and quantify greenhouse gas sources and sinks. ReMO also includes several participants of the Joint Exploration of the Twilight Zone Ocean Network (**JETZON**), (i.e. Robinson, Arístegui, Iversen, Tamburini, Dall'Olmo, Kriest, Álvarez-Salgado) which will ensure data sharing and intercomparisons of ReMO microbial respiration estimates with those of mesozooplankton respiration and quantification of the biological and particle pumps in the mesopelagic zone. We are in contact with Andreas Oschlies, the Chair of the Global Ocean Oxygen Network (**GO2NE**; https://en.unesco.org/go2ne), to ensure interaction between ReMO and the network in terms of capacity building and research in understanding the distribution and changes in the distribution of dissolved oxygen in the mesopelagic zone. Herndl and Robinson were involved in the development of the BioGEOTRACES component of GEOTRACES and are in contact with Alessandro Tagliabue to ensure interaction between ReMO and the emerging BioGeoSCAPES programme.

9.2 Other SCOR working groups

ReMO will build on some of the work started and ongoing by Robinson, Herndl, Álvarez-Salgado and Nianzhi Jiao on respiration of recalcitrant dissolved organic carbon as part of WG 134 The Microbial Carbon Pump, and incorporate and progress the recommendations made by Arne Körtzinger and colleagues in WG 142 Quality control procedures for oxygen sensors on floats and gliders. Through JETZON and ReMO member Iversen, we will interact with members of WG 150 on Optical measurements for particle content and flux (TOMCAT) led by Sari Giering. We will investigate opportunities to work with WG 159 Deep sea biology (DeepSeaDecade) led by Kerry Howell and Ana Hilario on capacity building activities and linkages with the Deep Ocean Observing Strategy (DOOS), and in assessing the impact of decreasing dissolved oxygen and increasing carbon dioxide on microbial respiration, through Biswas, ReMO will interact with WG 149 Changing ocean biological systems (COBS): how will biota respond to a changing ocean ? led by Philip Boyd. Although not specifically working in oxygen minimum zones, our work on microbial respiration and deoxygenation will be of relevance to WG 155 Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change.

10. Key References

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Appendix : Five key publications for each full member

Carol Robinson

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6 May 2020

Dr. Patricia Miloslavich
SCOR Executive Director
University of Delaware
USA

Dear Patricia,

I am writing to confirm that IMBeR strongly supports the proposal for a SCOR Working Group on 'Respiration in the Mesopelagic Ocean; Reconciling ecological, biogeochemical and model estimates", which would be co-chaired by Carol Robinson, a microbial ecologist from the UK, Javier Arístegui, a biogeochemist from Spain and Iris Kriest, a biogeochemical modeller from Germany. Carol is the current Chair of the Scientific Steering Committee of IMBeR, due to rotate out of the position in 2021.

The objectives of the working group, to improve understanding of mesopelagic respiration, a major determinant of the storage of carbon in the ocean, ocean deoxygenation and acidification and atmospheric carbon dioxide concentrations, align well with the IMBeR vision of 'Ocean sustainability under global change for the benefit of society', and in particular, IMBeR's Grand Challenges to 1) Understand and quantify the state and variability of marine ecosystems and 2) Improve scenarios, predictions and projections of future ocean-human systems at multiple scales.

IMBeR also has a commitment to supporting early career researchers, so we would be particularly pleased to link the mesopelagic respiration training course participants with our Interdisciplinary Marine Early Career Network (IMECaN) and the Doctoral training conferences held in Shanghai.

If funded, IMBeR will support the SCOR working group in terms of ensuring networking and capacity building opportunities within the IMBeR community (including the IMBeR West Pacific Symposium series) and access to the logistical and organizational expertise of the IMBeR International Project Offices in Shanghai and Halifax.

We look forward to the opportunity to work closely with this potential new SCOR Working Group.

All the best,

John Claydon
Executive Director, IMBeR International Project Office - Canada

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