



European Marine Board Expert Working Group

Ocean Oxygen:

The science behind 'Every Second Breath' and the threat of Ocean deoxygenation

Terms of Reference

November 2021

Contents

1. Background and Rationale
2. Working Group Objectives
3. Working Group Composition
4. Mode of Operation
5. Deliverables
6. Target Audience and Expected Impact
7. Indicative timetable
8. References

1. Background and Rationale

Background

Scientists, science communicators and policy makers often say “every second breath you take comes from the Ocean” or similar¹ to highlight the importance of the Ocean for humans. Despite the widespread use of this phrase, its scientific foundations are unclear and there is growing debate among scientists about the correctness of the sentence². There is therefore a need to clarify the science underpinning the actual connection between the oxygen reservoir in the atmosphere and primary production in the Ocean, including differences in timelines for marine- and terrestrially-produced oxygen.

Moreover, the Ocean is slowly losing its oxygen due to global warming. This is of great concern and there is a need for stronger communication and heightened awareness about the looming threat of deoxygenation.

History of Earth’s oxygenation

Although many of us take our richly oxygenated atmosphere for granted, free oxygen was negligible (<0.001% of today’s O₂ in the atmosphere) during most of Earth’s 4.5-billion-year history (Lyons et al., 2014). Today, the percentage of oxygen in our modern atmosphere has stabilised at ~21% and this stability is due to a balance in the global O₂ cycle, i.e. the processes that produce molecular oxygen and consume it. Oxygenation of Earth’s atmosphere is thought to have occurred across three major oxygenation events (the Great Oxidation Event ca. 2.4-2.1 billion years ago, the Neoproterozoic Oxygenation Event ca. 800-540 million years ago, and the Paleozoic Oxygenation Event ca. 450 to 400 million years ago; Alcott et al., 2019). The Ocean, below its surface waters, only became oxygenated during the second major oxygenation event, and periodic deep-water anoxia remained frequent until the third major rise in atmospheric oxygen (Alcott et al., 2019). Cyanobacteria are the most ancient microorganisms capable of oxygenic photosynthesis and are thought to be responsible for the first major oxidation event (Hess et al., 2016; Lyons et al., 2014). The evolution of land plants is thought to be responsible for the rise of O₂ during the last oxygenation event (Lenton et al., 2016; Wallace et al., 2017). At geological time scales, it is not clear to which extent terrestrial versus marine organisms contributed to the oxygenation of the Earth.

¹ Examples of ‘every second breath’ statements and variations of it:

<https://www.nationalgeographic.com/science/article/101004-coml-complete-census-vin-video>
<https://science.nasa.gov/earth-science/oceanography/living-ocean/ocean-color>
https://www.ted.com/talks/sylvia_earle_my_wish_protect_our_oceans/transcript?language=en
<https://portals.iucn.org/library/sites/library/files/documents/03.4%20DEOX.pdf>
<https://oceanexplorer.noaa.gov/facts/oceanproduction.html>
<https://ocean.si.edu/ocean-life/plankton/every-breath-you-take-thank-ocea>

² Examples of debate about the ‘every second breath’ statement:

<https://twitter.com/duarteoceans/status/1402364366910111745?s=20>
https://twitter.com/Natalya_Gallo/status/1402368426325258242
<https://twitter.com/drbenward/status/1402544485016518656>
<https://twitter.com/duarteoceans/status/1413221104110424070>

What is clear is that the rise of atmospheric oxygen is closely linked with the evolution of progressively more complex life-forms on Earth (Alcott et al., 2019). Conversely, anoxic environments, especially in the Ocean, are thought to be connected with four out of the five mass extinction events (Huang et al., 2021).

The modern oxygen cycle and the role of the Ocean

The approximate balance between global photosynthesis and global respiration is critical in the global stability of oxygen (Duursma & Boisson, 1994). The total amount of oxygen on Earth is distributed mainly between the atmosphere and the Ocean, with the remainder being stored in numerous oxidized terrestrial and oceanic compounds. The oxygen inventory in the Ocean is estimated at <1% of the O₂ present in the atmosphere (Duursma & Boisson, 1994).

Approximately 50% of all primary production (i.e. photosynthetic fixation of CO₂ and subsequent O₂ release) occurs in marine surface waters by phytoplankton (Del Giorgio & Duarte, 2002; Duursma & Boisson, 1994; Petsch, 2003). Phytoplankton are characterised by a high functional diversity (e.g., different photosynthetic pigments, wide size-ranges, distinct chemical/biochemical composition and sinking properties), which reflects on biogeochemical cycles and modulates biological processes, including oxygen production and CO₂ drawdown. However, although the Ocean produces approximately half of all oxygen on Earth, marine life consumes nearly as much oxygen as it produces. Although a small amount of oxygen does transfer from the Ocean surface waters into the atmosphere.

The Ocean is losing its 'breath'³: Ocean deoxygenation and projected consequences

The loss of dissolved oxygen from the Ocean to the atmosphere, also known as Ocean deoxygenation, is one of the most worrying changes occurring in marine ecosystems and yet it is heavily under-communicated (Laffoley & Baxter, 2019). Global warming leads to oxygen loss, both directly, by reducing the solubility of oxygen in sea water, and indirectly, through changes in biogeochemical and physical dynamics, such as intensifying stratification, which reduces the transport of oxygen into the Ocean interior and slows down Ocean circulation. Decreased oxygen solubility, intensified stratification, and slowed down circulation are all thought to be responsible for a loss of Ocean oxygen. Another major source of Ocean oxygen loss is eutrophication as a result of nutrient run-off. The global Ocean oxygen content has decreased on average by ~2 % since the middle of the 20th century. Ocean model simulations predict a decline in dissolved oxygen in the Ocean of 1 to 7% by the year 2100, and comparisons of models and observations suggests that models underestimate the true rate of ocean oxygen loss (Levin, 2018; Long et al., 2019). The effects of Ocean deoxygenation are further amplified by Ocean warming and Ocean acidification, as these three major stressors commonly co-occur because they share a common cause (i.e. anthropogenic CO₂ emission; Laffoley & Baxter, 2019).

Consequences of Ocean deoxygenation include decreased biodiversity, shifts in species distributions, displacement or reduction in fisheries resources, and changes in biogeochemical cycling (Breitburg et al.,

³ See Global Ocean Oxygen Network GO2NE policy brief with the same title:
https://orbi.uliege.be/bitstream/2268/232585/1/Technical%20Brief_Go2NE.pdf

2019). These changes are taking place on such a large scale that experts foresee that they will have implications for the global biochemistry and climate, with a less productive Ocean and a lower capacity of both land and Ocean to serve as carbon sinks (Long et al., 2019). The continued spreading of deoxygenated areas in the Ocean is therefore of great concern, with potentially great impacts on biodiversity and human societies (Laffoley & Baxter, 2019).

Rationale for the Working Group

The WG topic ‘Every Second Breath: The Real Relationship between Ocean Primary Productivity and Atmospheric Oxygen’ was proposed by the EMB Secretariat in 2017 after preparatory discussions for the EMB Ocean Climate Nexus Statement revealed that this topic can be quite ambiguous. Scientists from VLIZ subsequently reviewed this topic, which resulted in a short draft document describing the current and past role of the Ocean in the production of atmospheric oxygen and highlighting uncertainties.

During the 2021 EMB Spring Plenary meeting this topic was discussed as part of the top three preferred topics, with input from Ferdinando Boero (CoNISMa, Italy), Isabel Sousa Pinto (University of Porto, Portugal), Francois Lallier (Marine Universities Consortium, France), Fiona Grant (Marine Institute, Ireland) and Thorsten Kiefer (JPI Oceans). It was noted that the ‘Every Second Breath’ topic would give good visibility to EMB and that it would be a service to the community. The Board also stressed that it would be important to consider how the Ocean takes up oxygen and that this topic should be modified to cover not only primary production but also the whole oxygenation cycle within the Ocean. Following the discussion, delegates voted in favour of this topic being the new WG topic.

The ‘Every Second Breath’ sentence has become a flagship statement in science communication to illustrate the importance of the Ocean. Although the core of the sentence is correct, small modifications can render the sentence incorrect (e.g. referring to ‘atmospheric oxygen’ instead of just ‘oxygen’, or to ‘we’ as humans instead of life on Earth) and it is often used incorrectly. A Working Group illustrating the science behind this sentence could contribute to science literacy by heightening the understanding and correct use of this statement, without undermining the validity that the Ocean is a fundamental source of oxygen on Earth.

At the same time, awareness of Ocean deoxygenation is very timely for the UN Decade of Ocean Science for Sustainable Development. Further progress in the science of Ocean deoxygenation is needed to better predict patterns and consequences of Ocean oxygen decline and to improve the development of effective strategies that address the problem of Ocean deoxygenation. Although the scientific community is already very concerned and acting on Ocean deoxygenation (e.g. through the Global Ocean Oxygen Network GO2NE⁴ and the ‘Kiel Declaration on Ocean Deoxygenation’⁵), there is still a lack of awareness of the problem among policy makers, regulators and the public. For instance, most nations recognised Ocean warming as a key stressor under their nationally determined contributions of the Paris Agreement. Yet

⁴ <https://en.unesco.org/go2ne>

⁵ https://en.unesco.org/sites/default/files/kiel_declaration_fin_02.pdf

only one nation, Mauritania, mentioned Ocean deoxygenation. Similarly, the planet boundary framework⁶ does not recognise Ocean deoxygenation to be a major threat, suggesting the need for much stronger communication about the issue.

2. Working Group Objectives

The EMB Working Group on Ocean oxygen should have two main objectives:

- (1) explaining the science behind the statement ‘every second breath comes from the Ocean’ to contribute to the correct use of this sentence, without undermining the validity of communications that state that the Ocean is a fundamental source of oxygen on Earth;
- (2) communicating the problem of Ocean deoxygenation, which can be neatly linked to the ‘every second breath statement’.

Specific topics that could be addressed in relation to the two main objectives include (but are not limited to):

- Providing an overview of the current global oxygen cycle, i.e. the primary production and consumption of oxygen on Earth, including the role of marine and terrestrial ecosystems;
- Providing an account of the history of Earth’s oxygenation and elaborating on whether oxygen was produced by marine or terrestrial sources on geological time scales;
- Highlighting correct examples of sentences related to the “every second breath” statement that can be used in science communication (e.g. in a separate box and based on information in the full text). The same could be done for incorrect sentences with an explanation of what part of the sentence is incorrect;
- Raising awareness of the problem of Ocean deoxygenation: explaining drivers, consequences and future projections, as well as further science and management needs, such as:
 - expanding oxygen observations and monitoring systems (and including oxygen as an essential variable for Global Ocean Observing Systems);
 - improving our understanding of deoxygenation effects on biological, biogeochemical and ecological processes (particularly in combination with multiple stressors), through experiments and observations;
 - improving our understanding of the role of functional diversity of primary producers (phytoplankton) in biogeochemical cycles and trophic dynamics, including its effects on oxygenation/deoxygenation of the oceans, through experiments and observations;
 - incorporating deoxygenation in the development of policy and management strategies;
- Raising awareness of the interconnectedness of all life (and across marine-terrestrial boundaries) through biochemical cycles. For instance, by:
 - providing specific examples on interconnectedness (e.g., whales indirectly promote the production of oxygen in the Ocean by excreting fecal plumes, which act as fertilisers and

⁶ <https://www.stockholmresilience.org/research/planetary-boundaries.html>

- stimulate phytoplankton growth and propagation. The healthiness of whale populations is therefore linked to Ocean oxygen⁷);
- o providing examples of how Ocean deoxygenation will affect terrestrial ecosystems and humans (including on geological time scales, e.g. by comparing with previous deoxygenation rates in Earth's history).

3. Deliverables

The Working Group will deliver a Future Science Brief. The final document should be concise (~ 36 pages) and it should be based on existing academic publications.

The document will be peer-reviewed by a minimum of two external reviewers (one European and one international) selected from proposals by the working group members, and will be coordinated by the EMB Secretariat. In accordance with the EMB procedures, the document will also be sent to EMB Member organizations for internal review and approval prior to finalization and publication.

The impact of the publication will be achieved via a targeted dissemination strategy. Working Group members will be required to make suggestions on how to reach end-user contacts and to contribute to the dissemination. Promotion of the document may include dedicated presentations at stakeholder events. Working Group members will also be asked to notify the Secretariat of any dissemination activities or observed uptake / impact for up to two years following publication, for future impact reporting.

A full outline of the decision-making procedure and system for Working Group operations is outlined in Annex 2.

4. Target Audience and Expected Impact

The foreseen role of this document is to increase the understanding on the Ocean's role in oxygen production and raise awareness about Ocean deoxygenation among policy makers, regulators and the public. The key messages should inform future science communication as well as the development of strategies and policies that address Ocean deoxygenation. This document may also influence research funding organizations to mobilize more funding for research on Ocean deoxygenation and in monitoring oxygen in the Ocean. The document should therefore target a wide range of audiences, from policy makers and regulators, to science communicators and the public.

Two additional potential audience groups would be: (1) international organizations that address societal needs, such as such as the UN Sustainable Development Goal partnership, Intergovernmental Panel on

⁷ https://www.pewtrusts.org/en/research-and-analysis/articles/2021/05/20/whales-generate-and-promote-life?utm_campaign=conservation_chpt_____&utm_source=twitter_environment&utm_medium=social&utm_content=article_marineleader_____linkcard_&utm_term=

Climate Change reporting and UN Food and Agriculture Organization for regional fisheries management, since Ocean deoxygenation and its consequences are relevant to these organizations and it may be integrated into their programs, and (2) the UN Climate Change Conference of the Parties, since Ocean deoxygenation should be dealt within the framework of international climate change negotiations, due to the strong links between anthropogenic CO₂ emissions and Ocean deoxygenation, as well as the scale of Ocean deoxygenation and its possible impacts.

Finally, the publication should link to relevant international initiatives, such as the UN Decade of Ocean Science for Sustainable Development, the Global Ocean Oxygen Network (GO2NE) and the “Kiel Declaration on Ocean Deoxygenation”.

5. Working Group Composition

Working group Chair and Co-chair

The WG Chair and Co-Chair represent the Working Group and take responsibility for its deliverables.

Profile

The WG Chairs should be persons with significant experience and expertise and a leading role in a field related to Ocean oxygen at national and/or European level. It is important that the Chairs have a big picture and interdisciplinary approach to ensure a balanced approach to the topic. The Chairs should demonstrate strong leadership skills and have sufficient time to commit to leading and facilitating the writing of the document.

Selection process

The WG Chairs will be selected based on a call for WG member nominations issued by the EMB Secretariat to EMB Member Organizations, and short interviews with shortlisted candidates. The EMB Secretariat and EMB Chair, in consultation with the ExCom, make the final selection of the Chair. A WG Co-Chair will be selected by the WG Chair with assistance from the EMB Secretariat. The EMB Secretariat work together with the WG Chairs to select the WG members while ensuring a balance of expertise and experience within the Working Group, as well as gender and geographic balance.

Roles and responsibilities of WG Chairs

The WG co-Chairs are responsible for ensuring the scientific quality of the Working Group outputs and its timely delivery according to the WG Terms of Reference and as agreed at the kick-off meeting. The WG Chairs provides scientific leadership and act as the driving force for the WG activities with the support of a dedicated European Marine Board Science Officer who acts in the capacity of WG facilitator.

The WG Chairs (primarily the Chair, and the co-Chair when the lead Chair is not available):

- Chair WG meetings i.e. moderate discussions and ensure delivery of meeting outputs
- Coordinate the scientific contributions to the document draft according to the objectives defined at the kick-off meeting;

- Maintain an overview of the content and quality of the various inputs and requests additional expertise if necessary;
- Ensure timely delivery of the WG document; and
- Enhance the document's strategic impact by promoting WG activities and the output.

Working Group Members

A Working Group of no more than 12 members is proposed.

The WG experts should comprise European scientists (mostly from EMB member organizations), practitioners and technologists who are participating in leading networks and/or research groups across different research relevant domains (e.g. biogeochemistry, marine biology, marine ecology, marine chemistry, palaeontology).

Working Group Member selection process

WG Members will be drawn from the list of nominations provided by EMB Member organizations. After the WG Chair has been selected from the call for WG Members, the WG Chair(s) will select WG Members from the resulting pool of experts, supported by the EMB Secretariat. Decisions on the composition of the WG are guided by achieving the correct balance of expertise required to comprehensively address the topic at hand as well as ensuring a wide geographic distribution and gender balance. If needed the WG can also include Members from relevant European projects and initiatives, industry and non-profit organizations. Non-selection of some nominated candidates is therefore normal, and bears no relation to the scientific excellence of those candidates.

Roles and responsibilities of Working Group members

WG Members are responsible for ensuring the scientific quality of their inputs and their timely delivery according to the WG Terms of Reference.

WG Members:

- Prepare for and attend the WG meetings;
- Submit written contributions in a timely manner as agreed at the kick-off meeting;
- Guide and adhere to the high-level strategic objectives of the document;
- Promote the resulting publication at national level and European levels;
- Provide feedback on dissemination activities and opportunities, impact and uptake to the EMB Secretariat.

Engaging the wider community

During the course of the WG, members may invite a selection of stakeholders or observers from the wider community to participate (e.g. from science, industry, policy, funding agencies).

Interaction with relevant international and European initiatives working in the field of Ocean deoxygenation should be explored. This could be achieved through informal interactions during the

writing process, through consultation and/or workshops held during the lifetime of the activity, by engaging key scientists as external reviewers, or by selecting several key experts to serve as members of the WG.

EMB Secretariat facilitation

The European Marine Board Executive Director is an *ex officio* WG manager. She nominates one or two Secretariat officers to support and facilitate the Working Group.

The EMB Secretariat will coordinate this activity with the Chair and co-Chair. A dedicated EMB Science Officer will act in the capacity of facilitator and other EMB Secretariat staff may be involved depending on the specific topic for each WG activity.

For this WG the facilitator is: Ana Rodriguez, EMB Science Officer

6. Mode of Operation

Work Programme

The work programme will consist of:

- One kick-off meeting (probably virtual);
- Regular (monthly or bi-monthly) online progress meetings;
- Writing assignments;
- Regular email interactions;
- Editing to publication standard by the WG Chair/co-Chair and EMB Secretariat;
- External and internal peer review coordinated by EMB Secretariat;
- Revisions based on peer review comments; and
- Final copy-editing and design by the EMB Secretariat and WG Chair /co-Chair.

Support from the European Marine Board:

- Organizational support for WG meetings;
- Cost of all catering associated with WG meetings, including a WG dinner;
- Costs of publication and dissemination of the publication to relevant stakeholders; and
- Writing and disseminate of meeting minutes, and maintenance of regular dialogue with the WG Chair and co-Chair to ensure timely delivery of the document.

Note: WG members and Chairs are not financially supported by the EMB (unless an extraordinary contribution is secured by one or more EMB Member Organizations). WG member participation (e.g. travel costs) is normally funded by their institution or the EMB member that proposed them for the WG. The establishment of a WG is for a limited duration and the WG will be disbanded by the Board when it has fulfilled its mandate.

General Data Protection Regulation (GDPR) policy for EMB Working Groups

Personal data for EMB Working Group members and those involved in other EMB core activities is used for internal communication with the activity as well as external communication of the EMB activity via publications, the EMB website and EMB social media outlets.

For any new EMB activities, consent is sought at the kick-off of the activity to cover all relevant use and storage of personal data. It is anticipated that the subjects would also be added to the EMB mailing list, and thus their data would continue to be stored and used beyond the end of the activity, unless consent is later withdrawn. A template consent form can be found in Annex 1.

Reviewers are also contacted within the context of EMB activities. The template email they receive clearly outlines their right to act that their input remains anonymous, in which case the reviewer would simply be listed as “Anonymous”. The reviewer will be informed of how and where their personal data will be stored. The consent of the reviewer will also be specifically sought for their personal data to be used outside of any activities directly relating to their role as reviewer, using the template text included in this document.

The [EMB privacy policy](#) contains information about our compliance with GDPR (data protection law). In this document you can find how to send us a request to let you access your data that we have collected, request us to delete your data, correct any inaccuracies or restrict our processing of your data. Please contact us at info@marineboard.eu for more information or concerns. You have the right to lodge a complaint about the way we handle your data with [Belgian Data Protection Authority](#).

7. Indicative Timetable

The WG activities are foreseen to start in Spring 2022 and are expected to run for 1 year from the kick-off meeting. The kick-off meeting may be held in-person or online, as agreed by the group and depending on Covid-19 restrictions. The final document is foreseen to be published in Spring 2023, which can include a dedicated launch event (tbc) and electronic and hard copy dissemination to relevant stakeholders. The European Marine Board conduct impact reporting, based on feedback from WG members and wider stakeholders, for a period of up to 2 years following publication.

An indicative time-table and order of activities is presented below.

Tasks (2021-2023)	2021			2022												2023			
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Approval of ToR by EMB member organizations																			
Nominations and expert selection																			
Appointment of WG co-Chairs																			

WG member list confirmed, invitations and planning for kick-off meeting																			
Kick-off meeting <ul style="list-style-type: none"> ▪ present expertise ▪ discussion of ToR ▪ objectives and scope of the WG ▪ discussion and agreement on table of contents and work plan ▪ allocation of writing assignments ▪ consideration of dissemination and communication opportunities 																			
Content drafting (with remote meetings between EMB, Chair and co-authors as necessary)																			
Meeting 2 & editing: <ul style="list-style-type: none"> ▪ review of the draft ▪ finalize the structure of the document ▪ Identify image needs Editing by Chairs & EMB Secretariat																			
Finalize (text and illustrations)																			
Approval of publication by WG members and EMB delegates																			
External review and revisions																			
Design of the publication																			
Publication and news release, followed by dissemination and uptake /impact tracking																			

8. References

Alcott, L. J., Mills, B. J. W., & Poulton, S. W. (2019). Stepwise Earth oxygenation is an inherent property of global biogeochemical cycling. *Science*, 366(6471), 1333–1337. <https://doi.org/10.1126/science.aax6459>

Breitburg, D., Conley, D. J., Isensee, K., Levin, L. A., Limburg, K. E., & Williamson, P. (2019). What can we

- do? Adaptation and solutions to declining ocean oxygen. In D. Laffoley & J. M. Baxter (Eds.), *Ocean deoxygenation: Everyone's problem - Causes, impacts, consequences and solutions* (pp. 545–562). IUCN. https://portals.iucn.org/library/sites/library/files/documents/11_DEOX.pdf
- Del Giorgio, P. A., & Duarte, C. M. (2002). Respiration in the open ocean. *Nature*, *420*(6914), 379–384. <https://doi.org/10.1038/nature01165>
- Duursma, E. K., & Boisson, M. (1994). Global oceanic and atmospheric oxygen stability considered in relation to the carbon-cycle and to different time scales. *Oceanologica Acta*, *17*(2), 117–141. <https://archimer.ifremer.fr/doc/00099/21024/>
- Hess, W. R., Garczarek, L., Pfreundt, U., & Partensky, F. (2016). Phototrophic microorganisms: the basis of the marine food web. In *The Marine Microbiome* (pp. 57–97). Springer. https://doi.org/10.1007/978-3-319-33000-6_3
- Huang, J., Liu, X., He, Y., Shen, S., Hou, Z., Li, S., Li, C., Yao, L., & Huang, J. (2021). The oxygen cycle and a habitable Earth. *Science China Earth Sciences*, *64*(4), 511–528. <https://doi.org/10.1007/s11430-020-9747-1>
- Laffoley, D., & Baxter, J. M. (Eds.). (2019). *Ocean deoxygenation: Everyone's problem - Causes, impacts, consequences and solutions*. IUCN. <https://portals.iucn.org/library/sites/library/files/documents/2019-048-En.pdf>
- Lenton, T. M., Dahl, T. W., Daines, S. J., Mills, B. J. W., Ozaki, K., Saltzman, M. R., & Porada, P. (2016). Earliest land plants created modern levels of atmospheric oxygen. *Proceedings of the National Academy of Sciences*, *113*(35), 9704–9709. <https://doi.org/10.1073/pnas.1604787113>
- Levin, L. A. (2018). Manifestation, drivers, and emergence of open ocean deoxygenation. *Annual Review of Marine Science*, *10*, 229–260. <https://doi.org/10.1146/annurev-marine-121916-063359>
- Long, M. C., Ito, T., & Deutsch, C. (2019). Oxygen projections for the future. In D. Laffoley & J. M. Baxter (Eds.), *Ocean deoxygenation: Everyone's problem - Causes, impacts, consequences and solutions* (pp. 171–211). https://portals.iucn.org/library/sites/library/files/documents/04_DEOX.pdf
- Lyons, T. W., Reinhard, C. T., & Planavsky, N. J. (2014). The rise of oxygen in Earth's early ocean and atmosphere. *Nature*, *506*(7488), 307–315. <https://doi.org/10.1038/nature13068>
- Petsch, S. T. (2003). The global oxygen cycle. *Treatise on Geochemistry*, *8*, 682. <https://doi.org/10.1016/B0-08-043751-6/08159-7>
- Wallace, M. W., Shuster, A., Greig, A., Planavsky, N. J., & Reed, C. P. (2017). Oxygenation history of the Neoproterozoic to early Phanerozoic and the rise of land plants. *Earth and Planetary Science Letters*, *466*, 12–19. <https://doi.org/10.1016/j.epsl.2017.02.046>

Annex 1: Consent form for Core Activities

EMB holds personal data for anyone involved in core EMB activities, including Working Groups.

The following personal data may be held by the EMB Secretariat:

- Name
- Title
- Job title
- Areas of expertise and research interests
- Previously held roles
- Institute
- Country
- Institutional email address
- Institutional postal address
- Institutional telephone number
- Photographs
- Video

This information is stored in a secure spreadsheet and folder locations, that only EMB Secretariat staff have access to.

EMB may:

- Contact you regarding the EMB activity that you are directly involved with
- Contact you regarding other EMB activities
- Add you to the EMB stakeholder mailing list
- Make your name, institution and country publicly available on the EMB website, in EMB communications, e.g. presentations regarding the activity you are involved in, and in EMB publications
- Take your photograph during EMB activities and use these pictures in publications, on the EMB website and on EMB social media outlets
- Take video footage during EMB activities and use these pictures in publications, on the EMB website and on EMB social media outlets

The data held may be reviewed and revised by the subject, and consent for any or all of the above may be withdrawn at any time.

Please tick this box to confirm that you understand the above, and that you give EMB permission to obtain, use and store your personal data as outlined above.

Name:

Date:

Annex 2: Decision Making Procedure

EMB Working Groups & Publications

Decision making procedures

Horizon Scanning



① Brainstorming

Topics of strategic importance for marine sciences are discussed by EMB members at plenary meetings (Board)



② Topic selection

Board selects topics to be further elaborated in a short scoping document



③ Topic approval

Board discusses topic content and approves the set-up of a new EMB Working Group (WG)

Establishment of EMB Working Group



⑥ Expert selection

EMB Secretariat & ExCom select WG Chair (and co-Chair); the Chair and co-Chair select the WG members from the nominations



⑤ Call for Nominations

EMB members propose experts from within their network to participate in the EMB Working Group



④ Terms of Reference

The content, purpose, and format of the WG are described in the ToR and submitted for Board

EMB Working Group Operations



⑦ WG meetings

The selected experts meet in person at least once to discuss the work plan/content of the working group



⑧ Publication development

WG members work remotely to provide input to the publication. EMB Secretariat & WG Chair(s) collate info into a draft document



⑨ Design

Finalized draft is circulated to all members of WG for comments & designed by EMB Secretariat

EMB Publication



⑫ Impact tracking

Impact of the document is tracked for up to 2-years



⑪ Launch & dissemination

The publication is launched at a dedicated event, promoted to targeted stakeholders online and hard copies are distributed



⑩ Review process

The draft publication is sent for internal review to all EMB member organisations and to at least 2-3 external reviewers