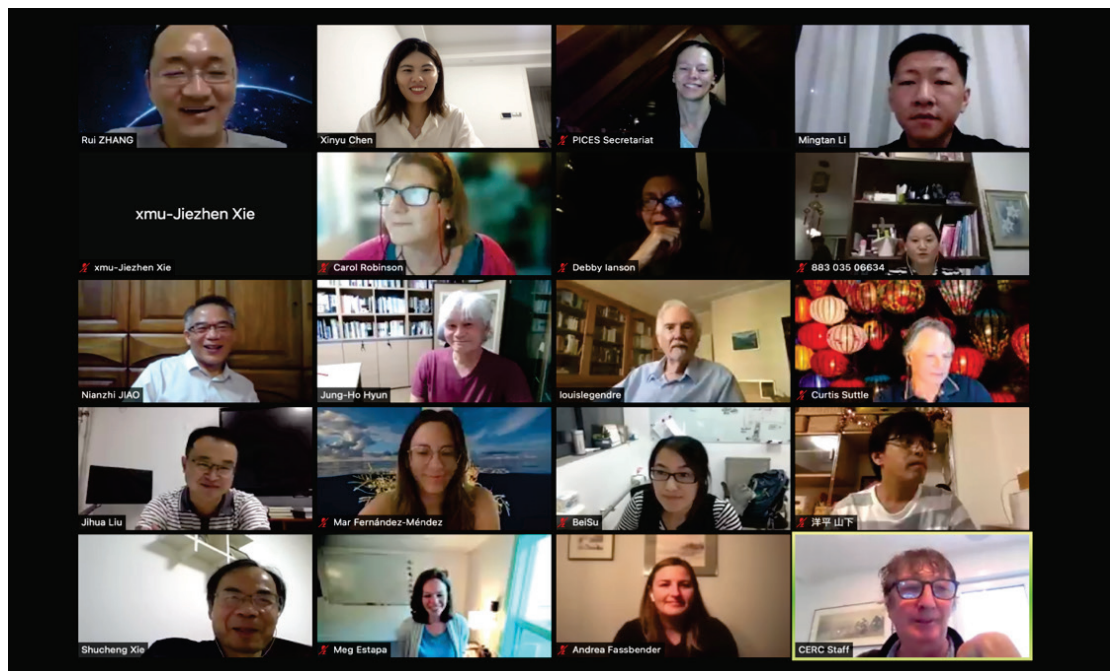


## 2021 Report of joint PICES/ICES Working on *Ocean Negative Carbon Emissions*

The joint PICES/ICES Working Group on *Ocean Negative Carbon Emissions* (ONCE) (Working Group 46) was established with all members being officially assigned on April 6, 2021.

The first meeting of WG 46 was held virtually on September 24, 2021 21:00–23:00 (Shanghai Time) at PICES-2021. Eighteen members were in attendance, including the two Co-Chairs representing PICES, Drs. Nianzhi Jiao (China) and Douglas Wallace (Canada) and the two Co-Chairs representing ICES, Dr. Carol Robinson (IK) and Louis Legendre (France) (*WG 46 Endnotes 1 and 4*). Dr. Jiao welcomed everyone to the meeting and self introductions were made. During the meeting, recent activities and gatherings of the WG, and the rationale that WG 46 was built upon, were reviewed, updates on the progresses made by each task team within the WG were provided, and further steps for WG 46 were discussed. The agenda for the meeting is presented in *WG 46 Endnote 2*.



WG 46 virtual meeting participants during PICES-2021.

### AGENDA ITEM 2 Activities in 2021

#### *Kick-off meeting*

WG 46 held its kick-off meeting virtually, due to COVID-19, on July 8, 2021. The rationale for establishing WG 46 was introduced and the objectives (terms of reference) were clarified. During the meeting task teams were created to address the ToRs (see Agenda Item 4). The matters about a logo design and setting up Working Group website were also discussed.

*Co-Chairs' meeting*

To better discuss preparations for the WG 46 annual meeting at PICES-2021, a Co-Chairs' meeting was held virtually on September 17, 2021, between PICES Co-Chair Prof. Jiao and ICES Co-Chair Prof. Legendre while Co-Chair Prof. Wallace and Co-Chair Prof. Robinson took a part in follow-up email exchanges. The structure, specific arrangements, and length of the annual meeting were discussed. Prof. Jiao also shared the updates on ONCE progress in China.

*Meeting of the Chinese members sub-group*

The meeting of group members from China was convened virtually on September 20, 2021. The members shared their progress made towards the scientific objectives of WG 46, and tasks on preparations for the WG annual meeting were discussed. Views on the next steps to assist in the achievement of WG objectives were also exchanged.

Three task team meetings were convened after the September 24 WG annual meeting:

*Task team 2 meeting*

The task team 2 (TT2) meeting was convened virtually on October 16, 2021. Its task is to use data from coastal and open ocean time-series and macrocosm facilities to assess proposed ocean negative carbon emission models. Members discussed the links between TT2 and TT1, and highlighted the knowledge gaps related to time-series. TT2 agreed that instead of proposing a new time-series station, it is more feasible for the TT to take advantage of the international nature of the Working Group to re-define the capabilities of time-series by focusing on the need of carbon measurement based on the established time-series.

*Task team 3a meeting*

The TT3a meeting was convened virtually on October 28, 2021. Its aim is to propose integrated experimental studies to better understand carbon sequestration under paleo-, current and future oceanic conditions. Considering the travel restrictions due to the pandemic, it would be too difficult for members to conduct field investigation altogether in the near future, but TT3a would like to collect experimental designs and ideas from all the members of WGONCE.

During the meeting, the deliverable of TT3a further clarified its deliverables, in which research directions needed to be prioritized based on funding availability, readiness of implementation, research interest of the members, policies in different regions, *etc.*

*The meeting of task team 3b*

The TT3b meeting was convened virtually on October 29, 2021. Prior to the meeting, an ONCE Methods and Effects form prepared by Prof. Jiao was sent out to members for comments and suggestions before the meeting. During the meeting, participating members agreed to narrow down the scope of methods for discussion to ensure more in-depth exploration and original findings.

AGENDA ITEM 3

**Review of Terms of Reference**

The main objectives of WG 46 are to:

- Identify current knowledge gaps in negative carbon emission in the oceans; and
- Propose future research directions and applications to the enhancement of negative carbon emissions including the items below:

- Developing additional long-term time series stations to observe carbon sequestration in representative coastal and offshore waters;
- Proposing integrated experimental studies to better understand carbon sequestration under paleo-, current and future oceanic conditions;
- Proposing an international collaborative project or program dedicated to ocean negative carbon emission.

#### AGENDA ITEM 4

#### **Formation of Task Teams to address the ToRs**

Following the first meeting of WG 46, five task teams (TTs) were formed, corresponding to the five missions and sub-missions of the WG. Each WG member was invited to join at least one of the five TTs (*WG 46 Endnote 3*). The results of discussions for each TT will form the basis of final products of WG 46, and in this regard and in an extraordinary pandemic context, each TT will be expected to convene routinely through a virtual platform. The TTs and their respective goals are below, followed by TT meeting discussions:

***Objective 1 - To Identify current knowledge gaps in negative carbon emission in the oceans;***

*Task team 1a:* Produce a note on terminology/definitions: what is and is not a ‘nature-based’ solution (‘natural climate solutions’ – defined by Griscom *et al.* (2017)<sup>1</sup> – referring to terrestrial habitats/coastal blue carbon). Review the terminology used for negative carbon emission methods to include ocean-based solutions (Gattuso *et al.* 2021)<sup>2</sup> (including ocean-dissolved carbon sinks which are difficult to apportion to national contributions).

*Task team 1b:* Produce a paper to summarize and compare the assumptions and conclusions of existing studies on proposed ocean-based negative carbon emission methods, including an assessment of the amount of carbon (likely and maximum) that could be sequestered globally by each proposed method and compare these values to the expected increase in anthropogenic release of CO<sub>2</sub> in the atmosphere in the coming decades. None of the methods could in itself offset this release, but some could perhaps contribute to an offset.

#### *Meeting discussions of TT1a and TT1b*

Prof. Wallace has posted a blog for the Canadian Institute of Climate Choices, and a short note from the Canadian perspective could form the basis for a broader note produced by TT1a. WG 46 members discussed ‘nature-based’ solutions, land vs. ocean, biotic vs. abiotic, and national and cultural values of ‘Nature’. The next steps are for members to keep surveying existing studies and organize task team meetings for more in-depth discussion.

TT1b is to review the evidence based on the existing studies to quantify carbon sequestration potential of ocean-based negative carbon emission methods. Members raised concerns about overusing assumptions and modellings in the field by overlooking potential evidence from experimental data, so WG members thought it would be beneficial to invest more effort on realistic field investigations and experiments. A synthesis will be prepared.

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<sup>1</sup> Griscom, B.W., Adams, J., Ellis, P.W., Houghton, R.A., et al. 2017. Natural climate solutions. *Proceedings of the National Academy of Sciences of the United States of America*. 114: 11,645–11,650.

<sup>2</sup> Gattuso, J.P., Williamson, P., Duarte, C.M., Magnan, A.K. 2021. The potential for ocean-based climate action: Negative emissions technologies and beyond. *Frontiers in Climate*, doi:10.3389/fclim.2020.575716.

**Objective 2 - To plan the development of additional long-term time series stations**

*Task team 2:* Produce a paper or report on the development of a global network of time series stations dedicated to (or including) ocean negative carbon emissions: define what observational platforms, sensors and capabilities are required; analyze the benefits and risks of using time series stations as ‘testbed’ sites for negative carbon emission methods; use examples of previous ‘analogue experiments’, e.g., Baltic/North Sea nutrient enhancement and then removal; use biogeochemical float observations in the World Ocean as a virtual time series.

*Meeting discussions of TT2*

WG 46 members agreed that the potentials of ocean time-series extend beyond observation platforms, and may be adopted for experimentation and intervention. For that, members discussed that the locations, sensors, and capabilities of time-series stations need to be defined, and what the time series efforts should be internationally or nationally. Proposals for a report on the development of a global network of time-series stations dedicated to ocean negative carbon emissions will be discussed in the following task team meetings.

**Objective 3 - To propose integrated experimental studies**

*Task team 3a:* Produce a paper or report based on the participation of WG members, in person or virtually, in the integrated carbon sequestration experimental study proposed in the subtropical sea near Xiamen, and a coastal aquaculture area near Shandong, China.

*Task team 3b:* Produce a paper focused on the methods/approaches that could be used at sea to differentiate the local, regional and global sequestration of carbon by the different ocean-based methods for negative carbon emissions from the background levels of carbon sequestration. This could also include the approach of evaluating the efficacy and environmental impacts of ocean-based negative carbon emission analogues (processes that could theoretically be scaled up or increased).

*Meeting discussions of TT3a and TT3b*

TT3a members discussed a combination of time-series stations near Xiamen, and how the integrated carbon sequestration experimental studies could better facilitate the understanding of the combined effect of different principles that ocean-based carbon sequestration is based on, and to help maximize the total effect of ocean negative carbon emissions. Guest, Mr. Mingtan Li as a representative from China’s seaweed aquaculture, introduced China’s seaweed farming in Shandong, and the opportunity to employ seaweed cultivations for integrated experimental studies.

Prof. Jiao will synthesise ideas of TT3b and produce a draft for a paper on methods/approaches that could be used at sea to differentiate the local, regional and global sequestration of carbon by different ocean-based methods for negative carbon emissions from the background levels of carbon sequestration. One or more TT meetings in the coming months will be convened to discuss the outline of the draft paper (or report).

AGENDA ITEM 5

**Planning for 2022**

- WG 46 members will continue surveying through related existing studies to recognize latest state of knowledge in the areas, and to identify the knowledge gaps stated in the ToRs;
- The outlines of reports by each TT will be drafted and shared among members;

- TT meetings will convene routinely through virtual platforms while the physical meetings are restricted by pandemic situation;
- A report on WG 46's missions and activities is under preparation and expected to be published;
- More specific activities aiming at ToRs will be proposed and encouraged.

## AGENDA ITEM 6

**Update on WG 46 ocean negative carbon emission research and publications**

In the first year, four papers were published based on the discussion among WG 46 members:

- **Jiao N, Liu J**, Jiao F, Chen Q, Wang X (2020) Microbes mediated comprehensive carbon sequestration for negative emission in the ocean. National Science Review 7: 1858-1860.
- **Jiao N, Zhang R**, Chen Y (2021) Ecological barrier for virus epidemic prevention. Science China: Earth Science 51: 167-170.
- **Jiao, N** (2021) Developing Ocean Negative Carbon Emission Technology to Support National Carbon Neutralization, Bulletin of Chinese Academy of Sciences (Chinese Version) 36. <https://doi.org/10.16418/j.issn.1000-3045.20210123001>
- Wang, F., Harindintwali, J.D., Yuan, Z., Wang, M., Wang, F., Li, S., Yin, Z., Huang, L., Fu, Y., Li, L., Chang, S.X., Zhang, L., Rinklebe, J., Yuan, Z., Zhu, Q., Xiang, L., Tsang, D.C., Xu, L., Jiang, X., **Liu, J.**, Wei, N., Kästner, M., Zou, Y., Ok, Y.S., Shen, J., Peng, D., Zhang, W., Barcelo, D., Zhou, Y., Bai, Z., Li, B., Zhang, B., Wei, K., Cao, H., Tan, Z., Zhao, L.-b., He, X., Zheng, J., Bolan, N., Liu, X., Huang, C., Dietmann, S., Luo, M., Sun, N., Gong, J., Gong, Y., Brahushi, F., Zhang, T., Xiao, C., Li, X., Chen, W., **Jiao, N.**, Lehmann, J., Zhu, Y.-G., Jin, H., Schaeffer, A., Tiedje, J.M., Chen, J.M., Technologies and perspectives for achieving carbon neutrality, The Innovation (2021), <https://doi.org/10.1016/j.xinn.2021.100180>.

**WG 46 Endnote 1****WG 46 participation list**Members

Nianzhi Jiao (China, PICES Co-Chair)  
 Douglas Wallace (Canada, PICES Co-Chair)  
 Carol Robinson (UK, ICES Co-Chair)  
 Louis Legendre (France, ICES Co-Chair)  
 Debby Ianson (Canada, PICES)  
 Curtis Suttle (Canada, PICES)  
 Jingfeng Fan (China, PICES)  
 Jihua Liu (China, PICES)  
 Bei Su (China, ICES)  
 Shucheng Xie (China, ICES)  
 Rui Zhang (China, PICES)  
 Mar Fernandez Mendez (Germany, ICES)  
 Youhei Yamashita (Japan, PICES)  
 Jung-Ho Hyun (Korea, PICES)  
 Pavel Ya Tishchenko (Russia, PICES)  
 Galen McKinley (USA, PICES)  
 Andrea Fassbender (USA, ICES)  
 Meg Estapa (USA, ICES)

Members unable to attend

Lihini Aluwihare (USA, PICES)  
 Jianfang Chen (China, PICES)  
 Phil Renforth (UK, ICES)  
 Elizabeth Shadwick (Australia, ICES)  
 Helmuth Thomas (Germany, ICES)  
 Jack Middelburg (Netherlands, ICES)  
 Greg Rau (USA, ICES)

Observers

Xinyu Chen (China)  
 Mingtan Li (China)  
 Jiezheng Xie (China)

**WG 46 Endnote 2**

**WG 46 annual meeting agenda**

2100-2300 CST, Friday, 24 September 2021

1. Welcome and introduction (Nianzhi Jiao)
2. Activities in 2021
3. Review of Terms of Reference
4. Formation of Task Teams to address the ToRs.
  - Task team 1a session (Carol Robinson)
  - Task team 1b session (Carol Robinson)
  - Task team 2 session (Douglas Wallace)
  - Task team 3a session (Nianzhi Jiao)
  - Task team 3b session (Nianzhi Jiao)
5. Planning for 2022
6. Update on WG 46 ocean negative carbon emission research and publications
7. Summary and final comments (Louis Legendre)

**WG 46 Endnote 3**

**Membership of task teams**

Members of task team 1a:

Douglas Wallace	Nianzhi Jiao	Carol Robinson
Debby Ianson	Curtis Suttle	

Members of task team 1b:

Carol Robinson	Galen McKinley	Andrea Fassbender
Meg Estapa	Jack Middelburg	Nianzhi Jiao
Louis Legendre	Douglas Wallace	Jung-Ho Hyun
Youhei Yamashita	Debby Ianson	

Members of task team 2:

Carol Robinson	Galen McKinley	Andrea Fassbender
Meg Estapa	Douglas Wallace	Nianzhi Jiao
Louis Legendre	Jianfang Chen	Elizabeth Shadwick
Helmuth Thomas	Lihini Aluwihare	

Members of task team 3a:

Nianzhi Jiao	Helmuth Thomas	Douglas Wallace
Carol Robinson	Louis Legendre	Shucheng Xie
Jihua Liu	Rui Zhang	

Members of task team 3b:

Nianzhi Jiao	Helmuth Thomas	Douglas Wallace
Carol Robinson	Louis Legendre	Phil Renforth
Pavel Ya Tishchenko	Elizabeth Shadwick	Jingfeng Fan
Mar Fernández-Méndez	Bei Su	

## WG 46 Endnote 4

## WG 46 member list

<i>Name</i>	<i>Country</i>	<i>Institution</i>
<u>Co-Chairs:</u>		
<i>Nianzhi Jiao</i>	China	Xiamen University
<i>Douglas Wallace</i>	Canada	Dalhousie University
<i>Louis Legendre</i>	France	Sorbonne University
<i>Carol Robinson</i>	UK	University of East Anglia
<u>Members:</u>		
<i>Debby Ianson</i>	Canada	Fisheries and Oceans Canada, Institute of Ocean Sciences
<i>Curtis Suttle</i>	Canada	University of British Columbia
<i>Youhei Yamashita</i>	Japan	Hokkaido University
<i>Jung-Ho Hyun</i>	Korea	Hanyang University
<i>Pavel Ya Tishchenko</i>	Russia	Pacific Oceanological Institute
<i>Lihini Aluwihare</i>	USA	Scripps Institution of Oceanography, University of California San Diego
<i>Galen McKinley</i>	USA	Columbia University/Lamont Doherty Earth Observatory
<i>Jianfang Chen</i>	China	Second Institute of Oceanography, MNR
<i>Jingfeng Fan</i>	China	National Marine Environmental Monitoring Center (NMEMC)
<i>Rui Zhang</i>	China	Xiamen University
<i>Jihua Liu</i>	China	Shandong University
<i>Helmuth Thomas</i>	Germany	Institute of Carbon Cycles, Helmholtz Center Hereon
<i>Jack Middelburg</i>	Netherlands	Utrecht University
<i>Mar Fernández-Méndez</i>	Germany	GEOMAR Helmholtz Centre for Ocean Research, Kiel
<i>Andrea Fassbender</i>	USA	NOAA Pacific Marine Environmental Laboratory (PMEL)
<i>Meg Estapa</i>	USA	University of Maine
<i>Greg Rau</i>	USA	University of California, Santa Cruz
<i>Shucheng Xie</i>	China	China University of Geosciences
<i>Bei Su</i>	China	Shandong University
<i>Elizabeth Shadwick</i>	Australia	The Commonwealth Scientific and Industrial Research Organization (CSIRO)
<i>Phil Renforth</i>	UK	Heriot-Watt University