

## PACECS Annual Report 2020

### Processes and Approaches of Coastal Ecosystem Carbon Sequestration (PACECS)

#### 1. Selected highlights

##### 1.a. Selected scientific highlights since last report

*Last report was submitted to Brest SSC meeting, June 2019. Each highlight needs to be VERY short, bullet points, with a link to publication if applicable.*

##### **Subproject 1:**

- ✓ Homeostasis in the lower epipelagic and mesopelagic nitrogen cycle is characterized by an interplay of contrasting life strategies of ammonia- and nitrite-oxidizing microbial assemblages with similar affinities maintaining nearly equal oxidation rates of their respective nitrogen substrates in the energy-poor environment of the dark ocean. Our analysis suggests that chemoautotrophic nitrification is associated with a global carbon fixation rate of  $\sim 1 \times 10^{13}$  to  $\sim 2 \times 10^{13}$  mol C yr<sup>-1</sup> in the dark ocean. (<https://www.pnas.org/content/117/9/4823>)
- ✓ The in situ incubation experiments, N<sub>2</sub>O isotopic composition and concentrations, and gene abundances indicated that the high concentration of N<sub>2</sub>O (oversaturated) was mainly produced from strong nitrification by the relatively high abundance of AOB in the upper reaches and was the major source of N<sub>2</sub>O emitted to the atmosphere in the Pearl River estuary. (<https://www.biogeosciences.net/16/4765/2019/>)
- ✓ Ocean global change drivers (ocean acidification, warming, solar UV radiation, and deoxygenation) interact to affect marine primary producers. (<https://www.frontiersin.org/articles/10.3389/fmars.2019.00322/full>)
- ✓ The N<sub>2</sub>-fixing cyanobacterium, *Trichodesmium* sp., when grown under light-limiting conditions, is less sensitive to ocean warming over multiple generations, but becomes more susceptible when exposed to abrupt temperature changes, such as those induced by cyclones and heat waves. (<https://www.biogeosciences.net/17/1169/2020/>)
- ✓ Compared to microalgae, macroalgal primary productivity is lower. However, the lower farming and processing costs for macroalgae are more promising toward development of algal biofuels. (<https://doi.org/10.1515/bot-2019-0065>)

### **Subproject 2:**

- ✓ Using of triazine herbicides in the coastal ocean resulted in the serious negative impacts on phytoplankton physiology as well as the phytoplankton-driven ecological functions, e.g. oceanic carbon fixation and substance transport in the food web. (<https://www.sciencedirect.com/science/article/pii/S0160412019312139?via%3Dihub>)
- ✓ Glomalin-related soil protein (GRSP) can bind a large number of metal elements in soil. We systematically revealed the metal sequestration mechanism and water quality improvement of GRSP. (<https://www.sciencedirect.com/science/article/abs/pii/S0304389419316097>)
- ✓ By GRSP infrared fingerprints coupled with multivariate analyses, we developed a technique for source identification of heavy metal pollution, giving more reliable evidence about contributing sources. (<https://www.sciencedirect.com/science/article/pii/S0048969719360474>)
- ✓ The sediment texture controls the metal sequestration capacity of GRSP, and it was significantly associated with the mitigation of ecological and health risks, which may provide new insights into the in situ remediation of anoxic estuarine wetlands. (<https://www.sciencedirect.com/science/article/pii/S0269749119349607>)

### **Subproject 3:**

- ✓ Carbon isotopic ( $\delta^{13}\text{C}$  and  $\Delta^{14}\text{C}$ ) composition of bulk organic carbon as well as specific biomarkers were applied on the Yellow River suspended sediments to investigate the influence of hydrodynamic sorting and selective transport on organic matter export. Hydrodynamic sorting resulted in significant heterogeneity of OC%, SA,  $\Delta^{14}\text{C}$ , *n*-FAs contents, and FA- $\delta^{13}\text{C}$  and  $-\Delta^{14}\text{C}$  compositions among size fractions, as well as resulting in two distinct types of selective terrestrial OC transport. (<https://www.sciencedirect.com/science/article/pii/S0016703719304648>)

### **Subproject 4:**

- ✓ Ecological engineering by artificial upwelling for enhancing seaweed growth and consequently increasing nutrient removal from seawater has proved promising in combating intense coastal eutrophication. Our research results show that this ecological engineering could increase the natural kelp yield by 291,956 t and the removal of nitrogen (N) and phosphorus (P) nutrients by 4875–6422 t and 730–1080 t, respectively. (<https://www.mdpi.com/2073-4441/11/9/1754>)

## 1.b. Publications since last report

Please add all publications since last report to the table below (see notes for details on “Class” and “Activity” fields).

Publication with DOI	Class 1, 2, 3	Activity*
<b>Subproject 1 :</b>		
1. Zhang, Y.*; Qin, W.; Hou, L.; Zakem, E. J.; Wan, X.; Zhao, Z.; Liu, L.; Hunt, K. A.; Jiao, N.; Kao, S-J.; Tang, K.; Xie, X.; Shen, J.; Li, Y.; Chen, M.; Dai, X.; Liu, C.; Deng, W.; Dai, M.; Ingalls, A.E.; Stahl, D.A.; Herndl, G.J. Nitrifier adaptation to low energy flux controls inventory of reduced nitrogen in the dark ocean. <i>Proceedings of the National Academy of Sciences of the United States of America</i> , <b>2020.3.3</b> , 117 (9), 4823-4830. <b>DOI: 10.1073/pnas.1912367117.</b>	Class 2	
2. Ma, L.; Lin, H.; Xie, X.; Dai, M.; Zhang, Y.* Major role of ammonia-oxidizing bacteria in N <sub>2</sub> O production in the Pearl River estuary, <i>Biogeosciences</i> , <b>2019.12.16</b> , 16(24), 4765–4781. <b>DOI: 10.5194/bg-16-4765-2019.</b>	Class 2	
3. Gao, K.*; Beardall, J.; Häder, D-P.; Hall-Spencer, J.M.; Gao, G.; Hutchins. D.A. Effects of ocean acidification on marine photosynthetic organisms under the concurrent influences of warming, UV radiation and deoxygenation. <i>frontiers in Marine Science</i> . <b>2019.6.18</b> , 6, 322. <b>DOI: 10.3389/fmars.2019.00322.</b>	Class 2	
4. Yi, X.; Fu, F.-X.; Hutchins, D. A.; Gao, K.* Light availability modulates the effects of warming in a marine N <sub>2</sub> fixer. <i>Biogeosciences</i> . <b>2020.2.28</b> , 17, 1169-1180. <b>DOI: 10.5194/bg-17-1169-2020.</b>	Class 2	
5. Gao, G.*; Burgess, J. G.; Wu, M.; Wang, S.; Gao, K.* Using macroalgae as biofuel: current opportunities and challenges. <i>Botanica Marina</i> , <b>2020.3.20</b> , <b>DOI: 10.1515/bot-2019-0065.</b>	Class 2	
6. Cai, R.; Zhou, W.; He, C.; Tang, K.*; Guo, W.; Shi, Q.; Gonsior, M.; Jiao, N.* Microbial processing of sediment-derived dissolved organic matter: Implications for its subsequent biogeochemical cycling in overlying seawater. <i>Journal of Geophysical Research-Biogeosciences</i> . <b>2019.11.7</b> , 124(11), 3479-3490. <b>DOI:10.1029/2019JG005212.</b>	Class 2	
7. Tang K.* Chemical Diversity and Biochemical Transformation of Biogenic Organic Sulfur in the Ocean. <i>frontiers in Marine Science</i> , <b>2020.2.20</b> , 7, 68. <b>DOI: 10.3389/fmars.2020.00068.</b>	Class 2	
8. Zhan, P.; Ye, J.; Lin, X.; Zhang, F.; Lin, D.; Zhang, Y.; Tang, K.* Complete genome sequence of <i>Echinicola rosea</i> JL3085, a xylan and pectin decomposer. <i>Marine Genomics</i> , <b>2019.10.31</b> . <b>DOI: 10.1016/j.margen.2019.100722.</b>	Class 2	
<b>Subproject 2 :</b>		
9. Yang, L.; Li, H.; Zhang, Y.*; Jiao, N. Environmental risk assessment of triazine herbicides in the Bohai Sea and the Yellow Sea and their toxicity to phytoplankton at environmental concentrations. <i>Environment International</i> , <b>2019.10.16</b> , 133, 105175. <b>DOI: 10.1016/j.envint.2019.105175.</b>	Class 2	

10. Wang, Q.; Chen, J.; Chen, S.; Qian, L.; Yuan, B.; Tian, Y.; Wang, Y.; Liu, J.; Yan, C.*; Lu, H.* Terrestrial-derived soil protein in coastal water: Metal sequestration mechanism and ecological function. <i>Journal of Hazardous Materials</i> , <b>2020.3.15</b> , 386, 121655. <b>DOI: 10.1016/j.jhazmat.2019.121655.</b>	Class 2	
11. Wang, Q.; Lu, H.; Chen, J.; Jiang, Y.; Williams, M.; Wu, S.; Li J.; Liu J.; Yang, G.; Yan, C.* Interactions of soil metals with glomalin-related soil protein as soil pollution bioindicators in mangrove wetland ecosystems. <i>Science of the Total Environment</i> , <b>2019.12.10</b> , 709, 136051. <b>DOI: 10.1016/j.scitotenv.2019.136051.</b>	Class 2	
12. Wang, Q.; Hong, H.; Yang, D.; Li, J.; Chen, S.; Pan, C.; Lu, H.; Liu, J.*; Yan, C.* Health risk assessment of heavy metal and its mitigation by glomalin-related soil protein in sediments along the South China coast. <i>Environmental Pollution</i> , <b>2020.4.11</b> , 263, 114565. <b>DOI: 10.1016/j.envpol.2020.114565.</b>	Class 2	
13. Zhang, H.; Wang, Z.; Feng, Y.; Cui, Q.*; Song, X.* Phytohormones as stimulators to improve arachidonic acid biosynthesis in <i>Mortierella alpina</i> . <i>Enzyme and Microbial Technology</i> . <b>2019.12</b> , 131, 109381. <b>DOI: 10.1016/j.enzmictec.2019.109381.</b>	Class 2	
14. Wang, Y.; Song, X.; Feng, Y.; Cui, Q.* Changes in peptidomes and Fischer ratios of corn-derived oligopeptides depending on enzyme hydrolysis approaches. <i>Food Chemistry</i> , <b>2019.11.1</b> , 297, 124931. <b>DOI: 10.1016/j.foodchem.2019.05.205.</b>	Class 2	
15. Liang, Y.; Zhang, Y.*; Zhou, C.; Li, H.; Kang, X.; Wang, L.; Song, J.; Jiao, N. Cumulative impact of long-term intensive mariculture on total and active bacterial communities in the core sediments of the Ailian Bay, North China. <i>Science of the Total Environment</i> . <b>2019.7.16</b> , 691, 1212-1224. <b>DOI: 10.1016/j.scitotenv.2019.07.200.</b>	Class 2	
16. Zhao, J.; Wang, L.; Tang, L.; Ren, R.; You, W.; Farooq, R.; Wang, Z.*; Zhang, Y. Changes in bacterial community structure and humic acid composition in response to enhanced extracellular electron transfer process incoastal sediment. <i>Archives of Microbiology</i> , <b>2019.9</b> , 201(7), 897-906. <b>DOI: 10.1007/s00203-019-01659-3.</b>	Class 2	
17. Liang, Y.; Wang, L.; Wang, Z.; Zhao, J.; Yang, Q.; Wang, M.; Yang, K.; Zhang, L.; Jiao, N.; Zhang, Y.* Metagenomic Analysis of the Diversity of DNA Viruses in the Surface and Deep Sea of the South China Sea. <i>Frontiers in Microbiology</i> , <b>2019.8.23</b> , 10, 1951. <b>DOI: 10.3389/fmicb.2019.01951.</b>	Class 2	
18. Wang, Z.; Zhao, J.; wang, L.; Li, C.; Liu, J.; Zhang, L.; Zhang, Y. A novel benthic phage infecting <i>Shewanella</i> with strong replication ability, <i>Viruses</i> , <b>2019.11.19</b> , 11(11), 1081. <b>DOI: 10.3390/v11111081.</b>	Class 2	
19. Hu, Z.; Wang, Z.; Zhang, Z.; Li, H.; Zhang, Y.; Liu, J.*; Jiao, N. <i>Flavicella sediminum</i> sp. nov., isolated from marine sediment. <i>Int J Syst Evol Microbiol</i> , <b>2019.11.12</b> , 70, 868-873, <b>DOI: 10.1099/ijsem.0.003839.</b>	Class 2	
<b>Subproject 3 :</b>		
20. Yu, M.; Eglinton, T. I.*; Haghypour, N.; Montlucon, D.B.; Wacker,	Class 2	

L.; Wang, Z.; Jin, G.; Zhao, M.* <i>Molecular isotopic insights into hydrodynamic controls on fluvial suspended particulate organic matter transport, <i>Geochimica et Cosmochimica Acta</i>, 2019.10.1, 262, 78-91.</i> <b>DOI: 10.1016/j.gca.2019.07.040.</b>		
<b><u>Subproject 4 :</u></b>		
21. Lin, T.; Fan, W.*; Xiao, C.; Yao, Z.; Zhang, Z.; Zhao, R.; Pan, Y.; Chen, Y. <i>Energy Management and Operational Planning of an Ecological Engineering for Carbon Sequestration in Coastal Mariculture Environments in China. <i>Sustainability</i>, 2019.6.5, 11(11), 3162.</i> <b>DOI: 10.3390/su11113162.</b>	Class 2	
22. Fan, W.; Zhao, R.; Yao, Z.; Xiao, C.; Pan, Y.; Chen, Y.; Jiao, N.; Zhang, Y.* <i>Nutrient Removal from Chinese Coastal Waters by Large-Scale Seaweed Aquaculture Using Artificial Upwelling. <i>Water</i>, 2019.8.22, 11(9), 1754.</i> <b>DOI: 10.3390/w11091754.</b>	Class 2	
23. Zhou, S.; Fan, W.*; Yao, Z.; Qiang, Y.; Pan, Y.; Chen, Y. <i>Experimental study on the performance of a wave pump for artificial upwelling in irregular waves. <i>Ocean Engineering</i>, 2019.10, 189, 106353.</i> <b>DOI: 10.1016/j.oceaneng.2019.106353.</b>	Class 2	
24. Jiang, Z-P.; Cai*, W.-J.; Lehrter, J.; Chen, B.; Ouyang, Z.; Le, C.; Roberts, B. J.; Hussain, N.; Scaboo, M. K.; Zhang, J.; Xu, Y. <i>Spring net community production and its coupling with the CO<sub>2</sub> dynamics in the surface water of the northern Gulf of Mexico. <i>Biogeosciences</i>, 2019.9, 16(18), 3507-3525.</i> <b>DOI: 10.5194/bg-16-3507-2019.</b>	Class 2	
25. Le, C.; Gao, Y.; Cai, W.-J.; Lehrter, J. C.; Bai, Y.; Jiang, Z-P.* <i>Estimating summer sea surface pCO<sub>2</sub> on a river-dominated continental shelf using a satellite-based semi-mechanistic model. <i>Remote Sensing of Environment</i>, 2019.5, 225, 115–126.</i> <b>DOI: 10.1016/j.rse.2019.02.023.</b>	Class 2	
26. Yao, Z.; Fan, W.*; Xiao, C.; Lin, T.; Zhang, Y.; Zhang, Y.; Liu, J.; Zhang, Z.; Pan, Y.; Chen, Y. <i>Numerical Studies on the Suitable Position of Artificial Upwelling in a Semi-Enclosed Bay. <i>Water</i>, 2020.1.8, 12(1), 177.</i> <b>DOI: 10.3390/w12010177.</b>	Class 2	
27. Pan, Y.; Li, Y., Fan, W.*; Zhang, D.; Qiang, Y.; Jiang Z.; Chen, Y. <i>A sea trial of air-lift concept artificial upwelling in the East China Sea. <i>Journal of Atmospheric and Oceanic Technology</i>, 2019.11.12, 36, 2191-2204.</i> <b>DOI: 10.1175/JTECH-D-18-0238.1.</b>	Class 2	
28. Yao, Z.; Fan, W.*; Xiao C.; Qiang Y.; Pan Y.; Liang N.; Chen Y. <i>Theoretical and experimental study on influence factors of bubble-entrained plume in air-injection artificial upwelling. <i>Ocean Engineering</i>, 2019.11.1,192(15),106572.</i> <b>DOI: 10.1016/j.oceaneng.2019.106572.</b>	Class 2	

*\*If appropriate, please list the IMBeR activity through / by / from / during which the publication arose*

\*\*\*\* **Notes on publications** \*\*\*\*

Publications are logged in the IMBeR Zotero library which is publicly accessible online - [https://www.zotero.org/groups/2448334/imber\\_library\\_2/library](https://www.zotero.org/groups/2448334/imber_library_2/library)

[Due to space limitations, publications from 1999-2017 are in a separate Zotero library - [https://www.zotero.org/groups/38770/imber\\_library\\_1/library](https://www.zotero.org/groups/38770/imber_library_1/library)]

Publications are categorised by “Class” and linked to “Activities”:

**Class 1 publications** are specifically generated through/by/from/during **IMBeR activities** - for example, arising from IMBIZOs and IMBeR conferences such as the IMBeR open science meeting and the IMBeR CJK symposia and from the activities of the working groups, regional programmes and the SPIS scoping teams.

**Class 2 publications** are on topics relevant to the IMBeR Science Plan that benefitted from some interaction with IMBeR or **IMBeR activities**, for example by IMBeR symposium attendees, past and present SSC members, working group, regional programme and endorsed project members, or national contacts.

**Class 3 publications** are on topics relevant to the IMBeR Science Plan but for which there is no direct link to or benefit from an IMBeR activity. These might include publications by SSC members, working group, regional programme or endorsed project members or members of the IMBeR international community that were written as part of the normal scientific activity of the authors and would have occurred irrespective of IMBeR’s existence. You can report Class 3 publications, but they will no longer be logged in the IMBeR database.

[See <https://drive.google.com/open?id=1OQWn41KJvQ-LyWJlkiYnc5qZ2luNQOrg> or <https://pan.ecnu.edu.cn/p/DTrpUb4QiFAYoQ4> for further information on “What is an IMBeR publication?”.]

**Why list ‘Class’ and ‘Activity’?** This helps us to declare authentically which publications IMBeR has helped to generate, and it makes it easier for us to demonstrate the value of the Regional Programmes, the Working Groups, the Endorsed Projects, and IMBeR in general, and it helps us to justify support for IMBeR activities when we can list tangible outputs.

### 1.c. Events, Meetings, and Workshops

*List all international and national events, meetings and workshops. Describe the level of participation: e.g. chairing session/workshop, organising meeting. Include Endorsed Project meetings and workshops.*

*Format: Title of event. Date. Location. Description of participation. Any other pertinent details.*

- ✓ The PACECS project, together with another National Key Research and Development Program project and an NSFC Key project, jointly organized the cruise KK1902 SILICON (Spring time cyclonic eddy in the northwest Pacific Ocean off Taiwan) during March 15 to April 20, 2019, and the time-series study cruise of the SEATS station in the South China Sea during July 9 to 22, 2019.

- ✓ The PACECS project, together with the project of the Chinese Academy of Sciences, jointly organized the workshop and the on-situ inspections on the ocean carbon sink monitoring system in Xiamen on April 29, 2019.
- ✓ The project team held a seminar to integrate and discuss the annual progress of the four subprojects in Xiamen on November 28-29, 2019.
- ✓ The Ministry of Science and Technology held the annual meeting in Beijing on December 15, 2019.
- ✓ The subprojects 1, 2, and 4 teams jointly organized the Artificial Upwelling System Tests in the Aoshan Bay, Jimo, Qingdao from March 9 to 13 and January 15 to 21, 2019.

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## 2. International collaboration and links

The project team and Dalhousie University have jointly carried out long-term large-scale ecological simulation experiments using the Aquatron experimental system since September 2016 and obtained a series of important understandings of the microbial carbon pump processes and mechanism.

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## 3. Input to management, policy and governance

*Add anything that in line with the IMBeR Grand Challenge III: Improving and achieving sustainable ocean governance*

Ocean is the largest carbon pool on earth, serving as the buffer of global climate change, absorbing about 1/3 of CO<sub>2</sub> produced by human activities. Carbon sink captured by marine ecosystem is called the "Blue Carbon Sink" (hereinafter referred to as "blue carbon"), which is one of the most important mechanisms for the sea to store carbon. The initial form of blue carbon is visible plant carbon sequestration in the coastal zone. As a matter of fact, the invisible microorganisms (phytoplankton, bacteria, archaea, and protozoa), which have always been ignored, account for 90% of the marine biomass and constitute the main component of blue carbon. The marginal sea covers one third of the total territory of China, and it is of urgent need to explore the immense potential of carbon sinks. This project aims at the key processes and mechanisms of the carbon sequestration in coastal ecosystems and ways to increase ocean carbon sink: (1) key processes and regulatory mechanisms of ocean carbon sink and its relationship with environment and global climate changes; (2) an index system for carbon storage including a series of physical-chemical and biological indices and parameters and main core measurements protocols; (3) demonstrations of increasing carbon sink and engineering carbon sequestration in the ocean. These outputs will support the sustainable development of marine ecosystem and national carbon emissions trading.

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#### 4. Education and outreach

The project team made a model showing a dynamic Artificial Upwelling System at the 8<sup>th</sup> Xiamen University Ocean Sciences Day (November 3, 2019), and introduced the principles of the natural upwelling and artificial upwelling and the significance of artificial upwelling system for carbon sink in coastal oceans to the public.

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#### 5. Planned activities for next year

##### Activities and Outreach (Convening sessions, meetings, etc)

- ✓ The project team will hold the annual internal inspection meeting in 2020.
- ✓ The project team will basically finish establishing the demonstration area for increasing coastal ocean's carbon sinks based on artificial upwelling in the Aoshan Bay, Jimo, Qingdao.
- ✓ The project team will hold a meeting and invite a board of experts to discuss and demonstrate part of the main core measurements protocols aiming at establishing an index system for carbon storage.
- ✓ The project team will show the model of Artificial Upwelling System to the public at the 9<sup>th</sup> Xiamen University Ocean Sciences Day.

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#### 6. Changes to data management

*Please note this will be placed on the endorsed project webpage*

Name and e-mail of the person in charge of data management:

Ms. Xiabing Xie, Technician, xiexiabing@xmu.edu.cn

Name of the data centre where your project data are stored:

"Data Management Centre"

Direct Web link where the project data are available:

<http://ime.xmu.edu.cn/bluecarbonmcp/data.asp>