Supplementary information for:

Stoichiometric deviation and regulatory mechanisms of AOU-nutrient ratio in the oligotrophic Northwest Pacific Ocean

Detong Tian[1], Xuegang Li[2,3*], Jinming Song[2,3], Yunping Xu[1], Feng Zhao[2], Jun Ma[2,3], Shanshan Liu[2,3], Muhammad Inayat Ullah Khan[1], Weichao Wu[1,4*]

[1]College of Oceanography and Ecological Science, Shanghai Ocean University, Shanghai, 201306, China

[2]Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266000, China

[3]Laboratory for Marine Ecology and Environmental Science, Qingdao Marine Science and Technology Center, Qingdao 266237, China

[4]International Research Center for Marine Biosciences at Shanghai Ocean University, Ministry of Science and Technology, China

*Correspondence: W. Wu (wcwu@shou.edu.cn) and X. Li (lixuegang@qdio.ac.cn)

Contents of this file:

Text S1-S2, Figure S1, Table S1-S2.

Text S1:

Supplementary Method 1. Preparation of the xanthan gum calibration curve

A fresh xanthan gum stock solution (75 mg L^{-1}) was diluted to obtain five standards. Aliquots of 0.125, 0.250, 0.500, 0.750, and 1.000 mL of the stock solution were pipetted into clean 5 mL polypropylene tubes, and the final volume of each standard was adjusted to 1 mL with ultrapure water. This produced standards containing 9.37, 18.75, 37.50, 56.25, and 75.00 µg xanthan gum, respectively, with three replicates at each level. Each standard was mixed with 0.5 mL of Alcian Blue solution (400 mg L^{-1}, pH 2.5) for 5−10 s and filtered through a 0.45 µm polycarbonate membrane (Whatman) under a vacuum below 175 mmHg. Procedural blanks were processed in parallel. The filters were extracted with 6 mL of 80% sulfuric acid for 10 h, and absorbance was measured at 787 nm. A linear regression of xanthan gum mass against absorbance after blank correction yielded:

$$M_{XG} = 100.15A_{787} + 1.67 \quad (1)$$

where M_{XG} is the xanthan gum equivalent mass in µg and A_{787} is the absorbance at 787 nm (R^2=0.99; Fig. S1). TEP concentrations were calculated by dividing the xanthan gum equivalent mass by the filtered seawater volume and are reported as µg Xeq L^{-1}.

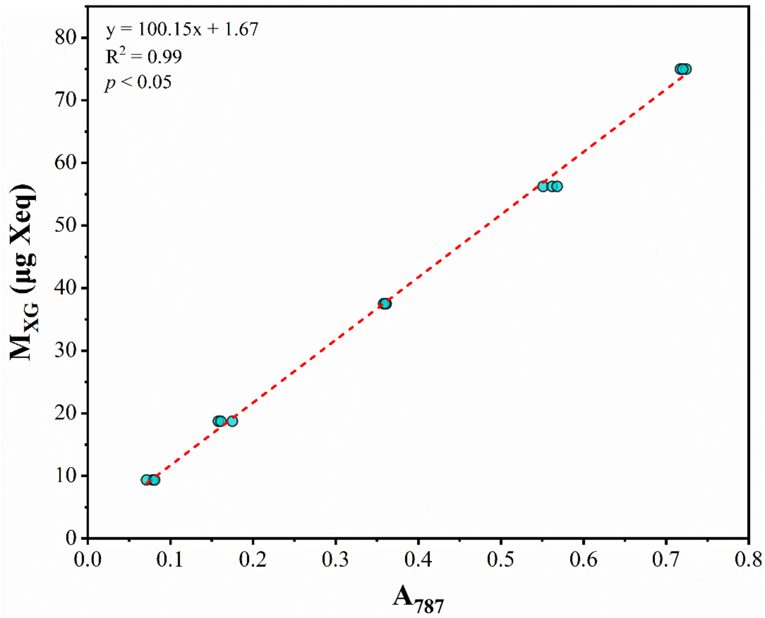

Figure S1. Xanthan gum calibration curve for TEP quantification.

Text S2:

Supplementary Method 2. Calculation of $rPreNO_3$ and $rPrePO_4$

$rPreNO_3$ was computed as:

$$rPreNO_3 = NO_{3meas} - \left(f_{DOM} \bullet \frac{AOU}{r_{DOM}} + f_{POM} \bullet \frac{AOU}{r_{POM}}\right) \quad (2),$$

where measured nitrate (NO_{3meas}) is defined as the sum of the concentrations of NO_3-N and NO_2-N. AOU is given by:

$$AOU = DO_{sat} - DO_{meas} \quad (3),$$

where DO_{sat} is the saturated DO concentration at a given temperature, salinity, and pressure (Garcia and Gordon, 1992), and DO_{meas} is the measured DO concentration. f_{DOM} and f_{POM} represent the fractions of total oxygen consumption attributed to DOM and POM, respectively. r_{DOM} and r_{POM} denote the moles of O_2 consumed per mole of nitrogen regenerated during DOM and POM remineralization, respectively. f_{DOM} and f_{POM} were each evaluated at 0.4, 0.5, and 0.6 (0.5 ± 0.1), while r_{POM} was assigned values of 6.9, 8.75, and 10.6, representing the minimum, Redfield, and maximum estimates reported in the literature (Table S2) (Letscher and Villareal, 2018; Smyth and Letscher, 2023). All combinations produced 27 calculations for each observation. These calculations were used to represent the uncertainty associated with applying empirical parameters to the broader Pacific Ocean. For each observation, the 27 estimates were summarized as minimum–maximum (arithmetic average ± standard deviation). The arithmetic average was used as the central diagnostic value in the manuscript, whereas the minimum, maximum, and standard deviation describe sensitivity to the prescribed parameter combinations. The complete summaries are available in the public data set (Tian, 2026).

Similarly, $rPrePO_4$ was computed as:

$$rPrePO_4 = PO_{4meas} - \frac{1}{16}\left(f_{DOM} \bullet \frac{AOU}{r_{DOM}} + f_{POM} \bullet \frac{AOU}{r_{POM}}\right) \quad (4)$$

Because the remineralization parameters specific to phosphorus could not be independently constrained, the nitrogen regeneration terms derived from DOM and POM were converted to phosphorus equivalents using an N:P ratio of 16:1 (Letscher and Villareal, 2018).

Table S1. The review of the surface TEP concentrations and TEP-C/POC ratios in the literature.

Region	Depth	TEP concentration (μg Xeq L^{-1})	TEP-C/POC (%)	Reference
*Tropical Northwest Pacific	0–300 m	7.53–34.22 (22.52 ± 8.54)	15.45–71.75 (43.81 ± 14.62)	This study
Fram Strait	5-150 m	5–517 (75 ± 78)	13.8 ± 6.1	Engel et al. (2017)
Northern South China Sea	0–200 m	0.6–78.6	5.6–55.5 (27.4 ± 1.3)	Ge et al. (2022)
*South China Sea	0–220 m	14–47 (30 ± 8)	32.0–173 (75.0 ± 37.0)	Guo et al. (2022)
*Western tropical North Pacific	0–220 m	12–54 (34 ± 10)	45.0–114 (61.0 ± 40.0)	Guo et al. (2022)
Jaran Bay	Subsurface	26.5–1695.4 (215.9 ± 172.2)	2.4–67.3 (21.7 ± 11.4)	Lee et al. (2020)
East China Sea coast	Surface	11.25–509.58 (214.90)	30.2	Wen et al. (2022)
North of the South Orkney Islands	Surface	144.4 ± 21.7	45.9 ± 5.1	Zamanillo et al. (2019a)
South of the South Orkney Islands	Surface	48.1 ± 6.5	40.8 ± 10.2	Zamanillo et al. (2019a)
Northwest of South Georgia	Surface	125.5 ± 21.1	30.6 ± 5.1	Zamanillo et al. (2019a)
West of Anvers Island	Surface	111.6 ± 13.0	25.5 ± 5.1	Zamanillo et al. (2019a)
*Open Atlantic Ocean	Surface	18.3–131.7 (59.8 ± 27.4)	34.0–103 (66.0 ± 19.0)	Zamanillo et al. (2019b)
Southwestern Atlantic Shelf	Surface	98.6–427.2 (255.7 ± 130.4)	28.0–110 (73.0 ± 36.0)	Zamanillo et al. (2019b)

*Oligotrophic ocean; A factor of 0.51 was used to convert TEP (μg Xeq L^{-1}) to TEP-C (μg C L^{-1}).

Table S2. Parameters for the calculation of residual $PreNO_3$/$PrePO_4$ in the Pacific Ocean

Depth (m)/neutral density (γ_n)	f_{DOM}	f_{POM}	r_{POM}	r_{DOM}
0−100 m/γ_n: 24.2−24.7	0.5±0.1	0.5±0.1	6.9, 8.75, 10.6	18.1
γ_n> 24.7	0.5±0.1	0.5±0.1	6.9, 8.75, 10.6	18.9

References:

Engel, A., Piontek, J., Metfies, K., Endres, S., Sprong, P., Peeken, I., et al.: Inter-annual variability of transparent exopolymer particles in the Arctic Ocean reveals high sensitivity to ecosystem changes, Scientific Reports. 7(1), 4129, https://doi.org/10.1038/s41598-017-04106-9, 2017.

Garcia, H. E.,Gordon, L. I.: Oxygen solubility in seawater: Better fitting equations, Limnol. Oceanogr., 37(6), 1307-1312, https://doi.org/10.4319/lo.1992.37.6.1307, 1992.

Ge, Z., Li, Q. P., Yang, W., Liu, X.,Wu, Z.: Transparent exopolymer particle dynamics along a shelf-to-sea gradient and impacts on the regional carbon cycle, Science of The Total Environment. 808, 152117, https://doi.org/10.1016/j.scitotenv.2021.152117, 2022.

Guo, S., Wu, Y., Zhu, M.,Sun, X.: Concentrations of transparent exopolymer particles (TEPs) and their role in the carbon export in the South China Sea and western tropical North Pacific, Marine Environmental Research. 179, 105699, https://doi.org/10.1016/j.marenvres.2022.105699, 2022.

Lee, J. H., Lee, W. C., Kim, H. C., Jo, N., Jang, H. K., Kang, J. J., et al.: Transparent Exopolymer Particle (TEPs) Dynamics and Contribution to Particulate Organic Carbon (POC) in Jaran Bay, Korea, Water. 12(4), 1057, https://doi.org/10.3390/w12041057, 2020.

Letscher, R. T.,Villareal, T. A.: Evaluation of the seasonal formation of subsurface negative preformed nitrate anomalies in the subtropical North Pacific and North Atlantic, Biogeosciences., 15(21), 6461-6480, https://doi.org/10.5194/bg-15-6461-2018, 2018.

Smyth, A. J.,Letscher, R. T.: Spatial and temporal occurrence of preformed nitrate anomalies in the subtropical North Pacific and North Atlantic oceans, Mar. Chem., 252, 104248, https://doi.org/10.1016/j.marchem.2023.104248, 2023.

Tian, D.: Stoichiometric deviation and regulatory mechanisms of AOU-nutrient ratio in the oligotrophic Northwest Pacific Ocean, Figshare [data set], https://doi.org/10.6084/m9.figshare.31841125, 2026.

Wen, L., Li, X., Song, J.,Ma, J.: Transparent exopolymer particle (TEP) and its impact on marine carbon transport along the East China Sea coast, Ecological Indicators. 137, 108791, https://doi.org/10.1016/j.ecolind.2022.108791, 2022.

Zamanillo, M., Ortega-Retuerta, E., Nunes, S., Estrada, M., Sala, M. M., Royer, S. J., et al.: Distribution of transparent exopolymer particles (TEP) in distinct regions of the Southern

Ocean, Science of The Total Environment. 691, 736-748, https://doi.org/10.1016/j.scitotenv.2019.06.524, 2019a.

Zamanillo, M., Ortega-Retuerta, E., Nunes, S., Rodríguez-Ros, P., Dall'Osto, M., Estrada, M., et al.: Main drivers of transparent exopolymer particle distribution across the surface Atlantic Ocean, Biogeosciences. 16(3), 733-749, https://doi.org/10.5194/bg-16-733-2019, 2019b.