

Supplementary information

A 1-km weekly dataset of floating *Ulva prolifera* and *Sargassum horneri* blooms in China's marginal seas derived from multi-sensor satellite observations

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95 **S1. Supporting Tables**

Table S1 summarizes the details of the HYCOM surface ocean current products used in this study, corresponding to the environmental data described in **Section 2.1.3**. These products were integrated to ensure continuous temporal coverage for the numerical particle tracking experiments from 2018 to 2025.

Tables S2 and S3 present detailed species-specific extraction accuracies for *U. prolifera* and *S. horneri*, respectively, complementing the results described in **Section 3.1**.

Tables S4 and S5 provide comparisons of seasonal peak biomass estimates derived from monthly and weekly composites for *U. prolifera* and *S. horneri*, respectively, demonstrating the influence of temporal aggregation on peak biomass characterization and supporting the selection of weekly composites for long-term bloom monitoring (**Section 3.3**).

TableS1. Version information of ocean current data.

Version	Time range	Temporal resolution	Spatial resolution
ESPC-D-V02-expt_03.1	2024.09.01–2025.12.31	Daily	0.08° lon × 0.04° lat
GLBy0.08-expt_93.0	2018.12.01–2024.08.31		
GLBv0.08-expt_93.0	2018.01.01–2018.11.30		0.08° lon × 0.08° lat

Table S2. Accuracy of FANet-based *U. prolifera* extraction across MODIS, OLCI, VIIRS SNPP, and VIIRS NOAA-20.

Sensor	Precision	Recall	F1 score	IoU
MODIS	94.68%	96.68%	95.67%	91.70%
OLCI	93.57%	97.17%	95.33%	91.08%
VIIRS SNPP	96.83%	93.25%	95.01%	90.49%
VIIRS NOAA-20	96.01%	96.91%	96.46%	93.17%

Table S3. Accuracy of FANet-based *S. horneri* extraction across MODIS, OLCI, VIIRS SNPP, and VIIRS NOAA-20.

Sensor	Precision	Recall	F1 score	IoU
MODIS	92.75%	92.81%	92.78%	86.54%
OLCI	88.50%	95.80%	92.00%	85.20%
VIIRS SNPP	86.50%	84.20%	85.34%	74.42%
VIIRS NOAA-20	82.71%	85.27%	83.97%	72.37%

Table S4. Comparison of seasonal peak biomass estimates derived from monthly and weekly composites for *U. prolifera* during 2018–2025.

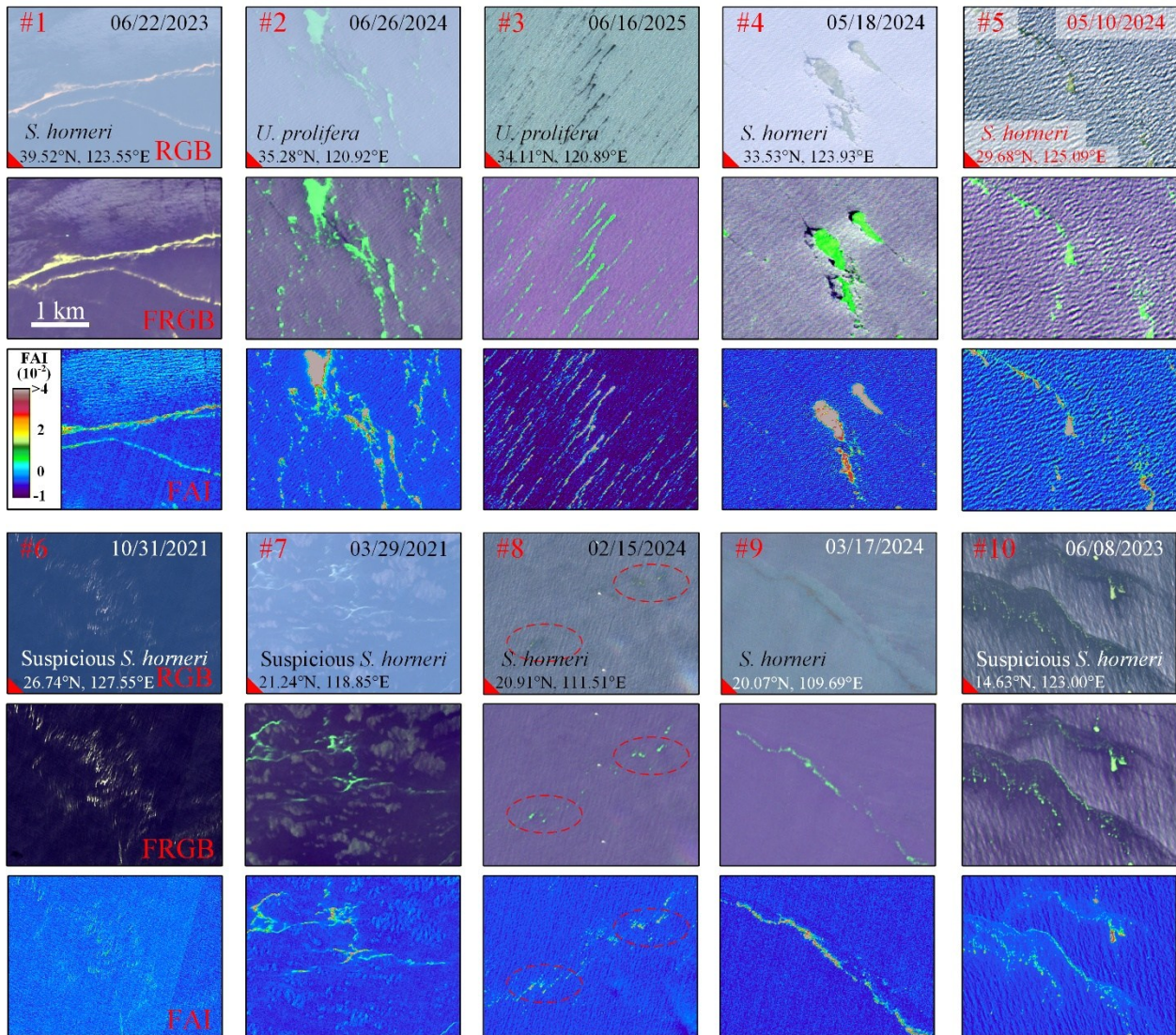
Year	Monthly biomass (tons)	Weekly biomass (tons)	Difference (tons)	Relative difference (%)
2018	732,799	1,252,402	519,603	41.49%
2019	3,045,299	4,529,120	1,483,821	32.76%
2020	518,302	591,164	72,862	12.32%
2021	3,451,459	5,315,601	1,864,142	35.07%
2022	383,728	653,503	269,775	41.28%
2023	1,212,836	2,011,171	798,335	39.69%
2024	1,080,874	1,364,629	283,755	20.79%
2025	1,860,185	3,857,027	1,996,842	51.77%

Table S5. Comparison of seasonal peak biomass estimates derived from monthly and weekly composites for *S. horneri* during 2018–2025.

Year	Monthly biomass (tons)	Weekly biomass (tons)	Difference (tons)	Relative difference (%)
2018	184,994	251,321	66,327	26.39%
2019	642,870	886,950	244,080	27.52%
2020	432,541	703,005	270,464	38.47%
2021	164,541	265,559	101,018	38.04%
2022	497,714	652,363	154,649	23.71%
2023	86,638	138,775	52,137	37.57%
2024	1,311,557	2,326,154	1,014,597	43.62%
2025	48,657	97,389	48,732	50.04%

S2. Supporting Figures

125 In **Figure S1**, Sentinel-2 RGB, false RGB (FRGB), and floating algae index (FAI) images corresponding to **Figure 1(b)** are presented, providing representative examples of satellite observations and spectral characteristics of floating macroalgae in China's marginal seas.



130 **Figure S1.** The Sentinel-2 RGB, FRGB, and FAI images corresponding to those shown in **Figure. 1(b).**

Figures S2 and S3 provide representative examples of *Trichodesmium* detected in China's marginal seas. These examples include MODIS, MSI, and OCI observations, together with their corresponding reflectance spectra. The OCI AFAI imagery further highlights *Trichodesmium* occurrences in the northern South China Sea (Beibu Gulf). As *Trichodesmium* can exhibit strong near-infrared reflectance and form elongated surface slicks with pronounced AFAI signals, it can also be detected in medium-resolution satellite imagery. These cases illustrate the distinct hyperspectral reflectance characteristics used to distinguish *Trichodesmium* from floating macroalgae and to exclude it from the analysis.

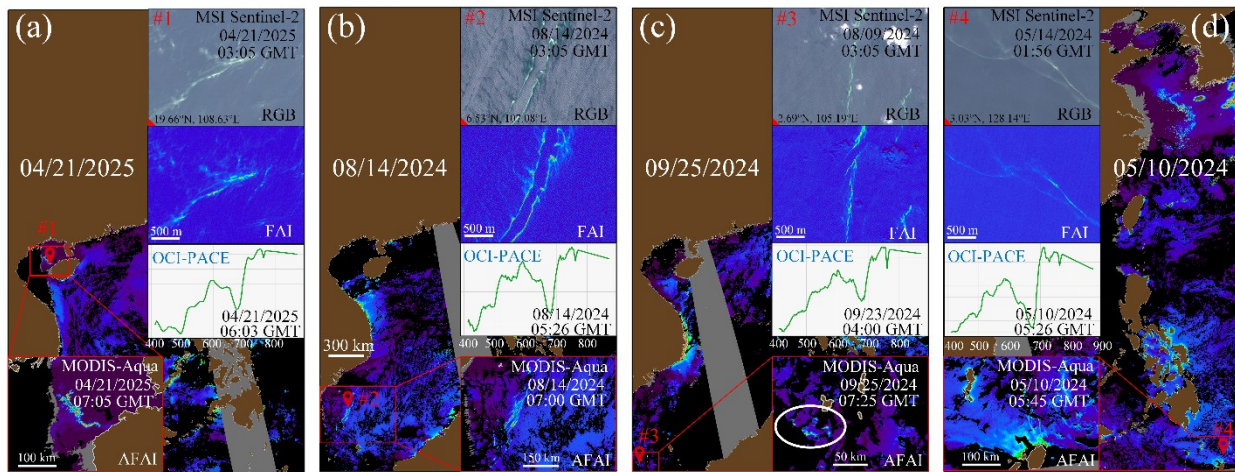


Figure S2. Representative examples of *Trichodesmium* in China's marginal seas, including MODIS and MSI imagery, along with its reflectance spectra derived from OCI observations.

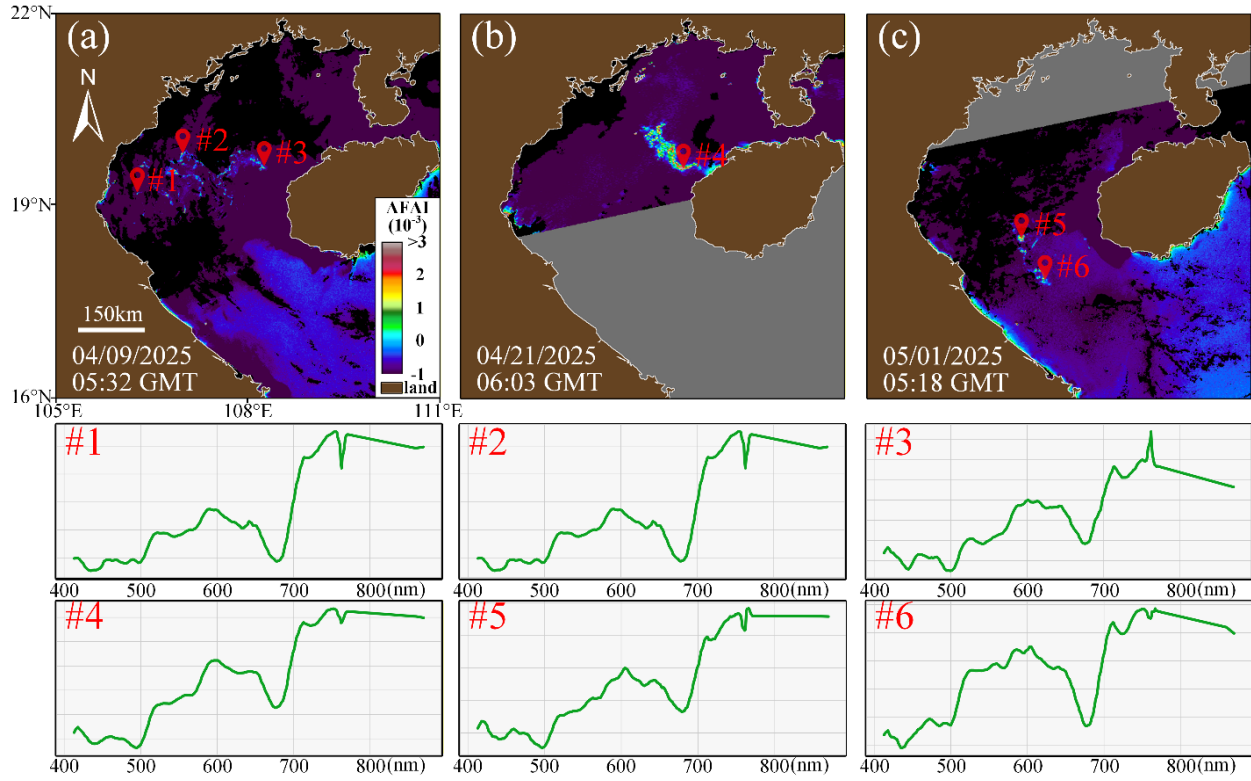


Figure S3. *Trichodesmium* observed in the northern South China Sea (Beibu Gulf) from OCI AFAI imagery, together with the corresponding reflectance spectra.

150 **Figures S4 and S5** present additional inter-sensor comparisons of daily biomass estimates for *U. prolifera* and *S. horneri*, respectively, using expanded cloud masks to account for potential macroalgal drifting. Compared with the results shown in **Figures 5 and 6**, the regression slopes exhibit minimal changes after applying the expanded cloud masks, indicating that drifting has a negligible impact on cross-sensor consistency. These results further confirm the robustness of

155 the multi-sensor integration approach and support the generation of continuous, high-frequency bloom datasets despite variations in observation conditions.

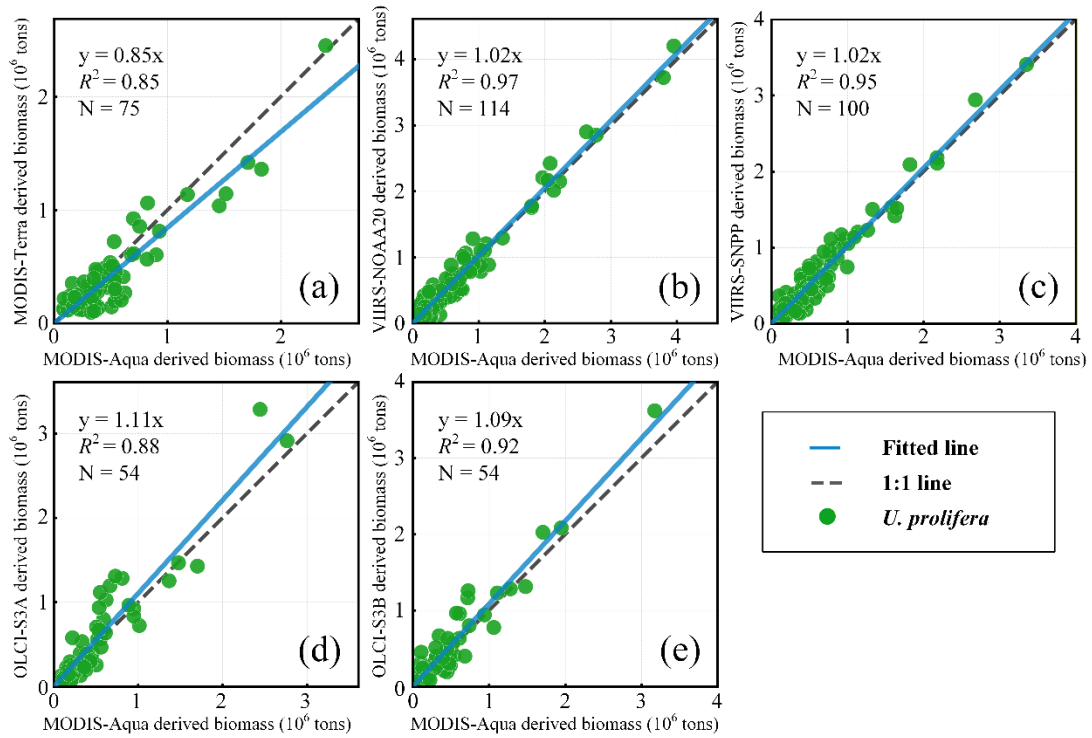


Figure S4. Scatter plots of daily satellite-derived *U. prolifera* biomass in the Yellow Sea from MODIS Aqua compared with MODIS Terra (a), VIIRS NOAA-20 (b), VIIRS SNPP (c), OLCI S3A (d), and OLCI S3B (e), using the expanded cloud masks to account for potential macroalgal drifting. The dashed lines represent the 1:1 lines.

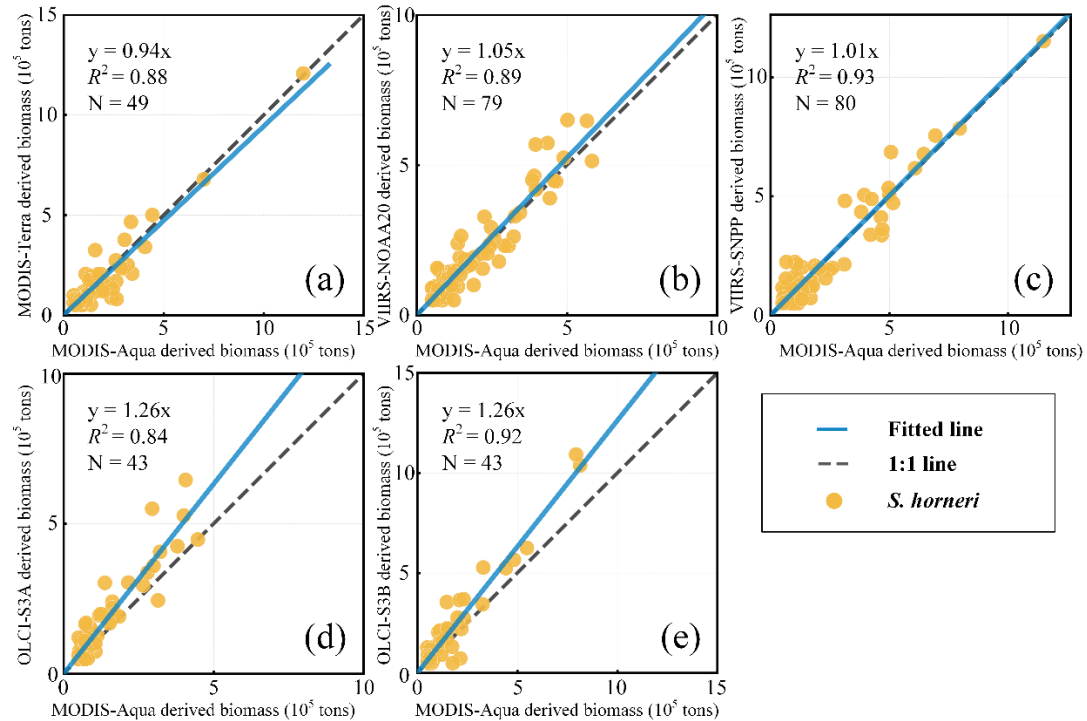


Figure S5. Scatter plots of daily satellite-derived *S. horneri* biomass in Yellow Sea and East China Sea from MODIS Aqua compared with MODIS Terra (a), VIIRS NOAA-20 (b), VIIRS SNPP (c), OLCI S3A (d), and OLCI S3B (e), using the expanded cloud masks to account for potential macroalgal drifting. The dashed lines represent the 1:1 lines.

Figure S6 compares annual peak biomass estimates of *U. prolifera* derived from daily and weekly composites during 2018–2025. This comparison evaluates the influence of temporal aggregation on the characterization of interannual bloom intensity. Daily composites retain high-frequency biomass variations but may be affected by short-term fluctuations, which can influence the identification of dominant bloom years. Weekly composites reduce these transient variations while preserving major bloom signals, providing a more consistent basis for long-term interannual comparisons.

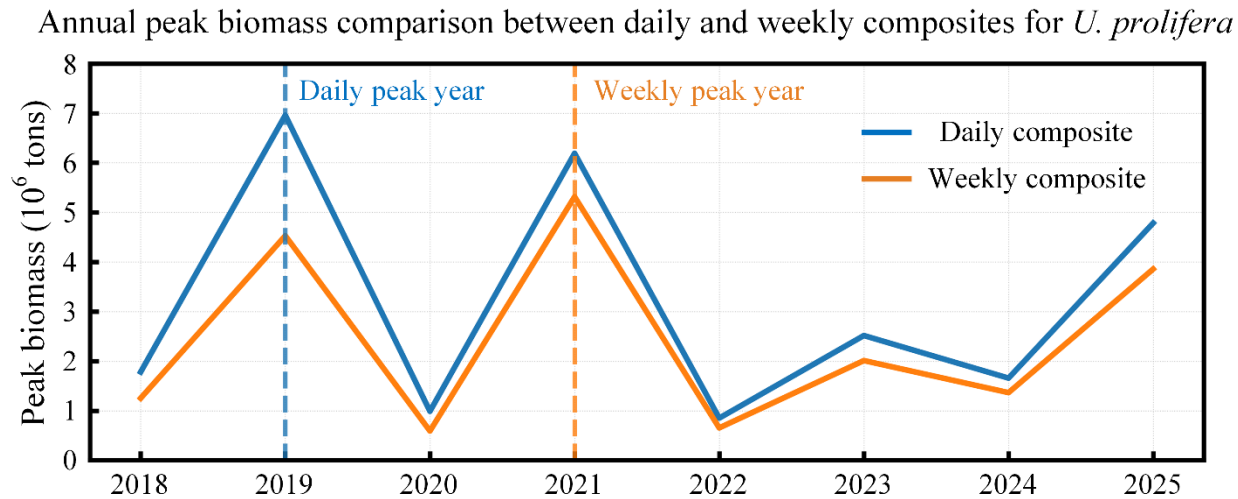


Figure S6. Annual peak biomass comparison between daily and weekly composites for *U. prolifera* during 2018–2025. Dashed lines indicate the peak biomass years identified from daily and weekly composites.

Figures S7–S14 and S17–24 present the weekly cumulative footprint and mean biomass density of *U. prolifera* and *S. horneri*, respectively, for each year from 2018 to 2025 during their bloom seasons. These figures illustrate the week-to-week evolution of bloom spatial distributions.

Figures S15 and S25 summarize the cumulative footprint and mean biomass density during the bloom seasons for *U. prolifera* and *S. horneri*, respectively. These figures highlight interannual variability in bloom extent and intensity and provide an integrated view of seasonal bloom conditions across years.

Figures S16 and S26 show multi-sensor observations during representative weeks with anomalous biomass fluctuations in **Figures 10 and 13**. These figures demonstrate that such fluctuations are primarily associated with reduced valid observations caused by extensive cloud coverage.

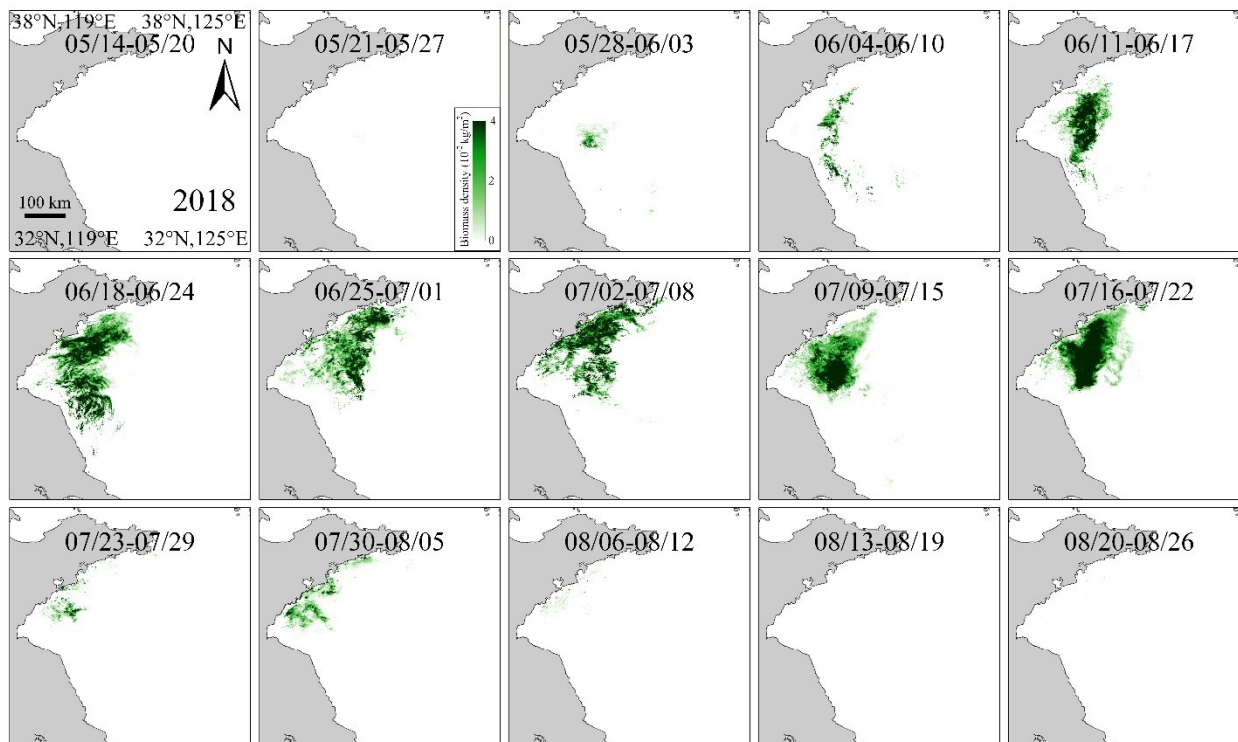


Figure S7. Weekly cumulative footprint and mean biomass density of *U. prolifera* in the Yellow Sea from mid-May to August 2018.

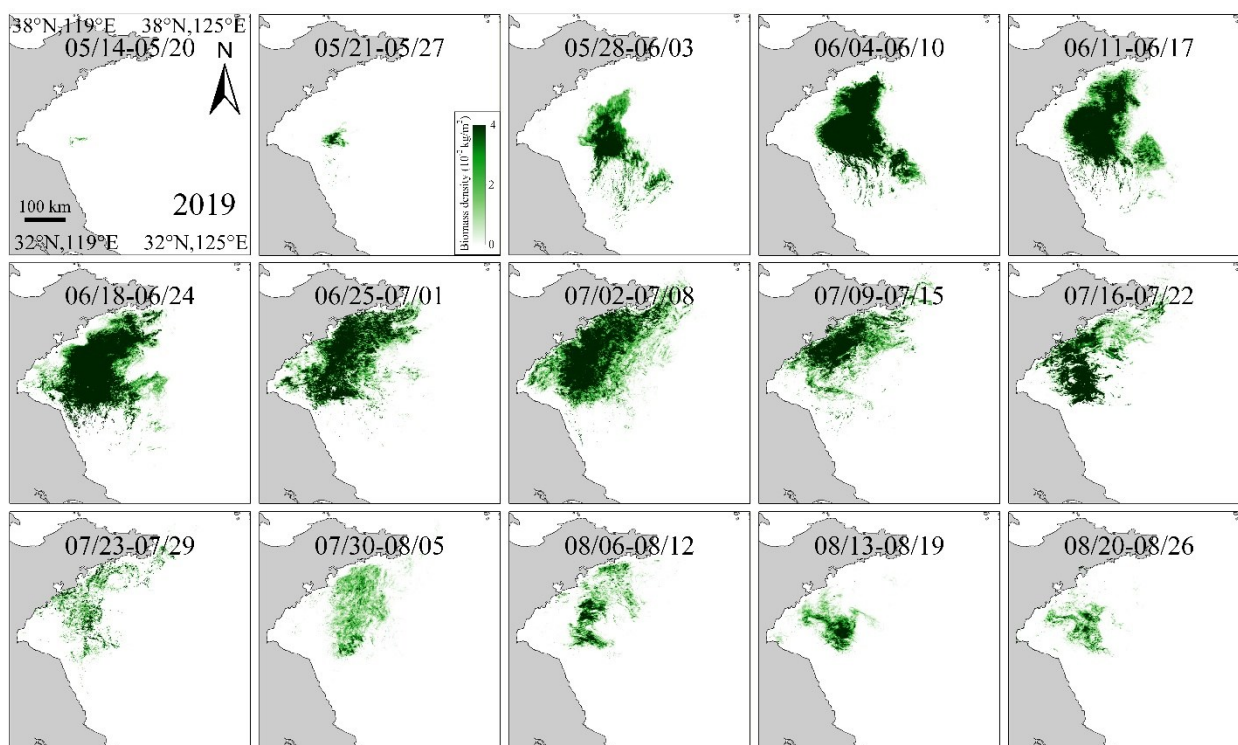


Figure S8. Weekly cumulative footprint and mean biomass density of *U. prolifera* in the Yellow Sea from mid-May to August 2019.

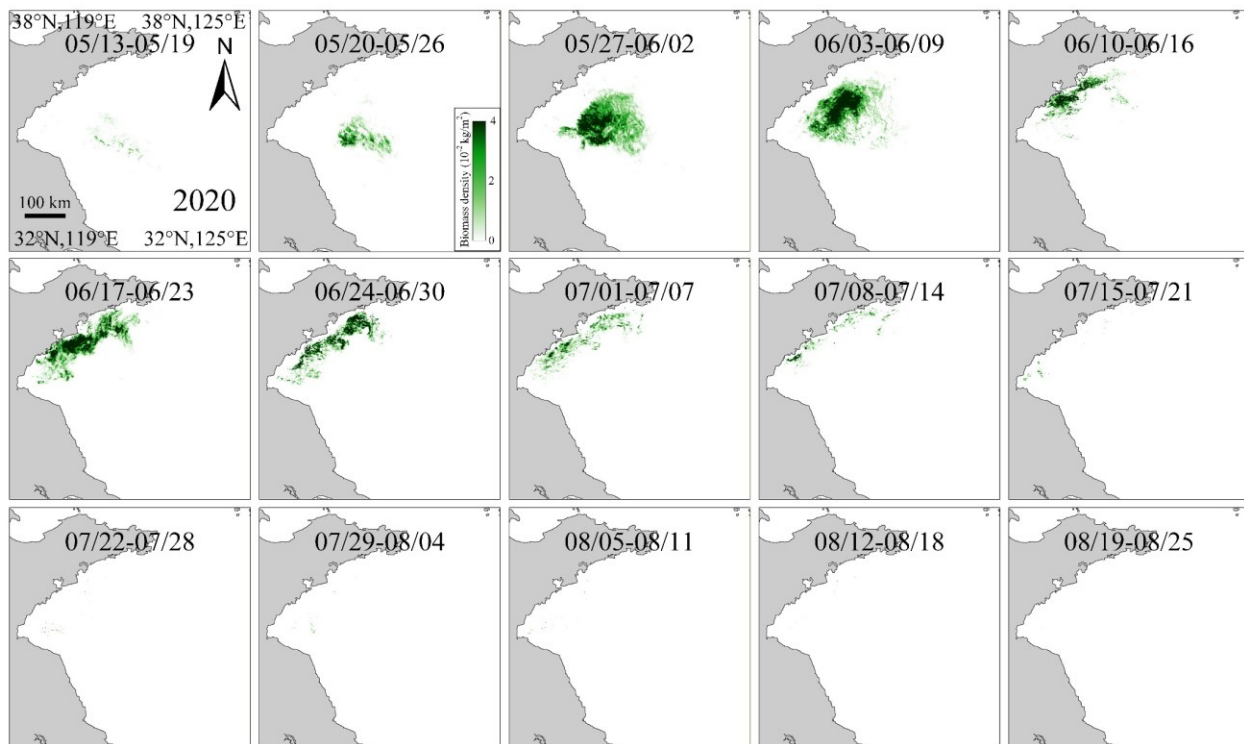


Figure S9. Weekly cumulative footprint and mean biomass density of *U. prolifera* in the Yellow Sea from mid-May to August 2020.

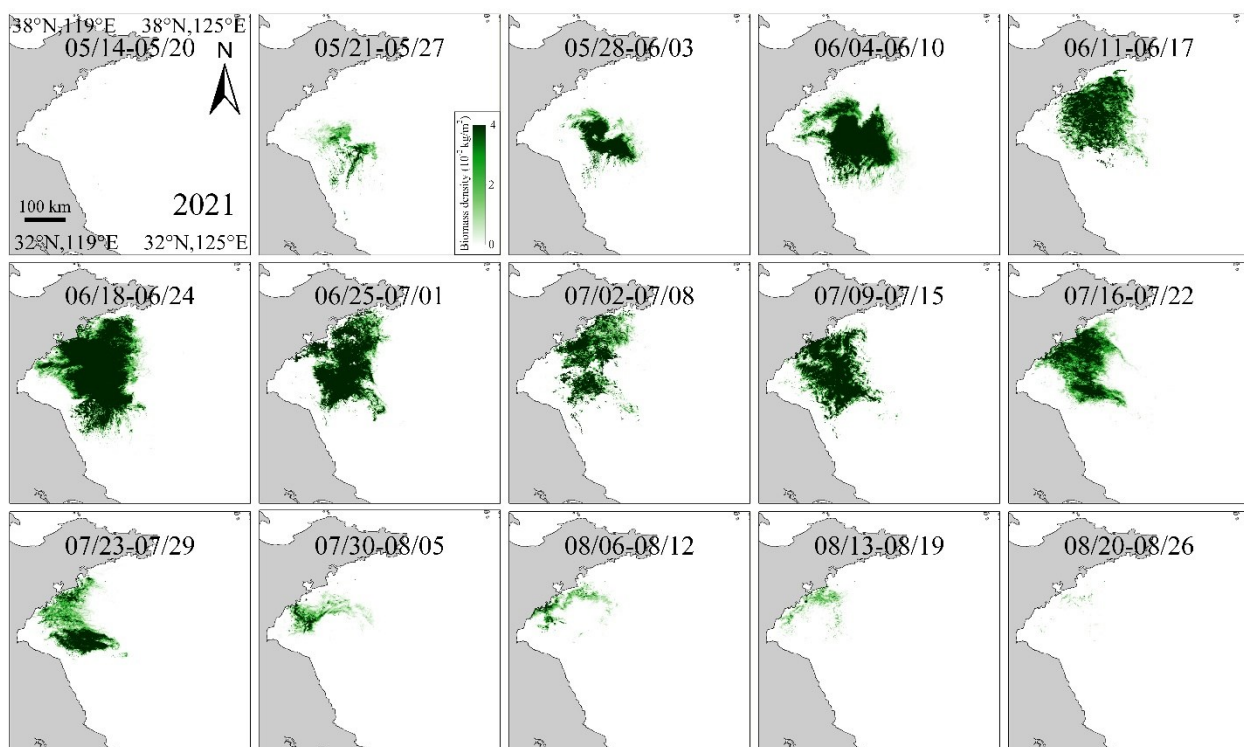


Figure S10. Weekly cumulative footprint and mean biomass density of *U. prolifera* in the Yellow Sea from mid-May to August 2021.

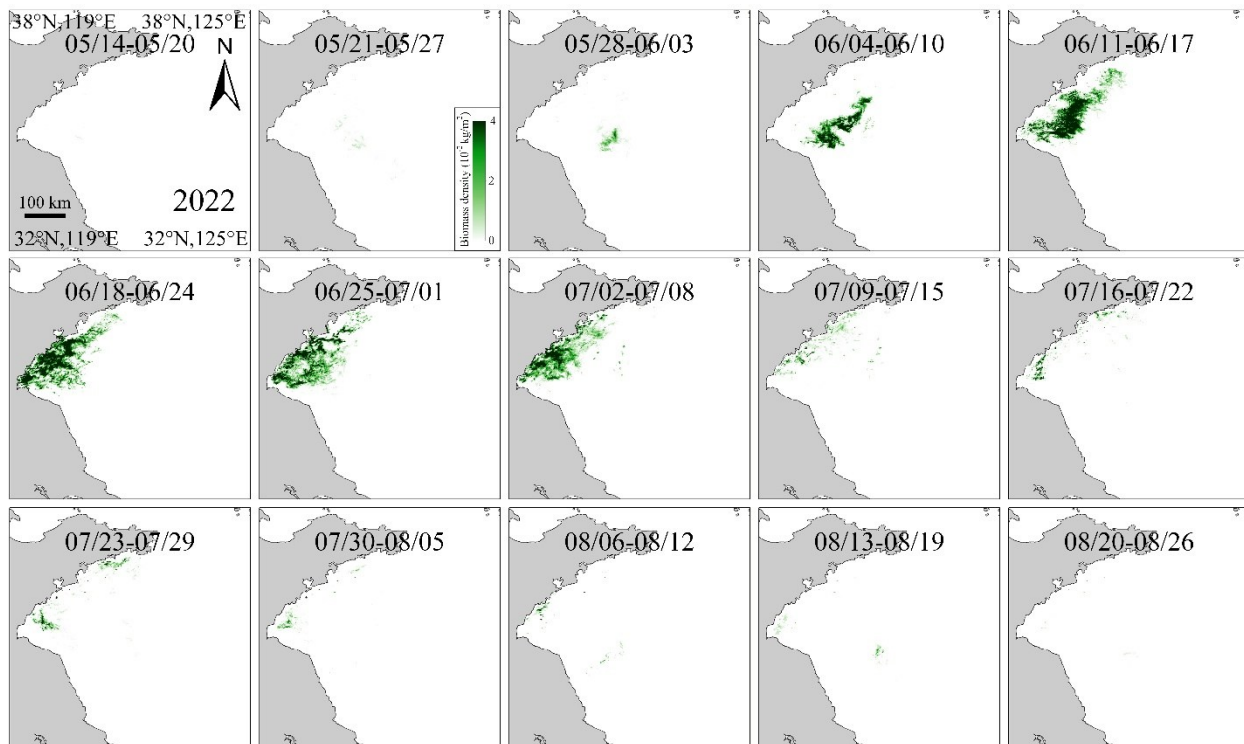


Figure S11. Weekly cumulative footprint and mean biomass density of *U. prolifera* in the Yellow Sea from mid-May to August 2022.

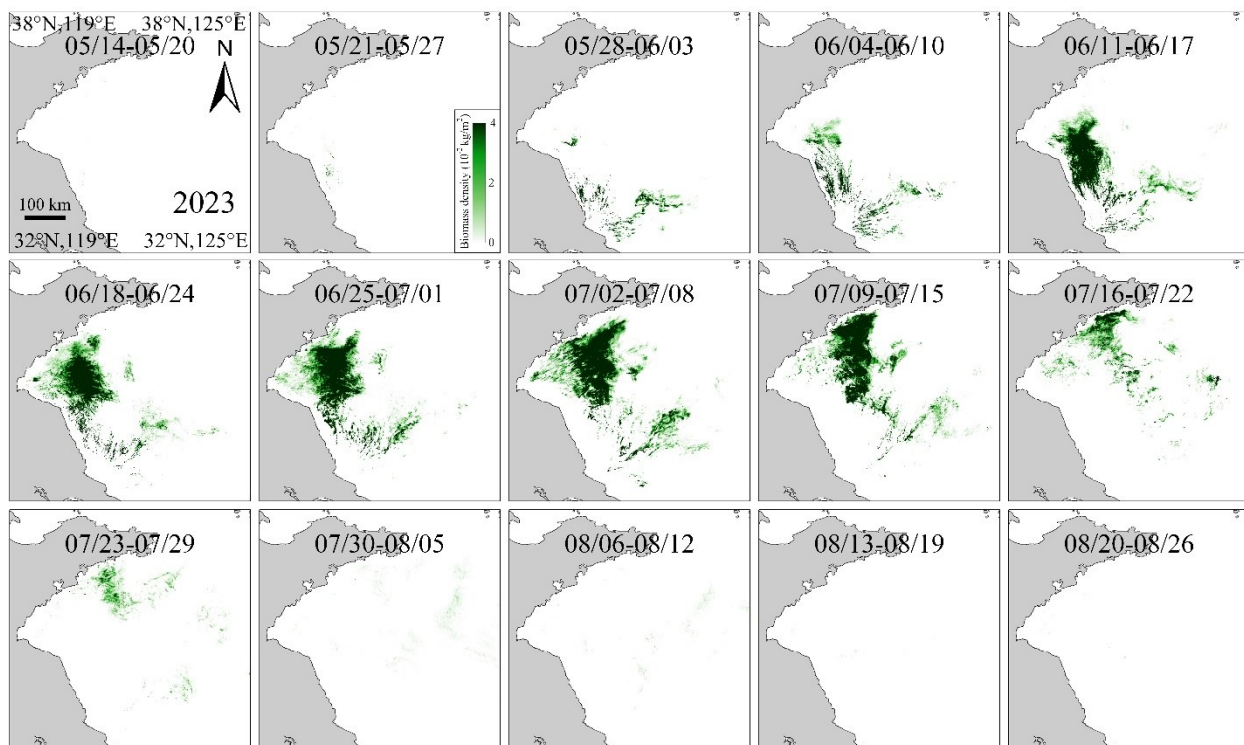


Figure S12. Weekly cumulative footprint and mean biomass density of *U. prolifera* in the Yellow Sea from mid-May to August 2023.

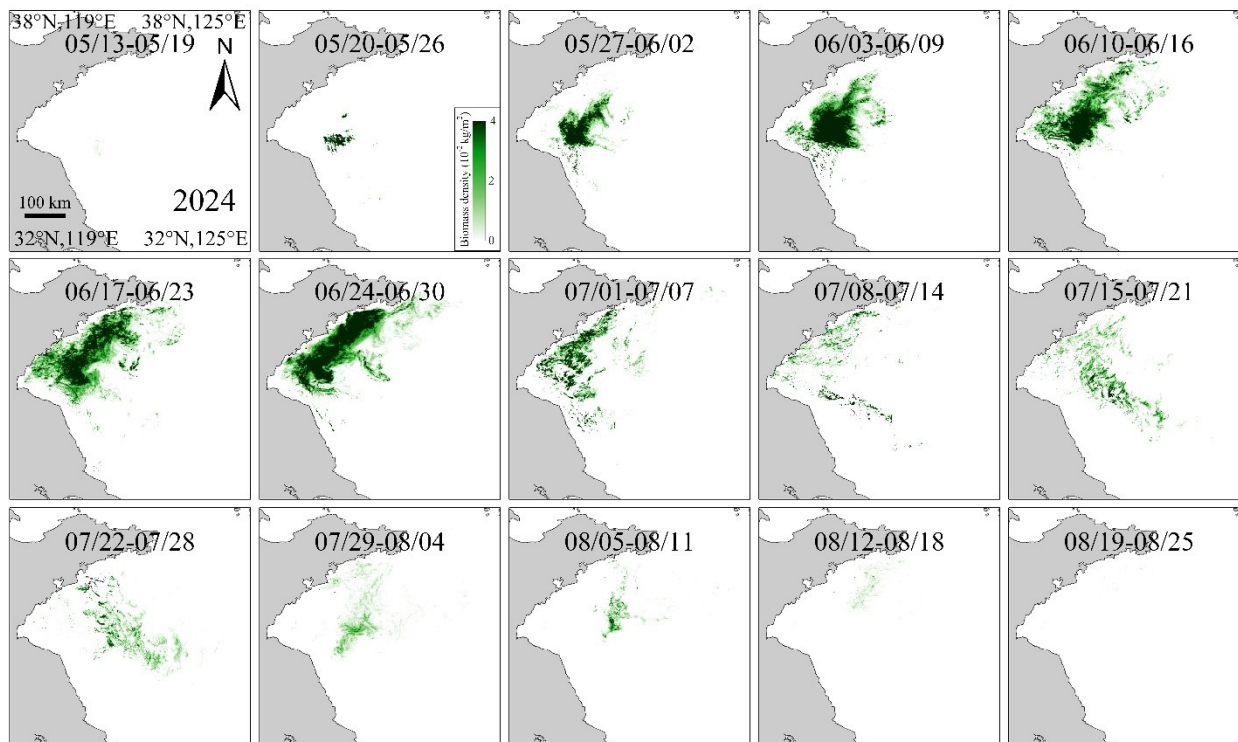


Figure S13. Weekly cumulative footprint and mean biomass density of *U. prolifera* in the Yellow Sea from mid-May to August 2024.

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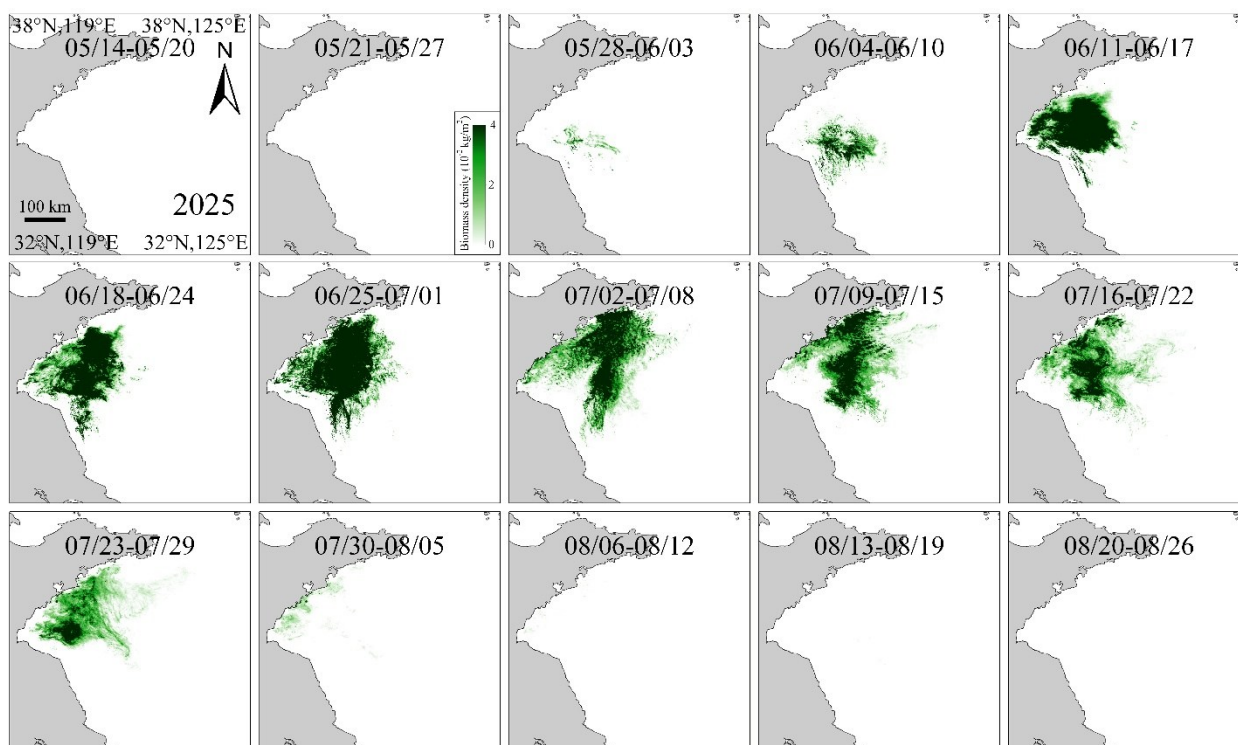


Figure S14. Weekly cumulative footprint and mean biomass density of *U. prolifera* in the Yellow Sea from mid-May to August 2025.

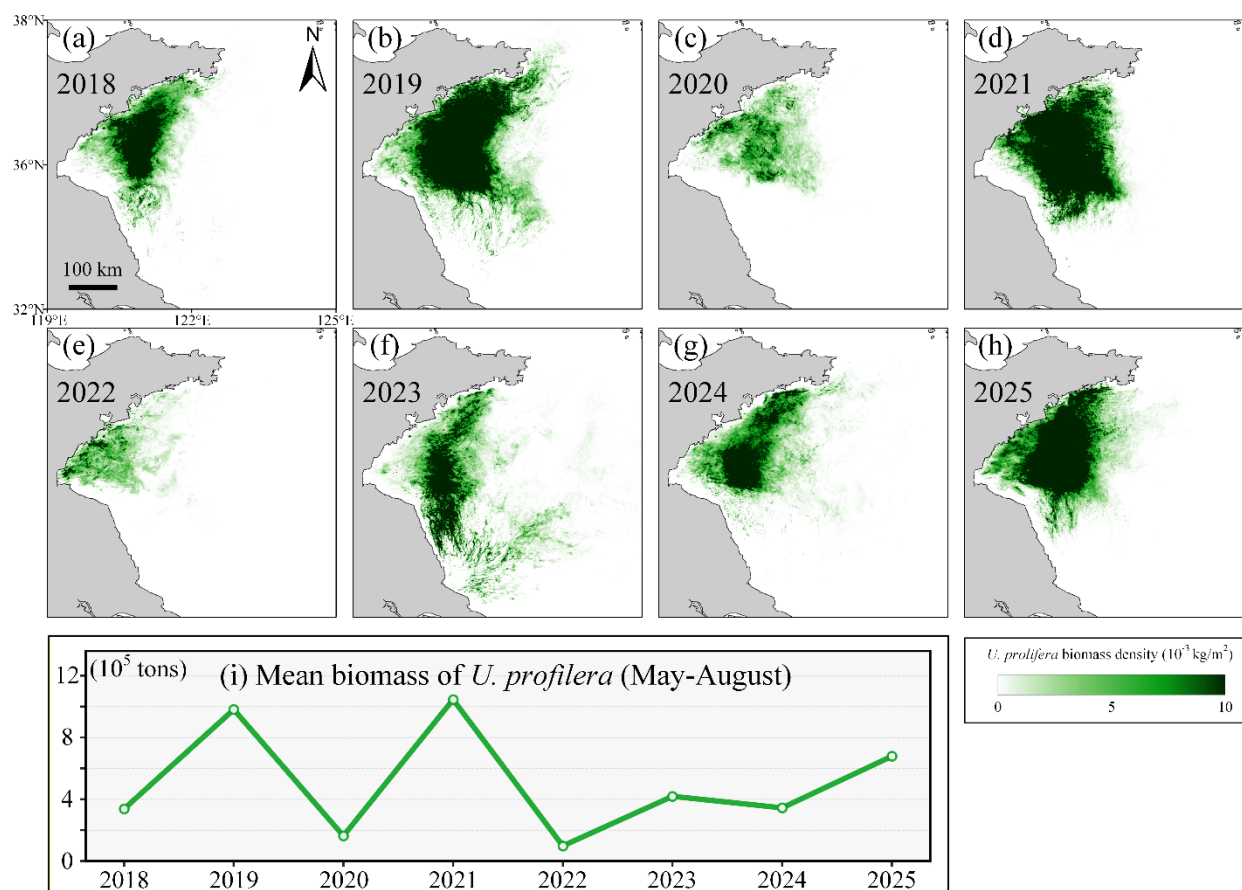


Figure S15. Cumulative footprint and mean biomass density of *U. prolifera* in the Yellow Sea from 2018 to 2025. (a–h) Cumulative footprint and mean biomass density from May to August for each year. (i) Interannual variation in mean biomass from May to August, 2018–2025.

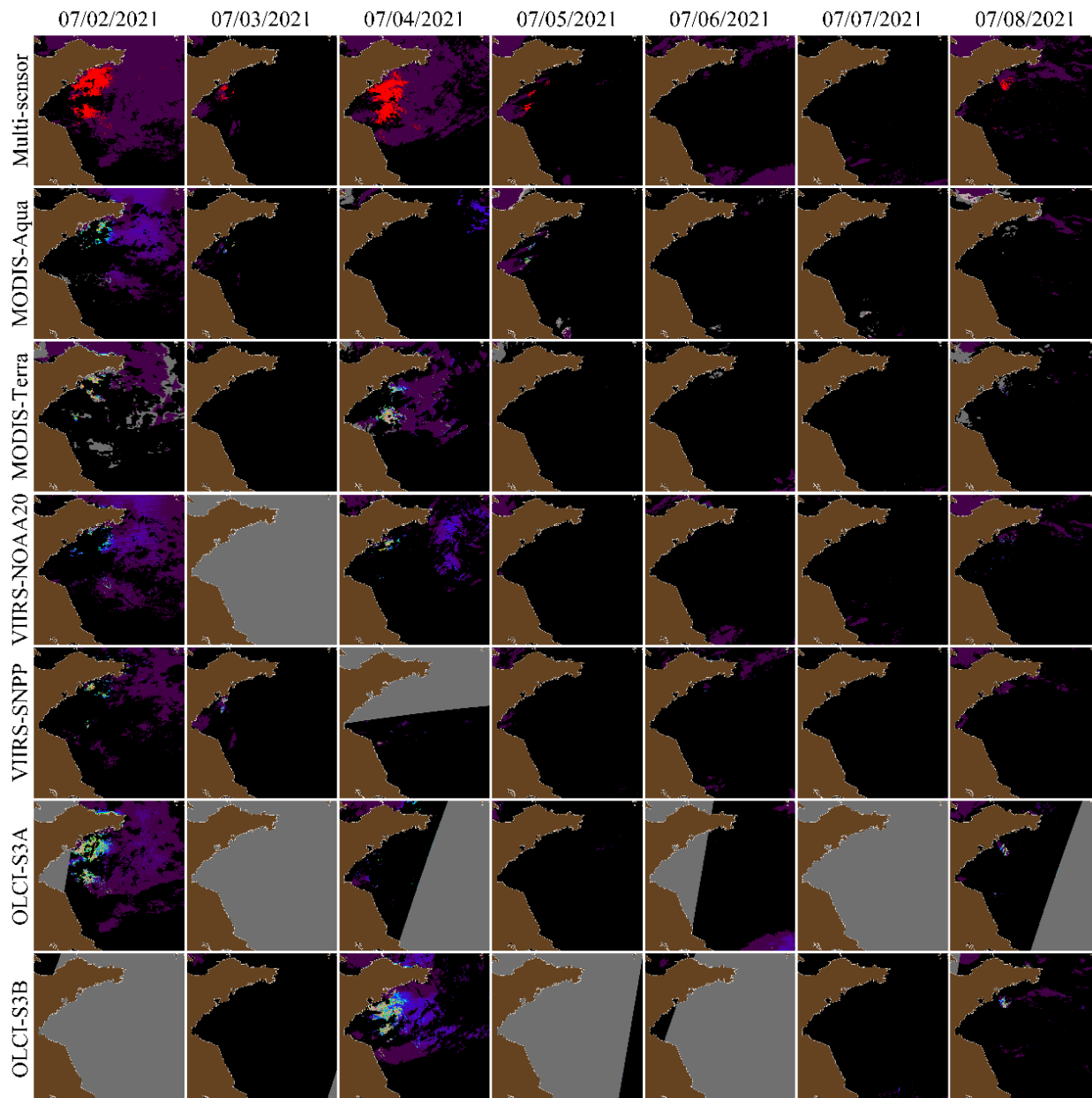


Figure S16. AFAl images of the Yellow Sea from July 2 to 8, 2021, obtained from six satellite sensors (MODIS Aqua, MODIS Terra, VIIRS NOAA-20, VIIRS SNPP, OLCI S3A, and OLCI S3B). Black indicates clouds, while gray denotes no-data or invalid observations.

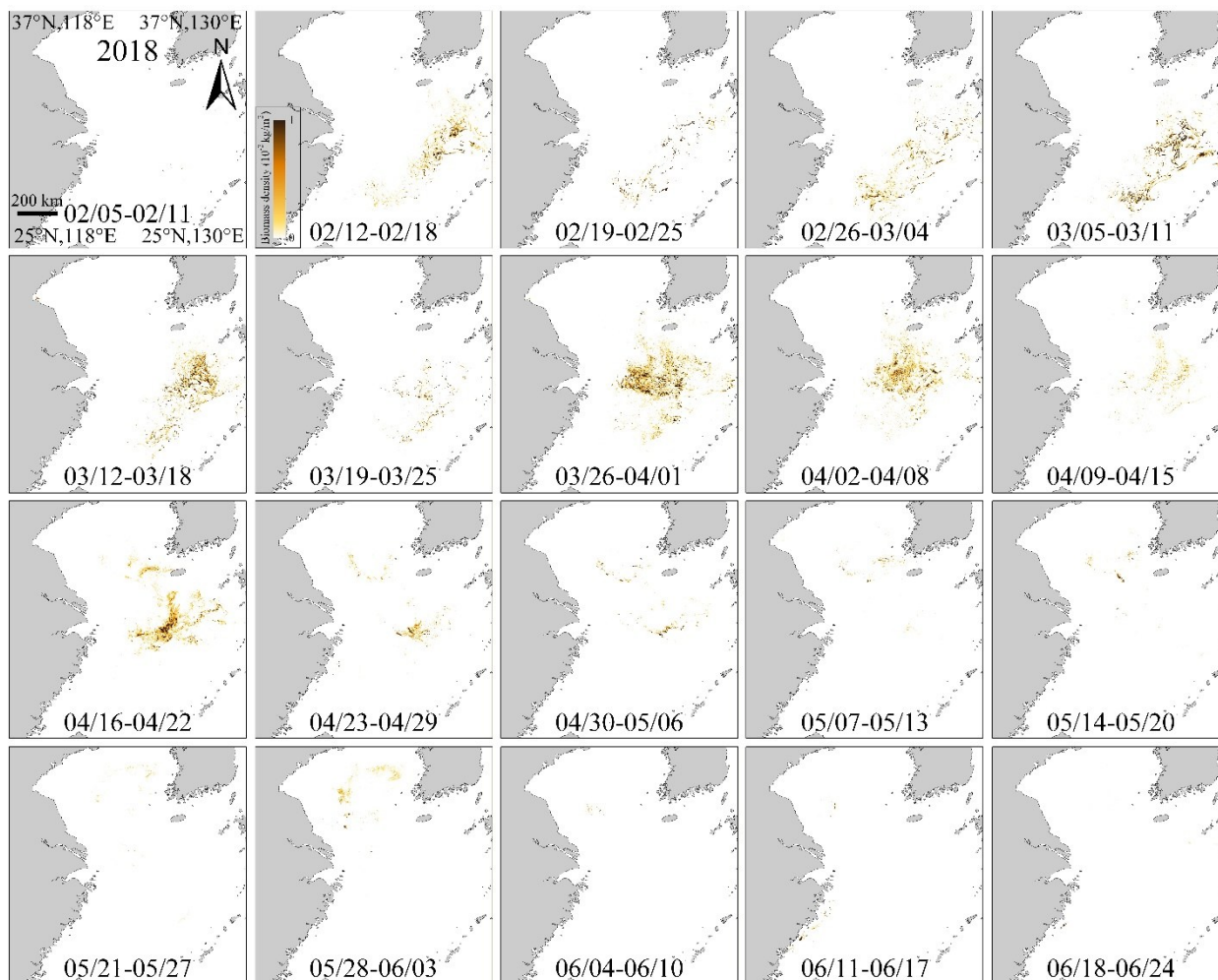


Figure S17. Weekly cumulative footprint and mean biomass density of *S. horneri* in the East China Sea and Yellow Sea from mid-May to August 2018.

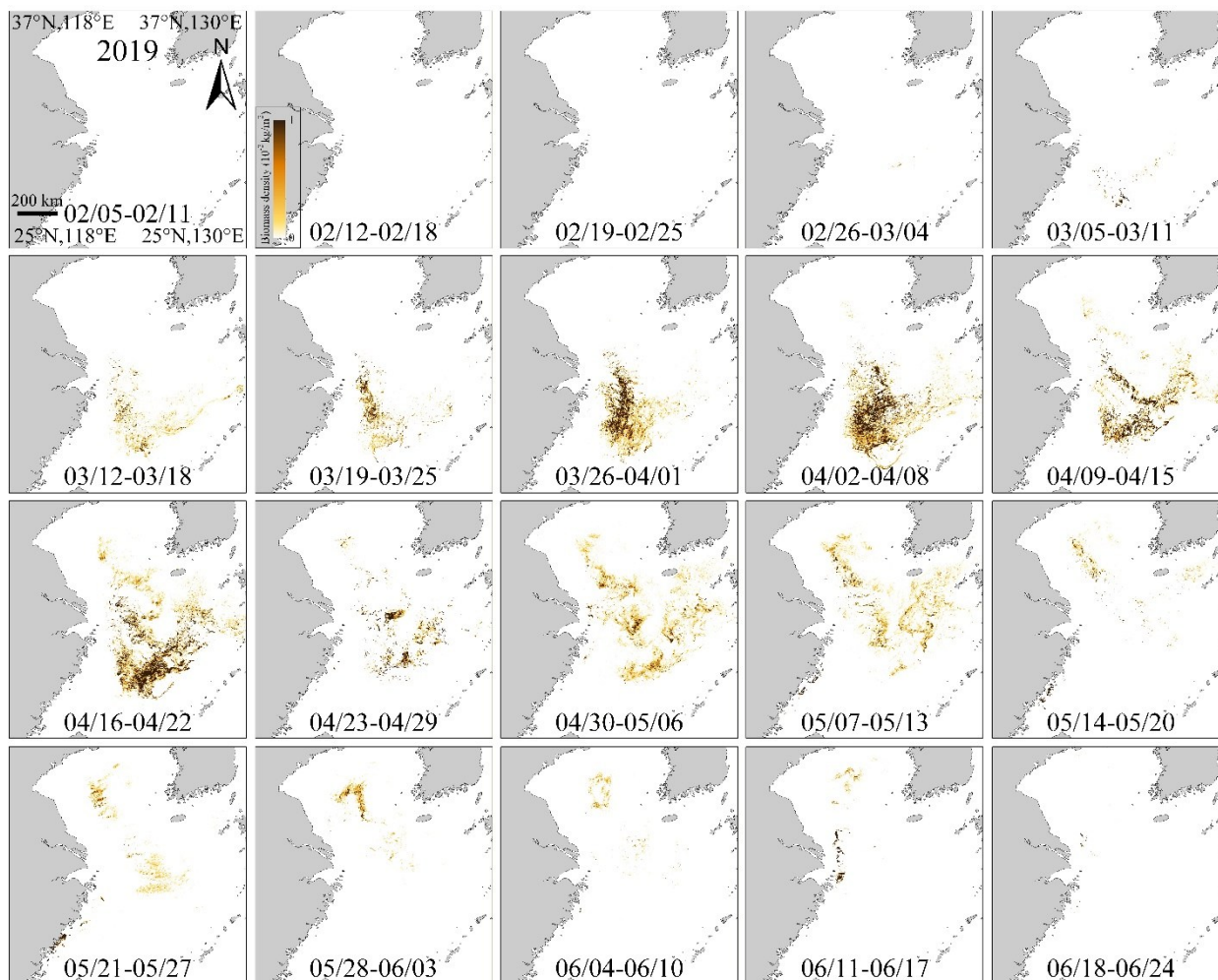


Figure S18. Weekly cumulative footprint and mean biomass density of *S. horneri* in the East China Sea and Yellow Sea from mid-May to August 2019.

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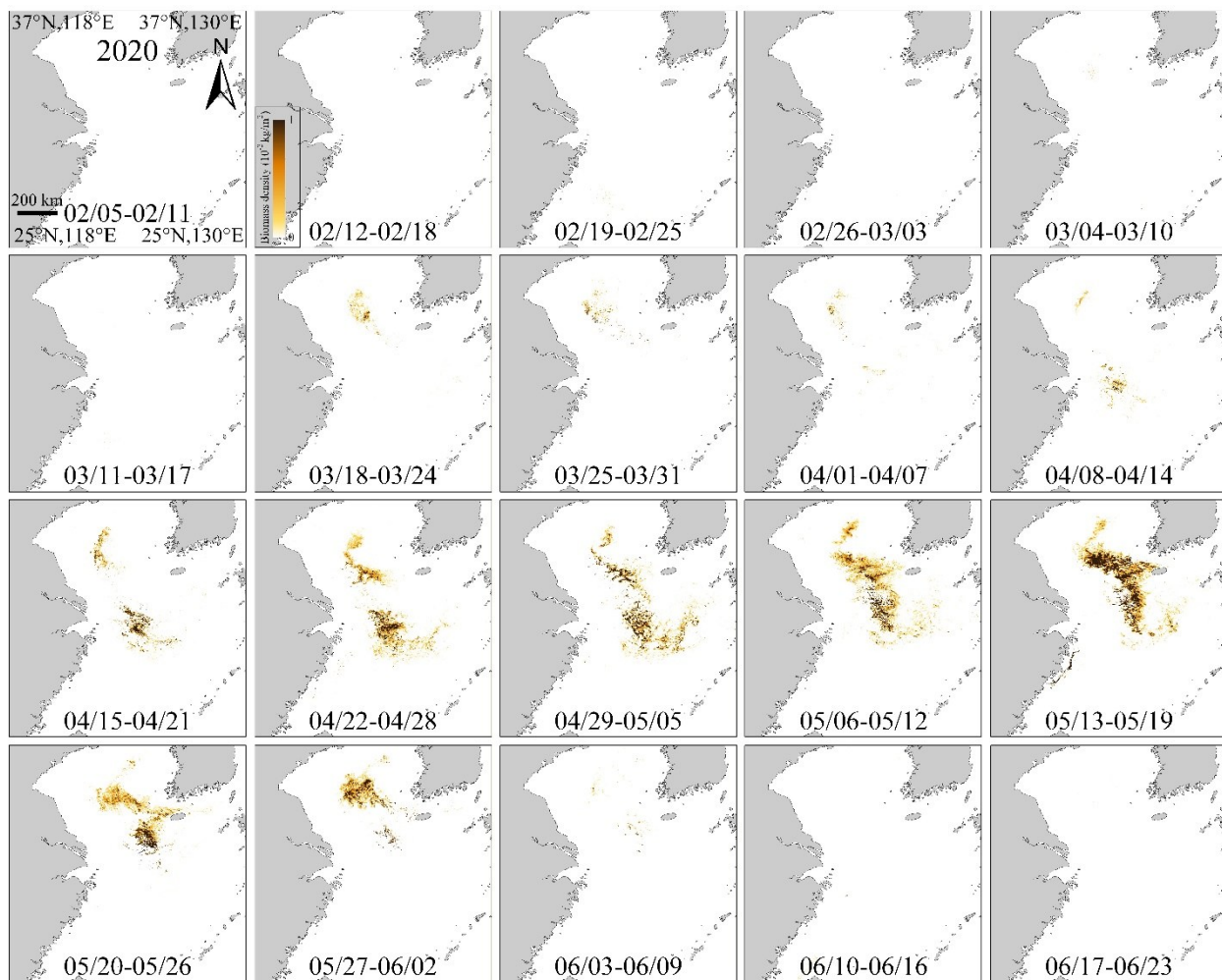


Figure S19. Weekly cumulative footprint and mean biomass density of *S. horneri* in the East China Sea and Yellow Sea from mid-May to August 2020.

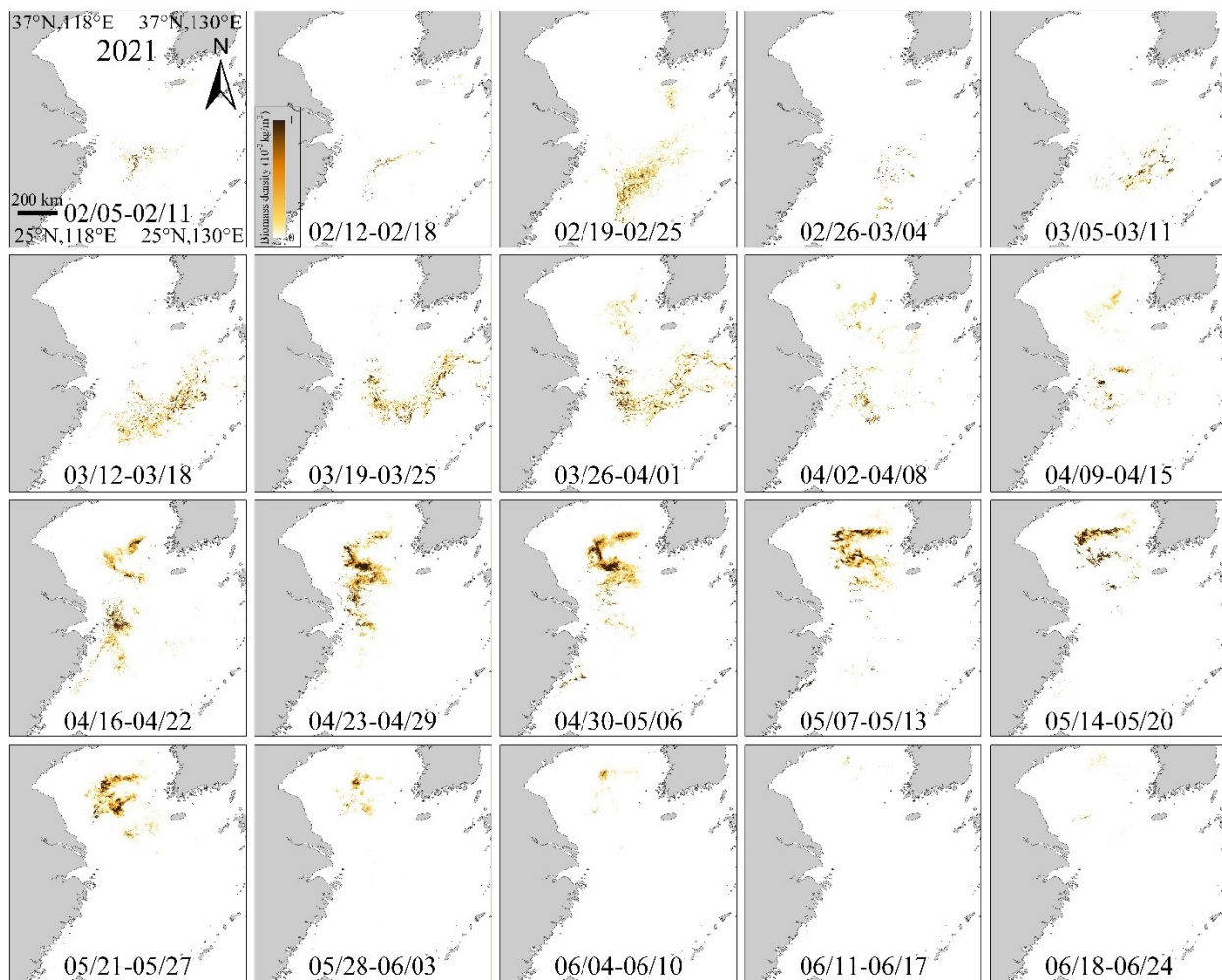


Figure S20. Weekly cumulative footprint and mean biomass density of *S. horneri* in the East China Sea and Yellow Sea from mid-May to August 2021.

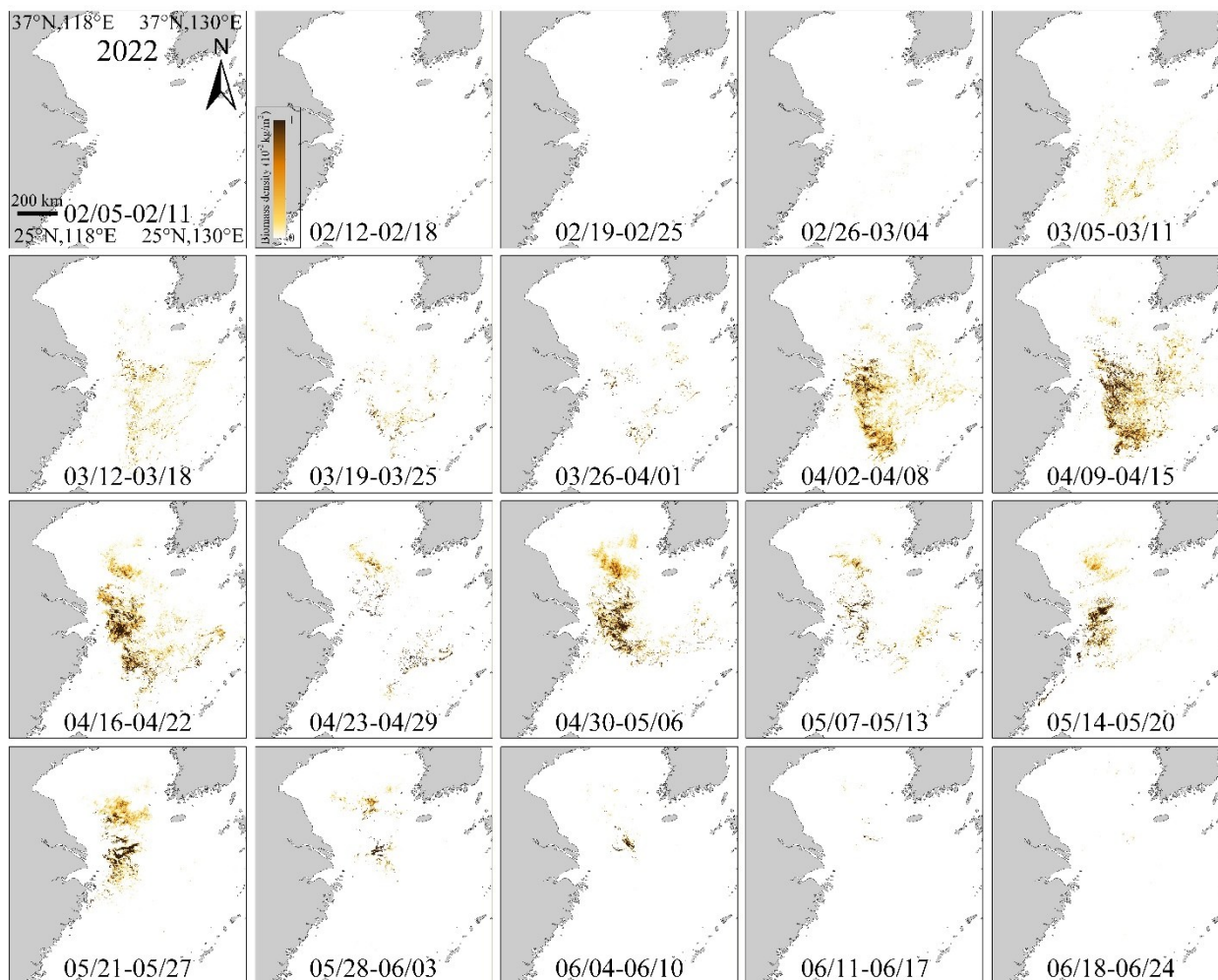
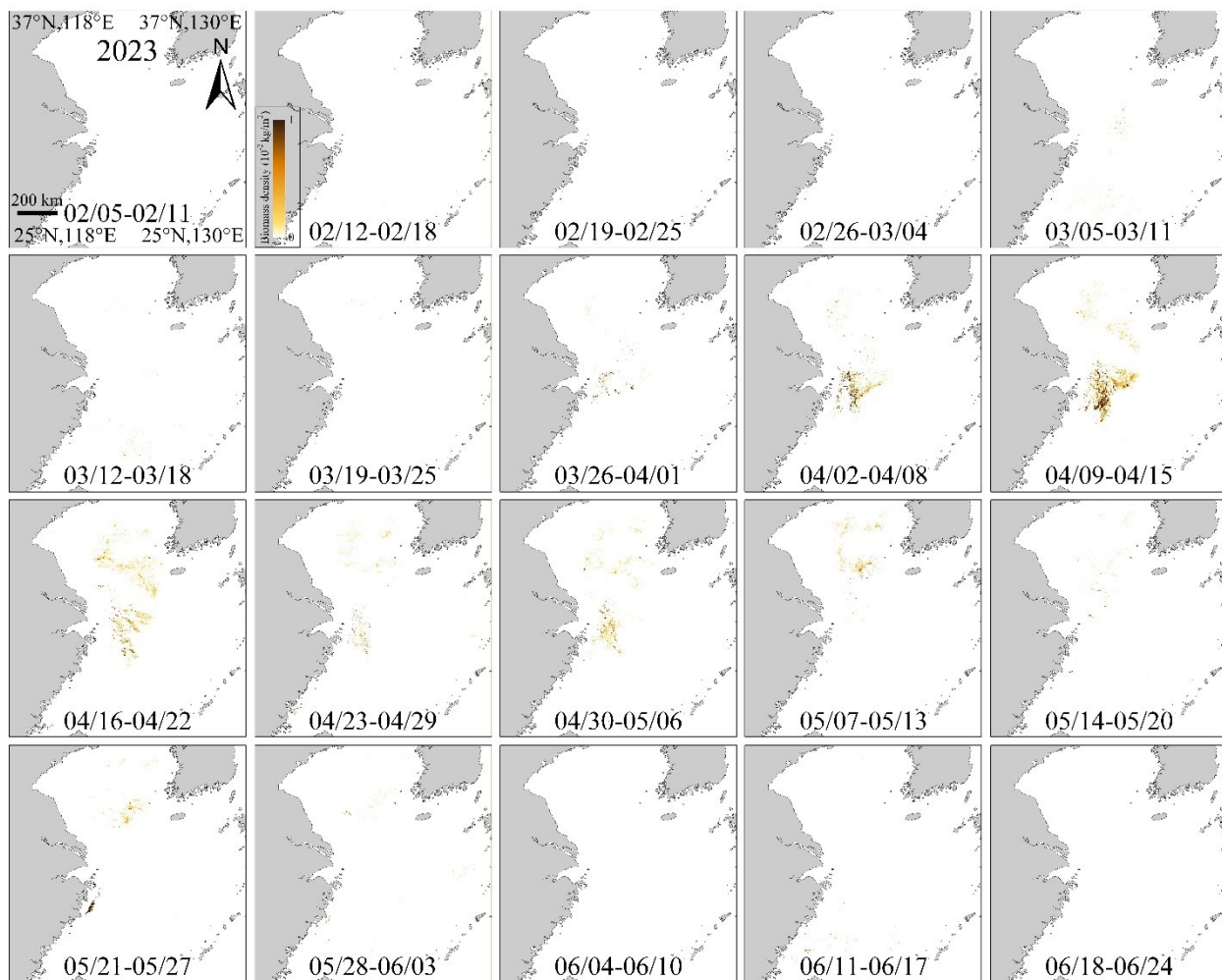


Figure S21. Weekly cumulative footprint and mean biomass density of *S. horneri* in the East China Sea and Yellow Sea from mid-May to August 2022.



255 **Figure S22. Weekly cumulative footprint and mean biomass density of *S. horneri* in the East China Sea and Yellow Sea from mid-May to August 2023.**

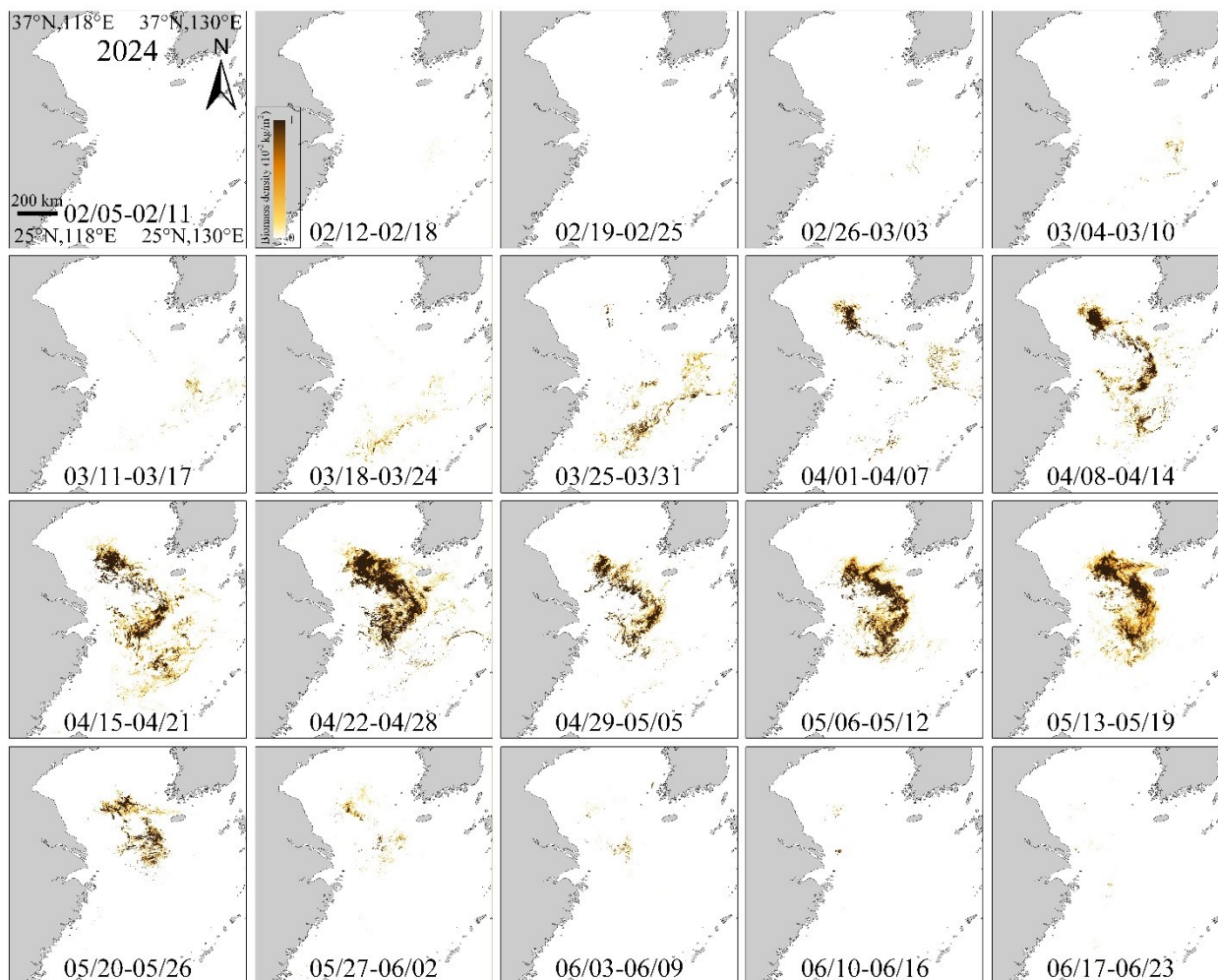


Figure S23. Weekly cumulative footprint and mean biomass density of *S. horneri* in the East China Sea and Yellow Sea from mid-May to August 2024.

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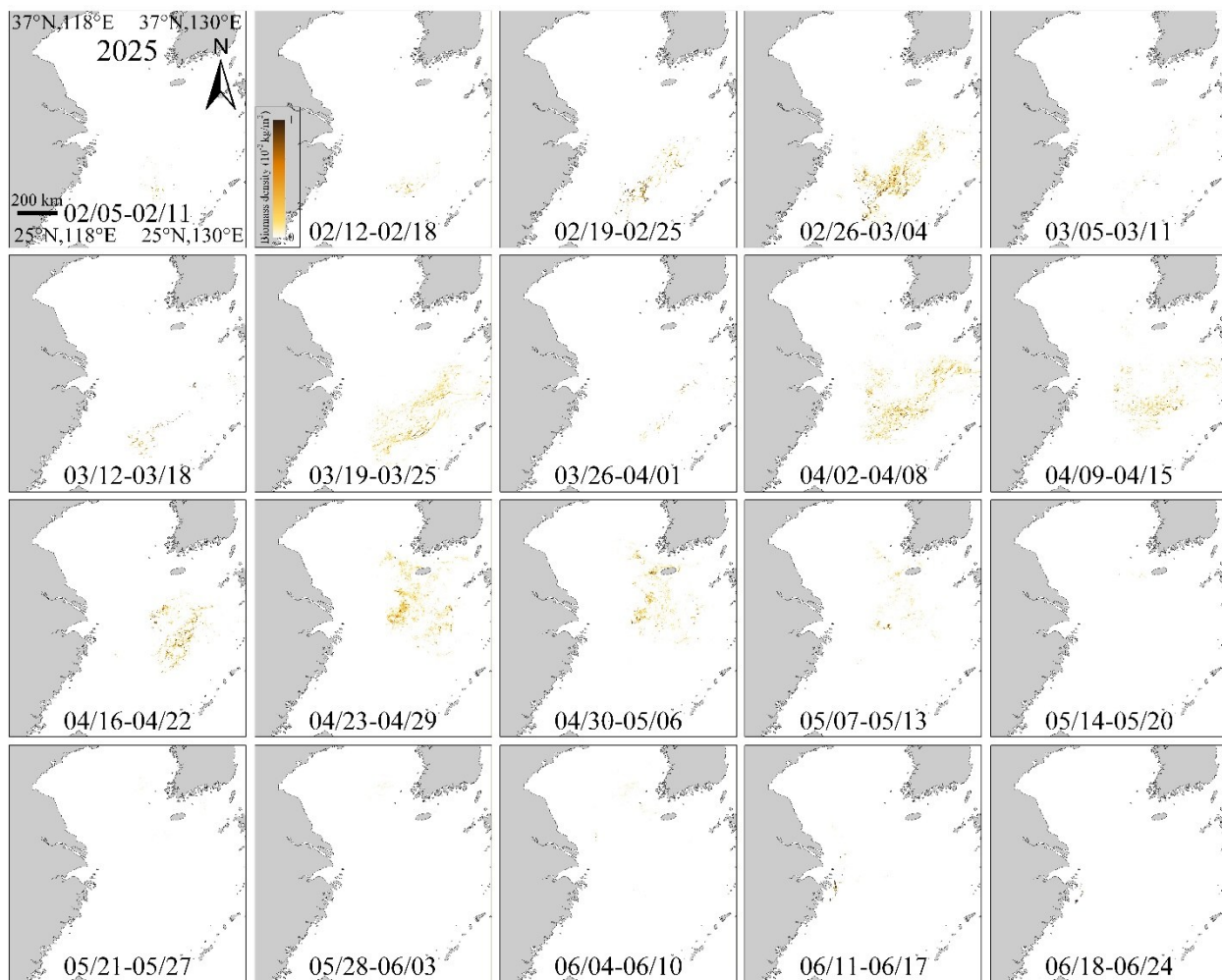


Figure S24. Weekly cumulative footprint and mean biomass density of *S. horneri* in the East China Sea and Yellow Sea from mid-May to August 2025.

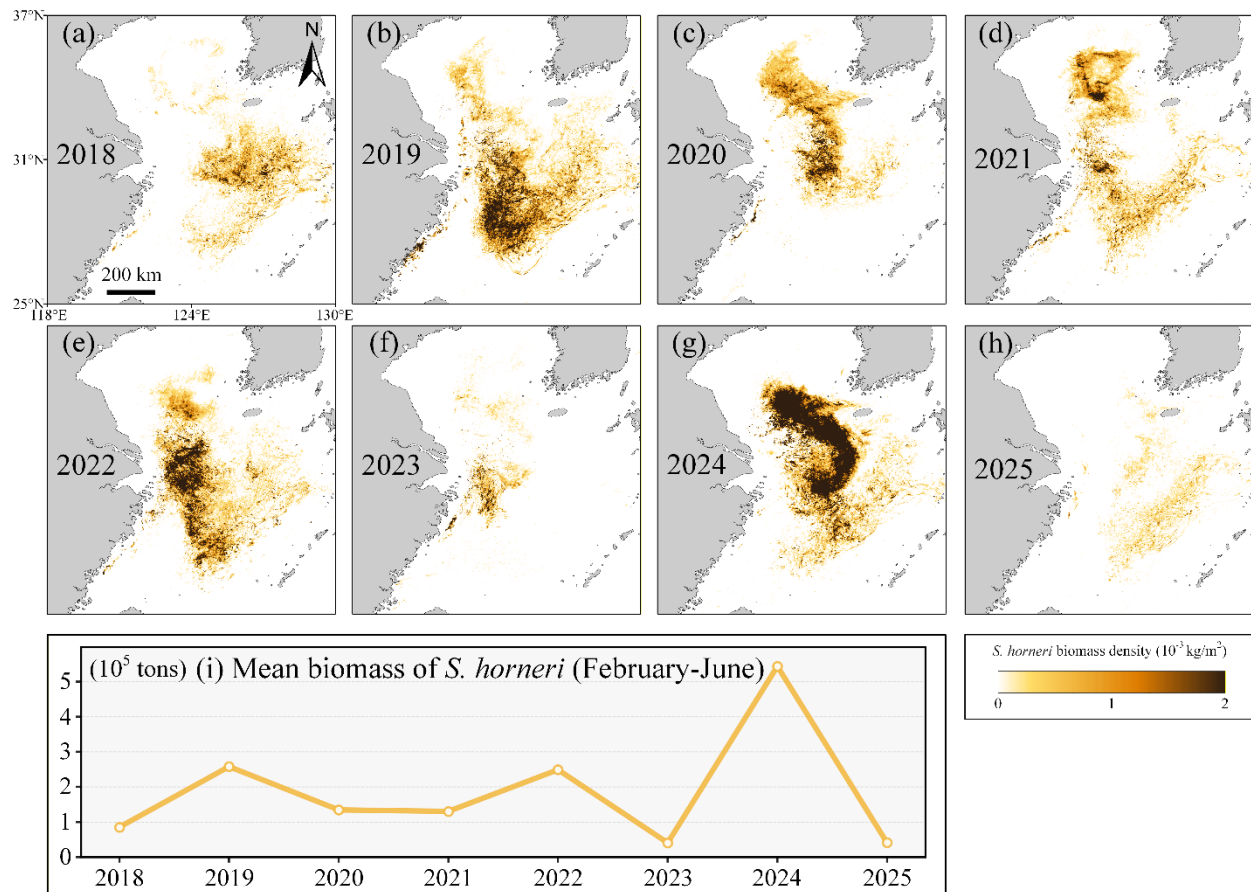


Figure S25. Cumulative footprint and mean biomass density of *S. horneri* in the East China Sea and Yellow Sea from 2018 to 2025. (a–h) Cumulative footprint and mean biomass density from May to August for each year. (i) Interannual variation in mean biomass from February to June, 2018–2025.

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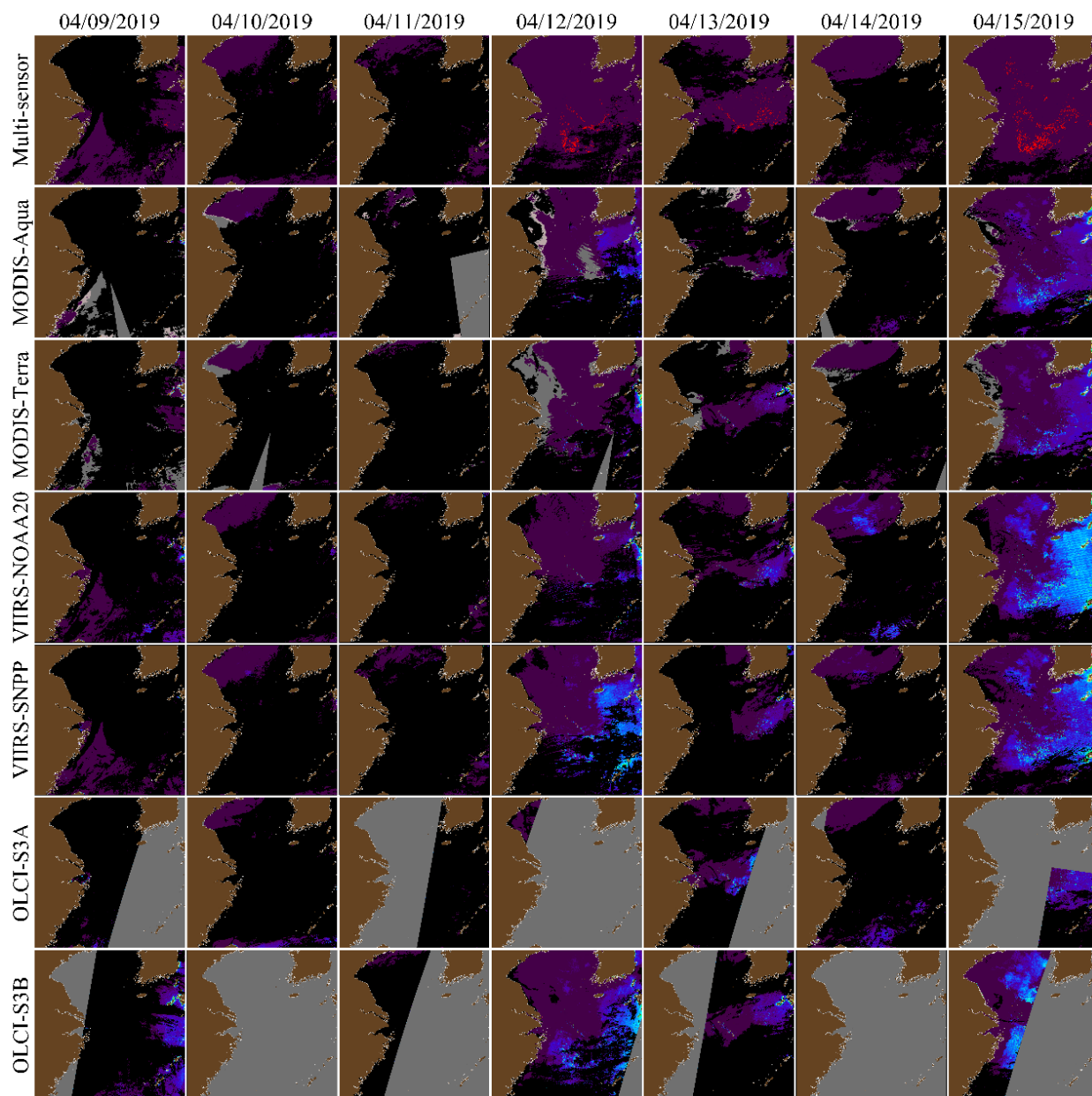


Figure S26. AFAl images of the Yellow Sea and East China Sea from April 9 to 15, 2019, obtained from six satellite sensors (MODIS Aqua, MODIS Terra, VIIRS NOAA-20, VIIRS SNPP, OLCI S3A, and OLCI S3B). Black indicates clouds, while gray denotes no-data or invalid observations.

Figure S27 presents the results of numerical particle tracking experiments for *S. horneri* in the Yellow Sea and East China Sea, based on HYCOM daily surface currents and NCEP/NCAR wind forcing. The initial conditions and background maps were derived from multi-sensor weekly

mean biomass composited across the 2018–2025 bloom seasons. Backward tracking (19 March–19 February) and forward tracking (26 March–28 May) simulations are shown. The particle trajectories closely match the observed satellite distributions, confirming that ocean circulation and wind play key roles in shaping *S. horneri* spatial patterns. These results validate that transport pathways drive short-lived bloom peaks and contribute to interannual variability.

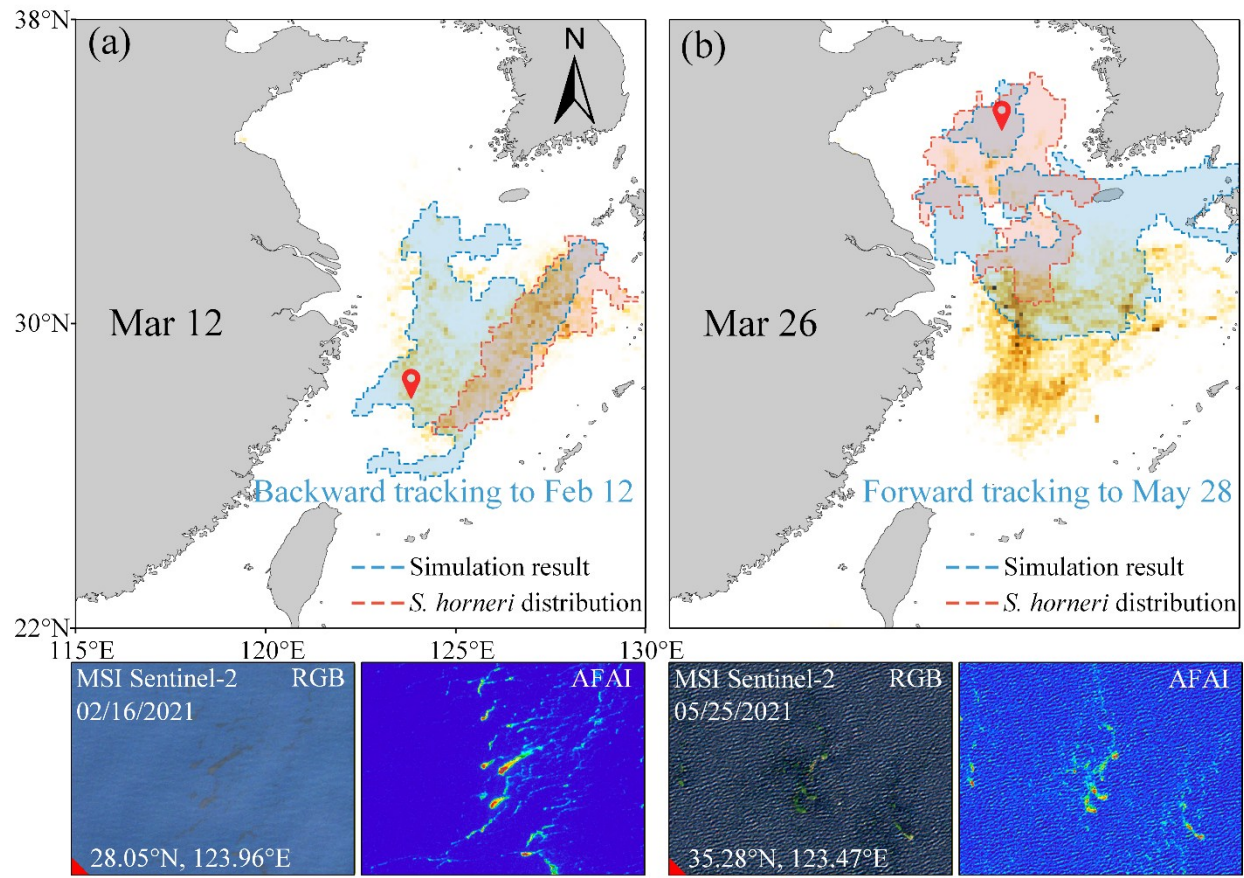


Figure S27. Results of numerical particle tracking experiments for *S. horneri* in the Yellow Sea and East China Sea, based on HYCOM daily surface currents and NCEP/NCAR wind forcing. The initial condition and background map are derived from the multi-sensor weekly mean biomass of *S. horneri*, composited across the 2018–2025 bloom seasons. (a) Backward tracking from 19 March to 19 February, and (b) forward tracking from 26 March to 28 May. The blue dashed lines indicate the simulated drift areas from the particle model, while the red dashed lines denote the satellite-derived average distribution of *S. horneri* during the same period.

To evaluate the consistency of our derived macroalgal bloom dataset with existing products, we conducted a series of comparisons illustrated in **Figures S28–S33**. **Figures S28 and S29** show qualitative comparisons of monthly composite coverage maps for *U. prolifera* (May–August 2021) and *S. horneri* (March–June 2021), respectively, between our dataset and [Qi et al. \(2022\)](#). The spatial patterns, bloom extents, and seasonal progression are highly consistent, indicating that our methodology reliably captures the major bloom events.

Figures S30 and S31 present quantitative comparisons at the pixel and biomass levels for the 2018–2021 bloom periods. Pixel-level comparisons (**Figure S30**) demonstrate strong agreement for both species, while monthly biomass comparisons (**Figure S31**) confirm that our dataset reproduces bloom magnitude and temporal variability comparable to [Qi et al. \(2022\)](#). Minor differences are primarily associated with differences in cloud masking approaches.

Figures S32 and S33 illustrate comparisons with more recent datasets. Daily *U. prolifera* coverage area from 2018–2022 is compared with [Gao et al. \(2024\)](#) (**Figure S32**), showing strong agreement with R^2 values exceeding 0.85 for both MODIS Aqua and Terra. Daily biomass estimates from 2018–2024 are compared with [Pan et al. \(2026\)](#) (**Figure S33**), showing a strong linear relationship with $R^2 = 0.81$. Overall, the results confirm that our dataset captures spatial and temporal bloom dynamics in close agreement with these previously published MODIS-based products, providing a reliable and consistent dataset for further analysis and modeling.

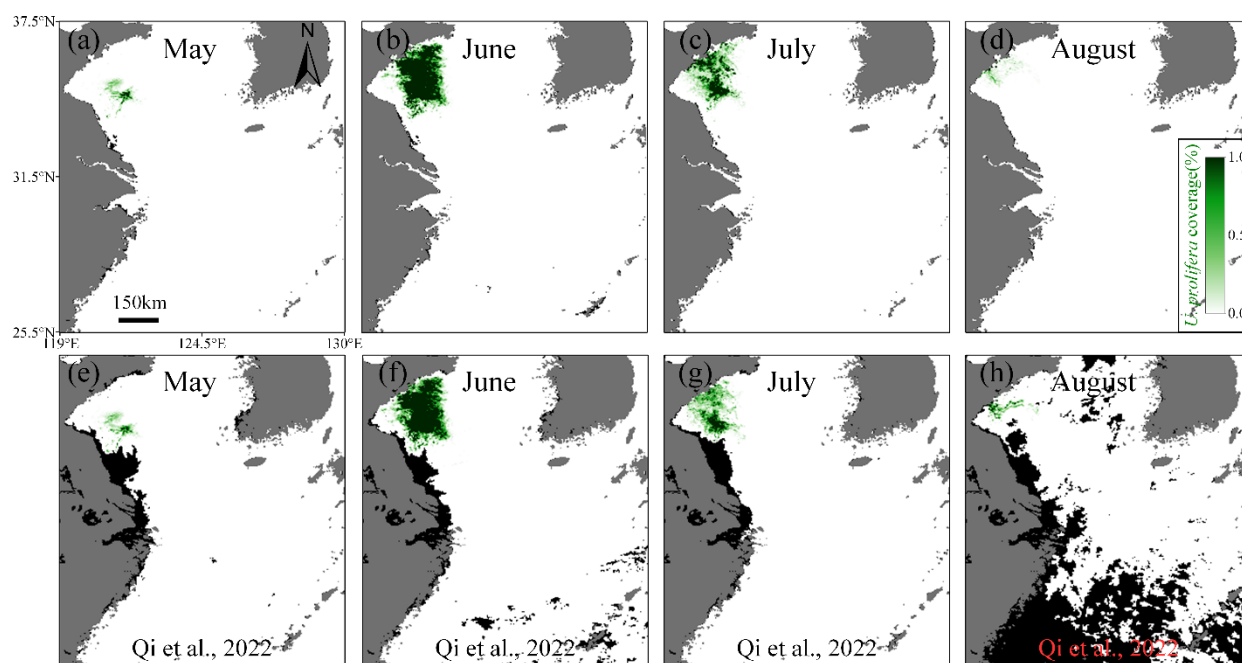


Figure S28. Monthly composite coverage maps of *U. prolifera* during the 2021 bloom season. Panels (a–d) show monthly coverage derived from the present dataset for May–August 2021. Panels (e–h) show the corresponding monthly products from Qi et al. (2022).

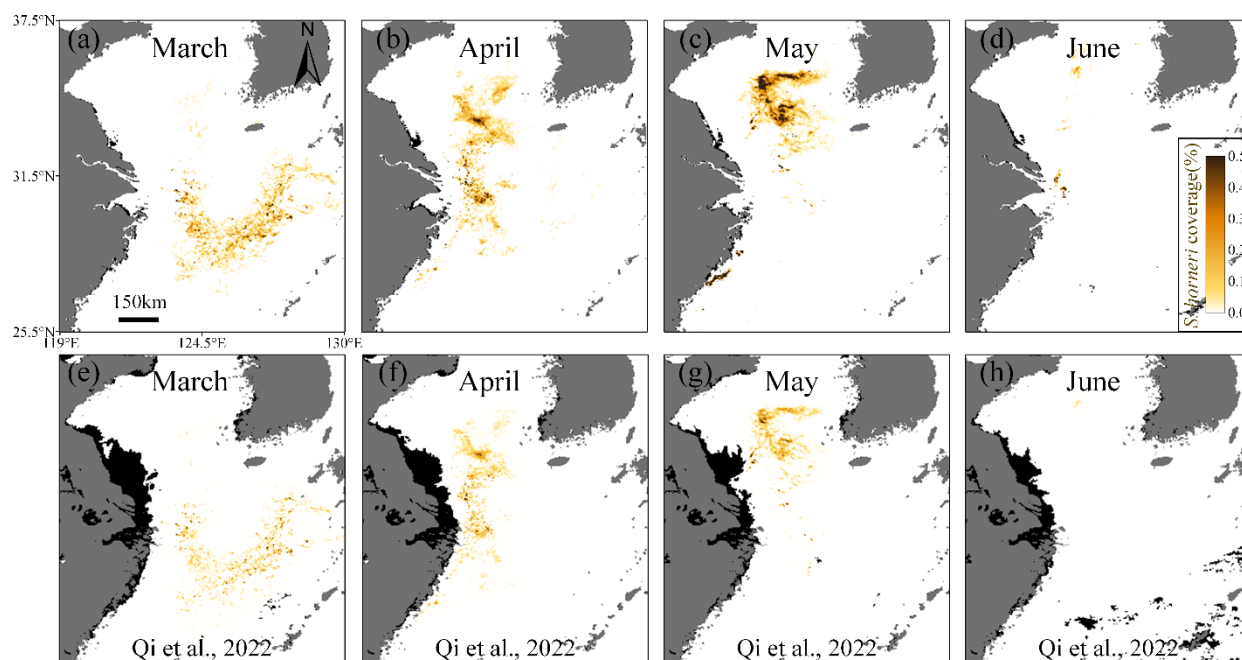


Figure S29. Monthly composite coverage maps of *S. horneri* during the 2021 bloom season. Panels (a–d) show monthly coverage derived from the present dataset for March–June 2021. Panels (e–h) show the corresponding monthly products from Qi et al. (2022).

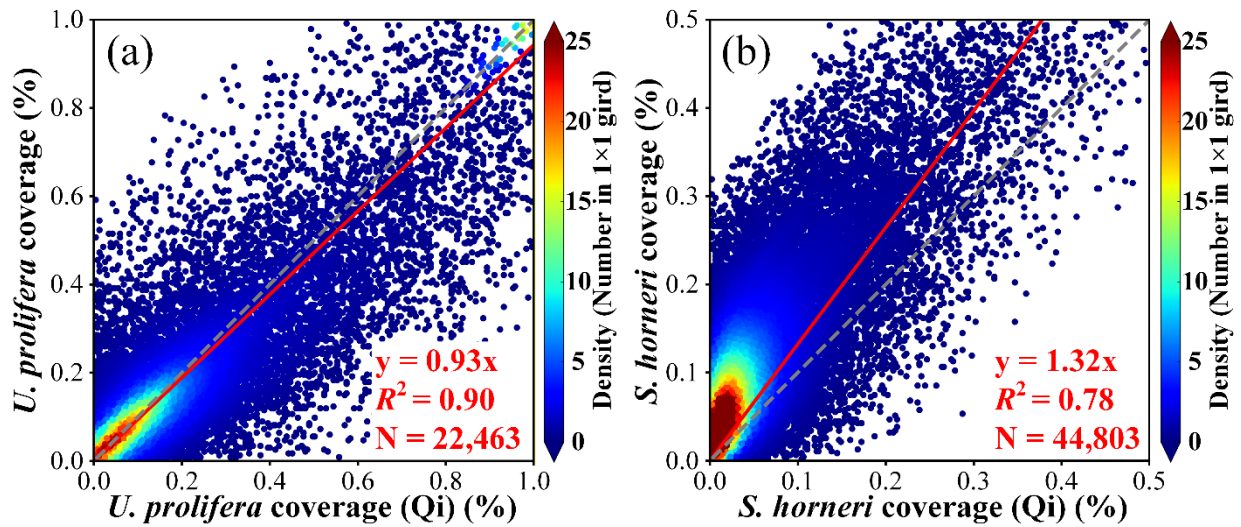


Figure S30. Pixel-level comparison of monthly coverage between the present dataset and Qi et al. (2022) for the 2018–2021 bloom seasons. Panel (a) shows the comparison for *U. prolifera*, and panel (b) for *S. horneri*.

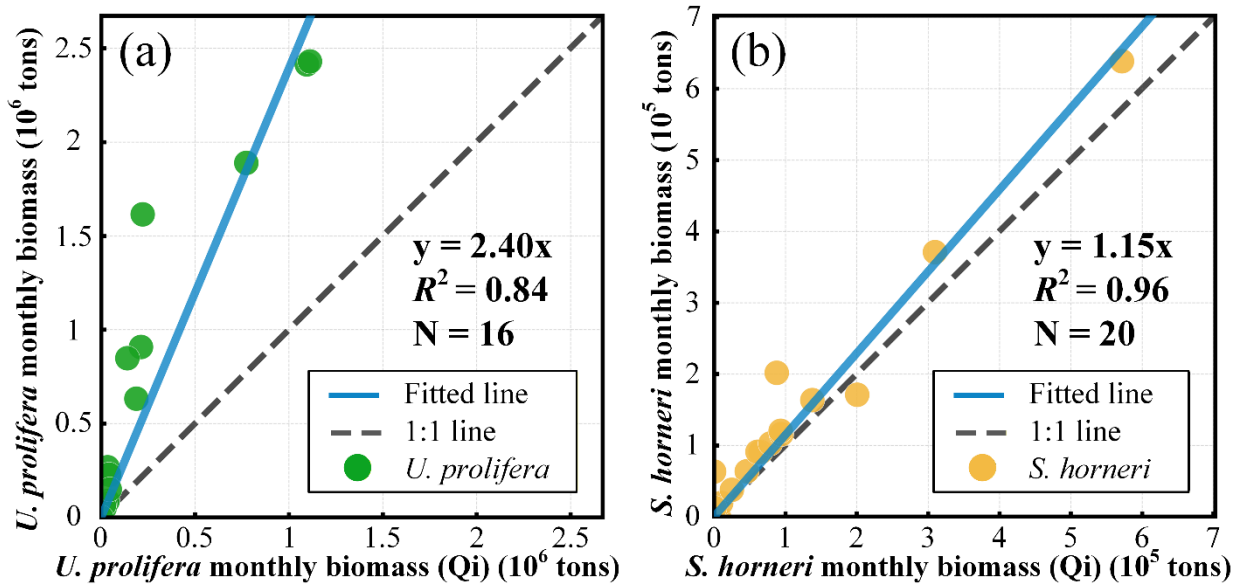


Figure S31. Comparison of monthly biomass estimates during bloom periods from 2018 to 2021. Panel (a) shows *U. prolifera* monthly biomass from the present dataset versus Qi et al. (2022), and panel (b) shows *S. horneri*.

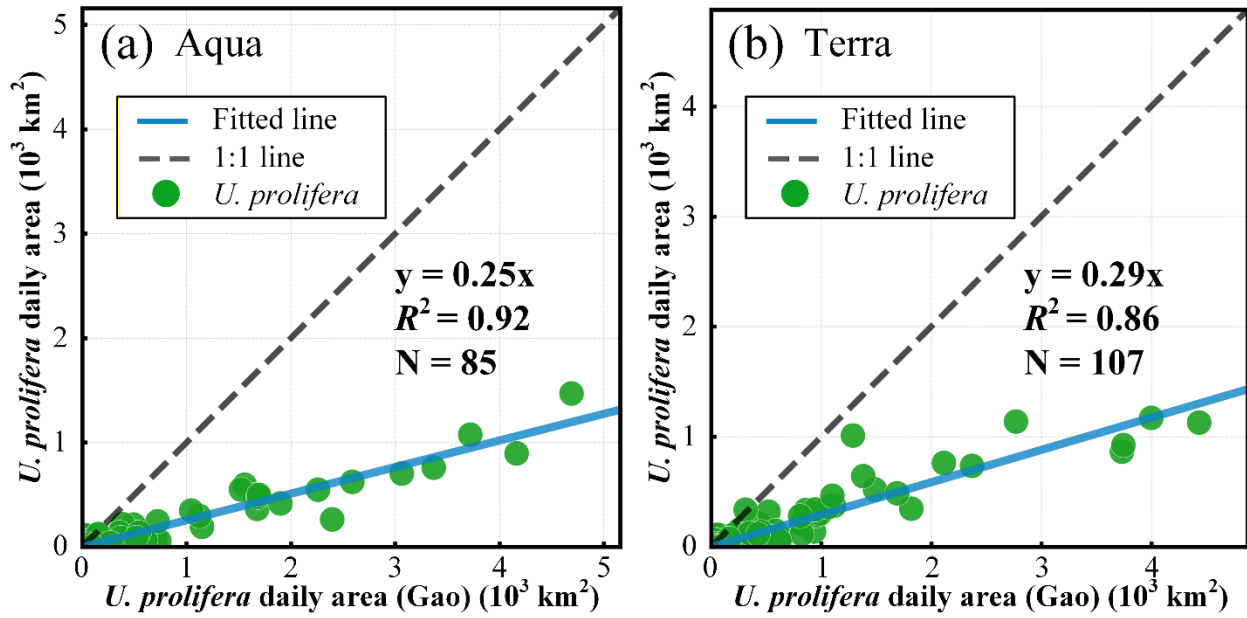


Figure S32. Comparison of daily *U. prolifera* coverage area between the present dataset and Gao et al. (2024) for 2018–2022. Panel (a) shows results derived from MODIS Aqua, and panel (b) shows MODIS Terra. Extreme cases caused by inconsistent cloud masking were excluded.

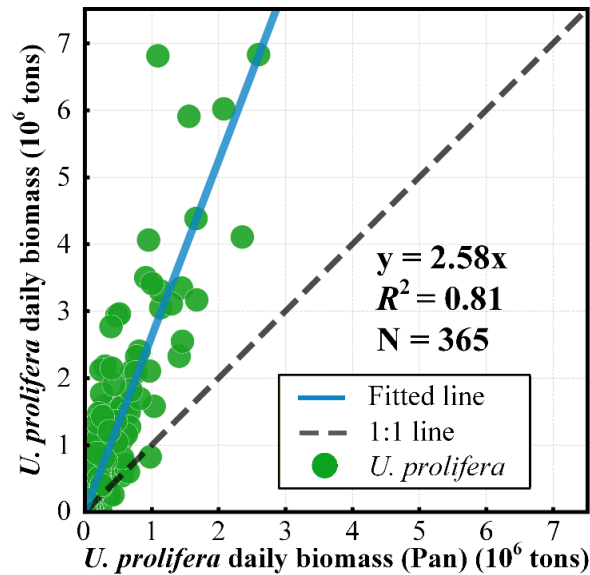


Figure S33. Comparison of daily *U. prolifera* biomass estimates between the present dataset and Pan et al. (2026) for 2018–2024. Extreme cases caused by inconsistent cloud masking were excluded.

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