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The impact of summer Yangtze River runoff fluctuations on estuarine fronts dynamics and zooplankton communities from 2016 to 2023

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- The concept of front (Front) originates from the interface between cold and warm air masses in **meteorology**;
- Ocean front is a **mesoscale physical process** in the ocean, which is a **narrow three-dimensional structure** that **dynamically** divides water masses with different properties;
- It can be divided into **salinity front, turbidity front, temperature front** and so on according to different factors;
- They can be divided into **estuarine front, tidal front** and **shelf slope fold front** according to different causes.

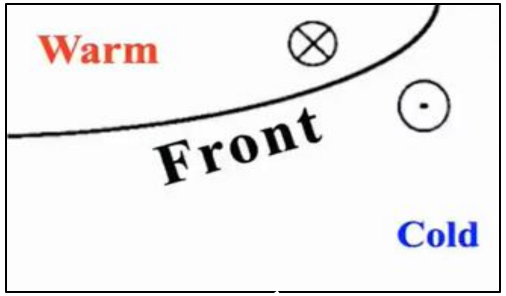
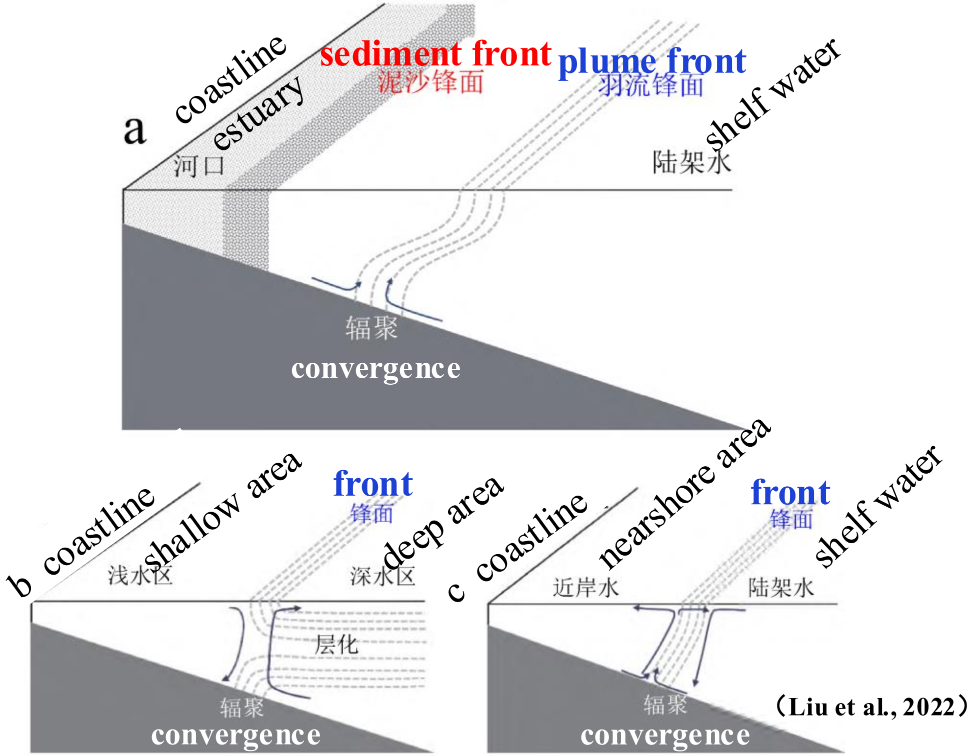


Figure 1 origin of the Front concept



（Liu et al., 2022）

Figure 2 (a) Estuarine front (b) tidal front (c) shelf slope fold front

The strong convergence flow associated with the frontal system can gather plankton and other floating substances effectively. Then, if there is divergence in the frontal area, an upwelling will occur, which can bring nutrient-rich sub-surface or bottom water into the upper layer, forming high productivity in the frontal area.

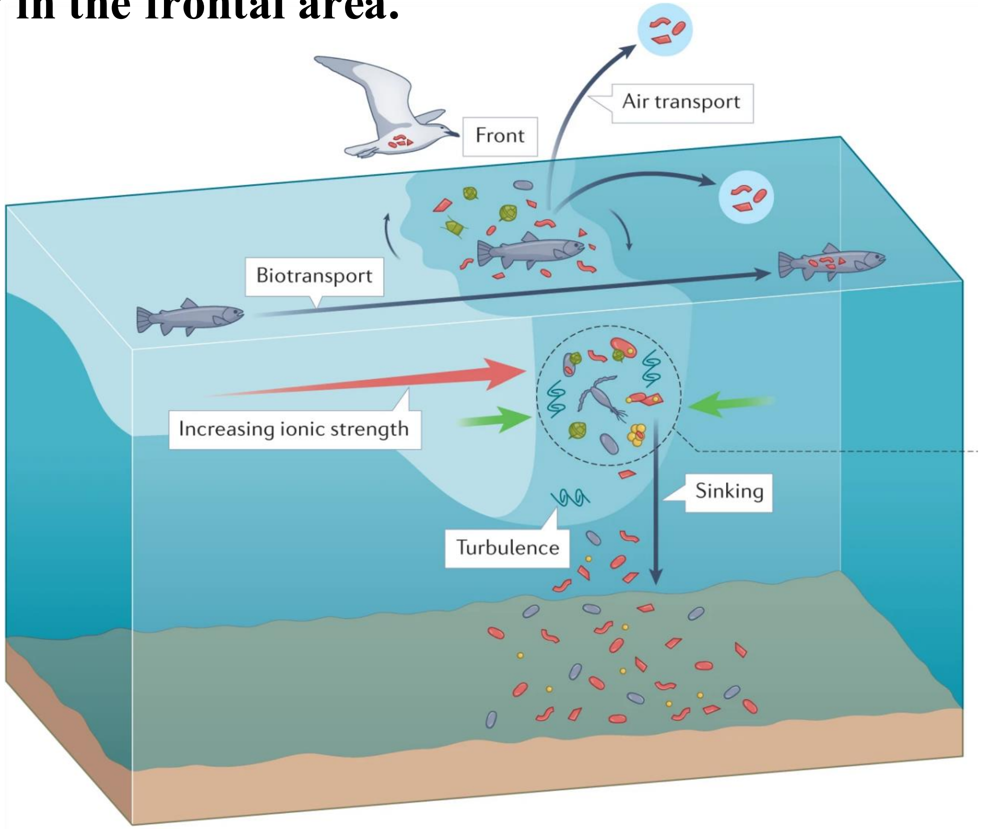
Ecological effects of estuarine fronts are diverse

- ☐Differentiate biome structure and ecological gradient
- ☐Trigger algal blooms
- ☐Form and regulate of hypoxic zone
- ☐Pollutant retention and natural filtration

Ecological double-edged sword

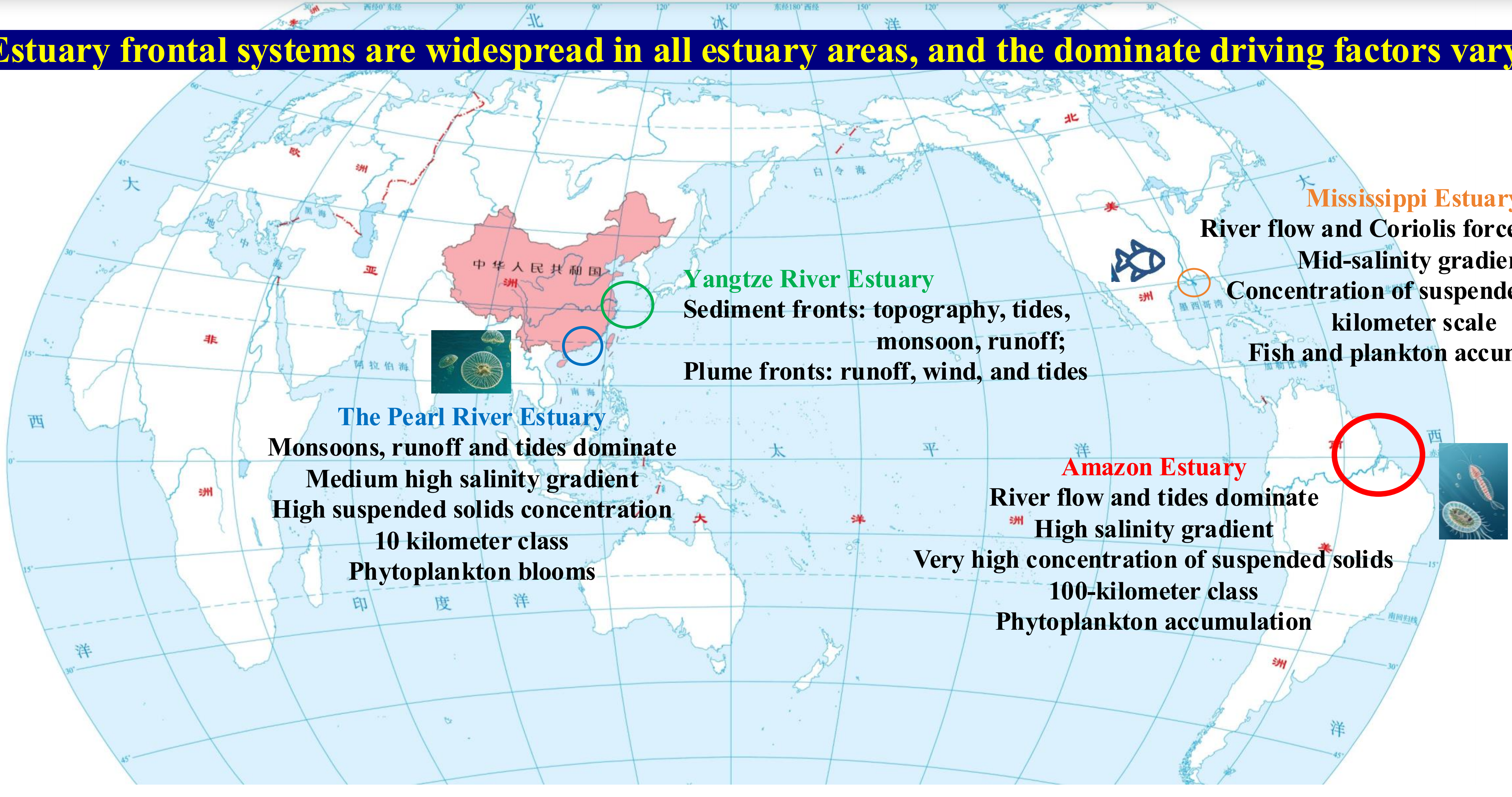
✅ Nutrient and phytoplankton enrichment support fishery resources;

❌ Oxygen deficiency and pollutant accumulation threaten biodiversity.



（Wang et al., 2022）

Estuary frontal systems are widespread in all estuary areas, and the dominate driving factors vary



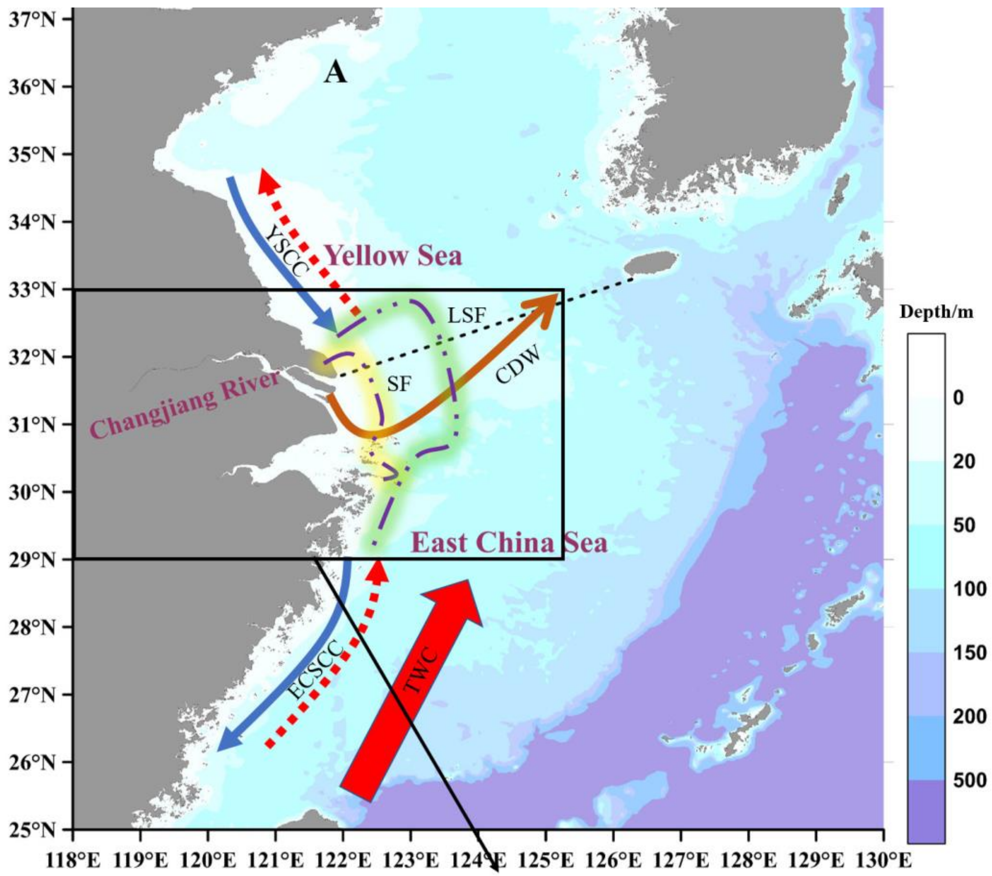
Yangtze River Estuary
Sediment fronts: topography, tides, monsoon, runoff;
Plume fronts: runoff, wind, and tides

The Pearl River Estuary
Monsoons, runoff and tides dominate
Medium high salinity gradient
High suspended solids concentration
10 kilometer class
Phytoplankton blooms

Mississippi Estuary
River flow and Coriolis force dominate
Mid-salinity gradient
Concentration of suspended solids kilometer scale
Fish and plankton accumulate

Amazon Estuary
River flow and tides dominate
High salinity gradient
Very high concentration of suspended solids
100-kilometer class
Phytoplankton accumulation

● Yangtze Estuary: sediment front and plume front



Circulation and frontal system at the Yangtze River estuary

SF: sediment front;
LSF: low-salinity front (plume front)

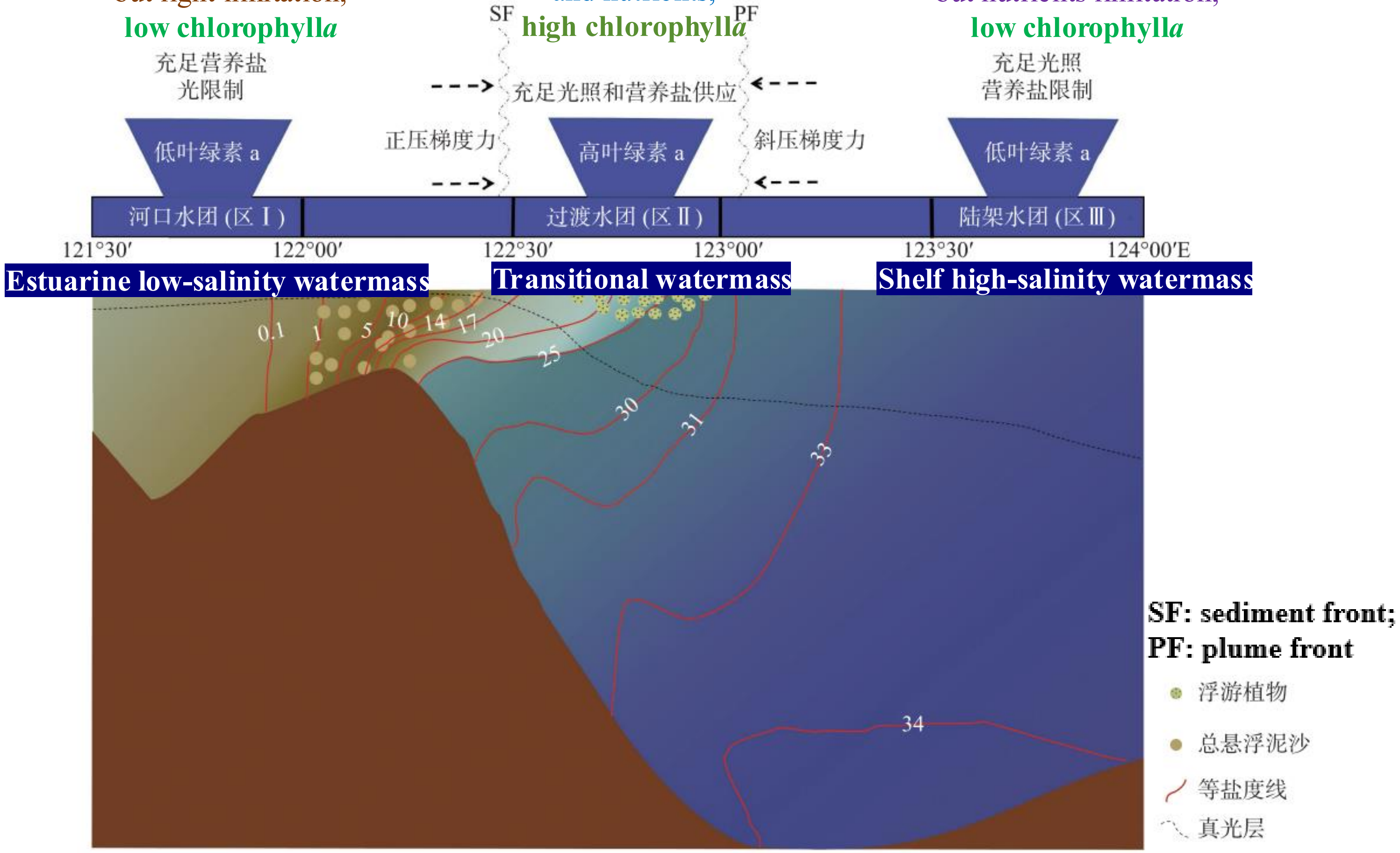
（Du et al., 2022）

● Three water masses of different properties —— "sandwich" structure

Sufficient nutrients, but light limitation, **low chlorophyll *a***

Sufficient light and nutrients, **high chlorophyll *a***

Sufficient light, but nutrients limitation, **low chlorophyll *a***

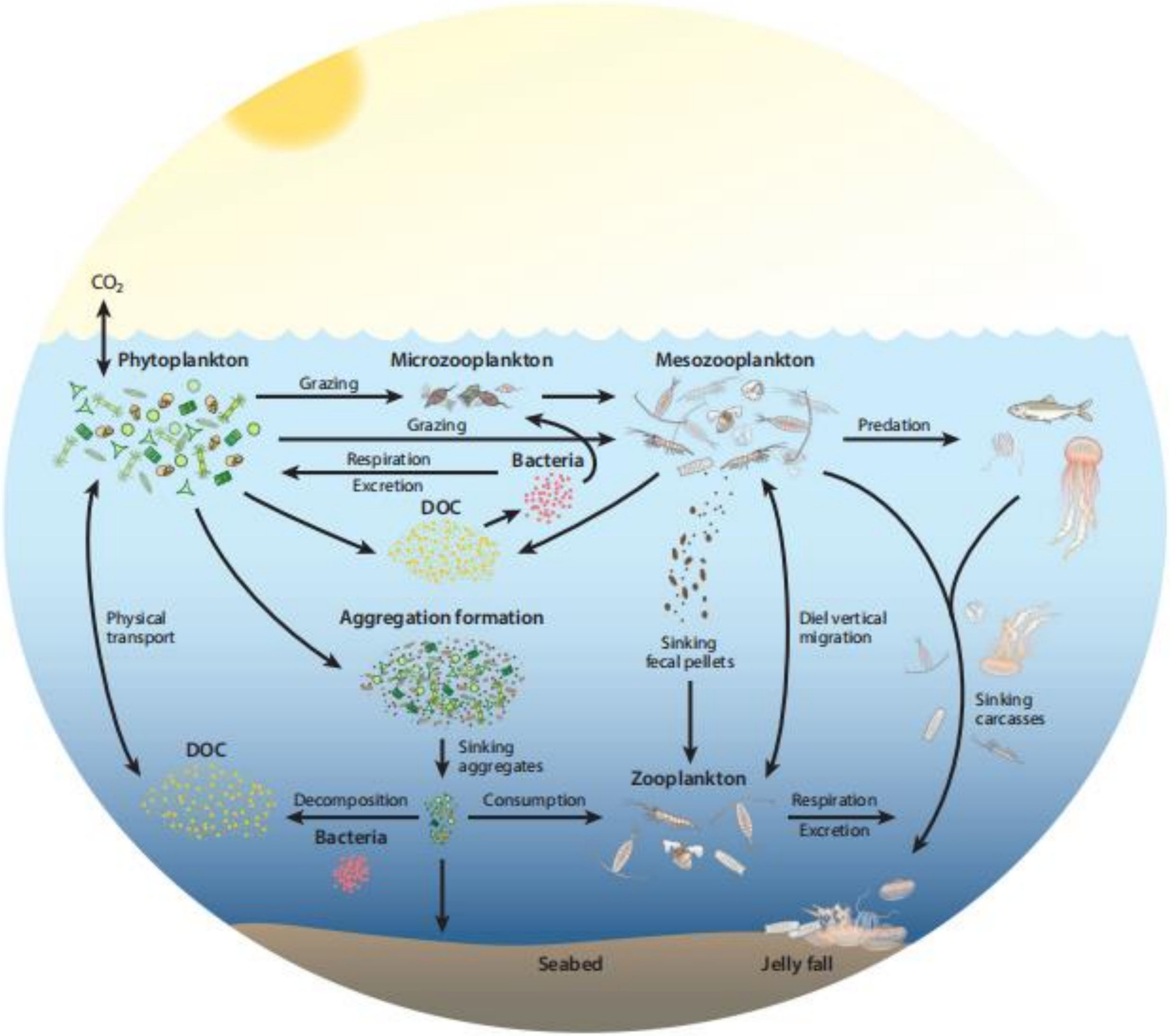


“Sandwich” structure of the Yangtze Estuary

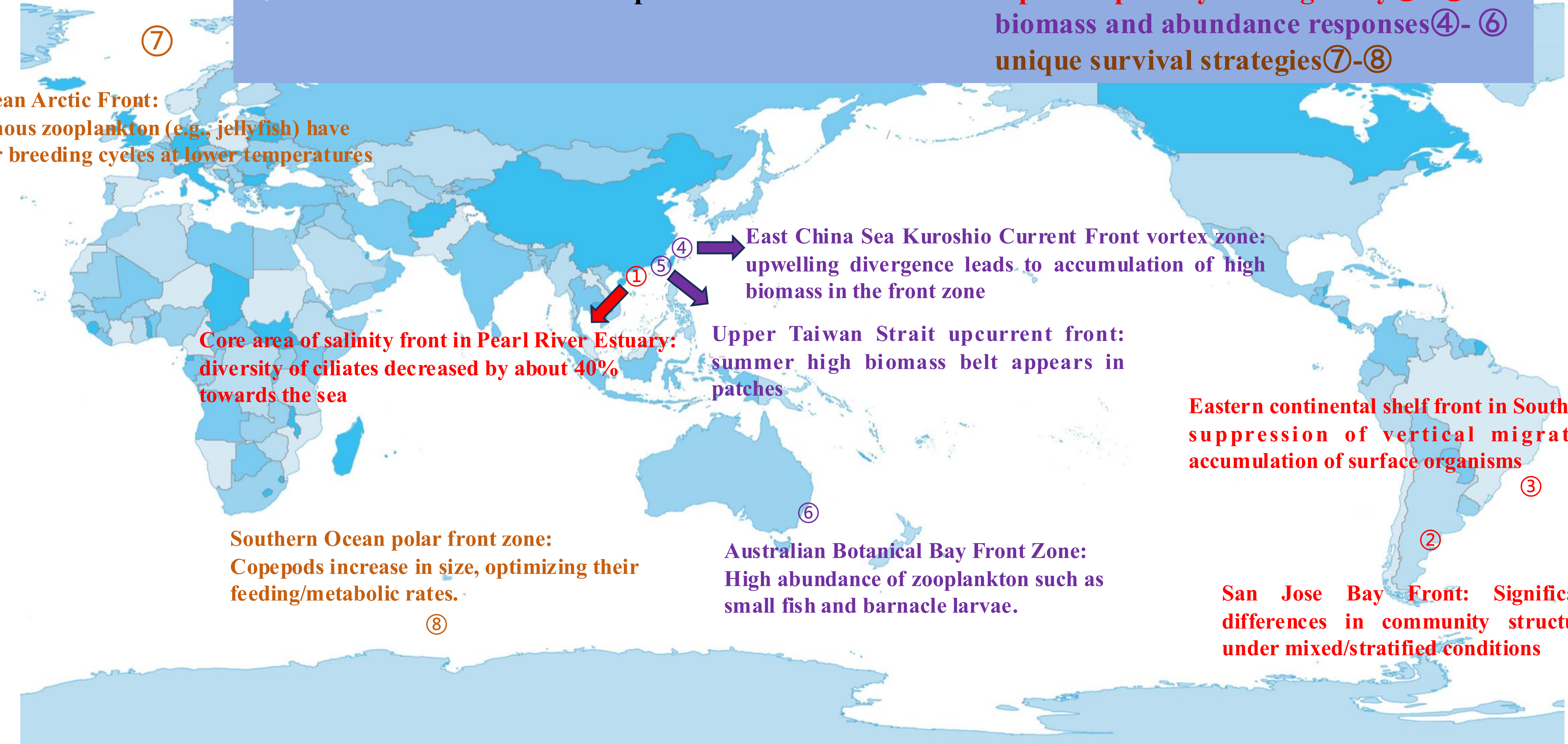
（Liu et al., 2022）

multiple ecological roles

- The transformation of primary productivity into secondary productivity
- Regulate phytoplankton quantity to inhibit red tide
- Main bait for fish——Influence on distribution of fishery resources
- Highly sensitive to environmental change——Influence on ecosystem stability



Core characteristics of zooplankton in the frontal zone: species spatially heterogeneity①- ③
biomass and abundance responses④- ⑥
unique survival strategies⑦-⑧



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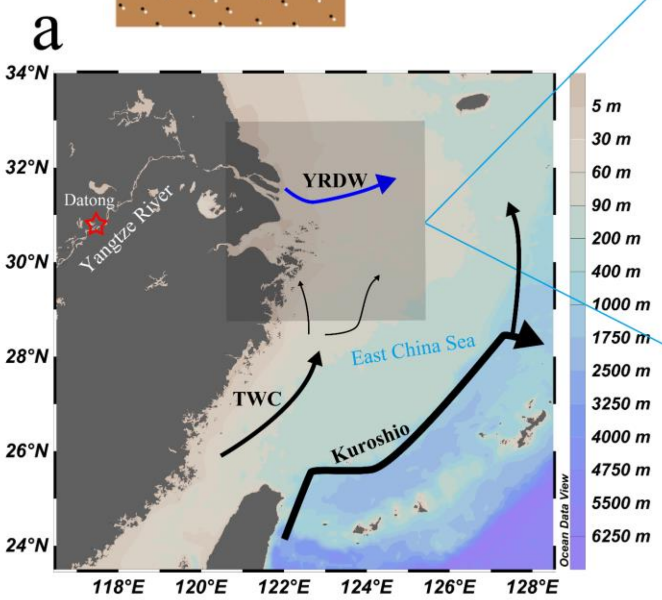
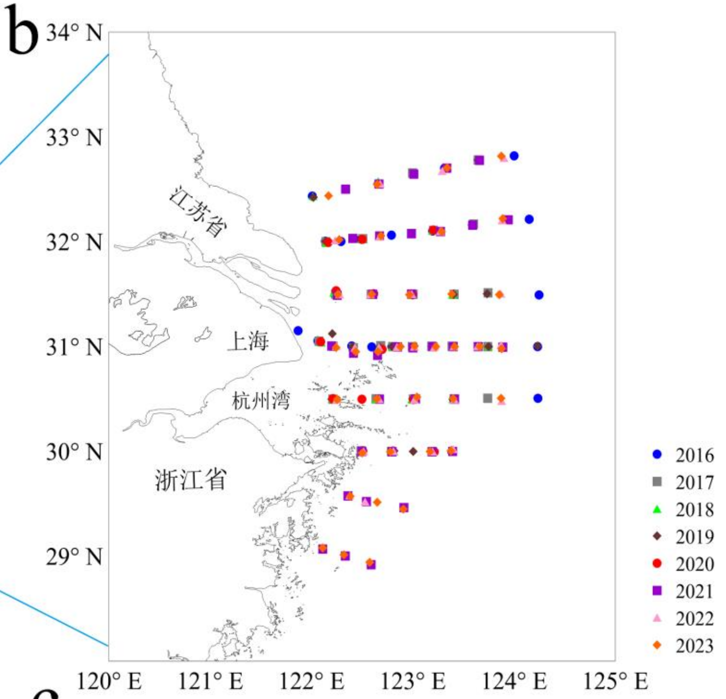


Datong: hydrological station Yangtze River

YRDW: Yangtze River diluted water

TWC: Taiwan Warm Current



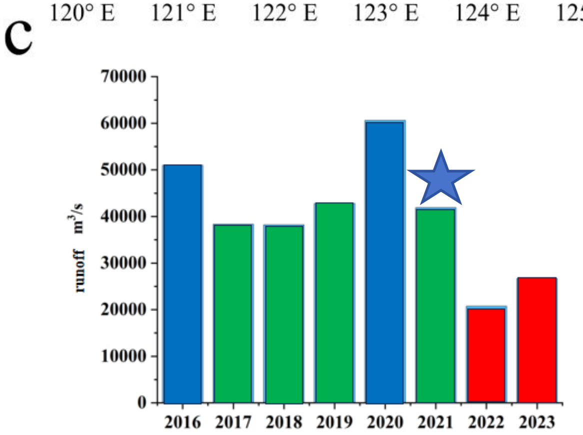


Figure (a) Yangtze River Estuary circulation; (b) Sampling station location; (c) Yangtze River runoff in August

Sample collection time:

2016.8.17-8.26 Flood year

2017.8.25-9.6 Normal year

2018.8.29-9.5 Normal year

2019.8.16-8.21 Normal year

2020.8.17-8.22 Flood years

2021.8.17-9.3 Normal year

2022.8.17-8.25 Dry years

2023.8.20-8.27 Dry years

2021 sampling period Omis

Sampling parameters:

Sea water temperature (surface + average water column)

Sea water salinity (surface + average of the water column)

Sea water turbidity (surface + average water column)

Surface water Chlorophyll *a* concentration

Mesozooplankton samples (>200 μm water column)

Data analysis:

Cluster analysis based on species abundance

PCoA analysis based on species abundance

Spearman correlation analysis

CCA/RDA analysis

Interannual variation of the Plume Front: expand in flood years and shrink in dry years

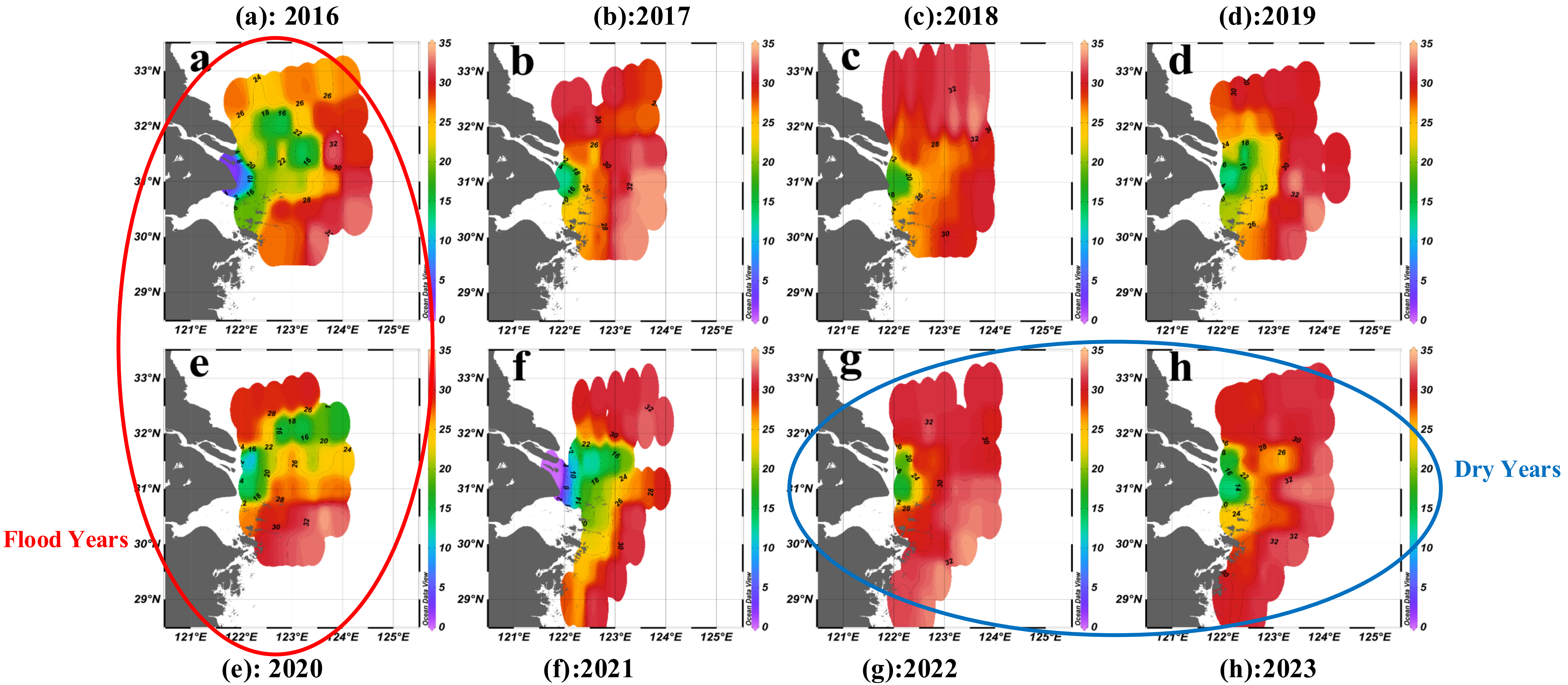


Figure 1 Distribution of surface seawater salinity in summer at the Yangtze River Estuary from 2016 to 2023

Interannual variation of Sediment Front: remarkable in flood years and absent in dry years

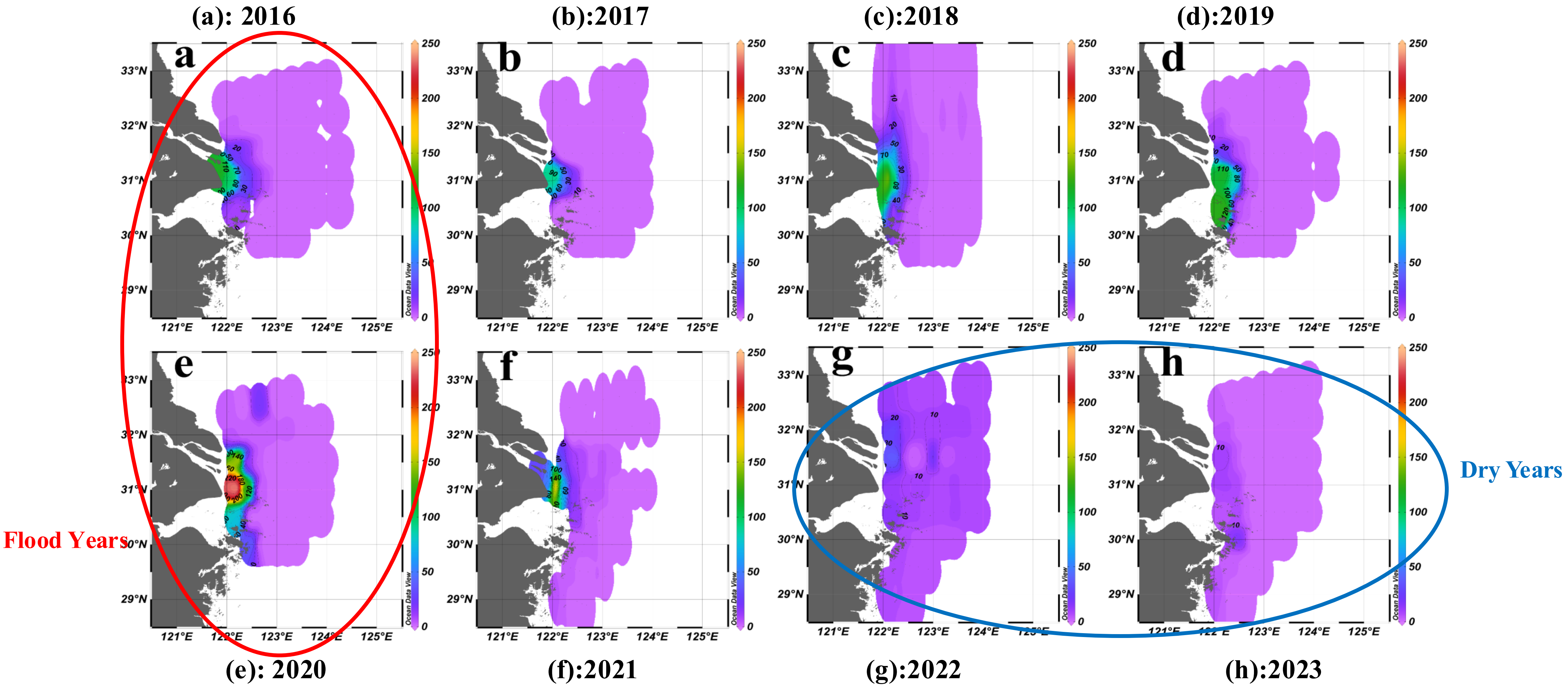


Figure 2 Distribution of surface seawater turbidity in summer at the Yangtze River Estuary from 2016 to 2023

Interannual variation of "Sandwich" structure of chlorophyll *a*: peak value is close to the shore in 2022

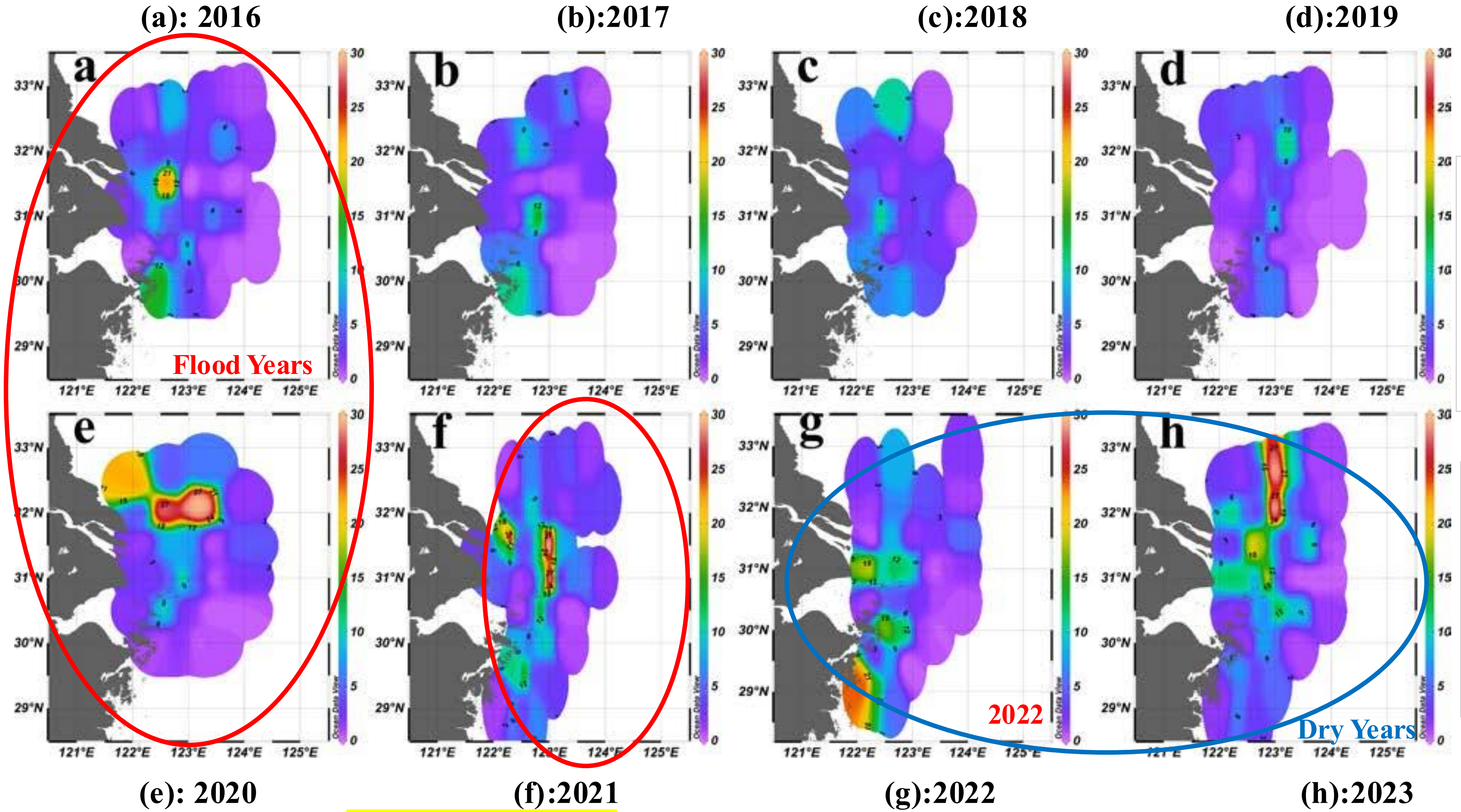
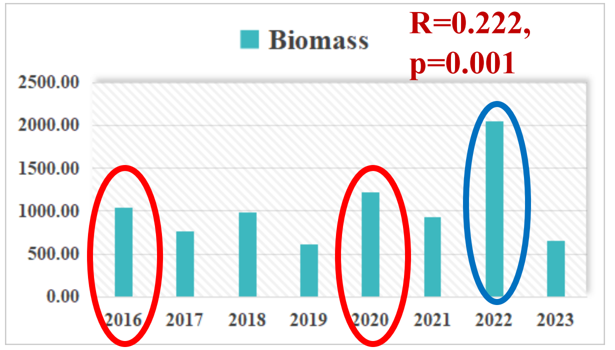
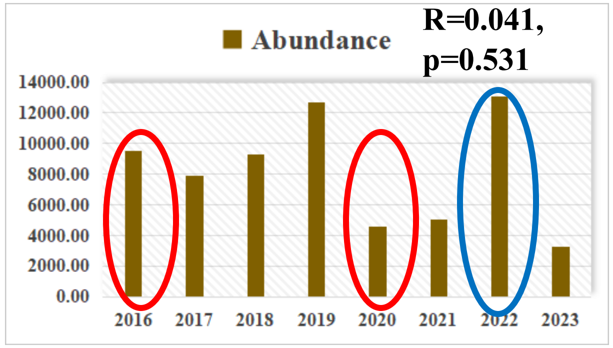


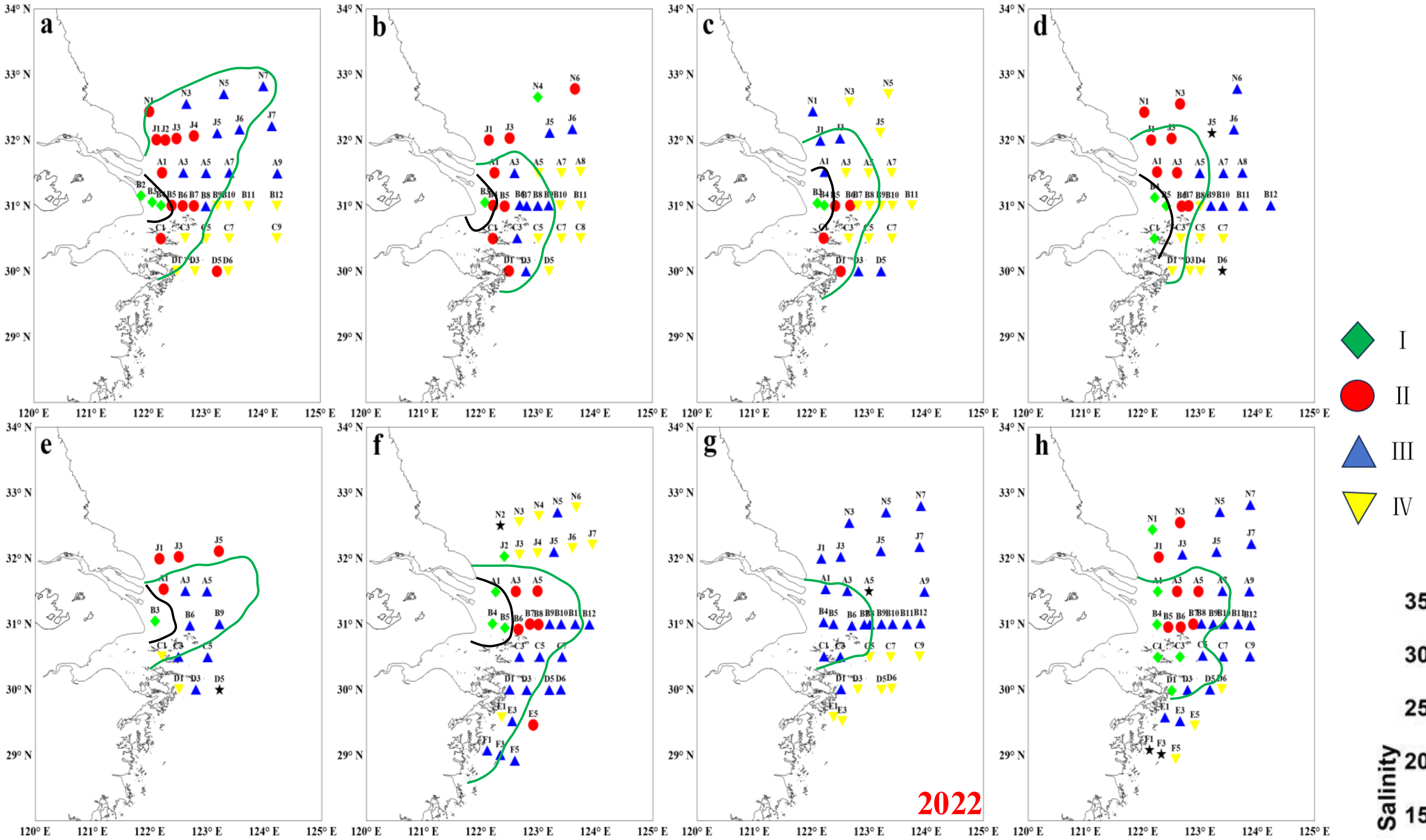
Figure 3 Distribution of **Chl *a* concentration** (μg/L) at 2m in summer at the Yangtze River Estuary from 2016 to 2023

The peak value is relatively low in normal years.





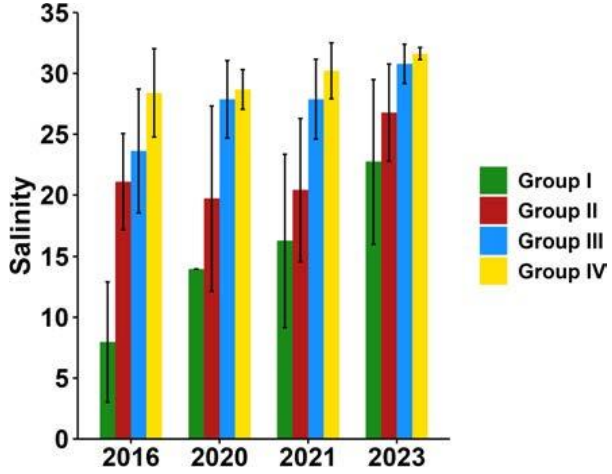
Interannual variation of spatial differentiation of zooplankton communities



black lines: sediment front;
green lines: plume front

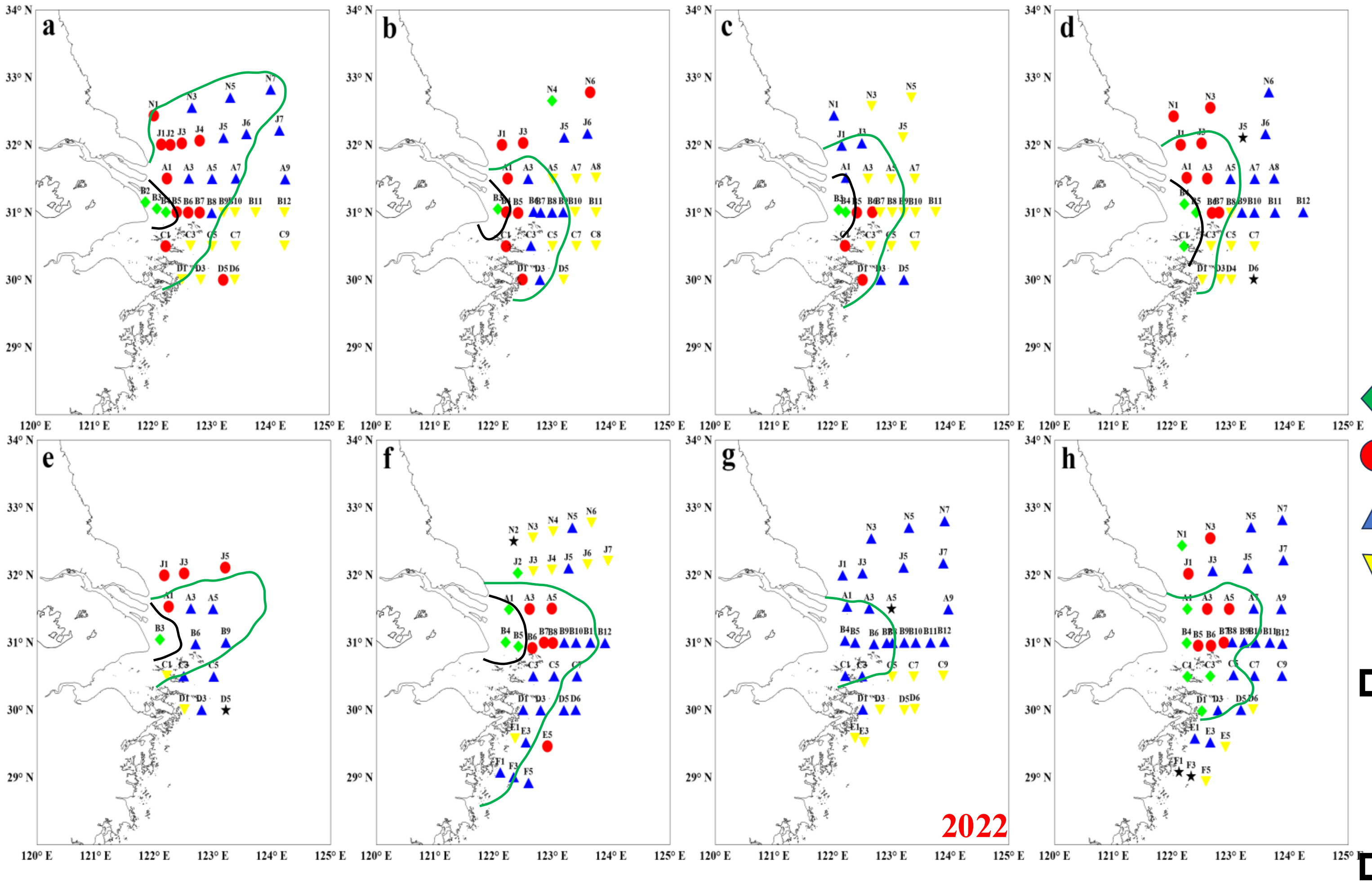
Figure 4 Zooplankton communities based on taxon abundance in summer. (a): 2016; (b):2017; (c):2018; (d):2019; (e): 2020;(f):2021; (g):2022; (h) :2023.

- The zooplankton communities were spatially divided into four groups in most years,
- In 2022, the zooplankton communities were only categorized into either Group III or Group IV.
- Group I was primarily located in west of Sediment Front,
- Group IV were mostly situated in the out of Plume Front,
- Groups II and III were usually located between Sediment Front and Plume Front.



Average salinity in different regions during 2016, 2020, 2021 and 2023.

Interannual variation of spatial differentiation of zooplankton communities —— regulating factors



black lines: sediment front;
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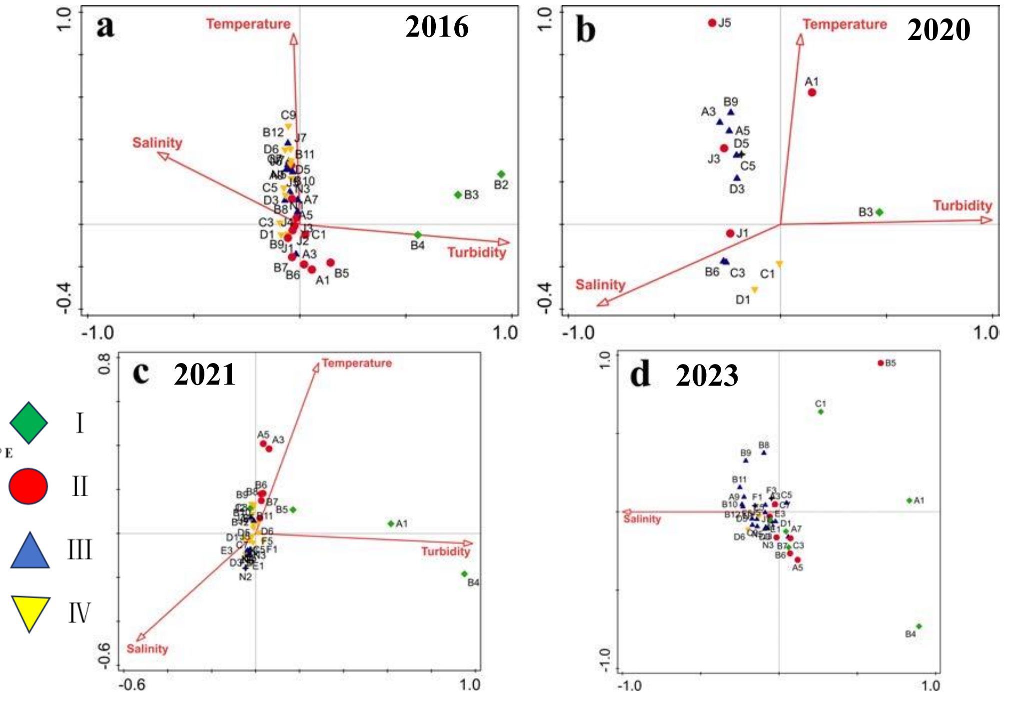
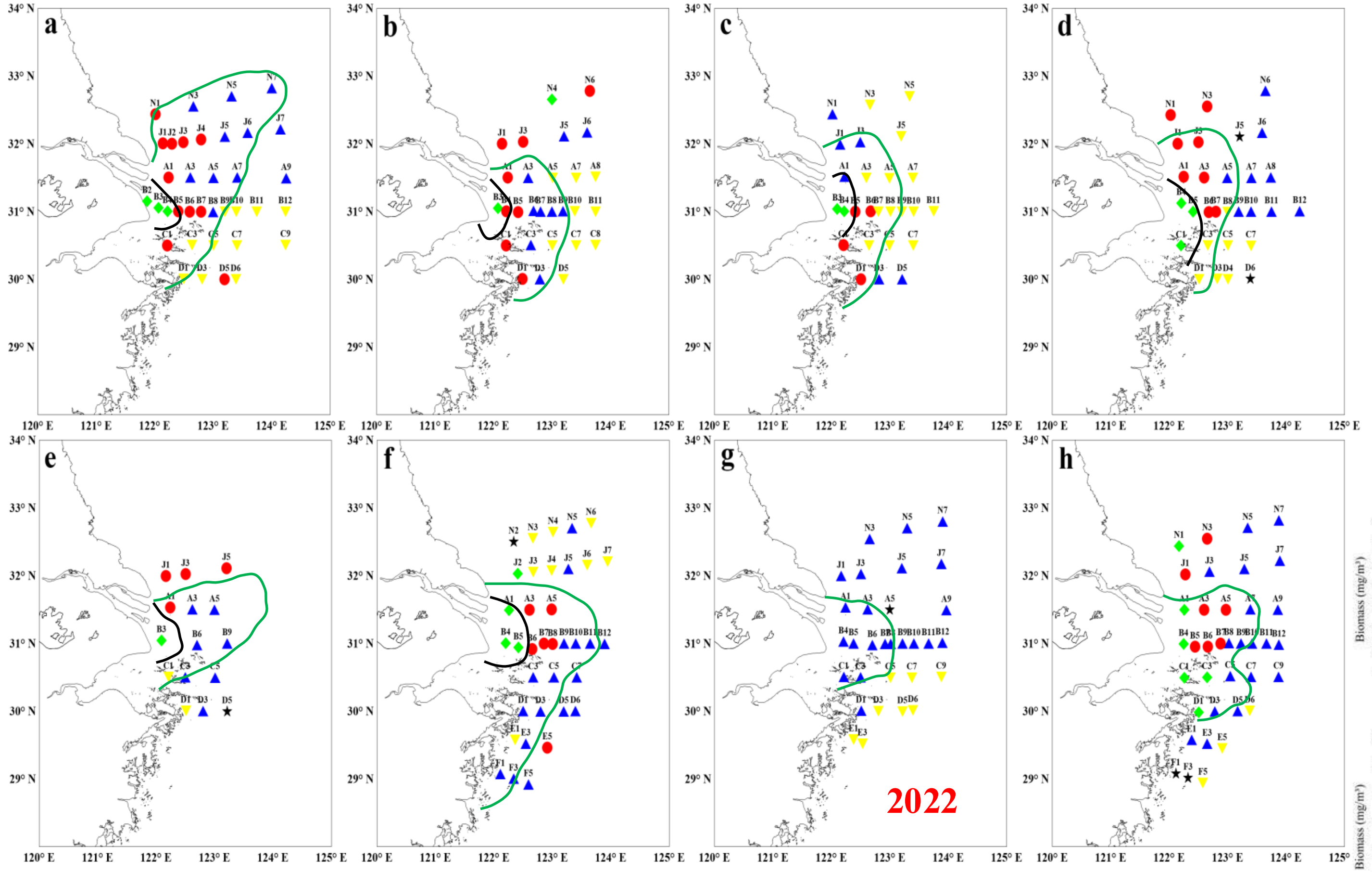
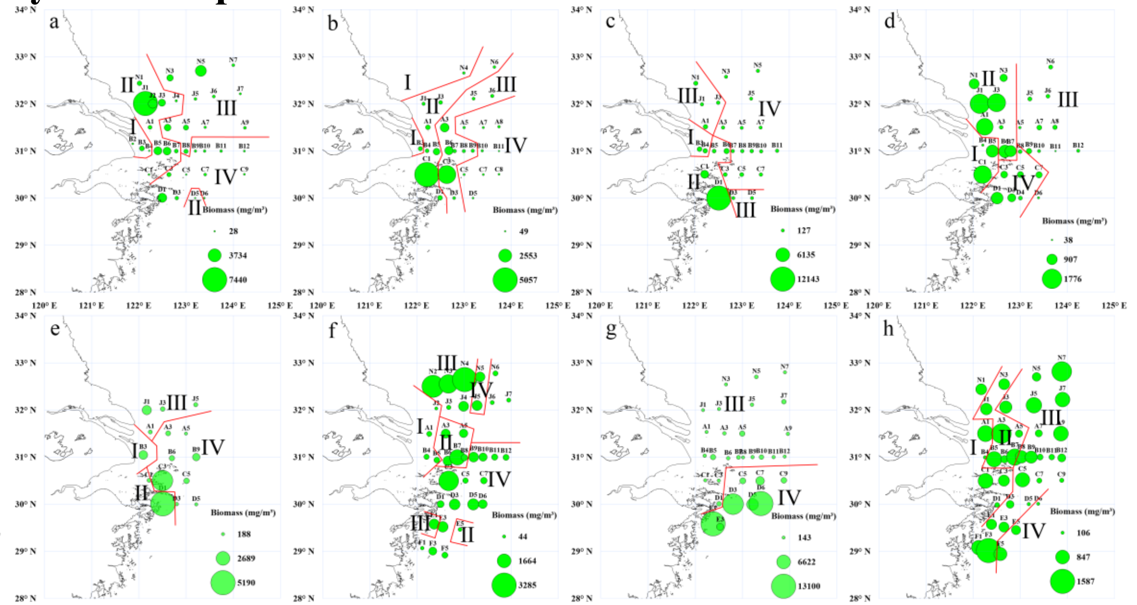


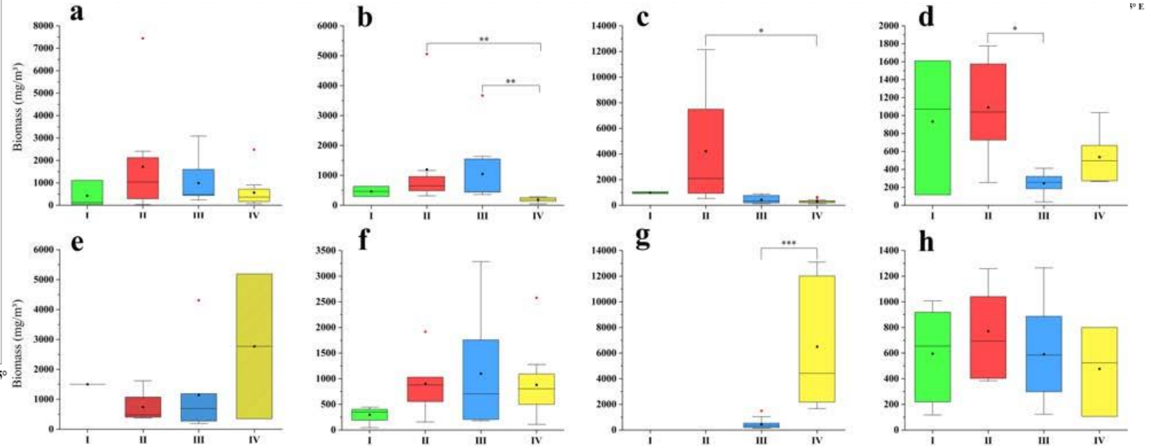
- During flood years (2016, 2020 and 2021), salinity, temperature and turbidity were the significant environmental factors that regulated the spatial variations of zooplankton community.
- During dry year (2023), salinity was the relatively important environmental factor.
- During normal years (2017, 2018 and 2019) and 2022, there were no significant influencing factors.

Interannual variation of spatial variation of zooplankton communities biomass

- The highest biomass in most years (2016, 2017, 2018, 2019 and 2023)occurred in Group II or III (between two fronts);
- The biomass of zooplankton within the sediment front was indeed relatively low except for 2019.
- in 2022,the biomass in Group IV was higher than that in Group III.

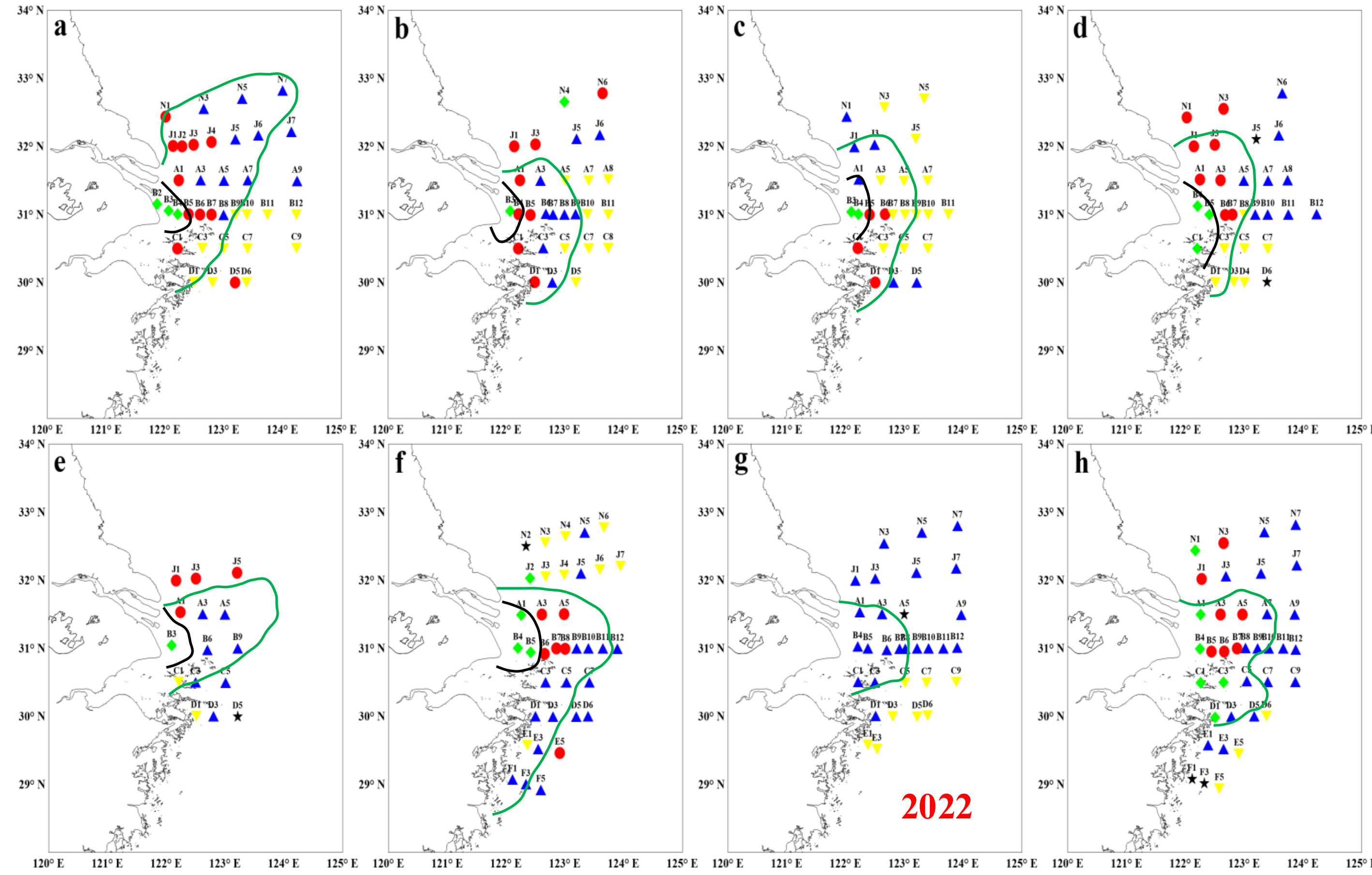


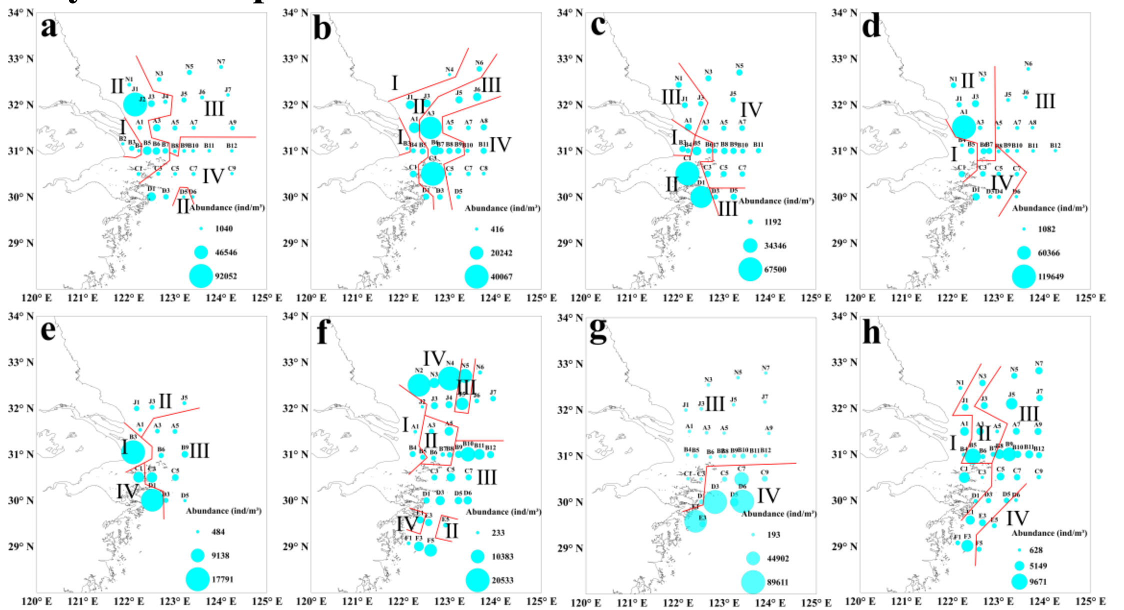


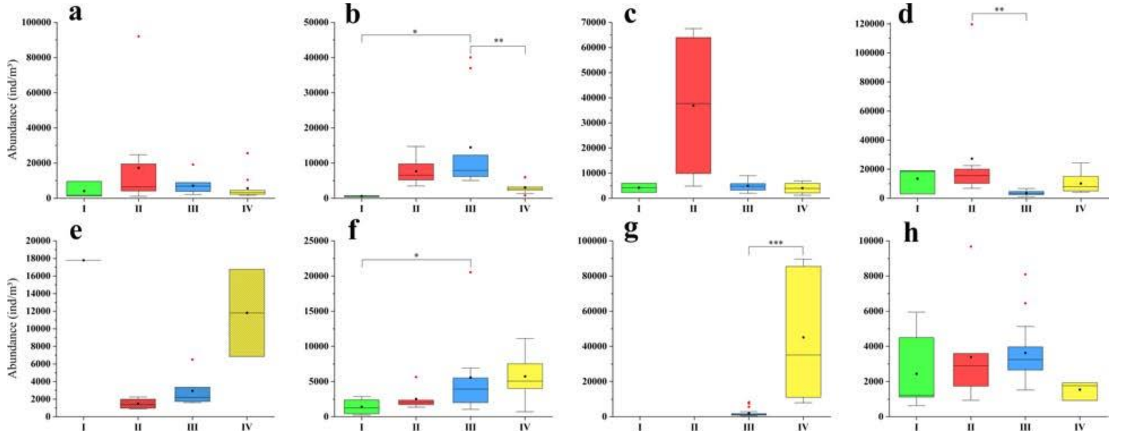


Interannual variation of spatial variation of zooplankton communities abundance

- The highest abundance in most years (2016, 2017, 2018, 2019 and 2023)occurred in Group II or III (between two fronts);
- The abundance of zooplankton within the sediment front was indeed relatively low except for 2019.
- in 2022,the abundance in Group IV was higher than that in Group III.







environmental factors regulating spatial variation of zooplankton biomass/ abundance

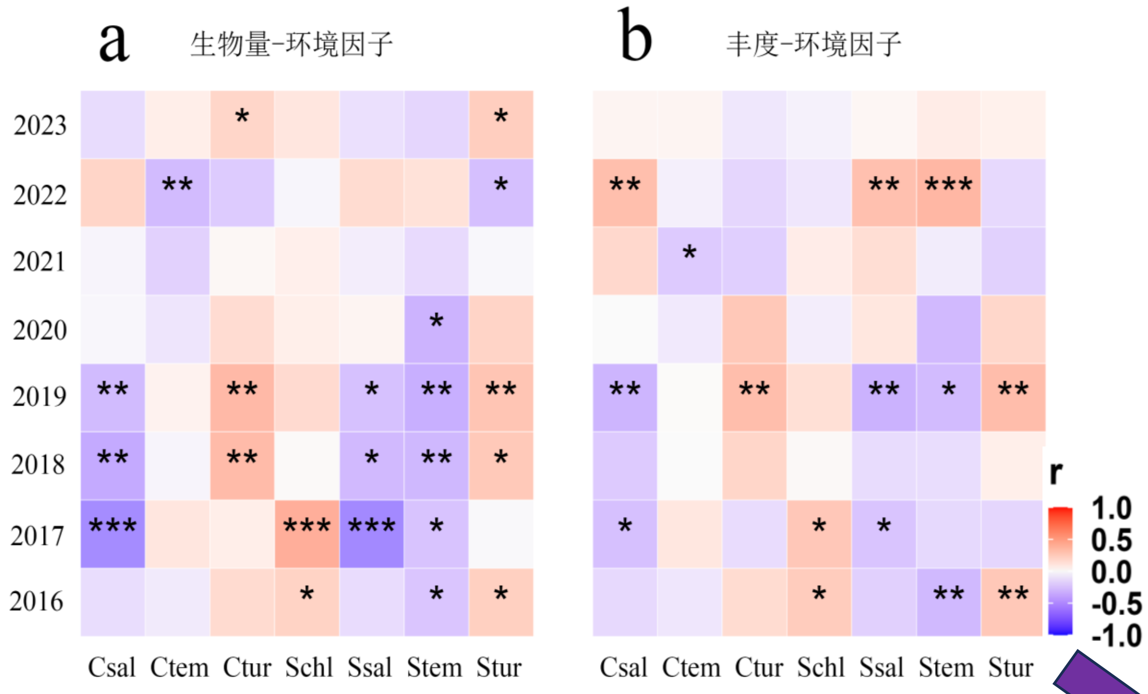


Figure Spearman correlation between zooplankton biomass/ abundance and environmental factors

Csal/Ctem/Ctur-Average salinity/temperature/turbidity of water column

Schl/Saal/Stem/Stur-Surface seawater Chl a/ salinity/ temperature/turbidity

- **For the GAM models with biomass as the dependent variable, Temperature was a significant factor in regulating zooplankton biomass space variation in 2016/2019/2020**
- **For the GAM models with abundance as the dependent variable, Temperature was a significant factor in regulating zooplankton abundance space variation in 2016**
- **No significant factors in other years**

Table Results of GAM model of zooplankton biomass/ abundance and environmental factors

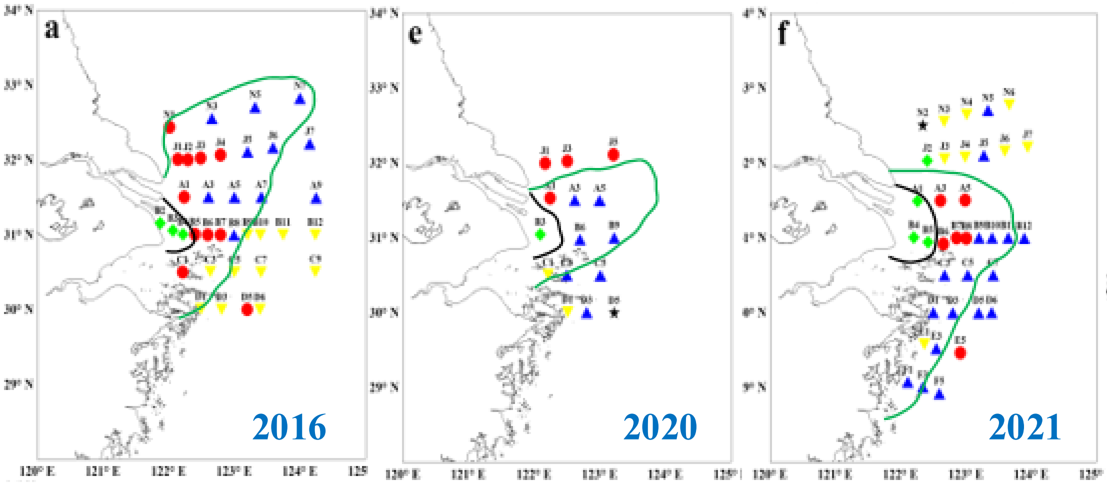
	Model interpretability	P values for surface temperature	Adjusted R 2
2016 biomass	17.0%	0.091.	0.063
2016 abundance	18.2%	0.065.	0.077
2019 biomass	23.6%	0.032*	0.064
2020 biomass	39.4%	0.065.	0.151

GAM: generalize linear model; Only the significant and near-significant independent variables surface temperature are listed in the table

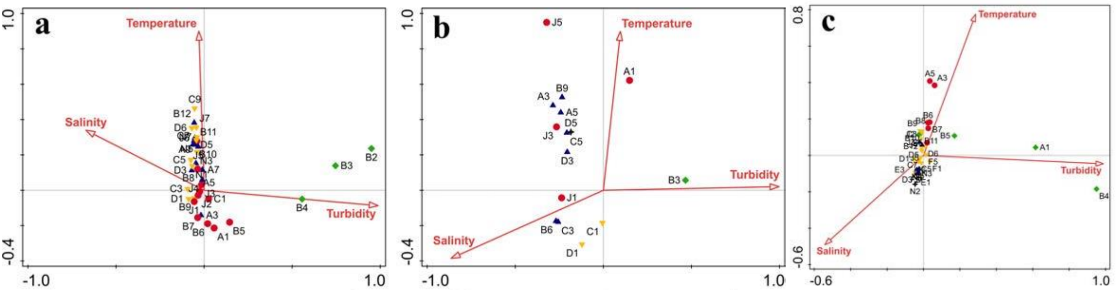
.Indicates 0.05 <P <0.1-close to significant * indicates P <0.05-significant

★ the interannual variations of the **fronts** in Yangtze River estuary aligned with the runoff

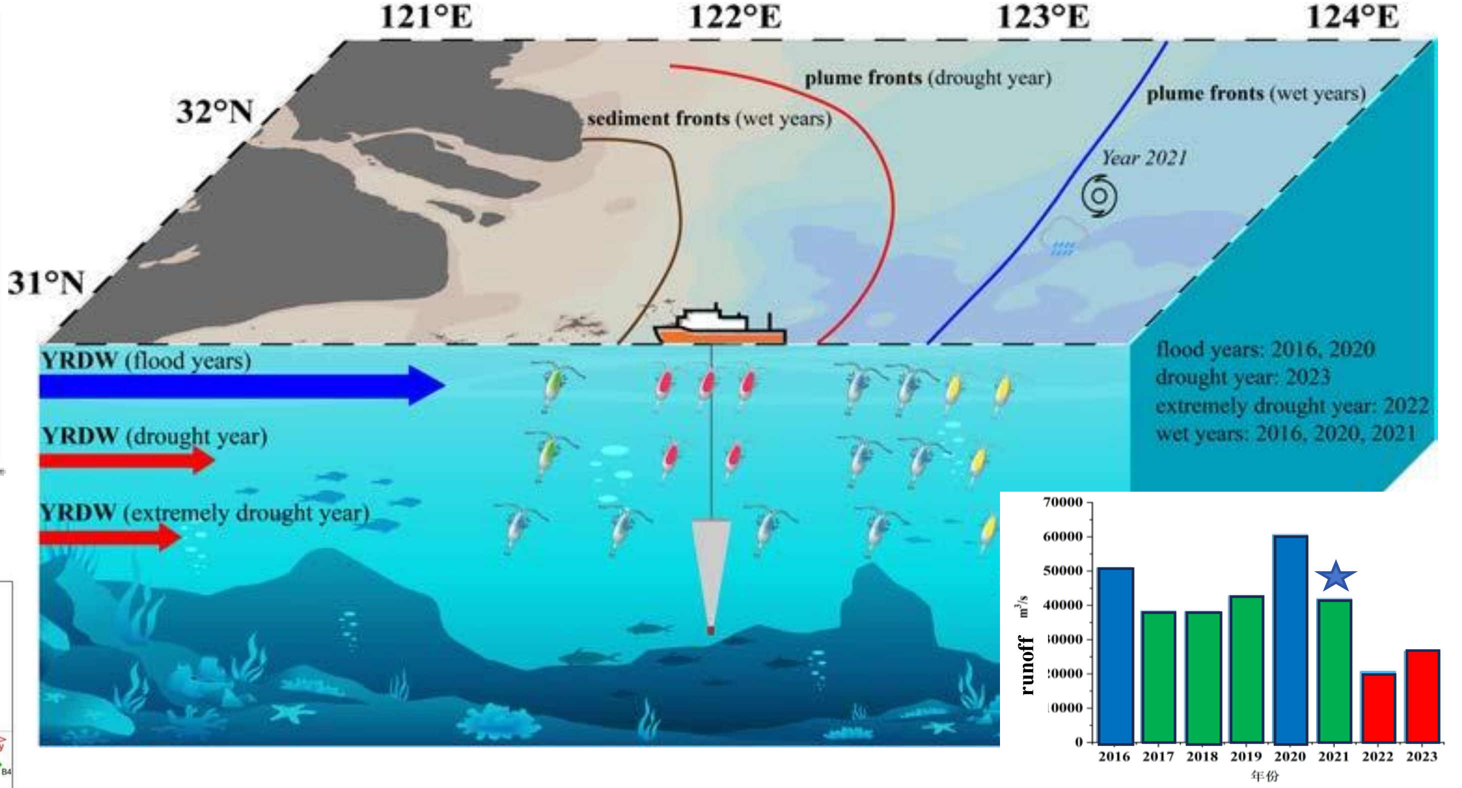
★ in wet years, **the spatial variation of zooplankton communities were shaped by sediment and plume fronts**



spatial differentiation of zooplankton communities



environmental factors regulating spatial variation of zooplankton communities

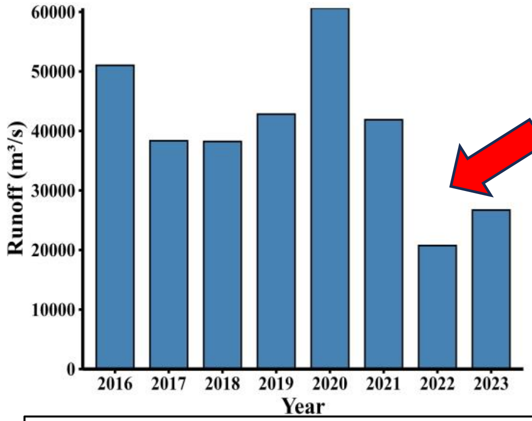


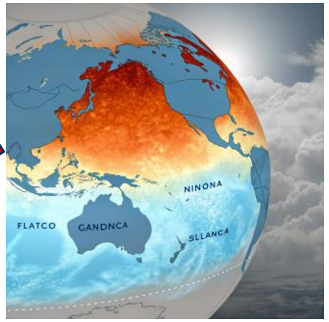
Schematic diagram of influence of different runoff on front at Yangtze River estuary

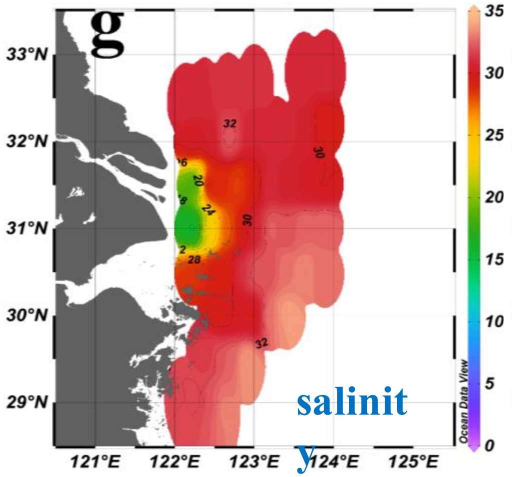
The four different colors of copepods represent four groups of zooplankton

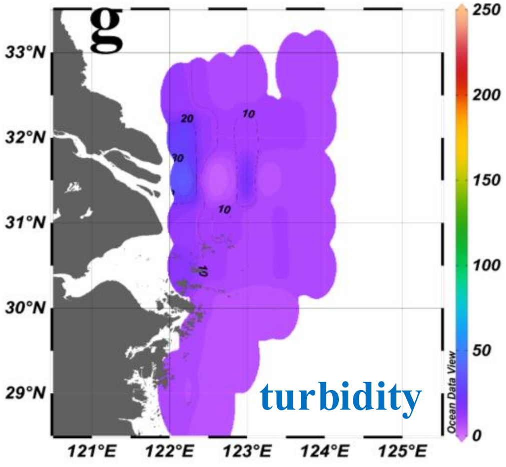
plume fronts expanded in 2016 and 2020—— resulting by higher Yangtze River runoff;
plume fronts expanded in 2021— with heavy rainfall from typhoons— Classified as a wet year

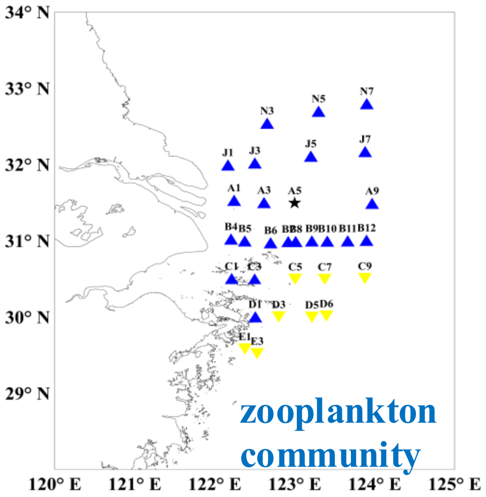
★ Effects of extreme drought on zooplankton communities in 2022

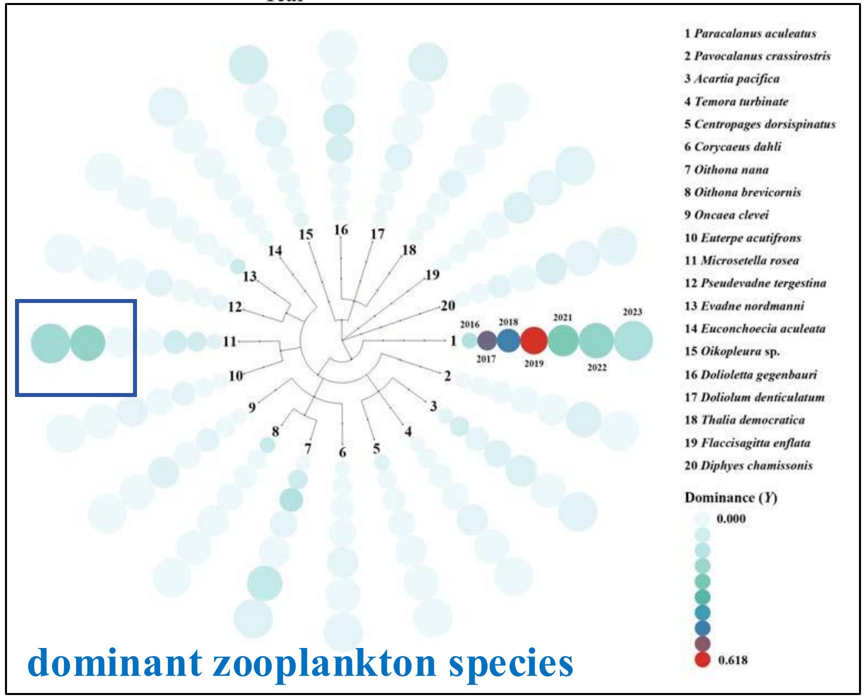












- The extreme drought event in 2022 at the Yangtze River estuary caused a significant increase in salinity,
- the disappearance of the sedimentary front,
- marked changes in zooplankton communities,
- the dominance of wide-temperature and wide-salinity species rising substantially.

① The interannual variations of the sediment fronts and plume fronts in summer generally aligned with the magnitude of the Yangtze River runoff from 2016 to 2023.

② The dynamic process of estuarine fronts had a significant impact on the zooplankton community in the Yangtze Estuary.

③ During wet years, sediment fronts, plume fronts and temperature regulated the spatial variations of zooplankton community.

④ During dry years, the sediment front disappears and the plume front becomes the main factor driving the distribution of zooplankton communities.

⑤ The extreme drought event in 2022 at the Yangtze River estuary caused marked changes in zooplankton communities. Against the backdrop of climate change intensifying the frequency of extreme events, these changes call for people to pay attention to the changes in fishery resources and ecological risks.

Thank you for your attention ！

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