Gelatinous zooplankton from shift from jellyfish-thaliaceans to larvaceans during the past 30 years in a subtropical coastal bay , China



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PICES-2025 Nov 8-14, 2025 | Yokohama, Japan

Introduction

- **Gelatinous zooplankton**(GZ), are a polyphyletic group of transparent and fragile marine organisms that are characterized by high tissue water content (> 90%) and unique physiological adaptations.
- GZ span from mucous-mesh grazers to carnivorous predators, playing vital yet overlooked roles in food webs and carbon cycling. **Despite their influence on trophic dynamics and carbon sequestration under global change, limited long-term monitoring constrains our understanding of their ecological roles.**
- Similar to warming effects such as ocean warming and marine heatwaves, **cold climatic events**, including temperature decreases and cold spells, **can also severely disrupt plankton ecosystems; however, their ecological impacts have received far less attention**.
- Daya Bay, a semi-enclosed subtropical bay strongly influenced by the climate and intensive human activities, serves as an ideal natural laboratory to investigate how climatic and anthropogenic pressures jointly drive long-term ecological transformations in coastal ecosystems.

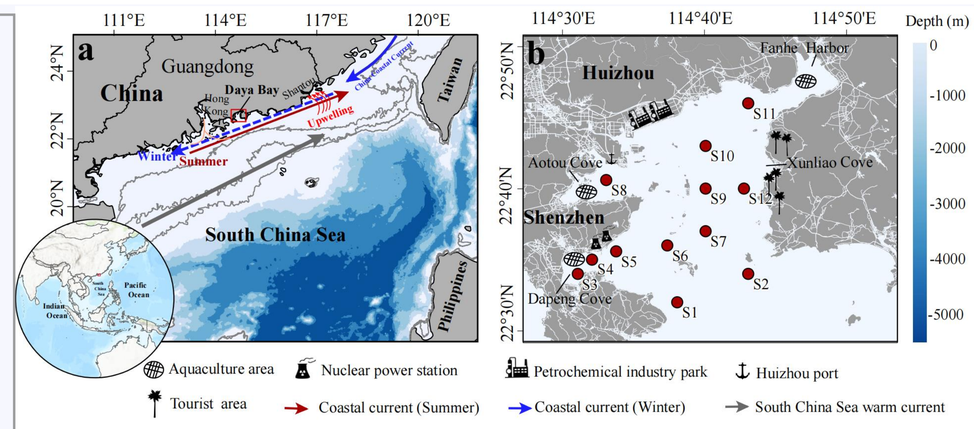


Figure 1. Map of the study area showing (a) schematic diagrams of seasonal ocean currents in the northern South China Sea and (b) the sampling stations and human activity zones in Daya Bay.

Temporal trends in climatic, environmental, and biological variables

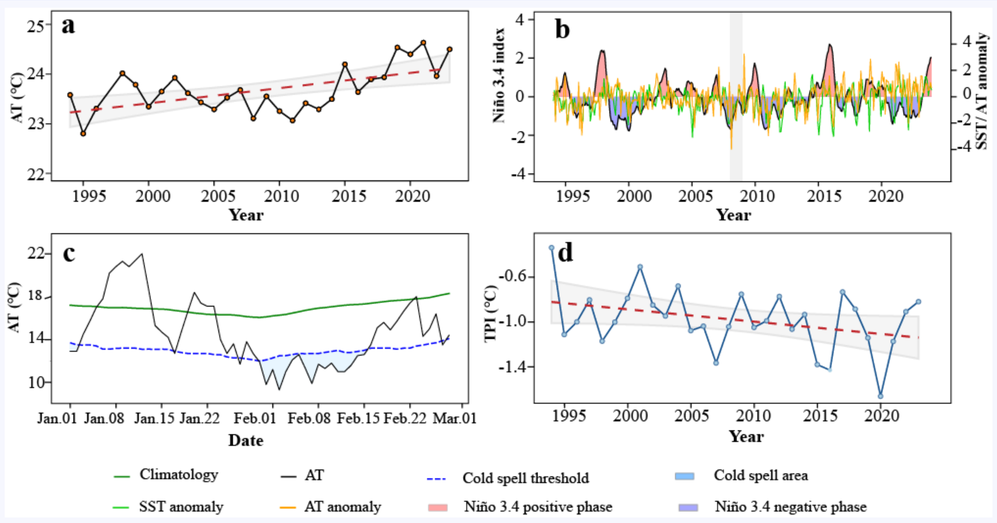


Figure 2. Long-term variation in air temperature (AT) (a), relationship among the Niño 3.4 index, sea surface temperature (SST) anomaly, and AT anomaly (b), daily values and climatological mean of AT (c), and long-term variation in the topographic position index (TPI) (d).

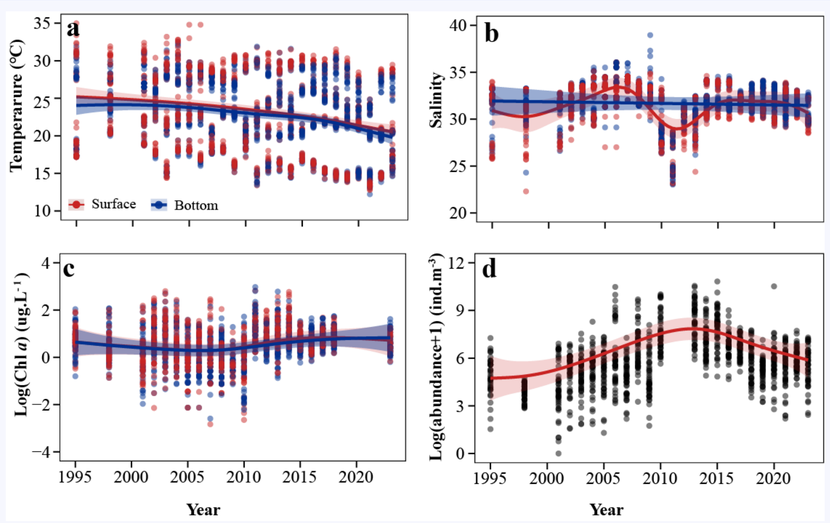


Figure 3. Long-term variation in water temperature (a), salinity (b), Chl *a* (c), zooplankton abundance (d).

- An extreme cold spell associated with a strong La Niña event occurred in January–February 2008, representing the longest cold event in nearly three decades and resulting in a marked decline in sea surface and air temperatures(Fig.2b-c).
- TPI values exhibited interannual fluctuations but showed an overall decreasing trend during the study period (Fig. 2d), indicating an enhanced intrusion of coastal upwelling from eastern Guangdong into Daya Bay.
- Both Sea surface and bottom temperatures decreased significantly (MKtest, $p < 0.05$).No significant long-term trends were detected in salinity or Chl *a* ($p > 0.05$; Fig. 3b–c).

Shifts in gelatinous zooplankton following the tipping point

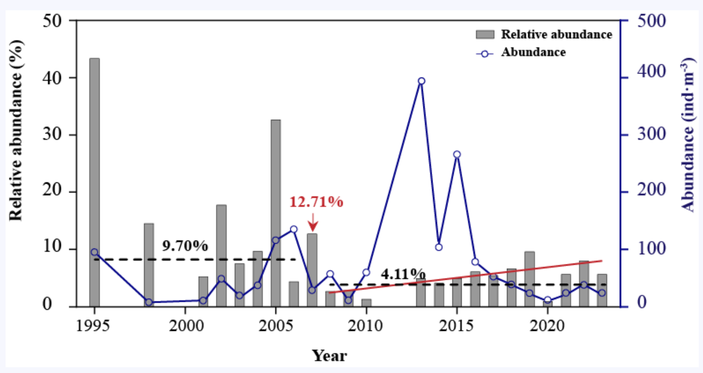


Figure 4 Long-term variation in the abundance and relative abundance of GZ.

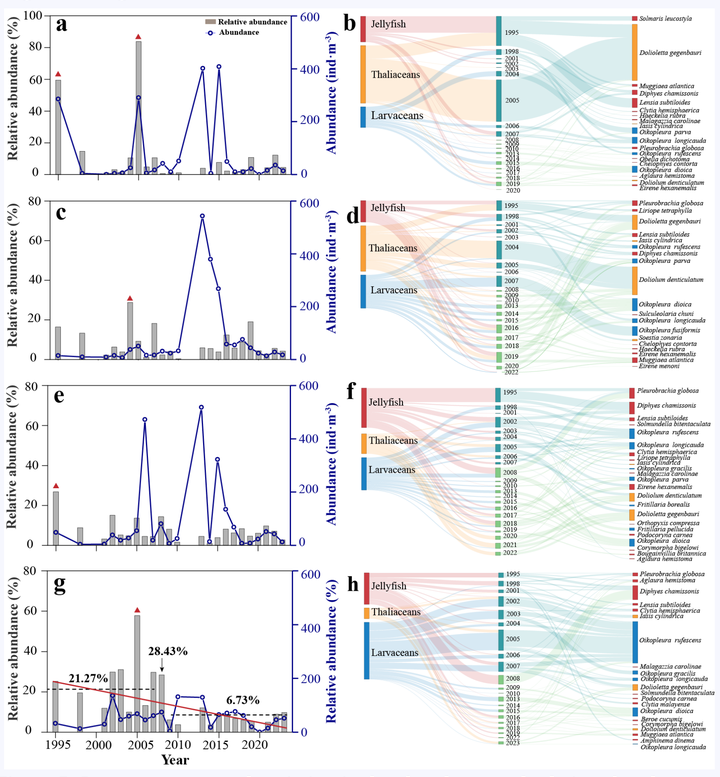


Figure 5 Long-term seasonal variation in the abundance and relative abundance of GZ(a,c,e, g); Seasonal shifts in GZ groups and dominant species composition (b,d,f,g). (a–b) Spring, (c–d) Summer, (e–f) Autumn, (g–h) Winter.

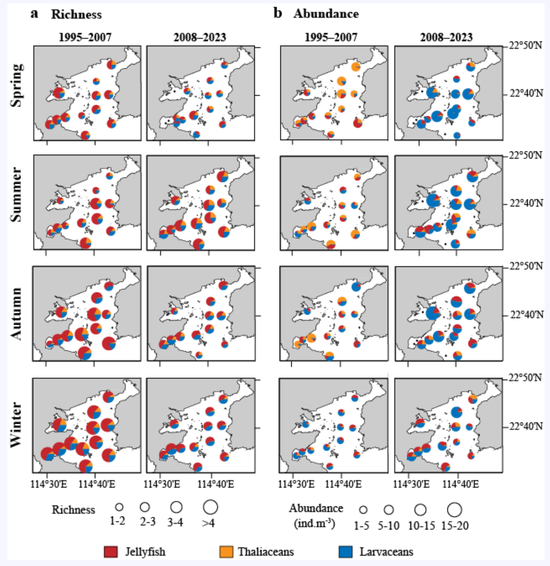


Figure 6 Spatial distributions of species richness (a) and abundance (b) of gelatinous groups during 1995–2007 and 2008–2023.

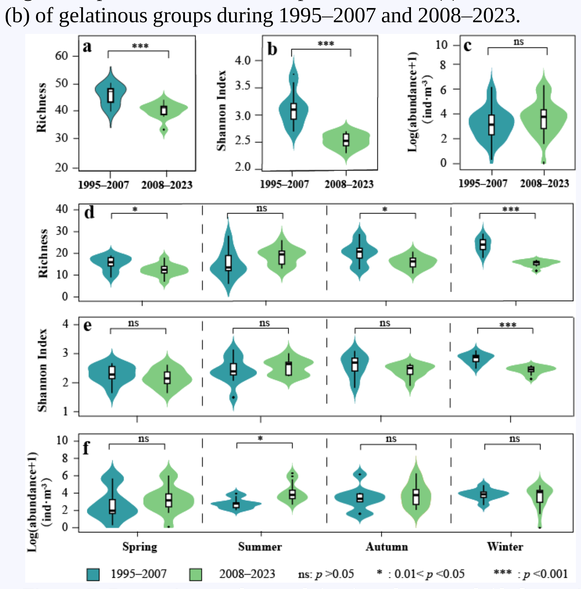


Figure 7 Comparisons of annual (a–c) and seasonal (d–f) species richness, diversity (Shannon index), and abundance of gelatinous zooplankton between 1995–2007 and 2008–2023.

Drivers of gelatinous zooplankton succession

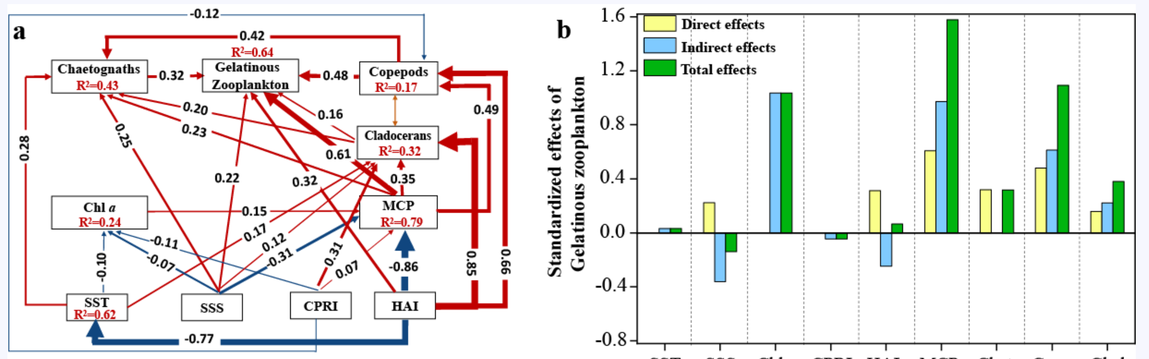


Figure 8 Piecewise structural equation model illustrating the direct and indirect pathways through which climatic, hydrological, biotic, and anthropogenic drivers influence the abundance of GZ. (a) Arrows represent significant unidirectional relationships ($p < 0.05$). Arrow thickness is proportional to standardized path coefficients, which are indicated on each path.

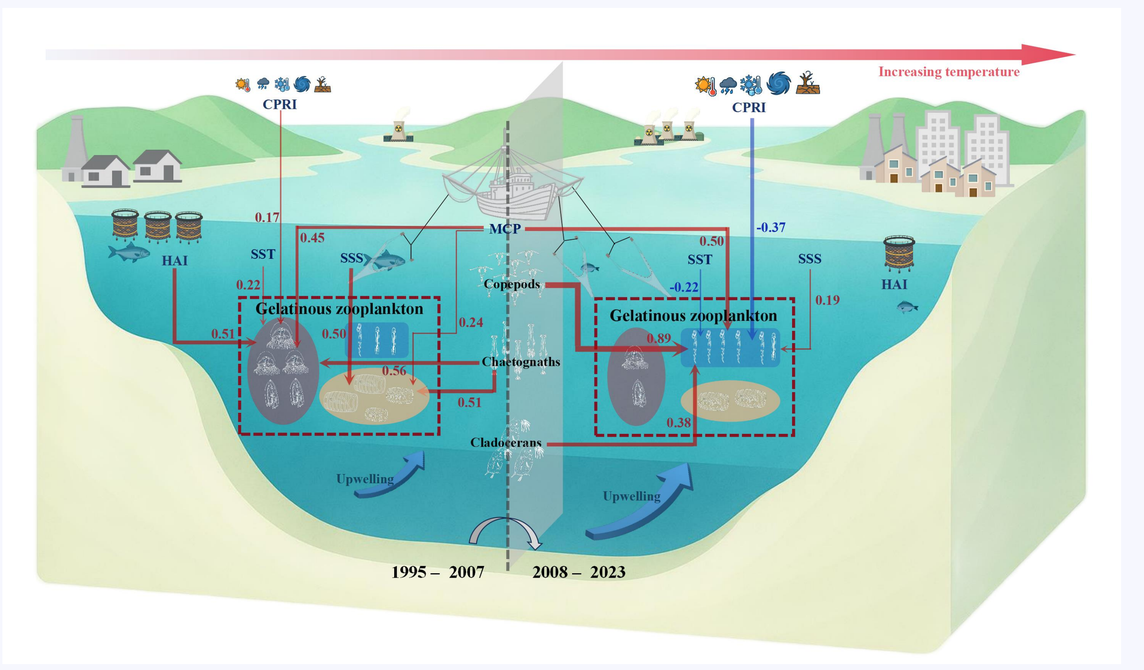


Figure 9 Conceptual illustration of regime shift and the changing pathways through which climatic, hydrological, biotic, and anthropogenic drivers influenced the abundance of GZ groups in DYB from 1995–2023.CPRI: climate physical risk index; MCP: marine catch production; HAI: human activity index.

- An abrupt shift in the gelatinous zooplankton community occurred around 2008, when the mean relative abundance decreased compared with the pre-shift period($p < 0.05$), but subsequently showed a consistent increasing trend ($p < 0.05$)(Fig.4).
- Following 2008, GZ community shifted from jellyfish and thaliacean dominance to larvacean dominance, driven largely by species turnover within larvaceans, with *Oikopleura rufescens* dominating before 2008 and *O. dioica* becoming overwhelmingly dominant afterward, particularly during winter (Fig. 5–7).
- A pronounced decline in both species richness and diversity was observed after 2008 ($p < 0.05$)(Fig.7).
- MCP showed the strongest positive effect on total GZ abundance as well as on all three gelatinous groups (Fig. 8–9). Jellyfish were mainly influenced by chaetognaths, SST, and HAI; thaliaceans by chaetognaths, SSS, and SST; and larvaceans by copepods and SST.

Conclusions

- A clear ecological regime shift occurred in the gelatinous zooplankton community of Daya Bay, with a abrupt change around 2008 triggered by an extreme cold anomaly.
- The shift was facilitated by cumulative anthropogenic stress and intensified summer upwelling, indicating the joint influence of climatic and human pressures.
- The post-shift decline in species diversity may weaken ecosystem resilience, whereas increasing larvacean dominance suggests enhanced efficiency of energy and material transfer in the planktonic food web.