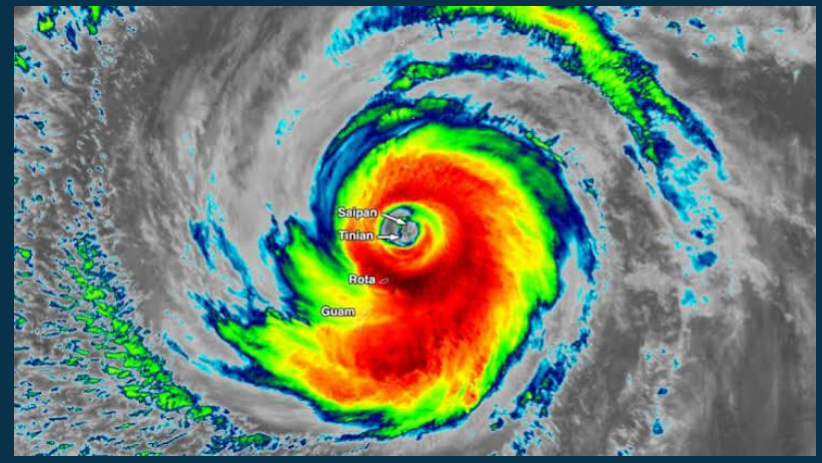
Storm intensity alters dominant physical controls on coastal pelagic ecosystem dynamics

High-frequency plankton imaging across five typhoons in the northern South China Sea



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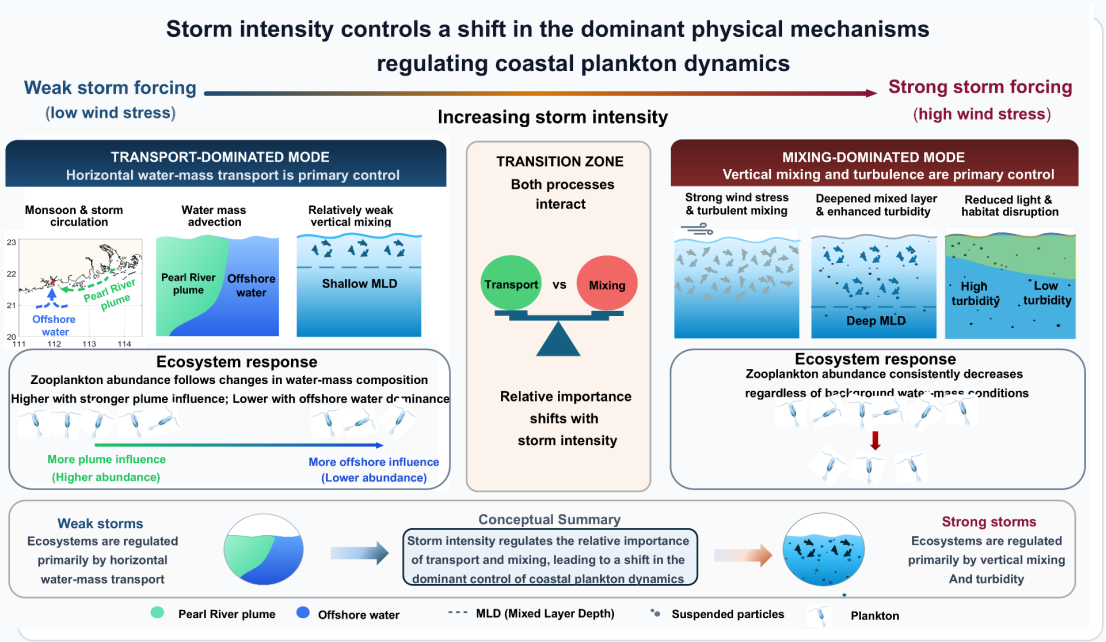
5. Oasis Photobio Technology LTD

The central argument is a shift in mechanism, not simply a change in abundance.

Typhoon effects look contradictory until we separate two physical pathways.



1 Storm forcing varies

Five events span weak to strong local wind stress.

2 Dominant control shifts

Weak: water-mass transport
Strong: mixing + turbidity

3 Plankton reveals response

High-frequency imaging captures rapid ecosystem reorganization.

Why storm responses are hard to predict

Previous studies report enhancement, suppression, or weak responses after tropical cyclones.

The same type of disturbance can lead to different biological outcomes.

Abundance increases

Nutrient supply or plume transport can enhance plankton.

Abundance declines

Mixing, turbidity, or offshore intrusion can suppress abundance.

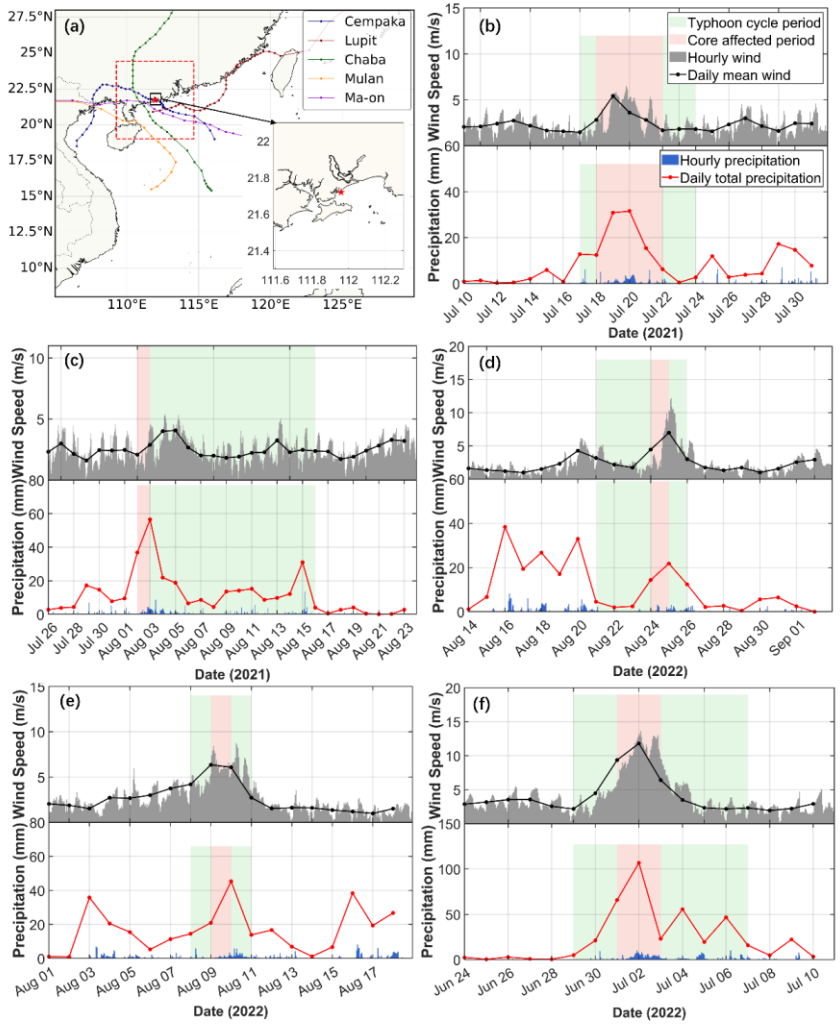
Weak or mixed response

Competing processes can offset one another.

Working hypothesis: storm intensity changes the balance between regional connectivity and local disturbance.

Study design: five typhoons at one coastal observing site

Northern South China Sea, 2021–2022.



A fixed station allowed direct comparison across events.

Five typhoons

Cempaka, Lupit, Ma-on, Mulan, Chaba

Core affecting period

Typhoon center within ±2.7° of the observing site

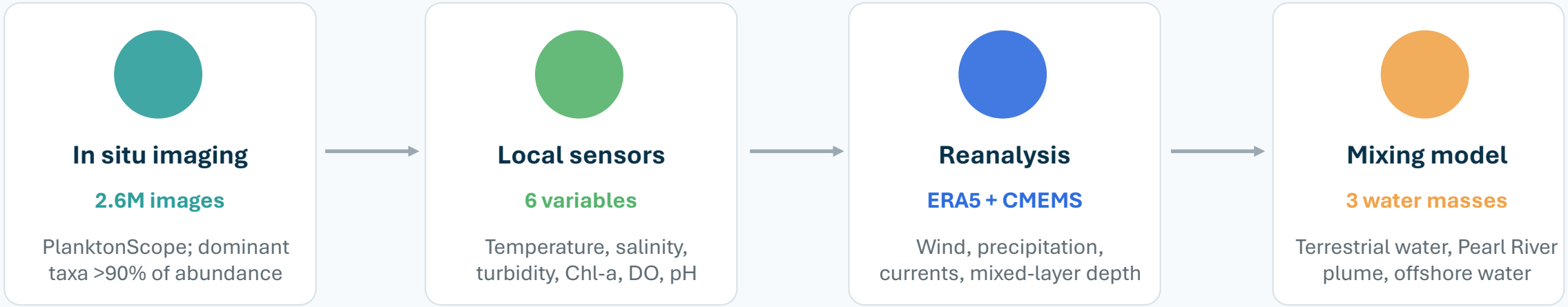
Before/after

Seven-day pre- and post-impact windows

Data fusion: biological sentinels + physical context

The study combines continuous plankton imaging with local and regional physical data.

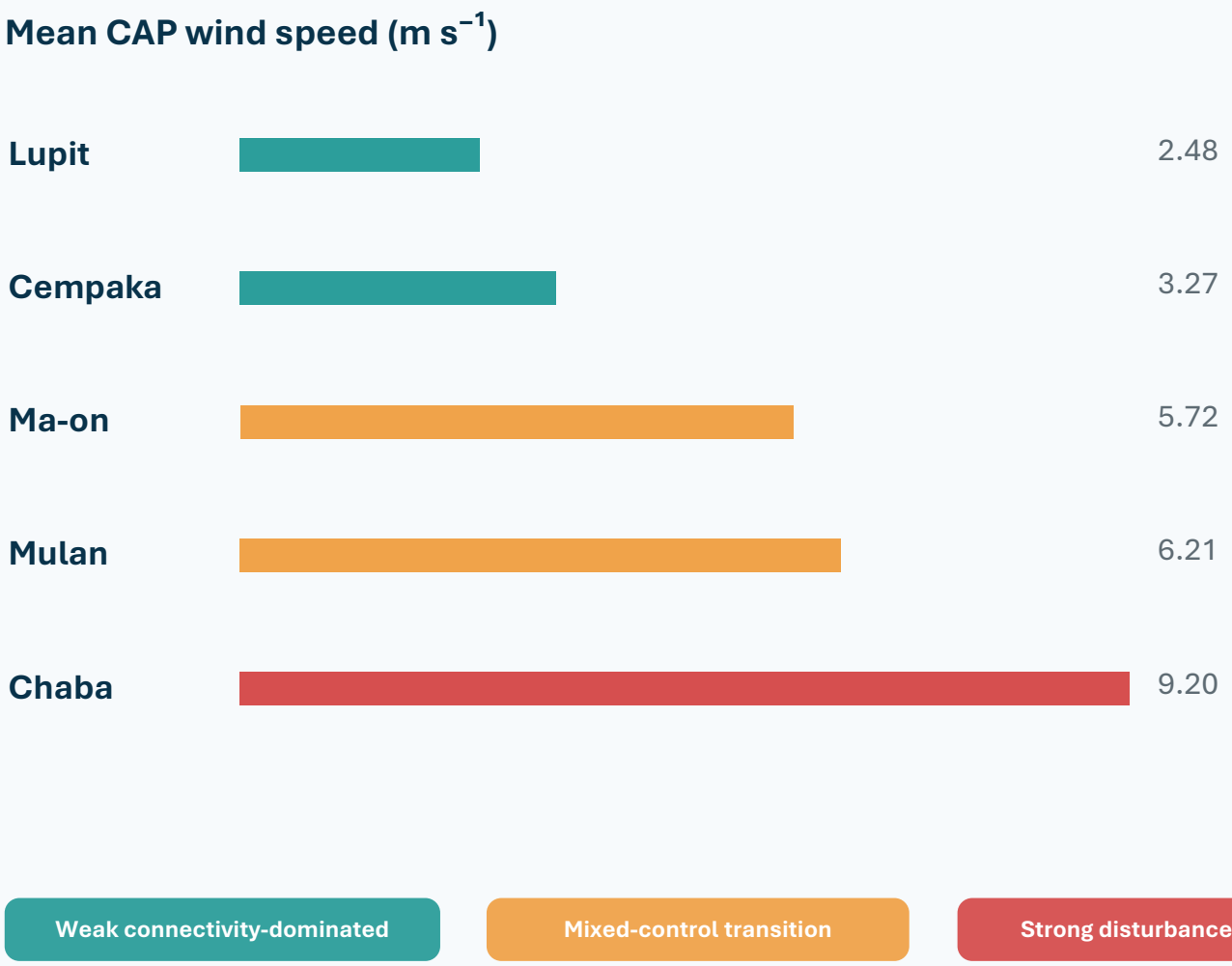
Plankton were treated as high-frequency sentinels of pelagic ecosystem response.

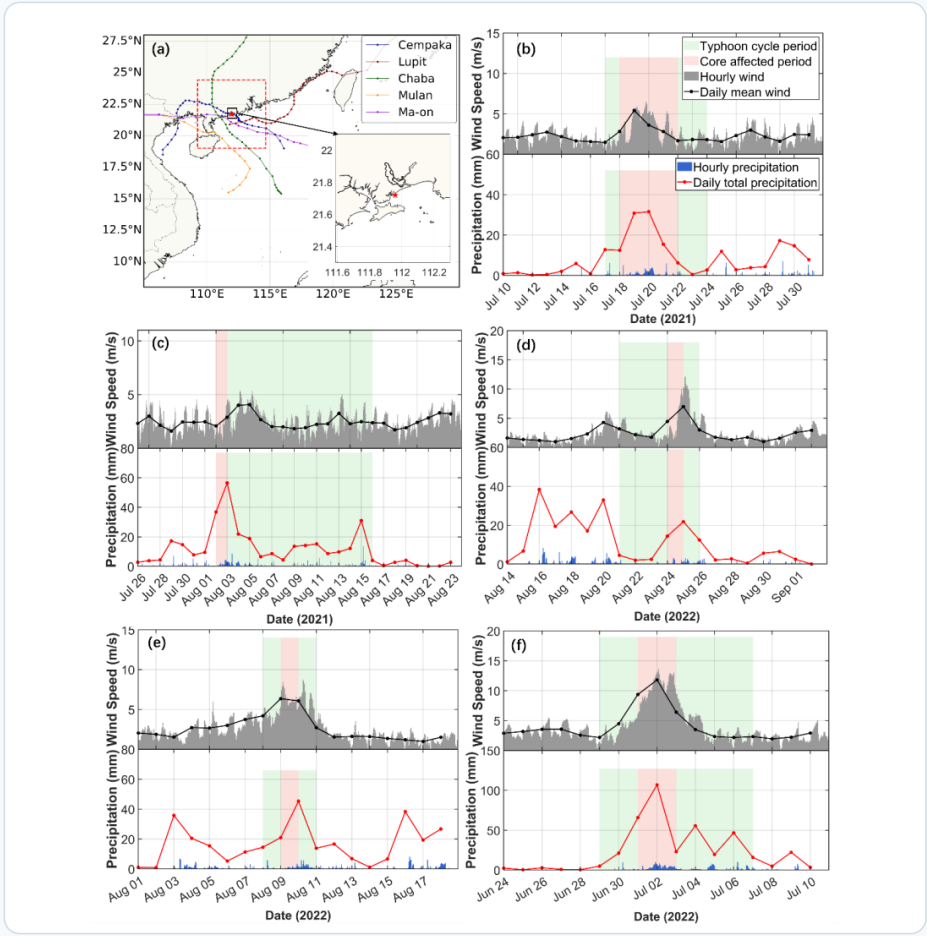


Final analyses linked taxon-specific abundance changes to water-mass connectivity and disturbance metrics.

Five typhoons formed a weak-to-strong local intensity gradient

Local storm intensity was represented by mean wind speed during the core affecting period.





Weak connectivity-dominated | **Mixed-control transition** | **Strong disturbance-dominated**

Ecosystem responses were contrasting, not uniform

Storm occurrence alone did not predict the direction of plankton response.

The same observing site showed declines, increases, and mixed responses.

Lupit: broad declines across most groups despite weak local turbidity signal.

Ma-on: increases in several taxa under moderate forcing and strong plume influence.

Chaba: community-wide suppression under strongest local disturbance.

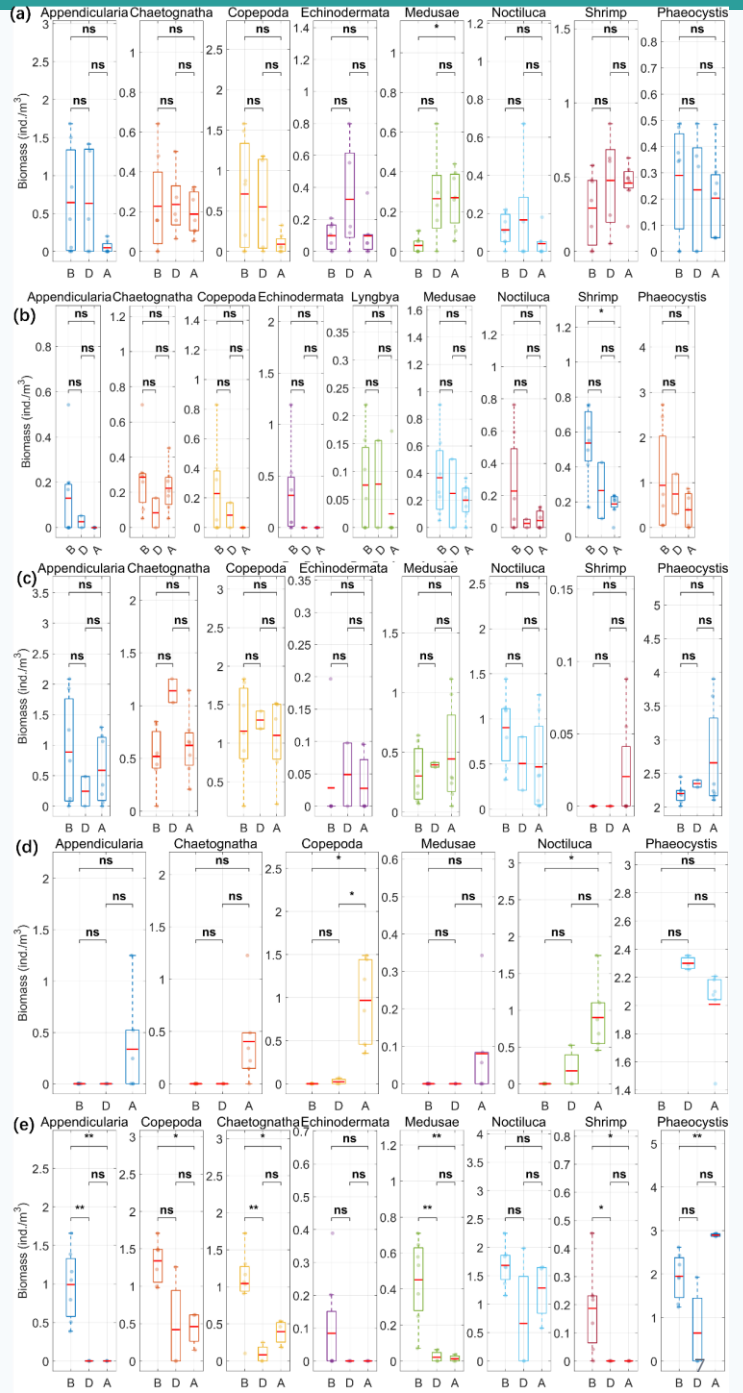
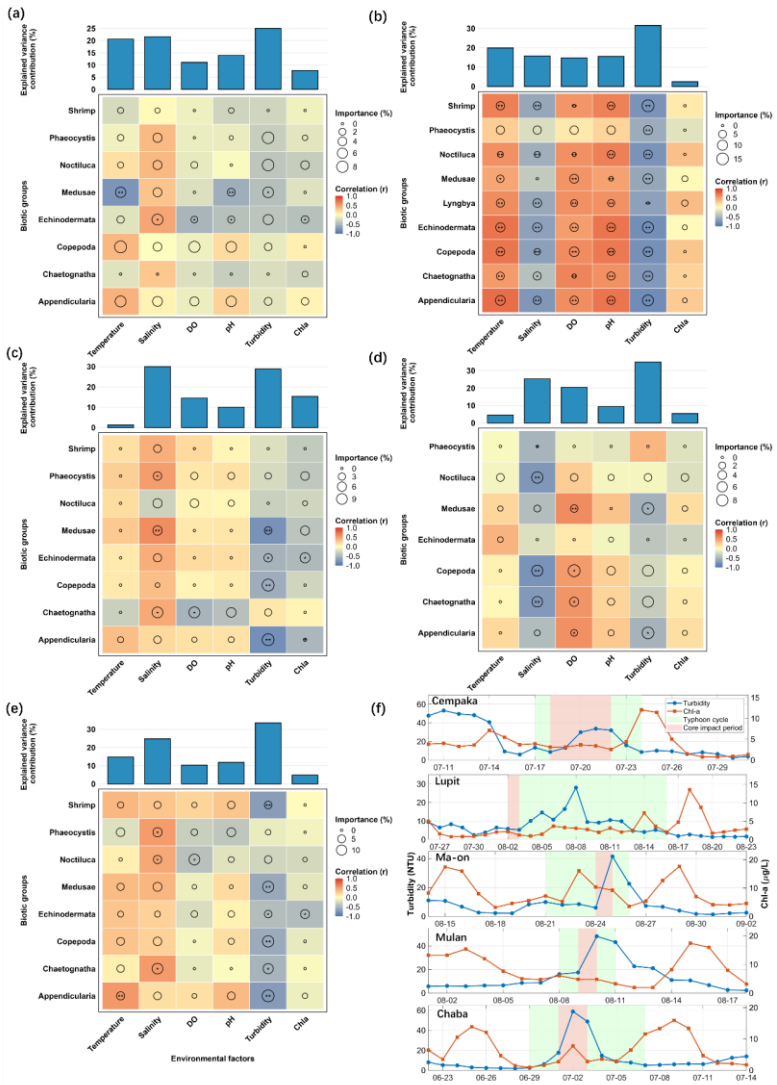


Figure: before/during/after abundance distributions across taxa and typhoons.

Environmental drivers: turbidity is the most consistent disturbance signal

Random forest and correlation analyses linked environmental variability to plankton abundance.



Turbidity connects physical disturbance to biological response.

Elevated turbidity integrates sediment resuspension, turbulent mixing, particle redistribution, and reduced light.

Key nuance: similar biological declines can arise from different mechanisms — offshore intrusion versus local turbidity.

Across events, turbidity was the most consistent negative predictor of zooplankton abundance.

Connectivity pathway: plume water versus offshore intrusion

When local disturbance is limited, water-mass exchange becomes the main control.

Water masses carried different biological signatures into the observing site.

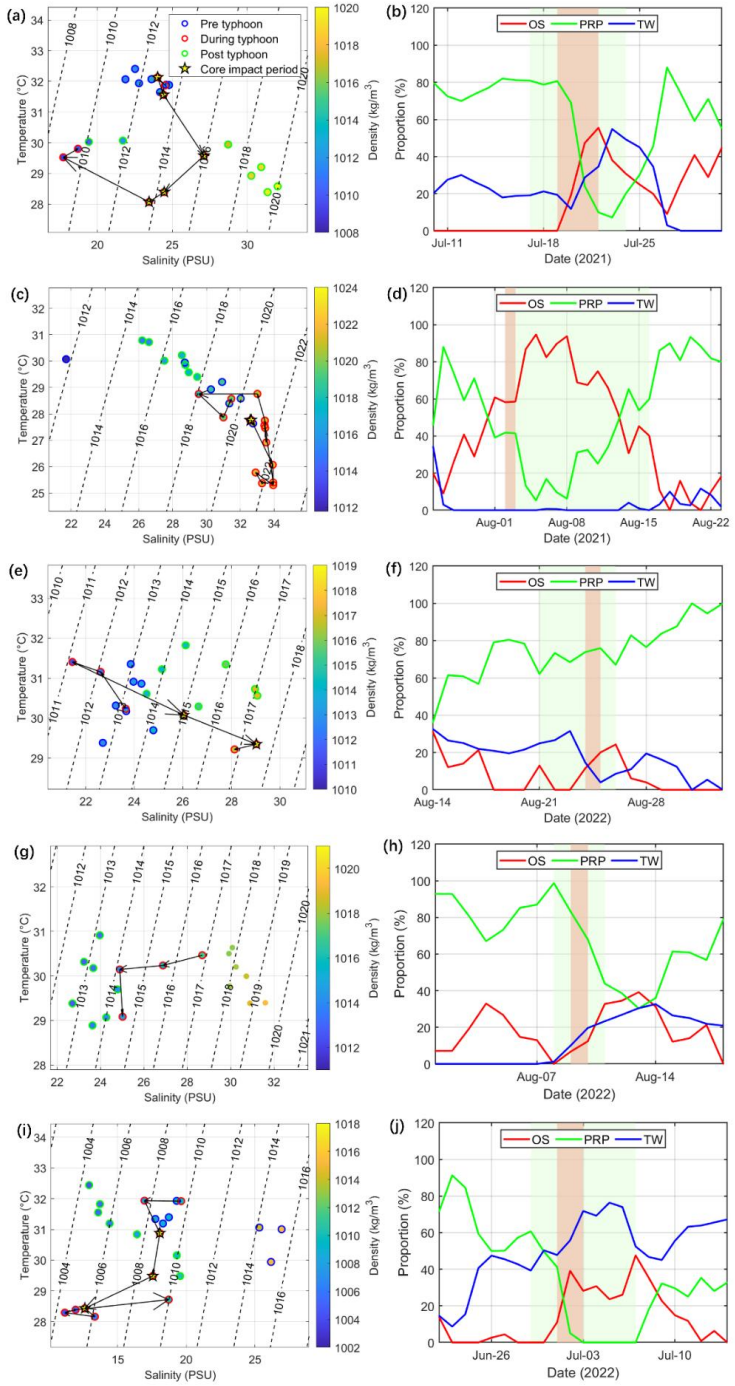
Offshore intrusion

Lupit
58.37% offshore water
Low chlorophyll a
Broad declines

Plume influence

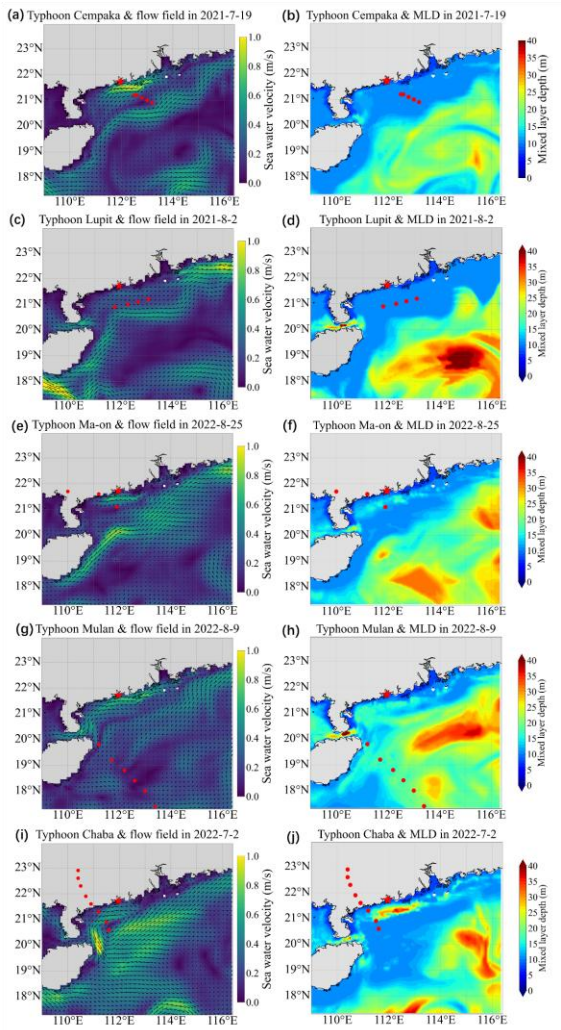
Ma-on / Mulan
~75% PRP fraction
High PRP signal
Several taxa increase

Interpretation: weak and moderate events are strongly shaped by which water masses arrive.



Local disturbance pathway: mixing and resuspension

Strong storm forcing can override the biological signature of water-mass transport.



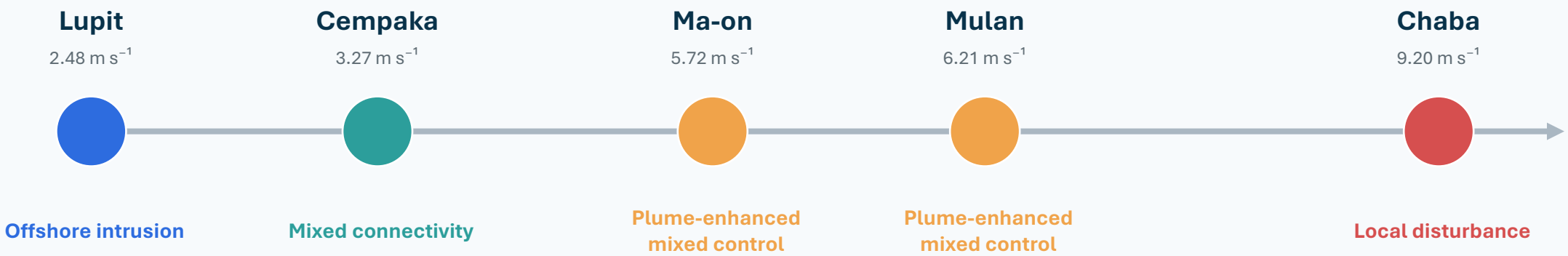
Chaba showed the clearest disturbance-dominated response.

9.20 m s^{-1}	highest mean wind intensity
12.38 m	deepest mean mixed layer
58.87 NTU	maximum turbidity
866.67%	maximum turbidity increase

Outcome: widespread zooplankton declines largely independent of background water-mass conditions.

Synthesis: storm intensity reorganizes dominant controls

The five events form a connectivity–disturbance continuum.



Connectivity dominates

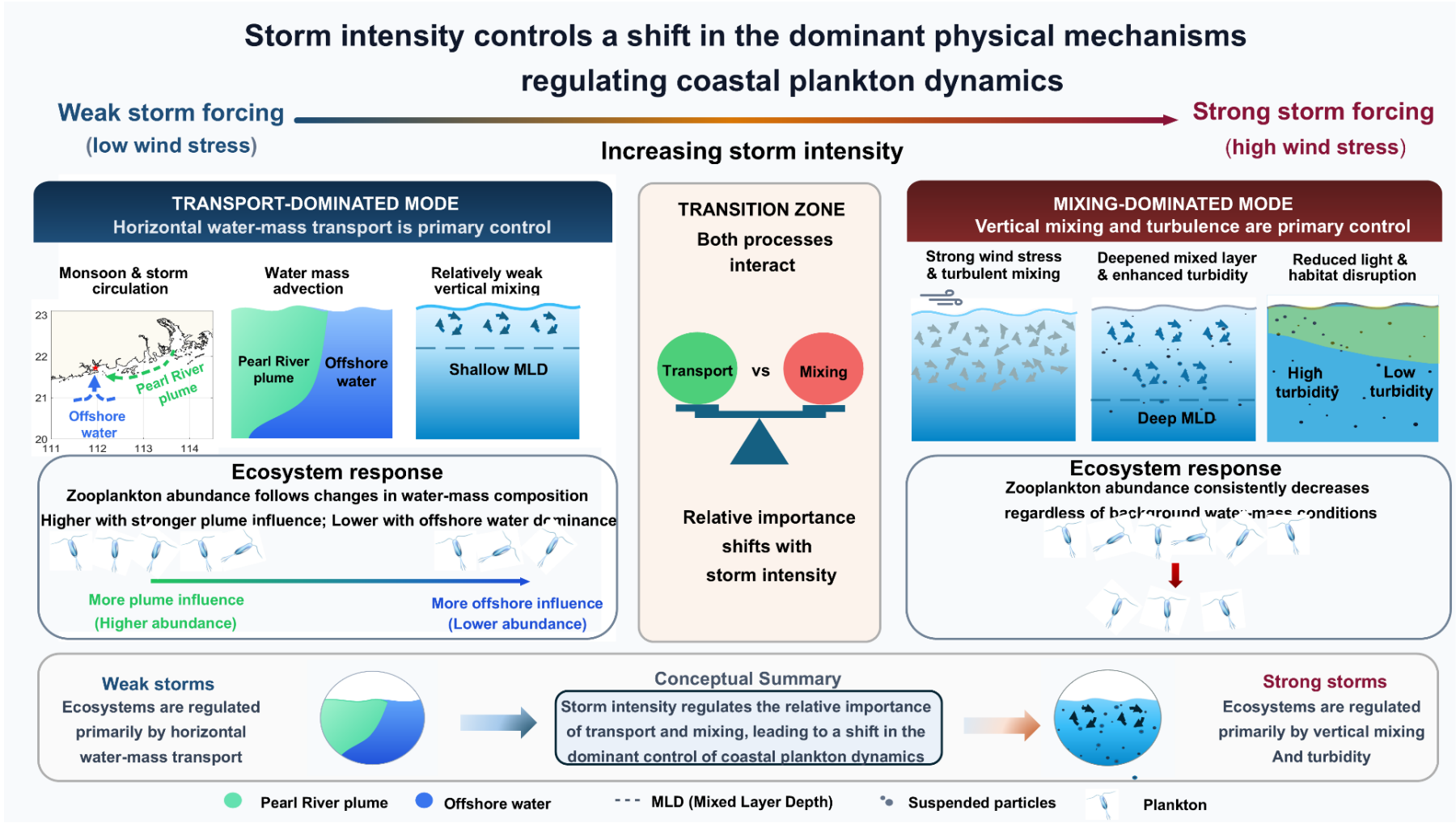
Connectivity + disturbance interact

Disturbance dominates

The transition is a continuum, not a universal threshold.

Conceptual framework: connectivity–disturbance continuum

Storm intensity changes the relative importance of transport and mixing.



Same biological outcome, different physical mechanisms

Declines alone do not diagnose storm impact. Mechanism matters.

Two storms can reduce plankton abundance for different reasons.

Lupit: transport-driven decline

Weak wind forcing
Low turbidity response
High offshore-water contribution
Plankton decline reflects offshore intrusion

Chaba: disturbance-driven decline

Strong wind forcing
Deep mixed layer
Extreme turbidity increase
Plankton decline reflects local disturbance

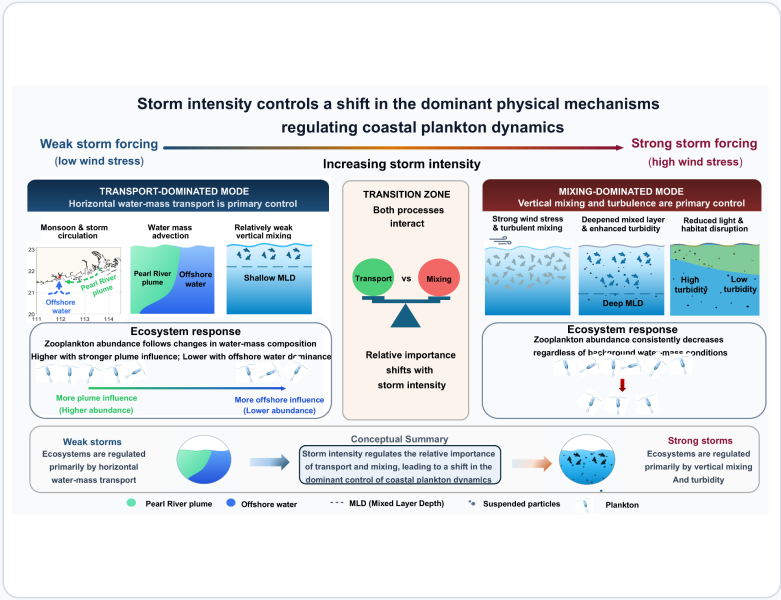
Plankton response must be interpreted jointly with connectivity and disturbance metrics.

Implications under intensifying storms

The framework helps anticipate how coastal pelagic ecosystems may respond to stronger events.

Stronger storms may push shallow coastal systems toward disturbance-dominated states.

- **Prediction** — More frequent deep mixing, sediment resuspension, and turbidity pulses.
- **Ecosystem consequence** — Short-term suppression of zooplankton and altered trophic transfer.
- **Monitoring need** — High-frequency imaging is essential to resolve the core storm period.
- **Transferability** — The continuum can be tested in other plume-influenced and shallow coastal systems.



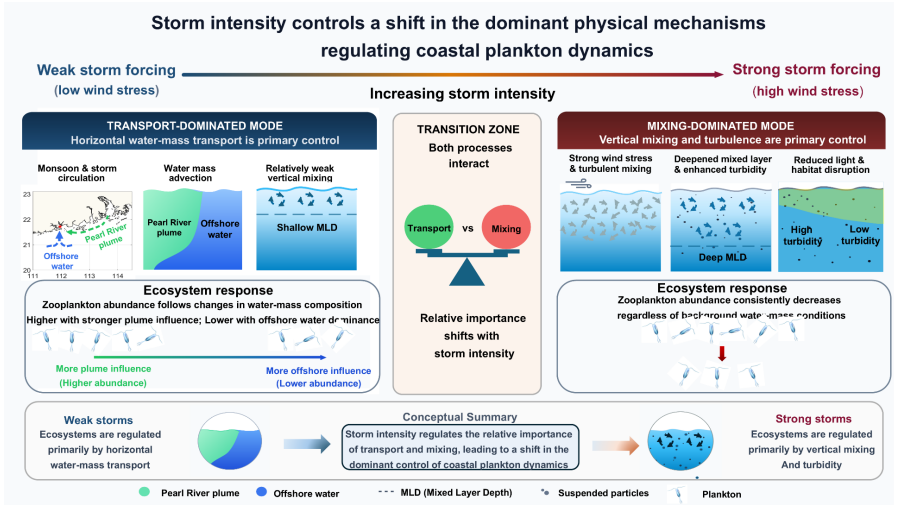
The contribution is process-based: a mechanism for reconciling divergent typhoon impacts, not a universal numeric threshold.

Take-home messages

1. Typhoon impacts are best interpreted as shifts in dominant physical control.

2. Weak to moderate events are strongly shaped by water-mass connectivity.

3. Strong events can override connectivity through mixing, turbidity, and local disturbance.



Questions?

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