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Phytoplankton community structure responses to episodic summer storms in the eastern English Channel

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PhD thesis: Impact of storms on the marine environment and the phytoplankton communities

PhD thesis: 2023–2026

Université du Littoral Côte d'Opale, Boulogne-sur-Mer

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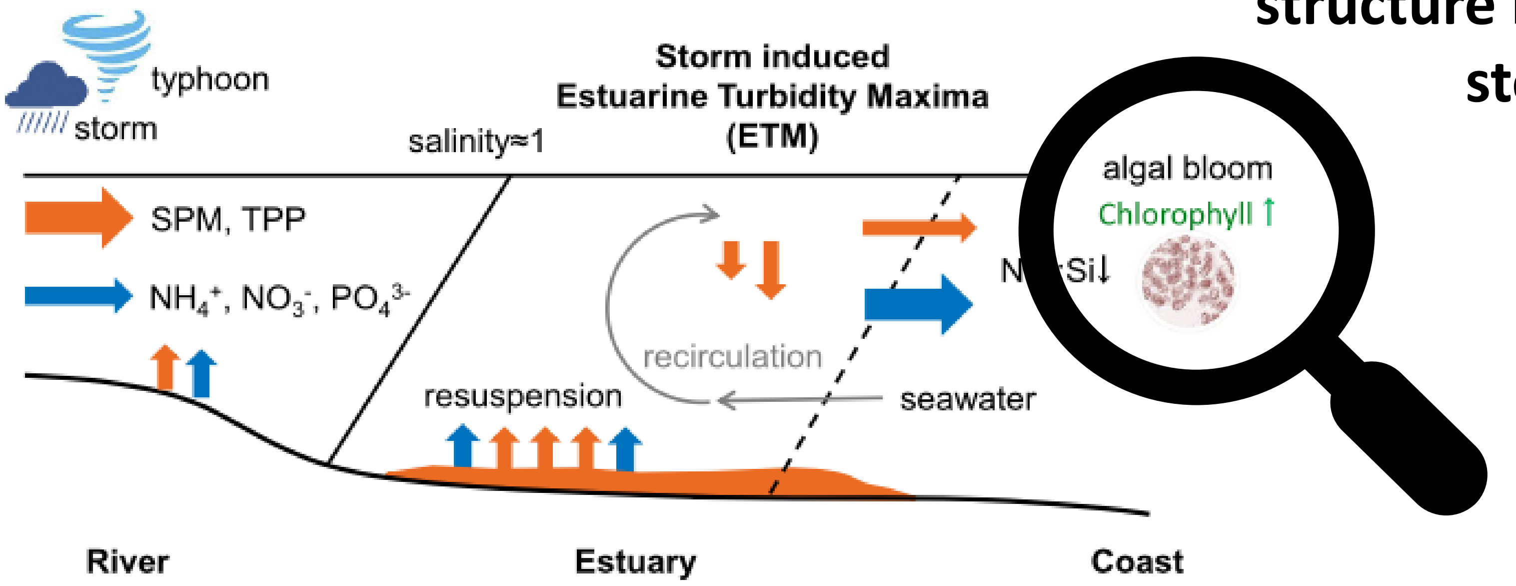
Following Storm Impacts: Understanding Coastal Ecosystem Variability

- Nutrients in the temperate coastal seas are strongly depleted in summer.
- Storm forcing introduces nutrients through mixing and river inflow.

Phytoplankton community structure responses to storm forcing?

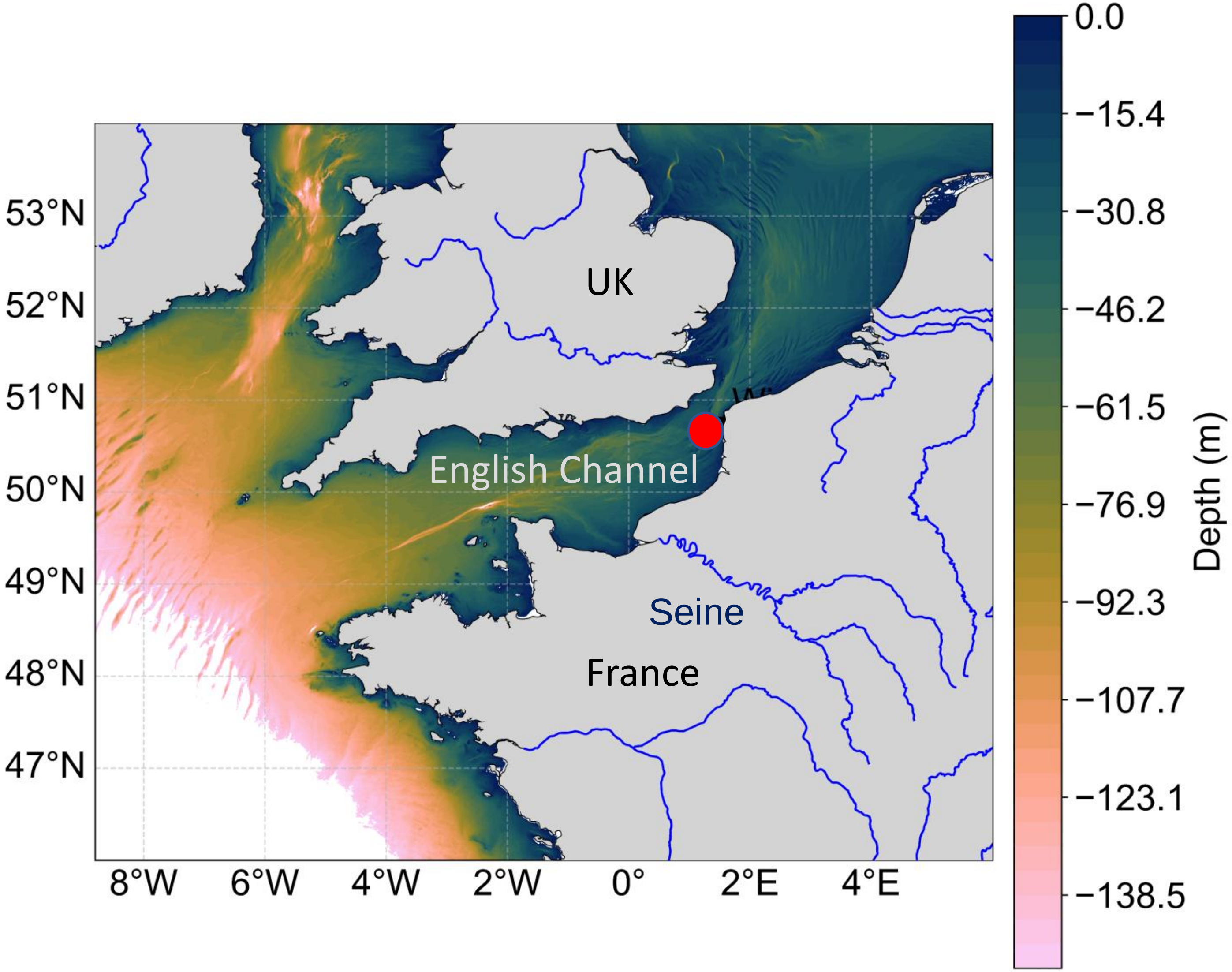
Example of storm impacts on an estuarine ecosystem (from *Chen et al. 2018*)



Study area: Eastern English Channel (EEC)

- Temperate coastal sea
- Macro tidal region
- Influence of the rivers in coastal waters

- In-situ flow cytometry counts of phytoplankton:
  DYPHYRAD campaign (2012–2022)

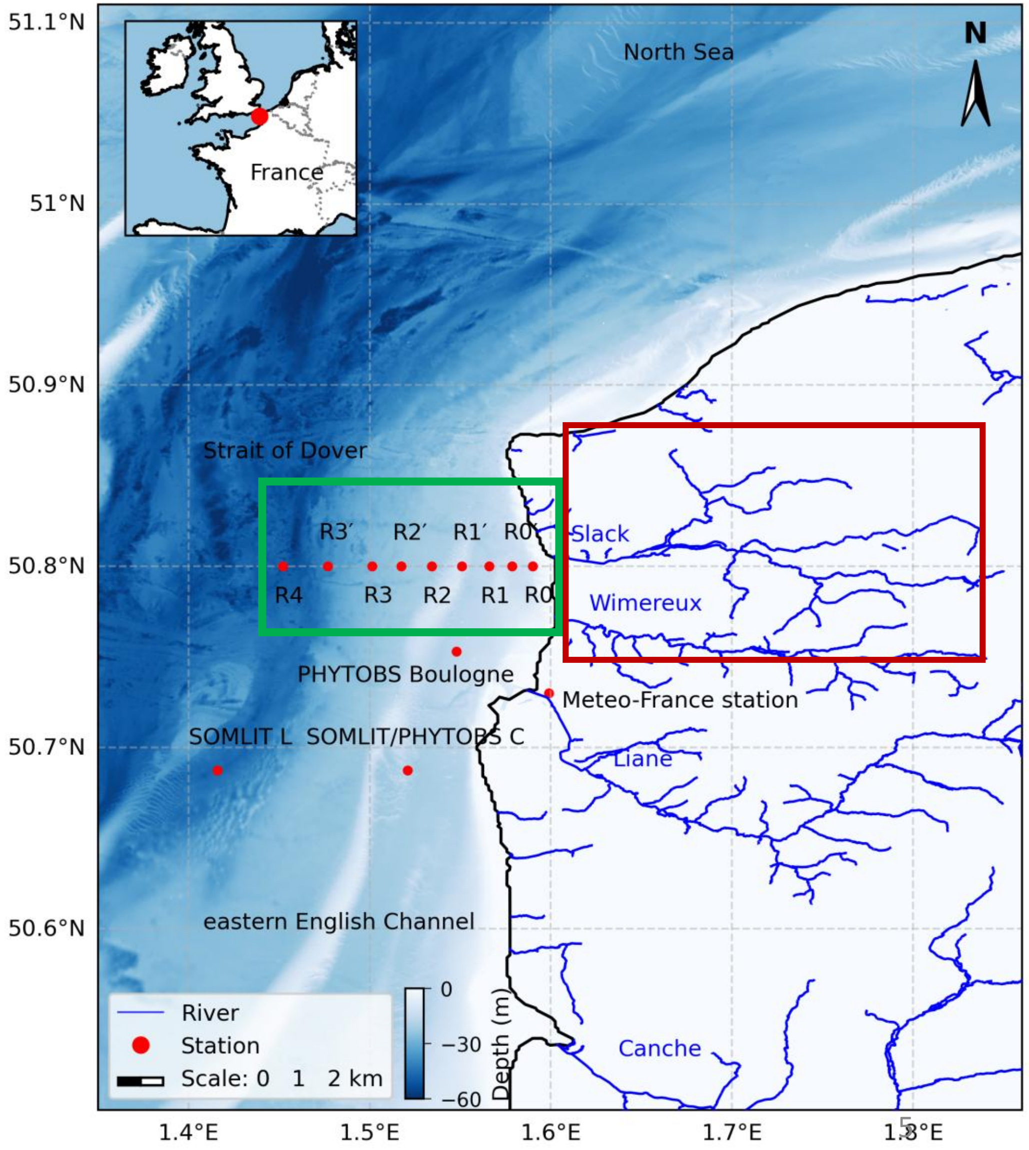


Material: DYPHYRAD campaign (~ weekly frequency)

- **DYPHYRAD campaign (9 location; R0–R4)**:
  - Coastal stations: R0–R2
  - Offshore stations: R2′–R4
  - Frontal system: R1′–R2′
  - All observation are collected at the subsurface 1–2 m.

DYPHYRAD dataset

ESSD article



- Météo-France: Wind & precipitation (Boulogne-sur-Mer).
- River inflow data**:** Eaufrance data for **Slack and Wimereux rivers (local rivers)**.

Flow cytometry counts of phytoplankton groups

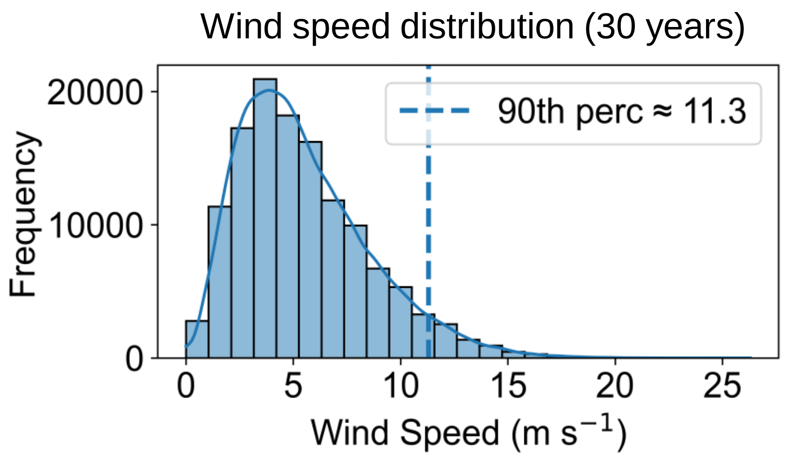
(*Hubert et al., 2026; Thyssen et al., 2022*)

Phytoplankton groups	**Phytoplankton**
OraPicoProk (< 3 µm)	*Synechococcus*, unicellular photosynthetic cyanobacteria
RedPico (< 3 µm)	Picoeukaryotes
RedNano (≈ 3–20 µm)	Nanoeukaryotes including haptophytes (*Phaeocystis globosa*)
OraNano (≈ 3–20 µm)	Cryptophytes
HsNano (≈ 3–20 µm)	Coccolithophorids
RedMicro (cells or chains > 20 µm)	Diatoms, *Phaeocystis globosa* colony

- Size based PFG classification (6 groups)
- In vivo by automated “pulse-shape recording” flow cytometry
- Flow cytometers (CytoSense and CytoSub, manufactured by CytoBuoy b.v., Woerden, the Netherlands)

Methods

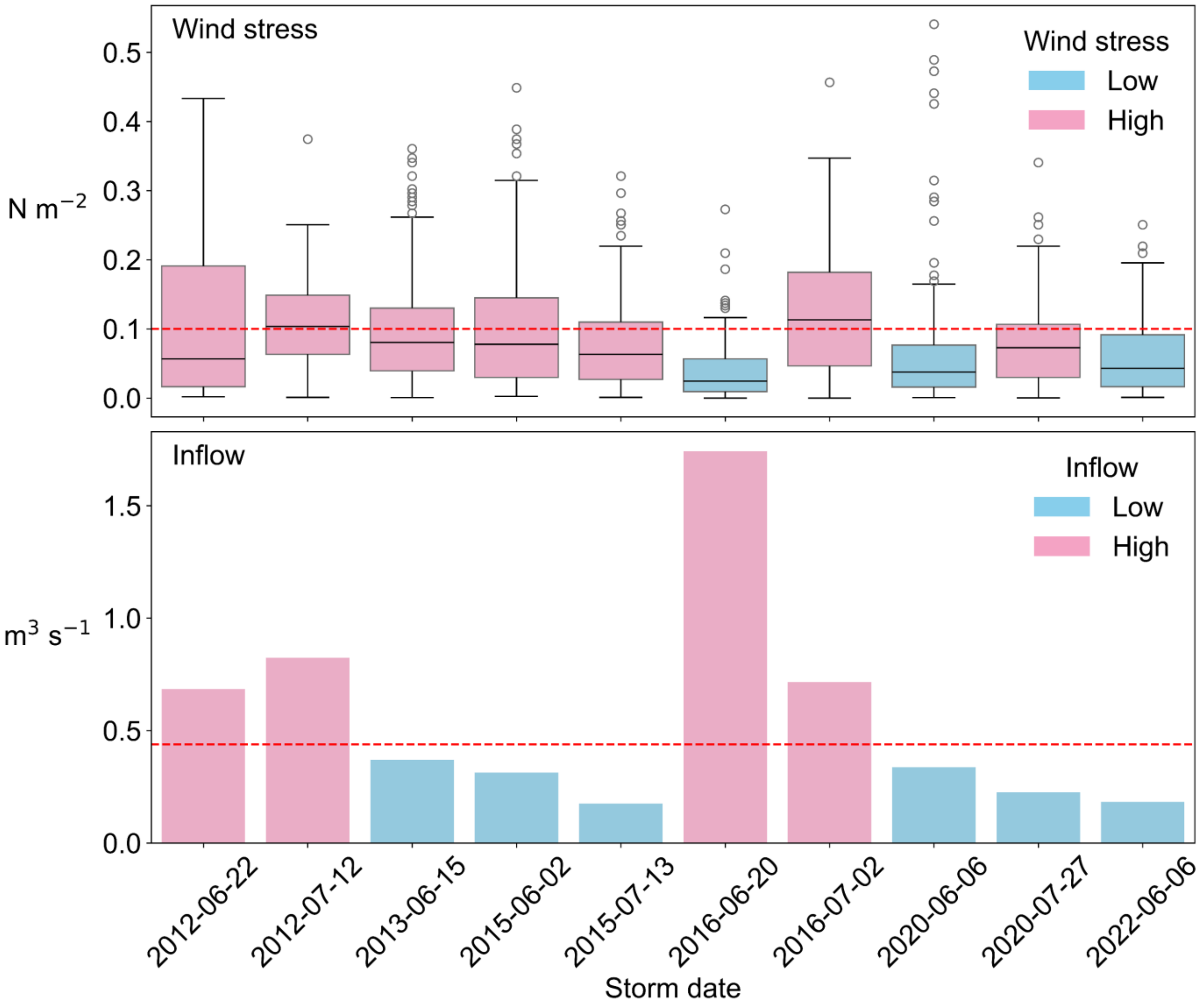
- **Storm identification**: Extreme wind events, with a threshold 11.3 m s^{-1}



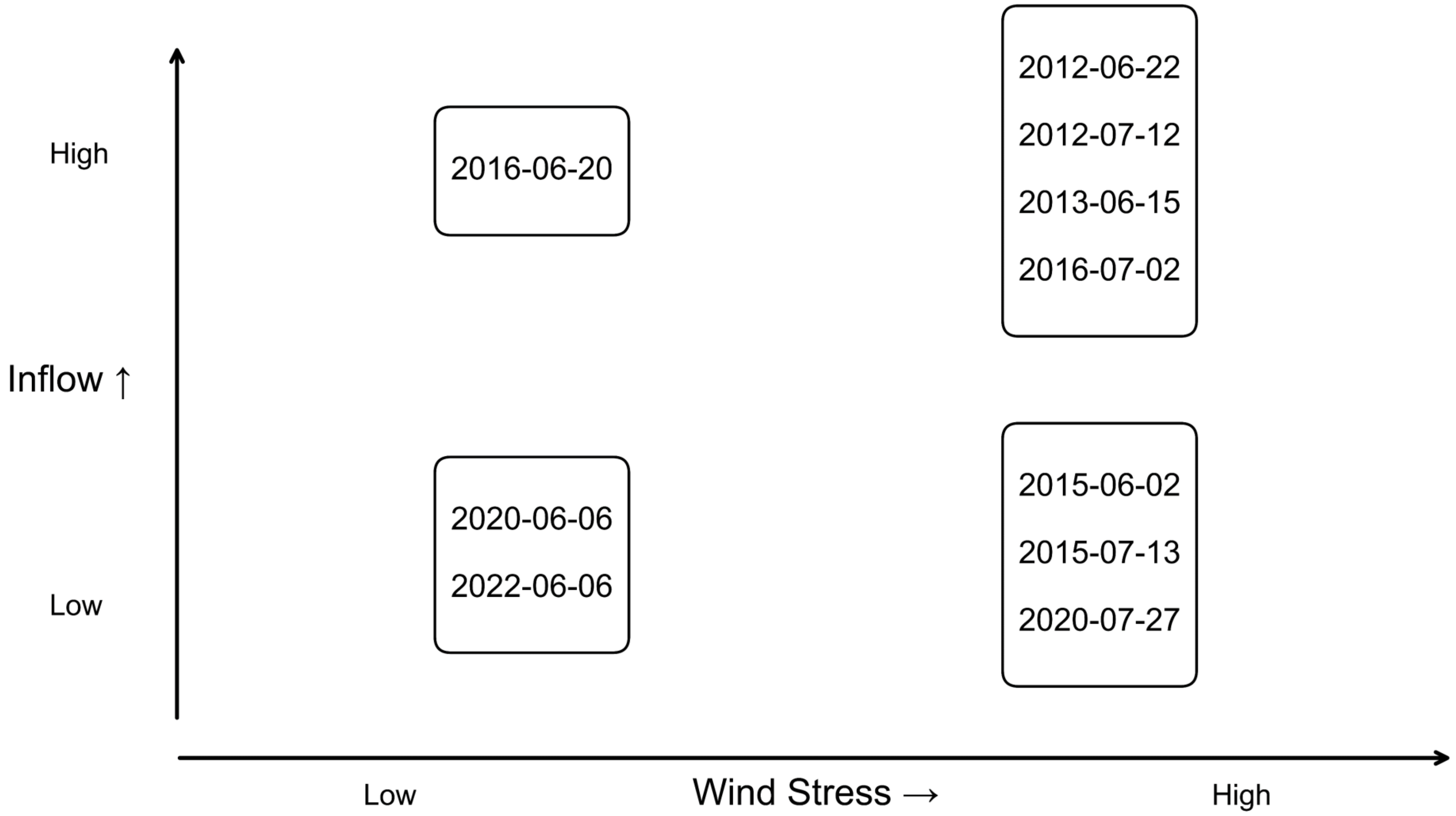
- Storm selection: **10 Events** were selected for the period 2012–2022, focusing on the months of **June and July**.
- Wind and river data analyzed over a ±3-day storm period.
- Pre- and post-storm chlorophyll a (Chl-a) and phytoplankton abundances were compared.

Methods: Wind stress & River inflow response to storm (±3-day)

- Third quartile (Q3) of Wind stress > 0.1 N m^{-2} threshold for "High" wind stress
- High wind stress reflects prolonged periods of strong wind (11.3 m s^{-1})
- Low wind stress reflects brief episodes of strong wind (11.3 m s^{-1})
- Mean Inflow during storm > June–July inflow (threshold: 80th percentile): "High inflow"
  "High inflow" – proxy for nutrient input

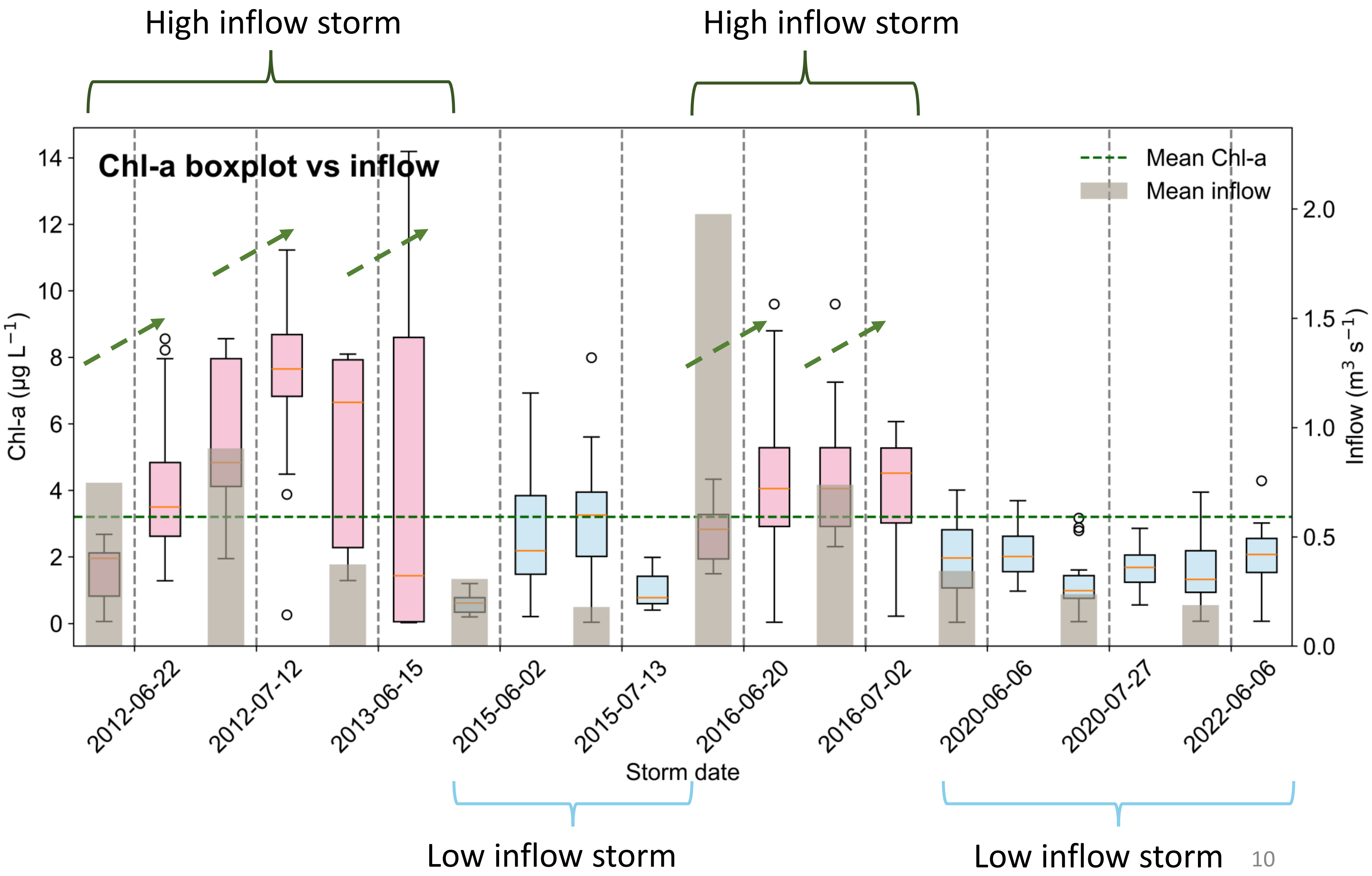


Four combinations of impacts (Inflow/Wind stress)



Impact of inflow on Chl-a (±14-day)

- High inflow storms: Increased Chl-a > June–July mean (3.20 µg L^{-1}).
- Post-storm low inflow Chl-a < 3.20 µg L^{-1} across many stations.

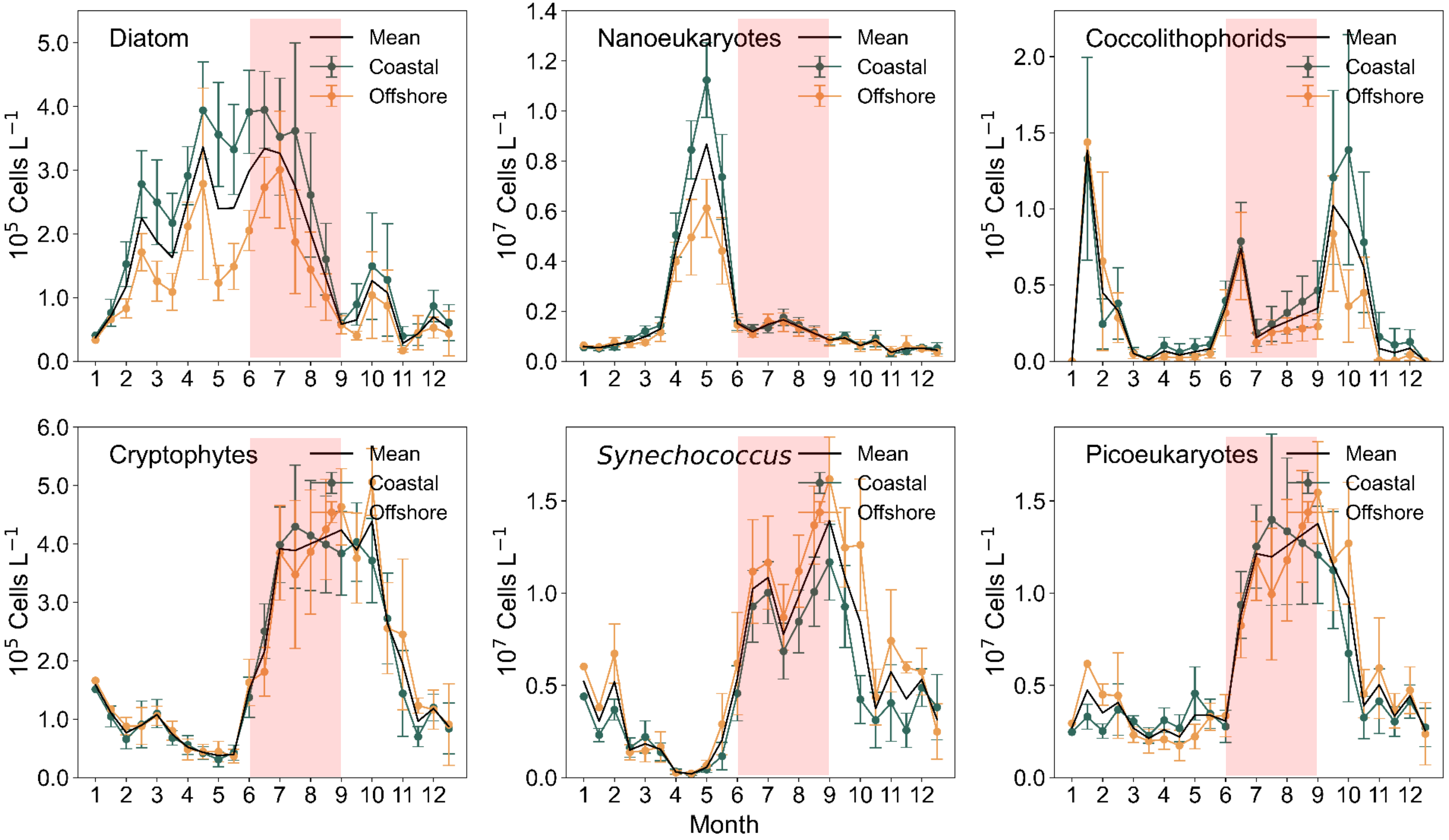


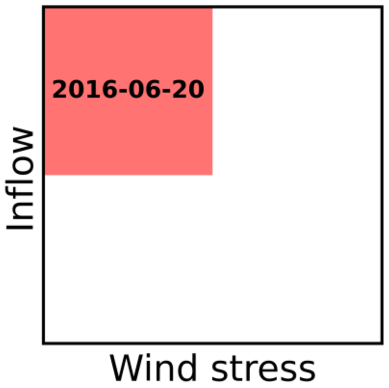
Seasonality of phytoplankton groups

- Decadal 15-day climatological mean (R0–R4), **Coastal stations (R0–R2)** and **Offshore stations (R2′–R4)**

- Summer bloom: Diatoms, nanoeukaryotes, Cryptophytes and Picophytoplankton

- Strong summer spatial gradient in diatoms and *synechococcus*.





Storm impact on phytoplankton groups

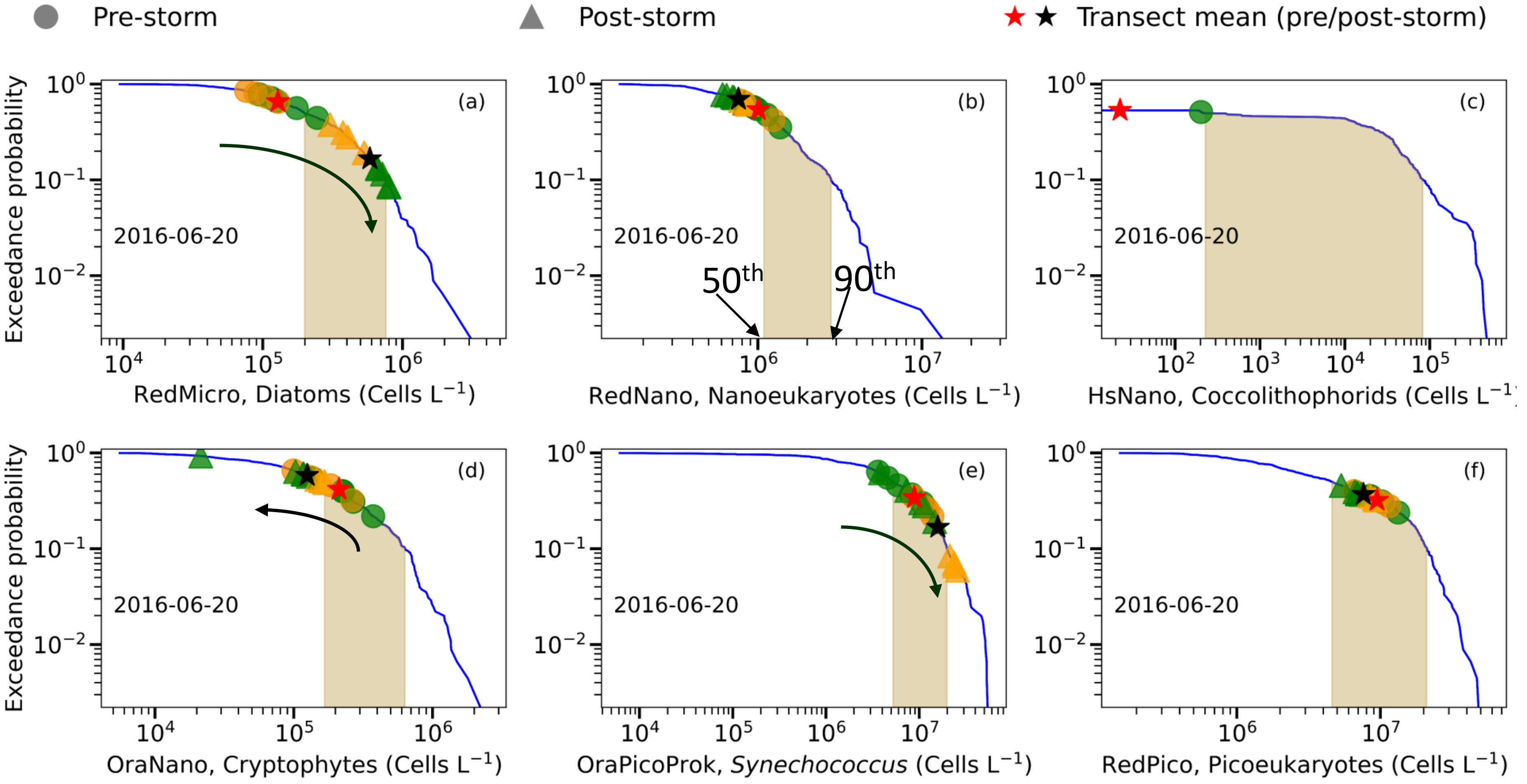
represents the DYPHYRAD transect observations (June–July)

50–90th percentiles in June–July (typical abundance)

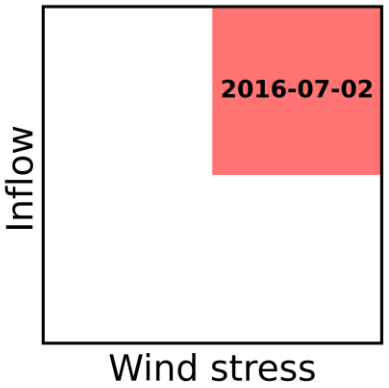
Coastal stations (R0–R2) **Offshore stations (R2′–R4)**

Increased Diatom, *Synechococcus*

- Extreme diatom abundances in coastal stations (R0–R2)
- Extreme *Synechococcus* abundances in offshore stations (R2′–R4)



Decreased Cryptophytes, Nanophytoplankton



represents the DYPHYRAD transect observations (June–July)

50–90th percentiles in June–July (typical abundance)

Coastal stations (R0–R2) **Offshore stations (R2′–R4)**

● Pre-storm ▲ Post-storm ★ ★ Transect mean (pre/post-storm)

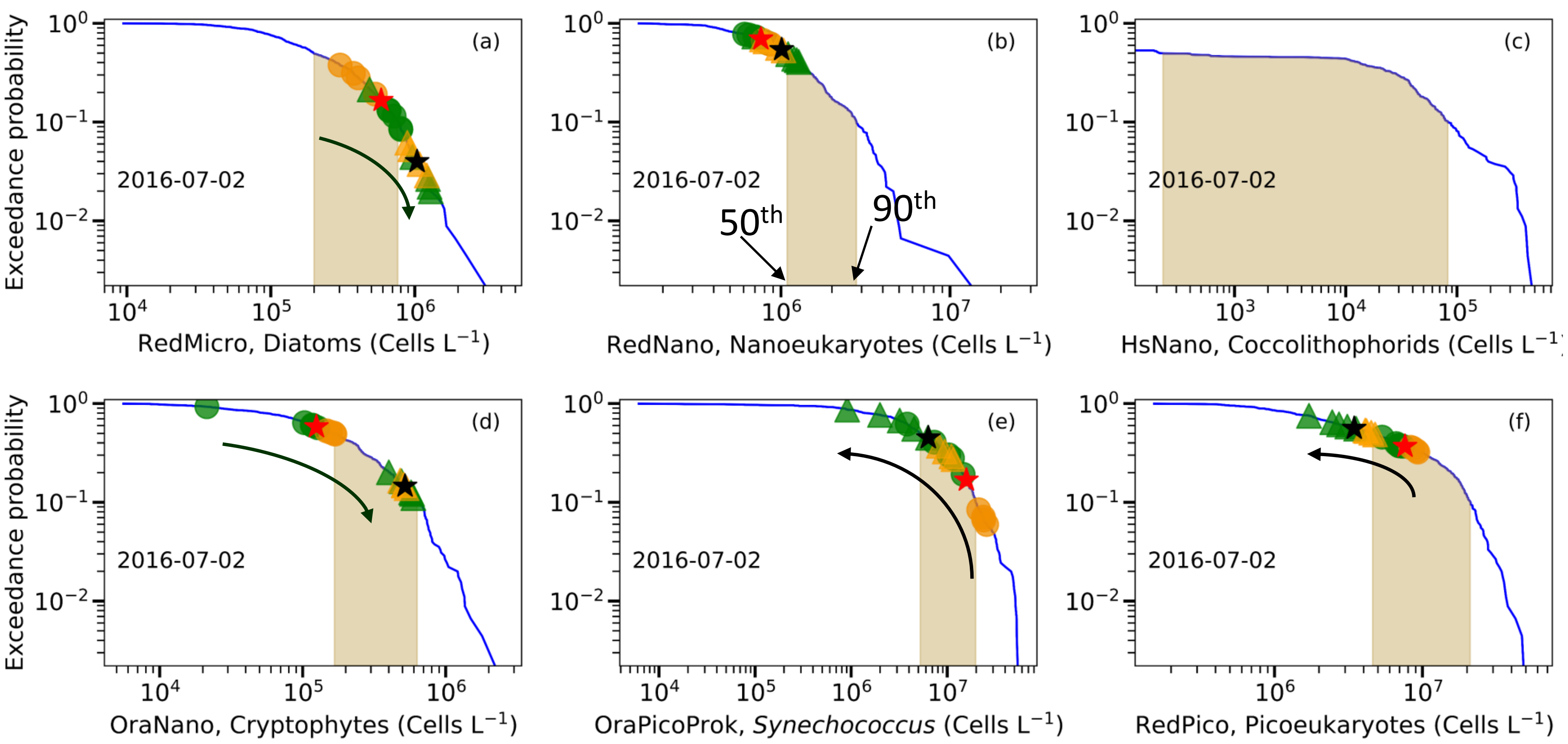
Increased Diatom

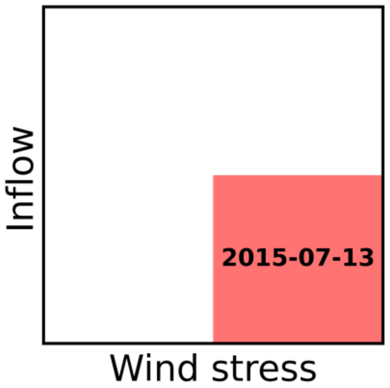
Cryptophytes

- Extreme abundances in all stations (R0–R4)

Decreased *Synechococcus*

Picoeukaryotes





represents the DYPHYRAD transect observations (June–July)

50–90th percentiles in June–July (typical abundance)

Coastal stations (R0–R2) **Offshore stations (R2′–R4)**

Pre-storm Post-storm Transect mean (pre/post-storm)

Increased Nanoeukaryotes,

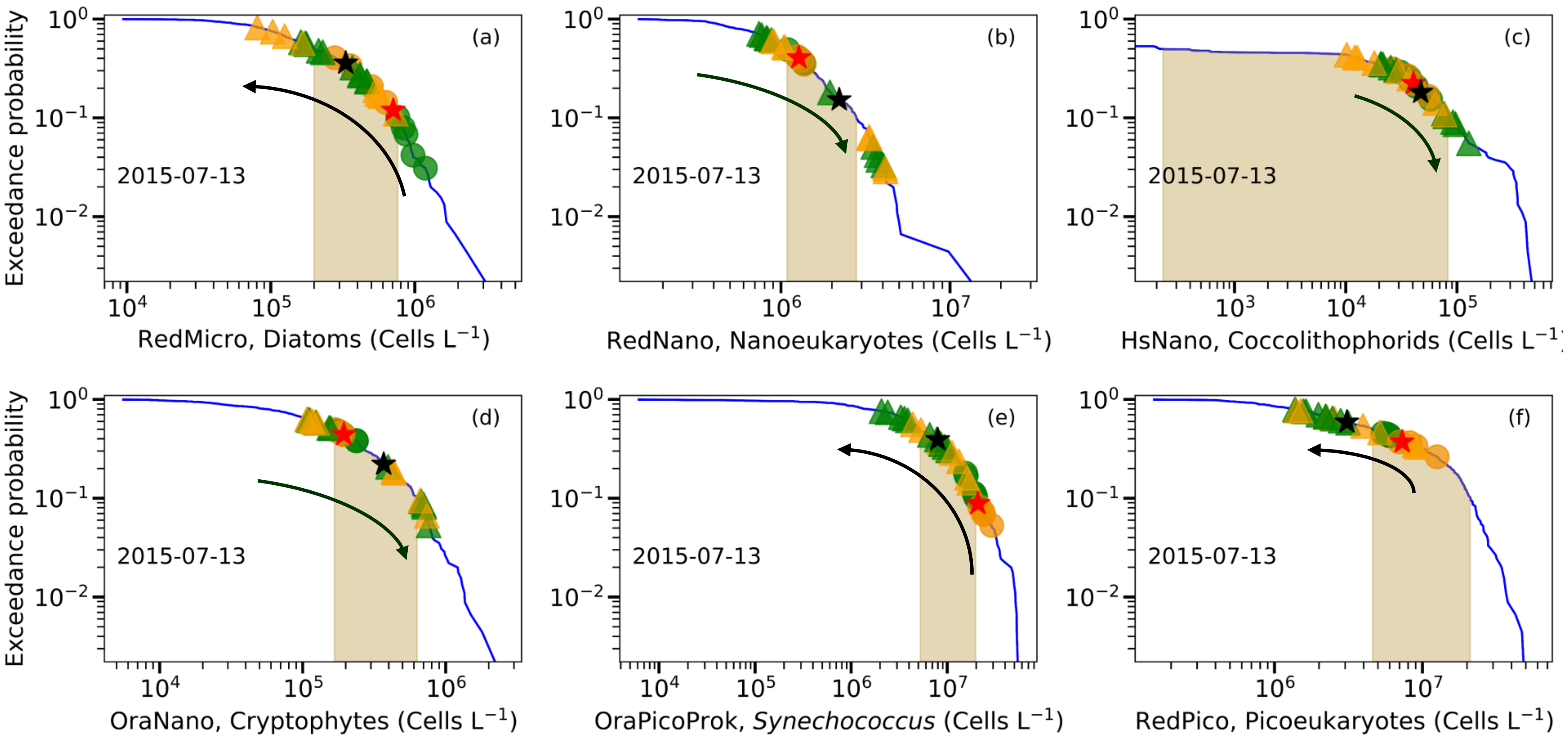
Cryptophytes

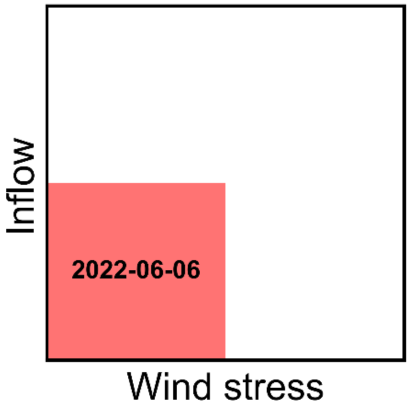
- Extreme abundances in all stations (R0–R4)

Decreased Diatoms,

Synechococcus,

Picoeukaryotes

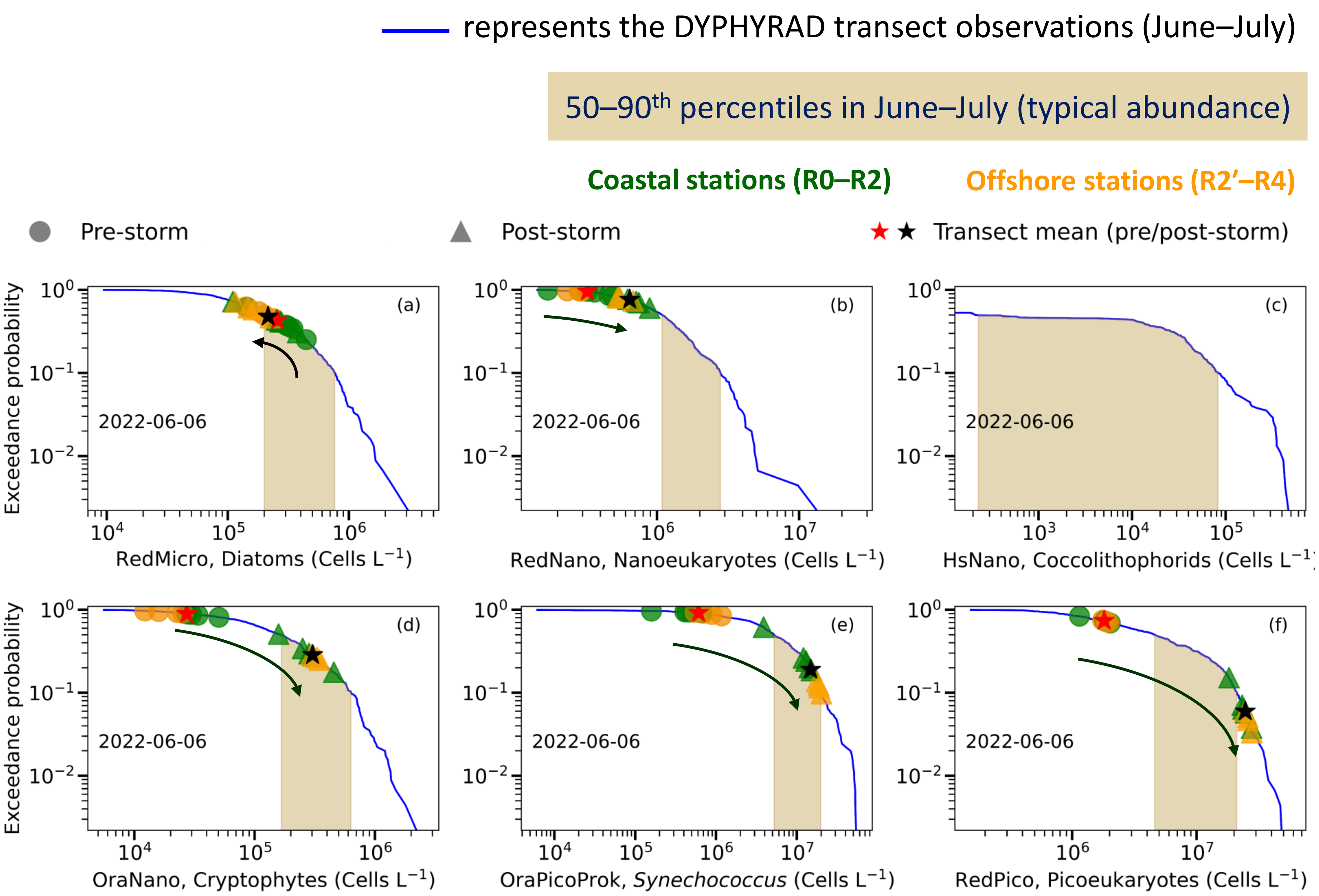




Increased *Synechococcus*, Picoeukaryotes

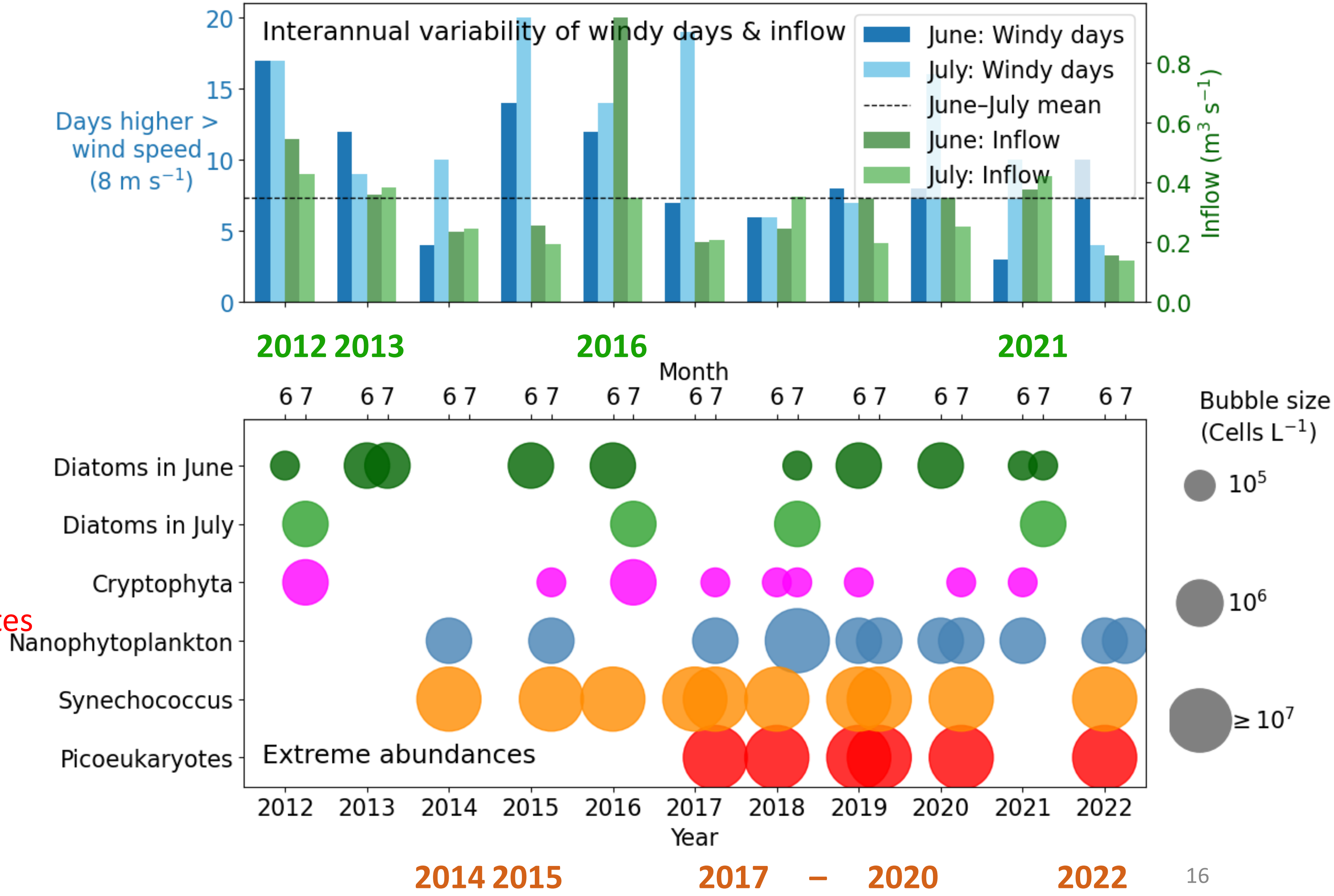
- Extreme abundances in all stations (R0–R4)

No increase in diatoms

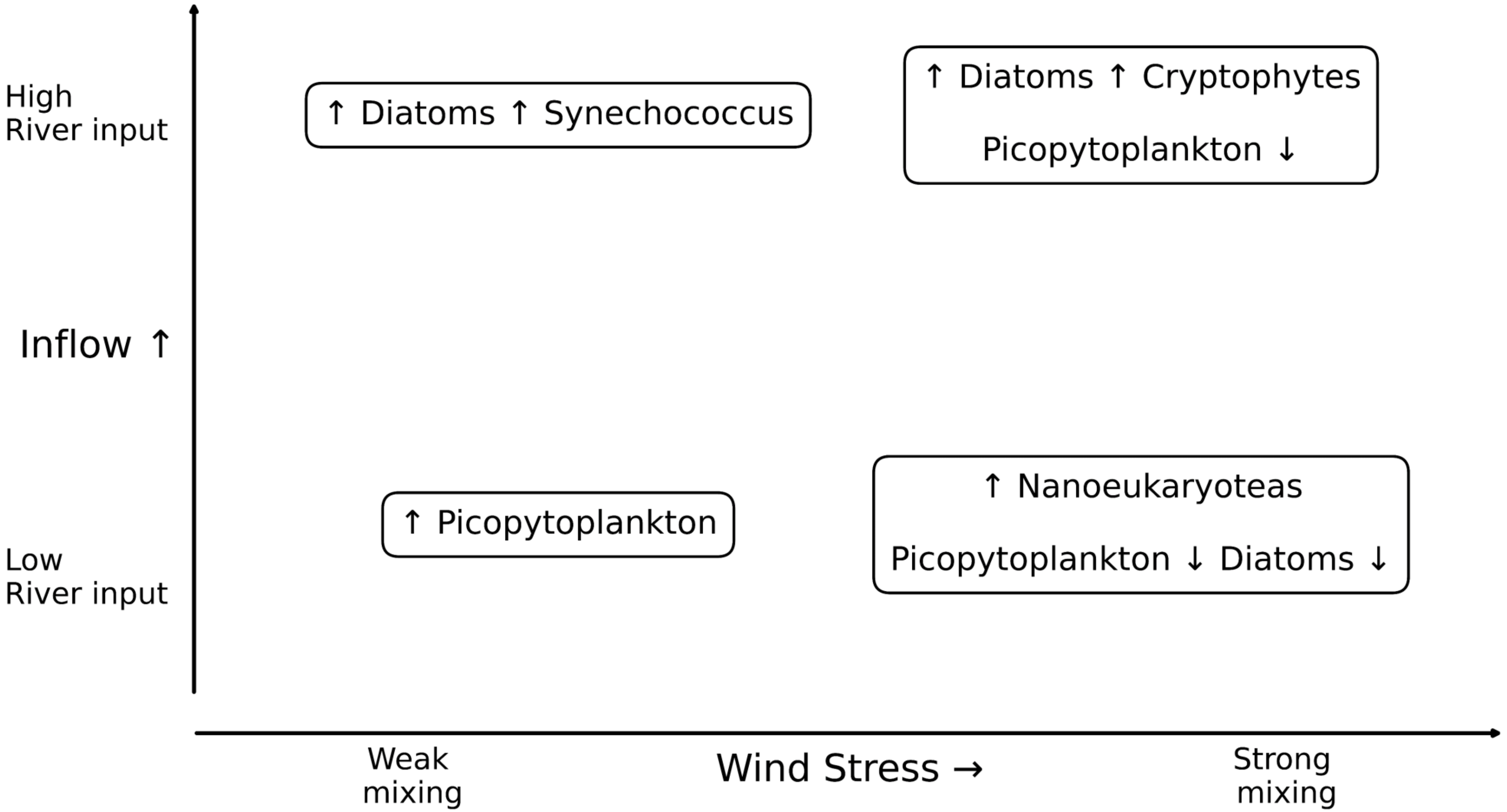


Interannual variability: Wet vs dry summer

- **Wet summers:** Extreme abundances of diatoms and less extreme of picoeukaryotes
- **Dry summers:** Extreme abundances of nano- , *synechococcus* and picoeukaryotes but less extremes of diatoms



Summary: Storm impact on phytoplankton composition



Conclusion

- Summer storms maintained environmental heterogeneity in the EEC and repeatedly reset ecological succession.
- Interannual variability in storm impacts (wind/river inflow) is reflected in community structure.

Key references

Hubert, Z., Louchart, A. P., Robache, K., Epinoux, A., Gallot, C., Cornille, V., Crouvoisier, M., Monchy, S., and Artigas, L. F.: Decadal changes in phytoplankton functional composition in the Eastern English Channel: possible upcoming major effects of climate change, Ocean Sci., 21, 679–700, https://doi.org/10.5194/os-21-679-2025, 2025.

Skouroliakou, D.-I., Breton, E., Irion, S., Artigas, L. F., and Christaki, U.: Stochastic and Deterministic Processes Regulate Phytoplankton Assemblages in a Temperate Coastal Ecosystem, Microbiol. Spectr., 10, e02427-22, https://doi.org/10.1128/spectrum.02427-22, 2022.

Submitted to OS

https://doi.org/10.5194/egusphere-2025-6235

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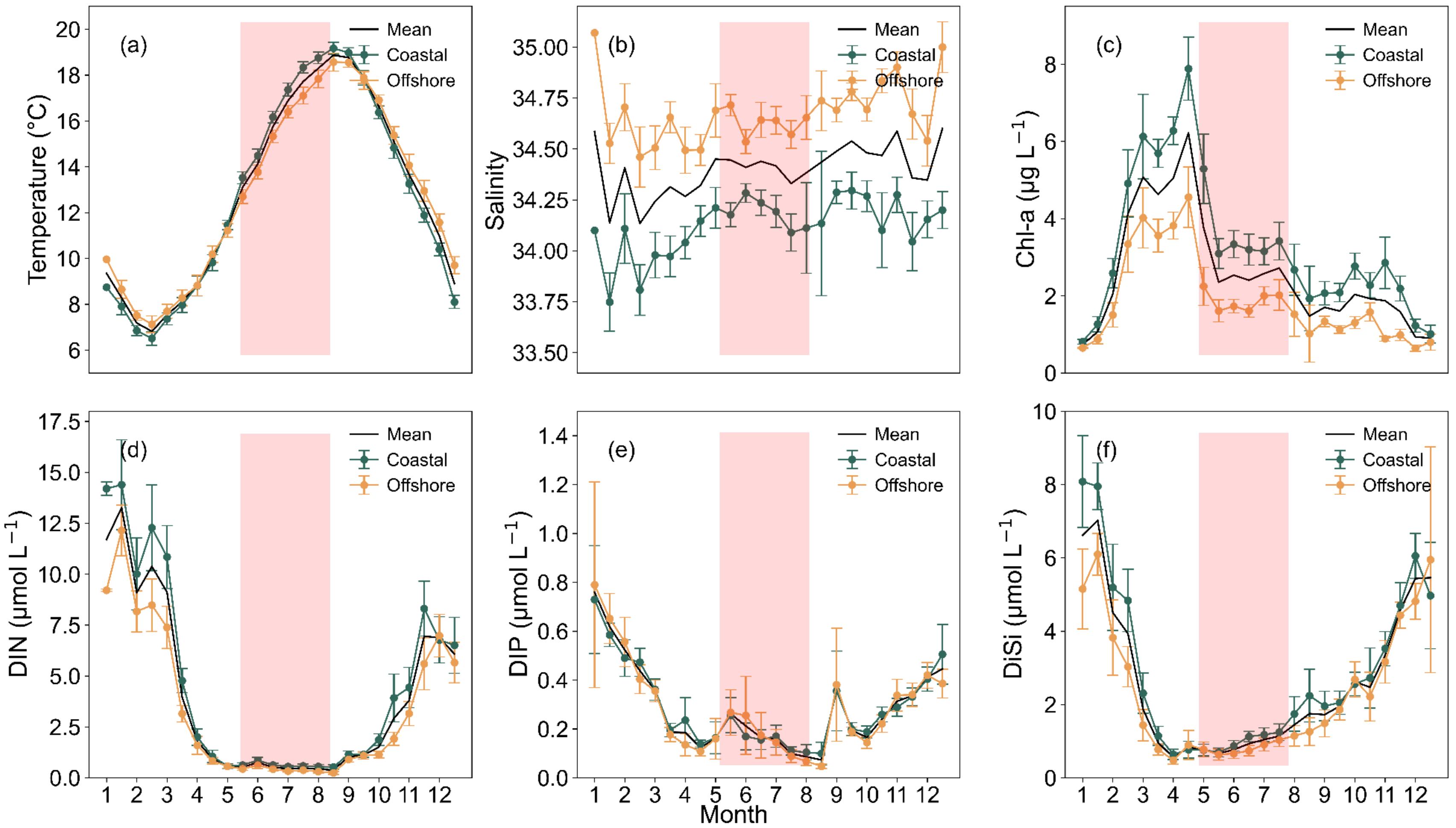
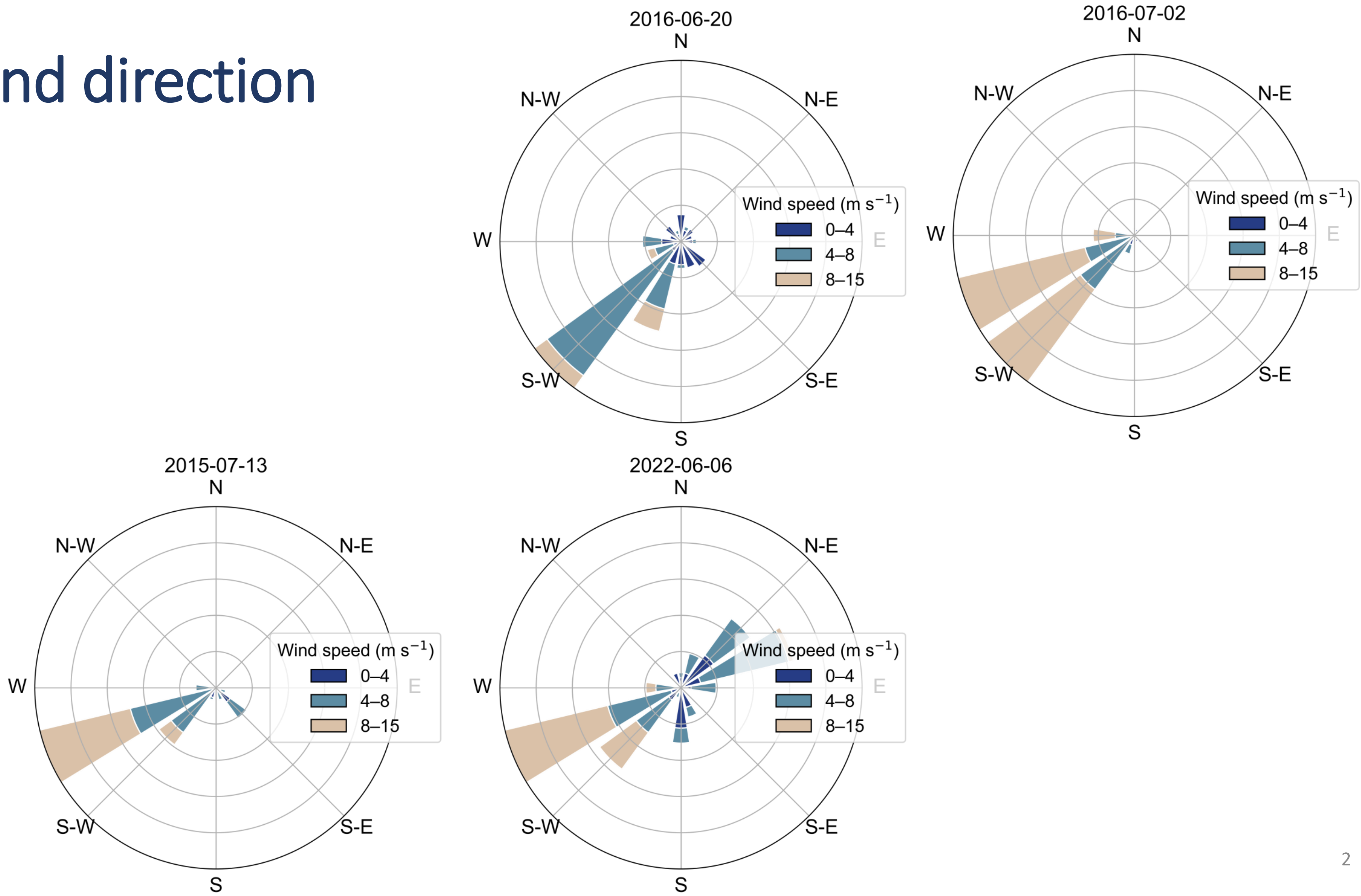
Seasonality of environmental variables

- Decadal 15-day climatological mean (R0–R4), **Coastal stations (R0–R2)** and **Offshore stations (R2’–R4)**

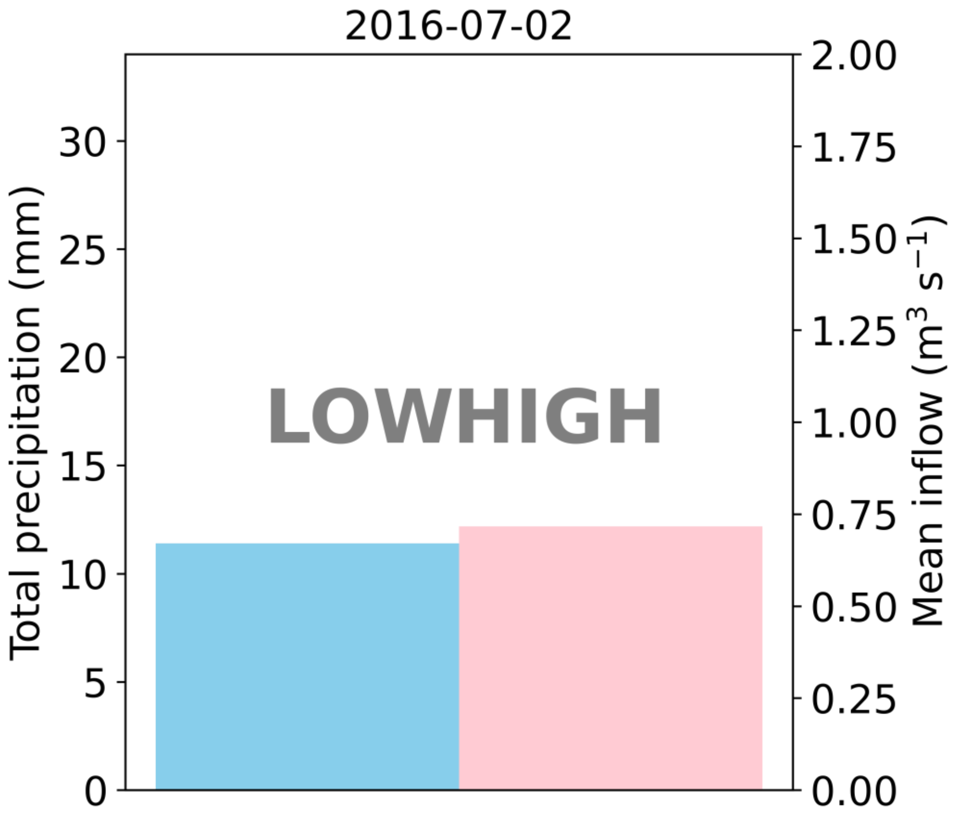
- Salinity convergence in summer
- Nutrients are depleted in the summer
- Chl-a additional peaks in summer and autumn



Wind direction



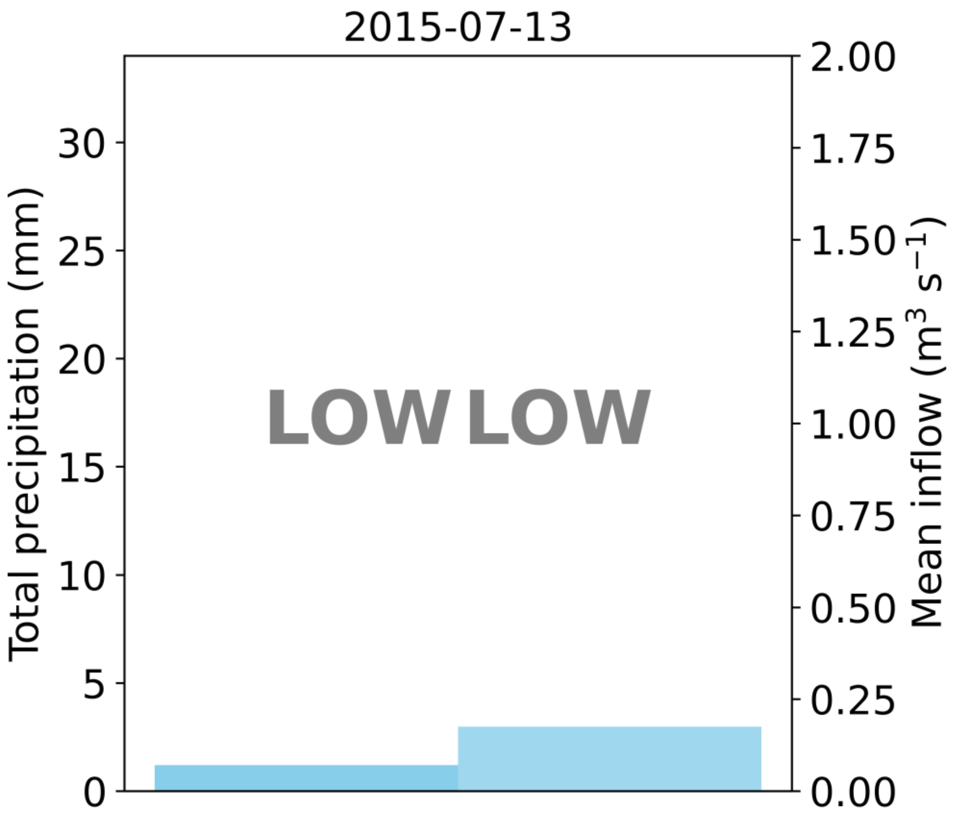
2016-07-02: High Inflow, High Wind Stress Storm



Q3 > 0.1 Pa; Wind stress is above 0.1 Pa for most observation

South-westerly winds: 68.3%

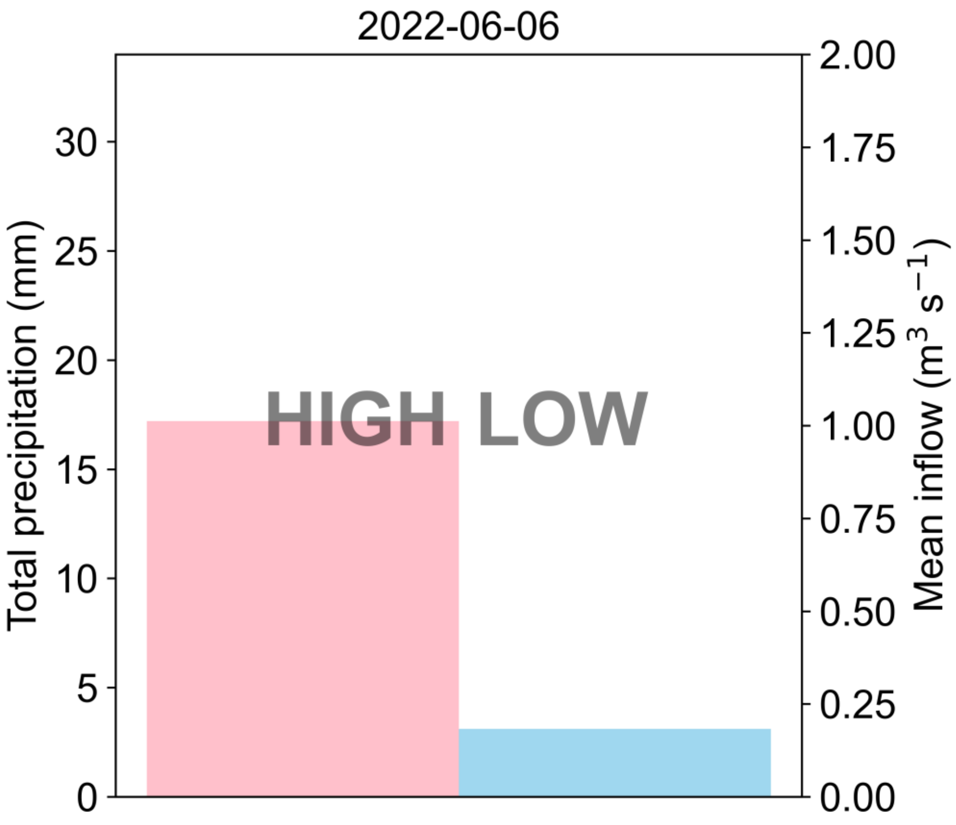
2015-07-13: Low Inflow, High Wind Stress Storm



Q3 > 0.1 Pa; Wind stress is above 0.1Pa for most observation

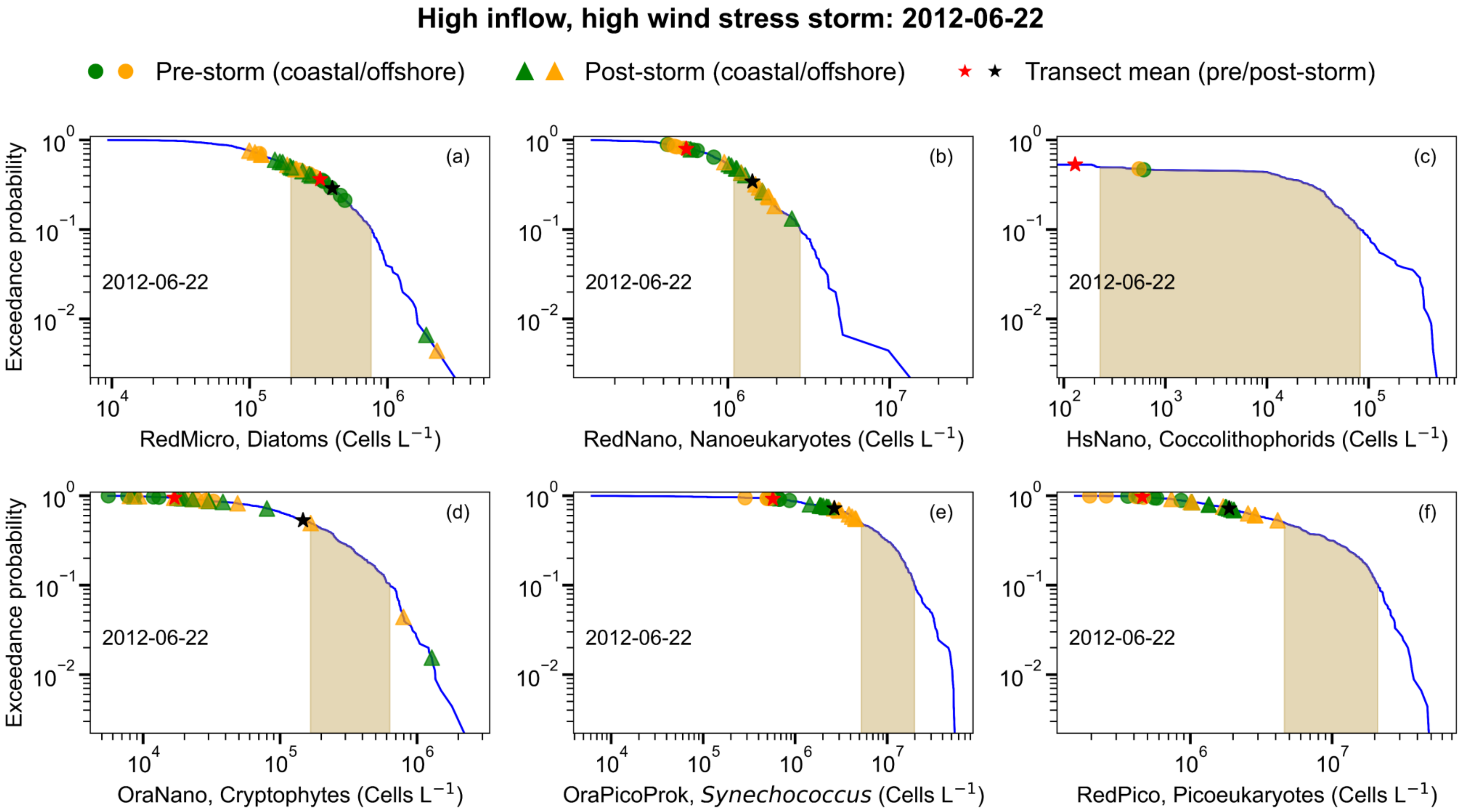
South-westerly winds: 55.2%

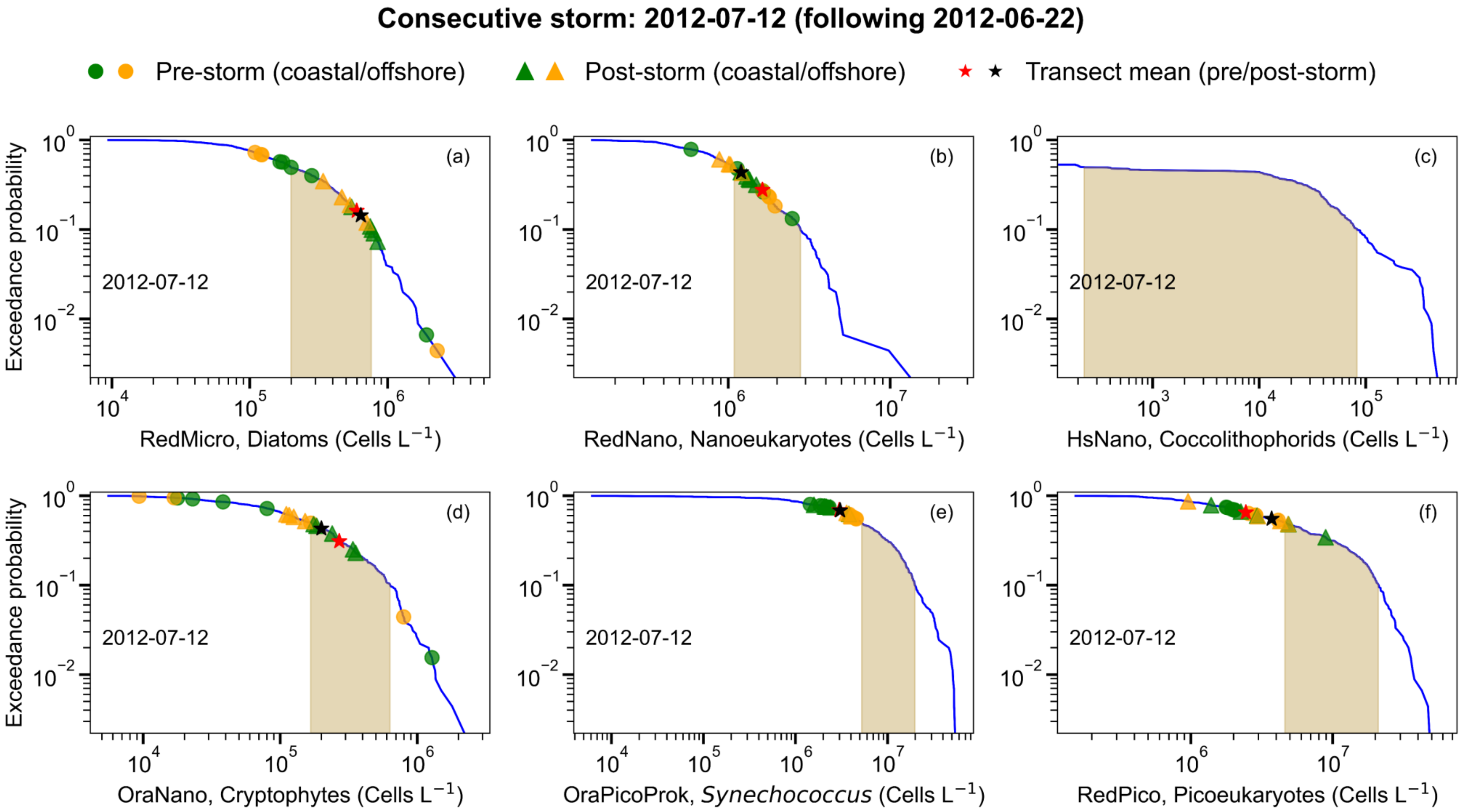
2022-06-06: Low Inflow, Low Wind Stress Storm

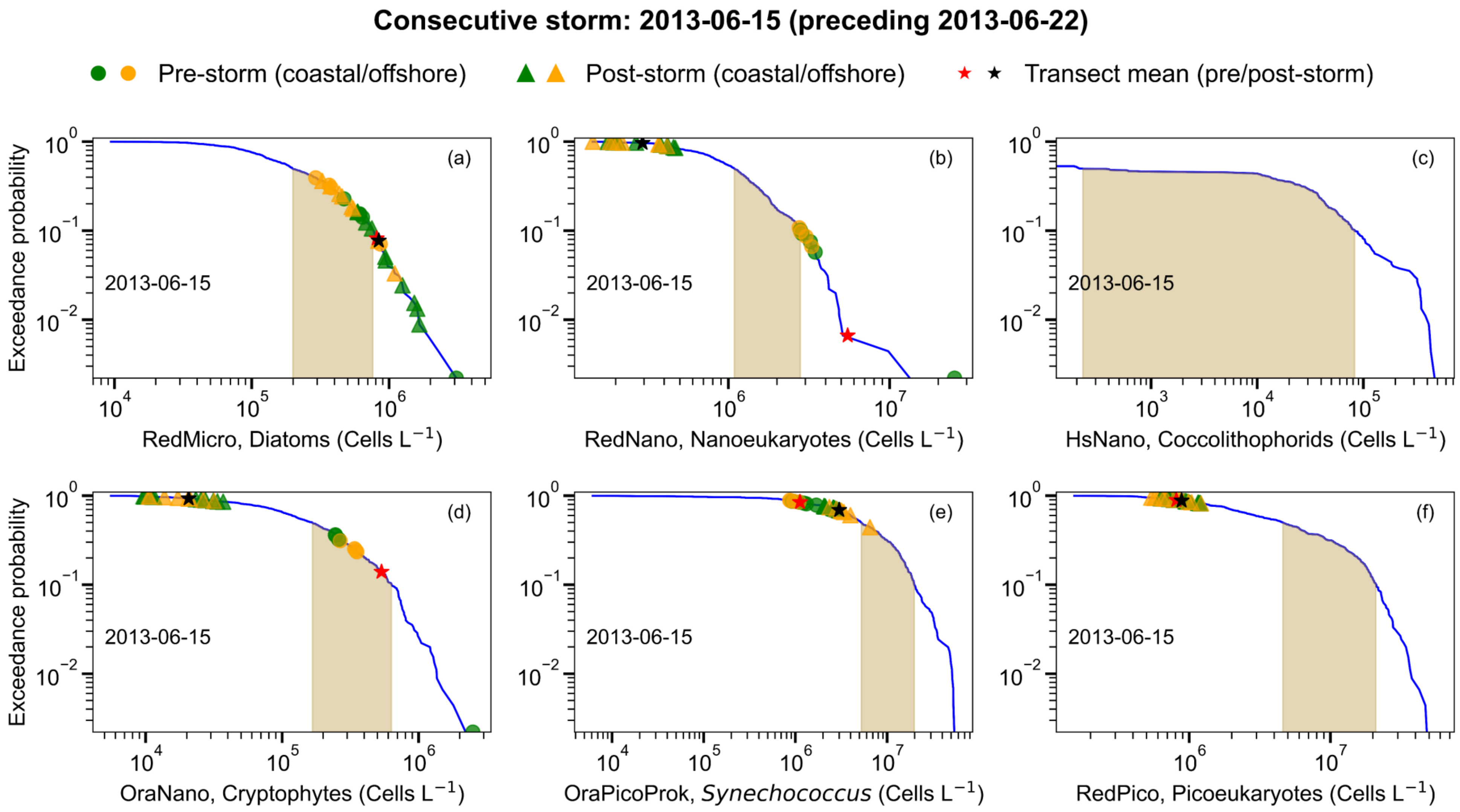


Q3 < 0.1 Pa; Wind stress is below 0.1Pa for most observation

South-westerly winds: 33.1%

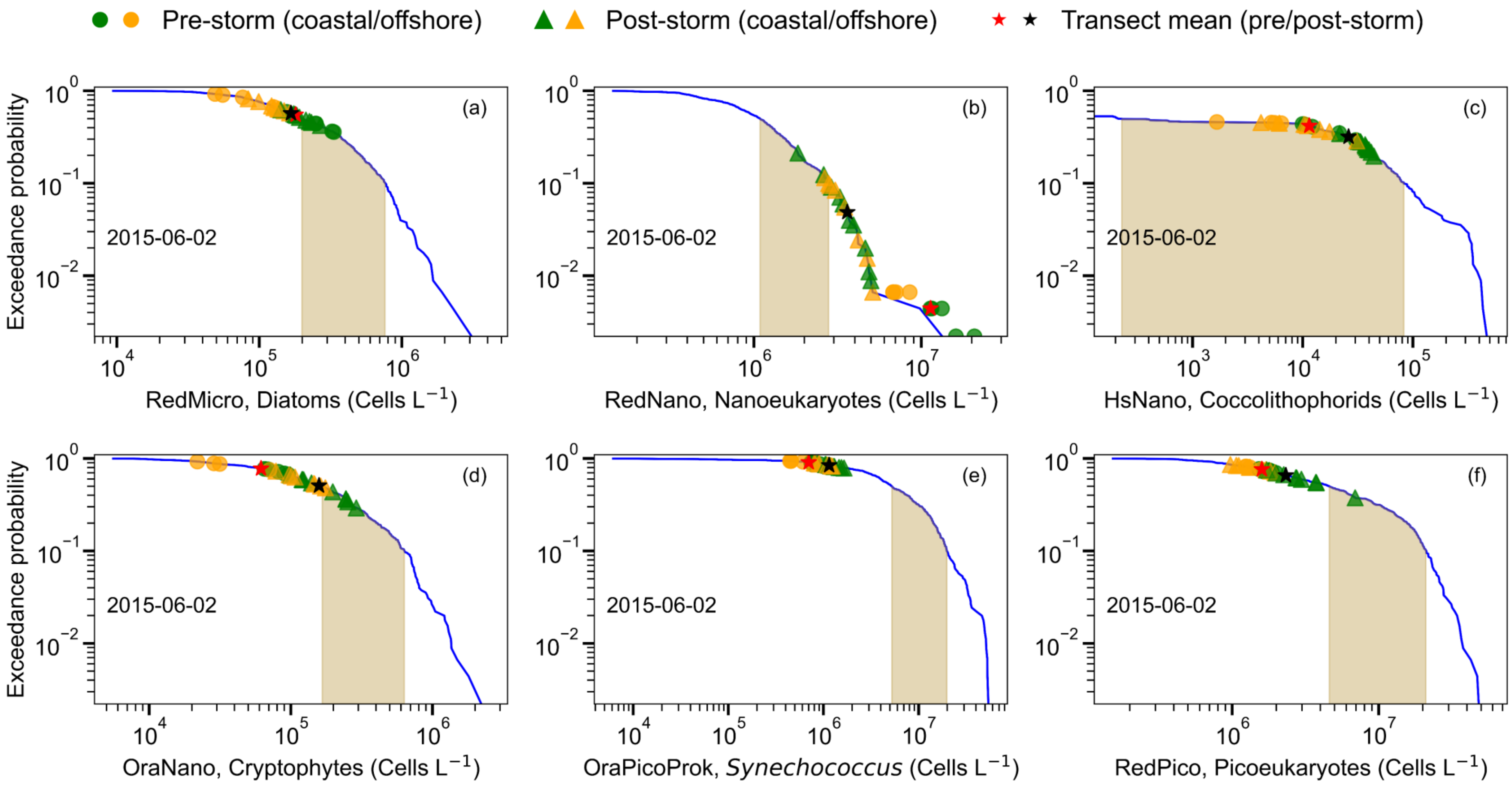

High inflow, high wind stress storm: 2012-06-22
Pre-storm (coastal/offshore)
Post-storm (coastal/offshore)
Transect mean (pre/post-storm)
Exceedance probability
(a)
(b)
(c)
(d)
(e)
(f)
2012-06-22
RedMicro, Diatoms (Cells L^{-1})
RedNano, Nanoeukaryotes (Cells L^{-1})
HsNano, Coccolithophorids (Cells L^{-1})
OraNano, Cryptophytes (Cells L^{-1})
OraPicoProk, *Synechococcus* (Cells L^{-1})
RedPico, Picoeukaryotes (Cells L^{-1})

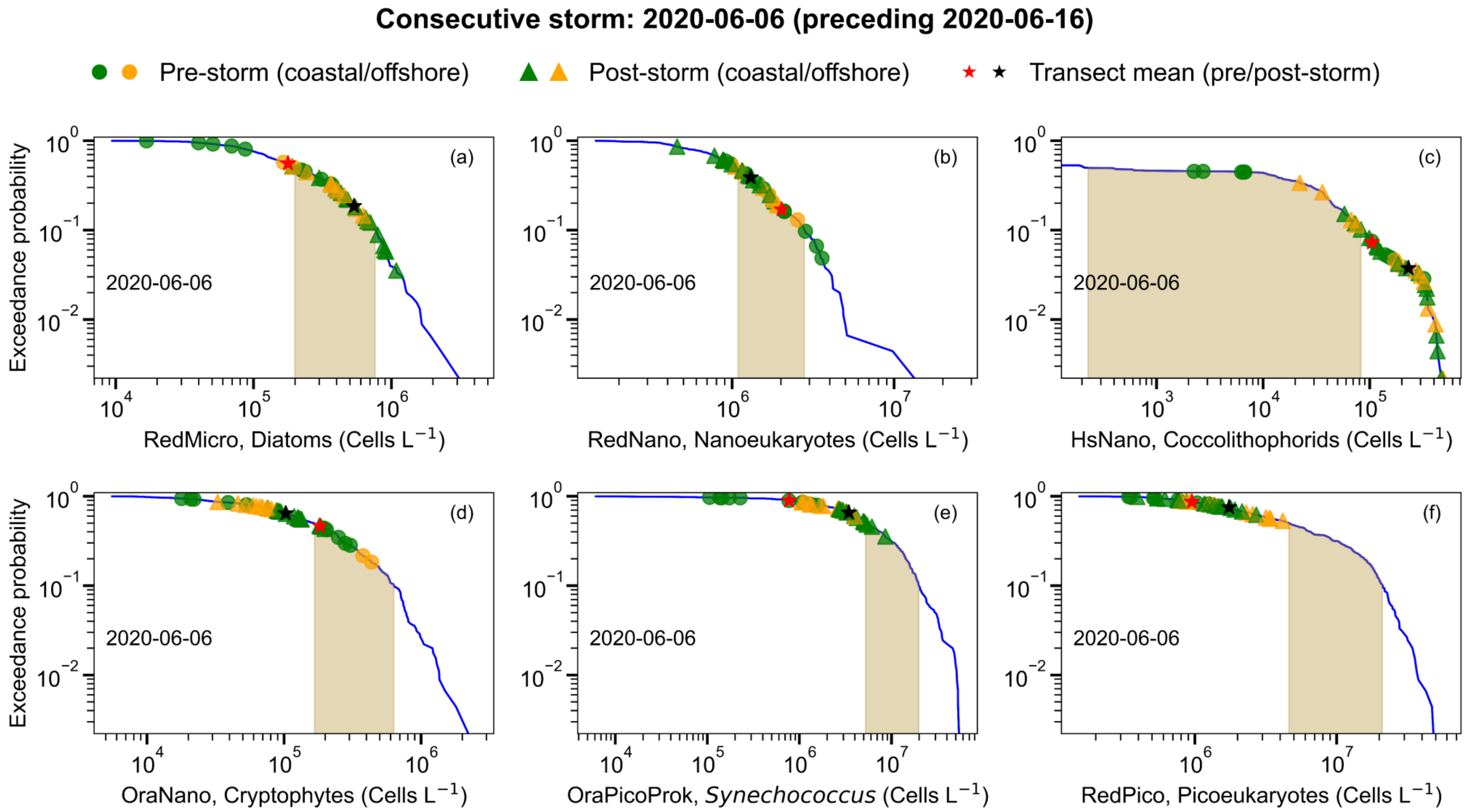

Consecutive storm: 2012-07-12 (following 2012-06-22)
Pre-storm (coastal/offshore)
Post-storm (coastal/offshore)
Transect mean (pre/post-storm)
Exceedance probability
(a)
2012-07-12
RedMicro, Diatoms (Cells L^{-1})
(b)
2012-07-12
RedNano, Nanoeukaryotes (Cells L^{-1})
(c)
2012-07-12
HsNano, Coccolithophorids (Cells L^{-1})
Exceedance probability
(d)
2012-07-12
OraNano, Cryptophytes (Cells L^{-1})
(e)
2012-07-12
OraPicoProk, *Synechococcus* (Cells L^{-1})
(f)
2012-07-12
RedPico, Picoeukaryotes (Cells L^{-1})



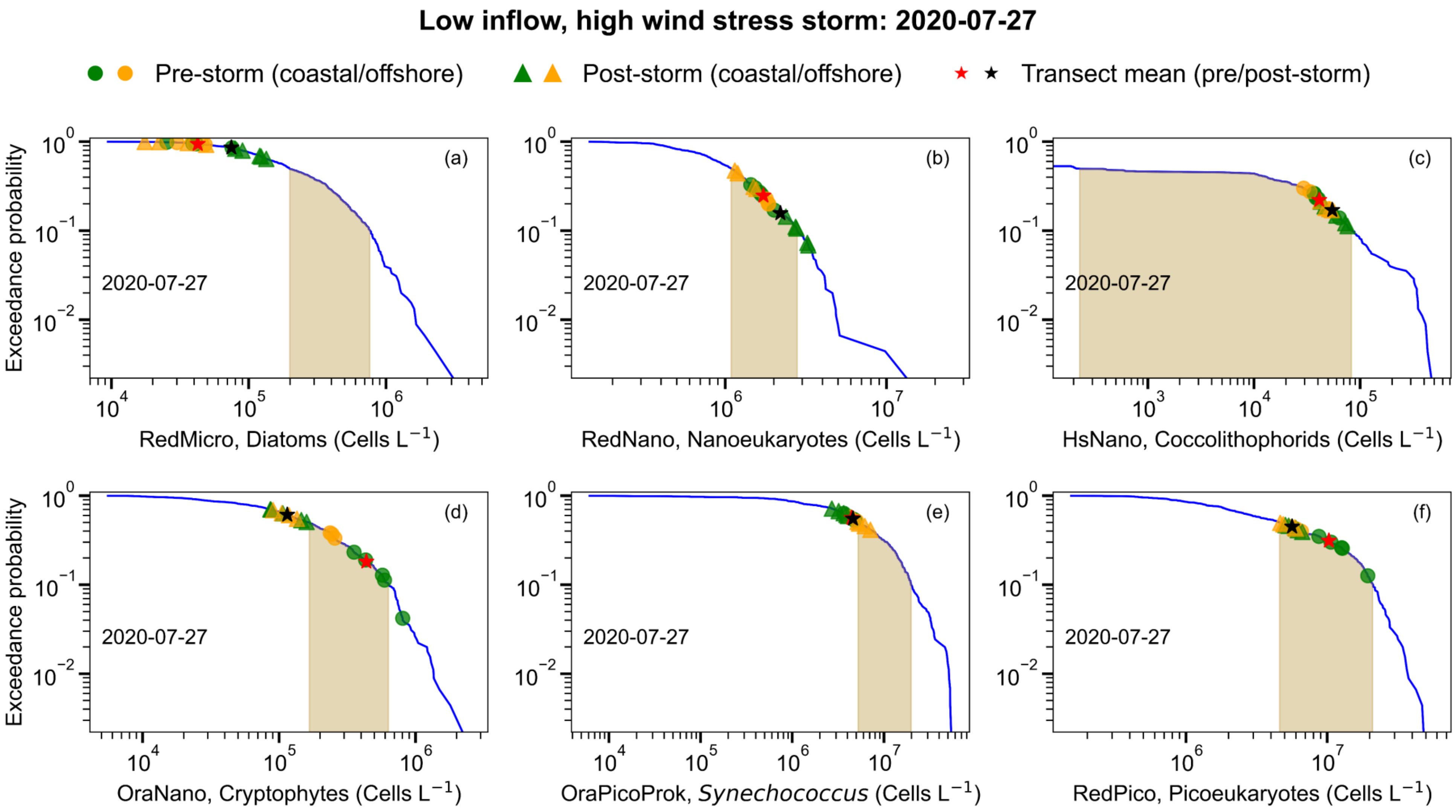
Consecutive storm: 2013-06-15 (preceding 2013-06-22)
Pre-storm (coastal/offshore)
Post-storm (coastal/offshore)
Transect mean (pre/post-storm)
Exceedance probability
(a)
2013-06-15
RedMicro, Diatoms (Cells L^{-1})
(b)
2013-06-15
RedNano, Nanoeukaryotes (Cells L^{-1})
(c)
2013-06-15
HsNano, Coccolithophorids (Cells L^{-1})
(d)
2013-06-15
OraNano, Cryptophytes (Cells L^{-1})
(e)
2013-06-15
OraPicoProk, *Synechococcus* (Cells L^{-1})
(f)
2013-06-15
RedPico, Picoeukaryotes (Cells L^{-1})

Low inflow, high wind stress storm: 2015-06-02





Consecutive storm: 2020-06-06 (preceding 2020-06-16)
Pre-storm (coastal/offshore)
Post-storm (coastal/offshore)
Transect mean (pre/post-storm)
Exceedance probability
(a)
2020-06-06
RedMicro, Diatoms (Cells L^{-1})
(b)
2020-06-06
RedNano, Nanoeukaryotes (Cells L^{-1})
(c)
2020-06-06
HsNano, Coccolithophorids (Cells L^{-1})
(d)
2020-06-06
OraNano, Cryptophytes (Cells L^{-1})
(e)
2020-06-06
OraPicoProk, *Synechococcus* (Cells L^{-1})
(f)
2020-06-06
RedPico, Picoeukaryotes (Cells L^{-1})



Low inflow, high wind stress storm: 2020-07-27
Pre-storm (coastal/offshore)
Post-storm (coastal/offshore)
Transect mean (pre/post-storm)
Exceedance probability
(a)
(b)
(c)
(d)
(e)
(f)
2020-07-27
RedMicro, Diatoms (Cells L^{-1})
RedNano, Nanoeukaryotes (Cells L^{-1})
HsNano, Coccolithophorids (Cells L^{-1})
OraNano, Cryptophytes (Cells L^{-1})
OraPicoProk, *Synechococcus* (Cells L^{-1})
RedPico, Picoeukaryotes (Cells L^{-1})