

Esperanza Broullón Mandado

Supervised by Beatriz Mouriño Carballido and Bieito Fernández Castro

28th June, 2024

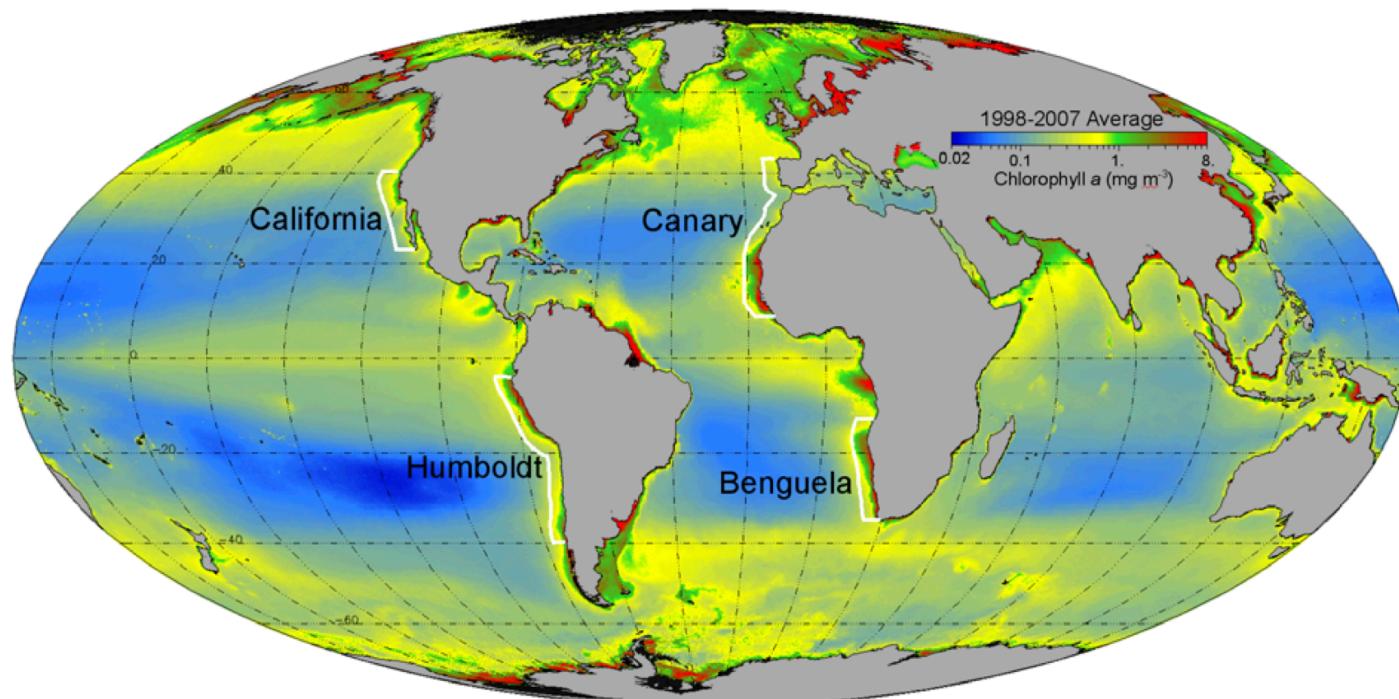
Thin layers of phytoplankton in the Rías Baixas (NW off Iberia): occurrence, formation and relevance

PhD defense

Phytoplankton

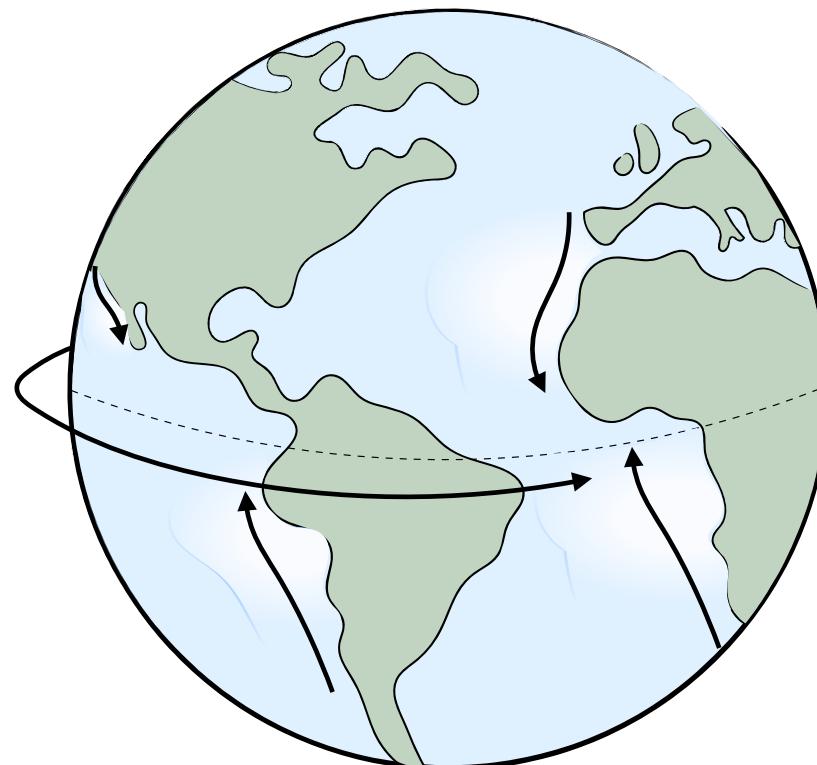


Eastern Boundary Upwelling Systems



Freón et al., 2009 (*Progress in Oceanography*)

Eastern Boundary Upwelling Systems



EBUS: upwelling bays

a. California Current System



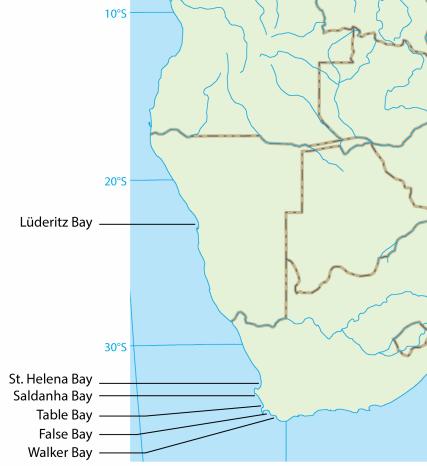
b. Humboldt Current System



c. Canary Current System



d. Benguela Current System



Largier, 2020 (Annual Review of Marine Science)

EBUS: upwelling bays

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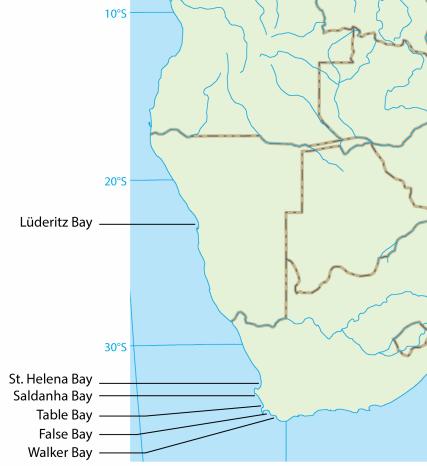
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Retention time

Largier, 2020 (Annual Review of Marine Science)

EBUS: upwelling bays

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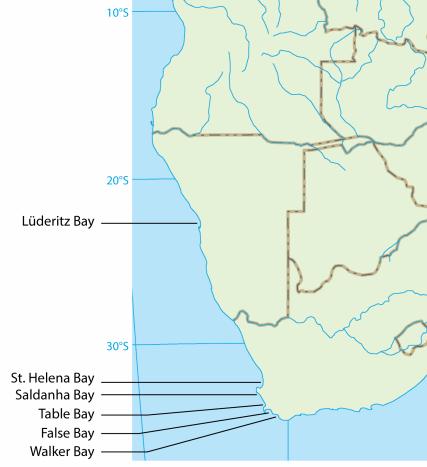
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Retention time

Enhanced upwelling and
stratification

EBUS: upwelling bays

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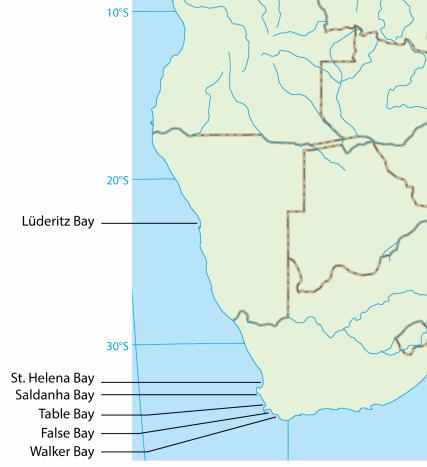
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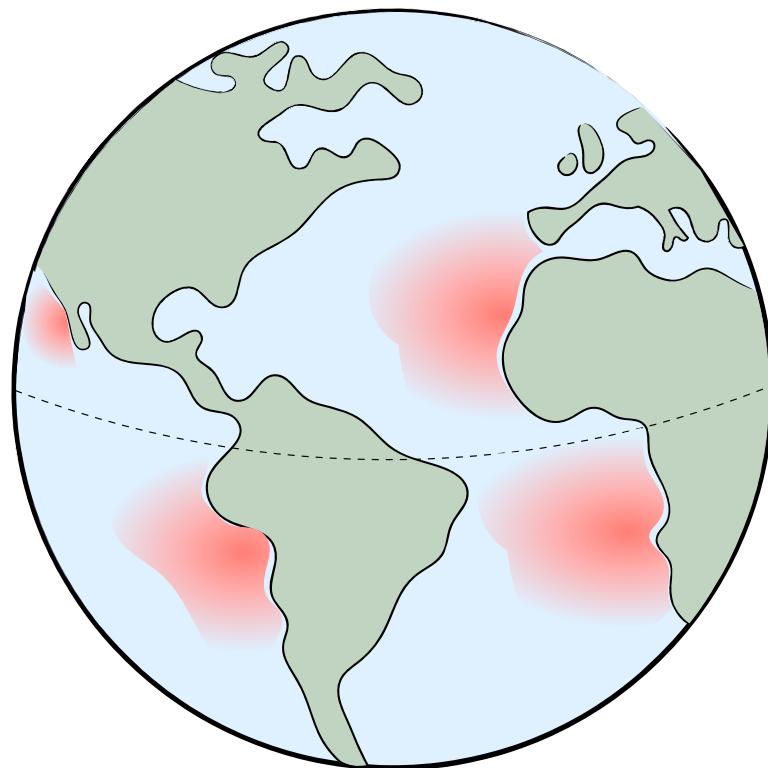


Retention time

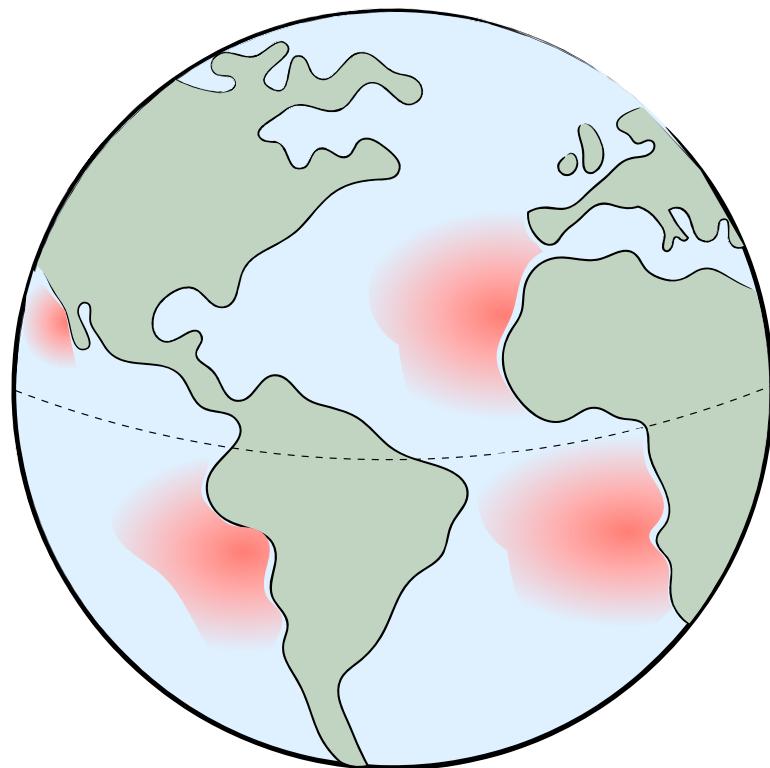
Enhanced upwelling and
stratification

Extra nutrient input

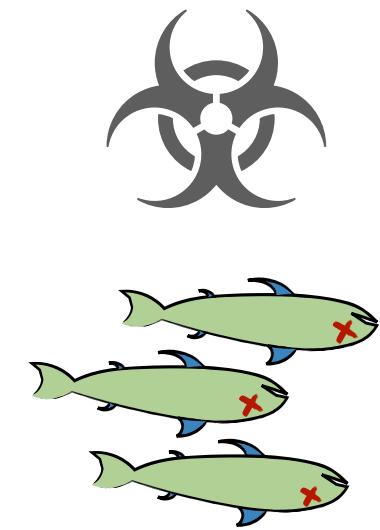
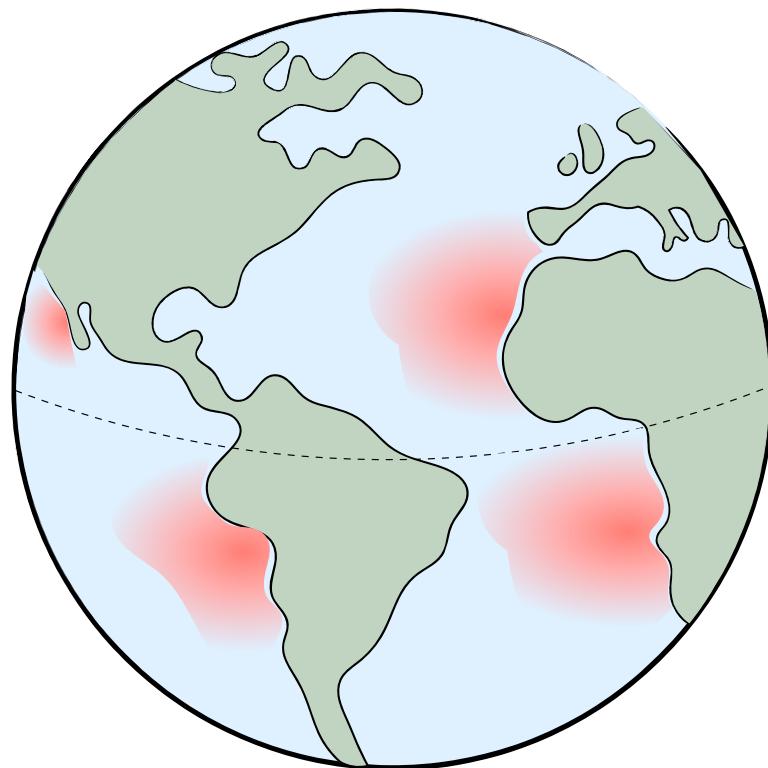
EBUS: harmful algal blooms



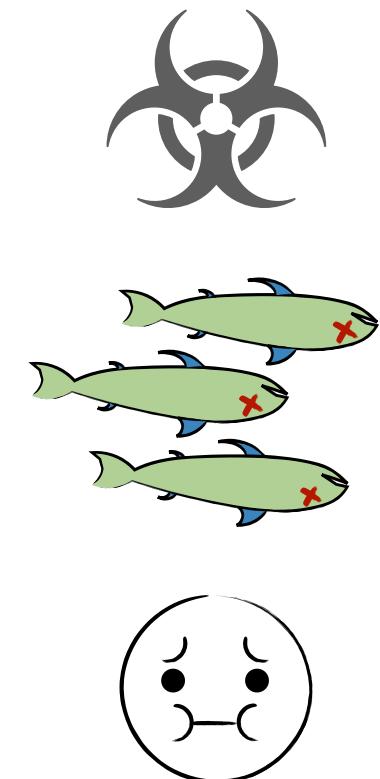
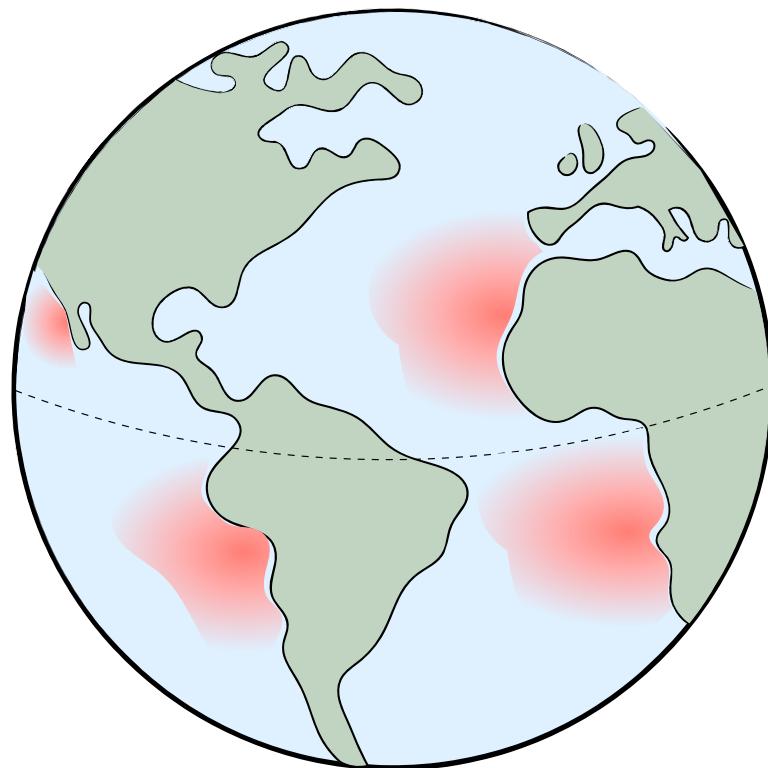
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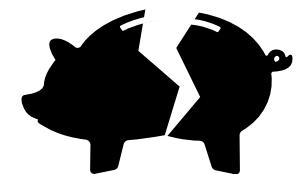
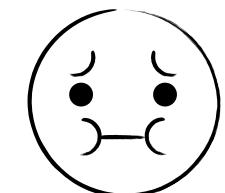
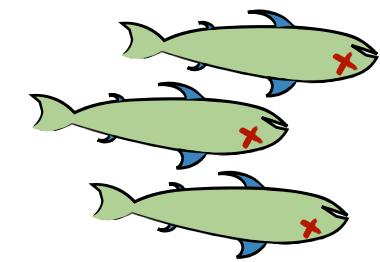
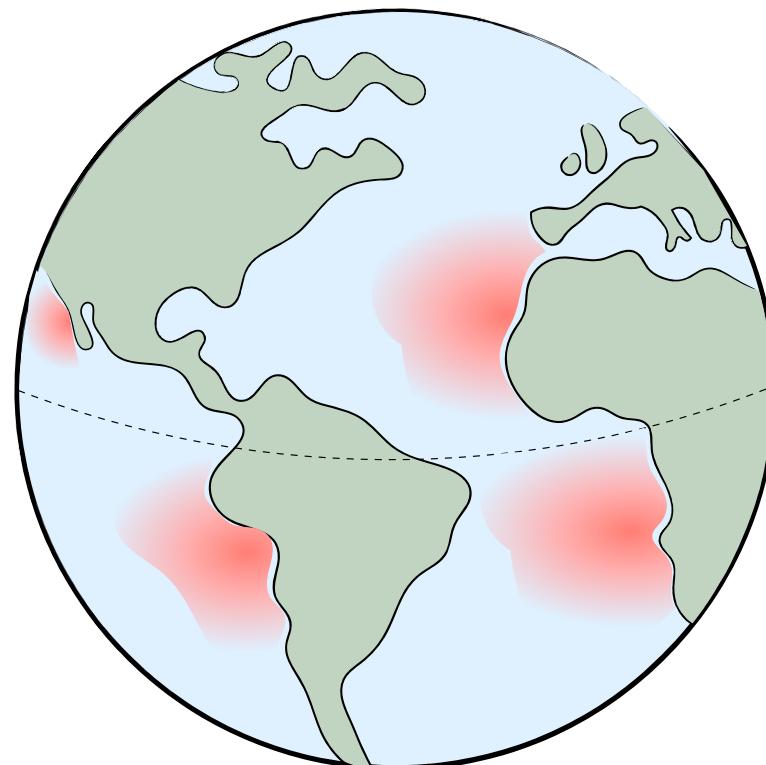
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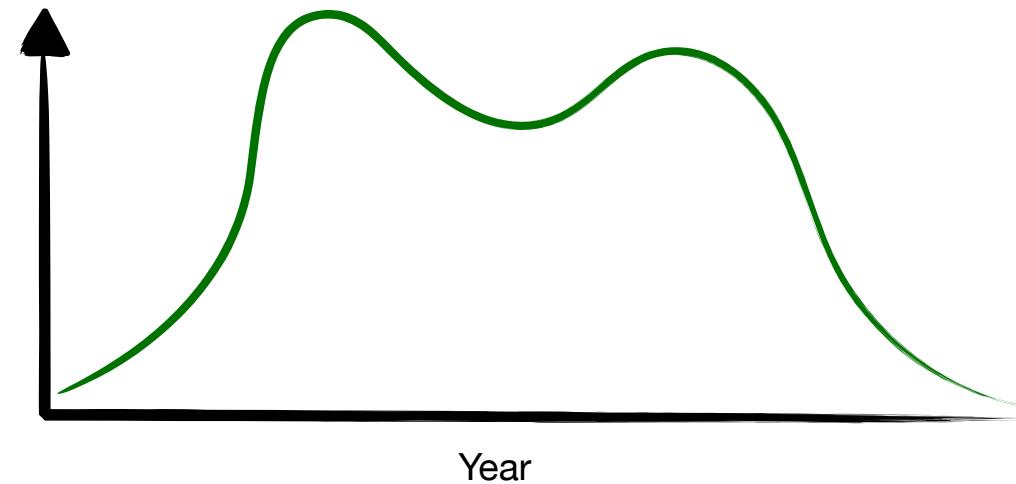
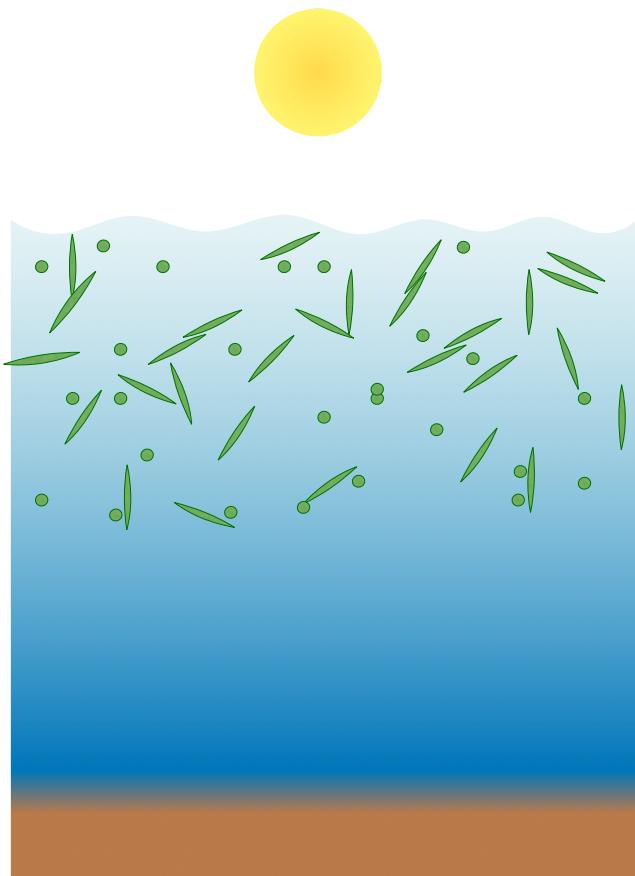
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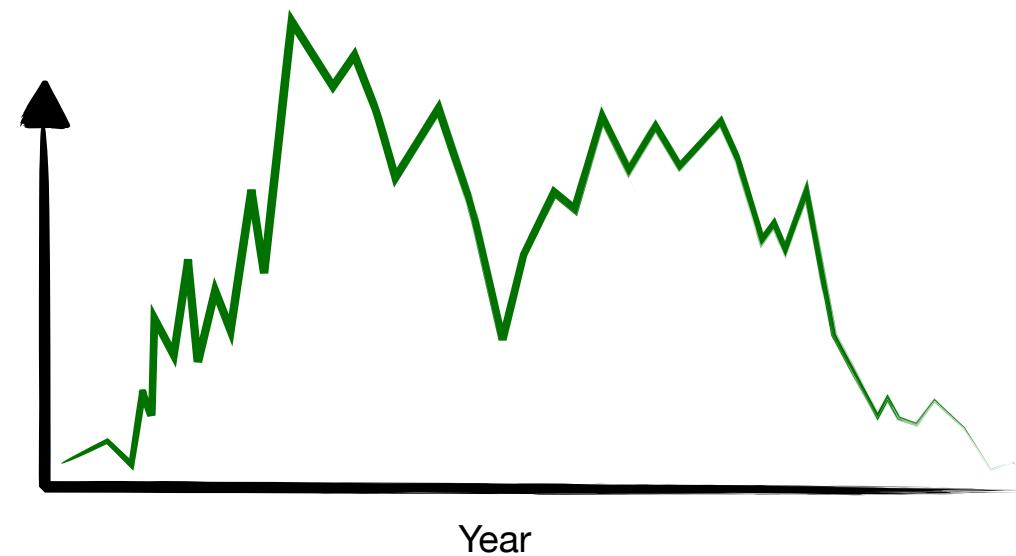
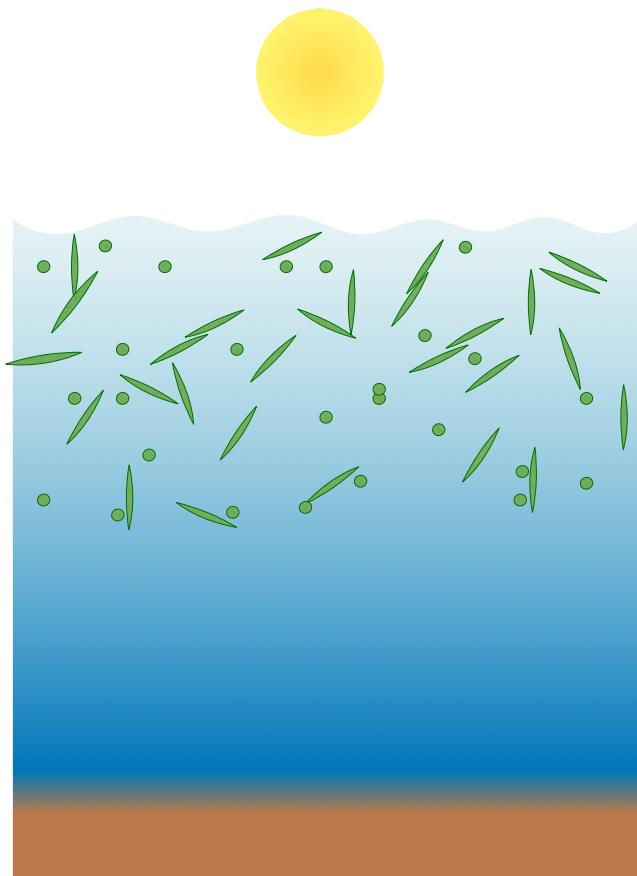
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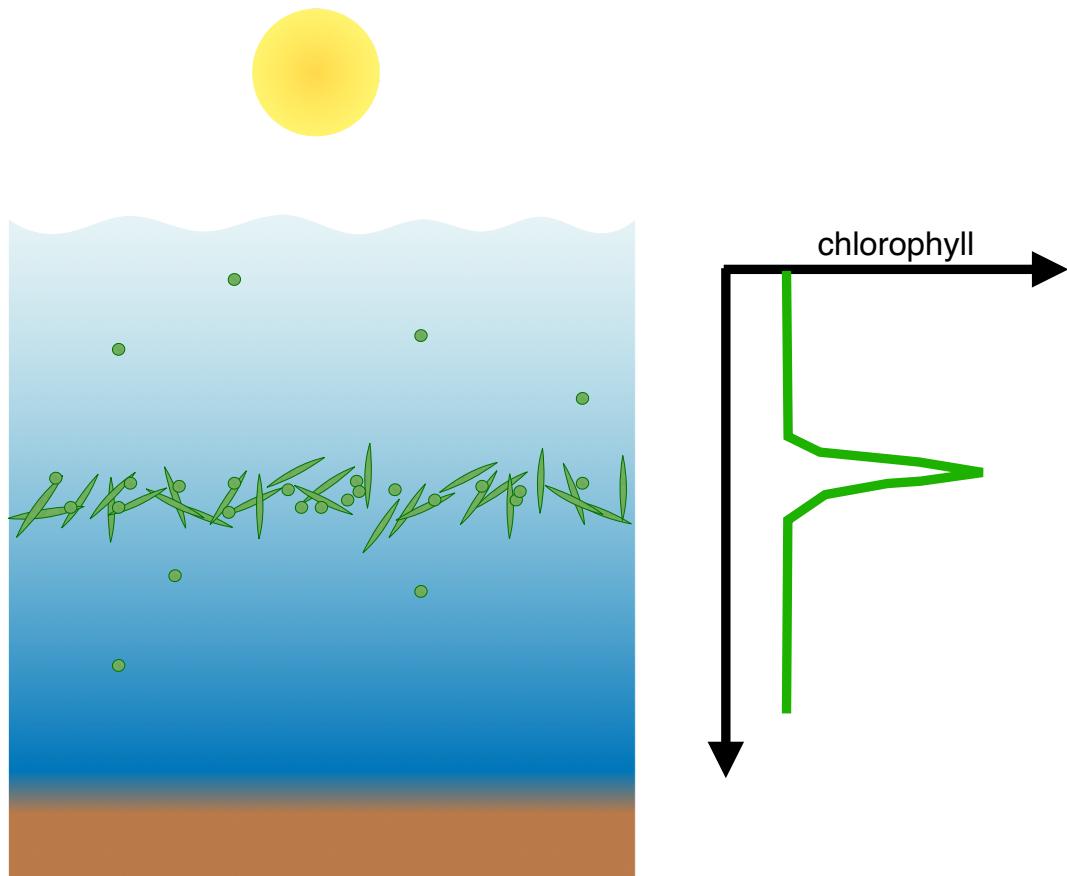
Phytoplankton bloom dynamics



Phytoplankton bloom dynamics

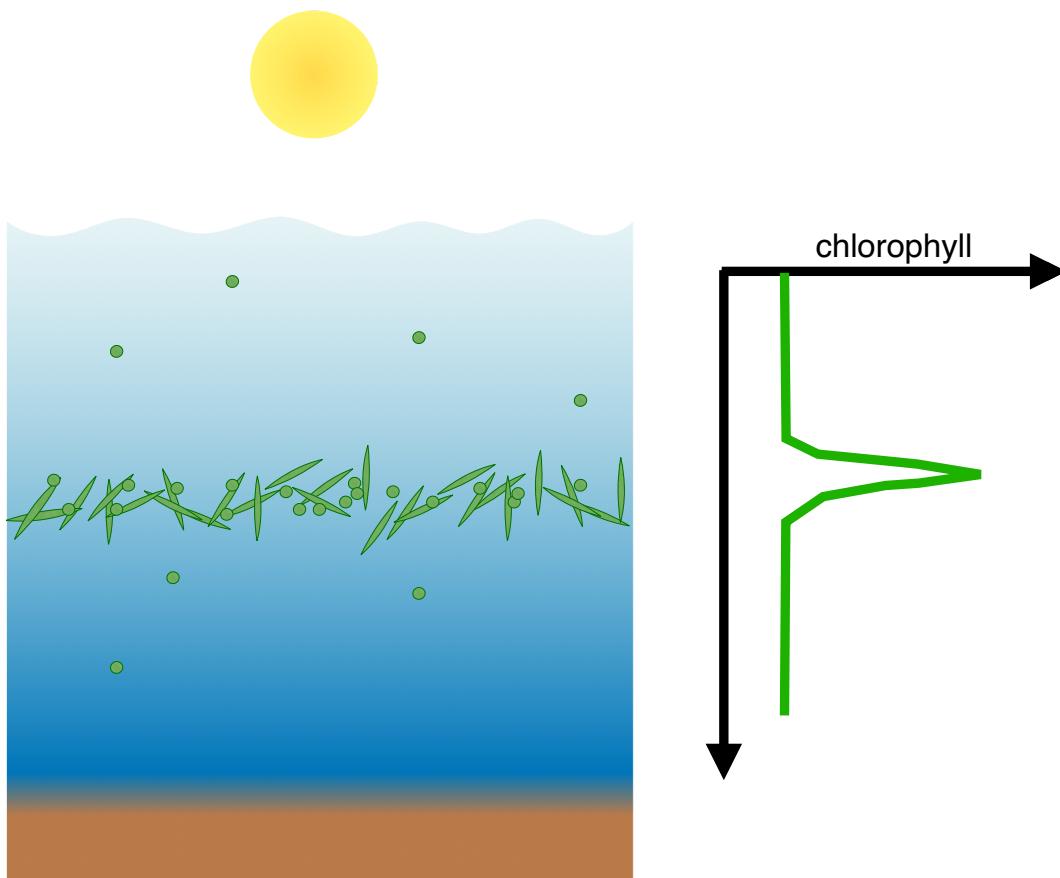


What are *thin layers of phytoplankton*?



Strickland (1968), Durham & Stocker (2012)

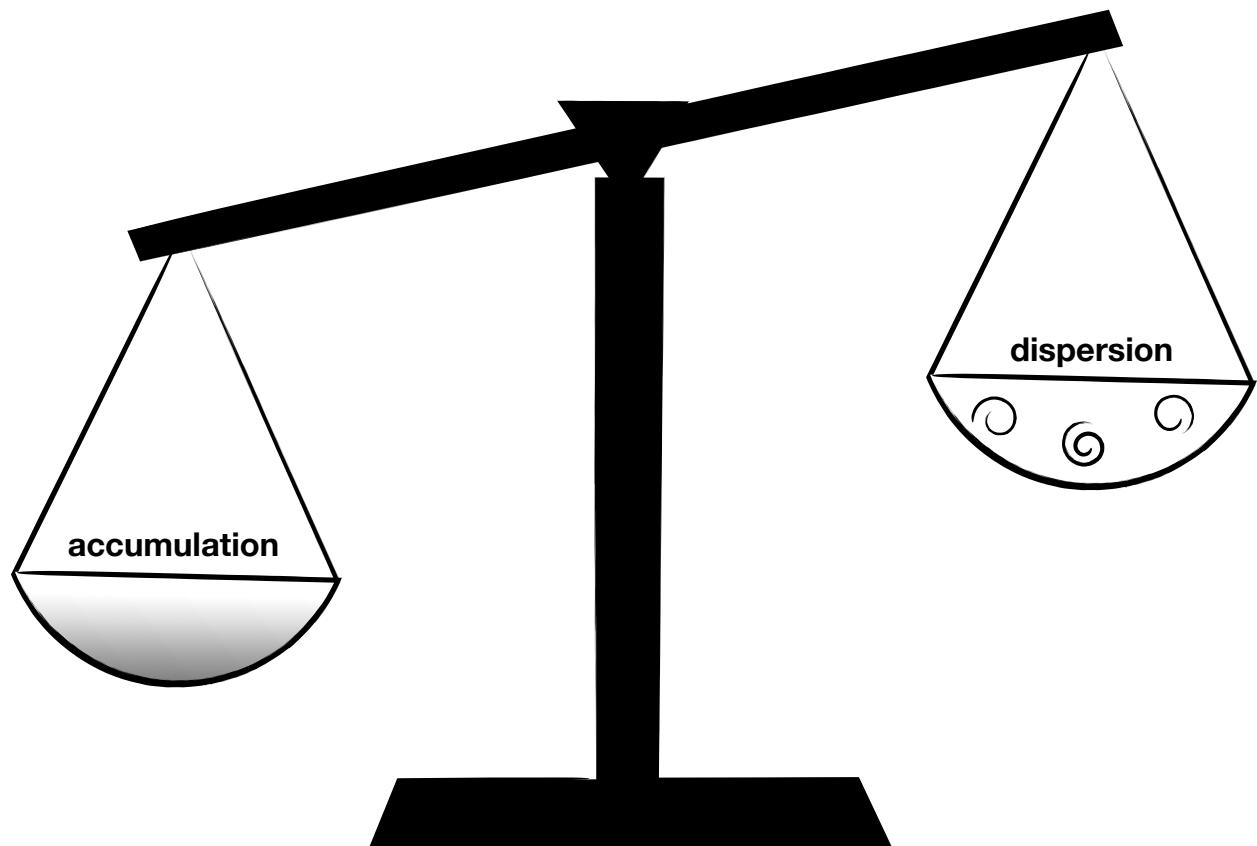
What are *thin layers* of phytoplankton?



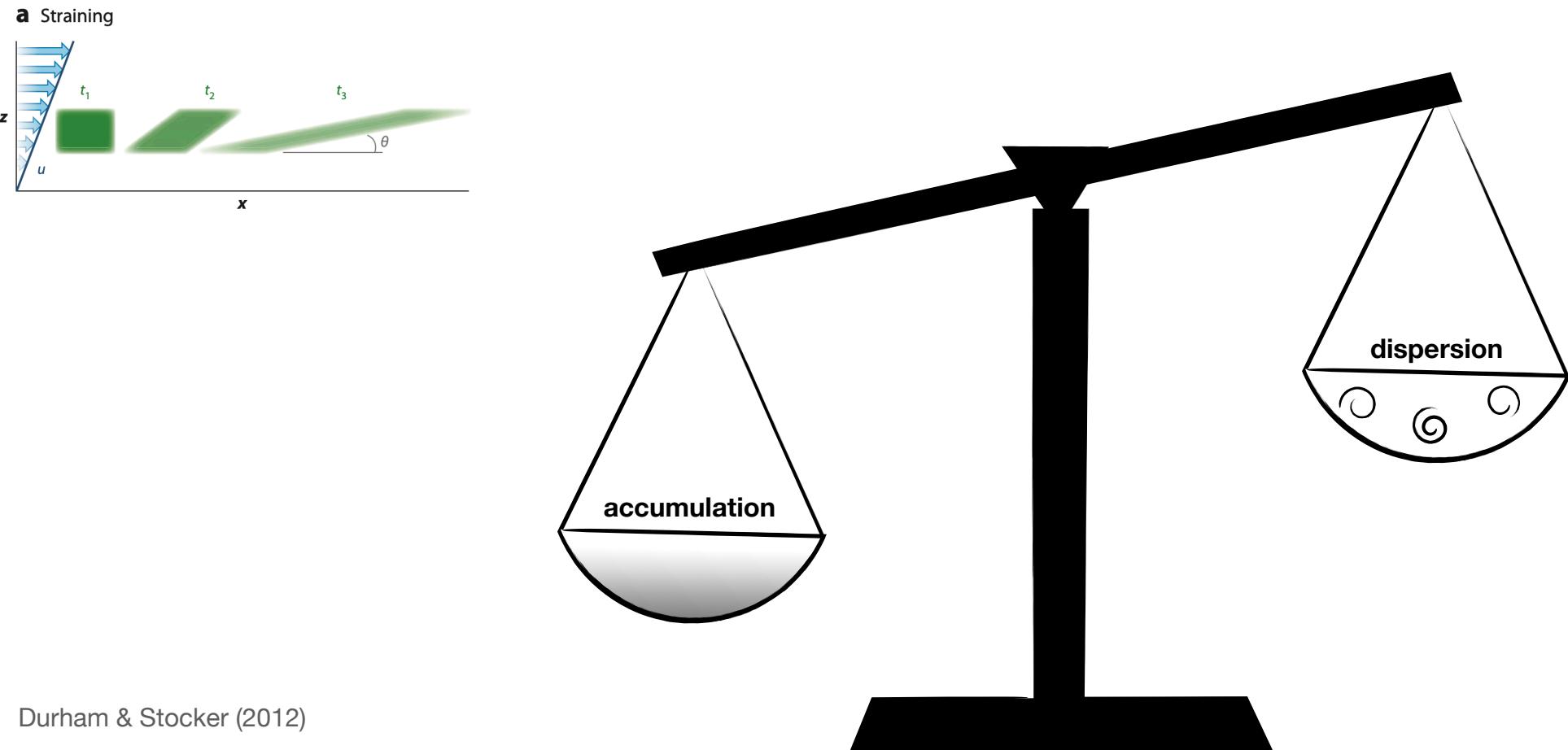
- Thickness < 5 m
- Intensity > 2 x Background
- TLP can extent horizontally over several km and persist for several days

Strickland (1968), Durham & Stocker (2012)

How do TLP form?



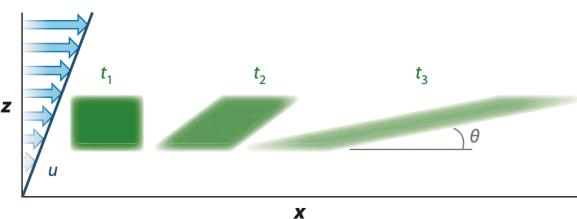
How do TLP form?



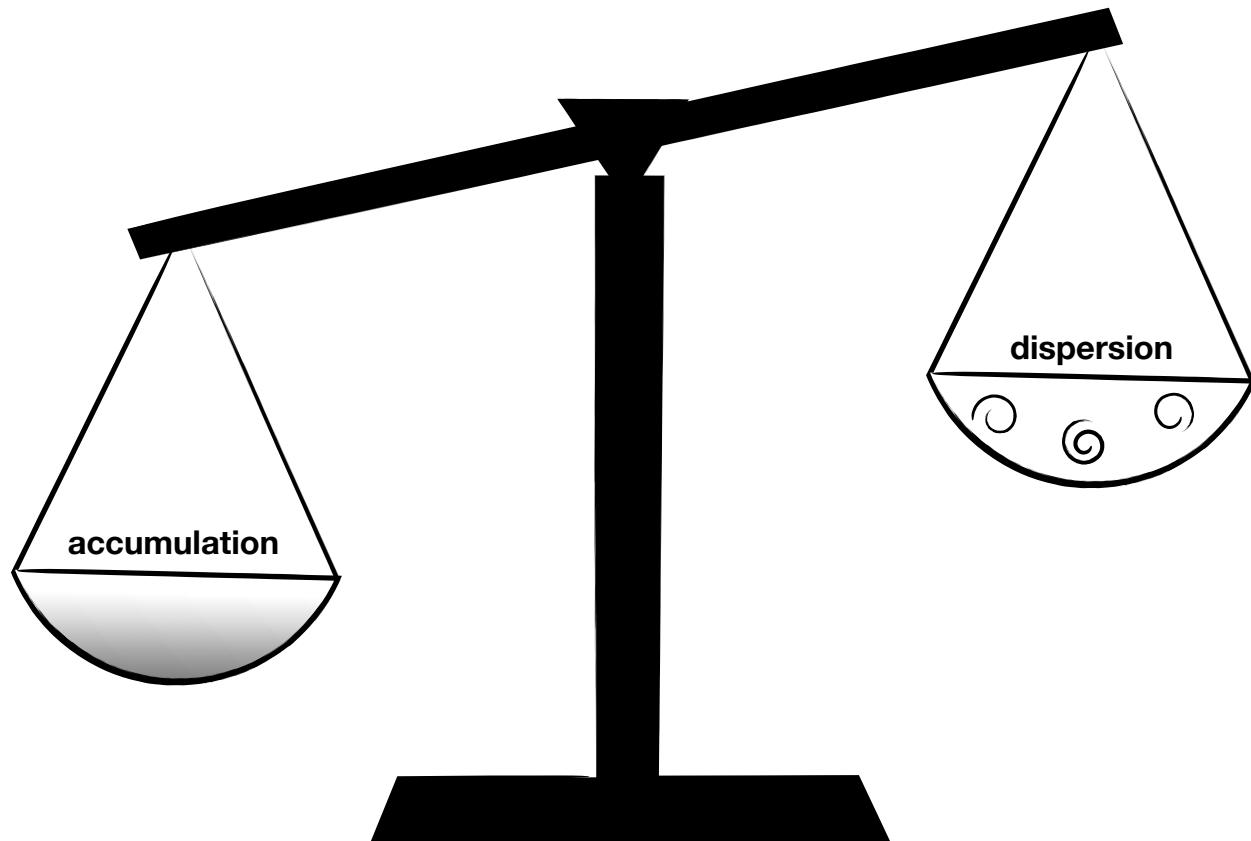
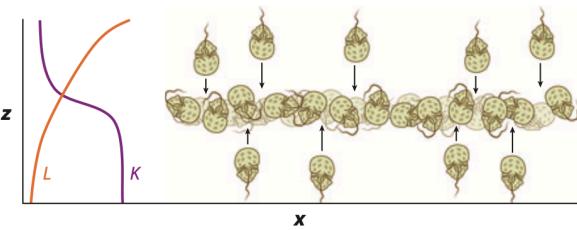
Durham & Stocker (2012)

How do TLP form?

a Straining



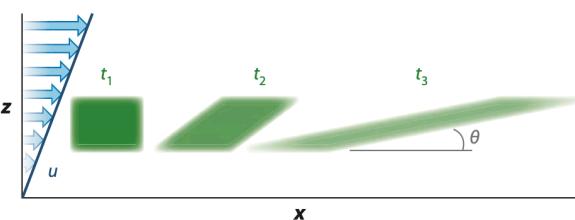
b Convergent swimming



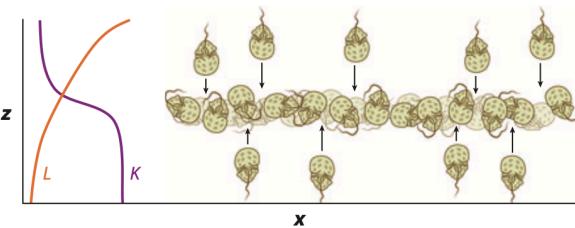
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How do TLP form?

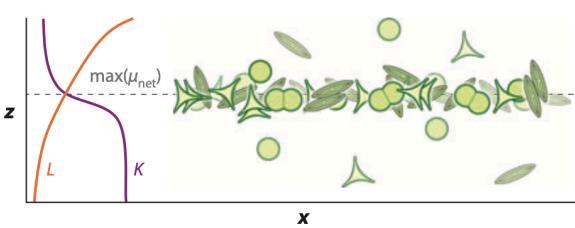
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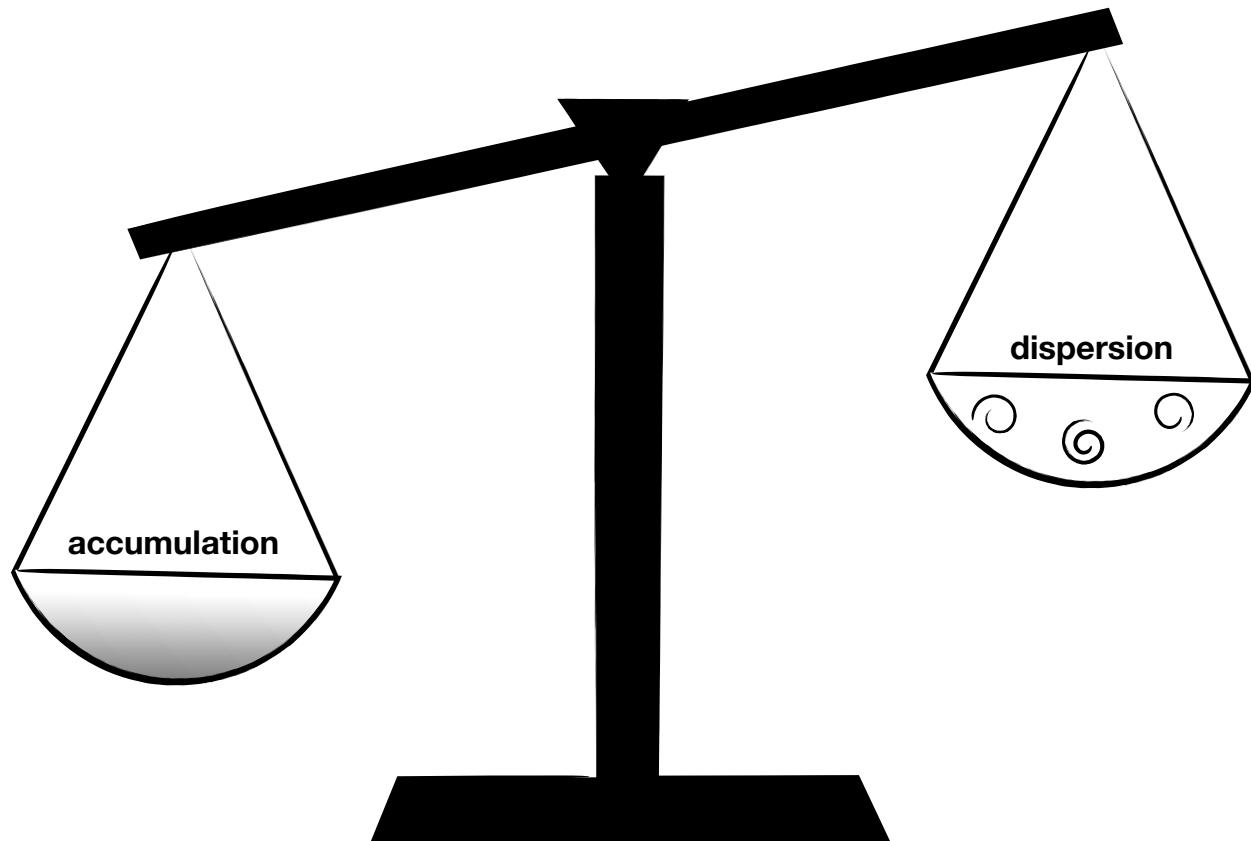
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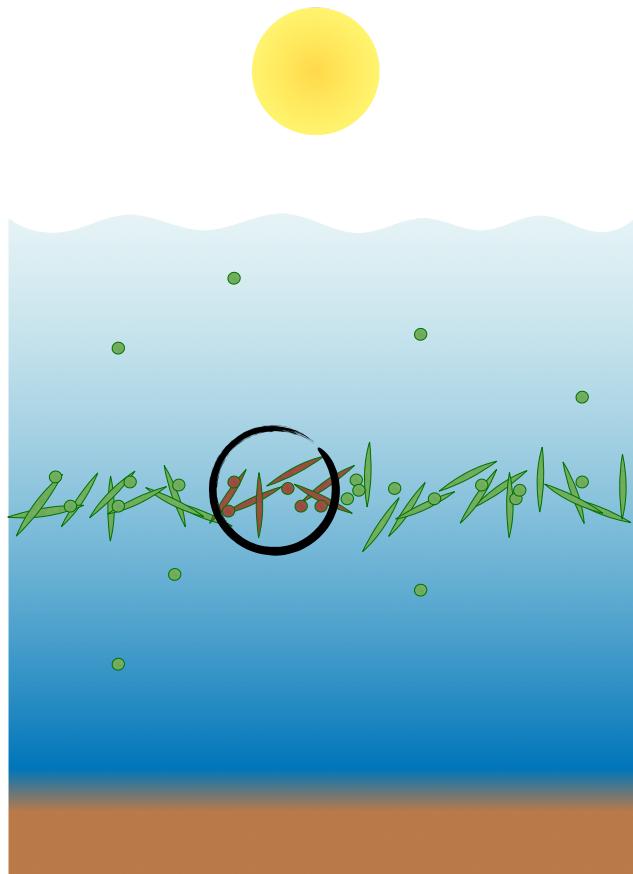
e In situ growth



Durham & Stocker (2012)



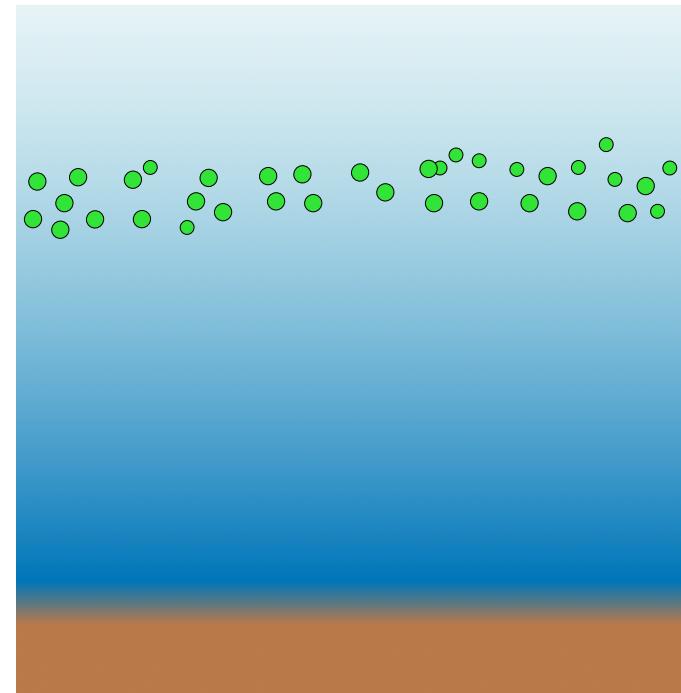
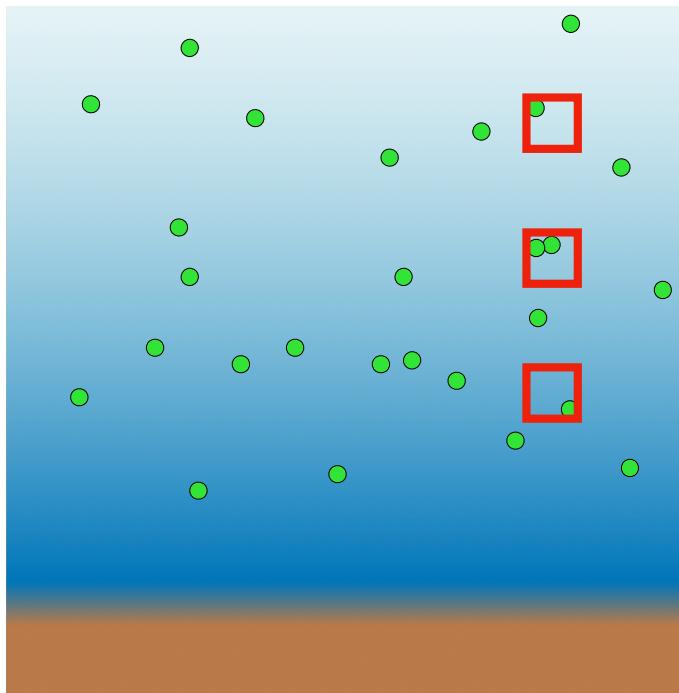
Thin layers and harmful algal blooms



Several studies showed the presence of toxin-producing species within TLP

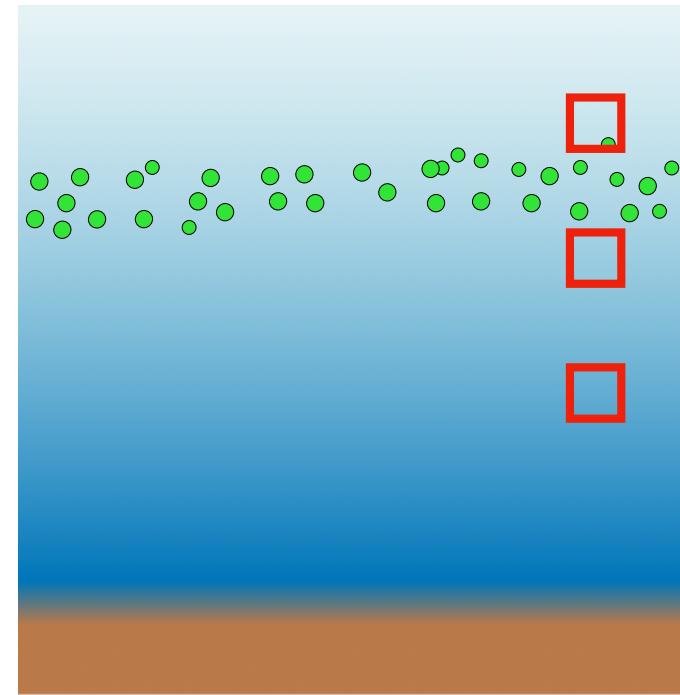
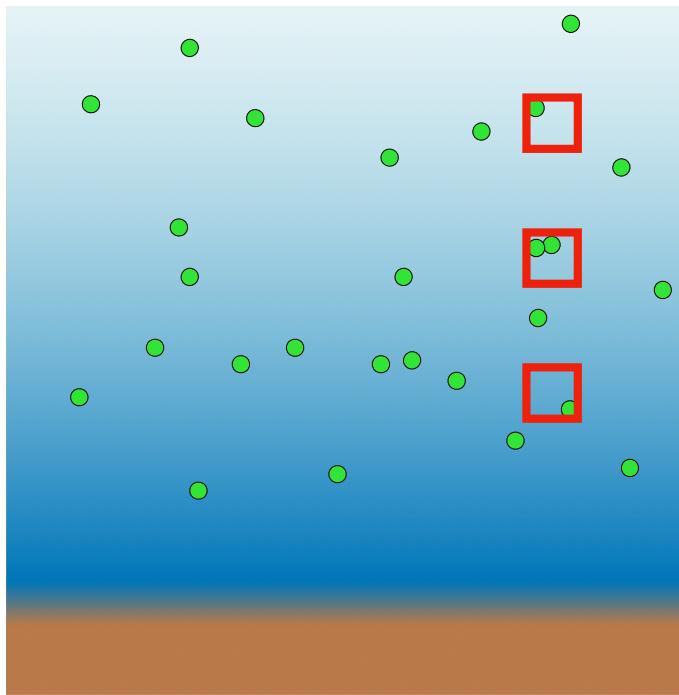
Velo-Suárez et al. (2008), Díaz et al. (2014, 2019), McManus et al., (2003)

Thin layers detection



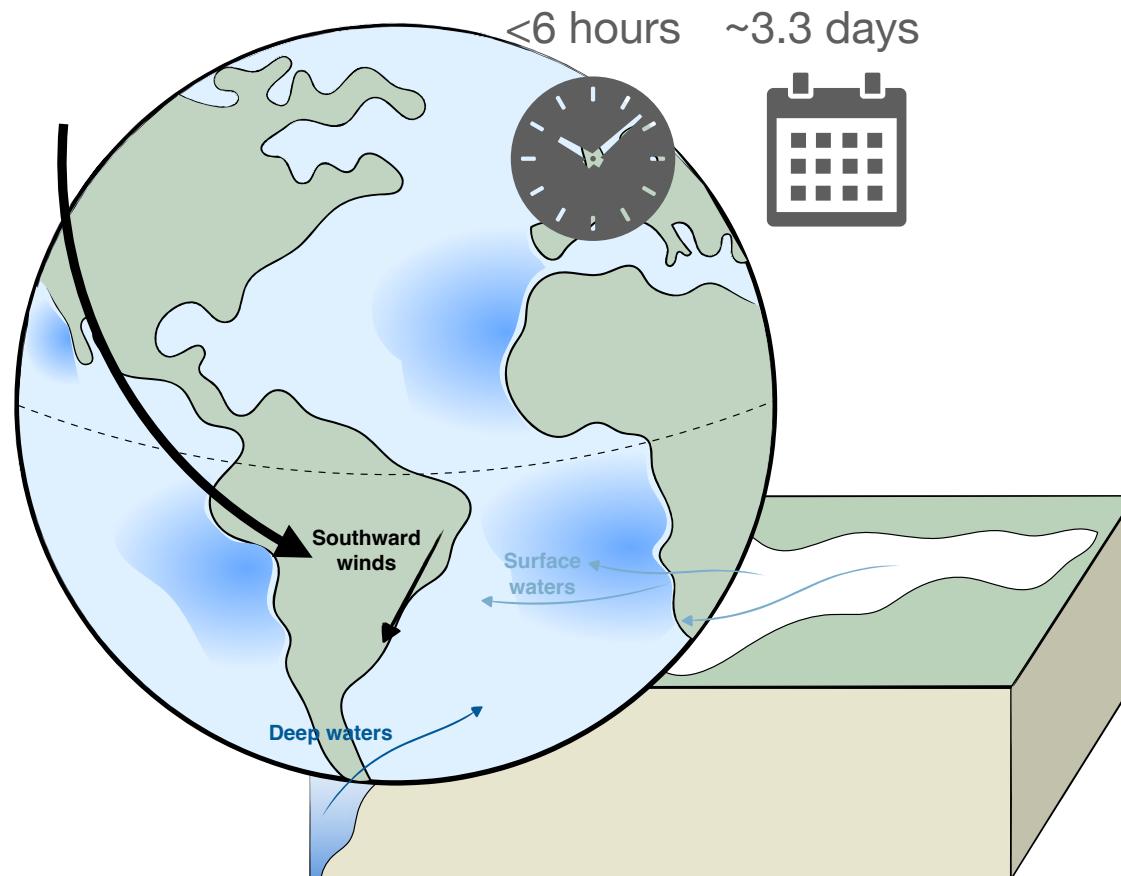
Escalera et al., 2012 (*Marine Pollution Bulletin*)

Thin layers detection



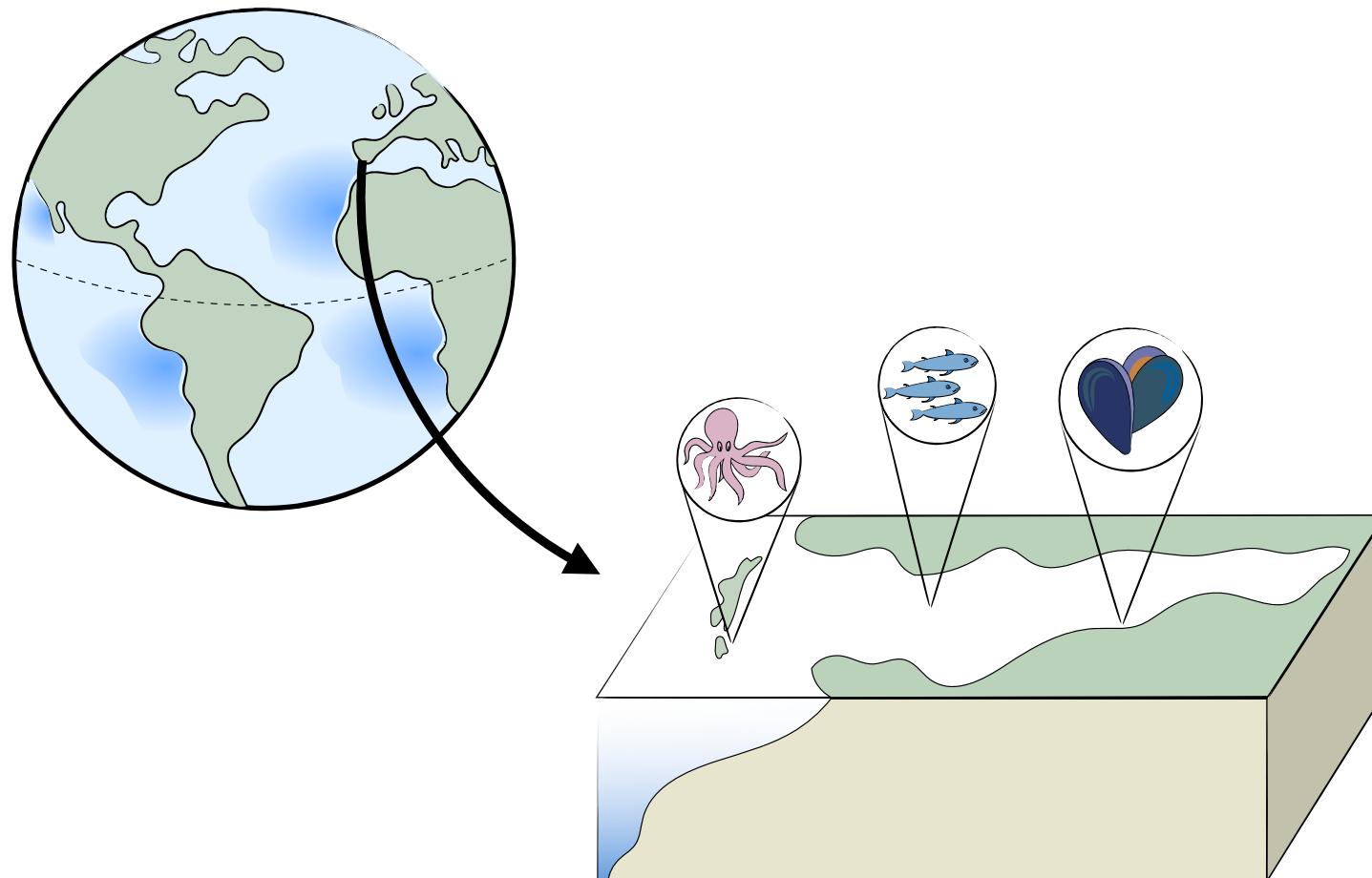
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Upwelling bays: the Galician Rías Baixas

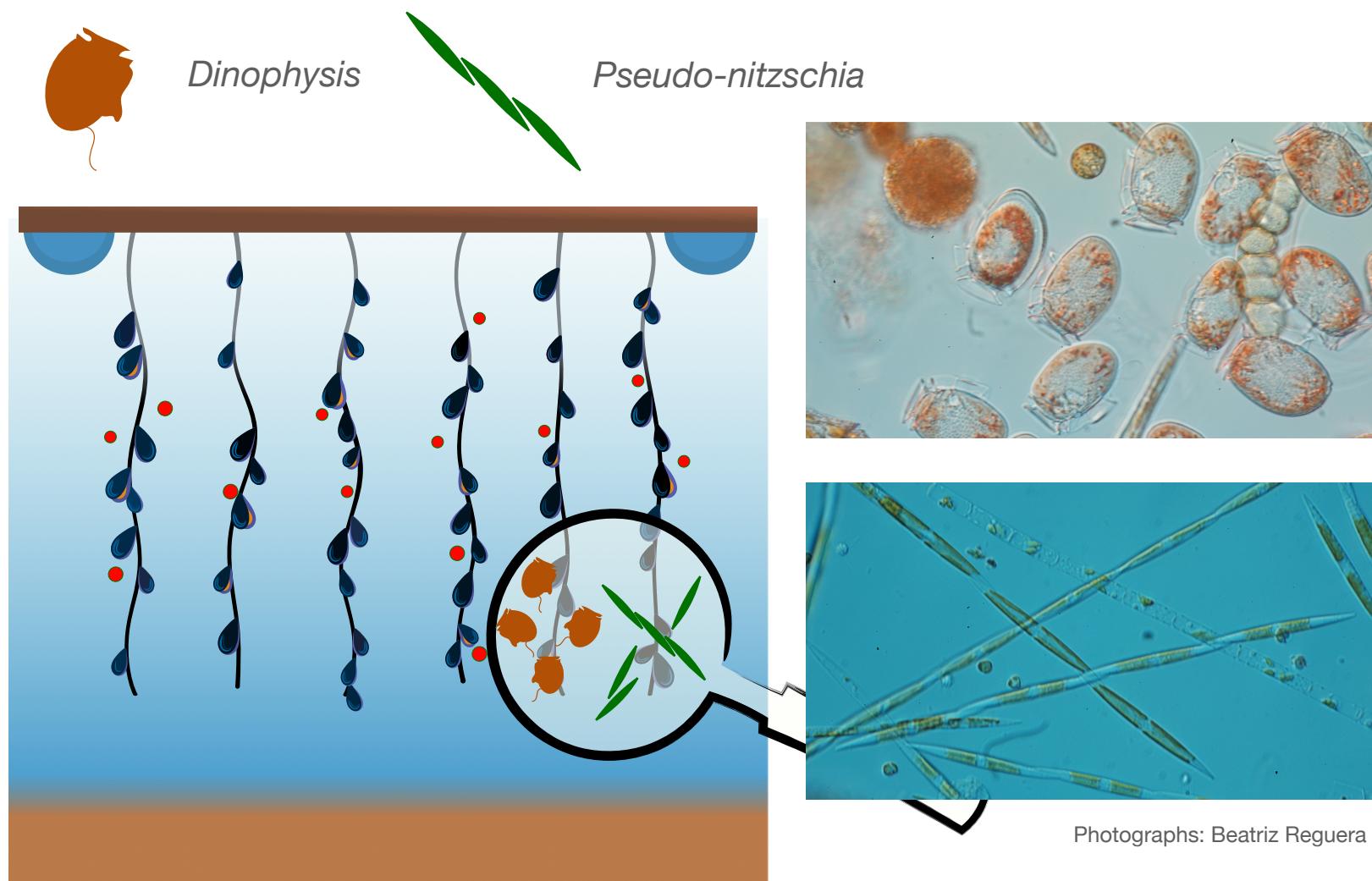


Gilcoto et al., 2017 (*Geophysical Research Letters*)

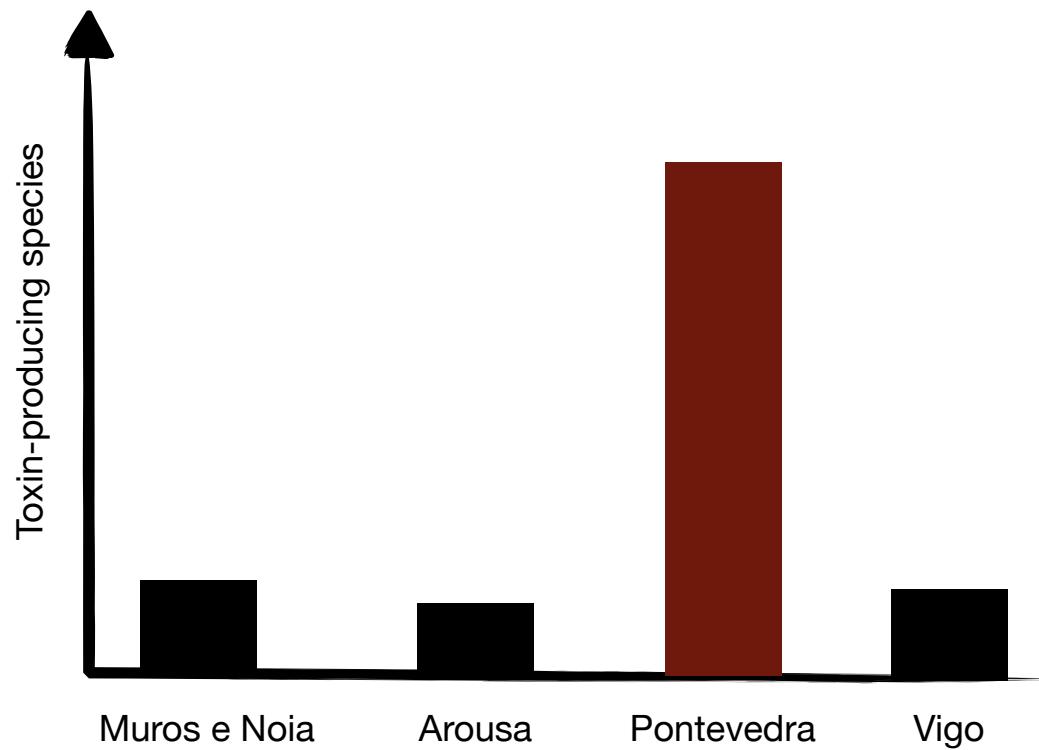
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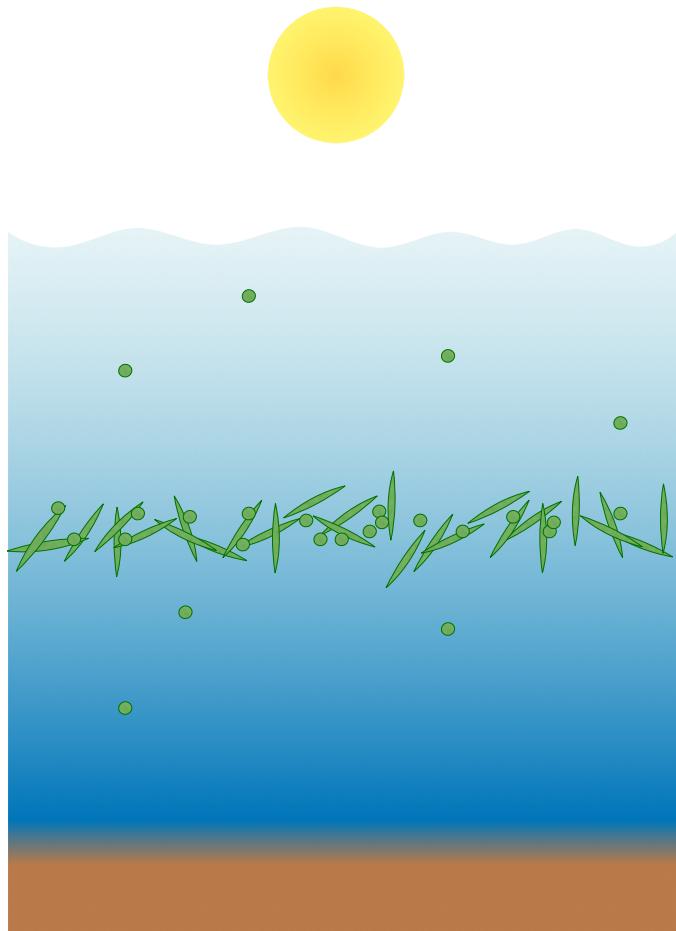
Harmful algal blooms in the Galician Rías



Harmful algal blooms in the Galician Rías



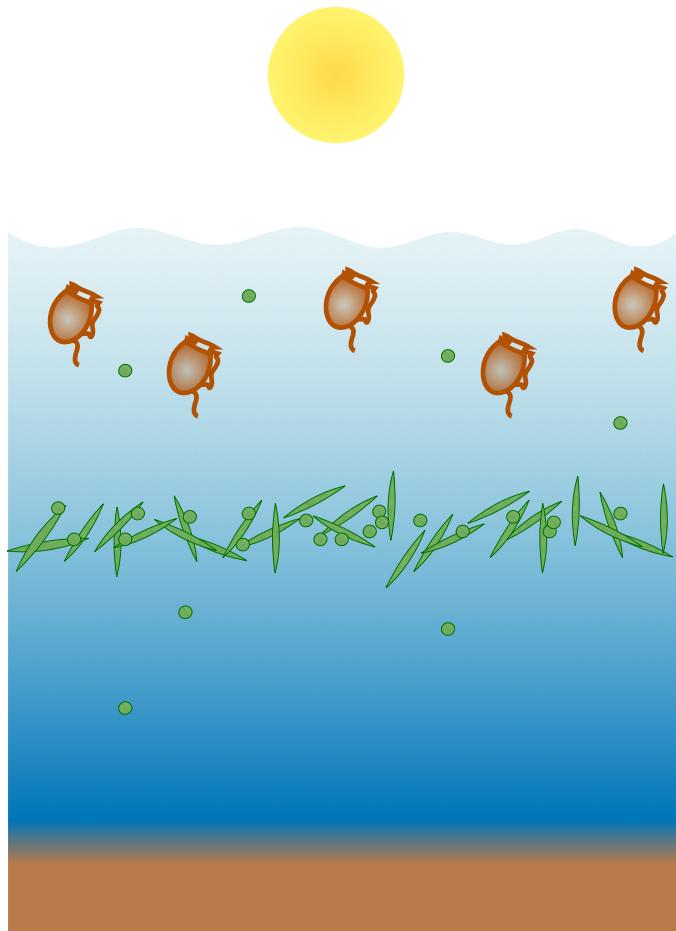
TLP and HAB in the Galician Rías



- May-June 2005
- Toxin-producing *Pseudo-nitzschia* TLP
- Ría de Pontevedra (Bueu-222)
- Associated with stratification

Velo-Suárez et al., (2008, 2010)

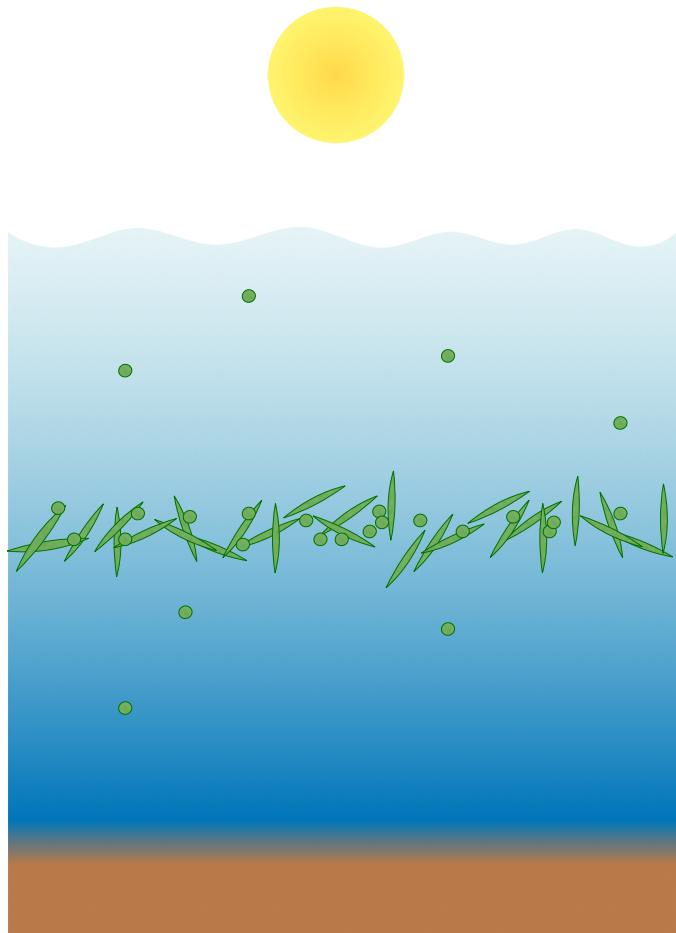
TLP and HAB in the Galician Rías



- May-June 2005
- Toxin-producing *Pseudo-nitzschia* TLP
- Ría de Pontevedra (Bueu-222)
- Associated with stratification
- Co-occurrence with surface *Dinophysis acuminata* populations

Velo-Suárez et al., (2008, 2010)

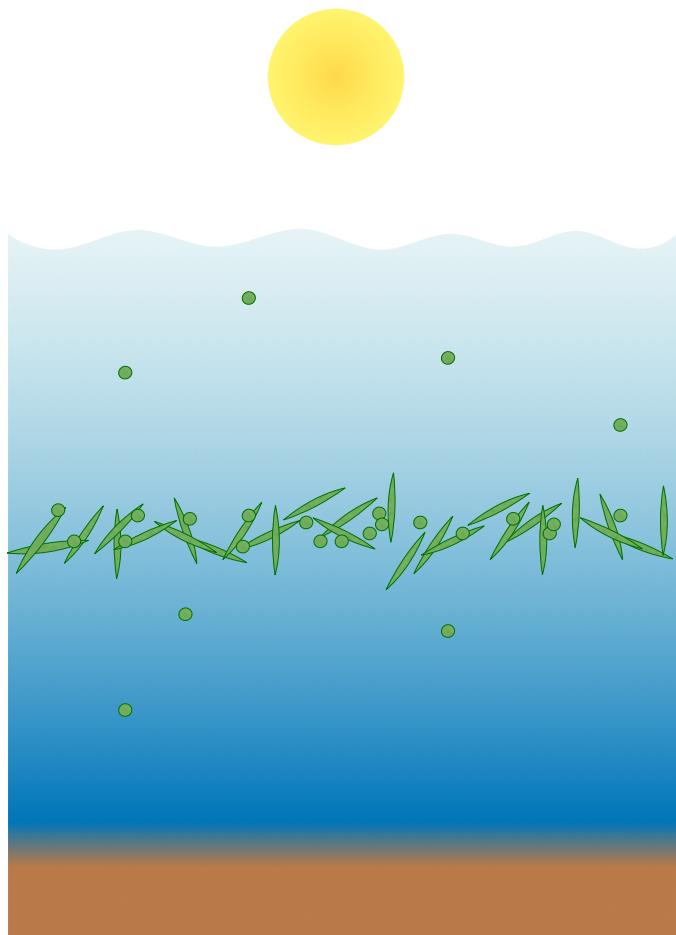
TLP and HAB in the Galician Rías



- May-June 2007
- Toxin-producing *Pseudo-nitzschia* TLP
- Same station in the Ría de Pontevedra (Bueu-222)
- Modulated by the tidal cycle: high temporal variability

Díaz et al., (2014)

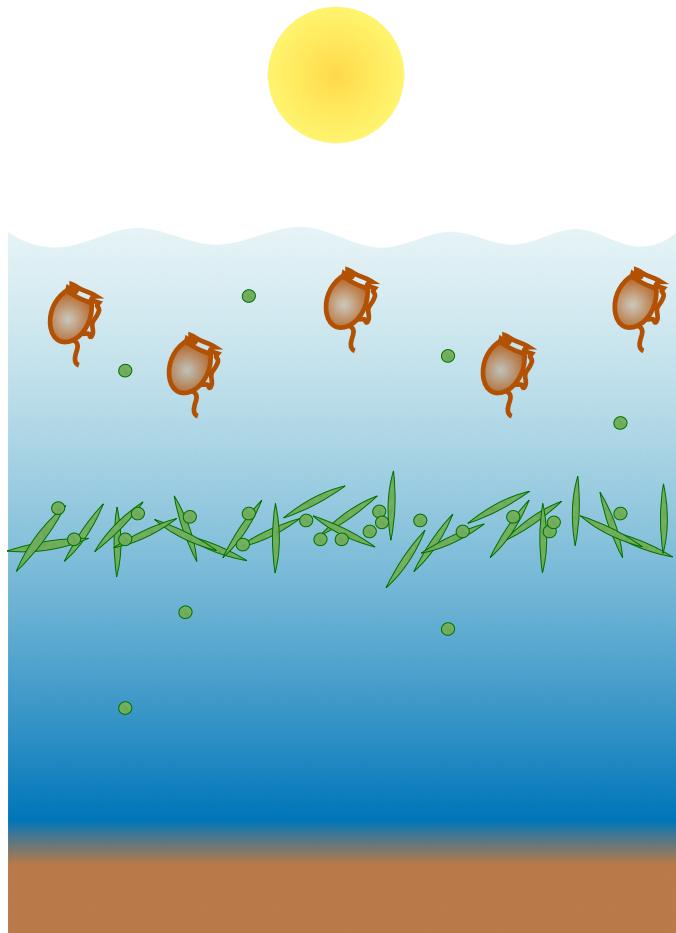
TLP and HAB in the Galician Rías



- June 2013
- Diatom-dominated TLP
- Same station in the Ría de Pontevedra (Bueu-222)
- Modulated by the upwelling cycle, associated with the isotherms

Díaz et al., (2019)

TLP and HAB in the Galician Rías



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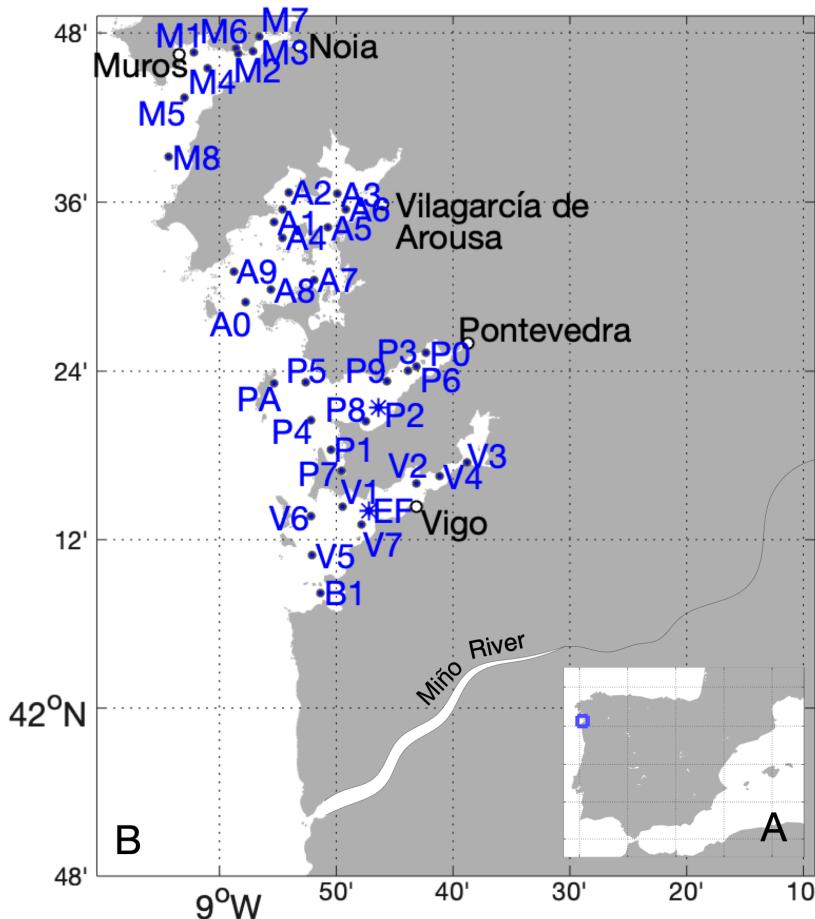
Question 1: is there a relationship between TLP and HAB in the Galician Rías?

Question 2: what are the mechanisms responsible for TLP formation?

Question 3: why is the Ría de Pontevedra a hotspot for toxicity?

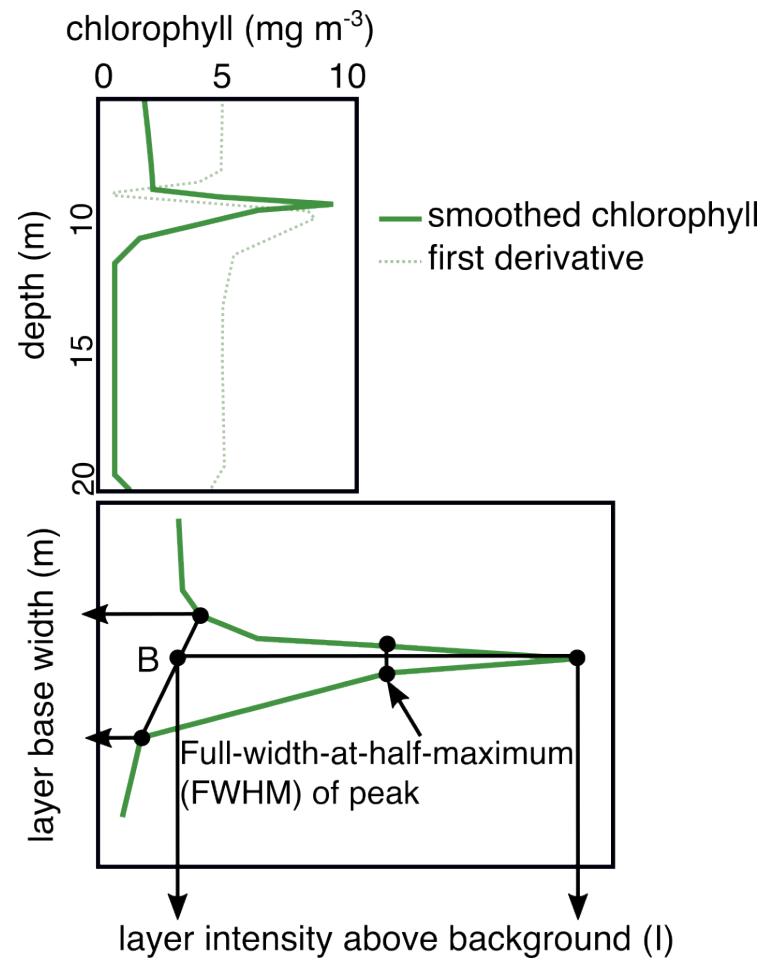
Part 1. Historical dataset

Monitoring program (INTECMAR)



- Weekly CTD (+ fluorescence)
- Period: 2012-2015
- 39 stations
- > 6000 profiles

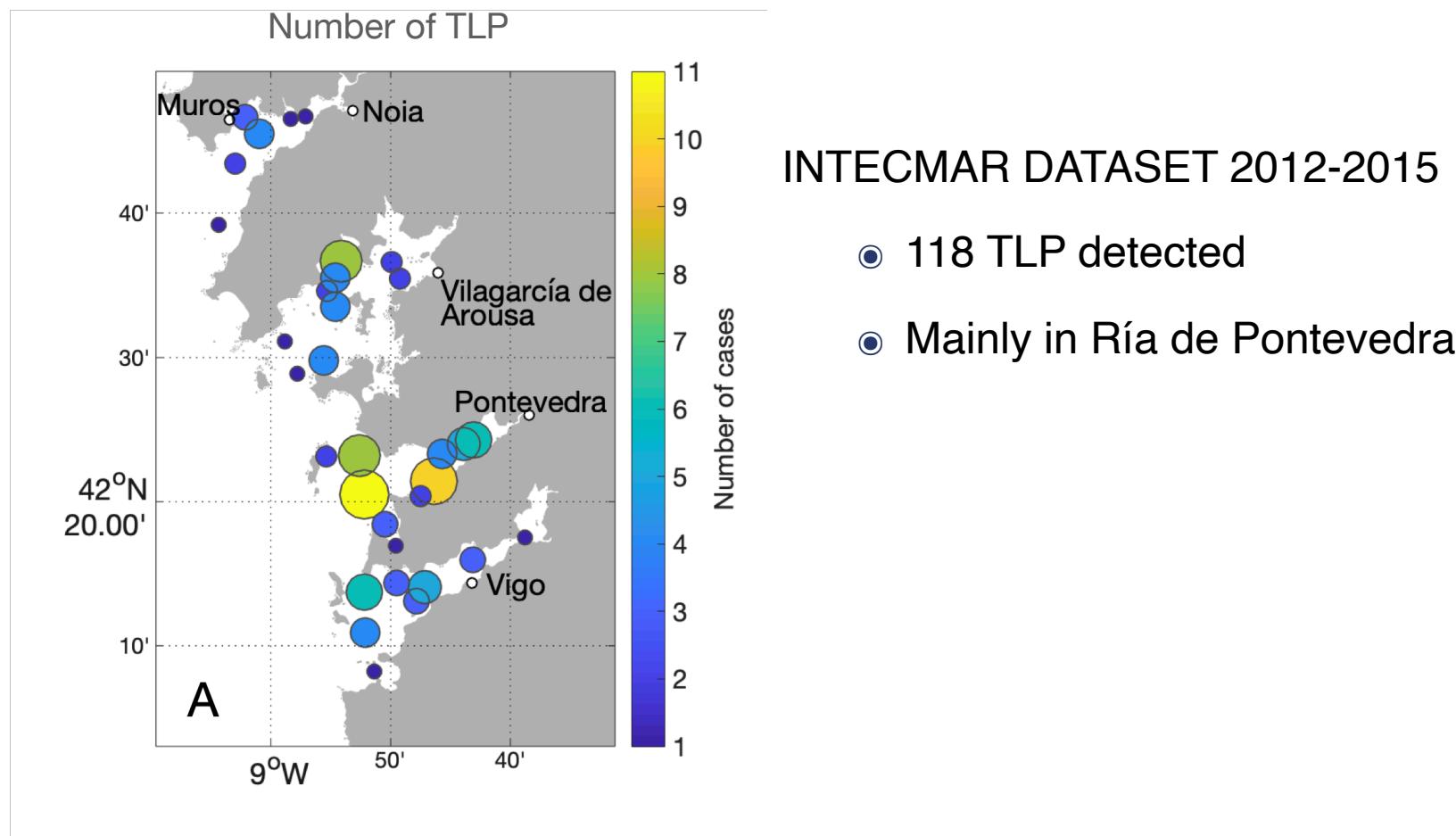
TLP detection



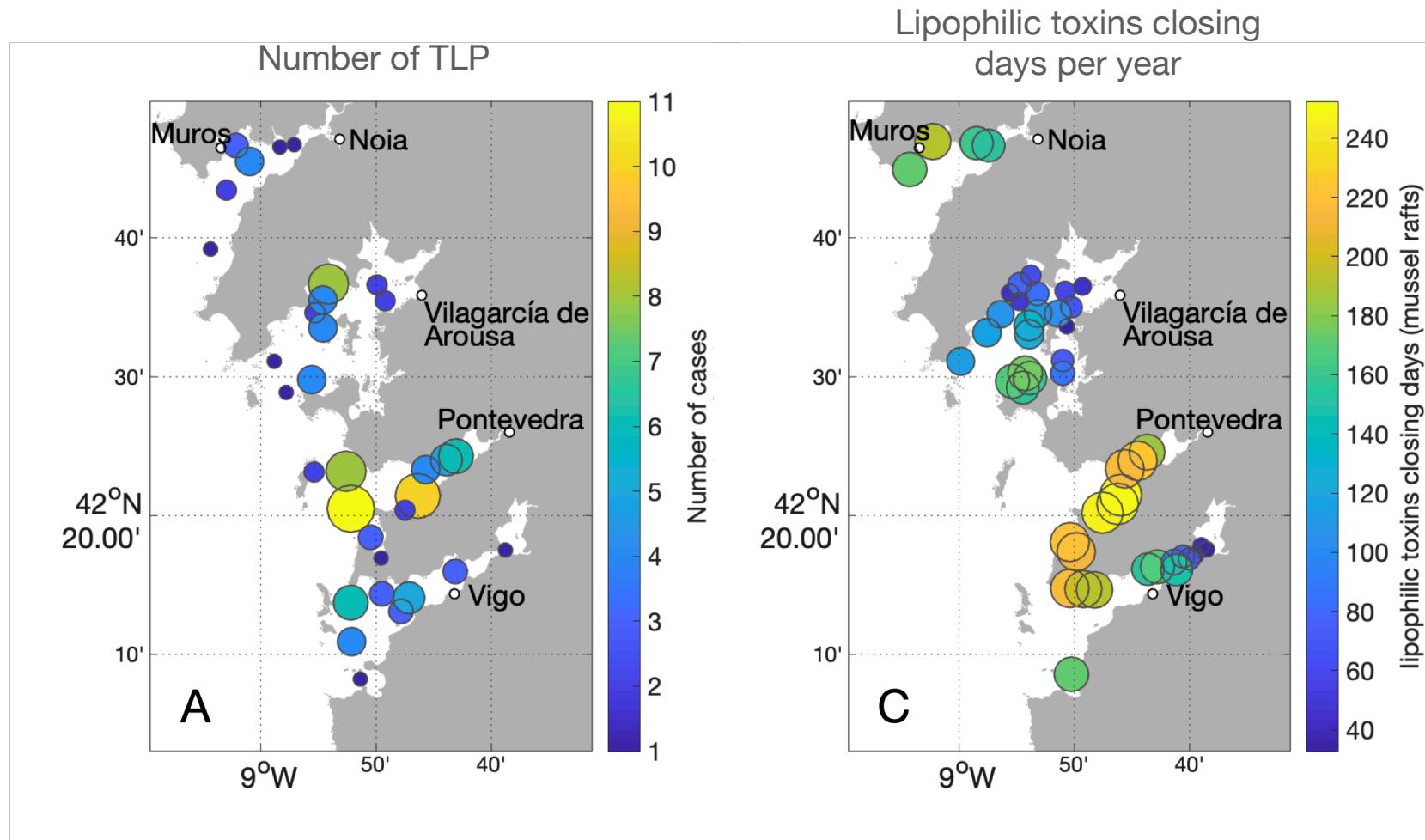
- Full width at half maximum < 3 m
- Peak value > 2x(background level)
- Peak intensity = Peak value - background level

Based on Sullivan et al. (2010) criteria

TLP characteristics



TLP characteristics

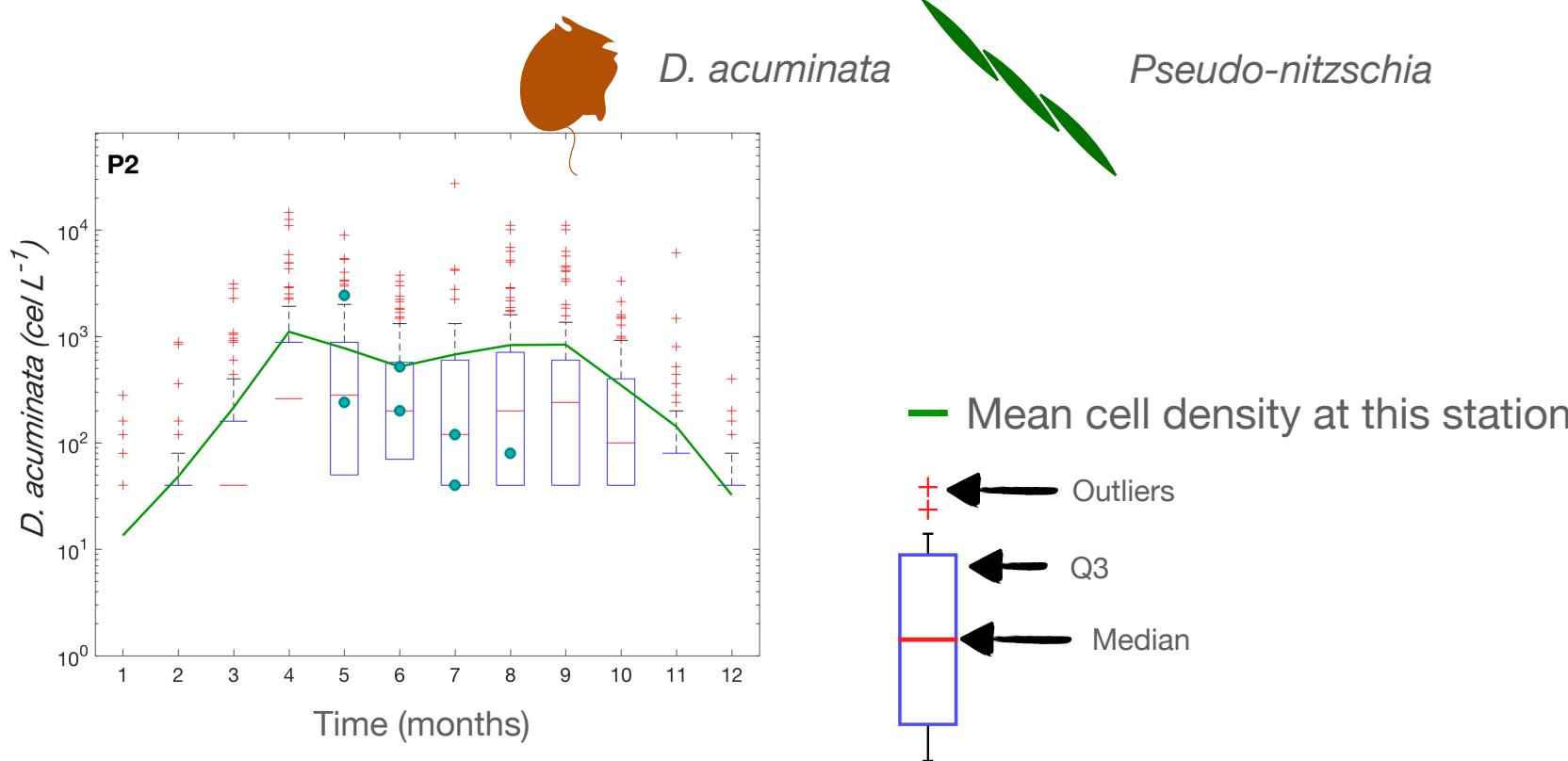


Relationship between TLP and HAB

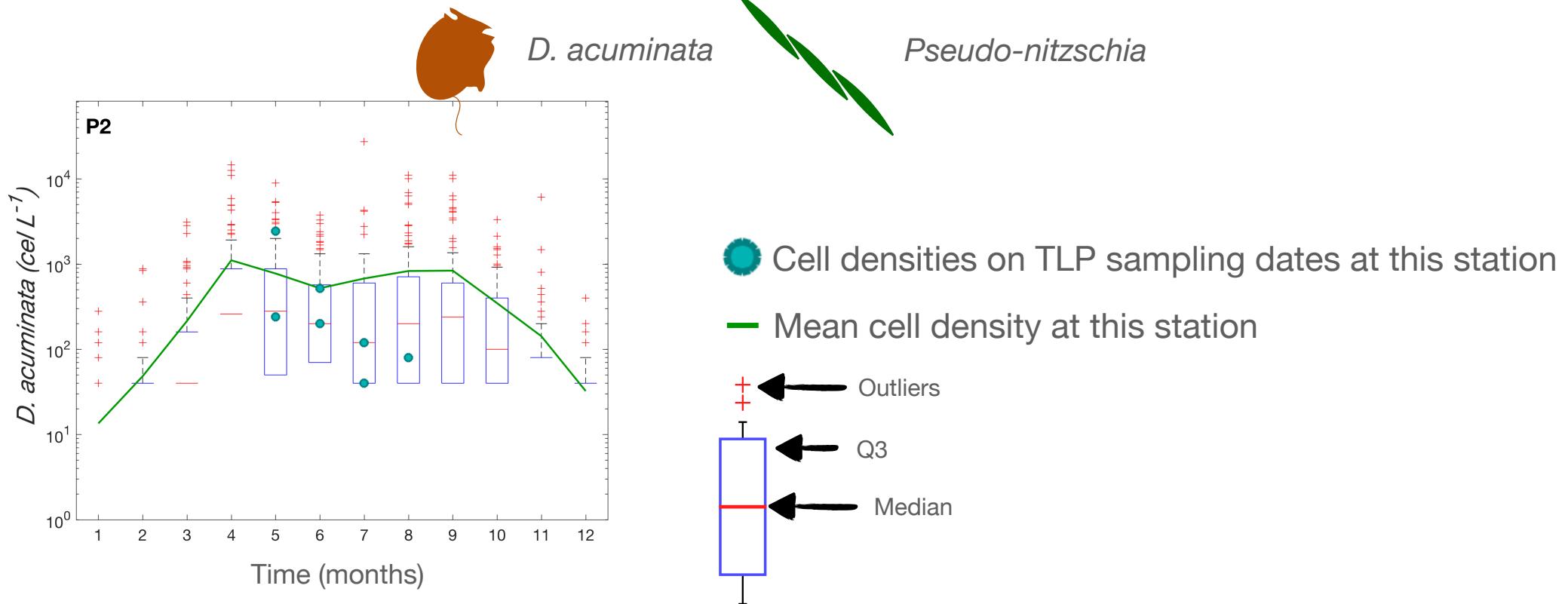
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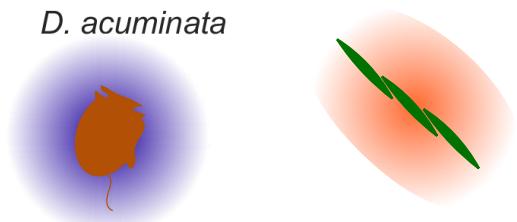
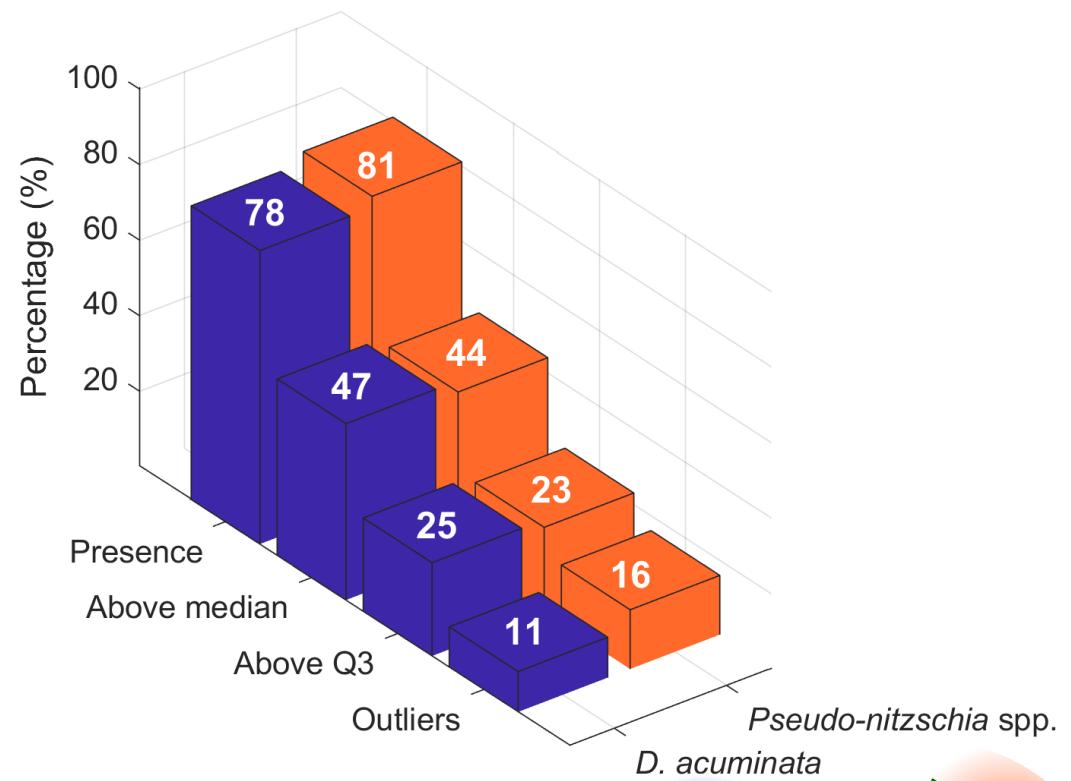
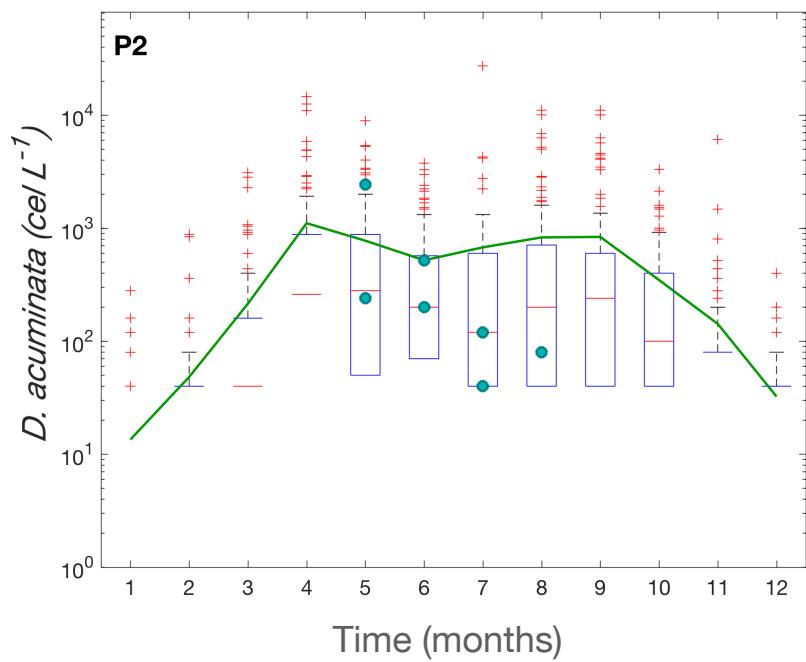
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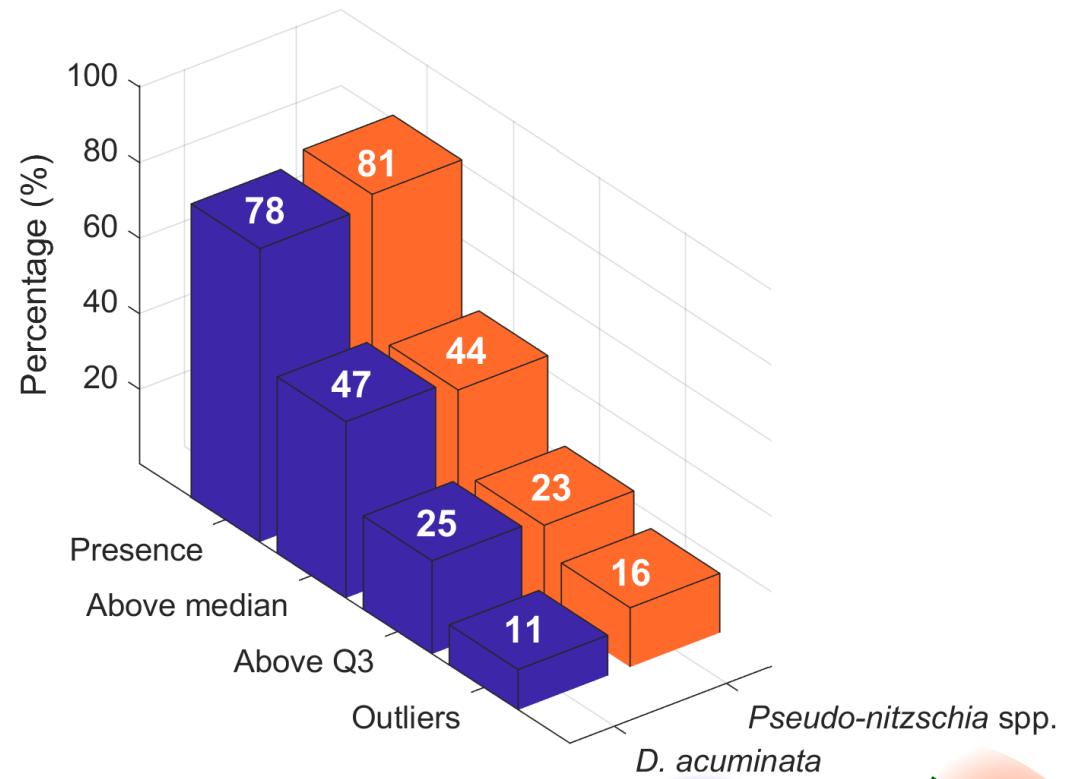
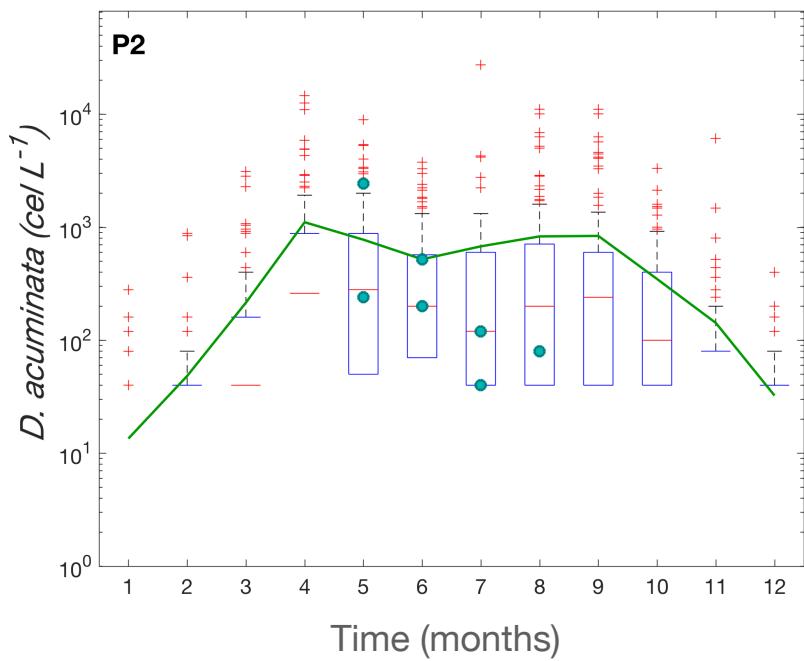
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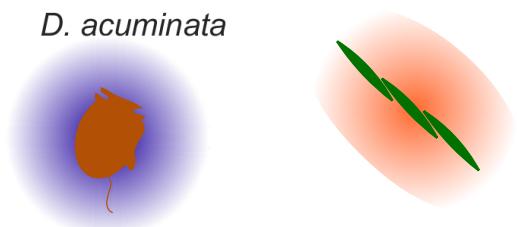
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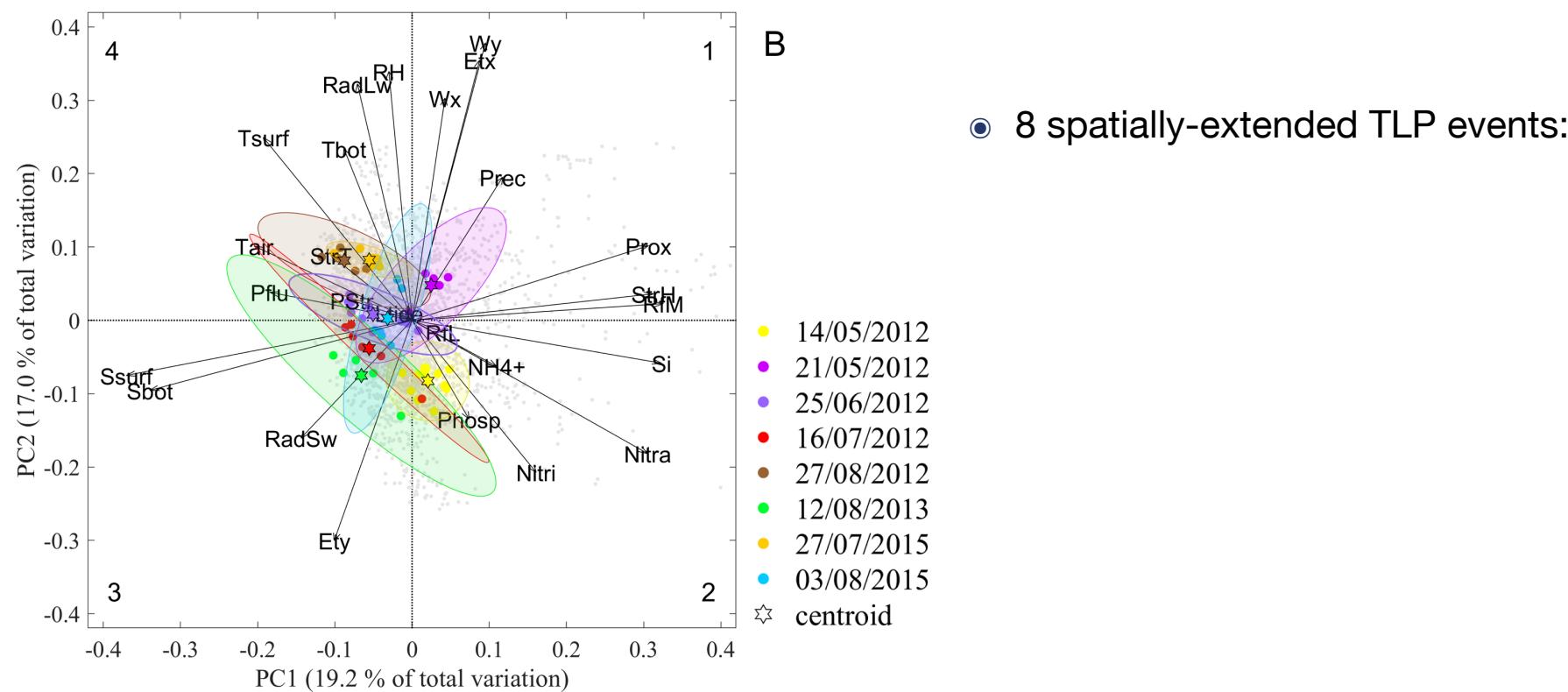
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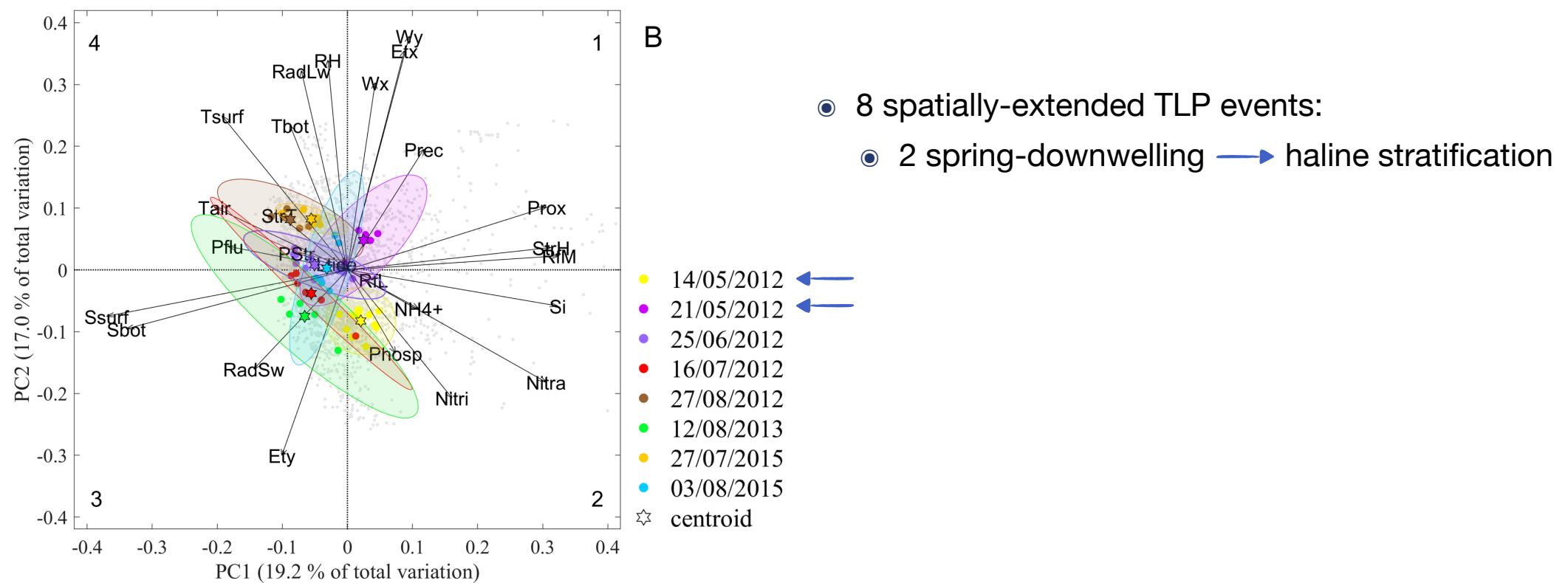
- ~25 % of the TLP were related to *Pseudo-nitzschia* and *D. acuminata*



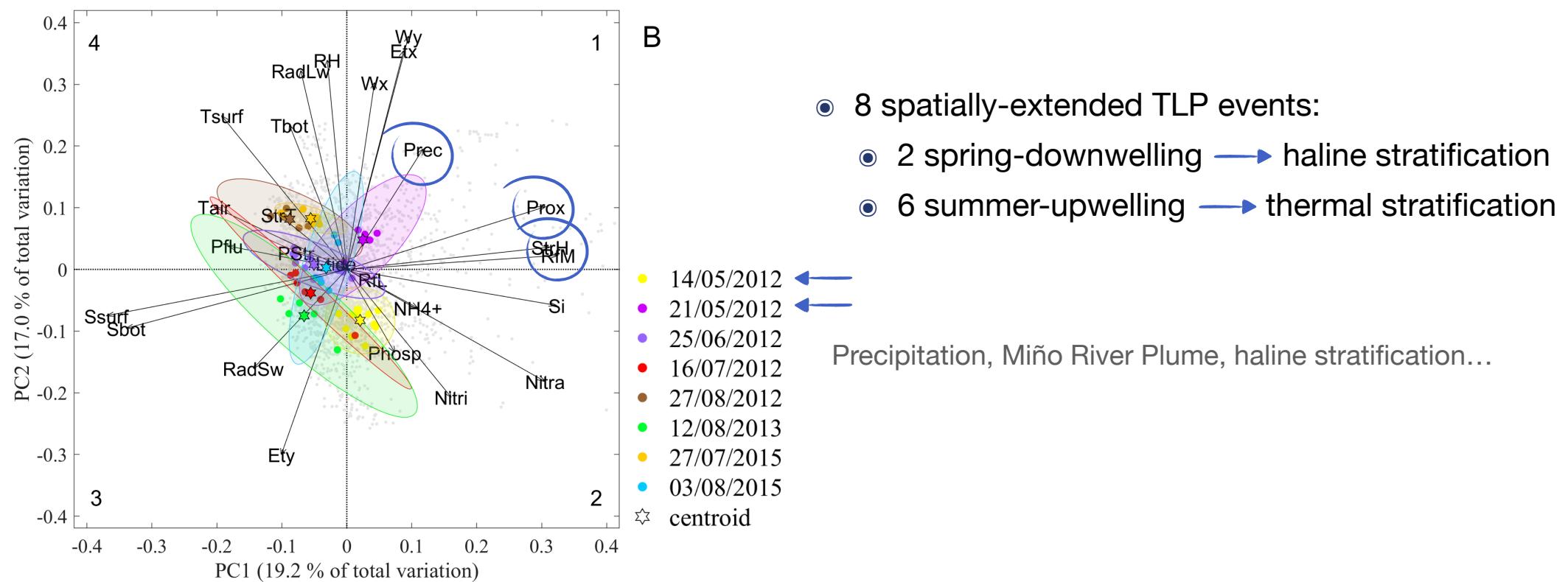
Environmental conditions of the spatially-extended TLP



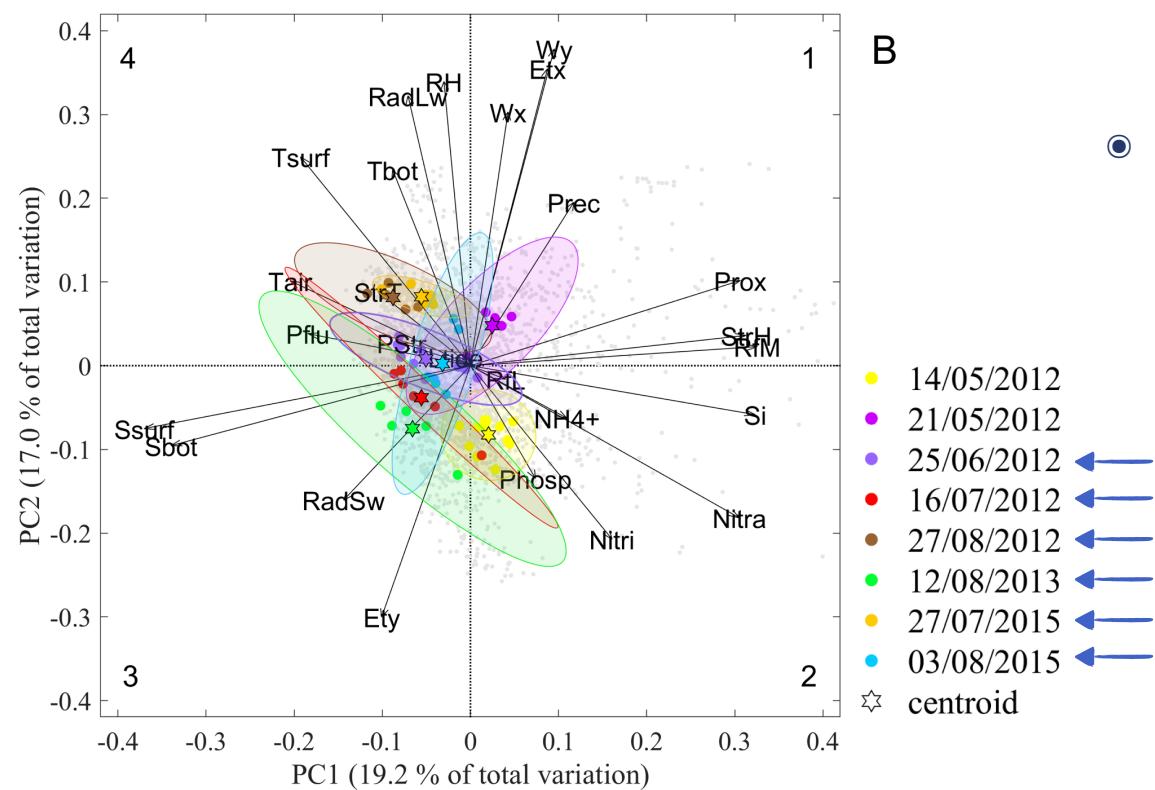
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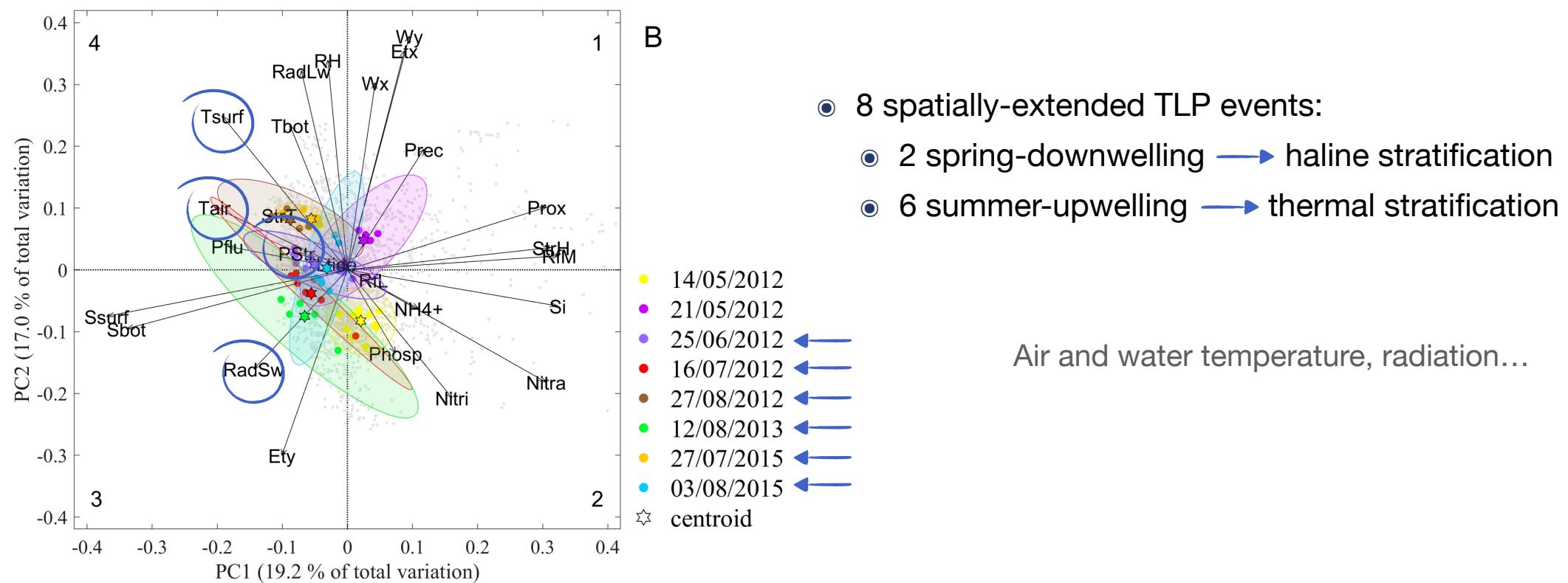


Environmental conditions of the spatially-extended TLP



- 8 spatially-extended TLP events:
 - 2 spring-downwelling → haline stratification
 - 6 summer-upwelling → thermal stratification
- | Date | PC1 (19.2 % of total variation) | PC2 (17.0 % of total variation) |
|------------|---------------------------------|---------------------------------|
| 14/05/2012 | -0.05 | 0.05 |
| 21/05/2012 | 0.05 | 0.05 |
| 25/06/2012 | 0.05 | 0.05 |
| 16/07/2012 | 0.05 | 0.05 |
| 27/08/2012 | 0.05 | 0.05 |
| 12/08/2013 | 0.05 | 0.05 |
| 27/07/2015 | 0.05 | 0.05 |
| 03/08/2015 | 0.05 | 0.05 |
| centroid | 0.05 | 0.05 |

Environmental conditions of the spatially-extended TLP



Part 1. Wrap-up

- TLP were **more common in the Ría de Pontevedra**, also characterized by longer **toxicity** episodes due to *Dinophysis* toxins
- Our results suggest a relationship between TLP and two HAB groups *D. acuminata* and *Pseudo-nitzschia*
- TLP formation appears to be related to **stratification** processes

Part 1. Wrap-up

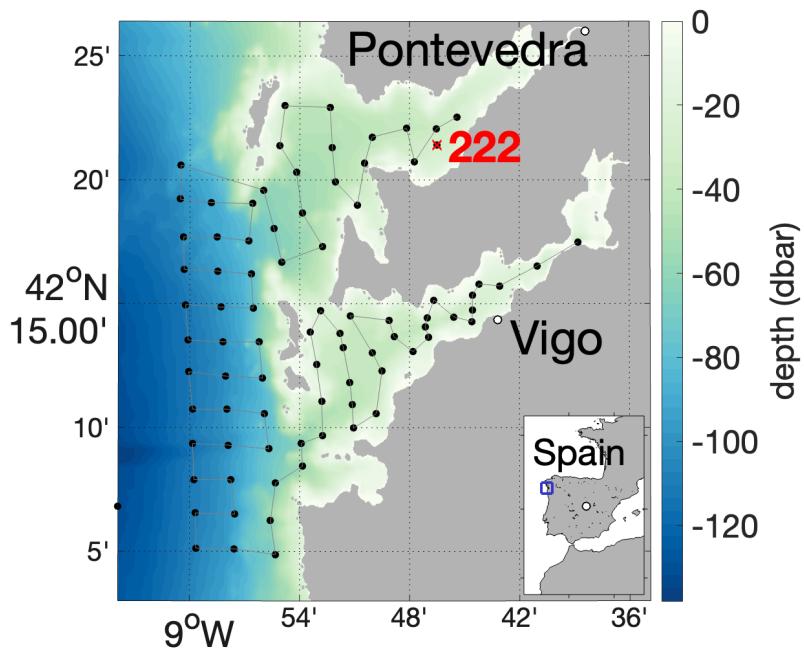
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We need specific observations!



Part 2. Field observations

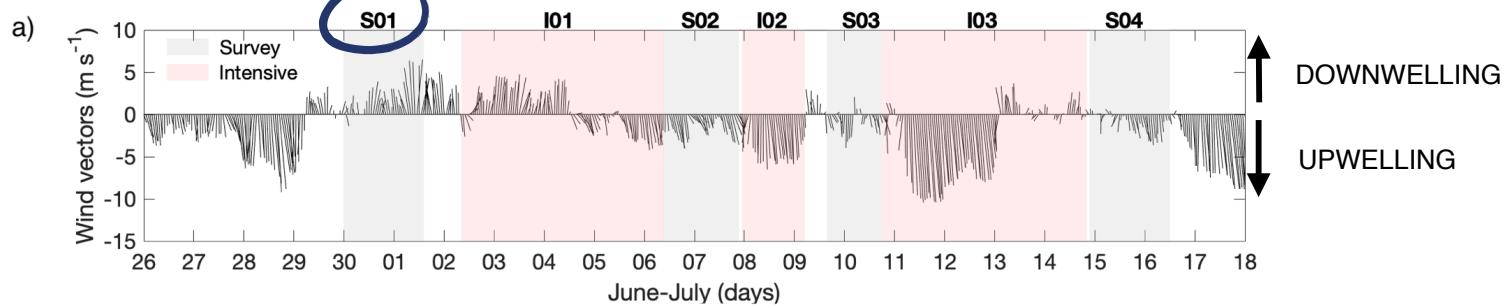
REMEDIOS-TLP cruise



- Summer 2018
- 4 SURVEY (84 stations)
 - 1 CTD cast per station (225 profiles)
- 3 INTENSIVES at st. 222
 - 5 high resolution CTD cast every 30 min (1674 profiles)
 - 1 water sampling at different depths every 6 h



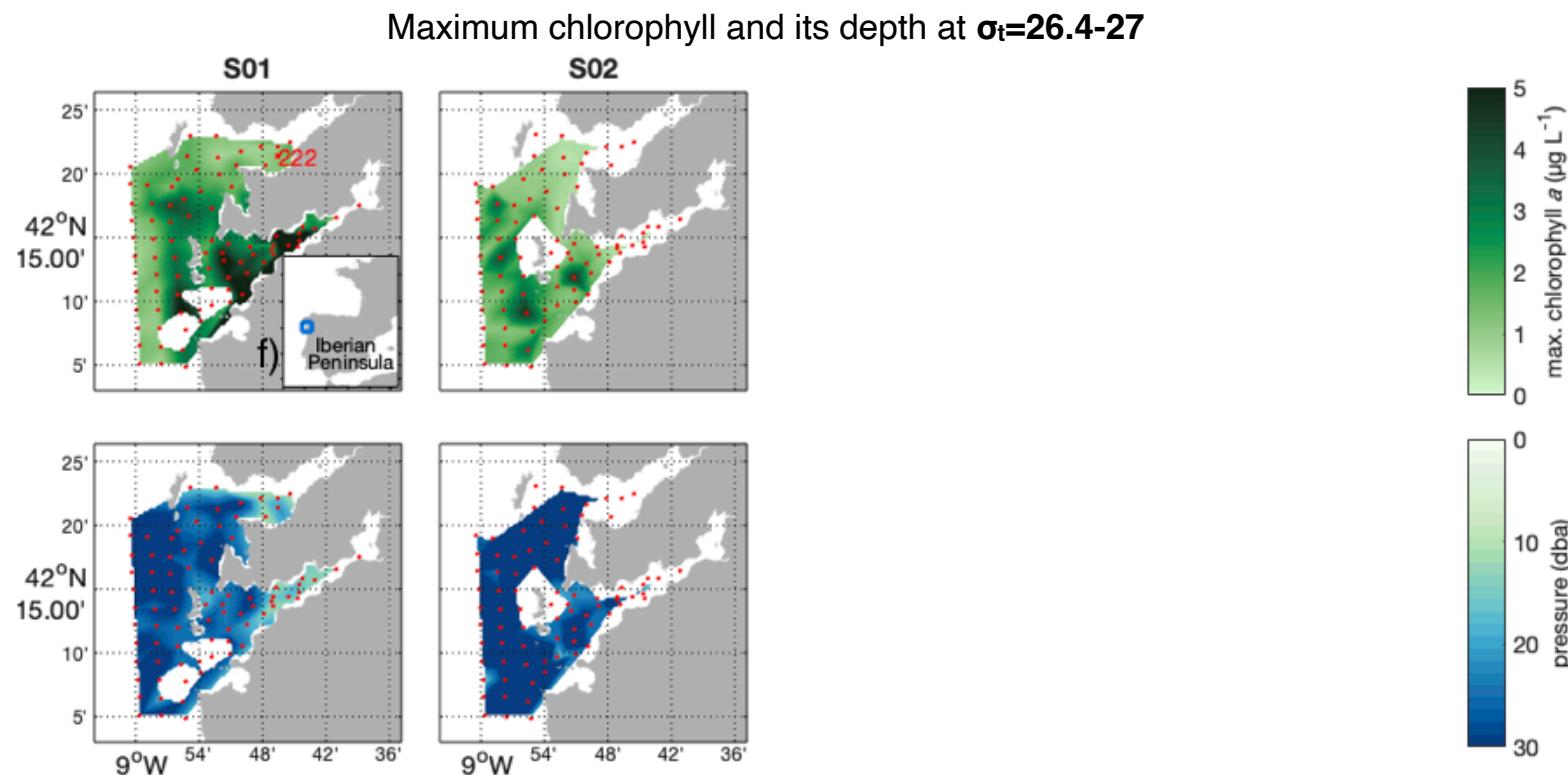
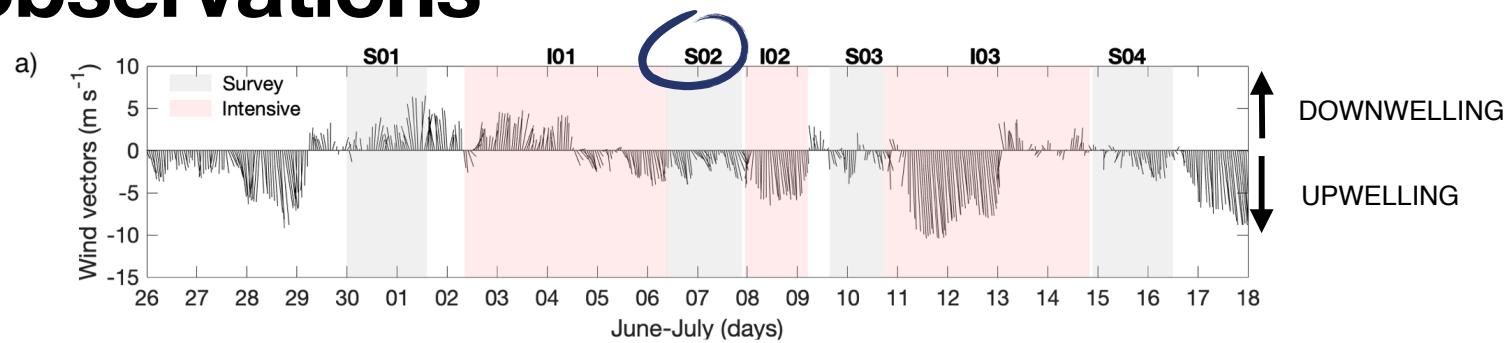
Spatial observations



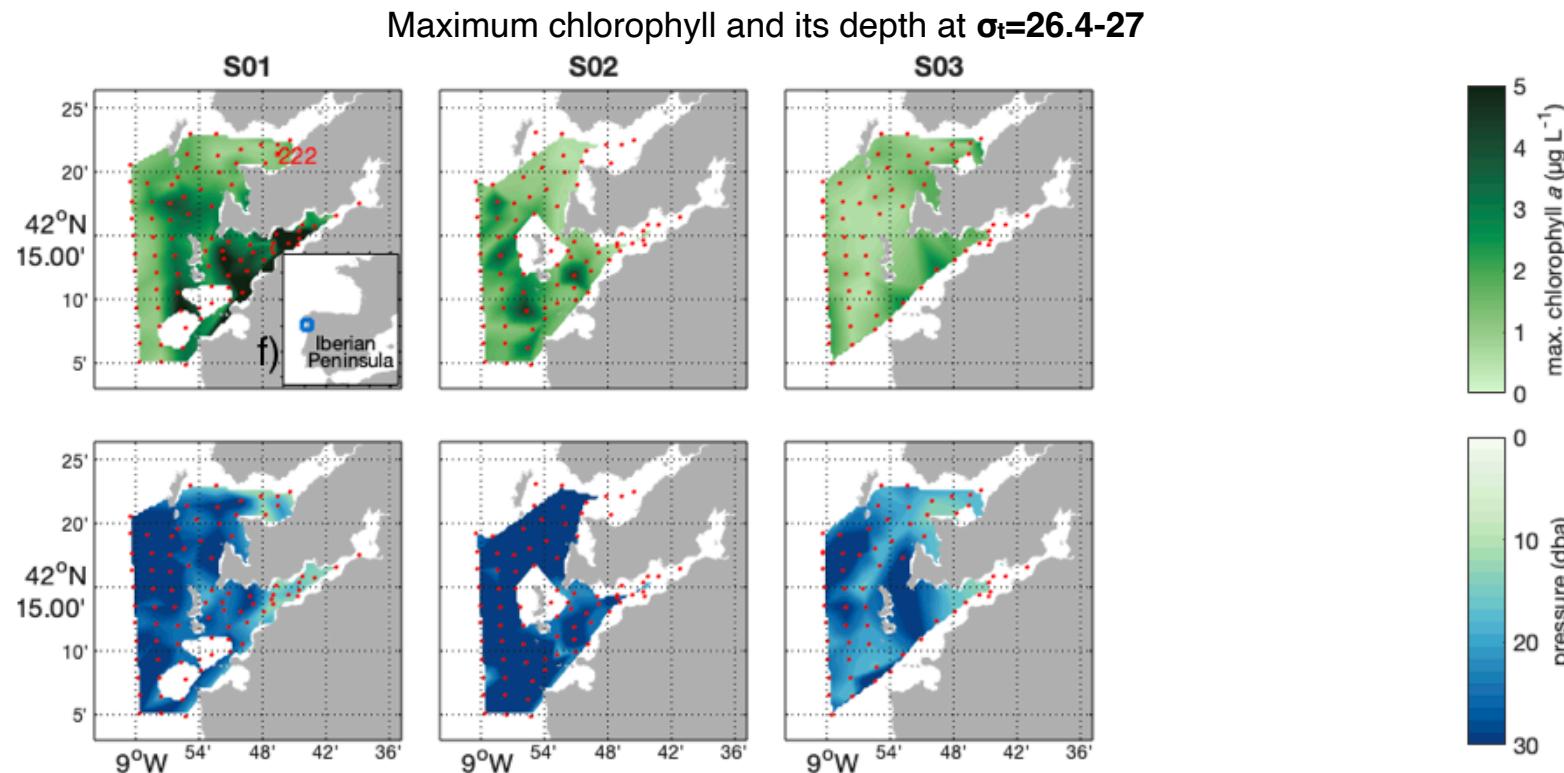
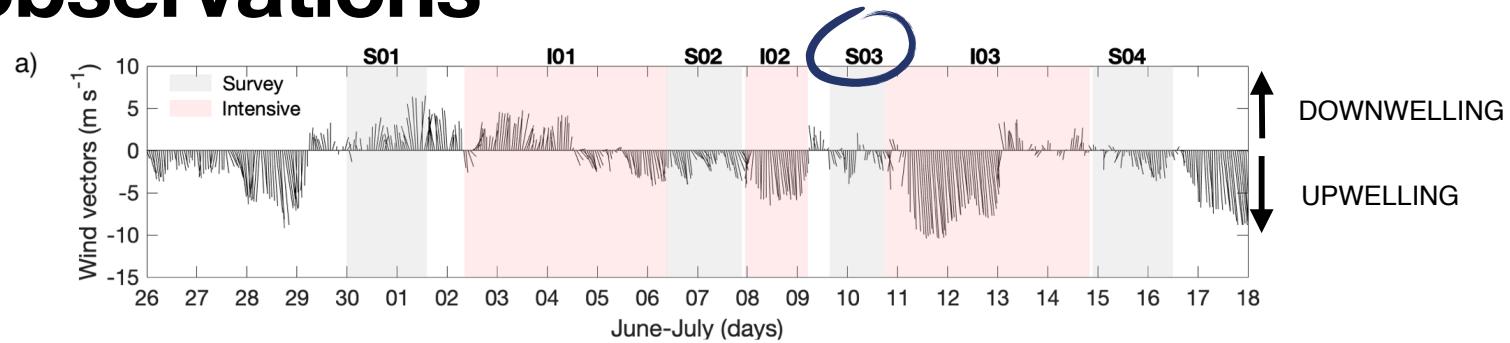
Maximum chlorophyll and its depth at $\sigma_t=26.4-27$



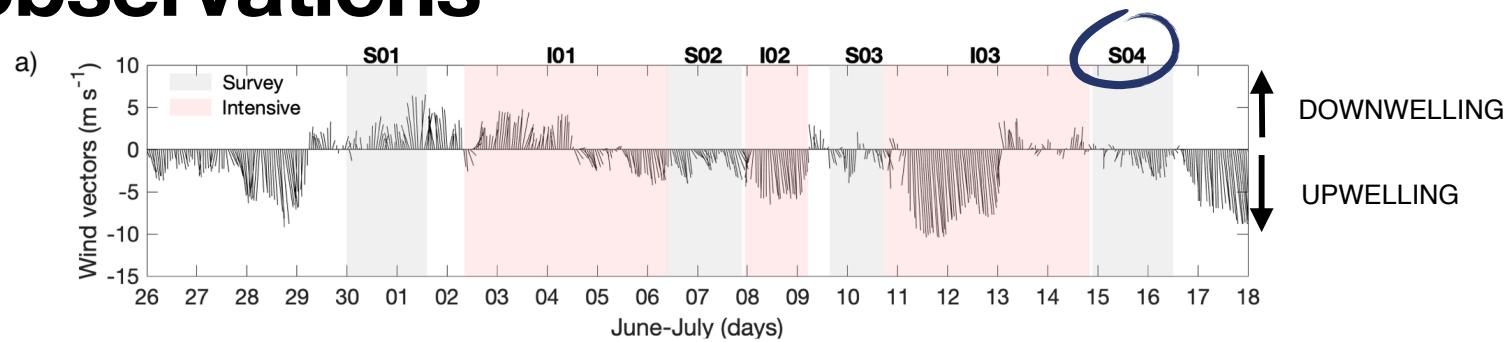
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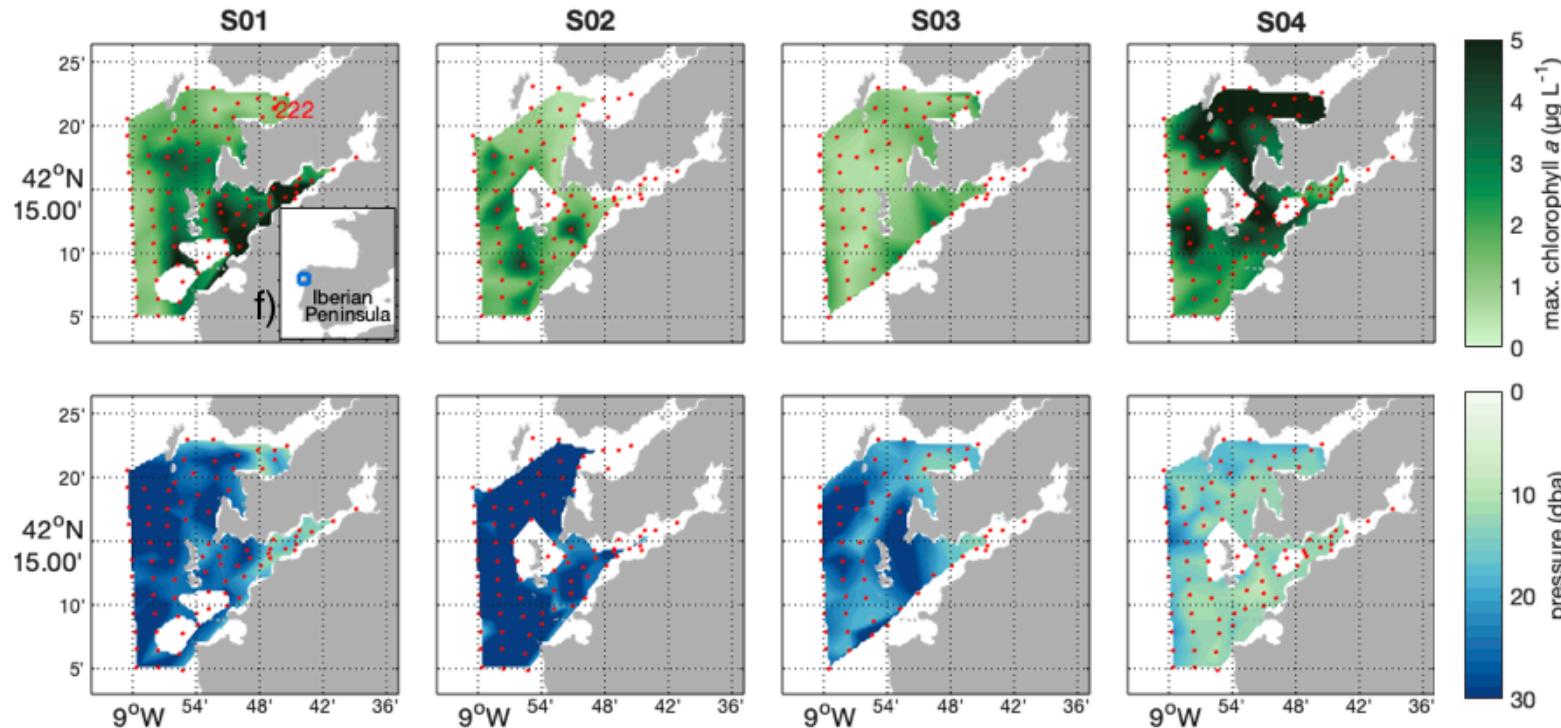
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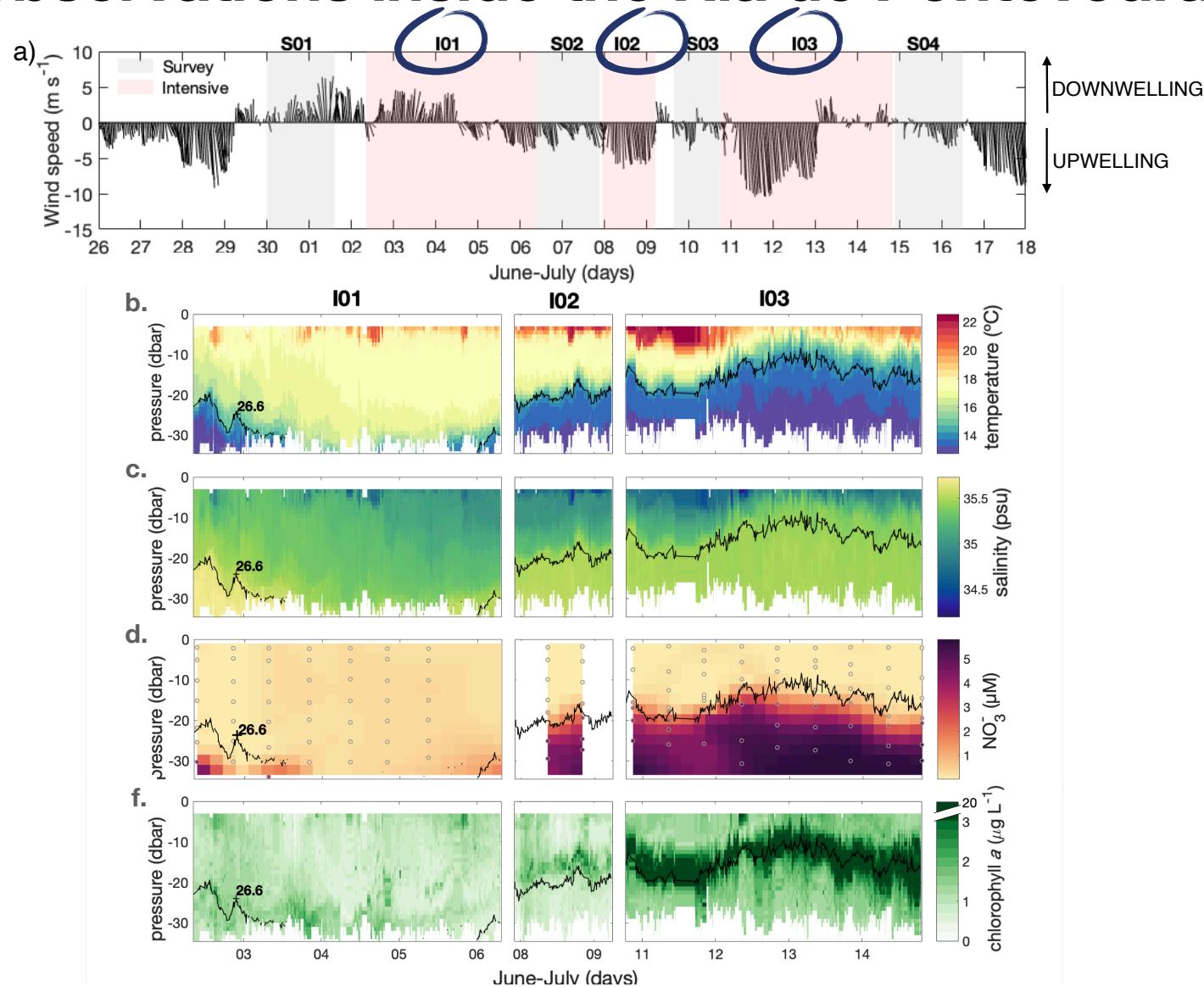
Spatial observations



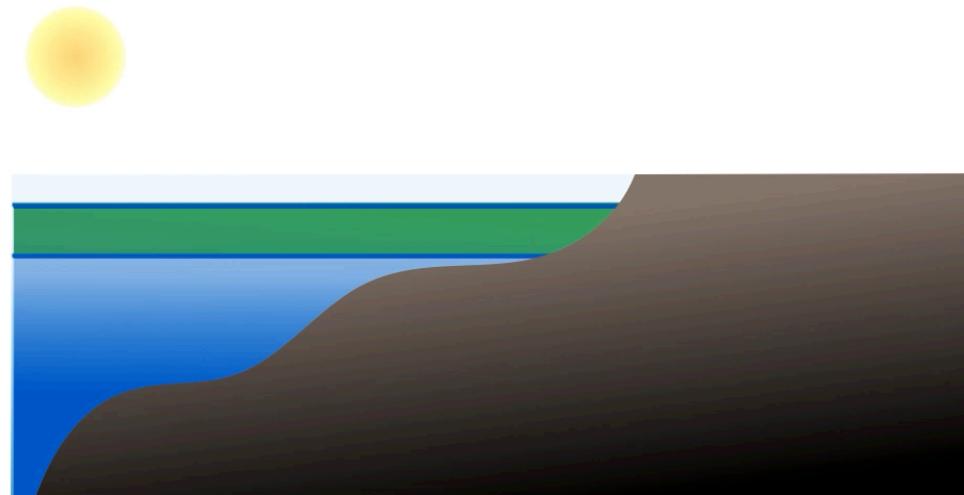
Maximum chlorophyll and its depth at $\sigma_t=26.4-27$



Intensive observations inside the Ría de Pontevedra



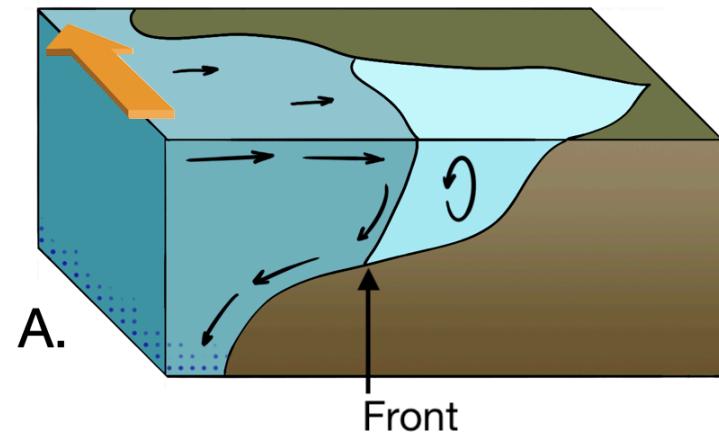
Bloom dynamics



- Phytoplankton bloom was associated with a narrow isopycnal interval
- Nutrient-rich isopycnals could seed and hide toxin-producing species offshore

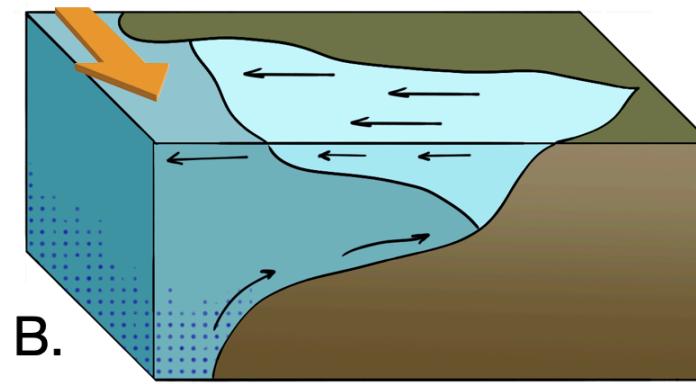
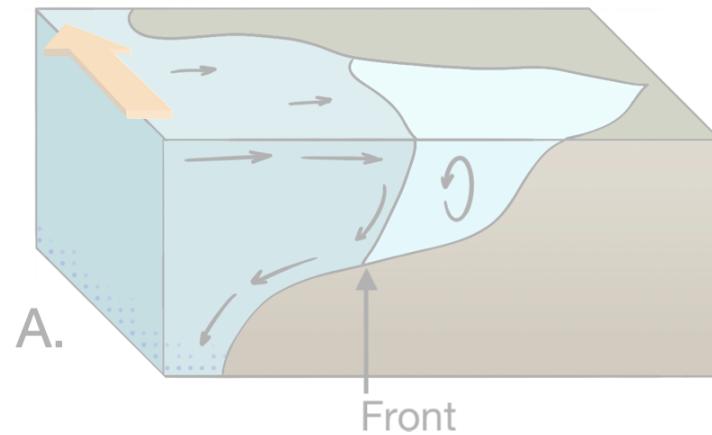
Seegers et al., (2015)

Mechanisms of TLP formation



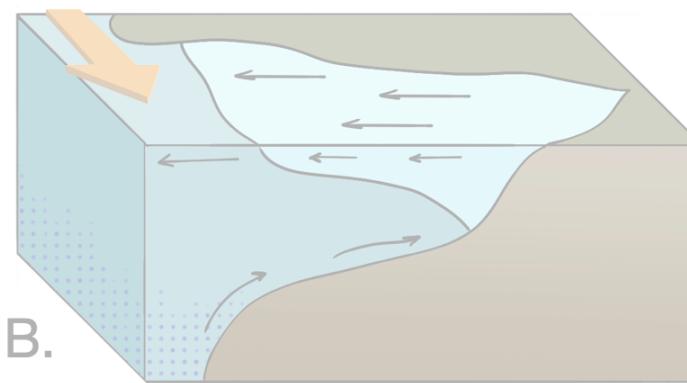
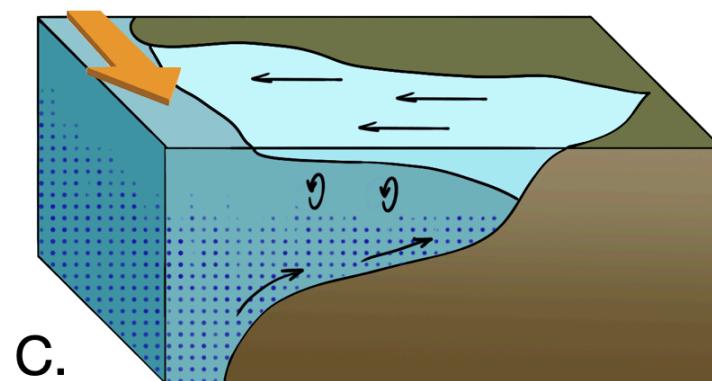
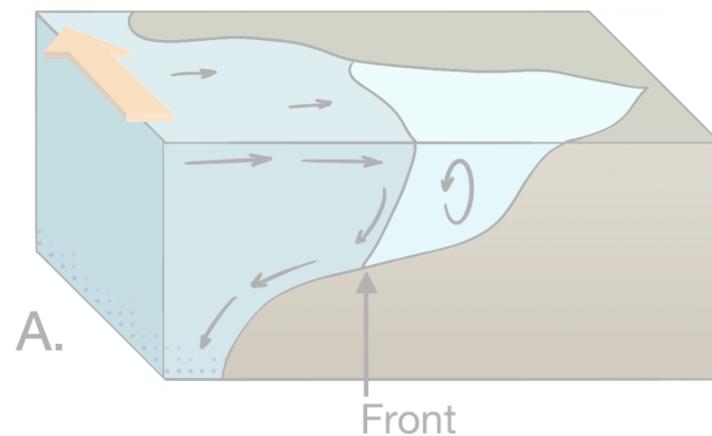
- Circulation
- ⟳ Mixed water
- Lighter water
- Oceanic water
- Nutrients
- Phytoplankton

Mechanisms of TLP formation



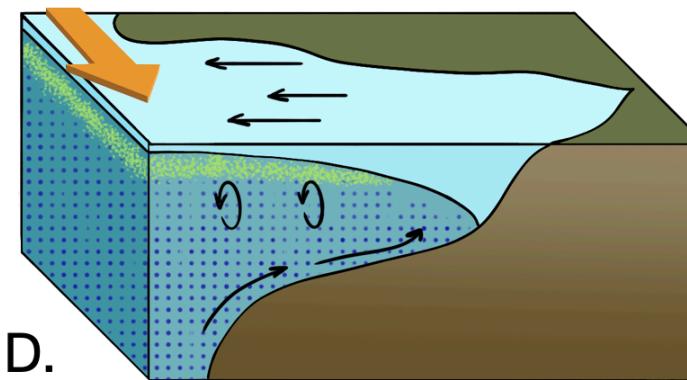
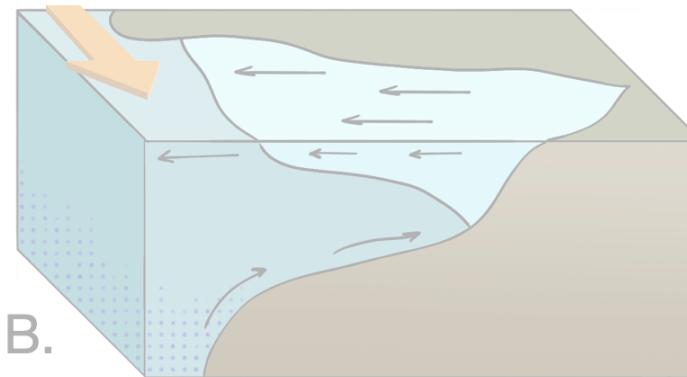
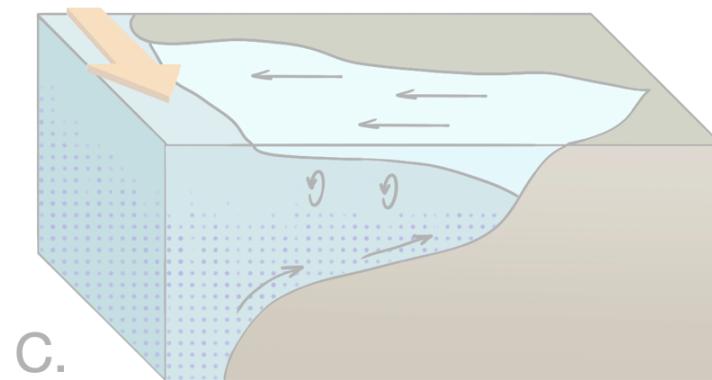
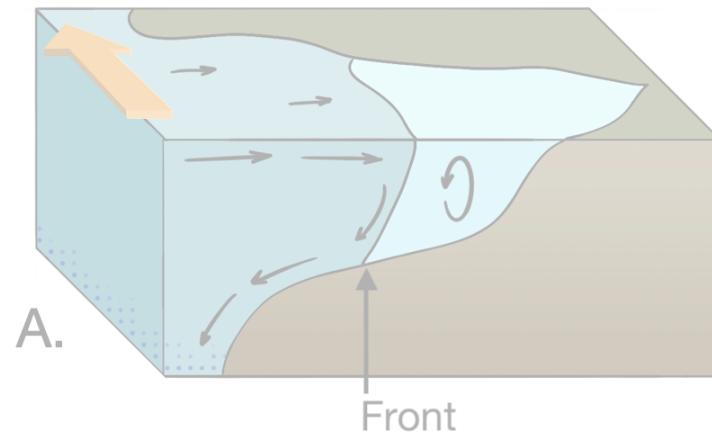
- Circulation
- ⟳ Mixed water
- Lighter water
- Oceanic water
- Nutrients
- Phytoplankton

Mechanisms of TLP formation



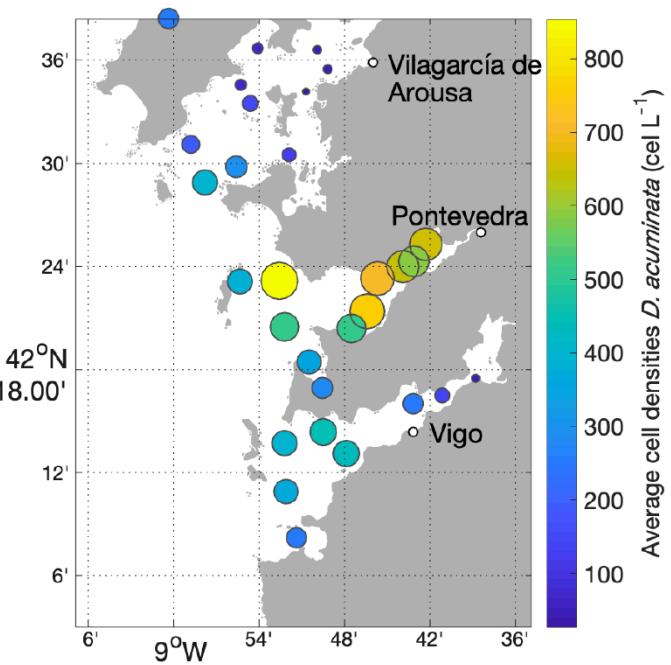
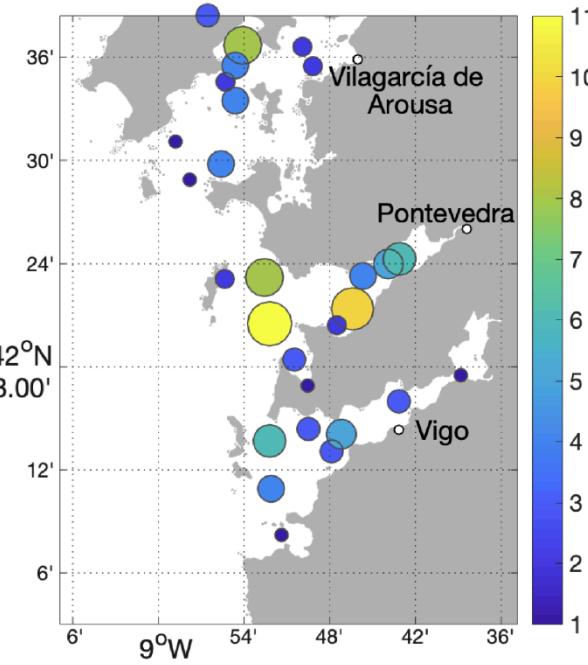
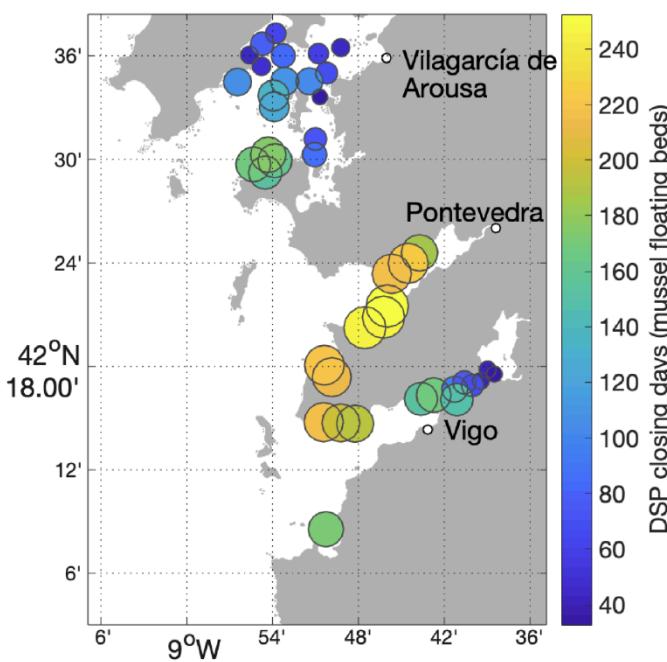
- Circulation
- ⟳ Mixed water
- Lighter water
- Oceanic water
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- Phytoplankton

Mechanisms of TLP formation

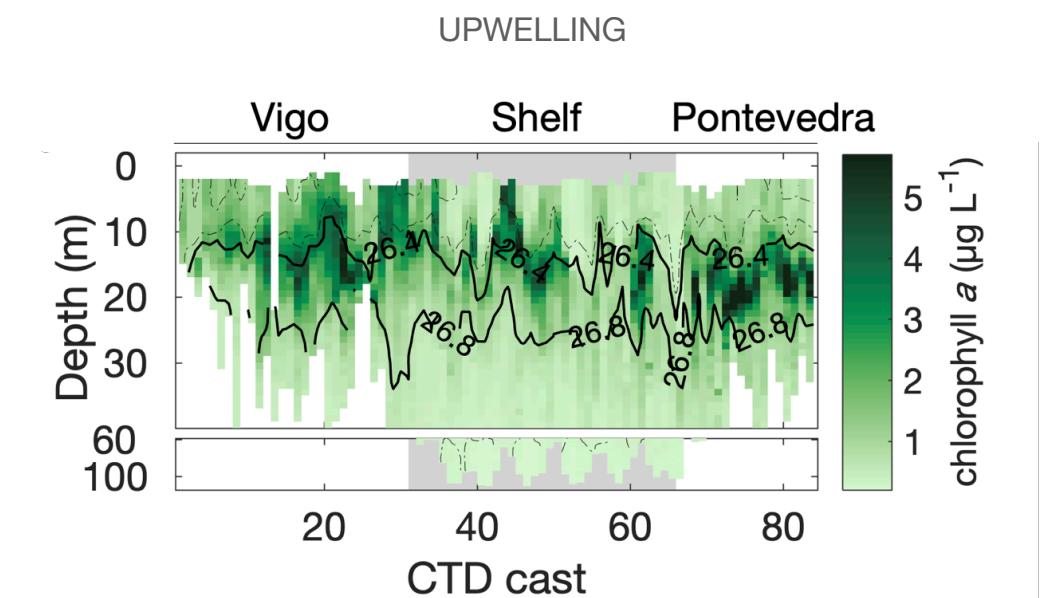
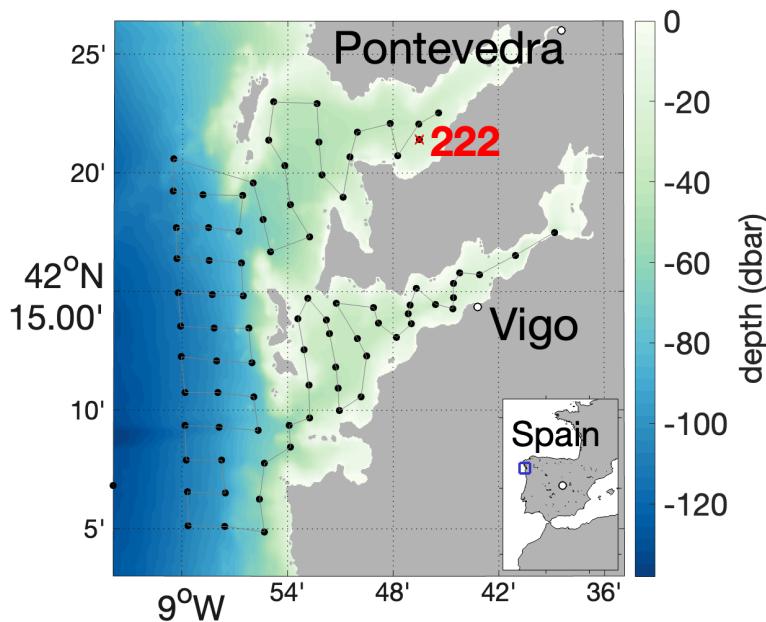


- Circulation
- ⟳ Mixed water
- Lighter water
- Oceanic water
- Nutrients
- Phytoplankton

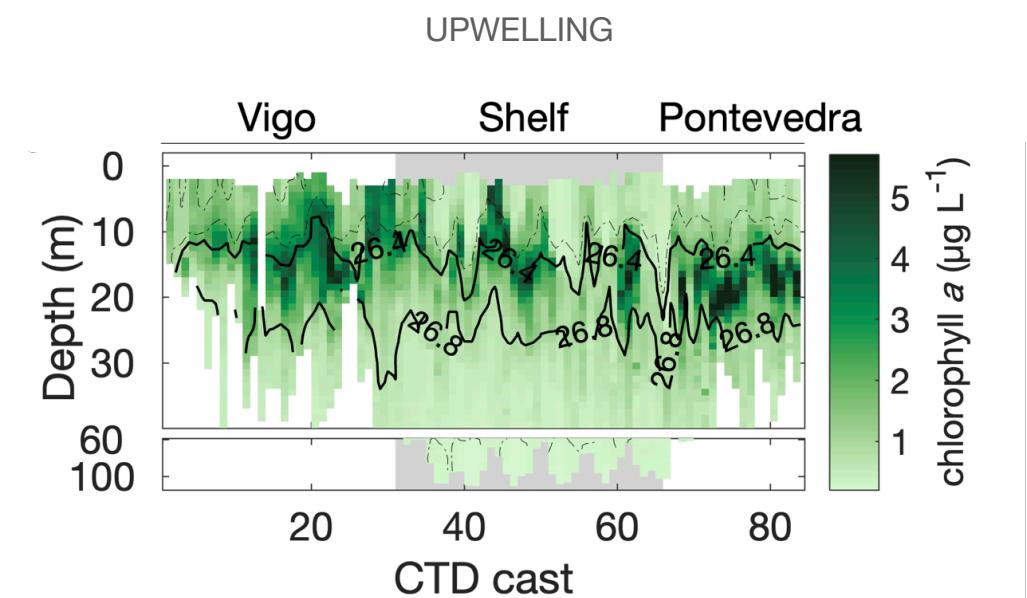
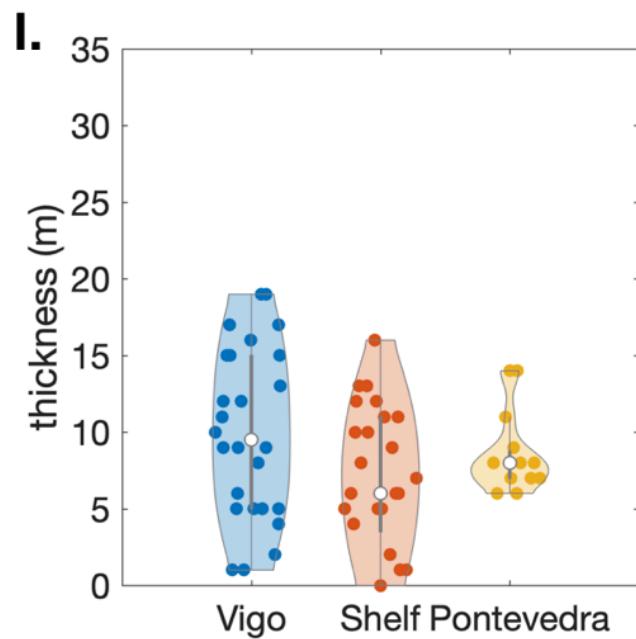
Ría de Pontevedra: a hotspot for toxicity and TLP



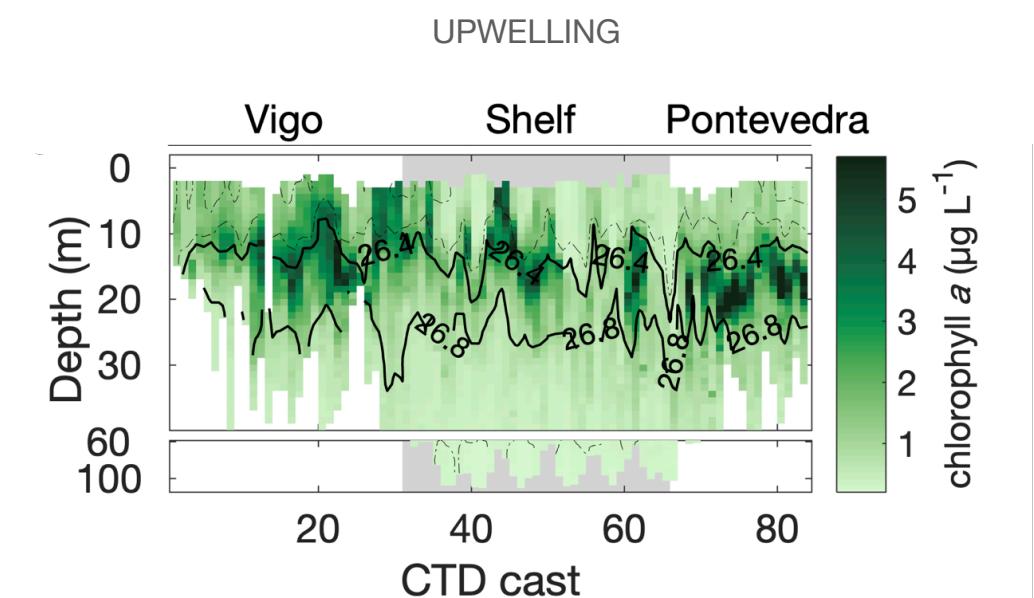
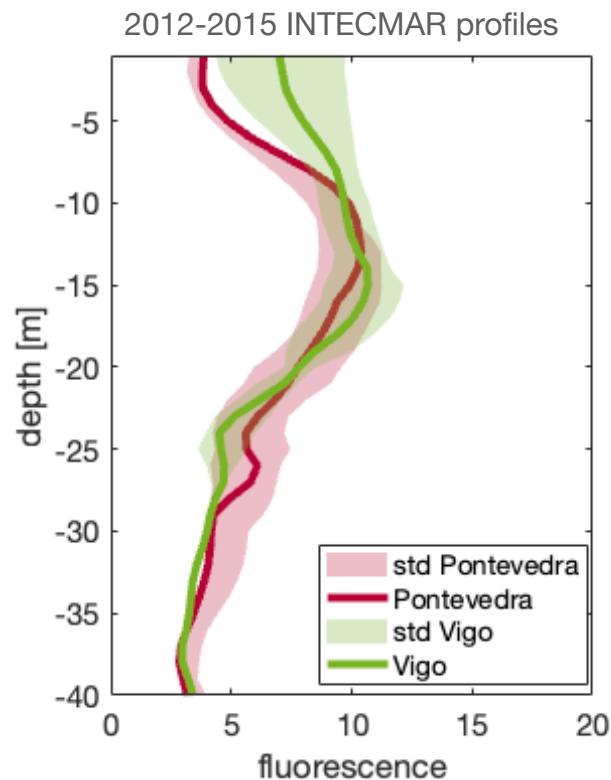
Subsurface chlorophyll maximum observations



Subsurface chlorophyll maximum observations



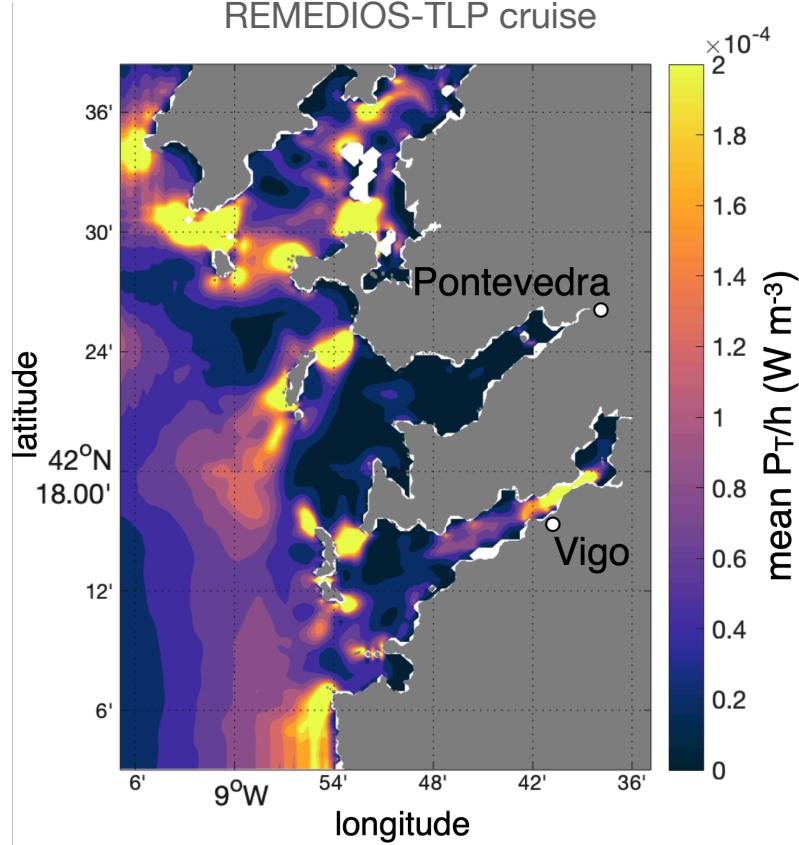
Subsurface chlorophyll maximum observations



From on-going master thesis by Blanca Marigomez

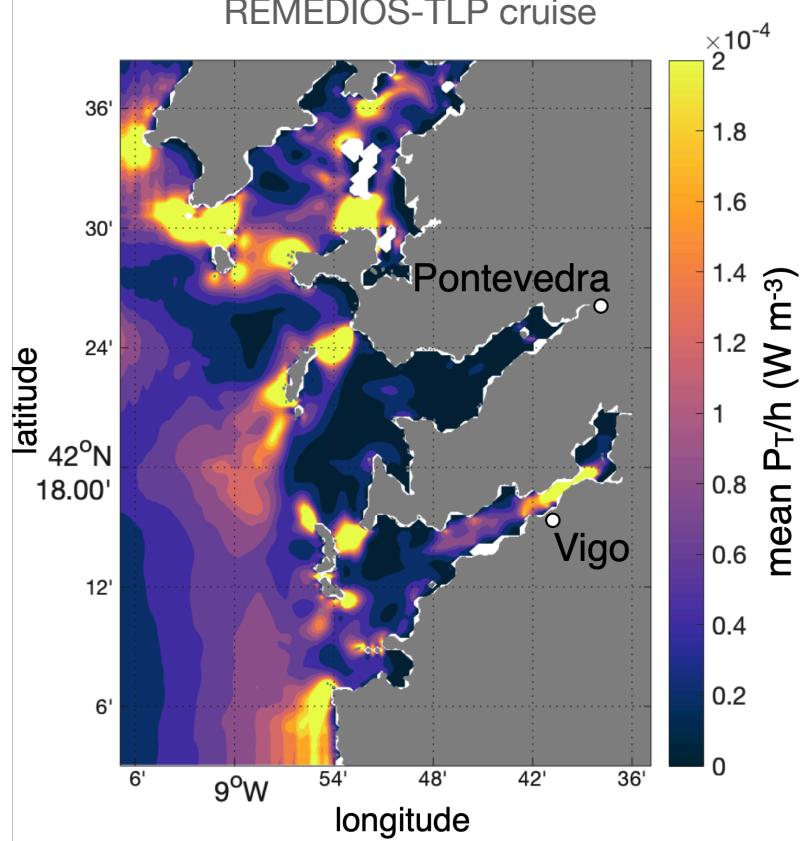
The Ría de Pontevedra: a hotspot for toxicity

Turbulent energy production due to bottom friction during 1.5 months spanning the REMEDIOS-TLP cruise

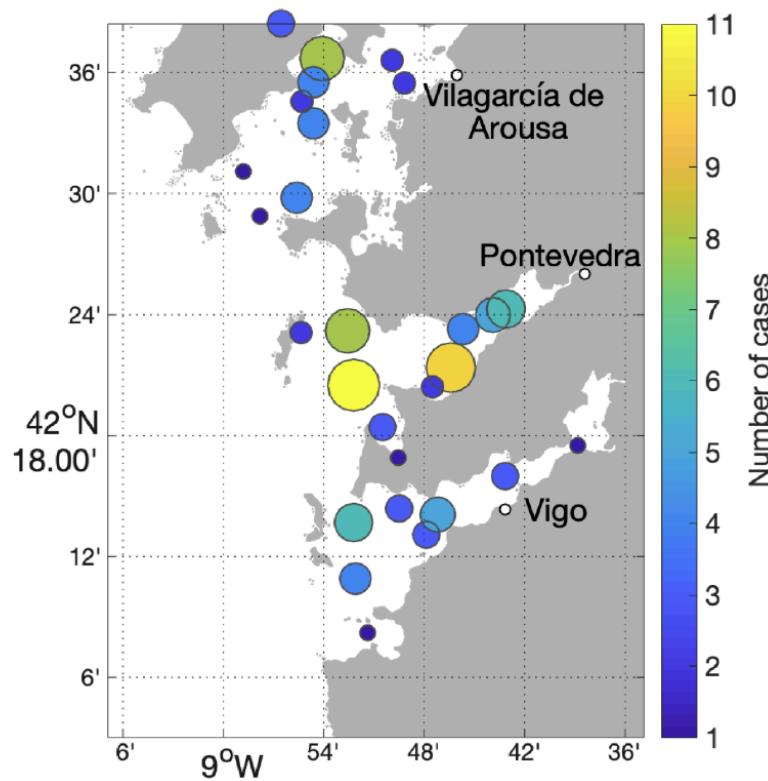


The Ría de Pontevedra: a hotspot for toxicity

Turbulent energy production due to bottom friction during 1.5 months spanning the REMEDIOS-TLP cruise

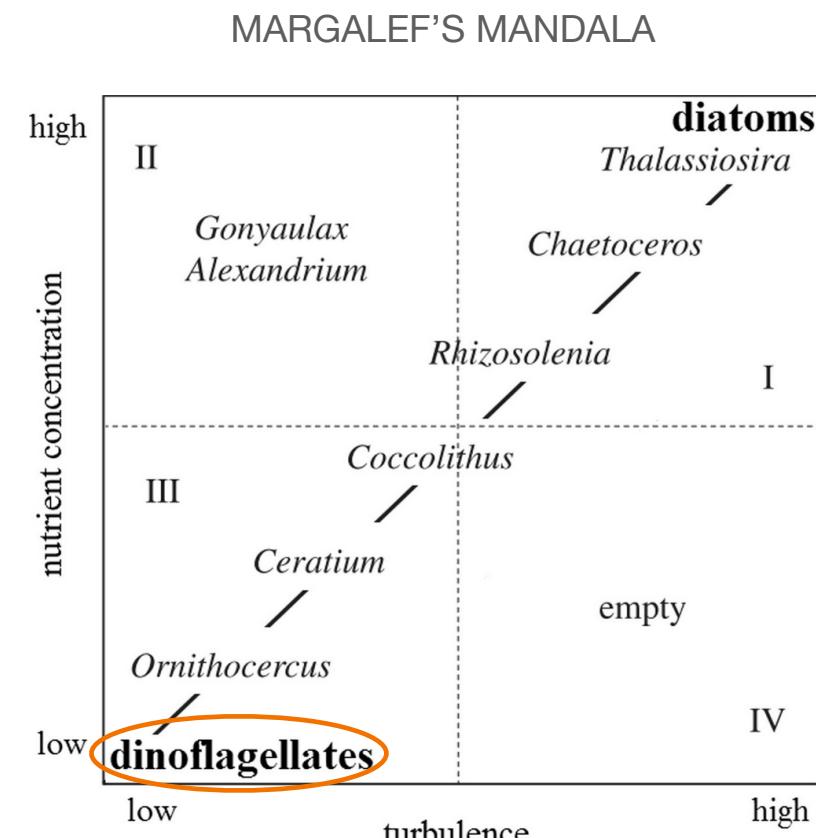
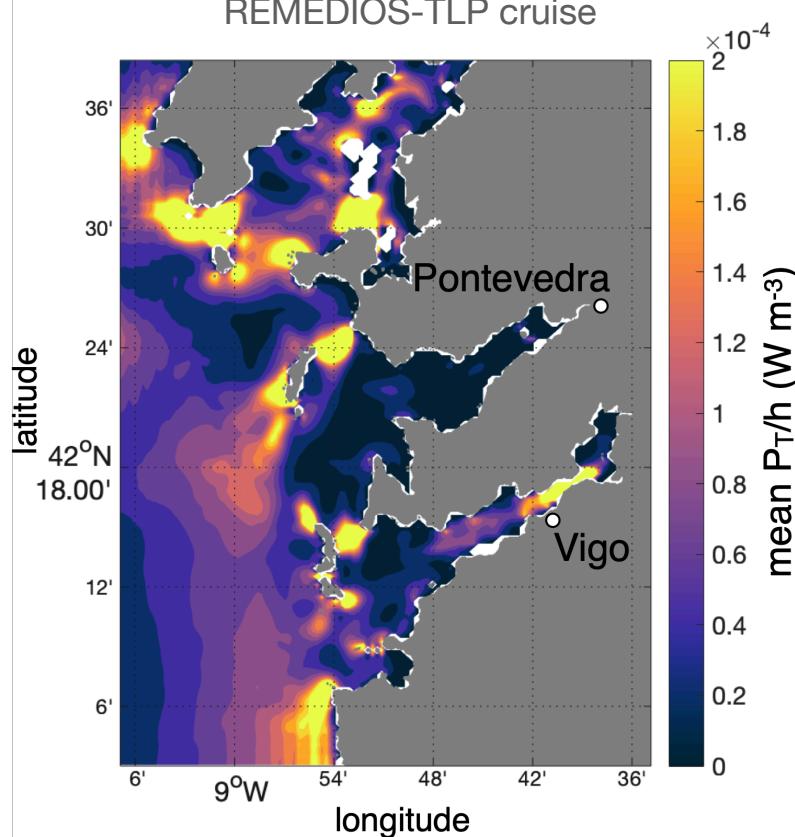


TLP number of cases



The Ría de Pontevedra: a hotspot for toxicity

Turbulent energy production due to bottom friction during 1.5 months spanning the REMEDIOS-TLP cruise

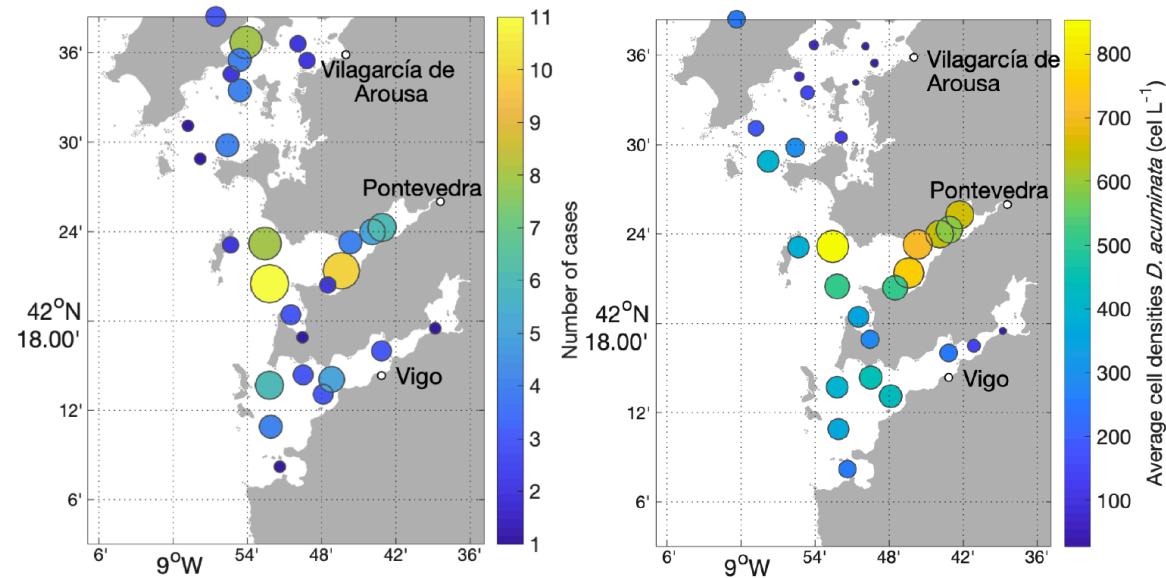


Margalef (1978)

Answers

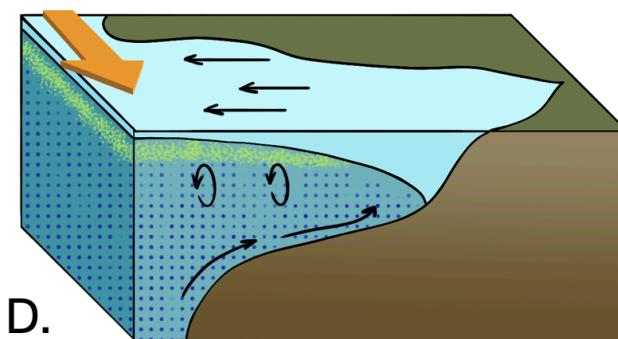
Question 1: is there a relationship between TLP and HAB in the Galician Rías?

25% of the TLP were related to elevated densities of HAB phytoplankton groups:
D. acuminata and *Pseudo-nitzschia*



Question 2: what are the mechanisms responsible for TLP formation?

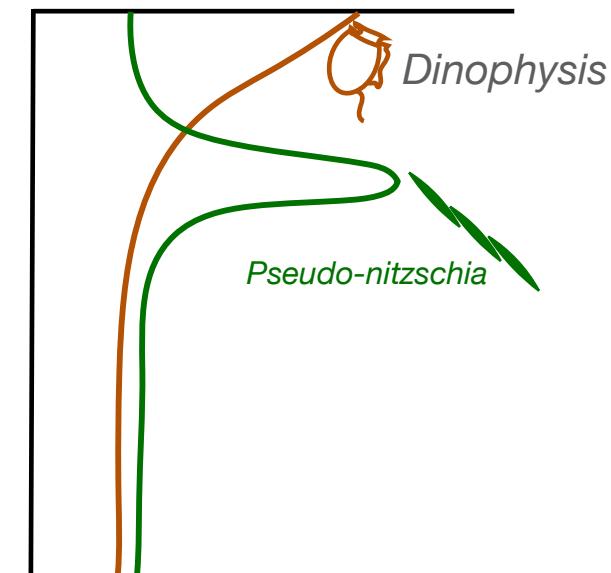
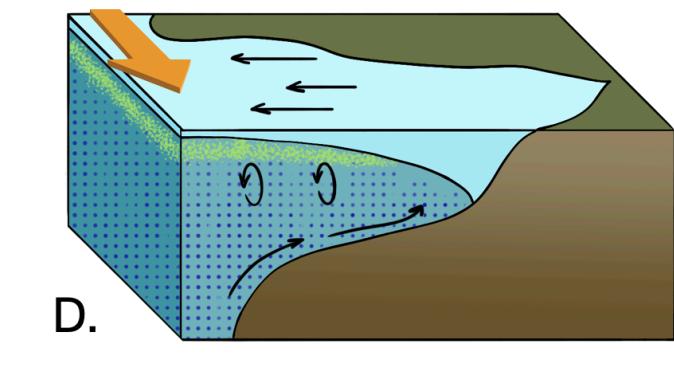
Straining and *in situ* growth under stratification conditions could explain the TLP formation in the Ría de Pontevedra



Question 2: what are the mechanisms responsible for TLP formation?

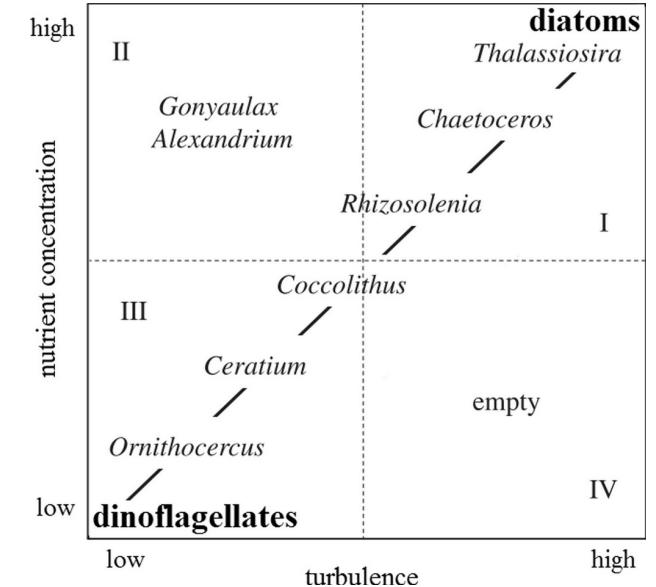
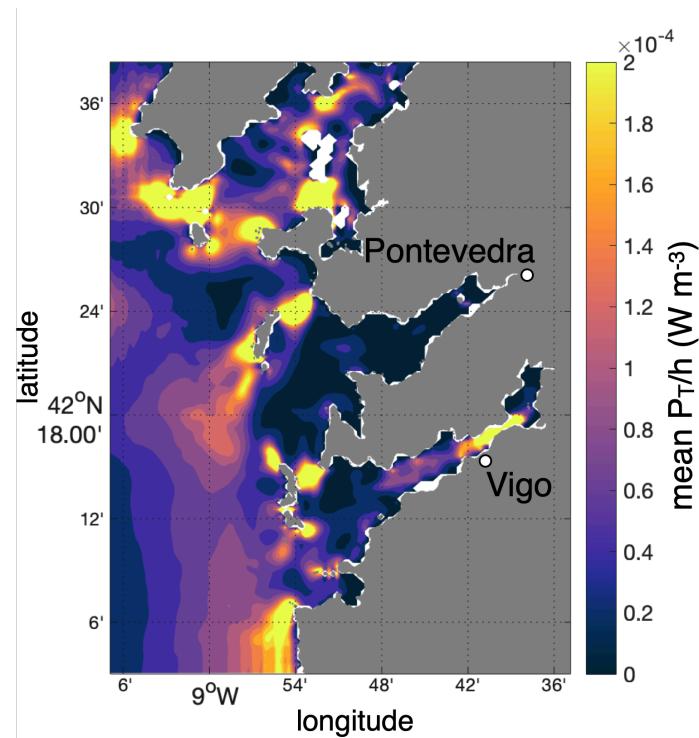
Straining and *in situ* growth under stratification conditions could explain the TLP formation in the Ría de Pontevedra

This mechanism could explain the co-occurrence of HABs dominated by *Dinophysis* in the surface, and thin layers of *Pseudo-nitzschia* within the chlorophyll maximum



Question 3: why is the Ría de Pontevedra a hotspot for toxicity?

The persistance of **stratified** conditions in time could be explained by **the lower rate of turbulent energy production** that characterizes this Ría



Margalef (1978)

