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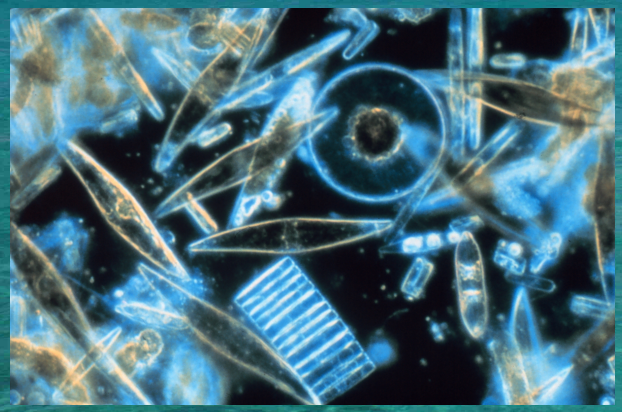
Diagnostic phytoplankton pigments as indicators for measuring restoration success in coastal waters

Anne Goffart



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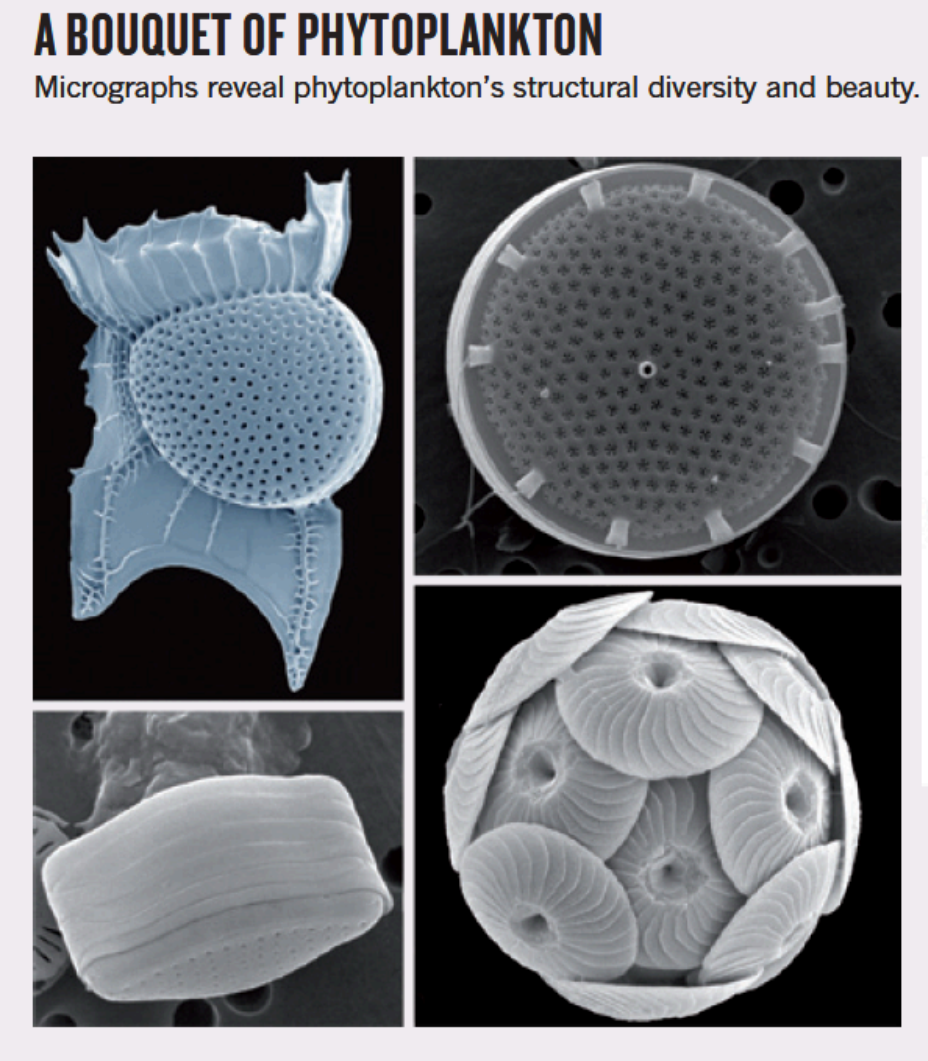
Marine phytoplankton : a bioindicator of ecosystem change

Phytoplankton are :

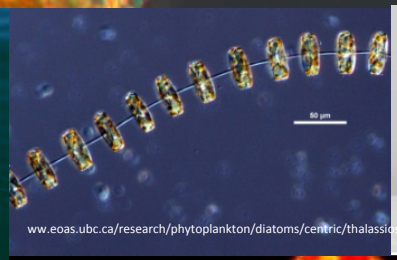
- **tiny one-celled organisms;**
- **dominant marine primary producers : phytoplankton primary production produces approximately 50% of atmospheric O_2;**
- **at the foundation of the ocean food webs.**

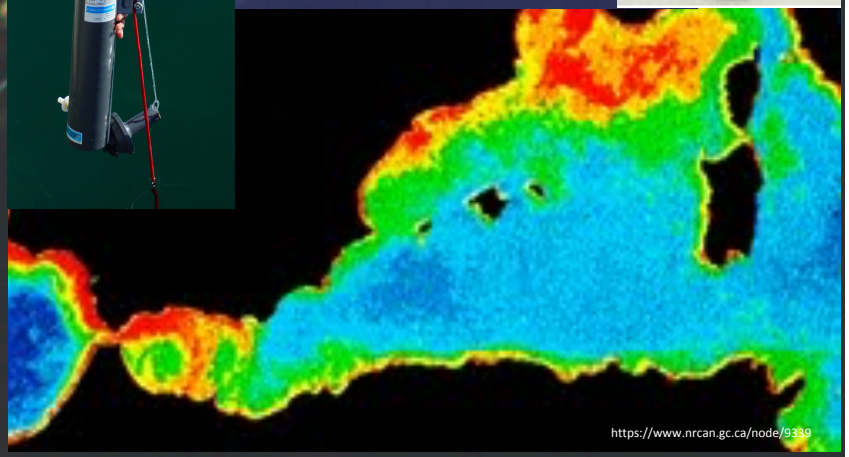


Falkowsky 2012

Marine phytoplankton : a bioindicator of ecosystem change

- As key primary producers, phytoplankton are changing rapidly in response to fluctuations in the input of nutrients in coastal oceans.





- Phytoplankton are excellent indicators of marine ecosystem change.

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Marine phytoplankton : a bioindicator of ecosystem change

- **Phytoplankton are promoted by various organizations (*e.g.* European Commission) as a tool to perform biomonitoring and evaluate the effects of anthropogenic pressure on the ecosystem.**

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Marine phytoplankton : a bioindicator of ecosystem change

- **Phytoplankton are promoted by various organizations (*e.g.* European Commission) as a tool to perform biomonitoring and evaluate the effects of anthropogenic pressure on the ecosystem.**

However, most of indicators based on phytoplankton composition are NOT operational (wide range of scientific instruments, high level of expertise, high effort in time and cost, …).

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Context and objectives

1. To present a new phytoplankton composition index (PPCI) which is useful for assessing ecosystem status and water quality;

2. To present case studies : impact of aquaculture on phytoplankton & phytoplankton recovery after an aquaculture closure in the Mediterranean Sea.

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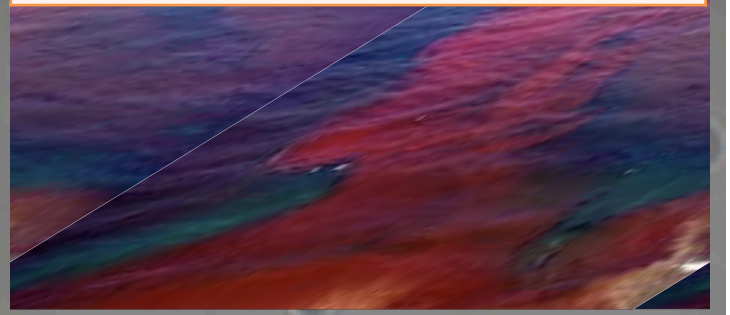
1. PPCI : a new phytoplankton composition index

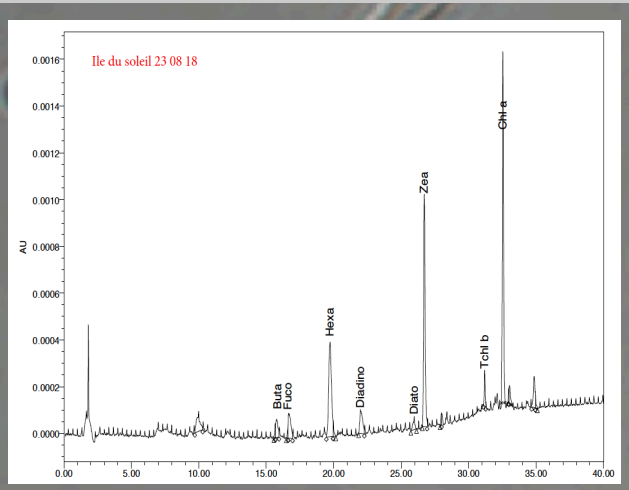
- PPCI is based on phytopigments (carotenoids) that are diagnostic of phytoplankton functional groups (1 pigment ➔ 1 group);

- Phytopigments, which have different colours (*i.e.* distinct absorbance characteristics) are separated and quantified by HPLC.

- Analyses are performed on total phytoplankton, which means that all size classes are considered.

Pigment	Colour	Algal group
Peridinin	Brick red	Dinoflagellates





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1.1. Methodology : studied area & selection of the metrics

- **PPCI was developed initially in the French coastal waters of the Mediterranean Sea where a robust dataset of nutrients and phytopigments was collected in reference sites and impacted water masses (Goffart 2019, 15 stations, 744 pairs of samples)**

A prerequisite for ecologically meaningful indicators are well established pressure - impact relationships (Garmendia 2013).

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1.1. Methodology : studied area & selection of the metrics

- **For one specific area (*e.g.* WFD-ecotype 3W), only pigments responding positively to pressures (*i.e.* nutrient concentrations) are integrated into the composition index;**

- **One pigment per group.**

Significant Spearman's correlation coefficients between phytoplankton variables and nutrients

3W data set, monthly sampling frequency, sampling between 2009 and 2017

	NO_3^- n = 261	NO_2^- n = 265	$NO_3^- + NO_2^-$ n = 270	NH_4^+ n = 270	DIN n = 266
Tchl *a*	0.48	0.58	0.51	0.25	0.52
Chl *a*	0.47	0.58	0.50	0.26	0.52
Divinyl chl *a*	0.16	0.23	0.20	-0.19	-
Peri	0.38	**0.47**	0.39	0.35	0.46
Buta	0.27	0.31	0.29	-0.13	0.19
Fuco	0.44	0.52	0.49	0.29	**0.53**
Neo	0.37	0.52	0.41	-	0.39
Prasino	0.46	**0.61**	0.51	0.18	0.49
Viola	0.27	0.40	0.31	0.21	0.36
19'HF	0.22	0.24	0.23	-0.18	0.12
Allo	0.48	**0.57**	0.52	0.23	0.51
Zea	-	-	-	-0.17	-
Tchl b	0.55	0.64	0.58	0.26	0.59
	P<0.0001	*P*<0.001	*P*<0.05	- NS	

ICPP Medit =

$$(IC_{Peridinin} + IC_{Fucoxanthin} + IC_{Alloxanthin} + IC_{Prasinoxanthin}) / 4$$

Dinoflagellates **Diatoms** **Cryptophytes** **Prasinophytes**

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1.2. Methodology : reference conditions and curves

Reference (*i.e.* undisturbed) conditions are well known in the Western Mediterranean Sea (*e.g.* Goffart et al. 2015).

1. Reference curves which describe the seasonal succession of the pigments embedded in the index are established.

2. Reference curves differ between different geographical regions.

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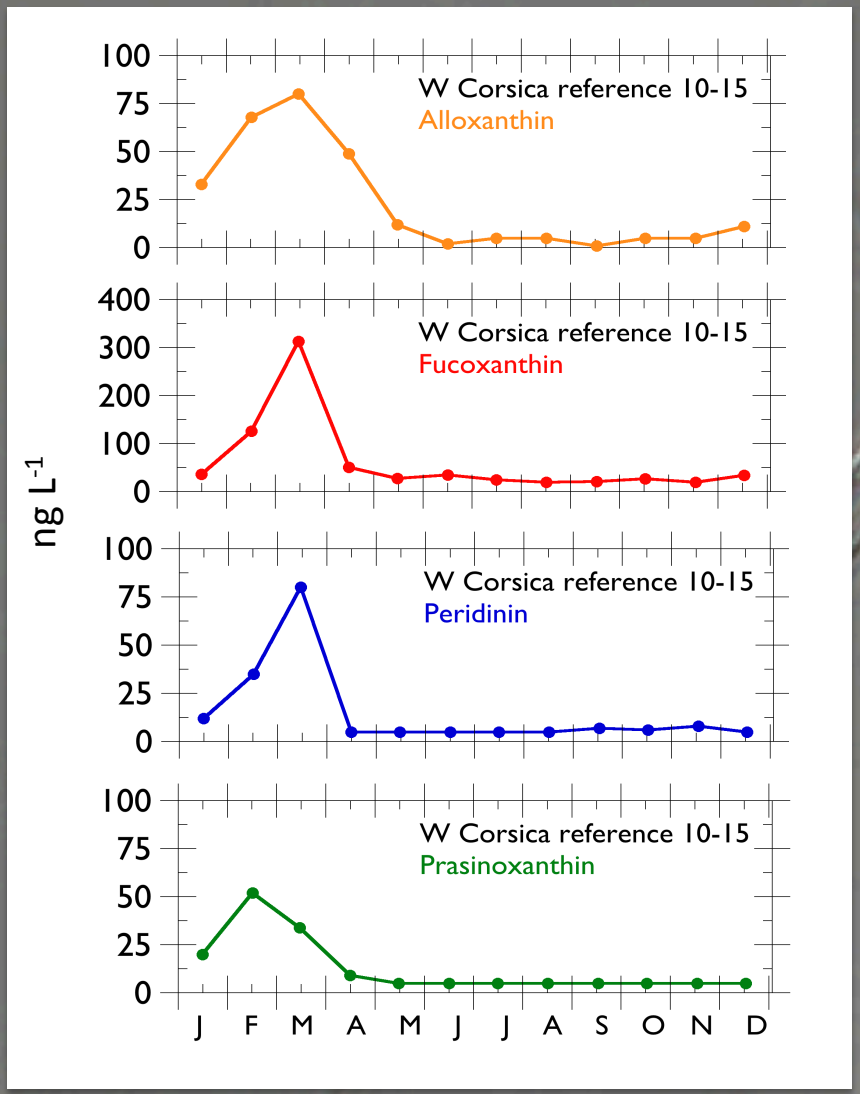
1.2. Methodology : reference conditions and curves



3. **Reference curves are calculated using ideally 6 years of data (bi-monthly sampling frequency and moving reference : *e.g.* 2011-2016, 2012-2017, …),**

   Monthly 90th percentile pigment concentrations + 50% to account for natural variability.

Reference curves deliver a baseline for the studied area.

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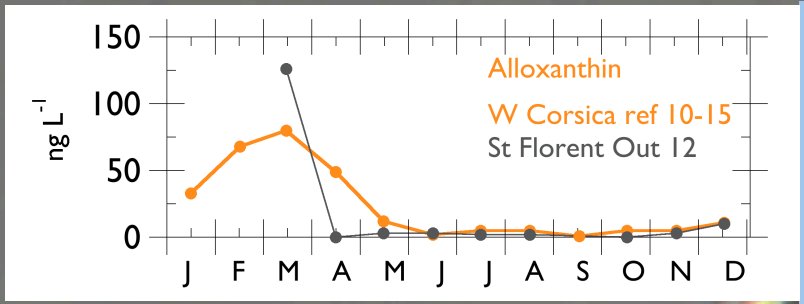
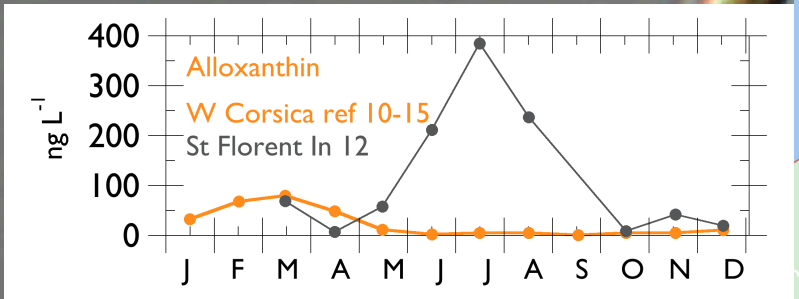
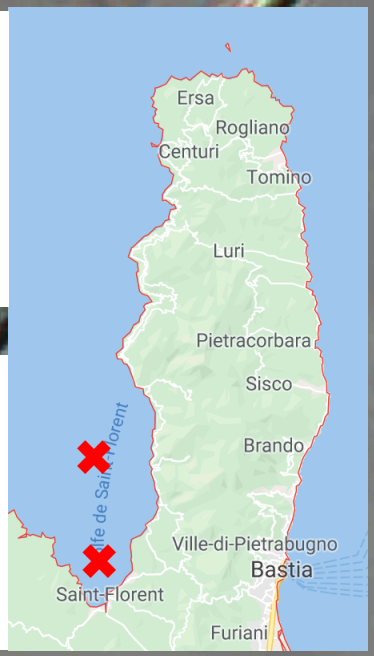
1.3. Methodology : calculation of the PPCI index

- **Data acquired in the investigated areas are plotted against the reference curves, respecting the temporality.**







4. **A score is computed for each pigment. It takes into account the frequency of measurements situated above the reference (A) and the relative importance of the overtakings (B).**

Score Pigment n =

(A x B) / 1000

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1.3. Methodology : calculation of the PPCI index

5. **Each score is converted in EQR.**

EQR Pigment n = 1 - (0.050 x score Pigment n); If score > 20, EQR = 0.

6. **The final EQR is the arithmetic mean of the EQRs obtained for each pigment. EQR values range between 0 and 1, 0 being the most degraded and 1 being the least degraded.**

EQR ICPP Medit =

$$(EQR_{Peri} + EQR_{Fuco} + EQR_{Allo} + EQR_{Prasino}) / 4$$

Dinoflagellates Diatoms Cryptophytes Prasinophytes

	High		Good	Moderate	Poor	Bad
ICPP Médit	1	0.90	0.70	0.50	0.20	0

Class boundaries used for the assessment of phytoplankton composition in the Western Mediterranean. Classification has been developed based on expert knowledge and use of historical phytoplankton data.

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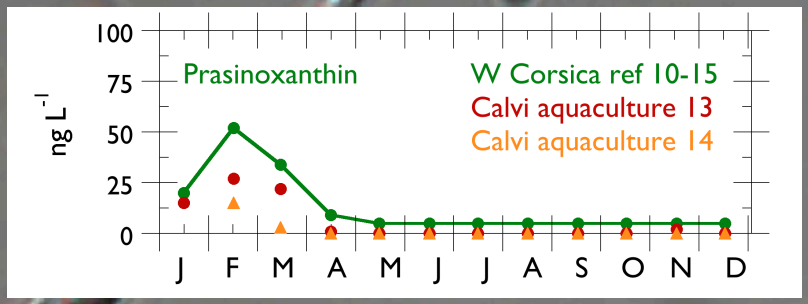
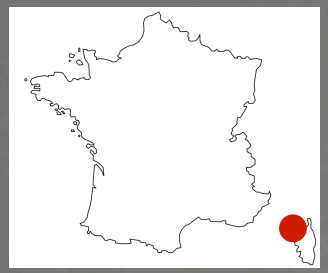
2. Application of the PPCI to Mediterranean coastal sites

- **Study cases : small fish aquaculture (production : 40 T y^{-1}, Calvi Bay, Corsica, W Med)**





	High		Good	Moderate	Poor	Bad
ICPP Médit	1	0.90	0.70	0.50	0.20	0

No detectable impact on phytoplankton composition

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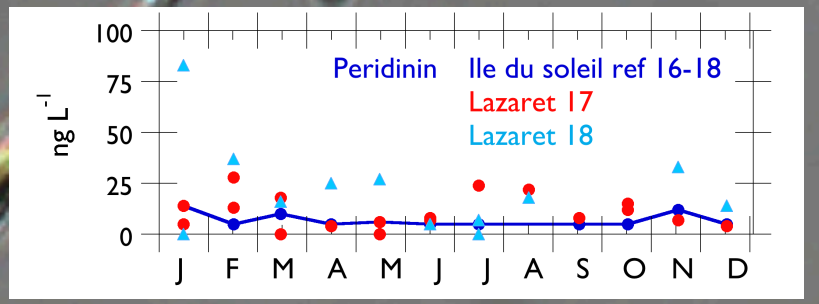
2. Application of the PPCI to Mediterranean coastal sites

- **Study cases : mussels farms in a highly urbanized area (Lazaret Bay, France, W Med)**



High		Good	Moderate	Poor	Bad
1	0.90	0.70	0.50	0.20	0

Phytoplankton composition is strongly affected by human pressures

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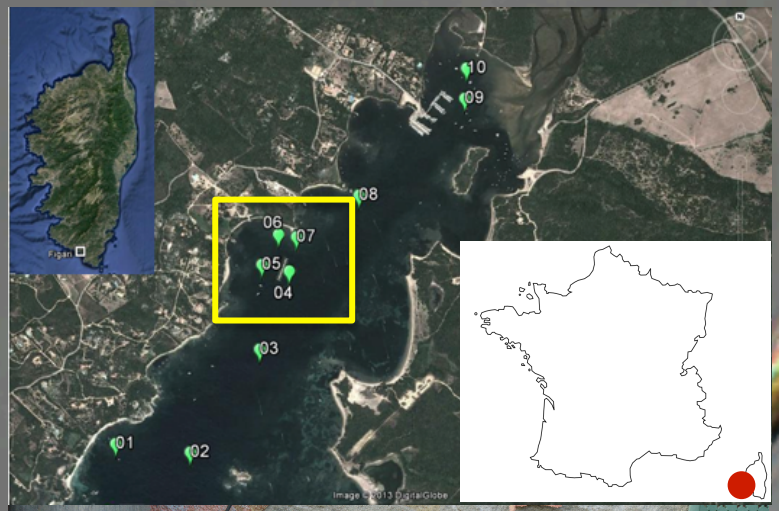
2. Application of the PPCI to Mediterranean coastal sites

- **Study cases : response of phytoplankton communities after an aquaculture closure (Figari, Corsica, W Med)**



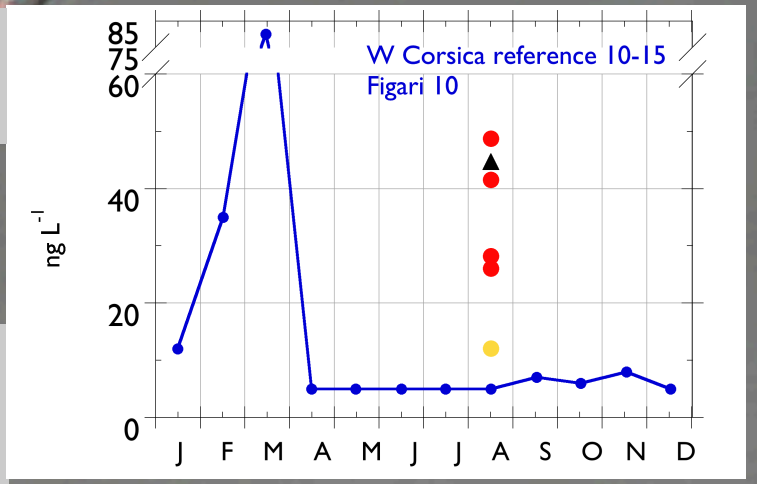
Running aquaculture

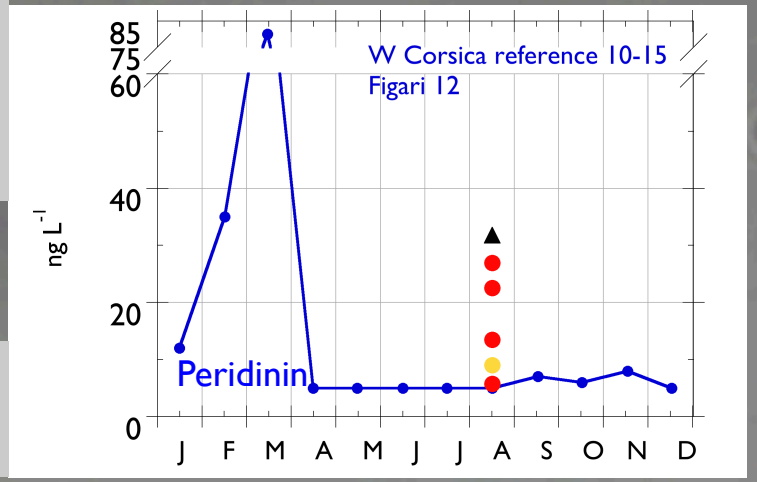
Outer most station

Aquaculture stations

Inner most station

1 year after closure





2. Application of the PPCI to Mediterranean coastal sites

- **Study cases : response of phytoplankton communities after an aquaculture closure (Figari, Corsica, W Med)**

Before closure

	High		Good	Moderate	Poor	Bad
ICPP Médit	1	0.90	0.70	0.50	0.20	0

1 year after closure

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Conclusions

- **PPCI is a new multimetric phytoplankton composition index based on phytopigments.**
- **It detects the effects of anthropogenic disturbances on both quantitative and qualitative phytoplankton communities structure over different spatial and temporal scales.**
- **It can be used a useful tool for assessing long-term effects of restoration measures and benefits of nutrient reduction strategies.**
- **It is transferable over a broad range of coastal zones.**
- **It is easily implemented which enables it to be used by environment managers who are not experts in phytoplankton taxonomy.**

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Thank you for your attention !