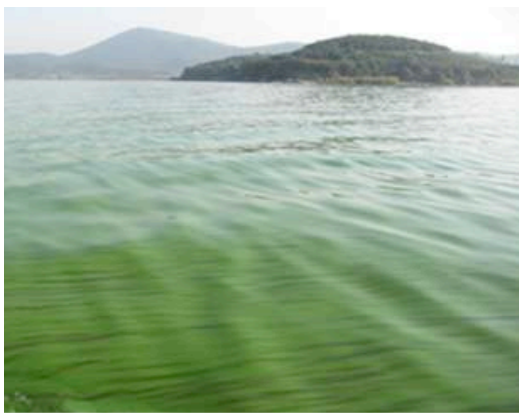
Prolifération rapides des cyanobactéries au cours des 200 dernières années : conséquences sur la toxicité des floraisons

Taranu ZE[1], Gregory-Eaves I[2], Steele R[2], Beaulieu M[3] & Legendre P[1]




1. Université de Montréal | 2. McGill University | 3. Université de Sherbrooke

Prolifération globale des floraisons de cyanobactéries

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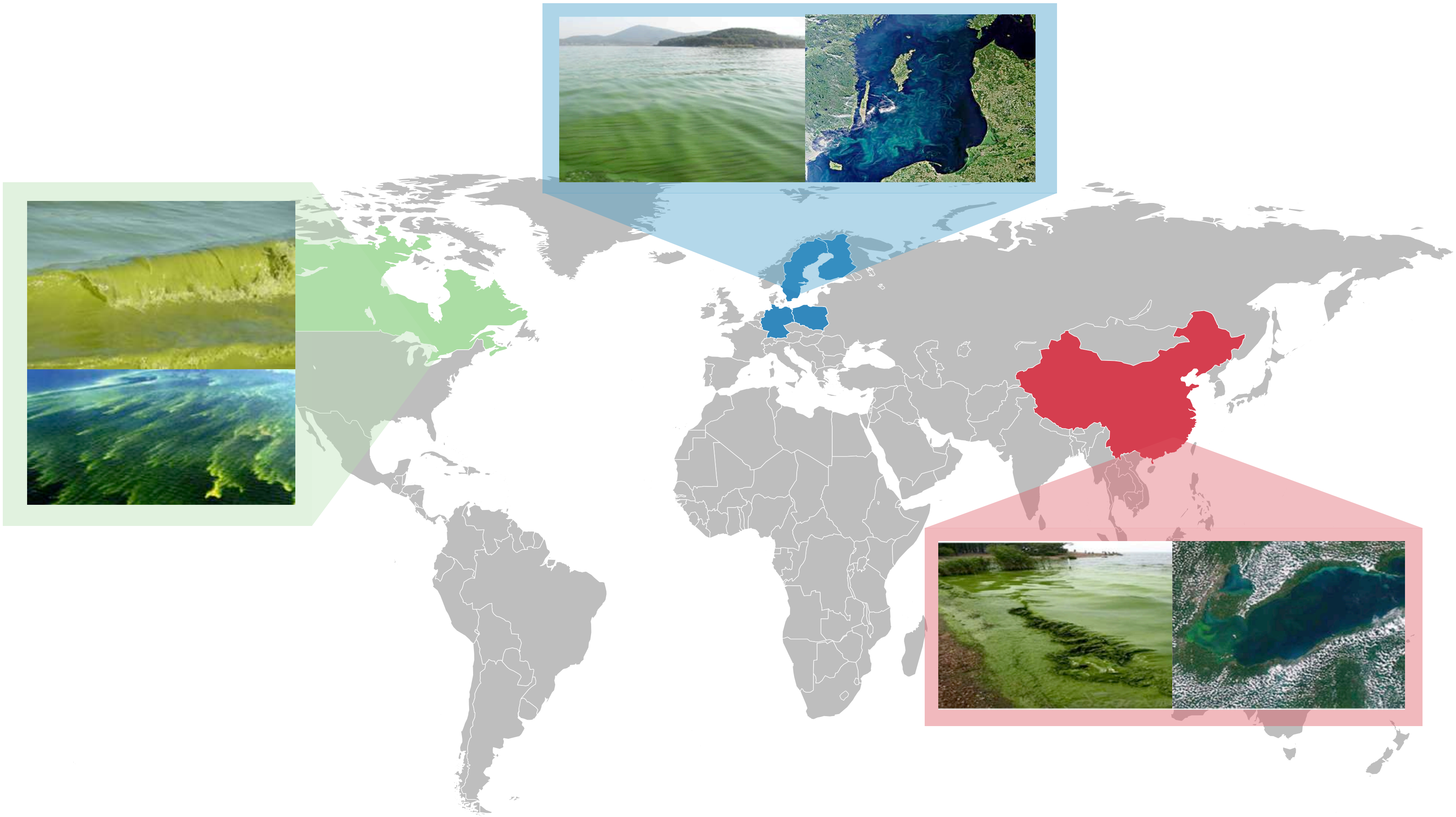

Paerl & Paul (2012)

Causes de la prolifération des floraisons de cyanobactéries

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Global Warming Favors Proliferation of Toxic Cyanobacteria

July 3, 2012 — Cyanobacterial populations, primitive aquatic microorganisms, are frequently-encountered in water bodies especially in summer. Their numbers have increased in recent decades and scientists suspect that global warming may be behind the phenomenon, and are particularly concerned by the increase in toxic cyanobacteria, which affect human and animal health.

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Eutrophication makes toxic cyanobacteria more toxic

Published: Monday, December 6, 2010 - 11:32 in Ea

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How blue-green algae is taking over Canadian lakes

Microscopic cynobacteria cells can form soup-like layer on water surfaces

By Kathryn Weatherley, CBC News Posted: Feb 26, 2013 10:06 AM ET | Last Updated: Feb 26, 2013 10:00 AM ET

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Thick cyanobacteria, commonly referred to as blue green algae
Photo Credit: Photos courtesy of Dr. Ron Zurawell, Ph.D., P.Biol. Limnologist/Water Quality Specialist, Alberta E

Potentially toxic blue-green algae increasing everywhere

By Marc Montgomery | english@rcinet.ca
Tuesday 3 March, 2015 , 1 Comment ↓

How blue-green algae is taking over Canadian lakes

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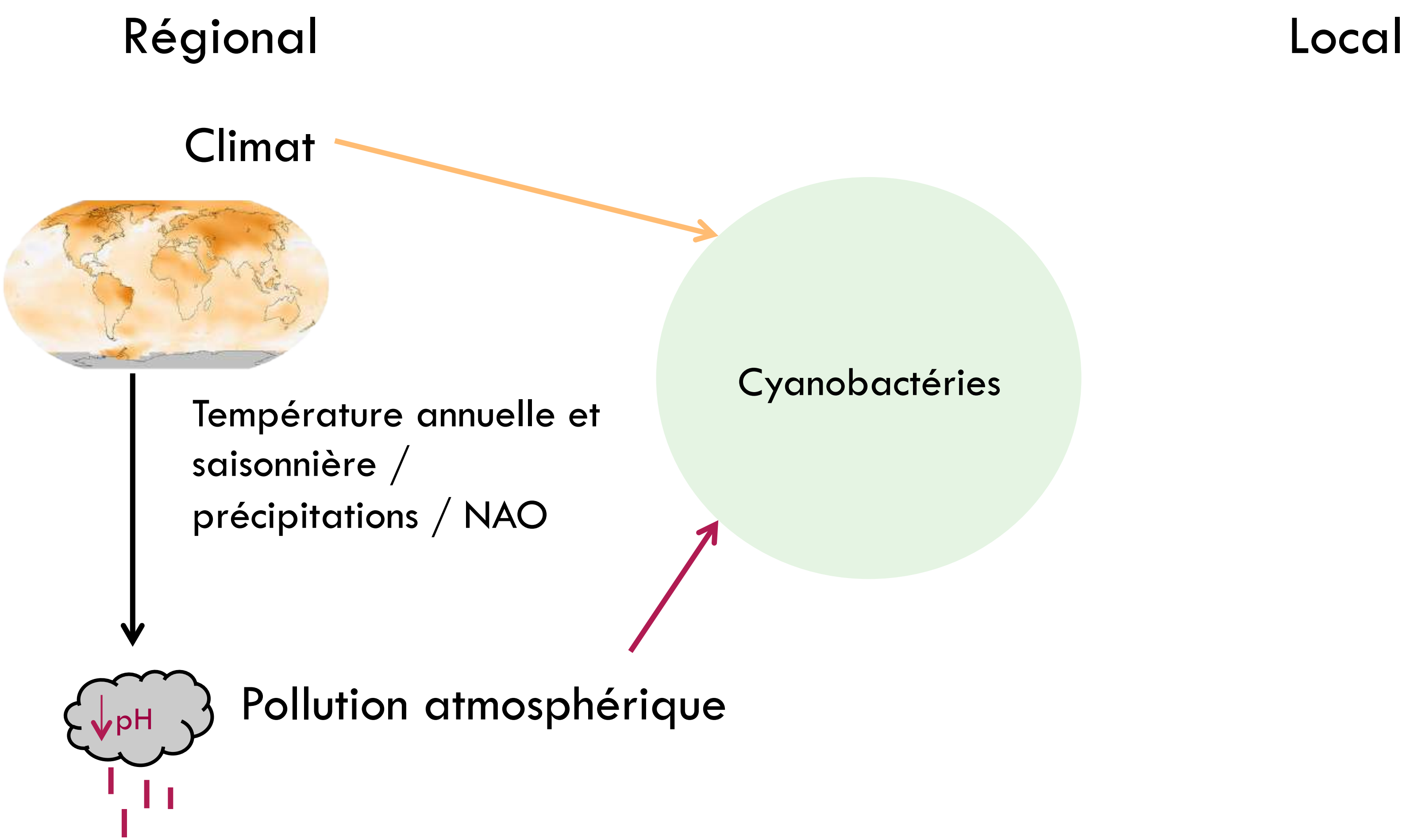
Causes régionales vs locales

Régional

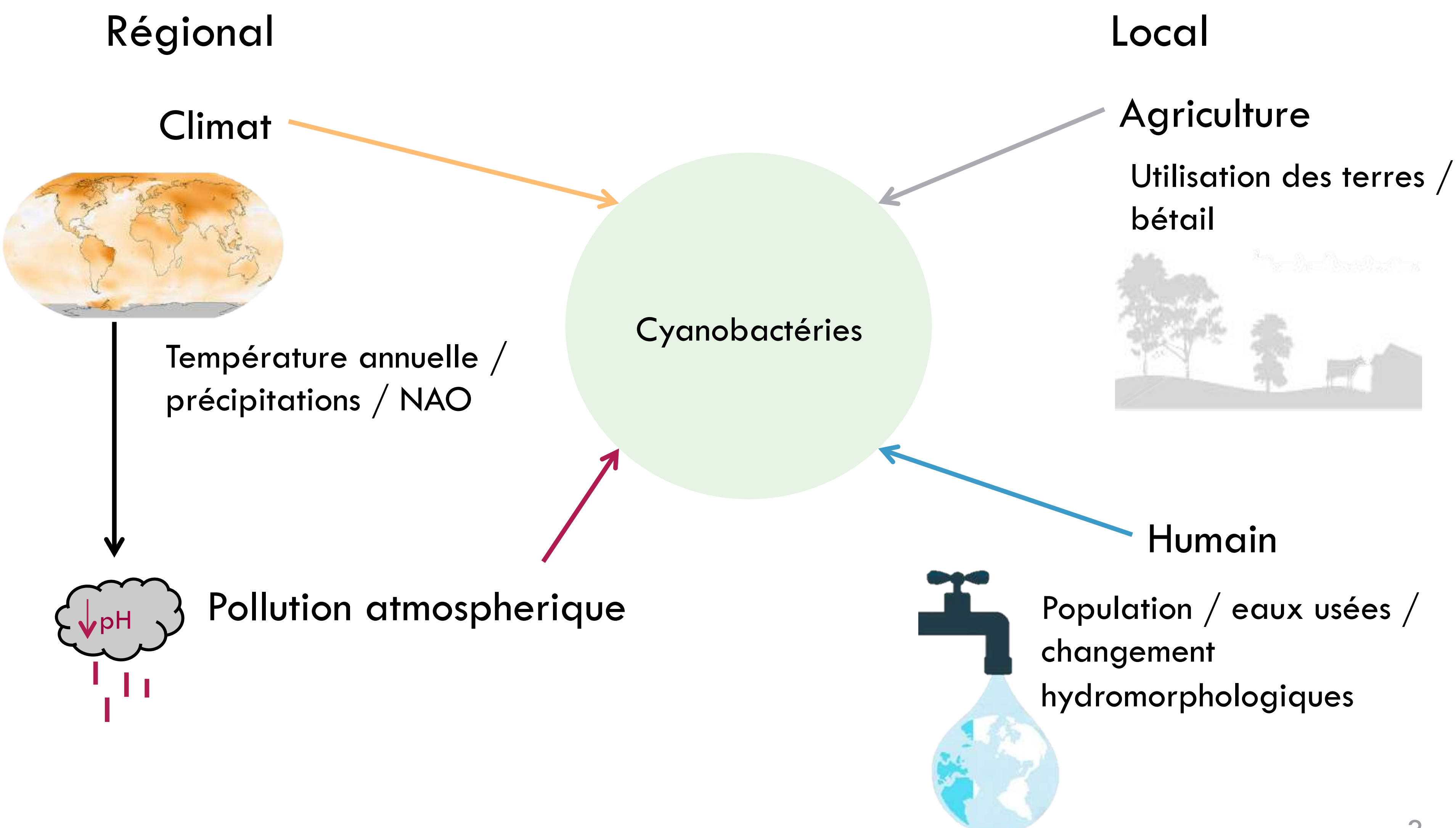
Local

Cyanobactéries

Causes régionales vs locales



Causes régionales vs locales



Changements à travers le temps?

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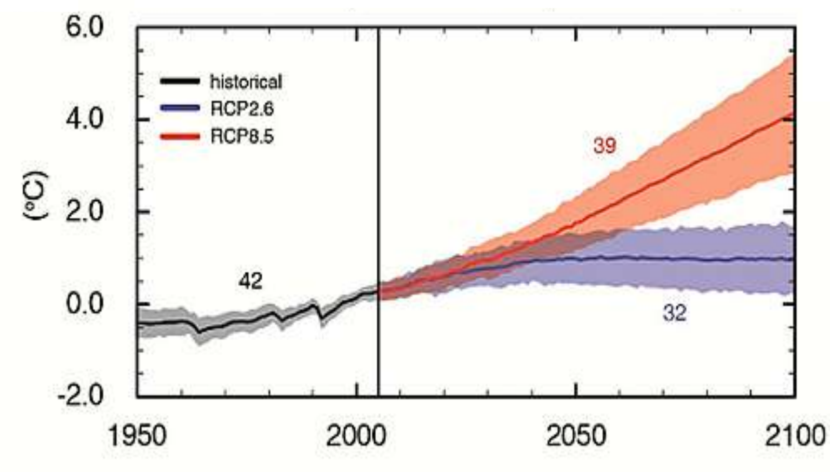
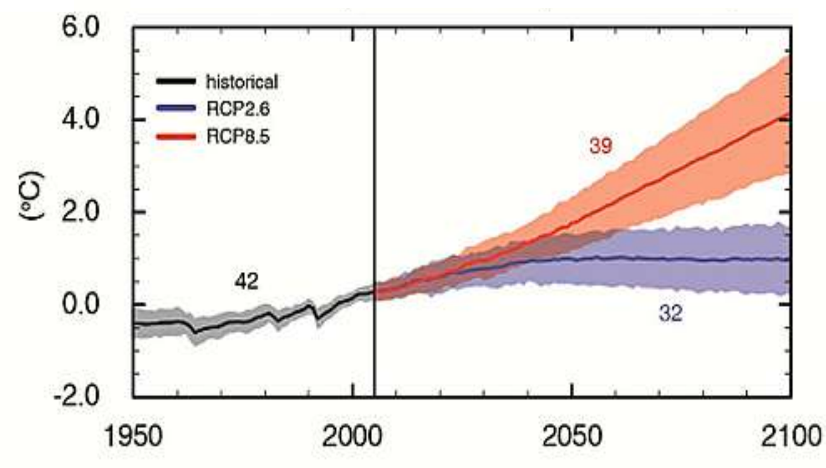
① Hausse de la température mondiale



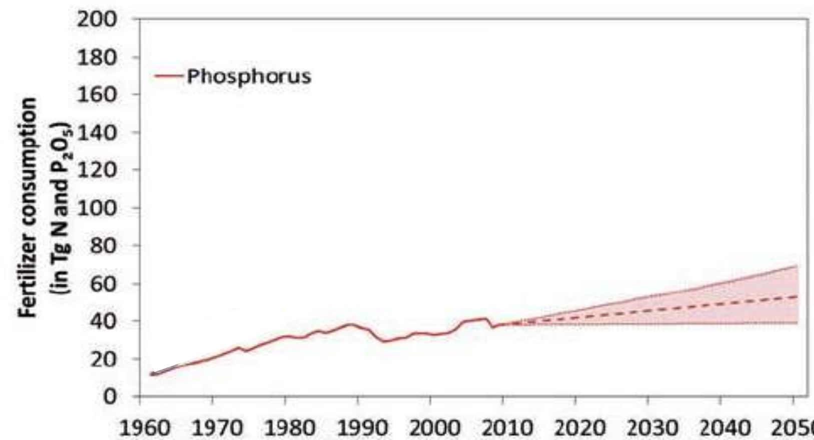
GEIC (2014)

Changements à travers le temps?

1 Hausse de la température mondiale



2 Excédent de chargement P et N



GEIC (2014); Sutton *et al*. (2013)

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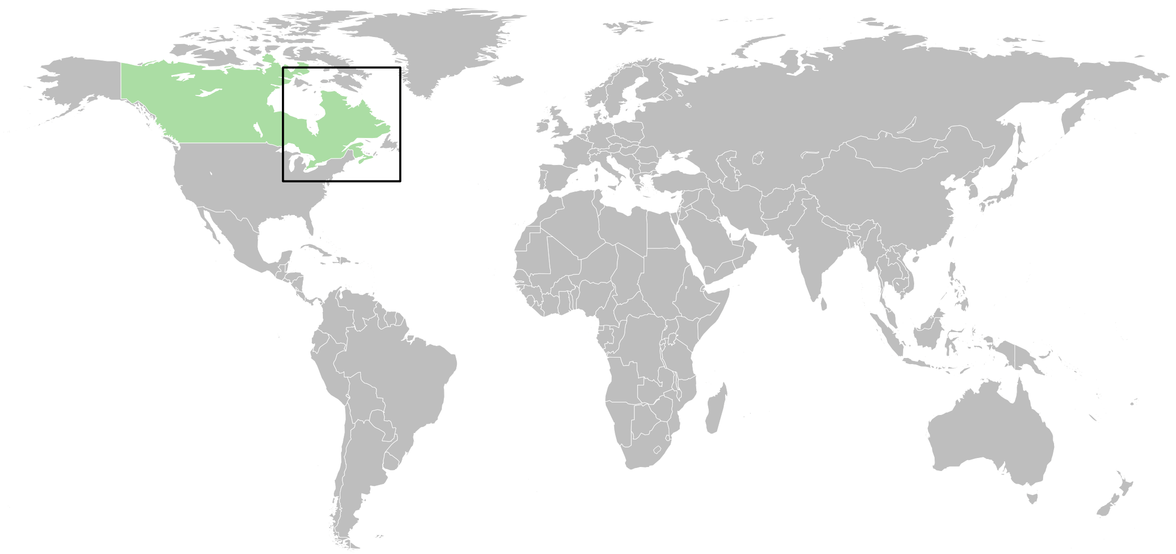

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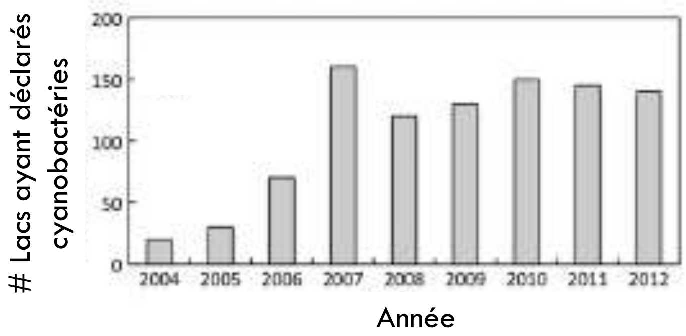
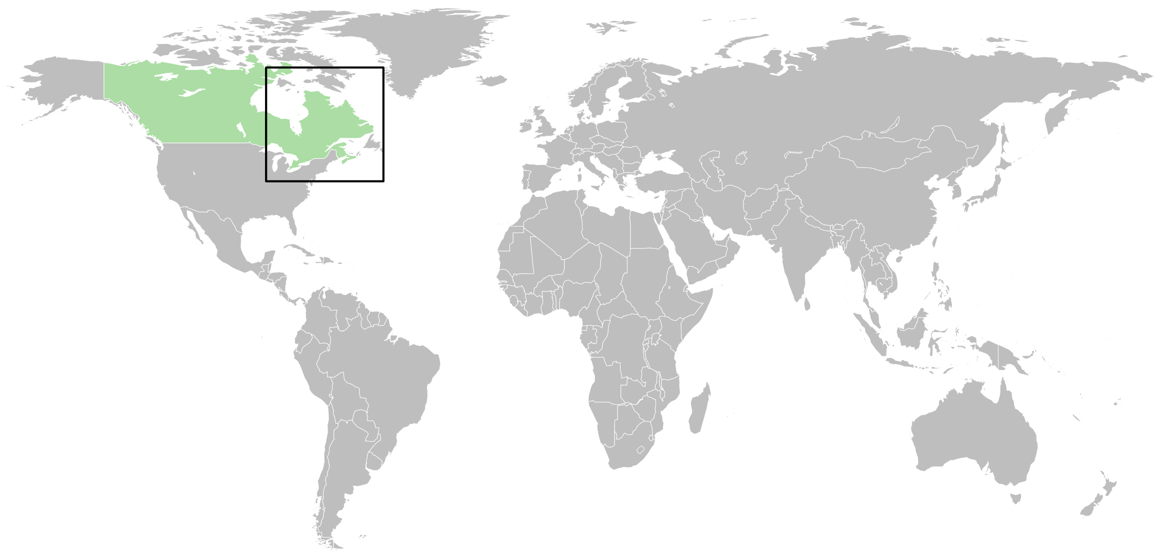
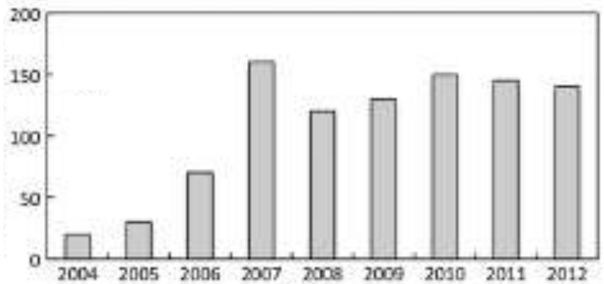




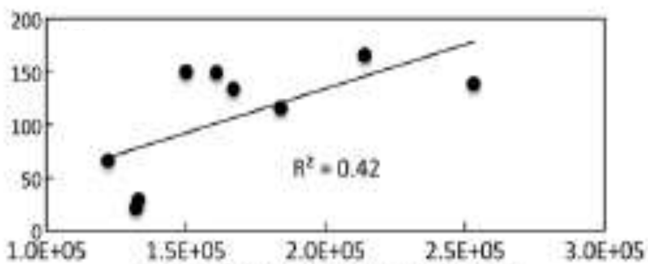
Glibert *et al*. (2014)

Changements à travers le temps?



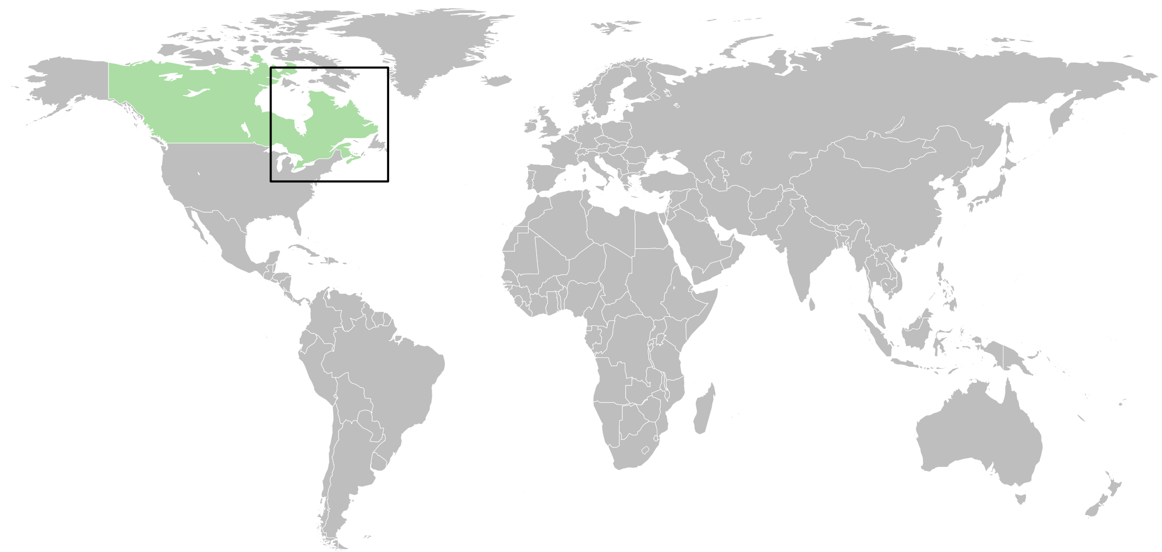
Lacs ayant déclarés cyanobactéries

Année



Lacs ayant déclarés cyanobactéries

Engrais azoté (tonnes)



Glibert *et al.* (2014)

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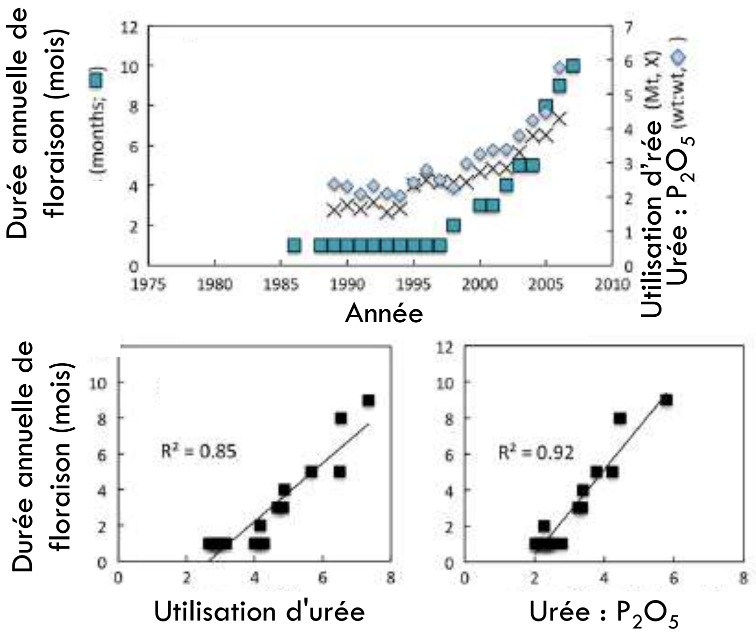
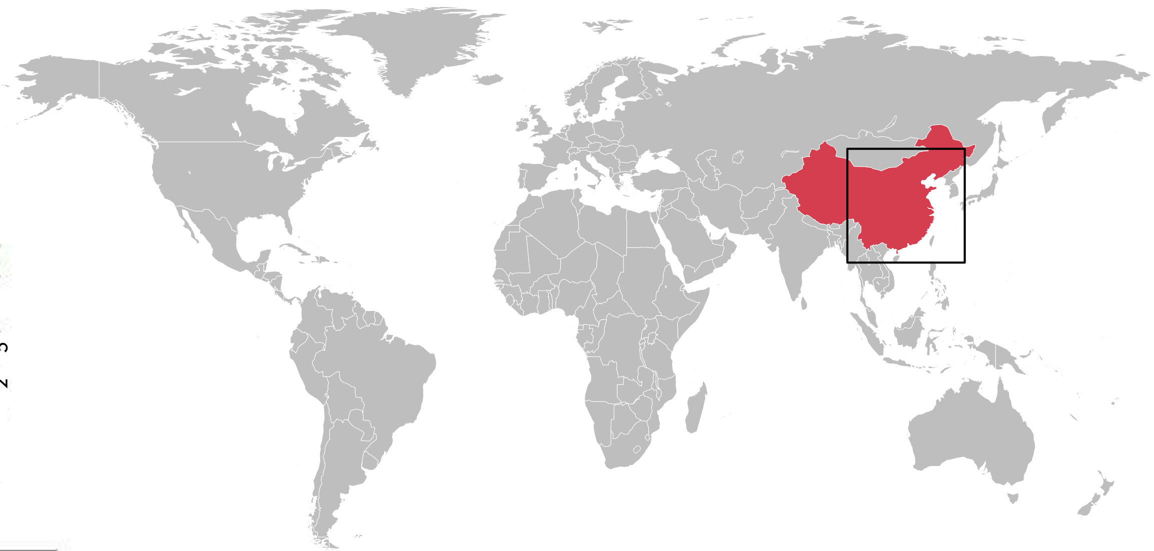
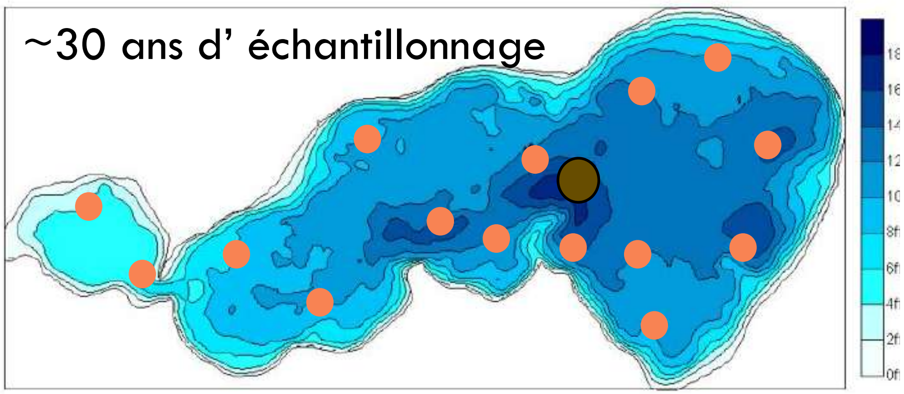




Glibert *et al.* (2014)

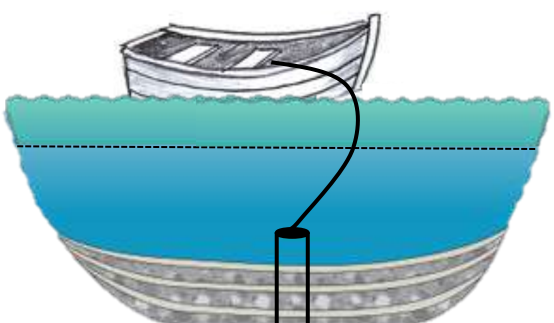
Cyanobactéries plus abondantes aujourd'hui?

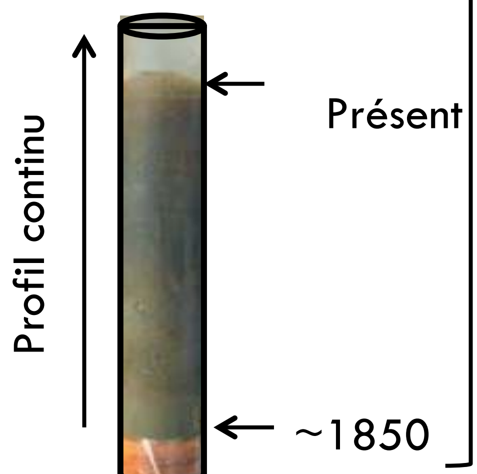
1. Méta-analyse de suivis limnologiques



Gradient trophique

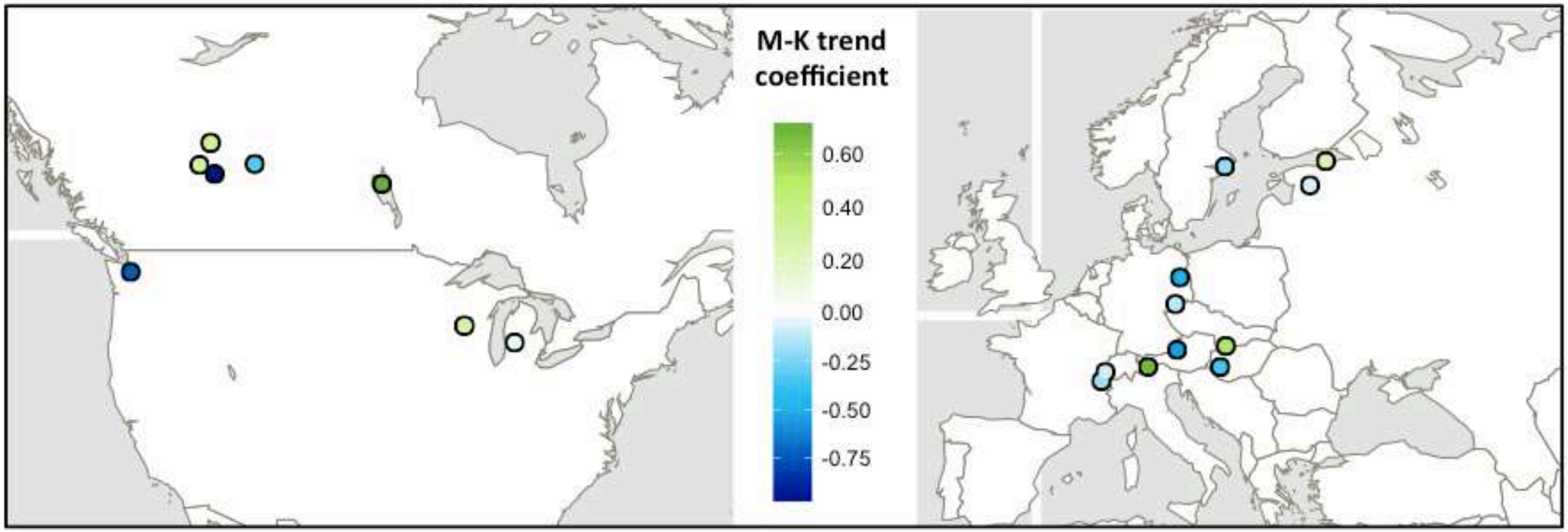
2. Méta-analyse de suivis paléolimnologies





① Méta-analyse de suivis limnologiques

Suivi limnologique long-terme provenant de 18 lacs



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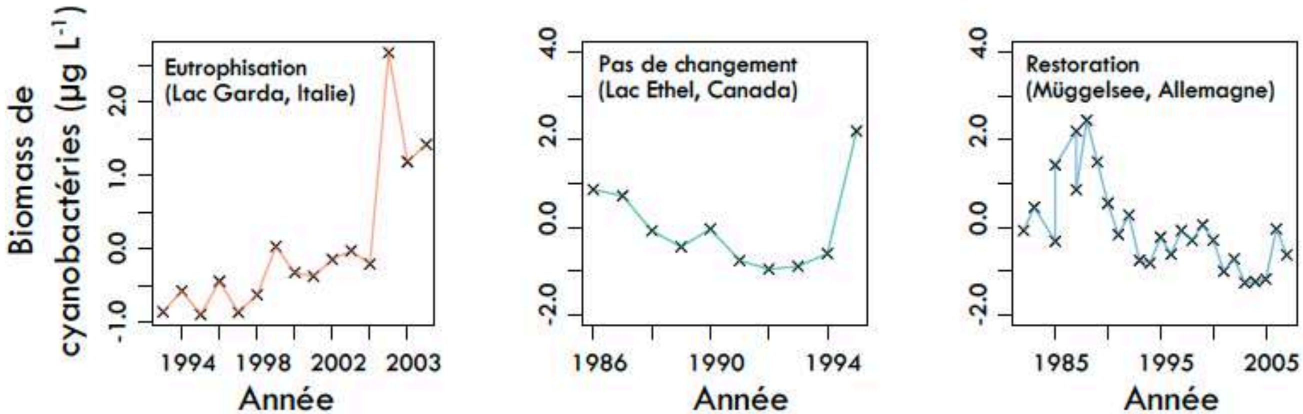

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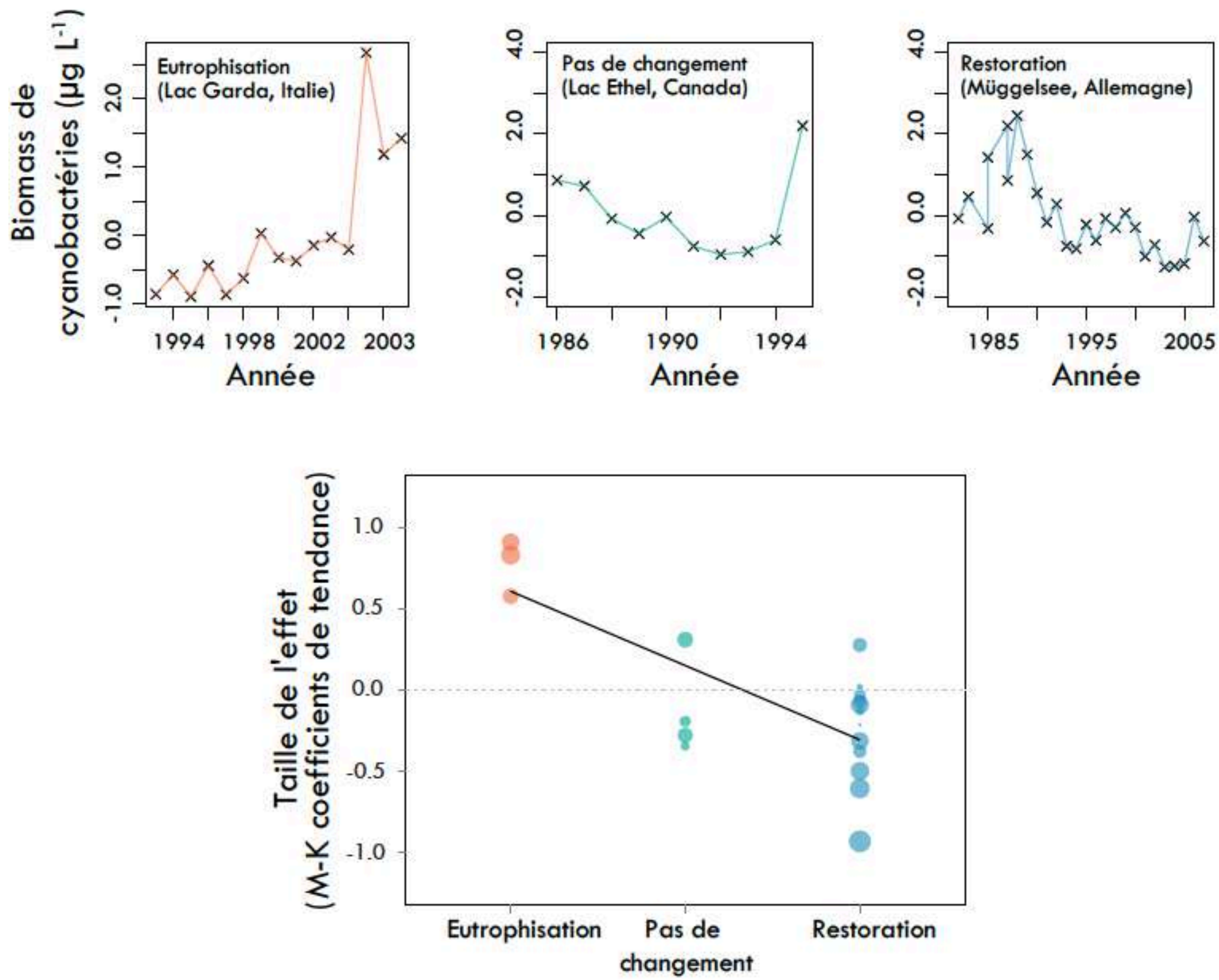

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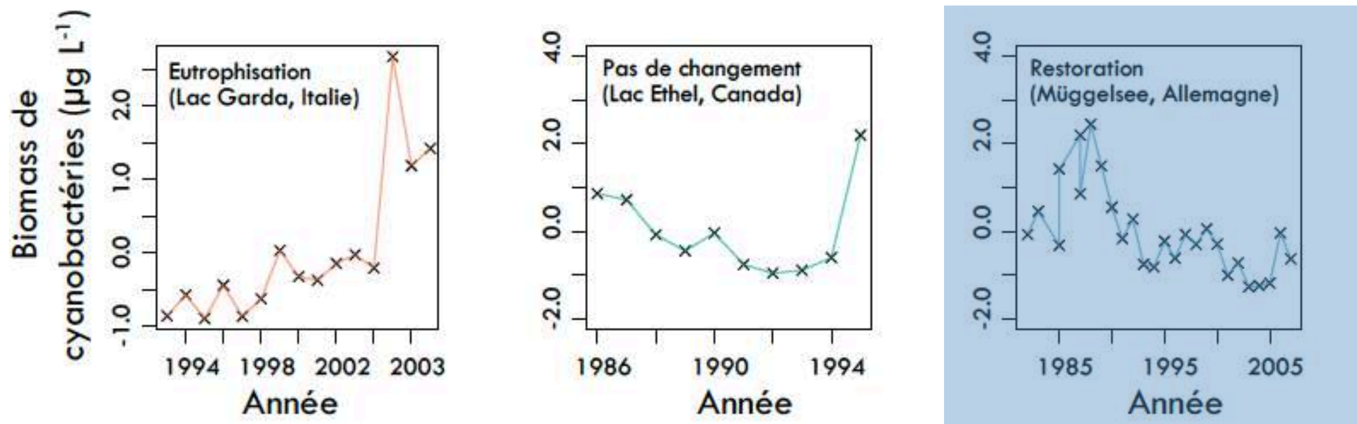

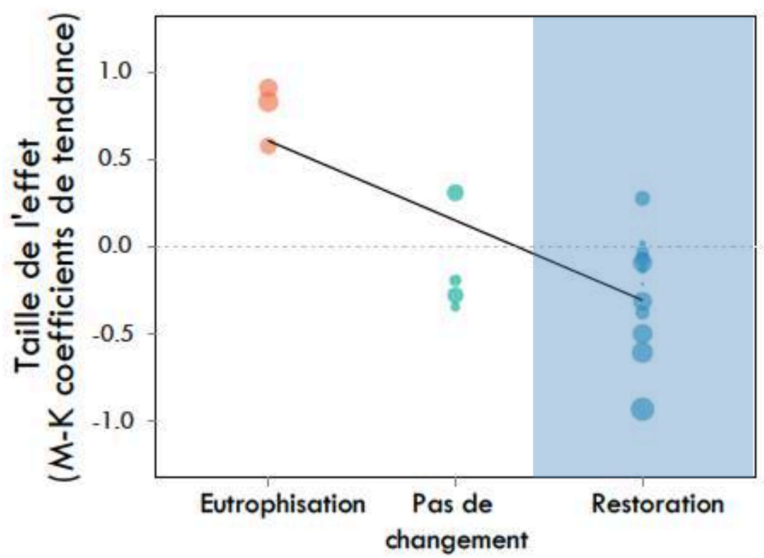

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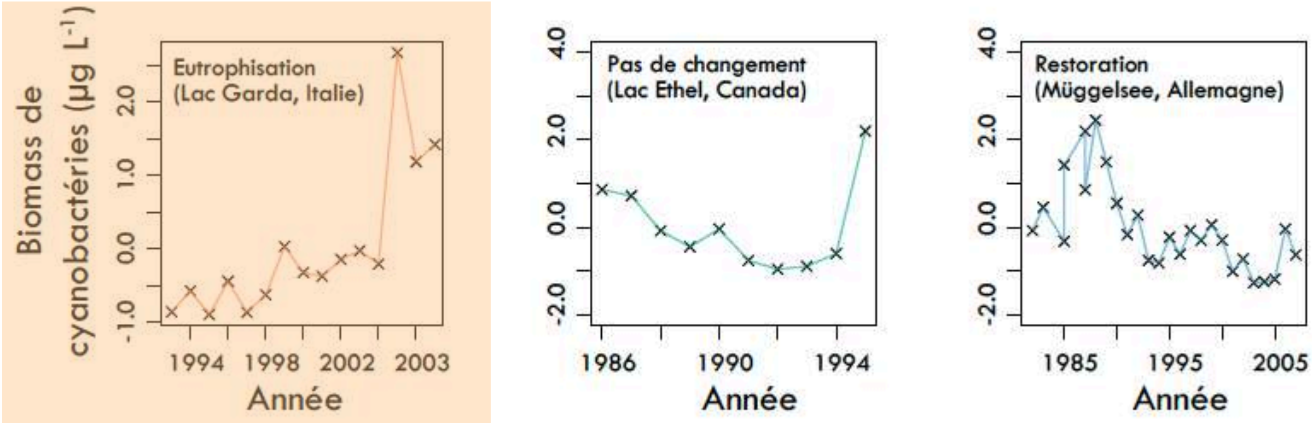

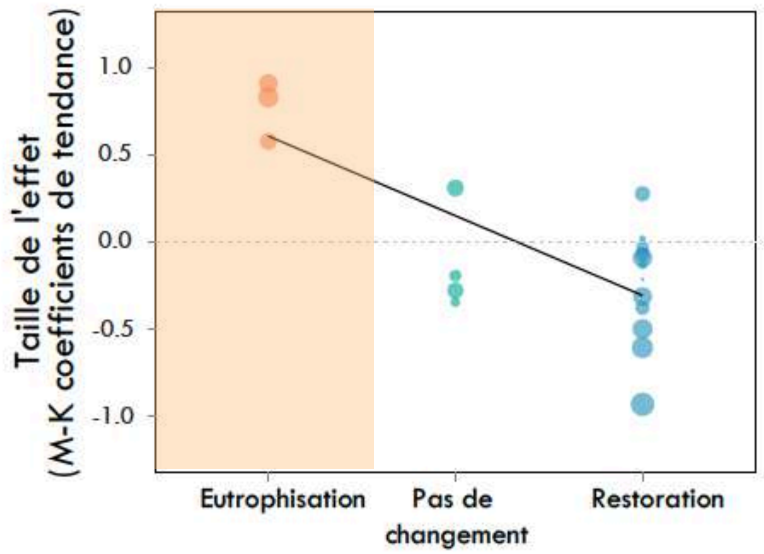

② Méta-analyse de suivis paléolimnologiques

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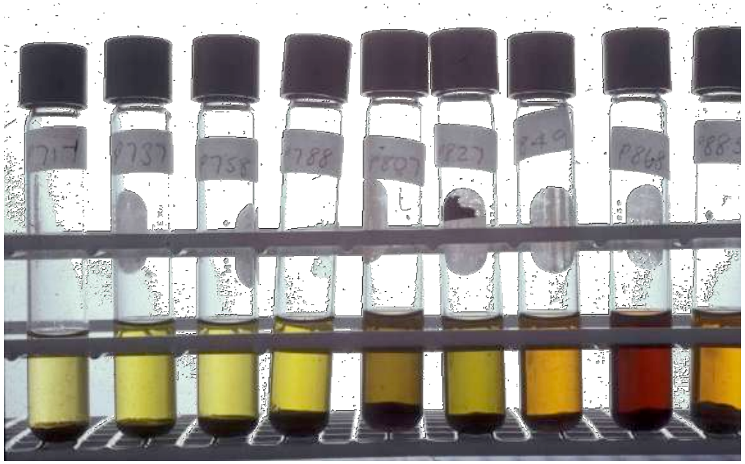
Pigments d'algues sédimentaires

i Taxonomiquement spécifique

ii Détectent l'eutrophisation et d'autres changements environnementaux

iii Chromatographie Liquide à Haute Performance (HPLC)

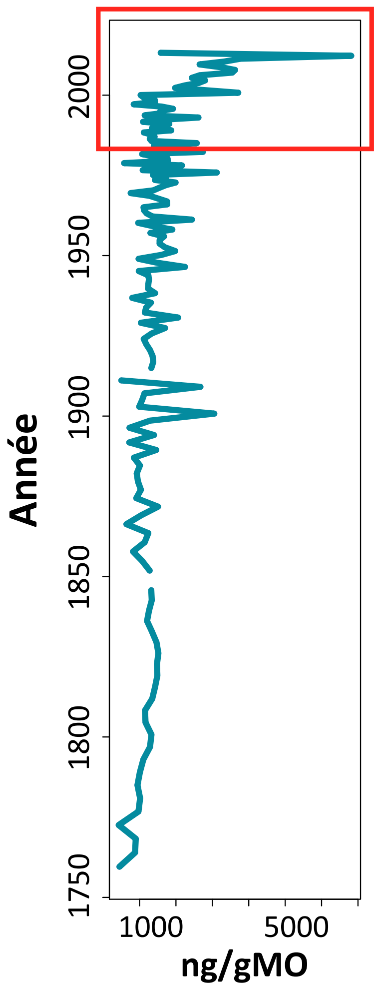
Sépare / Identifie / Quantifie

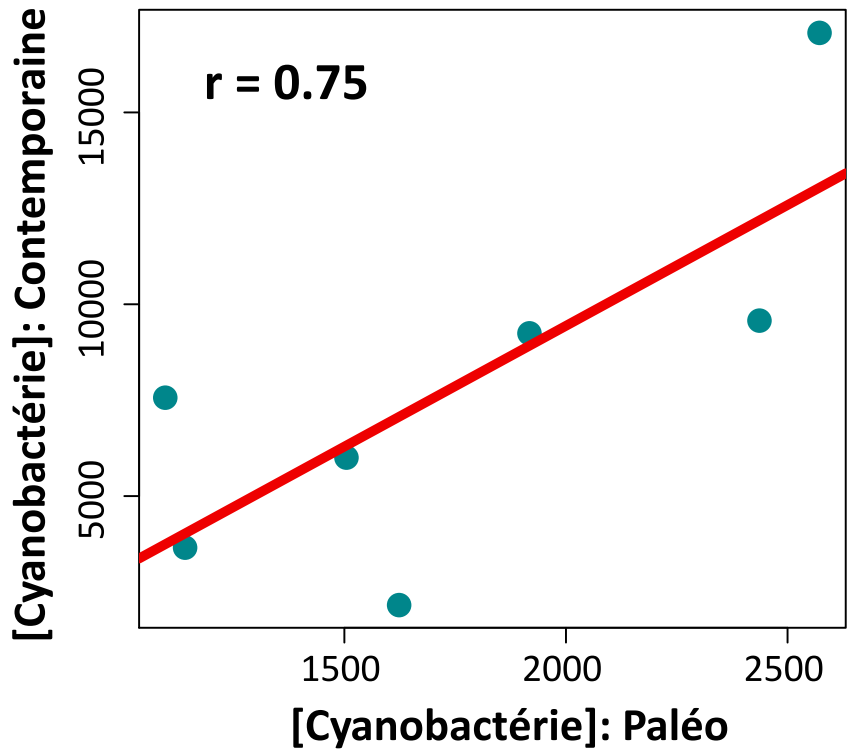


Source: McGowan (2011)

② Méta-analyse de suivis paléolimnologiques

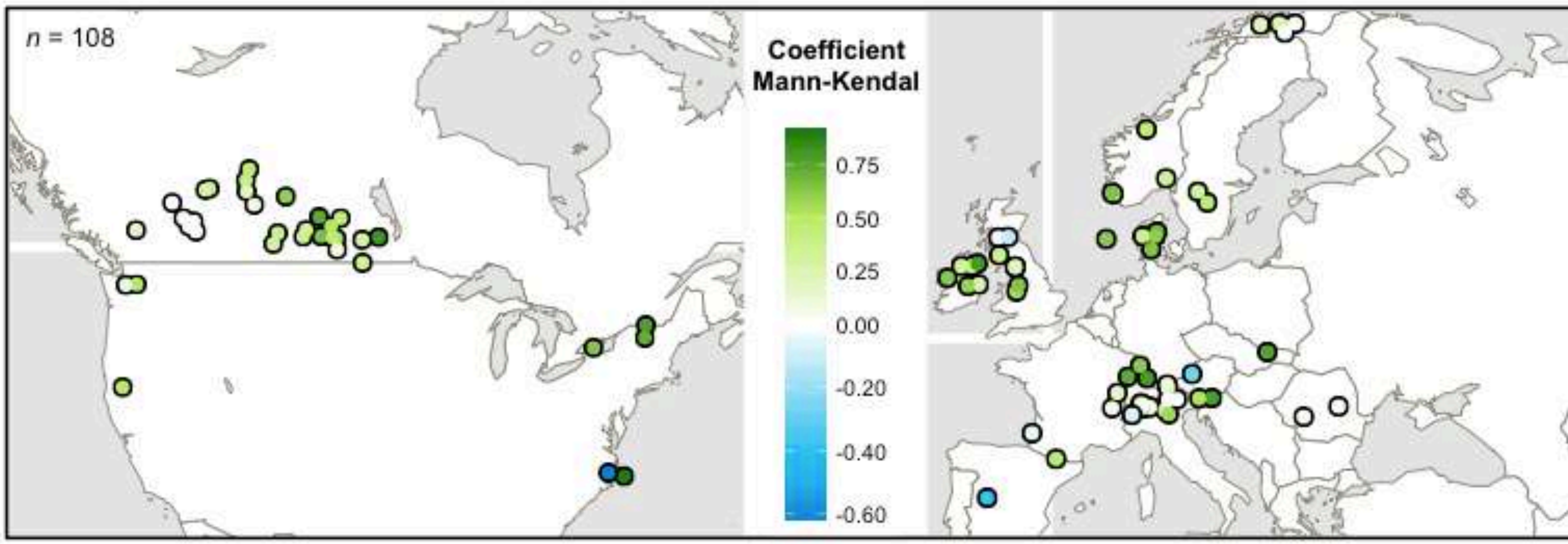
Pigments cyanobactériens





② Méta-analyse de suivis paléolimnologiques

~200 ans de données provenant de 108 lacs



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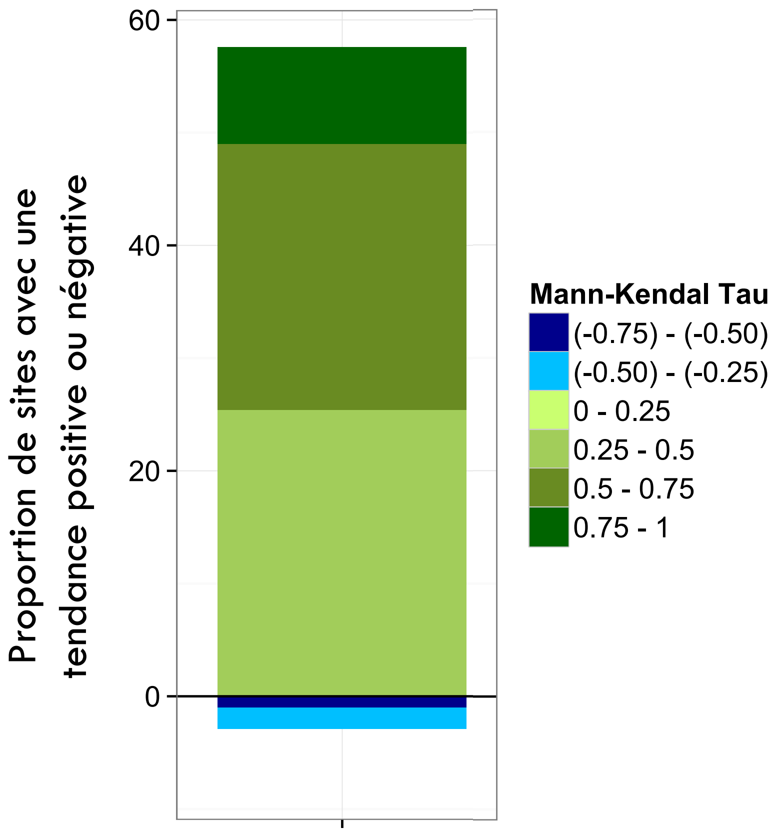
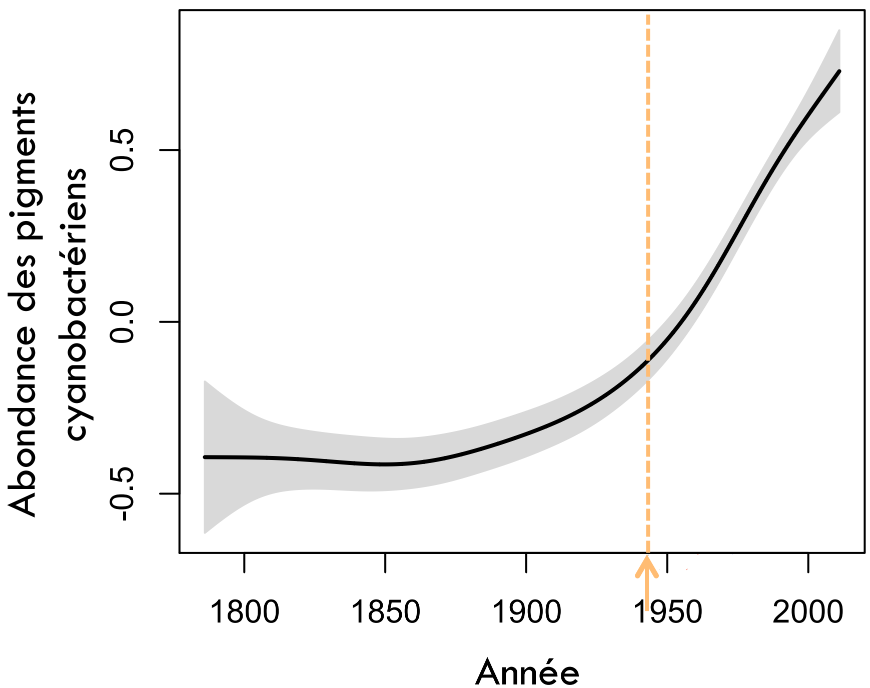


58% des lacs ont connu une augmentation significative des concentrations de pigments de cyanobactéries

Diminution significative dans seulement 3% des lacs

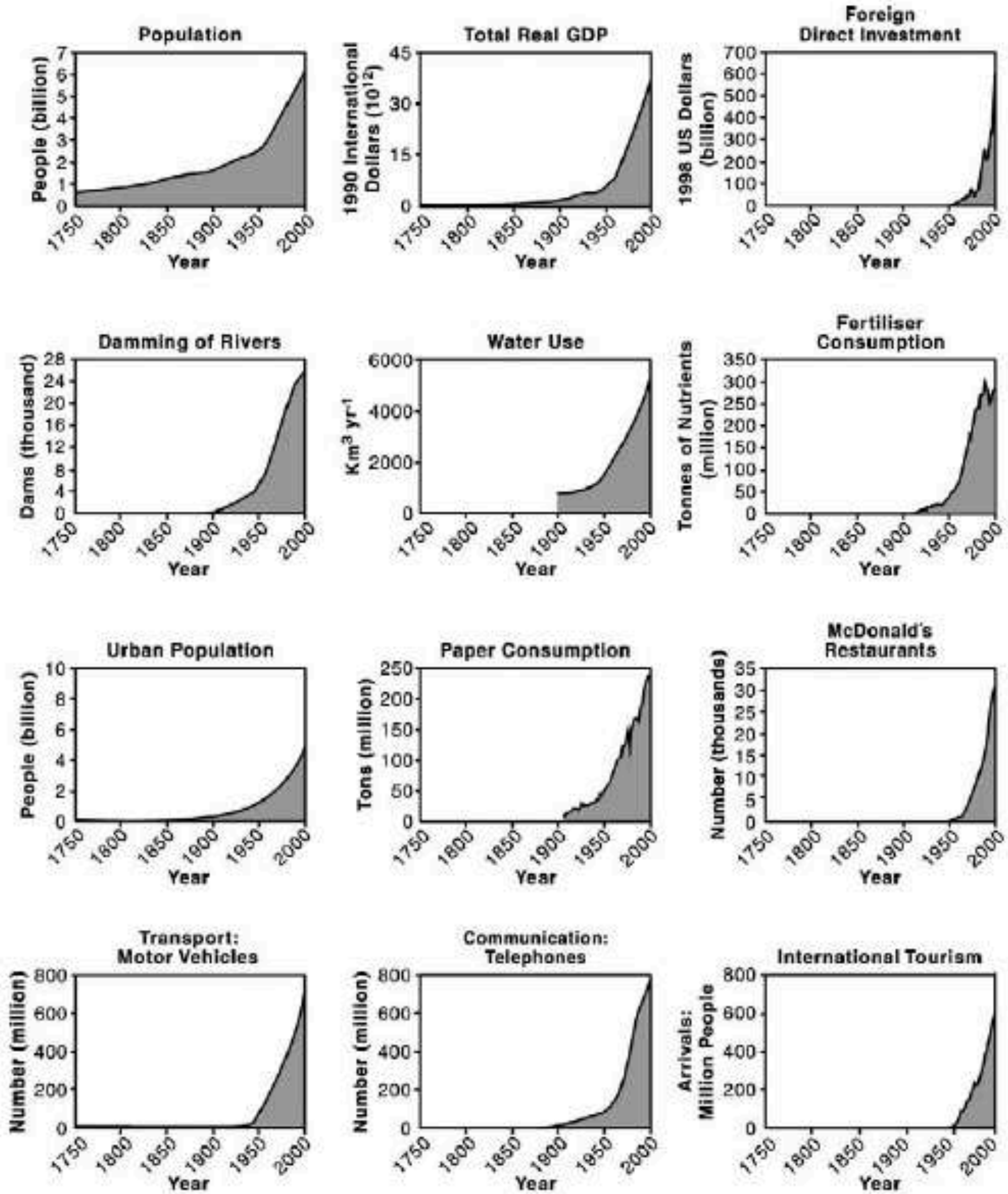
② Méta-analyse de suivis paléolimnologiques

Augmentation non-linéaire de l'abondance des cyanobactéries



Taux de croissance accéléré depuis ca. 1945

La « grande accélération » de l'anthropocène



Steffen *et al.* (2007)

② Méta-analyse de suivis paléolimnologiques

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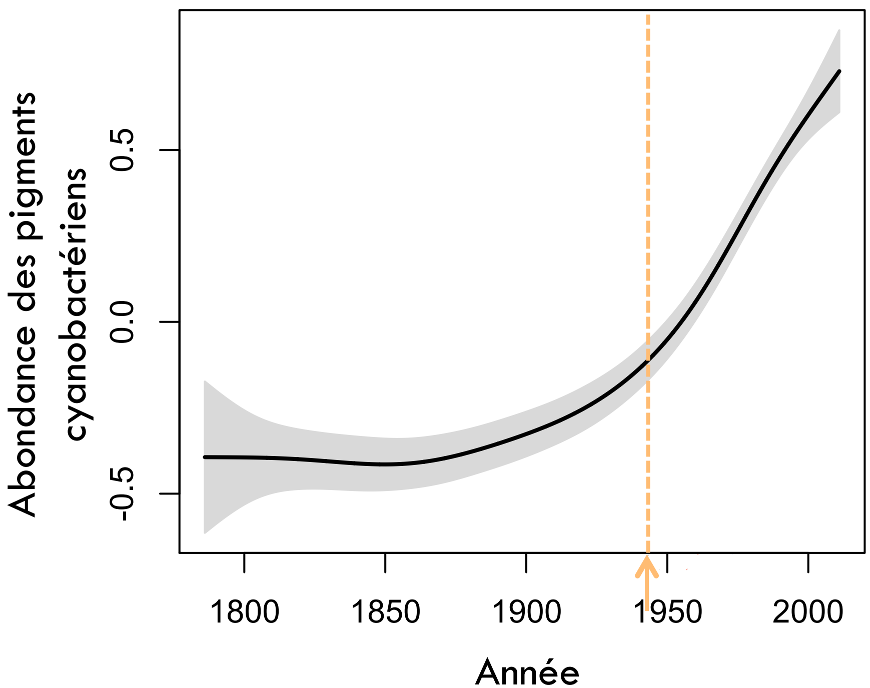


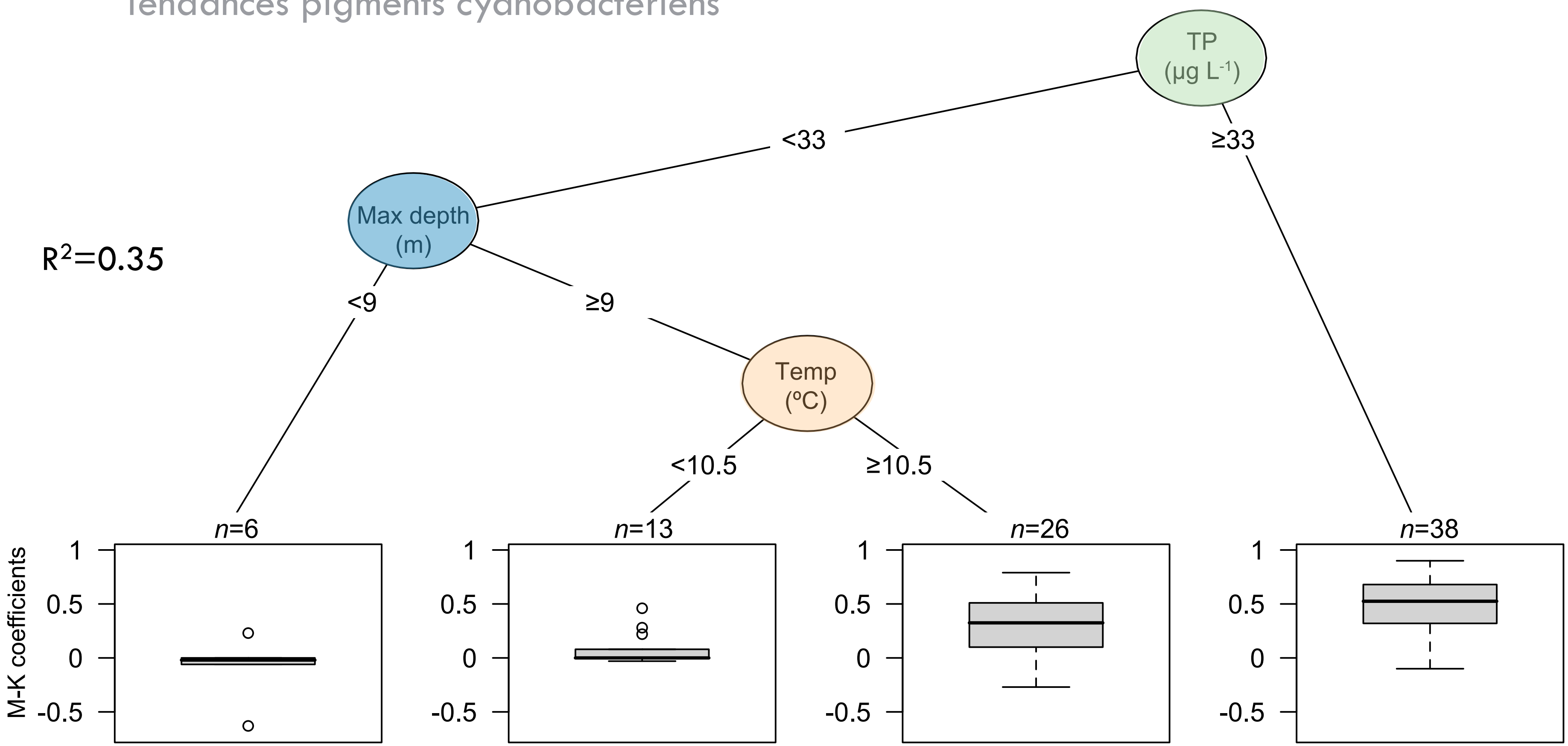
Taux de croissance accéléré depuis ca. 1945

② Méta-analyse de suivis paléolimnologiques

Variable réponse :

Tendances pigments cyanobactériens

$R^2=0.35$



Augmentation des cyanobactéries

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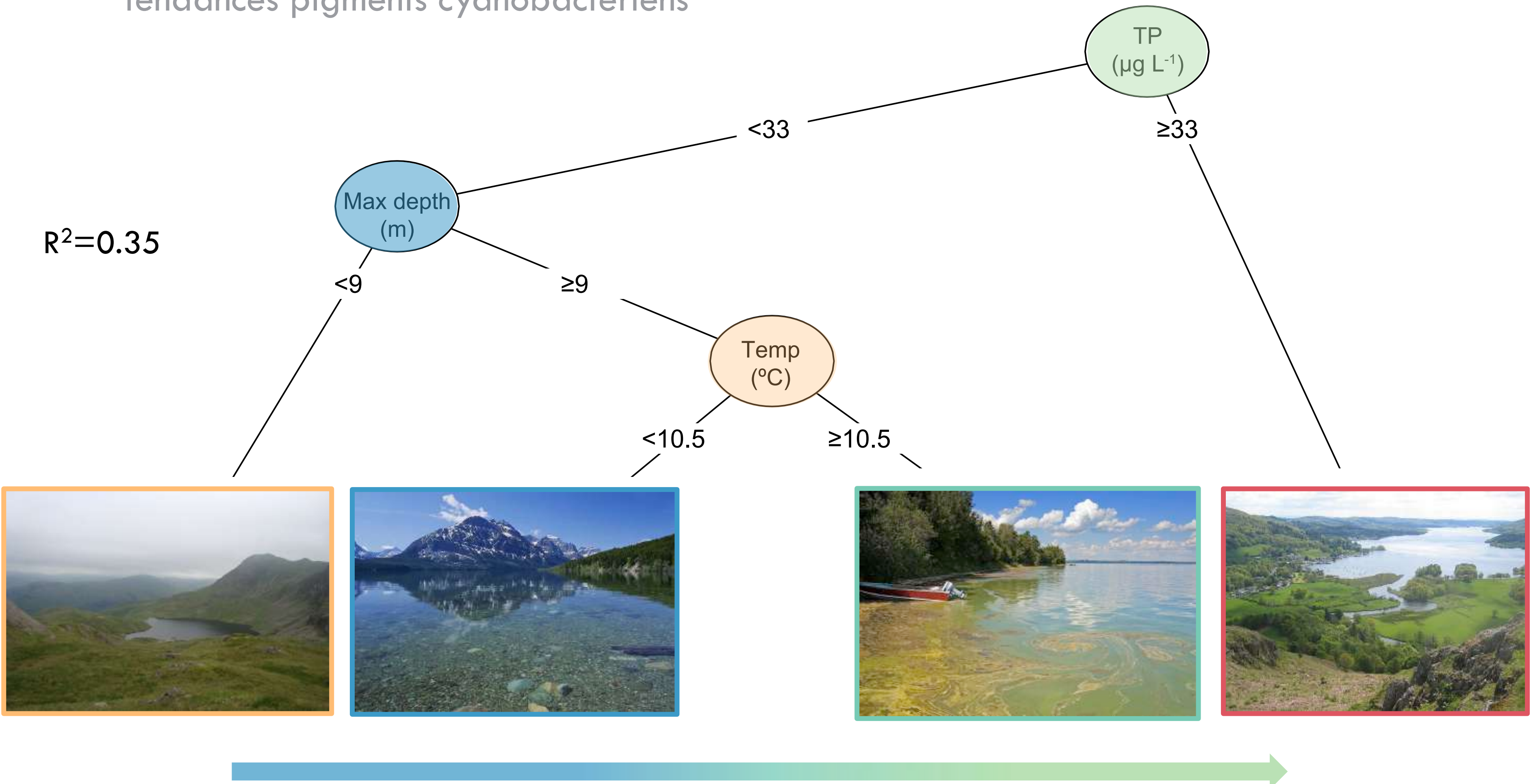
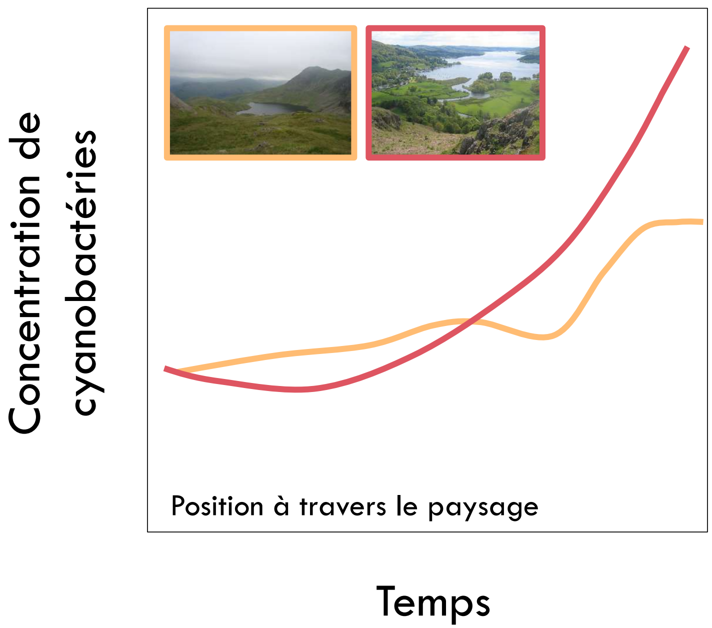
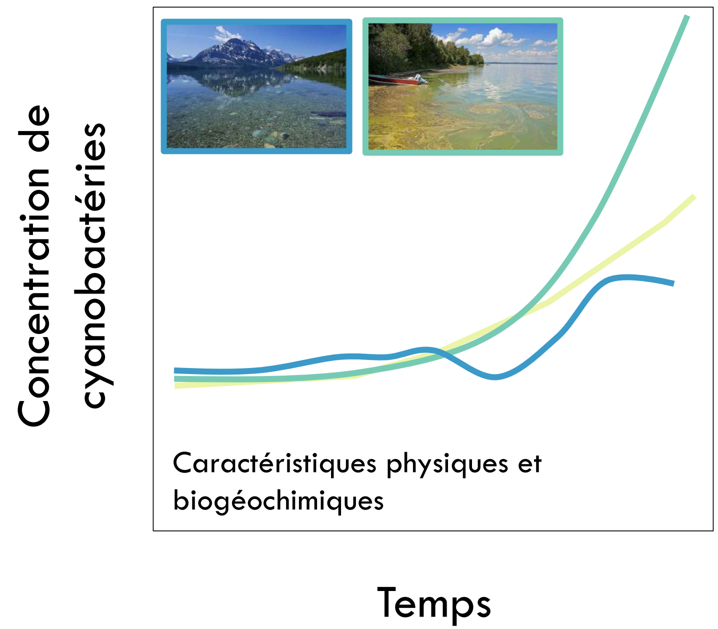


Augmentation des cyanobactéries

Réponse des cyanobactéries à l'eutrophisation et au changement climatique

Conclusion

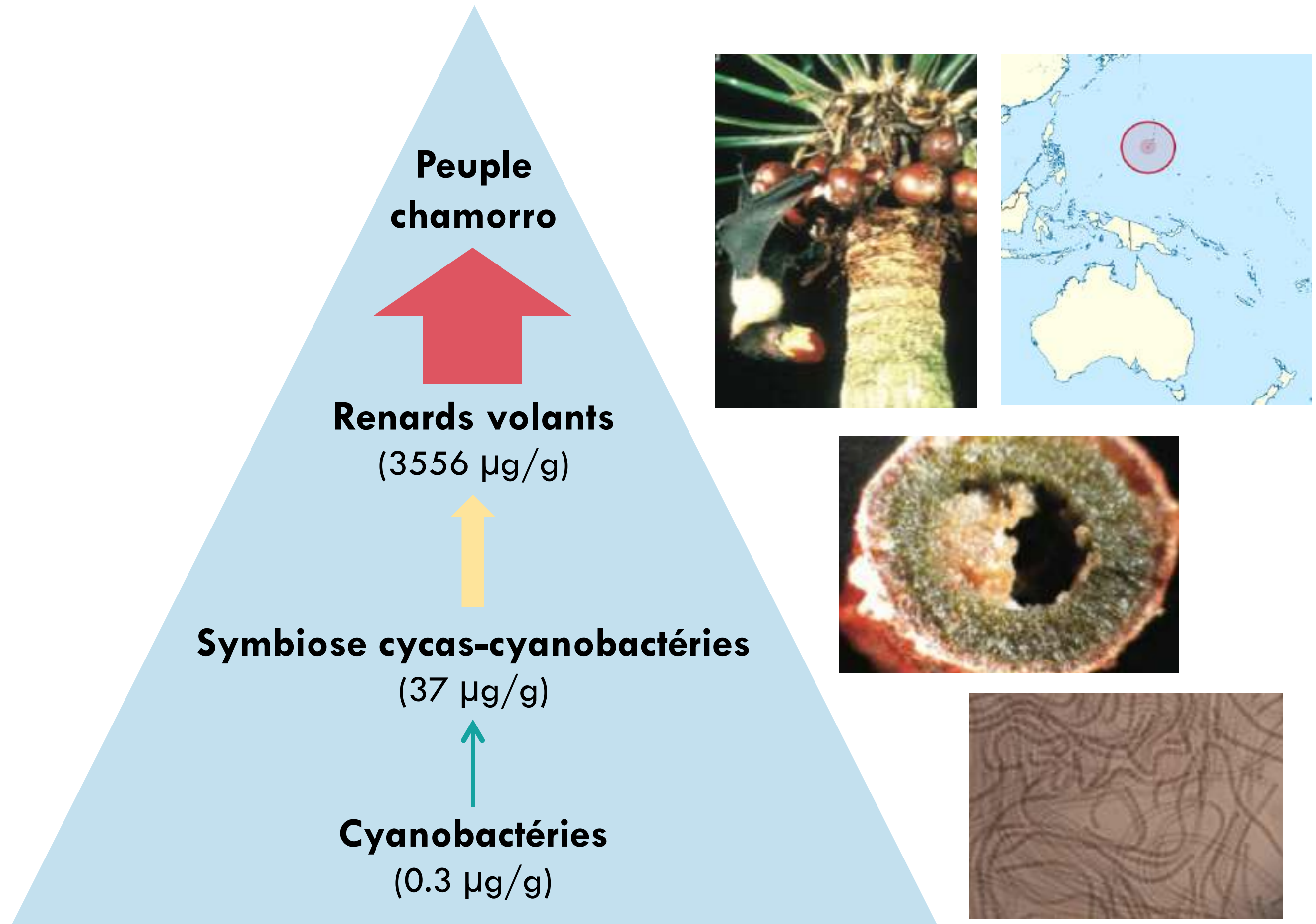




Important de comprendre les facteurs locaux et régionaux impactant la qualité des eaux dans le cadre d'une gestion pérenne des lacs

Conséquence de l'augmentation des cyanobactéries?

Bioamplification liée aux maladies neurodégénératives chez l'humain

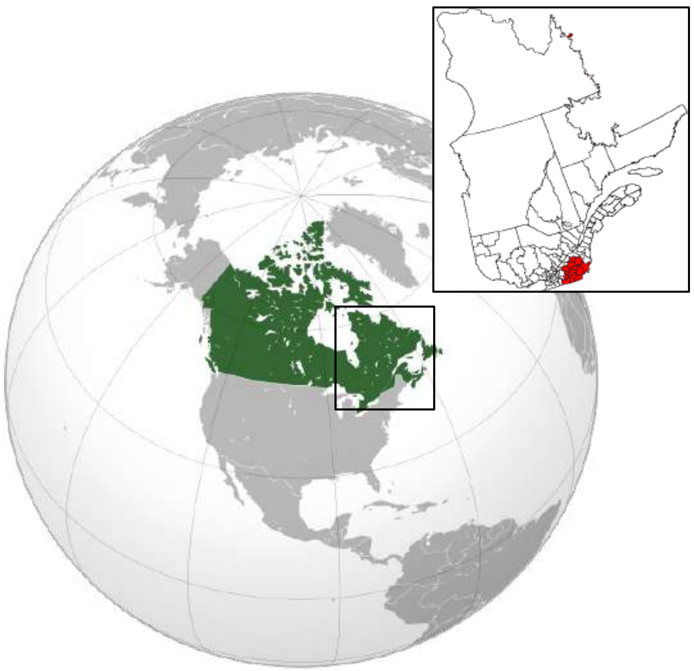


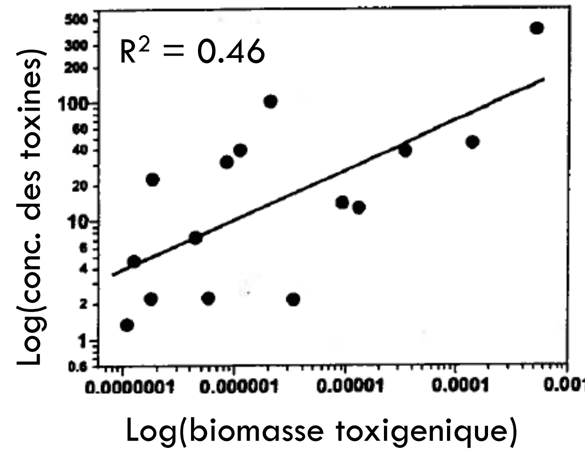
Cox *et al.* (2003)

Toxicité des floraisons à l'échelle régionale

Échelle régionale

Échelle régionale

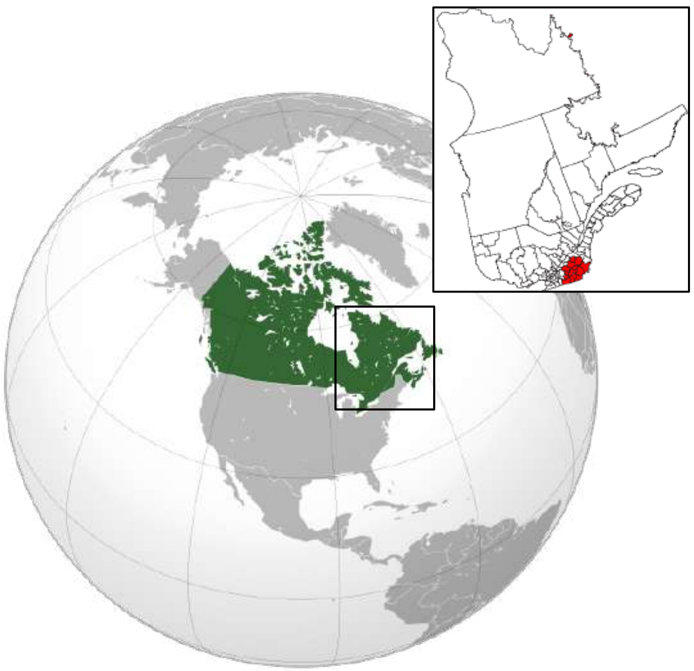


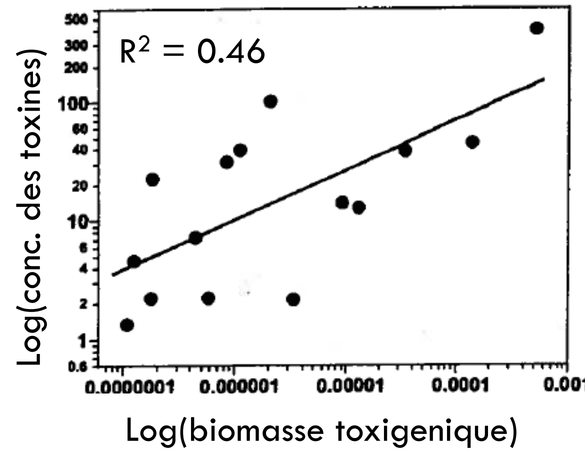


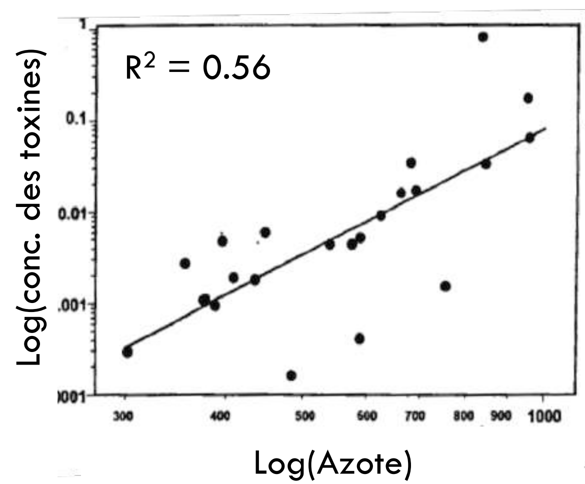
Giani *et al.* (2005)

Toxicité des floraisons à l'échelle régionale

Échelle régionale





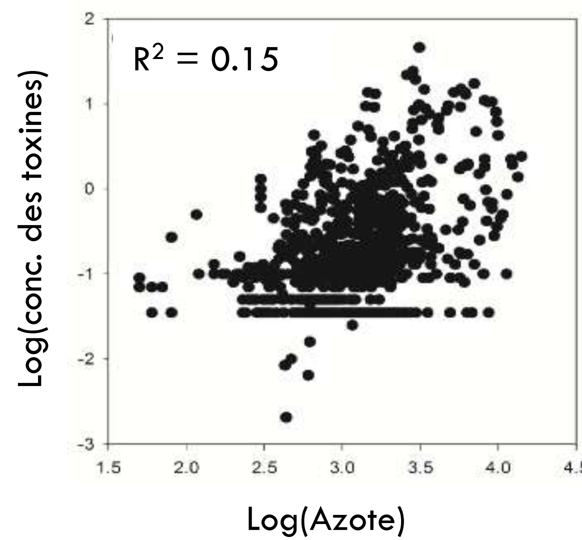


Giani *et al.* (2005)

Toxicité des floraisons à l'échelle nationale

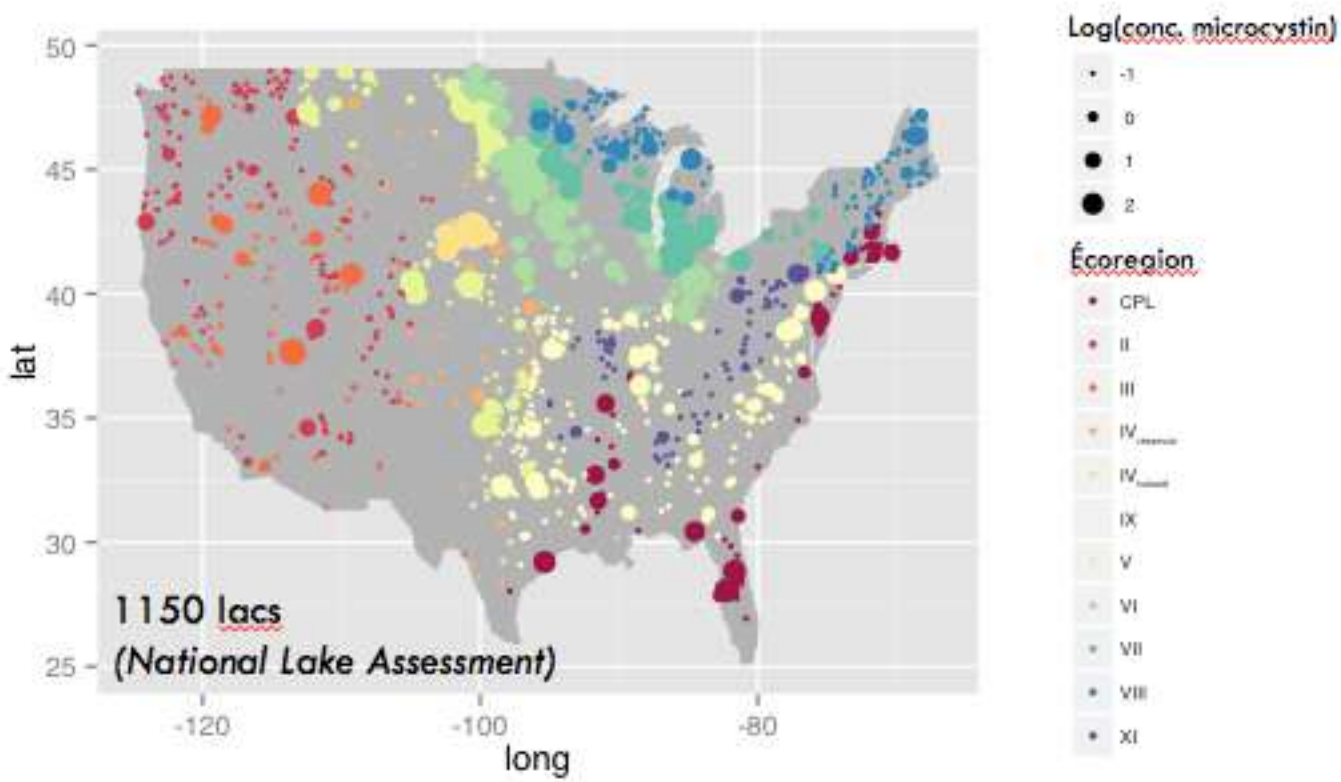
Échelle nationale

Échelle nationale



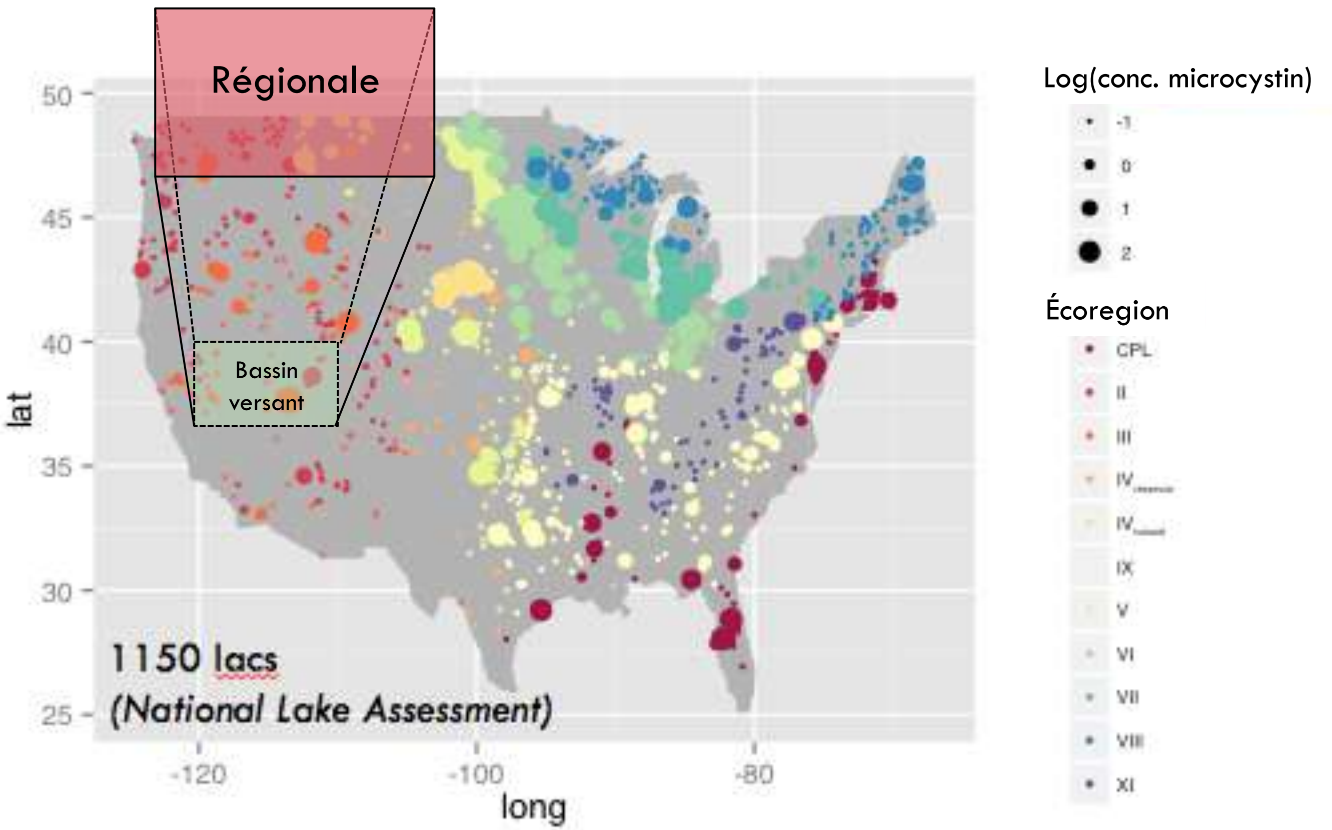
Orihel *et al.* (2012)

Toxicité des floraisons le long d'un gradient spatial



Toxicité des floraisons le long d'un gradient spatial

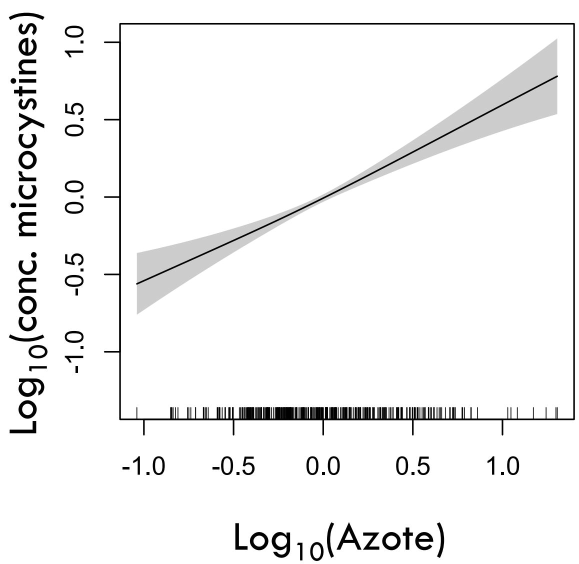
H_0 Facteurs régionaux jouent un rôle important pour prédire le risque de prolifération d'algues toxiques

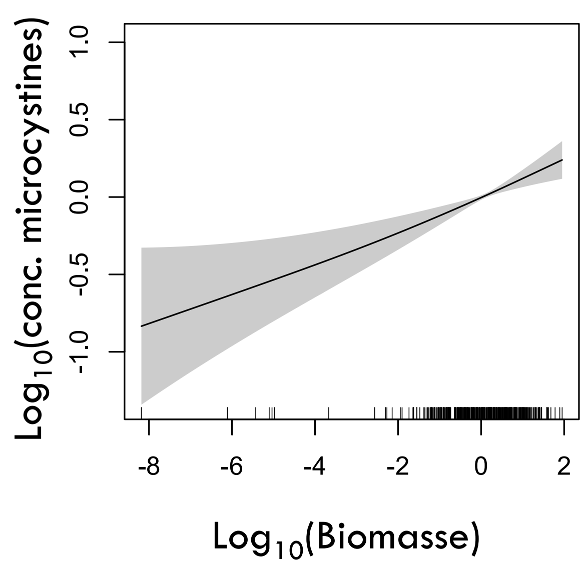


Risque de prolifération floraisons toxiques

Échelle locale

➠ Explique 25 % de la variance

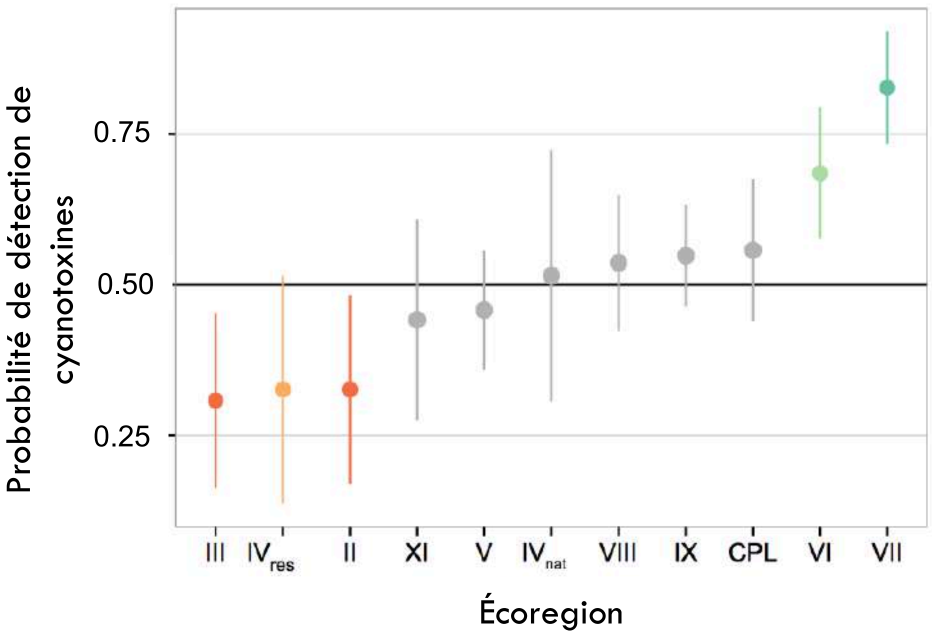


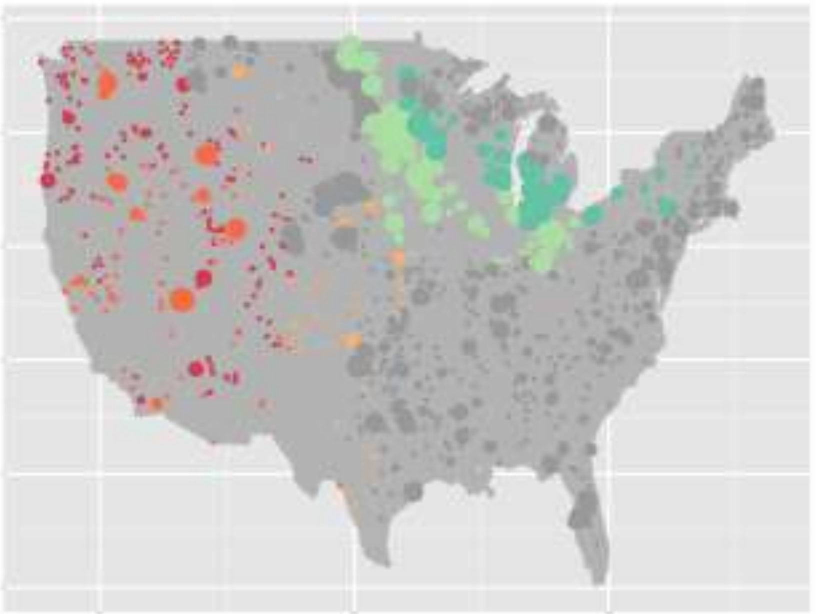


Risque de prolifération floraisons toxiques

Échelle régionale

- ➠ Explique 48 % de la variance

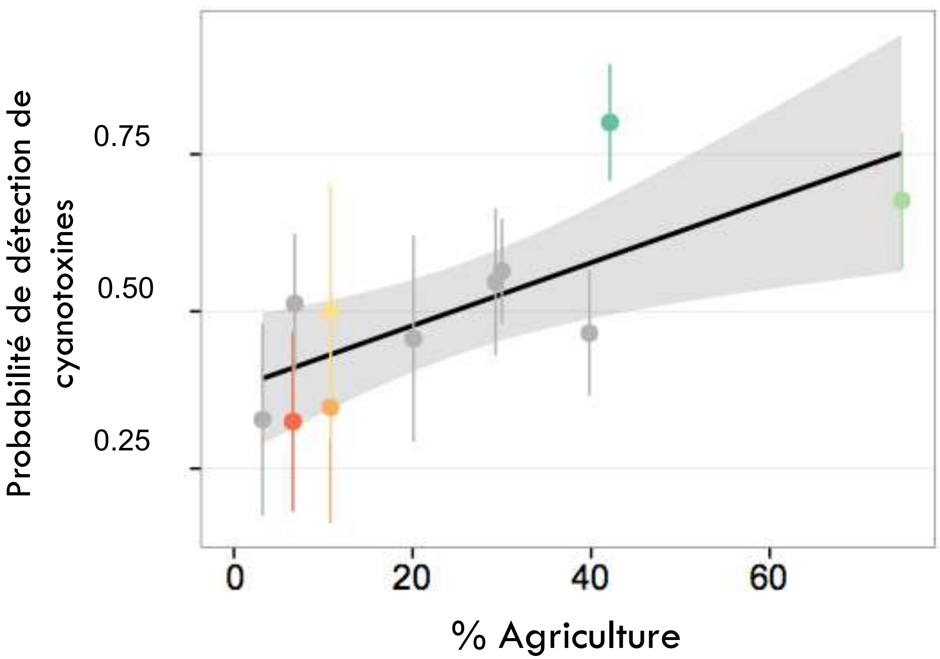


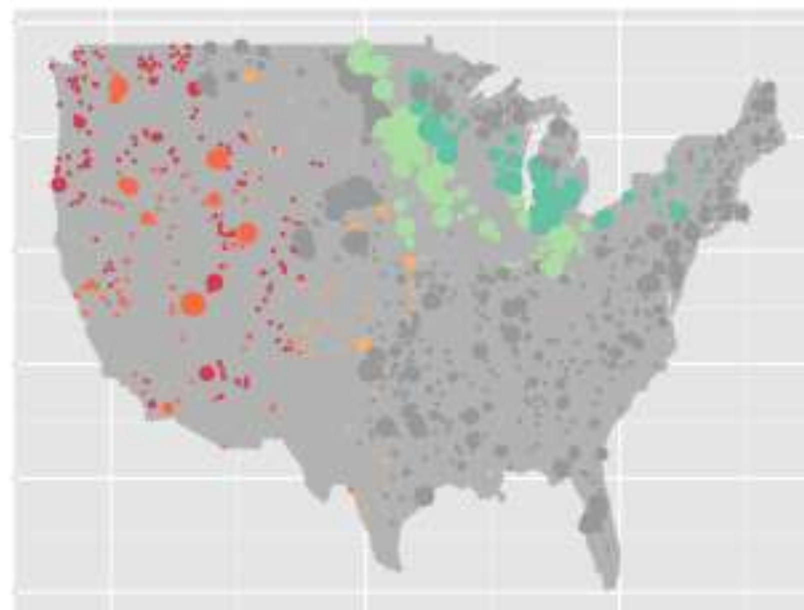


Risque de prolifération floraisons toxiques

Échelle régionale

➠ Explique 48 % de la variance

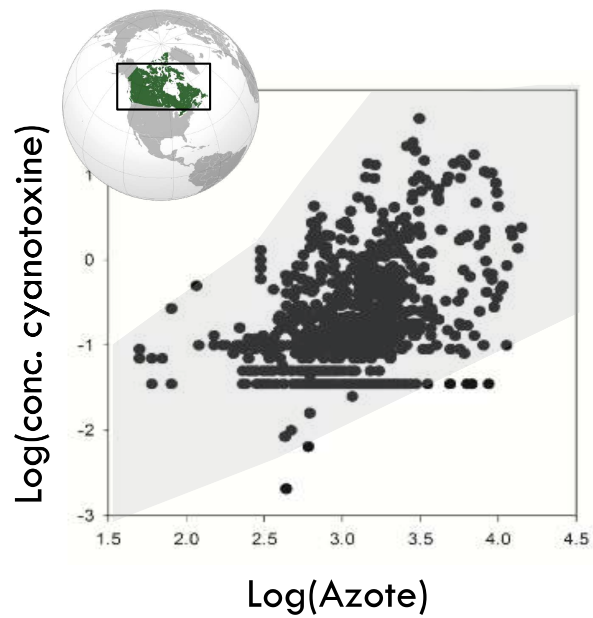




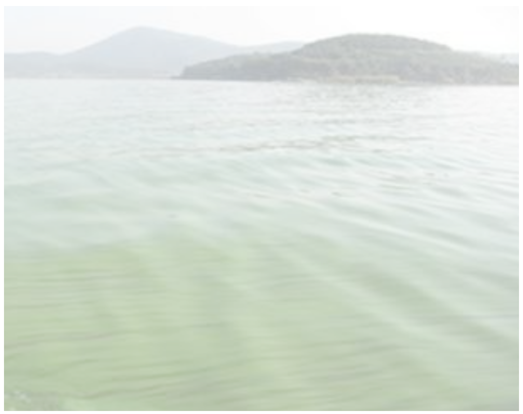
Travaux à venir!

Évaluer l'interaction espace-temps en utilisant les données 2007 & 2012 du NLA

➠ Tester si la structure spatio-temporelle explique la variabilité inexpliquée



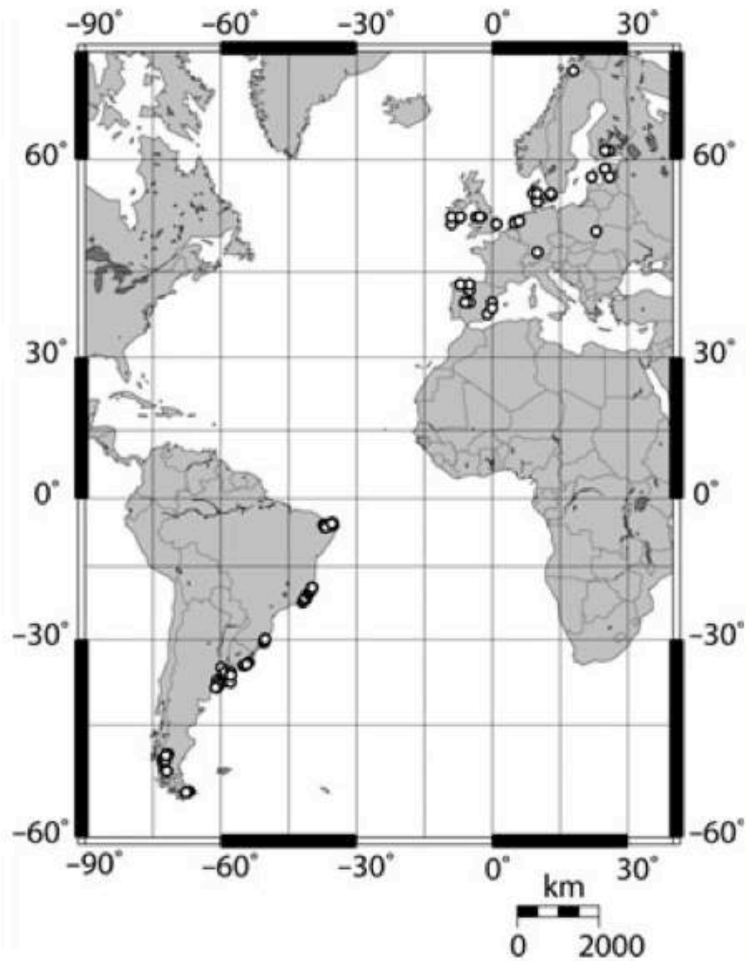
Merci!




Fonds de recherche sur la nature et les technologies Québec

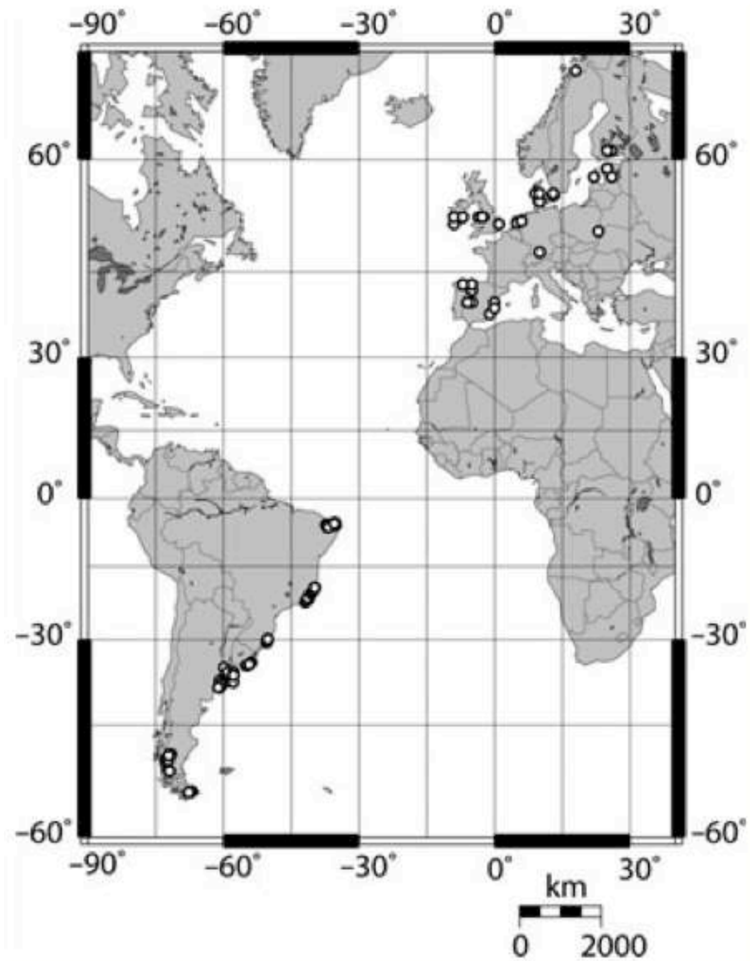
GRIL

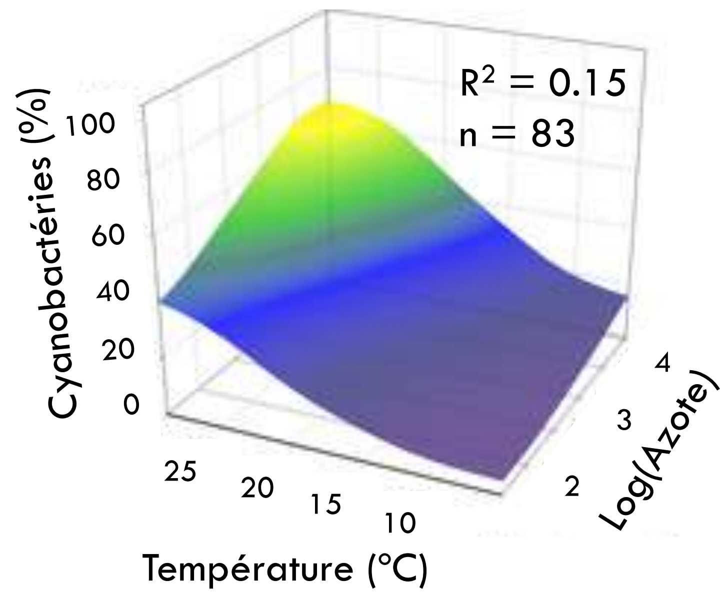
Causes de prolifération à travers le paysage



Kosten *et al*. (2011)

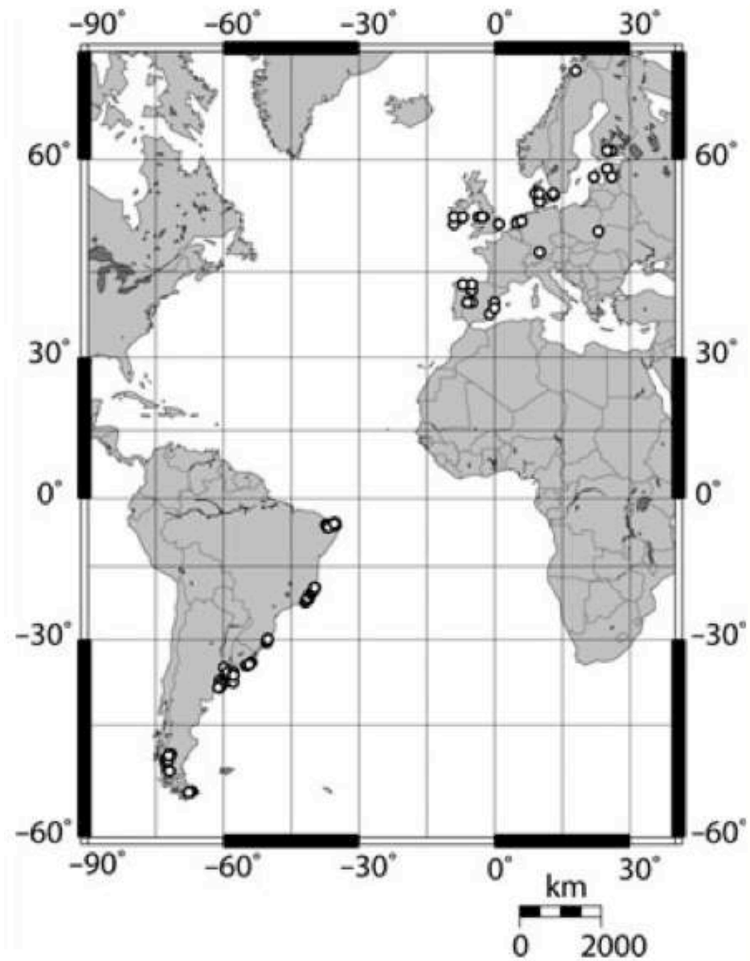
Réponses à travers le paysage

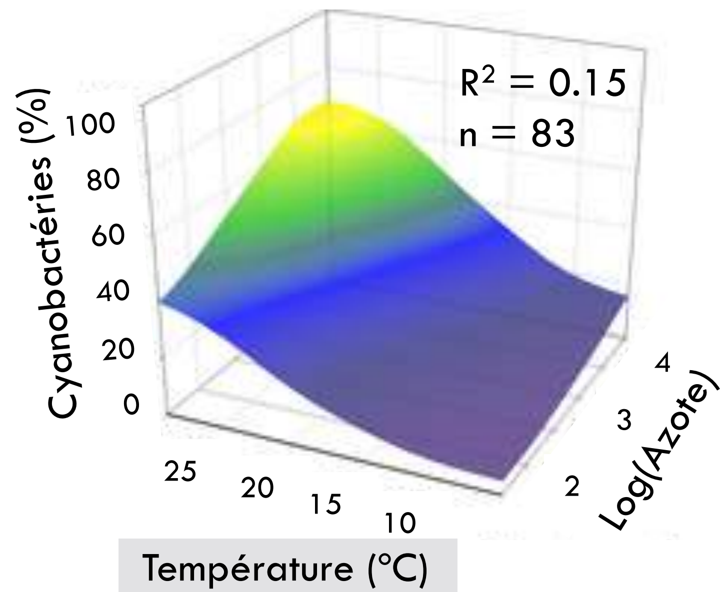




Kosten *et al.* (2011)

Réponses à travers le paysage

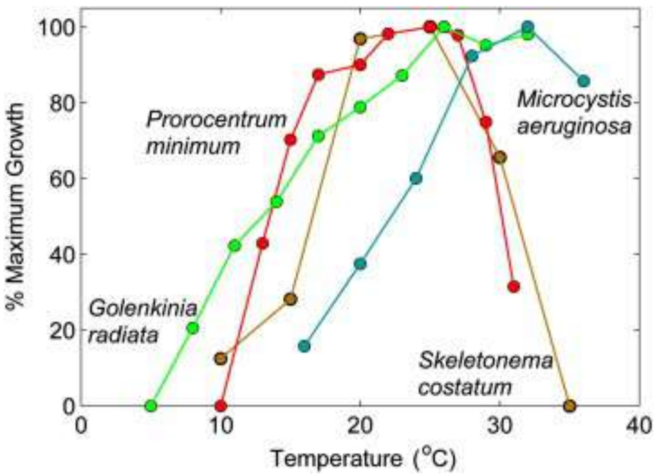


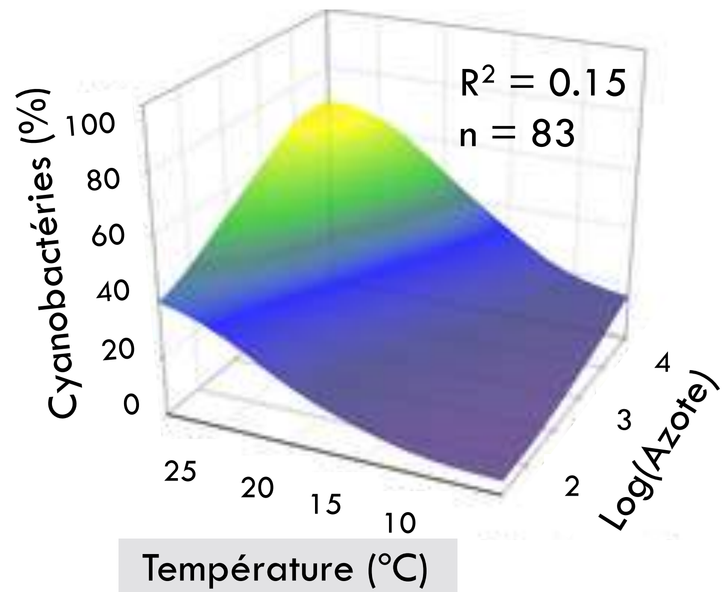


Kosten *et al.* (2011)

Réponses à travers le paysage

(1) Effet direct

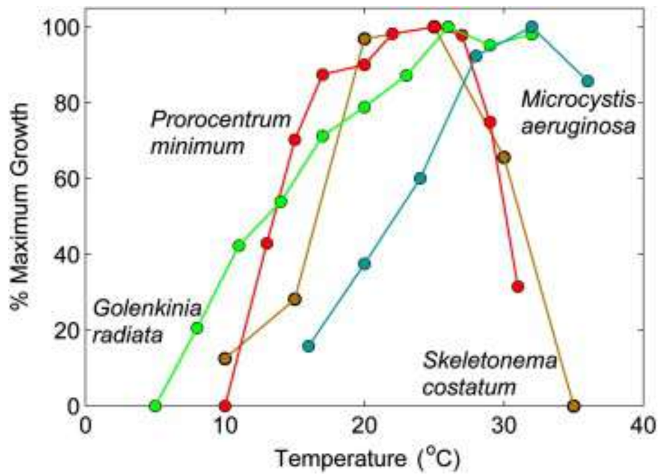




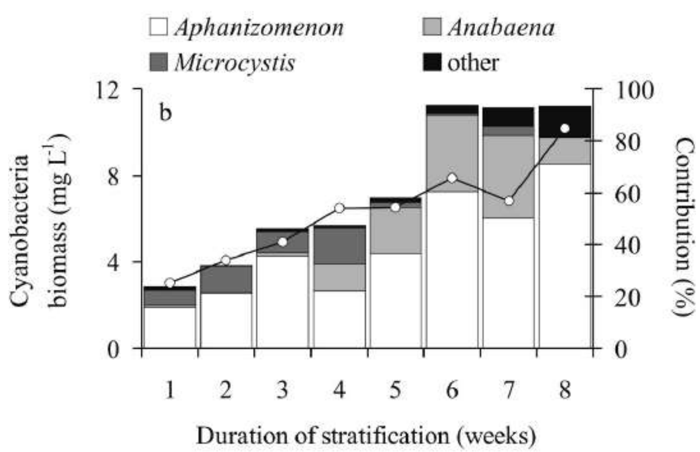
Kosten *et al.* (2011)

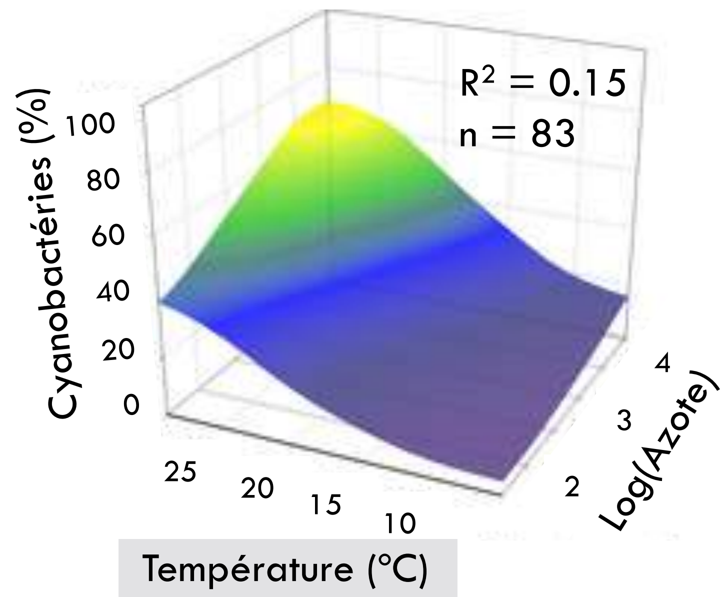
Réponses à travers le paysage

1 Effet direct



2 Effet indirect





Kosten *et al.* (2011)

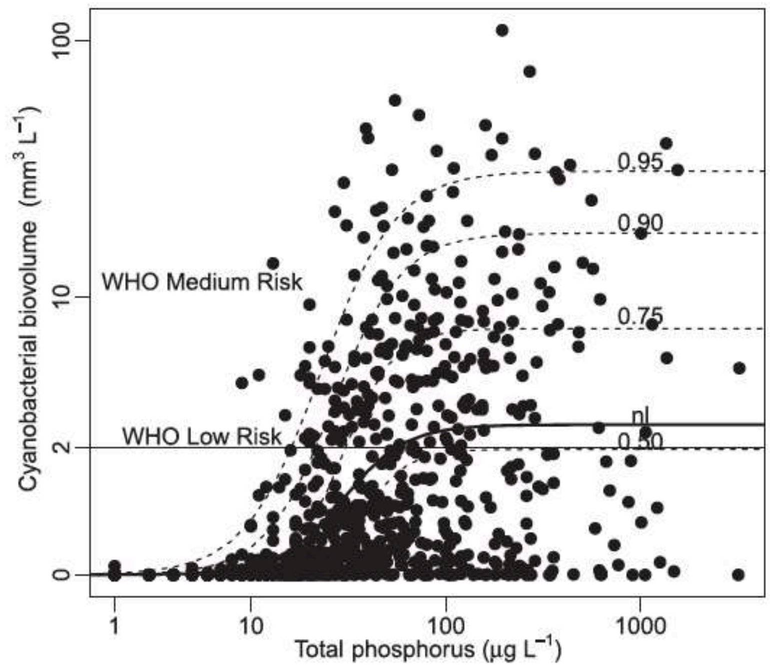
Dépassement des limites de l'OMS

> 1500 lacs couvrant quatre régions biogéographiques européennes et 16 pays

Carvalho *et al.* (2013)

Dépassement des limites de l'OMS

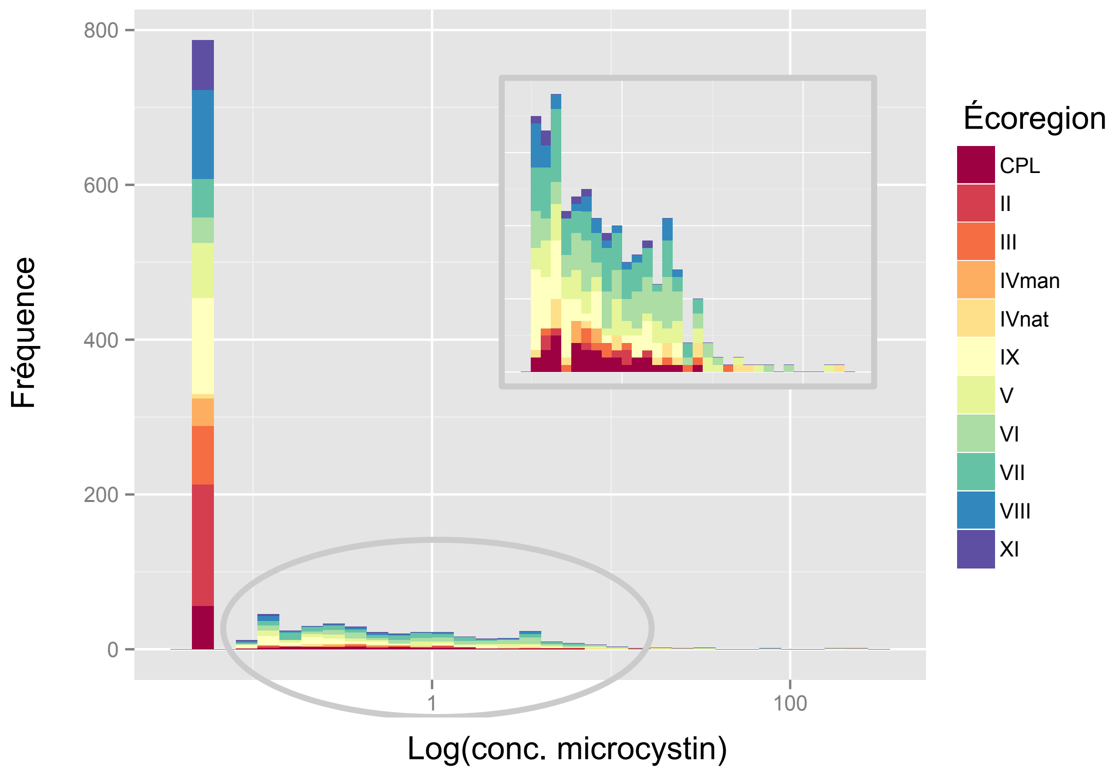
> 1500 lacs couvrant quatre régions biogéographiques européennes et 16 pays



Carvalho *et al.* (2013)

Toxicité des floraisons de cyanobactéries le long d'un gradient spatial

Cyanotoxines trouvées au-dessus de la limite de détection dans seulement 32% des lacs



1 Prédire le risque de prolifération d'algues toxiques

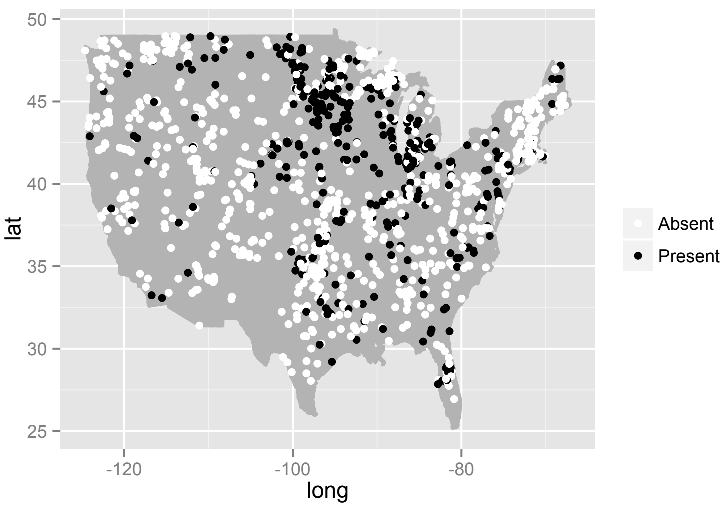
1 Prédire le risque de prolifération d'algues toxiques

Modèle zéro-altéré *(à obstacle)*

1 Prédire le risque de prolifération d'algues toxiques

Modèle zéro-altéré *(à obstacle)*

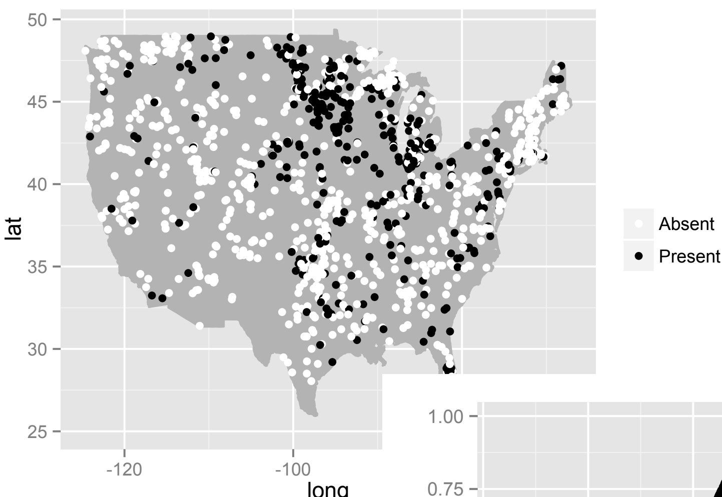
Partie binomiale
(n=1149)

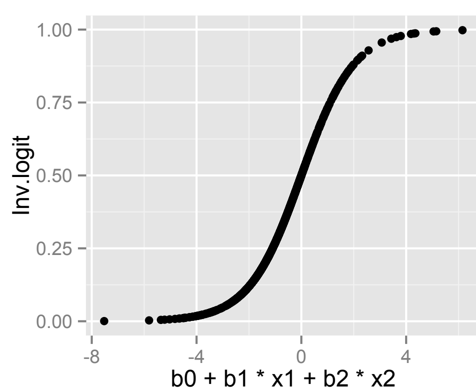


1 Prédire le risque de prolifération d'algues toxiques

Modèle zéro-altéré *(à obstacle)*

Partie binomiale
(n=1149)

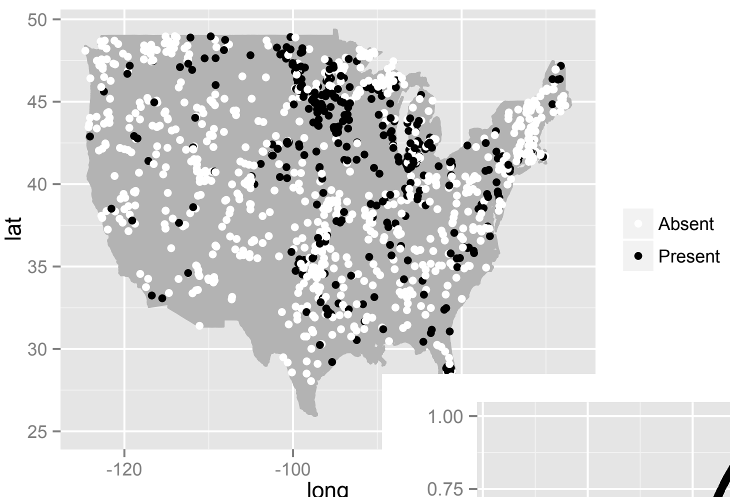


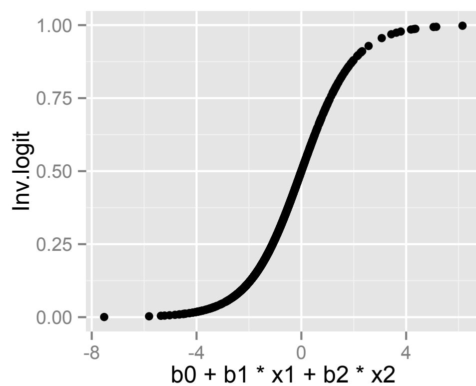


1 Prédire le risque de prolifération d'algues toxiques

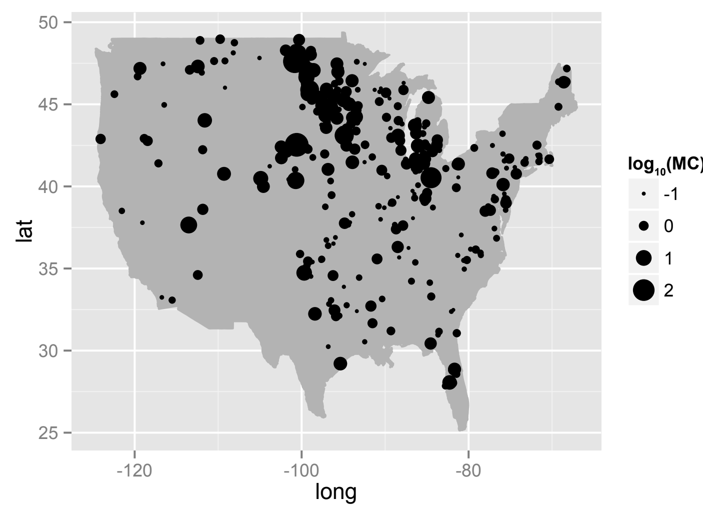
Modèle zéro-altéré *(à obstacle)*

Partie binomiale (n=1149)





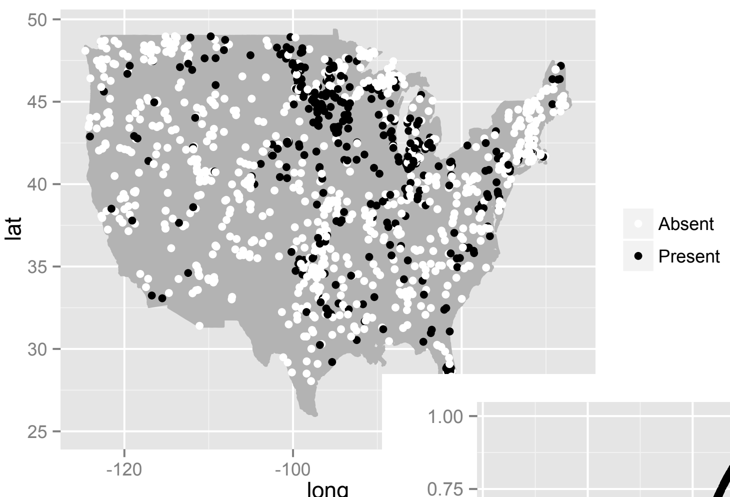
Partie zéro-tronquée (n=362)

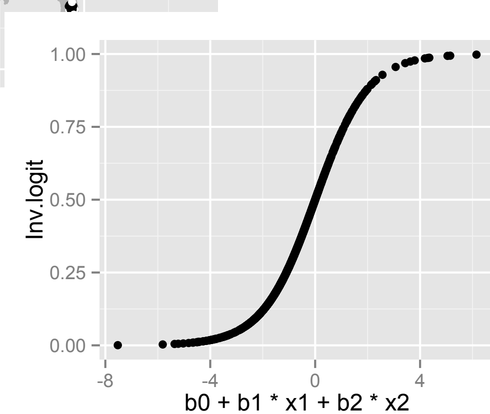


① Prédire le risque de prolifération d'algues toxiques

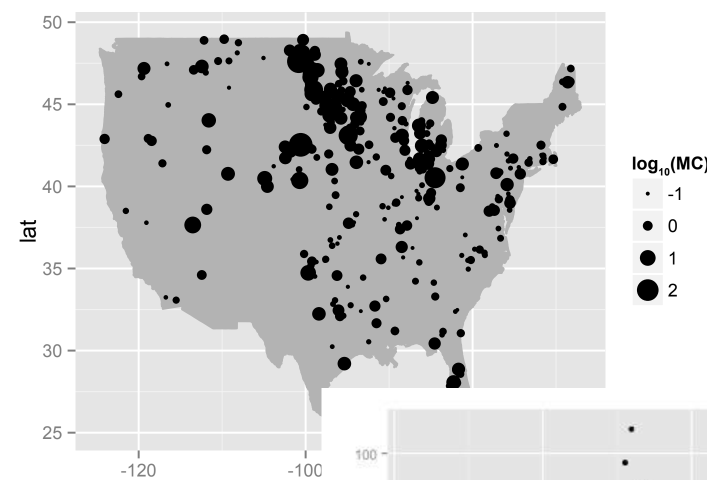
Modèle zéro-altéré *(à obstacle)*

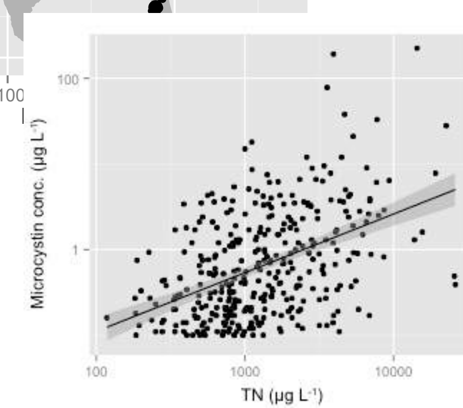
Partie binomiale
(n=1149)





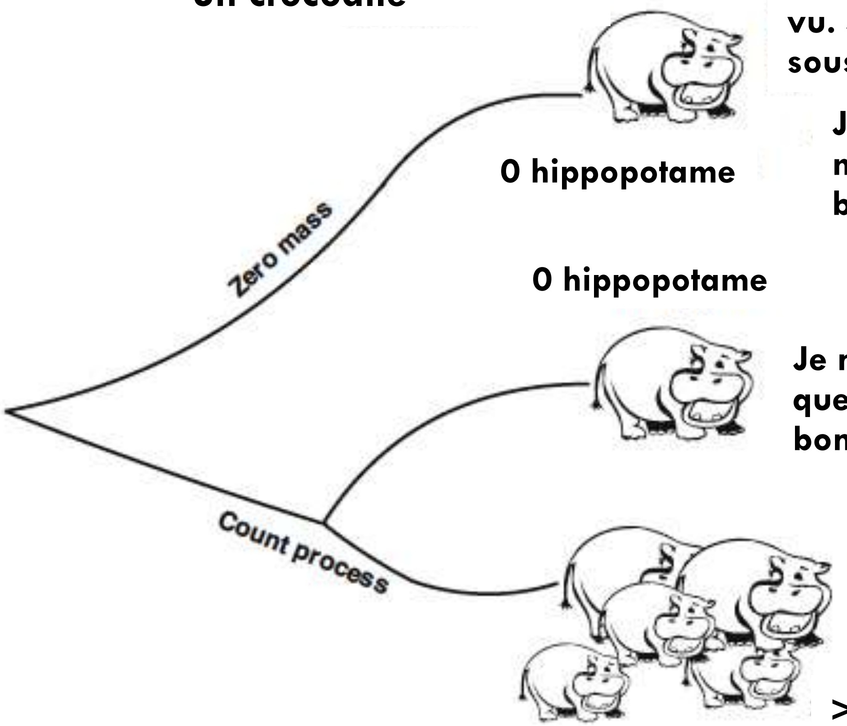
Partie zéro-tronquée
(n=362)





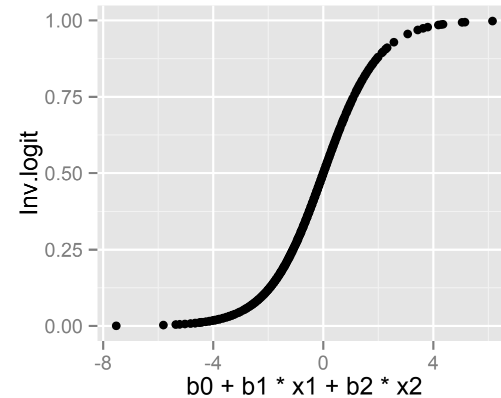
Modèle zéro-altéré (*à obstacle*)

Tu croyais que j'étais un crocodile



0 hippopotame

Tu ne m'as pas vu. J'étais juste sous l'eau! →

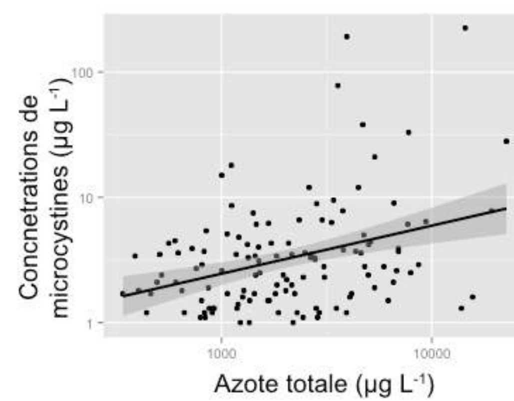


Je ne suis pas ici, mais l'habitat est bon

0 hippopotame

Je ne suis pas ici parce que l'habitat ne est pas bon

Nous voici →



>0 hippopotames

Zurr *et al.* (2009)

1 Prédire le risque de prolifération d'algues toxiques

Modèle zéro-altéré *(à obstacle)*

Partie binomiale
(n=1149)

1 Prédire le risque de prolifération d'algues toxiques

Modèle zéro-altéré *(à obstacle)*

Partie binomiale

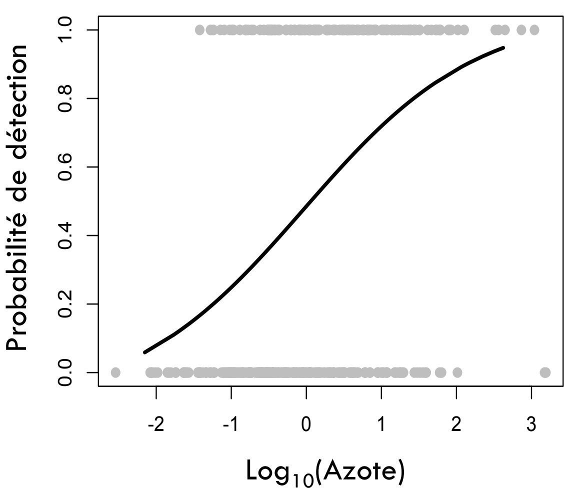
➡ Variabilité à l'échelle locale & régionale

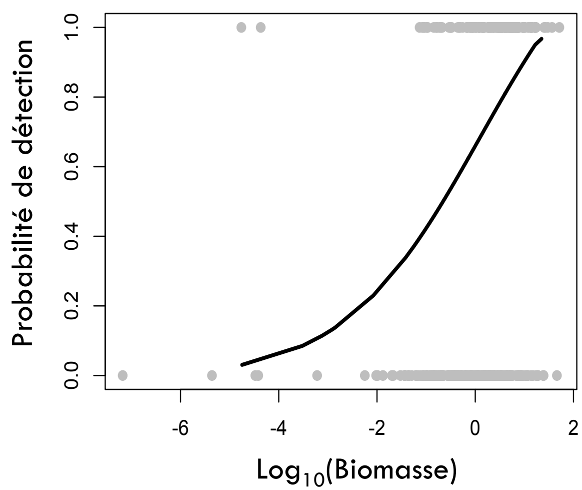
① Prédire le risque de prolifération d'algues toxiques

Modèle zéro-altéré *(à obstacle)*

Partie binomiale

➠ Variabilité à l'échelle locale & régionale





1 Prédire le risque de prolifération d'algues toxiques

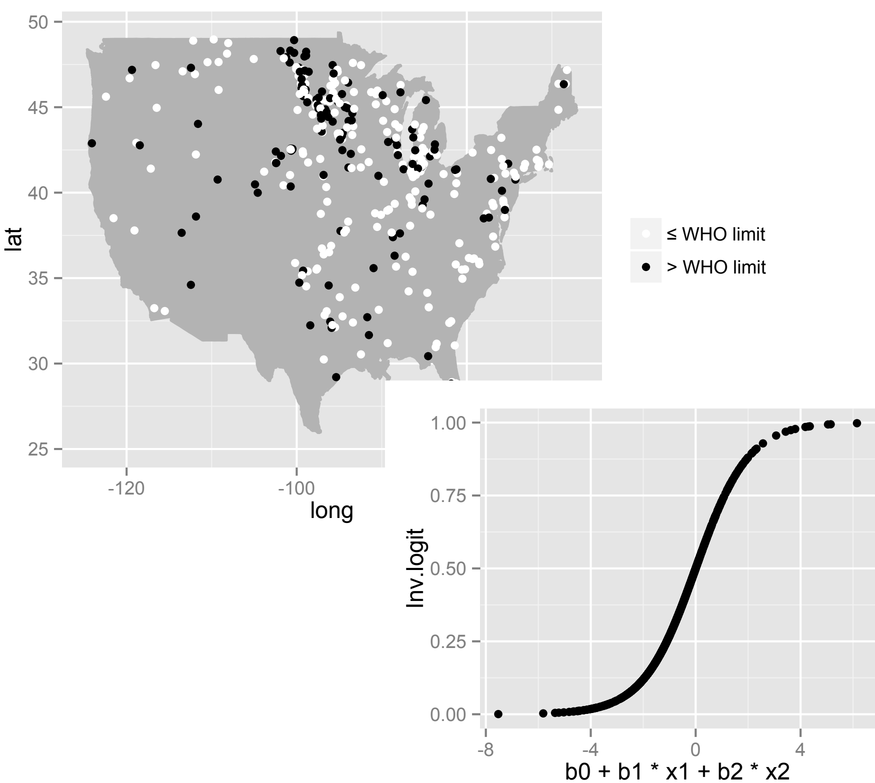
Modèle zéro-altéré *(à obstacle)*

Partie zéro-tronquée

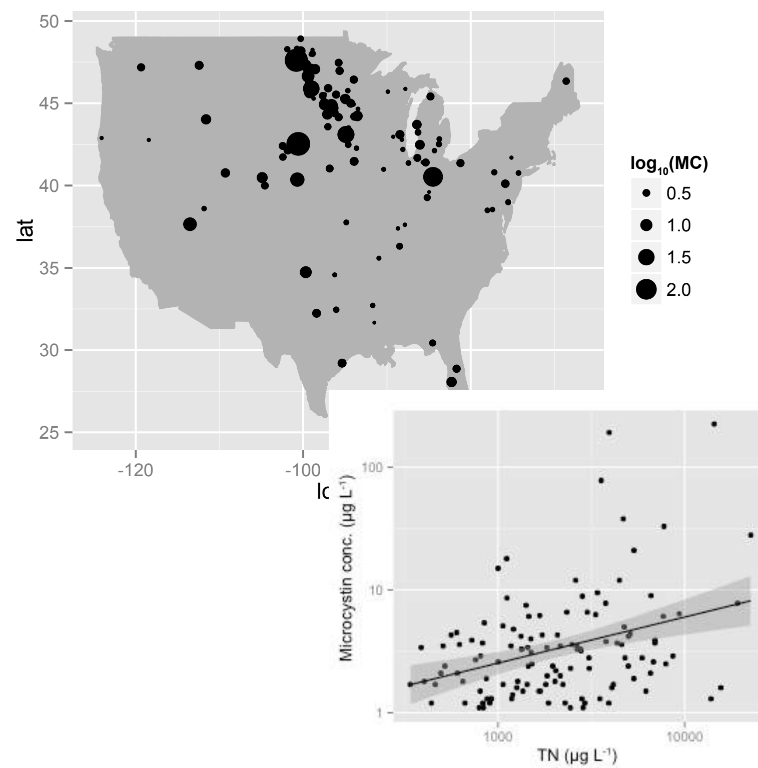
② Prédire le dépassement des limites de l'OMS

Modèle zéro-altéré *(à obstacle)*

Partie binomiale
(n=362)



Partie OMS-tronquée
(n=125)



2 Prédire le dépassement des limites de l'OMS

Modèle zéro-altéré *(à obstacle)*

Partie binomiale

- ➠ Variabilité à l'échelle locale SEULEMENT
- ➠ Aucune interaction inter-échelles (IIE)

Partie OMS-tronquée

- ➠ Variabilité à l'échelle locale SEULEMENT
- ➠ Aucune IEE

2 Prédire le dépassement des limites de l'OMS

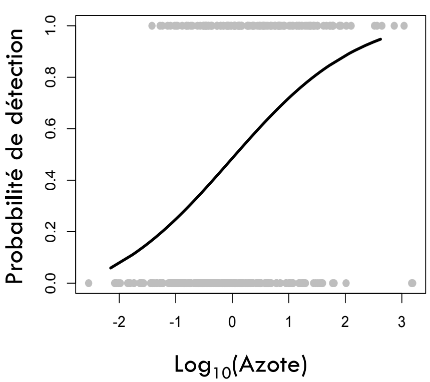
Modèle zéro-altéré *(à obstacle)*

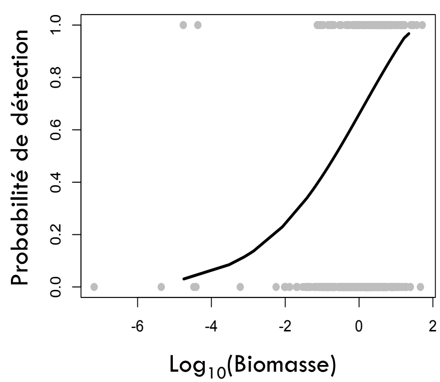
Partie binomiale

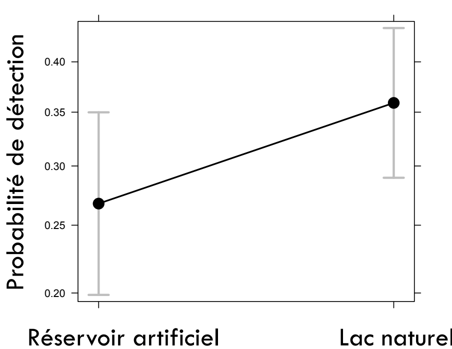
- ➠ Variabilité à l'échelle locale SEULEMENT
- ➠ Aucune interaction inter-échelles (IIE)

Partie OMS-tronquée

- ➠ Variabilité à l'échelle locale SEULEMENT
- ➠ Aucune IEE







② Prédire le dépassement des limites de l'OMS

Modèle zéro-altéré *(à obstacle)*

Partie binomiale

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Partie OMS-tronquée

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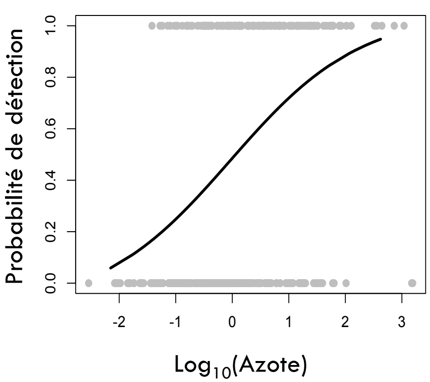
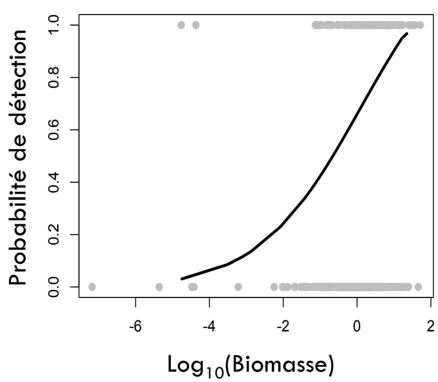
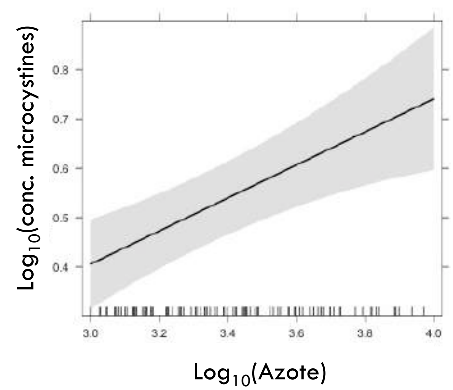
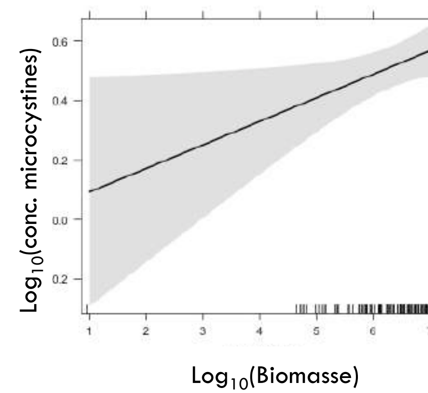
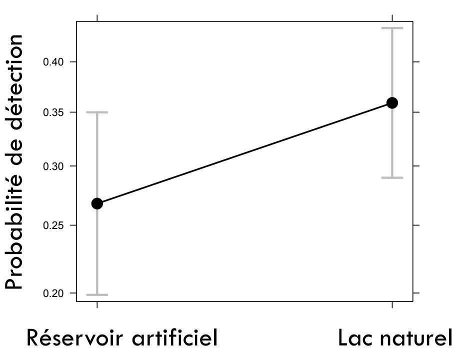








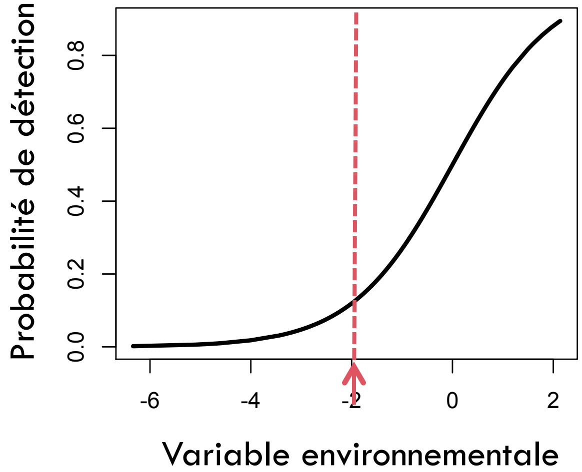


Conclusion

Conclusion

70% des lacs sous la limite de détection

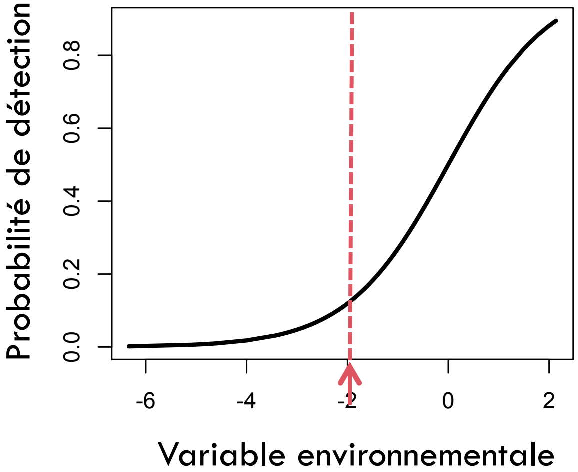
1



Conclusion

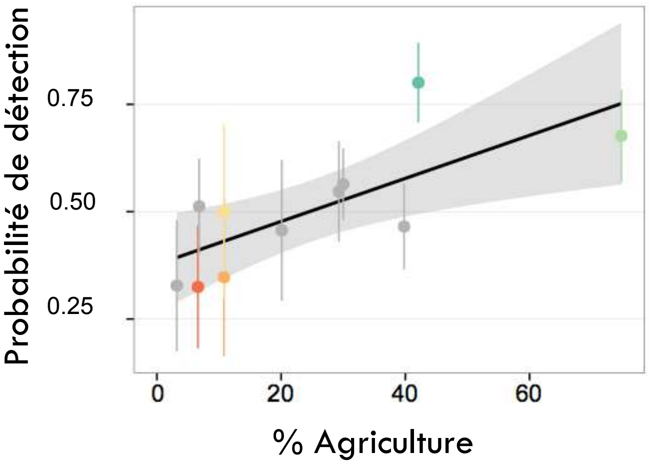
1

70% des lacs sous la limite de détection



2

Interaction inter-échelles



Conclusion

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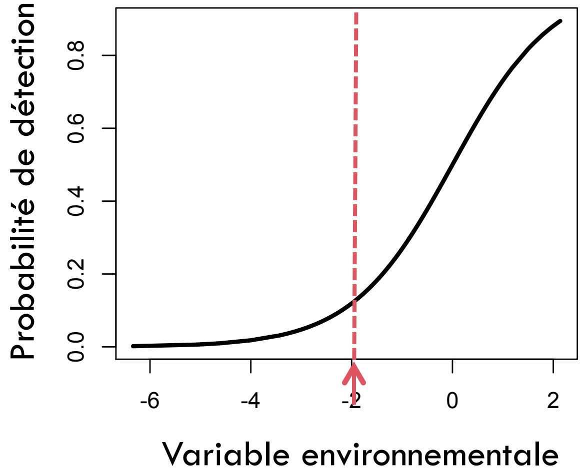
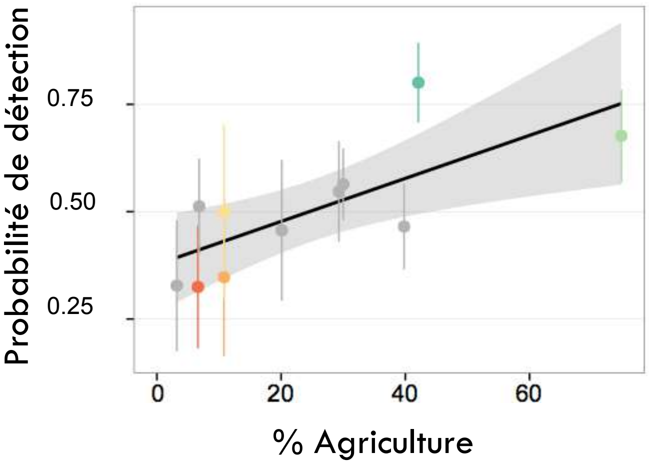
70% des lacs sous la limite de détection

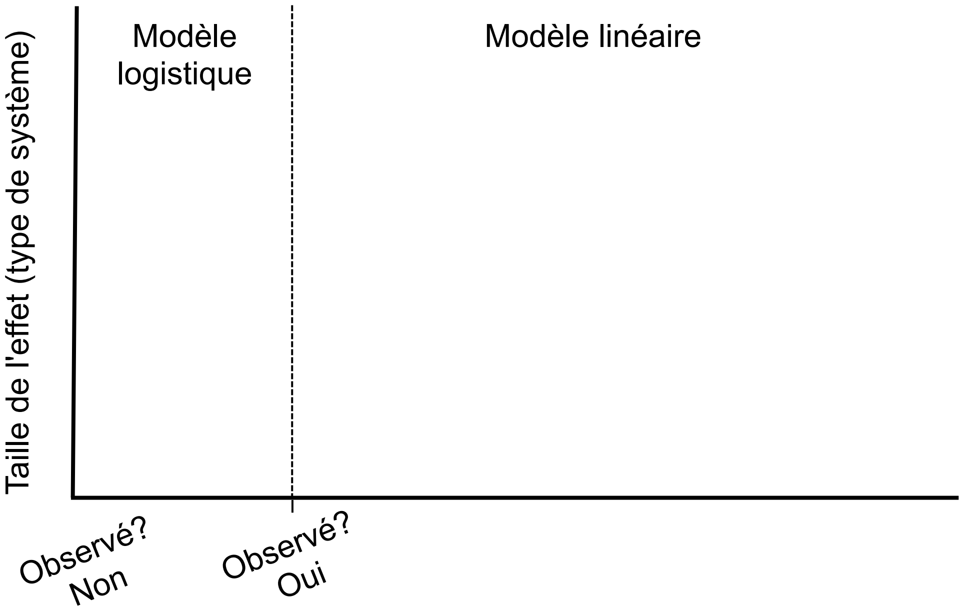


2

Interaction inter-échelles



3



Conclusion

1

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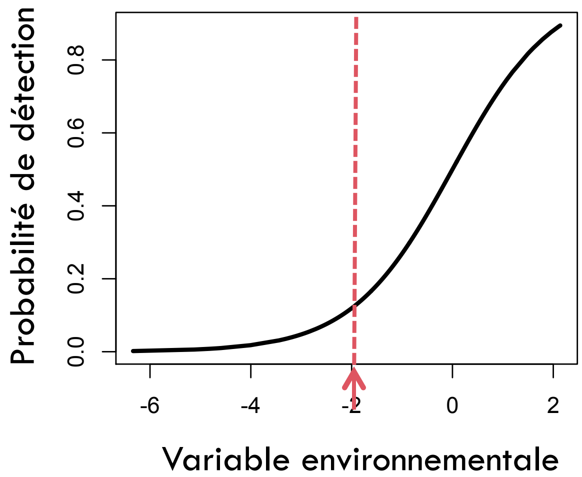
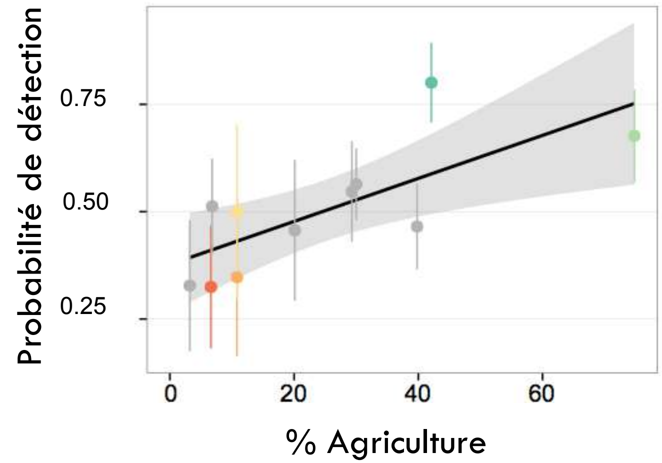
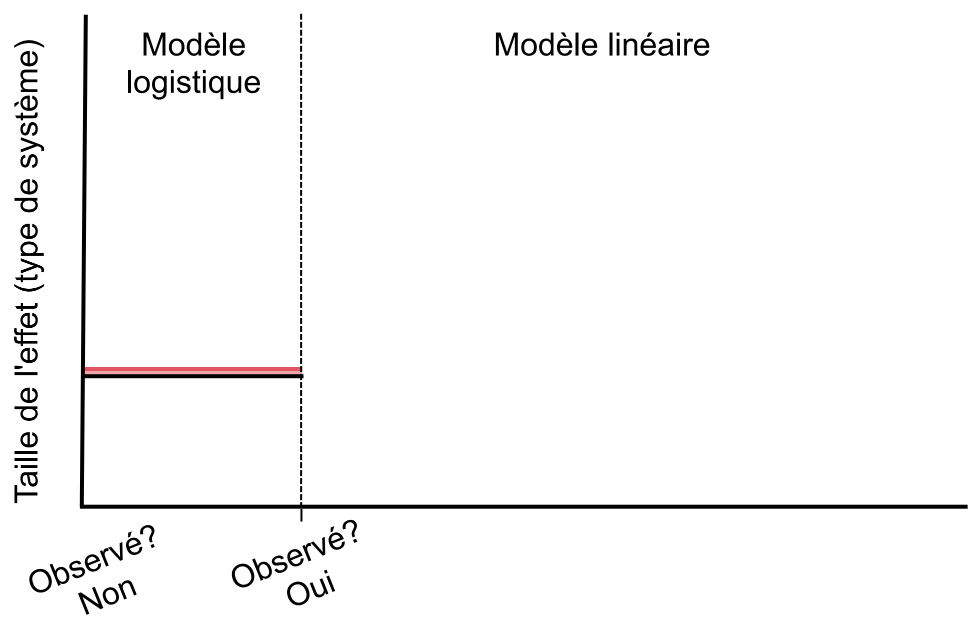


2

Interaction inter-échelles



3



Conclusion

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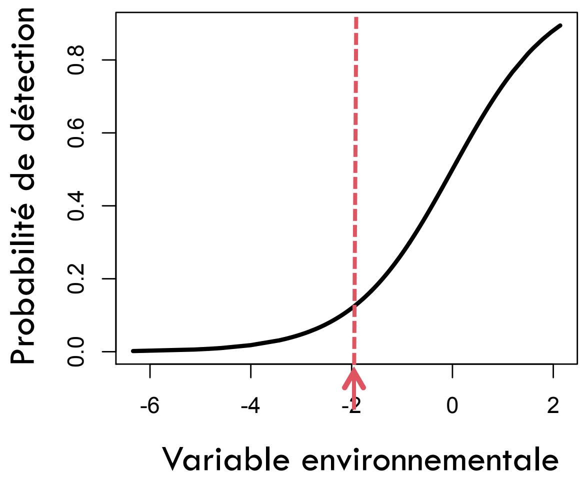
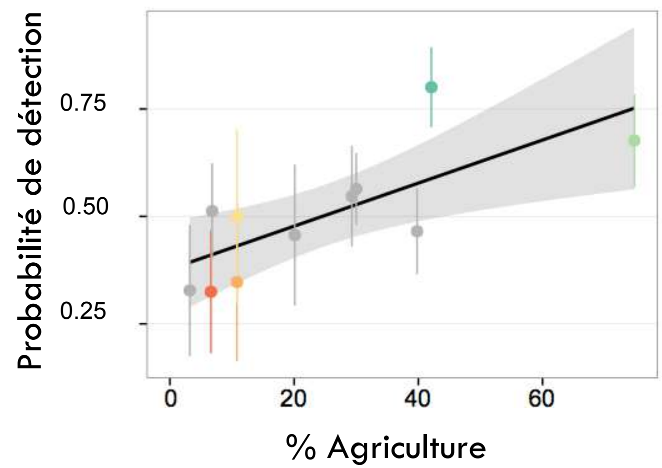


2

Interaction inter-échelles



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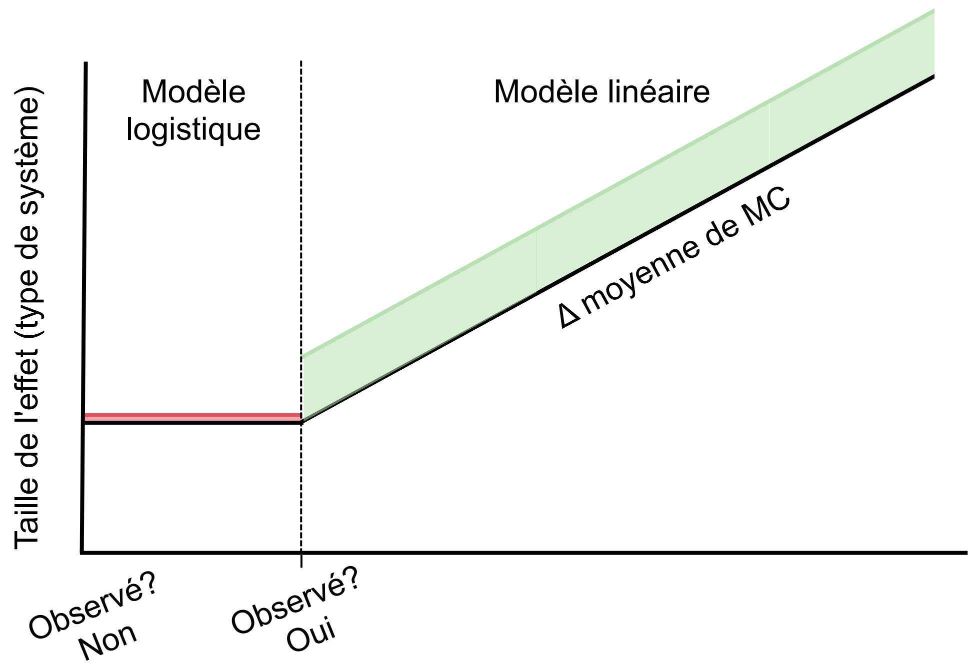

Conclusion

70% des lacs sous la limite de détection

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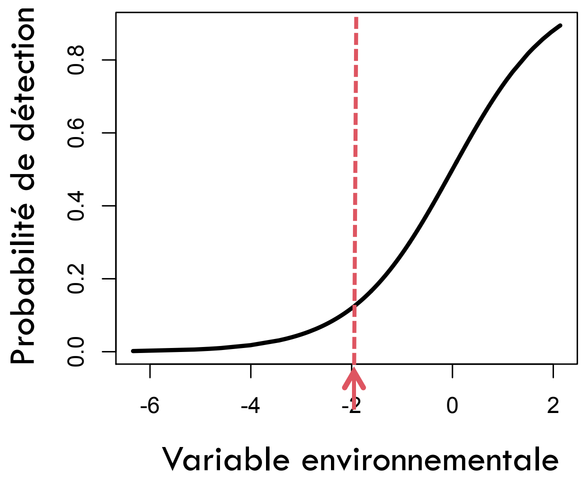
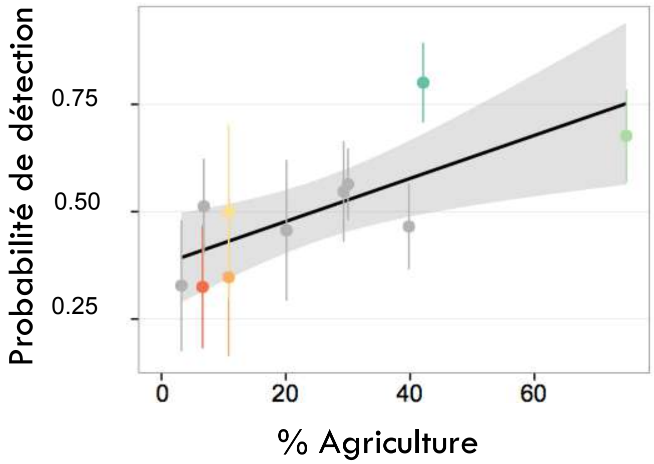


Interaction inter-échelles

2



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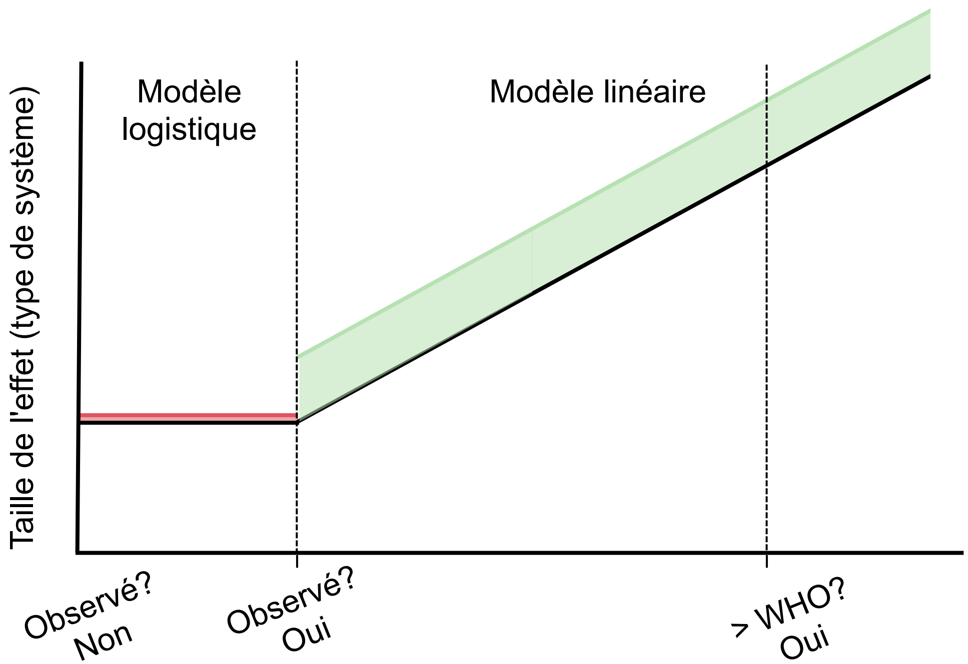
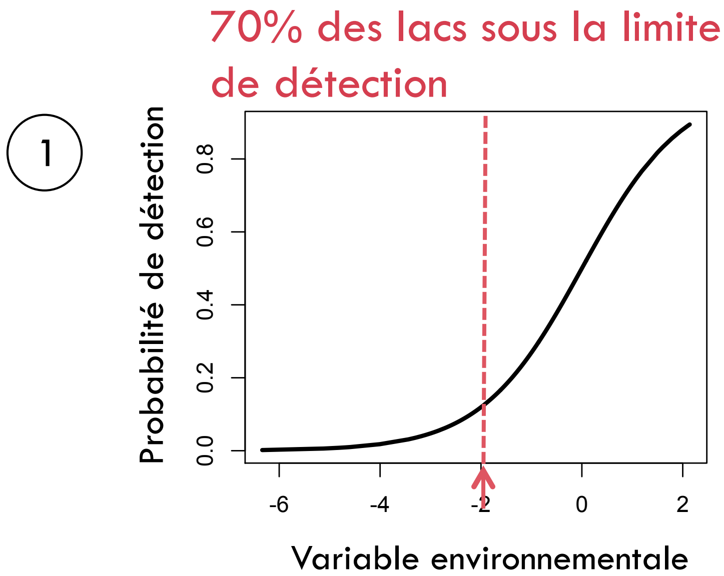
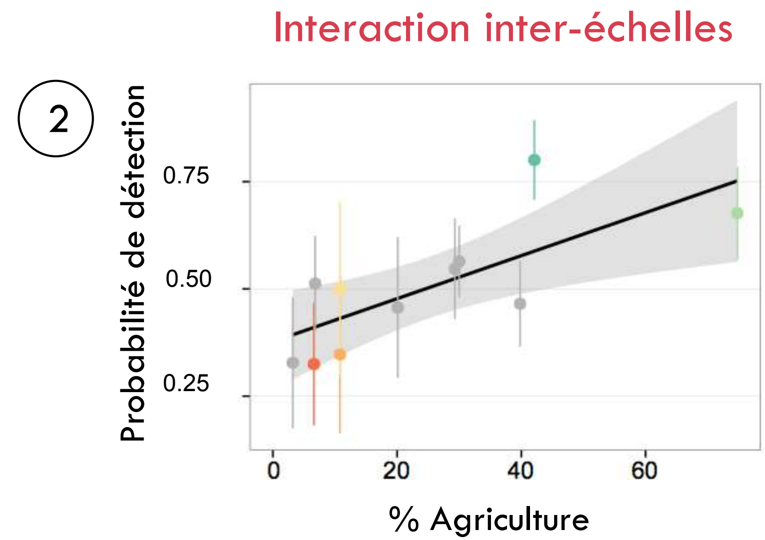
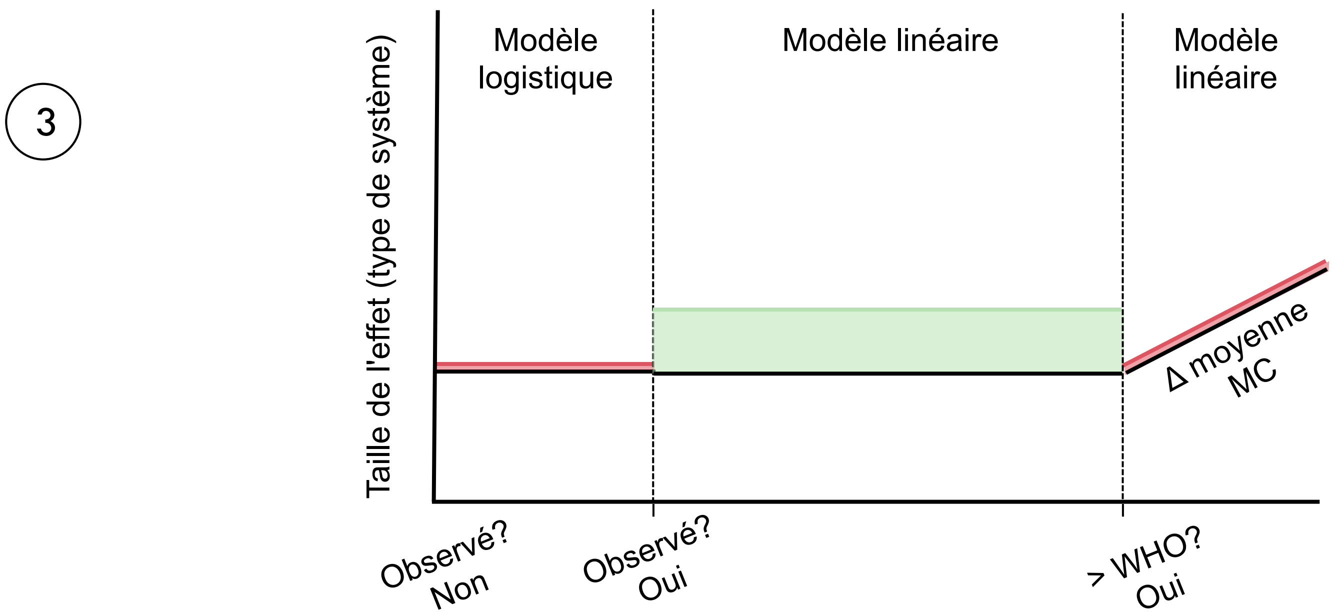


Conclusion


1
70% des lacs sous la limite de détection
Probabilité de détection
0.0
0.2
0.4
0.6
0.8
-6
-4
-2
0
2
Variable environnementale


2
Interaction inter-échelles
Probabilité de détection
0.25
0.50
0.75
0
20
40
60
% Agriculture


3
Taille de l'effet (type de système)
Modèle logistique
Modèle linéaire
Modèle linéaire
Δ moyenne MC
Observé? Non
Observé? Oui
> WHO? Oui