Paleolimnological records provide no evidence of long-term eutrophication of three lakes in Glacier National Park (Northern Rocky Mountains) despite ongoing environmental changes

Brooke Bain-White , Ashley P. Ballantyne,
Cale A.C. Gushulak, Peter R. Leavitt, James J. Elser

Glacier National Park

Chris Downs

University of Montana

Dr. Ashley Ballantyne

Dr. Bob Hall

Dr. Philip Higuera

Dr. Jill Baron

Dr. Arthur Endsley

Dr. James J. Elser

Dr. Ben Colman

Dylan White

Matt Young

University of Regina

Dr. Peter Leavitt

Ryan Rimas

University of Manitoba

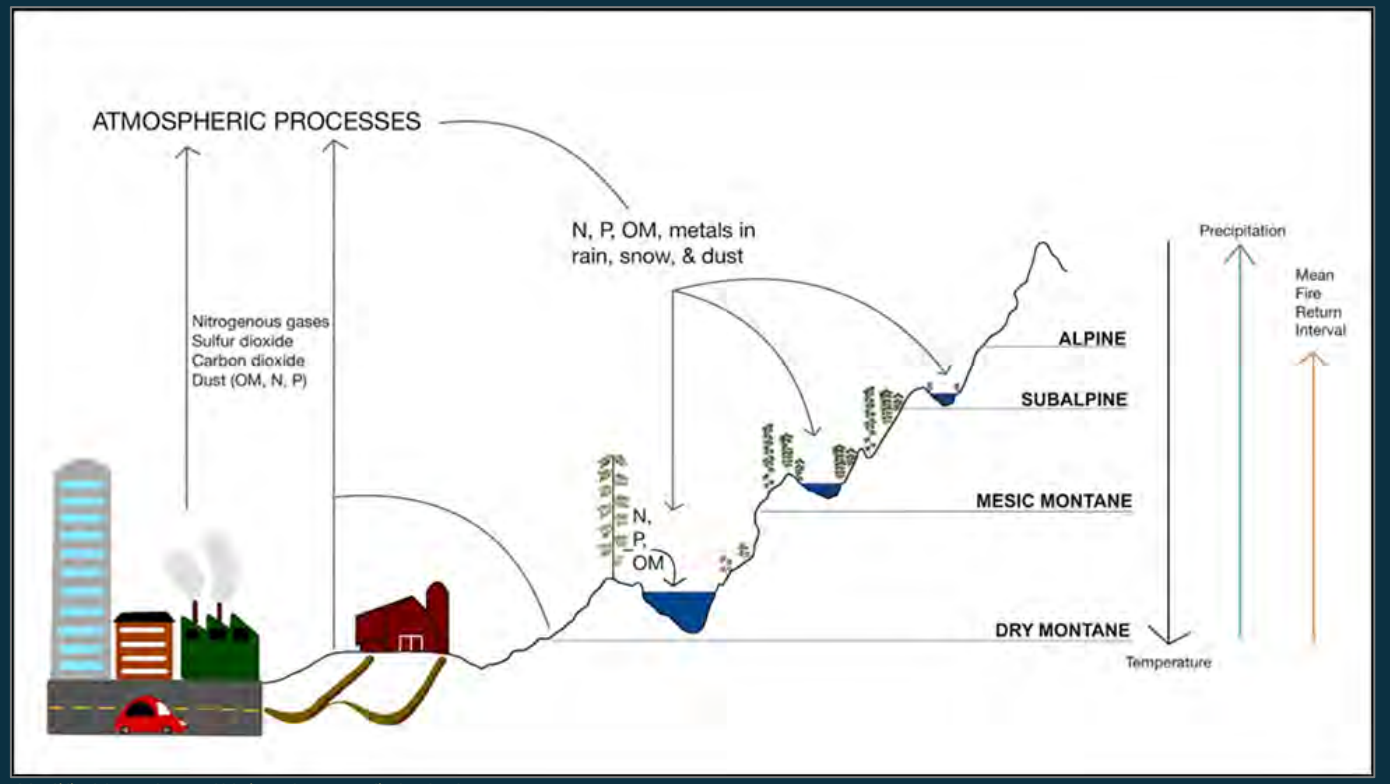
Dr. Cale Gushlack

University of Arkansas

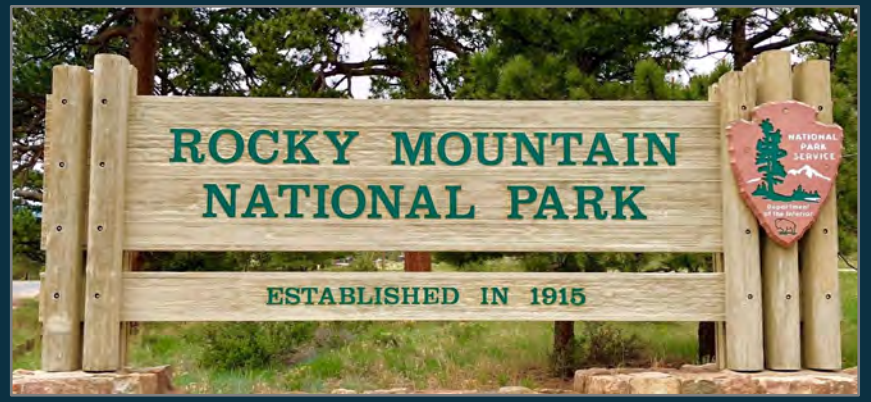
Nellie Little

Nutrient enrichment may occur by way of…

- Atmospheric N deposition
- Climate change
  - More dust deposition
  - Glacial retreat
- Wildfire
- Development



Modified from: https://doi.org/10.1016/j.gloplacha.2019.04.001



Nutrients and warming interact to force mountain lakes into unprecedented ecological states

Isabella A. Oleksy[1,2], Jill S. Baron[3,1], Peter R. Leavitt[4,5] and Sarah A. Spaulding[6]

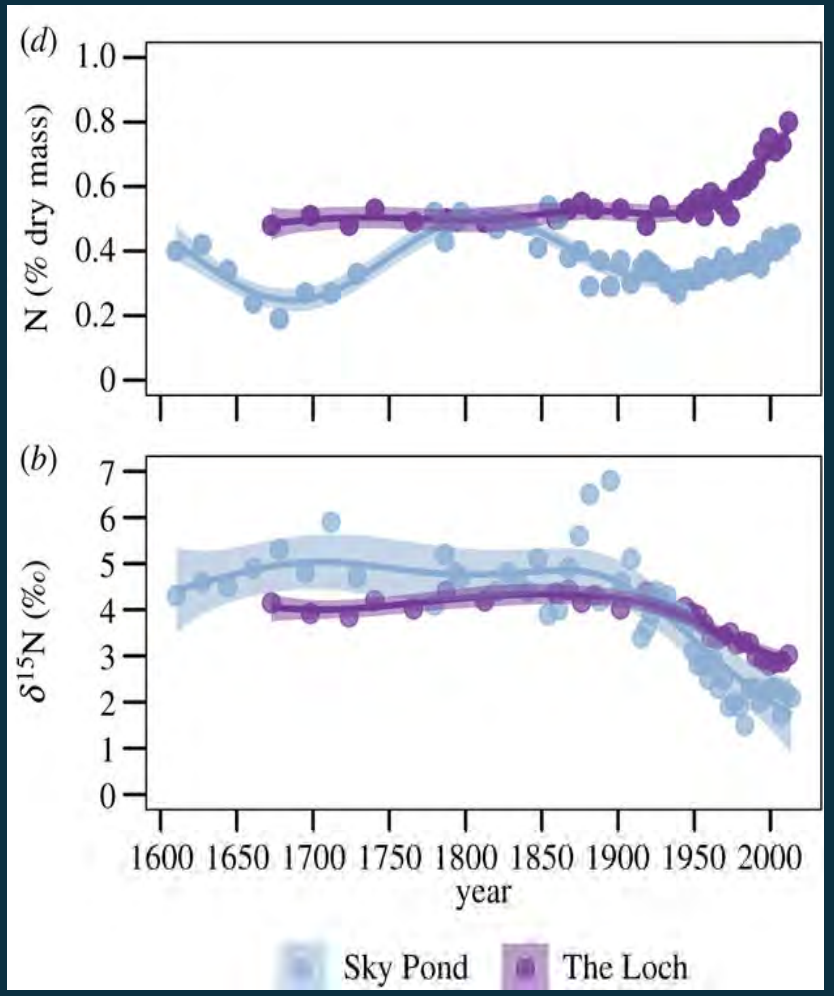


Image sources: https://www.nps.gov/articles/loch-vale.htm
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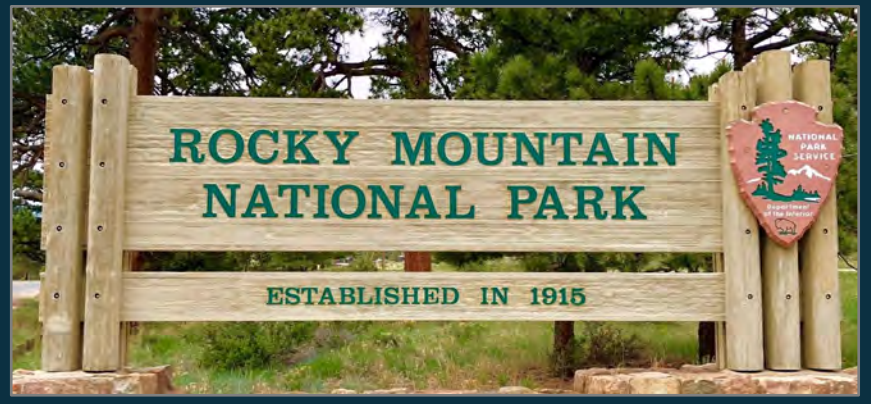

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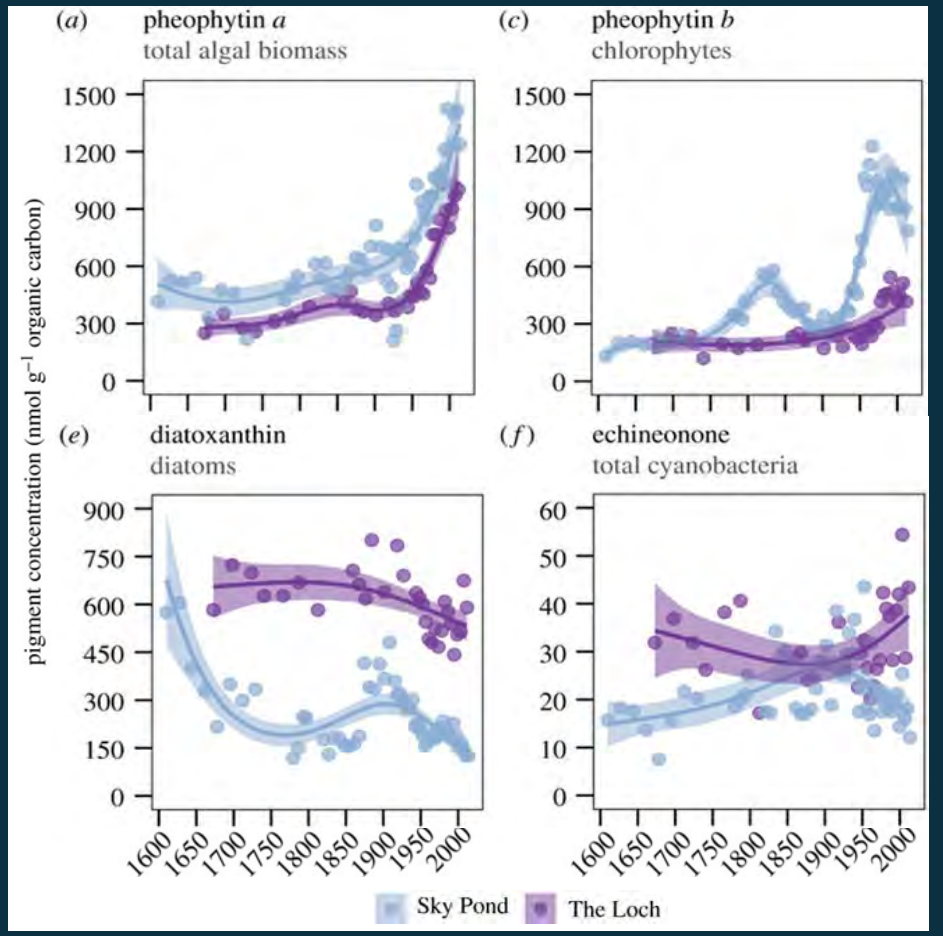

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https://www.usgs.gov/media/images/loch-vale-lake-summer
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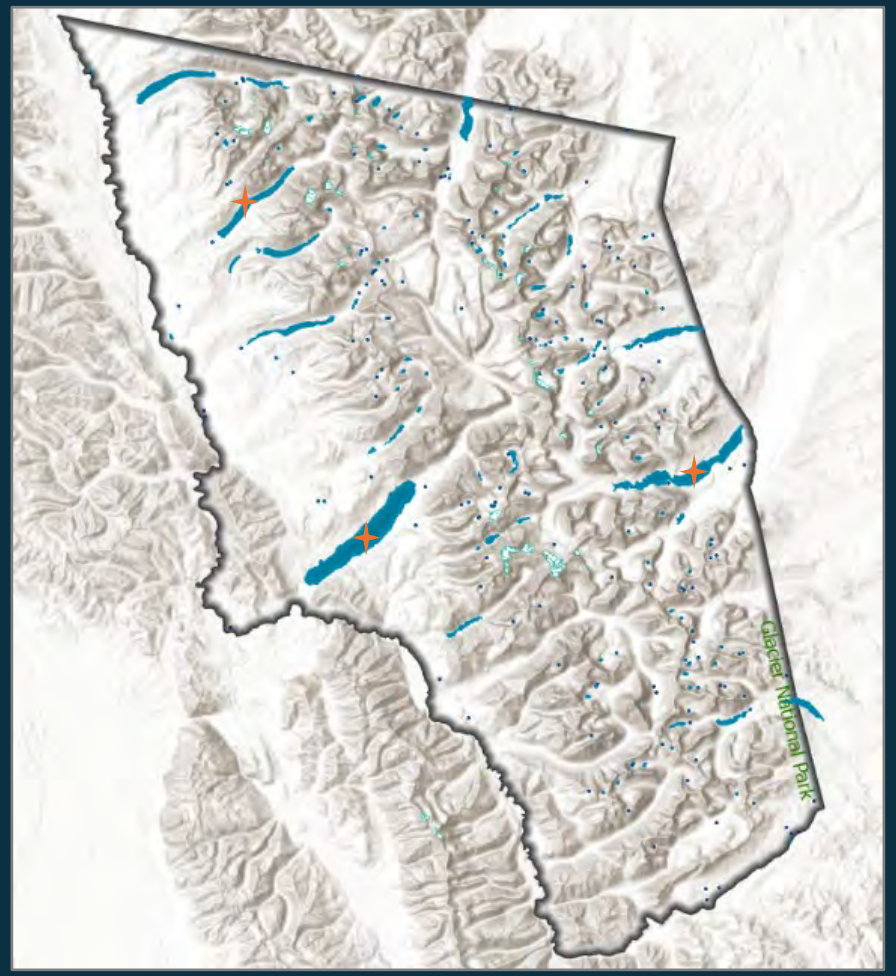
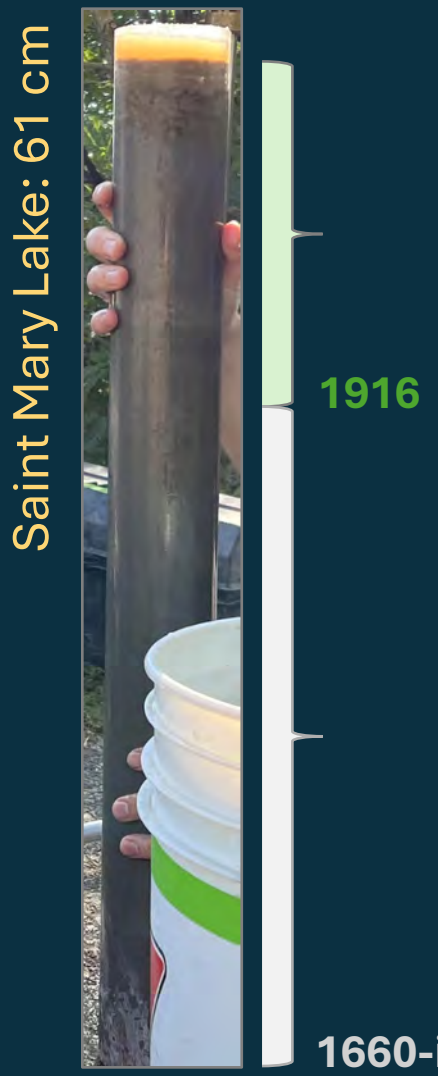
How have environmental changes affected total algal biomass and assemblage in mountain lakes in the Northern Rocky Mountains?





University of Regina

UCDAVIS Stable Isotope Facility

PEARL
Paleoecological Environmental Assessment & Research Laboratory

Thanks Montana Water Center!

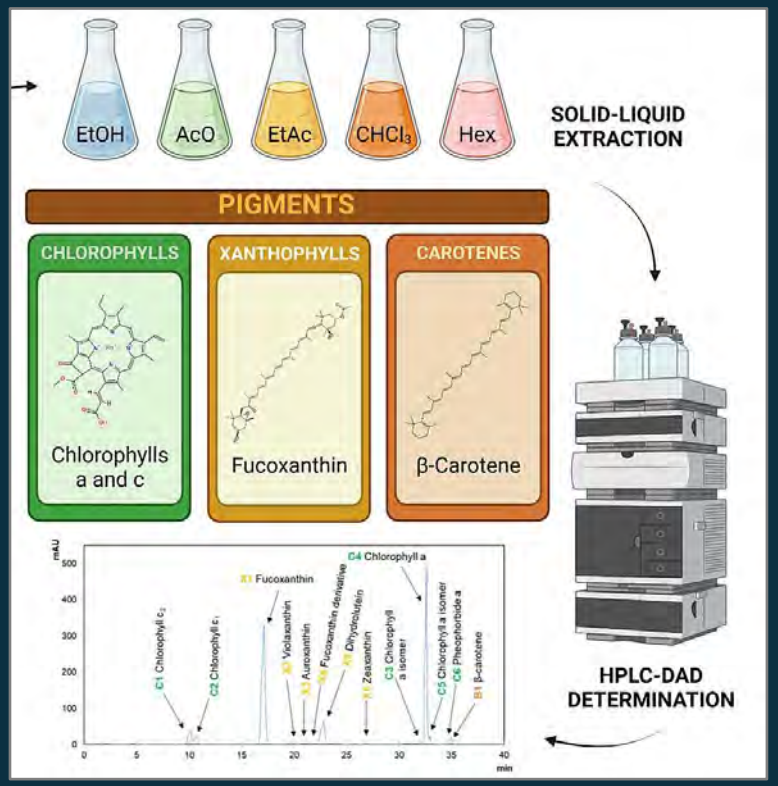
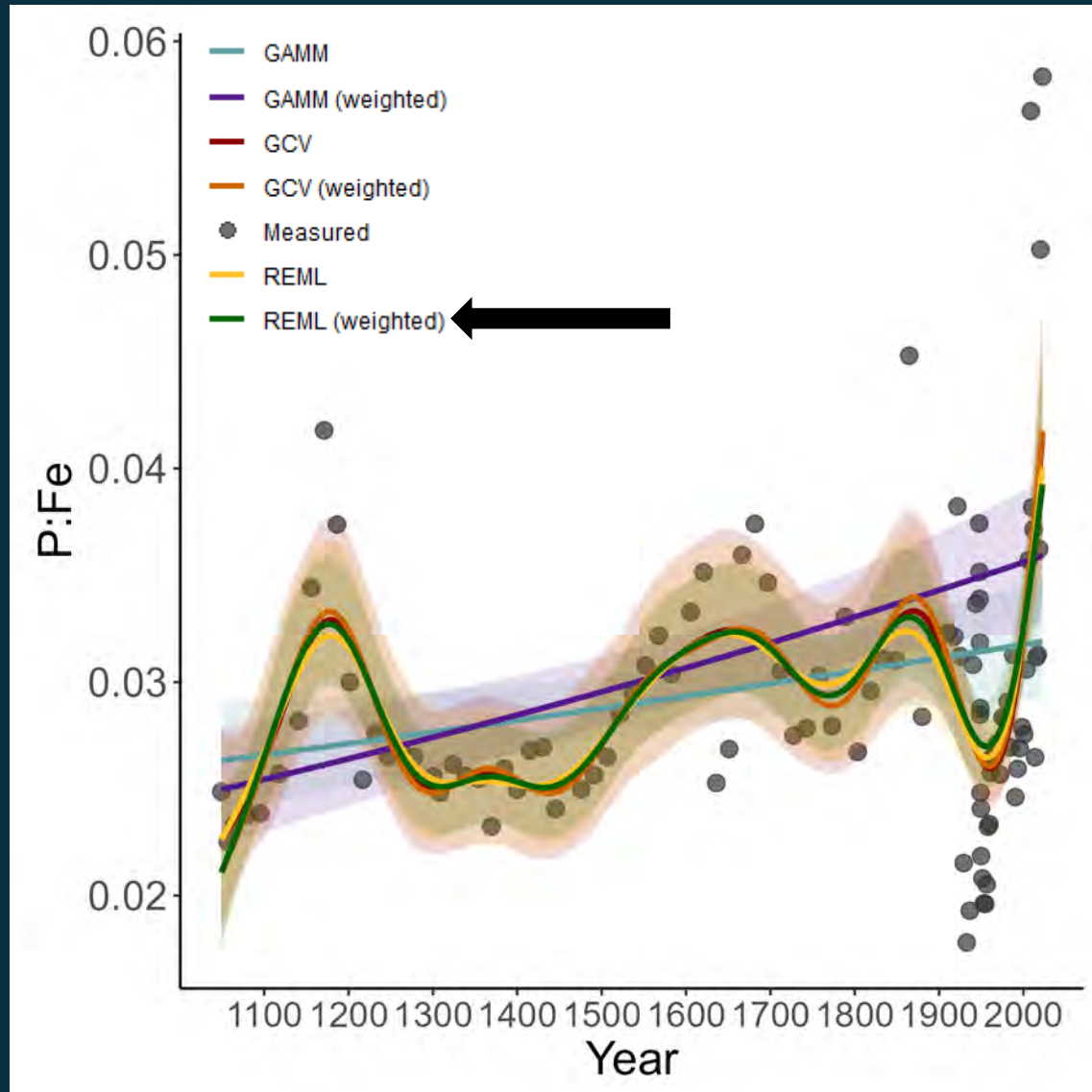


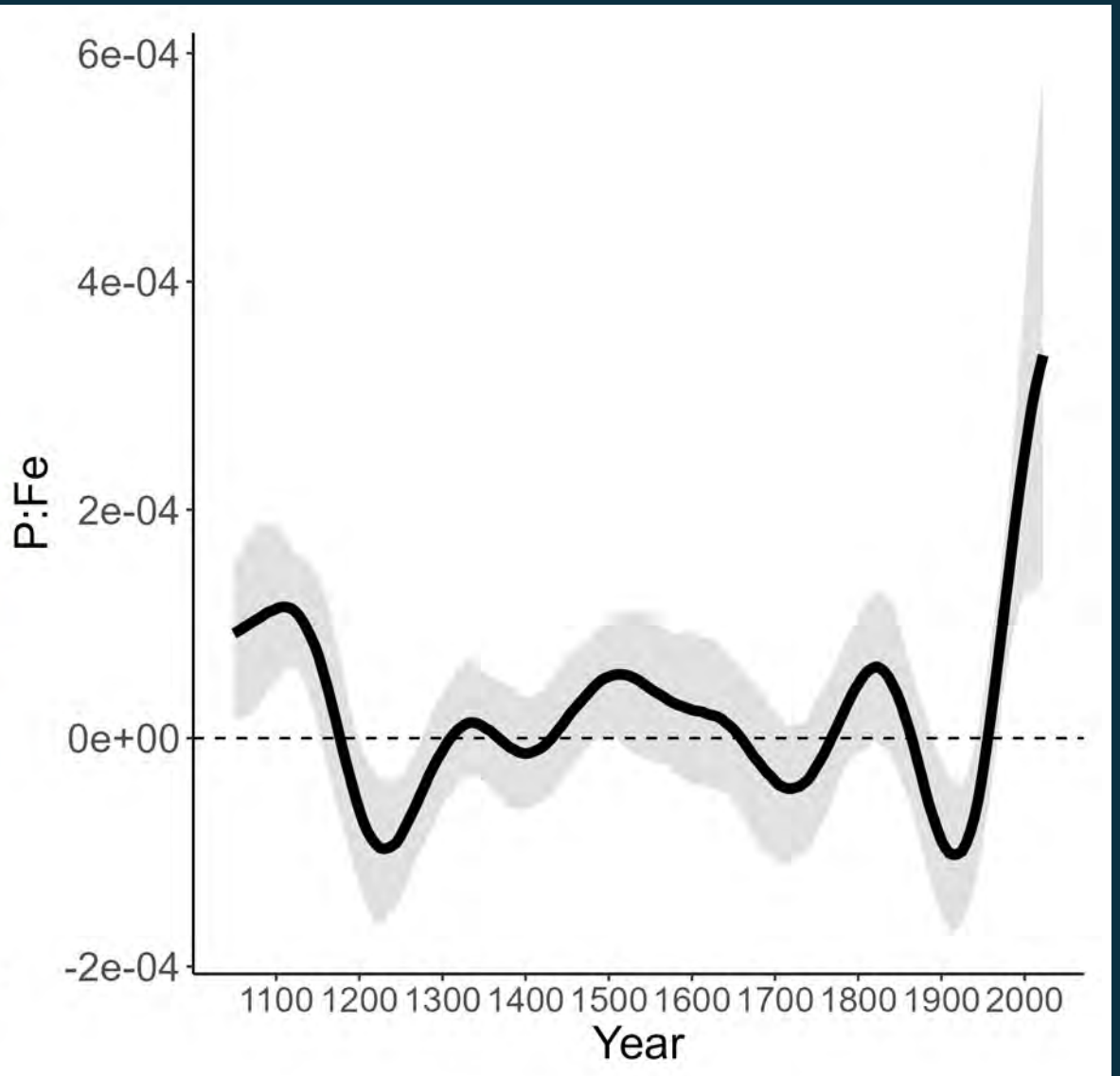
Figure source: https://doi.org/10.3390/md20020113

Modelling Palaeoecological Time Series Using Generalised Additive Models

Gavin L. Simpson*

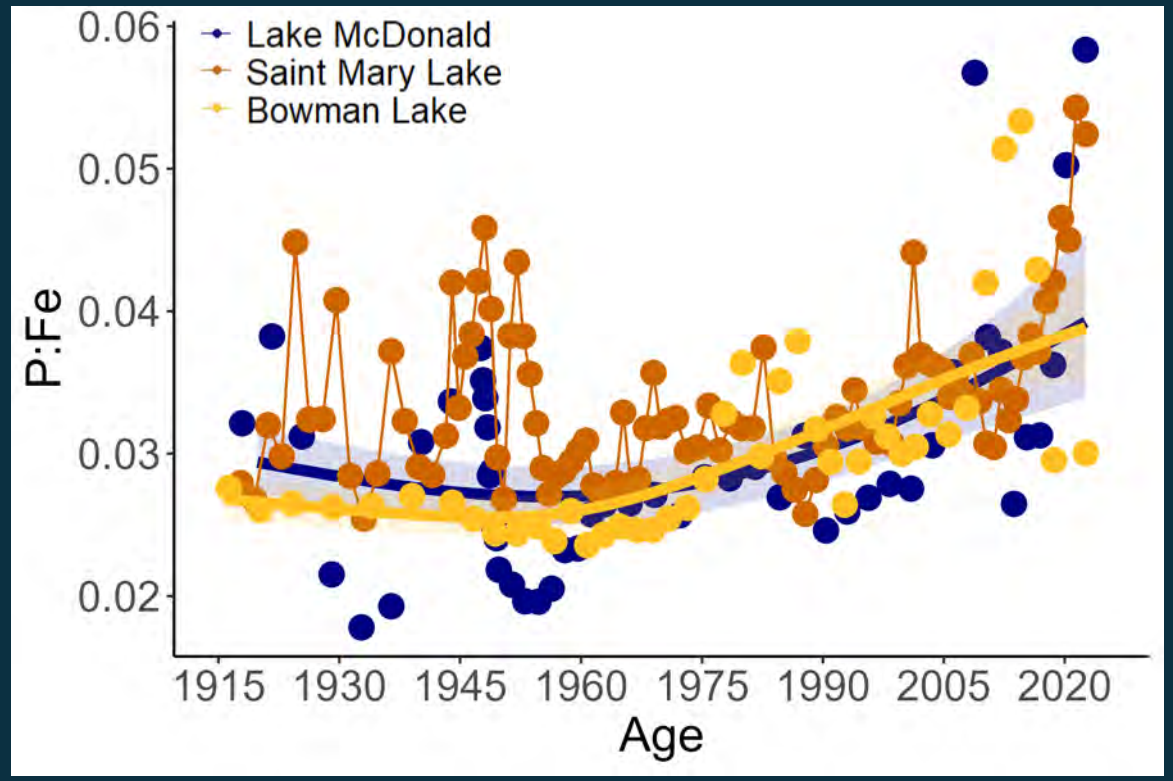
Institute of Environmental Change and Society, University of Regina, Regina, SK, Canada



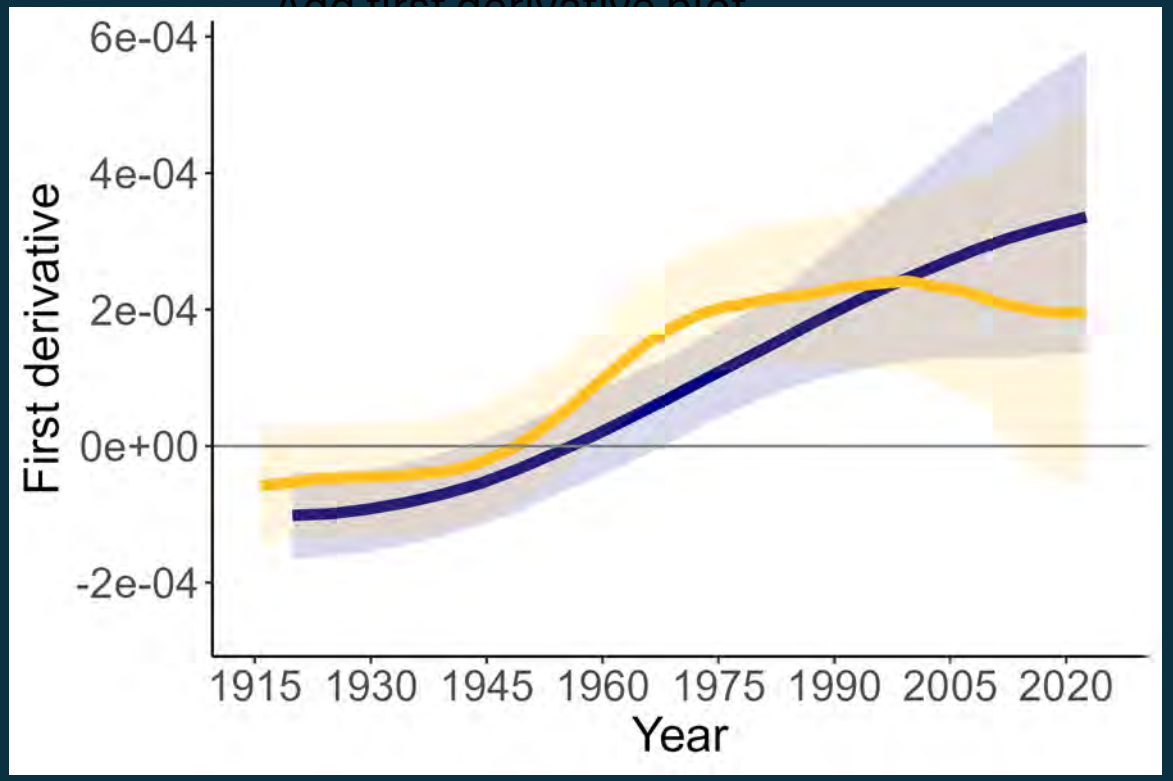


How have environmental changes affected total algal biomass and assemblage in mountain lakes in the Northern Rocky Mountains?

	P	N	Total Algal Biomass	Chlorophytes	Cyanobacteria	Diatoms
Central Rockies *(Oleksy et al. 2020)*		+	+	+	+	-
Lake McDonald						
Saint Mary Lake						
Bowman Lake						

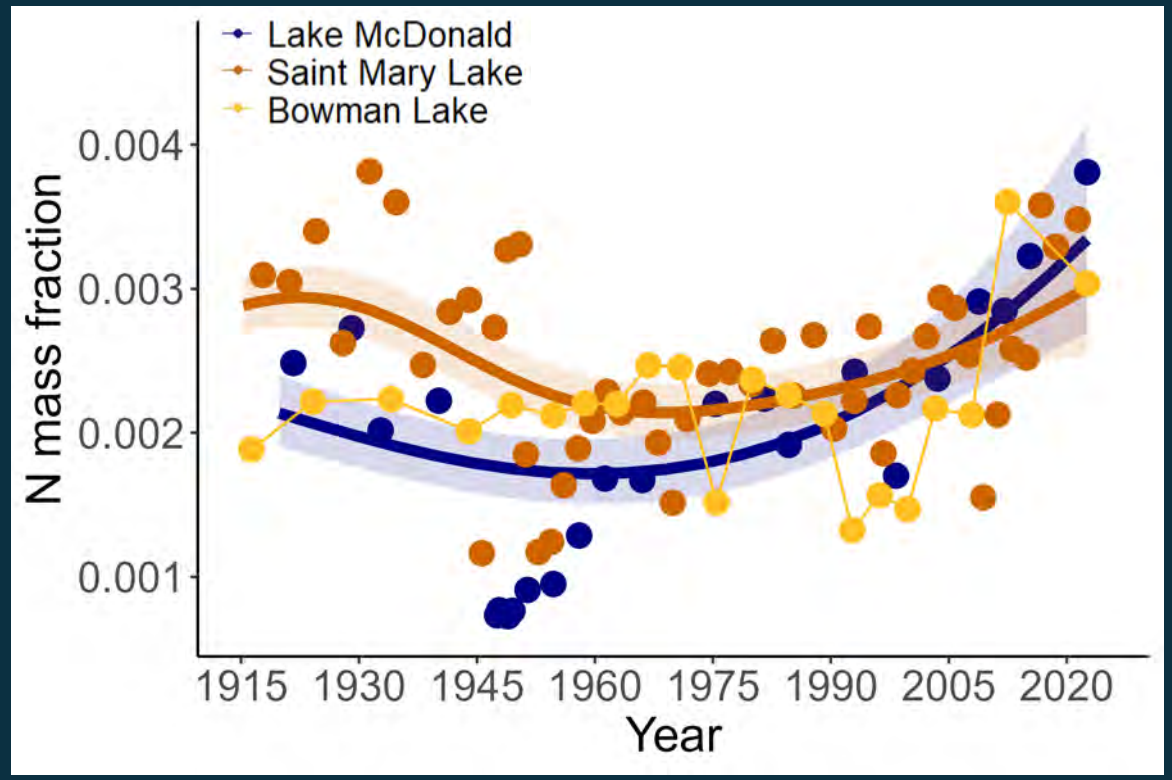


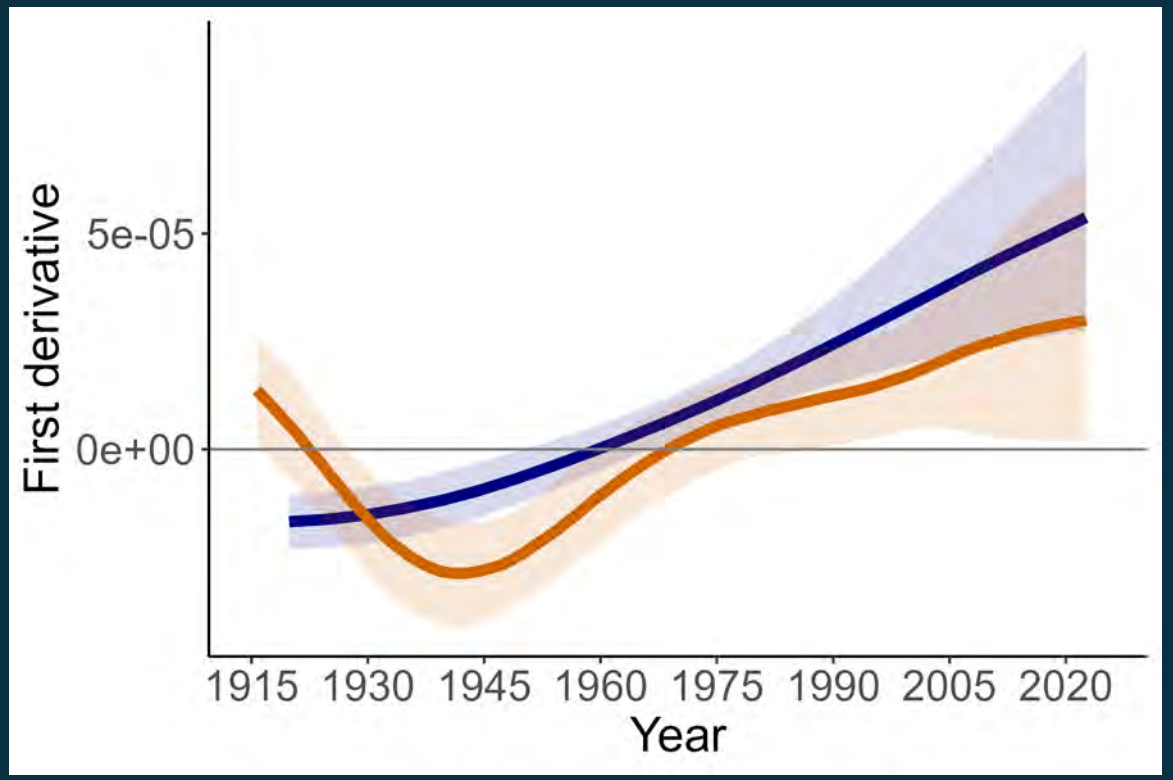
Add first derivative plot

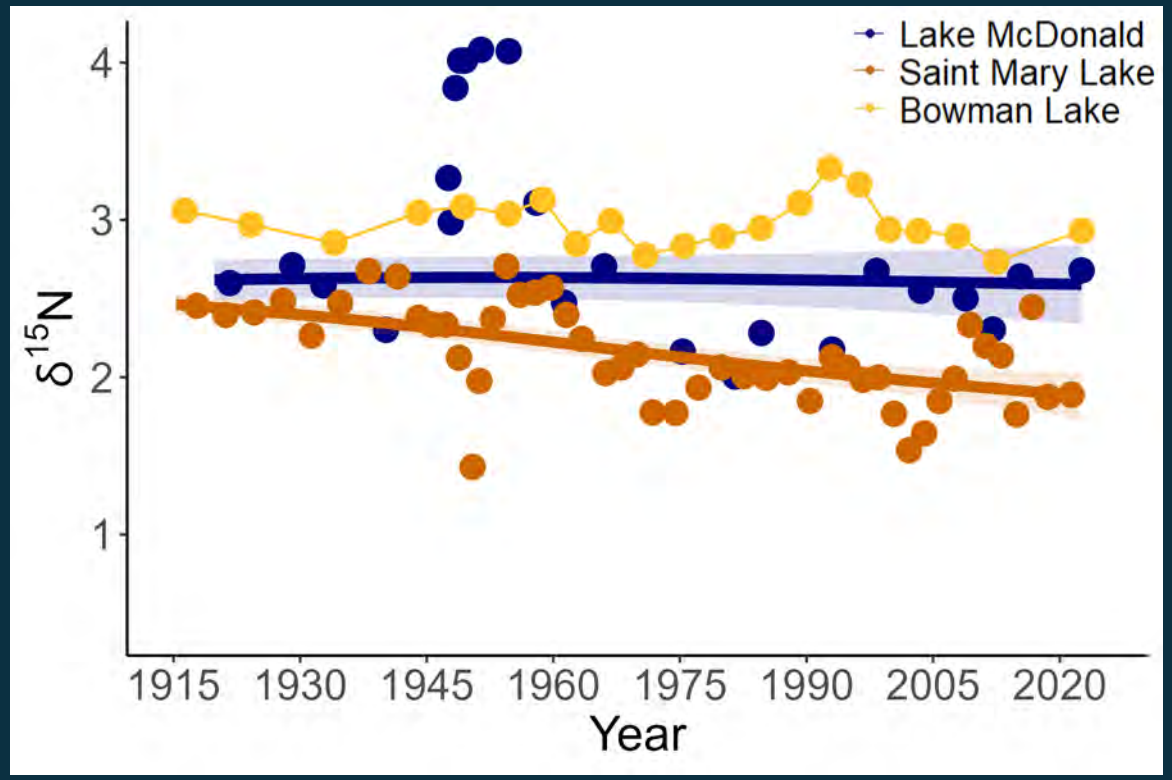


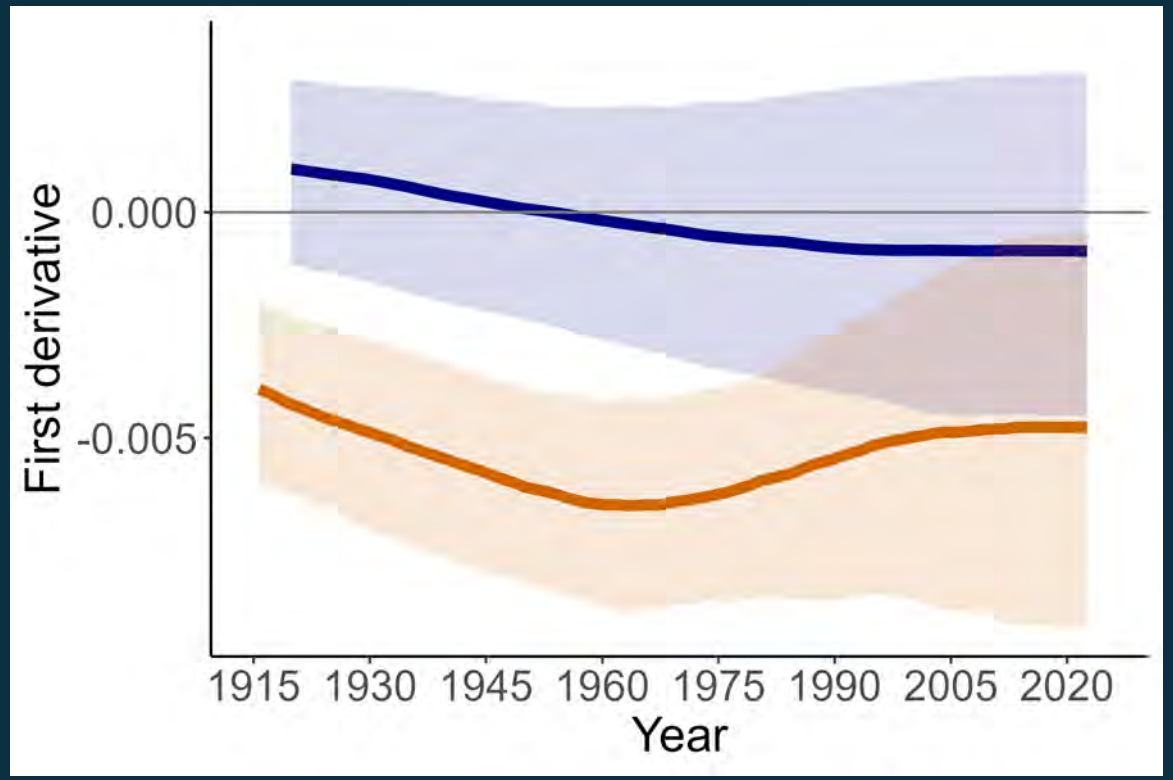
How have environmental changes affected total algal biomass and assemblage in mountain lakes in the Northern Rocky Mountains?

	P	N	Total Algal Biomass	Chlorophytes	Cyanobacteria	Diatoms
Central Rockies *(Oleksy et al. 2020)*		+	+	+	+	-
Lake McDonald	+					
Saint Mary Lake	No Δ					
Bowman Lake	+					


Lake McDonald
Saint Mary Lake
Bowman Lake
N mass fraction
0.004
0.003
0.002
0.001
1915
1930
1945
1960
1975
1990
2005
2020
Year

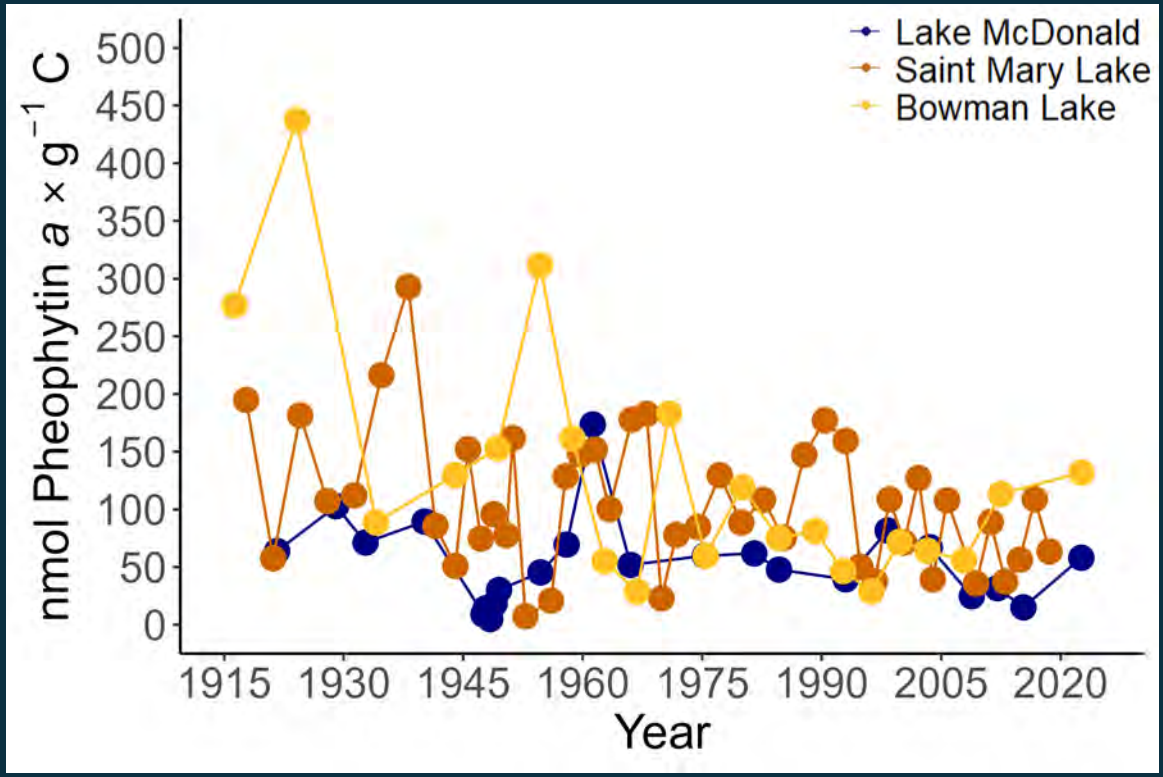

First derivative
5e-05
0e+00
1915
1930
1945
1960
1975
1990
2005
2020
Year

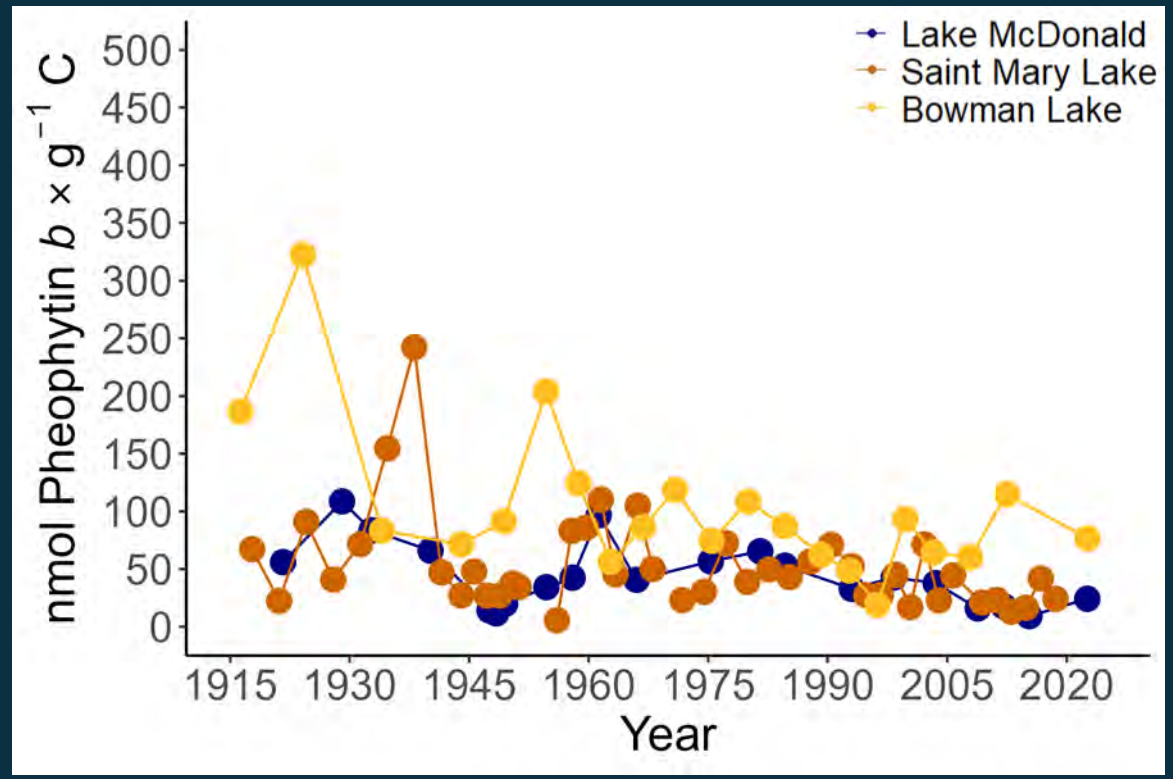

Lake McDonald
Saint Mary Lake
Bowman Lake
$\delta^{15}N$
4
3
2
1
1915
1930
1945
1960
1975
1990
2005
2020
Year


First derivative
0.000
-0.005
1915
1930
1945
1960
1975
1990
2005
2020
Year

How have environmental changes affected total algal biomass and assemblage in mountain lakes in the Northern Rocky Mountains?

	P	N	Total Algal Biomass	Chlorophytes	Cyanobacteria	Diatoms
Central Rockies *(Oleksy et al. 2020)*		+	+	+	+	-
Lake McDonald	+	+				
Saint Mary Lake	No Δ	+				
Bowman Lake	+	No Δ				


Lake McDonald
Saint Mary Lake
Bowman Lake
nmol Pheophytin a × g⁻¹ C
500
450
400
350
300
250
200
150
100
50
0
1915
1930
1945
1960
1975
1990
2005
2020
Year


Lake McDonald
Saint Mary Lake
Bowman Lake
nmol Pheophytin b × g⁻¹ C
500
450
400
350
300
250
200
150
100
50
0
1915
1930
1945
1960
1975
1990
2005
2020
Year

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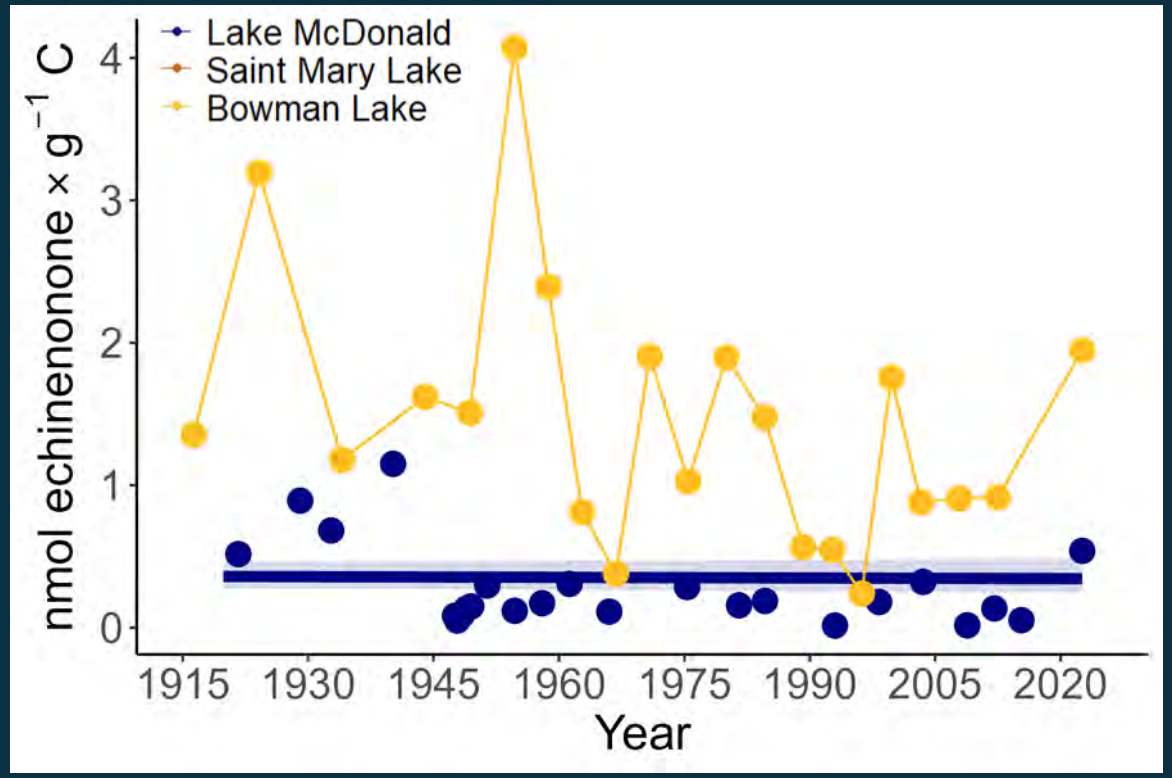
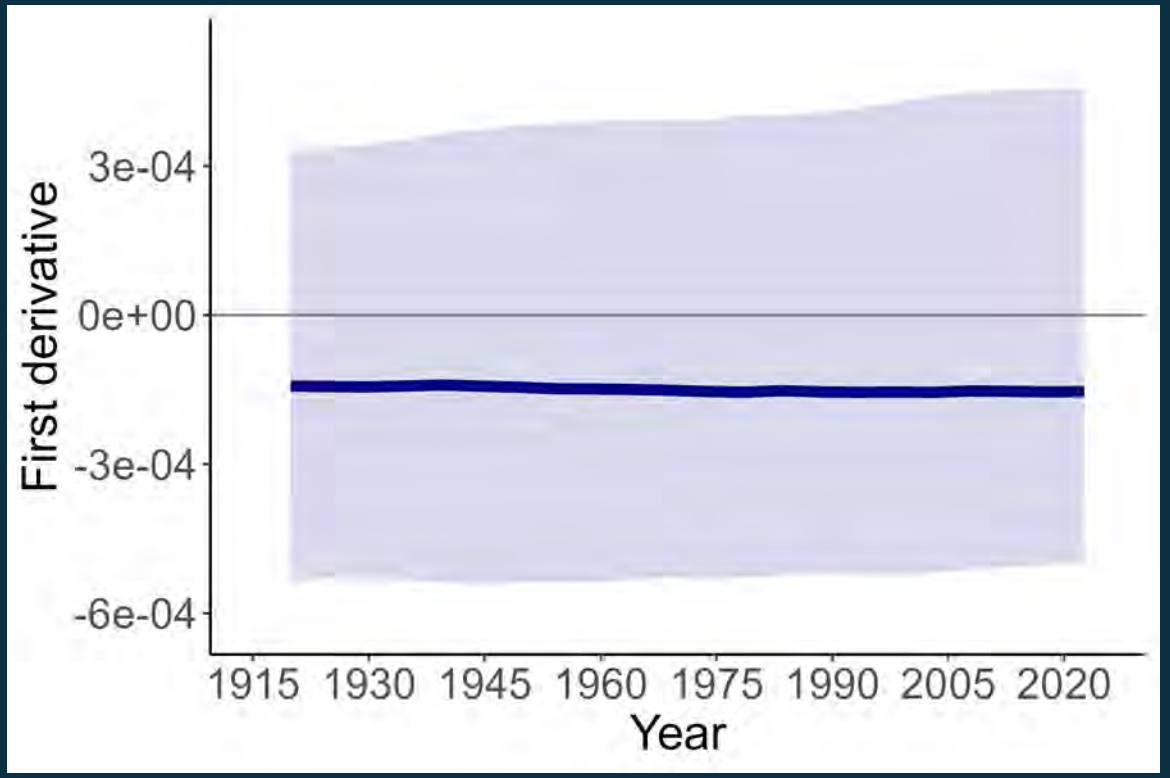
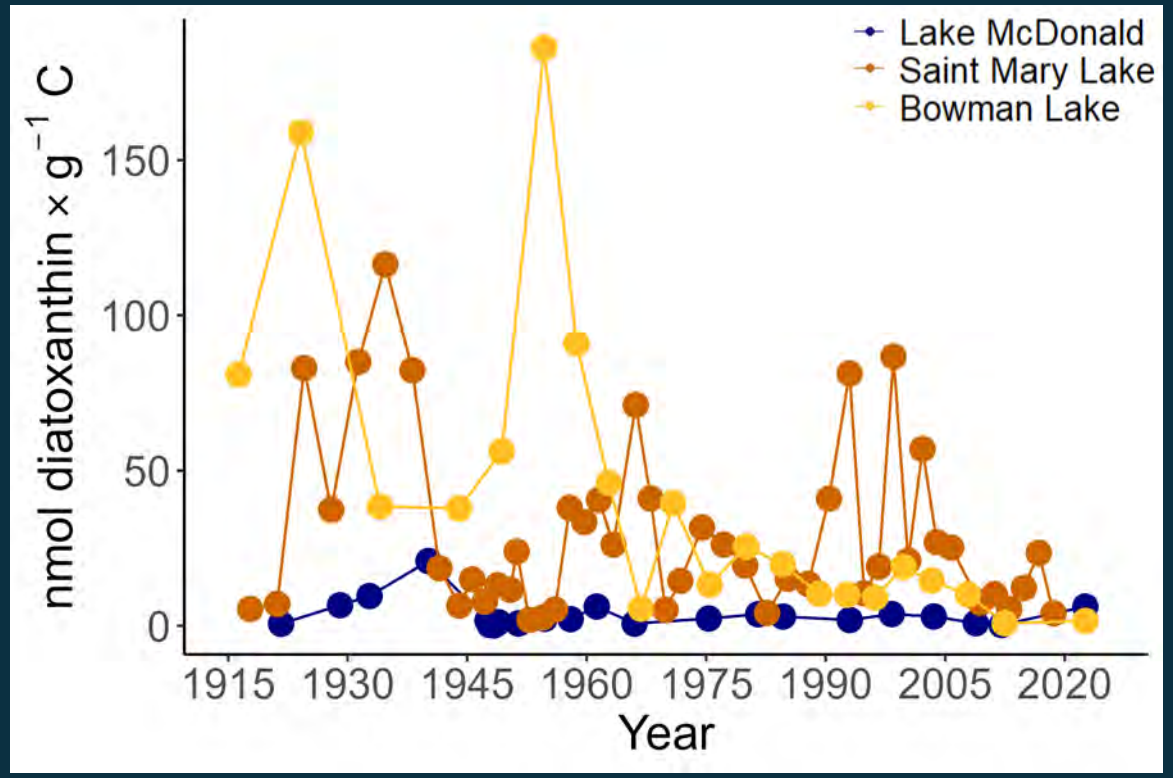
Lake McDonald	+	+	No Δ	No Δ		
Saint Mary Lake	No Δ	+	No Δ	No Δ		
Bowman Lake	+	No Δ	No Δ	No Δ		


Lake McDonald
Saint Mary Lake
Bowman Lake
nmol echinenonone × g⁻¹ C
0
1
2
3
4
1915
1930
1945
1960
1975
1990
2005
2020
Year


First derivative
3e-04
0e+00
-3e-04
-6e-04
1915
1930
1945
1960
1975
1990
2005
2020
Year

How have environmental changes affected total algal biomass and assemblage in mountain lakes in the Northern Rocky Mountains?

	P	N	Total Algal Biomass	Chlorophytes	Cyanobacteria	Diatoms
Central Rockies *(Oleksy et al. 2020)*		+	+	+	+	-
Lake McDonald	+	+	No Δ	No Δ	No Δ	
Saint Mary Lake	No Δ	+	No Δ	No Δ	Not detectable	
Bowman Lake	+	No Δ	No Δ	No Δ	No Δ	


Lake McDonald
Saint Mary Lake
Bowman Lake
nmol diatoxanthin × g⁻¹ C
0
50
100
150
1915
1930
1945
1960
1975
1990
2005
2020
Year

How have environmental changes affected total algal biomass and assemblage in mountain lakes in the Northern Rocky Mountains?

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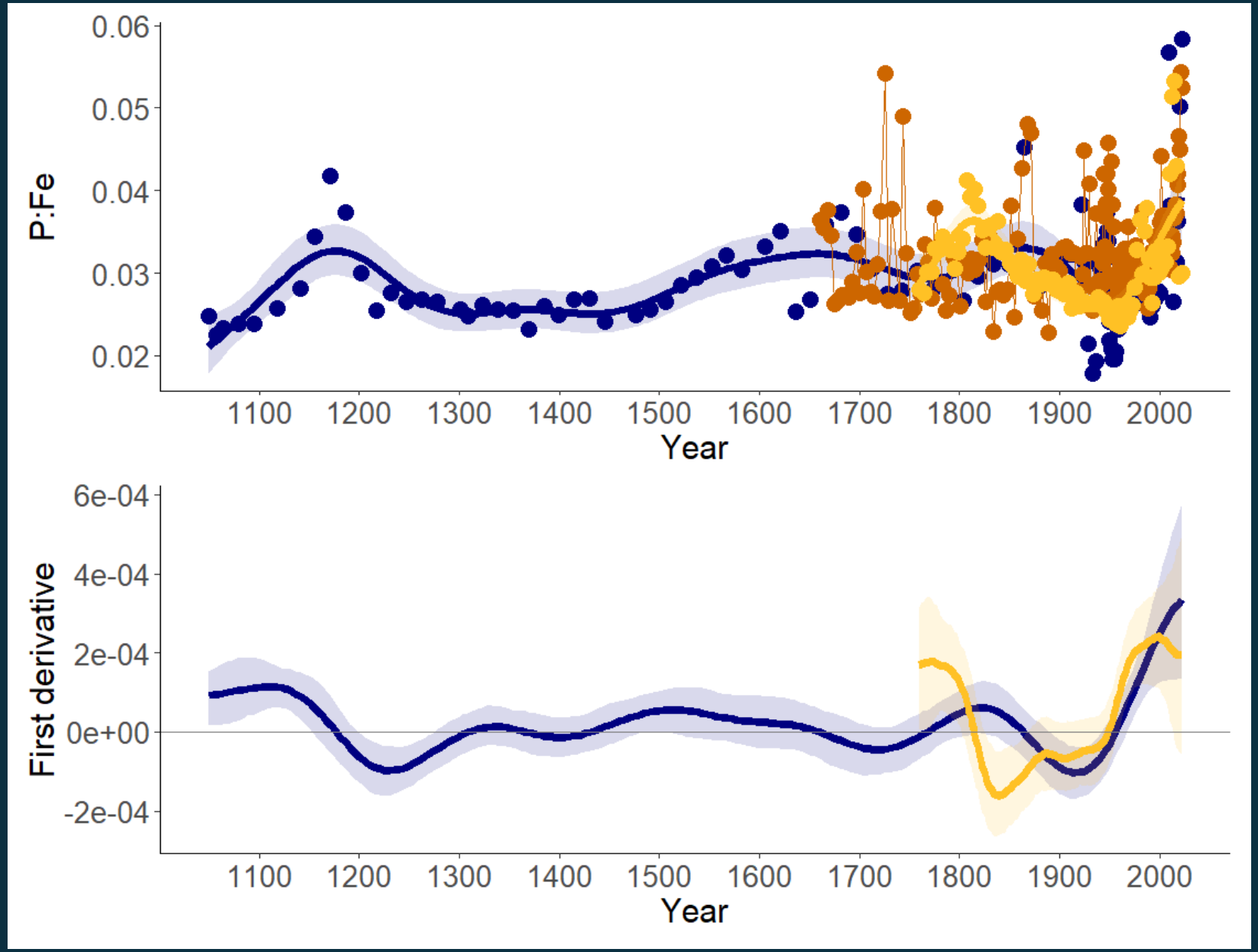
Lake McDonald	+	+	No Δ	No Δ	No Δ	No Δ
Saint Mary Lake	No Δ	+	No Δ	No Δ	Not detectable	No Δ
Bowman Lake	+	No Δ	No Δ	No Δ	No Δ	No Δ

Preliminary findings & next steps

1. More P loading Lake McDonald and Bowman Lake
2. More N loading to Lake McDonald and Saint Mary Lake
3. No evidence of changes in total algal biomass or assemblage

- ❑ Refine GAM models
- ❑ Interpret trends in other pigments
- ❑ Describe geochemical and biological changes after episodic disturbances

Questions?


0.06
0.05
0.04
0.03
0.02
P:Fe
1100
1200
1300
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1900
2000
Year
6e-04
4e-04
2e-04
0e+00
-2e-04
First derivative
1100
1200
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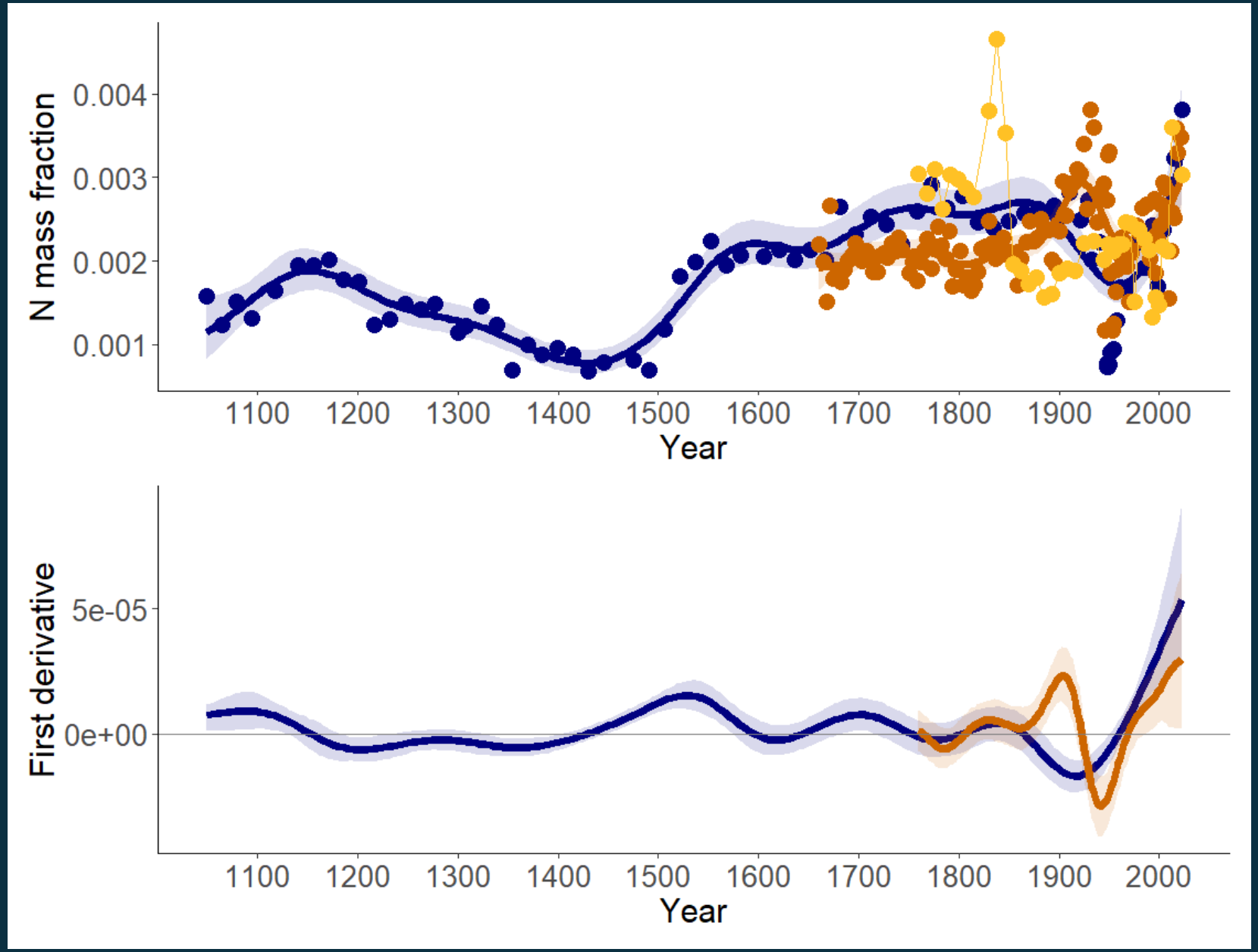
1400
1500
1600
1700
1800
1900
2000
Year


N mass fraction
0.004
0.003
0.002
0.001
1100
1200
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Year
First derivative
5e-05
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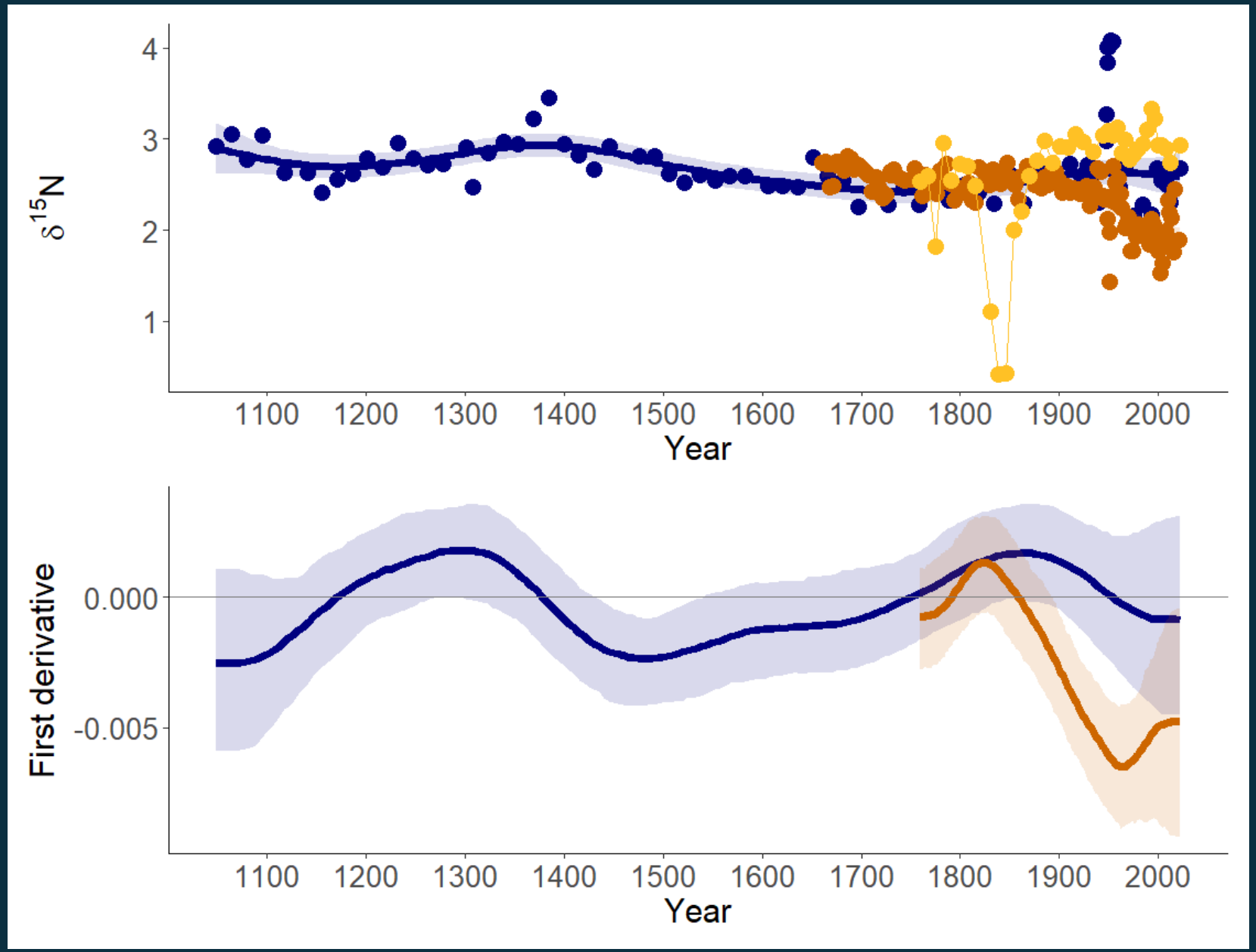
Year


4
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δ15N
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Year
First derivative
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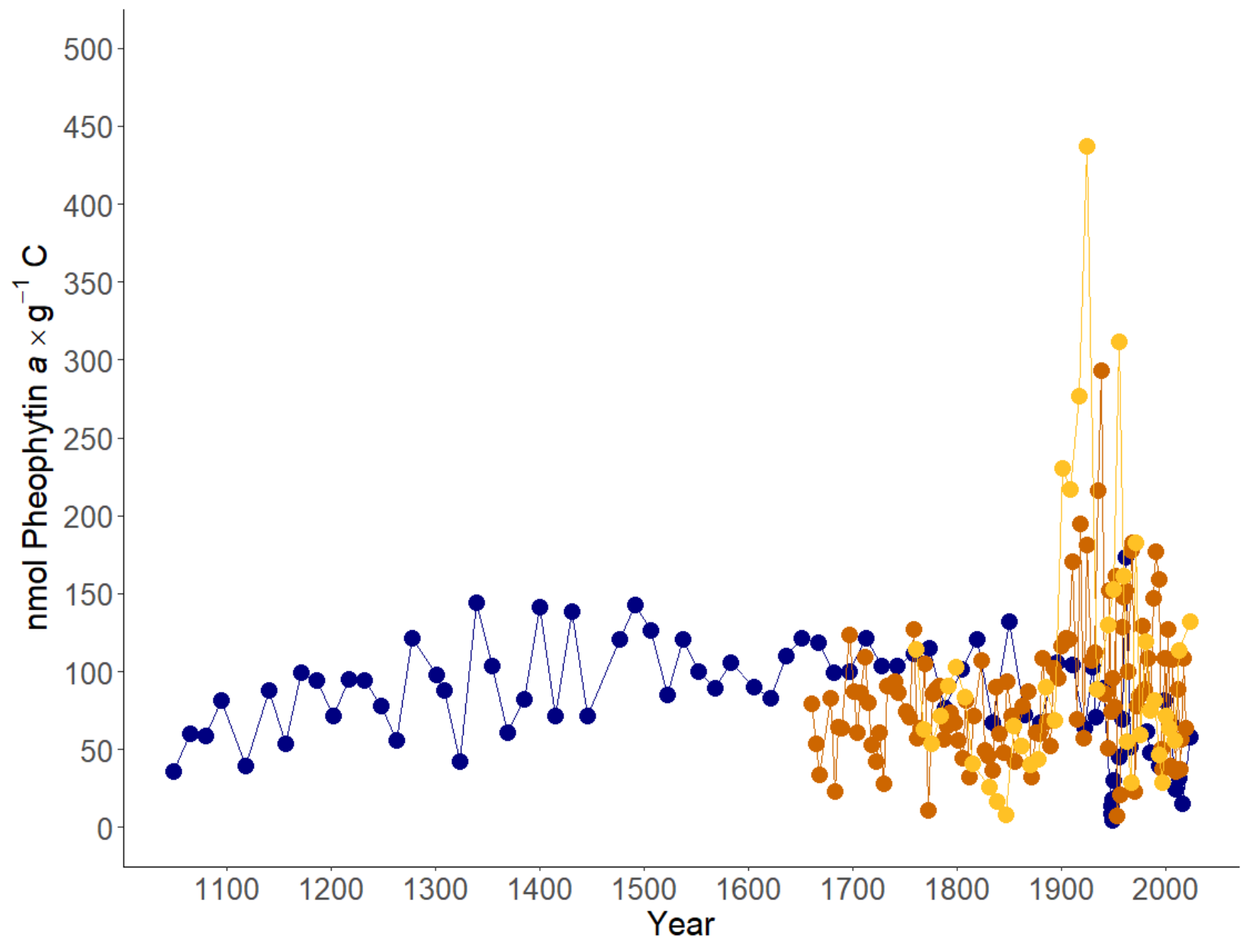
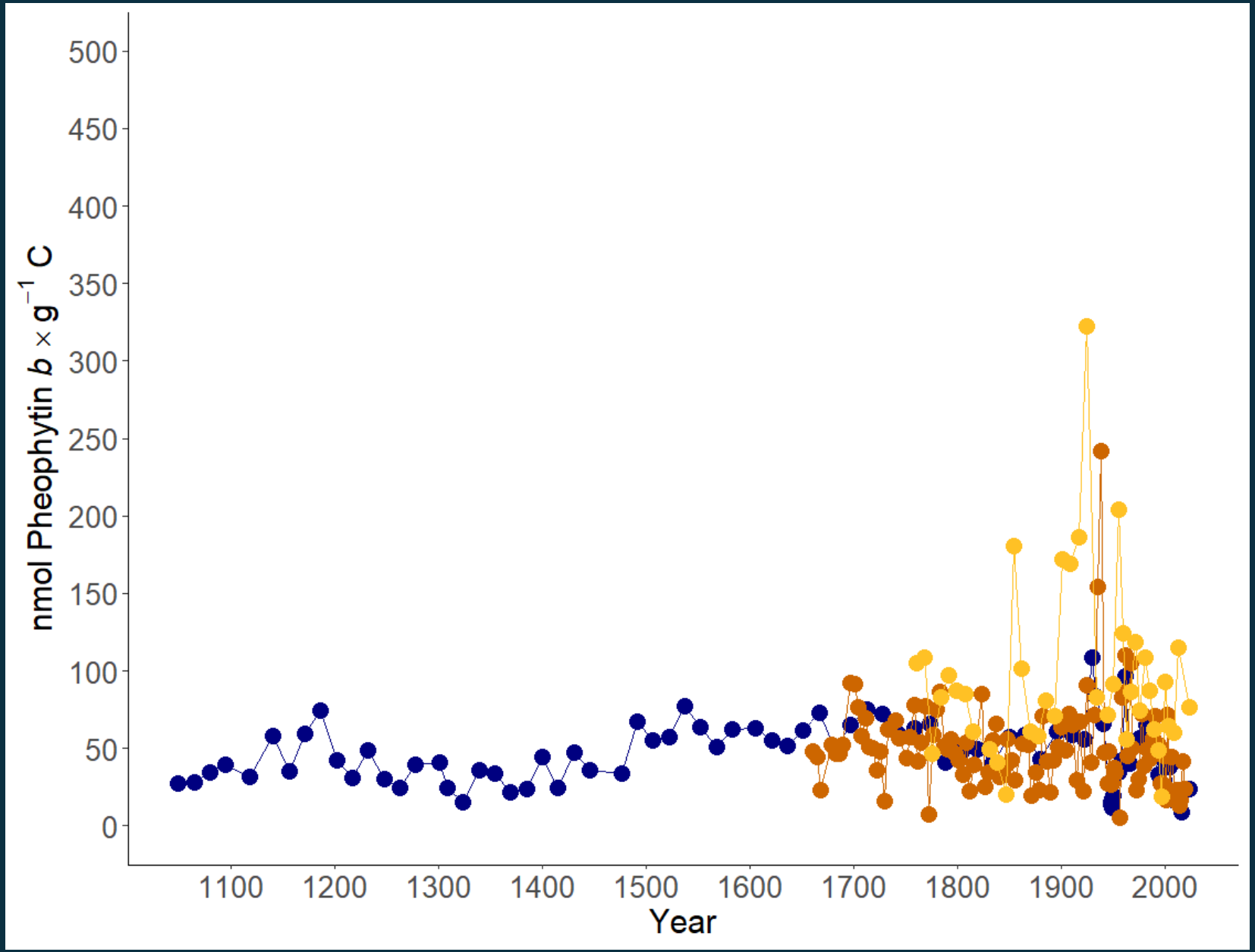
2000
Year


500
450
400
350
300
250
200
150
100
50
0
nmol Pheophytin a × g−1 C
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Year


500
450
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200
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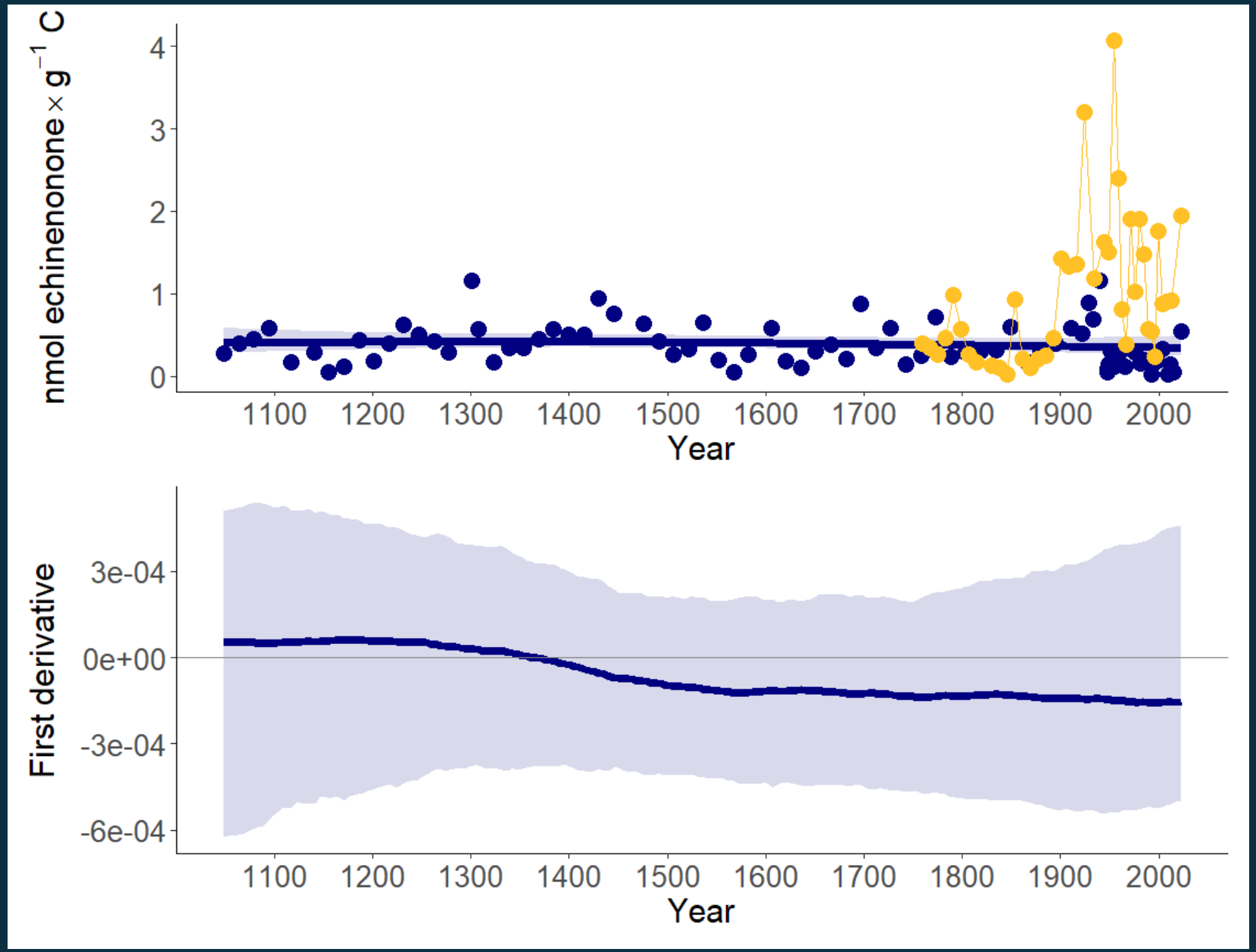
50
0
nmol Pheophytin $b \times g^{-1}$ C
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Year


nmol echinenonone × g⁻¹ C
4
3
2
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1100
1200
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1500
1600
1700
1800
1900
2000
Year
First derivative
3e-04
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-3e-04
-6e-04
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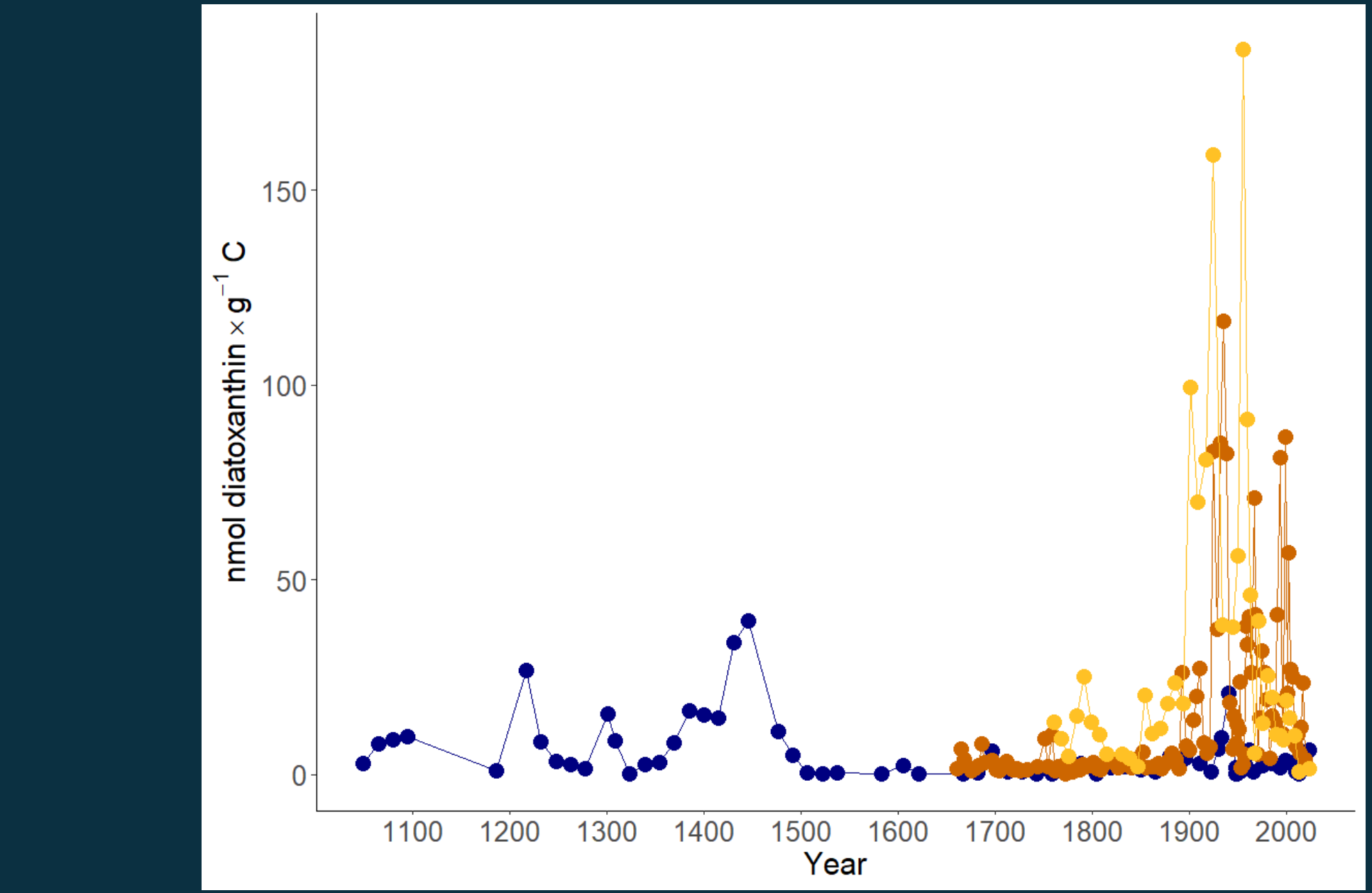
Year


nmol diatoxanthin × g^{-1} C
150
100
50
0
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Year