Temporal Variation in Nutrients and Phytoplankton Productivity in Flathead and Whitefish Lakes

2023 Montana Lakes Conference

Matthew J. Church, Tyler H. Tappenbeck, James A. Craft,
Mike Koopal, Carolyn Lober, Kate A. Evans, Bonnie K. Ellis

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UNIVERSITY OF MONTANA

“Small steps taken by many people in their backyards add up”

Nancy Knowlton

- Jim Craft
- Tyler Tappenbeck
- Adam Baumann
- Syd Racki
- Jeremy Nigon
- Tom Bansak
- Bonnie Ellis
- Jim Elser
- Whitefish Lake Institute
- CSKT
- And many more…

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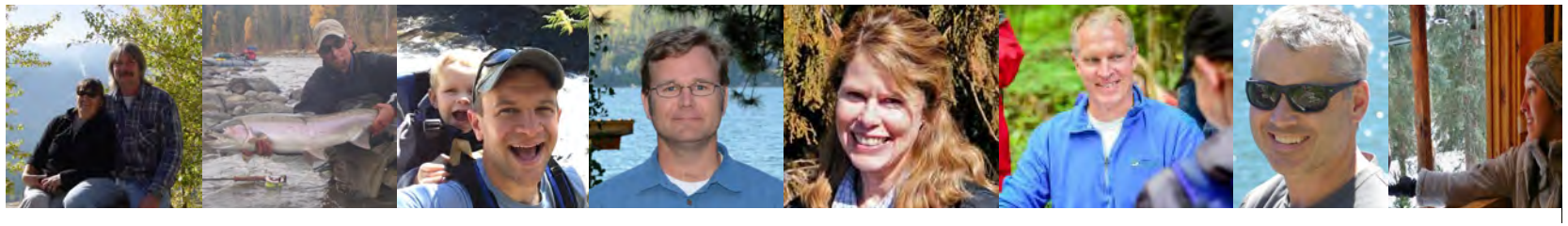
Whitefish Lake INSTITUTE



The Flathead Lake Biological Station is on the ancestral lands of the Séliš, Kootenai, and Pend d’Oreille peoples and within the present-day Flathead Reservation

Limnol. Oceanogr., 54(6, part 2), 2009, 2283–2297

Lakes as sentinels of climate change

Rita Adrian,[a,*] Catherine M. O'Reilly,[b] Horacio Zagarese,[c] Stephen B. Baines,[d] Dag O. Hessen,[e] Wendel Keller,[f] David M. Livingstone,[g] Ruben Sommaruga,[h] Dietmar Straile,[i] Ellen Van Donk,[j] Gesa A. Weyhenmeyer,[k] and Monika Winder[l]

Geophysical Research Letters

RESEARCH LETTER
10.1002/2015GL066235

Rapid and highly variable warming of lake surface waters around the globe

Catherine M. O'Reilly, Sapna Sharma,

Catherine M. O'Reilly[1], Sapna Sharma[2], Derek K. Gray[3], Stephanie E. Hampton[4], Jordan S. Read[5],

+ many more

nature geoscience

2019

ARTICLES

Worldwide alteration of lake mixing regimes in response to climate change

R. Iestyn Woolway[1,3*] and Christopher J. Merchant[1,2]

nature COMMUNICATIONS

2020

ARTICLE

OPEN

Global lake thermal regions shift under climate change

Stephen C. Maberly[1✉], Ruth A. O'Donnell[2], R. Iestyn Woolway[3], Mark E.J. Cutler[4], Mengyi Gong[2,5], Ian D. Jones[1,6], Christopher J. Merchant[7,8], Claire A. Miller[2], Eirini Politi[4], E. Marian Scott[2], Stephen J. Thackeray[1] & Andrew N. Tyler[6]

nature climate change

ARTICLES

OPEN

Climate change drives widespread shifts in lake thermal habitat

Benjamin M. Kraemer[1✉], Rachel M. Pilla[2], R. Iestyn Woolway[3,4], Orlane Anneville[5], Syuhei Ban[6], William Colom-Montero[7], Shawn P. Devlin[8], Martin T. Dokulil[9], Evelyn E. Gaiser[10],

+ many more

Globally lakes are changing: temperatures, food webs, habitat structure, nutrients, and more

communications earth & environment

ARTICLE

OPEN

The vulnerability of lakes to climate change along an altitudinal gradient

Love Råman Vinnå[1✉], Iselin Medhaug[2], Martin Schmid[1] & Damien Bouffard[1✉]

2021

nature climate change

2012

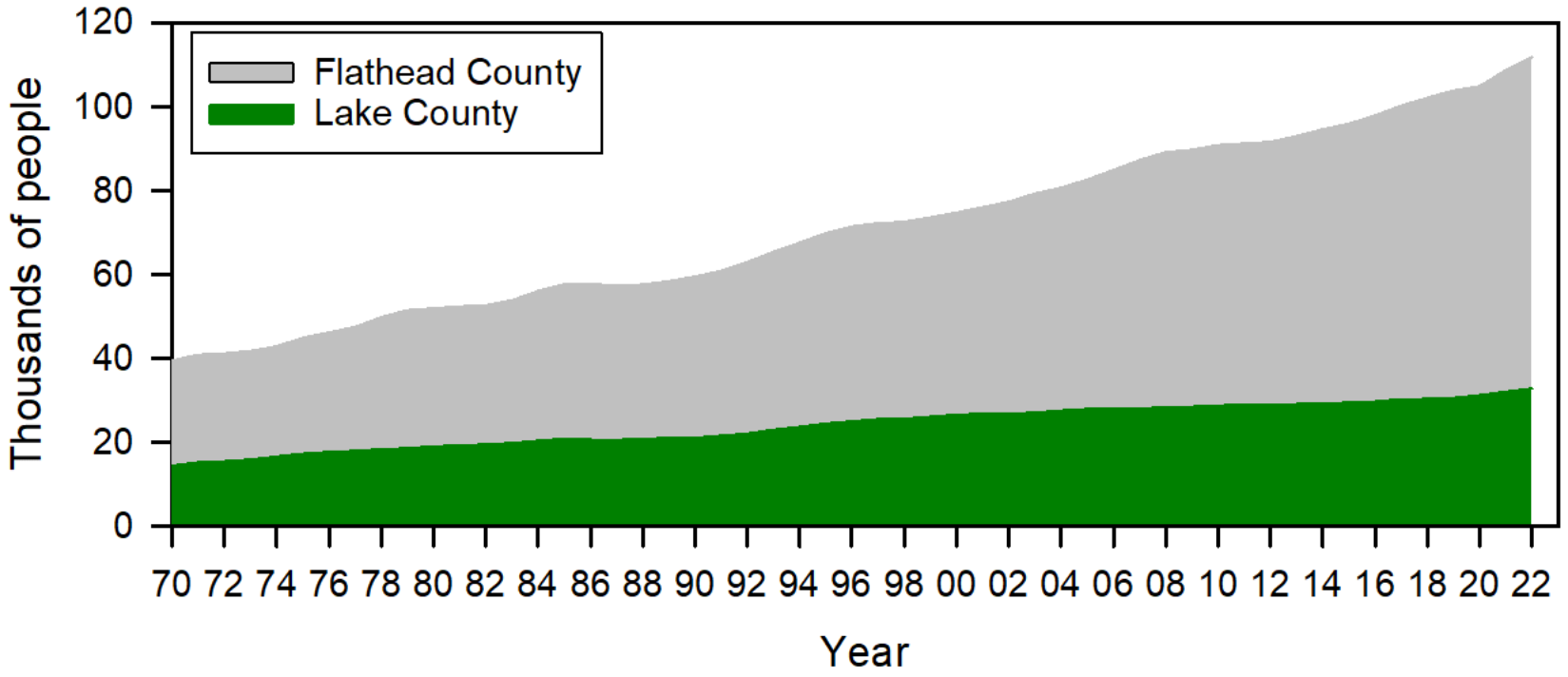
LETTERS

PUBLISHED ONLINE: 8 JULY 2012 | DOI: 10.1038/NCLIMATE1581

Harmful filamentous cyanobacteria favoured by reduced water turnover with lake warming

Thomas Posch[1]*, Oliver Köster[2], Michaela M. Salcher[1] and Jakob Pernthaler[1]

Flathead and Lake Counties are growing rapidly



Water quality risks that accompany increasing human population:

- Septic and sewar
- Loss of floodplains and wetlands
- Increasing impervious surfaces (e.g., pavement) and runoff

Monitoring Flathead and Whitefish Lakes

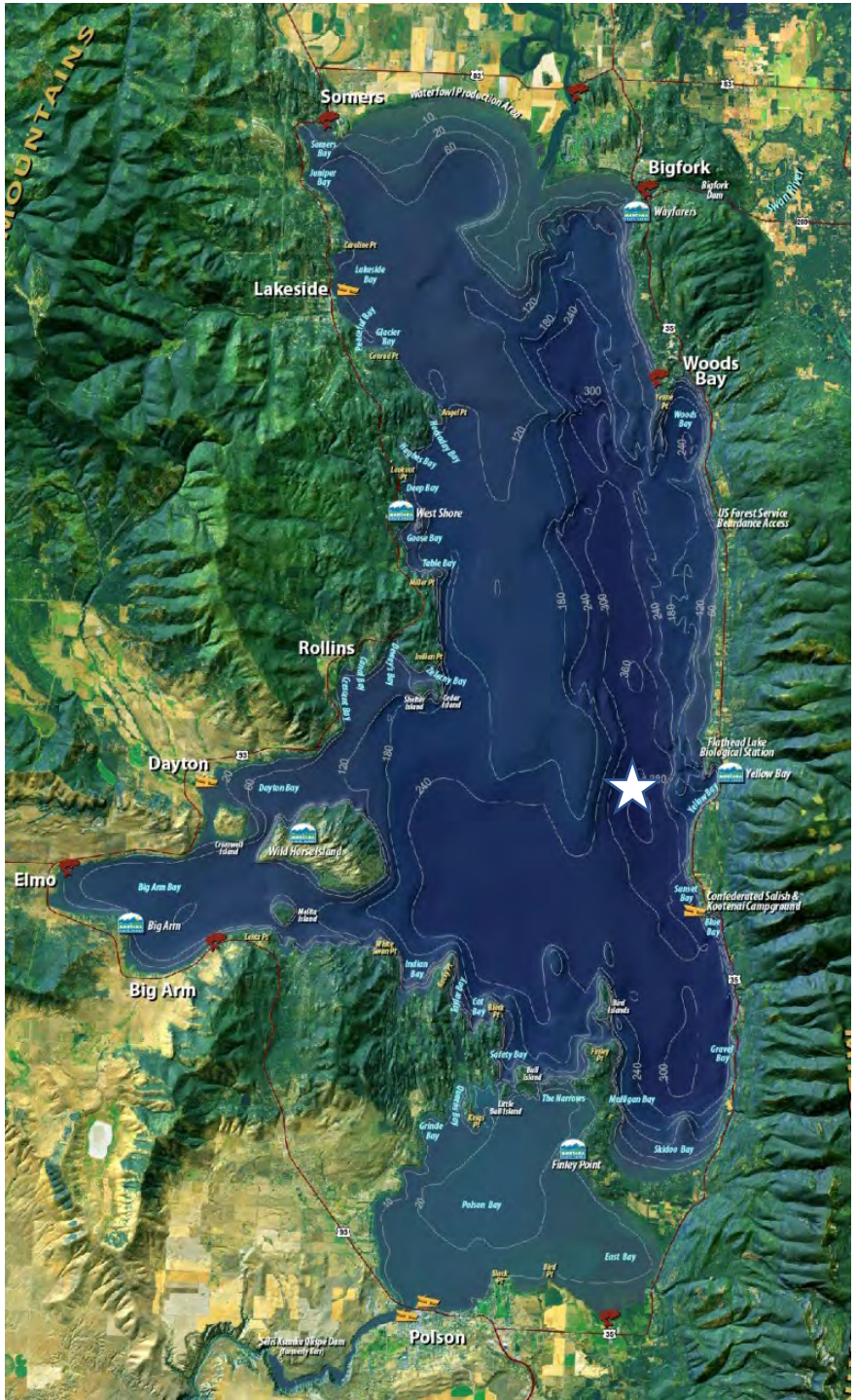
Flathead Lake:1977-present

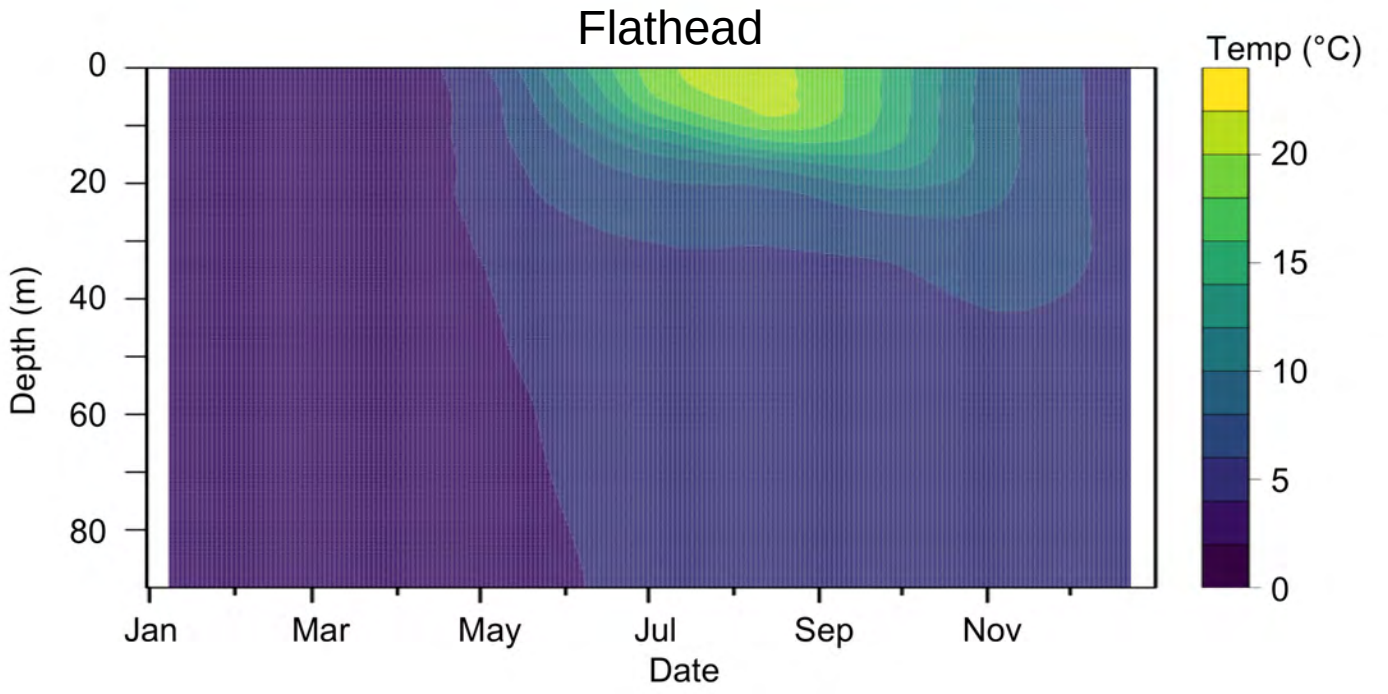
- 15x per yr (Dec-Jan)

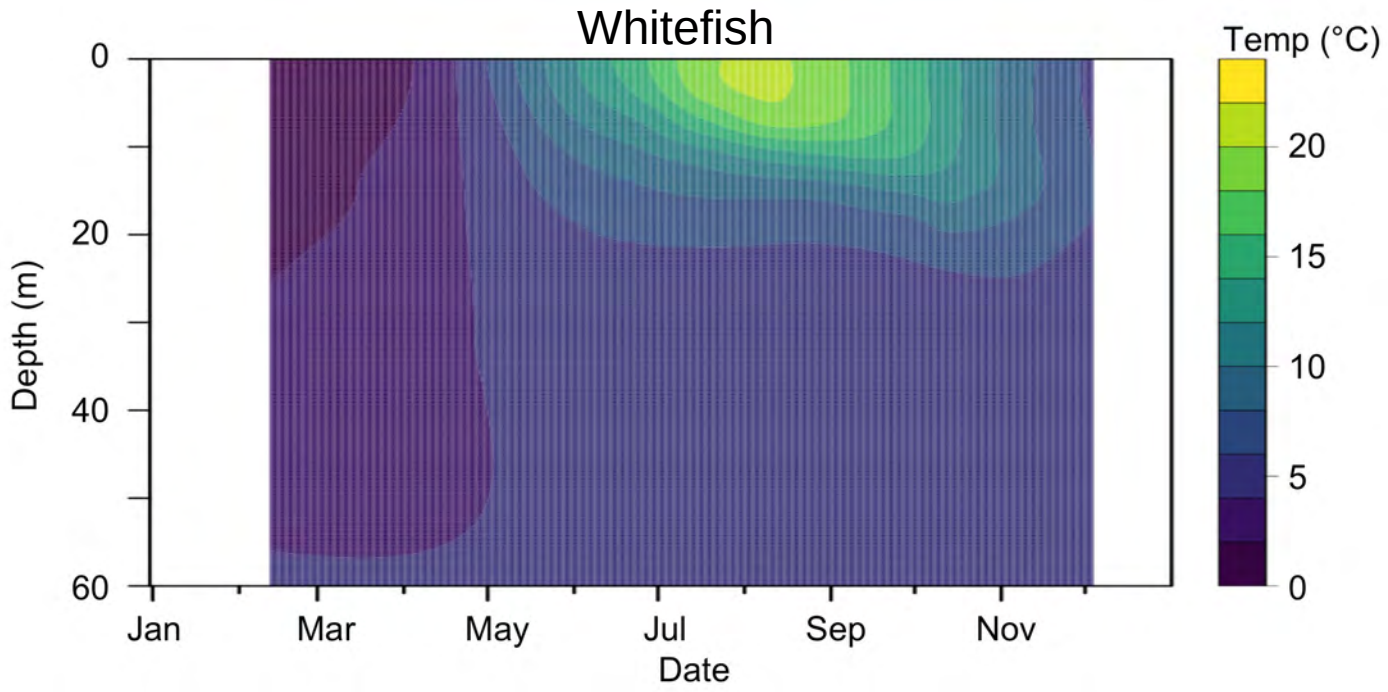
Whitefish Lake: 2007-present

- 8X per yr (Mar-Oct)

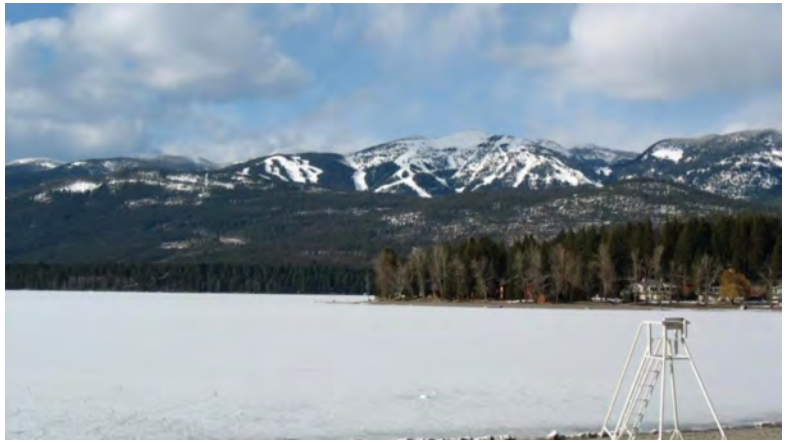
- Nutrients, light, hydrography, primary productivity, algal biomass and composition, zooplankton biomass and composition

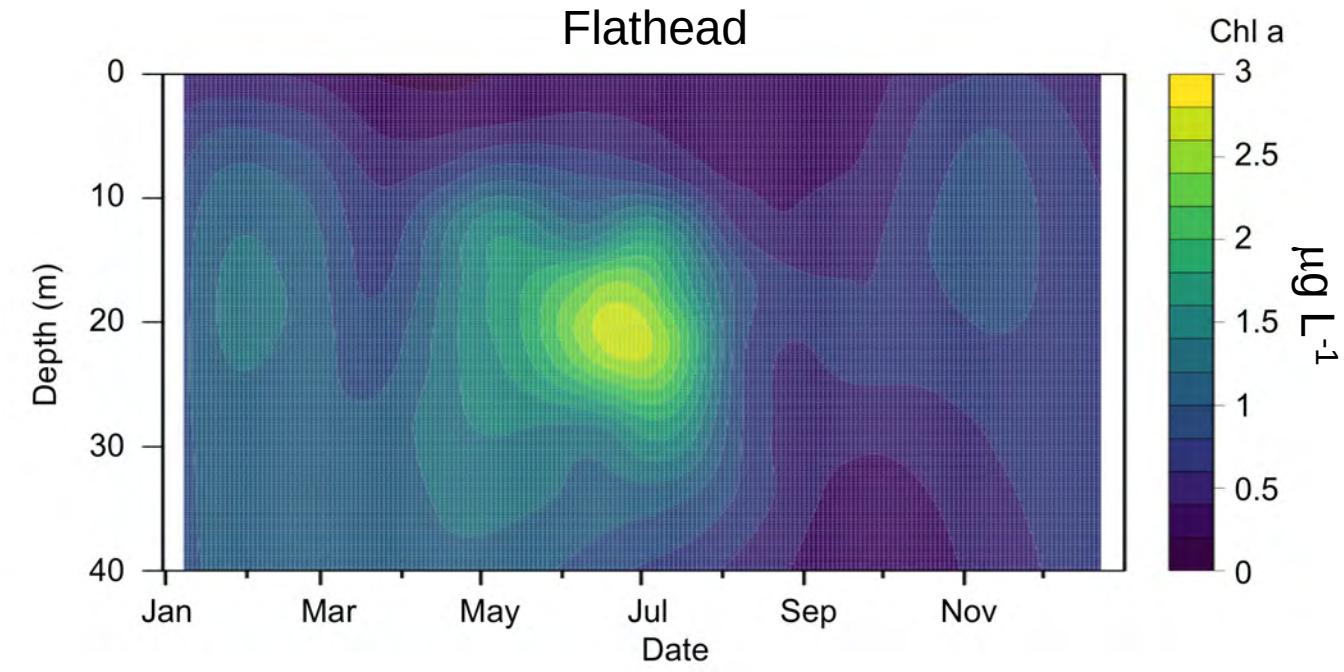


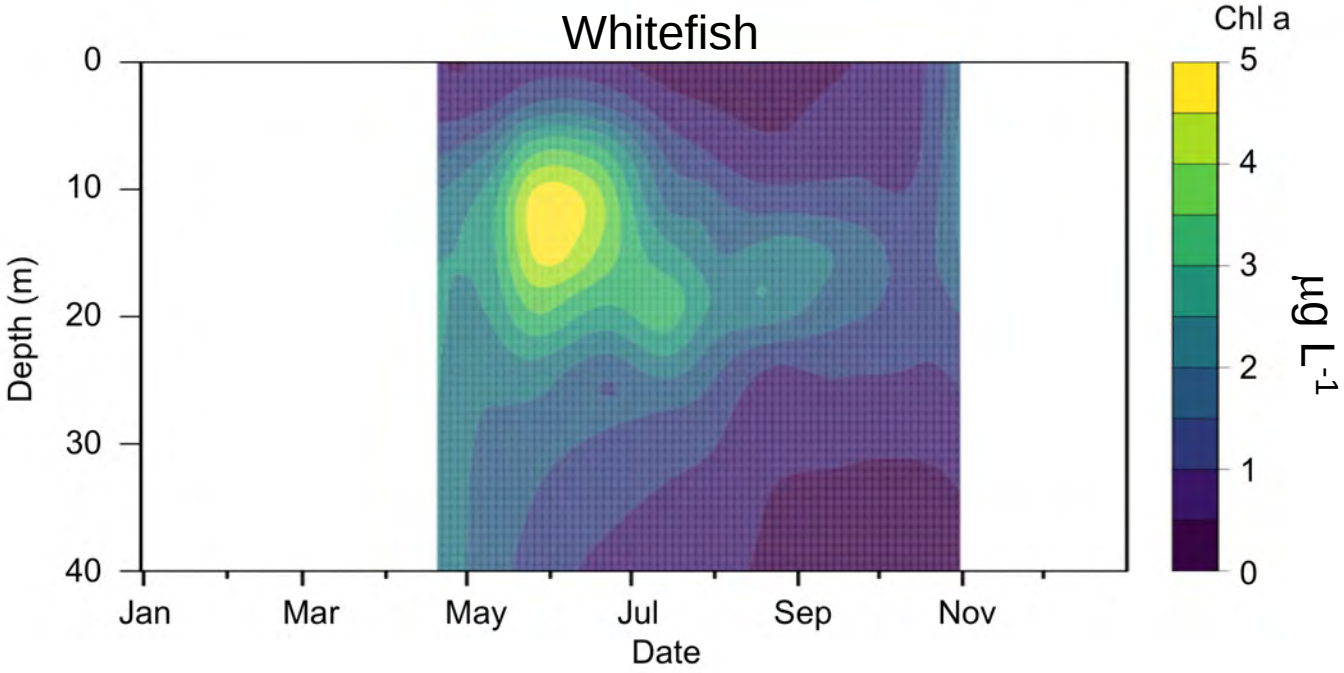




- Similar seasonal variation in water temperature
- Both lakes demonstrate inverse stratification, but Whitefish Lake freezes







Seasonal variation in chlorophyll concentrations

- Both lakes develop a seasonal subsurface chlorophyll maximum
- Concentrations of chlorophyll in both lakes peak in spring (April-June)
- Whitefish Lake has ~1.5-fold higher chlorophyll concentrations

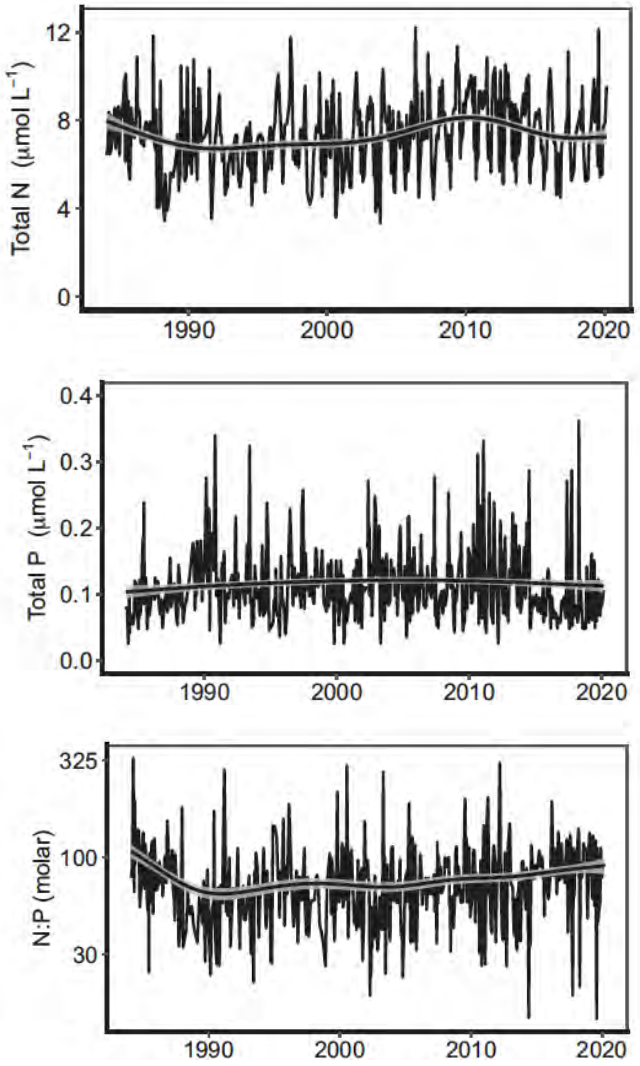
PNAS INAUGURAL ARTICLE | ECOLOGY OPEN ACCESS

Sustained stoichiometric imbalance and its ecological consequences in a large oligotrophic lake

James J. Elser[a,1], Shawn P. Devlin[a], Jinlei Yu[b], Adam Baumann[a], Matthew J. Church[a], John E. Dore[c], Robert O. Hall Jr.[a], Melody Hollar[d], Tyler Johnson[e], Trista Vick-Majors[a,f], and Cassidy White[g]

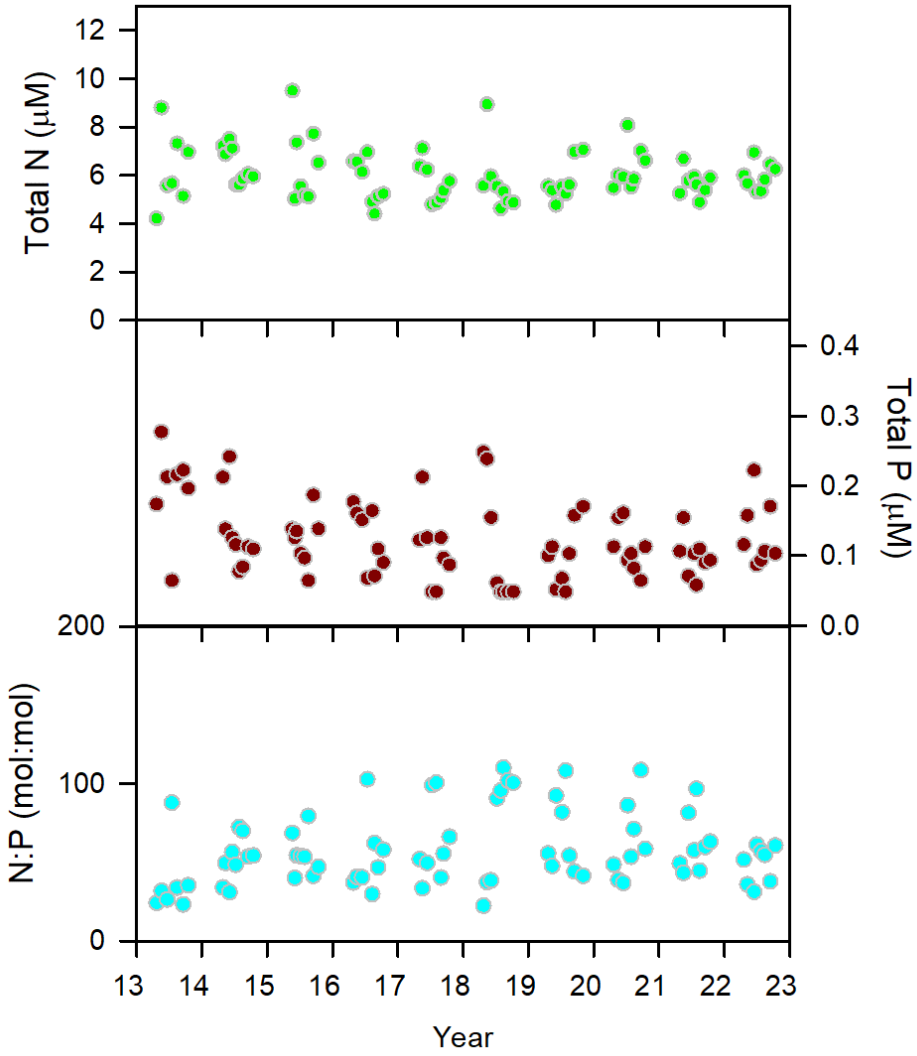
Sustained oligotrophy

Flathead

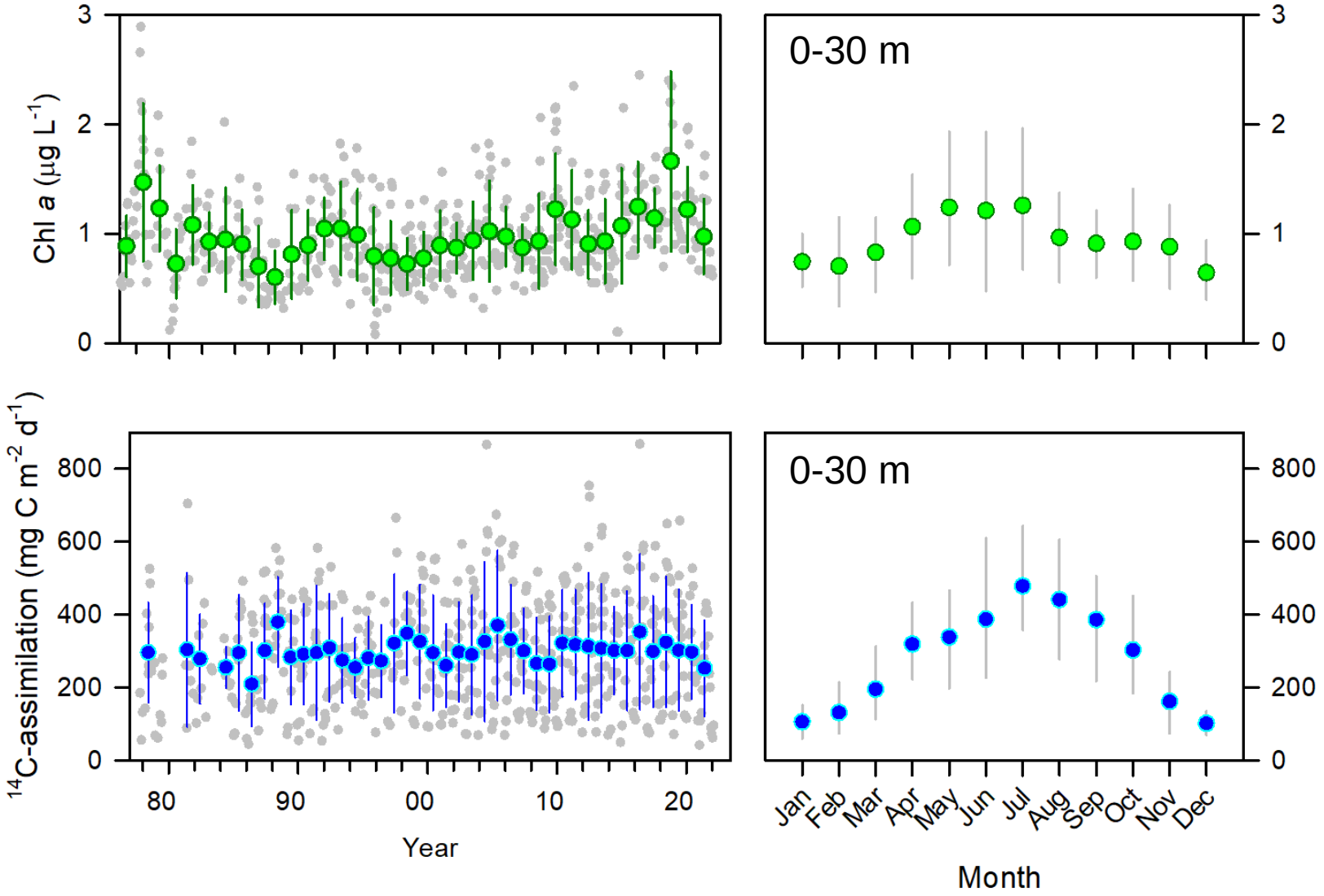


- No long-term change in N and P
- Both lakes persistently enriched in N relative to P

Whitefish (2013-2022)

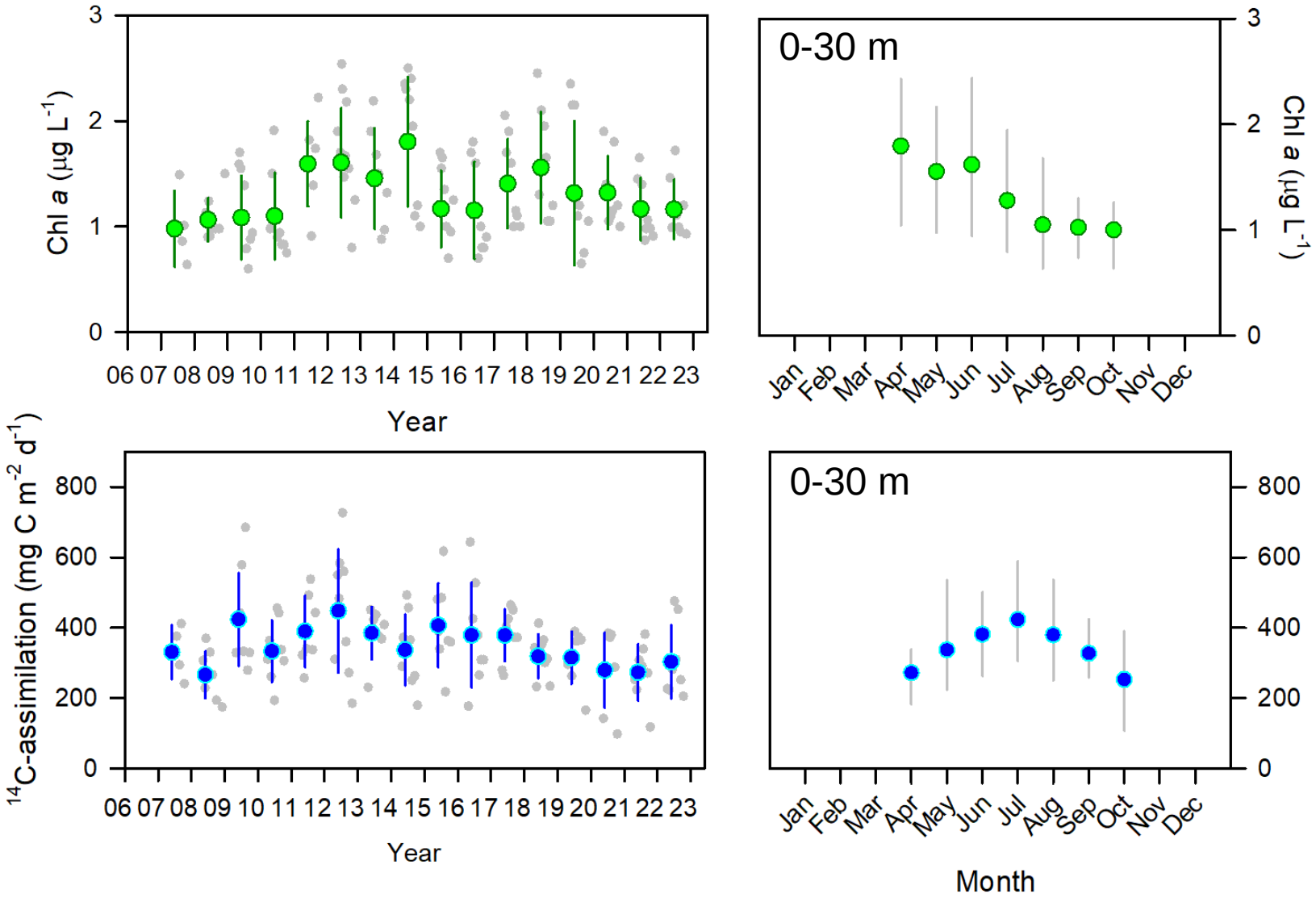


Time varying concentrations of chlorophyll and rates of primary production in Flathead Lake



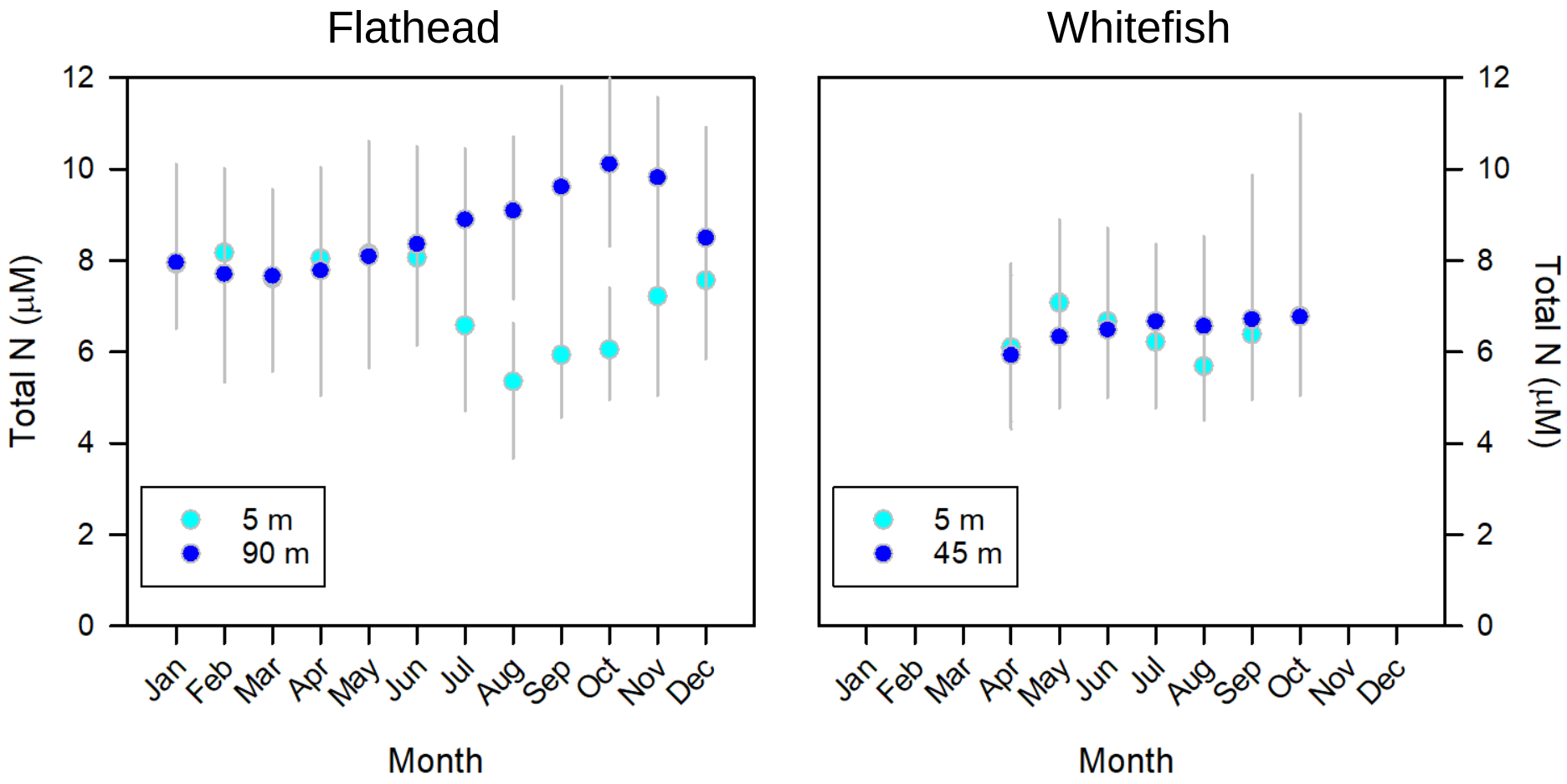
- No long-term trends
- Concentrations of chlorophyll greatest May-July
- Rates of primary production increase ~5-fold into the summer

Time varying concentrations of chlorophyll and rates of primary production in Whitefish Lake



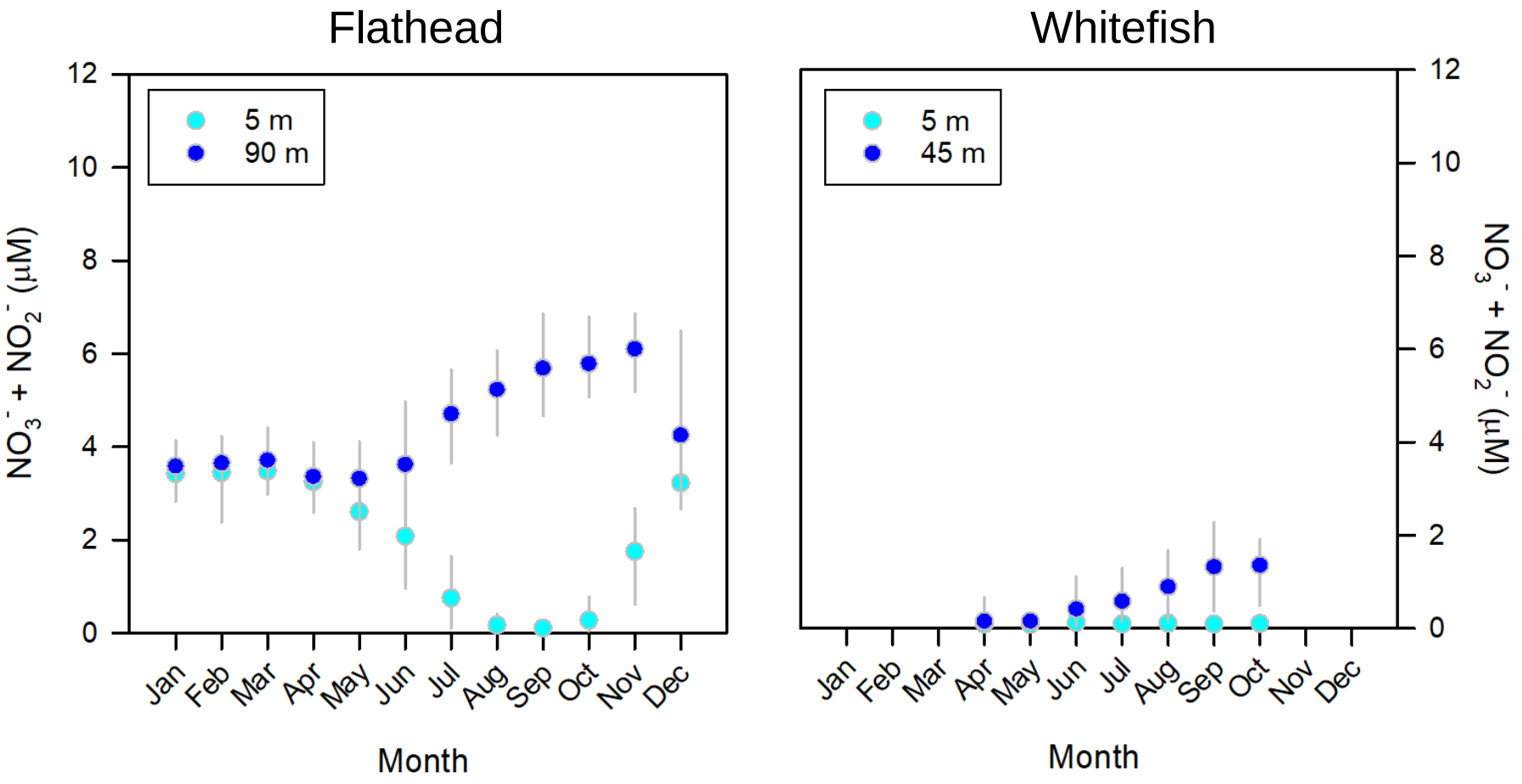
- No long-term trends
- Higher concentrations of chlorophyll during spring maximum
- Comparable rates of primary production

Seasonal variation in total N



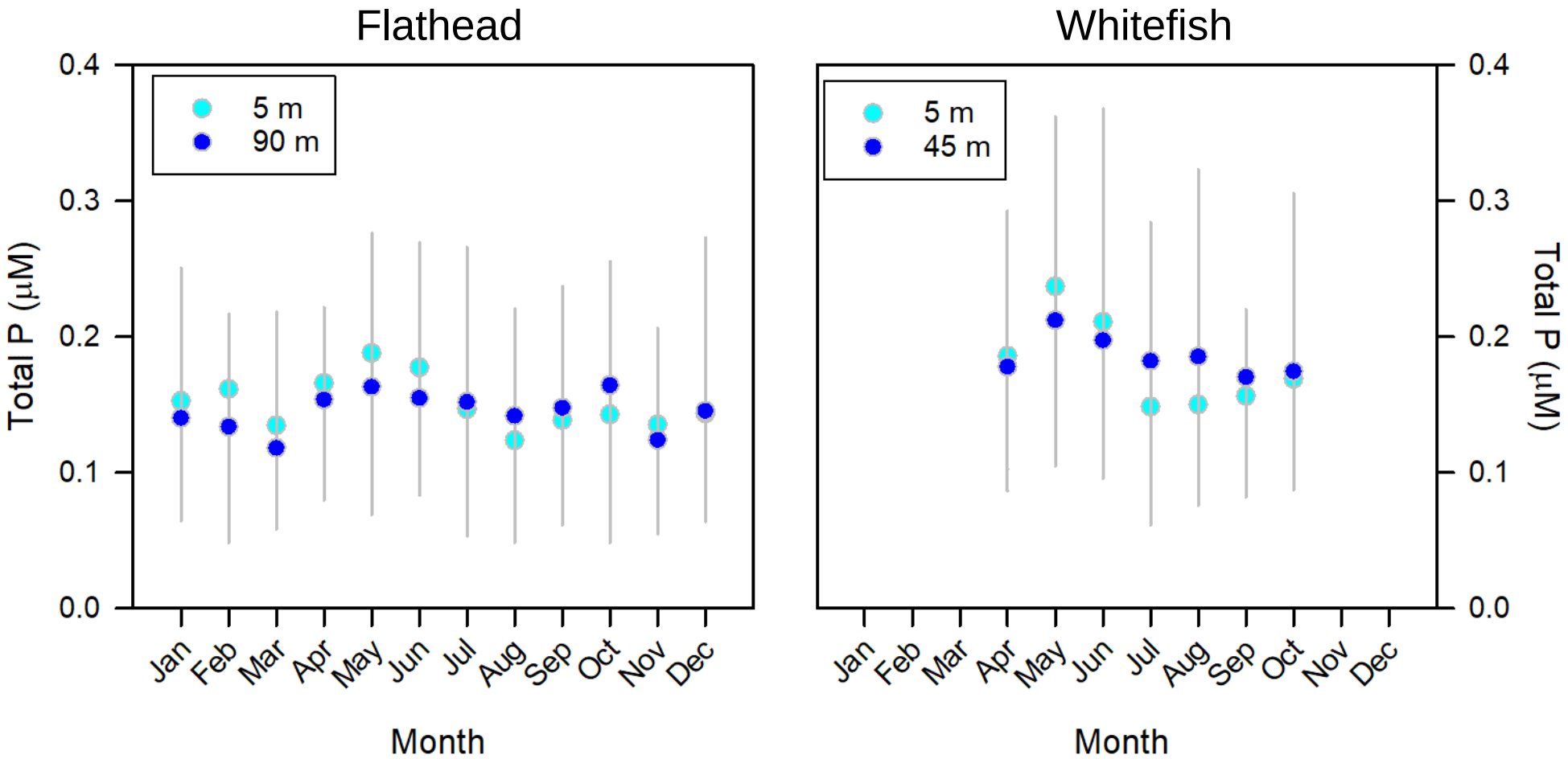
- Total N ~20% greater in Flathead Lake
- Seasonal changes in Flathead, no clear seasonality in Whitefish

Seasonal variation in nitrate concentrations



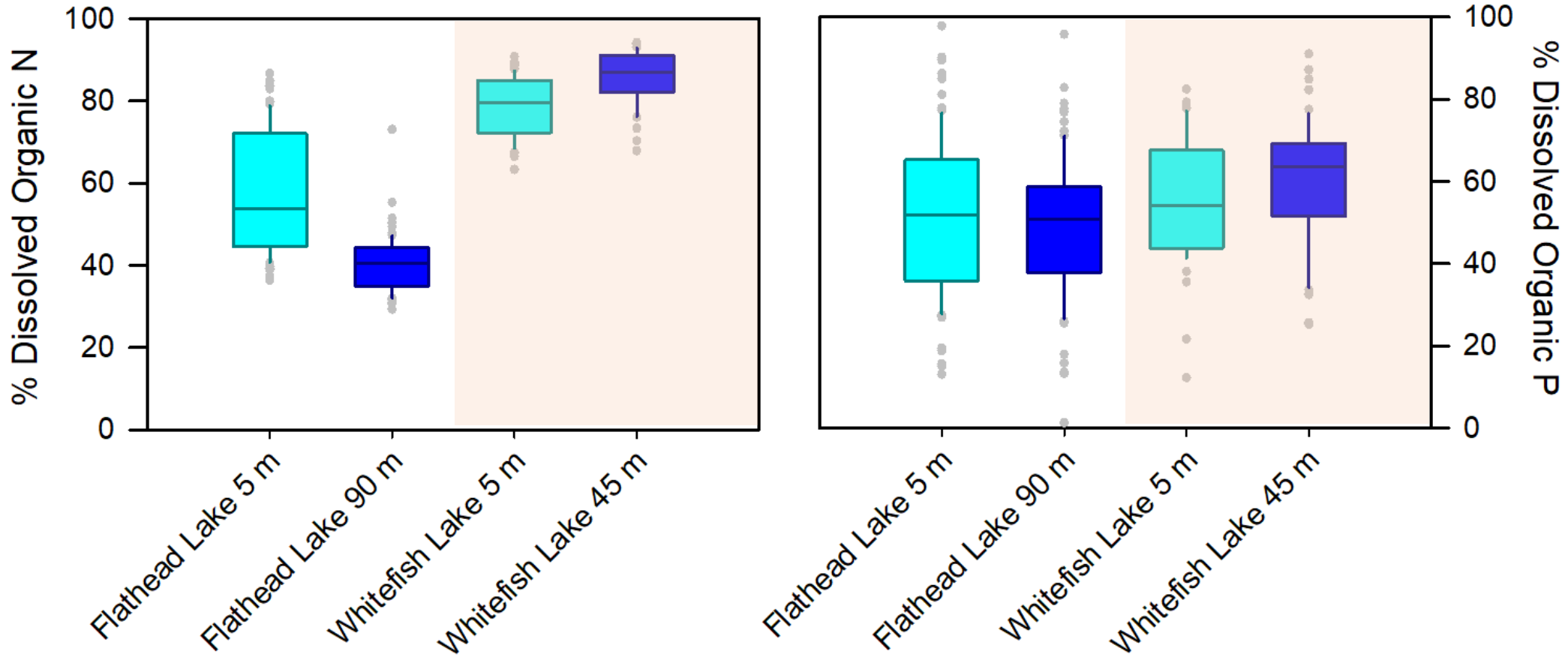
- Whitefish has much lower concentrations of nitrate
- Flathead nitrate concentrations demonstrate well-resolved seasonality in both surface and dep waters.

Seasonal variation (or lack thereof) in total P

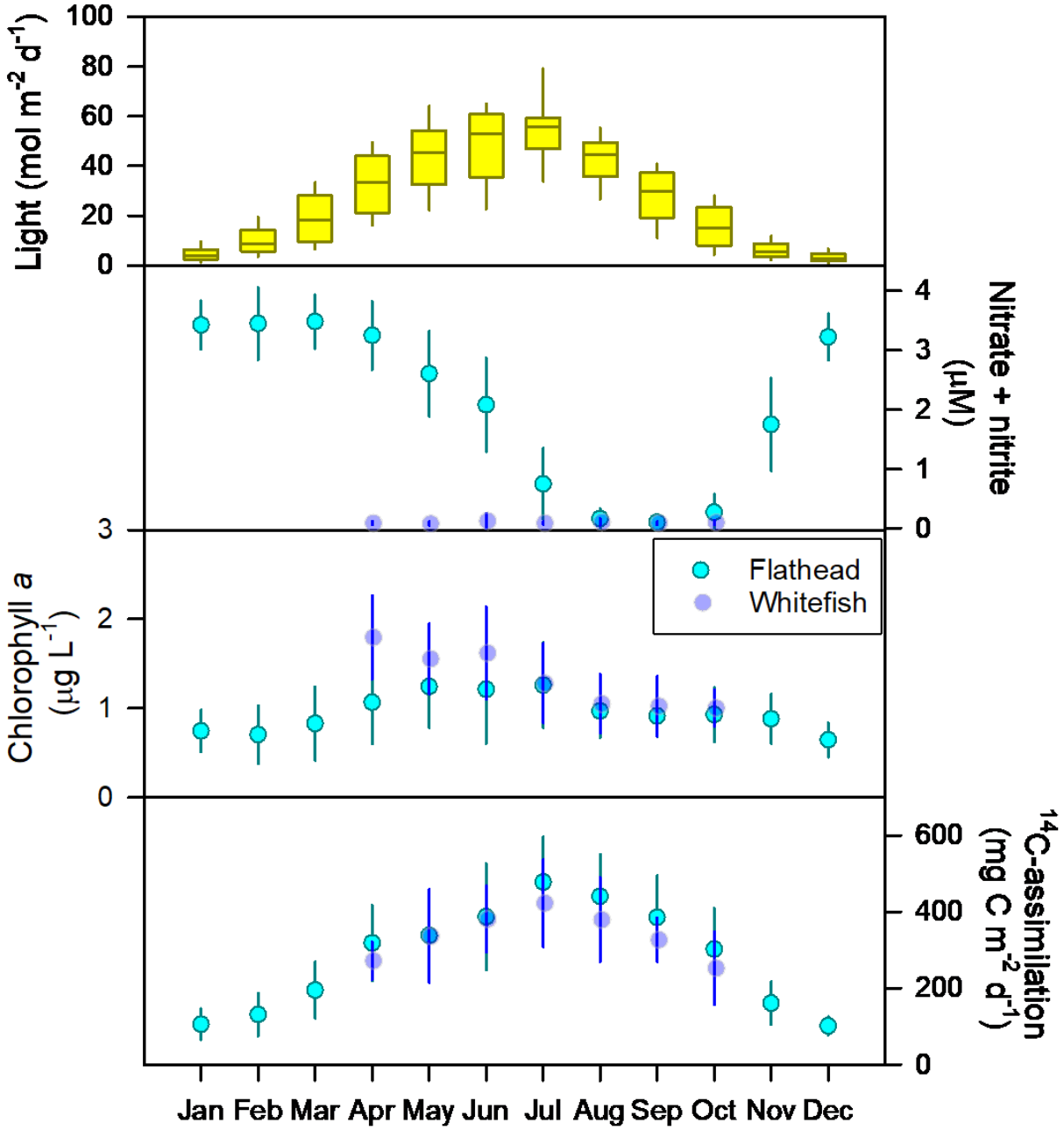


- Total P is low and comparable in both lakes

Dissolved organic matter is major reservoir of N and P



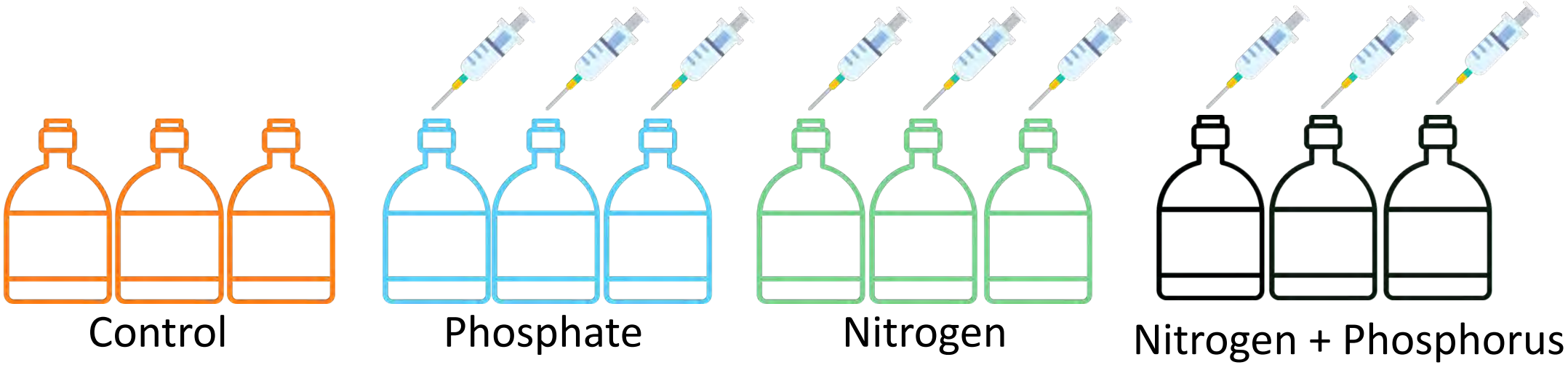
- More than half of the total N and P are contained in dissolved organic matter pools
- Bioavailability of these pools is largely unknown



- Primary production seasonally tuned to changes in light
- Strong differences in nitrate availability between lakes
- Chlorophyll slightly higher in Whitefish with seasonal maximum in both lakes in the early Spring

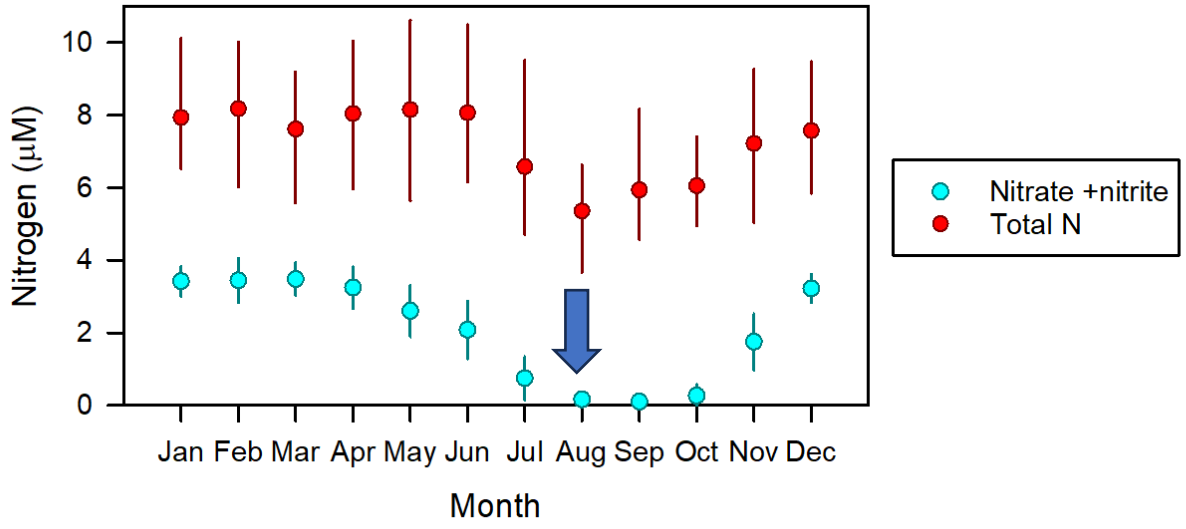
Question:

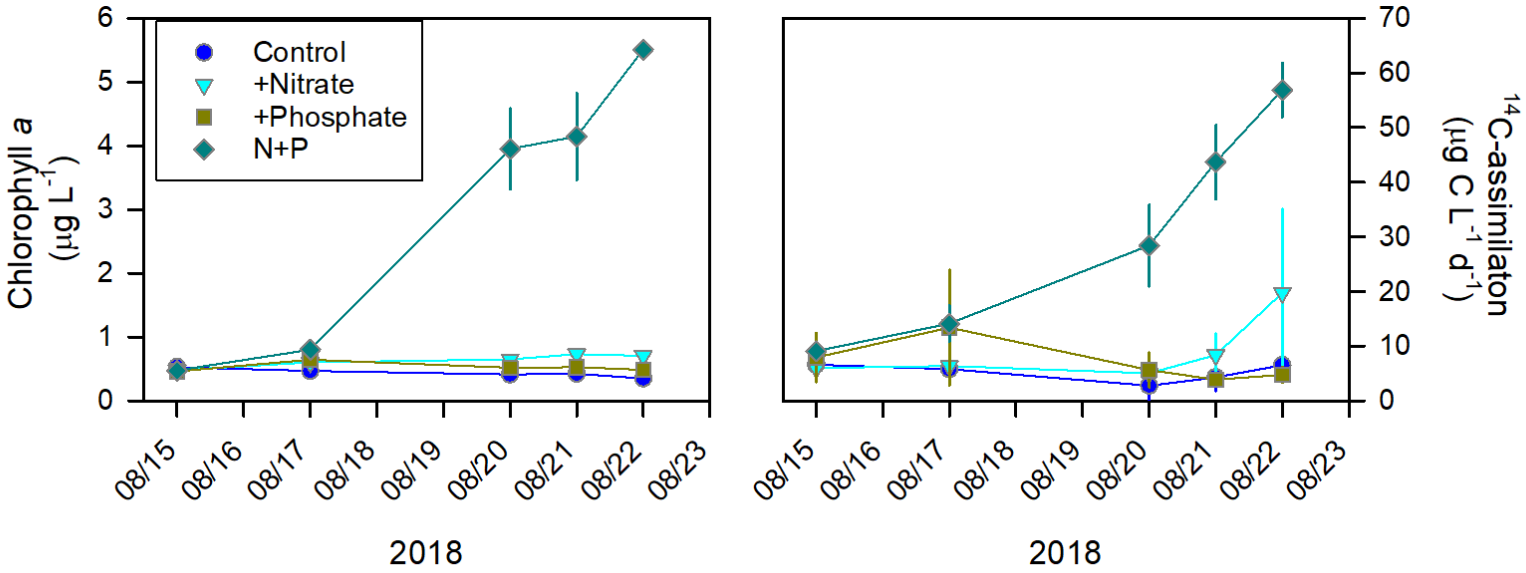
What nutrients limit algal growth in Flathead Lake during the summer?



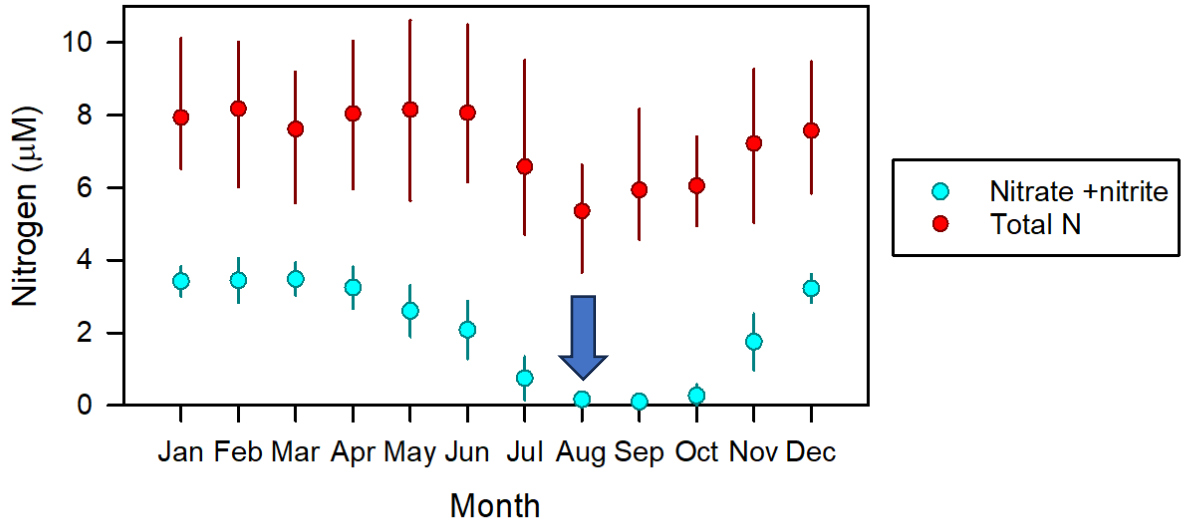
Experimental Design

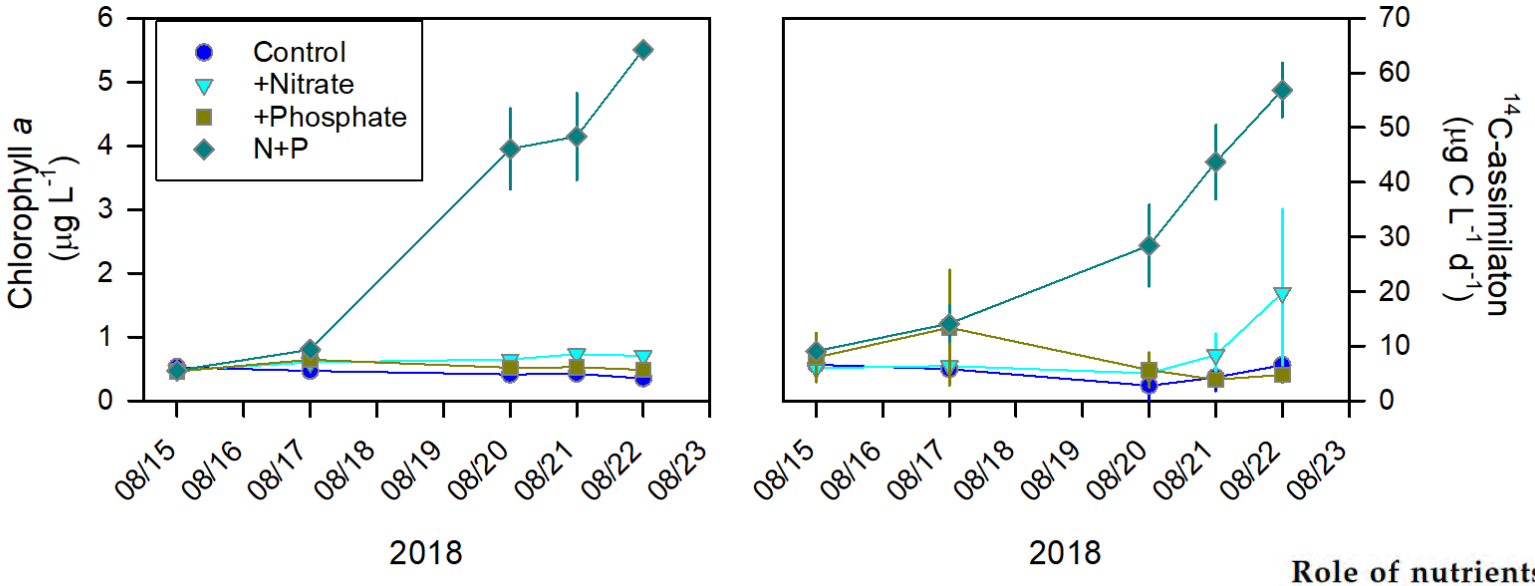
- June-November 2018
- Measure changes in photosynthetic carbon fixation (^{14}C-assimilation) and biomass (Chl *a*)





- Additions of N+P resulted in large increases in both chlorophyll and primary production
- Responses to P depend on nitrate availability





Simultaneous Nitrogen and Phosphorus Deficiency in Natural Phytoplankton Assemblages: Theory, Empirical Evidence, and Implications for Lake Management

Walter K. Dodds
Kirk R. Johnson
John C. Priscu
Department of Biology, Montana State University, Bozeman, Montana 59717

- Additions of N+P resulted in large increases in both chlorophyll and primary production
- Responses to P depend on nitrate availability

Co-limitation by phosphorus and nitrogen, and effects of zooplankton mortality, on phytoplankton in Flathead Lake, Montana, U.S.A.

Craig N. Spencer and Bonnie K. Ellis

Role of nutrients and zooplankton in regulation of phytoplankton in Flathead Lake (Montana, U.S.A.), a large oligotrophic lake

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**Flathead Lake Biological Station, The University of Montana, Polson, Montana 59860, U.S.A.*

Summary

- Time-resolved observations continue to enable detection of changes to Flathead and Whitefish Lakes
- Sustained, decadal-scale excellent water quality in both Flathead and Whitefish Lake
- Both lakes have low concentrations of bioavailable N and P - keeping both elements low is essential to maintain water quality

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Thank you!