Global trends in timing and rates of chlorophyll-*a* increase in cold-temperate and temperate lakes

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Background

- Lakes in cold and cold-temperate climates are impacted by climate warming: changes in water temperature, ice phenology, water column stratification, and algal community structure are altering the primary productivity of these lakes.
- **Chlorophyll-*a* (chl-*a*)** is a common proxy for algal primary production.
- We compiled time series of *in situ* chl-*a* concentrations and ancillary data for 340 lakes at latitudes above 40°N from open data sources covering the period 1964-2019.
- Monthly sampling is most common, followed by bi-weekly and weekly sampling.
- For each lake and year, we delineated the seasonal **periods of chl-*a* increase (PCIs)** and the corresponding **rates of chl-*a* increase (RCIs)** and compiled them into a new database containing a total of 52116 PCIs.
- The new PCI and RCI database is now available as an online, open-access community resource.

Lakes in dataset

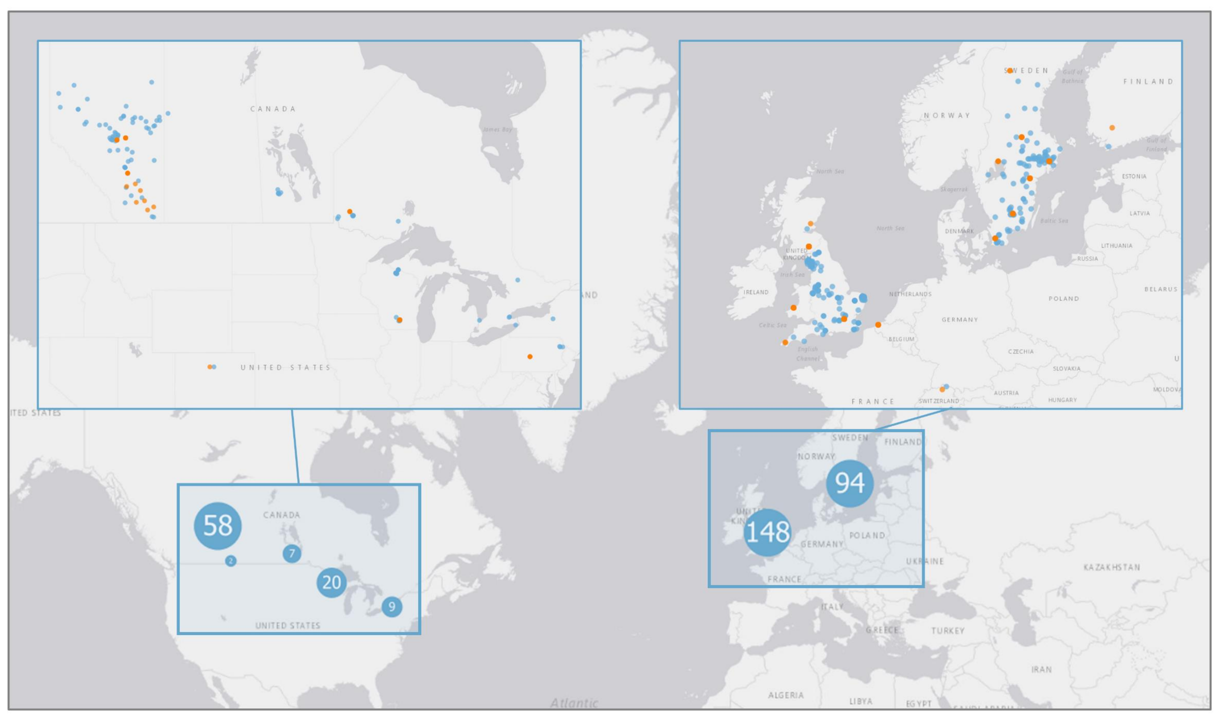


Figure 1: Distribution of 340 northern lakes (blue dots) included in the new chl-*a* database; also shown are the closest solar radiation stations paired with the lakes (orange dots).

Methodology

Step 1: Time series chl-*a* data are smoothed;
Step 2: PCI starts when instantaneous RCI exceeds threshold value (here 0.4 day^{-1});
Step 3: PCI ends when smoothed chl-*a* concentration reaches its maximum;
Step 4: PCI timing, duration and average RCI are compiled in the dataset.

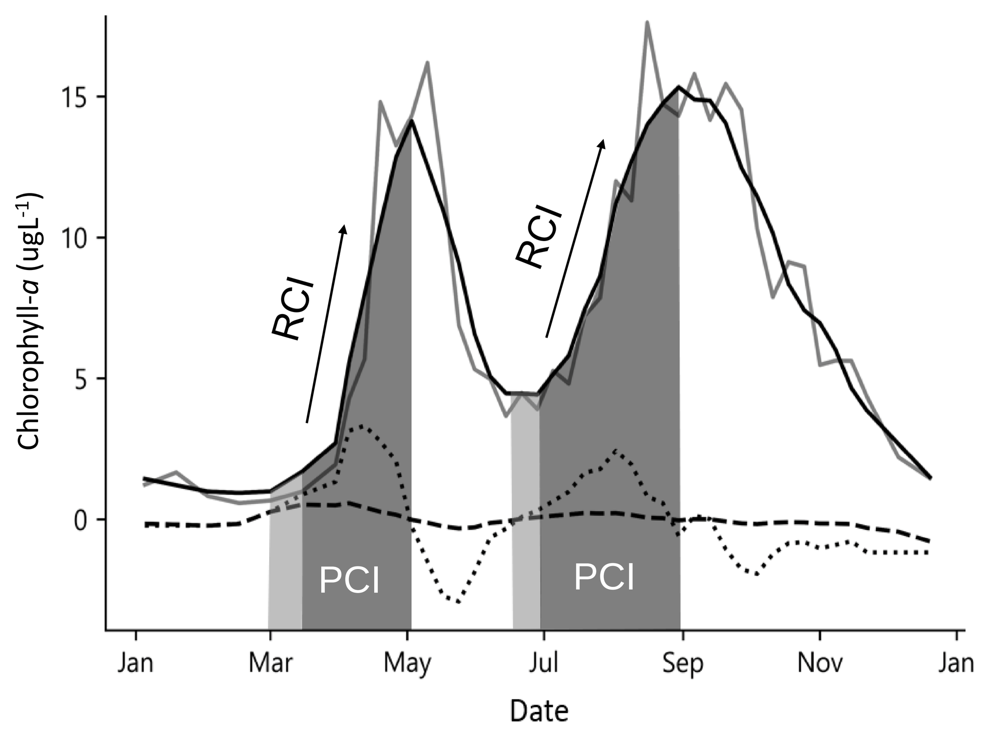


Figure 2: Example of lake with two PCIs (spring and summer-fall). Data shown are for year 1988 in Lake Windermere, United Kingdom.

Dataset: periods of chl-*a* increase (PCI)

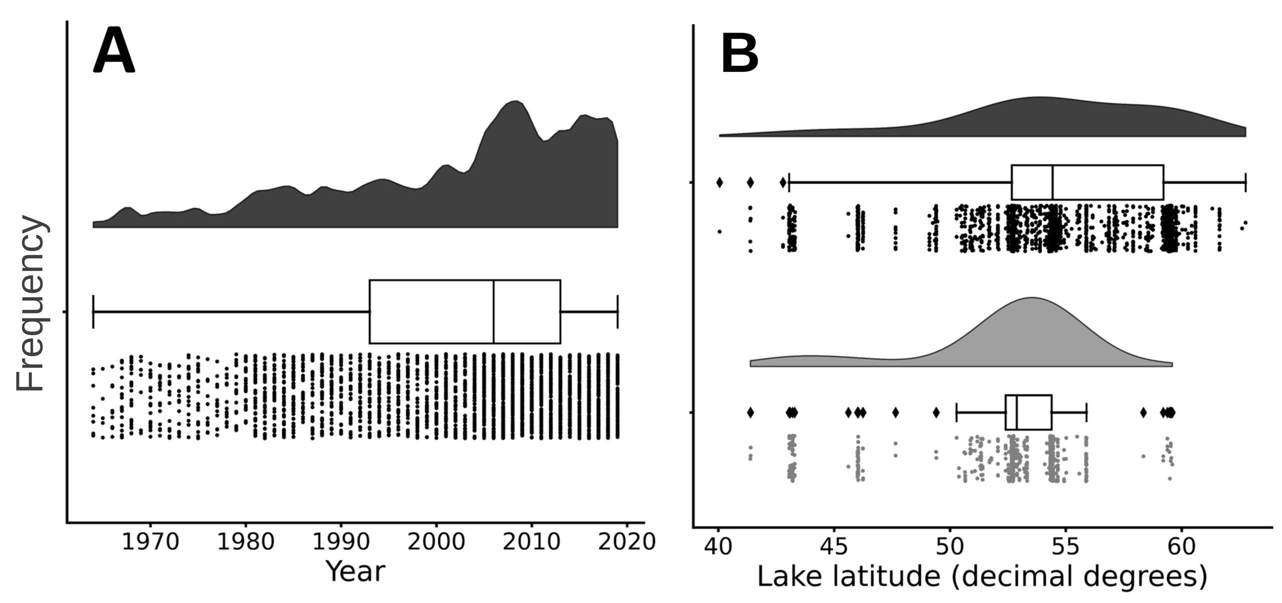
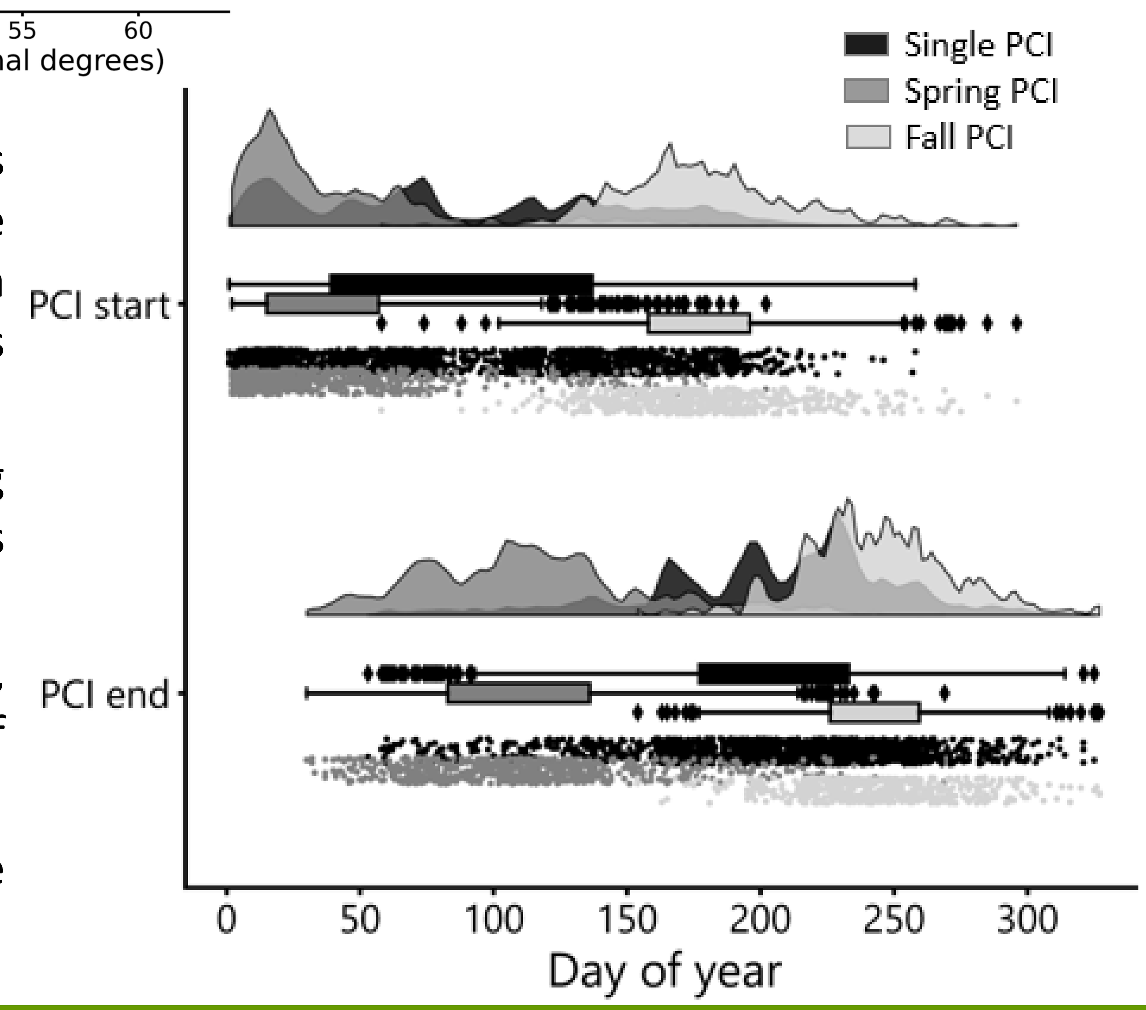


Figure 3 (left): Frequency distributions of (A) years with chl-*a* data, and (B) latitude of lakes in the dataset.

Figure 4 (below): Frequency distributions of the start and end dates of all the PCIs in the dataset.



- Availability of time series chl-*a* measurements is higher in recent years (Fig 3A), likely because of greater monitoring efforts and open data requirements by funding agencies and journals [1,2].
- At latitudes 40-60°N lakes with two PCIs (spring and fall blooms) dominate; above 60°N lakes with single PCI dominate (Fig 3B).
- Start dates of single PCIs cover a wide range, mostly between mid-February and the end of May (Fig 4).
- The average durations of spring, fall and single PCIs are 73, 65, and 88 days, respectively.

Dataset: rates of chl-*a* increase (RCI)

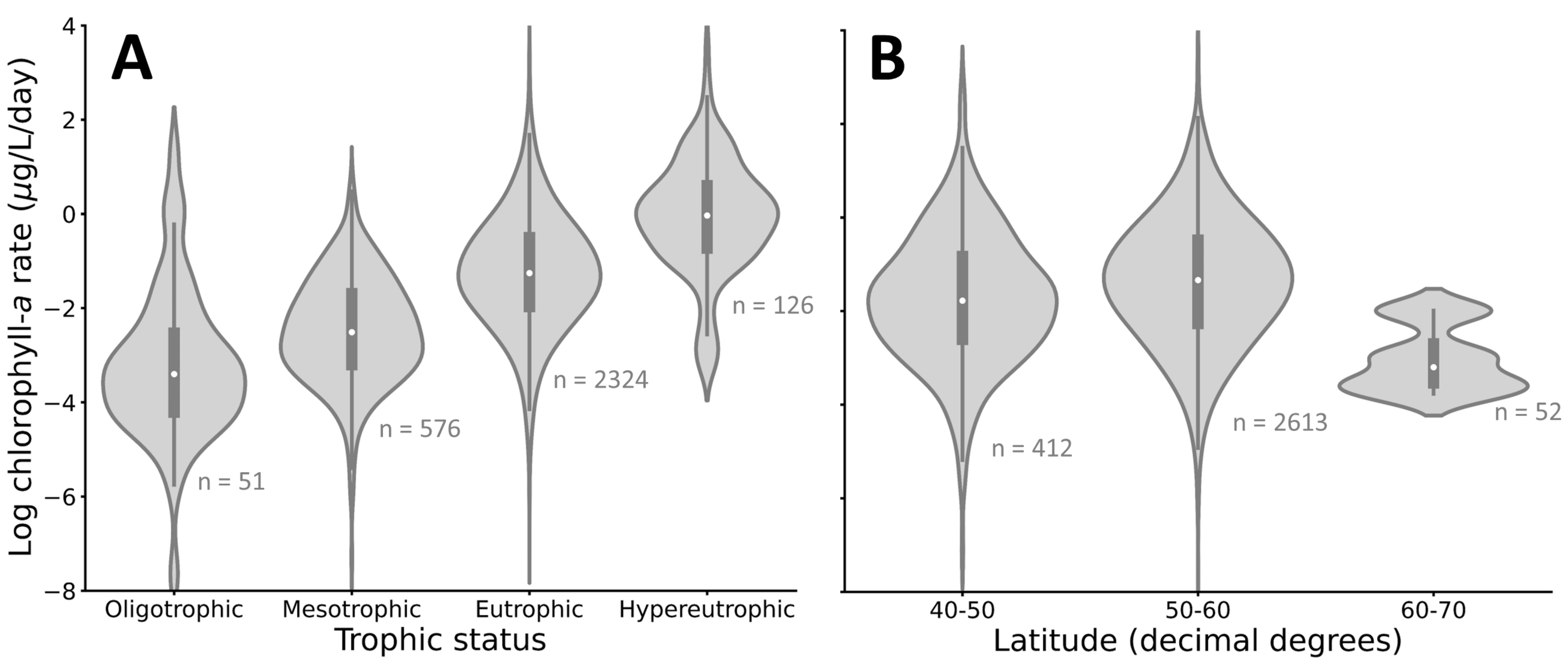


Figure 5: Log RCIs grouped by (A) trophic status and (B) latitude.

- Mean RCI increases with trophic status as a result of greater nutrient availability (Fig 5A).
- High latitude lakes (60-70°N) tend to have lower RCIs (Fig 5B), likely due to cooler temperatures and lower solar irradiance at these latitudes [3].

Example data trends: PCI start dates

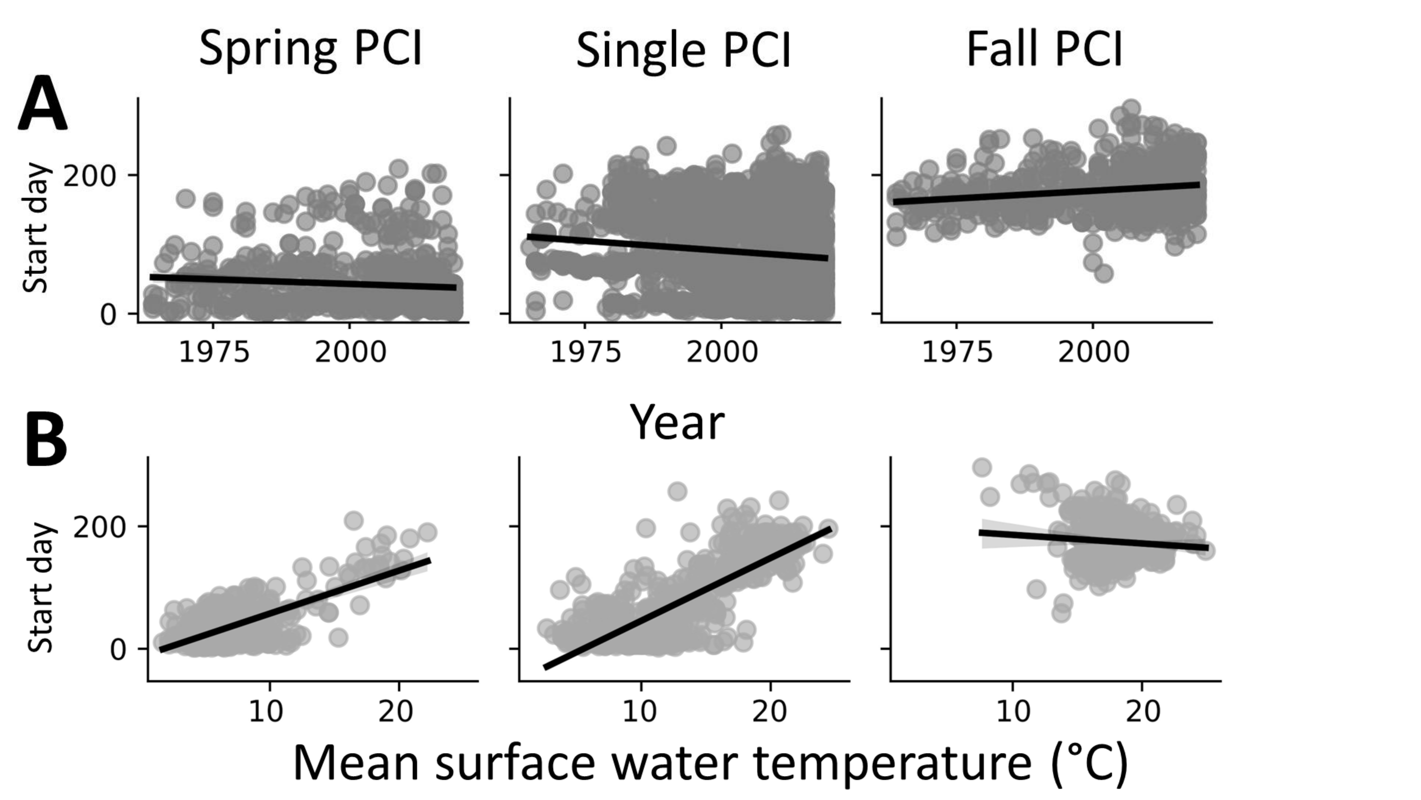


Figure 6: Distribution of PCI start dates (A) versus time and (B) versus water temperature. For each panel, the average trend line is shown.

- On average, spring and single PCIs are starting earlier in the year (Fig 6A).
- Starting dates for spring and single PCIs correlate positively with water temperature (Fig 6B).
- These chl-*a* trends are consistent with algal growth starting earlier in the year because of climate warming.

Takeaways

1. PCI and RCI represent novel metrics to uncover and analyze spatial and temporal **trends in lake productivity**, based on relatively abundant data on chl-*a*.
2. Spring and single PCIs of lakes at latitudes above 40°N are **trending towards earlier start dates**, likely due to climate warming.

Code and data

Code available on Github:
https://github.com/hfadams/growth_window

Data available on Federated Research Data Repository: https://doi.org/10.20383/102.0488

Manuscript under review. Preprint:
https://essd.copernicus.org/preprints/essd-2021-329/

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