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Estimating and Projecting Internal Phosphorus Loading in Piedmont Reservoirs

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Introduction

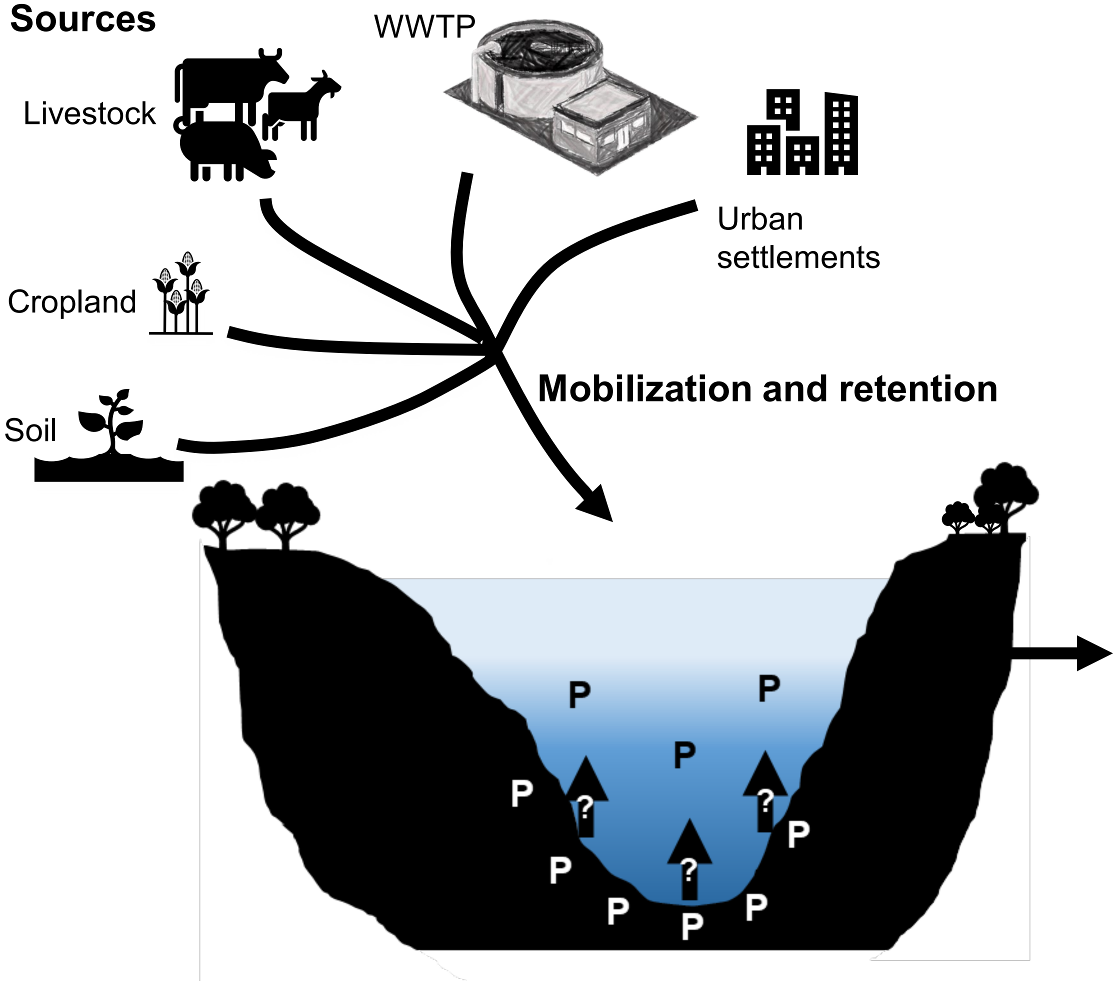


Fig : Various sources of P loading to a lake or reservoir

Internal P loading (IPL) can delay water quality improvements by 10-100 years[1].

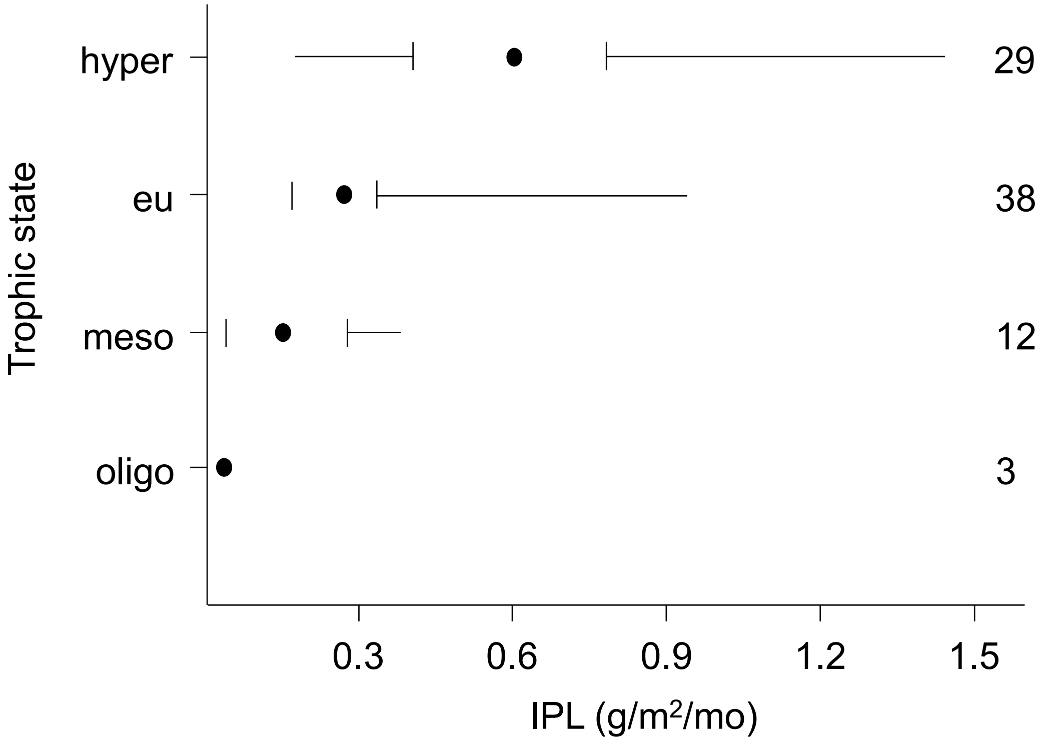


Fig : IPL across different trophic states in worldwide lakes. Median (circle), non-parametric 95% confidence limits (vertical bars), ranges (horizontal lines), and number of lakes (on the right) are indicated. Figure adapted from Nürnberg (1988)[2].

Research questions

1. How much IPL in Jordan Lake and Falls Lake?
2. How is climate change (i.e., lake warming) going to change the P dynamics in a reservoir?
3. How will P management scenarios affect the P dynamics?
4. What about internal nitrogen loading?

Model

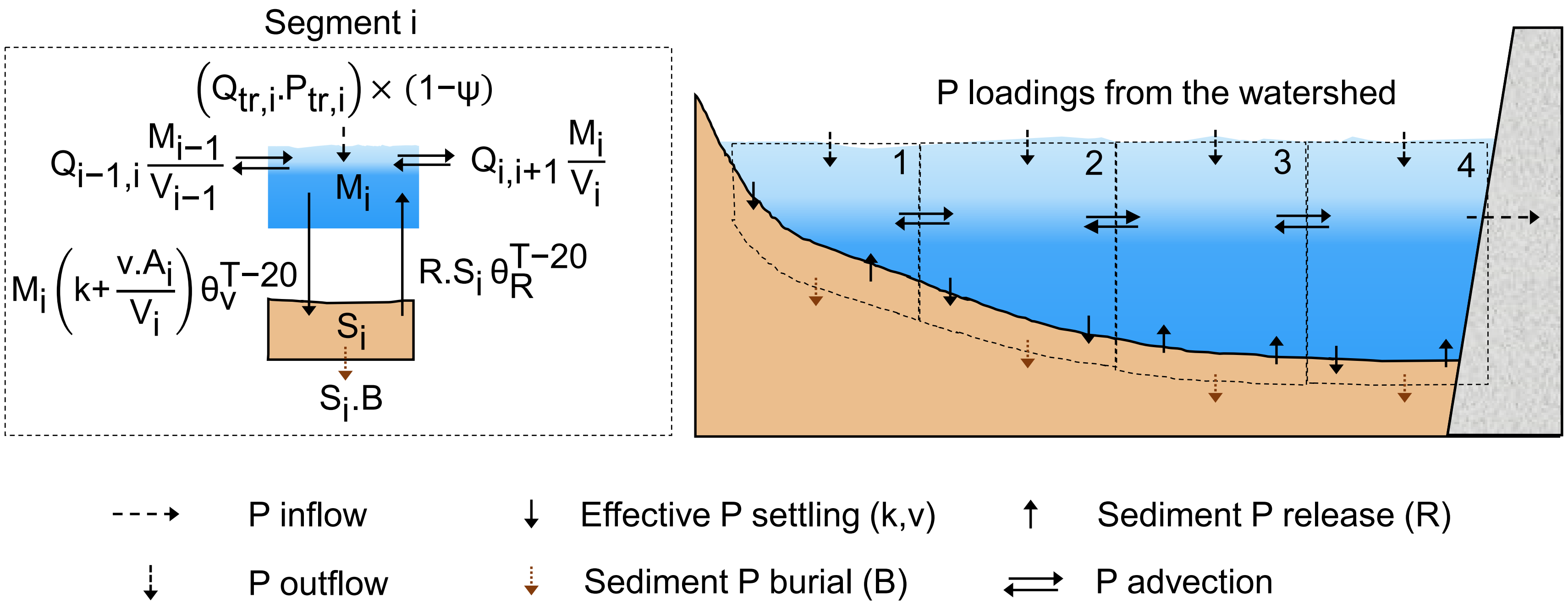


Fig. Model schematic of P flows within the water and sediment layers of the four reservoir segments.

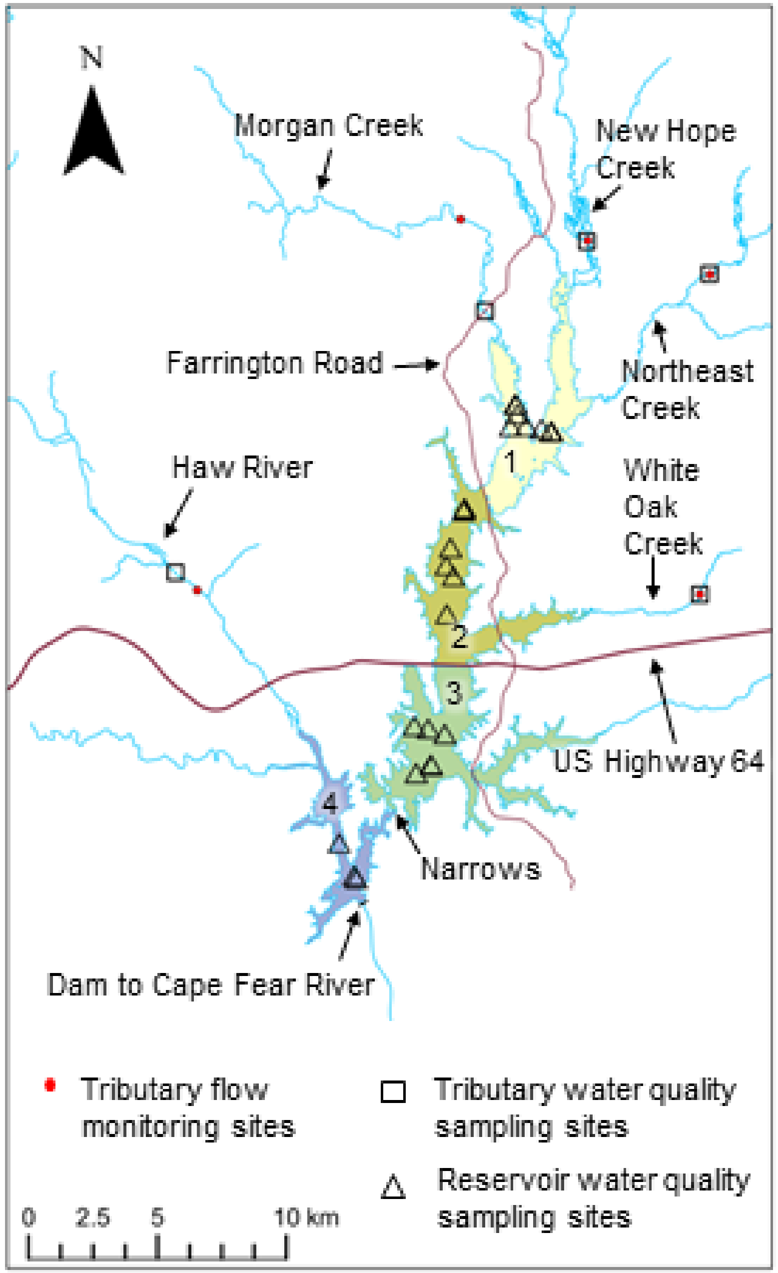


Fig. Study area: B. Everett Jordan Lake, NC, USA.

Long term and seasonal trends in P fluxes

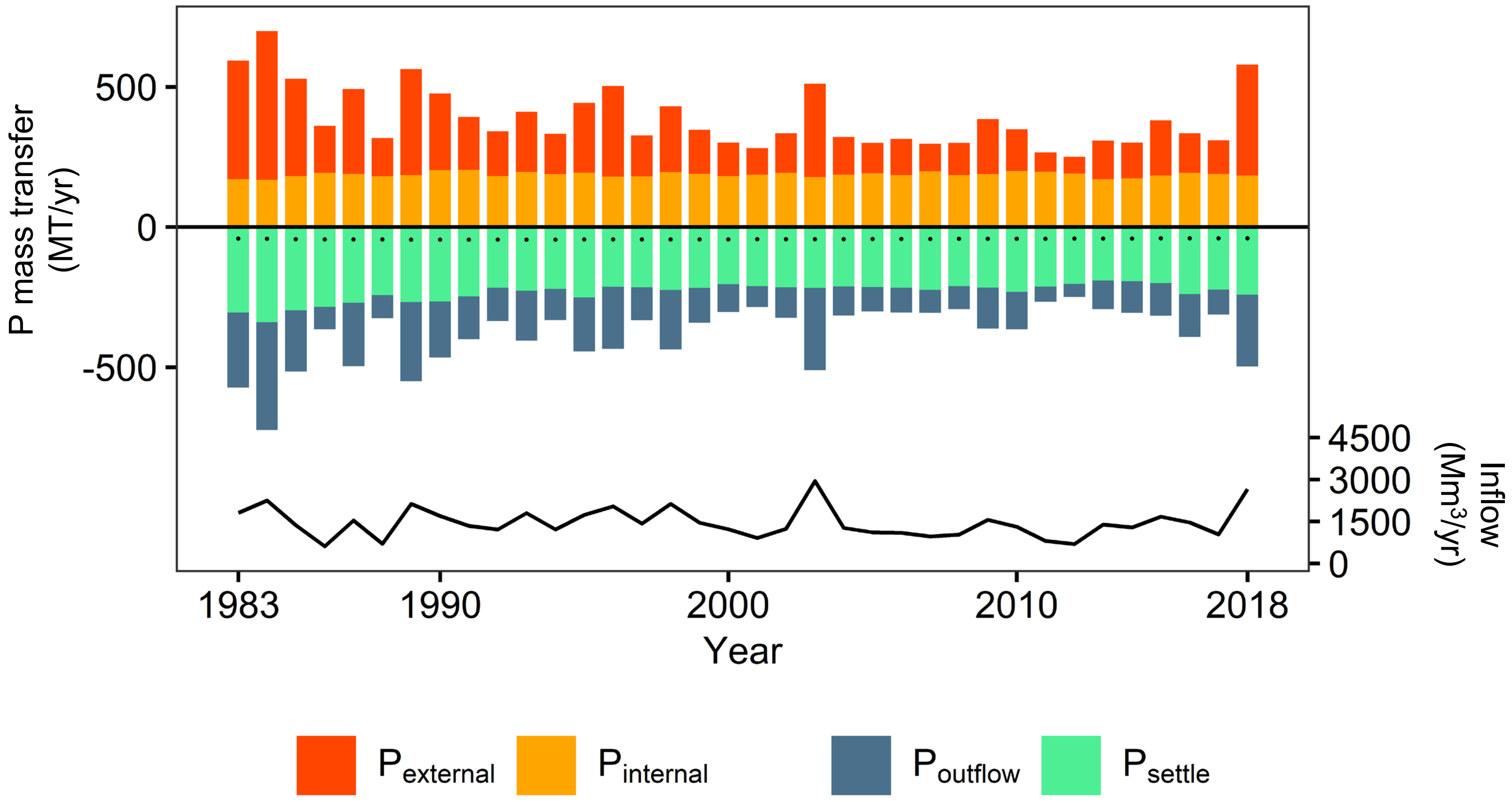


Fig. Annual Mass transfers of P across the water-column in Jordan Lake.

Long term and seasonal trends in P fluxes

Annual variations

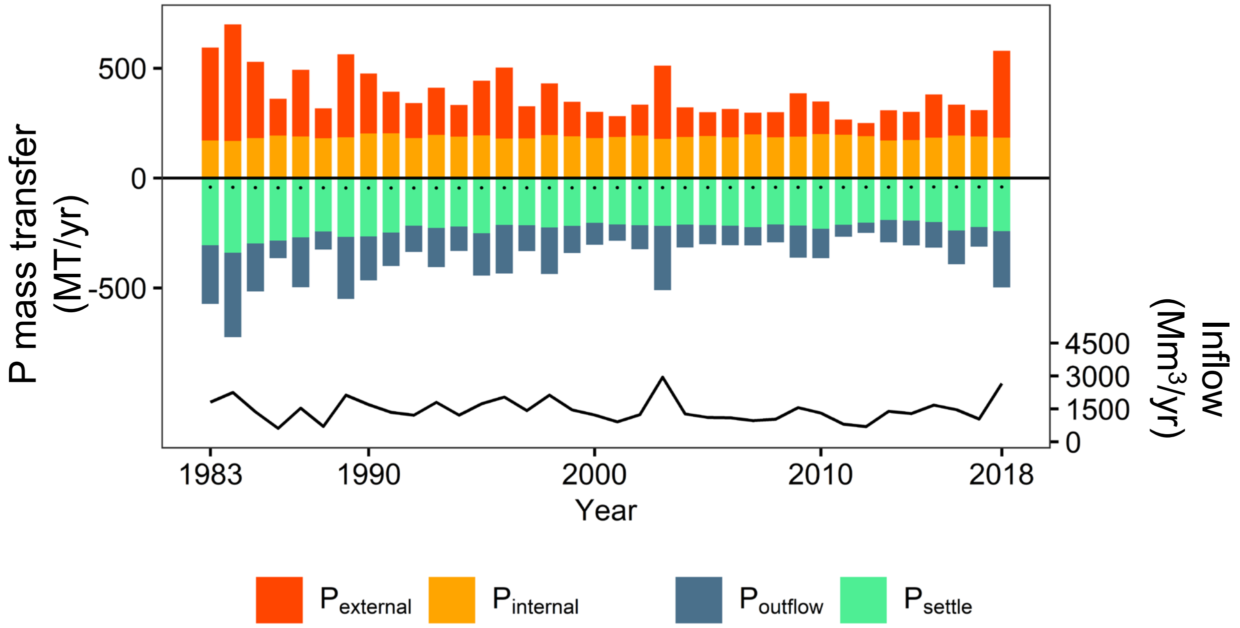


Fig. Annual Mass transfers of P across the water-column in Jordan Lake.

Seasonal variations

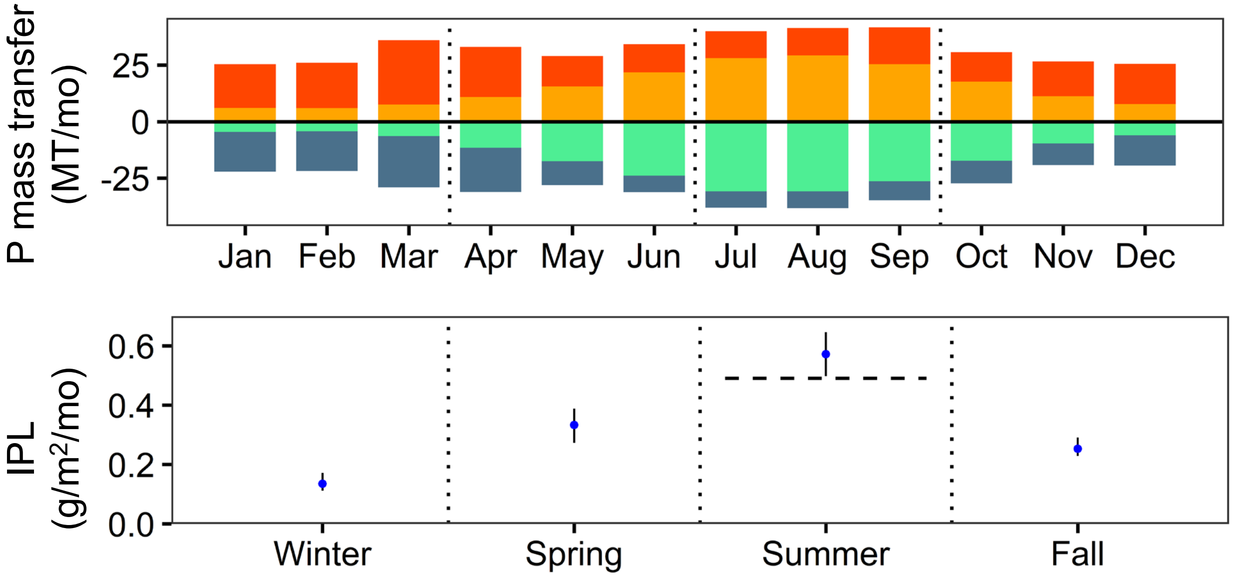


Fig. Seasonal variation in IPL. The dashed horizontal line represents the mean IPL flux for anoxic summer conditions across previous studies[3-8].

Recent study[9] suggest atmospheric P deposition over Jordan Lake was 0.00075 $g/m^2/mo$ in 2012.

Future trends and climate change

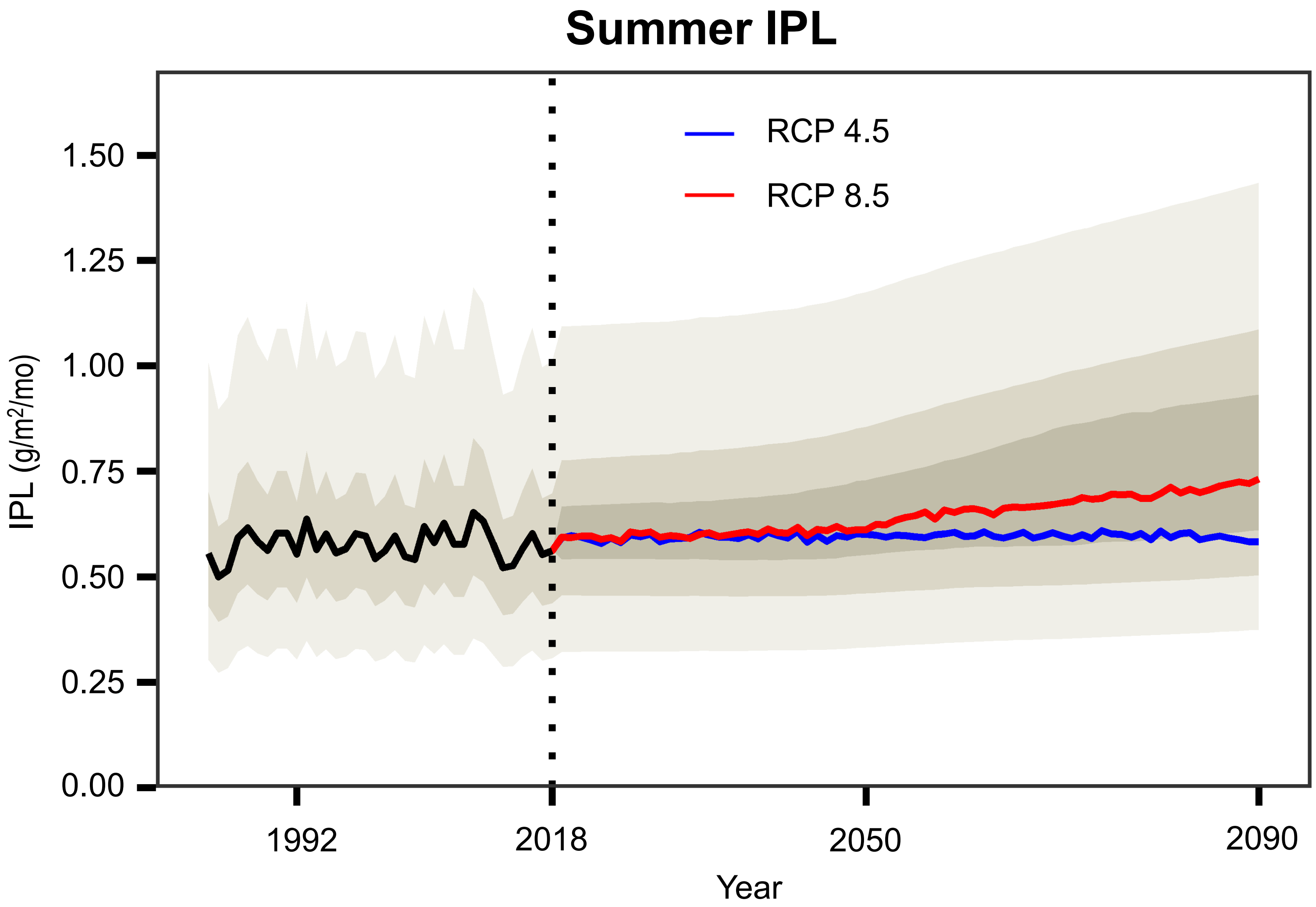
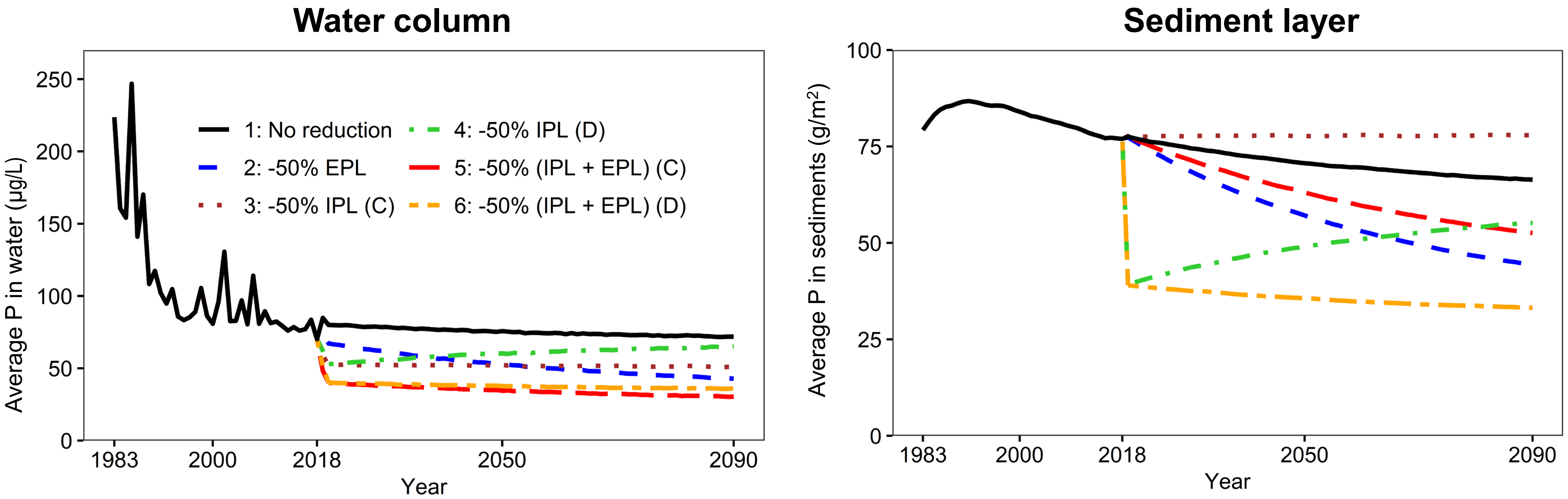


Fig. Future projections: summer IPL under RCP 4.5, and RCP 8.5 across the reservoir (2019-2090).

Reservoir management scenarios


Water column

Sediment layer

Fig. Projected annual-average P concentration under different management scenarios in water-column in Segment 1 (left panel) and sediment layer across Jordan Lake (right panel). The lines represent the median projected values under RCP 8.5 with 50% reduction in external P load (EPL) and/or internal P load (IPL). Two stylized internal load reduction scenarios are considered: sediment capping (C) and sediment dredging (D).

Internal phosphorus loading in Piedmont reservoirs

Jordan Lake

Our long-term model estimates:

Season	IPL (g/m^2/mo)
Winter	0.13 ± 0.06
Spring	0.33 ± 0.17
Summer	0.55 ± 0.24
Fall	0.25 ± 0.14

Sediment core studies by Zeller and Alperin (2021)[10] :

Season	IPL (g/m^2/mo)
Winter, 2018 (oxic)	0.01 ± 0.01
Spring, 2018 (anoxic)	0.22 ± 0.07

Falls Lake

Alperin/UNRBA (2019)[11]: Sediment core study (summer, 2015; oxygenated waters):

mean IPL = 0.004 g/m^2/mo

Flexner/EPA (2019)[12]: Box chamber study (summer, 2018):

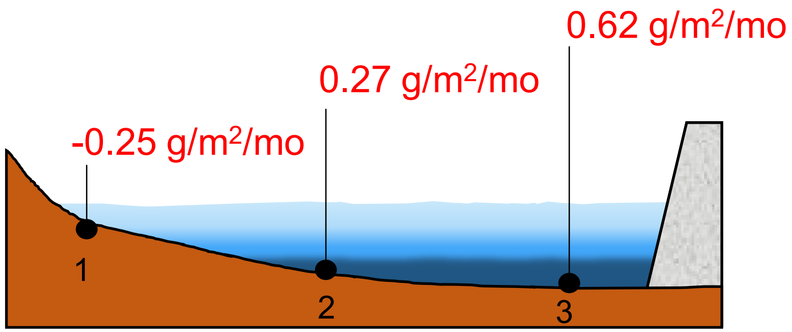


Fig. Pictorial representation of IPL observed in the Flexner study (2019). Aerobic conditions generally existed in location 1.

UNRBA/EFDC modeling: model predicts summer IPL of about 0.1 g/m^2/mo.

Internal nitrogen loading in Piedmont reservoirs

Jordan Lake

Our long-term model estimates of TN fluxes[13]:

Season	INL (g/m^2/mo)
Winter	2.62
Spring	5.95
Summer	9.25
Fall	3.88

Sediment core studies for ammonium fluxes by Zeller and Alperin (2021)[10] :

Season	INL (g/m^2/mo)
Winter, 2018 (oxic)	-0.6 to 1.5
Spring, 2018 (anoxic)	0 to 1.5

Falls Lake

Alperin/UNRBA (2019)[11]: Sediment core study (summer, 2015):

mean ammonia flux (main stem)= 0.9-2.7 g/m^2/mo

Flexner/EPA (2019)[12]: Box chamber study (summer, 2018):

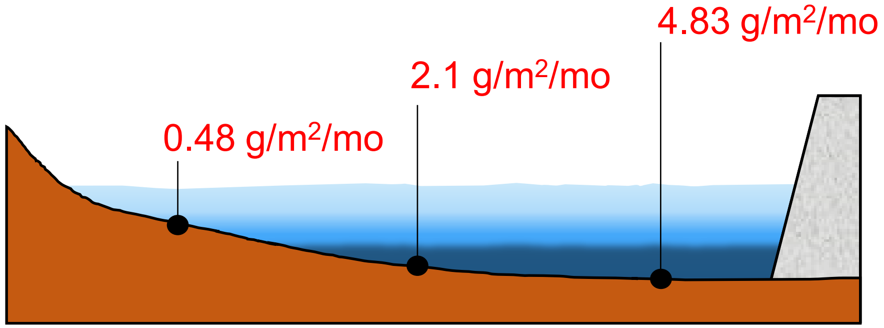


Fig. Pictorial representation of ammonia observed in the Flexner study (2019). Aerobic conditions generally existed in location 1.

UNRBA/EFDC modeling: model predicts summer ammonia flux of about 0.9 g/m^2/mo.

Take-home message

Jordan Lake

- Internal loading accounts for >50% of total load in the lake, and it will thus take many decades for external loading reductions to fully translate to water quality improvements.
- In-lake management (e.g., dredging, capping) could substantially accelerate water quality improvements, but the socio-economic feasibility of these options was not explored.

Falls Lake

- Internal loading estimates are quite variable. Assuming lower estimates (e.g., EFDC) are correct, Falls Lake will respond more quickly to external loading reductions.
- Given the substantial uncertainties in internal loading, continued monitoring and model updating may be important for assessing how the lake is responding to changing inputs.

Thanks

NC Policy Collaboratory

SOUTHEAST
Climate Adaptation Science Center

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Scan the QR code for references.

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