Storm Impacts on Phytoplankton Community Dynamics in Lakes

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The impact of storms on lake conditions and thus phytoplankton is not just a simple consideration of storm "strength"

1. Extreme weather events, such as storms, have increased in many regions across the globe

- However, our understanding of how short-term disturbances translate from meteorological forcing to phytoplankton dynamics is poor
- GLEON Project Storm-Blitz links storm-induced changes in lake conditions to phytoplankton traits via system attributes across lakes

2. We synthesize how storms may impact :

- Temperature, light and nutrient conditions of lakes, and how such changes may subsequently shape…
- Lake phytoplankton community dynamics based on life history and trait-based concepts

3. Storms do not operate in a vacuum

- Lake morphometry, catchments and antecedent conditions mediate storm impacts on lake conditions (Fig 1)
- Phytoplankton traits determine their responses to post-storm conditions and possible alterations to ecosystem function (Fig 1)

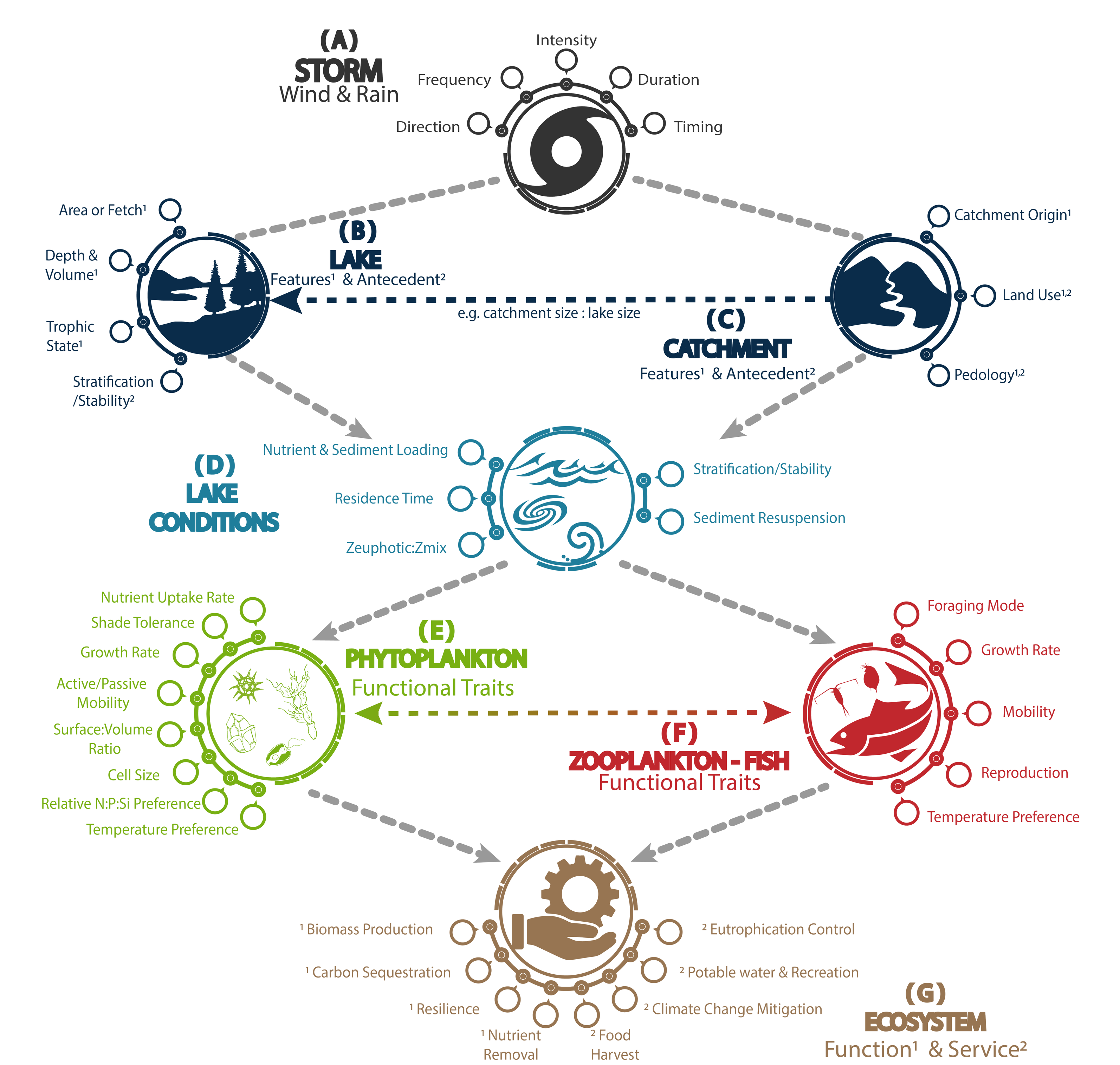


Fig 1 Conceptual model of how storm, lake and catchment attributes, and antecedent conditions, combine to alter light, nutrient and thermal conditions of lakes. Examples of phytoplankton and higher trophic level functional traits, which likely play important roles in phytoplankton competition for survival and growth after storm-induced disturbances, and ultimately ecosystem functions and services are shown.

4. Rain and wind are filtered through lake and catchment features and existing conditions

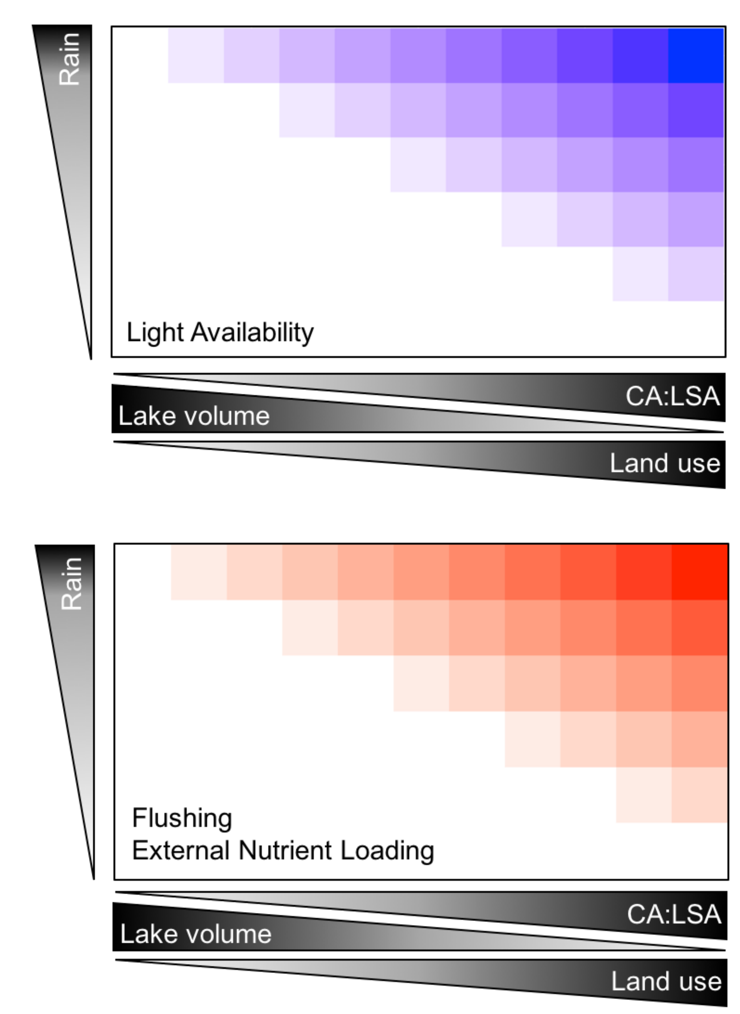
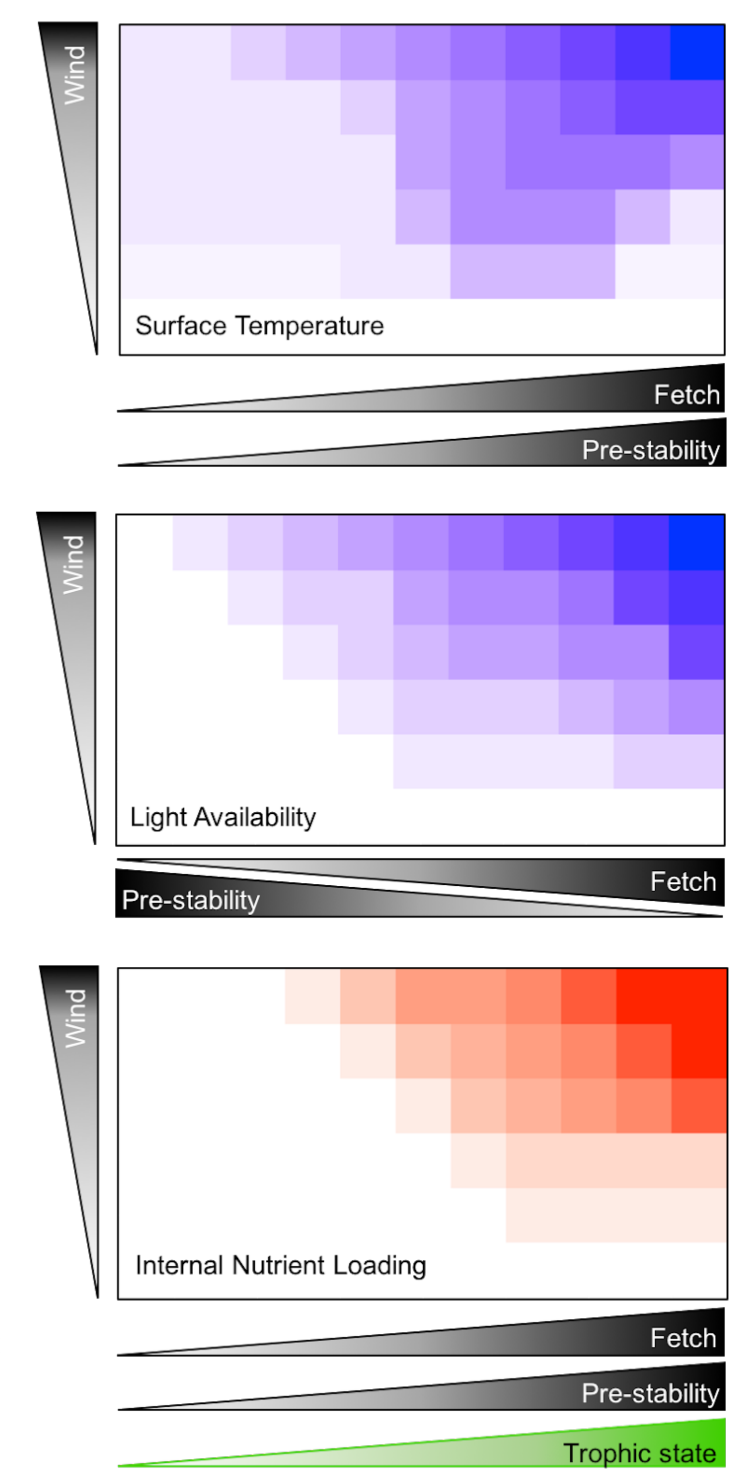


Fig 2 (↑) Expectations of how rain events will interact with lake and watershed features to alter post-storm light and nutrient conditions of lakes. Red is increase, white neutral, and blue decrease. Land use refers to human modification to the landscape such as agriculture, forestry and urban development.

Fig 3 (→) Expectations of how wind events will interact with lake fetch, antecedent ("pre") water column stability and trophic state to alter post-storm temperature, light and nutrient conditions of lakes



- Rain impacts on light availability, system flushing and external nutrient loading influenced by catchment to lake surface area (CA:LSA), lake volume and land use (Fig 2)
- Wind impacts on water temperature, light availability and internal nutrient loading influenced by lake fetch, antecedent ("pre") water column stability and trophic state (Fig 3)

5. PEG model elucidates possible phytoplankton responses

- Physical, nutrient and temperature conditions dictate seasonal phytoplankton community composition
- The functional traits associated with constituent species available to respond to storm-induced changes are seasonally-dependent (Fig 4)
- The PEG model formalizes seasonality of storm impacts on community dynamics (Fig 4)

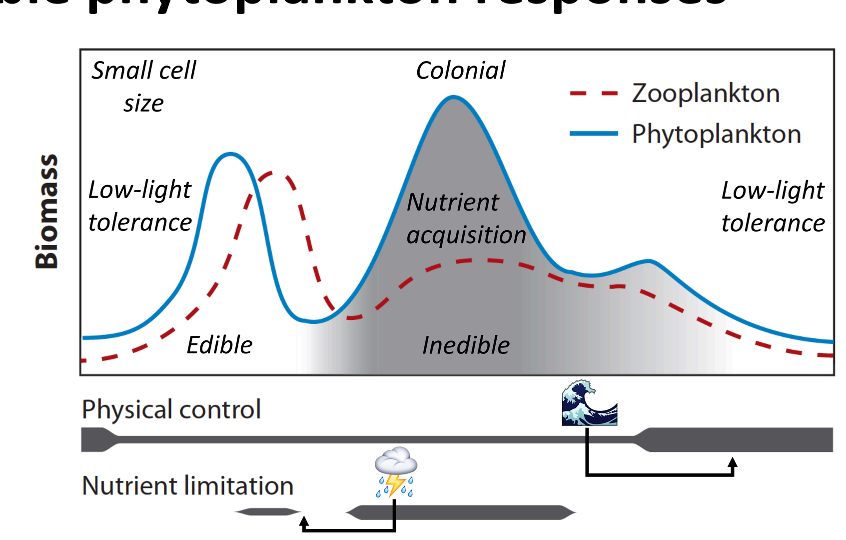


Fig 4 PEG model of seasonal phytoplankton biomass and relative importance of *example functional traits* in eutrophic lakes. Horizontal bars indicate seasonal relative importance of physical and nutrient conditions in lakes. Storms may cause deviations from typical seasonal trajectories. Note grazing control is not shown. Based on Figure 1 from Sommer et al. (2012).

6. A predictive framework for how phytoplankton functional traits mediate community responses to storm events

- Frameworks such as competitive (C), stress-tolerant (S) and ruderal (R) strategies and morpho-functional traits provide a basis for community change with increased nutrients or decreased light (Fig 5)

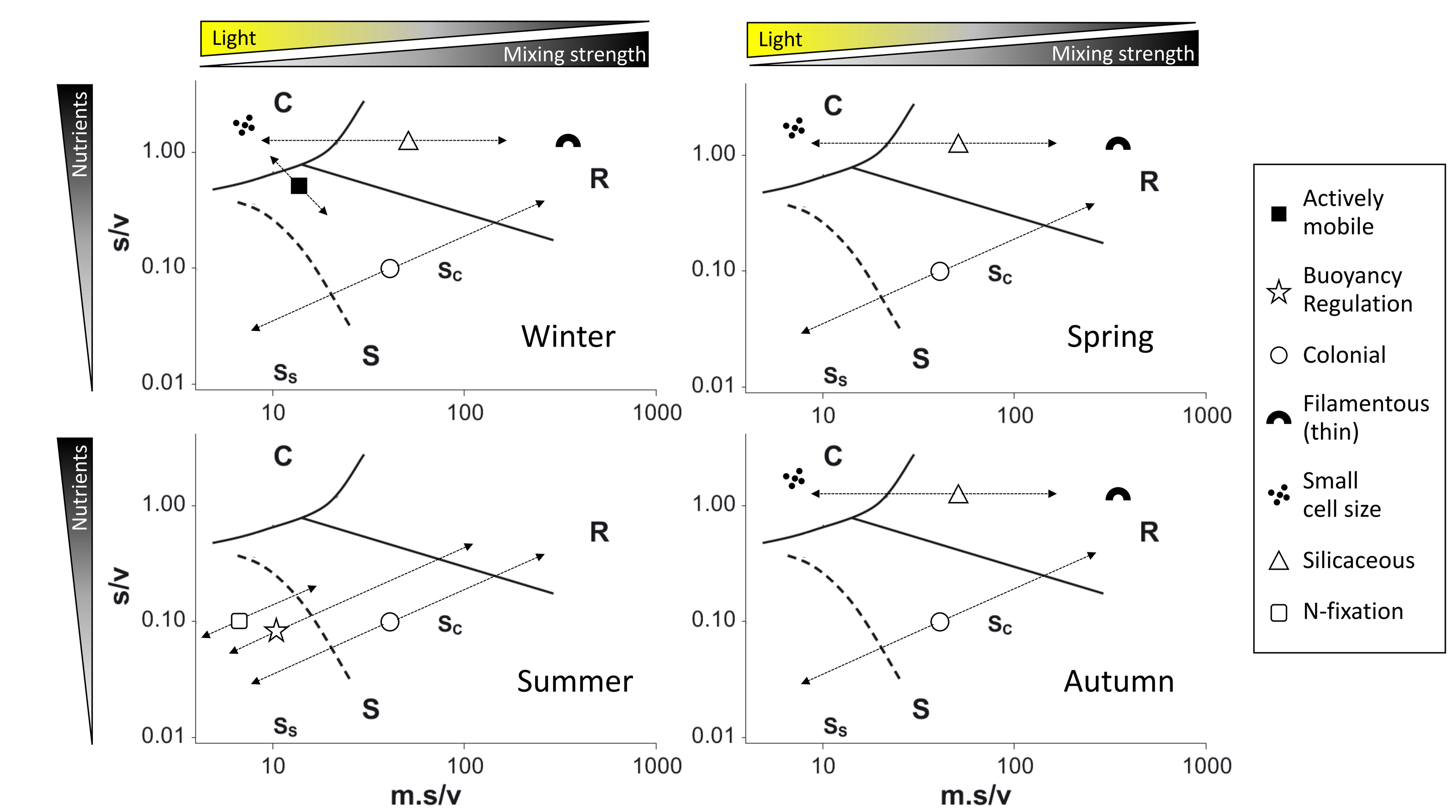


Fig 5 Seasonal mapping of C-S-R strategies and functional traits in shape (max linear dimension (m) x surface (s) to volume (v) ratio, m.s/v) and s/v "space" for environmental conditions susceptible to storm-induced rain and wind events mediated by lake and catchment features and antecedent conditions (Figs 2-4). Dashed arrows represent the range of shapes, sizes and environmental conditions a functional trait can span. Figure modified from Madgwick et al. (2006). Seasonal plots of functional trait composition derived from temperature-dependent growth of phytoplankton groups associated with each trait (Paerl and Otten 2013).

- Groups with high growth rates (small cell sizes) and low-light tolerance (silicaceous, filamentous) could benefit from storm-induced increases in nutrients and mixing in winter, spring, and autumn, but may not be present in summer to respond (Fig 5)
- Conversely, S strategists with N-fixation and buoyancy regulation likely not to benefit (in the short-term) from storms in any season

7. Next Steps

- Place expectations in context of ecological theory (e.g., resilience and resistance, succession and intermediate disturbance hypothesis)
- Evaluate time scales of storms, lake responses and phytoplankton growth to understand how sampling frequency may constrain or confound insights into storm impacts
- Test strength of wind and rain on temperature changes across lakes
- Outline promising research directions for "limnological storms"
- Submit synthesis paper to Global Change Biology in early 2019

8. Acknowledgements

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