Factors Determining the Timing of the Peak of the Spring Bloom in Two Estuarine Systems

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Introduction:
The two systems are proximate and have similar phytoplankton species and weather. Both are light limited in the winter and the spring bloom terminates due to nitrate limitation. Both are estuarine systems with strong stratification. The Strait of Georgia (Fig 1) is the larger of the two and is semi-enclosed. Rivers Inlet (Fig 1) is a typical fjord, open on its western end.

Model:
We use a vertical one dimensional mixing model with two dimensional processes parametrized (Fig 2, [1]). Model is for the upper 40 m of the water column and is highly resolved (0.25m - 0.5m grid cells). The model is forced by hourly winds and cloud fraction and by daily river flows. This physical model is coupled to a simple NPP phytoplankton model (Fig 3, [1]). For each system one biological parameter was tuned and blooms in multiple years were successfully hindcast ([1], Fig 4).

Modelled System:

\[ \frac{dP}{dt} = \text{growth} - \text{grazing} - \text{mortality} + \text{physics} \quad (1) \]

Growth is light or nitrate limited. Light is calculated based on sun angle, clouds, chl self-shading, river carried particulates. Grazing is by a specified mesozooplankton population that increases monotonically through the spring. Mortality is a fixed percentage of phytoplankton biomass. Physics includes 1) mixing, 2) advection due to estuarine flow 3) advection out of the fjord due to wind.

Response to Physical Forcing:
The mixing layer depth is shallow in both systems, often 1 m and rarely below 15 m. This leads to very rapid changes in the physical system (Fig 5) and thus the biological system. The strongly affected terms are the growth term through the mixing layer depth and the wind driven advection. Grazing and estuarine advective loss are also big terms but they change both less quickly and vary less between years. A single storm can delay the bloom by weeks (Fig 6).

Strait of Georgia Spring Bloom:
The timing of the spring bloom is dependent primarily on the wind speed and secondarily on the cloud fraction (Fig 7). Both of these are impacting the growth term, so in a broad sense, this timing is consistent with the critical depth hypothesis. The spring bloom occurs when the growth term increases sufficiently.

Rivers Inlet Spring Bloom:
Interannual variability is dependent largely on variations in retention. Losses are due to the surface layer being blown out the Strait (Fig 8) or by increased river flow leading to increased estuarine flow and advective loss. The spring bloom occurs when losses are sufficiently low that the increasing growth term can win.

References: