Revisiting the Role of Freshwater in the timing of the Spring Bloom in the Strait of Georgia

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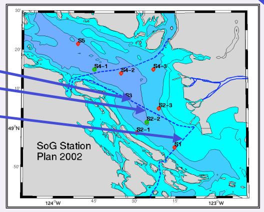
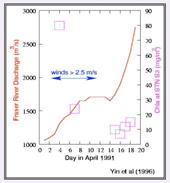
Abstract



The Strait of Georgia is a highly productive, semi-enclosed, marine ecosystem lying between Vancouver Island and mainland British Columbia. The Strait receives large quantities of fresh water from the Fraser River with peak values (6-fold larger than winter values) occurring in late May/early June associated with the freshet. Tidal currents within the Strait itself are moderately strong (order 50 cm/s). The predominantly along-strait winds are weaker than those experienced off the west coast of Vancouver Island. Yin et al (1997) proposed a model for the timing of the spring bloom in the Strait of Georgia. Stratification for the bloom was thought to be provided by the start of the Fraser River freshet and was destroyed by strong winds. If the bloom was sufficiently delayed, it could be greatly suppressed by the grazing pressure from *Neocalanus plumchrus*. Recent high frequency sampling, particularly from a BC Ferry, has show that the 2002 and 2003 blooms occurred before the start of the freshet. A review of late 1990's data suggest a similar timing. We will present the evidence for a revision of the model and suggest an updated one.

Previous theory



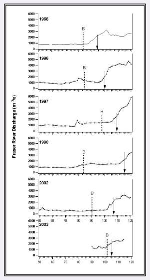
- Stratification for the bloom is provided by start of the Fraser River freshet
- Winds can destroy the stratification and delay the bloom
- If sufficiently delayed, the bloom can be limited by zooplankton grazing

The figure shows the Fraser River outflow (red line) which increases from the winter value of about 1000 m^3s^{-1} at the beginning of April 1991 toward 3000 m^3s^{-1} at the end of April. Freshet values are 10000 m^3s^{-1}, so April 1991 marks the beginning of the freshet.

The magenta squares show Chla values at a mid-Strait station (near S3).

The blue line shows a period of strong winds, coinciding with the Chla decrease.

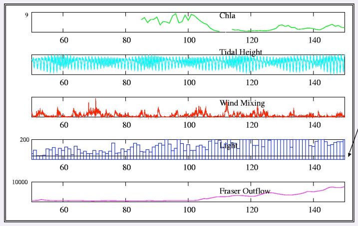
Observations of the Timing of the Spring Bloom



The figure shows, for six years, the Fraser River outflow as a line, the **peak** of the bloom (marked B) in the southern Strait of Georgia and the time at which the outflow from the Fraser river reaches twice its winter average value (marked with an arrow).

In each year the peak of the bloom occurs before the freshet starts (it is close in 2003). So the stratification provided by the Fraser River freshet is apparently not needed to start the spring bloom. *The timing of the spring bloom must be independent of the timing of the freshet.*

2002

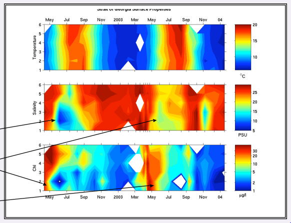


The figure shows time series data for the Spring of 2002. The Chla is measured from the Ferry intake on the Strait of Georgia section of the southern ferry route. The tidal height is for Vancouver Harbour (Pt. Atkinson). The wind mixing is the wind speed cubed from the east end of the southern ferry route (Sandheads). The light is astronomical with a correction based on cloud cover, humidity and temperature measured in Vancouver (Airport). The Fraser River outflow is measured at Hope, 150 km upstream of the mouth.

The spring bloom occurs before the freshet, during a period of light winds, as the surface light intensity reaches about 100 W m^{-2}. High values of Chla occur throughout a spring-neap cycle.

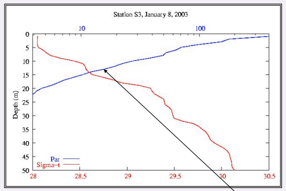
2002/2003

The figure shows the sea surface temperature, salinity and Chla changes with distance north along the Strait during our sampling period. Note that in 2002 the start of the freshet occurs after the bloom. In 2003 the start of the freshet coincides with end of the spring bloom.



Discussion

The black line on the 2002 data figure light panel is the light intensity required at the surface in order for the average mixed layer illumination to equal the saturation value for *Thalassiosira* . *Thalassiosira* is the first diatom species to bloom in the spring. This data would suggest that *Thalassiosira* should bloom much earlier.



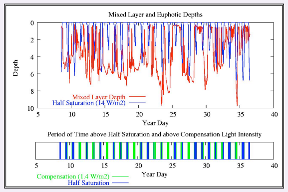
The figure shows irradiance (par) and density (sigma-t) for station S3 in January 2003. The saturation intensity for *Thalassiosira* is 14 W m^{-2} and the compensation intensity is 0.7-1.4 W m^{-2} (Jitts *et al,* 1964, Raymont, 1980) . The combination gives a Sverdrup depth of 39 m.

Thus in a simple system one would expect a spring bloom could occur in January in the Strait of Georgia.

We believe the the missing pieces are advective and turbulent loss of phytoplankton from the upper layer, and temperature effects on growth. The Strait of Georgia system is stratified by the Fraser River outflow (even at low winter values) and mixed by episodic wind events. Thus the mixed layer is highly variable, less than 1 m during calm periods and 5 to 10 m during mixing. Secondly the estuarine circulation leads to a net loss of surface water from the system. Thirdly, January sea surface temperatures are low and so diatom growth rates will be reduced.

Model Results

A one-dimensional numerical model based on Large *et al* (1994) was constructed for the Strait of Georgia. The influence of the Fraser River inflow is to force the sea surface salinity and to cause entrainment parameterized based on Knutson's relations and the observed salinity. The effect of a closed basin is included by the integrated effect of horizontal velocities on baroclinic pressure gradients in a ellipsoidal basin.



Run for the month of Jan 8 -- Feb 6, 2003 (to compare to two sets of observations) we see that light levels (at the mixed layer depth) are above compensation each day but that on many days are not above the half saturation level. Incorporating phytoplankton growth into the model will be necessary to determine the importance of detrainment and advective loss on the system.

Conclusions

1. The spring bloom occurs before the beginning of the Fraser River freshet and thus the timing of the spring bloom cannot be dependent on the timing of the freshet.
2. Typically the first species to bloom in the spring, *Thalassiosira* has low light requirements and based on observed mixed layer depth and light intensities it should bloom as early as January (observations show March/April)

Hypothesis

The spring bloom is suppressed in January due to:

- Temperature limitations on growth
- Integral effect of rapid variations in light compared to that required for growth.
- Detrainment from the rapidly varying mixed layer
- Advective loss due to estuarine flow (Lucas *et al,* 1998)

The timing of the spring bloom is due to increases in light overcoming the suppression mechanisms.

References

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