Modeling Fish-killing Blooms of *Heterosigma akashiwo* in the Salish Sea

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[Image: Video courtesy of Brian Bill]
Overview

- Damage to farmed and wild fish (Rensel et al. 2010, Harmful Algae).
- Existing conceptual model of bloom initiation and transport
- Key components to steer us toward a successful numerical model
- What our modeling group is doing with a practical physical sub model that links to a NPZ submodel

Central Puget Sound 2006
Heterosigma akashiwo – Fish Kills & Food Webs

- Raphidophyte (golden brown) microflagellate, prevalent in temperate to subtropical.
- Kills farmed fish in many locations throughout the Pacific and wild fish in Puget Sound, B.C., Delaware (?), North Carolina, Texas and other locations due to effect on gill or other unknown causes.

- Considered the most versatile and allelopathic harmful algal bloom species (T. Smayda).
- Forms massive, unialgal blooms, extirpates or kills other algae, zooplankton, mollusc larvae, shrimp, and other food web components.
- Vertical migration possible, up in day for light, down at night for nutrients. Variable range to 15 m possible.
- Attracted to brackish layer, will raft up on surface/daylight when calm, but can be physically mixed to 40 m or more at fish-killing concentrations.
- Several ecotypes known to exist with different characteristics.
SSG = South Strait of Georgia, CPS = Central Puget Sound, NPS = North Puget Sound
Why Model These Blooms?

Early warning for fish farmers but likely also important wild salmon and marine fish (Rensel et al. 2010)

Chilko stock marine survival, juvenile seawater entry 1989-2007
Adult return years 1991-2009

Major Bloom years
mean survival = 2.7%  \( (N = 7) \)

Minor or no bloom years
mean survival = 10.9%  \( (N = 8) \)

Correlation coefficients, bloom index vs. salmon survival \( \sim 0.83 \) to 0.91

Missing fish data 1 y, algal data 3 y
(S. Georgia Strait only)
First six months of herring survival in the Strait of Georgia predicts entire two year seawater survival of (Chilko stock) Fraser River sockeye with $R^2 = 0.89$

Schweigert et al., 2009 and Pacific Salmon Commission, 2010
Heterosigma Bloom Conceptual Model Components:
South Strait of Georgia (SSG) and North Puget Sound (NPS)

• Sunny, warm conditions from May thru October, once bloom begins modest winds not an impediment
• Late May to July blooms commonly seen, September in NPS, SSG more variable
• 15°C water temperature in shallow bays for cyst germination (deep bays too cold)
• Snowpack Melt – River Flow: snowpack that melts early and fast, high correlation
• Tides: Neap tides result in more fish kills, cells may collect more near surface
• SSG blooms last up to 4 months
• Some advected south, but in NPS never exceed a weeks duration in NPS.
• Other blooms move north (Taylor and Haigh 1993), vertical distribution unknown.
• No single factor is a reliable predictor or indicator of a major bloom
• Fraser River discharge + hot weather are the key factors for SSG and NPS bloom forecasting from May through July.
Key Forcing Factors in **spring and early summer**: Fraser River Discharge & Weather

Snowpack depth alone is not enough..... Early and hot weather is required
Key Forcing Factors in **mid summer and fall:**
Weather and river flow mediated vertical stratification

- Higher probability of hot weather after July 4\textsuperscript{th} coincides with blooms
- Blooms in Central Puget Sound more common at this time
- No August blooms in North Puget Sound (yet)
- Blooms in Central Puget Sound in August
- Timing of blooms overall in Puget Sound once approximated that of Narragansett Bay, but no longer the case

In British Columbia, Area D (South Strait of Georgia) has the highest frequency of positive Heterosigma observations
Salish Sea – Heterosigma Physical Submodel Considerations

Transport a function of winds, tides and fortnightly lag effect (Griffin & LeBlond 1990)

In late spring and early summer in the Salish Sea weather predictions are relatively good for about one week.

We need a model that can continuously poll sensors, weather, wind and satellite data to update on a real time basis and there could be many models but we use would like to use our AquaModel 3D GIS aquatic Environmental Assessment System (EASy) because….

- Couples with regional circulation models (e.g., ADCIRC),
- Has a particle tracking model to simulate the algal species,
- Merges single or multiple current meter data into the far field regional circulation if we want better resolution in discrete areas (e.g., breeder bays).

An example of this approach is from the Island of Hawaii…
Model Simulation Demonstration
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