Rivers, tides, diatoms, oysters, and Fortran

Big-picture biophysical coupling in recent models of the Northwest coast and estuaries

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collaborators:

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PNCERS (NOAA)
+ WA SeaGrant
climate change

changes in streamflow magnitude & timing

1) how big a bite out of this can one expect a current-generation model to take?

2) what are these pathways for the PNW coast & estuaries?

impacts on estuaries & coastal zone

eutrophication, hypoxia
flushing of pollutants
bottom-up controls on aquaculture and fishery productivity

physics

nutrients

plankton dynamics

primary production
landscape of biophysical ocean models

- hundreds of biological components
- 1-3 biological components
- a few big boxes ("box models")
- lots of little boxes (e.g. ROMS, POM, GCMs)

this talk: in praise of these
Part 1

the Columbia River plume and coastal productivity
Water moving offshore due to Coriolis effect

Wind from north

a Upwelling
in the PNW, as on the U.S. West Coast as a whole, chlorophyll increases to the north but upwelling increases to the south.

(Ware and Thomson, *Science*, 2005)

(A. Thomas, U Maine)
MacCready circulation model: ROMS (Regional Ocean Modeling System)

500 m resolution near CR mouth, 
~ 8 km at boundaries
b.c.s from Foreman summer climatology

winds + shortwave radiation from MM5
variable riverflow
10 tidal constituents

remember to play the salinity movie
Circulation pathways during one day of upwelling (Jul 25, 2004)

Columbia River plume as cross-shelf exporter and along-coast barrier
Custom nitrogen budget (NPZD)

- **Phytoplankton**
  - Uptake/growth
  - Total grazing

- **Zooplankton**
  - Ingestion
  - Net growth
  - Egestion
  - Excretion
  - Mortality/higher predation

- **Detritus**
  - Sinking
  - Remineralization

- **Nutrients** (nitrate + ammonium)
  - Uptake/growth
  - Total grazing
DESIGN PRINCIPLE: The parameter values are part of the model.

Are these the same model?
<table>
<thead>
<tr>
<th><strong>phytoplankton parameters</strong></th>
<th></th>
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<td>$\mu_{max}$</td>
<td>maximum growth rate</td>
<td>1.7 d$^{-1}$</td>
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<td>$att_{sw}$</td>
<td>light attenuation by seawater</td>
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<td>$att_{p}$</td>
<td>light attenuation by phytoplankton</td>
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<tr>
<td>$\alpha$</td>
<td>initial slope of growth-light curve</td>
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<td>$k_s$</td>
<td>half-saturation for nutrient uptake</td>
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<td>$m$</td>
<td>“other” mortality</td>
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<tr>
<td>$\xi$</td>
<td>higher predation + other mortality</td>
<td>1 d$^{-1}$ $\mu$M$^{-1}$</td>
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<td>half-saturation for ingestion</td>
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<td>$f_{egesi}$</td>
<td>fraction of ingestion egested to D</td>
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<td>$f_{excr}$</td>
<td>fraction of ingestion excreted to N</td>
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<td>$r$</td>
<td>remineralization rate</td>
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<td>$W_{sink}$</td>
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Integrated chlorophyll, CTDs vs model

CTDs, Jul 22–27 2004

8 d model average

N-S wind stress (N m$^{-2}$)

DOWNWELLING

UPWELLING
with river and estuaries

no river or estuaries
difference in total surface nitrogen (N+P+Z+D),

river case minus no-river case

again, CRP as cross-shelf exporter & along-coast barrier
Point #1:

The Columbia River plume may explain up to 50% of the north-south gradient in phytoplankton biomass / productivity on the PNW coast.

(The remaining ≥50%: the Juan de Fuca eddy region?)

In our model, transient eddies on the 10 km scale are the major mechanism behind a 200 km productivity gradient!

Point #2:

Even a very simple nutrient-plankton model pushes the limits of our ability to deal with unknown free parameters in a biologically satisfying way.
Part 2

Willapa Bay
channels
10–25 m deep

50% of bay volume is intertidal
summer and fair weather, upwelling

low riverflow

winter and foul weather, downwelling

high riverflow

Columbia River plume intrusions (north coast only)

N–S wind (m s\(^{-1}\))

Riverflow (m\(^3\) s\(^{-1}\))
winter storm (downwelling)

MOUTH

head

20 m

40 km

salinity (psu)

northward (foul weather; downwelling-favorable)

southward (fair weather; upwelling-favorable)

Columbia R. plume intrusion (spring downwelling)

spring upwelling + local riverflow

N-S wind (m s\(^{-1}\))

Riverflow (m\(^3\) s\(^{-1}\))

late-summer upwelling

Aug

Oct

Dec

Feb

Apr

Jun

Aug

1999

2000
9% of U.S. commercial oysters come from Willapa (Ruesink et al., 2005)
good oyster growth

poor growth (though not bad in the 1930s)

So does this mean that Willapa’s oysters are competing for food bay-wide?
The model: GETM (General Estuarine Transport Model)

This talk: tides only

(Although we also ran an 11 month hindcast with variable river input and variable ocean water properties)
“It was well-known among the oystermen that if an imaginary line were drawn angling across Willapa Bay from the south quarter of the Nemah State Oyster Reserve... to the west shore a mile or so south of Nahcotta that the best setting grounds would be south and east of this line and the best fattening and growing grounds would be north and west of it.”

(Chapman and Esveldt 1943)
Is the bay a net source of primary production or a sink for oceanic primary production?

(happens occasionally in summer, during a strong upwelling event)

(the typical pattern during summer)
upwelled N depleted close to mouth

offshore blooms

tidal exchange

stratification & vertical mixing control blooms

terrestrial N

South San Francisco Bay
(Cloern 1996)

Grays Harbor, Oregon small estuaries a blend of the two?

Willapa Bay
Summary:
Willapa Bay is a giant oyster.

internal, small-scale transport pathways limit total transfer to benthic grazers—tidal "digestion," not just tidal "intake"
Effects of changes in streamflow magnitude and timing: some guesses

Puget Sound

- altered residence time: \( \checkmark \)
- altered nutrient levels (where more = bad: eutrophication, hypoxia): \( \checkmark \)

OR estuaries

- ?
- altered nutrient levels (where more = good: nut-limited productivity): \( \checkmark \)

Willapa Bay & Grays Harbor (WA)

- ?
- altered nutrient levels (where more = good: nut-limited productivity): \( \checkmark \)

WA coast

- ?
- altered Columbia River plume influence: \( \checkmark \)
http://coast.ocean.washington.edu/~neil/risemodeling.html
http://coast.ocean.washington.edu/willapa/