Climatic regulation of the toxin domoic acid in shellfish

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MOCHA

Monitoring Oregon Coastal Harmful Algae

NCCOS

National Centers for Coastal Ocean Science

OSU

Oregon State University

Shellfish Harvesting in Oregon

Estimated annual revenue of ~$36 million

(commercial + recreational + coastal visits; Runyan & Associates, 2009)

Methods Outline

1. *Are DA events in Oregon significantly related to climatic indexes?*
   a. Cross correlation analysis (monthly scale)
   b. Linear regression analysis (annual scale)

2. Are the parameters identified above an effective metric of risk for elevated DA in Washington, Oregon & California shellfish?
   a. Risk assessment (annual scale)

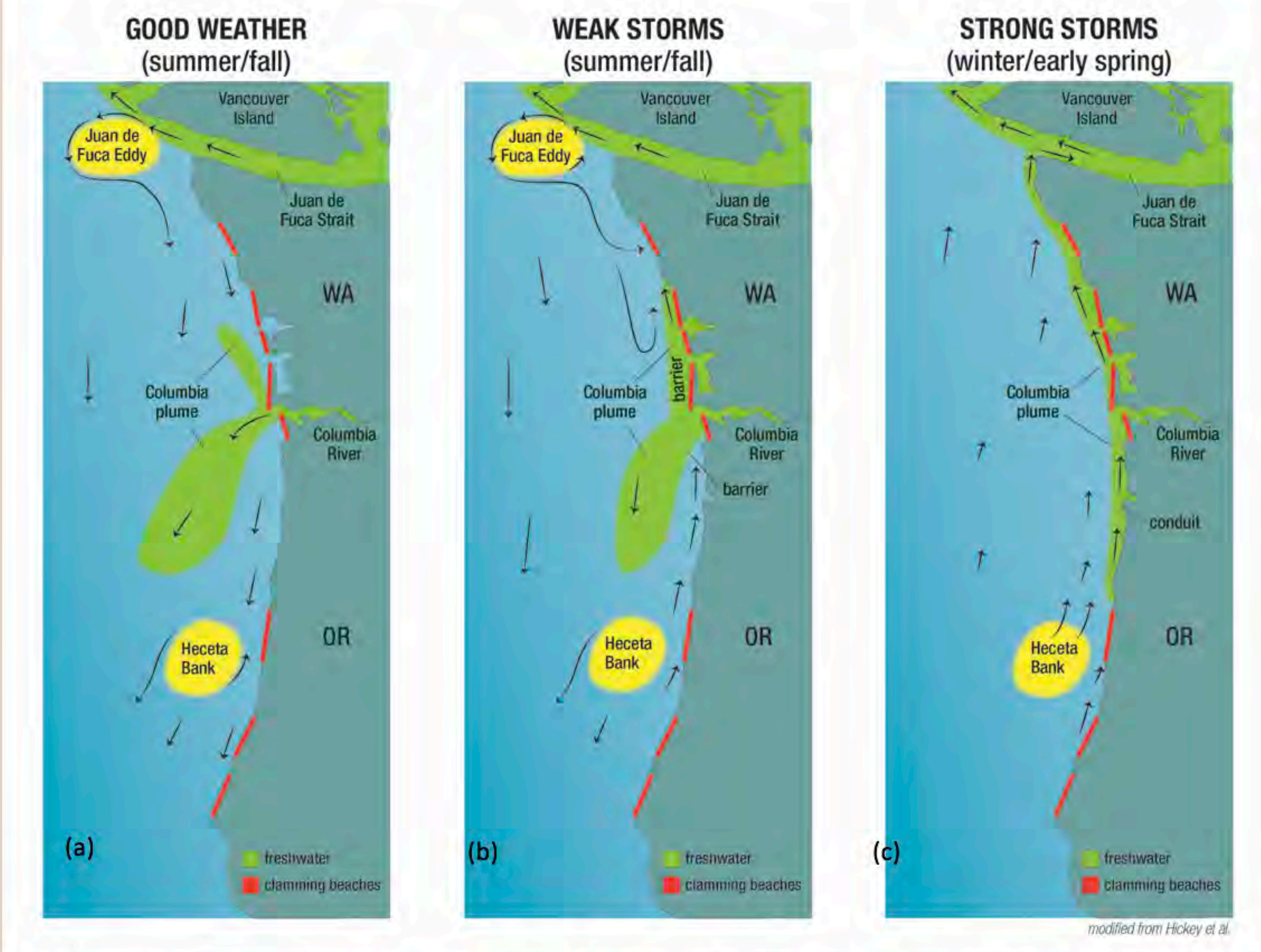
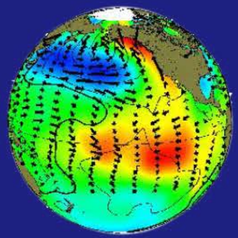


Fig. 7 Environmental conditions in the U.S. Pacific Northwest that transport *Pseudo-nitzschia* cells (a) southward from the Juan de Fuca Eddy in summer/fall, or during good weather conditions, (b) during weak storms, or downwelling-favorable wind reversals, and (c) in the late winter/spring during strong storms. Surface currents are shown with arrows, clamming beaches in red, and green shading indicates freshwater from the Columbia River and Juan de Fuca Strait. The Columbia River plume can act as a conduit or barrier. The offshore retentive sites, Juan de Fuca Eddy and Heceta Bank, locations where harmful algal blooms typically initiate, are shown as yellow ovals (redrawn from Fig. 9 in Hickey *et al.*, 2013).

1) Dataset:

Climate indexes + Oregon parameters (1996-2015)

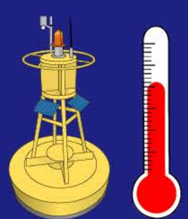


Ocean indexes:

PDO (north Pacific)

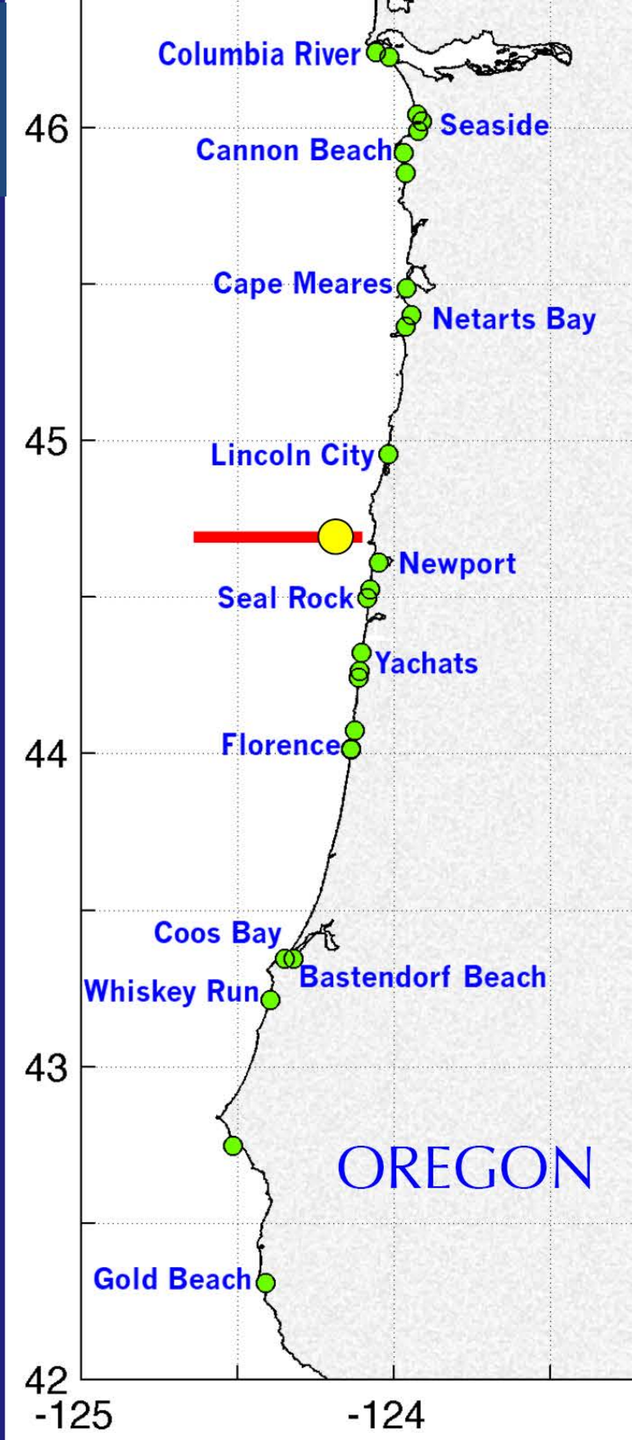
Oceanic Niño Index (ONI, equatorial Pacific)

DA in razor clams along the coast (green dots)

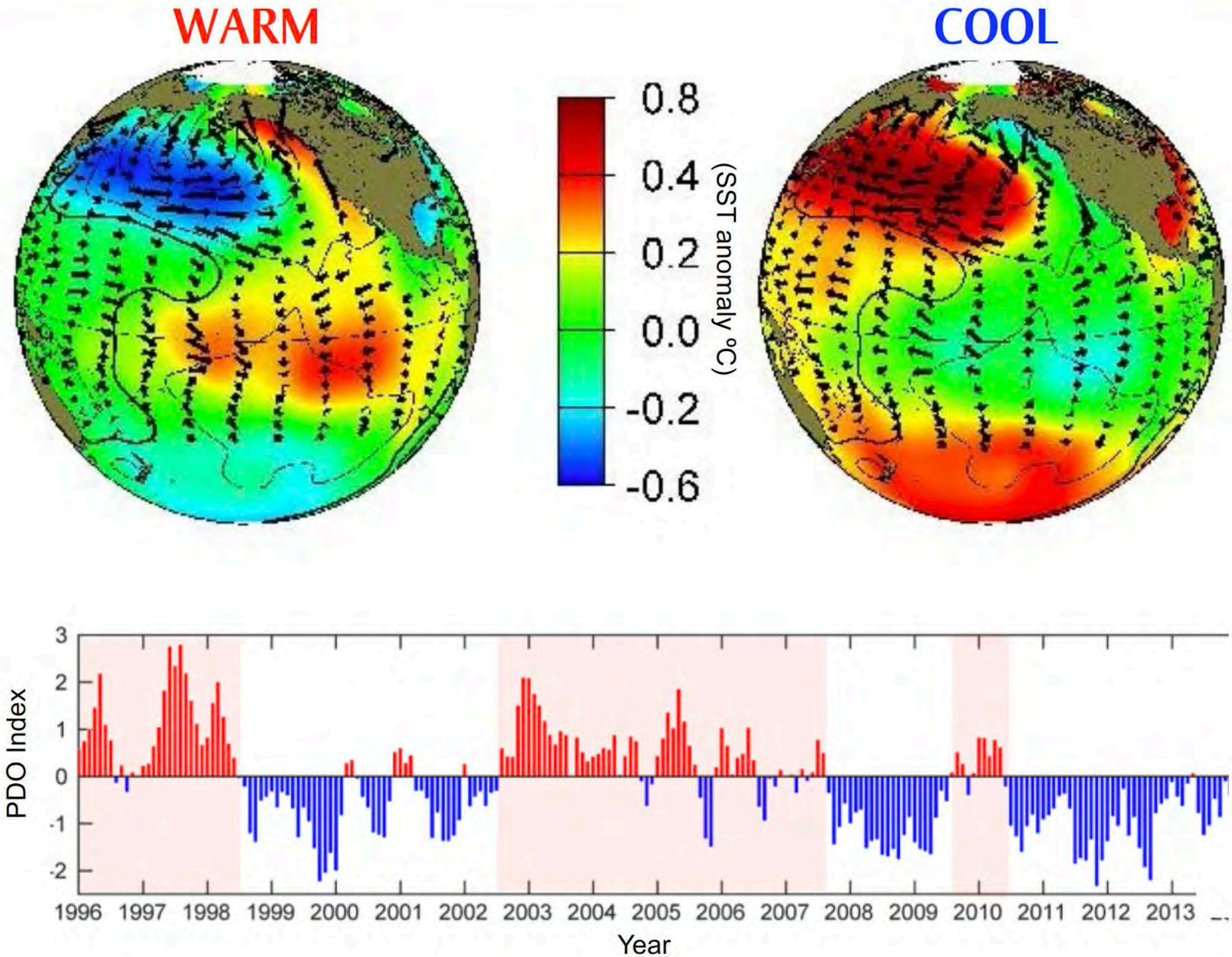


Sea surface temperature anomaly (yellow dot)

Ship Surveys, copepods (**zooplankton**; red line)

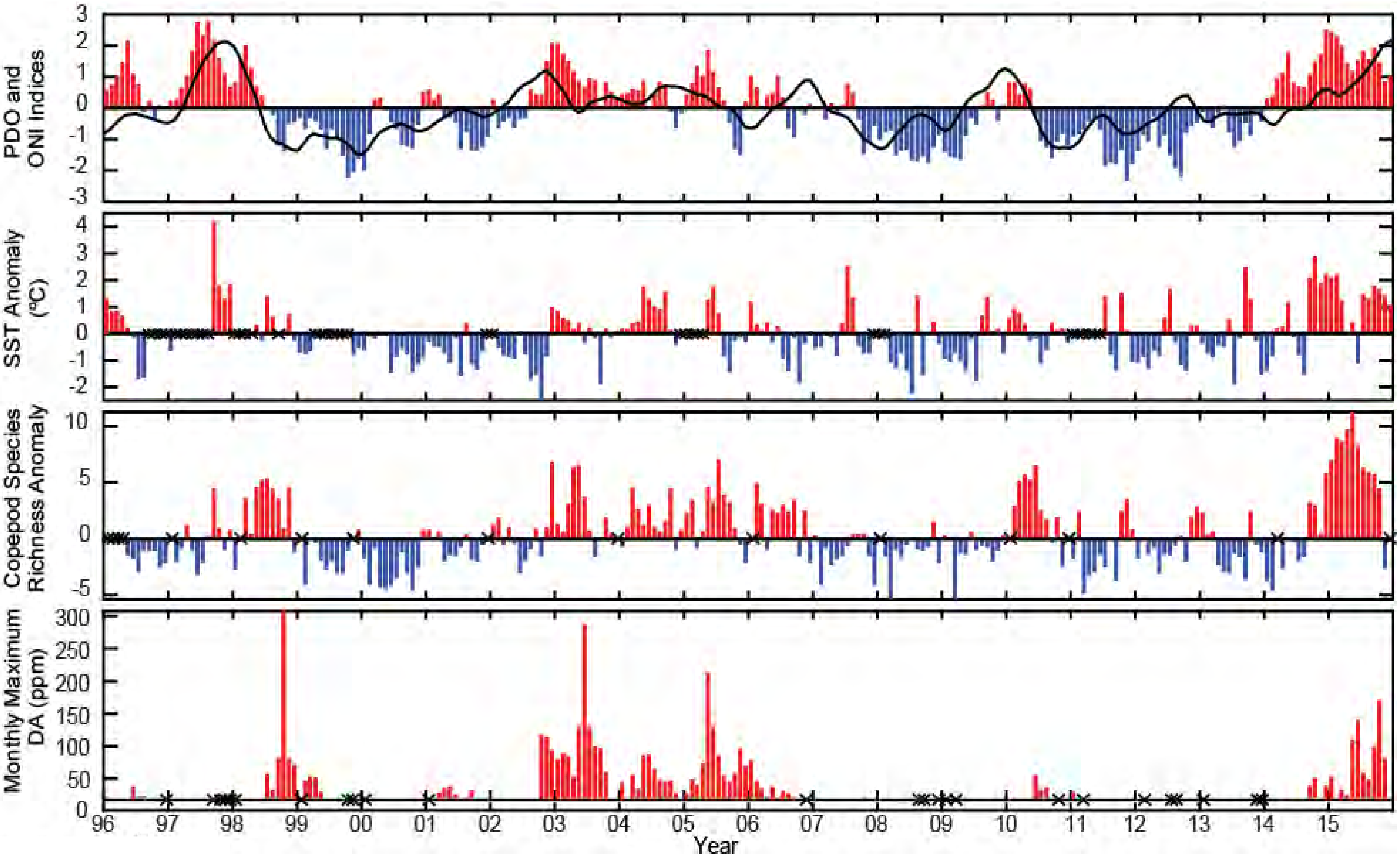


Climate-Scale Variability: Pacific Decadal Oscillation (PDO)



http://jisao.washington.edu/pdo

1a) Cross Correlation- a measure of similarity of two series as a function of the displacement of one relative to the other. **Cross-correlations** are useful for determining the time delay between two signals



1a) Cross Correlation

Monthly scale evaluation:

- X=PDO
  Y = ONI, SST anomaly, CSR anomaly,
  monthly max DA

- X=ONI
  Y = SST anomaly, CSR anomaly,
  monthly max DA

Result: climatic and local biological and physical variables are all significantly lag related (months)

1b) Linear Regression

Annual scale evaluation:

X= March PDO value, March ONI, March PDO+ONI, annual max DA

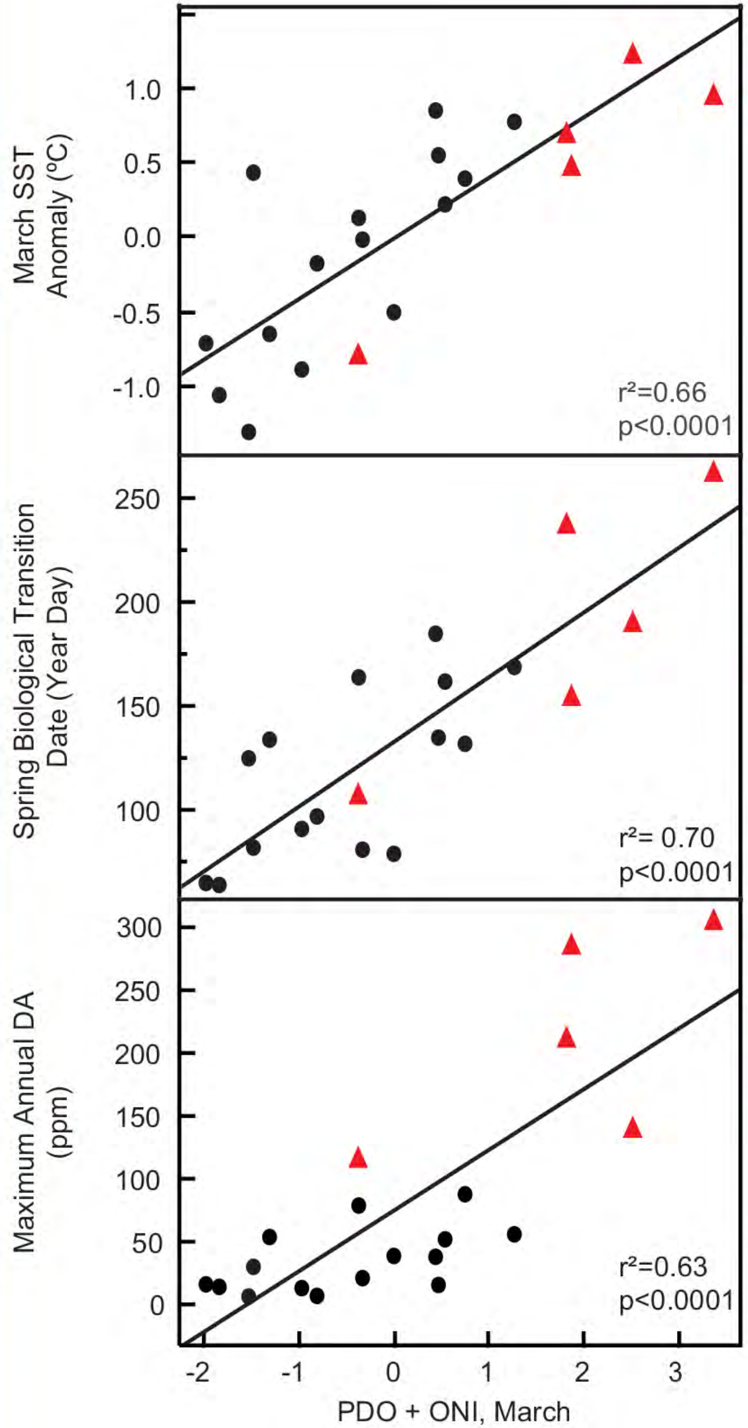
Y = SST anomaly, CSR anomaly, monthly max DA, mean alongshore currents (March-April), annual biological spring transition

1b) Linear regression, results

- tested combinations of March climate indexes & physical/biological metrics
- *nearly all significantly, positively correlated*
- red triangles = 5 highest DA values

RESULT:

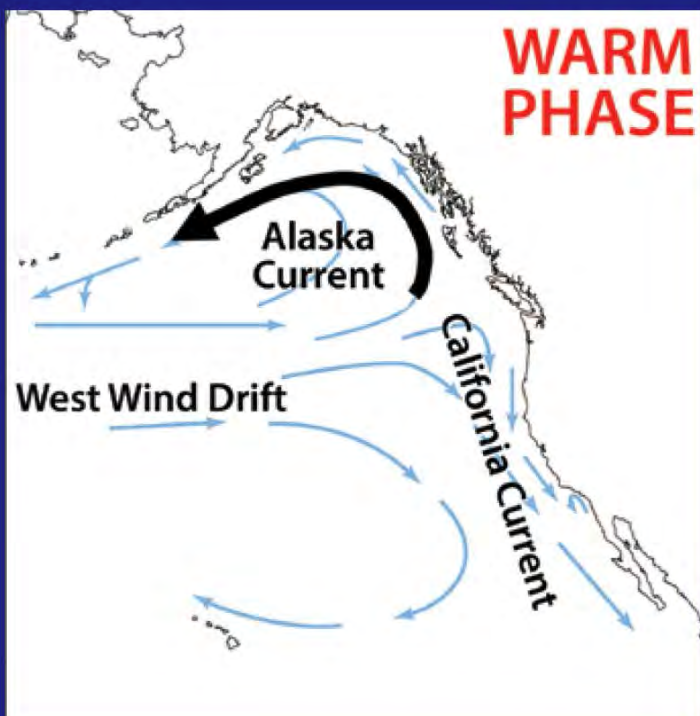
Conditions leading into the spring/ summer upwelling season are a strong predictor of annual max DA toxicity

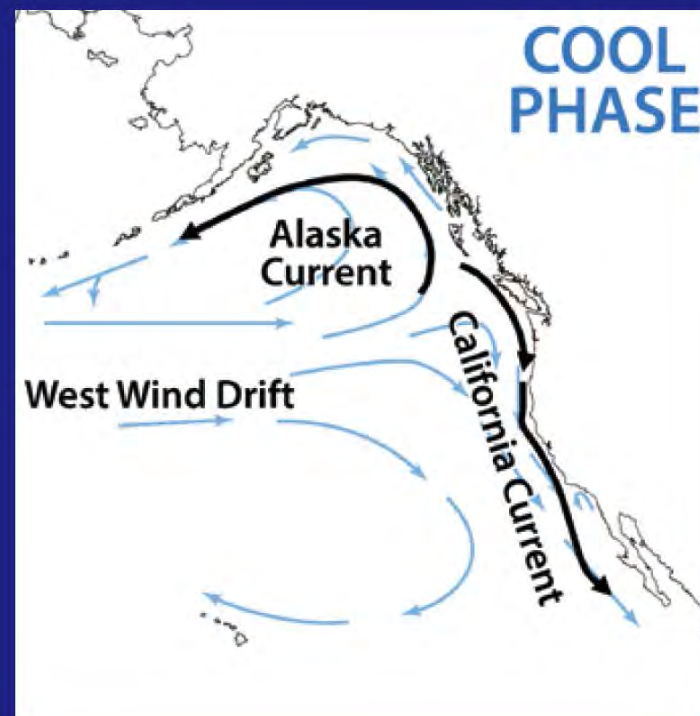


What mechanisms explain the significant relationships observed in parts 1a and 1b?

Warm PDO conditions along the west coast:

- California Current (CC) weaker during warm phases
- Southern/offshore waters enter the CC, reach the continental shelf
- Coastal circulation patterns enhance onshore transport (retention)





Strub et al. 2006; Batchelder et al. 2013

Planktonic Regime Shifts

Strength of California Current (latitudinal transport) during warm vs. cool phases impacts local population structure of plankton

Warm phases (Oregon)

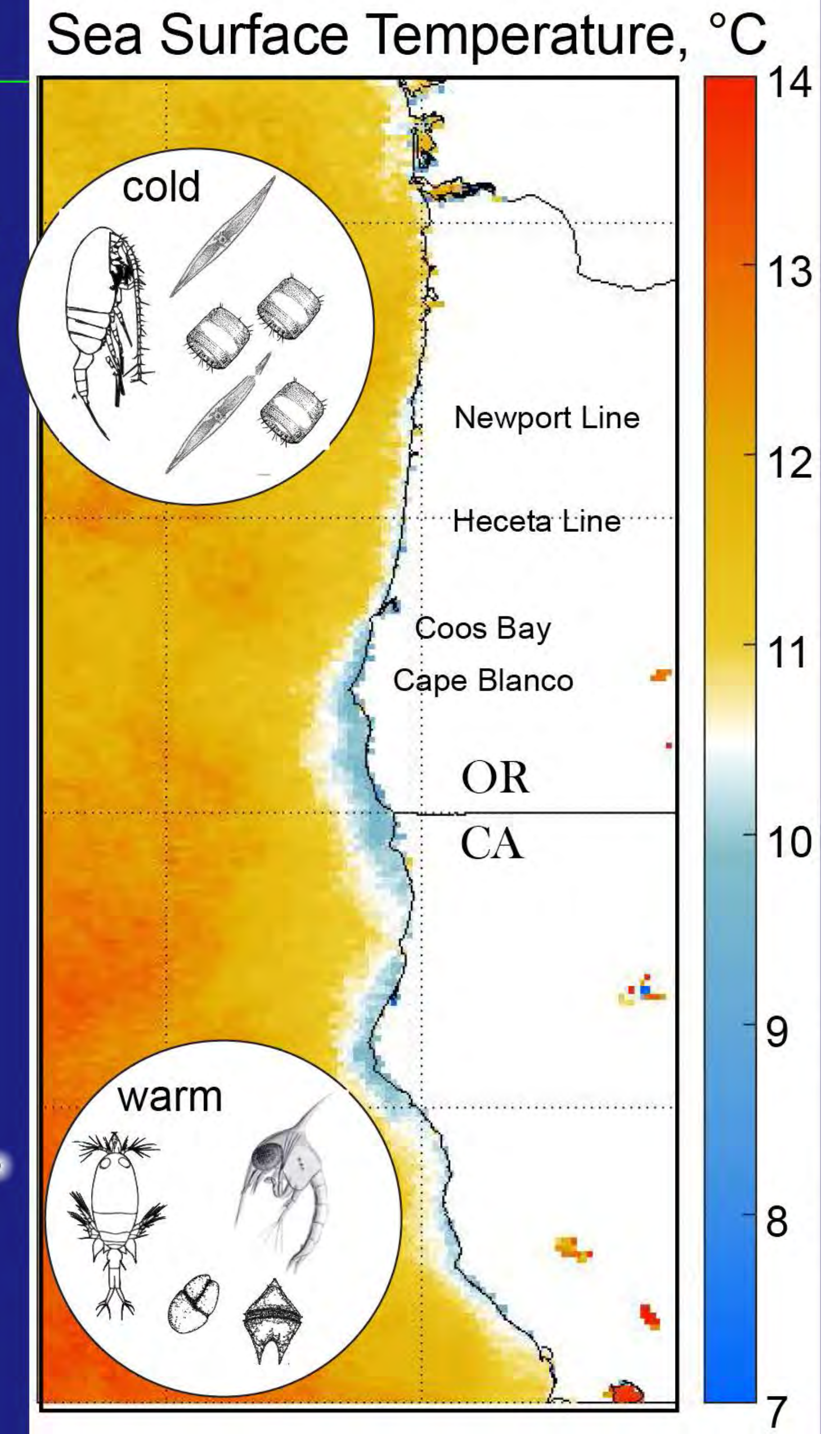
SALMON

INVASIVE GREEN CRAB

DA IN RAZOR CLAMS

Pseudo-nitzschia

Domoic Acid



Climatic Regulation of Oregon DA: The Evidence

1) Physical

- Positive Pacific Decadal Oscillation
- Moderate/strong El Niño events
- Positive local SST anomaly
- Seasonal upwelling ("springtime")

2) Biological

- Domoic acid in Oregon shellfish
- Copepod community shifts

Tell a common story of shifts in water masses and plankton communities during warm phases along the Oregon coast

3) West Coast DA risk assessment

Are these parameters an effective metric of risk?

Methods Outline

1. *Are DA events in Oregon significantly related to climatic indexes?   YES*
   a. Cross correlation analysis (monthly scale)
   b. Linear regression analysis (annual scale)

2. Are the parameters identified above an effective metric of risk for elevated DA in Washington, Oregon & California shellfish?
   a. Risk assessment (annual scale)

2) Risk assessment: Parameters

- What parameters from part 1 are available in OR, WA, & CA?
  - DA in shellfish
    - Earliest DA records were in 1991, defining the time frame for risk assessment (1991-2015)
  - PDO, ONI indexes
  - Satellite SST
    - Used available data to create a monthly SST anomaly product
  - Monthly average upwelling
  - Copepod species richness Oregon only, not included

2) Risk assessment: Methods

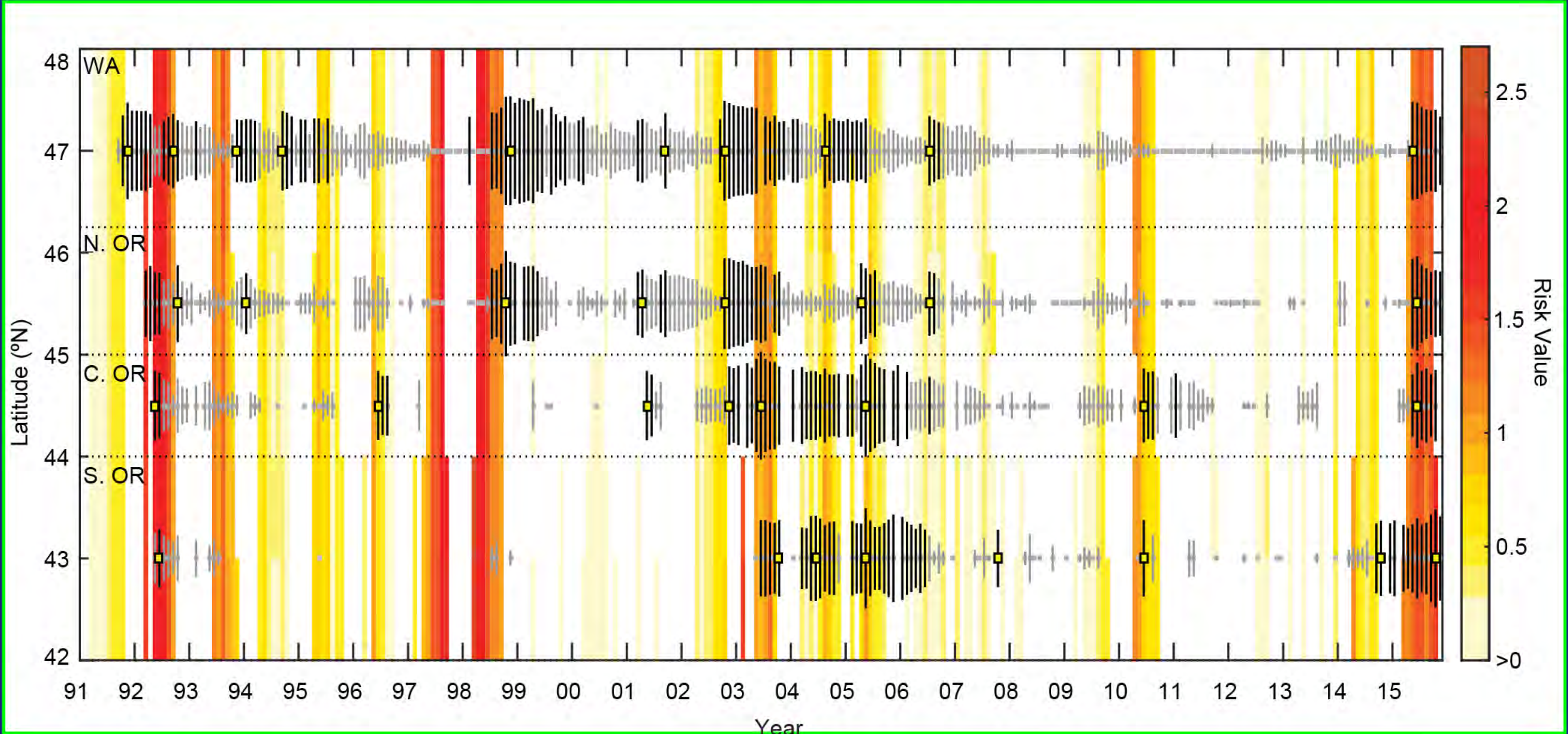
Two types of data:

- "Actual" event occurrence = DA levels in coastal shellfish
  - Binning: monthly maxi value for 1º-2º of coast (size based on sampling frequency/hydrography)
- "Expected" events described by risk proxy

Risk proxy calculated as follows:

1. Data binned
   - Temporally, to monthly intervals (if not already)
   - Spatially, to 1º latitude
2. Data scaled, reduced:
   - each dataset divided by its max value between 1991-2015
   - negative values (cool conditions) removed from PDO, ONI, SST anomaly data
3. Data summed to calculate risk:
   - Risk in a given month = the sum of the scaled physical data
   - Risk ONLY calculated during upwelling season
   - Increased risk assigned to any upwelling season following moderate/strong El Nino Events
4. Evaluation:
   - Annual regressions of risk value vs. DA max
   - Annual comparison of # of "expected" and "actual" DA event occurrences

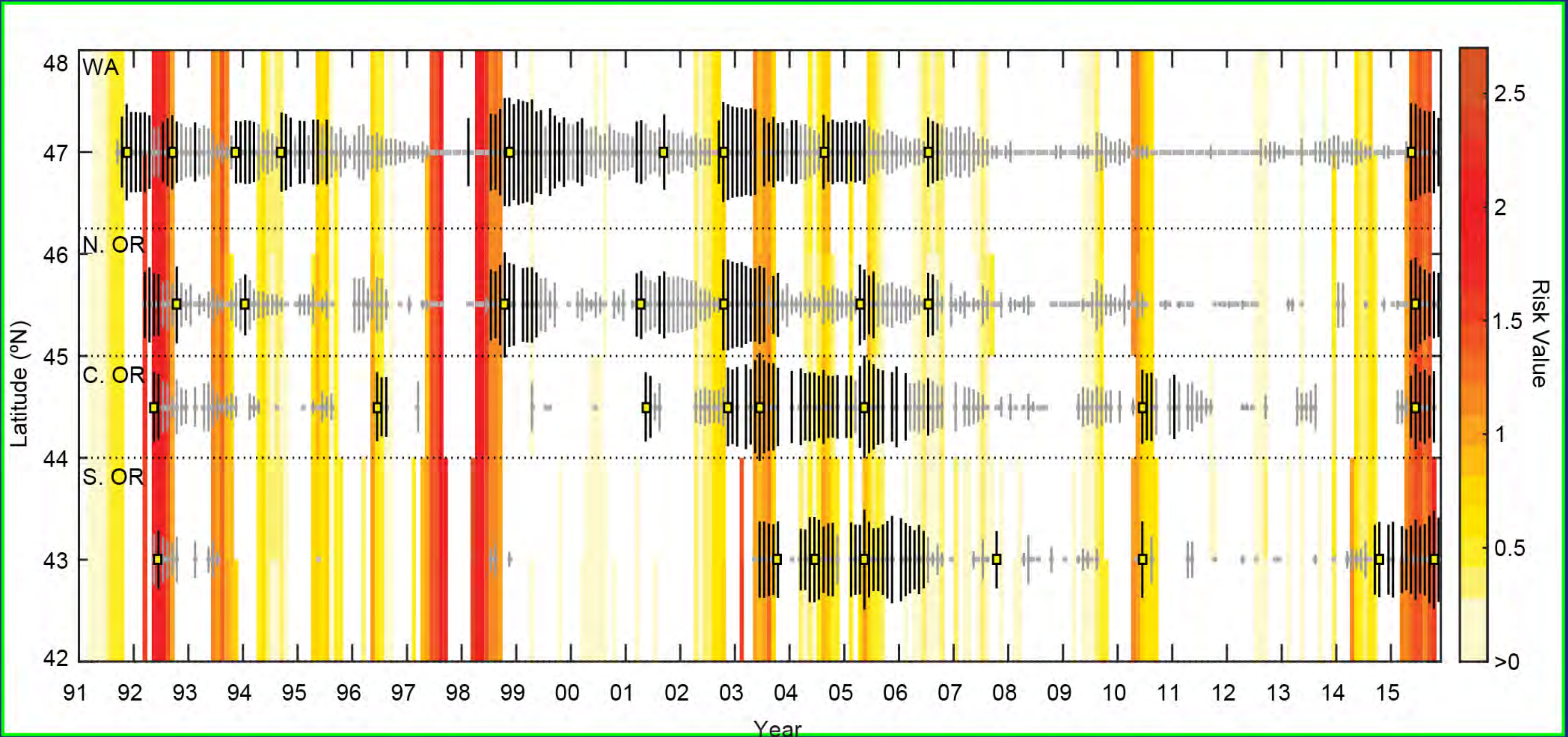
Pacific NW Risk Assessment



- Onset and maxima
- Evaluated annually and by bin
- Risk increases with cumulative positive indexes
- Upwelling only

Bars = monthly max DA in shellfish
Black > closure threshold
Grey < closure threshold
Yellow squares: annual maxima

Pacific NW Risk Assessment

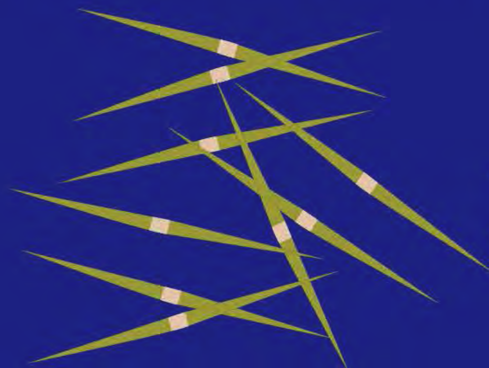


Seasonal/annual scale risk assessment model for Pac NW (to some extent California)

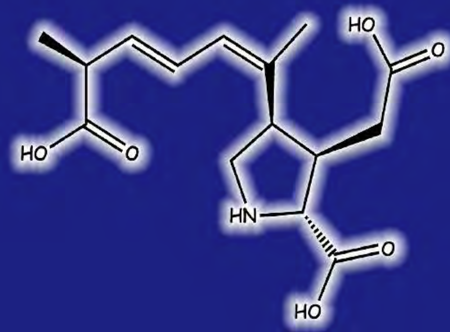
Higher risk, more latitudinally extensive, higher DA

What's Next?

- **Why are Pseudo-nitzschia that are associated with warm phases apparently more toxic?**



Pseudo-nitzschia



Domoic Acid

  - Advection of *more toxic* southern/offshore species?
  - Out competing in warmer, lower nutrient conditions?

- **Refine risk assessment into a regionally-specific forecasting tool (incorporate local parameters that control blooms, transport)**

- **Incorporate findings into existing W. Coast models (C-HARM, Live Ocean Model + HABs)?**

Conclusions

1) First evidence for climate-scale regulation of domoic acid in West Coast shellfish

2) Seasonal risk assessment --> forecasting

3) Long term (decades) ocean monitoring data crucial to connecting key events to larger patterns of variability


FUNDING
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