Climate Change and Marine HABs

…and new monitoring capabilities for the WA coast

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Take home messages!

1. Make friends with a climate scientist!

*"**Collaboration** is the cornerstone of climate services"*

[Climate Services Partnership Working Group on Climate Services Ethics, 2015]

2. One size does not fit all

3. Understand the limitations of your findings

4. Communicate findings in the context of the decision frameworks of users

Expected impacts of climate change on HABs

- Geographic range changes in both warm- and cold-water species, with some expansions and some contractions
- Species-specific changes in abundance and toxicity
- Changes in the timing of the seasonal window of growth, with earlier timing of peak production for some species

[Laws, 2007; Moore et al., 2008; Paerl and Huisman, 2008; Backer and Moore, 2010; Hallegraeff, 2010; Anderson et al., 2012; Paerl and Paul, 2012]

Photo credits: Ecology, WDOH

The challenge…

Our limited understanding of (1) the **environmental conditions that favor HABs** and (2) **interactions among climate and non-climate drivers** hinders our ability to forecast the direction and magnitude of change

…especially for dynamic coastal environments

Where to start?

"As a b tline
wl
env B
even ers

1. What are the drivers of HABs in your system?

2. Are they sensitive to climate?

[Wells et al, 2015]

Climate drivers and biological responses of HABs

- Climate drivers
  - Temperature
  - Precipitation
  - Light
  - CO_2
  - Winds
  - Upwelling
  - Extreme weather
  - Etc.

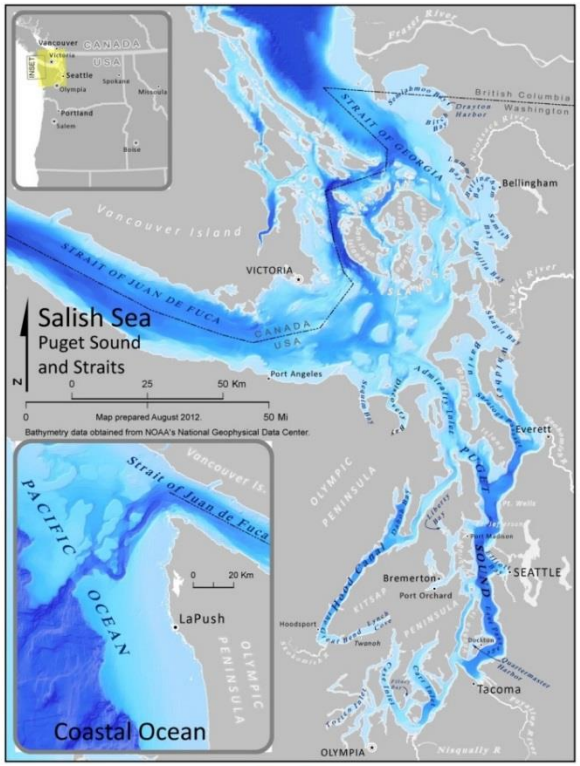
→ Future climate projections

- Biological responses
  - Growth
  - Photosynthesis
  - Cyst germination
  - Toxicity
  - Grazing
  - Competition
  - Etc.

→ Thoughtfully designed experiments to investigate decadal- or century-scale trends

[see Hallegraeff 2010; Fu et al., 2012; Wells et al., 2015]

Puget Sound *Alexandrium* spp.



REGIONAL CLIMATE
atmospheric warming

WATERSHED
river flow

OCEAN
upwelling

Alexandrium spp.

[Moore et al, 2009]

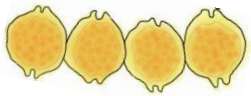
Puget Sound *Alexandrium* spp.

GLOBAL CLIMATE CHANGE

REGIONAL CLIMATE
atmospheric warming

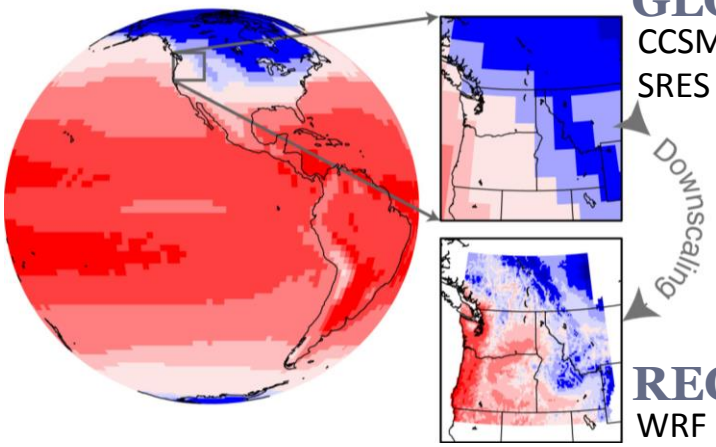
OCEAN
upwelling

WATERSHED
river flow



Alexandrium spp.

Puget Sound *Alexandrium* spp.



Salathé et al. (2010): Climatic Change

GLOBAL CLIMATE

CCSM3 model: ~150 km resolution
SRES scenario A1B

REGIONAL CLIMATE

WRF model: 12-km resolution

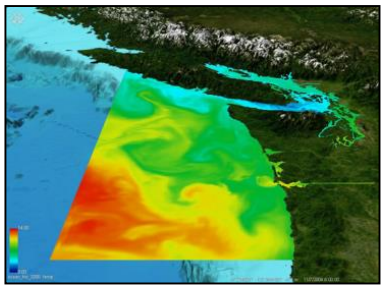
WATERSHED

River flow composites from multiple GCMs using monthly means

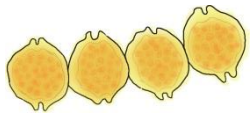
- Puget Sound rivers
- Fraser River
- Columbia River

The ROMS-based MosSea model

(Modeling the Salish Sea)



700-m resolution, stretching to 3-km at coast; T and S fields applied to empirical habitat model for *Alexandrium* growth



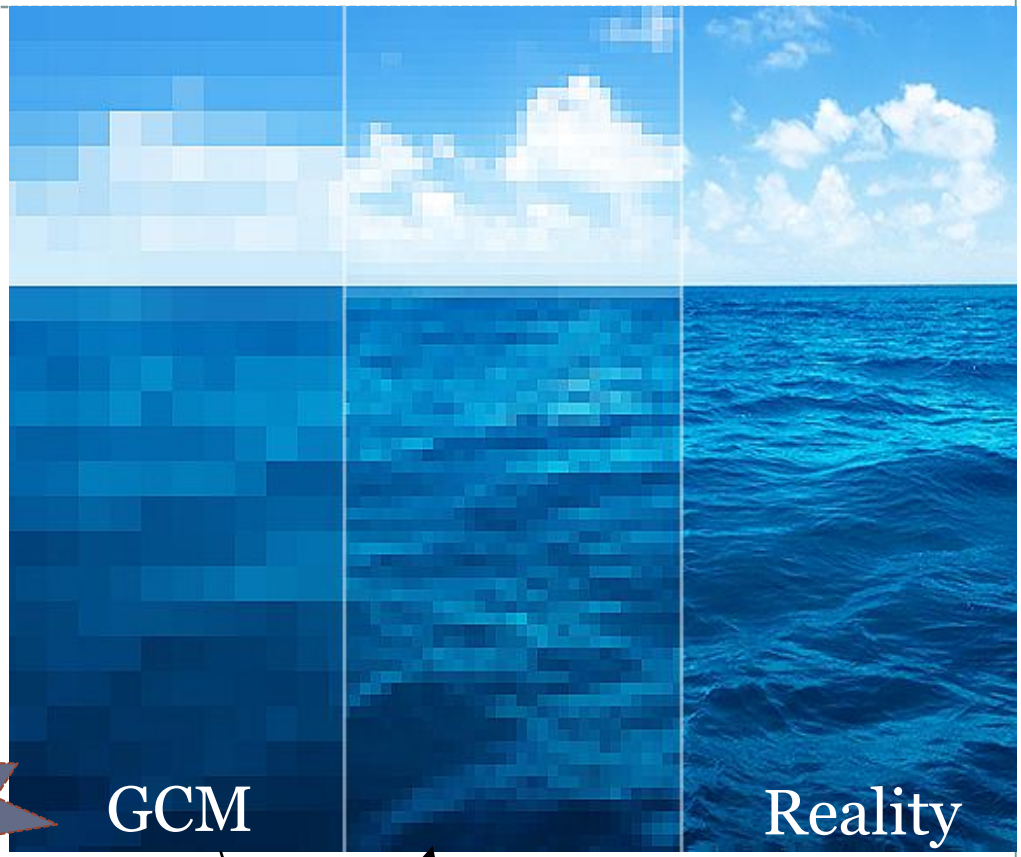
OCEAN

Open ocean boundary condition is year 2006 from NCOM Global (Navy Coastal Ocean Model)

General Circulation Models (GCMs)

- Can a GCM provide projections of the variable you need?
- **Is the scale appropriate?**
- How confident are you in those projections?

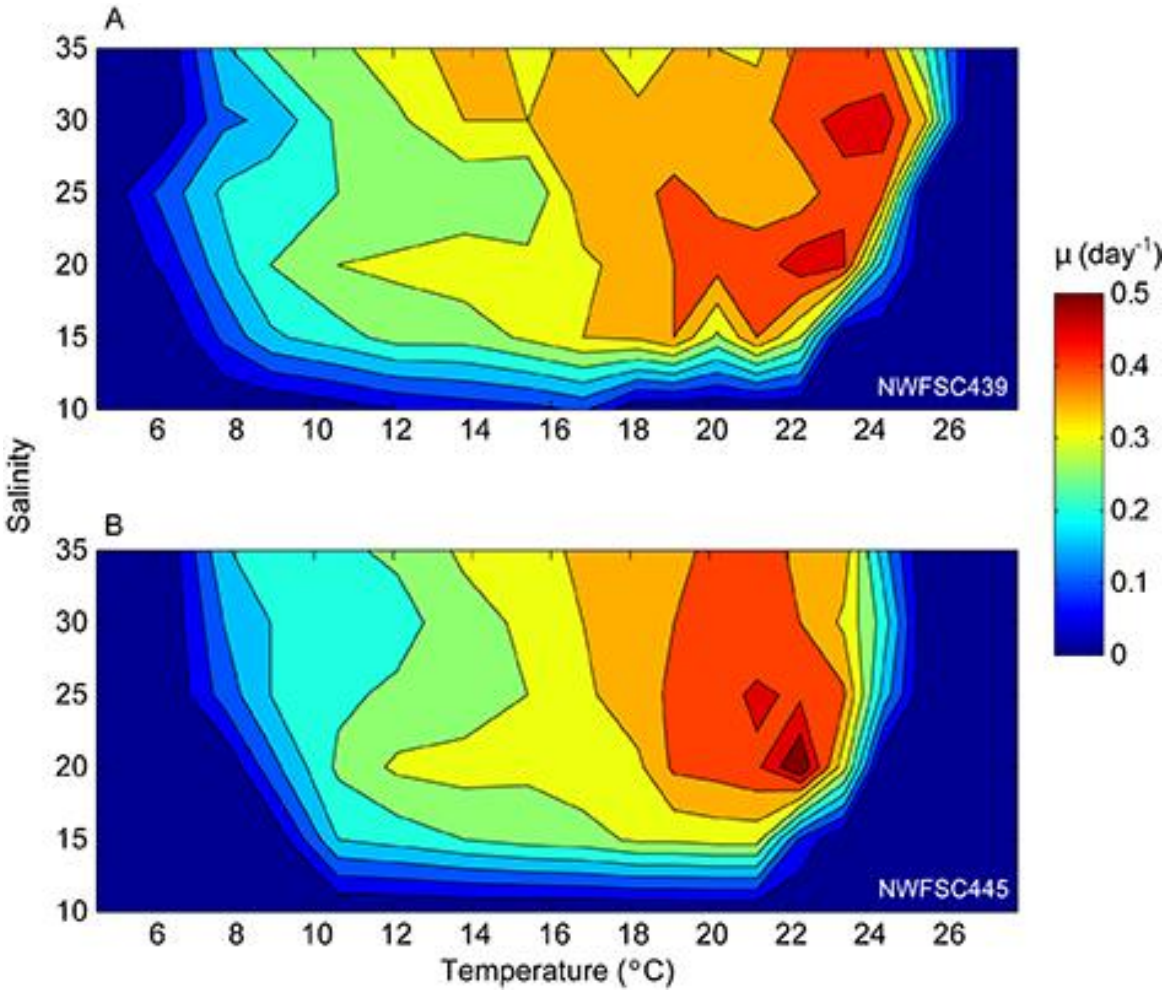
Unlikely!

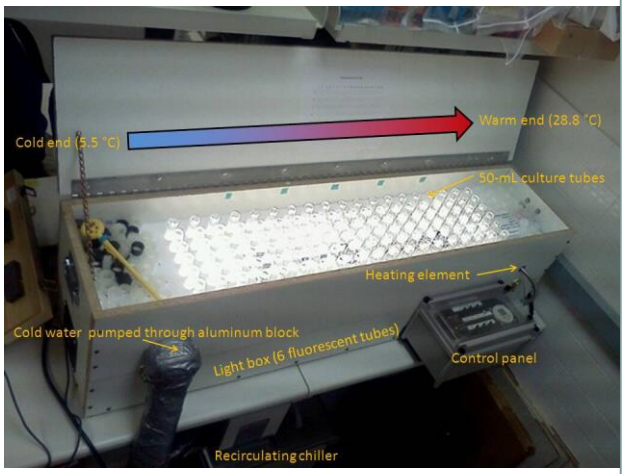


Downscaling → relates the BIG to the small
→ "bridges the gap"

Image credit: PNNL

Alexandrium growth *f* (temperature, salinity)





Temperature Gradient Bar
(Watras et al. 1982)

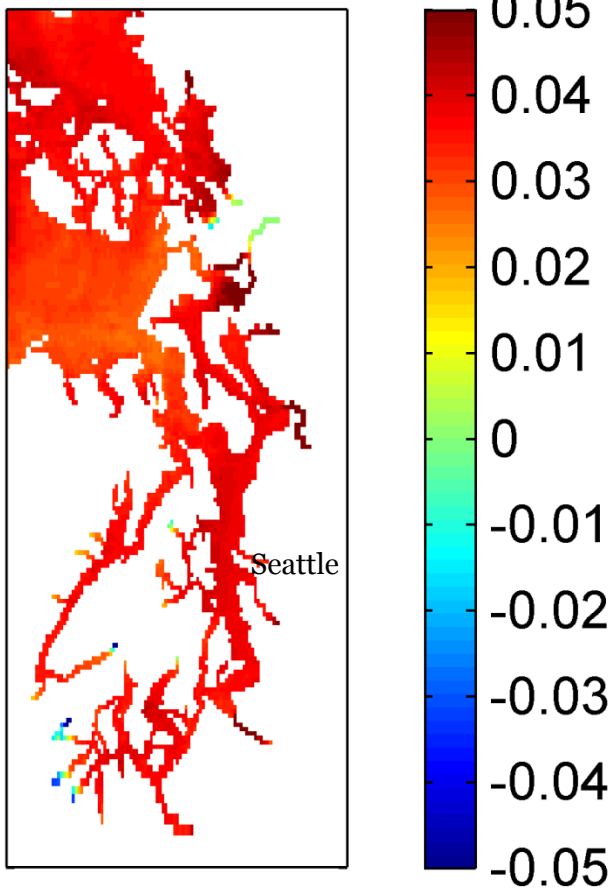
- Chilling/heating elements
- 12L:12D
- 6 salinities × 19 temps × 2 strains (n=2)

[Bill et al, 2016]

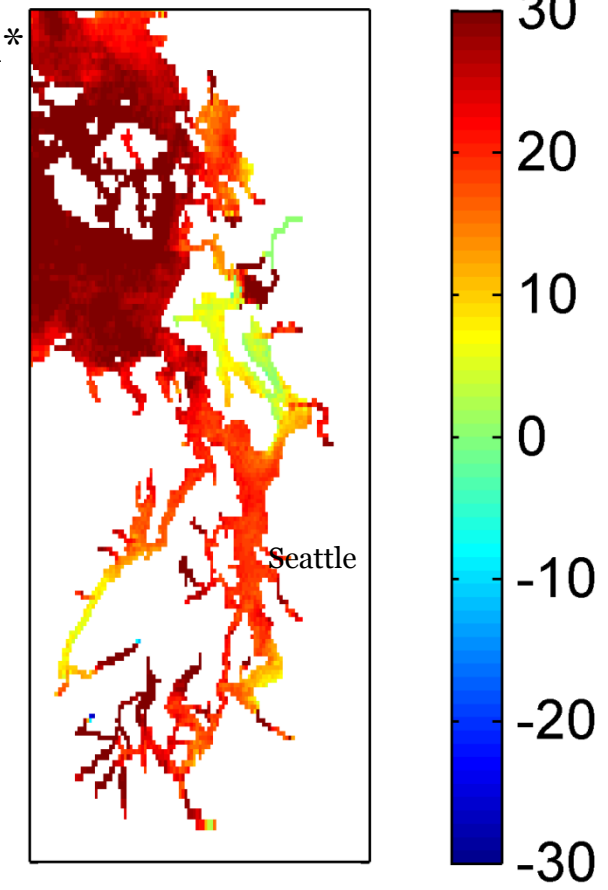
- Δs to *Alexandrium* habitat almost entirely driven by warmer SSTs
- Small ↑ growth rate, big ↑ duration of HAB season

[Moore et al, 2015]

Δ Growth rate
Future-climate – Present-day⁺



Δ HAB season*
Future-climate – Present-day⁺

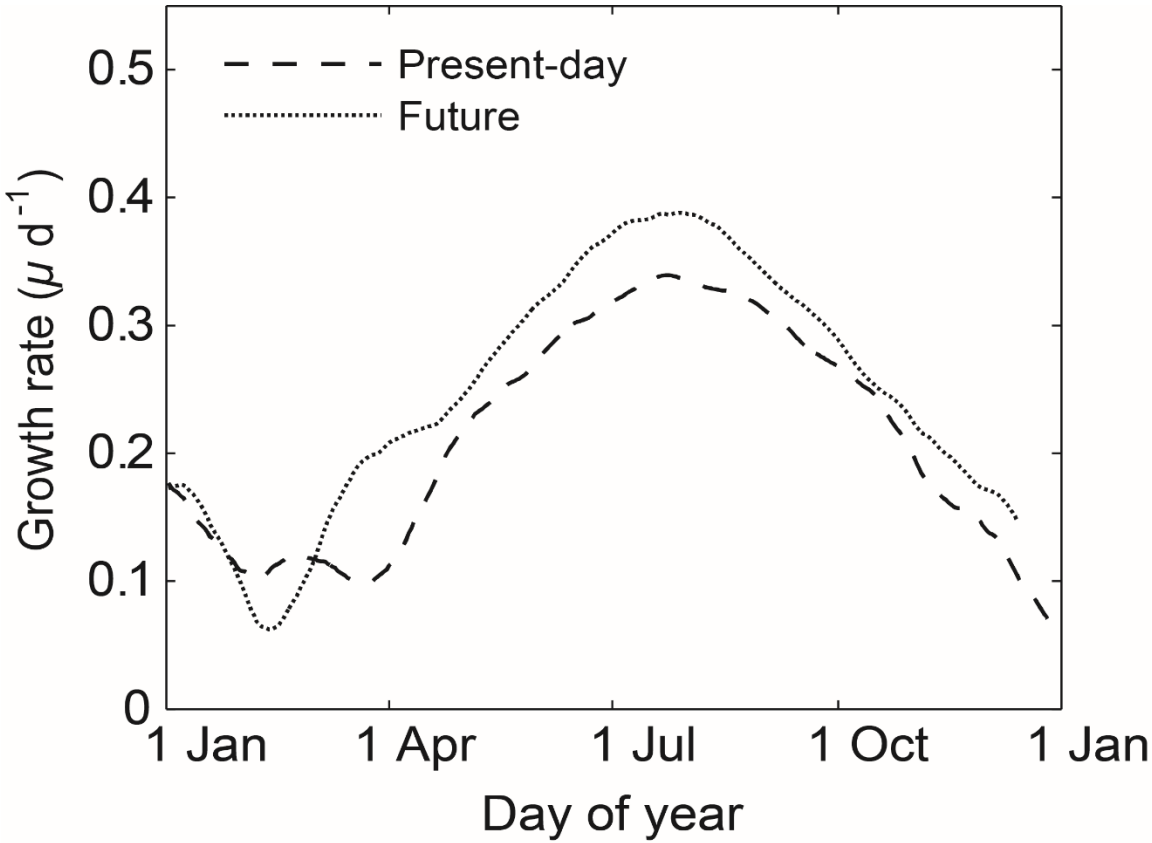


⁺Calculated over the bloom season (May-Oct)

*Based on conditions that support growth rates μ>0.25 d^{-1}

Favorable conditions begin earlier in the year and persist for longer

[Moore et al, 2015]



Washington State Department of Health

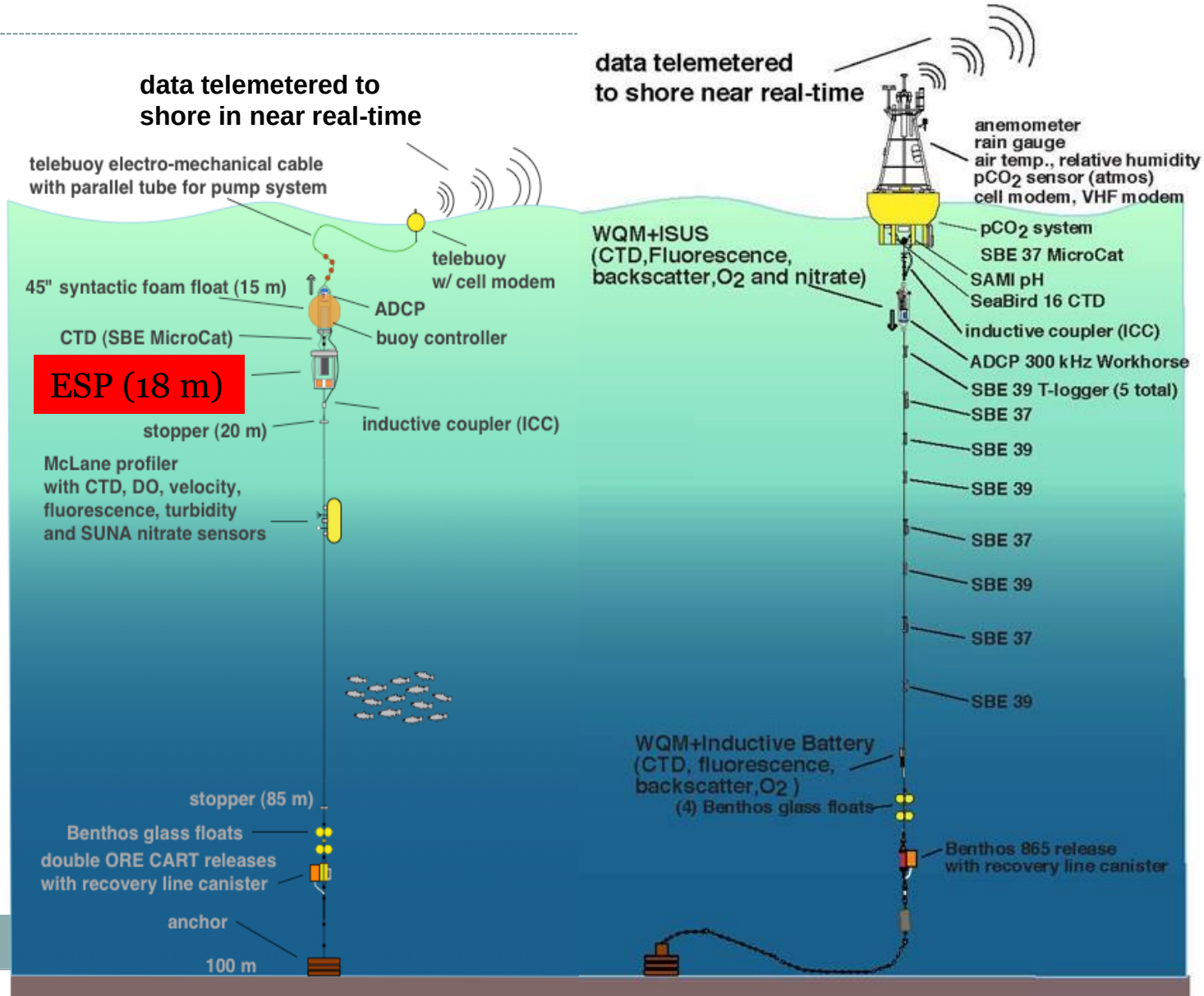
Value system of end-users?

- Should I be testing shellfish for emerging biotoxins? What other biotoxins should I be concerned about?
- Should I start testing shellfish for biotoxins earlier in the season? How much earlier?
- Do I need to expand my monitoring sites into new geographic areas? Which areas are at risk?

Interpreting results and communicating risk

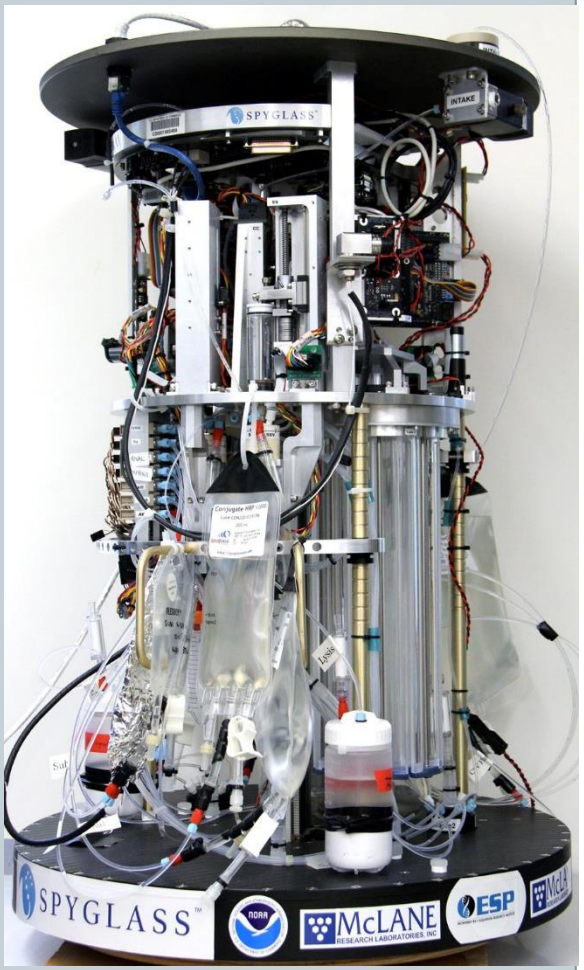
- What do I tell Jerry?
- Sensitivity experiments
  - Mechanistically understand the effects of upwelling, streamflow, and atmospheric warming on Puget Sound oceanography
- Puget Sound waters will become warmer
  - High confidence
- Warming SST will likely increase the risk of PSP
  - Blooms could begin up to a month earlier in the year and persist for longer in Puget Sound
  - Medium confidence
- Limitations
  - Temperature and salinity only
  - Interactive effects with other climate and non-climate drivers are not considered

2014-2016 IOOS Ocean Technology Transfer PI: John Mickett, UW Applied Physics Lab



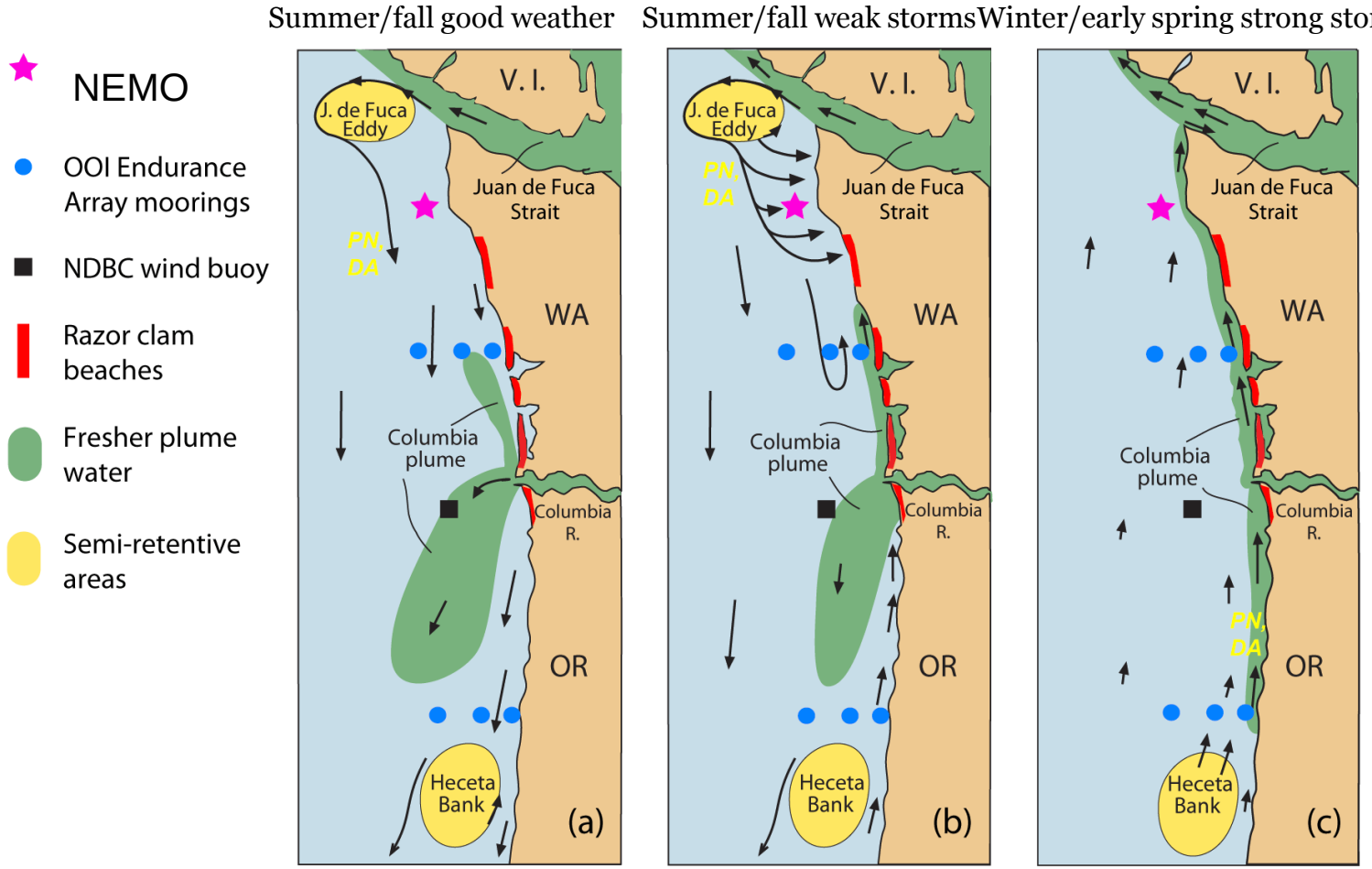
Environmental Sample Processor (ESP)

- Advanced, automated, quantitative, in situ, biological sensing system
- Near real-time data delivery
- Extended, high frequency, and responsive surveys
- Early warning of HABs and their toxins



NWFSC's ESPfriday

"The goal of this project is to place an ESP on a well-established, real-time, moored observatory in the PNW to obtain reliable information on PN and DA escaping from the Juan de Fuca eddy bloom initiation site."



Modified from Hickey et al. 2013

Puget Sound trial underwater deployment

- New mooring design
- New pump system
- Dual HAB species and toxin detection
- August 6-19, 2015

Preparing ESPfriday

NWIC intern Jessica Williams with NWFSC Nick Adams

Fabrication of the underwater housing

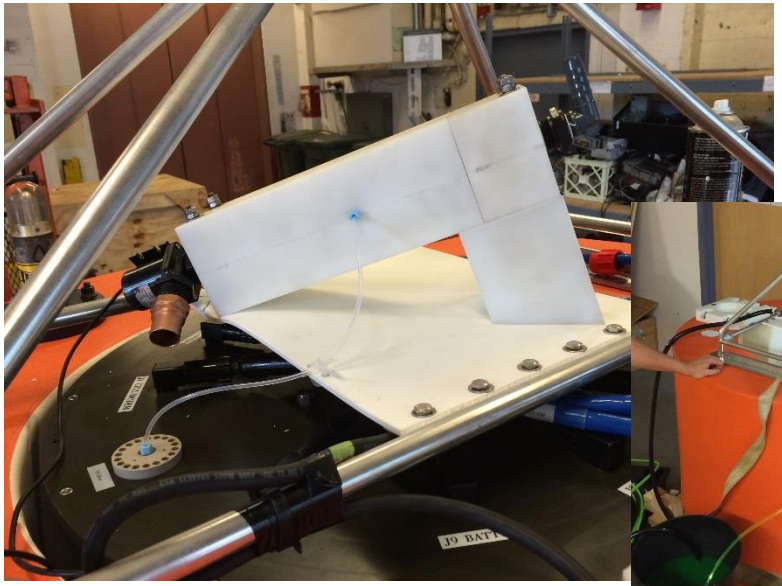
UW/APL John Mickett with IOOS Director Zdenka Willis

Canning ESPfriday

UW/APL Keith Magness and John Mickett assist NWFSC Linda Rhodes to "can" ESPfriday

Building the mooring

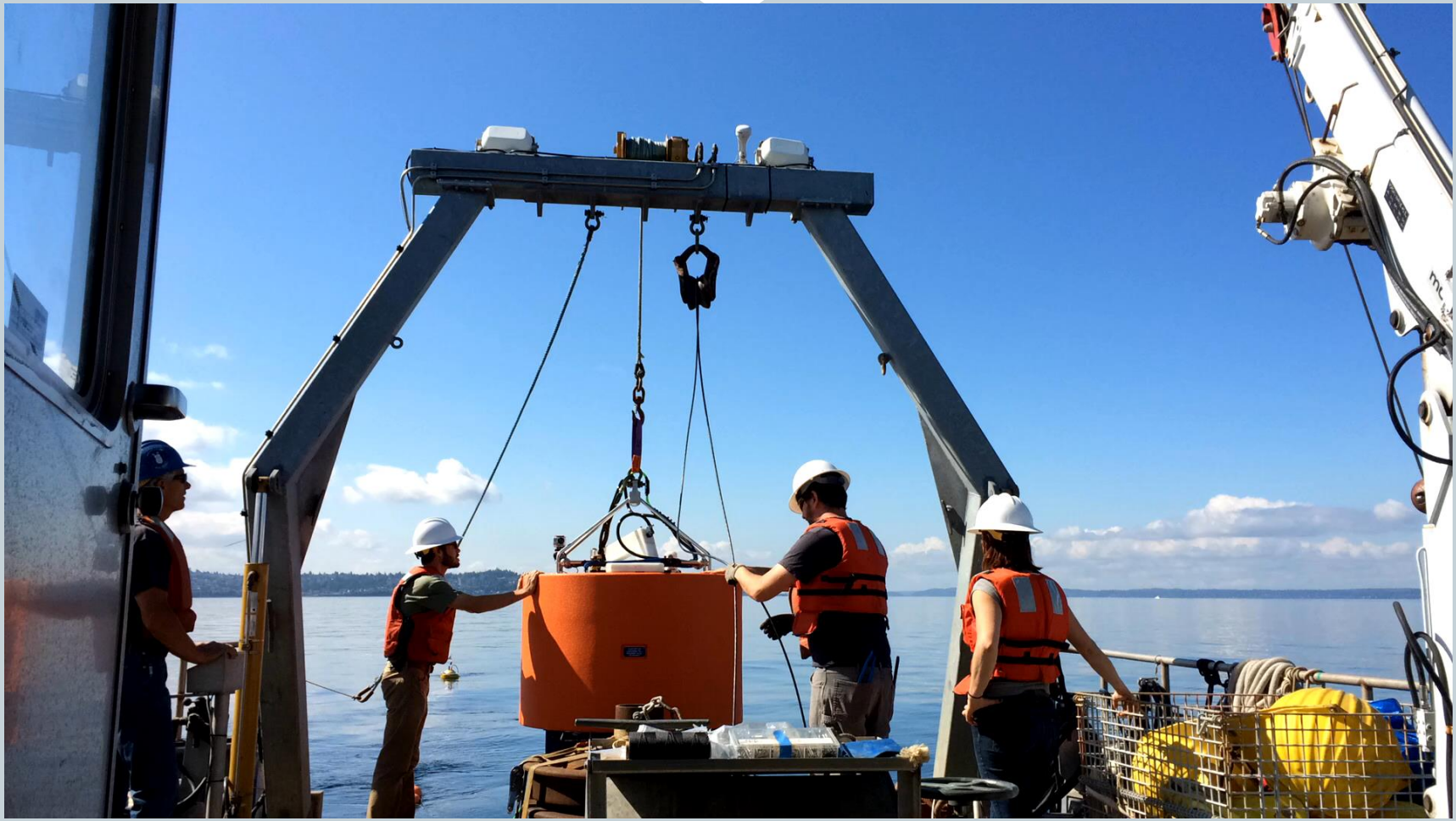
NWIC intern Jessica Williams with UW/APL Nick Michele-Hart



Testing the pump

UW/APL Derek Martin tests the "transit time" of the pump system using fluorescein dye

ESPfriday's first underwater deployment!



2016 (almost) spring deployment

- Spring ESP deployment was requested by several stakeholders following congressional briefing in November 2015
- IOOS supported this request
- UW provided ship time
  - R/V Thompson transiting from Newport to Seattle
  - UW Oceanography provided 2 education days for research activities
  - May 24-26, 2016
- Active deployment dates May 25 – July 11, 2016
  - habda; 3×week

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  - Jerry Borchert

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  - Chris Siani
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  - Nick Adams
  - Bill Nilsson
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