# Marine Water Quality, and Indicators of Eutrophication

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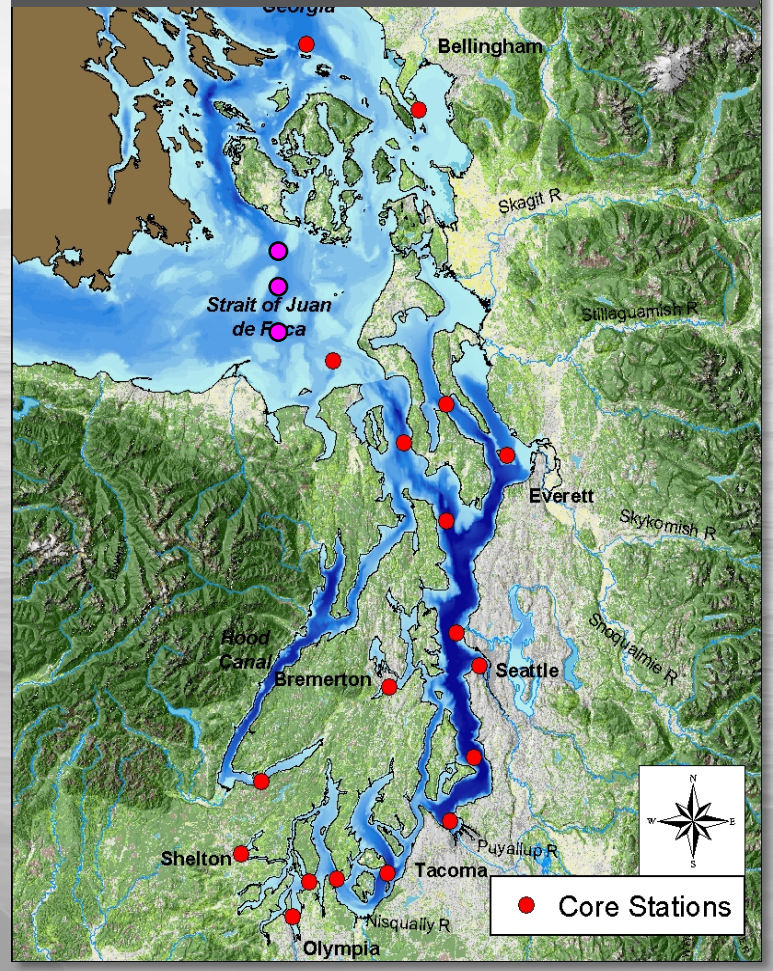
## Marine Monitoring Unit, Environmental Assessment Program

Definition Eutrophication – an increase in the rate of supply of organic matter to an ecosystem (Nixon 1994)

# Measuring long-term trends in eutrophication, dissolved oxygen, and physical variables

## Greater Puget Sound region




## Water Quality variables measured monthly at 27 stations




**Physical variables**
- Temperature
- Salinity
- Density

**Chemical variables**
- Oxygen
- Nitrate
- Silicate
- Phosphate
- Ammonium
- Nutrient ratios
- pH

**Bio-optical variables**
- Water clarity
- Chlorophyll a
- Euphotic depth

**Monthly Baselines 1999-2008**

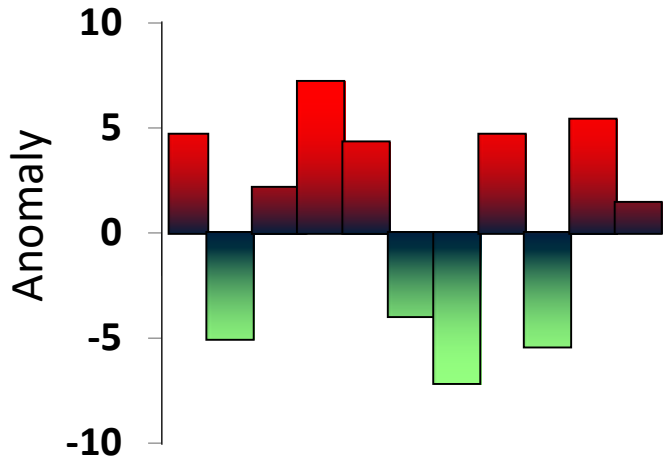
**"The Holy Grail"**

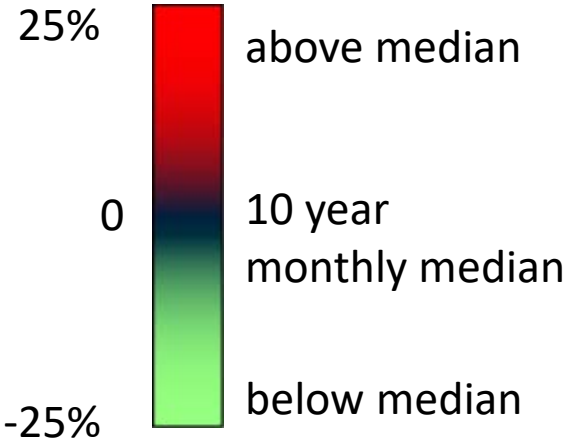
How much are humans influencing water quality?

If natural influences are known, human influences can be determined.

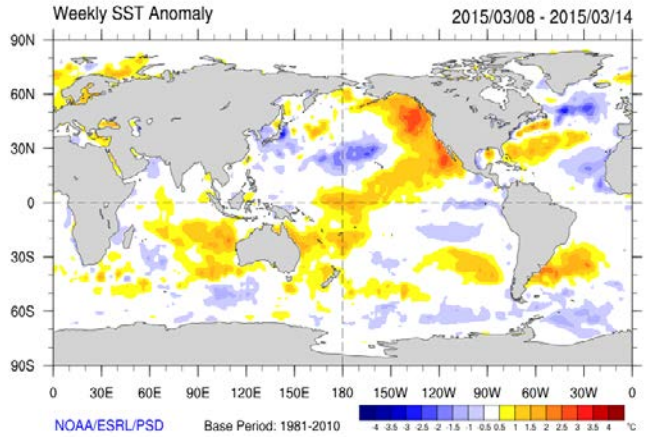
# Anomaly plots (baseline 1999-2008)

*"Example of recent climate impacts"*



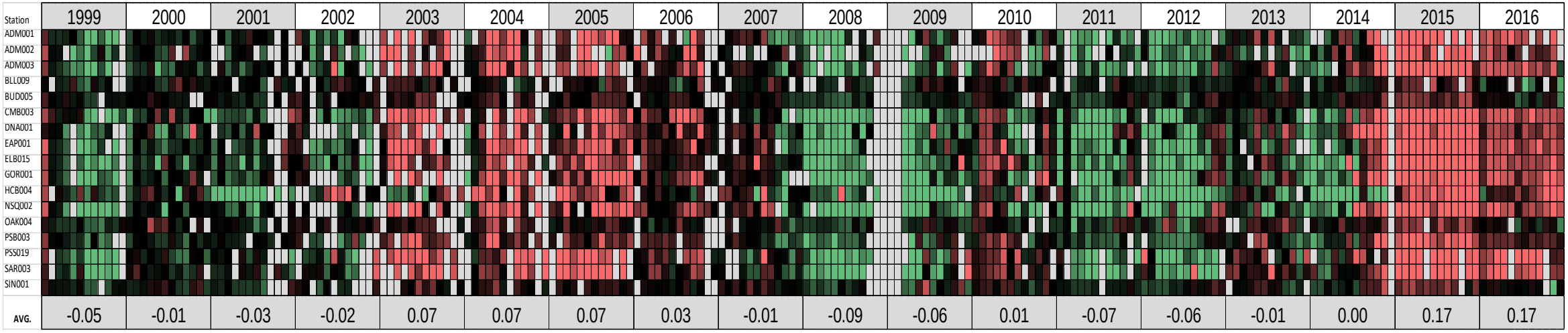




## The Blob, SST (March 8-14, 2015)




**Thermal energy content (Temperature) in surface water 0-50m**

**Stations** (north to south)

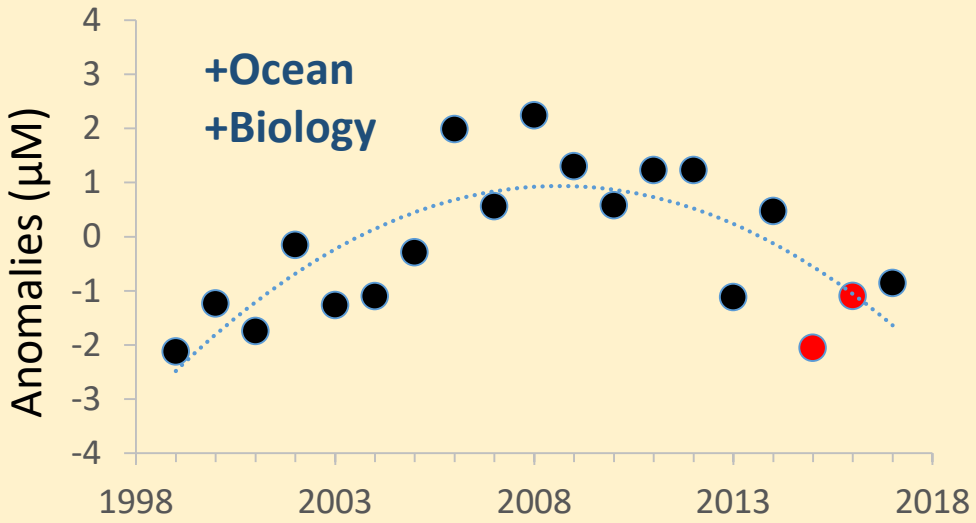


# Are things looking good for water quality?

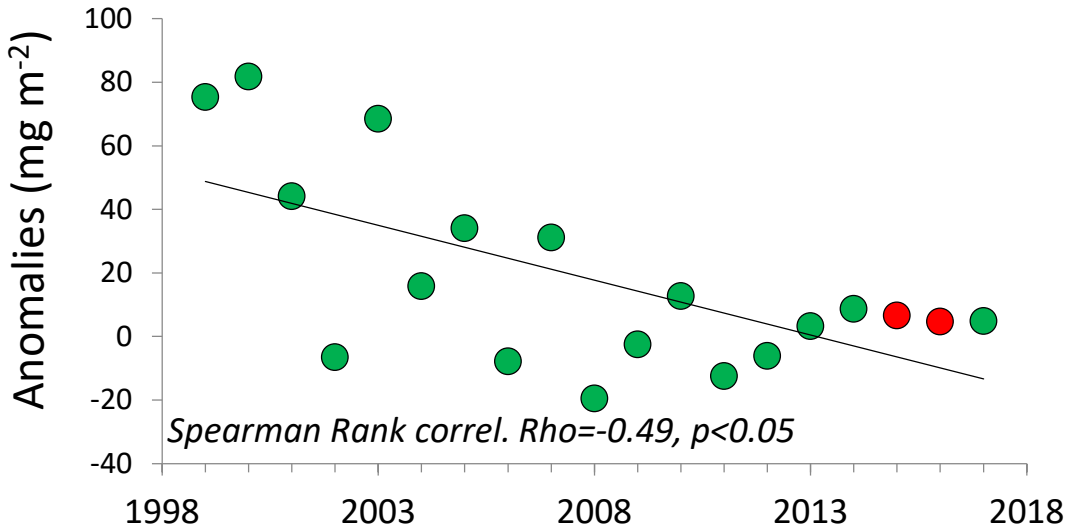
*"The classic story of eutrophication"*

**Depth 0-50 m**

**Nitrate 0-50m**




**Chl *a* 0-50m**

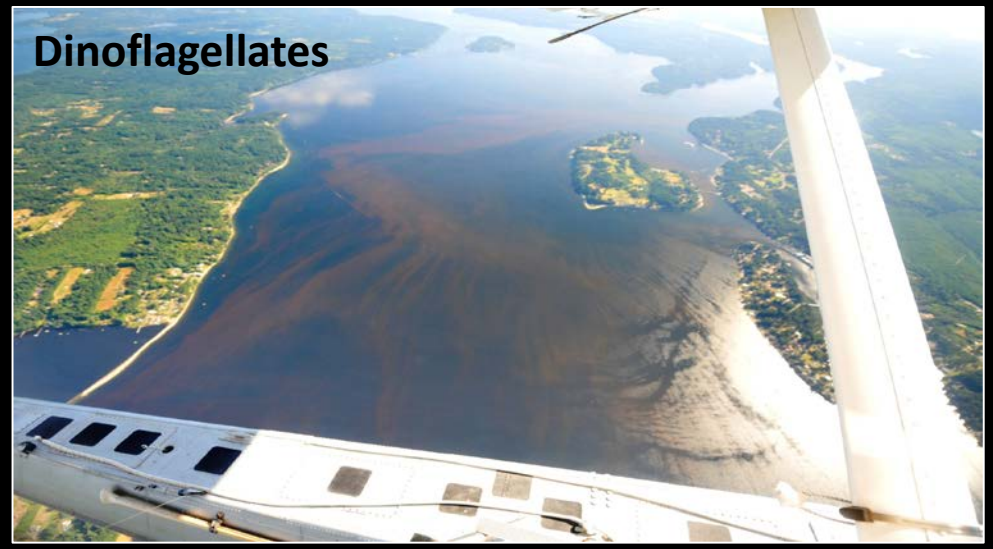


# We live in a unique place worth protecting…

Things you might have missed…

?

# Marine eutrophication indicators persist (little-assessed info gap)

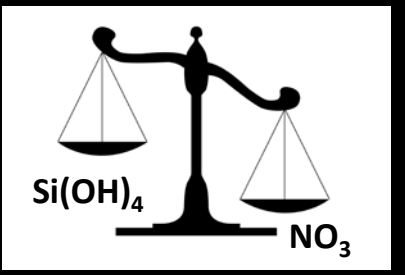





**Benthic indicators**
***Parvilucina***



**Nutrient balance**




*Green bloom.*
Location: North Bay, Case Inlet (South Sound), 12:59 PM.

A diverse assemblage of phytoplankton naturally occurs in Puget Sound.

Environmental conditions can trigger unusually high concentrations called “bloom”.

Publication No. 18-03-071

DEPARTMENT OF ECOLOGY State of Washington

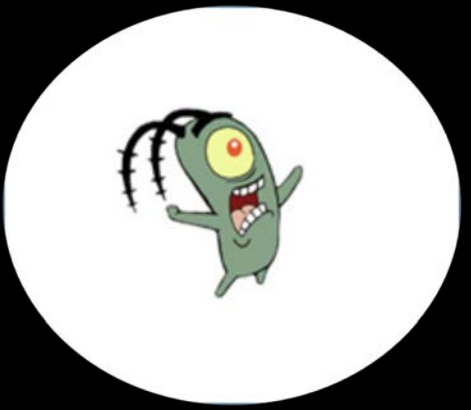
# Eyes Over Puget Sound

Summary | Stories | Diving & critters | Climate & streams | Combined factors | Marine water | Aerial photos | Info

## Surface Conditions Report, *April 19, 2018*

*Up-to-date observations of water quality conditions in Puget Sound and coastal bays*

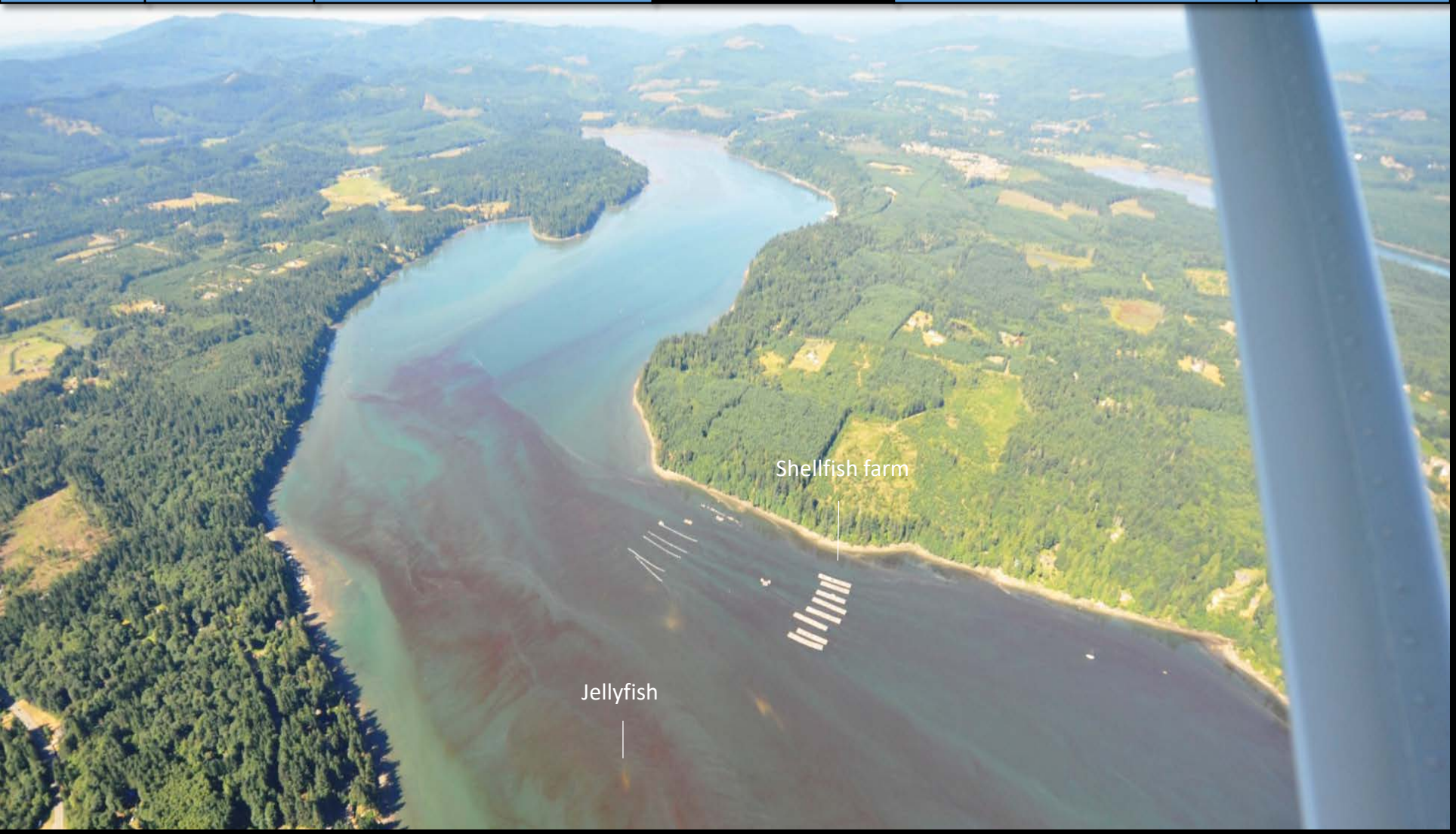
Start here



Many flagellate species form Harmful Algae Bloom species (HABs)

# Eyes Over Puget Sound, our monthly condition report

Field log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings




*Red-brown bloom mixed into sediment-rich river plume. Jellyfish patches.*
Location: Deepwater Point, Totten Inlet (South Sound), 10:27 AM.

Flagellates thrive in water:

- rich in organic molecules
- that is stratified

# Aerial photography 8-28-2017



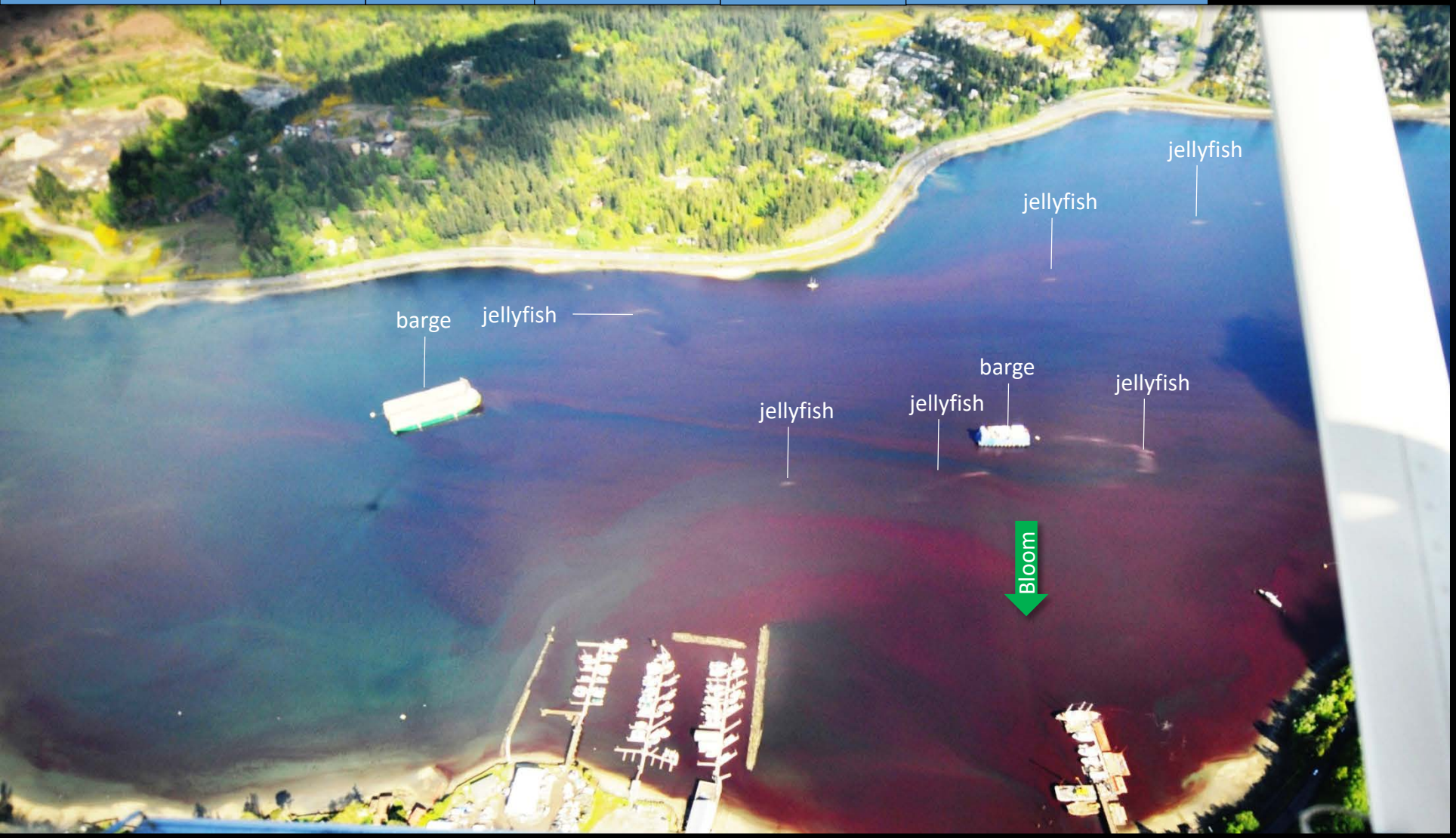

*Large red-brown bloom and front.*
Location: Elwood Point, Dyes Inlet (Central Sound), 12:49 PM.

Flagellates thrive in water:

- rich in organic molecules
- that is stratified
- flagellates are auto, mixo or heterotrophic

# Aerial photography 4-29-2015






*Red bloom and patches of jellyfish.*
Location: Kitsap Marina, Sinclair Inlet (Bremerton), 9:52 AM.

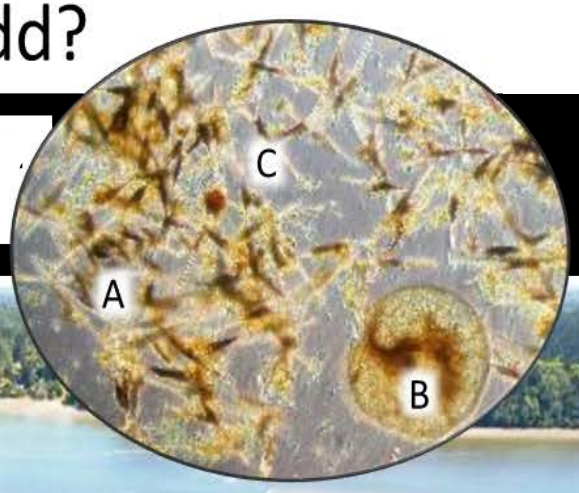
Flagellates thrive in water:

- rich in organic molecules
- that is stratified
- flagellates are auto, mixo or heterotrophic
- Opportunistic (huge genome)

Pacific Shellfish Institute

# What's Blooming in Budd?

Aimee Christy collecting & analyzing samples




*Ceratium fusus (A)* and one *Noctiluca (B)*, and *Hypophysis* (C) under the microscope

boat

Bloom

marker

Date: 7-24-2017

*Large, very patchy orange-brown bloom.*
Location: Budd Inlet (South Sound), 11:56 AM.

Very limited verification what species bloom because of large scale and patchy nature

# Eyes Over Puget Sound

## June 2011

*Up-to-date observations of visible water quality conditions in Puget Sound and the Straits*

Noctiluca has an impact on:

- food web structure

# Aerial photography 6-12-2012




Large *Noctiluca* bloom in Central Sound. Location: Bainbridge Island (Central Sound), 8:08 AM

Noctiluca has an impact on:

- food web structure
- nutrient cycling

# Eyes Over Puget Sound

| Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings |
|---|---|---|---|---|---|


*Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca*

Noctiluca has an impact on:

- food web structure
- nutrient cycling
- eutrophication indicator

# Aerial photography 6-8-2015




*Large Noctiluca bloom surfacing and gathering in large quantities at tidal front.*
Location: Commencement Bay (Central Sound), 3:32 PM.

Noctiluca has an impact on:

- food web structure
- nutrient cycling
- eutrophication indicator

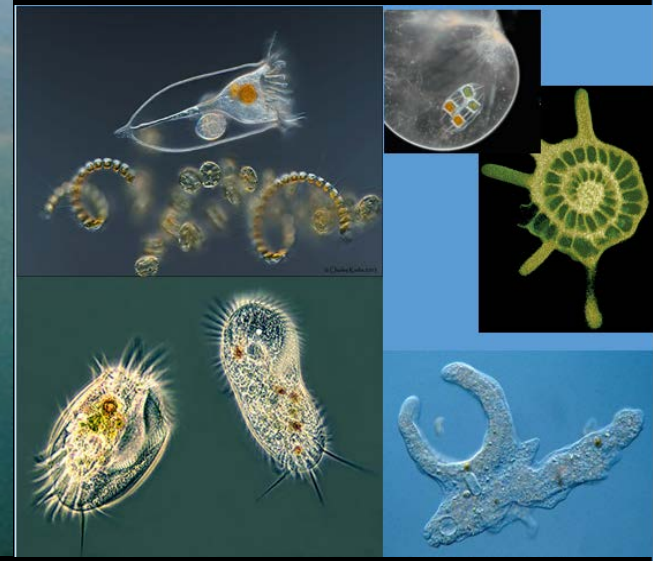
# Aerial photography 8-28-2017




**The lower food web responds to organic nutrient sources.**

Noctiluca stands for an important component of the food web.

Micrograzers



*Organic material accumulating at tidal front next to intense green and orange bloom.*
Location: Off Samego Point, McNeil Island, Carr Inlet (South Sound), 1:32 PM.

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DEPARTMENT OF ECOLOGY State of Washington

# Eyes Over Puget Sound

Field log | Climate | Water column | Aerial photos | Ferry and Satellite | Moorings

## Surface Conditions Report

### October 29, 2014

Guest: Gabriela Hannach

Start here

*Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca*

Jellyfish:

- Eutrophication indicator

# Aerial photography 10-29-2014



A.


Jellyfish:

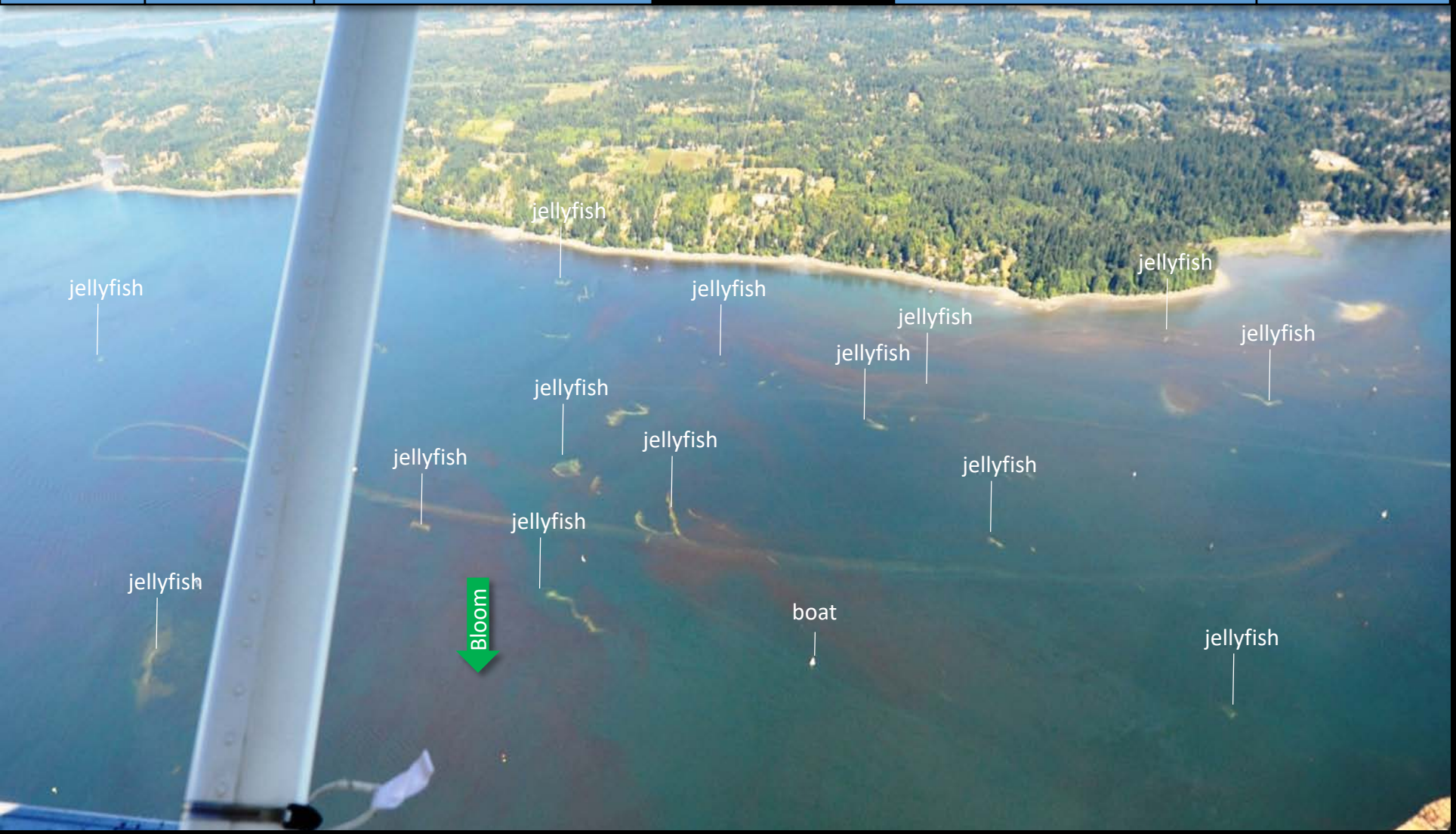
- Eutrophication indicator

*Extensive smacks of moon jellies both in size and density with pinkish tint.*

Location: A. On the water, B. From air showing location on the water, Budd Inlet (South Sound), 3:50 PM.

# Aerial photography 8-4-2015






*Numerous large patches of jellyfish in water containing red-brown algal bloom.*
Location: Budd Inlet (South Sound), 3:12 PM.

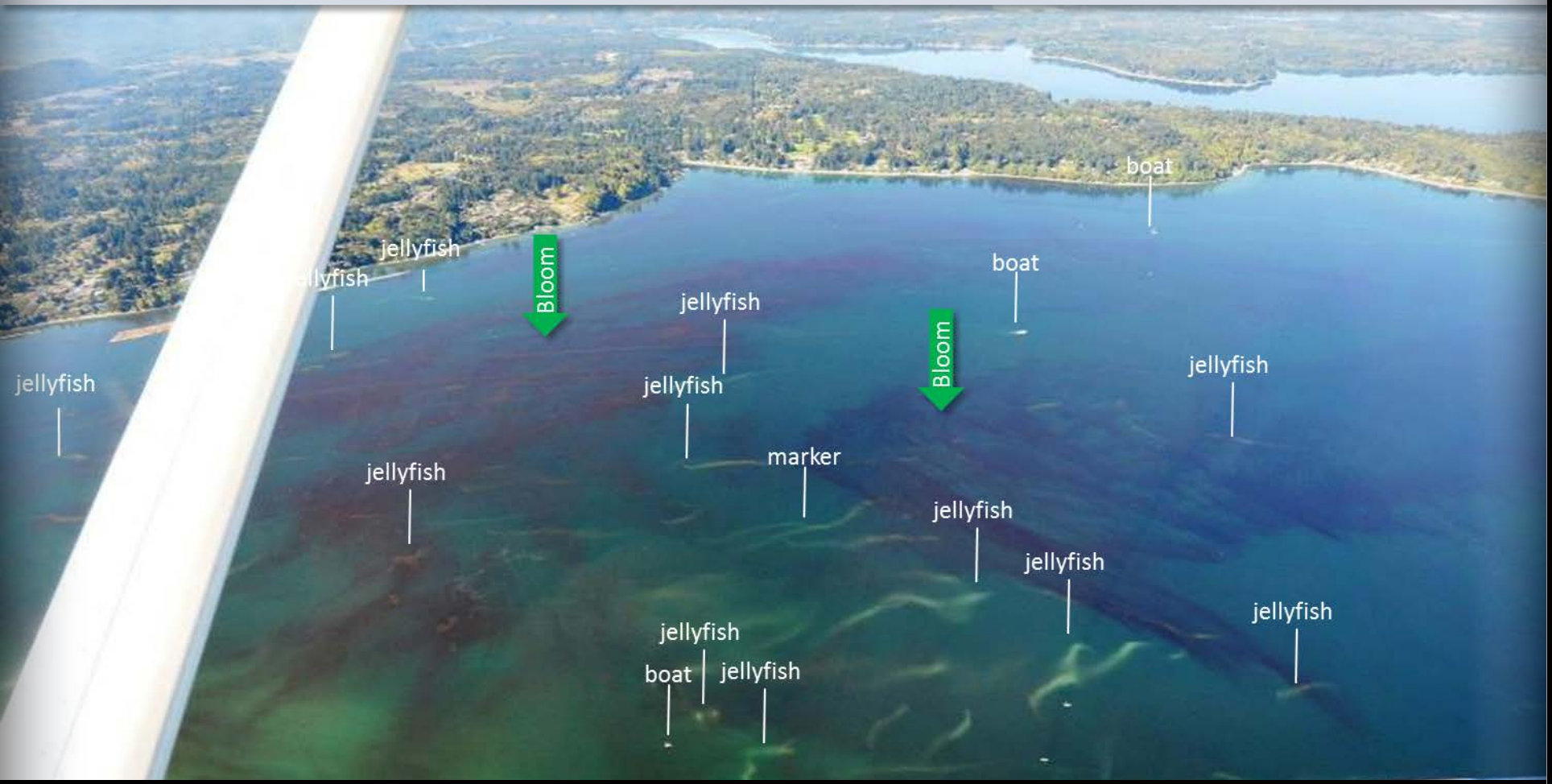
Jellyfish:

- Eutrophication indicator
- occur abundantly in summer-fall

# 2016 – Species indicating eutrophication



Jellyfish and red-brown dinoflagellate blooms thriving in warm, stagnant water in late summer.




*Two differently colored red-brown blooms and abundant jellyfish patches.*
Location: Budd Inlet (South Sound), September 2016.

Jellyfish:

- eutrophication indicator
- occur abundantly in summer-fall
- poor food for plankton species (sink)

# Aerial photography 7-6-2015




*Extensive accumulations of organic debris, a brown algal bloom, and a large oil sheen.*
Location: Between Port Madison and Shilshole (Central Sound), 3:05 PM.

Macro-algae:

- eutrophication indicator

# Aerial photography 8-28-2017



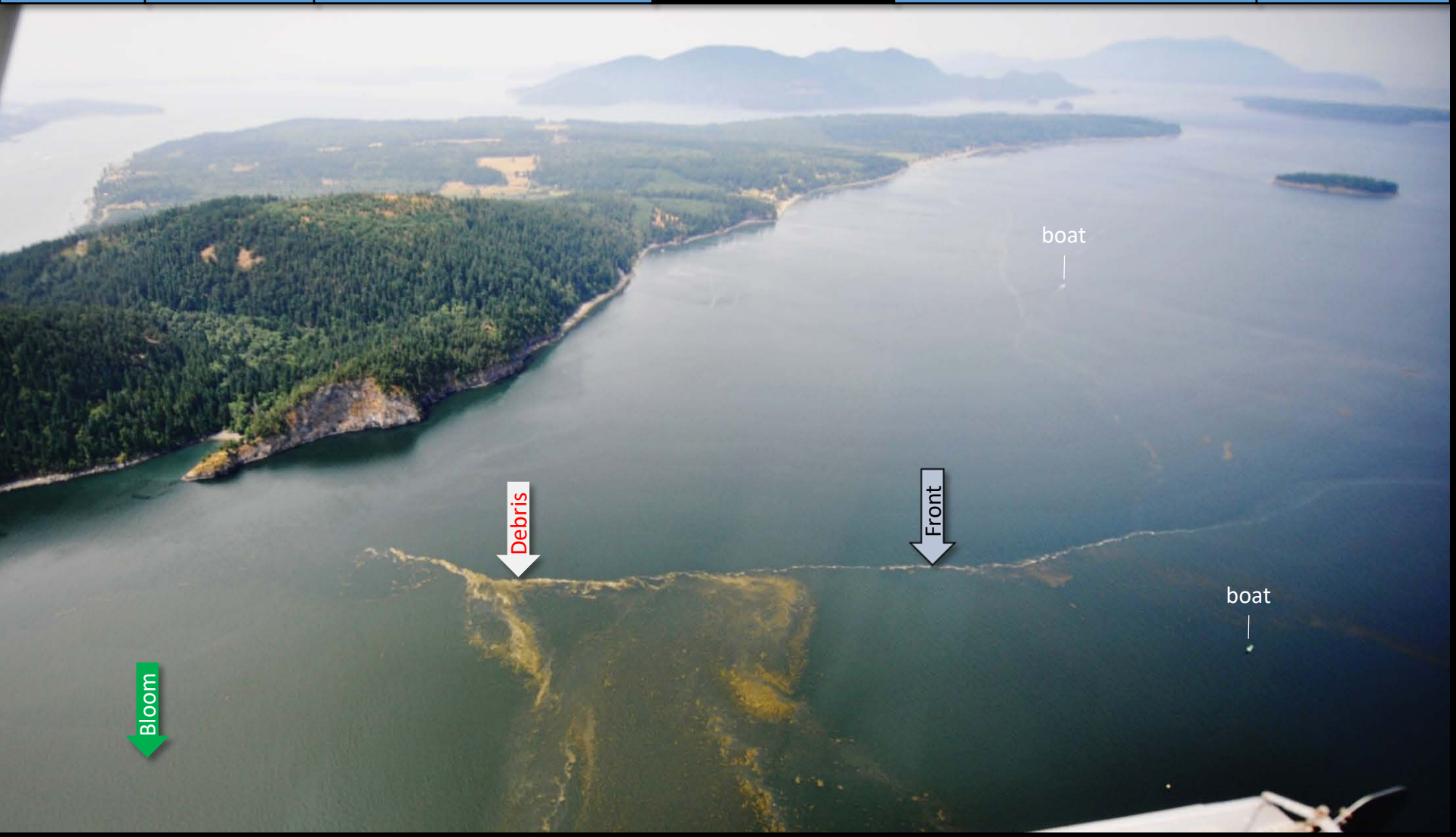

*Large rafts of macroalgae accumulating along front. Plume of Puyallup River extending north.*
Location: Off Maury Island (Central Sound), 1:45 PM.

Macro-algae:

- eutrophication indicator
- occur in summer

# Aerial photography 7-6-2015






*Large islands of organic material drifting at the surface off Guemes Island.*
Location: Padilla Bay (North Sound), 1:05 PM.

Macro-algae:

- Eutrophication indicator
- occur in summer
- poor food for plankton species
- decompose at depth?

# 2016 – Species indicating eutrophication

Algae washed up on beaches in thick layers and rotting

Location: Edmonds Underwater Park, Snohomish County, July 2016.

# 2016 – Species indicating eutrophication

Algae washed up on beaches in thick layers and rotting

Location: Edmonds Underwater Park, Snohomish County, July 2016.

# 2016 – Species indicating eutrophication

Algae washed up on beaches in thick layers and rotting

Location: Freeland, Holms Harbor Whidbey Island, Aug 2017.

Rotting algae washed into marinas and decomposing

Des Moines Marina

Concerned citizen: 5/24/2018

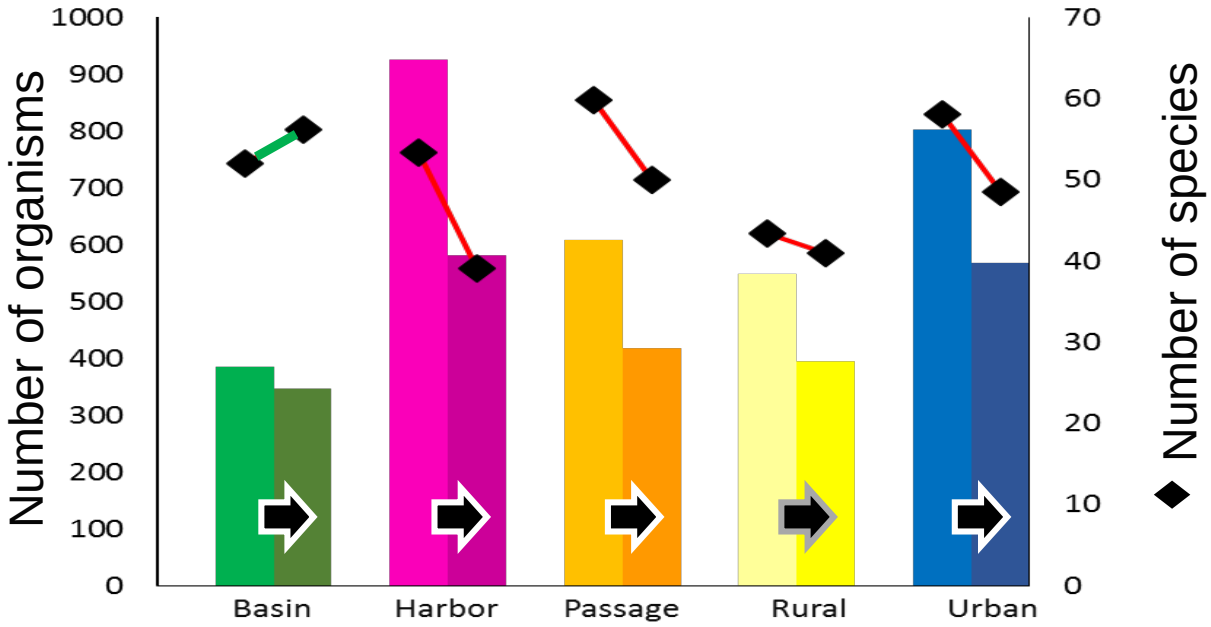
# Increase in some benthic eutrophication indicators and declining benthic community

**Average Abundance of *Parvilucina***

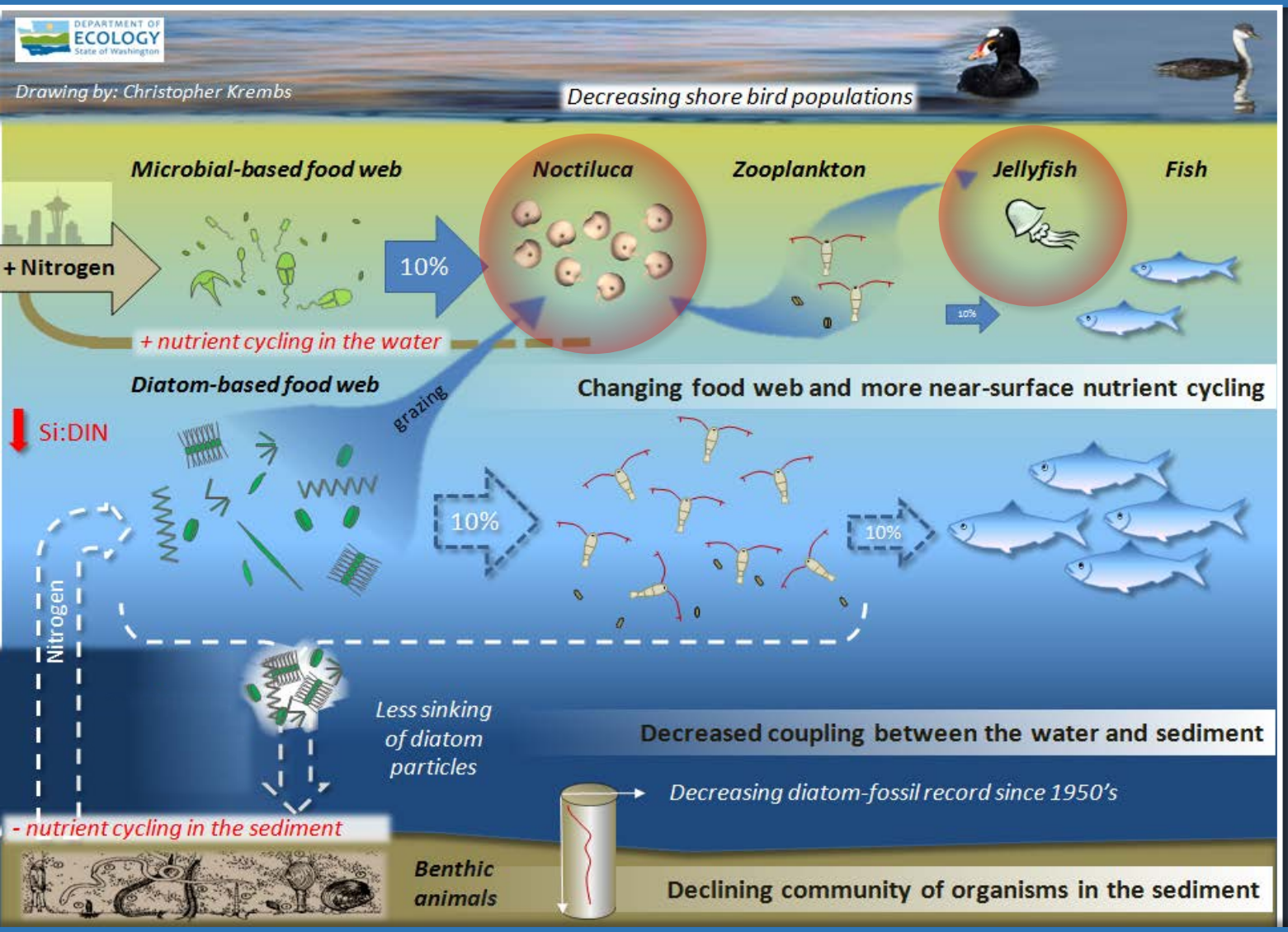

Increasing abundance:
**Central** and **South Sound,**
**Whidbey Basin** and
**Admiralty Inlet**




**Puget Sound benthic community**
Baseline (1997-2003) vs 2nd Round (2004-2014)



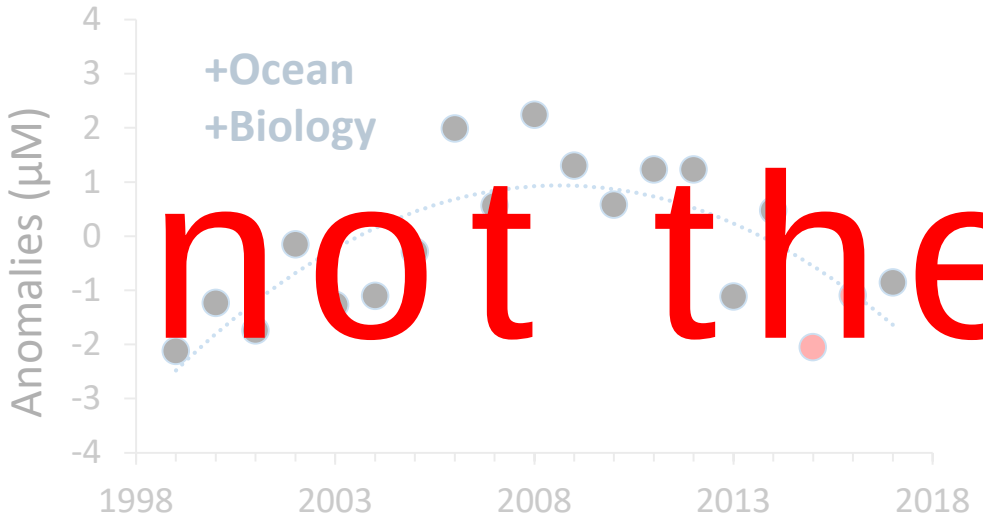
# Hypothesis: Changes in the lower foodweb




- The energy and material cycling through the lower food web of Puget Sound are changing.
- How do climate effects shape these changes?

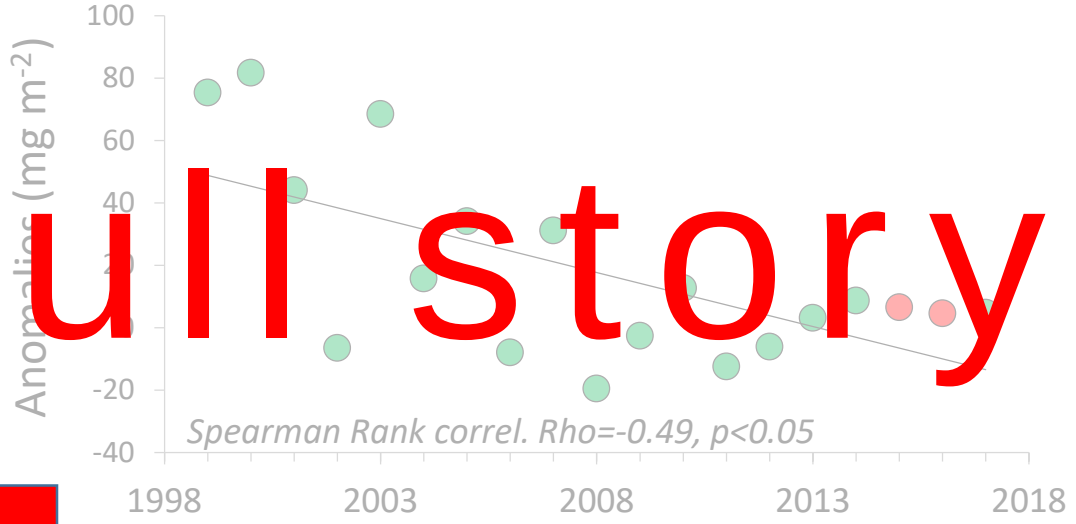
# What can cause the massive blooms and eutrophication indicators?

## Nitrate 0-50m

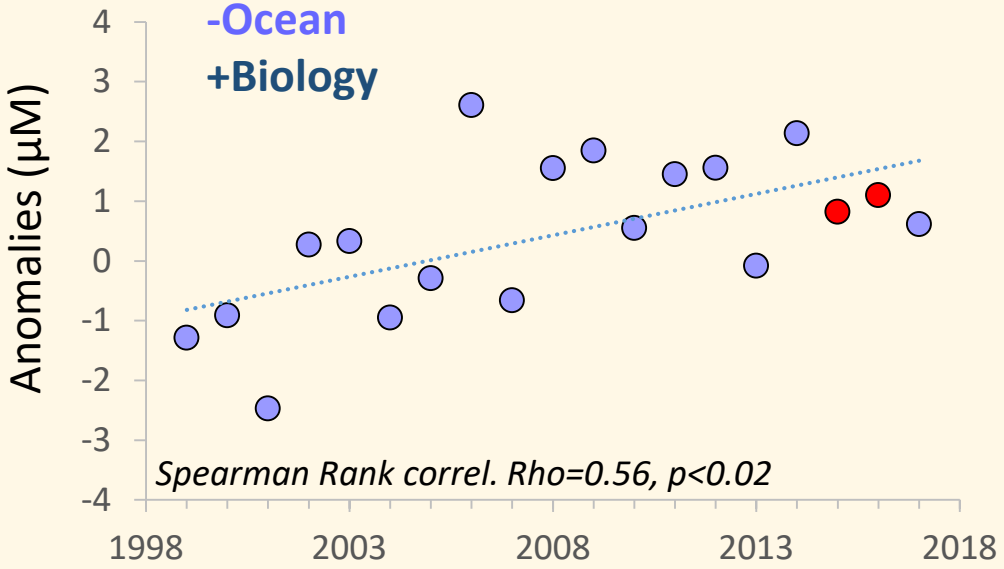



not the full story

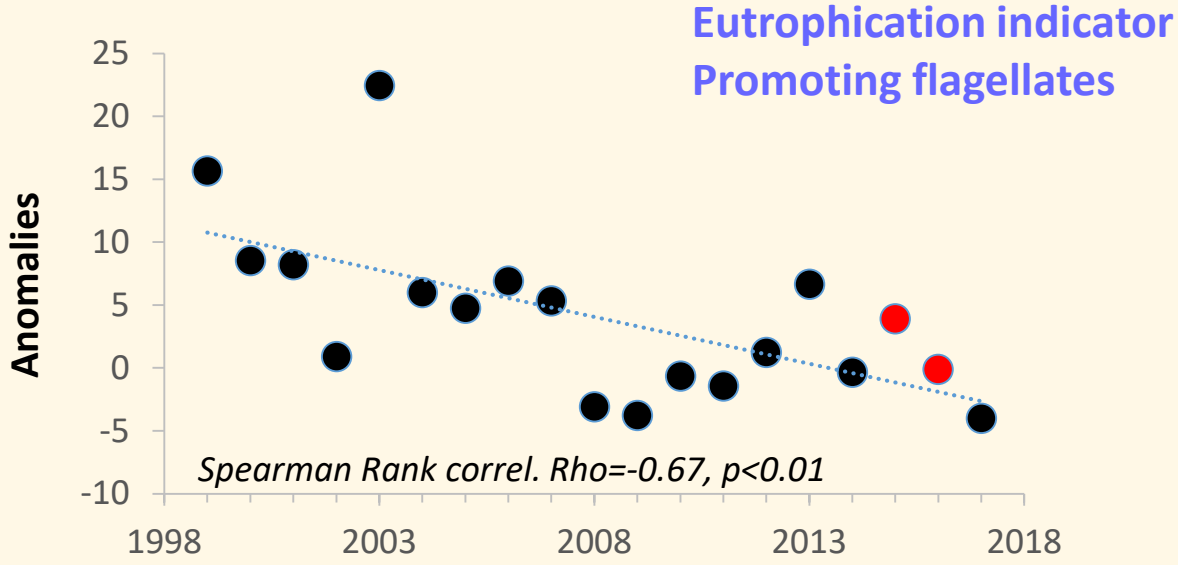
## Chl a content 0-50m




## Nitrate : Salt ratio relative to ocean source water

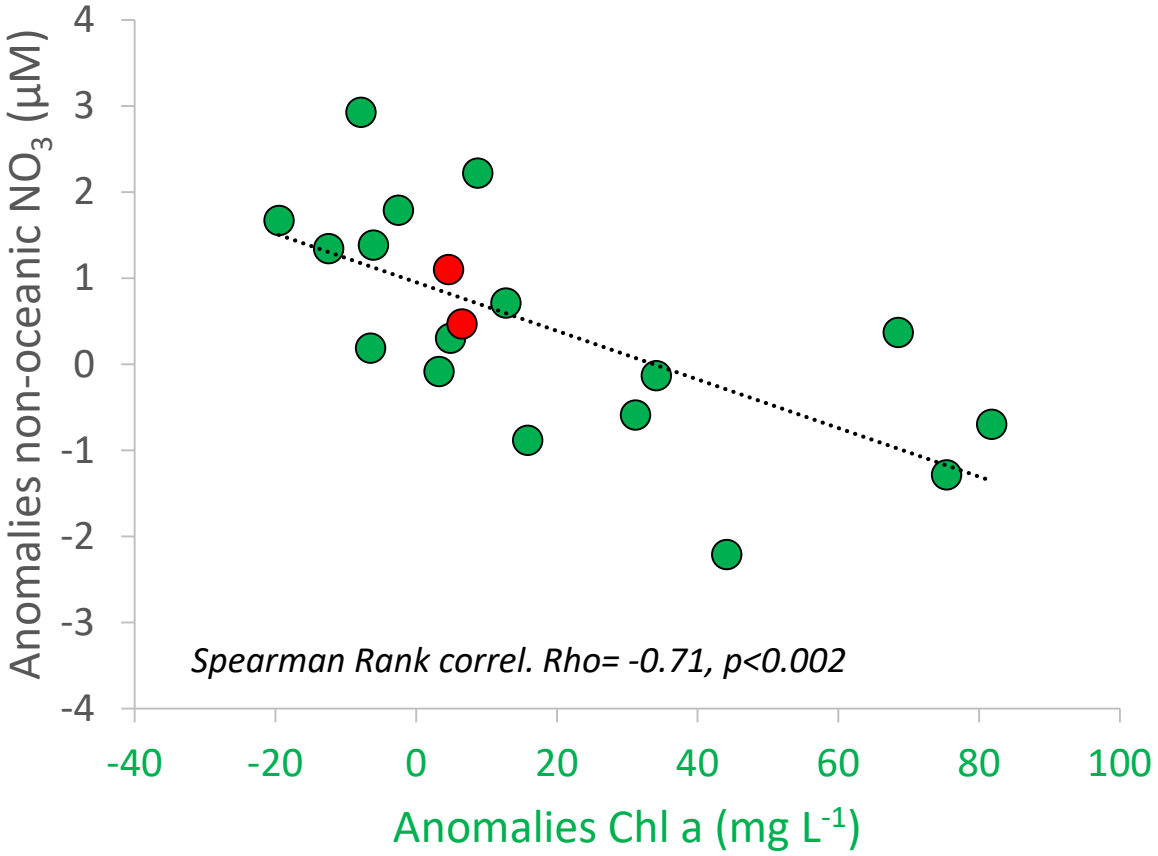


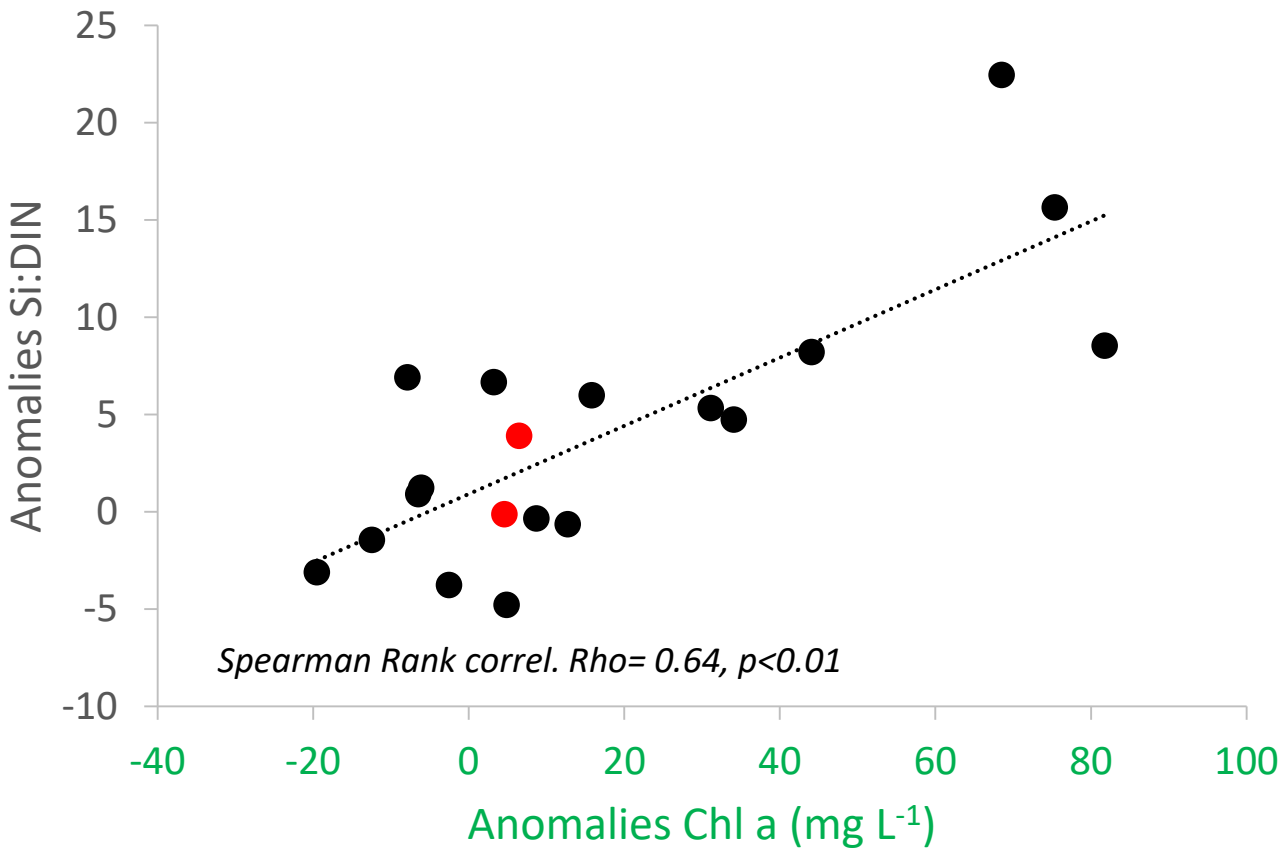

## Silicate: DIN *(dissolved inorganic nitrogen)*



# Are non-oceanic nitrate trends driven by changes in algae nutrient uptake, which also affects the Si:DIN ratio?

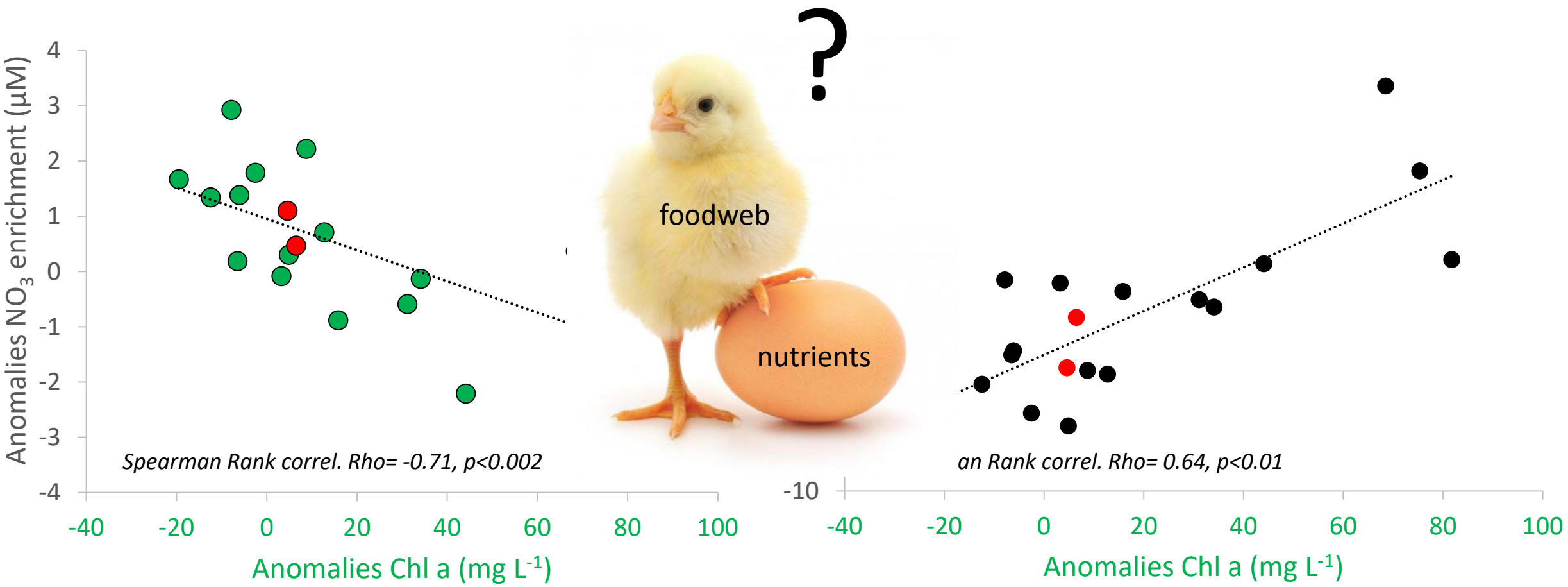
**Depth 0-50 m**



# Are non-oceanic nitrate trends driven by changes in algae nutrient uptake, which also affects the Si:DIN ratio?

**Depth 0-50 m**



It is time to revisit and rethink what's going on in Puget Sound…

Correlation does not prove causation, models needed

## Info gaps:

- Nutrient trends in the organic form (marine, rivers)

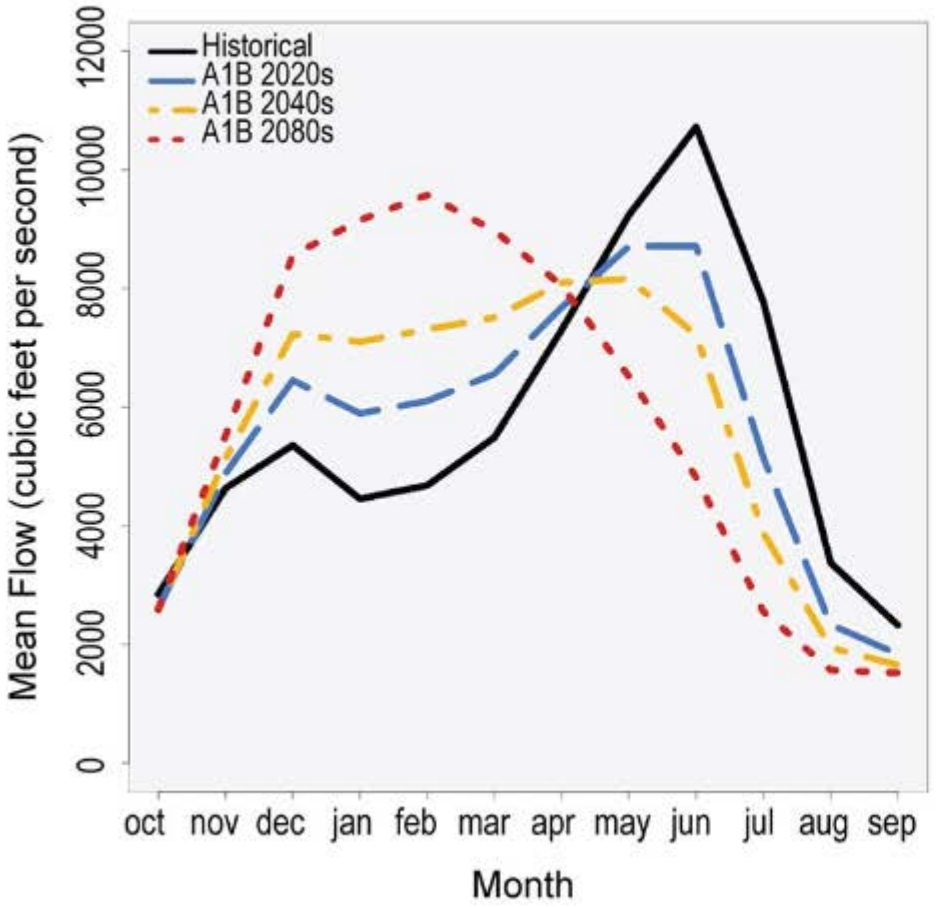
feed me through the winter!
organic food->

- Foodweb information at the base (species, PP, energy and material cycling)

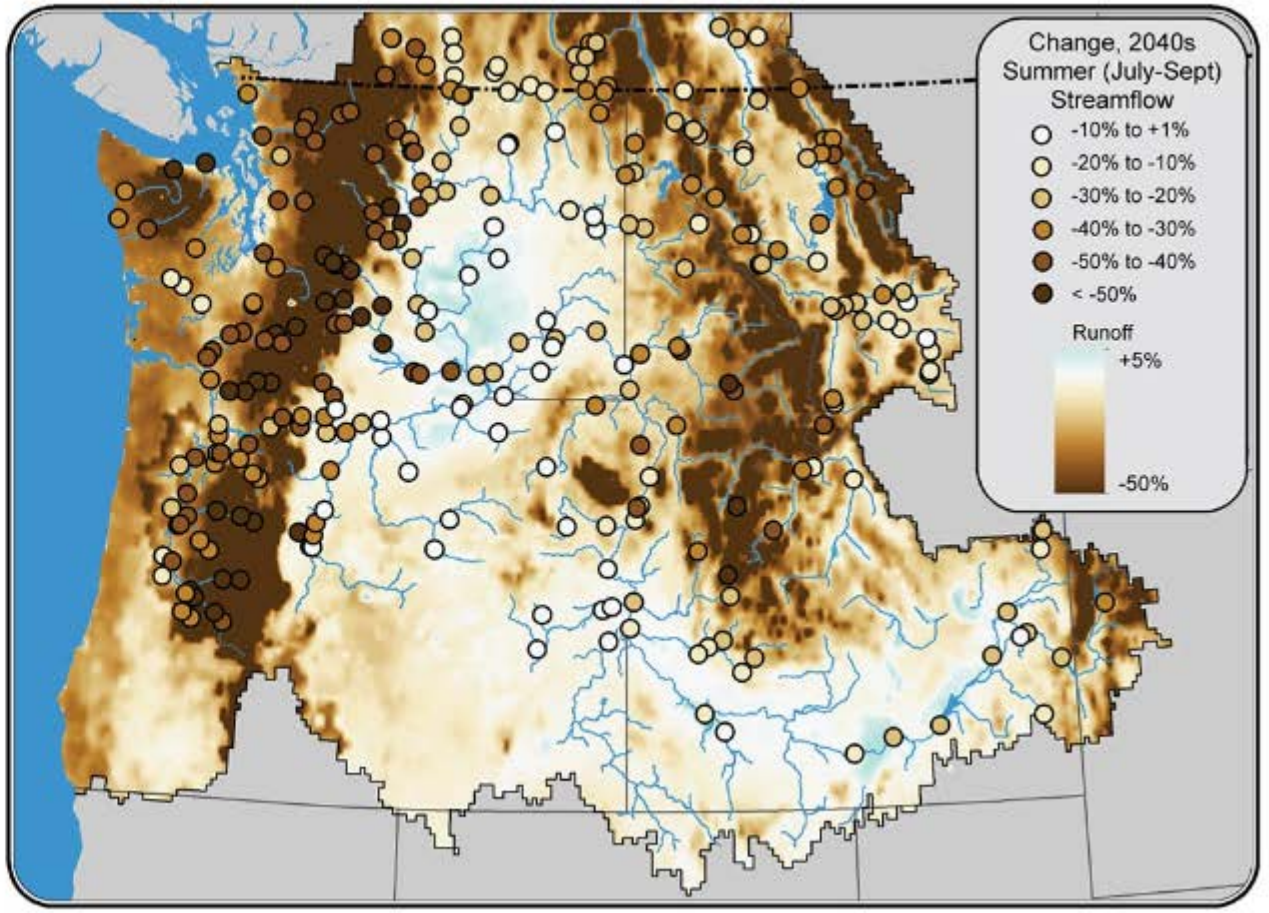
- Climate impact

# Predicted changes in the timing and character of river flows
# Climate change impacts in the United States, 2014

Future Shift in Timing of Stream Flows



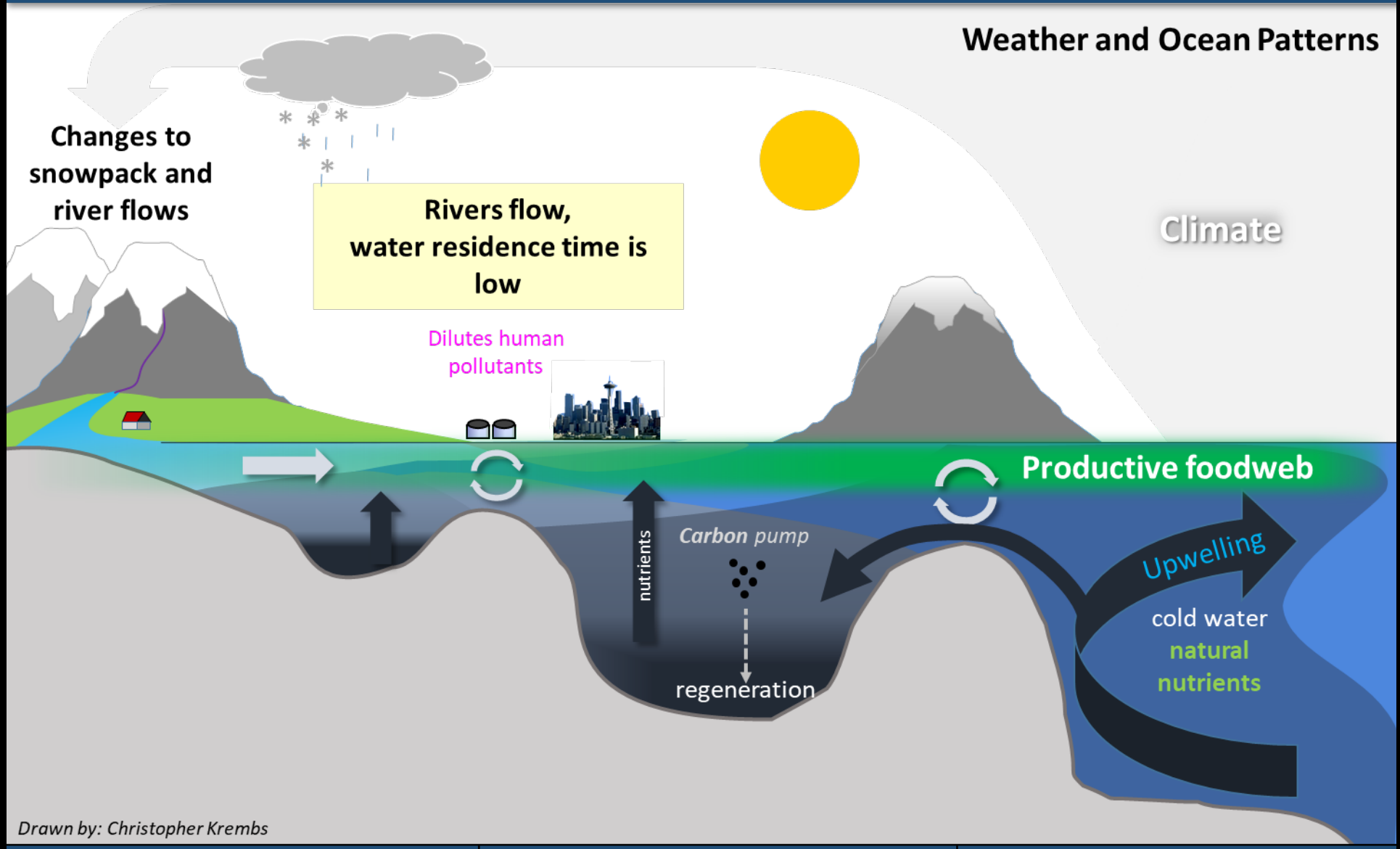

Reduced Summer Flows




Mote et al., Eds., U.S. Global Change Research Program, 487-513. doi:10.7930/J04Q7RWX.

**On the Web:** http://nca2014.globalchange.gov/report/regions/northwest:

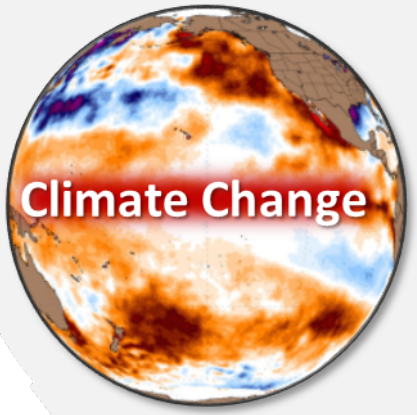
# The timing of processes will be affected by future climate




Estuaries and Bays | Basins | Ocean

meltwater  “warmer migration corridor
“lower food quality”  upwelled water

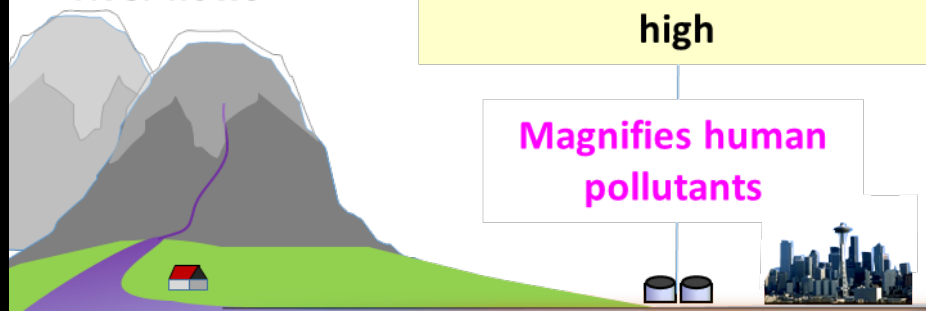
Weather and Ocean Patterns




Changes to snowpack and river flows

Rivers are dry, water residence time is high

Magnifies human pollutants



Less desirable foodweb

Productive foodweb

regeneration

warmer water

Upwelling

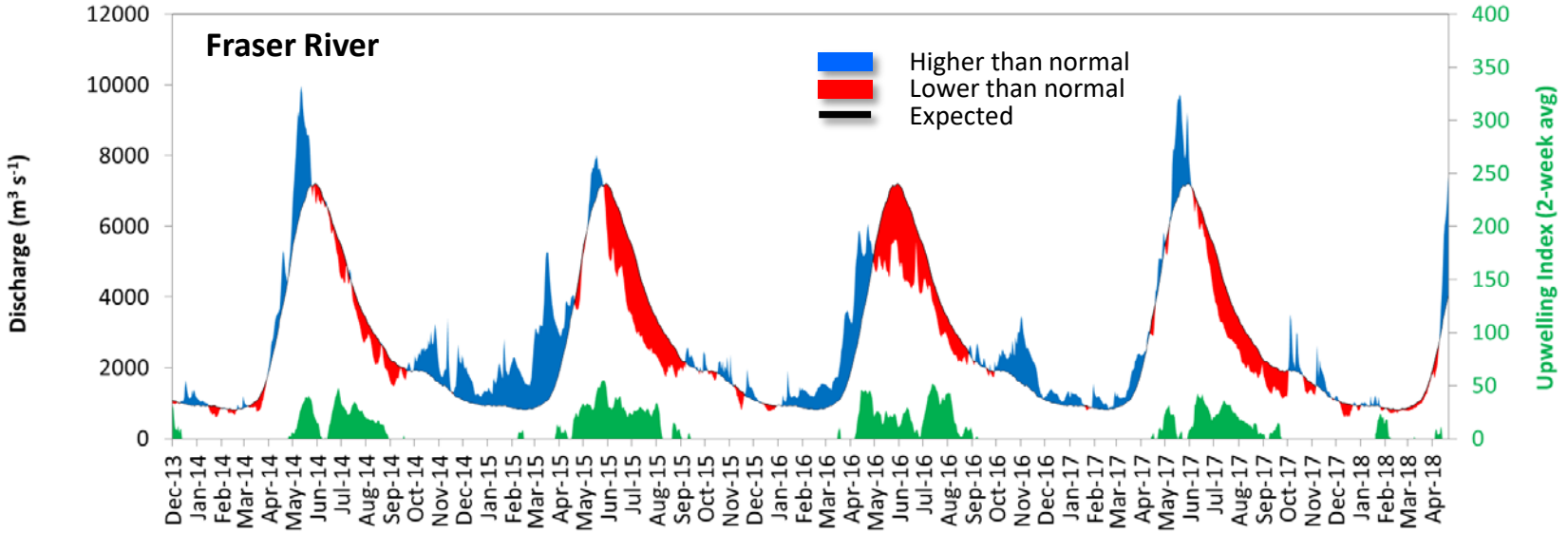
cold water
natural
nutrients

Water has more time to warm in summer

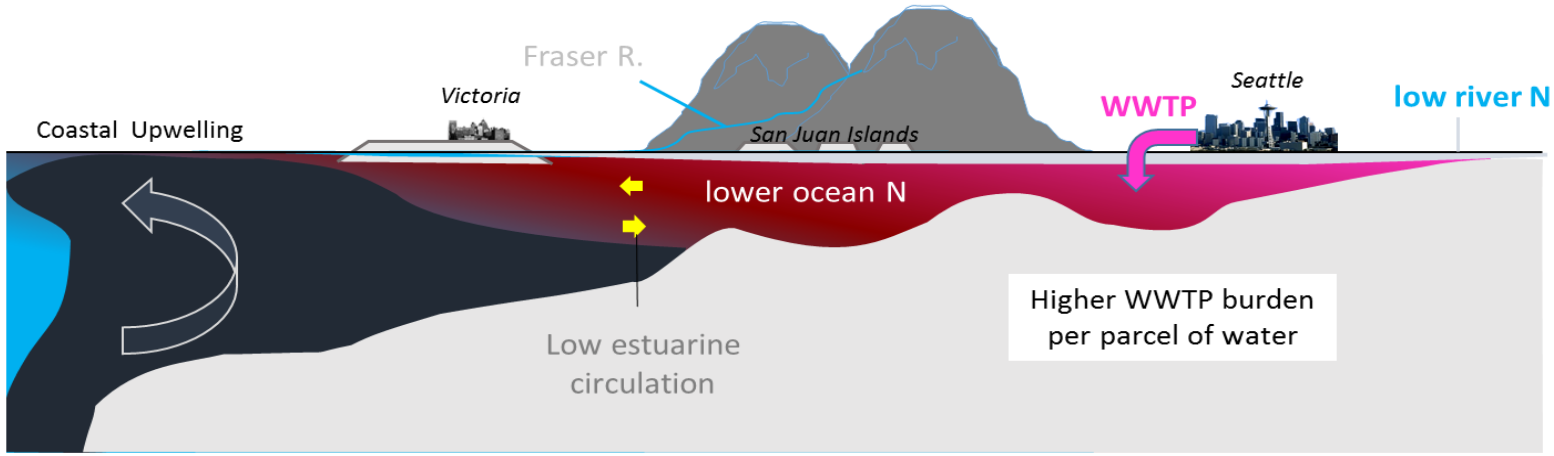
*Drawn by: Christopher Krembs*

Estuaries and Bays | Basins | Ocean

# Fraser River is the biggest driver of estuarine circulation for Salish Sea

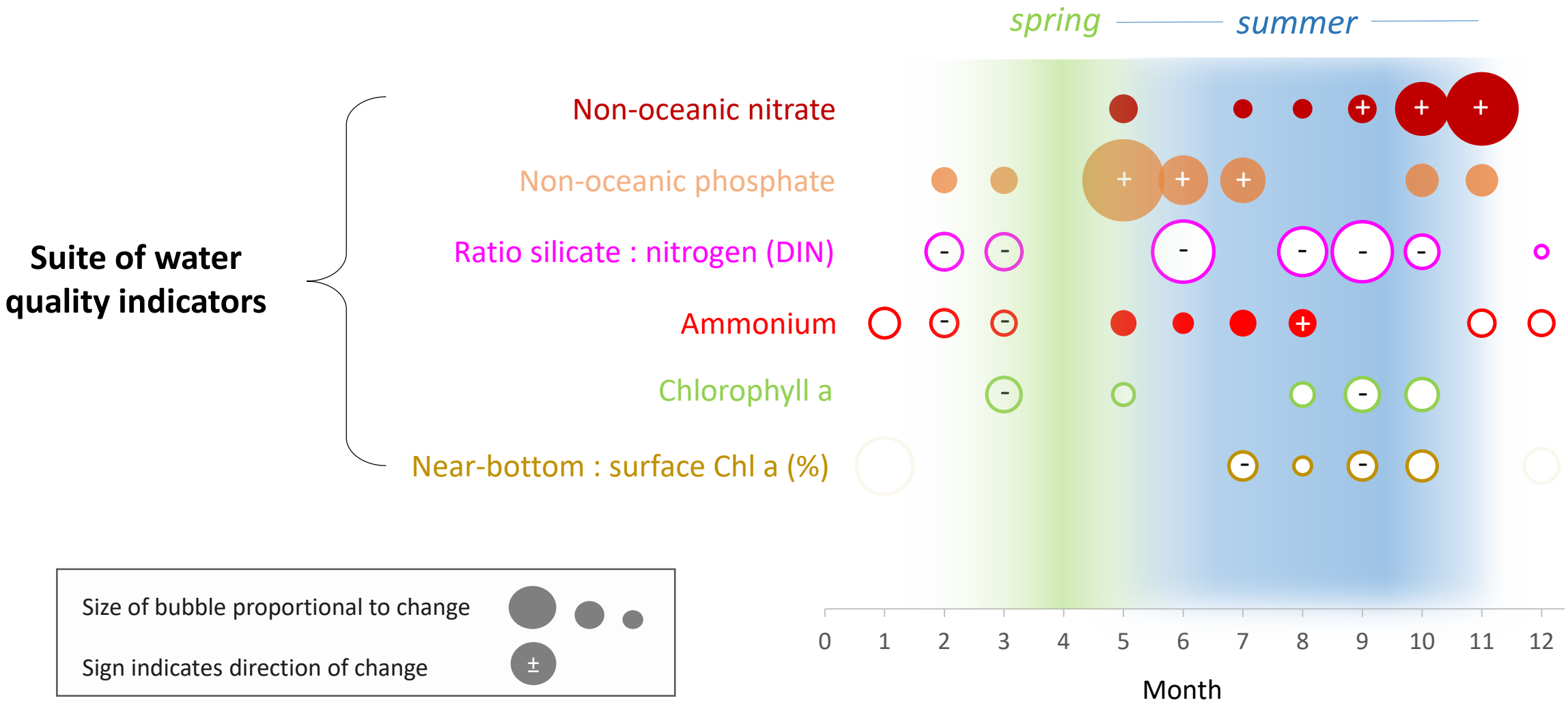

**Long surface water residence time** reduced snowpack




Ocean water exchange affects nutrients, oxygen, pH and temperature

# Percent significant change since 1999

## (Spearman Rank Correl., n=17 years, significant at 10%)



# Human and climate impacts combine

- The relative timing and magnitude of Fraser river and upwelling matter for Salish Sea water quality. **Land-Ocean-Climate Connection.**
- The ocean drives nitrogen. When the ocean is removed, nitrate **is still increasing.** The cause is unclear!
- In summer **eutrophication indicators are prevalent: nuisance species, nutrient ratios.** Information gap = base of the food web!
- Climate affects water quality more strongly in summer months.
- **Humans** could have an increasing impact on WQ during future summers.