



# Eyes Over Puget Sound

[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Marine Water Condition Index*



## Surface Conditions Report

September 16, 2014

[Start here](#)

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

Field log

Climate

Water column

Aerial photos

Ferry and Satellite

Moorings

LONG-TERM MARINE MONITORING UNIT

*Mya Keyzers  
Laura Hermanson  
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*Skip Albertson*



*Julia Bos  
Suzan Pool*



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Krembs*



**Guest:**  
*Dr. Brandon  
Sackmann,  
Integral*



## Personal field log

[p. 4](#)

What is a phytoplankton bloom, really?

## Climate conditions

[p. 6](#)

Sunshine and warm temperatures continue. The Fraser River flow is below normal, PDO and upwelling are above normal.

## Water column

[p. 7](#)

As summer ends, temperatures are high in South Sound. Low dissolved oxygen levels are widespread in Puget Sound, yet remain high in Hood Canal.

## Moorings

[p. 38](#)

At Mukilteo, continuous water temperature fluctuated and salinity declined. Upper mooring measured strong tidal effects.

## Aerial photography

[p. 11](#)

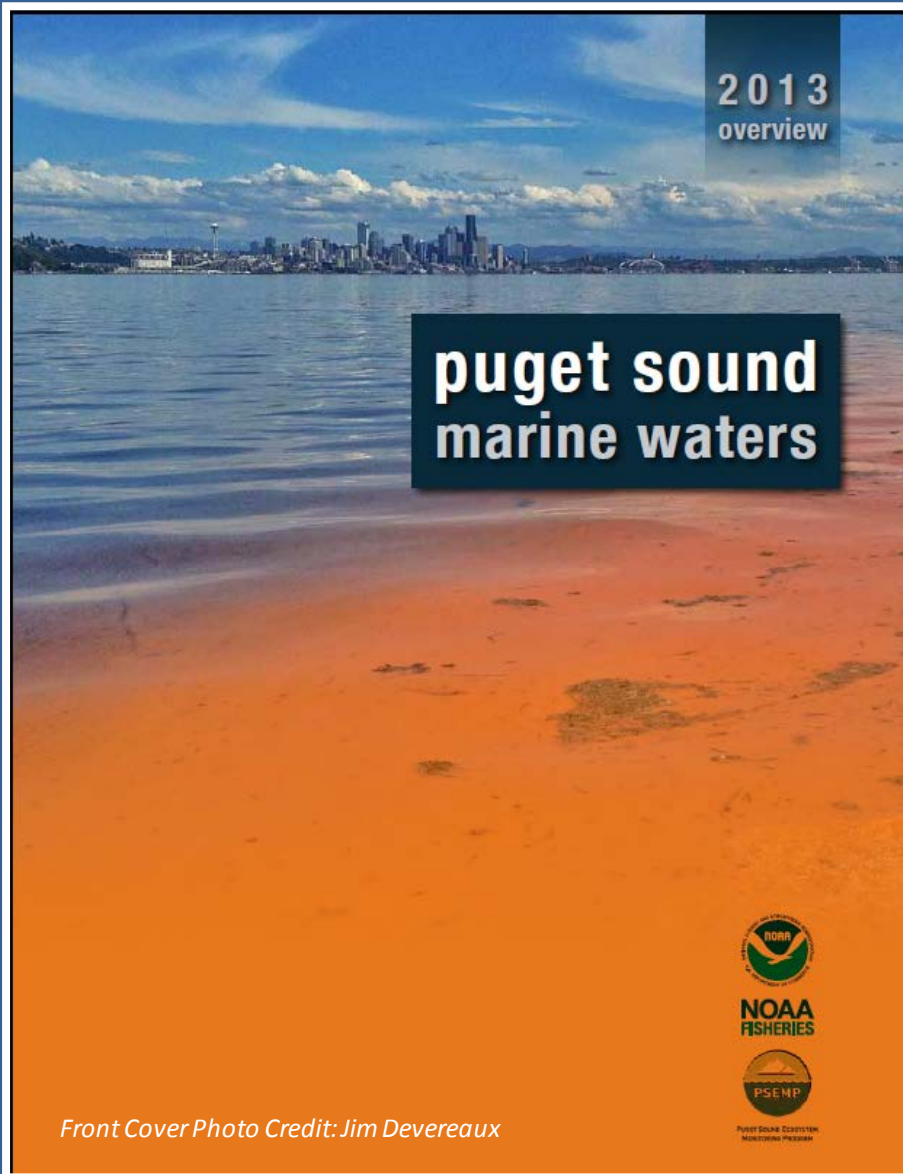
Numerous and large patches of jellyfish seen in finger inlets of South Sound and East Sound (Orcas Island). Red-brown blooms remain strong in smaller bays inside Puget Sound. Suspended sediment from Nooksack and Skagit rivers are very visible.

## Ferry and satellite

[p. 40](#)

Bloom in central Puget Sound begins to fade as temperatures cool. MODIS reveals extensive bloom at entrance to Strait of Juan de Fuca. Thermal imagery from Landsat 8 shows relatively warm water in Strait of Georgia, Whidbey Basin, and finger inlets of South Puget Sound.





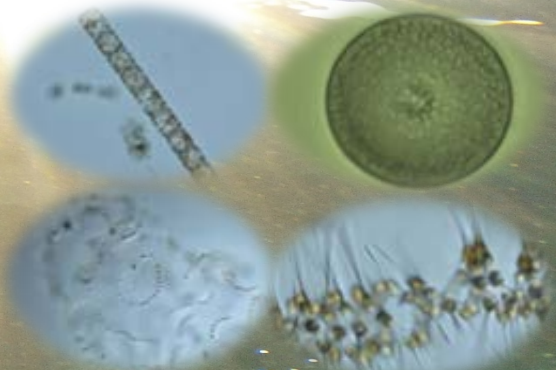
## The Puget Sound Marine Waters: 2013 Overview

- Informs on the marine water conditions and associated biota in Puget Sound. It compiles the physical, chemical, and biological information obtained from diverse marine monitoring and observing programs.
- Represents a collaboration among agencies and scientists forming a collective view of marine water conditions to enhance the ecological understanding of Puget Sound.
- Includes many observations from bacteria to birds presented in context of climatic and physical conditions affecting our water ways.

[http://www.psp.wa.gov/downloads/psemp/PSmarinewaters\\_2013\\_overview.pdf](http://www.psp.wa.gov/downloads/psemp/PSmarinewaters_2013_overview.pdf)



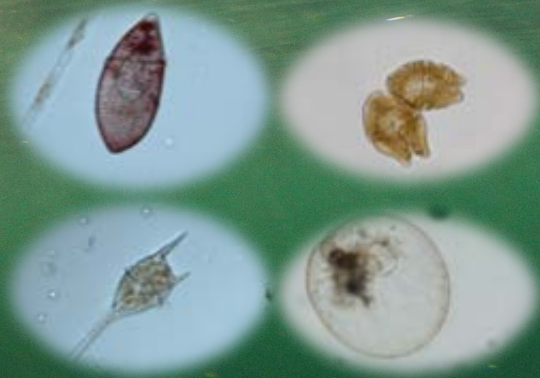
## All About Phytoplankton: Part 1



Diatoms come in many shapes and sizes, and are usually green or brown in color.

Have you ever looked at water from Puget Sound under a microscope? You may be surprised at what you see! Microscopic single-celled algae called phytoplankton are a crucial part of the marine ecosystem and are the foundation of the Puget Sound food web. Two main types of phytoplankton are diatoms and dinoflagellates.

Diatoms have a rigid cell wall made of silica, can form chains, and contain chloroplasts which make them purely photosynthetic. They make their own food using sunlight.



Dinoflagellates are also diverse and can be brown, red, orange, or green.

Dinoflagellates have 1-2 flagella that help them migrate vertically in the water column and can form chains. Dinoflagellates have the ability to be photosynthetic, heterotrophic (consume other cells), or even mixotrophic (able to photosynthesize and consume other cells). When it comes to the lower food web, dinoflagellates rule because they are able to break all the rules!



## What is a Bloom?

Blooms occur when planktonic cells divide at such high rates that their large biomass is visible to the eye. This typically happens in the spring and fall when nutrient and sunlight conditions are optimal.

While not always visible from the water, we can easily see the color and expanse of blooms from the air. The color is caused by chlorophyll and other light-harvesting pigments.

The majority of blooms are not harmful and are in fact naturally occurring. However, excess nutrients (mainly nitrogen) can fuel blooms and have negative effects on water quality. Over time, the location of blooms could indicate persistent nutrient sources.



*Green algal mats.*



*Orange Noctiluca (dinoflagellate) bloom.*



*Green diatom bloom.*



*Red bloom (dinoflagellates and diatoms).*

Stay tuned for "All About Phytoplankton: Part 2" next month!

Field log

Climate

Water column

Aerial photos

Ferry and Satellite

Moorings



**New section! Climate and natural influences** are conditions that influence our marine waters, including weather, rivers, and the adjacent ocean (previously called Weather). For an explanation of the figure, see: [http://www.ecy.wa.gov/programs/eap/mar\\_wat/weather.html](http://www.ecy.wa.gov/programs/eap/mar_wat/weather.html), page 26.

## Summary:

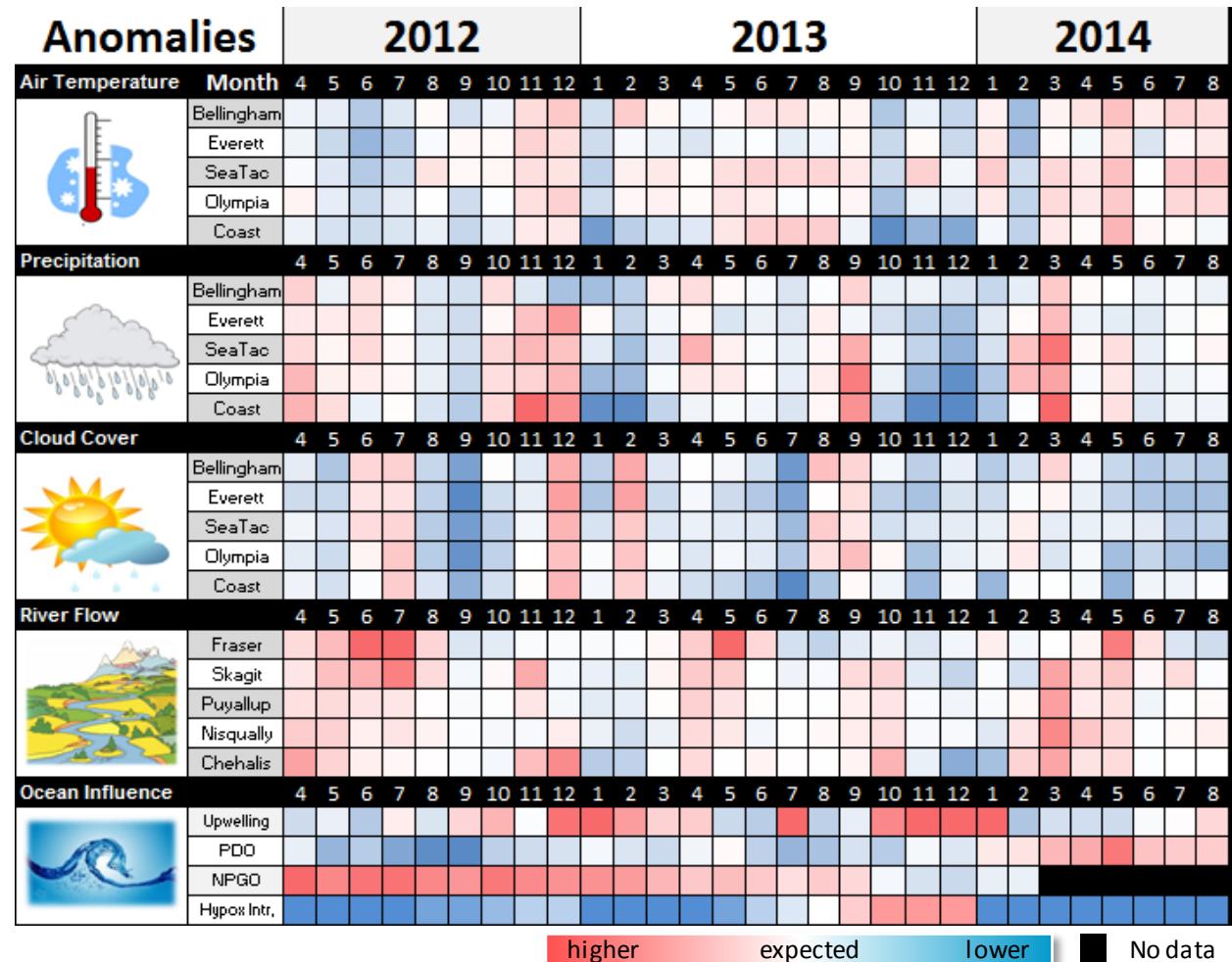
**Air temperatures** have generally been above normal continuing the trend of the past six months.

**Precipitation** has not occurred for several days. The summer has been dry, yet a few large rain events have made it average normal.

**Sunshine** levels have been above normal.

**River flows** are below normal for the Fraser River, but near expected elsewhere.

**PDO** remains in the warm phase and **upwelling** is above normal for the first time this summer, yet ocean intrusions (using a new [Intrusion index](#)) of low DO water have been sparse.





# Our long-term marine monitoring stations in Washington



Field log

Weather

Water column

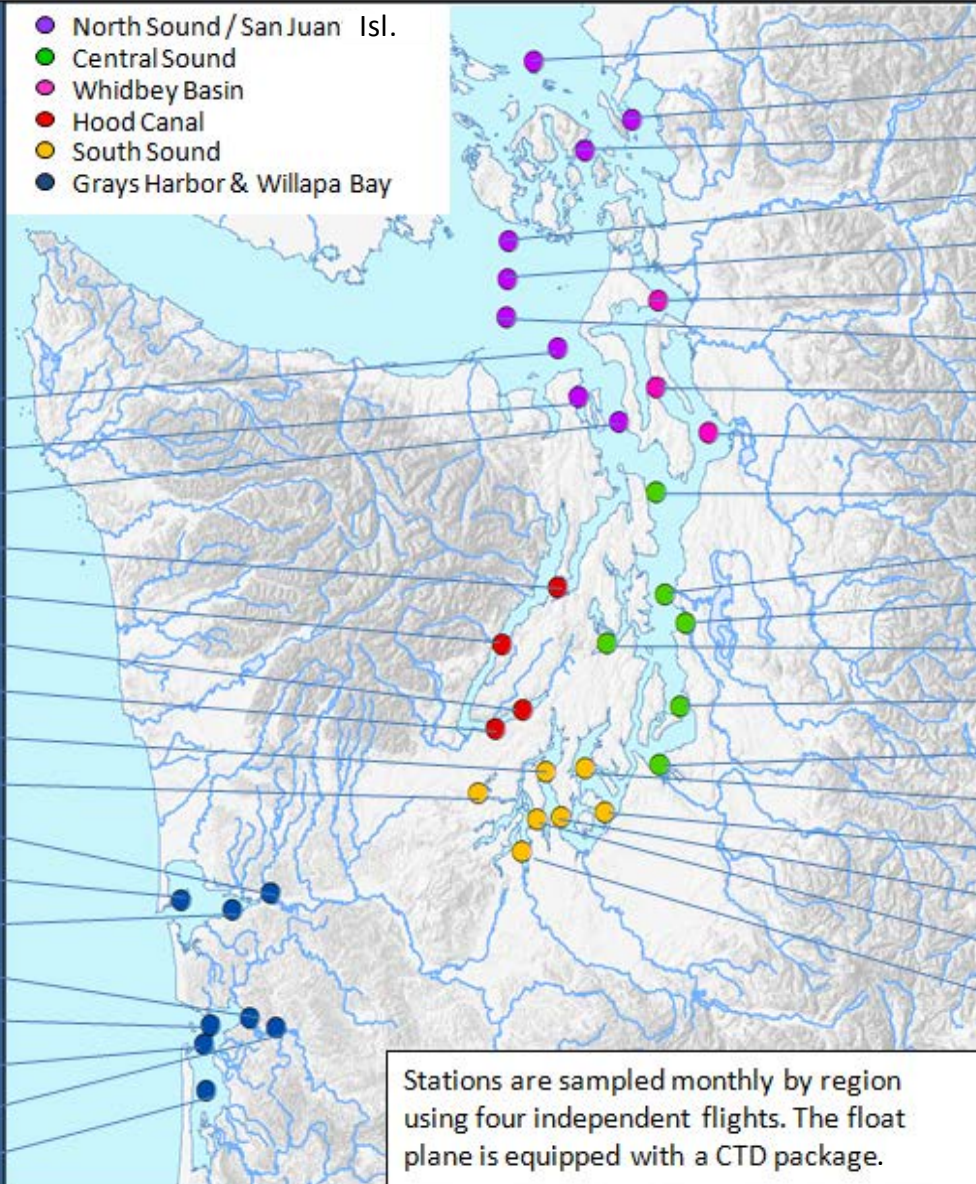
Aerial photos

Ferry and Satellite

Moorings



- North Sound / San Juan Isl.
- Central Sound
- Whidbey Basin
- Hood Canal
- South Sound
- Grays Harbor & Willapa Bay



## Stations:

ADM002

PTH005

ADM001

HCB010

HCB003

HCB007

HCB004

CSE001

OAK004

GYS004

GYS016

GYS008

WPA003

WPA004

WPA113

WPA001

WPA006

GRG002

BLL009

RSR837

SJF000

SJF001

SKG003

SJF002

SAR003

PSS019

ADM003

PSB003

ELB015

SIN001

EAP001

CMB003

CRR001

GOR001

NSQ002

DNA001

BUD005

We use a chartered float plane to access our monthly monitoring stations most cost effectively.

Start here

We communicate data and environmental marine conditions using:

1. Marine Water Condition Index (MWCI)
2. Eyes Over Puget Sound (EOPS)
3. Anomalies and source data

# Physical conditions tracked in statistically historic context



Field log

Weather

Water column

Aerial photos

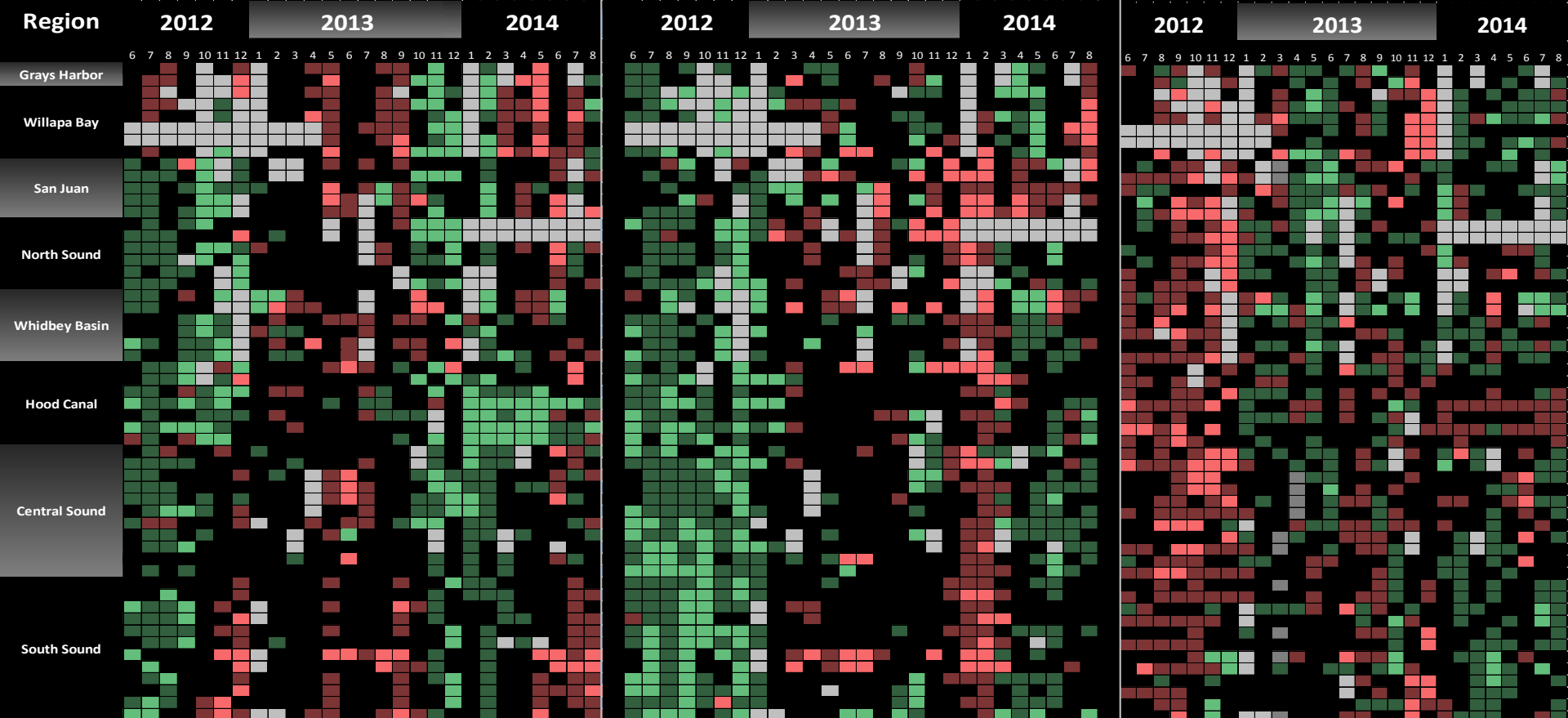
Ferry and Satellite

Moorings

## August 2014: Temperature variable

## Salinity Variable

## Oxygen Stays Lower



■ = higher than expected (>IQR, n>13) ■ = expected (=IQR, n>13) ■ = lower than expected (>IQR, n>13)  
■ = higher than previous measurements ■ = no data ■ = lower than previous measurements

In 2013, Puget Sound was warmer. Early 2014 started colder, and saltier with lower oxygen, then became fresher due to rain. At the end of summer, temperatures are high in South Sound and salinities and dissolved oxygen are low in Central Sound. Hood Canal remains unusually cold and high in DO.

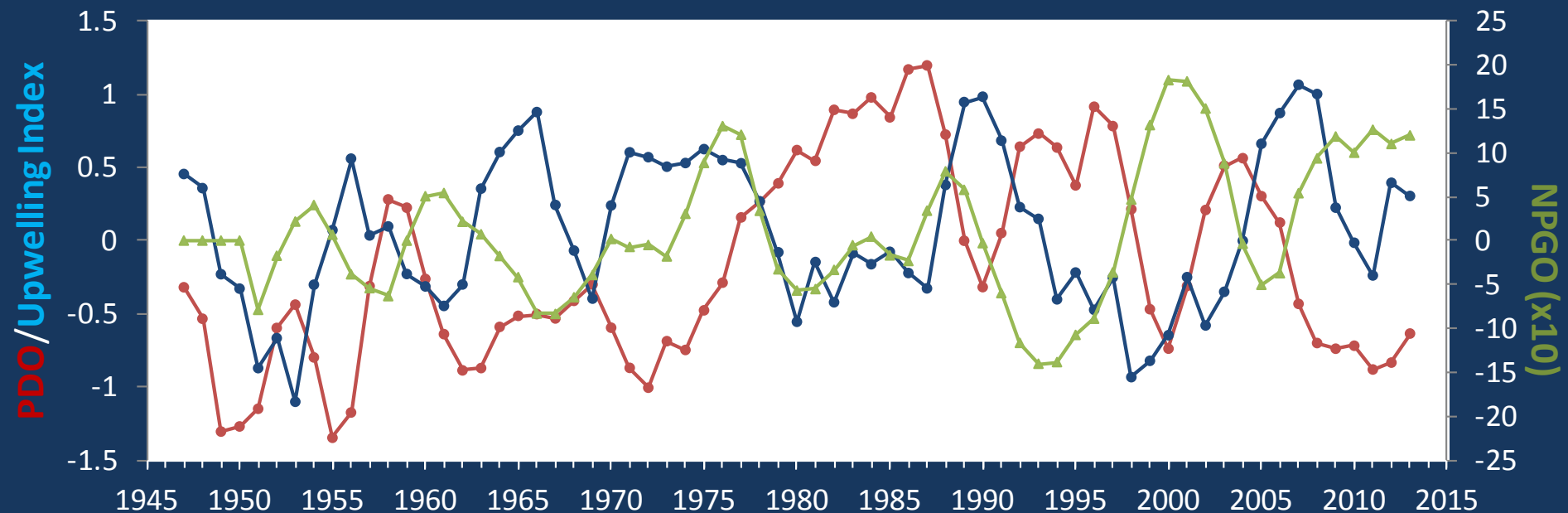


# The ocean affects water quality: Ocean Climate Indices

[Field log](#)[Weather](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

- a) Pacific Decadal Oscillation Index (**PDO, temperature**) [\(explanation\)](#)
- b) Upwelling Index (anomalies) (**Upwelling, low oxygen**) [\(explanation\)](#)
- c) North Pacific Gyre Oscillation Index (**NPGO, productivity**) [\(explanation\)](#)

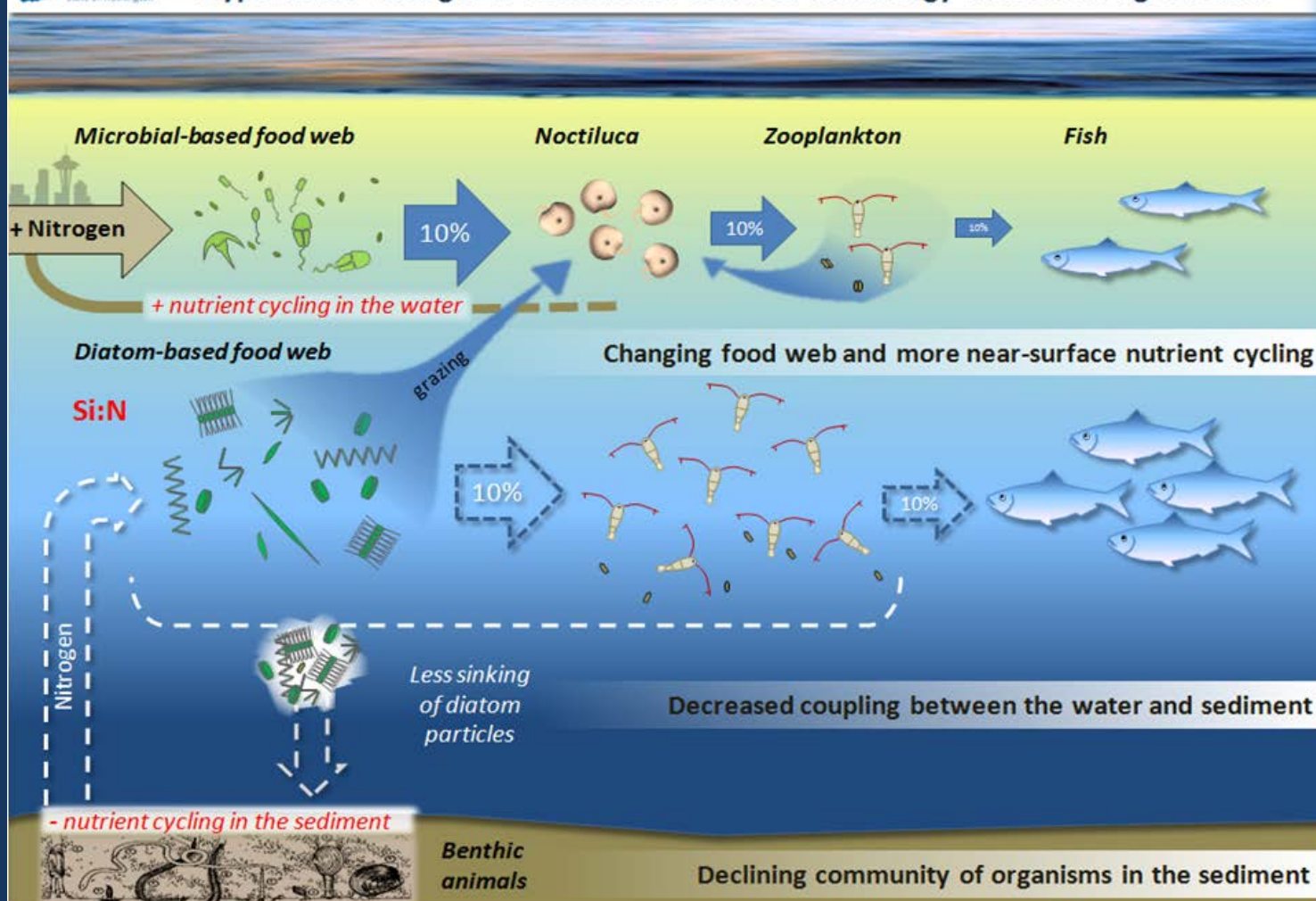
## Three-year running average of PDO, Upwelling, and NPGO indices scores



Ocean boundary conditions have been favorable for water quality in Puget Sound: (a) colder water (PDO), (b) less upwelled low oxygen and high nutrient ocean water reaching Puget Sound (Upwelling Index), and (c) higher surface productivity along the coast (NPGO). Where are we heading next?

# Is the food web changing in Puget Sound?

## Hypothesis: Changes in the Marine Food Web and Energy Transfer in Puget Sound



Drawn by Christopher Krembs

## Hypothesis!

Should we pay greater attention to nutrient ratios, energy transfer, and material cycling in Puget Sound?

*Noctiluca* blooms are a visible harbinger of a changing microbial food web in Puget Sound waters.

[The story in 5 min](#)

[Explore the data](#)

[Follow the experts](#)



[Field log](#)
[Weather](#)
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[Moorings](#)


Numerous and large patches of jellyfish seen in finger inlets of South Sound and East Sound (Orcas Island). Red-brown blooms remain strong in smaller bays inside Puget Sound. Suspended sediment from Nooksack and Skagit Rivers are very visible.

[Start here](#)

Nothing at the surface in Port Gamble



Green: What is golf course, what is water?



Front

**Mixing and Fronts:** [5](#) [7](#)

[Click on numbers](#)

Developed fronts and mixing visible by colored surface water.



**Jellyfish:** [1](#) [2](#) [8](#) [18](#)

Jellyfish patches large and numerous in southern inlets of South Sound and East Sound (Orcas Island).

Plume

**Suspended sediment:** [7](#) [9](#) [13](#) [14](#)

Sediments in glacier-fed Skagit and Nooksack rivers influence a wide area.

Bloom

**Visible blooms:** [1](#) [2](#) [3](#) [4](#) [6](#) [10](#) [11](#) [13](#) [15](#) [16](#) [17](#) [18](#)

Green-brown: Fidalgo Bay, Skagit Bay, Saratoga Passage, [19](#)

Red-brown: Budd, Eld, Henderson, Carr, and Sinclair Inlets and Eagle Harbor. [20](#)

Debris

**Debris:** [1](#) [10](#) [11](#) [13](#) [17](#) [18](#) [19](#)

Localized organic debris north and south of Lummi Island and along tidal fronts.



Seattle Tides: H. tide: 12:53 PM, L. tide: 5:08 AM, 6:36 PM



## Aerial photography and navigation guide

**Date: 9-16-2014**

Click on numbers

### Flight Information:

#### **Morning flight, photos 1-8**

Overcast low visibility, calm

#### **Afternoon flight, photos 9-20:**

Overcast, hazy, calm

--- Flight route and fueling stop

### Observation Maps:

Central and North Sound

South Sound





Field log

Climate

Water column

Aerial photos

Ferry and Satellite

Moorings

A.



B.



*Red-brown bloom and many patches of jellyfish.*

Location: A. Cooper Point. B. Gull Harbor, Budd Inlet (South Sound), 9:29 AM.



Field log

Climate

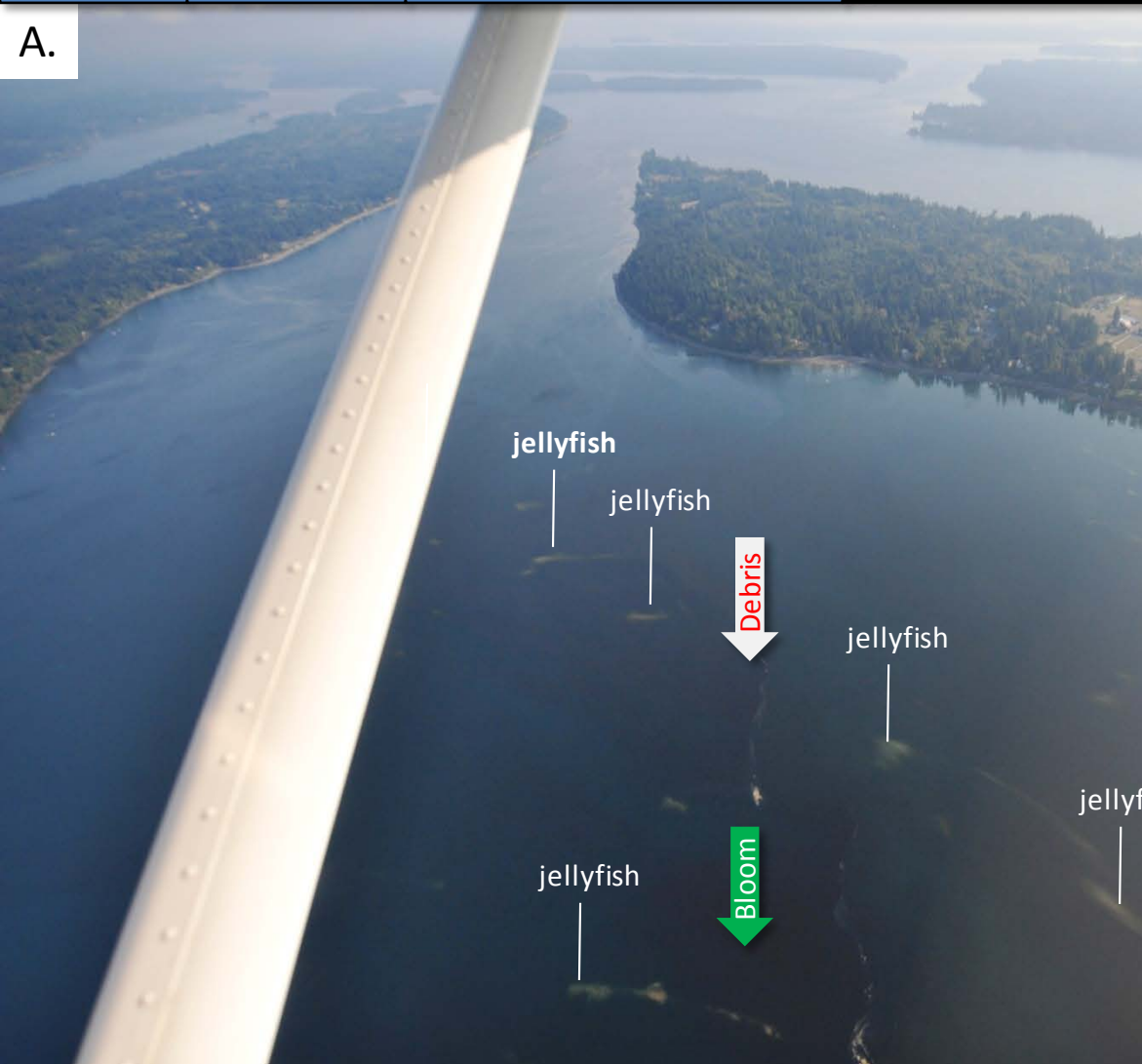
Water column

Aerial photos

Ferry and Satellite

Moorings

A.



B.



*Red-brown bloom and many jellyfish patches.*

Location: A. Off Frye Cove. B. Near Young Cove Eld Inlet (South Sound), 9:35 AM.



[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Red-brown and turquoise blooms inside bay.*  
Location: Sinclair Inlet (Central Sound), 9:53 AM.



Field log

Climate

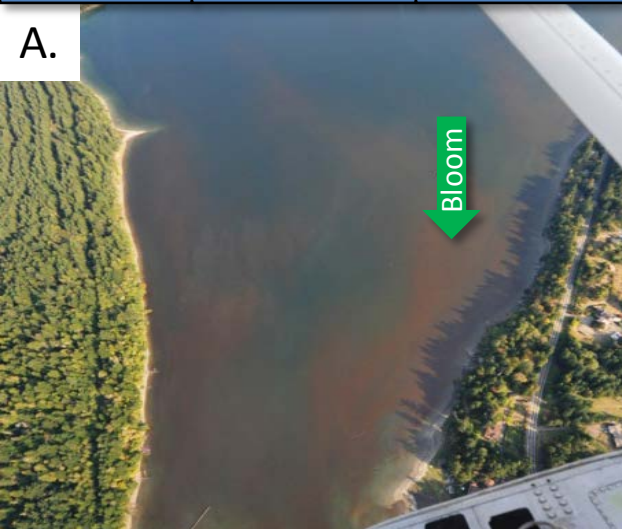
Water column

Aerial photos

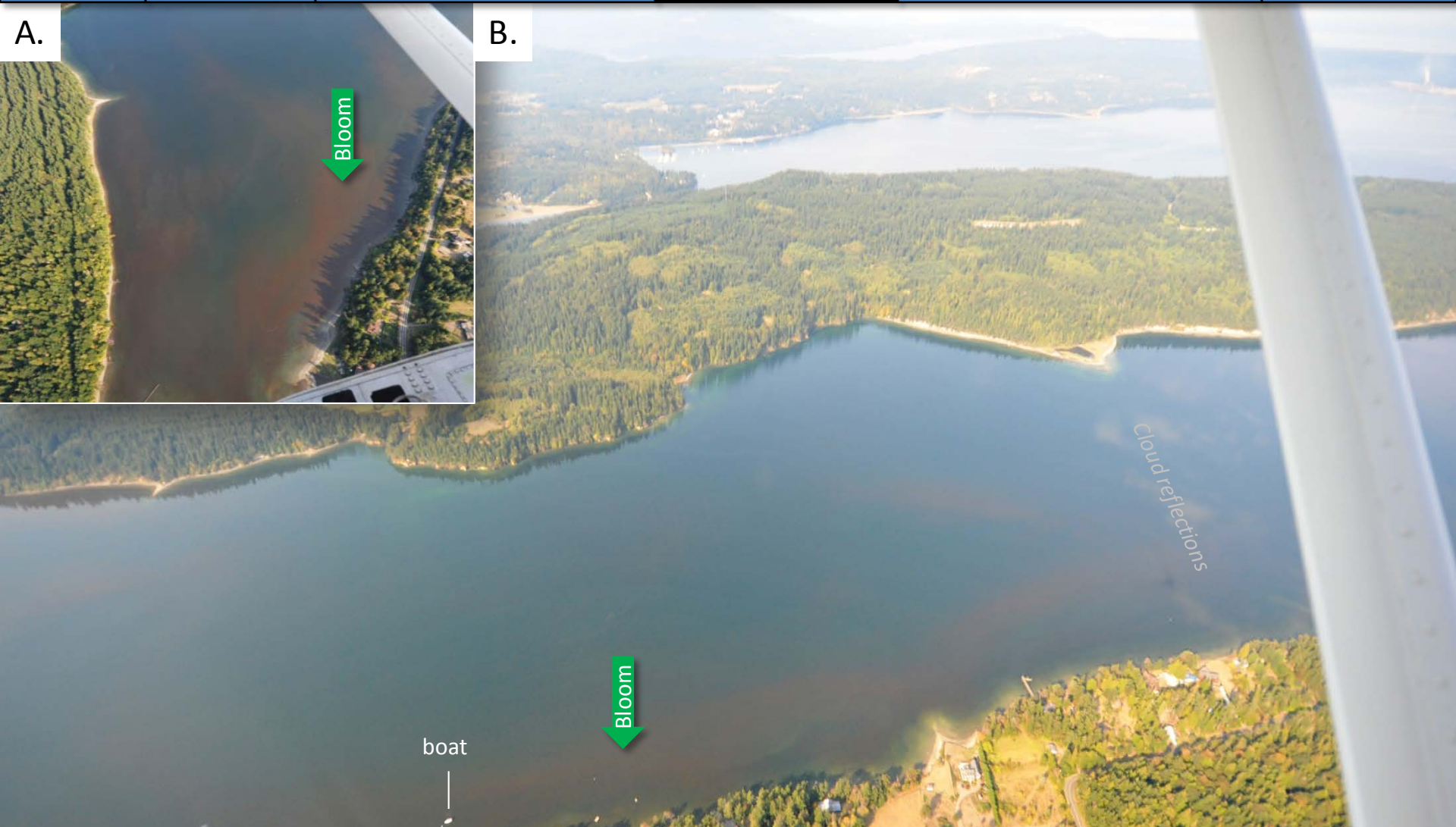
Ferry and Satellite

Moorings

A.



B.



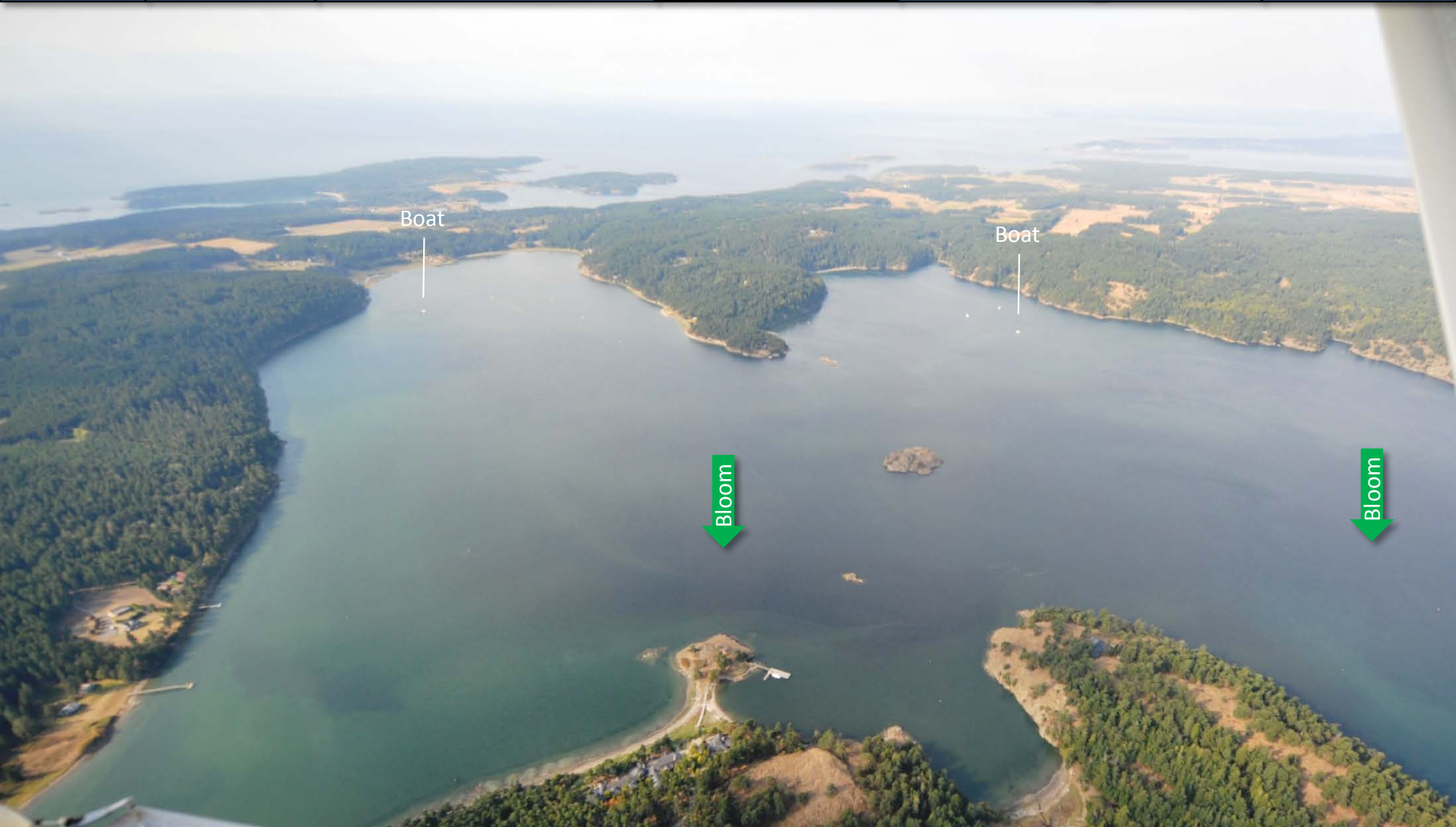
*Red-brown bloom inside the inlet.*

Location: Scow Bay, Marrowstone Island (Central Sound), 10:14 AM.



[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Two distinguishable water masses outline surface water movements.*  
Location: Fort Ebey, Admiralty Reach (Central Sound), 10:21 AM.

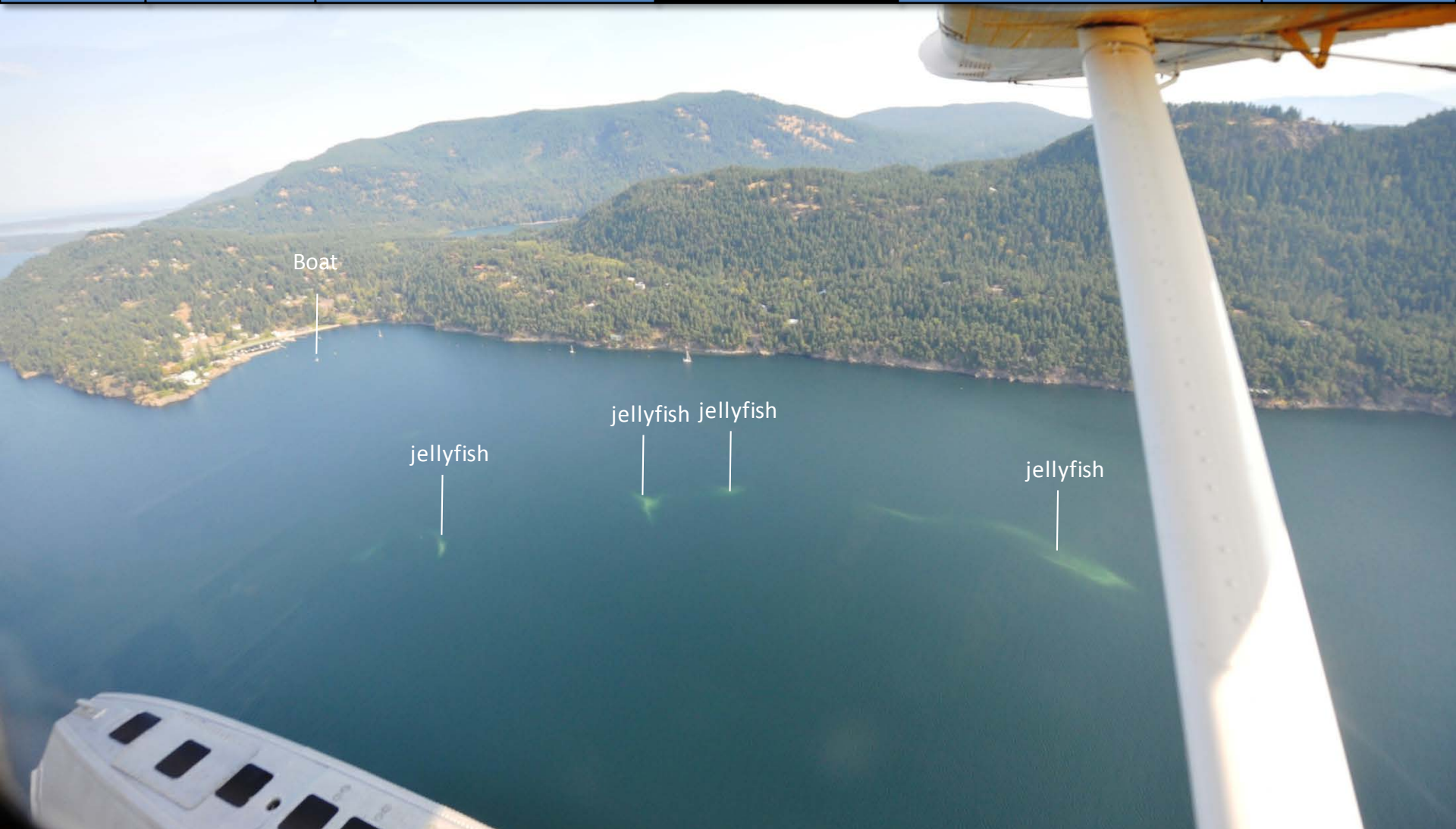
[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Red-brown bloom traces patterns of water circulation in bay.*  
Location: Mud Bay, Lopez Sound (San Juan Islands), 10:30 AM.



[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Suspended sediment highlights mixing patterns of water entering from East Sound.*  
Location: Deer Point, Obstruction Pass (San Juan Islands), 10:25 AM.

[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Numerous patches of jellyfish.*

Location: Cascade Bay, East Sound (San Juan Islands), 11:14 AM.



[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Two distinguishable water masses with sediment-rich water from the Nooksack River.*  
Location: Off Point Migley, Lummi Bay (North Sound), 12:05 PM.



Field log

Climate

Water column

Aerial photos

Ferry and Satellite

Moorings



*Small red-brown phytoplankton bloom following local pattern of advection.*  
Location: Fishermans Cove, Whatcom Chief Ferry (North Sound), 12:07 PM.



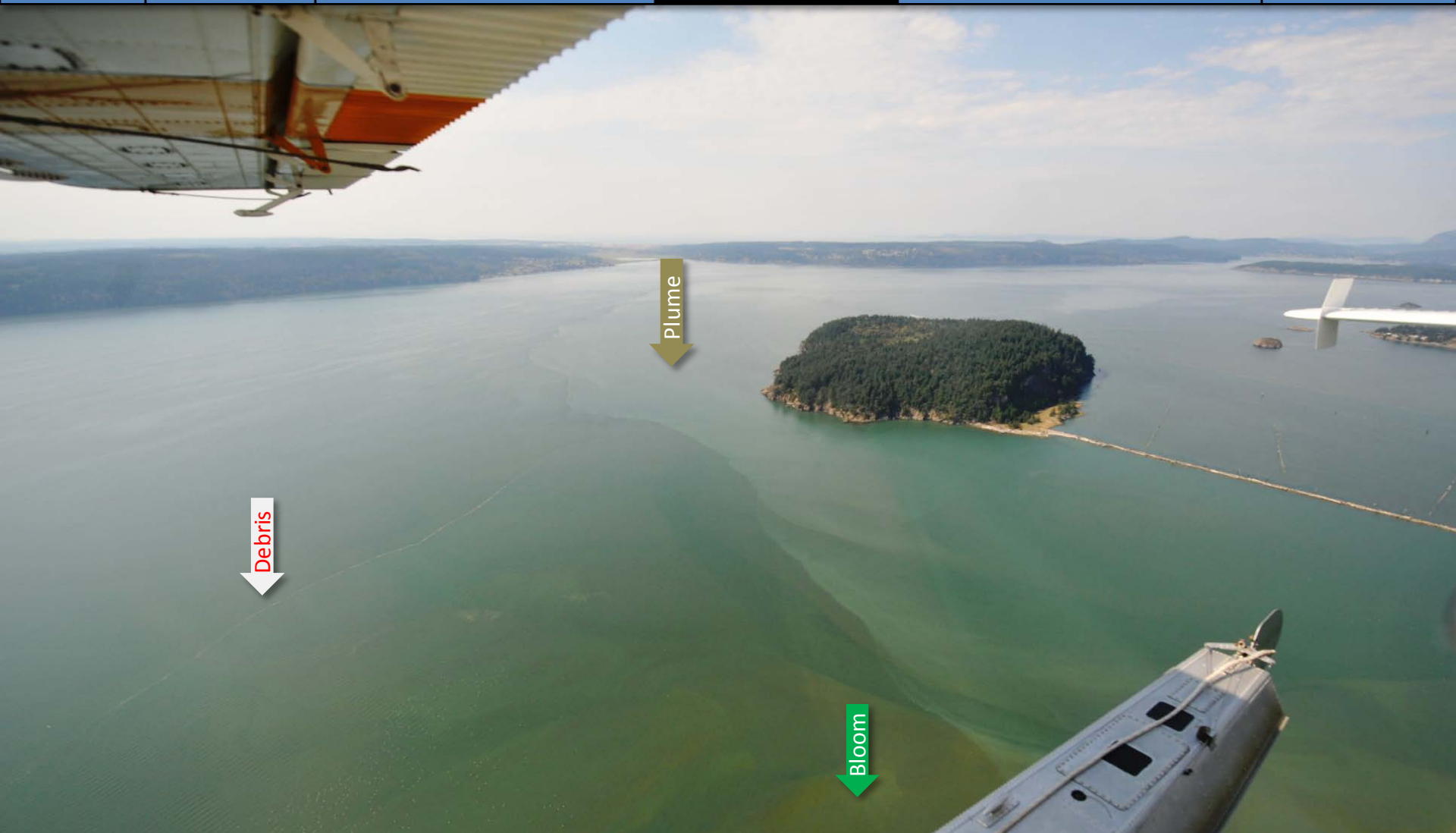
[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Large patches of organic surface debris and phytoplankton-rich water leaving bay.*  
Location: Off Samish Island, Samish Bay (North Sound), 12:50 PM.

[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Glacial-fed water from the Skagit River drives estuarine circulation in Whidbey Basin in the summer.*  
Location: Swinomish Channel, Skagit Bay (Whidbey Basin), 1:22 PM.



[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Skagit River plume flowing northwest next to near-shore phytoplankton bloom.*  
Location: Goat Island, Skagit River estuary (Whidbey Basin), 1:22 PM.

[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Sediment-rich water entering from Davis Slough by flowing over flooded mudflats.*  
Location: Livingston Bay, Port Susan (Whidbey Basin), 1:51 PM.



[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*A mix of sediment- and phytoplankton-rich water drifting southward over shallow water.  
Location: Off Triangle Cove, Port Susan (Whidbey Basin), 1:53 PM.*

[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Strong red-brown bloom highlights circulation pattern in bay.*  
Location: Eagle Harbor, Bainbridge Island (Central Sound), 3:57 PM.





Field log

Climate

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Ferry and Satellite

Moorings



*Red-brown and golden-brown blooms along with small amounts of organic surface debris.*  
Location: A. Allen Point, B. Henderson Bay, Carr Inlet (South Sound), 4:10 PM.

[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Red-brown bloom and patches of jellyfish.*

Location: Over Woodland Bay Conservation Area, Henderson Inlet (South Sound), 4:20 PM.



Field log

Climate

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Moorings



*Red-brown bloom and patches of organic debris outlining pattern of circulation in inner bay.*  
Location: Southern Henderson Inlet (South Sound), 4:20 PM.



[Field log](#)[Climate](#)[Water column](#)[Aerial photos](#)[Ferry and Satellite](#)[Moorings](#)

*Red-brown bloom outlining pattern of circulation in inner bay.*  
Location: Southern Henderson Inlet (South Sound), 4:21 PM.



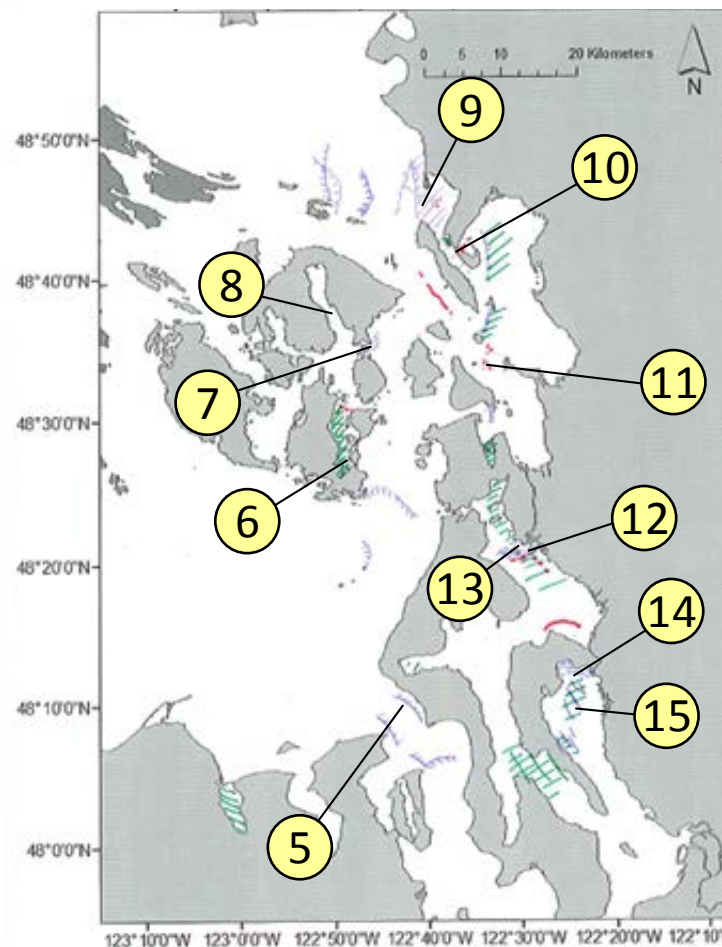
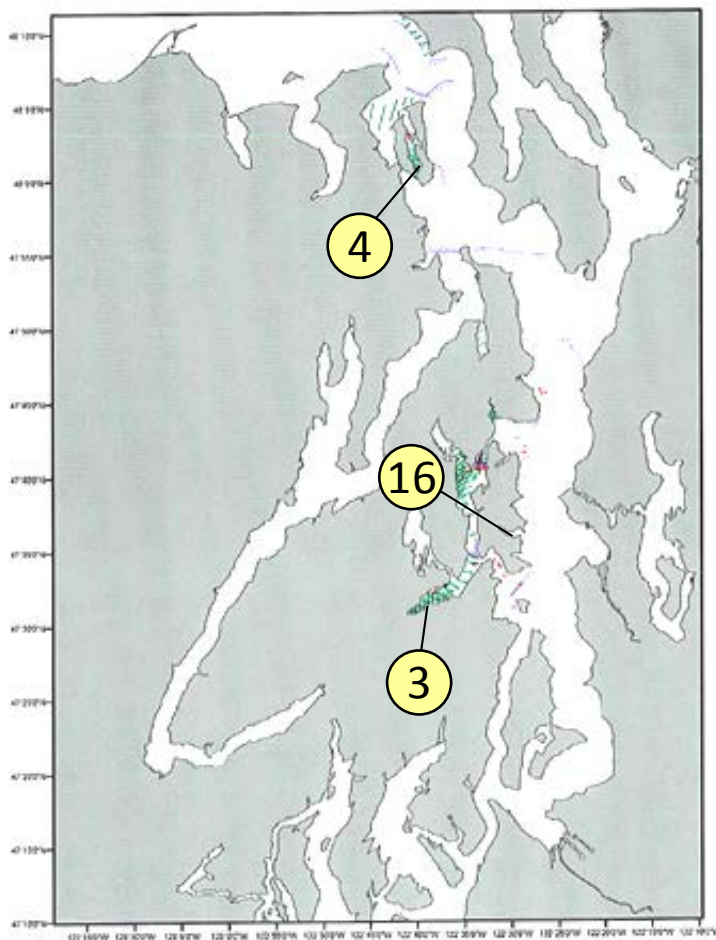
# Observations in Central and North Sound

[Navigate](#)

**Date: 9-16-2014**

Central Sound

North Sound/San Juan Islands



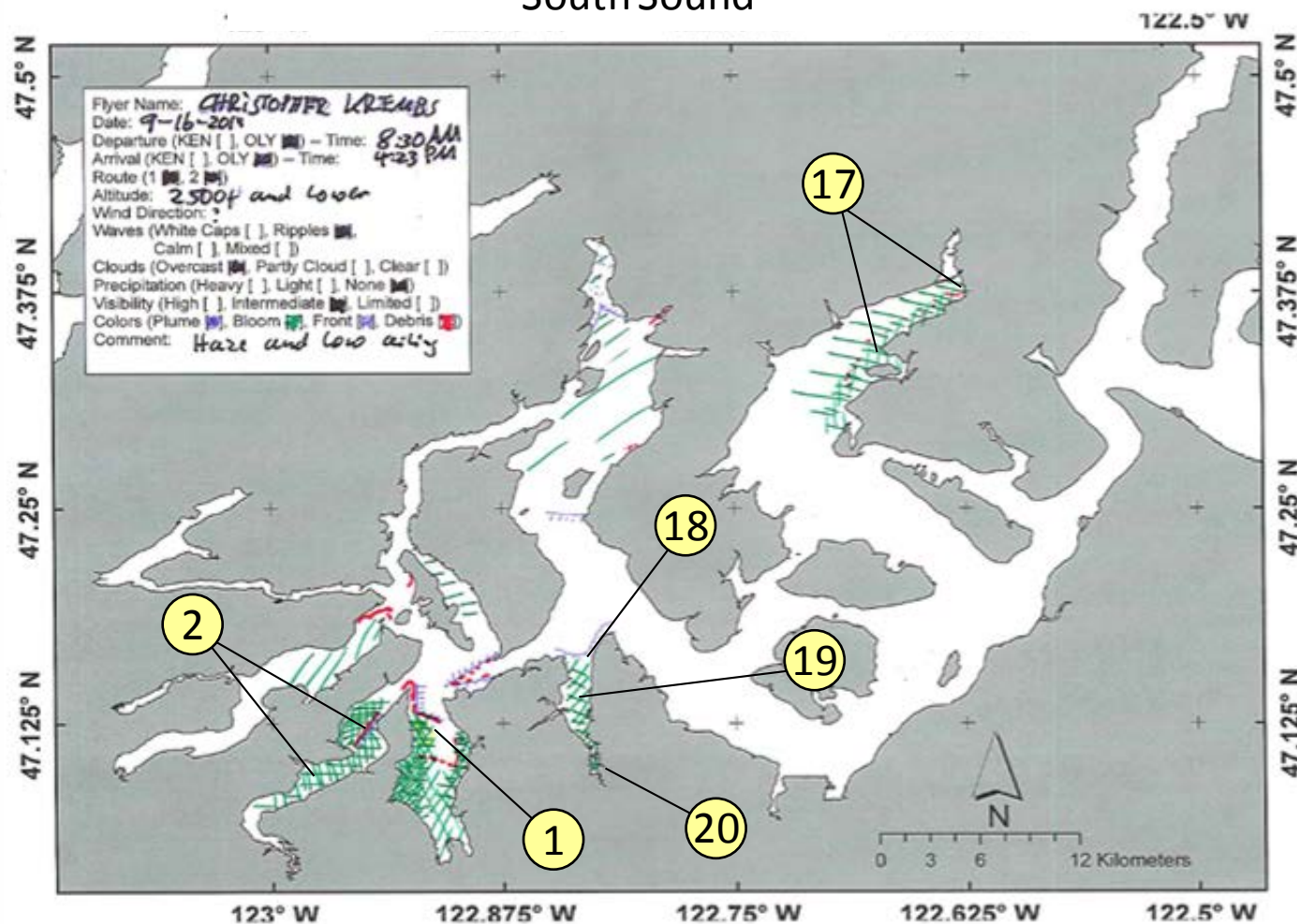
*Numbers on map refer to picture numbers for spatial reference*

# Observations in Hood Canal and South Sound

[Navigate](#)










Date: 9-16-2014

South Sound



Numbers on map refer to picture numbers for spatial reference



Plumes	
• Freshwater with sediment <b>solid</b>	
• Freshwater with sediment <b>dispersed</b>	
• Coastal erosion with sediment	
Blooms	
• Dispersed	
• Solid	
Debris	
• Dispersed	
• Solid	
Front	
• Distinct water mass boundaries	
• Several scattered	

## Comments:

Maps are produced by observers during and after flights. They are intended to give an approximate reconstruction of the surface conditions on scales that connect to and overlap with satellite images in the section that follows.

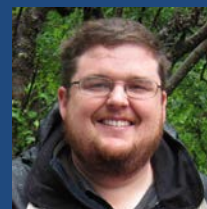
## Debris:

Debris can be distinguished into natural and anthropogenic debris floating at the surface *sensu* Moore and Allen (2000). The majority of organic debris in Puget Sound is natural and mixed with discarded man-made pieces of plastic, wood, etc. From the plane, we cannot differentiate the quality of debris at the surface and therefore, call it for reasons of practicality just “debris”.

*S.L. Moore, M. J. Allen. 2000. Distribution of Anthropogenic and Natural Debris on the Mainland Shelf of the Southern California Bight. Marine Pollution Bulletin, 40(1): 83–88.*

26 July 2014

Hardware upgrades on the *Victoria Clipper IV* successfully restored near real-time data collection as of July 23, 2014; we are back online!

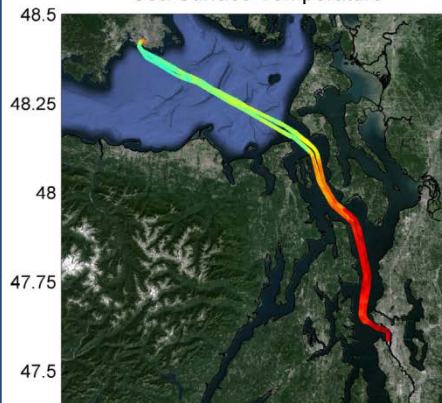


**Brandon Sackmann**

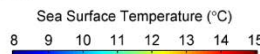
Contact: [bsackmann@integral-corp.com](mailto:bsackmann@integral-corp.com)

Start here

Sea Surface Temperature



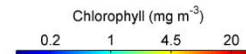
Sea surface temperature (SST) is the water temperature close to the surface (2-3 m below). Warm colors show higher SST.



Algal Biomass (Chlorophyll Fluor.)



Chlorophyll a fluorescence gives an estimate of algal concentration/biomass. Warm colors show larger concentrations.



## Current Conditions:

Bloom in central Puget Sound begins to fade as temperatures cool; max temperatures generally <15 °C. MODIS reveals extensive bloom at entrance to Strait of Juan de Fuca. Thermal imagery from Landsat 8 shows warmer water in Strait of Georgia, Whidbey Basin, and finger inlets of South Puget Sound.





Field log

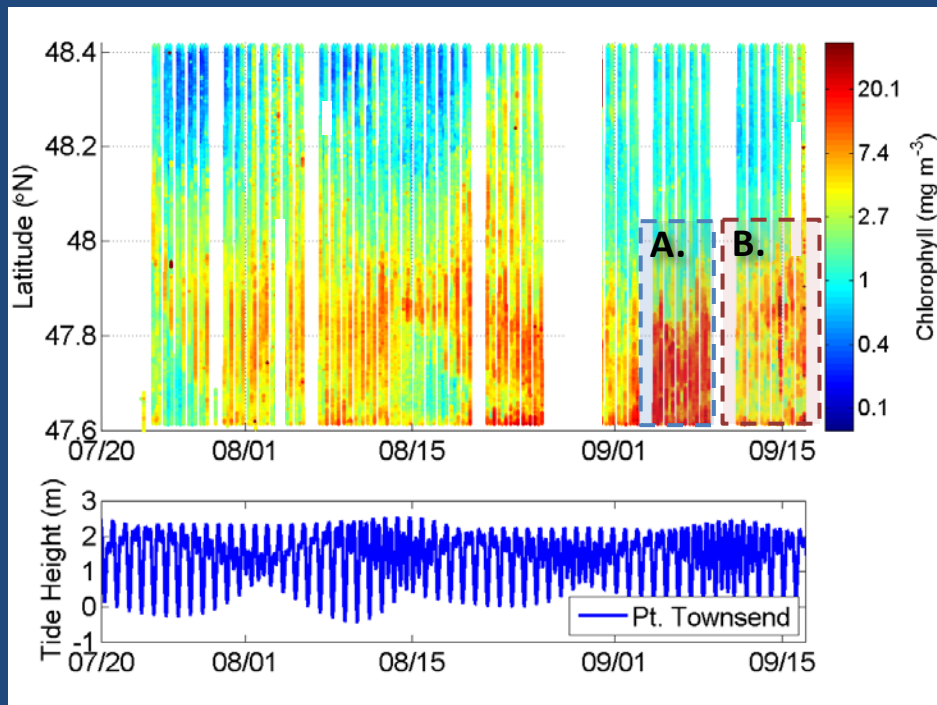
Climate

Water column

Aerial photos

Ferry and Satellite

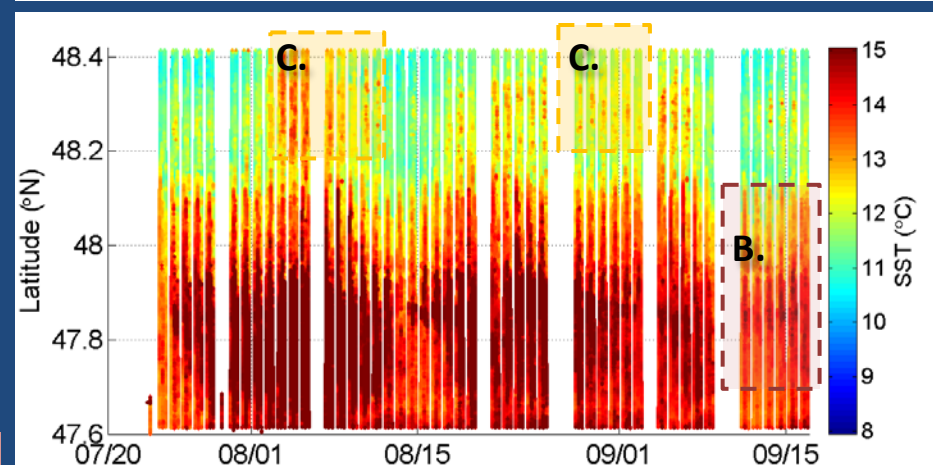
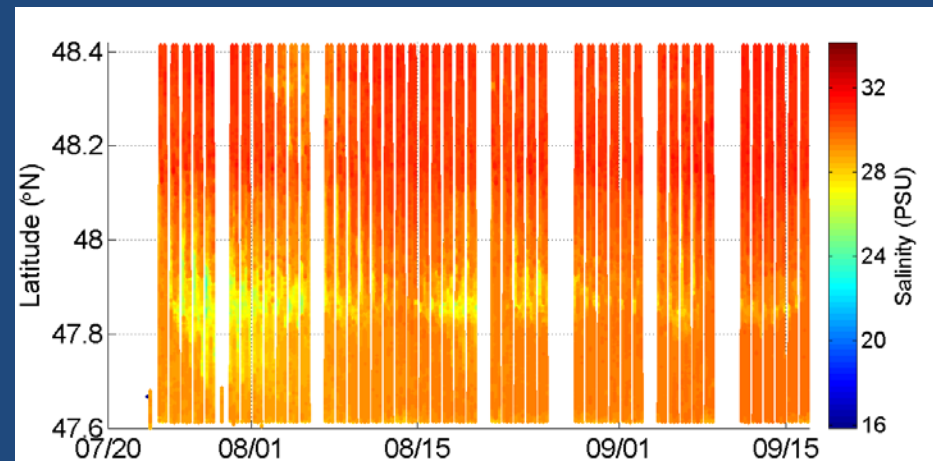
Moorings



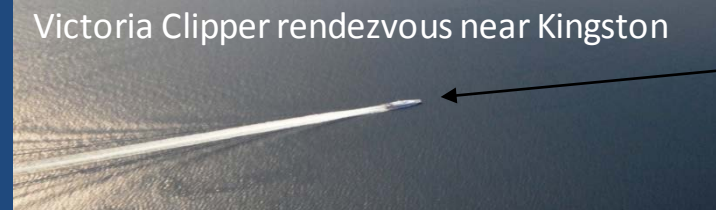
**A.** Strong algae bloom in central Puget Sound during first week of September.

**B.** Stratification shows signs of weakening (temperature is declining indicating mixing) and bloom is dissipating.

**C.** Weak tides in August and September associated with warmer temperatures in Strait of Juan de Fuca.

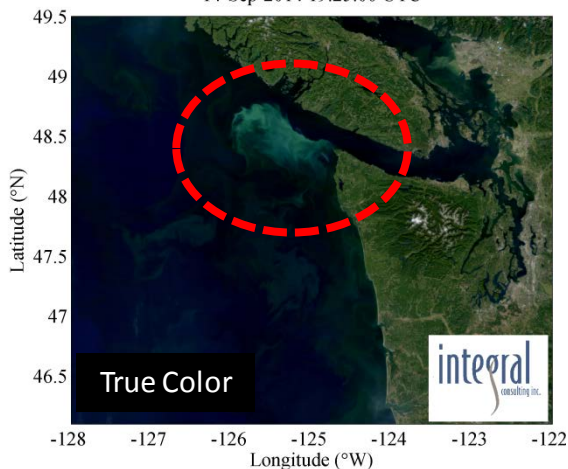


Victoria Clipper rendezvous near Kingston

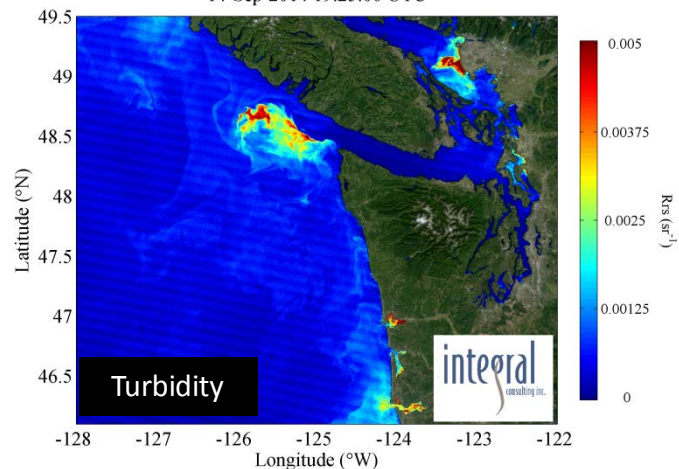


3:47 PM

14-Sep-2014 19:25:00 UTC

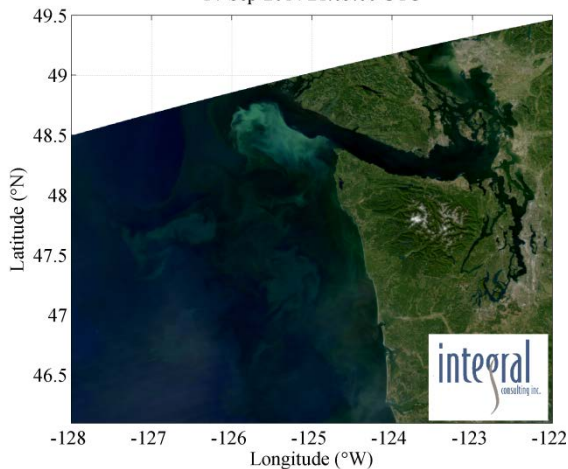


14-Sep-2014 19:25:00 UTC

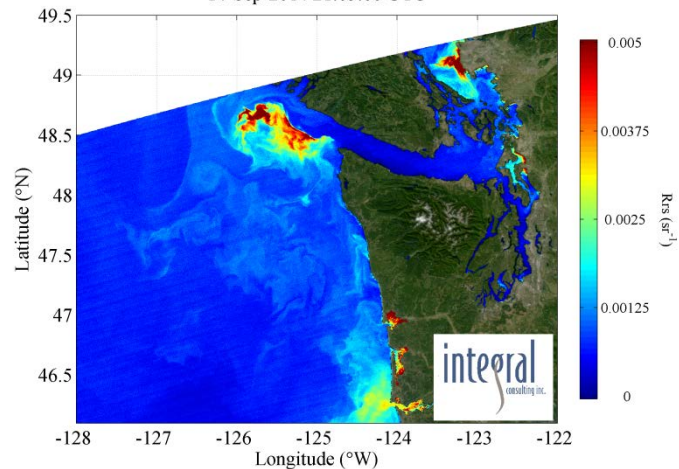


MODIS-Terra (top) and MODIS-Aqua (bottom) reveal intense offshore bloom near entrance to Strait of Juan de Fuca!

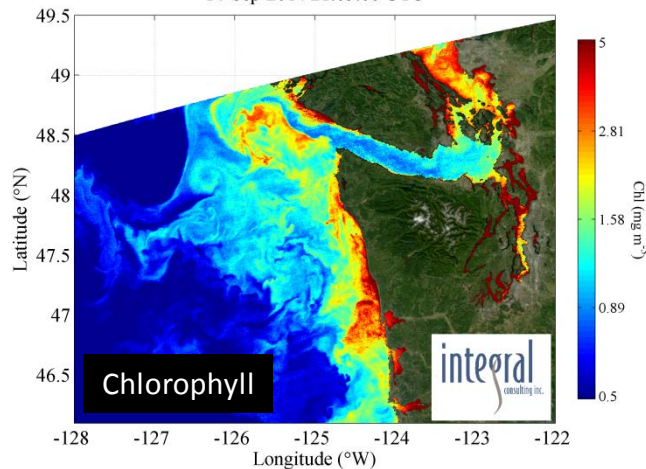
14-Sep-2014 21:05:00 UTC



14-Sep-2014 21:05:00 UTC



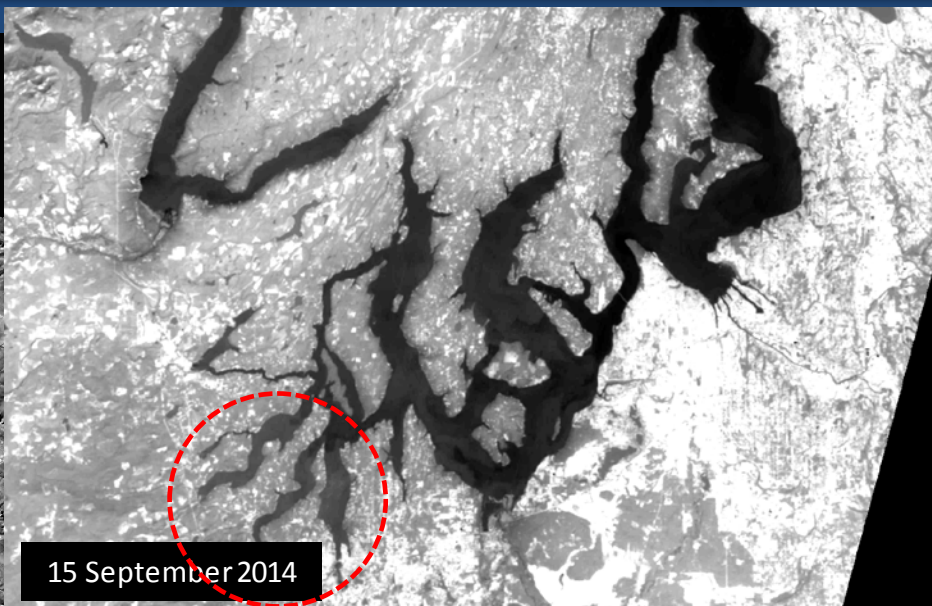
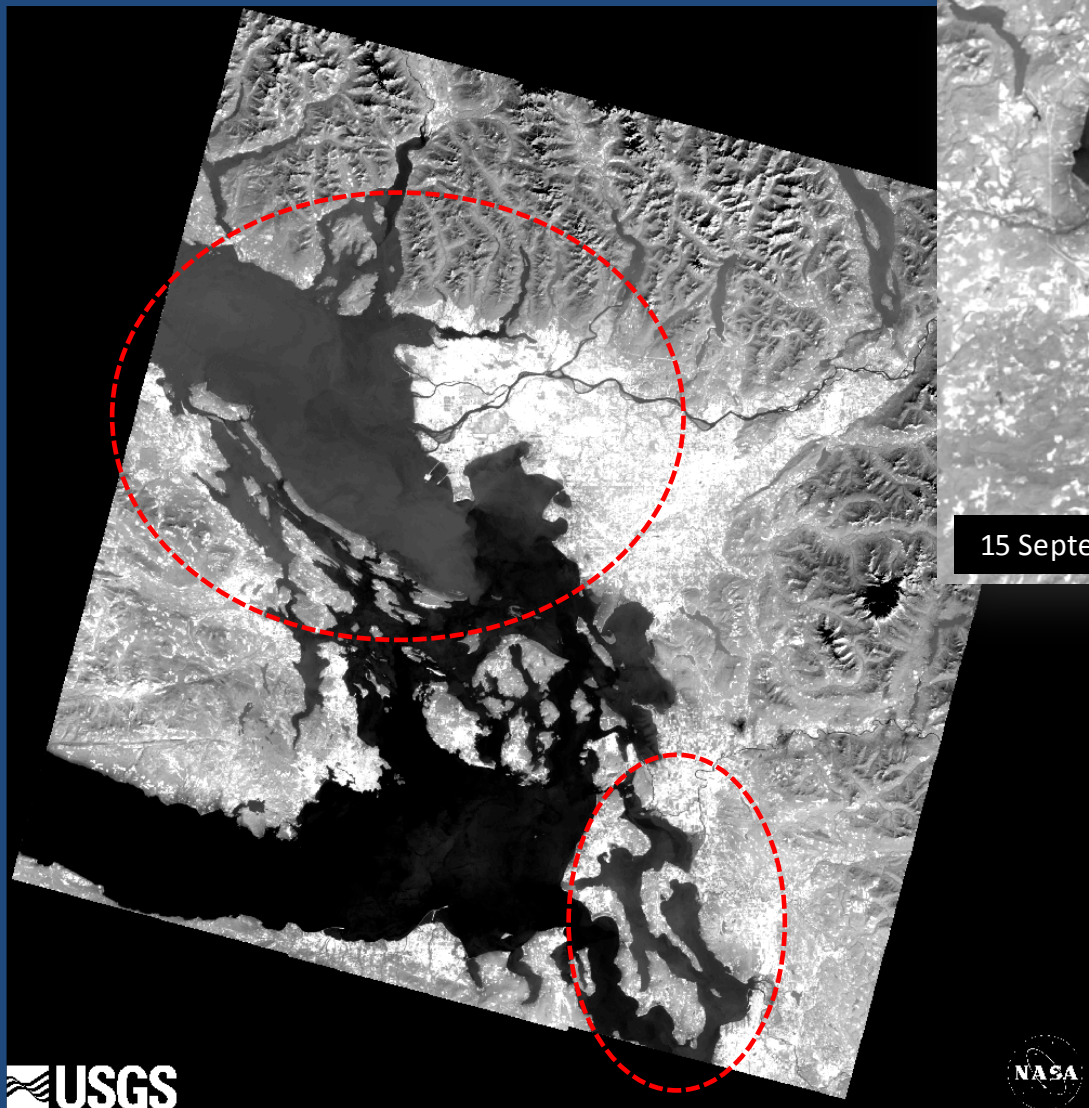
14-Sep-2014 21:05:00 UTC



Imagery obtained from NASA's OceanColor WEB

<http://oceancolor.gsfc.nasa.gov/>





Thermal imagery from the Landsat 8 satellite show warm waters throughout Strait of Georgia and Whidbey Basin (left). Warmer temperatures were in finger inlets throughout South Puget Sound; cooler temperatures highlight areas experiencing increased mixing (top).

# Mooring observations and trends

## 9-4-2014 to 9-16-2014



Field log

Climate

Water column

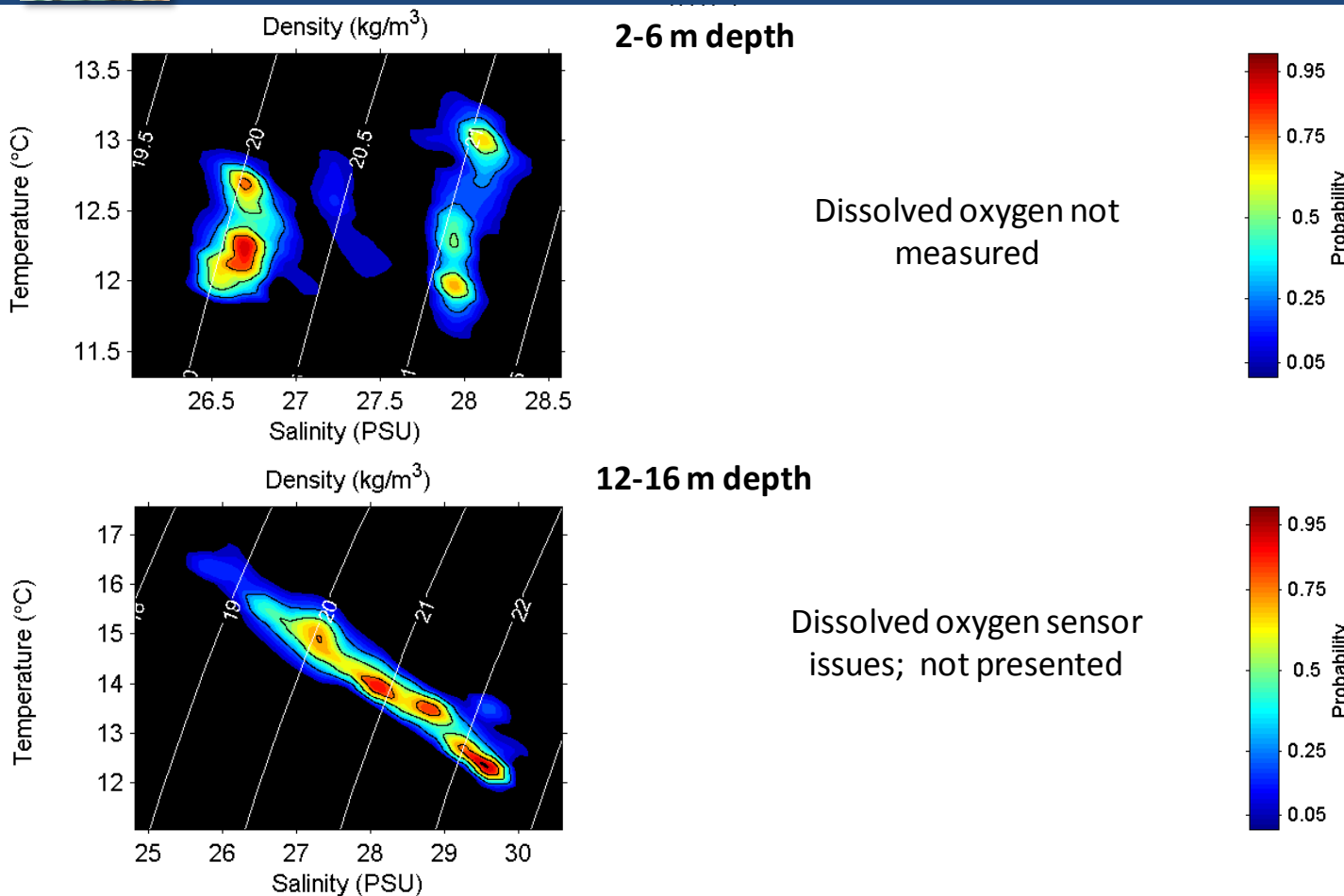
Aerial photos

Ferry and Satellite

**Moorings**



At Mukilteo, we observed strong tidal effects from our upper mooring. On the lower mooring, temperature fluctuated, with a temporal pattern somewhat reverse of the daily tidal range. Technical issues may have affected the near-bottom salinity measurements. Variable winds and reduced river flows lessen the export of freshwater leaving Puget Sound.



These plots show the probability of observations over the past two-week period. High probability shown in warm colors.

**Left Panels:** Density is defined by salinity and temperature.

**Right Panel:** Dissolved oxygen concentration in relation to salinity.

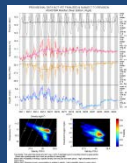


Our mooring station in Mukilteo is located in Whidbey Basin near Everett. It is also located at the transition between Possession and Central Sounds at a depth that is influenced by the Skagit and Snohomish river discharges, prevailing winds, and tidal mixing.

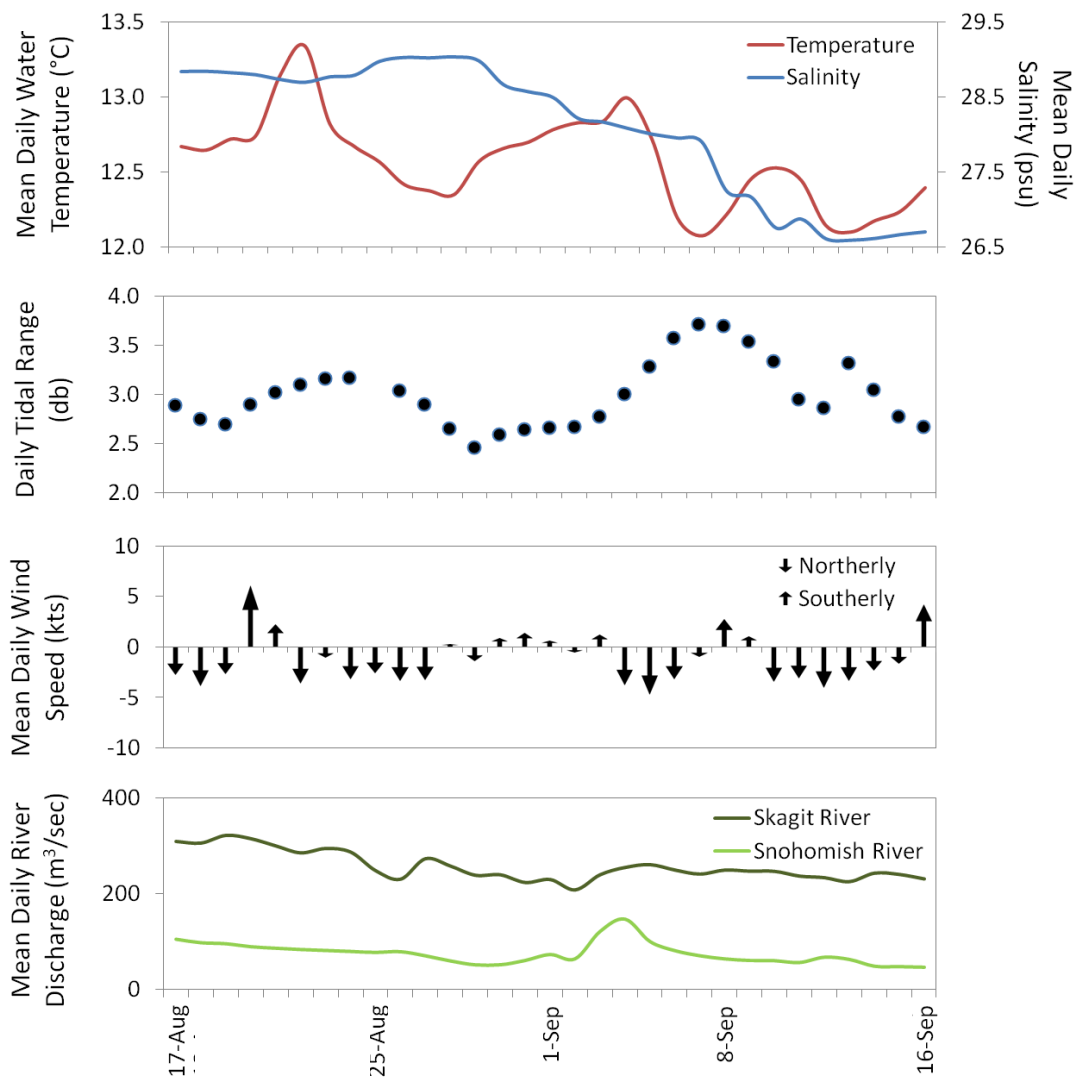
As the largest regional contributor of freshwater to Puget Sound, understanding the timing and magnitude of the Skagit river flow is important.

We present data of daily means for the past 31 days. Data are plotted in Pacific Standard Time. Wind data are from Paine Field in Everett. River flow data are from USGS.

*Click on icon to view real-time data of the moorings*



### Near-bottom sensor and associated environmental data at Mukilteo



# Mooring observations and trends Mukilteo 2010 to 2014


[Field log](#)
[Climate](#)
[Water column](#)
[Aerial photos](#)
[Ferry and Satellite](#)
[Moorings](#)

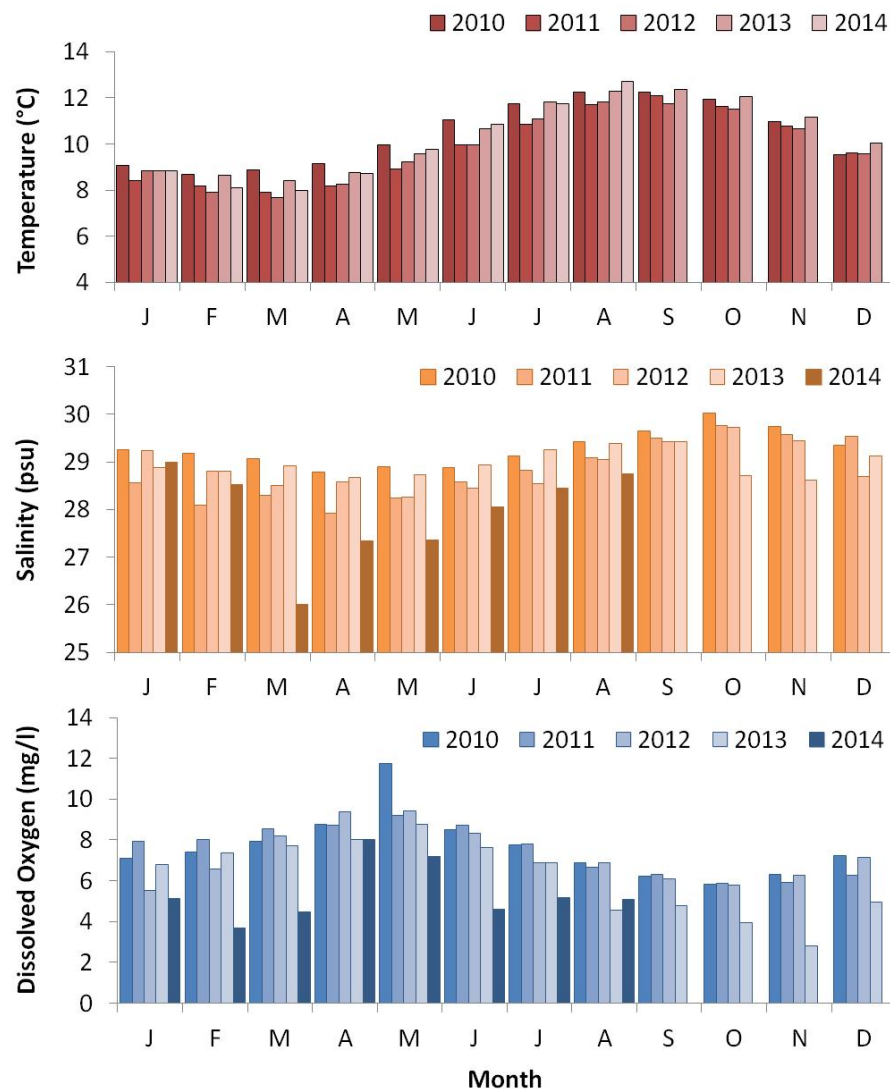
At the Mukilteo mooring, we use the near-bottom sensor (12-16 m deep) to measure significant inter-annual variability in temperature, salinity and dissolved oxygen.

Inter-annual variability is shown over a 4.5-year period. All three variables show strong seasonality.

In 2014, trends in salinity and dissolved oxygen appear to decline whereas trends in temperature are similar to 2013. Our bath verifications indicated the dissolved oxygen sensor failed in early July and thus, dissolved oxygen data for July 2014 is from latter half of the month.

*Please note that data are provisional. Data are in GMT.*

Monthly means of temperature, salinity, and dissolved oxygen  
from near-bottom sensor at Mukilteo





# Get data from Ecology's Marine Monitoring Programs



Field log

Climate

Water column

Aerial photos

Ferry and Satellite

Moorings

## Long-Term Monitoring Network

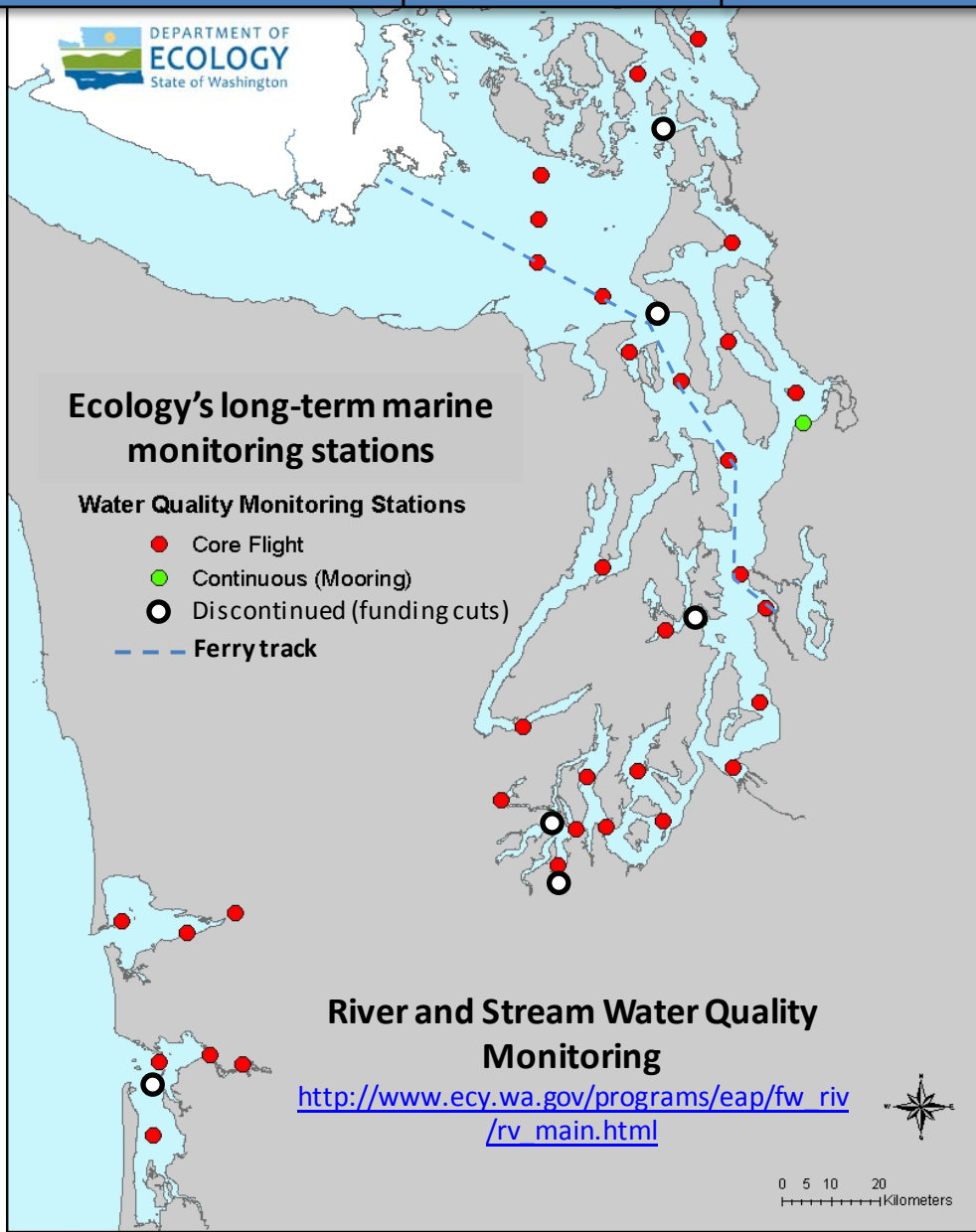


[christopher.krembs@ecy.wa.gov](mailto:christopher.krembs@ecy.wa.gov)



## Access core monitoring data:

<http://www.ecy.wa.gov/apps/eap/marinewq/mwdataaset.asp>



## Real-Time Sensor Network



[Suzan.Pool@ecy.wa.gov](mailto:Suzan.Pool@ecy.wa.gov)



## Access mooring data:

[ftp://www.ecy.wa.gov/eap/Mooring\\_Raw/Puget\\_Sound/](ftp://www.ecy.wa.gov/eap/Mooring_Raw/Puget_Sound/)

You may subscribe or unsubscribe to the Eyes Over Puget Sound email listserv by going to:

<http://listserv.wa.gov/cgi-bin/wa?A0=ECOLOGY-EYES-OVER-PUGET-SOUND>



Field log

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We are looking for feedback to improve our products.

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**Marine Monitoring Unit  
Environmental Assessment Program  
WA Department of Ecology**

