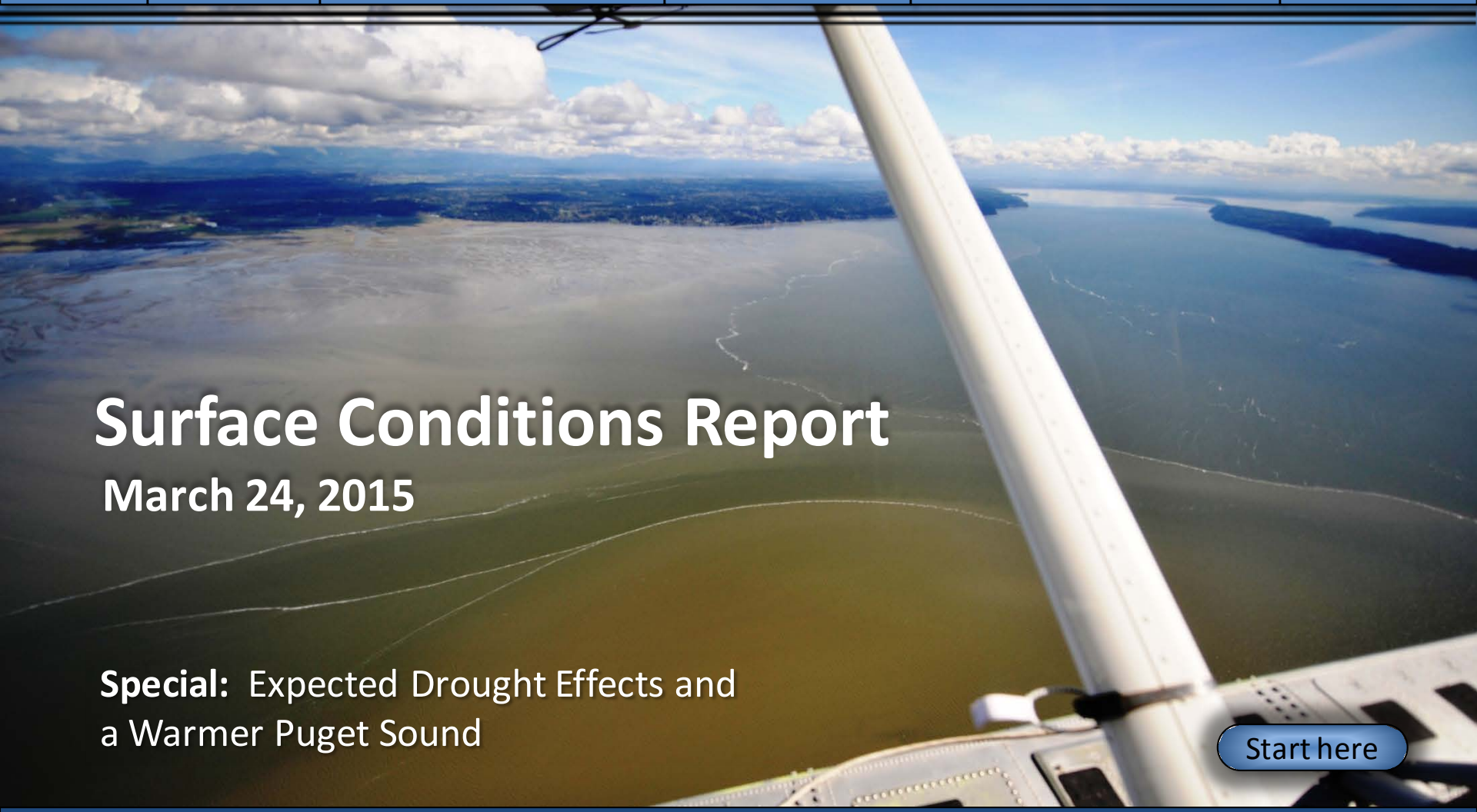
Publication No. 15-03-072

DEPARTMENT OF ECOLOGY State of Washington

Eyes Over Puget Sound



Surface Conditions Report

March 24, 2015

Special: Expected Drought Effects and a Warmer Puget Sound

Start here

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

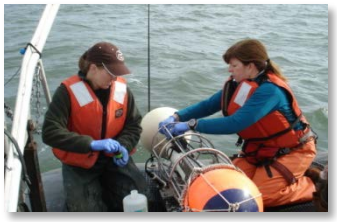
Marine conditions from 3-24-2015 at a glance

LONG-TERM MARINE MONITORING UNIT

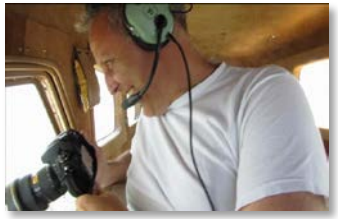
Mya Keyzers
Laura Hermanson
Brooke McIntyre

Skip Albertson

Julia Bos
Suzan Pool



Dr. Christopher Krembs



Suzan Pool
Guest:
Dr. Brandon Sackmann, Integral

Please give us feedback

Editorial assistance provided by: Julianne Ruffner, Suzan Pool, Carol Maloy

Publication No. 15-03-072

DEPARTMENT OF ECOLOGY State of Washington

Eyes Over Puget Sound

Special Report Insert:

Expected drought effects and a warmer Puget Sound

March 24, 2015

Return to Eyes over Puget Sound EOPS

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

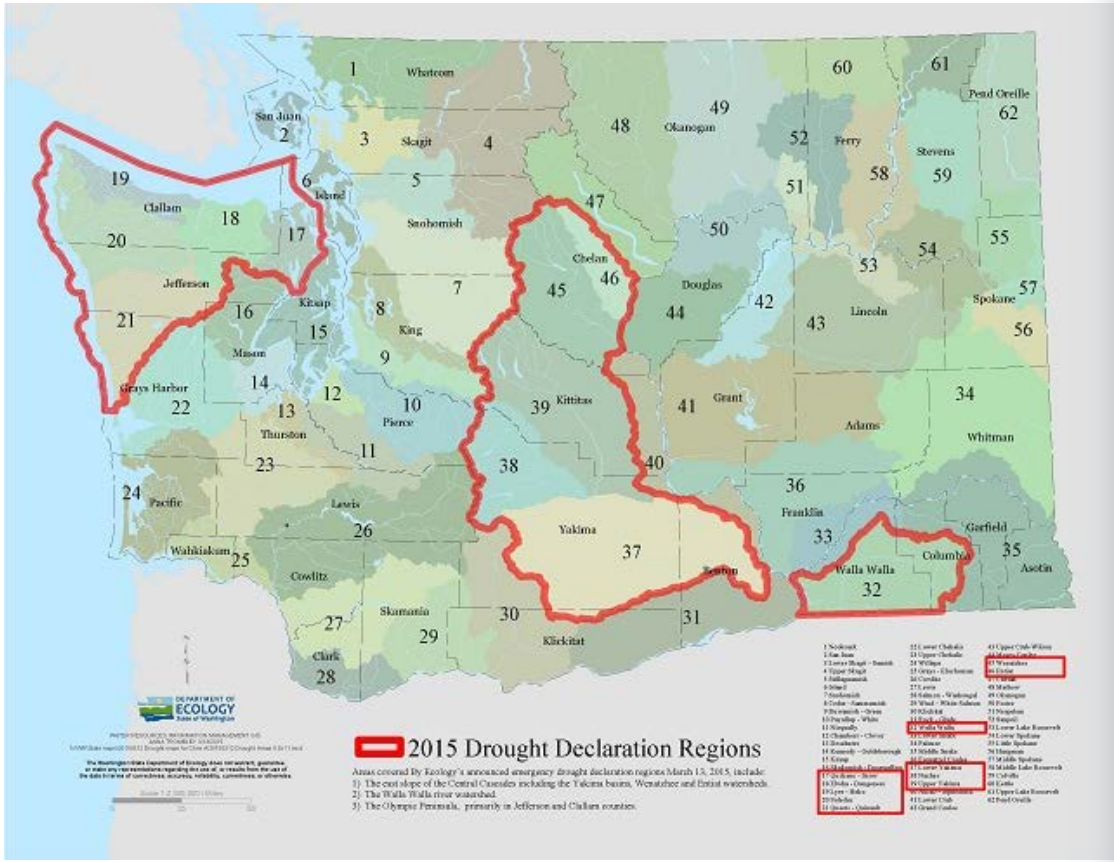
Extreme low snowpack has triggered a drought

Governor Jay Inslee declared a drought on March 13 in three regions of Washington state. State law allows Ecology to declare a drought emergency if we determine that all or part of a geographical area is suffering from drought conditions.

Snowpack is like a frozen reservoir for river basins, usually collecting over the winter and then slowly melting, providing a water supply for rivers and streams.

Currently snowpack statewide is 26 percent of normal, with little to no snowfall predicted into the spring, and warmer-than-normal temperatures through the summer.

Read the story on Ecology's website

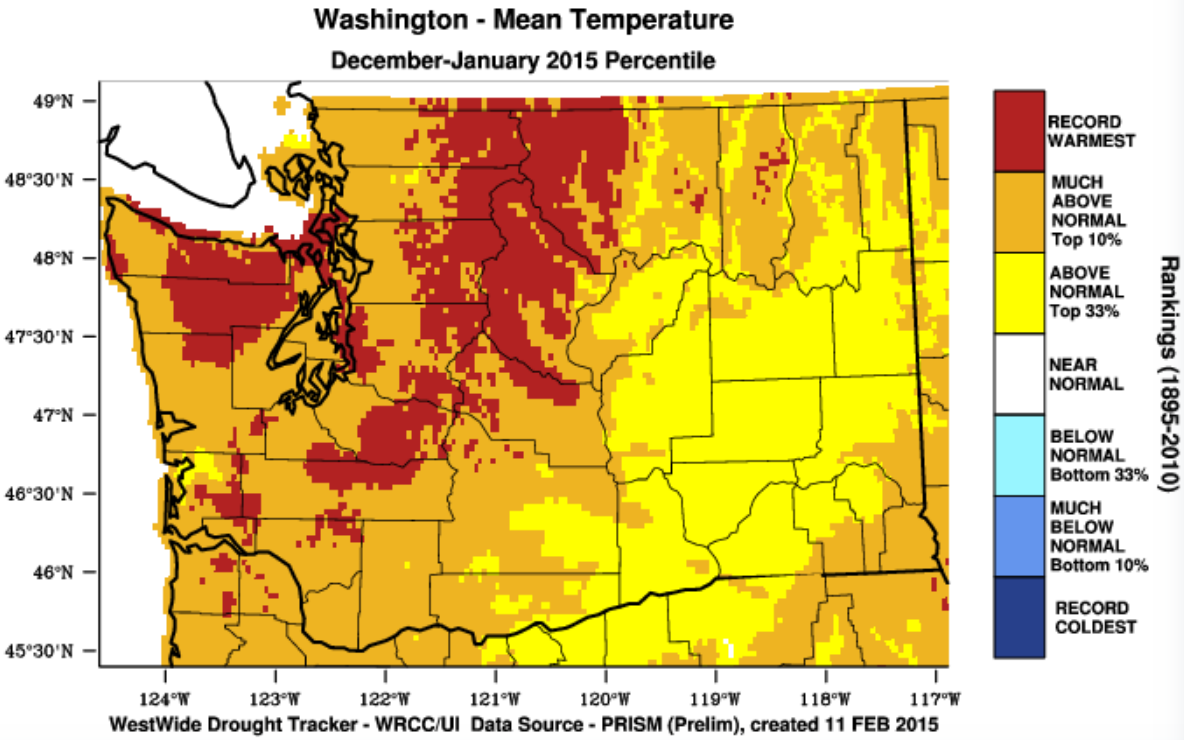


Record high winter temperatures mean rain, not snow

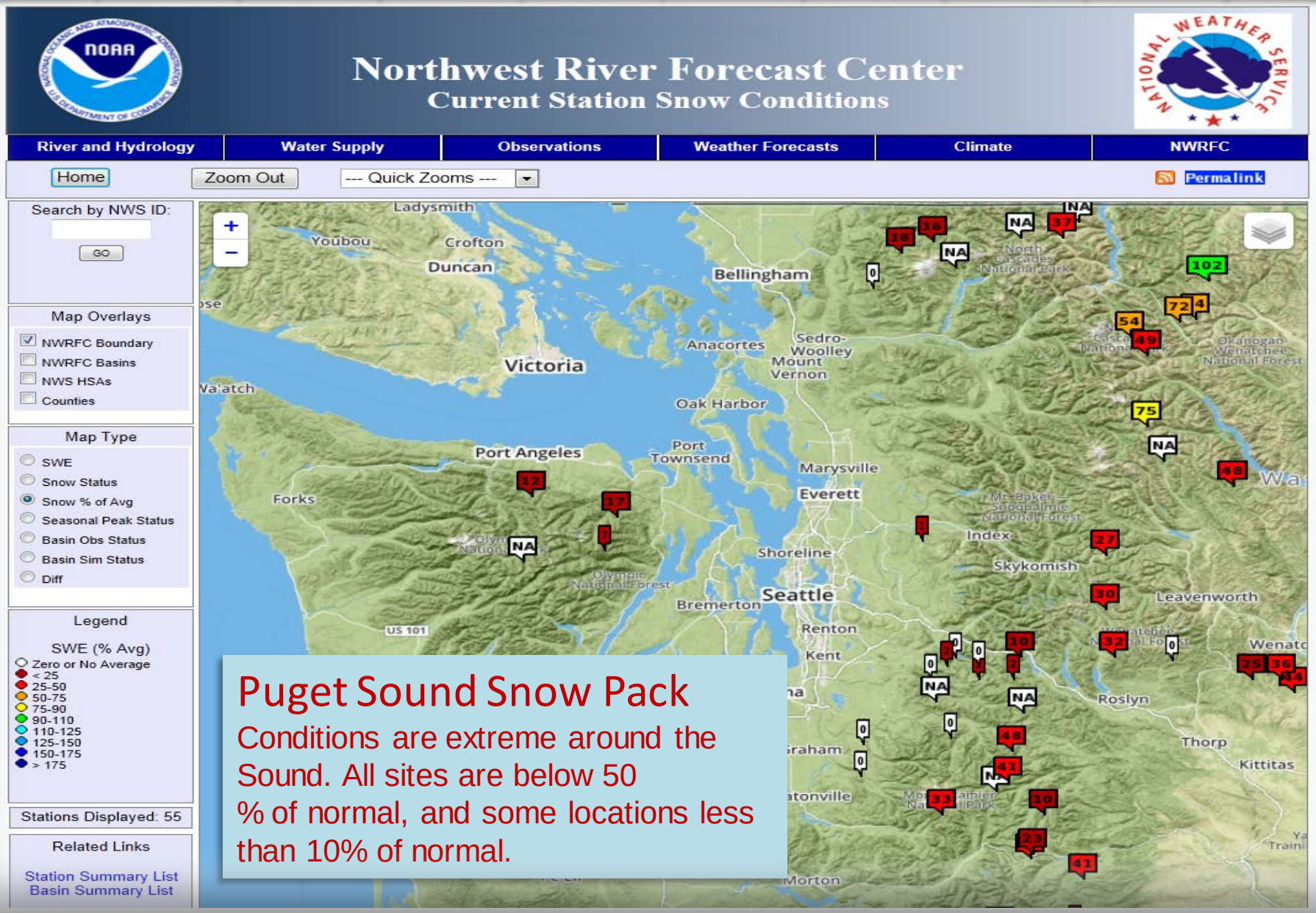
Although we've had plentiful precipitation, warm temperatures have pushed the snow line to high elevations and reduced the snowpack in most areas. Some areas that are relatively cold, like the North Cascades, have avoided this problem.

This year's warm temperatures follow a long-term trend in warming.
[Trends in PNW Climate]

Climate change modeling suggests that this winter's weather conditions, although extreme compared to the historical record, will become more common in the future.
[Future Northwest Climate]

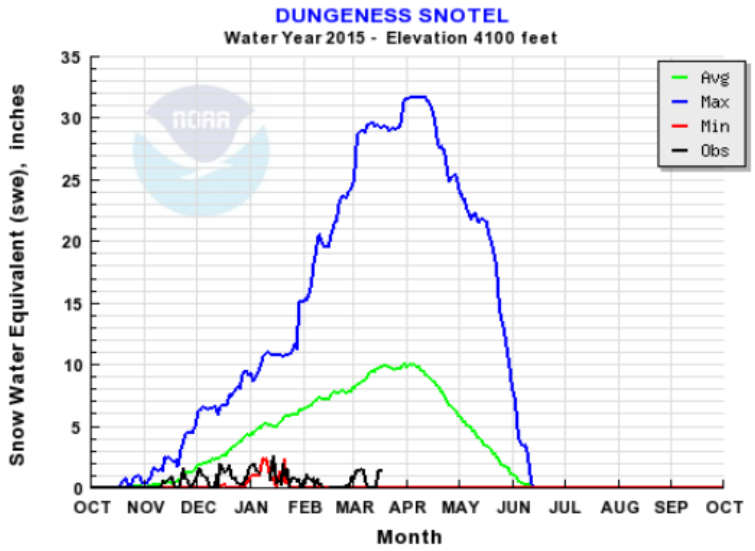


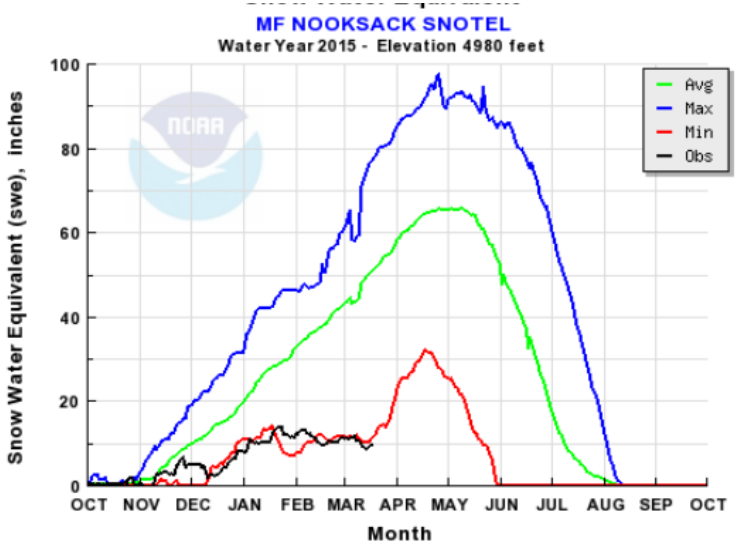
Expected drought effects and a warmer Puget Sound

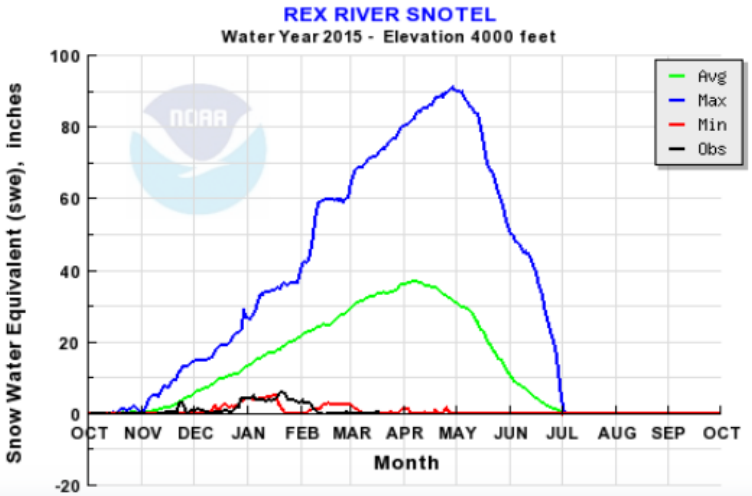


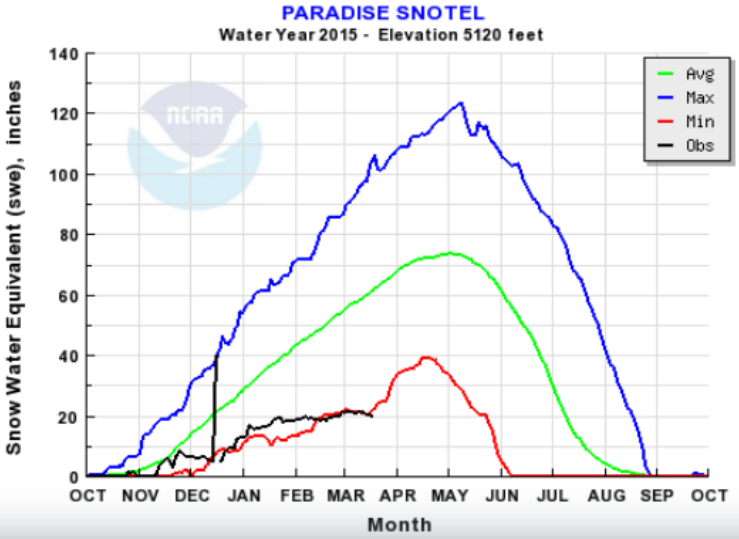
Expected drought effects and a warmer Puget Sound

Four examples: snowpack tracking lowest on record









Expected drought effects and a warmer Puget Sound

April 2010

March 2015

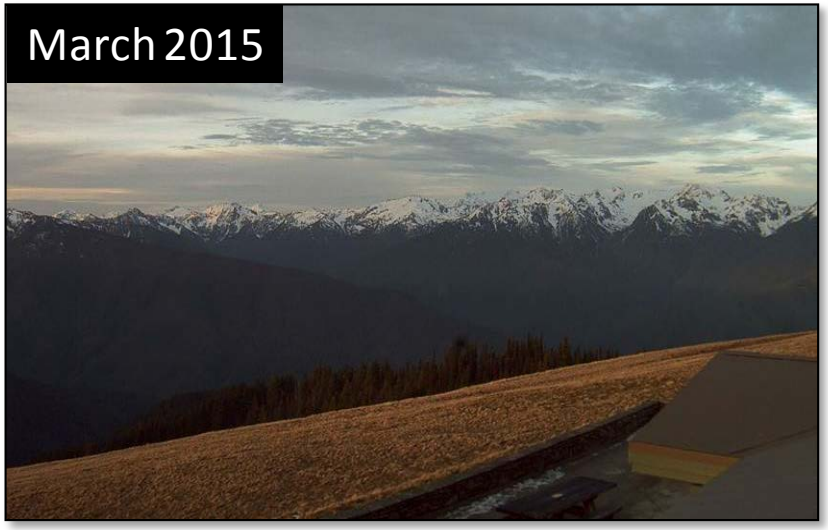
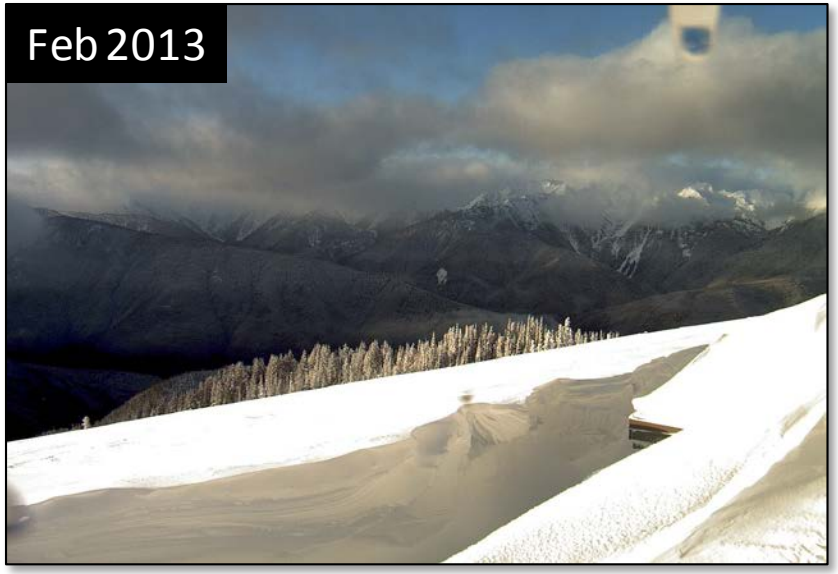


Photo by Bill Baccus, Olympic National Park

Feb 2013



Hurricane Ridge:
winter snow is gone.

Low snow has only occurred twice since 1960 (1977 & 2005).

Expected drought effects and a warmer Puget Sound

Low snowpack means low flows

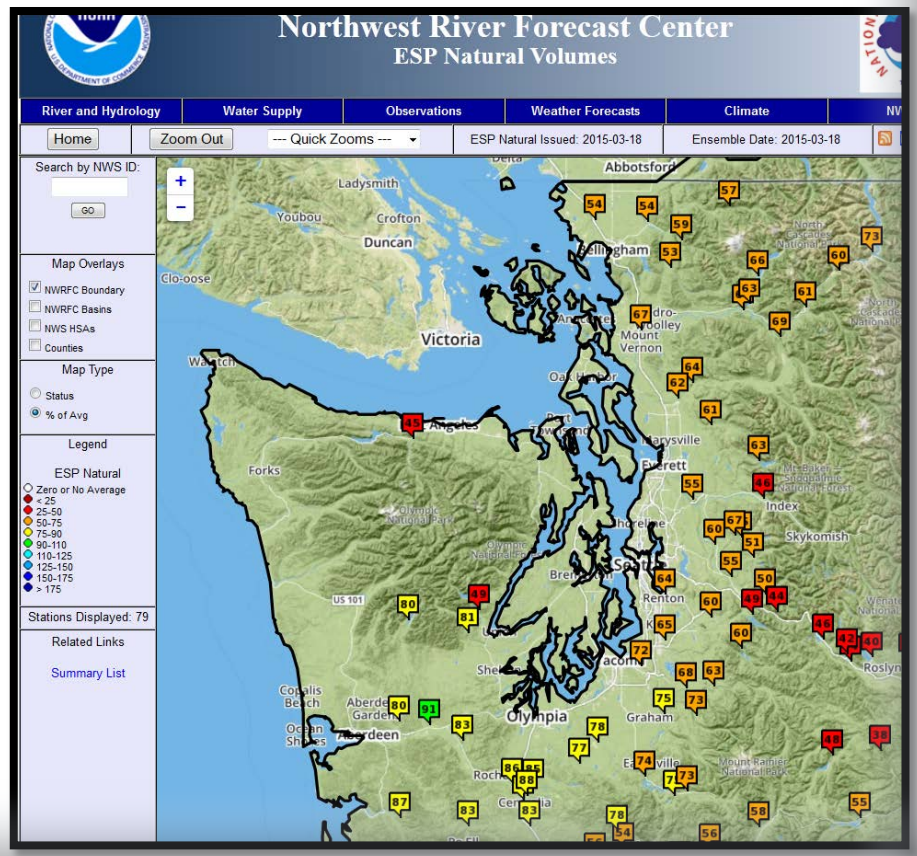
Many of the major rivers draining to Puget Sounds are considered snowmelt-dominated. In these systems, melting snowpack in the upper elevations maintains streamflows well into the summer and recharges groundwater. Snowpack below normal means that low summer flows will begin earlier and continue to drop below normal into the fall.

Encyclopedia of Puget Sound:
Section 5. Seven-Day Low Flow

Basins most strongly affected have high elevation headwaters and no reservoirs.

Examples include:

- Dungeness River
- Nooksack River
- Snohomish River



Northwest River Forecast Center
Flow Volume Projections
as percent of normal

Low flows can harm salmon

Hal Beecher of Washington Dept. of Fish and Wildlife:

Low snowpack and consequent summer low flow have a variety of negative effects on salmon and trout in rivers flowing to Puget Sound:

- *Many species spend at least a year growing in upland water bodies before going to sea. Lower flows mean less space to live in and higher temperatures, so that fewer young fish go to the ocean following a dry summer, and fewer return as adults.*
- *When low flows extend into the upstream migration season, shallow water may prevent fish from reaching their home spawning grounds. High temperatures may have the additional impact of low oxygen levels and the spread of disease.*
- *Low flows may force salmon to spawn nearer the middle of the river channel, so that subsequent winter storm and high flows may scour redds and kill eggs.*
- *Several species spawn in the spring. If low flow comes earlier than normal, some eggs may be left high and dry before the young can emerge to swim away.*
- *Most ocean-going salmon and trout migrate downstream in spring. Higher flows from spring snowmelt usually help move those fish. Low spring flows from low snowpack means they move more slowly, putting them at greater risk of predation.*

Expected drought effects and a warmer Puget Sound

Low inflows affect Puget Sound circulation and quality

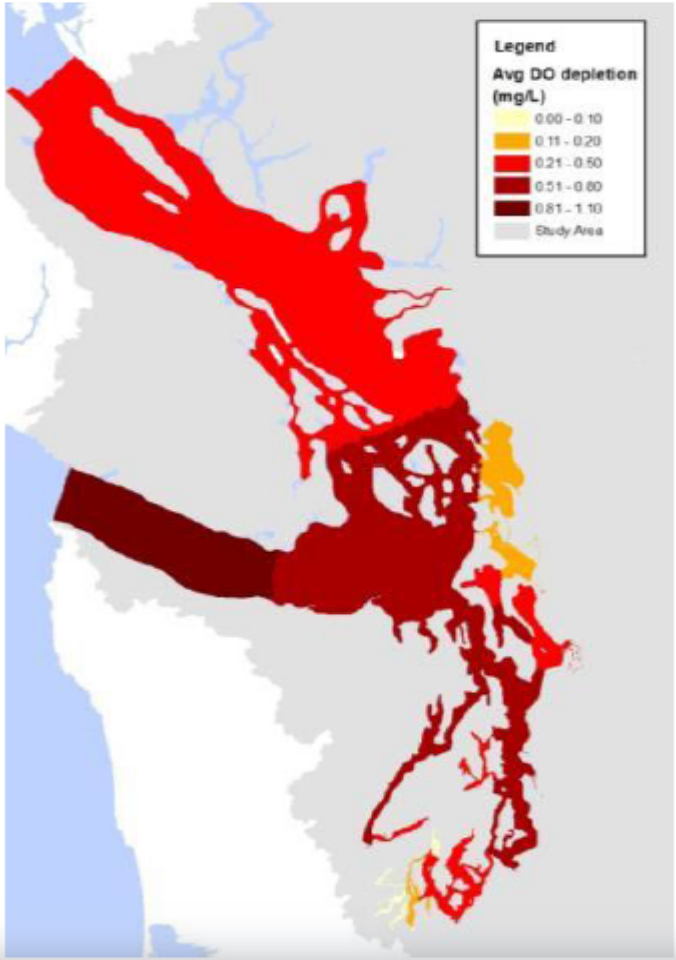
- Modeling shows that lower summer inflows change circulation and reduce net outflows.

- Slower summer circulation can decrease oxygen levels in the Sound to lower than normal levels.

- Climate change modeling demonstrates the effect of reduced inflows on the Sound. By 2070, circulation changes from low flows will significantly reduce oxygen. These reductions may be as large as reductions from doubling the population in the Puget Sound watershed.

- Ecology Report: Puget Sound and the Straits Dissolved Oxygen Assessment - Impacts of Current and Future Nitrogen Sources and Climate Change through 2070

2070s Human Sources and Ocean Conditions – Average regional depletion with future circulation (Run 34)



Expected drought effects and a warmer Puget Sound

This information brought to you by:

- **Paul Pickett**, low flow trend indicator lead
- **Markus Von Prause**, water quality indicator lead
- **Mindy Roberts**, Puget Sound modeling lead
- **Tyler Burks**, stream hydrology lead
- **Jeff Marti**, Water Resources drought policy lead
- **Hal Beecher**, WDFW fishery flow lead





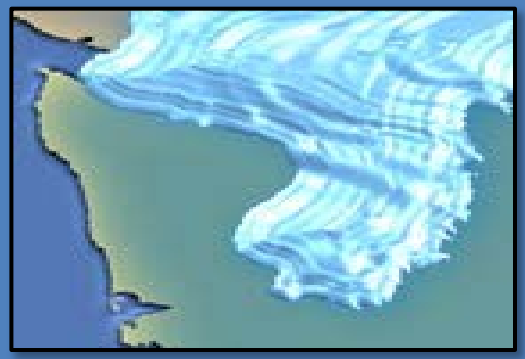

How was Puget Sound Formed?

Puget Sound is a glacial fjord that was carved by nearly mile-thick glaciers.

What is a glacier?

A mass of ice flowing like a very slow river formed by the compaction of snow.

Vashon Glacier is the last huge glacier that covered Puget Sound and began to retreat 14,000 year ago.



During the retreat, the Vashon Glacier left behind many clues in the landscape.

Let's look at some glacial evidence in Puget Sound…

Deep channels, passages, and bays – characteristic of glacial fjords.

Gig Harbor and Fox Island

Sucia Island

Personal Field Impression 3-24-15

Glaciomarine drift – The mud, rocks, sand, silt, clay, and gravel left behind as glacial ice melted.

Tulalip Bay

Commencement Bay

Erratics – Large boulders dropped by glaciers.

Granite Erratic
White Rock, BC

Erratic in North
Puget Sound

Glacial layers – Layers of sediment deposited by glaciers in many shoreline bluffs.

Fort Ebey State Park

Discovery Park Bluff

Near San Juan Islands

Photograph Credits: Brooke McIntyre 2014, Laura Hermanson 2014, http://www.openhousewhiterock.com/blog/entertainment/ever-been-to-white-rock-21, http://gravelbeach.blogspot.com/2009_10_01_archive.html , https://evstnaturalhistory.files.wordpress.com/2011/05/bluff.jpg, http://www.ecy.wa.gov/programs/sea/pugetsound/tour/geology.html, http://www.fhs.d211.org/departments/science/jadcock/glacier_webquest.htm, http://www.marlimillerphoto.com/faves110226-24.html

Climate and natural influences before 3-24-2015

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, page 26.

Summary:

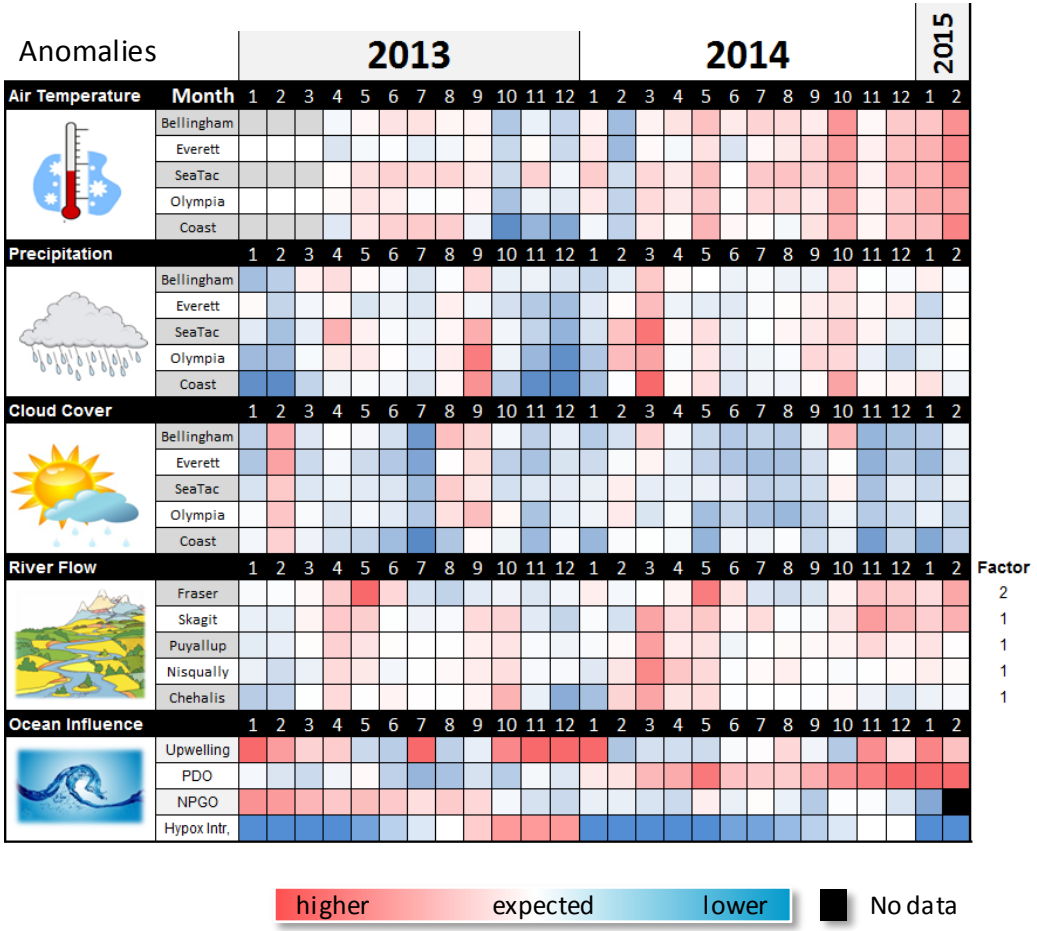
Air temperatures remain above normal, continuing an 11-month trend.

Precipitation levels have increased since January.

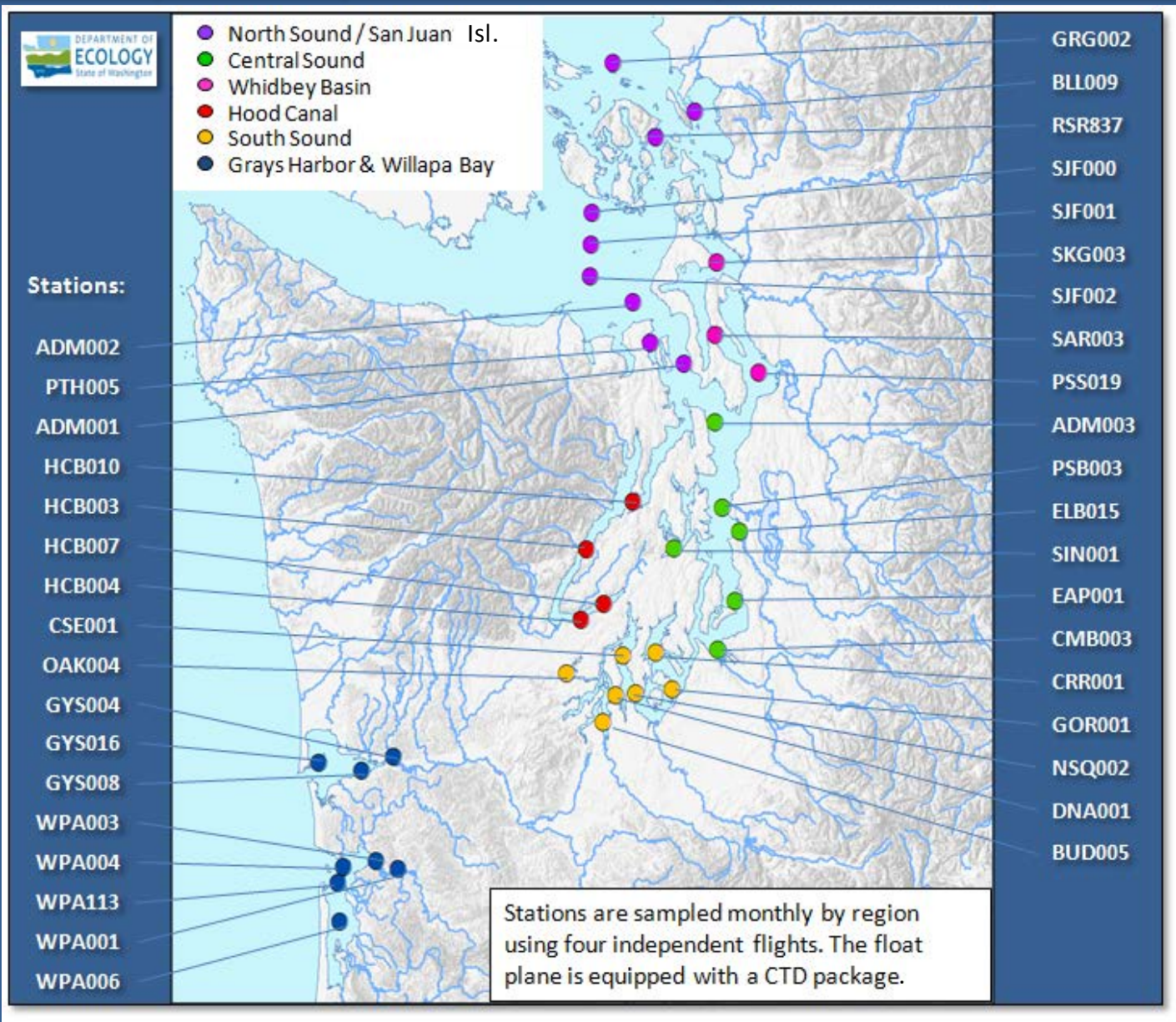
Sunshine has been intermittent for the past week but above normal for the winter (the inverse of cloud cover).

River flows are higher across the Puget Sound region, especially to the north. **Normally, the precipitation would be captured in the snowpack.**

PDO remains in the warm phase and **upwelling** is above normal.



Our long-term marine monitoring stations in Washington



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

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**

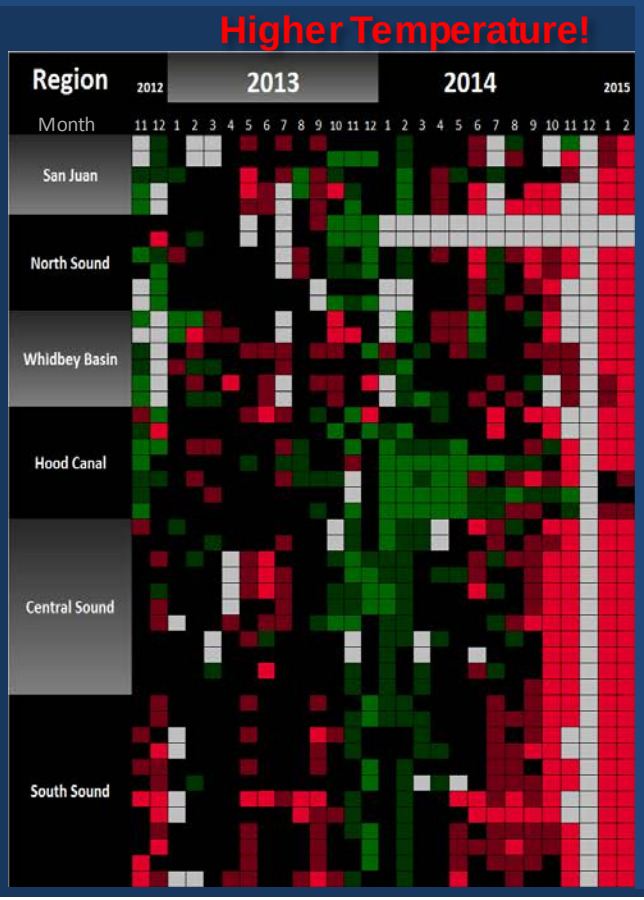
Physical conditions tracked in statistically historic context

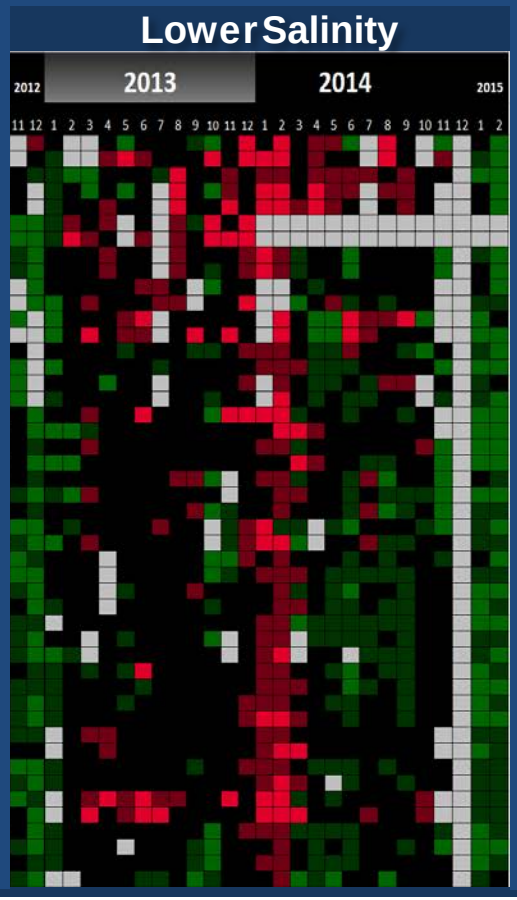
Conditions were dominated by **warm water** associated with the NE Pacific Ocean warm surface anomaly. Starting in October, temperatures are the highest on our record since 1989. Oxygen and salinities are becoming lower.

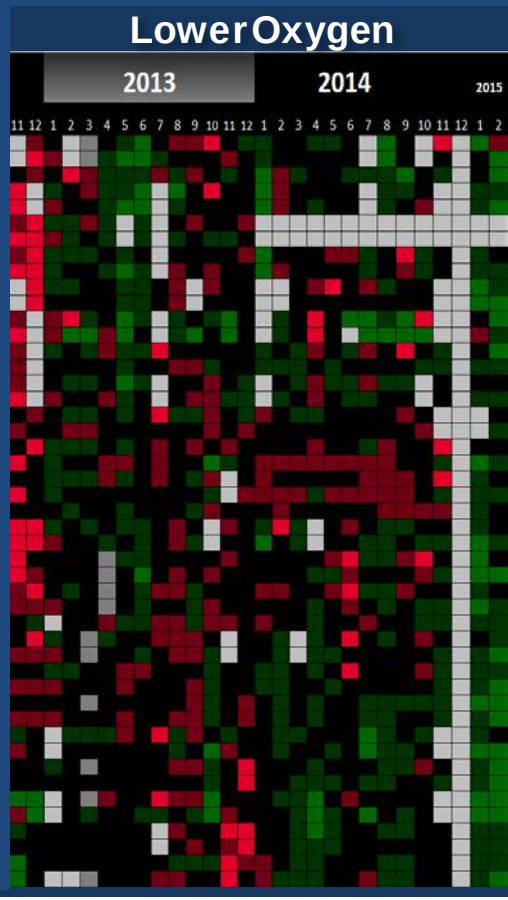
Feb. 2015:

Red boxes show that the water measured is warmer than any of our measurements since 1989.

Explore profiles at all stations







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

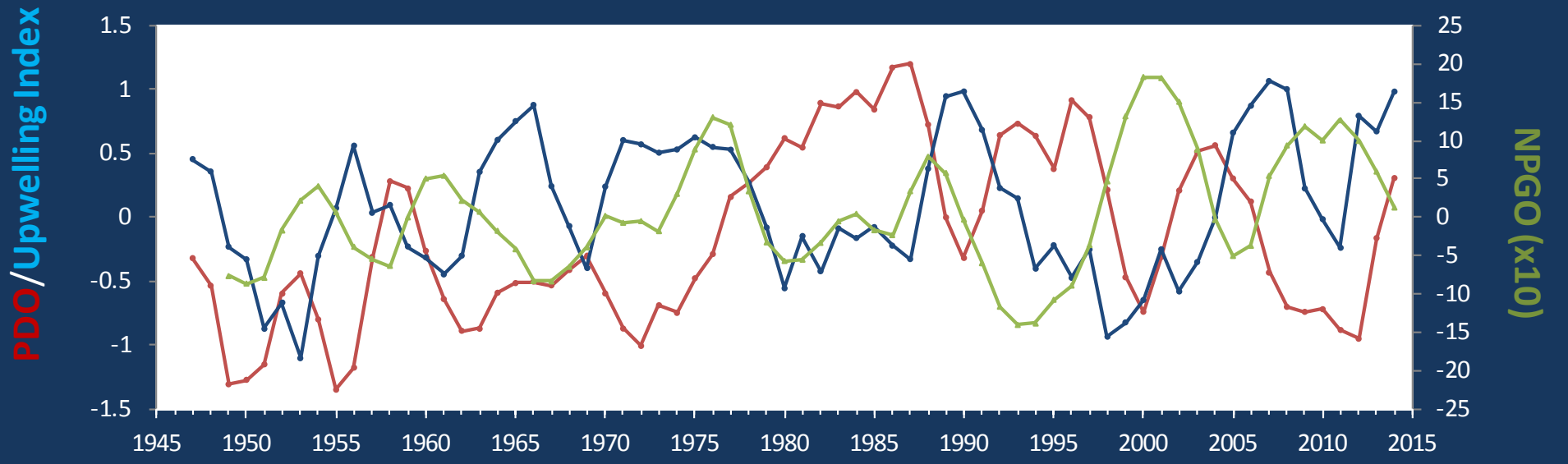
The ocean affects water quality: Ocean Climate Indices

a) *Pacific Decadal Oscillation Index (**PDO, temperature**)* *(explanation)*

b) *Upwelling Index (anomalies) (**Upwelling, low oxygen**)* *(explanation)*

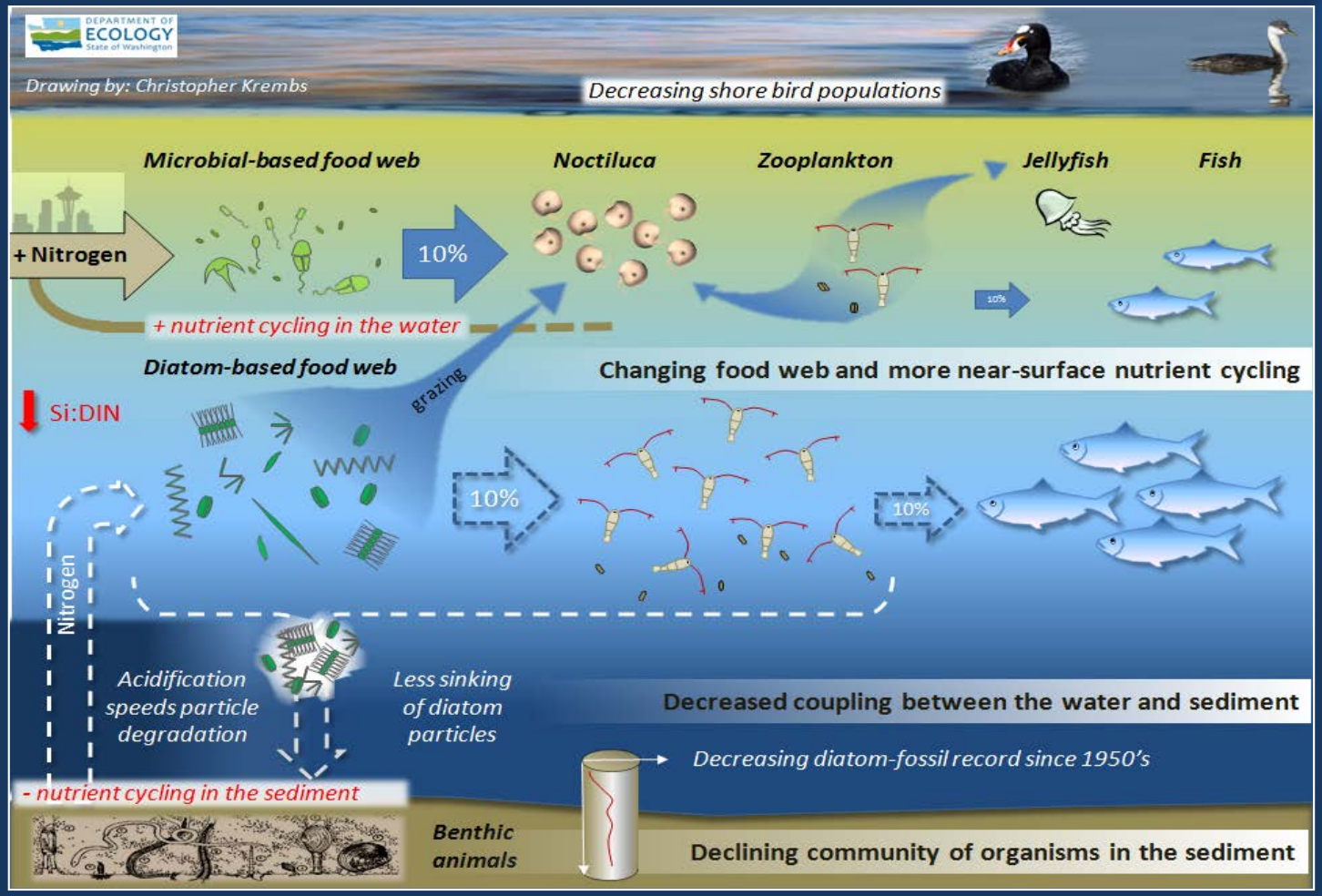
c) *North Pacific Gyre Oscillation Index (**NPGO, productivity**)* *(explanation)*

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



Ocean boundary conditions are no longer favorable for water quality in Puget Sound: (a) water is warming (PDO), (b) upwelling of low oxygen and high nutrient ocean water is again increasing (Upwelling Index), and (c) higher surface productivity along the coast (NPGO) is falling. Where are we heading next?

Hypothesis for combining a series of recent observations affecting energy and material transfer to higher trophic levels



Hypothesis!

Increases in nitrate concentrations could be caused by a top-down control on phytoplankton biomass.

Is *Noctiluca* a visible harbinger of a food web change?

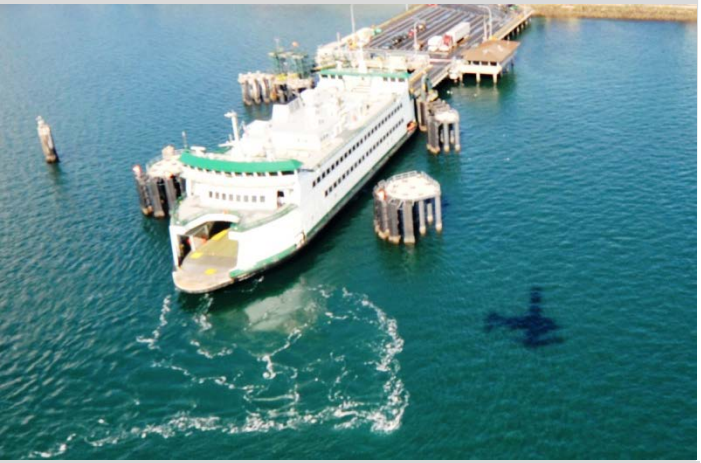
Are changes in higher tropic levels part of a story of the low food web?

Follow the experts WebEx

Summary: Aerial photography 3-24-2015

Patches of jellyfish are still present in finger inlets of South Sound. Waters show signs of blooms only in confined, stratified bays (East Sound, Saratoga Passage). Otherwise, the surface waters appear blue or carry dramatic loads of suspended sediment near rivers.

DOT and Ecology collaborate on monitoring



Tidal flat in Cultus Bay (Whidbey Island)

Click on numbers

Start here

Front

Mixing and Fronts: 1 2 10 12 17 18

Strong tides mobilize nearshore sediment and show dramatic patterns of mixing of sediment-rich water in the San Juan Islands.

Jellyfish: 1

Sizable jellyfish patches still persist in southern inlets of South Sound (Totten, Eld, and Budd Inlets).

Plume

Suspended sediment: 4 5 6 7 8 9 10 11 12 13 14

Large suspended sediment plumes from rivers all around San Juan Islands, Rosario Strait, Bellingham Bay, and Port Susan. Suspended sediment near beaches during strong outgoing tide. 16 17 18 19 20

Bloom

Visible blooms: 7 8

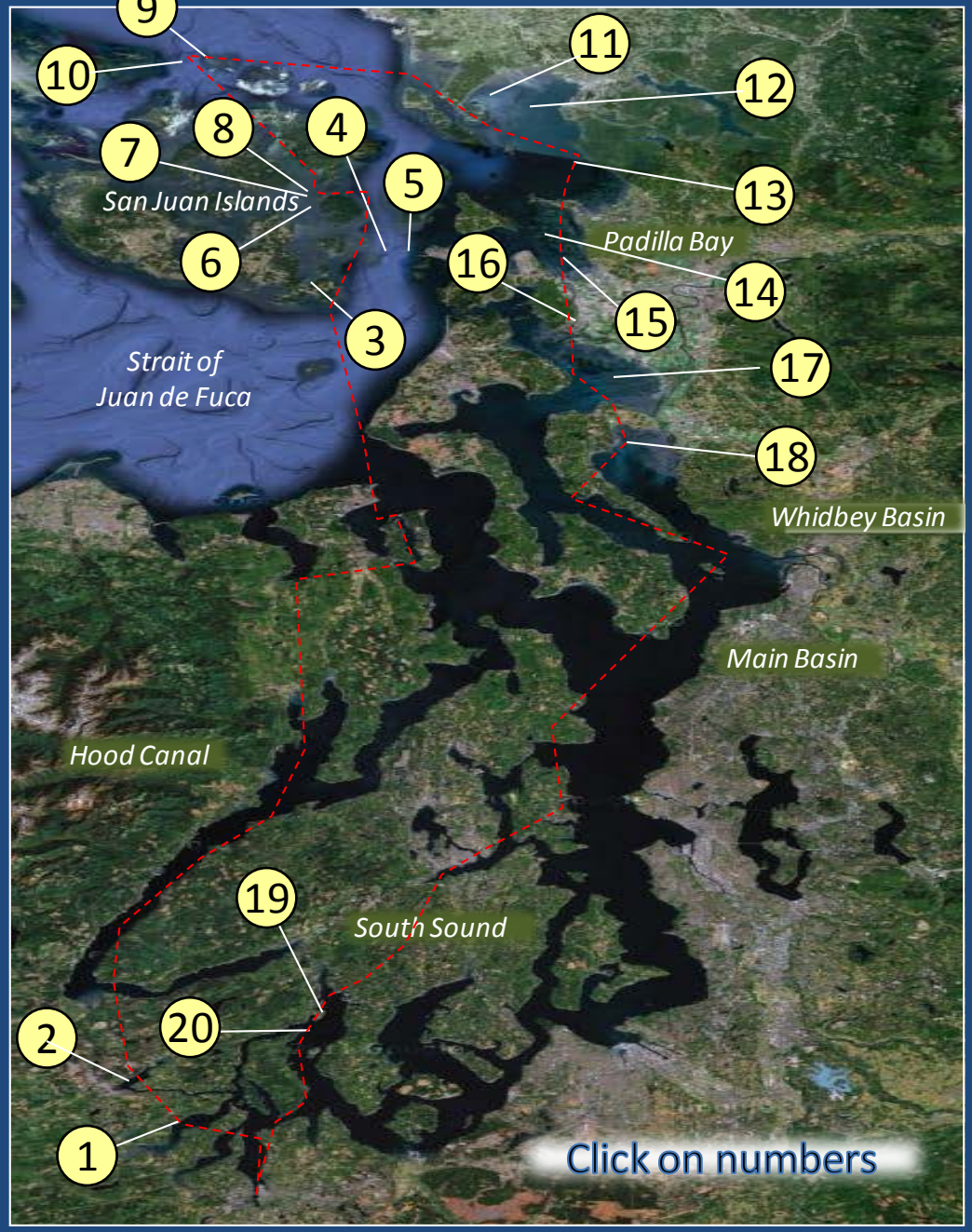
Green-brown: Saratoga Passage (Whidbey Basin)

Red-brown: East Sound (Orcas Island)

Debris

Debris: 1 2 5 13 17 18

Mostly lines of foam and small debris (eelgrass) forming along tidal fronts.



Aerial photography and navigation guide

Date: 3-24-2015

Tides (Seattle)	Feet	Stage
2:24 AM	4.13	L
8:11 AM	11.59	H
2:50 PM	-0.36	L
9:39 PM	10.81	H

Flight Information:

Morning flight, photos 1-5
Sunny, mild, high visibility, clouds

Afternoon flight, photos 6-20
Sunny, high visibility, locally windy and cloudy

– – – Flight route and fueling stop

Observation Maps:

Central and North Sound

South Sound

Aerial photography 3-24-2015

Jellyfish patches and debris lines.

Location: Kamilche Shores, Totten Inlet (South Sound), 9:51 AM.

Long tidal front outlined by debris line.

Location: Oakland Bay (South Sound), 9:54 AM.

Aerial photography 3-24-2015

No noticeable activity.

Location: Mud Bay, Lopez Sound (San Juan Islands), 11:21 AM.

Large sediment-rich water being upwelled by tidal currents.

Location: Bird Rocks (San Juan Islands), 11:24 AM.

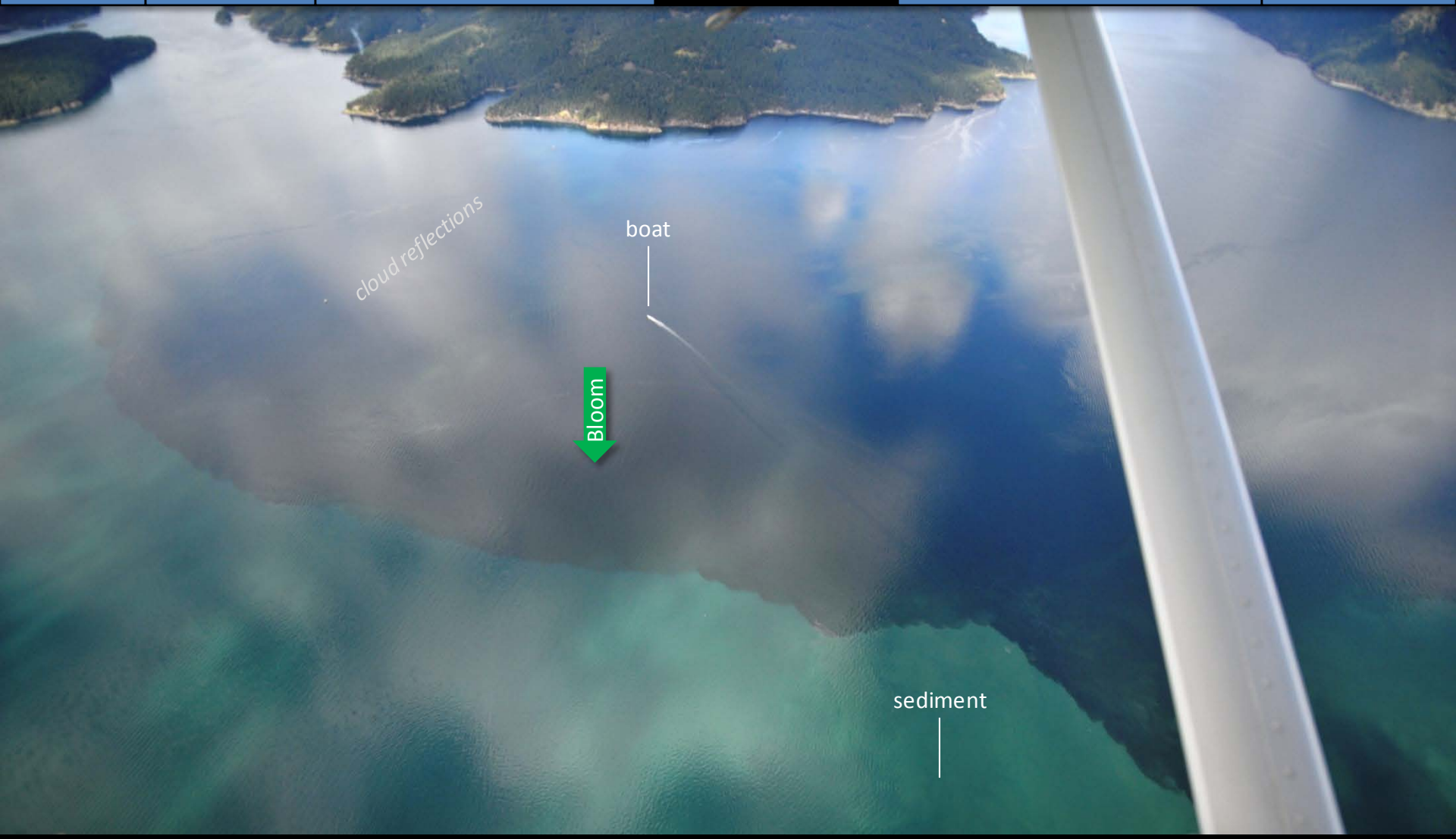
DEPARTMENT OF ECOLOGY State of Washington

Aerial photography 3-24-2015

Large sediment-rich water coming out of Guemes Channel.
Location: Off Fidalgo Head (San Juan Islands), 11:25 AM.

Long tidal eddy carrying sediment.

Location: West of Blakely Island (San Juan Islands), 12:08 PM.



Distinct front between sediment-rich water and a red-brown bloom at entrance to East Sound.

Location: West of Obstruction Island (San Juan Islands), 12:09 PM.

Distinct front between sediment-rich water and a red-brown bloom at entrance to East Sound.

Location: West of Obstruction Island (San Juan Islands), 12:11 PM.

Aerial photography 3-24-2015

Strong tidal currents outlined by fine suspended sediments show structures of turbulence and shear.

Location: Patos Island (San Juan Islands), 12:19 PM.

Aerial photography 3-24-2015

Strong tidal currents outlined by fine suspended sediments show structures of turbulence and shear.

Location: Looking at Gulf Islands in Canada (San Juan Islands), 12:20 PM.

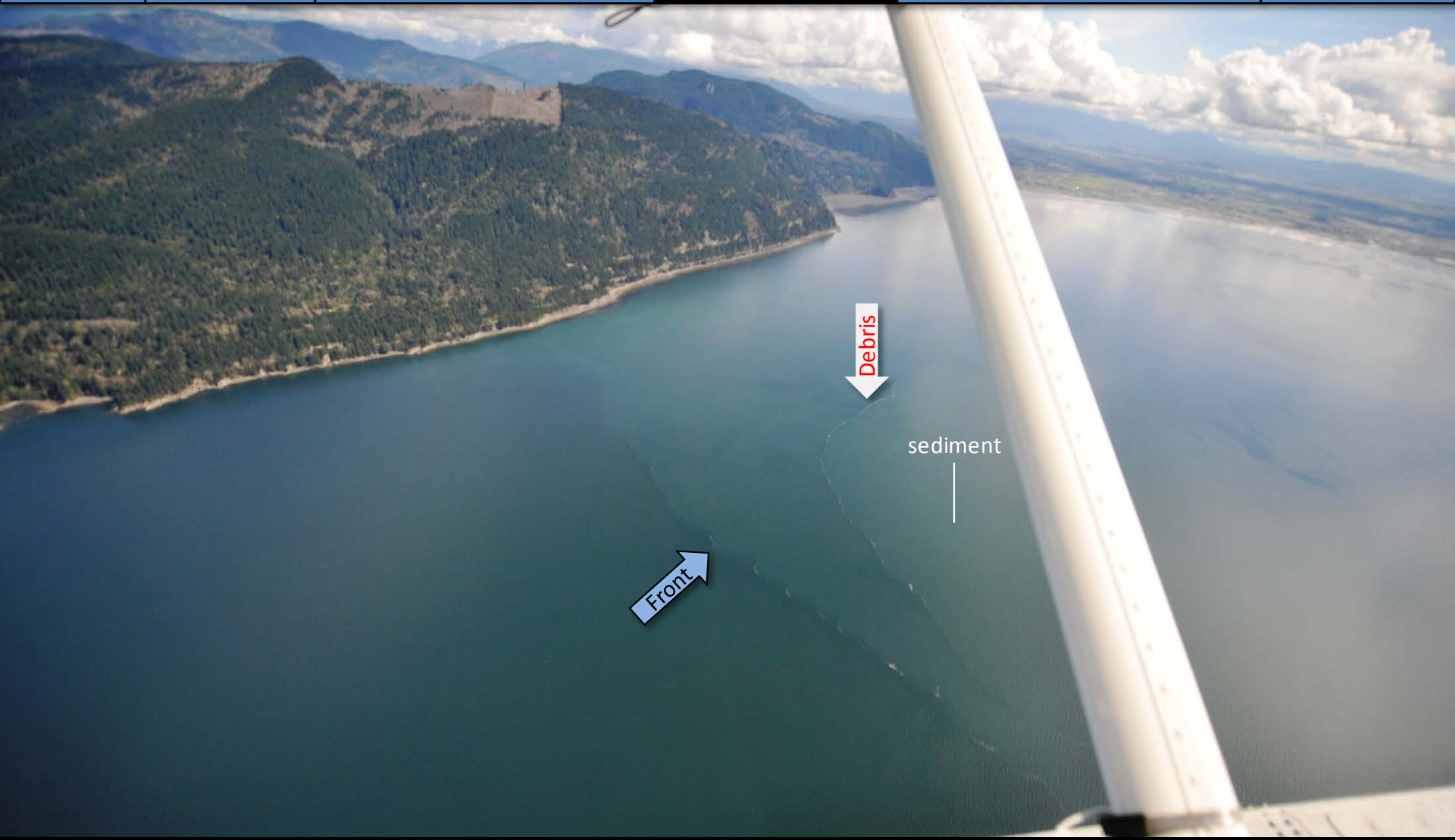
Aerial photography 3-24-2015

Sediment-rich water from the Nooksack River.

Location: East of Lummi Reservation (Bellingham Bay), 1:27 PM.

Sediment-rich Nooksack River plume with internal waves and ship track.

Location: Bellingham Bay (Bellingham Bay), 1:29 PM.



Front separating water from Bellingham Bay and Samish Bay.
Location: Off Larrabee State Park (Bellingham Bay), 2:01 PM.

Aerial photography 3-24-2015

Fine lines of sediment rich water being advected through large gullies without mixing.

Location: Padilla Bay (North Sound), 2:06 PM.

Mudflats with gullies and patches of eelgrass.

Location: From above Bay View, (Padilla Bay), 2:08 PM.

Aerial photography 3-24-2015

Sediment-rich water entering the Swinomish Channel flowing southward.

Location: La Conner (Whidbey Basin), 2:11 PM.

Aerial photography 3-24-2015

Long front of the Skagit River crossing the entire bay.

Location: Skagit Bay (Whidbey Basin), 2:14 PM.

Plumes of a murky sediment-rich water showing different tidal fronts.
Location: Across from Warm Beach, Port Susan (Whidbey Basin), 2:47 PM.

DEPARTMENT OF ECOLOGY State of Washington

Aerial photography 3-24-2015

Plume of sediment-rich water near beach during outgoing tide.
Location: Stretch Island (Case Inlet), 4:52 PM.

Sediment-rich water near beach during outgoing tide.

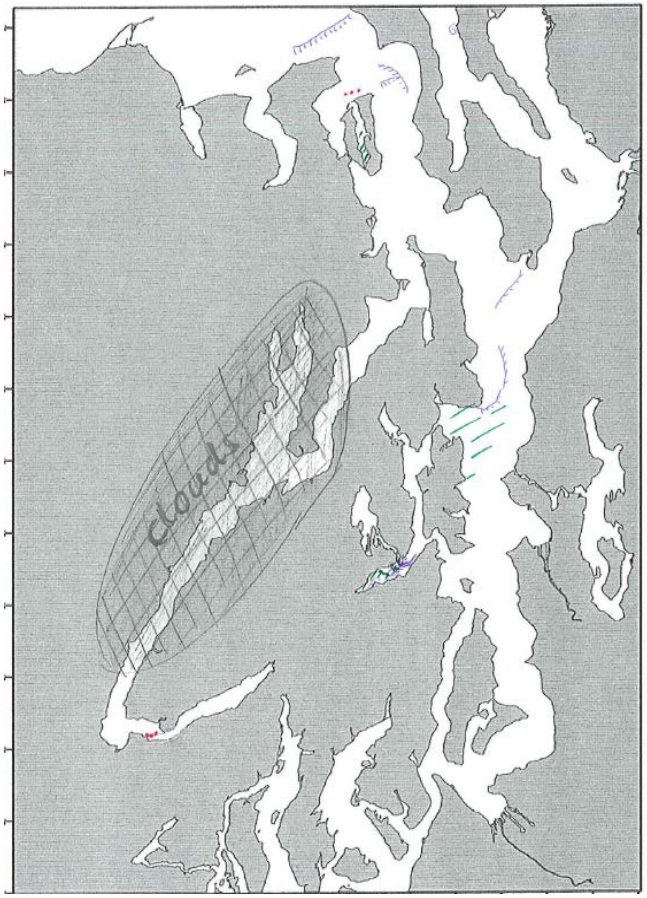
Location: Near Dougall Point on Harstine Island, Case Inlet (South Sound), 4:53 PM.

Qualitative aerial observer map during transit

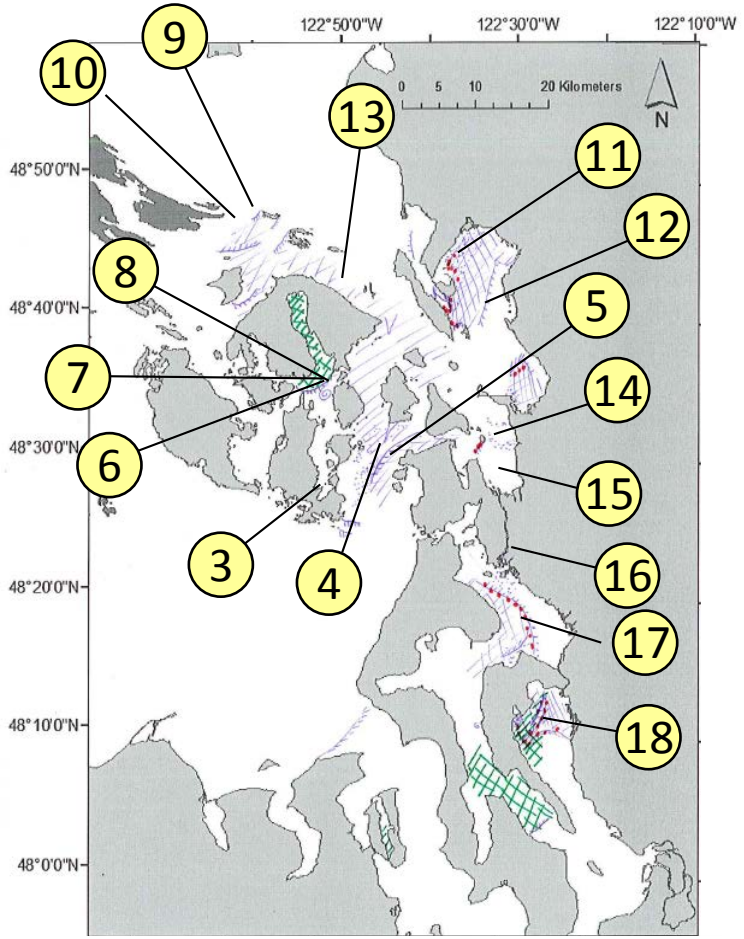
Navigate

Date: 3-24-2015

Central Sound



North Sound/San Juan Islands



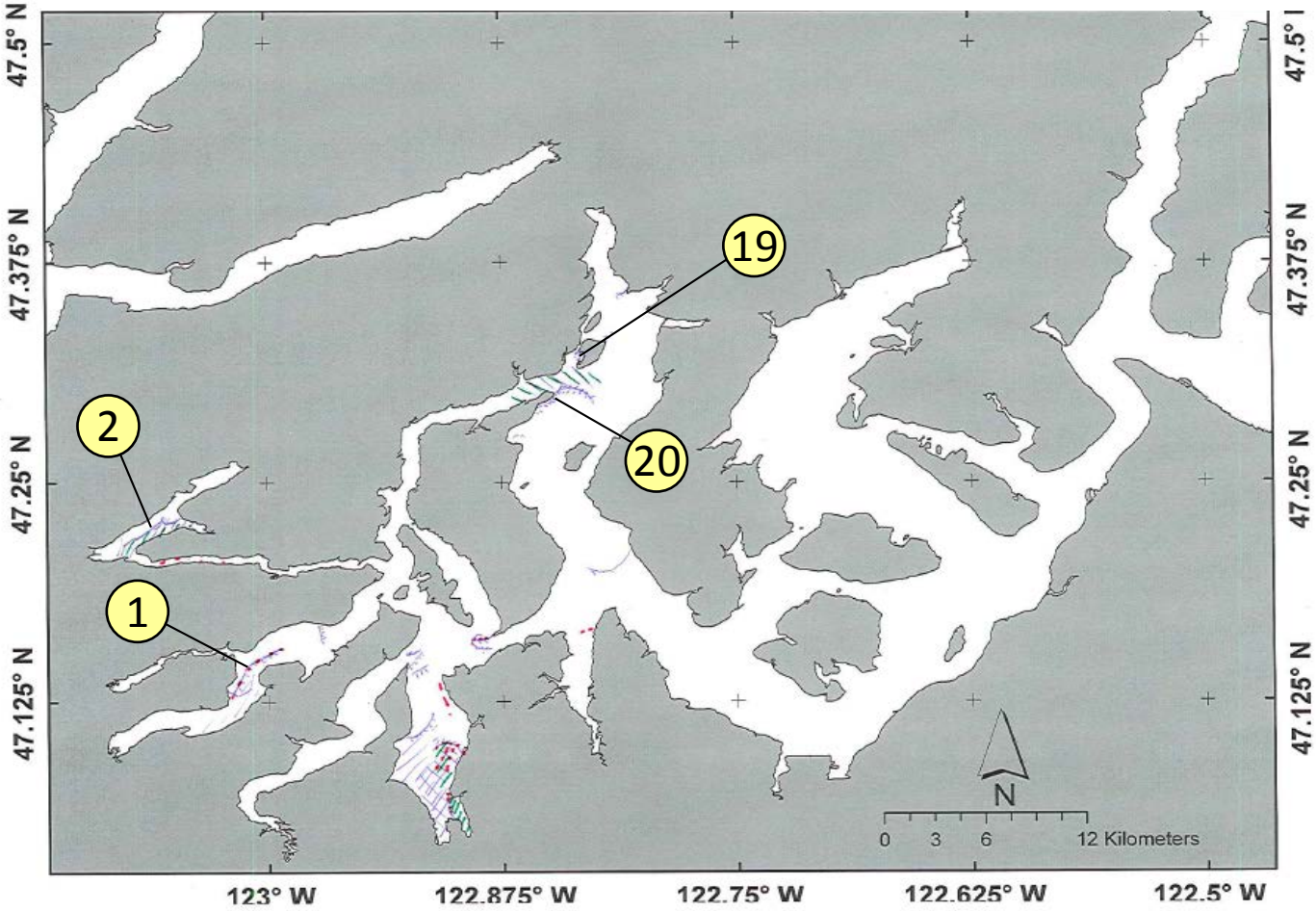
Numbers on map refer to picture numbers for spatial reference

Qualitative aerial observer map during transit

Navigate

Date: 3-24-2015

South Sound



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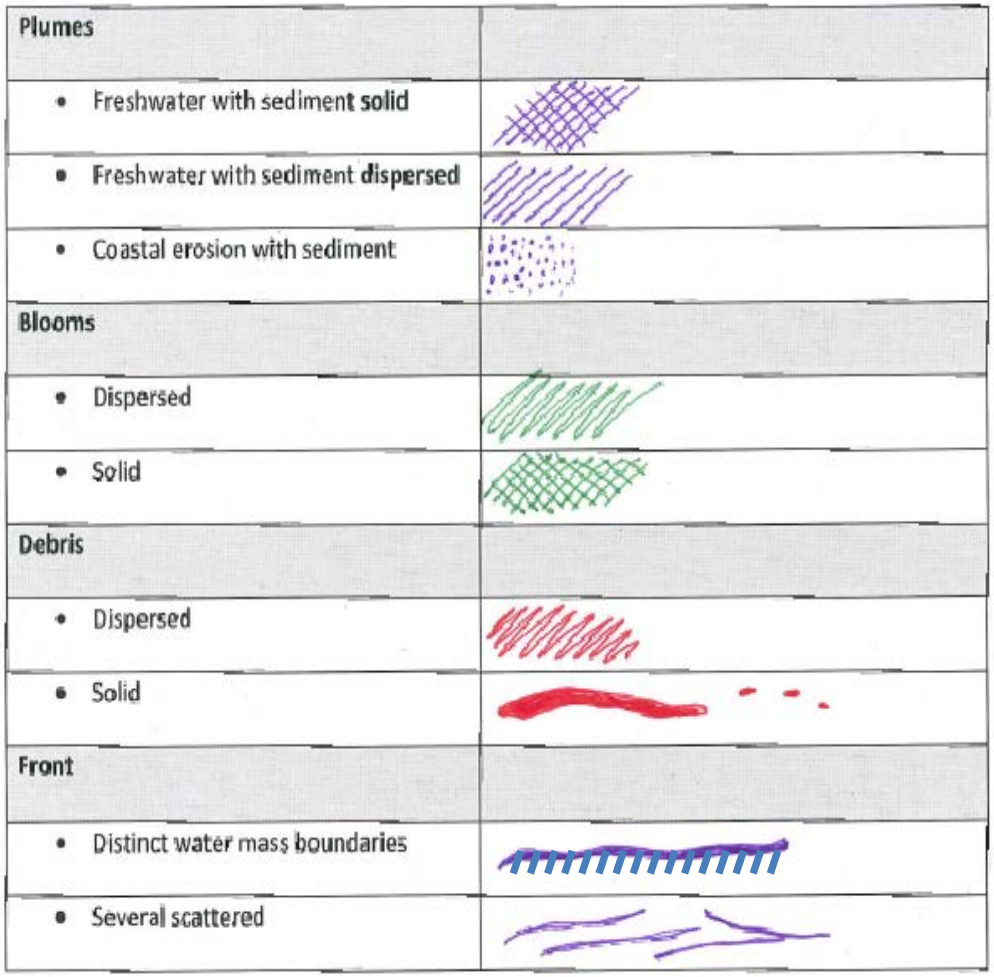
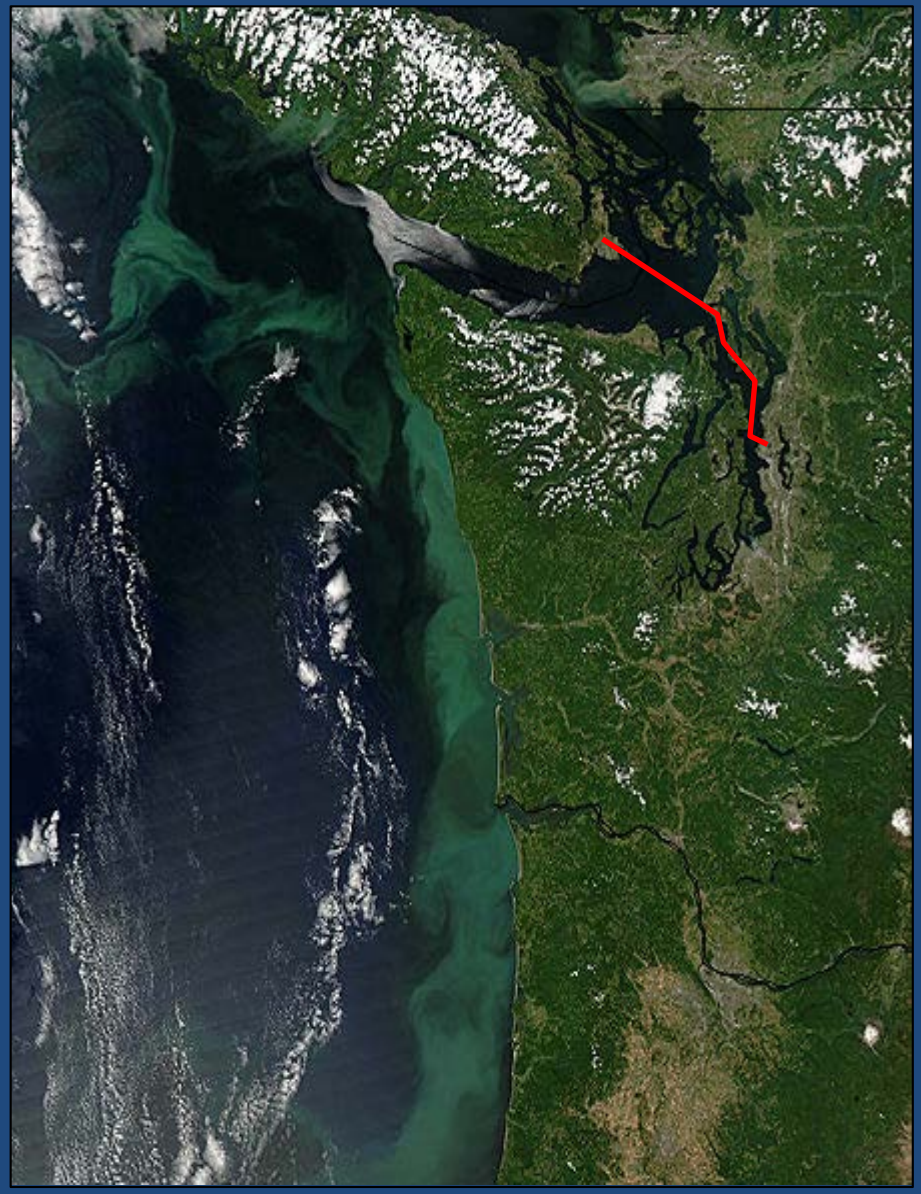


Comments:
Maps are produced by observers during and after flights. They are intended to give an approximate reconstruction of the surface conditions on scales that connect to and overlap with satellite images in the section that follows.

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”.

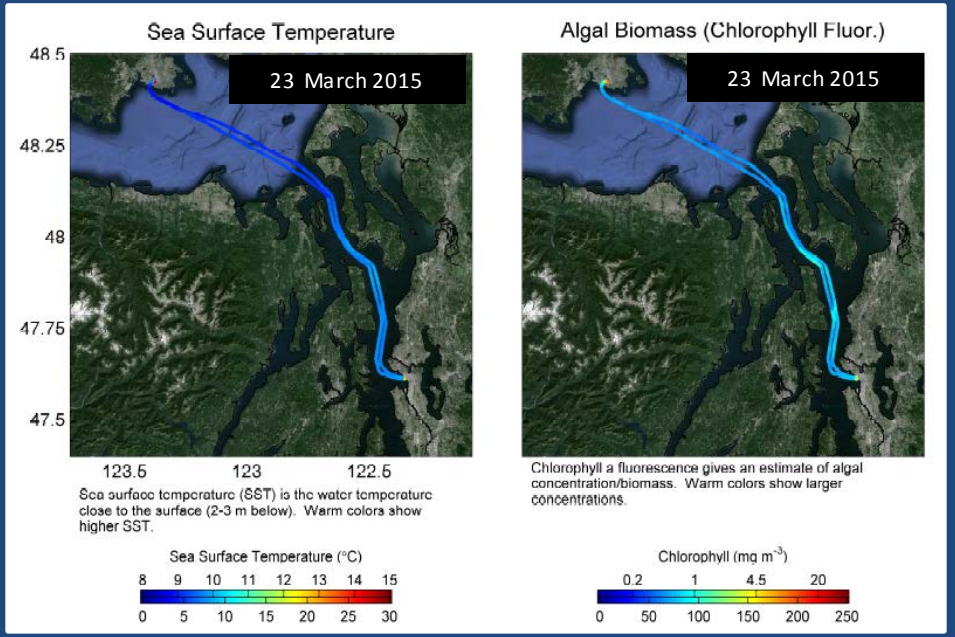
S.L. Moore, M. J. Allen. 2000. Distribution of Anthropogenic and Natural Debris on the Mainland Shelf of the Southern California Bight. Marine Pollution Bulletin, 40(1): 83–88.

Ferry and satellite observations 3-24-2015



Brandon Sackmann
Contact: bsackmann@integral-corp.com

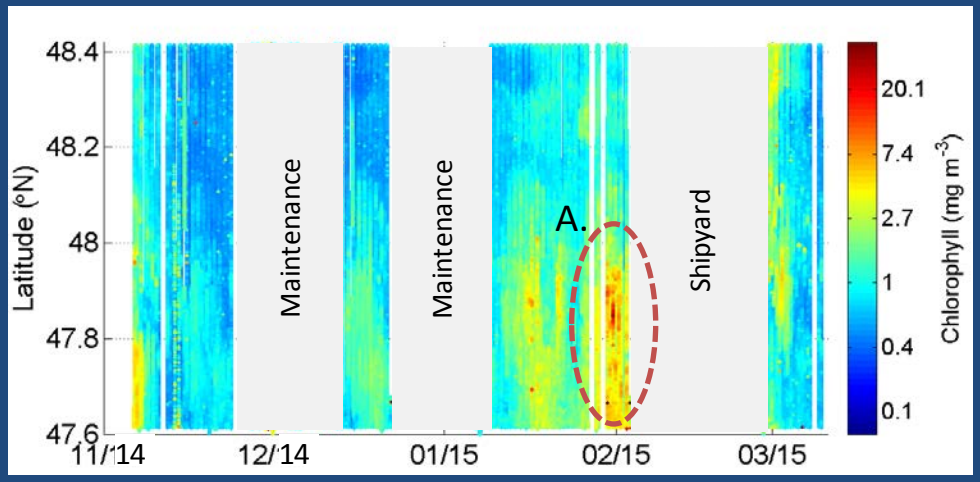
Start here

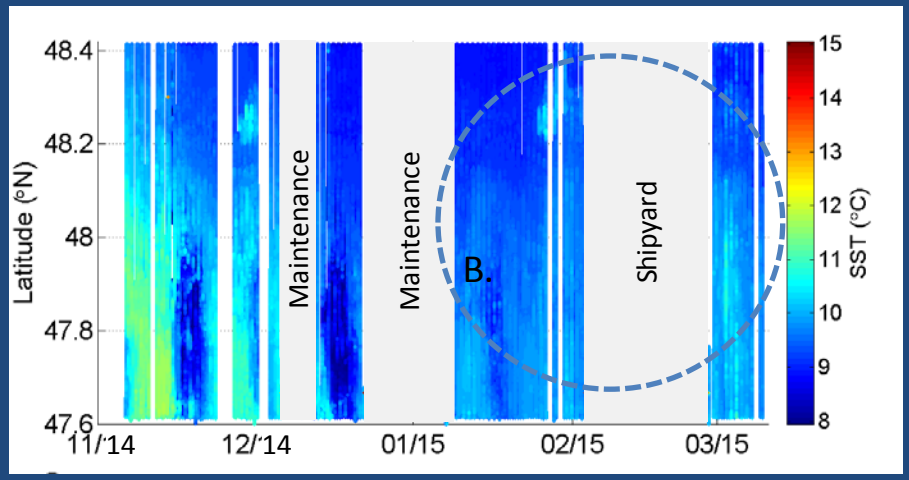


Current Conditions:

Isothermal conditions appear across Central Basin and the Straits with little signs of phytoplankton growth.

Ferry and satellite observations 3-24-2015





The *Victoria Clipper IV* carries sensors in its sea chest. The sensors allow us to get surface transects of temperature, chlorophyll, salinity, and other bio-optical measurements between Seattle and Victoria, BC twice per day.

A. Phytoplankton started to increase during a mild and sunny period in February, but concentrations have dropped across the main part of Central Basin and the Strait of Juan de Fuca.

B. Isothermal surface water near 10.5 °C persists for more than a month.

Mooring observations and trends 03-12-2015 to 03-25-2015

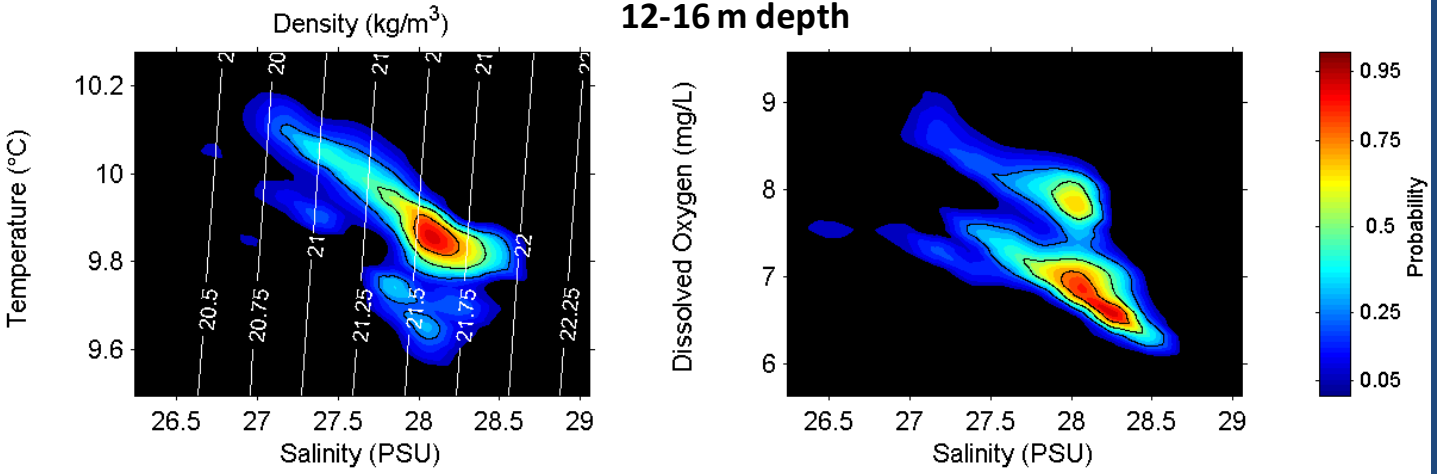
At the Mukilteo mooring, water properties appear somewhat influenced by southerly winds and river flows until mid-March. This is when a shift in wind direction may have contributed to lower salinity and higher temperature, tidal height, and river flows. Afterwards, trends in temperature and salinity coincide with changes in tidal height and wind speed, but not river flows.

2-6 m depth

Data are not available for this time period. Look for them next month.

Dissolved oxygen is not measured.

12-16 m depth



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.

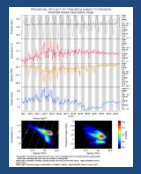
Mooring observations and trends 01-18-2015 to 03-24-2015

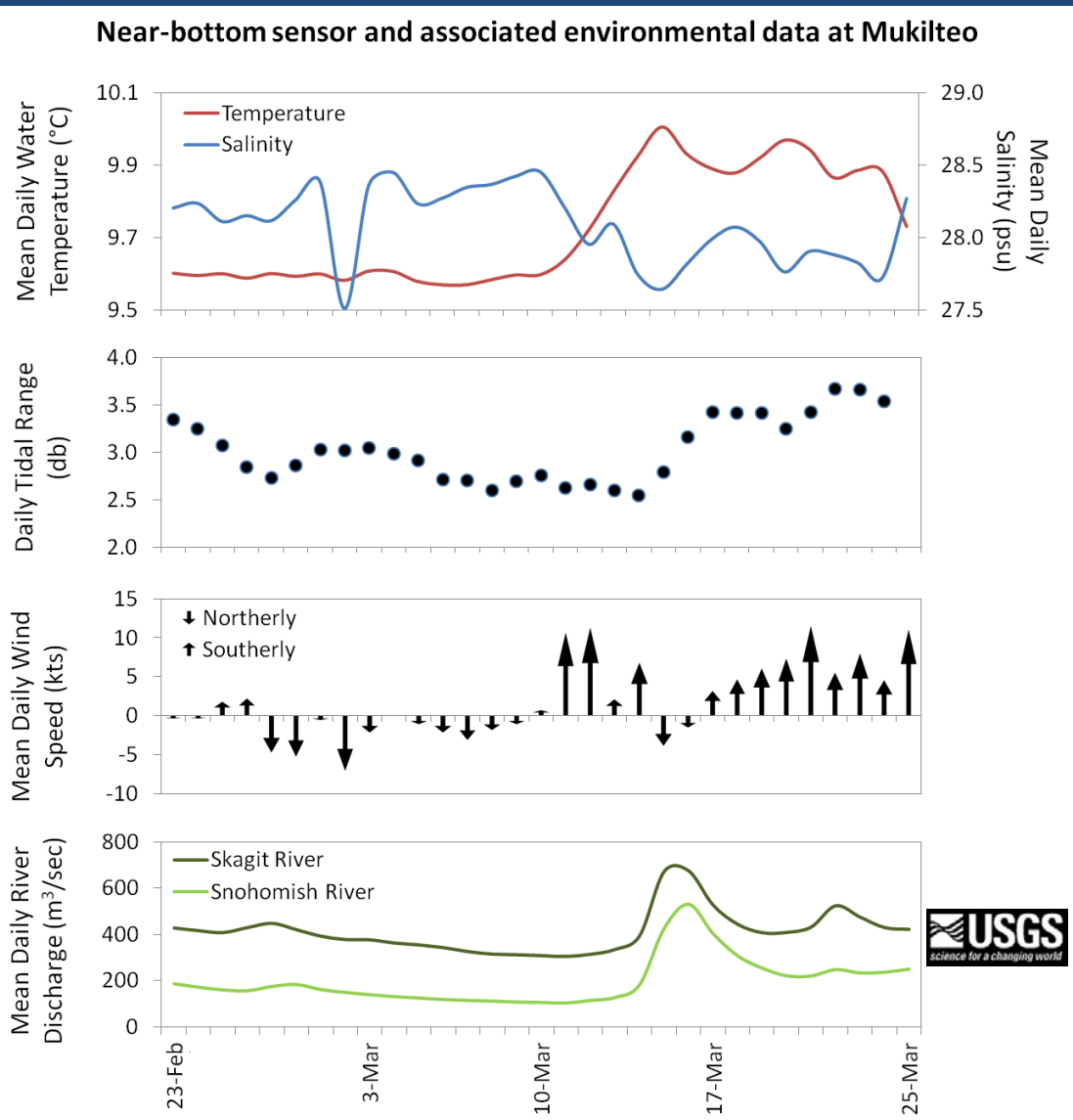
Our mooring station in Mukilteo is located in Whidbey Basin near Everett. It is also located at the transition between Possession and Central Sounds at a depth that is influenced by the Skagit and Snohomish river discharges, prevailing winds, and tidal mixing.

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





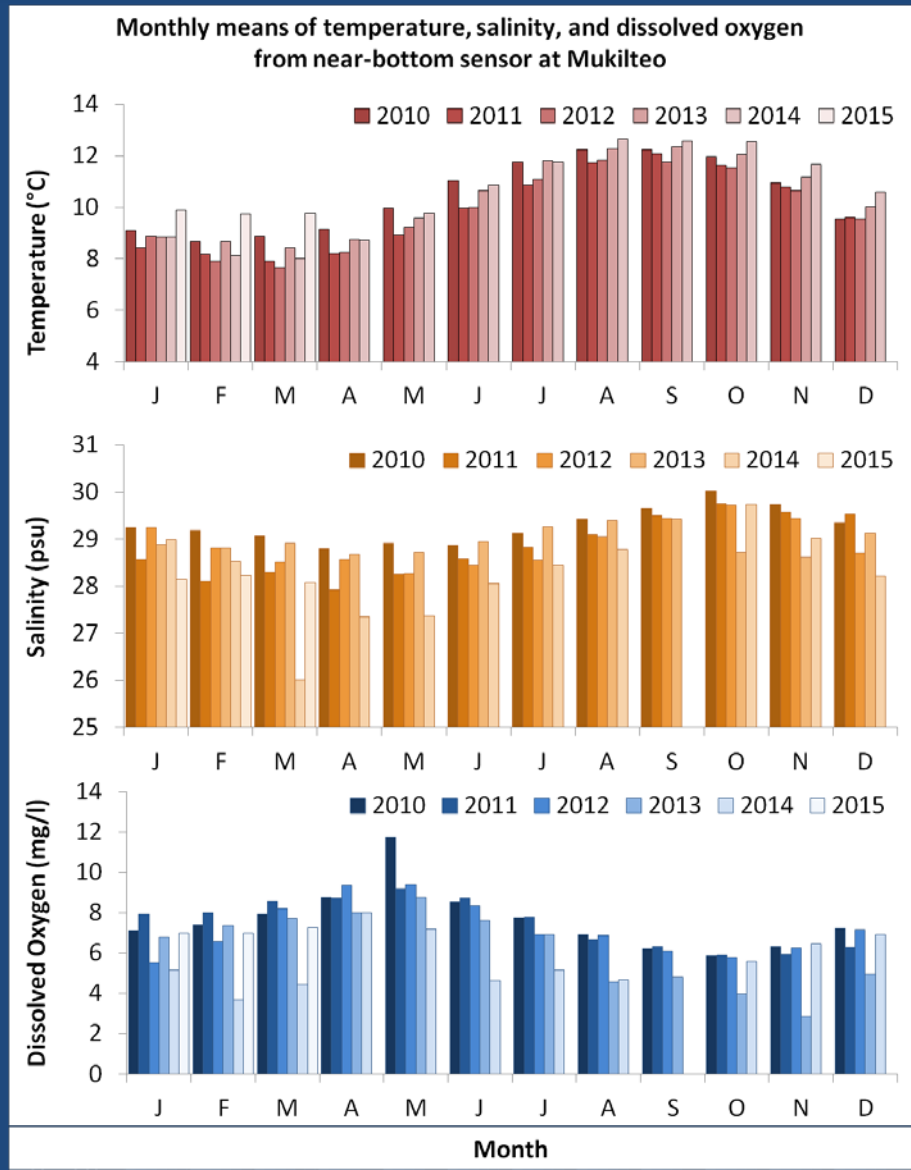
Mooring observations and trends Mukilteo 2010 to 2015

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 5-year period. All three variables show strong seasonality.

Water around the mooring continues to be warmer and generally fresher than past several years. The amount of dissolved oxygen is roughly similar to 2010, 2011, and 2013.

Seasonally, variability of each parameter remains minimal from January to March.



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

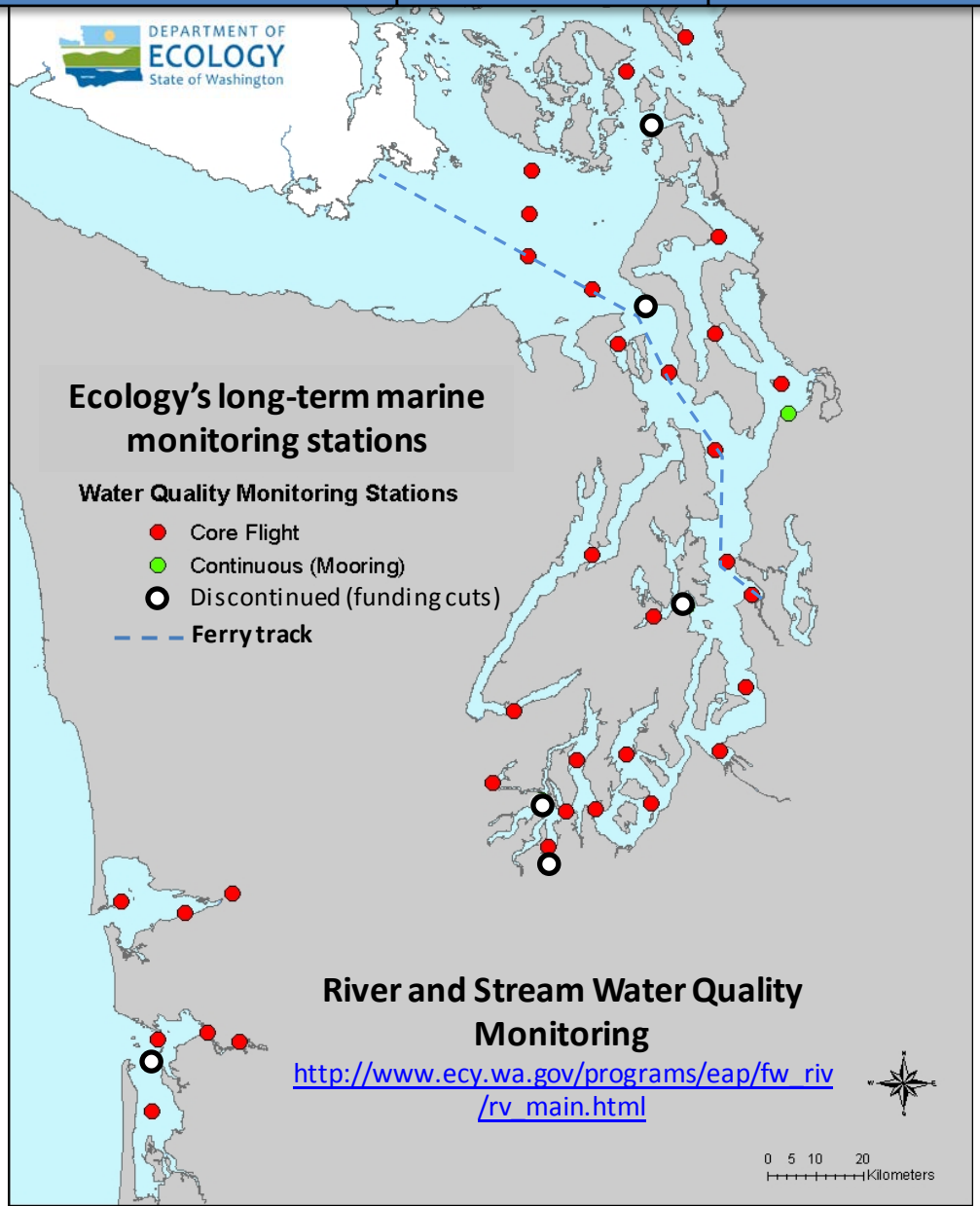
Get data from Ecology's Marine Monitoring Programs

Field log	Climate	Water column	Aerial photos	Ferry and Satellite	Moorings

Long–Term Monitoring Network

christopher.krembs@ecy.wa.gov

Access core monitoring data:
http://www.ecy.wa.gov/apps/eap/marinewq/mwdataset.asp



Real–Time Sensor Network

Suzan.Pool@ecy.wa.gov

Access mooring data:
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

We are looking for feedback to improve our products.

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Marine Monitoring Unit
Environmental Assessment Program
WA Department of Ecology

Many thanks to our business partners: Clipper Navigations, Swantown Marina, and Kenmore Air.