Sediment Exchange

October 17 2022

Sediment Exchange

Agenda

8:00 AM	Intro
8:10 AM	Monitoring: David Shull
8:40 AM	Q&A
8:55 AM	Modeling: Parker & Stefano
9:10 AM	Q&A
9:25 AM	Discussion
9:55 AM	Wrap-up

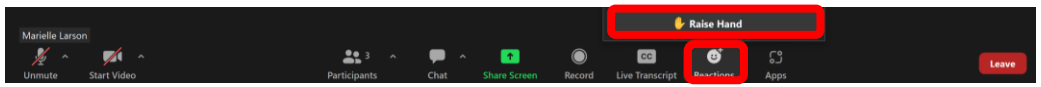
Navigating the Workshop

Welcome! While we wait, please:

- Update your name to include your pronouns and organization
- Message Marielle with any access needs
- Introduce yourself in the chat. We've muted participants and turned off your videos to minimize technical issues, so we encourage you to use the chat to say hello instead

Questions or Comments?

- Add them to the chat
- Raise your hand and we'll unmute you

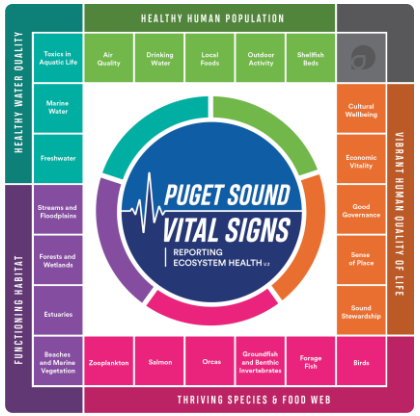


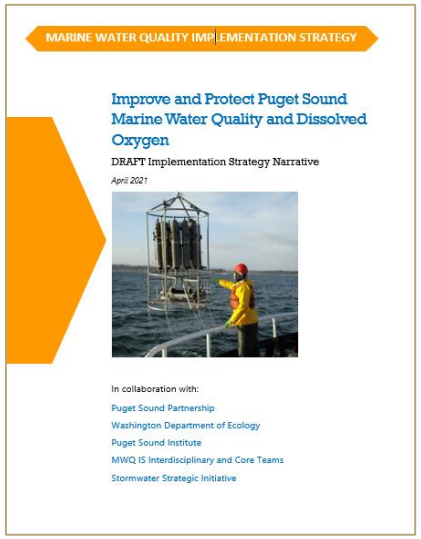
The slides, recording, and summary will be available on [Puget Sound Institute's website]

Land Acknowledgement

University of Washington Puget Sound Institute's Role

Puget Sound Partnerships' Marine Water Quality Implementation Strategy





Technical Uncertainties

Research, Modeling, and Monitoring to Reduce Uncertainties

Nutrient Science Community in Puget Sound

PUGET SOUND INSTITUTE
UNIVERSITY of WASHINGTON | TACOMA

SALISH SEA MODELING CENTER
UNIVERSITY of WASHINGTON

Help address technical uncertainties and advance modeling tools to assist decision-making.

- Facilitate scientific workshops and regional collaboration
- Convene Model Evaluation Group
- Lead complementary model runs
- Expand access to models, outputs, tools, and scientific knowledge

Refine Research Actions

Targeted Technical Uncertainties

- Improve confidence in modeling of the Salish Sea and share findings
- Kickoff (7/26)
- Tools to Evaluate Water Quality (9/29)
- Biological integrity of key habitats and species (10/6)

Upcoming Workshops

- **Sediment exchange** *(10/17)*
- **Phytoplankton and primary production** *(11/2)*
- **Change in interannual variability of rivers and ocean impact** *(week of 11/14)*
- **Improve watershed modeling to evaluate source reduction strategies to adaptively manage strategies** *(week of 12/12)*

Improved Confidence in Actions

Driving Scientific Question

When and where does sediment have an important impact on nitrogen cycling and low dissolved oxygen impacts?

David Shull

Western Washington University

Pamatmat and Banse, 1969

OXYGEN CONSUMPTION BY THE SEABED. II. *IN SITU* MEASUREMENTS TO A DEPTH OF 180 m[1]

Mario M. Pamatmat and Karl Banse
Department of Oceanography, University of Washington, Seattle 98105

ABSTRACT

Oxygen consumption by the seabed in Puget Sound was measured *in situ* in bell jars pushed into the bottom while monitored by television. Eleven stations were visited irregularly between January and August 1967. Depths ranged from 11 to 180 m, and sediment varied from coarse sand to mud. Observed short-term rates were between 4 and 40 ml O_2 m^{-2} hr^{-1} and were unrelated to depth (pressure), mean grain size, fine fraction of the sediment, organic matter or organic nitrogen in the upper 0.5 cm, or the biomass of macrofauna. Temperature accounted for only about 30% of the total variation in rates. We suggest that the seasonal changes of rates, and possibly the differences between stations, are caused primarily by changes of activity of small organisms as governed by the rate of supply of organic matter from the plankton. Estimates of annual rates of oxidation of organic matter on the seabed correspond to 17 and 25% of the phytoplankton production (^{14}C uptake) near the stations in northern and southern Puget Sound, respectively.

Sheibley and Paulson (2014) review

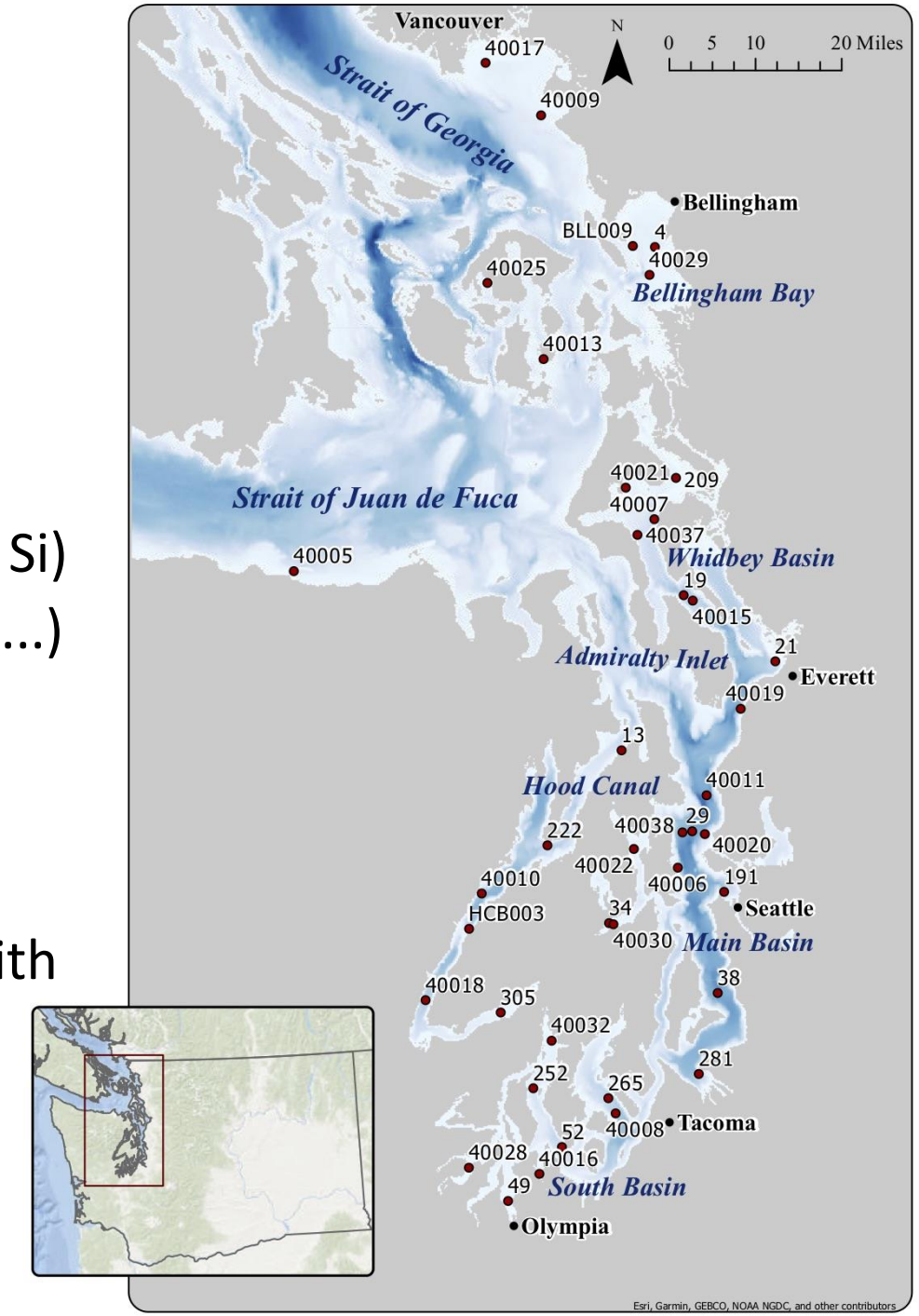
Table 1. General site information for benthic chamber sites in Puget Sound, Washington.

[For detailed site metadata, see table A1]

Station/site identifier	Date sampled	Depth (meters)	Study details	Reference
Carkeek pelagic site (PS17)	June 8–9, 1982	175	Single site, measured once	Murray (1982)
Carkeek pelagic site	Unknown	200	Single site, measured once	Grundmanis (1989)
Holmes Harbor	August 1993	50–70	Three sites, measured once	Brandes and Devol (1997)
Dabob Bay	January 1987–January 1988	110	Single site, measured 20 times during the year	Colbert and others, unpub. data (2010)
Budd Inlet	September 1996–September 1997	5–15	Four sites measured 17–19 times during the year	Aura Nova Consultants and others (1998)
Case Inlet	September–October 2007	5–25	Three depths measured 3 times	Roberts and others (2008)
Carr Inlet	September–October 2007	5–25	Three depths measured 3 times	Roberts and others (2008)
Eld Inlet	September–October 2007	5–25	Three depths measured 3 times	Roberts and others (2008)
Budd Inlet	September–October 2007	3–25	Three depths measured 3 times	Roberts and others (2008)
Quartermaster Harbor	September 1–2, 2010	4–17	Five sites measured once	King County (2012)

Benthic solute fluxes in Puget Sound

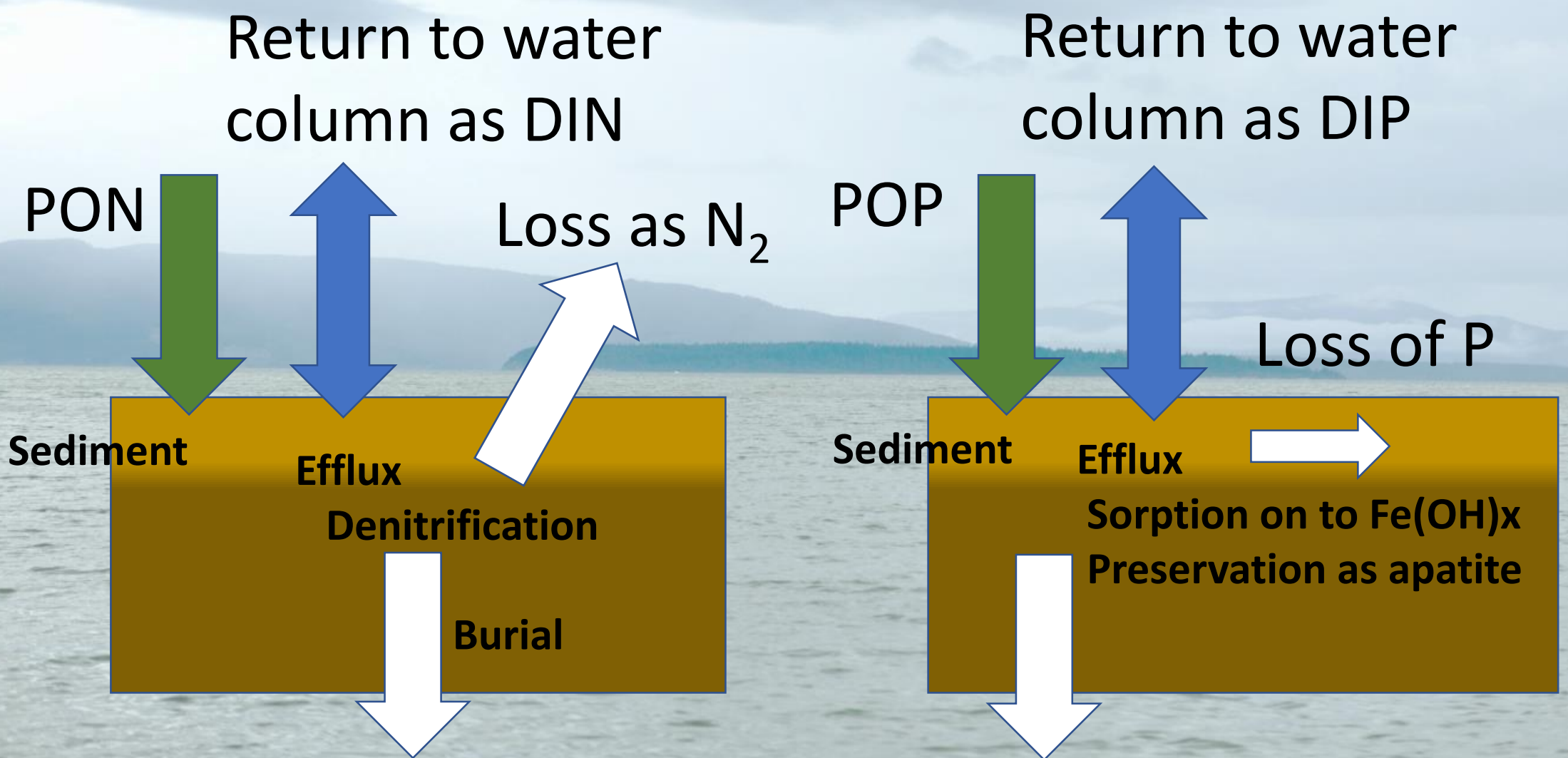
- Large-scale survey (April and May 2018)
  - 40 stations (duplicate flux cores)
  - DO, DIC, pH (alkalinity), NH_4^+, NO_2^-+NO_3^-, P, Si)
  - Environmental variables (T, S, grain size, OC...)
- Bellingham Bay survey (June 2017)
  - 25-station survey
  - Seasonal survey at one station
  - 15-years of water column nutrient work (with undergraduate students)
- Sources of uncertainty and next steps



Acknowledgements

- Dept. of Ecology Sediment Monitoring Team
- Graduate student Emma (Rigby) Santana
- Undergraduates Everitt Merritt, Ryan McGinnis, Spencer Johnson
- Recent collaborators: Sam Kastner (WWU), Kal Delong, Riley Heath

Potential pathways for N & P - recycling efficiency



Processes that consume oxygen and release DIC and nutrients

- Aerobic respiration (consumption of organic matter)
- Oxidation of reduced byproducts of anaerobic respiration
- Sulfate reduction can account for ~50% of organic matter oxidation
- DIC and DO fluxes do not always correlate

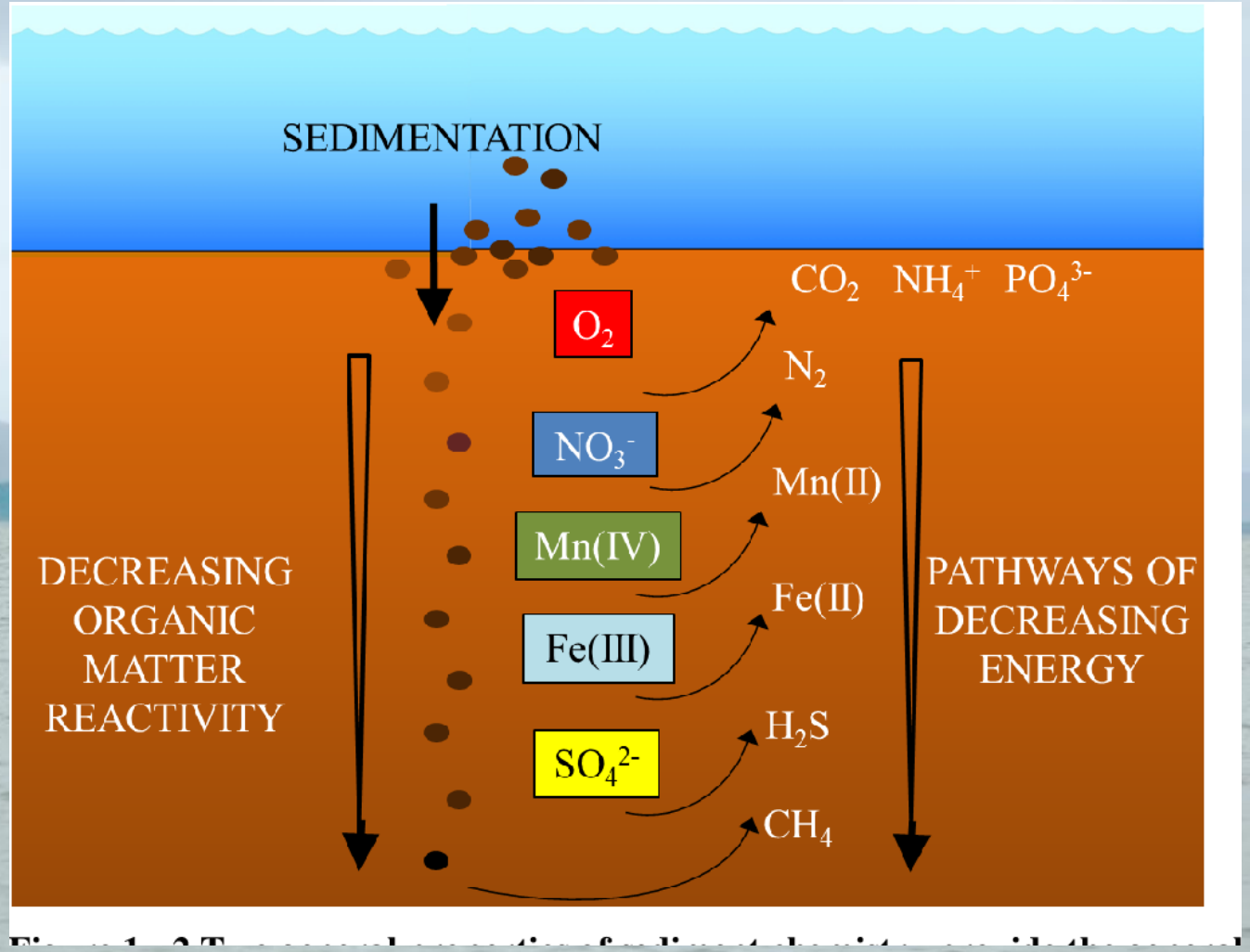
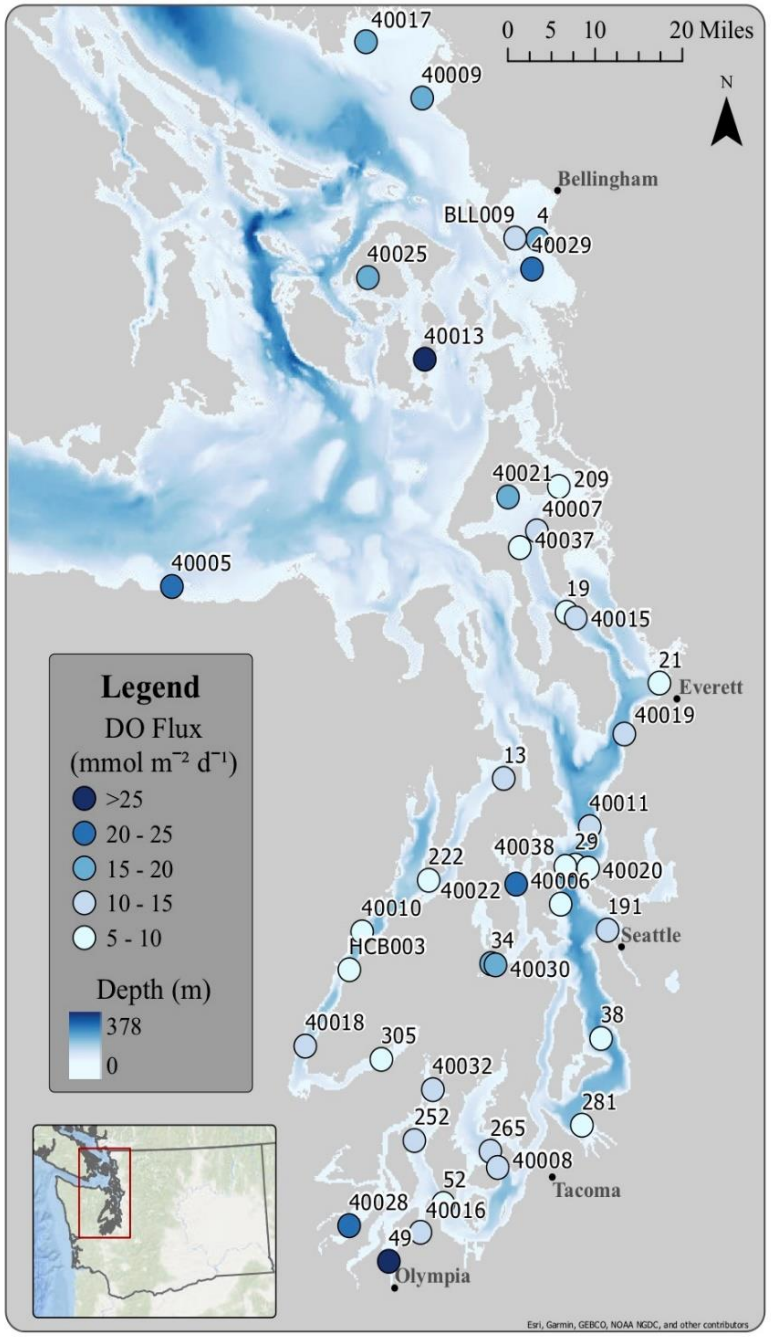


Figure from Paraska 2016


1


0 5 10 20 Miles
N
Bellingham
Everett
Seattle
Tacoma
Olympia
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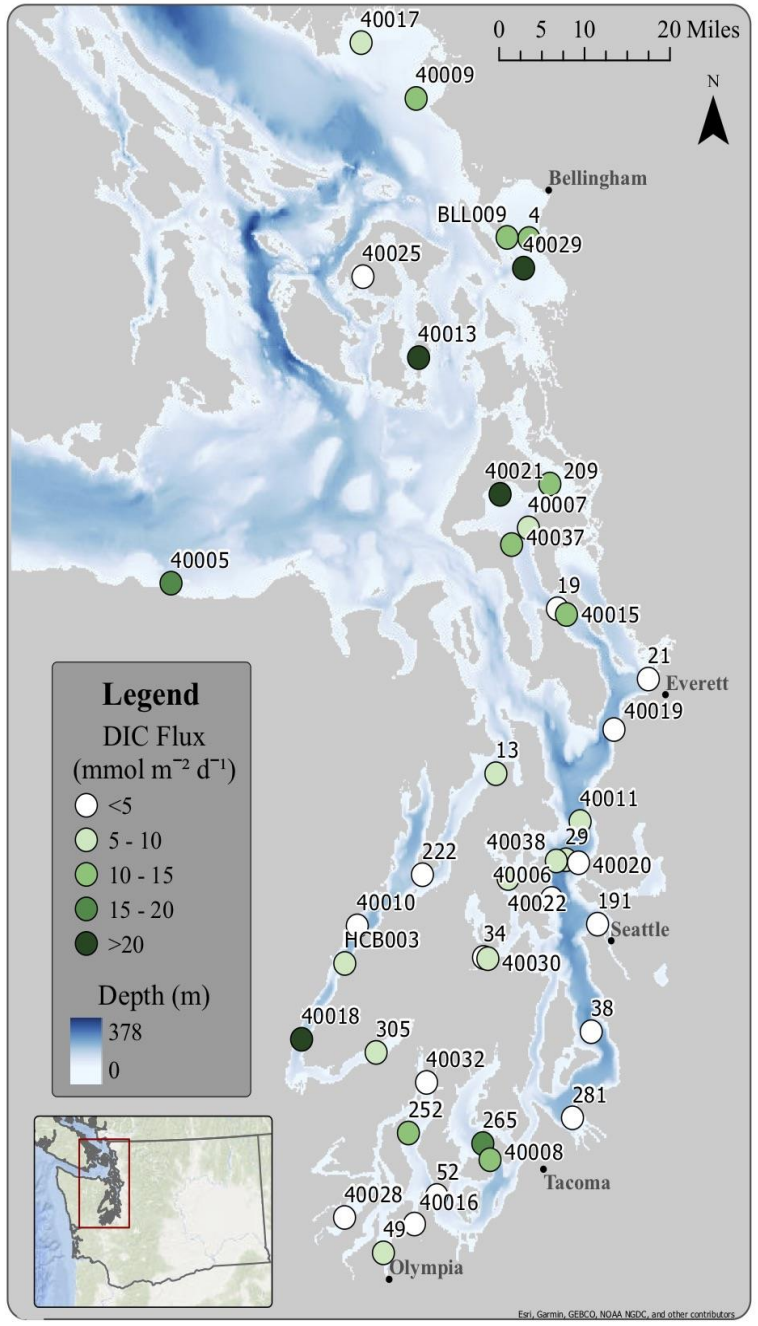
40009
BLL009
4
40029
40025
40013
40021
209
40007
40037
40005
19
40015
21
40019
13
40011
222
40038
29
40020
40022
40006
40010
191
HCB003
34
40030
40018
305
38
40032
281
252
265
40008
52
40028
40016
49
Legend
DO Flux
(mmol m⁻² d⁻¹)
>25
20 - 25
15 - 20
10 - 15
5 - 10
Depth (m)
378
0
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors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40032
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265
40008
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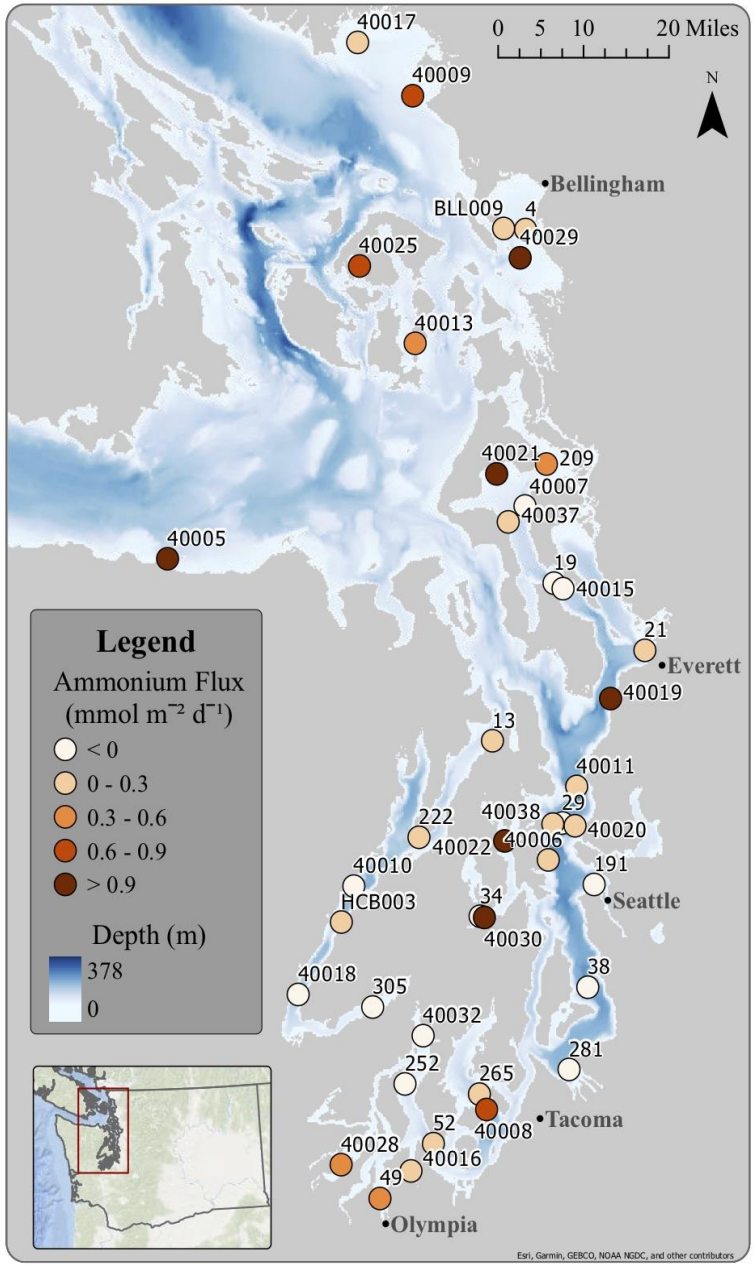
40028
40016
49
Legend
DIC Flux
(mmol m⁻² d⁻¹)
<5
5 - 10
10 - 15
15 - 20
>20
Depth (m)
378
0
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors


0 5 10 20 Miles
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Everett
Seattle
Tacoma
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40007
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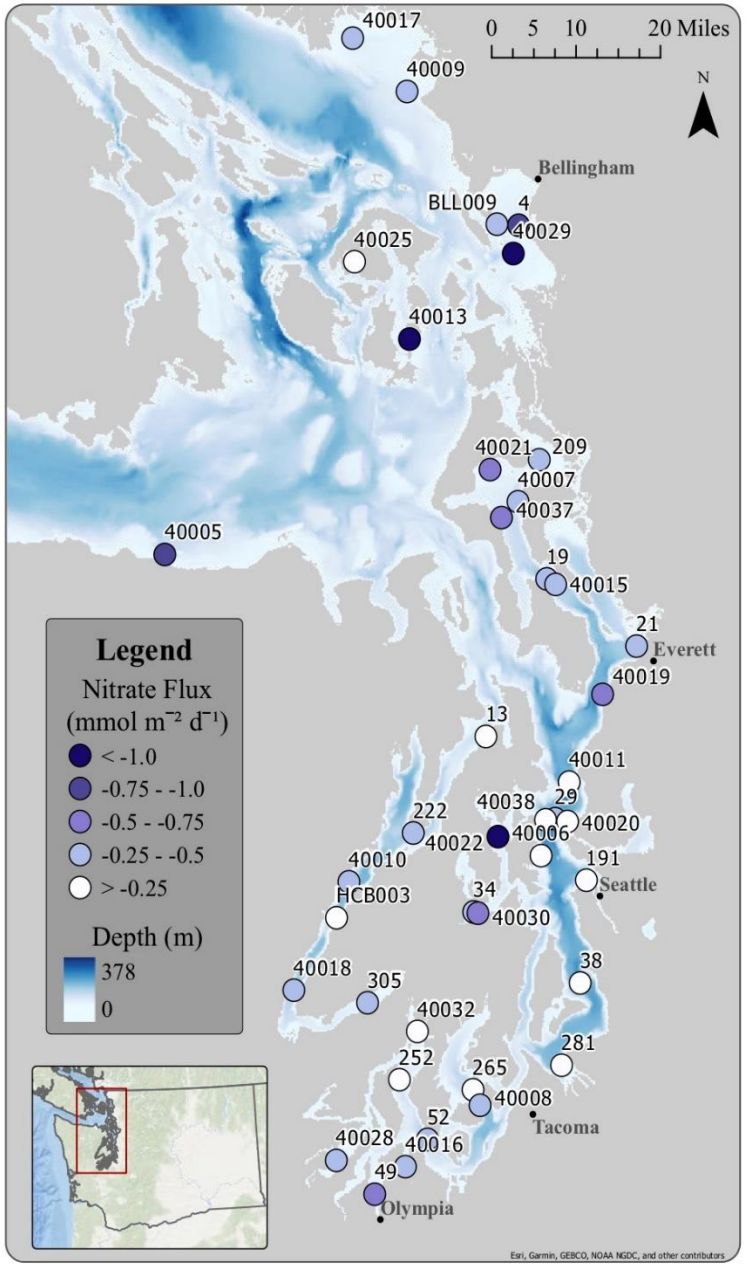
40010
191
HCB003
34
40030
40018
305
38
40032
281
252
265
52
40008
40028
40016
49
Legend
Ammonium Flux
(mmol m⁻² d⁻¹)
< 0
0 - 0.3
0.3 - 0.6
0.6 - 0.9
> 0.9
Depth (m)
378
0
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors


0 5 10 20 Miles
N
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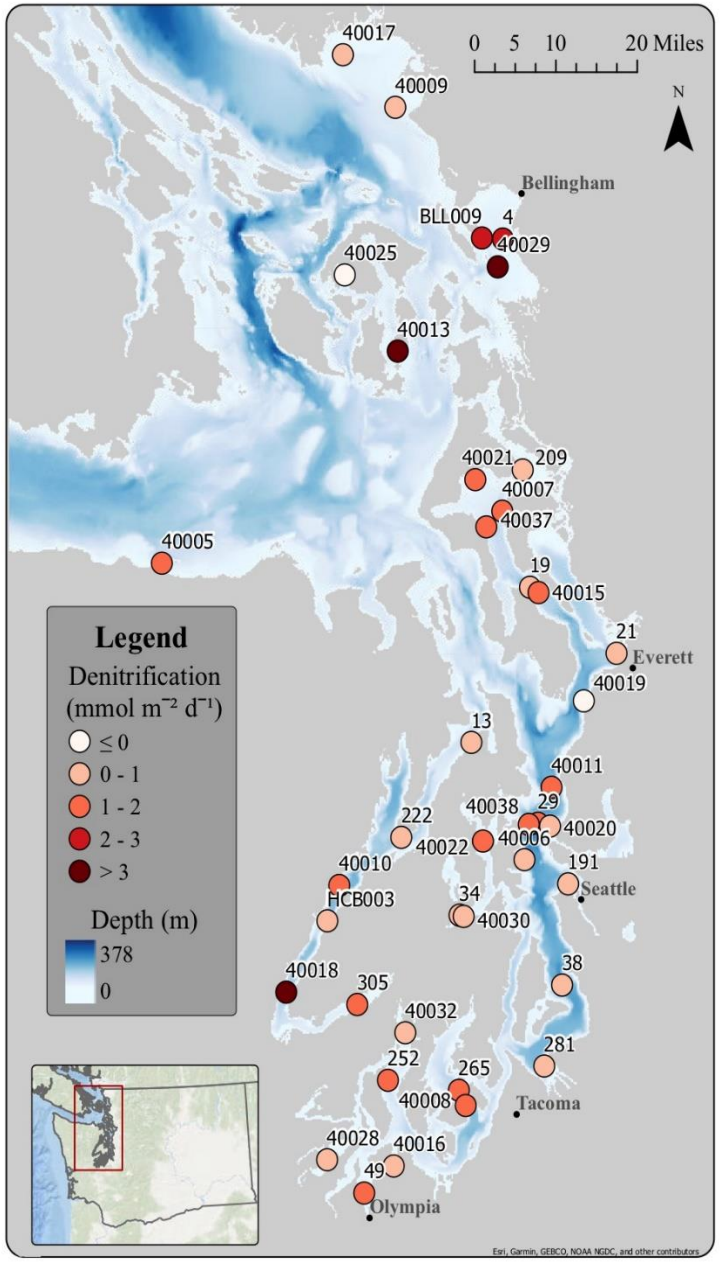
191
HCB003
34
40030
40018
305
38
40032
281
252
265
40008
52
40028
40016
49
Legend
Nitrate Flux
(mmol m⁻² d⁻¹)
< -1.0
-0.75 - -1.0
-0.5 - -0.75
-0.25 - -0.5
> -0.25
Depth (m)
378
0
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors


0 5 10 20 Miles
N
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Seattle
Tacoma
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40010
191
HCB003
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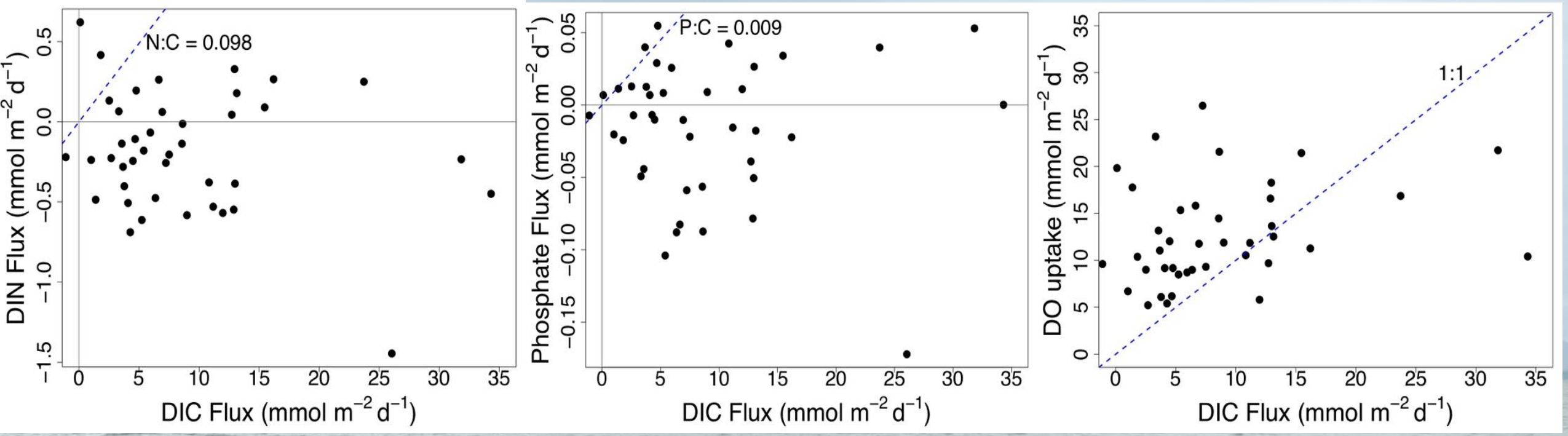
40030
40018
305
38
40032
281
252
265
40008
40028
40016
49
Legend
Denitrification
(mmol m⁻² d⁻¹)
≤ 0
0 - 1
1 - 2
2 - 3
> 3
Depth (m)
378
0
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

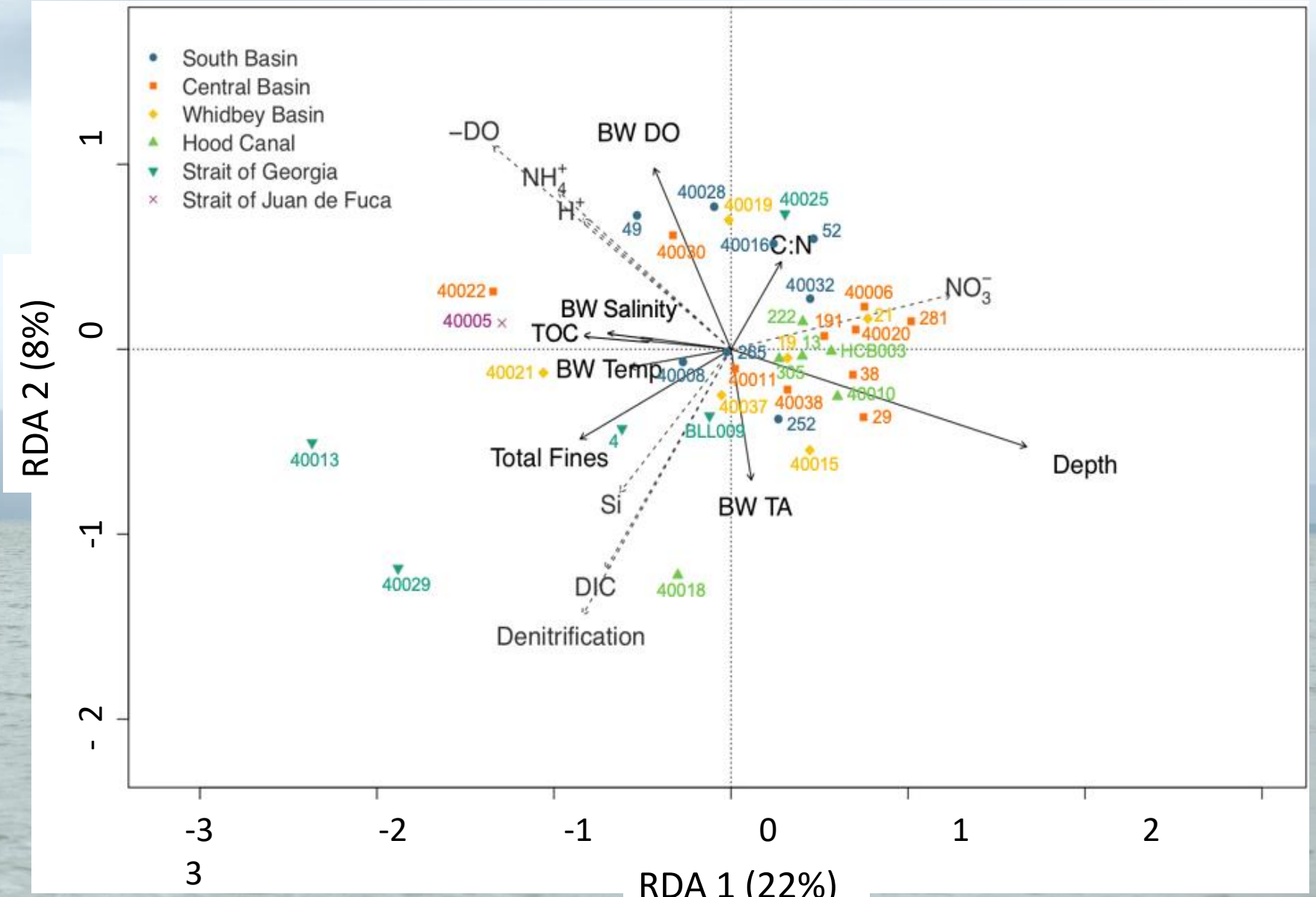
Correlations with DIC in spring 2018



- Dotted lines: N:C ratio in bottom water organic matter, P:C Redfield ratio
- Nutrient fluxes do not correlate with organic matter mineralization rates
- DO vs DIC plot suggests sediments have an oxygen demand “memory”

Sources of variation in solute fluxes

- DO flux: Water depth and bottom water DO
- DO flux correlates with H^+ flux
- DIC correlates with Si flux



Sediment contributions to water quality in spring

Average rates of dissolved oxygen consumption among basins

(Units: mmol O_2 m^{-3} d^{-1})

Basin	Water Column	Benthos	% Removed by sediment
Main	?	0.13	7.5%?
Whidbey	1.7 (a)	0.19	10%
South Sound	2.2 (a)	0.5	18.4%
Hood Canal	0.92 (s)	0.22	19.4%

(a) From Apple (2019) report, April and May averages. (s) From Shull et al. July average

Sediment contributions to water quality in spring

Basin	Percent DIN supply removed by denitrification*	Percent phosphorus stored in sediments**
Main	1.2%	94 ± 37%
Whidbey	2.8%	136 ± 46%
South Sound	2.7%	146 ± 37%
Hood Canal	10.9%	111 ± 43%

* DIN supply = Avg deep-water DIN/Avg basin residence time (from Babson et al. 2006)

** Comparison of DIC to P flux, assuming Redfield proportions of C and P

Sediment contributions to water quality in spring

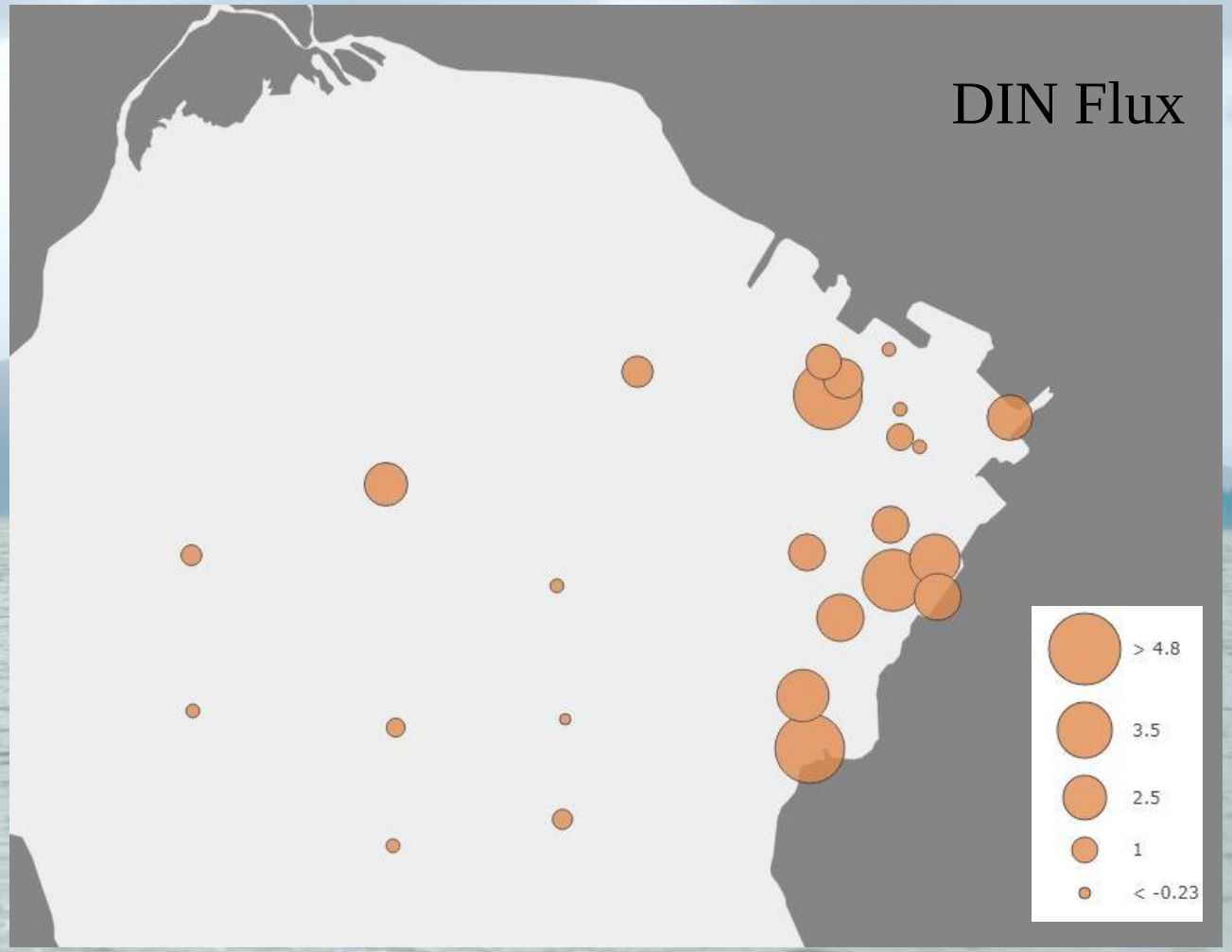
Basin	Denitrification mmol/m2/d	Nitrogen burial mmol/m2/d*
Main	0.76	3.0
Hood Canal	1.3	1.15

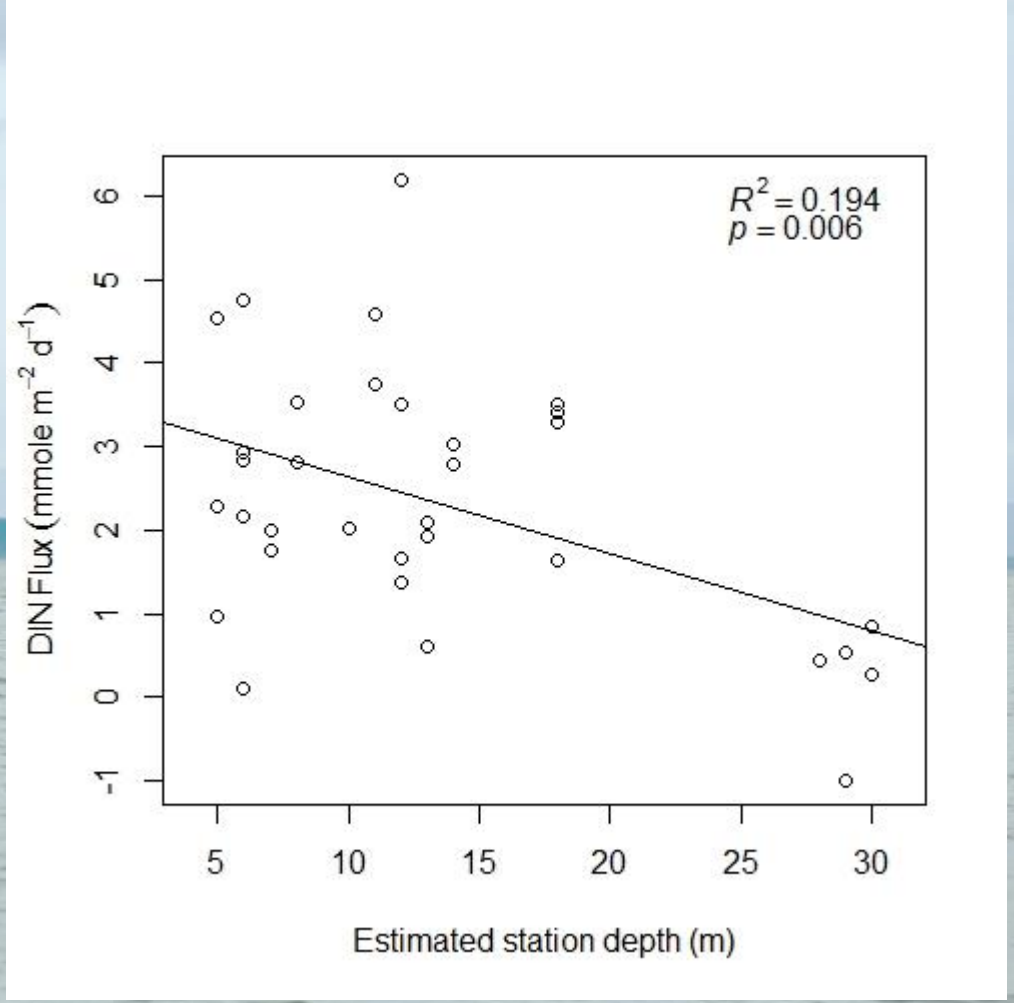
*Data from Brandenberger et al. (2008), (mass accumulation rate)(N/mass sediment). Two locations in the Main Basin and Hood Canal

Solute fluxes in an urban estuary

- Bellingham Bay – a classic estuary
- Sources of nitrogen: Deep water, Nooksack R, Post Point WWTP
- 25 stations with duplicate flux cores
- Samples collected in June (after spring phytoplankton bloom)
- Seasonal study at one site

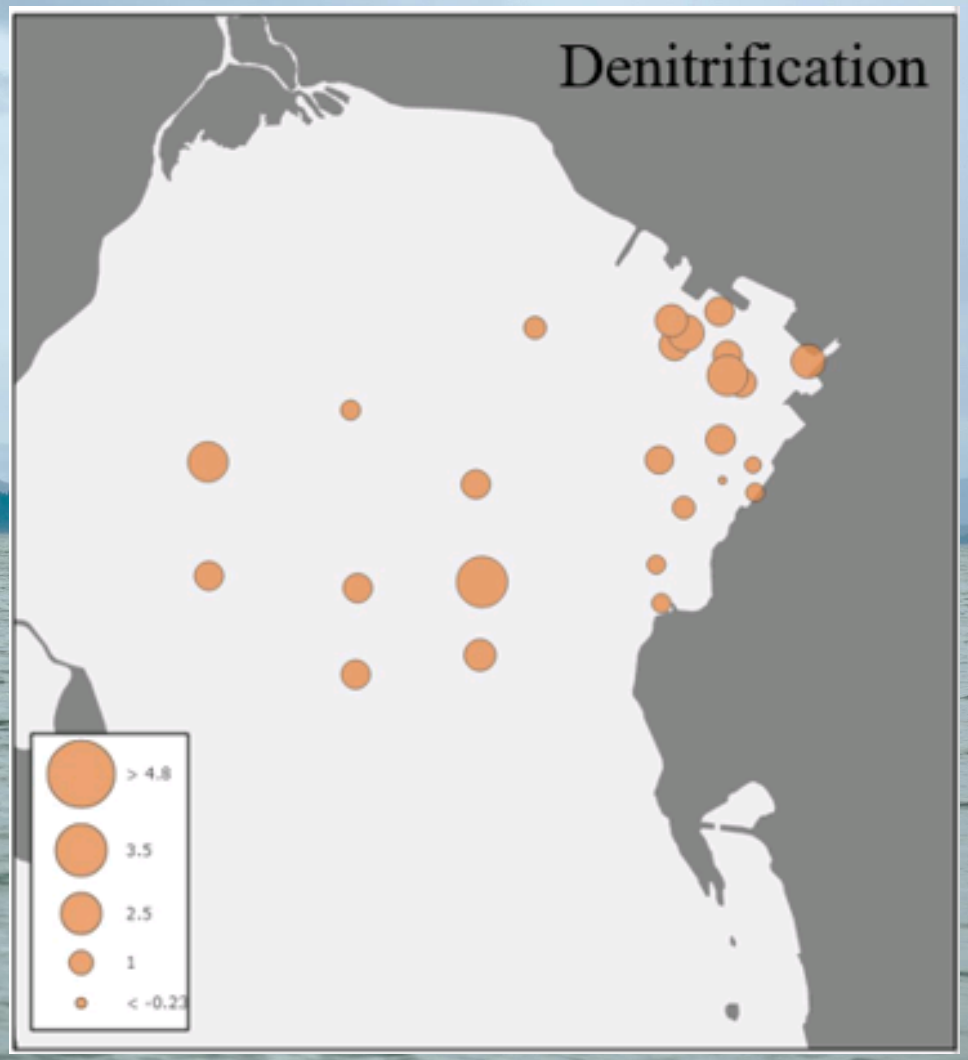
DIN Flux: More DIN released nearshore





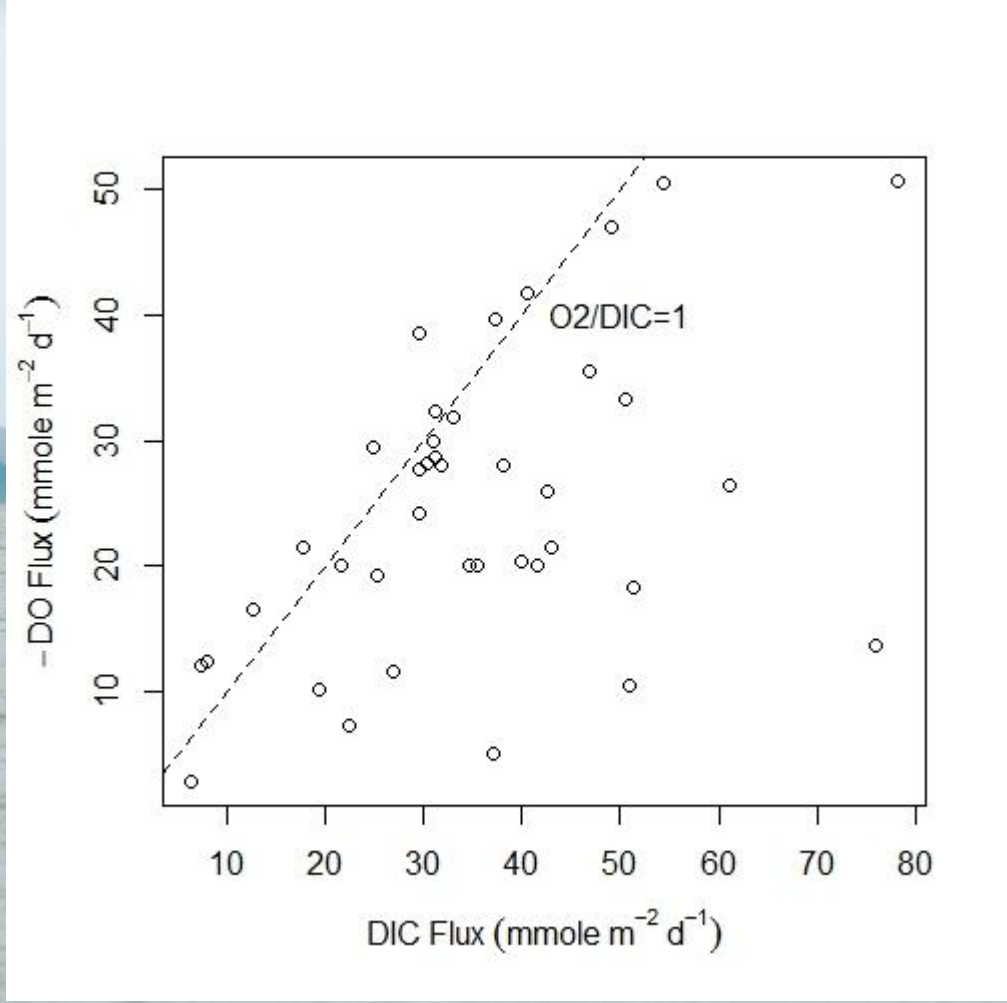
Estimated rates of denitrification

- Rates are more spatially uniform
- Average rate: 2.9 mmol N m^{-2} d^{-1} assuming Redfield C:N ratio
- Median rate in Puget Sound 1.05 mmol N m^{-2} d^{-1}

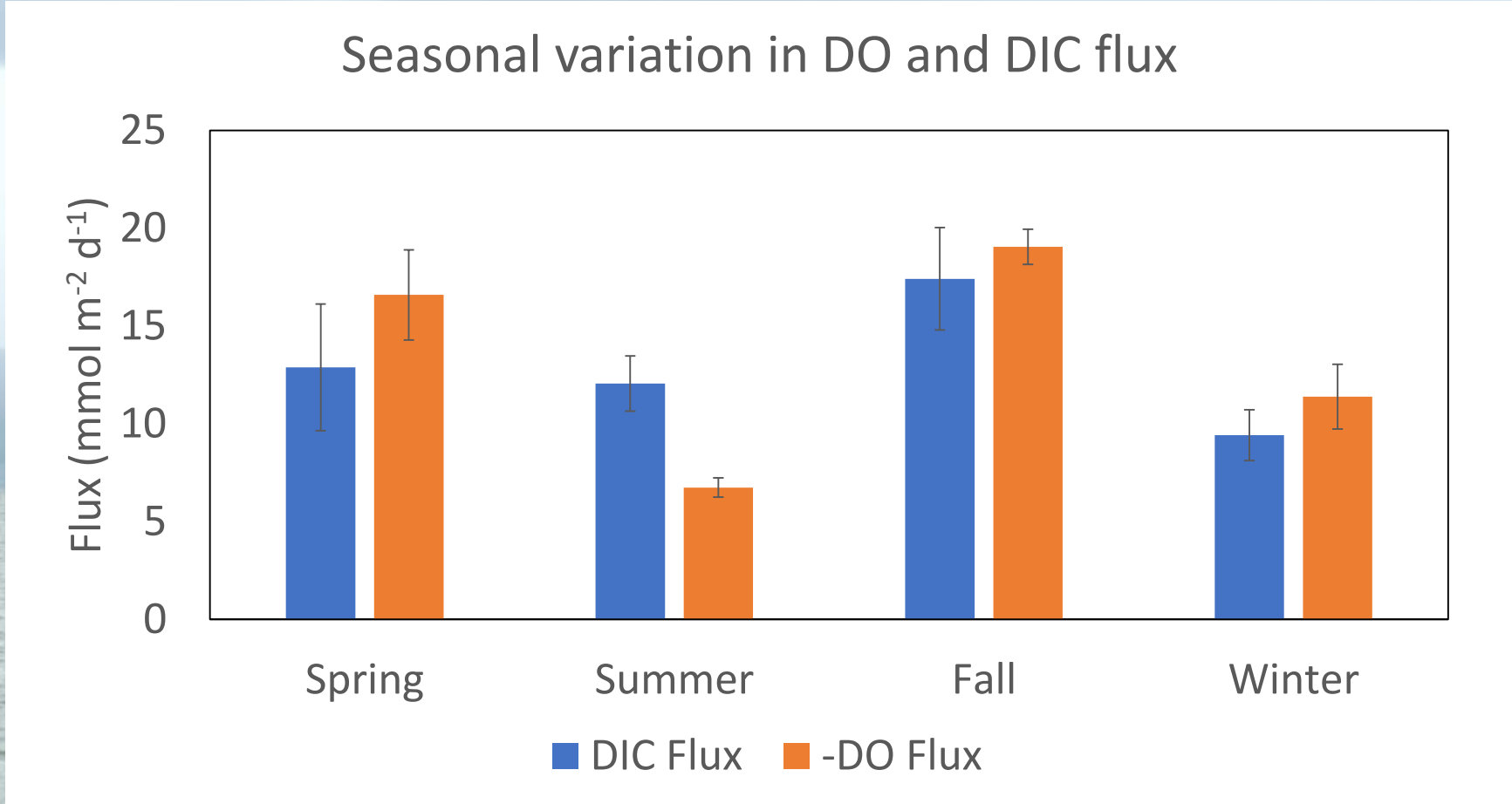


Oxygen flux low compared to DIC flux

- Dashed line: 1:1 ratio
- Suggests storage of sulfides and other reduced compounds (such as FeS)
- Expect seasonal storage and reoxidation of reduced compounds, particularly sulfides



Seasonal variation in DIC and DO fluxes



Role of sediments in Bellingham Bay N cycle

Sources of DIN to Bellingham Bay, spring 2022 (ESCI 322)

Source	Input (mol N/d)	(% input)
Nooksack River	1.6×10^5	3.8
Post Point WWTP	7.5×10^4	1.8
Deep-water inflow	1.07×10^6	94.4

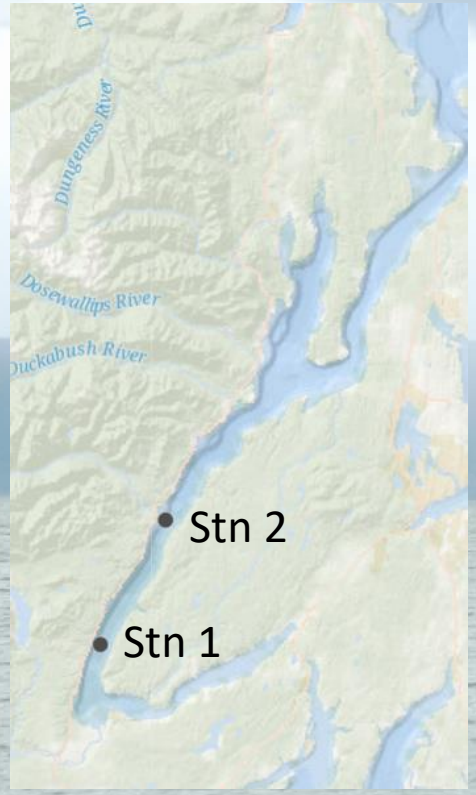
Removal of DIN by denitrification (mol N/d)*	% of total input
1.46×10^5	11.2%

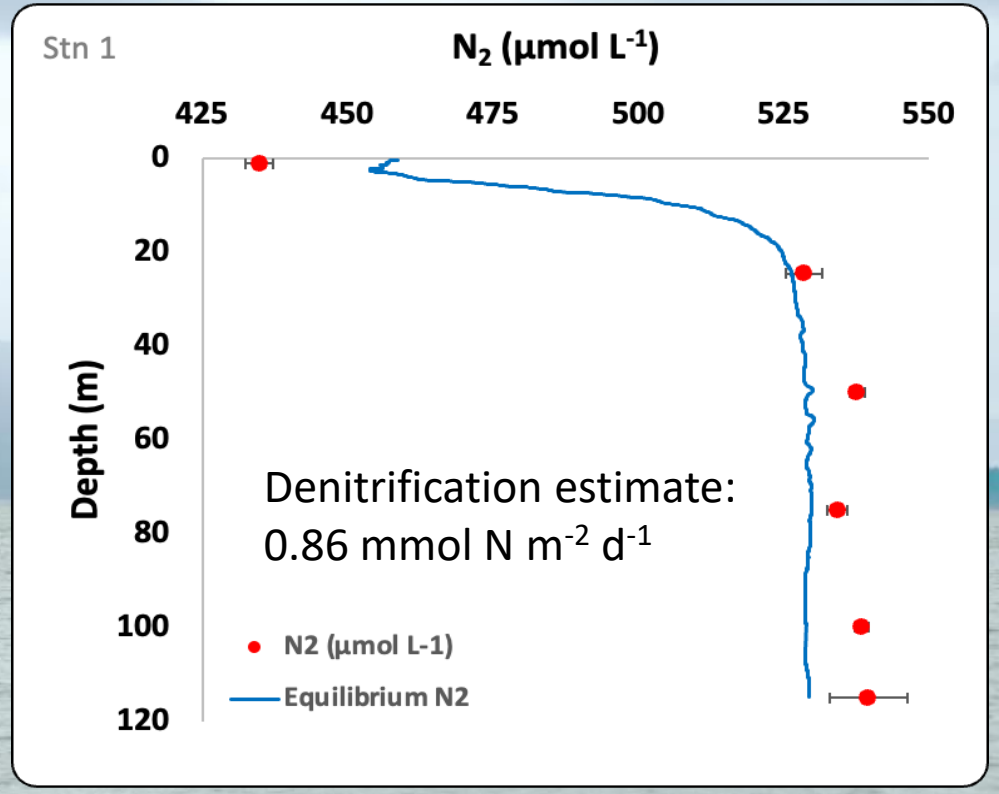
*Denitrification rate multiplied by area of bottom sediments in study region

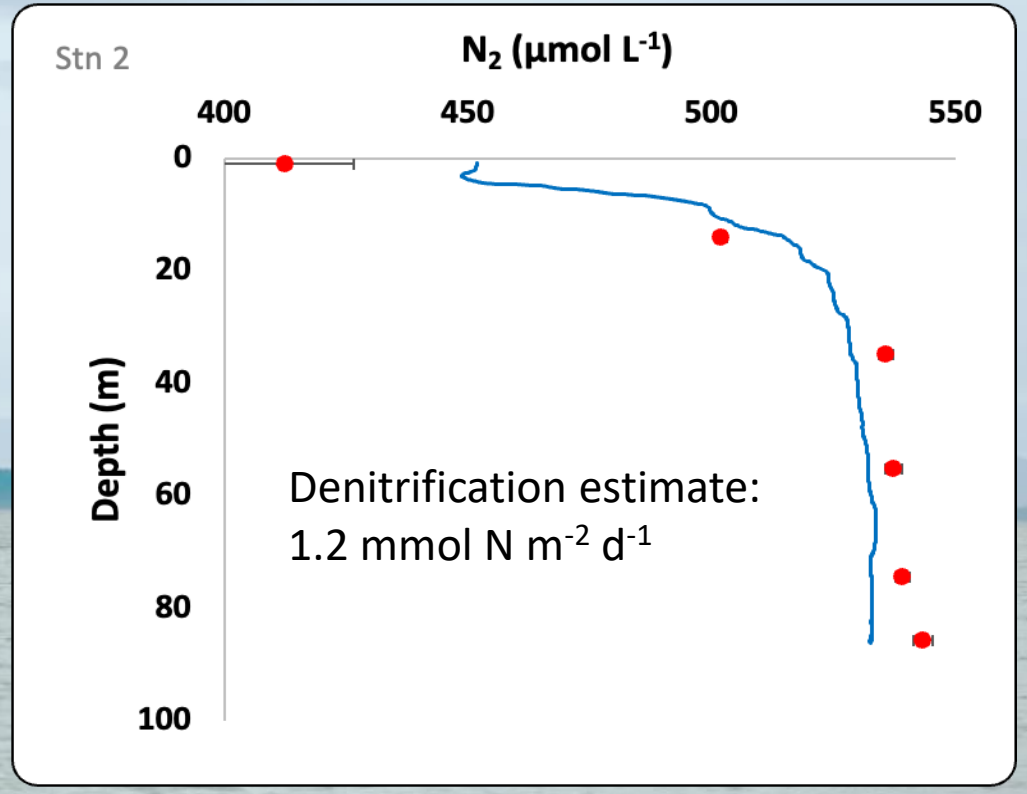
Gaps in understanding sediment fluxes

- Need seasonal measurements, particularly from deep basins
- Sediment cores show high variability among replicates
- Sulfate reduction and sulfide oxidation strongly influence DO uptake
- The reason for spatial variation in denitrification is not understood. (Not correlated with organic matter remineralization rate.)
- Burial of N may be significant but few estimates

Water column estimates of denitrification in Hood Canal = $K_e(dN/dz)$



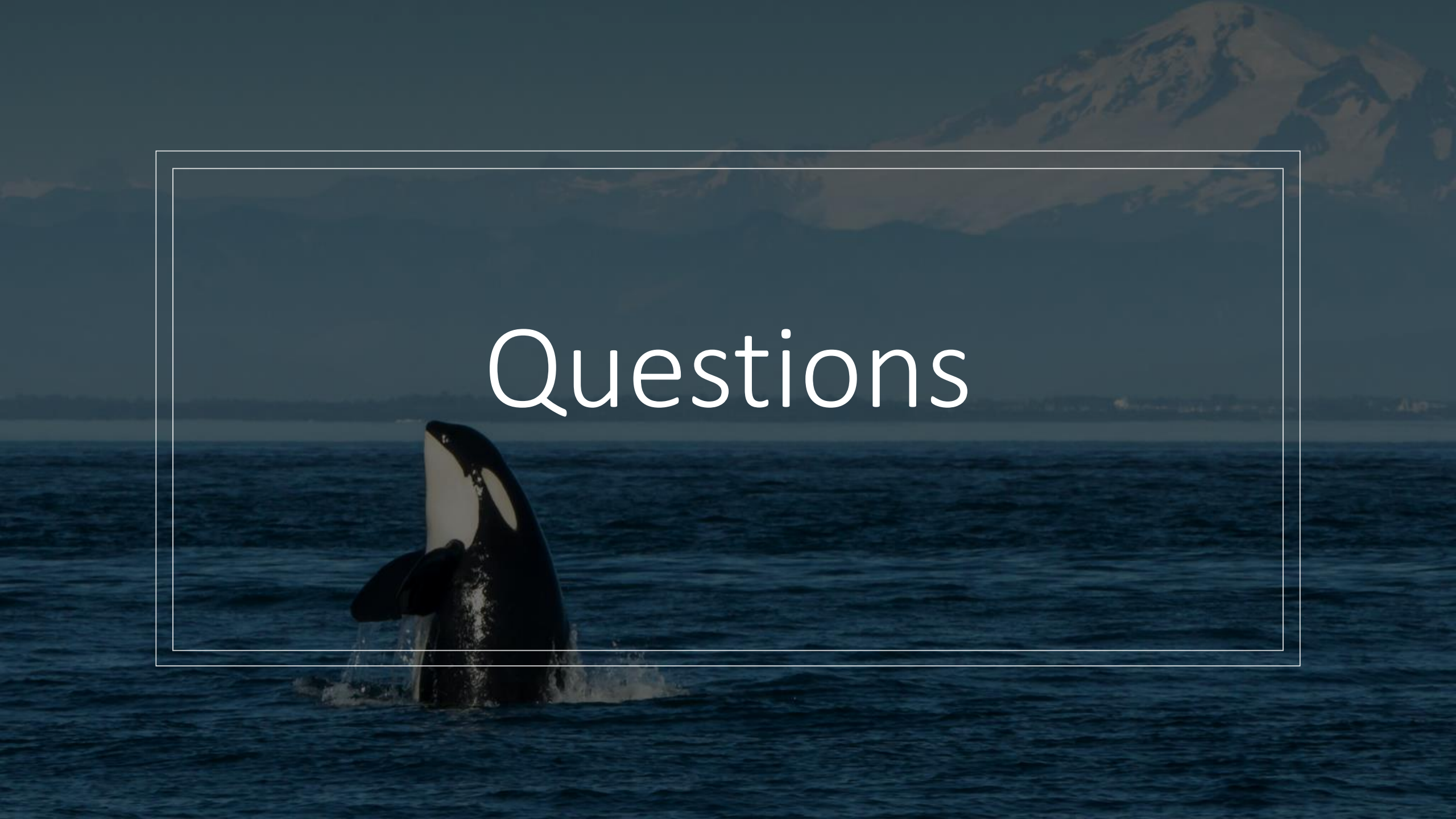




Range of denitrification rates from core incubations in this region: 0.6 - 3.26 mmol m^{-2} d^{-1}

Take-home messages

- Sediments contribute nearly 20% of oxygen demand in some basins of Puget Sound
- Sediments have an oxygen demand “memory” that decouples DO consumption from organic matter mineralization
- Sulfate reduction and sulfide oxidation play important roles
- Denitrification and burial remove a significant fraction of N in Hood Canal due its long residence time. Denitrification also important in shallow bays such as Bellingham Bay
- Seasonal data are needed to better quantify the role of sediment-water exchange on nitrogen and dissolved oxygen
- Burial rates of N may be significant (≈ rates of denitrification)



Questions

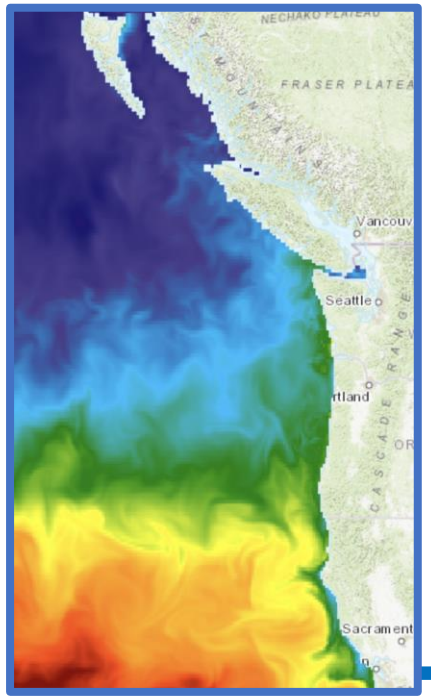
Benthic Fluxes in the LiveOcean Model

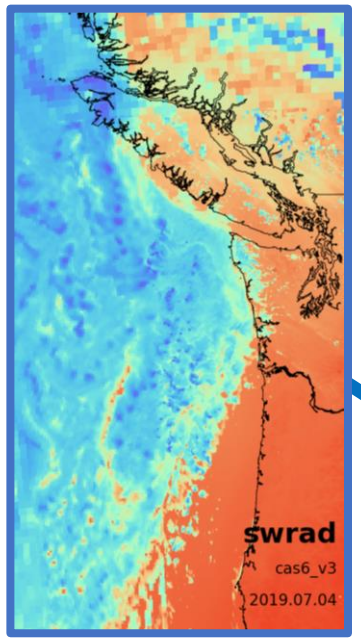
Parker MacCready & Samantha Siedlecki

Univ. Washington, Univ. Connecticut

LiveOcean System Overview

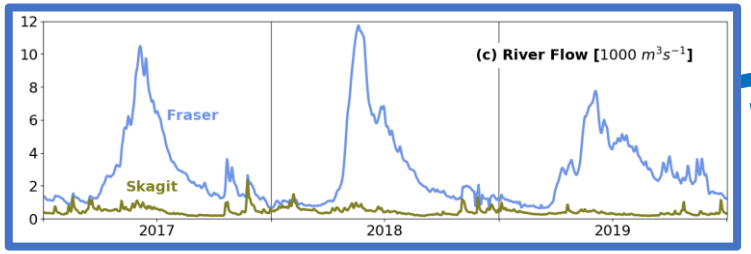
3-Day forecast appears daily on NANOOS NVS





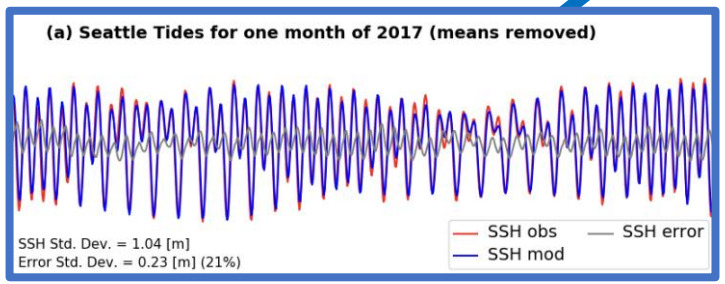
WRF Winds & Heating

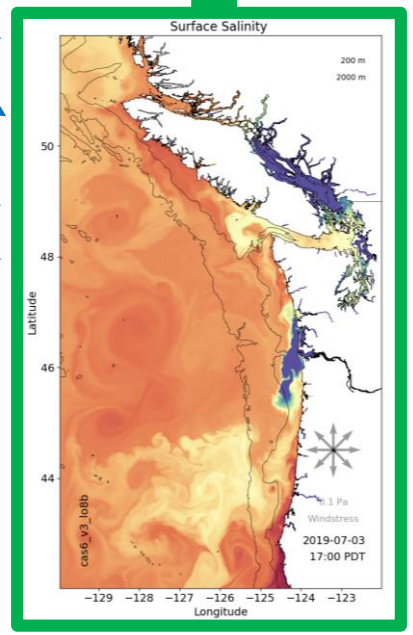
HYCOM Ocean Fields



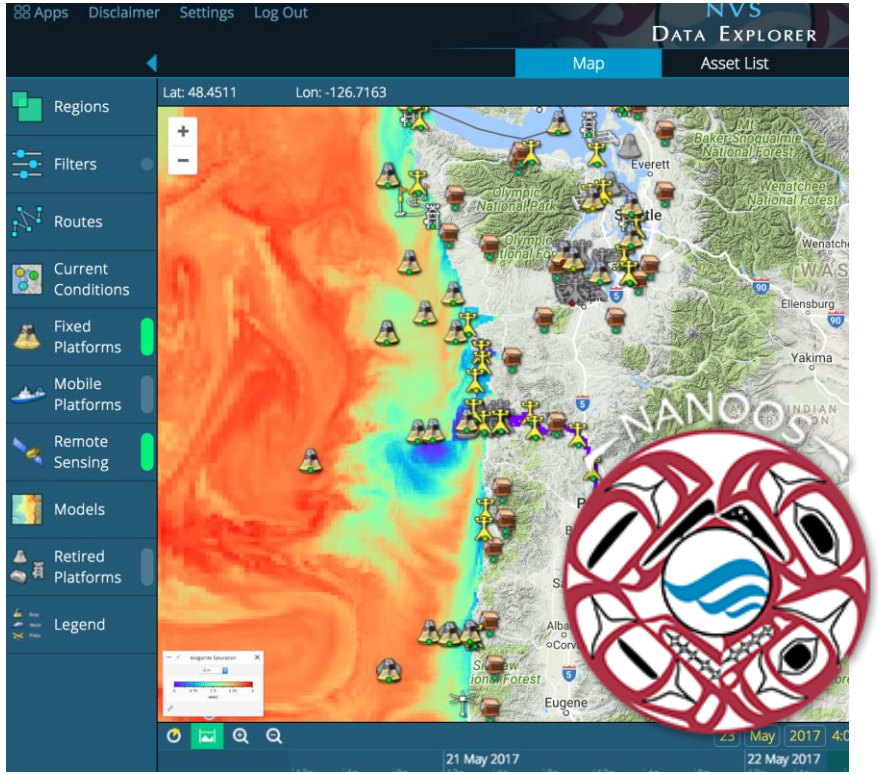
USGS & Canadian Rivers

TPXO Tides





ROMS

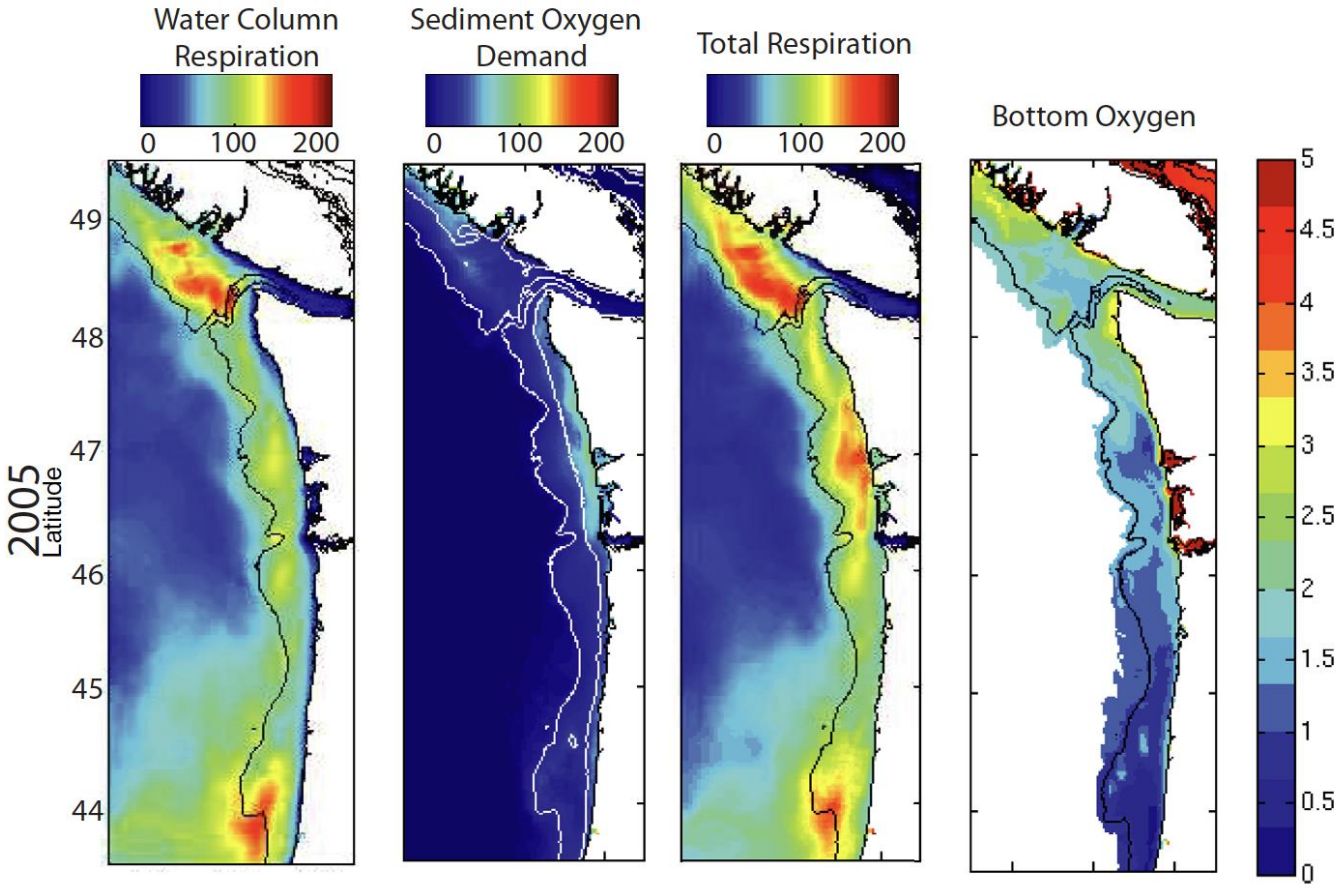


Also see: faculty.washington.edu/pmacc/LO/LiveOcean.html

LiveOcean Benthic Fluxes

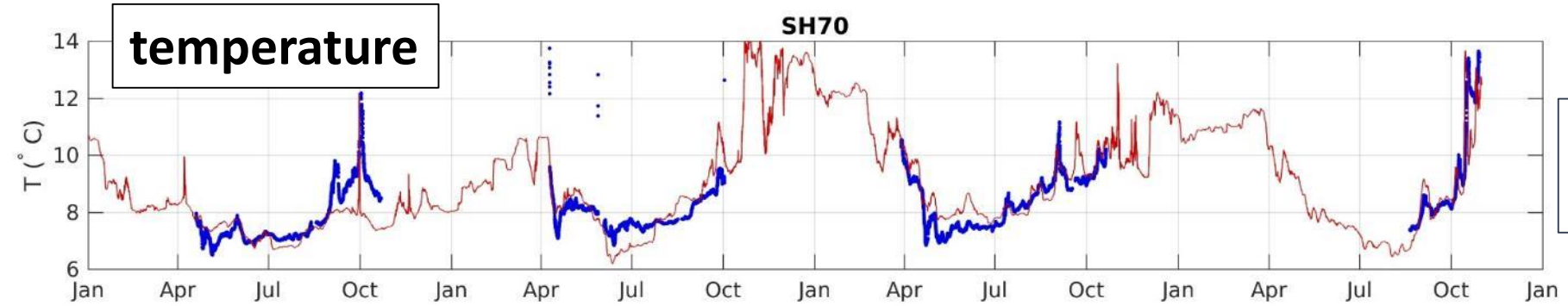
- NPZD-O Model is described in Siedlecki at al. (2015)
- Organic particles (N units) sink at 8 and 80 m/day
- For flux “F” of organic particles that get to the sea floor:
- Generally, we use “instantaneous remineralization” of F back to NH_4 and DO is lost at at rate of (108/16)F
- There is also a steady drawdown of bottom NO_3 of 1.2 mmol N m-2 day-2 (if F can support it)
- If instead bottom water has very low DO, we assume denitrification, and bottom NO_3 is lost at a rate F
- All based on observations on the WA shelf in Fuchsman et al. (2015)

In general water column remineralization is greater than benthic

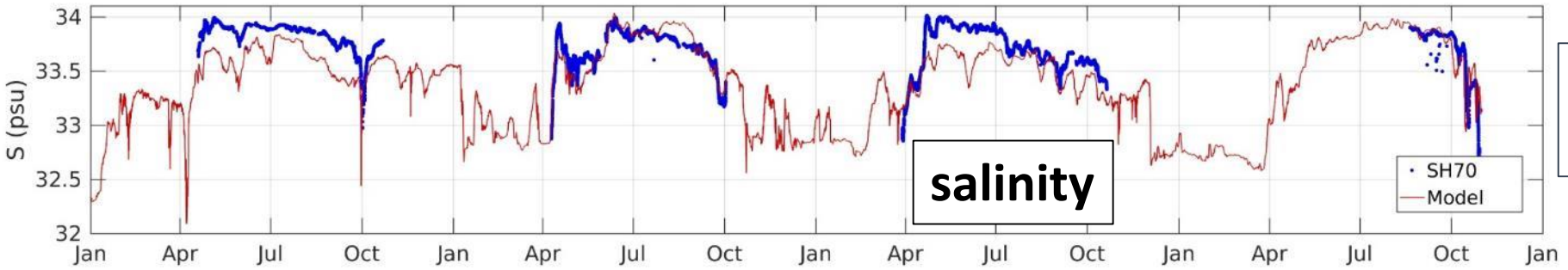


Model-Observation Comparison

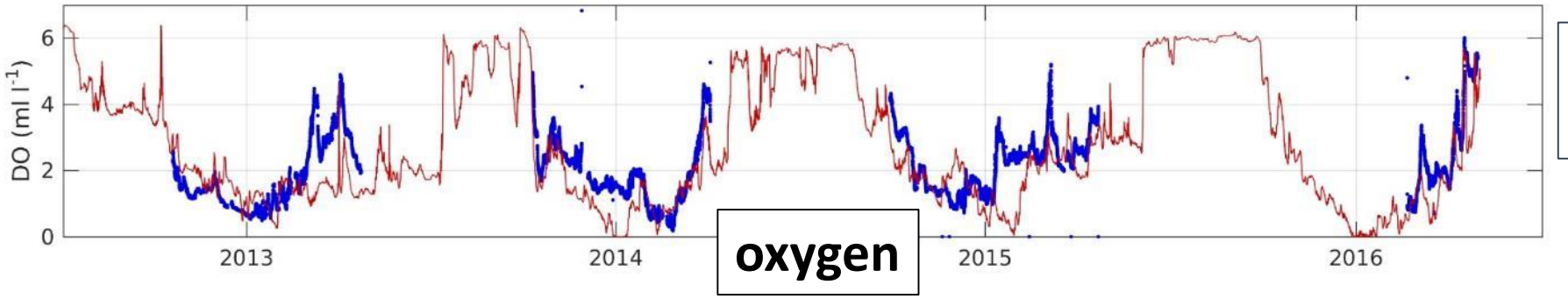
Mid-shelf, on-bank mooring: T, S, Dissolved Oxygen



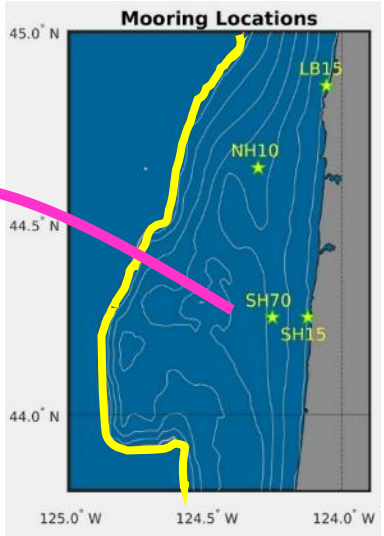
Corr.coef = 0.81
RMS diff. = 0.68
Bias(M-O) = 0.06



Corr.coef = 0.71
RMS diff. = 0.19
Bias(M-O) = -0.11



Corr.coef = 0.63
RMS diff. = 0.96
Bias(M-O) = -0.50



Source: Jack Barth and Scott Durski (OSU)

Likely differences between the shelf and the Salish Sea

- Less wave resuspension of bottom sediment
- Estimate 20% (or less) burial of organic matter
- And...

Benthic Flux References

- Shull, D. H. (2021). Sources of Corrosive Bottom Water to Bellingham Bay, Washington State. *Estuaries and Coasts, 44*(5), 1250-1261. doi:10.1007/s12237-020-00859-1
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- Belley, R., Snelgrove, P. V., Archambault, P., & Juniper, S. K. (2016). Environmental Drivers of Benthic Flux Variation and Ecosystem Functioning in Salish Sea and Northeast Pacific Sediments. *PloS one, 11*(3), e0151110. doi:10.1371/journal.pone.0151110
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- Archer, D., & Devol, A. (1992). Benthic oxygen fluxes on the Washington shelf and slope: A comparison of in situ microelectrode and chamber flux measurements. *Limnology and Oceanography, 37*(3), 614-629. doi:10.4319/lo.1992.37.3.0614
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Stefano Mazzilli

Topics to Cover

- Sediment module in Salish Sea Model
- Validation with observed data
- Existing Salish Sea Model analysis and sensitivity
- Proposed modeling analysis

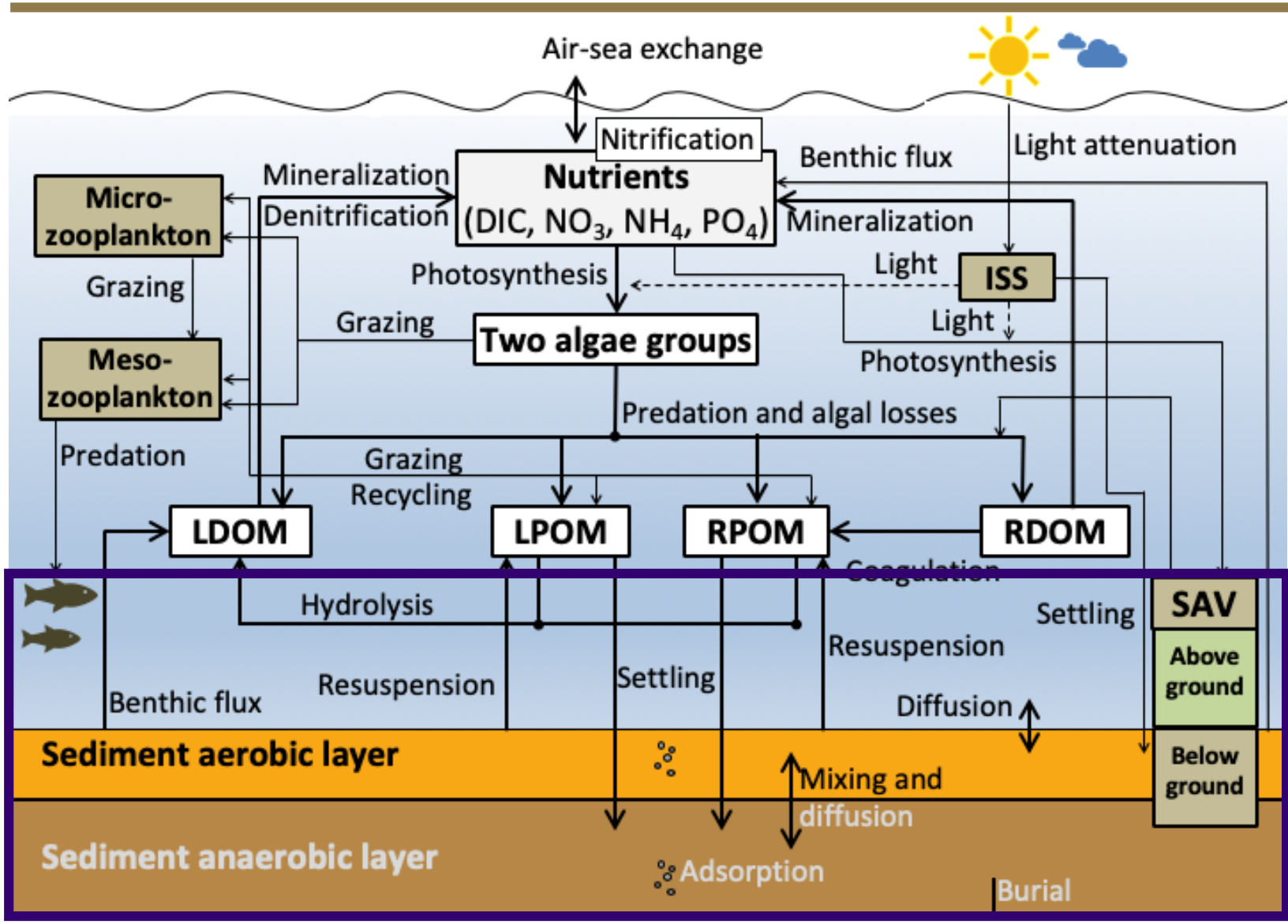
Salish Sea Model: Sediment Diagenesis Module

- Coupled with FVCOM-ICM biogeochemical process
- Based on Di Toro et al. (2001) & applied in WASP (Martin and Wool, 2013)

For Additional Information

- Ahmed et al. (2019) + appendices
- Pelletier et al. (2017a)
- Bianucci et al. (2018)

Biogeochemical Process Configuration



Khangaonkar et al. (2018)

Salish Sea Model: Sediment Diagenesis Module

Processes

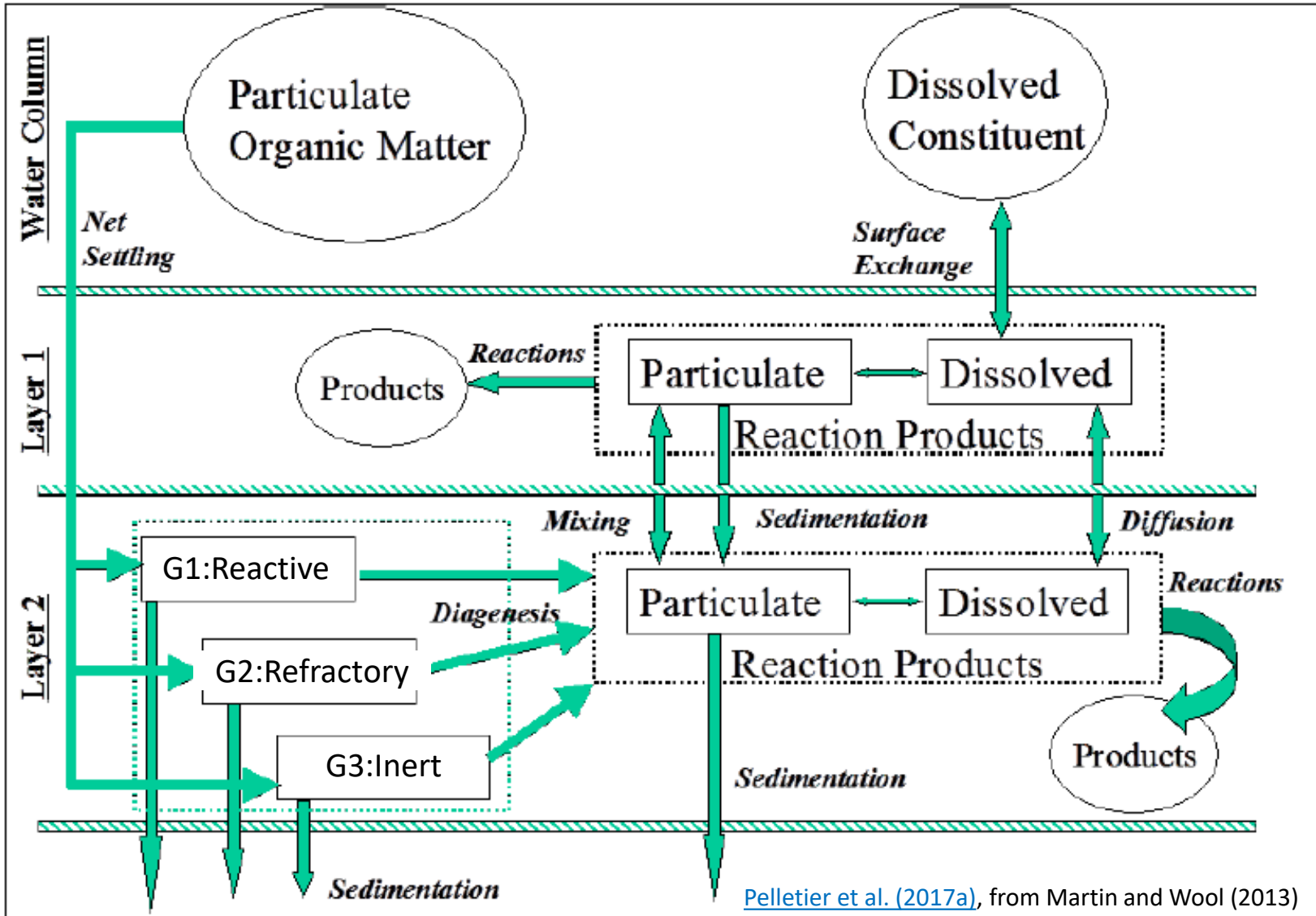
2 layer aerobic & anaerobic

- Deposition of particulate organic matter
- Diagenesis/decomposition
- Solute form exchange (e.g., DO), and burial

Model Considerations

- Uniform parameters (Khangaonkar, 2018), similar to Chesapeake Bay
- Uniform layer depth:
  - First Layer: 0.1 cm
  - Second Layer: 10 cm
- Resuspension is not explicit

Sediment Diageneses Module



Pelletier et al. (2017a), from Martin and Wool (2013)

Sensitivity Analysis

Appendix E1, Ahmed et al. (2019)

Parameter (summarized in Ap.E1 Ahmed et al. 2019)	Used Khangaonkar et al. 2018	Comparison for Sensitivity
Settling Rates		
Labile (WSLAB) and refractory (WSREF)	5 m/day	10 m/day
For Diatoms (WS1)	0.4 m/d	0.6 m/d
For Dinoflagellates (WS2)	0.2 m/d	0.3 m/d
Nitrification *Half-saturation concentration of ammonium ion required for nitrification (KHNNT)*	0.5 g/N/m3	1 g/N/m3
Mineralization *Minimum heterotrophic respiration rate (KLDC)*	0.025 d	0.05 d
Parameter (earlier: Bianucci, et al., 2018)	*Used:*	**Comparison for Sensitivity**
Freshwater at ambient seawater concentration	Including FW in FVCOM and ICM (baseline)	Including FW only FVCOM only
High DIC at the Ocean Boundary	Baseline	DIC at SJF Ocean Boundary 2% from baseline (+40mmol m-3)
High DIC in freshwater	Baseline	High DIC in FW ↑2%

Maintained because no significant improvement

Validation: Pelletier et al. (2017)

Compare annual predictions from 2006 to a specific time

SOD: 0.73 RMSE
(02g/m^2/d)

Compare same location

Includes embayments with Low Modeled DO

	Model	Observed
Mean	1.23	0.63
Range	0.32 – 4.41	-0.03 – 1.72
RMSE	0.73*	

similar to 0.64 RMSE from Brady et al. (2013)

		Model predictions (gO2/m^2/d)				Observed data (gO2/m^2/d)			
Stations	Node	Year	Mean	Min	Max	Year (Month)	Mean	Min	Max
BUDD05	8615	2006	1.60	0.93	2.00	2007 (Sep-Oct)	0.44	0.08	0.99
BUDD15	8374	2006	1.54	0.95	1.89	2007 (Sep-Oct)	0.82	0.63	1.13
BUDD25	8372	2006	1.43	0.91	1.75	2007 (Sep-Oct)	0.62	0.50	0.70
CARR05	8016	2006	1.01	0.73	1.33	2007 (Sep-Oct)	0.51	0.33	0.79
CARR15	7950	2006	1.05	0.82	1.37	2007 (Sep-Oct)	0.69	0.64	0.77
CARR25	7846	2006	1.26	1.06	1.45	2007 (Sep-Oct)	0.25	0.21	0.27
CASE05	8858	2006	0.88	0.59	1.07	2007 (Sep-Oct)	0.33	-0.03	0.69
CASE15	8756	2006	1.08	0.73	1.29	2007 (Sep-Oct)	0.53	0.39	0.62
CASE25	8656	2006	1.28	0.84	1.54	2007 (Sep-Oct)	0.70	0.49	1.03
ELD05	8741	2006	1.34	0.66	1.89	2007 (Sep-Oct)	1.49	1.23	1.71
ELD15	8579	2006	1.48	0.78	2.01	2007 (Sep-Oct)	0.94	0.89	1.02
ELD25	8397	2006	1.60	1.00	1.99	2007 (Sep-Oct)	0.74	0.22	1.08
QMH_A	6817	2006	1.30	0.94	1.69	2010 (Sep)	1.72	1.72	1.72
QMH_B	6783	2006	1.19	0.89	1.44	2010 (Sep)	0.72	0.72	0.72
QMH_C	6684	2006	1.16	0.97	1.29	2010 (Sep)	0.64	0.64	0.64
QMH_D	6645	2006	1.14	0.99	1.25	2010 (Sep)	0.95	0.95	0.95
QMH_E	6574	2006	1.20	1.05	1.27	2010 (Sep)	0.16	0.16	0.16
BD-2	8374	2006	1.03	0.36	1.96	1996-7 (Sep-Sep)	0.57	0.26	0.92
LOON-1	8492	2006	1.03	0.41	1.87	1996-7 (Sep-Sep)	0.59	0.36	1.01
BA-1	8615	2006	1.24	0.54	2.24	1996-7 (Sep-Sep)	0.57	0.32	0.87
BI-5	8775	2006	2.37	1.26	4.41	1996-7 (Sep-Sep)	0.58	0.17	1.14
DABOB	5380	2006	0.61	0.32	0.97	1981-2 (Jan-Jan)	0.17	0.07	0.36
HOLMES	4786	2006	0.95	0.94	0.97	1993 (Aug)	0.14	0.12	0.16
CARKEEK	4276	2006	0.64	0.52	0.74	1982 (Jun)	0.17	0.17	0.17

Primarily flux chambers

Further validation: +Merritt 2017

- Little change in annual model years Sound-wide (0.4g/m2/d peak)
- -13.66 to 42.62% difference at Bellingham (seasonal) specifically

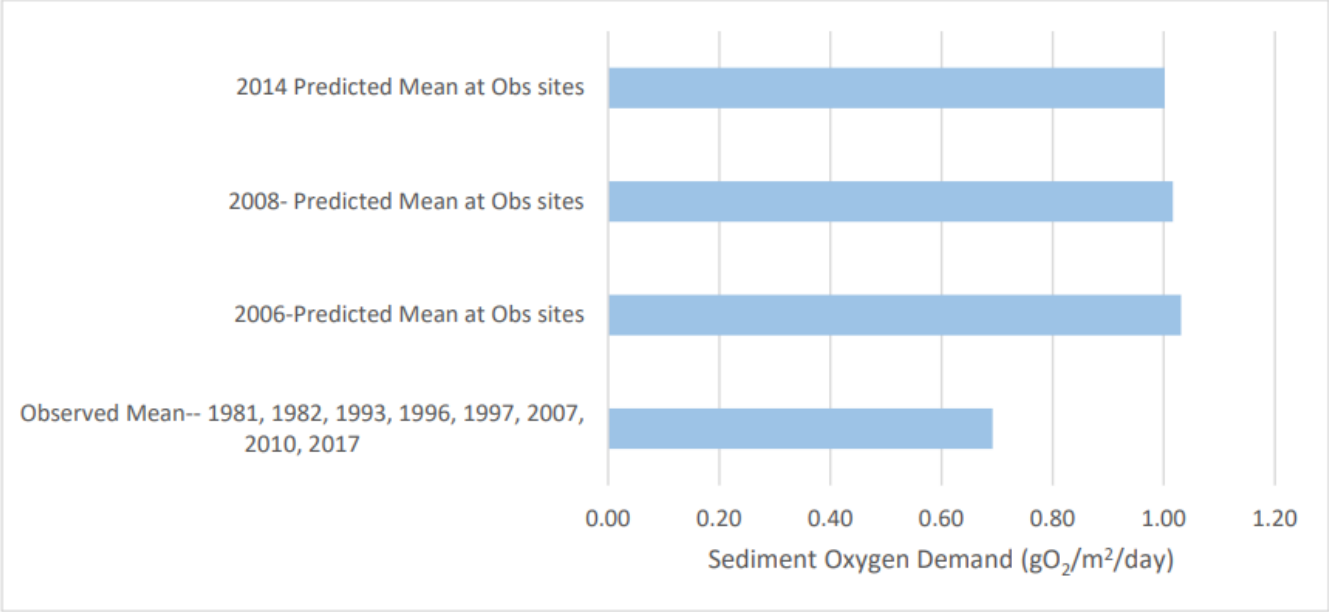
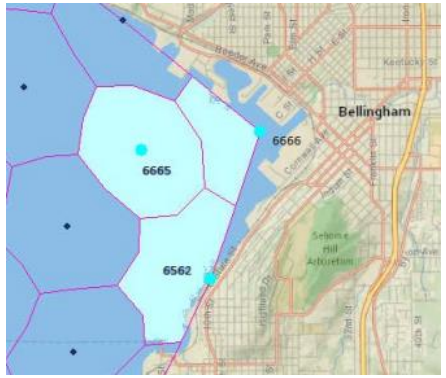


Figure I2. Comparison of predicted and observed SOD at multiple locations but different times.

Annual modeled vs specific time periods, sound-wide

Comparison to 3 Grid Cells



Sediment core incubation Bellingham Bay

Model grid cell identifiers	6562	6666	6665
June 2017 Observations			
Mean	0.71	0.88	1.25
Standard deviation	0.21	0.07	0.28
Coefficient of variation	29.97%	8.28%	22.02%
June-2006 Predictions			
Mean	1.01	1.15	1.21
Standard deviation	0.04	0.05	0.05
Percent difference of means compared to observations	42.62%	31.29%	-3.66%
June-2008 Predictions			
Mean	0.94	1.06	1.12
Standard deviation	0.05	0.07	0.07
Percent difference of means compared to observations	32.84%	21.41%	-10.74%
June-2014 Predictions			
Mean	0.88	1.05	1.08
Standard deviation	0.05	0.07	0.07
Percent difference of means compared to observations	24.19%	19.62%	-13.66%

Appendix I, Ahmed et al. (2019)

Proposed Modeling Analysis

1. **Further validation of the sediment module using measured data**
   - ⊕ Expanded data set for model development and validation across models

2. **Examination of modeled sediment flux responses to changing nutrient loading**

3. **Analysis of Salish Sea Model sediment exchange model spin up and stability**

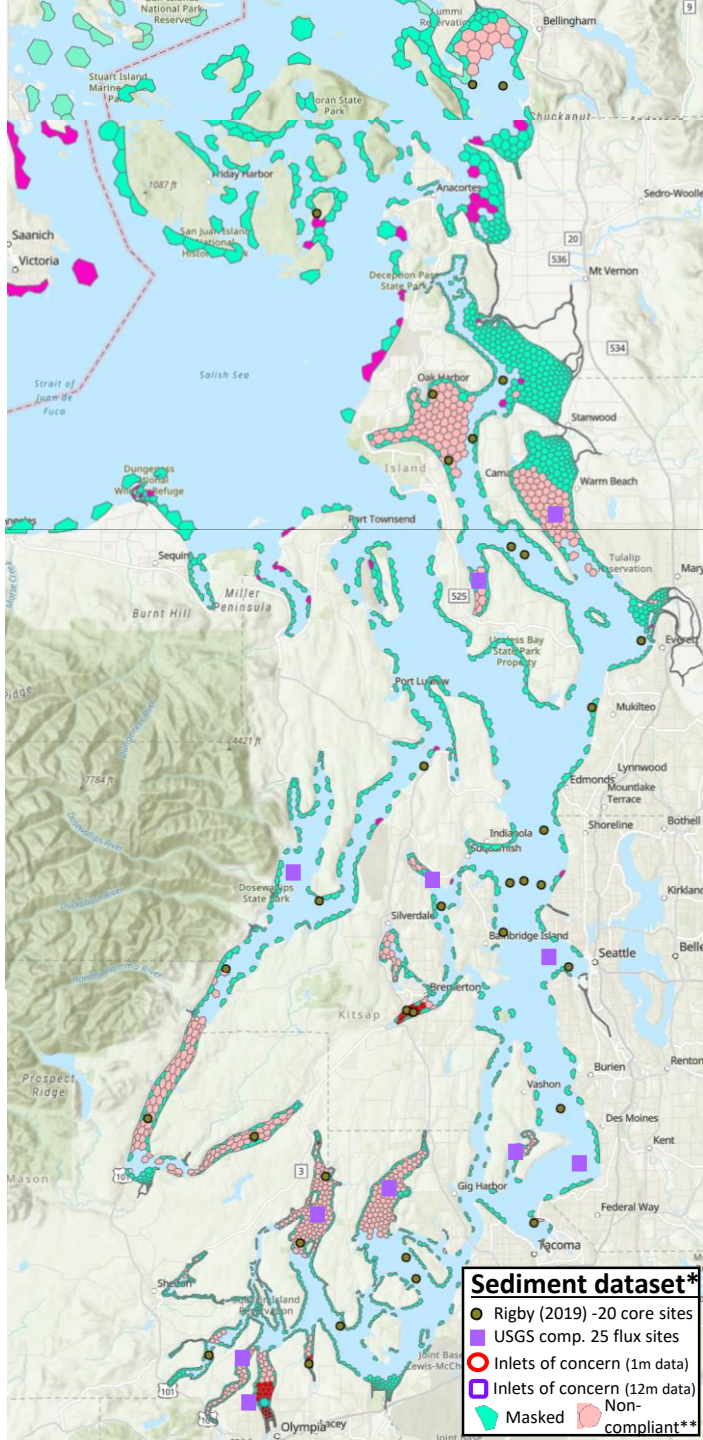
1. Further validation of the sediment module using available measured data

Extends previous validation to consider

1. **Expanded regional validation dataset**
   - Compare monthly averages of DO and N to USGS (2014) and Pelletier et al. (2017) data

2. **Seasonal variations in N fluxes**
   - Compare monthly averages at Dabob, Budd and Bellingham in 2014 to USGS (2014) and Merritt (2017) data

3. **Springtime comparison to consolidated data on DO, N, C, P and Silicate**
   - Compare 40 sites including shallow embayments in April and May, 2018 to Rigby (2019) data



*not shown: Merritt (2017) and USGS (2014) diffusive flux measurements

**Masked and non-compliant cells defined in Ecology 2021 and GIS data available here.

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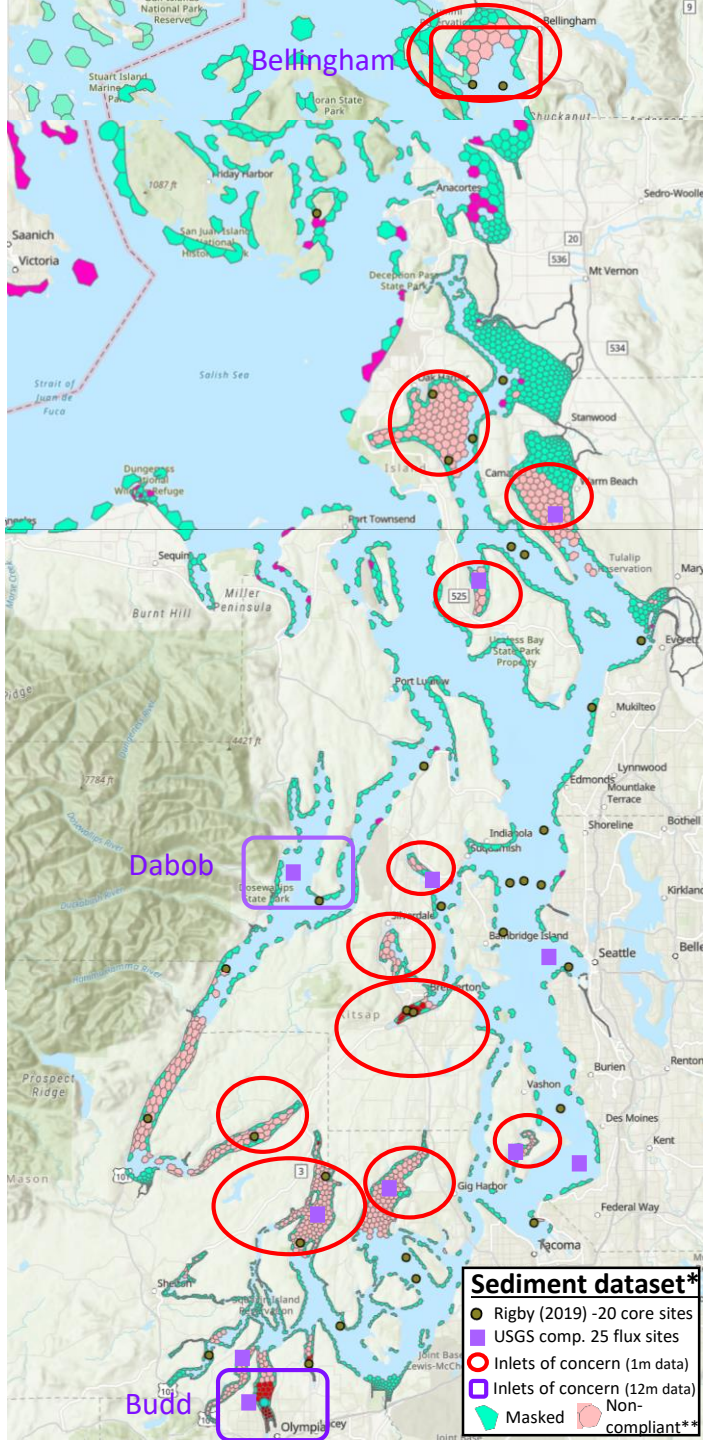


*not shown: Merritt (2017) and USGS (2014) diffusive flux measurements

**Masked and non-compliant cells defined in Ecology 2021 and GIS data available here.

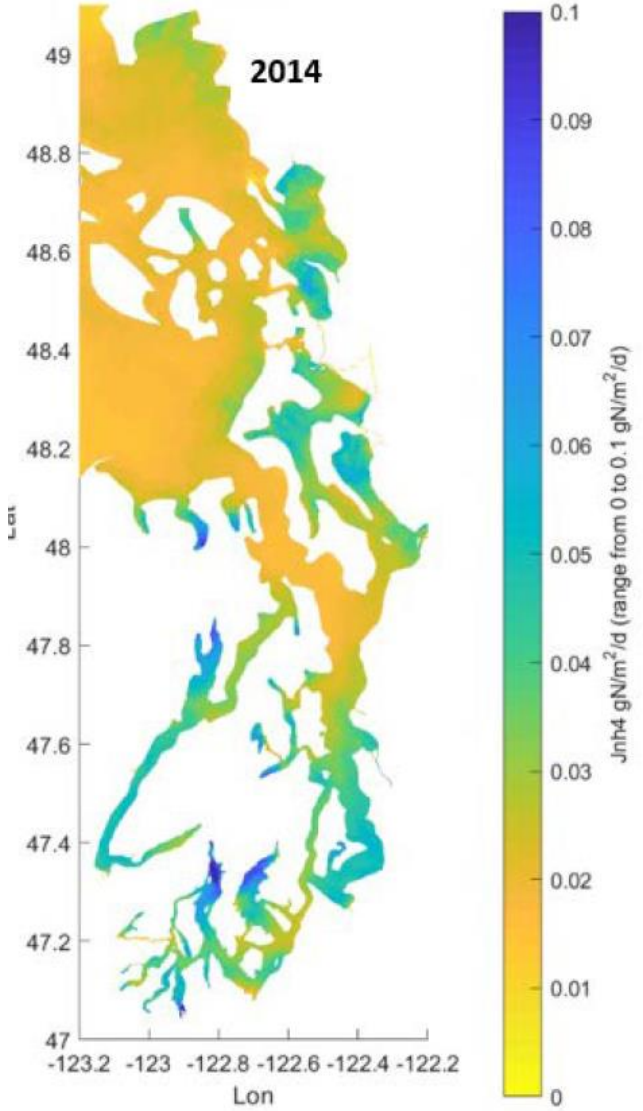
2. Examination of sediment flux response to changing nutrient loading

Does the model behave as expected with varying loadings across different seasons and depths?

Calculate existing, reference, and the difference between the two for 2014

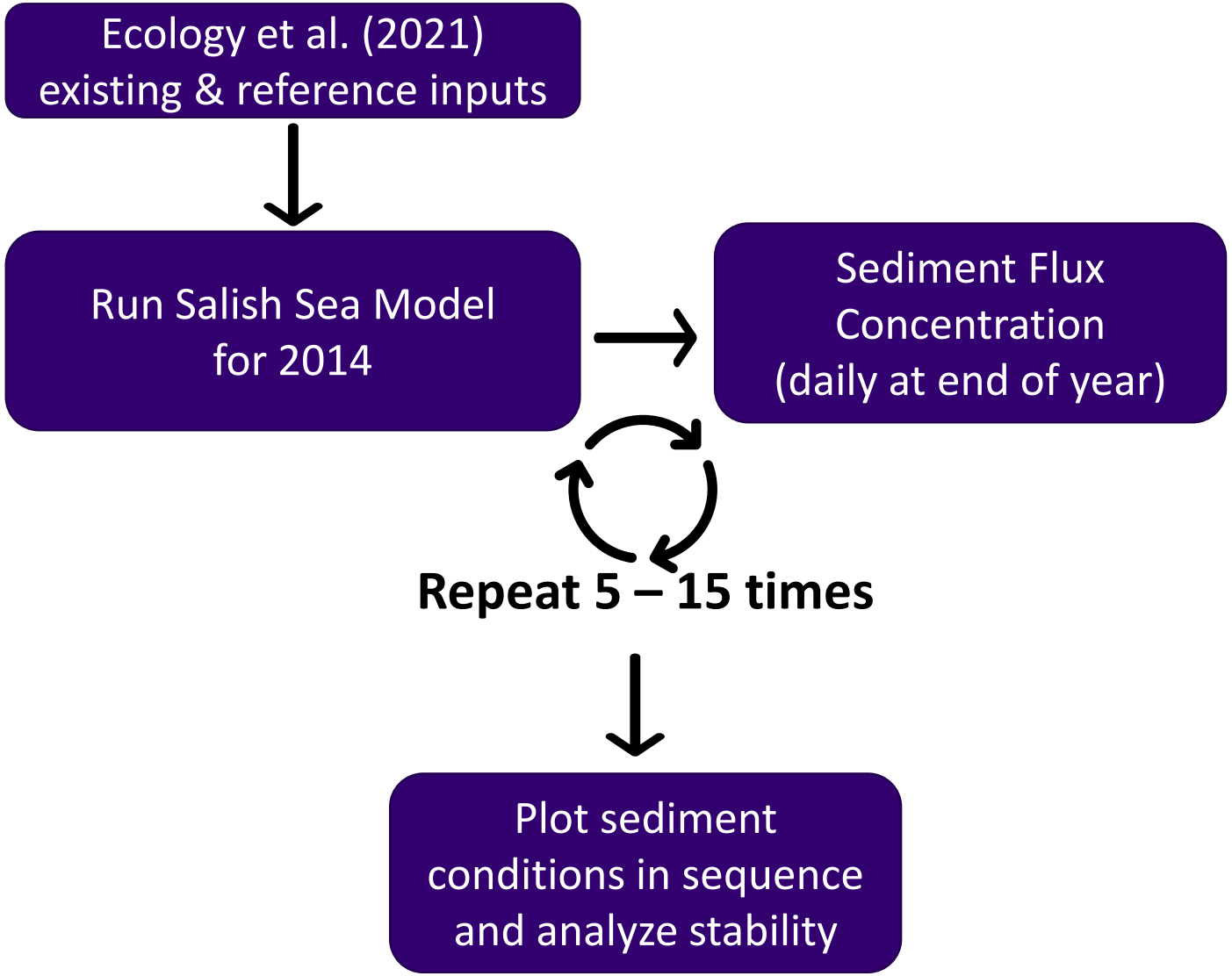
- Compare fluxes of Nitrate, Ammonium, and Sediment Oxygen Demand respectively to:
  - Bottom water nitrate
  - Indicators of phytoplankton in overlying waters (Net Primary Production)
  - Circulation and physical forcing (temperature and salinity)

E.G Modeled flux of ammonium-nitrogen from sediments



Appendix C, Ahmed et al. (2019)

3. Analysis of Salish Sea Model sediment exchange spin up and stability



Preliminary results: measured to modeled comparison

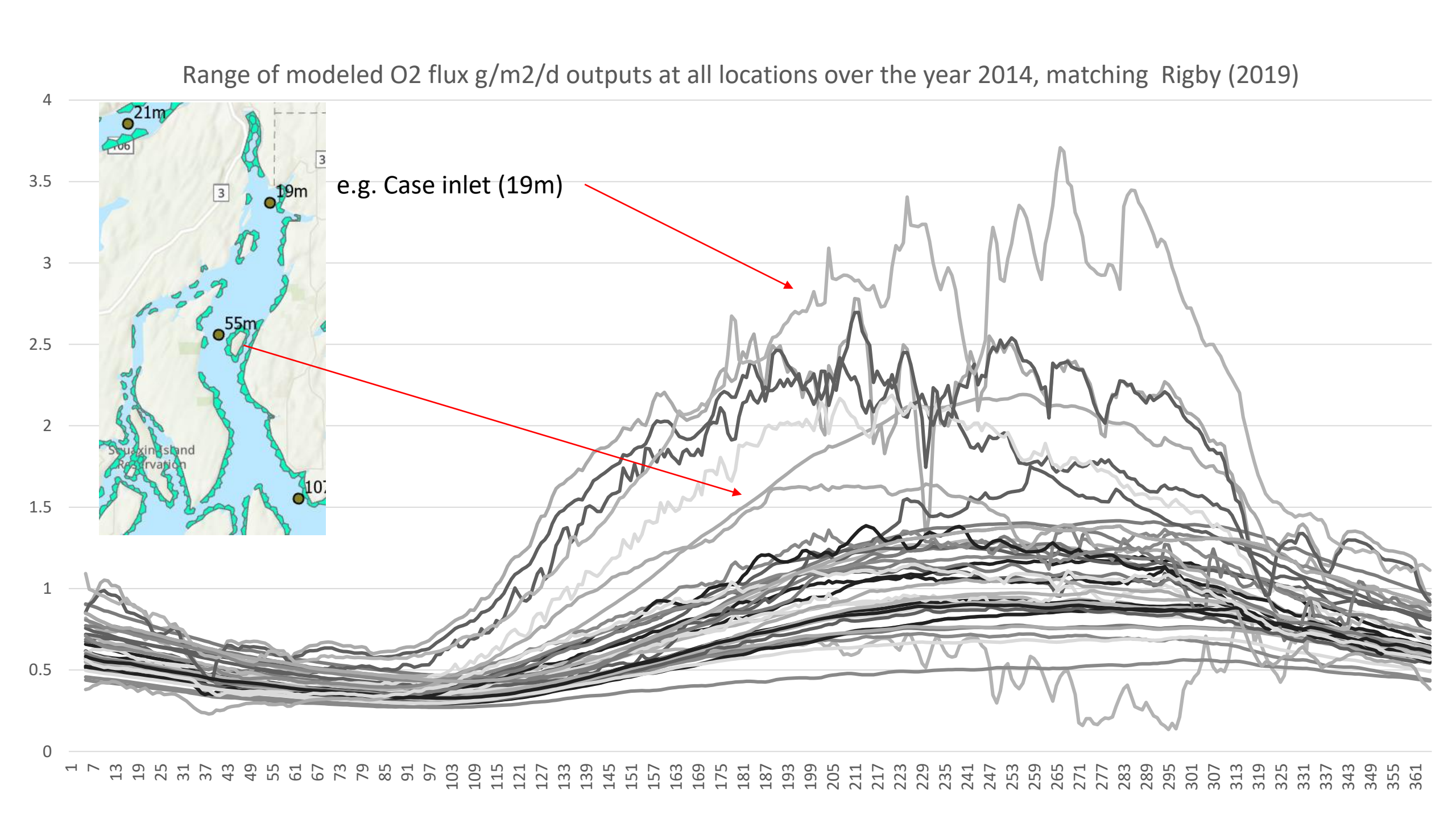
Pelletier et al. (2017a) prior Sediment flux comparison –annual modelled to measured time period:

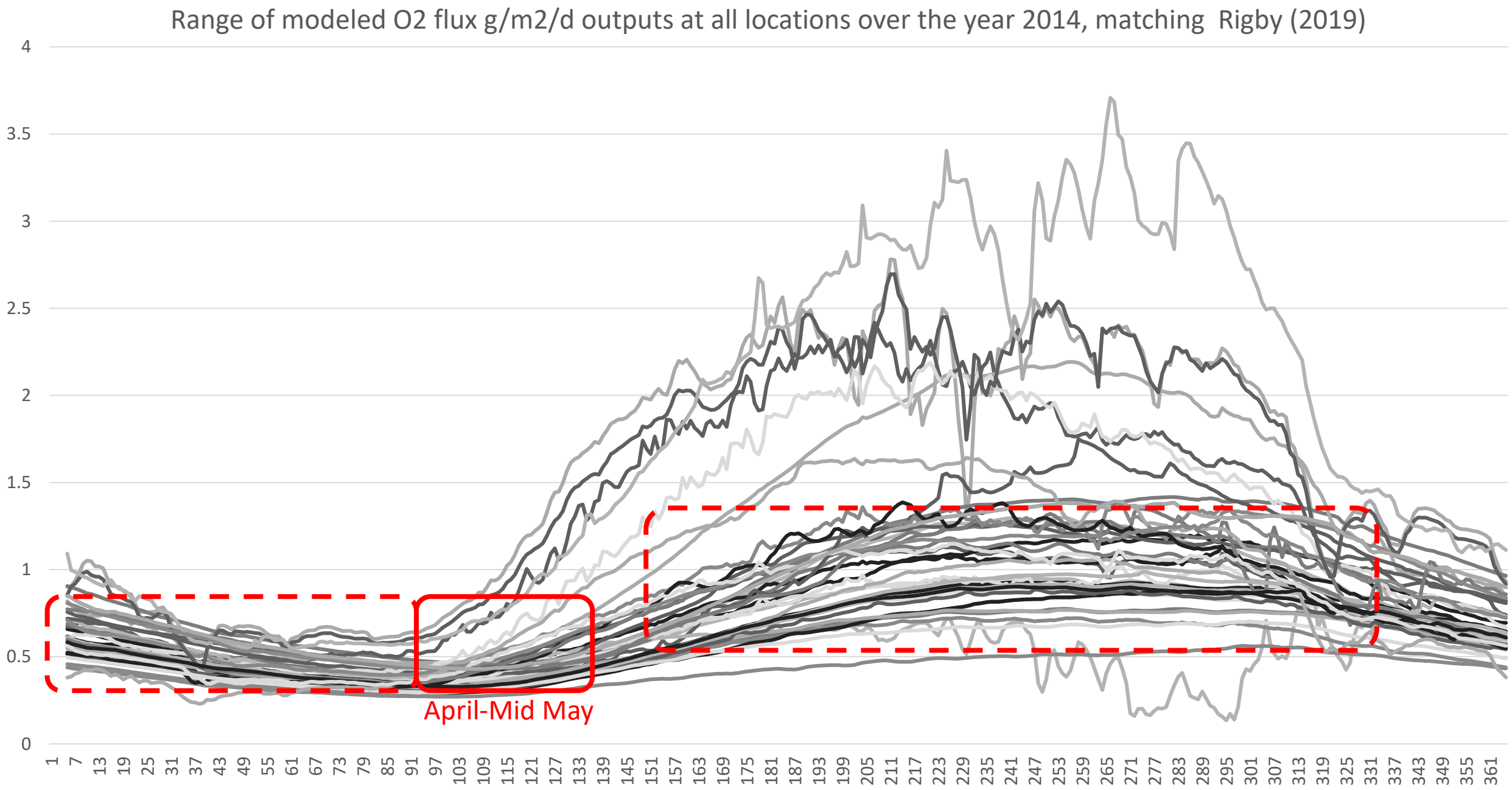
	Modelled predictions 2006 (Pelletier et al. 2017a) – annual mean			Observed data (Sheibley and Paulson, 2014) – specific time period				Compared annual to specific time period means at each site
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**	**n**	**RMSE**
SOD (O2) O2g/m^2/d	1.230	0.320	4.410	0.630	-0.030	1.720	23	0.73
Ammonium (JNH4) Ng/m^2/d*	0.060	0.000	0.180	0.056	-0.004	0.189	25	0.038
Nitrate+Nitrite (JNO3) Ng/m^2/d*	-0.015	-0.025	0.008	-0.009	-0.081	0.021	24	0.014

Current comparison: similar results for annual modelled to measured time period:

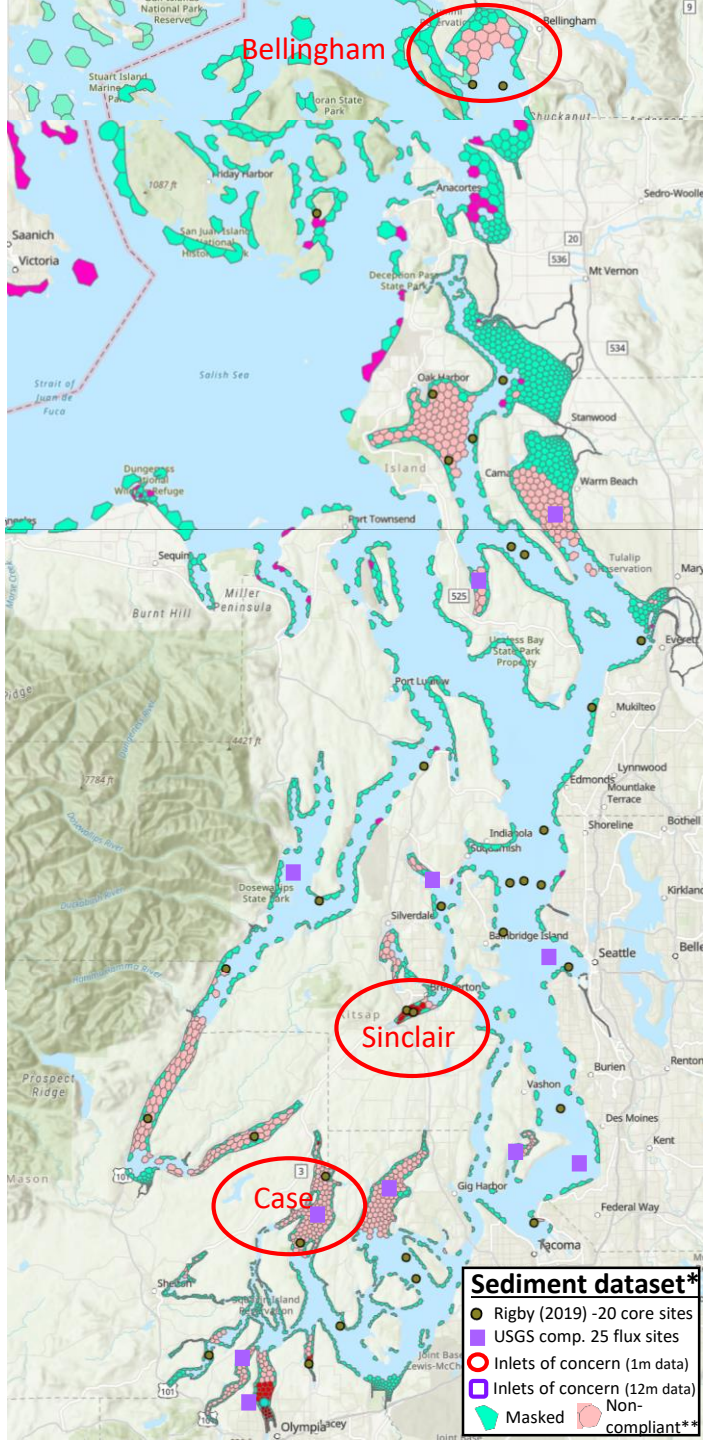
	Modelled predictions 2014 (Current study) – annual mean			Observed data (Rigby, 2019)* - April/early May		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
SOD (O2) g/m^2/d	0.821	0.134	3.709	0.426	0.167	1.227
Ammonium (JNH4) g/m^2/d	0.040	0.002	0.233	0.003	-0.006	0.017
Nitrate+Nitrite(JNO3) g/m^2/d	-0.011	-0.022	0.007	-0.006	-0.027	0.0001

*Measured data from April and early May 2018
SOD originally presented as -02 in Rigby (2019) presented here as +SOD


Range of modeled O2 flux g/m2/d outputs at all locations over the year 2014, matching Rigby (2019)
e.g. Case inlet (19m)
21m
19m
55m
4
3.5
3
2.5
2
1.5
1
0.5
0
1 7 13 19 25 31 37 43 49 55 61 67 73 79 85 91 97 103 109 115 121 127 133 139 145 151 157 163 169 175 181 187 193 199 205 211 217 223 229 235 241 247 253 259 265 271 277 283 289 295 301 307 313 319 325 331 337 343 349 355 361


Range of modeled O2 flux g/m2/d outputs at all locations over the year 2014, matching Rigby (2019)
4
3.5
3
2.5
2
1.5
1
0.5
0
1 7 13 19 25 31 37 43 49 55 61 67 73 79 85 91 97 103 109 115 121 127 133 139 145 151 157 163 169 175 181 187 193 199 205 211 217 223 229 235 241 247 253 259 265 271 277 283 289 295 301 307 313 319 325 331 337 343 349 355 361
April-Mid May

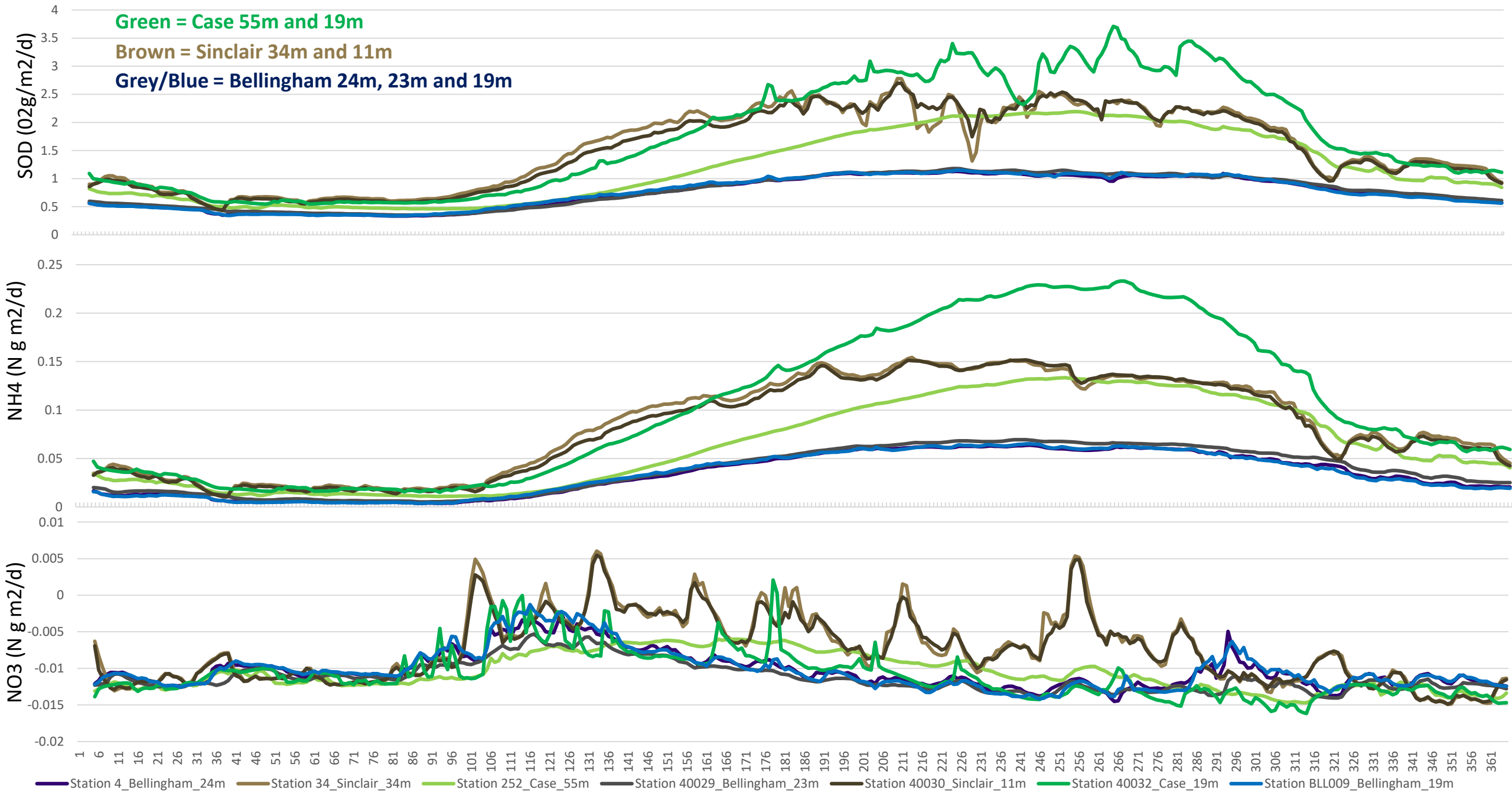
1. Further validation of the sediment module using available measured data



*not shown: Merritt (2017) and USGS (2014) diffusive flux measurements

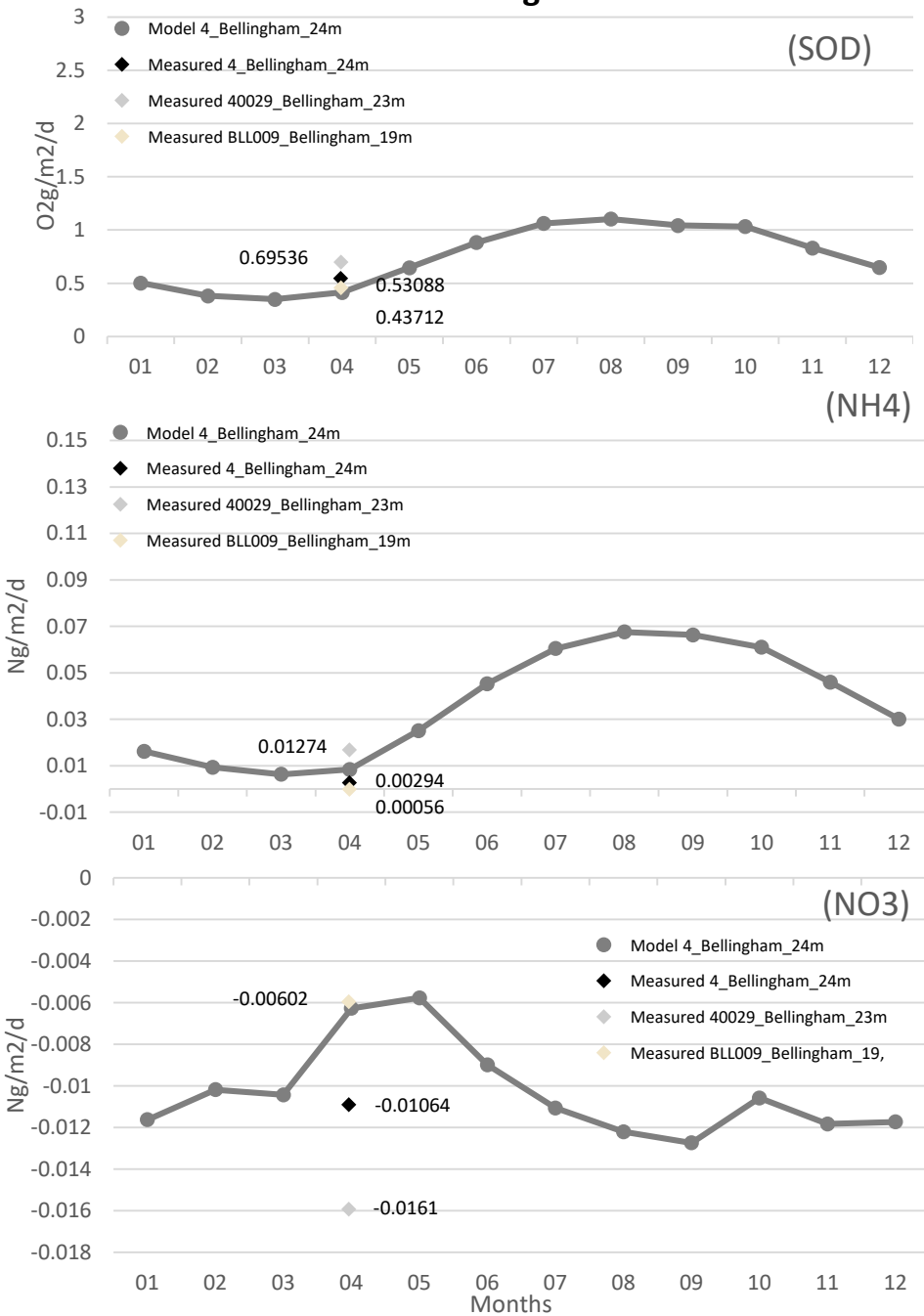
**Masked and non-compliant cells defined in Ecology 2021 and GIS data available here.

Modeled fluxes at inlets over the year 2014, matching Rigby (2019) sites

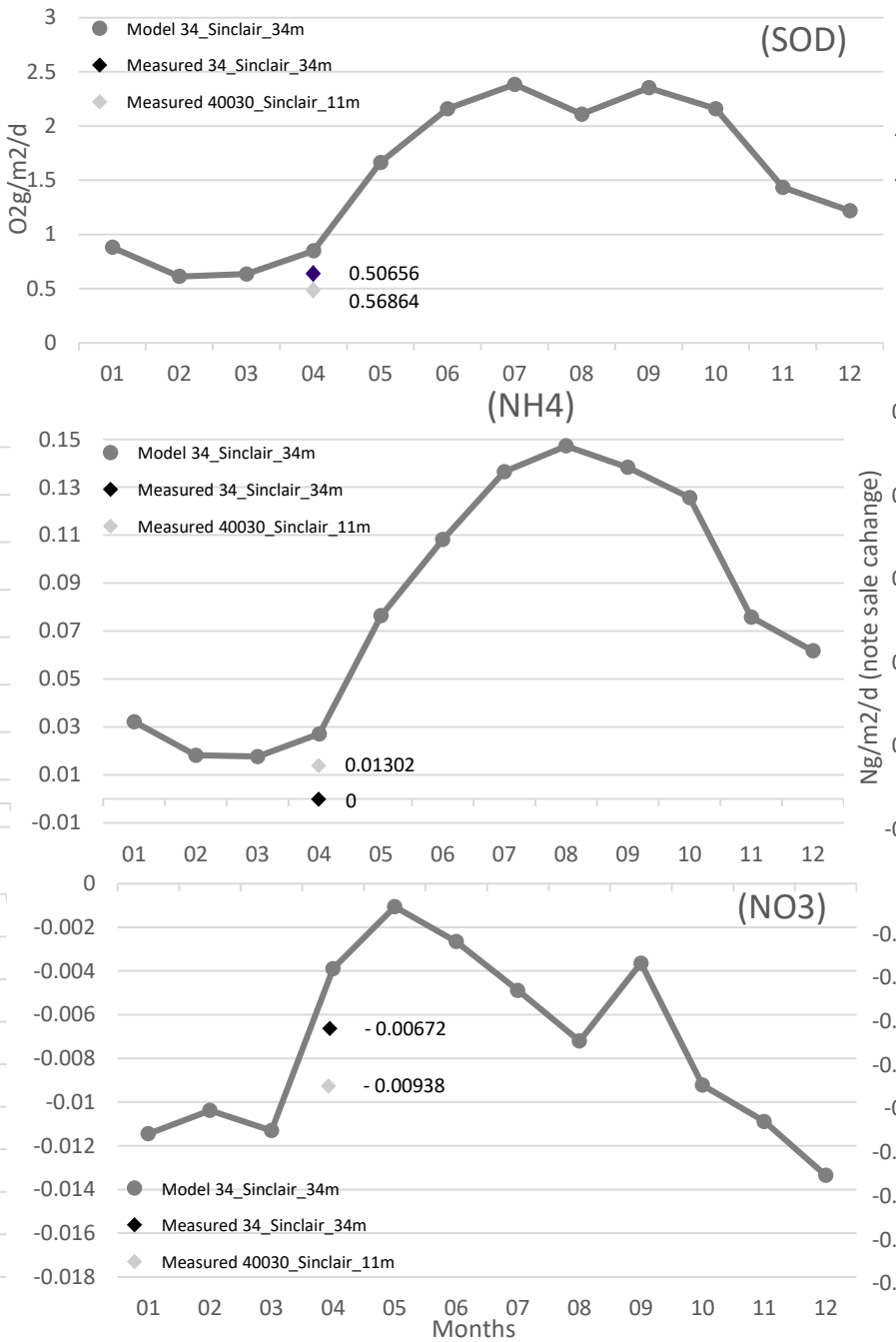


Modeled 2014 to Measured 2018

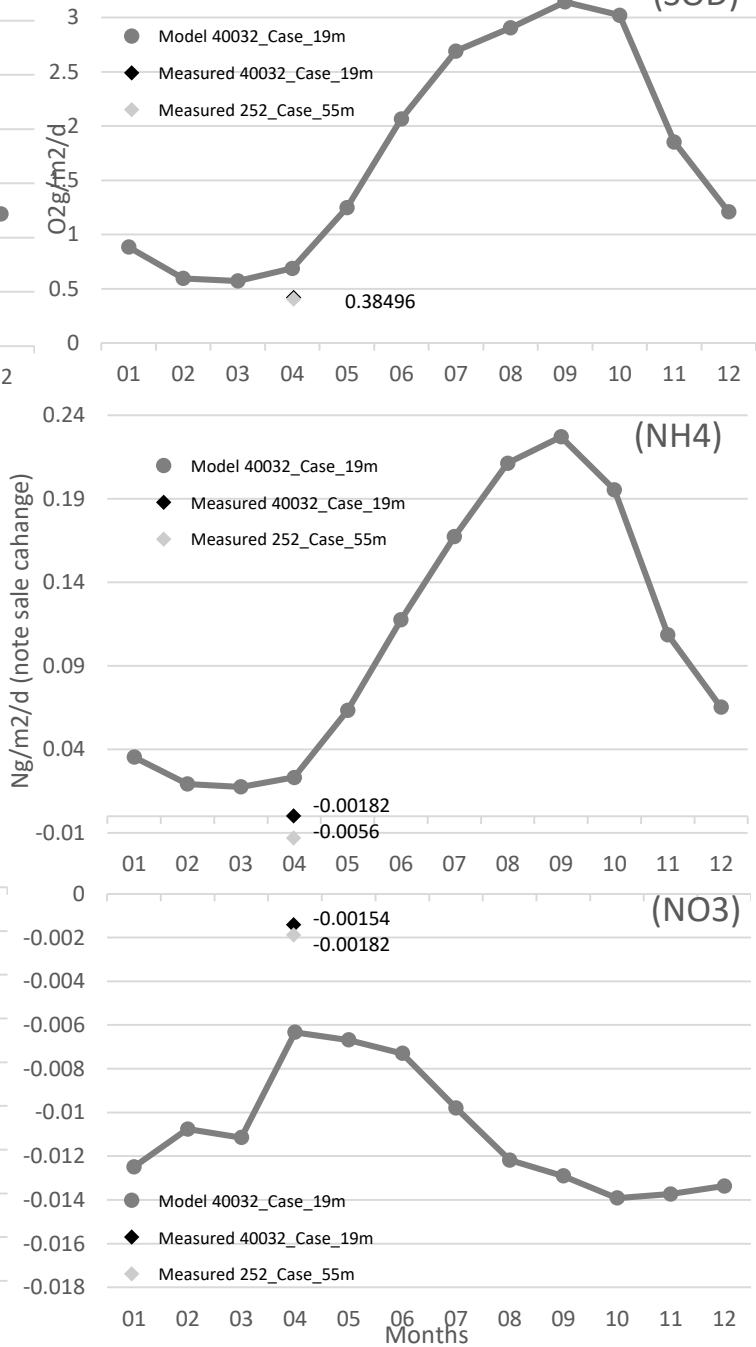
Bellingham

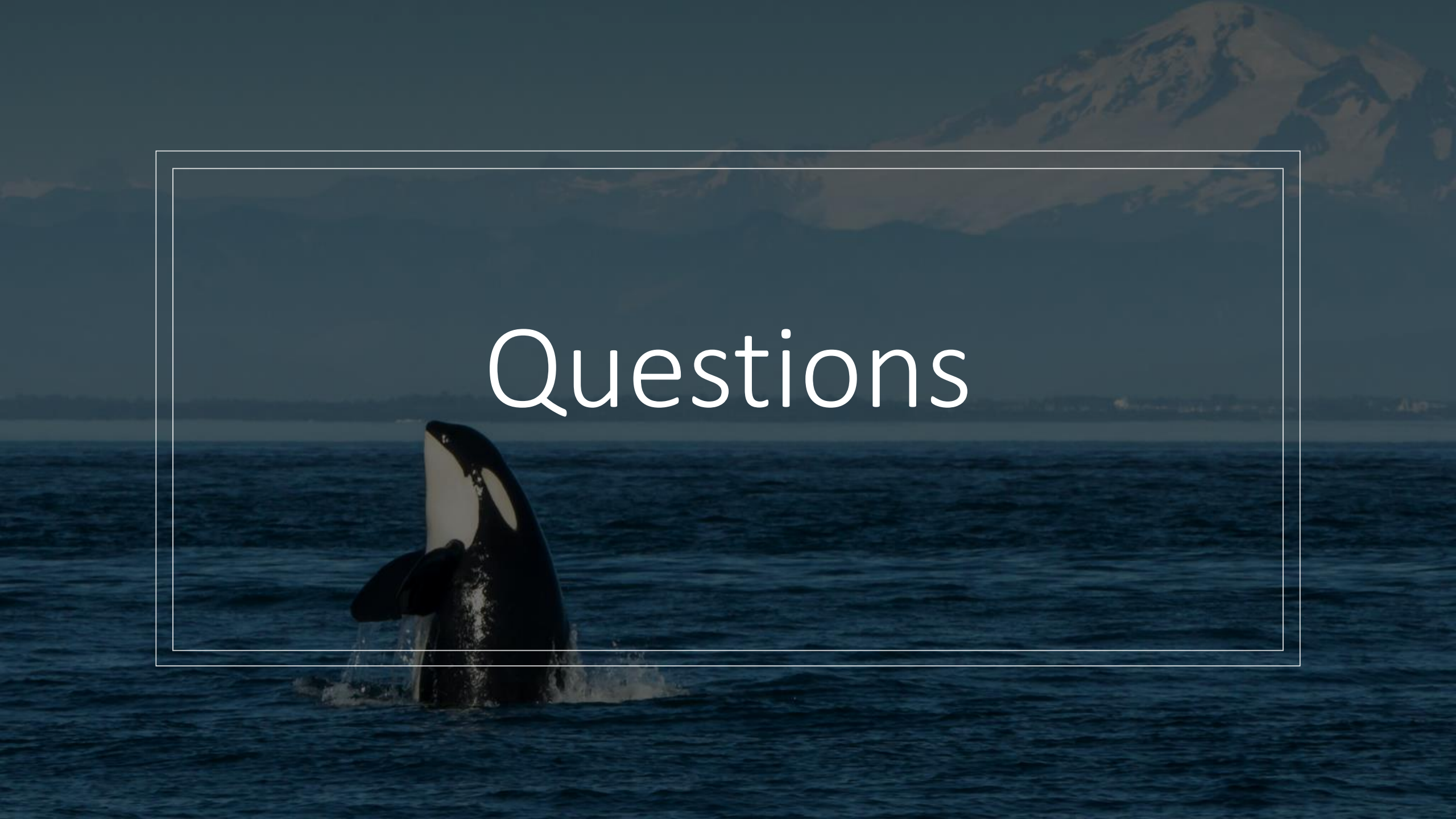


Sinclair



Case





Questions

Discussion

- Are we satisfied with our state of knowledge on sediment exchange in terminal embayments?
    - If not, what additional modeling and monitoring would you propose to improve our understanding?
- In addition to Ahmed et al. (2019) and prior papers what further validation and sensitivity analysis would you like to see?
- How would you further improve confidence in the application of the models in terms of sediment exchange?

When and where does sediment have an important impact on nitrogen cycling and low dissolved oxygen impacts?

Wrap up

- We'll share the presentation materials, recording, and a summary of the discussion
- Subscribe for updates at http://eepurl.com/h5nxsr
- Share any people, programs, or studies we should connect with
- Continue the discussion
  - Email Stefano Mazzilli (mazzilli@uw.edu) and Marielle Larson (marlars@uw.edu)
  - Join the upcoming workshops to dig in further

Upcoming Workshops

Phytoplankton and primary production *(11/2)*

Change in interannual variability of rivers and ocean impact *(week of 11/14)*

Improve watershed modeling to evaluate source reduction strategies to adaptively manage strategies *(week of 12/12)*