

# Data Driven Study of Estuary Hypoxia

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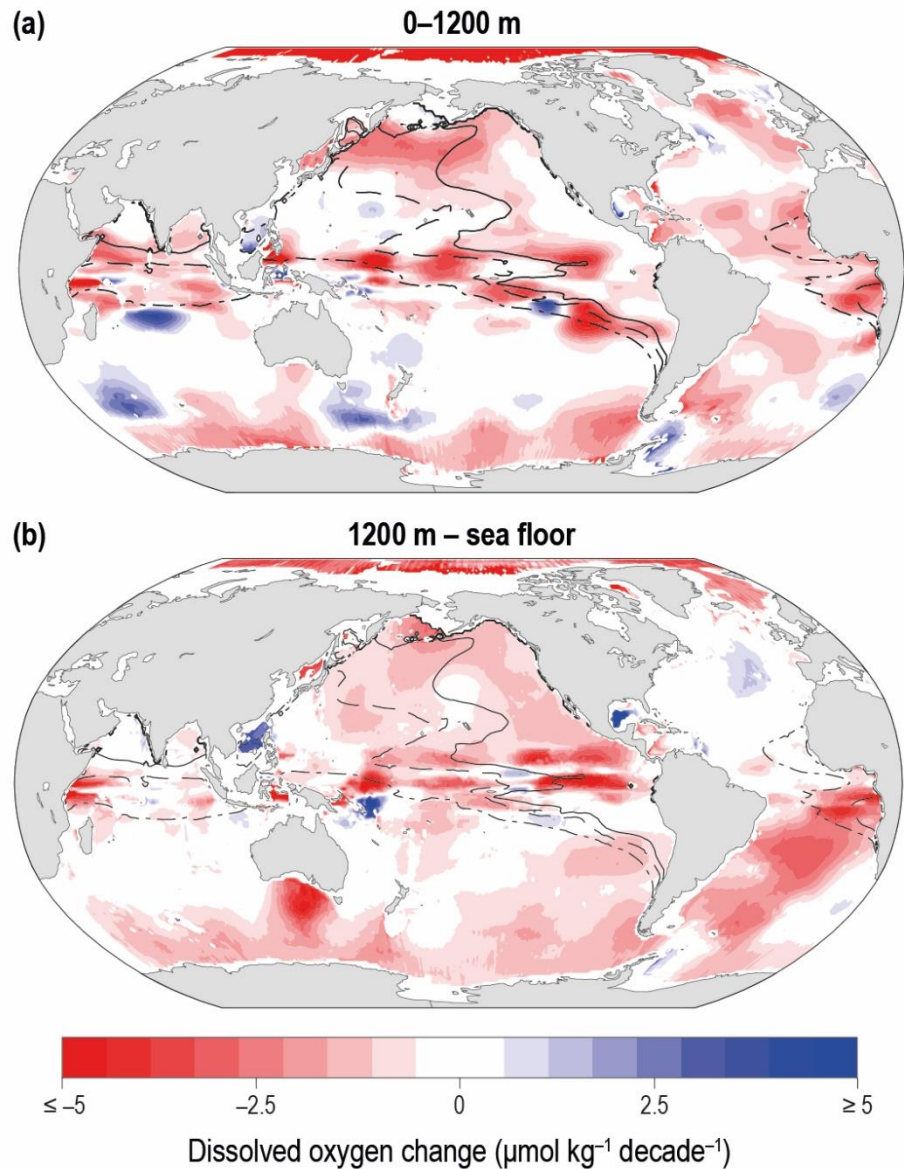
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# Climate change and dissolved oxygen (DO) in the Oceans

*“Absolute change in dissolved oxygen ( $\mu\text{mol kg}^{-1}$  per decade) between water depths of (a) 0 and 1200 m, and (b) 1200 m and the sea floor over the period 1960–2010. Lines indicate boundaries of OMZs with less than  $80 \mu\text{mol kg}^{-1}$  oxygen anywhere within the water column (dashed/dotted), less than  $40 \mu\text{mol kg}^{-1}$  (dashed) and less than  $20 \mu\text{mol kg}^{-1}$  (solid).”* Redrawn from Oschlies et al. (2018).

*“Overall there is medium confidence that the oxygen content of the upper 1000 m has declined with a very likely loss of 0.5–3.3% between 1970-2010”*

*“The total oxygen content of the ocean is very likely to decline by 3.2–3.7% by 2100”*



# Eutrophication of estuaries

## Oligotrophic

- Eelgrass
- Normoxic
- High diversity



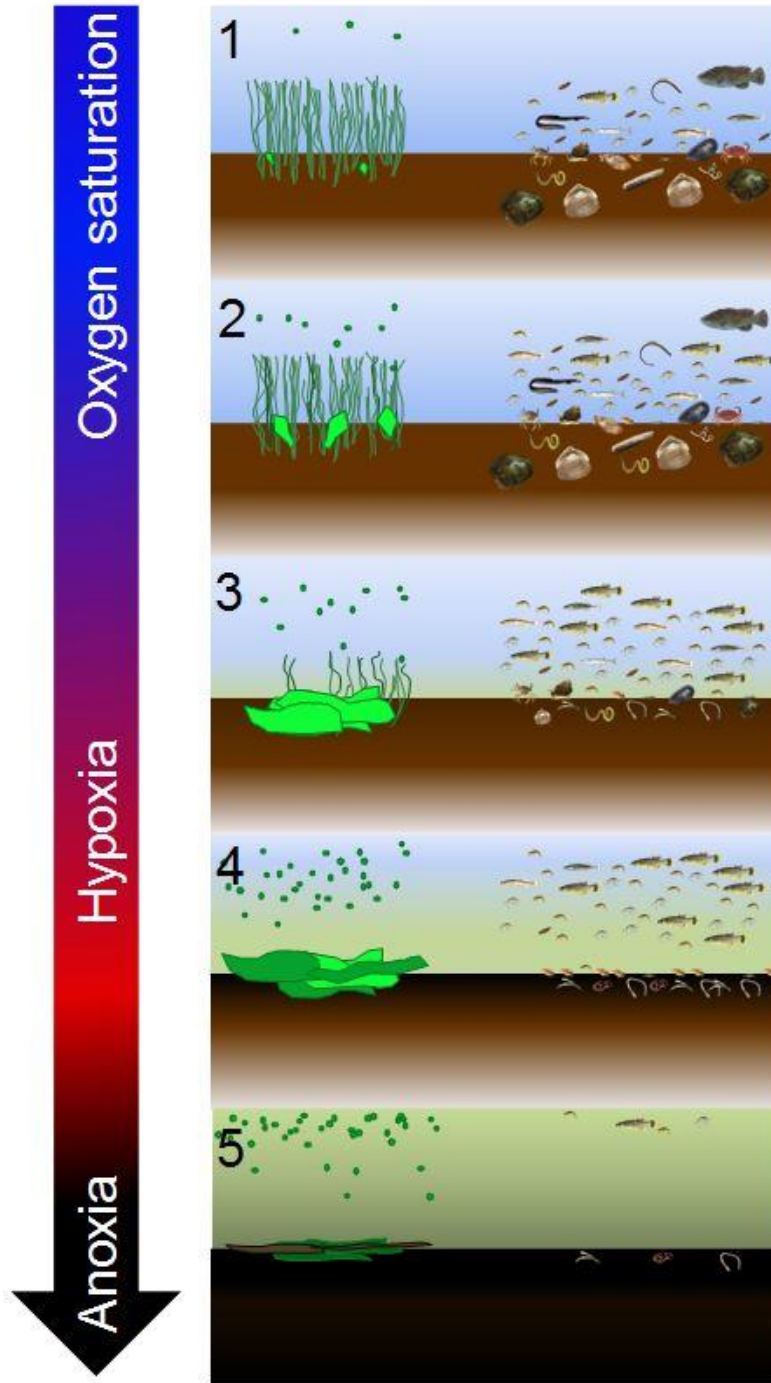
## Mesotrophic

- Eelgrass & *Ulva*
- Intermittent hypoxia
- Still diverse; increased abundance of fewer species

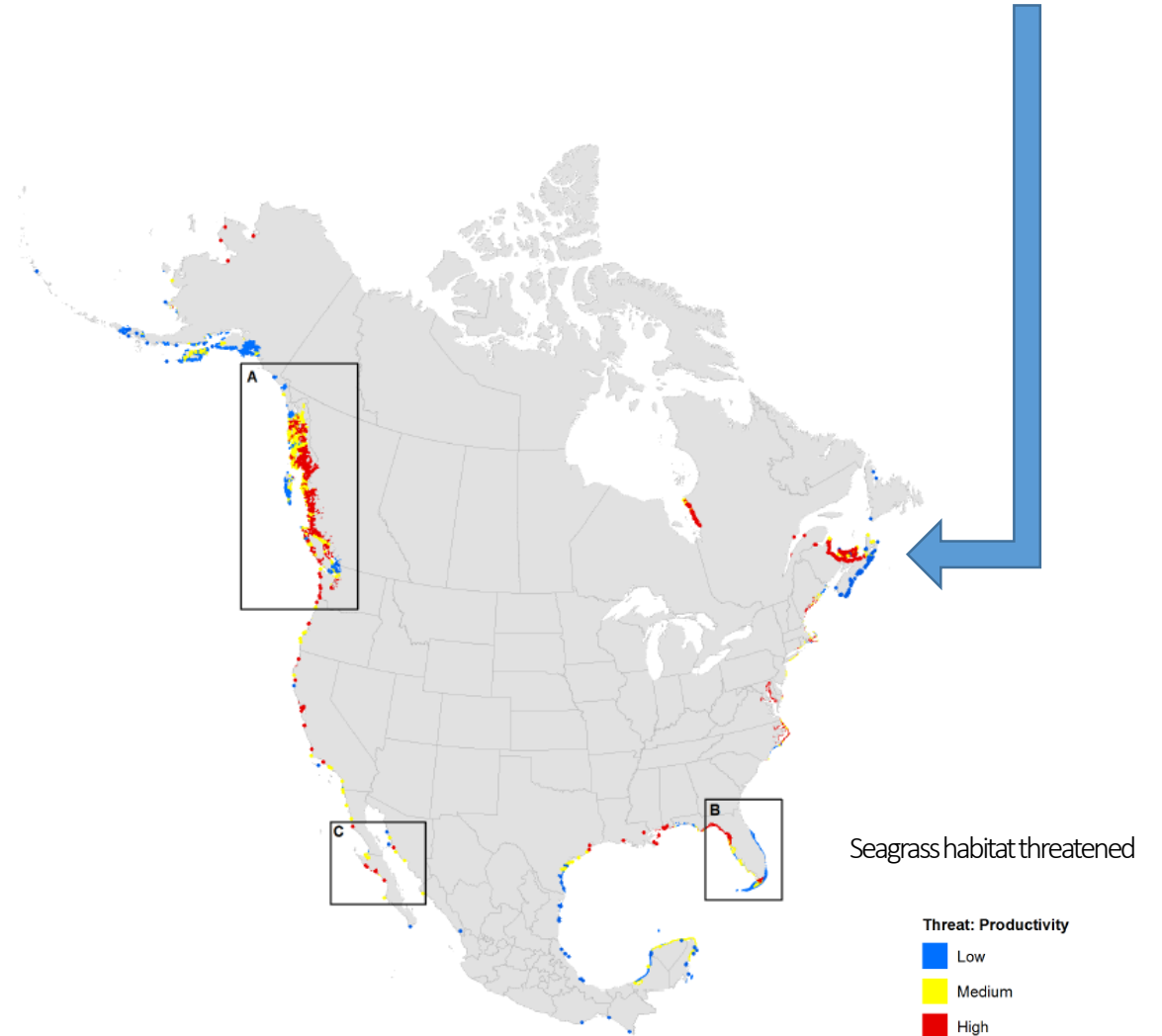
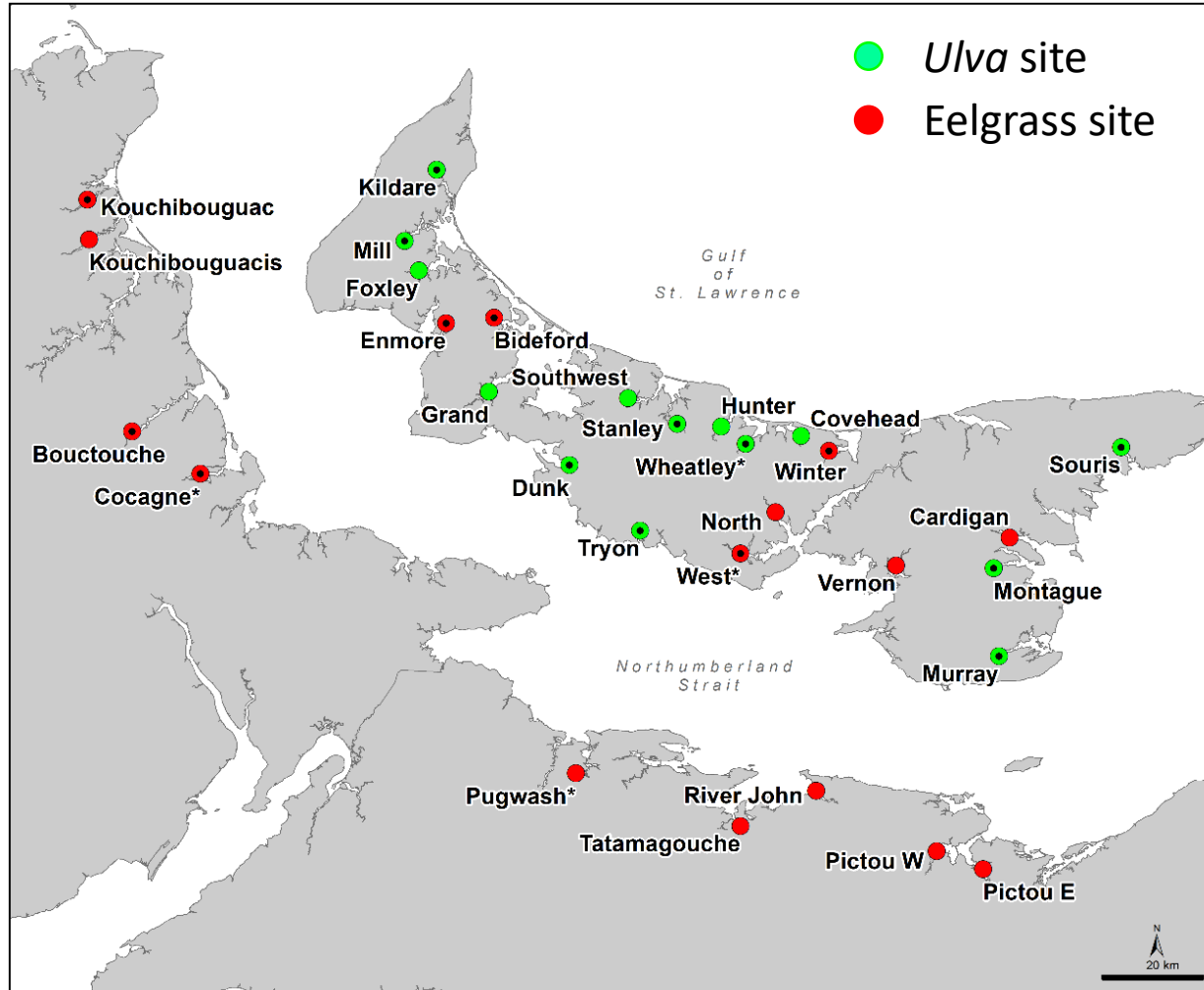


## Eutrophic

- No vegetation or *Ulva*
- Intermittent anoxia
- Decreased diversity; low abundance



# Southern Gulf of St. Lawrence estuaries

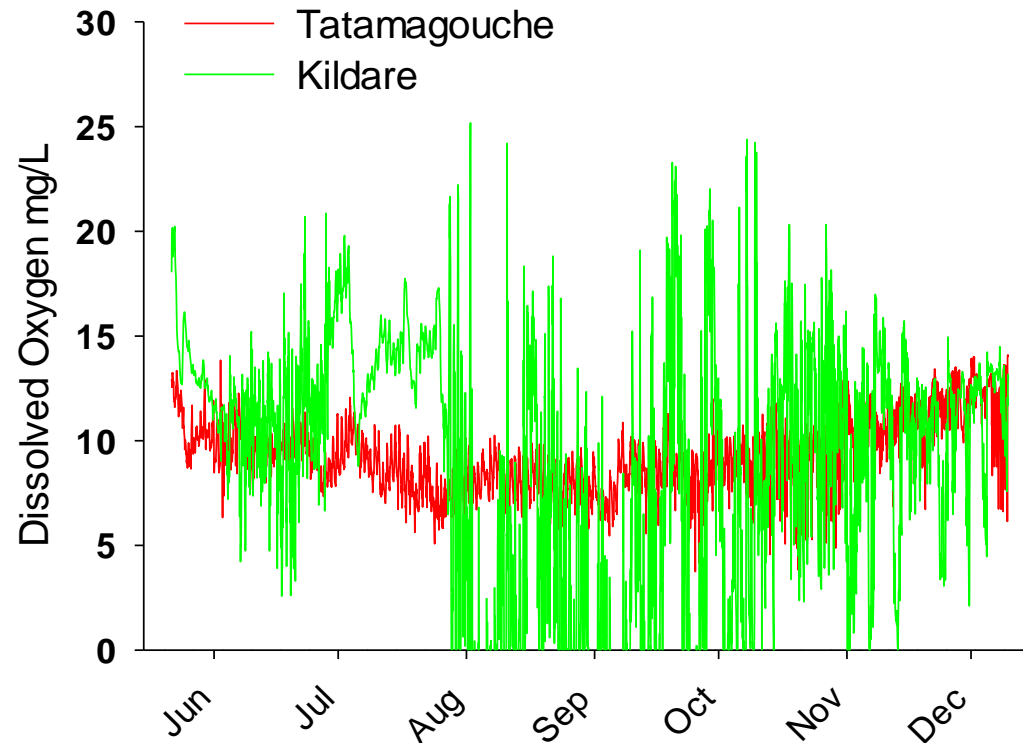


Source: Adapted from Short FT & AI



# Data

Data set contains a total of 62 time series from 2013 to 2020 (hourly measurement of Dissolved Oxygen) from which 37 without missing data were retained for analyses



# DO series clustering

Distance Method/ Cluster Method	DTW	Area	PCM	Frechet Distance	Curve Length
Optics	0.706	0.699	1.278	1.628	1.349
HDBscan	0.706	0.699	0.783	0.680	1.048
Spectral Clustering	0.999	1.000	1.272	0.957	0.953
Gaussian Mixture	0.589	0.587	0.716	0.569	0.653
K-Means	0.700	0.696	0.718	0.569	0.653
K-Medoids	1.035	0.830	1.088	0.725	1.421

Table 1: Davies Bouldin scores for different clustering methods and similarity measures (Lower values indicating better clustering)

Gaussian Mixture Clustering on Area distance		
Cluster-1	Cluster-2	Cluster-3
Bideford 2014	Kildare 2014	Enmore 2014
Mill 2014	Kildare 2013	Bideford 2013
<b>Wheatley 2014</b>	<b>Montague 2013</b>	Bouctouche 2013
Mill 2013	Stanley 2013	Dunk 2013
Souris 2013	Kildare 2018	Enmore 2013
Wheatley 2013	Hunter River 2019	Tatamagouche 2013
Wilmot 2013		<b>Tryon 2013</b>
Wheatley 2018		West 2013
Covehead 2019		Pugwash 2018
Mill 2019		River John 2018
Wilmot 2019		etc...

Table 2: Cluster information for Gaussian Mixture Model on Area Distance

## Oligotrophic

- Eelgrass
- Normoxic
- High diversity

Cluster 3

## Mesotrophic

- Eelgrass & *Ulva*
- Intermittent hypoxia
- Still diverse; increased abundance of fewer species

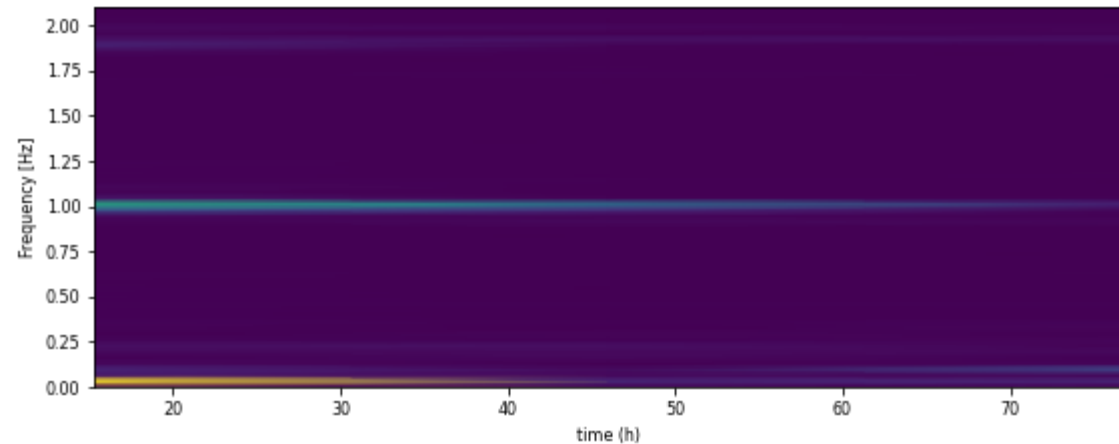
Cluster 1

## Eutrophic

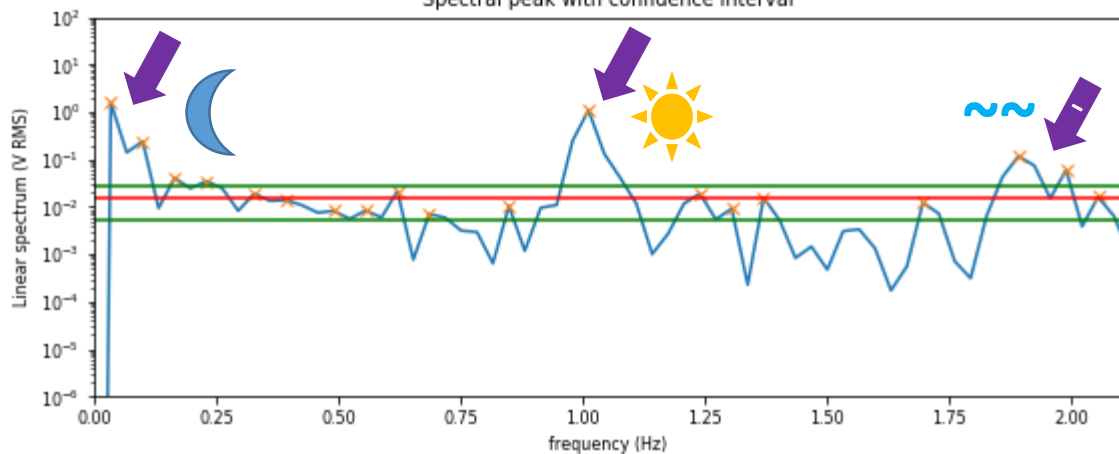
- No vegetation or *Ulva*
- Intermittent anoxia
- Decreased diversity; low abundance

Cluster 2

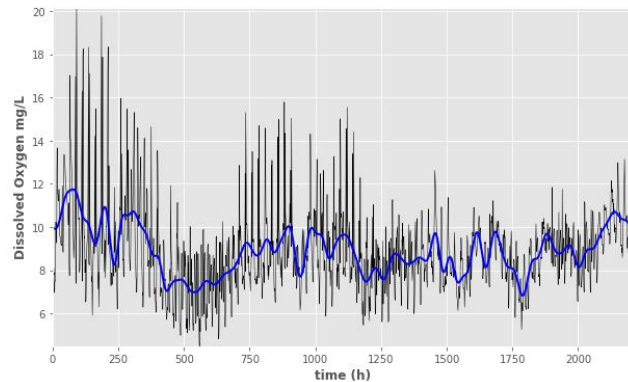
Spectrogram for Tryon 2013



Spectral peak with confidence interval

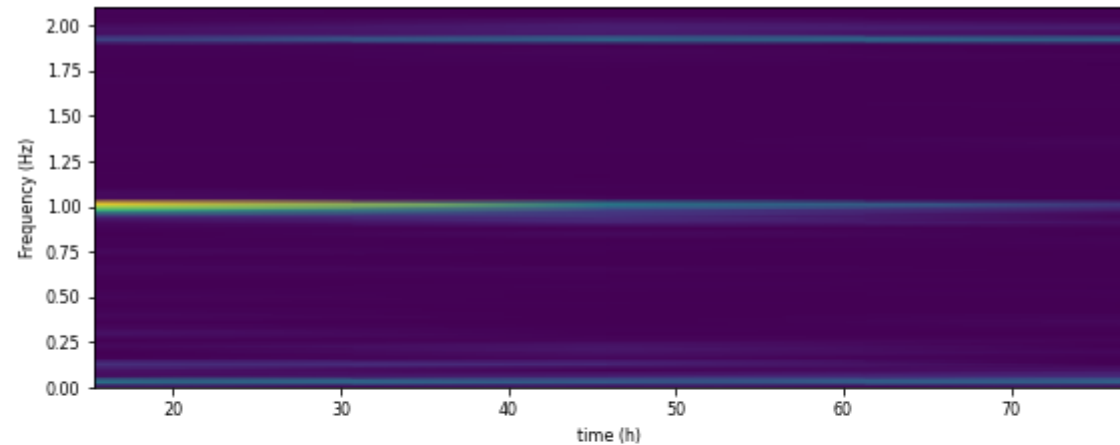


Tryon 2013

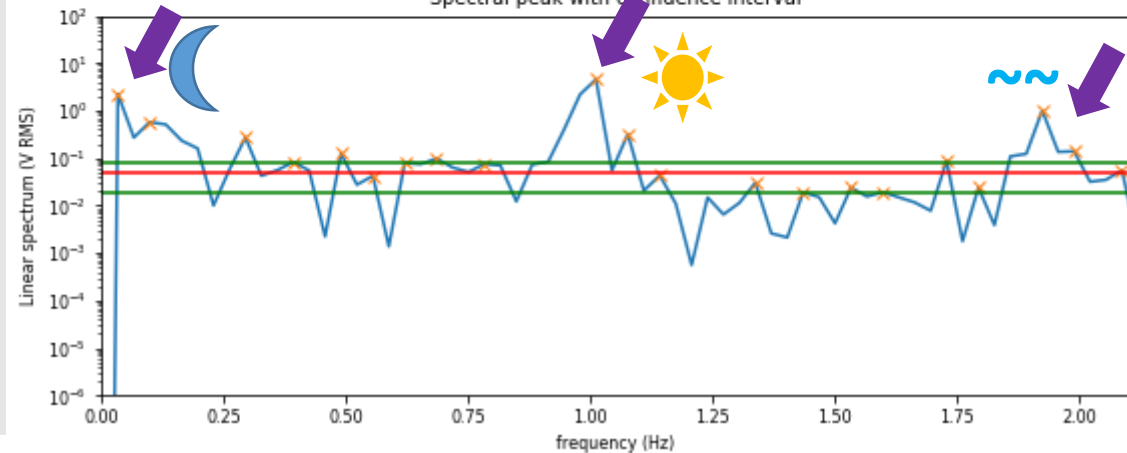


DO series  
understanding

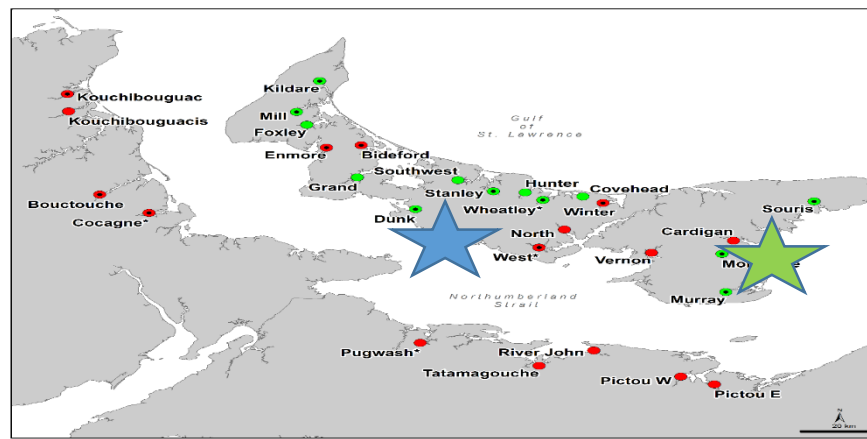
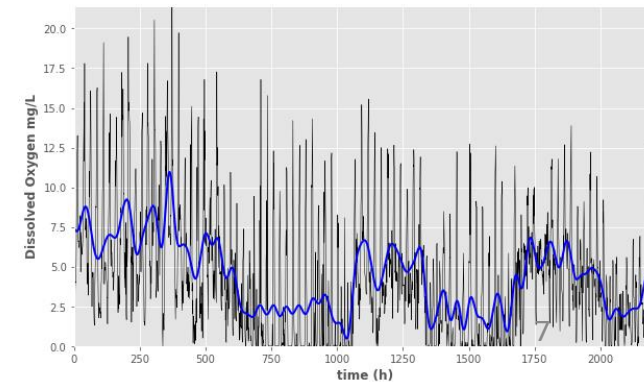
Spectrogram for Montague 2013



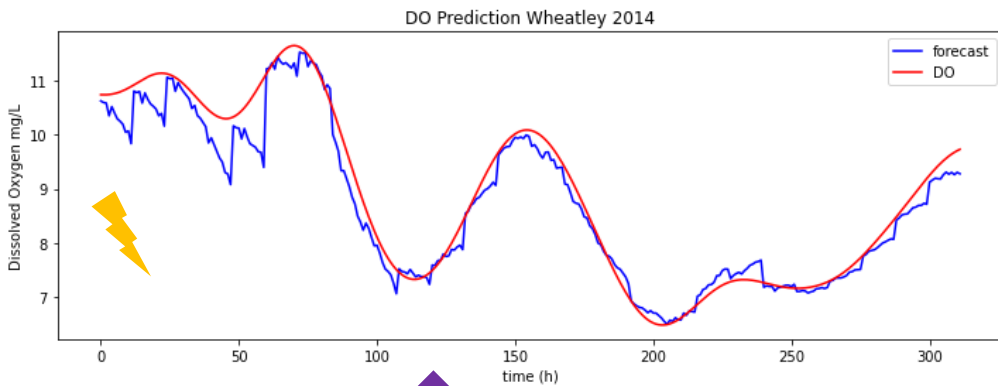
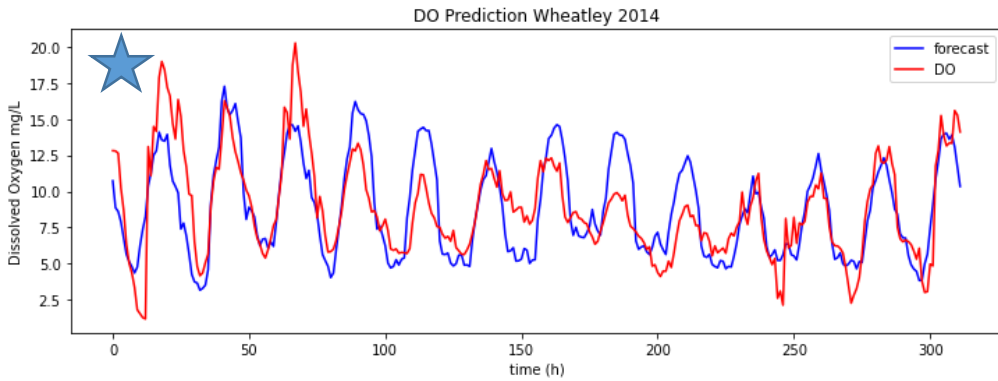
Spectral peak with confidence interval



Montague 2013

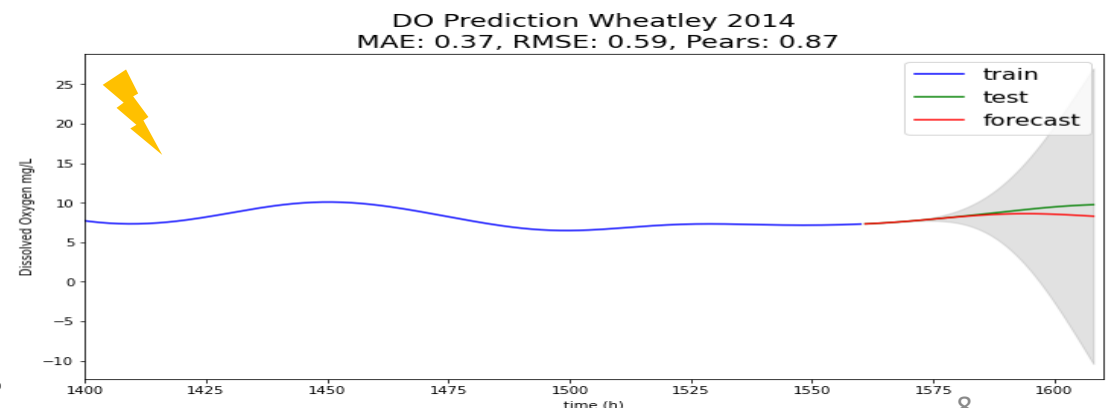
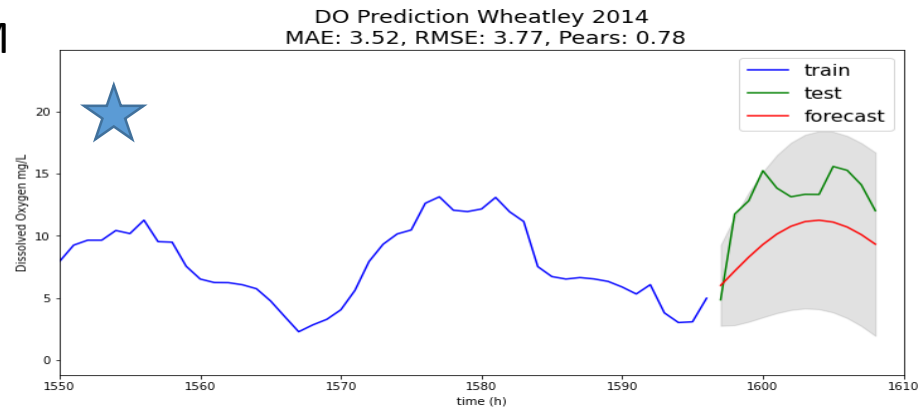


# DO series forecasting



↑  
LSTM

ARIMA →



Data	Method	Time series	Prediction Horizon	RMSE	MAE	Pearson
Unfiltered Data ★	LSTM	Wheatley 2014	12h	2.38	1.87	0.76
		Tryon 2013		1.52	1.09	0.50
		Montague 2013		2.82	1.88	0.55
	ARIMA	Wheatley 2014	12h	3.52	3.77	0.78
		Tryon 2013		1.81	1.92	-0.52
		Montague 2013		4.25	5.96	0.21
Filtered Data ⚡	LSTM	Wheatley 2014	12h	0.34	0.24	0.99
		Tryon 2013		0.14	0.09	0.96
		Montague 2013		0.35	0.26	0.97
	ARIMA	Wheatley 2014	48h	0.37	0.59	0.87
		Tryon 2013		0.12	0.17	1
		Montague 2013		0.36	0.56	0.66

Table 3: Prediction results of LSTM and ARIMA on unfiltered and low-pass filtered data. RMSE is the Root Mean Squared Error and MAE is the Mean Absolute Error.



# Next steps

From univariate to multivariate approach

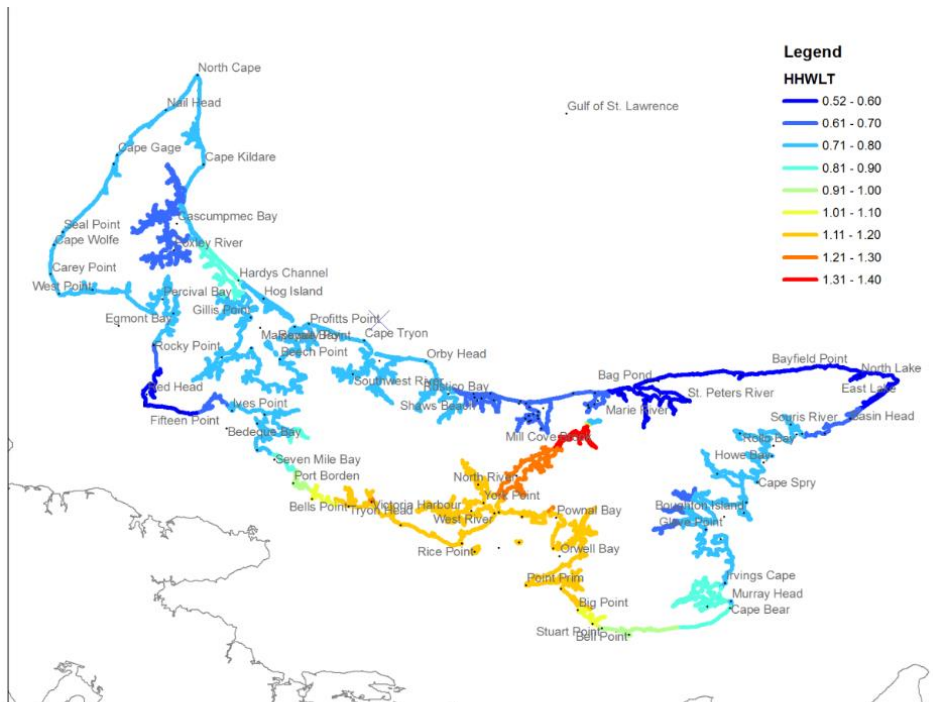
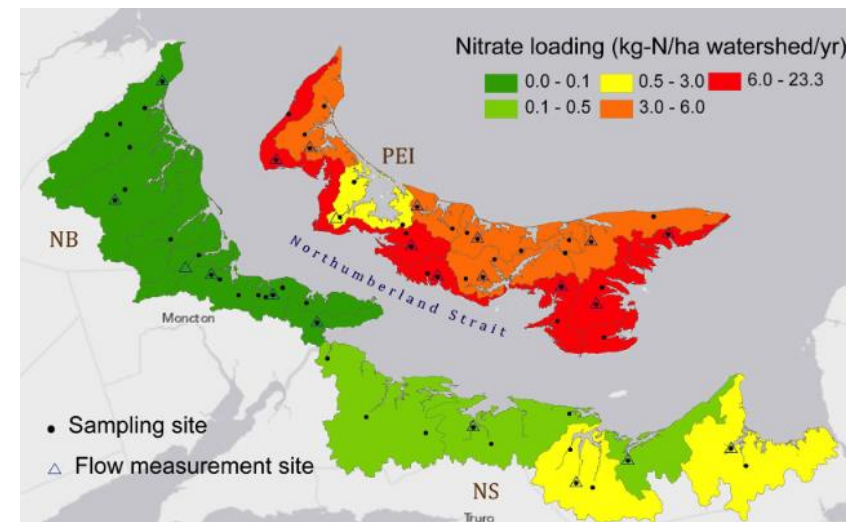


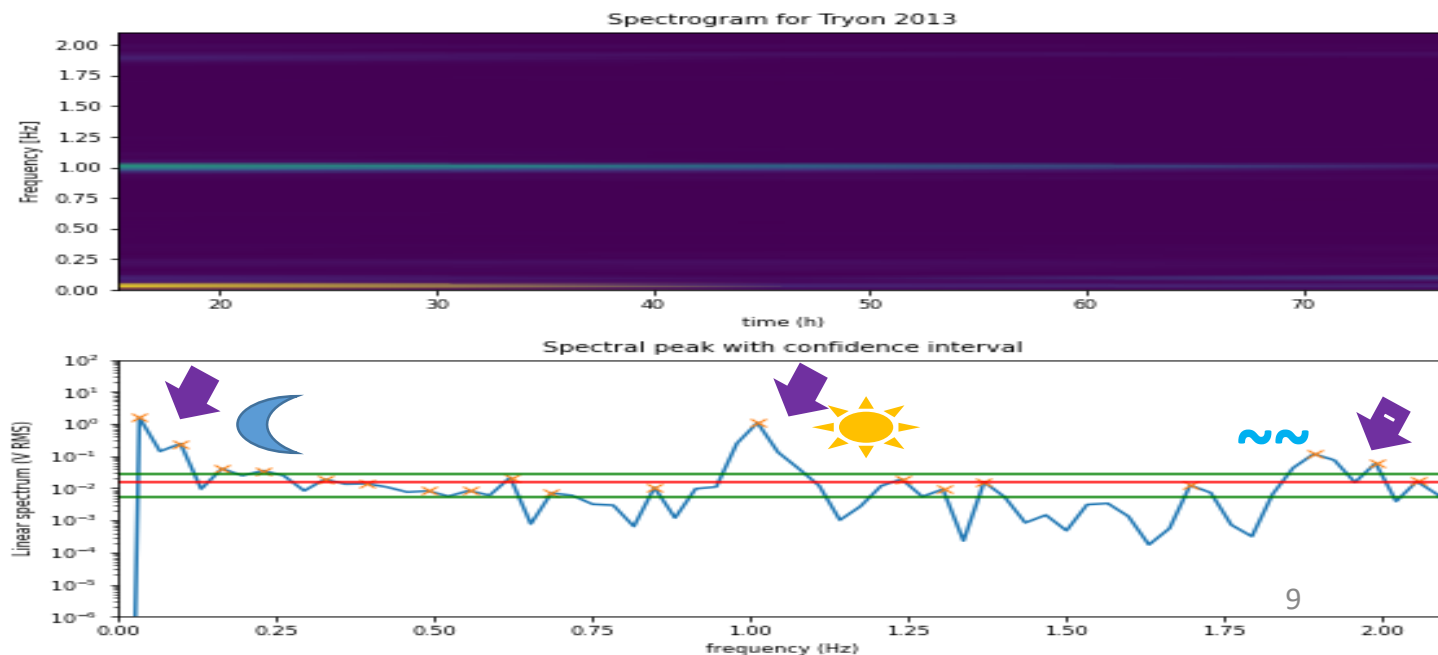
Figure 33 Elevation of peak tides (HHWLT) above mean sea level.

Source: Cold Water Consulting Ltd.  
<https://atlanticadaptation.ca/en/islandora/object/acasa%3A311/datastream/OBJ/view>

Go deeper on time frequency analysis



Source: Canadian Rivers Institute  
<https://cwn-rce.ca/wp-content/uploads/2018/07/CWN-EN-NorthumberlandStrait-2016-Web.pdf>







# Questions ?

Boucliche Dune In New-Brunswick