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Extending observations further: using historic biogeochemical data to understand trends in Puget Sound

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Extending Observations Further: Using Historical Biogeochemical Data to Understand Changes in an Estuary

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Beach site on Vashon Island, looking over Puget Sound

King County's Point Williams monitoring buoy in Central Puget Sound near Lincoln Park

Why use historical data?

Increased understanding of biogeochemical changes over decadal scales is needed to help explain long-term water quality status and trends. Traditionally, monitoring programs use their own data. Here, other available data measured at different temporal scales are combined to explore deep dissolved oxygen and nutrient dynamics at a single location in Central Puget Sound, a deep inland estuary.

King County's marine monitoring program began in the 1960's to assess Puget Sound receiving waters for impacts from municipal wastewater discharges but did not become routine until the 1980's. Data from the Atlas of Puget Sound (Collias et. al, 1974) are included, with some data back to the 1930's. Natural conditions and variability within a waterbody can at times mask anthropogenic impacts. Extended data records can help to inform water quality trends and management decisions to effectively address marine water quality.

Marine Offshore Monitoring

King County

- Sampled bi-weekly at 14 sites (monthly Jan & Dec and pre-2014)
- Full CTD profiles since 1998 (temperature, salinity, density, DO, fluorescence, PAR, transmissivity, nitrate)
- Discrete samples since 1994 for dissolved nutrients (ammonia, nitrate+nitrite, silica, orthophosphate),TSS, fecal indicator bacteria, chlorophyll-*a*
- Discrete samples since 1985 for dissolved oxygen by Winkler
- CTD and mooring data can be accessed at: http://green2.kingcounty.gov/marine

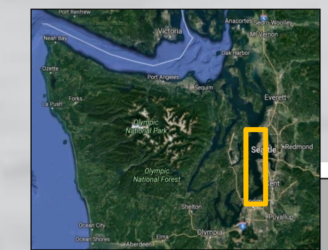
Collias Atlas

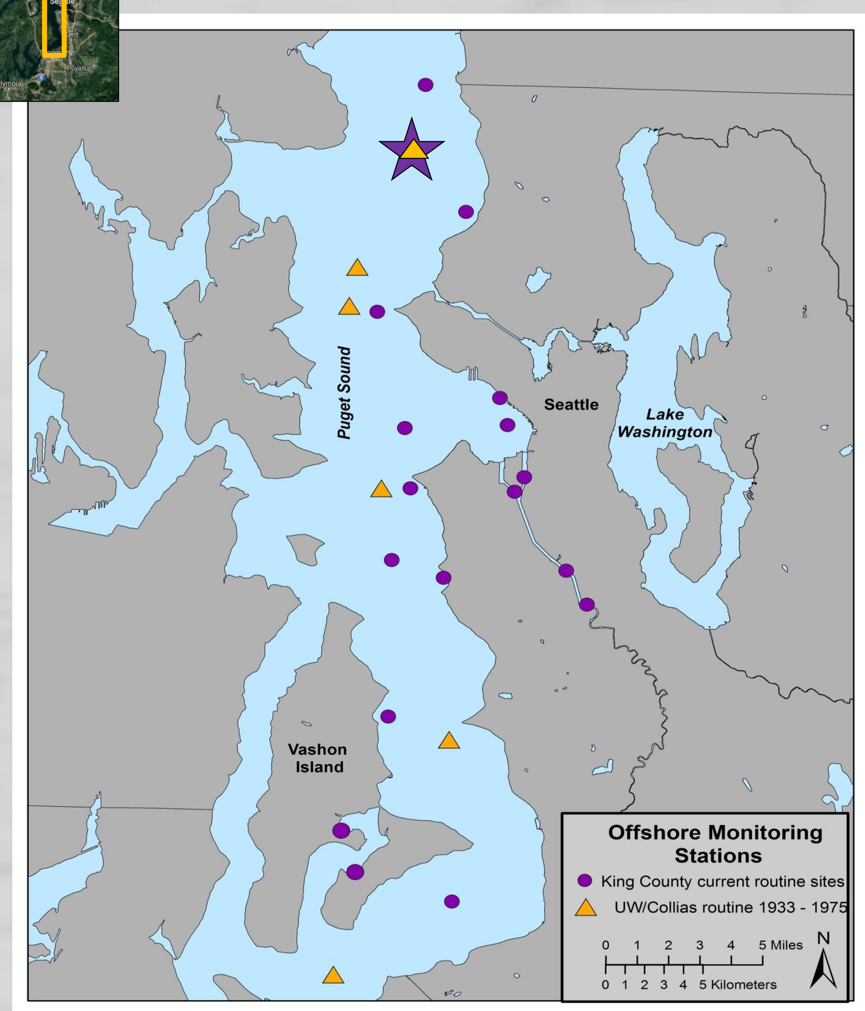
- Data available between 1932 – 1975
- Collection frequency varied from weekly (for spring in some years) to roughly quarterly, with some years missing
- Discrete samples for temperature, salinity, dissolved oxygen by Winkler, and dissolved nutrients (nitrate, nitrite, silica, orthophosphate, and some ammonia).
- Due to method constraints, nitrate was measured only briefly in 1933, and then again from 1965 – 1975 when large method improvements were made (Armstrong et. al, 1967).
- Data obtained from UW, and can also be accessed through EPA STORET: https://www.epa.gov/waterdata/water-quality-data-wqx

Methods

- This analysis focuses primarily on one site near Point Jefferson (shown as the purple star to the right), where both programs were co-located. This site is in the deepest part of Central Puget Sound (~280-m).
- Date ranges, sampling frequency, and data distribution explored
  - King County samples at 1, 15, 25, 35, 55, 100, & 200-m discrete depths
  - Collias data varies, collected primarily at 0, 10, 20, 50, 100, 200, & 250-m
- Deep data outside of the euphotic zone are examined first for trends.

- Detection limits have changed over time for King County nutrient analyses; however, no detection limits are reported for the Collias dataset. When values are below a reported detection limit, values are substituted as ½ of the limit for the purpose of this analysis. In deep data, these low values are rare for the parameters analyzed.





Location of routine offshore stations in Central Puget Sound for King County (purple) and UW/Collias data (orange). Point Jefferson (starred) is a long-term site for both King County and Collias datasets.

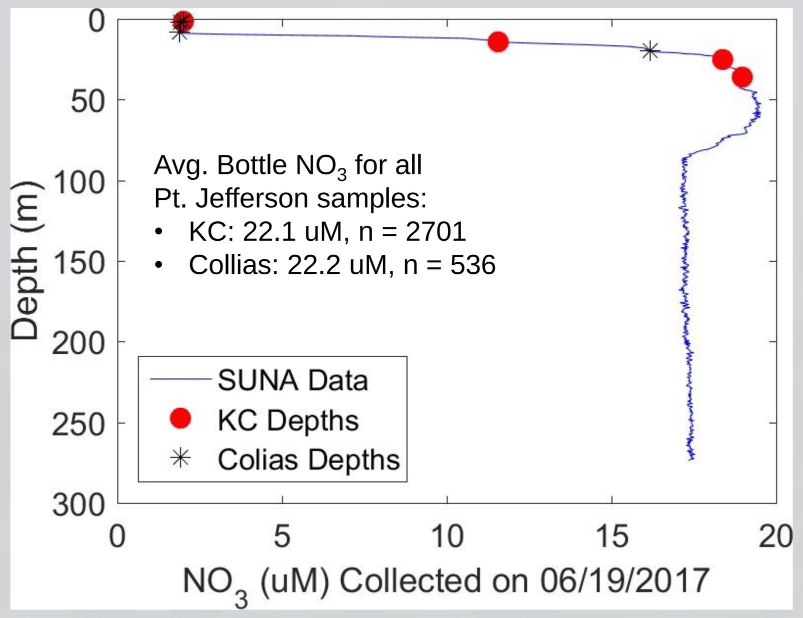
King County R/V Sound Guardian

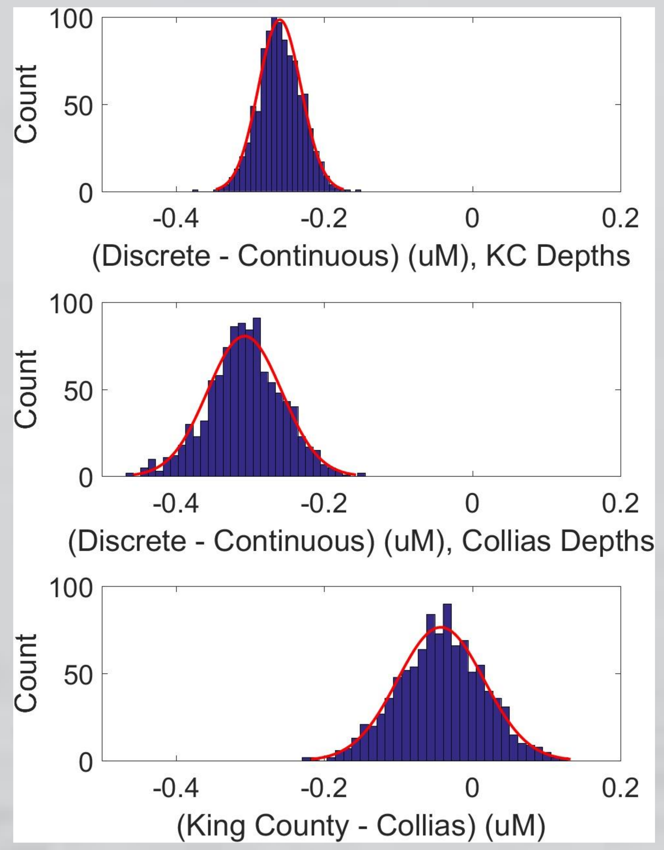
R/V Brown Bear (From Eugene and Dorothy Collias Collection)

What are some challenges?

Objective 1: How does changing target sample depth impact our results? Application: Surface NO_3

In order to simulate and quantify the impact of the choice of depth for sample collection, typical target depths from the Collias and King County sampling programs are used as part of a bootstrapping protocol to determine uncertainty in depth integrated averages.



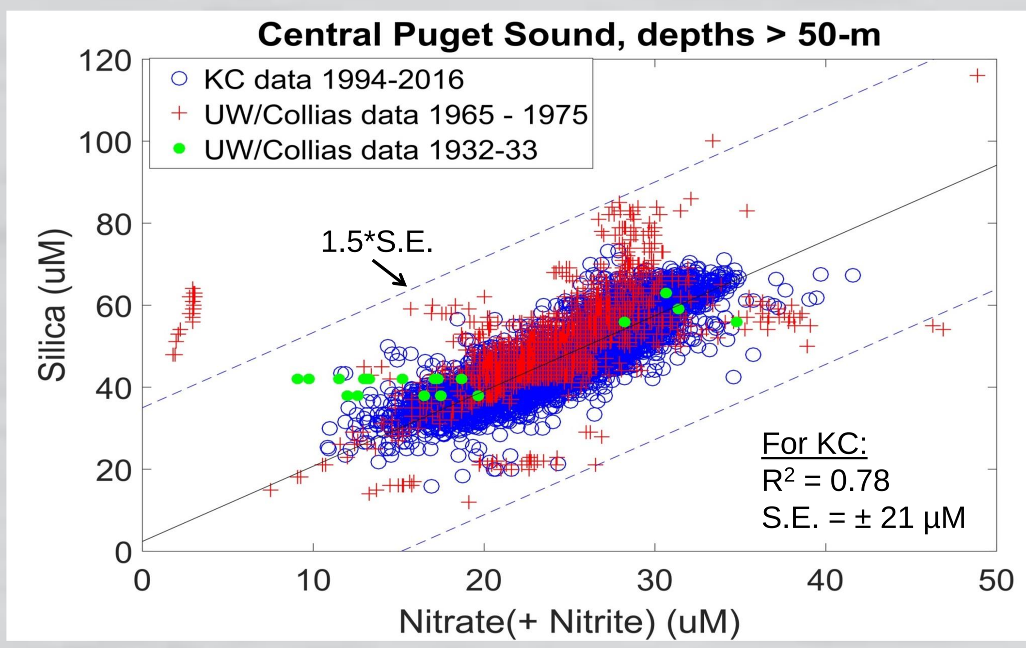


***Top:** Example of a CTD profile from Pt. Jefferson used for the bootstrap method. Symbols show the locations of target depths for each program. Actual discrete data were not used for this analysis. **Right:** Differences in depth-integrated average nitrate (uM). KC and Collias are slightly lower than continuous, and similar to each another.*

Method: a discrete nitrate profile was generated from continuous sensor data using typical target depths of the KC sampling program. The exact depth of sampling was allowed to vary around a target depth based on the observed distribution of sample depths in the data. The depth integrated average was calculated based on this discrete profile, and the difference computed relative to the value from the continuous profile. The process was repeated using typical Collias depths. Lastly, a difference was similarly computed between KC and Collias. 112 individual profiles collected from a total of 6 sites from April – December, 2017 were bootstrap sampled 1,000 times and used as the basis for the calculations.

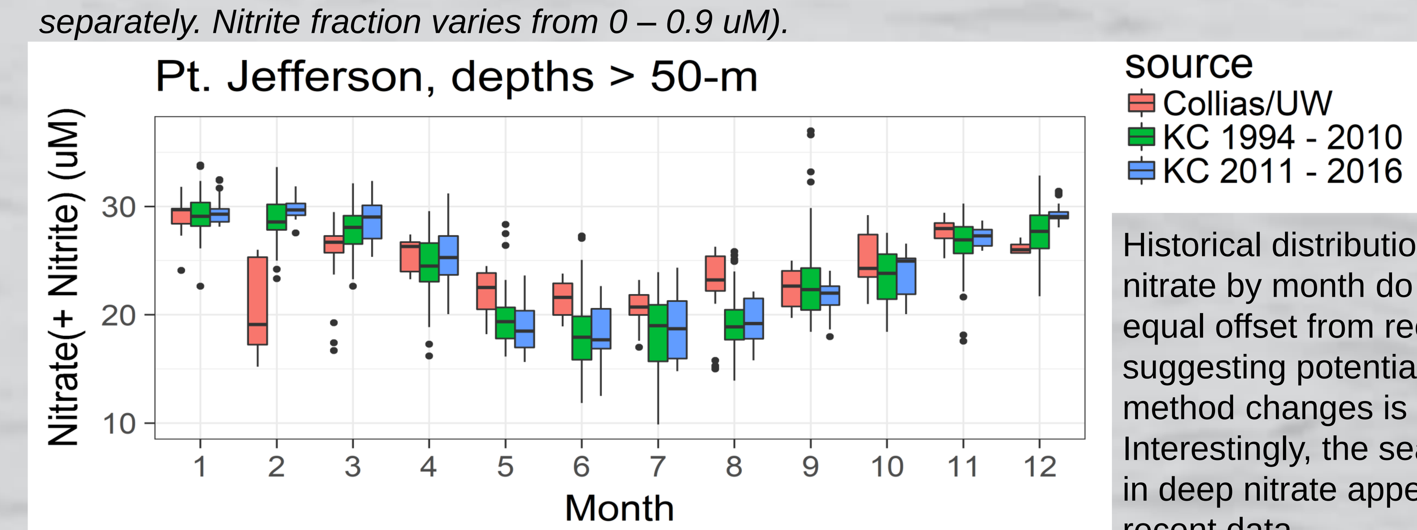
Objective 2: Can we evaluate how method changes over time may impact our results? Application: Mid to Deep NO_3

In this case, historical data are not provided with any qualifiers or detection limits, so data are evaluated first in context of the last two decades. Ranges and parameter co-variates can be used to identify data for further scrutiny before including in trends over time. For nitrate, while the autoanalyzer has been in use since the 1960's, reducing agents and procedures have made improvements (Moorcroft et. al, 2001).



Elemental ratios in plankton and seawater can be described in Redfield ratios as a baseline: 106 C:16 N(Si):1 P (Redfield, 1958). While departures can depend on biological processes and physical fluxes (such as watershed loading), general relationships are found. One application of this linear relationship of nutrients can be to identify outliers. These data can be further evaluated for any possible method problems.

Nitrate vs. silica for all Central Basin sites (at depths deeper than 50-m) from King County and Collias datasets. (Note: King County reports nitrate+nitrite together, while Collias reported nitrate separately. Nitrite fraction varies from 0 – 0.9 uM).



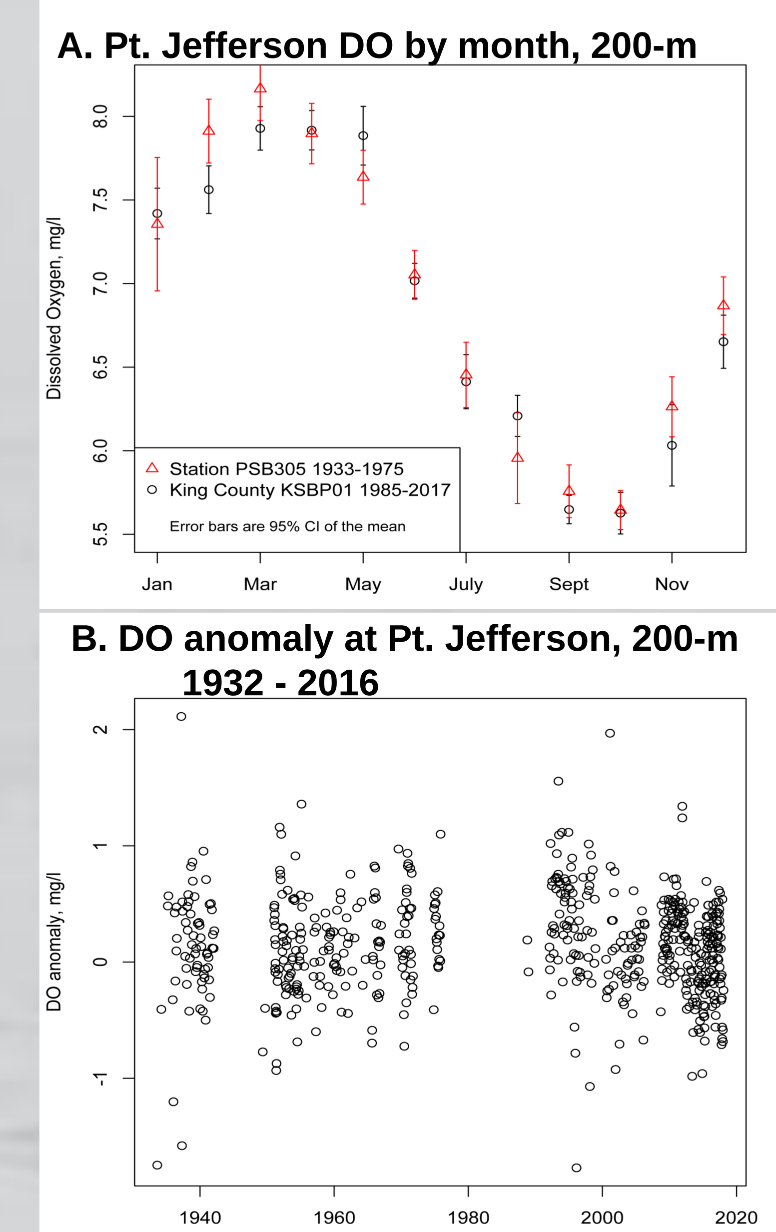
Historical distributions of deep nitrate by month do not show an equal offset from recent data, suggesting potential bias due to method changes is not consistent. Interestingly, the seasonal signal in deep nitrate appears stronger in recent data.

Nitrate ranges by month for one site at depths from 50 to 200-m. Bars show medians, boxes show 25th and 75th percentiles, and whiskers show 5th and 95th percentiles. Number of samples ranges from 13 per month for Collias (with the exception of 4 samples in December) and 24 – 70 samples for KC datasets.

What are some benefits?

Objective 3: Can this lead to improvements in understanding trends over time? Application: Deep O_2

The King County routine site (Pt. Jefferson) was co-located near the historical site, allowing for dissolved oxygen (DO) observations over an 85-year period. To assess trends, DO at 200-m was selected as the deepest depth with overlap by both King County and UW/Collias sampling.



QC: To minimize bias due to method changes, only Niskin samples analyzed by Winkler titration were used. Data quality was verified by comparing bottle measurements to the in-situ DO sensor. The difference between measurements were approximately normally distributed, and measurements with a difference beyond three standard deviations were rejected.

Trends: The seasonal component in DO (shown to the left in panel **A**) was first removed by subtracting the mean from a set 16-year period (2002 – 2017) from both datasets. Multiple linear regression was used on the anomaly with time, salinity anomaly, and water temperature as co-variates. As shown in the plot of monthly anomalies on the left (panel **B**), no significant temporal trend was found. A slight correlation with temperature is present ($p<0.05$).

Splitting data into two periods (1933-1975 and 1985-2017) shows some differences in the seasonal pattern (panel **A**). DO concentrations appear to have decreased in winter months (November – March), with similar or increased levels for the remainder of the year.

Dissolved oxygen dynamics from one site.
A) Split by dataset and shown by month for samples near 200-m as means and 95th %confidence interval. At least 16 samples are available for each month.
B) Monthly DO anomalies from both datasets from 1933 – 2017, using 2002 – 2017 as the baseline in this example.

Summary

- In the absence of metadata and qualifiers, historical data requires careful evaluation before including in water quality status and trends, particularly due to method changes.
  - Variance in a quality-assured dataset can be used to predict and identify outliers in a historical dataset, with an understanding that some relationships can change over decadal scales.
- Integrating samples over a depth range from upper water layers can be used to compare datasets with different target depths, with an estimate of variance from continuous profiles.
- Next steps include assessing additional sites and parameters, such as chlorophyll-a, and precipitation and river inputs, to better understand seasonal differences over time.
  - For example, investigate if higher DO concentrations in May/August and lower nitrate levels in the summer may be a reflection of higher phytoplankton growth. In Puget Sound, deep waters are a mix of oceanic sources and refluxed surface waters due to mixing at sills at the entrance.
- More work is needed in order to better understand drivers over decadal scales in Central Puget Sound, including any links to climate oscillations and changes in watershed loading over time.

References

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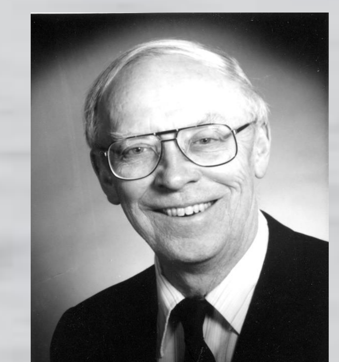

Eugene E. Collias (1926-2017) greatly contributed to the collection and preservation of early Puget Sound data. (Photo from Eugene and Dorothy Collias Collection)

King County Marine Monitoring Webpage and data access: http://green2.kingcounty.gov/marine