Trend analysis of four decades of water quality data in the upper San Francisco Estuary

Marcus W. Beck[1], David Senn[2], Emily Novick[2], Phil Bresnahan[2], James D. Hagy III[1], Thomas Jabusch[2]
[1]US Environmental Protection Agency ORD NHEERL, Gulf Ecology Division, Gulf Breeze, FL
[2]San Francisco Estuary Institute, Richmond, CA

Abstract

Recent methods for trend analysis have been developed that leverage the descriptive potential of long term time series. Combined with these methods, multi-decadal datasets of water quality in the San Francisco Estuary (SFE) could provide a valuable opportunity to gain insight into ecosystem properties and drivers of change in estuaries. This study explores the use of an estuarine adaptation of the Weighted Regression on Time, Discharge, and Season (WRTDS) approach to describe nutrient trends in the northern region of SFE (Suisun Bay and the Delta), a primary source of nutrients into the system. This novel technique is data-driven where the parameterization of the functional model changes smoothly over time following dynamic patterns of season and flow. By doing so, changes over time that have not been previously quantified can be described, including variation in flow-normalized concentrations, frequency occurrence of extreme events, and response to historical changes in the watershed, all of which are important needs for understanding trends in the northern SFE. The goal of the analysis is to apply the WRTDS model at multiple stations in the Delta and Suisun Bay regions of SFE to describe variation over time and relationships between key species of dissolved inorganic nitrogen (ammonium, nitrate/nitrite, total). This variation is considered in the context of varying contributions of input flows from the Sacramento and San Joaquin rivers, as well as tidal exchange with the central SFE. Overall, this analysis is expected to further an ecological and management-based understanding of dynamics in SFE, with implications for water quality restoration and protection of this prominent system.

Analysis components

- WRTDS trend analysis method applied to nine stations in SFE
- Models were developed for three nitrogen analytes: DIN, NO_2^-/NO_3^{2-}, NH_4^+
- Results were evaluated as flow-normalized trends

Water Quality and Flow Data

- Nine nutrient stations with bimonthly samples and daily flow estimates from major inflows

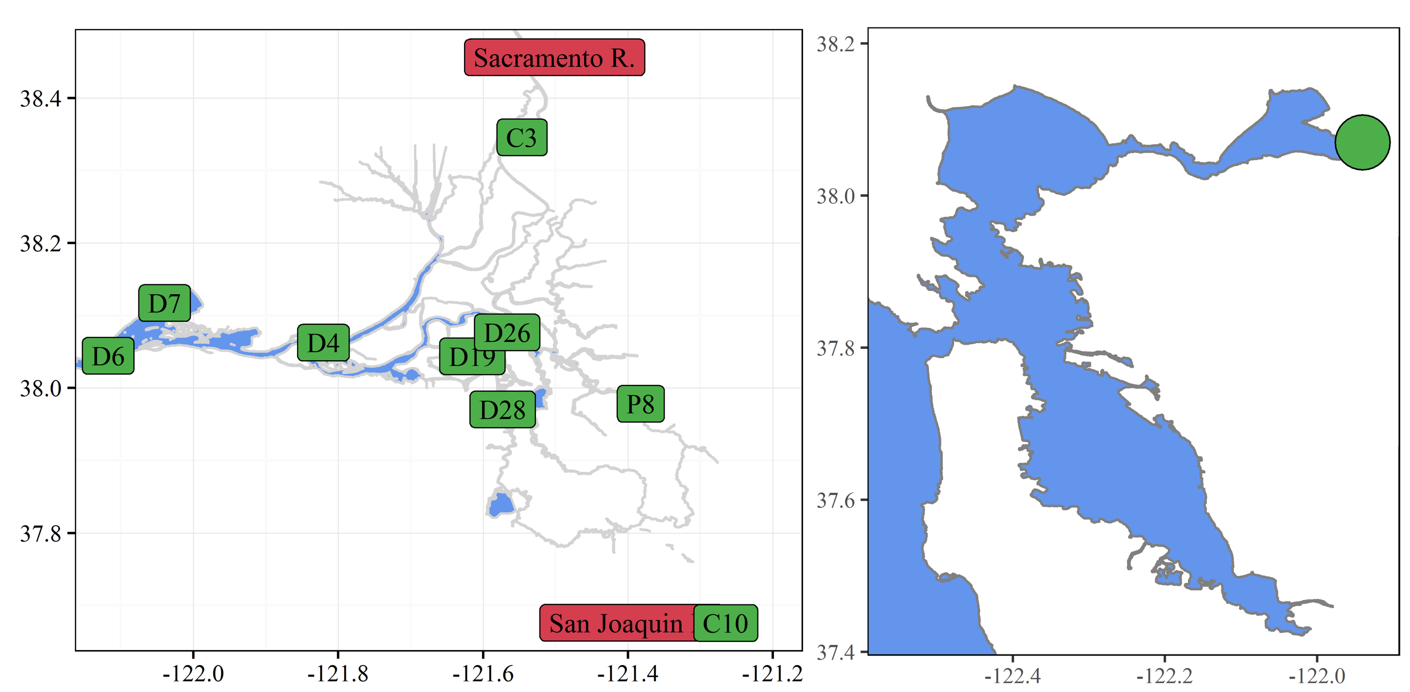


Figure : Locations of bimonthly nutrient (green) and daily flow (red) stations in SFE.

Applying Weighted Regression (WRTDS)

WRTDS is applied to nutrient observations in relation to time, discharge, and season

$$\ln(N) = \beta_0 + \beta_1 t + \beta_2 \ln(Q) + \beta_3 \sin(2\pi t) + \beta_4 \cos(2\pi t)$$

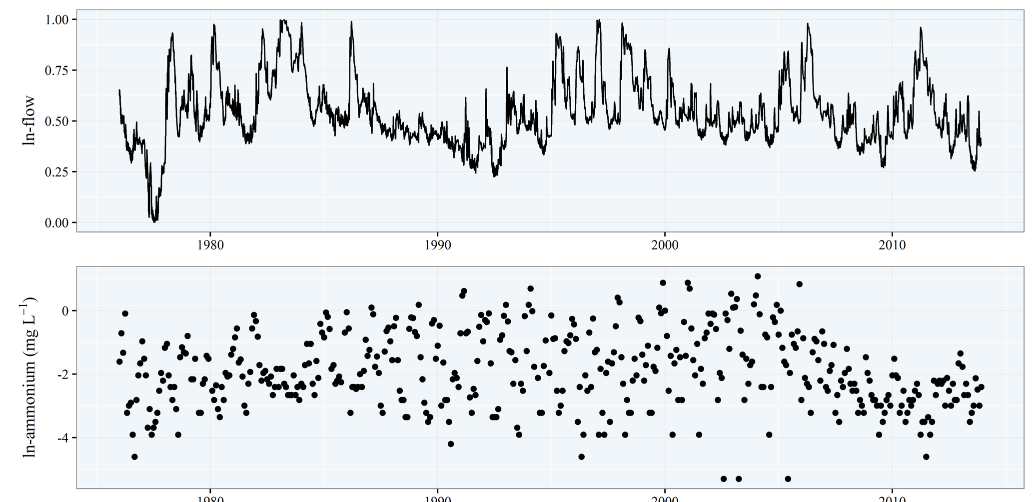
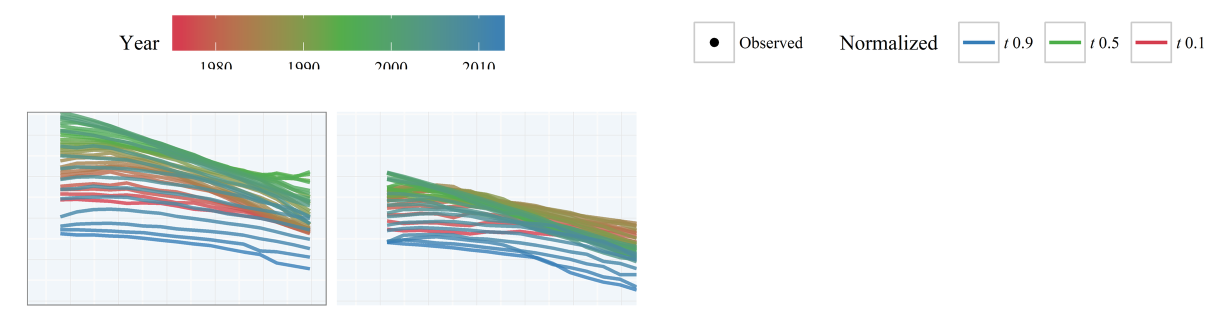


Figure : Example of flow and nitrogen data at C10.

WRTDS output monthly variation to flow changes and for different quantile distributions of nitrogen.



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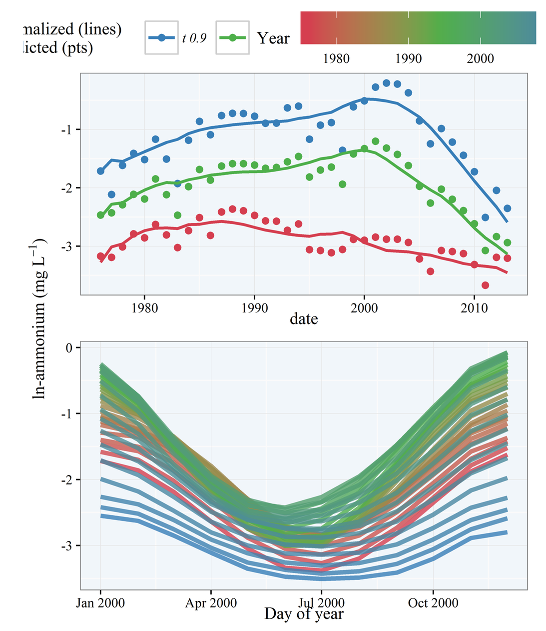

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Trend Analyses

Table : Percent changes in DIN by years/months.

Site	1976-1988	1989-2000	2001-2012	JFMA	MJJA	SOND
C10	***28.3***	***17.4***	-41.7	-25.7	-10.1	***1.7***
C3	***23.9***	***26.8***	-13.9	***30.7***	***54.8***	***42.8***
D19	-19.8	***3.3***	-15.3	-28.6	-35.1	-15.6
D26	-5.2	***10.9***	-19.4	-10.9	-3.4	-2.6
D28	-21.7	***3.9***	-37.3	-32.9	-53.3	-48.8
D4	-10.9	***20.3***	-7.1	***11.4***	***4.8***	***10.7***
D6	-7.4	***21.6***	-8.5	-4.7	***45.6***	***34.7***
D7	-24.2	***17***	-6.1	-6.9	***19***	***21.4***
P8	***49.9***	***38.4***	-35.7	***31.6***	***52.8***	***45.4***

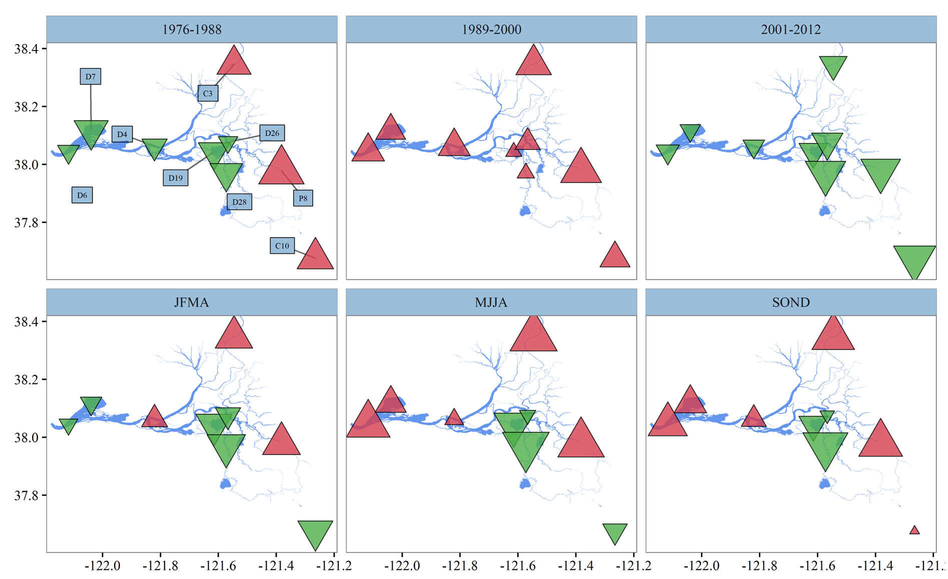


Table : Percent changes in ammonium by years/months.

Site	1976-1988	1989-2000	2001-2012	JFMA	MJJA	SOND
C10	-39	-54.1	-46.5	-77.1	-88.7	-90.9
C3	***53.6***	***41.6***	-18.1	***81.8***	***95.8***	***74.6***
D19	***8.8***	-5.6	-7.5	-16	-21.8	-4.8
D26	***22.8***	***8.4***	-20.9	-0.9	***7.9***	***18.7***
D28	-11.8	-16.9	-18.2	-42.3	-24.7	-34.7
D4	***5.3***	***46.8***	-5.1	***66.9***	***33.6***	***68.3***
D6	***11.8***	***33***	-9.7	***36***	***56.4***	***45.3***
D7	-20.8	***25.2***	-11.6	***21.2***	-16	***34***
P8	***143.1***	***46.7***	-86.5	-52.7	-23.9	-61.1

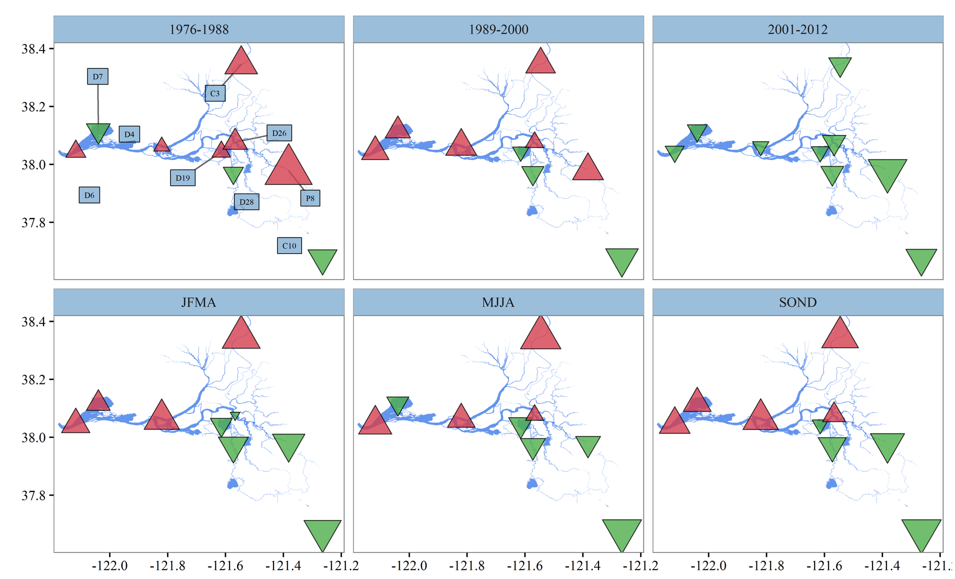
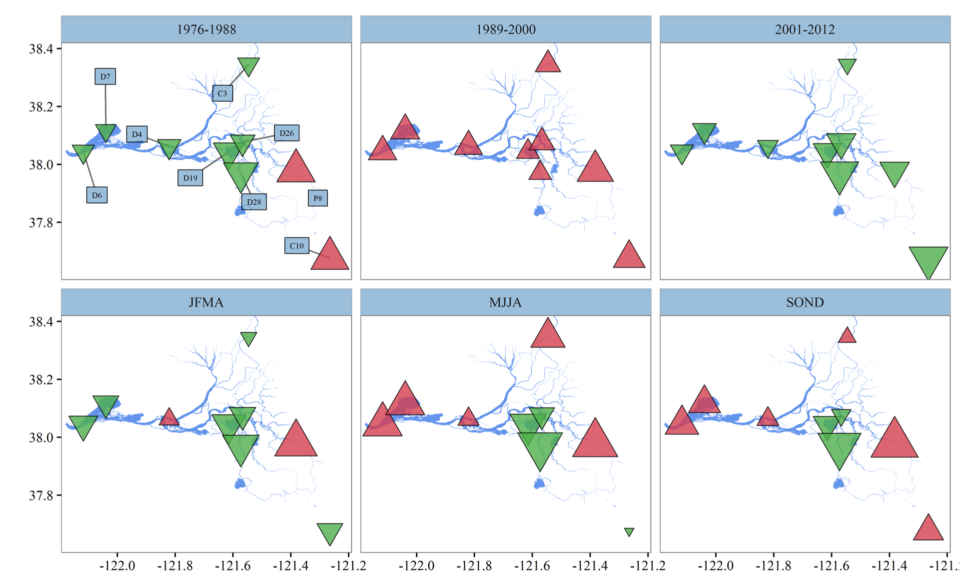


Table : Percent changes in nitrite/nitrate by years/months.

Site	1976-1988	1989-2000	2001-2012	JFMA	MJJA	SOND
C10	***38.7***	***23.7***	-40.8	-12.5	-0.2	***20.4***
C3	-7.2	***11.9***	-3.6	-2.3	***29.4***	***3.3***
D19	-21.8	***8.7***	-16.5	-28.6	-34	-16.3
D26	-11	***12.9***	-18.9	-13.4	-11.8	-4.7
D28	-30.2	***7.9***	-39.1	-34.5	-59.1	-53.8
D4	-9.2	***15.9***	-6.0	***5.4***	***6.6***	***7.3***
D6	-7.8	***16.7***	-8.8	-17.9	***42.6***	***27.6***
D7	-6	***18***	-9.9	-12.7	***41.9***	***24.4***
P8	***39.1***	***33.9***	-18.8	***52.2***	***60.6***	***67.3***



Further Evaluation

Covariation among indicators can provide mechanistic clues

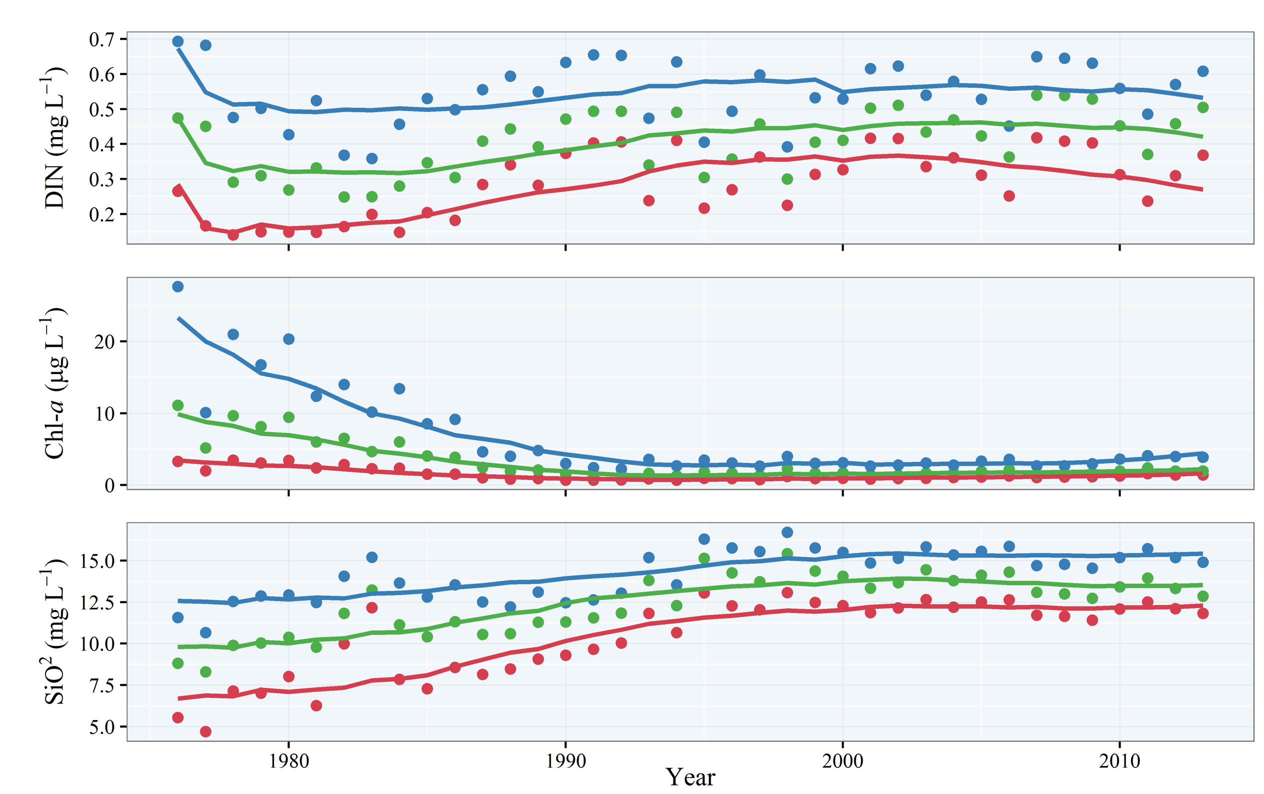


Figure : Flow-normalized trends of DIN, Chl-*a*, and SiO^2 at D7 (Suisun Bay).

Conclusions

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- two
- Interactive data app of full results: https://beckmw.shinyapps.io/sf_trends/

USEPA ORD NHEERL - Gulf Ecology Division - Gulf Breeze, FL
Mail: beck.marcus@epa.gov
WWW: http://fawda123.github.io/sf_trends/README