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Four decades of water quality change in the upper San Francisco Estuary

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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 coastal systems can provide valuable opportunities to gain insights into ecosystem properties and drivers of change. This study describes use of an estuarine adaptation of the Weighted Regressions on Time, Discharge, and Season (WRTDS) model to describe water quality trends over four decades in the Delta region of the San Francisco Estuary (SFE). This region is a complex mosaic of inflows that are primary sources of nutrients into the larger Bay. To date, a comprehensive evaluation of the long-term monitoring dataset at multiple stations in the Delta has not been conducted despite the importance of nutrient transport from the region for water quality in the entire bay. The WRTDS technique is data-driven where the parameterization of the functional model changes smoothly over time following dynamic patterns of season and flow. Water quality trends 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 changes in the SFE. Model results from multiple stations in the Delta provided novel descriptions of historical trends and relationships between key species of dissolved inorganic nitrogen (ammonium, nitrate/nitrite, total). This variation was described 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. Conceptual relationships between water quality and drivers of change were used to generate and test hypotheses of mechanistic relationships using selected examples from the trend descriptions. Overall, this analysis provides an ecological and management-based understanding of historical trends in the SFE as a means to interpret potential impacts of recent changes and expected trends in this dynamic system. An argument is also made for more comprehensive evaluations of long-term monitoring datasets to understand relationships between response endpoints and causal mechanisms in coastal waters.

1 Introduction

1. How and why are trends interpreted - assessment of raw data, surrogates, various methods (kendall, GAM, WRTDS), what have been implications of using different approaches, see Kratzer USGS report <http://pubs.usgs.gov/sir/2010/5228/pdf/sir20105228.pdf> and data

35 http://pubs.usgs.gov/sir/2010/5228/, need to interpret eutrophication trends in estuaries - it's
36 confusing ([Cloern and Jassby 2010](#))

37 2. WRTDS, original method ([Hirsch et al. 2010, 2015](#))

38 3. WRTDS application to Tampa Bay as test set ([Beck and Hagy III 2015](#)), further validation
39 in Patuxent and other tidal waters [Beck et al. \(2015\)](#)

40 4. SF estuary, unique and prominent location, full story is complex (historical context and
41 recent changes) ([Cloern and Jassby 2012](#)), why is the delta important (a vigorous
42 biogeochemical reactor) ([Jassby and Cloern 2000, Jassby et al. 2002, Jassby 2008](#)), no one
43 has empirically described the data in the delta using data-intensive methods

44 San Francisco Bay on the Pacific Coast of the United States is one of the most prominent
45 estuaries in the western hemisphere. Background nutrient concentrations in the Bay often
46 exceed those associated with excessive primary production, although eutrophication events
47 have historically been infrequent. Recent changes in response to additional stressors (e.g.,
48 variation in freshwater inputs/withdrawals, invasive species, climate change) suggests that
49 Bay condition has not followed historical trajectories and more subtle spatial and temporal
50 variation could provide clues that describe underlying properties of this system. The unique
51 ecological and social context of the Bay, including a rich source of monitoring data from
52 the last four decades, provides a valuable opportunity to gain insight into ecosystem
53 properties of estuaries.

54 5. Study goal and objectives

- 55 • Provide a description of trends - annual, seasonal, spatial, response to flow, change by
56 analytes
- 57 • Detailed description of selected sites in the context of conceptual relationships - 1)
58 nonlinear or extreme quantile changes, site TBD, 2) P8 and WWTP improvements, 3)
59 Suisun DIN, SiO₂, Chla, and clams
- 60 • What this means for understanding other systems

61 **2 Methods**

62 **2.1 Study location and data**

63 The San Francisco Estuary (SFE)... exchange with ocean, freshwater inputs (rivers and
64 watershed drainage), runoff variation (drought years), climate, support of natural resources,
65 subembayments, POTW (publicly owned treatment works), nutrient loading relative to other
66 locations

67 **2.2 Analysis method and application**

$$\ln(N) = \beta_0 + \beta_1 t + \beta_2 \ln(Q) + \beta_3 \sin(2\pi t) + \beta_4 \cos(2\pi t) \quad (1)$$

68 nine discrete sampling stations with data from 1976 to 2012, dissolved inorganic
69 nitrogen (DIN), ammonium, total nitrate, effects of different flow variables
70 Annual, seasonal trends of flow-normalized predictions

71 **2.3 Case studies**

72 These are science questions that are relevant outside of the region.

73 **2.3.1 Disaggregating observed nitrogen time series**

74 Hypothesis: Because multiple factors influence nutrient concentrations at different times,
75 relationships between nutrients, time, and flow/salinity are non-linear and complex, so we expect
76 1) annual trend independent of seasonal trend, 2) changes in seasonal amplitudes and quantile
77 trends over time, 3) varying flow contribution, either as difference between
78 predicted/flow-normalized results or changes in nutrient v flow scatterplots at different annual
79 periods.

80 **2.3.2 Effects of wastewater treatment**

81 Hypothesis: Modal response of nutrient concentrations at P8 over time is result of WWTP
82 upgrades, so we expect 1) a shift in load contributions before/after upgrade, 2) a flow-normalized
83 annual trend at P8 to show a change concurrent with WWTP upgrades, and 3) different nitrogen
84 species will have different changes depending on change in load outputs. See [here](#)

85 **2.3.3 Effects of biological invasions**

86 Hypothesis: Biological invasions by benthic filter feeders have shifted abundance and
87 composition of phytoplankton communities in Suisun Bay, so we expect 1) decline in annual,
88 flow-normalized chlorophyll concentrations over time coincident with increase in abundance of
89 invaders, 2) changes in ratios of limiting nutrients (nitrogen, SiO₂) suggesting different uptake
90 rates with shift in community composition, and 3) seasonal shifts in limiting nutrients based on
91 changes in community composition and relative abundances with seasonal succession.

92 **3 Results**

93 **3.1 Trends**

94 **3.2 Selected examples**

95 **3.2.1 Disaggregating observed nitrogen time series**

96 Fig. 3, Fig. 4

97 Emphasize the information the model provides relative to the observed time series. A
98 distinct annual trend with a maximum in the middle of the time series is observed, with lower
99 values at the beginning and end of the period. The seasonal patterns generally showed that DIN
100 concentrations were highest in January with higher values at moderate to low flow rates
101 depending on the year. Interestingly, summer and fall concentrations have showed a slight
102 increase later in the time series (2004-2009). The confounding effect of flow is also very
103 apparent such that higher flows were associated with lower concentration. Dynaplot showed that
104 there was always a negative association between the two (i.e., no modal response). The quantile
105 distributions showed similar trends over time in both predicted values and flow-normalized
106 predictions, although some exceptions were observed. In particular, high flow (1984, 2008)
107 reduced concentrations of all quantiles but the magnitude of the effect increased at higher
108 quantiles (i.e., the effect was disproportionate). The opposite was observed for low flow, i.e., the
109 ninetieth percent showed the greatest increase for low flow.

110 Emphasize the summer/fall change in the 2000s, why is this? Check ([Cloern et al. 2007](#)),
111 showed seasonal changes in early 2000s in chlorophyll (NE Pacific shifted to cool phase), is there
112 a mechanism here with DIN? Relate to conceptual diagram.

113 ***3.2.2 Effects of wastewater treatment***

114 Overall reduction in total nitrogen load was observed as a result of reduction in
115 ammonium (Fig. 5). Nitrate is the primary constituent of total nitrogen after 2007. Organic
116 nitrogen is a larger percentage of the total after nitrification. What was reduction in ammonium
117 starting in 2002?

118 Nitrogen trends at P8 shifted in response to upstream wastewater treatment plant (WWTP)
119 upgrades (Fig. 6), with ammonium showing the largest reduction. Interestingly, nitrite/nitrate
120 concentrations also showed a similar but less dramatic decrease. Percent changes are shown in
121 Table 2, where both nitrogen species shows large percent increases prior to WWTP upgrades
122 followed by decreases after upgrades with ammonium showing the largest percentage. Seasonally,
123 increases prior to upgrades were most apparent in the July-August-September (JAS) months for
124 both analytes. Seasonal reductions post-upgrades were also largest in JAS for nitrite/nitrate,
125 whereas percent reductions were similar across all monthly groupings for ammonium.

126 Relationships of nitrogen with flow showed the typical inverse flow/concentration
127 dynamic with flushing at high flow, although patterns differed by nitrogen species. Seasonal
128 variation was more apparent for ammonium, although both typically had the highest
129 concentrations in the winter. Additionally, strength of the flow/nutrient relationship changed
130 throughout the time series the year where the strongest relationship differed by analyte.
131 Nitrite/nitrate typically had the strongest relationship flow later in the time series, whereas
132 ammonium had the strongest relationship with flow in the early 2000s.

133 ***3.2.3 Effects of biological invasions***

134 Data from ([Crauder et al. 2016](#)), [Jassby \(2008\)](#) describes phytoplankton community
135 changes in the upper estuary, including chlorophyll response to flow. Figure 10 in [Jassby \(2008\)](#)
136 showed that chlorophyll generally decreased with flow in 1980 but increased with flow in 2000.

137 Note the decrease in Potamocorbula abundance in 2011, 2012. These are wet years where
138 abundance/biomass of the clams is driven down by lower salinity. Contrased wtih the annual
139 chlorophyll trends in the same years, the predicted values are above the flow-normalized trend
140 suggesting an increase in chlorophyll with higher flow. The potential mechanism is therefore a
141 decrease in clam abundance with high flow that releases phytoplankon from filtration pressure.
142 This also explains the positive association of chlorophyll with flow in recent years (bottom right

143 dynaplot).

144 Further, chlorophyll trends early in the time series generally show a decrease with high
145 flow with a distinct maximum at moderate flow. This may suggest stratification events at
146 moderate flow contributed to phytoplankton blooms early in the time series. Water withdrawals
147 later in the time series could have also altered environmental conditions to reduce the frequency
148 occurrence of stratification events. Look into this more...

149 What about biomass/density relationships for Potamocorbula? Although clam density
150 increases throughout the period, What about initial decrease in chlorophyll prior to clam invasion?
151 Is this related to water withdrawals (i.e., decrease in stratification events at moderate flow)?

152 Fig. 7, Fig. 8, Table 3, Table 4

153 **4 Discussion**

154 Trends as percent change depend on the mean value, lower values will have larger percent
155 changes.

156 Second case study showed typical inverse relationships between nutrients and flow, more
157 flow means greater flushing and dilution of nutrient concentrations. Conversely, low flow means
158 less flushing and higher nutrient concentrations, although this may not always be observed if the
159 available nutrients are biologically available. Low-flow events during warmer months show the
160 lowest ammonium concentrations, which corresponds to seasonal maxima in chlorophyll
161 concentration. A similar but weaker relationship was observed with nitrite/nitrate where increased
162 flow was related to decreased concentration and lower concentrations overall were observed in the
163 summer. However, low-flow events still had higher concentrations than high-flow events in July,
164 as compared to ammonium which was low regardless of flow. This suggests that ammonium
165 concentrations are driving phytoplankton production at P8. Annual trends in chlorophyll
166 concentration (not shown) showed an overall decrease from the 1970s to present, although a slight
167 peak is observed in the 2000s. This peak is likely related to the maximum ammonium
168 concentration shown in Fig. 6. Moreover, flow/chlorophyll relationships have generally been
169 constant throughout the period of record such that a change in flow has not been related to a
170 change in phytoplankton production. This suggests that nutrient loads that contribute to
171 production at P8 are primarily from point sources at WWTP outflows as a change in flow does not

¹⁷² affect the load output. But what are watershed loads?

¹⁷³ What do nitrogen trends mean? Have to interpret relative to trends in other variables. A
¹⁷⁴ decrease in nitrogen or constant nitrogen does not mean nitrogen inputs have stayed the same,
¹⁷⁵ they might actually be increasing if nitrogen. A change in chlorophyll relative to change in
¹⁷⁶ nitrogen could be informative, and even moreso, a change in silica relative to change in
¹⁷⁷ chlorophyll suggests diatom biomass has changed. However, there are mismatches in these trends
¹⁷⁸ that suggest other processes are at play, e.g., residence times and flow inputs, etc. Trends in
¹⁷⁹ Suisun relative to trends in Delta provide an example, e.g., Suisun is decrease in chlorophyll,
¹⁸⁰ increase in silica, increase in nitrogen, delta is decrease in silica, increase/decrease in DIN
¹⁸¹ (depending on time period/season), decrease in chlorophyll, what's going on? See Senn slide 14
¹⁸² (from burial?). The WRTDS model lets us at least address trends in the context of season, time,
¹⁸³ and flow. This allows for more improved interpretation relative to observing raw data. Also explain
¹⁸⁴ more information by looking at ammonium, nitrate/nitrite, relative to DIN. What about other
¹⁸⁵ variables (light level as suspended particulate matter, temperature)?

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

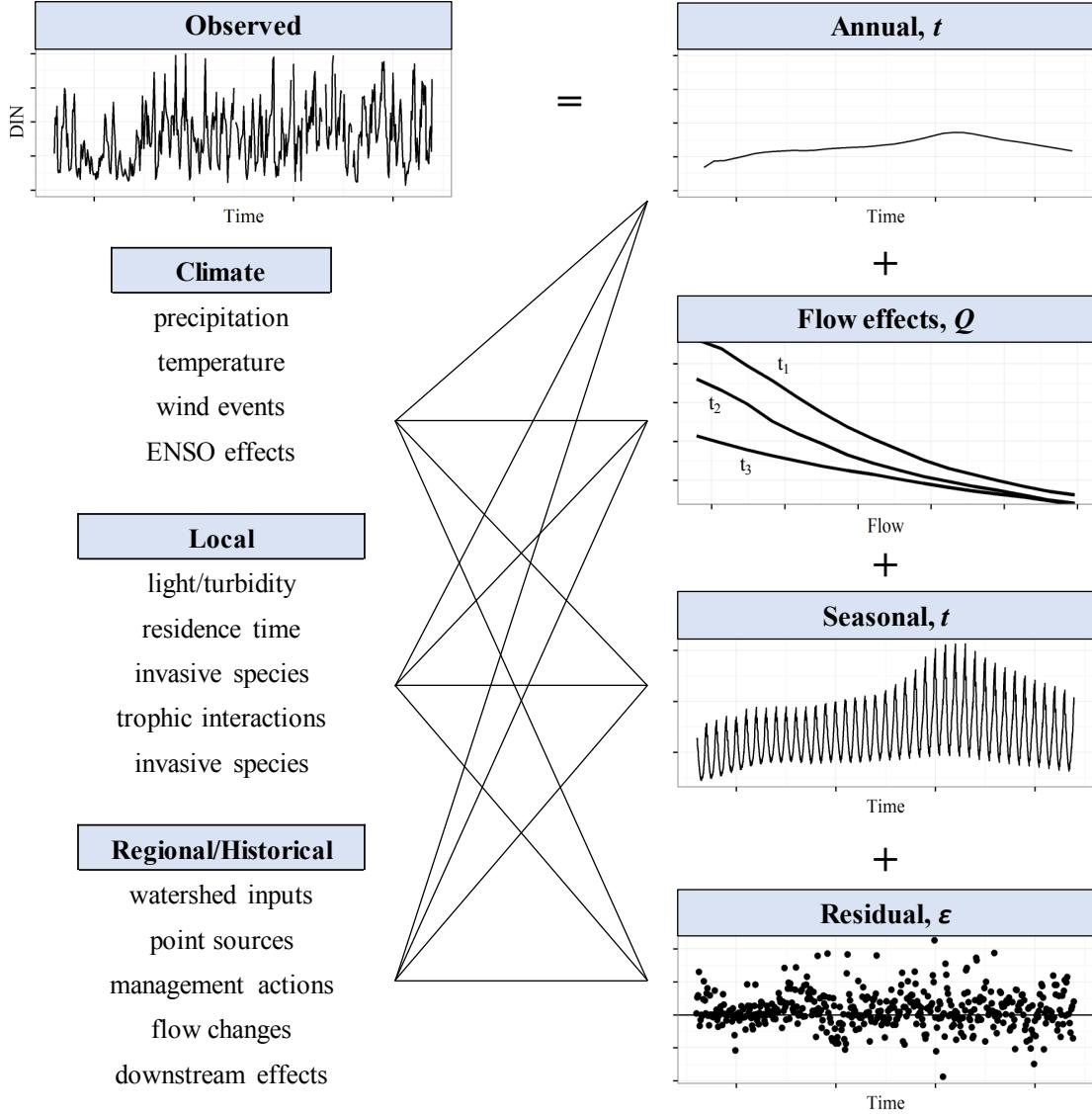


Fig. 1: Conceptual diagram illustrating use of WRTDS to decompose trends in observed nitrogen time series and potential forcing factors that can explain model output. Results from the model are described as annual and seasonal trends, changes in flow-nutrient dynamics for different time periods, and residual variation independent of time, flow, and season. Relationships between environmental factors (climate, local, regional/historical) and nitrogen trends are more easily related to the separate components of the observed time series using results from the model.

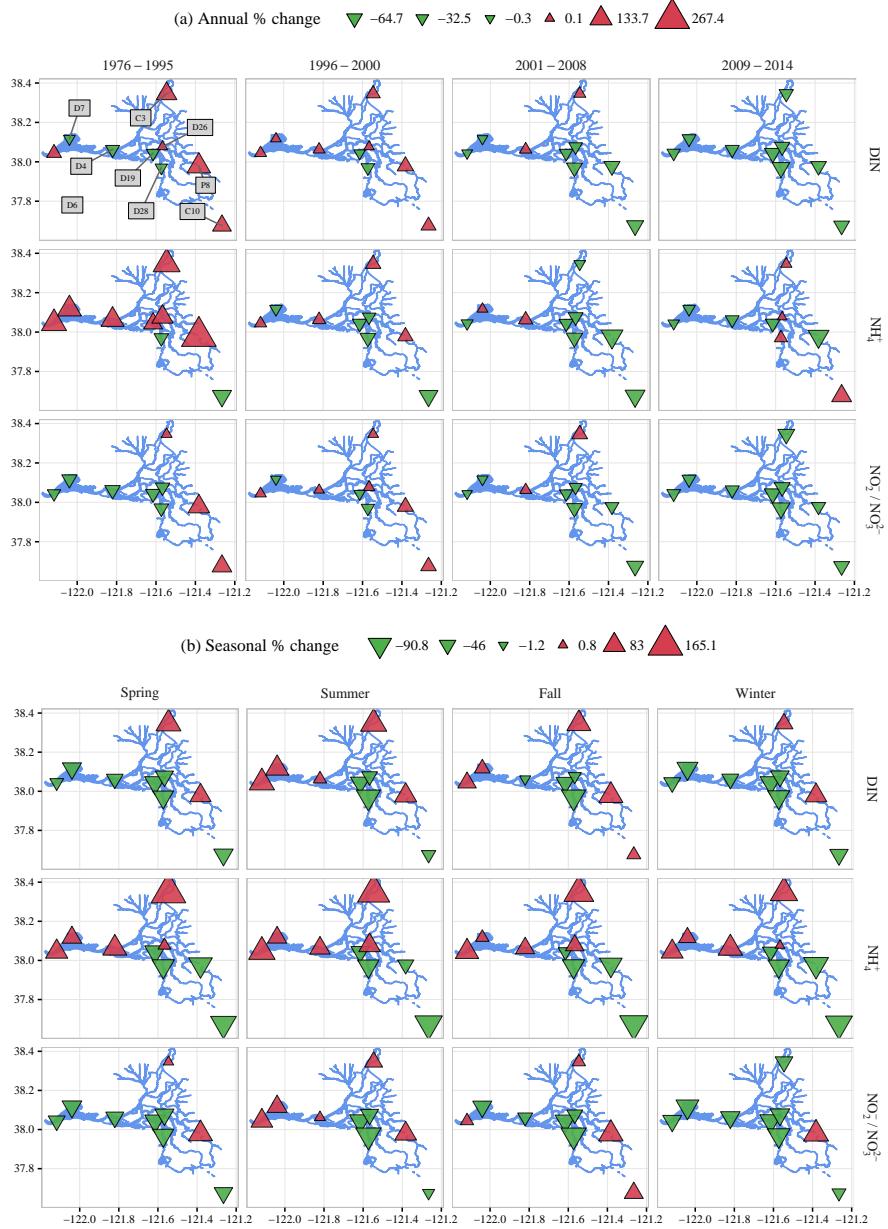


Fig. 2: Percent changes in nitrogen analytes for (a) annual and (b) seasonal (monthly) periods in the record. Changes are based on the difference between the ending and starting estimates for the flow-normalized estimates within each period. Points are colored for direction (red increasing, green decreasing) and sized for relative magnitude. Station names are shown in the top left panel. Months for each season are Spring: MAM, Summer: JJA, Fall: SON, Winter: DJF.

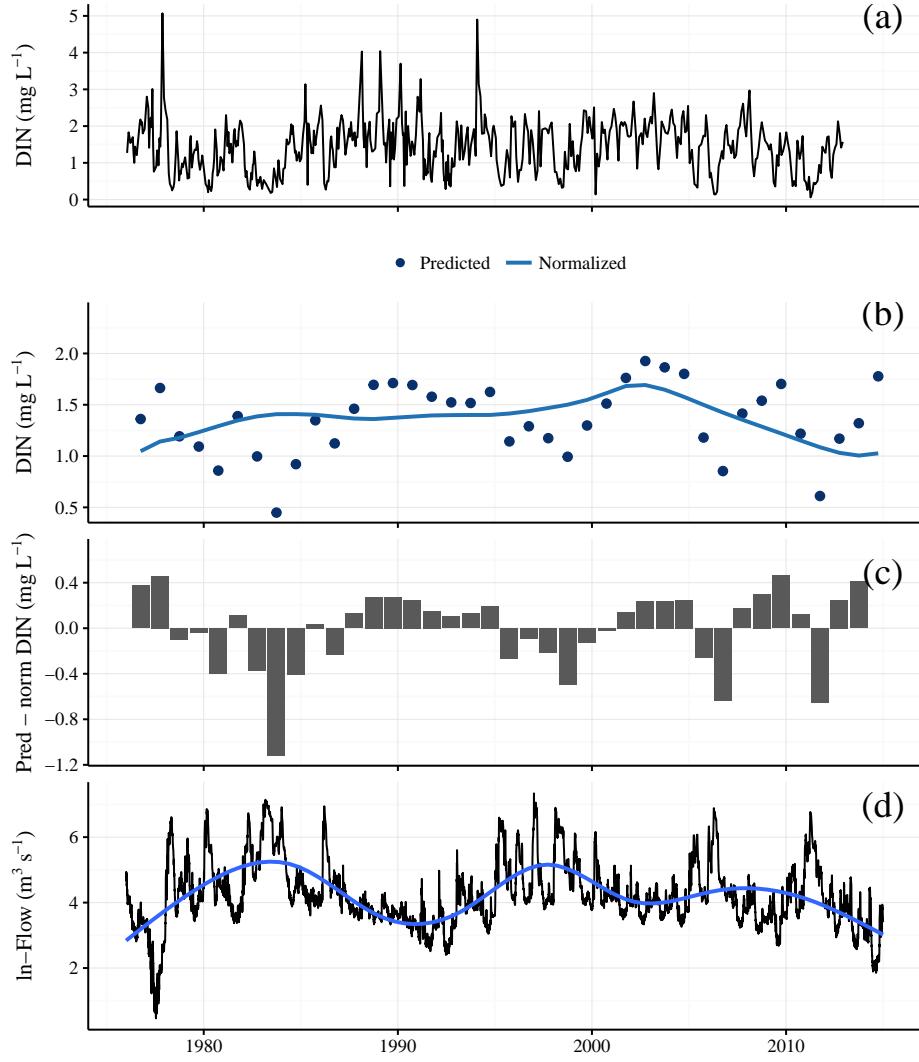


Fig. 3: Time series of DIN and flow at station C10. Subfigure (a) shows the observed DIN time series and subfigure (b) shows the annual (water year starting in October) predictions from WRTDS at different conditional quantiles ($\tau = 0.1, 0.5, 0.9$). The points in subfigure (b) are predictions of observed DIN and the lines are flow-normalized predictions. Subfigure (c) shows the difference between the model predictions and flow-normalized predictions at the fiftieth conditional quantile. Subfigure (d) shows the flow time series of the San Joaquin River with a locally-estimated (loess) smooth to emphasize the long-term trend.

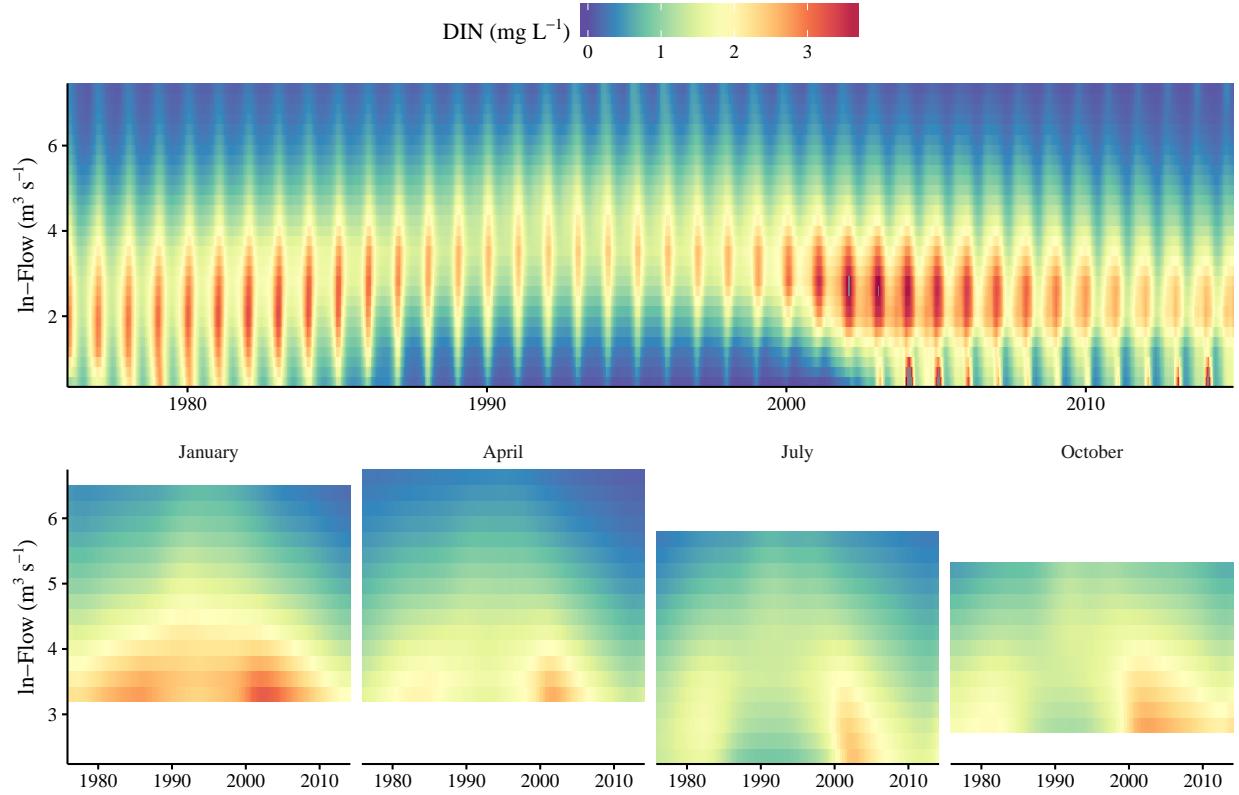


Fig. 4: Modelled relationships between DIN, flow, and time at station C10. The top figure shows the annual and seasonal variation over the entire time series and the bottom figure shows annual variation for selected months to remove seasonal variation. Warmer colors indicate higher DIN concentrations. The y-axis on the bottom figure is truncated by the fifth and ninety-fifth percentiles of flow within each month. Model results are for the fiftieth conditional quantile of DIN.

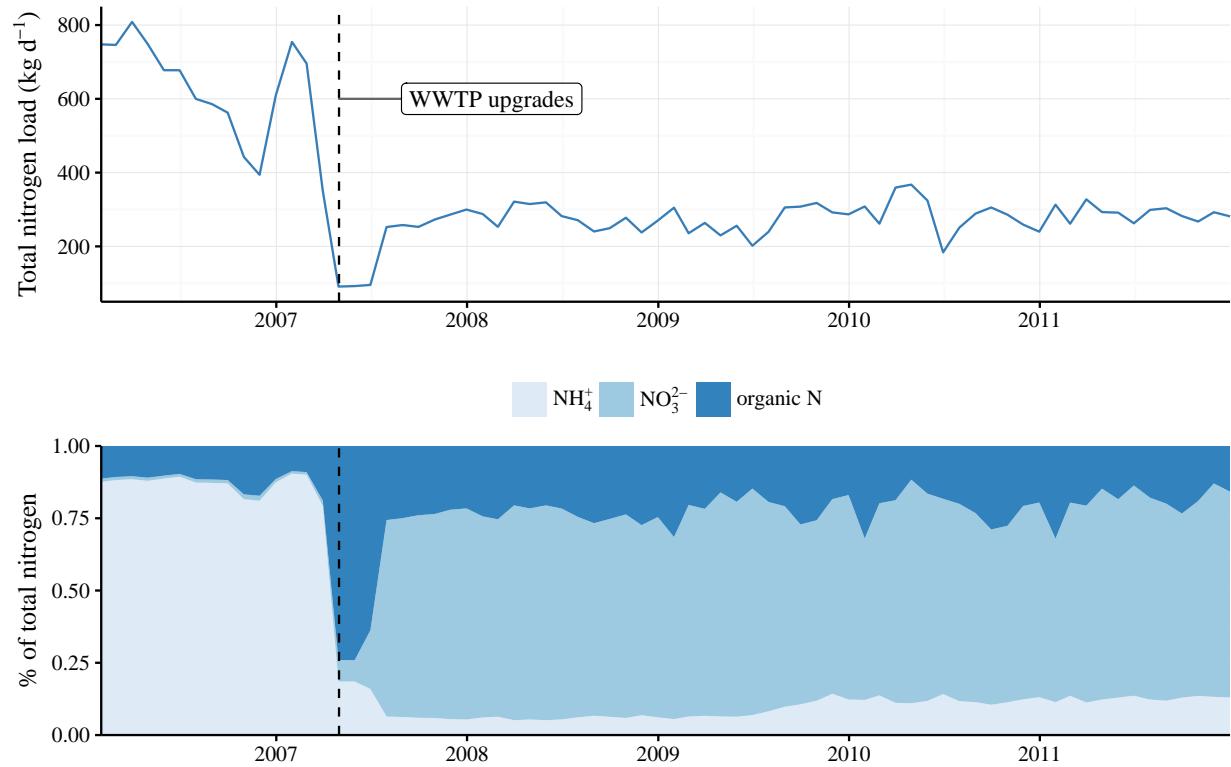


Fig. 5: Nitrogen load measurements (kg d^{-1}) at the City of Tracy Wastewater Treatment Plant, San Joaquin County. Wastewater discharge requirements were implemented in May, 2007 to include nitrification/denitrification and tertiary filtration causing a reduction in total nitrogen effluent discharged to the Delta. Reductions were primarily observed for ammonium.

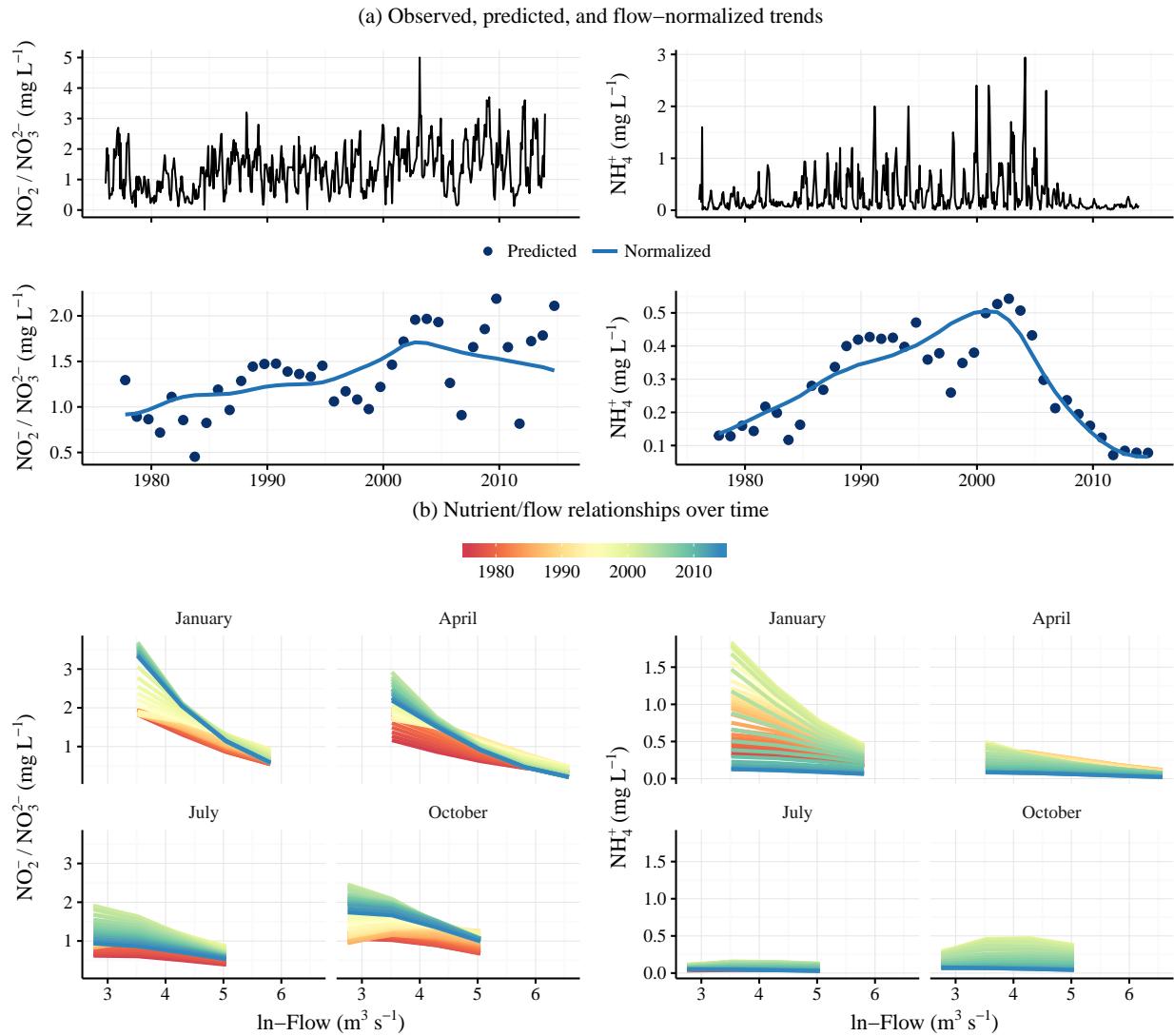


Fig. 6: Nitrogen trends at P8 as observed (a, top), predicted and flow-normalized estimates from WRTDS (a, bottom), and relationships with flow over time (b). Nitrite/nitrate trends are on the left and ammonium trends are on the right. Wastewater treatment plant upgrades at the City of Tracy (San Joaquin County), were completed in May 2007 (Fig. 5), coincident with a dramatic decrease in ammonium at P8.

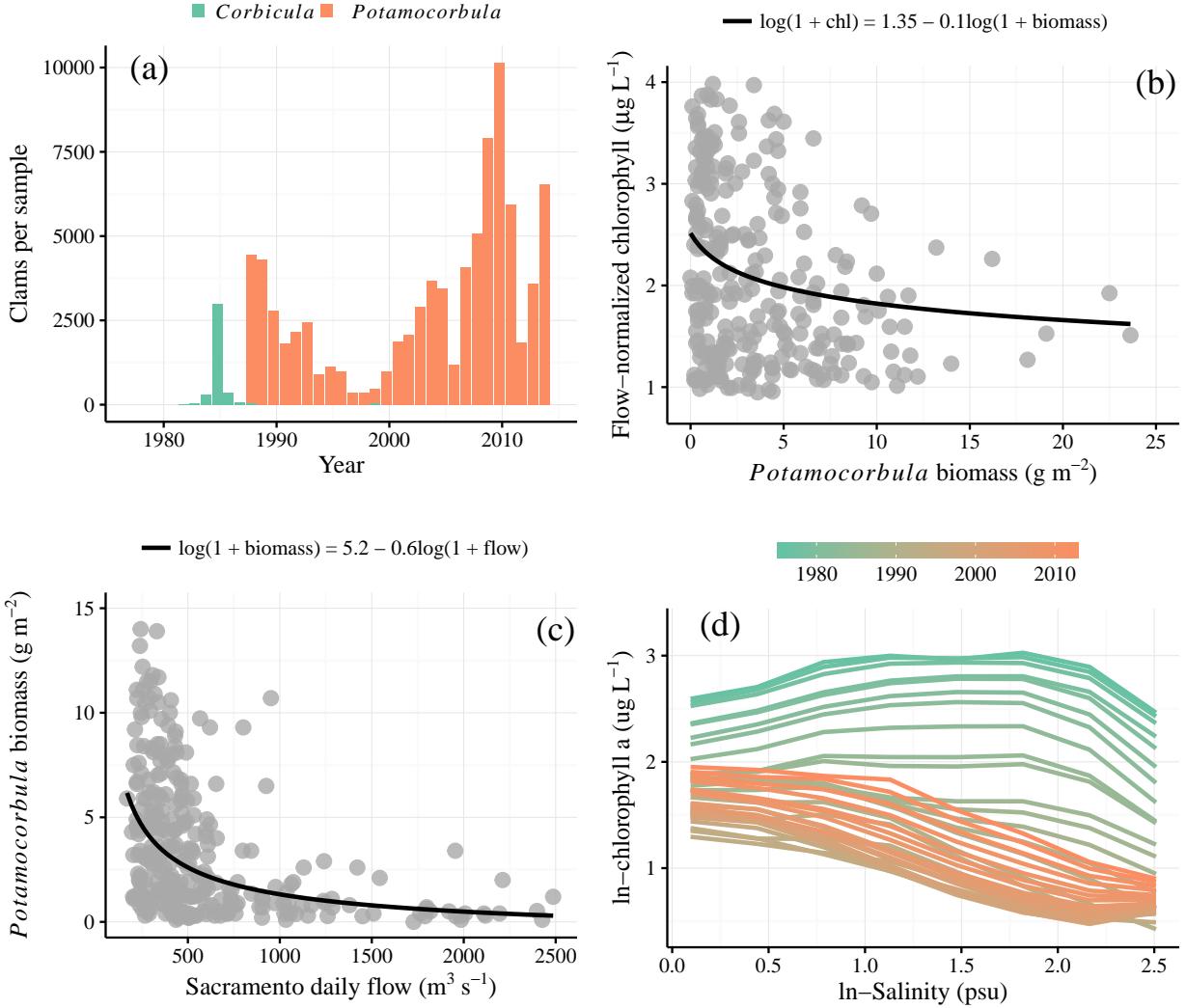


Fig. 7: Trends in clam abundance and chl-*a* concentration from 1976 to 2014 at station D7 in Suisun Bay. Invasion by *Potamocorbula amurensis* clams in the late 1980s and displacement of *Corbicula fluminea* was shown by changes in clam density (a, annual means). A coincident decrease in chl-*a* concentration was also observed (c). A weak but significant ($p < 0.001$) relationship between clam biomass and chl-*a* concentration is shown in subfigure (b). Flow relationships with chl-*a* concentration have also changed over time (d, observations from June). Chlorophyll shows a slight positive then dominantly negative association with increasing flow (decreasing salinity) early in the time series, whereas the trend is reversed in recent years.

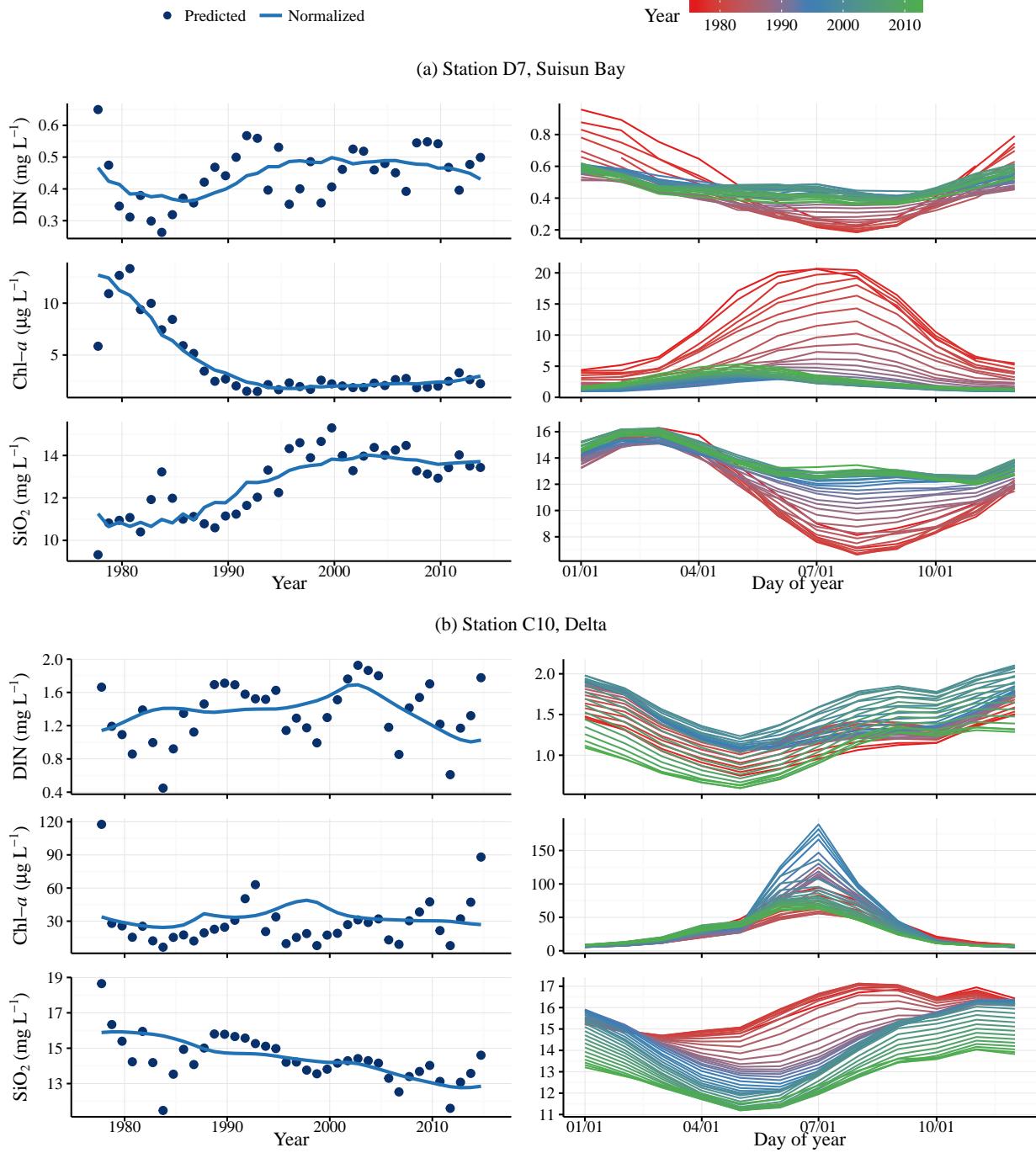


Fig. 8: Flow-normalized trends of annual (left) and seasonal (right) variation in DIN, chl- a , and SiO_2 at station D7 (top) and C10 (bottom). Covariation between nutrients, chl- a , and SiO_2 is observed at D7 but not C10, although an overall decrease in SiO_2 at C10 is shown. Seasonal changes at D7 are most pronounced during the summer.

Table 1: Summaries of flow-normalized trends in nitrogen analytes for all stations and different time periods. Summaries are averages (mg L^{-1}) and percent changes in parentheses (increasing in bold-italic). Changes are based on the difference between the ending and starting estimates within each period. See Fig. 2 for a summary of spatial trends. Months for each season are Spring: MAM, Summer: JJA, Fall: SON, Winter: DJF.

Analyte/Station	Annual		Seasonal			
	1976-1995	1996-2014	Spring	Summer	Fall	Winter
DIN						
C10	1.3 (35)	1.4 (-28.6)	1.1 (-25.8)	1.2 (-6.3)	1.5 (5.5)	1.7 (-20.7)
C3	0.4 (51.1)	0.5 (3)	0.4 (62.2)	0.3 (71.9)	0.5 (54.4)	0.5 (18.3)
D19	0.5 (-5.5)	0.4 (-30.7)	0.5 (-33.9)	0.3 (-25.4)	0.3 (-21.7)	0.7 (-33.5)
D26	0.4 (0.3)	0.5 (-19.6)	0.5 (-19.2)	0.3 (-10.2)	0.4 (-3.5)	0.6 (-21.7)
D28	0.5 (-3.1)	0.4 (-45.6)	0.5 (-32.9)	0.2 (-56.5)	0.3 (-57.4)	0.8 (-40.2)
D4	0.4 (-8.1)	0.4 (-7.5)	0.4 (-13.6)	0.3 (4.3)	0.4 (-1.2)	0.5 (-15)
D6	0.4 (11.6)	0.5 (-6.1)	0.5 (-5)	0.4 (64.1)	0.4 (21)	0.5 (-14.6)
D7	0.4 (-1.7)	0.5 (-11.8)	0.5 (-23.8)	0.4 (49.9)	0.4 (10.4)	0.6 (-34.6)
P8	1.4 (81.1)	1.8 (-15.8)	1.5 (35.5)	1 (42)	1.6 (55)	2.3 (38.7)
NH₄⁺						
C10	0.1 (-37.7)	0 (-55.5)	0.1 (-68.6)	0 (-85)	0.1 (-90.8)	0.2 (-78.8)
C3	0.2 (127)	0.3 (14.1)	0.2 (165.1)	0.2 (133.3)	0.3 (107.7)	0.2 (81.2)
D19	0.1 (35.6)	0.1 (-32.6)	0.1 (-32.9)	0 (-21)	0 (-6.4)	0.1 (-12)
D26	0.1 (58.4)	0.1 (-18.7)	0.1 (3.3)	0.1 (38.1)	0.1 (21.1)	0.1 (0.8)
D28	0.1 (-10)	0 (-31.8)	0.1 (-42.8)	0 (-36.9)	0 (-42.2)	0.1 (-35.7)
D4	0.1 (74.6)	0.1 (0.3)	0.1 (54.2)	0 (30.8)	0.1 (23.8)	0.1 (56.9)
D6	0.1 (100.2)	0.1 (-3.5)	0.1 (42.2)	0.1 (74.1)	0.1 (49.2)	0.1 (39.8)
D7	0.1 (88.2)	0.1 (-13.3)	0.1 (26.8)	0 (25.1)	0.1 (4.3)	0.1 (16.8)
P8	0.3 (267.4)	0.3 (-85.1)	0.2 (-51.8)	0.1 (-12)	0.3 (-44.5)	0.6 (-61.2)
NO₂⁻/NO₃²⁻						
C10	1.2 (42.8)	1.3 (-26.9)	1.1 (-21)	1.2 (-2.3)	1.4 (23.3)	1.5 (-5.6)
C3	0.2 (0.7)	0.2 (-6.6)	0.2 (0.9)	0.1 (18)	0.1 (4.3)	0.2 (-17.4)
D19	0.4 (-11.7)	0.4 (-31.1)	0.4 (-32.3)	0.2 (-36.7)	0.3 (-31.6)	0.6 (-38.4)
D26	0.3 (-9.8)	0.4 (-20.1)	0.4 (-23.5)	0.2 (-18.7)	0.3 (-10.5)	0.5 (-26.4)
D28	0.4 (-10.5)	0.4 (-47.2)	0.5 (-34.6)	0.2 (-66.3)	0.3 (-64.4)	0.7 (-45.7)
D4	0.3 (-14.6)	0.3 (-9.8)	0.3 (-19.2)	0.3 (1.1)	0.3 (-8)	0.4 (-25.9)
D6	0.3 (-5.6)	0.4 (-8)	0.4 (-14.5)	0.3 (38.8)	0.3 (4)	0.4 (-23.2)
D7	0.4 (-13.4)	0.4 (-13.6)	0.4 (-27.3)	0.3 (28.7)	0.4 (-23.7)	0.5 (-46.8)
P8	1.1 (59.8)	1.5 (3.3)	1.2 (53.9)	1 (38.8)	1.4 (58.3)	1.8 (62.3)

Table 2: Summaries of flow-normalized trends in nitrite/nitrate and ammonium (mg L^{-1}) concentrations before and after WWTP upgrades upstream of station P8. Upgrades were completed in May 2007 at the City of Tracy WWTP (San Joaquin County, Fig. 5). Summaries are means and percent changes based on annual means within the pre- and post-upgrade time periods (1976-2007, 2008-2013). Increasing values are in bold-italics. Months for each season are Spring: MAM, Summer: JJA, Fall: SON, Winter: DJF.

Period	$\text{NO}_2^-/\text{NO}_3^{2-}$		NH_4^+	
	Mean	% change	Mean	% change
Annual				
1976-2007	1.3	74.3	0.34	93.1
2008-2013	1.5	-7.3	0.11	-62
Seasonal, pre				
Spring	1.24	79.5	0.25	57.1
Summer	0.99	95	0.09	143.5
Fall	1.32	77	0.29	137.7
Winter	1.67	69.2	0.69	72.5
Seasonal, post				
Spring	1.27	0.9	0.09	-49.2
Summer	0.92	-18.7	0.06	-49.2
Fall	1.58	-8.7	0.1	-58.2
Winter	2.17	-5.1	0.18	-62.1

Table 3: Summaries of flow-normalized trends in dissolved inorganic nitrogen (mg L^{-1}), chlorophyll ($\mu\text{g L}^{-1}$), and silicon dioxide (mg L^{-1}) concentrations for different time periods at station D7. Summaries are means and percent changes based on annual means within the time periods. Increasing values are in bold-italics. Months for each season are Spring: MAM, Summer: JJA, Fall: SON, Winter: DJF.

Period	DIN		Chl- <i>a</i>		SiO ₂	
	Mean	% change	Mean	% change	Mean	% change
All						
1976-2013	0.4	-7.8	4.1	-76.7	12.7	21.8
Annual						
1976-1985	0.4	-22.5	9.3	-57.1	10.9	-0.1
1986-1994	0.4	29.4	3	-61.7	12.2	18.6
1995-2003	0.5	-0.1	2	21.1	13.7	5.2
2004-2013	0.5	-11.9	2.4	34.2	13.7	-1.7
Seasonal						
Spring	0.5	-23.8	4.2	-60.3	14.5	0.6
Summer	0.4	49.9	6.4	-82.3	11.2	51.3
Fall	0.4	10.4	3.7	-84.9	11.1	43.3
Winter	0.6	-34.6	2	-63.8	14.2	4.2

Table 4: Summaries of flow-normalized trends in dissolved inorganic nitrogen (mg L^{-1}), chlorophyll ($\mu\text{g L}^{-1}$), and silicon dioxide (mg L^{-1}) concentrations for different time periods at station C10. Summaries are means and percent changes based on annual means within the time periods. Increasing values are in bold-italics. Months for each season are Spring: MAM, Summer: JJA, Fall: SON, Winter: DJF.

Period	DIN		Chl- <i>a</i>		SiO ₂	
	Mean	% change	Mean	% change	Mean	% change
All						
1976-2013	1.4	-10.1	33.2	-20.6	14.4	-19.1
Annual						
1976-1985	1.3	22.8	27.5	-21.6	15.8	-3.2
1986-1994	1.4	1.2	35.3	31.5	14.8	-4.1
1995-2003	1.6	16.4	41	-27.5	14.2	-3.3
2004-2013	1.3	-36.3	30.2	-12.8	13.2	-7.6
Seasonal						
Spring	1.1	-25.8	26.2	3.1	13.2	-20
Summer	1.2	-6.3	79.6	-23.2	13.9	-25.4
Fall	1.5	5.5	19	-39.8	15.6	-18
Winter	1.7	-20.7	7.7	7.3	15.1	-14.1