Supporting Information

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

Marcus W. Beck (beck.marcus@epa.gov), Thomas W. Jabusch,Philip R. Trowbridge, David B. Senn

The following files are available free of charge: Figures S1 to S3, Tables S1 to S3 (7 pages)

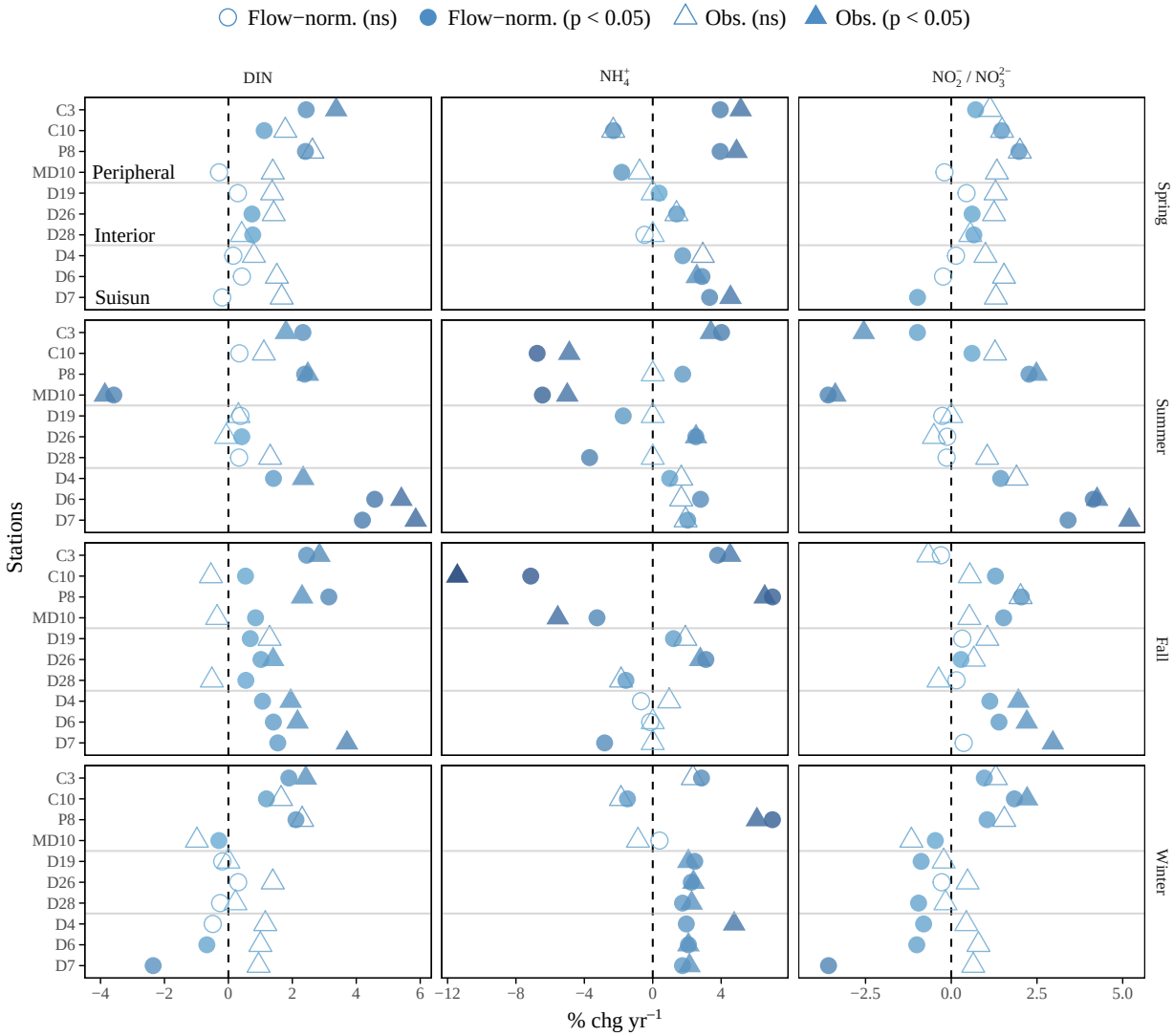

Figure S1: Results from seasonal Kendall tests on observed data (triangles) and flow-normalized predictions (circles) from WRTDS for nitrogen analytes. Results are shown as the percent change per year as the estimated Theil-Sen slope divided by the median for a given aggregation period (significance evaluated at $\alpha = 0.05$, based on τ). Trends are shown separately for different seasonal groupings from 1976-1995. Months for each season are Spring: MAM, Summer: JJA, Fall: SON, Winter: DJF. See Figure 3 for annual comparisons.

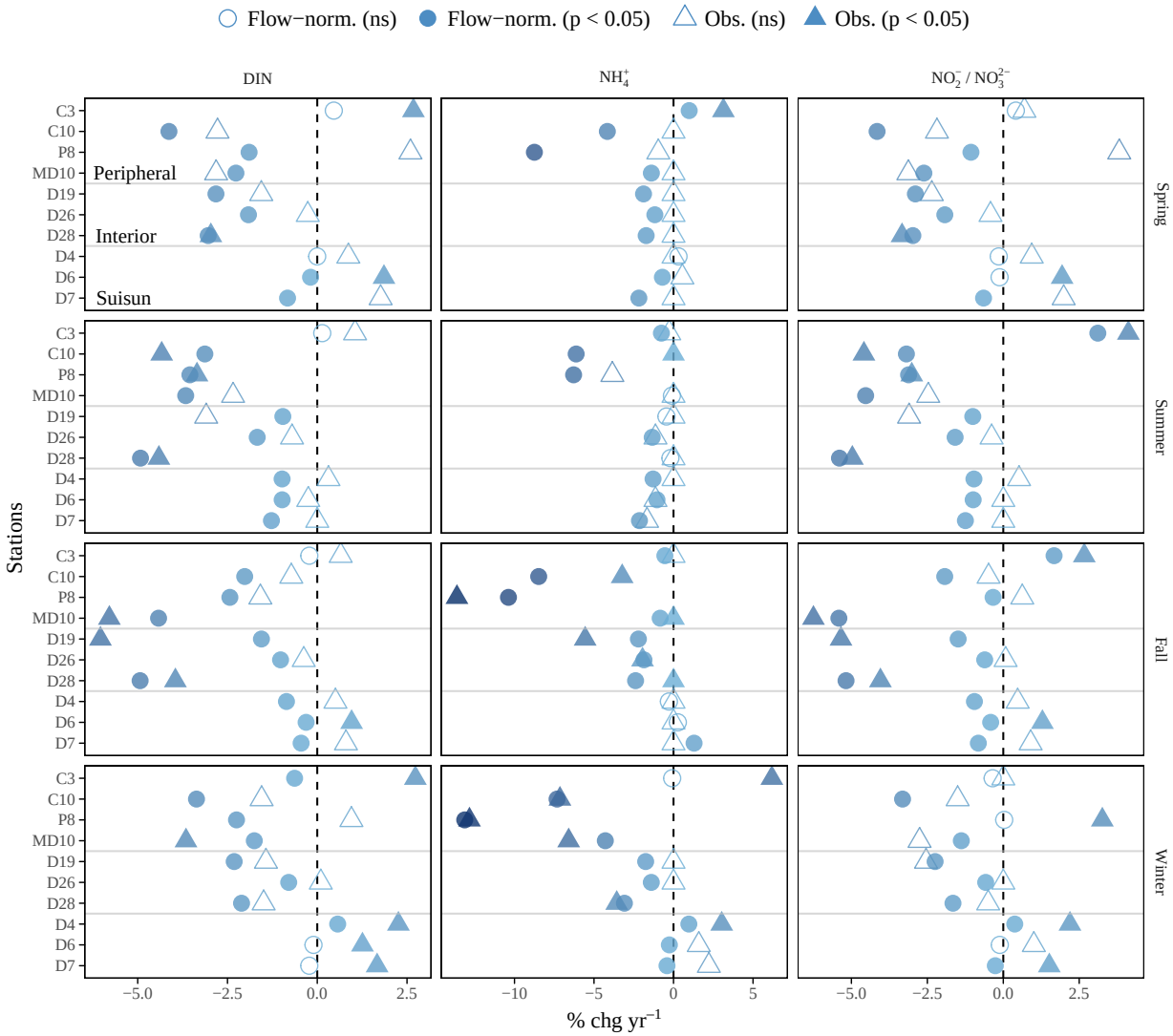

Figure S2: Results from seasonal Kendall tests on observed data (triangles) and flow-normalized predictions (circles) from WRTDS for nitrogen analytes. Results are shown as the percent change per year as the estimated Theil-Sen slope divided by the median for a given aggregation period (significance evaluated at $\alpha = 0.05$, based on τ). Trends are shown separately for different seasonal groupings from 1996-2013. Months for each season are Spring: MAM, Summer: JJA, Fall: SON, Winter: DJF. See Figure 3 for annual comparisons.

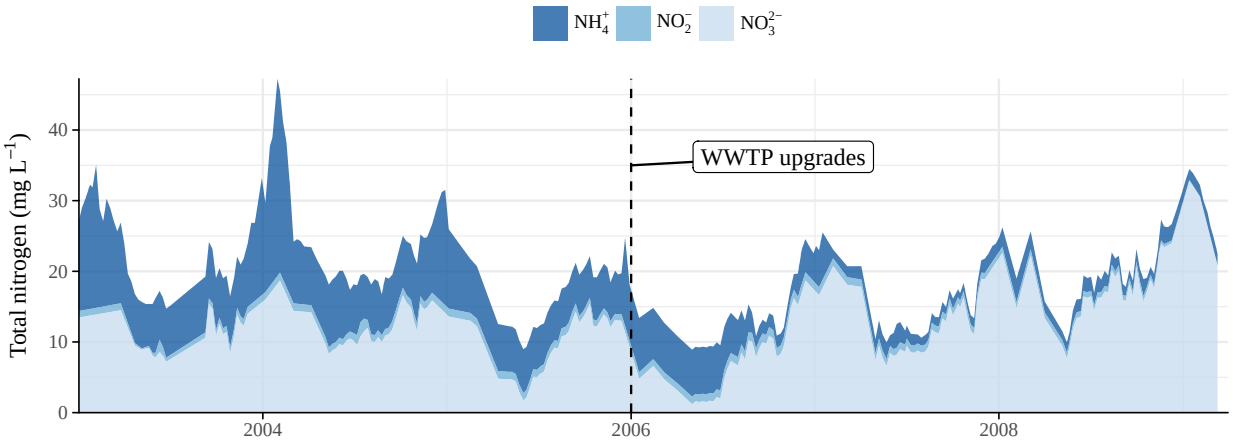

Figure S3: Nitrogen concentration measurements (mg L^{-1}) from the City of Stockton Wastewater Treatment Plant, San Joaquin County. Wastewater discharge requirements were implemented in 2006 for nitrification/denitrification and tertiary filtration to convert ammonium to nitrate.

Table S1: Summaries of flow-normalized trends in nitrogen analytes for all stations and annual aggregations

Analyte/Station	**Annual**	
	1976-1995	1996-2013
DIN		
C10	1.3 (***0.8***)**	1.4 (-3.1)**
C3	0.3 (***2.2***)**	0.5 (-0.1)**
D19	0.4 (***0.2***)**	0.4 (-1.9)**
D26	0.4 (***0.4***)**	0.5 (-1.2)**
D28	0.4 (***0.1***)**	0.4 (-3.1)**
D4	0.3 (***0.6***)**	0.4 (-0.3)**
D6	0.4 (***1.8***)**	0.5 (-0.3)**
D7	0.4 (***1.7***)**	0.5 (-0.7)**
MD10	0.4 (-1.1)**	0.3 (-2.4)**
P8	1.3 (***2.5***)**	1.7 (-2)**
$\mathbf{NH_4^+}$		
C10	0.1 (-3.4)**	0 (-5.2)**
C3	0.2 (***3.7***)**	0.3 (***0***)
D19	0 (***0.4***)**	0 (-1.7)**
D26	0.1 (***2.2***)**	0.1 (-1.5)**
D28	0 (-1.1)**	0 (-1.4)**
D4	0 (***0.9***)**	0.1 (***0***)
D6	0.1 (***2.4***)**	0.1 (-0.5)**
D7	0.1 (***1.5***)**	0.1 (-1.2)**
MD10	0.1 (-2.8)**	0 (-1.1)**
P8	0.2 (***4.9***)**	0.1 (-10.3)**
$\mathbf{NO_2^-/NO_3^{2-}}$		
C10	1.2 (***1.4***)**	1.4 (-3)**
C3	0.1 (-0.1)**	0.2 (***0.7***)**
D19	0.4 (-0.1)**	0.4 (-1.9)**
D26	0.3 (***0***)	0.4 (-1.1)**
D28	0.4 (-0.2)**	0.4 (-3.1)**
D4	0.3 (***0.7***)**	0.3 (-0.4)**
D6	0.3 (***1.3***)**	0.4 (-0.3)**
D7	0.4 (***0.7***)**	0.4 (-0.7)**
MD10	0.4 (-1)**	0.3 (-2.5)**
P8	1.2 (***1.7***)**	1.5 (-0.6)**

Summaries are medians (mg L^{-1}) and percent change per year in parentheses (increasing in bold-italic). Changes and significance estimates are based on seasonal Kendall tests of flow-normalized results within each time period. *$p < 0.05$; **$p < 0.005$

Table S2: Summaries of flow-normalized trends in nitrogen analytes for all stations and seasonal aggregations from 1976-1995

Analyte/Station	**Seasonal, 1976-1995**			
	Spring	Summer	Fall	Winter
DIN				
C10	1.2 (***1.1***)**	1.2 (***0.3***)	1.3 (***0.5***)**	1.7 (***1.2***)**
C3	0.3 (***2.4***)**	0.3 (***2.3***)**	0.4 (***2.4***)**	0.4 (***1.9***)**
D19	0.5 (***0.3***)	0.2 (***0.4***)	0.3 (***0.7***)**	0.7 (-0.2)
D26	0.4 (***0.7***)**	0.3 (***0.4***)*	0.4 (***1***)**	0.6 (***0.3***)
D28	0.5 (***0.8***)*	0.2 (***0.3***)	0.3 (***0.5***)*	0.8 (-0.3)
D4	0.4 (***0.2***)	0.3 (***1.4***)**	0.3 (***1.1***)**	0.5 (-0.5)
D6	0.4 (***0.4***)	0.3 (***4.6***)**	0.4 (***1.4***)**	0.5 (-0.7)*
D7	0.4 (-0.2)	0.3 (***4.2***)**	0.4 (***1.5***)**	0.6 (-2.4)**
MD10	0.6 (-0.3)	0.2 (-3.6)**	0.3 (***0.8***)**	1.3 (-0.3)*
P8	1.3 (***2.4***)**	0.9 (***2.4***)**	1.3 (***3.1***)**	1.9 (***2.1***)**
$\mathbf{NH_4^+}$				
C10	0.1 (-2.3)**	0 (-6.8)**	0.1 (-7.1)**	0.3 (-1.5)**
C3	0.2 (***3.9***)**	0.2 (***4***)**	0.3 (***3.8***)**	0.2 (***2.9***)**
D19	0.1 (***0.4***)*	0 (-1.7)**	0 (***1.2***)**	0.1 (***2.5***)**
D26	0.1 (***1.4***)**	0.1 (***2.5***)**	0.1 (***3.1***)**	0.1 (***2.3***)**
D28	0.1 (-0.5)	0 (-3.7)**	0 (-1.6)**	0.1 (***1.7***)**
D4	0.1 (***1.7***)**	0 (***1***)**	0 (-0.7)	0.1 (***2***)**
D6	0.1 (***2.9***)**	0.1 (***2.8***)**	0.1 (-0.1)	0.1 (***2.1***)**
D7	0.1 (***3.3***)**	0 (***2***)**	0.1 (-2.8)**	0.1 (***1.7***)**
MD10	0.1 (-1.8)**	0 (-6.5)**	0 (-3.3)**	0.2 (***0.4***)
P8	0.2 (***3.9***)**	0.1 (***1.8***)**	0.2 (***7***)**	0.6 (***7***)**
$\mathbf{NO_2^-/NO_3^{2-}}$				
C10	1.1 (***1.5***)**	1.2 (***0.6***)**	1.2 (***1.3***)**	1.5 (***1.8***)**
C3	0.2 (***0.7***)**	0.1 (-1)**	0.1 (-0.3)	0.2 (***1***)**
D19	0.4 (***0.4***)	0.2 (-0.3)	0.3 (***0.3***)	0.6 (-0.9)*
D26	0.4 (***0.6***)*	0.2 (-0.1)	0.3 (***0.3***)*	0.5 (-0.3)
D28	0.5 (***0.7***)*	0.2 (-0.1)	0.3 (***0.2***)	0.7 (-1)**
D4	0.3 (***0.1***)	0.3 (***1.4***)**	0.3 (***1.1***)**	0.4 (-0.8)*
D6	0.4 (-0.2)	0.3 (***4.1***)**	0.3 (***1.4***)**	0.4 (-1)**
D7	0.4 (-1)*	0.3 (***3.4***)**	0.4 (***0.4***)	0.4 (-3.6)**
MD10	0.5 (-0.2)	0.2 (-3.6)**	0.2 (***1.5***)**	1.2 (-0.5)*
P8	1.2 (***2***)**	0.9 (***2.3***)**	1.1 (***2***)**	1.4 (***1***)**

Summaries are medians (mg L^{-1}) and percent change per year in parentheses (increasing in bold-italic). Changes and significance estimates are based on seasonal Kendall tests of flow-normalized results within each time period. Months for each season are Spring: MAM, Summer: JJA, Fall: SON, Winter: DJF. *$p < 0.05$; **$p < 0.005$

Table S3: Summaries of flow-normalized trends in nitrogen analytes for all stations and seasonal aggregations from 1996-2013

Analyte/Station	**Seasonal, 1996-2013**			
	Spring	Summer	Fall	Winter
DIN				
C10	1.1 (-4.1)**	1.3 (-3.1)**	1.6 (-2)**	1.7 (-3.4)**
C3	0.5 (***0.5***)	0.4 (***0.1***)	0.6 (-0.2)	0.5 (-0.6)**
D19	0.5 (-2.8)**	0.2 (-1)*	0.3 (-1.6)**	0.7 (-2.3)**
D26	0.5 (-1.9)**	0.3 (-1.7)**	0.4 (-1)**	0.6 (-0.8)**
D28	0.5 (-3)**	0.2 (-4.9)**	0.2 (-4.9)**	0.7 (-2.1)**
D4	0.4 (***0***)	0.4 (-1)**	0.4 (-0.9)**	0.5 (***0.6***)**
D6	0.5 (-0.2)*	0.5 (-1)**	0.5 (-0.3)*	0.5 (-0.1)
D7	0.5 (-0.8)**	0.4 (-1.3)**	0.4 (-0.4)**	0.6 (-0.2)
MD10	0.4 (-2.3)**	0.2 (-3.7)**	0.2 (-4.4)**	1 (-1.8)**
P8	1.5 (-1.9)**	1.2 (-3.5)**	1.8 (-2.4)**	2.7 (-2.2)**
$\mathbf{NH_4^+}$				
C10	0 (-4.2)**	0 (-6.1)**	0 (-8.5)**	0.1 (-7.3)**
C3	0.3 (***1***)**	0.3 (-0.8)*	0.4 (-0.5)*	0.2 (-0.1)
D19	0 (-1.9)**	0 (-0.4)	0 (-2.2)**	0.1 (-1.8)**
D26	0.1 (-1.2)**	0.1 (-1.3)**	0.1 (-1.9)**	0.1 (-1.4)**
D28	0 (-1.7)**	0 (-0.2)	0 (-2.4)**	0.1 (-3.1)**
D4	0.1 (***0.3***)	0 (-1.3)**	0.1 (-0.3)	0.1 (***1***)**
D6	0.1 (-0.7)**	0.1 (-1)**	0.1 (***0.3***)	0.1 (-0.3)**
D7	0.1 (-2.2)**	0 (-2.1)**	0.1 (***1.3***)**	0.1 (-0.4)*
MD10	0 (-1.4)*	0 (-0.1)	0 (-0.8)**	0.1 (-4.3)**
P8	0.2 (-8.7)**	0.1 (-6.3)**	0.2 (-10.4)**	0.5 (-13.1)**
$\mathbf{NO_2^-/NO_3^{2-}}$				
C10	1.1 (-4.2)**	1.2 (-3.2)**	1.6 (-1.9)**	1.6 (-3.3)**
C3	0.2 (***0.4***)	0.1 (***3.1***)**	0.2 (***1.7***)**	0.2 (-0.4)
D19	0.4 (-2.9)**	0.2 (-1)*	0.3 (-1.5)**	0.6 (-2.2)**
D26	0.4 (-1.9)**	0.2 (-1.6)**	0.3 (-0.6)*	0.5 (-0.6)**
D28	0.5 (-3)**	0.2 (-5.4)**	0.2 (-5.2)**	0.7 (-1.7)**
D4	0.3 (-0.1)	0.3 (-1)**	0.3 (-1)**	0.4 (***0.4***)**
D6	0.4 (-0.1)	0.4 (-1)**	0.4 (-0.4)*	0.4 (-0.1)
D7	0.4 (-0.6)**	0.4 (-1.2)**	0.4 (-0.8)**	0.4 (-0.3)*
MD10	0.4 (-2.6)**	0.1 (-4.5)**	0.2 (-5.4)**	1 (-1.4)**
P8	1.3 (-1.1)**	1.1 (-3.1)**	1.6 (-0.3)*	2.2 (***0***)

Summaries are medians (mg L^{-1}) and percent change per year in parentheses (increasing in bold-italic). Changes and significance estimates are based on seasonal Kendall tests of flow-normalized results within each time period. Months for each season are Spring: MAM, Summer: JJA, Fall: SON, Winter: DJF. *$p < 0.05$; **$p < 0.005$