Supporting Information

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

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

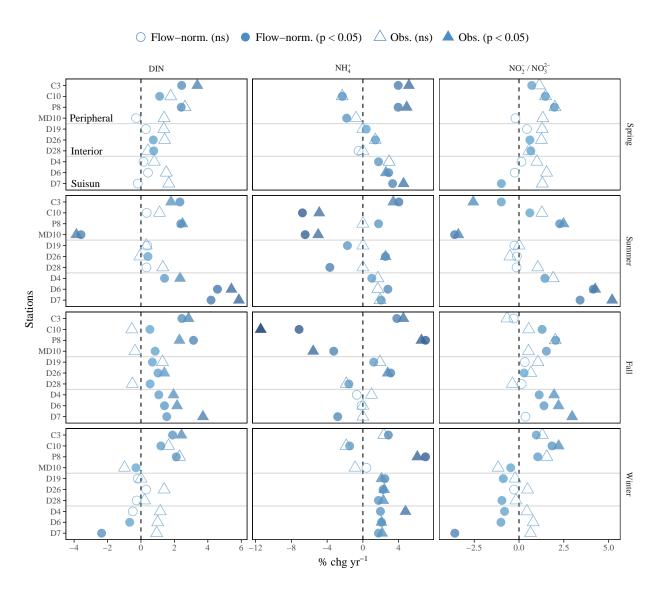


Figure S1: Results from seasonal Kendall tests on observed data (triangles) and flow-normalized predictions (circles) from WRTDS for nitrogen analytes. Results are shown as the percent change per year as the estimated Theil-Sen slope divided by the median for a given aggregation period (significance 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.

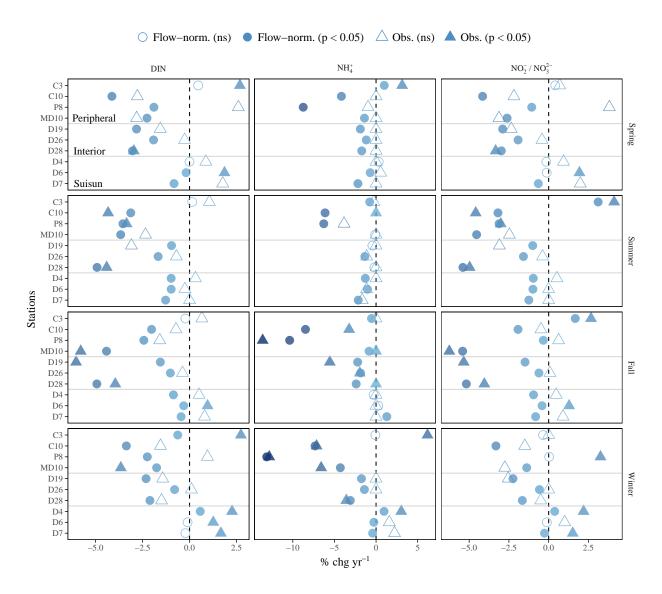


Figure S2: Results from seasonal Kendall tests on observed data (triangles) and flow-normalized predictions (circles) from WRTDS for nitrogen analytes. Results are shown as the percent change per year as the estimated Theil-Sen slope divided by the median for a given aggregation period (significance 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.

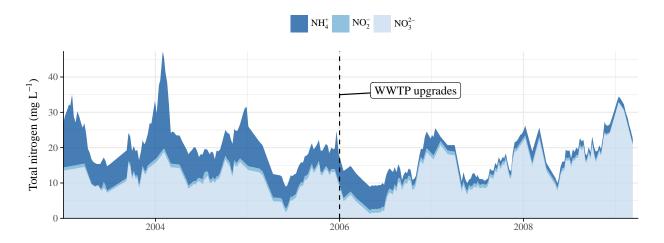


Figure S3: Nitrogen concentration measurements (mg $\rm L^{-1}$) from the City of Stockton Wastewater Treatment Plant, San Joaquin County. Wastewater discharge requirements were implemented in 2006 for nitrification/denitrification and tertiary filtration to convert ammonium to nitrate.

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

$\overline{-}$ 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	$0.1 \ (\textbf{1.5})^{**}$	0.1 (-1.2)**	
MD10	0.1 (-2.8)**	0 (-1.1)**	
P8	0.2 (4.9)**	0.1 (-10.3)**	
$\mathrm{NO}_2^-/\mathrm{NO}_3^{2-}$			
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 $\rm L^{-1}$) 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)**	$0.4 \ (\textbf{1.9})**$
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	$0.5 (0.8)^*$	$0.2 \; (\textbf{0.3})$	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)**	$0.2 \; (\textbf{0.4})$
P8	0.2 (3.9)**	0.1 (1.8)**	0.2 (7)**	0.6 (7)**
$\mathrm{NO_2^-/NO_3^{2-}}$				
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	$0.4 \; (\textbf{0.6})^*$	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 $\rm L^{-1}$) 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)	$0.4 \; (\textbf{0.1})$	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)**	$0.5 \ (\textbf{0.6})^{**}$
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)**
$ m 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)**
$\mathrm{NO_2^-/NO_3^{2-}}$				
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)**	$0.4 \ (\textbf{0.4})^{**}$
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 $\rm L^{-1}$) 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