Does Elevated Ammonia-N Negatively Impact Phytoplankton Biomass and Community Composition in Freshwater or Brackish Water?

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March 8, 2013

Central Contra Costa Sanitary District

Protecting Public Health and the Environment

Background
General Concensus

- Phytoplankton biomass, Chl(a), in the SFE has significantly dropped from the late 1970's.
- Diatom abundance in the SFE has significantly dropped from the late 1970's.
- Cyanobacteria and flagellates abundance has generally increased from the late 1970's.

Baxter et al. (2010); Solger-Muller et al. (2002); Jassby (2008)

Background
Potential causes of the change:

- Salinity
- Freshwater flows
- Turbidity/irradiance
- Temperature
- Grazing pressures (clams)
- Inhibitory contaminants (Herbicides)
- Nutrients
- Other unknown factors

Baxter et al. (2010); Cloren and Jassby (2012)

Background
Nutrients

Hypotheses:

- Elevated NH_4 (>4 µmol) suppresses phytoplankton NO_3 and/or NH_4 uptake – eliminating phytoplankton blooms that were regular in the 1970's

Dugdale et al. (2007)
Parker et al. (2012a)
Parker et al. (2012b)

- Increased N:P and NH_4:NO_3 ratios have shifted phytoplankton composition from diatoms to cynobacteria/flagellates dominance

Glibert (2010)
Glibert et al. (2011)

Background
Caution Flags

1. Elevated NH_4 (>4 µm) does not always inhibit phytoplankton blooms.

- From 1968 – 1979, phytoplankton blooms regularly occurred in the SFE at NH_4 concentrations >4 µmol

Ball & Arthur (1979)

- In Delaware Estuary, generally more phytoplankton biomass, Chl(a), occurs at relatively high NH_4 levels compared to SFE

Yoshiyama & Sharp (2006)

Background
Caution Flags

2. Reduced NH_4, <4 µmol, offer no reasonable assurance that phytoplankton blooms will occur, even though NO_3 is plentiful.

- In 2010, field sampling blooms occurred only on four sampling events out of 30 when NH_4 was <4 µmol in the SFE

Dugdale et al. (2012)

- "At low ammonium concentrations, while some nitrate uptake rates are high, most are quite low, implying that other factors besides external NH_4…."

Dortch, Q. (1990)

Background
Caution Flags

3. Increased N:P and NH_4:NO_3 ratios do not always mean reduced abundance of diatoms and increased abundance of dinoflagellates and cyanobacteria

McCarthy et al. (2009)

Chlorophyll (a) and NH_4 concentrations in Delaware Estuary vs. SFE

	Delaware Estuary*[1]	SFE[2]
NH_4, µmol	11	6
Chl(a), µg/L	14	4**

[1] – 26 year average

[2] – 29 year average

*Yoshiyama and Sharp (2006) Table 1

**Jassby (2008) Table 5

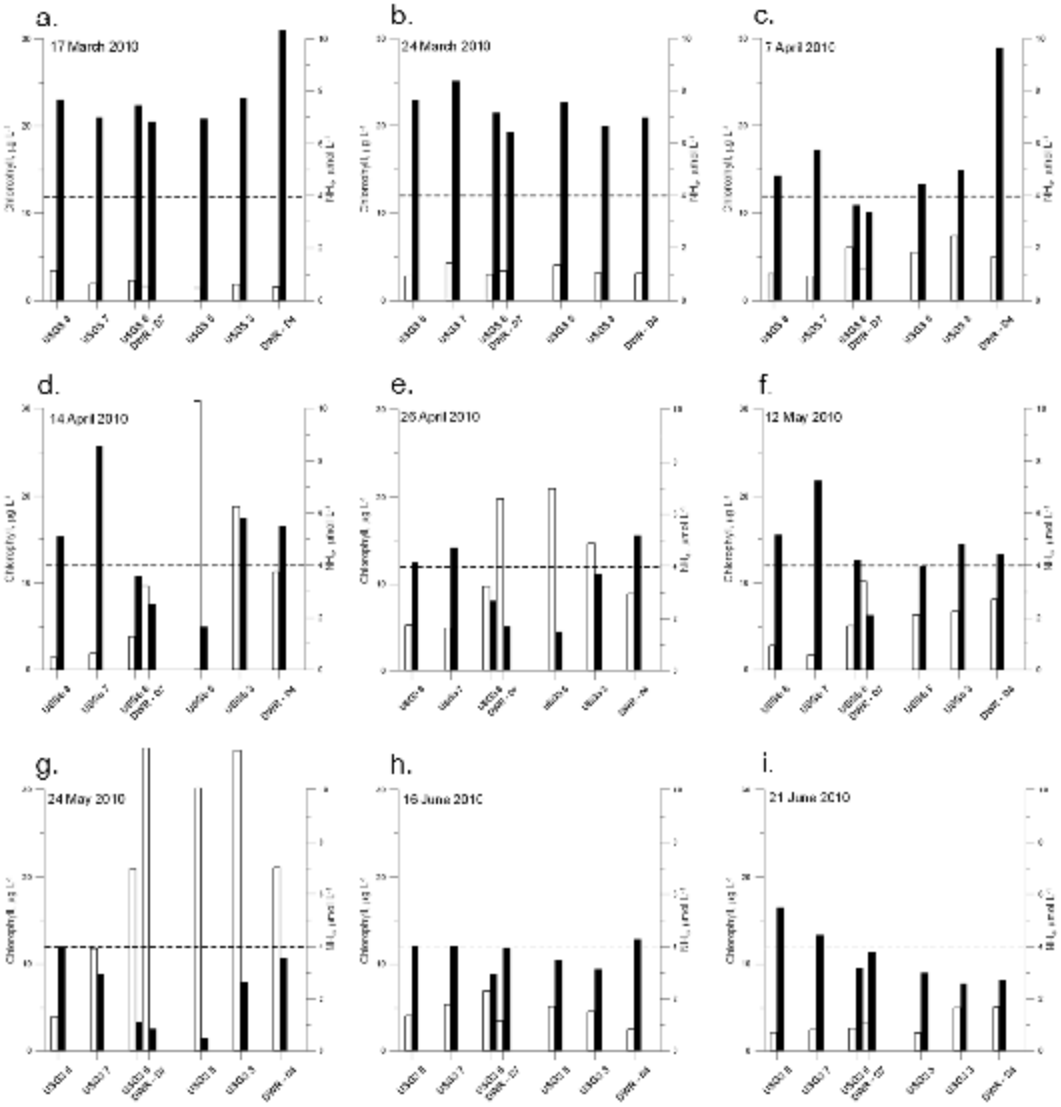
Dr. Richard Dugdale et. al.

Source: River flow and Ammonium discharge determine spring phytoplankton blooms in an urbanized estuary.

Revised manuscript for submission to Estuarine, Coastal and Shelf Science

August 6, 2012

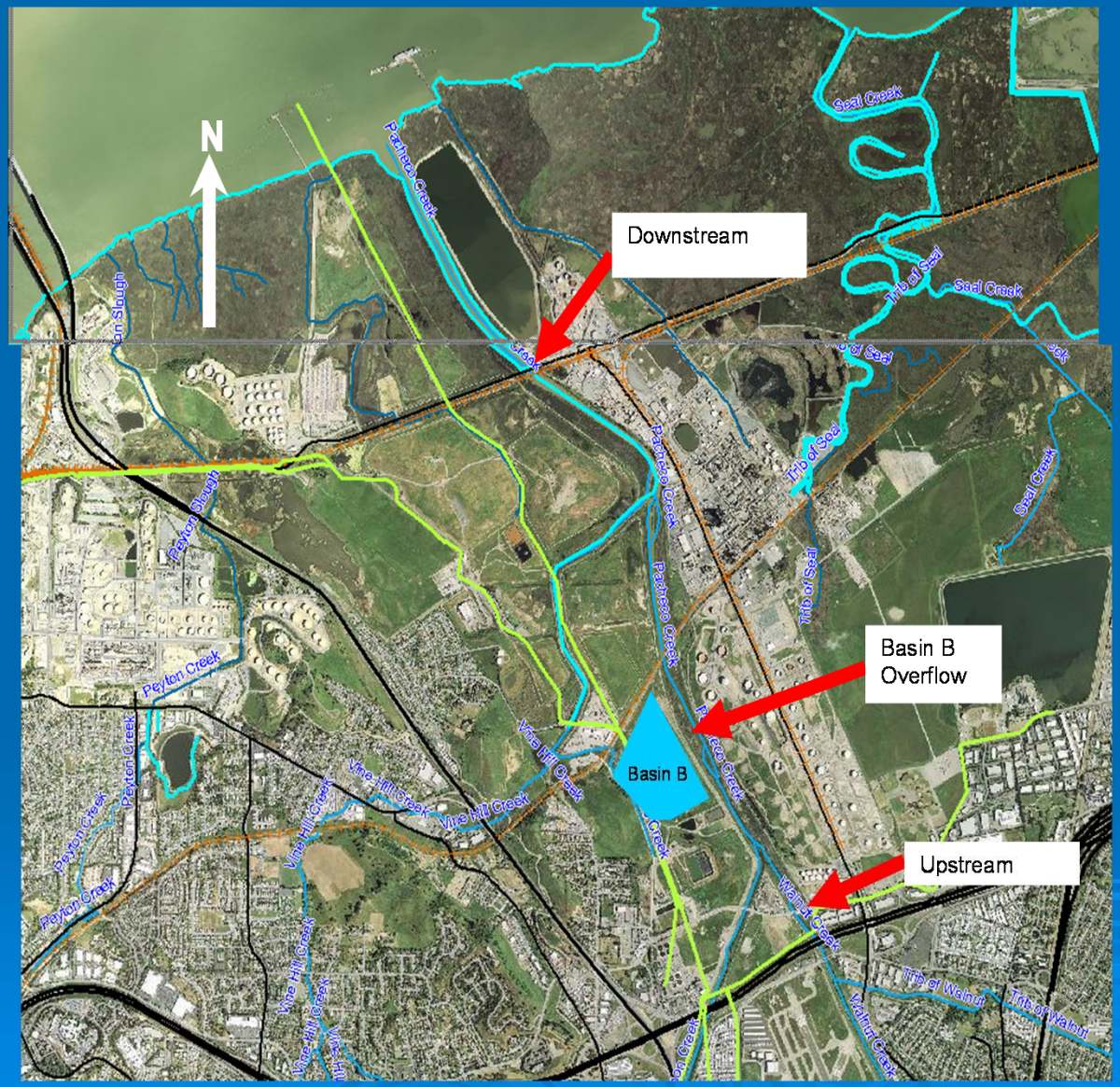
Fig. 3



CCCSD Field Experiment
Test the Nutrient Hypotheses

- Nutrient rich effluent diverted to holding basin
- After about two days in the basin, the effluent overflowed into Pacheco Slough
- Samples collected from the overflow, Pacheco Slough upstream and downstream of the overflow

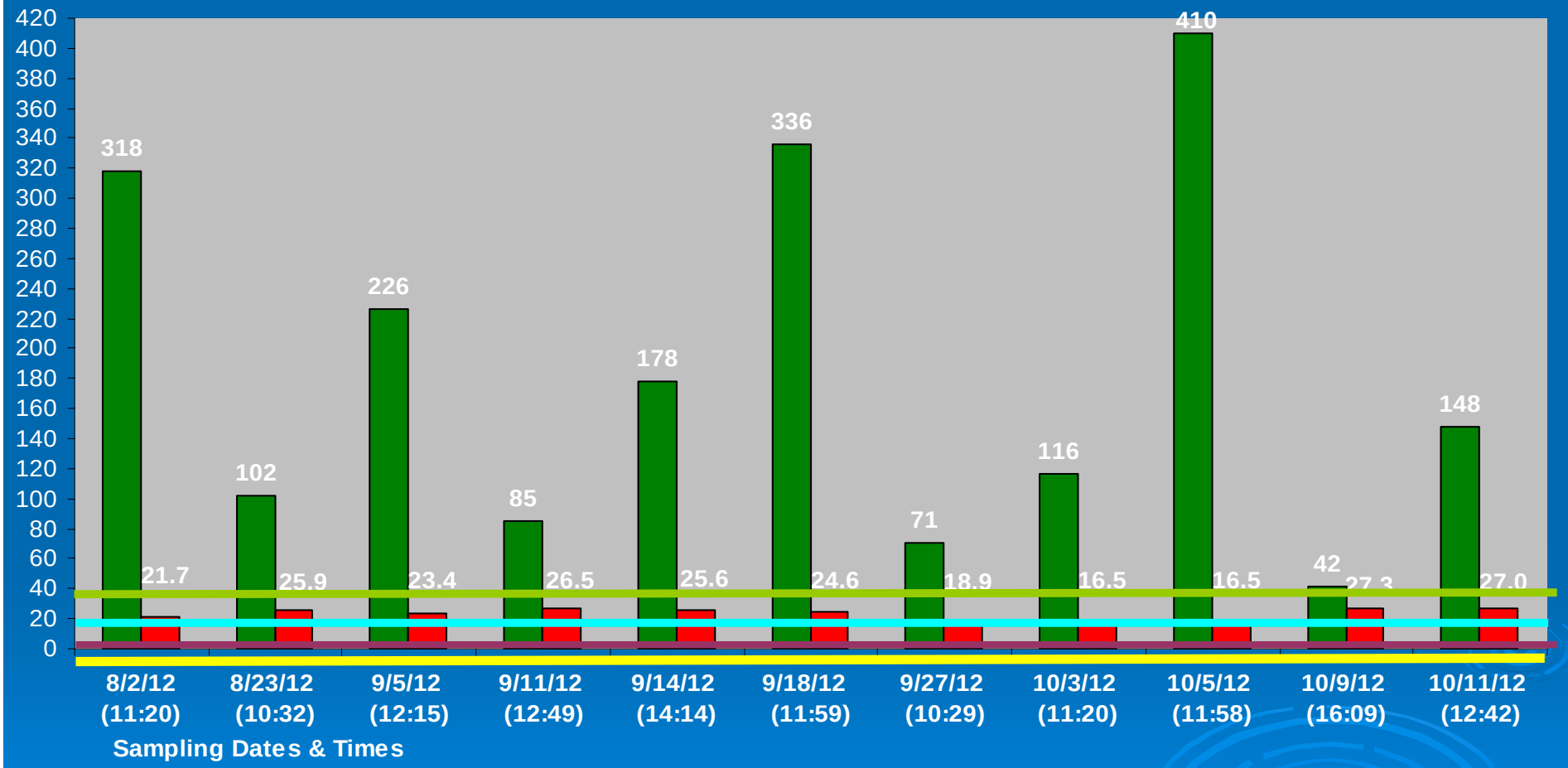
Sampling Locations with Aerial



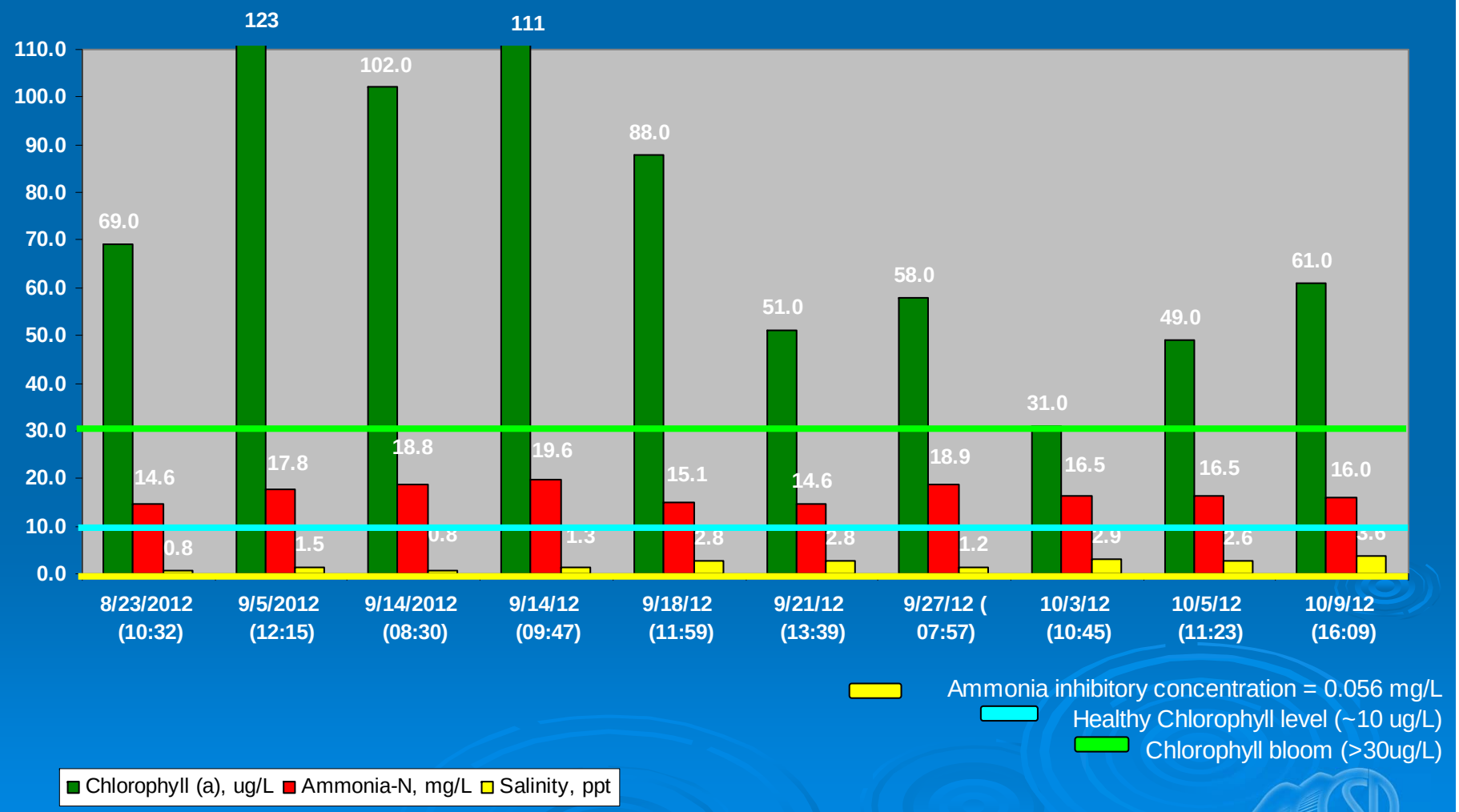
Water Quality Characteristics

Characteristics		Concentrations, Mean, Range	Concentrations, Mean ± sd n=9
Dissolved oxygen, mg/L			7.5 ± 1.7
ph, units			7.6 ± 0.2
Turbidity, NTU			5.4 ± 1.6
Salinity, ppt			0.5 ± 0
Temperature, °C			23.0 ± 2.3
TSS, ug/L		8 (3 - 17)	14 ± 8
BOD, mg/L		6 (2 - 23)	8 ± 5
Soluable COD, mg/L			45 ± 13
NH_4-N, mg/L		26.2 (14 - 30.5)	26.7 ± 1.1
NO_3-N, mg/L		0.78 (0.3 - 1.9)	0.28 ± 1.1
NO_2-N, mg/L		0.34 (0.4 - 1.4)	0.27 ± 0.19
Total-P, mg/L		1.13 (0.7 - 1.8)	1.14 ± 0.27

Ammonia-N and Chl(a) in Freshwater in relation to NO_3 and NH_4 uptake inhibitory thresholds and Chl(a) levels considered healthy and blooming. (August 2 – October 11, 2012)



Ammonia-N and Chl(a) in Brackish Water in relation to NO_3 and NH_4 uptake inhibitory thresholds and Chl(a) levels considered healthy and blooming.
(August 2 – October 11, 2012)

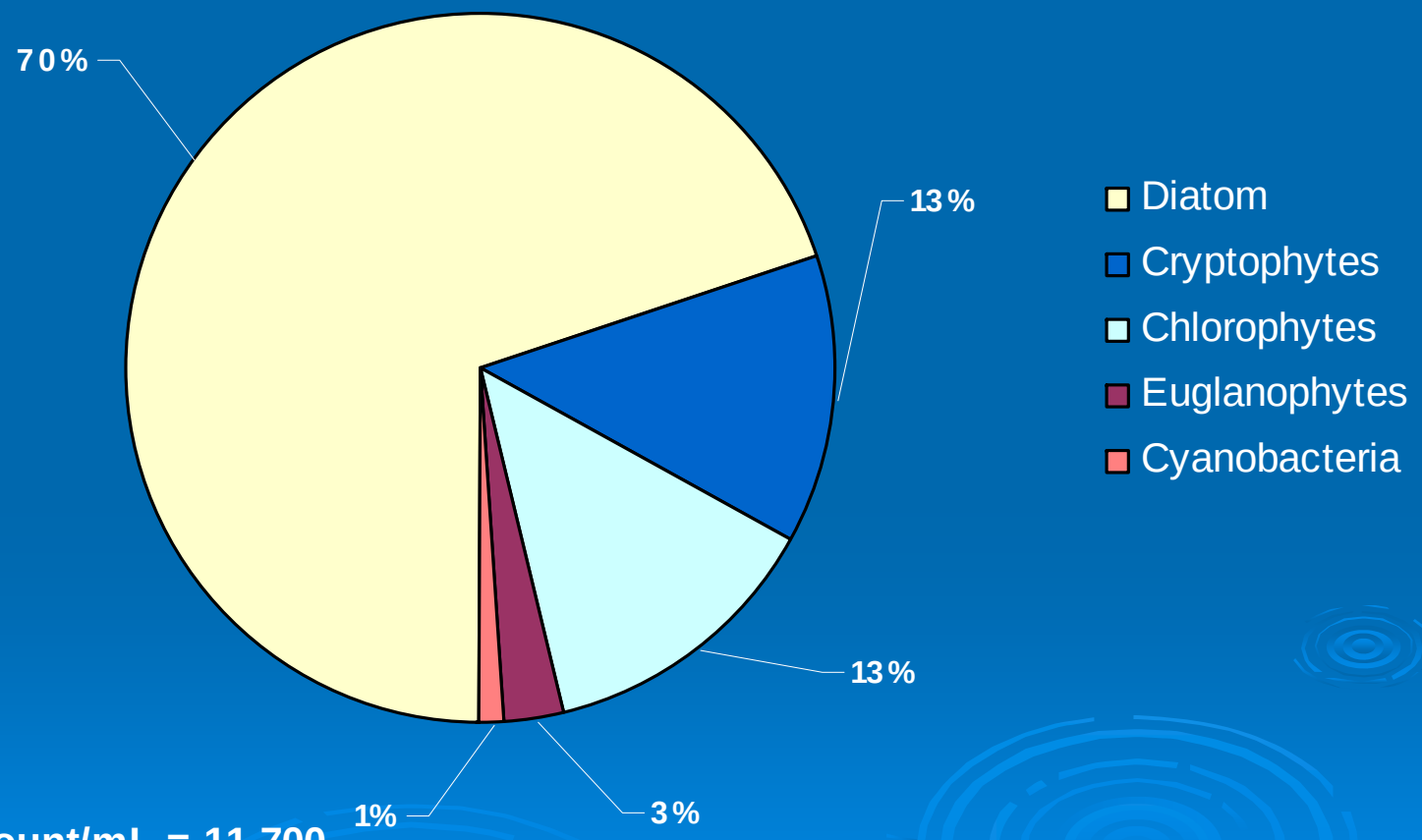


Summary

Freshwater and brackish water Chl(a) data shows that elevated NH_4 is not inhibitory to phytoplankton blooms as has been suggested by Dugdale et al. (2007), Dugdale et al. (2012) and Parker et al. (2012a), (2012b).

Does elevated NH_4 reduce the diatom abundance in brackish water?

Phytoplankton Composition of Brackish Water Downstream of Basin Overflow (August 2 – October 11, 2012)



Average total cell count/mL = 11,700

Phytoplankton Biomass and Composition in Relation to Ammonia Loads in the Bay-Delta System 2001 - 2010

Year	Chlorophyll-a[1]	Diatoms[2]	Ammonia Loads[3]
	ug/L	%	tons/month
2001-02	4.7	60	460
2003	4.3	43	–
2004	4.1	51	–
2005	3.5	40	550
2006	3.5	39	–
2007	3.9	52	–
2008	5.2	22	–
2009	4.4	68	–
2010	3.8	73	555

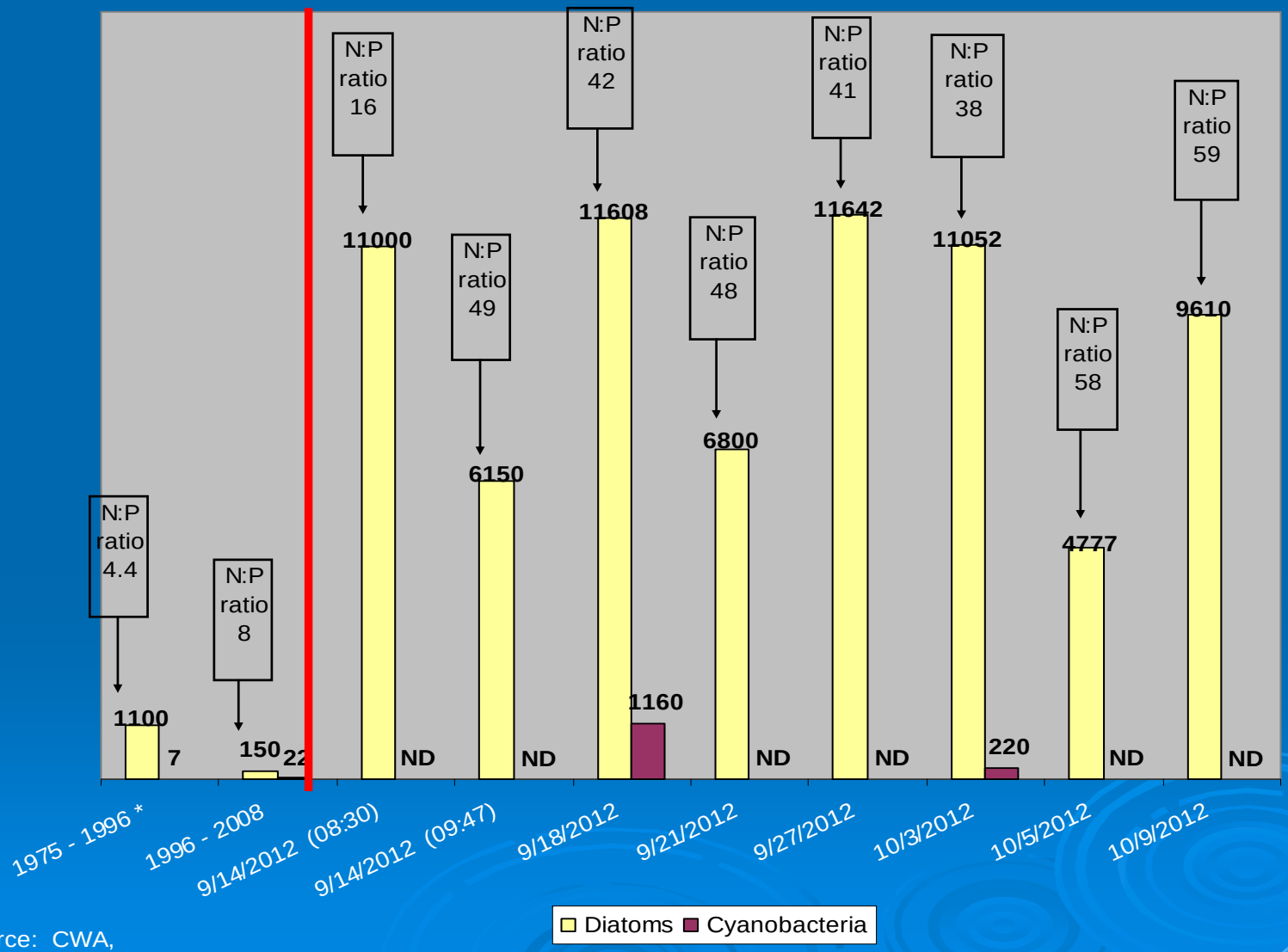
[1] - Average for all IEP stations except San Pablo Bay

[2] - Average for all IEP stations

[3] - Sacramento and Central San loads

Does increasing NH_4:NO_3 ratio reduce diatom abundance while encouraging dinoflagellates?

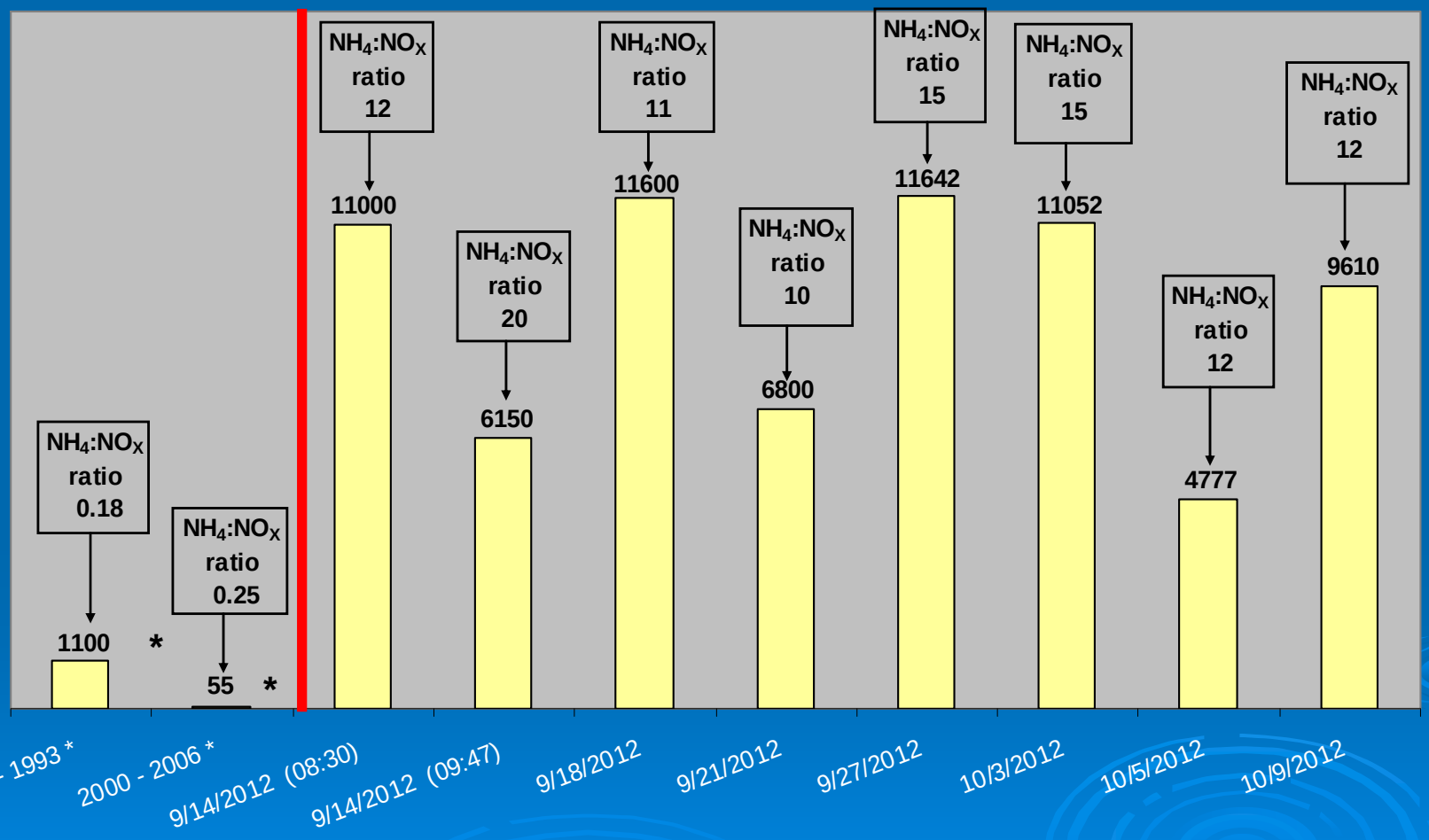
NH_4:NO_X (NO_3+NO_2) ratio vs. Diatom abundance (cells/mL) in Pacheco Slough Downstream of Basin overflow compared to Suisun Bay (D8)



* Source: CWA, 2012

Does increasing NH_4:NO_3 ratio reduce diatom abundance while encouraging dinoflagellates?

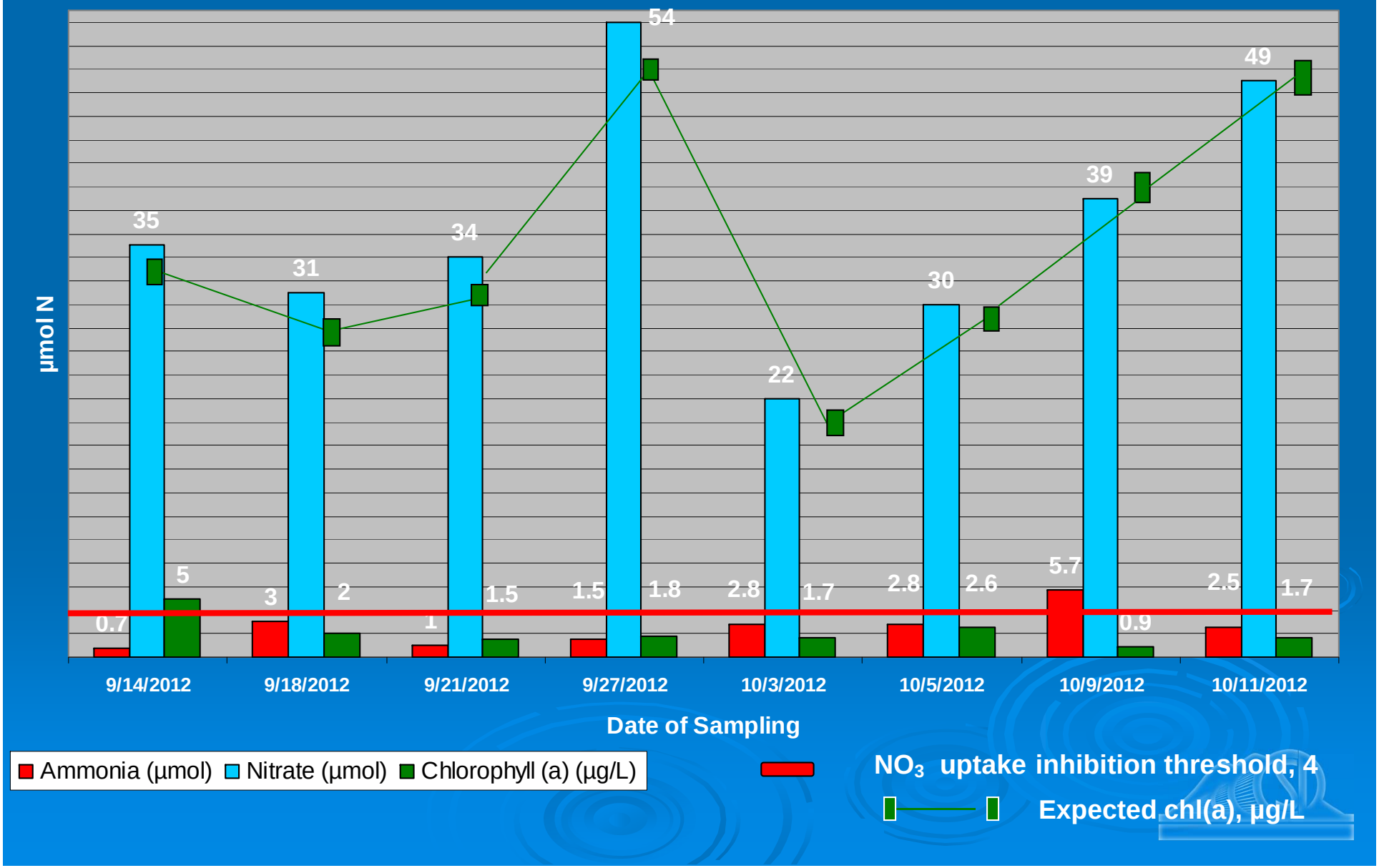
N:P Molar ratio vs. Diatom abundance (cells/mL) in Pacheco Slough Downstream of Basin overflow in relation to Suisun Bay Historic Data



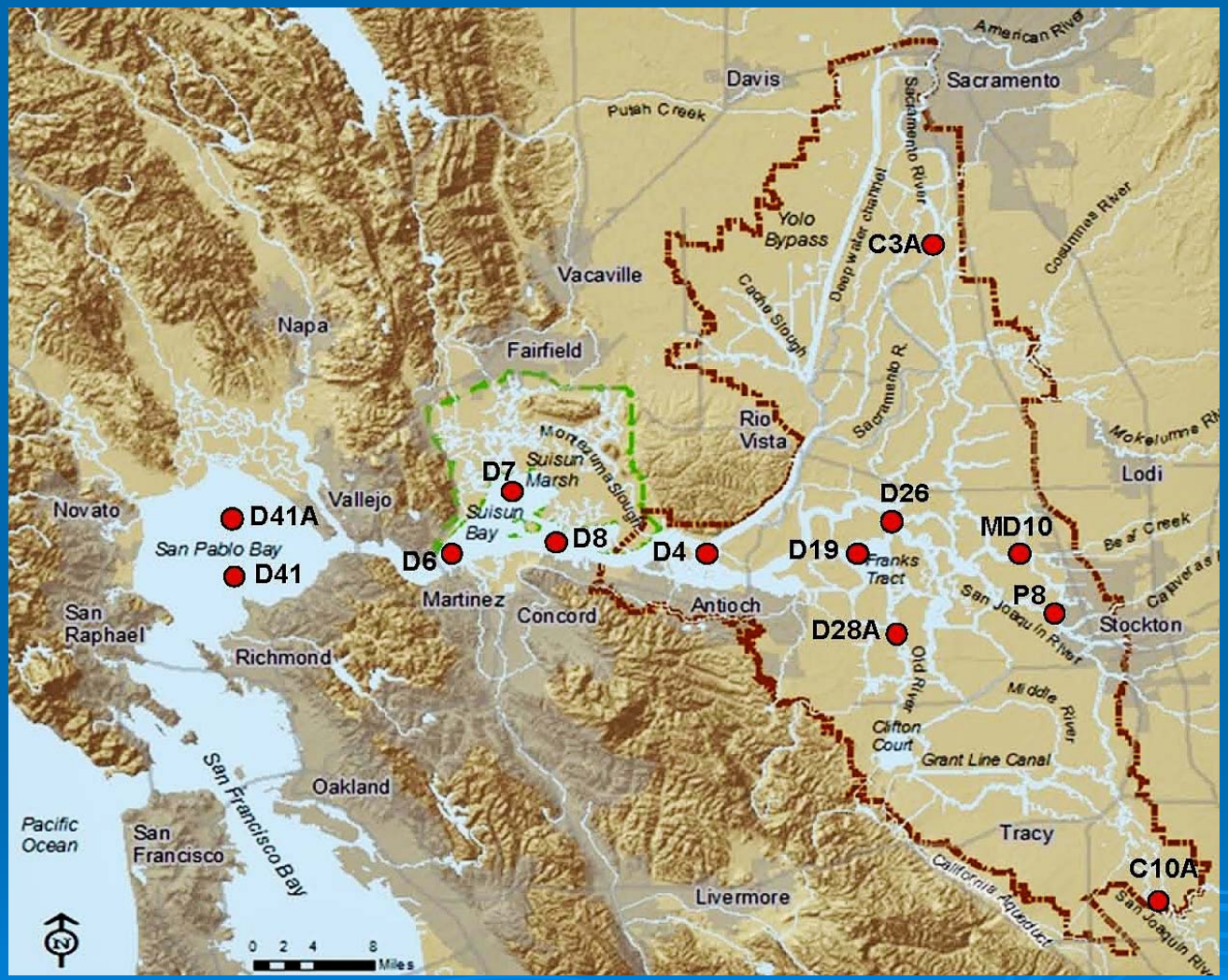
* Source IEP Data for Station D8

Would ammonia removal assure NO_3 uptake and increased phytoplankton biomass?

Nitrate and Ammonia vs. Diatom abundance (cells/mL) in Pacheco Slough Downstream of Basin overflow in relation to Suisun Bay Historic Data



IEP Monitoring Stations



Source: DWR, (2009); (2010)

NH_4:NO_x (NO_3+NO_2) and Chl(a) concentrations at selected IEP sampling stations in 2009 and 2010

	Station	Analyte	Median Concentration	No. of samples	
2009	C10A	NH_4, µmol	0.7	12	
		NO_X, µmol	90	12	
		Chl(a), ug/L	14	12	
	P8	NH_4, µmol	4	12	
		NO_X, µmol	107	12	
		Chl(a), ug/L	2	12	
	D19	NH_4, µmol	2	12	
		NO_X, µmol	22	12	
		Chl(a), ug/L	2	12	
	D28A	NH_4, µmol	1	12	
		NO_X, µmol	20	12	
		Chl(a), ug/L	1	12	
	D7	NH_4, µmol	6	12	
		NO_X, µmol	27	12	
		Chl(a), ug/L	2	12	

	Station	Analyte	Median Concentration	No. of samples
2010	C10A	NH_4, µmol	1	12
		NO_X, µmol	90	12
		Chl(a), ug/L	12	12
	P8	NH_4, µmol	4	12
		NO_X, µmol	128	12
		Chl(a), ug/L	3	12
	D19	NH_4, µmol	3	12
		NO_X, µmol	24	12
		Chl(a), ug/L	2	12
	D28A	NH_4, µmol	2	12
		NO_X, µmol	25	12
		Chl(a), ug/L	1	12
	D7	NH_4, µmol	5	12
		NO_X, µmol	28	12
		Chl(a), ug/L	2	12

Source: DWR, (2009); (2010)

DIN:DIP (N:P) and NH_4:NO_X ratios[1] vs. phytoplankton biomass[2] and composition[3] at selected IEP stations in the Bay-Delta system

	Station	N:P Ratio	NH_4:NO_X Ratio	Chl(a) µg/L	Diatom Abundance (Annual Avg) %
2009	C10A	14.4	0.01	14	68
	P8	28.1	0.04	2	2
	D19	9.2	0.09	2	27
	D28A	8	0.05	1	22
	D7	9.4	0.22	2	58
	C3A	13.3	1.1	2	94

	Station	N:P Ratio	NH_4:NO_X Ratio	Chl(a) µg/L	Diatom Abundance (Annual Avg) %
2010	C10A	15.6	0.01	12	83
	P8	27.5	0.03	3	8
	D19	14.2	0.12	2	68
	D28A	14.2	0.08	1	30
	D7	9.4	0.17	2	88
	C3A	9.2	1.5	2	87

1 – Annual Median molar ratio values

2 – Annual Median

3 – Annual Average

Source: DRW, (2009); (2010)

Conclusions

1. High phytoplankton biomass co-exists with elevated Ammonia-N concentrations in freshwater and brackish water.

2. High diatom abundance, cell density and biovolume co-exists with elevated Ammonia-N concentration in brackish water.

3. Elevated Ammonia-N concentrations did not encourage dinoflagellates or cyanobacteria over diatoms in brackish water.

Conclusions

4. Removal of anthropogenic ammonia (<4 umol) offers little or no guarantee that NO_3 uptake would take place resulting in increased phytoplankton biomass.
5. Increased N:P ratios were associated with increased abundance of diatoms with no dinoflagellates.
   - Reducing N:P ratios may not increase diatoms abundance over dinoflagellates or blue green algae
6. Increased NO_3:NH_4 ratios were associated with increased abundance of diatoms
   - Increasing NO_3:NH_4 ratio may not encourage diatom abundance over dinoflagellates or blue-green algae

Mean Copepod Abundance
(September 21, 27 and October 9, 2012)
Estimated Count (# m^3)

	Mean at Downstream (X2) n=3	Mean at Station near Suisun Bay n=3
Salinity, ppt	2.5	9.8
Ammonia-N, mg/L	16.5	7.7
Copepod Nauplii	13066	12356
Cyclopoid copepods		
Adults	233	46
Copepodid	2026	846
Limnothiona spp		
Adults	781	3779
Copepodid	919	5087
Eurytemora		
Adult	7	0
Copepodid	86	0
Pseudodiaptomus sp		
Adult	7	8
Eurytemora/Pseudodiaptomus spp		
Juvenile	15	9
Acartiella spp		
Adult	3	0
Other copepods	147	18

Melvin D. Ball and James F. Arthur:

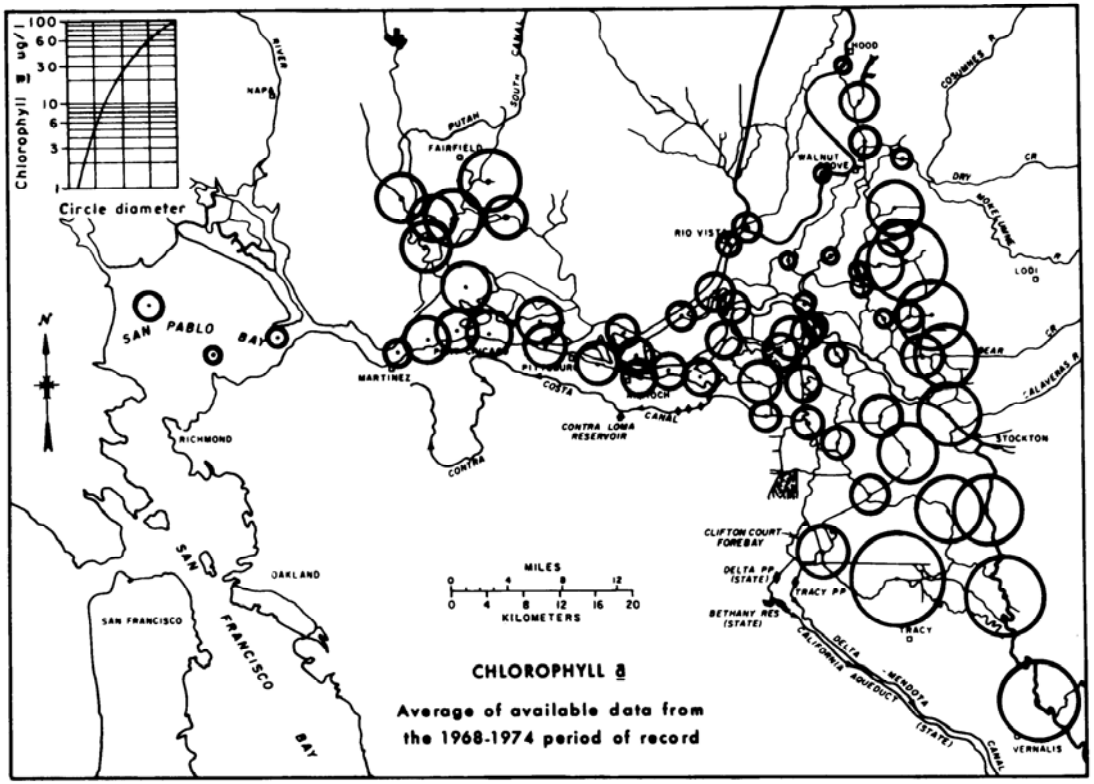
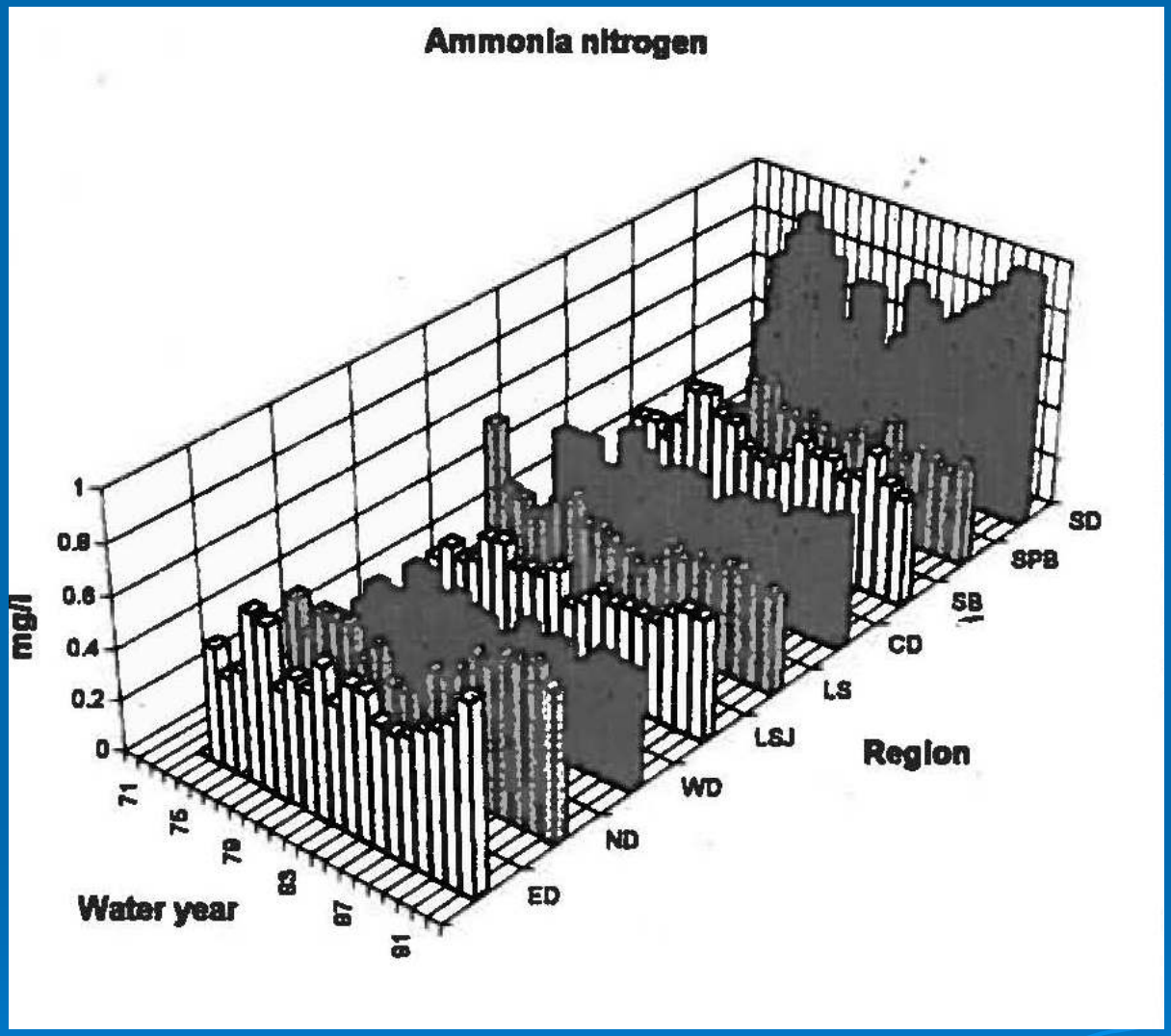


Fig. 4. Average chlorophyll *a* concentration from September 1968-1974. The area of each circle is proportional to the concentration.

Source: Ball & Arthur: Planktonic Chlorophyll Dynamics in the Northern San Francisco Bay Delta
T.J. Conomos, Editor
American Association of Advancement of Science
Pacific division, 1979



Source: Water Quality Conditions in the Sacramento – San Joaquin Delta
DWR Report 1996