Dissolved Organic Carbon in Water of the Sacramento-San Joaquin River Delta: Sources, Sinks and Why Do We Care?

Presented by

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Problem: Decline of Aquatic Resources

Alternative scenarios to consider

Presumptive Cause: Loss of Shallow water Habitat

Eaten by the Pumps

The Clam did it

Global Climate Change

ETC.

Solution: Create More Shallow Water Habitat

Build Hatcheries

Screen Intakes

Feed Clams to Something

Oops…

ETC.

Consequence 1: Recovery of Aquatic Resources (+, desired outcome)

Increase tidal prism (+/-)

Increase SAV and Emergent Vegetation (+?)

ETC

Indirect Consequence: Increase DOC → **Increase DBP Formation Potential** → **Drinking Water Quality Suffers (undesired outcome)**

Hypotheses:

- Diverse types of shallow-water habitats have differing effects on the concentration and bioavailability of DOC in the Delta;

- The prospective conversion of Delta agricultural land into wetlands will increase DOC export from the Delta;

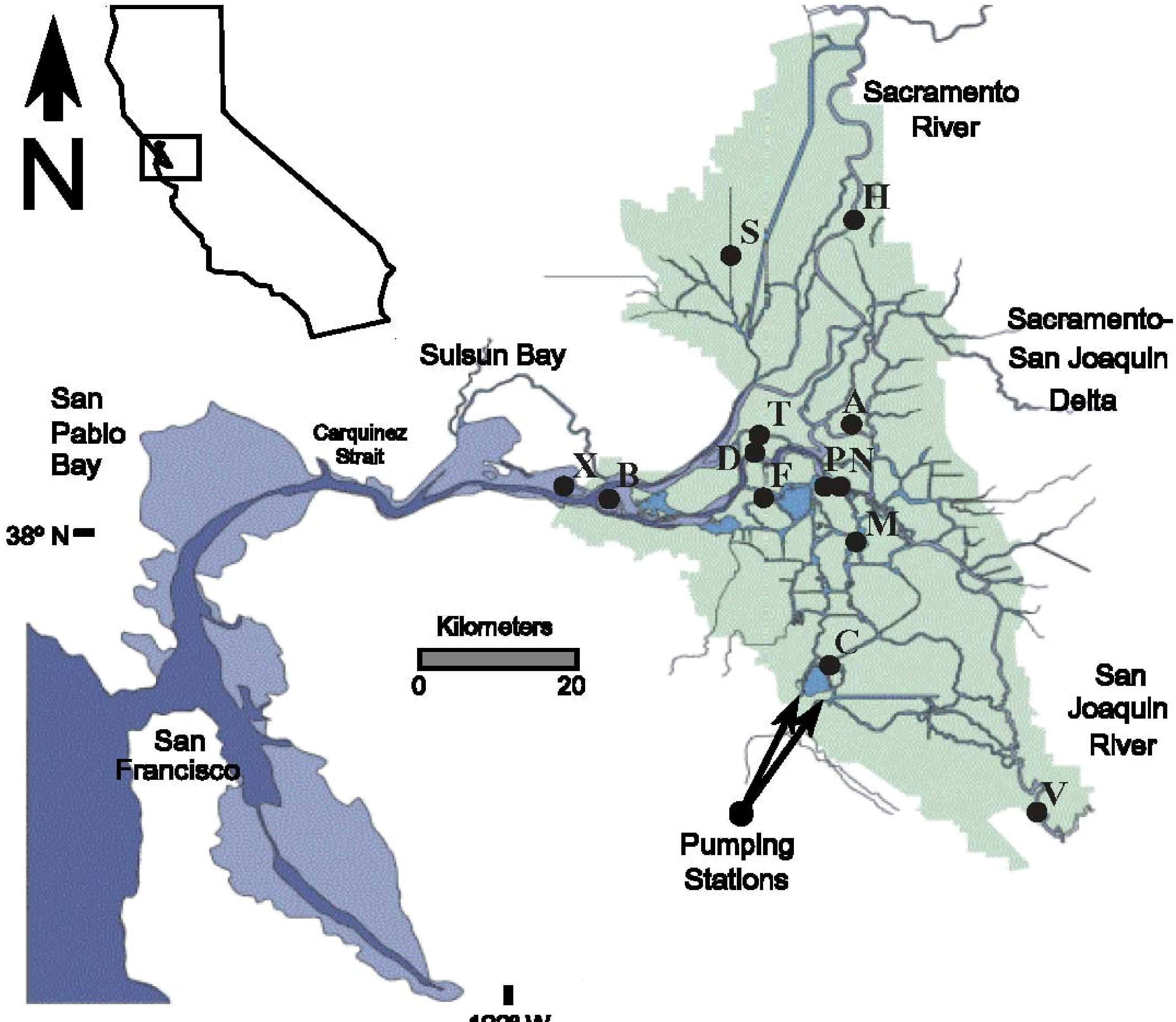
- Microbial food web based on DOC is an important the Delta foodweb
-
- Solar radiation enhances the bioavailability of Delta DOC.

How Do We Evaluate This?

- Assess DOC production by remnant habitats – Does it vary with Habitat?

- Assess DBP formation of that DOC. Is All DOC the Same?

- Assess DOC degradation during passage through Delta. Does DBP-producing DOC Breakdown faster or slower than bulk DOC?



N
Sacramento River
H
S
Sacramento-San Joaquin Delta
Sulsun Bay
San Pablo Bay
Carquinez Strait
T
A
D
X
B
P
N
F
M
38° N
Kilometers
0
20
C
San Joaquin River
San Francisco
V
Pumping Stations
122° W

Table 1. Sampling stations and sampling time.

Abbreviation and full name	Habitat type	Coordinates	Sampling time
A - Staten Island	Drain from an agricultural, below-sea-level island	38°07'33"N, 121°31'30"W	varying
B – Brown's Island	Natural brackish marsh dominated by *Scirpus*	38°02'20"N, 121°52'01"W	max ebb
C - Clifton Court	Main inlet to the California State Water Project	37°49.85'N, 121°33.35'W	During water influx
D - Demo site	Marsh reconstructed in 1997, dominated by *Typha* and *Scirpus*	38°06'29"N, 121°38'52"W	varying
F – Frank's Tract	Lake created from a flooded island in 1930s	38°02'46"N, 121°38'50"W	max ebb
H - Hood	Sacramento River upstream of the Delta	38°22'07"N, 121°31'12"W	max ebb
M - Mildred Island	Lake created from a flooded island in 1983	37°59'43'"N, 121°30'52"W	max ebb
N - Mandeville Tip	Natural freshwater marsh dominated by *Scirpus*	38°03'34"N, 121°32'20"W	max ebb
P – Prisoner's Point	Deep water channel in the central Delta	38°03'35"N, 121°33'26"W	max flood
S - Shag Slough	Channel of the Yolo Bypass floodplain	38°18'22"N, 121°41'32"W	max ebb
T - Twitchel Island	Drain from an agricultural, below-sea-level island	38°05'48"N, 121°39'01"W	varying
V - Vernalis	San Joaquin River upstream of the Delta	37°40'32"N, 121°15'49"W	varying
X - X2	2 psu front in North San Francisco Bay	varying	varying

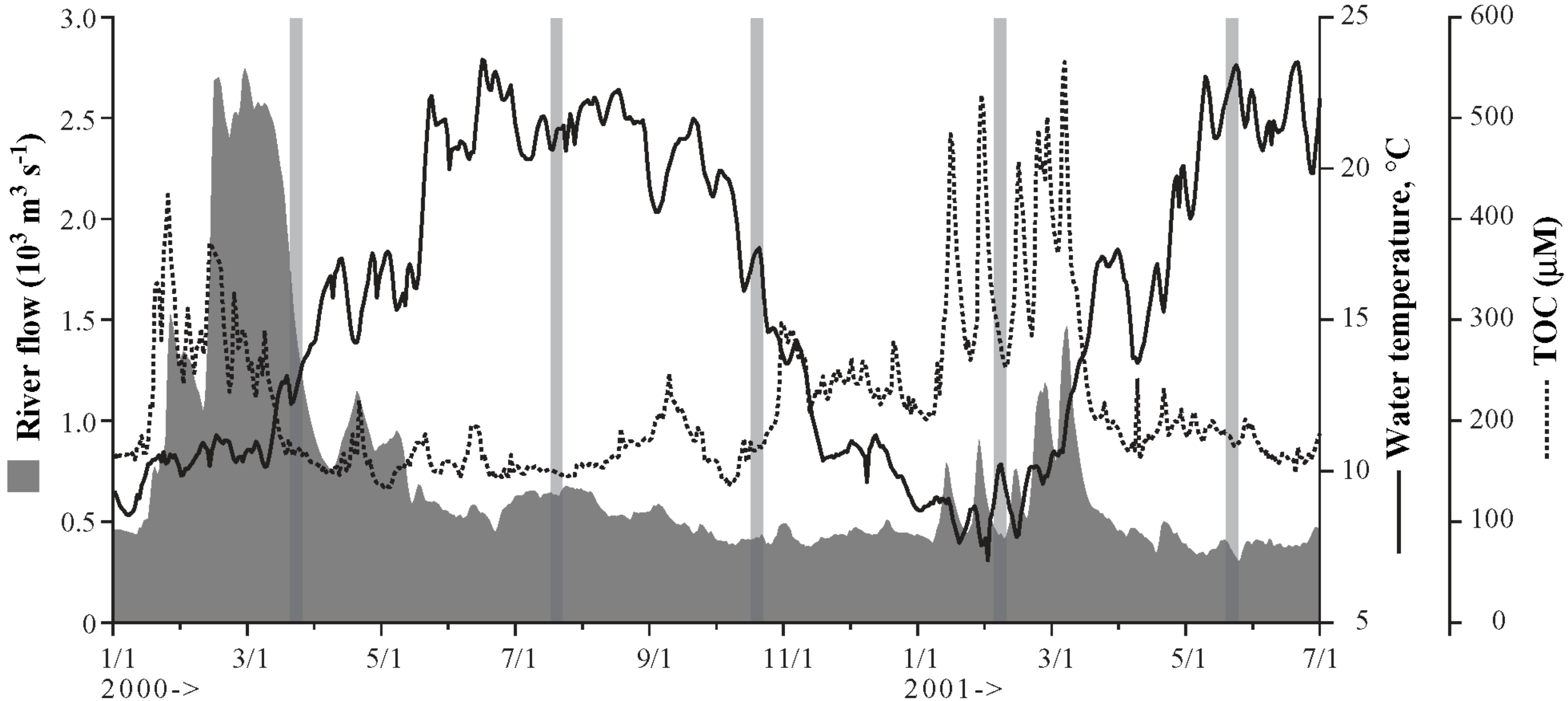


Fig. 2. Stepanauskas et al.

Methods

Simulated solar irradiation:

160-ml quartz flasks in a water bath at 4 C for 4 h, exposed to simulated solar irradiation (Xe lamp) at 286 W m^2 in the range of 280–700 nm, of which 33 W m^2 were in the range of 280–400 nm (equivalent to ~1/2 d during summer at water surface).

DOC: High temperature combustion

Bioavailability: Oxygen consumption after 14 d incubation

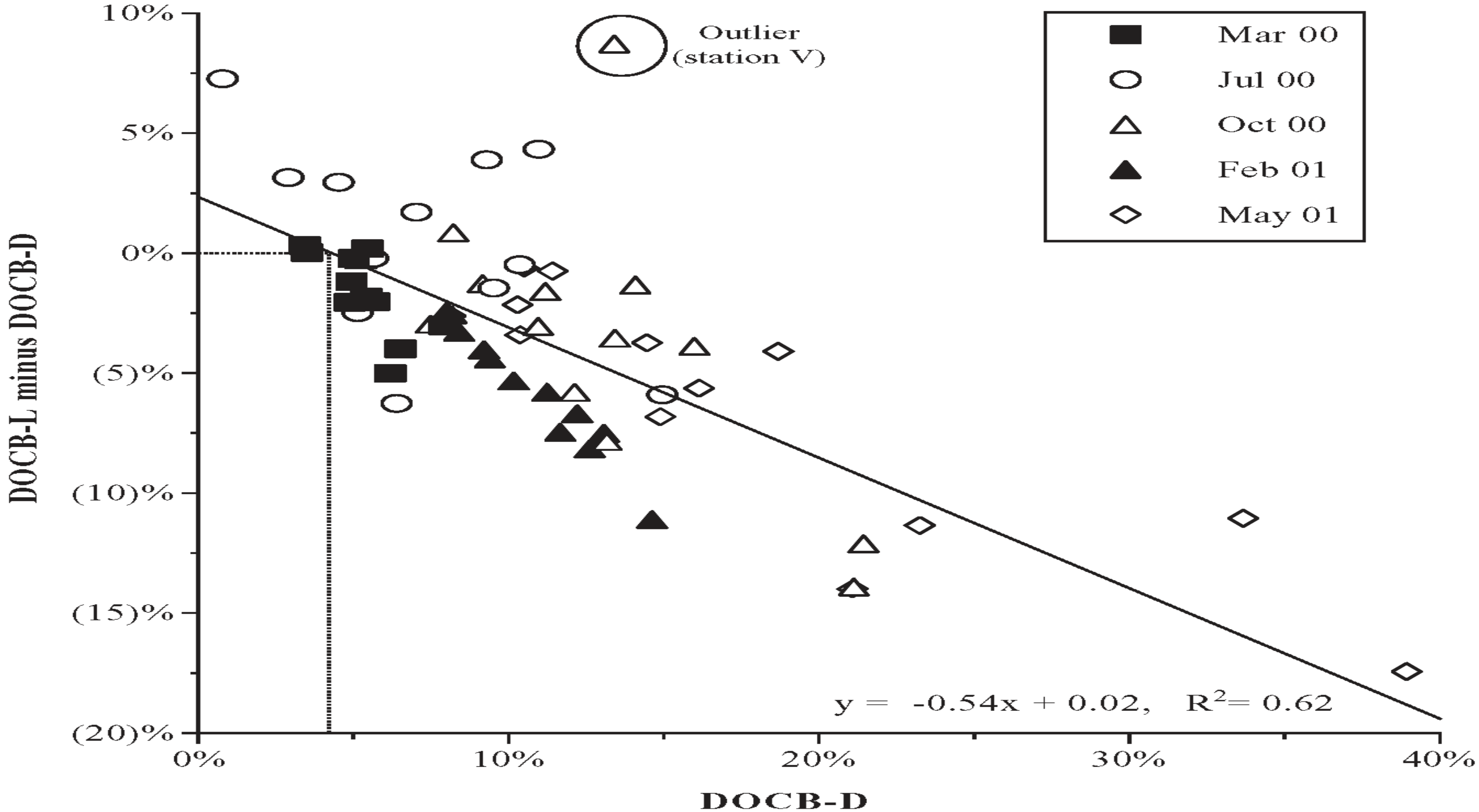
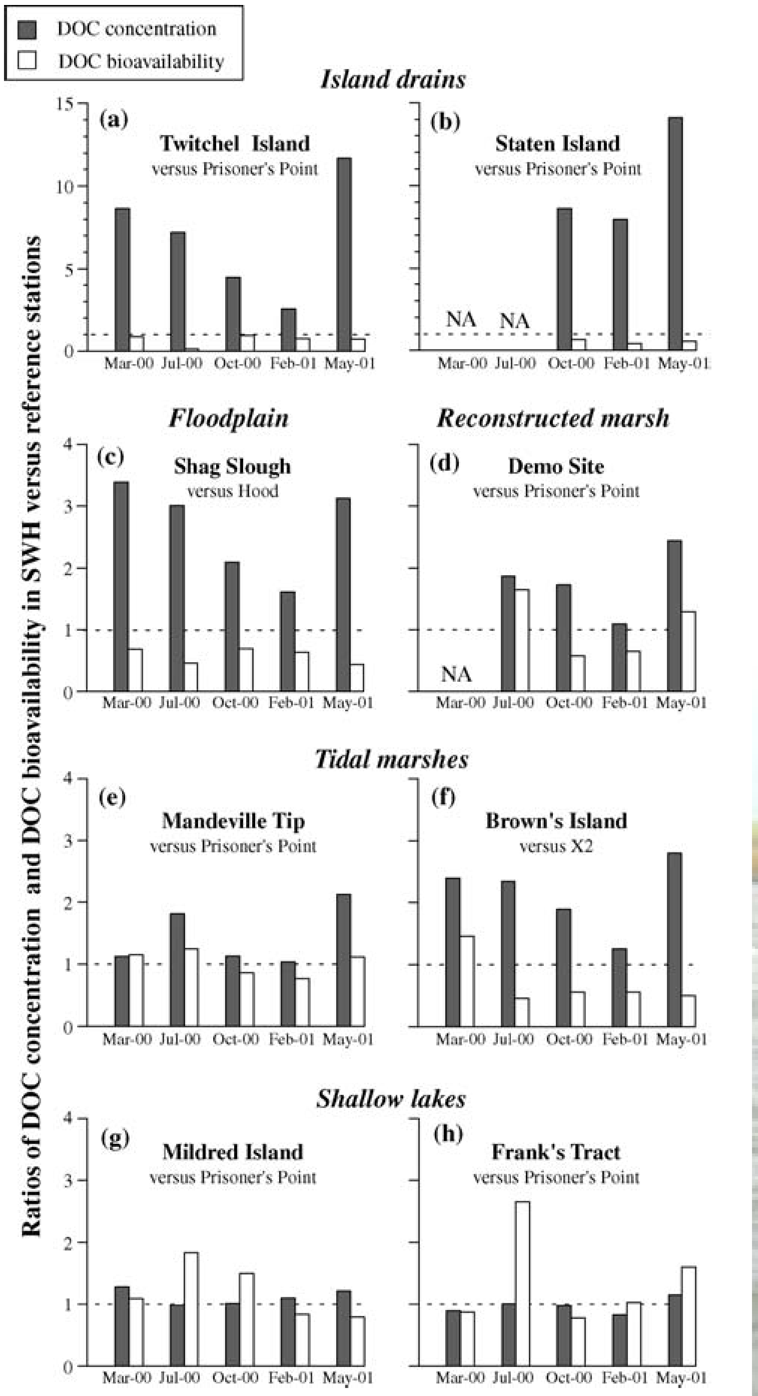


Fig. 3. Stepanauskas et al.

Ratio of DOC Concentration and bioavailability at Delta site relative to river reference sites



DOC Characteristics and Source

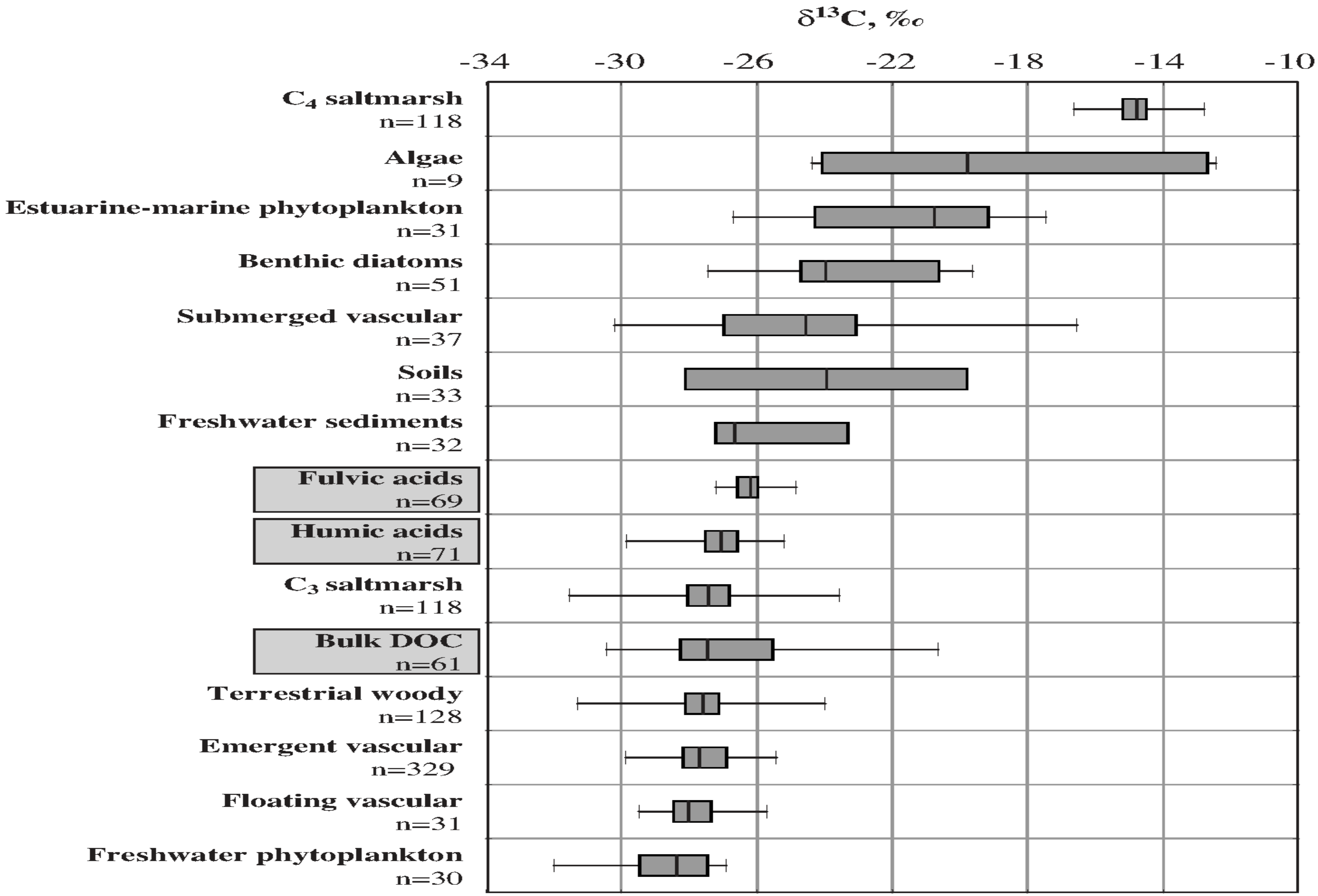


Fig. 8. Stepanauskas et al.

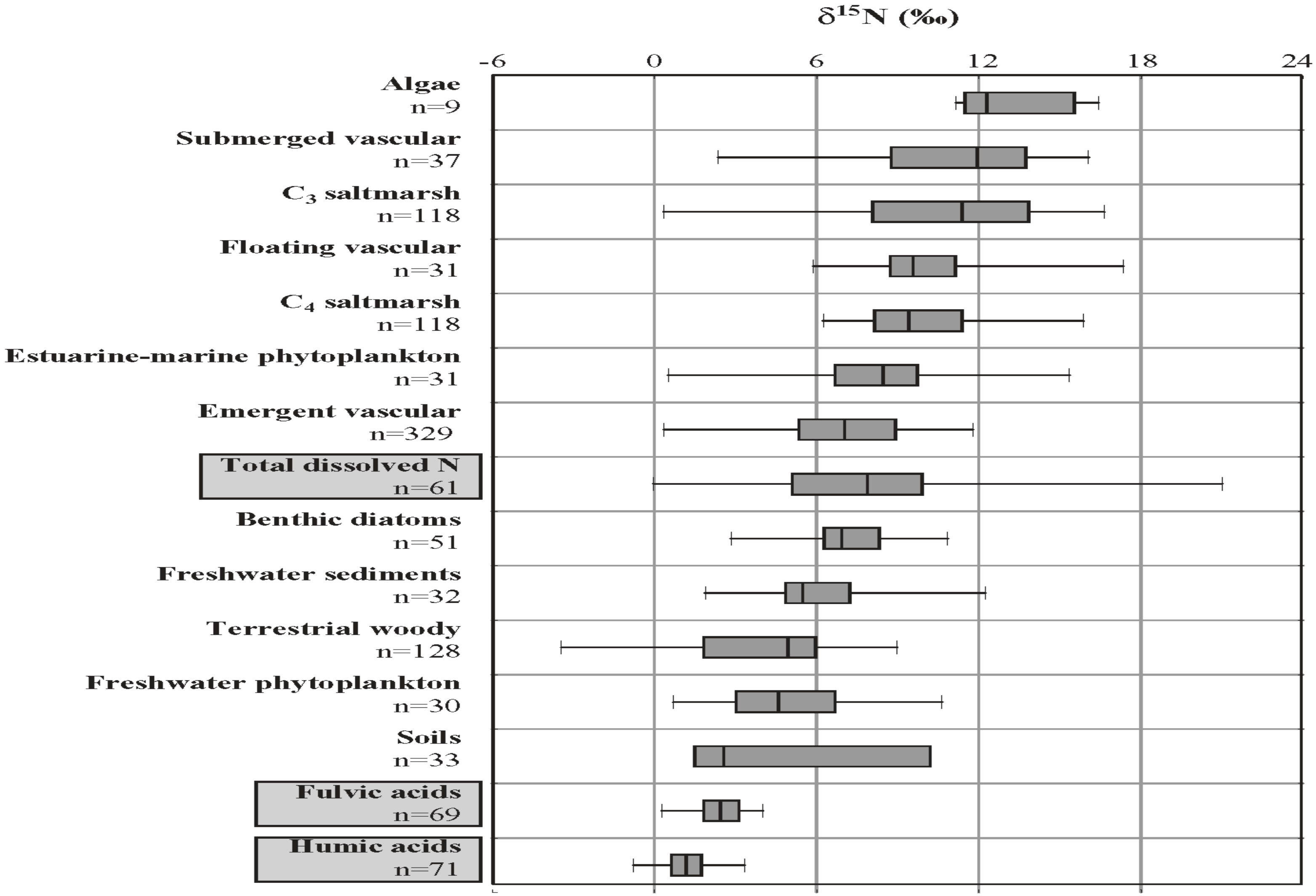


Fig. 9. Stepanauskas et al.

Table 2. Seasonal variability in chemical and microbiological variables: DOC concentration (DOC); DOC bioavailability before and after solar irradiation (DOCB-D and DOCB-L); fluorescence ratio (FluR); DOC-specific absorbance at 350 nm (a350/C); absorbance slope (AbS); DOC fractions of humic acids, fulvic acids, and hydrophilic compounds (Hum, Ful, and Hydr); and $\delta^{13}C$ and $\delta^{15}N$ of these fractions as well as bulk DOC and dissolved solids (DS). Data represent medians and ranges. Stars indicate the level of significance in comparisons of winter (Mar 00 and Feb 01) and summer (Jul 00, Oct 00, and May 01) sampling campaigns, obtained from unpaired t-tests on log-transformed data; $p<0.05$, <0.005, and <0.001 are indicated by *, **, and ***.

Variable	Units	Entire study	Mar-00	Jul-00	Oct-00	Feb-01	May-01
DOC **	µM	285(81-3704)	320(108-2452)	206(109-1105)	190(136-1449)	466(284-3704)	252(81-2006)
DOCB-D*	%	10.2(0.8-38.9)	5.4(3.4-7.9)	6.7(0.8-15.0)	13.2(7.5-21.4)	10.2(5.2-14.6)	14.9(8.1-38.9)
DOCB-L***	%	6.2(0.1-22.6)	3.6(1.2-5.7)	8.1(0.1-15.3)	9.1(4.5-22.1)	5.1(3.5-5.6)	10.5(5.5-22.6)
FluR**		1.60(1.36-1.77)	1.44(1.39-1.47)	1.62(1.45-1.77)	1.62(1.45-1.71)	1.58(1.36-1.74)	1.63(1.40-1.76)
a350/C***	μM^{-1}	28.1(13.0-46.7)	33.1(23.1-46.7)	28.1(17.4-37.5)	19.9(13.4-38.7)	25.8(13.0-36.7)	37.5(28.1-42.3)
AbS***	pm^{-1}	14.3(11.2-17.5)	13.2(11.2-15.7)	15.1(12.8-16.6)	16.7(15.1-17.5)	14.0(11.7-16.7)	14.1(12.0-16.5)
Hum	%	50(35-60)	52(36-55)	50(45-55)	48(35-57)	50(42-60)	51(42-56)
Ful	%	28(20-50)	27(24-50)	28(24-35)	30(22-45)	28(20-40)	26(20-40)
Hydr	%	22(14-26)	21(14-26)	21(18-23)	22(20-24)	22(18-23)	22(18-24)
$\delta^{13}C$-Hum	‰	-27.3(-28.7 to -25.3)	-27.6(-28.2 to -26.9)	-27.3(-28.4 to -26.5)	-26.9(-27.9 to -25.6)	-27.3(-28.1 to -25.3)	-27.3(-28.7 to -25.3)
$\delta^{13}C$-Ful	‰	-26.3(-27.2 to -24.8)	-26.6(-27.2 to -26.0)	-26.2(-27.1 to -25.5)	-26.0(-26.7 to -24.9)	-26.2(-26.9 to -24.8)	-26.3(-27.1 to -24.8)
$\delta^{13}C$-DOC	‰	-27.3(-29.3 to -23.1)	-27.5(-28.1 to -26.8)	-26.8(-28.7 to -24.5)	-27.5(-29.4 to -24.7)	-27.2(-29.3 to -23.1)	-27.1(-28.3 to -23.1)
$\delta^{15}N$-humic**	‰	1.2(-0.8-3.3)	0.9(-0.8-1.5)	1.6(0.2-3.1)	1.2(-0.7-2.3)	0.7(-0.4-2.2)	1.7(0.1-3.3)
$\delta^{15}N$-fulvic***	‰	2.5(0.3-4.0)	2.2(0.3-3.0)	2.9(1.9-3.6)	2.7(0.6-3.3)	2.0(0.6-3.7)	2.9(1.3-4.0)
$\delta^{15}N$-DS	‰	8.1(0.0-21.0)	6.7(3.6-10.1)	6.1(0.0-12.1)	8.7(2.6-15.6)	9.3(3.2-21)	9.9(5.6-21.0)

Spearman Rank Correlation Coefficients

	DOCB-D	DOCB-L
DOC concentration, µM	-0.54 ***	-0.35 **
Fluorescence ratio	0.36 **	0.49 ***
a350/C, μM^{-1}	0.03	-0.08
Absorbance slope	0.12	0.19
Humic fraction of DOC, %	-0.01	0.01
Fulvic fraction of DOC, %	0.04	-0.01
Hydrophilic fraction of DOC, %	-0.02	0.07
$\delta^{13}C$ of humic acids, ‰	0.24	0.28 *
$\delta^{13}C$ of bulk DOC, ‰	0.06	0.14
$\delta^{15}N$ of humic acids, ‰	0.39 **	0.08

Model Delivery to Clifton Court using Conservative Tracers after Paulsen (1997)

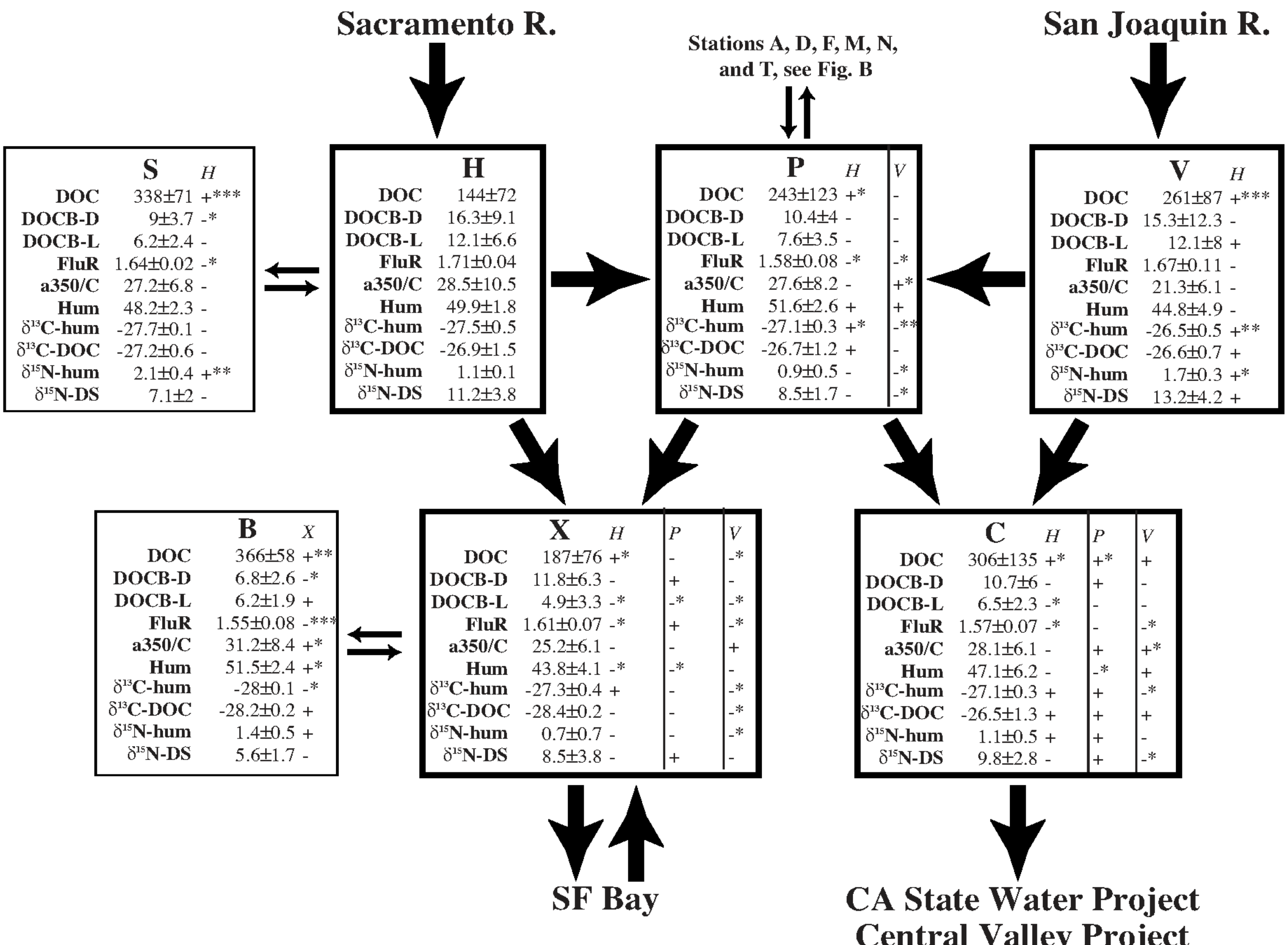


Fig. 5. Stepanauskas et al.

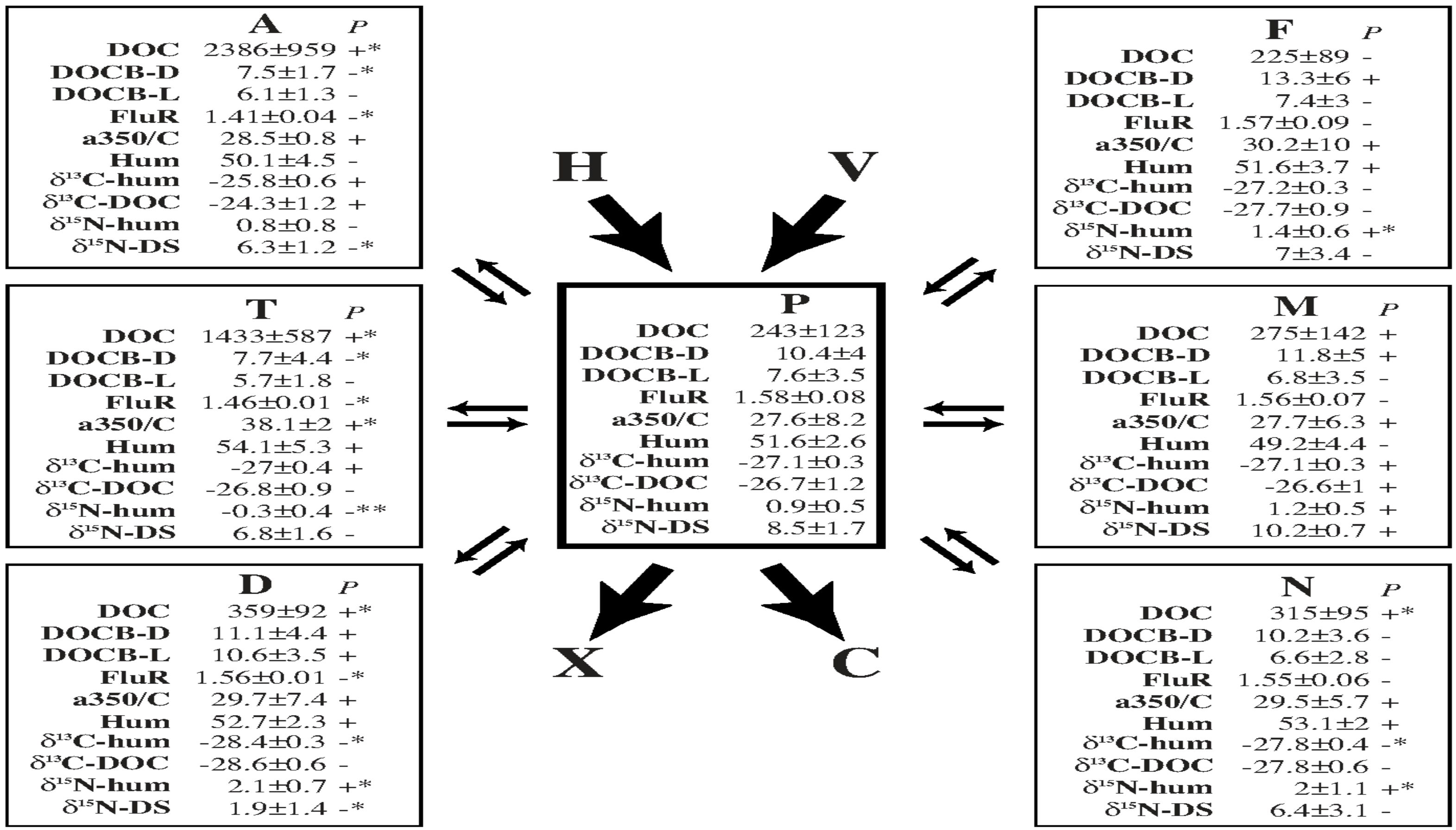


Fig. 6. Stepanauskas et al.

Table 4. Estimate of DOC sources to the Clifton Court forebay (station C).

	Na, Ca, and Mg, mg L^{-1}			f[a], %		DOC, µM			DOCB-D[b], % DOC			DOC contribution[c], %		
Station	H	V	C	H	V	H	V	C	H	V	C	H	V	Delta
July 00	8; 10; 5	63; 32; 15	22; 14; 8	81±0	19±0	109	234	178	11	10	5	50 (44)	25 (22)	25 (33)
October 00	8; 10; 6	47; 25; 11	61; 17; 13	63±1	36±1	136	265	186	16	13	21	46 (39)	51 (45)	3 (17)
February 01	17; 16; 10	110; 46; 23	48; 22; 13	81±0	19±1	284	412	539	13	11	12	43 (37)	15 (13)	43 (50)
May 01	14; 13; 8	33; 18; 8	40; 21; 12	-50±18	150±18	81	143	260	34	39	10	N.D.	N.D.	N.D.

[a] **f** is the fraction of water arriving at station C from stations H or V. Mean±SD for the estimates based on two tracer pairs: Mg & Ca and Na and Ca.

[b] DOCB-D is DOC bioavailability in unirradiated samples.

[c] Contribution to the DOC pool at station C originating from the stations H and V as well as from sources in the Delta. The first value is calculated assuming no riverine DOC is consumed between stations. The value in parenthesis is calculated assuming all of the bioavailable DOC was consumed before reaching station C. Bioavailable DOC was estimated from DOC alteration in bioassays of non-irradiated samples. N.D. = not determined because of a model failure to estimate **f** values.

Sac R contribution = 34-50%
San J R contribution = 15-51%
Delta contribution = 3-43%

Conclusions

- DOC is produced in the Delta from vascular plants and soil
- It doesn’t break down in transit through Delta
- Source not important for DBP formation
- Delta DOC not bioavailable
- Less available after solar exposure
- DOC not a significant contribution to Delta foodwebs via microbial loop

Therefore:

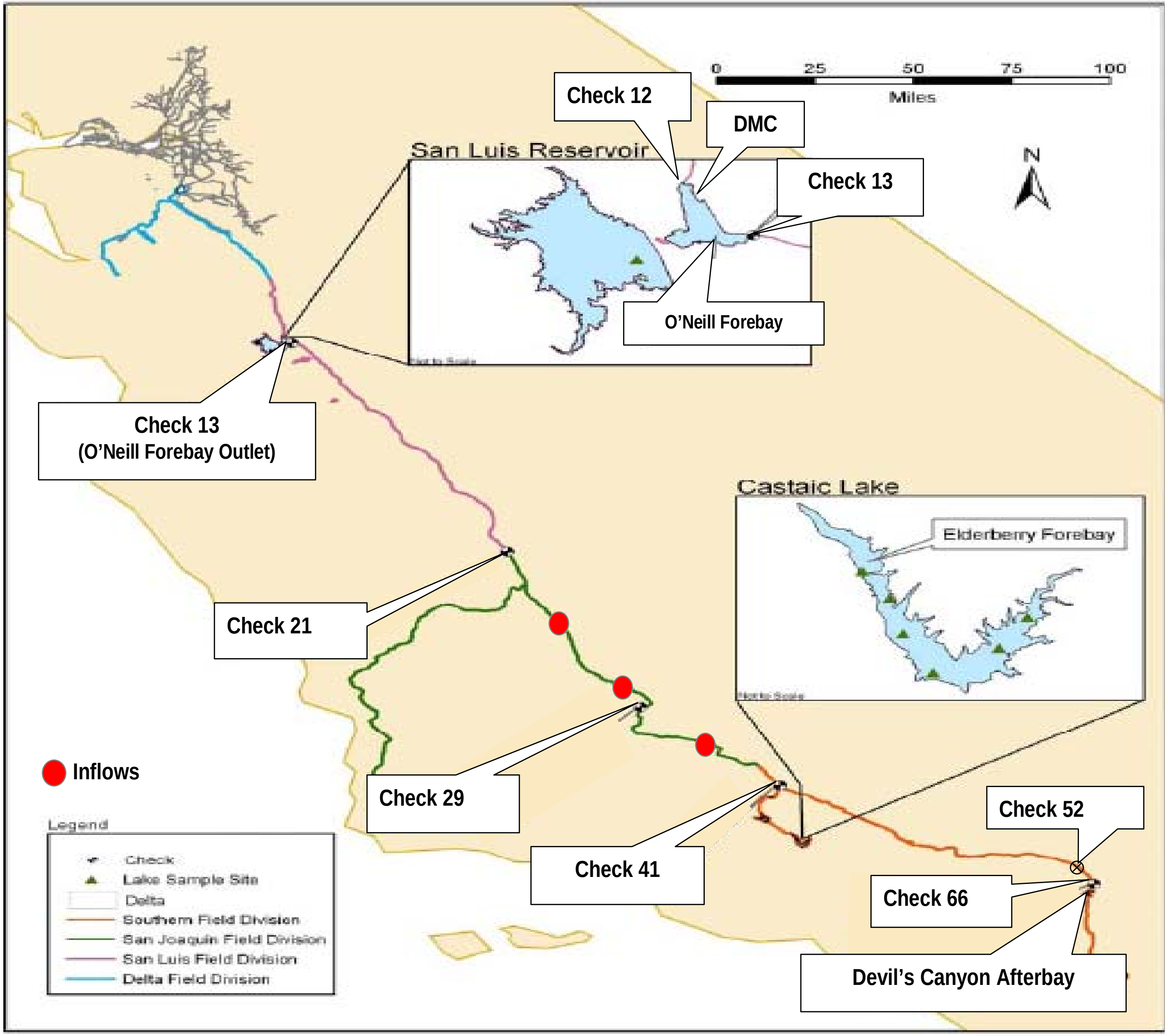
- Creating marshes will lower water quality with regard to drinking water and
- It doesn’t matter where you put the marshes

Questions

- What happens during transit through SWP?
- What happens during storage in San Luis Reservoir?
- Are there other significant allochthonous or autochthonous sources of DOC in the system?
- How do microbial populations change through system, esp Actinobacteria?

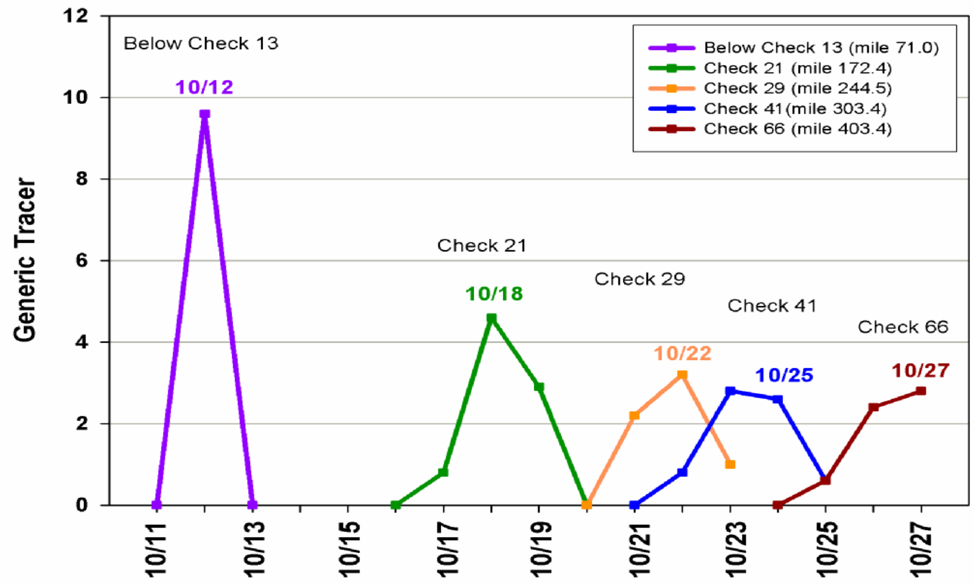
Study Goals

- DOC Concentrations in SWP
  - Spatial and temporal variation
  - Bioavailability
  - Effect or irradiance on bioavailability
- Chemical Properties of DOC (Bergamaschi, USGS)
- Disinfectant By-Product Formation Potential (Losee, MWD)
- Characterize Microbial Assemblages esp Actinobacteria

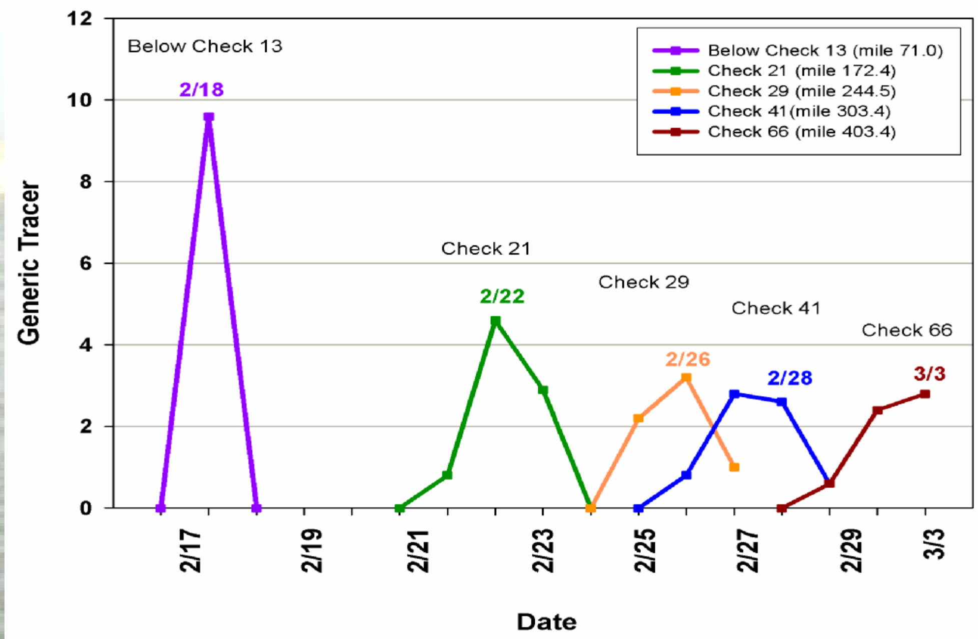


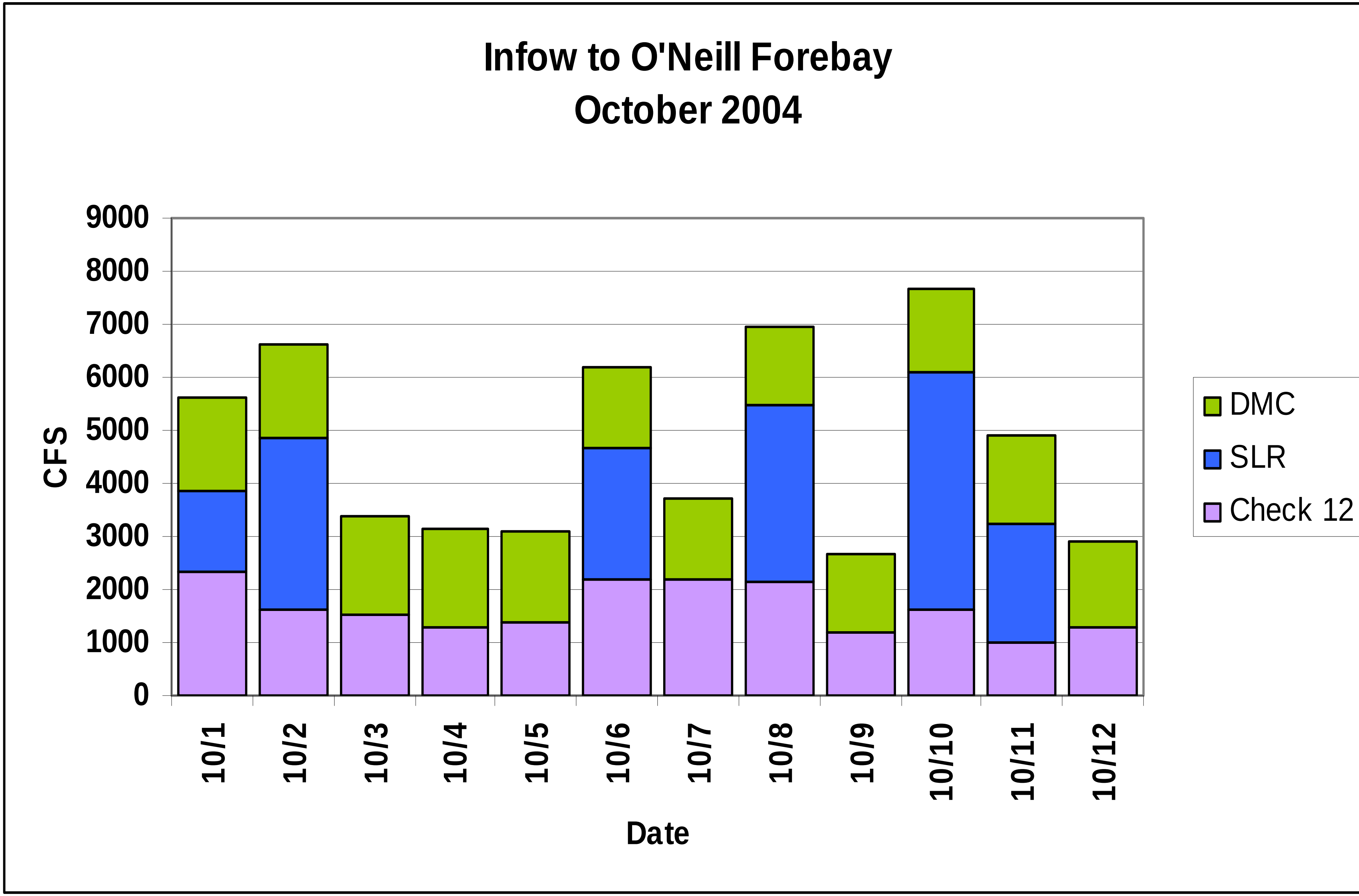
Sampling Stations

Modeled tracer dispersion along aqueduct - October

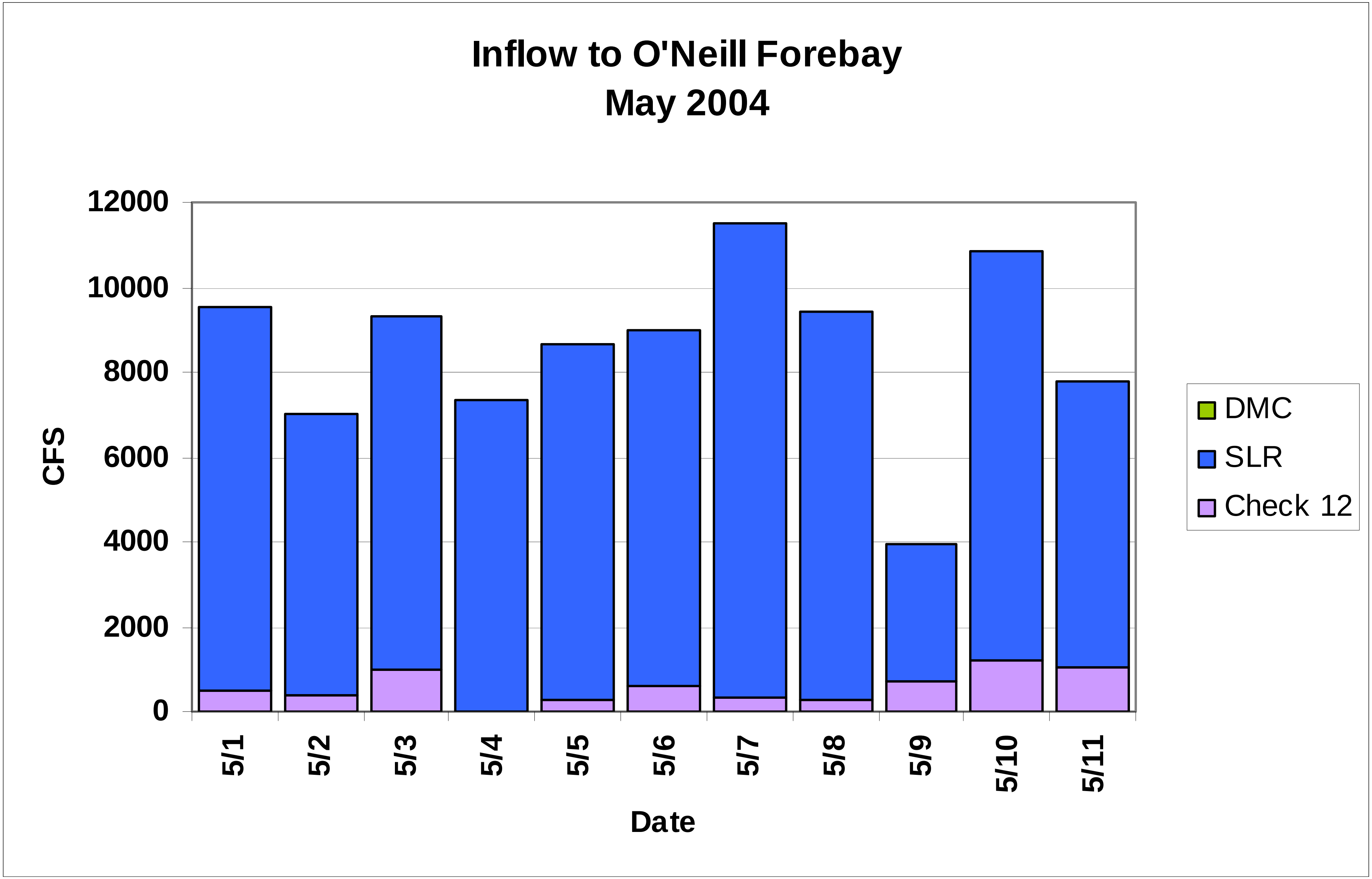


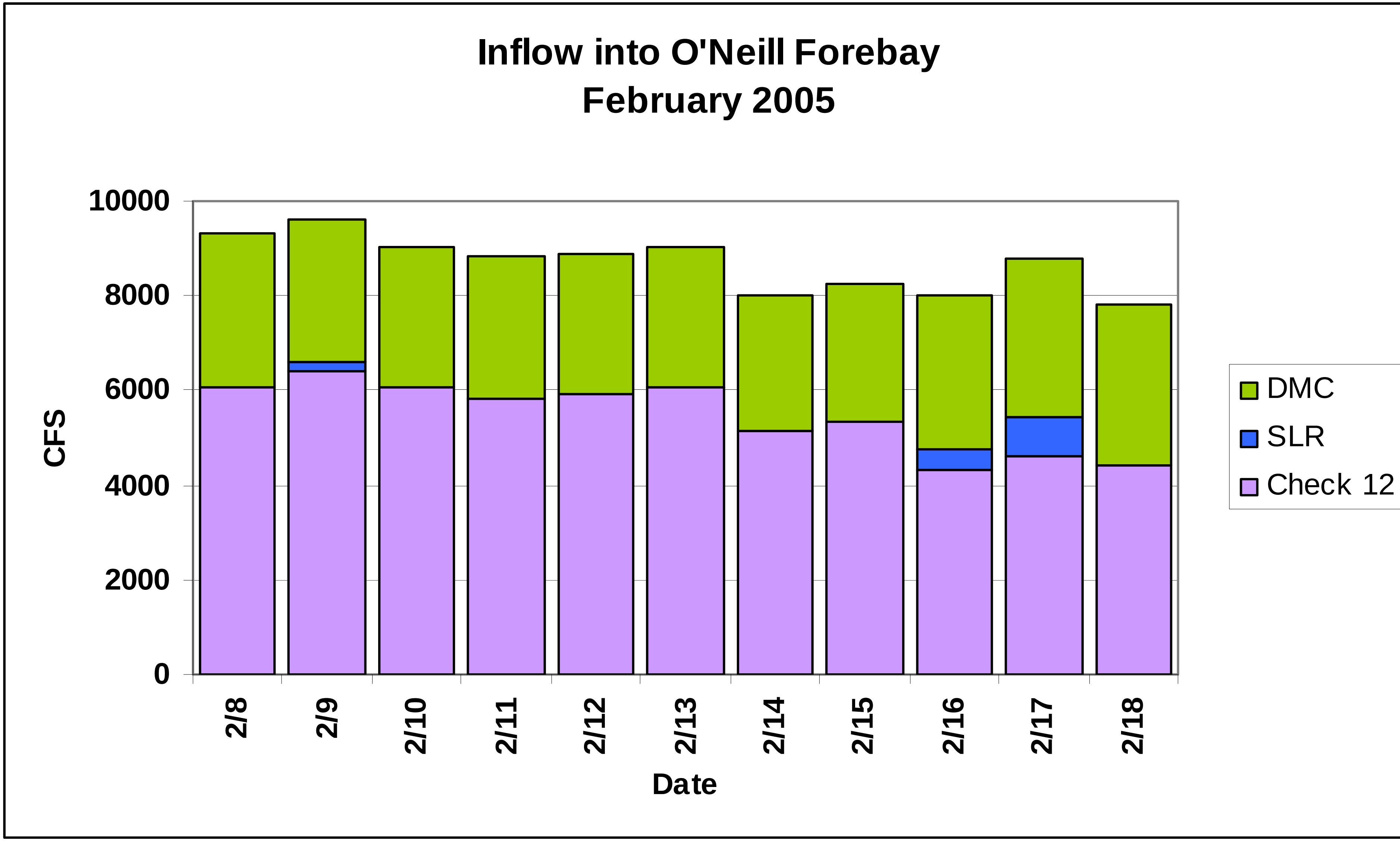
Modeled tracer dispersion along aqueduct - February



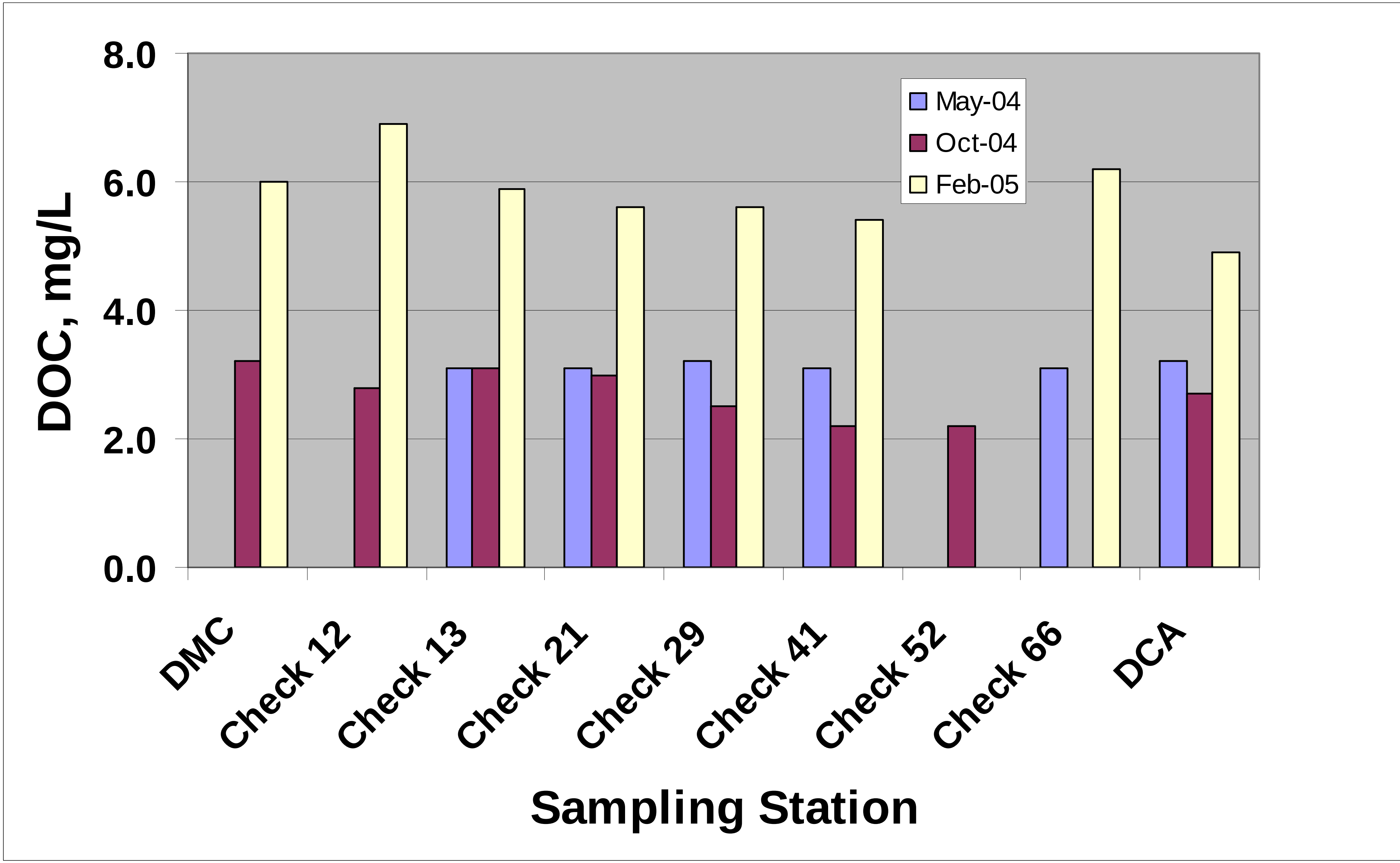


Infow to O'Neill Forebay
October 2004
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
CFS
10/1
10/2
10/3
10/4
10/5
10/6
10/7
10/8
10/9
10/10
10/11
10/12
Date
DMC
SLR
Check 12

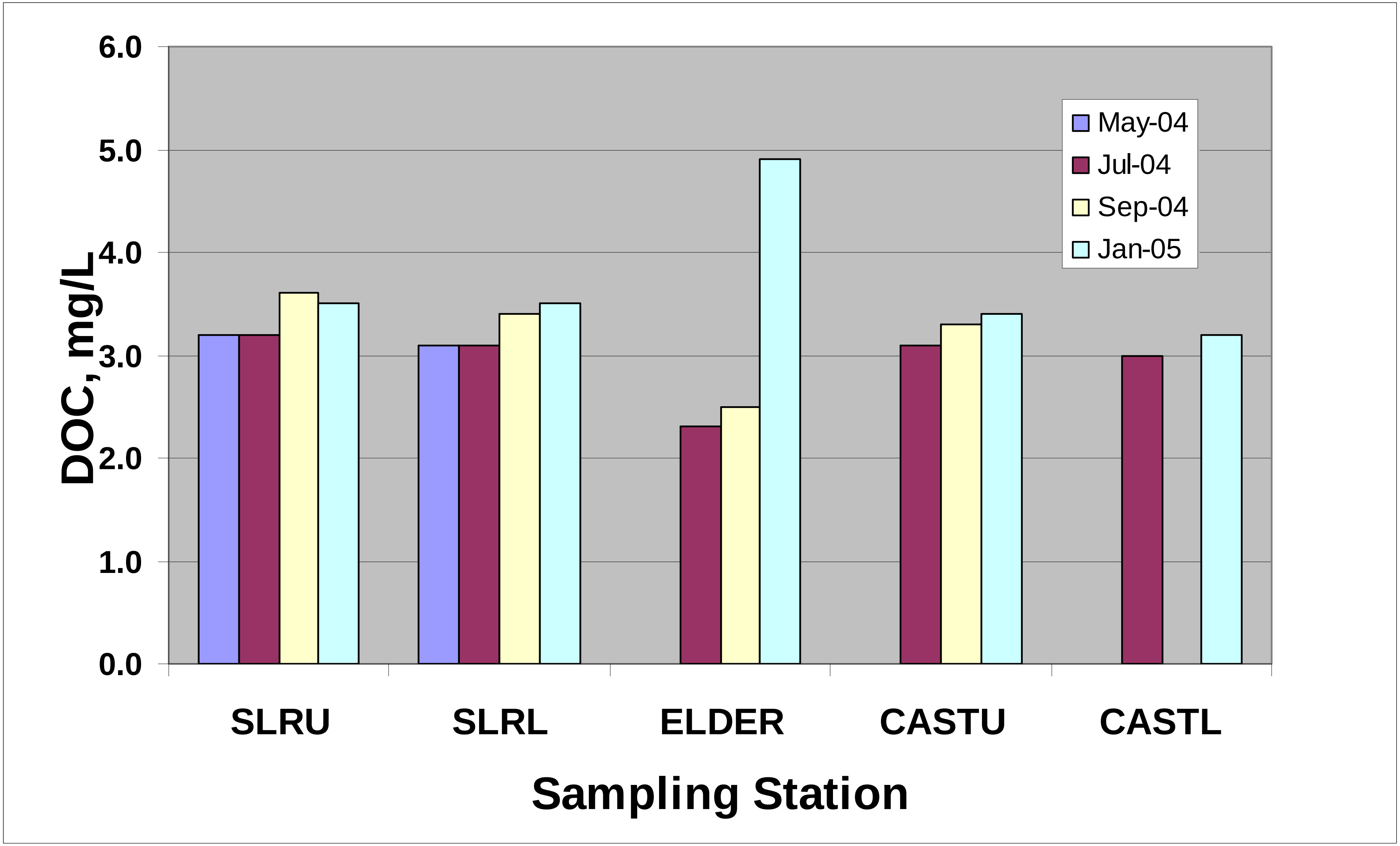

Inflow to O'Neill Forebay
May 2004
12000
10000
8000
6000
4000
2000
0
CFS
5/1
5/2
5/3
5/4
5/5
5/6
5/7
5/8
5/9
5/10
5/11
Date
DMC
SLR
Check 12



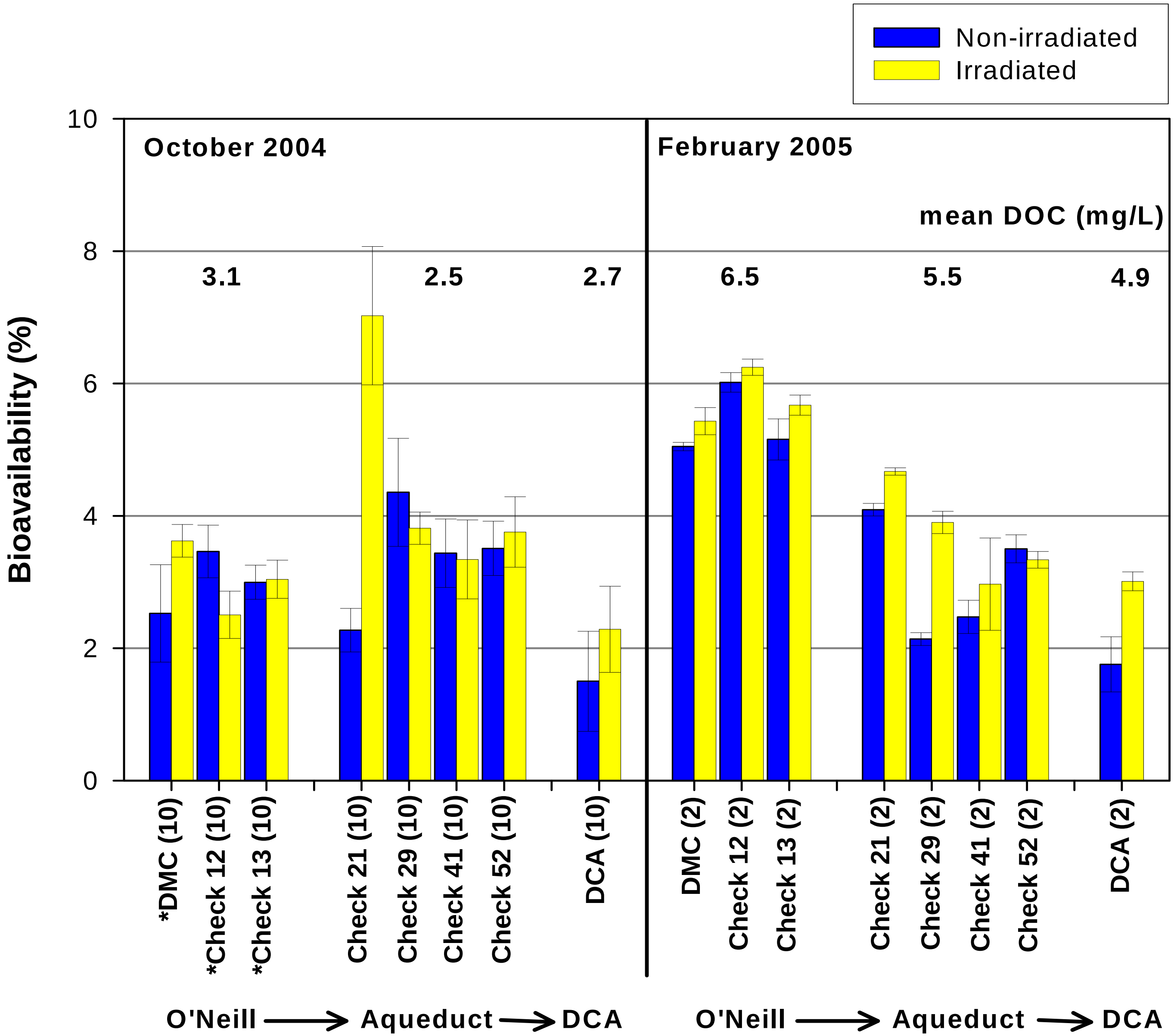
Inflow into O'Neill Forebay
February 2005
10000
8000
6000
4000
2000
0
CFS
2/8
2/9
2/10
2/11
2/12
2/13
2/14
2/15
2/16
2/17
2/18
Date
DMC
SLR
Check 12



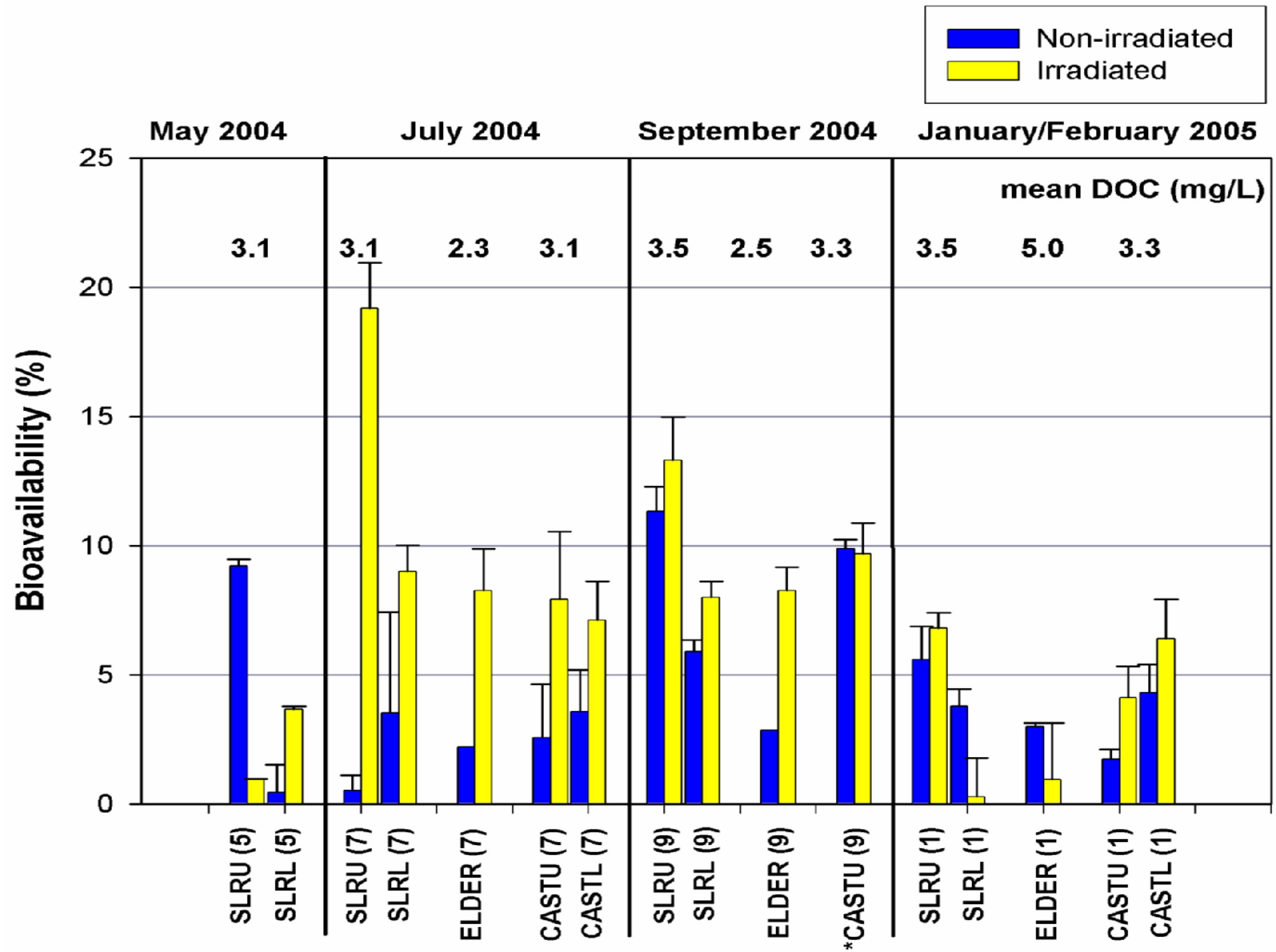
8.0
6.0
4.0
2.0
0.0
DOC, mg/L
May-04
Oct-04
Feb-05
DMC
Check 12
Check 13
Check 21
Check 29
Check 41
Check 52
Check 66
DCA
Sampling Station



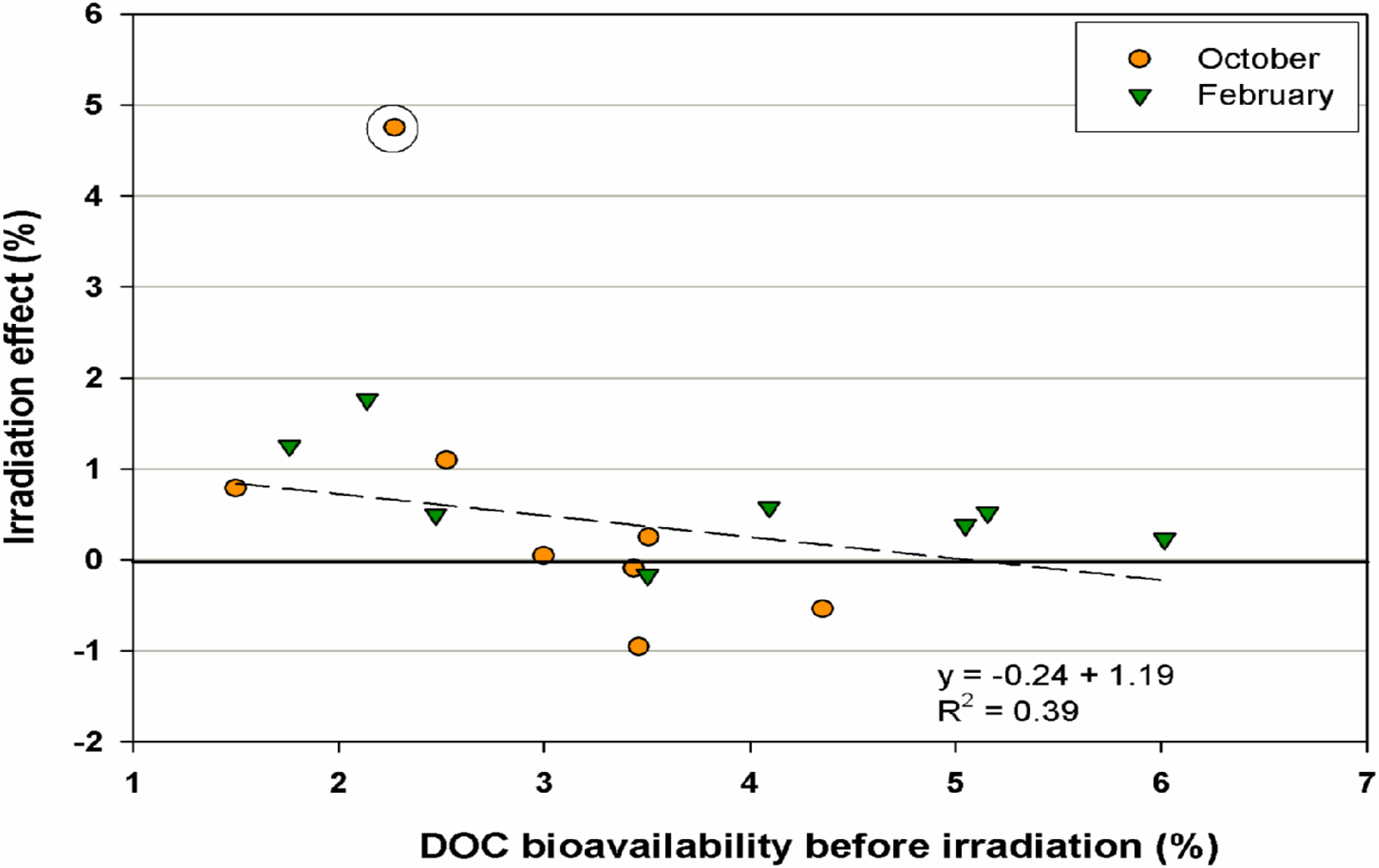
6.0
5.0
4.0
3.0
2.0
1.0
0.0
DOC, mg/L
May-04
Jul-04
Sep-04
Jan-05
SLRU
SLRL
ELDER
CASTU
CASTL
Sampling Station

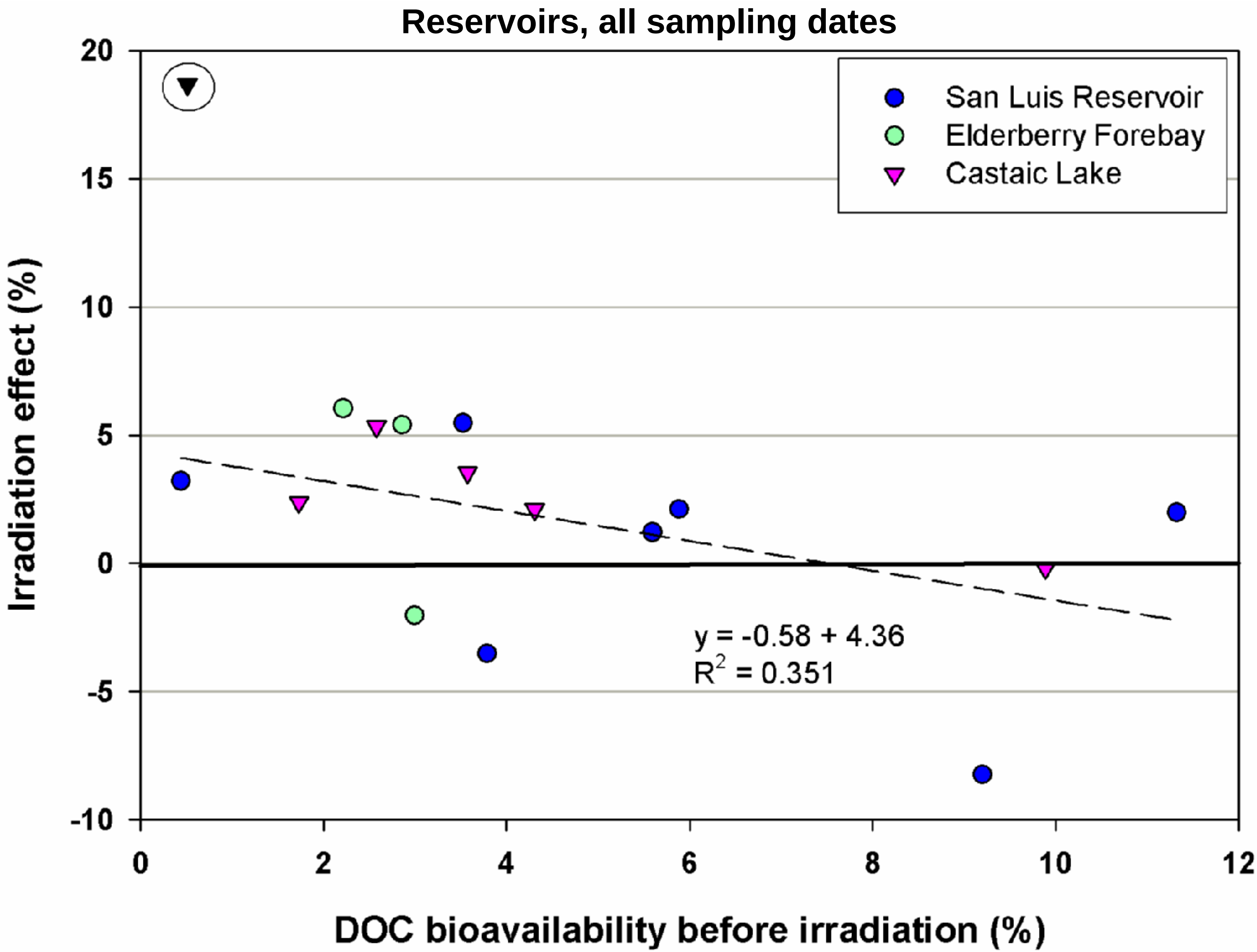


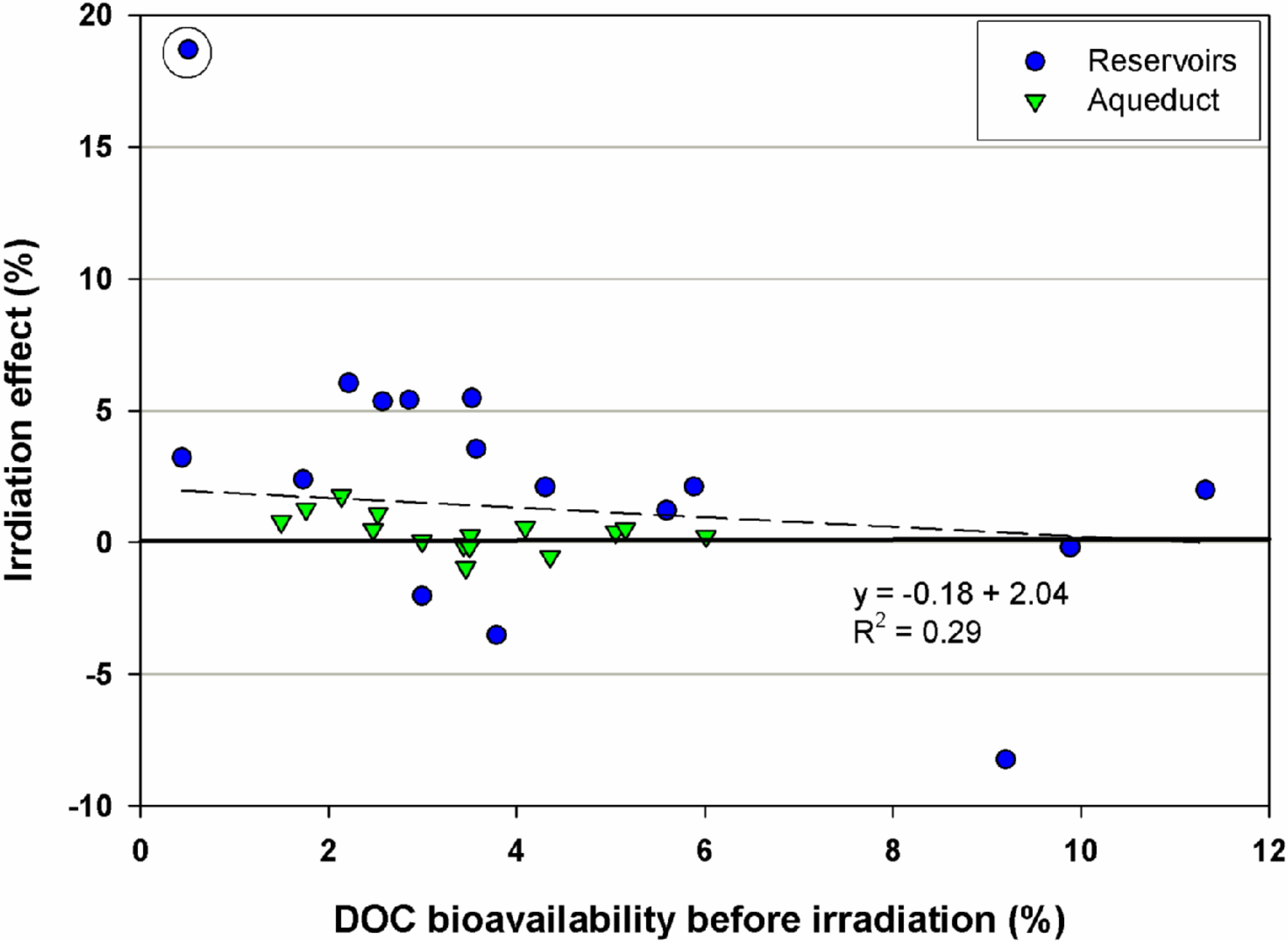
Non-irradiated
Irradiated
Bioavailability (%)
10
8
6
4
2
0
October 2004
February 2005
mean DOC (mg/L)
3.1
2.5
2.7
6.5
5.5
4.9
*DMC (10)
*Check 12 (10)
*Check 13 (10)
Check 21 (10)
Check 29 (10)
Check 41 (10)
Check 52 (10)
DCA (10)
DMC (2)
Check 12 (2)
Check 13 (2)
Check 21 (2)
Check 29 (2)
Check 41 (2)
Check 52 (2)
DCA (2)
O'Neill → Aqueduct → DCA
O'Neill → Aqueduct → DCA

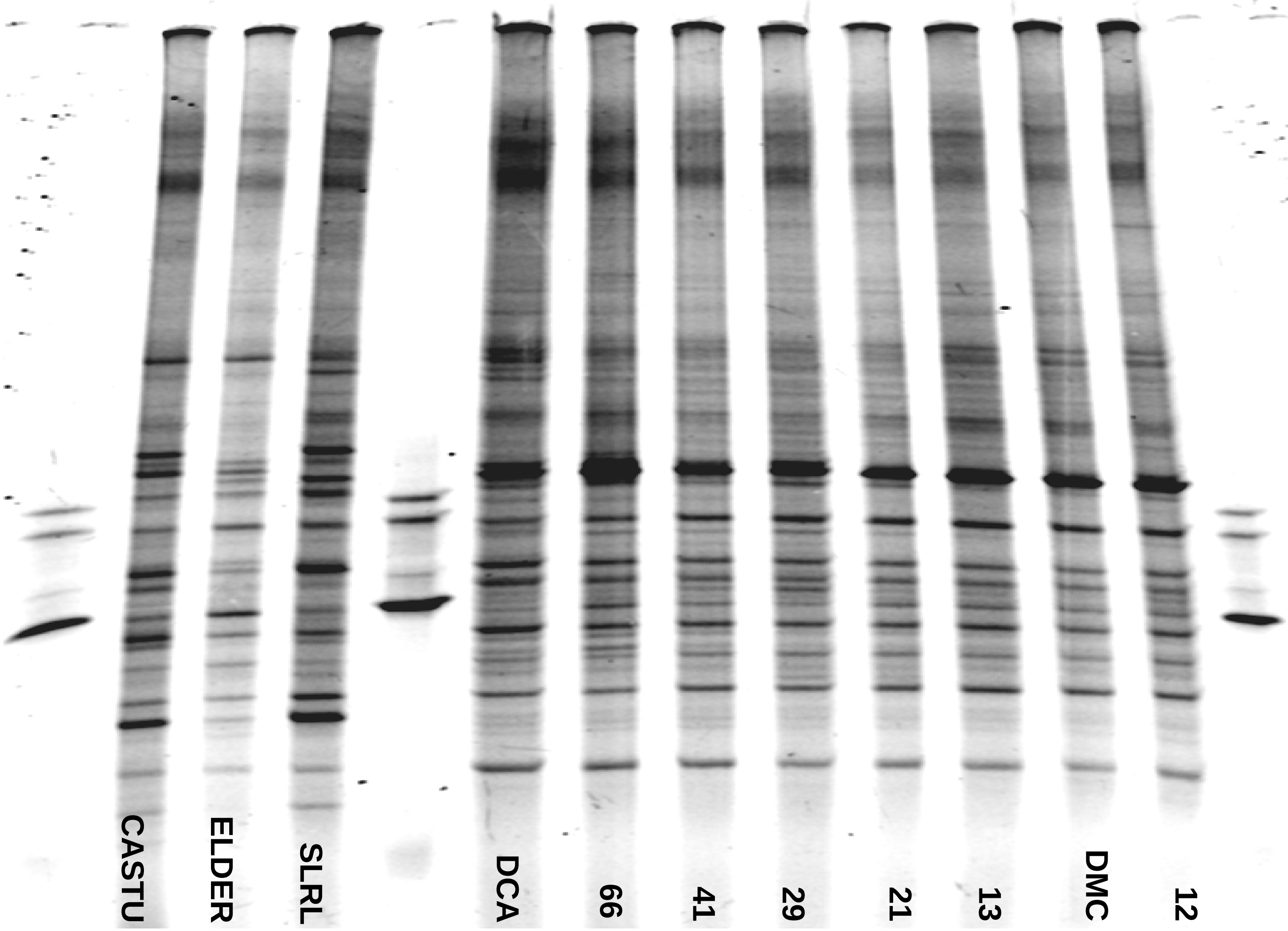

Non-irradiated
Irradiated
May 2004
July 2004
September 2004
January/February 2005
mean DOC (mg/L)
3.1
3.1
2.3
3.1
3.5
2.5
3.3
3.5
5.0
3.3
Bioavailability (%)
25
20
15
10
5
0
SLRU (5)
SLRL (5)
SLRU (7)
SLRL (7)
ELDER (7)
CASTU (7)
CASTL (7)
SLRU (9)
SLRL (9)
ELDER (9)
*CASTU (9)
SLRU (1)
SLRL (1)
ELDER (1)
CASTU (1)
CASTL (1)

California Aqueduct Stations




Reservoirs, all sampling dates
Irradiation effect (%)
DOC bioavailability before irradiation (%)
San Luis Reservoir
Elderberry Forebay
Castaic Lake
y = -0.58 + 4.36
R2 = 0.351
20
15
10
5
0
-5
-10
0
2
4
6
8
10
12


Reservoirs
Aqueduct
y = -0.18 + 2.04
R2 = 0.29
Irrdiation effect (%)
DOC bioavailability before irradiation (%)
20
15
10
5
0
-5
-10
0
2
4
6
8
10
12



Actinobacteria in the SWP

Conclusions

- Seasonal change in aqueduct DOC driven by changes in Delta
- Reservoirs, esp San Luis, different from aqueduct
- Not very labile/bioavailable
- Little effect of light on bioavailability

- Actinobacteria in aqueduct same as in Delta
- Actinobacteria in San Luis Reservoir different
- Actinobacteria are NOT washed in from land

Questions?