Farmington Bay Wetlands and Open Water
Beneficial Use Assessment

Great Salt Lake Steering Committee

March 22, 2005

Are Elevated Nutrient Concentrations Exceeding
the Assimilatory Capacity of the Wetlands and the Bay?
Do Any Toxics (e.g. Se) Exceed Standards?
How Do We Assess Impairment?

Traditional: Compare Sample Results
With (EPA-Derived) Water Quality Standards

However,

We Do Not Have Nutrient Standards;

We Do Not Have Assessment Methods for Wetlands
We Do Not Have Assessment Methods For Farmington Bay
Or the GSL Open Water

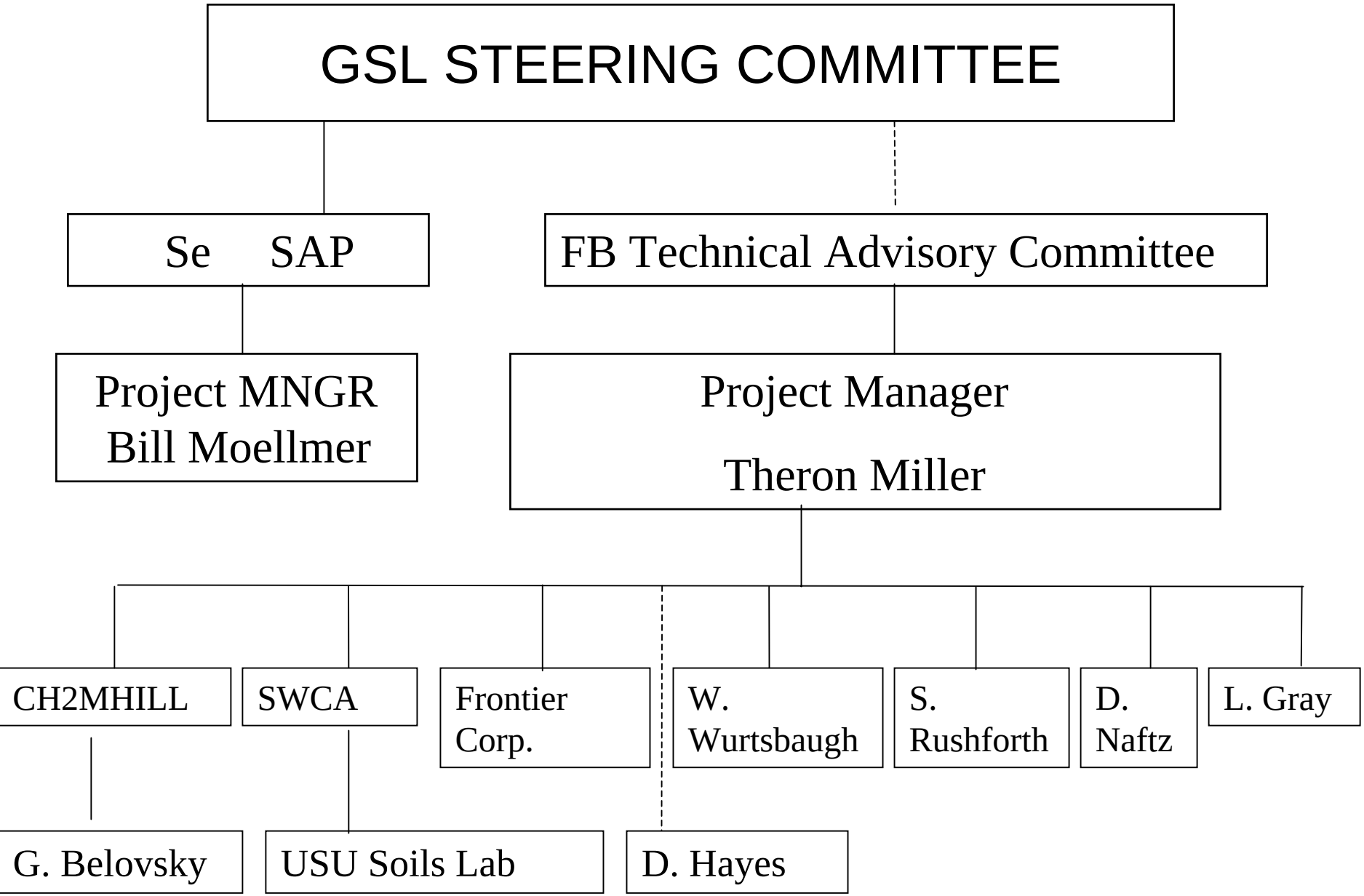
NEEDS

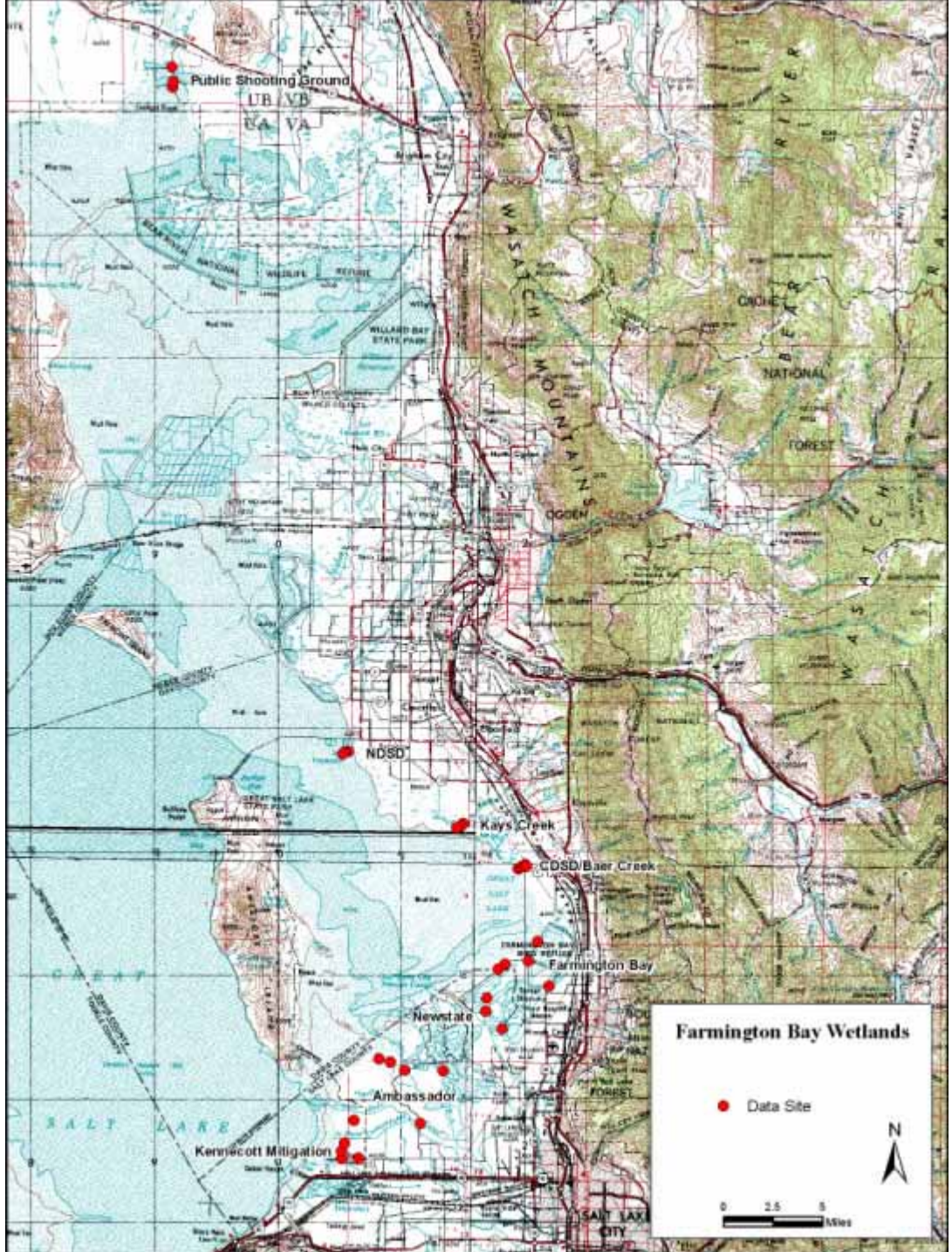
DEVELOP APPROPRIATE METHODOLOGY FOR ASSESSMENT AND SITE-SPECIFIC CRITERIA

- **UNDERSTAND "HOW THE ECOSYSTEM WORKS"**
- **IDENTIFY SENSITIVE HABITAT, SEASON AND FOODCHAIN LINKS (LITERATURE REVIEW)**
- **IDENTIFY (TOLERANCE) THRESHOLDS (IF THEY EXIST)**

Farmington Bay Study Chronology

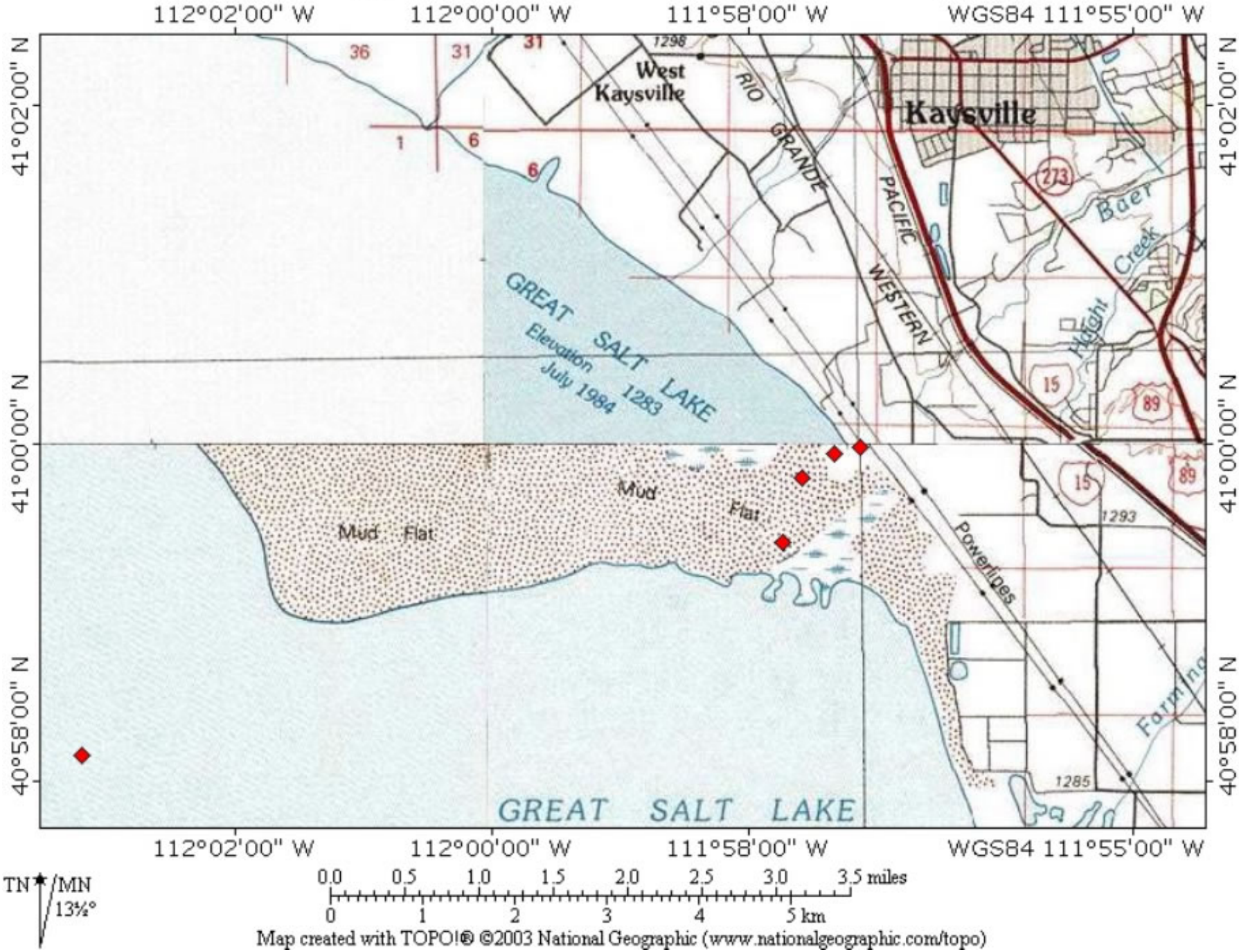
- 2002 ……303(d) List Released
  - Public Comments Question Absence of GSL/FB Asmnt
  - Division Applies for EPA Grants
- Jan. 2003 …….FB Tech. Advisory Committee Formed
  - March ……First Work Plan in Place
- Oct. 2003…….. $70,000 EPA Grant Awarded
  - ONLY WETLANDS ARE FUNDED
    $200,000 from CDSD Loan Adjustment
- Apr. 2004 ……RFP is Released
- Apr. Sole Source Contract to Frontier Corp.
- Sole Source Contract to Dr. Wurtsbaugh at USU
- May CH2MHill and SWCA Selected – Share Tasks
- Aug. Contracts Signed for First Year
- Sole Source Contract to Dr. Rushforth at UVSC
  Sole Source Contract to Dr. Gray at UVSC
- Nov. Field Work Completed
- March 2005 Most Sample Analysis Complete


GSL STEERING COMMITTEE
Se SAP
FB Technical Advisory Committee
Project MNGR
Bill Moellmer
Project Manager
Theron Miller
CH2MHILL
SWCA
Frontier Corp.
W. Wurtsbaugh
S. Rushforth
D. Naftz
L. Gray
G. Belovsky
USU Soils Lab
D. Hayes


Farmington Bay Wetlands
Data Site
N
0 2.5 5 Miles
Public Shooting Ground
UB VB
UA VA
WASATCH MOUNTAINS
WILLARD BAY STATE PARK
OGDEN
NDSD
Kays Creek
CDSD/Baer Creek
Farmington Bay
Newstate
Ambassador
Kennecott Mitigation
SALT LAKE
SALT LAKE CITY

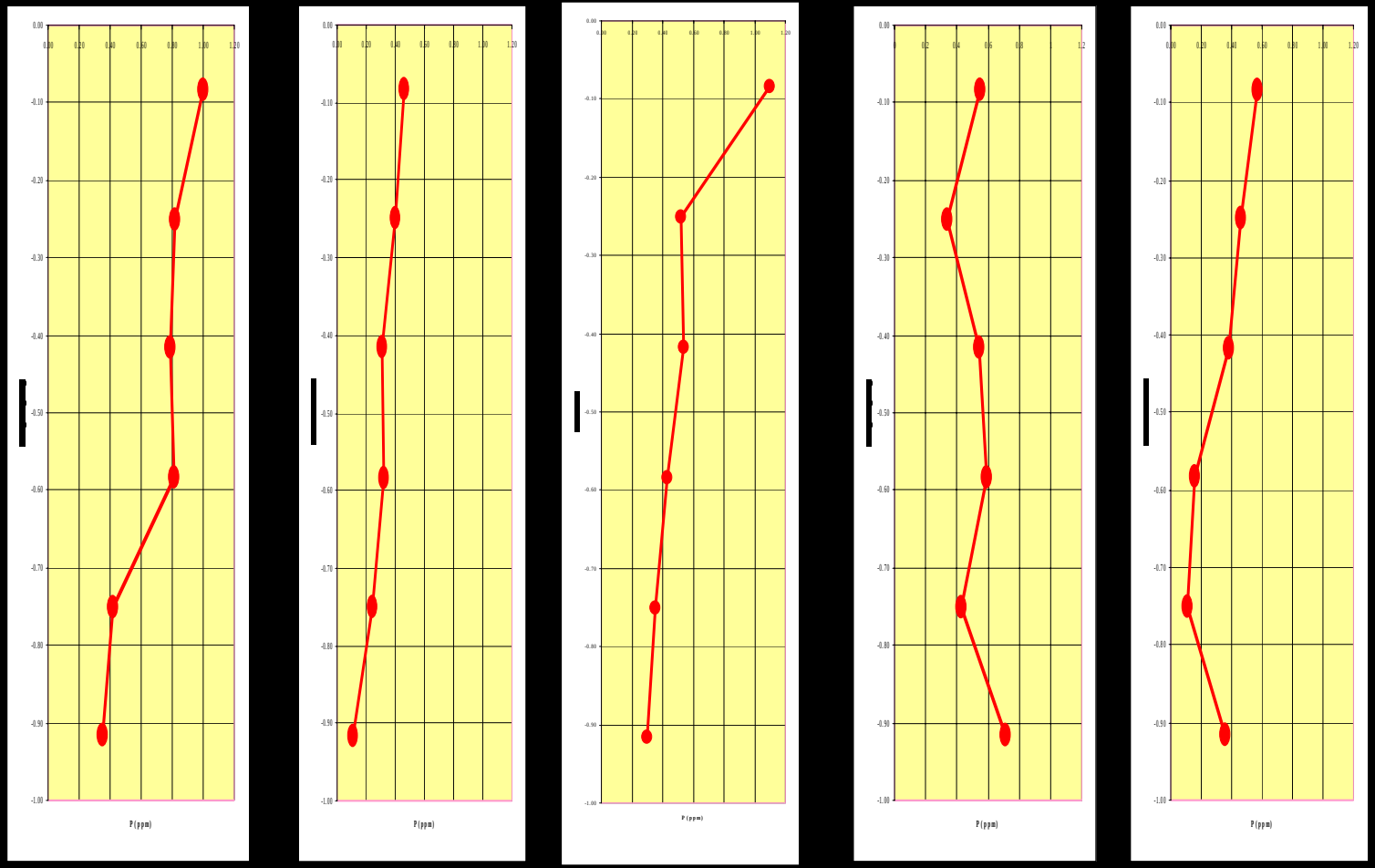
Sediment Sampling Locations

TOPO! map printed on 03/17/05 from "Great Salt Lake Study.tpo"



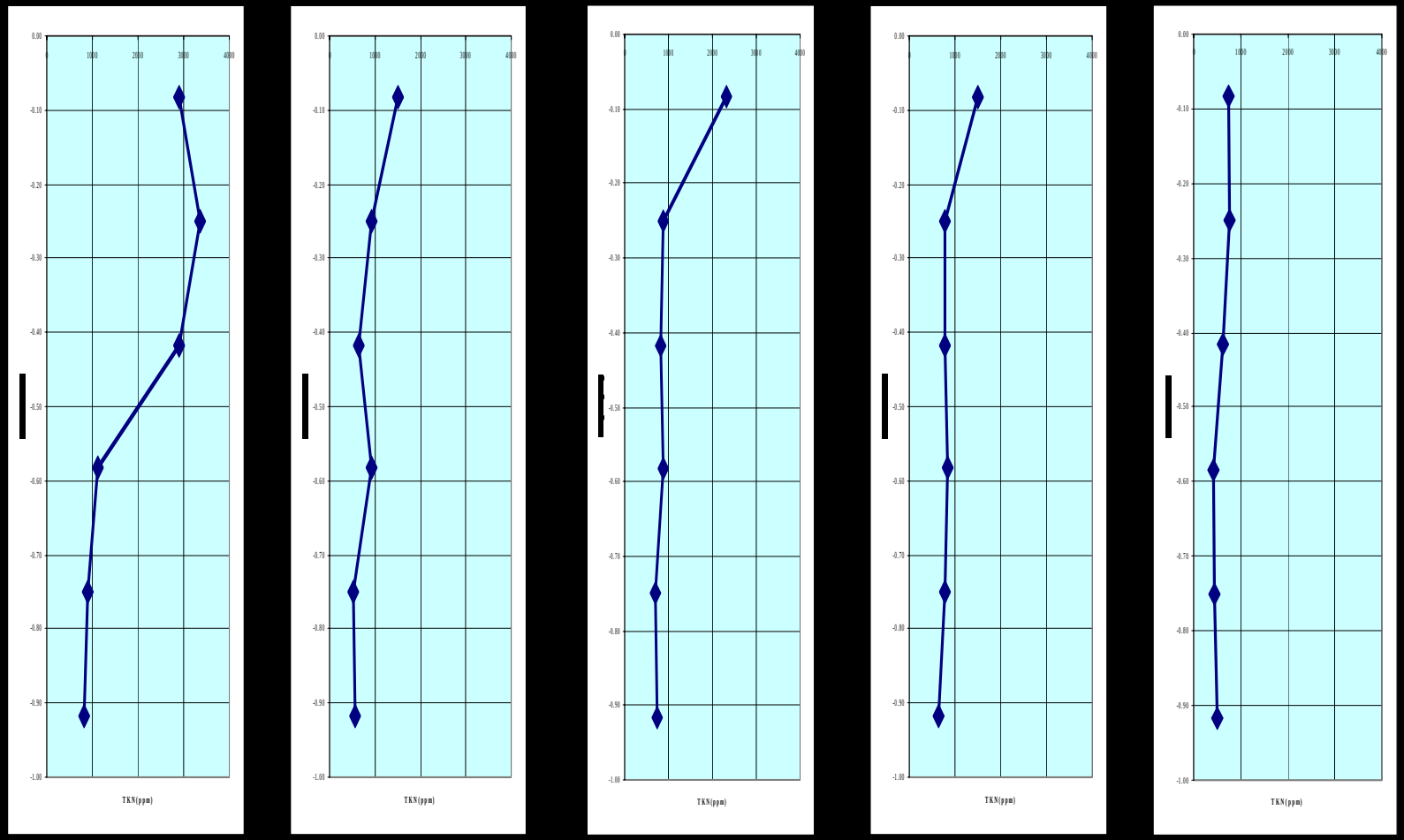
Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)

Sediment Selenium Concentrations



X-Axis All Samples 0 ppm to 1. 2 ppm

Sediment TKN Concentrations



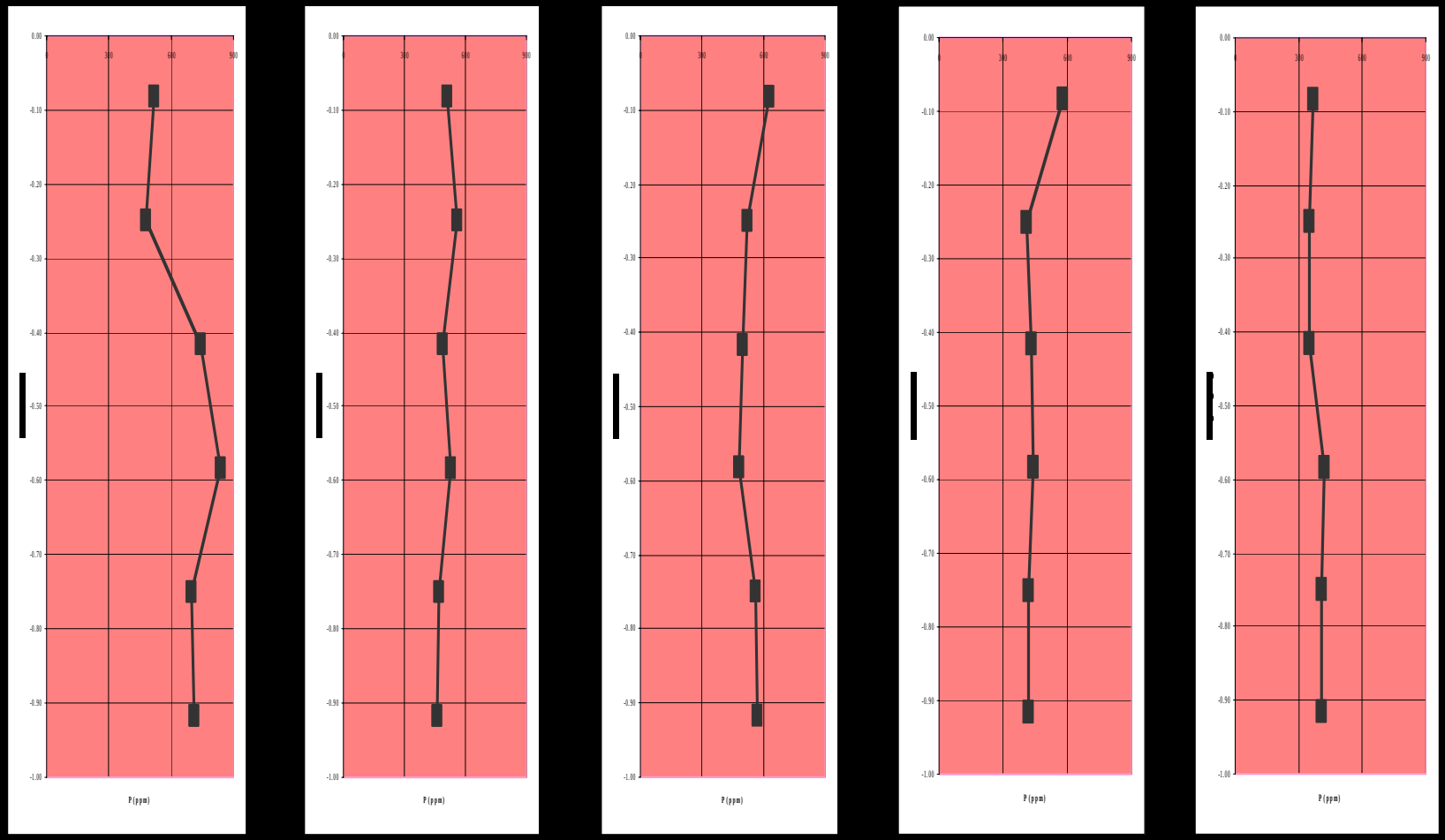
Surface Elev

1-Ft Deep

X-Axis All Samples 0 ppm to 4,000 ppm

Sediment Total P Concentrations

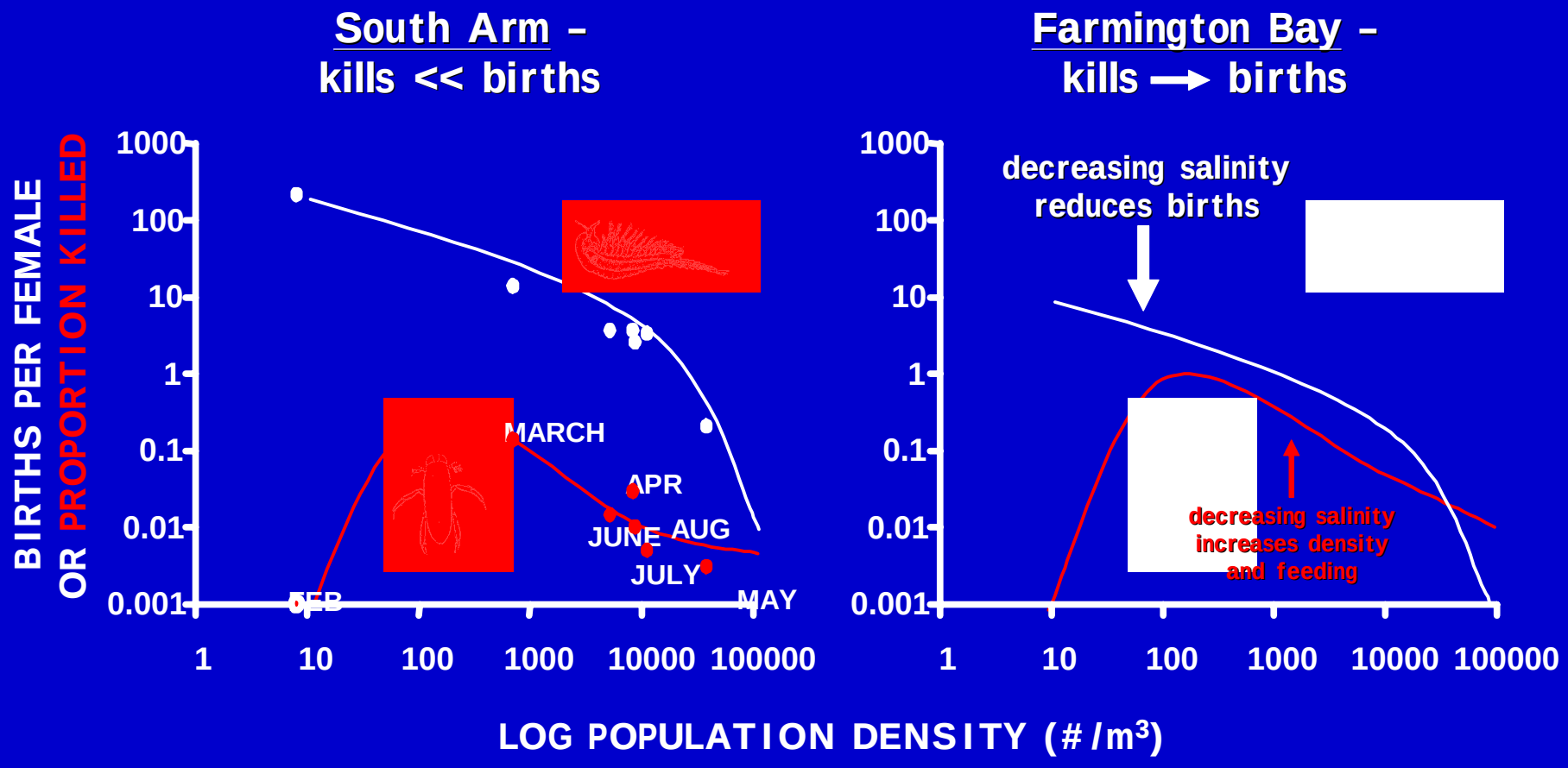
Surface Elev.



1-Ft Deep

X-Axis All Samples 0 ppm to 900 ppm

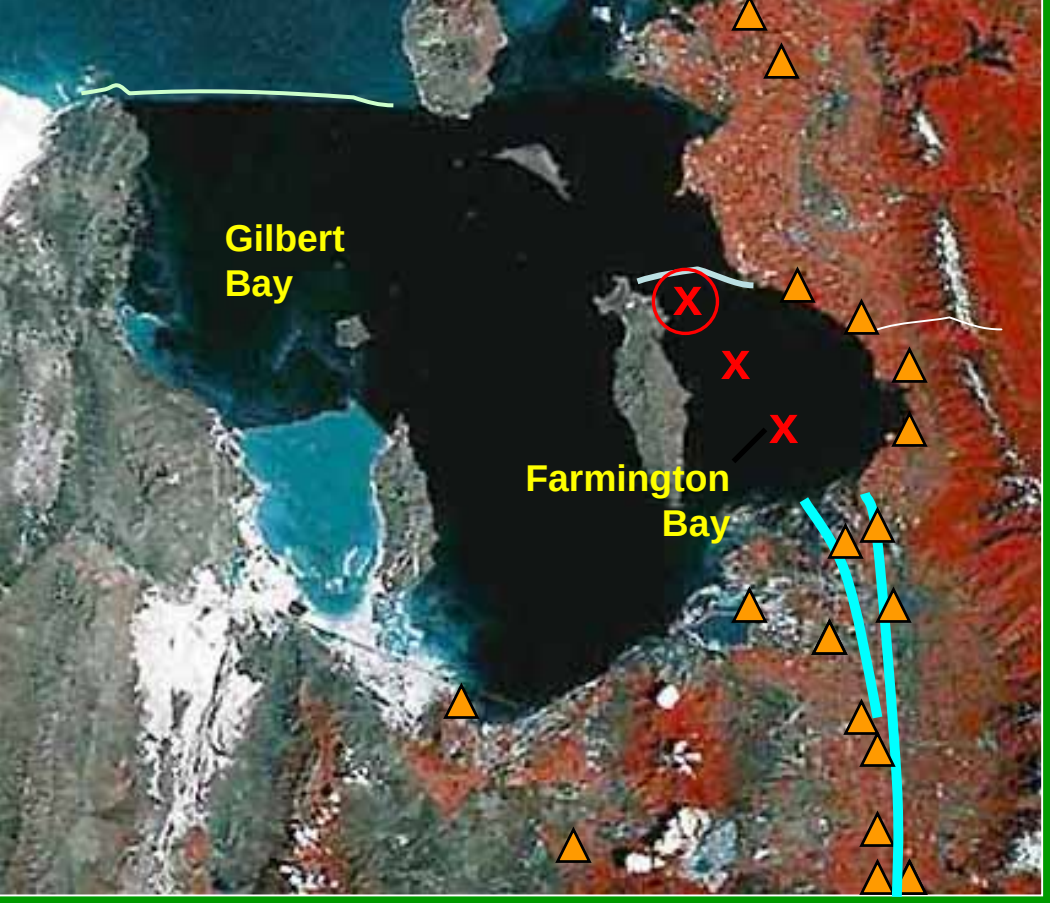
FOR A POPULATION TO BE LIMITED BY PREDATION ONE EXPECTS BIRTH AND PREDATION RATES TO APPROACH EACH OTHER



Beneficial Use Issues in Farmington Bay

Wayne Wurtsbaugh
Amy Marcarelli
Utah State University

Farmington Bay Technical Committee
March 22, 2005

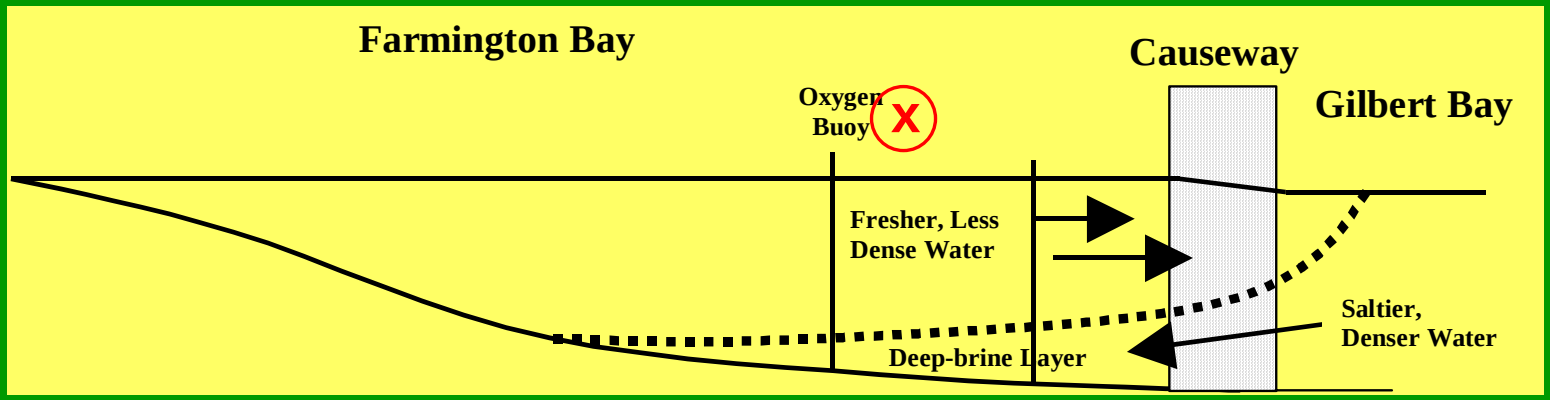


Farmington Bay

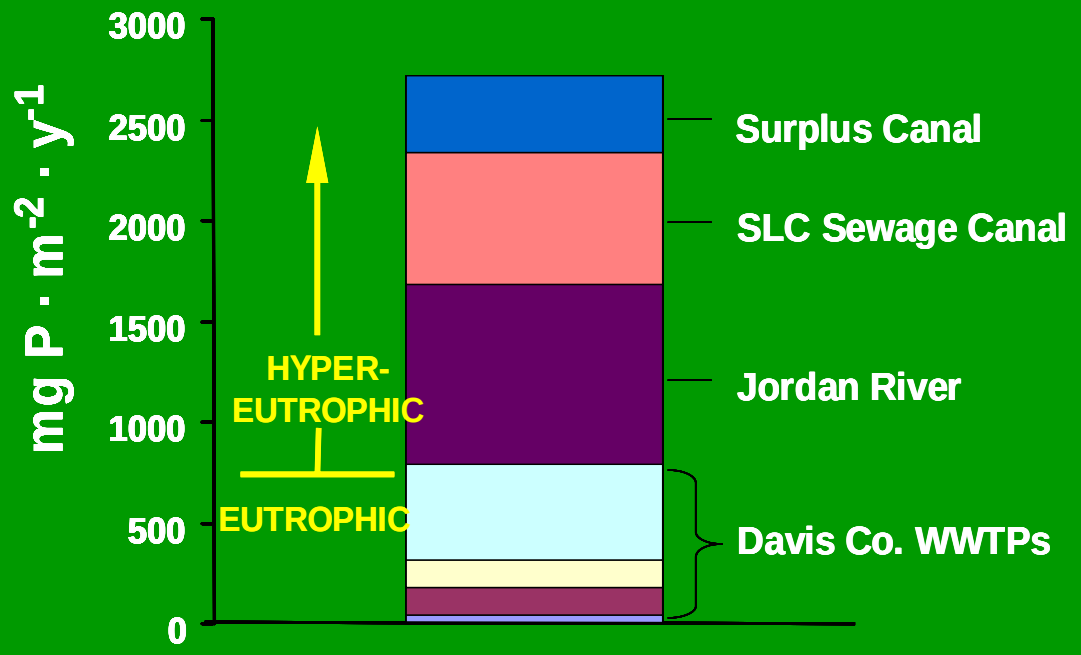
- Area: 228 km^2
- Mean depth: 0.9 m
- Salinity: 0.5 - 9%

Waste Water Treatment

X Sampling stations

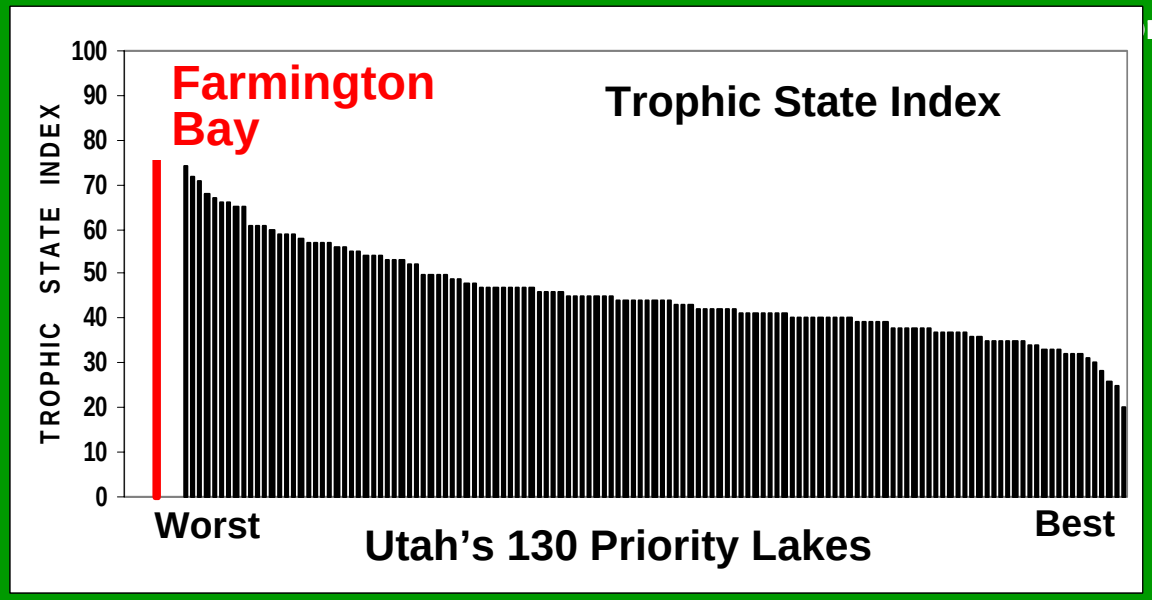


Very High Nutrient Loading and Eutrophication



• Source: D. Gross in Wurtsbaugh et al. 2002

r 1999 & 2000: Storet database



Beneficial use issues

- Aquatic Wildlife
  - Brine shrimp
  - Brine flies
  - Birds

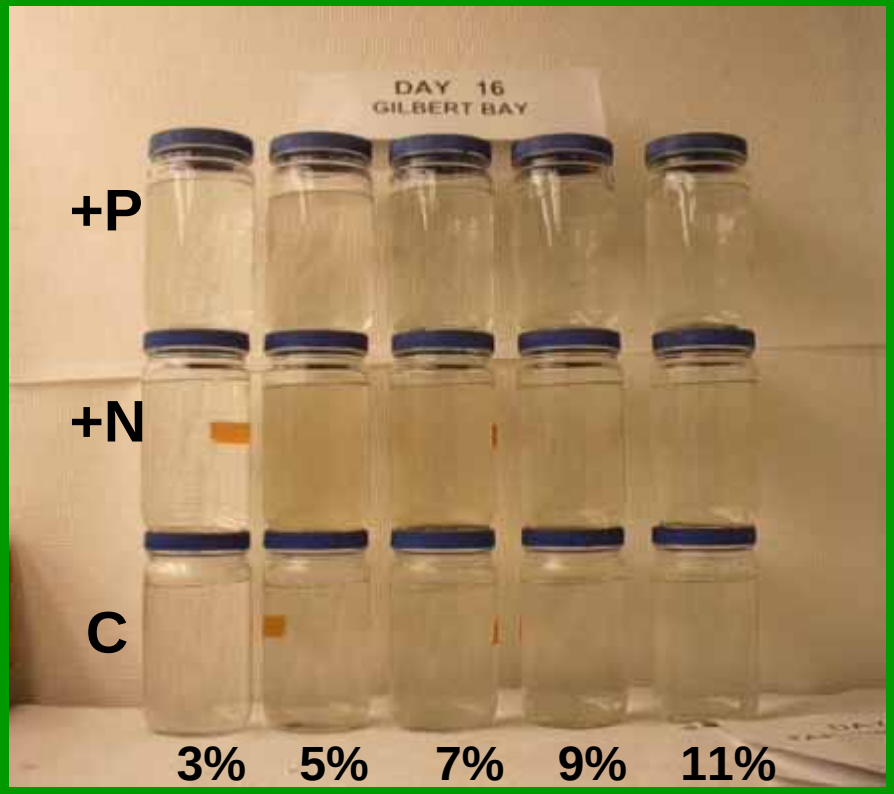
- Recreational use
  - Odors
  - Contact recreation

What limits phytoplankton?

- Light (Median Secchi transparency - 0.3 m)
- Zooplankton grazing (usually low)
- Nitrogen or Phosphorus

Factorial Bioassays: Salinity x Nutrient

FB, Gilbert Bays
5 Salinities x 3 treatments
3 replicates each = 90

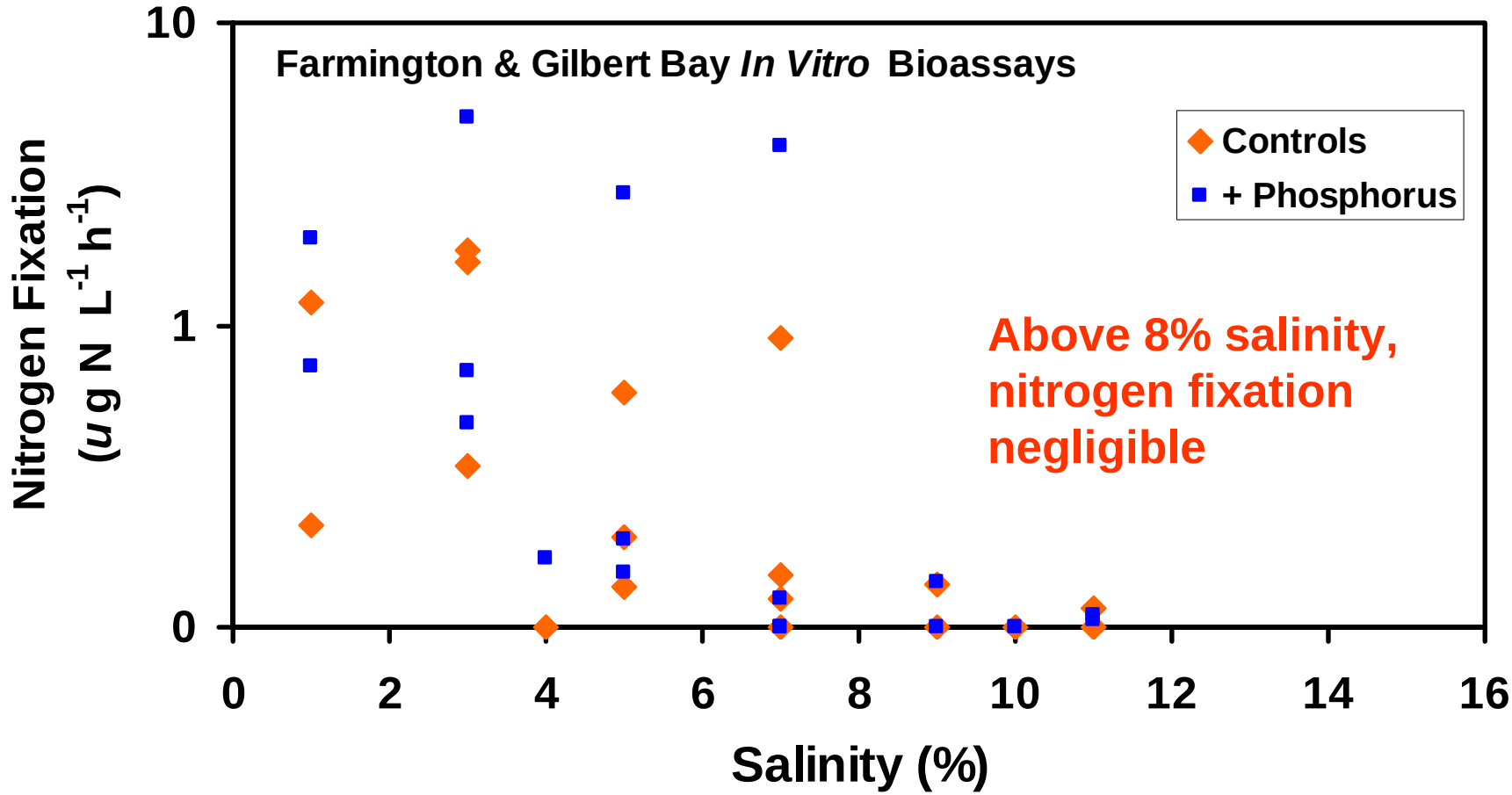


Nutrient Treatment

Salinity

< 7% salinity	**P Limitation**
> 7% salinity	**N Limitation**

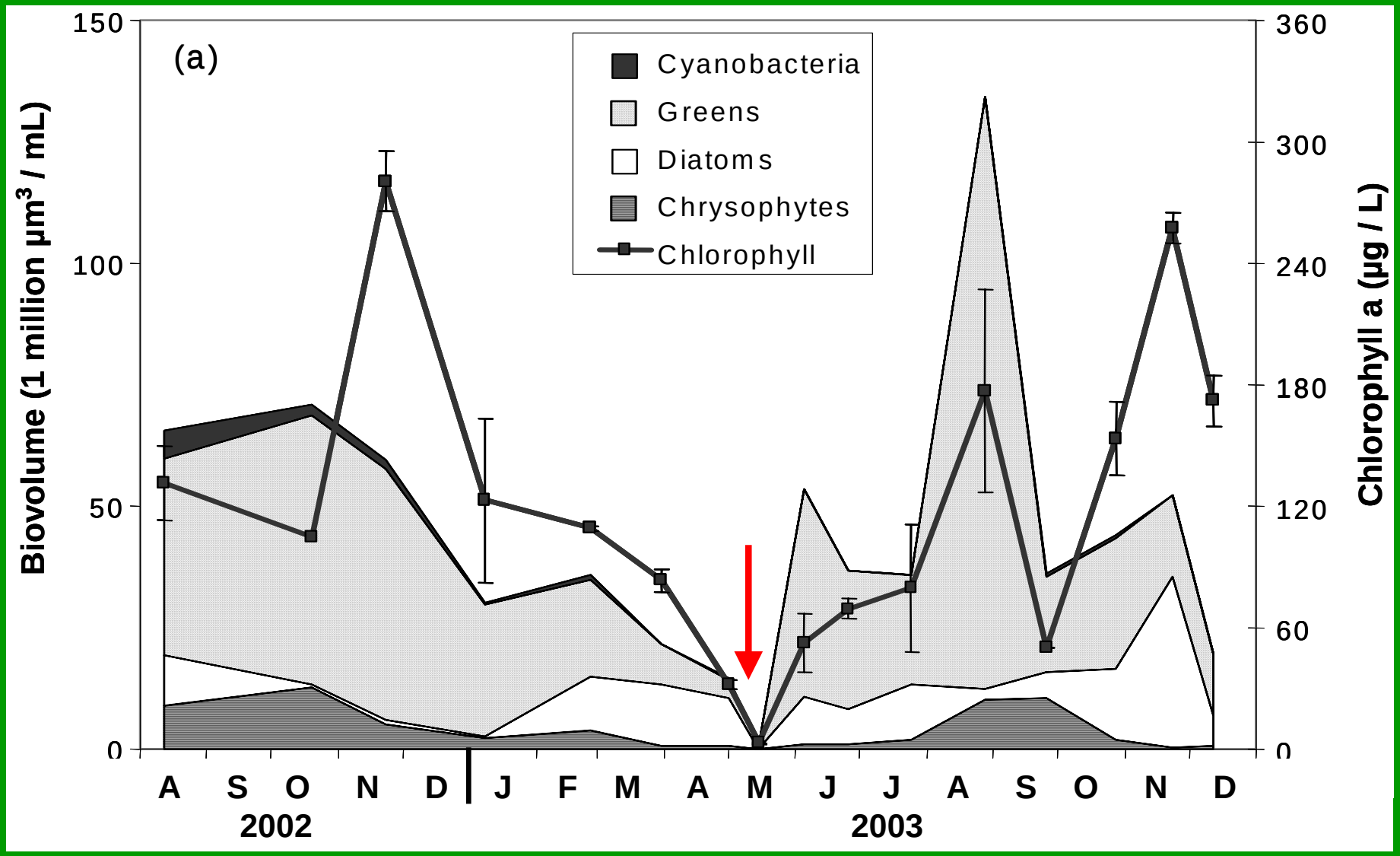
1. High Salinity Levels Control Nitrogen Fixation



Adapted from Wurtsbaugh & Marcarelli (2004)

Plankton Monitoring
17 mo (2002-2003)*

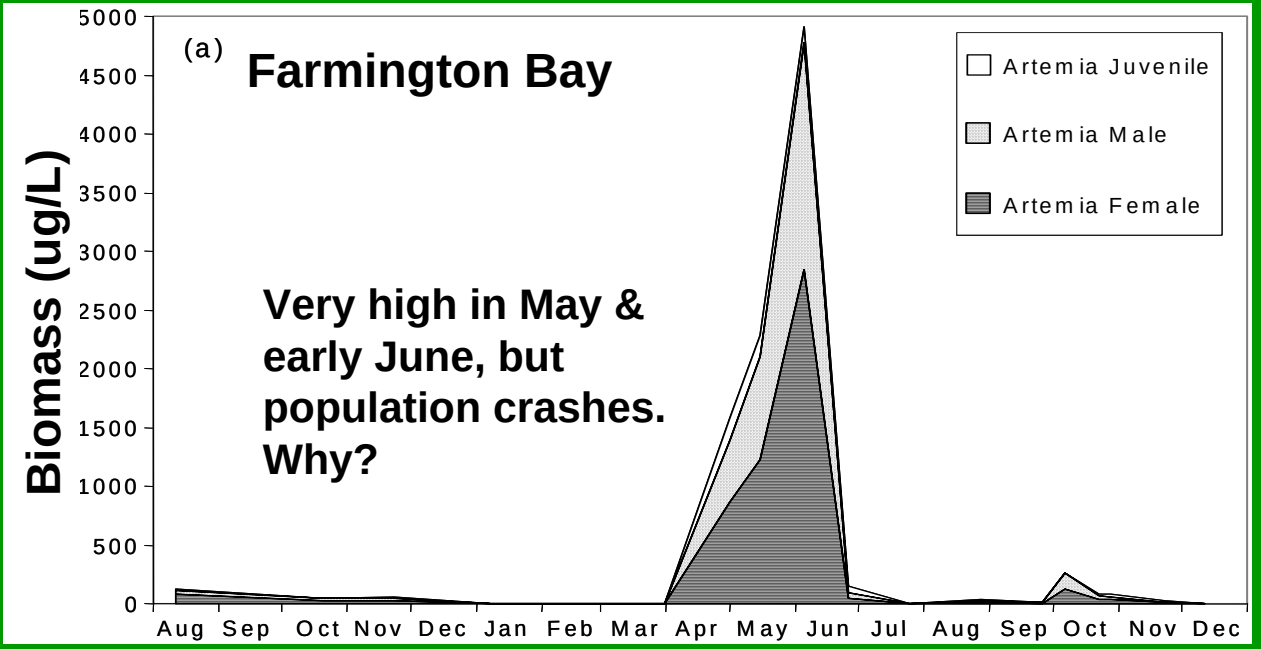
Phytoplankton

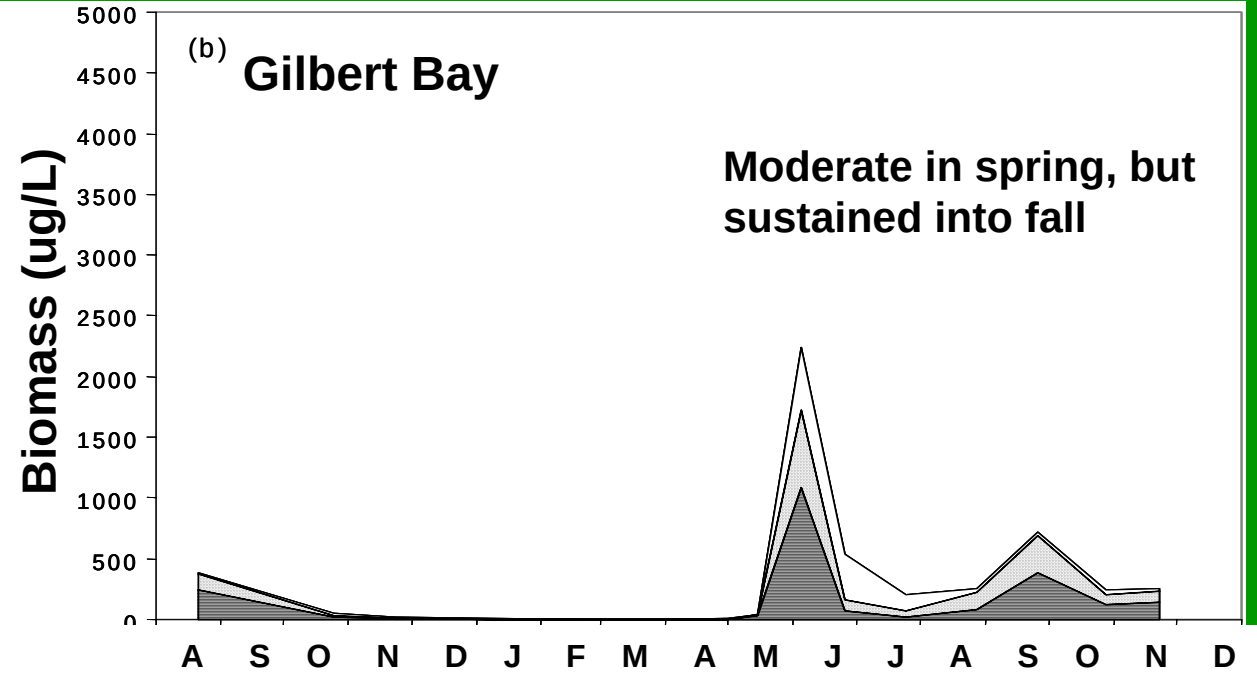


*Funded by USU & Central Davis Sewer Improvement District

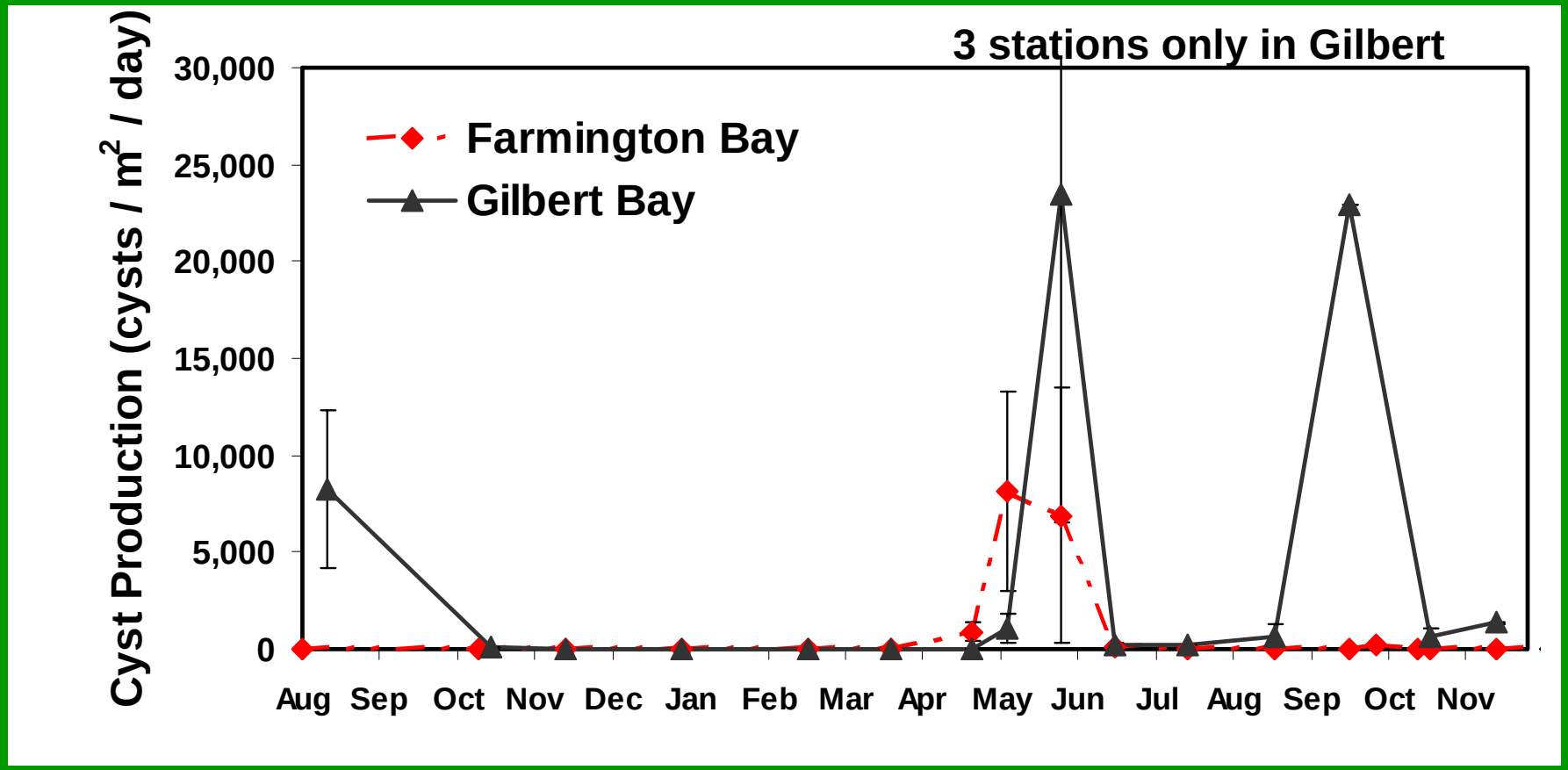
Brine Shrimp

Plankton Monitoring 17 mo (2002-2003)*





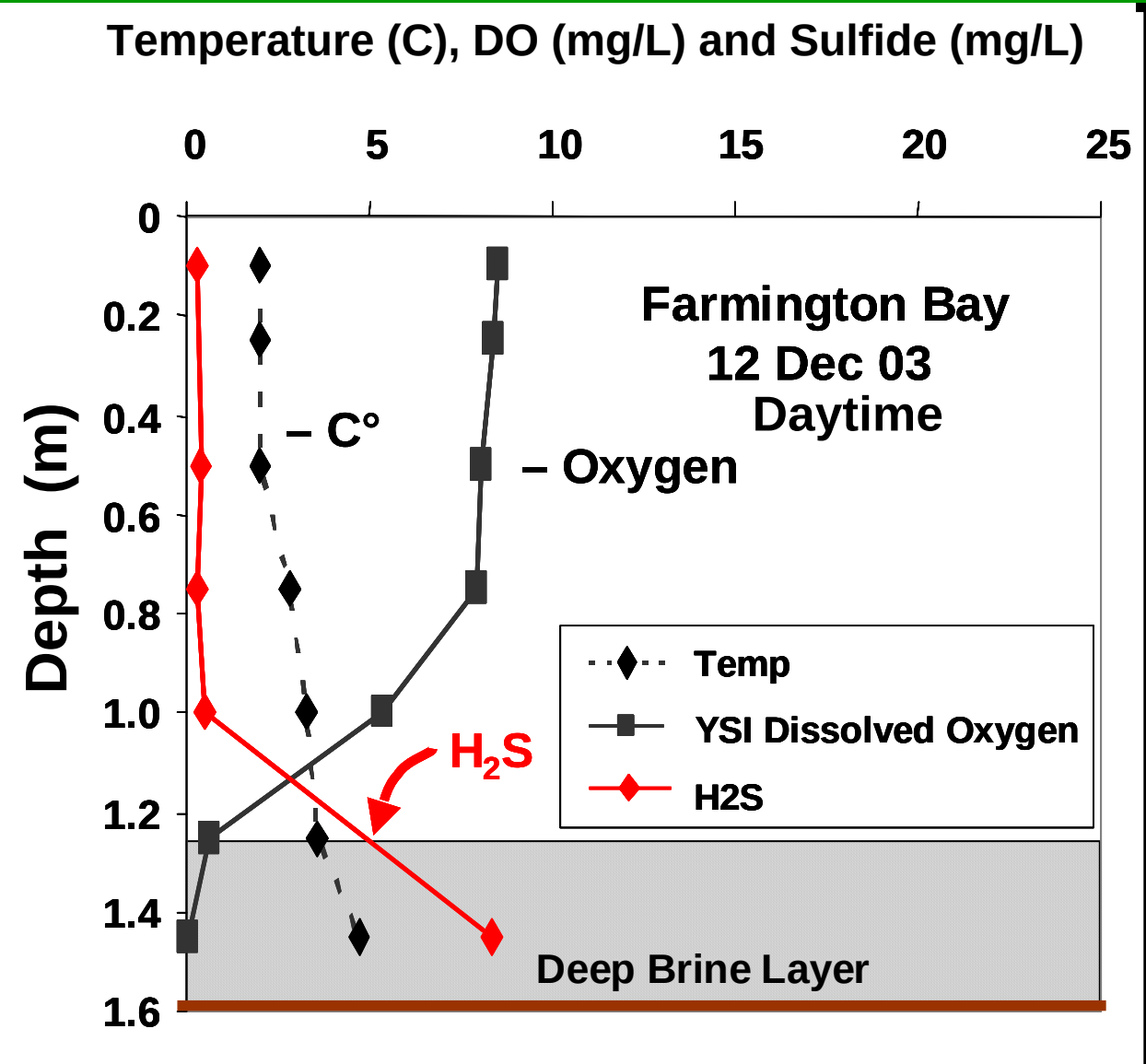
Brine Shrimp
Cyst Production



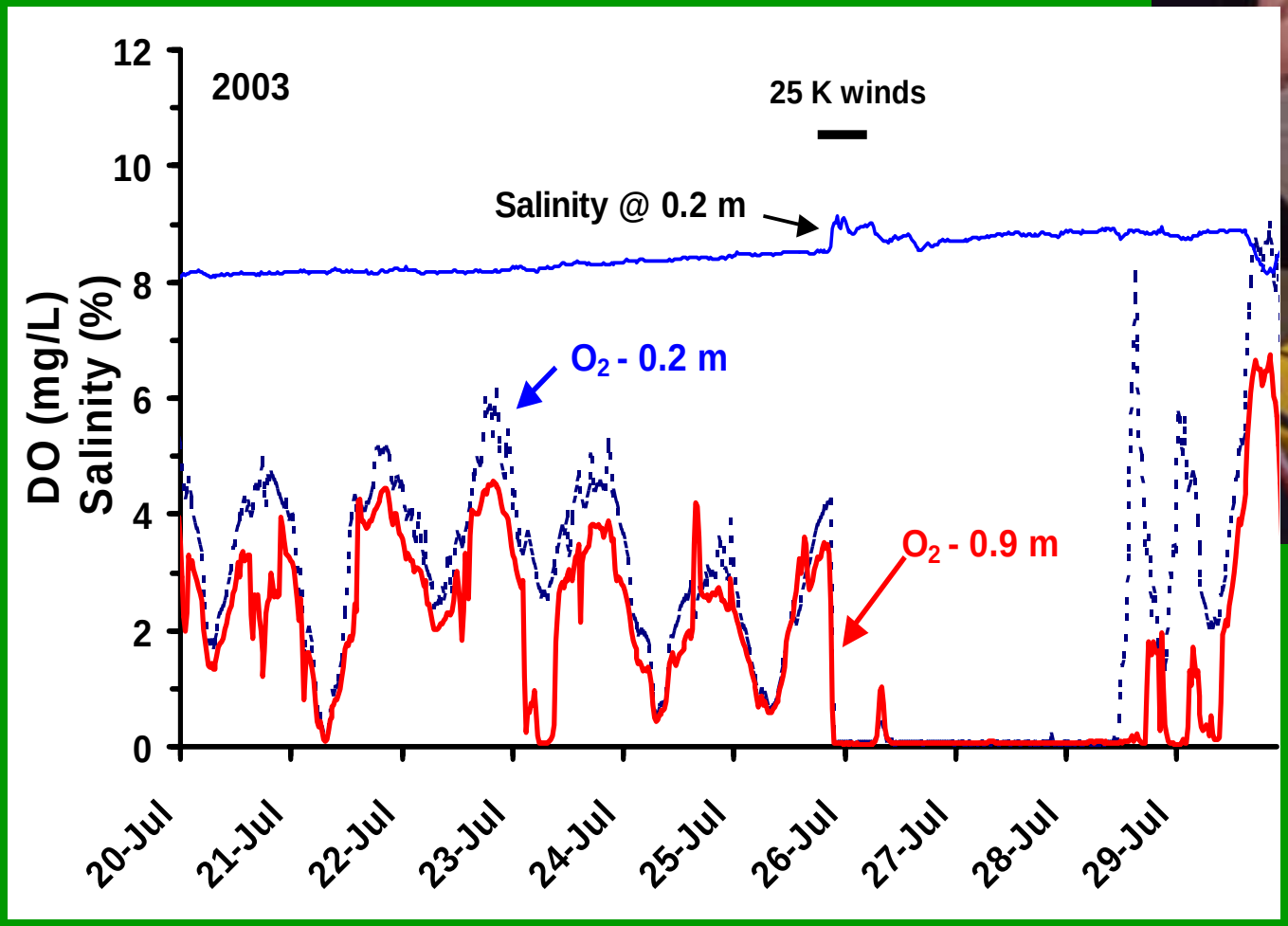
*Wurtsbaugh, W.A. and A. M. Marcarelli. 2003. Phytoplankton and zooplankton in Farmington Bay and the Great Salt Lake, Utah. Report to the Central Davis Sewer Improvement District, Kaysville, Utah. 57 p.

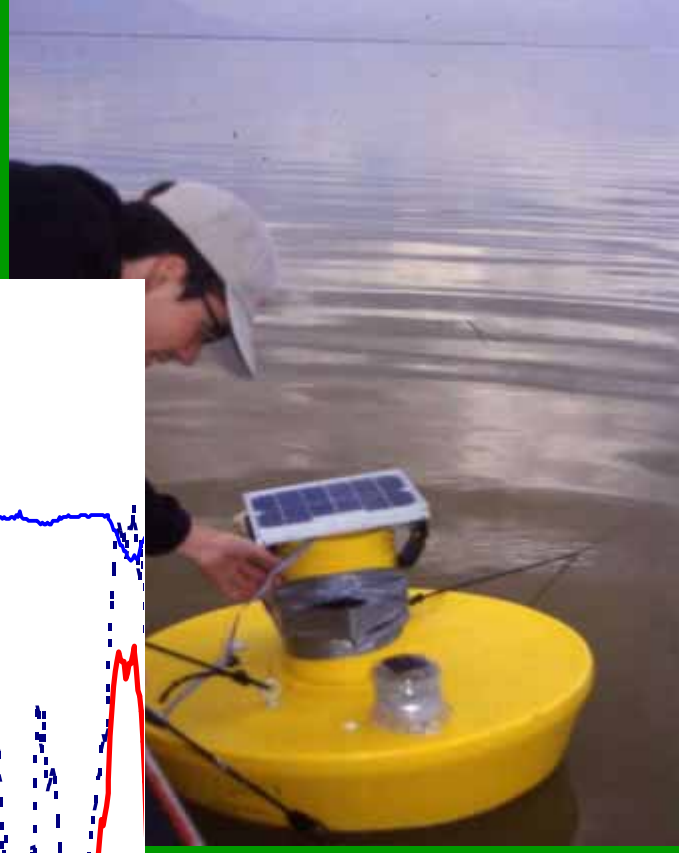
Water Quality

Oxygen and H_2S Conditions



Wind-Induced Anoxia*





Deployed Buoy FB

- O_2 sensors 0.2 & 0.9 m
- Conductivity
- 15-min interv.

$$H_2S + 2\,O_2 \rightarrow SO_4^{=}$$

*Funded by USU CURI Grant

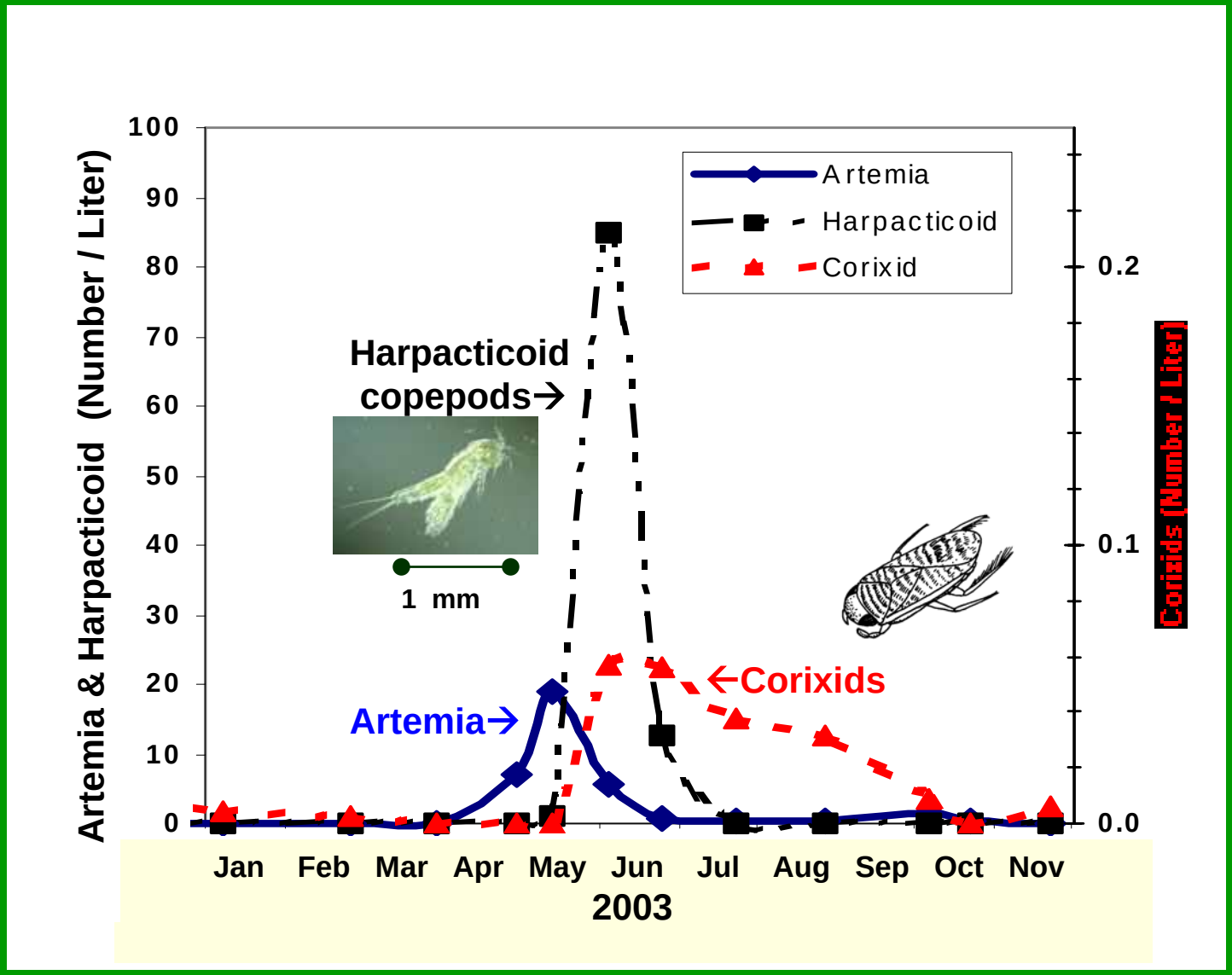
Wind-Induced Anoxia

- **Not an isolated event**
  Other Occurrences Encountered during field sampling
  4-5 Oct 2001 (or longer)
  18 Oct 2004 (or longer)

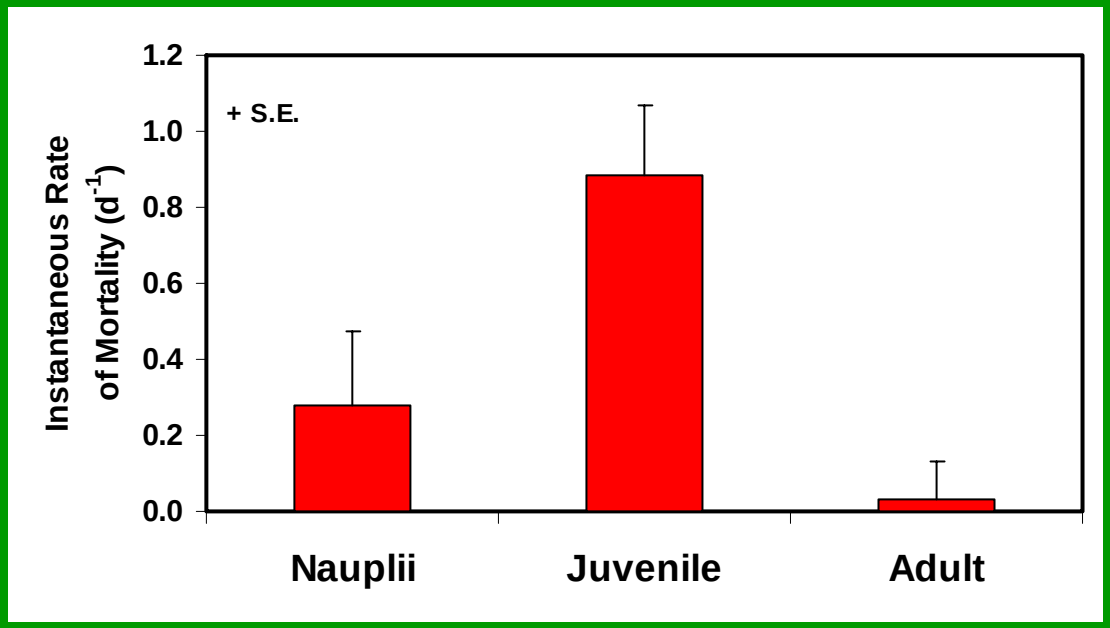
- **We don't know**
  - **Frequency of anoxic / H_2S events**
  - **Spatial extent (to date, all measurements at north end of bay)**

- **Diel anoxia and wind-induced anoxia (& likely H_2S exposure) indicate harsh conditions for biota**

Another hypothesis for the decline of brine shrimp:
Invertebrate Predation



Lab Experiments: Corixid Predation on Brine Shrimp*



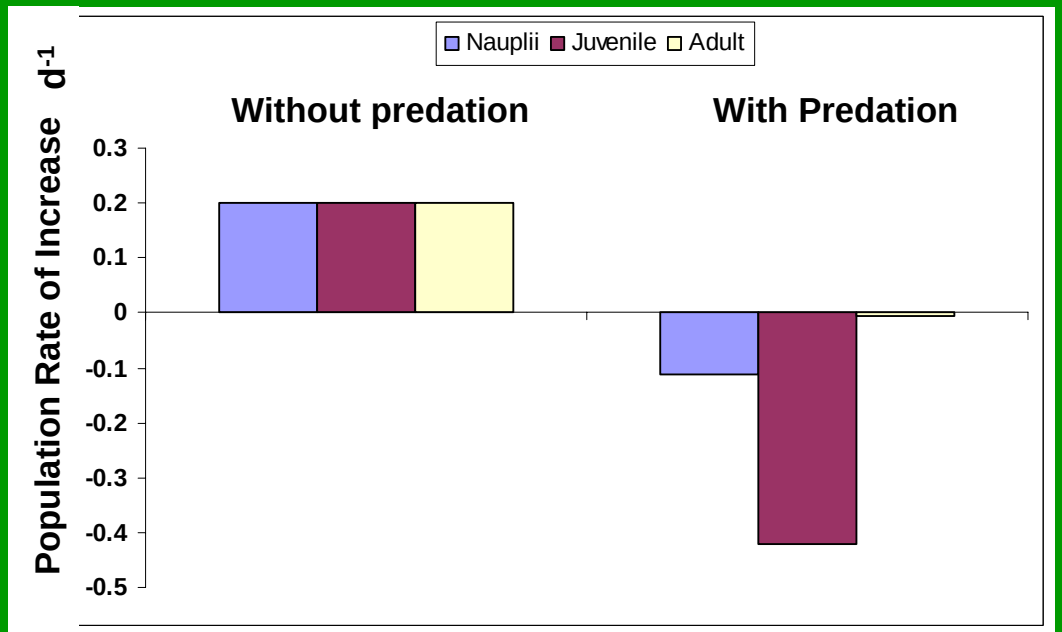
*M. Hadley in Marcarelli et al. 2003

Simple population model:

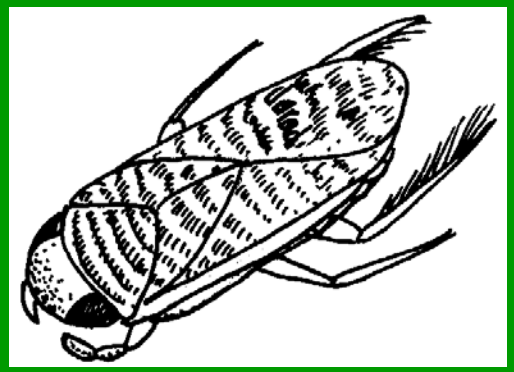
- Ambient corixid density (0.05 L^{-1})
- Published Artemia pop. growth rate

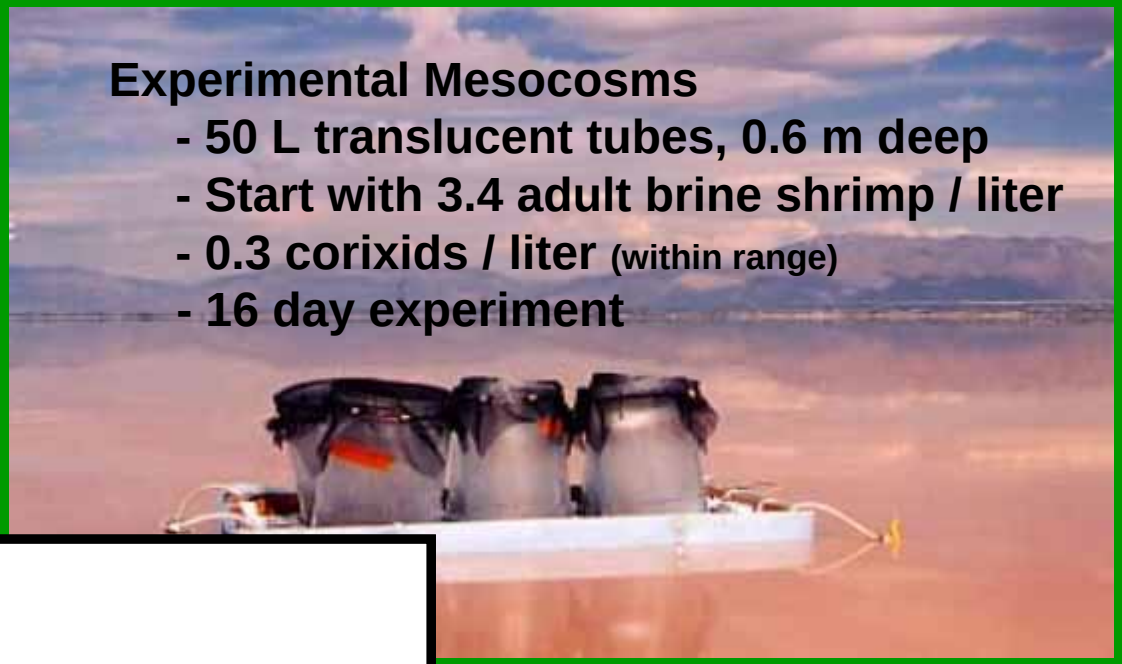
Limitations of lab experiments and models:

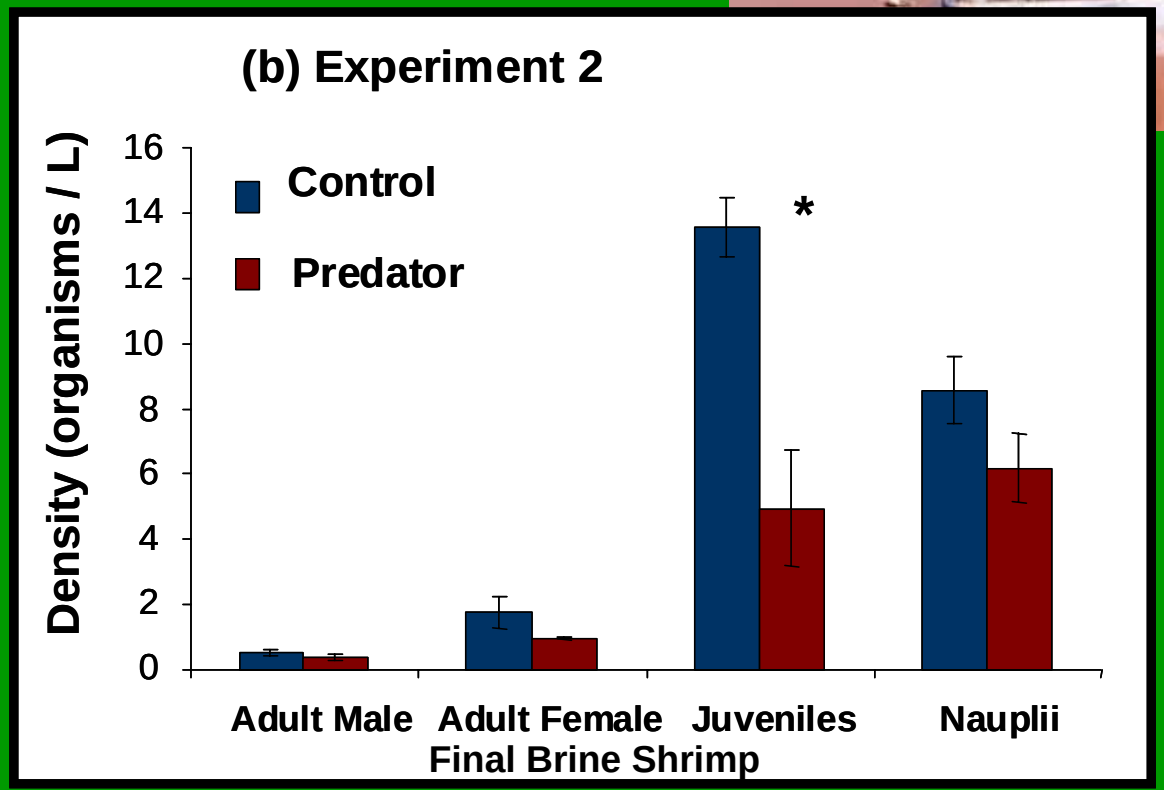
- Do not incorporate alternative prey
- Do not incorporate light intensities & turbidity
- Difficult to mimic free-swimming environment
- Other environmental factors



Field Experiments of Corixid predation on *Artemia*







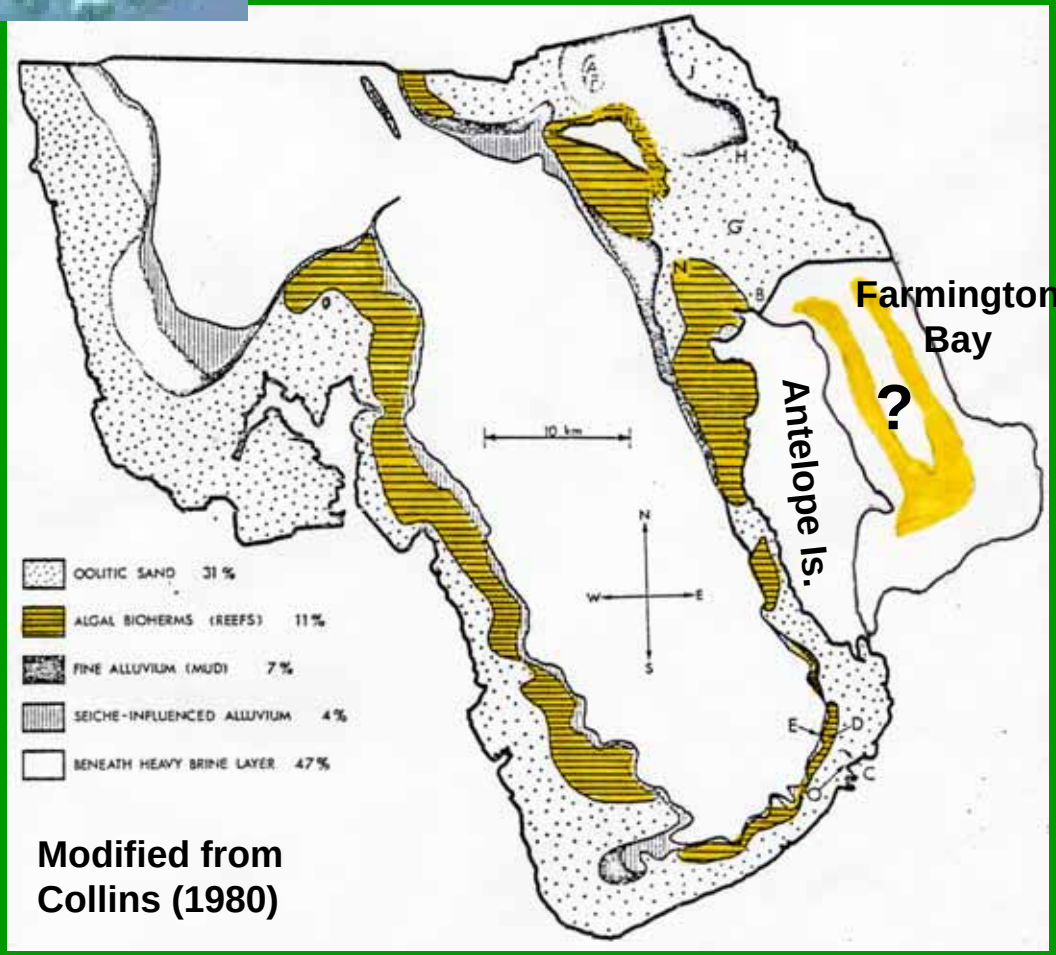
- Significant ($p < 0.05$) predation effects, but less impact than in lab

Stromatolites

Marine stromatolites

Benthic Habitats (lakes do have bottoms)

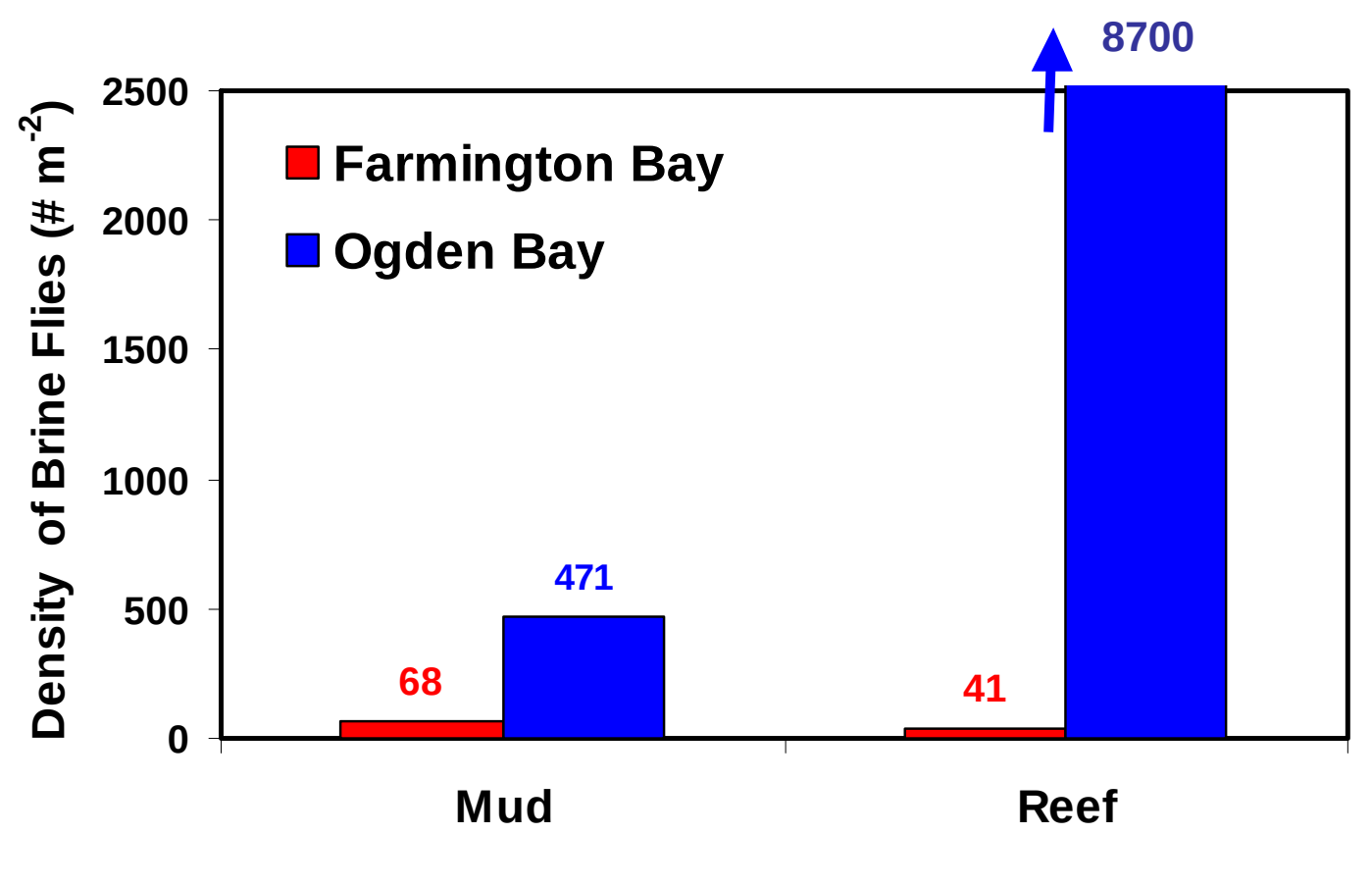
Distribution



Modified from Collins (1980)

Food Web Importance: Principal Brine Fly Habitat

Brine fly densities in Farmington Bay <u>may</u> be low*



<u>Very limited survey</u>, but low light would likely limit periphyton growth

***Te-hui Ting *in* Marcarelli et al. 2002**

Future Research

- **Monitoring (*several years needed in highly temporally and spatially variable system*)**
  - **Plankton**
  - **Brine flies**
  - **Oxygen & H_2S**
  - **Chemistry**

- ***In situ* bioassays of brine shrimp to test if poor water quality induces mortality**

- ***In situ* predation experiments to test importance of corixid and harpacticoid predators for brine shrimp and brine flies**

Conclusions

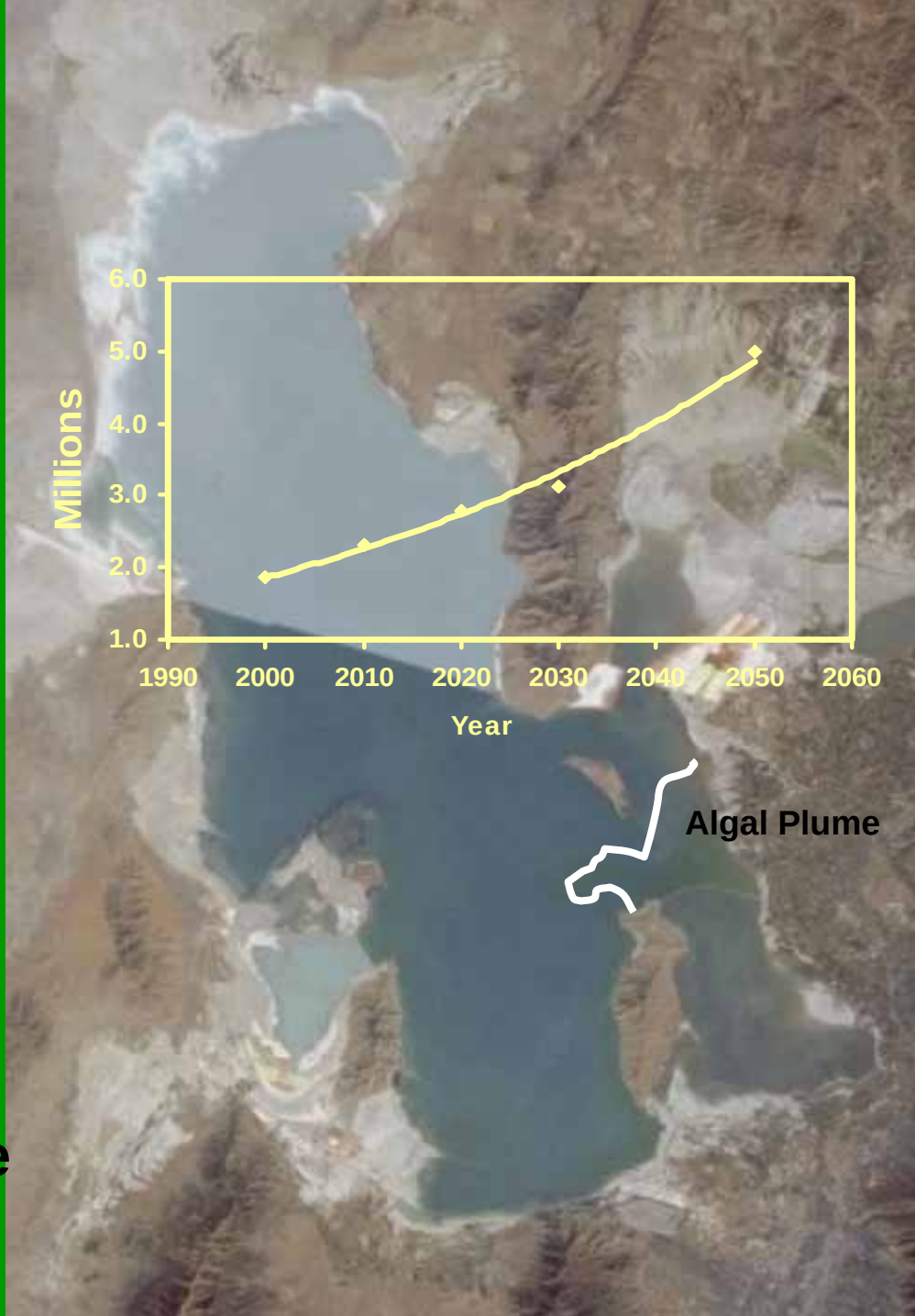
- Farmington Bay is highly eutrophic

- Are beneficial uses impacted? Unclear at this point

- Is the solution to pollution dilution?

- Eutrophication of FB likely influencing (+ -) Gilbert Bay as well

- How will a 250% increase in population influence the bay and Great Salt Lake?



Thanks

- **Funding**
  - Central Davis Sewer District
  - Utah State University
  - Aquatic, Watershed & Earth Resources Department
- **Scientific support**
  - Donovan Gross, Alan Ward, Kirsten Gallo
  - Maciej Gliwicz, Theron Miller
  - Many, many, graduate & undergraduate students

TOPICS

- Selenium loadings to Farmington Bay
- Infrastructure to measure chemical loadings from FB to main body GSL
- Nutrient loadings from FB to main body GSL
- Isotopic fingerprinting of FB outflow

SELENIUM LOADINGS

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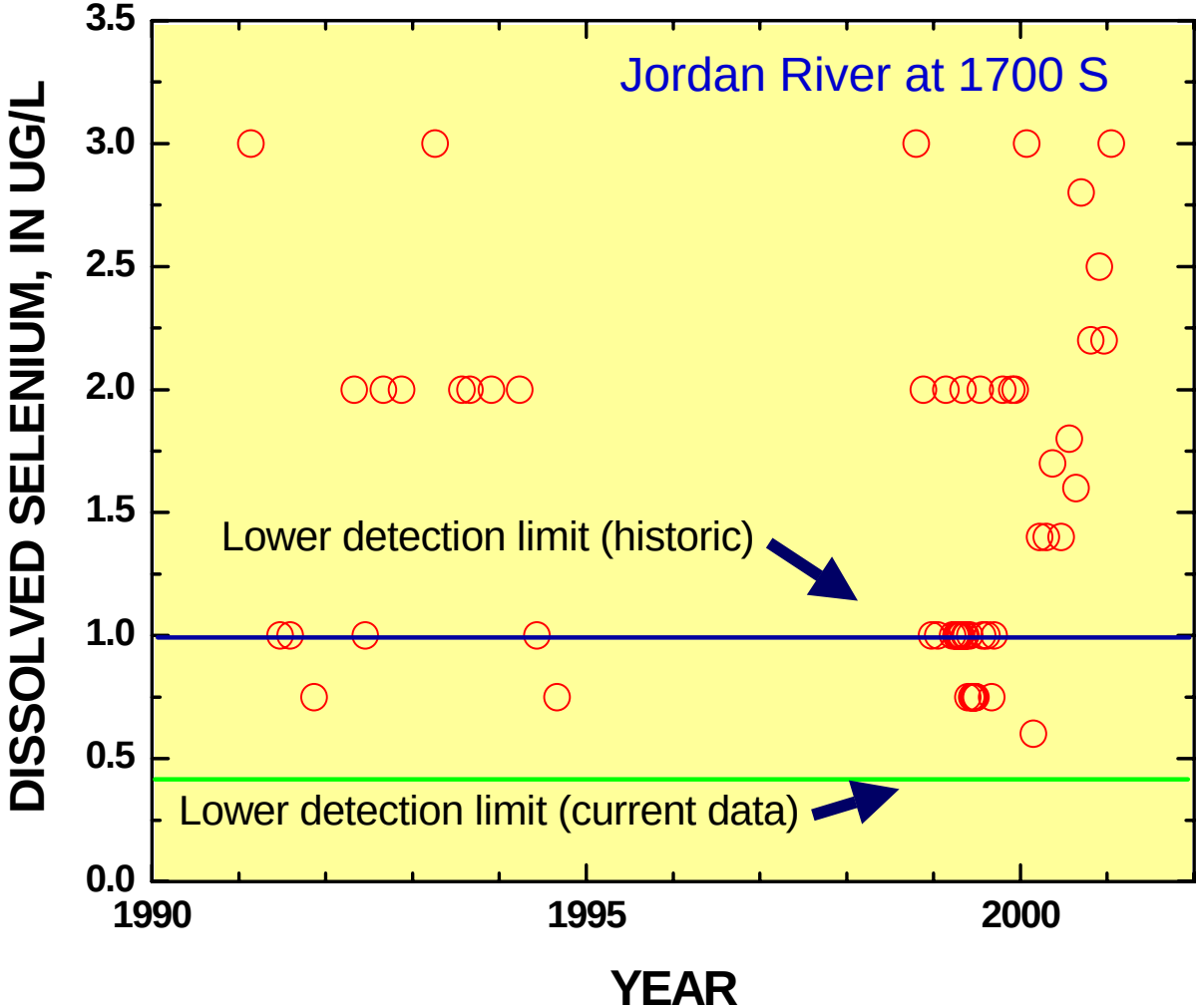
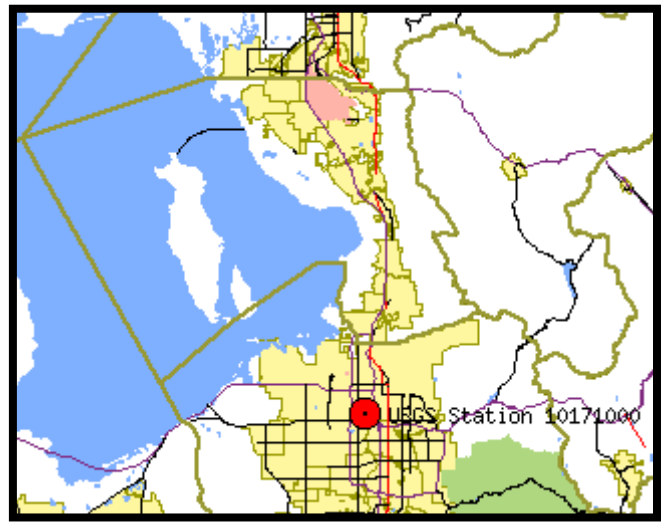
JORDAN RIVER SE INPUT

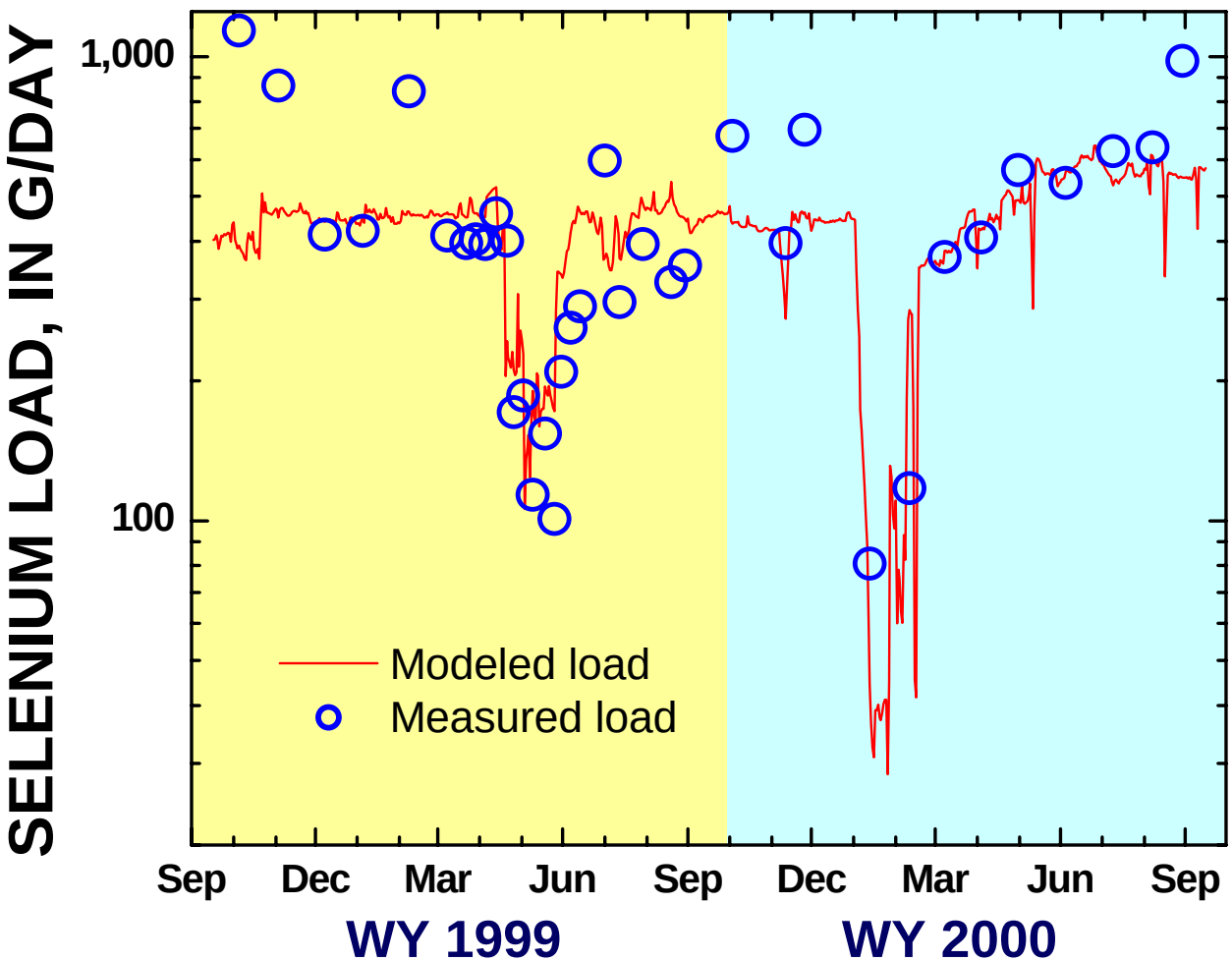
before wetland cycling





JORDAN R. MODELED LOADS

Ln(Se load) = 1.30 + 0.22(Date) + 0.92(Ln Q) $R^2 = 0.57$ $p < 0.0001$



Total load (kg)

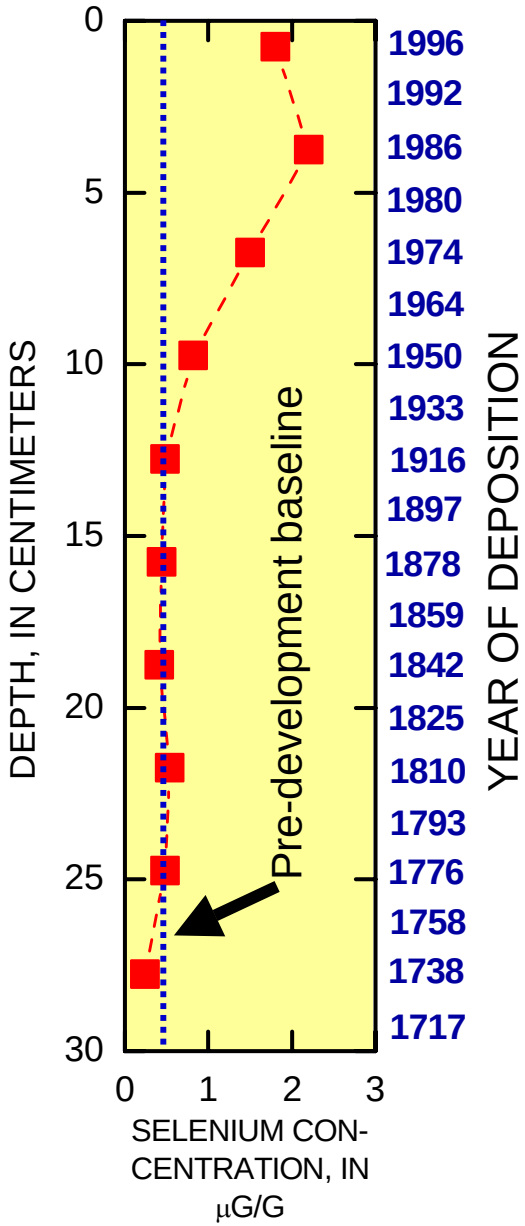
1999	2000
150	160

Avg. load (kg/d)

1999	2000
0.42	0.44

HISTORIC SE INPUT TO FARMINGTON BAY

Four- to five-fold increase in recent sediments



1998
sediment core

NEW GAGING NETWORK

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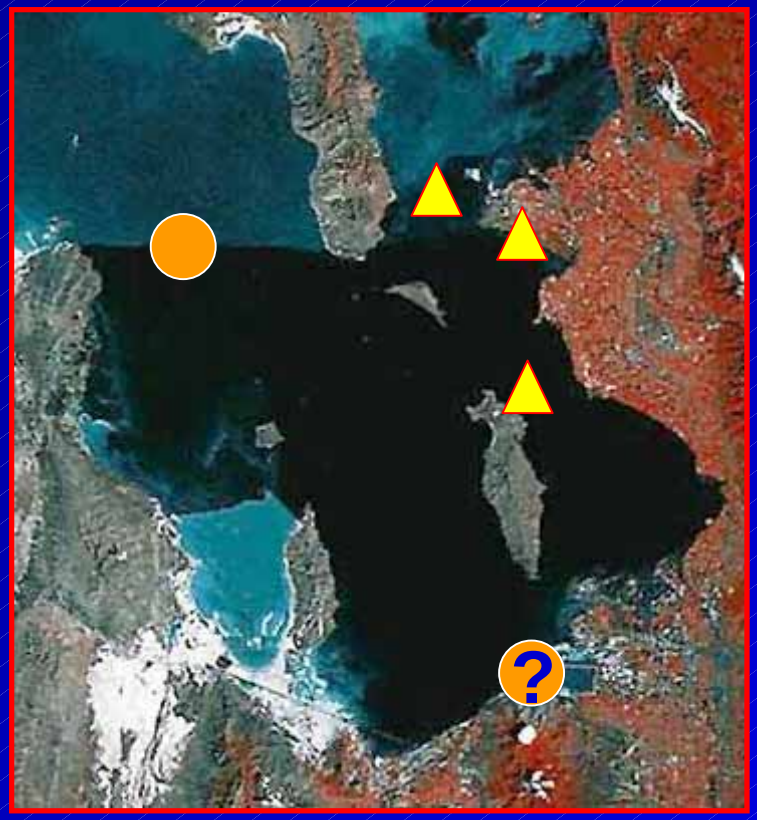
LOADINGS TO MAIN BODY GSL



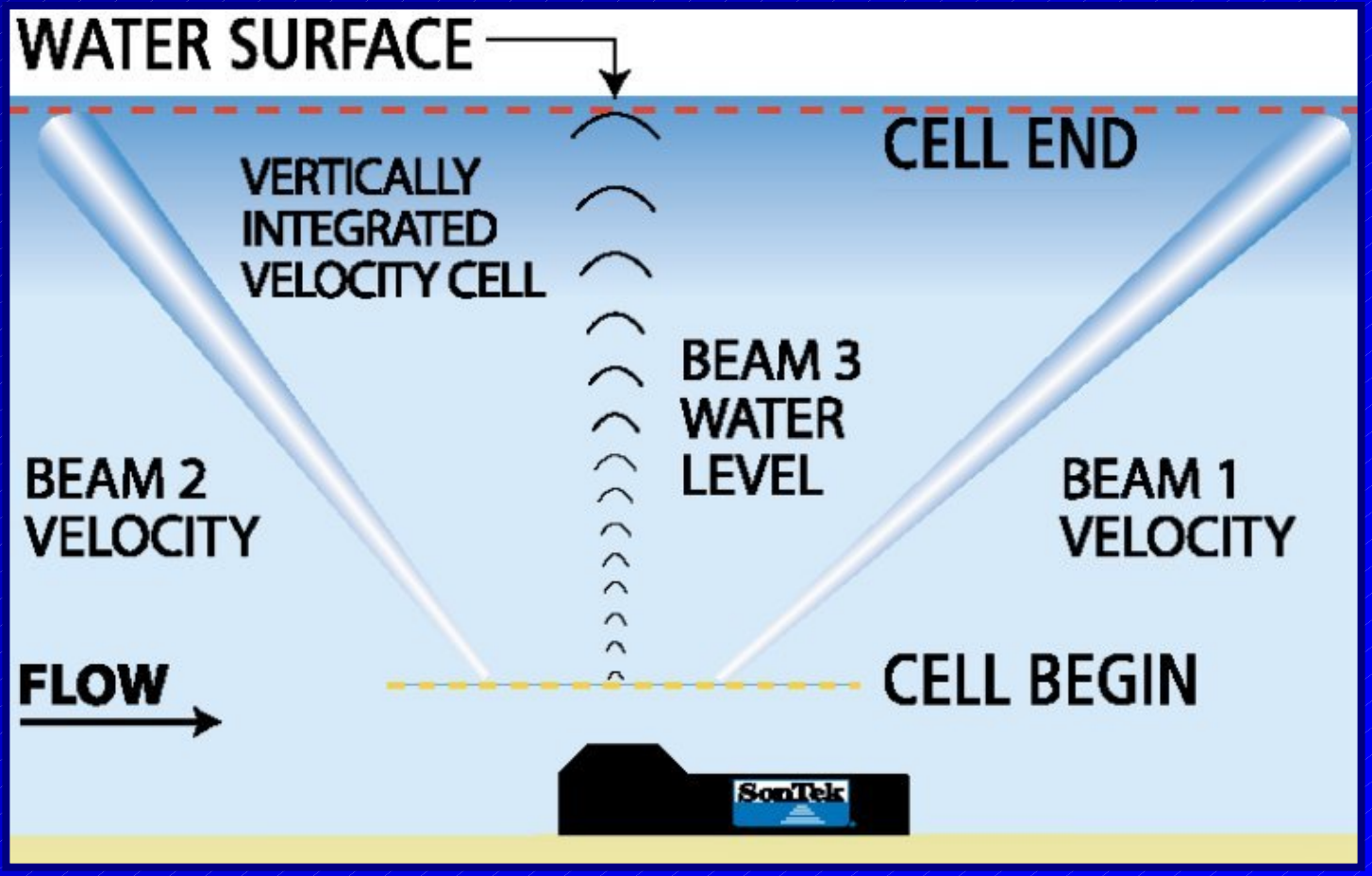
Existing acoustic gages

Needed acoustic gages

Why acoustics?

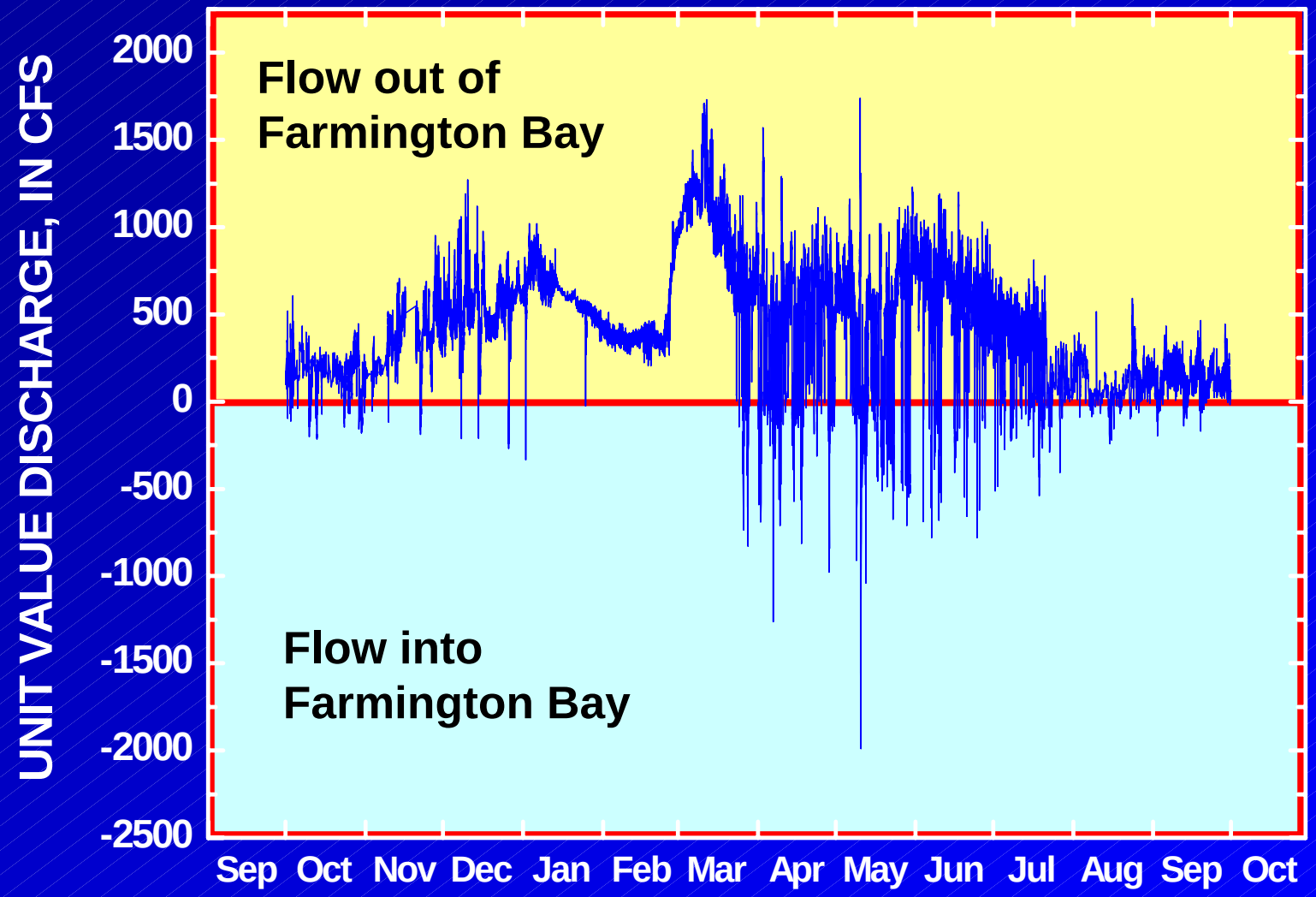
- **Bi-directional flow**
- **Density-driven flow**
- **Discharge/loadings controlled by wind speed, wind direction, lake level, salinity gradients, and other variables**

UPLOOKING ACOUSTICS



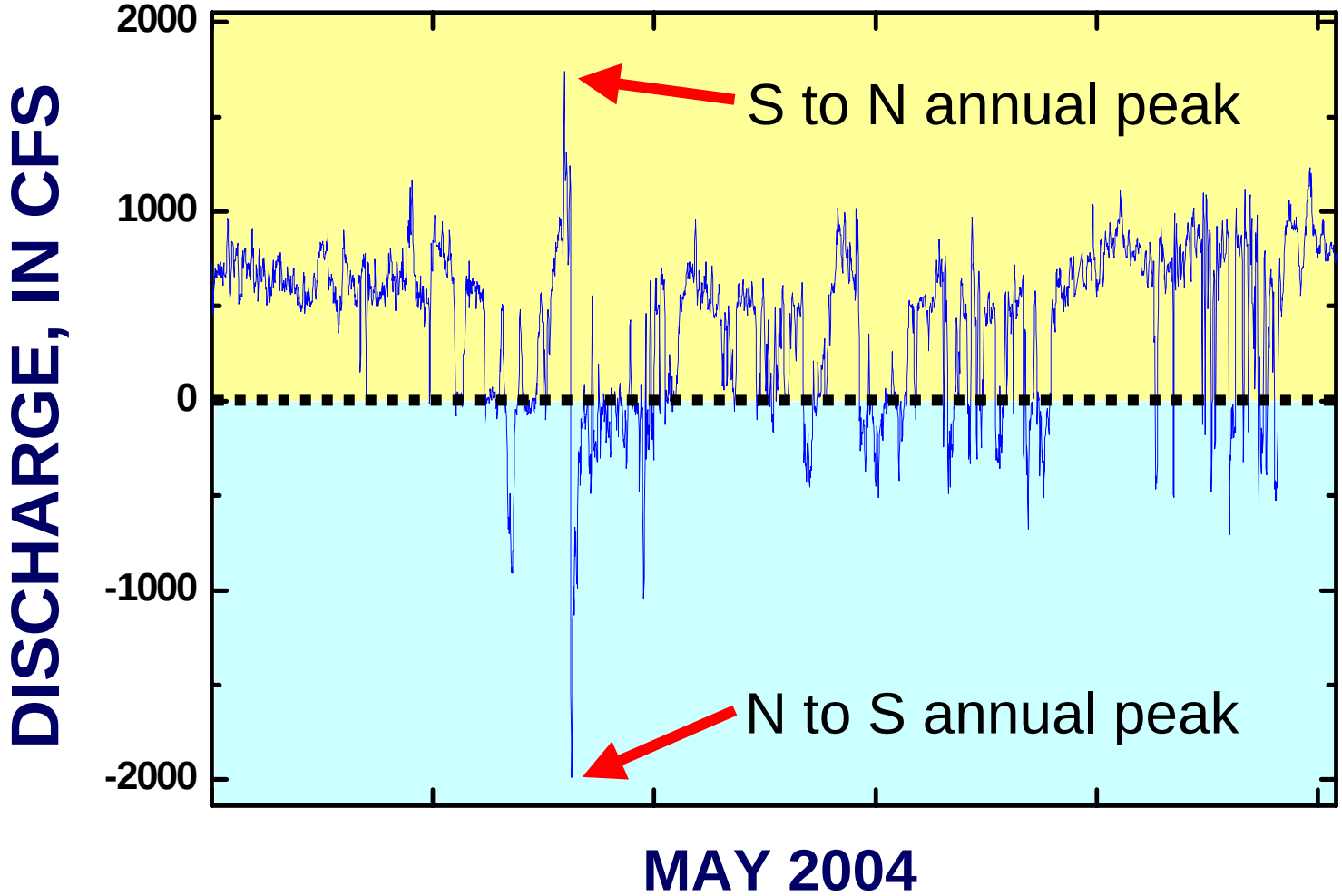
WY 04 FARMINGTON BAY RECORD

first acoustic record in Utah (funded by UDWR, Davis Co., and USGS)



A DYNAMIC FLOW SYSTEM!

Se load = lake level + wind speed + wind direction + NS disch + ...



NUTRIENT LOADINGS TO MAIN BODY GSL

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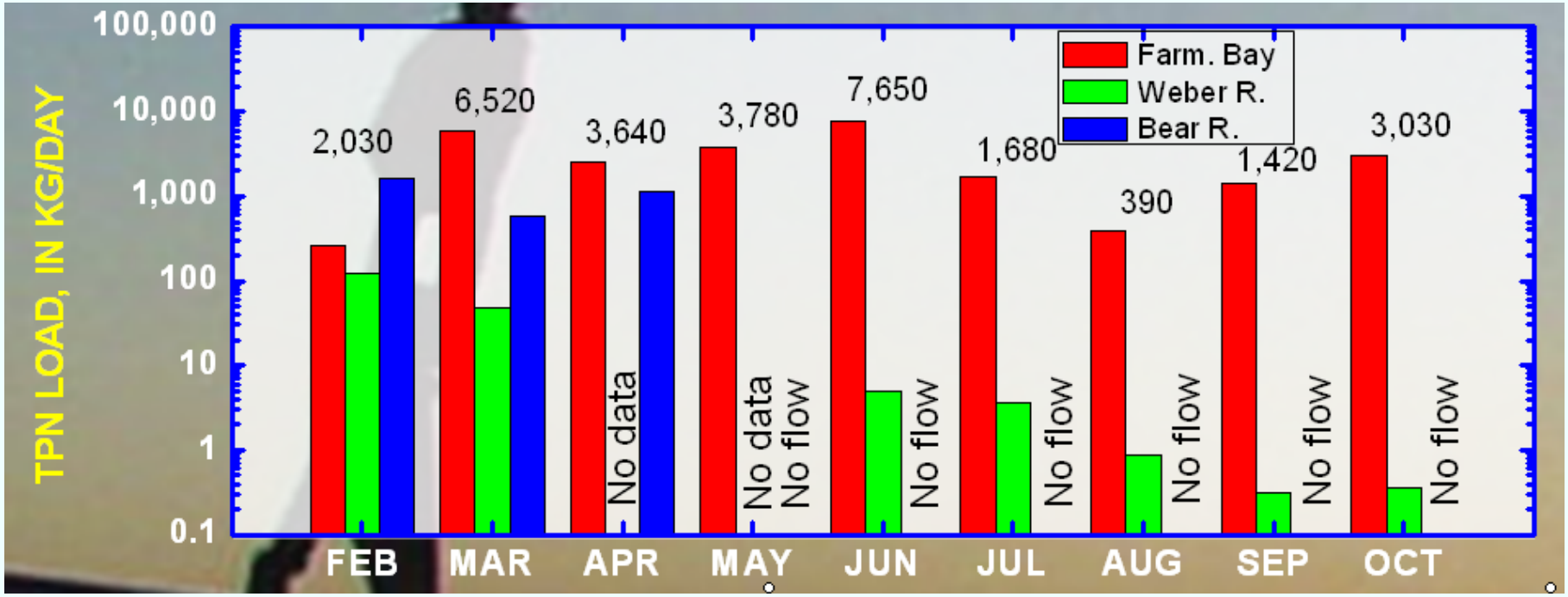
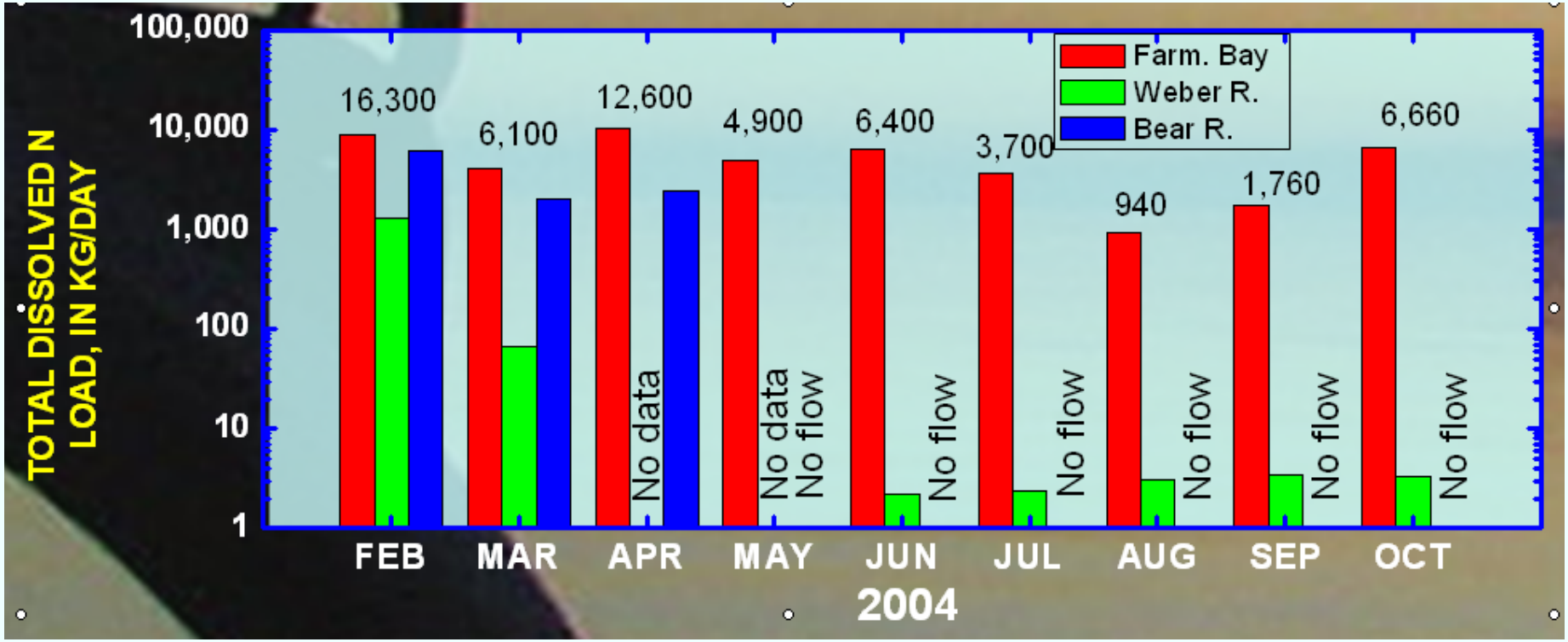
Total Particulate Nitrogen 2004



Total Dissolved Nitrogen 2004



ISOTOPIC FINGERPRINTING OF FB OUTFLOW

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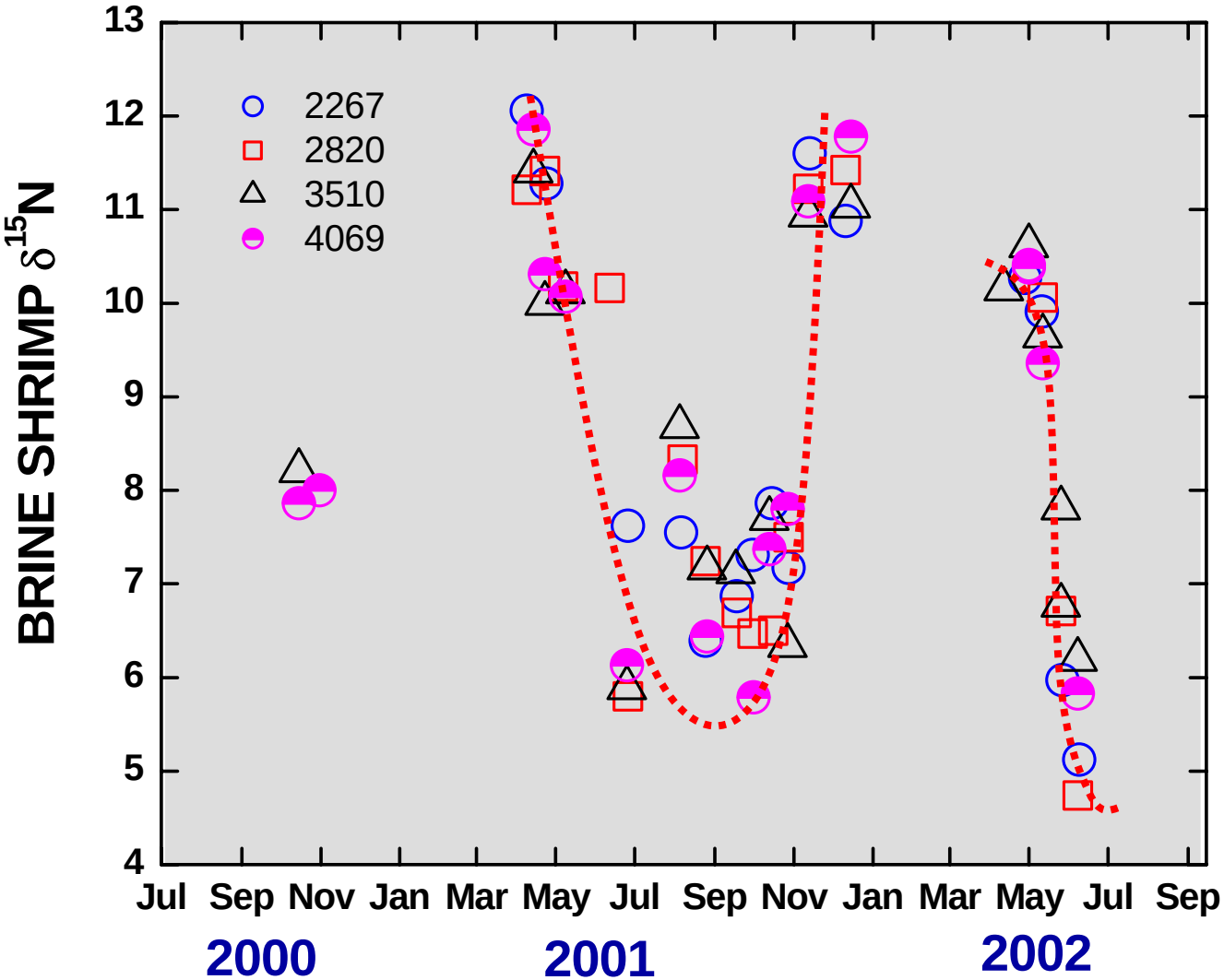
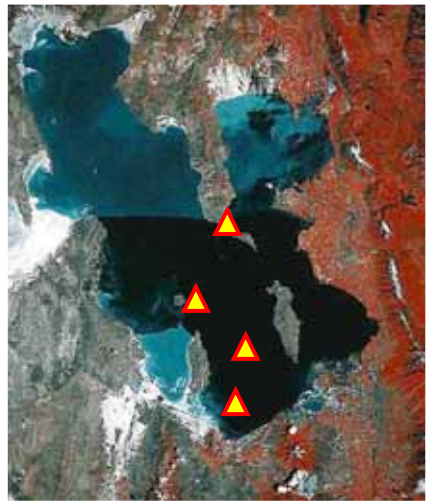
Environmental Isotopes

- Isotope: Same element/different mass
- Different isotopes react differently to various environmental processes

YOU ARE WHAT YOU EAT +3





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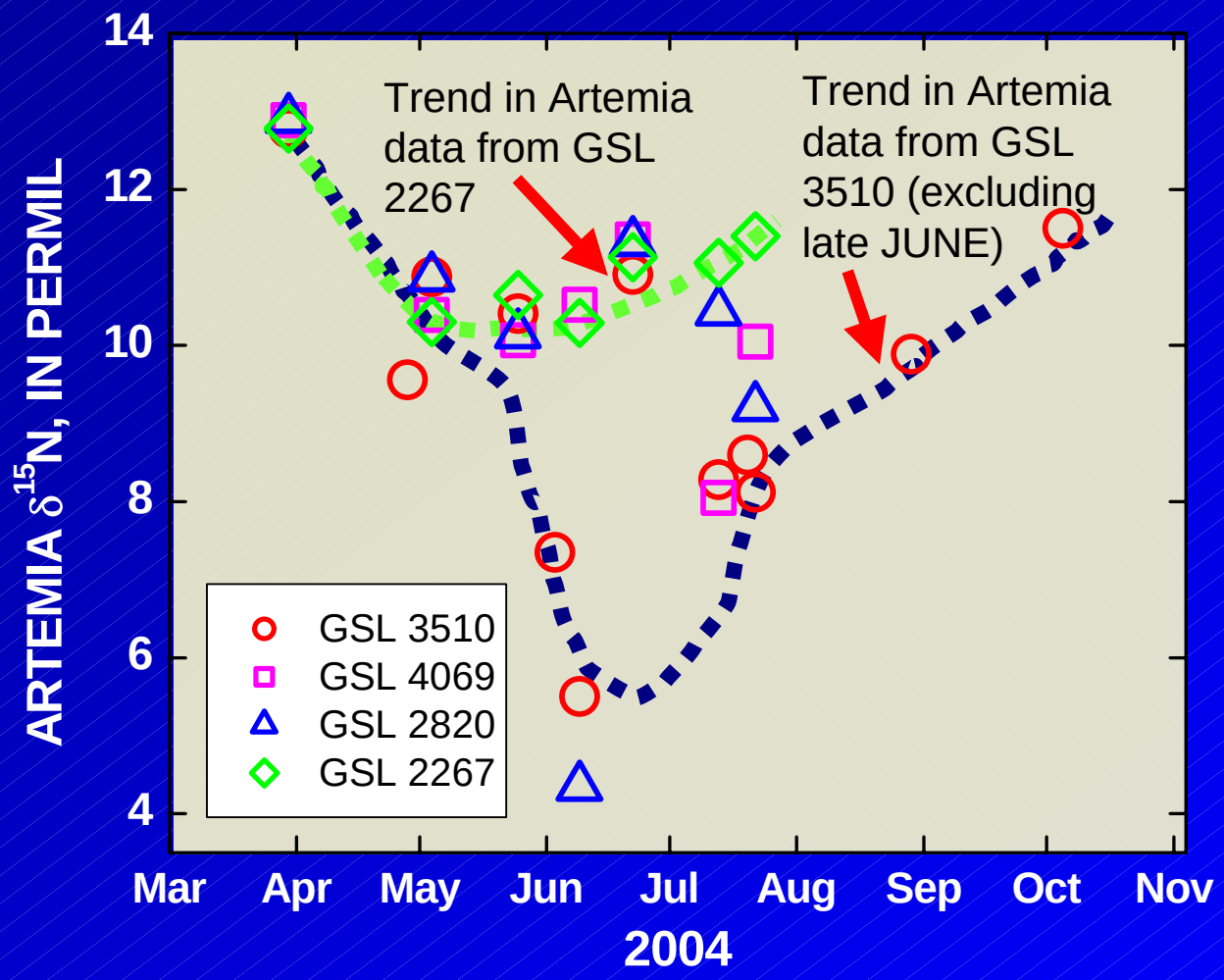
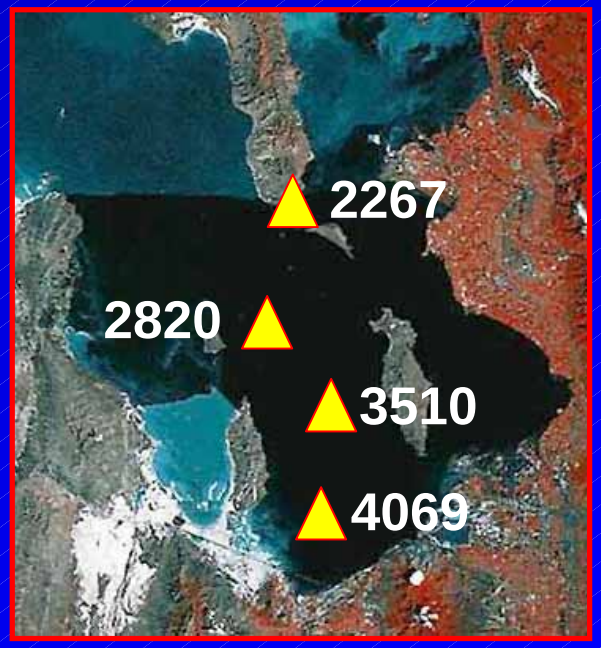
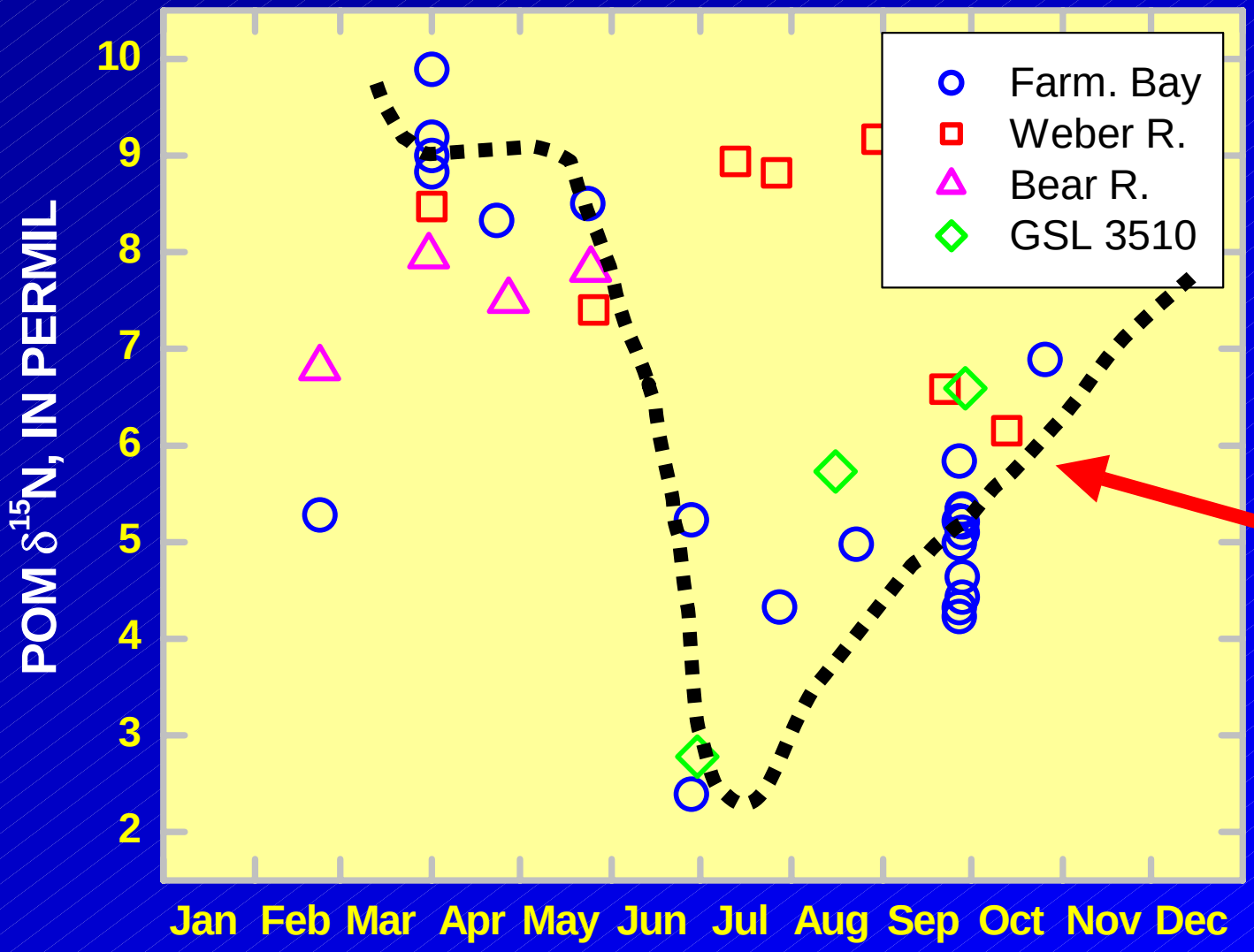
2004 BRINE SHRIMP DATA



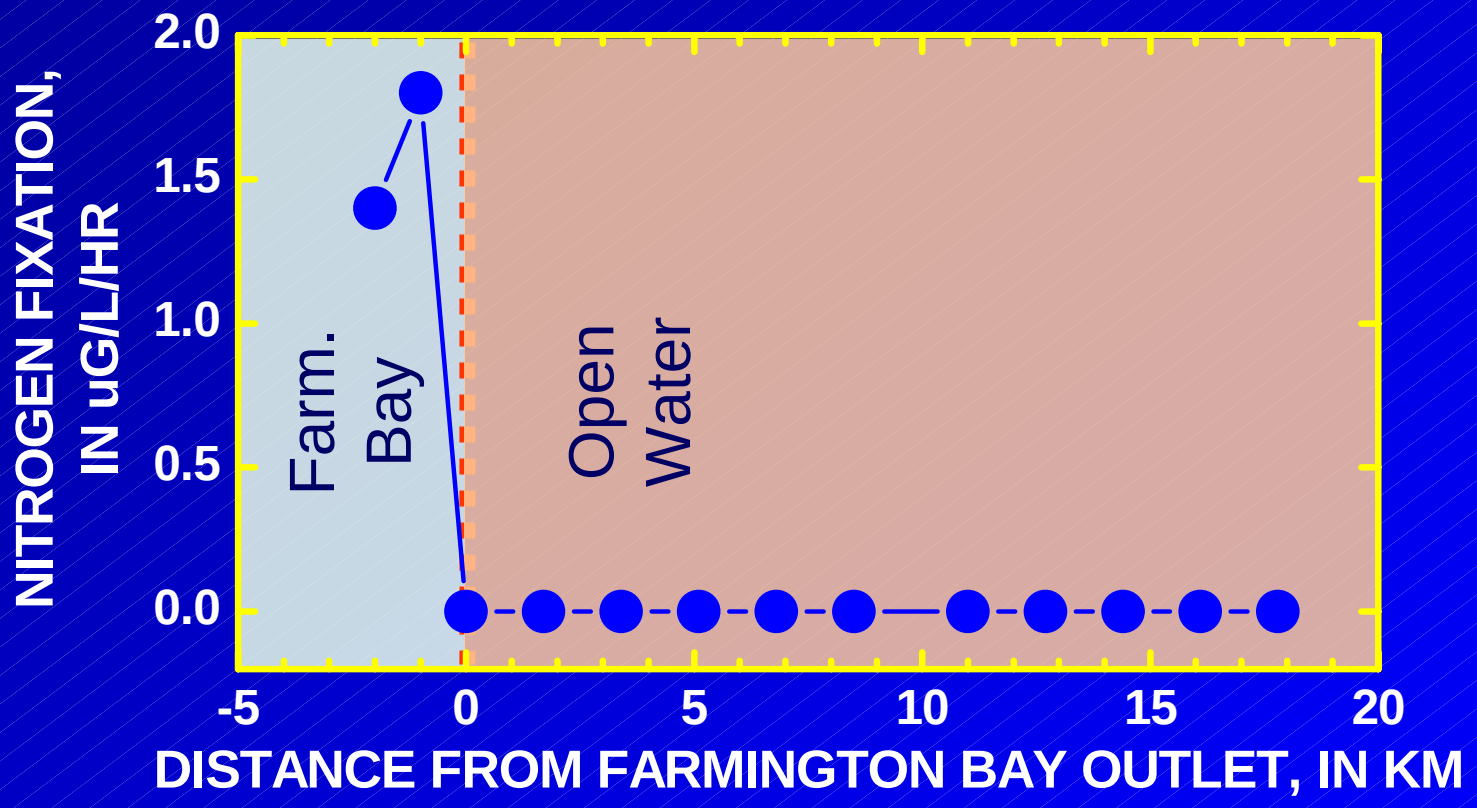


N-15 IN PART. ORG. MAT.



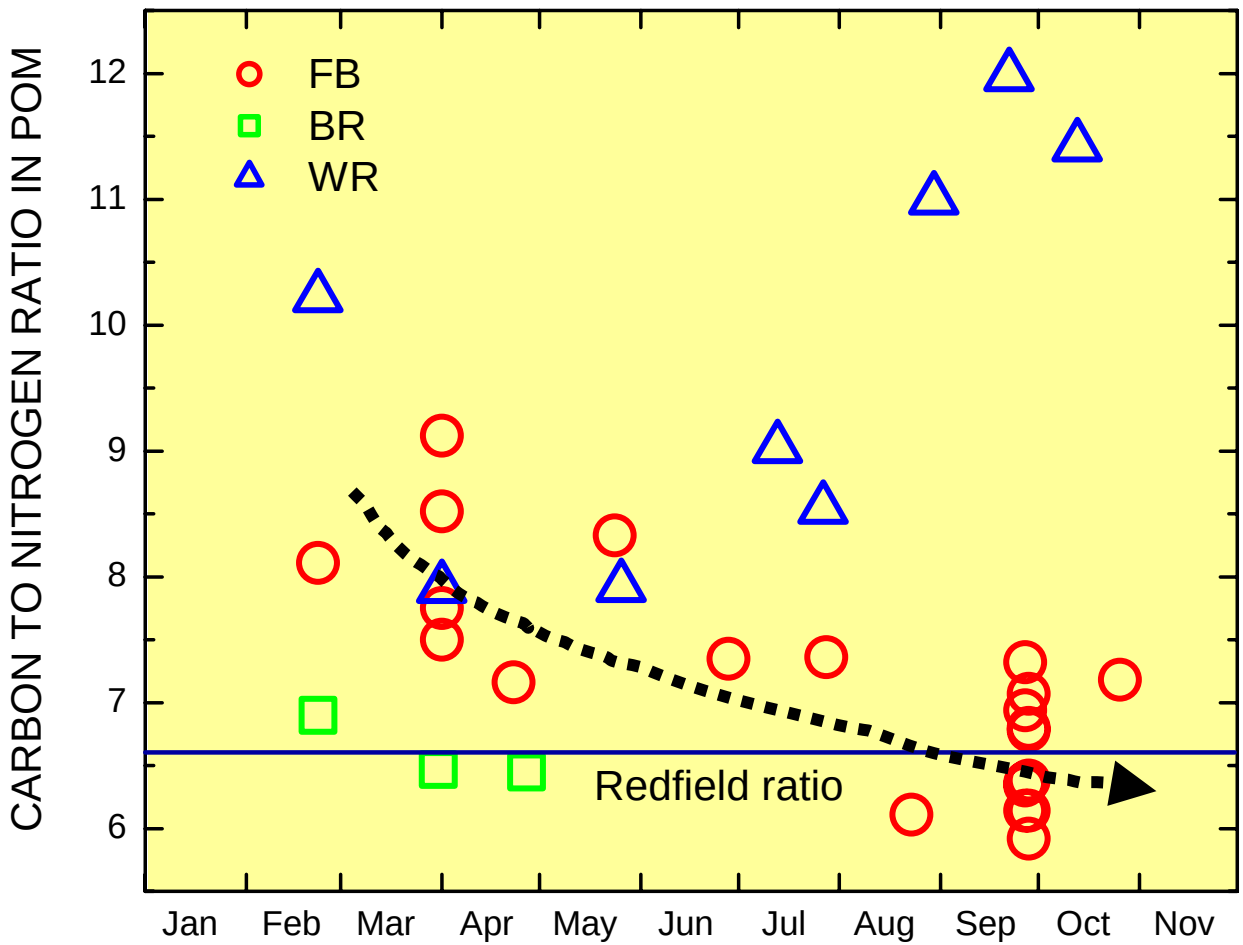
Trend in POM data from Farmington Bay

N-FIXATION NEAR ZERO



J. Robinson, USU, writ. commun., 2005

REDFIELD RATIO CHANGES



Higher proportion of terrestrial and macrophyte debris

SUMMARY

- Annual Se loads to FB are 160 kg
- Hydroacoustics provide excellent discharge records of outflow from FB
- Nutrient loadings from FB to GSL rule!
- Isotopic fingerprints provide critical information on changes in nutrient sources

Classification of Wetland Vegetation

Frontier Corporation & EMARS Inc.

- Acquire high resolution multispectral imagery
- Process and form calibrated mosaic
- Print field maps and conduct ground truth
- Extract signatures and conduct supervised classification
- Recode and edit
- Conduct field verification
- Error assessment

USU Airborne Multispectral Remote Sensing System

USU Piper Seneca II
Remote Sensing Aircraft

Kodak 4.2i digital cameras and Nikon lenses with interference filters mounted on carbon composite and high-grade aluminum mount

USU Multispectral Digital System equipment rack with thermal infrared scanner in the foreground

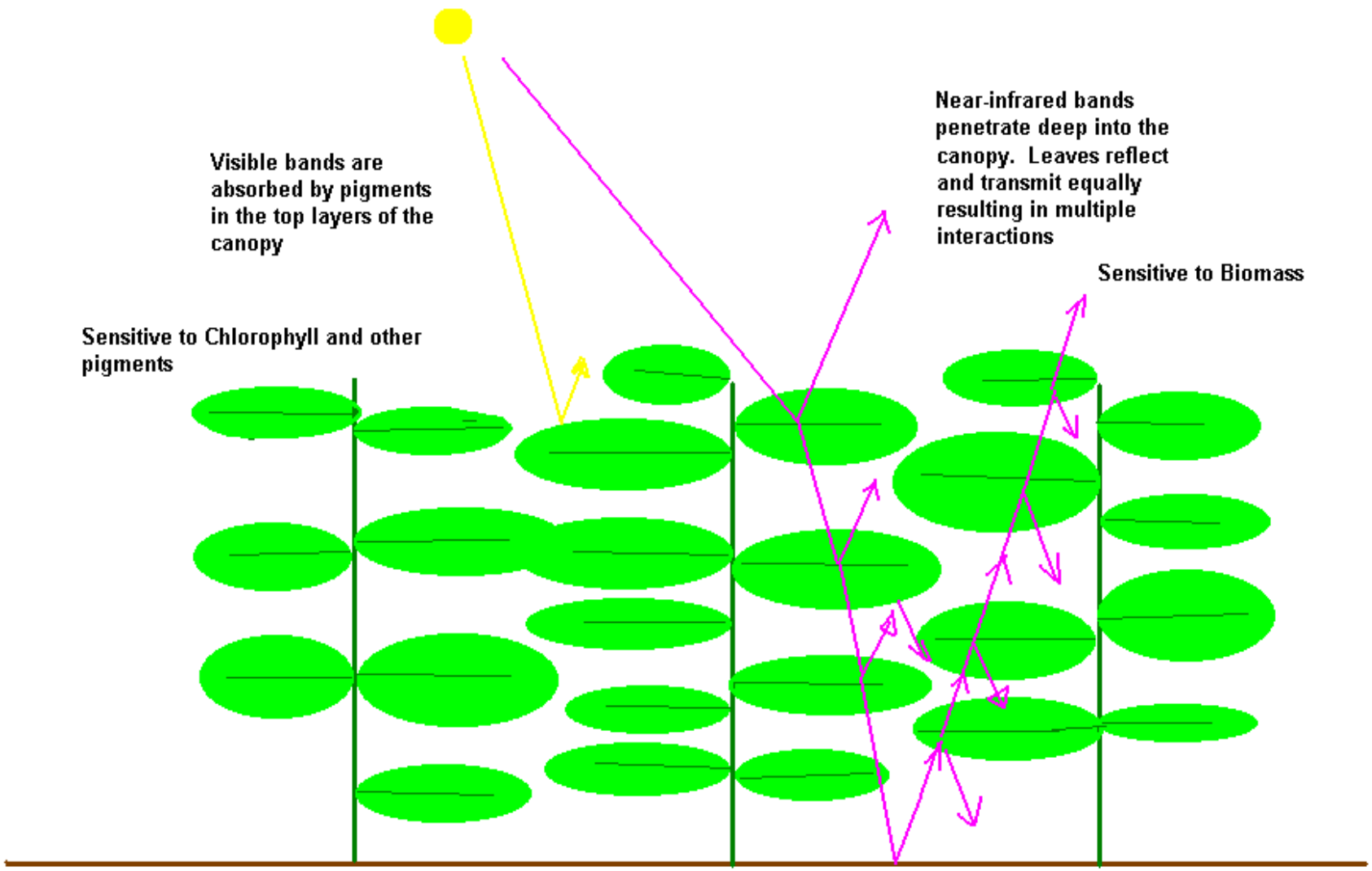
Green

Red

NIR

3 bands

Utah State UNIVERSITY



Near-infrared radiation is strongly absorbed
By water

Image Rectification

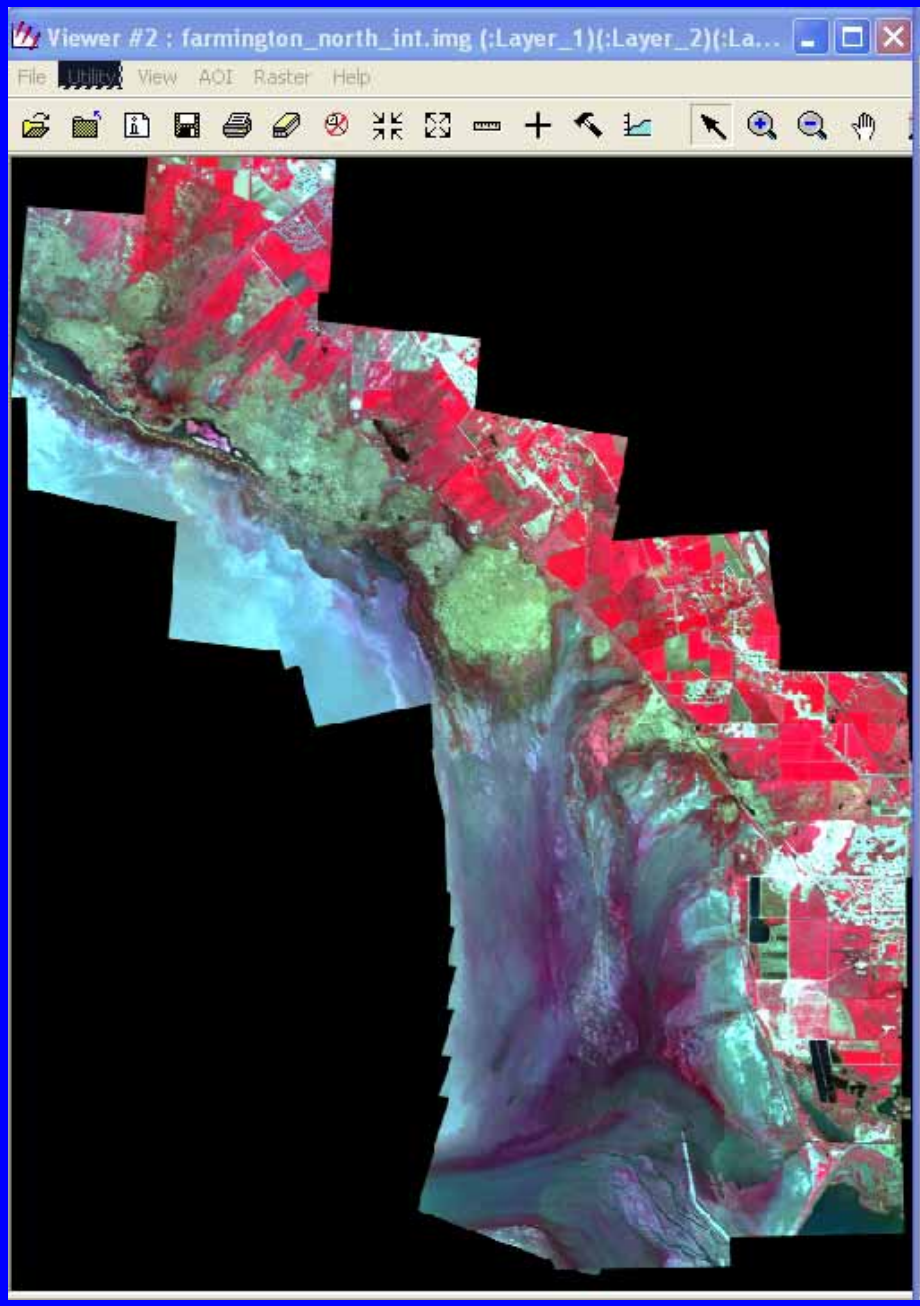
Used 1-meter color orthophotoquad as map base.

Over 50 individual images were used in the mosaic.

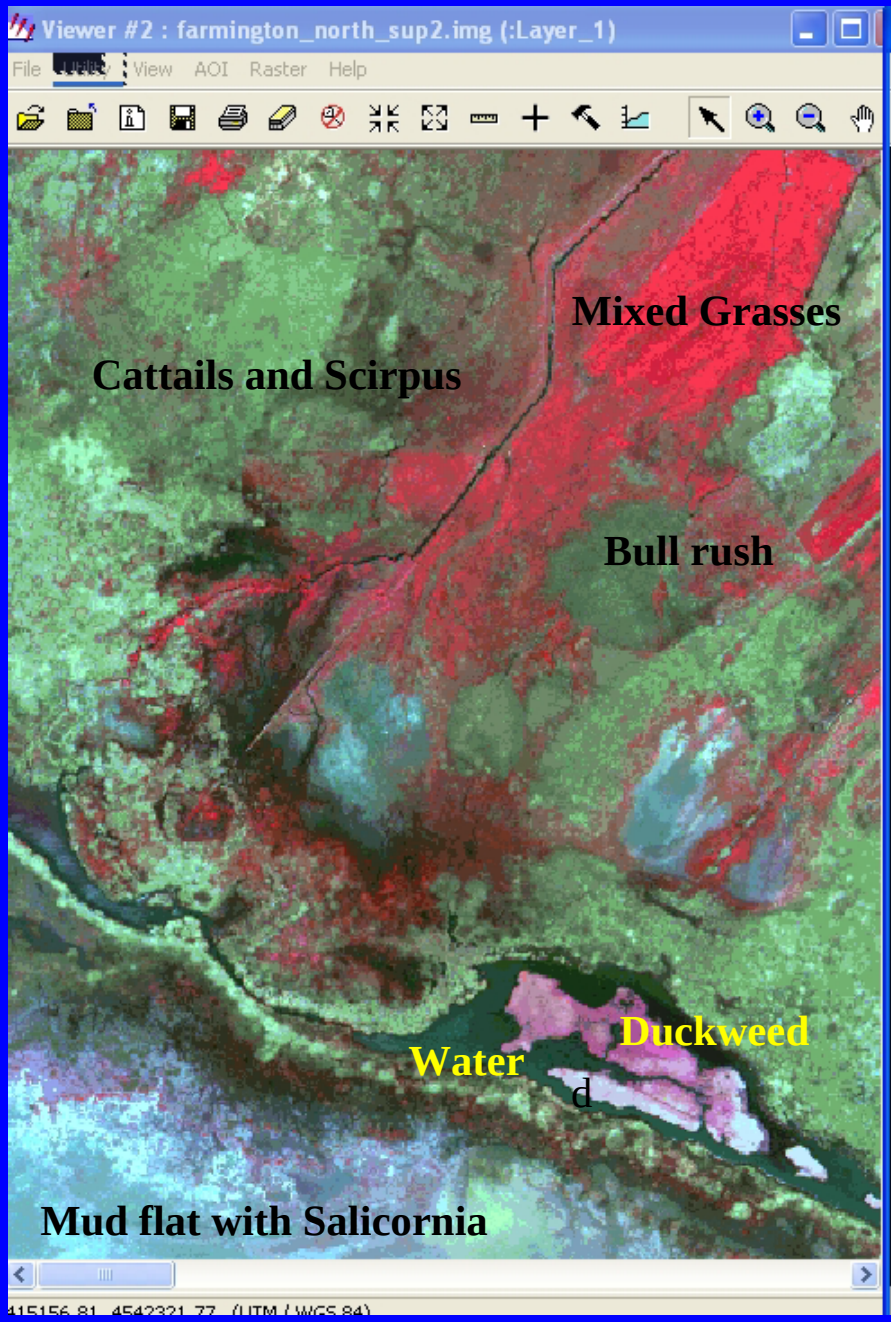
Ground truth verification

Marked-up printed field map & Digital Photos of different vegetation types

Multispectral Mosaic and Supervised Classification



154 Classes



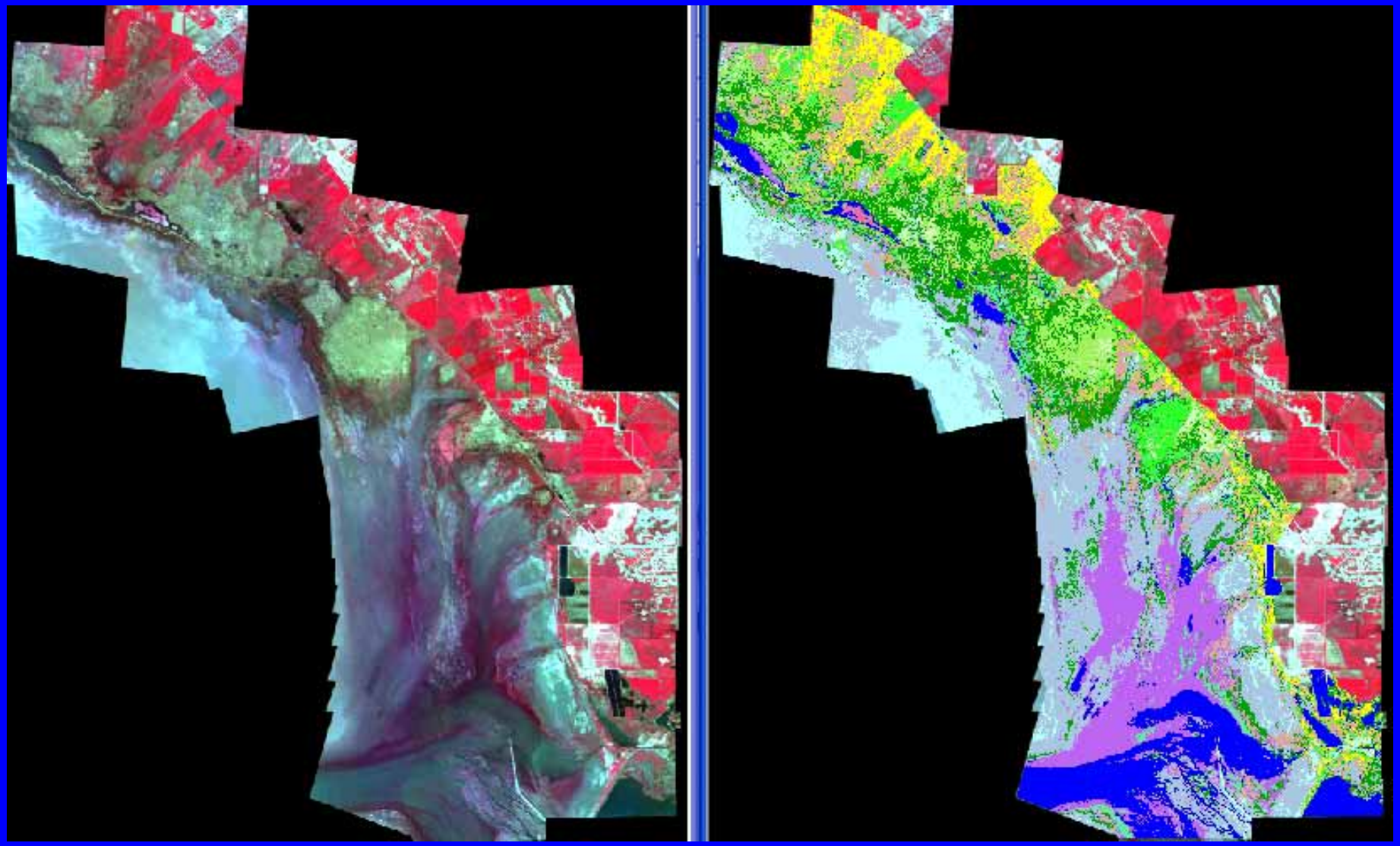
Raster Attribute Editor - farmington_nor...

File Edit Help

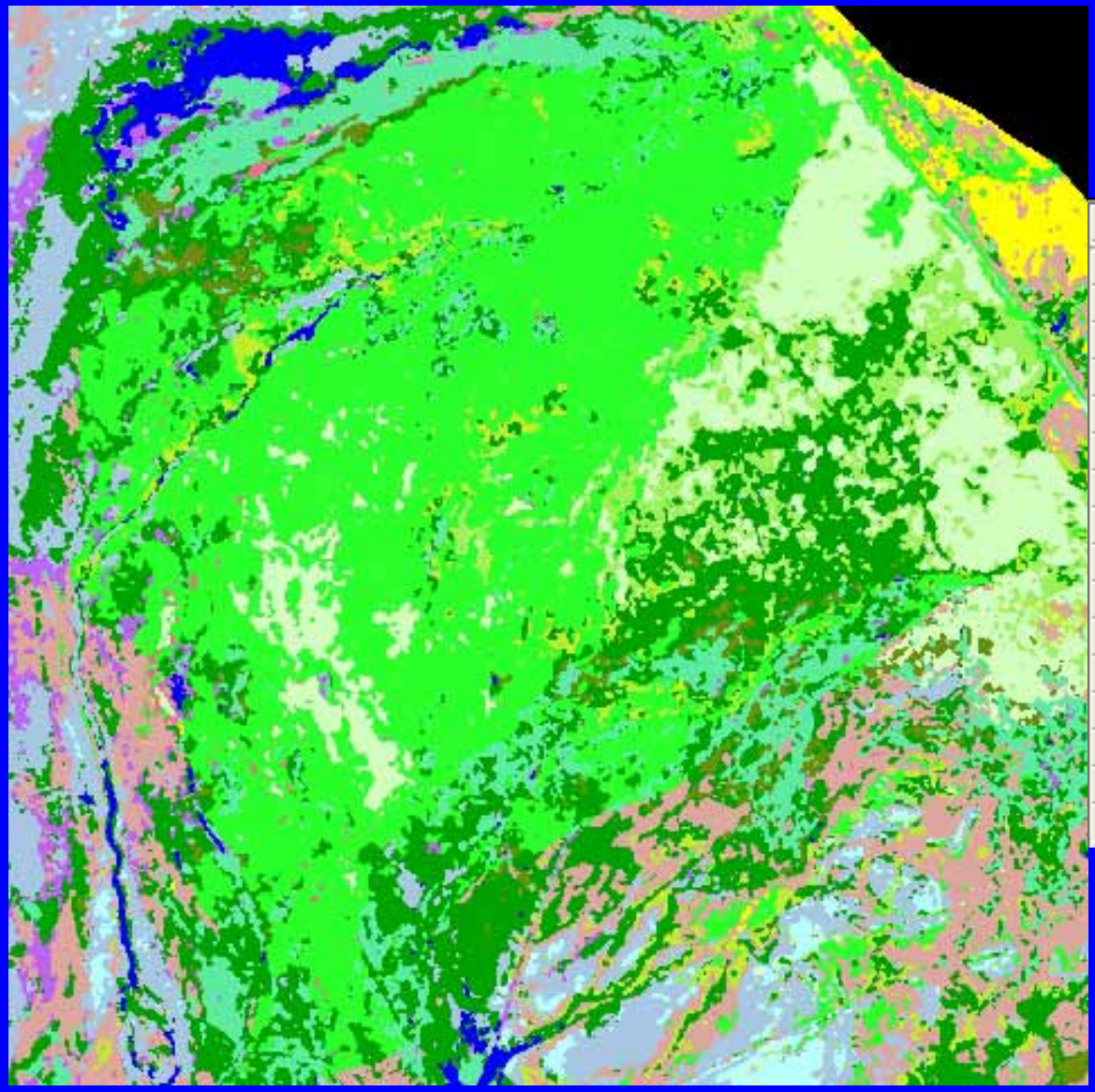
Layer Number: 1

Row	Class Names	Value	Color
0	Unclassified	0	
1	Phragmites 1	1	
2	Phragmites 2	2	
3	Phragmities 3	3	
4	Scirpus /Cattail / Phrag Poss	4	
5	Bullrush 1b	5	
6	Cattails 2	6	
7	Cattails 3	7	
8	Phragmites Growing	8	
9	Duck weed 3	9	
10	Clover/Cheatgrass Mix	10	
11	Wheatgrass 1	11	
12	Phragmites / Cattails 7	12	
13	Sedge 1 / Cattails Growing Early	13	
14	Bullrush / Phragmites	14	
15	Salt Grass 1	15	
16	Scirpus	16	
17	Bullrush 3	17	
18	Cattails / Phragmites	18	
19	Scirpus 1	19	
20	Duckweed 1	20	
21	Duckweed 2	21	
22	Playa with Salicornia 1	22	
23	Playa 1	23	
24	Playa 2	24	
25	Playa moist 1	25	
26	Playa with Salicornia Sparse	26	
27	Phragmites Growing 3	27	
28	Playa with growing salicornia	28	
29	Playa with growing Salicornia 2	29	
30	Scirpus 3	30	
31	Wet Playa 2	31	
32	Scirpus 1 / Pepperweed	32	
33	Salt Grass / Foxtail 3	33	
34	Phragmites/ Playa with Salicorni.	34	
35	Scirpus / Cattail 1	35	
36	Bullrush 2	36	

Classification Recoded into 15 Classes

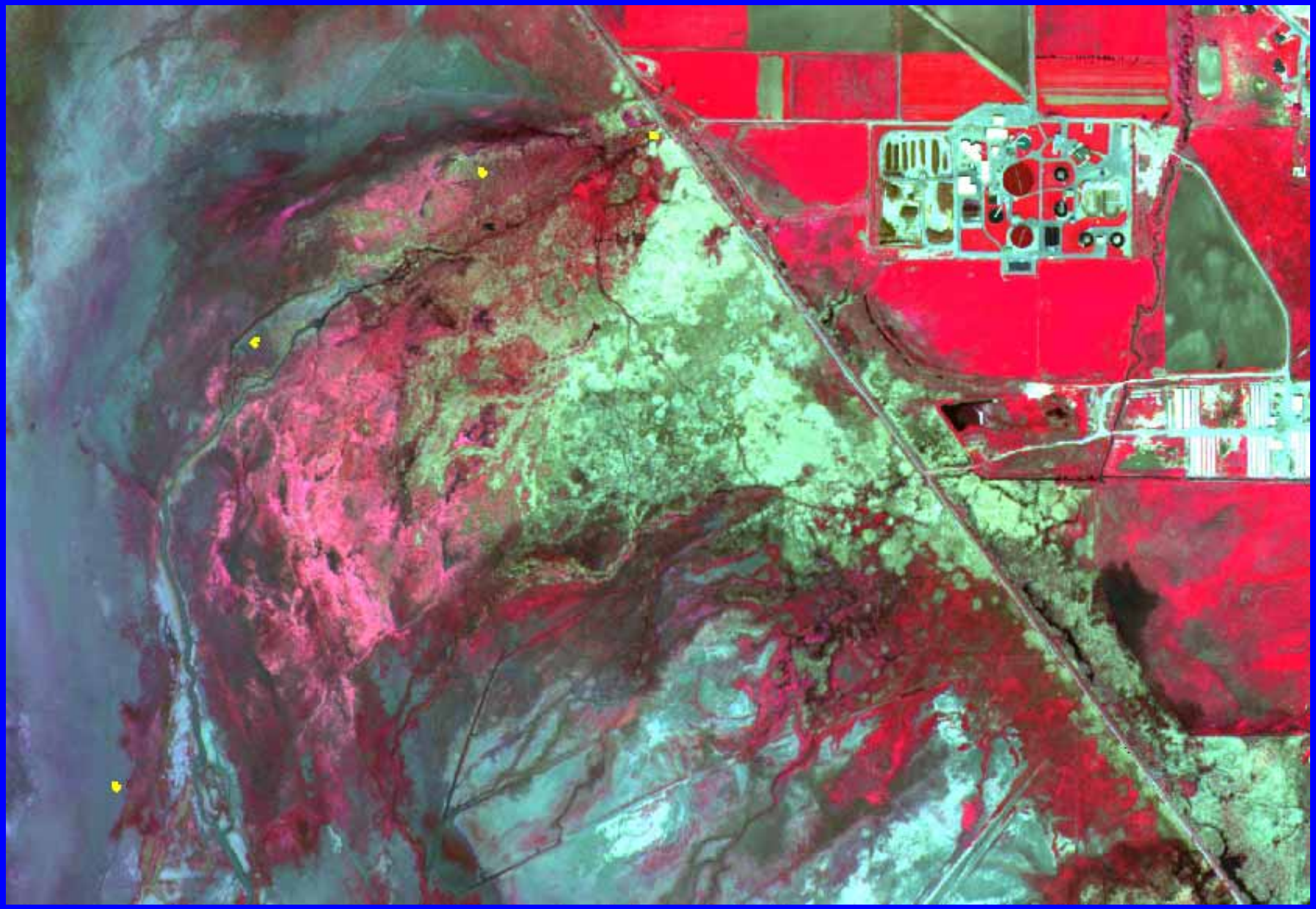


Recoded Classification Attribute Table

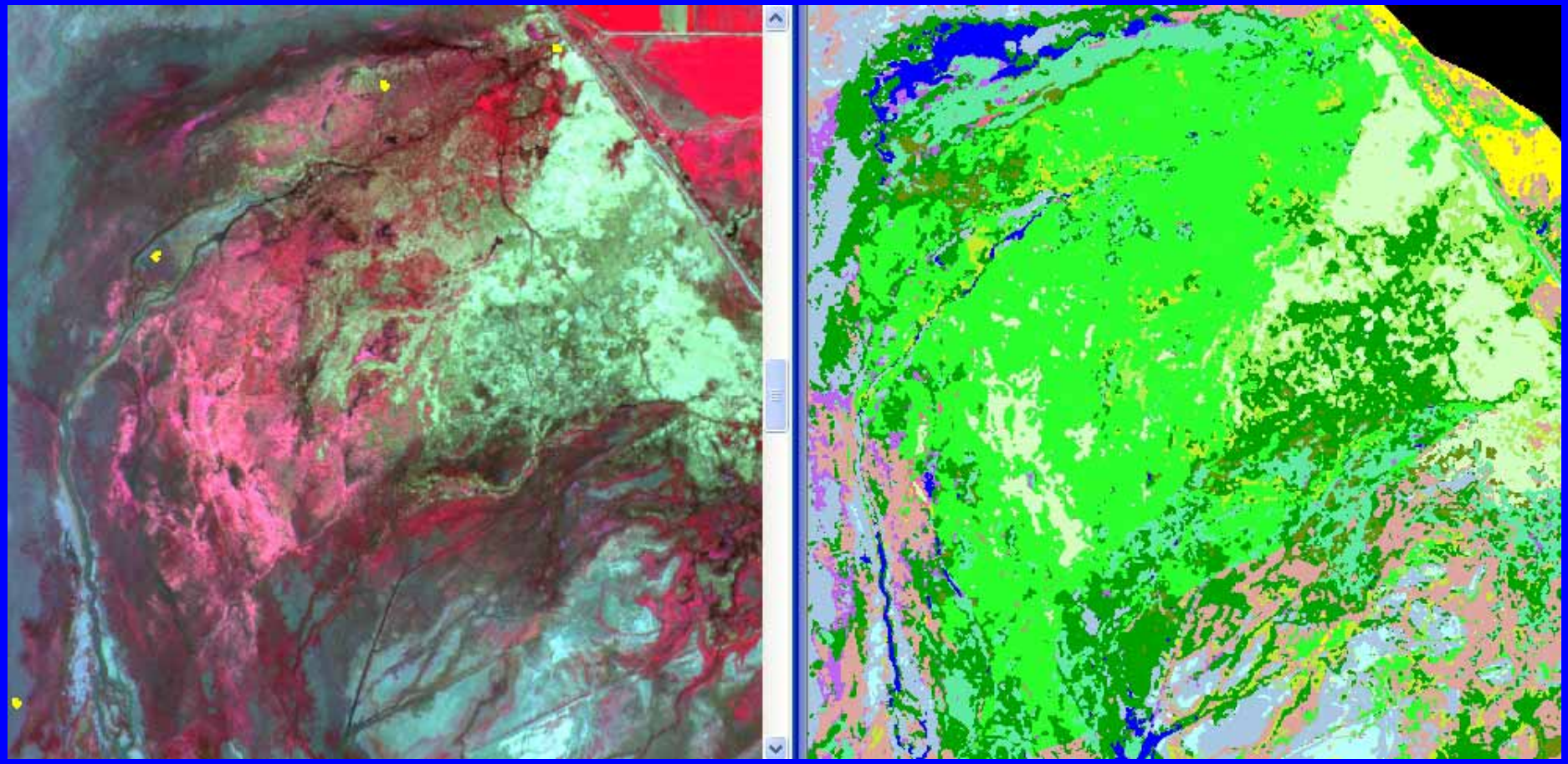


Row	Class Names	Color
0		
1	Phragmites	
2	Scirpus	
3	Cattails	
4	Cattails / Phragmites	
5	Cattails / Scirpus	
6	Scirpus / Cattails	
7	Scirpus / Wet Carex	
8	Duckweed	
9	Algae	
10	Playa with Unknown Vegetation	
11	Emergent Wet Meadow	
12	Playa with Salicornia	
13	Mud Flat Playa	
14	Upland	
15	Open Water	

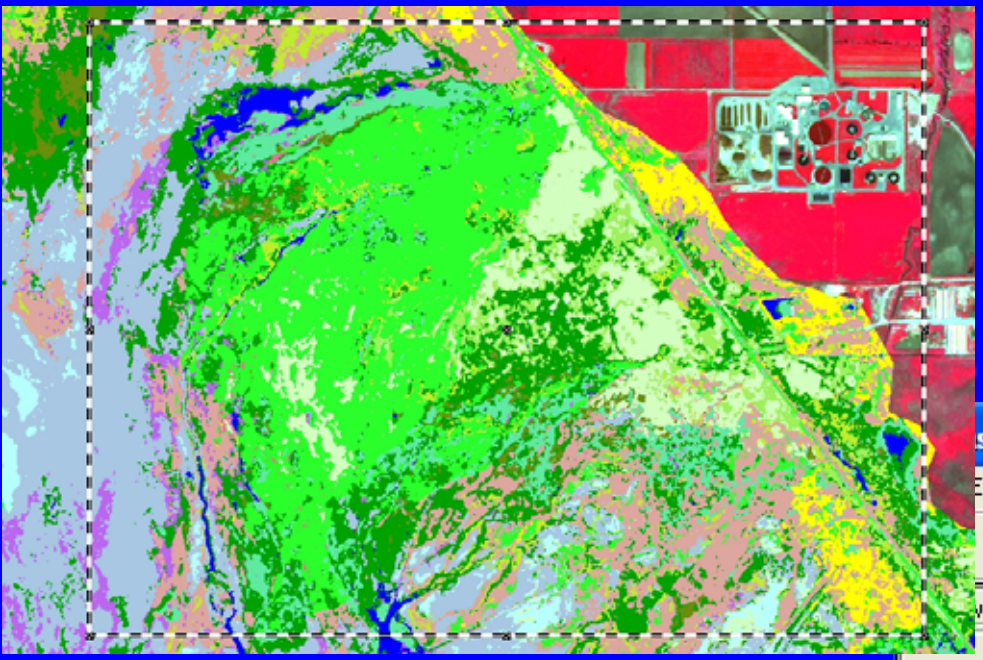
Soil Selenium Sampling Sites



Treatment Plant Outlet Marsh Recoded Classification



Example of Statistics



Davis County water treatment Plant marsh

ster Attribute Editor - sewer_marsh_subset.img(:Lay...

Edit Help

Layer Number: 1

	Class Names	Value	Color	Area (acres)
0		0		0.0
1	Phragmites	1		36.1
2	Scirpus	2		88.0
3	Cattails	3		106.4
4	Cattails / Phragmites	4		21.1
5	Cattails / Scirpus	5		16.6
6	Scirpus / Cattails	6		31.7
7	Scirpus / Wet Carex	7		7.3
8	Duckweed	8		0.8
9	Algae	9		0.0
10	Playa with Unknown Vegetation	10		11.5
11	Emergent Wet Meadow	11		70.2
12	Playa with Salicornia	12		68.8
13	Mud Flat Playa	13		7.7
14	Mixed Grasses and Upland Veg	14		17.0
15	Open Water	15		6.9

BRIGHAM CITY/PERRY CITY SAMP PROJECT 3/23/2004

Rolfe Property

Wetland Inventory & Mapping Accuracy Assessment

		GROUNDTRUTH/ACCURACY OBSERVATION							Comm. Error		
		UPR	MF*	EWM*	EM*	CRP	BS	W*	total	% correct	
	UPR	95	1	9	4				109	87	
	MF*	1	116	3	2				122	95	
MAP	EWM*	5		121	5				131	92	
	EM*	6		5	78				89	88	
CLASS-	CRP					10			10	100	
IFICATION	BS						12		12	100	
	W*				1			49	50	98	
Omm.	total	107	117	138	90	10	12	49	**523**		**Total observations**
Error	% correct	89	99	88	87	100	100	100		**481**	**Total correct**
										91.97%	**Overall accuracy**

Class	**Abbrev.**	*Wetland Classes	
Upland Rangeland	UPR		
Mudflat/Playa*	MF*	391	Total observations
Emergent Wet Meadow*	EWM*	364	Total Correct
Emergent Marsh*	EM*	93.09%	Wetland accurarcy
Crops	CRP		
Bare Soil	BS		
Open Water	W*		

The Rolfe Property is approximately 3,750 acres in size and is located on the low lakeplain of the Great Salt Lake shorelands, west of Interstate Highway 15 and south-east of Forest Street (aka Bear River Access Road).

Progress to Date

- Airborne image acquisition and processing of Davis County shore lands (Kaysville to Farmington)
- Ground truth field verification
- Supervised classification and preliminary results

Still Need:

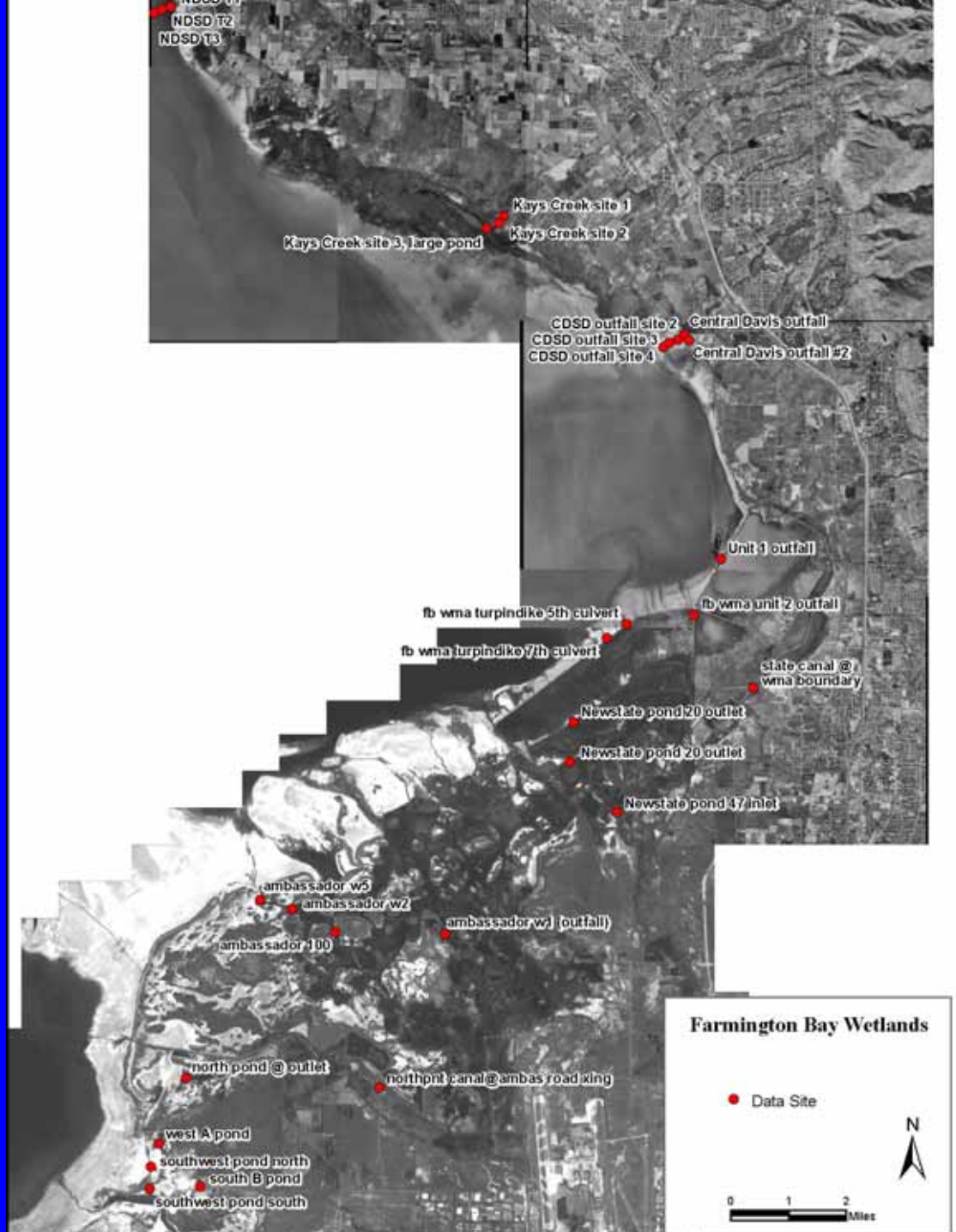
- Field verification of classification results of northern Farmington bay shore lands
- Error assessment and final results
- Process southern Farmington bay shore lands

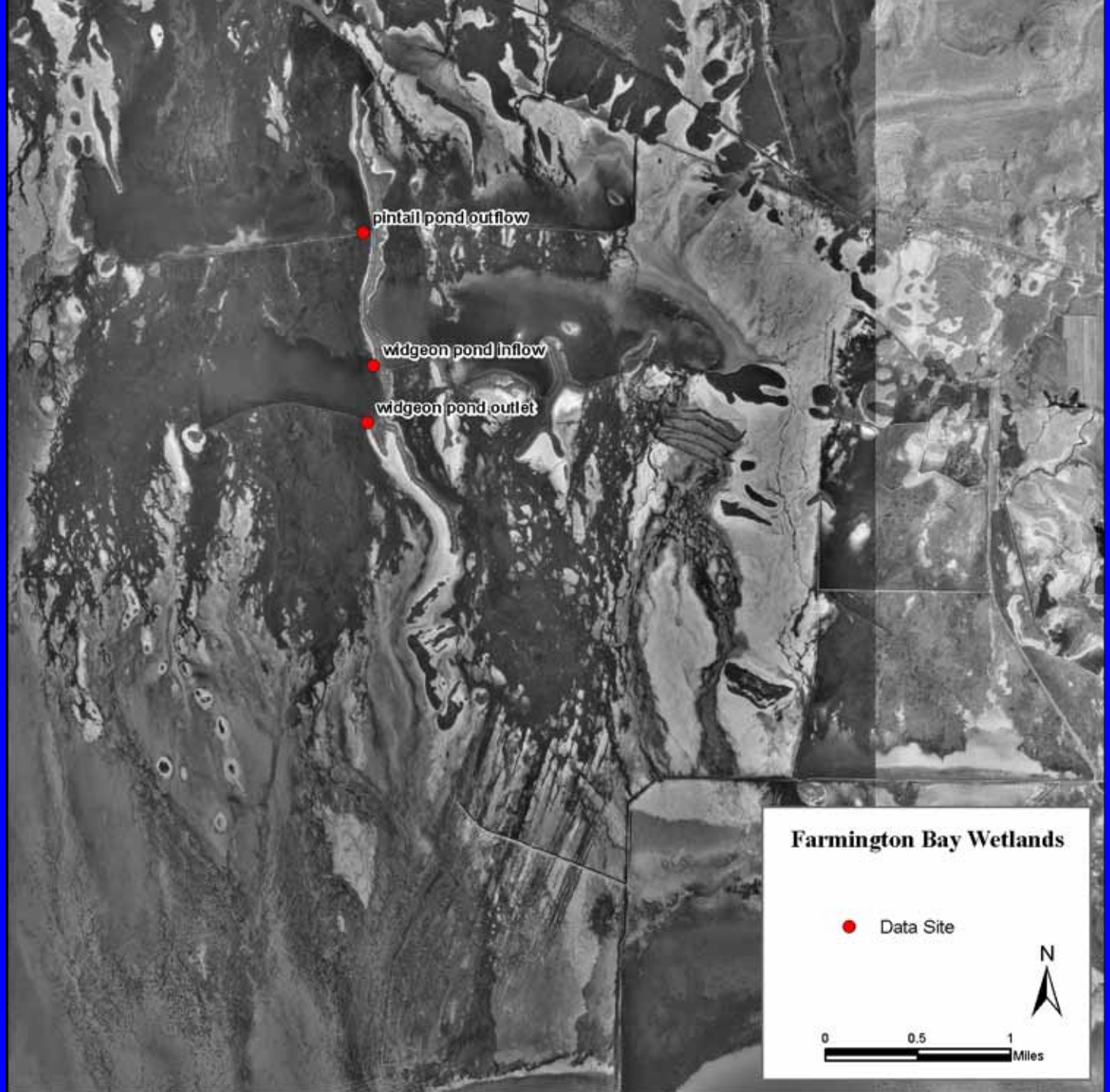
Wetland Vegetation and Soils

- What metrics are indicative of wetland condition?
- Can wetland condition metrics also indicate water quality?

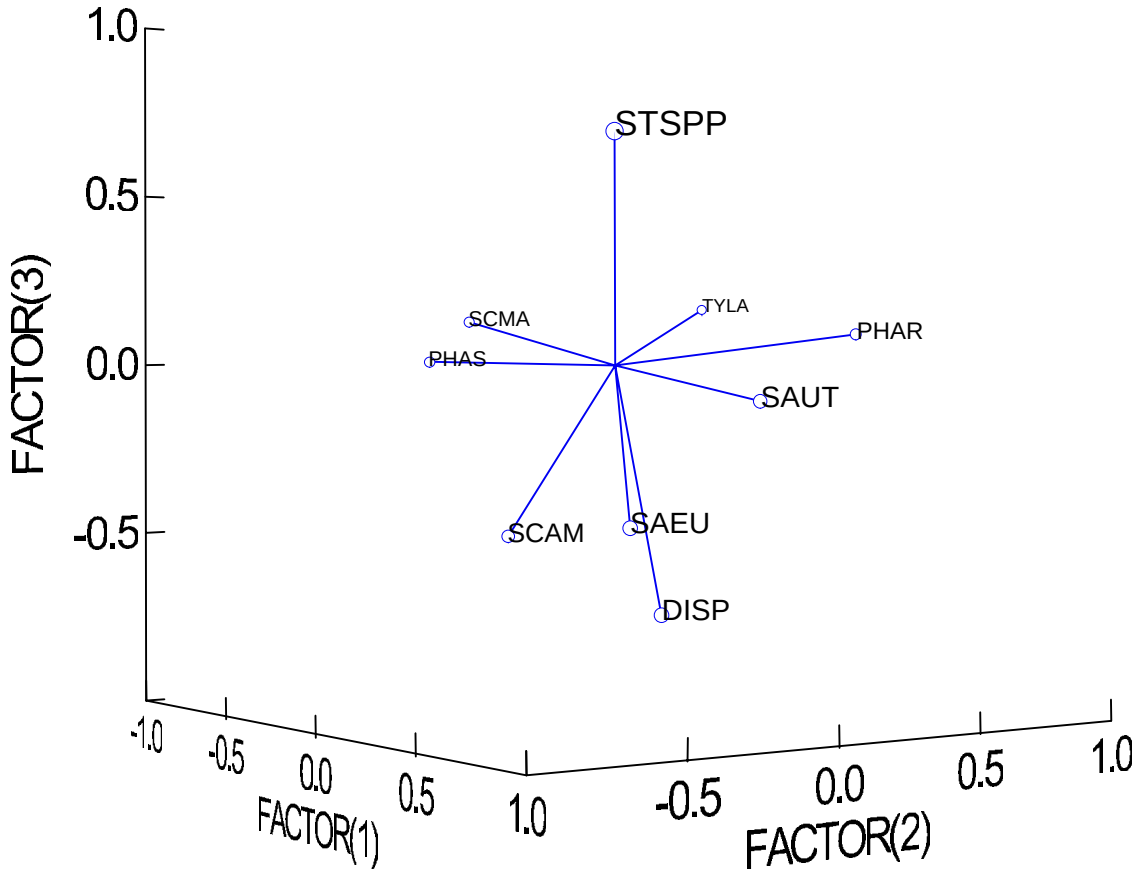
Sample Design

- 100 m Transects, 2 m^2 Quadrats
  - Impounded Reference and Target Sites (4 sites, 13 transects)
  - Sheetflow Reference and Target Sites (5 sites, 14 transects)
- Percent Cover
- Height
- Tissue C, N, P
- Soil Organic Carbon, pH, EC, and Texture

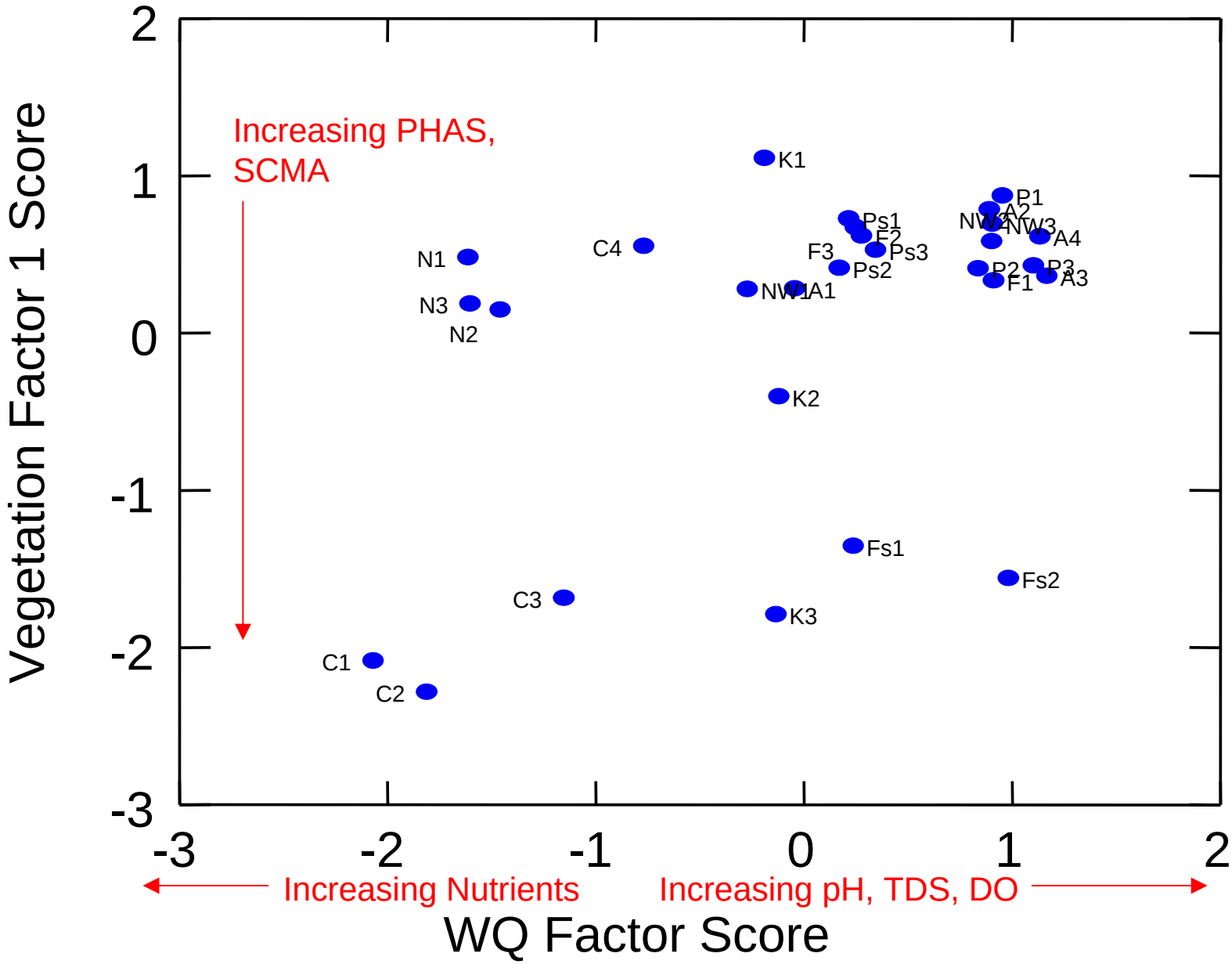

NDSD T2
NDSD T3
Kays Creek site 1
Kays Creek site 2
Kays Creek site 3, large pond
CDSD outfall site 2
CDSD outfall site 3
CDSD outfall site 4
Central Davis outfall
Central Davis outfall #2
Unit 1 outfall
fb wma turpindike 5th culvert
fb wma unit 2 outfall
fb wma turpindike 7th culvert
state canal @ wma boundary
Newstate pond 20 outlet
Newstate pond 20 outlet
Newstate pond 47 inlet
ambassador w3
ambassador w2
ambassador w1 (outfall)
ambassador 100
north pond @ outlet
northpnt canal@ambas road xing
west A pond
southwest pond north
south B pond
southwest pond south
Farmington Bay Wetlands
Data Site
N
0
1
2
Miles


pintail pond outflow
widgeon pond inflow
widgeon pond outlet
Farmington Bay Wetlands
Data Site
N
0
0.5
1
Miles

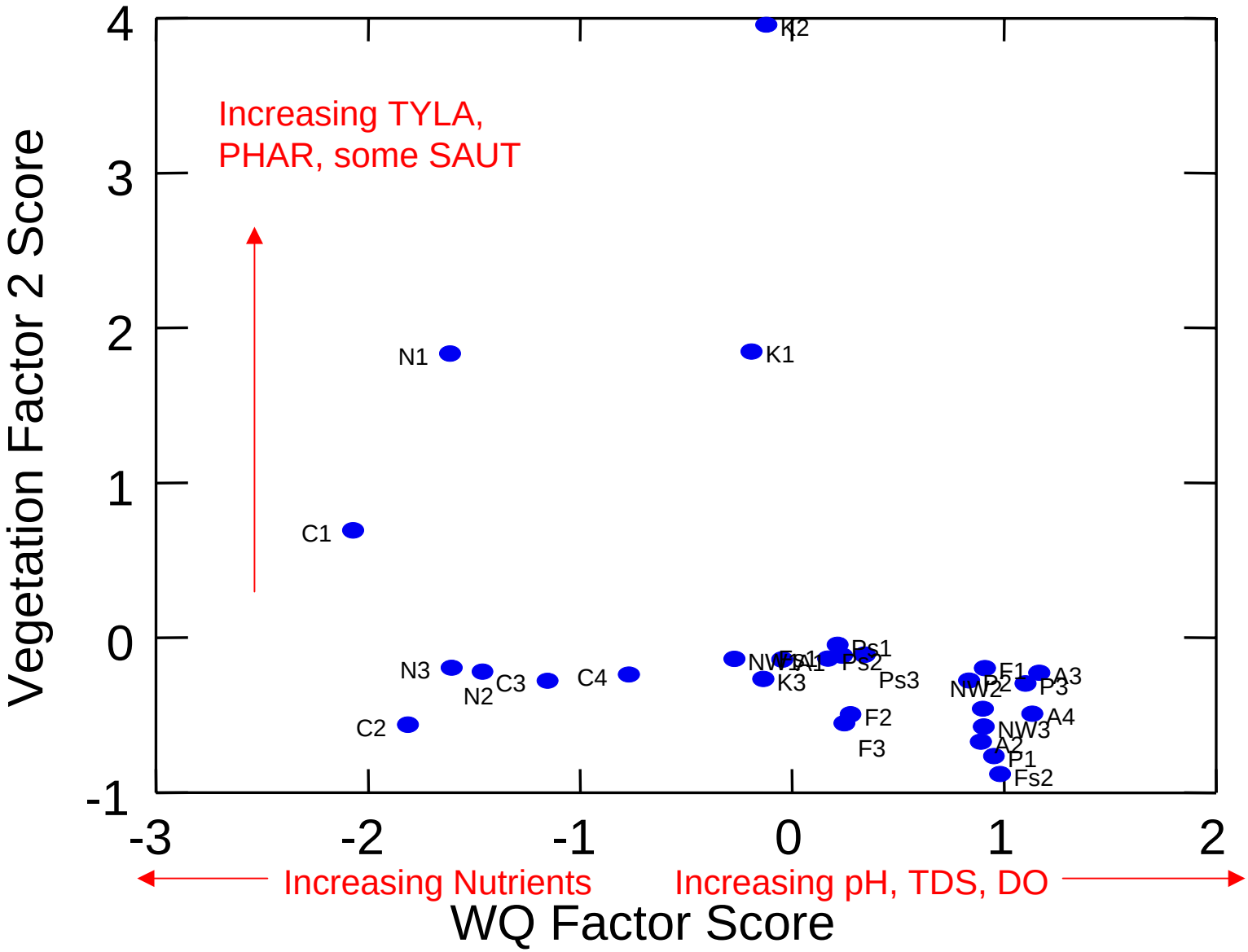
Vegetation Factor Loadings Plot



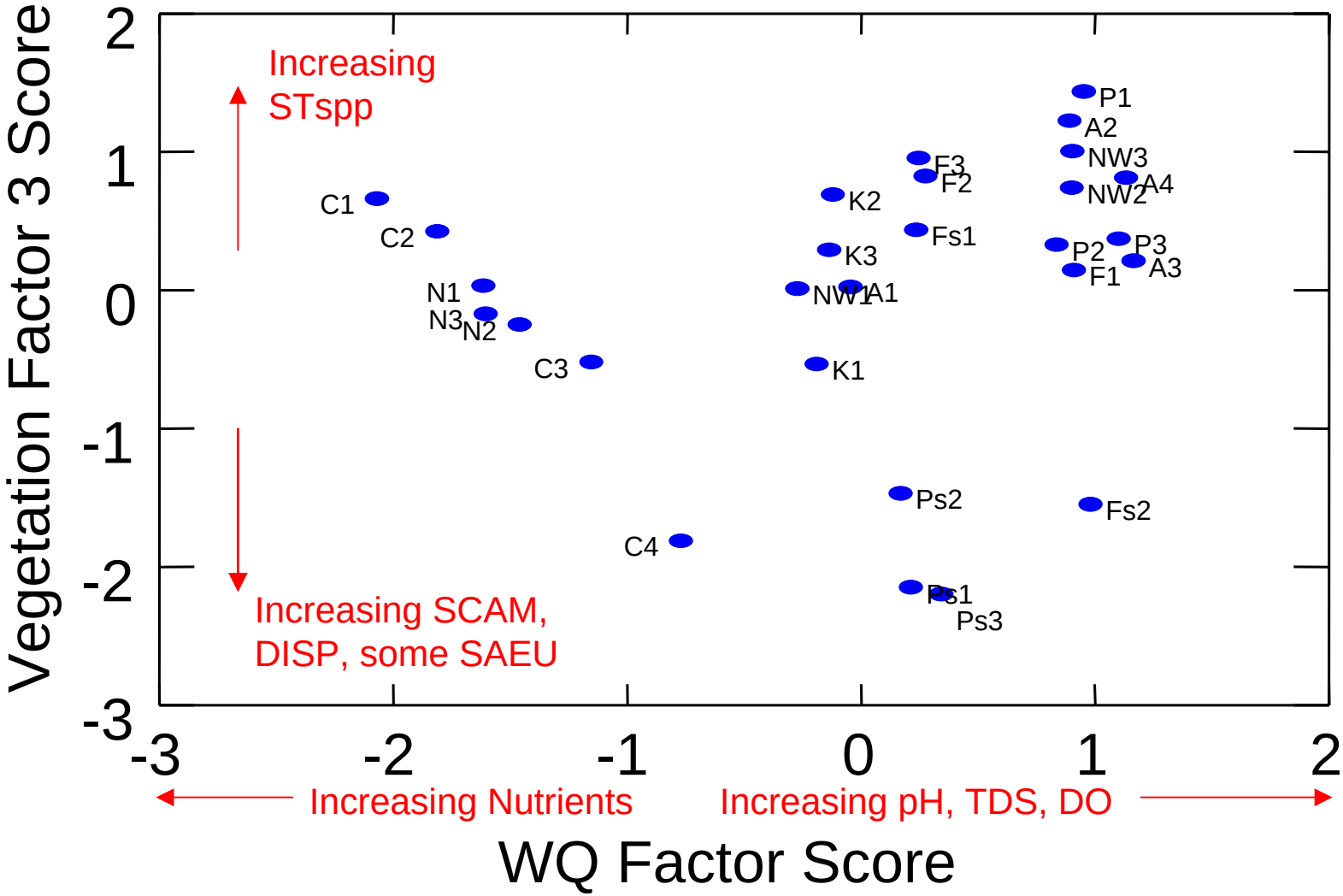
Vegetation Factor Analysis



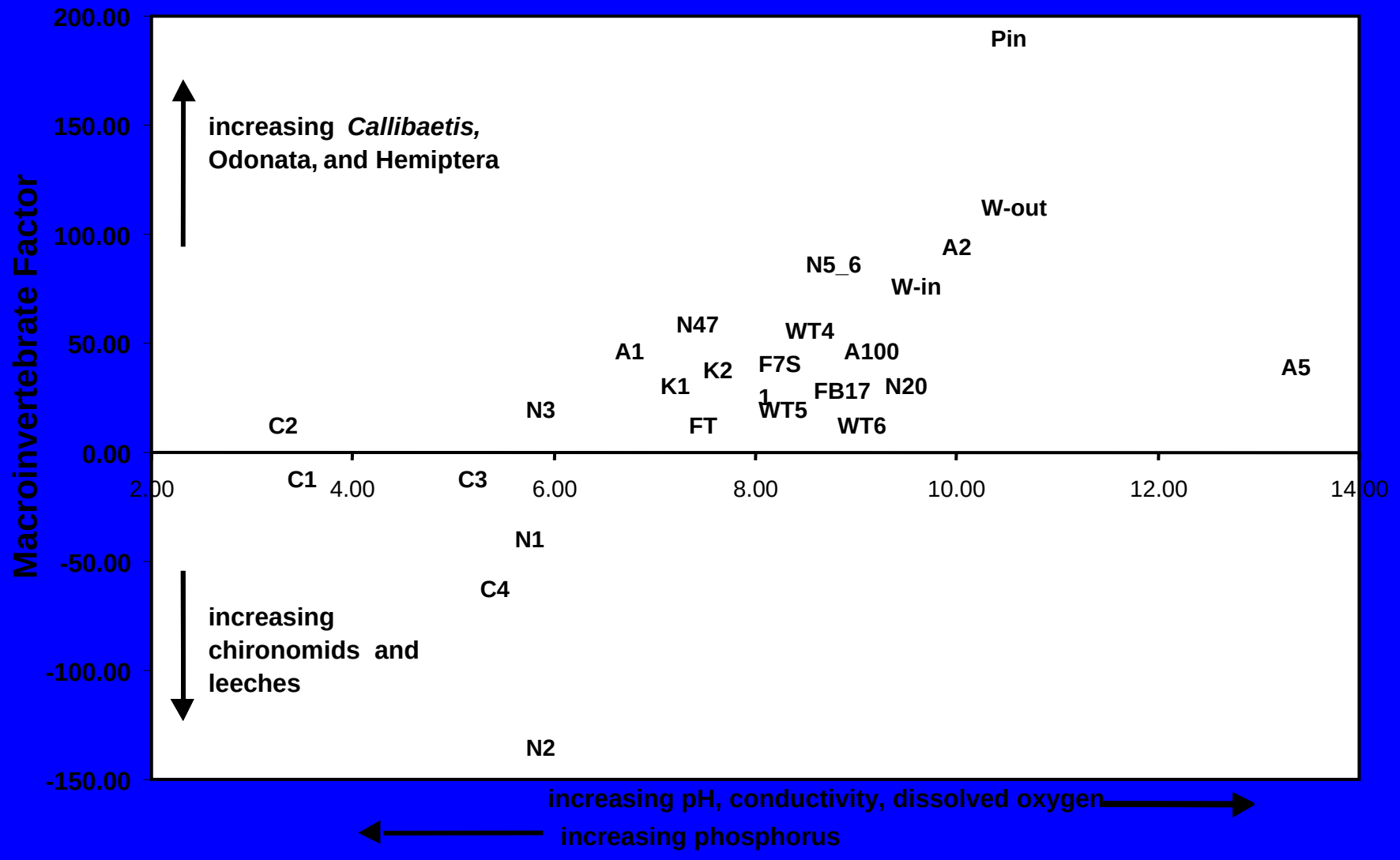
Vegetation Factor Analysis



Vegetation Factor Analysis



Macroinvertebrate Factor Analysis



Chemical Factor

Take Home Message

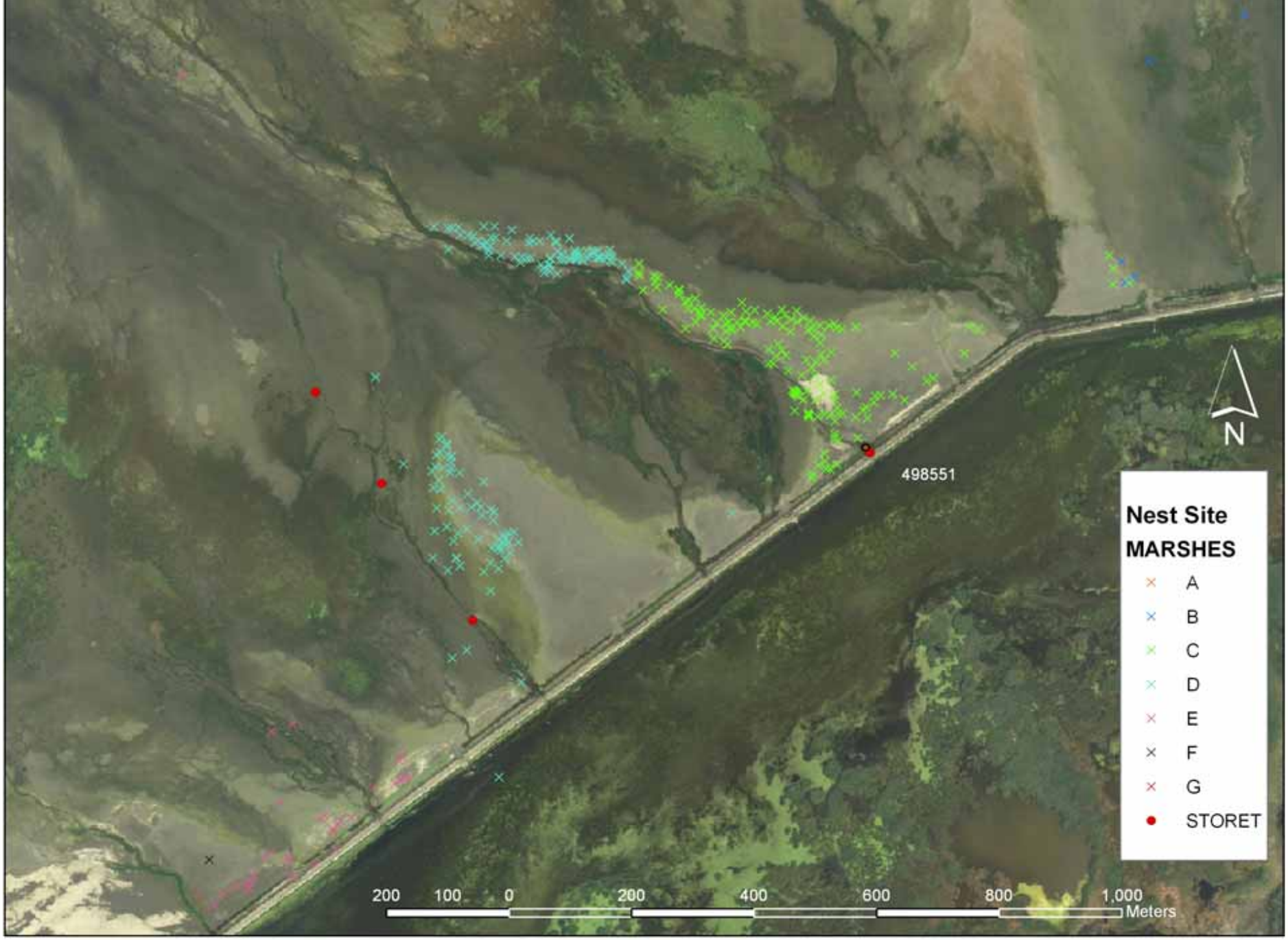
- Analytical method is sensitive enough (we have the right analytical tools) to make the link between ecological function and beneficial use.

Future Work

- Evaluate complete 2004 data set once the rest of the data is available
- Sample 2005
  - late spring (all sites)
  - mid to late summer (all sites)
  - fall (impounded only)
  - Add tissue and soil N isotope analysis
  - Add Soil Nutrients
- Assess independent parameters after factor analysis groupings (MDS)

FARMINGTON BAY TECHNICAL ADVISORY COMMITTEE

- Ann Neville, Wetland Scientist, Manager, ISSR, Kennecott
- Lou Cooper, Environmental Program, Davis County Env. Health
- Dennis Wenger, Wetlands Scientist, Frontier Corporation
- Heidi Hoven, Wetlands Scientist, SWCA
- Wayne Wurtsbaugh, Limnologist, USU
- Amy Defreeze, Wetlands Scientist, US Army Corps of Engineers
- John Cavett, Ornithologist (waterbirds), Weber State U
- Don Paul, Ornithologist (Waterbirds)
- Sam Rushforth, Phycologist, UVSC
- Larry Gray, Entomologist, UVSC
- Sharook Madon, Wetlands Scientist, CH2MHill
- Leland Myers, P.E., Manager, CDSD
- Theron Miller, Limnologist, UDEQ
- Florence Reynolds, SLC Public Utility
- Ella Sorensen, Ornithologist, National Audubon


498551
N
Nest Site
MARSHES
A
B
C
D
E
F
G
STORET
200
100
0
200
400
600
800
1,000
Meters

Comments?