# Nutrient limitation of average summer chlorophyll concentration in the freshwater Delta

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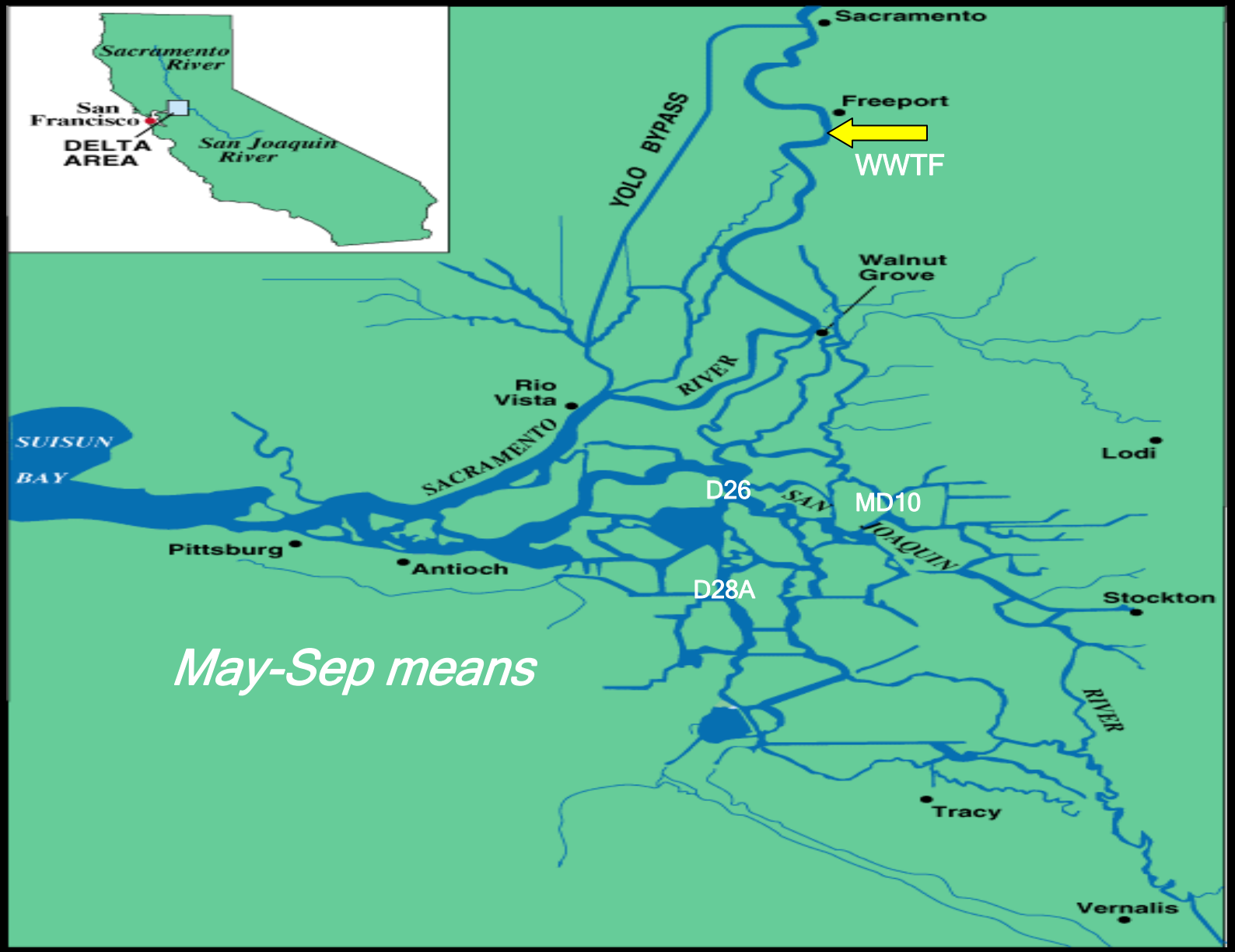
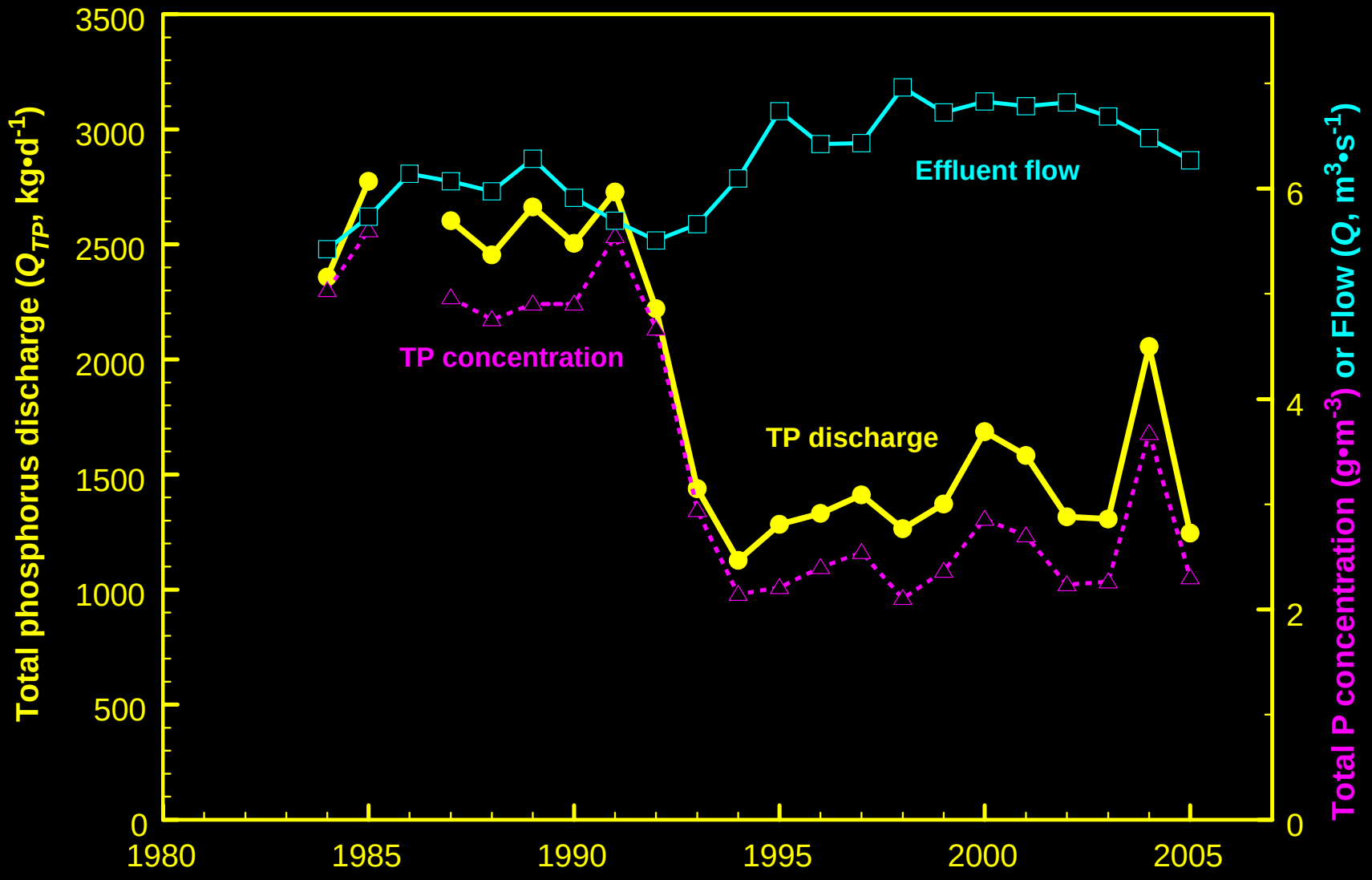
# Outline

- Whole-system response to nutrient reduction
- Mesocosm response to nutrient addition
- Ammonium and chlorophyll
- Management implications

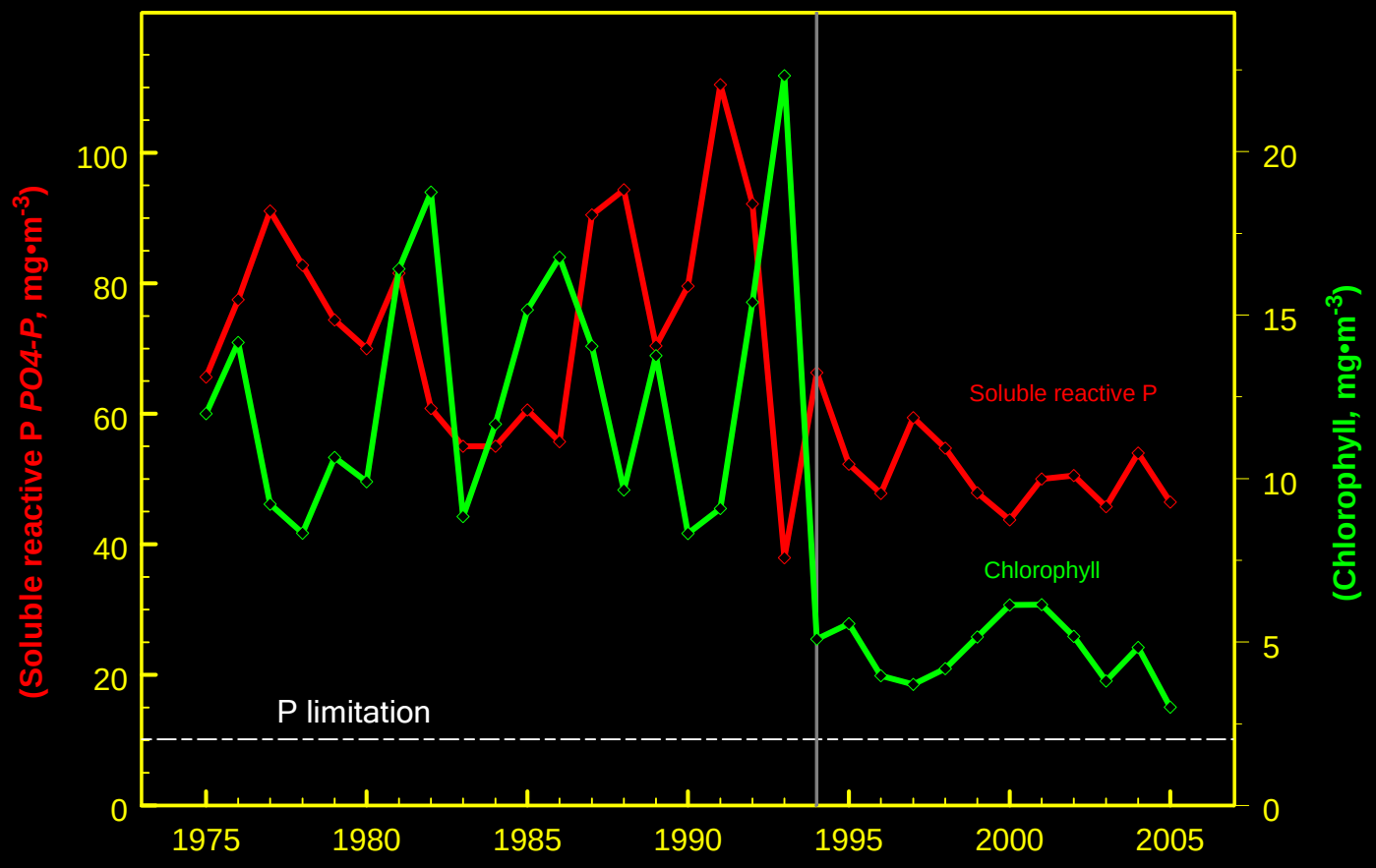
Whole-lake experiments, Experimental Lakes Area, Canada


Sacramento River
San Francisco
DELTA AREA
San Joaquin River
Sacramento
Freeport
WWTF
YOLO BYPASS
Walnut Grove
Rio Vista
RIVER
SACRAMENTO
SUISUN BAY
Lodi
D26
SAN
MD10
JOAQUIN
Pittsburg
Antioch
D28A
Stockton
May-Sep means
RIVER
Tracy
Vernalis

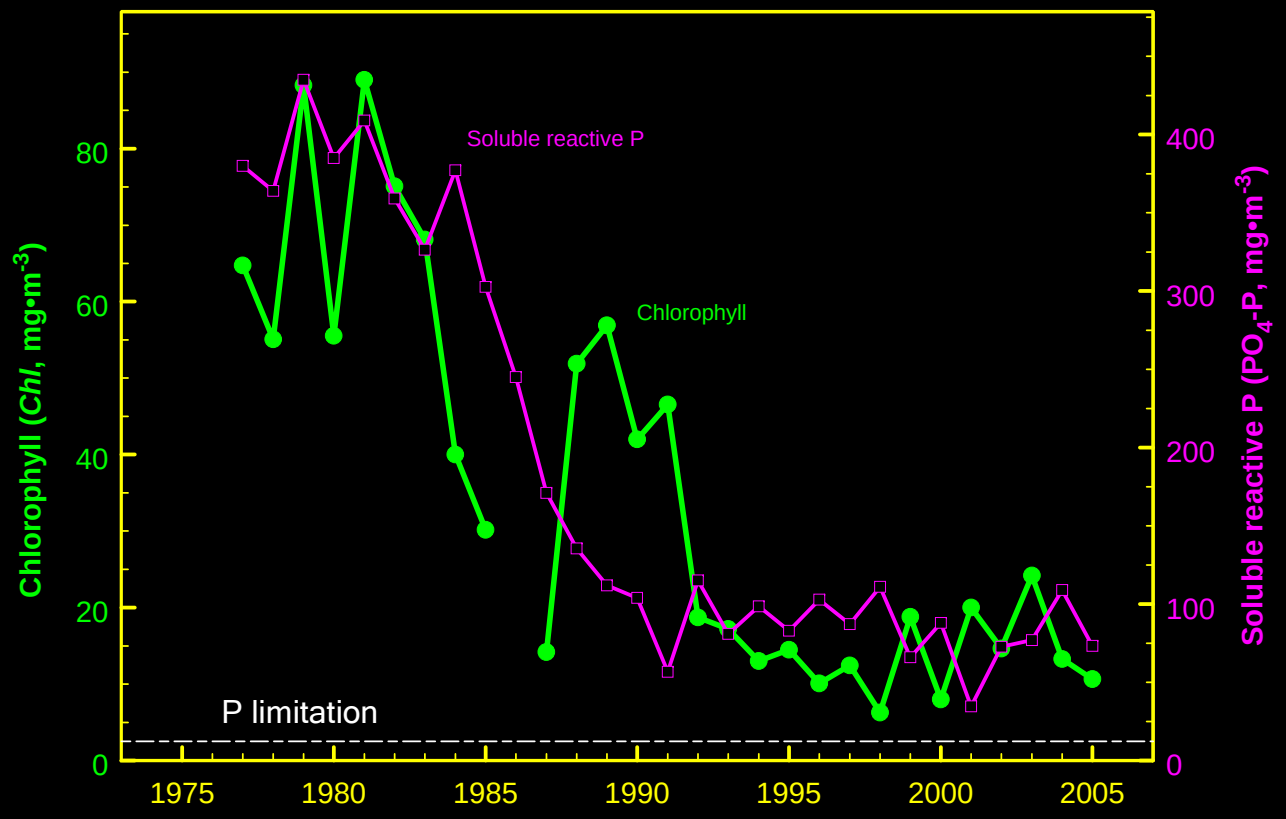
# Step decline in phosphorus loading to Delta



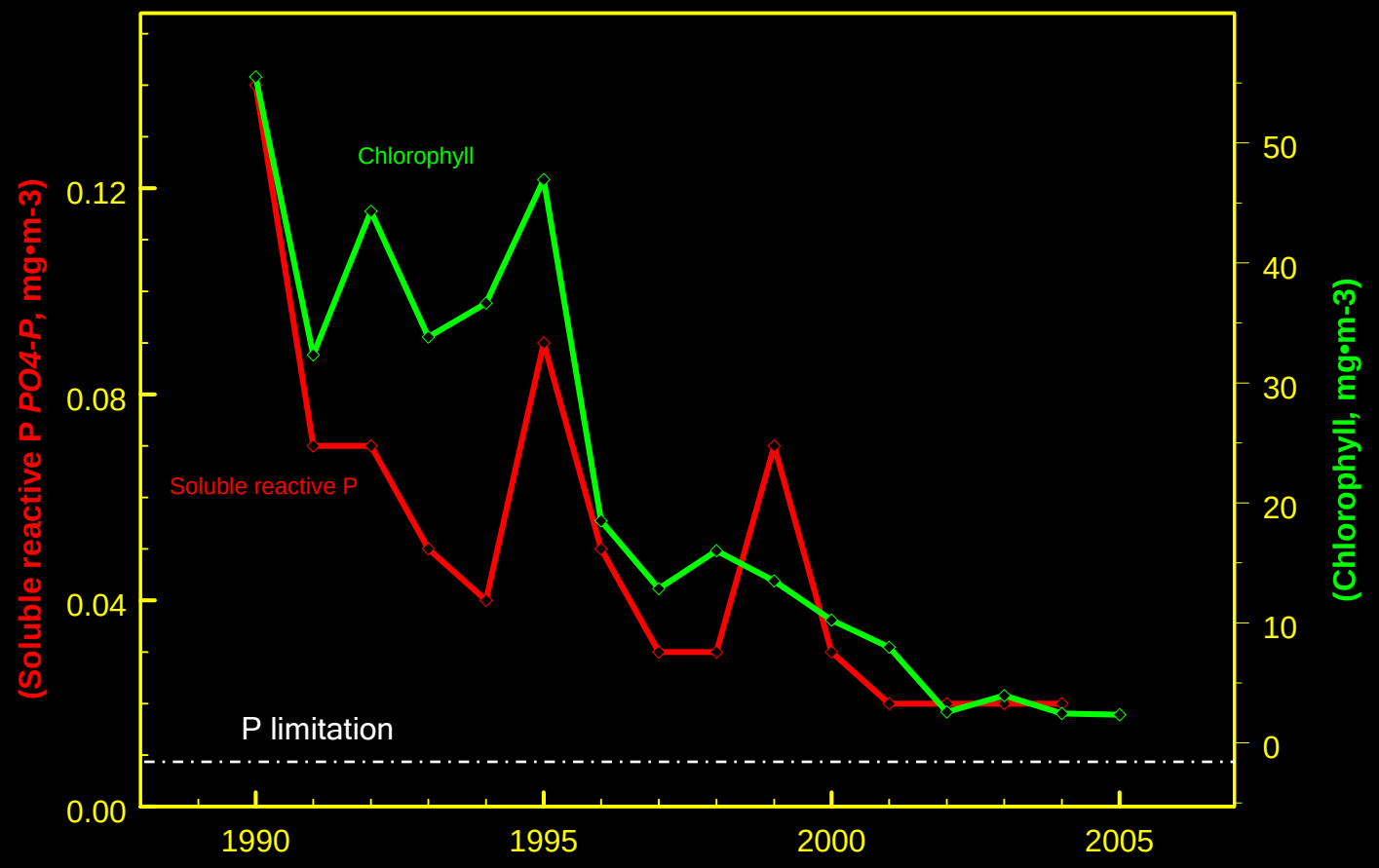
# Delta chlorophyll response to $PO_4$-P reduction



# Rhine River chlorophyll response to $PO_4$-P reduction

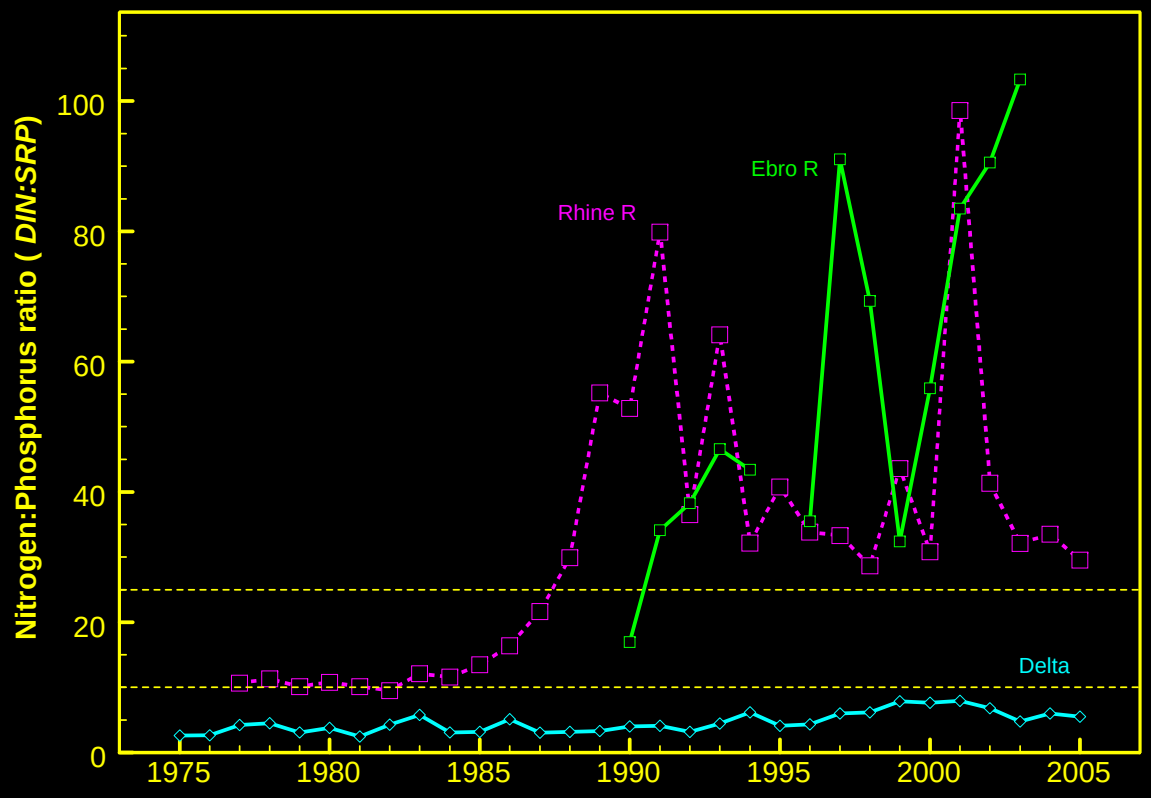


## Ebro River chlorophyll response to $PO_4$-P reduction

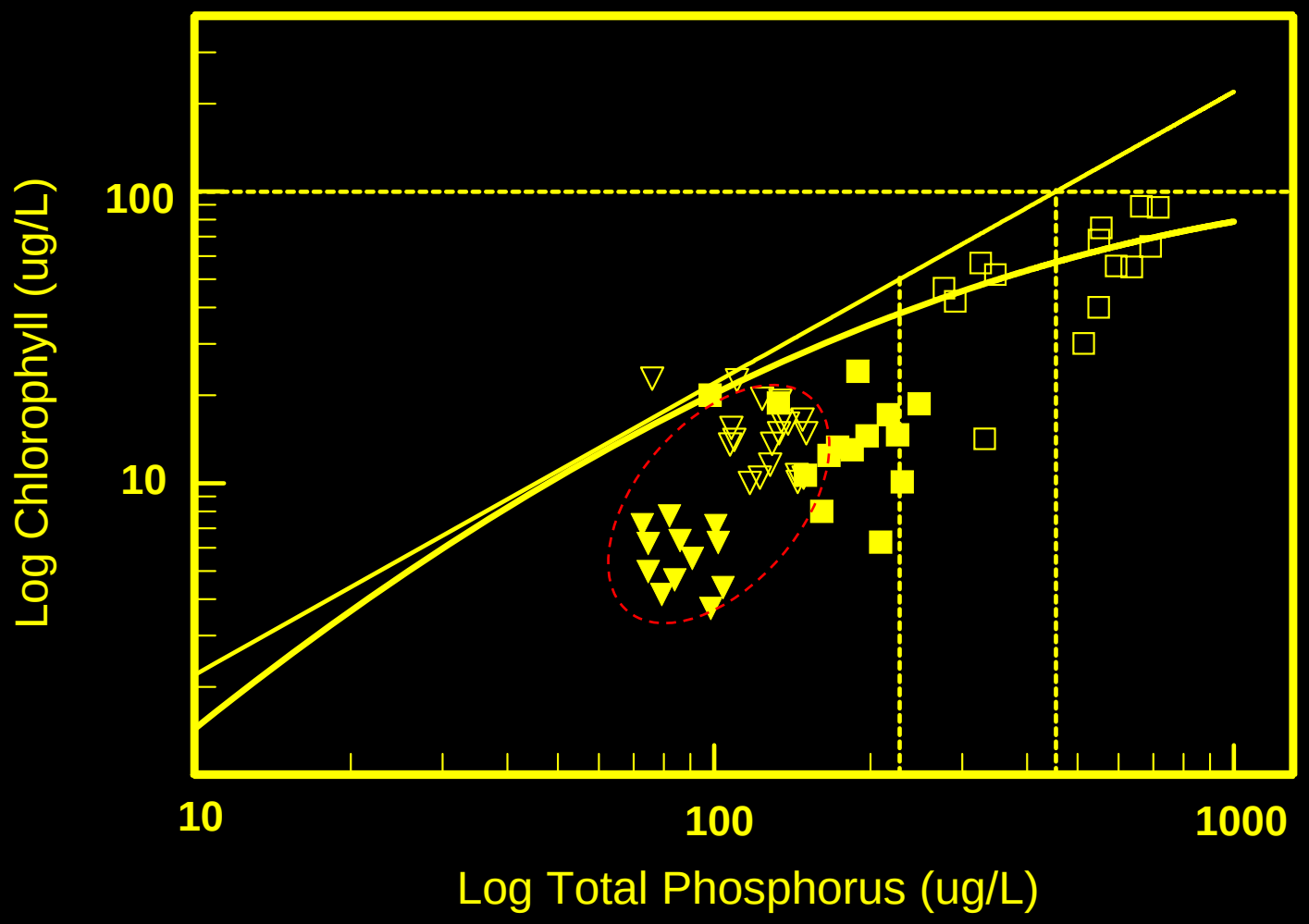



Source: Carles Ibanez, UEA-IRTA, Catalonia, Spain

Increase in ($NO_3$-N + $NH_4$-N):($PO_4$-P) ratio



## Comparison with global TP-Chl relationship for rivers



# Experimental design

- 3 x 3 x 3 reps = 27
- TP = 100-200-400 mg/m$^3$
- N:P = 5-10-20

| Treatment | TP | N:P | TN | Bucket | Tank Position |
|---|---|---|---|---|---|
| 1 | 100 | 5.0 | 500 | 1 | 3 |
| | | | | 2 | 8 |
| | | | | 3 | 7 |
| 2 | 200 | 5.0 | 1000 | 4 | 16 |
| | | | | 5 | 19 |
| | | | | 6 | 2 |
| 3 | 400 | 5.0 | 2000 | 7 | 27 |
| | | | | 8 | 11 |
| | | | | 9 | 10 |
| 4 | 100 | 10.0 | 1000 | 10 | 23 |
| | | | | 11 | 24 |
| | | | | 12 | 13 |
| 5 | 200 | 10.0 | 2000 | 13 | 21 |
| | | | | 14 | 15 |
| | | | | 15 | 5 |
| 6 | 400 | 10.0 | 4000 | 16 | 22 |
| | | | | 17 | 18 |
| | | | | 18 | 12 |
| 7 | 100 | 20.0 | 2000 | 19 | 25 |
| | | | | 20 | 9 |
| | | | | 21 | 1 |
| 8 | 200 | 20.0 | 4000 | 22 | 6 |
| | | | | 23 | 20 |
| | | | | 24 | 26 |
| 9 | 400 | 20.0 | 8000 | 25 | 4 |
| | | | | 26 | 14 |
| | | | | 27 | 17 |

# Day 5

In vivo fluorescence response to nutrient addition (Day 5)

| TP \ N:P | 5 | 10 | 20 |
|---|---|---|---|
| 100 | 9.3 | 21.8 | 21.9 |
| 200 | 22.4 | 36.8 | 37.7 |
| 400 | 37.6 | 42.4 | 37.4 |

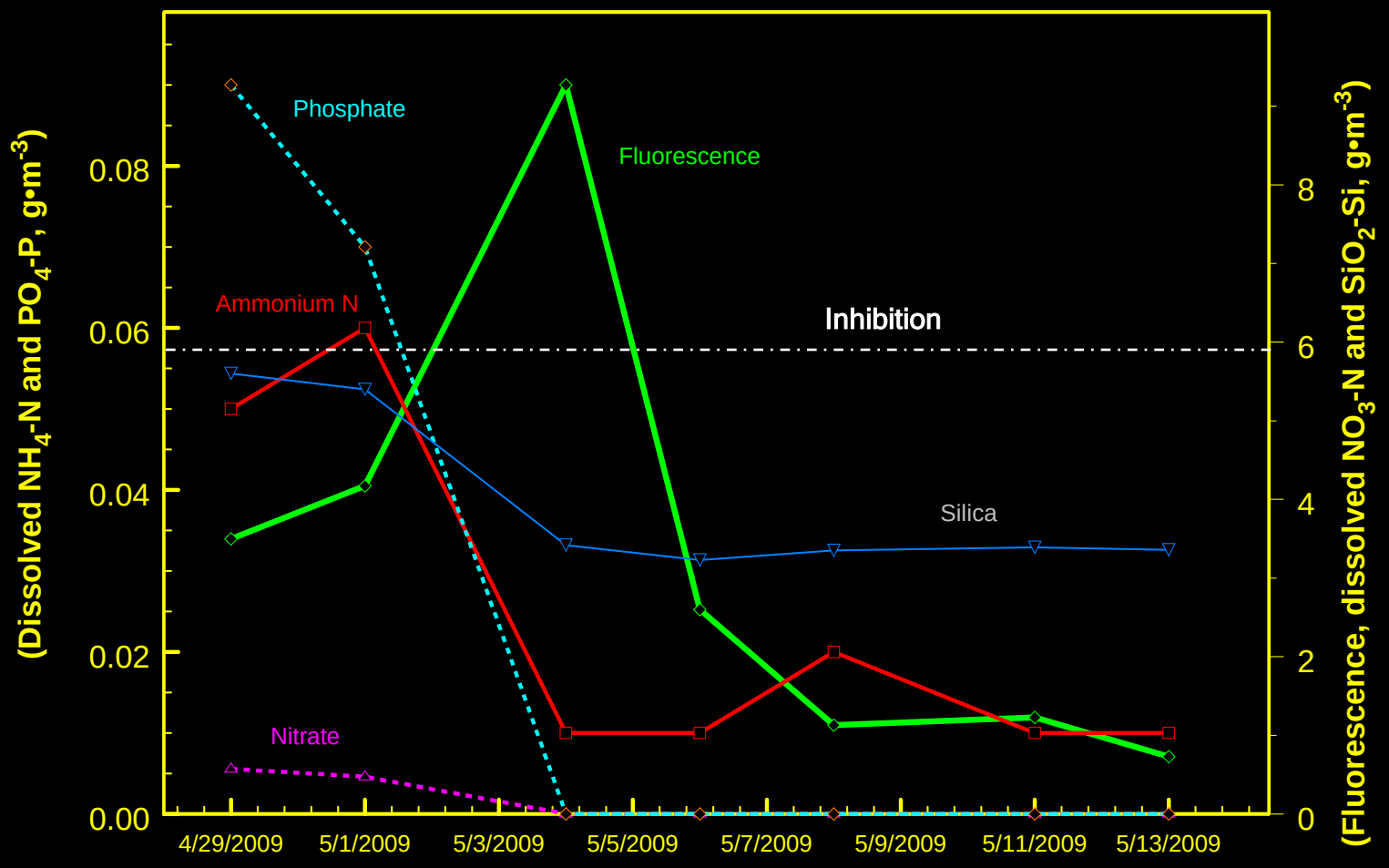
Increases with TP up to ~400 mg/m$^3$

Increases with TN up to N:P = 10

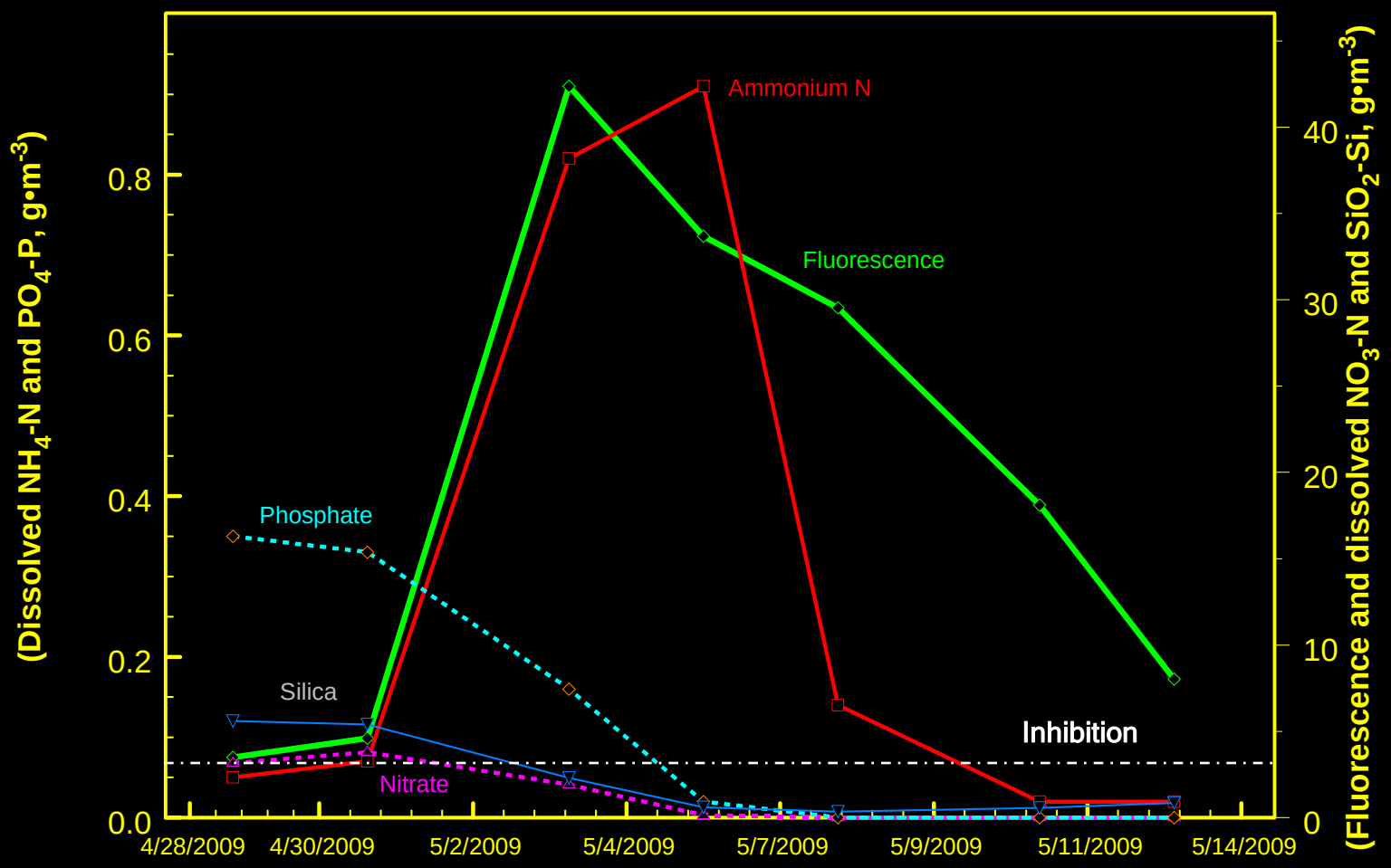
| | | ANOVA | |
|---|---|---|---|
| *Source* | *Type III SS* | *F value* | *p* |
| *TP* | 1389 | 20.8 | 0.0001 |
| *TN* | 706 | 10.6 | 0.0035 |
| *TP x TN* | 668 | 10.0 | 0.0043 |

| | General Linear Model | | |
|---|---|---|---|
| *Parameter* | *Estimate* | *t Value* | *p* |
| Intercept | -14.4 | -1.65 | 0.1123 |
| *TP* | 131.7 | 4.57 | 0.0001 |
| *TN* | 11.0 | 3.25 | 0.0035 |
| *TP x TN* | -26.5 | -3.17 | 0.0043 |

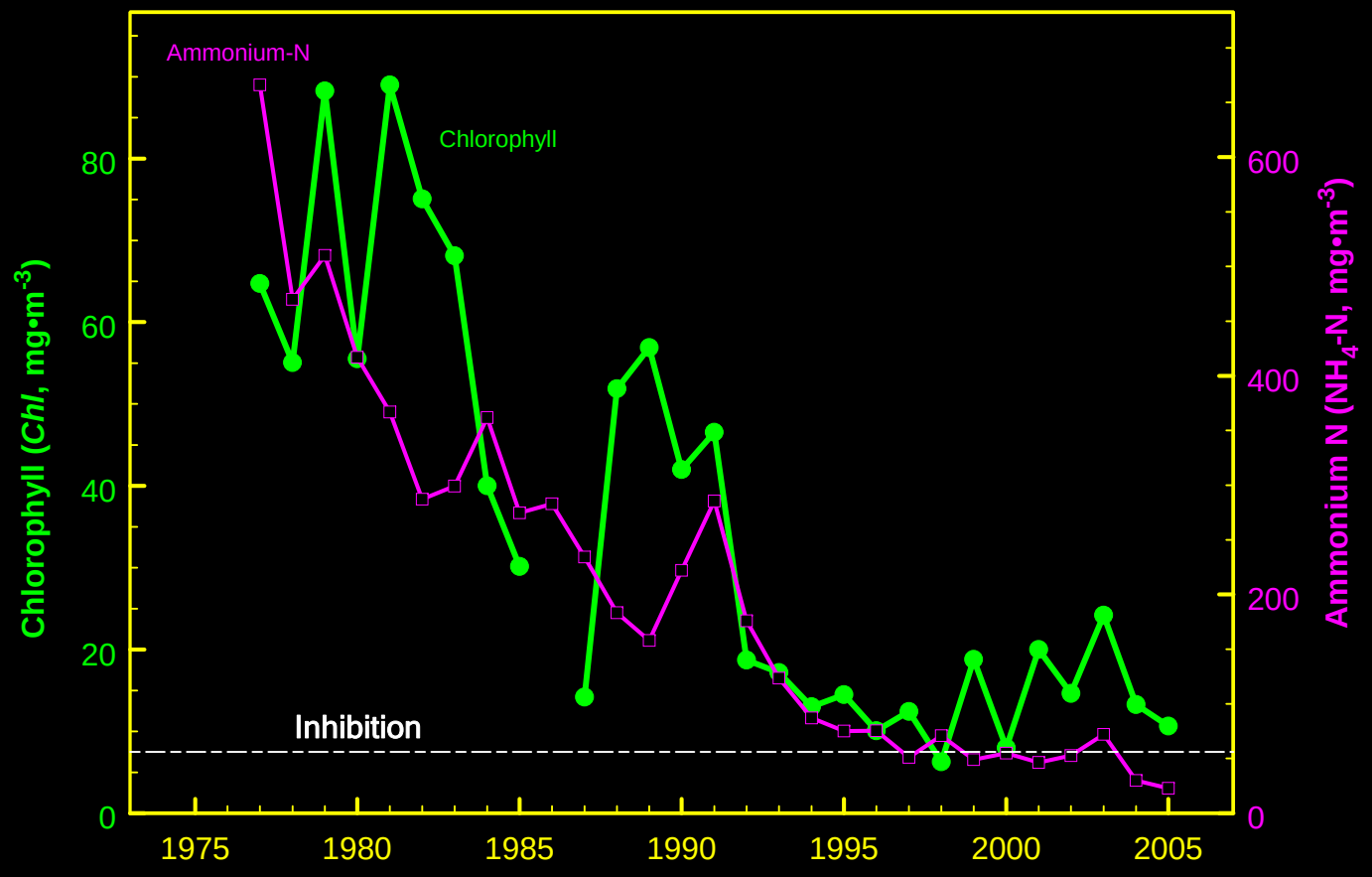
# Treatment 1 (Control): TP=0.1, TN=0.5 g/m$^3$



# Treatment 6: TP=0.4, TN=4.0 g/m$^3$



# Rhine River $NH_4$-N and Chlorophyll

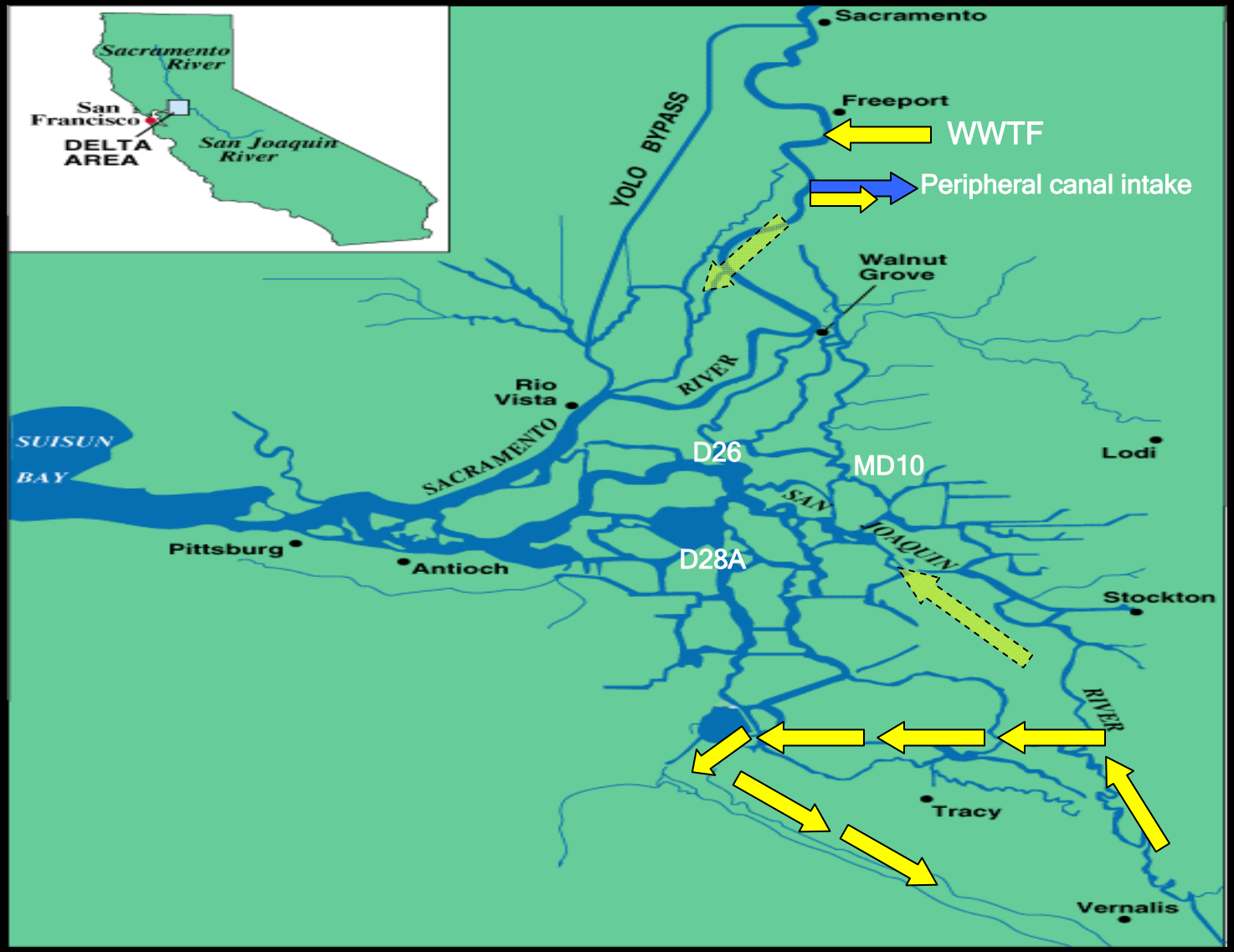


# Conclusions

- Whole-system ‘experiments’ indicate that Chl responds to change in nutrient supply
- Responses are consistent with global TP-Chl model
- Mesocosm experiment suggests sensitivity to P and N (N:P = 10)
- High $NH_4$-N does not preclude high Chl in rivers
- Actions that increase nutrient supply to Delta should increase its Chl

**So what?**

# Management implications



Questions?