All data and analyses are provisional and subject to revision

Influence of nutrients on agricultural stream ecosystems: integrating biomonitoring and experimental information

In cooperation with:

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Idaho State University

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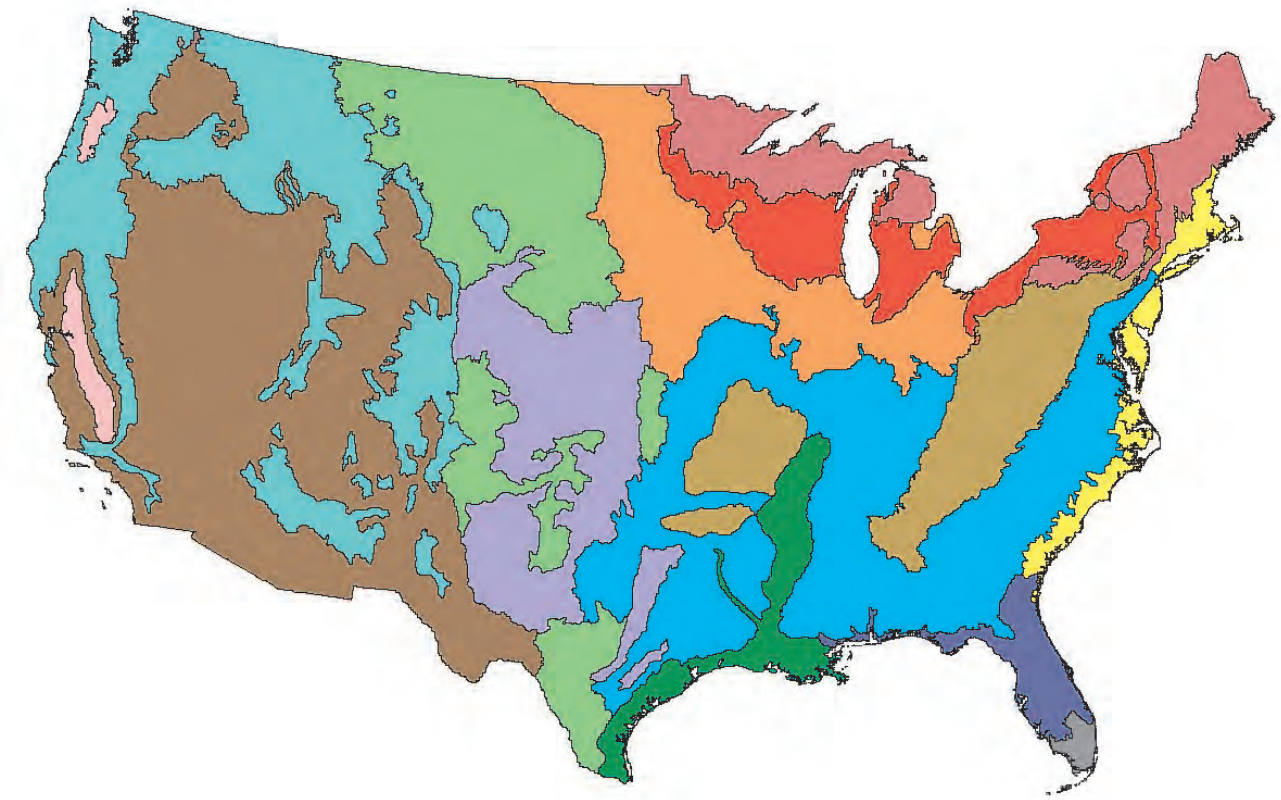
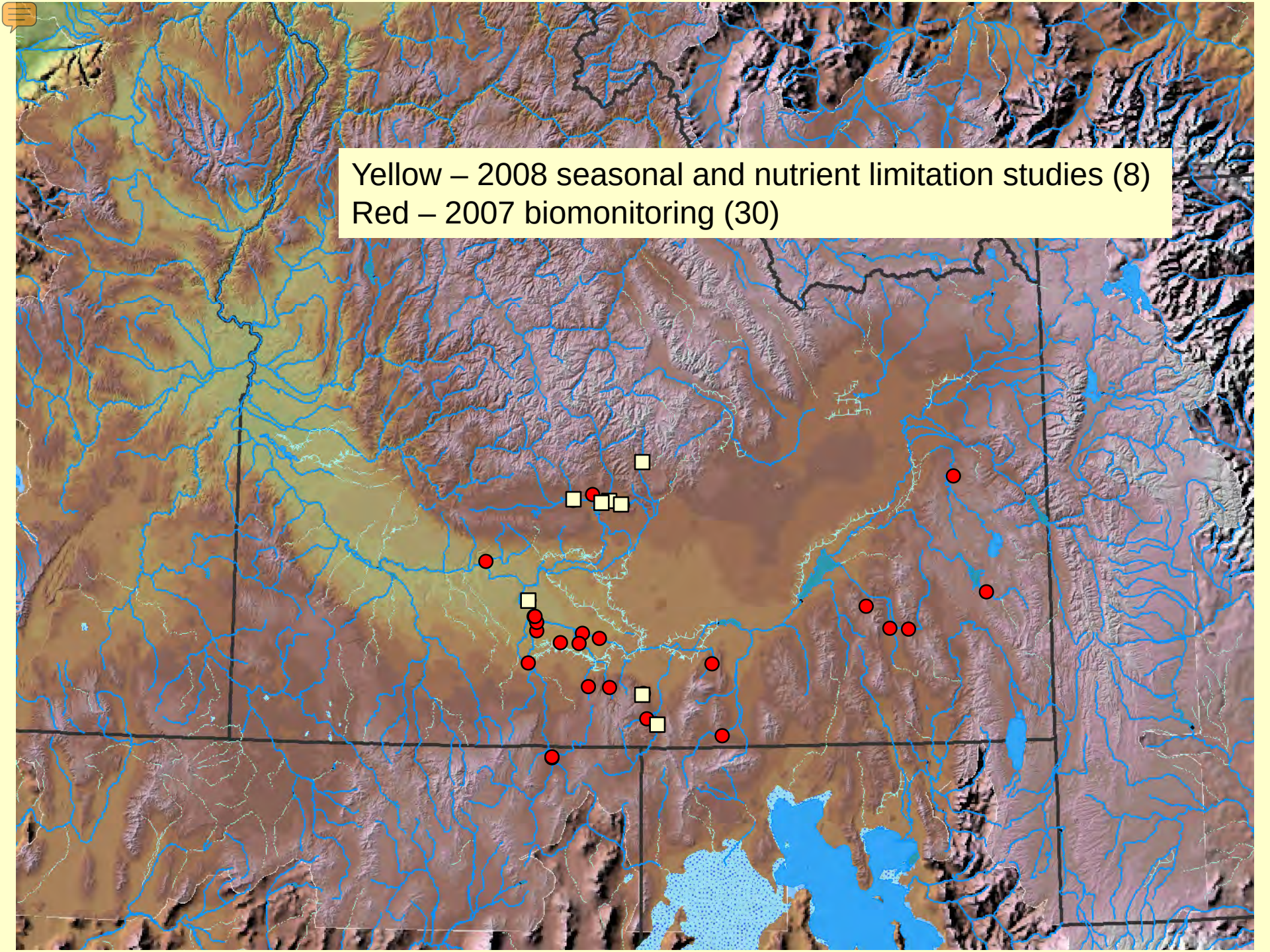


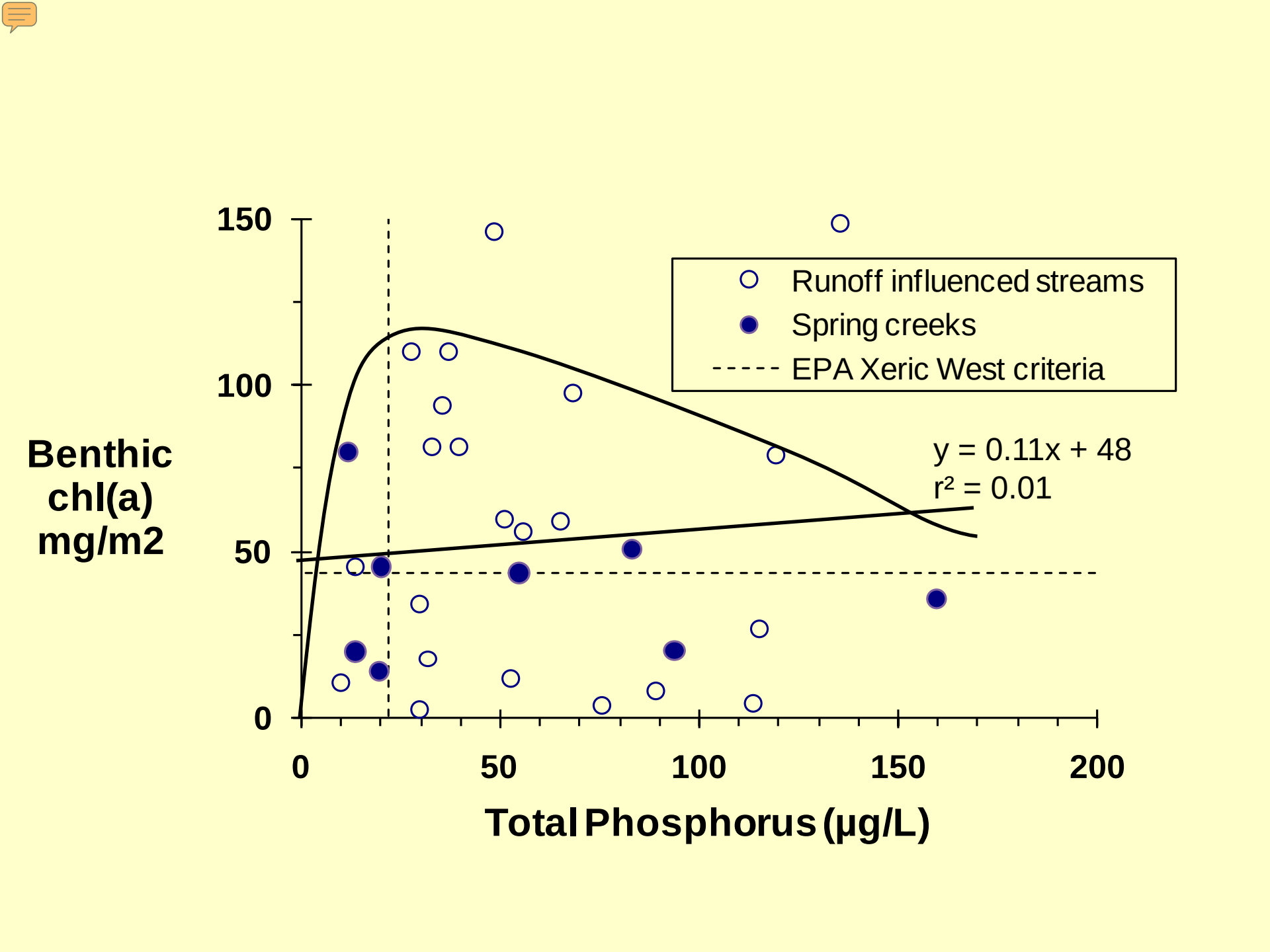
- **EPA developed 14 ecoregional nutrient criteria for total P, total N, seston chlorophyll, and turbidity.**
- **Not effect based, based on percentiles of found data**

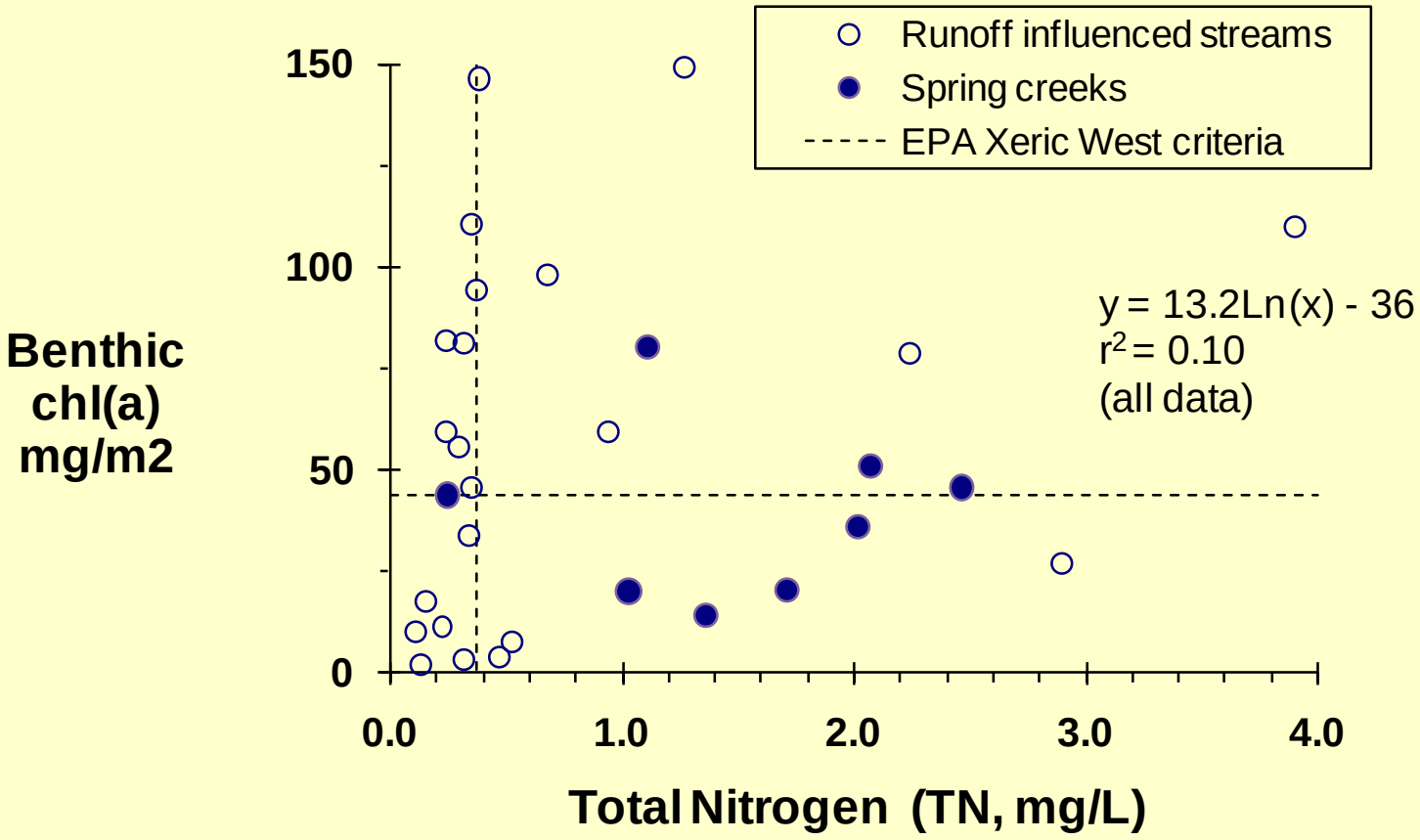
Nutrients (water and sediment) biological, and habitat co-occurrences


Yellow – 2008 seasonal and nutrient limitation studies (8)
Red – 2007 biomonitoring (30)

Conditions ranged from wasteways to pristine

Included several clear spring creeks

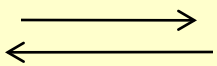

Benthic chl(a) mg/m2
150
100
50
0
0
50
100
150
200
Total Phosphorus (µg/L)
Runoff influenced streams
Spring creeks
EPA Xeric West criteria
y = 0.11x + 48
r² = 0.01


Runoff influenced streams
Spring creeks
EPA Xeric West criteria
y = 13.2Ln(x) - 36
r2 = 0.10
(all data)
Benthic chl(a) mg/m2
150
100
50
0
0.0
1.0
2.0
3.0
4.0
Total Nitrogen (TN, mg/L)

Theoretically important variables in relation to algal production

Many correlated, surrogate, or derivative variables:

- **Light**
  - Solar pathfinder
  - Canopy cover
  - Turbidity, susp. seds
- **Major Nutrients**
  - TP, PO_4, TN, DIN
- **Current**
  - Velocity
  - Discharge
  - Gradient
  - Flow Stability
  - Shear stress
- **Grazers**
- **Ionic strength of overlying water**
  - Specific conductance
  - Alkalinity
- **Temperature**



Response variables:

- **Algae Biomass**
  - Periphyton chlorophyll (a) biomass
  - Periphyton total biomass (AFDM)
  - Seston chl(a)
- **Algal species composition**
  - Green algae
  - Diatoms
  - Indicator taxa
- **Macroinvertebrates**
  - Biomass
  - Composition
- **Rooted aquatic plants**
  - Biomass, % areal cover, species
- **Organic Carbon**
  - Dissolved, particulates

Observational Field studies

- Algae, nutrients, flow, temperature, light, channel features
- Whole stream metabolism (processing or transporting nutrients)
- Nutrients in sediments and rooted aquatic weeds

Manipulative Lab and Field studies

•Nutrient limitation testing with site water and with green algae, periphyton, and duckweed

•Attempt to find nutrient response thresholds for nutrient limitation or saturation

• Test in situ whether N, P, or N+P in combination are limiting nutrients

Limitation Experiments: Low N stream

Total P ~ 20 – 35 µg/L (0.020 to 0.035 mg/L)

Total N ~ 40 to 400 µg/L (0.04 to 0.4 mg/L)

Big Cottonwood Creek

Pristine rangeland watershed: no diversions, roads, cows, or motorized access

Low P stream

Total P ~ 0.007 to 0.015 mg/L (7 to 15 µg/L)

Total N ~ 1.0 mg/L (1000 µg/L)

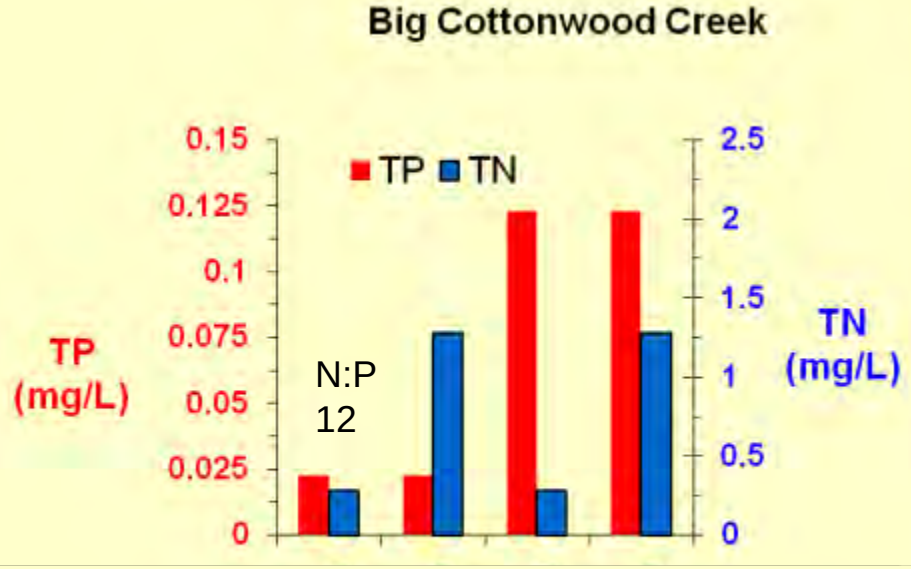
- **Stalker Creek**

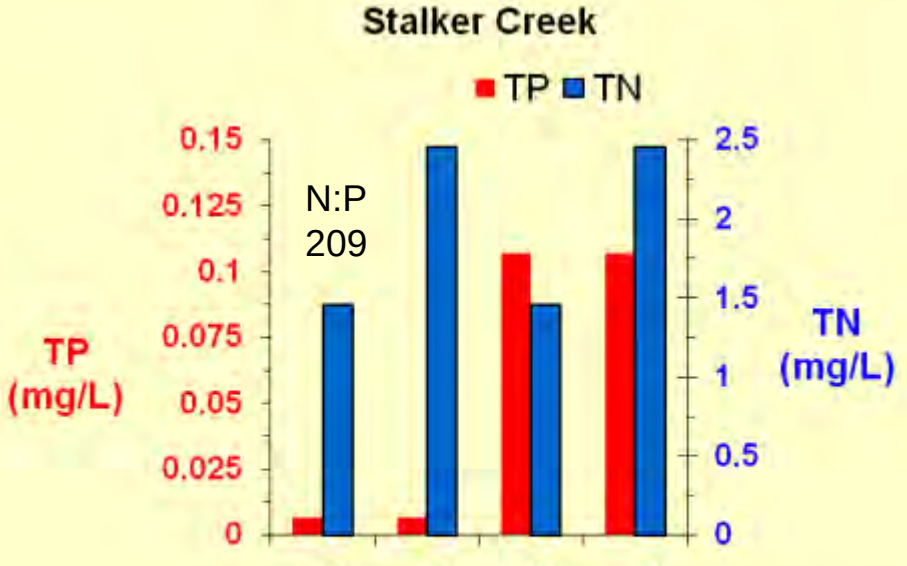
Few overt disturbances; located on The Nature Conservancy's Silver Creek Preserve

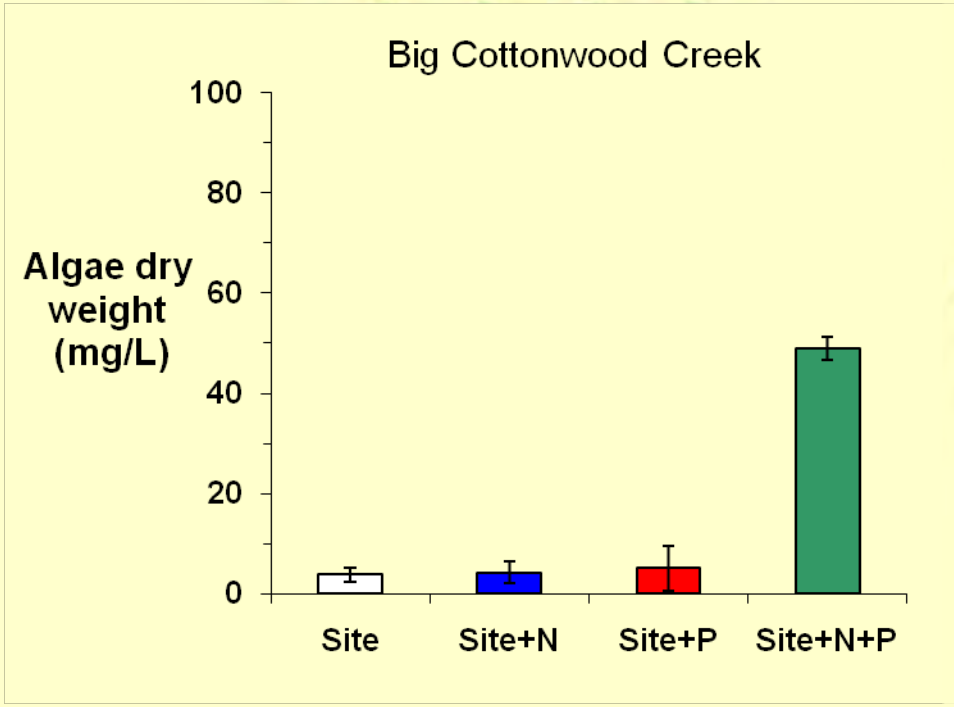
Sestonic green algal nutrient limitation assays

- **Variation on EPA's whole effluent test (WET)**
- **Green algae *Pseudokirchneriella subcapitata* (formerly *Selenastrum capricornutum*)**
- **Site water spiked with N, P or both**
- **12-14 days test duration**

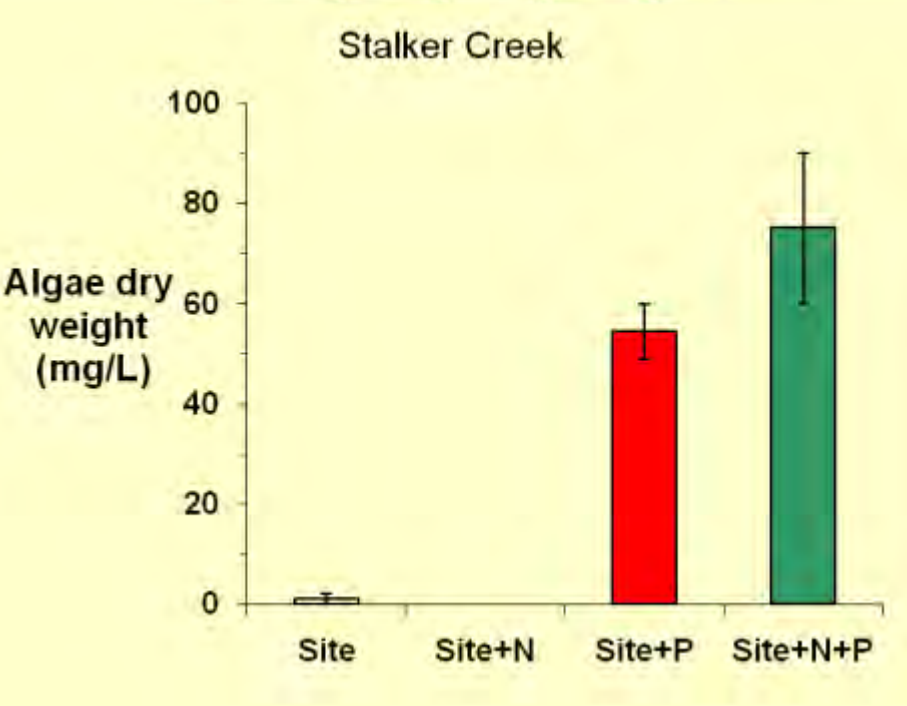
Suzanne Pargee, GEI Consultants-Chadwick Ecological, Littleton, CO





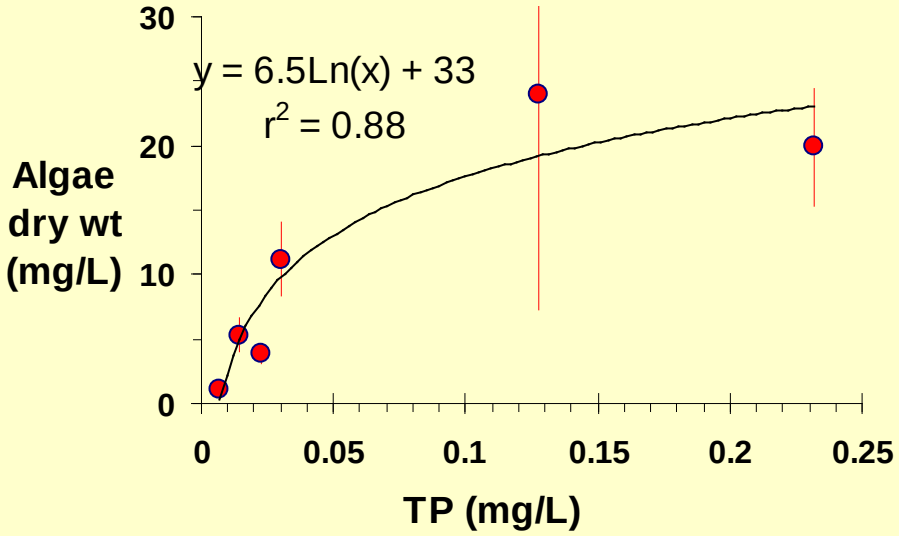


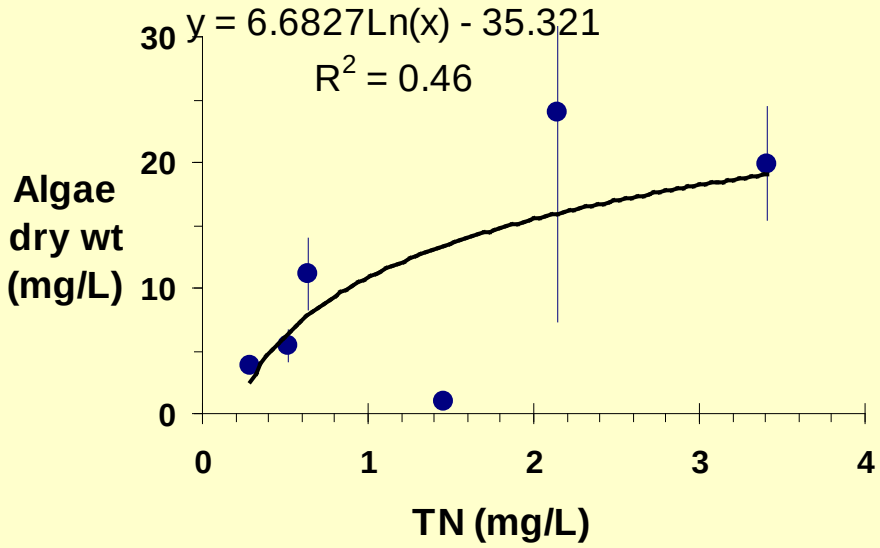
N+P co-limited



P limited

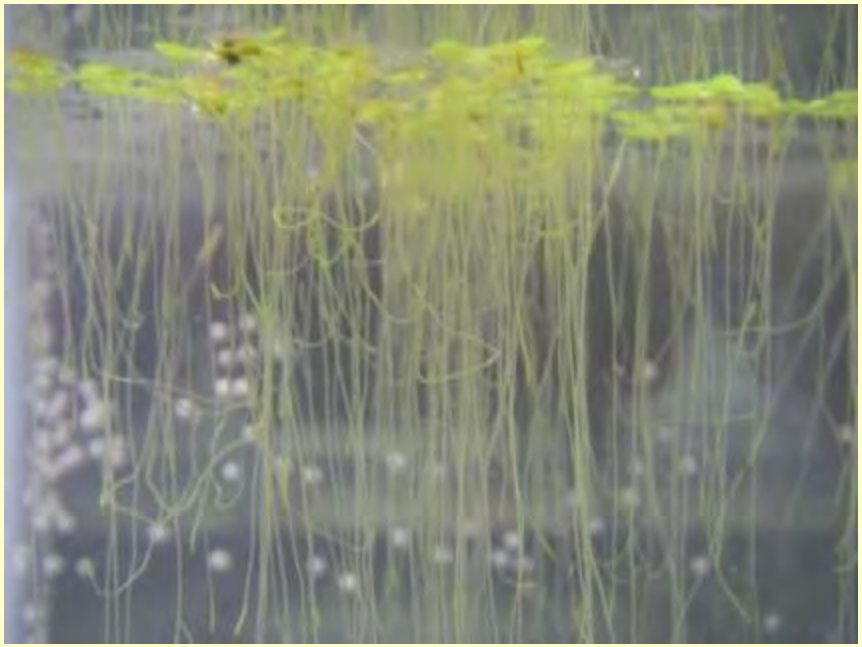
Green algae growth in ambient site water bottle assays



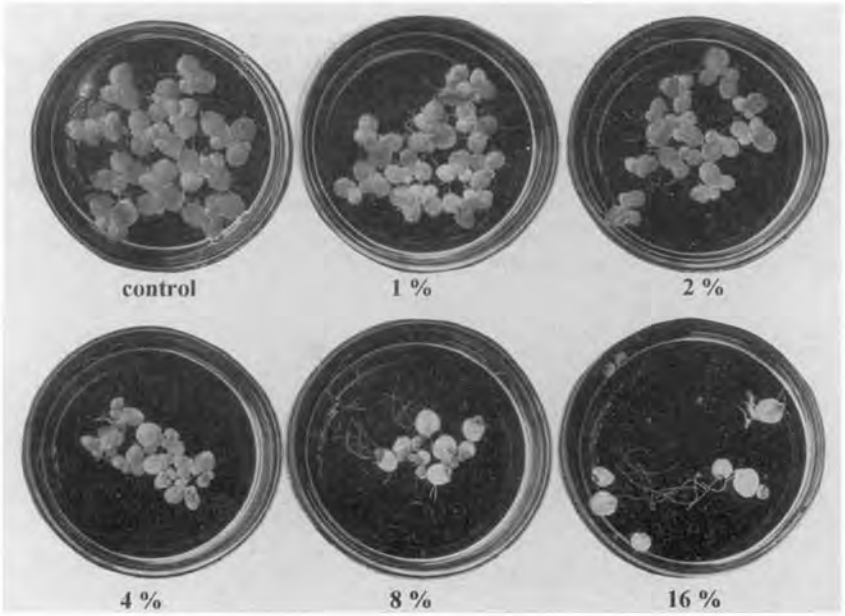


Tests with duckweed, *Lemna minor*, and native epiphytes

Duckweed ubiquitous in slow water areas, but treated as a model aquatic plant



Duckweed, aquaria at 10-days



Duckweed, typical test method

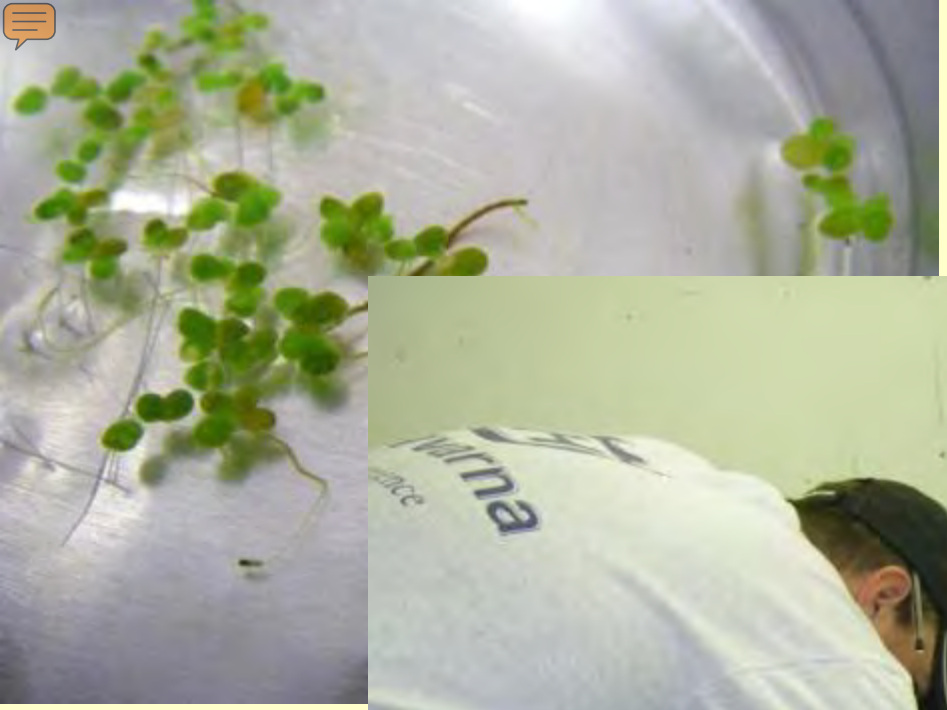
Fig. 4: Photographs of *Spirodela polyrhiza* after a 7-day exposure to pH_{stat}4-eluate

Schadbilder von *Spirodela polyrhiza* nach 7tägiger Belastung mit Eluat aus dem pH_{stat}-Test (pH_{stat} = 4)

Acta hydrochim. hydrobiol. *25* (1997) 3 135 – 140

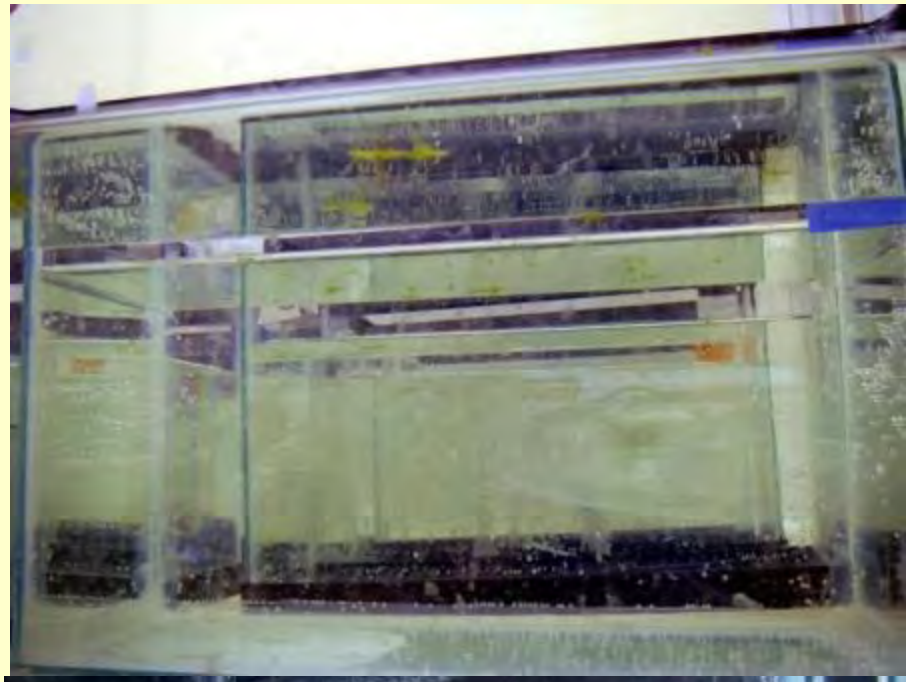
Sallenave and Fomin, 1997


WATER LINES



Duckweed tests

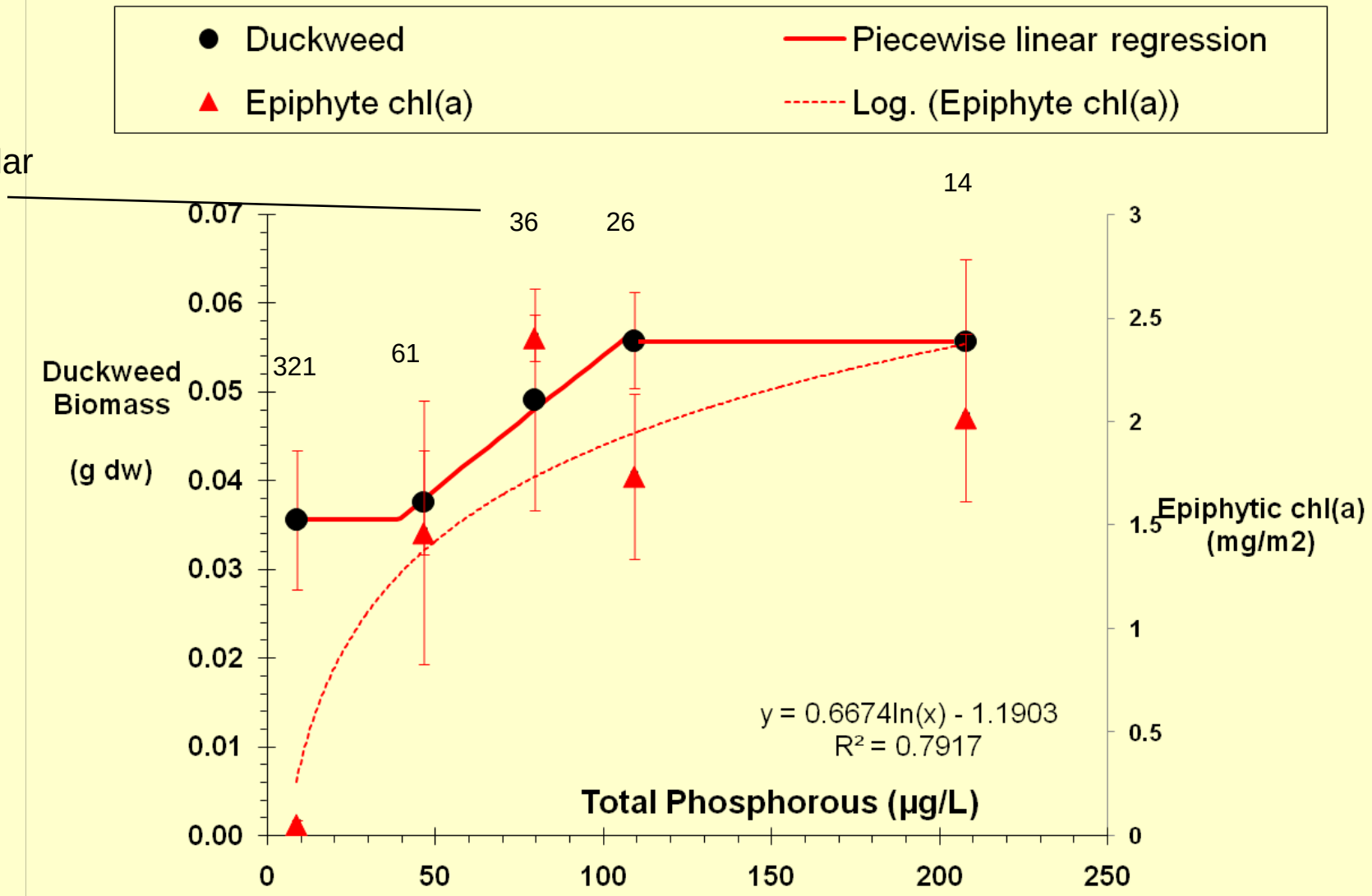
- Day 1 – roots barely visible



- Growth at day 11

Periphyton response: Epiphytic algae community was introduced with the duckweed


FIRST AID

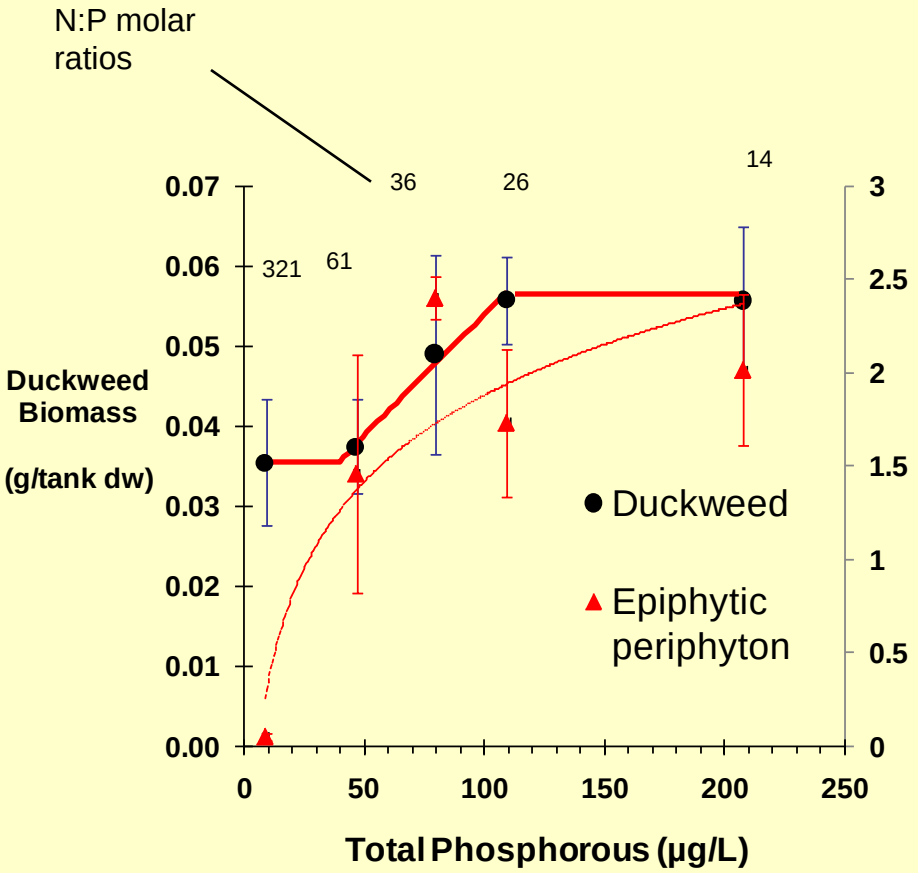


Using piecewise linear regression

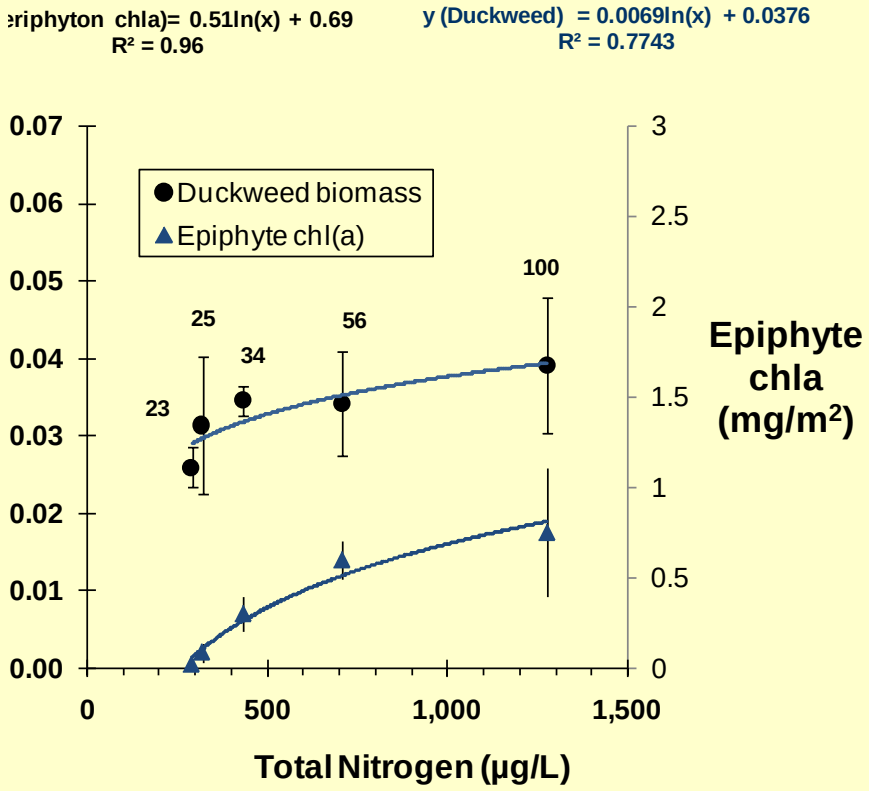
EC20 68 (31-149) µg/L TP

where EC20 = a 20% increase in duckweed biomass

Less growth with N, but adding N still increased duckweed and algae biomass even though P should have been limiting

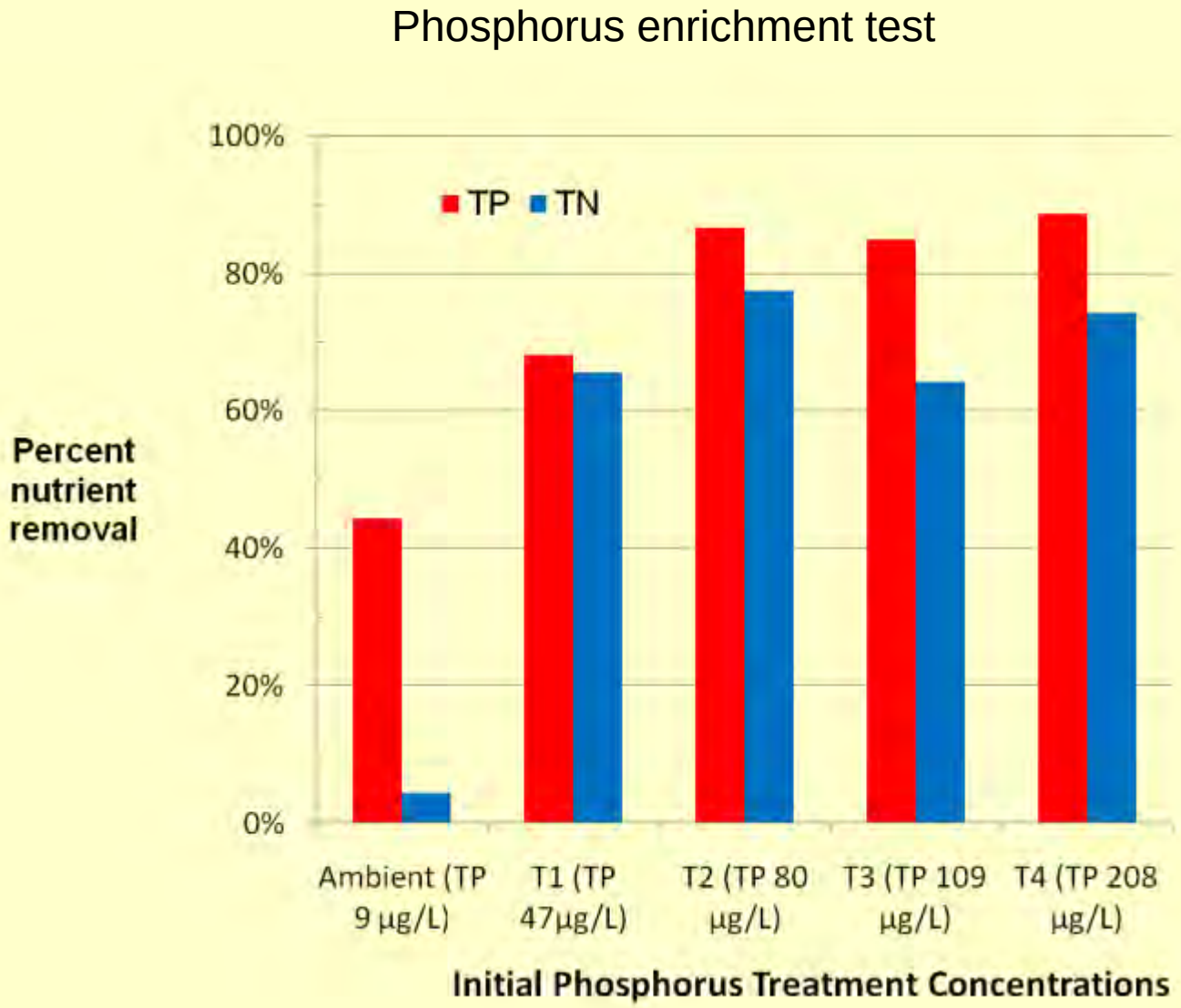


Initial ambient TN 1277 µg/L all treatments

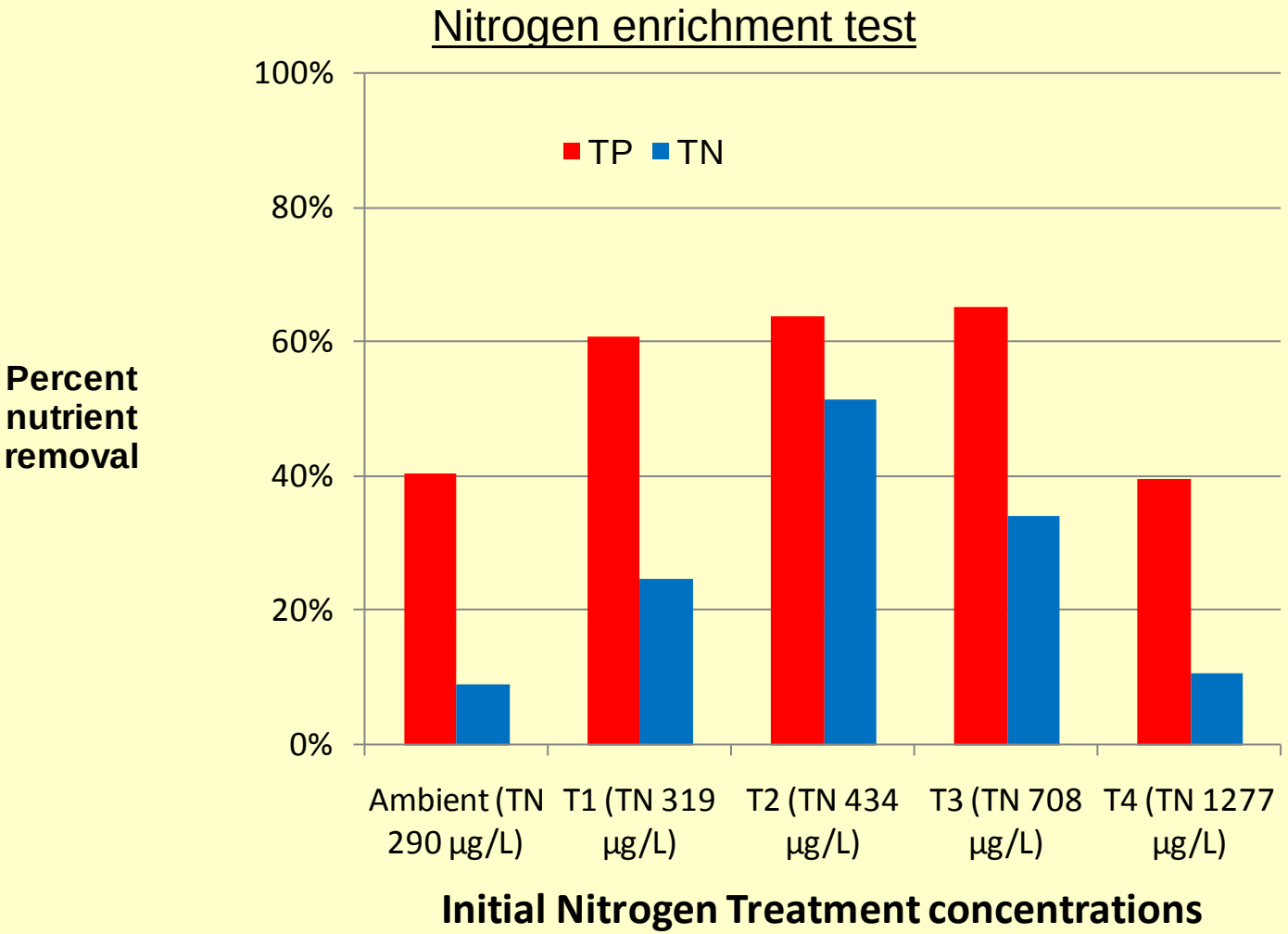


Initial ambient TP 28 µg/L all treatments

Up to 90% of the nutrients were removed by the plants over the 11 day test!



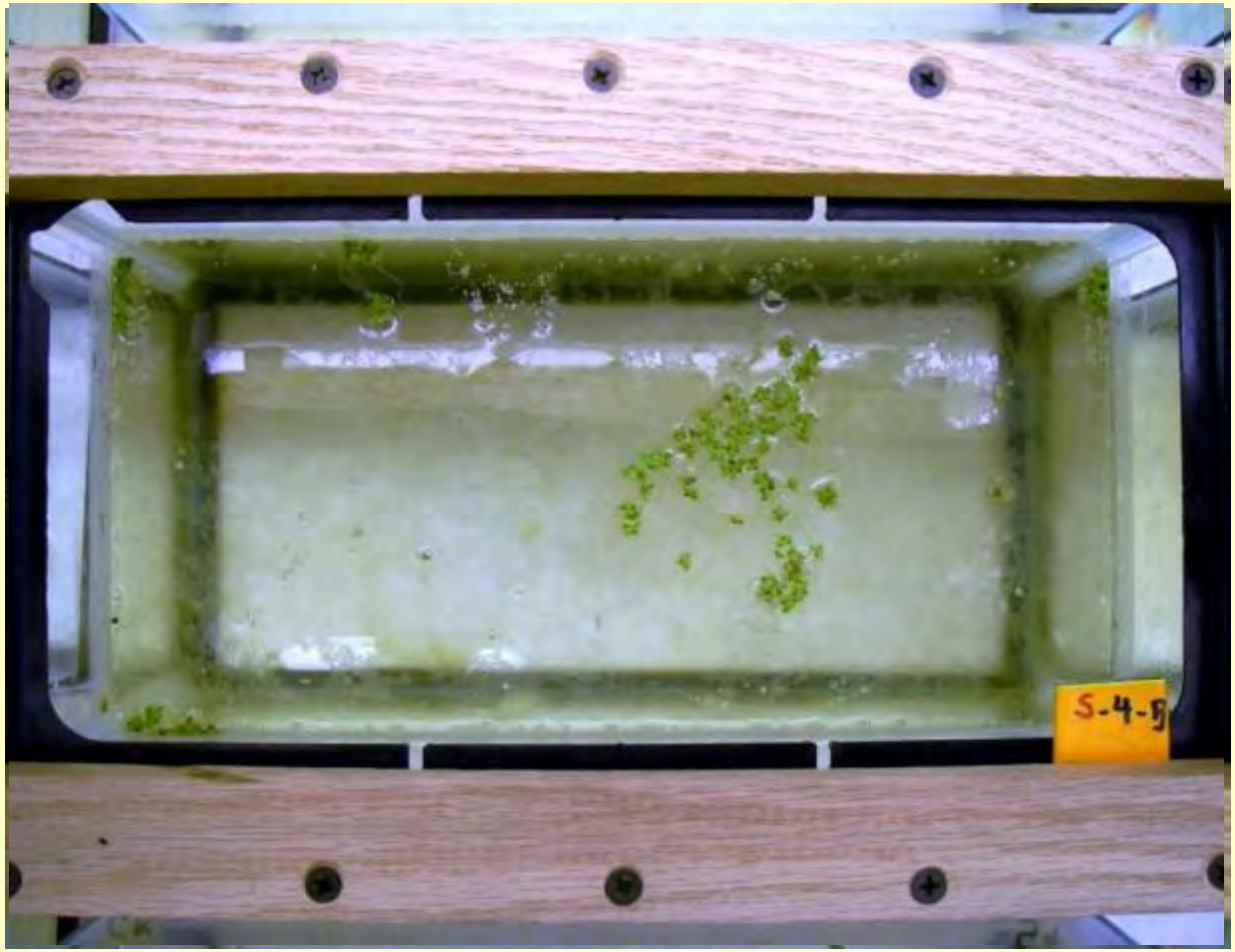
Even in the low growth N experiment, up to 50 to 60% of N and P respectively were removed



(Initial ambient TP was 28 µg/L in all treatments)

Initial plant loading

Growth at 11-days



In stream benthic periphyton limitation experiments with nutrient diffusing substrates

Red – Phosphorus (P), Blue – Nitrogen (N), Green – N+P, White - controls

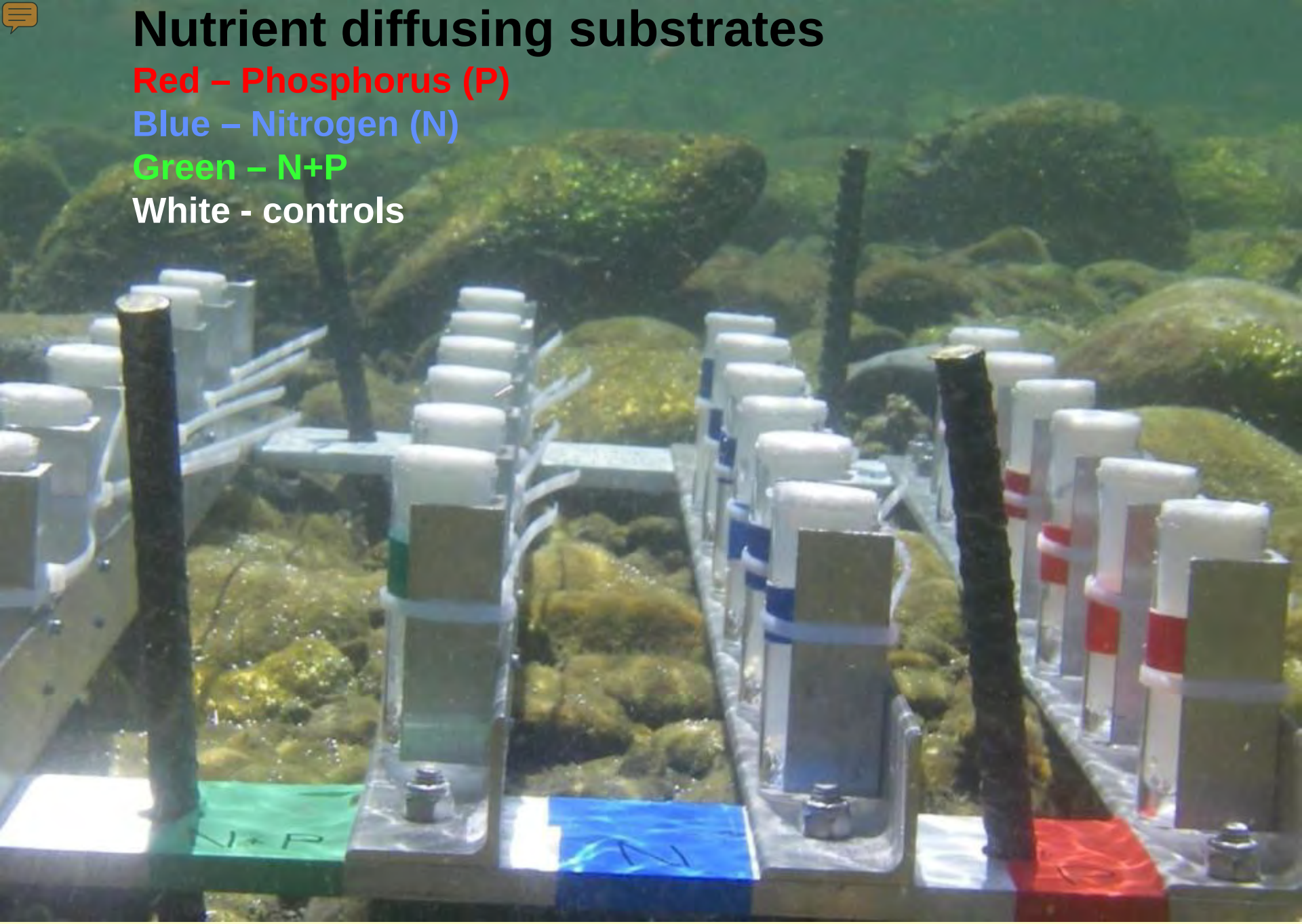
Nutrient diffusing substrates

Red – Phosphorus (P)

Blue – Nitrogen (N)

Green – N+P

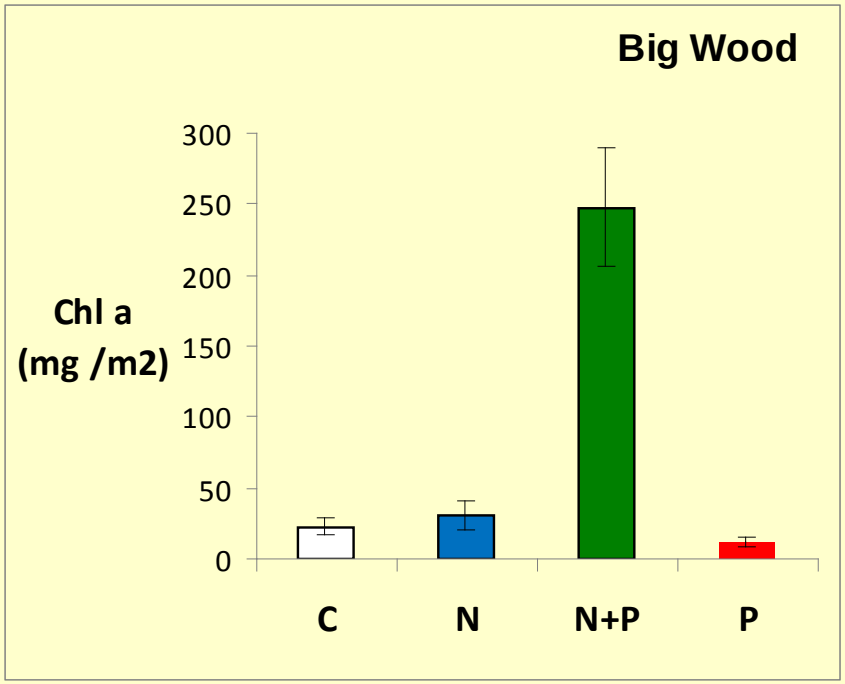
White - controls

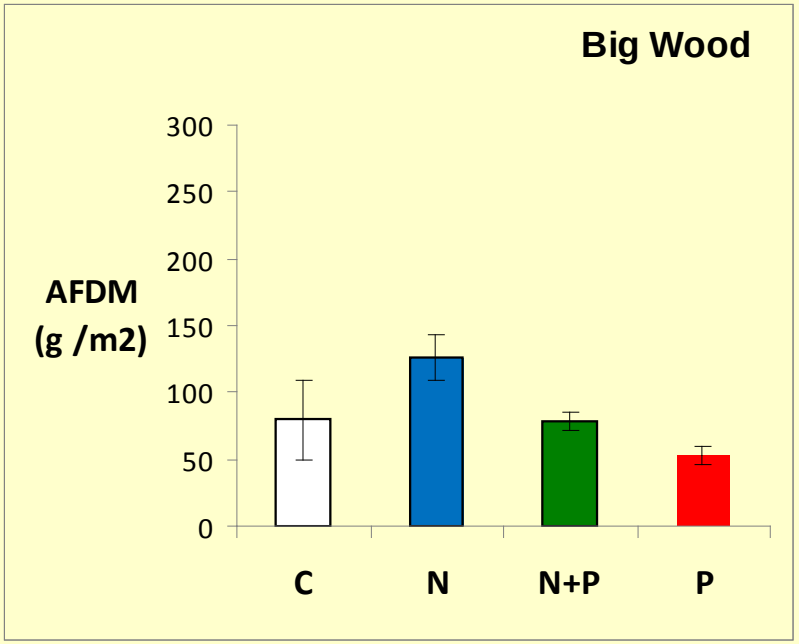


Big Wood River

N+P are co-limiting

TP: 7 – 10 µg/L
TN: 50 – 100 µg/L
N:P molar ratio: 15 – 22

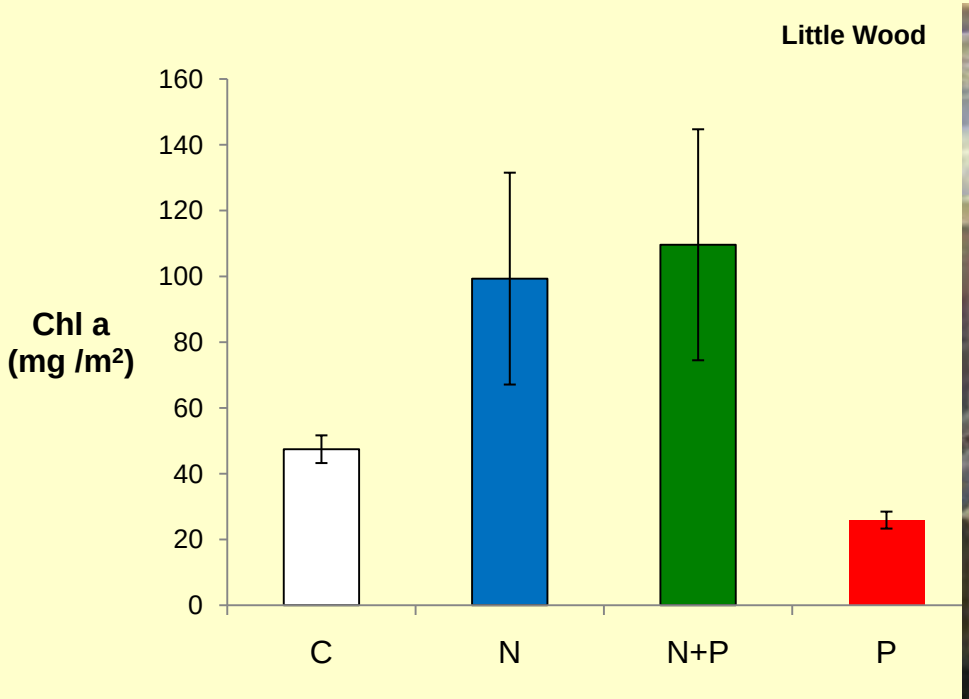


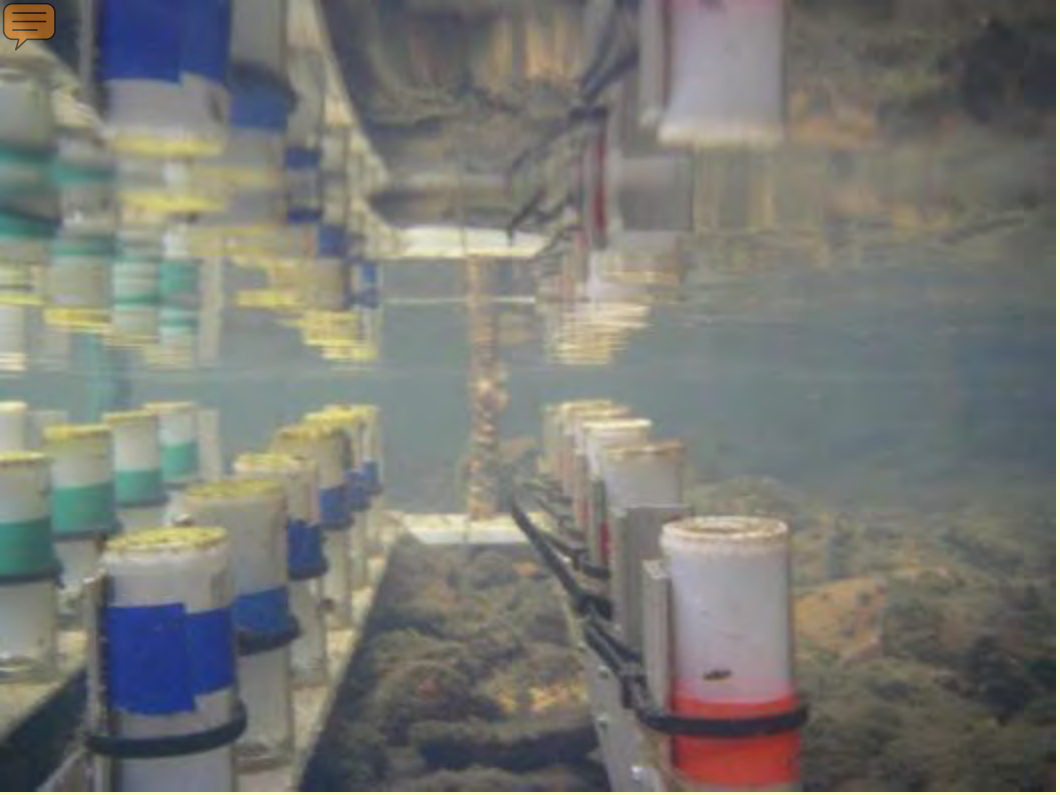


Little Wood River

Chla N limited

TP: 10 – 14 µg/L
TN: 93 – 118 µg/L
N:P molar ratio: 14 – 20

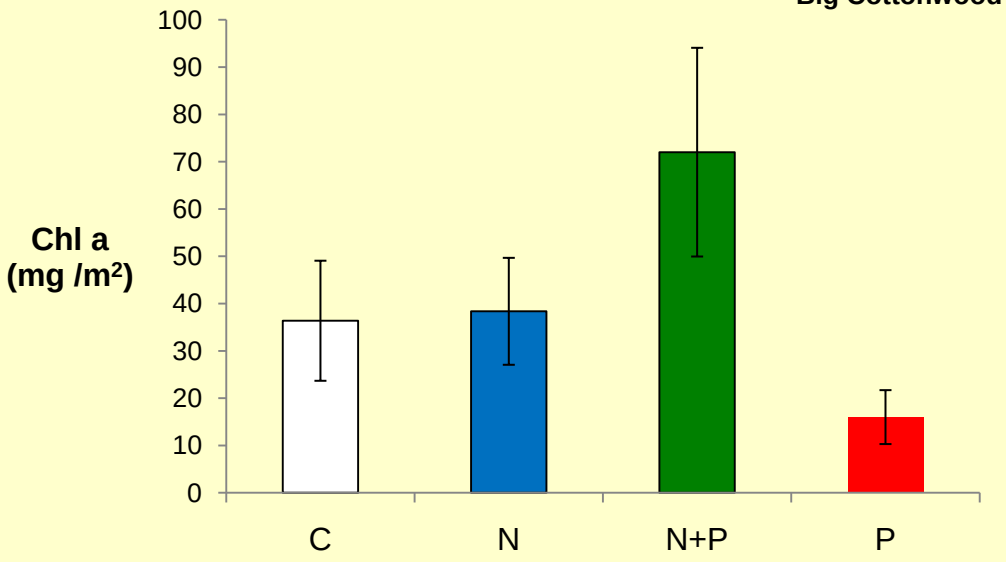


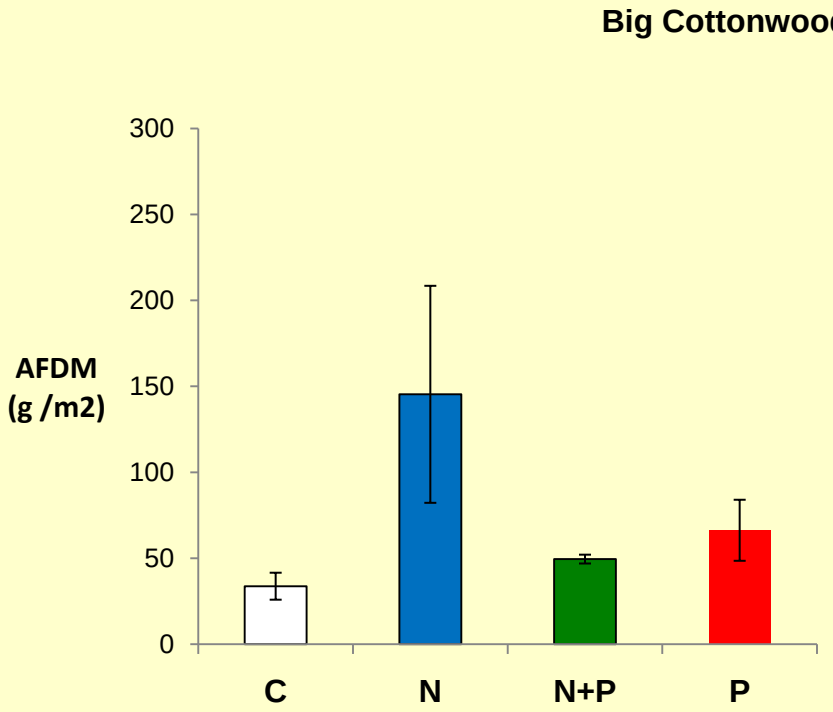


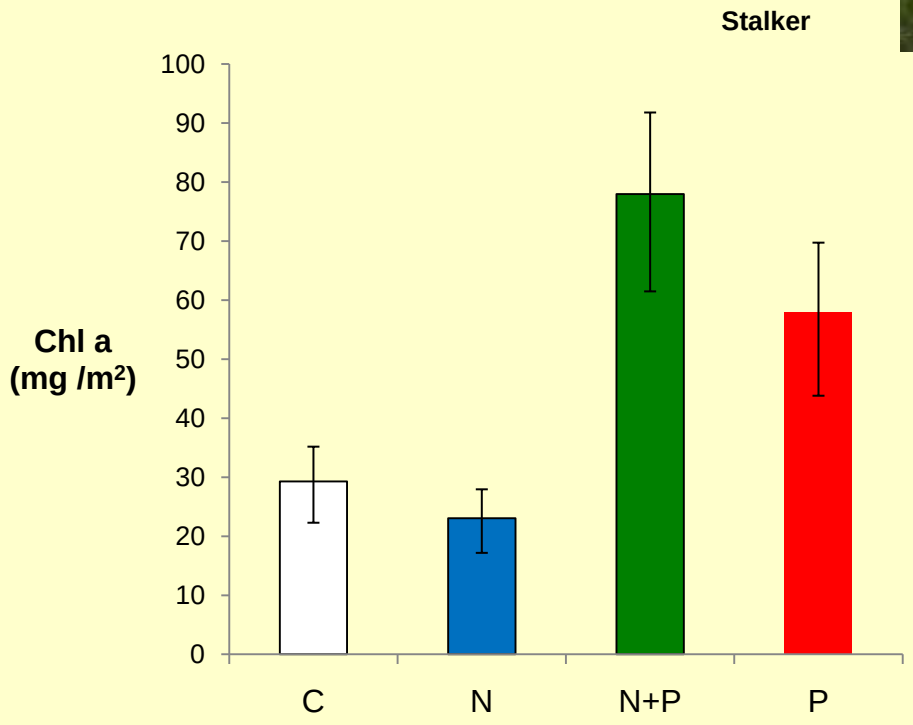
Big Cottonwood Creek

Chla – N+P co-limitation
AFDM – N limited

TP: 33 – 36 µg/L
TN: 35 – 135 µg/L
N:P molar ratio: 3 – 10







Stalker Creek

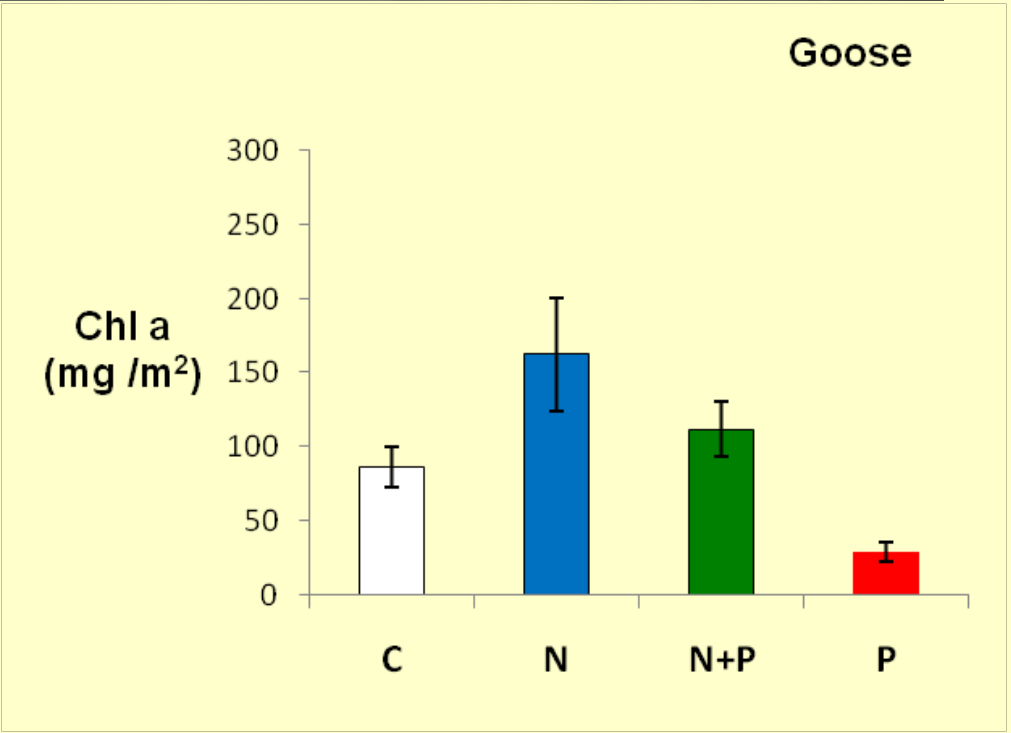
P limited

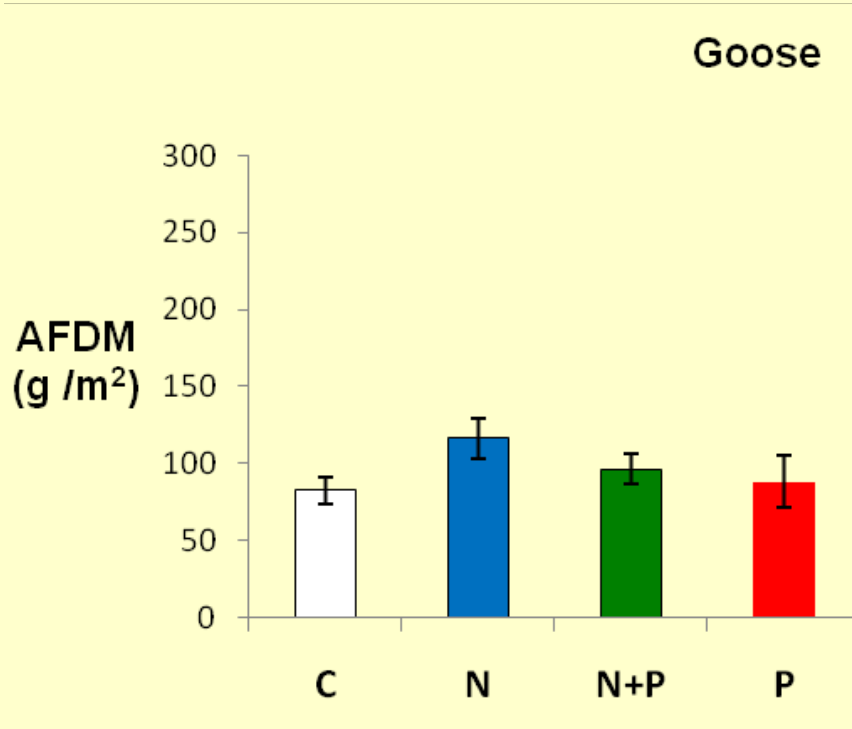
TP: 8 – 10 µg/L
TN: 1130 – 590 µg/L
N:P molar ratio: 340- 305

Goose Creek

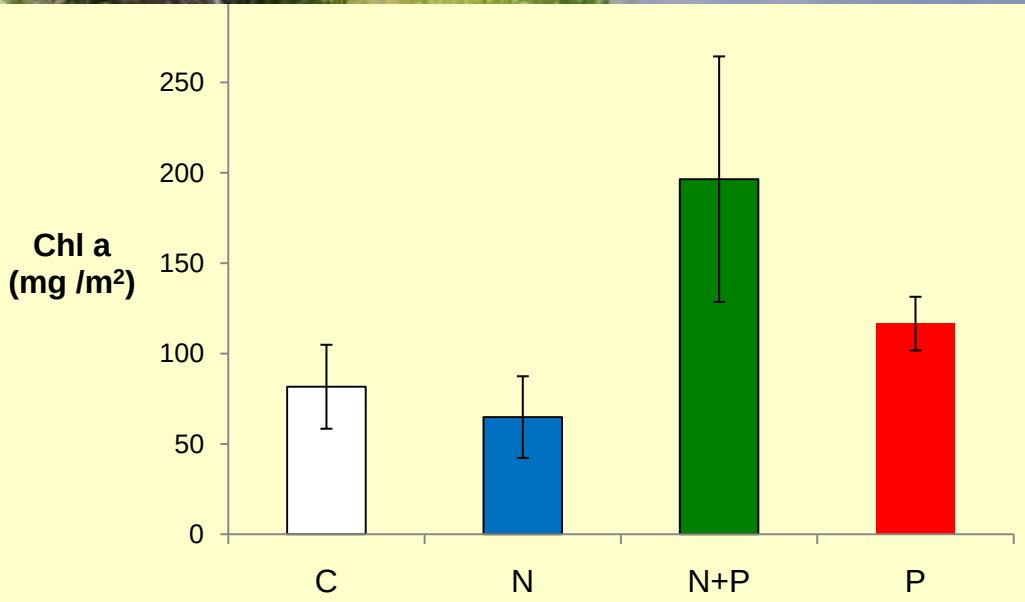
Chlorophyll N limited

TP: 30 – 44 µg/L
TN: 213 – 313 µg/L
N:P molar ratio: 16 – 19



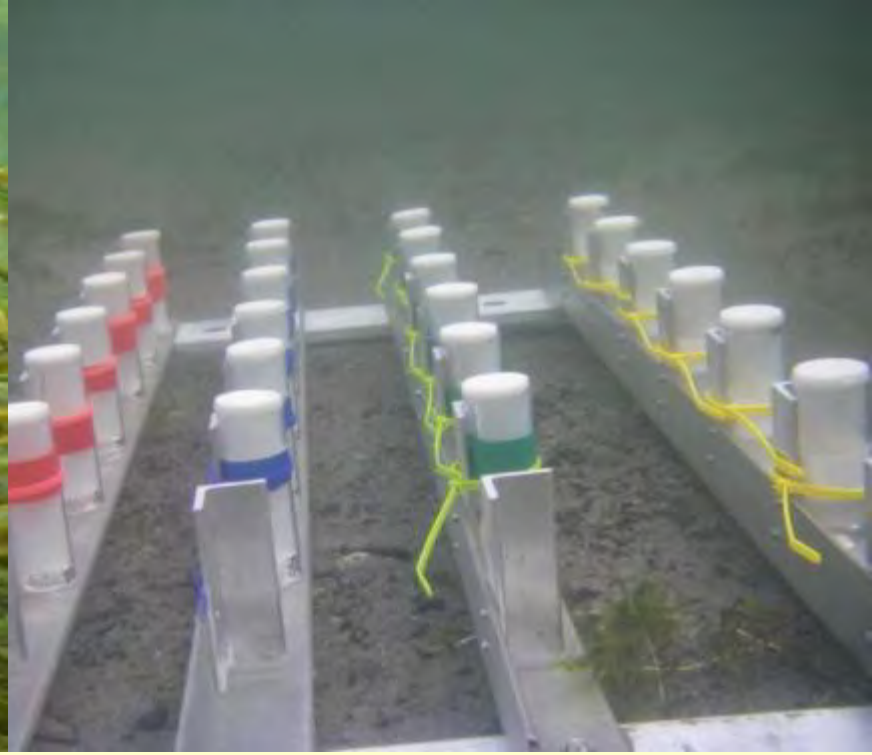


Camas Creek

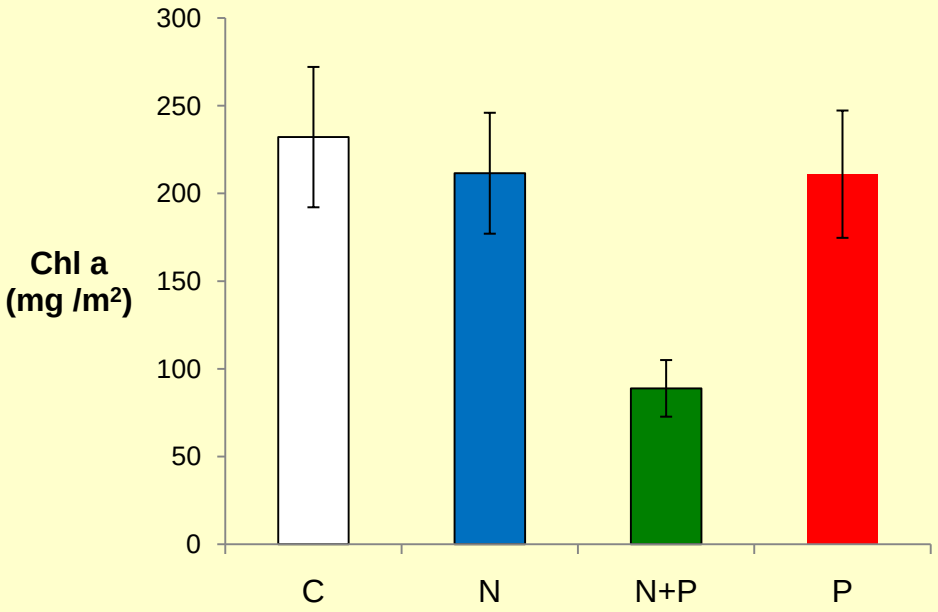


P primary limitation
N secondary limitation

TP: 30 – 45 µg/L
TN: 2500 – 3940 µg/L
N:P molar ratio: 123 – 291



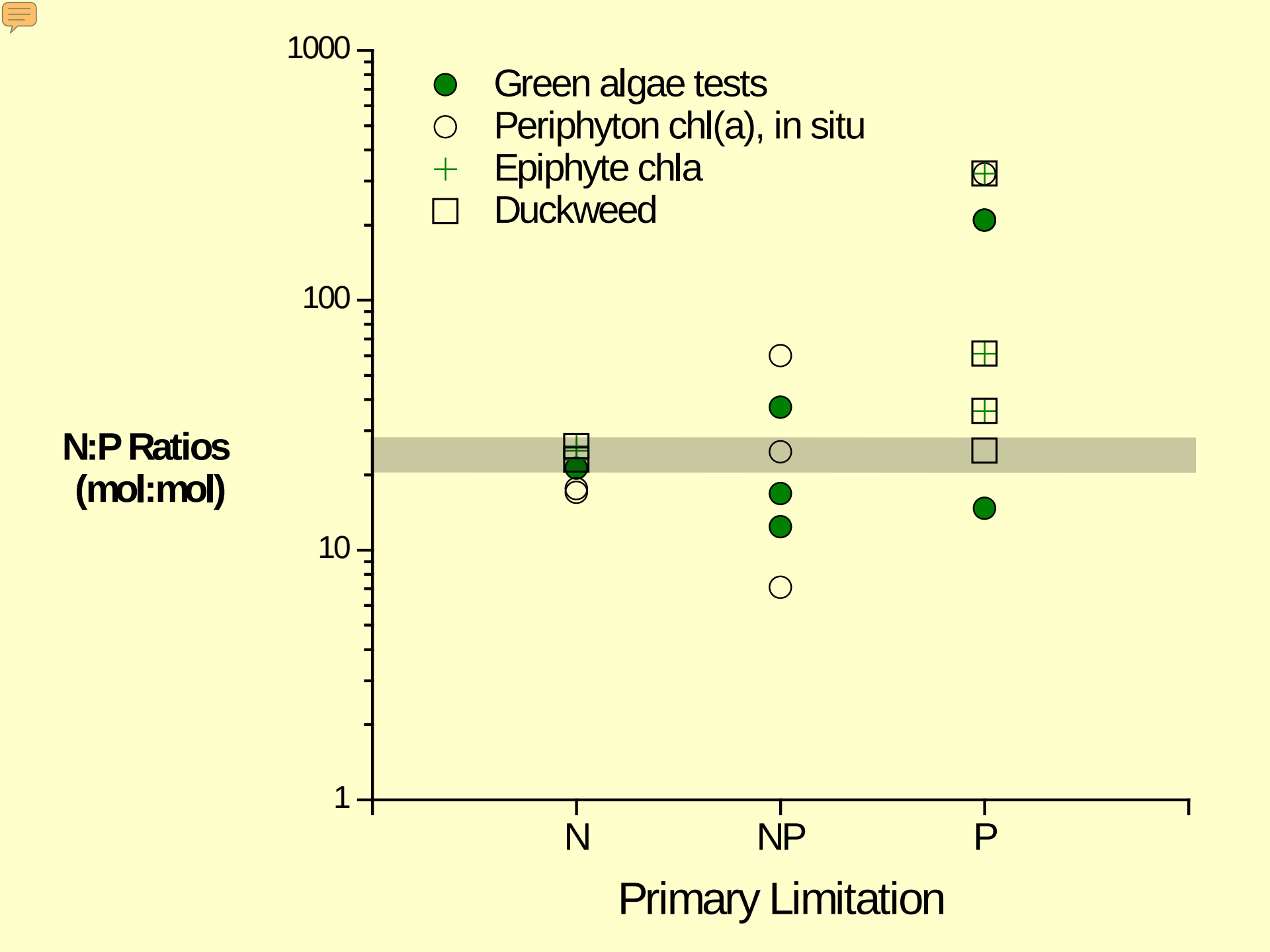
Billingsley

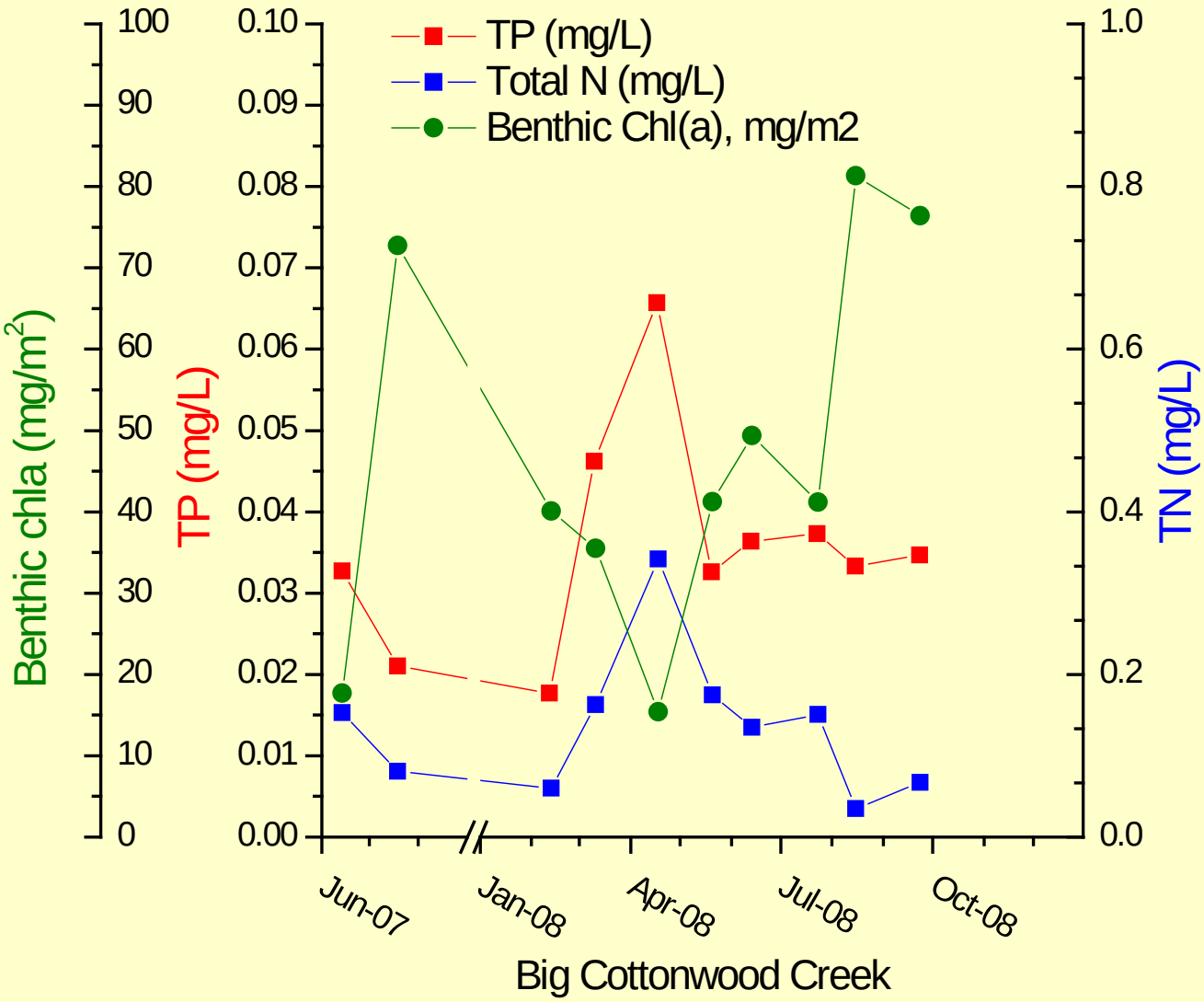


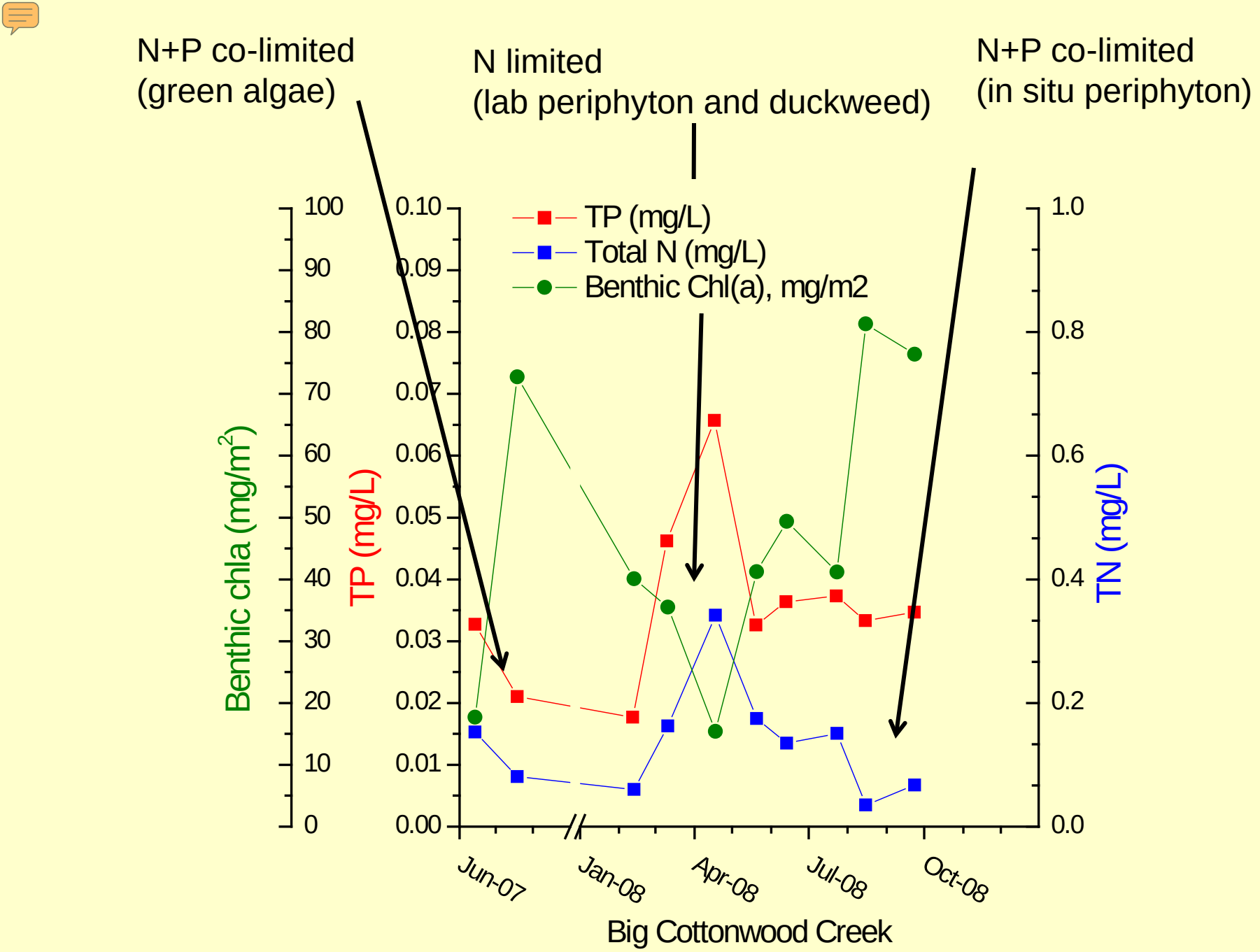
Billingsley Creek

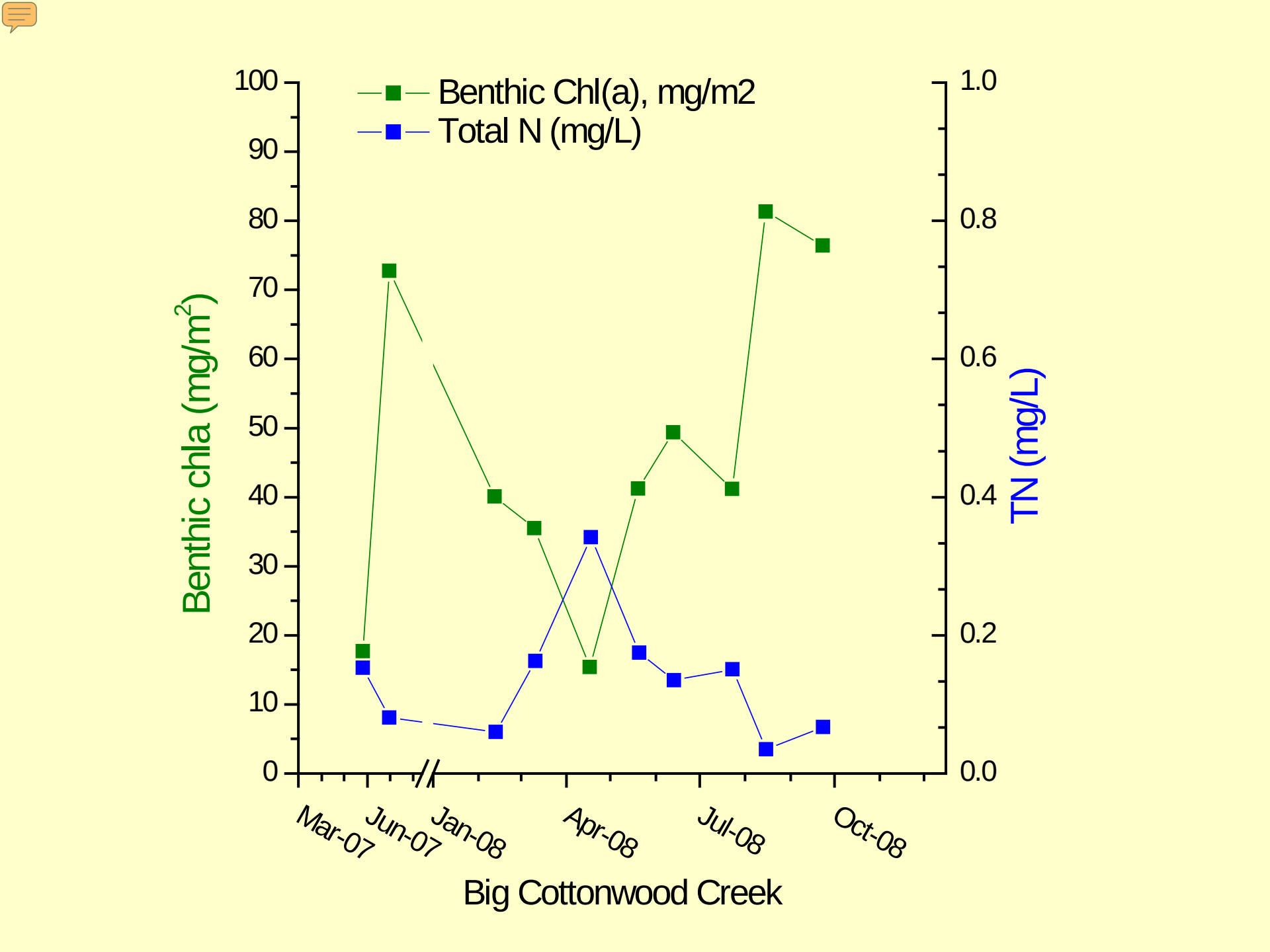
Periphyton are not limited by nutrients
NP addition suppressed chla

TP: 87 – 91 µg/L
TN: 1570 – 1820 µg/L
N:P molar ratio: 38 – 44

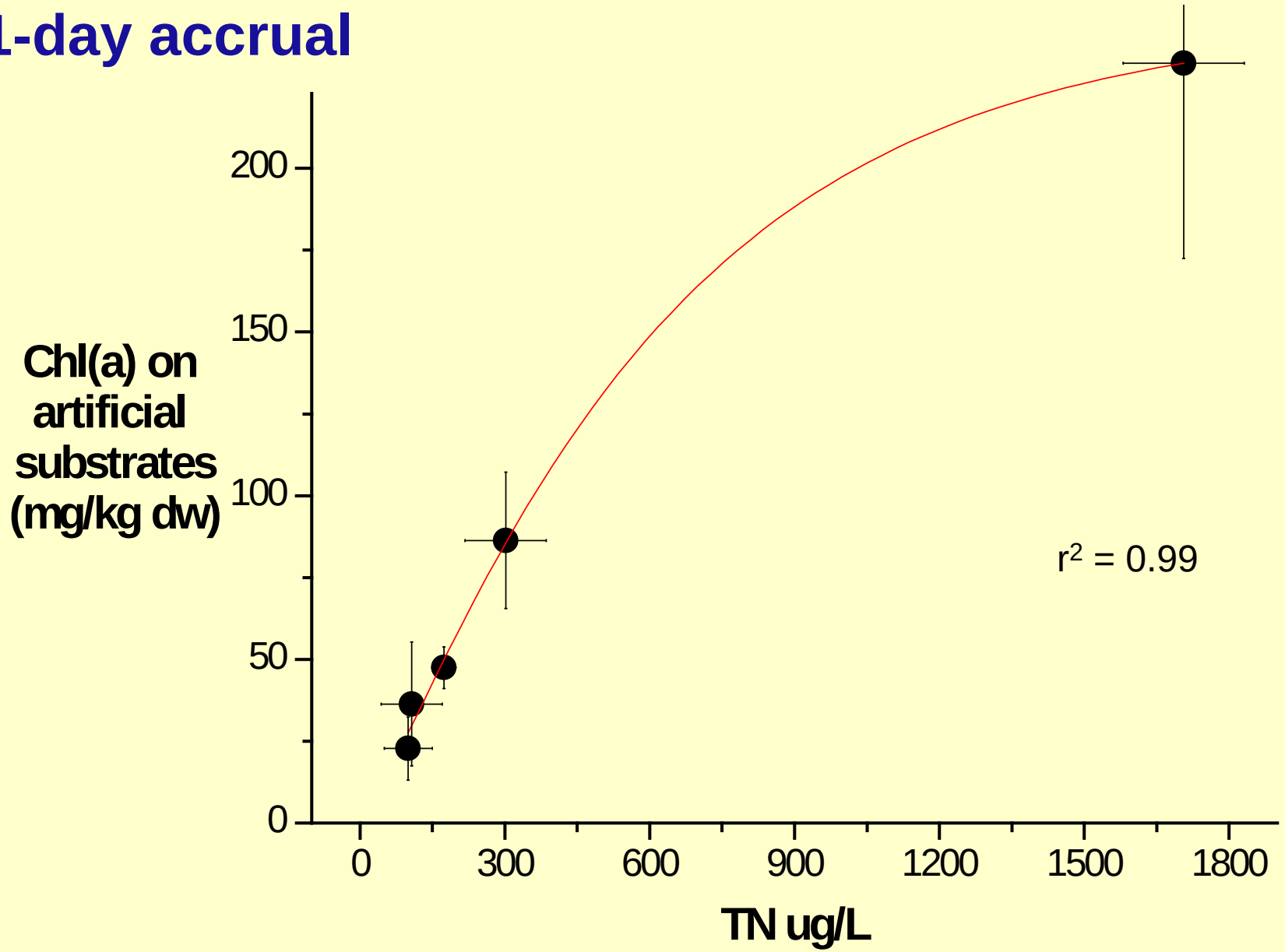

1000
100
10
1
Green algae tests
Periphyton chl(a), in situ
Epiphyte chla
Duckweed
N:P Ratios
(mol:mol)
N
NP
P
Primary Limitation

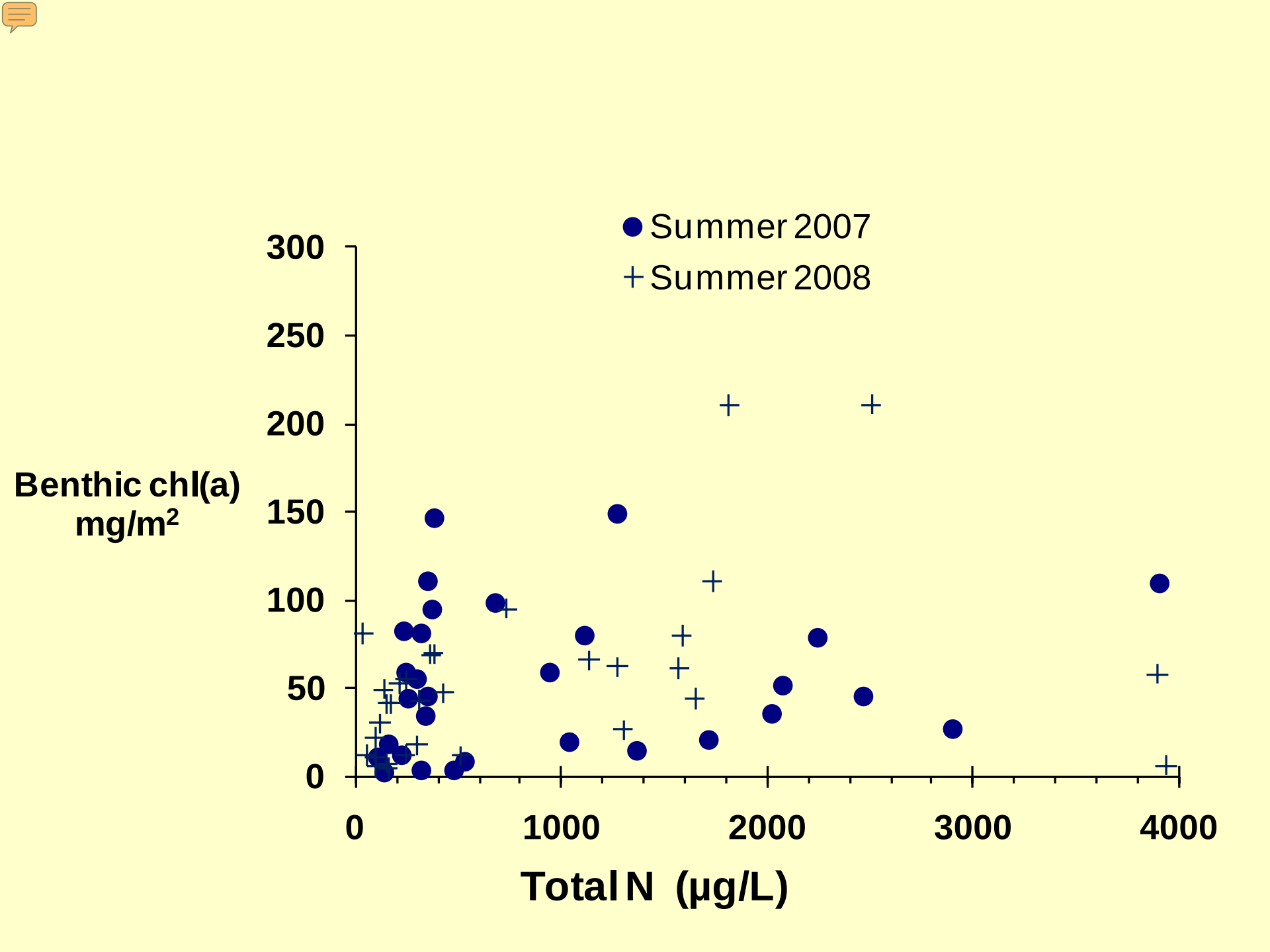

TP (mg/L)
Total N (mg/L)
Benthic Chl(a), mg/m2
Benthic chla (mg/m2)
TP (mg/L)
TN (mg/L)
100
90
80
70
60
50
40
30
20
10
0
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Jun-07
Jan-08
Apr-08
Jul-08
Oct-08
Big Cottonwood Creek

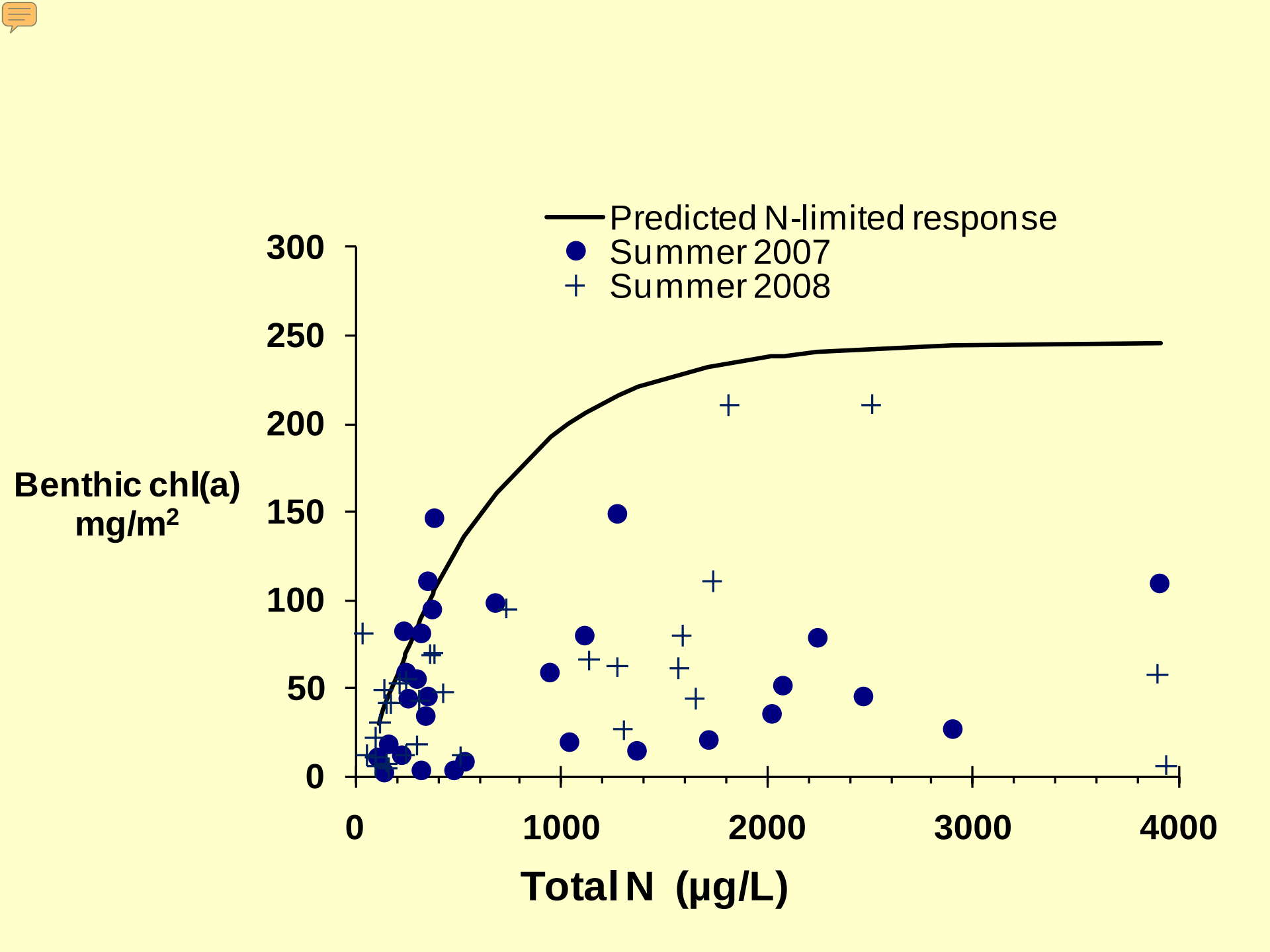

N+P co-limited
(green algae)
N limited
(lab periphyton and duckweed)
N+P co-limited
(in situ periphyton)
TP (mg/L)
Total N (mg/L)
Benthic Chl(a), mg/m2
Benthic chla (mg/m2)
TP (mg/L)
TN (mg/L)
100
90
80
70
60
50
40
30
20
10
0
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Jun-07
Jan-08
Apr-08
Jul-08
Oct-08
Big Cottonwood Creek

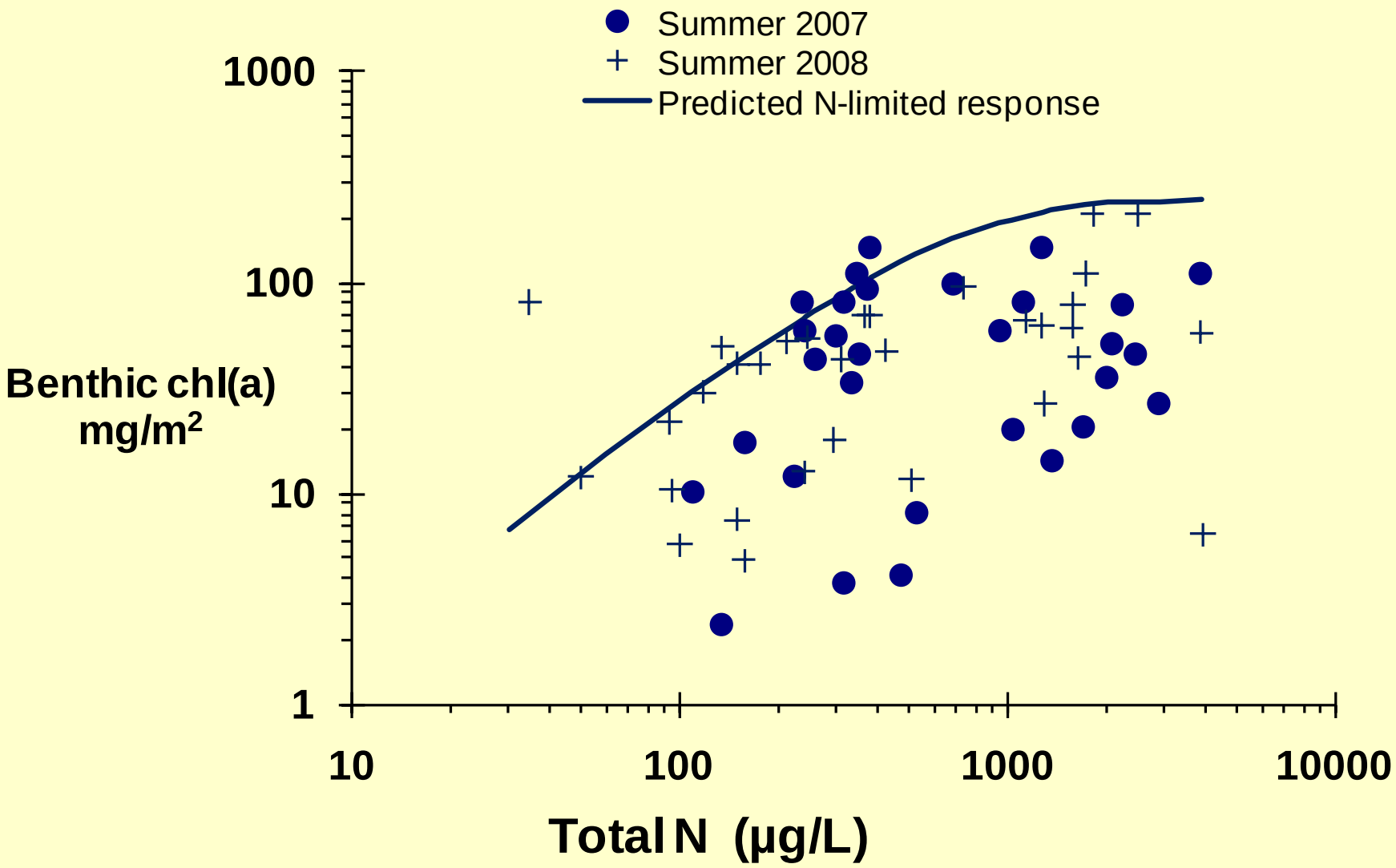

Benthic Chl(a), mg/m2
Total N (mg/L)
Benthic chla (mg/m2)
TN (mg/L)
100
90
80
70
60
50
40
30
20
10
0
1.0
0.8
0.6
0.4
0.2
0.0
Mar-07
Jun-07
Jan-08
Apr-08
Jul-08
Oct-08
Big Cottonwood Creek

N and chlorophyll at N limited sites, 21-day accrual

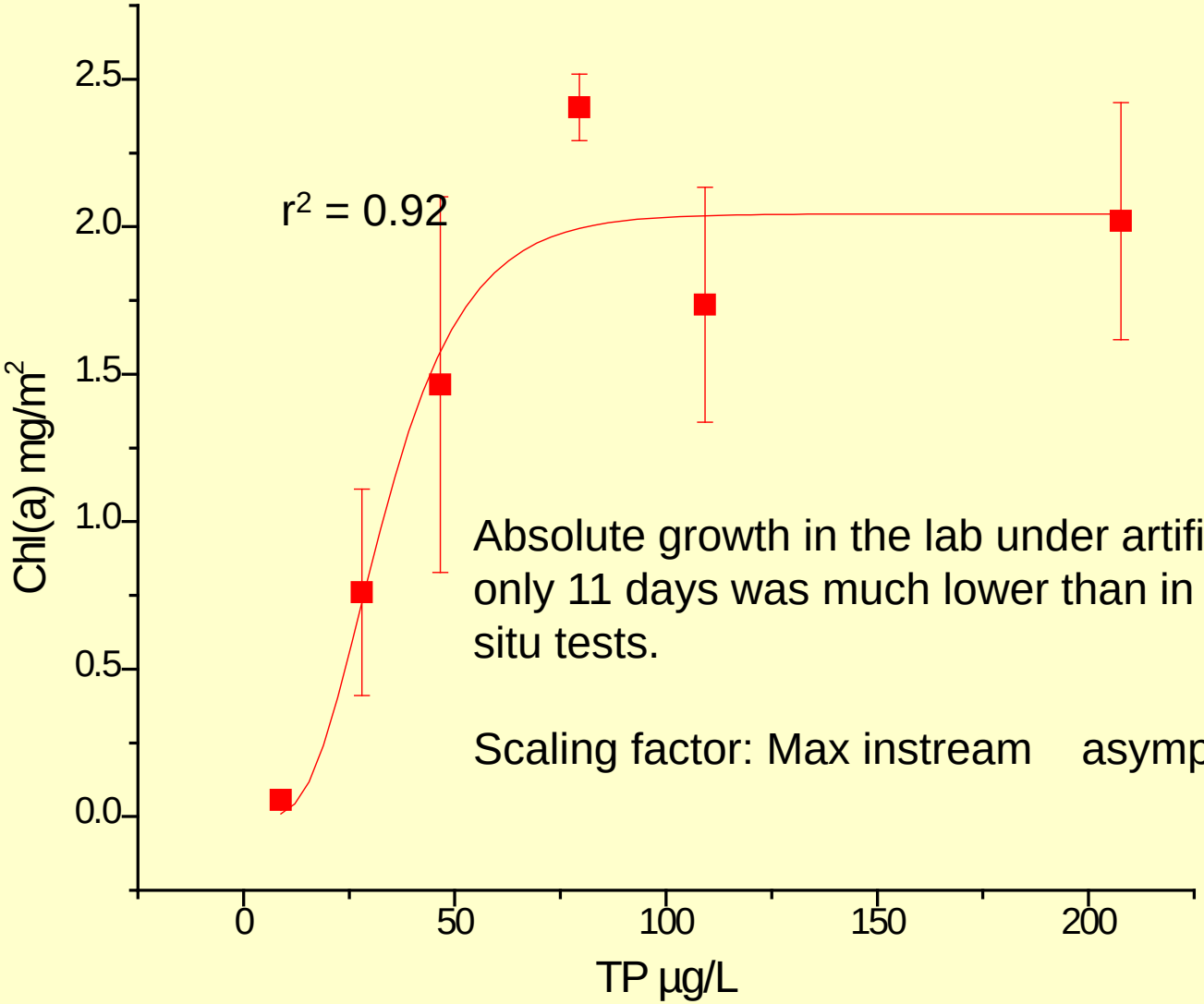



Summer 2007
Summer 2008
Benthic chl(a)
mg/m²
300
250
200
150
100
50
0
0
1000
2000
3000
4000
Total N (µg/L)


Predicted N-limited response
Summer 2007
Summer 2008
Benthic chl(a) mg/m²
300
250
200
150
100
50
0
0
1000
2000
3000
4000
Total N (µg/L)

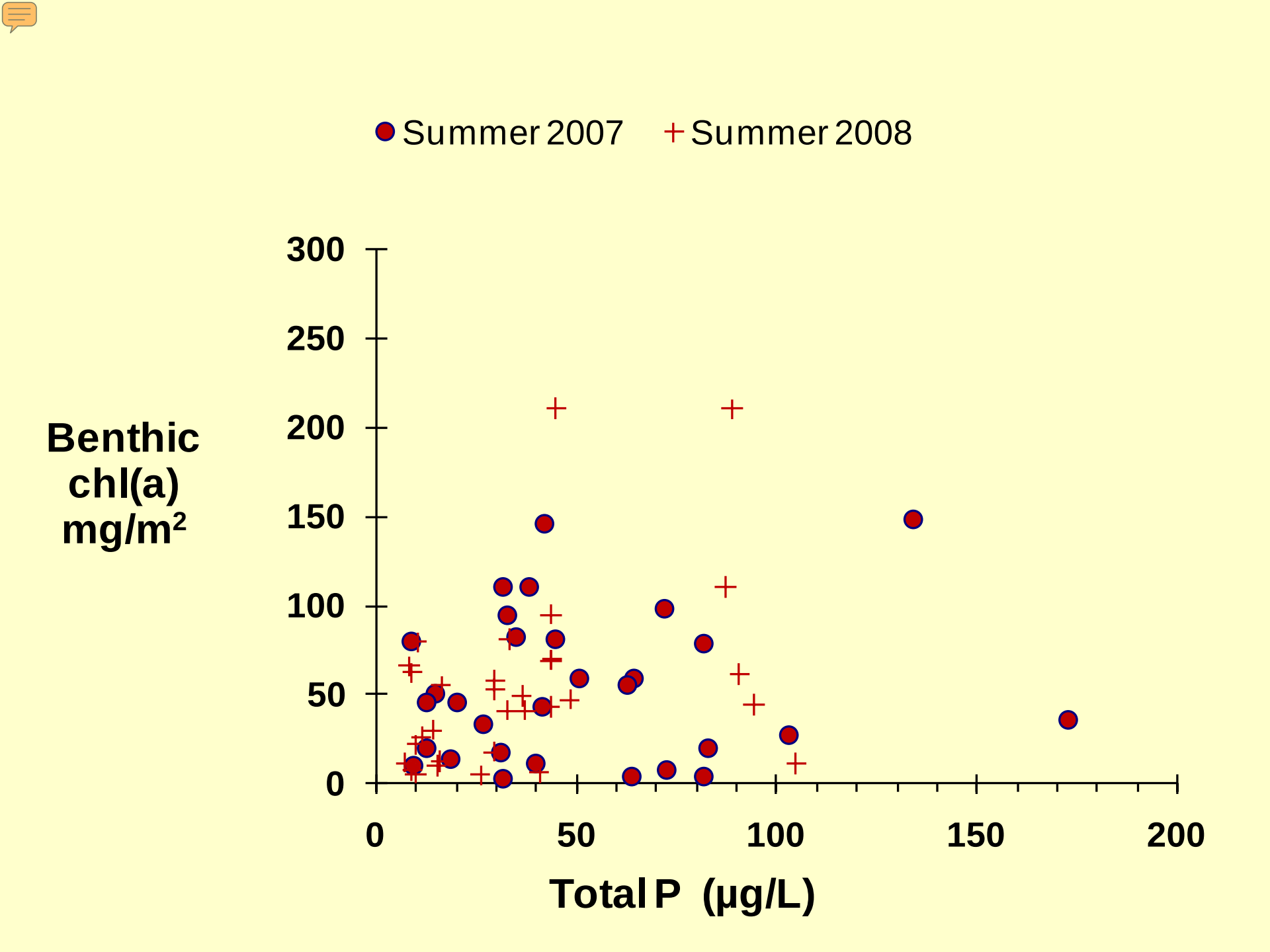

Summer 2007
Summer 2008
Predicted N-limited response
1000
100
10
1
Benthic chl(a)
mg/m2
10
100
1000
10000
Total N (µg/L)

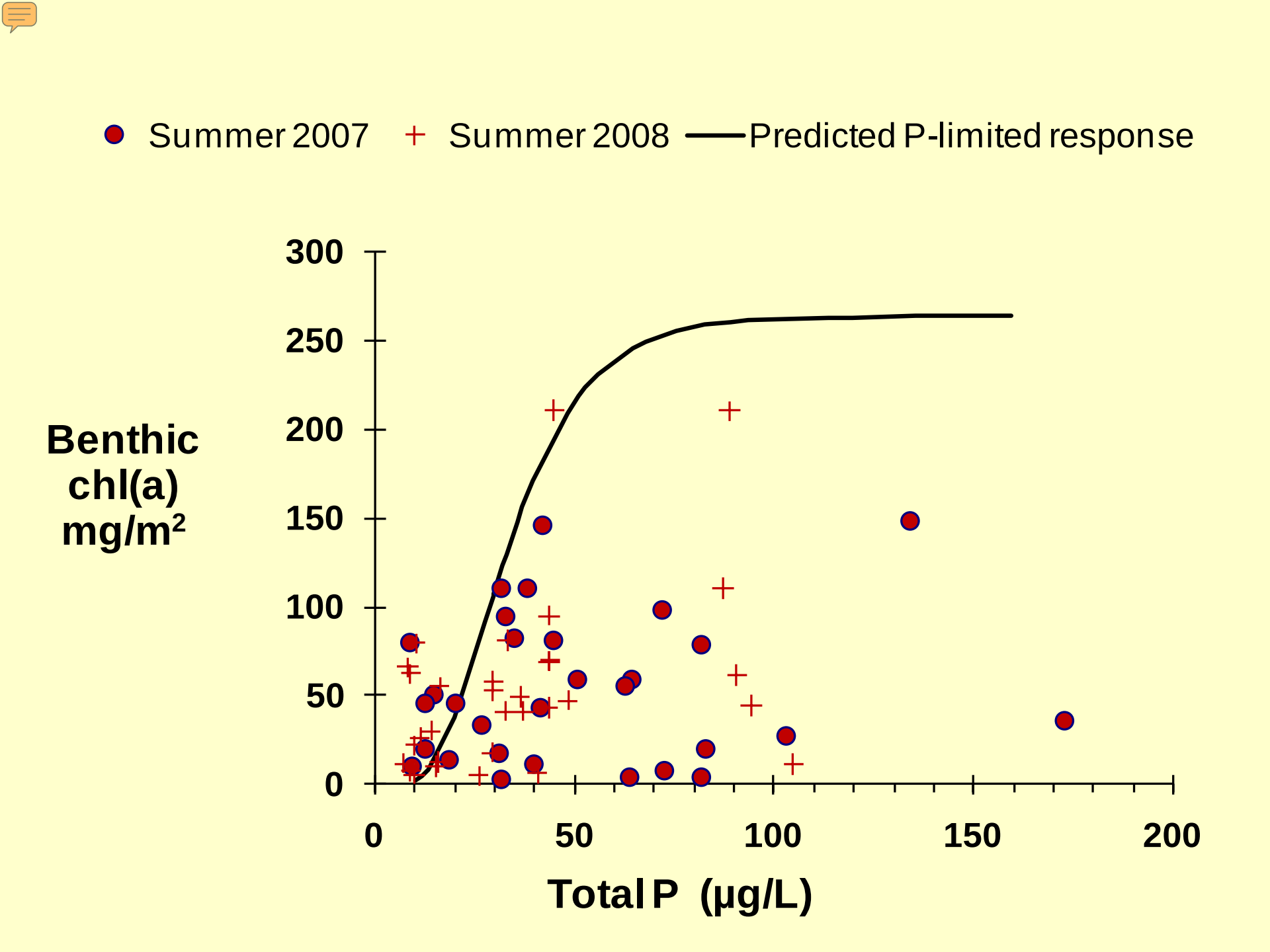
P and chlorophyll from the duckweed-epiphyte growth lab tests



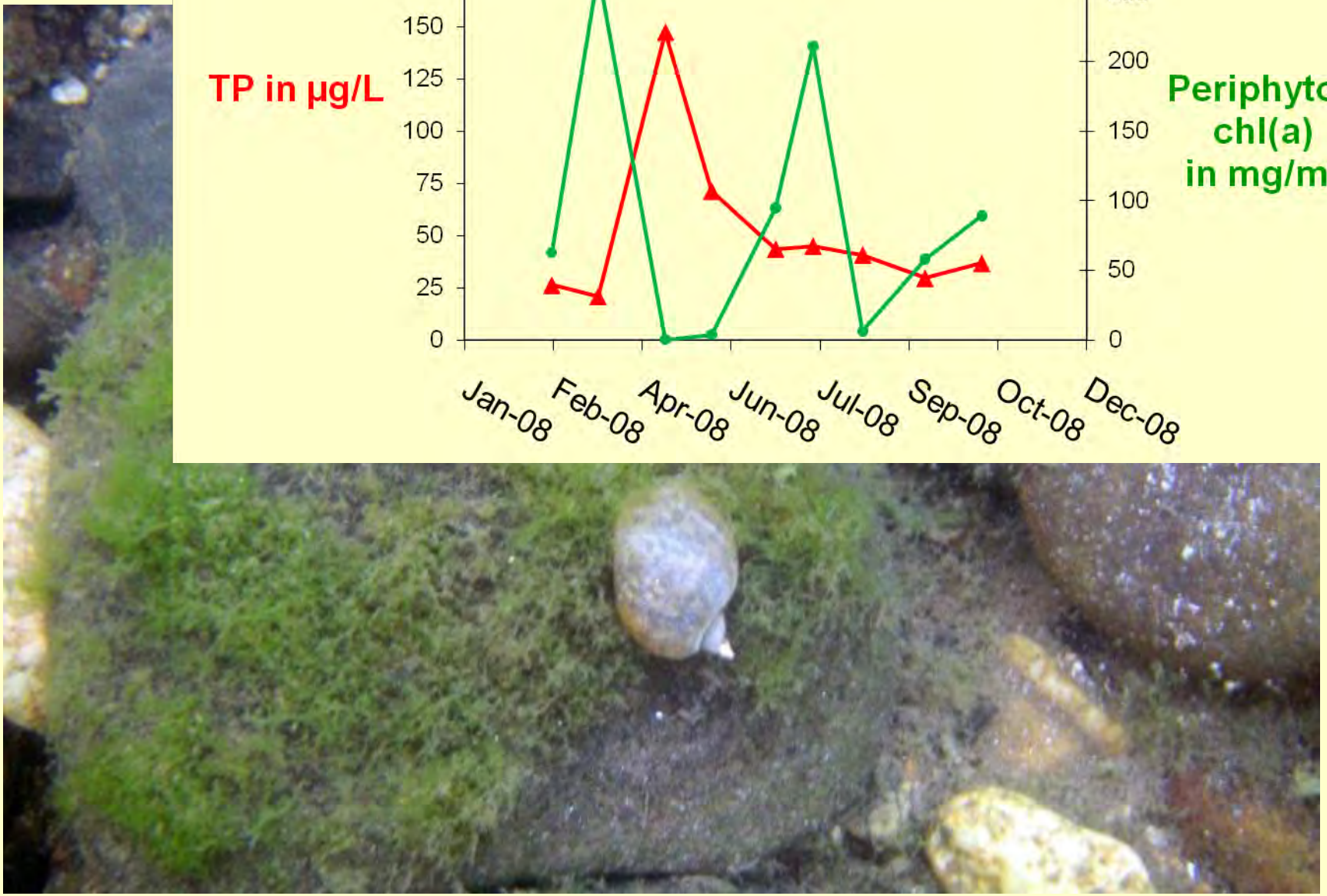
Absolute growth in the lab under artificial light and only 11 days was much lower than in the 21-day in situ tests.

Scaling factor: Max instream asymptote = 129


Summer 2007
Summer 2008
Benthic chl(a) mg/m²
300
250
200
150
100
50
0
0
50
100
150
200
Total P (µg/L)


Summer 2007
Summer 2008
Predicted P-limited response
Benthic chl(a) mg/m²
300
250
200
150
100
50
0
0
50
100
150
200
Total P (µg/L)

Grazing


TP
Benthic Chl(a), mg/m2
TP in µg/L
Periphyton chl(a) in mg/m²
200
175
150
125
100
75
50
25
0
300
250
200
150
100
50
0
Jan-08
Feb-08
Apr-08
Jun-08
Jul-08
Sep-08
Oct-08
Dec-08

Flow disturbance

Flow disturbance

Conclusions

1. N limitation or co-limitation was most common
2. Different endpoints often had different limiting nutrients
3. With periphyton or green algae, P had no minimum response threshold
4. With duckweed, P threshold of response was about 50 µg/L (0.050 mg/L)
5. About 40 µg/L TP and 600 µg/L TN corresponded with the 150 mg/kg “too-green” periphyton chlorophyll guideline
6. Uptake of N and P in at least oligotrophic likely confound relations between plant stock and nutrients.
7. Integrating controlled experiments and biomonitoring more informative than either alone