Nitrogen uptake and turnover in riparian woody vegetation: a tracer experiment

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Nitrogen Sources

Not from rocks
Plants fix N_2 from atmosphere (e.g., Alder)
Man-made fertilizers
Anadromous fish (e.g., salmon)

Anadromous Fish

Up to 24% of N in riparian vegetation can come from salmon N, and even more of the N in young fish

Helfield and Naiman 2001

Bilby et al. 2001


Might forest fertilization replace the nitrogen from the missing salmon?

How do we know the amount of salmon-derived N?

Nitrogen stable isotopes—natural tracers

$\delta^{15}N$ in salmon Carcasses

+13.9

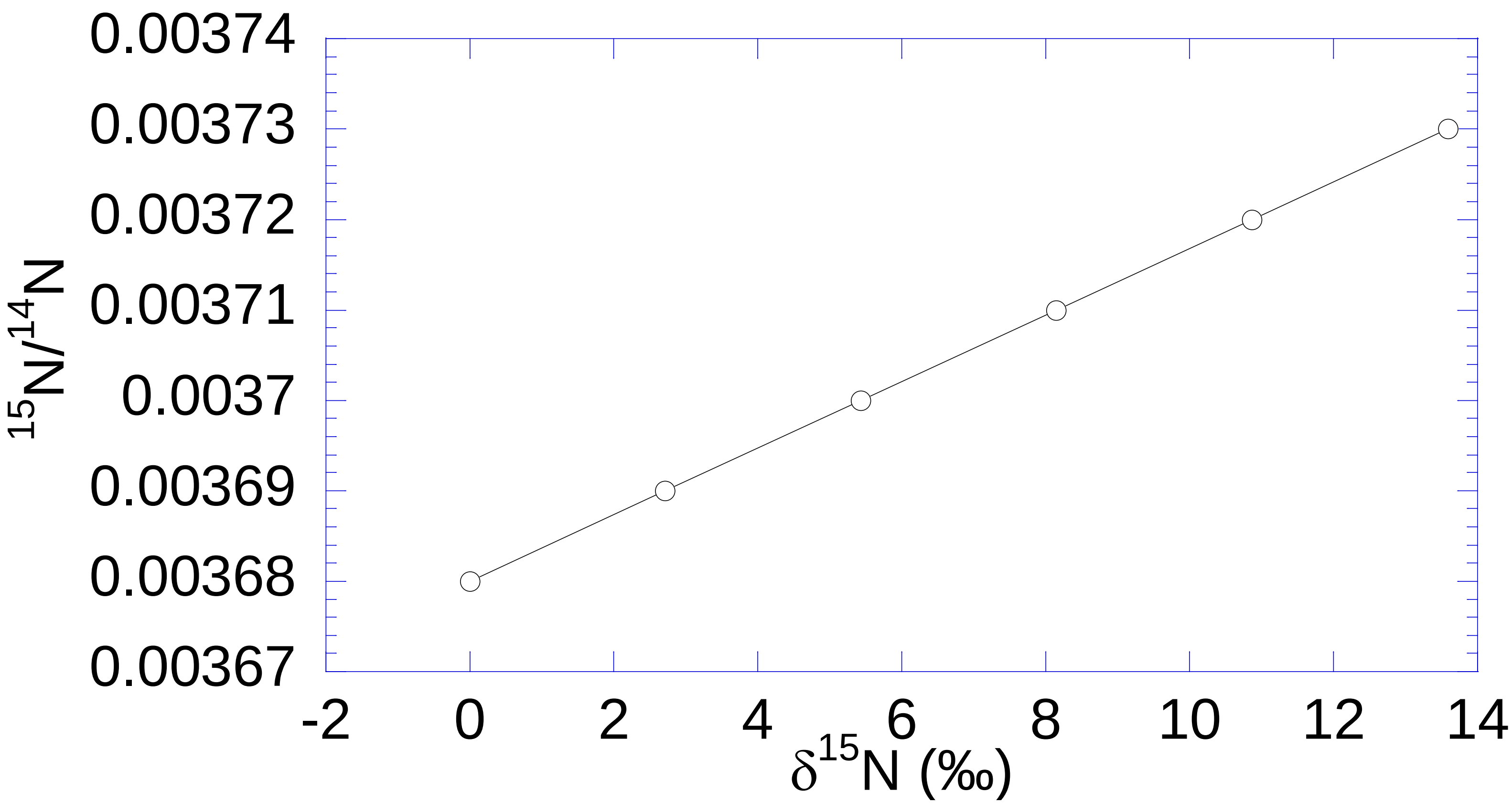
Bilby et al., 2001

$\delta^{15}N$ in vegetation in central Idaho

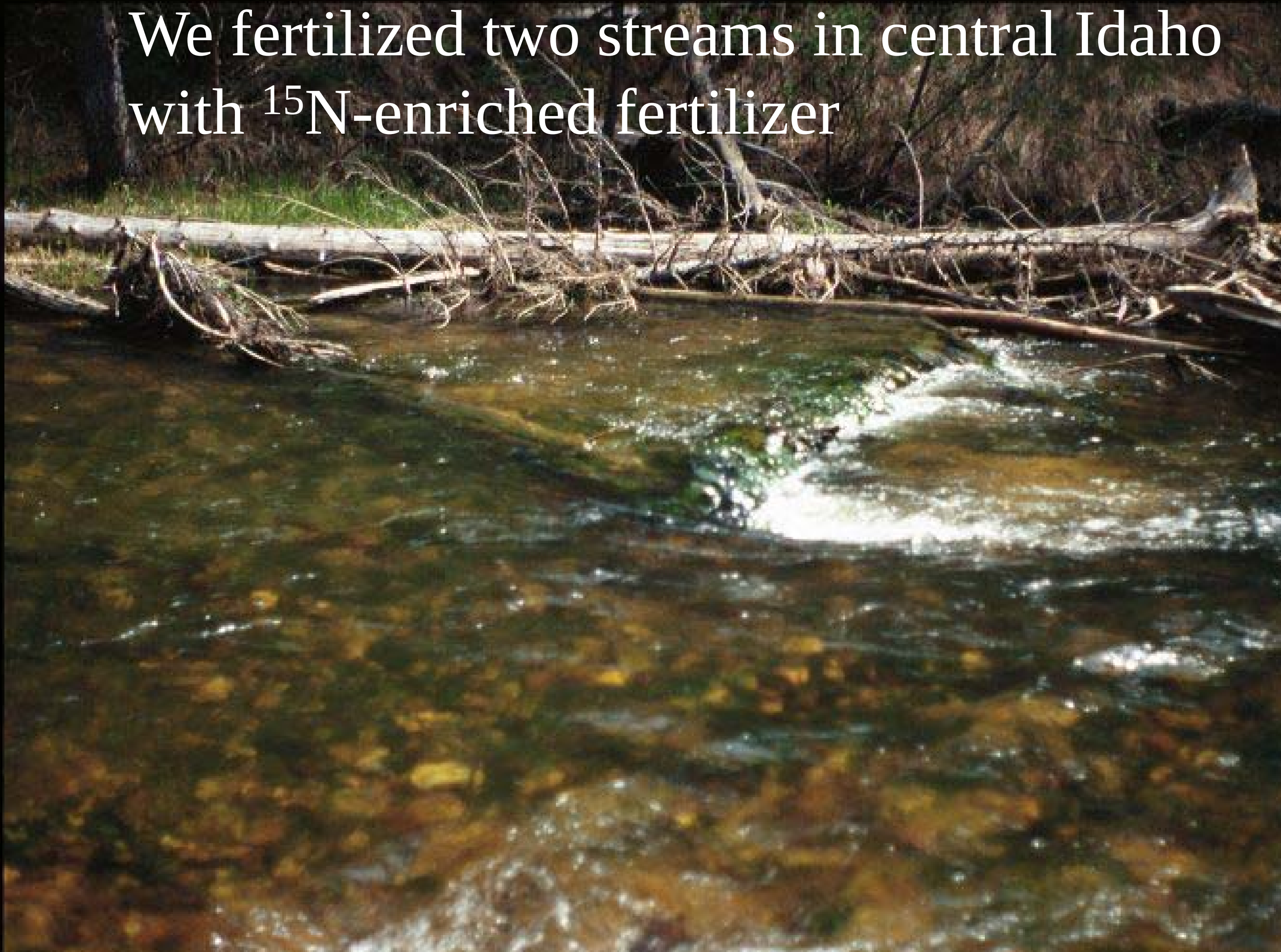
-3 to 0

This study

$\delta^{15}N$ is just a way of describing the ratio of $^{15}N:^{14}N$ —without all the decimals



We fertilized two streams in central Idaho with ^{15}N-enriched fertilizer



Riparian Zones

- Interface with stream channel
- 2-way flow of nutrients
  - Allochthnous inputs
  - Hyporheic exchange
  - Flood pulse events
  - Stream invertebrates

Objectives

- historic differences in N sources
- species differences
  - Alder
  - Spruce and fir vs. deciduous shrubs
- %N derived from fertilizer
- retranslocation effects on $\delta^{15}N$

Materials and Methods

Bogus Creek


Brushy


Confined channel


Forested and shrubby


Steeper Gradient

Clear Creek

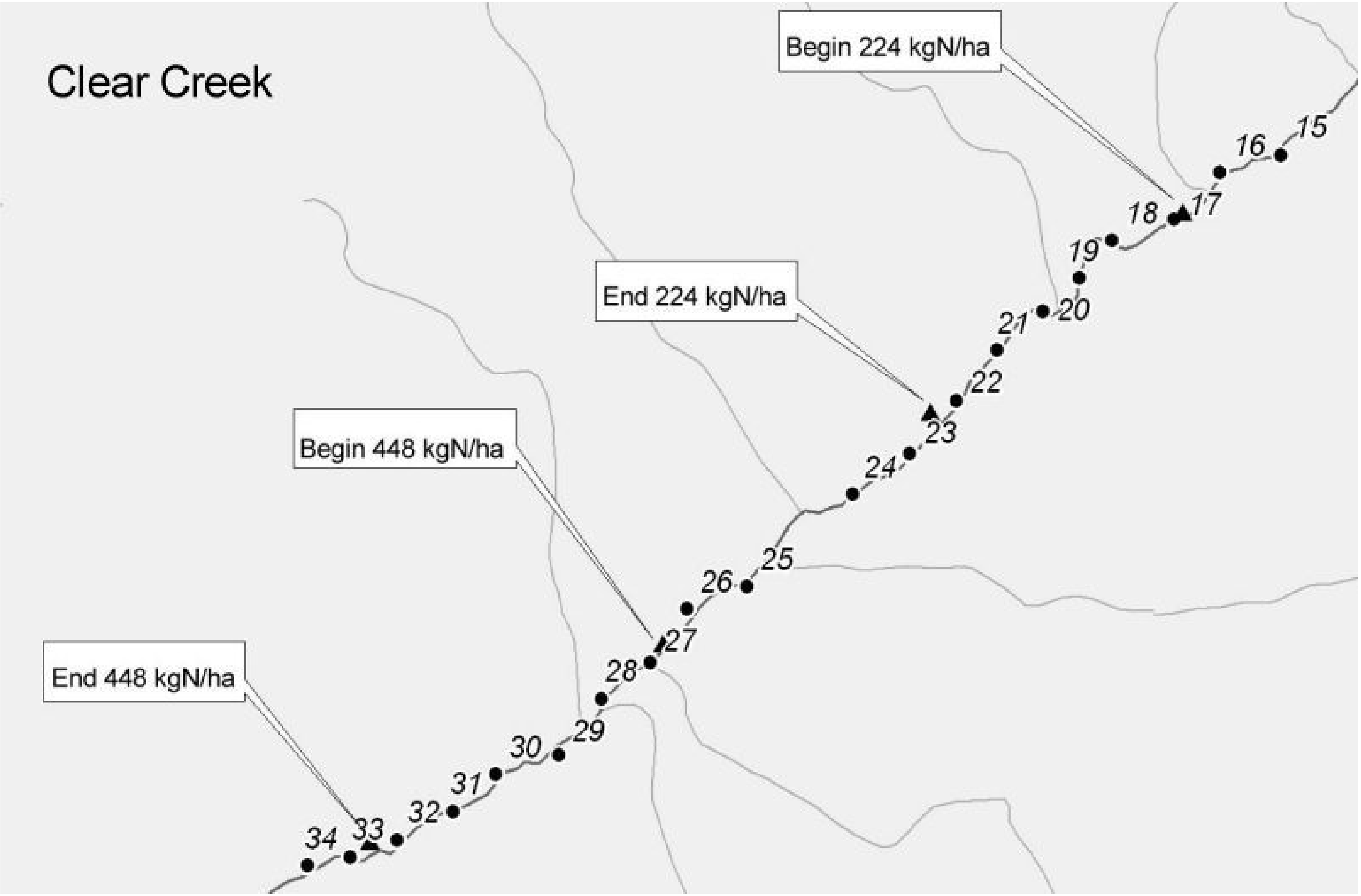
“Mandzak mix” + ^{15}N

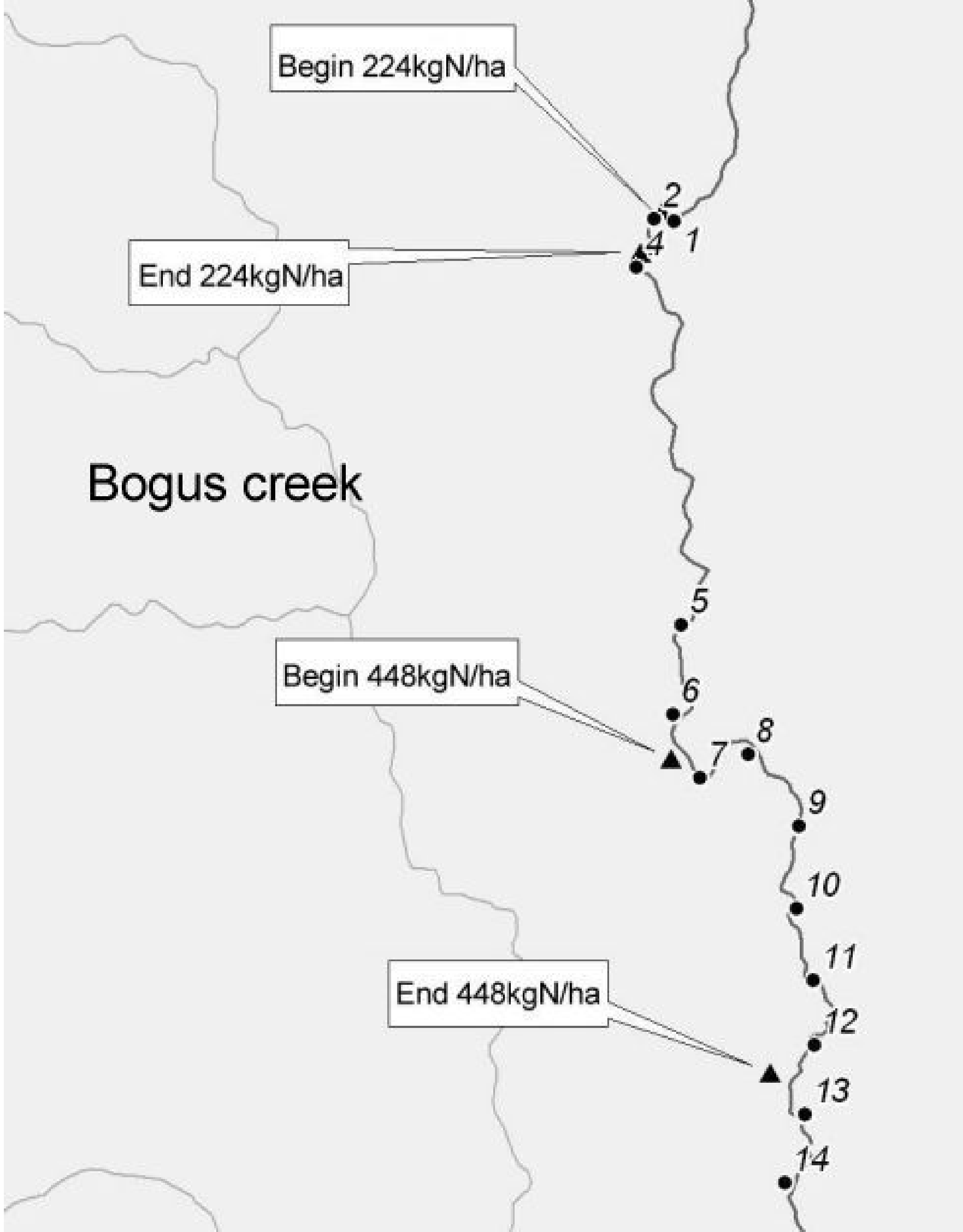
- Main N component: Urea
- Supplemental nutrients: potassium, copper, magnesium, boron, and other micronutrients
- Ammonium sulfate was added as a ^{15}N label
- Mixed 50 lbs. of label into 13 tons of fertilizer in an industrial mixer


δ^{15}N of the fertilizer was 18‰

Treatments

- Two levels:
  - 224 kg N/ha
  - 448 kg N/ha
- Swaths 1 km long, ~ 35 m wide
- Applied early November, 2001


Clear Creek
Begin 224 kgN/ha
End 224 kgN/ha
Begin 448 kgN/ha
End 448 kgN/ha
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

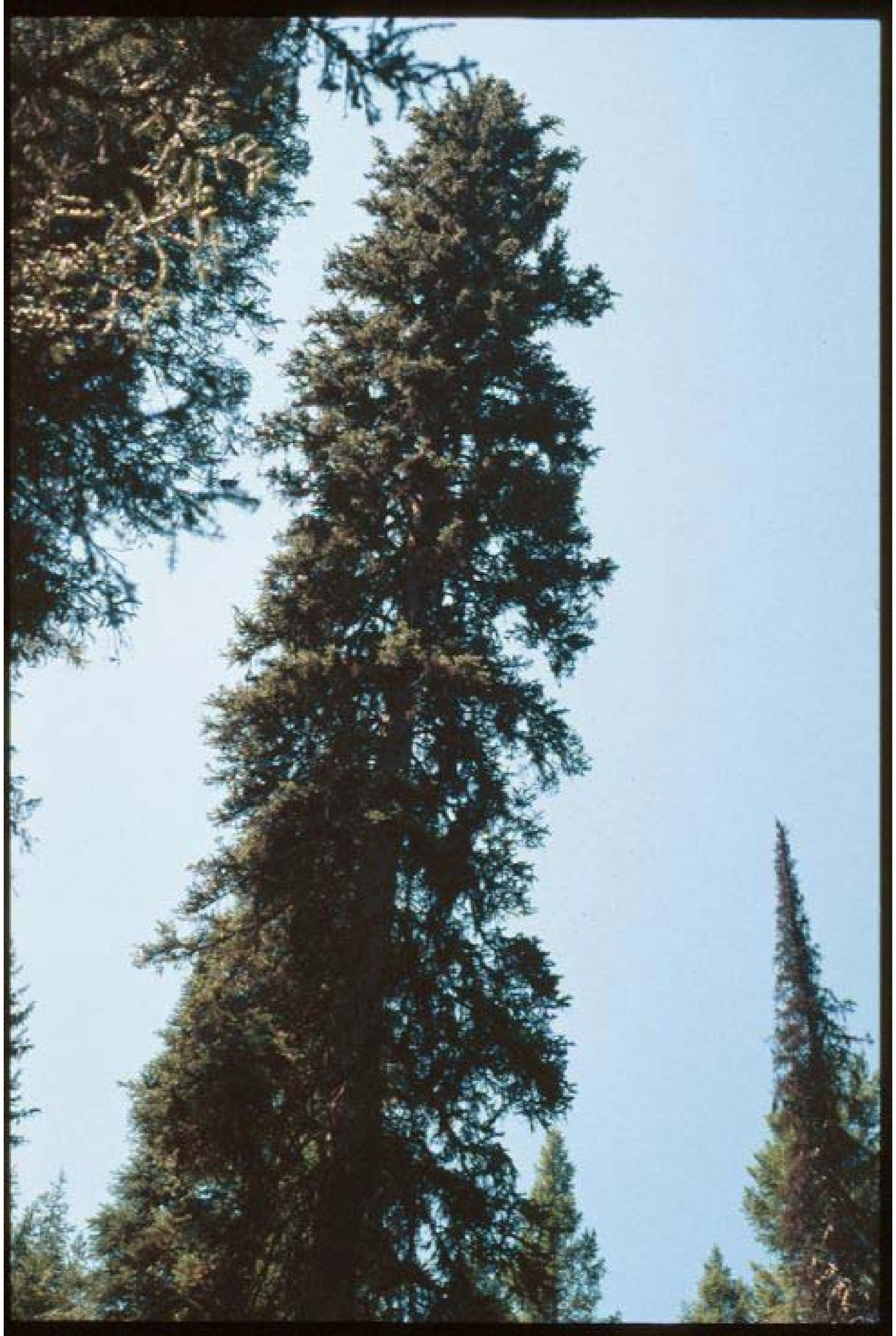

Begin 224kgN/ha
End 224kgN/ha
Bogus creek
Begin 448kgN/ha
End 448kgN/ha
1
2
4
5
6
7
8
9
10
11
12
13
14

Sampling

- Repeated sampling
  - 2001
  - 2002
- 34 Plots
  - Every 175m
  - Alternating sides of the stream.
- Sampled
  - Trees
  - Shrubs
  - Litter

Sampling

- Trees (> 5cm).
  - Lowest branch of contiguous live crown.
  - Same Height in both years.
  - Sorted by needle age.
  - Sun foliage where possible.
  - No unhealthy foliage.
- Shrubs
  - Every species on the plot.
  - “Batched” by species.
  - One observation per species per plot.
- Litter
  - 1 screen tray randomly placed per plot.
  - “Batched” by species.



Per cent Nitrogen Derived from Fertilizer (%Ndff)

$$\%Ndff = \frac{\delta^{15}N_{t+1} - \delta^{15}N_{t}}{\delta^{15}N_{fertilizer} - \delta^{15}N_{t}} \times 100$$

Where $\delta^{15}N$ of the fertilizer was 18‰

% N increase

$$\%N\ \text{increase} = \frac{N_{t+1} - N_t}{N_t} \times 100$$

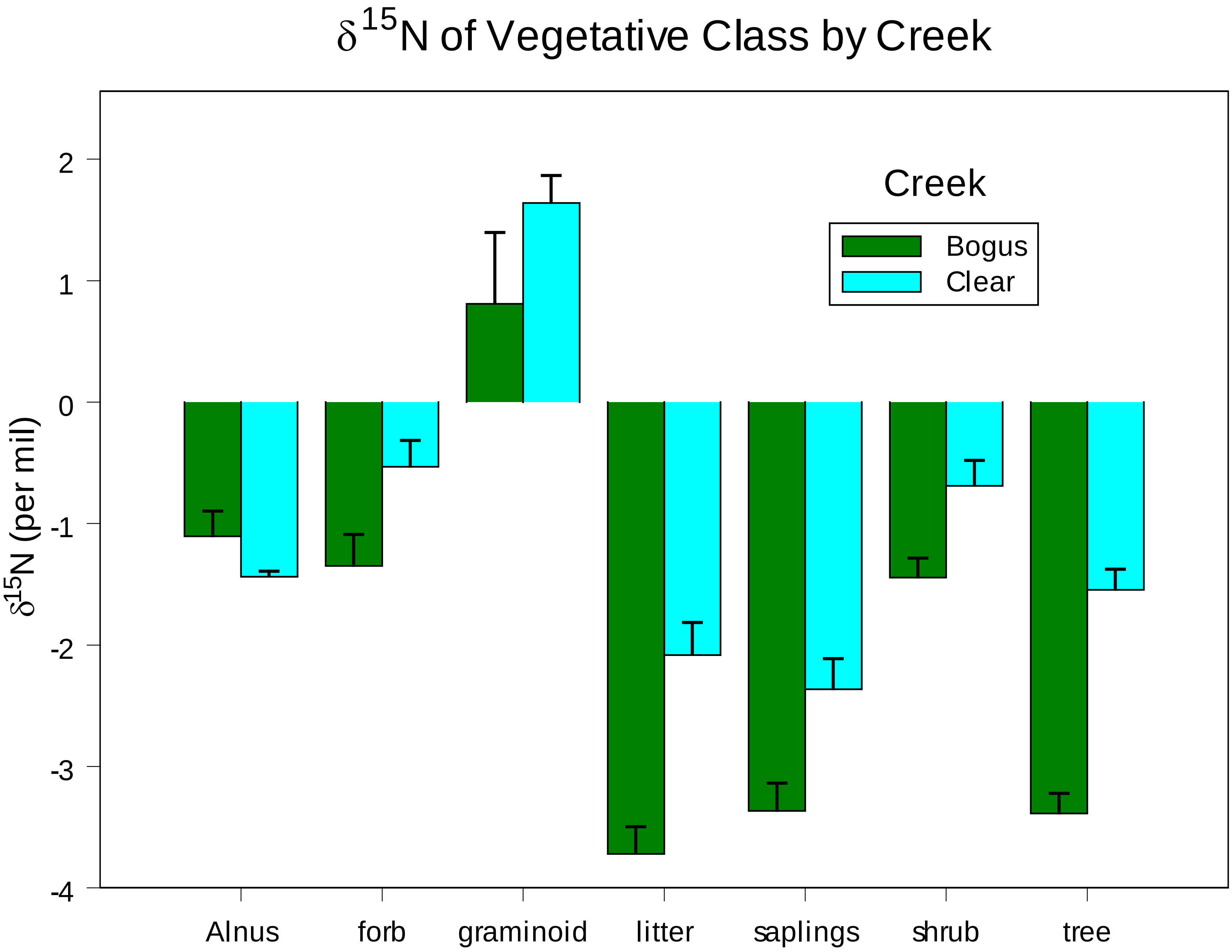
$$\%N\ \text{from fertilizer} = \frac{N_{t+1} - N_t}{N_{t+1}} \times 100$$

Statistics

- Mixed effects models
  - Accounts for repeated measures in $\delta^{15}N$ models.
  - Best account of differences in plant community composition.
- Random subset of *A. lasiocarpa* and *P. engelmannii* balanced between creek and treatment.

RESULTS

- Creek
  - Prior to treatment, Clear Creek vegetation was 1.75‰ more enriched than Bogus Creek
  - Consistent with predictions from salmon runs

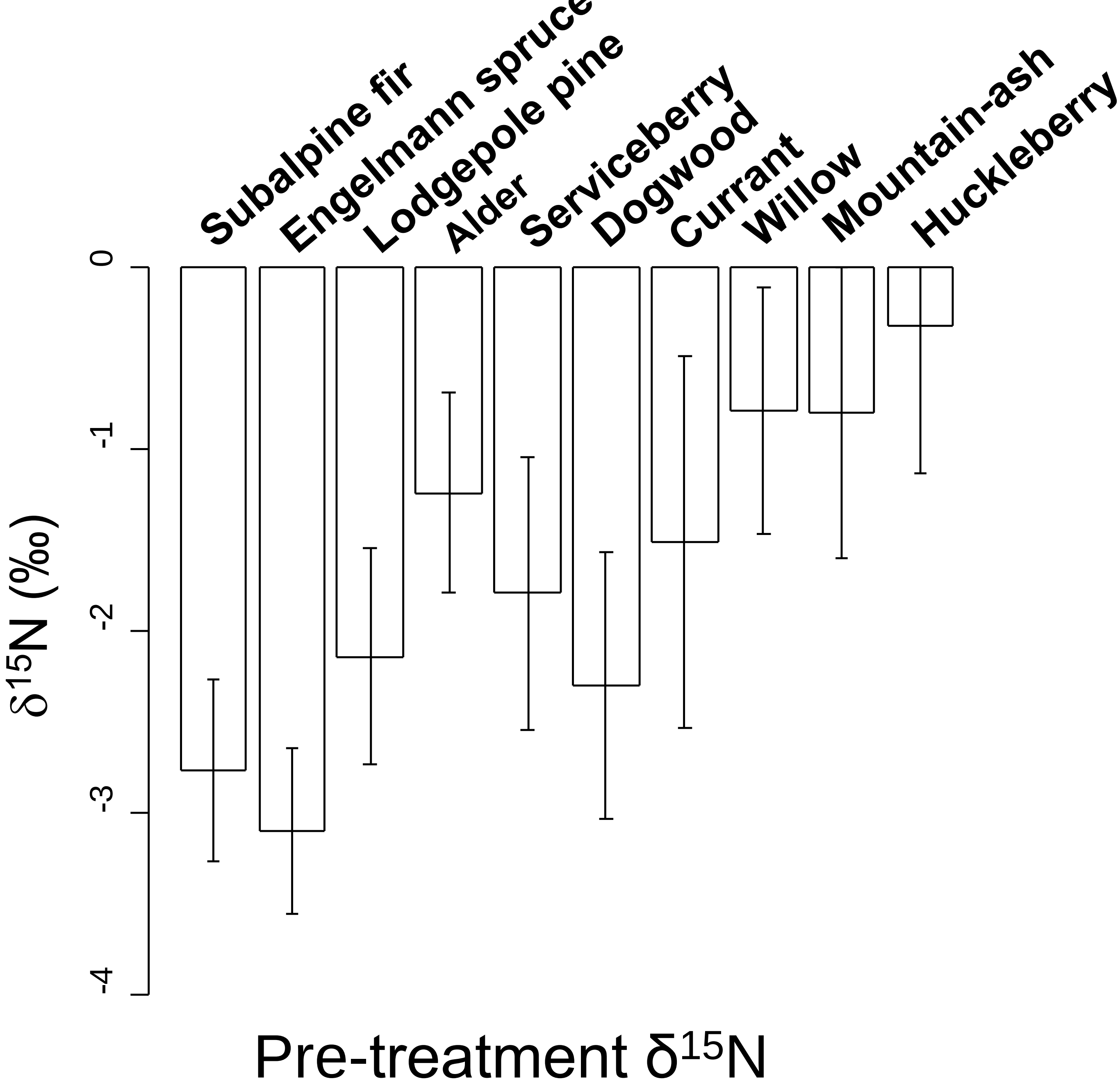


$\delta^{15}N$ of Vegetative Class by Creek
Creek
Bogus
Clear
$\delta^{15}N$ (per mil)
2
1
0
-1
-2
-3
-4
Alnus
forb
graminoid
litter
saplings
shrub
tree

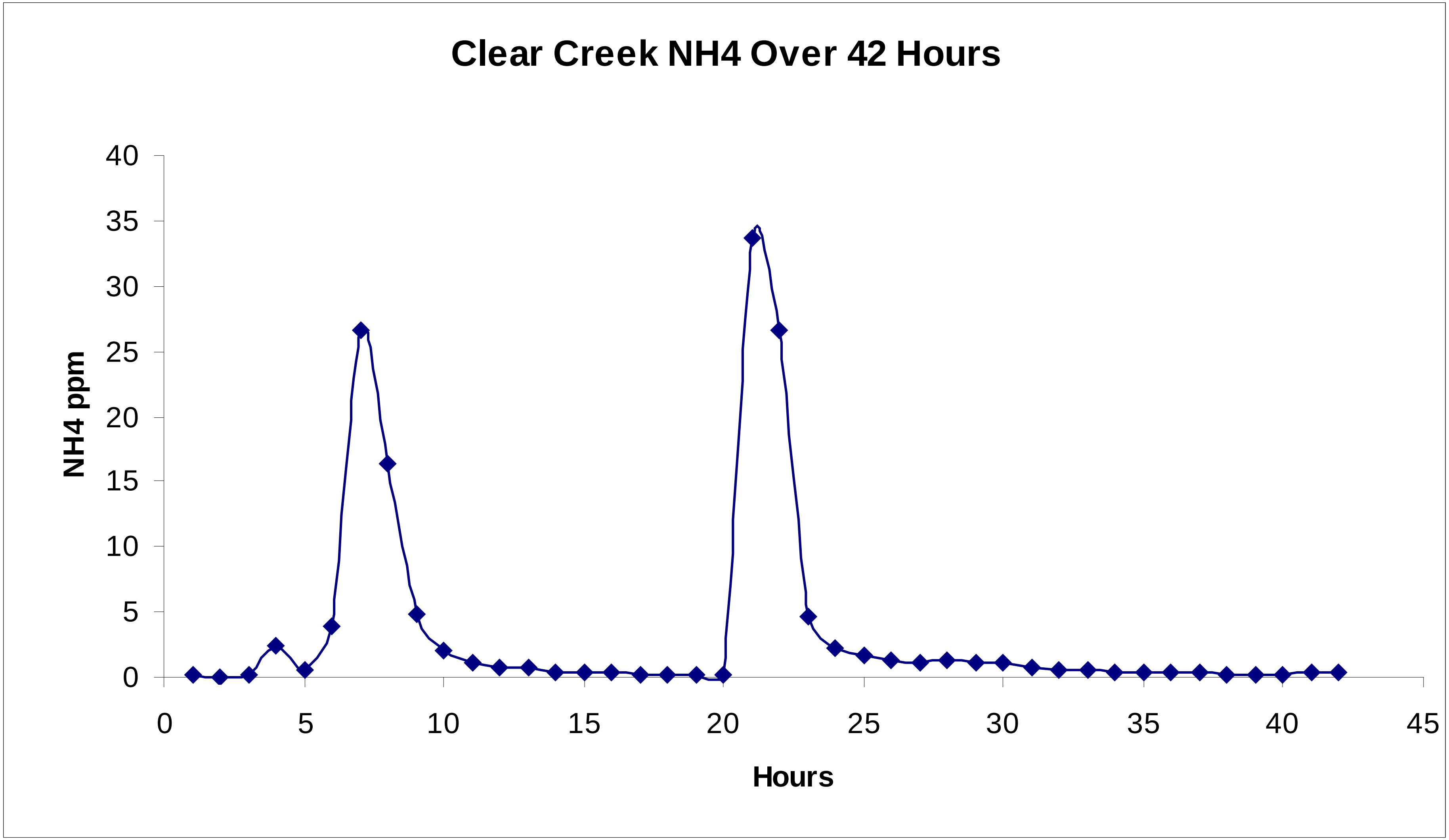
…Except in alder

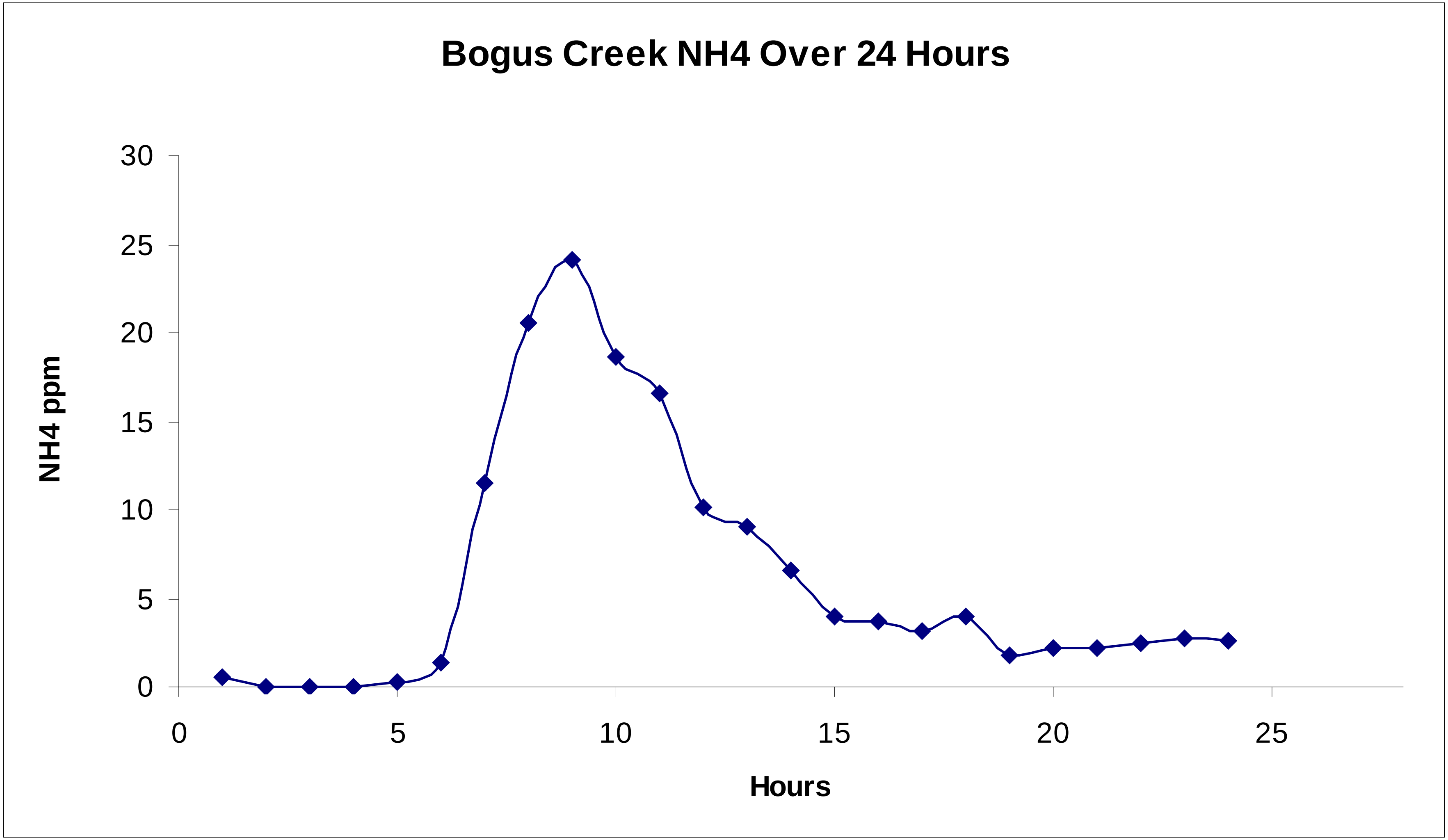
- Bogus: -1.12‰ ± 0.55
- Clear: -0.95‰ ± 1.4

….Nitrogen-fixation?



Subalpine fir
Engelmann spruce
Lodgepole pine
Alder
Serviceberry
Dogwood
Currant
Willow
Mountain-ash
Huckleberry
0
-1
-2
-3
-4
δ15N (‰)
Pre-treatment δ15N

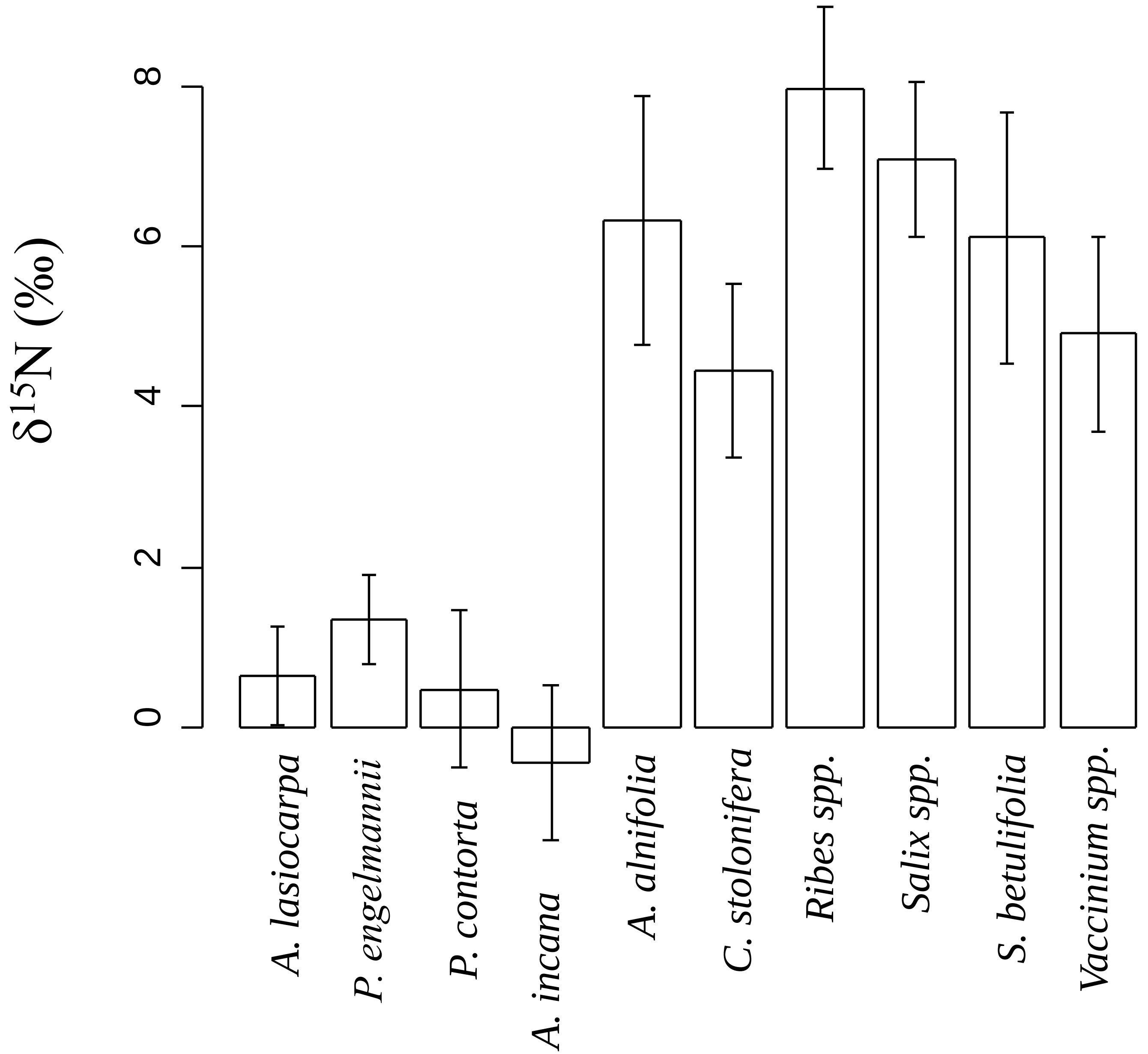

Clear Creek NH4 Over 42 Hours
NH4 ppm
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
40
45
Hours

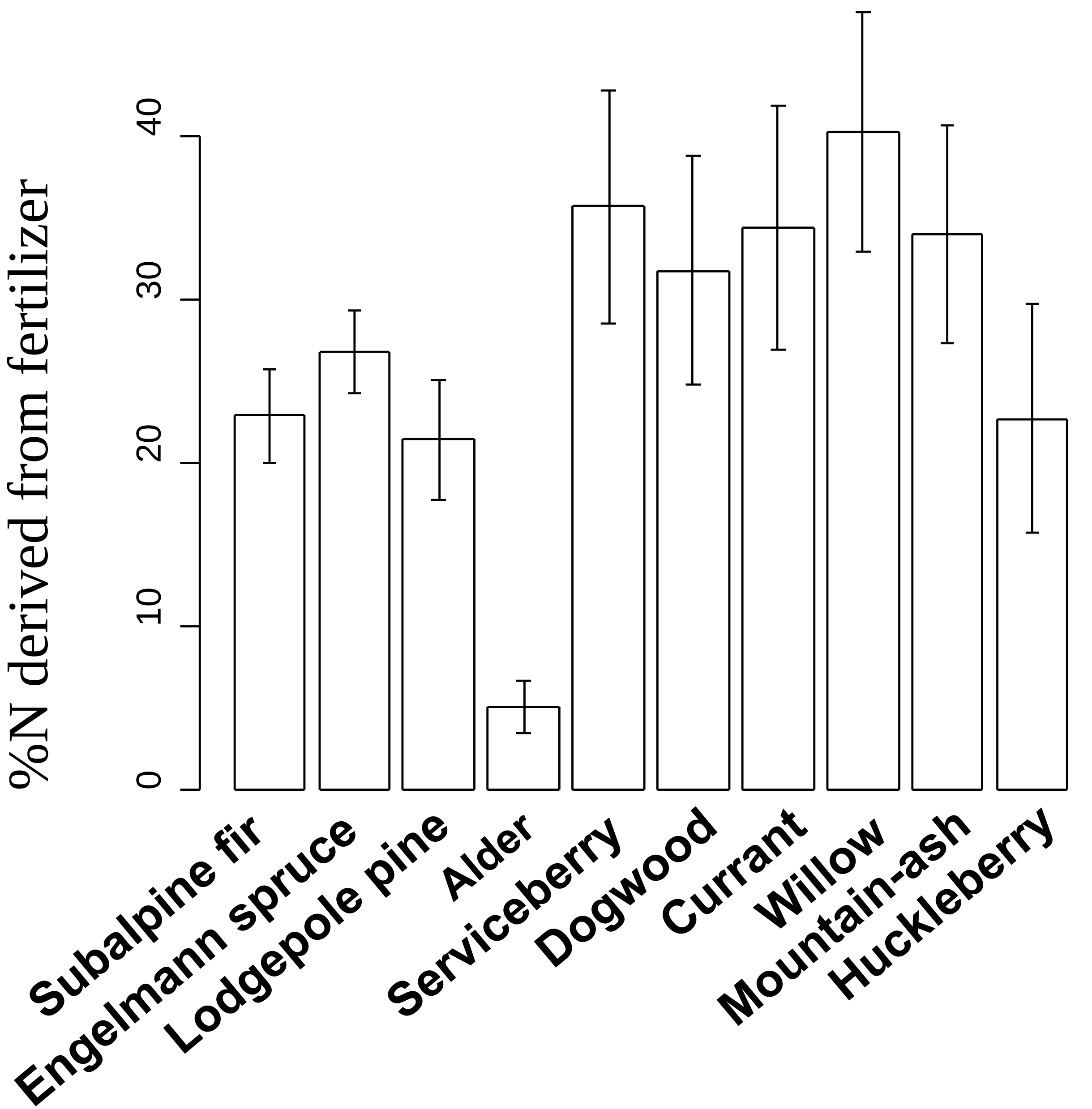

Bogus Creek NH4 Over 24 Hours
NH4 ppm
30
25
20
15
10
5
0
0
5
10
15
20
25
Hours

Foliar % N change (Δ)

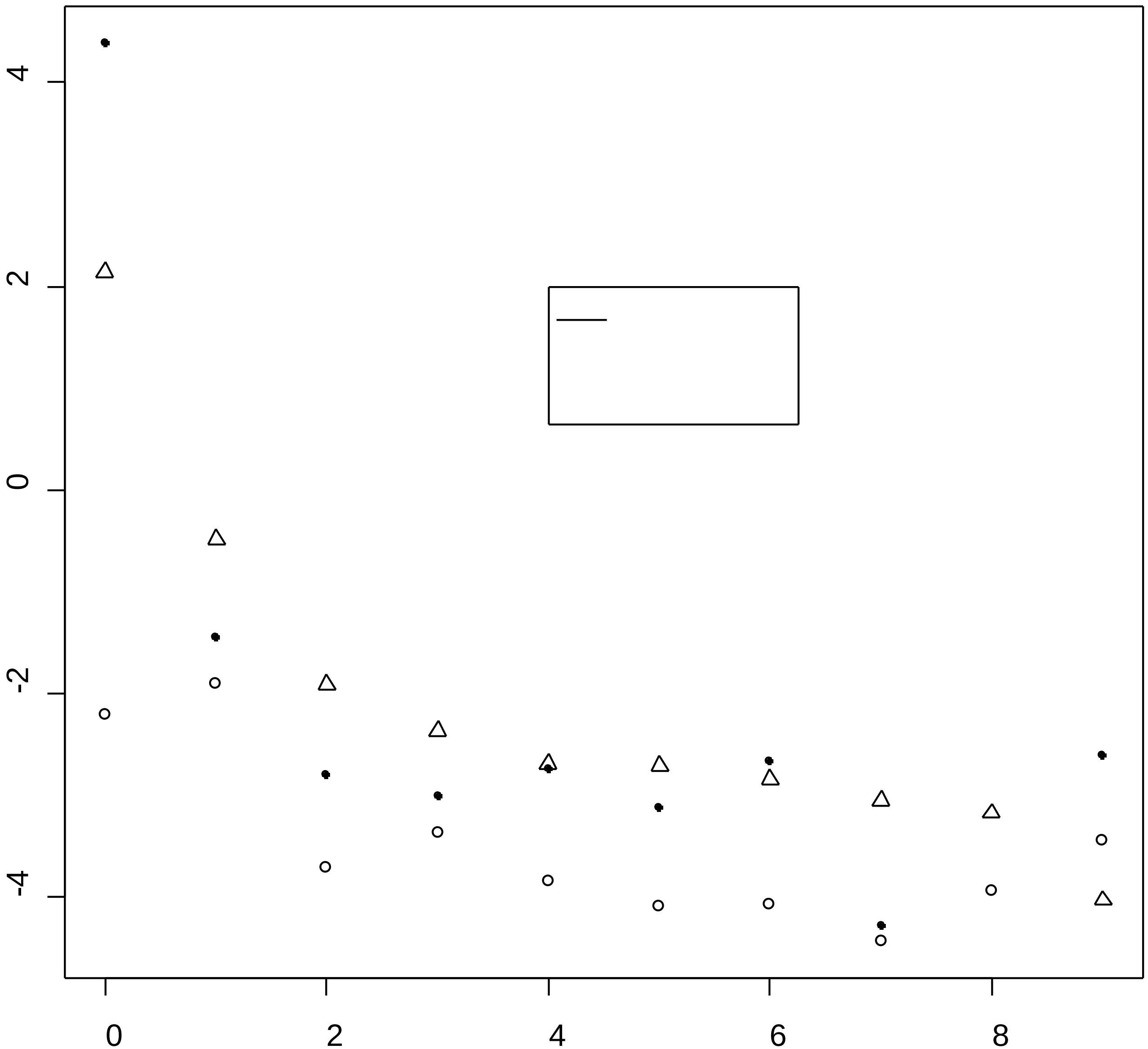
trt	creek	N_1	N_2	Δ
0N	bogus	1.12	1.18	0.05
0N	clear	1.14	1.16	0.01
200N	bogus	1.14	1.43	0.29
200N	clear	1.20	1.54	0.34
400N	bogus	1.14	1.70	0.56
400N	clear	1.19	1.70	0.51

Fig 5. Average values of post-treatment δ^{15}N of treated stream reaches.



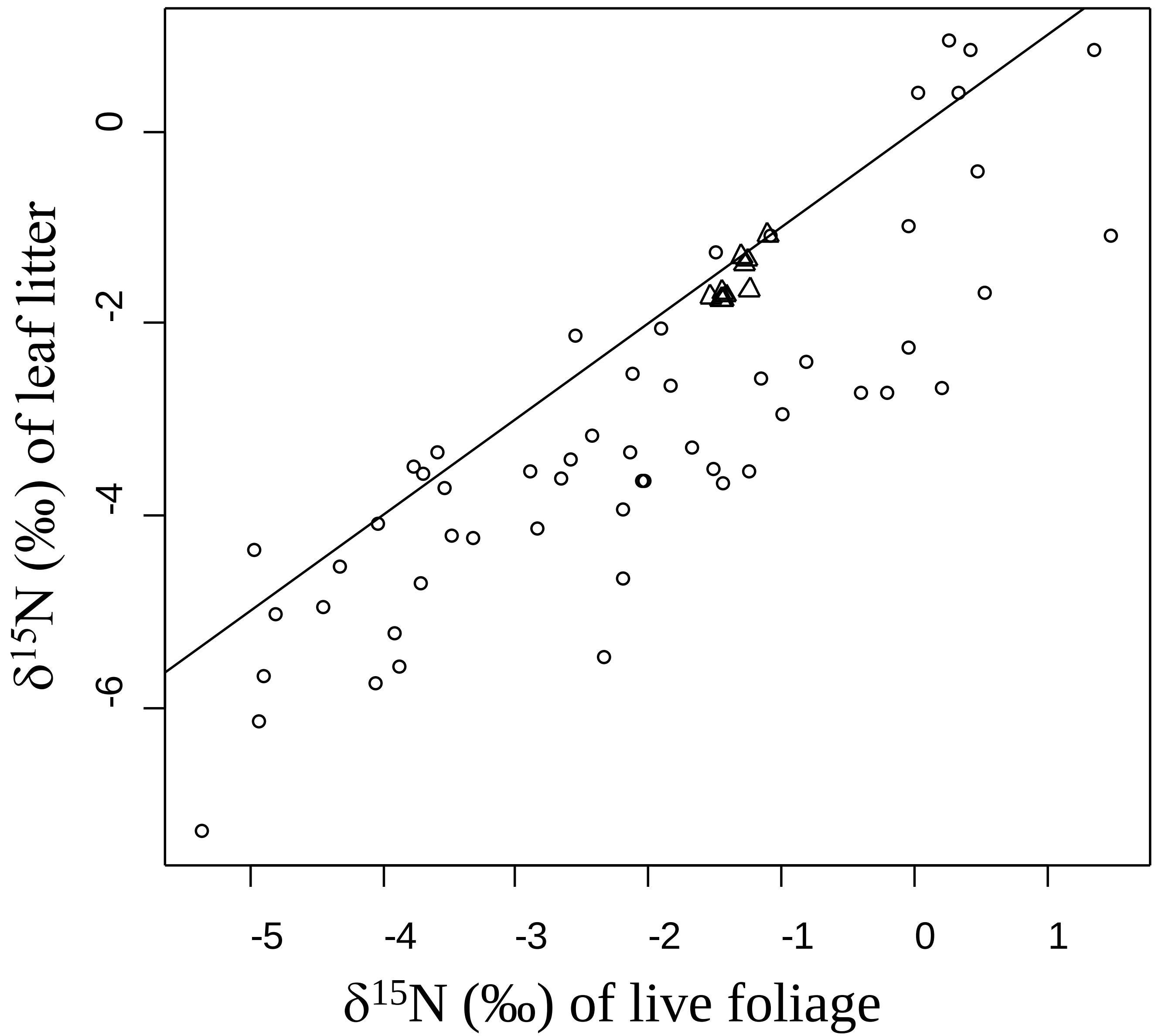


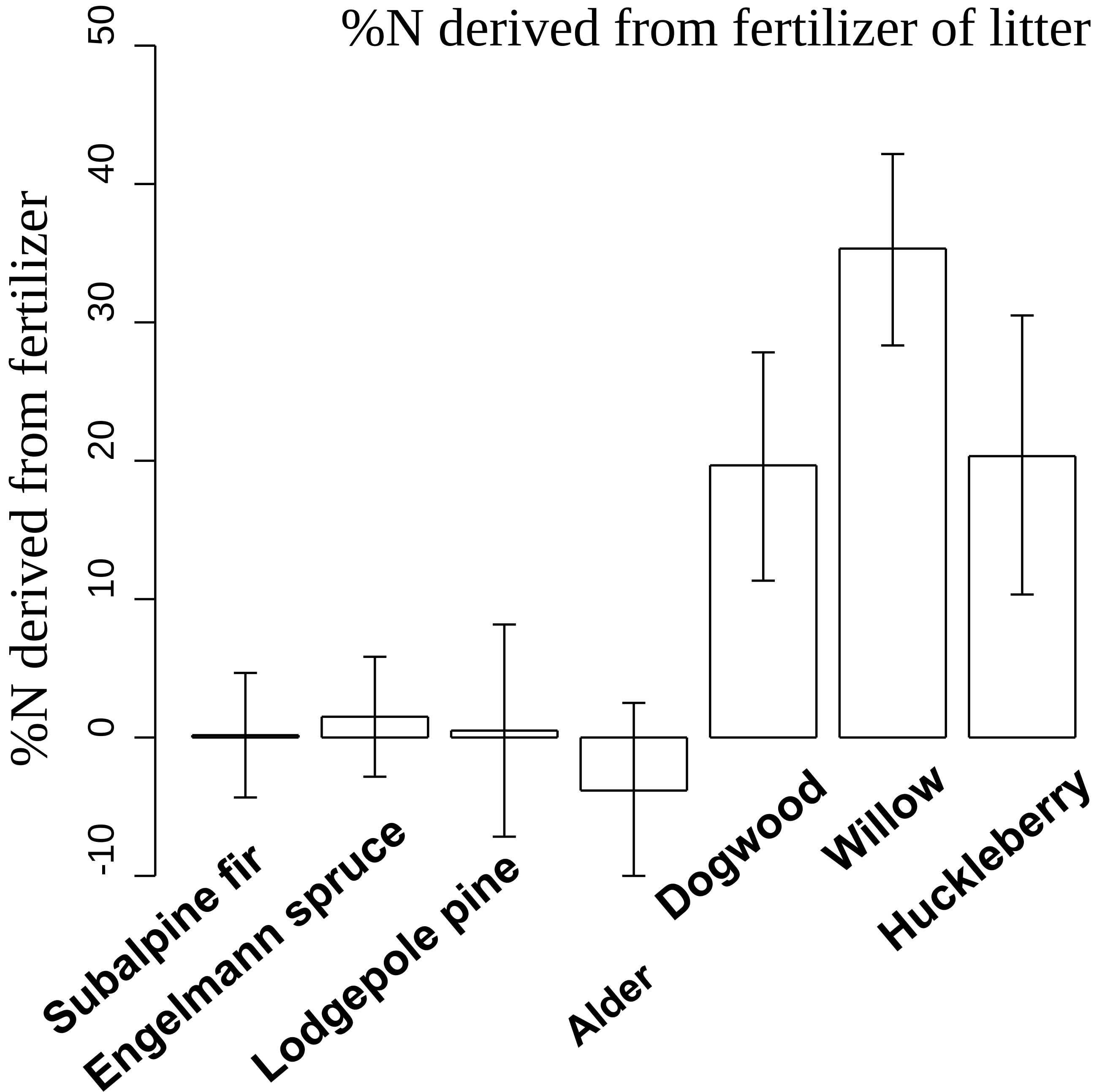
%N derived from fertilizer
0
10
20
30
40
Subalpine fir
Engelmann spruce
Lodgepole pine
Alder
Serviceberry
Dogwood
Currant
Willow
Mountain-ash
Huckleberry



4
2
0
-2
-4
0
2
4
6
8


Fig 6. $\delta^{15}N$ of leaf litter plotted against $\delta^{15}N$ of live foliage.




%N derived from fertilizer of litter
%N derived from fertilizer
50
40
30
20
10
0
-10
Subalpine fir
Engelmann spruce
Lodgepole pine
Alder
Dogwood
Willow
Huckleberry


That's cool, John, but why would the IFTNC care about all this?

Species effects

- Alder took up no fertilizer, must be fixing N, retranslocates nothing—leave it alone?
- Trees accumulated N in new foliage, did not recycle it, will eventually get it all?
- Litter of deciduous species began to cycle fertilizer N in the first year after treatment

Technical issues

- Even mixing
  - We mixed 50 lbs of tracer into 13 tons of the fertilizer batch
- Fractionation on uptake
  - A discrimination of 1‰ on uptake would result in an underestimation of %Ndff of 5%.
  - Reported discrimination against ^{15}N on uptake of ammonium: 0.9 to 6.5‰
    - (Högberg et al. 1999)

More generally…

Are forests so efficient at taking up nitrogen that little of it ever gets to the stream?

Can forest fertilization be presented as a means of remediating nutrient deficiencies in streams?