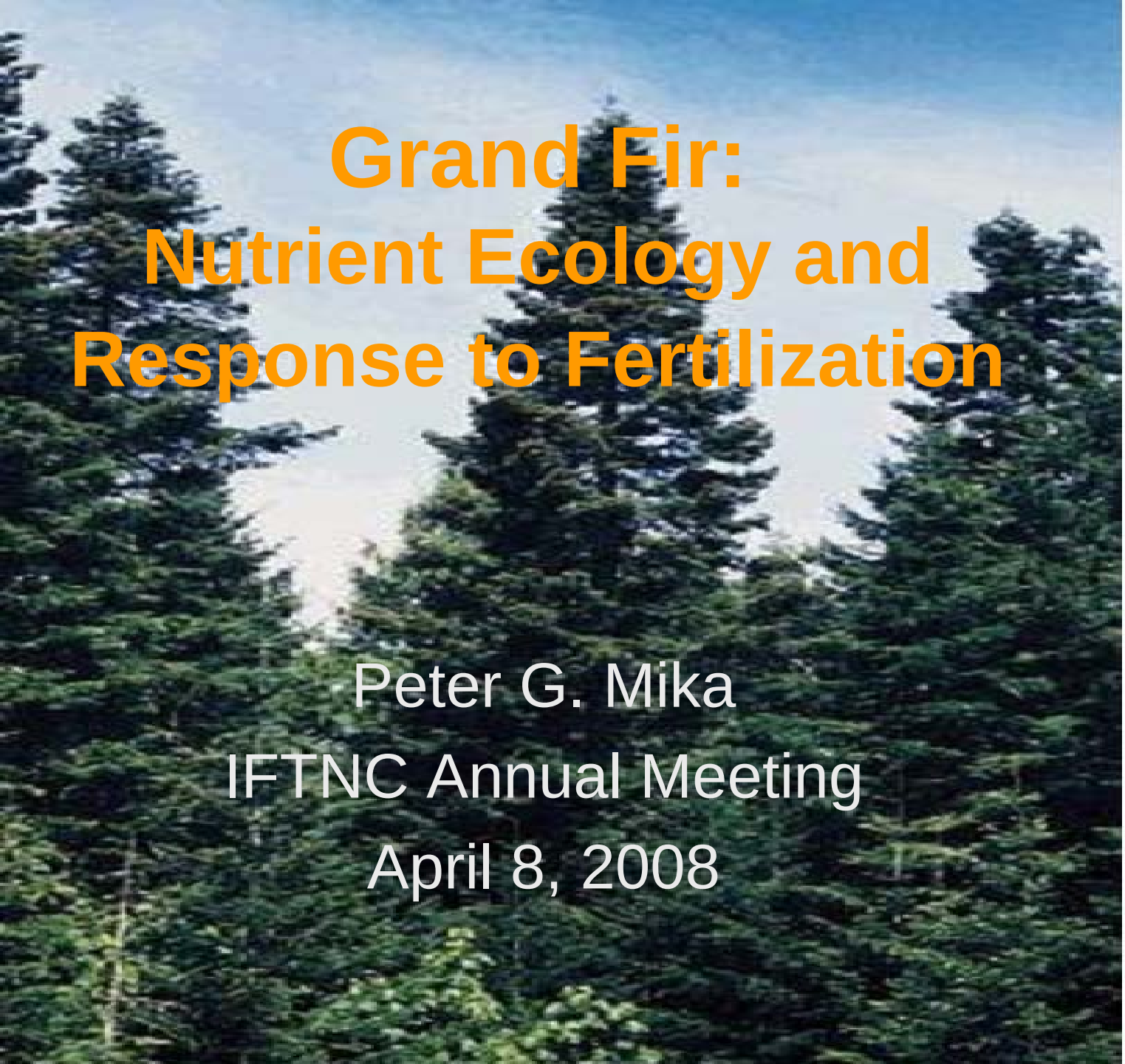


Grand Fir:
Nutrient Ecology and Response to Fertilization

Peter G. Mika

IFTNC Annual Meeting

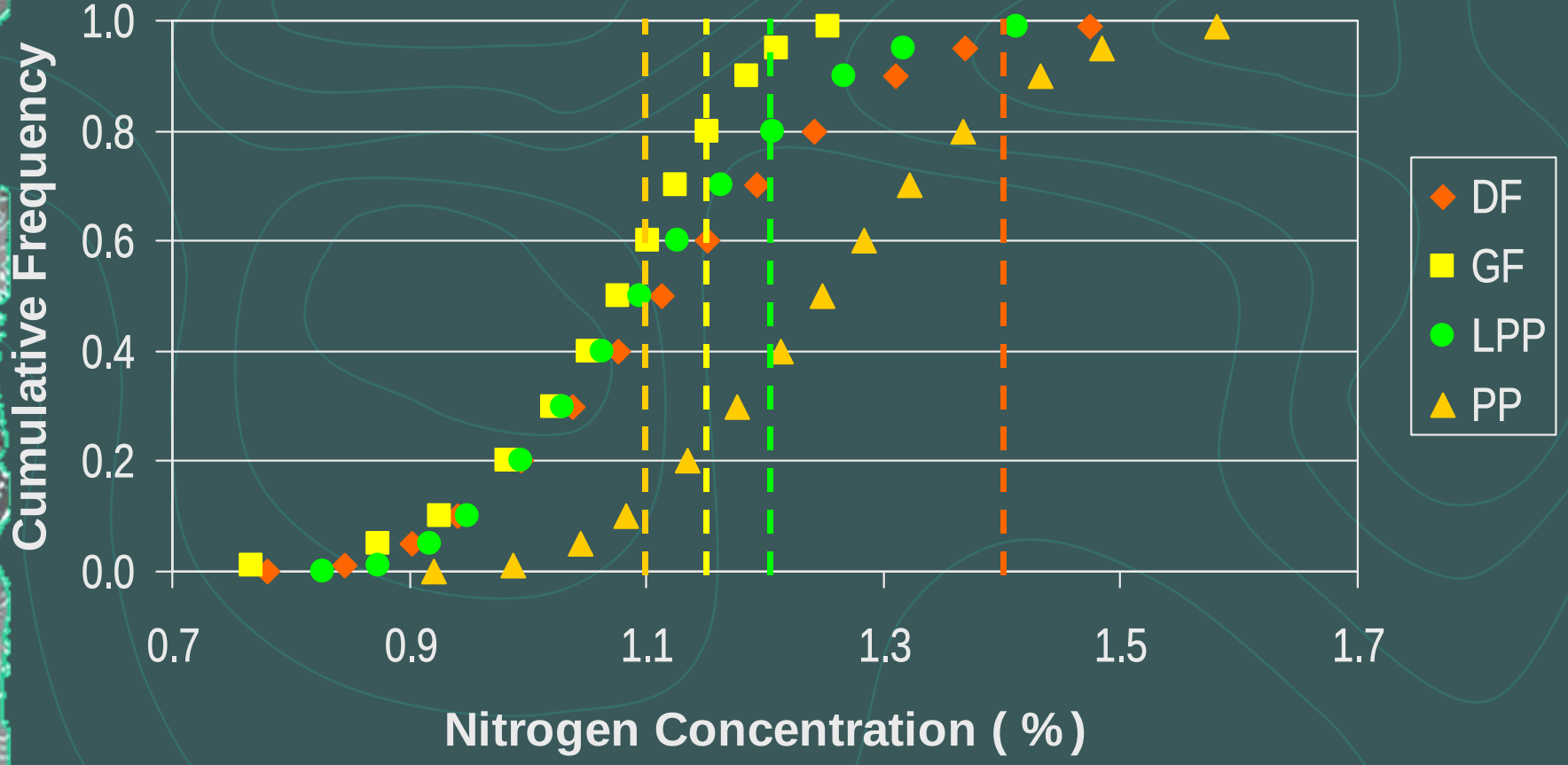
April 8, 2008

Grand Fir—the “nutrient hog”?

Sites with Foliar Response Data from Plot-based Experiments by Species, Vegetation Series, and Rock Type

Species	DF					PP		GF				LPP		
	Vegetation Series													
Rock Type	DF	GF	RC	WH	AF	DF	GF	GF	RC	WH	AF	DF	GF	AF
Basalt	15	25	5	3		6	12	4	1	2	1		1	1
Granite	11	9	3	1	1	4	2		1			1		3
Metasediment	8	6	12	2		3	1	1	2					
Mixed	17	4	4	1	1	3	4		1			1	1	1
Sediment	4	3					2							

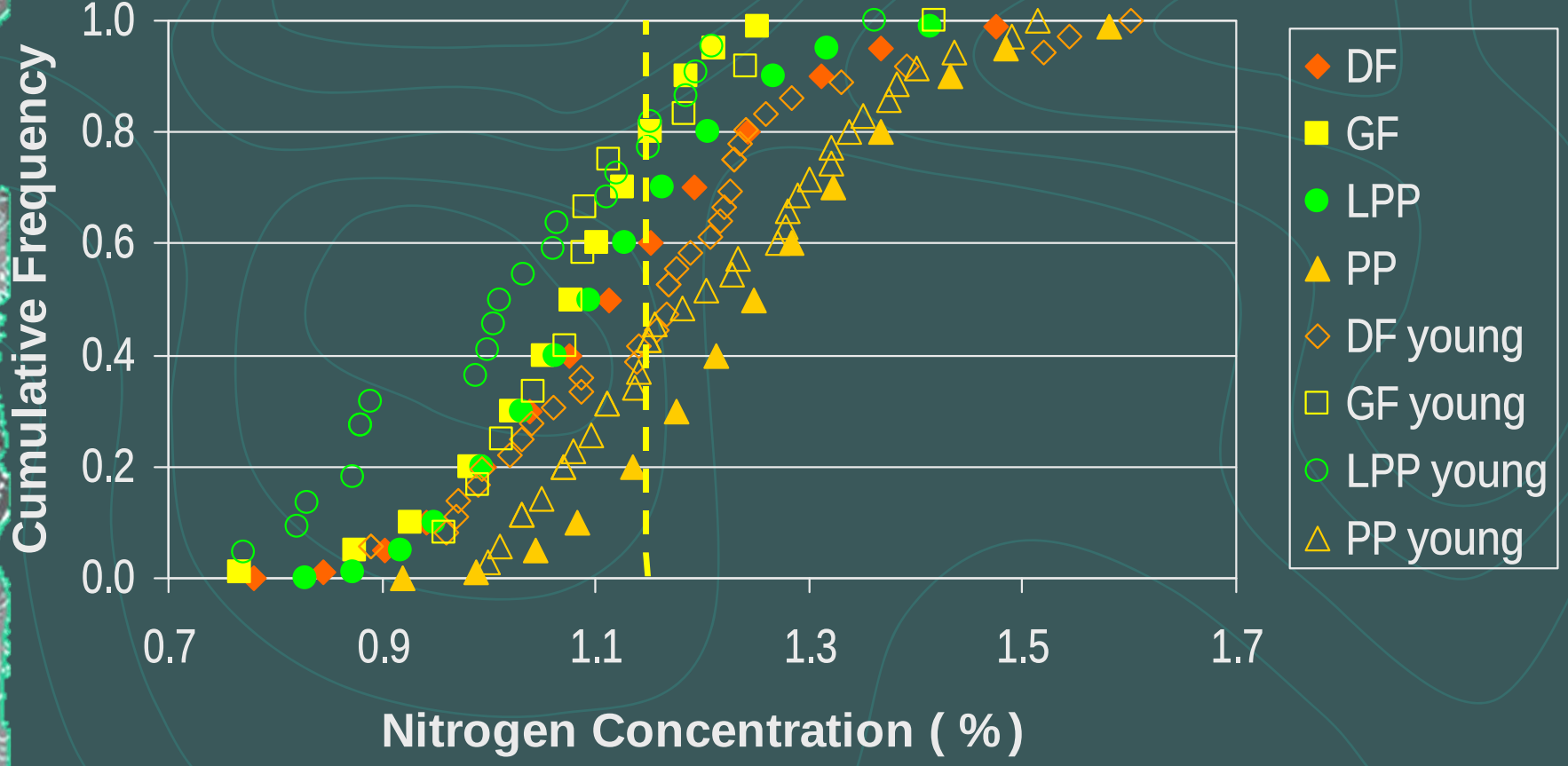
Foliar N Distribution by Tree Species
Mature Trees



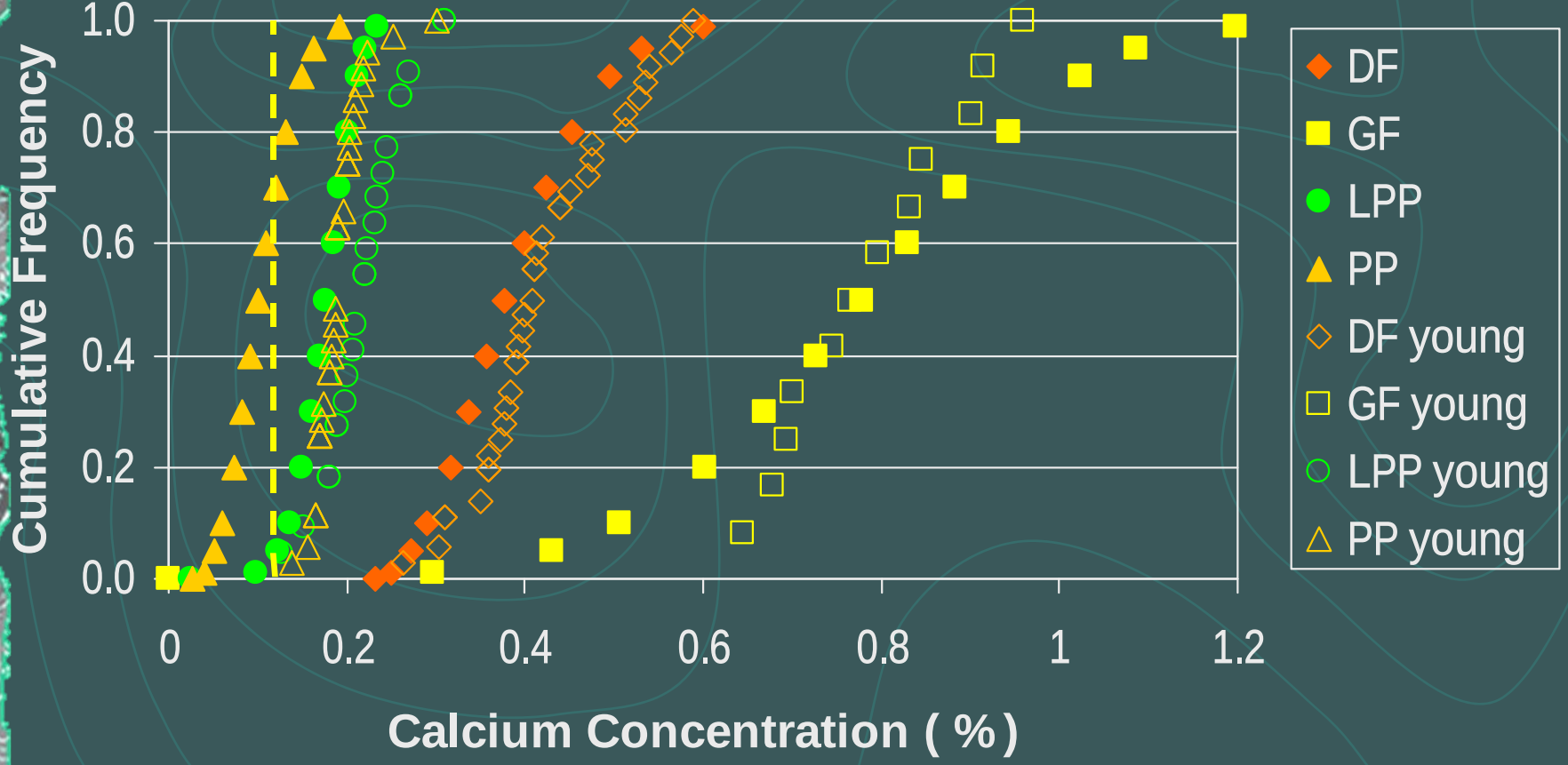
Sites with Foliar/Growth Response Data from Screening Trials by Species, Rock Type and Vegetation Series

	Rock Type								
	Extrusive		Intrusive			Metamorphic		Unconsolidated	
	Vegetation Series								
Species	DF	GF	DF	GF	WRC	GF	WRC	GF	WRC
DF		9/9		1/0	5/4		17/15	3/3	1/0
GF					2/2		9/9		1/1
LP	2/2	3/3		5/5	2/1	1/1	1/0	4/4	4/2
PP		15/14	2/2	5/4	3/2	1/1	3/1	4/4	2/1
WL		1/1			1/1		1/1	1/1	1/0
WP					1/1		2/2		

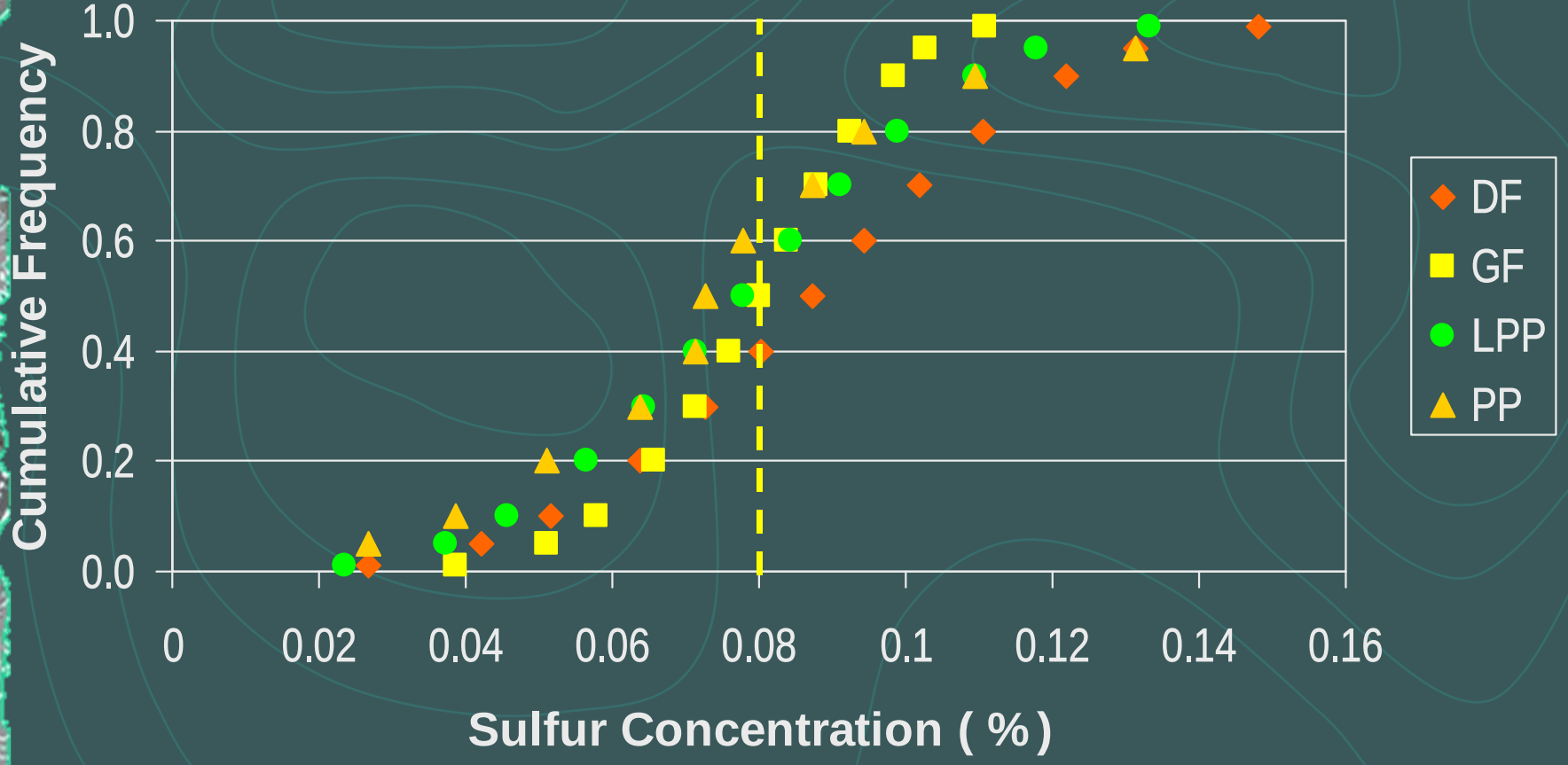
Foliar N Distribution by Tree Species
Mature vs. Young Trees



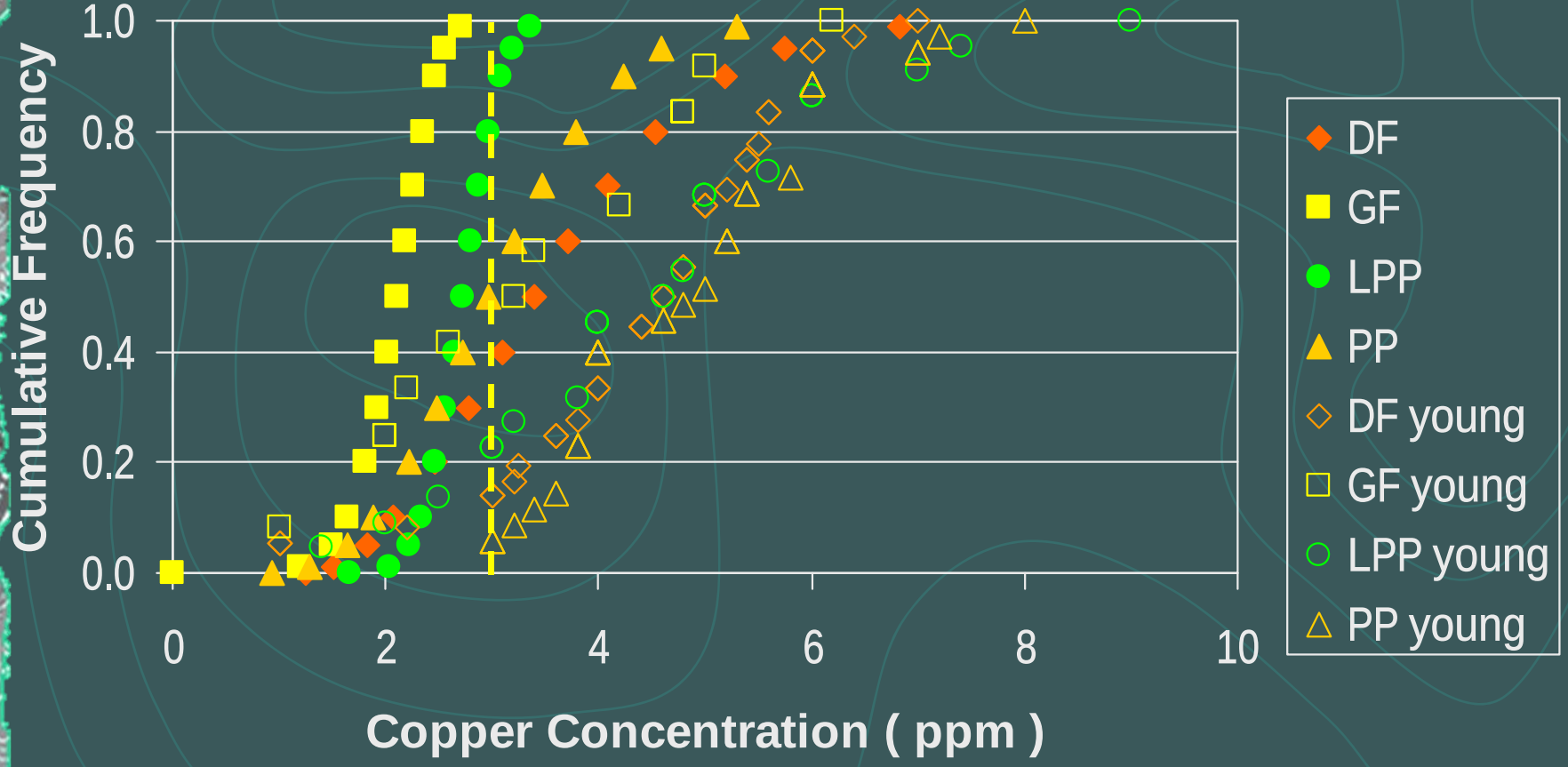
Foliar Ca Distribution by Tree Species
Mature vs. Young Trees



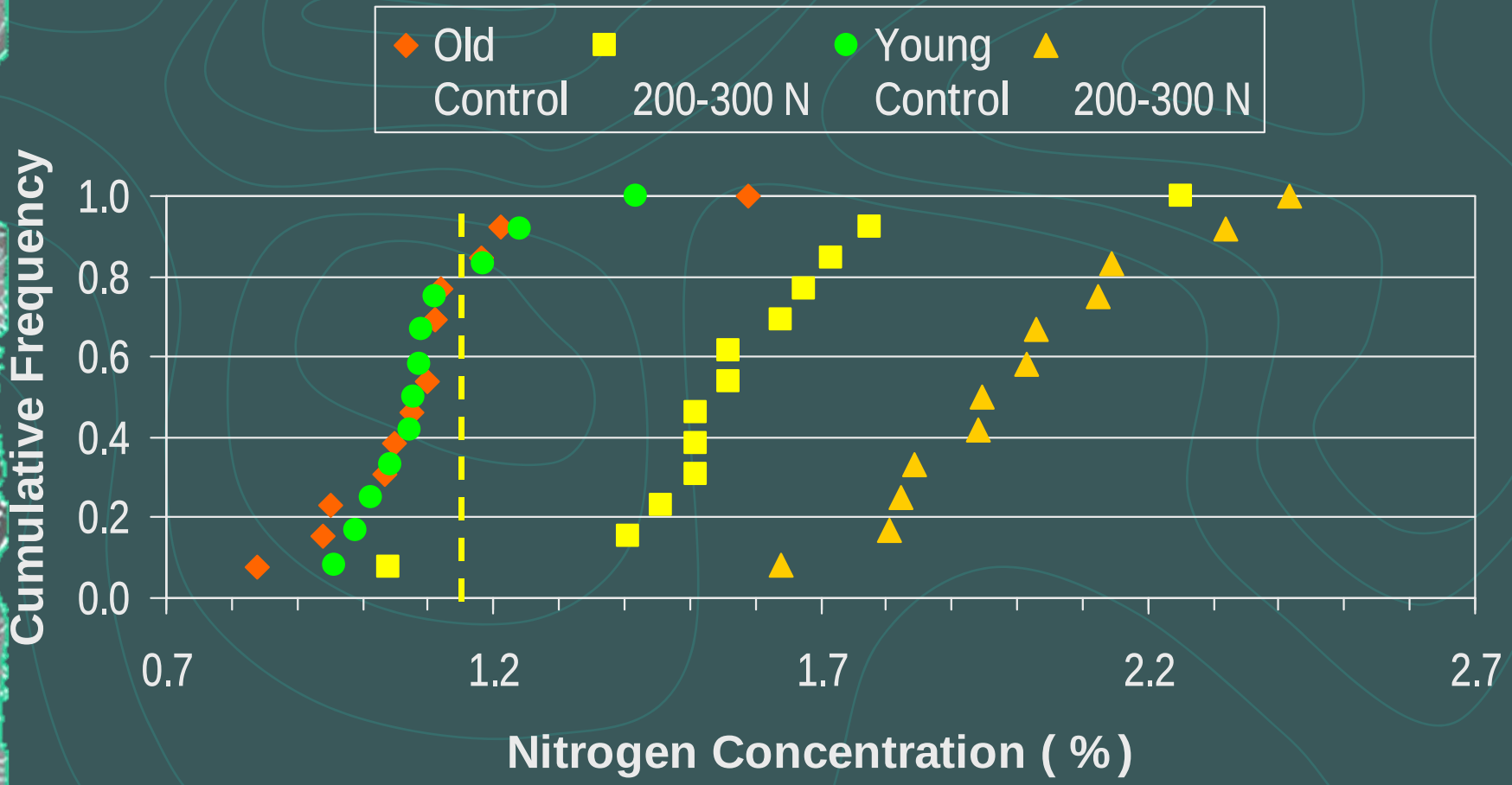
Foliar S Distribution by Tree Species
Mature Trees



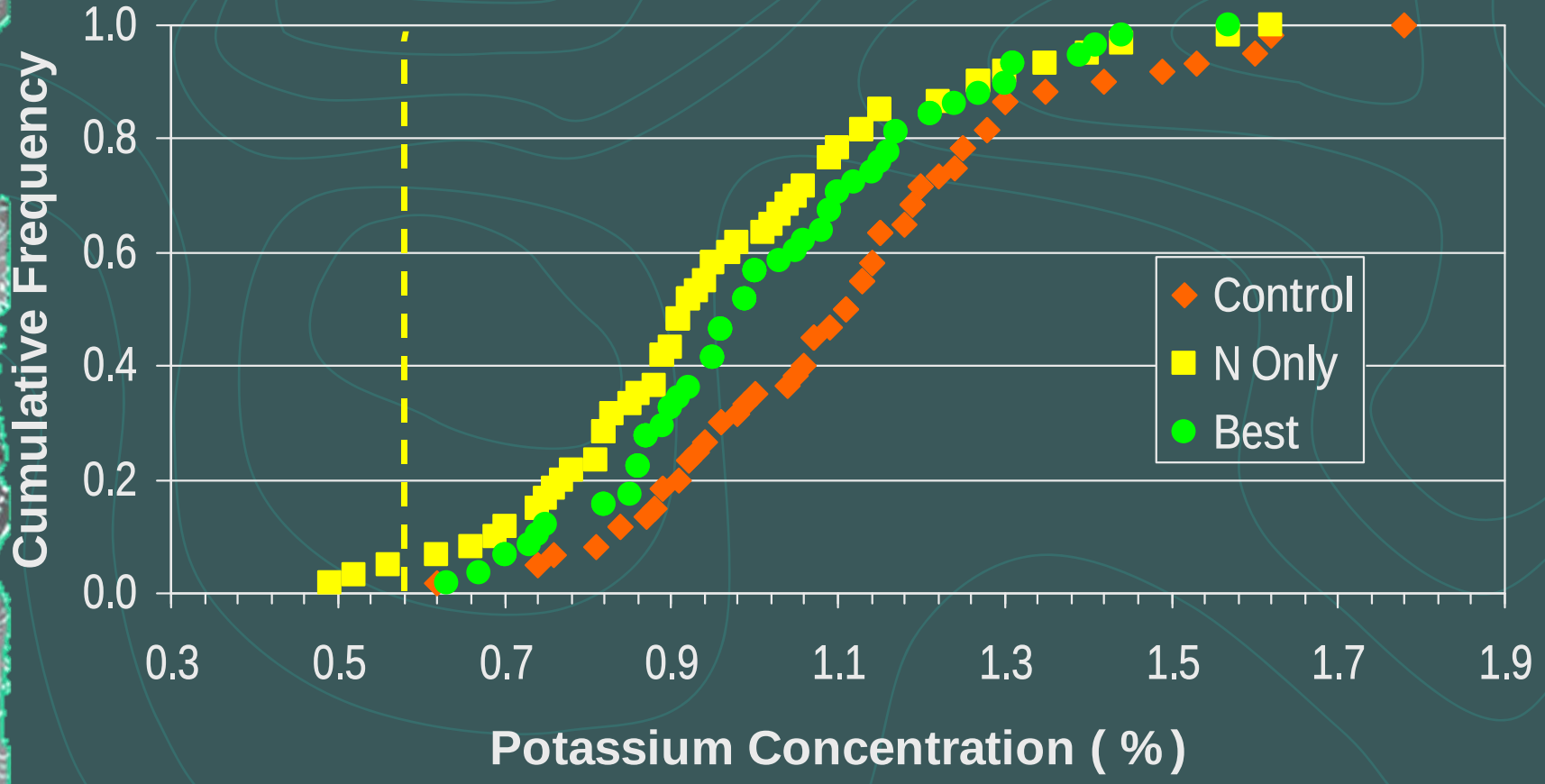
Foliar Cu Distribution by Tree Species
Mature vs. Young Trees



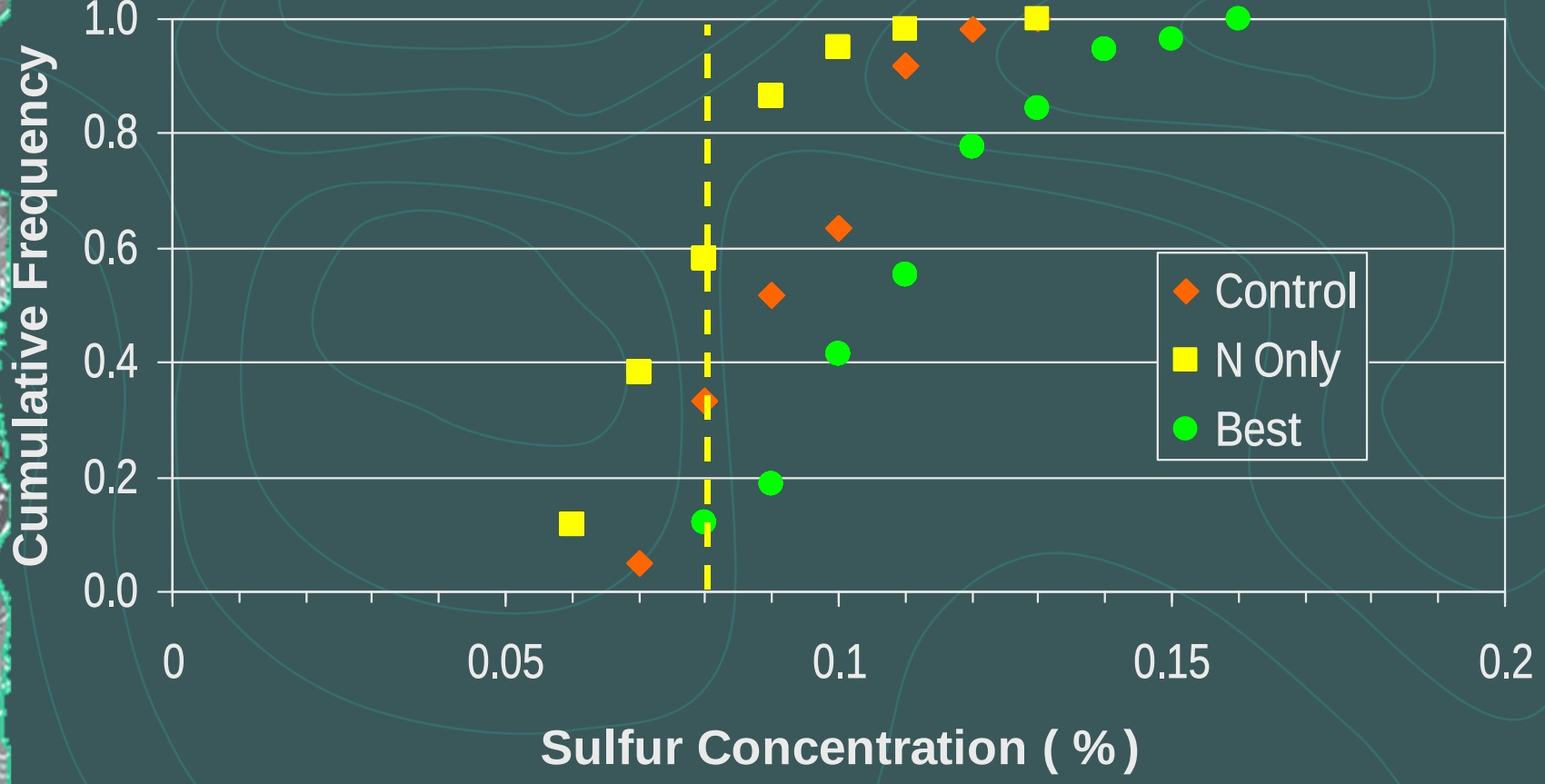
Distribution of Foliar N Concentration for Grand Fir



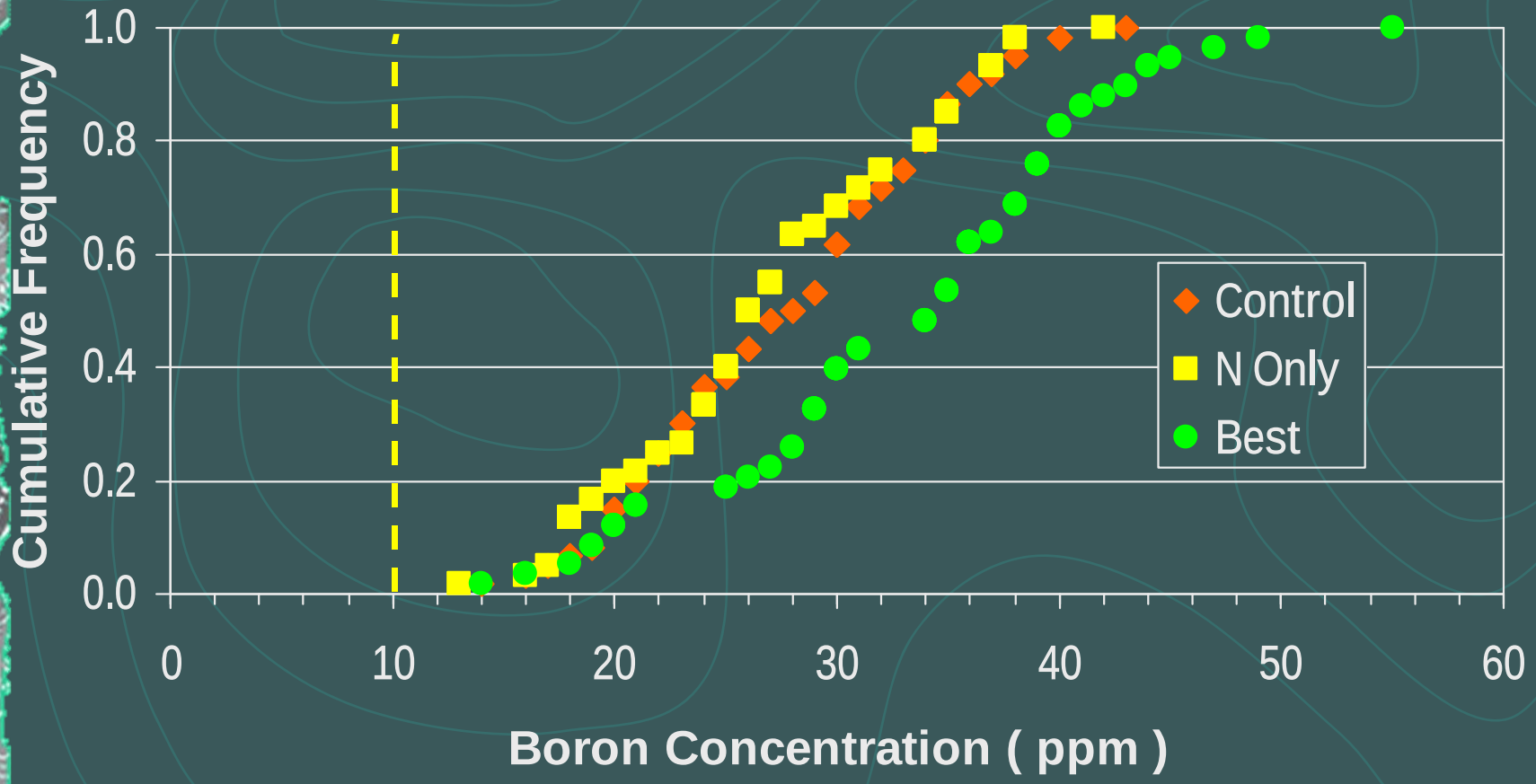
Distribution of Foliar K Concentration for Grand Fir



Distribution of Foliar S Concentration for Grand Fir

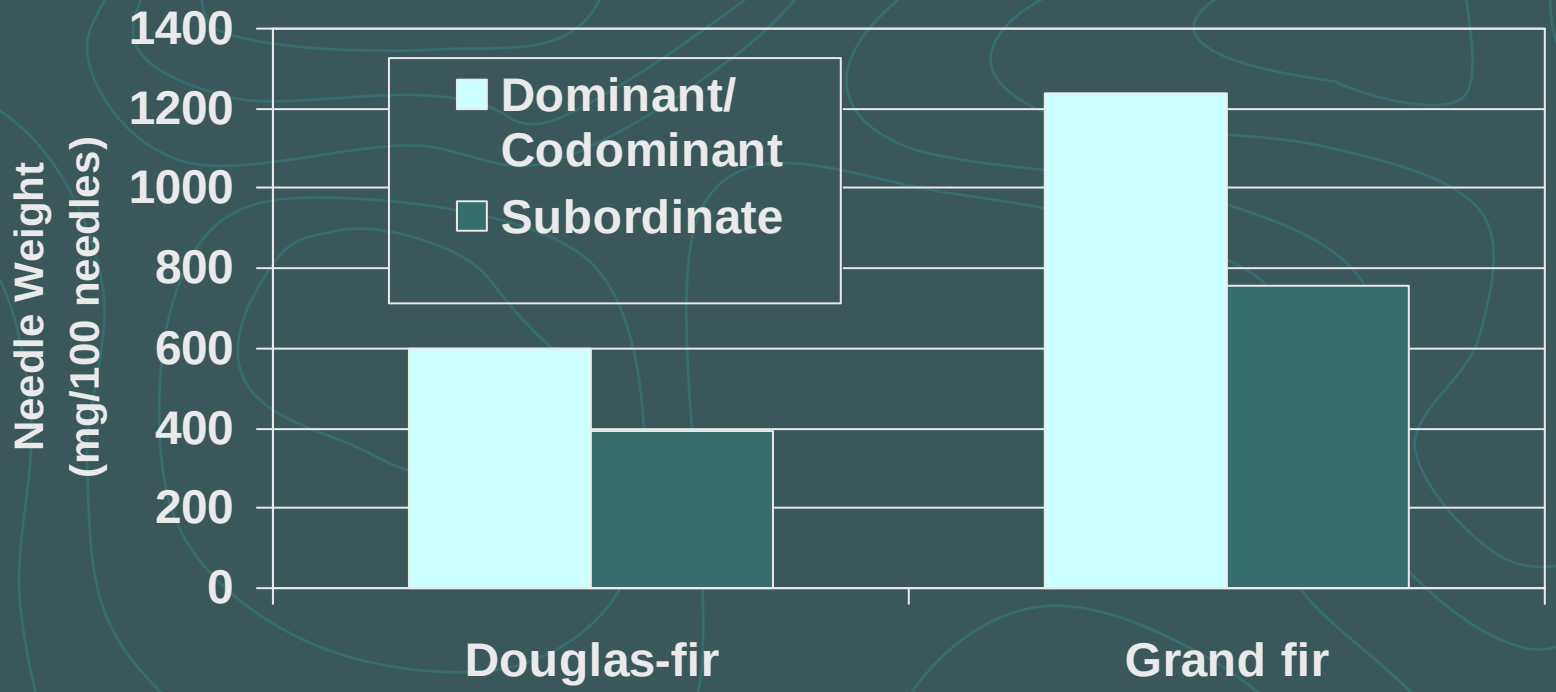


Distribution of Foliar B Concentration for Grand Fir



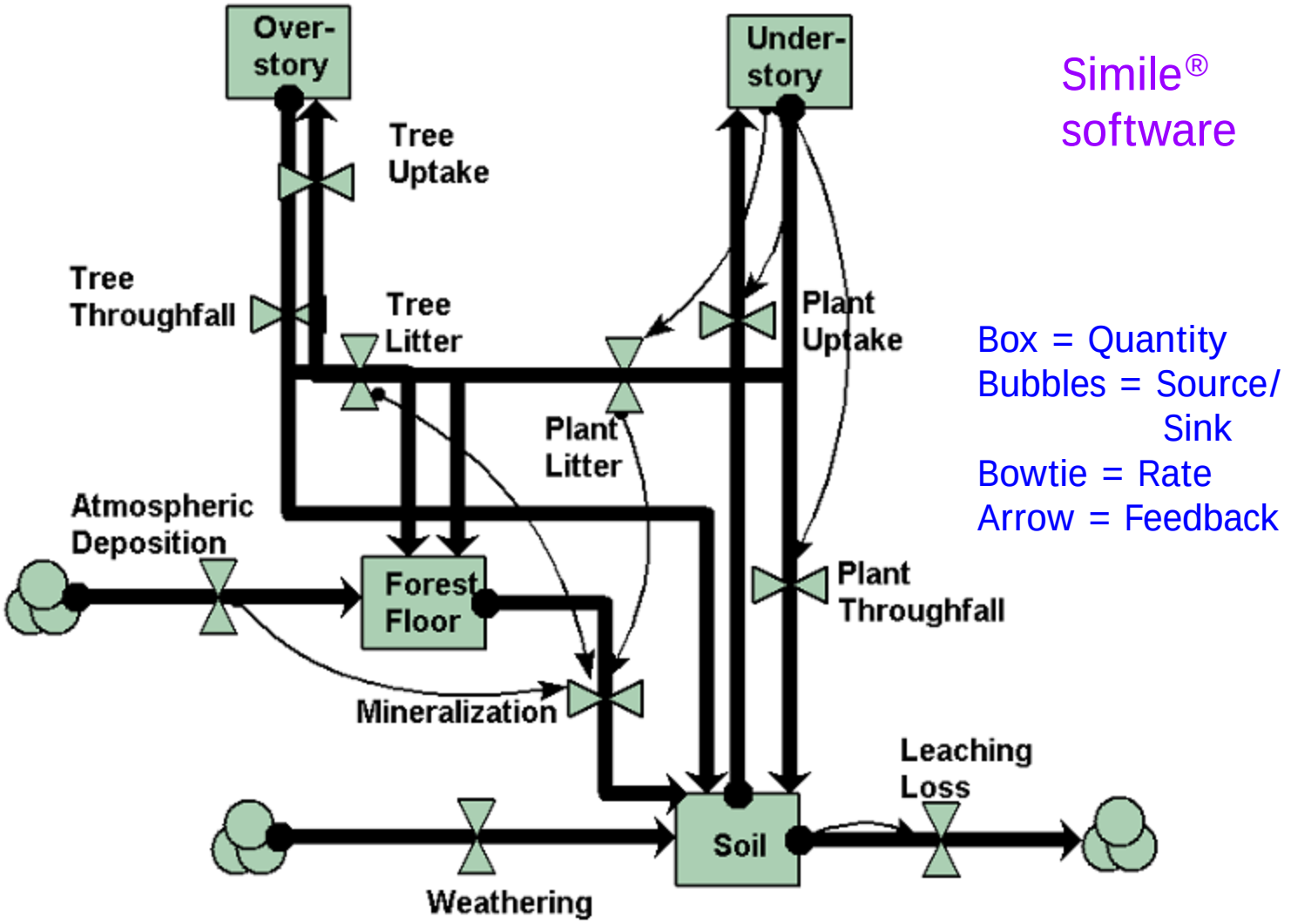
Mallory Creek Nutrient Cycling Study

Overstory foliage weight by species and crown class

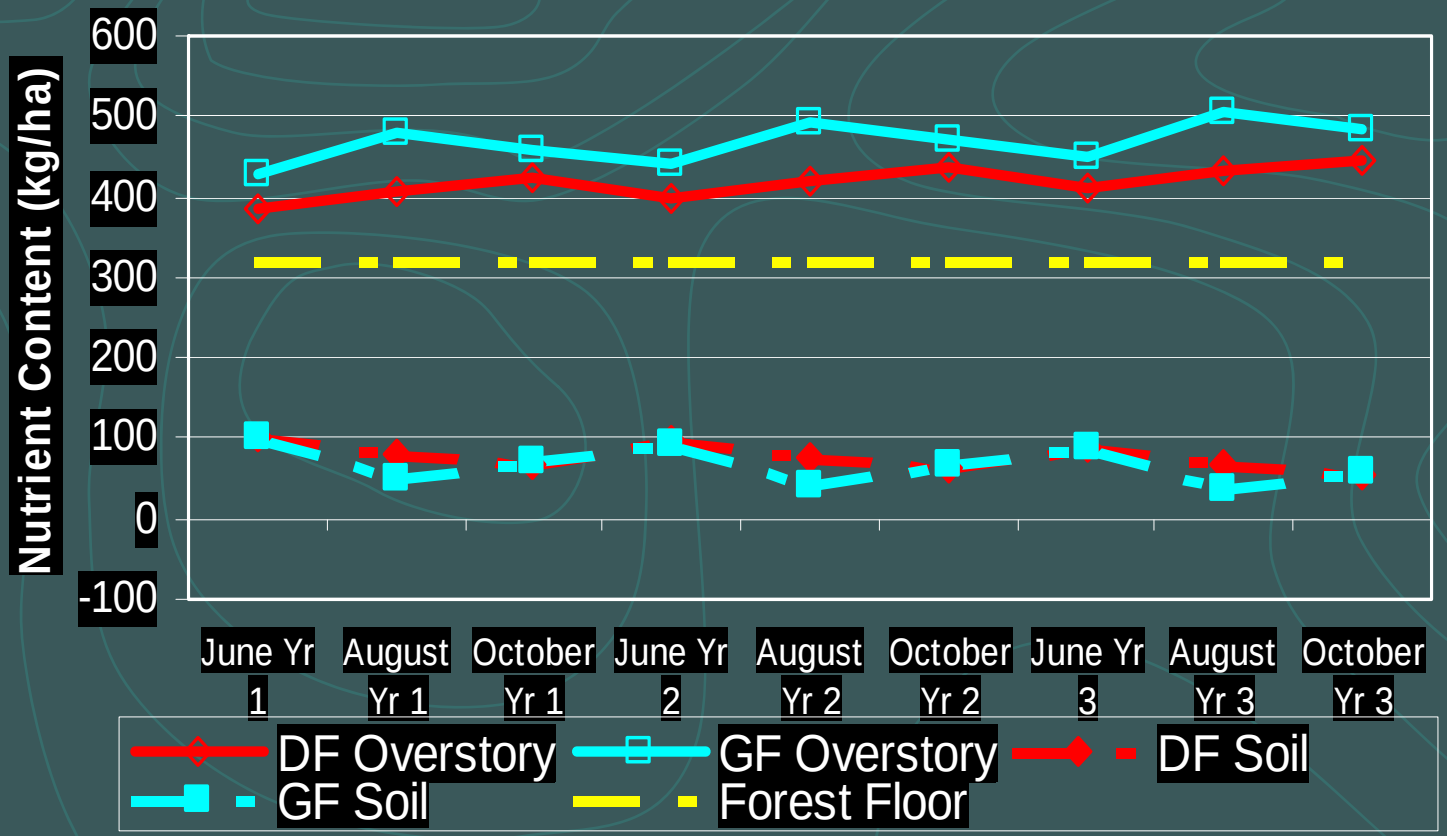


Grand fir contents higher than Douglas-fir contents for all elements.
Dominant tree contents greater than subordinate trees for all except Ca, Cu and Fe.

Nutrient Cycling Model: Simile



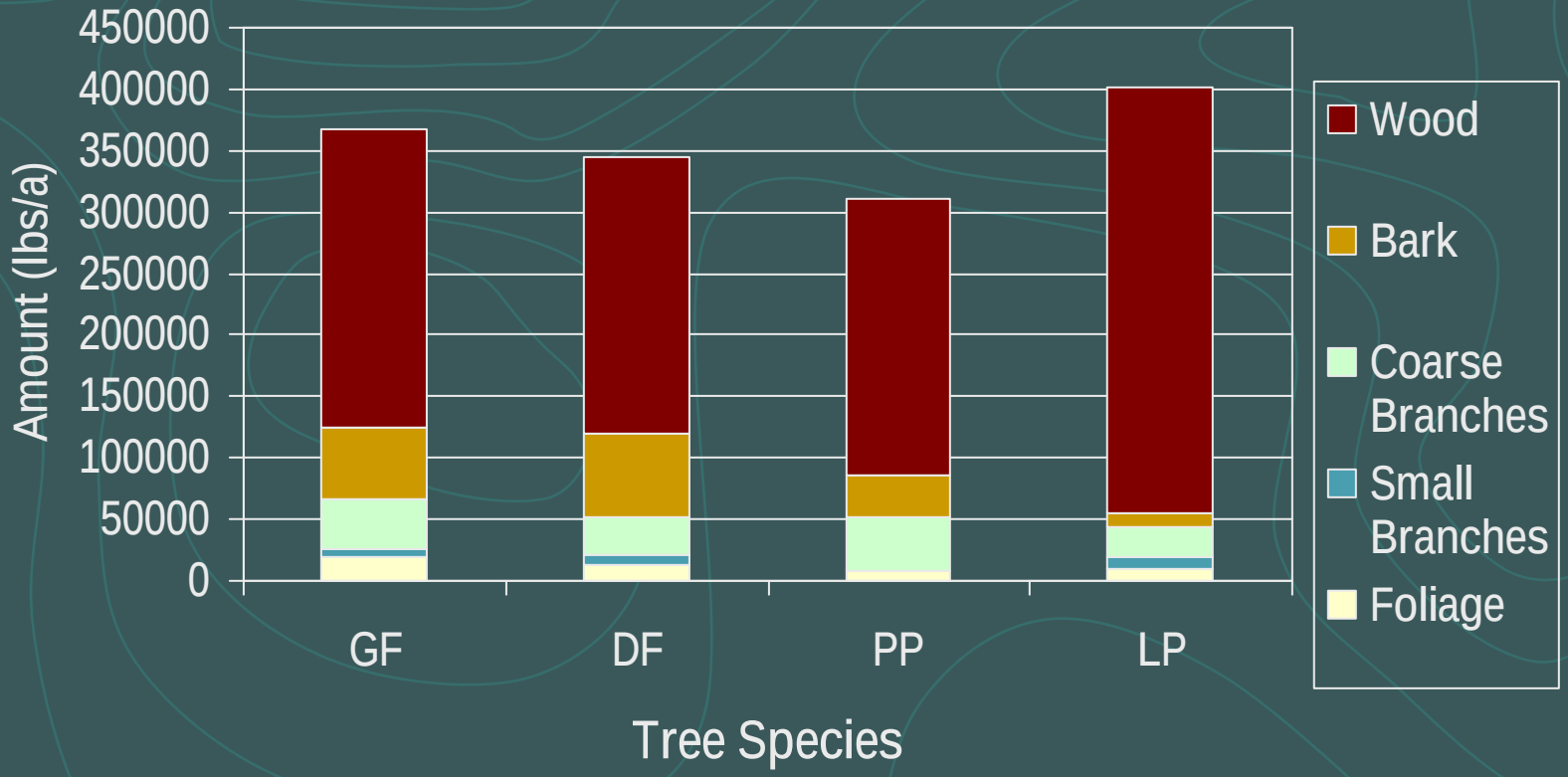
Nitrogen content of overstory, forest floor and soil



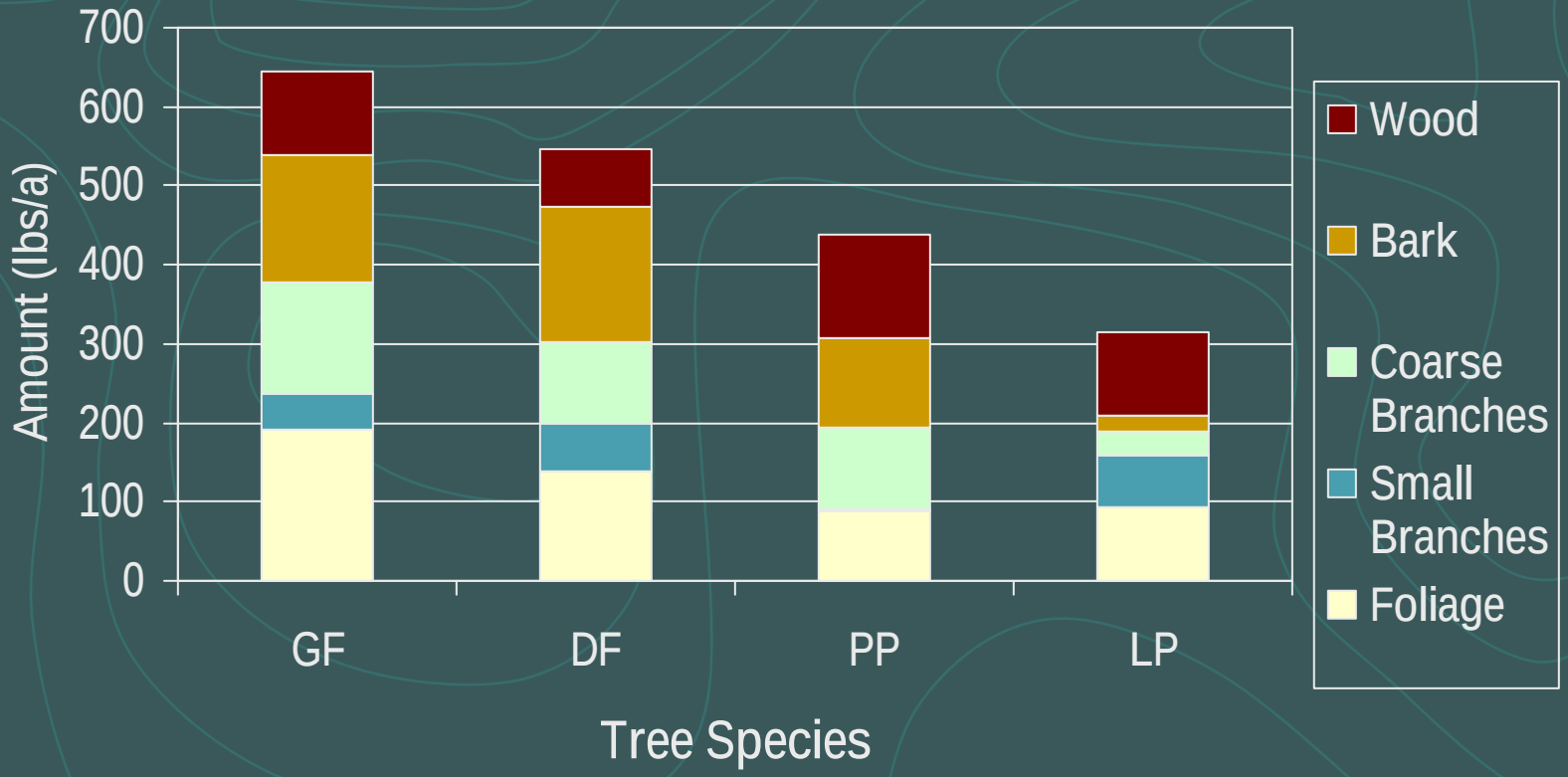
A Simulation Experiment using the IFTNC Nutrient Calculator

	Age	Trees	Basal Area	Volume	Biomass
Species		stems/a	ft^2/a	ft^3/a	lbs/a
Grand fir	40	253	238	7736	367550
Douglas-fir	40	253	238	6994	344603
Ponderosa pine	40	253	238	7774	310910
Lodgepole pine	40	253	238	8732	401472

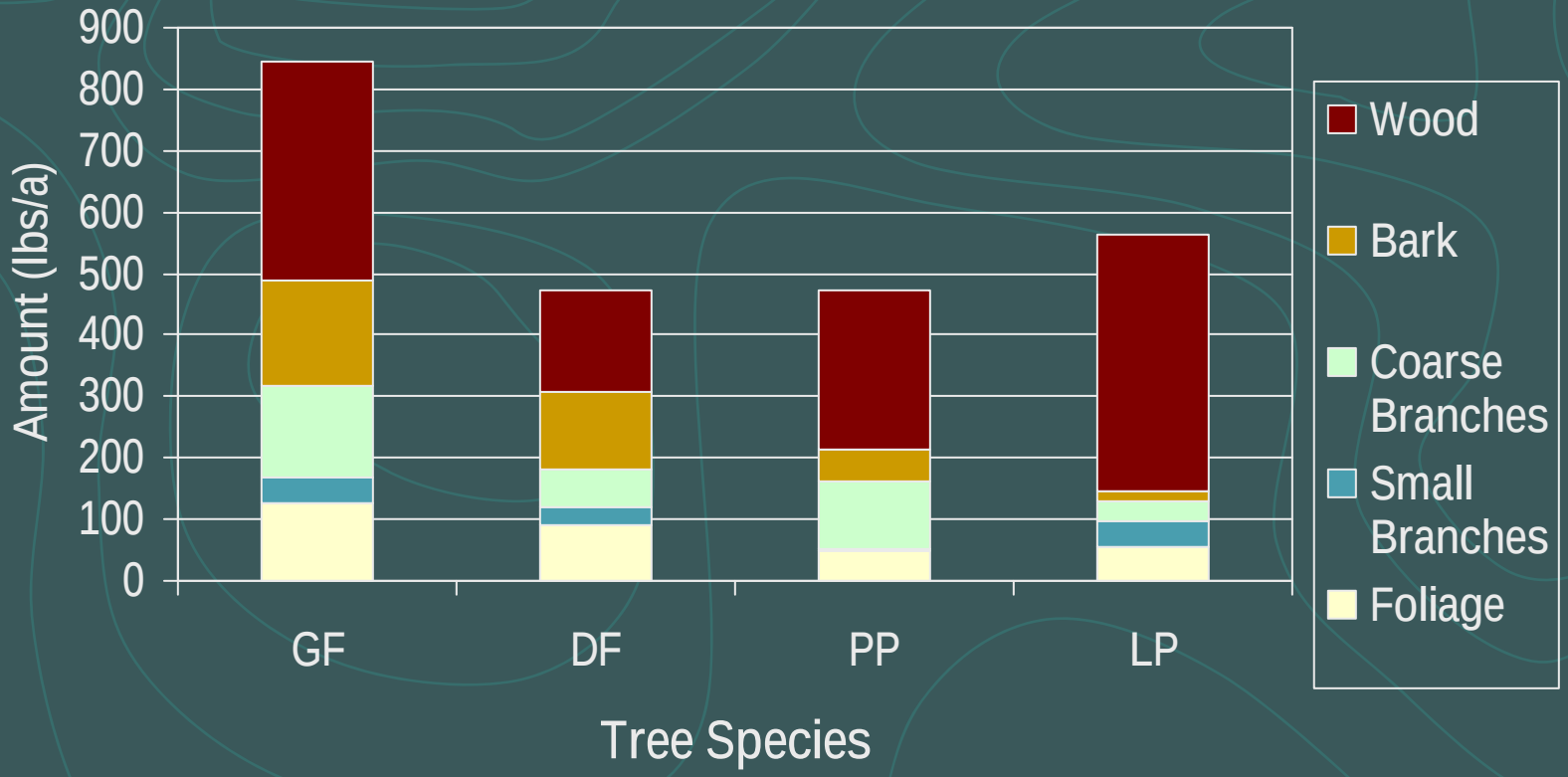
Above-ground Tree Biomass by Component



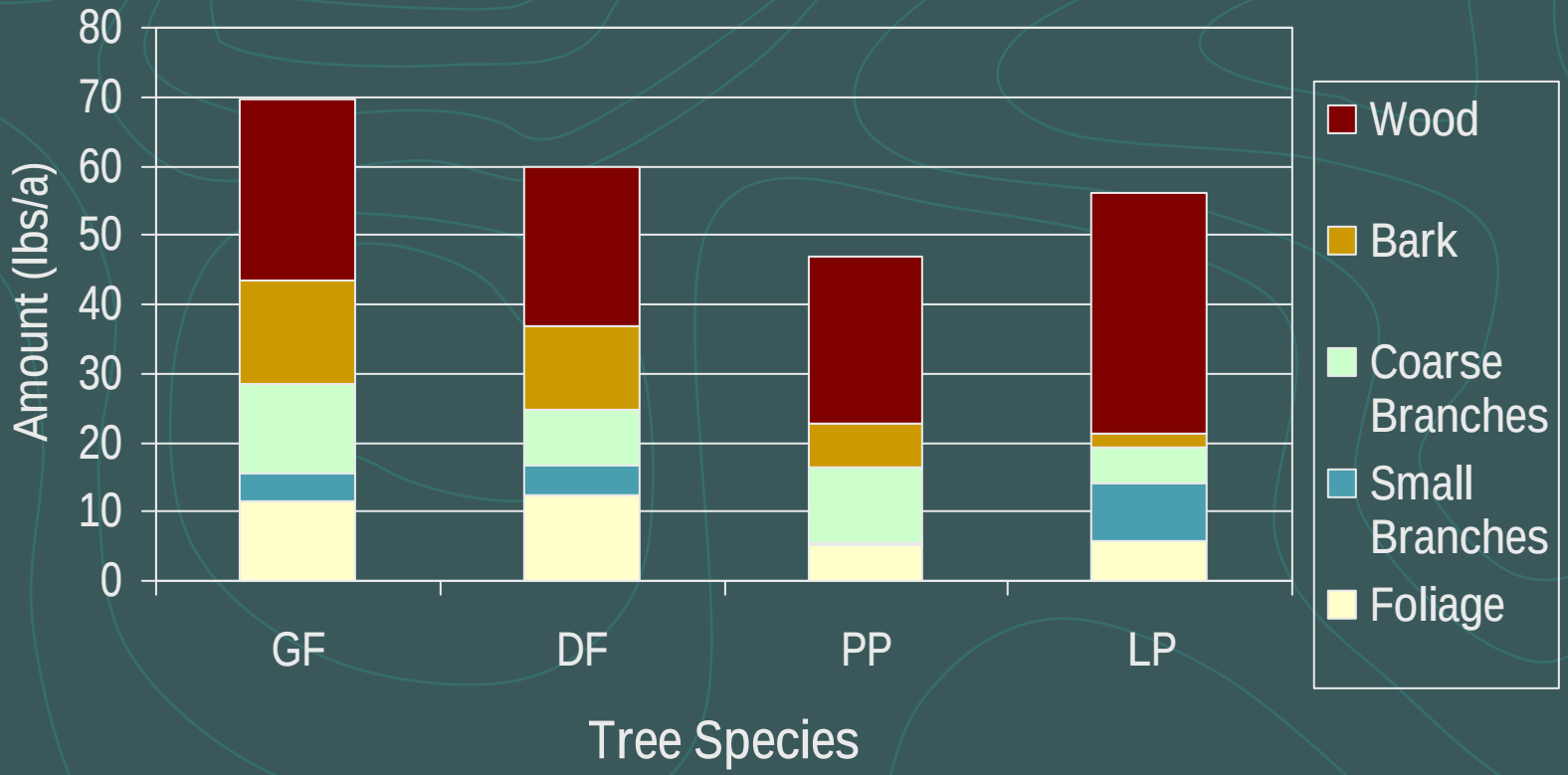
Above-ground Tree Nitrogen by Component



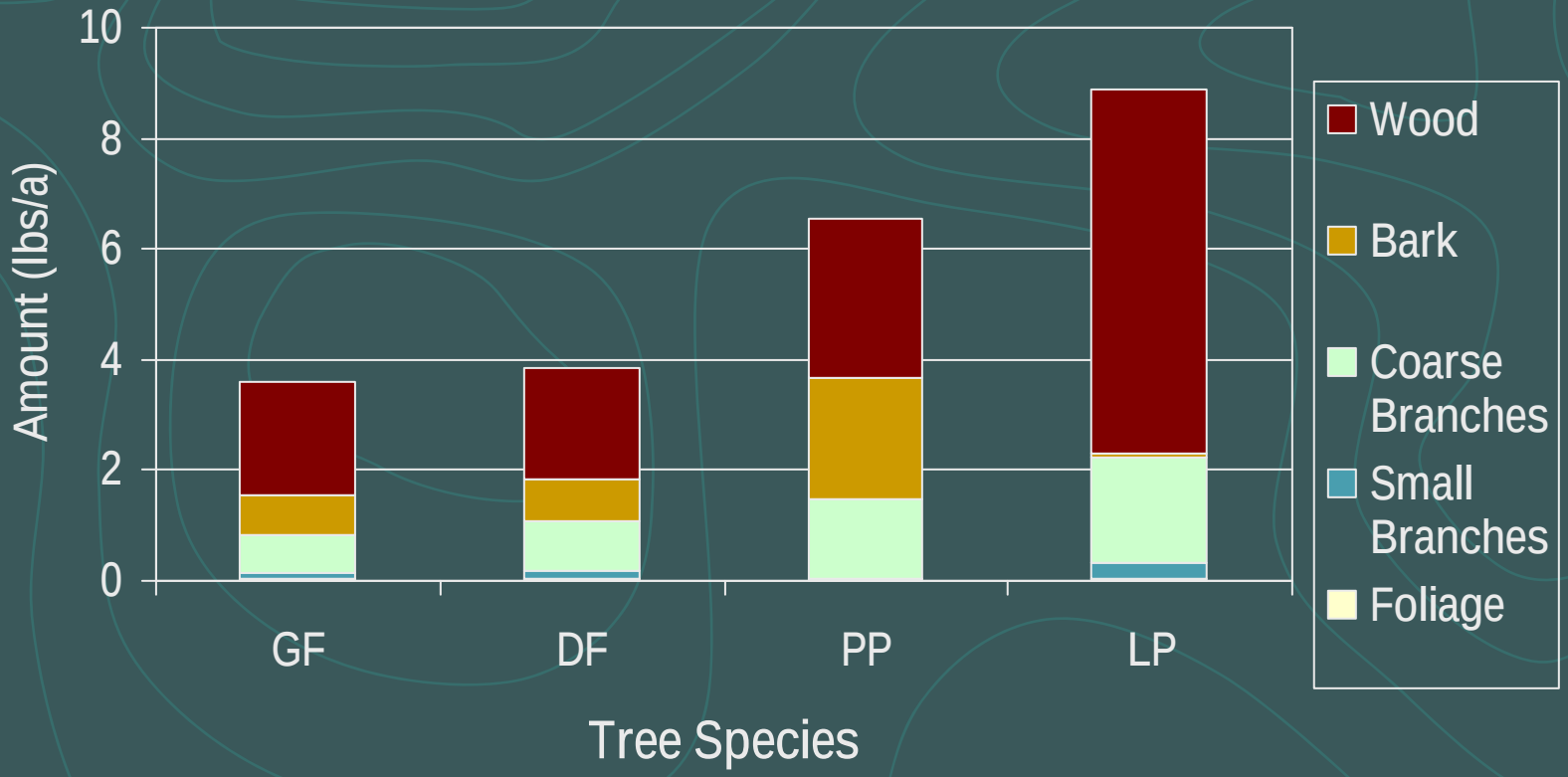
Above-ground Tree Potassium by Component



Above-ground Tree Sulfur by Component



Above-ground Tree Copper by Component



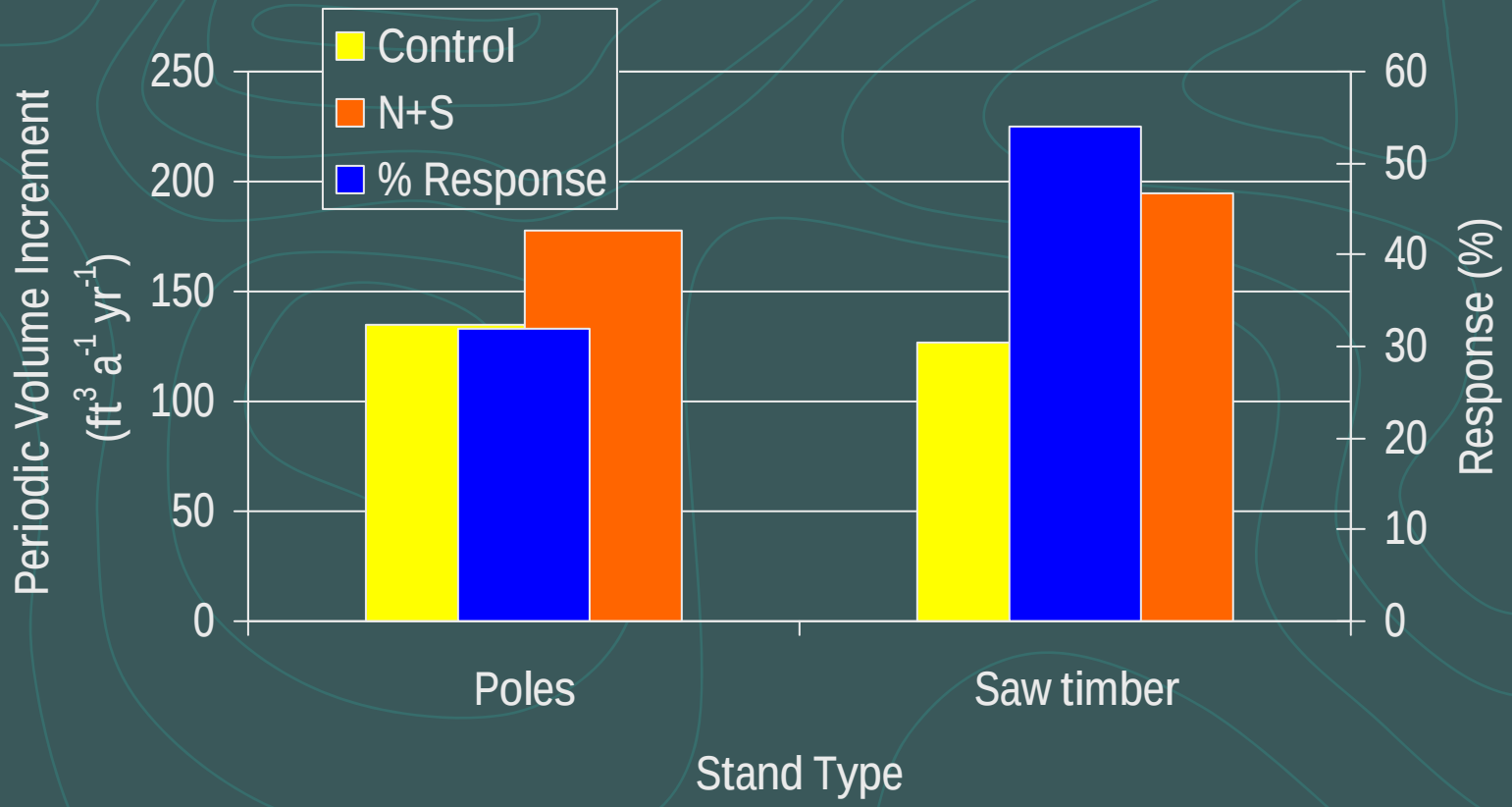
Grand Fir Nutrient Ecology

- Grand Fir foliage has higher concentrations of cations and B than other species, but is intermediate for most nutrients. Based on critical levels, N and S seem commonly deficient, while B, P and Cu deserve attention
- Foliar nutrient concentrations are similar for mature and young unfertilized trees
- GF foliage shows good response to N fertilization; young trees seem to take up more N than mature trees. Foliage also shows good response to S and B fertilization.
- Grand Fir retains greater amounts of the most commonly deficient elements (N, K, S, B) than DF, LPP, or PP—hence a nutrient hog

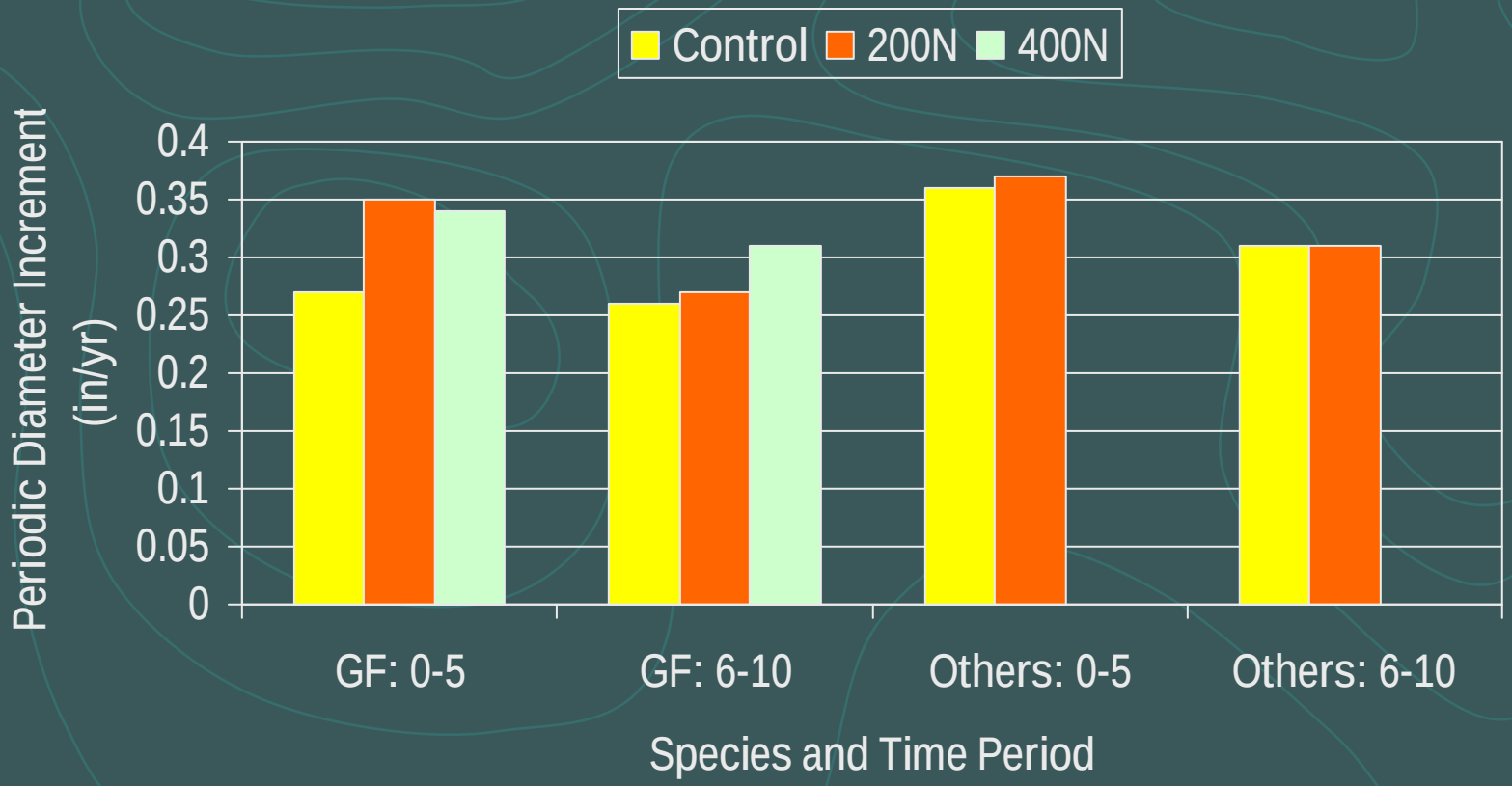
Grand Fir response to fertilization Early Results

- Lowenstein and Pitkin: GF in N Idaho
  - 150#N/a increased height and diameter growth of GF
  - No significant increase with addition of 65#P/a and 150#K/a
- Powers: White fir (A. concolor) in California
  - Substantial response (50%+) to 200-400lbs/a N
  - Response to P on high P-sorbing soils

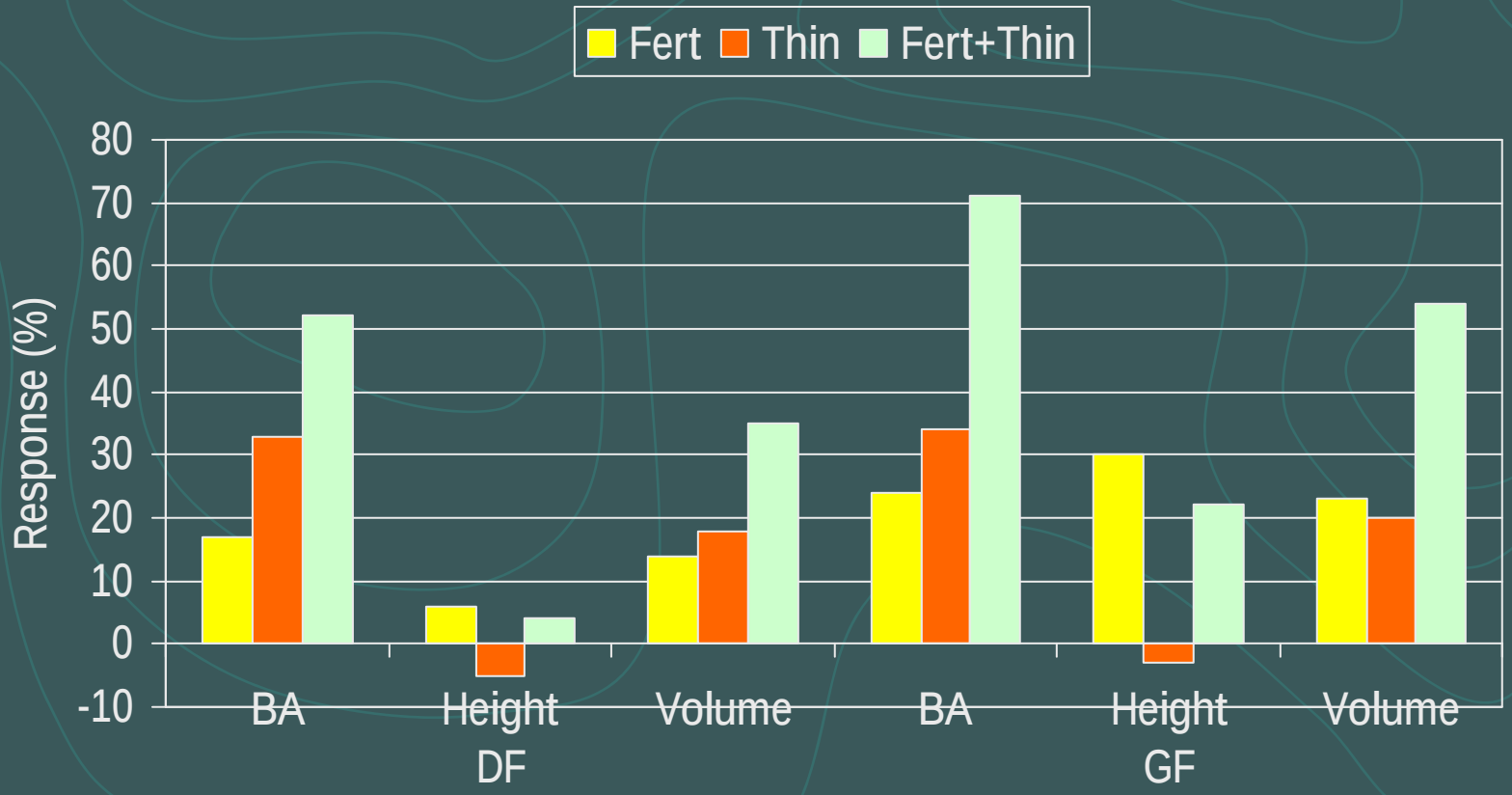
Response of thinned white fir to N + S fertilizer (Cochran)



10-year Response to N Fertilization Mixed Conifer on THSE/PAMA (Graham and Tonn)



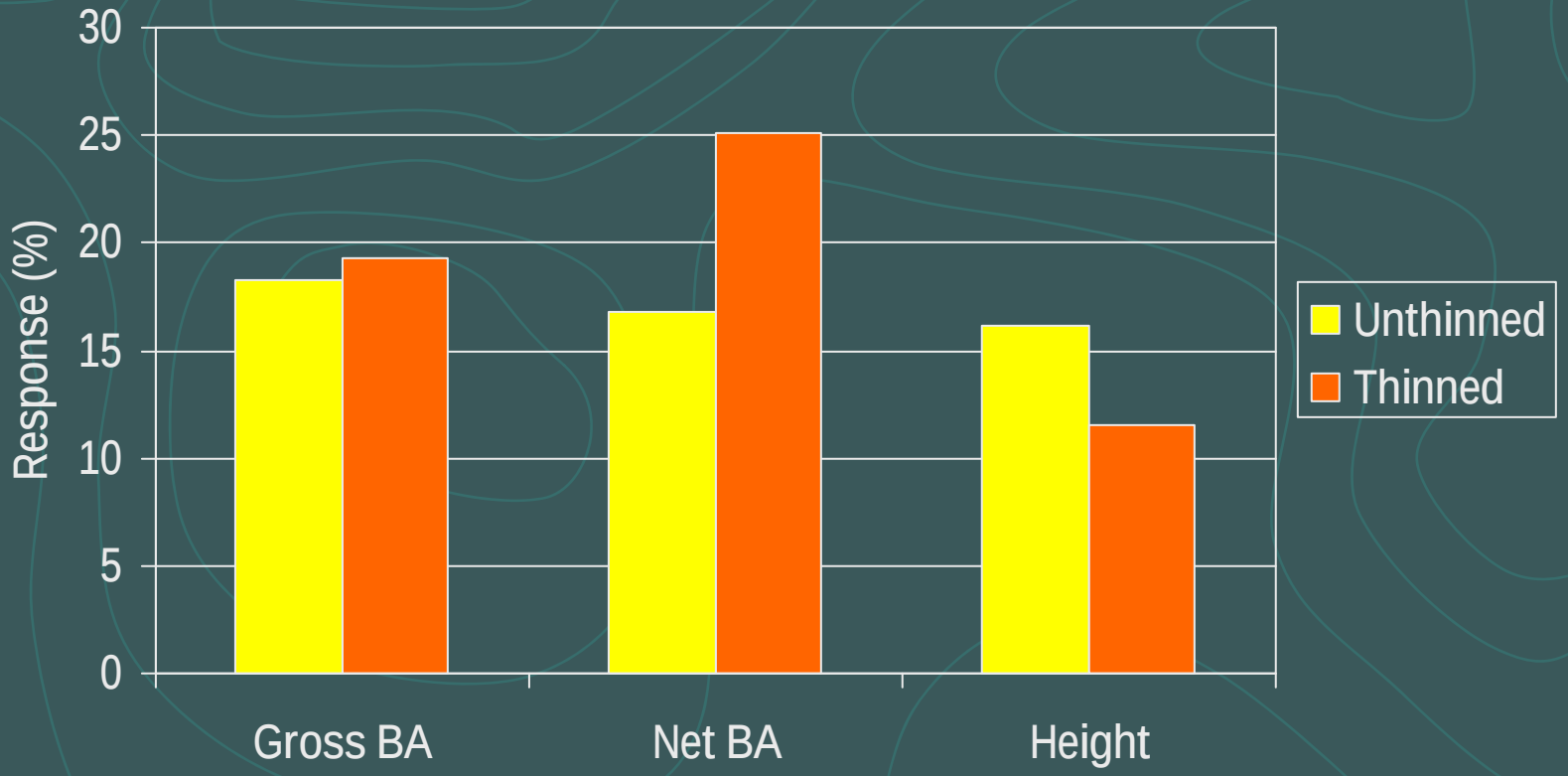
MS-16 Study: DF and GF in N Idaho 4-year response to fertilizer and thinning (Scanlin and Lowenstein)



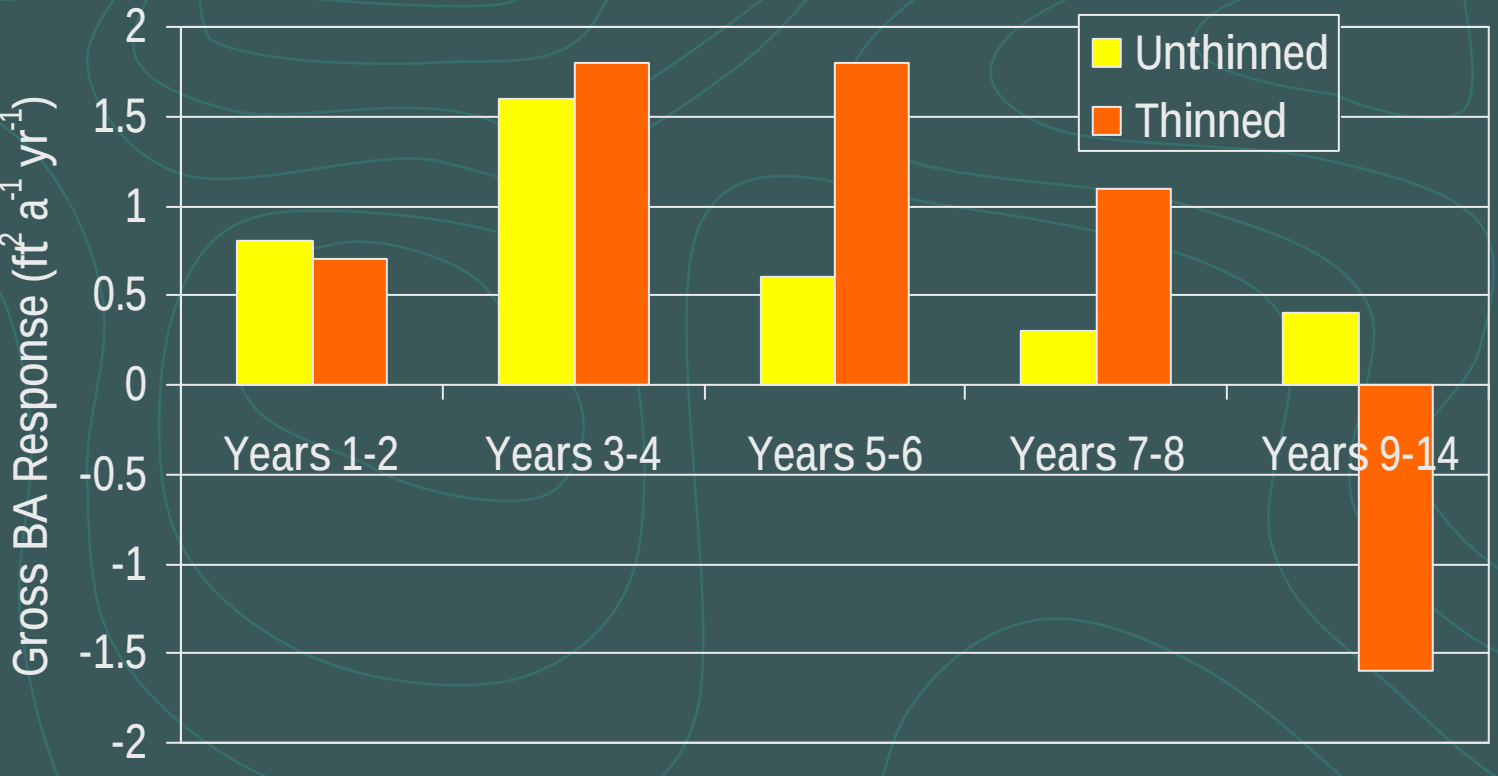
Intensive Forest Management Project 6-year response to fertilizer (Scanlin and Lowenstein)

- 42 sites, varying in age (8 – 65), species composition (DF, GF, WH, WL, LP, WWP, PP)
- 6-year results
  - All ages responded similarly to 200#N/a
  - Most species (DF, GF, LP, WWP, PP) responded moderately (20-30% BA response); no WL response; large WH response
  - Addition of 66#P/a did not increase response
  - Addition of more N (300#/a, 400#/a) did not significantly increase response, although a linear response trend did exist

Combined MS-16, ITC, Potlatch data 6-year response to fertilizer (Shafii, Moore, and Olson)



Combined MS-16, ITC, Potlatch data
Periodic BA response to fertilizer



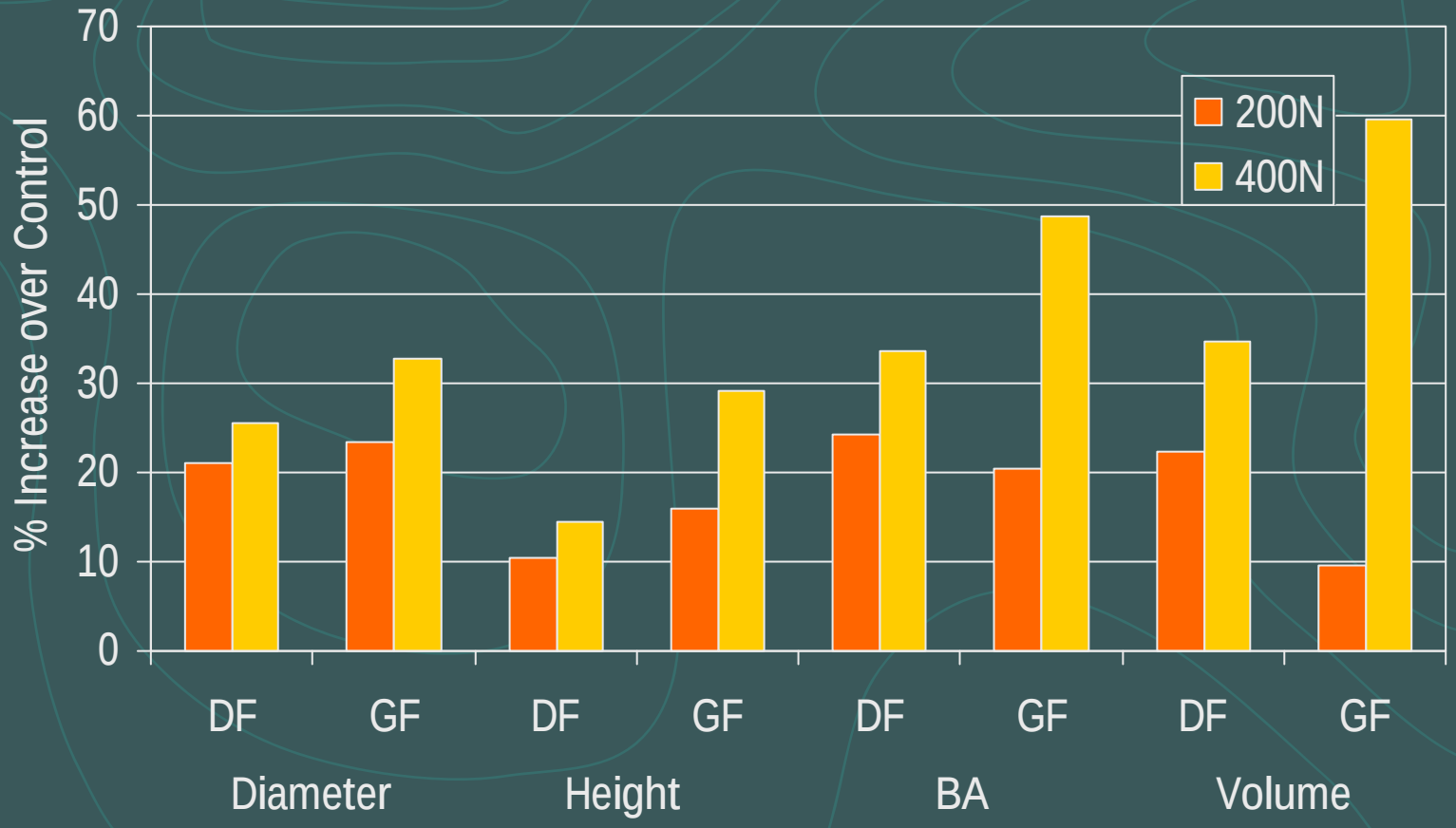
Combined MS-16, ITC, Potlatch data 14-year response to fertilizer

Treatment	Volume (ft^3/a)	Trees/a	Volume/Tree (ft^3)
Control	2358	954	2.5
Fertilized	2369	847	2.8
Thinned	2439	296	8.2
Thinned and fertilized	2477	244	10.2

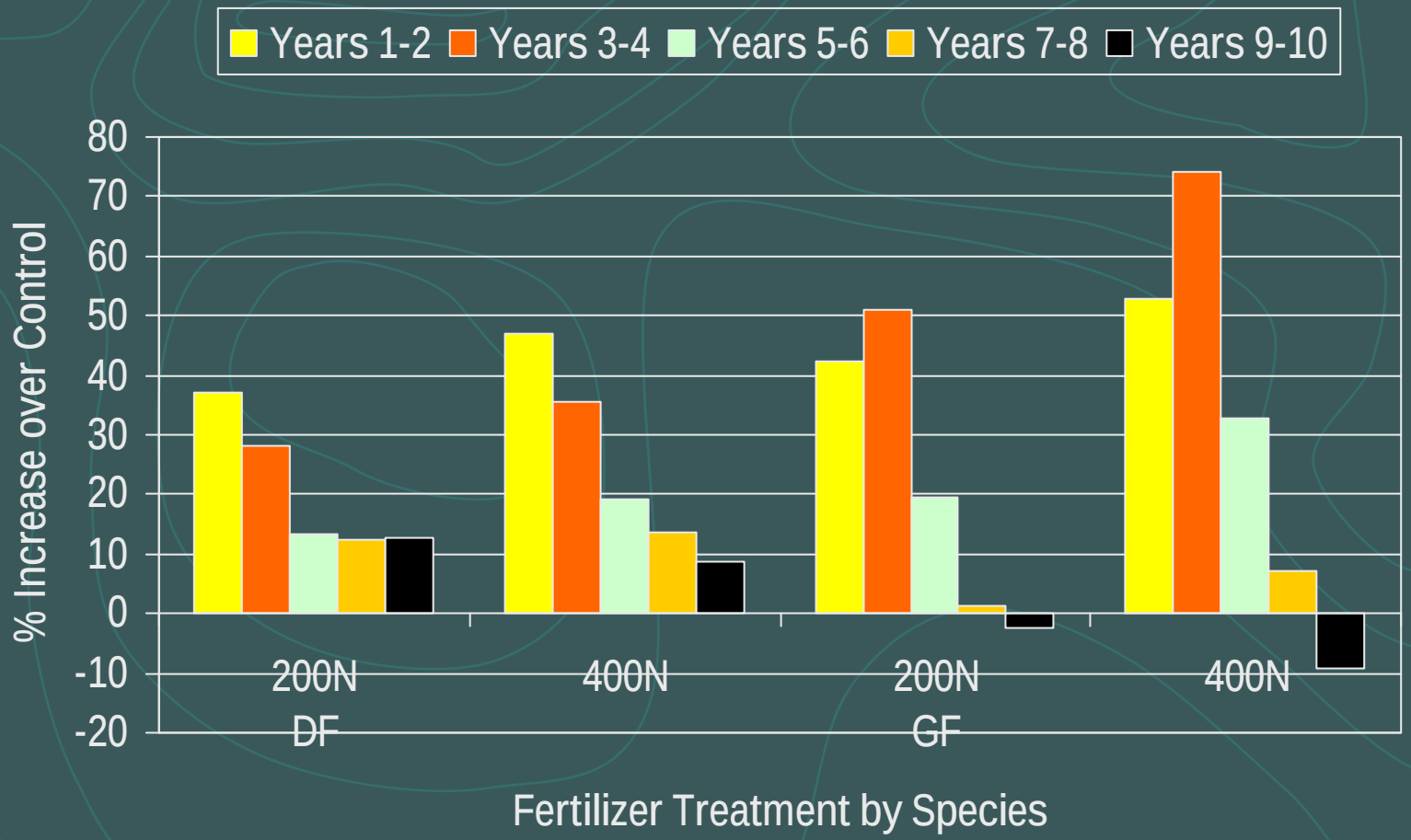
Distribution of Sites with Grand Fir within the DF Trials

Region			Vegetation Series		
N Idaho	15	Rock Type	GF	WRC	WH
Montana	1	Basalt	7	2	1
C Idaho	3	Glacial		1	
NE Oregon	3	Granite	3		1
C Wash	7	Metasediment	4	7	1
NE Wash	1	Modern Sediment	1		
		Sedimentary	2		

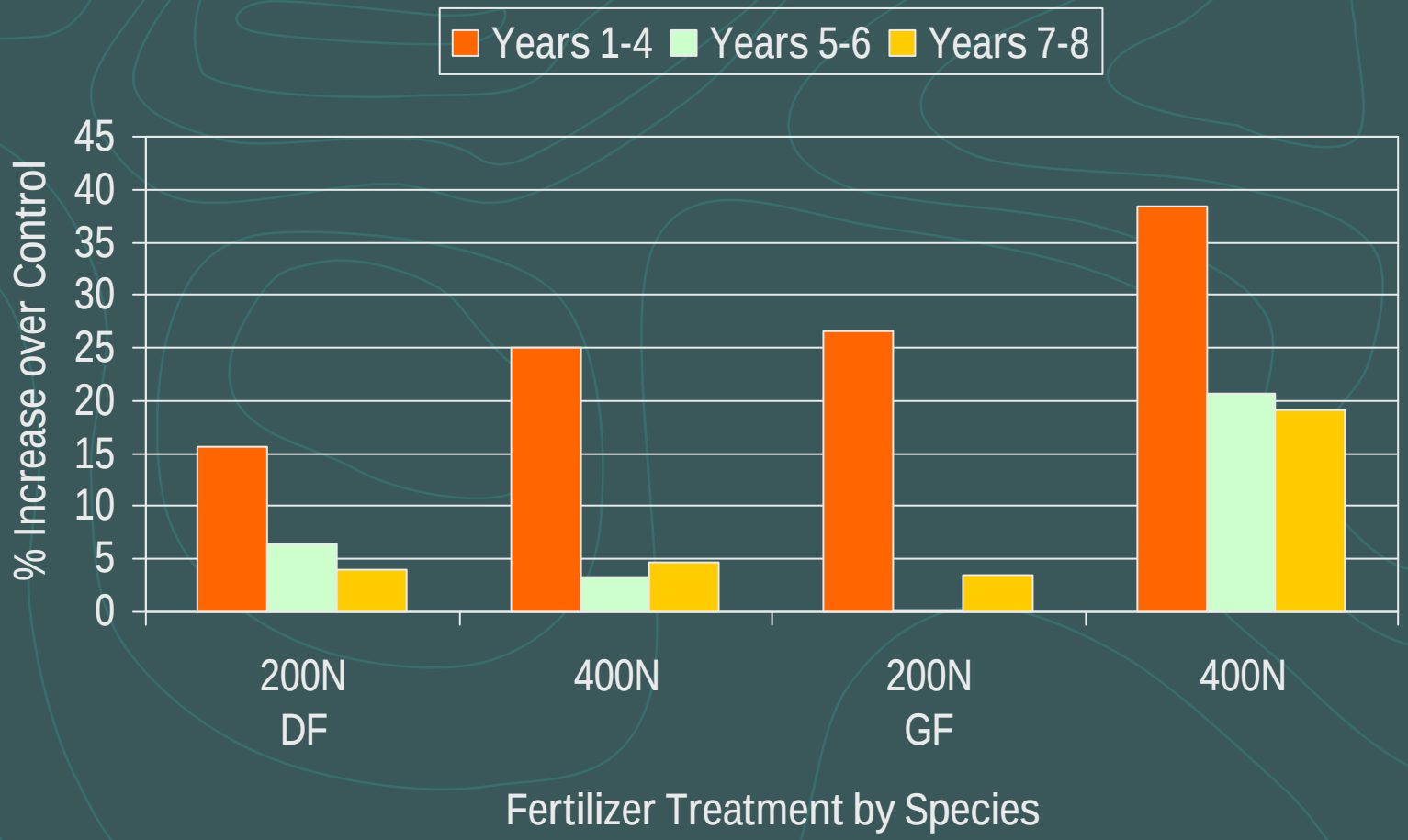
10-year Results from the DF Trials
Relative Response to N Fertilization



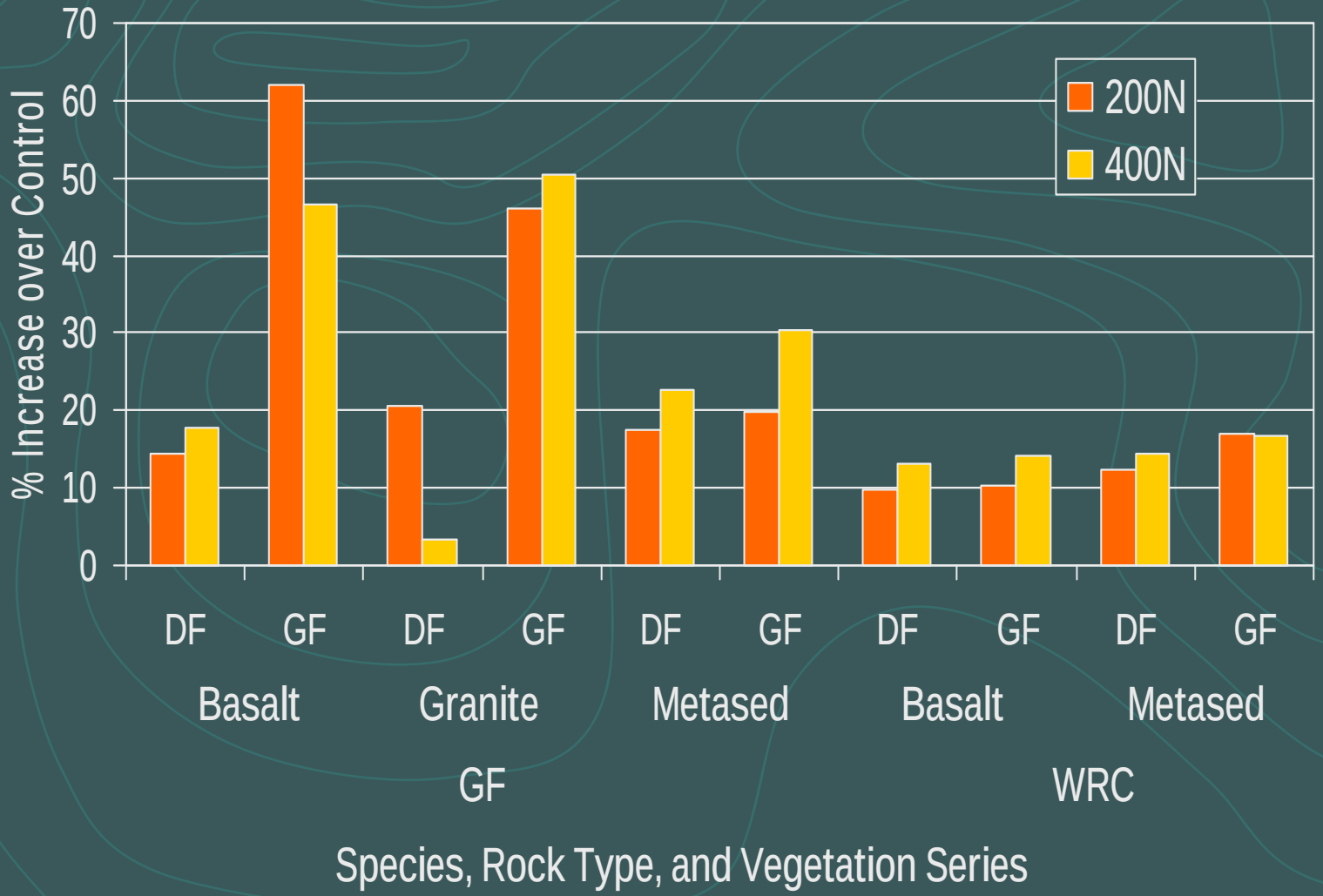
10-year Results from the DF Trials
Relative Periodic Diameter Growth



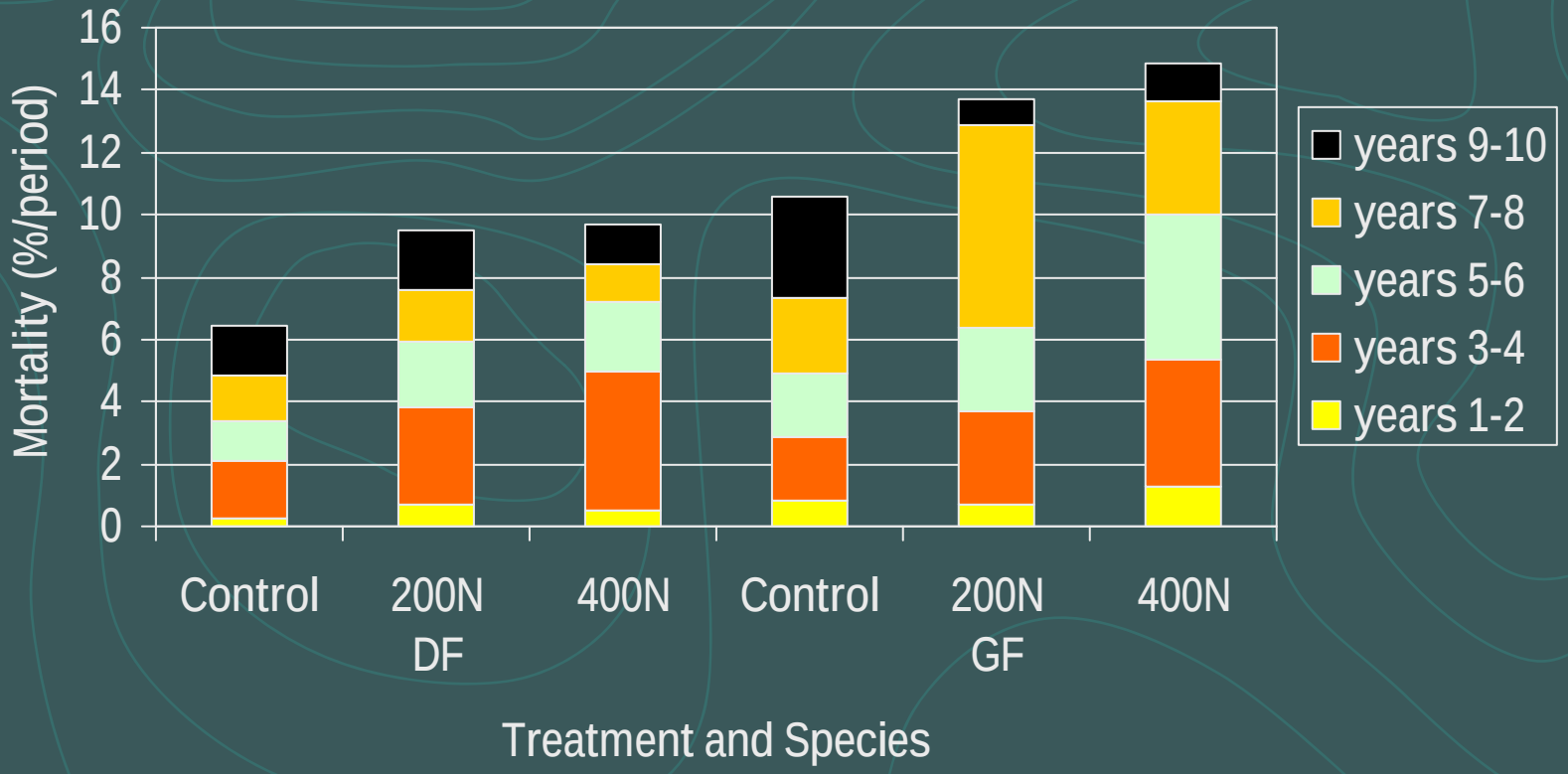
10-year Results from the DF Trials
Relative Periodic Height Growth



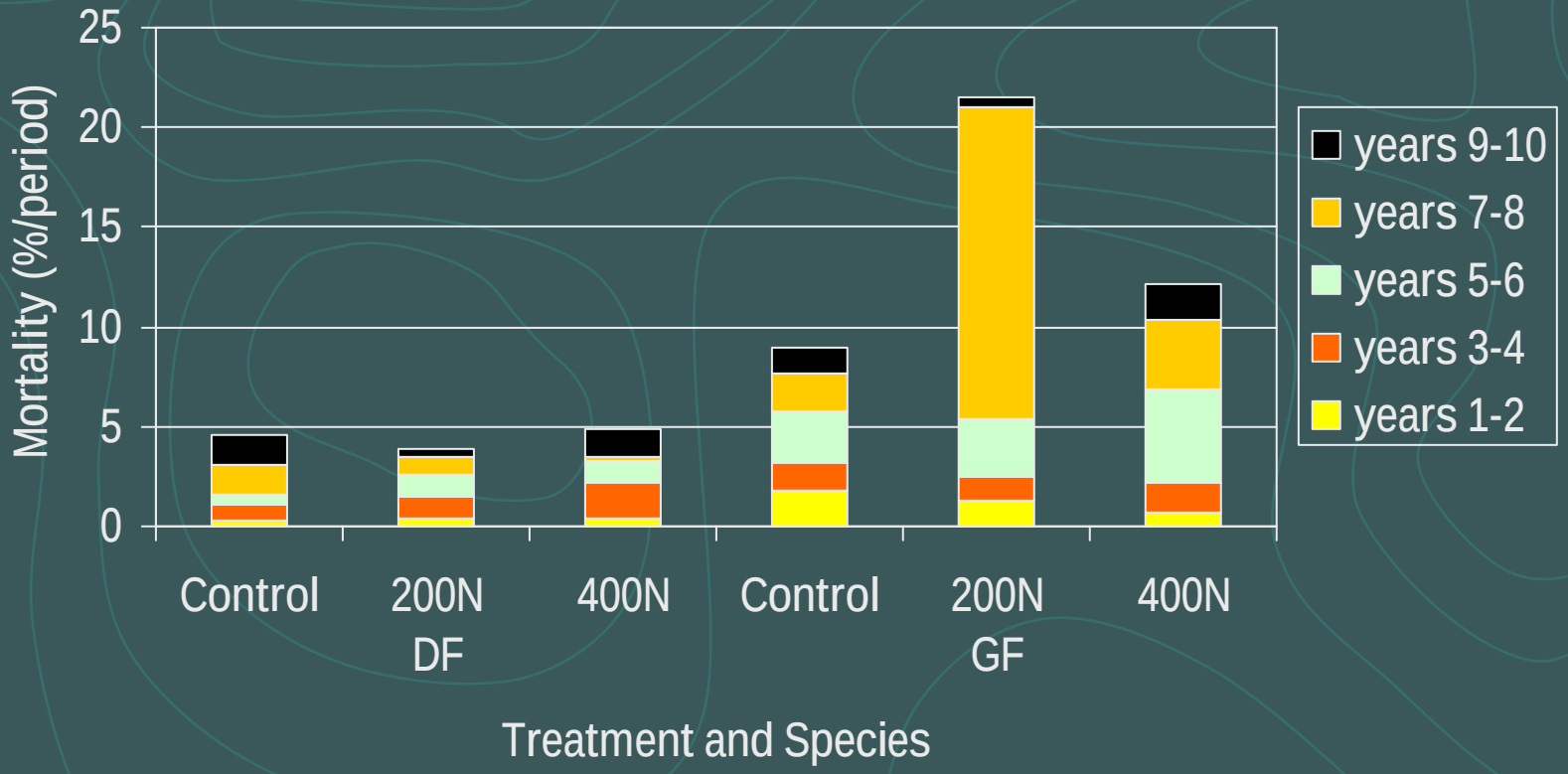
6-year Results from the DF Trials
Diameter Relative Response to N



10-year Results from the DF Trials
Periodic Mortality: stems/a



10-year Results from the DF Trials
Periodic Mortality: BA/a

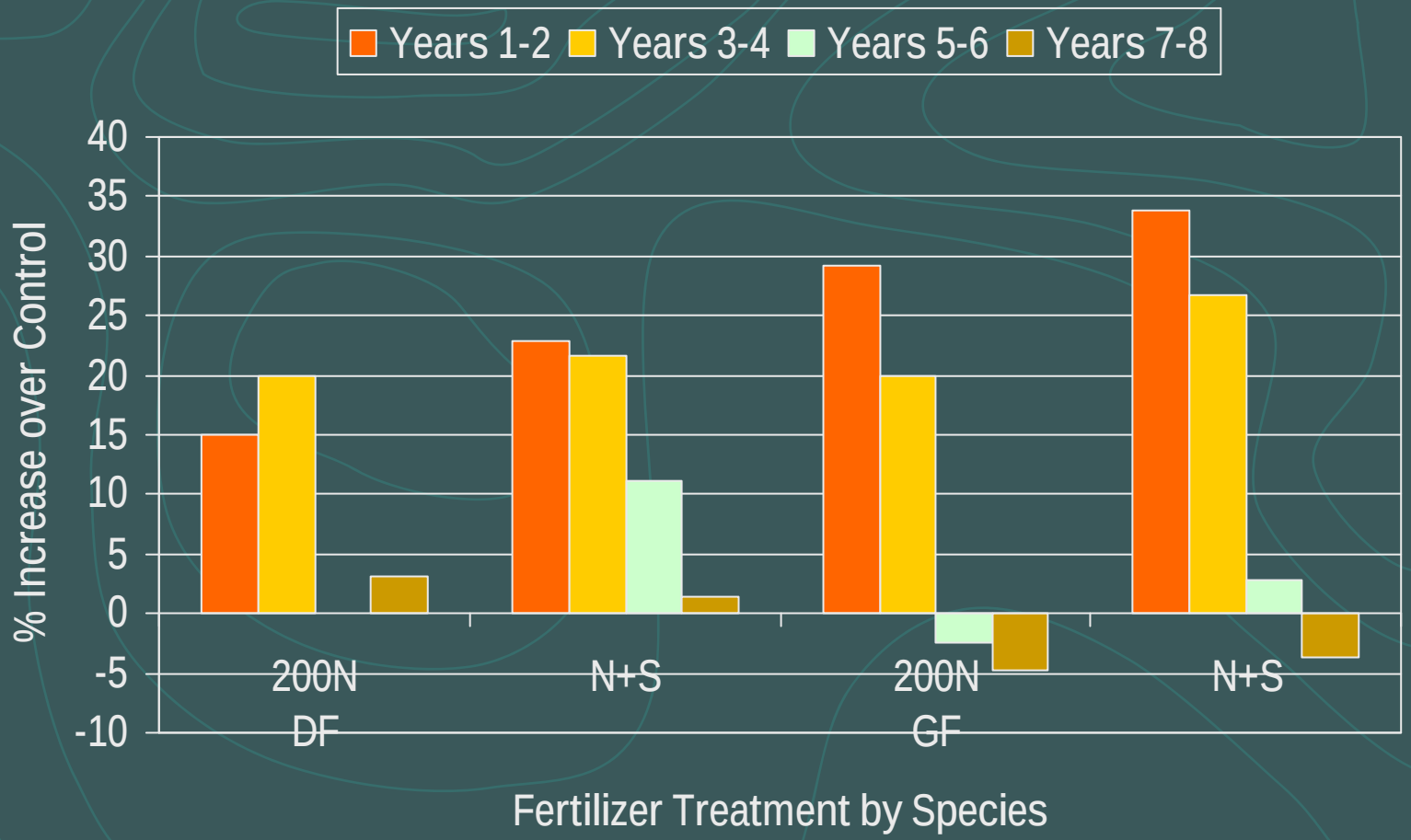


Umatilla Mixed-Conifer Trials Sites with Grand Fir

		Initial DBH (in)		Initial Height (ft)	
Sites	Initial BA (ft^2/a)	DF	GF	DF	GF
4	67	4.7	4.5	23	23
3	9	1.0	1.2	9	8

Umatilla Mixed-Conifer Trials
8-year Relative Response to N and S
Pole-size Stands

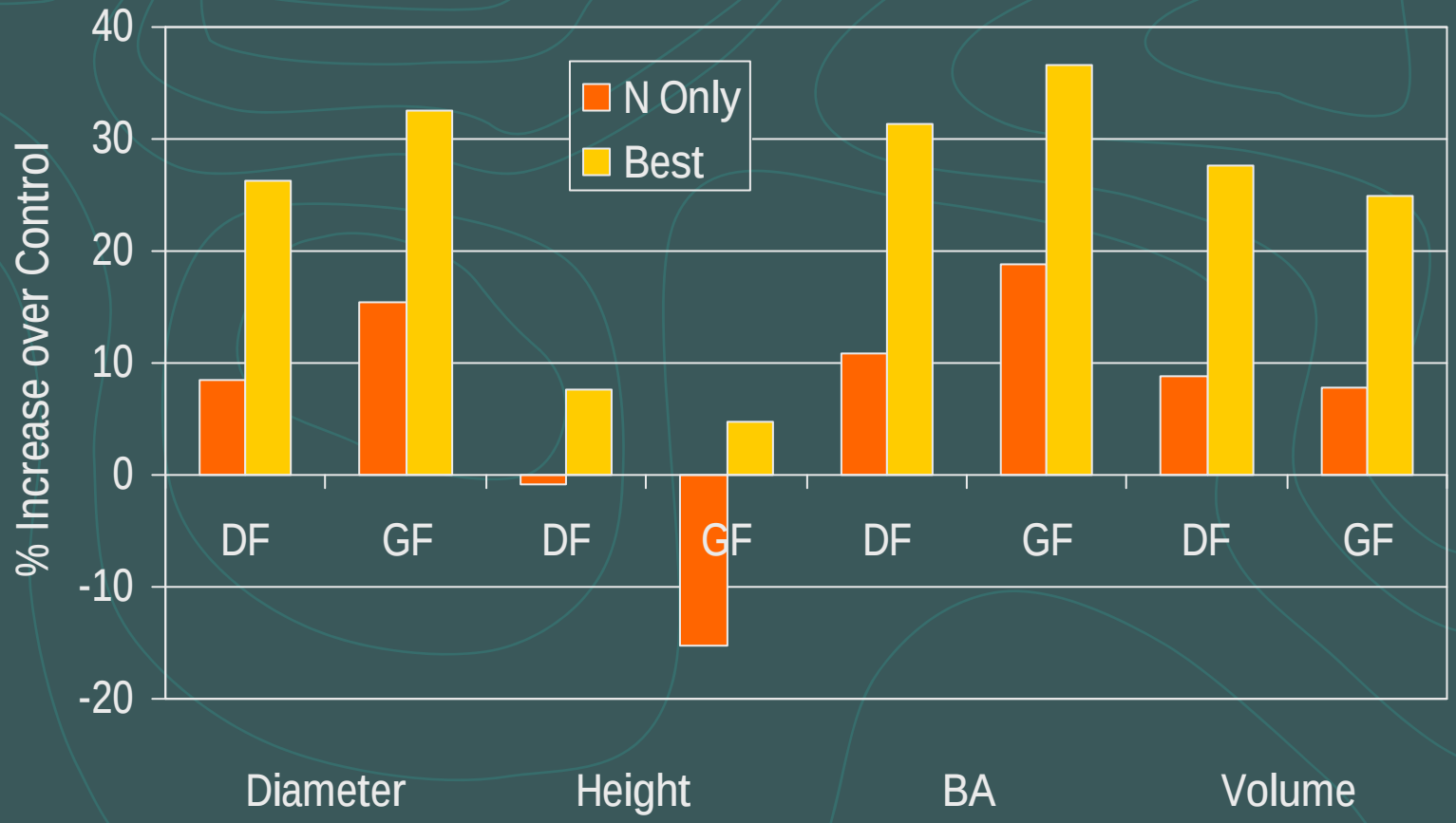
Umatilla Mixed-Conifer Trials
Relative Periodic Diameter Growth
Pole-size Stands



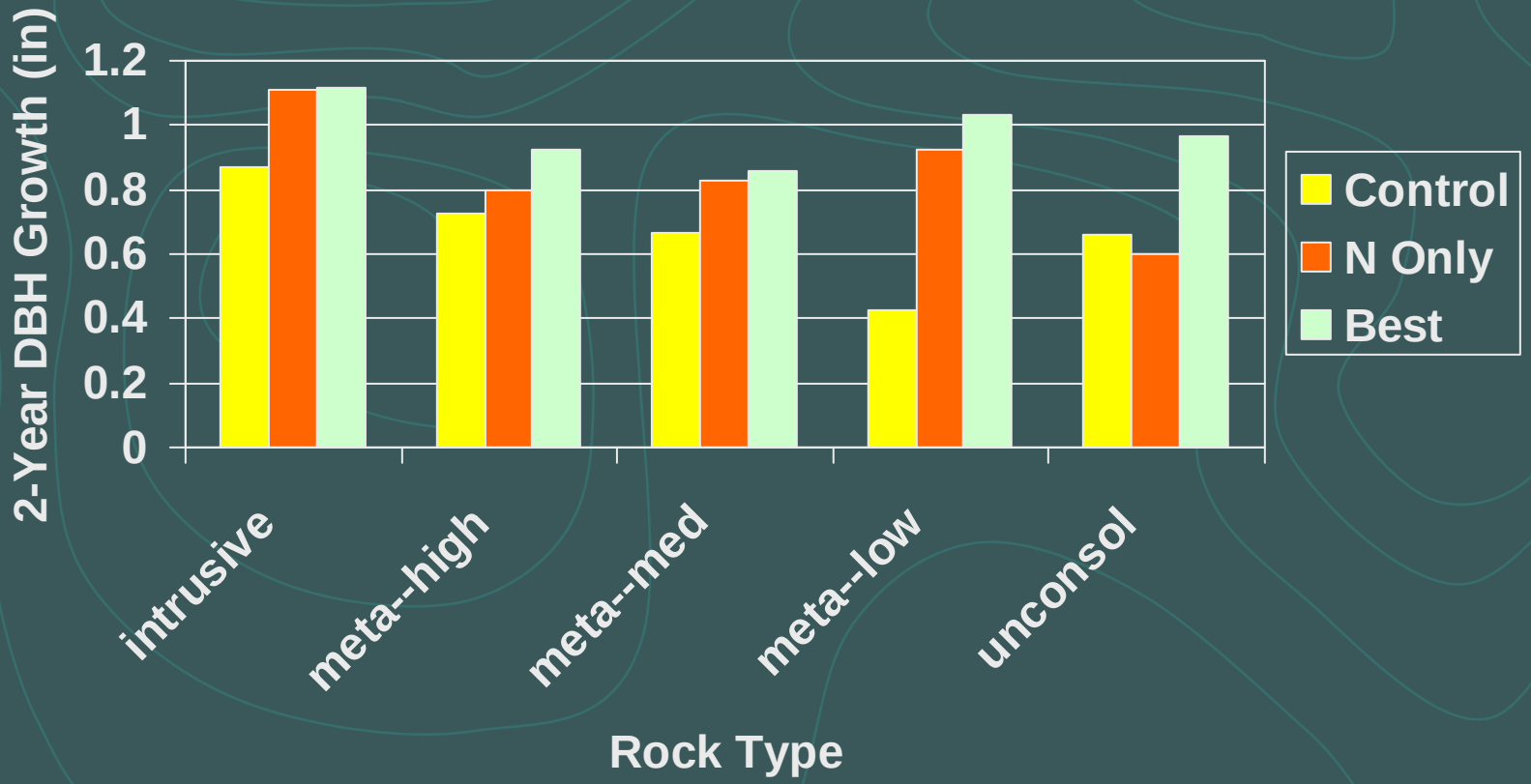
Multinutrient Fertilizer Screening Trials Sites with Grand Fir

- 13 sites, all in north Idaho on WRC series
  - Rock types include granite, metasediment, and alluvium
- 8 sites (all on metasediment) also have DF, allowing a species comparison
  - Trees range from 2.5 to 5 inches DBH, 16 to 25 feet height, no size difference between species

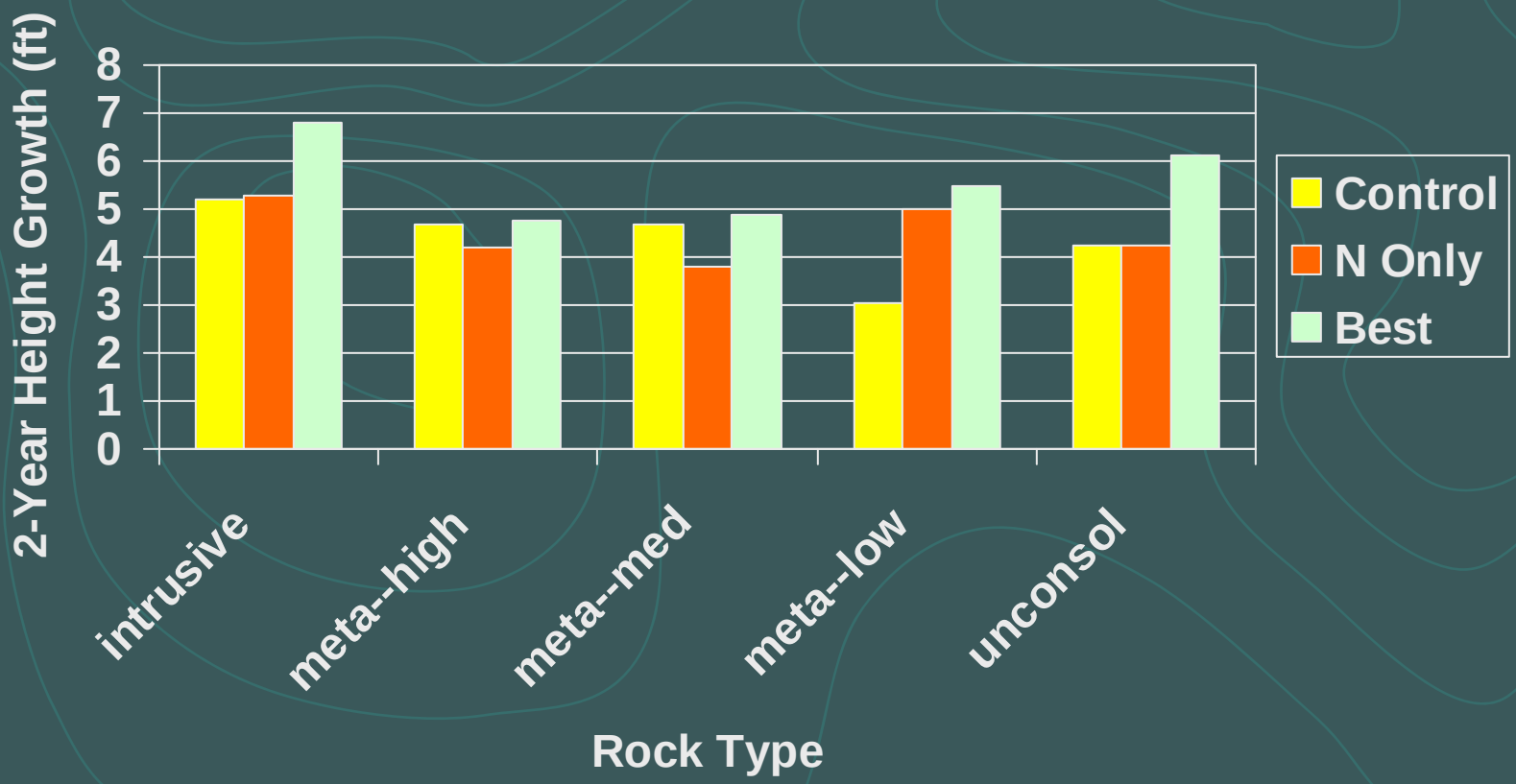
Multinutrient Screening Trials
2-year Relative Response



Fertilizer Treatment Effects on 2-Year DBH Growth by Rock Type Grand Fir



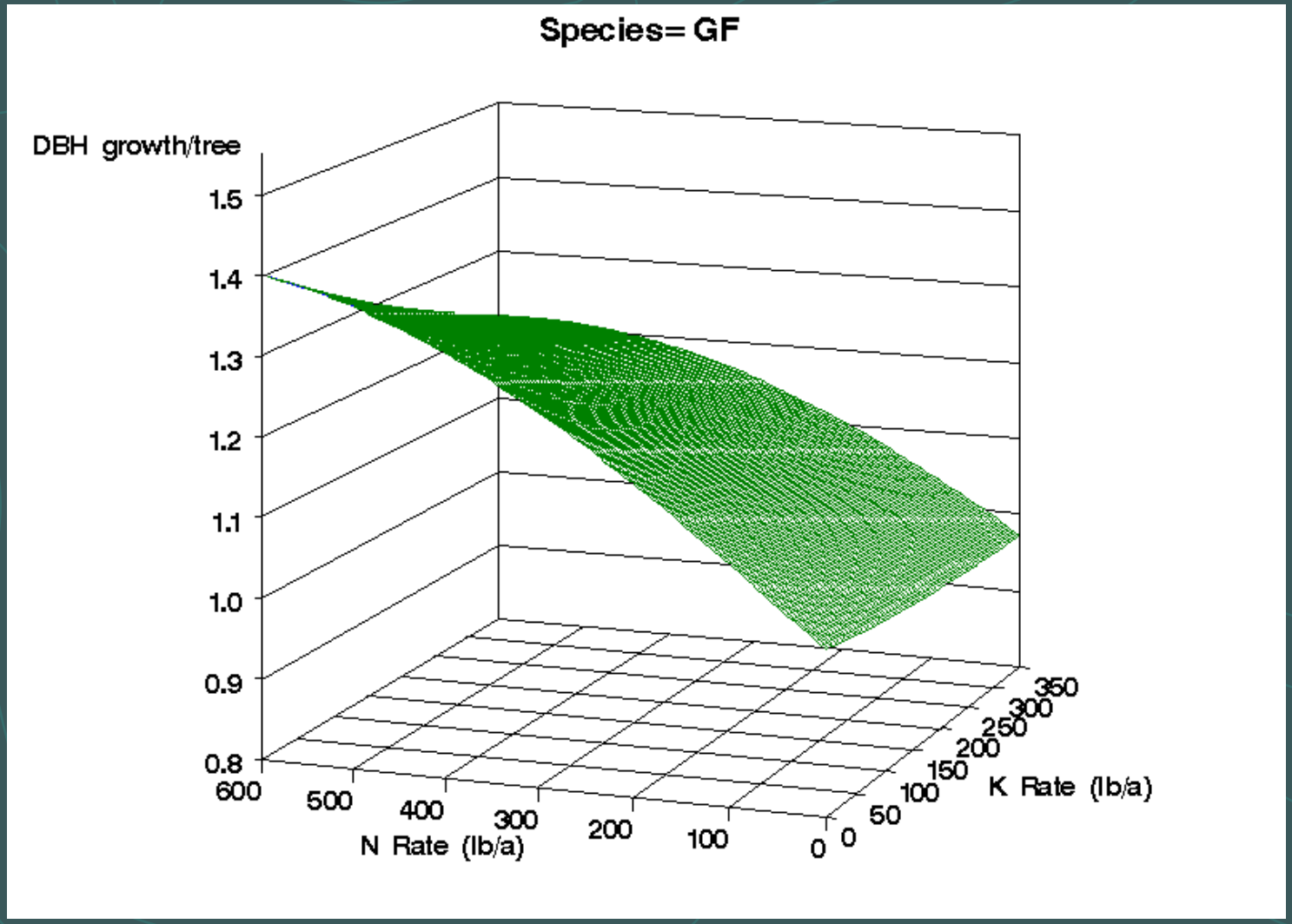
Fertilizer Treatment Effects on 2-Year Height Growth by Rock Type Grand Fir



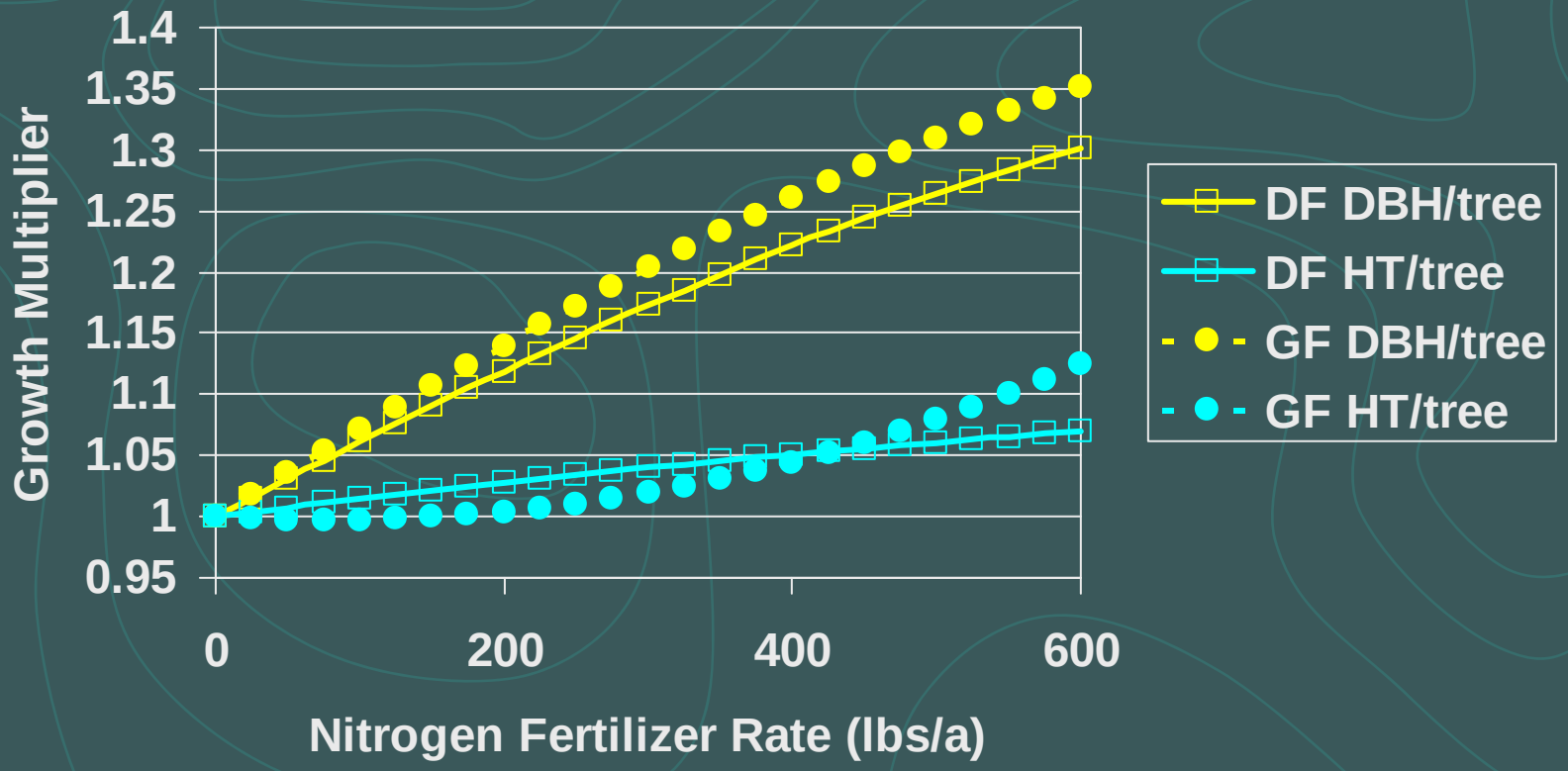
The Forest Health Study
Sites with species-specific growth data

	Vegetation Series								
	DF			GF			WRC/WH		
Rock	Species								
Type	DF	GF	PP	DF	GF	PP	DF	GF	PP
basalt	2		2	2	1	1			
mixed	1		1	2	1	2	2	2	
granite	4		4	2	1	1	1	1	
metased				2	1	1	4	3	
tert sed							5	5	

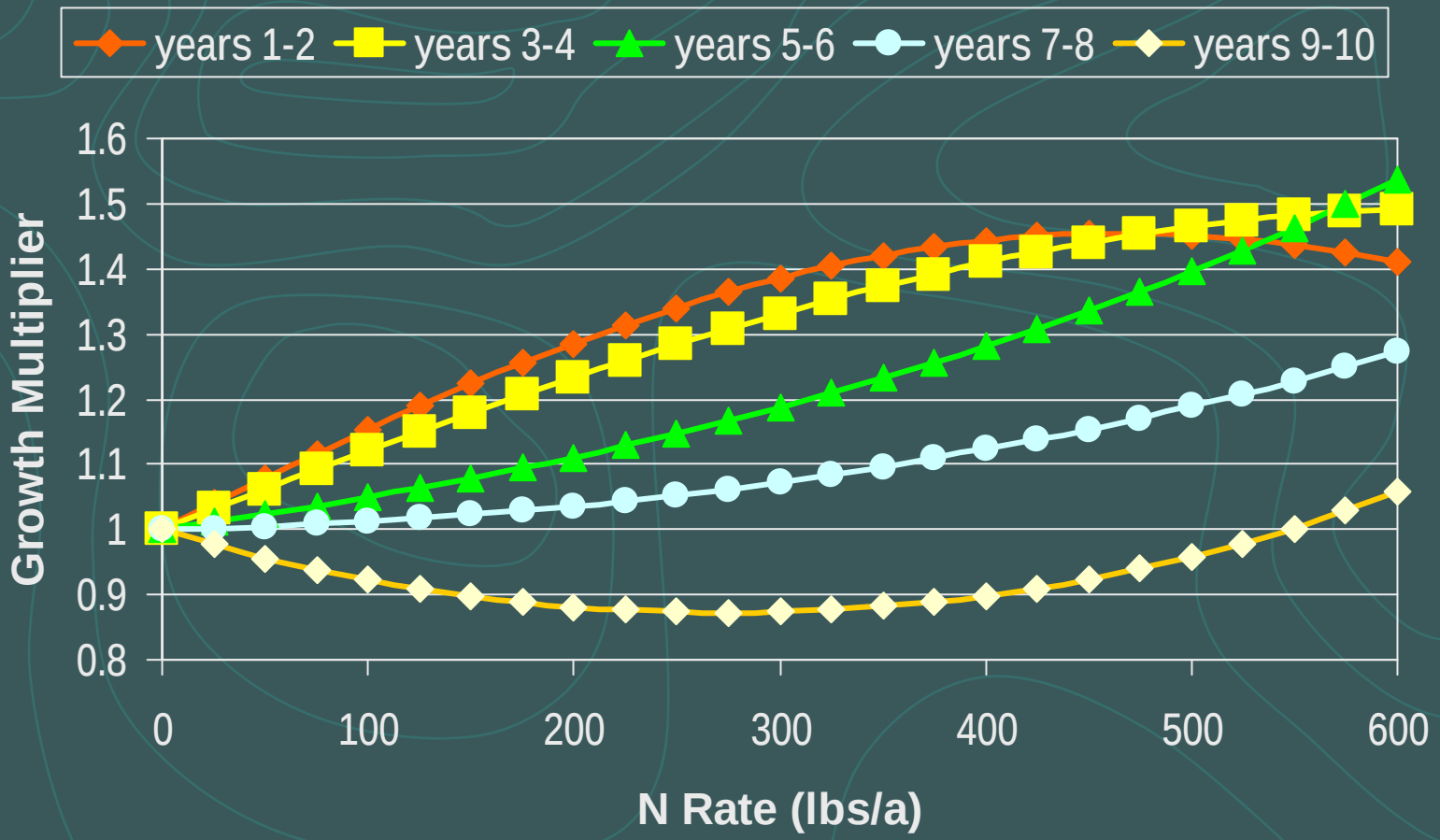
Forest Health Study
Diameter growth multipliers: GF



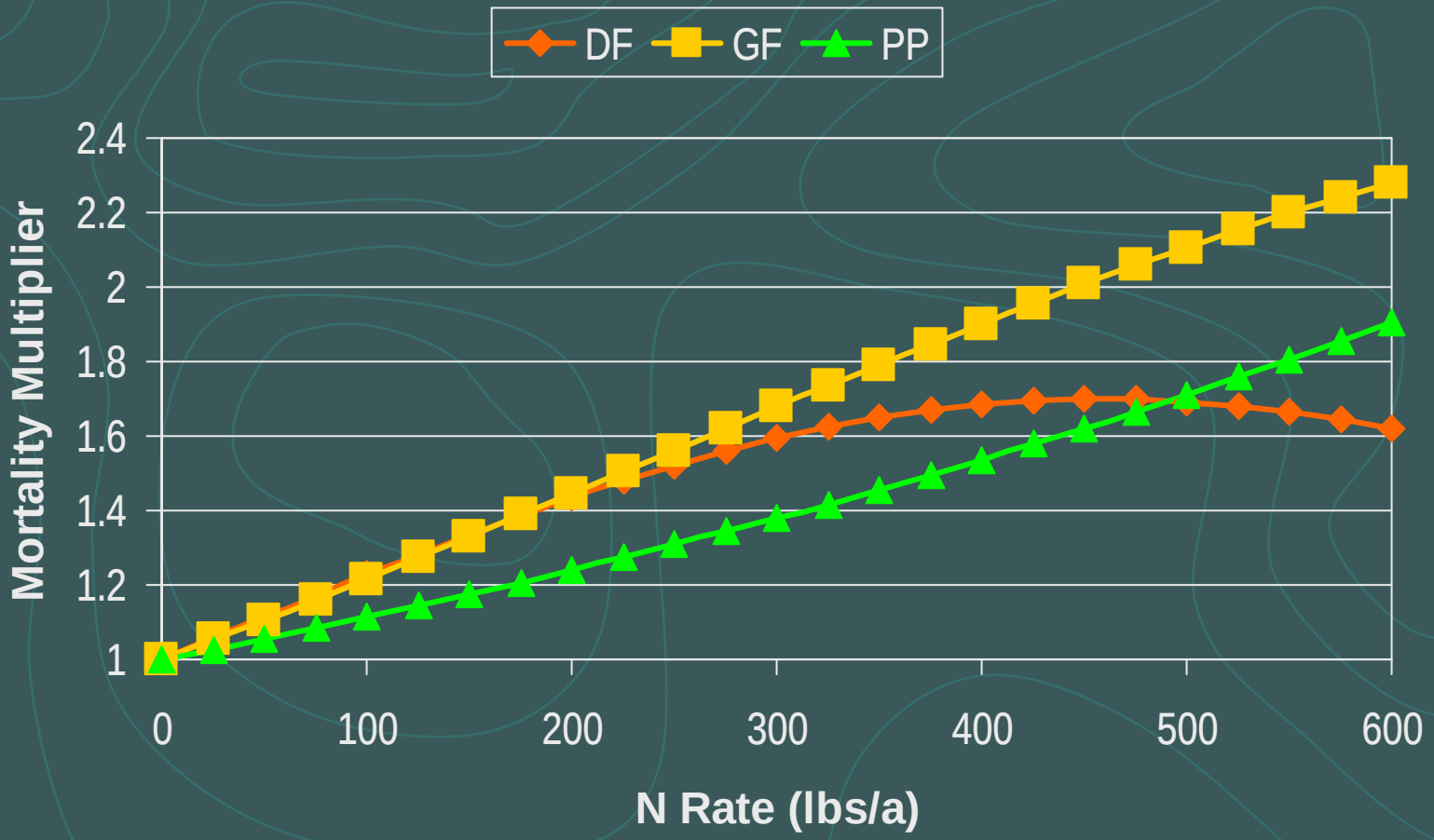
Forest Health Study
Growth Multipliers: GF vs. DF



Growth multipliers: GF Periodic diameter growth



Mortality multipliers
N effects on % volume/a mortality



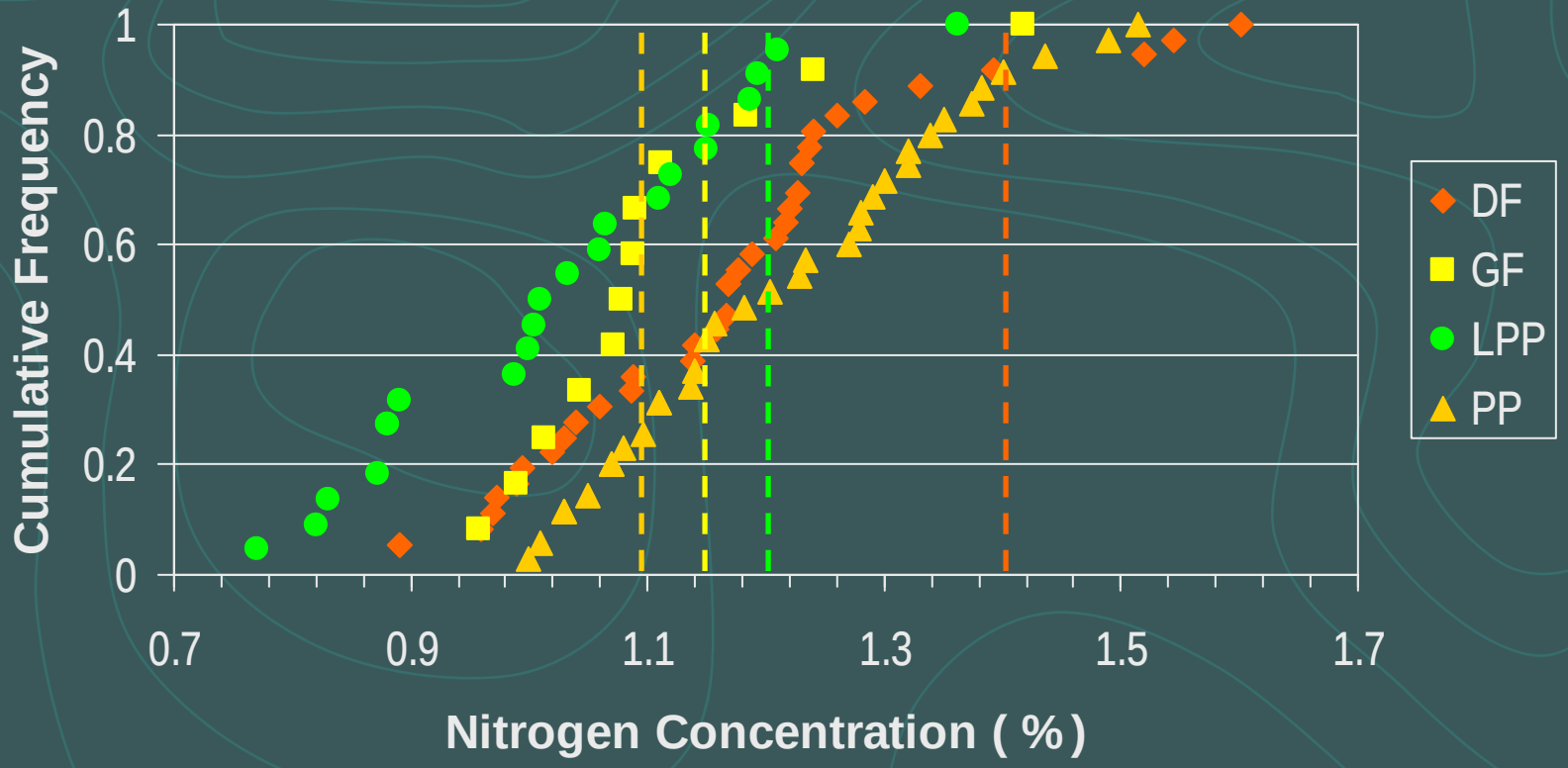
Grand Fir response to fertilization

- GF diameter growth generally responds well to N fertilization, with rates similar to or higher than DF. Height growth often also responds
- N fertilizer response lasts 4 to 6 years—higher N rates, addition of S, or thinning tend to extend the response period
- Response seems to vary by rock type, but data for testing this is sparse
- Addition of S or a multinutrient blend has been shown to significantly increase growth response over that obtained with N alone, but such additions have also failed to increase growth.
- Both trees/a and BA/a mortality is increased by N fertilization.

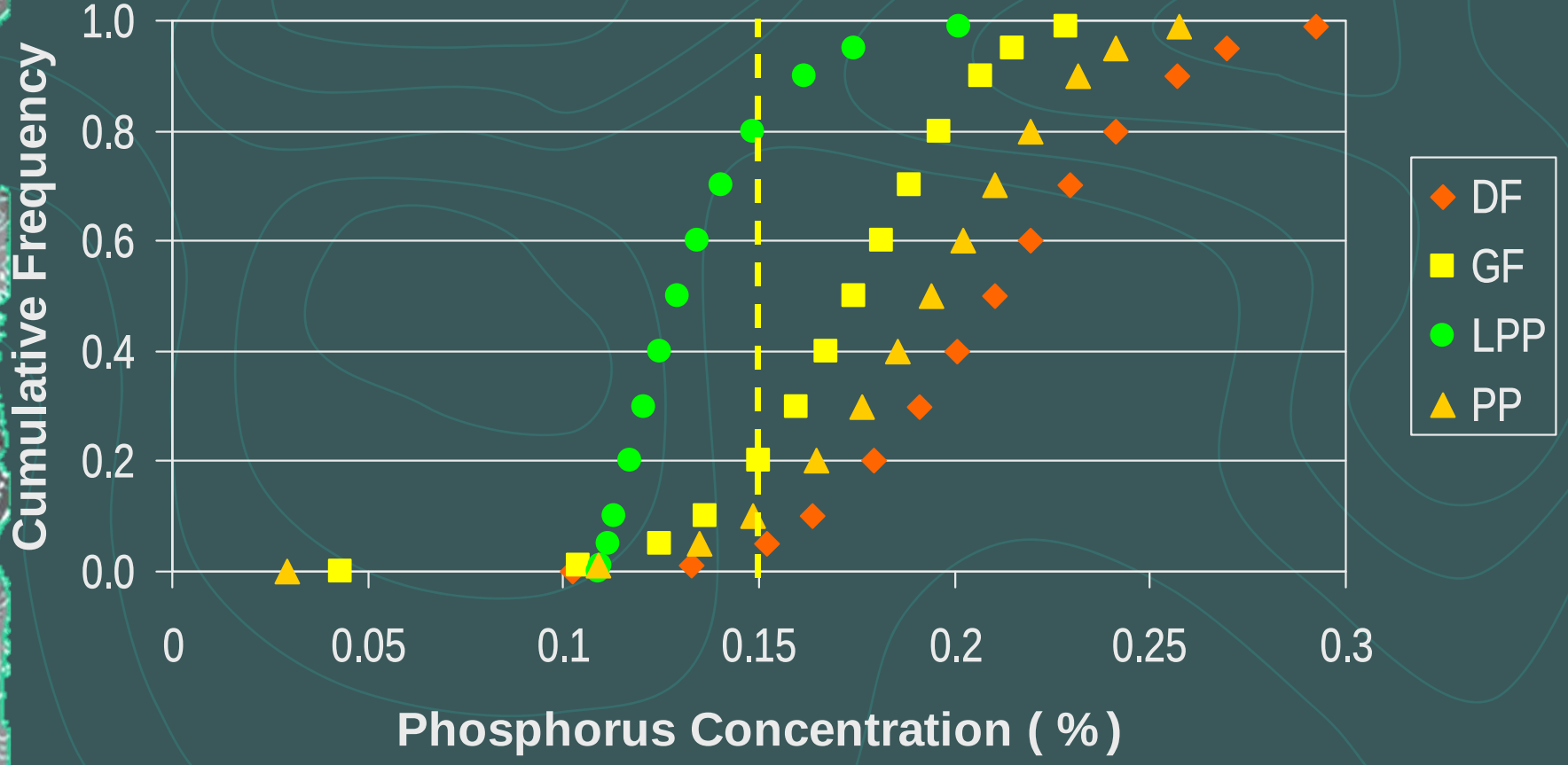
Critical Values for Foliar Nutrient Concentrations by Tree Species

Nutrient	Douglas-fir	True Fir	Lodgepole	Ponderosa
N (%)	1.4	1.15	1.2	1.1
P (%)	0.12	0.15	0.12	0.08
K (%)	0.6	0.58	0.5	0.48
S (%)	0.11	0.08	0.09	0.08
Ca (%)	0.15	0.12	0.08	0.05
Mg (%)	0.08	0.06	0.09	0.05
Mn (ppm)	15	100	48	60
Fe (ppm)	25	50	58	50
Zn (ppm)	10	10	52	30
Cu (ppm)	2	3	2.7	3
B (ppm)	10	10	4.3	20

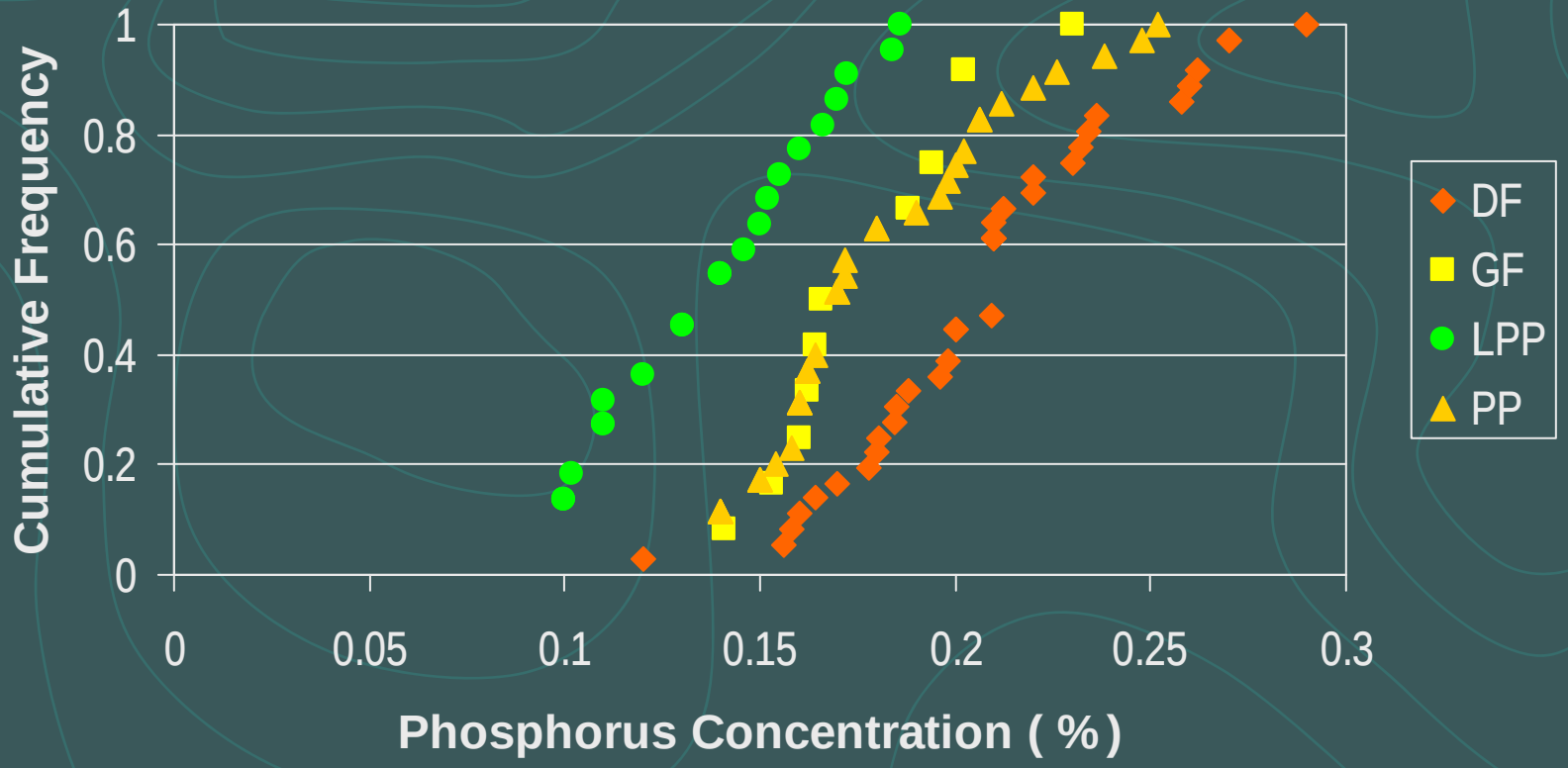
Nitrogen Distribution by Species
Young Trees



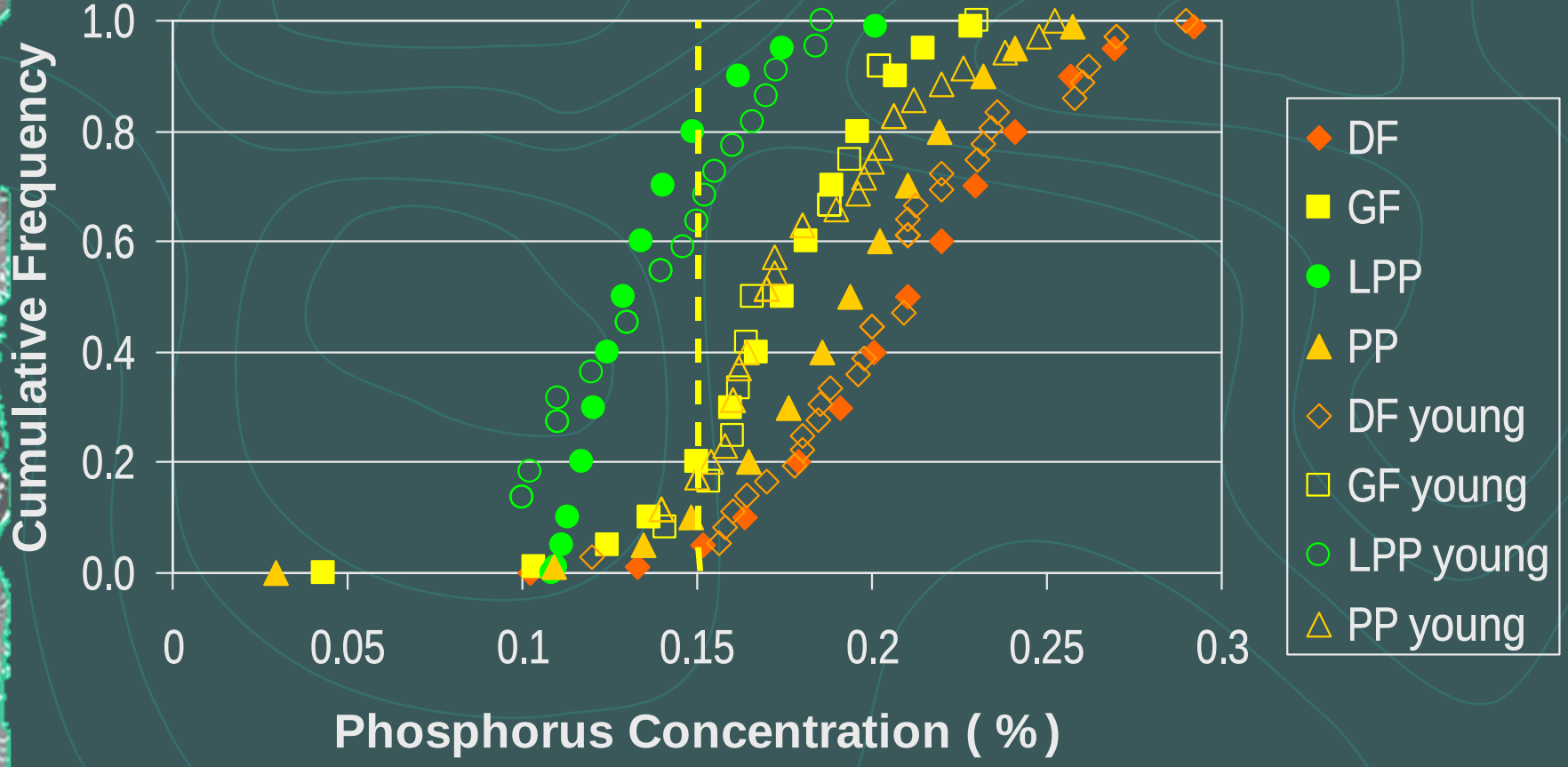
Foliar P Distribution by Tree Species
Mature Trees



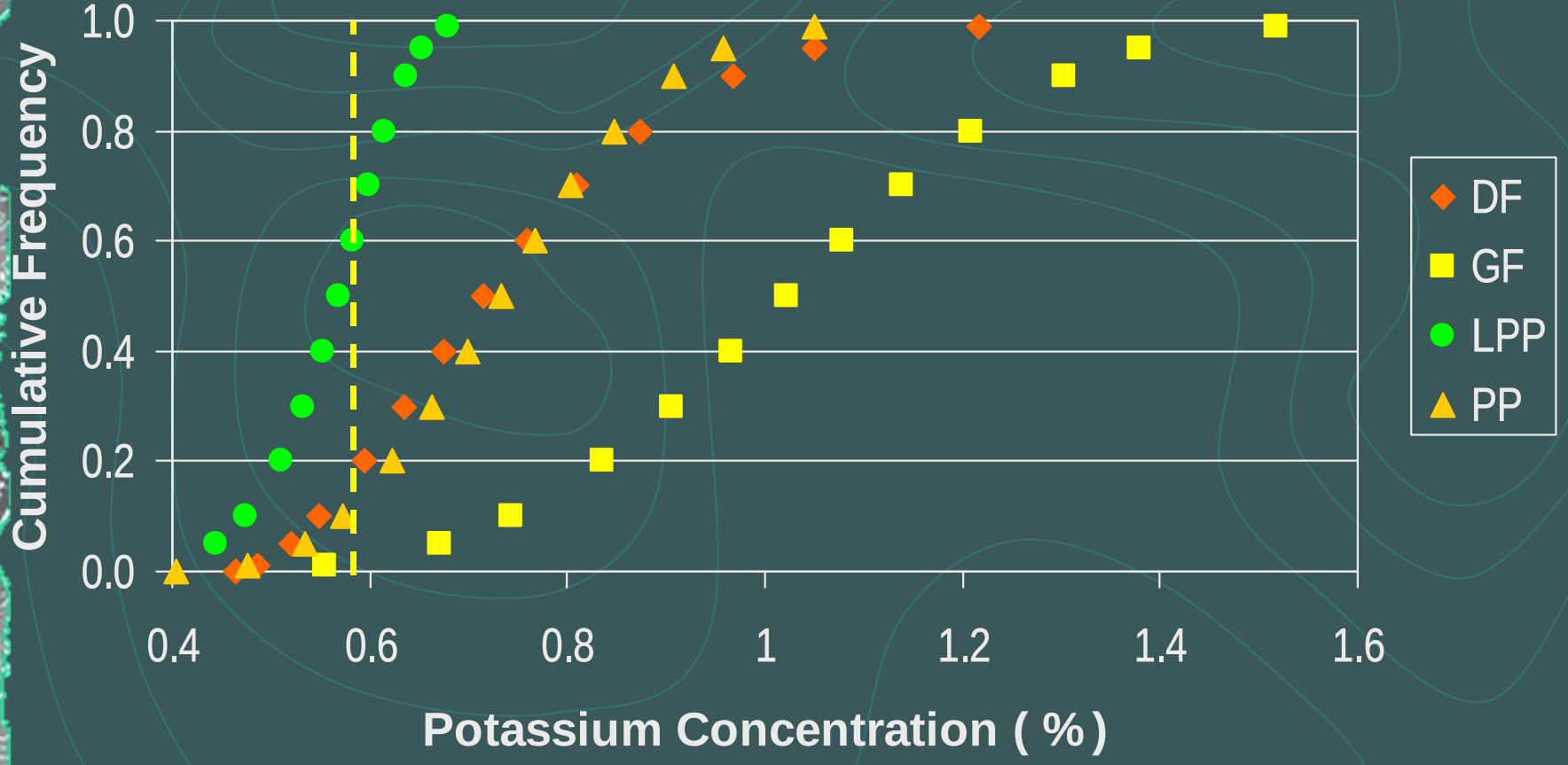
Phosphorus Distribution by Species
Young Trees



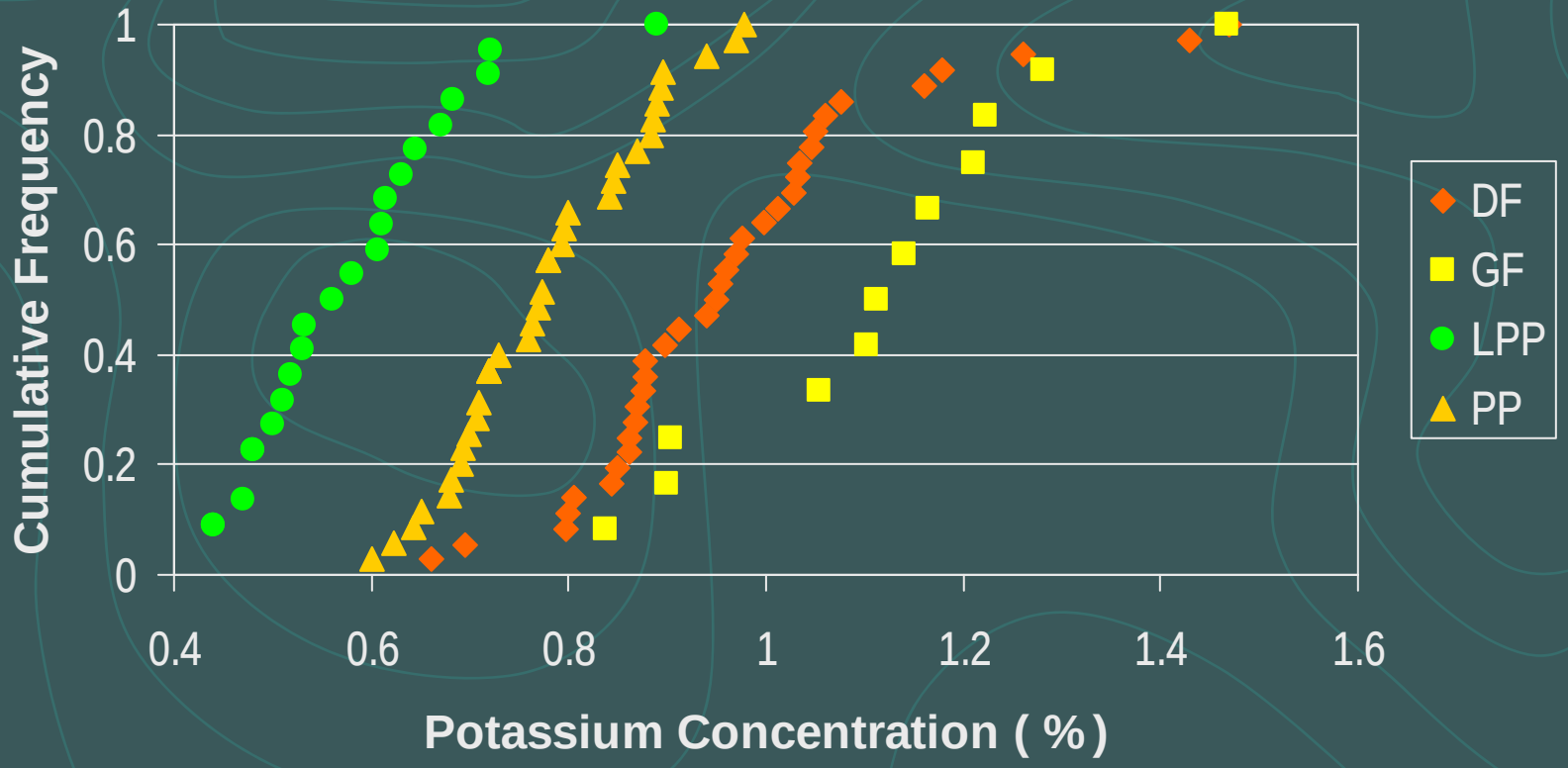
Foliar P Distribution by Tree Species
Mature vs. Young Trees



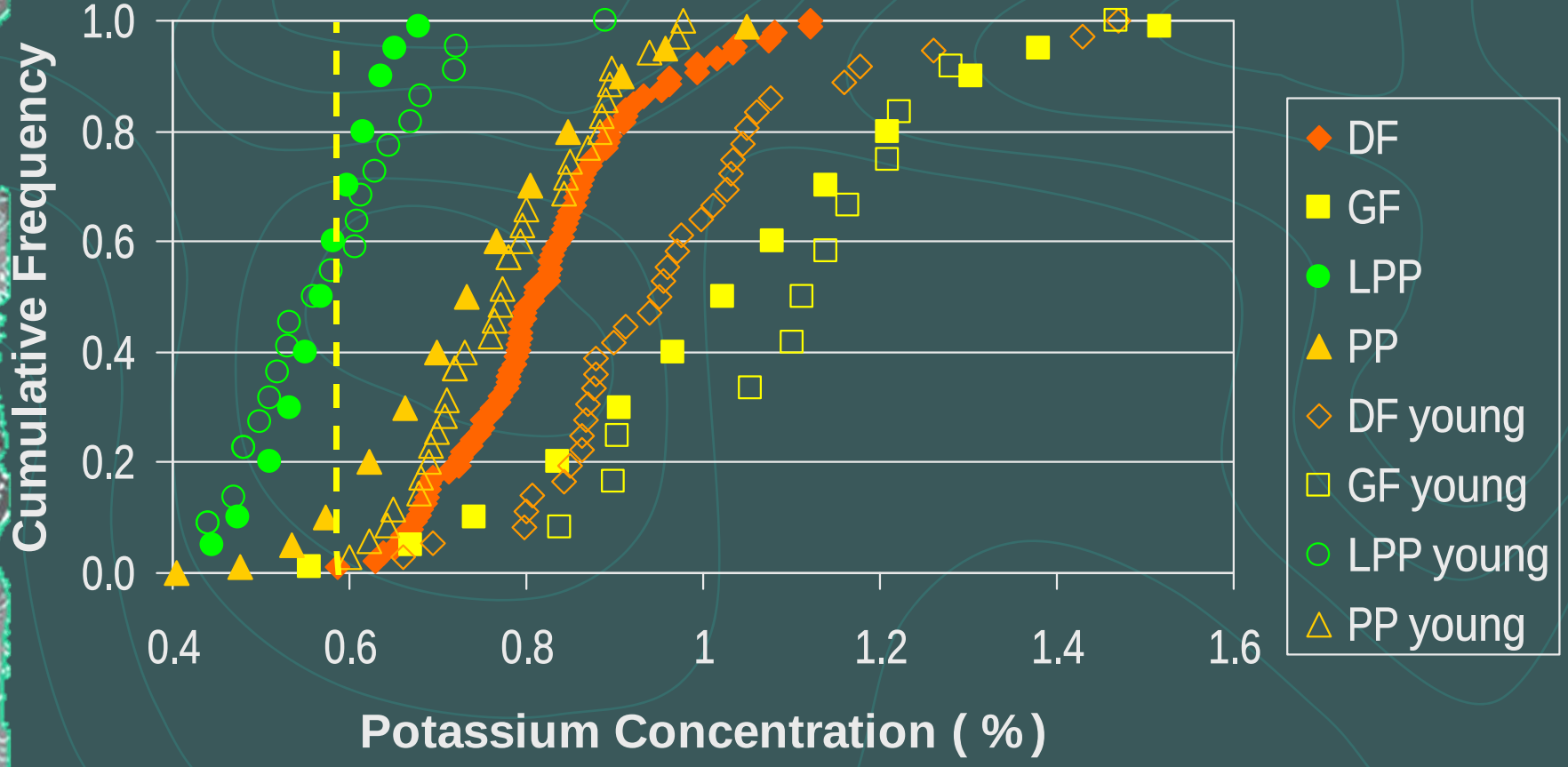
Foliar K Distribution by Tree Species
Mature Trees



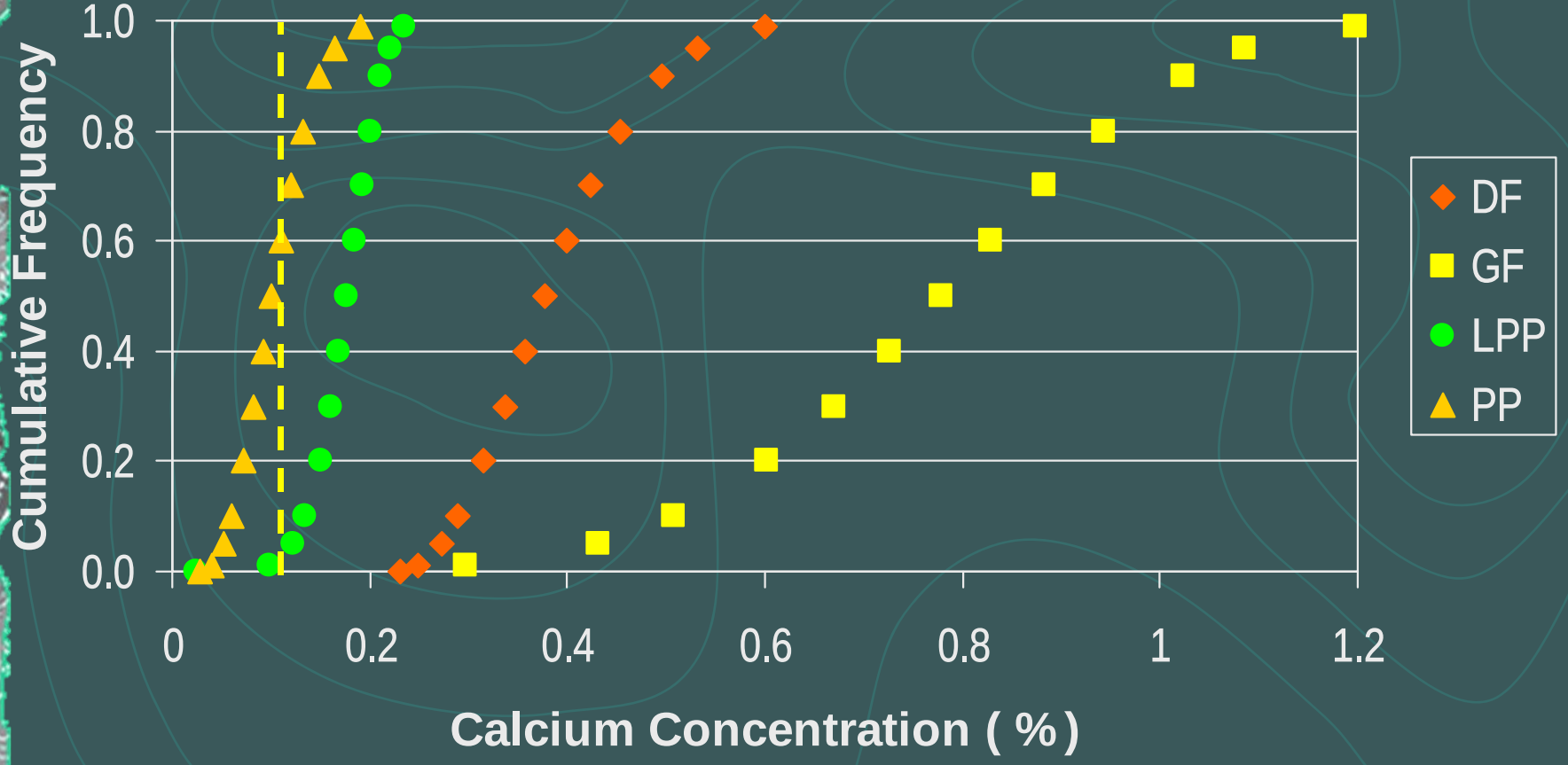
Potassium Distribution by Species
Young Trees



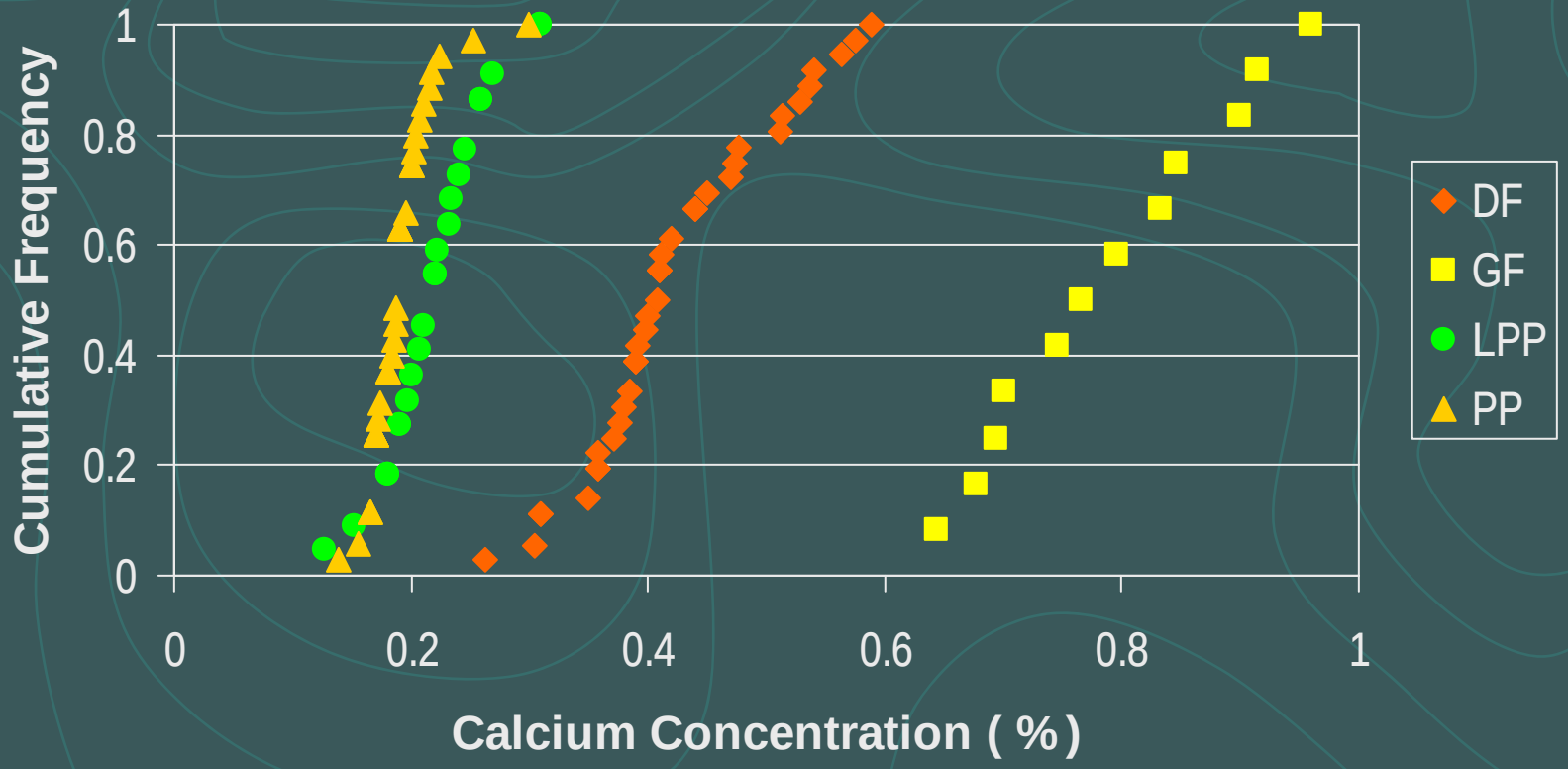
Foliar K Distribution by Tree Species
Mature vs. Young Trees



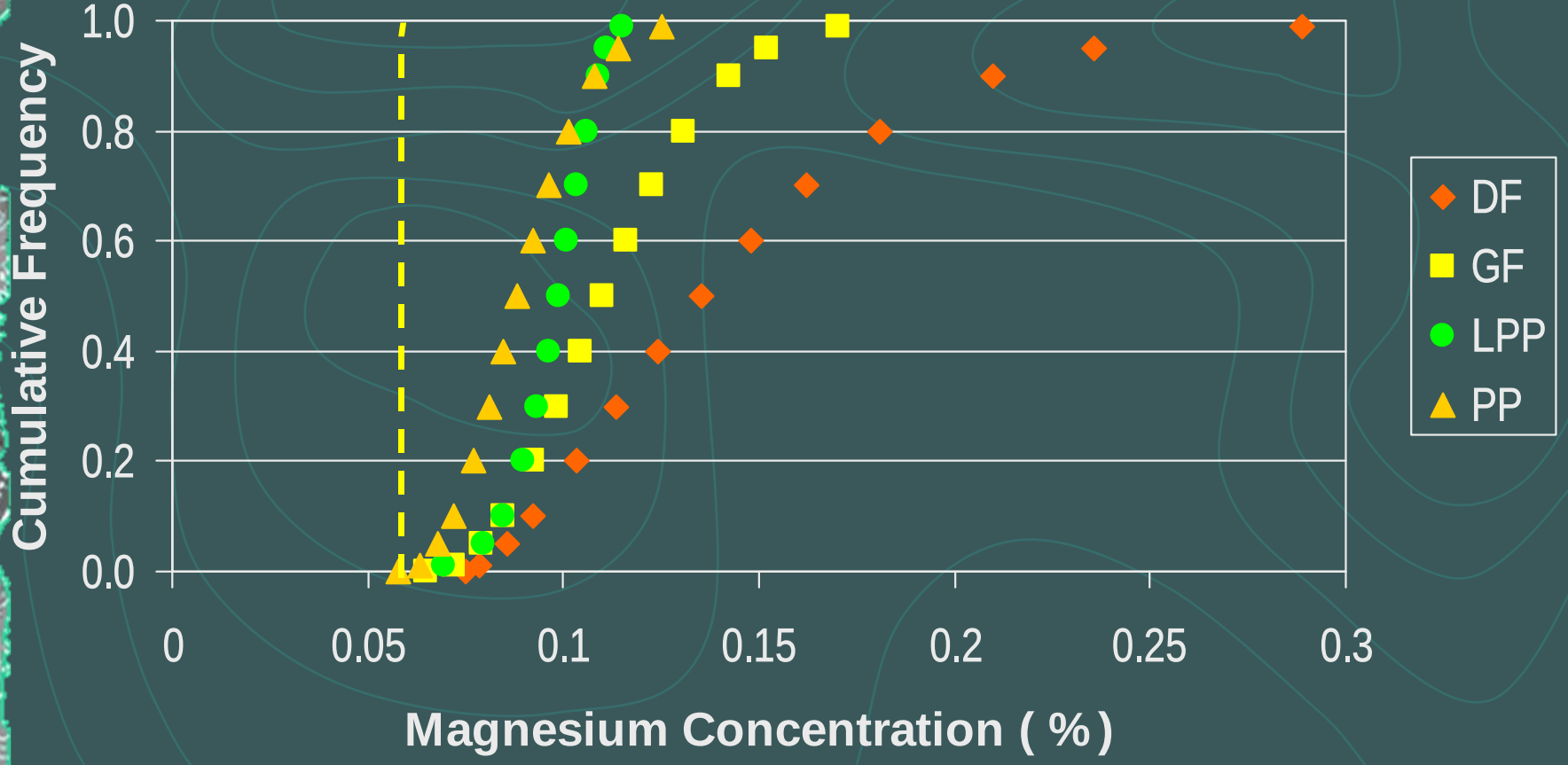
Foliar Ca Distribution by Tree Species
Mature Trees



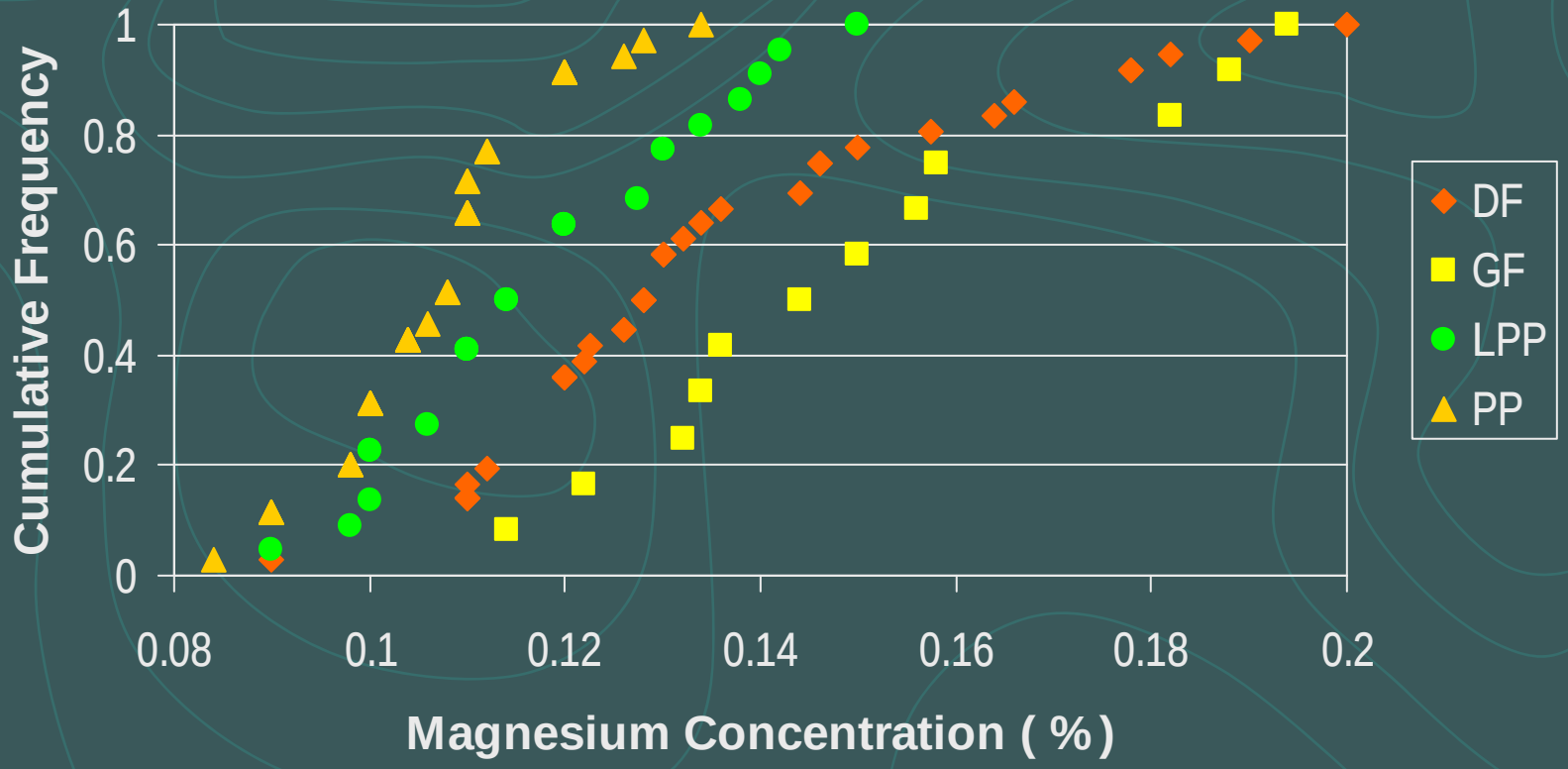
Calcium Distribution by Species
Young Trees



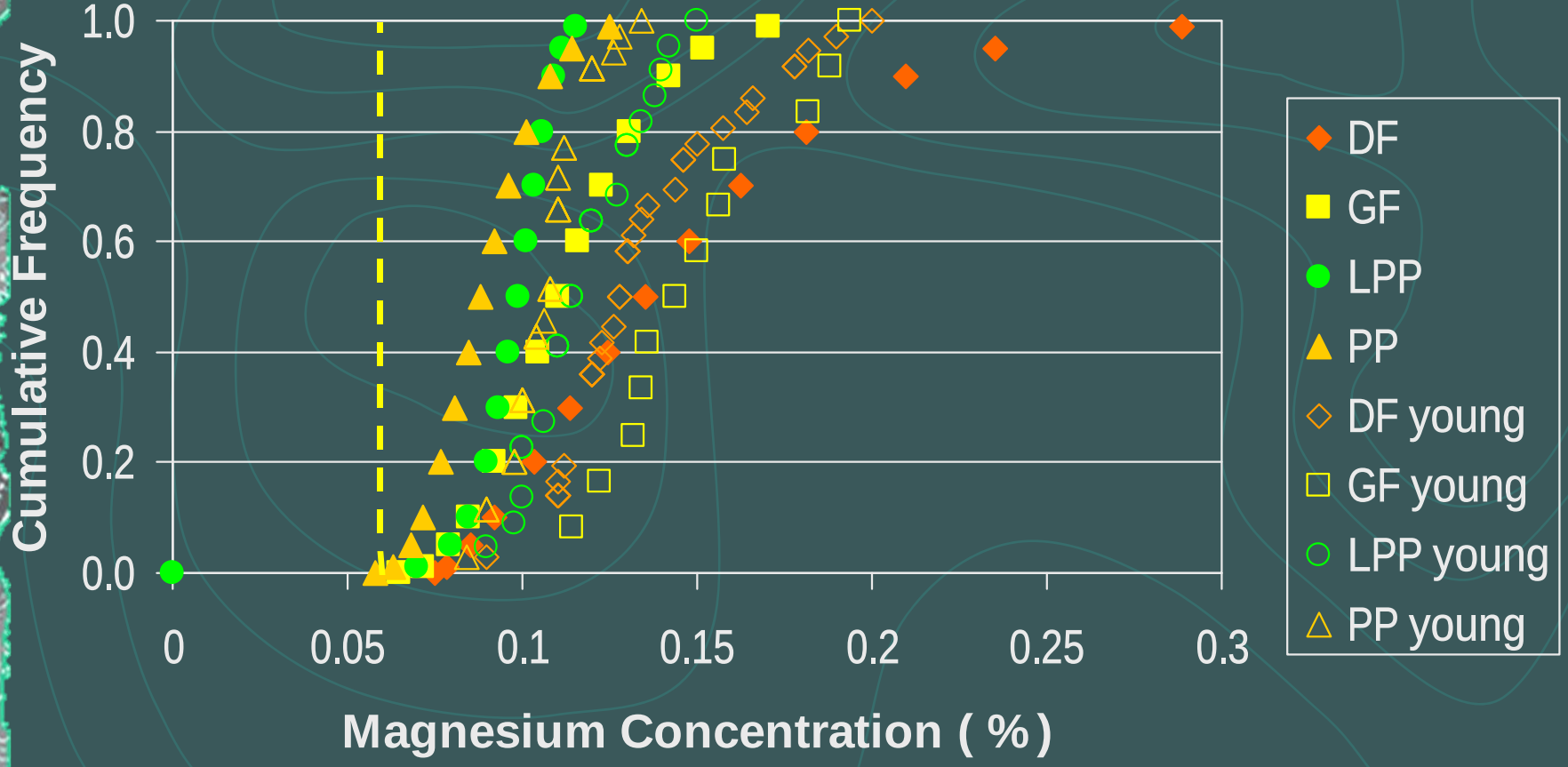
Foliar Mg Distribution by Tree Species
Mature Trees



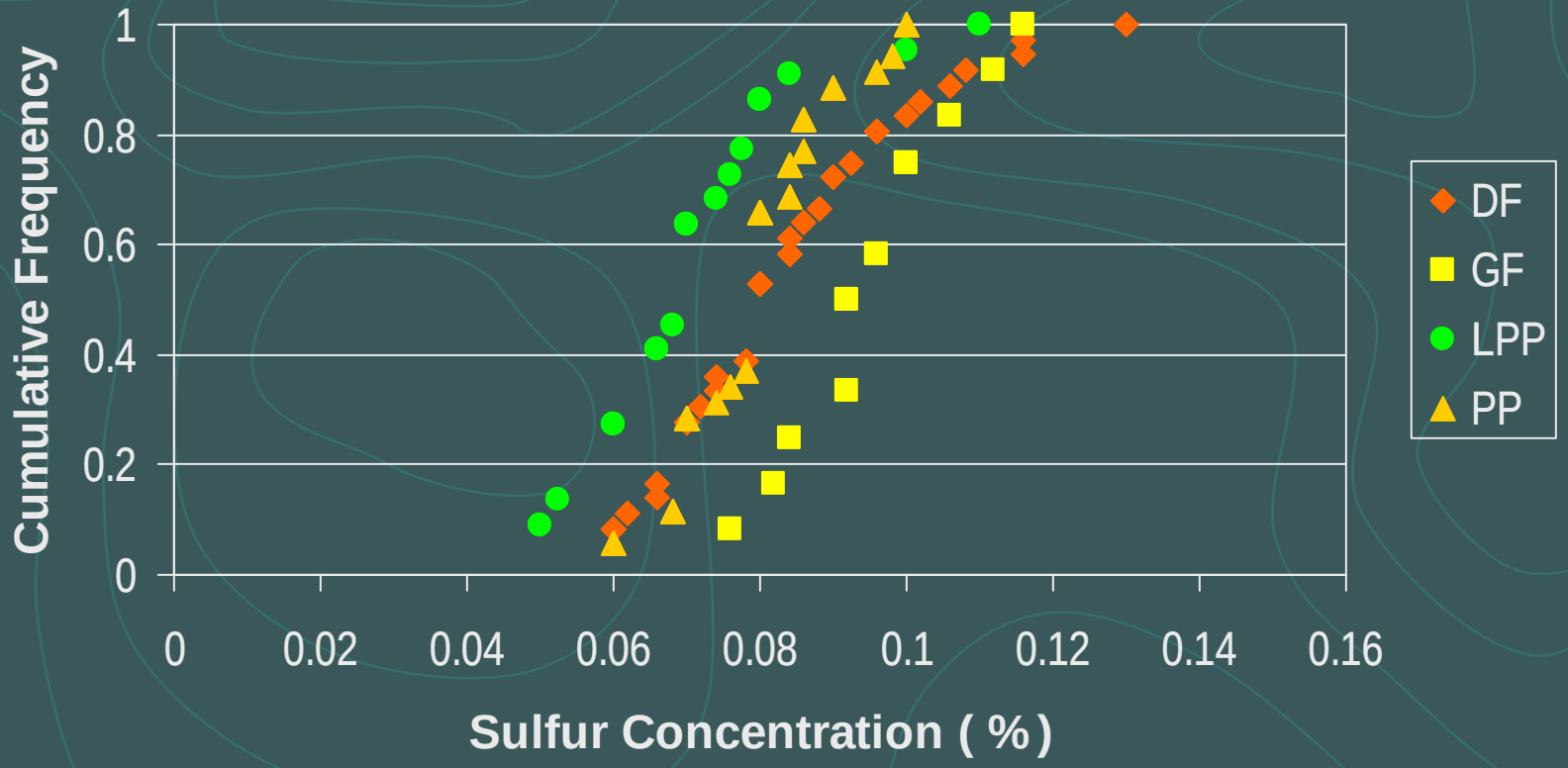
Magnesium Distribution by Species
Young Trees



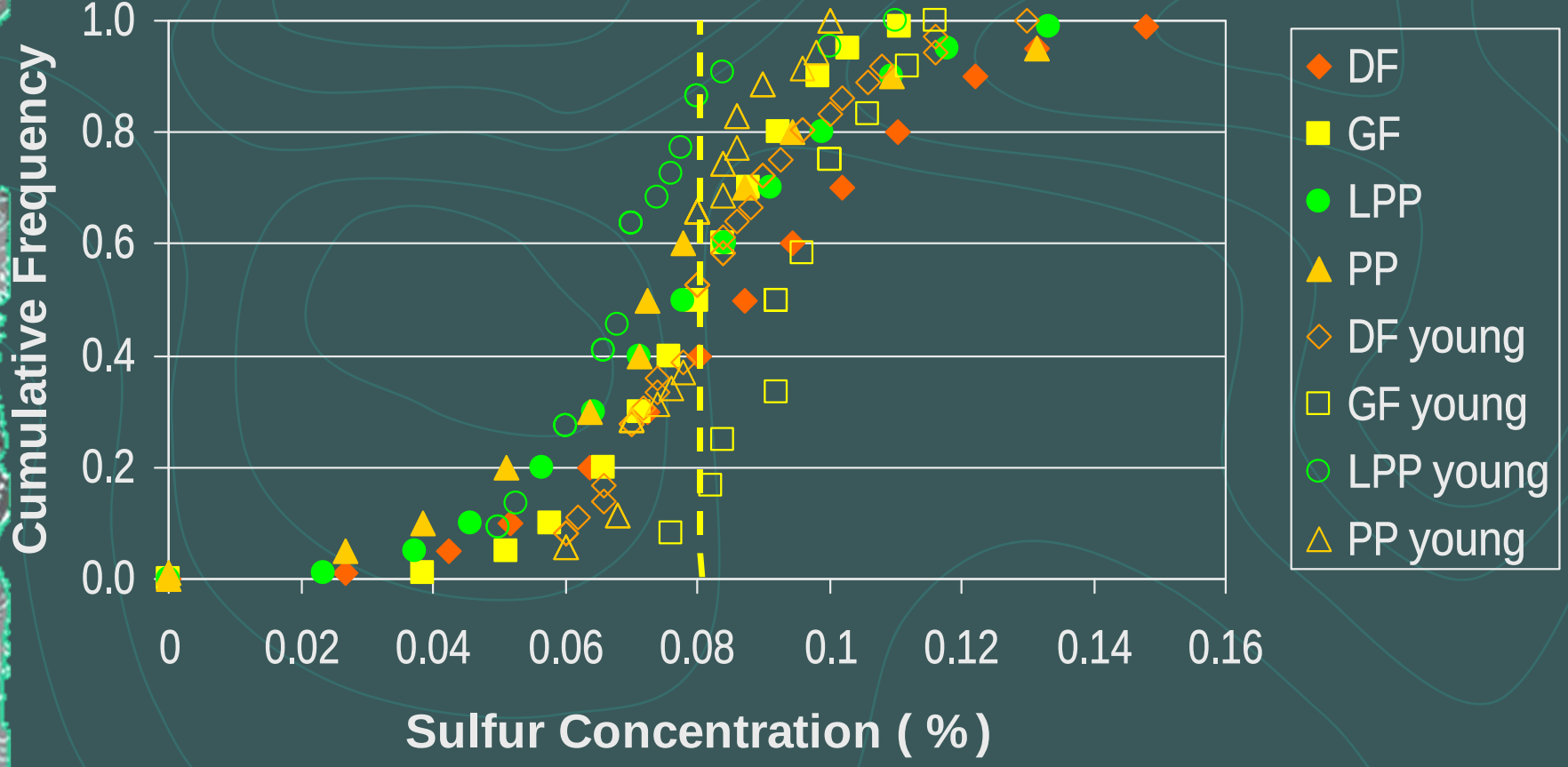
Foliar Mg Distribution by Tree Species
Mature vs. Young Trees



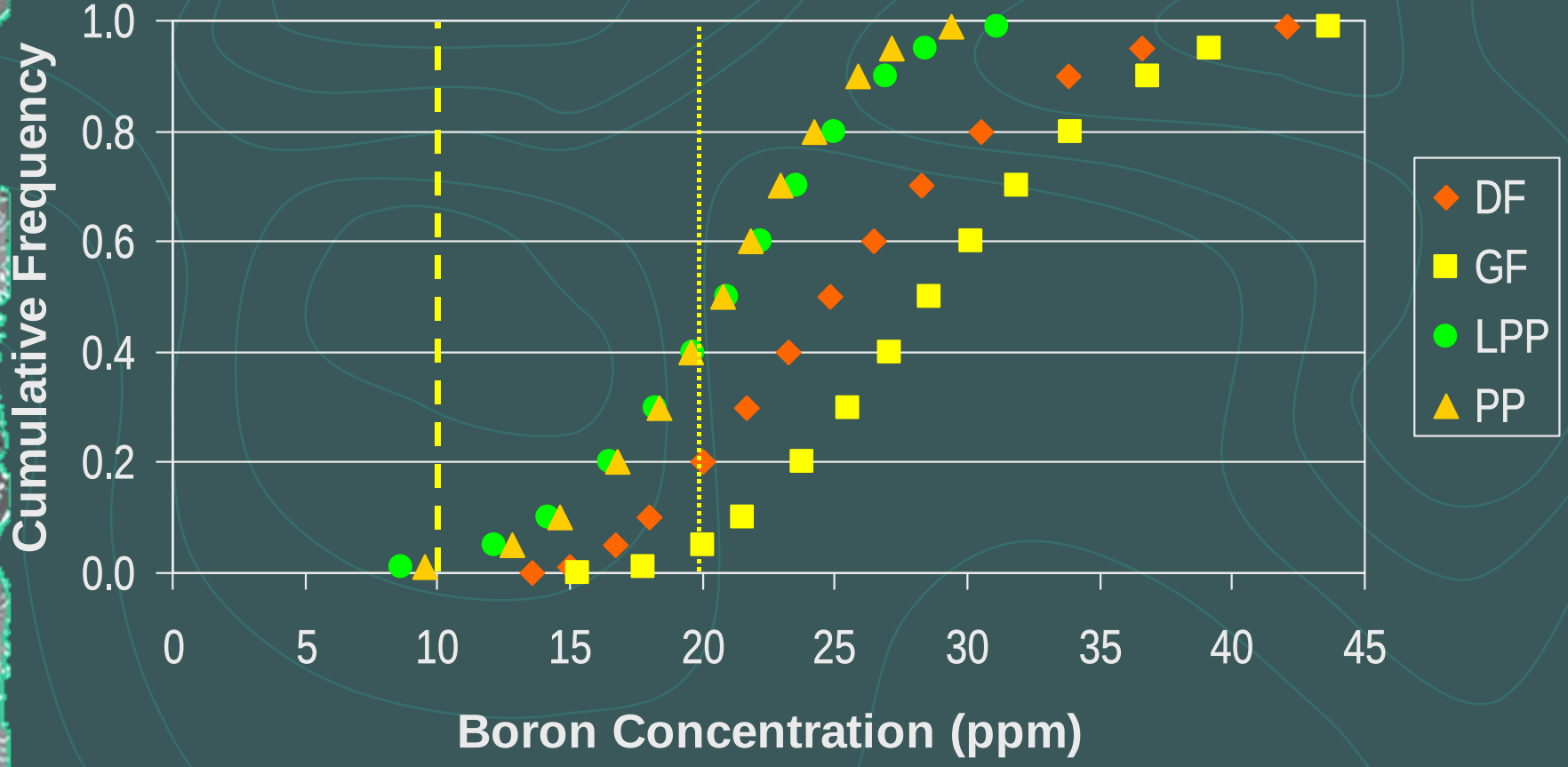
Sulfur Distribution by Species
Young Trees



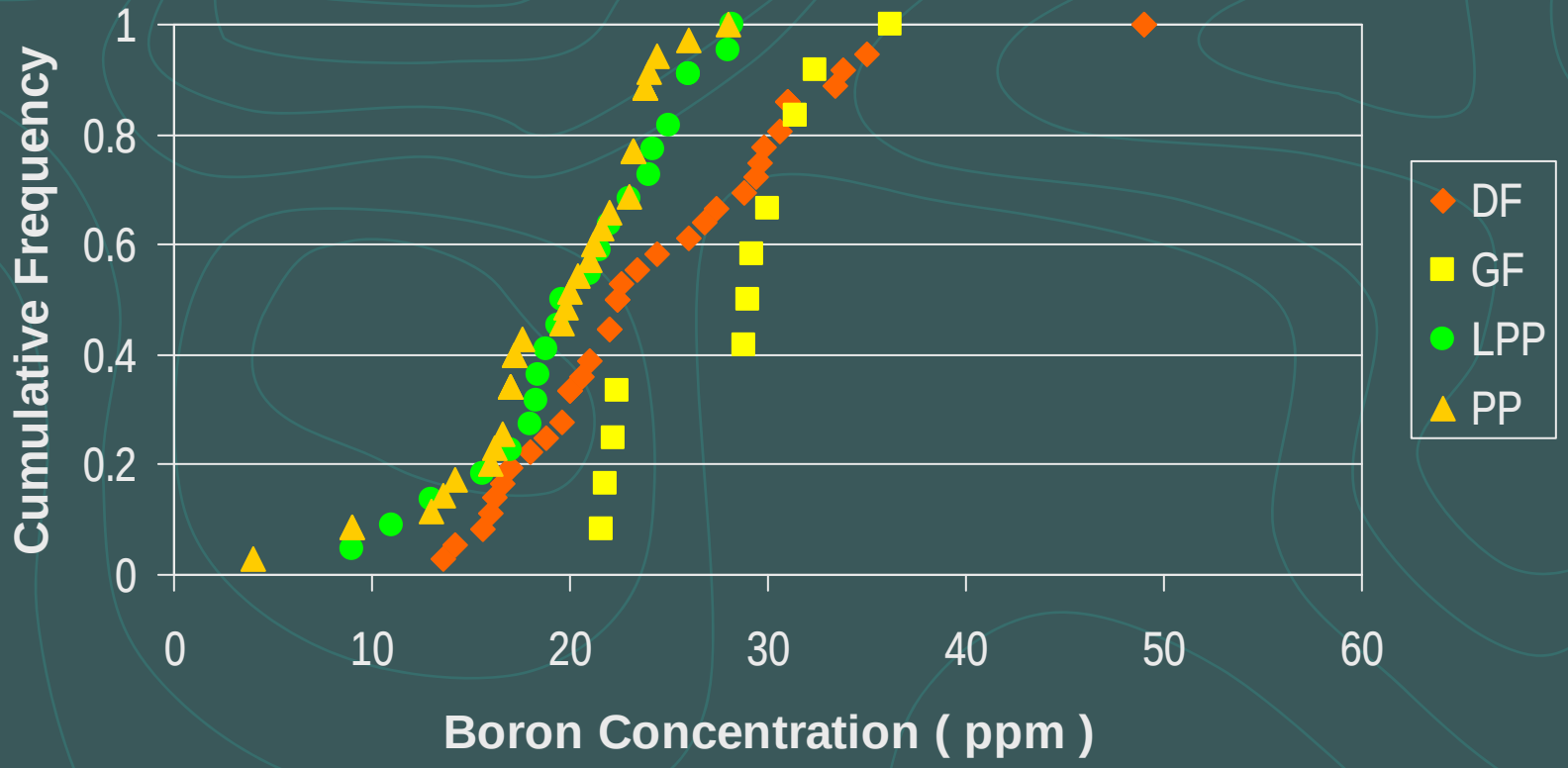
Foliar S Distribution by Tree Species
Mature vs. Young Trees



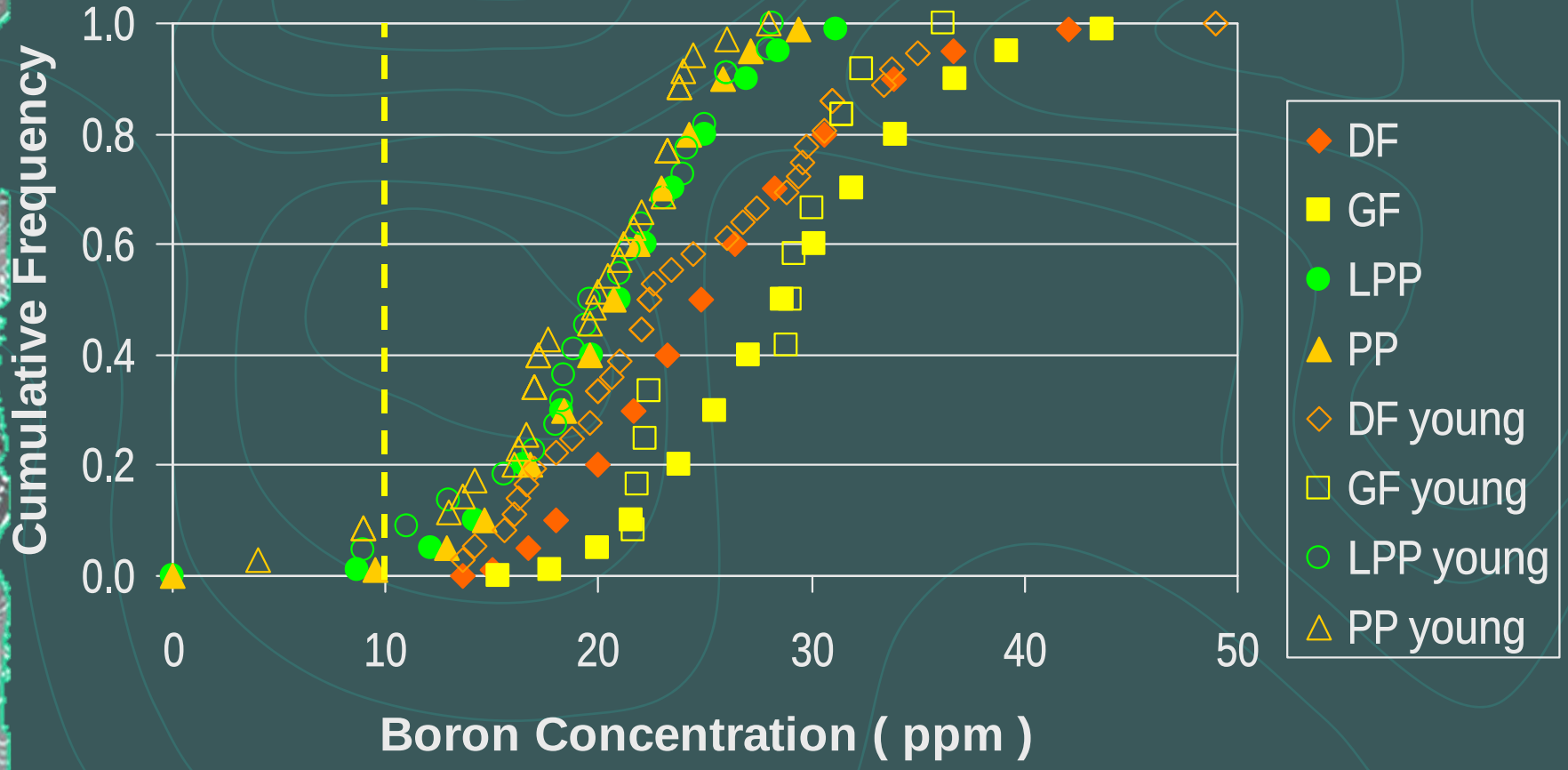
Foliar B Distribution by Tree Species
Mature Trees



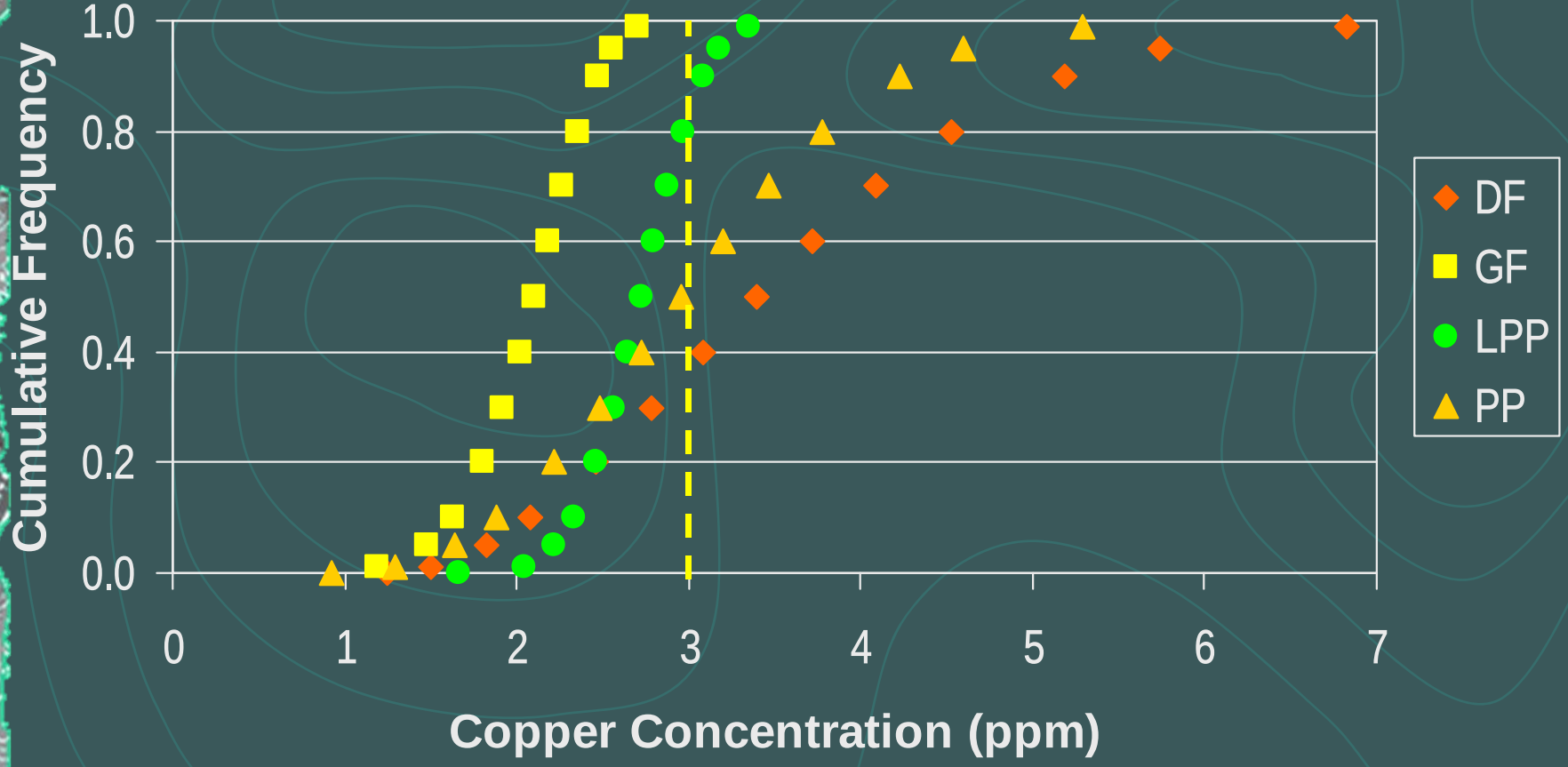
Boron Distribution by Species
Young Trees



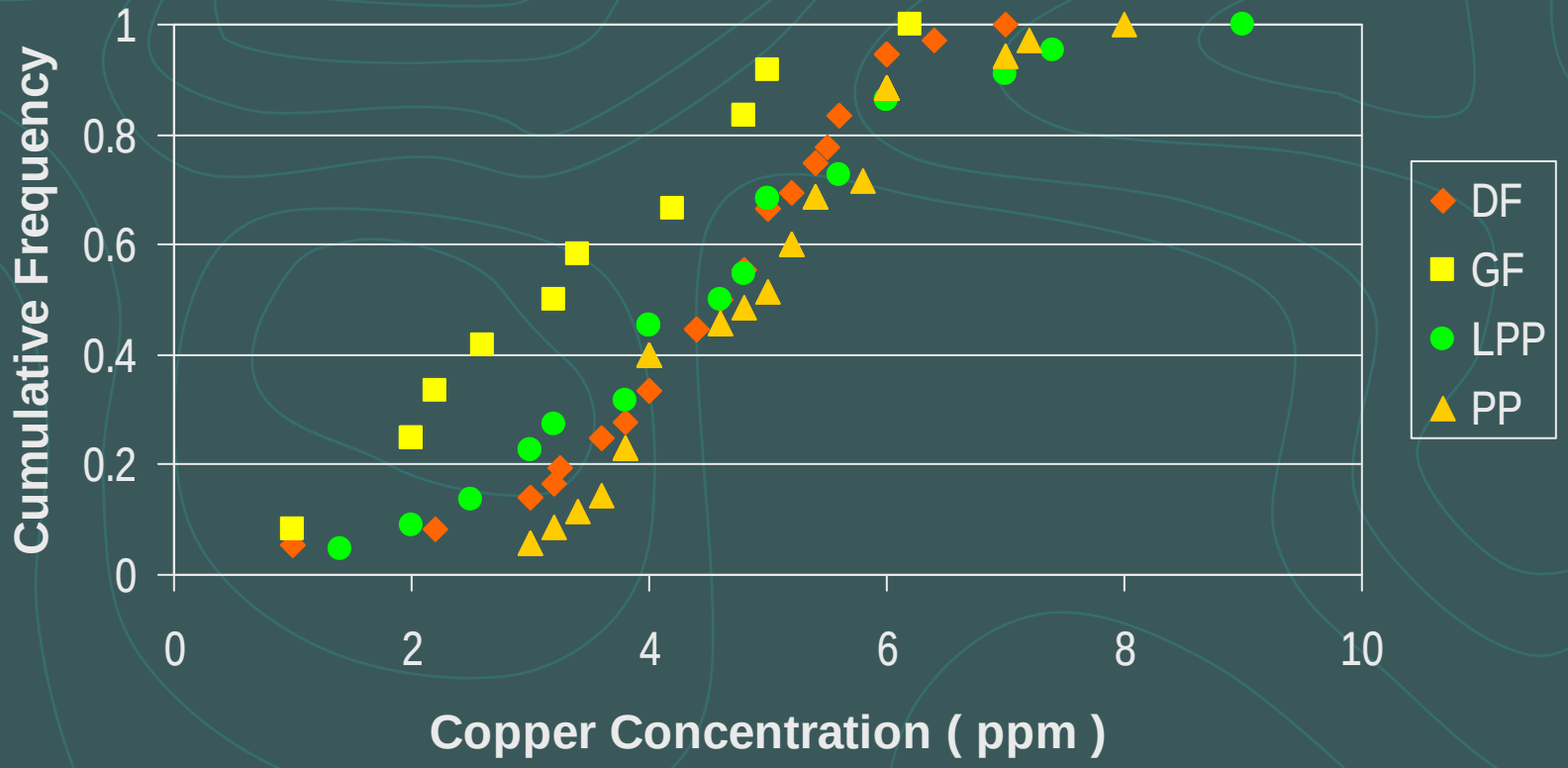
Foliar B Distribution by Tree Species
Mature vs. Young Trees



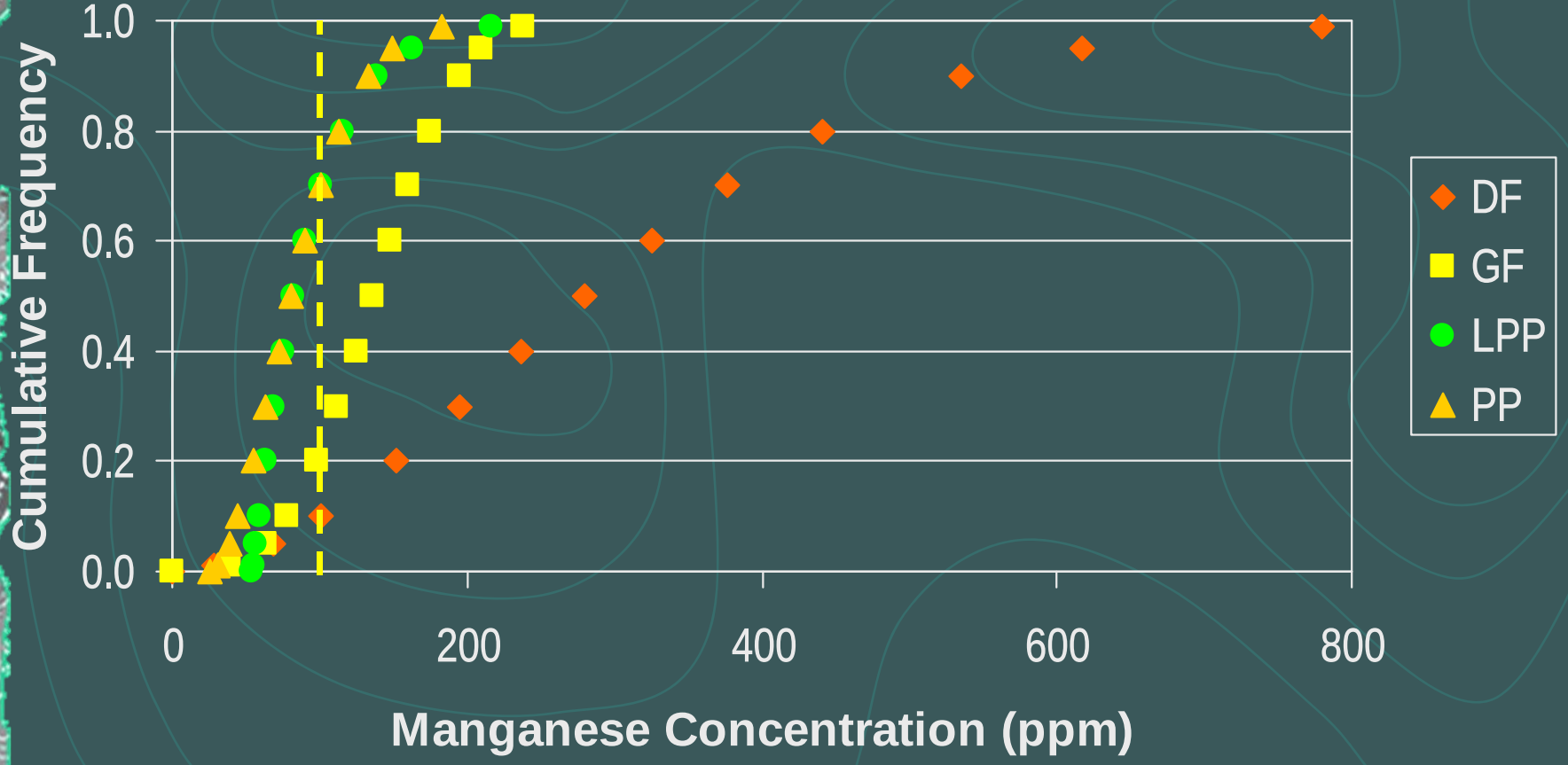
Foliar Cu Distribution by Tree Species
Mature Trees



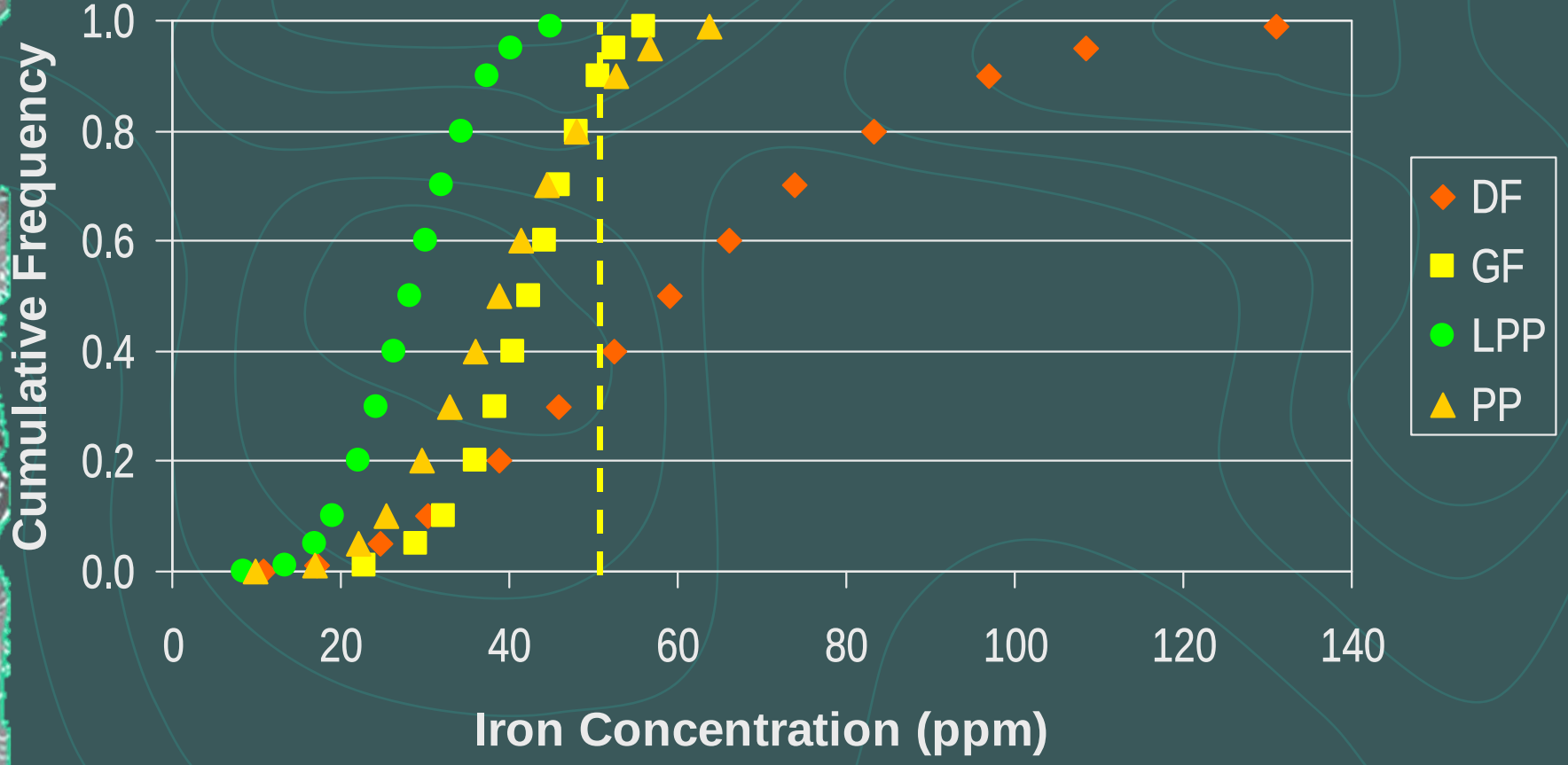
Copper Distribution by Species
Young Trees



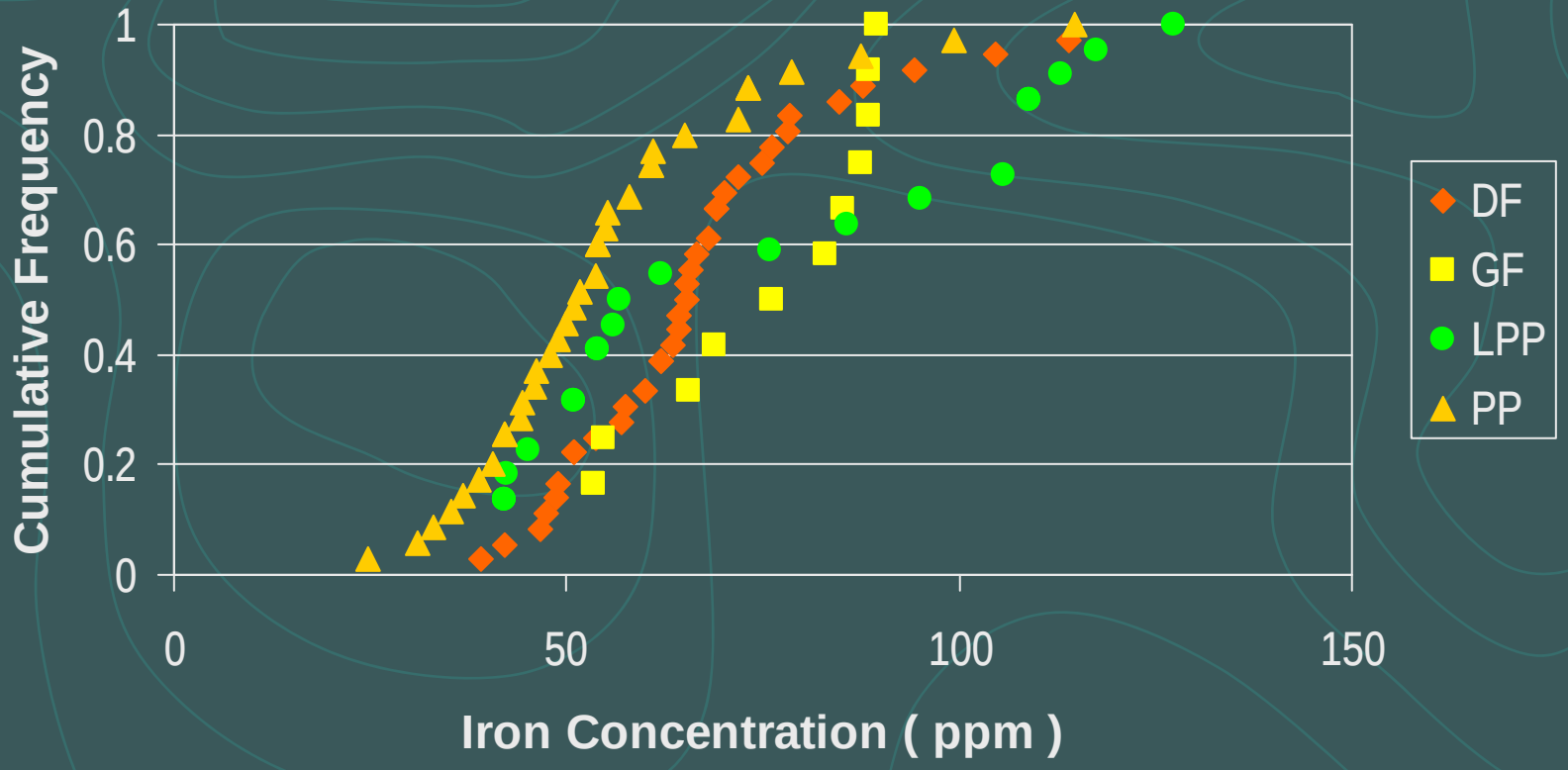
Foliar Mn Distribution by Tree Species
Mature Trees



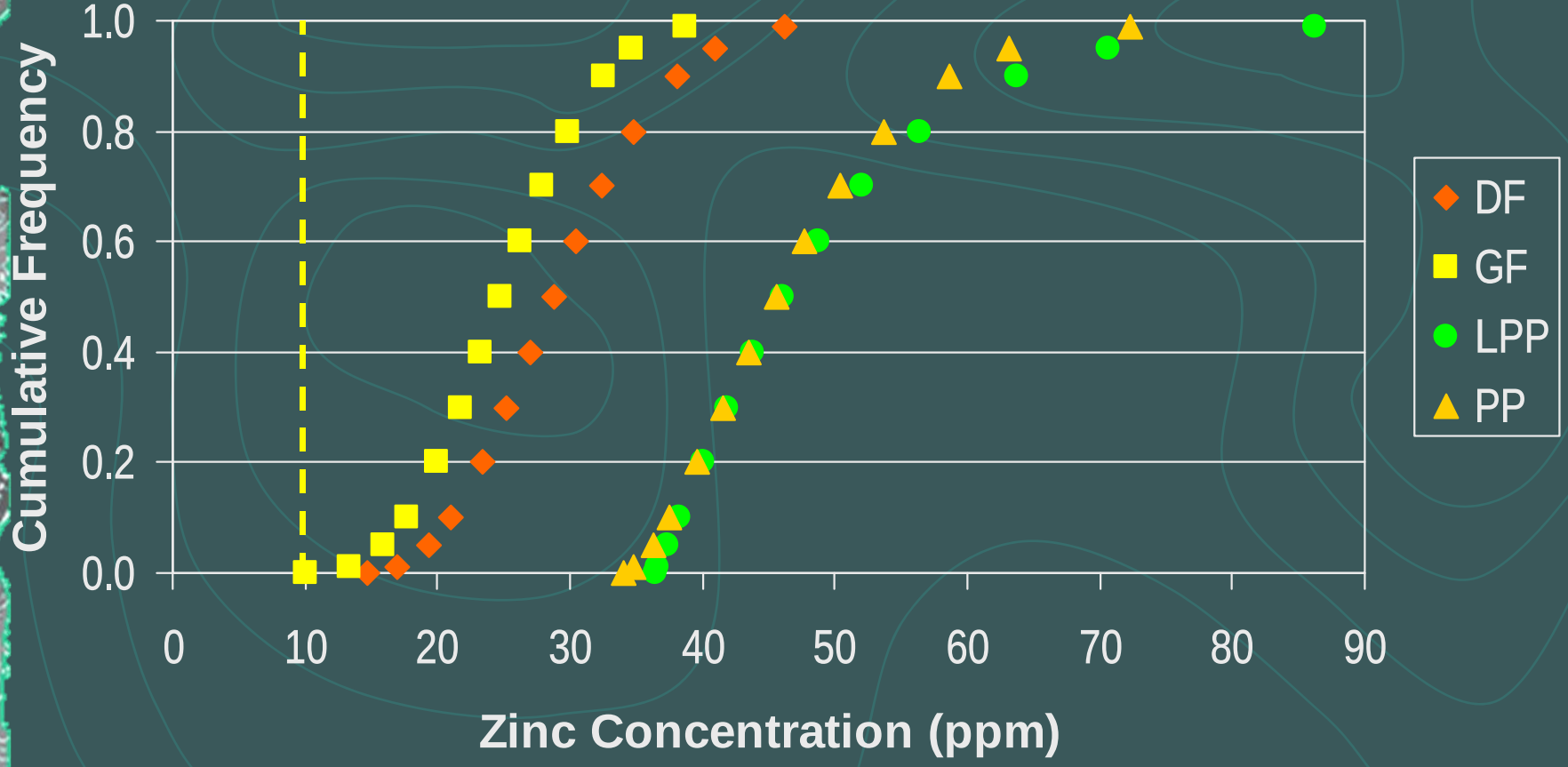
Foliar Fe Distribution by Tree Species
Mature Trees



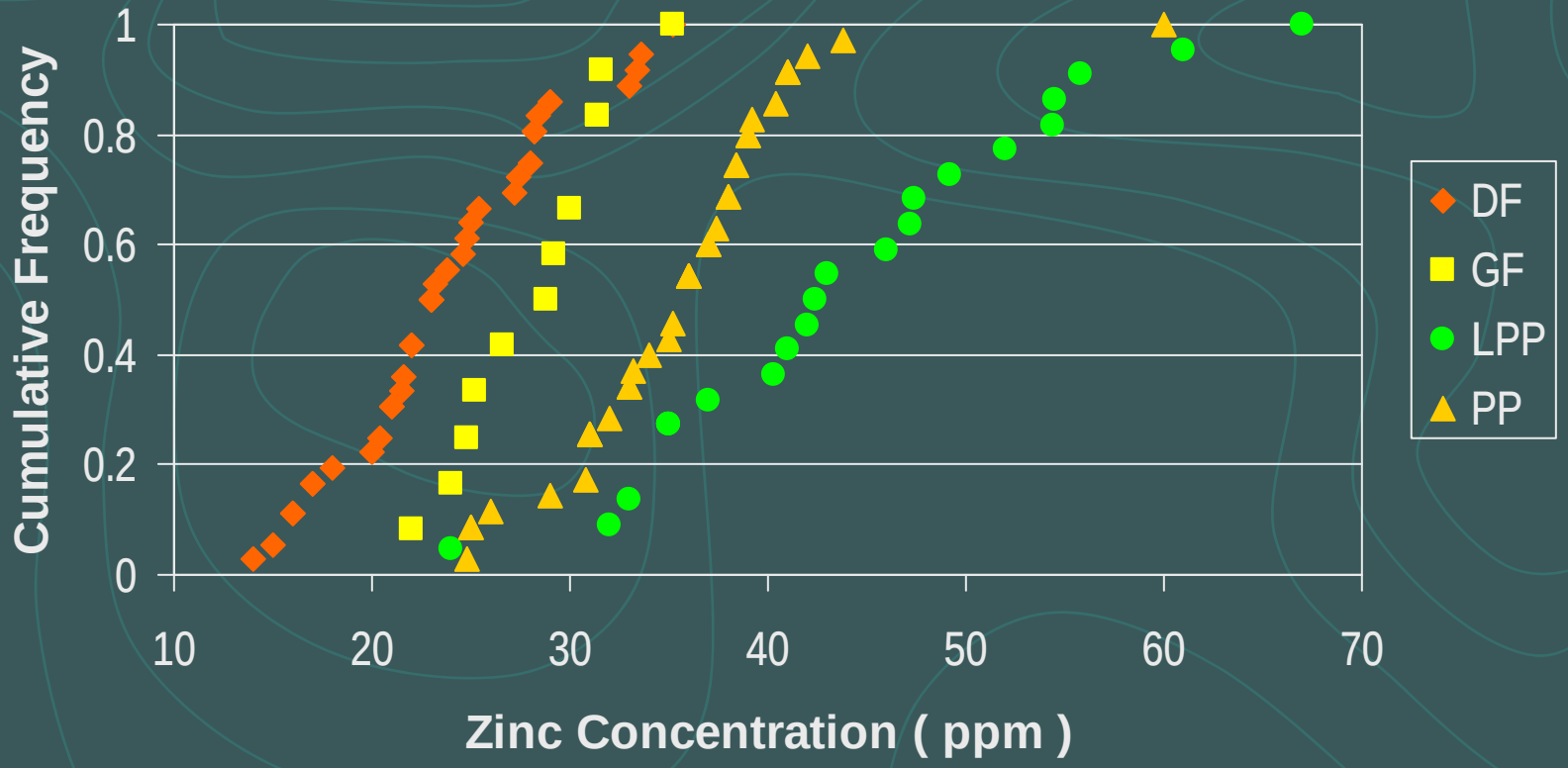
Iron Distribution by Species
Young Trees



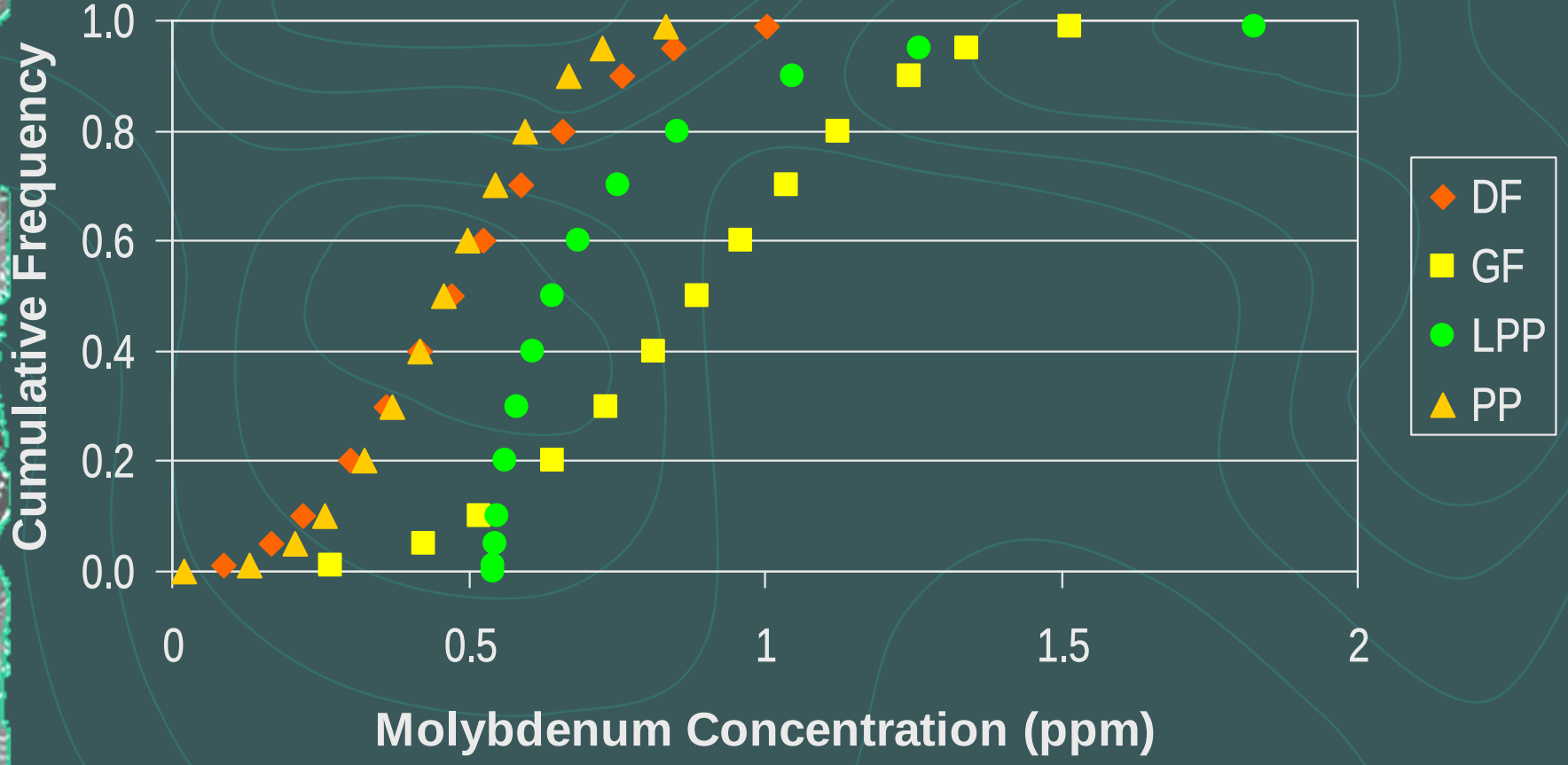
Foliar Zn Distribution by Tree Species
Mature Trees



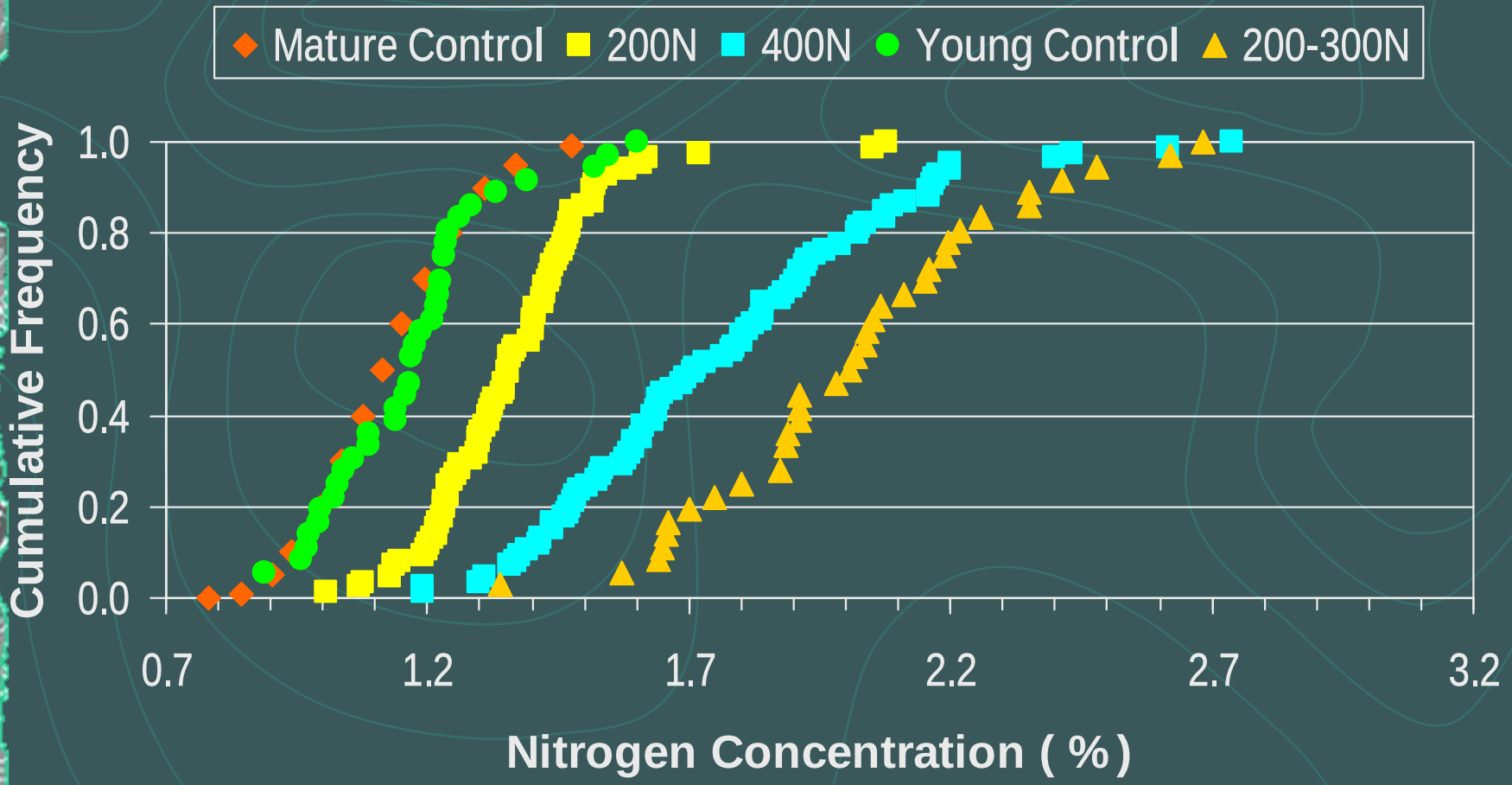
Zinc Distribution by Species
Young Trees



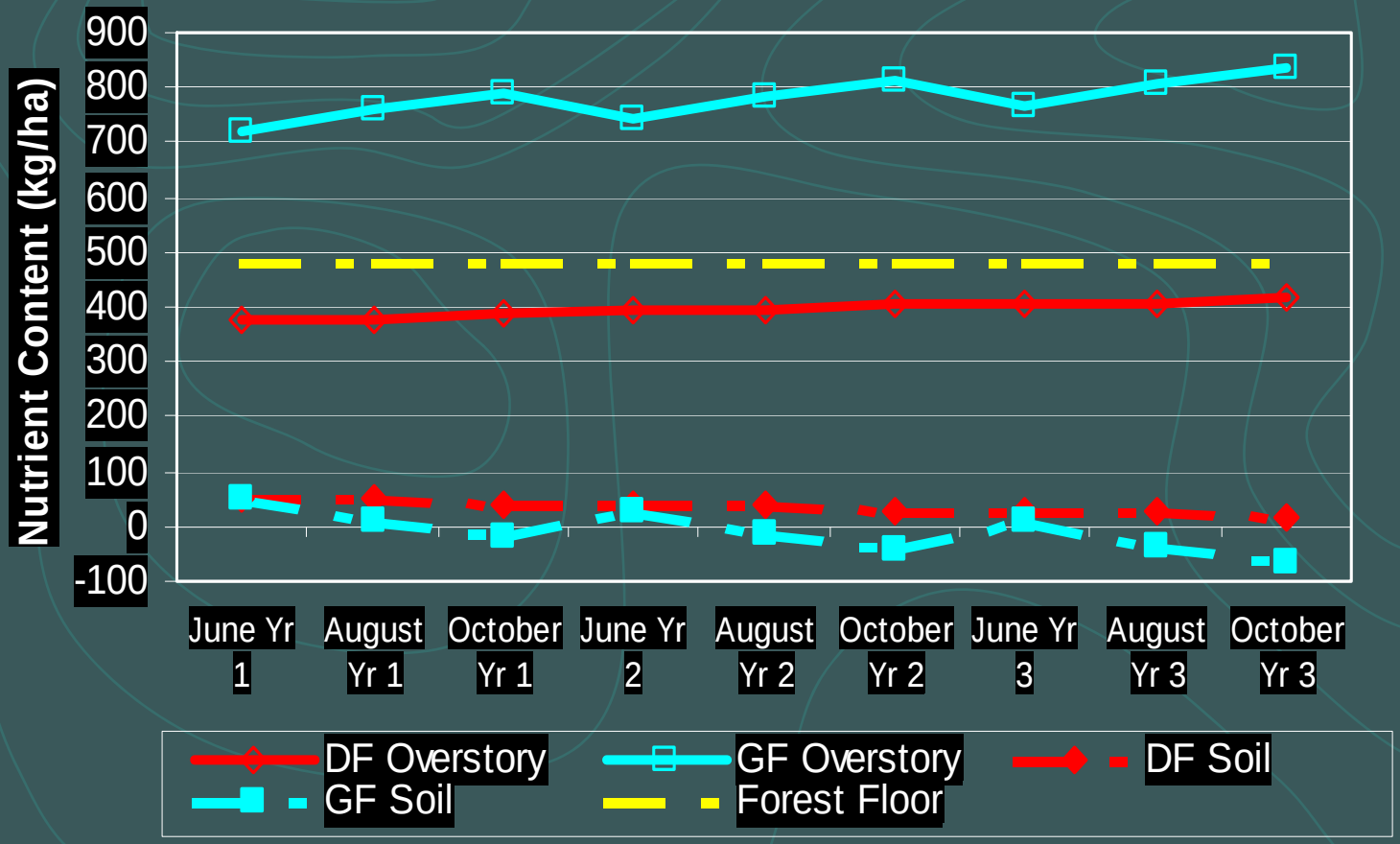
Foliar Mo Distribution by Tree Species
Mature Trees



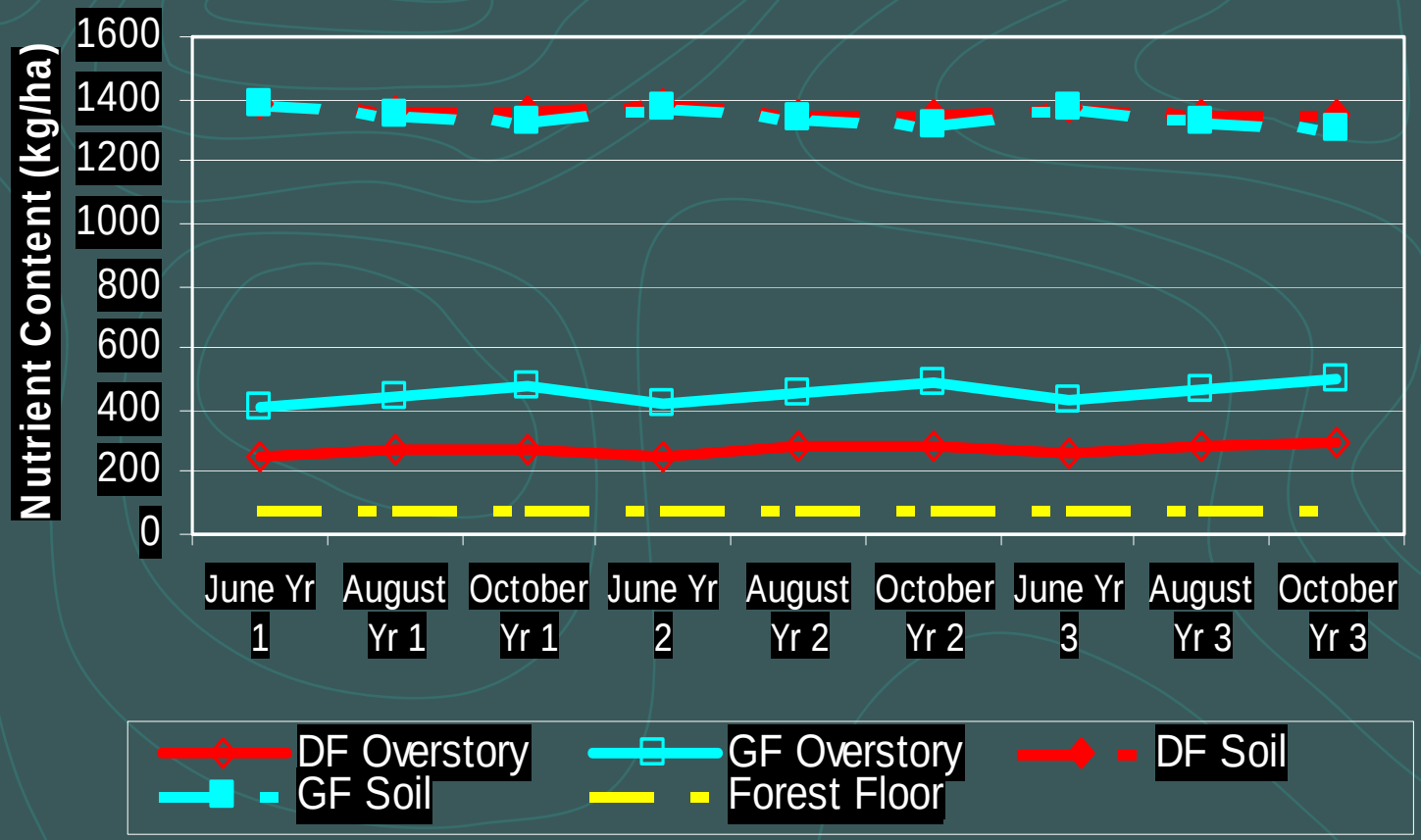
Distribution of Foliar N Concentration for Douglas-fir



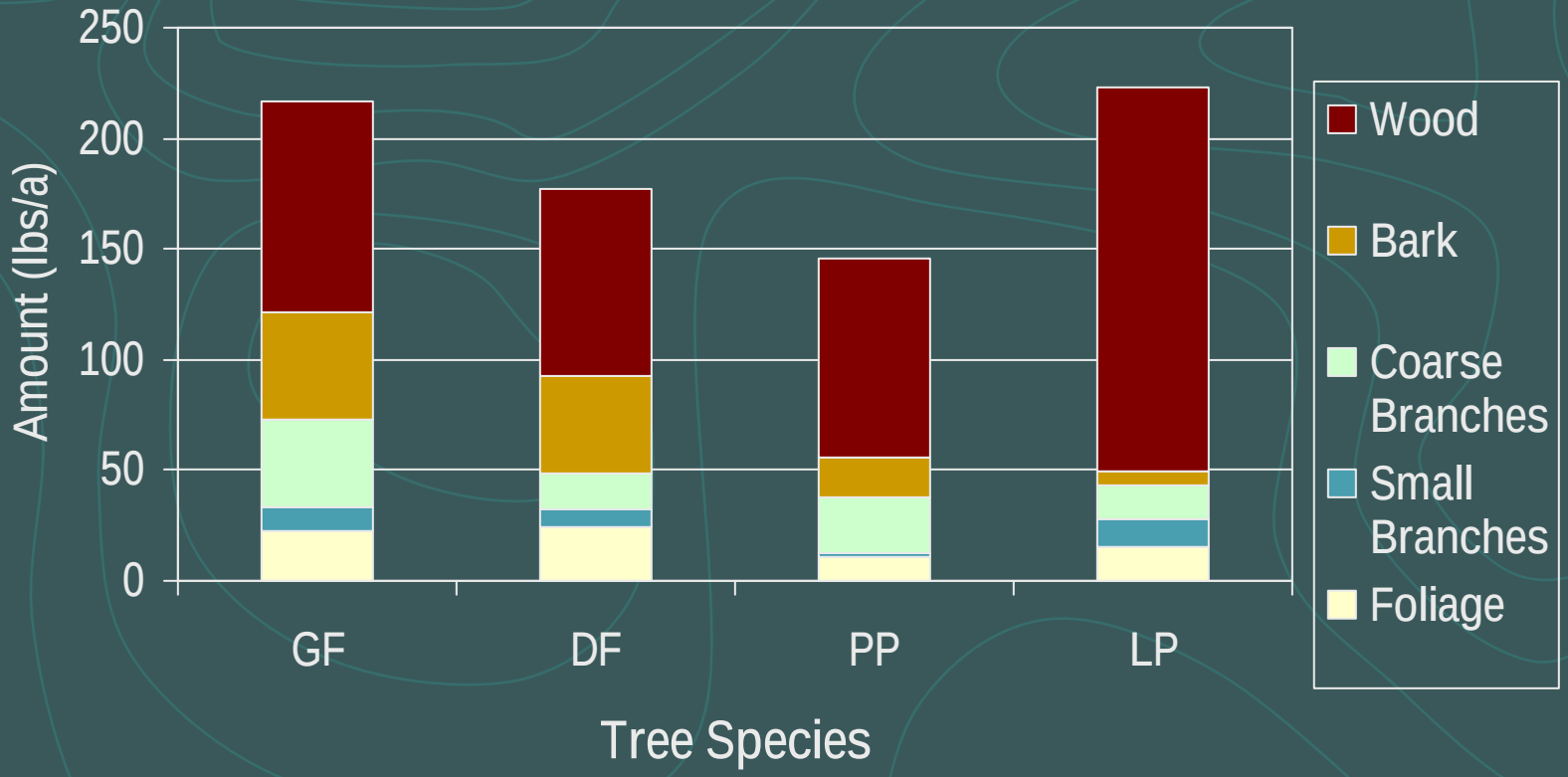
Calcium content of overstory, forest floor and soil



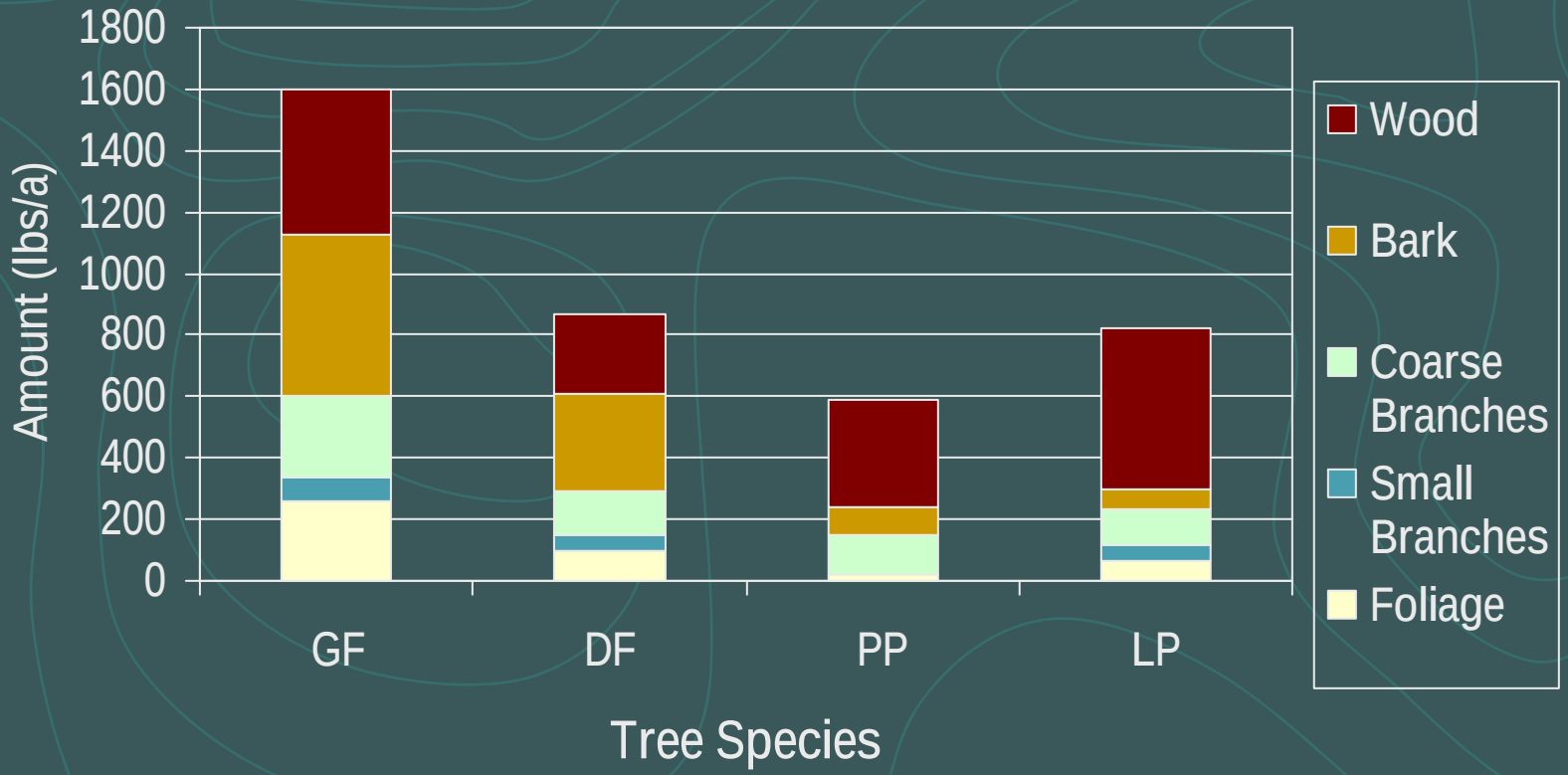
Potassium content of overstory, forest floor and soil



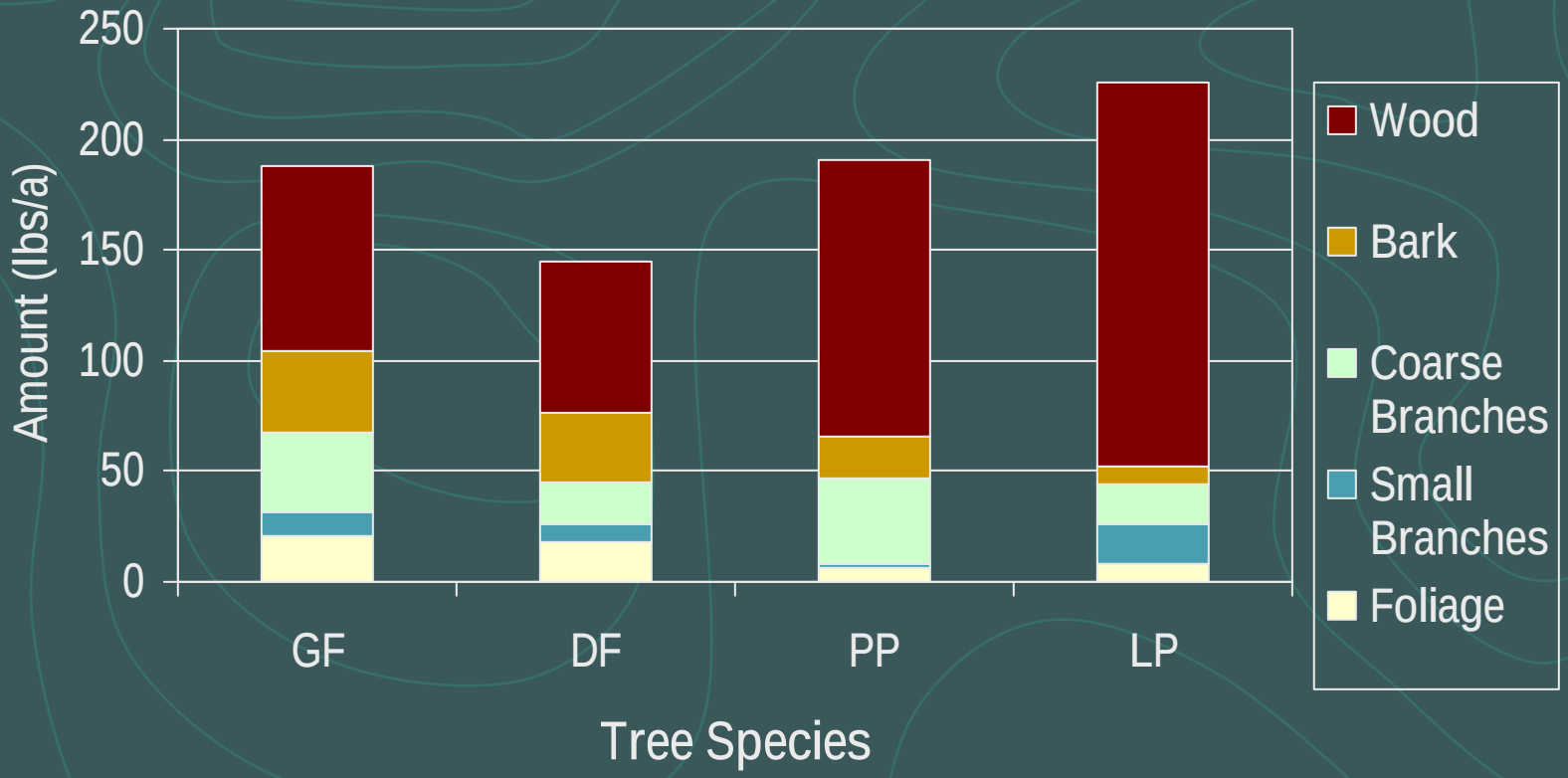
Above-ground Tree Phosphorus by Component



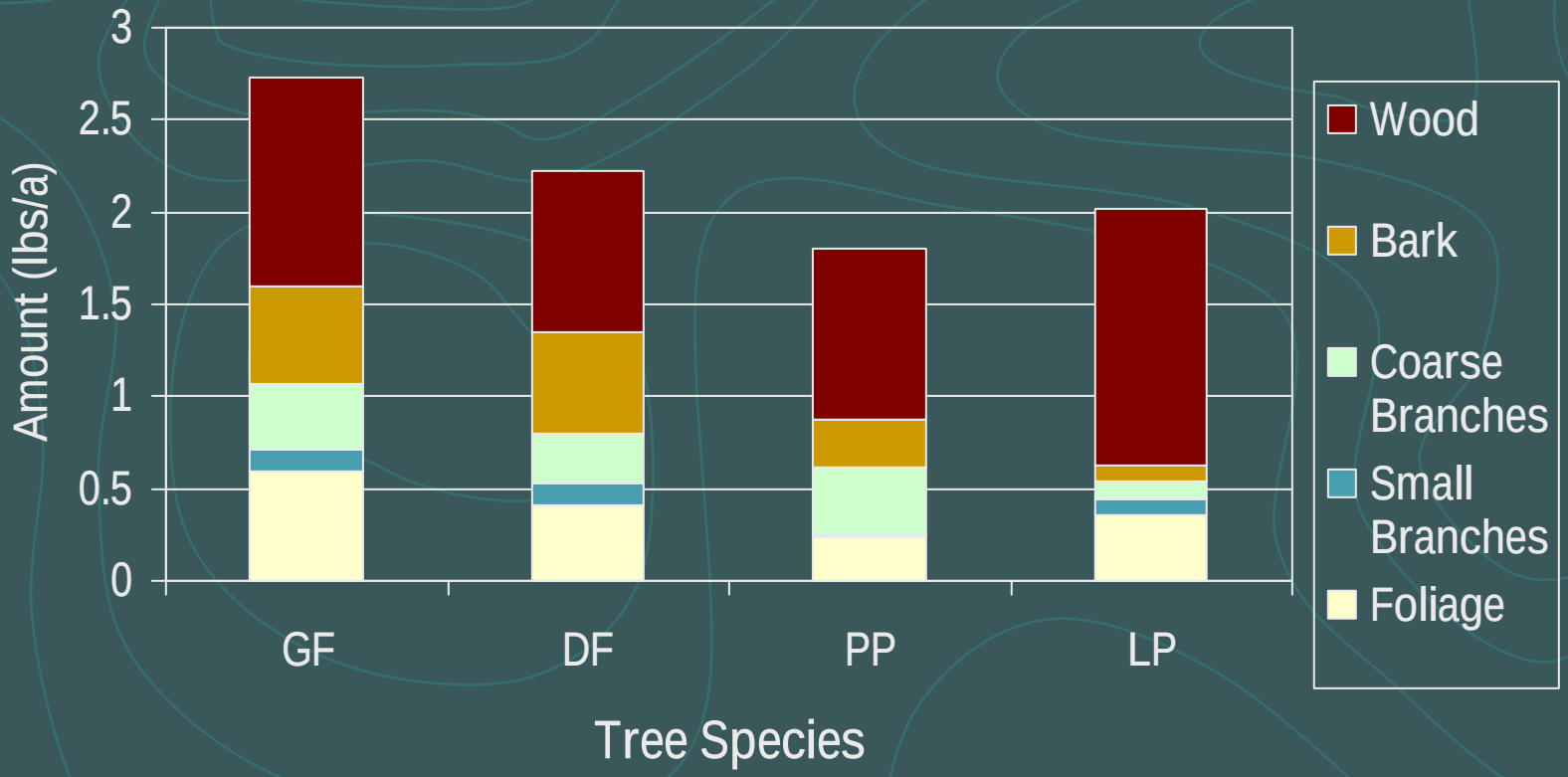
Above-ground Tree Calcium by Component



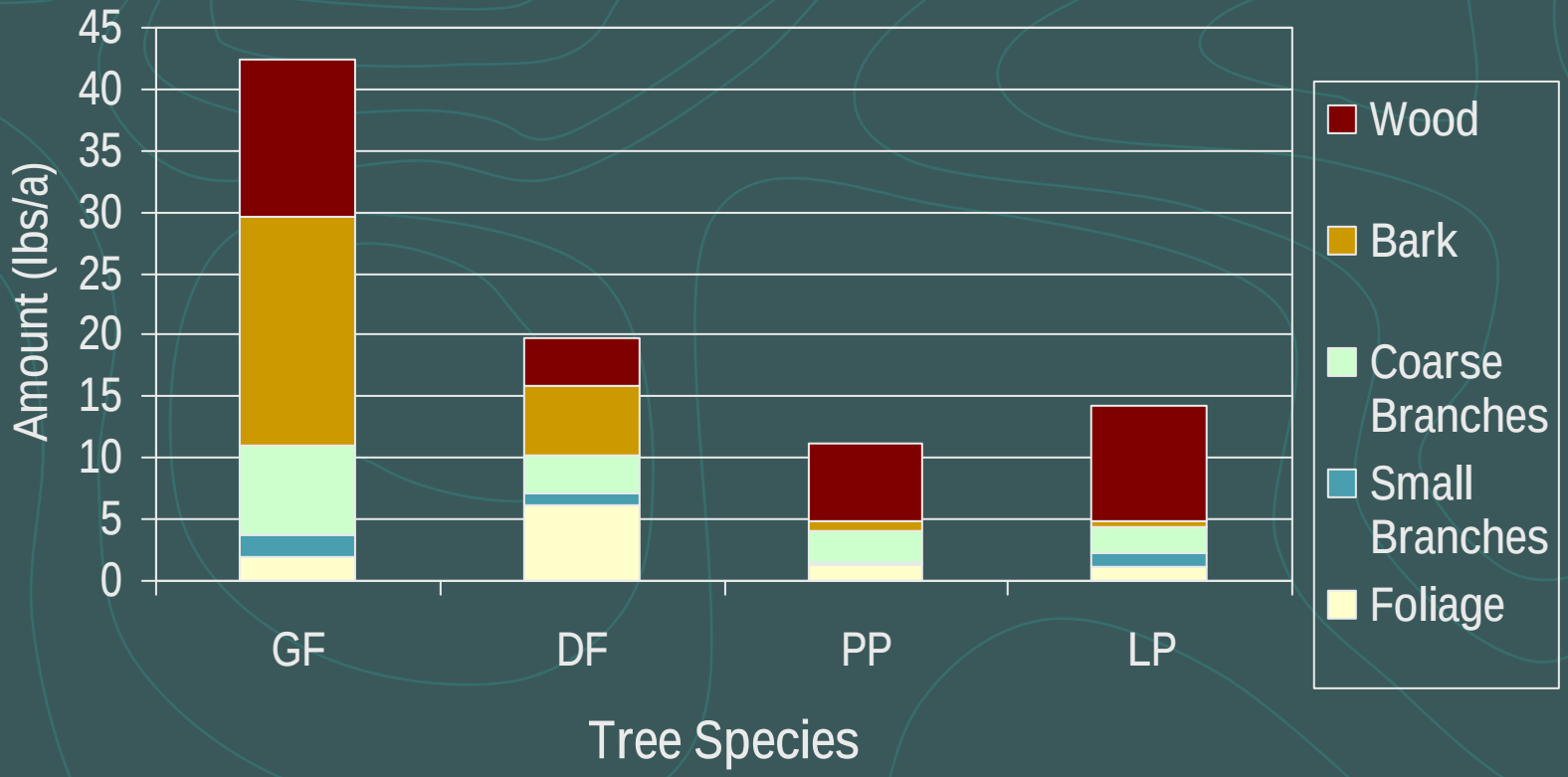
Above-ground Tree Magnesium by Component



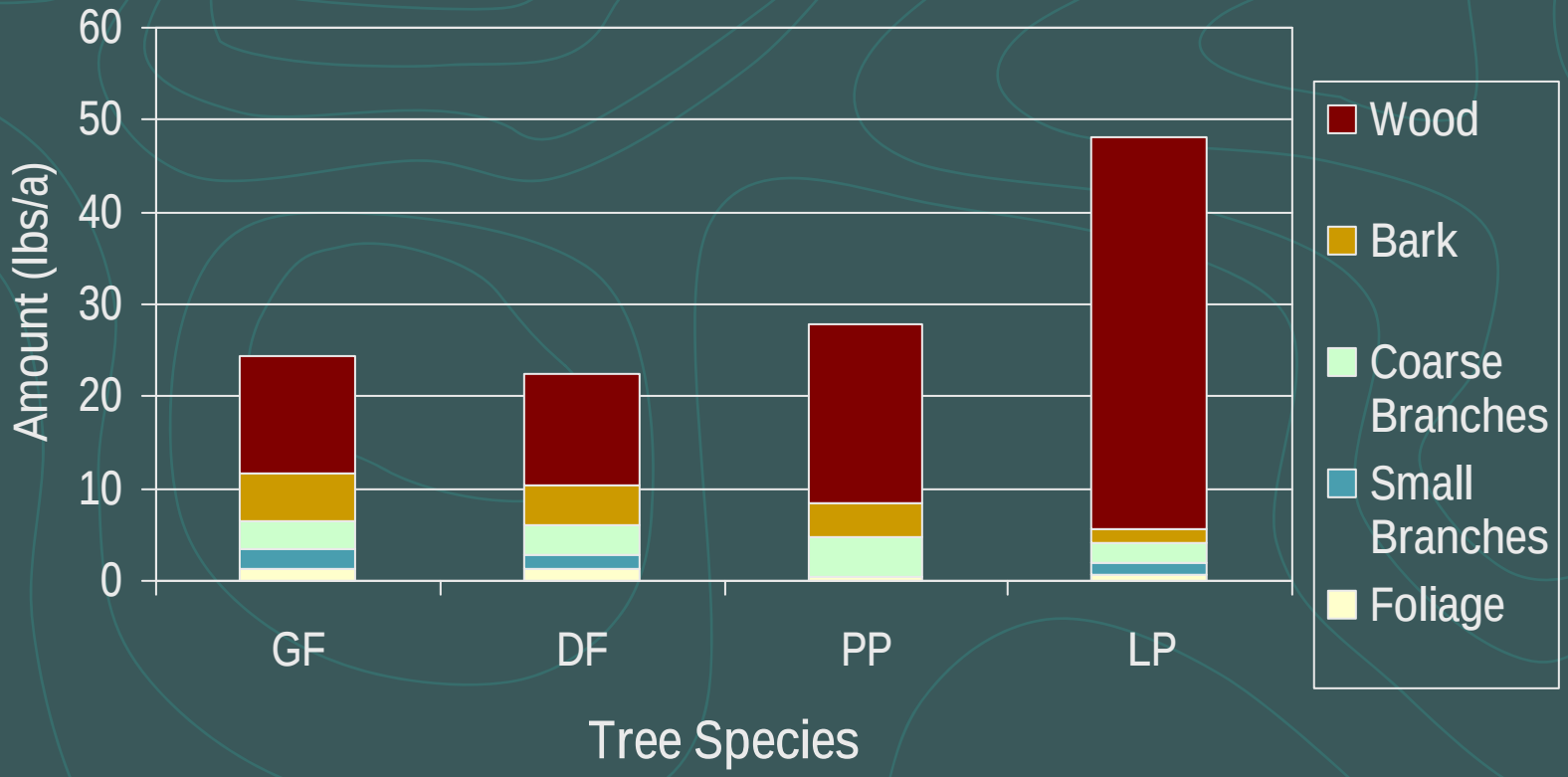
Above-ground Tree Boron by Component



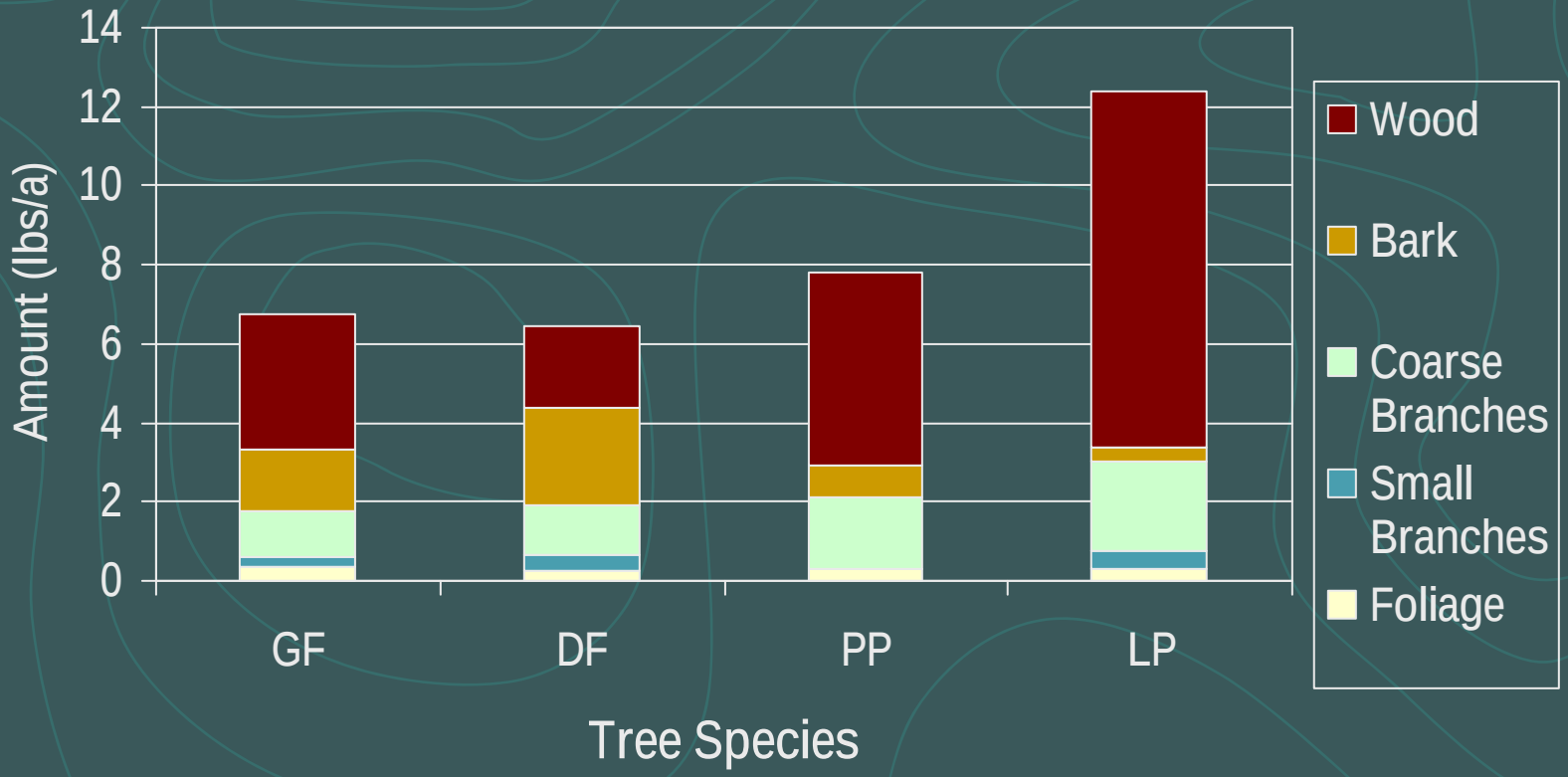
Above-ground Tree Manganese by Component



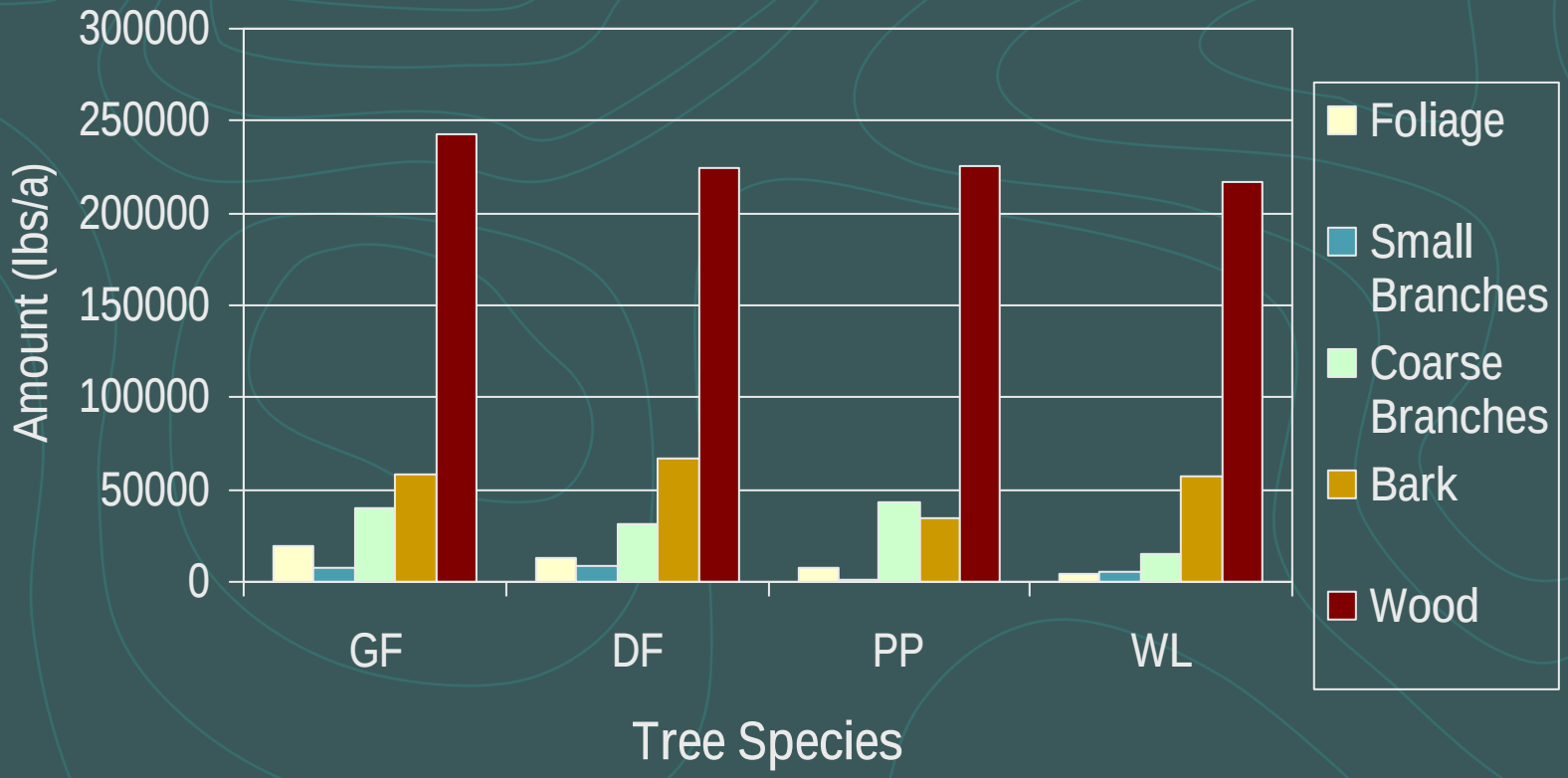
Above-ground Tree Iron by Component



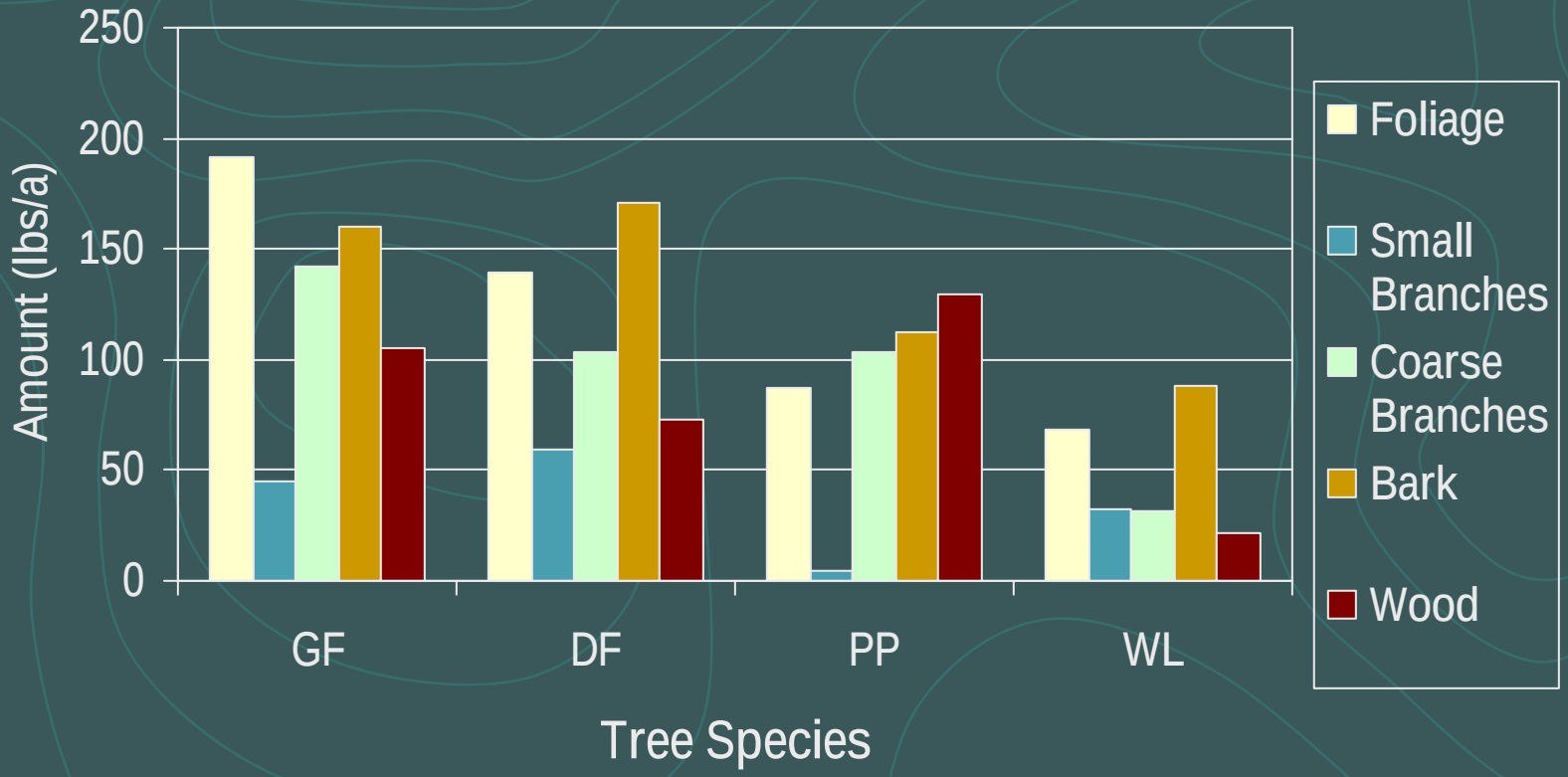
Above-ground Tree Zinc by Component



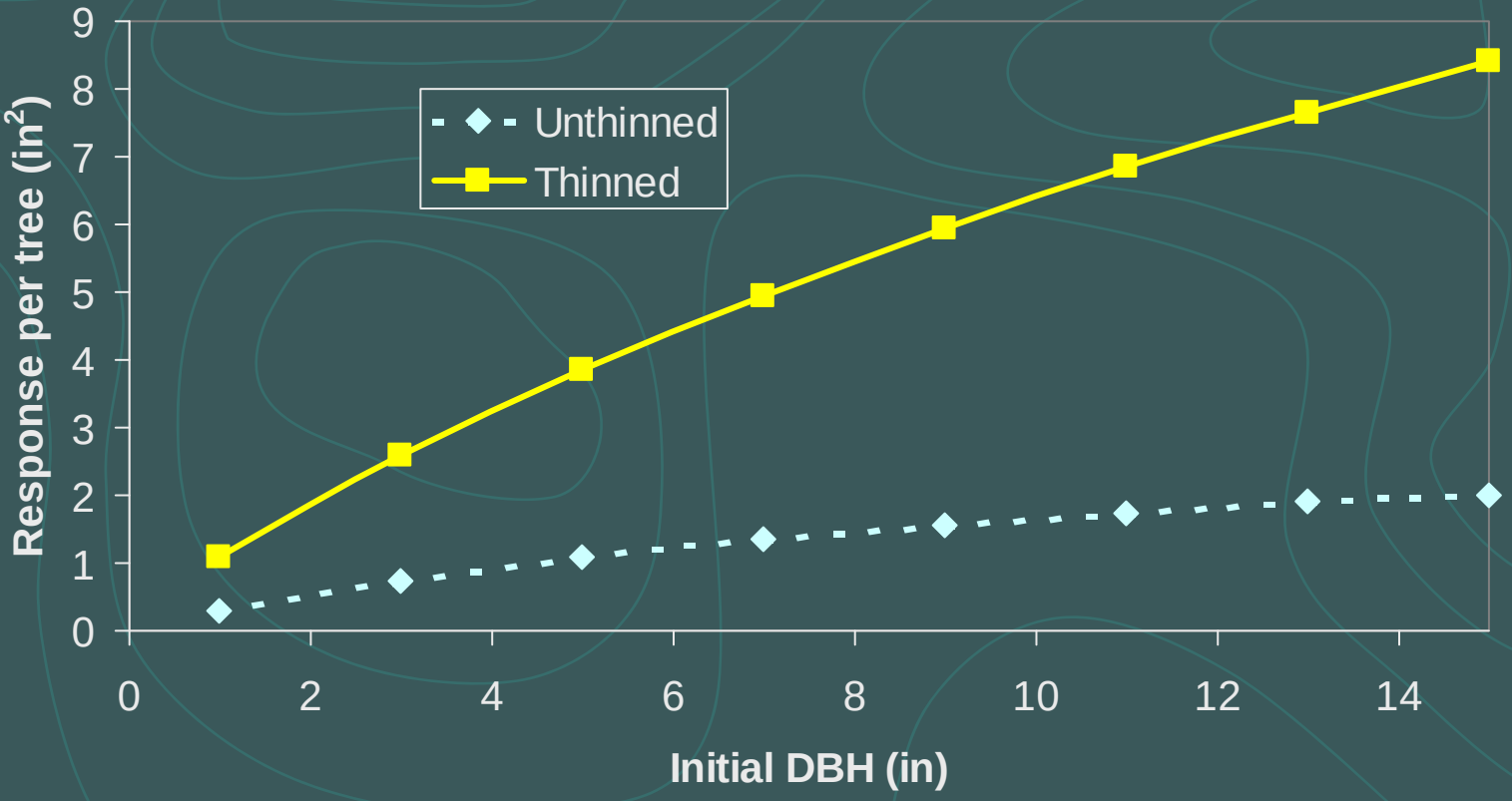
Above-ground Tree Biomass by Component



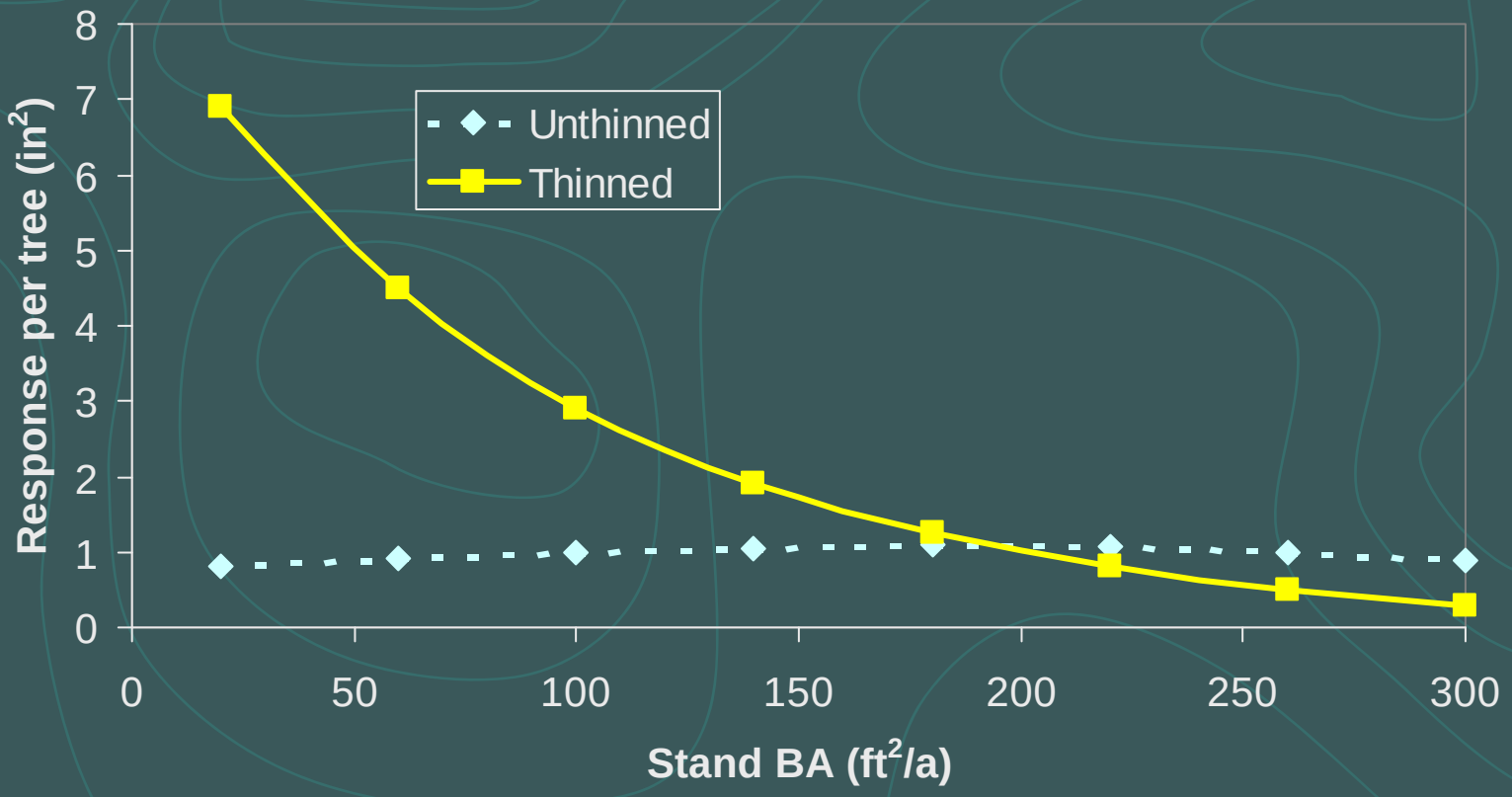
Above-ground Tree Nitrogen by Component



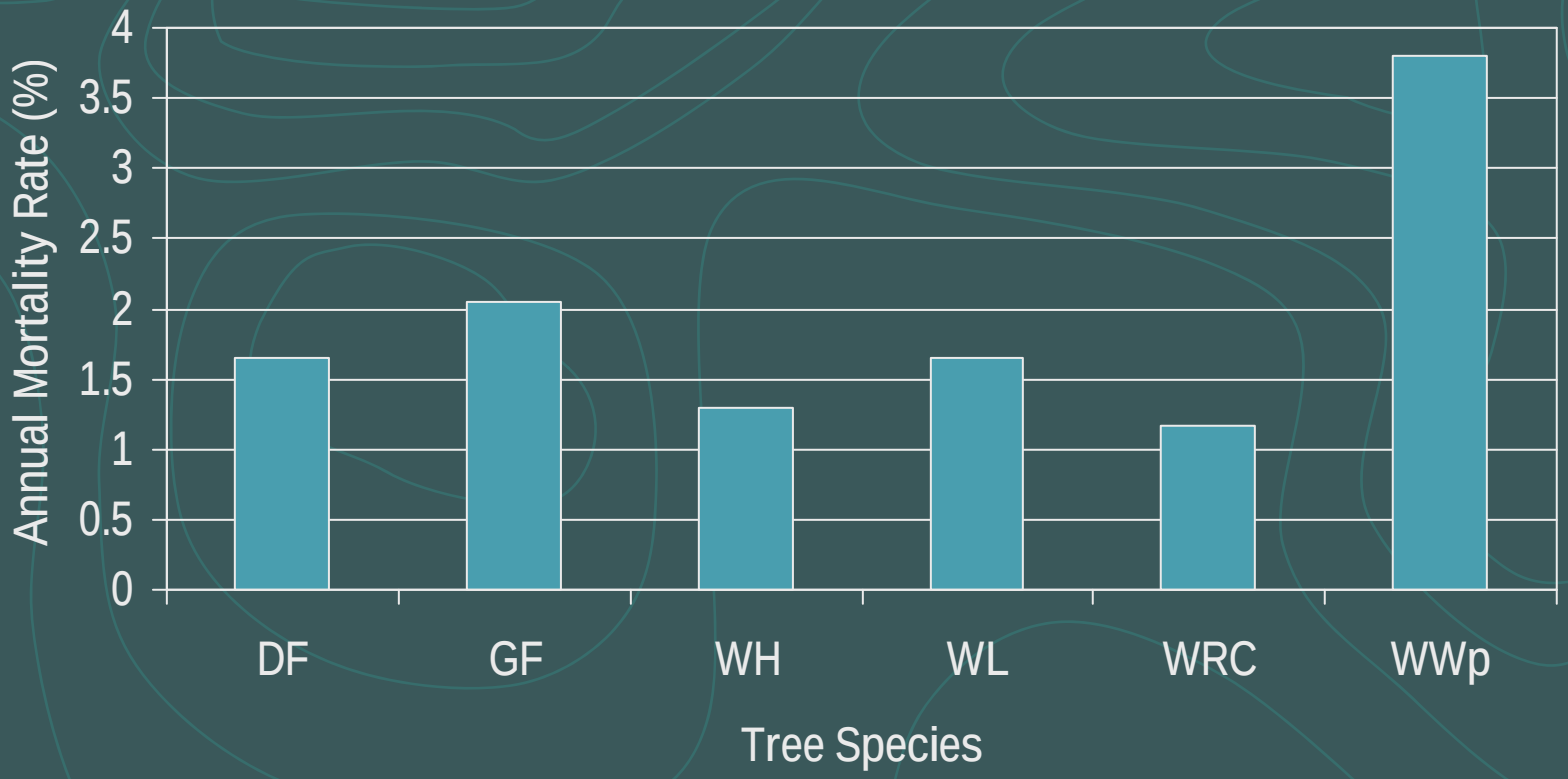
Combined MS-16, ITC, Potlatch data Individual tree response to N fertilizer (Shafii, Moore, and Newberry)



Combined MS-16, ITC, Potlatch data
Individual tree response to N fertilizer



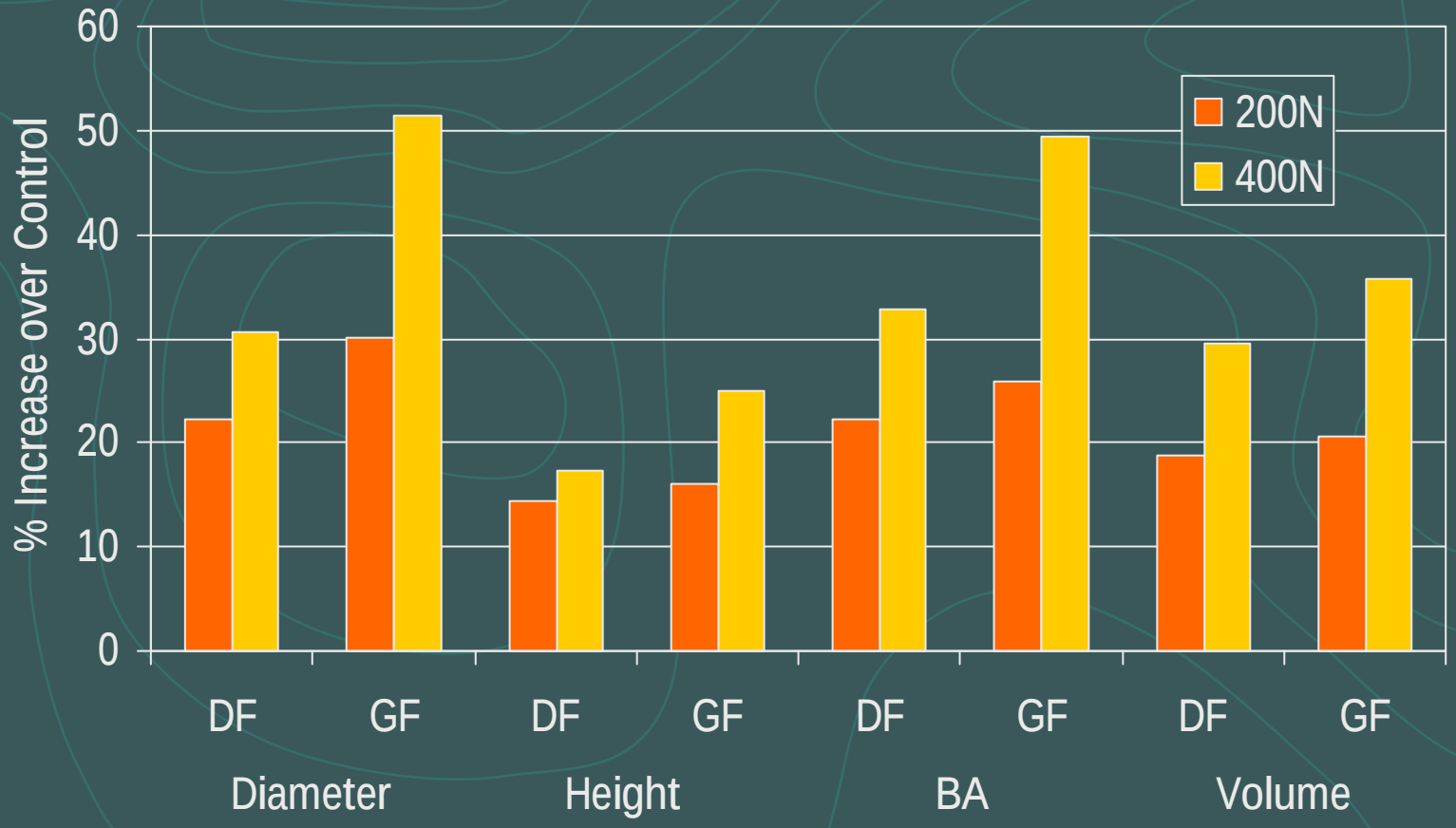
Individual tree mortality modeling



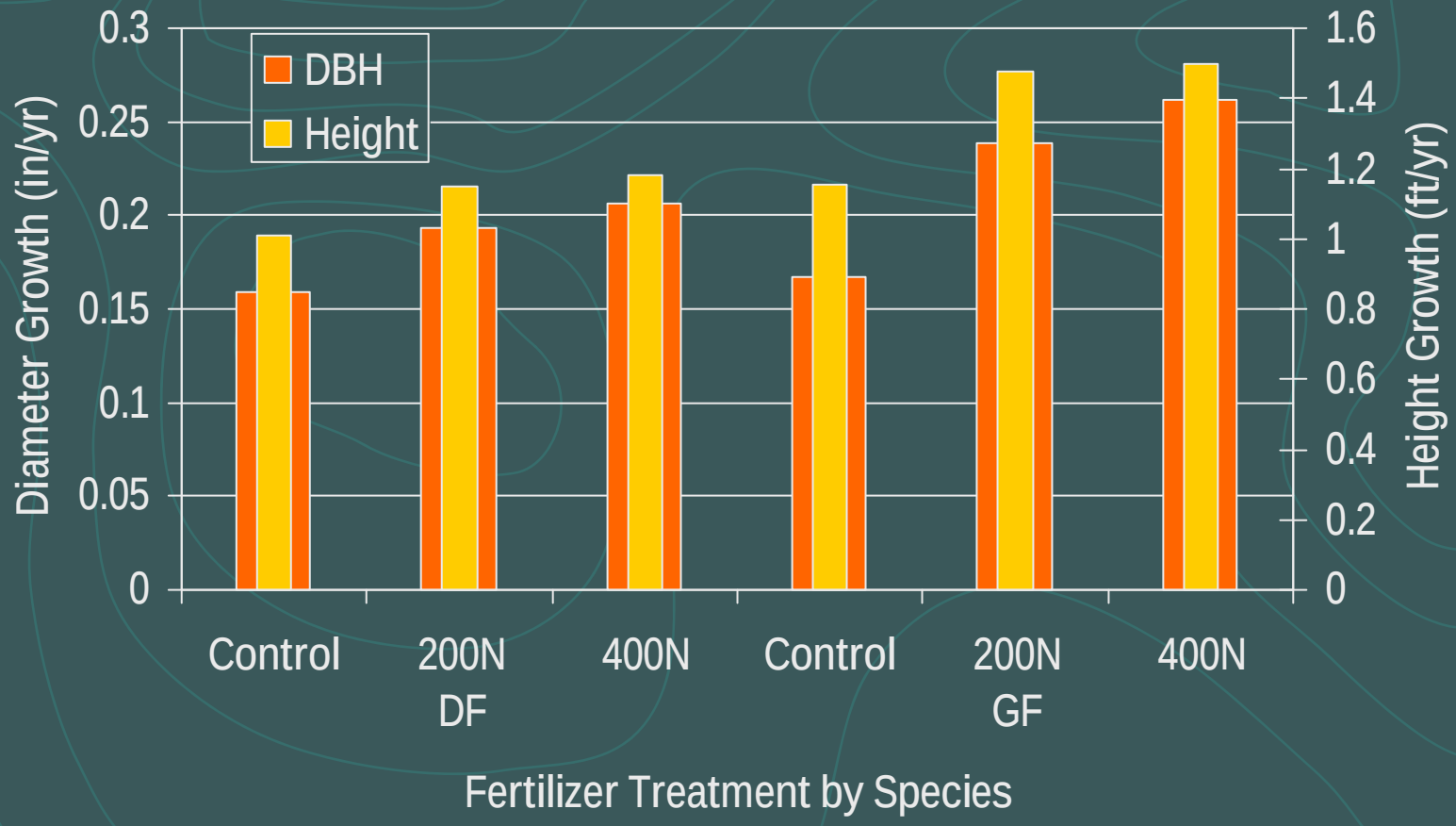
Stand Characteristics of the DF Trials

- DF-dominant stands with 80% in DF by BA
- Fully stocked, late rotation
  - Initial BA: mean=156, min=92, max=251
- GF is usually in subordinate positions
  - DF: average DBH=10.7, average Height=68
  - GF: average DBH=7.9, average Height=58

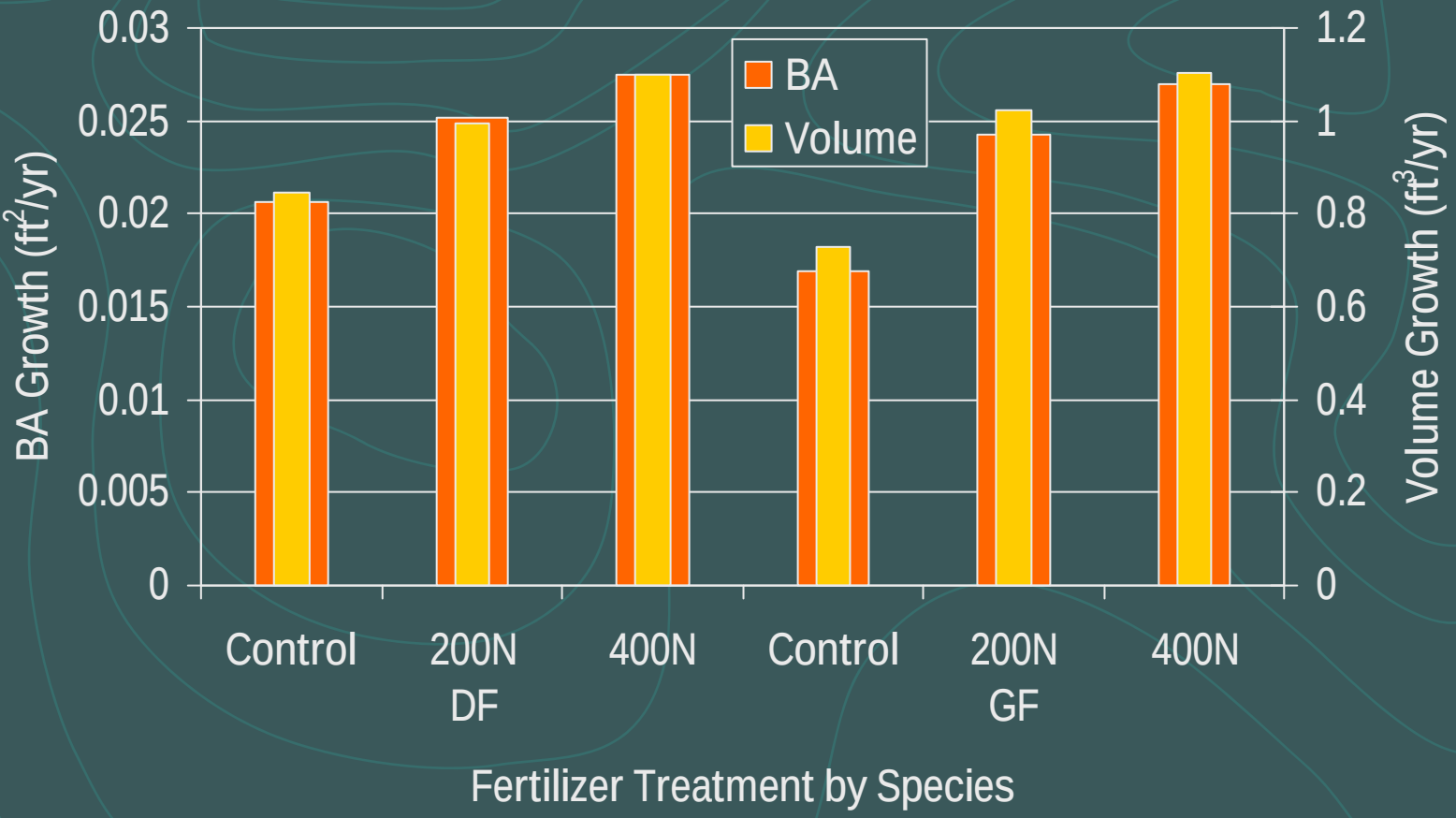
6-year Results from the DF Trials
Relative Response to N Fertilization



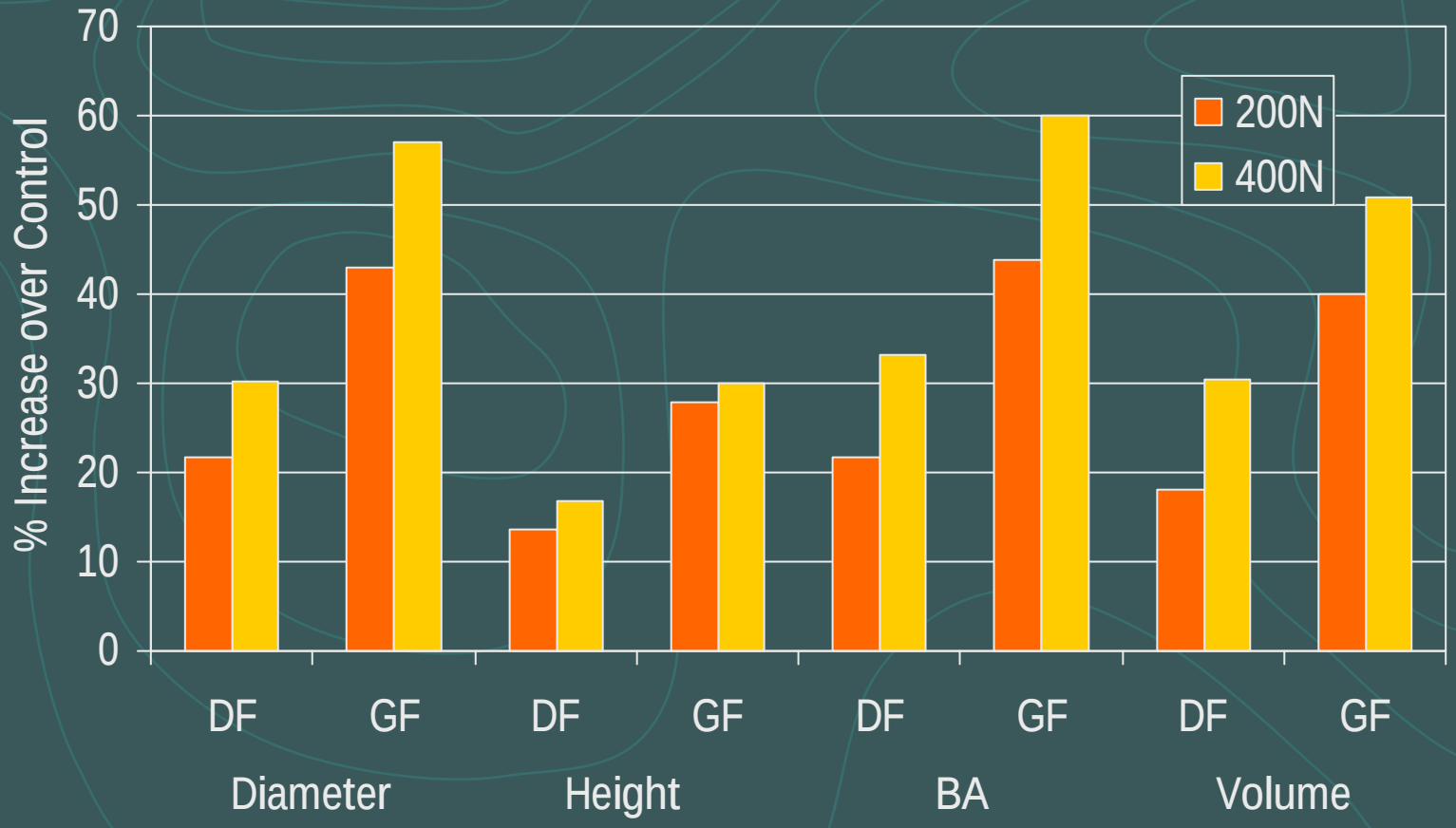
6-year Results from the DF Trials
DBH and Height Response to N



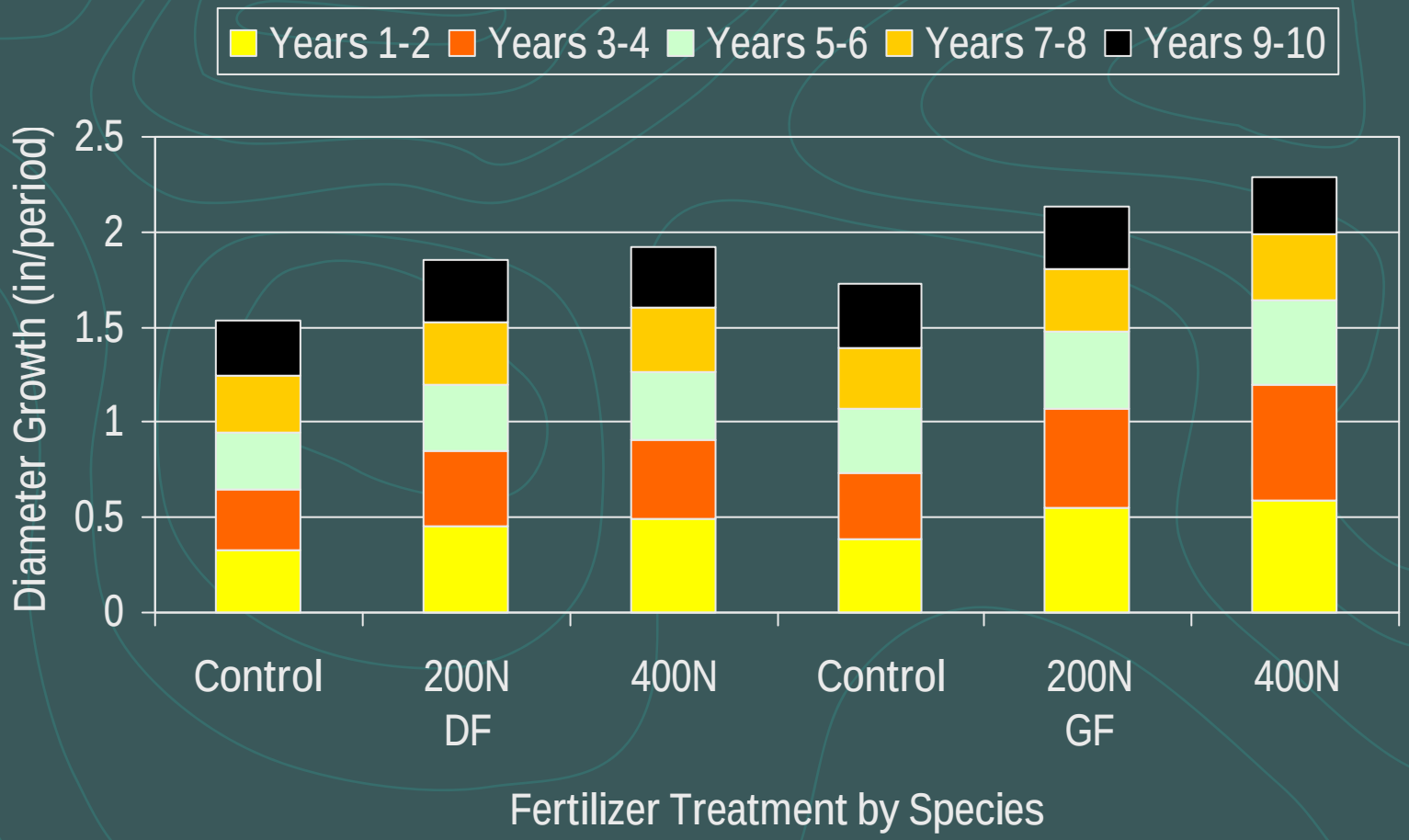
6-year Results from the DF Trials
BA and Volume Response to N



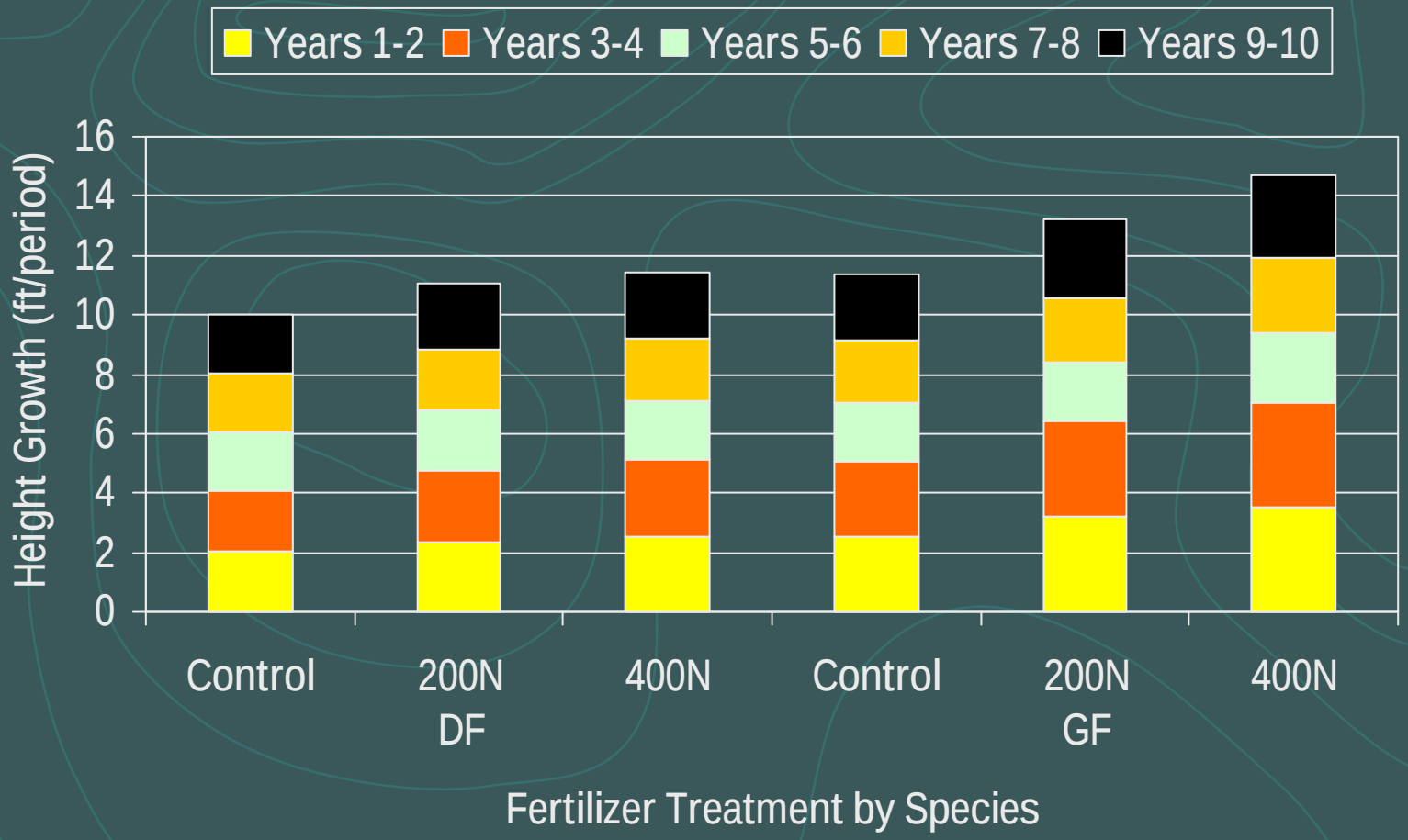
6-year Results from the DF Trials
Relative Response to N Fertilization



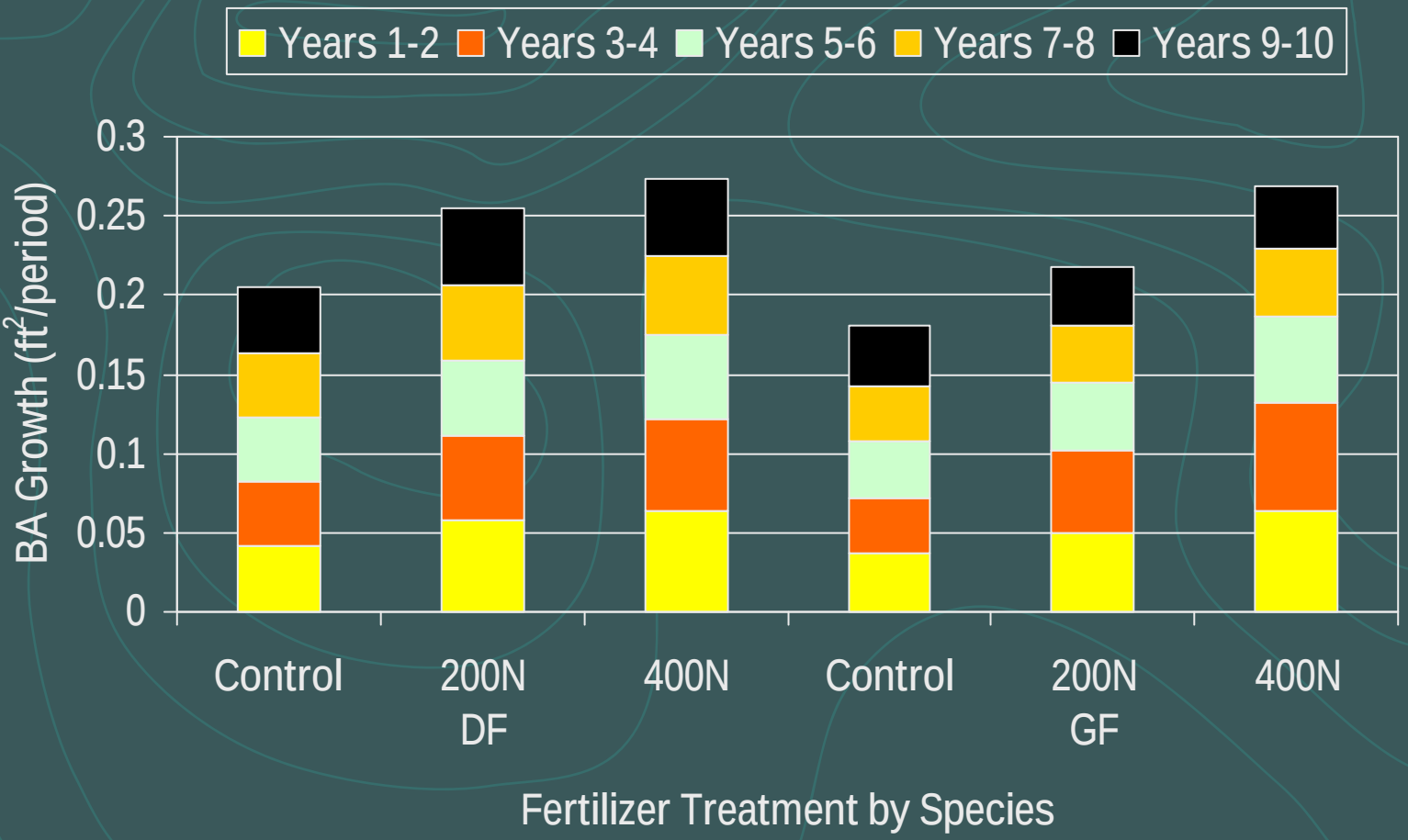
10-year Results from the DF Trials
Periodic Diameter Growth



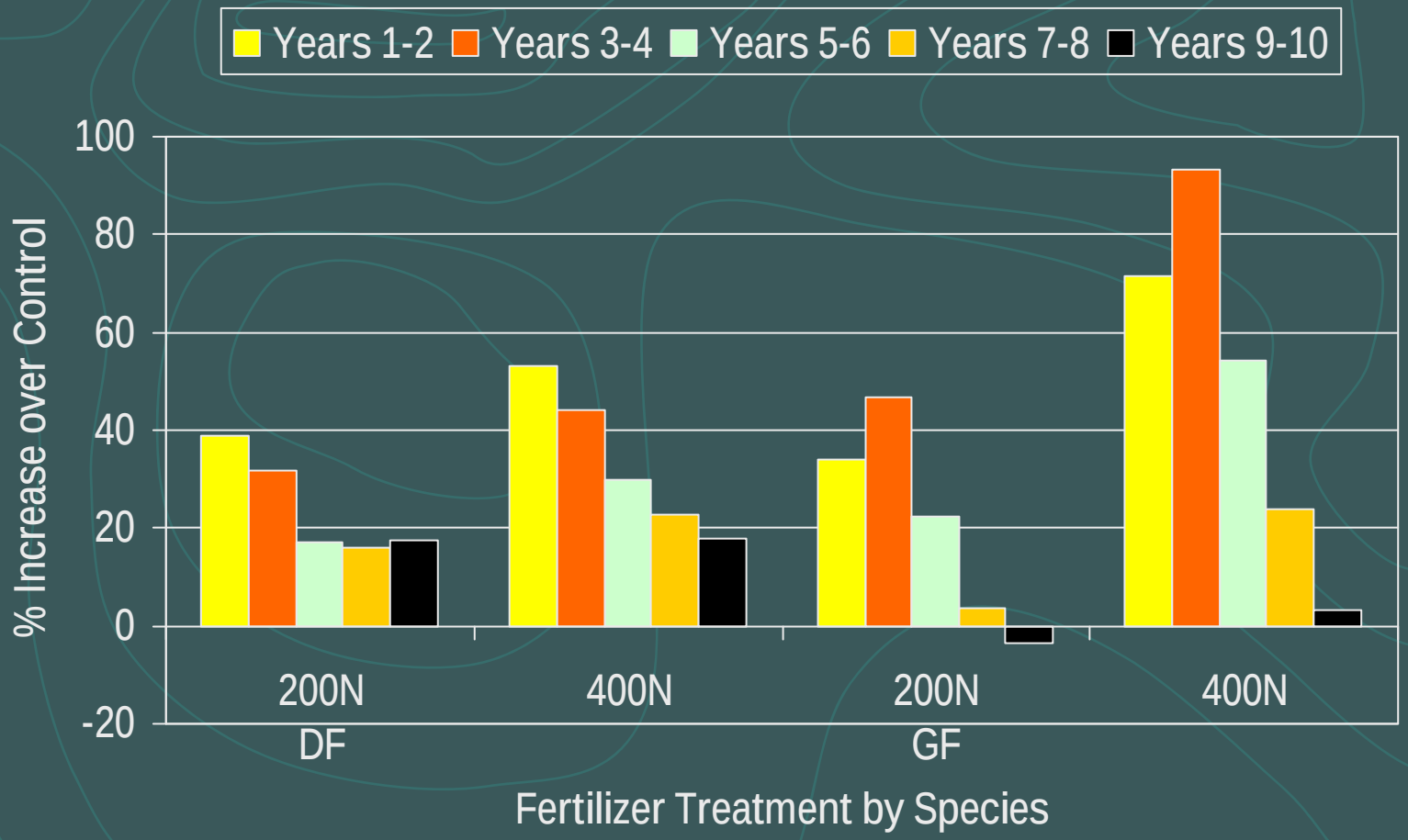
10-year Results from the DF Trials
Periodic Height Growth



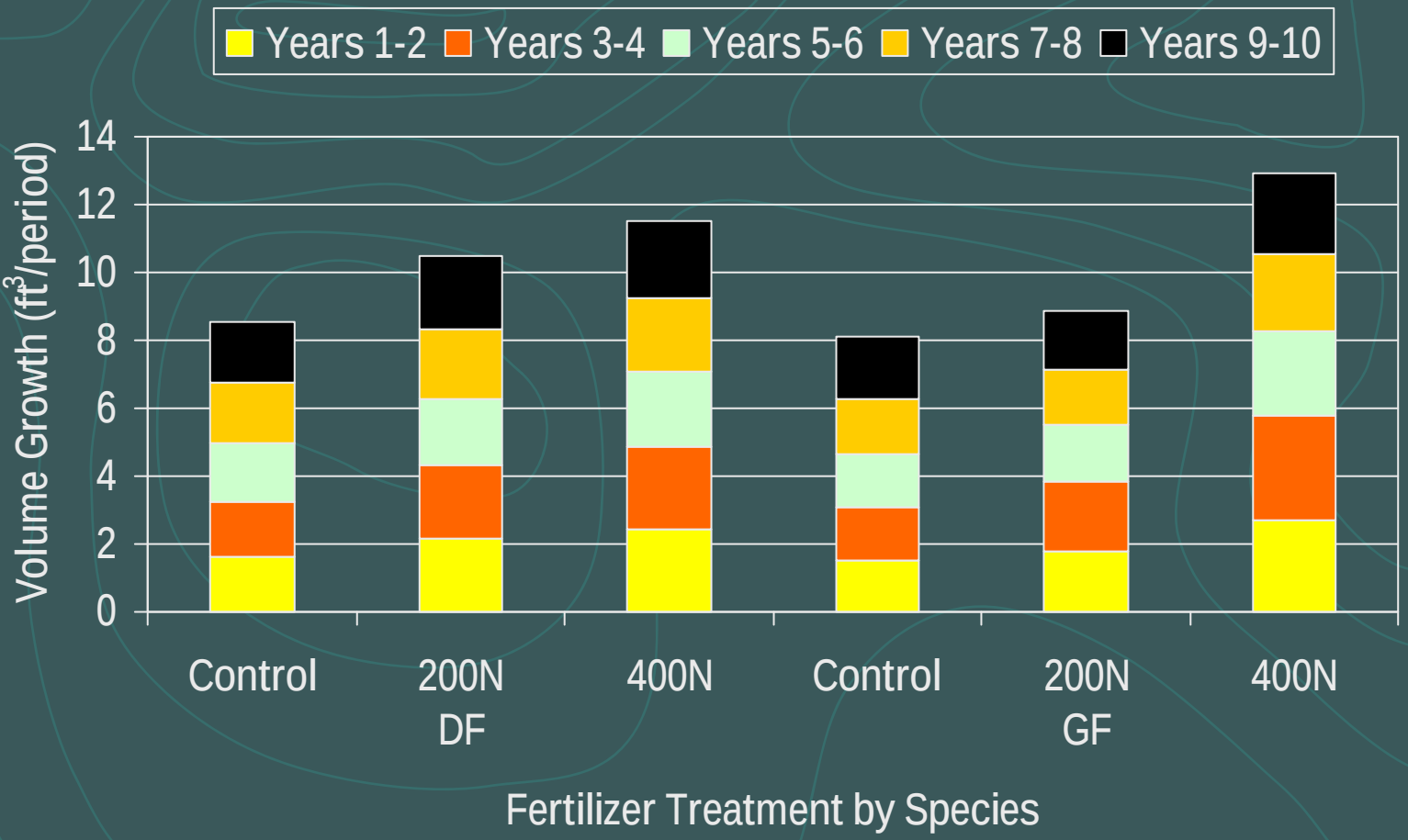
10-year Results from the DF Trials
Periodic BA Growth



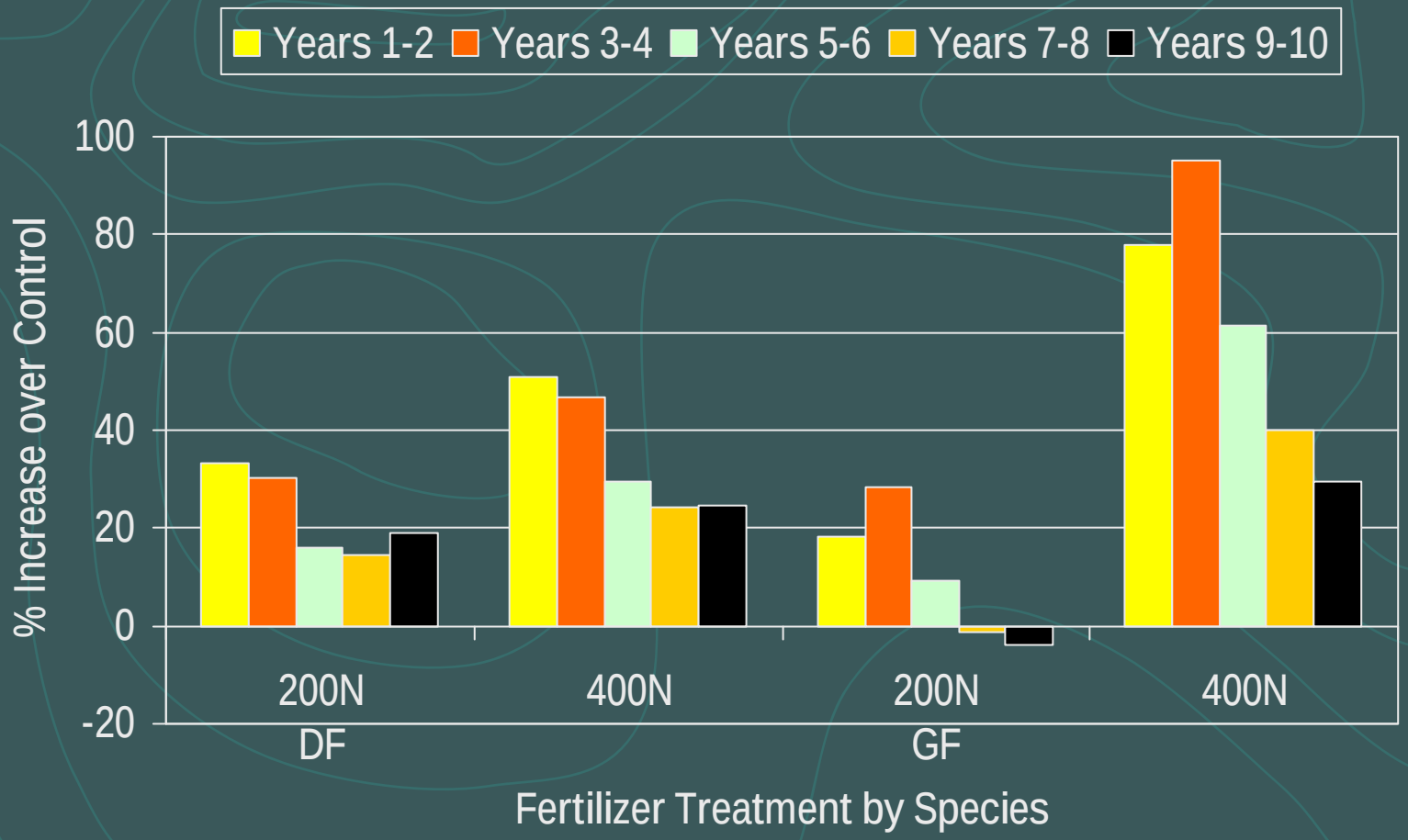
10-year Results from the DF Trials
Relative Periodic BA Growth



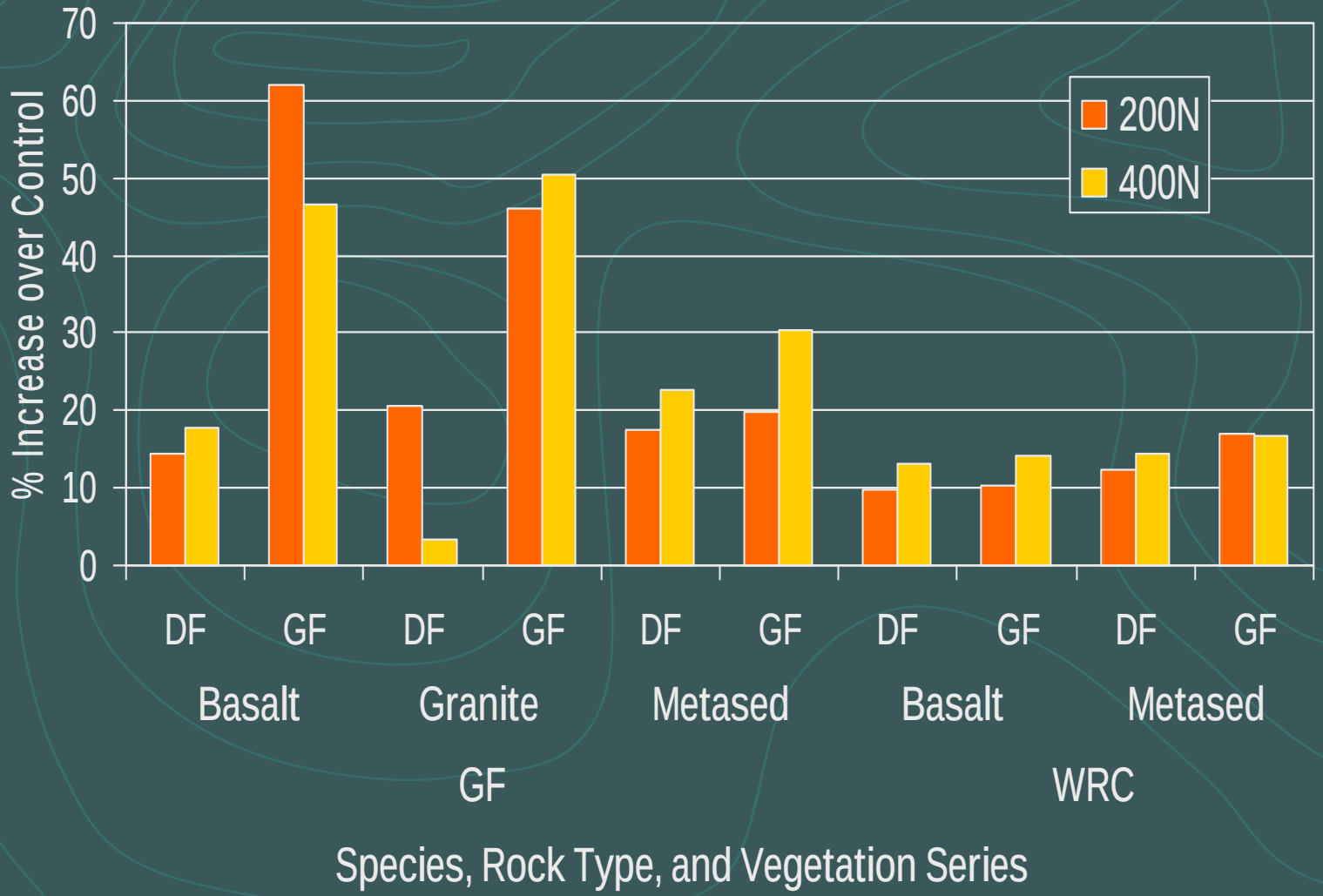
10-year Results from the DF Trials
Periodic Volume Growth



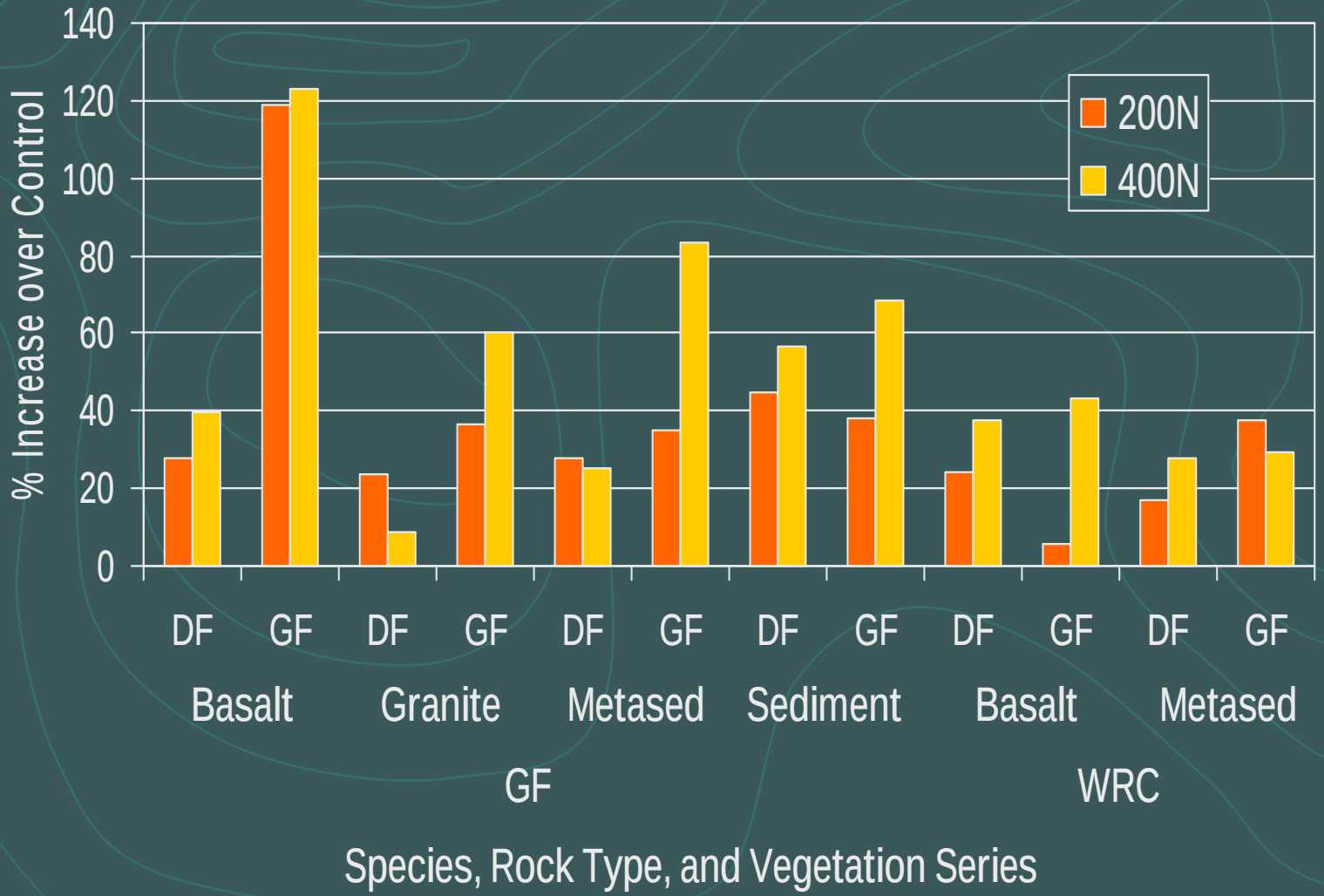
10-year Results from the DF Trials
Relative Periodic Volume Growth



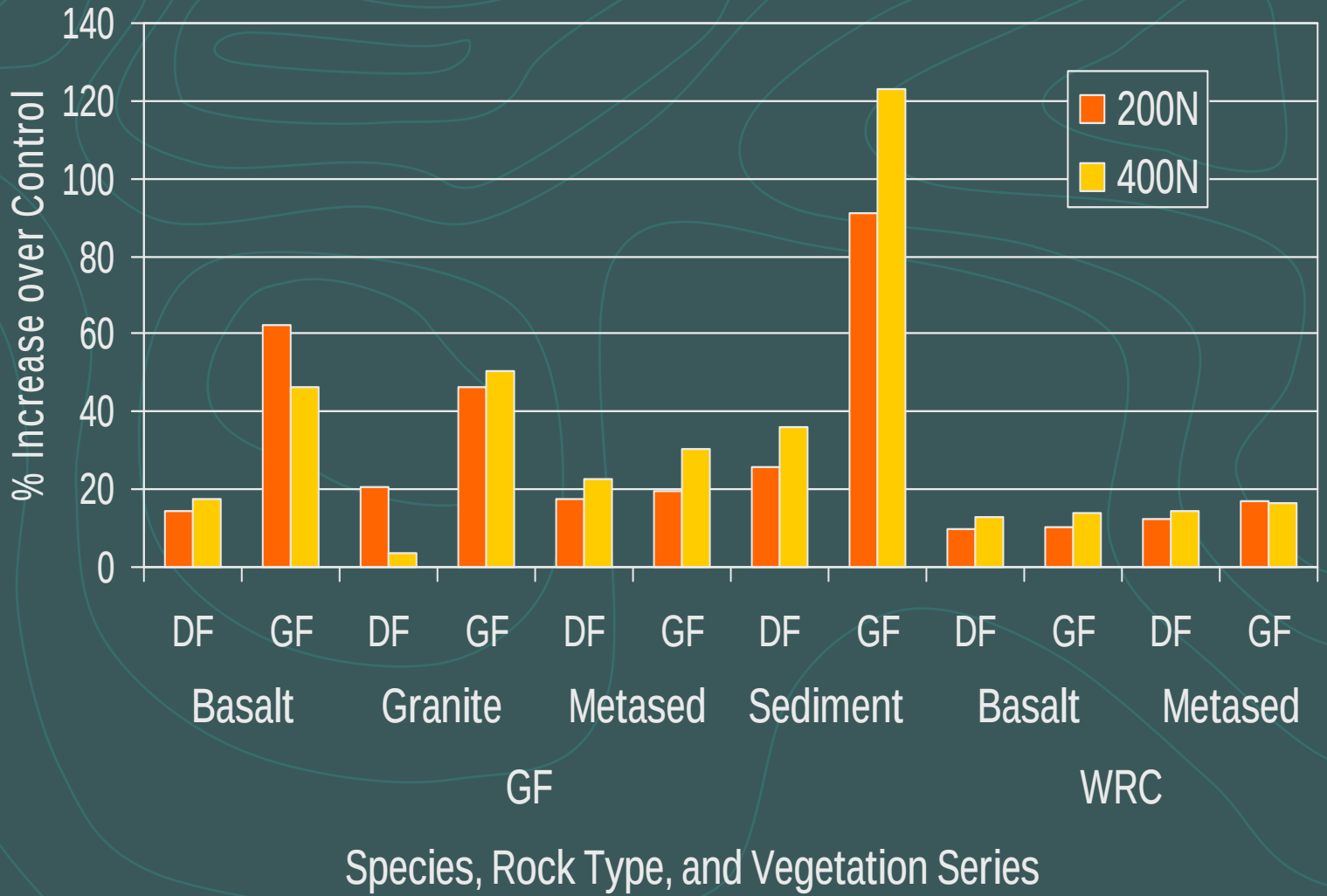
6-year Results from the DF Trials
Height Relative Response to N



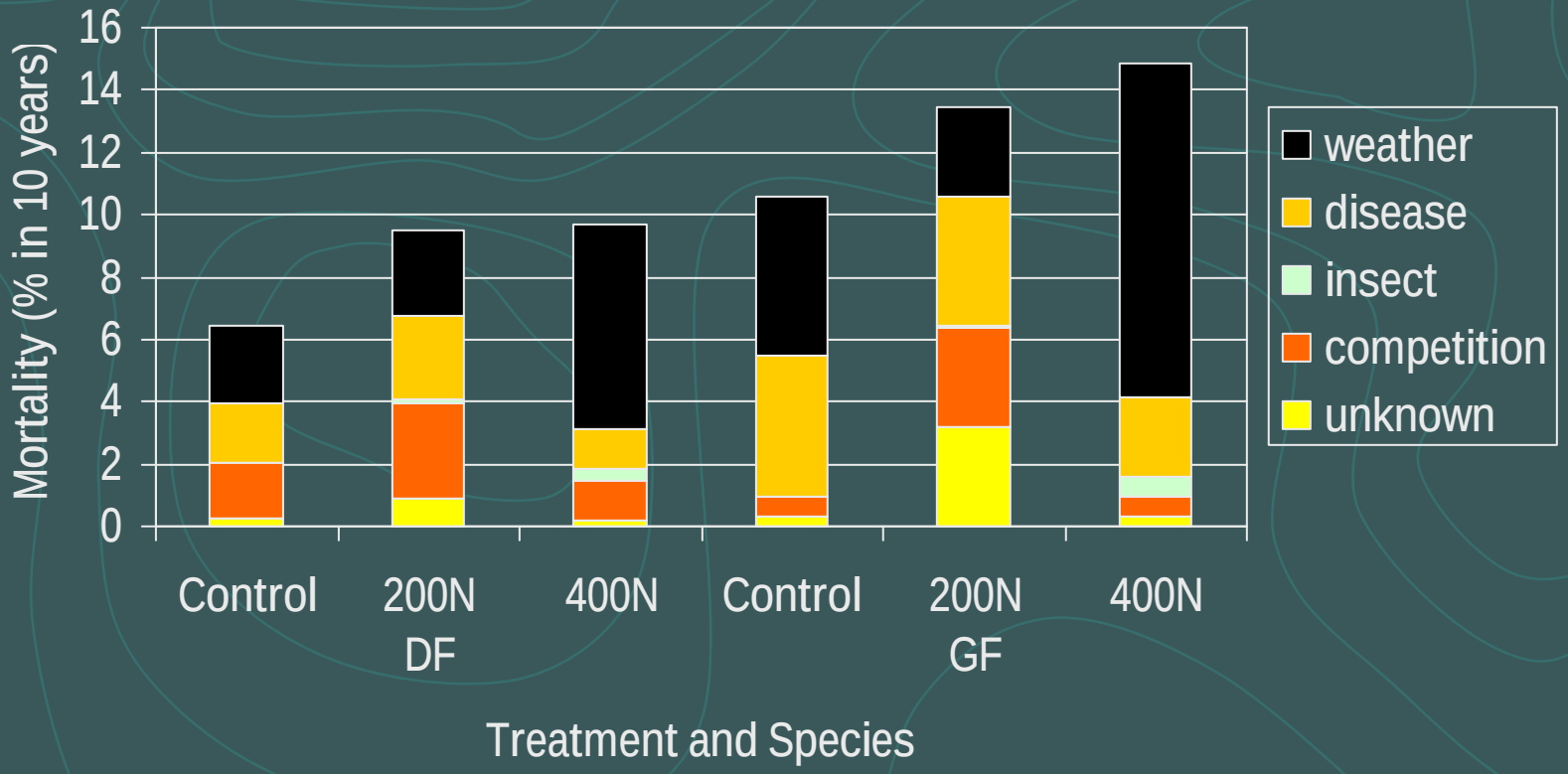
6-year Results from the DF Trials Diameter Relative Response to N



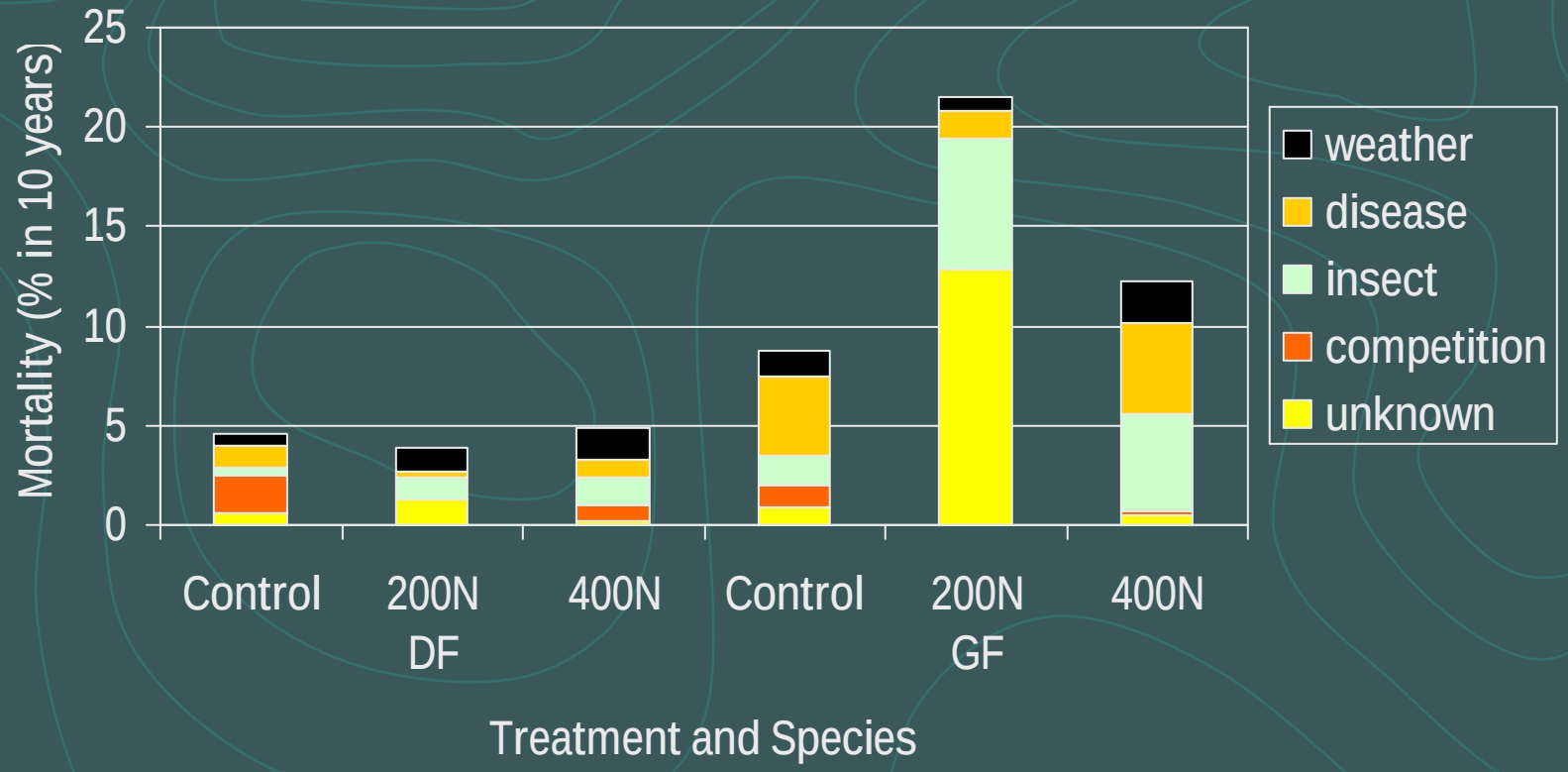
6-year Results from the DF Trials
Height Relative Response to N



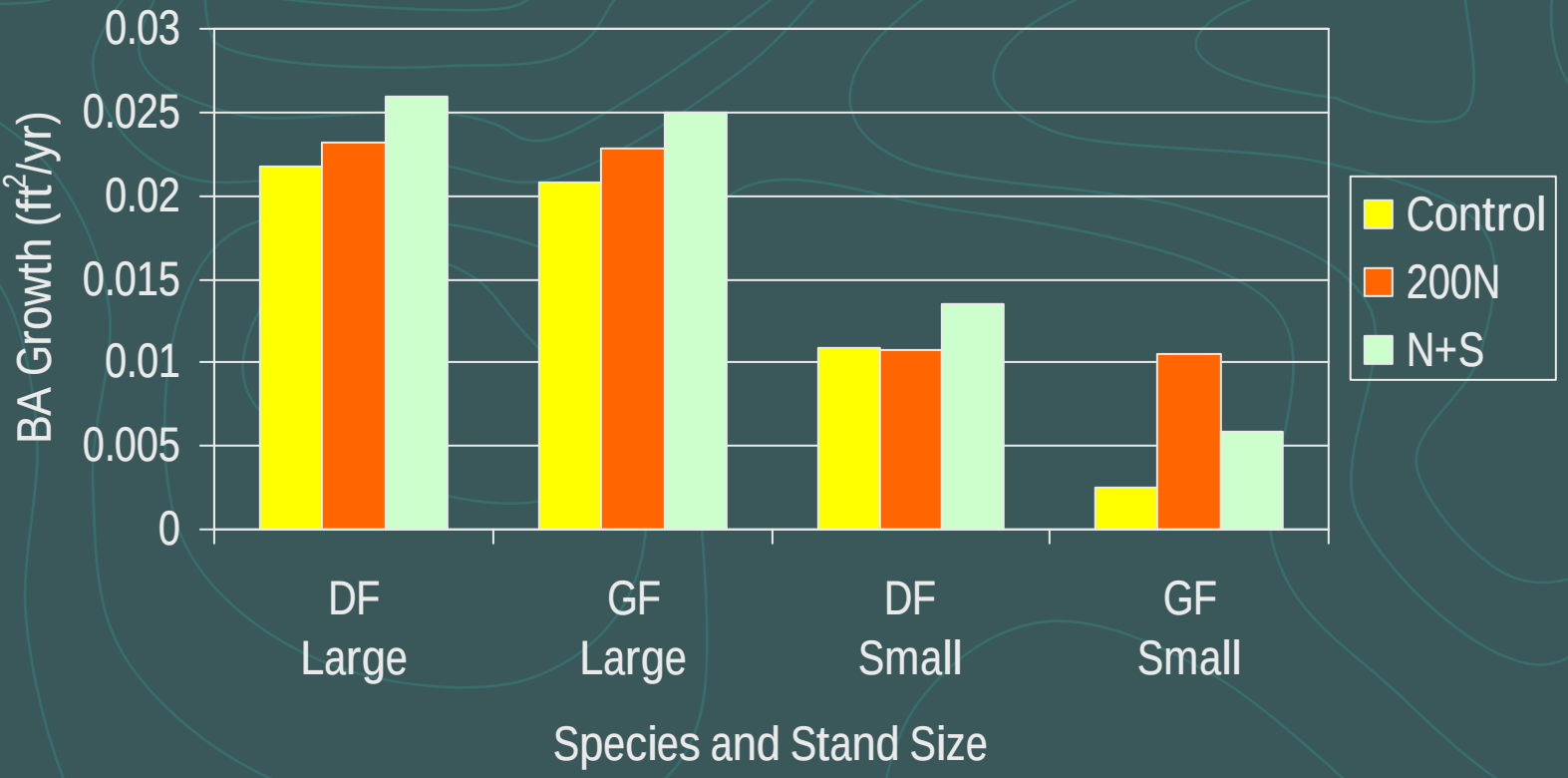
Results from the DF Trials
10-year Mortality by Cause: stems/a



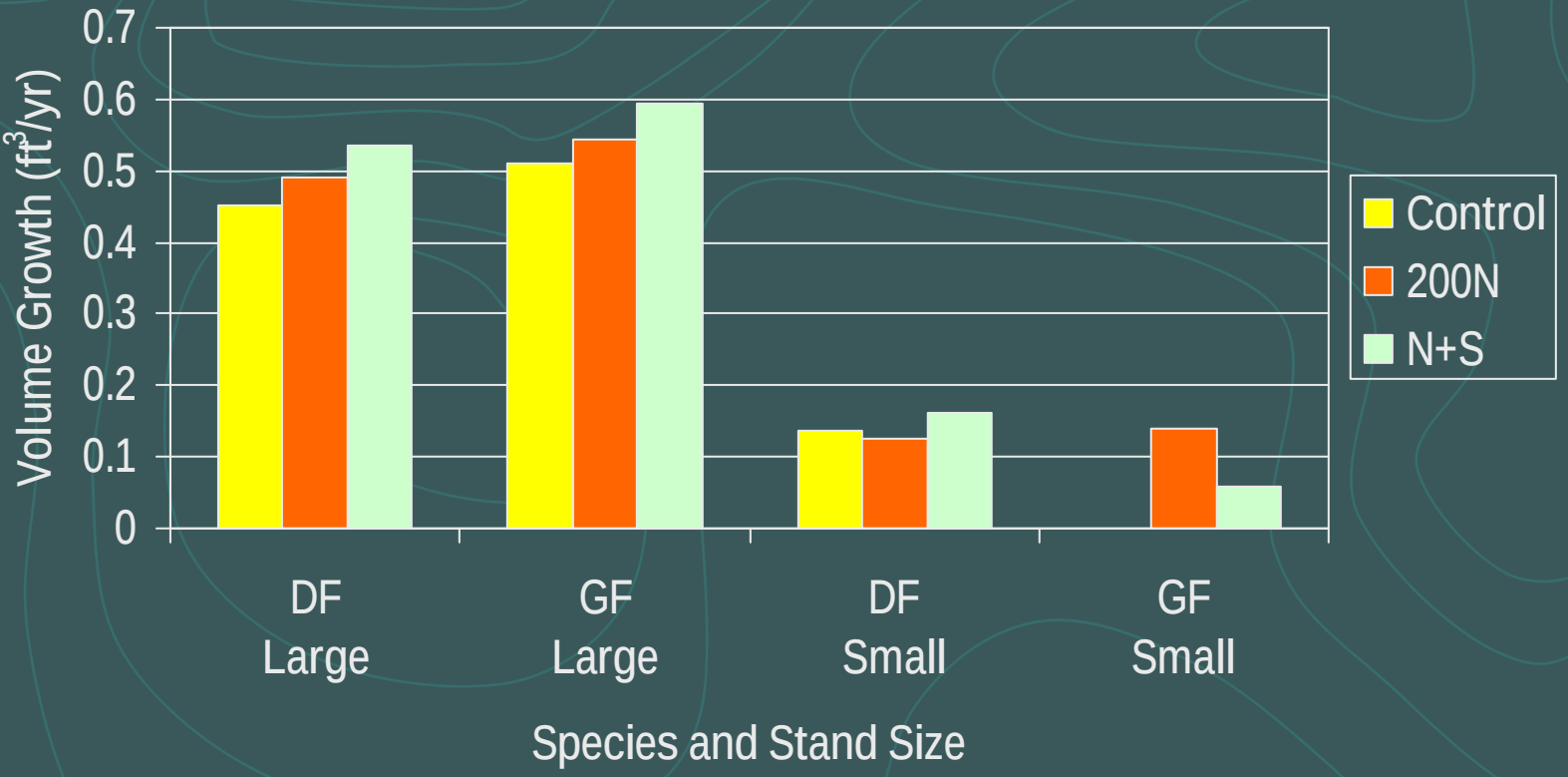
Results from the DF Trials
10-year Mortality by Cause: BA/a



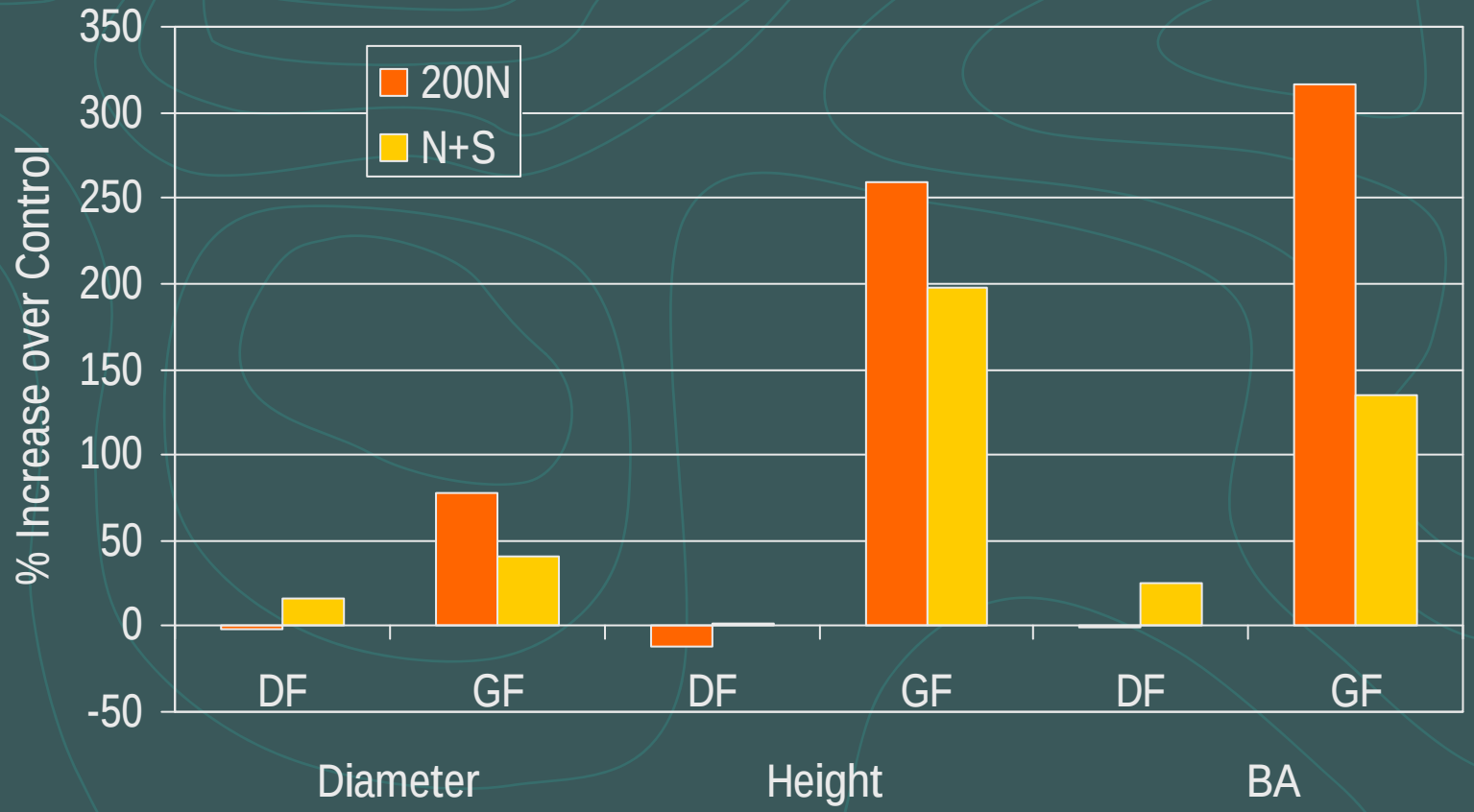
Umatilla Mixed-Conifer Trials
8-year BA Response to N and S



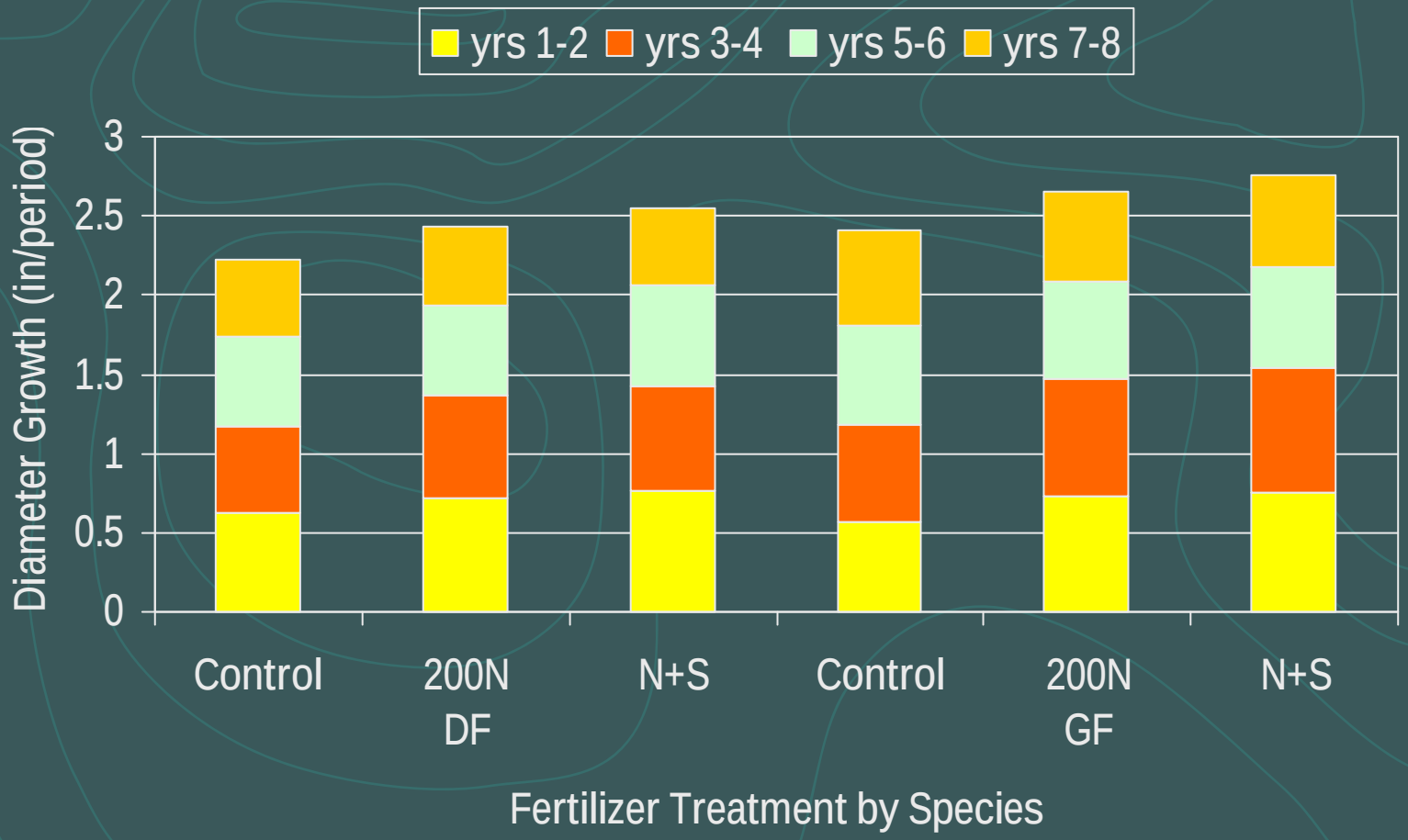
Umatilla Mixed-Conifer Trials
8-year Volume Response to N and S



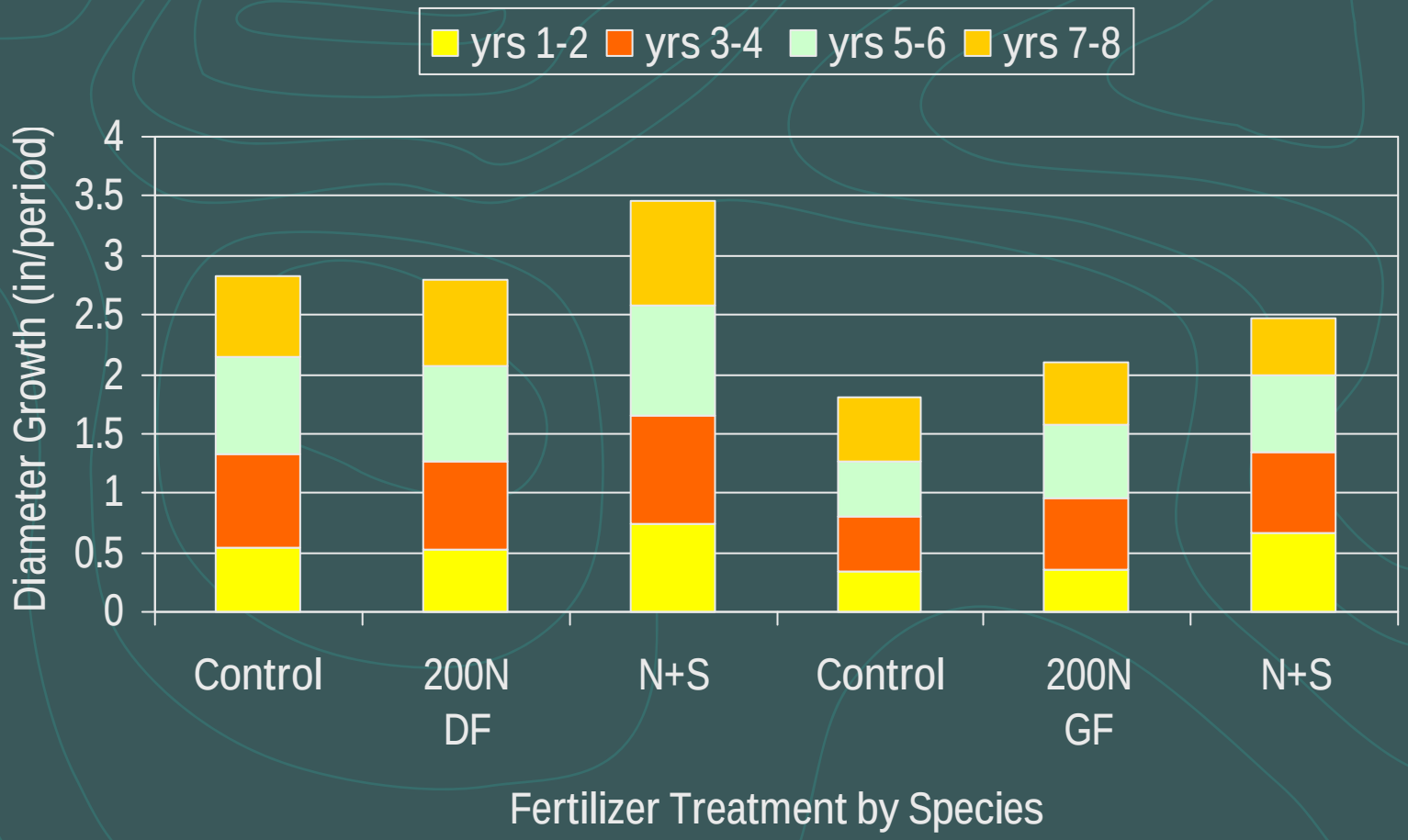
Umatilla Mixed-Conifer Trials
8-year Relative Response to N and S Plantations



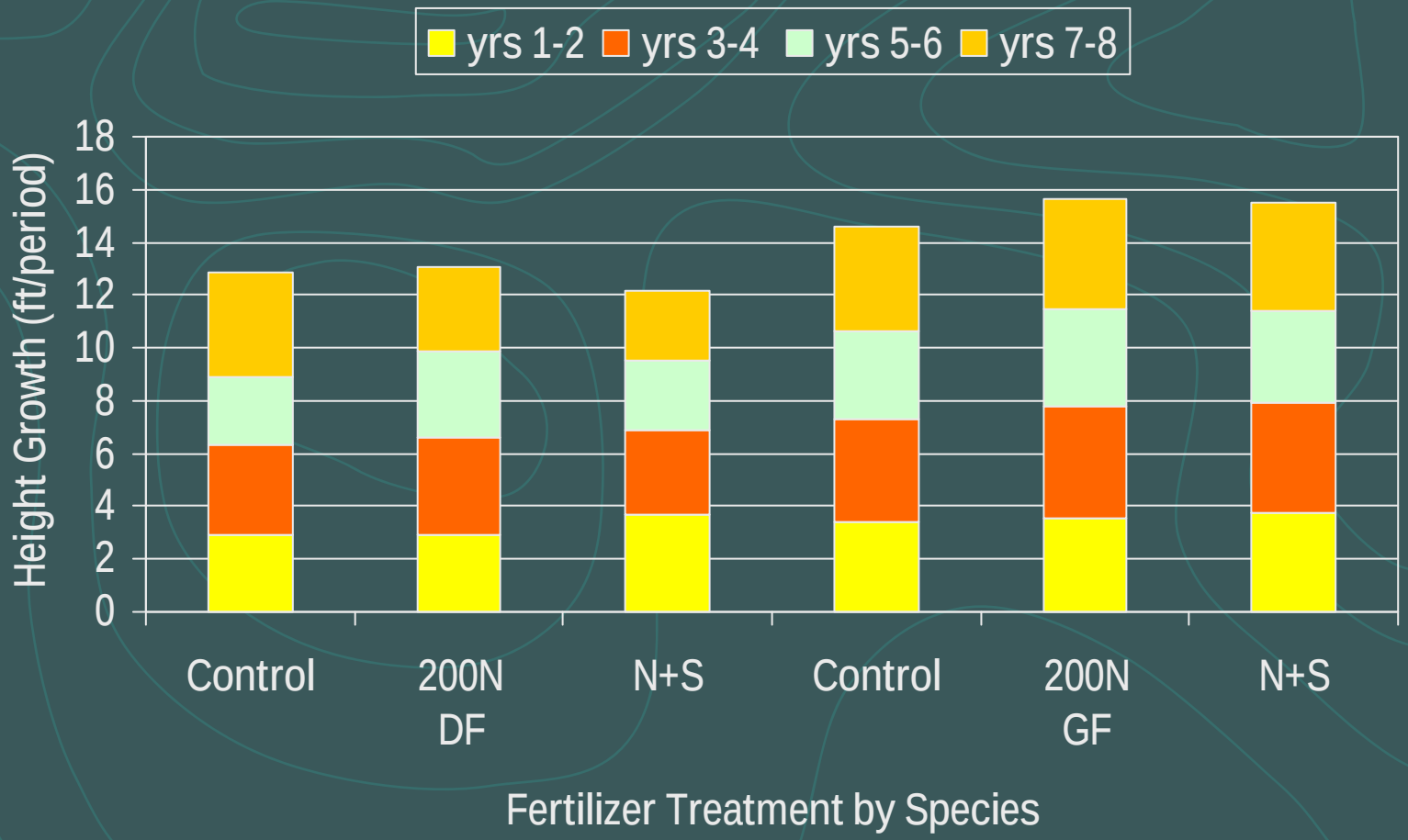
Umatilla Mixed-Conifer Trials
8-year Periodic Diameter Growth
Pole-size Stands



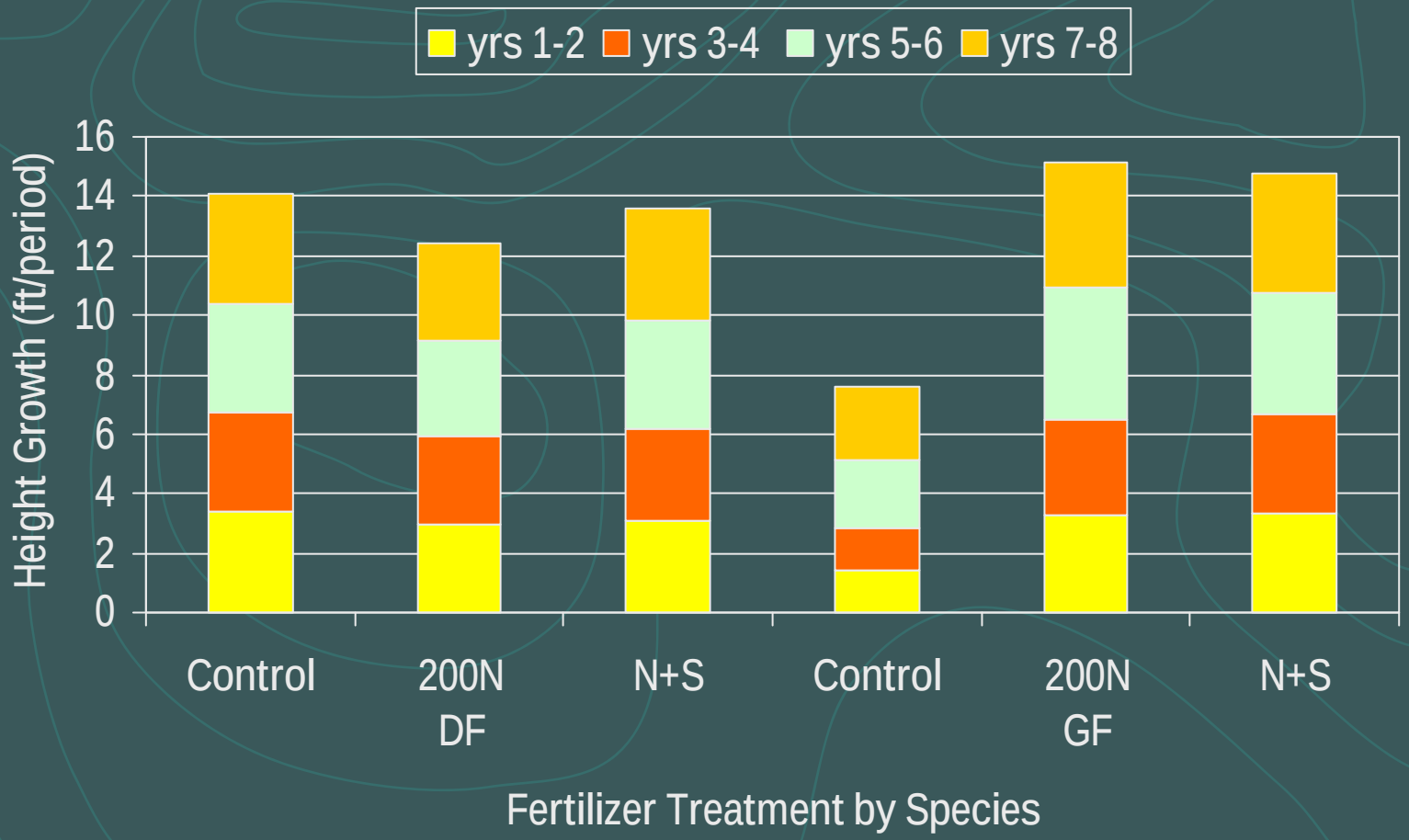
Umatilla Mixed-Conifer Trials
8-year Periodic Diameter Growth
Plantations



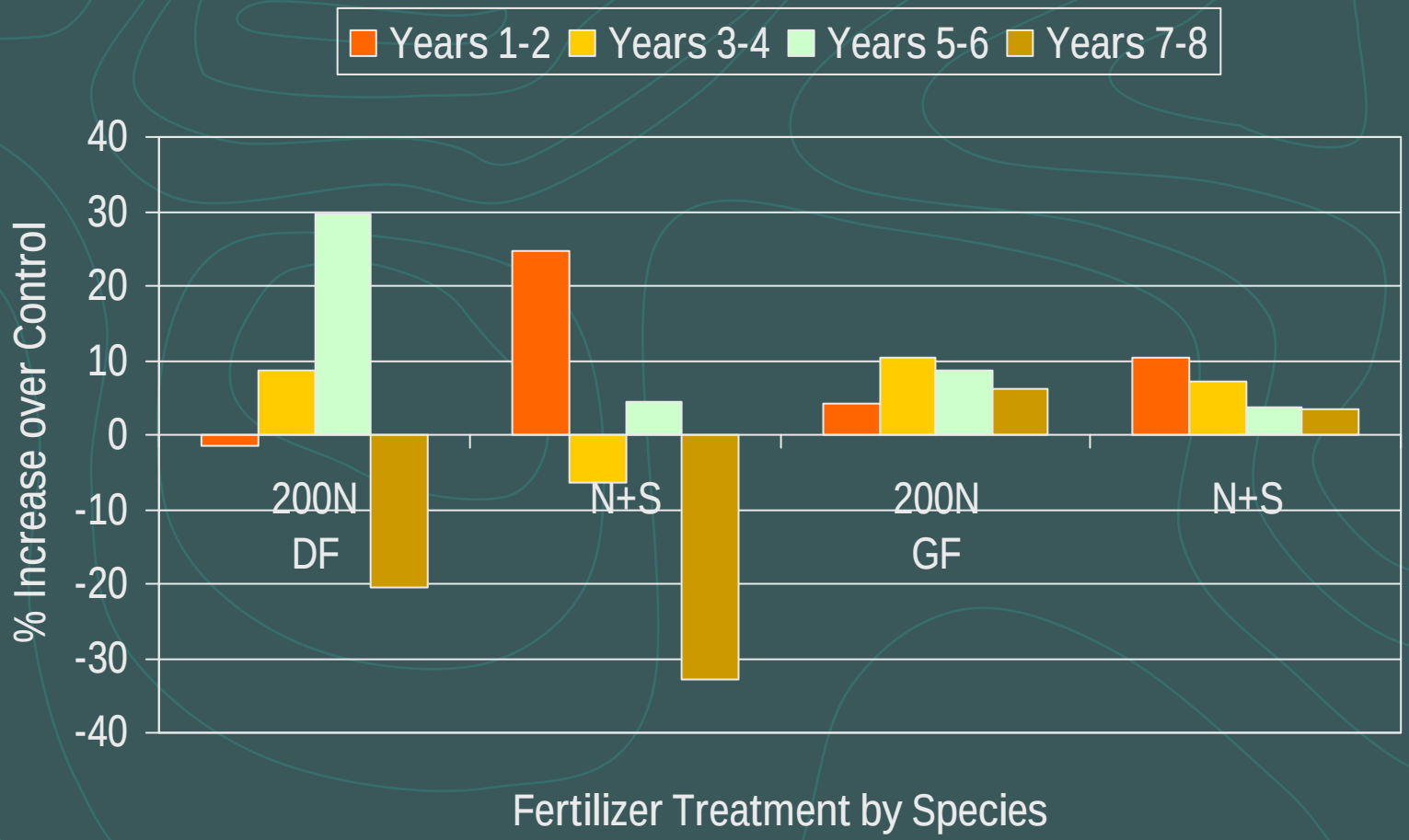
Umatilla Mixed-Conifer Trials
8-year Periodic Height Growth
Pole-size Stands



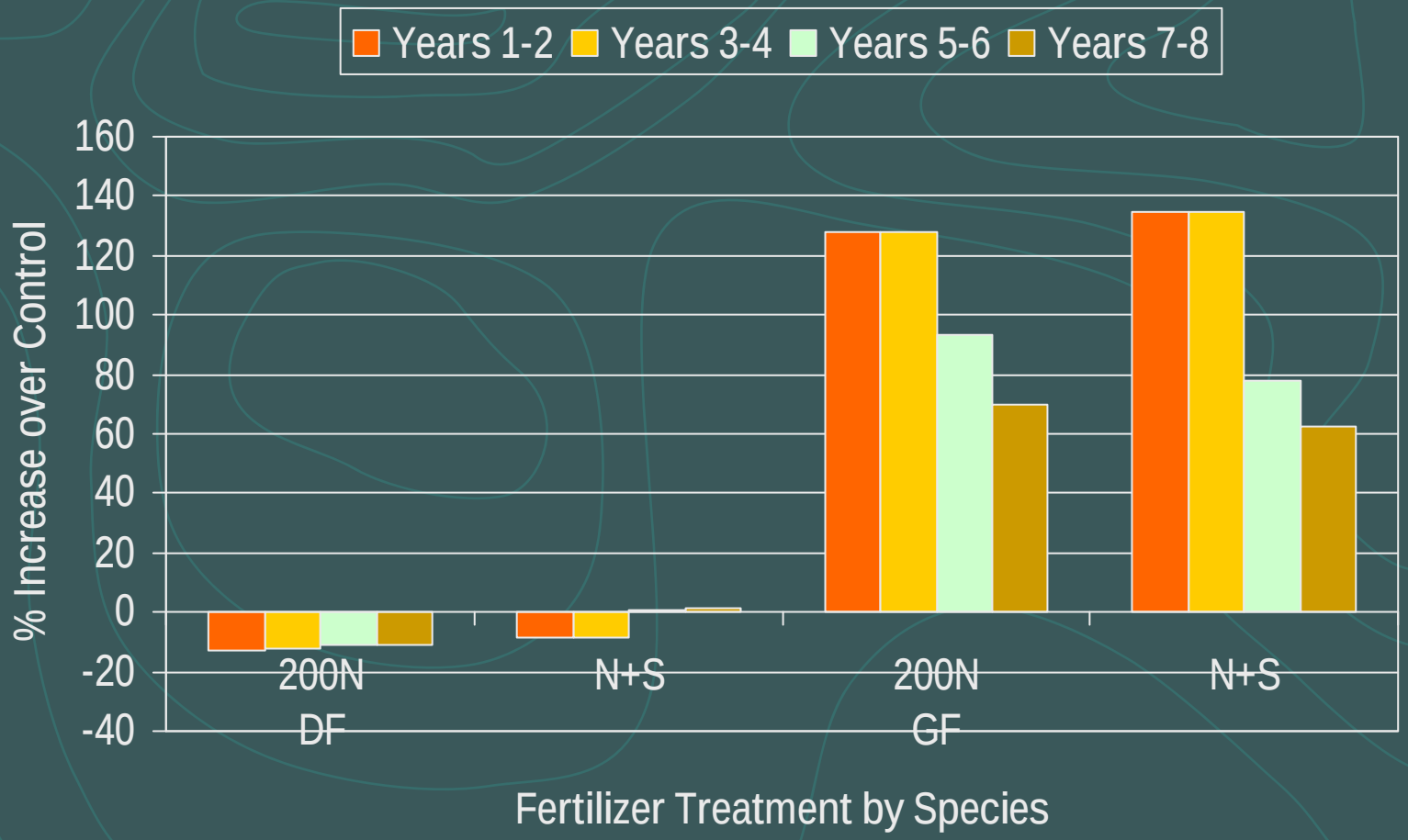
Umatilla Mixed-Conifer Trials 8-year Periodic Height Growth Plantations



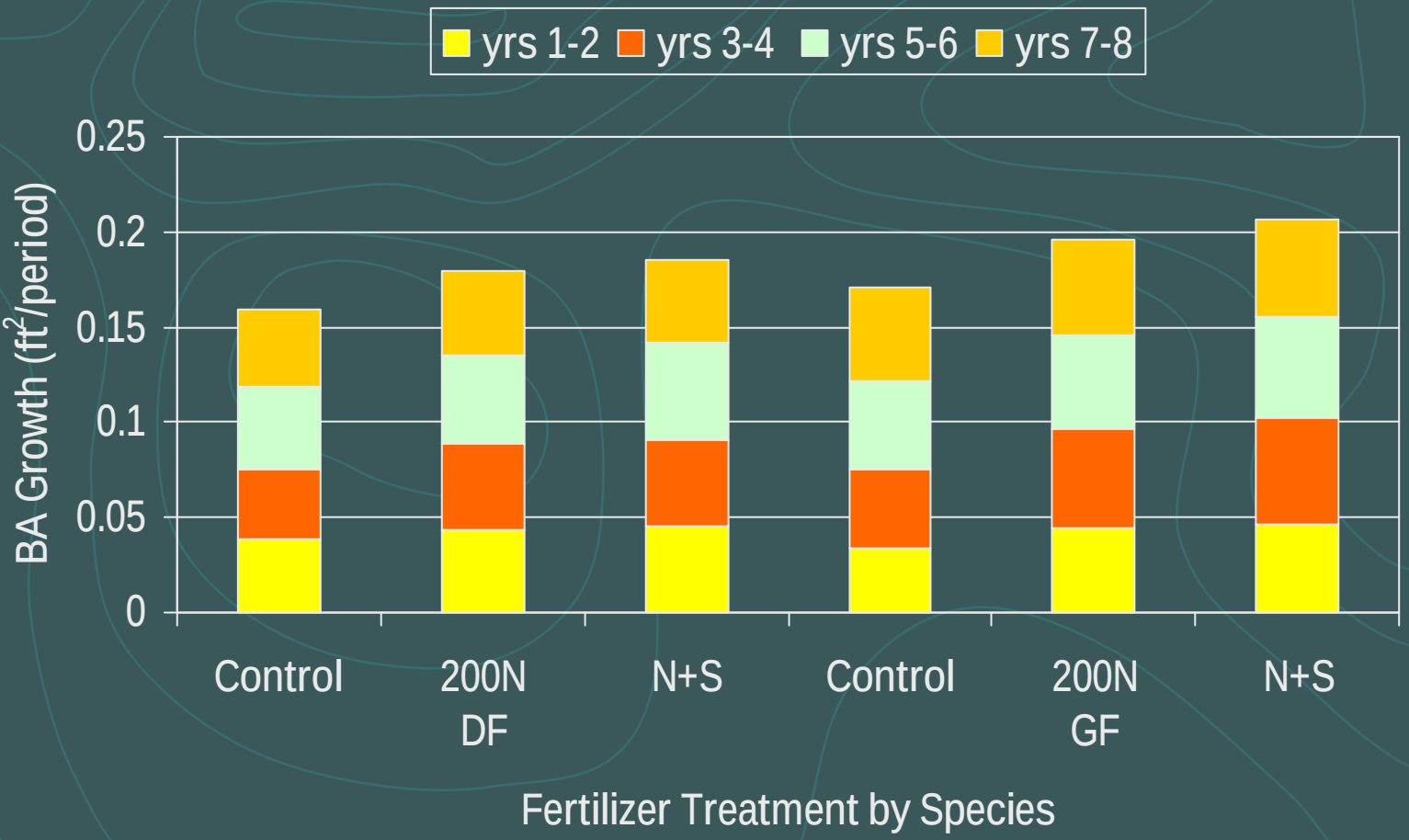
Umatilla Mixed-Conifer Trials
Relative Periodic Height Growth
Pole-size Stands



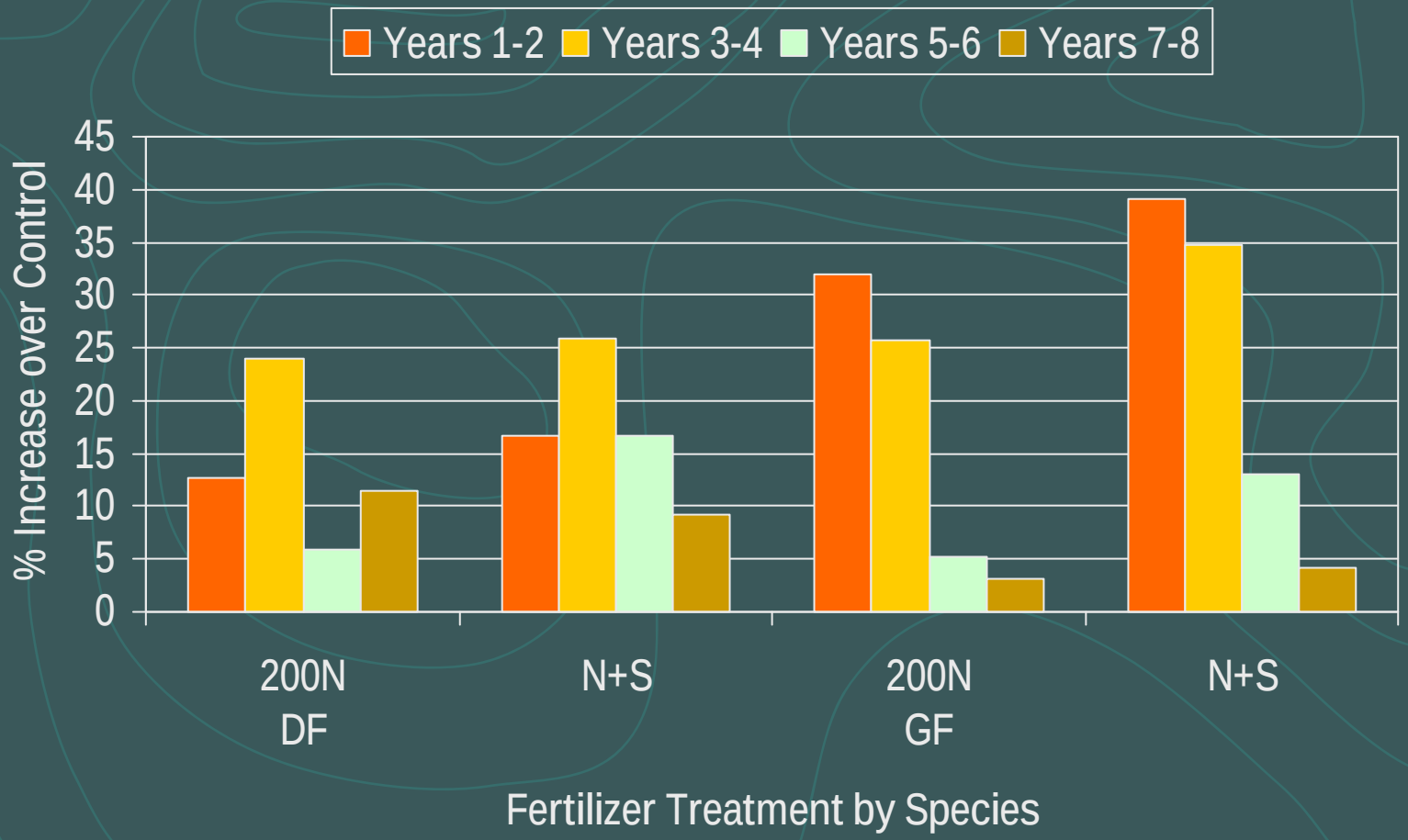
Umatilla Mixed-Conifer Trials Relative Periodic Height Growth Plantations



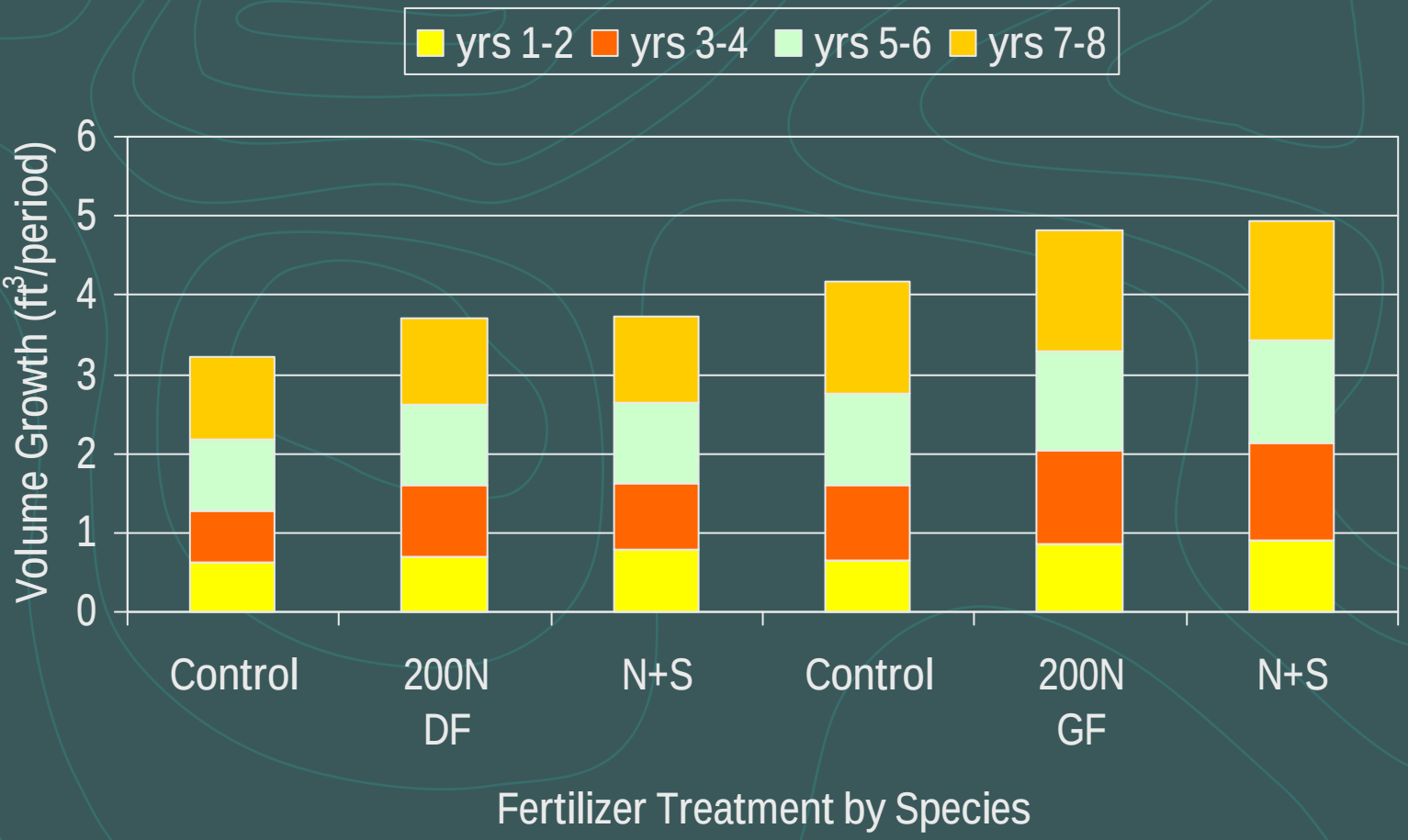
Umatilla Mixed-Conifer Trials
8-year Periodic BA Growth
Pole-size Stands



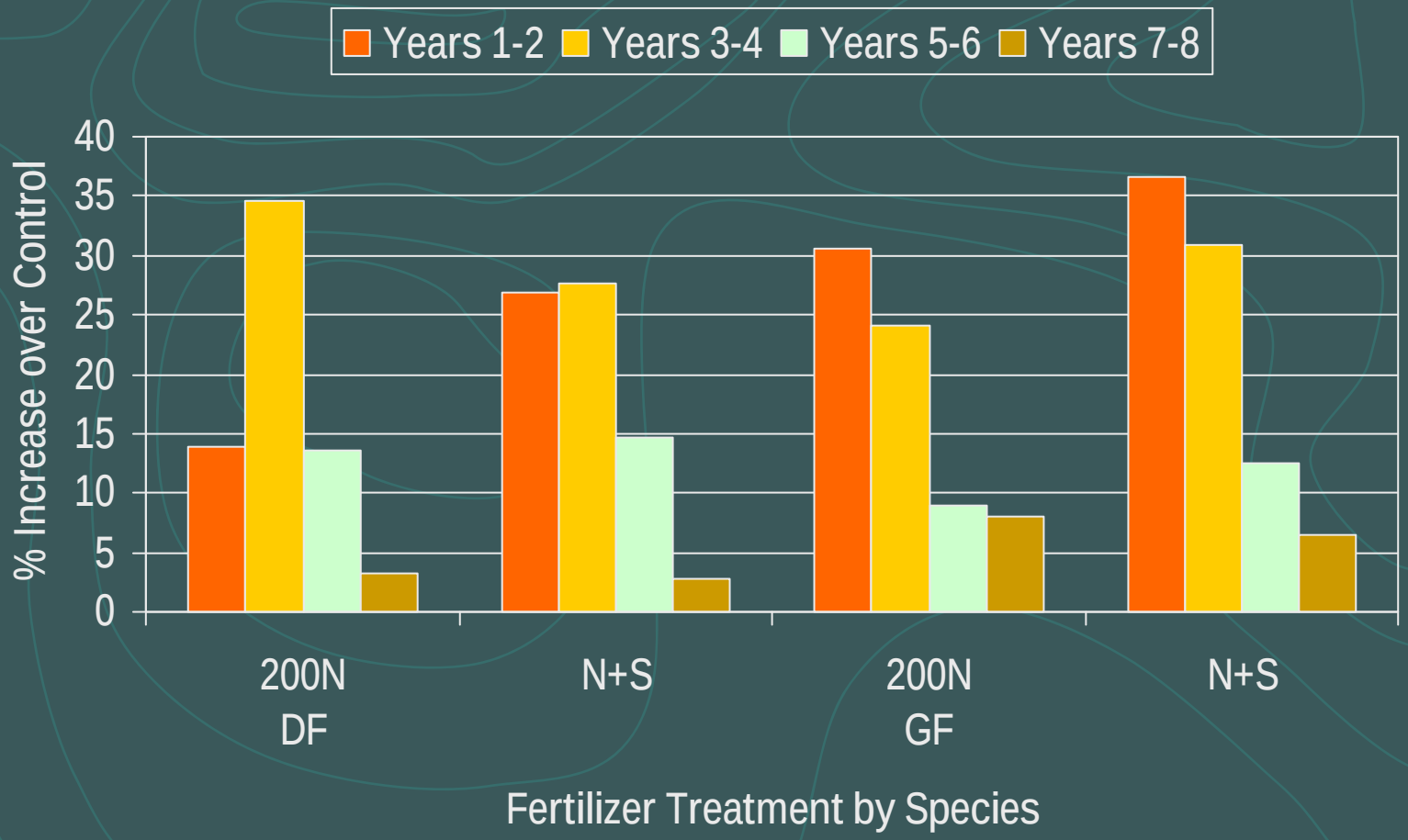
Umatilla Mixed-Conifer Trials
Relative Periodic BA Growth
Pole-size Stands



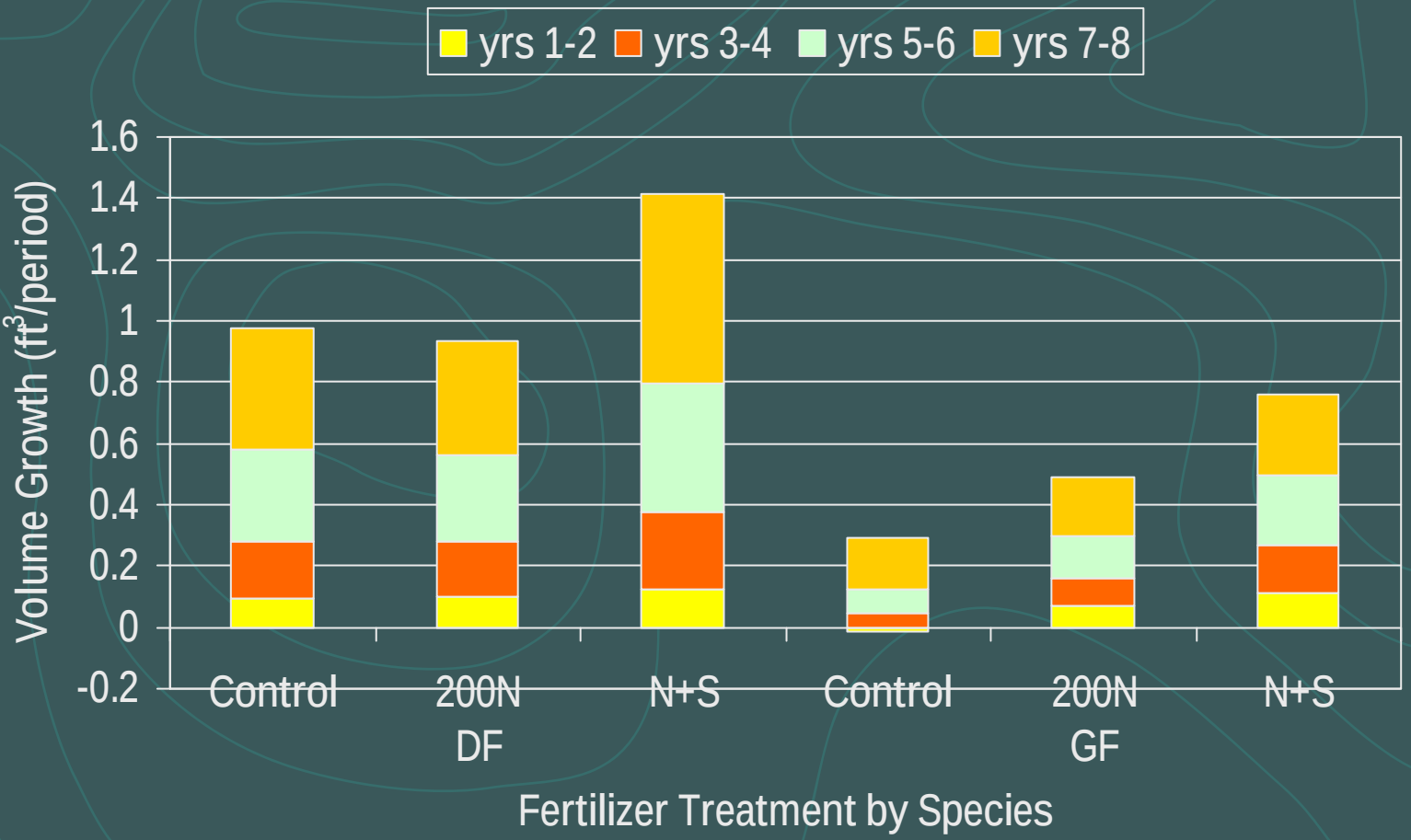
Umatilla Mixed-Conifer Trials
8-year Periodic Volume Growth
Pole-size Stands



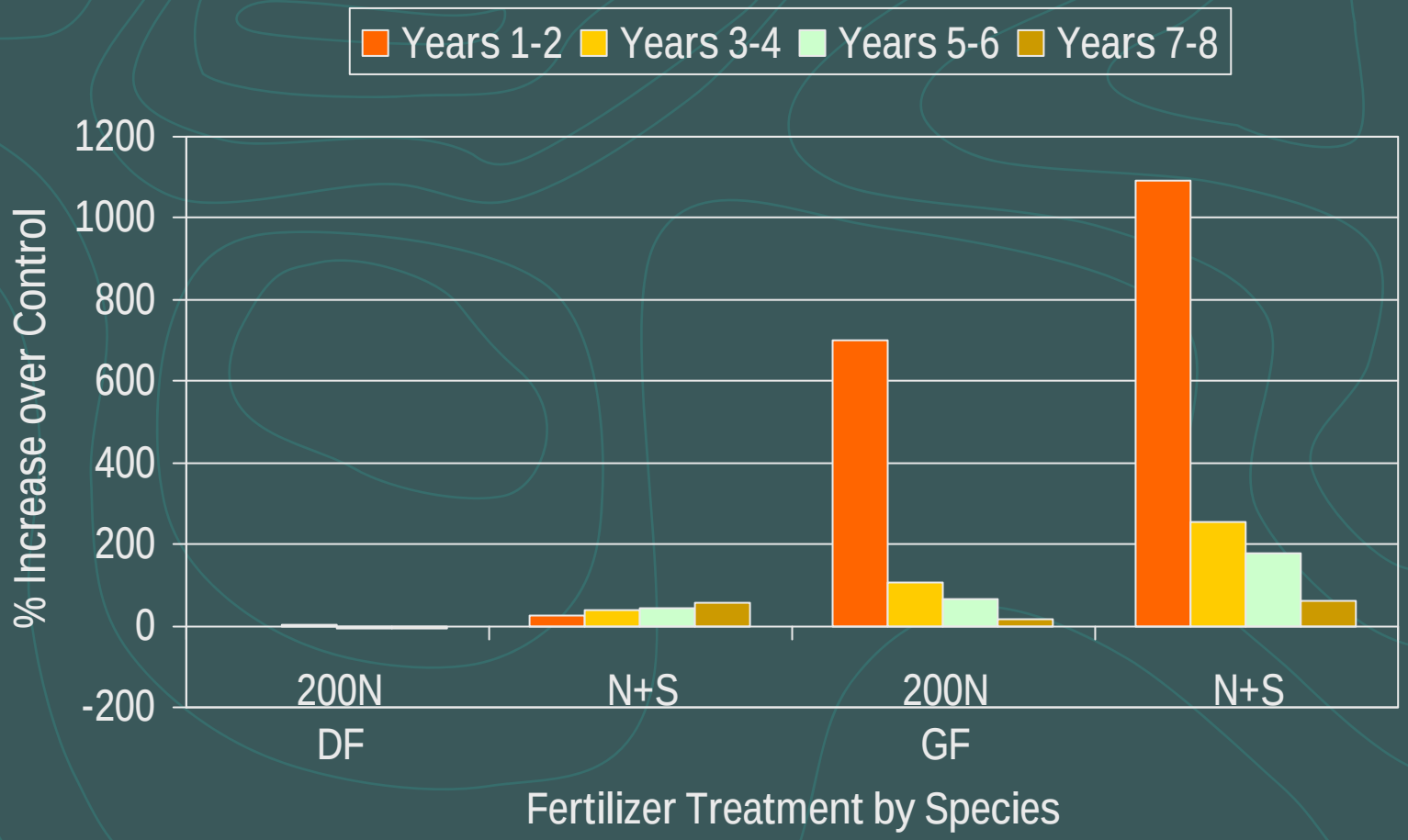
Umatilla Mixed-Conifer Trials
Relative Periodic Volume Growth
Pole-size Stands



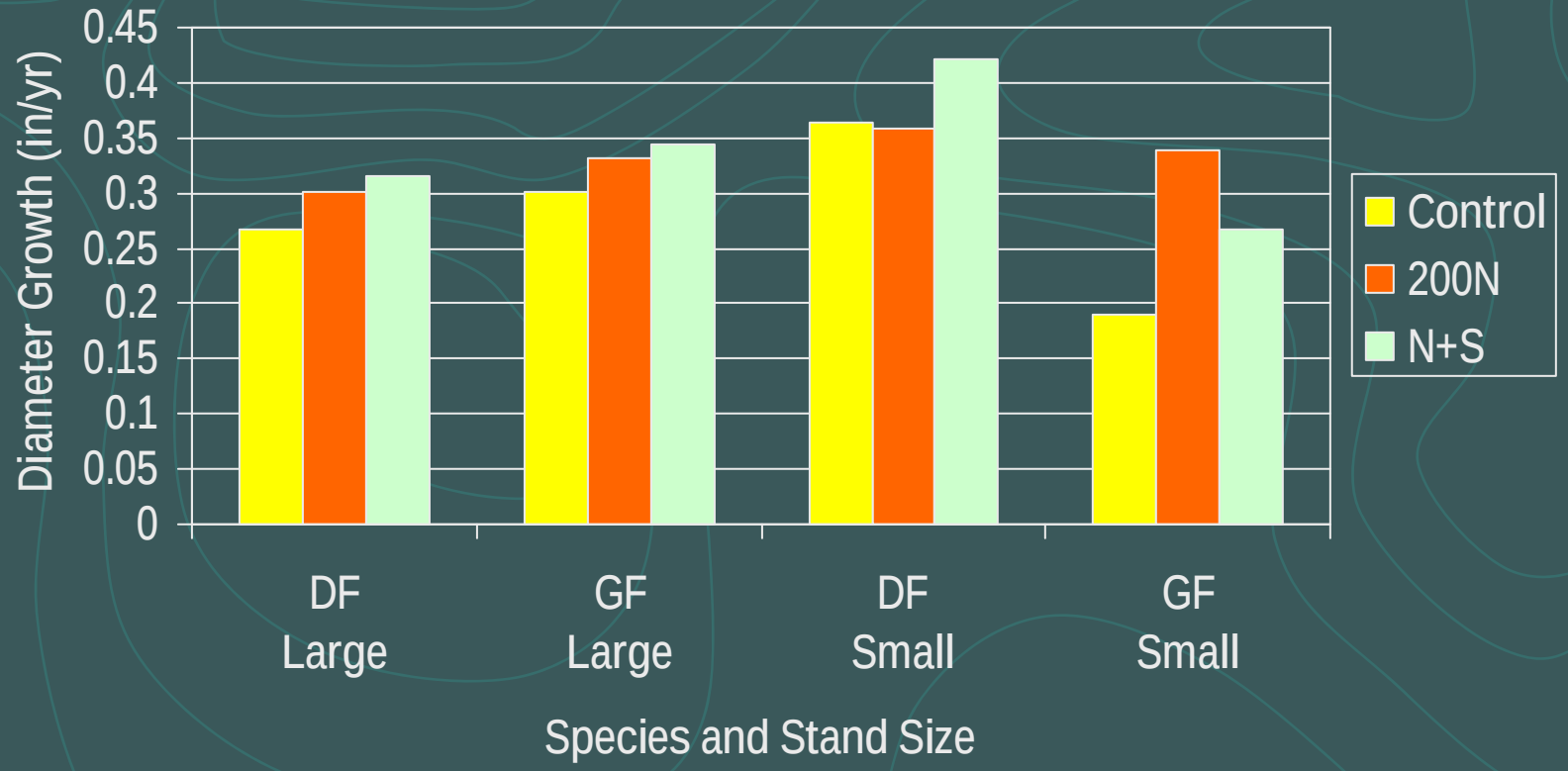
Umatilla Mixed-Conifer Trials
8-year Periodic Volume Growth
Plantations



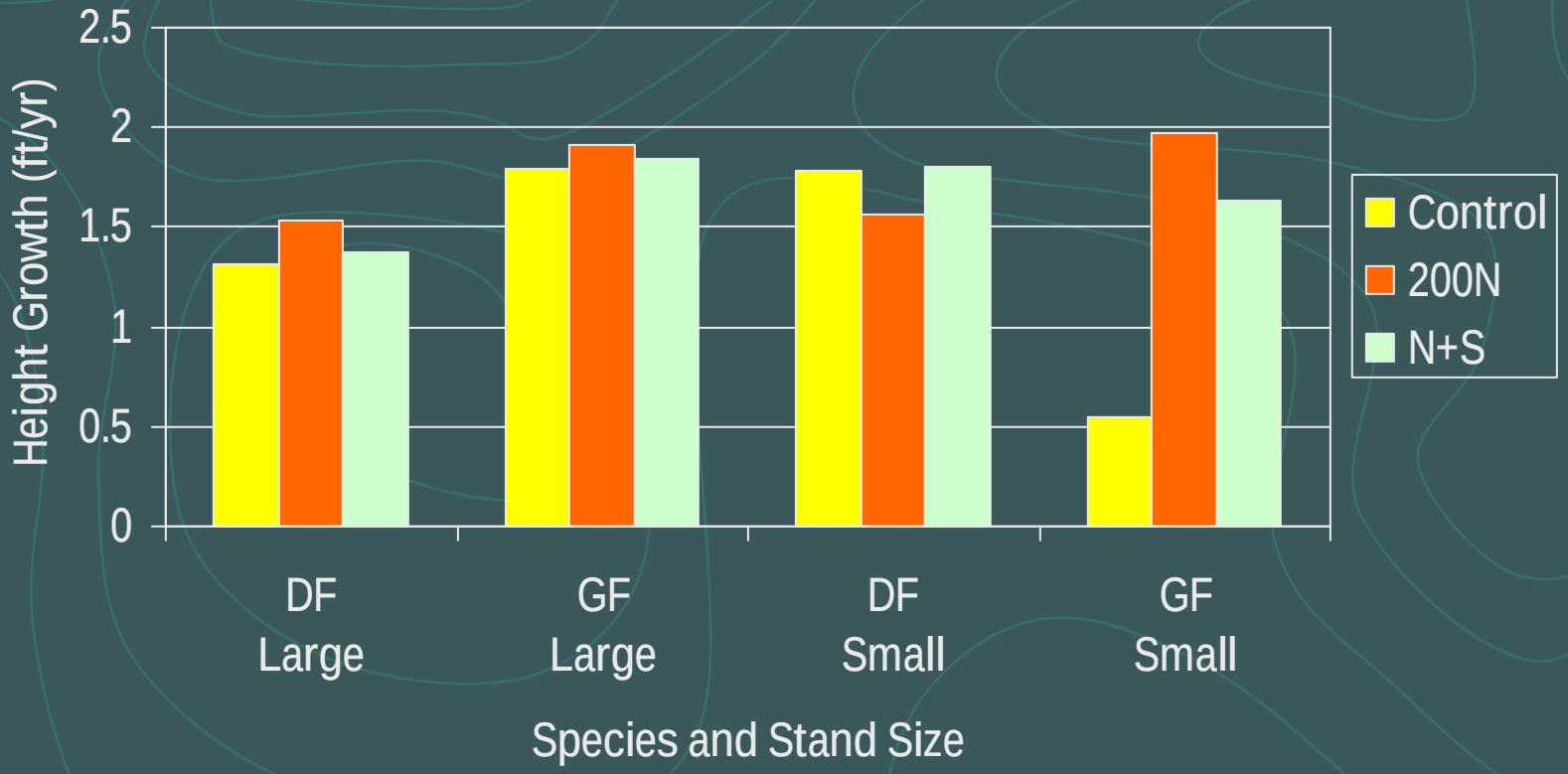
Umatilla Mixed-Conifer Trials Relative Periodic Volume Growth Plantations



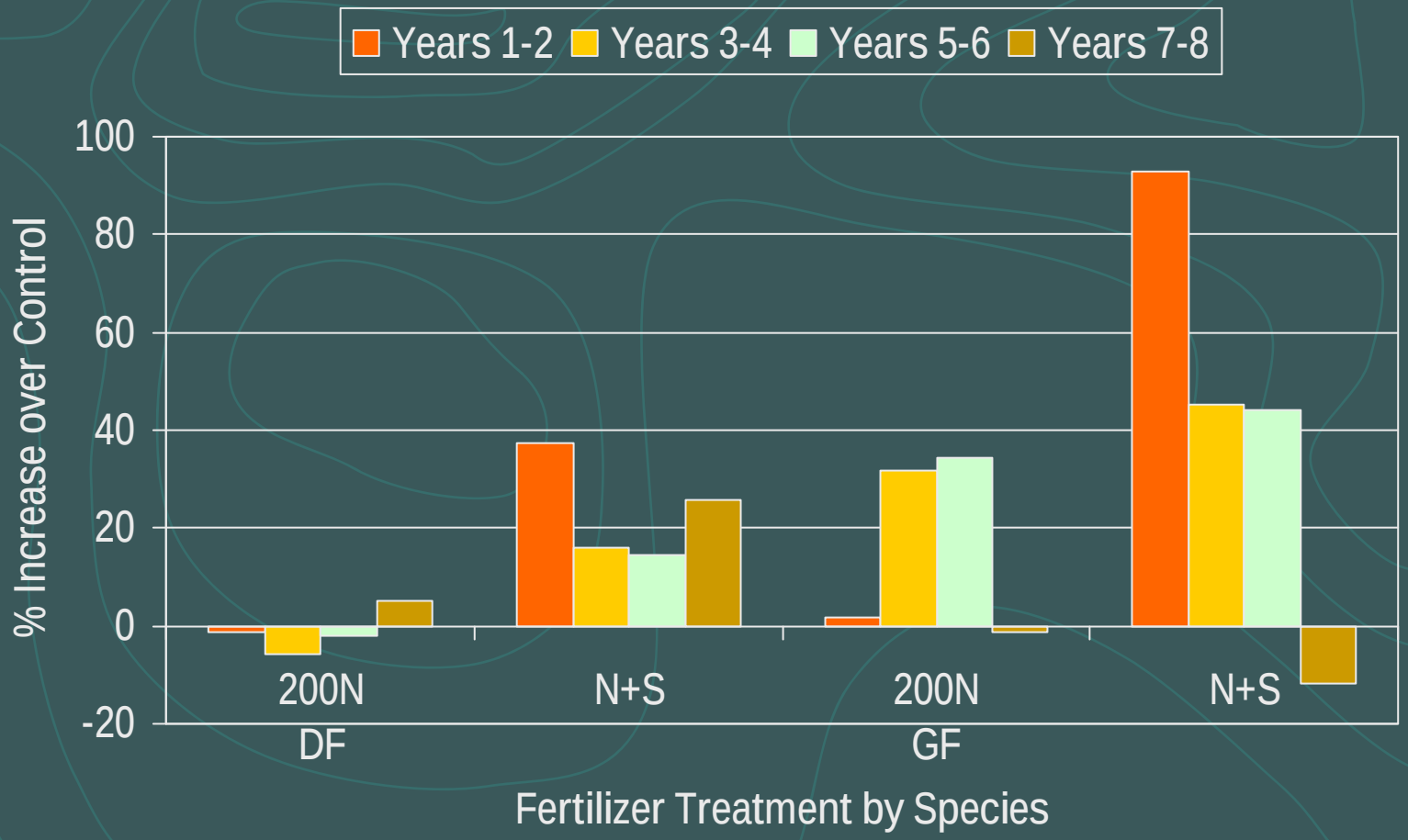
Umatilla Mixed-Conifer Trials
8-year Diameter Response to N and S



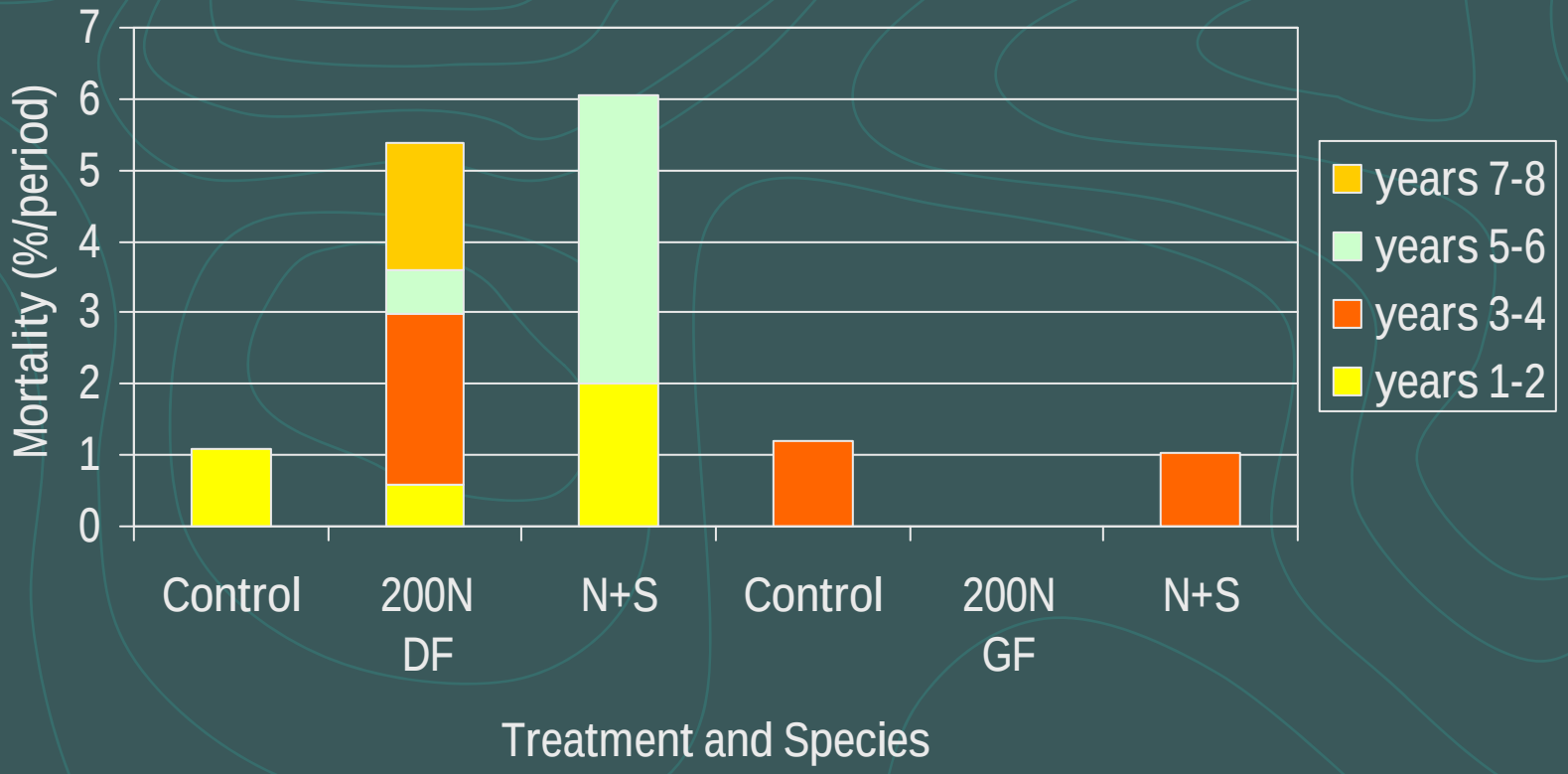
Umatilla Mixed-Conifer Trials
8-year Height Response to N and S



Umatilla Mixed-Conifer Trials Relative Periodic Diameter Growth Plantations

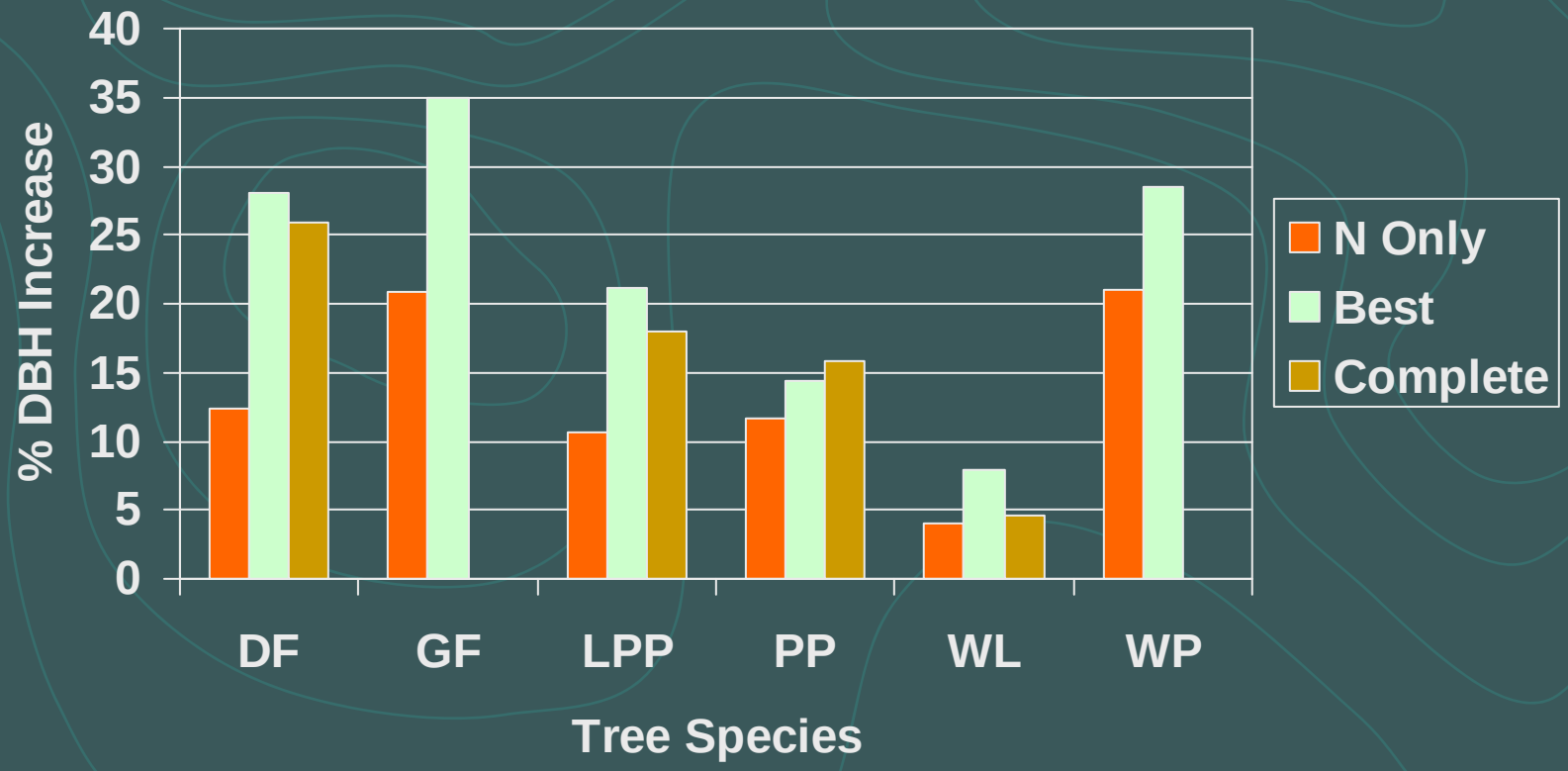


Umatilla Mixed-Conifer Trials
Periodic Mortality: stems/a

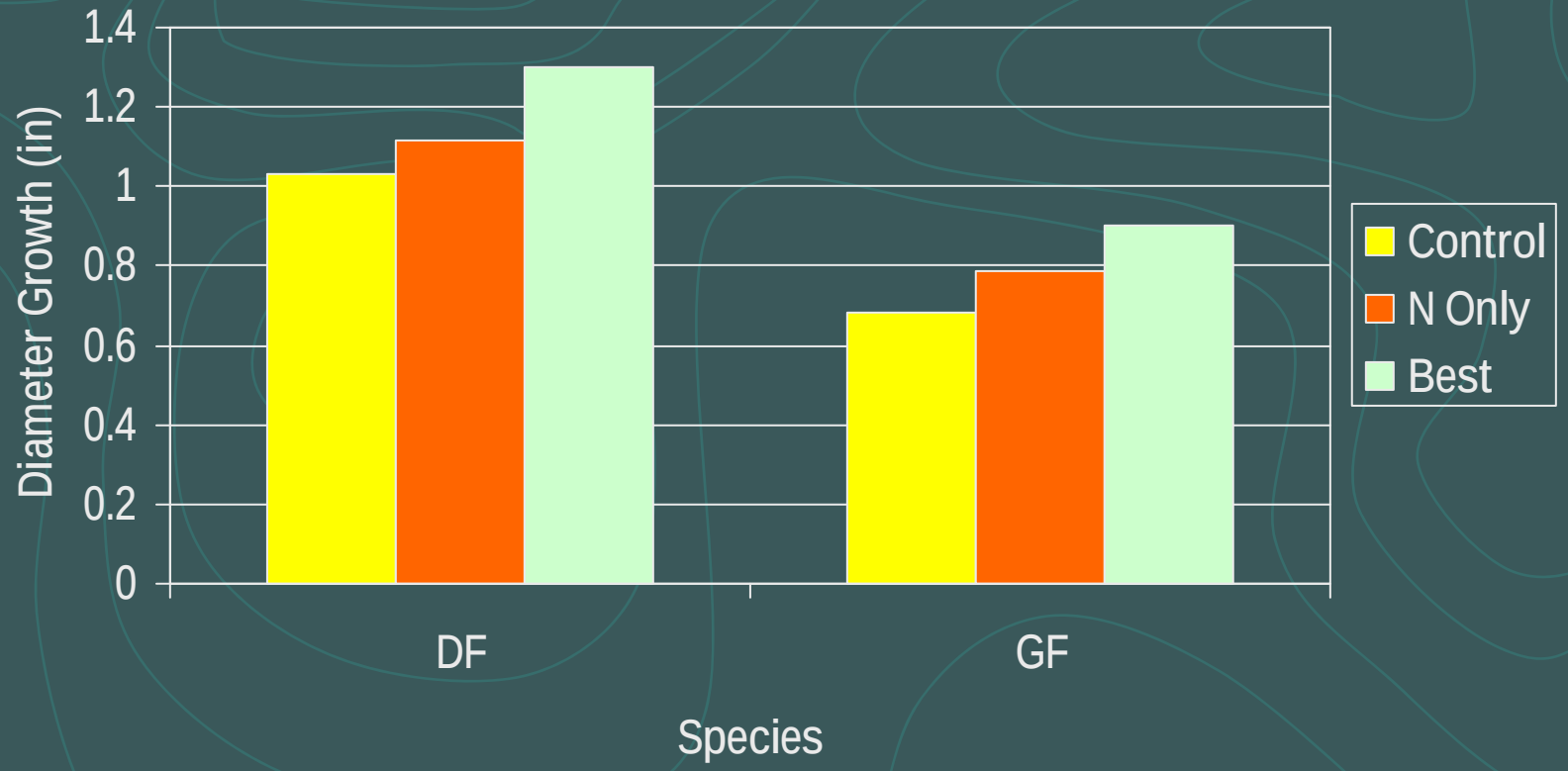


Multinutrient Screening Trials

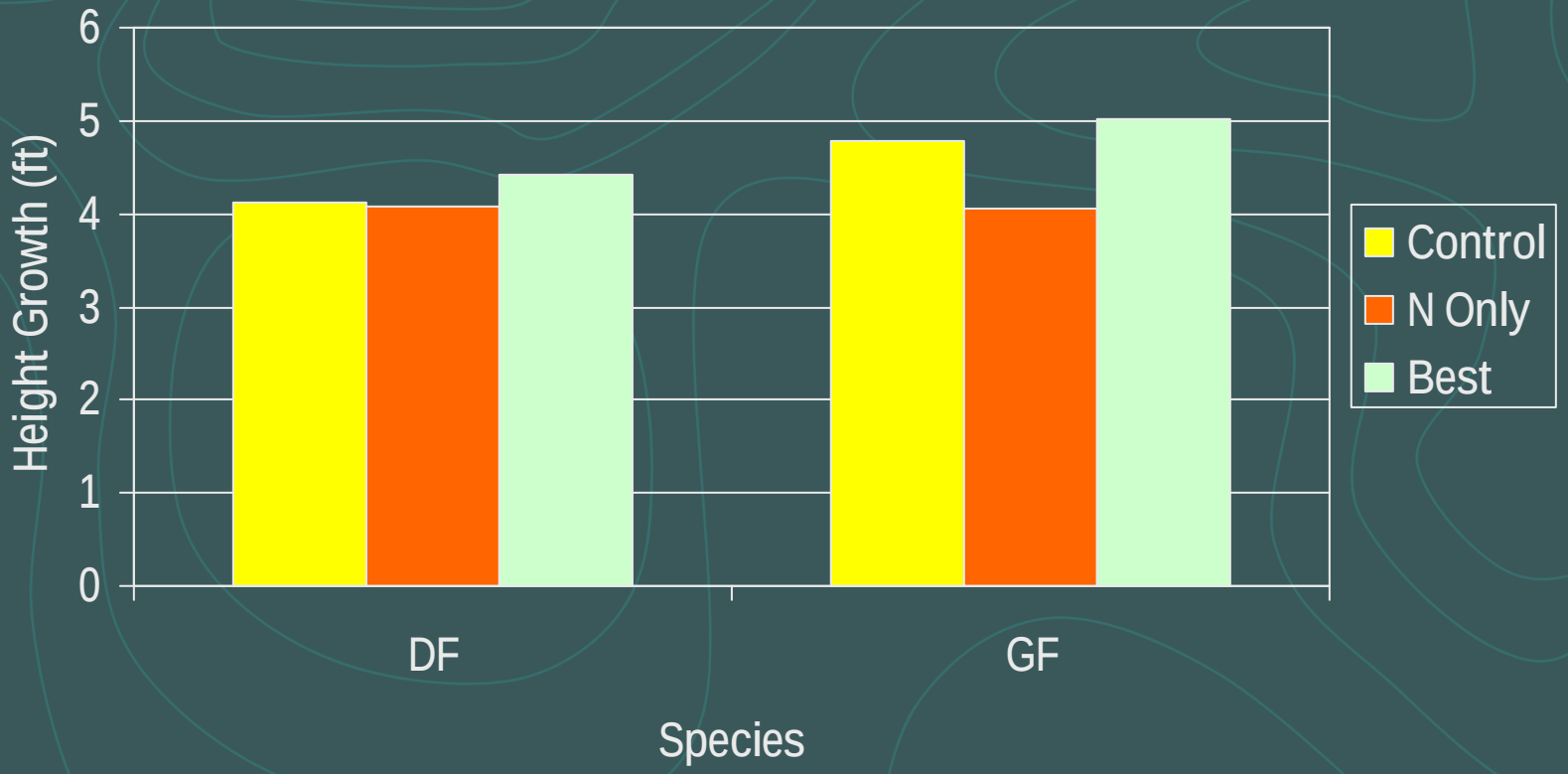
Effect of Treatment on 2-Year Diameter Growth by Species



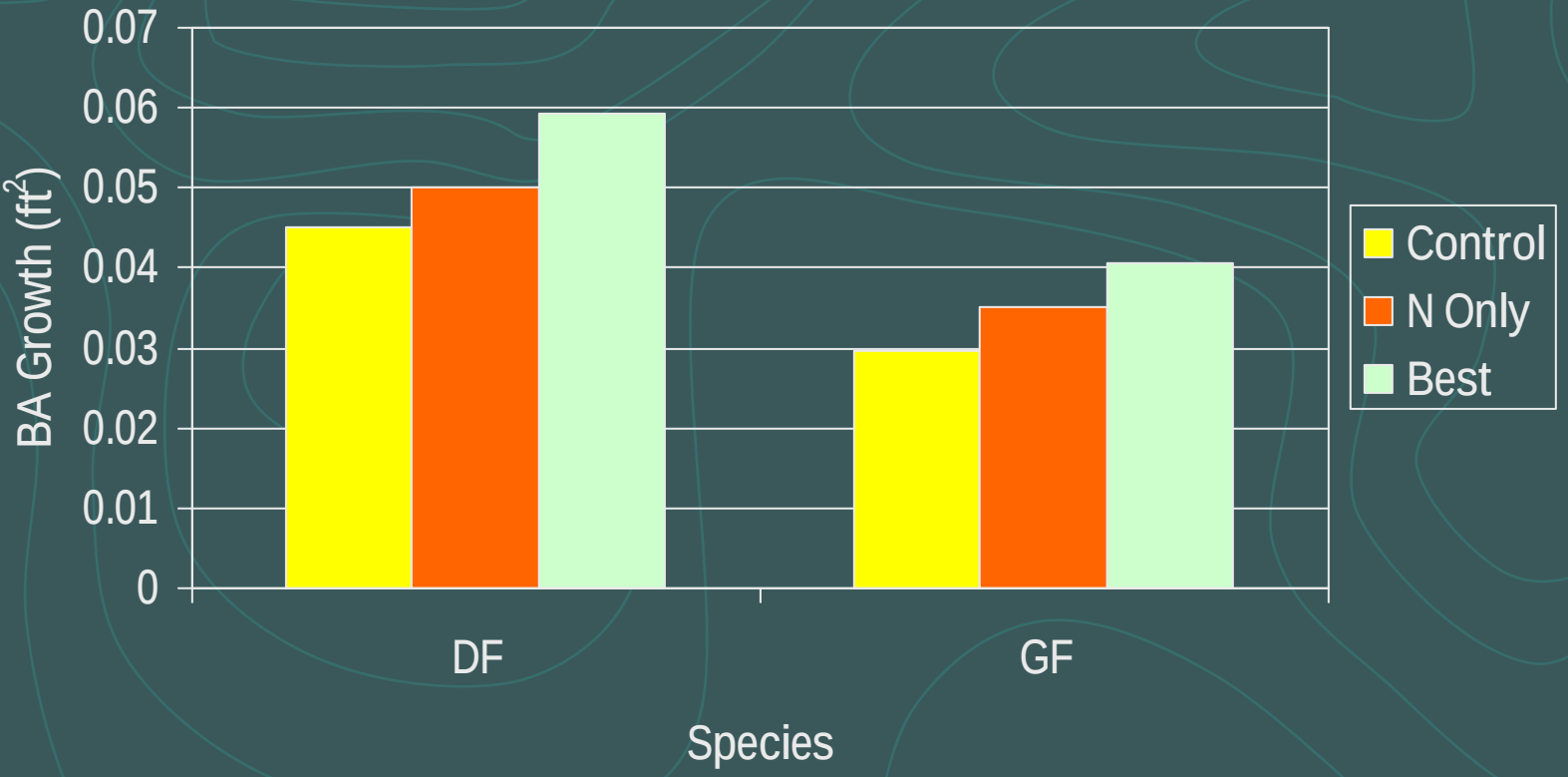
Multinutrient Screening Trials
2-year Diameter Growth



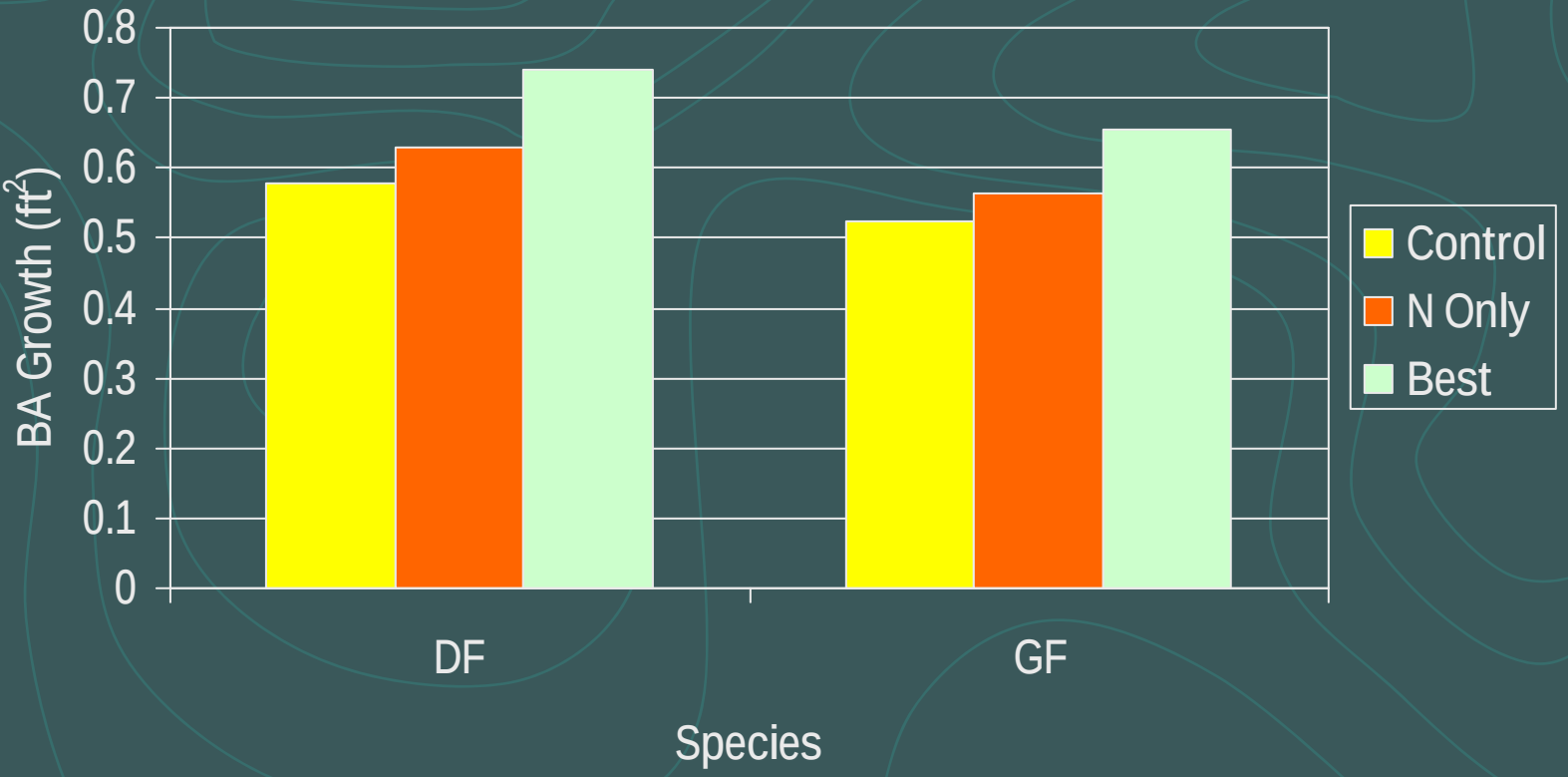
Multinutrient Screening Trials
2-year Height Growth



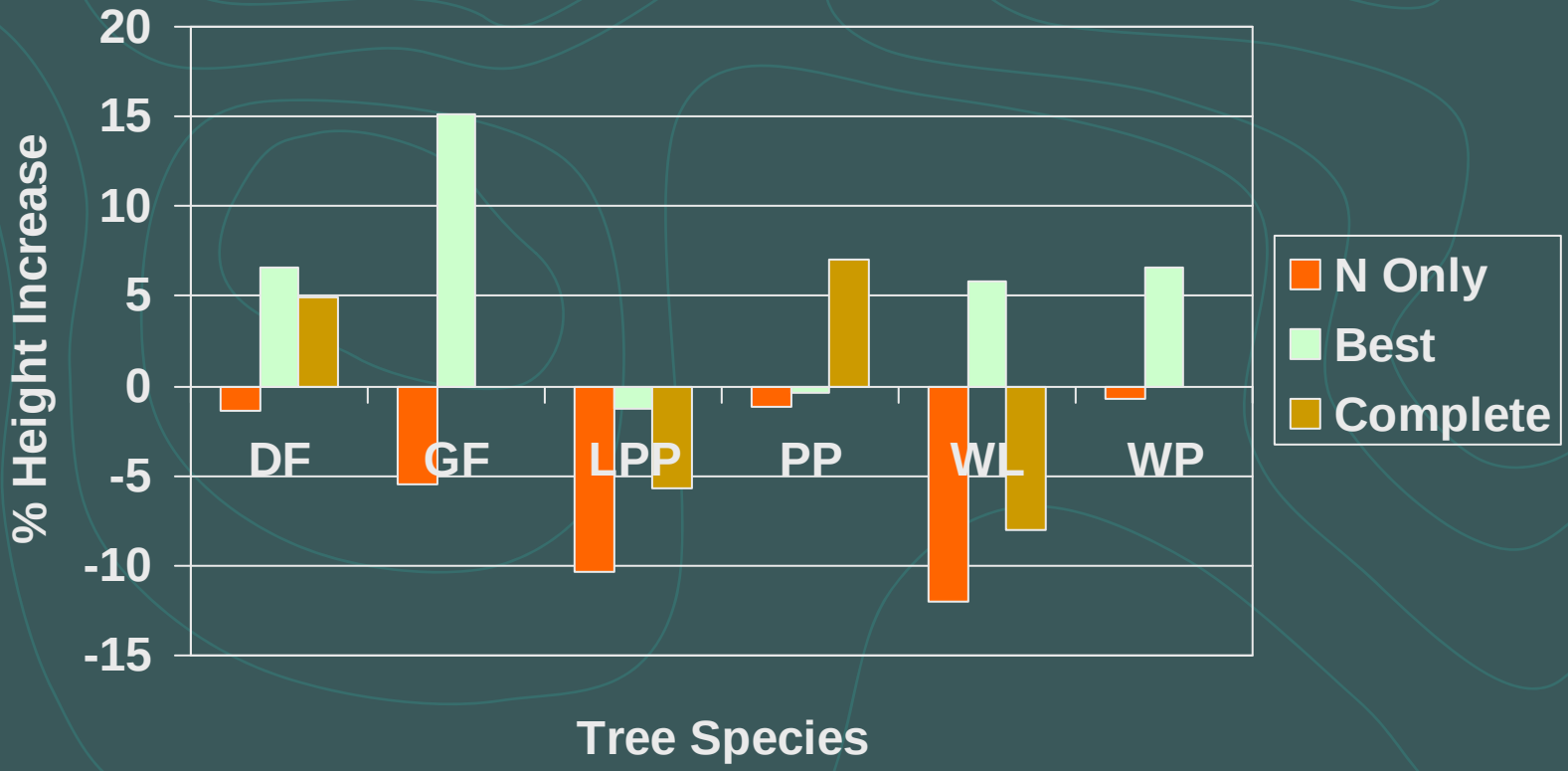
Multinutrient Screening Trials
2-year BA Growth



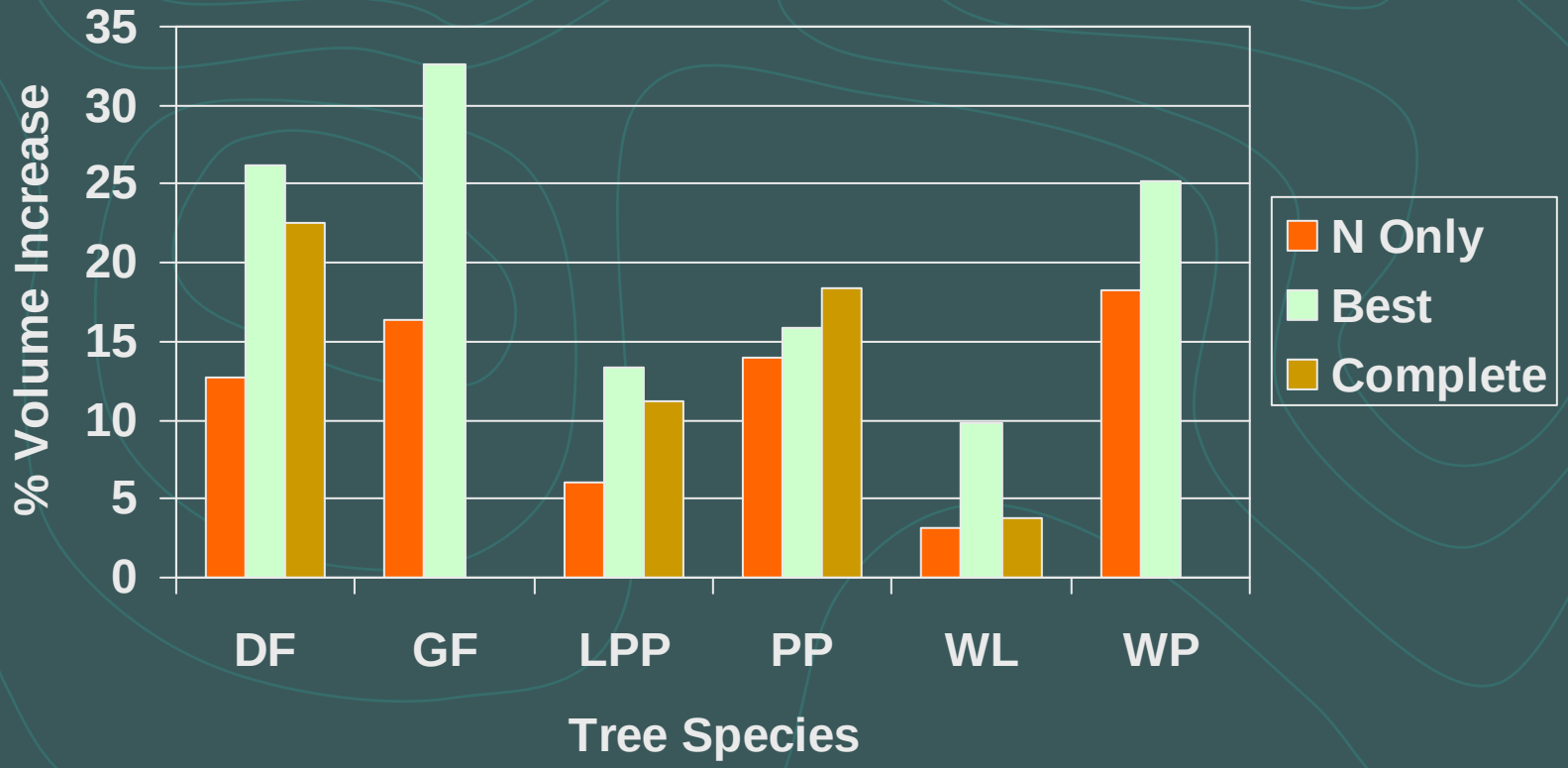
Multinutrient Screening Trials
2-year Volume Growth



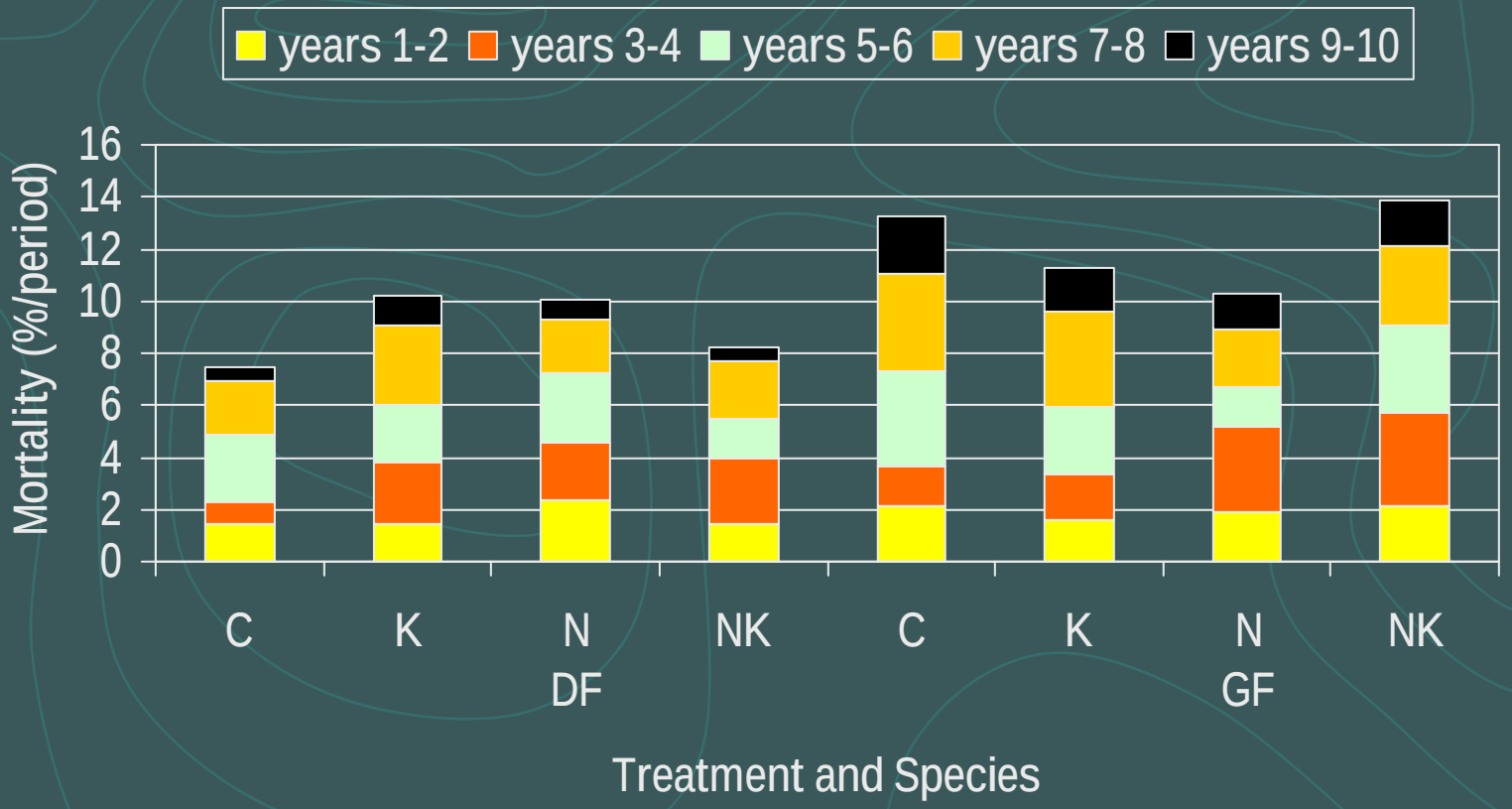
Increase in 2-Year Height Growth Over Control Rate by Treatment and Species



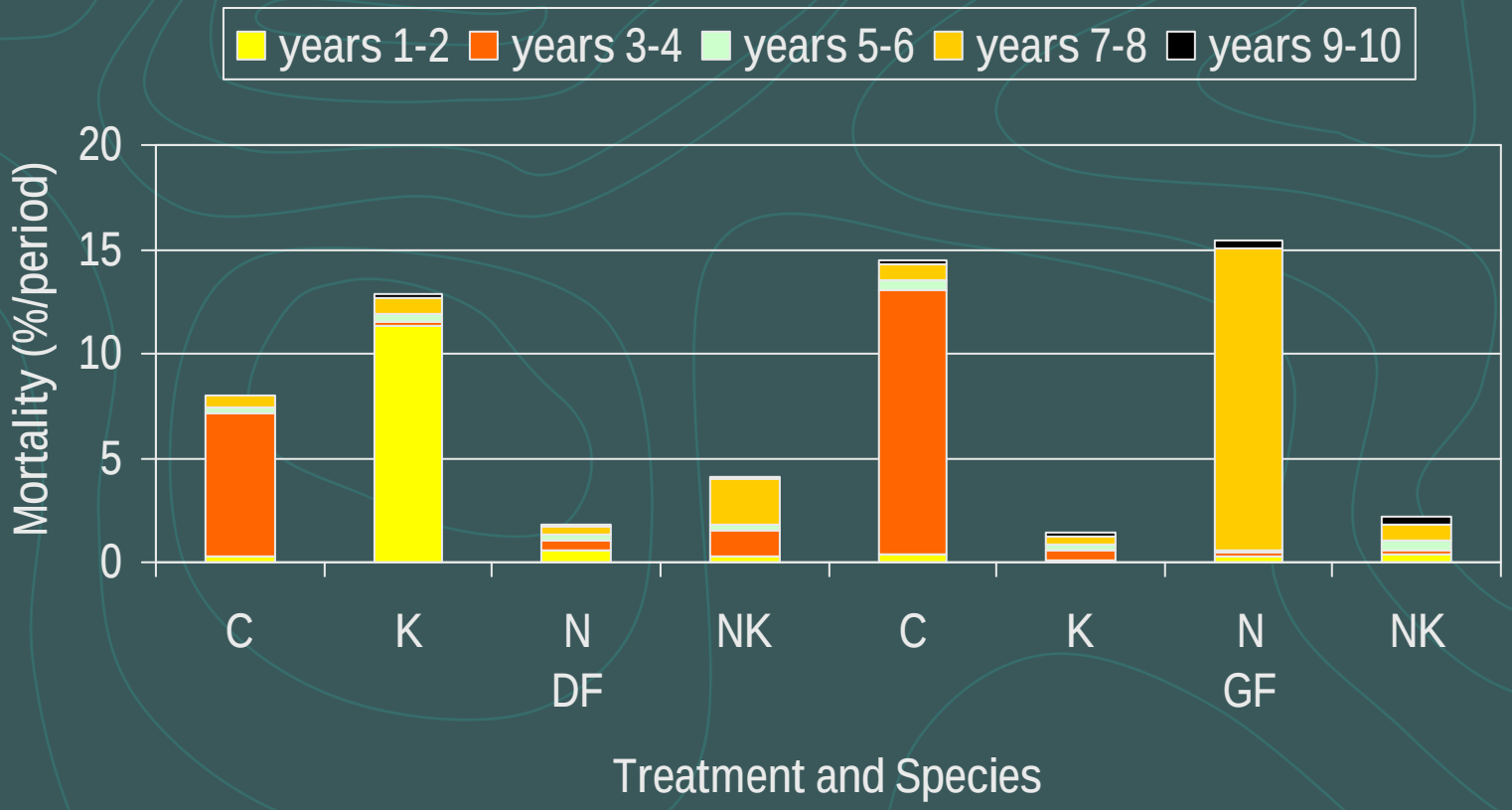
Increase in 2-Year Volume Growth Over Control Rate by Treatment and Species



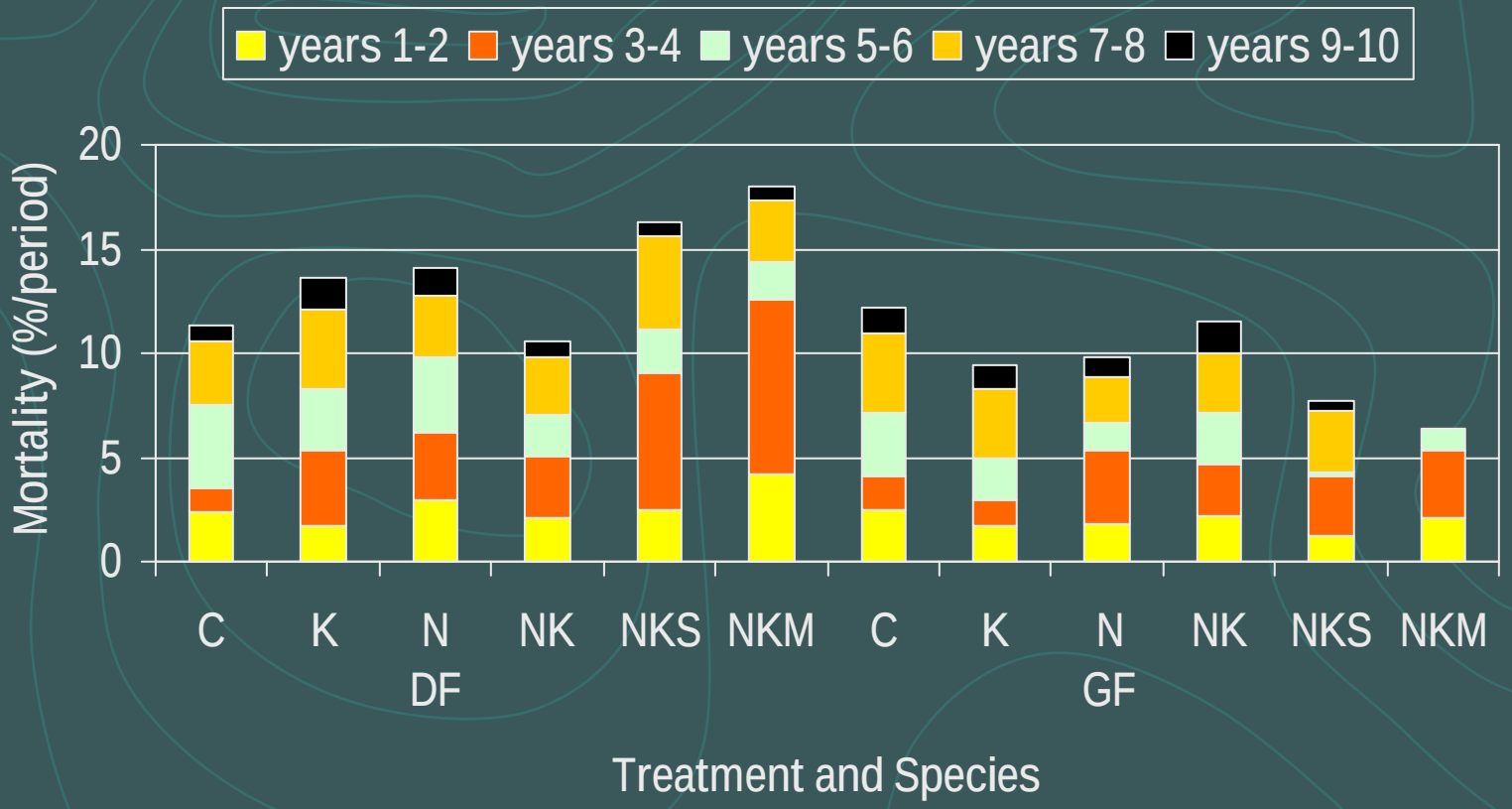
Forest Health and Nutrition Study
Periodic Mortality: stems/a



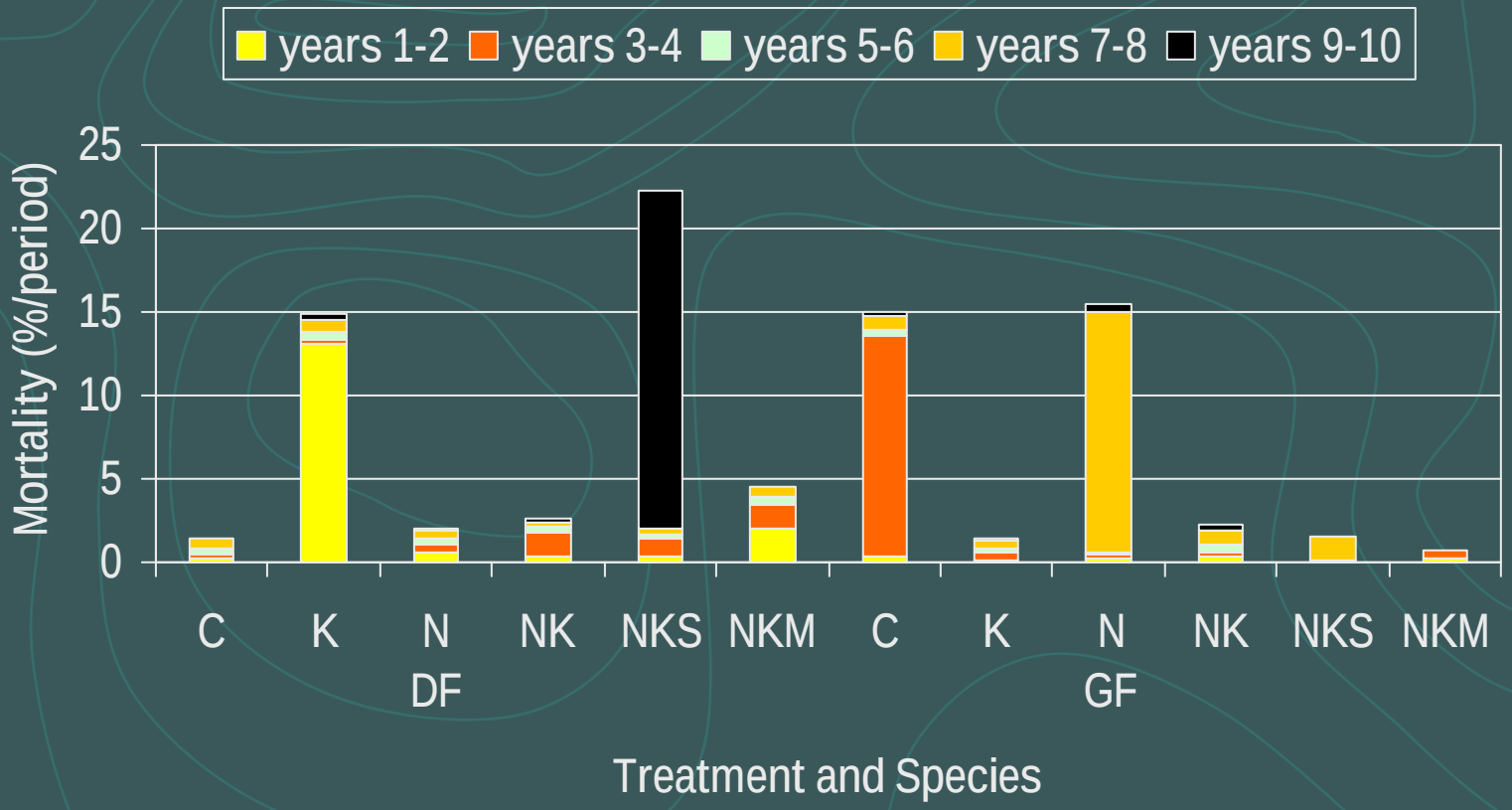
Forest Health and Nutrition Study
Periodic Mortality: BA/a



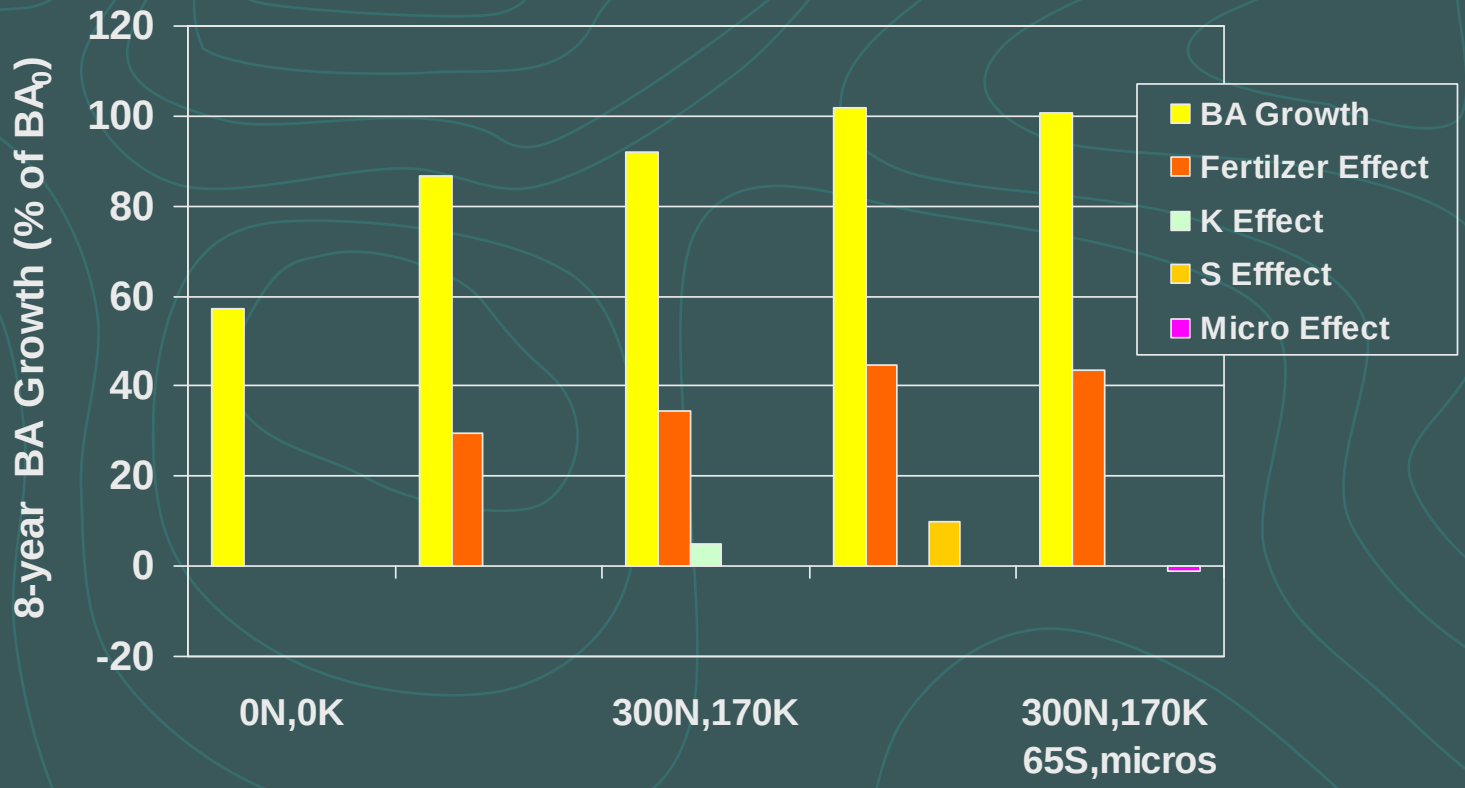
Forest Health and Nutrition Study
Periodic Mortality: stems/a



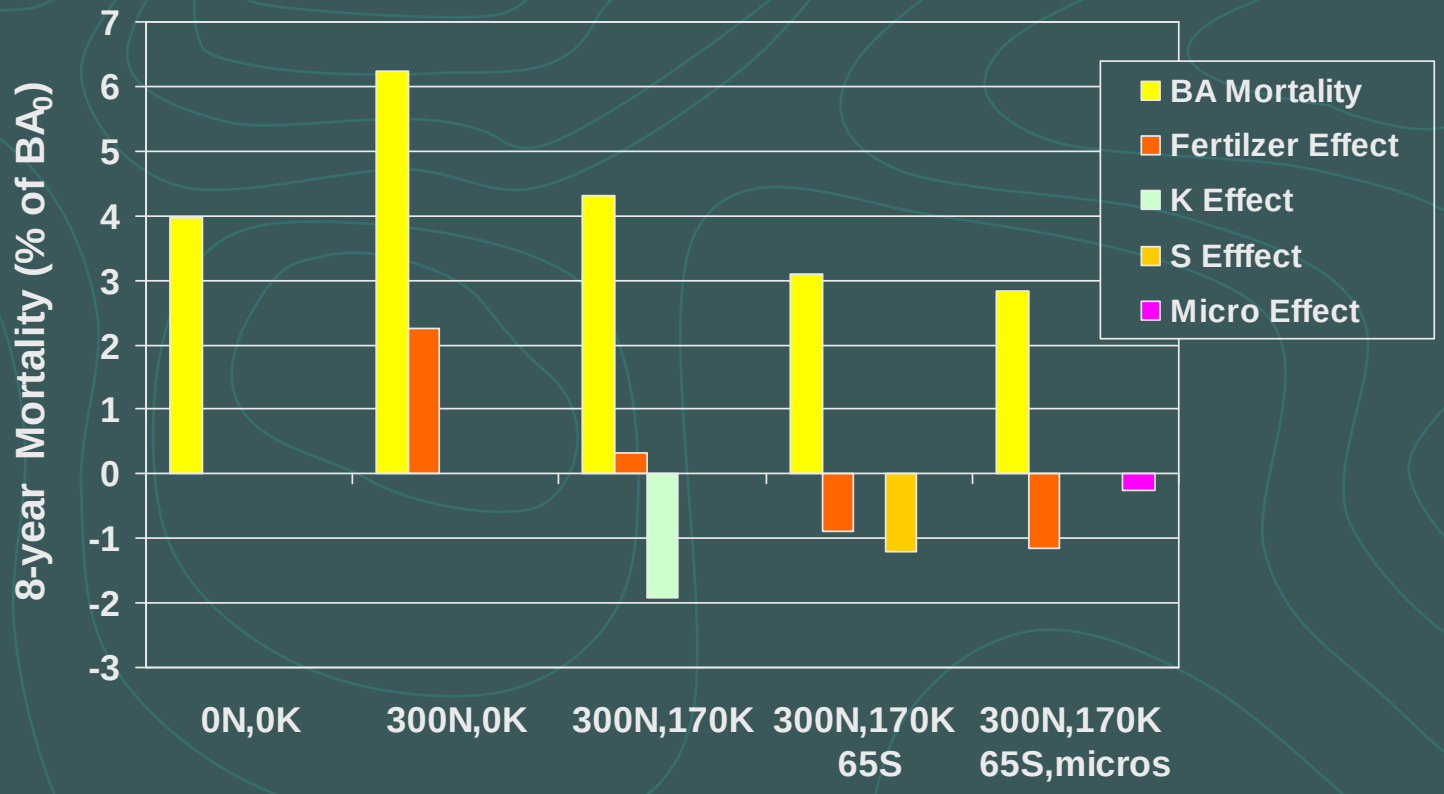
Forest Health and Nutrition Study
Periodic Mortality: BA/a



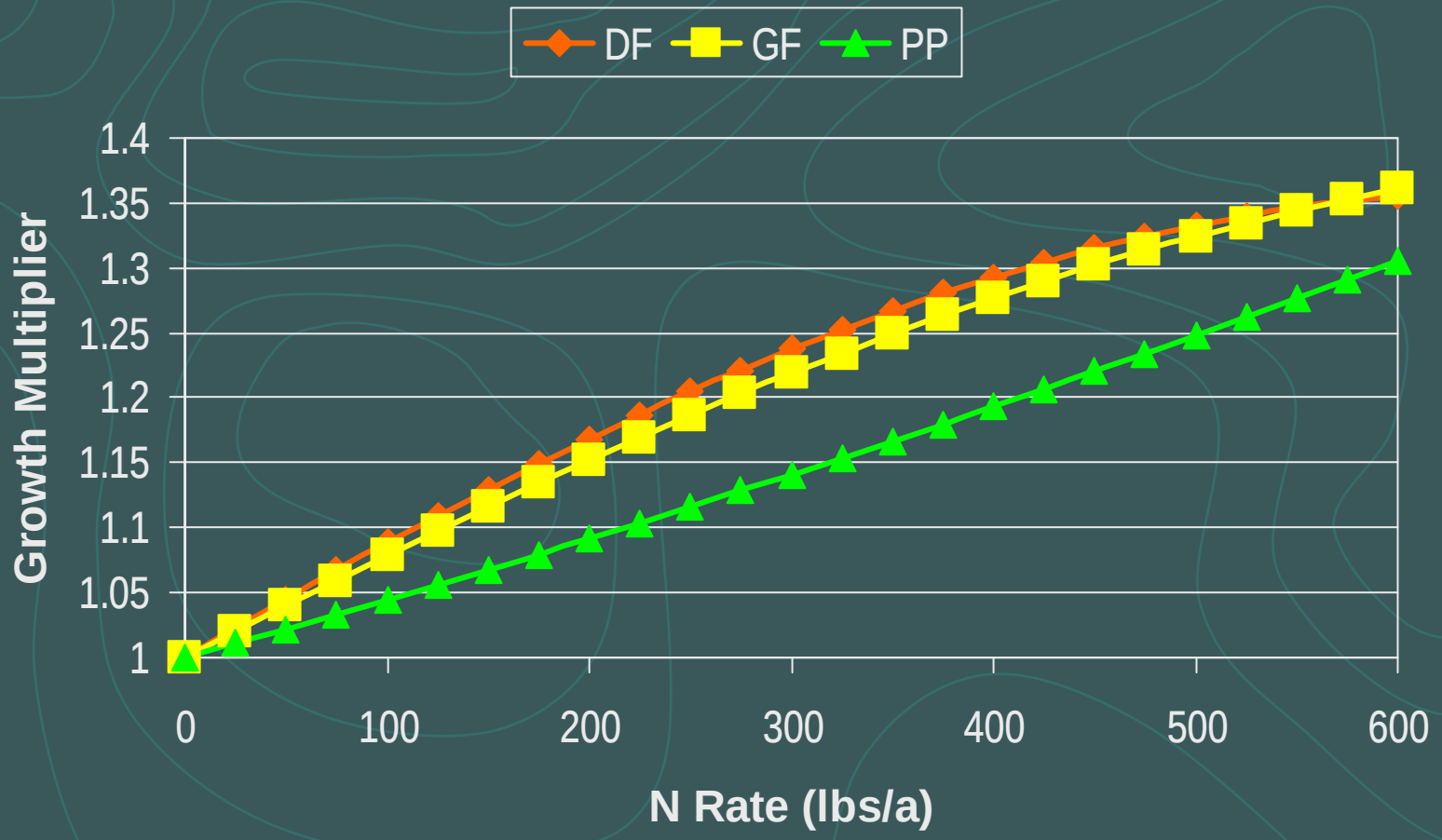
Sulfur and Micronutrients Effects: 8-year BA Response — Grand Fir



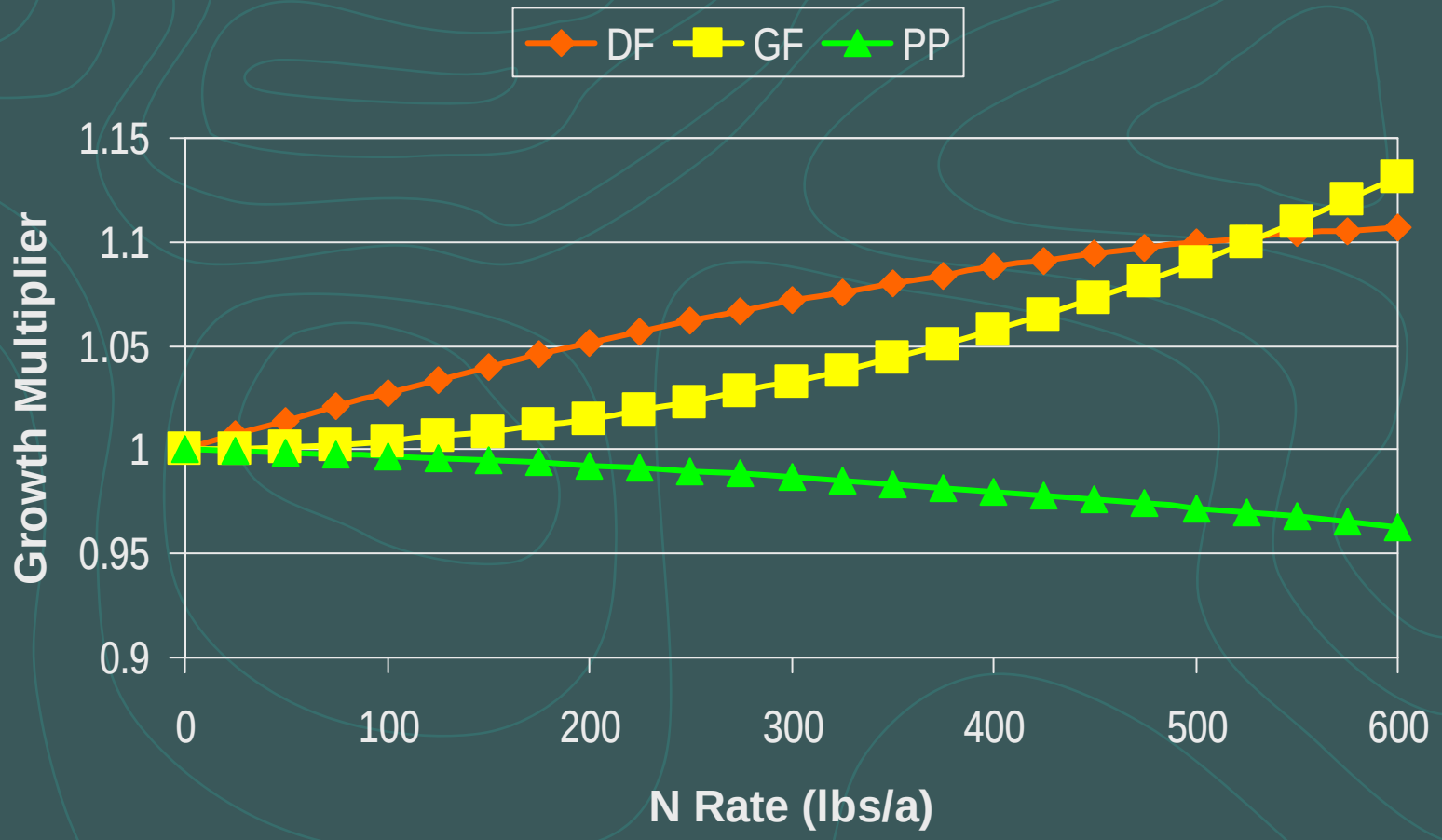
Sulfur and Micronutrients Effects: 8-year BA Mortality — Grand Fir



Species-specific growth multipliers: 10-year tree diameter growth



Species-specific growth multipliers: 10-year tree height growth



Forest Health Study
Diameter growth multipliers: DF