MIXING AND MATCHING: COMPOSITION AND DIVERSITY OF COMMERCIALLY AVAILABLE SEED MIXES COMPARED WITH REMNANT AND RESTORED TALLGRASS PRAIRIES

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NATIONAL NATIVE SEED STRATEGY

Action 3.3.3 Support field implementation of restoration tools

Species selection tool for restoration

Draft form

We can’t use it right now… BUT

Still lots of room for suggestions!

RESTORATION AND BIODIVERSITY

- Over 50 percent of managers purchase seed for prairie restoration (Rowe 2010)
- Commercial seed mixes are half as diverse as remnant prairies (Harmon-Threatt and Hendrix 2015)

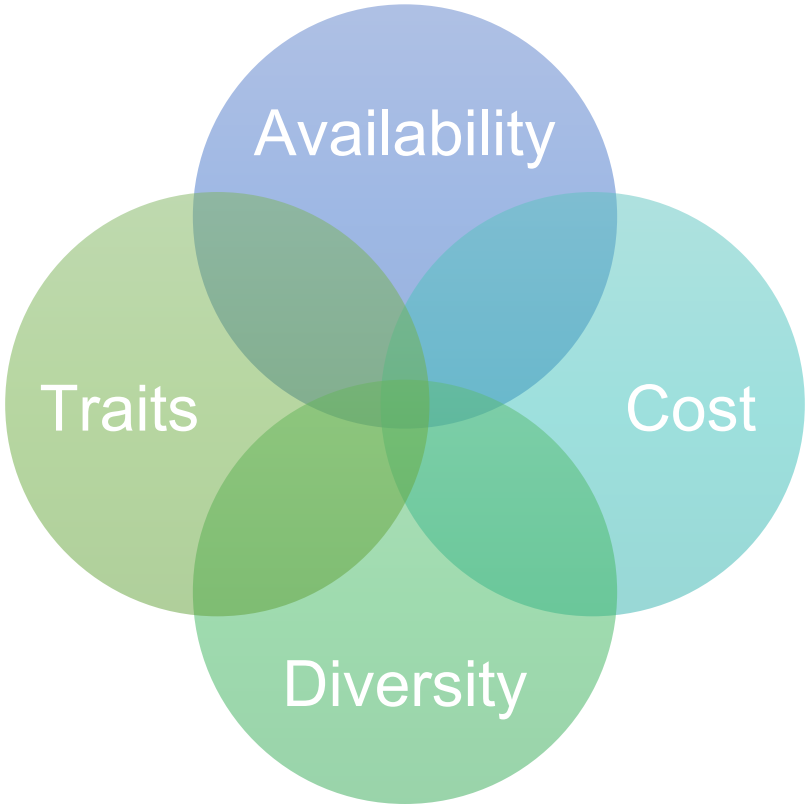
SPECIES SELECTION

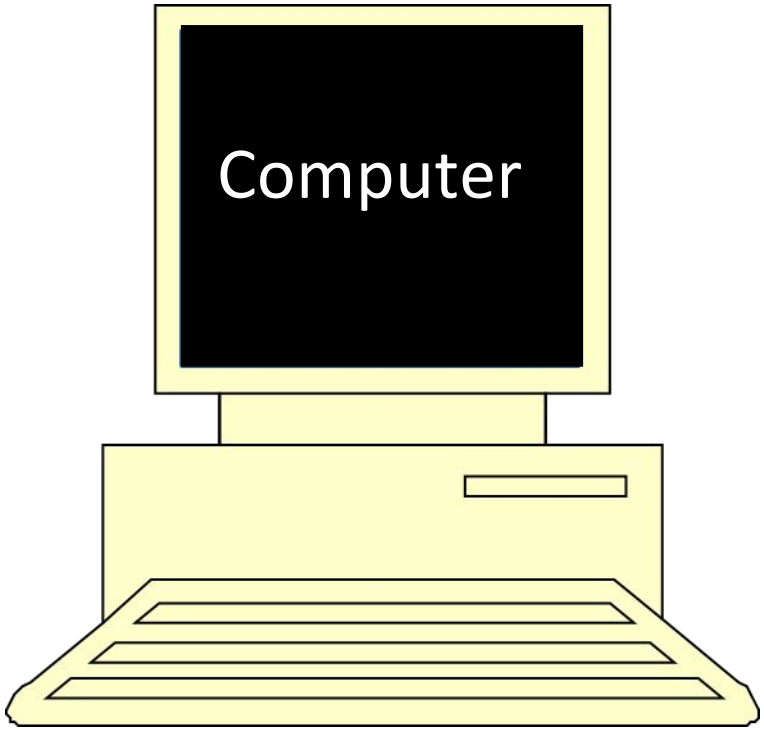
Constraints

- Availability
- Cost

Objectives

- Species richness
- Floristic quality (conservatism)
- Pollinator support
- Phylogenetic diversity




Computer


Prairie

1) How do commercially available seed mixes compare to remnant and restored prairies?

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Commercially available seed mixes

Community composition of remnant and restored prairies
Establishment from field seed mixes

2) HOW DO SEED MIXES BUILT BY COMPUTERS COMPARE TO ACTUAL SEED MIXES AND PRAIRIES?

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Computer model that incorporates species information, and price to create mixes with desired biodiversity characteristics

PART 1: COMMERCIALLY AVAILABLE MIXES

- Searched for “prairie seed mix,” “prairie mix,” and “native prairie seed mix”
- Collect information about the company and seed mix (ecosystem service, cost, seed rate, etc.)
- Collected species lists, % composition, seed rate, price for 4-5 mixes per company

PART 1: COMMERCIALLY AVAILABLE MIXES

- 67 mixes, 14 companies
- 215 species from 36 families

REMNANT AND RE
PRAIRIES (in Illinois)

Restored prairies

- 19 sites
- Initiated between 1998 and 2012
- Surveyed in 2015

Remnant prairies

- 41 reference sites
- Vegetation surveys: 2001 (Bowles and Jones)

BIODIVERSITY MEASURES

- Species richness
- Coefficient of conservatism (mean C)
- Phylogenetic diversity
- (Bloom time diversity)

Species richness

Species richness

F = 22.97, P < 0.0001

Commercial seed mixes had significantly lower species richness than remnant or restored prairies

Species richness of seed mixes ranged from 14-91 species (mean = 34.25)

Species richness

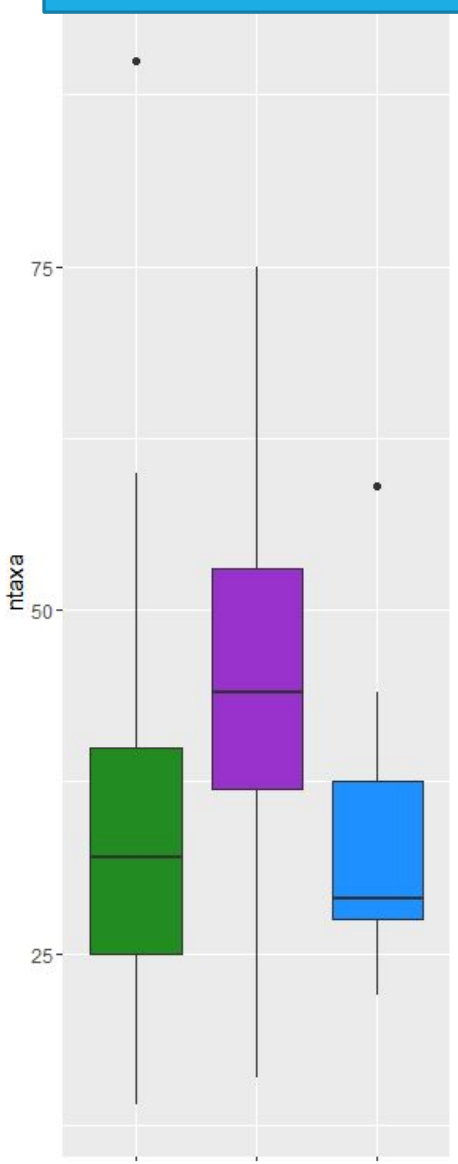
F = 9.77, P = 0.0001

What about weeds?

Commercial mixes had lower richness than both remnant and restored prairies (P=0.0002)

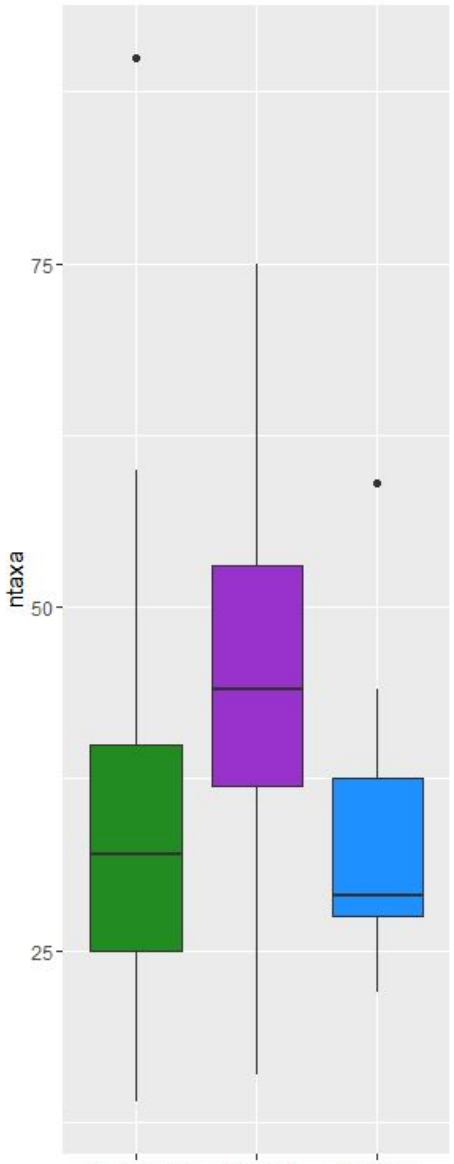
Species richness

Species richness (native)



Species richness

Species richness (native)



Mean C

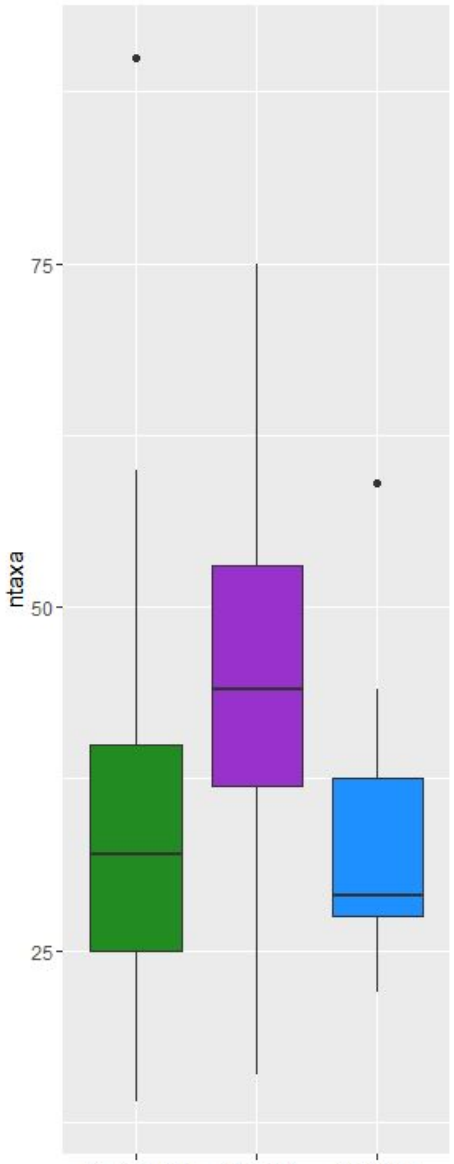
Coefficient of conservatism

0 – 10

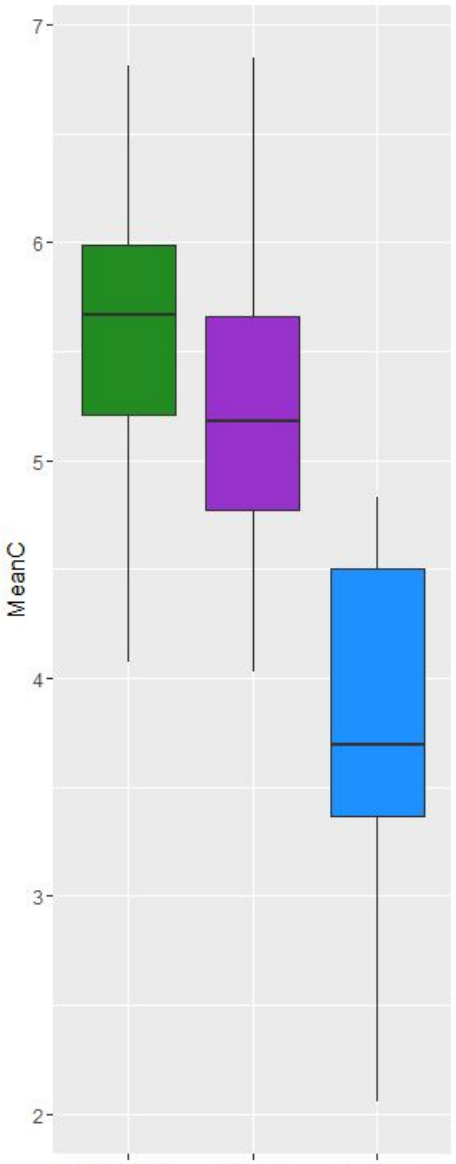
Habitat fidelity, disturbance tolerance

Species richness

Species richness (native)

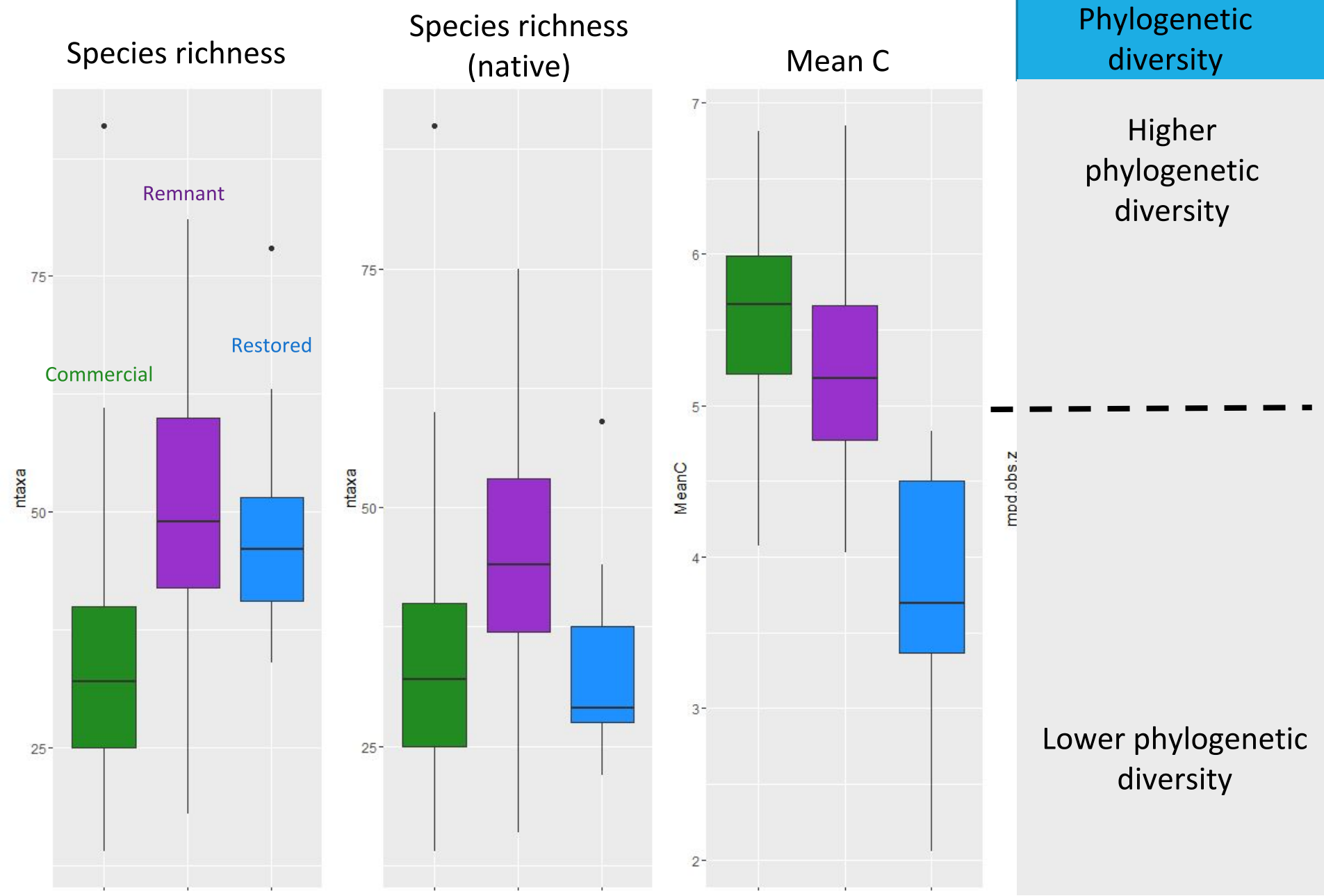


Mean C



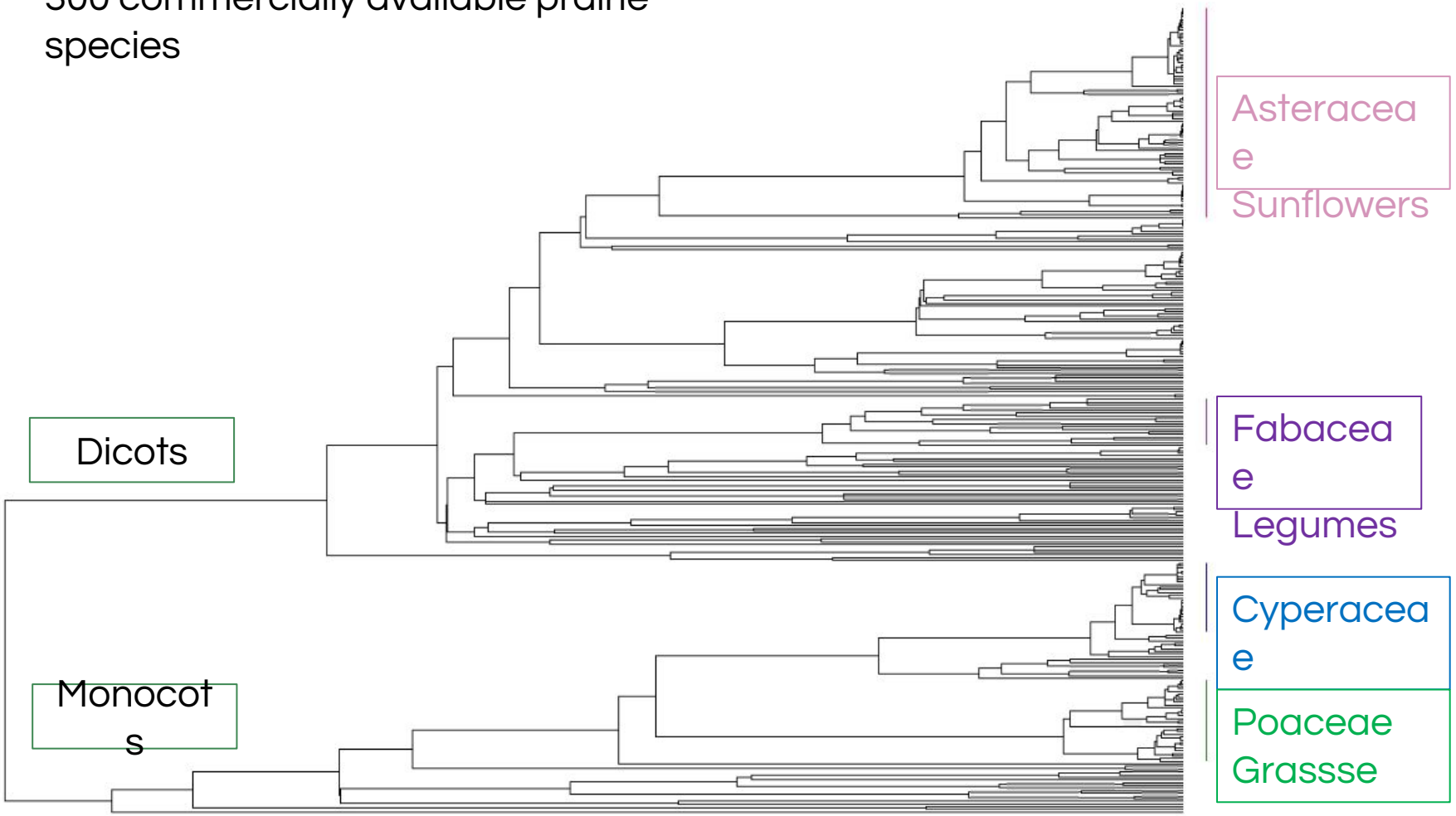
F = 59.05, P < 0.0001

Commercial seed mixes had higher mean C than remnants and restored prairies (P < 0.009).

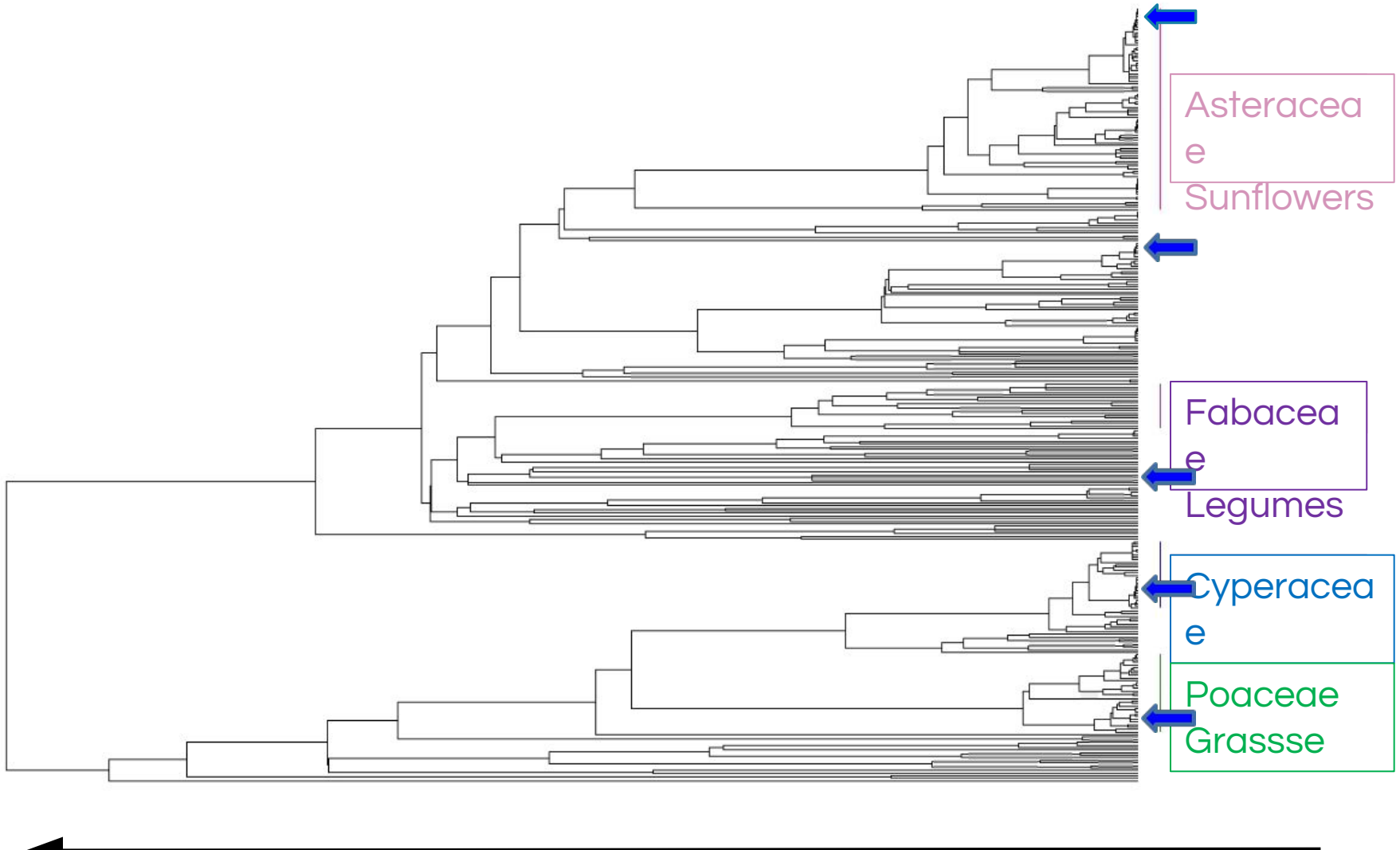

Species richness
Species richness (native)
Mean C
Phylogenetic diversity
Remnant
Commercial
Restored
ntaxa
ntaxa
MeanC
mpd.obs.z
75
50
25
7
6
5
4
3
2
Higher phylogenetic diversity
Lower phylogenetic diversity

PHYLOGENETIC DIVERSITY

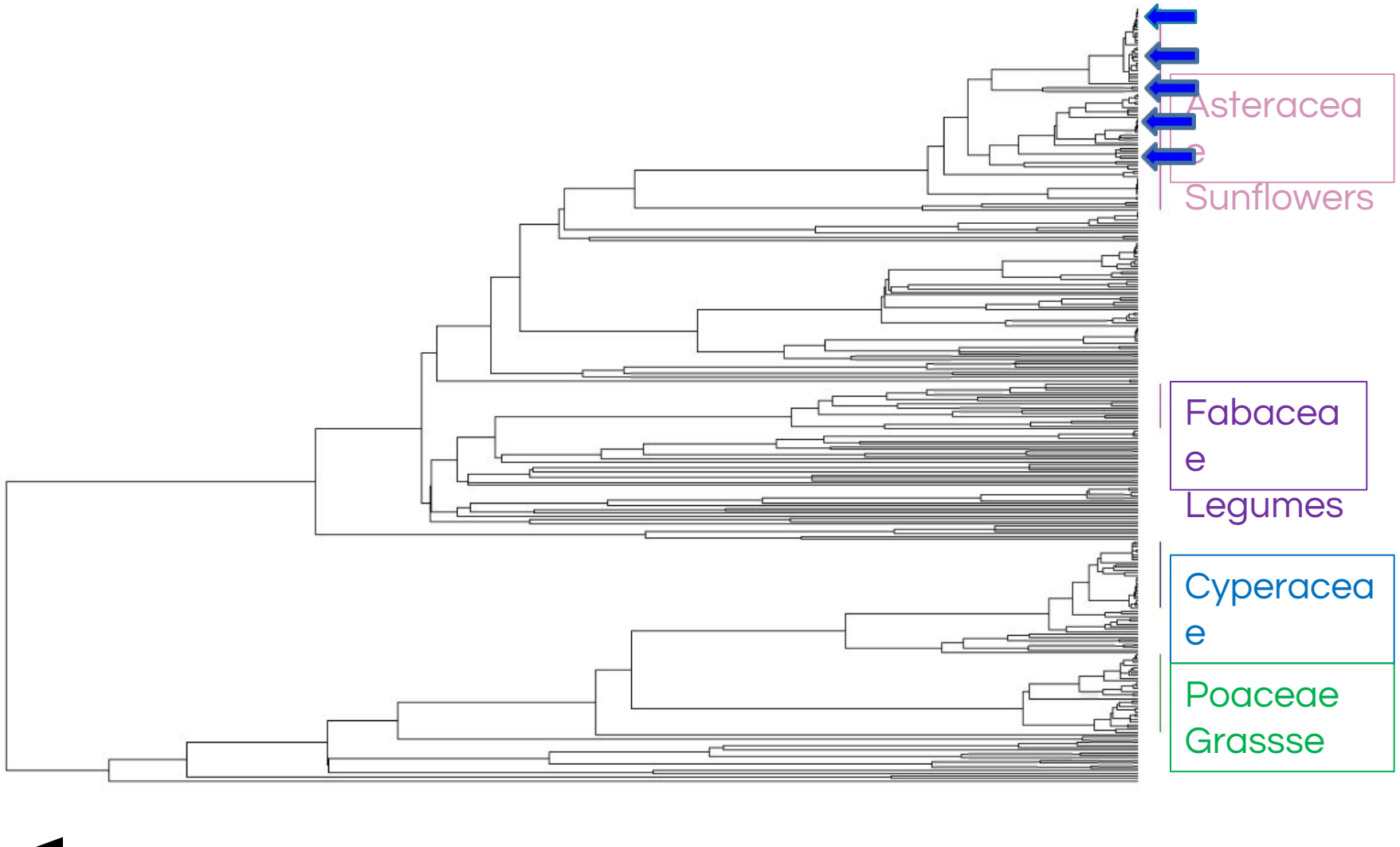
300 commercially available prairie species



PHYLOGENETIC DIVERSITY



PHYLOGENETIC DIVERSITY



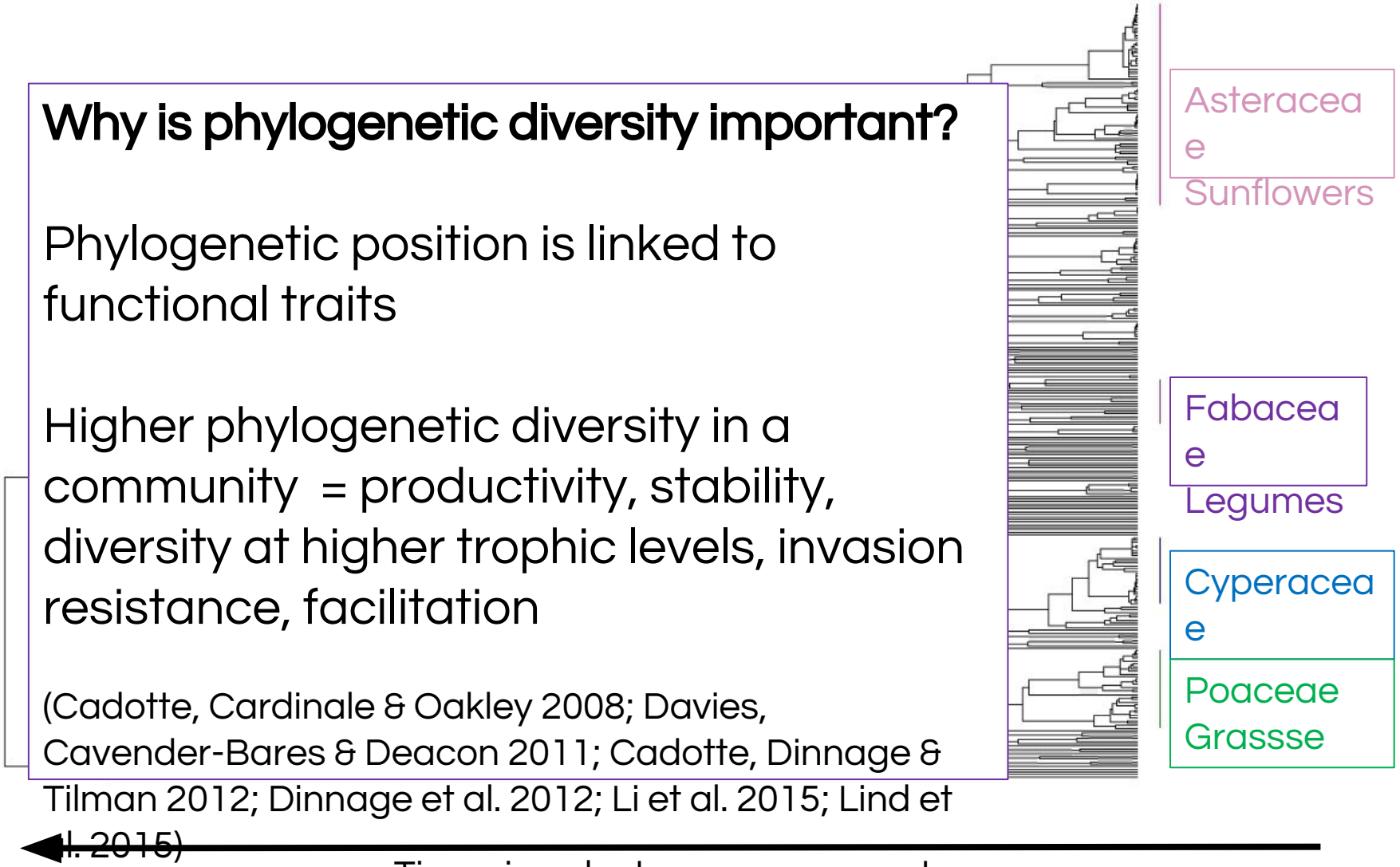
PHYLOGENETIC DIVERSITY

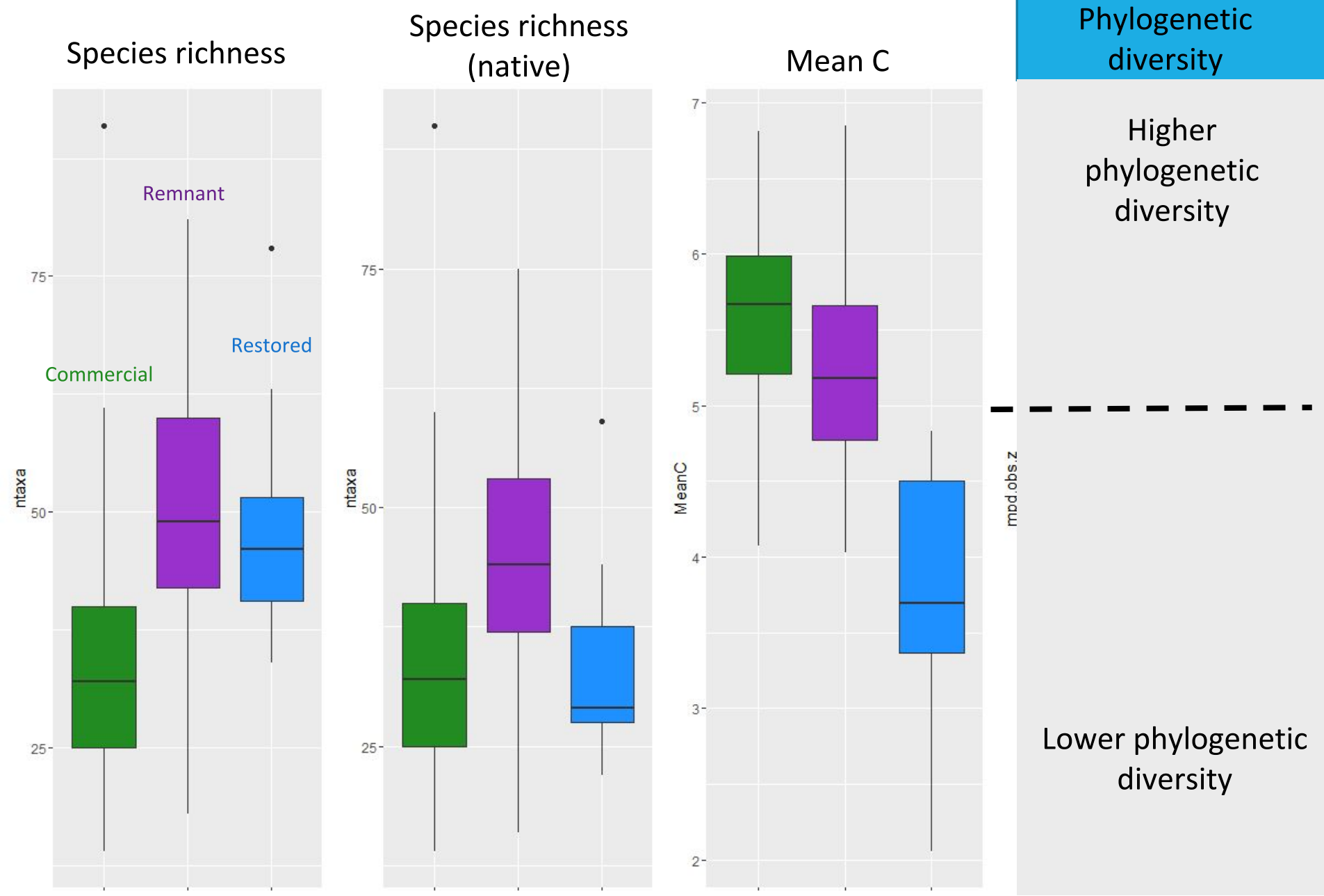
Why is phylogenetic diversity important?

Phylogenetic position is linked to functional traits

Higher phylogenetic diversity in a community = productivity, stability, diversity at higher trophic levels, invasion resistance, facilitation

(Cadotte, Cardinale & Oakley 2008; Davies, Cavender-Bares & Deacon 2011; Cadotte, Dinnage & Tilman 2012; Dinnage et al. 2012; Li et al. 2015; Lind et al. 2015)




Species richness
Species richness (native)
Mean C
Phylogenetic diversity
Remnant
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ntaxa
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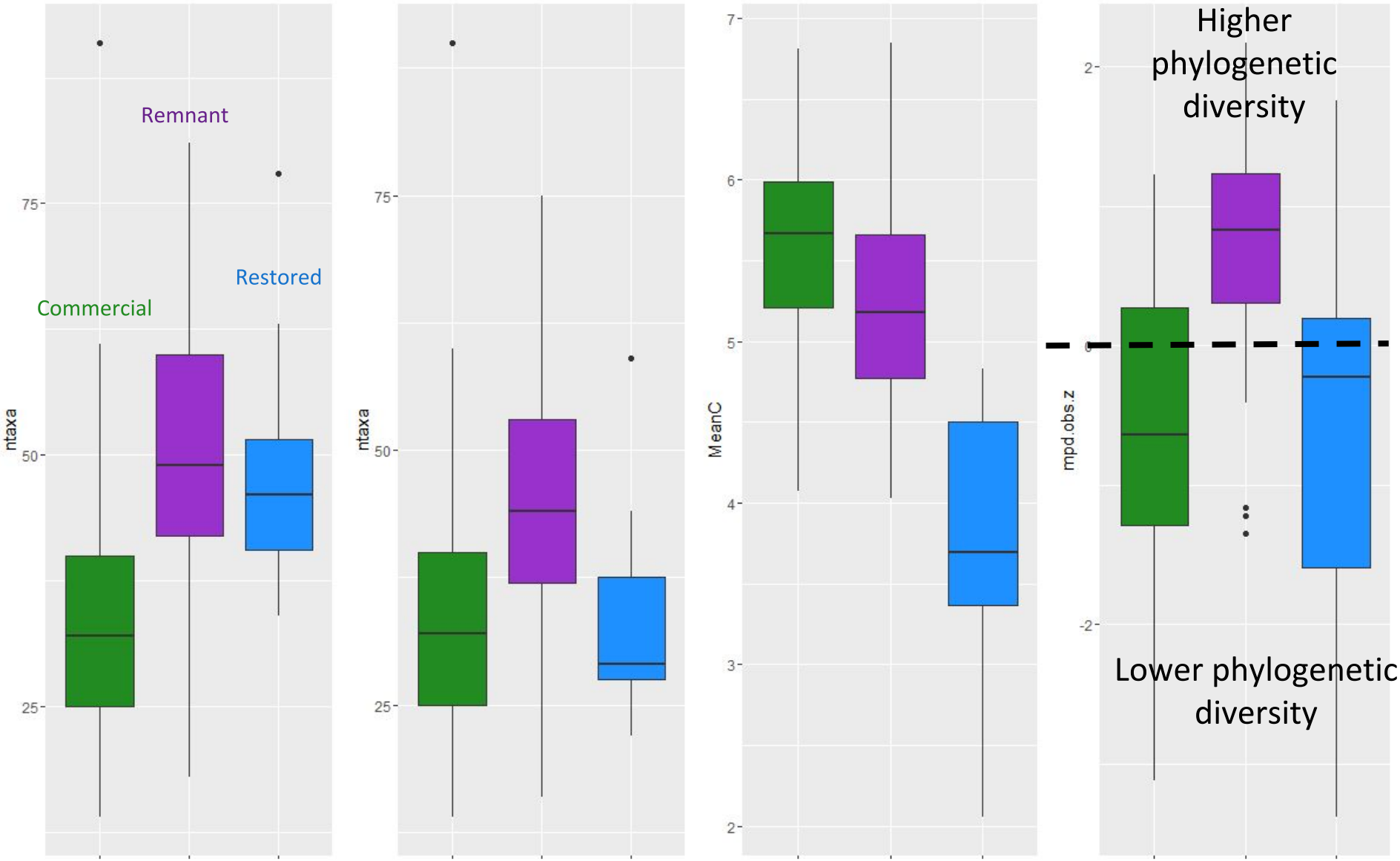
MeanC
mpd.obs.z
75
50
25
7
6
5
4
3
2
Higher phylogenetic diversity
Lower phylogenetic diversity

Species richness

Species richness (native)

Mean C

SES MPD



Commercial mixes had lower phylogenetic diversity than remnants ($P < 0.0001$) , but didn't differ from restored

$F = 21.05$, $P < 0.0001$

BUT…

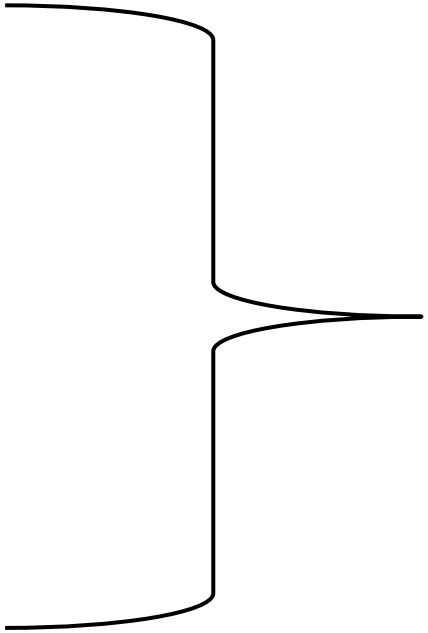
These mixes were (probably) not designed to maximize these multiple measures of biodiversity!

AND…

What if you want to meet all these objectives at once?

SPECIES SELECTION

- Constraints
  - Availability
  - Cost
- Objectives
  - Species richness
  - Floristic quality (conservatism)
  - Pollinator support
  - Phylogenetic diversity



How do you deal with these objectives all at once?

SPECIES SELECTION

- Constraints
  - Availability
  - Cost
- Objectives
  - Species richness
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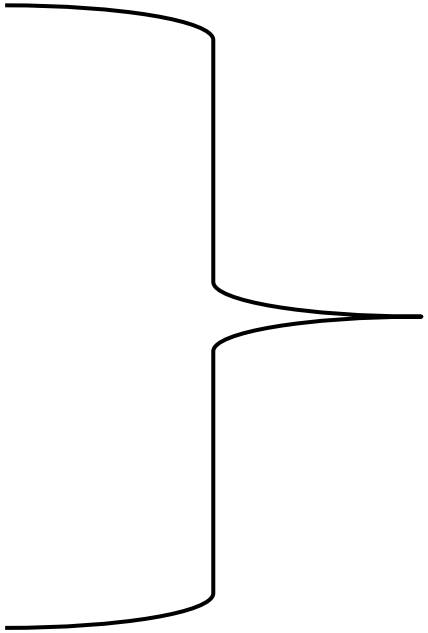
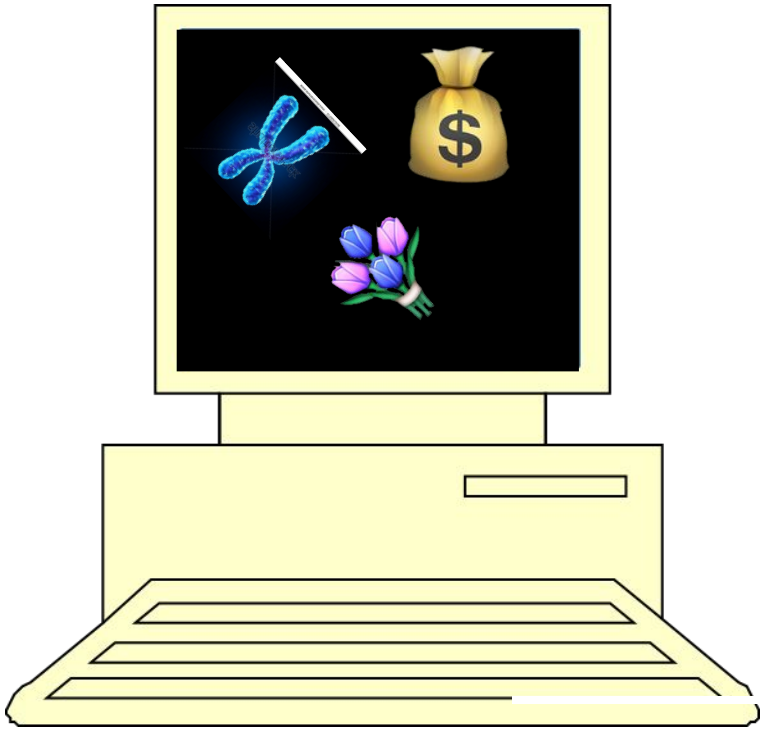
  - Pollinator support
  - Phylogenetic diversity



This is a **MULTI-OBJECTIVE RESTORATION PROBLEM**

COMPUTERS CAN HELP!



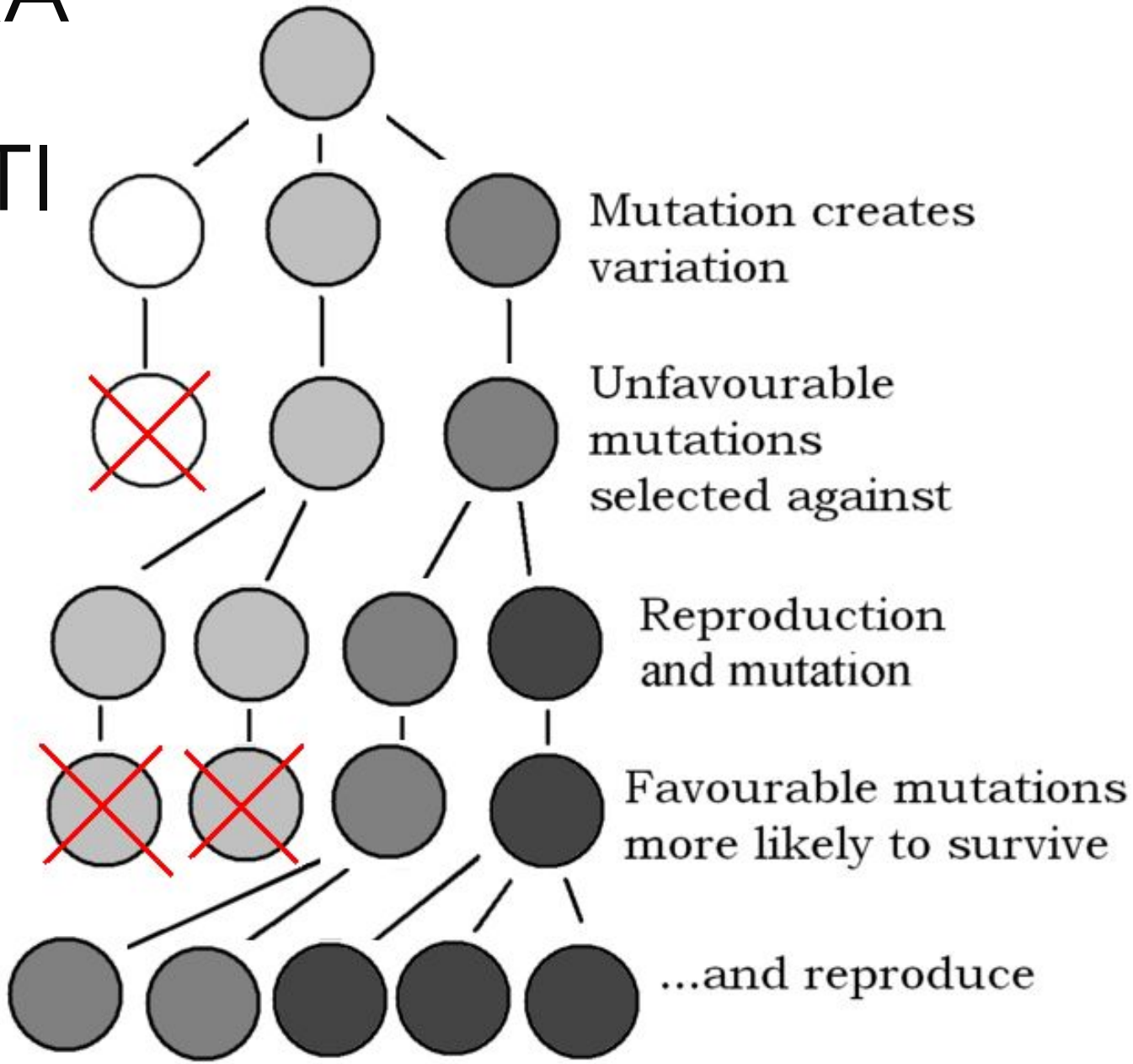
- How can we use machine learning to develop seed mixes that meet multiple biodiversity objectives?
- How do these mixes compare with currently available mixes and with prairies themselves?

PART 2:
COMPUTER – BUILT MIXES

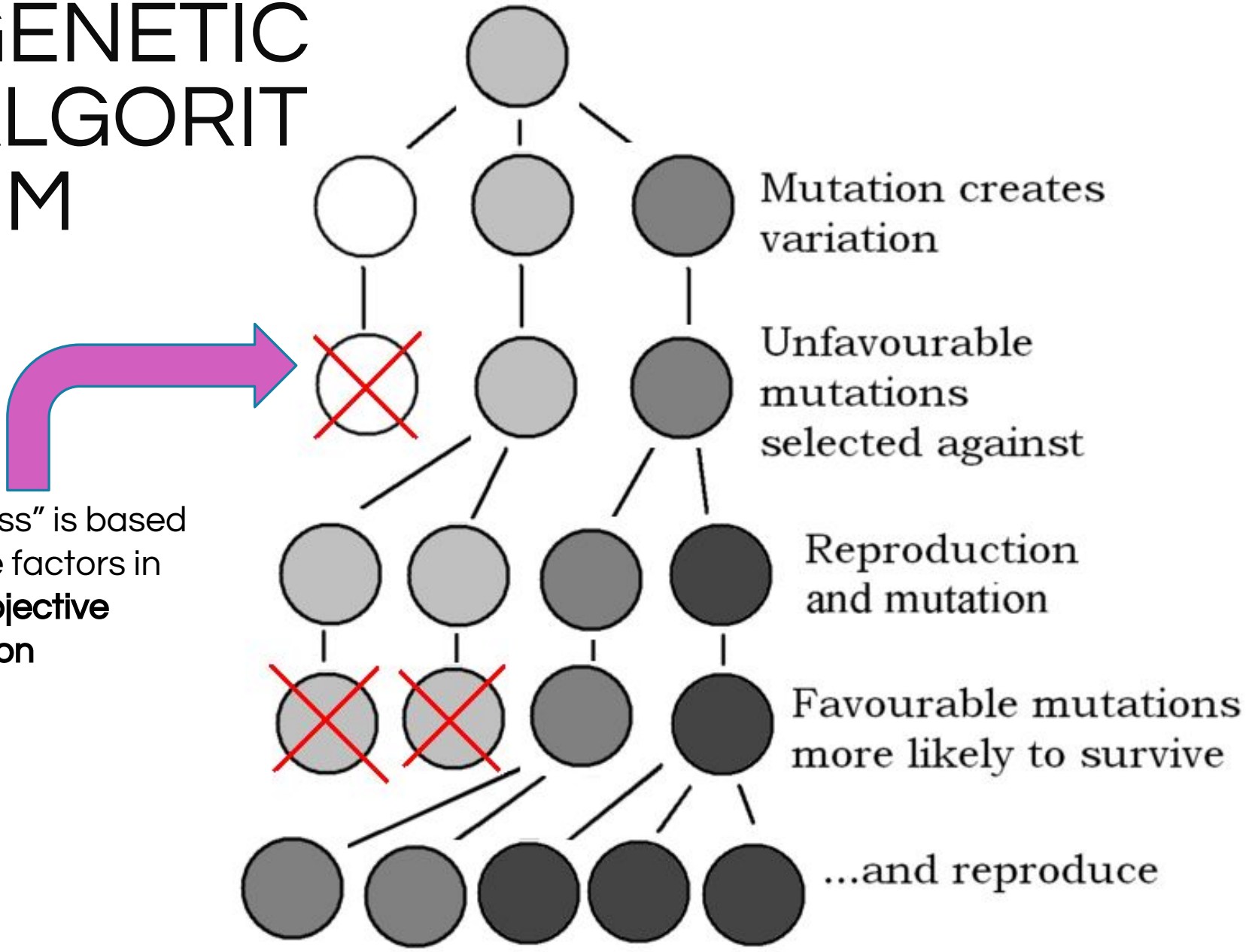
Decision analysis: *"formalization of common sense for decision problems which are too complex for informal use of common sense"*

–Keeney (1982)

NATURAL SELECTION



GENETIC ALGORITHM



"Fitness" is based on the factors in the **objective function**

GENETIC ALGORITHM

Individual = seed mix

"Fitness" = similarity to objective function

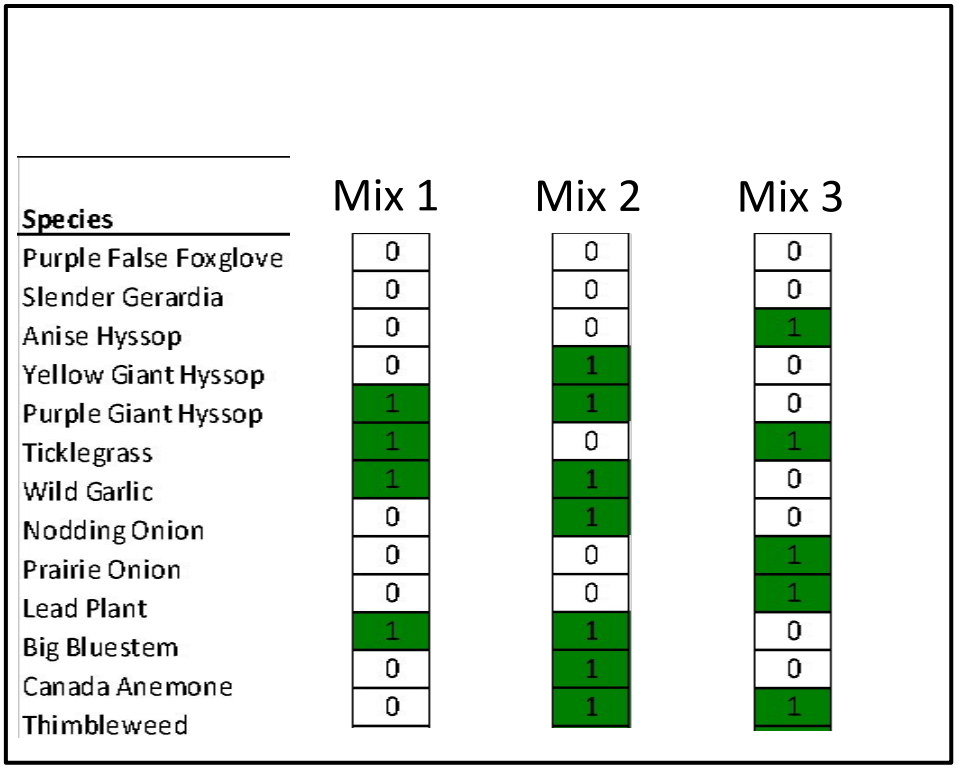
Objective function =

Species richness

C value

Bloom time diversity

Phylogenetic diversity



Species	Mix 1	Mix 2	Mix 3
Purple False Foxglove	0	0	0
Slender Gerardia	0	0	0
Anise Hyssop	0	0	1
Yellow Giant Hyssop	0	1	0
Purple Giant Hyssop	1	1	0
Ticklegrass	1	0	1
Wild Garlic	1	1	0
Nodding Onion	0	1	0
Prairie Onion	0	0	1
Lead Plant	0	0	1
Big Bluestem	1	1	0
Canada Anemone	0	1	0
Thimbleweed	0	1	1

WHAT ARE WE "FEEDING" THE GENETIC ALGORITHM?

- List of ~300 commercially available prairie species
- Price (Prairie Moon)
- C values (Swink and Wilhelm 1994)
- Bloom time variance (Prairie Moon)
- Phylogenetic distance matrix (from Zanne et al. 2014 phylogenetic tree)

SPECIES SELECTION TOOL

Scenario

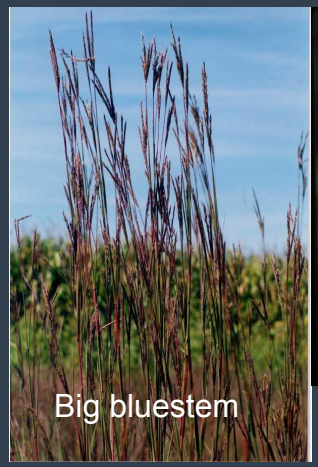
- Seeding: 10 lbs / acre
- Candidate species: 301
- Budget: $400 – $2,200 per acre

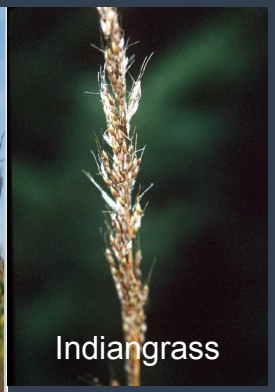
Photo: Justin Meissen

RESULTS FROM THE PRELIMINARY MODEL (40 SPECIES)

AcceptedName	Guild	Cost
Helianthus_maximiliani	FORB	$ 60
Oenothera_biennis	FORB	$ 90
Astragalus_canadensis	FORB	$ 90
Zizia_aurea	FORB	$ 90
Asclepias_syriaca	FORB	$ 120
Baptisia_alba	FORB	$ 150
Eupatorium_altissimum	FORB	$ 150
Allium_stellatum	FORB	$ 225
Oenothera_rhombipetala	FORB	$ 225
Zizia_aptera	FORB	$ 225
Eupatorium_maculatum	FORB	$ 300
Asclepias_tuberosa	FORB	$ 450
Cirsium_muticum	FORB	$ 600
Cirsium_discolor	FORB	$ 600
Helianthus_occidentalis	FORB	$ 600
Baptisia_bracteata	FORB	$ 750
Viola_sororia	FORB	$ 3,300
Andropogon_gerardii	GRAM	$ 12
Elymus_canadensis	GRAM	$ 15
Sorghastrum_nutans	GRAM	$ 18
Schizachyrium_scoparium	GRAM	$ 22
Sporobolus_compositus	GRAM	$ 30
Sporobolus_cryptandrus	GRAM	$ 30
Bromus_ciliatus	GRAM	$ 45
Bromus_kalmii	GRAM	$ 60
Sporobolus_heterolepis	GRAM	$ 120
Eleocharis_geniculata	GRAM	$ 150
Carex_hystericina	GRAM	$ 150
Juncus_interior	GRAM	$ 225
Carex_crinita	GRAM	$ 300
Eleocharis_acicularis	GRAM	$ 450
Carex_blanda	GRAM	$ 450
Juncus_tenuis	GRAM	$ 600
Juncus_nodosus	GRAM	$ 600
Eleocharis_compressa	GRAM	$ 2,100
Amorpha_canescens	WOOD	$ 225
Rosa_arkansana	WOOD	$ 375
Rosa_setigera	WOOD	$ 450
Chamaecrista_fasciculata	WOOD	$ 30

AcceptedName	Guild	Cost	$400	$600	$800
Helianthus_maximiliani	FORB	$ 60	0.160	0.501	0.314
Oenothera_biennis	FORB	$ 90	0.062	0.275	0.196
Astragalus_canadensis	FORB	$ 90	0.063	0.819	0.476
Zizia_aurea	FORB	$ 90	0.121	0.640	0.649
Asclepias_syriaca	FORB	$ 120	0.017	0.069	0.075
Baptisia_alba	FORB	$ 150	0.445	0.444	0.393
Eupatorium_altissimum	FORB	$ 150	0.000	0.020	0.006
Allium_stellatum	FORB	$ 225	0.000	0.063	0.086
Oenothera_rhombipetala	FORB	$ 225	0.000	0.007	0.000
Zizia_aptera	FORB	$ 225	0.082	0.091	0.064
Eupatorium_maculatum	FORB	$ 300	0.113	0.065	0.164
Asclepias_tuberosa	FORB	$ 450	0.000	0.063	0.063
Cirsium_muticum	FORB	$ 600	0.000	0.000	0.000
Cirsium_discolor	FORB	$ 600	0.000	0.000	0.000
Helianthus_occidentalis	FORB	$ 600	0.000	0.002	0.000
Baptisia_bracteata	FORB	$ 750	0.000	0.000	0.000
Viola_sororia	FORB	$ 3,300	0.000	0.000	0.000
Andropogon_gerardii	GRAM	$ 12	1.655	1.291	0.392
Elymus_canadensis	GRAM	$ 15	1.202	1.018	1.486
Sorghastrum_nutans	GRAM	$ 18	1.569	0.643	1.275
Schizachyrium_scoparium	GRAM	$ 22	0.386	0.786	0.669
Sporobolus_compositus	GRAM	$ 30	0.845	1.276	0.004
Sporobolus_cryptandrus	GRAM	$ 30	0.718	0.681	0.289
Bromus_ciliatus	GRAM	$ 45	1.053	0.111	0.407
Bromus_kalmii	GRAM	$ 60	0.644	0.078	1.162
Sporobolus_heterolepis	GRAM	$ 120	0.000	0.003	0.122
Eleocharis_geniculata	GRAM	$ 150	0.001	0.074	0.125
Carex_hystericina	GRAM	$ 150	0.001	0.107	0.477
Juncus_interior	GRAM	$ 225	0.000	0.064	0.370
Carex_crinita	GRAM	$ 300	0.000	0.063	0.063
Eleocharis_acicularis	GRAM	$ 450	0.000	0.001	0.000
Carex_blanda	GRAM	$ 450	0.000	0.012	0.000
Juncus_tenuis	GRAM	$ 600	0.000	0.002	0.000
Juncus_nodosus	GRAM	$ 600	0.000	0.000	0.000
Eleocharis_compressa	GRAM	$ 2,100	0.000	0.000	0.000
Amorpha_canescens	WOOD	$ 225	0.063	0.067	0.063
Rosa_arkansana	WOOD	$ 375	0.000	0.032	0.000
Rosa_setigera	WOOD	$ 450	0.000	0.008	0.192
Chamaecrista_fasciculata	WOOD	$ 30	0.799	0.627	0.418





Photos: USDA Plants

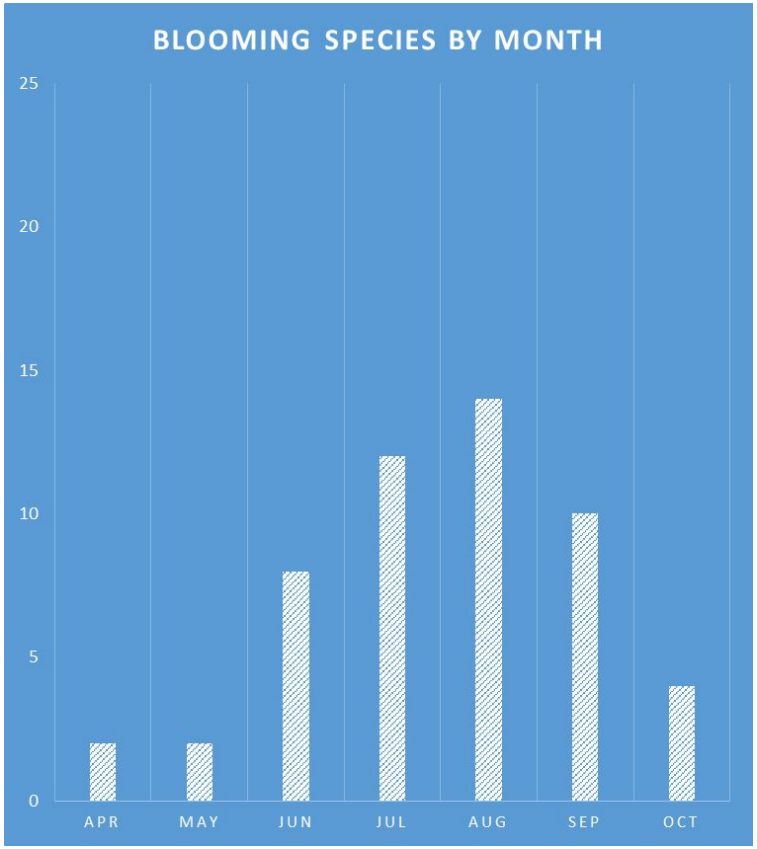
AcceptedName	Guild	Cost	$400	$600	$800	$1,000	$1,200	$1,400	$1,600	$1,800	$2,000	$2,200
Helianthus_maximiliani	FORB	$ 60	0.160	0.501	0.314	0.005	0.935	1.053	0.012	0.872	0.613	0.019
Oenothera_biennis	FORB	$ 90	0.062	0.275	0.196	0.377	0.069	0.118	0.108	0.001	0.041	0.185
Astragalus_canadensis	FORB	$ 90	0.063	0.819	0.476	0.084	0.182	0.607	0.175	0.092	0.157	0.082
Zizia_aurea	FORB	$ 90	0.121	0.640	0.649	0.306	0.084	1.379	0.612	0.236	0.621	0.079
Asclepias_syriaca	FORB	$ 120	0.017	0.069	0.075	0.022	0.127	0.028	0.138	0.805	0.010	0.024
Baptisia_alba	FORB	$ 150	0.445	0.444	0.393	0.461	0.219	0.588	0.150	0.072	0.069	0.234
Eupatorium_altissimum	FORB	$ 150	0.000	0.020	0.006	1.326	0.882	0.345	0.819	0.001	0.005	0.007
Allium_stellatum	FORB	$ 225	0.000	0.063	0.086	0.227	0.131	0.080	0.075	0.075	0.125	0.078
Oenothera_rhombipetala	FORB	$ 225	0.000	0.007	0.000	0.031	0.045	0.004	0.001	0.001	0.020	0.708
Zizia_aptera	FORB	$ 225	0.082	0.091	0.064	0.202	0.163	0.063	0.288	0.136	0.079	0.679
Eupatorium_maculatum	FORB	$ 300	0.113	0.065	0.164	0.082	0.506	0.015	0.228	0.003	0.001	0.131
Asclepias_tuberosa	FORB	$ 450	0.000	0.063	0.063	0.067	0.000	0.065	0.083	0.456	0.172	0.717
Cirsium_muticum	FORB	$ 600	0.000	0.000	0.000	0.003	0.000	0.194	0.265	0.063	0.079	0.065
Cirsium_discolor	FORB	$ 600	0.000	0.000	0.000	0.002	0.000	0.001	0.716	0.361	0.004	0.004
Helianthus_occidentalis	FORB	$ 600	0.000	0.002	0.000	0.066	0.000	0.313	0.002	0.086	0.066	0.118
Baptisia_bracteata	FORB	$ 750	0.000	0.000	0.000	0.002	0.000	0.001	0.083	0.063	0.684	0.272
Viola_sororia	FORB	$ 3,300	0.000	0.000	0.000	0.004	0.000	0.000	0.001	0.000	0.013	0.001
Andropogon_gerardii	GRAM	$ 12	1.655	1.291	0.392	0.937	0.333	0.010	0.566	0.940	0.025	0.024
Elymus_canadensis	GRAM	$ 15	1.202	1.018	1.486	0.838	0.248	0.436	0.901	0.002	0.222	1.693
Sorghastrum_nutans	GRAM	$ 18	1.569	0.643	1.275	0.237	0.410	0.501	0.785	1.009	0.949	0.030
Schizachyrium_scoparium	GRAM	$ 22	0.386	0.786	0.669	1.238	0.543	0.001	0.024	0.001	0.020	0.017
Sporobolus_compositus	GRAM	$ 30	0.845	1.276	0.004	0.028	0.388	0.007	0.292	0.012	0.688	1.084
Sporobolus_cryptandrus	GRAM	$ 30	0.718	0.681	0.289	0.652	0.269	1.321	0.672	0.071	0.007	0.097
Bromus_ciliatus	GRAM	$ 45	1.053	0.111	0.407	0.787	0.191	0.144	0.114	0.991	0.573	0.291
Bromus_kalmii	GRAM	$ 60	0.644	0.078	1.162	0.126	1.782	0.242	0.270	0.094	0.791	0.074
Sporobolus_heterolepis	GRAM	$ 120	0.000	0.003	0.122	0.286	0.001	0.378	0.074	0.088	0.816	0.114
Eleocharis_geniculata	GRAM	$ 150	0.001	0.074	0.125	0.372	0.117	0.595	0.182	0.078	0.748	0.597
Carex_hystericina	GRAM	$ 150	0.001	0.107	0.477	0.151	0.914	0.002	0.731	0.001	0.492	0.262
Juncus_interior	GRAM	$ 225	0.000	0.064	0.370	0.158	0.091	0.315	0.288	1.378	0.074	0.130
Carex_crinita	GRAM	$ 300	0.000	0.063	0.063	0.068	0.152	0.250	0.104	0.152	0.540	0.090
Eleocharis_acicularis	GRAM	$ 450	0.000	0.001	0.000	0.001	0.000	0.015	0.008	0.001	0.007	0.003
Carex_blanda	GRAM	$ 450	0.000	0.012	0.000	0.001	0.000	0.000	0.003	0.000	0.001	0.018
Juncus_tenuis	GRAM	$ 600	0.000	0.002	0.000	0.001	0.259	0.000	0.026	0.000	0.009	0.662
Juncus_nodosus	GRAM	$ 600	0.000	0.000	0.000	0.003	0.000	0.204	0.063	0.063	0.065	0.109
Eleocharis_compressa	GRAM	$ 2,100	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.089	0.069
Amorpha_canescens	WOOD	$ 225	0.063	0.067	0.063	0.200	0.063	0.177	0.091	1.155	0.746	0.653
Rosa_arkansana	WOOD	$ 375	0.000	0.032	0.000	0.104	0.002	0.080	0.117	0.509	0.064	0.075
Rosa_setigera	WOOD	$ 450	0.000	0.008	0.192	0.081	0.254	0.077	0.069	0.066	0.093	0.070
Chamaecrista_fasciculata	WOOD	$ 30	0.799	0.627	0.418	0.459	0.640	0.391	0.865	0.067	0.221	0.435

Photos: USDA Plants

RETURN ON INVESTMENT

Phenology

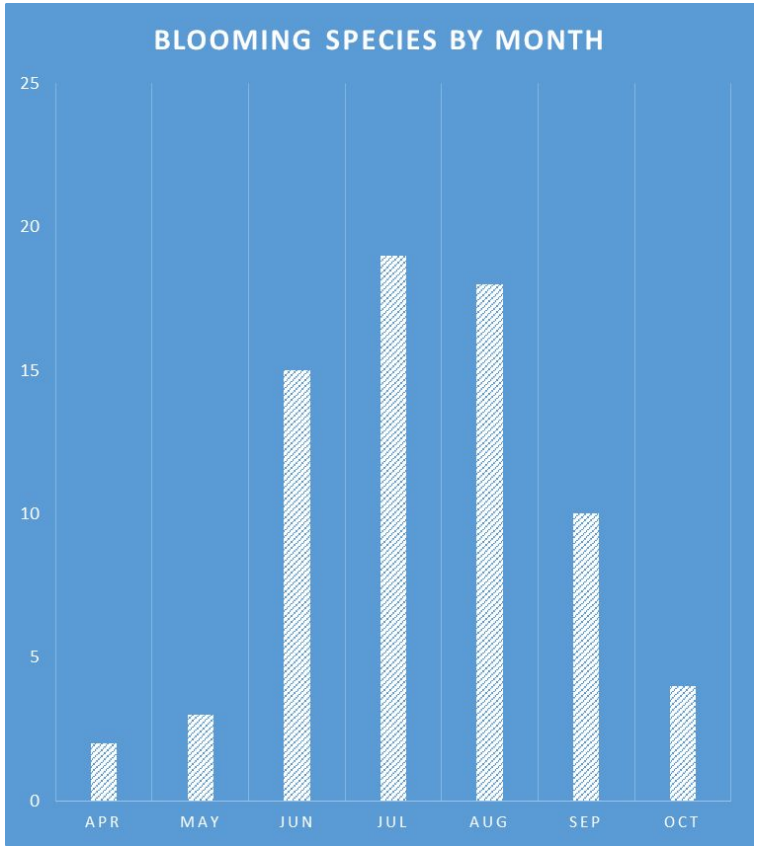
$400 mix



RETURN ON INVESTMENT

Phenology

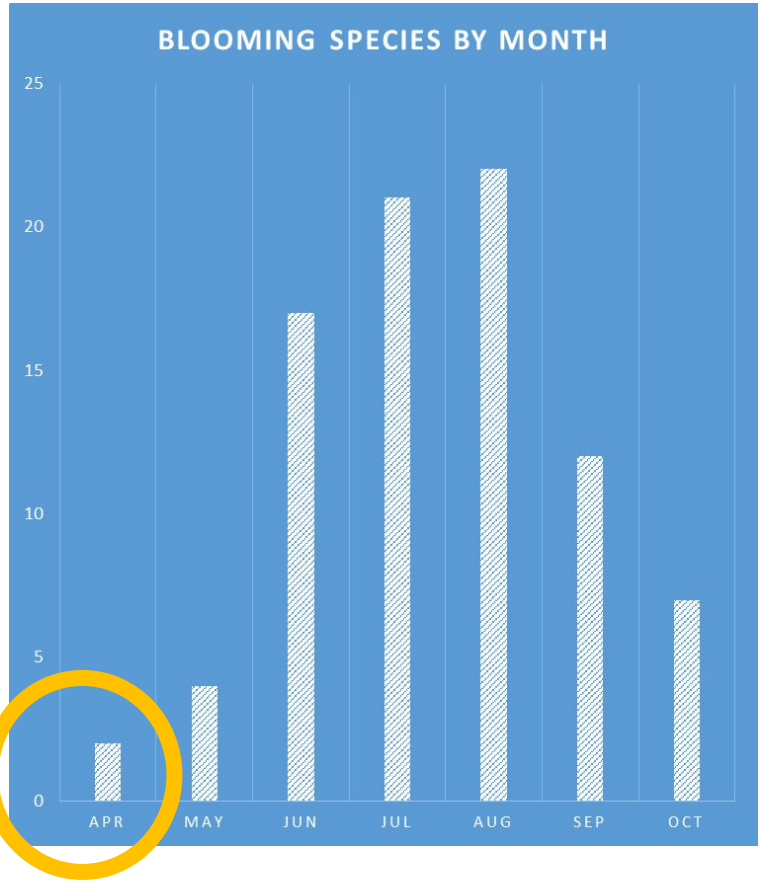
$800 mix

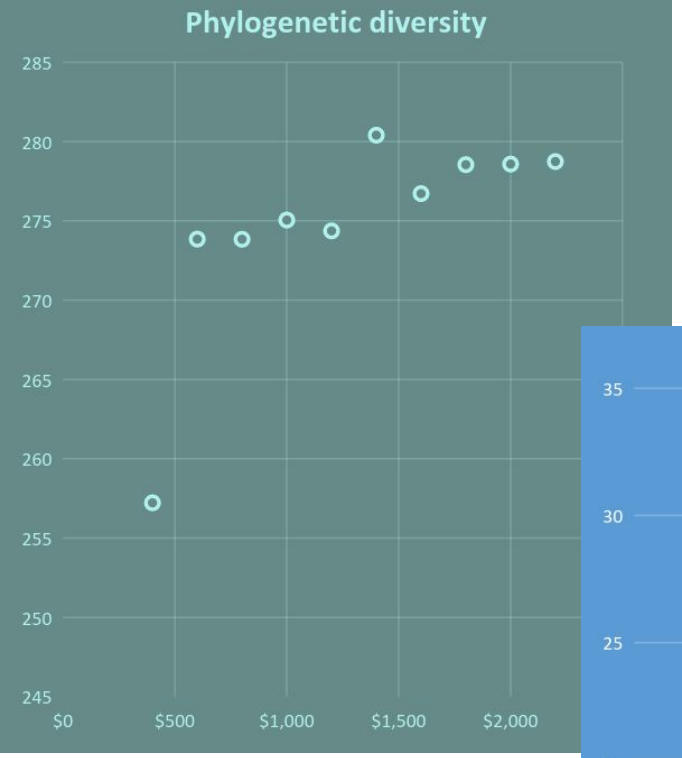


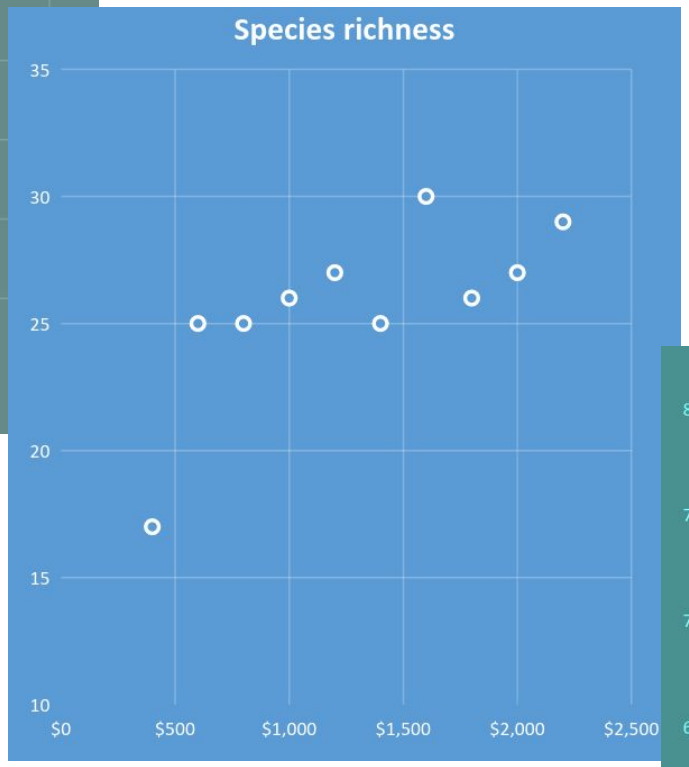
RETURN ON INVESTMENT

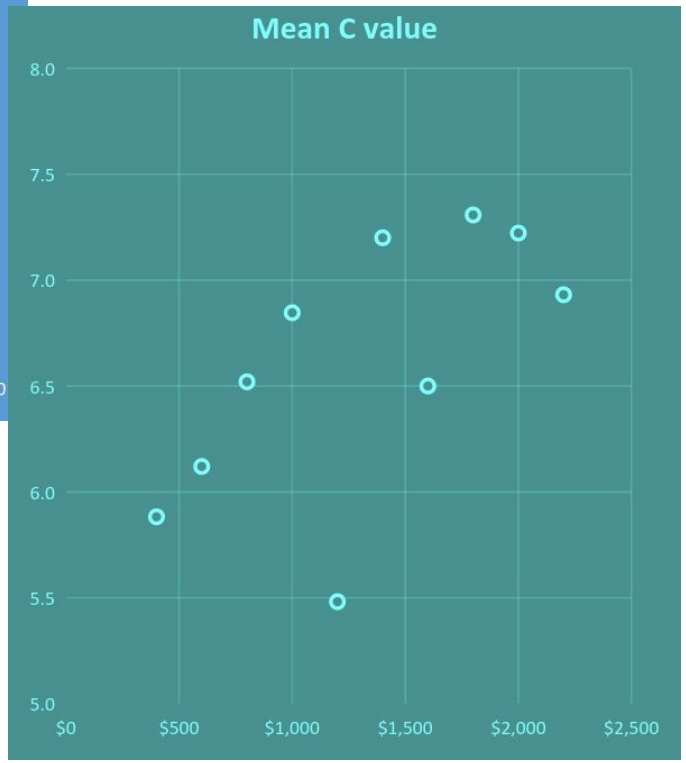
Phenology

$1,600 mix




Phylogenetic diversity
285
280
275
270
265
260
255
250
245
$0
$500
$1,000
$1,500
$2,000


Species richness
35
30
25
20
15
10
$0
$500
$1,000
$1,500
$2,000
$2,500


Mean C value
8.0
7.5
7.0
6.5
6.0
5.5
5.0
$0
$500
$1,000
$1,500
$2,000
$2,500

Conservation Letters
A journal of the Society for Conservation Biology

LETTER

A Tool for Selecting Plants When Restoring Habitat for Pollinators

Leithen K. M'Gonigle[1,2], Neal M. Williams[3], Eric Lonsdorf[4], & Claire Kremen[2]

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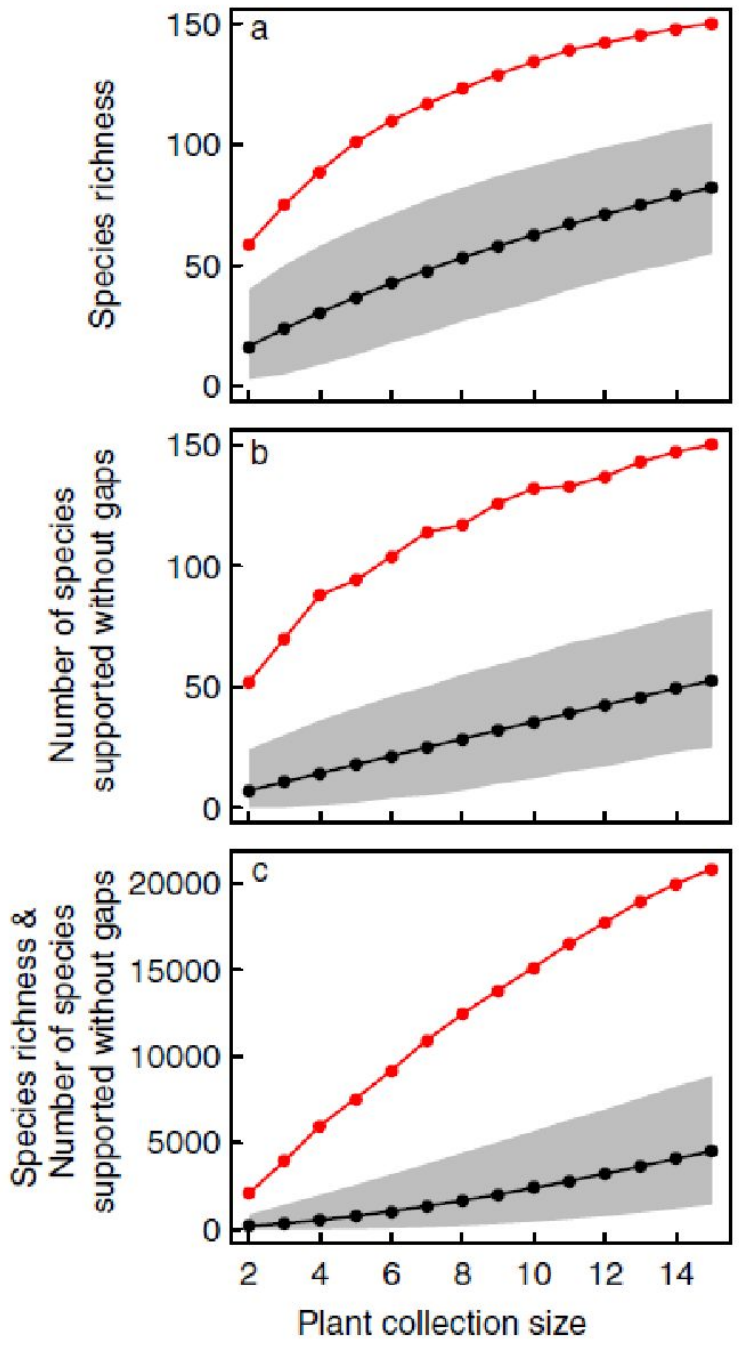
[4] Franklin and Marshall College, Lancaster, PA 17604, USA

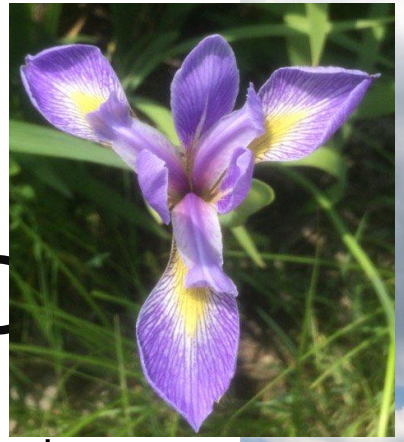


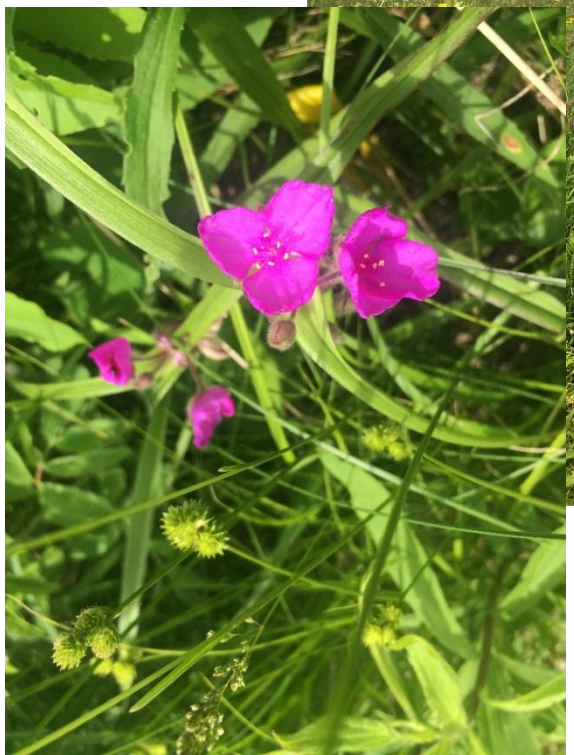

THE
PRAIRIE
ELEPHANT

SPECIES BIO

Germination & Establishment

Not all planted species become part of the realized community





GERMINATION AND ESTABLISHMENT

- 18/56 species didn't establish at all (Hillhouse and Zedler 2011)
- Restored prairies share only 1/3 of species with their planted seed mix (Grman et al. 2015)
- Between 25 – 77 percent (mean: 45 ± 4.0 %) of planted species found at sites

SYNTHESIS AND NEXT STEPS

Comparing computer designed results to ready-made mixes

Working in additional traits (i.e., establishment!)

Increasing customizability

- Constraints
- Objectives

Creating a (useful) decision-support tool for restoration design

TALK TO ME

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QUESTIONS

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This and additional presentations available at http://nativeseed.info

NATIVE SEED NETWORK

Institute for Applied Ecology