

Using a functional trait approach to study insect community ecology

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THE OHIO STATE UNIVERSITY

COLLEGE OF FOOD, AGRICULTURAL,
AND ENVIRONMENTAL SCIENCES

Community ecology

A group of organisms representing multiple species living in a specified place and time (Vellend 2010)

- Focal set of species
- Spatial and/or temporal scales of interest

Traditional research approach – focused on taxonomy

- Abundance
- Richness
- Evenness
- Diversity

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Limitations to taxonomic approaches

- Context dependencies

Trait-based ecology

Uses traits to generalize patterns beyond taxa and locations (de Bello et al. 2021)

- Allows comparison between studies, ecosystems, and biomes (Moretti et al. 2017)

Improve mechanistic understanding of ecological processes (Mason and Bello 2013)

Assumption: Traits are more predictable than species

Functional Ecology

 BRITISH
ECOLOGICAL
SOCIETY

What is a trait and what makes a trait functional?

Any morphological, physiological, phenological, or behavioral character measurable at the individual level, from the cell to the organism

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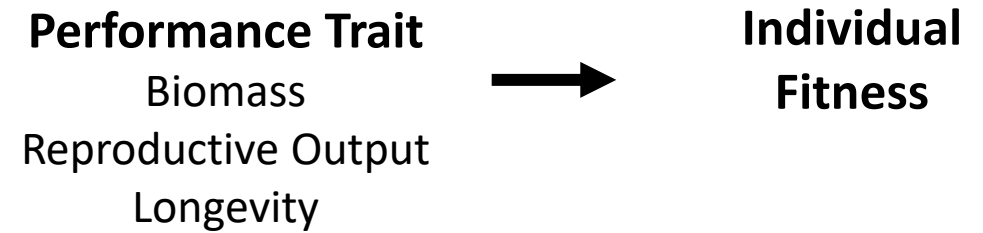
Impact fitness of an individual directly or indirectly via effects on growth, reproduction, and survival

- Should be heritable

Types of traits

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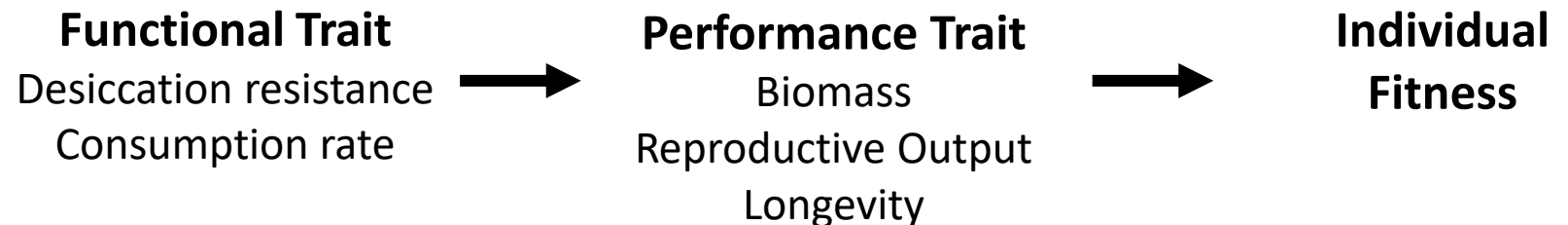
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Response traits: determines the response of an individual to environmental changes or to an interaction with another, affecting the performance

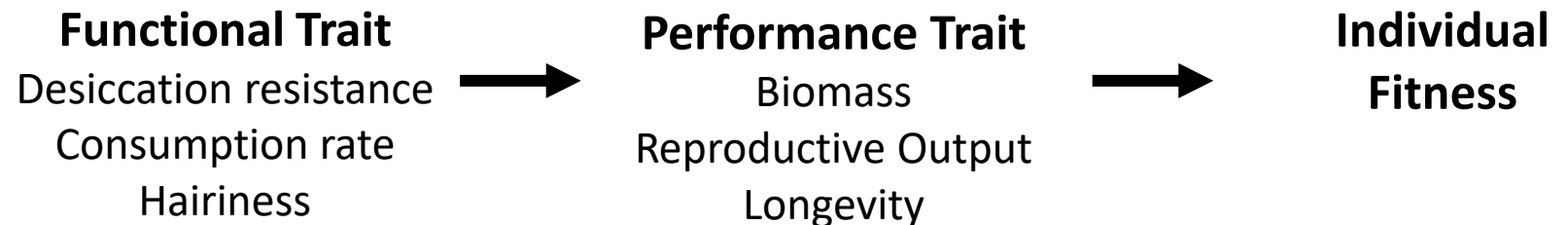


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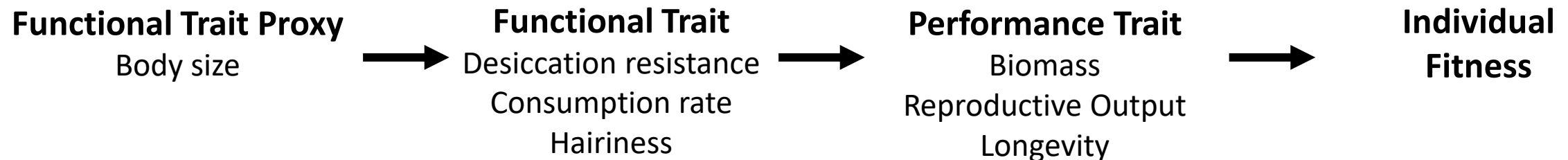
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Functional trait proxy: correlated with functional traits, but often easier to measure



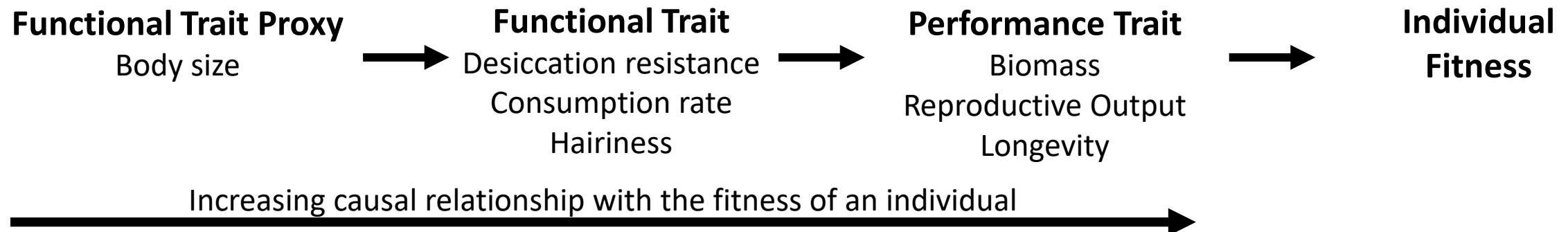
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Development of functional trait framework for arthropods



Insect Conservation and Diversity (2016) doi: 10.1111/icad.12211

TECHNIQUES & METHODOLOGY

***GlobalAnts*: a new database on the geography of ant traits (Hymenoptera: Formicidae)**

CATHERINE L. PARR,^{1,2} ROBERT R. DUNN,³ NATHAN J. SANDERS,⁴ MICHAEL D. WEISER,⁵ MANOLI PHOTAKIS,⁶ TOM R. BISHOP,^{1,7} MATTHEW C. FITZPATRICK,⁸ XAVIER ARNAN,⁹ FABRICIO BACCARO,¹⁰ CARLOS R. F. BRANDÃO,¹¹ LACY CHICK,¹² DAVID A. DONOSO,¹³ TOM M. FAYLE,^{14,15} CRISANTO GÓMEZ,¹⁶ BLAIR GROSSMAN,⁶ THINANDAVHA C. MUNYAI,¹⁷ RENATA PACHECO,¹⁸ JAVIER RETANA,¹⁹ ANDREW ROBINSON,⁶ KATAYO SAGATA,^{6,20} ROGÉRIO R. SILVA,²¹ MELANIE TISTA,²² HERALDO VASCONCELOS,¹⁸ MICHELLE YATES²³ and HELOISE GIBB⁶ ¹Department of Earth, Ocean and Ecological



Ecological Entomology (2015), **40**, 1–13

DOI: 10.1111/een.12158

INVITED REVIEW

Moving beyond the guild concept: developing a practical functional trait framework for terrestrial beetles

NICHOLAS M. FOUNTAIN-JONES,¹ SUSAN C. BAKER^{1,2} and GREGORY J. JORDAN¹ ¹School of Biological Science, University of Tasmania, Hobart, Australia and ²Forestry Tasmania, Hobart, Australia

Functional Ecology



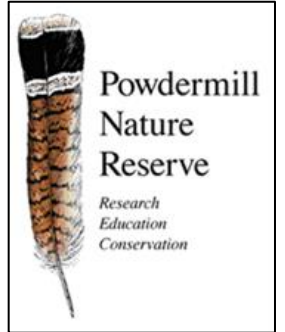
Functional Ecology 2017, **31**, 558–567

doi: 10.1111/1365-2435.12776

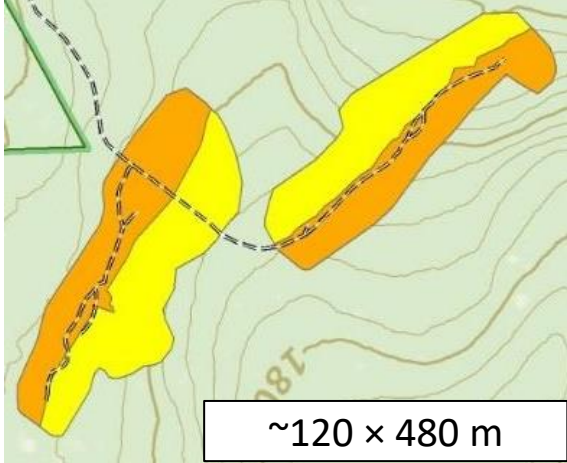
Handbook of protocols for standardized measurement of terrestrial invertebrate functional traits

Marco Moretti^{*,1}, André T. C. Dias², Francesco de Bello^{3,4}, Florian Altermatt^{5,6}, Steven L. Chown⁷, Francisco M. Azcarate⁸, James R. Bell⁹, Bertrand Fournier¹⁰, Mickaël Hedde¹¹, Joaquín Hortal^{12,13}, Sébastien Ibanez¹⁴, Erik Öckinger¹⁵, José Paulo Sousa¹⁶, Jacintha Ellers^{†,17} and Matty P. Berg^{†,17,18}

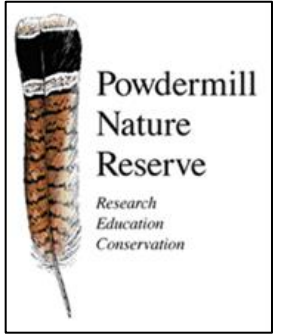
Objective: Investigate short-term effects of tornado and salvage logging disturbance on ground-dwelling beetles



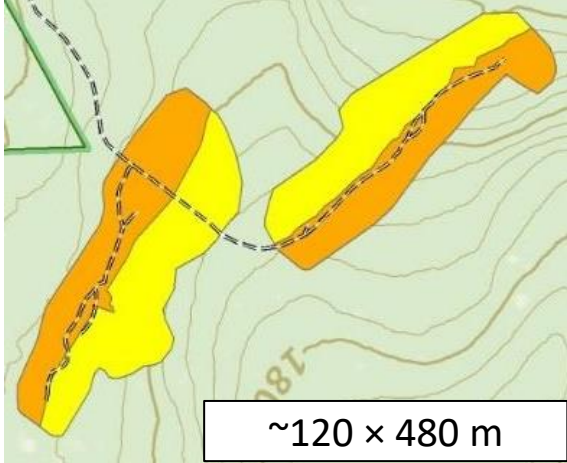
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Tornado
4 June 2012



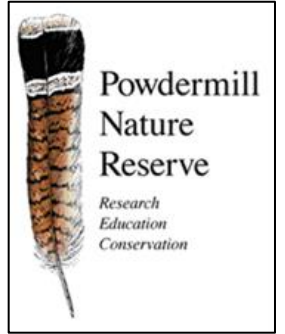
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Tornado
4 June 2012



Salvage Logging
2013



Quantifying ground-dwelling beetles

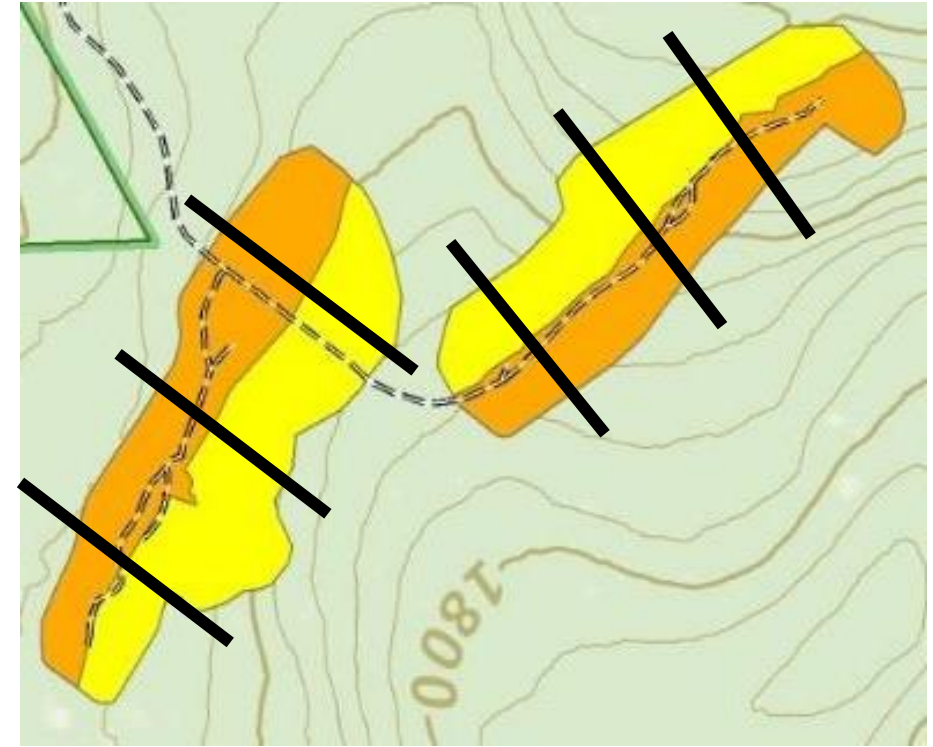
Pitfall traps along transects

June-September 2015

- Sampled continuously

Identified to species (56 species)

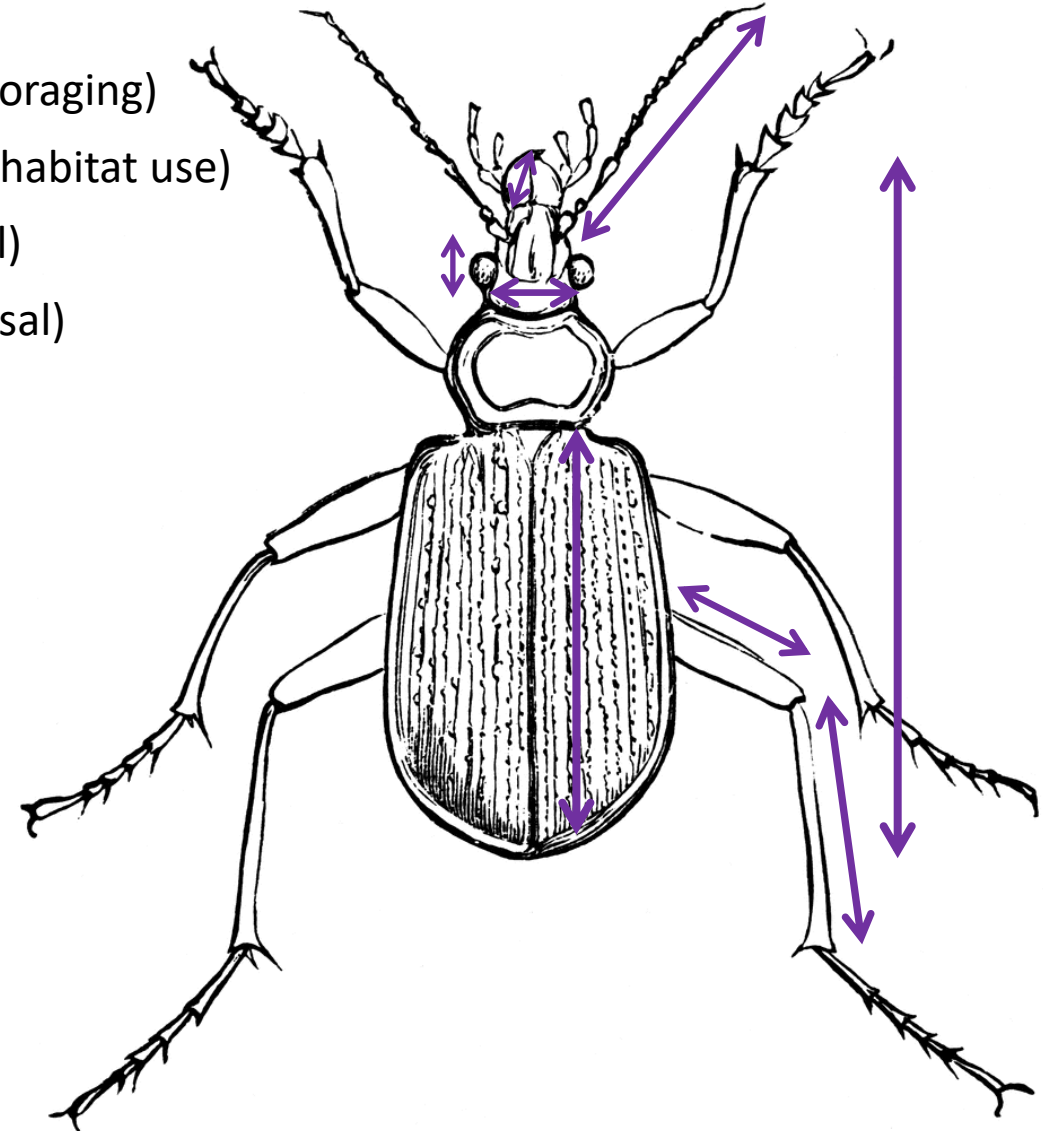
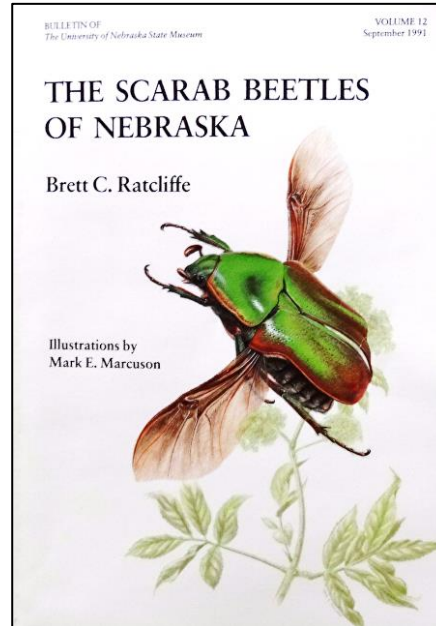
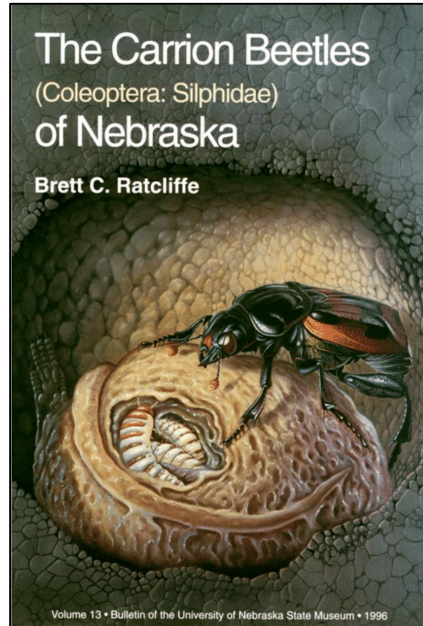
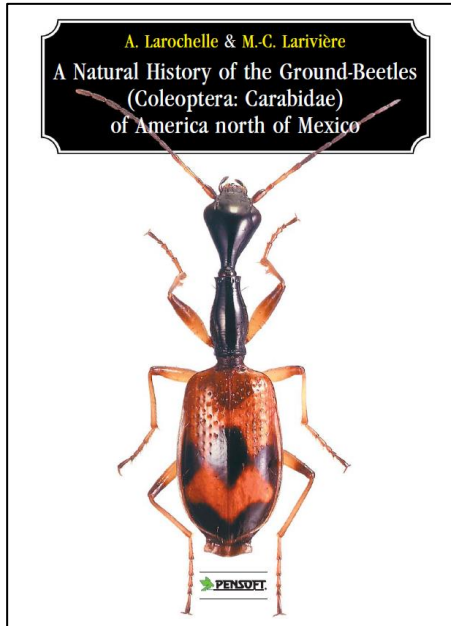
- Carabidae (37)
- Scarabaeoidea (14)
- Silphidae (5)



Morphological approach to evaluate beetle traits

Measured 8 traits (Fountain-Jones et al. 2015)

- Body size (fecundity)
- Head width (microhabitat use)
- Mandible length (resource use)
- Eye width (predator avoidance)
- Antennae length (foraging)
- Elytra length (microhabitat use)
- Leg length (dispersal)
- Flight ability (dispersal)



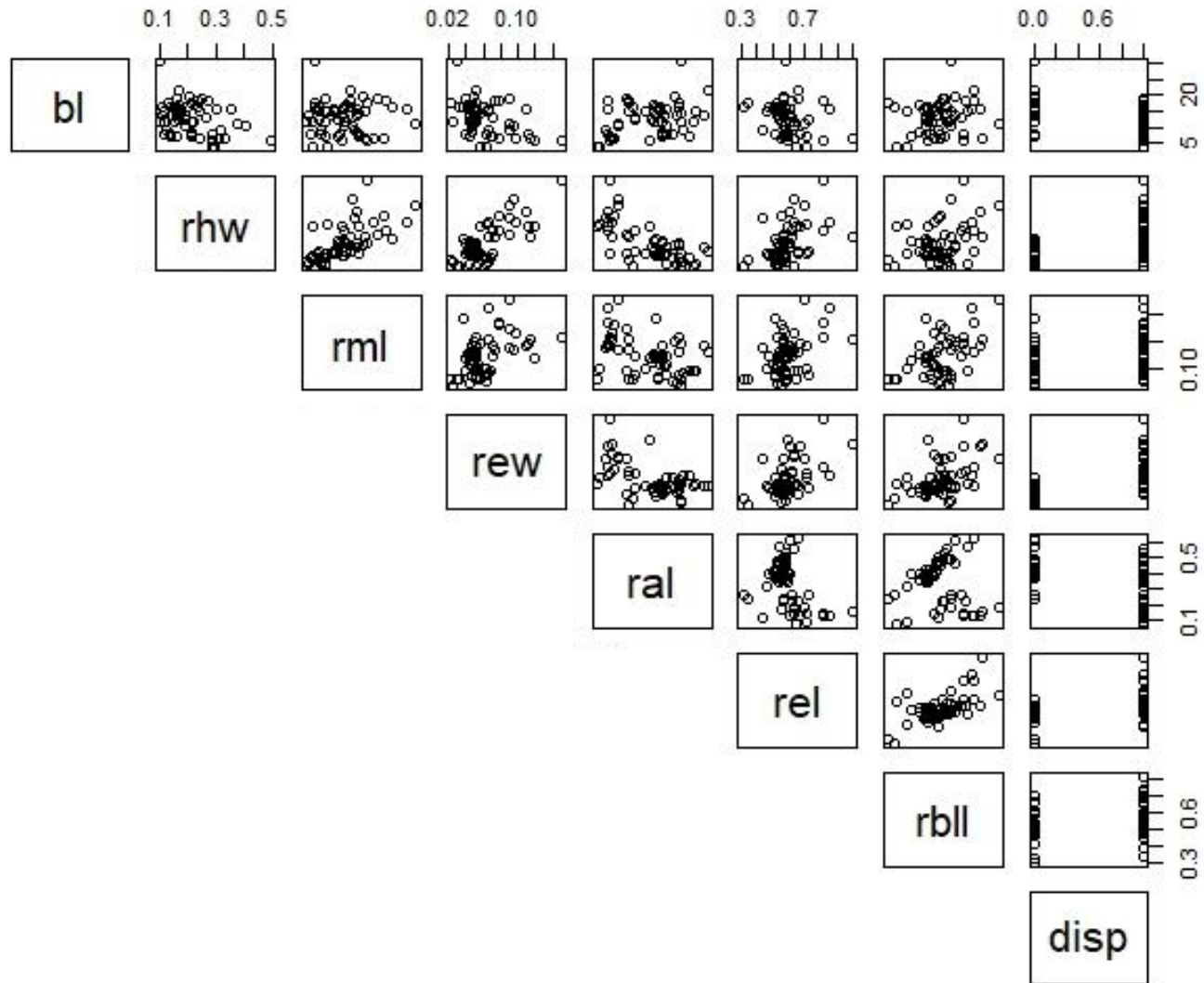
Trait Dataset

	A	B	C	D	E	F	G	H	I
1		BodySize	rHeadWidth	rMandible	rEyeWidth	rAntennae	rElytra	rHindLeg	Dispersal
2	Agfe	7.3	0.137	0.096	0.068	0.534	0.575	0.562	1
3	Agfi	9	0.122	0.089	0.067	0.5	0.578	0.533	1
4	Agre	8	0.113	0.088	0.063	0.425	0.513	0.5	0
5	Amin	10.6	0.189	0.123	0.047	0.425	0.566	0.481	1
6	Anha	12.5	0.192	0.112	0.048	0.344	0.544	0.48	1
7	Anme	12	0.208	0.125	0.05	0.4	0.6	0.508	1
8	Anni	11.5	0.217	0.122	0.043	0.357	0.583	0.487	1
9	Cago	21.5	0.167	0.13	0.051	0.623	0.656	0.698	0
10	Chem	14.5	0.159	0.145	0.055	0.49	0.566	0.579	1
11	Chla	16.5	0.139	0.085	0.061	0.485	0.576	0.576	1
12	Cyco	16.3	0.153	0.123	0.049	0.393	0.479	0.485	0
13	Cyfu	15.8	0.171	0.12	0.044	0.386	0.532	0.487	0
14	Cysi	16.2	0.105	0.08	0.031	0.259	0.309	0.327	0
15	Dipo	13.4	0.19	0.142	0.051	0.607	0.608	0.612	0
16	Dite	19.6	0.202	0.151	0.049	0.459	0.565	0.617	0
17	Hasp	17.5	0.131	0.08	0.023	0.234	0.337	0.303	0
18	Noni	8.5	0.212	0.141	0.047	0.4	0.588	0.447	1
19	Noae	5.9	0.288	0.119	0.119	0.339	0.593	0.492	1
20	Olpa	8	0.138	0.075	0.063	0.45	0.575	0.55	1
21	Plan	14.8	0.115	0.095	0.054	0.568	0.541	0.669	0
22	Plte	11.5	0.104	0.096	0.052	0.557	0.626	0.574	1
23	Psoe	7	0.214	0.114	0.042	0.4	0.571	0.414	0

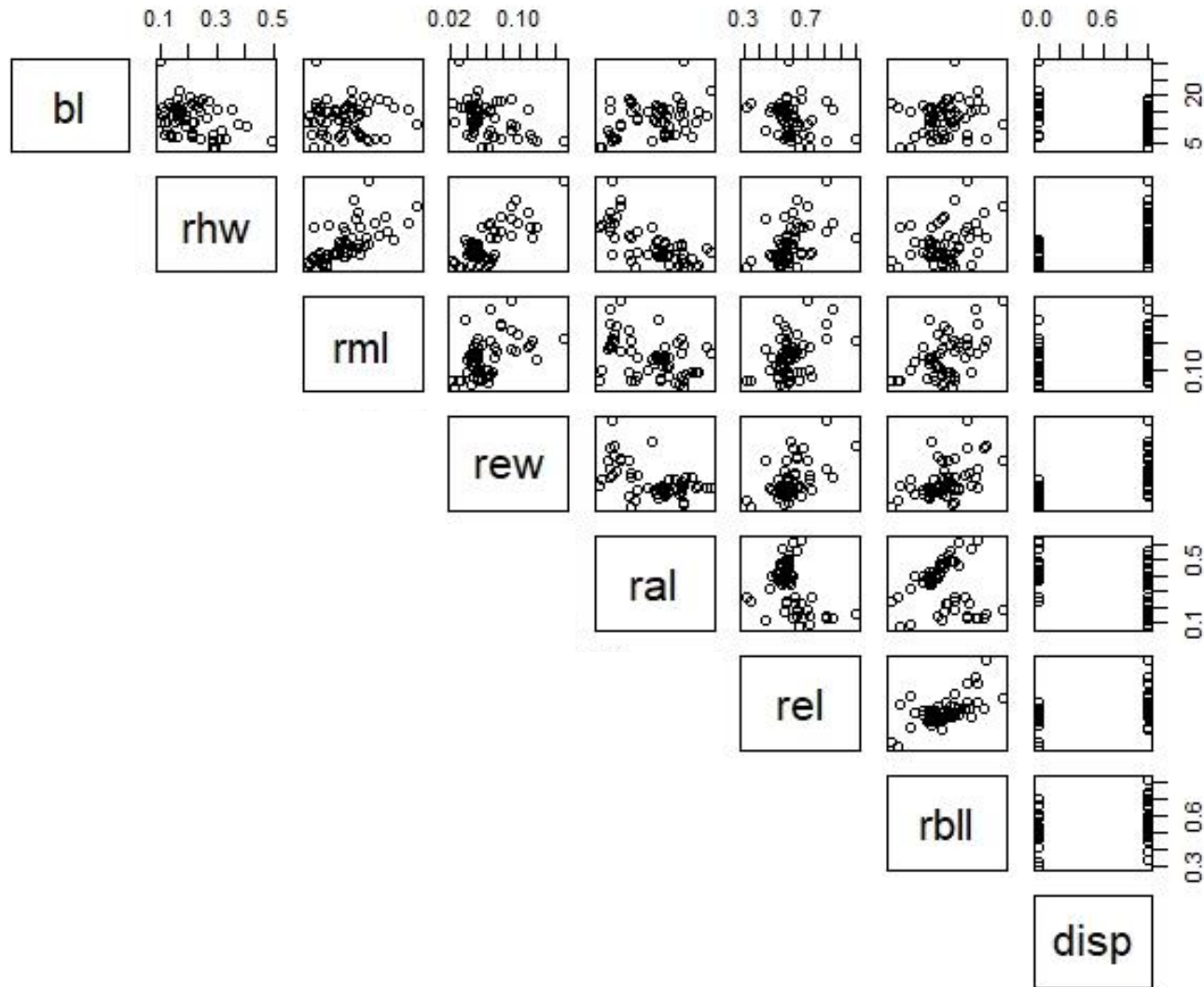
Relative Species Abundance Dataset

	A	B	C	D	E	F	G	H	I	J
1		Agfe	Agfi	Agre	Amin	Anha	Anme	Anni	Cago	C
2	C41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
3	BS42	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	
4	B43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
5	C44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	
6	C45	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	
7	BS46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
8	B47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
9	C48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	
10	BS49	0.01	0.26	0.00	0.01	0.02	0.01	0.00	0.00	
11	C50	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	
12	B51	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	
13	C52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	
14	BS53	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	
15	C54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
16	B55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	
17	C56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	
18	B57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
19	C58	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.07	
20	BS59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	
21	C60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
22	BS61	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	

Check data for correlated traits



Check data for correlated traits



Traits removed:

1. Head width
2. Eye width
3. Elytra length

Correlation coefficient ≥ 0.5

Calculate functional diversity measures in R

- 1) Community-weighted means for individual traits
- 2) Functional diversity indices

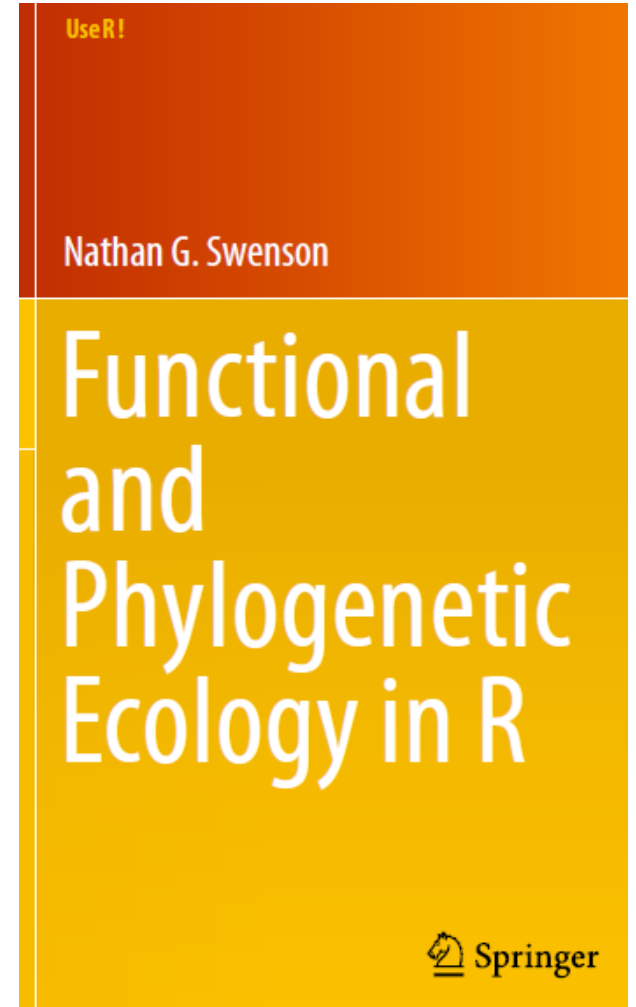
Calculate functional diversity measures in R

1) Community-weighted means for individual traits

2) Functional diversity indices

*FD package in R – dbFD function

(Laliberte and Legendre 2010; Laliberte et al. 2014)



Community-weighted mean (CWM) for functional traits

Mean trait value for a community (at a site) weighted by the relative abundance of species (Swenson 2014)

Use as response variables in another statistical analysis

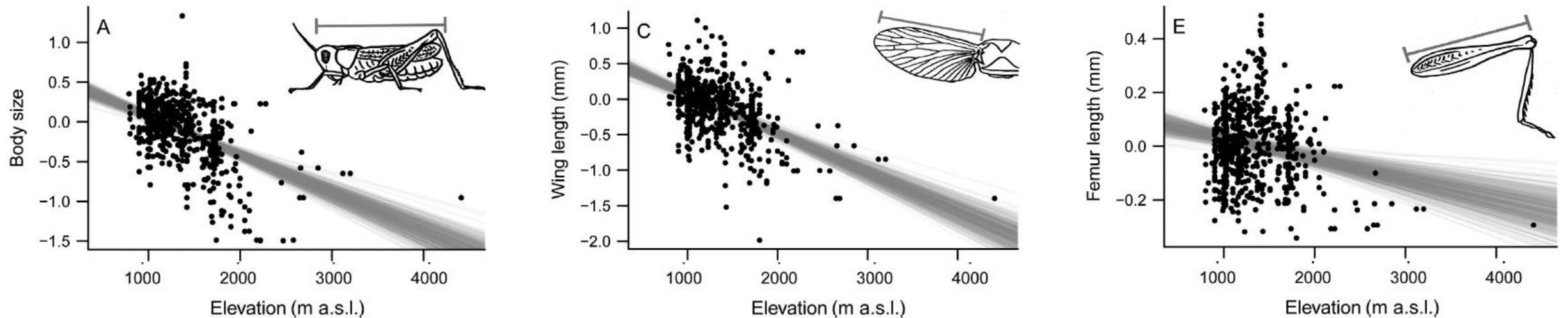
	A	B	C	D	E	
1		BodySize	rMandible	rAntennae	rHingLeg	
2	C41	16.02911392	0.157594937	0.327151899	0.557189873	
3	BS42	14.7897541	0.143360656	0.359385246	0.557061475	
4	B43	14.39655172	0.134689655	0.392862069	0.509448276	
5	C44	16.96305732	0.143261146	0.471273885	0.59643949	
6	C45	14.74266409	0.125359073	0.443474903	0.540548263	
7	BS46	15.28623656	0.127688172	0.445260215	0.560698925	
8	B47	14.84642857	0.107803571	0.457285714	0.528125	
9	C48	16.28017058	0.163264392	0.311558635	0.634356077	
10	BS49	13.67383101	0.098800656	0.394675144	0.513343724	
11	C50	14.60327869	0.123009836	0.420085246	0.570796721	
12	B51	14.36295585	0.12746833	0.434792706	0.552644914	
13	C52	17.84709596	0.134618687	0.49535101	0.608474747	
14	BS53	14.66150442	0.141586283	0.49807854	0.574161504	
15	C54	17.70754561	0.176810116	0.189954395	0.665458541	
16	B55	13.38653846	0.136603846	0.345903846	0.519092308	
17	C56	16.46761488	0.161527352	0.384643326	0.640422319	
18	B57	16.82305564	0.130358131	0.371381187	0.567979711	

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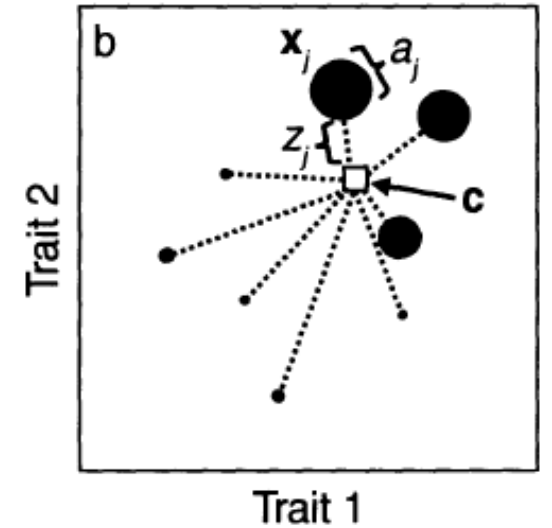
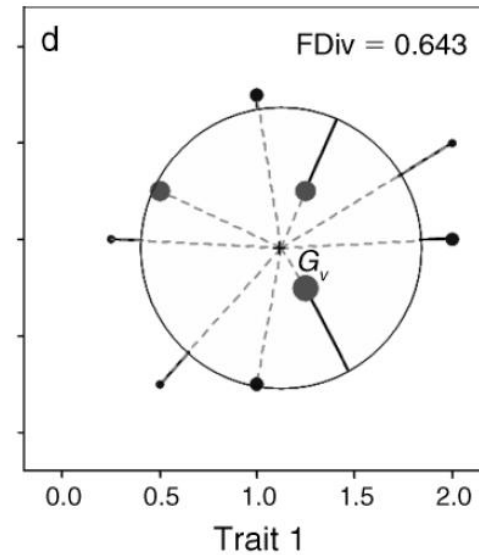
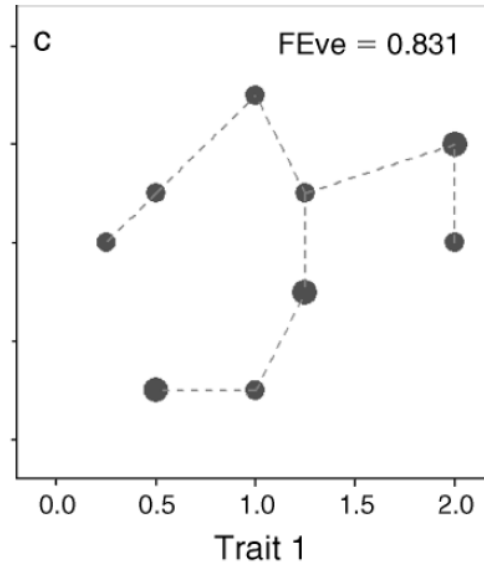
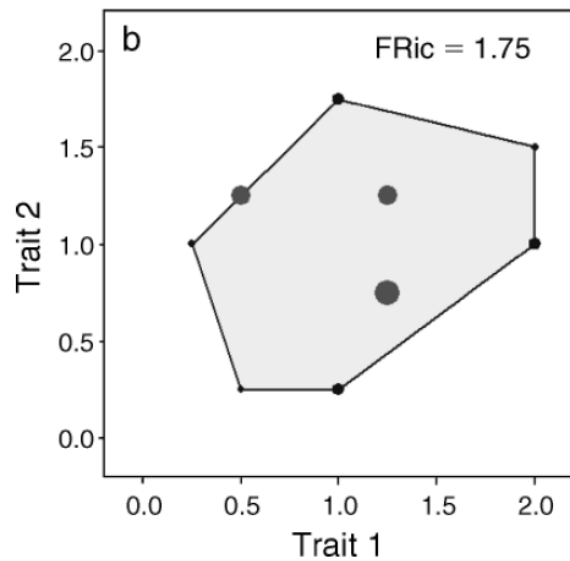
Orthopteran traits related to fecundity decreased with increasing elevation



Functional diversity indices

Four indices:

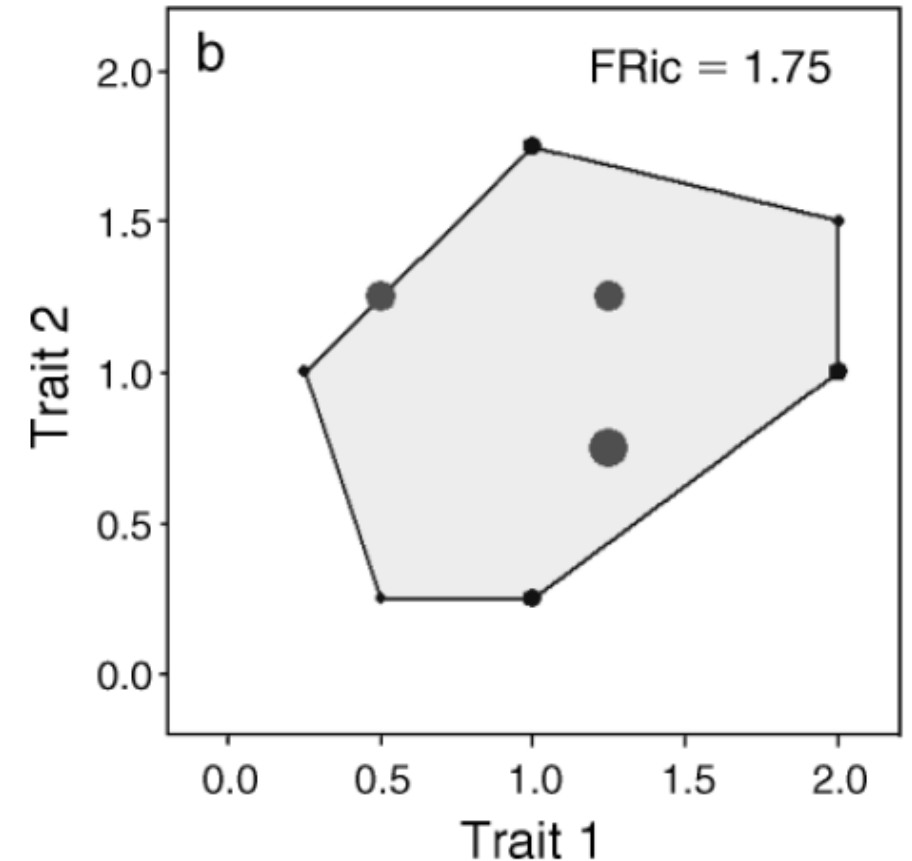
- Richness (Fric)
- Evenness (Feve)
- Divergence (Fdiv)
- Dispersion (Fdis)



Functional Richness (Fric)

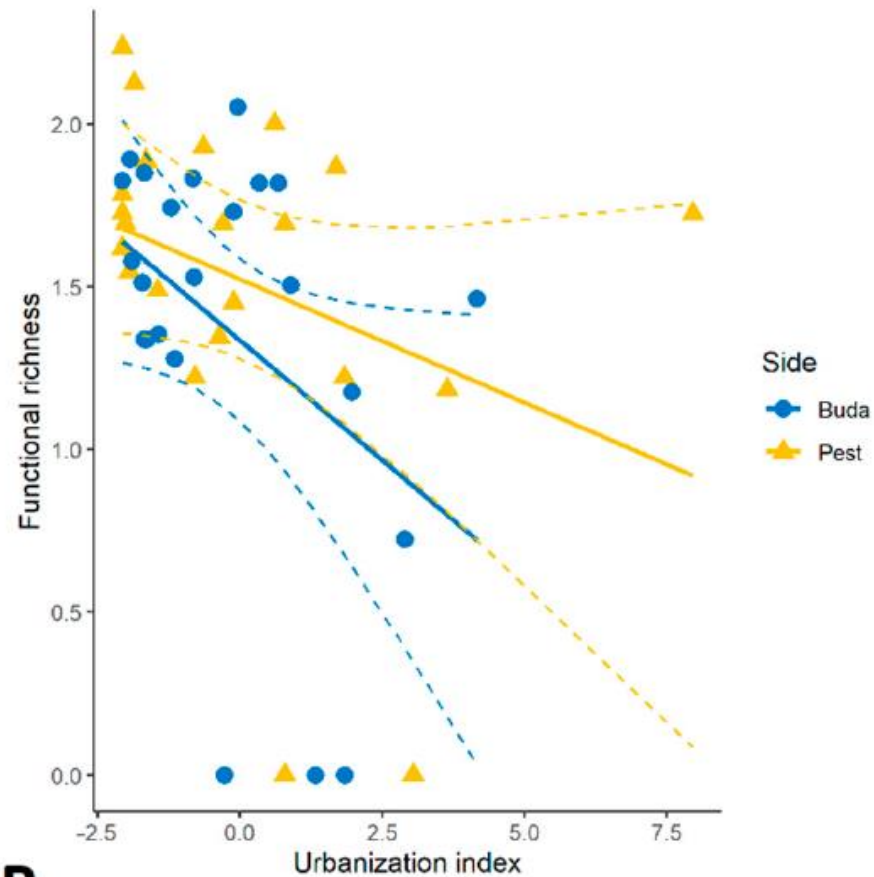
Convex hull volume or range of functional traits represented in a community (Villéger et al. 2008)

Low functional richness = species have more similar trait means

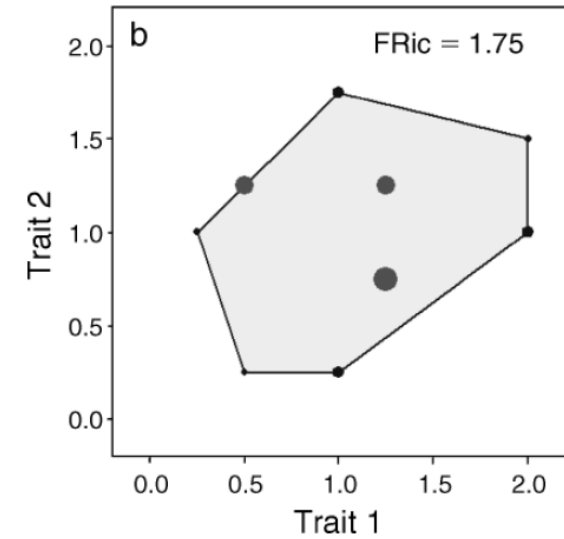


Functional Richness (Fric)

Convex hull volume or range of functional traits represented in a community (Villéger et al. 2008)



B

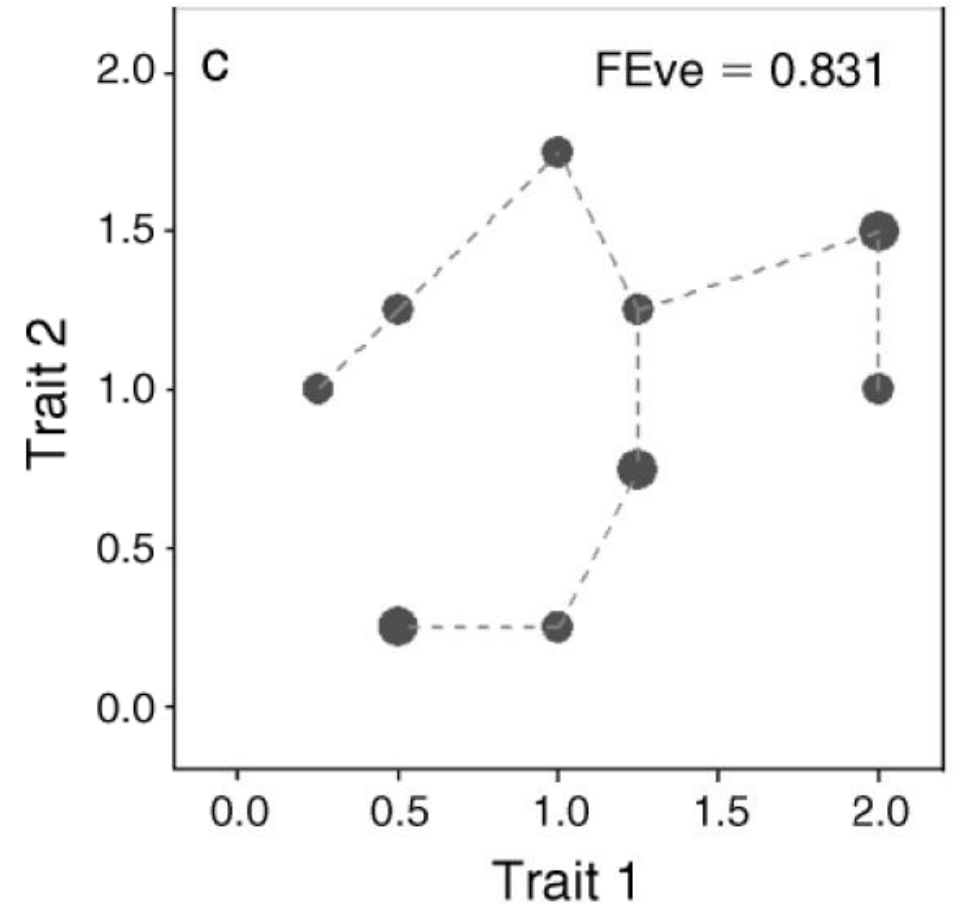


Functional richness of millipedes decreased with urban soil disturbance and urbanization

Functional Evenness (Feve)

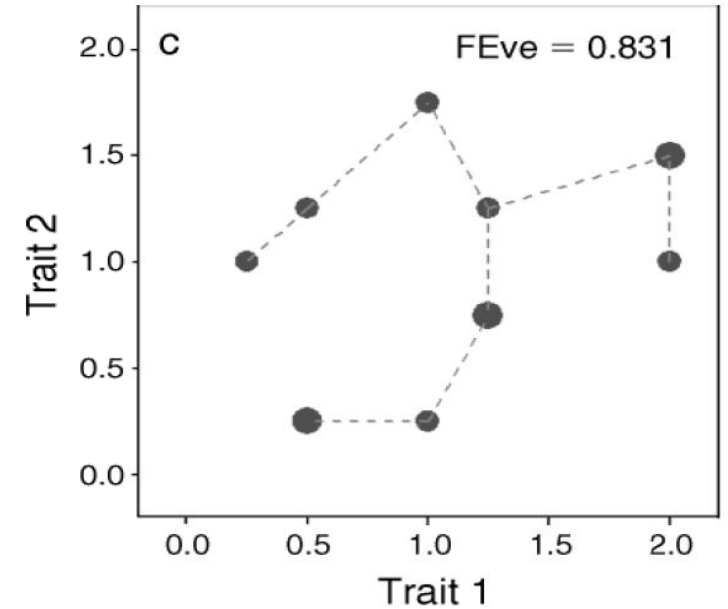
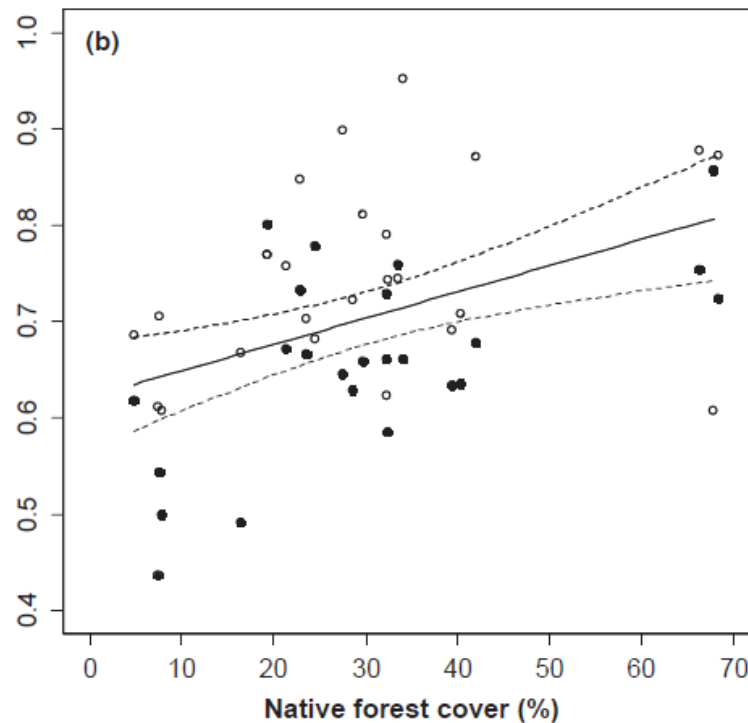
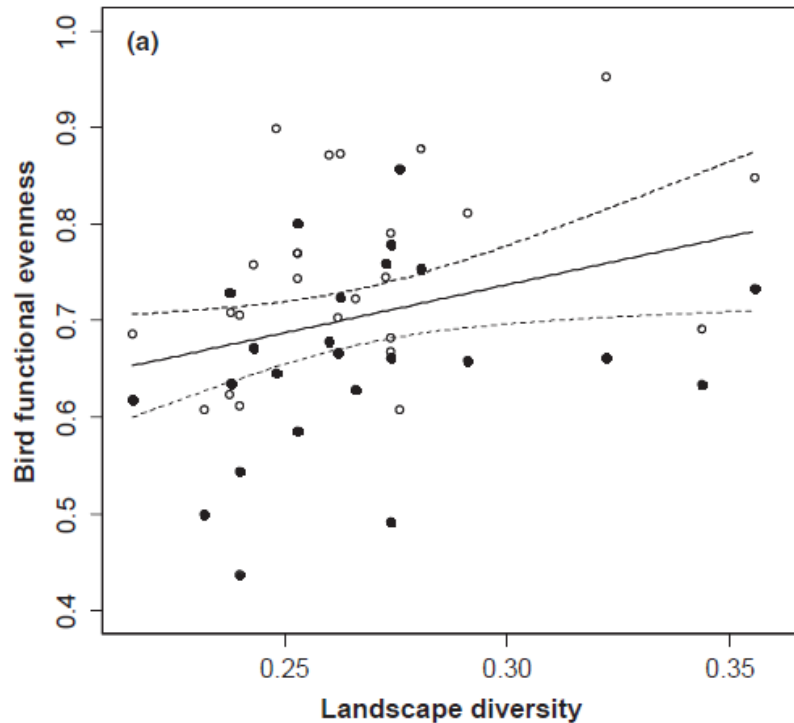
Uses a minimum spanning tree approach to connect all species in trait space and measures the regularity of species points and their abundances along the branches (Villéger et al. 2008)

Increased regularity = Higher evenness



Functional Evenness (Feve)

Uses a minimum spanning tree approach to connect all species in trait space and measures the regularity of species points and their abundances along the branches (Villéger et al. 2008)

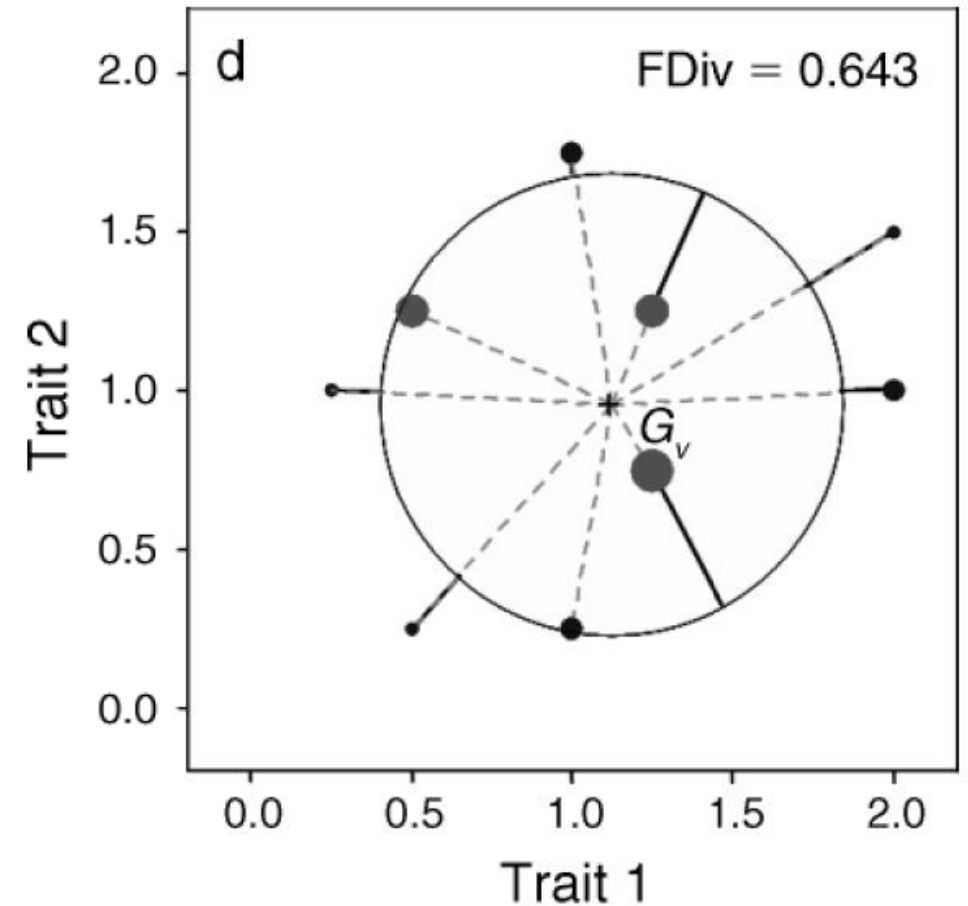


**Functional evenness
of birds increased
with landscape
diversity and native
forest cover**

Functional Divergence (Fdiv)

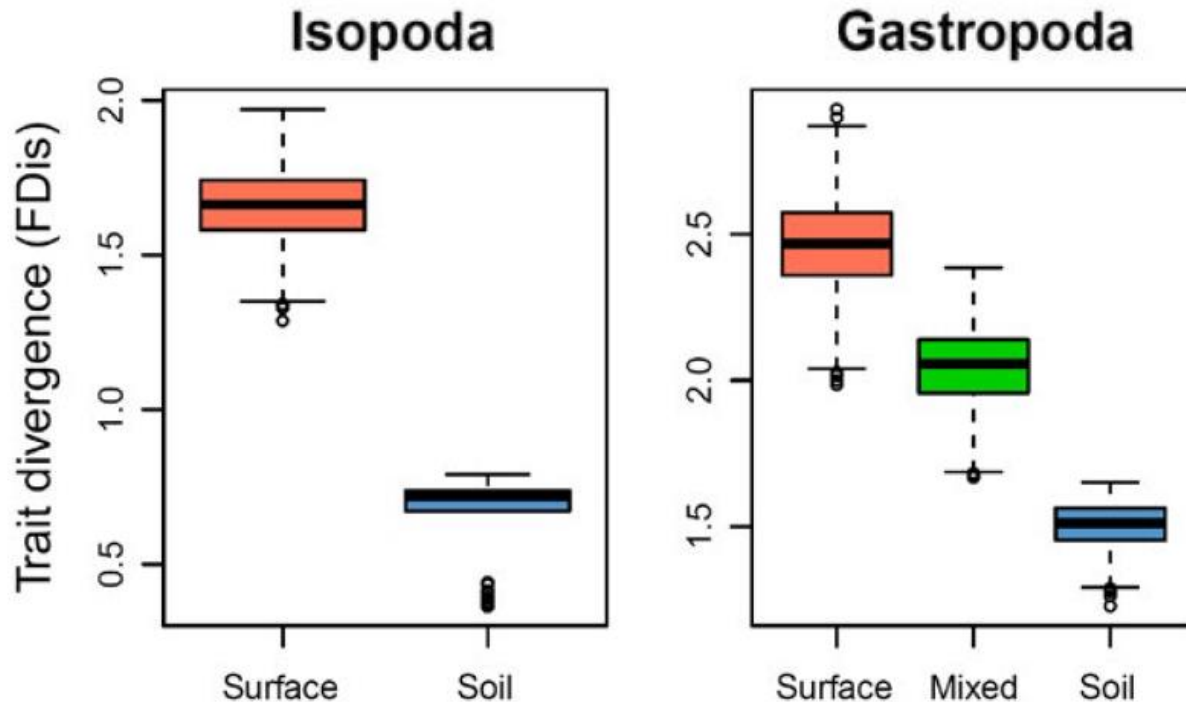
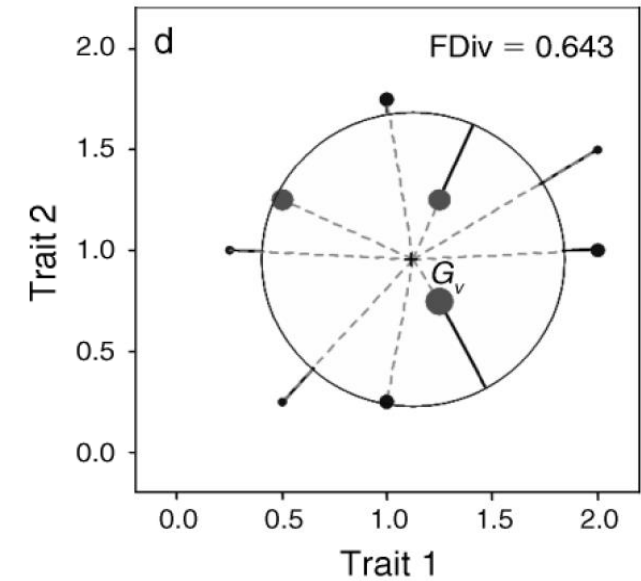
Measures average distance of all species from the centroid of trait space, then sums the divergences from that mean
(Villéger et al. 2008)

Higher value = greater deviation towards maximum and minimum trait values



Functional Divergence (Fdiv)

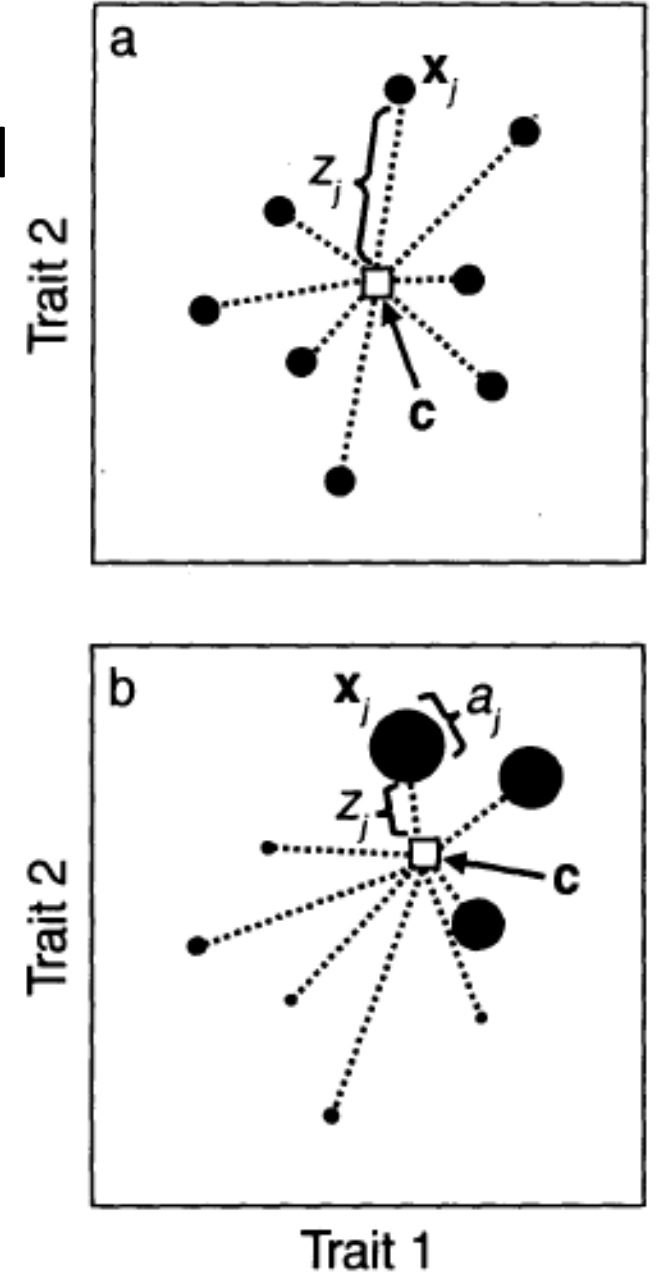
Measures average distance of all species from the centroid of trait space, then sums the divergences from that mean (Villéger et al. 2008)



Lower trait divergence in soil-dwelling than in surface-dwelling species

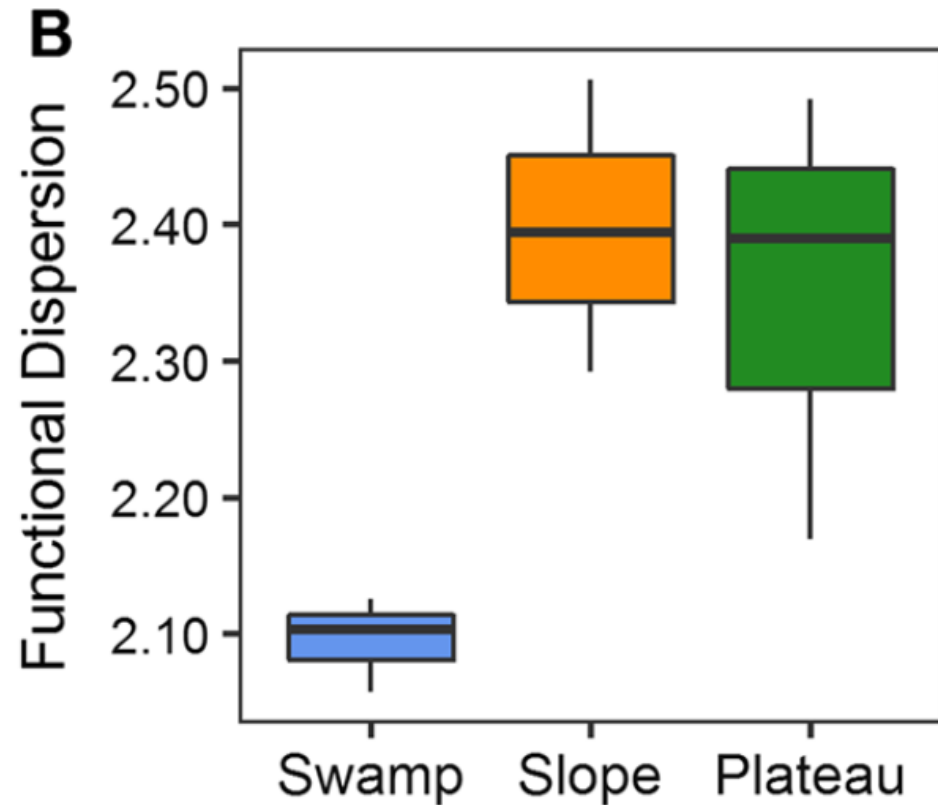
Functional Dispersion (Fdis)

Measures average distance of each species to the centroid in trait space (Laliberte and Legendre 2010)

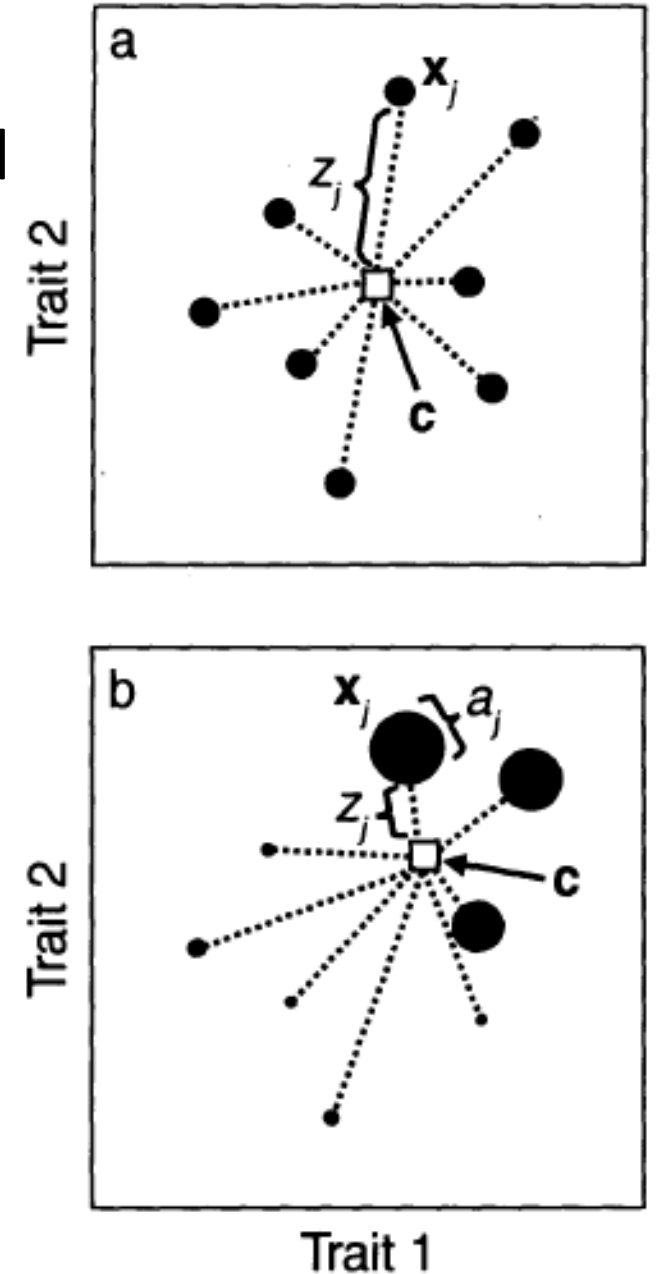


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Measures average distance of each species to the centroid in trait space (Laliberte and Legendre 2010)

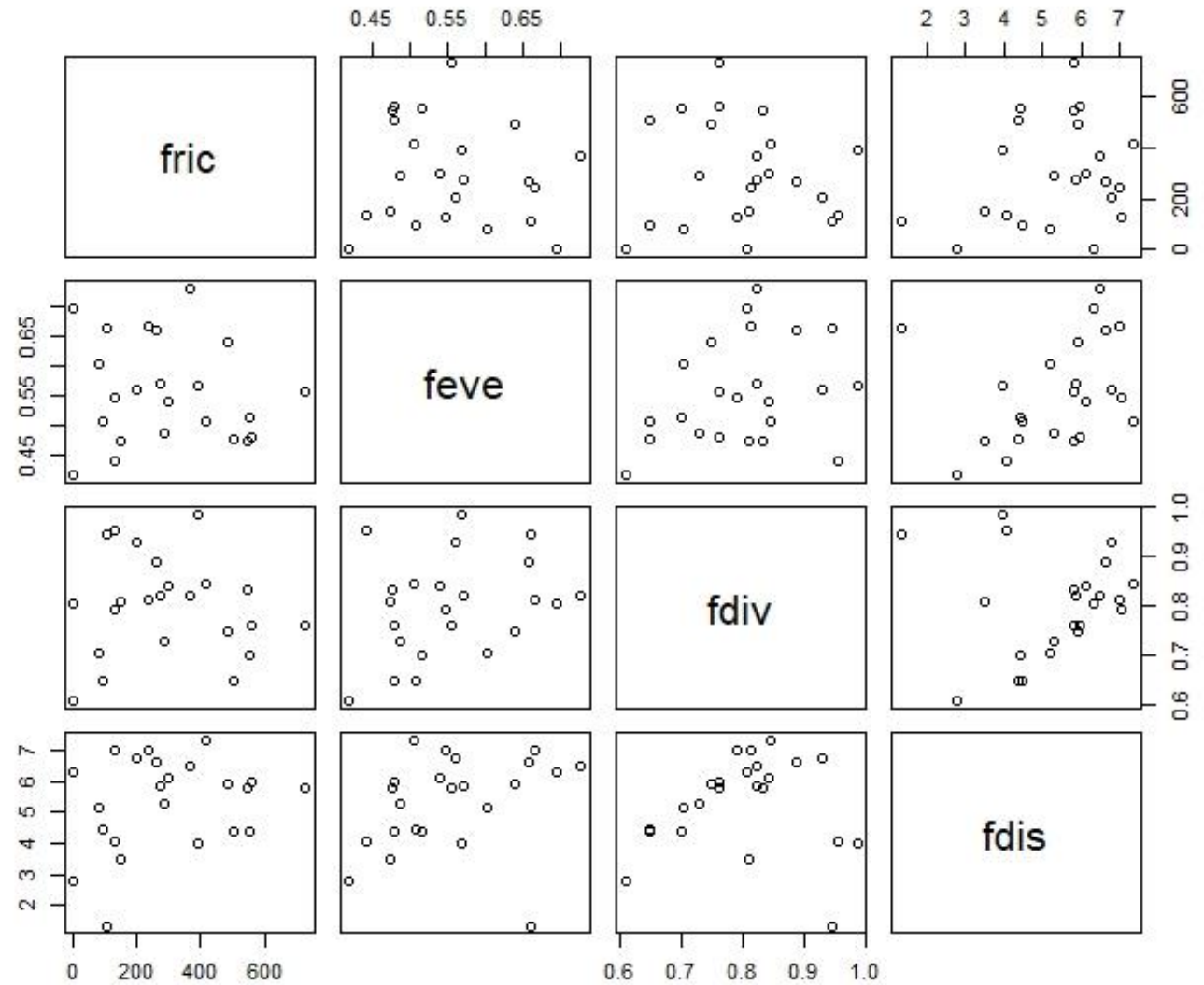


**Lower trait dispersion
of ants in swamp
forests than in slope or
plateau forests**

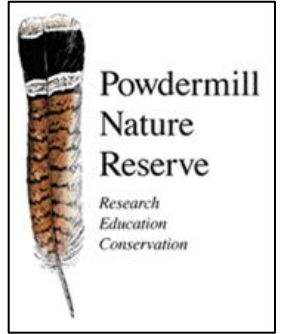


Use functional diversity indices as response variables in other analyses

	A	B	C	D	E	
1		fric	feve	fdiv	fdis	
2	C41	3.490665	0.69549	0.80457	6.342087	
3	BS42	263.8848	0.658042	0.887715	6.635554	
4	B43	NA	NA	NA	2.421579	
5	C44	93.59532	0.508194	0.64749	4.459163	
6	C45	287.8725	0.486829	0.72774	5.275598	
7	BS46	272.6698	0.569606	0.821247	5.843611	
8	B47	4.156816	0.418076	0.606906	2.776267	
9	C48	413.1023	0.505612	0.844491	7.34733	
10	BS49	295.6353	0.540234	0.839531	6.12348	
11	C50	368.0445	0.728331	0.821105	6.50555	
12	B51	726.9394	0.555767	0.759394	5.826202	
13	C52	148.6756	0.47298	0.808584	3.516524	
14	BS53	556.092	0.479286	0.760378	5.978893	
15	C54	131.0303	0.440389	0.954997	4.042442	
16	B55	201.6558	0.560655	0.928949	6.765773	



Objective: Investigate short-term effects of tornado and salvage logging disturbance on ground-dwelling beetles



**Undisturbed
Forest**



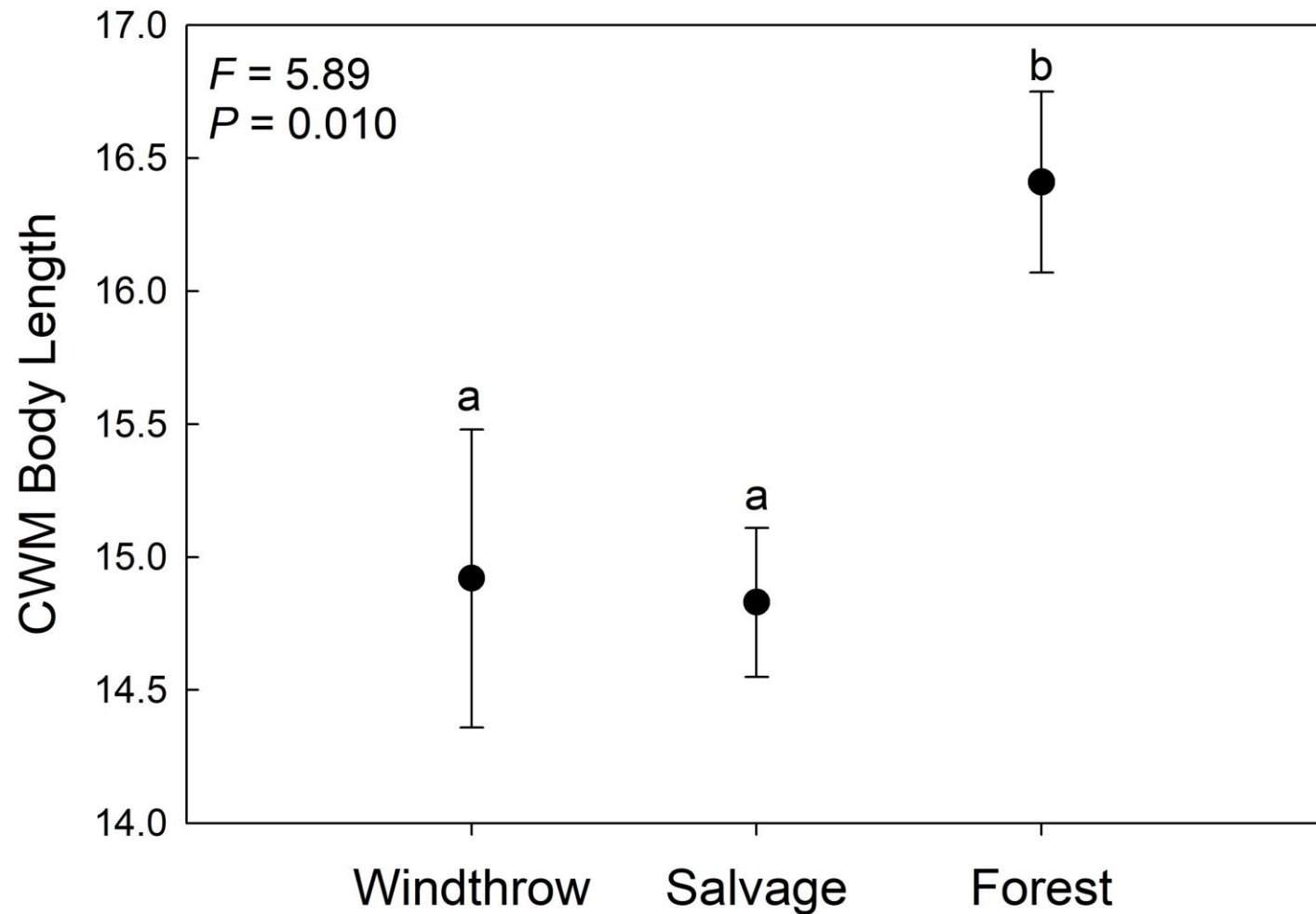
Windthrow



Salvaged



Smaller ground-dwelling beetle species found in disturbed forest



Carabus goryi

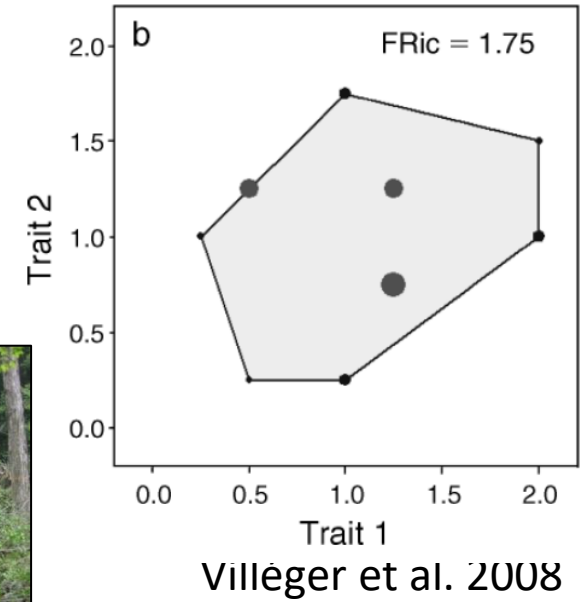
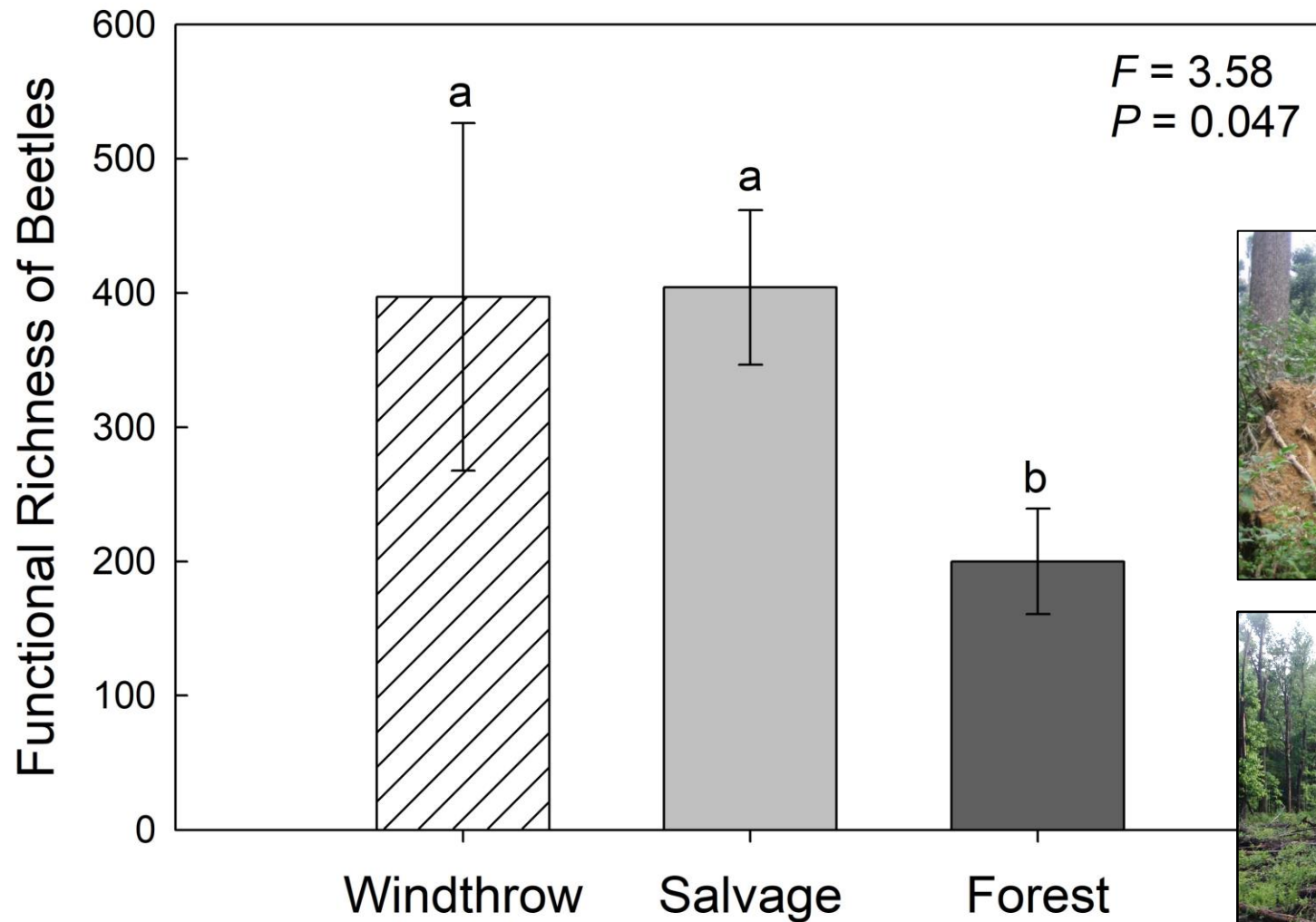


Geotrupes splendidus



Nicrophorus orbicollis

Ground-dwelling beetle functional richness higher in disturbed forest



Trait-based ecology – key points

- 1) Any character measurable at the individual level that directly or indirectly impacts fitness (growth, reproduction, survival)
- 2) Traits and functional diversity have greater comparative applicability among habitats and ecosystems than taxonomic metrics (de Bello et al. 2021)
- 3) Mechanistic basis for studying and predicting changes in community structure (Moretti et al. 2017)

Relevant resources

All resources available here: github.com/kiperry/ESA_NCB_2021

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Handbook of protocols for standardized measurement of terrestrial invertebrate functional traits

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