# Plant traits and biogeochemical cycling on land: parallels with marine ecosystems?

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# This talk from cucumber to sea cucumber

- Traits: brief Intro
- Response and effect traits: terrestrial examples
- Traits, environmental filters, phylogenies and (vulnerability of) ecosystem functions
- Parallels and differences between trait principles and practice on land *versus* in oceans

# What do we mean with (functional) ‘trait’?

“Any heritable morphological, anatomical, biochemical, physiological, phenological or behavioural feature measurable at the individual level, from the cell to the whole-organism scale”

Adapted from Violle *et al.* 2007, *TREE*

# …or in my simple world:

Characteristics of species (or genotypes) that inform us about their fitness for or their effects on the ecosystems they live in

Variation in traits between species is often larger than variation within species for the same traits*

*but see Elena Litchman: intraspecific variation, plasticity!

Defining functional traits as Response Traits and Effect Traits* may help us to predict effects of environmental changes on ecosystem functions *via changes in species composition*

* Lavorel & Garnier 2002 *Func. Ecol.*, Suding et al. 2008, *Global Change Biology*

Response traits help a species to live in and respond to changes in its environment, e.g. for plants:

- seed size, seed number per plant: dispersal, regeneration

- specific leaf area: fast growth
- temperature tolerances
- nutrient uptake strategy ($N_2$ fixation, mycorrhiza, carnivory….):

…. or from snow!

Snow roots in the Caucasus Mountains (Onipchenko et al. 2009, *Ecology Letters*)

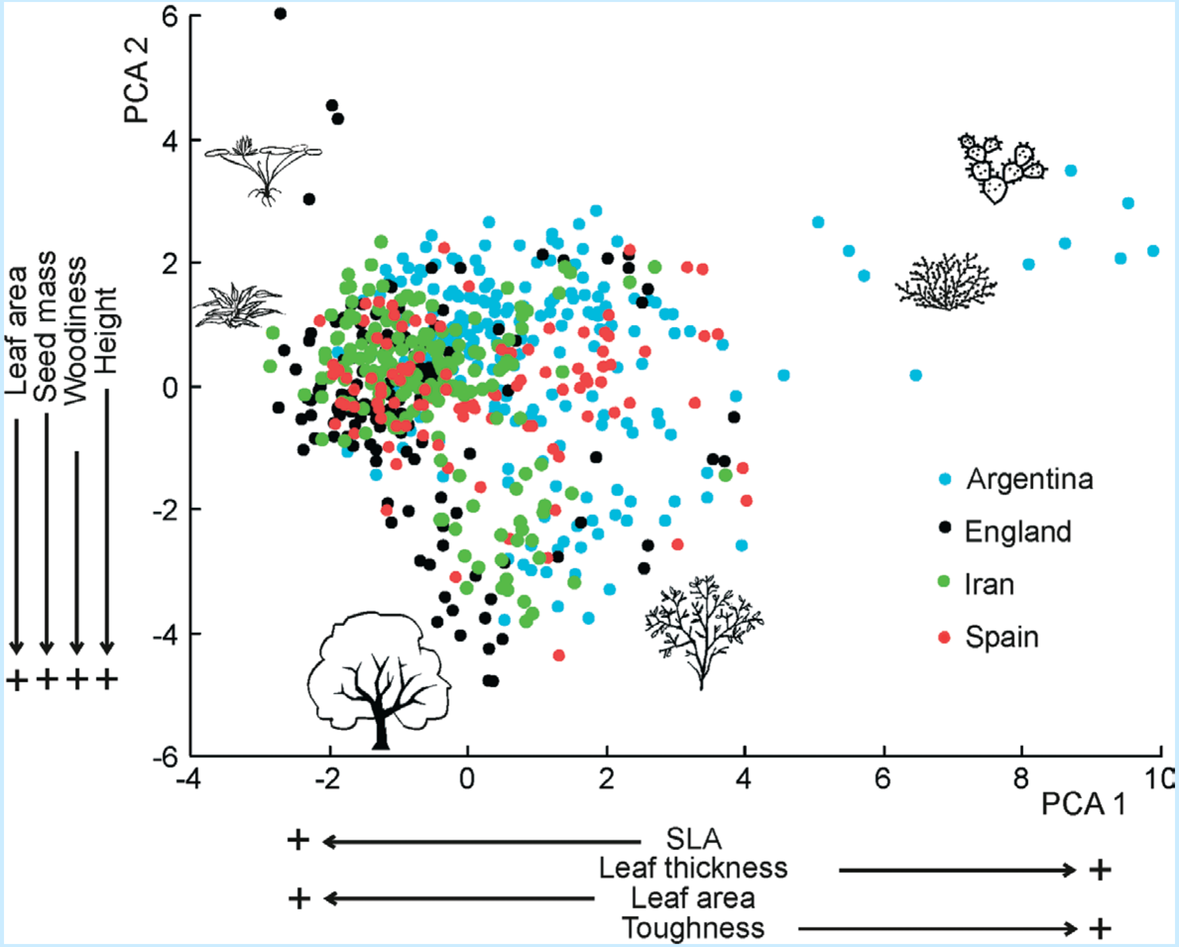
# Specific root length (length/mass)

*C. conorhiza*

- Snow roots 495 ± 65 m $g^{-1}$
- Soil roots 99 ± 3.6 m $g^{-1}$ (P=0.0016)

99 local species in the same alpine belt

- Soil roots 106 ± 6.0 m $g^{-1}$ (range 12 – 442)




At global scale plants vary along two major ecological strategy axes:

PCA 1: leaf quality (slow to fast growth)

PCA2: allometry; small to large plants or their parts

Diaz *et al.* 2004, *JVS;* Wright *et al. 2004, Nature*

| | | |
|---|---|---|
| Fast growth | → | Slow growth |
| high specific leaf area | → | thick, tough leaves |
| high pH, nutrients | → | high lignin, dry matter content |

# Popular response traits in animals

- Body size* (competitive vigor, prey choice), leg/fin length (mobility), bill/mouth dimensions (food)
- Growth rate
- Tolerance of drought, cold or hot temperature, high salt, etc.
- Ability to dig holes in trees or soil (safe hiding or breeding sites; birds, beetles, mammals, fish)
- Clutch size (reproduction)
- Physical (e.g. spines) and chemical defences

* see talk by Simon Jennings; trait tradeoffs: Thomas Kiørboe

# Response traits of single-celled organisms (on land or in the ocean)?

Archaea, Eubacteria, Protists

- Cytoskeleton traits? Morphology, [Ca], [Si]
- Nutritional traits: [N], [P], $N_2$ fixing
- Photosynthetic capacity
- Mobility-related traits
- Secondary chemistry

- ‘’ …omics’ and evolutionary approaches, see talks by Adam Martiny, Elena Litchman, Sonya Dyhrman

Effect traits are traits that define the potential effect an organism has on a particular ecosystem process or function

E.g. amount of nectar a plant species produces per flower to attract pollinators:

supports animal populations

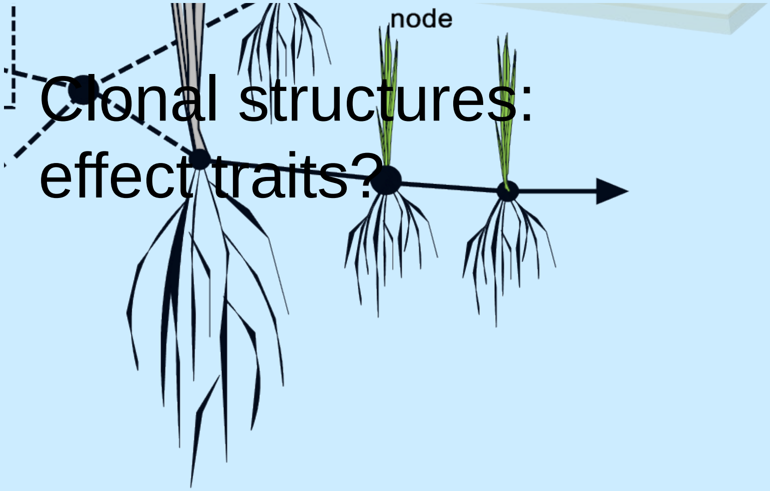
# Brief examples of (research into) variation in effect traits in the context of:

- Substrate stability and soil formation
- Carbon emissions from earth surface

# Early-successional clonal plants protect sand dunes and people during the lifetime of the plant

*Ammophila arenaria (marram grass)* in Holland

# Effect traits related to substrate stability and soil (organic matter) formation




Clonal structures:
effect traits?

Rhizome length, density, 3-D orientation, toughness


Clonality also matters after the lifetime of a plant

Tough rhizomes → longer-term substrate stabilisation, organic matter accumulation

Clonal grass in
Nei Mongu, China

- Decomposition of dead plant material (litter) provides nutrients for plant growth and reduces soil carbon pools

- Decomposition rates depend on
  1. abiotic environment (climate)
  2. decomposing organisms
  3. <u>litter quality: TRAITS</u>

Test for species trait contribution to decomposition rates in ‘common garden’ experiments

(1) Initial mass of undecomposed litter samples of many species → litterbag*

(2) Measure initial traits (e.g. [Lignin], [N], pH, dry matter content)

* subsamples to calculate dry mass from moisture content

(3) Litterbed: Simultaneous decomposition of all samples in the same environment

(4) Collect litterbags, dry and re-weigh litter samples

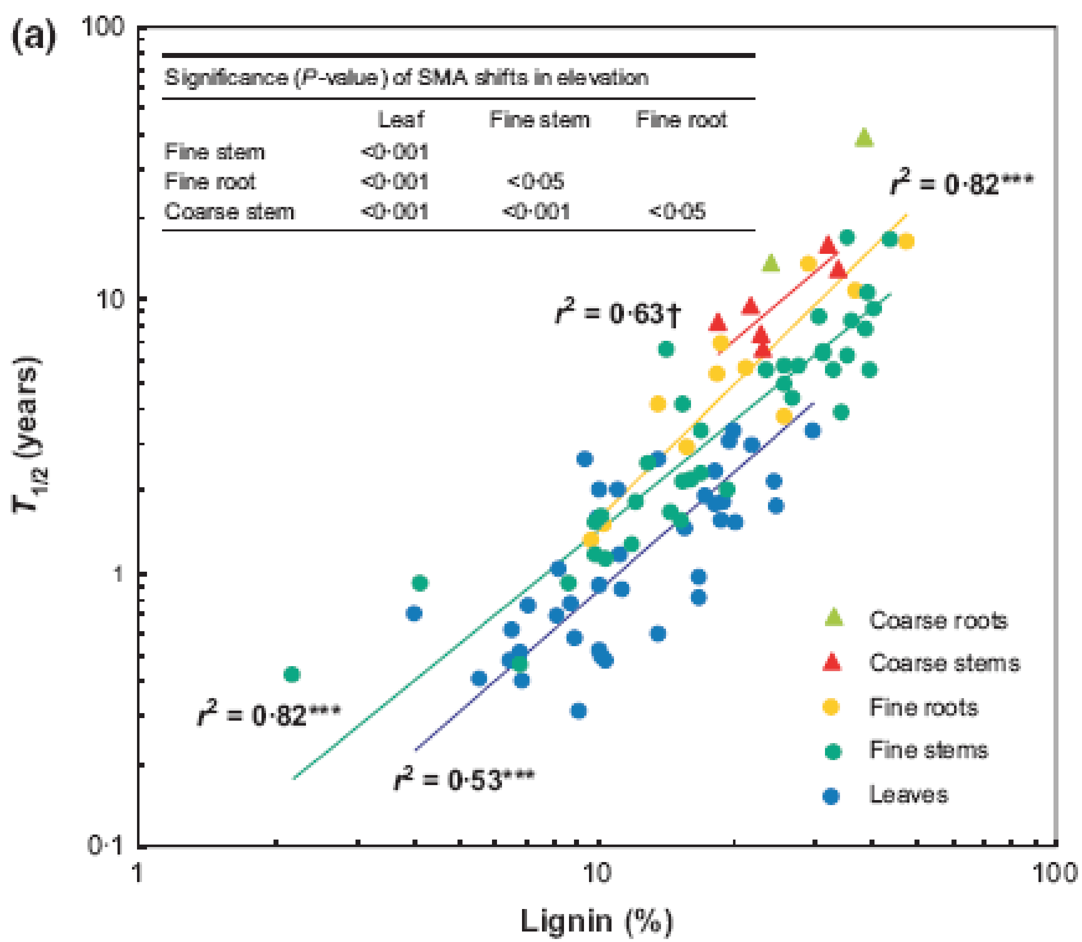
(5) % litter mass loss → time to 50 % mass loss = decomposability

Functional Ecology
British Ecological Society

*Functional Ecology* 2012, **26**, 56–65 doi: 10.1111/j.1365-2435.2011.01913.x

# A plant economics spectrum of litter decomposability

Grégoire T. Freschet*, Rien Aerts and Johannes H. C. Cornelissen




Great variation in T1/2 among species and organs

Coarse stems

Fine roots,
Fine stems

Leaves

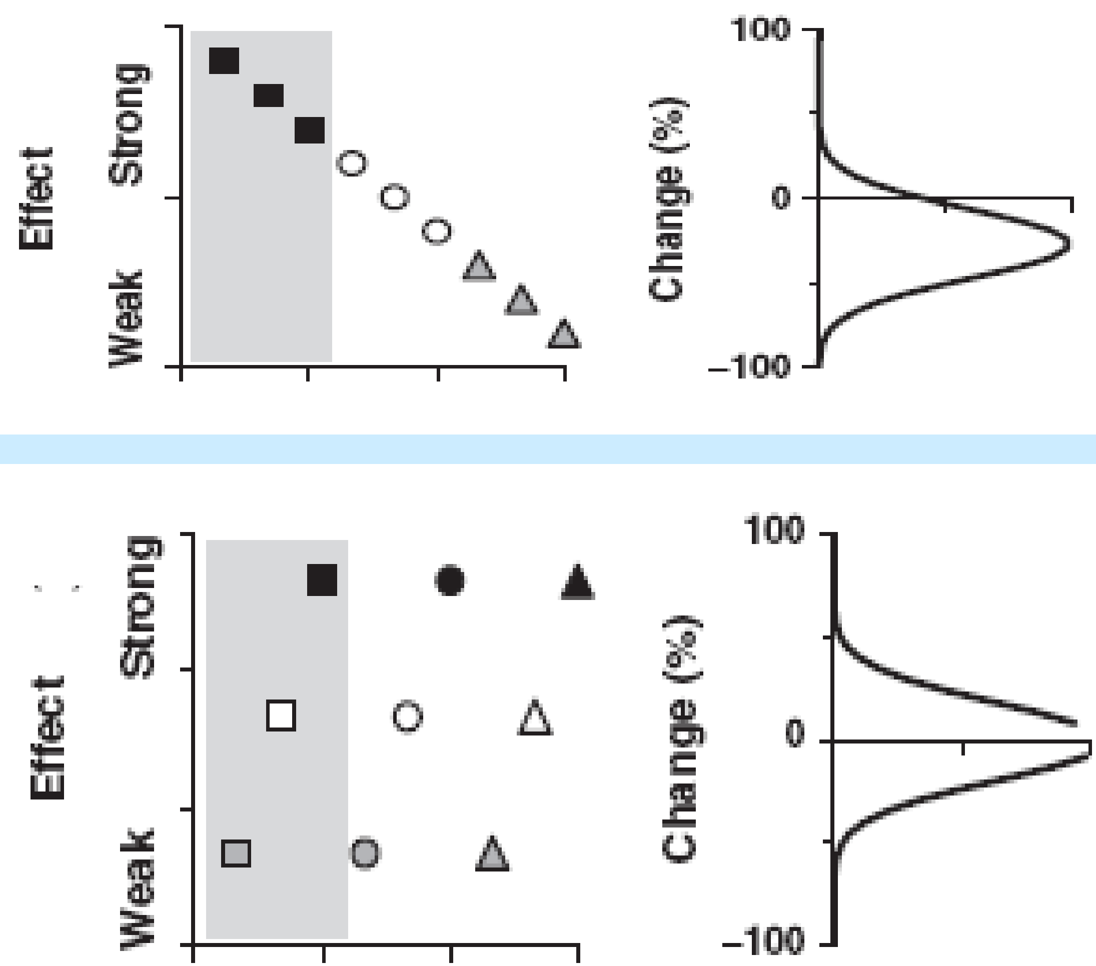
$T_{1/2}$= Time to 50 % mass loss

# LOGLIFE: Upscaling decomposition: 1 km of logs of 25 temperate tree species

Cornelissen et al. 2012, *Ambio*

How variation in response traits and variation in effect traits are related across species is important for predicting ecosystem functions from community composition in changing environments

# Or to show this graphically:




**Response traits (e.g. temperature tolerance)**

Ecosystem function sensitive to change

resistant to change

Suding et al. 2008, *Global Change Biology*

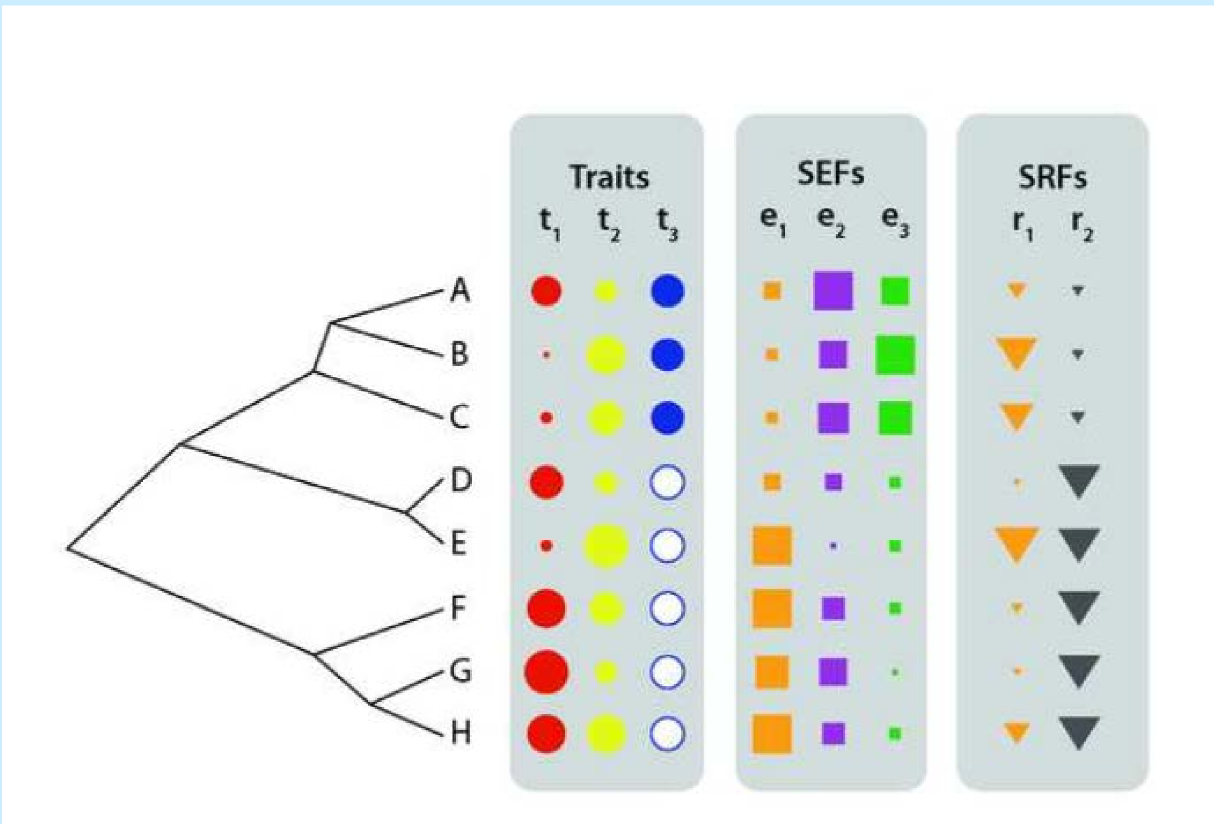
# A role for phylogeny?

Ecology and Evolution 2013

Open Access

**Functional traits, the phylogeny of function, and ecosystem service vulnerability**

Sandra Díaz[1,a], Andy Purvis[2,a], Johannes H. C. Cornelissen[3], Georgina M. Mace[2,4], Michael J. Donoghue[5], Robert M. Ewers[2], Pedro Jordano[6] & William D. Pearse[2]

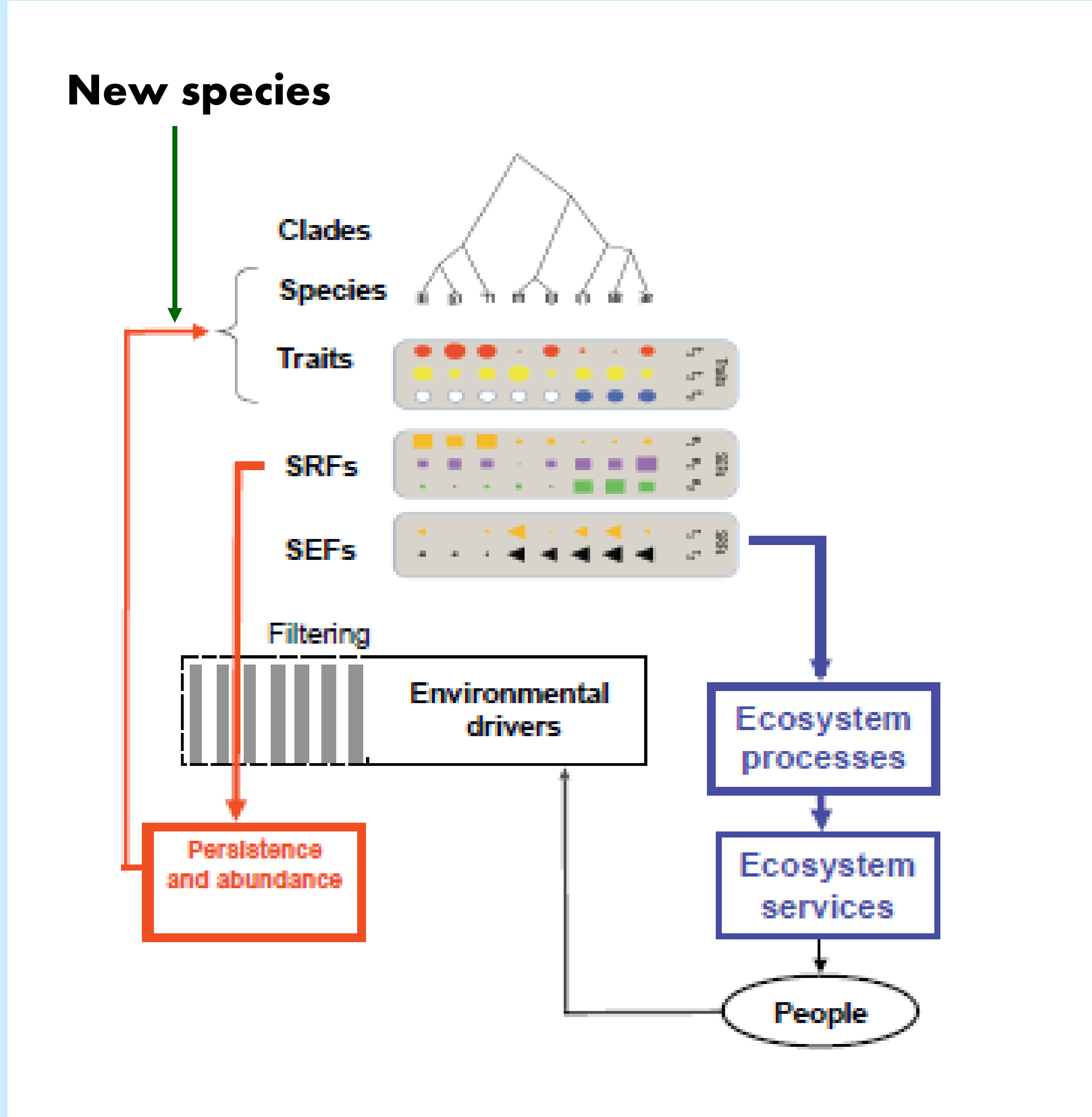



SEF, Specific effect function

SRF, Specific response function

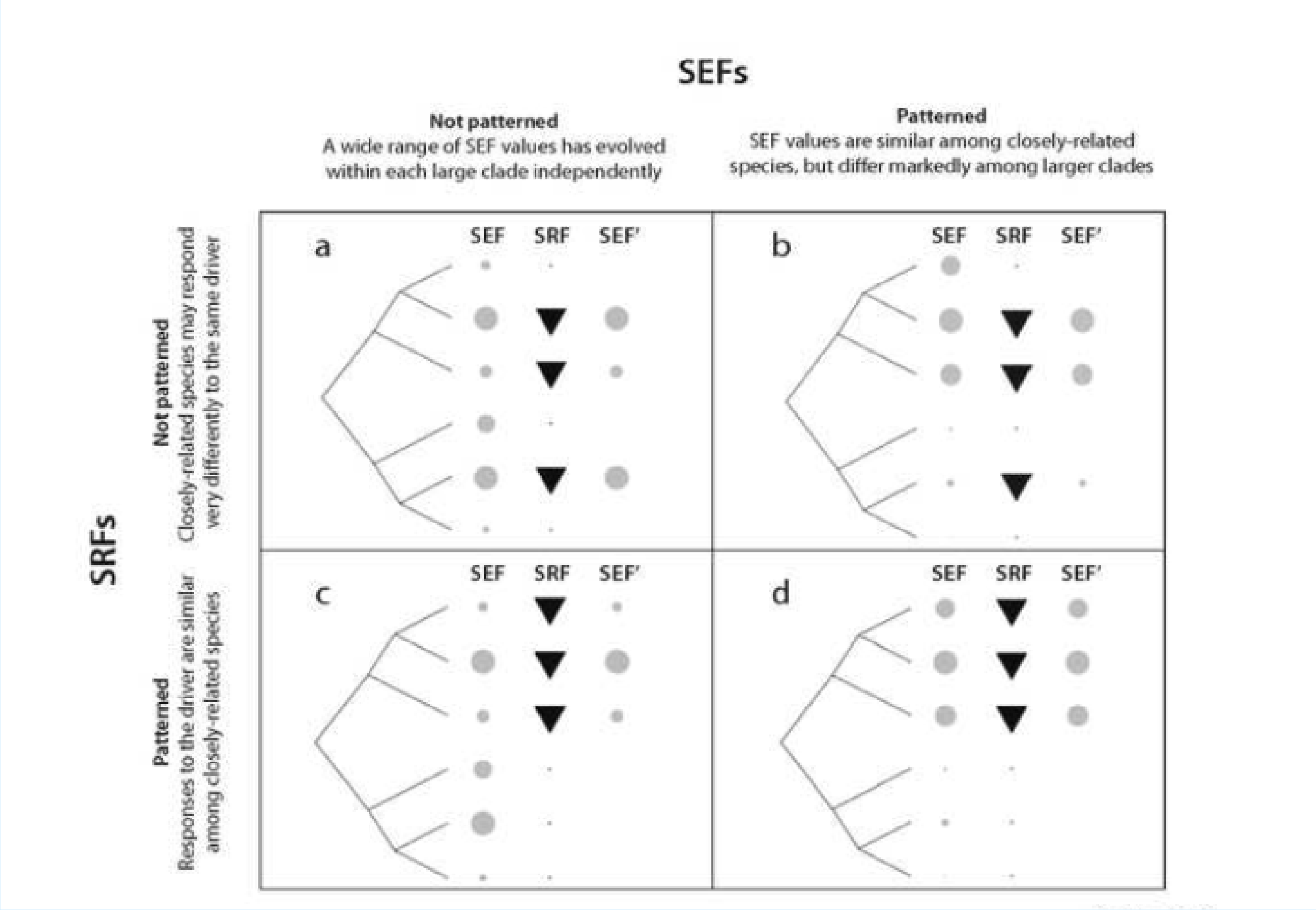
Function = potential per capita or per gram effect or response

# Response-Effect Framework, environmental filters and ecoystem functions in evolutionary context

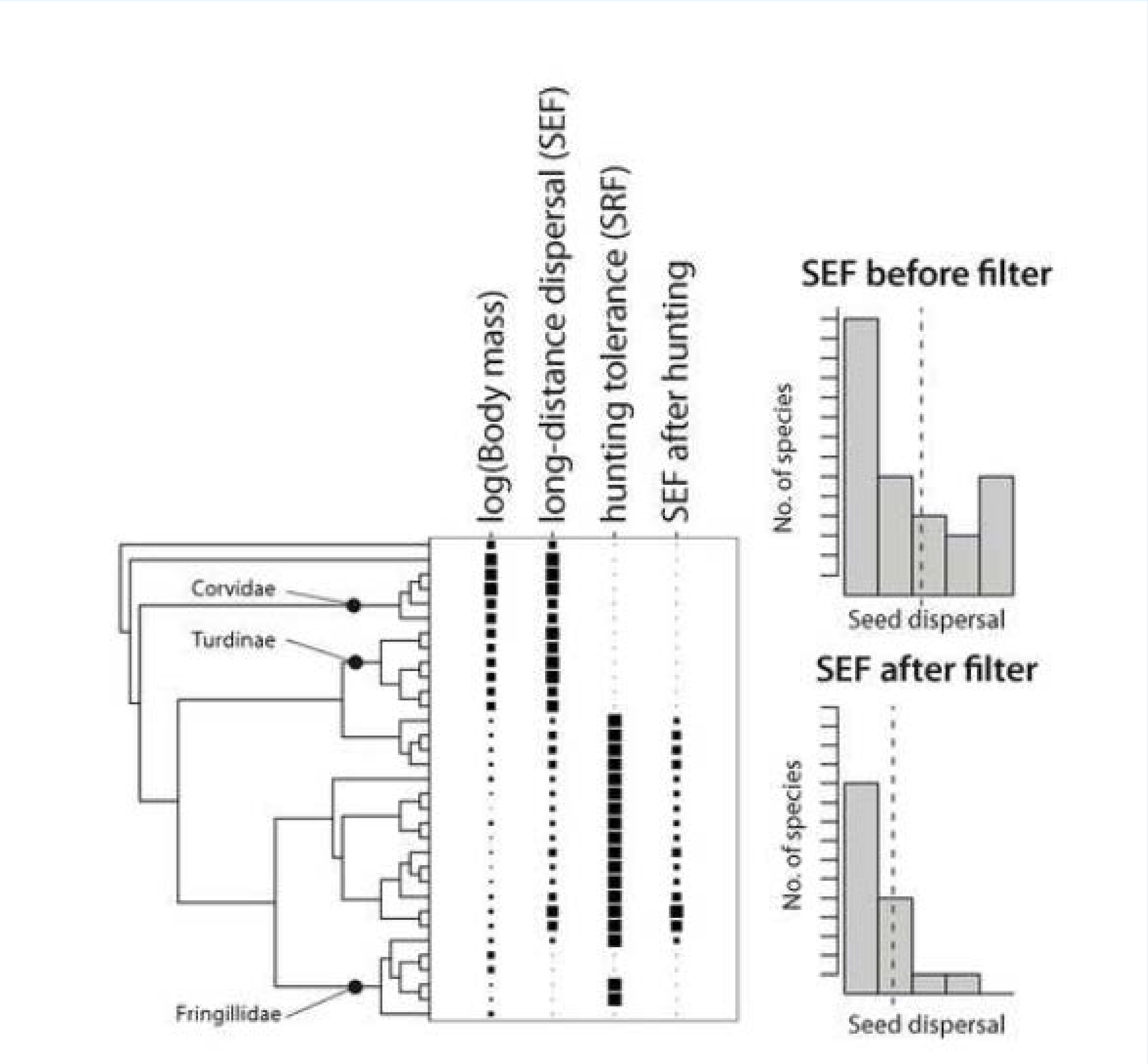



Diaz et al. 2013,
*Ecology and Evolution*

# Vulnerable ecosystems: SRFs and SEFs are correlated and phylogenetically patterned




Diaz et al. 2013, *Ecology and Evolution*

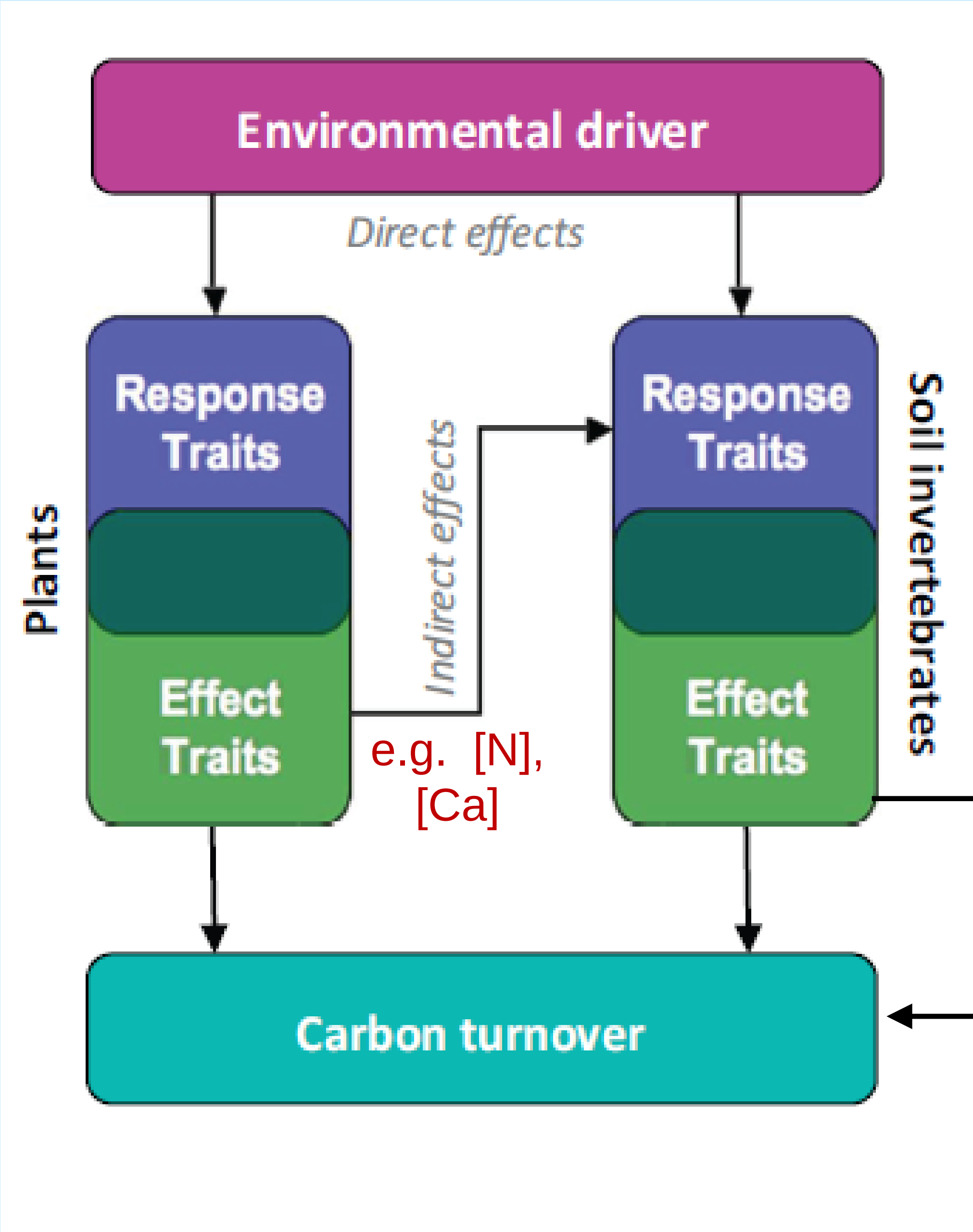



SRFs and SEFs both phylogenetically patterned and correlated across species.

Ecosystem consequence of bird hunting in S Europe

Diaz et al. 2013, *Ecology and Evolution*

# Traits from soil food webs to marine food webs?




E.J. Krab 2013, PhD thesis

# Challenge

- Does it help us to define traits of marine organisms in terms of response traits and effect traits?

- …in relation to
  - Environmental drivers (specific response functions)

  - Biogeochemical cycling
  - Providing safe feeding/reproduction sites (corals)
  - Other functions (specific effect functions)

# Drivers and effects of trait variation: land *versus* ocean

| | LAND | OCEAN |
|---|---|---|
| • Biogeochemistry | C,N,P, $H_2O$ | C,N,P, Ca, Si, Fe |
| • Drivers | [light, temperature, pH, fertility, salt] | |
| | moisture, wind | pressure*, $CO_2$, $O_2$ |
| • Role of ontogeny** | important | important |
| • Mobility*** | important | important |
| • Trophic interactions | important | important |
| • Substrate stability | important | important |

* Pressure of water body on top, wave action

** Reichstein et al. 2015 *Nature Comm.*, Cornelissen et al. 2003 *JVS*

*** Immigration/ emigration on short and long spatial and time scales

# Take home messages (1)

To understand (climatic, successional or human-induced) changes in ecosystem functions as related to community change (on land & in oceans!):

- focus not only on variation in response traits among organisms
- but also on variation in effect traits
- ….and especially on the relations between variation in response and effect traits
- whether or not in an evolutionary or in a trophic context

# Take home messages (2)

- Land and ocean ecosystems are not so very different (although one cannot drown on land)

- The Response-Effect Trait Framework may be relevant to ocean functions, because
  - mostly similar drivers (climatic, resource availability, disturbance regimes) affect marine and terrestrial organisms
  - many marine organisms also control biogeochemical cycling, substrate stability and performance of other organisms

Thank you to Gregoire Freschet, Vladimir Onipchenko, Sandra Diaz, Andy Purvis,  Will Cornwell, Russian-Dutch Team; LOGLIFE Team;  to EU & NWO for €€;

And to the workshop organisers and sponsors!

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AND THANK YOU ALL FOR LISTENING

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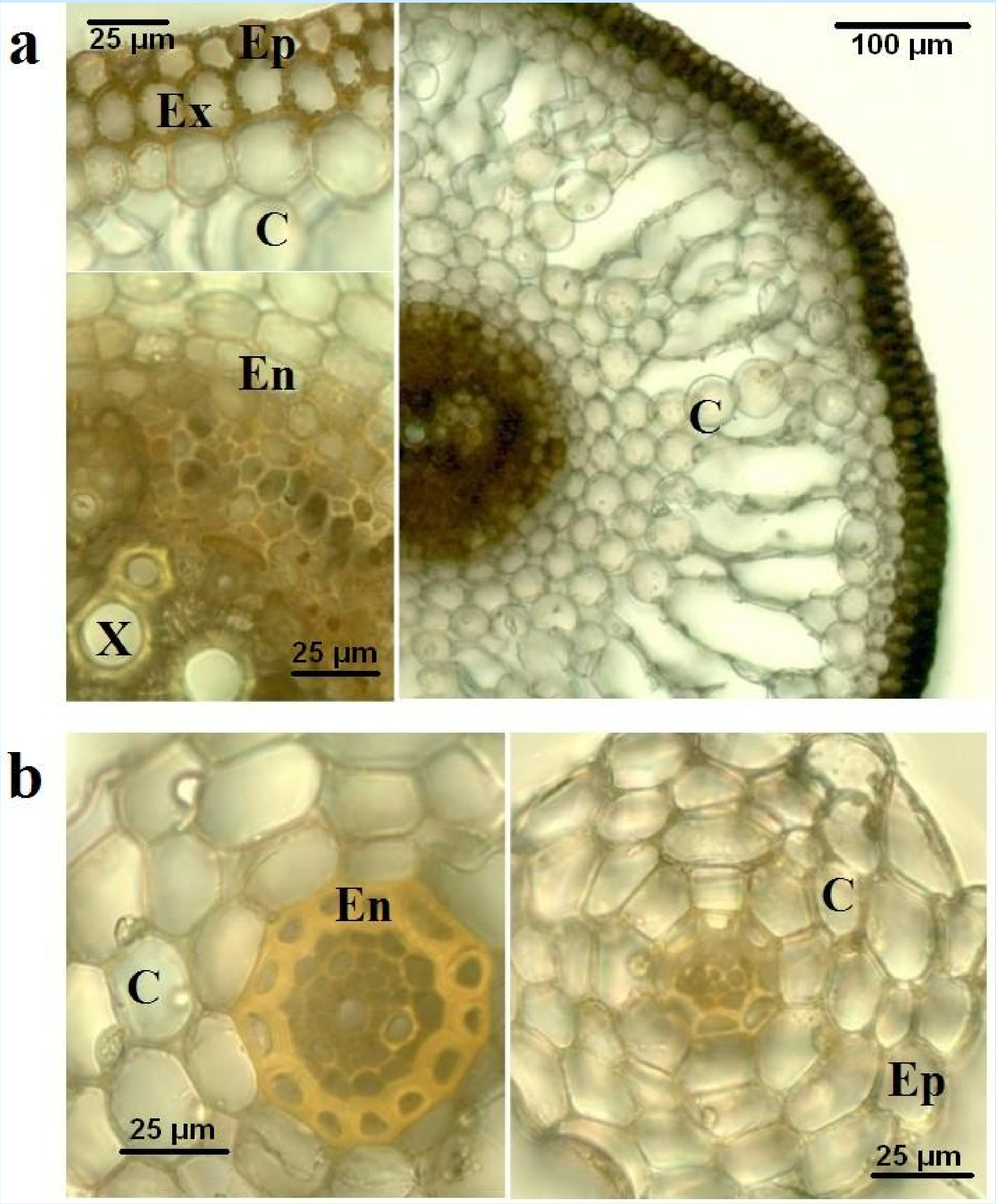
# Extra slides

# Root anatomy

Soil roots

Snow roots

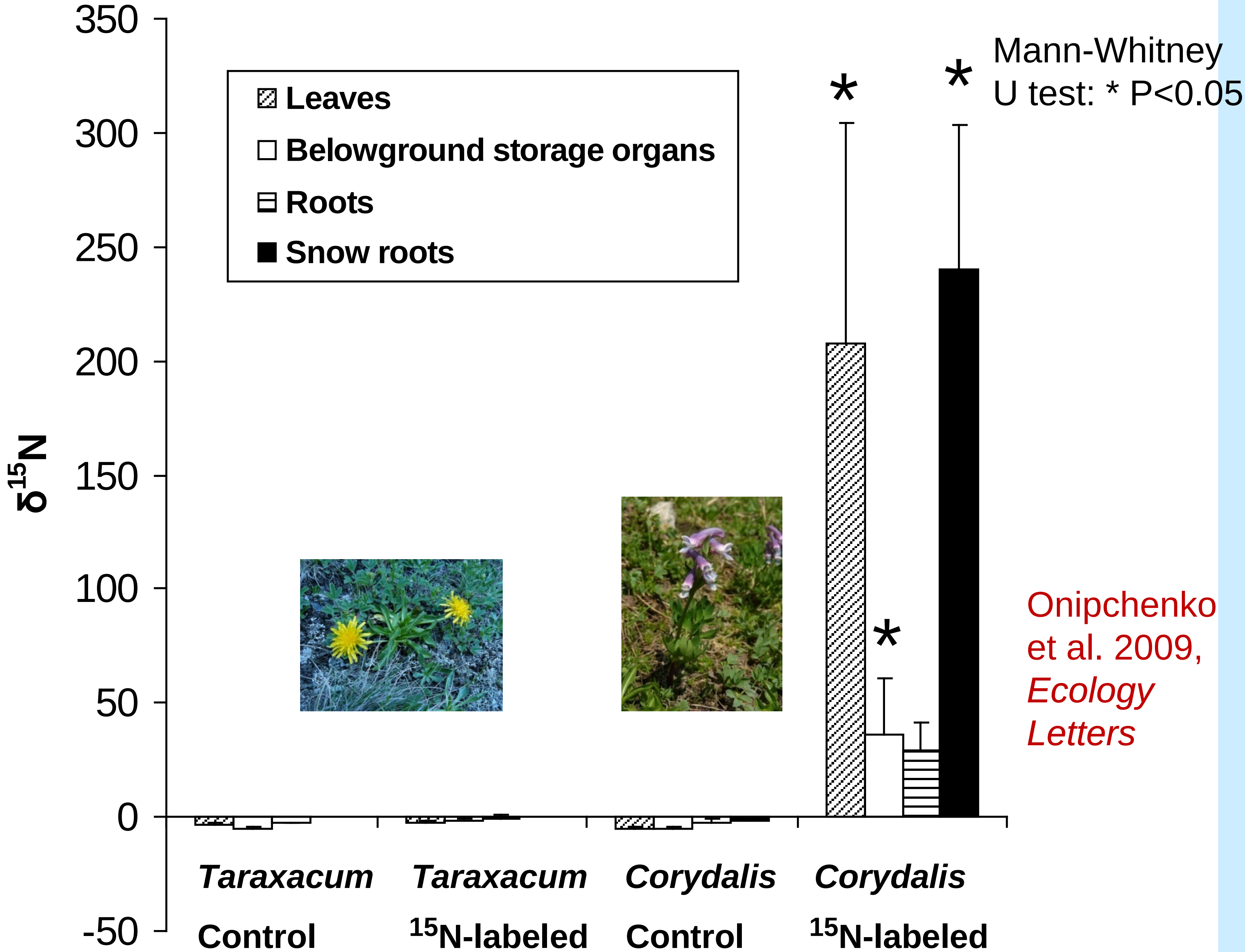


# $^{15}N$ snow-bed labeling experiment

- 4 plots with 98% enriched $NH_4^+$ $NO_3^-$ (4 L, 140 mg N / plot)

- 4 control plots (paired)

(15 July 2008)




Onipchenko et al. 2009, *Ecology Letters*

# Forest fires regimes are important for climate!

# Can plant effect traits help predict these?

Variation in flammability of gymnosperms (needle-leaf trees)

Collecting leaf litter from botanical gardens and (sub-) tropical greenhouses in the Netherlands

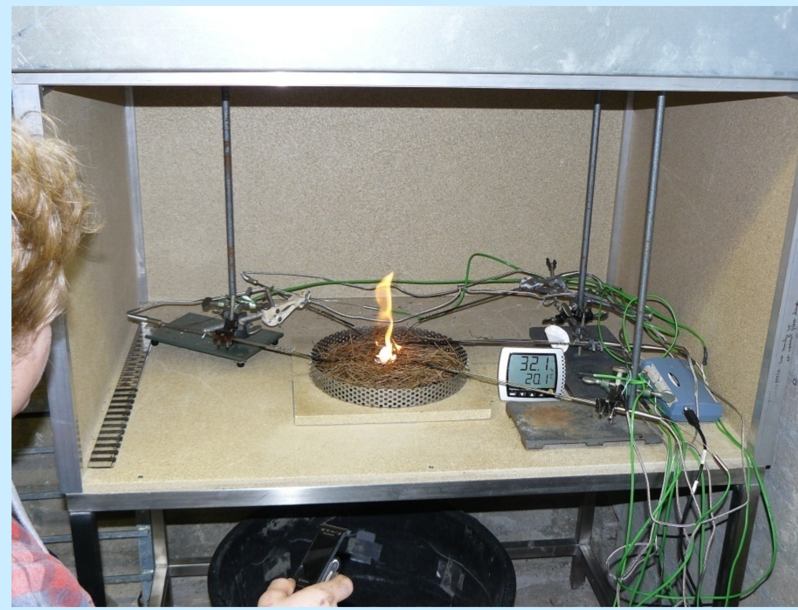


Collections of leaf litter of multiple gymnosperm species

# FLARE

**Fire Lab Amsterdam for Research in Ecology**

vrije Universiteit amsterdam

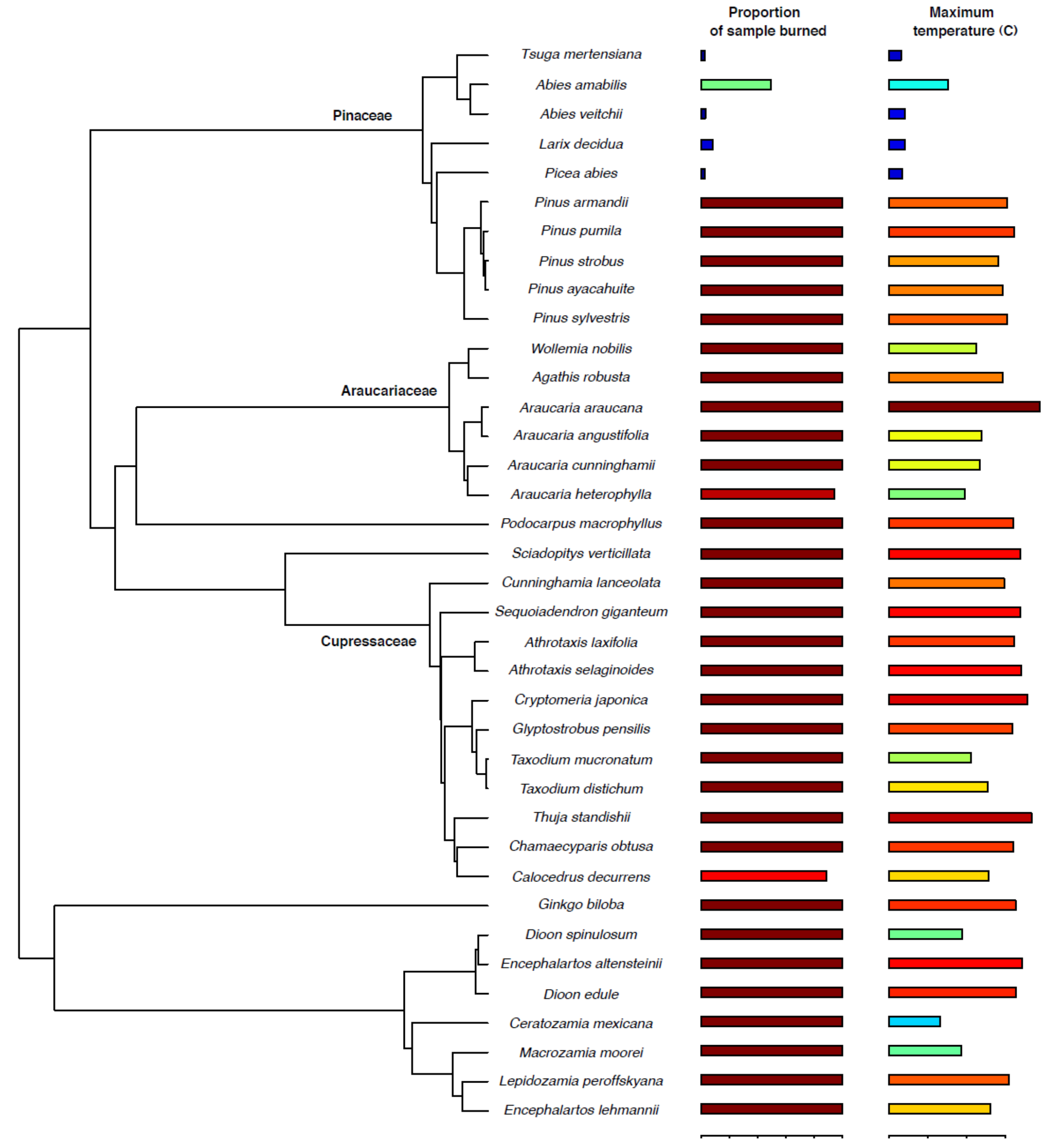


Screening species for flammability
in fuel beds of standard volume

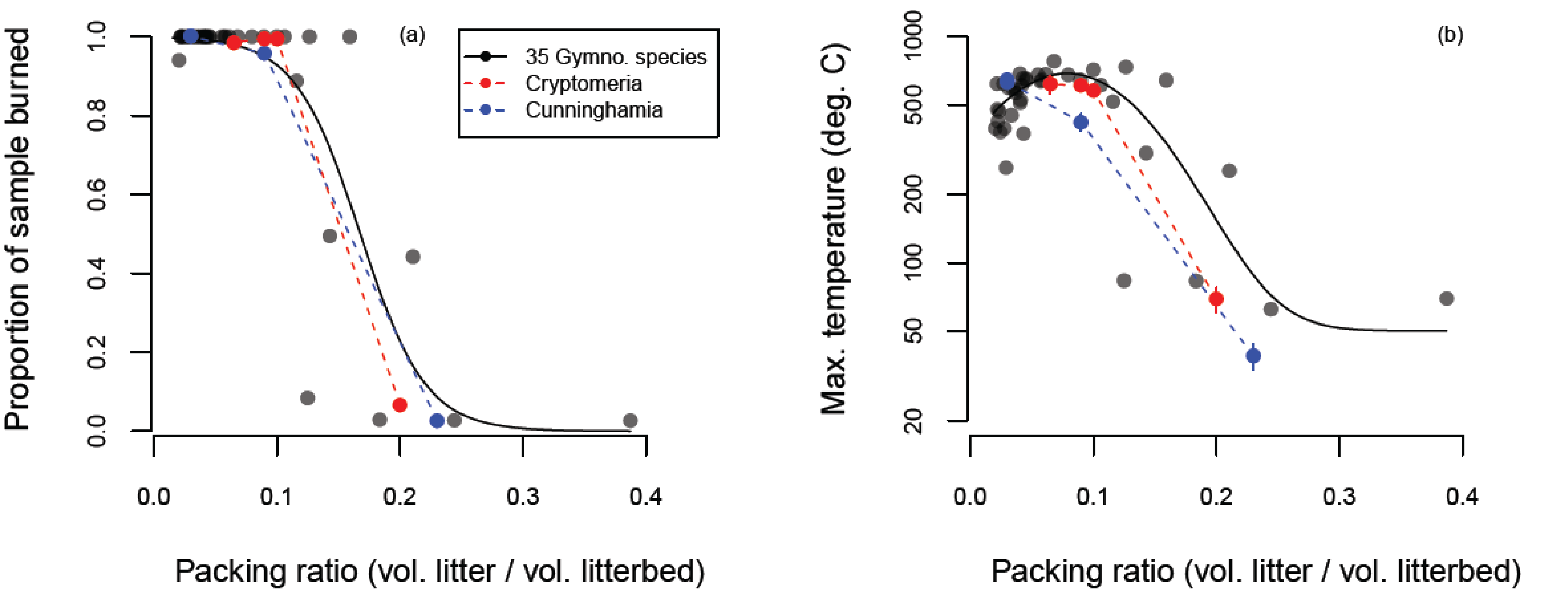
# Flammability of gymosperms on the Tree of Life

Fuel beds of non-*Pinus* Pinaceae burn poorly.

Small leaves → tight fuel packing → lack of $O_2$



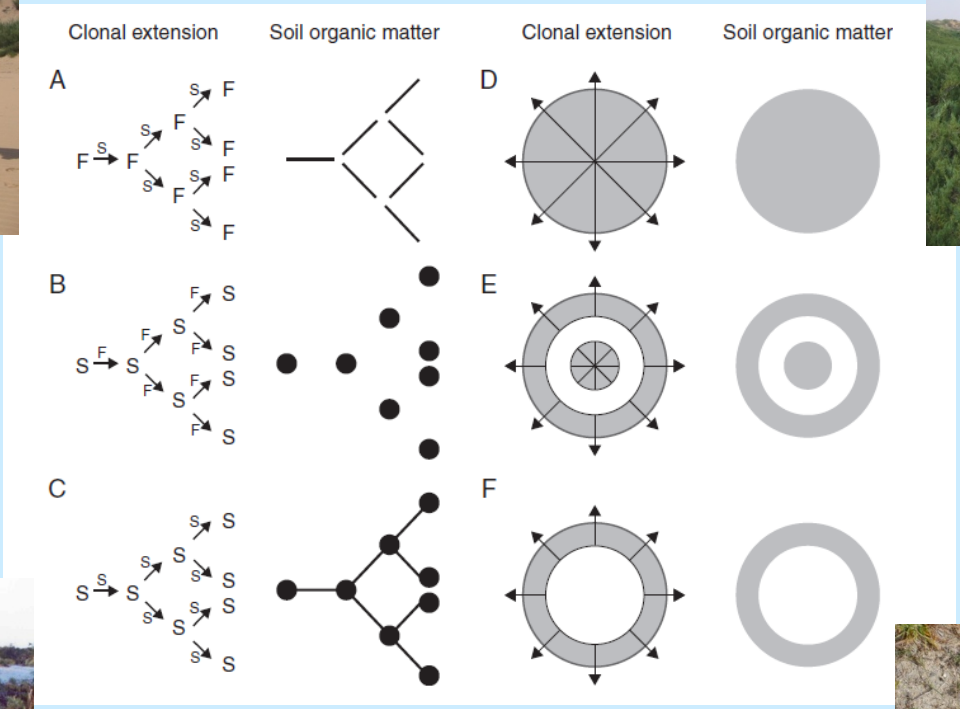
# Small leaves → tight litter packing → low flammability both between and within species




Implications for wildfire regimes?

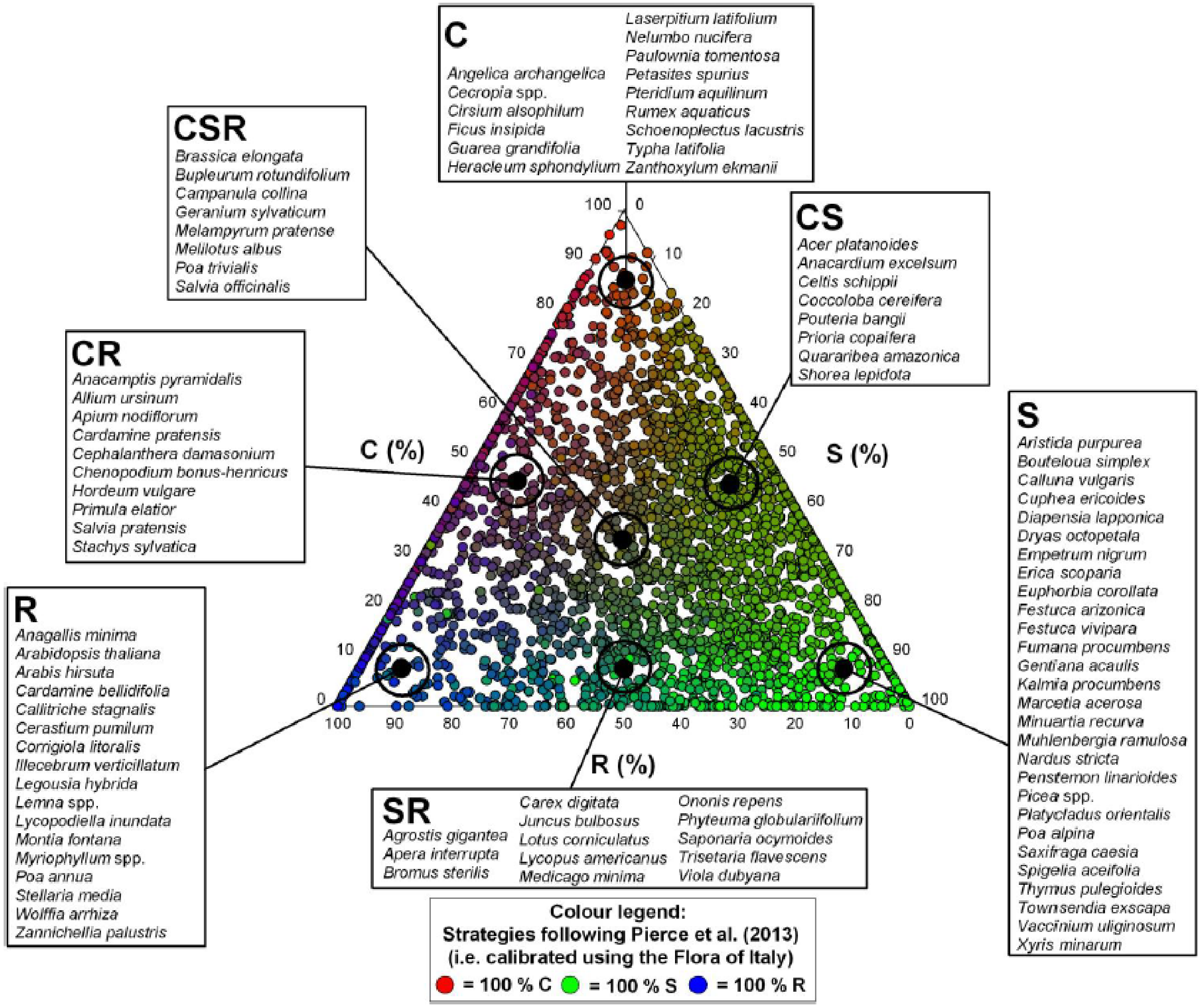
Cornwell et al. 2015 *New Phytologist*

# Clonality and spatial patterns of soil organic matter formation



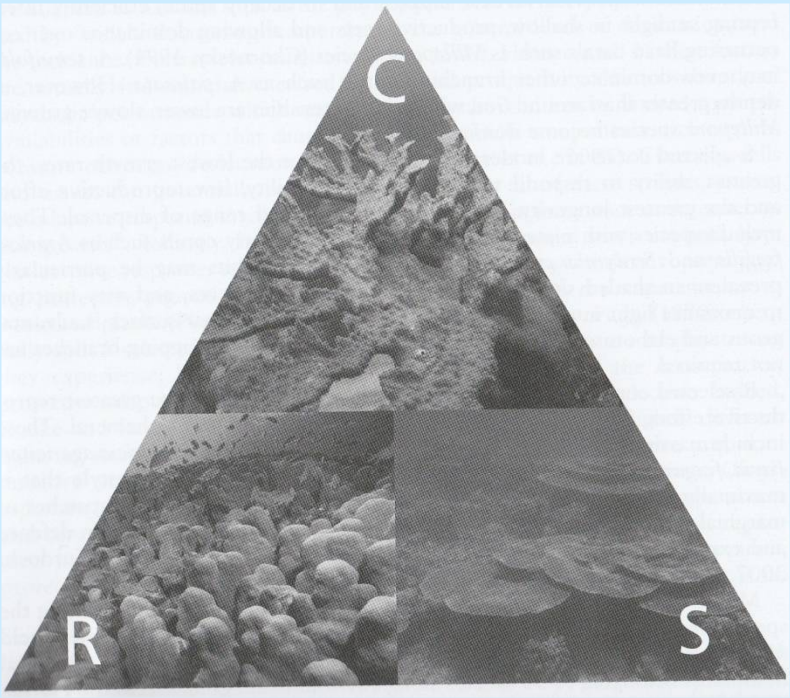

Cornelissen et al. 2014 *Annals of Botany*

# Plant strategies re. disturbance and stress regimes at global scale: Grime's CSR ( Pierce et al. submitted)

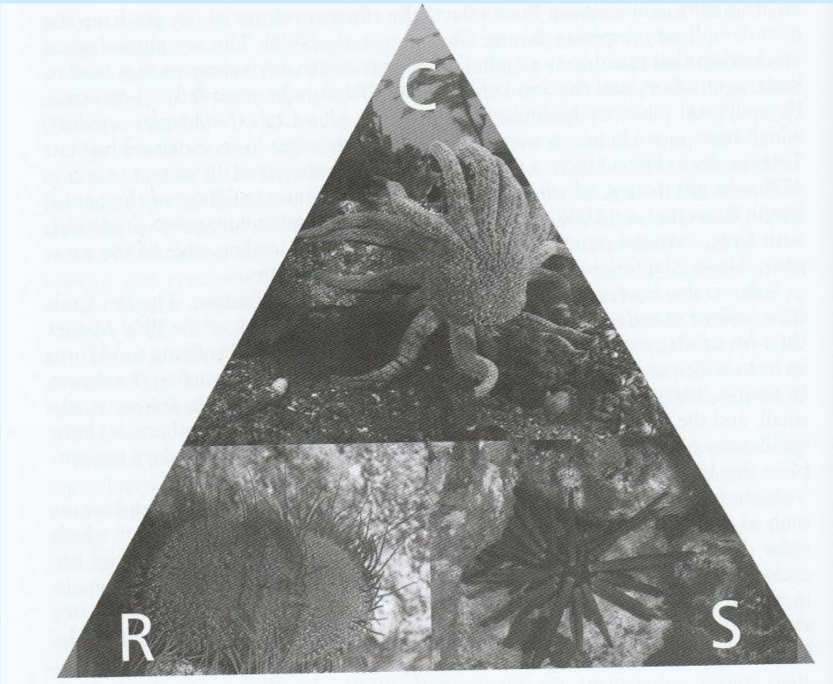


# Marine animal CSR-Strategies as adaptations to disturbance and stress regimes

Corals (after Murdoch 2007)




Echinoderms (after Lawrence 2007)




Grime & Pierce 2012, *The Evolutionary Strategies that Shape Ecosystems,* Wiley & Black