Three axes [of life history variation] to rule them all

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SalGo TEAM

IITE, 11 Oct 2022

Ecology needs better prediction

Prediction in ecology: promises, obstacles and clarifications

Virginie Maris ✉, Philippe Huneman, Audrey Coreau, Sonia Kéfi, Roger Pradel, Vincent Devictor

CONCEPTS & SYNTHESIS
EMPHASIZING NEW IDEAS TO STIMULATE RESEARCH IN ECOLOGY

A practical guide to selecting models for exploration, inference, and prediction in ecology

Andrew T. Tredennick [iD],[1] Giles Hooker,[2] Stephen P. Ellner,[3]

Prediction in ecology: a first-principles framework

Michael C. Dietze[1]

ECOLOGY LETTERS

A structured and dynamic framework to advance traits-based theory and prediction in ecology

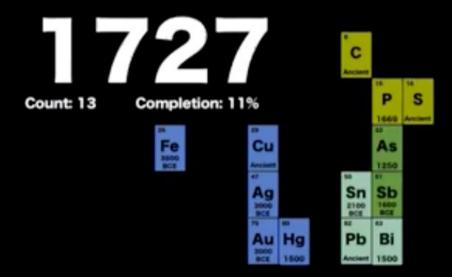Colleen T. Webb, Jennifer A. Hoeting, Gregory M. Ames, Matthew I. Pyne, N. LeRoy Poff

REVIEW
Predictive ecology in a changing world
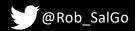
Nicolas Mouquet[1]*, Yvan Lagadeuc[2], Vincent Devictor[1], Luc Doyen[3], Anne Duputié[4], Damien Eveillard[5], Denis Faure[6], Eric Garnier[7], Olivier Gimenez[7], Philippe Huneman[8], Franck Jabot[9], Philippe Jarne[7], Dominique Joly[10,11], Romain Julliard[12], Sonia Kéfi[1], Gael J. Kergoat[13], Sandra Lavorel[14], Line Le Gall[15], Laurence Meslin[1], Serge Morand[1], Xavier Morin[7], Hélène Morlon[16], Gilles Pinay[2], Roger Pradel[7], Frank M. Schurr[1,17], Wilfried Thuiller[14] and Michel Loreau[18]

A science comes of age when it is able to predict

300 years of element discovery

1727

Count: 13   Completion: 11%
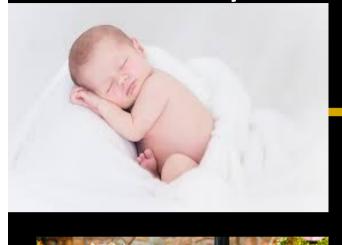
Life history traits: key events in the life of an organism
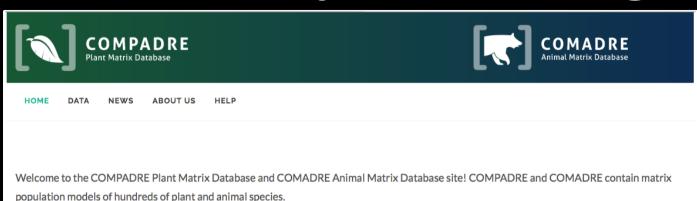
The Bank of Life History Traits

1

Of natural selection we have evidence

Development

Reproduction   Survival

www.compadre-db.org

Salguero-Gómez et al. J Ecol 2015
Salguero-Gómez et al. JAE 2016

https://github.com/padrinoDB/Padrino

`lifecycle` `experimental`

Padrino

This repo hosts the code used to generate and upload data to the `Padrino` data base, as well as the flat tables that comprise both raw and clean versions of it. Users will find a clean interface between the database and `R` in the `Rpadrino` package.

Currently, the data base is a set of 10 text files that consist of ASCII representation of model formulae, the coefficients associated with said models, and the upper/lower bounds of the state variables. Additionally, there are metadata to aid IPM selection, and further information on continuous and discrete environmental variation whenever it is present.

Since the database itself isn't especially useful without an engine that translates IPM formulae into parse-able code, I strongly suggest using the `Rpadrino` interface to download it, select models, and generate kernels! However, if you're interested in the structure, see the `padrino-database/clean` folder for the tables.

PADRINO
IPM Database

Useful Numbers

Current number of unique species, unique publications, and unique `ipm_id` s that are in PADRINO, and have been quality checked for accuracy. Quality checked means that for deterministic models, the asymptotic per-capita growth rate (λ) is within ± 0.03 of the published point estimate value. For stochastic models, we check for approximately the same stochastic population growth rate (λ_s), but do not try to replicate the analysis, as this usually requires too many computing resources to be feasible.

# of Species	# of Publications	# of IPM id's
56	40	280

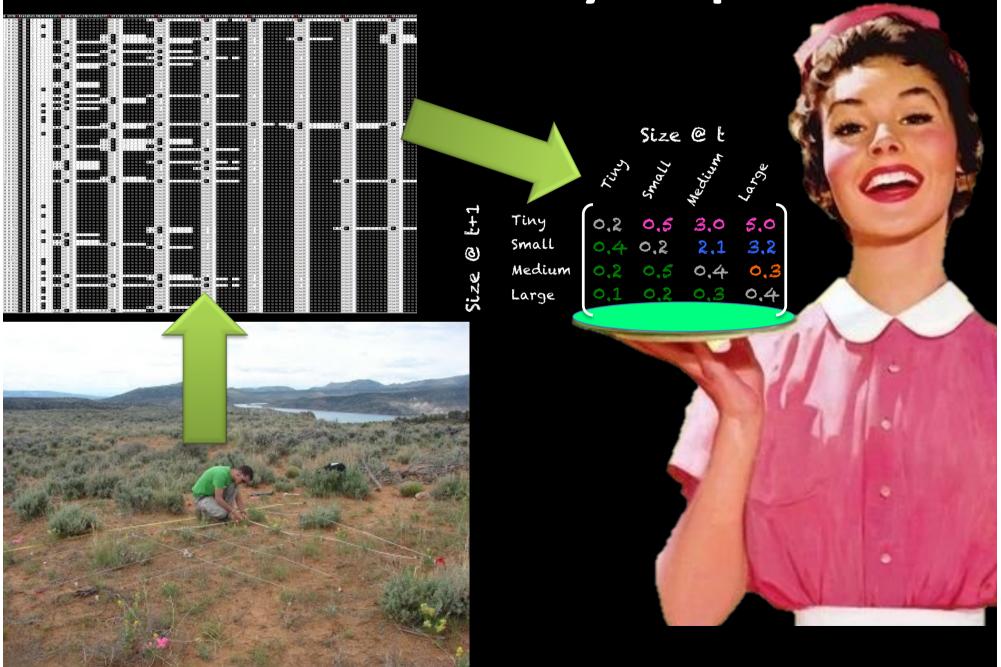**Methods in Ecology and Evolution**
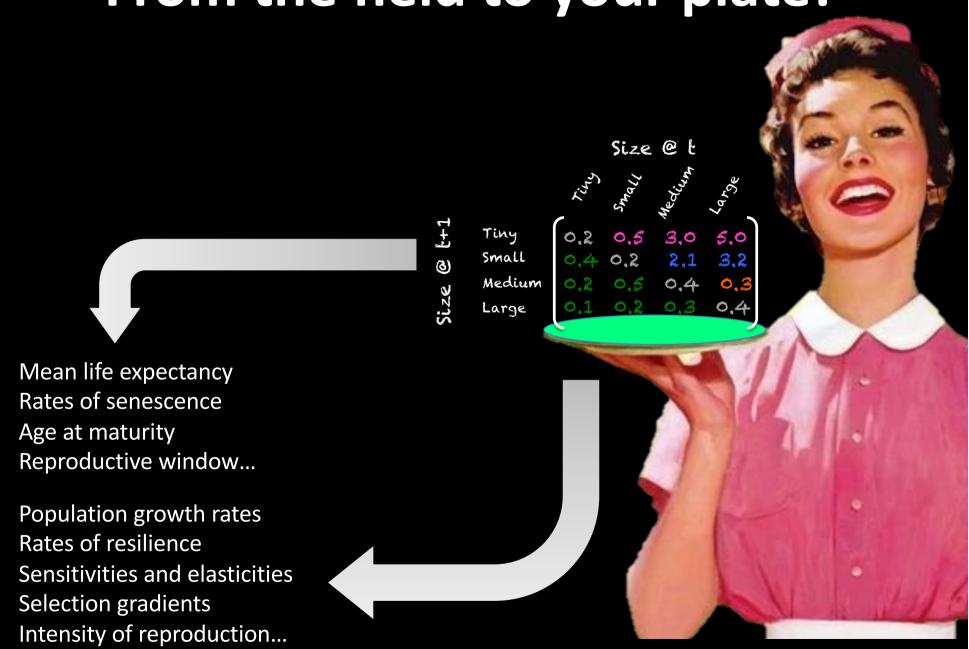BRITISH ECOLOGICAL SOCIETY

APPLICATION | Open Access | (cc) (i)

Rpadrino: An R package to access and use PADRINO, an open access database of Integral Projection Models

Sam C. Levin, Sanne Evers, Tomos Potter, Mayra Peña Guerrero, Dylan Z. Childs, Aldo Compagnoni, Tiffany M. Knight, Roberto Salguero-Gómez

Sam Levin
(iDiv-Oxford)

From the field to your plate!

Size @ t

	Tiny	Small	Medium	Large
Tiny	0.2	0.5	3.0	5.0
Small	0.4	0.2	2.1	3.2
Medium	0.2	0.5	0.4	0.3
Large	0.1	0.2	0.3	0.4

Size @ t+1

From the field to your plate!

Salguero-Gómez et al. J Ecol 2015

Salguero-Gómez et al. J Animal Ecol 2016
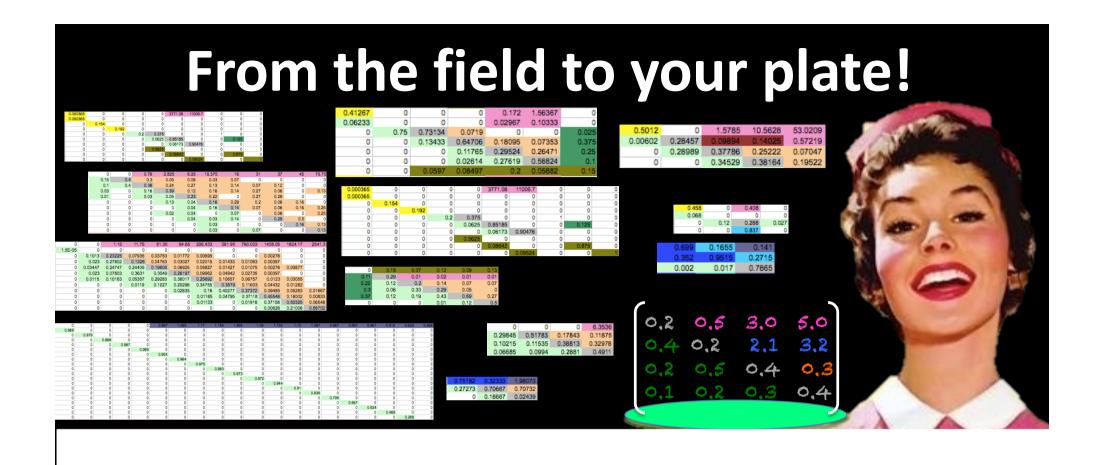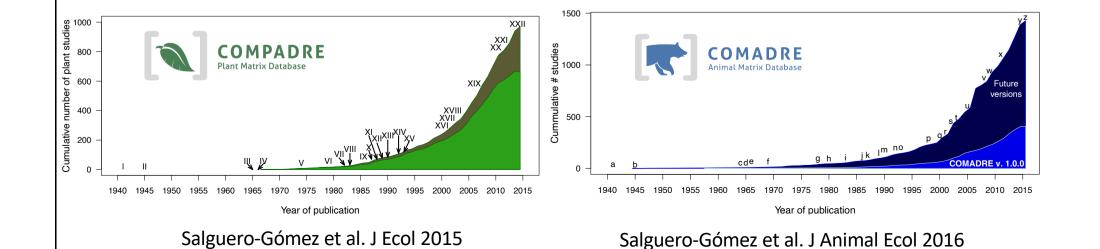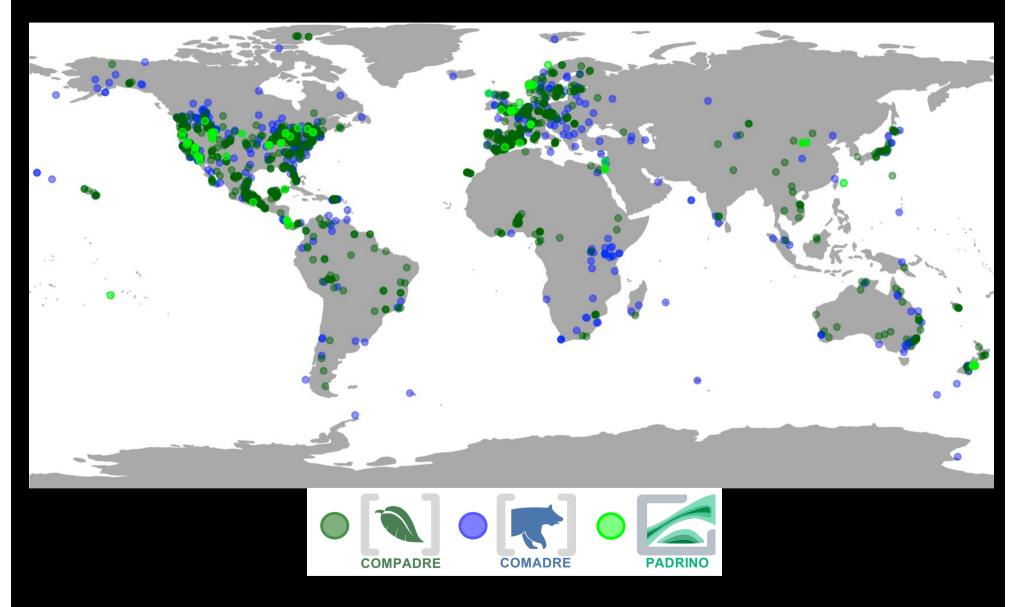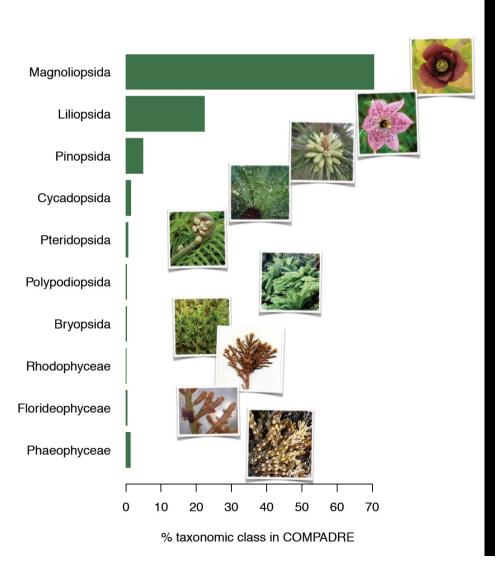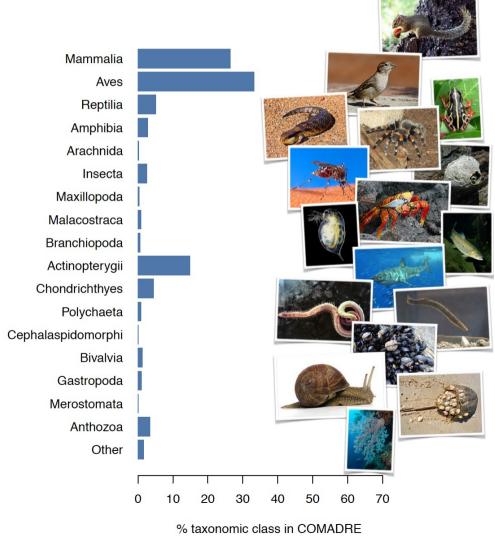
Biogeographic coverage

COMPADRE — Plant Matrix Database

COMADRE — Animal Matrix Database

COMPADRE classes (top to bottom): Magnoliopsida, Liliopsida, Pinopsida, Cycadopsida, Pteridopsida, Polypodiopsida, Bryopsida, Rhodophyceae, Florideophyceae, Phaeophyceae

% taxonomic class in COMPADRE

COMADRE classes (top to bottom): Mammalia, Aves, Reptilia, Amphibia, Arachnida, Insecta, Maxillopoda, Malacostraca, Branchiopoda, Actinopterygii, Chondrichthyes, Polychaeta, Cephalaspidomorphi, Bivalvia, Gastropoda, Merostomata, Anthozoa, Other

% taxonomic class in COMADRE

Do plants also have a fast-slow continuum?

Silvertown & Franco's ternary plot

Stage @ t

	Seedling	Juvenile	Adult
Seedling	0.1	0.0	3.0
Juvenile	0.3	0.3	0.0
Adult	0.0	0.5	0.6

Stage @ t+1

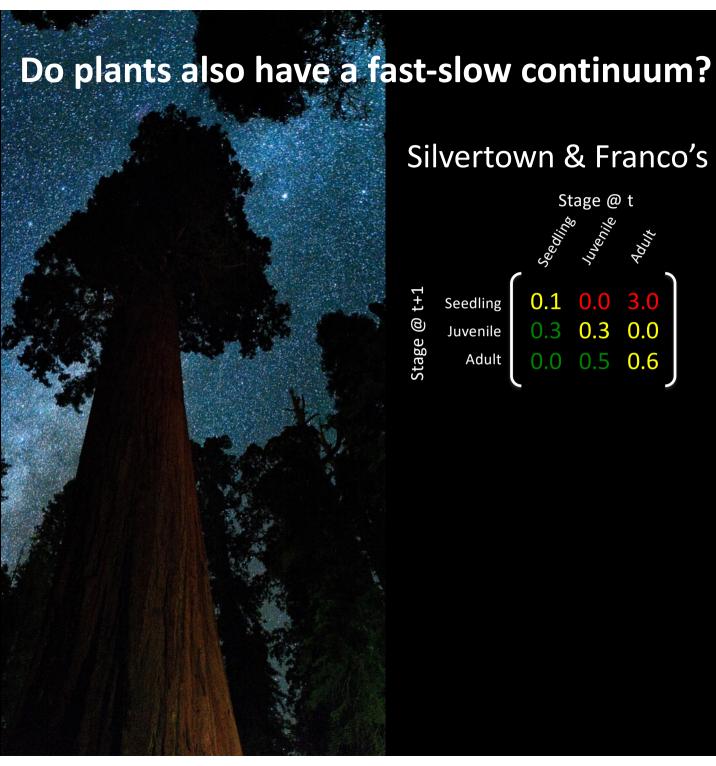# Do plants also have a fast-slow continuum?

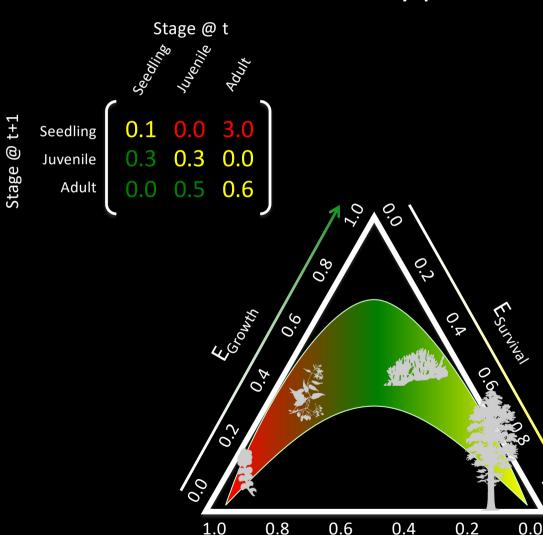## Silvertown & Franco's ternary plot

Do plants also have a fast-slow continuum?

Silvertown & Franco's ternary plot

Challenges:
  Elasticities – de Kroon et al. Ecol 2000
  Trade-offs – Shea et al. J Ecol 1994
  The *unpopulatable* space

Takada, Kawai & Salguero-Gómez Pop Ecol 2018

Does the fast-slow continuum apply to all organisms?

Turn-over T - Generation time

Longevity H - Rate of senescence
                       L_α - Age at maturity

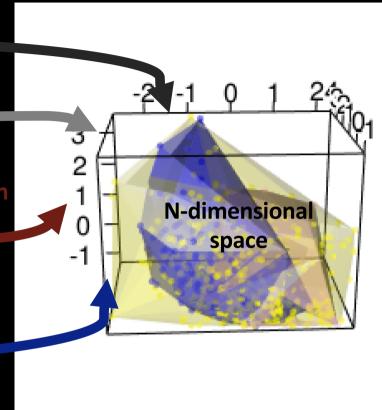**Reproduction** φ - Annual per-capita production
                       S - Degree of iteroparity
                       R_o - Net reproductive output
                       L_w - Reproductive window

Size change γ - Growth
                       ρ - Shrinkage

N-dimensional space

COMPADRE [ ]
Plant Matrix Database
www.compadre-db.org

Caswell & Salguero-Gómez *J Ecol* 2013; Metcalf et al. MEE 2013; Jones… Salguero-Gómez MEE 2022
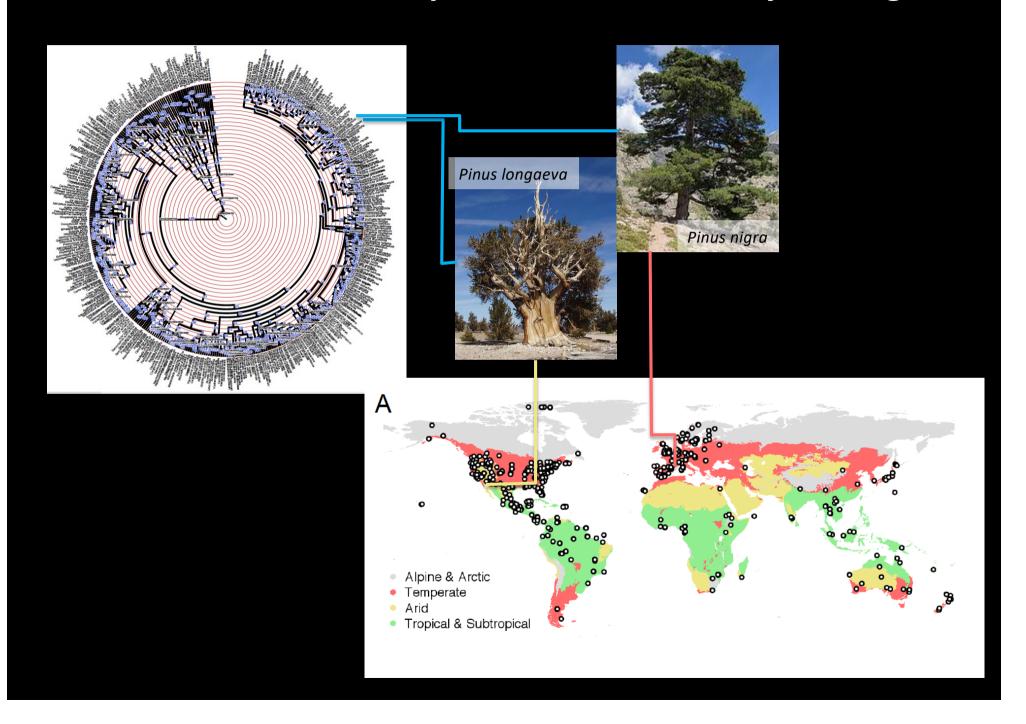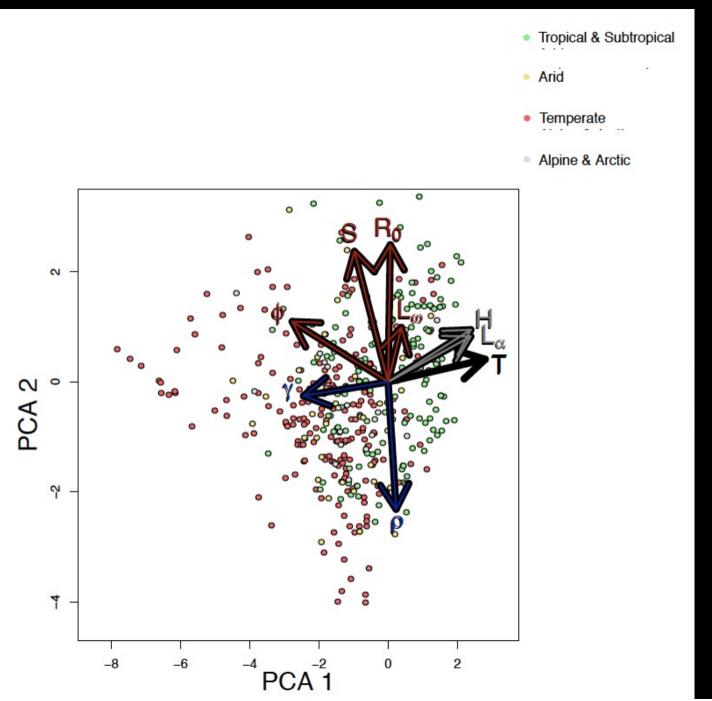
What determines the repertoire of life history strategies?

Pinus longaeva

Pinus nigra

A

- Alpine & Arctic
- Temperate
- Arid
- Tropical & Subtropical

Does the fast-slow continuum apply to other organisms?

Does the fast-slow continuum apply to other organisms?

1st axis: Fast-Slow continuum

- Tropical & Subtropical
- Arid
- Temperate
- Alpine & Arctic
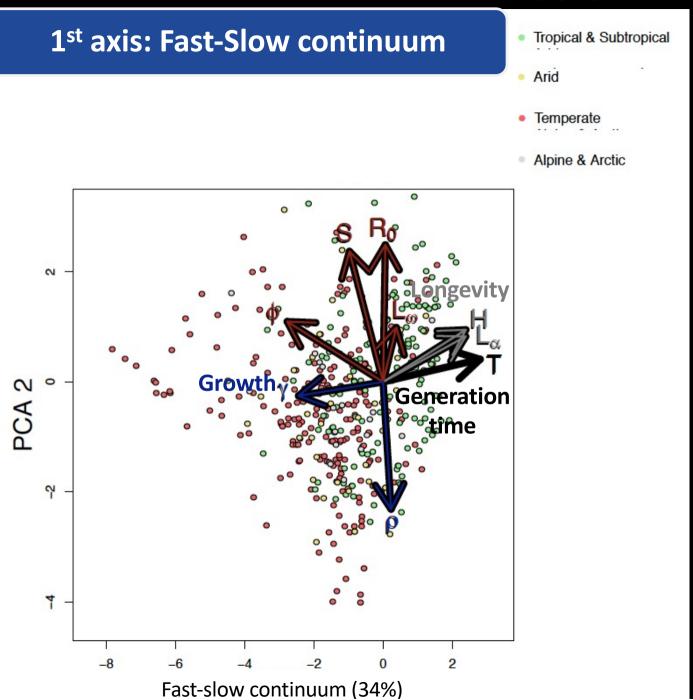
Variance < 60%

Salguero-Gómez et al.
PNAS 2016

Does the fast-slow continuum apply to other organisms?

1st axis: Fast-Slow continuum
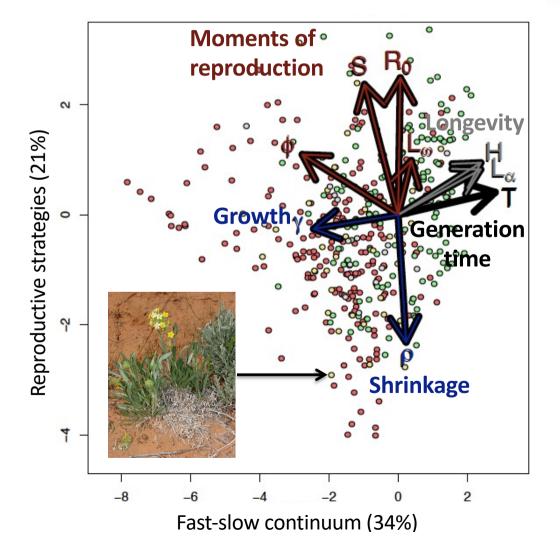
2nd axis: Reproductive strategies

Variance < 60%
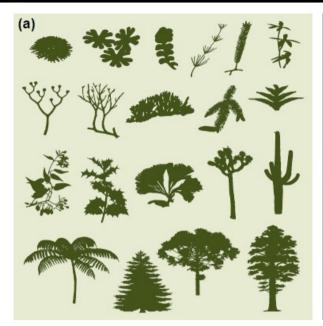
- Tropical & Subtropical
- Arid
- Temperate
- Alpine & Arctic
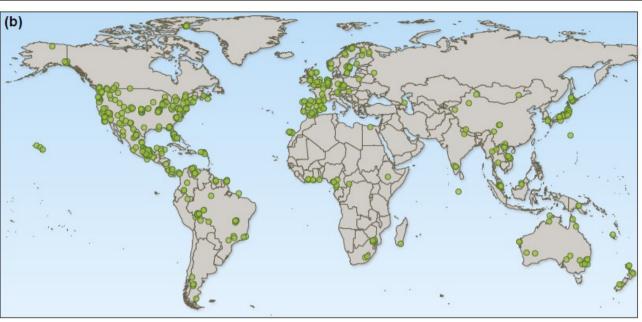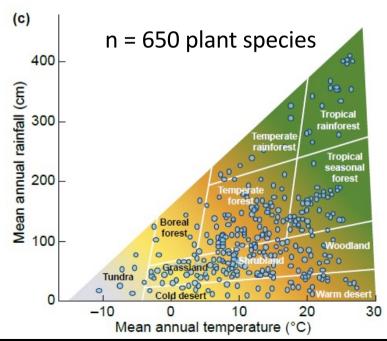
Salguero-Gómez et al.
PNAS 2016

Usefulness of classification of life history strategies now

(a)

(b)

(c)
n = 650 plant species

(d)
Turnover
1. Generation time
Longevity
2. Survivorship curve type
3. Age at sexual maturity
Growth
4. Progressive growth
5. Retrogressive growth
Reproduction
6. Mean sexual reproduction
7. Degree of iteroparity
8. Net reproductive rate
9. Mature life expectancy
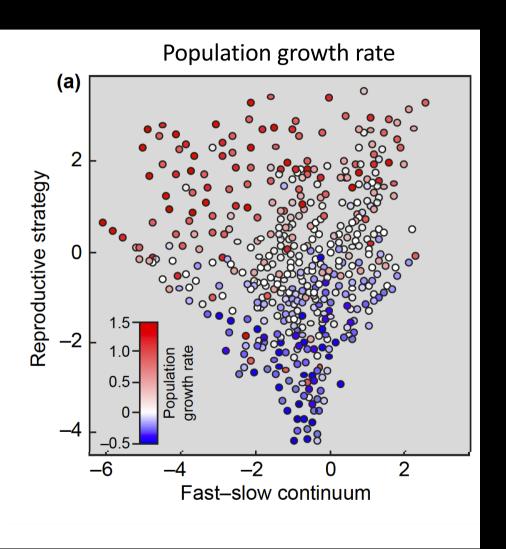
(e)

Usefulness of classification of life history strategies now

Population growth rate

(a)

Reproductive strategy

Fast–slow continuum
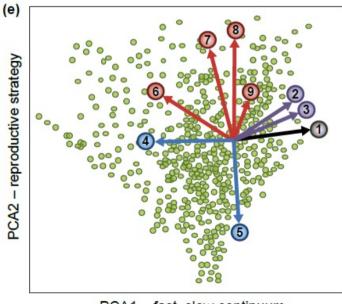
Population growth rate

1.5
1.0
0.5
0
−0.5

Towards a Comparative Framework of Demographic Resilience
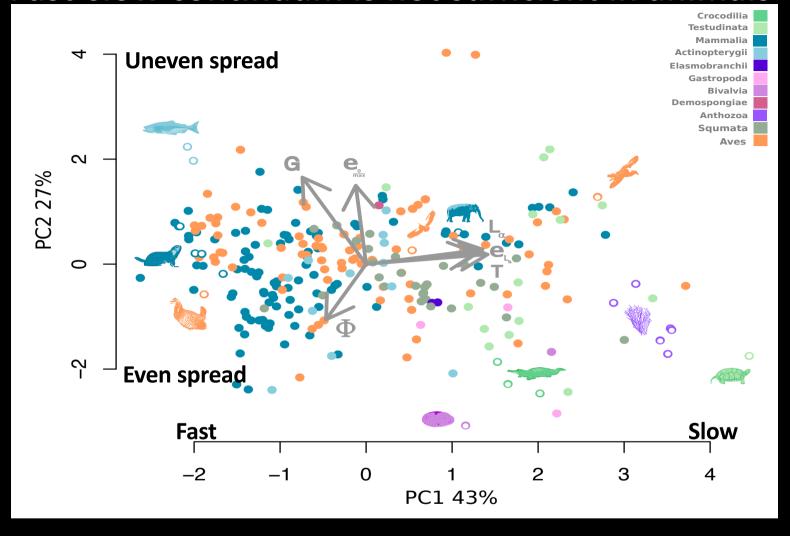
Pol Capdevila • Iain Stott • Maria Beger • Roberto Salguero-Gómez

Life history mediates the trade-offs among different components of demographic resilience

Pol Capdevila ✉, Iain Stott, James Cant, Maria Beger, Gwilym Rowlands, Molly Grace, Roberto Salguero-Gómez

Fast-slow continuum is not sufficient in animals
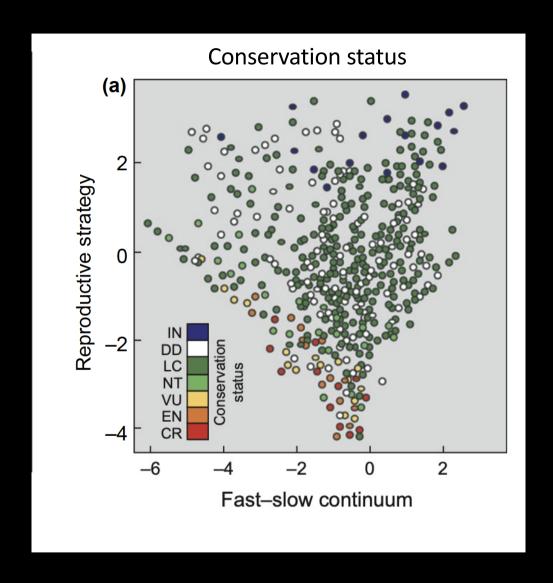
Kevin Healy et al.
Nature Ecol & Evol 2019

COMADRE
Animal Matrix Database
www.comadre-db.org

Usefulness of classification of life history strategies now

Fast-slow continuum revisited
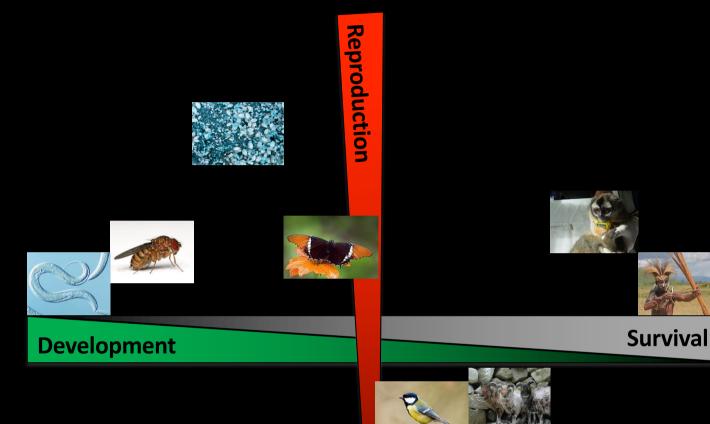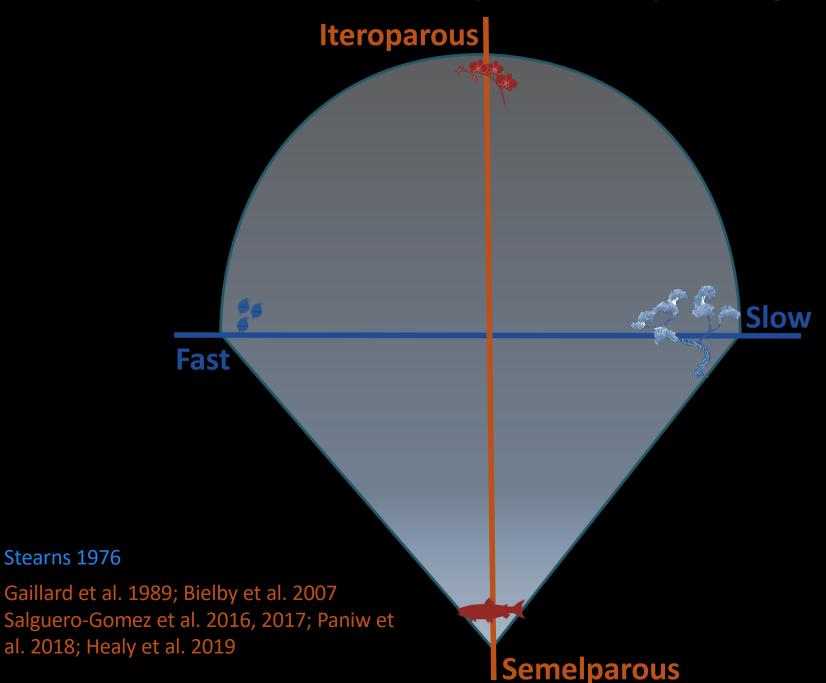
Fast-slow continuum revisited

A framework to classify life history strategies...

Iteroparous

Slow

Fast

Semelparous

Stearns 1976

Gaillard et al. 1989; Bielby et al. 2007
Salguero-Gomez et al. 2016, 2017; Paniw et
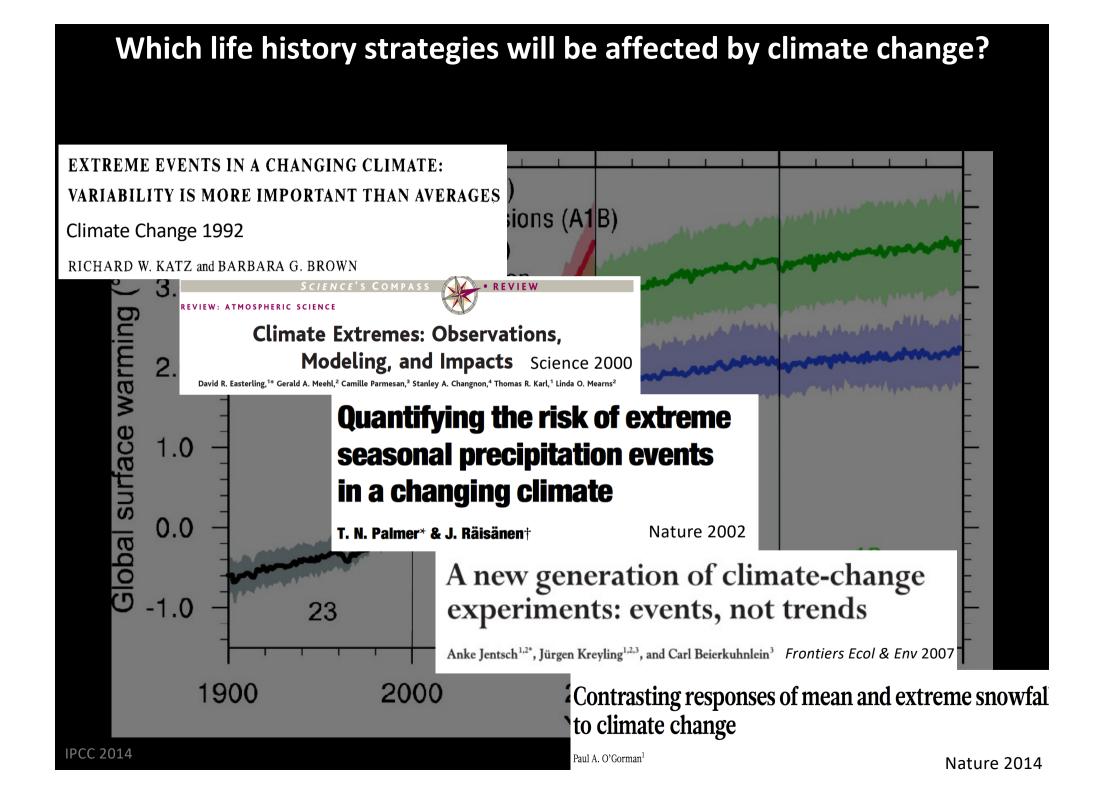al. 2018; Healy et al. 2019

@Rob_SalGo

Which life history strategies will be affected by climate change?

EXTREME EVENTS IN A CHANGING CLIMATE:
VARIABILITY IS MORE IMPORTANT THAN AVERAGES

Climate Change 1992

RICHARD W. KATZ and BARBARA G. BROWN

SCIENCE'S COMPASS • REVIEW

REVIEW: ATMOSPHERIC SCIENCE

**Climate Extremes: Observations,
Modeling, and Impacts**   Science 2000

David R. Easterling,[1*] Gerald A. Meehl,[2] Camille Parmesan,[3] Stanley A. Changnon,[4] Thomas R. Karl,[1] Linda O. Mearns[2]

Quantifying the risk of extreme seasonal precipitation events in a changing climate

T. N. Palmer* & J. Räisänen†   Nature 2002

A new generation of climate-change experiments: events, not trends

Anke Jentsch[1,2*], Jürgen Kreyling[1,2,3], and Carl Beierkuhnlein[3]   *Frontiers Ecol & Env* 2007

Contrasting responses of mean and extreme snowfall to climate change

Paul A. O'Gorman[1]

IPCC 2014

Nature 2014

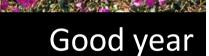# Which life history strategies will be affected by climate change?

Climatic variance can increase in different ways

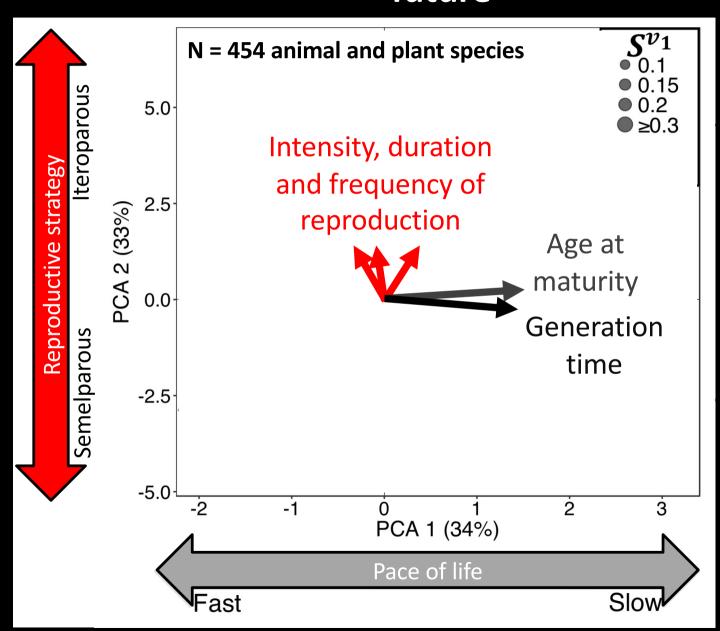iid: independent and identically distributed

Autocorrelations in environmental variation

Positive autocorrelation

Bad year

Good year

Usefulness of classification of life history strategies in the future
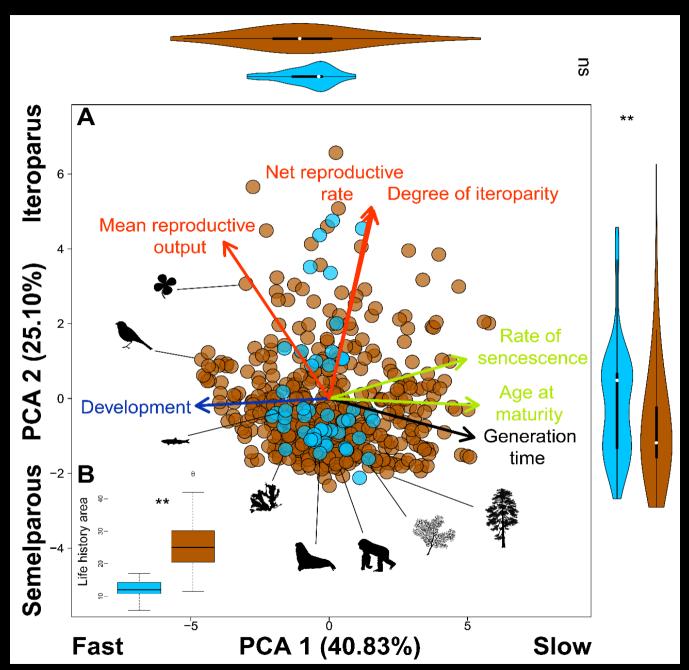

Paniw, Ozgul & Salguero-Gómez *Ecol Letts* 2018
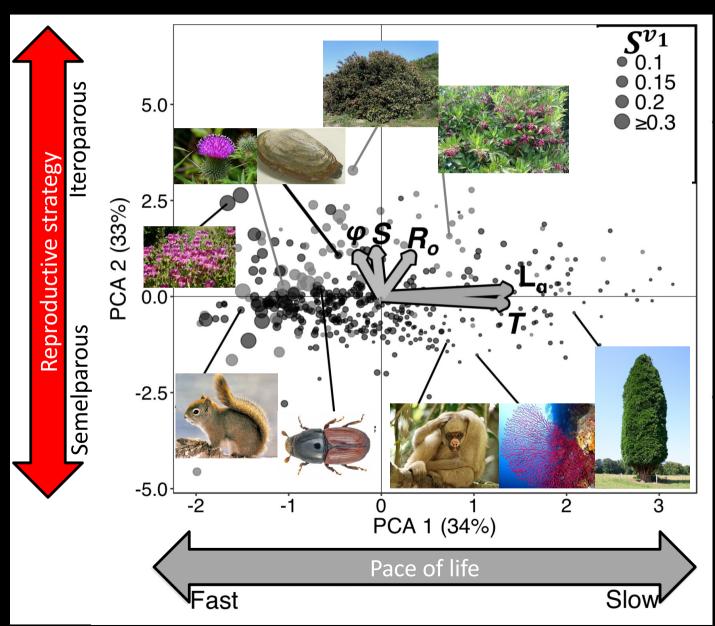
Maria Paniw

Usefulness of classification of life history strategies in the future

Terrestrial *vs.* marine life histories
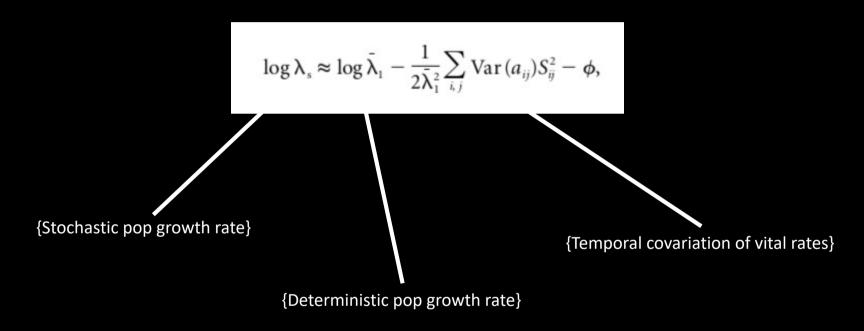
Pol Capdevila

Populations orchestrate responses in stochastic environments

axis: Fast-Slow continuum

axis: Reproductive strategies

3rd axis: Buffering-Lability

Iteroparous

Buffering

Slow

Fast

Labile

Semelparous

Stearns 1976

Gaillard et al. 1989; Bielby et al. 2007
Salguero-Gomez et al. 2016; Paniw et al. 2018

Couer et al. 2022, Santos et al. in review

Adaptations to stochastic environments via life history strategies

Tulja's small noise approximation

$$\log \lambda_s \approx \log \bar{\lambda}_1 - \frac{1}{2\bar{\lambda}_1^2} \sum_{i,j} \mathrm{Var}\,(a_{ij}) S_{ij}^2 - \phi,$$

{Stochastic pop growth rate}

{Temporal covariation of vital rates}

{Deterministic pop growth rate}
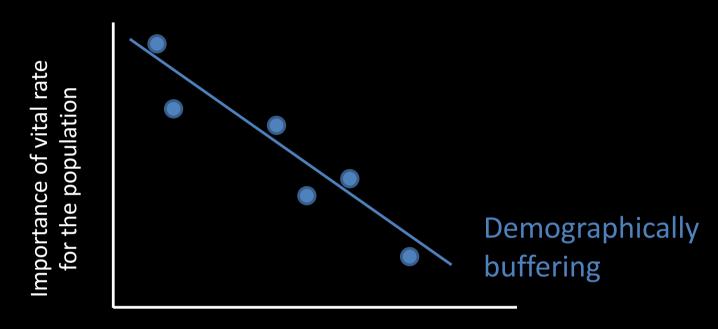
→ **The more covariation in vital rates the worse?**

Tuljapurkar (1982) Population dynamics in variable environments. III. Evolutionary dynamics of r-selection. Theoretical Population Biology 21:141–165
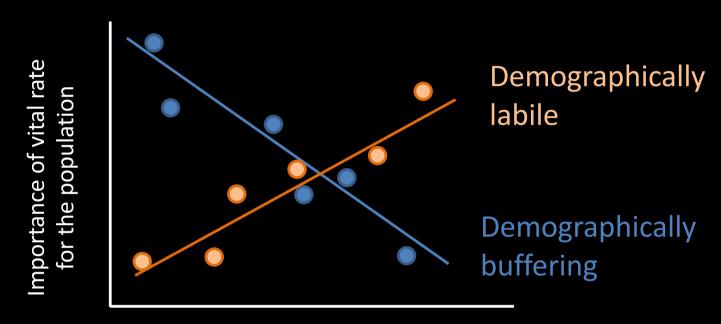
Adaptations to stochastic environments via life history strategies

Importance of vital rate for the population (y-axis)

Temporal variation in vital rates (x-axis)

Demographically buffering

Pfister (1998) Patterns of variance in stage-structured populations: evolutionary predictions and ecological implications. PNAS 95: 213218

Adaptations to stochastic environments via life history strategies

Importance of vital rate for the population

Temporal variation in vital rates
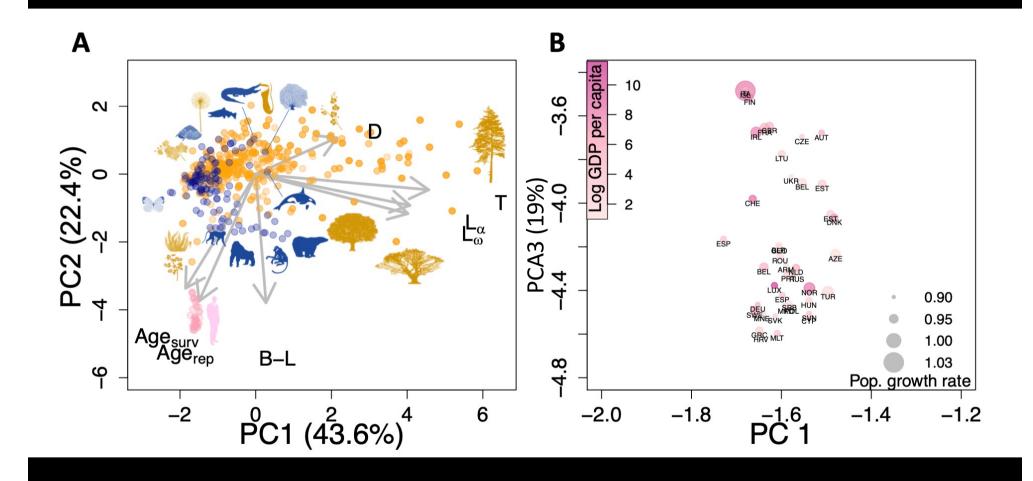
Demographically labile

Demographically buffering

Pfister (1998) Patterns of variance in stage-structured populations: evolutionary predictions and ecological implications. PNAS 95: 213218.
Koons et al. (2009) Is life-history buffering or lability adaptive in stochastic environments? Oikos 118:972-980

A

PC2 (22.4%)

PC1 (43.6%)

D

T

L_α

L_ω

Age$_{surv}$

Age$_{rep}$

B–L

B

PCA3 (19%)

PC 1

Log GDP per capita

10
8
6
4
2

ISL
FIN

FRR
IRL
CZE
AUT

LTU

UKR
BEL
EST

CHE

EST
DNK

ESP

GER
ROU

AZE

BEL
ARM
MLD
PRRUS

LUX
NOR
TUR

ESP
HUN

DEU
SRB
KOL
SWE
MNE
SVK
SVN
CYP

GRC
HRV
MLT

0.90
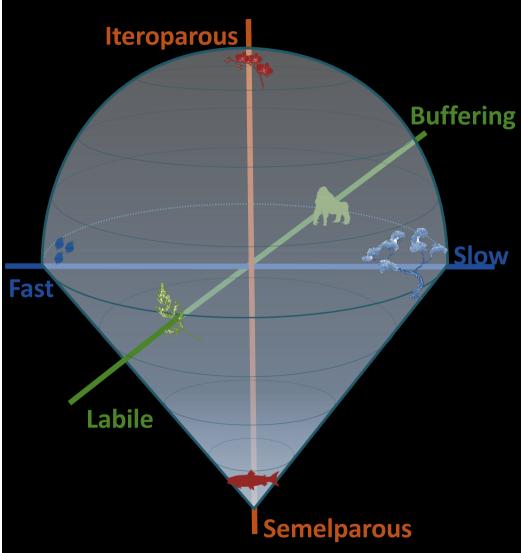0.95
1.00
1.03

Pop. growth rate

Life history adaptations to fluctuating environments: Combined effects of demographic buffering and lability

Christie Le Coeur ✉, Nigel G. Yoccoz, Roberto Salguero-Gómez, Yngvild Vindenes

A framework to classify life history strategies...
...and to predict:

- **Anatomic constraints**
    Salguero-Gomez et al. 2016
- **Demographic performance**
    Salguero-Gomez 2016, 2017a
- **Evolution of senescence**
    Salguero-Gomez 2017b
- **IUCN status**
    Salguero-Gomez 2017b, Healy et al j2019
- **Selection gradients**
    Salguero-Gomez 2017b
- **Dispersal ability**
    Beckman 2018
- **Functional traits**
    Salguero-Gomez 2017b, Piston et al. 2019
- **Pollen limitation**
    Bennet et al. in prep
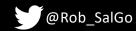- **Animal vs plant life histories**
    Healy et al. in 2019
- **Marine vs terrestrial life histories**
    Capdevila et al. 2020
- **Climate change**
    Paniw et al. 2018, Compagnoni et al., in prep

@Rob_SalGo

Thanks!

Fully-funded NERC PhD position:
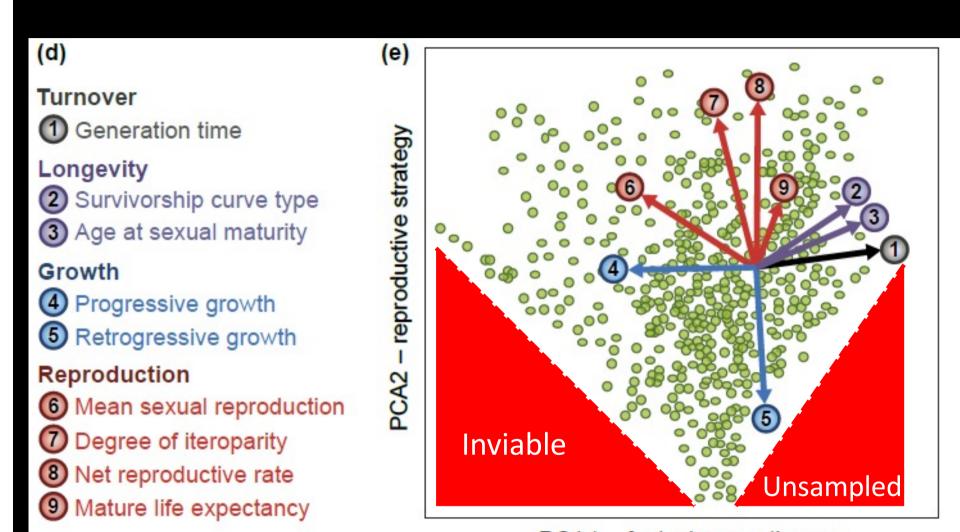https://envres.web.ox.ac.uk/article/plants-on-the-move

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Where are the limits of life history strategies?