Consequences of biological invasions on a global scale: addressing the multiple facets of threatened terrestrial diversity

CBGP Seminar – May, 14th 2024

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ÉCOLE DOCTORALE Sciences du végétal: du gène à l'écosystème (SEVE)

FRB FONDATION POUR LA RECHERCHE SUR LA BIODIVERSITÉ

CESAB CENTRE FOR THE SYNTHESIS AND ANALYSIS OF BIODIVERSITY

Multiple facets of biological diversity

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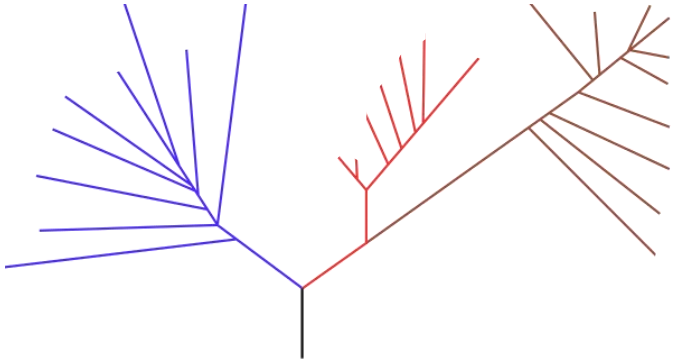
Evolutionary history



Multiple facets of biological diversity

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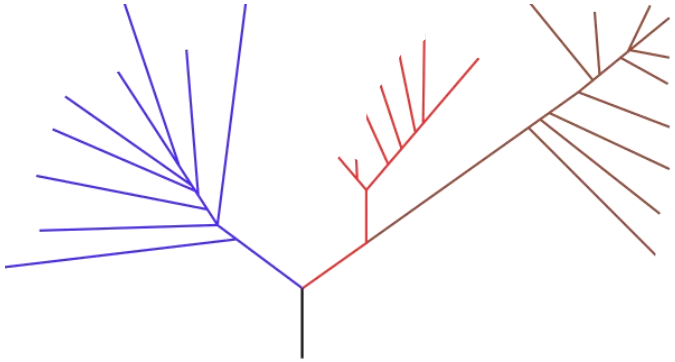
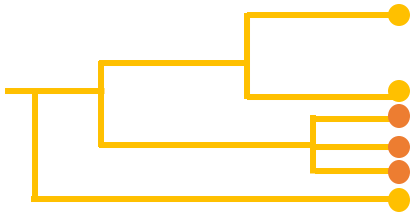
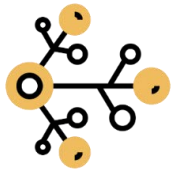


Phylogenetic diversity





Vane-Wright et al., 1991
Faith, 1992

Multiple facets of biological diversity

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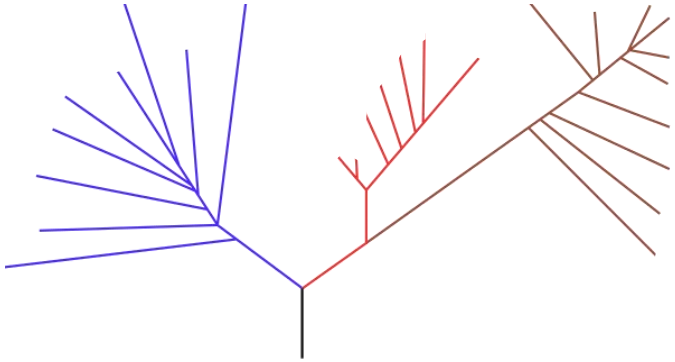

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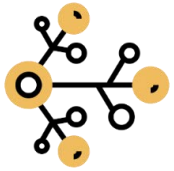

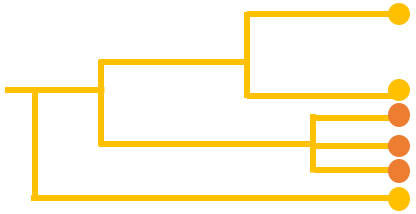

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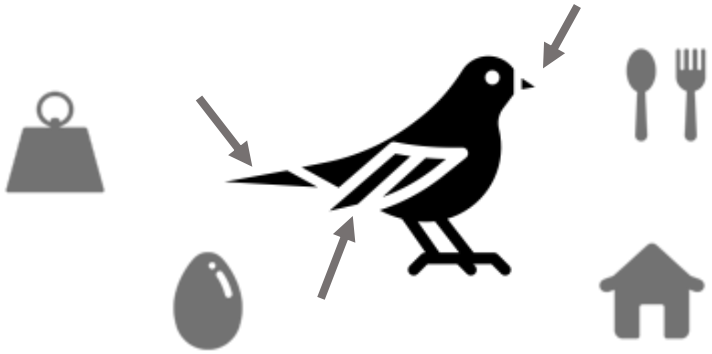
Species traits



Tilman 2001
Petchey & Gaston 2006

Multiple facets of biological diversity

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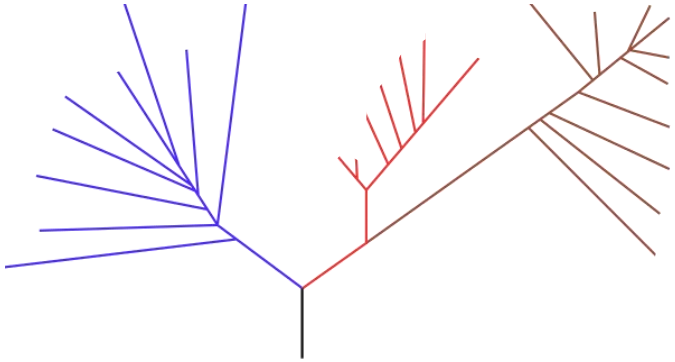

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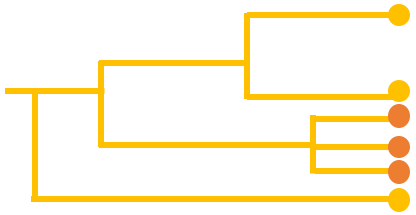

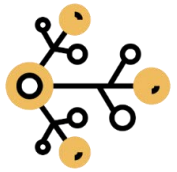

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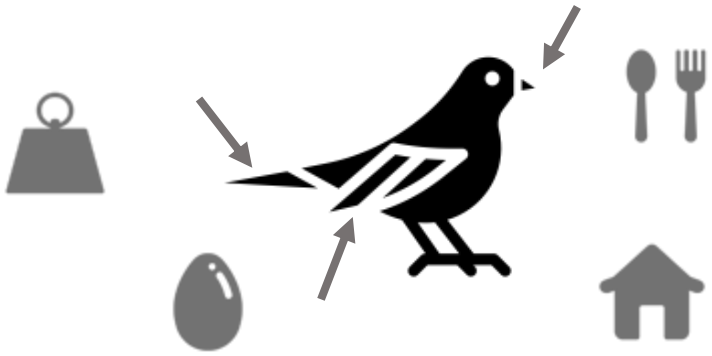

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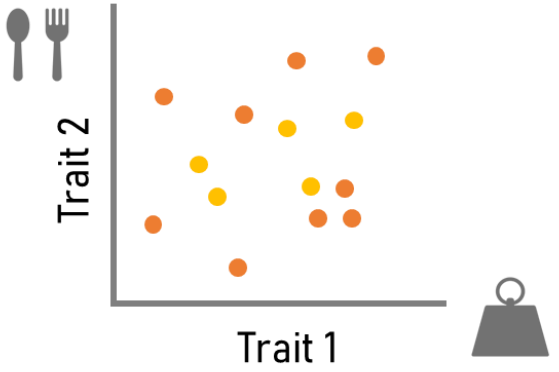
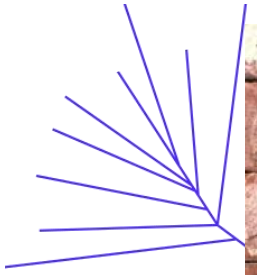
Functional diversity

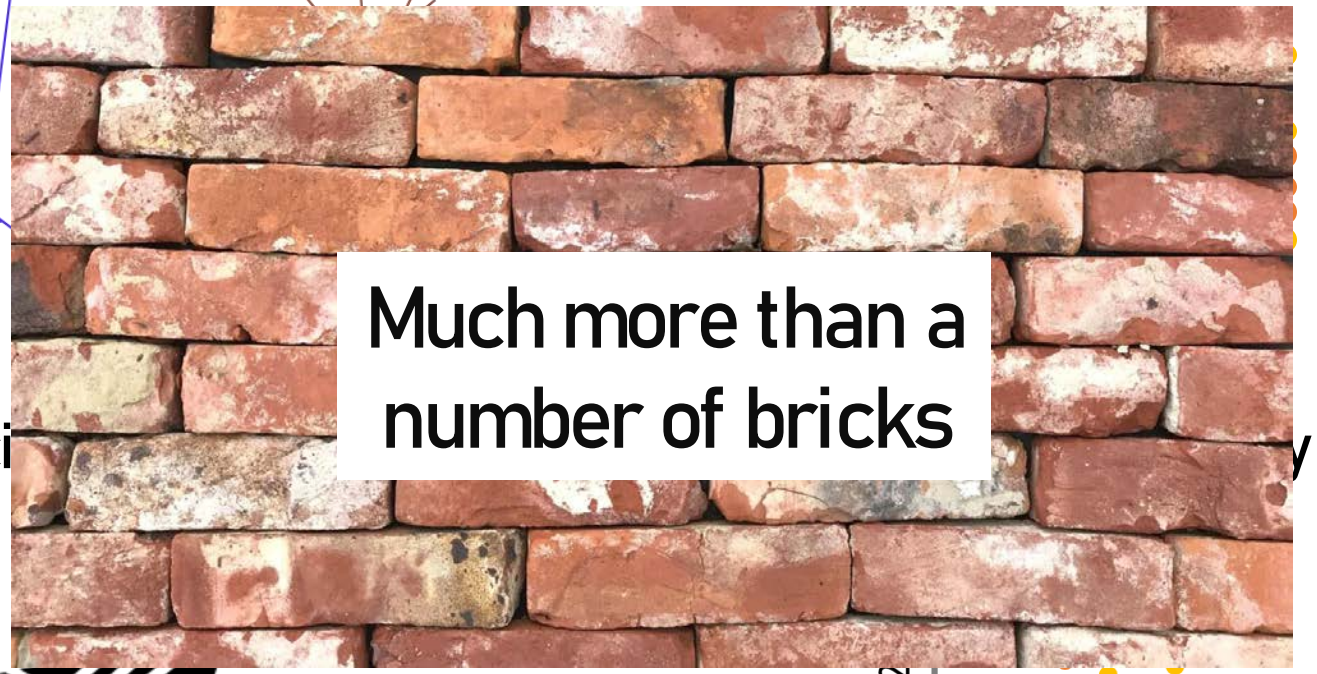


Rosenfeld 2002
Villéger et al., 2008

Multiple facets of biological diversity

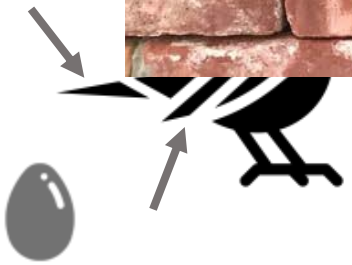
Evolutionary history → Phylogenetic diversity





Much more than a number of bricks

Speci … y



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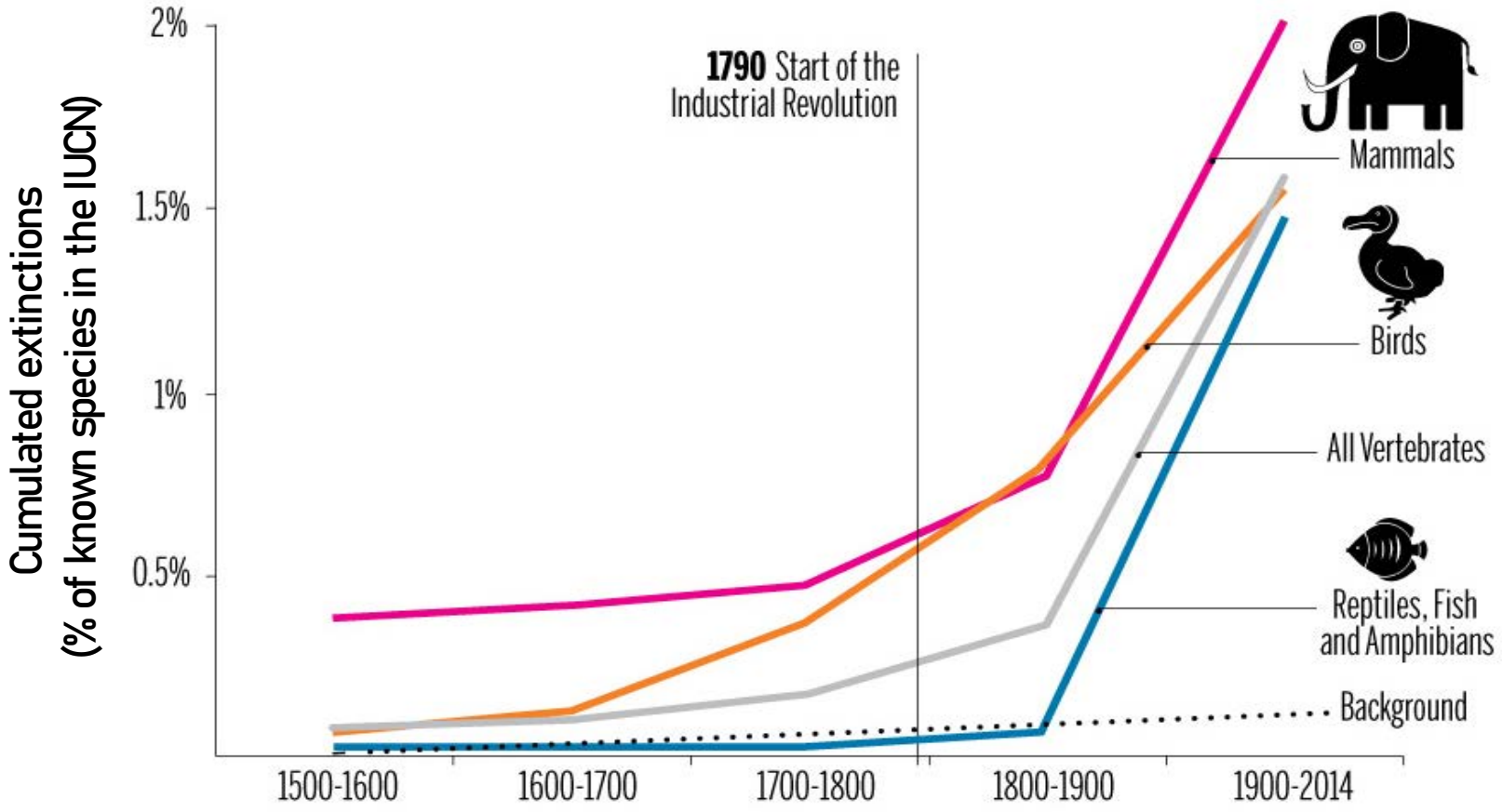
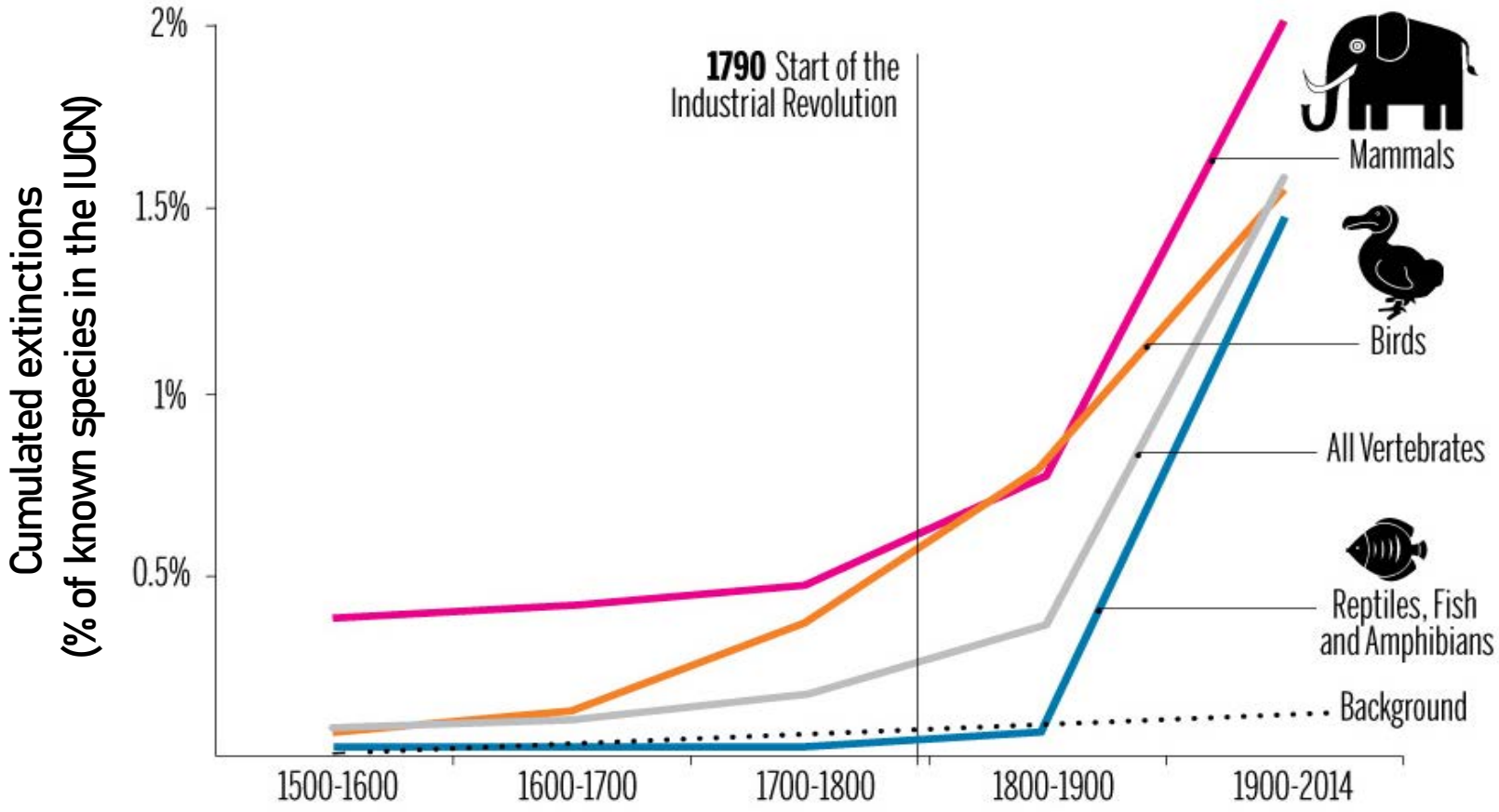
Threatened biodiversity



Ceballos et al., 2015; IPBES 2019

Threatened biodiversity



Climate change

Biological invasions

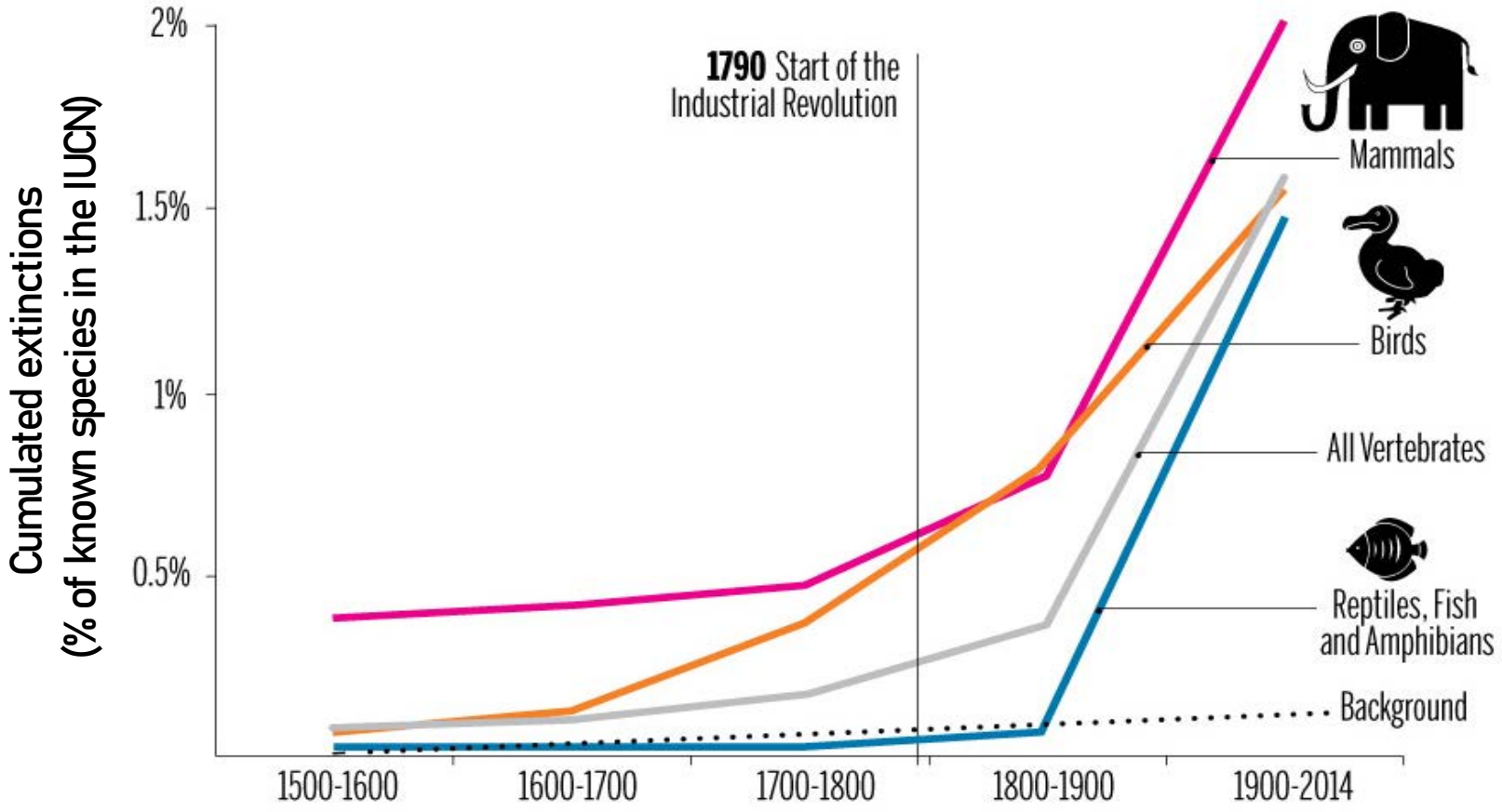
Land-use change

Pollution

Overexploitation

Ceballos et al., 2015; IPBES 2019

Threatened biodiversity



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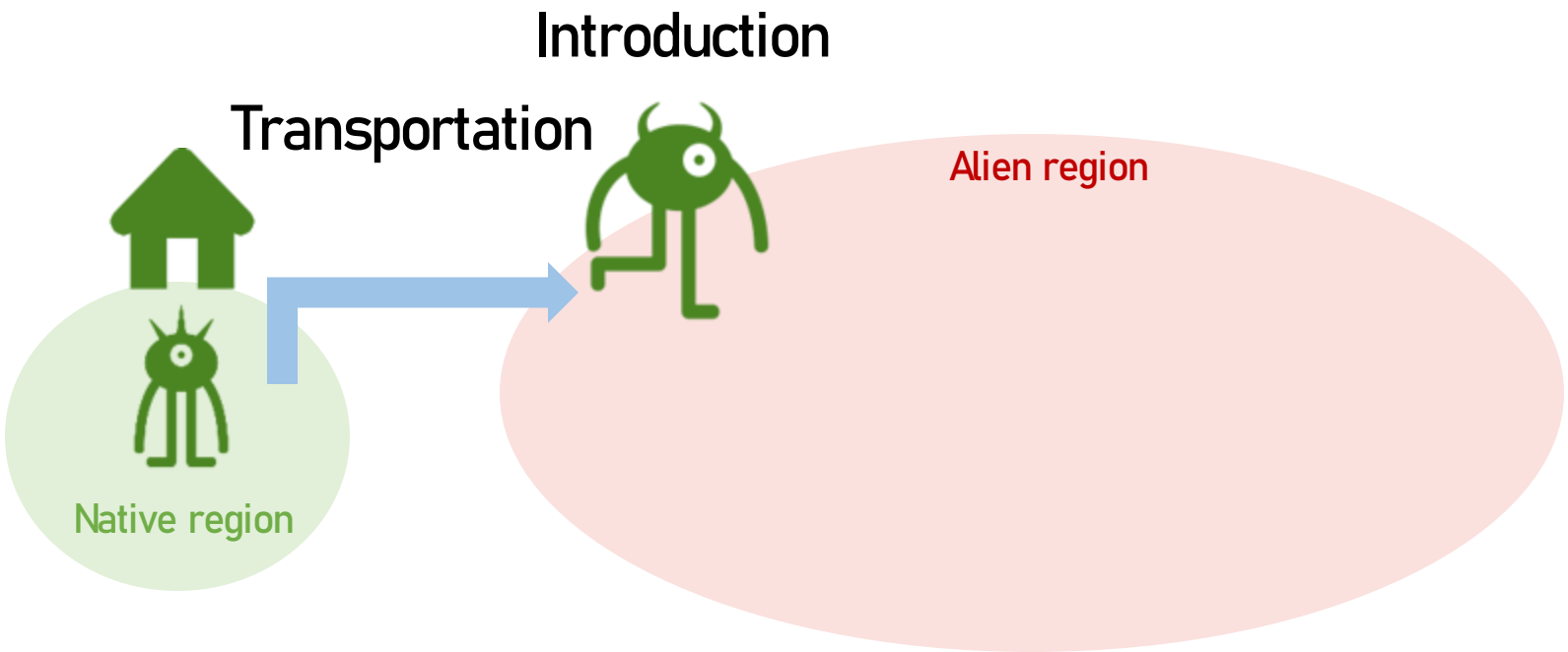
What is a biological invasion?

Native species

IUCN 2000; Blackburn et al., 2011

What is a biological invasion?



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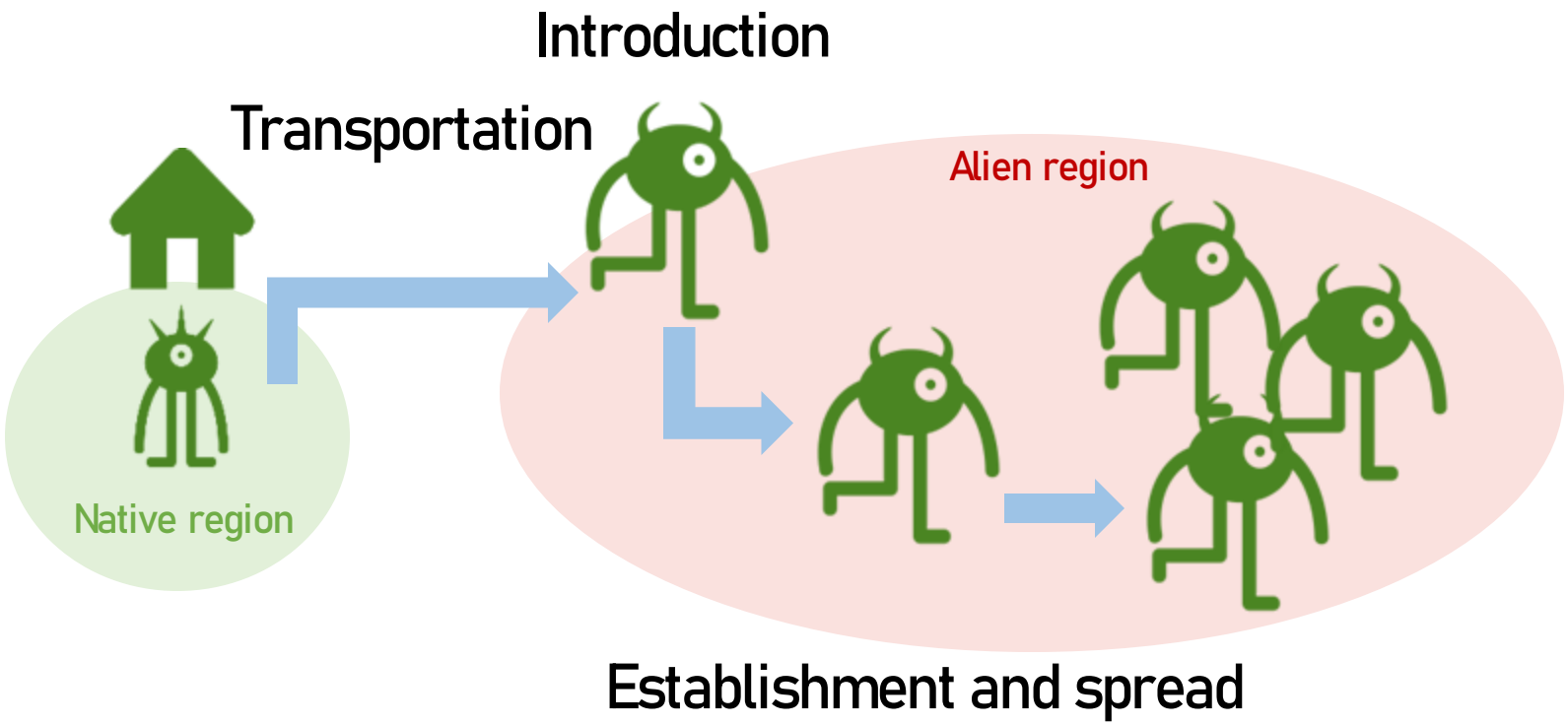

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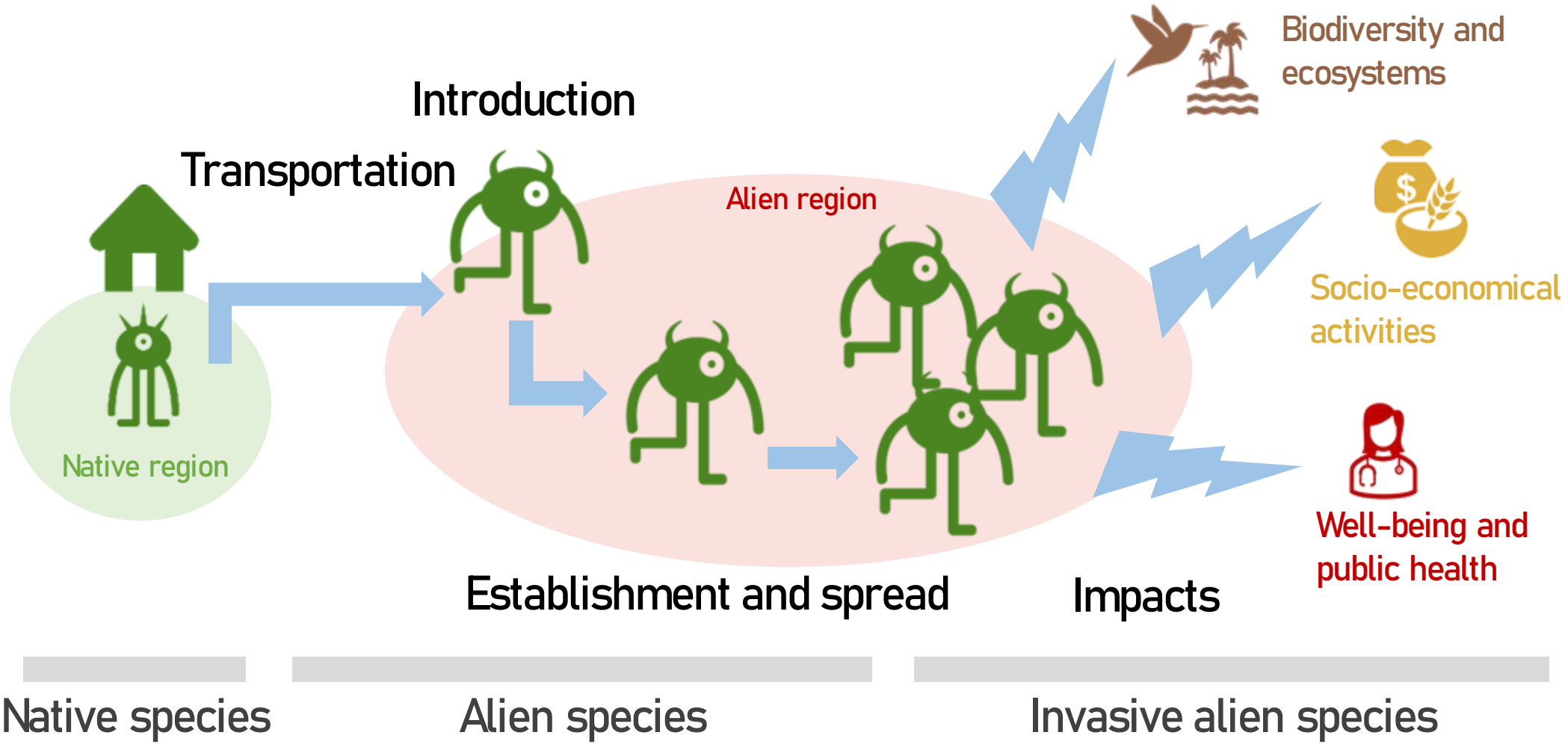

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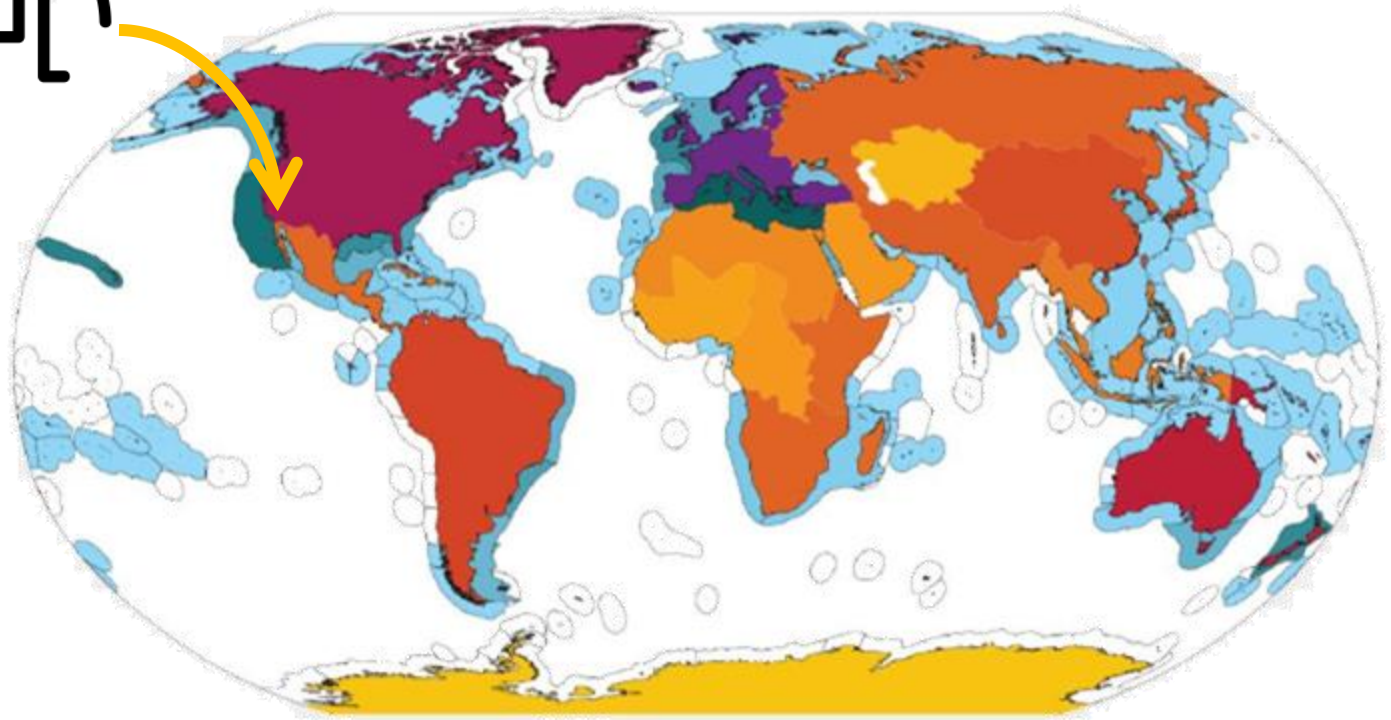
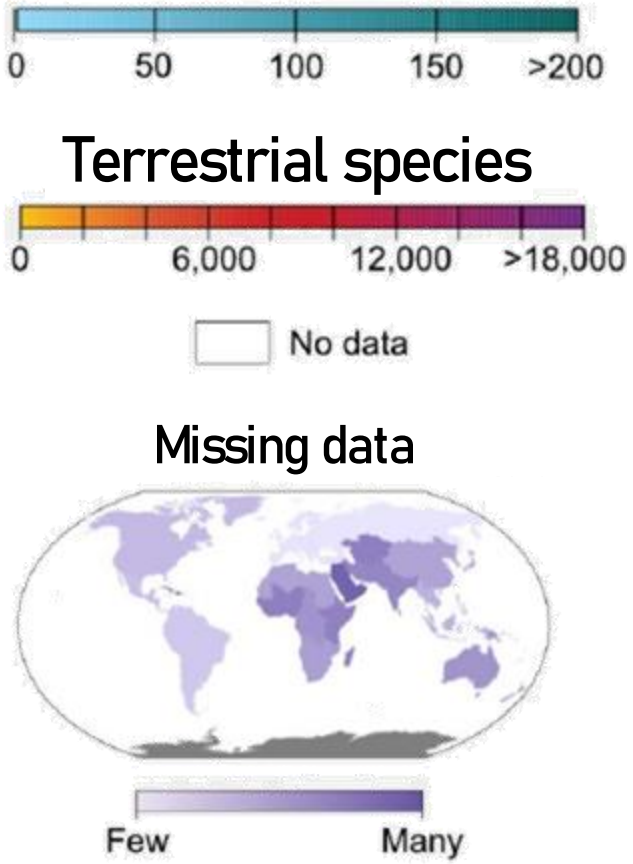
A global and rising threat

Established alien species in the world





IPBES, 2023

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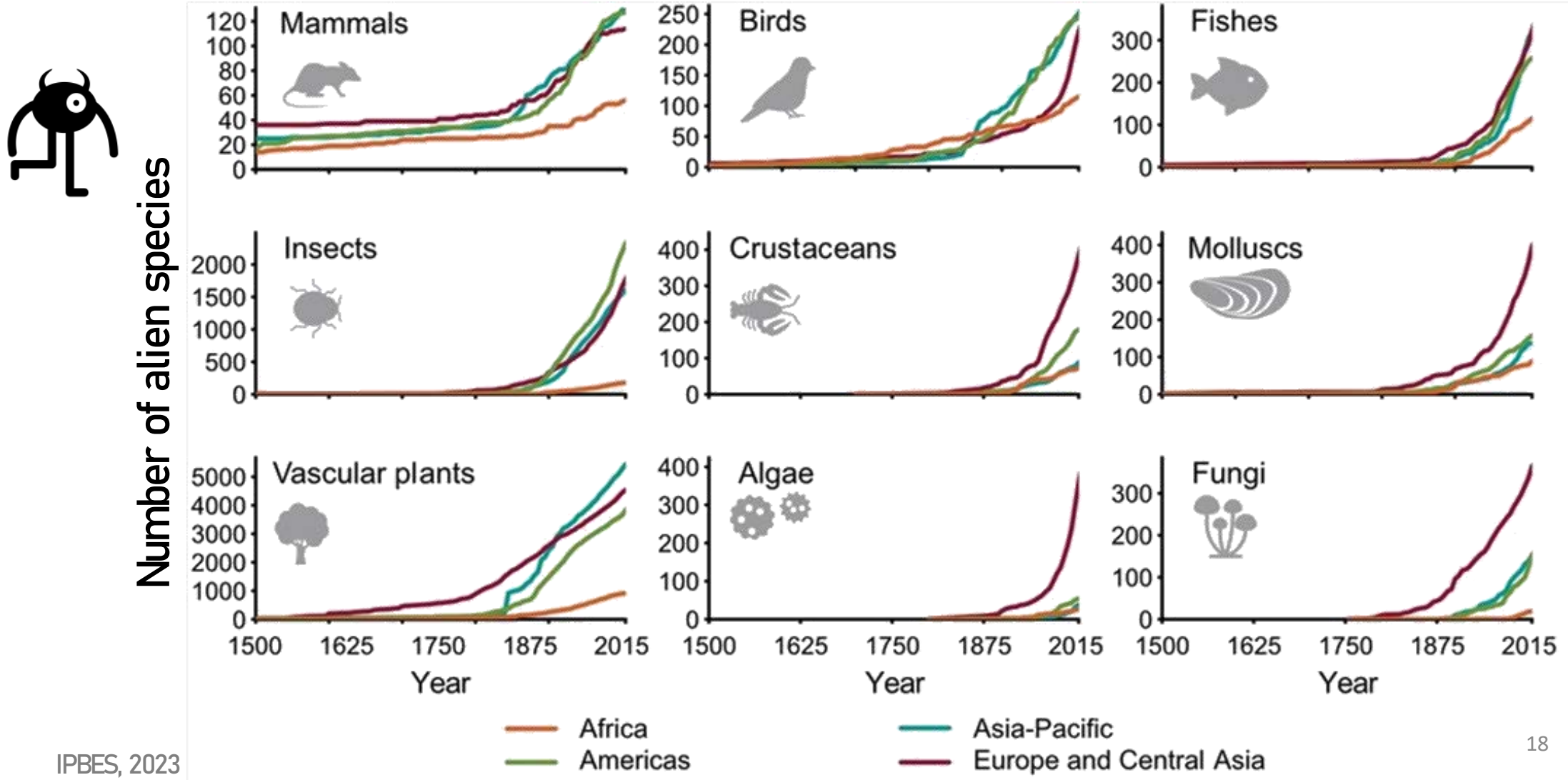
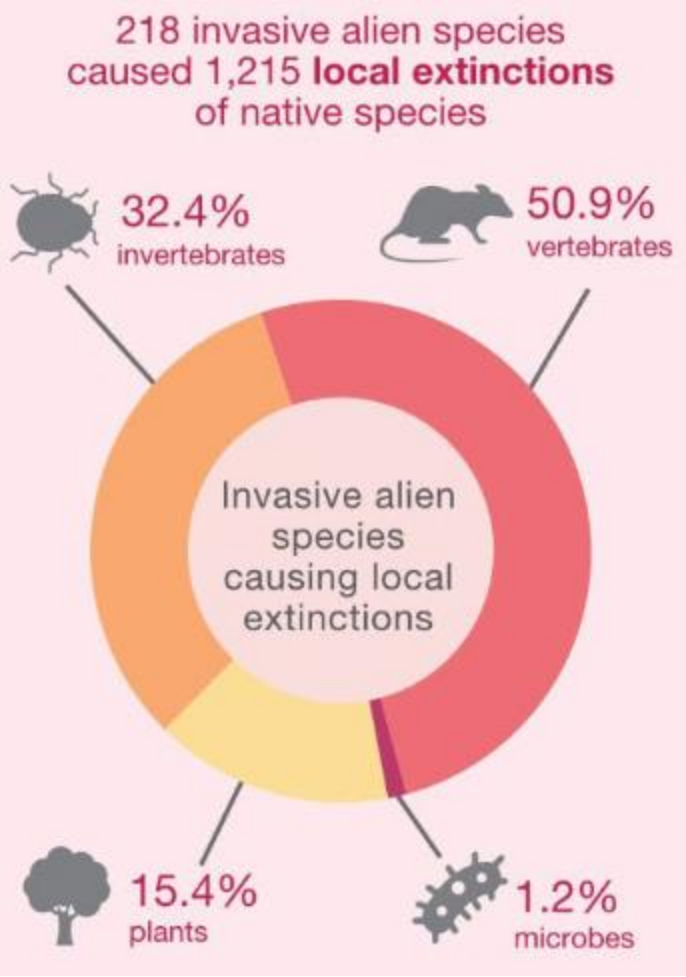


IPBES, 2023

With consequences on native diversity



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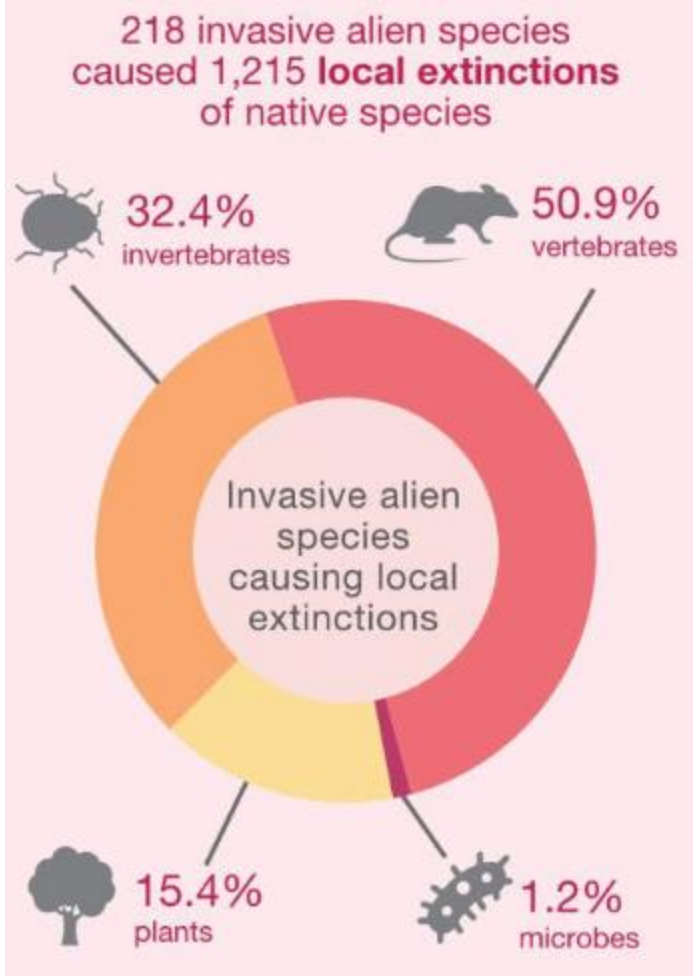
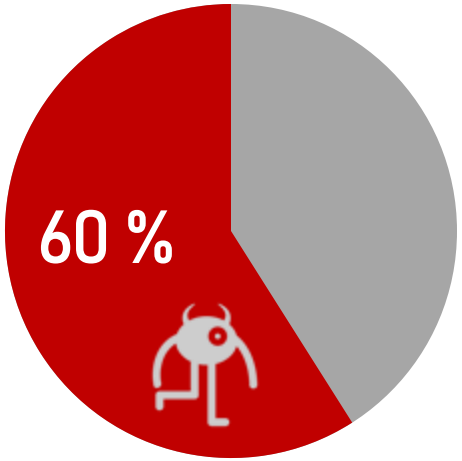


Global species extinctions



due to IAS

IPBES, 2023

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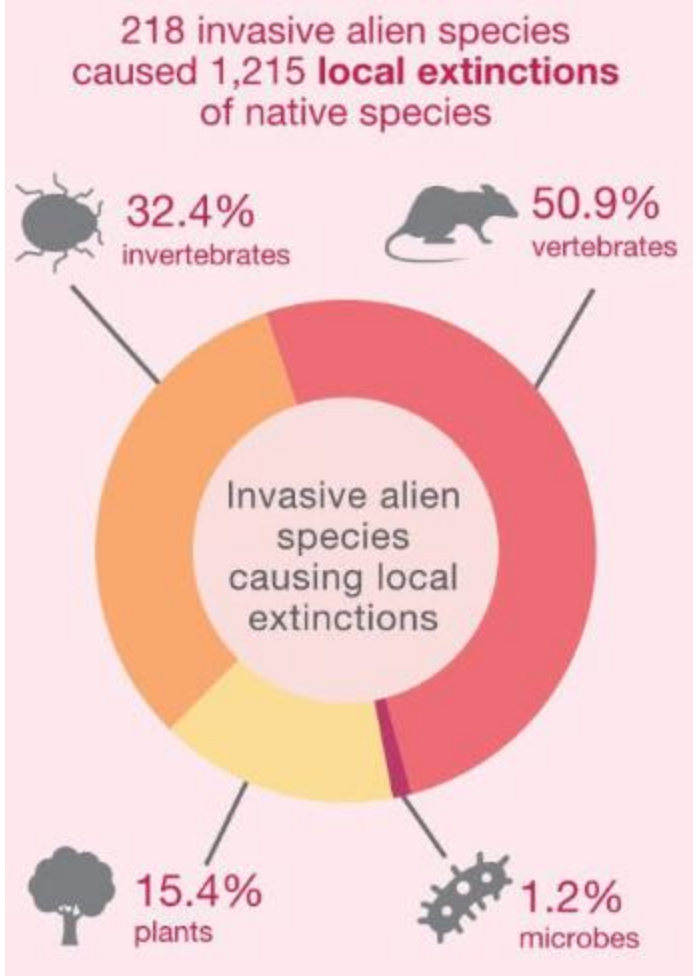

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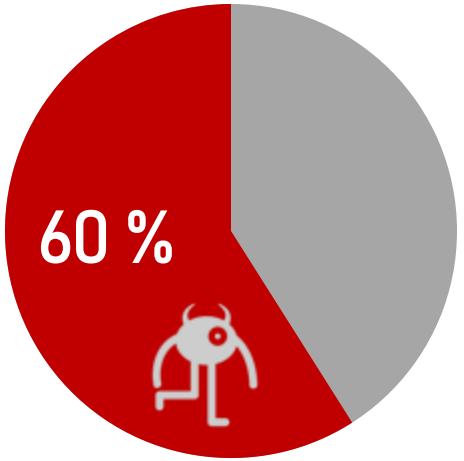

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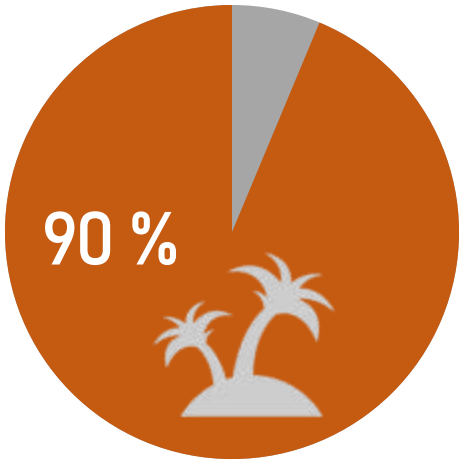

Current knowledge on biological invasions

- √ **Spatial and temporal distribution of IAS**

  Seebens et al., 2017, 2018, 2021; Dawson et al., 2017

- √ **IAS impact native diversity**

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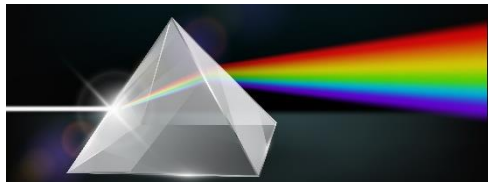

IPBES 2023; Matthews et al., 2023

Taxonomic diversity

Current knowledge on biological invasions

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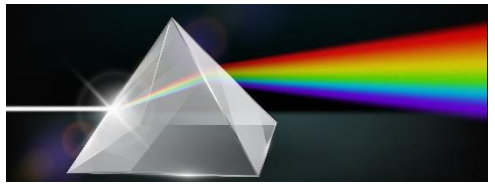
√ **Introductions/ extinctions of populations => community homogenization**

Clavel et al., 2011; Soares et al., 2022; Sayol et al., 2021

√ **Threatened species and alien species are not a random subset of all species**

Leclerc et al., 2021; Bellard et al., 2021; Dyer et al., 2017



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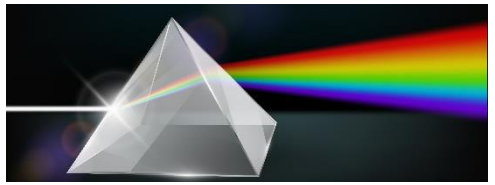

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Questions and summary

- What amount of functional diversity is threatened by IAS?
- What is the profile of native species threatened by IAS?

Part 1: the functional profile of an IAS victim

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What are the priority species and sites to conserve regarding the IAS threat?

Part 1: the functional profile of an IAS victim

Part 2: global conservation priorities facing IAS threats

Questions and summary

- What amount of functional diversity is threatened by IAS?
- What is the profile of native species threatened by IAS?

What are the priority species and sites to conserve regarding the IAS threat?

What is the vulnerability of systems to global change, across multiple diversity facets?

Part 1: the functional profile of an IAS victim

Part 2: global conservation priorities facing IAS threats

Part 3: my current postdoc project at Cesab

Part 1: the functional profile of an IAS victim

What make insular native species impacted by IAS?

Ecological traits and databases

6,015 species of insular endemic terrestrial vertebrates

Habitat breadth

Body size

Foraging stratum

Diet

Activity period

Reproductive mode

Ecological traits and databases

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Source A
Source B
Source C

	$Trait_1$	$Trait_2$	...	$Trait_n$
Sp_1	A	NA		1
Sp_2	B	0,5		0
...	...	...	...	...
Sp_n	B	12	...	1

1 Extraction

2 Compilation

VertLife

3 Imputation

	$Trait_1$	$Trait_2$	...	$Trait_n$
Sp_1	A	4,2		1
Sp_2	B	0,5		0
...	...	...	...	...
Sp_n	B	12	...	1

Building a functional space

	$Trait_1$	$Trait_2$	...	$Trait_n$
Sp_1	A	4,2		1
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...	...	...	...	...
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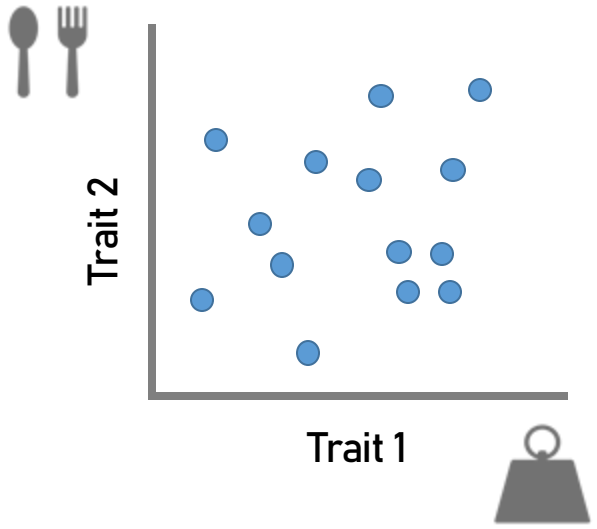
Complete trait matrix



Building a functional space and defining groups

	$Trait_1$	$Trait_2$	...	$Trait_n$
Sp_1	A	4,2		1
Sp_2	B	0,5		0
...	...	...	...	...
Sp_n	B	12	...	1

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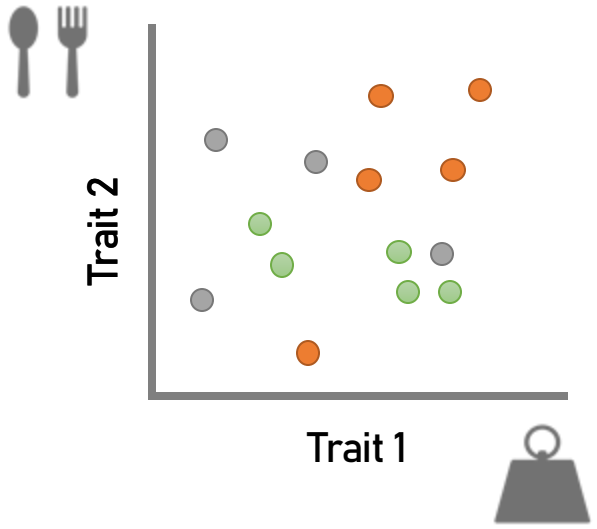


GUIDELINES & BROCHURES — GLOBAL

Threats Classification Scheme (Version 3.3)

LC NT VU EN CR

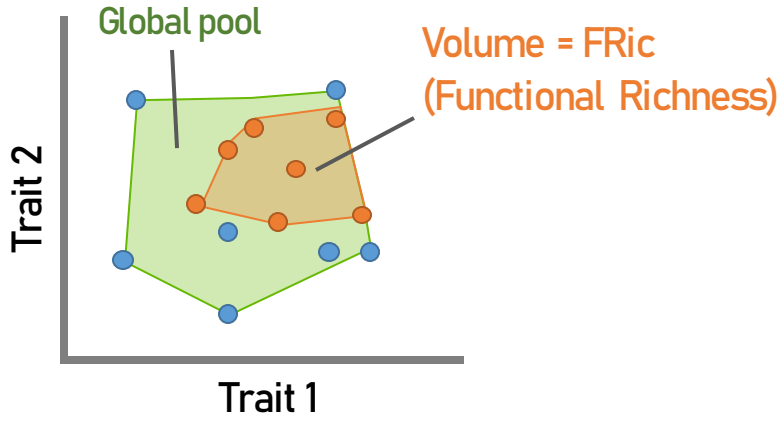
IAS-NT

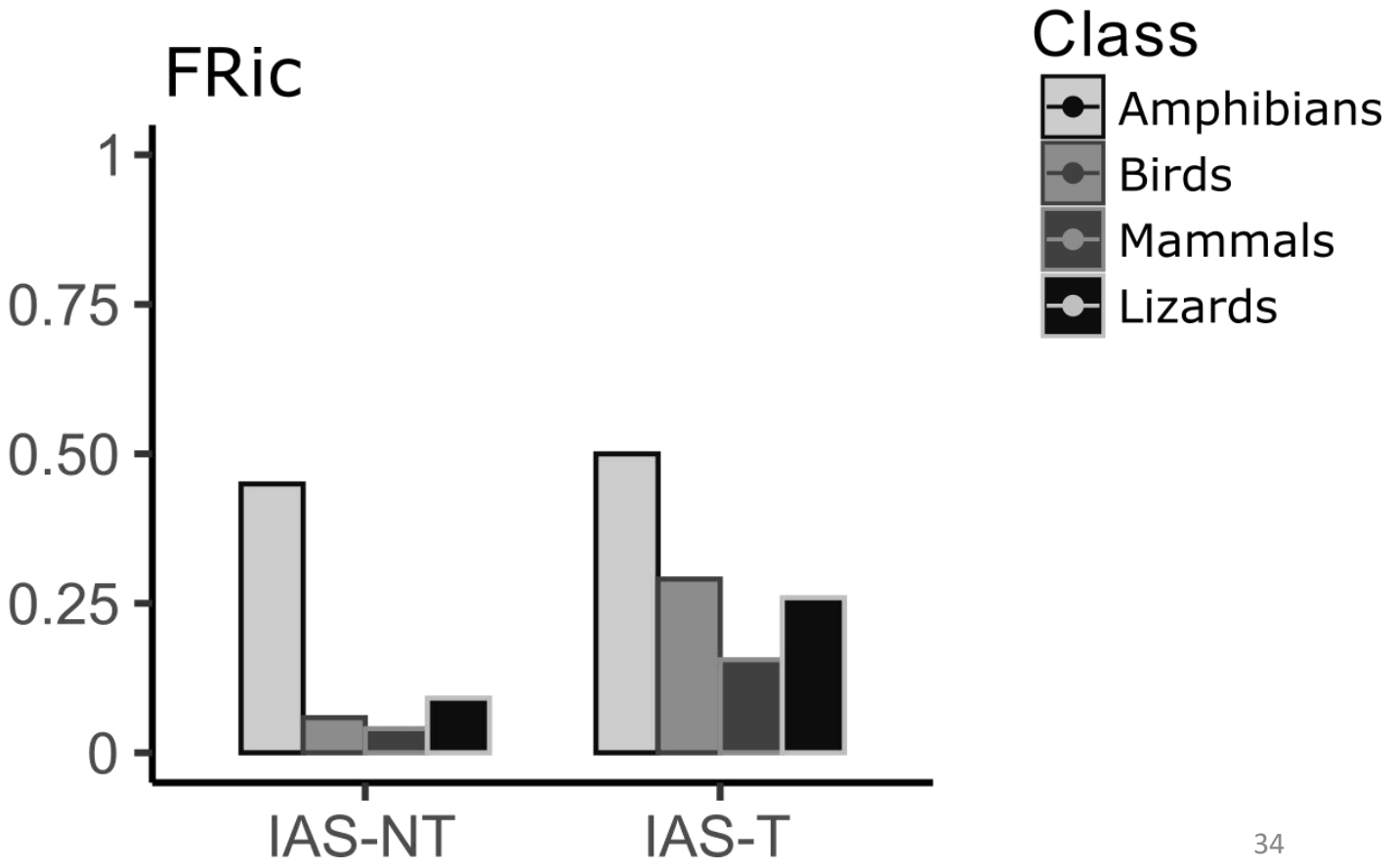
IAS-T

Other-threat-NT

Other-threat-T

Functional diversity represented by IAS-T vertebrates





Marino, Leclerc & Bellard, 2022

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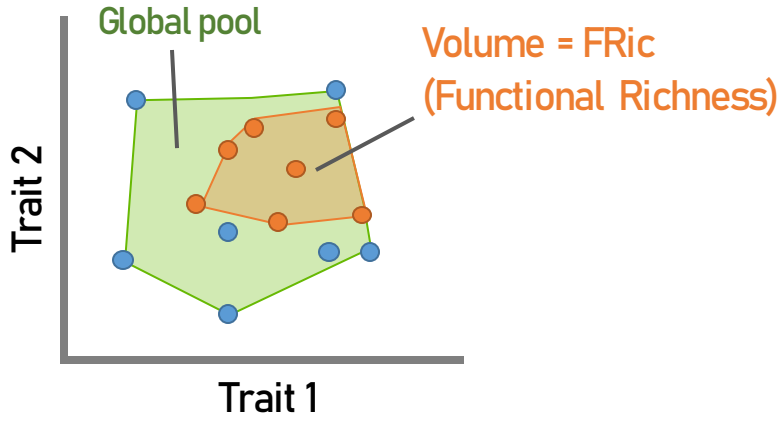
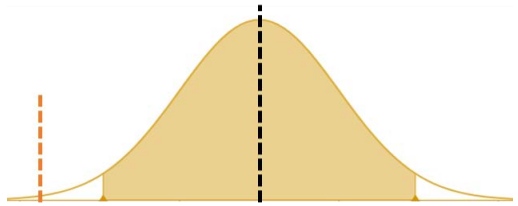
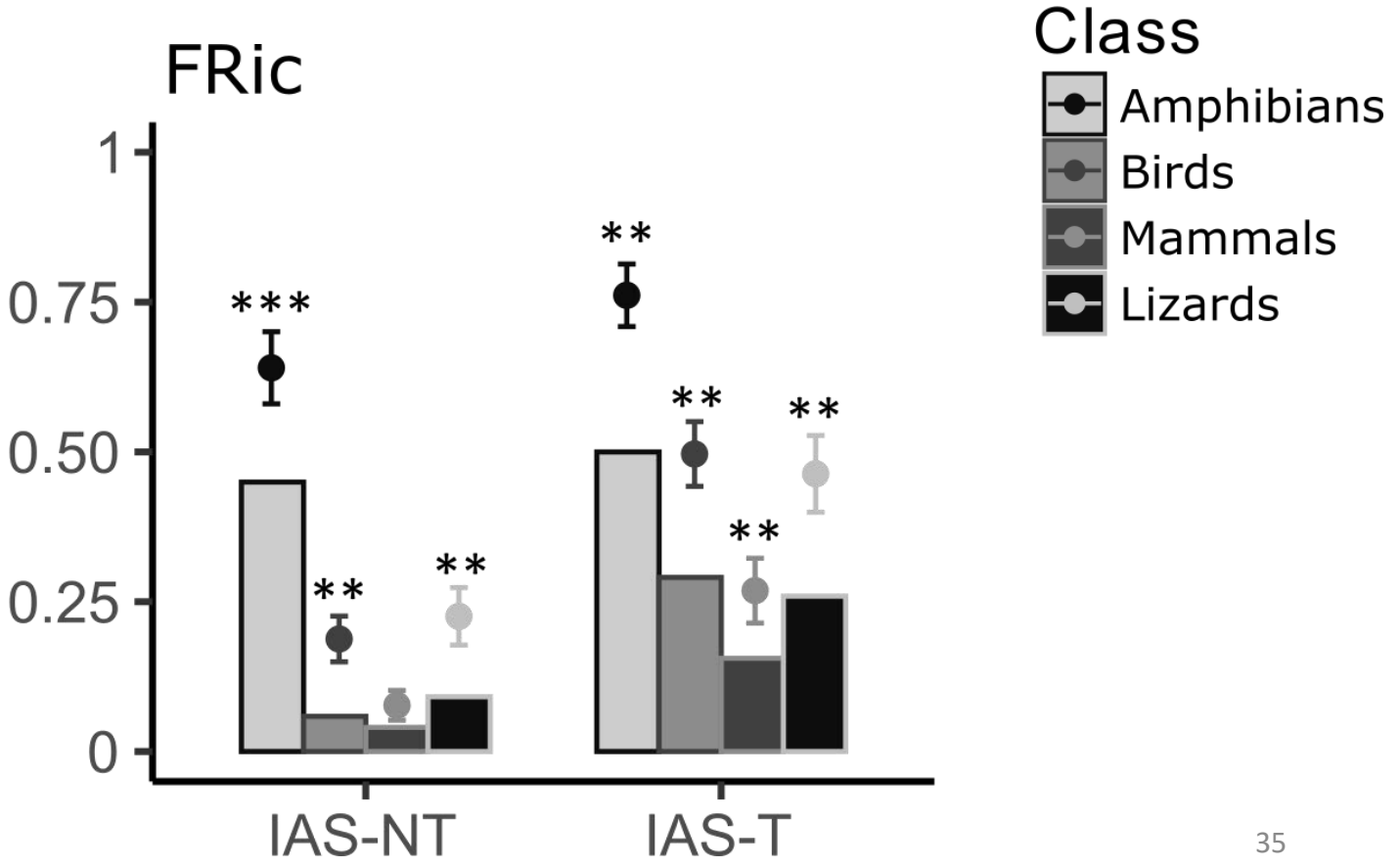


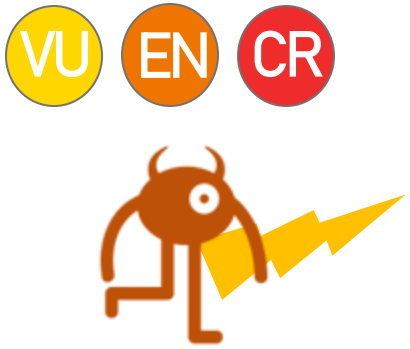
Null models





Marino, Leclerc & Bellard, 2022

Ecological profile of IAS-T vertebrates



IAS-T

For each taxonomic group:

- Prevalent trait modality
- Over-represented trait modalities compared to global pool (null models)

Prevalent traits of IAS-T vertebrates

Habitat breadth

1

2

Body size

Large

Very large

Foraging niche

Terrestrial

Multiple

Activity period

Diurnal

Nocturnal

Main diet

Plants

Invertebrates

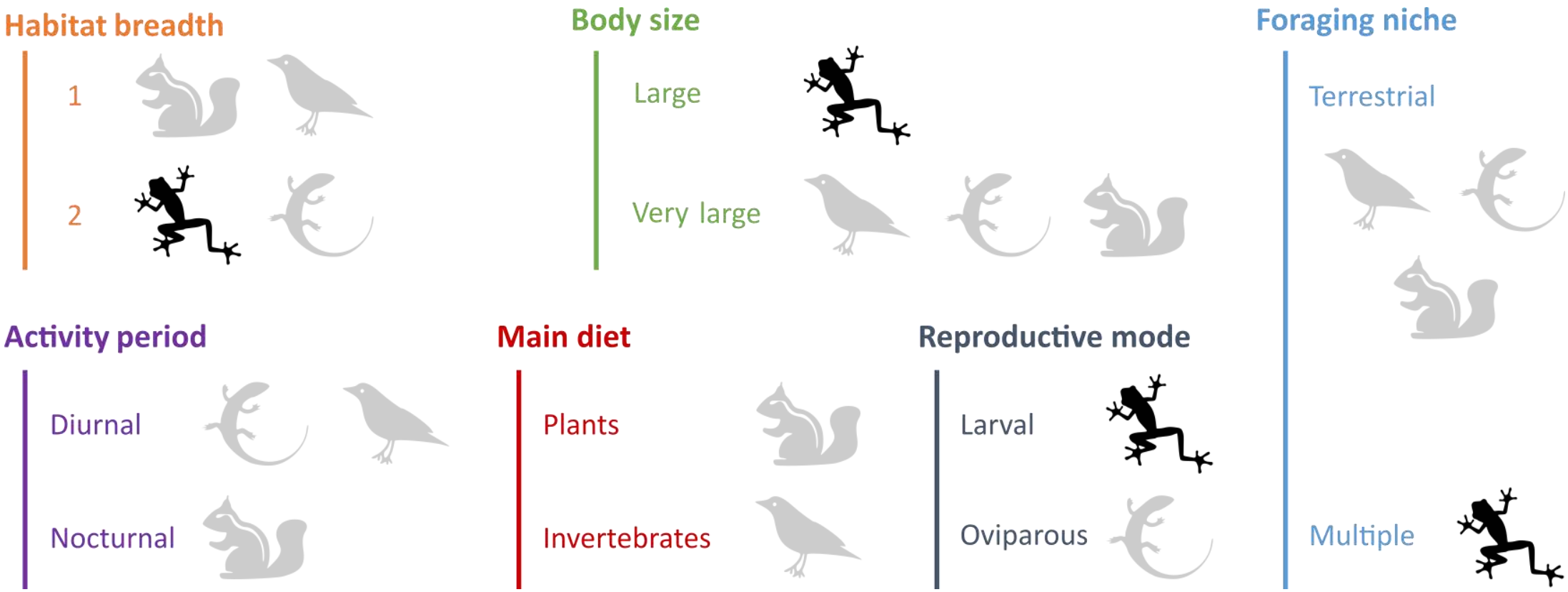
Reproductive mode

Larval

Oviparous

Marino, Leclerc & Bellard, 2022

Prevalent traits of IAS-T vertebrates



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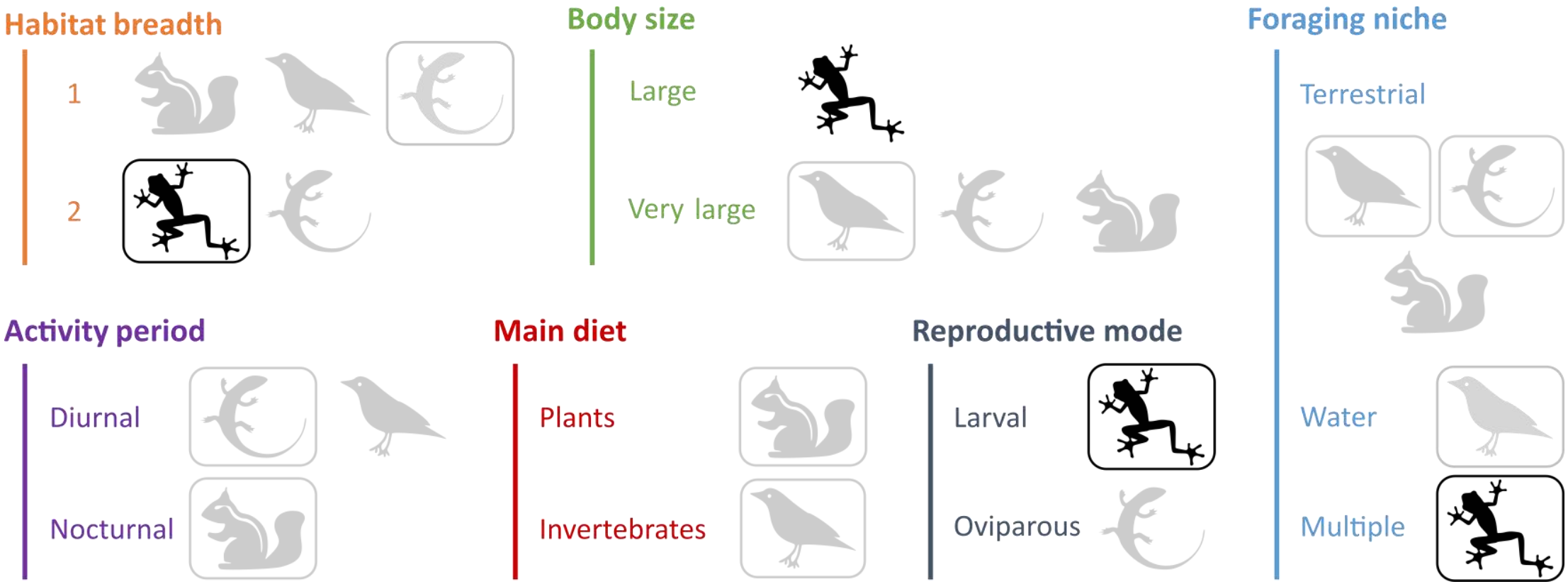
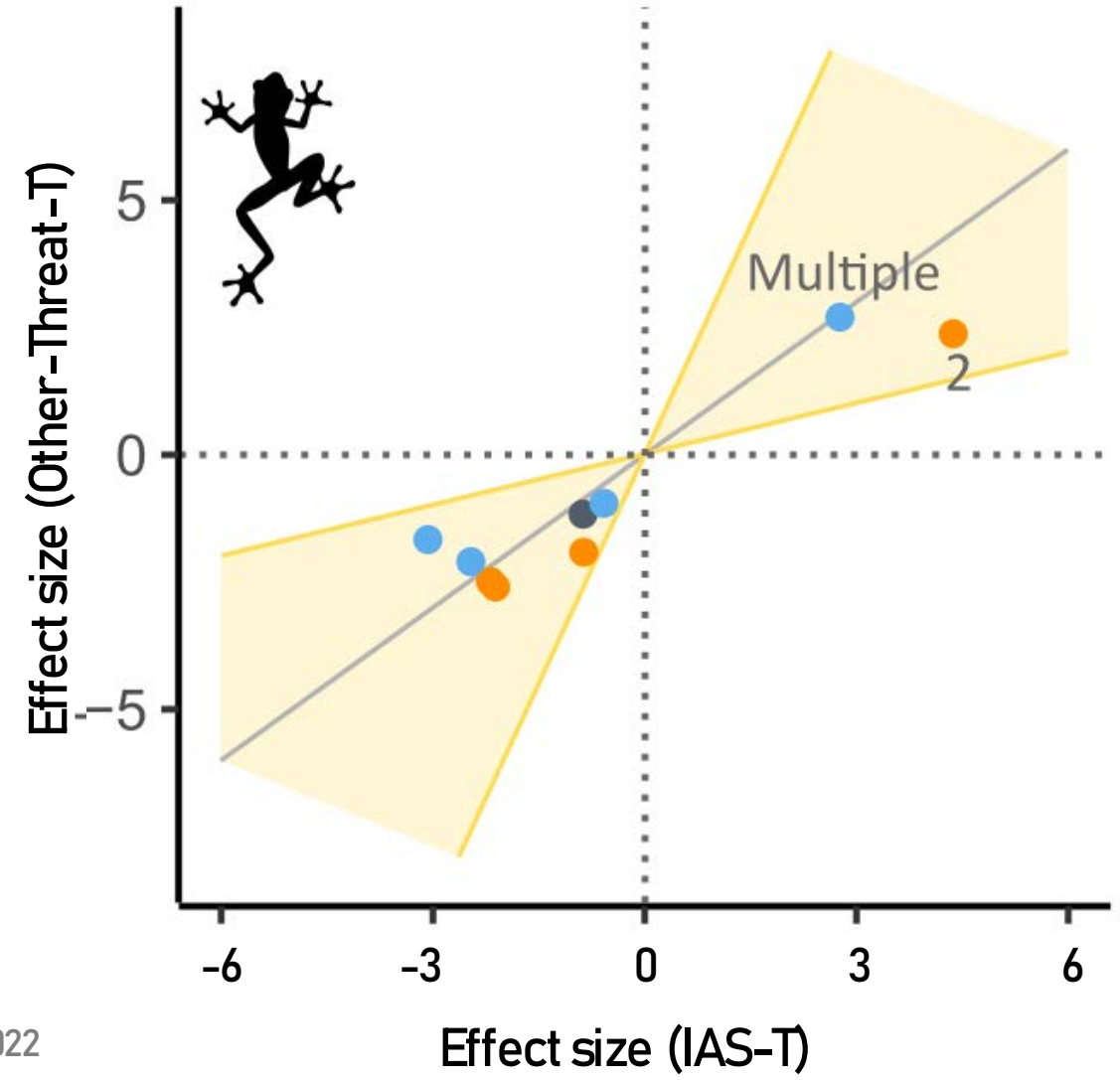


Marino, Leclerc & Bellard, 2022

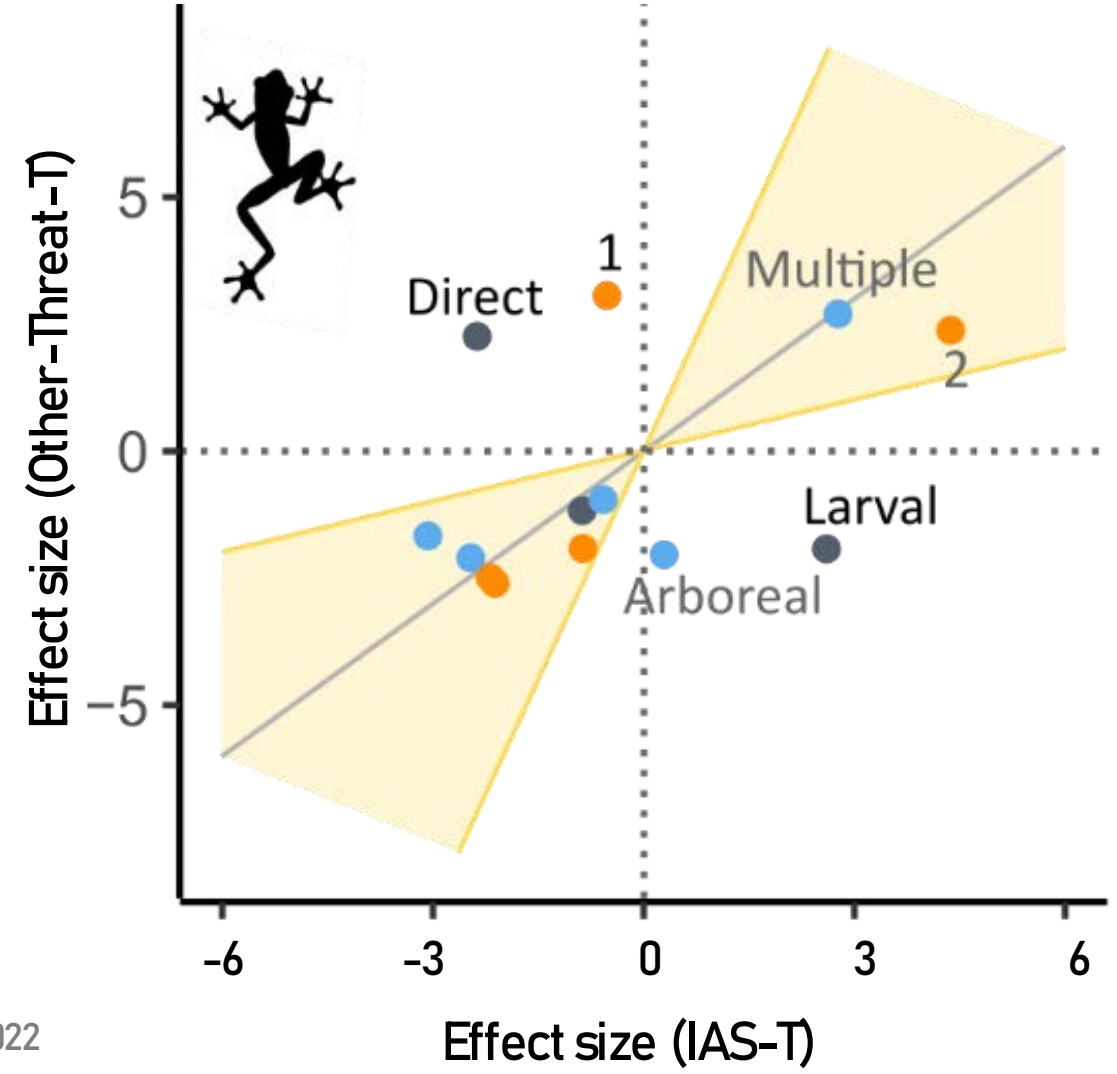
Some traits are linked with extinction risk



Ecological trait
- Habitat breadth
- Body size
- Foraging niche
- Reproductive mode

Marino, Leclerc & Bellard, 2022

But some traits are specific to the IAS threat



Ecological trait
- Habitat breadth
- Body size
- Foraging niche
- Reproductive mode

Marino, Leclerc & Bellard, 2022

Take home message

Insular endemic vertebrates threatened by biological invasions:

- Host a high amount of endemic functional richness

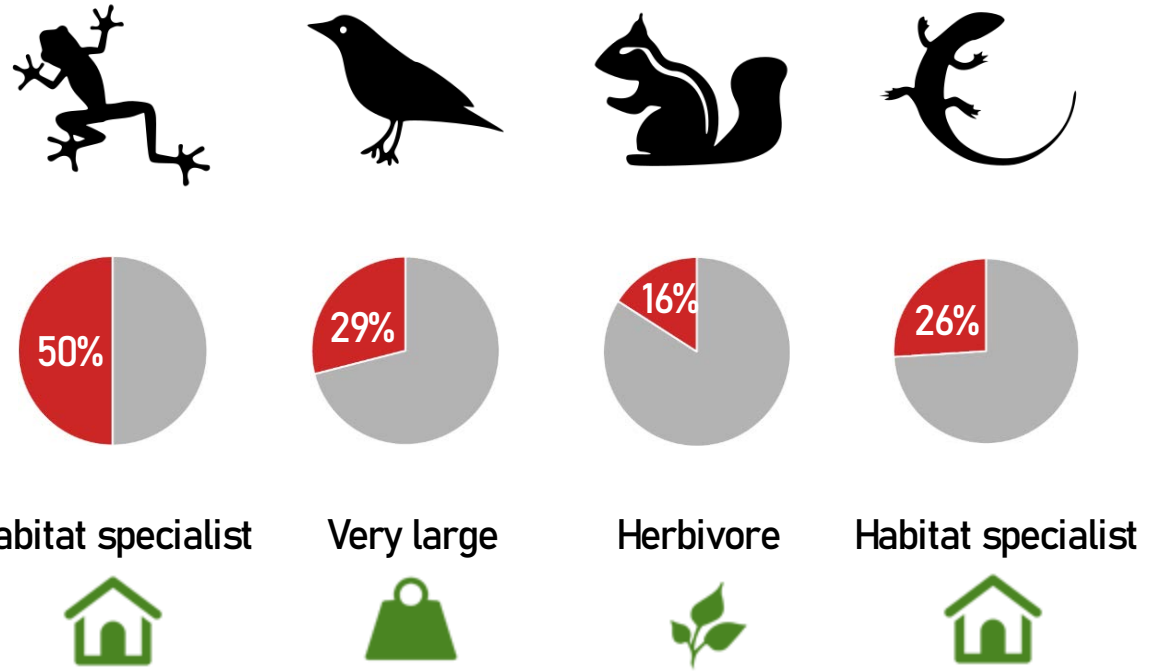
  Bellard et al., 2022

- Present general features of vulnerability to global threats

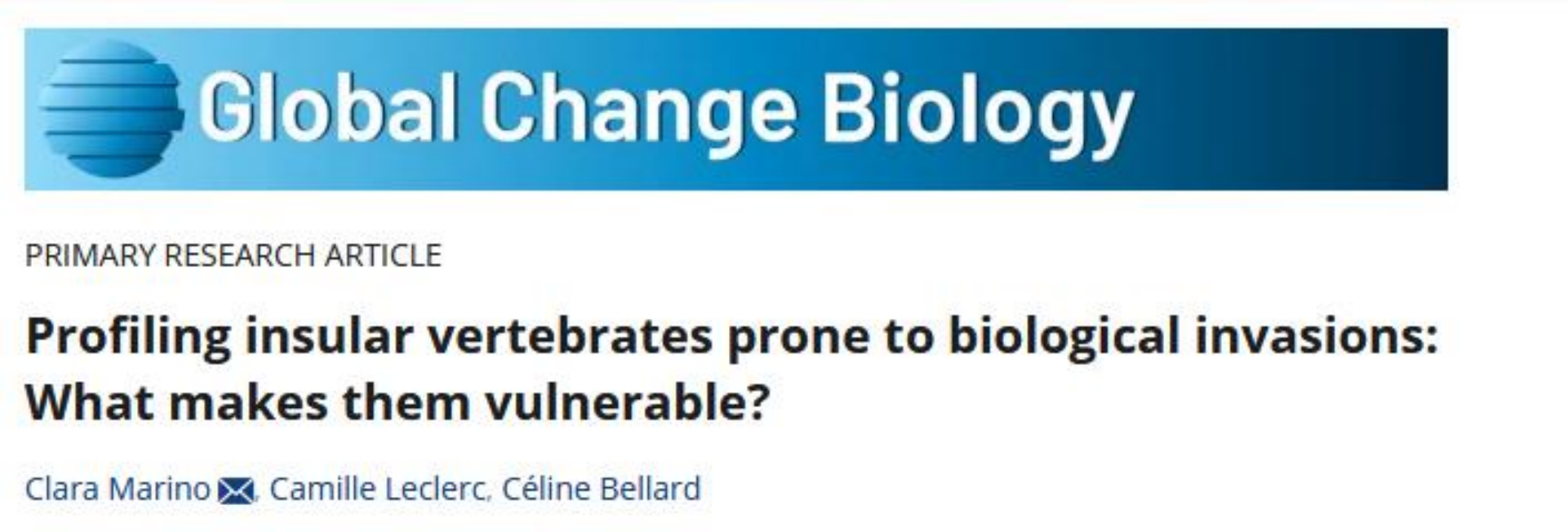
  Leclerc et al., 2021; Cooke et al., 2019; Atwood et al., 2020

- Harbor specific features of vulnerability to biological invasions

  Bucciarelli et al., 2014; Falashi et al., 2020



The whole story



https://doi.org/10.1111/gcb.15941

https://hal.archives-ouvertes.fr/hal-03404507

Questions and summary

- What amount of functional diversity is threatened by IAS?
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What are the priority species and sites to conserve regarding the IAS threat?

What is the vulnerability of systems to global change, across multiple diversity facets?

Part 1: the functional profile of an IAS victim

Part 2: global conservation priorities facing IAS threats

Part 3: my current postdoc project at Cesab

Part 2: Conservation priorities facing IAS threat

SUSTAINABLE DEVELOPMENT GOALS

Home | About | Goals | Take Action | Partnerships | News And Media | UN 2023 SDG Summit

Press Release: Nations Adopt Four Goals, 23 Targets for 2030 In Landmark UN Biodiversity Agreement

Part 2: Conservation priorities facing IAS threat

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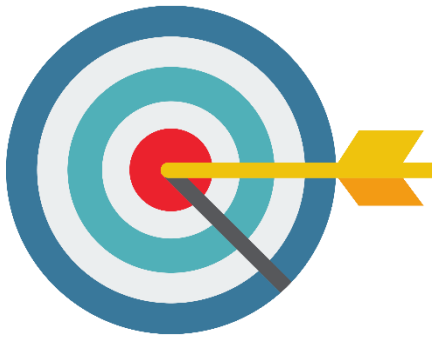

TARGET 6

Eliminate, minimize, reduce and or mitigate the impacts of invasive alien species on biodiversity and ecosystem services by identifying and managing pathways of the introduction of alien species, preventing the introduction and establishment of priority invasive alien species, reducing the rates of introduction and establishment of other known or potential invasive alien species by at least 50 per cent, by 2030, eradicating or controlling invasive alien species especially in priority sites, such as islands .

Part 2: Conservation priorities facing IAS threat

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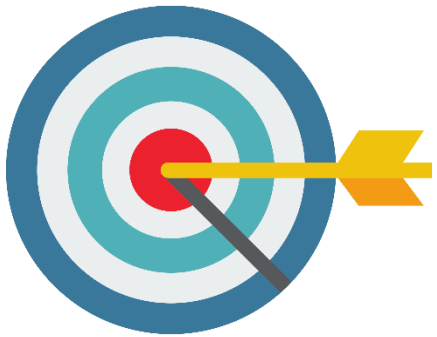

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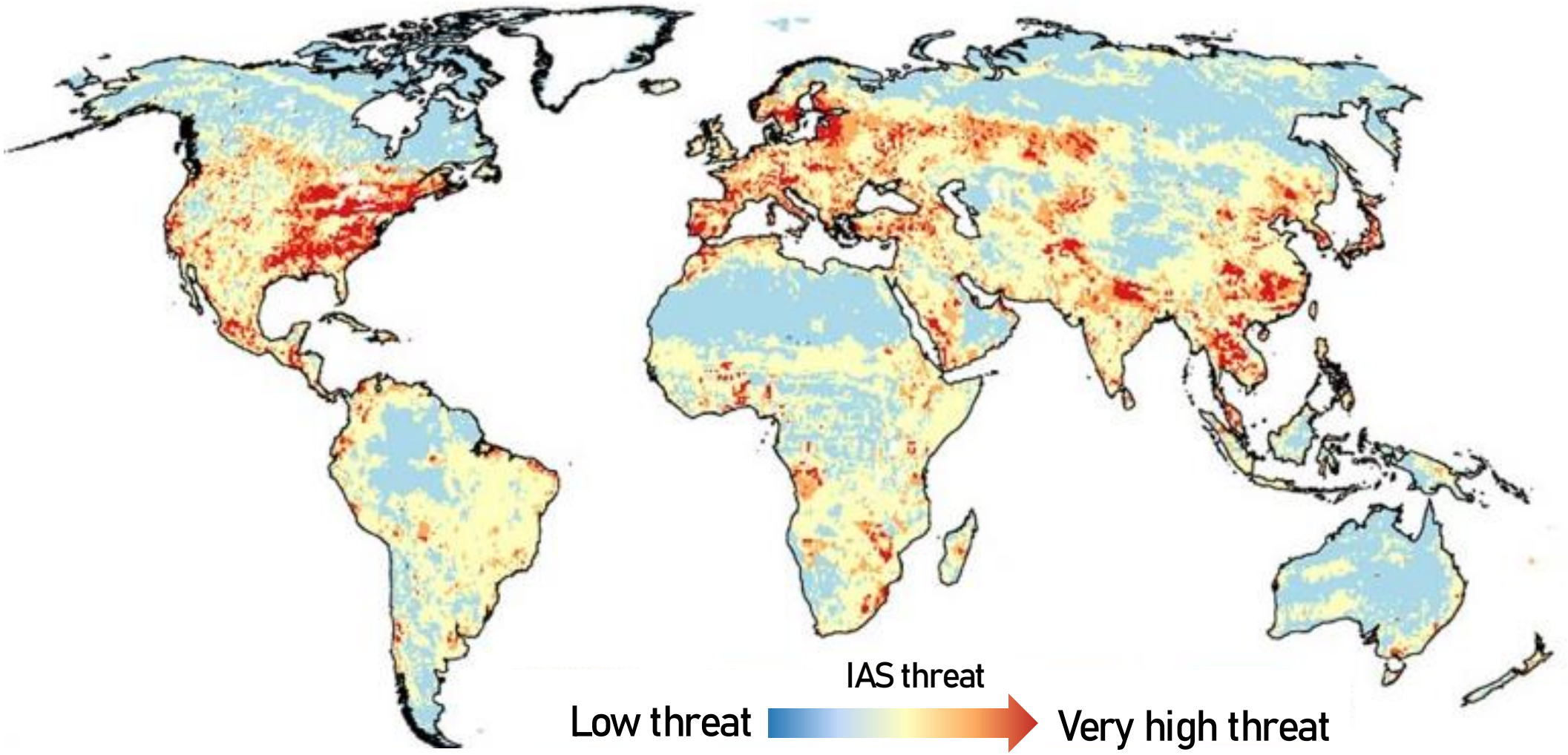
What do we already know?



Early et al., 2016

The BIVA framework

Latombe et al., 2022 ; Parker et al., 1999; Bellard et al., 2016 ; Bellard et al., 2022 ; Marino et al., 2022

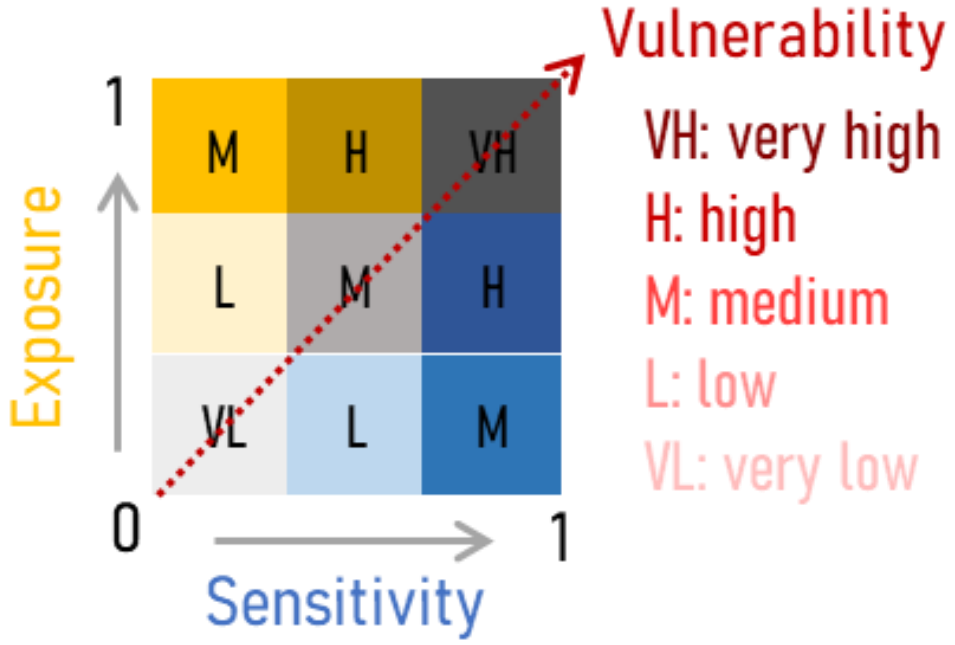
The BIVA framework

Exposure

Alien species richness
+
Median alien range
+
Median alien impact breadth

Sensitivity

Number of IAS-affected native species



Latombe et al., 2022 ; Parker et al., 1999; Bellard et al., 2016 ; Bellard et al., 2022 ; Marino et al., 2022

The BIVA framework

Exposure

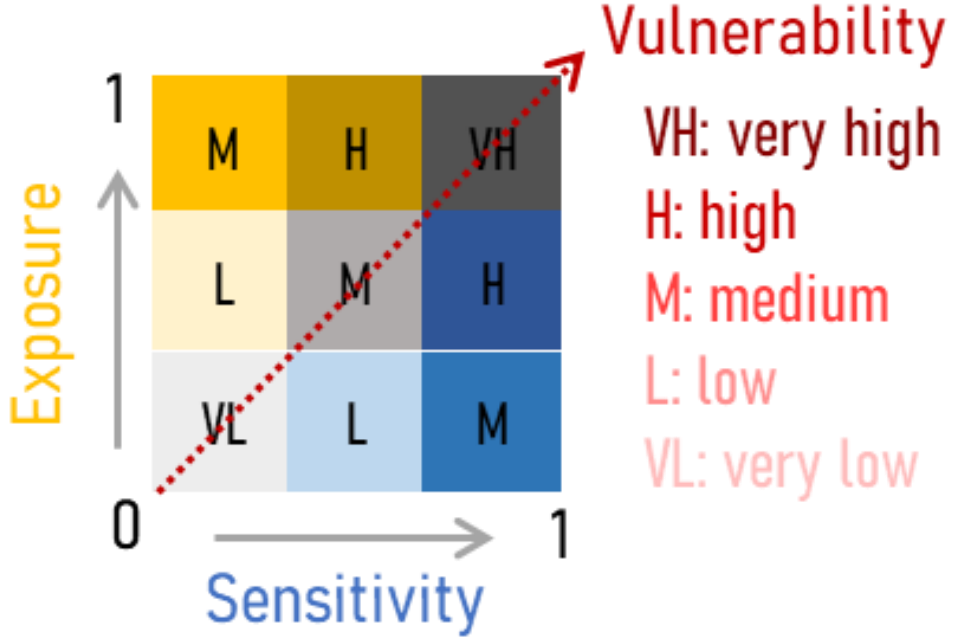
Alien species richness
+
Median alien range
+
Median alien impact breadth

Sensitivity

Number of IAS-affected native species

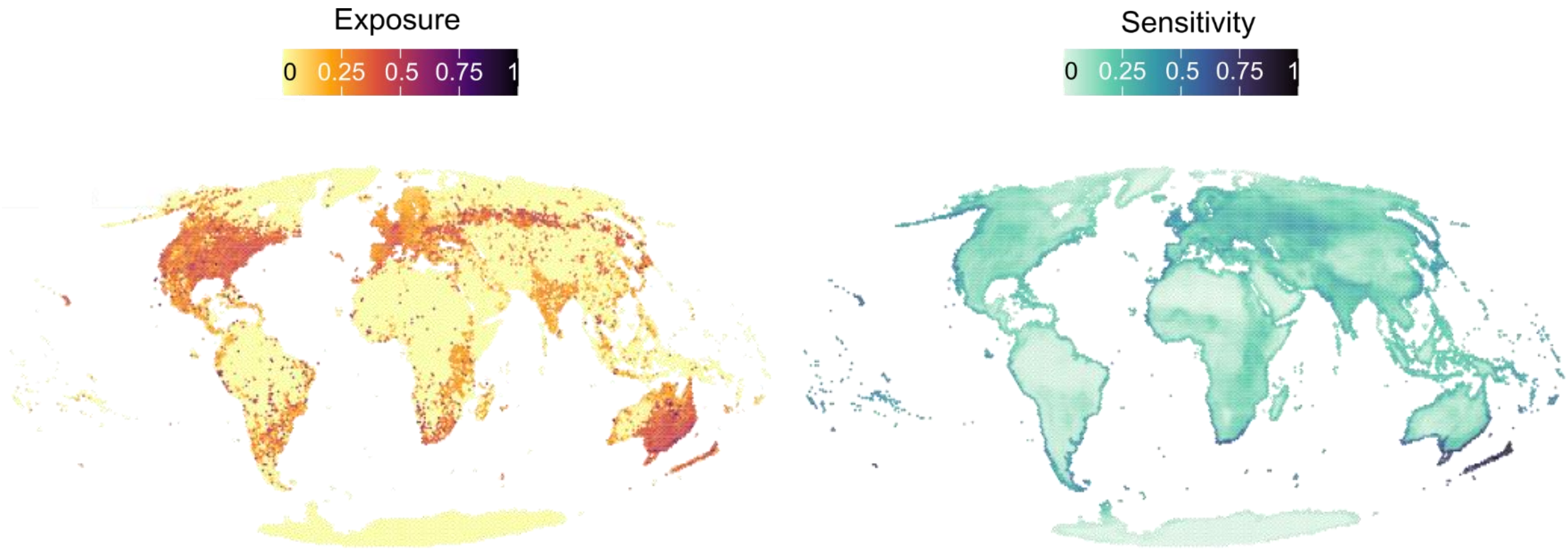
+300 IAS

+1600 native vertebrates



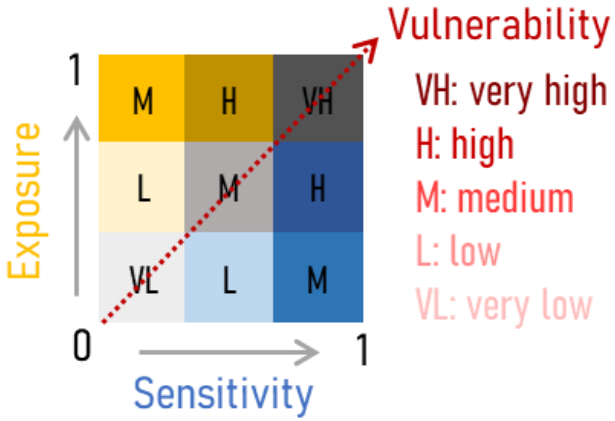
Latombe et al., 2022 ; Parker et al., 1999; Bellard et al., 2016 ; Bellard et al., 2022 ; Marino et al., 2022

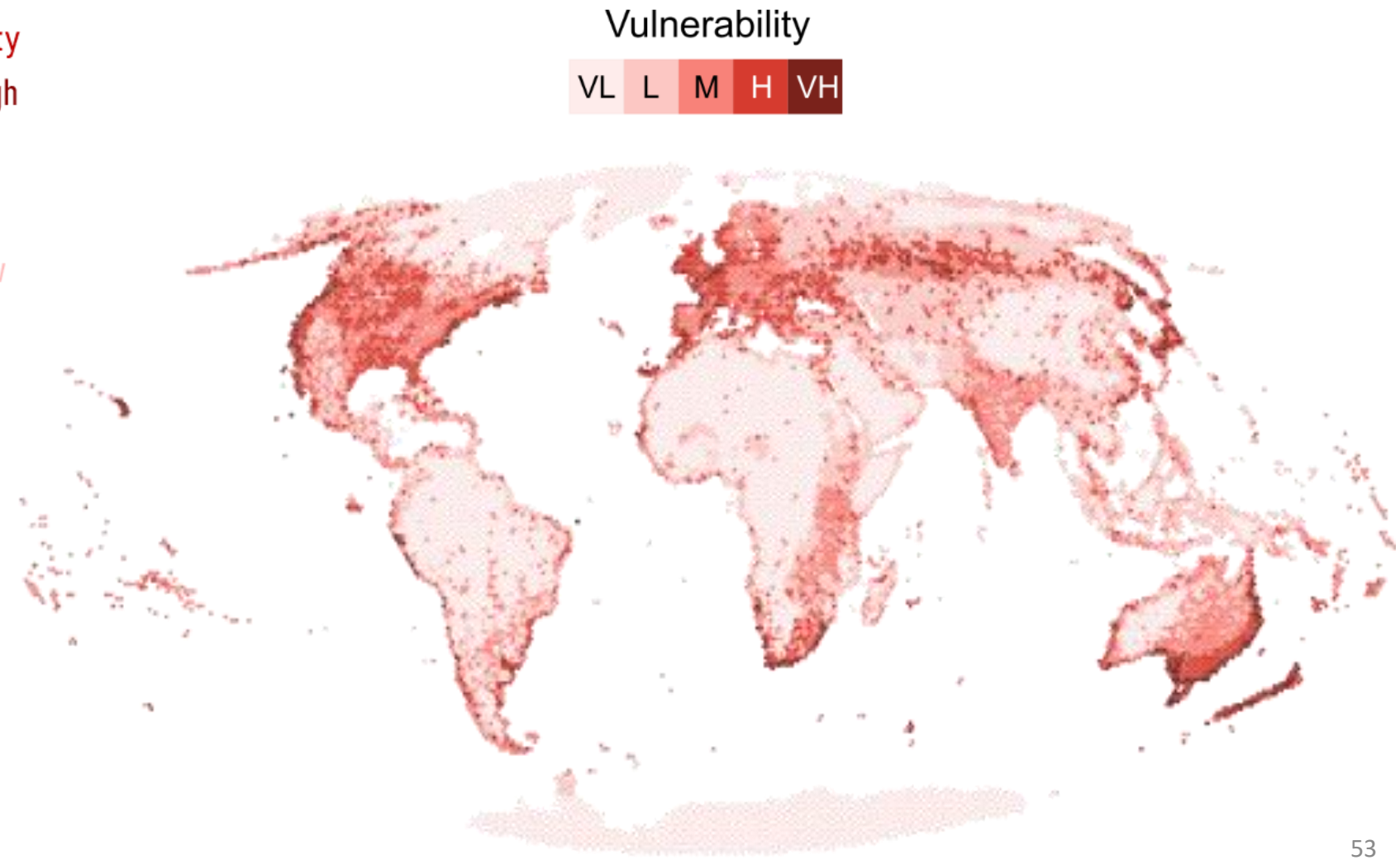
Exposure and sensitivity of birds to biological invasions



Marino et al. In prep.

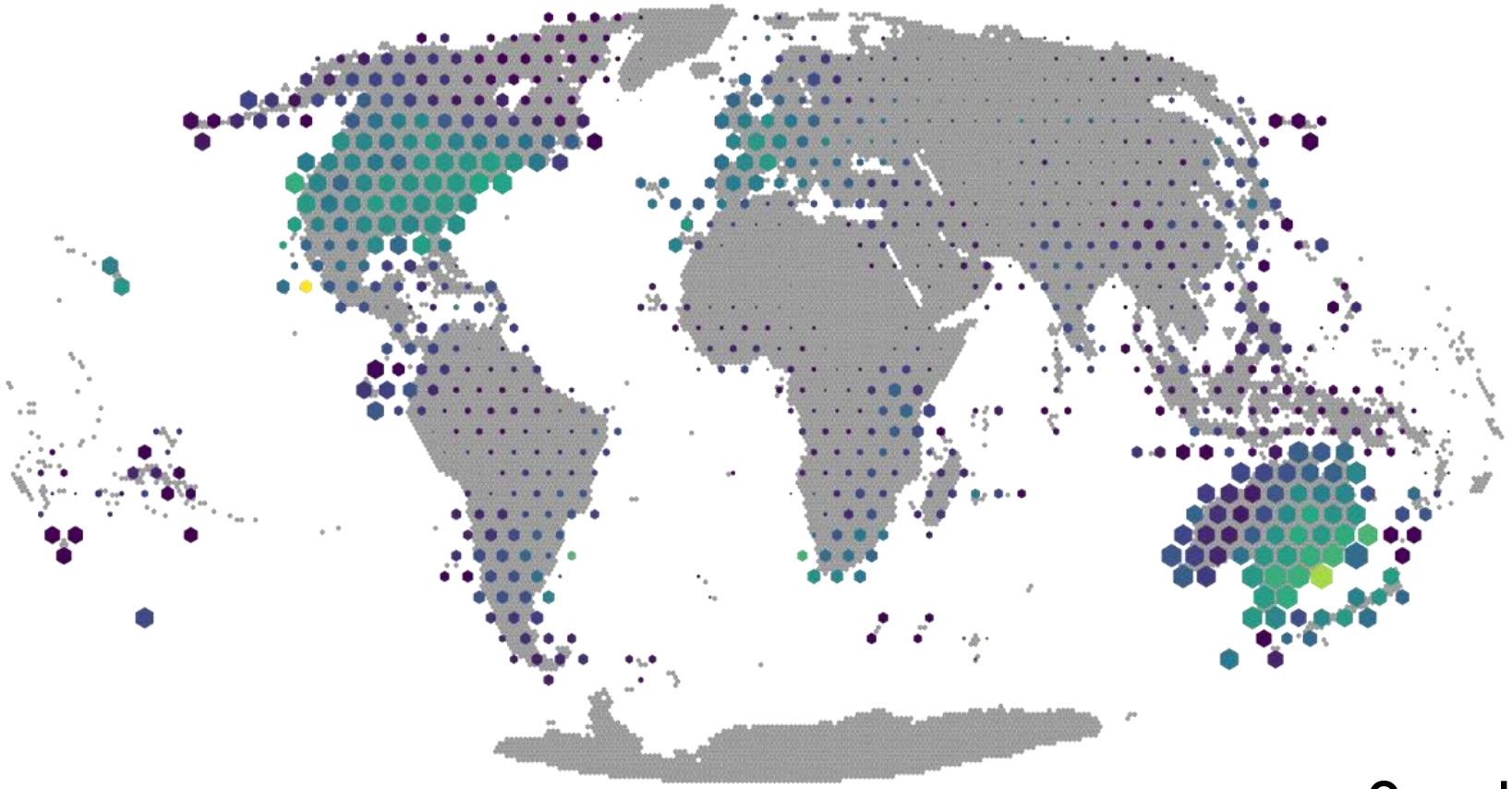
Final vulnerability





Marino et al. In prep.

What about uncertainty?



Exposure 0.2 0.4 0.6

Completeness

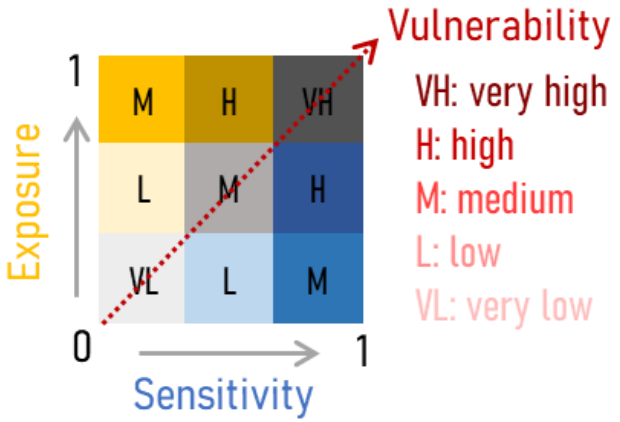
Marino et al. In prep.

Take-home message

The vulnerability of terrestrial vertebrates facing biological invasions:

- Can be defined as the combination of exposure and sensitivity of native species to IAS

  Ameca et al., 2012; Foden et al., 2019



- Is very high:
  - on coastal areas and oceanic islands for birds
  - in Eastern Australia for reptiles and mammals

  Jenkins et al., 2013; Cardillo et al., 2023

- Is subject to global biodiversity data shortfalls and is potentially highly biased because of knowledge gaps

  Hortal et al., 2015

Marino et al. In prep.

So priority sites... but what about species?

So priority sites... but what about species?

Mammals on the EDGE: Conservation Priorities Based on Threat and Phylogeny

Nick J. B. Isaac*, Samuel T. Turvey, Ben Collen, Carly Wate

Institute of Zoology, Zoological Society of London, London,

SCIENCE ADVANCES | RESEARCH ARTICLE

ECOLOGY

Functional diversity of marine megafauna in the Anthropocene

C. Pimiento[1,2]*, F. Leprieur[3,4], D. Silvestro[5,6†], J. S. Lefcheck[7], C. Albouy[8], D. B. Rasher[9], M. Davis[10,11], J.-C.

Functionally unique, specialised, and endangered (FUSE) species: towards integrated metrics for the conservation prioritisation toolbox

J. N. Griffin, F. Leprieur, D. Silvestro, J. S. Lefcheck, C. Albouy, D. B. Rasher, M. Davis, J.-C. Svenning, C. Pimiento

doi: https://doi.org/10.1101/2020.05.09.084871

This article is

Article | Open access | Published: 24 November 2023

Functional diversity of sharks and rays is highly vulnerable and supported by unique species and locations worldwide

Catalina Pimiento ✉, Camille Albouy, Daniele Silvestro, Théophile L. Mouton, Laure Velez, David Mouillot, Aaron B. Judah, John N. Griffin & Fabien Leprieur

Nature Communications **14**, Article number: 7691 (2023) | Cite this article

Introducing the FUSE-IAS index

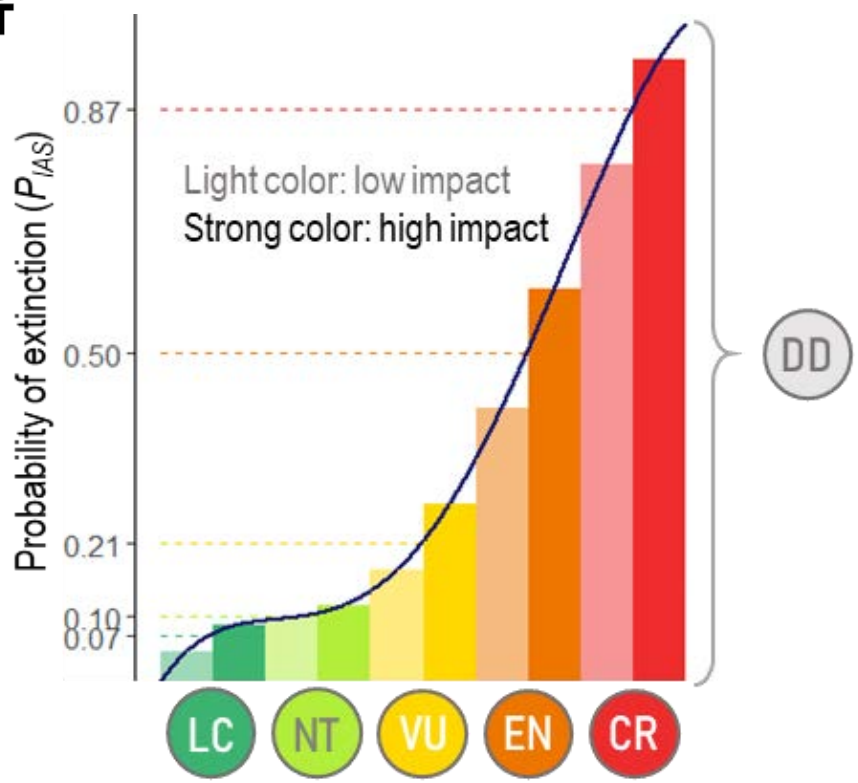
Conservation priorities for functionally unique and specialized terrestrial vertebrates threatened by biological invasions

Clara Marino, Filipa Coutinho Soares, Céline Bellard

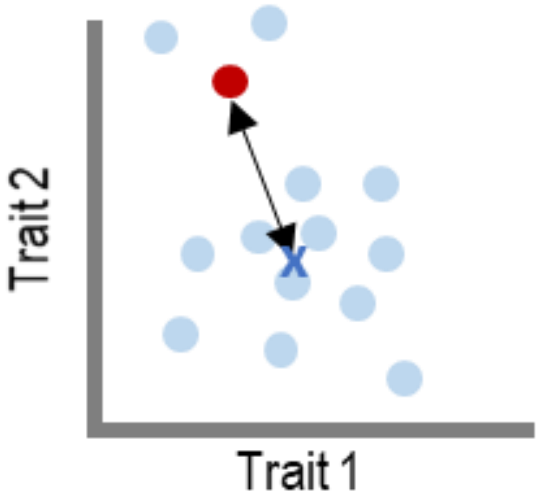
Marino et al. In review.

Introducing the FUSE-IAS index

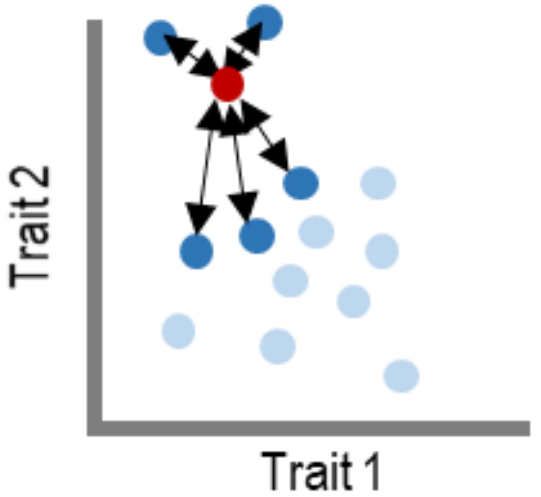
P_{IAS} = probability of extinction due to IAS



FSp = functional specialization

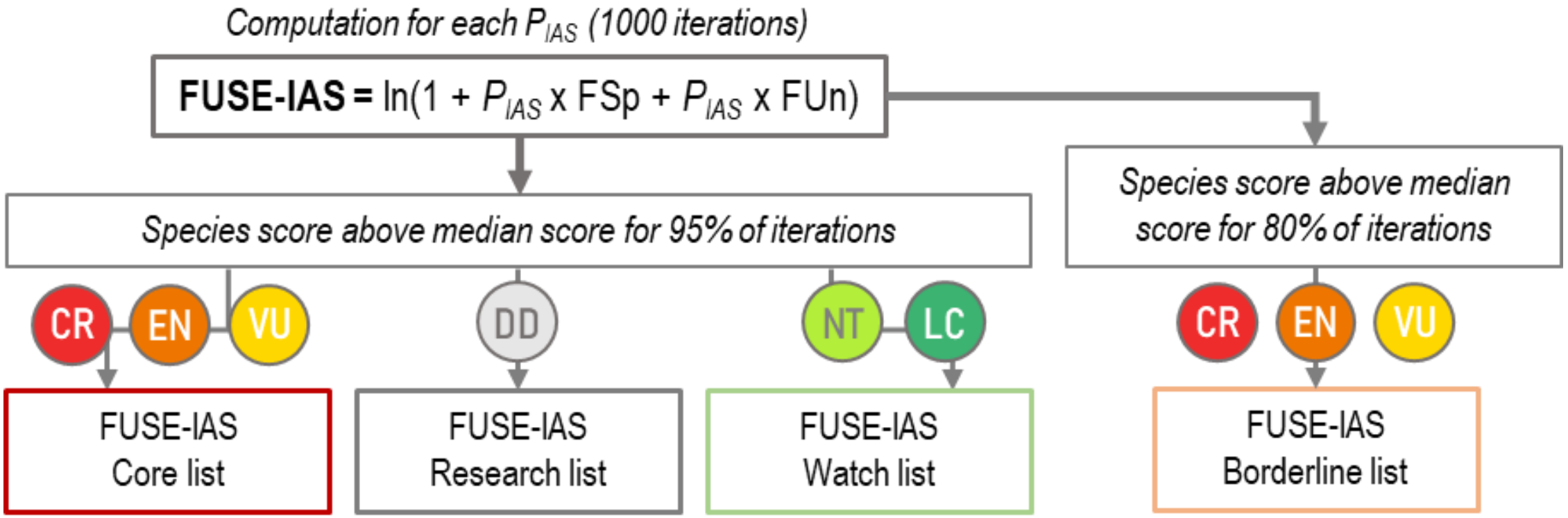


FUn = functional uniqueness



Marino et al. In review.

FUSE-IAS score and priority lists

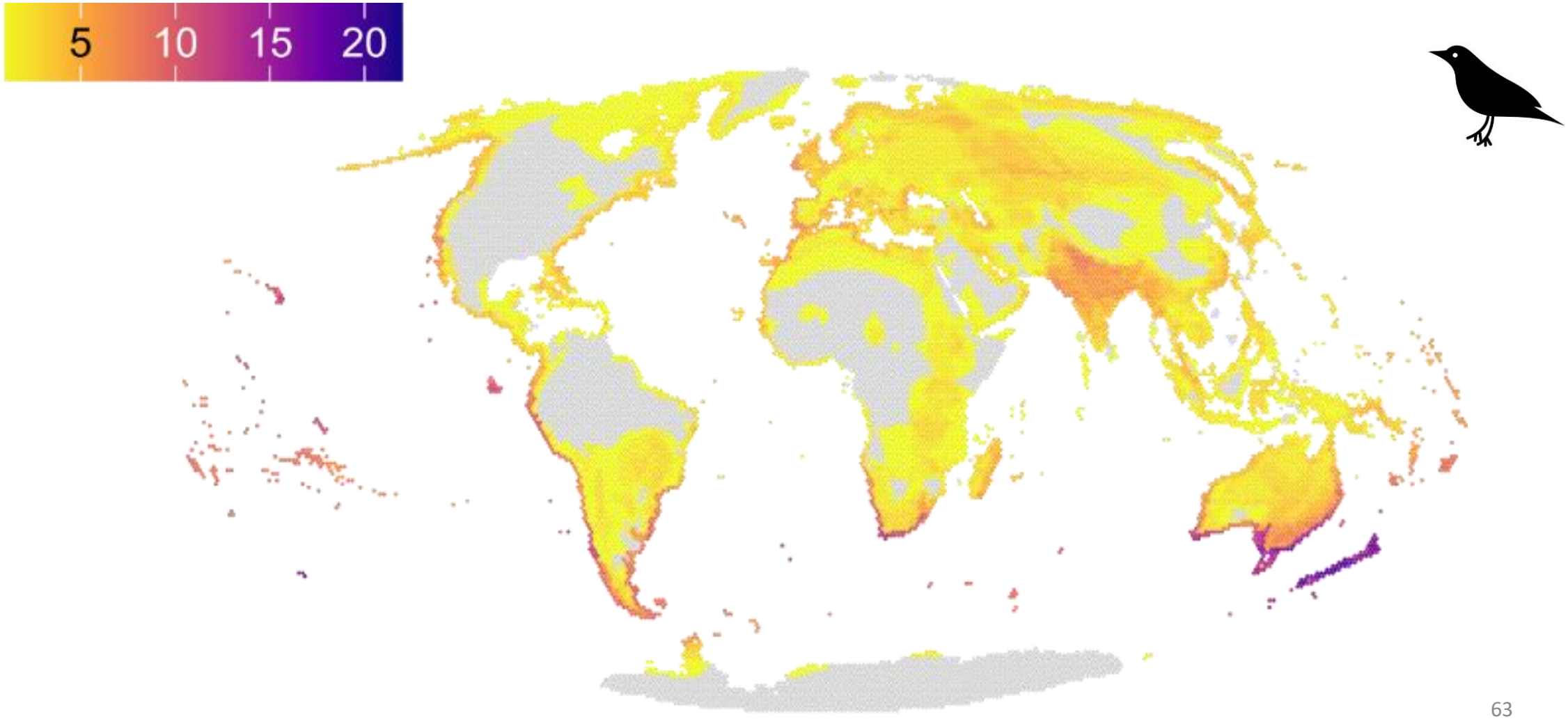


Marino et al. In review.

FUSE-IAS score of terrestrial vertebrates

Marino et al. In review.

Coinciding with vulnerability hotspots



Marino et al. In review.

Take-home message

Species that are functionally unique, specialized, and endangered by IAS:

- Can be defined by their extinction probability due to biological invasions, and their position in a functional space

  Gumbs et al., 2023; Pimiento et al., 2020; 2023

- Represent +1370 species of terrestrial vertebrates (Core List species)

- Are spread all over the world with hotspots depending on the taxonomic group

$$\text{FUSE-IAS} = \ln(1 + P_{IAS} \times \text{FSp} + P_{IAS} \times \text{FUn})$$

VU EN CR

Marino et al. In review.

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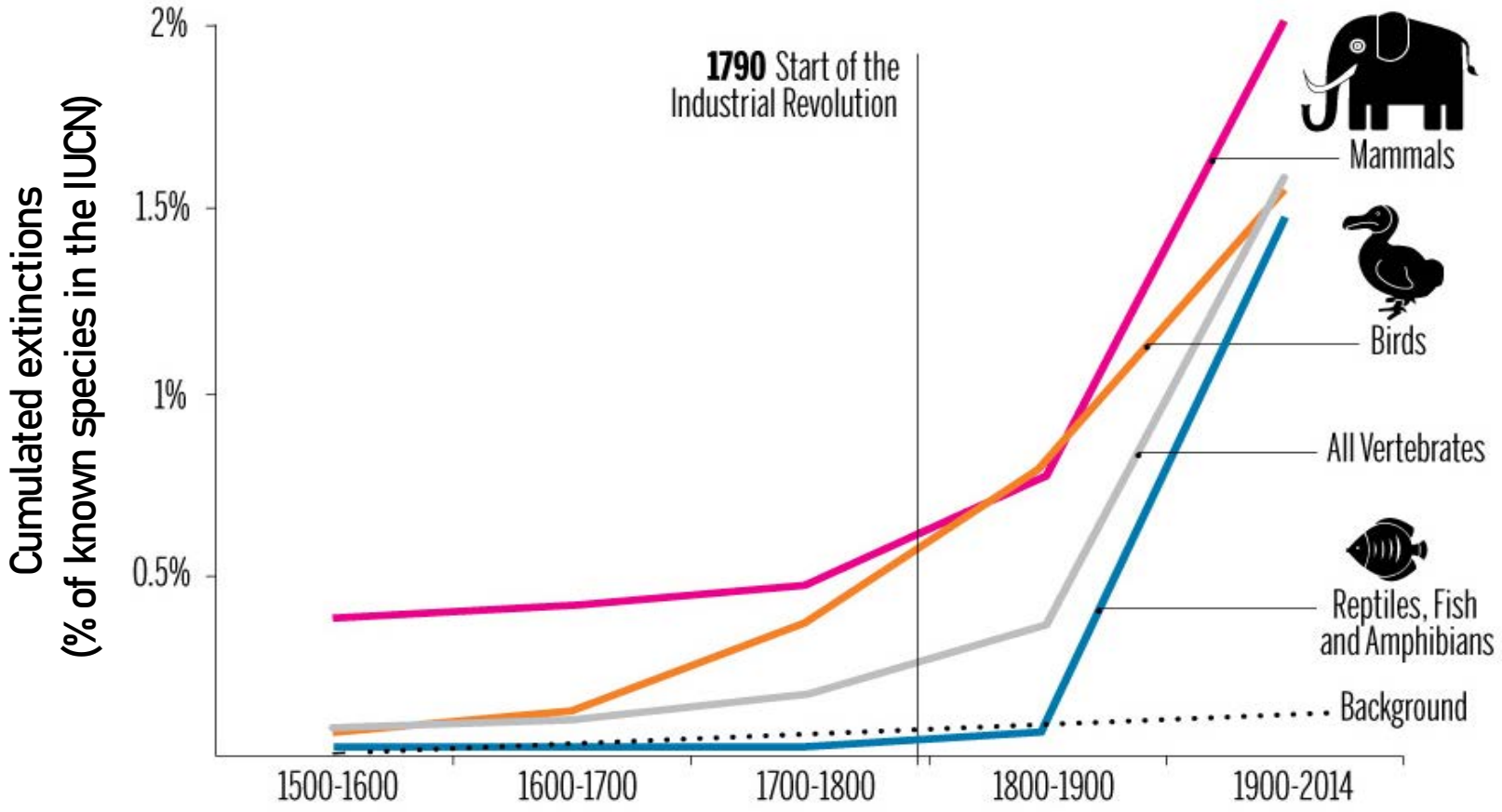
Not one but multiple stressors on biodiversity



Climate change

Biological invasions

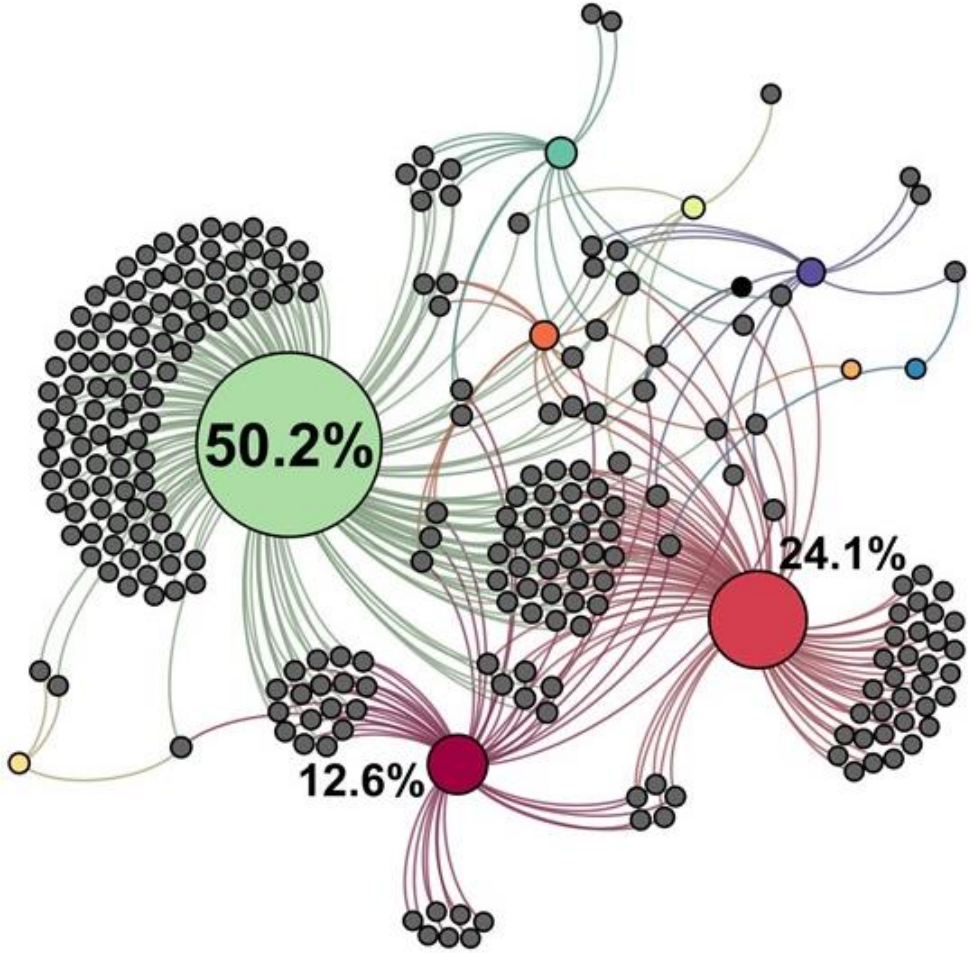
Land-use change

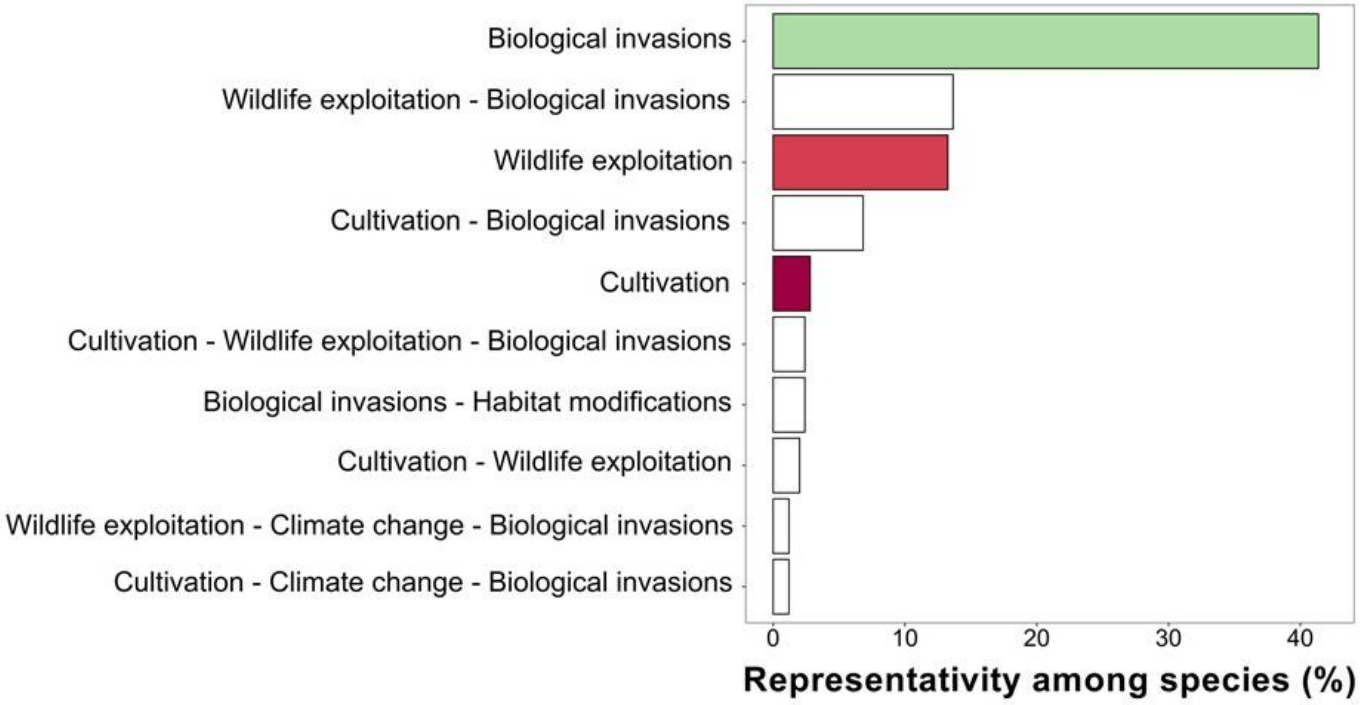
Pollution

Overexploitation

Ceballos et al., 2015; IPBES 2019

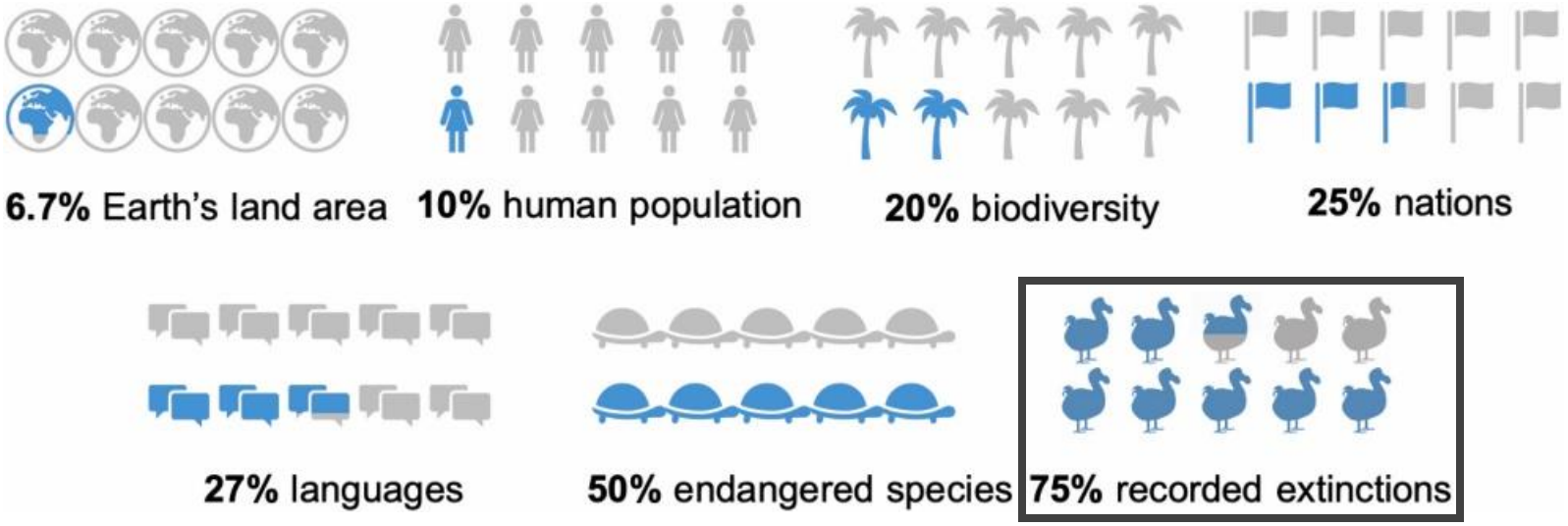
Not one but multiple stressors on biodiversity

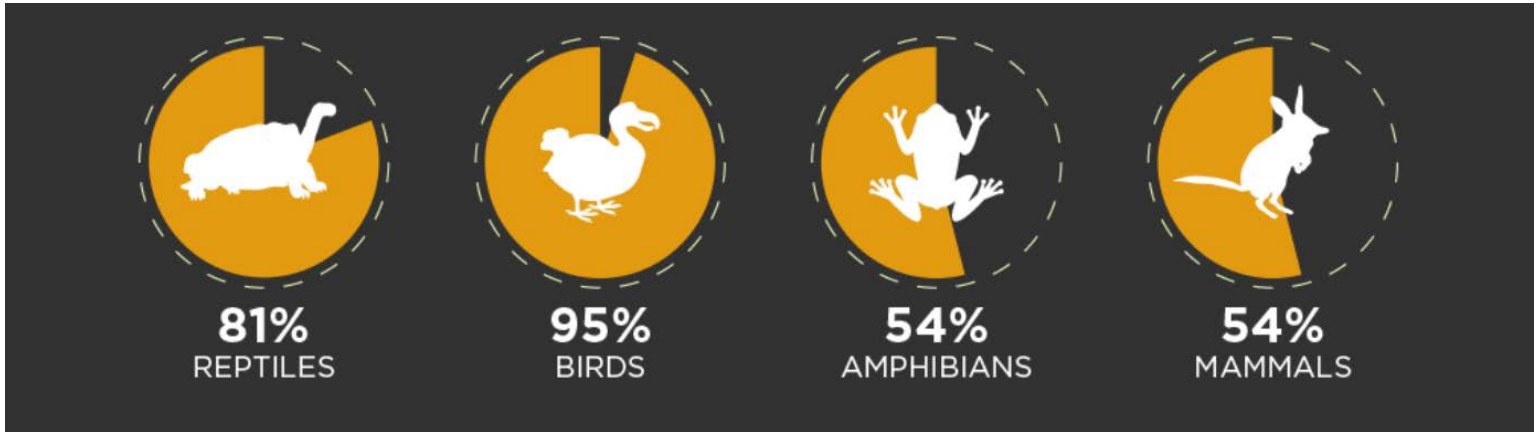




Leclerc *et al.*, 2018

Importance of island biota in conservation





Fernández-Palacios *et al.*, 2021

Objective of the RIVAGE project

Provide a global assessment of island vulnerability to three global change drivers

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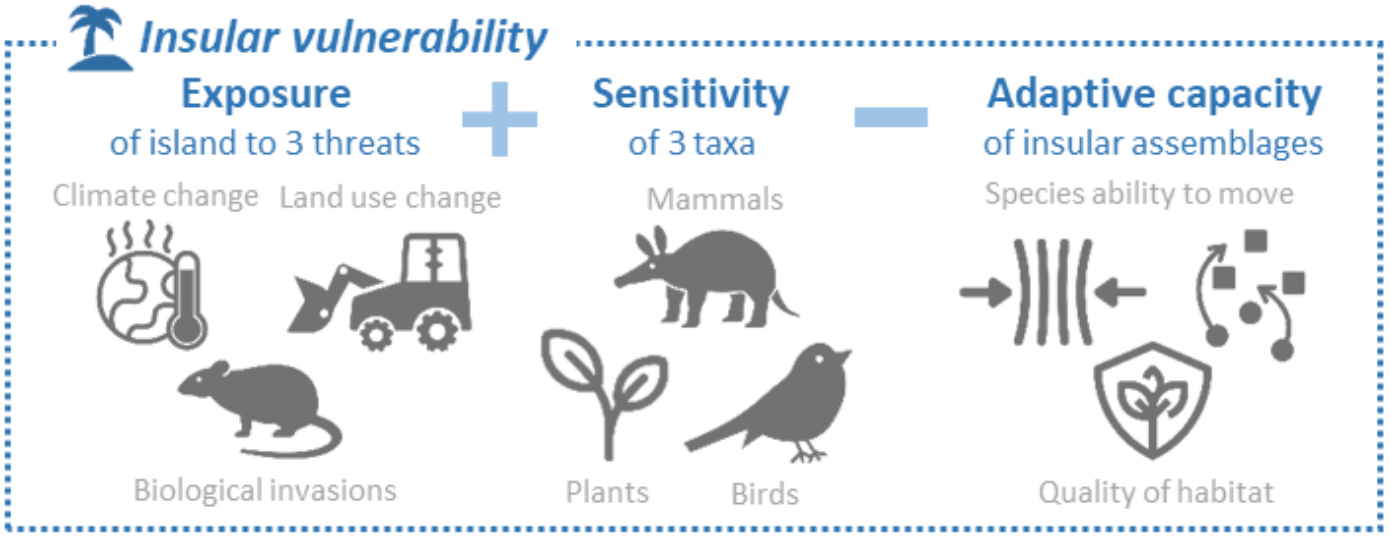

- Exposure: the extent to which the physical environment will change due to multiple threats
- Sensitivity: the intrinsic capacity of species to cope with threats
- Adaptive Capacity: the ability of species to shift in space, depending on species' intrinsic ability and habitat quality

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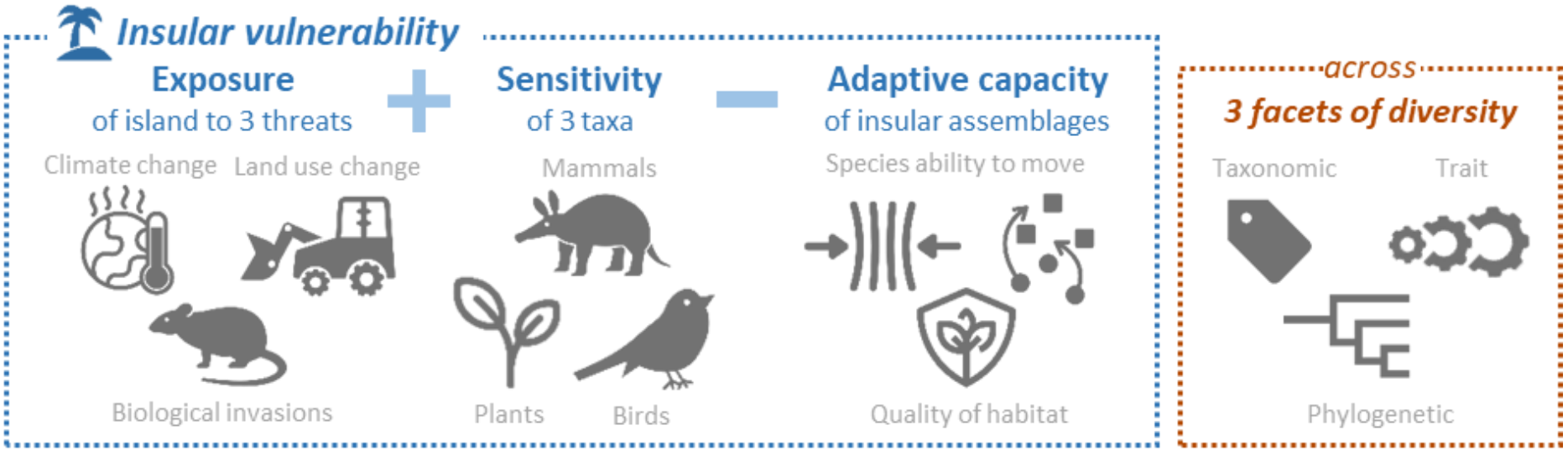

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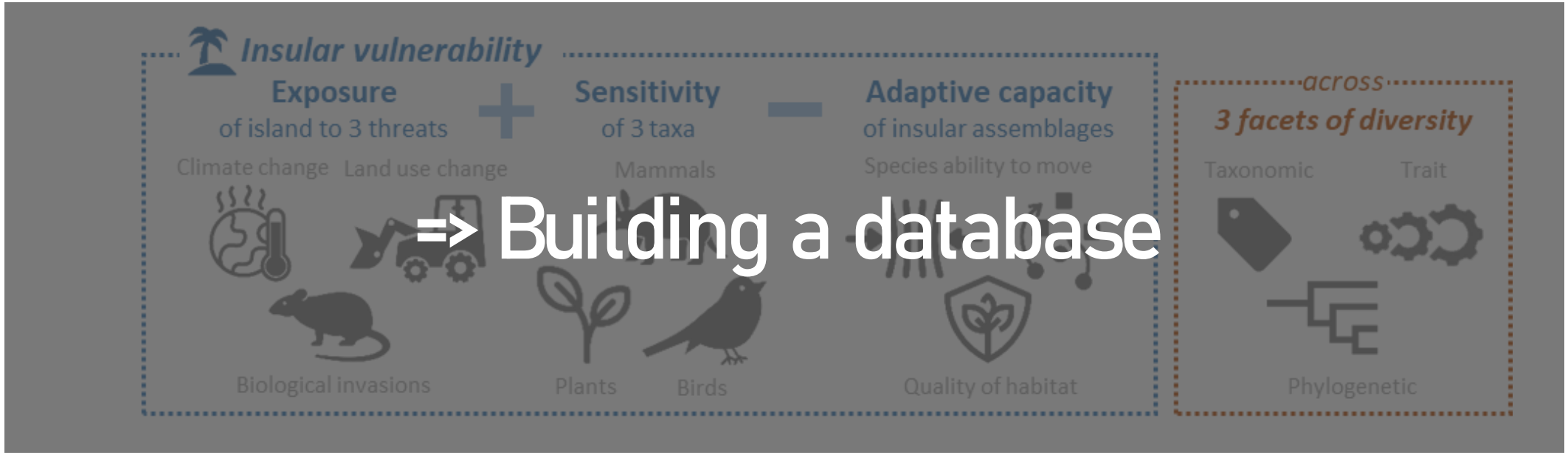

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Using the data to revisit the island biogeography theory...

WP2 – Analyses

Explore vulnerability patterns and their congruences with facets of diversity

2.1 Integrative measure of vulnerability

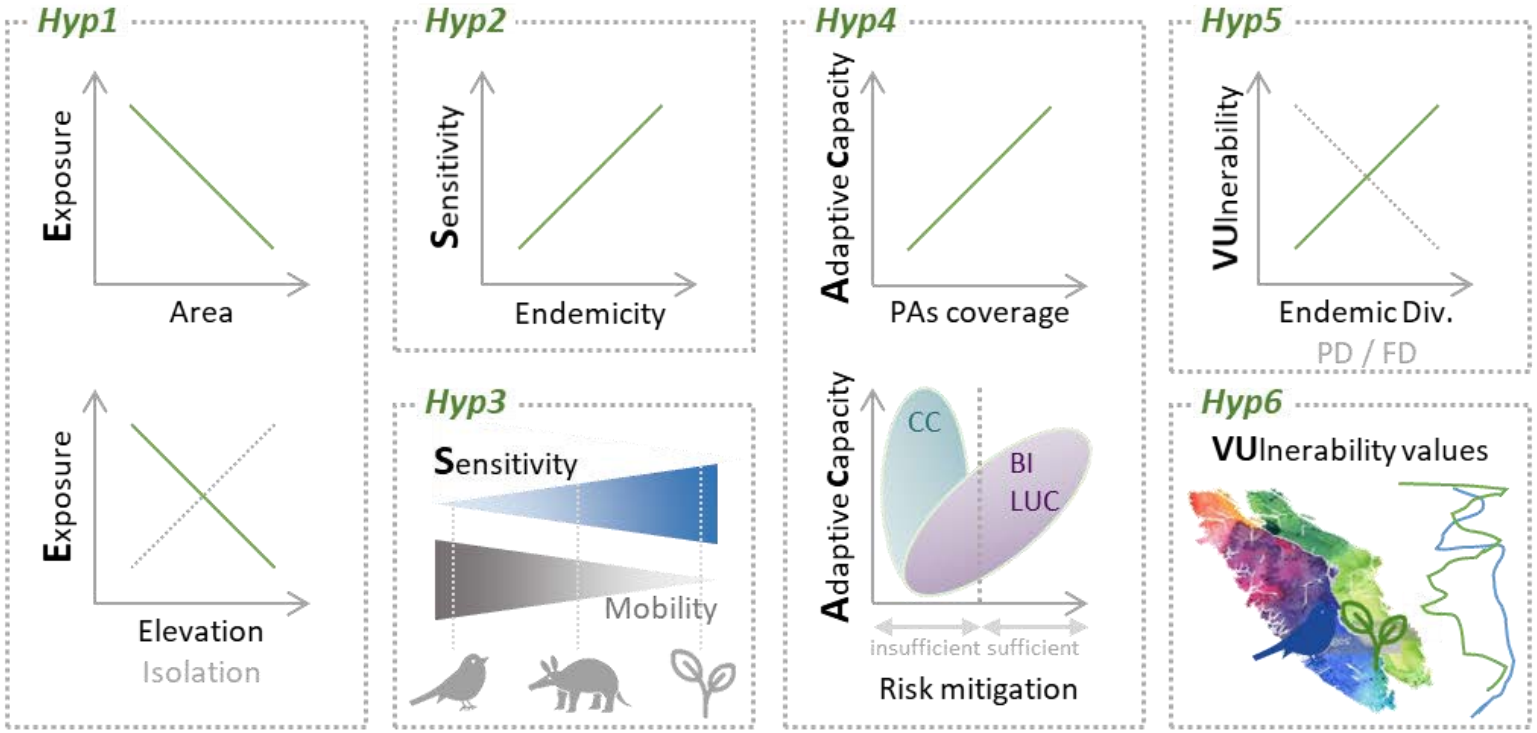
multi-criteria decision analysis

2.2 Patterns and **relative contribution** of vulnerability components

hotspots and coldspots identifications

2.3 Metrics for the **three facets of diversity** and **congruence** with vulnerability

taxonomic, phylogenetic and functional diversity



... and to provide informative conservation scenarios

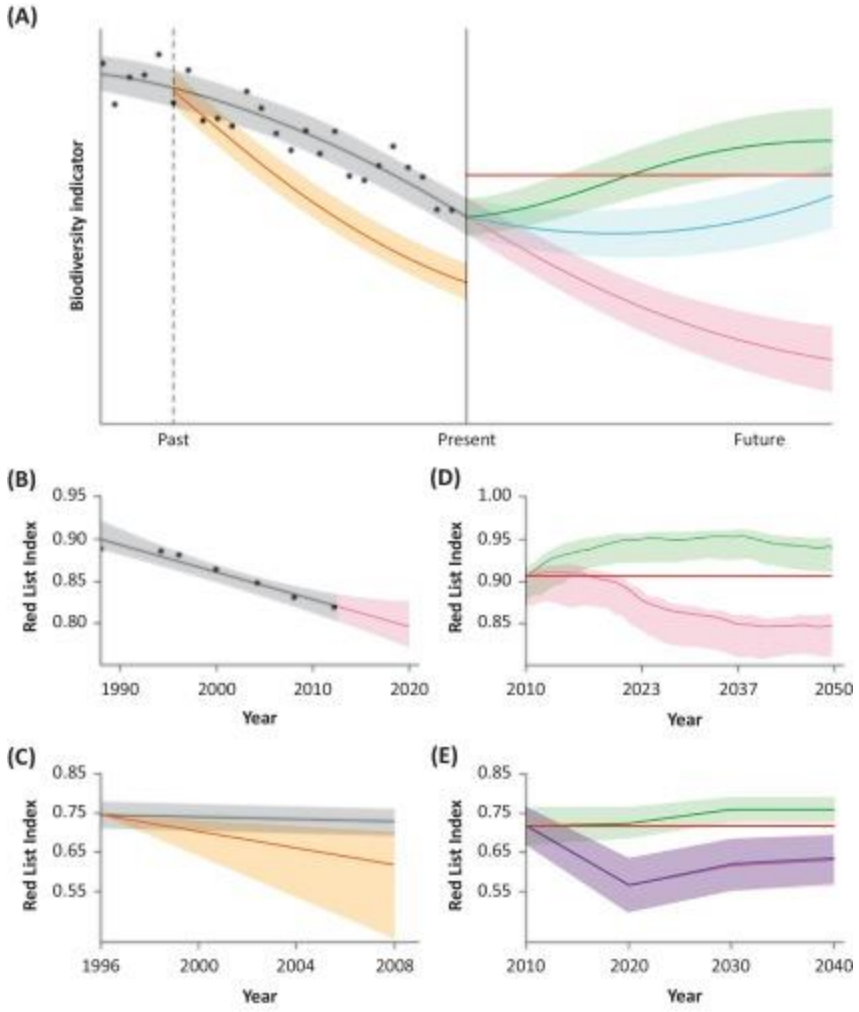
WP3 – Conservation scenarios

Recommend conservation priorities using multiple decision scenarios

3.1 Multiple decision scenarios of conservation
maximizing some facets of diversity with multicriteria decision analyses

3.2 Indicators of vulnerability and conservation priorities
concertation with IUCN actors

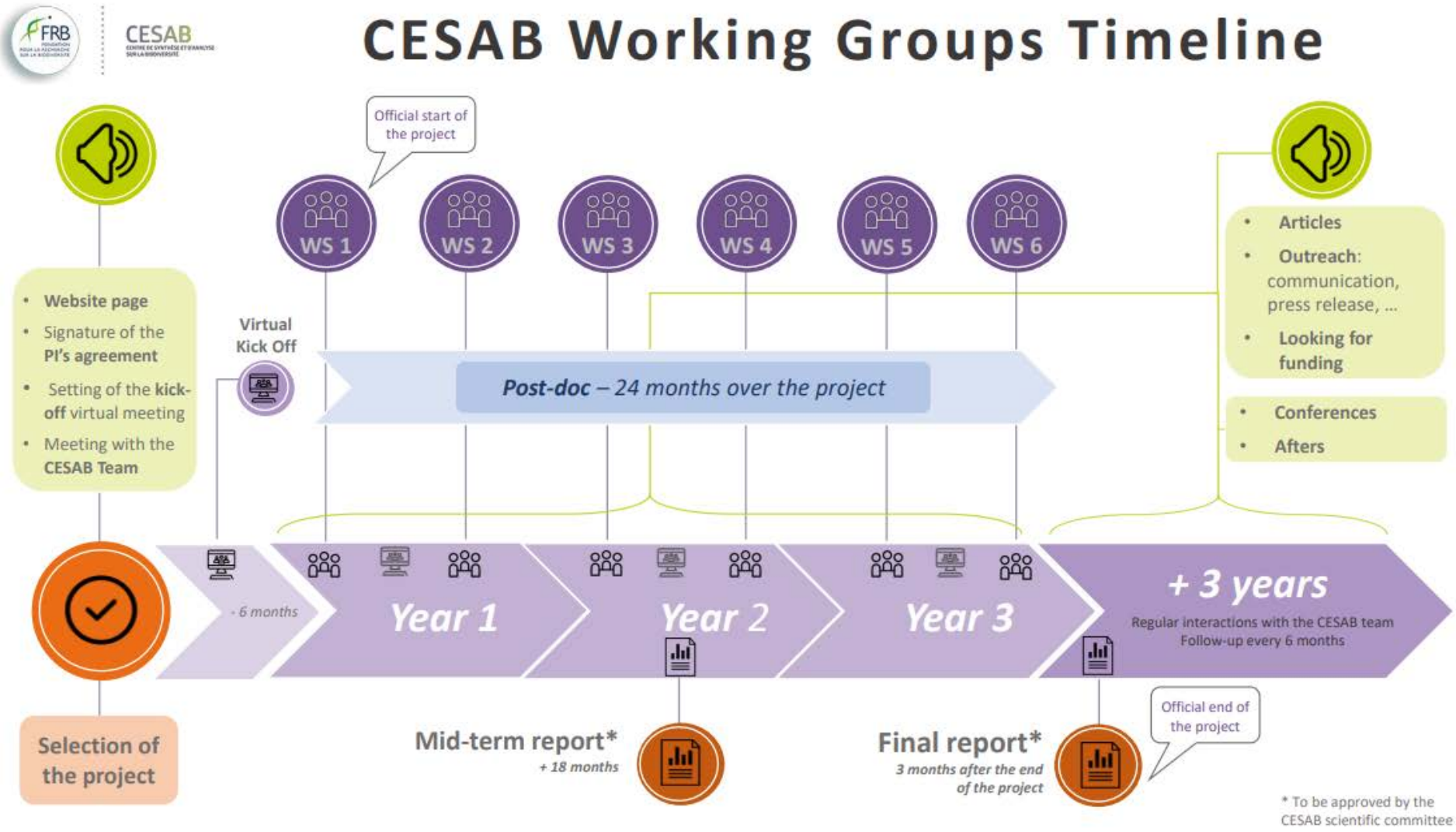
IUCN



Trends in Ecology & Evolution

Nicholson *et al.*, 2019

A 2-year postdoc inside a bigger project



Co-PIs:
Céline Bellard
W. Daniel Kissling

+ 14 other experts from different domains related to the project

Thanks for your attention!

And many thanks to:
- Céline Bellard
- all co-authors
- my PhD comittee & members of the jury
- colleagues from ESE & Cesab

@cl_marino

clara.marino@fondationbiodiversite.fr

Any questions ?