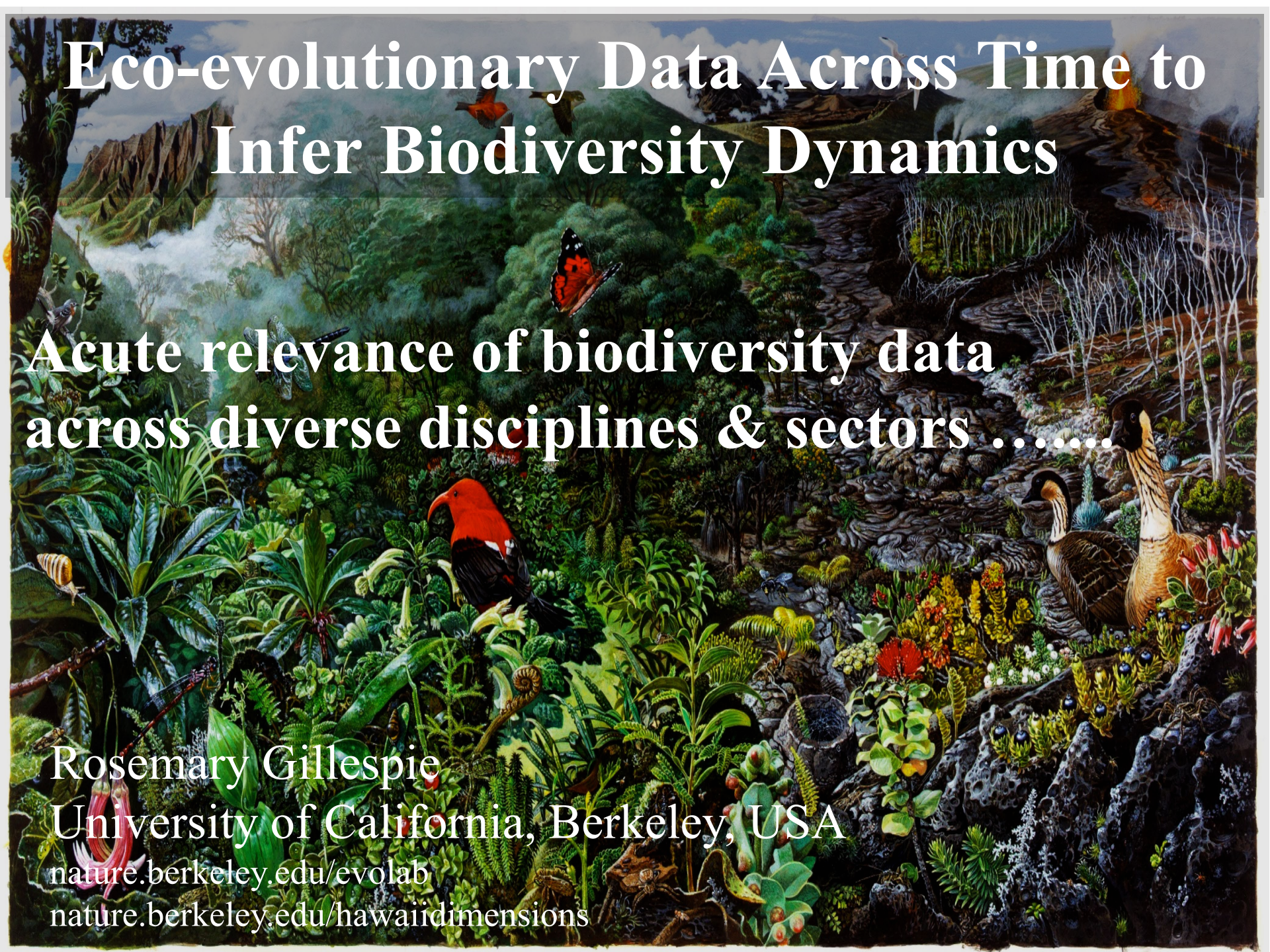
Eco-evolutionary Data Across Time to Infer Biodiversity Dynamics



Acute relevance of biodiversity data across diverse disciplines & sectors ……

Rosemary Gillespie
University of California, Berkeley, USA
nature.berkeley.edu/evolab
nature.berkeley.edu/hawaiidimensions

Collections in Biodiversity Dynamics

Museum specimens for understanding change - *Museum collections provide physical record of environments – both past and present*

Grinnell Resurvey
MVZ, UC Berkeley

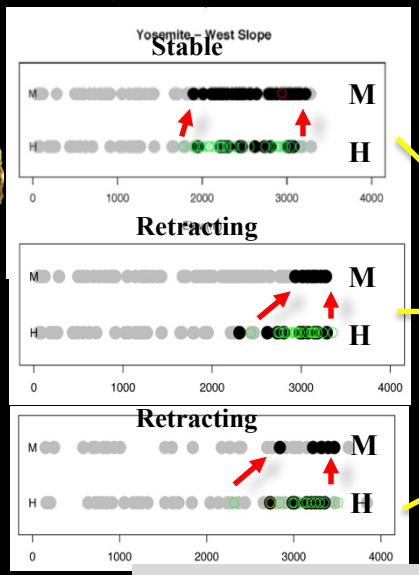
Tamias alpinus Alpine Chipmunk

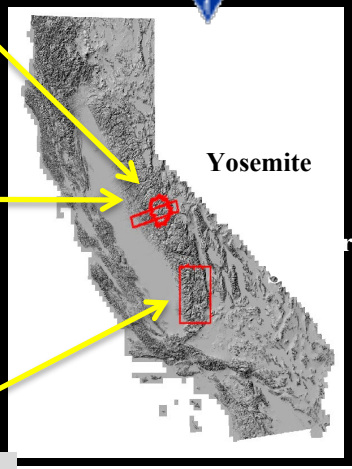
- High elevation specialist
- Range contracted at lower limit
- Reduced genetic diversity in modern era.

T.speciosus

T. alpinus

T. alpinus

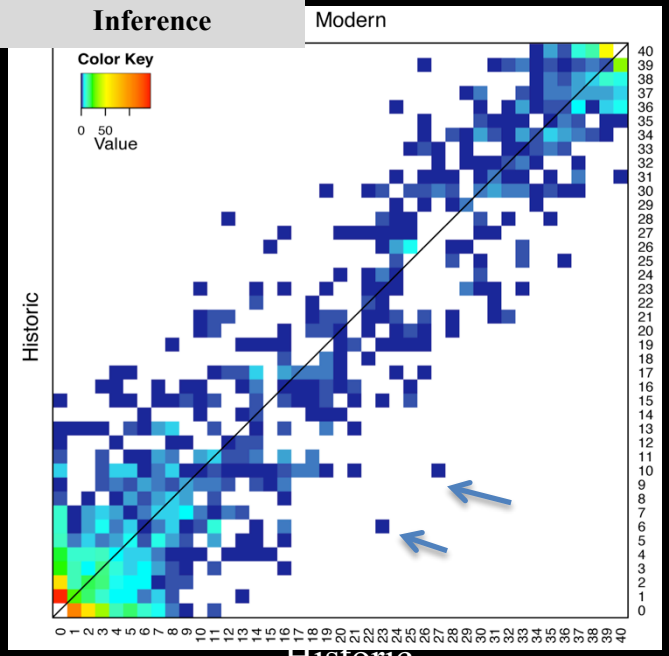




Tamias speciosus Lodgepole Chipmunk

- Overlaps with *T. alpinus* at upper range limit.
- No change in elevational range
- Current genetic diversity is the same as in historic era.

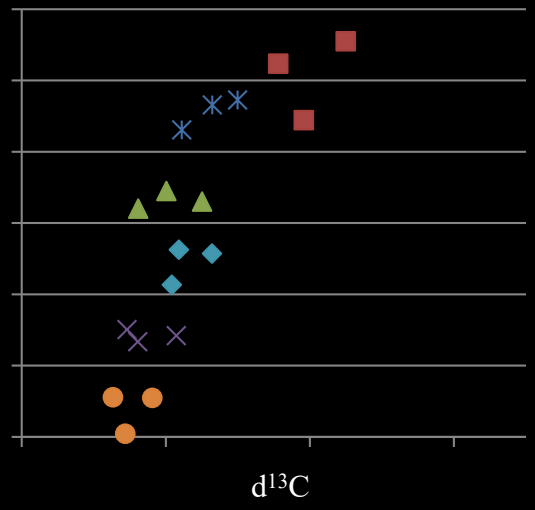
T. alpinus

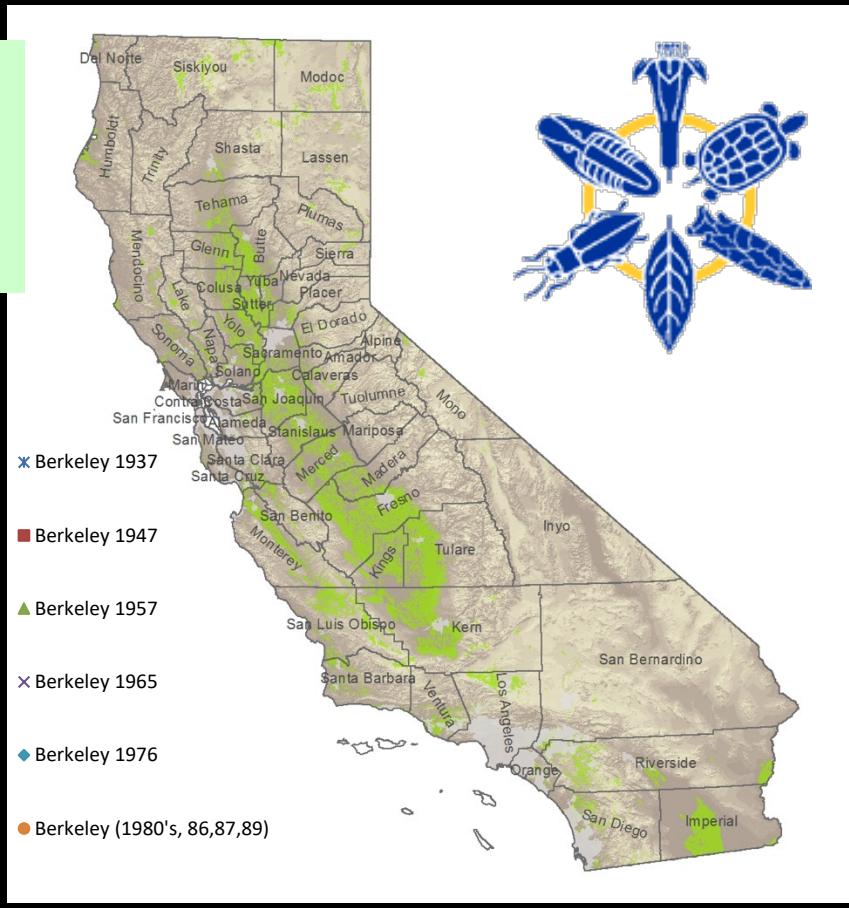


Moritz et al. 2008, Rubidge et al. 2012

Genomics, isotopes and pollen: California bees

Carbon ($d^{13}C$) and Nitrogen ($d^{15}N$) of Honey Bees over time



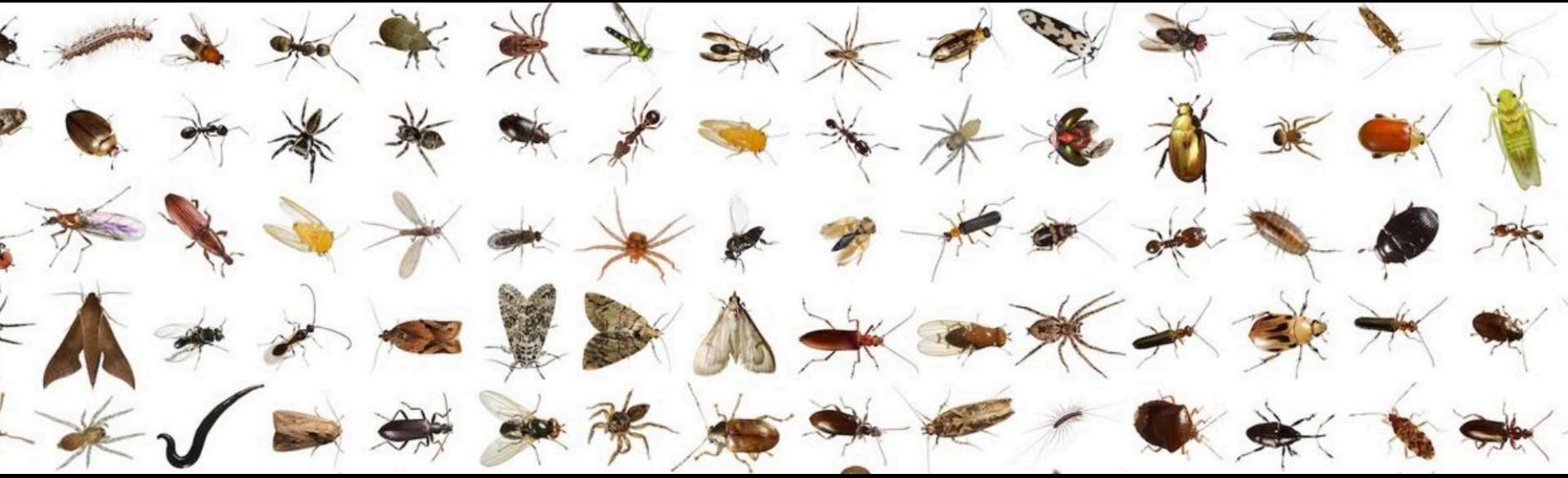


Reconstructing historical ecological interactions by **identifying pollen on preserved bees**.

Tracking the impacts of ecological, climate, and land use change by **quantifying stable isotope ratios**.

Analysis of historical collections to document how honey bees, native bees, plants, and pollination activities have changed over the last ~100 years in response to urbanization, agricultural land conversion, etc.

T. Dawson, Julie Truong (2012, unpubll)



But for most organisms, we have no information from the past

- **For many, we have no information even of identity**
- **How, then, do we understand response to change?**

First, do we really need to?

Photos David Liittschwager

The New York Times Magazine

The Insect Apocalypse Is Here

What does it mean for the rest of life on Earth?

ABC NEWS

Just In Politics World Business Sport Science Health Arts Analysis

Print Email Facebook Twitter More

One million species at risk of extinction, UN report warns, and we are mostly to blame

By Lexi Metherell

Updated 6 May 2019, 5:19pm

Forbes

9,498 views | May 9, 2019, 10:13am

UN Report: 1 Million Animal And Plant Species At Risk Of Extinction

GrrlScientist Contributor

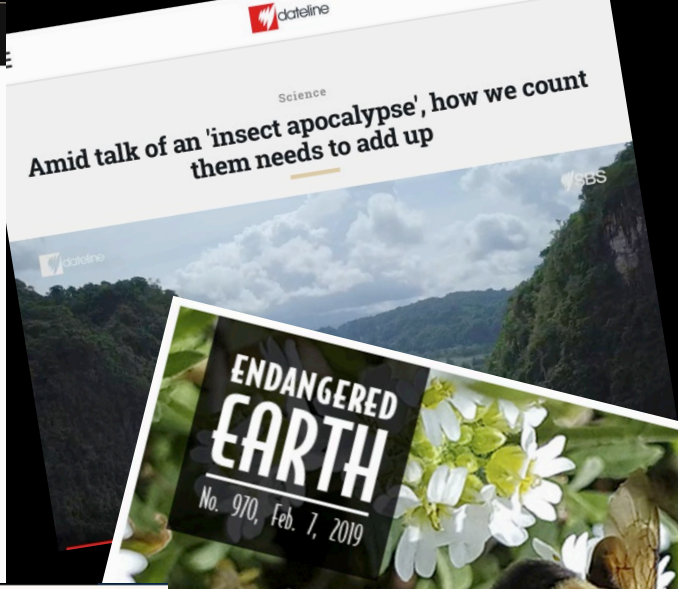
Science

Evolutionary & behavioural ecologist, ornithologist & science writer

dateline

Science

Amid talk of an 'insect apocalypse', how we count them needs to add up



NTER for BIOLOGICAL DIVERSIT

'e Curb the Insect Apocalypse?

bout stemming the catastrophic decline of insects, we must drastically re

ey findings of a major new scientific study in *Biological*

nsects worldwide are on a fast

1/24

An ensatina salamander (*Ensatina eschscholtzii eschscholtzii*).

PHOTOGRAPH BY JOEL SARTORE, NATIONAL GEOGRAPI

ANIMALS

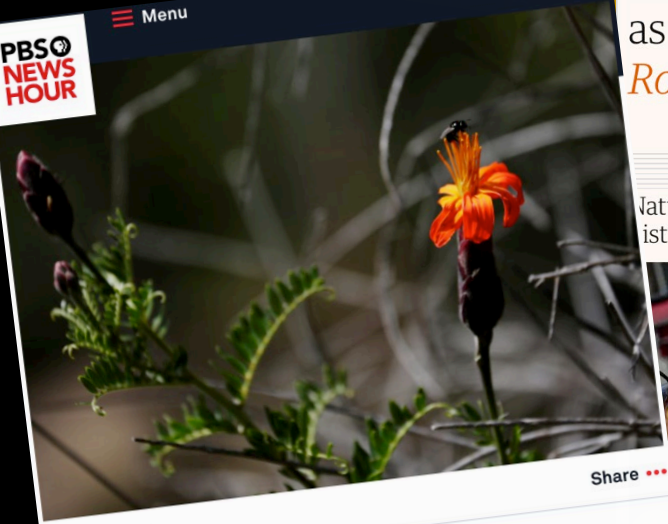
Half of all amphibian spec extinction

A new study finds that more than 1,000 amphibian spec are likely facing extinction, adding

PBS NEWS HOUR

Menu

Full Episodes



Share

9 comments

By — Seth Borenstein, Associated Press

Biodiversity loss accelerates with 1 million species at risk of extinction, UN report finds

Loss of biodiversity is just as catastrophic as climate change

Robert Watson

Nature is being eroded at rates unprecedented in human history but we still have time to stave off mass extinctions

A WWF demonstration for biodiversity in Paris on Saturday. Photograph: Kenzo Tribouillard/AFP/Getty Images

A colleague recently described how fish would swim into her clothing when she was a child bathing in the ocean off the coast of

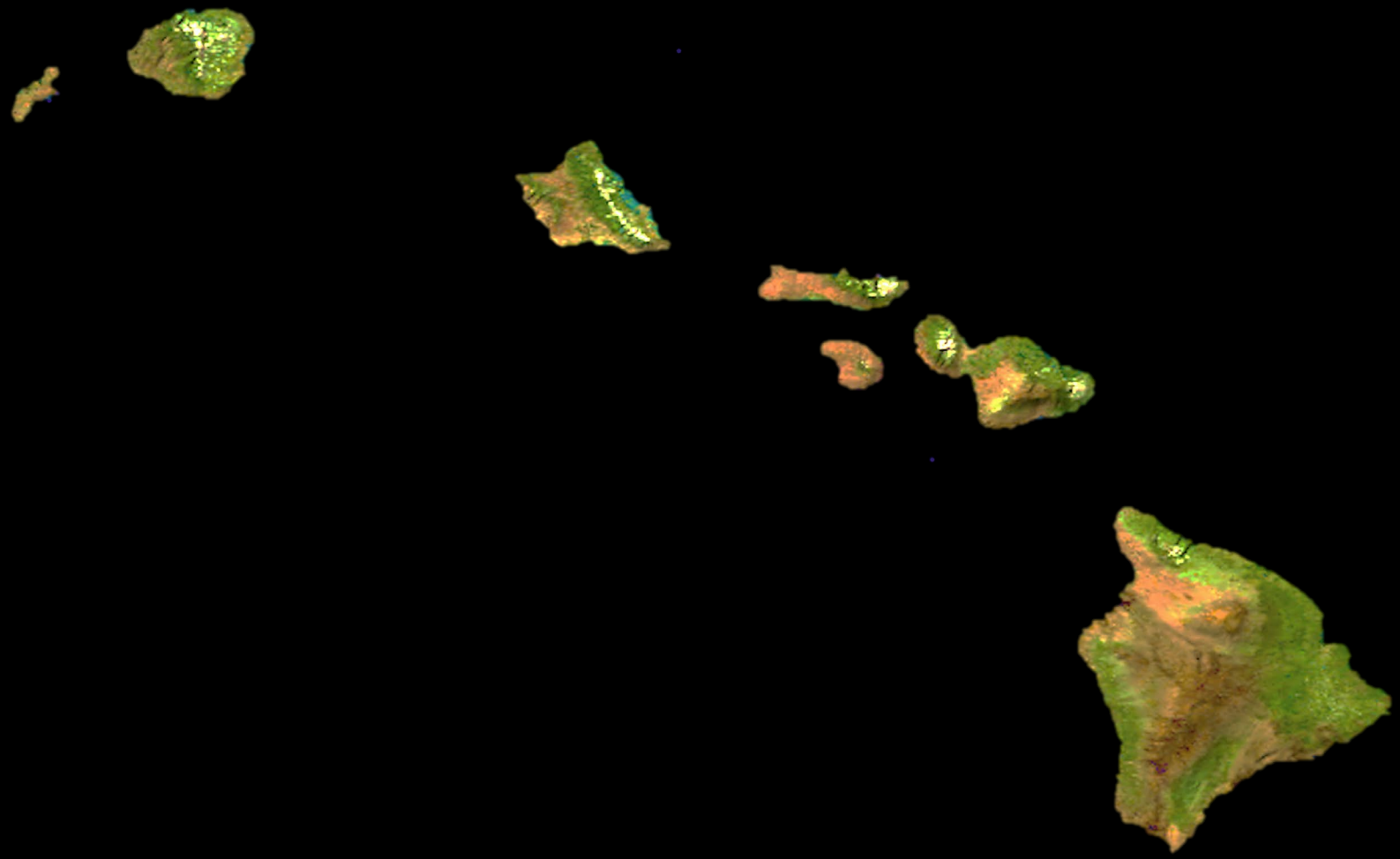
Threats to the world's ecosystems … complex mix of habitat destruction, climate change, disease, invasive species….

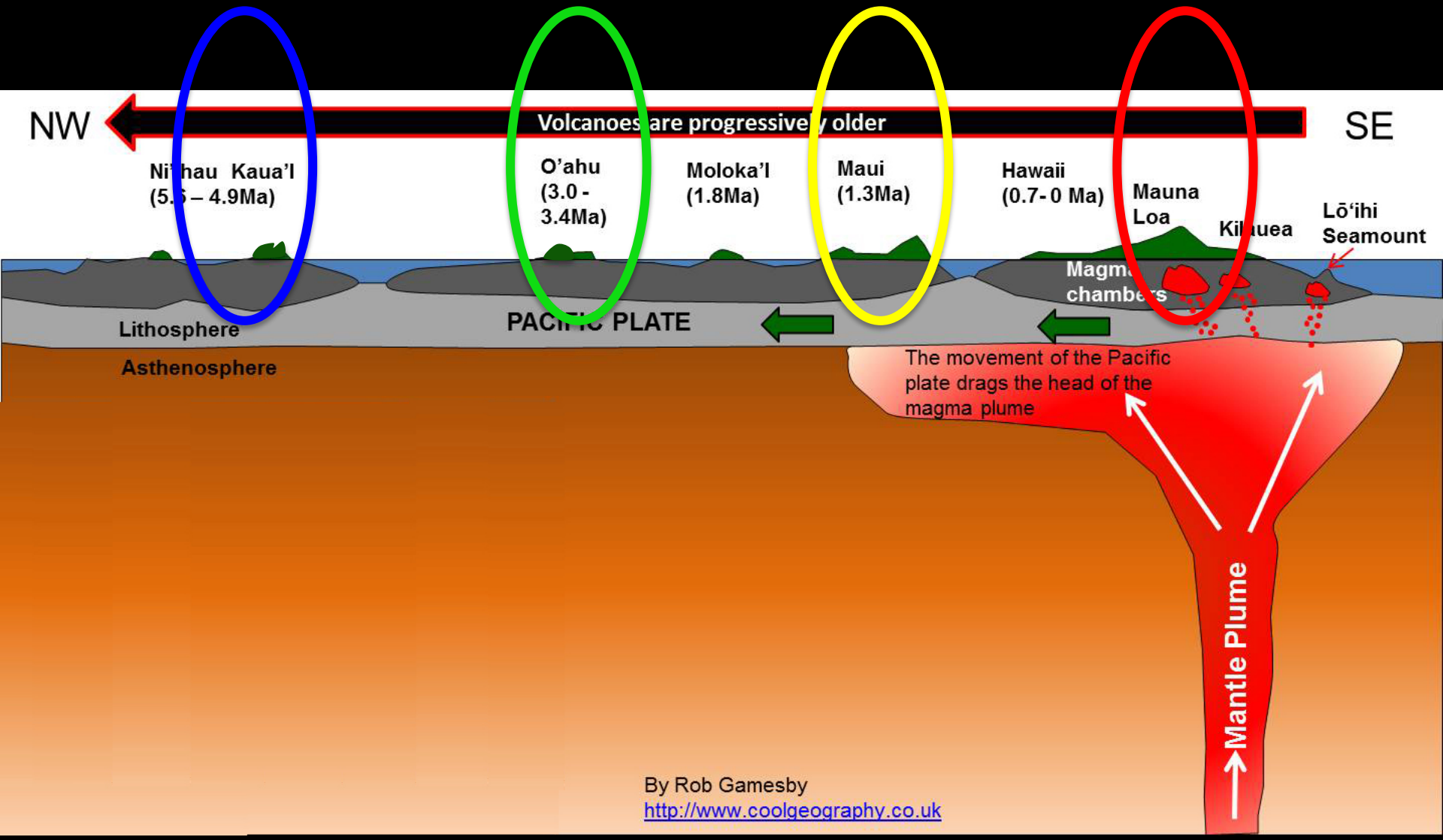
- No reliable way to quantify the overall health of an ecosystem.
- **Much needed are metrics that encapsulate the "status" of the biological component of an ecosystem and allows comparison across space and time, yet is agnostic to species identity.**


Islands allow development & testing of these ideas
Photo: George Roderick

Signatures of ecosystem change through time –

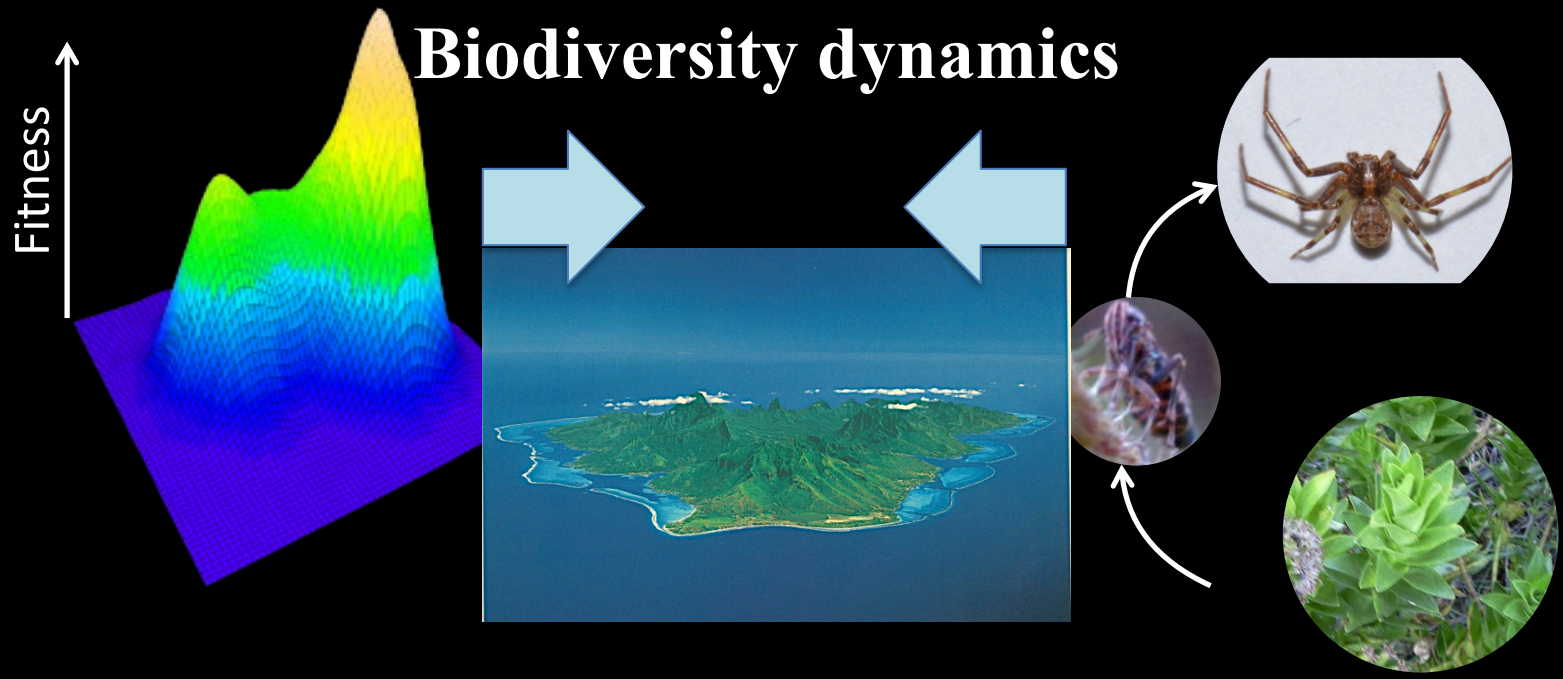
Using islands as microcosms to test theory



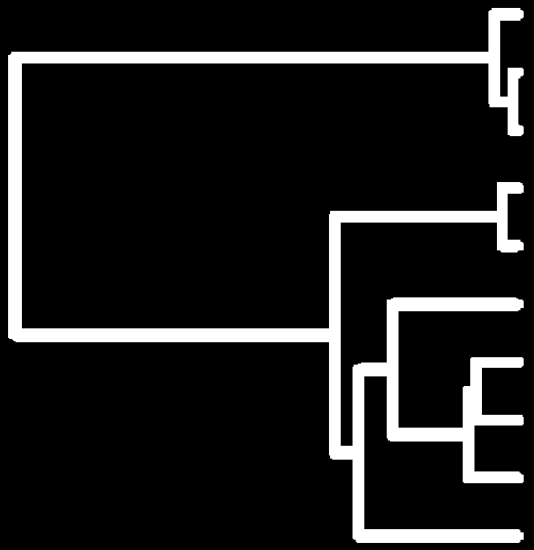


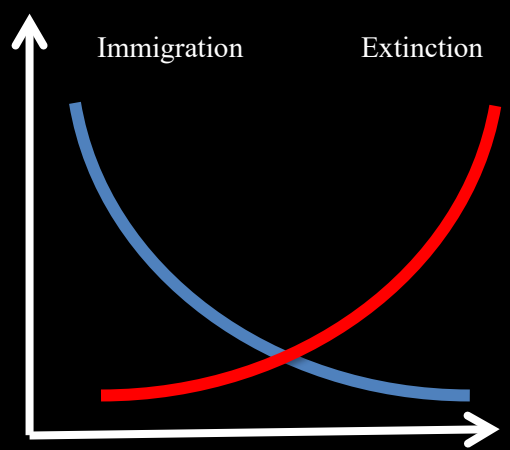
Provide a time series

Biodiversity dynamics



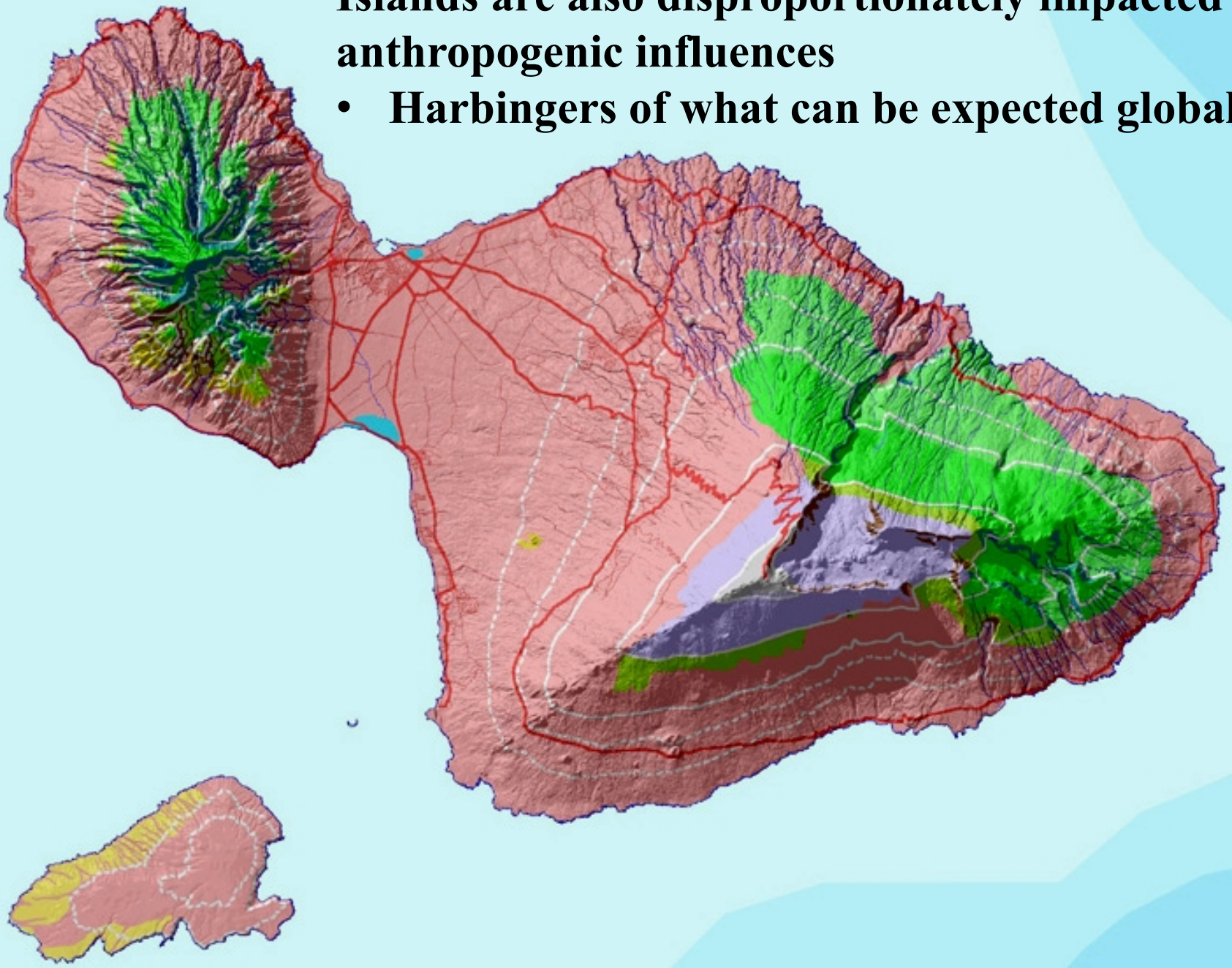
Information on organisms over gradients of space & time





Islands are also disproportionately impacted by anthropogenic influences

- **Harbingers of what can be expected globally**




Ginger Invasion!
Waikamoi Preserve, Maui, March 2015
Photo: Kari Goodman

Auwahi, Maui – “museum forest”

http://www.auwahi.org

Photo: Art Medeiros

Auwahi, Maui – recovery

Photo: Art Medeiros

Two advances

- **Empirical data – metabarcoding.**
- **Integrative and predictive theoretical framework.**

Together, these approaches can be used for

- **Biodiversity forecasting**
  - **Abundance distributions**
  - **Networks**

Linking back to specimens is then essential to understand the process


Andy Rominger

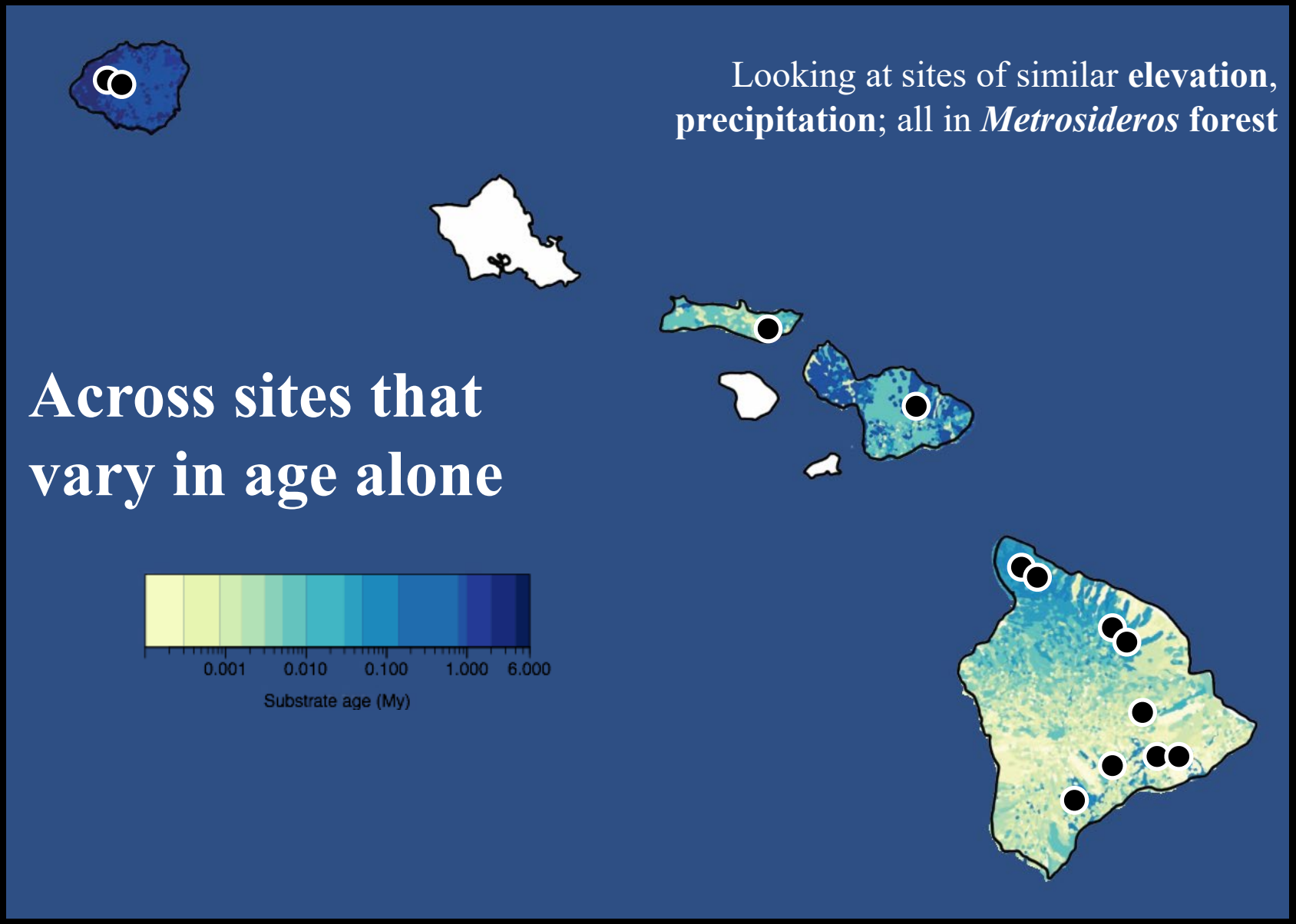

Henrik Krehenwinkel

Can use these island systems to …….

Photo : George Roderick

- **Identify "functionality"**
- **"Robustness" or resilience**

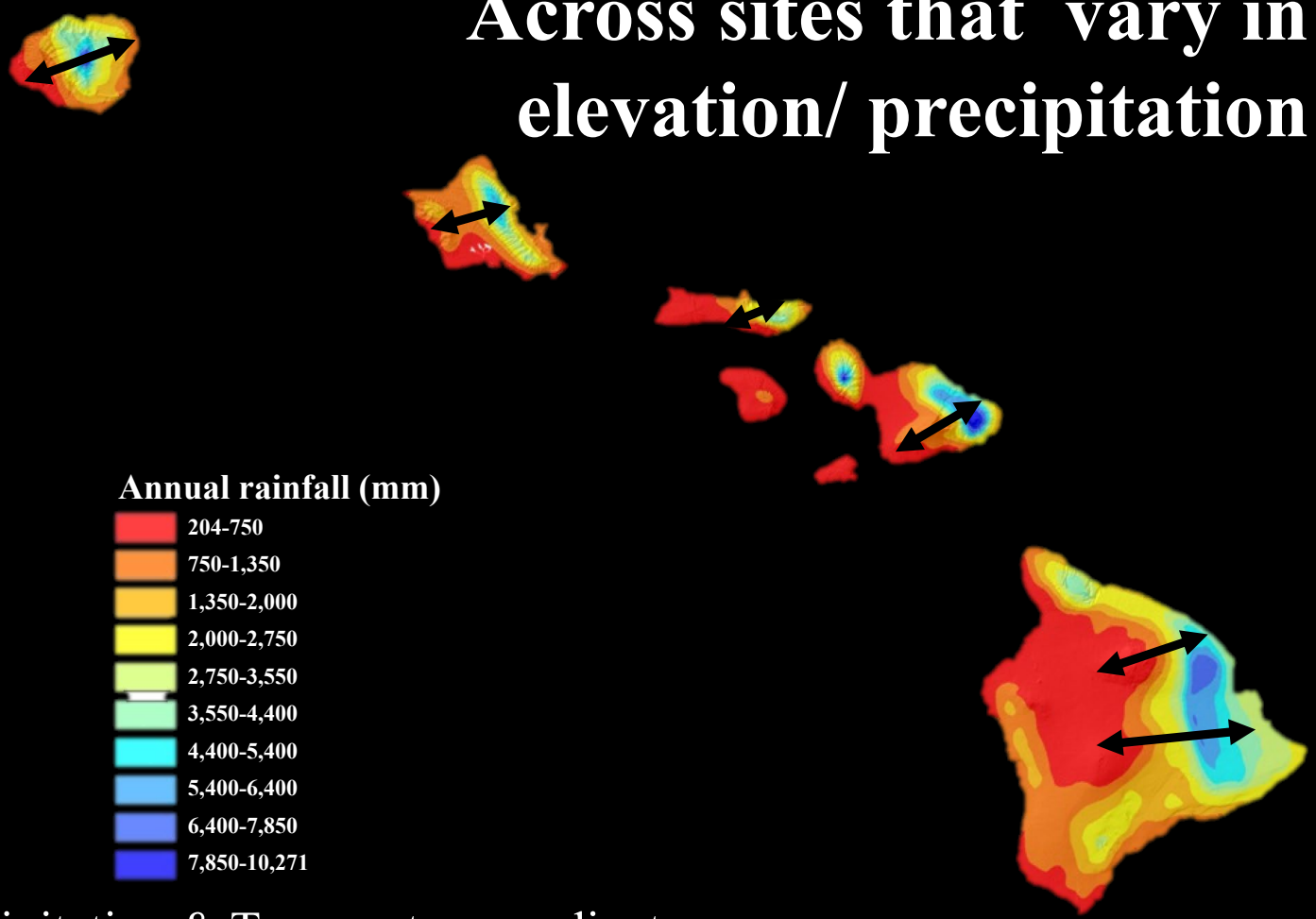
How to get “signatures” of community ……



Community Dynamics Across a Chronosequence

How to get “signatures” of community ……

Across sites that vary in elevation/ precipitation

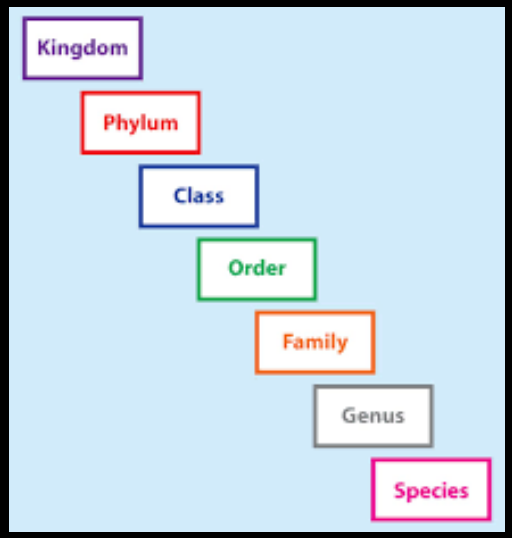


Precipitation & Temperature gradients

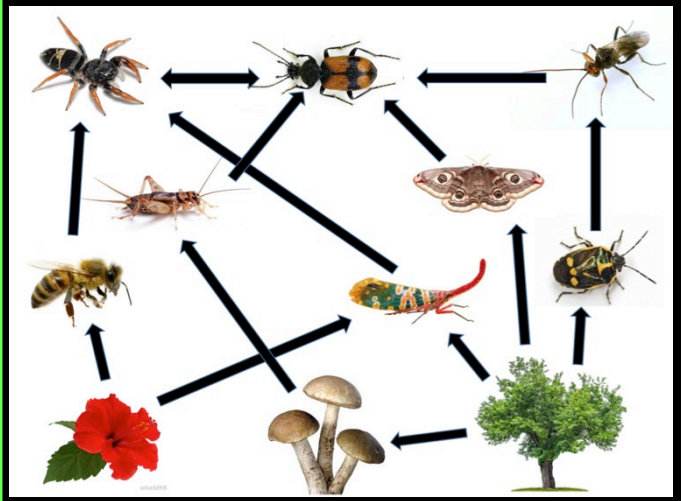
Community Dynamics Across a Chronosequence

Signatures of Community Status

Identity & abundance



Networks & interactions



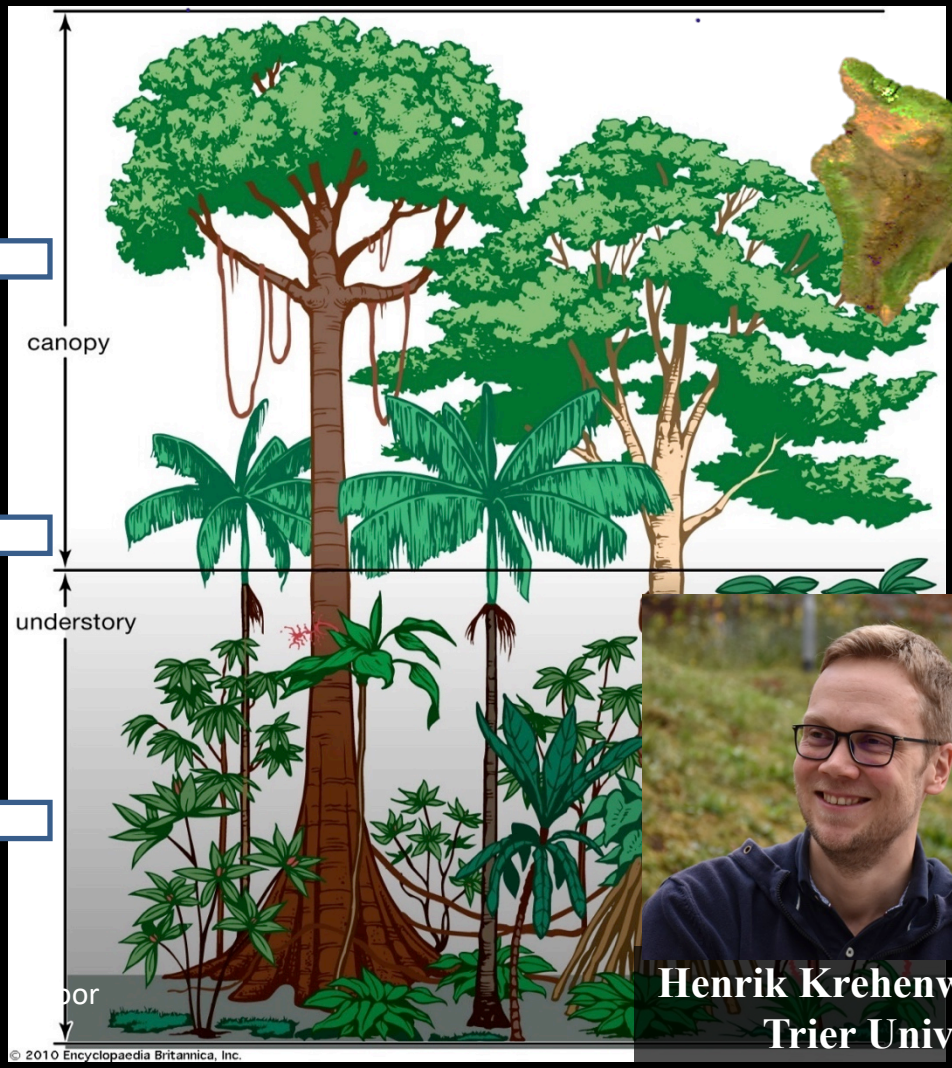
Invasion impact & vulnerability

For full videos, see https://nature.berkeley.edu/hawaiidimensions/?page_id=191

Community Assembly Across the Chronosequence

Metabarcoding

Changes in Community Structure & Dynamics



Henrik Krehenwinkel
Trier University

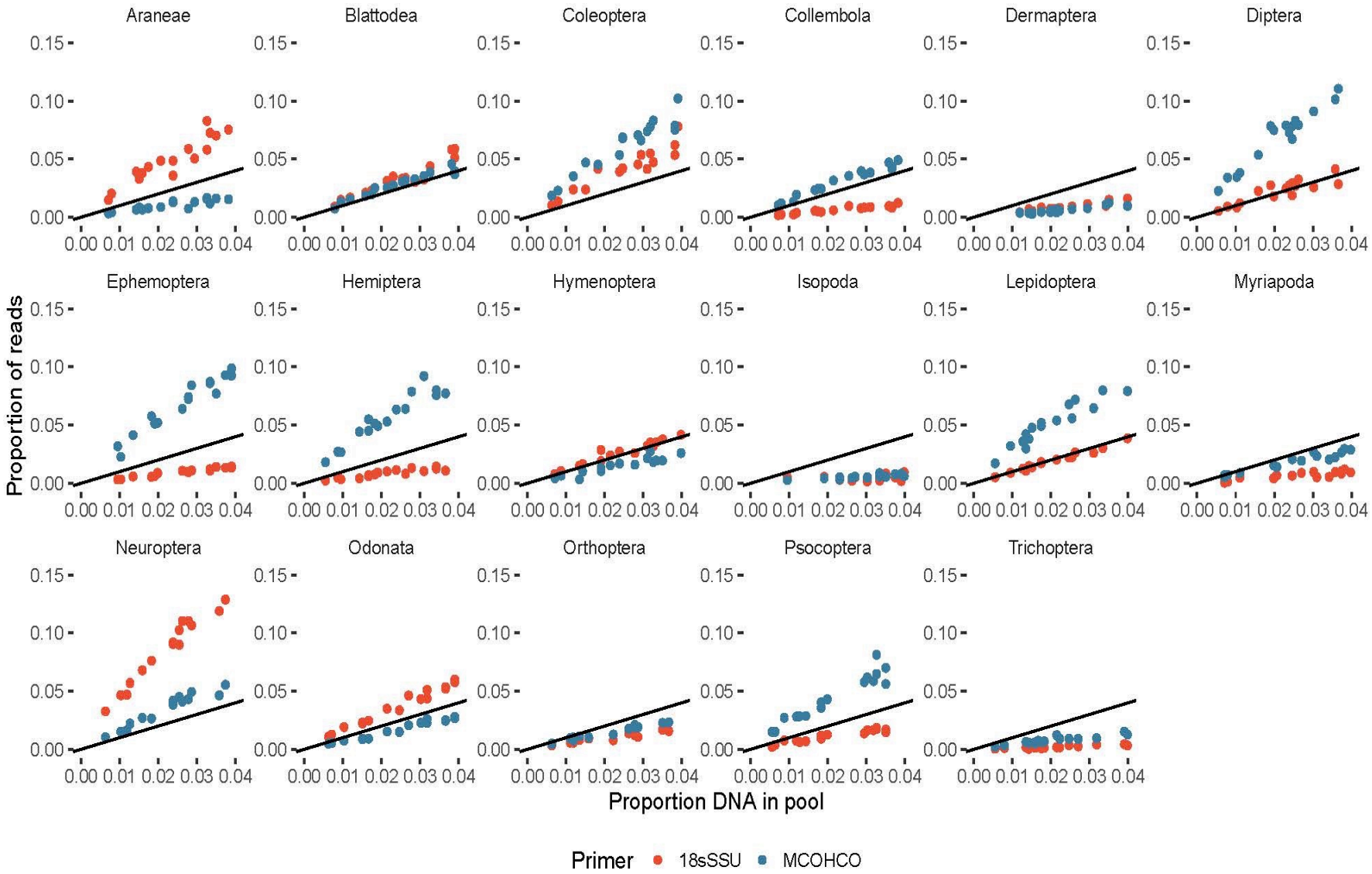
Problems with Metabarcoding

- Need information on
  - Abundance - abundance distributions can provide information on the “status” of a community
  - Identity of species in the sample

Krehenwinkel et al. . 2018. *PloS one* 13: e0189188
Krehenwinkel et al. 2019. *GigaScience*, *8*, p.giz006
Krehenwinkel et al. 2018. *Methods in Ecology and Evolution* 9, 2181-2193

Abundance

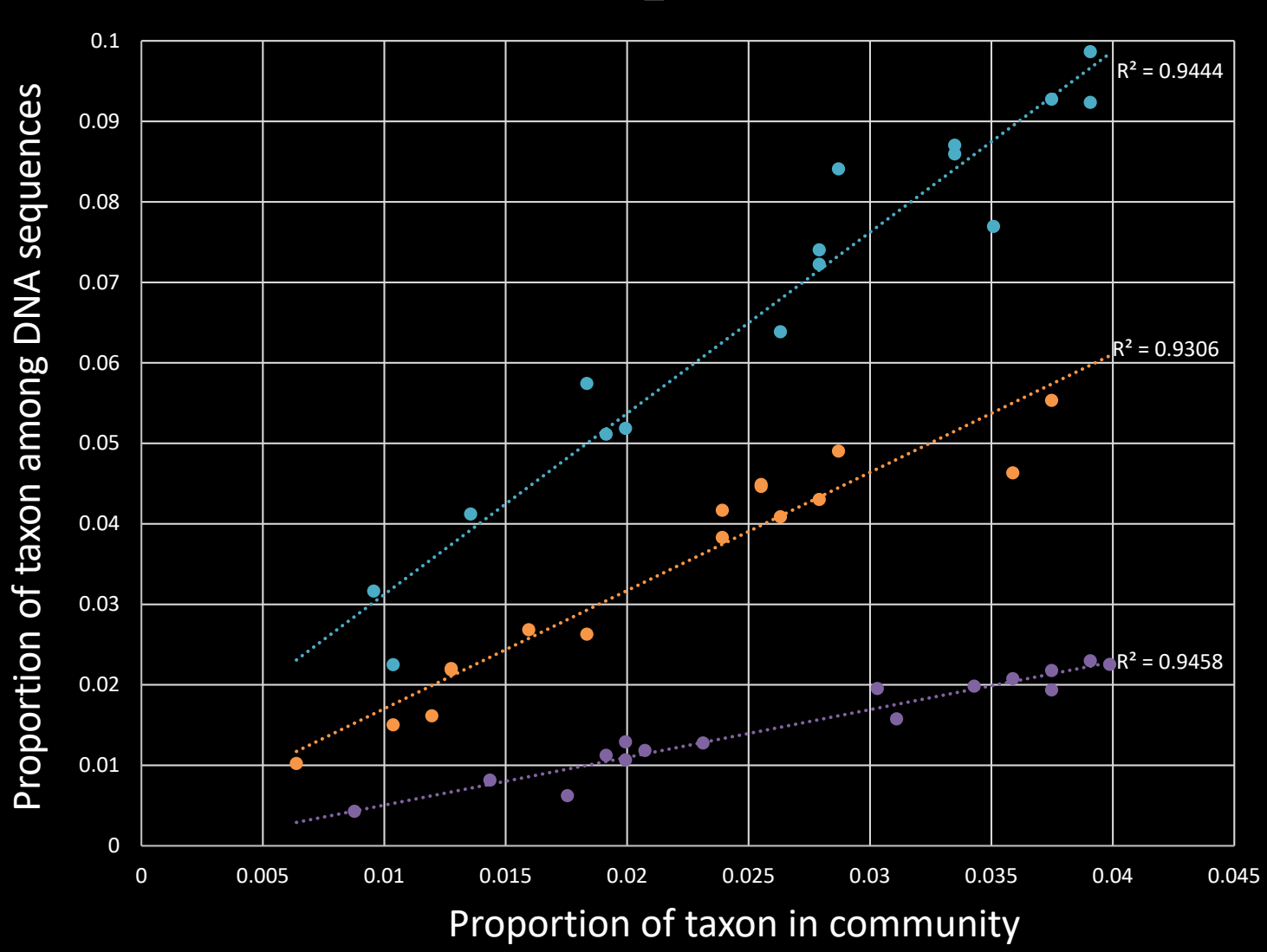
Multilocus amplificiation bias



Krehenwinkel …. & Gillespie. 2017 *Scientific Reports*. *7*, 17668

Abundance

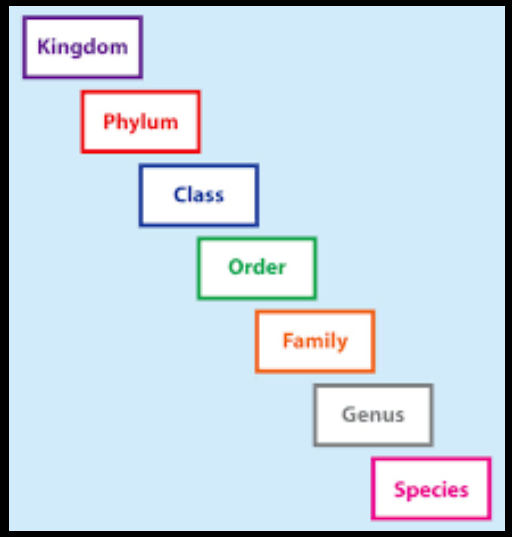
PCR amplification bias



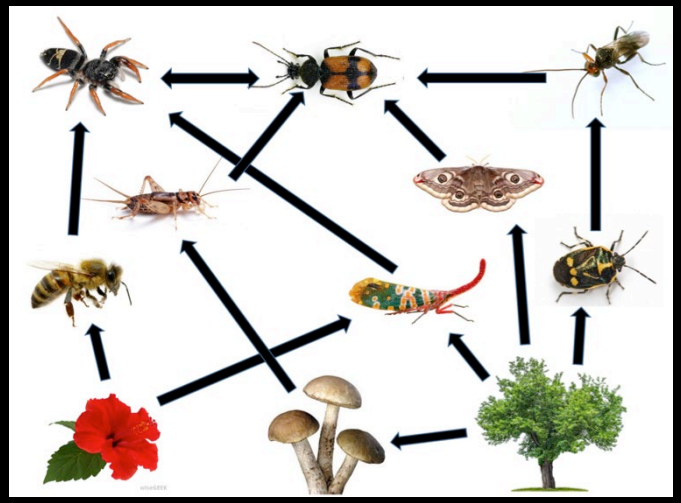
Krehenwinkel …. & Gillespie. 2017 *Scientific Reports*. *7*, 17668

Signatures of Community Status

Identity & abundance of all members



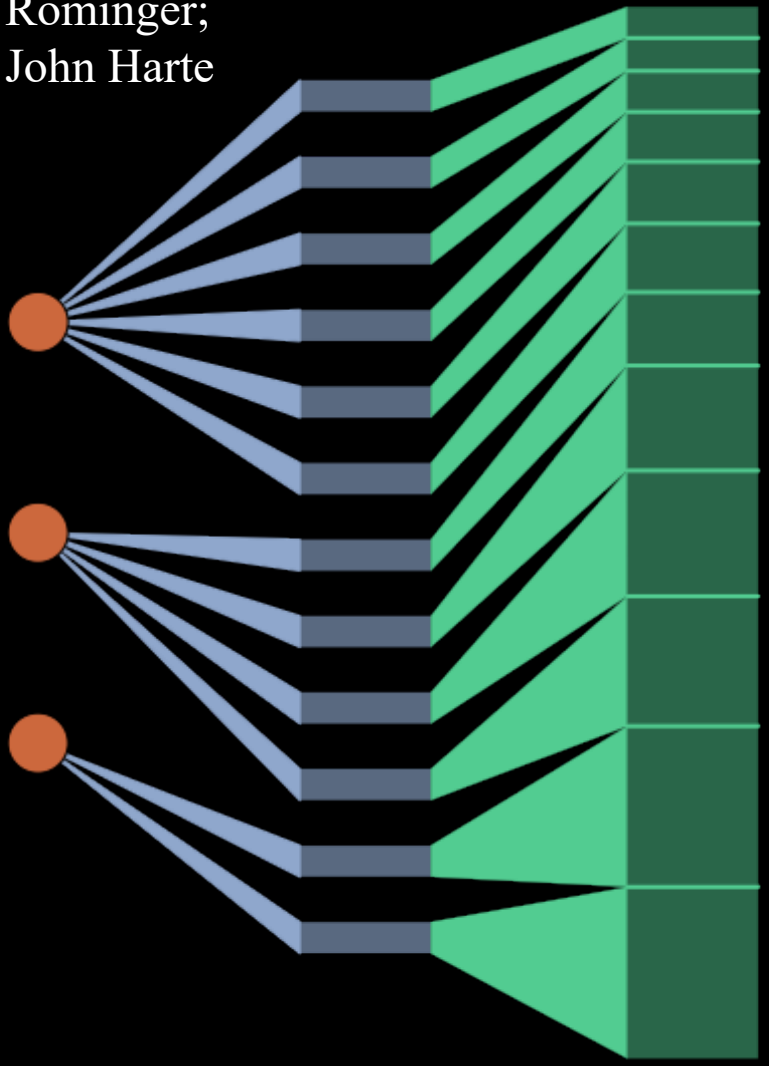
Network & interactions



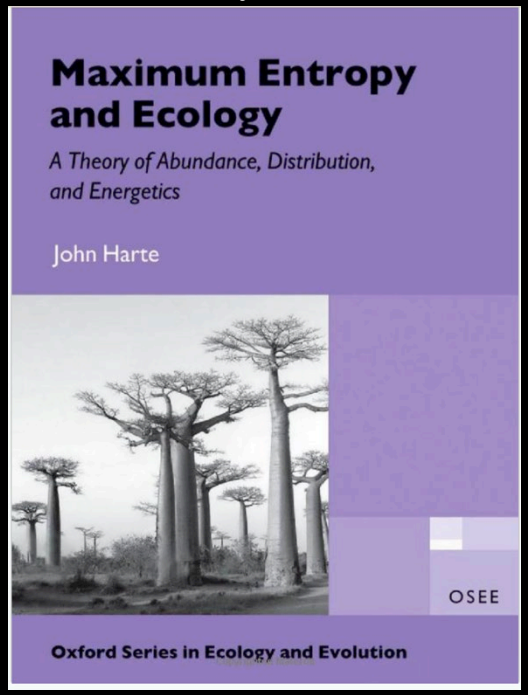
Invasion impact & vulnerability

Maximum Entropy Theory of Ecology

Andy Rominger; John Harte

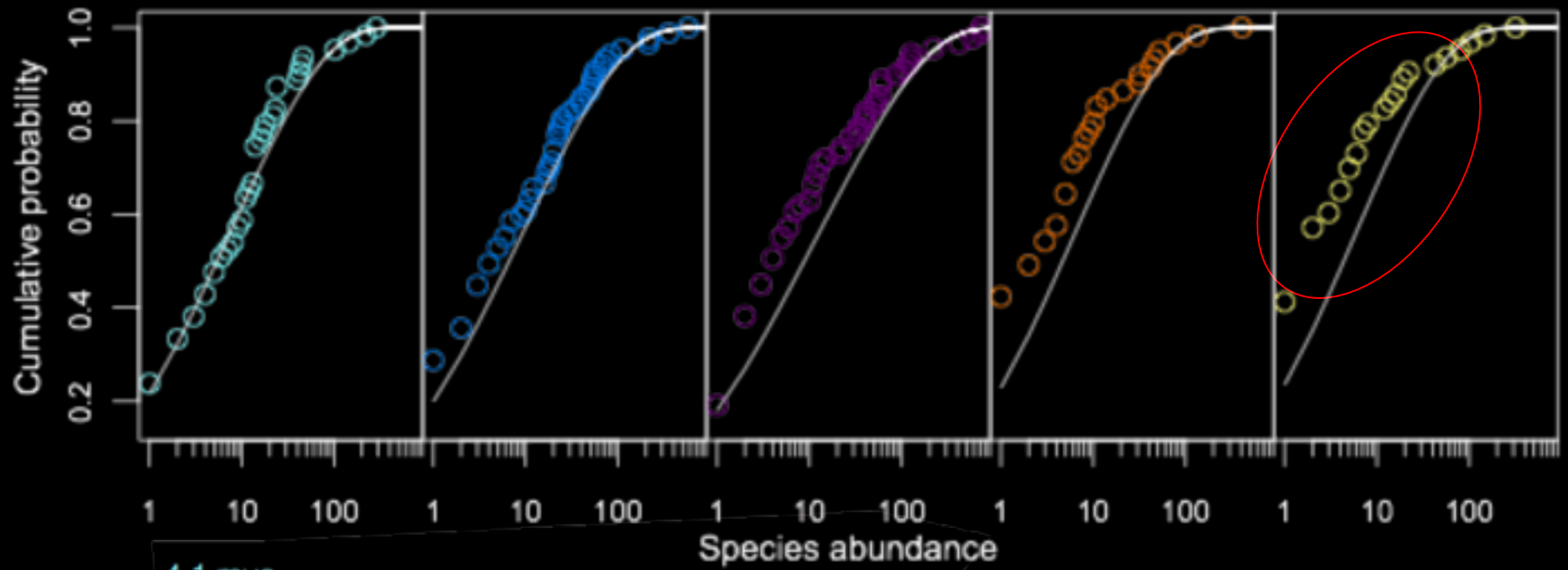


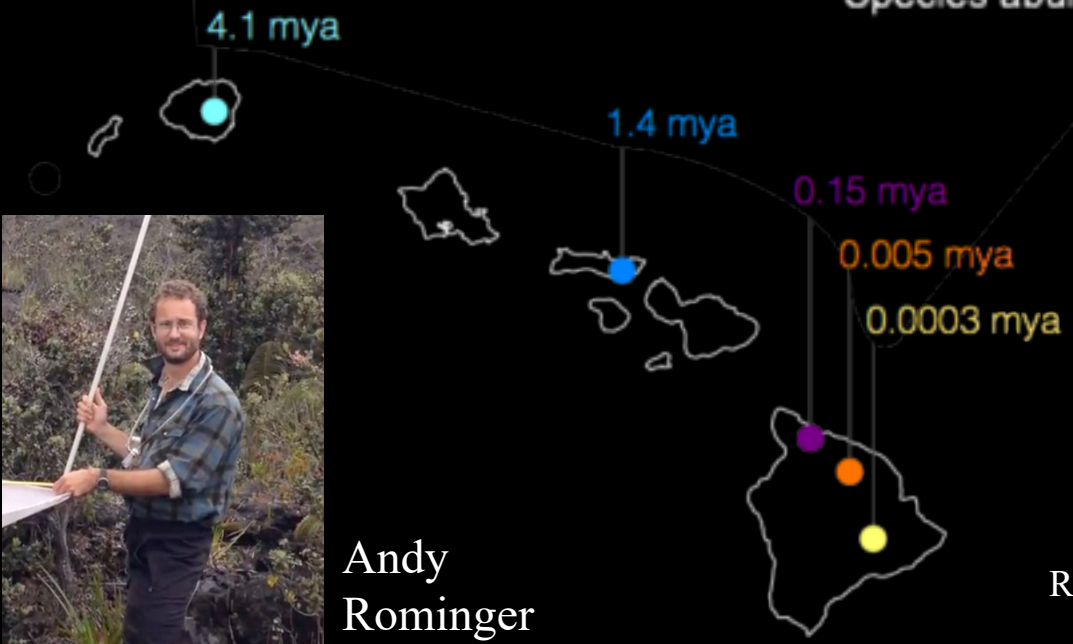
- Community-wide genetic divergence across space, environment and time (chronosequence)
- Testing novel theory



Harte (2011) Oxford University Press.

Fitting species abundance data to METE predictions





Andy Rominger

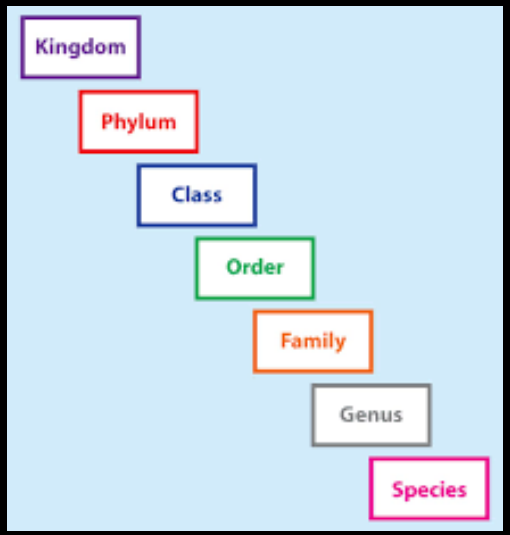
Deviation from predictions on youngest substrates may indicate that community has not yet reached steady state

- Allows identification of non steady state community
- Does not inform us on the cause

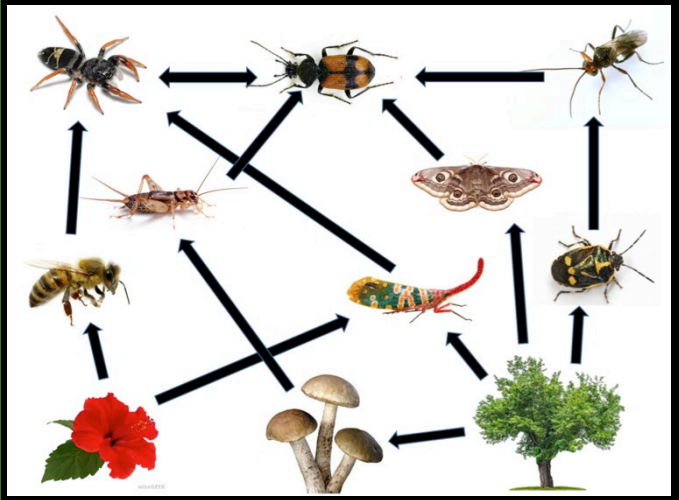
Rominger *et al.* 2015 *Global Ecology and Biogeography*

Signatures of Community Status

Identity & abundance of all members

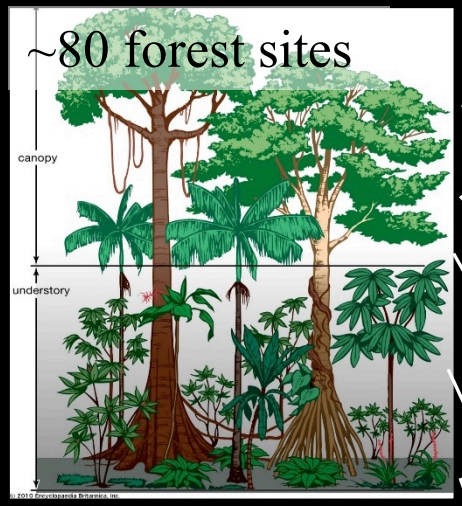


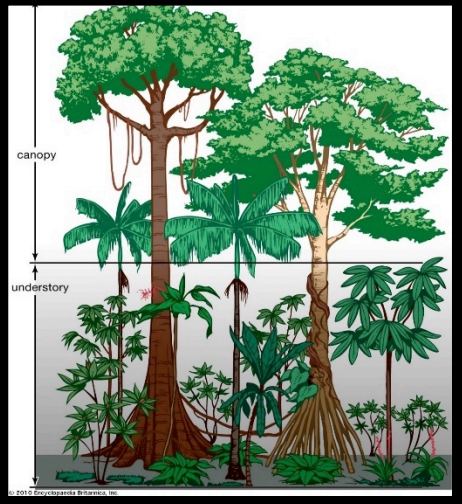
Network & interactions

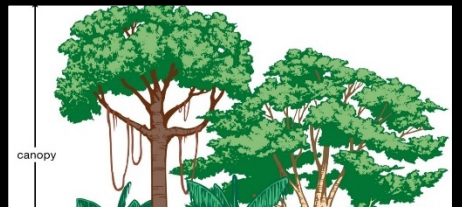


Invasion impact & vulnerability

Interactions







Changes in Community Structure & Dynamics

Plant 1

Plant 2

Plant 3

Plant 4

Plant N

~10 arthropod samples by plant

4 size classes per sample

Size 0-2

Size 2-4

Size 4-7

Size >7

Amplicon 1

Amplicon 2

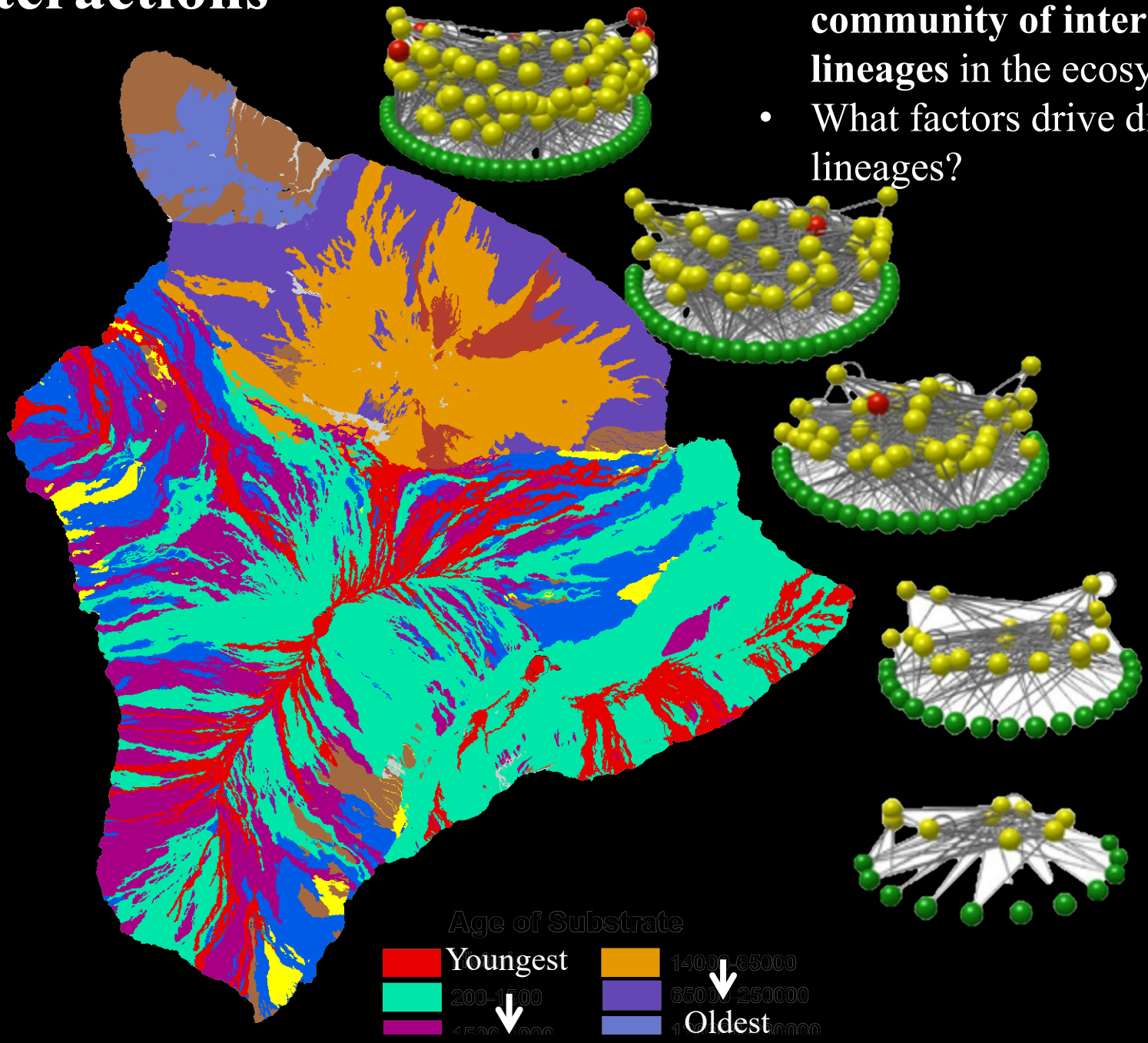
Two amplicons per size class

Data structure

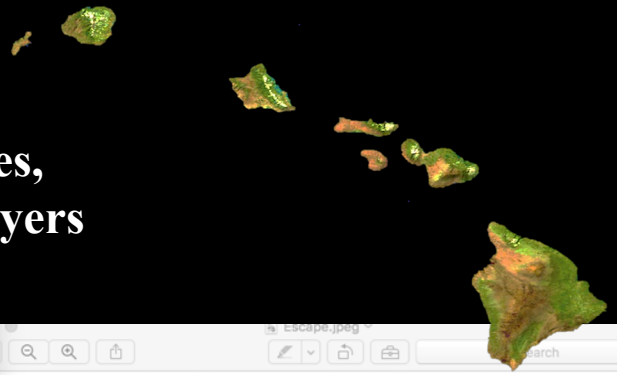
Henrik Krehenwinkel
Trier University

Interactions

- Genetic structure of **entire community of interacting lineages** in the ecosystem
- What factors drive divergence of lineages?



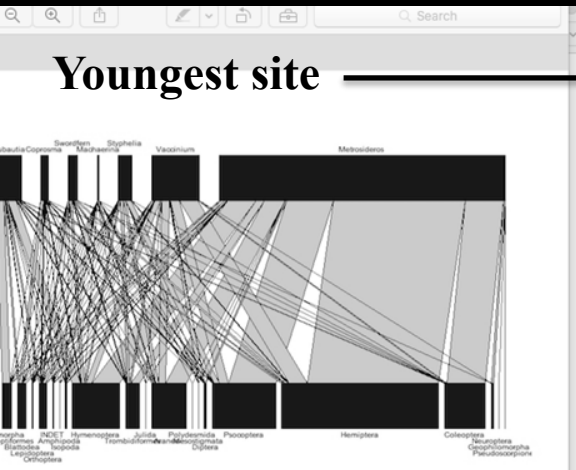
Changes in Network Structure Across the Chronosequence

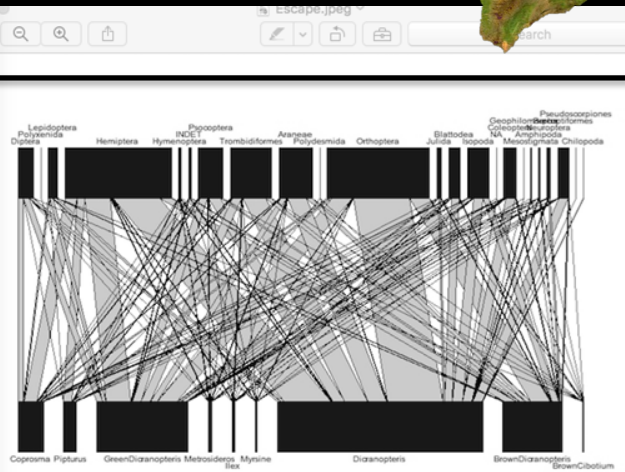


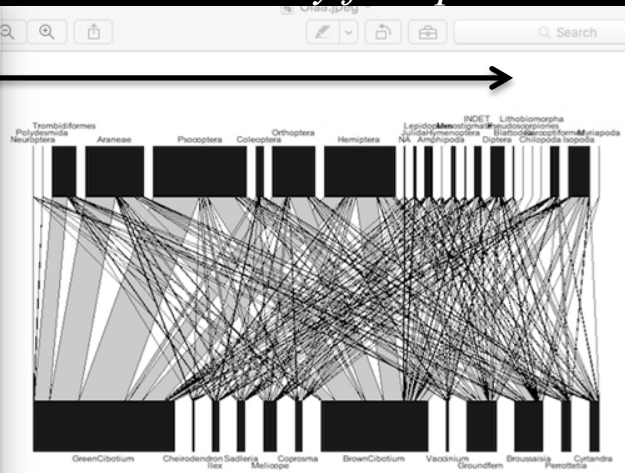
To understand the processes, need the identity of the players

Very first pass!!

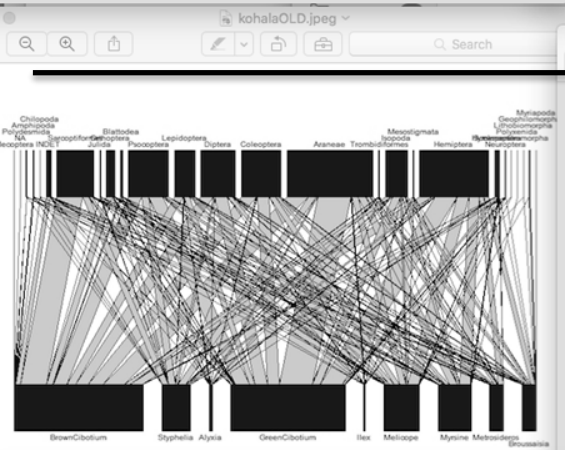
Youngest site →

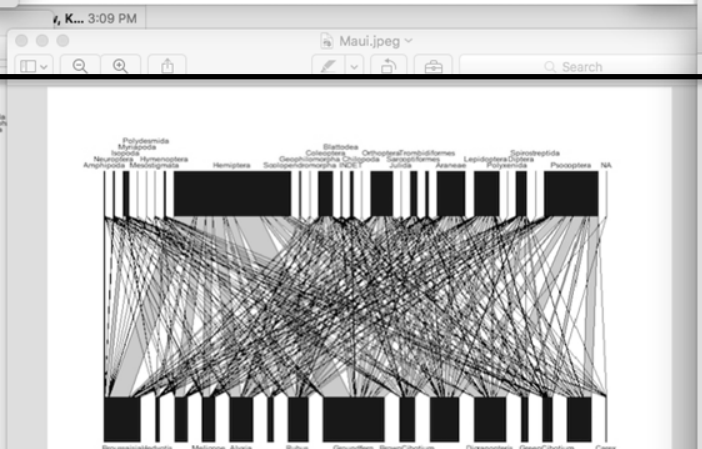


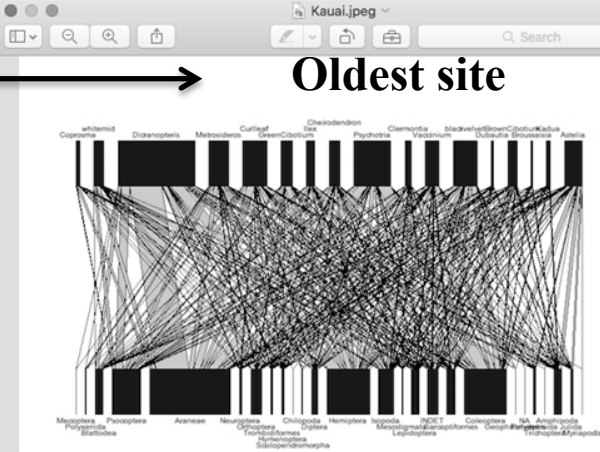




← **Oldest site**

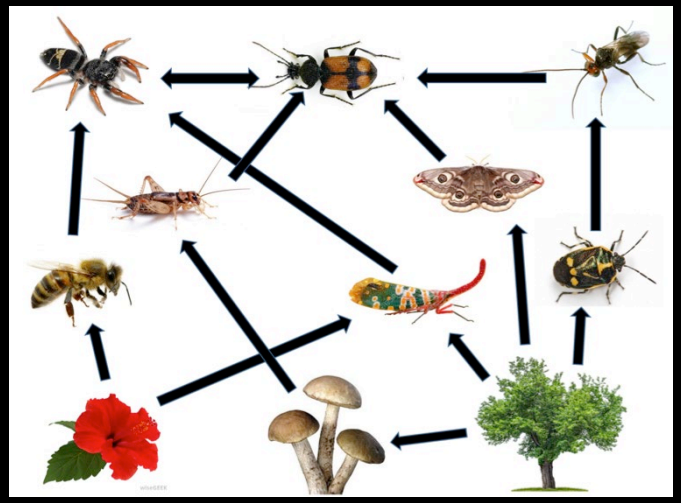




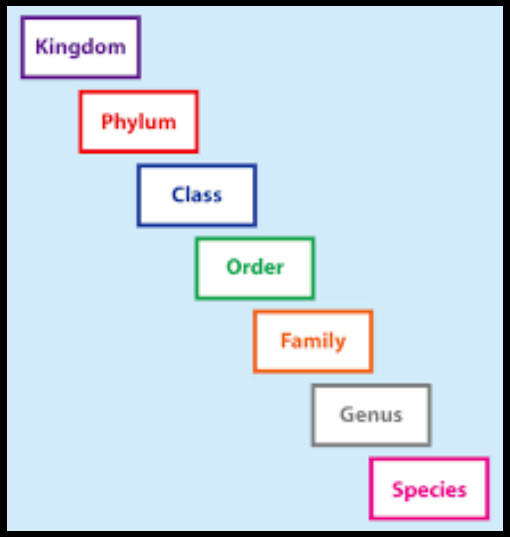


Signatures of Community Status

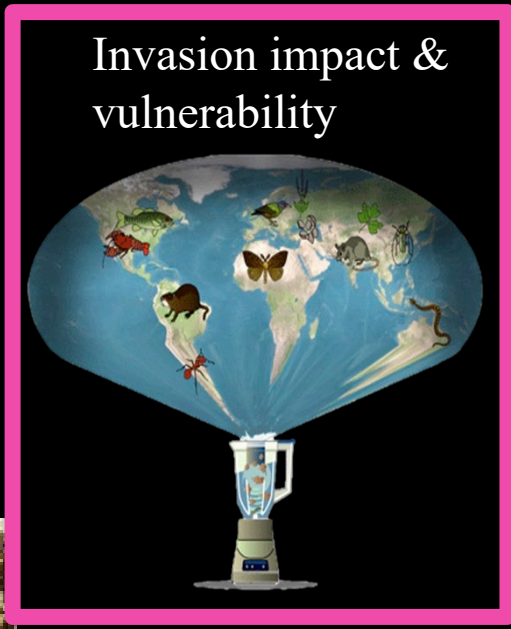
Networks & interactions



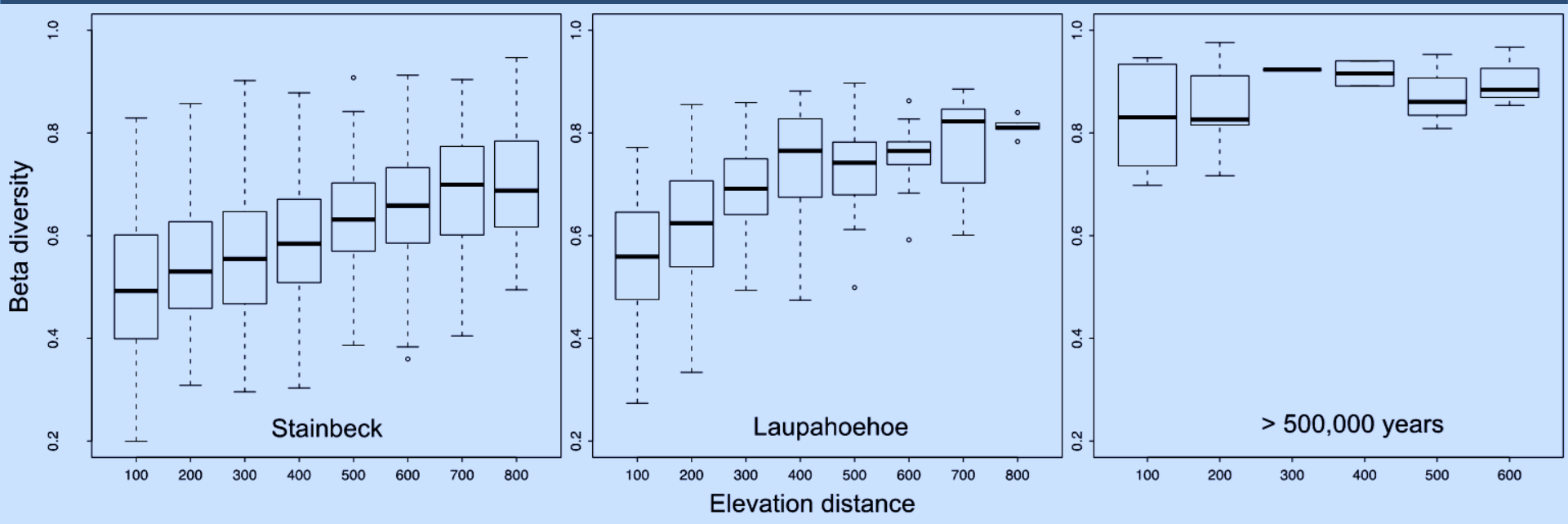
Identity & abundance of all members



Invasion impact & vulnerability



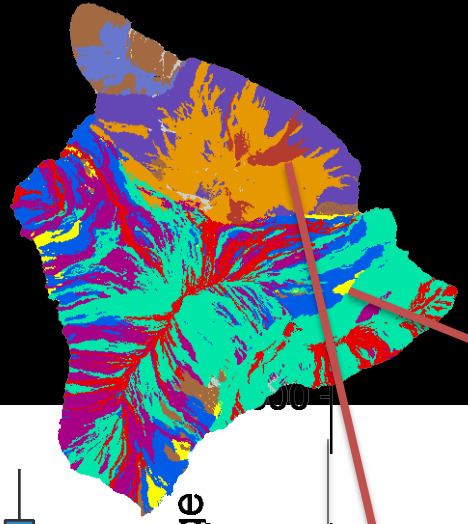
Elevational community turnover

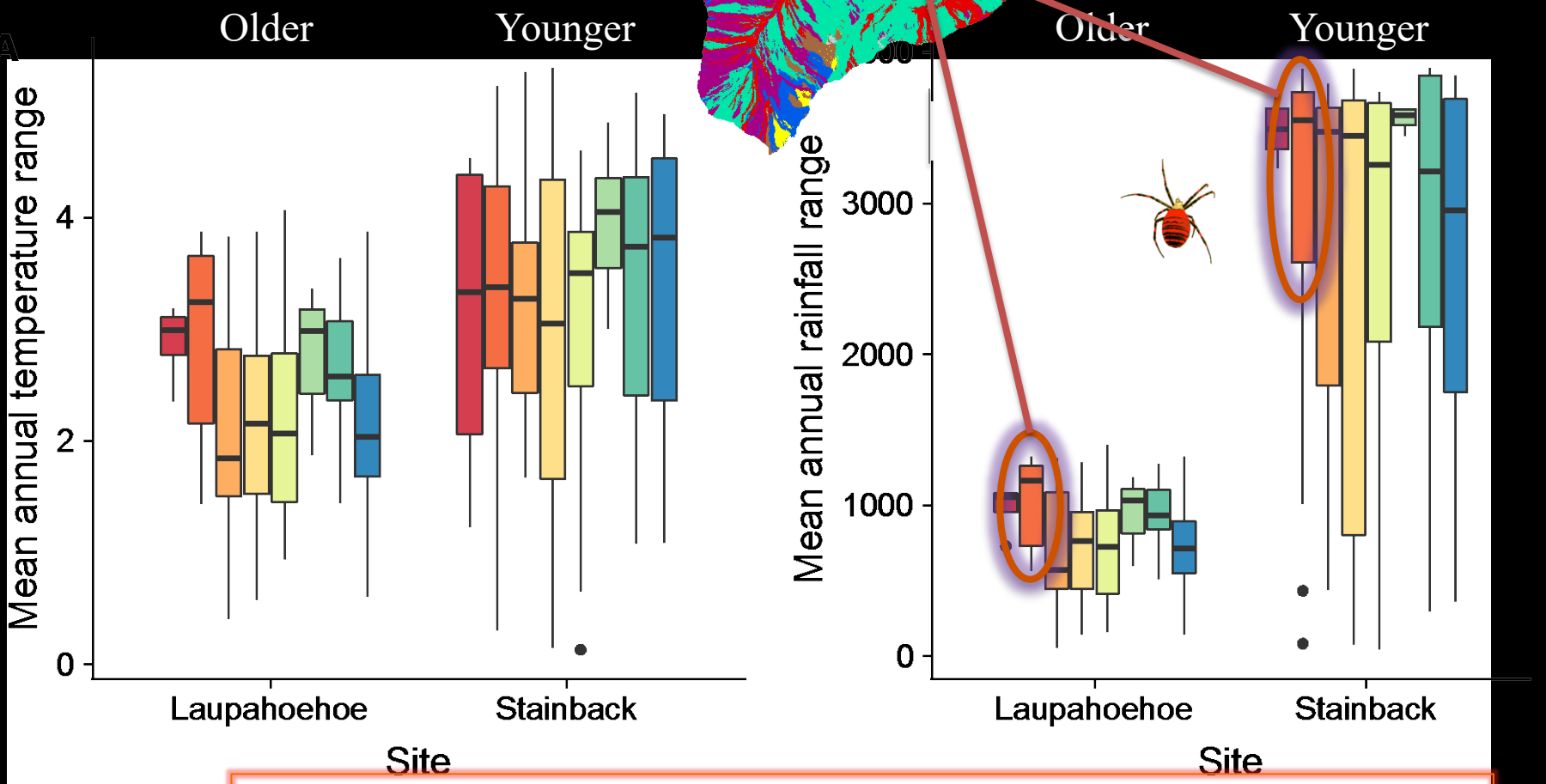


Young → Old

Ranges Occupied on Younger vs Older Sites

Prediction: younger sites more easily invaded





Younger substrates – broader range, less specialized

Order: Acari, Araneae, Coleoptera, Hemiptera, Lepidoptera, Neuroptera, Orthoptera, Psocoptera

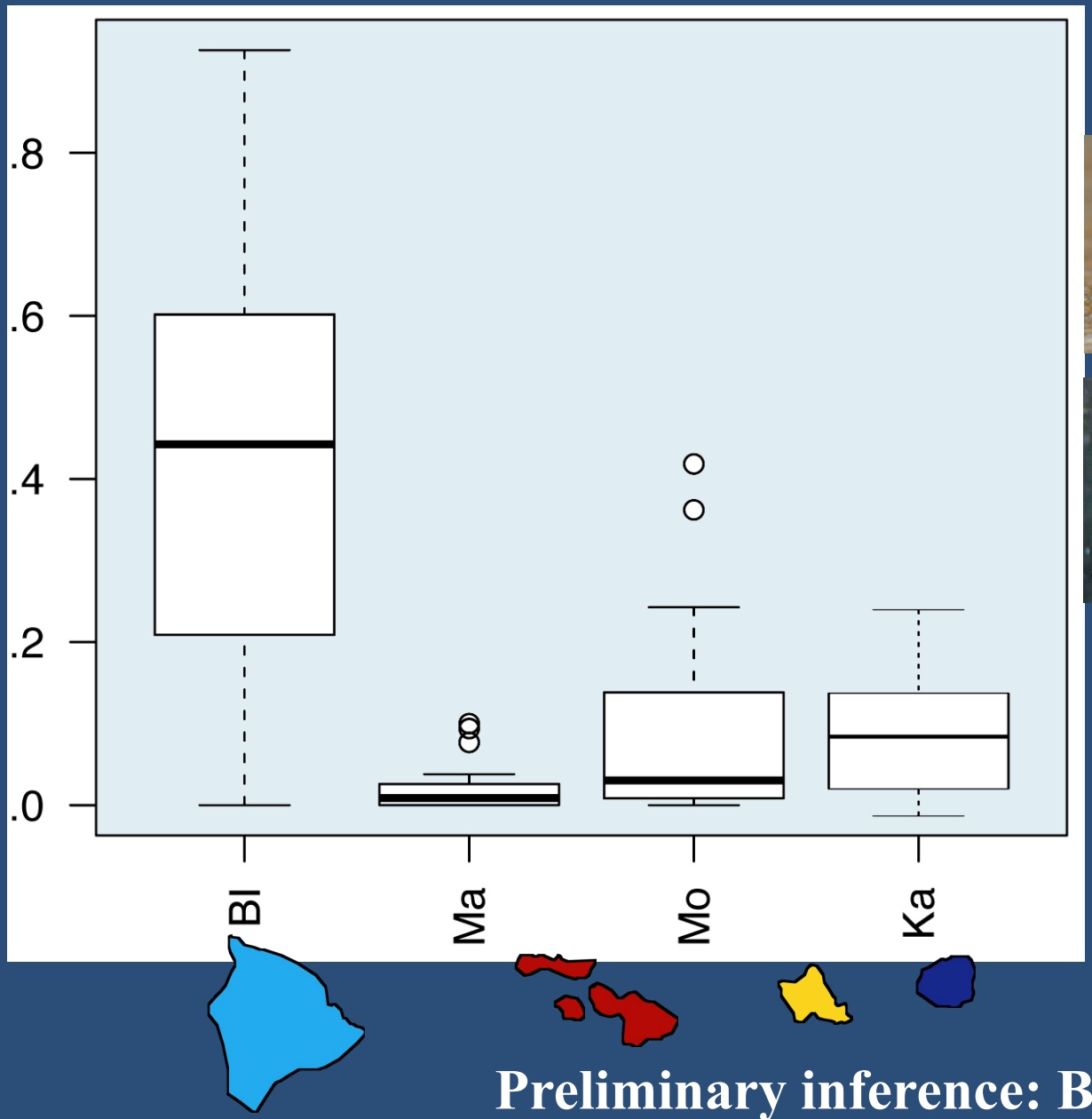
Collembolan invasions

44 % of all arthropods on average

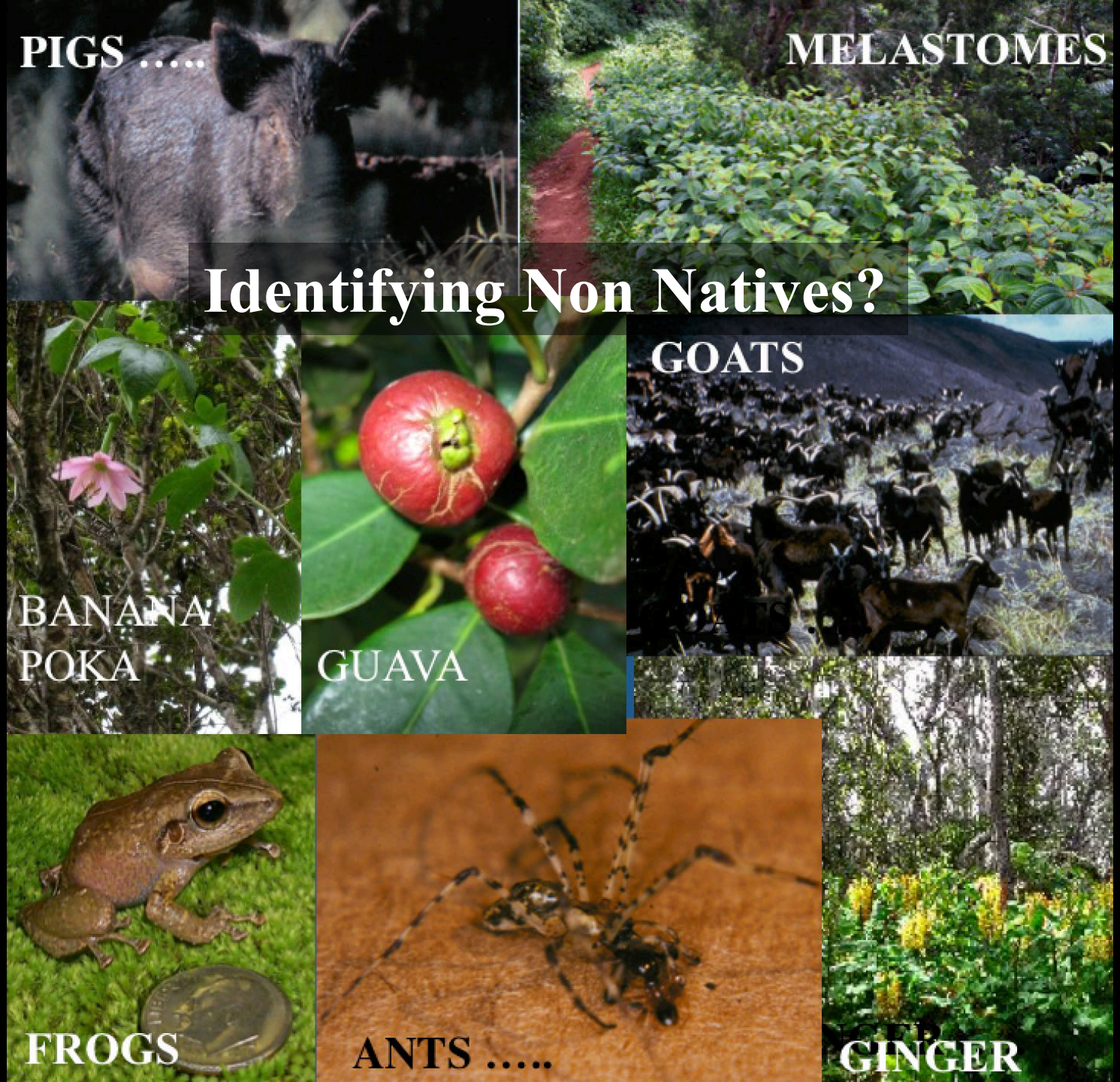
laulima.hawaii.edu; bugguide.net; freenatureimages.eu

Invasive Collembola Across Chronosequence

Proportion in a given sample



Preliminary inference: Biotic resilience


PIGS …..
MELASTOMES
Identifying Non Natives?
BANANA POKA
GUAVA
GOATS
FROGS
ANTS …..
GINGER

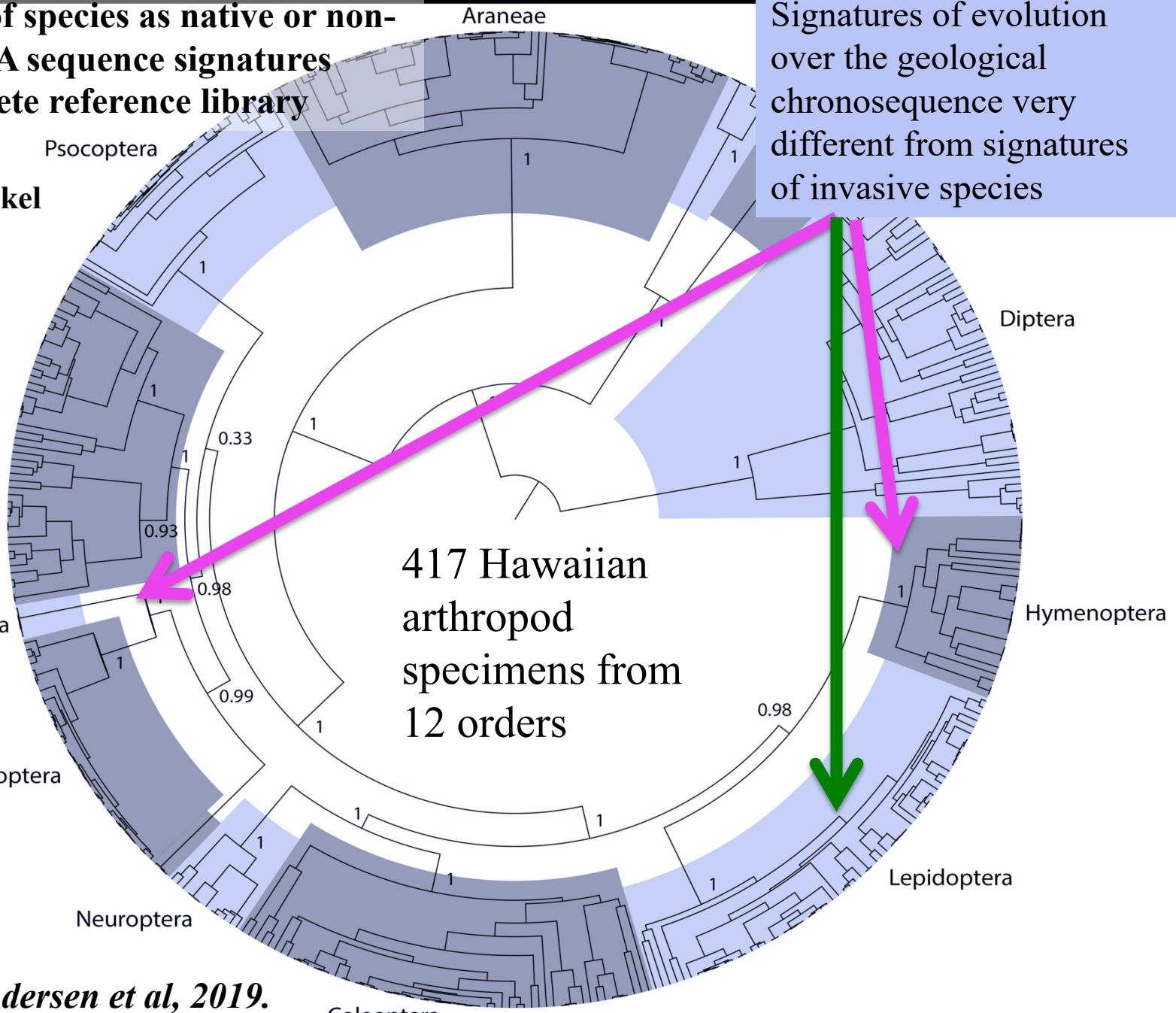
Categorization of species as native or non-native using DNA sequence signatures without a complete reference library

Henrik Krehenwinkel

Noriyuki Suzuki

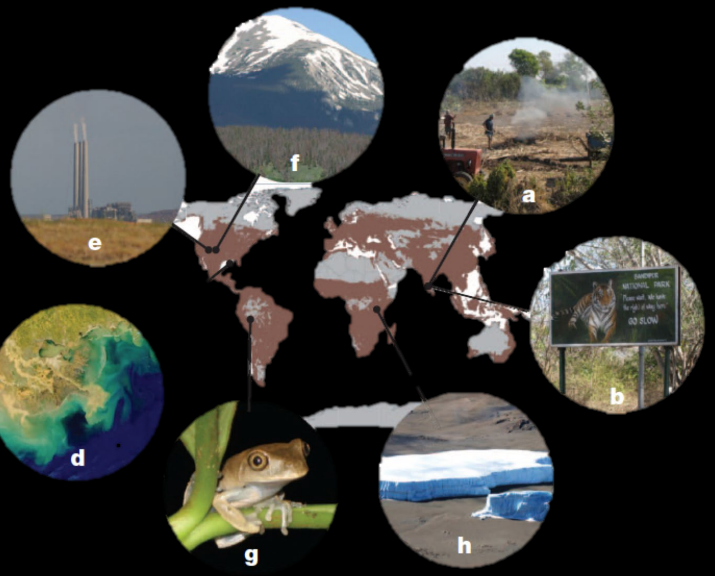
Jeremy Anderson

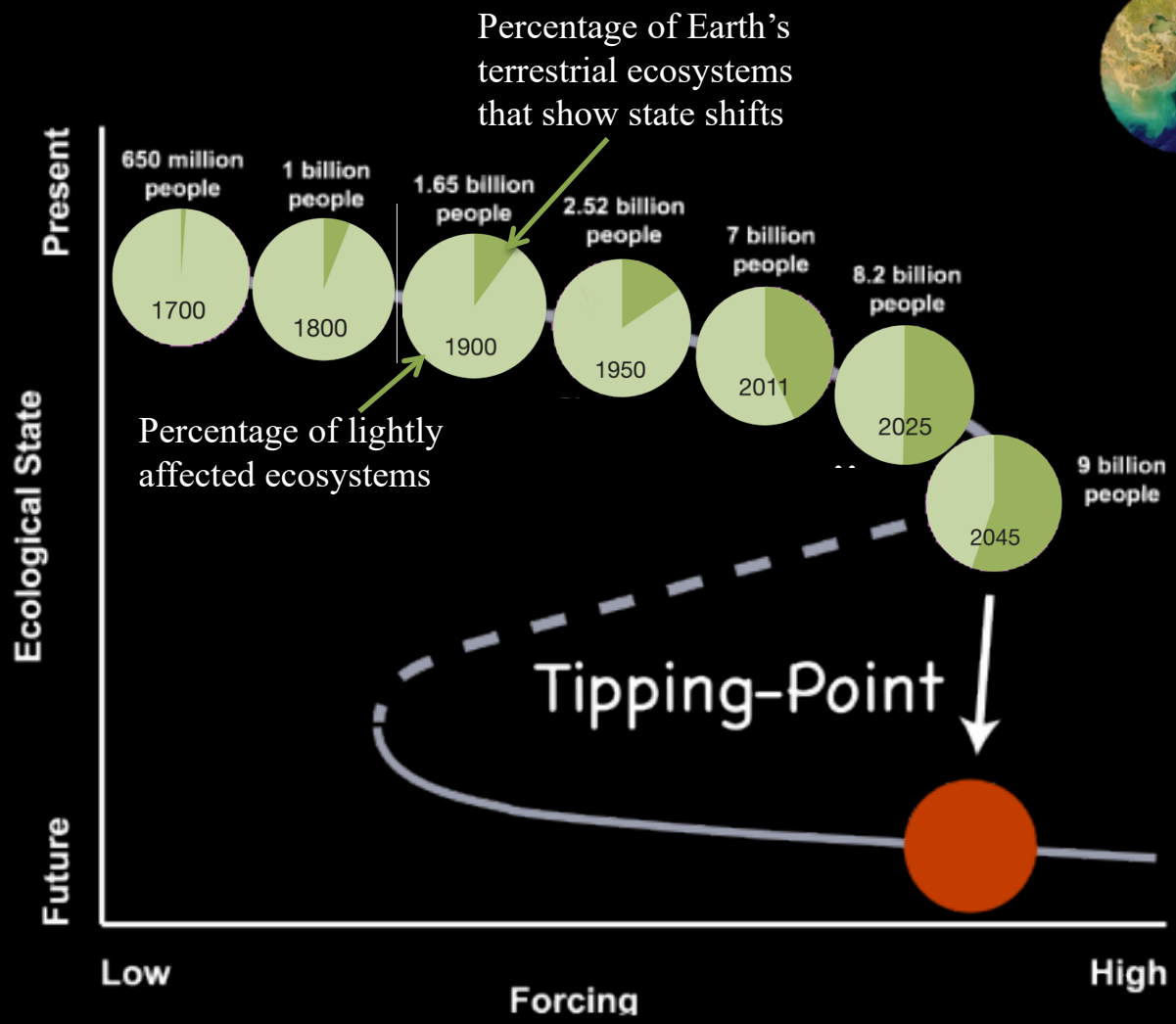
Signatures of evolution over the geological chronosequence very different from signatures of invasive species



Andersen et al, 2019.

Novel Interactions: Tipping points and state shifts

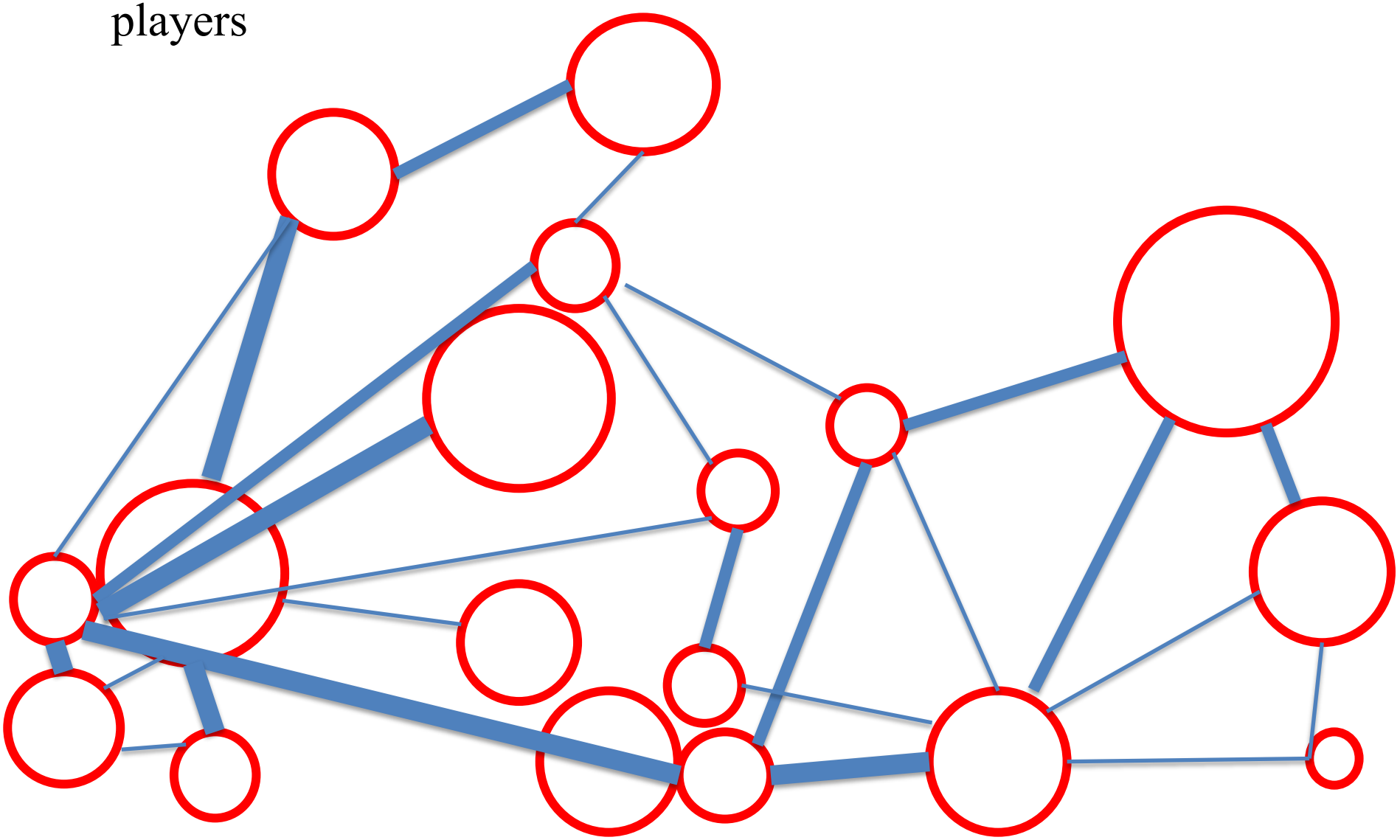


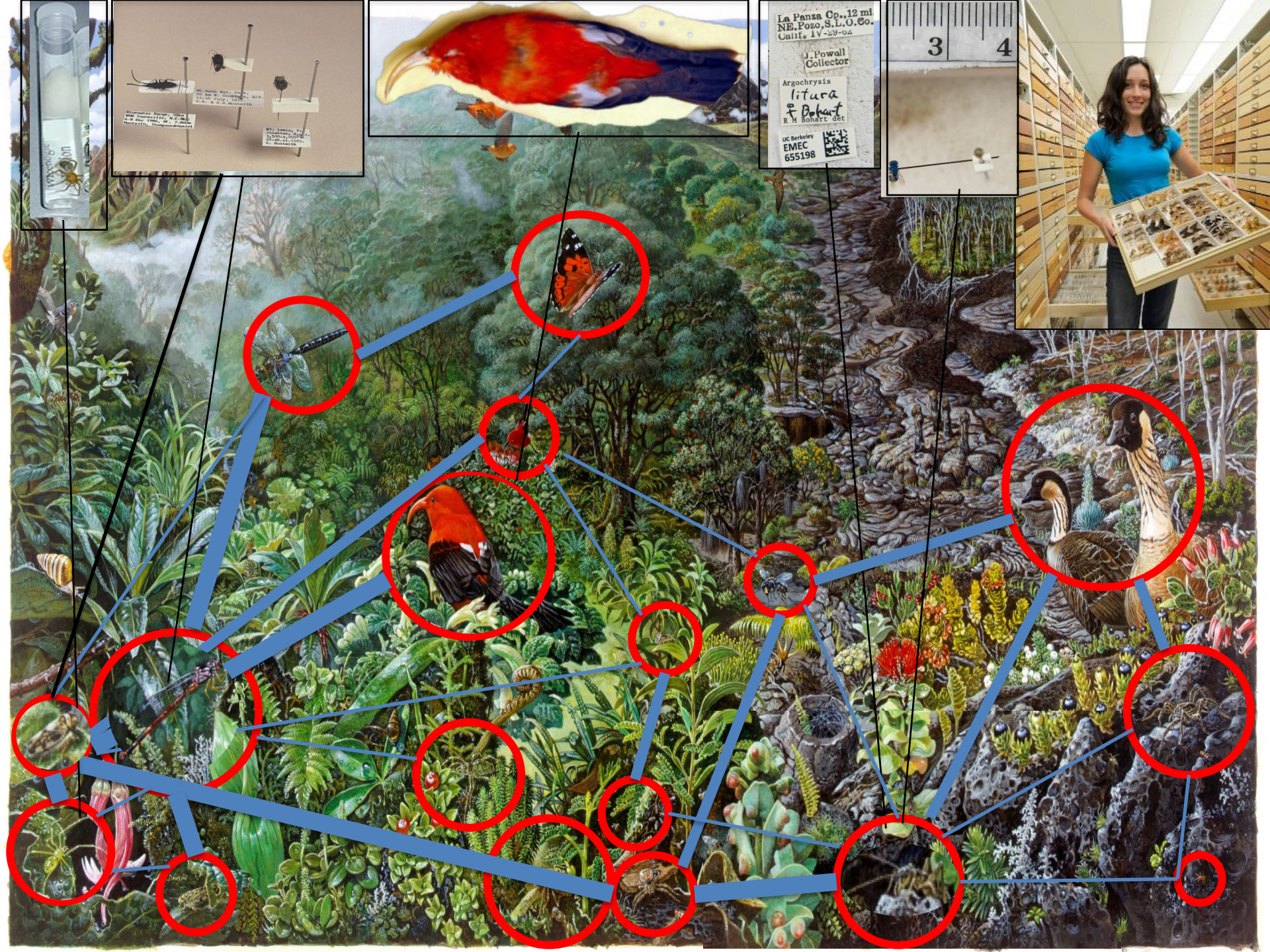


Can we understand our own biology soon enough to make a difference?

Barnosky et al. (2012) *Nature*

- Metrics derived from network structure can indicate resilience, resistance, and response
- However, to take action, we need to identify the players

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NE. Pozo, S.L.O. Co.
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J. Powell
Collector
Argochrysis
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UC Berkeley
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Key Importance of Reference Collection

On Borneo for a 2018 expedition to find new species, evolutionary biologist Marta Paterno of the University of Verona in Italy prepares samples for a portable DNA sequencer (center, right of laptop). PIERRE ESCOUBAS/TAXON EXPEDITIONS 2018

$180 million DNA ‘barcode’ project aims to discover 2 million new species

By **Elizabeth Pennisi** | Jun. 6, 2019 , 2:00 PM

For centuries biologists have identified new species at a painstakingly slow pace, describing specimens' physical features and other defining traits, and often trying to fit a species into the tree of life before naming and publishing it. Now, they have begun to determine whether a specimen is likely a novel

Digitized, with metadata

Collections in Biodiversity Dynamics

Signatures of ecosystem change through time

– Using islands as microcosms to test theory

Highlights the tremendous relevance and largely untapped potential of collections in providing signatures of ecosystem resilience, resistance, and response to change

And the relevance goes far beyond biology …...

Fire – Complex interactions

Disaster Mitigation

Hot and dry

Higher temperatures & drought create ideal conditions for wildfires

More dead wood

Dry weather means more dead trees, shrubs, & grass, and more fuel for the fire

New dry plants

Plants that like humidity are replaced by more flammable plants that withstand dry conditions

Longer fire season

Fire season in most places used to be about 2 months; now it has lengthened up to 5 in places, or even the full year

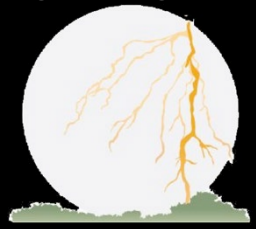
Thirsty trees drink more water

Water stressed trees send down deep roots to suck up every drop of water, further drying out the soil

Invading bugs killing trees

Warm weather causes wood beetles from south moving north, killing tree parts & increasing amount of flammable material

Lightening strikes



Warmer temperatures can trigger more lightening, which can set blazes

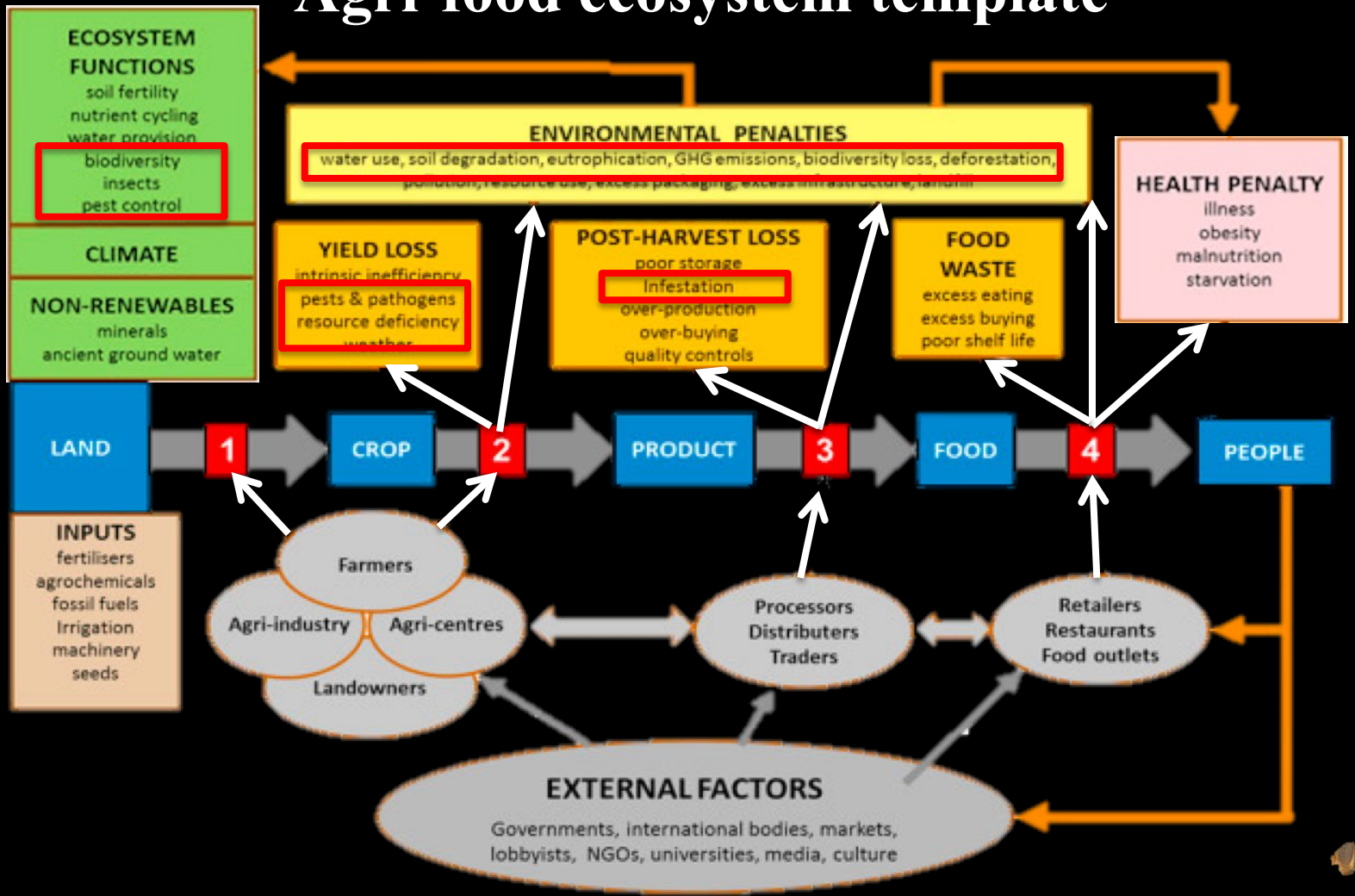
Feedback loop

Burning forests release stored carbon into the atmosphere, contributing to global warming

Blazes out of control

Climate change boosts the intensity of fires; heightened intensity neatralizes efforts to put out the blaze

Agri-food ecosystem template



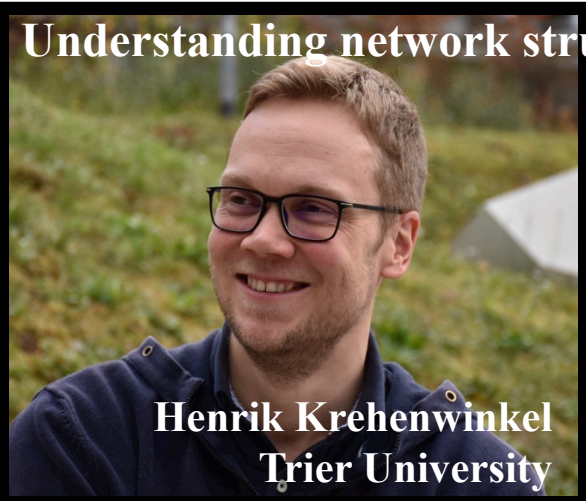
Four principle components

- ecosystem functions, climate, resource inputs
- key actors and external influences
- environmental and health penalties
- losses and wastes

Collections in Biodiversity Dynamics

- The biodiversity crisis is real and will affect every aspect of human existence
- Collections – both historic and current - provide the key to understanding resilience, resistance, and response to change
- Most important now is to communicate the relevance before it is too late


Carl Boettiger


Understanding network structure & tipping points

Henrik Krehenwinkel
Trier University


Natalie Graham


Andy Rominger

Santa Fe Inst

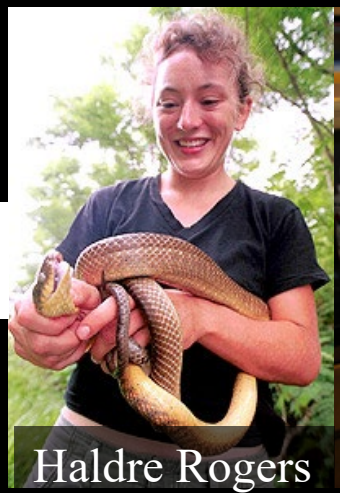

Allison Barner

Thanks – A team effort!

Combining forces with efforts across other Pacific Islands

sDiv | synthesis centre of iDiv

Global Synergies & Sustainability for Biodiversity Information


Haldre Rogers


Evan Economo

OIST


John LaSalle, deceased ALA


Jim Hanken, EoL

Donald Hobern, GBIF


Volker Mosbrugger


Larry Page, iDigBio