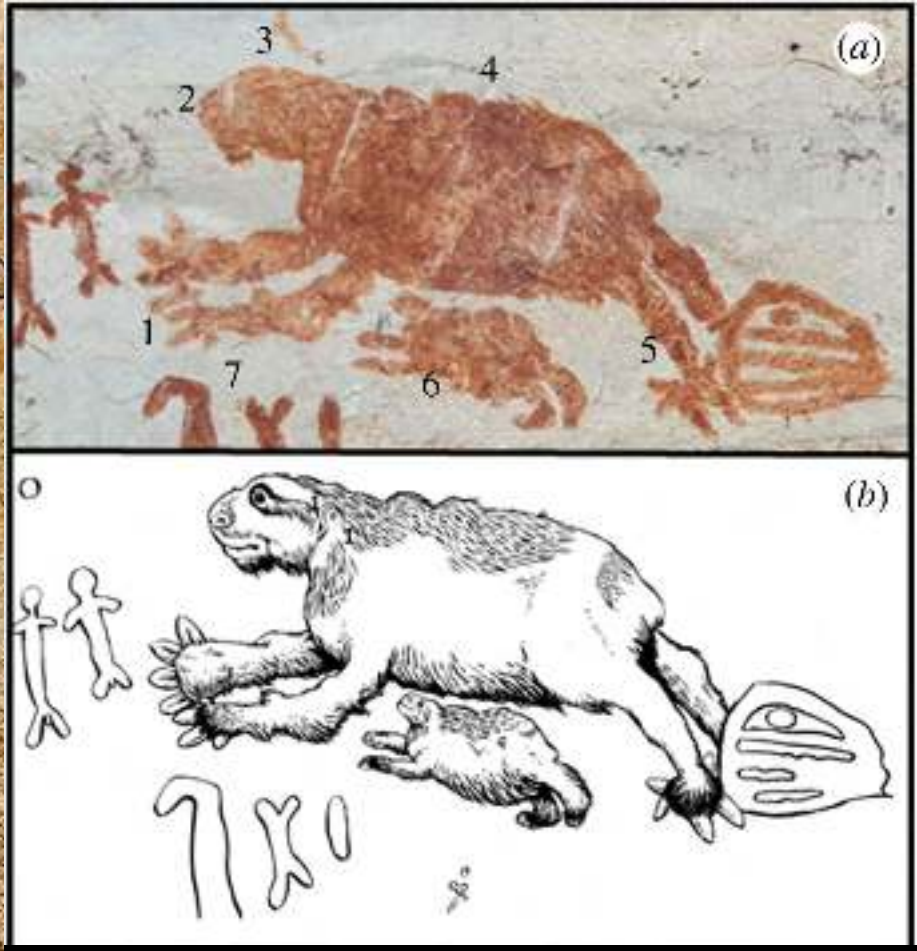
Socio-ecological networks

Rodrigo Cámara-Leret

April 6, 2022

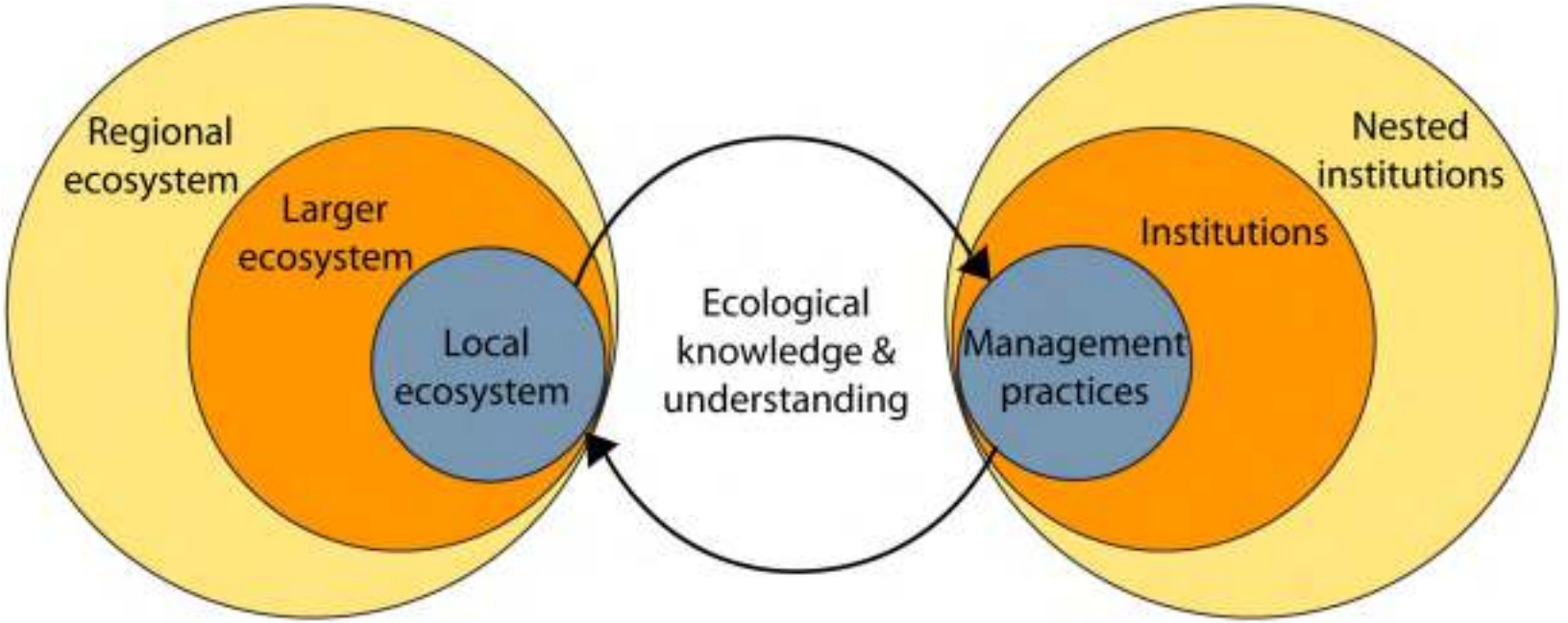


(a) Giant sloth painting at La Lindosa: 1. massive claws; 2. short rostrum; 3. large head; 4. robust thorax; 5. inverted pes; 6. offspring; 7. miniature men.

(b) Artistic reconstruction of *Eremotherium* patterned after its closest living relative *Bradypus*.

Iriarte et al. "Ice Age megafauna rock art in the Colombian Amazon?." *Philosophical Transactions of the Royal Society B* 377.1849 (2022): 20200496.

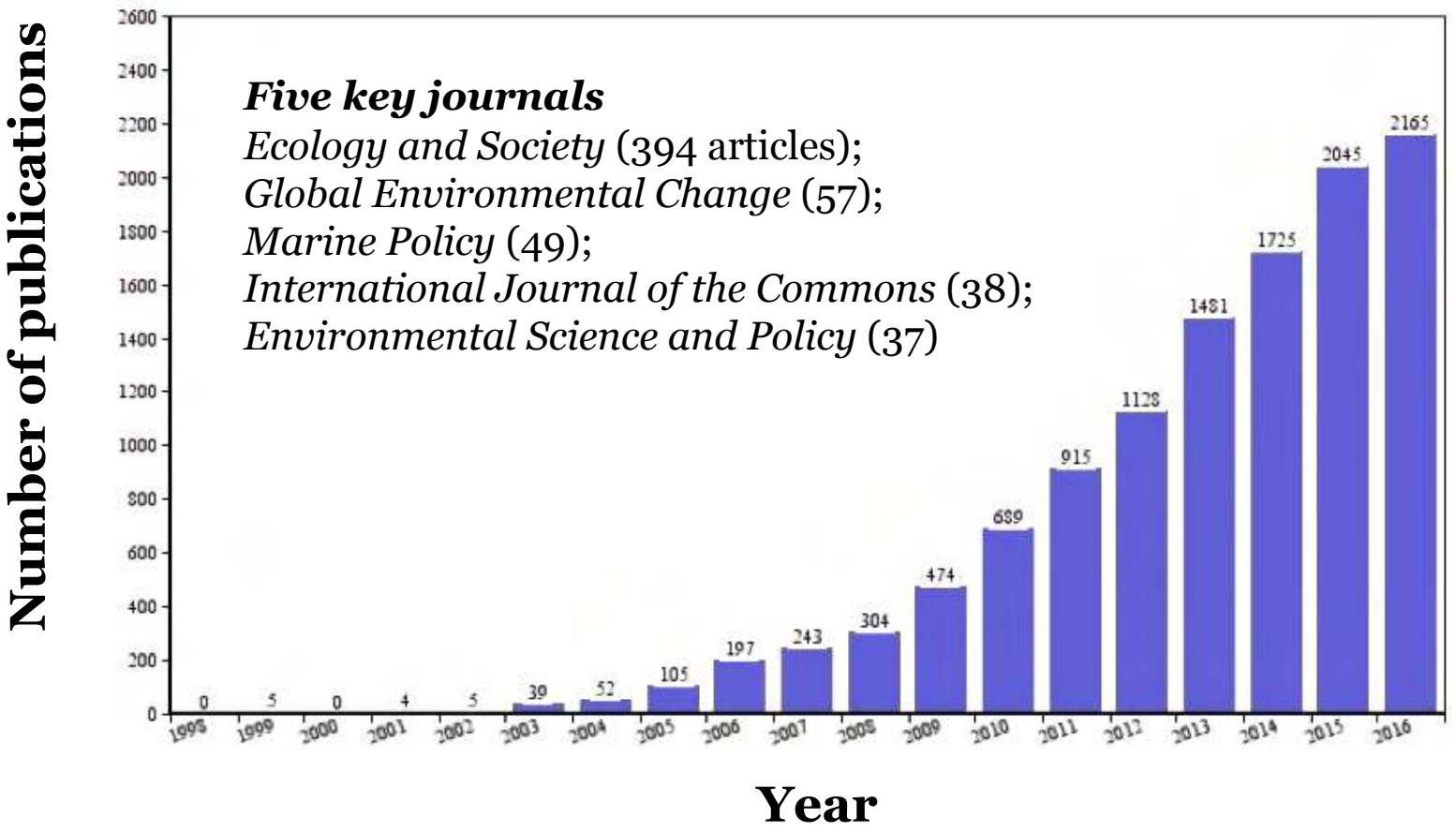
Focus: local resource management systems not dominated by conventional resource management and mechanistic, linear thinking and practice, and that had maintained practices for the building of resilience in local settings



Ecological system

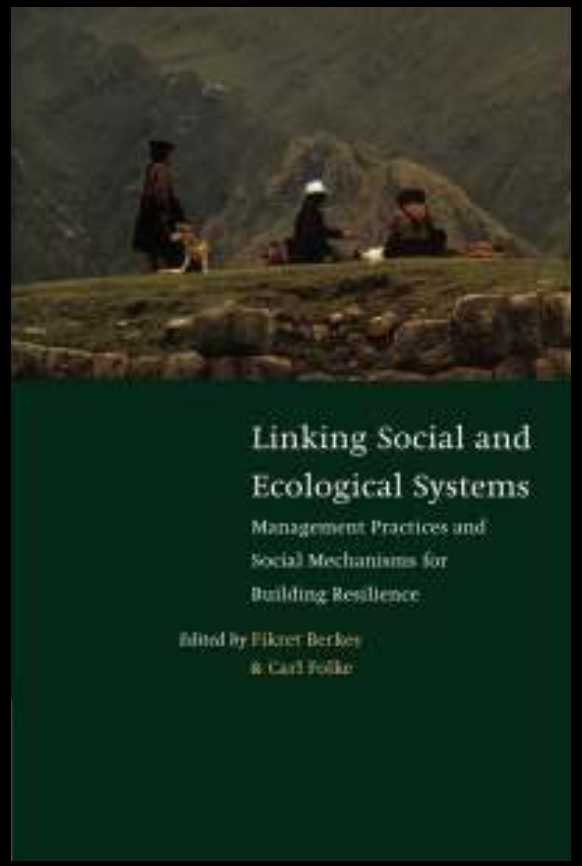
Social system

Twenty years later… *12,990 publications of SES*

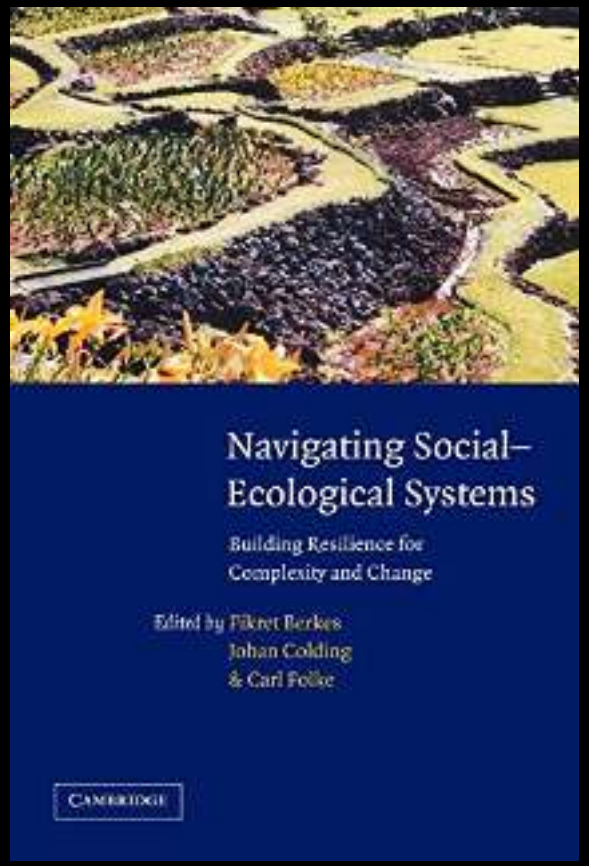


Colding and Barthel (2019) *Ecology and Society* 24

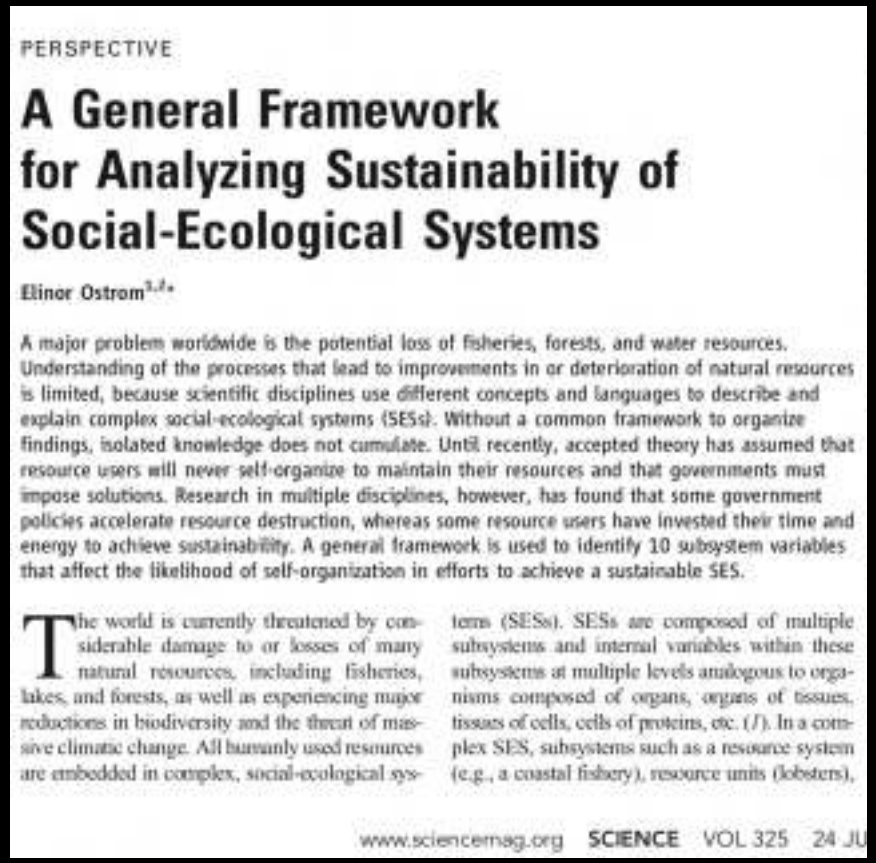
Most cited works



1998



2003



PERSPECTIVE

A General Framework for Analyzing Sustainability of Social-Ecological Systems

Elinor Ostrom[1,2]*

A major problem worldwide is the potential loss of fisheries, forests, and water resources. Understanding of the processes that lead to improvements in or deterioration of natural resources is limited, because scientific disciplines use different concepts and languages to describe and explain complex social-ecological systems (SESs). Without a common framework to organize findings, isolated knowledge does not cumulate. Until recently, accepted theory has assumed that resource users will never self-organize to maintain their resources and that governments must impose solutions. Research in multiple disciplines, however, has found that some government policies accelerate resource destruction, whereas some resource users have invested their time and energy to achieve sustainability. A general framework is used to identify 10 subsystem variables that affect the likelihood of self-organization in efforts to achieve a sustainable SES.

The world is currently threatened by considerable damage to or losses of many natural resources, including fisheries, lakes, and forests, as well as experiencing major reductions in biodiversity and the threat of massive climatic change. All humanly used resources are embedded in complex, social-ecological systems (SESs). SESs are composed of multiple subsystems and internal variables within these subsystems at multiple levels analogous to organisms composed of organs, organs of tissues, tissues of cells, cells of proteins, etc. (*1*). In a complex SES, subsystems such as a resource system (e.g., a coastal fishery), resource units (lobsters),

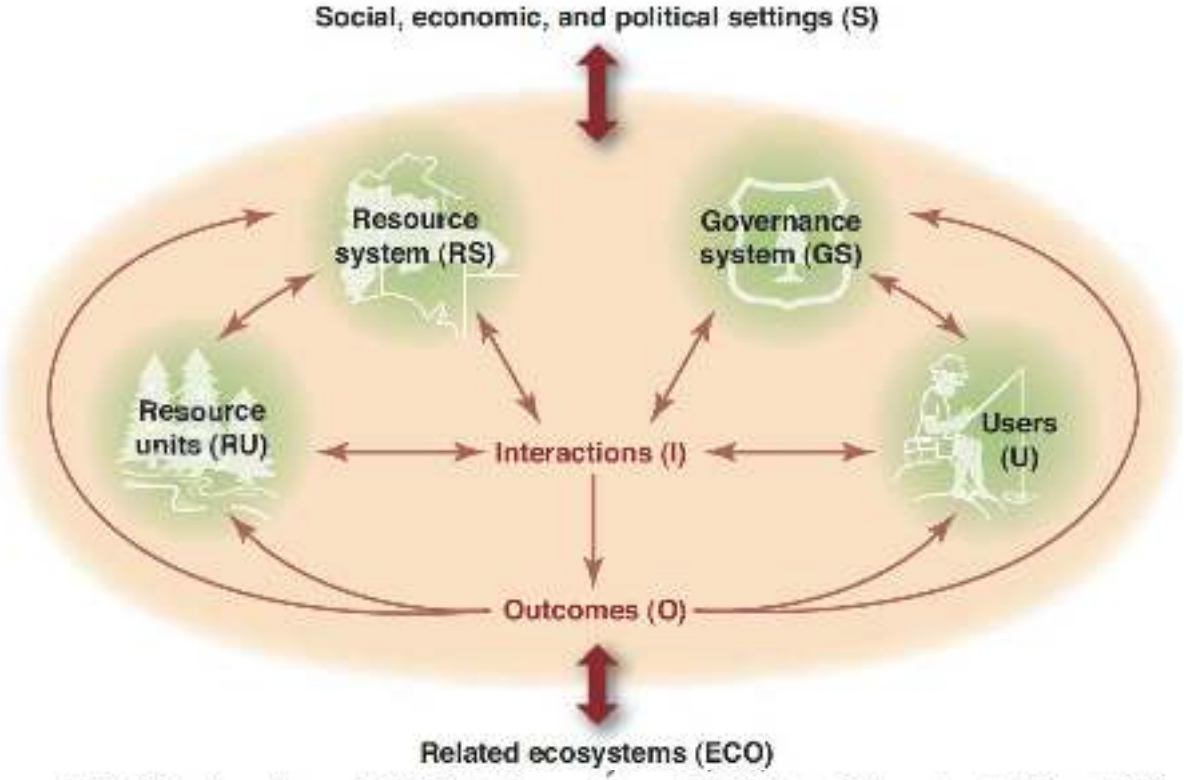
www.sciencemag.org SCIENCE VOL 325 24 JU

2009

Colding and Barthel (2019) *Ecology and Society* 24

Ostrom's framework

S1 Economic development. S2 Demographic trends. S3 Political stability.
S4 Government resource policies. S5 Market incentives. S6 Media organization.



ECO1 Climate patterns. ECO2 Pollution patterns. ECO3 Flows into and out of focal SES.

Resource systems (RS)

- RS1 Sector (e.g., water, forests, pasture, fish)
- RS2 Clarity of system boundaries
- RS3 Size of resource system*
- RS4 Human-constructed facilities
- RS5 Productivity of system*
- RS6 Equilibrium properties
- RS7 Predictability of system dynamics*
- RS8 Storage characteristics
- RS9 Location

Governance systems (GS)

- GS1 Government organizations
- GS2 Nongovernment organizations
- GS3 Network structure
- GS4 Property-rights systems
- GS5 Operational rules
- GS6 Collective-choice rules*
- GS7 Constitutional rules
- GS8 Monitoring and sanctioning processes

Resource units (RU)

- RU1 Resource unit mobility*
- RU2 Growth or replacement rate
- RU3 Interaction among resource units
- RU4 Economic value
- RU5 Number of units
- RU6 Distinctive markings
- RU7 Spatial and temporal distribution

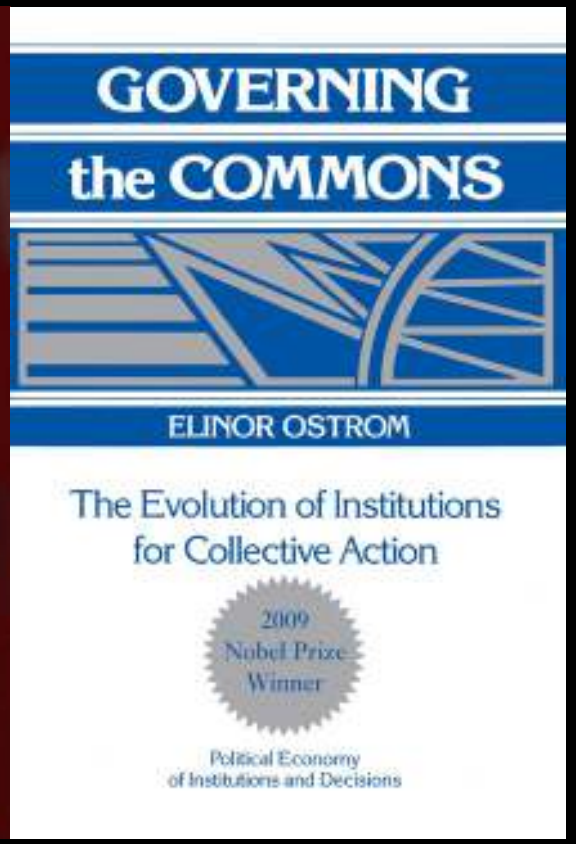
Users (U)

- U1 Number of users*
- U2 Socioeconomic attributes of users
- U3 History of use
- U4 Location
- U5 Leadership/entrepreneurship*
- U6 Norms/social capital*
- U7 Knowledge of SES/mental models*
- U8 Importance of resource*
- U9 Technology used

Interactions (I) → outcomes (O)

- I1 Harvesting levels of diverse users
- I2 Information sharing among users
- I3 Deliberation processes
- I4 Conflicts among users
- I5 Investment activities
- I6 Lobbying activities
- I7 Self-organizing activities
- I8 Networking activities

- O1 Social performance measures (e.g., efficiency, equity, accountability, sustainability)
- O2 Ecological performance measures (e.g., overharvested, resilience, bio-diversity, sustainability)
- O3 Externalities to other SESs



It was long unanimously held among economists that natural resources that were collectively used would be over-exploited and destroyed in the long-term ('tragedy of the commons'). Ostrom disproved this idea by conducting field studies on how people in small, local communities manage shared natural resources, such as pastures. She showed that when natural resources are jointly used, in time rules are established for how these are to be cared in a way that is economically and ecologically sustainable.

https://www.youtube.com/watch?v=hZAfyP7Alho

No unifying definition for SES exists

"A system of people and nature"

"A system where social and ecological systems are mutually dependent"

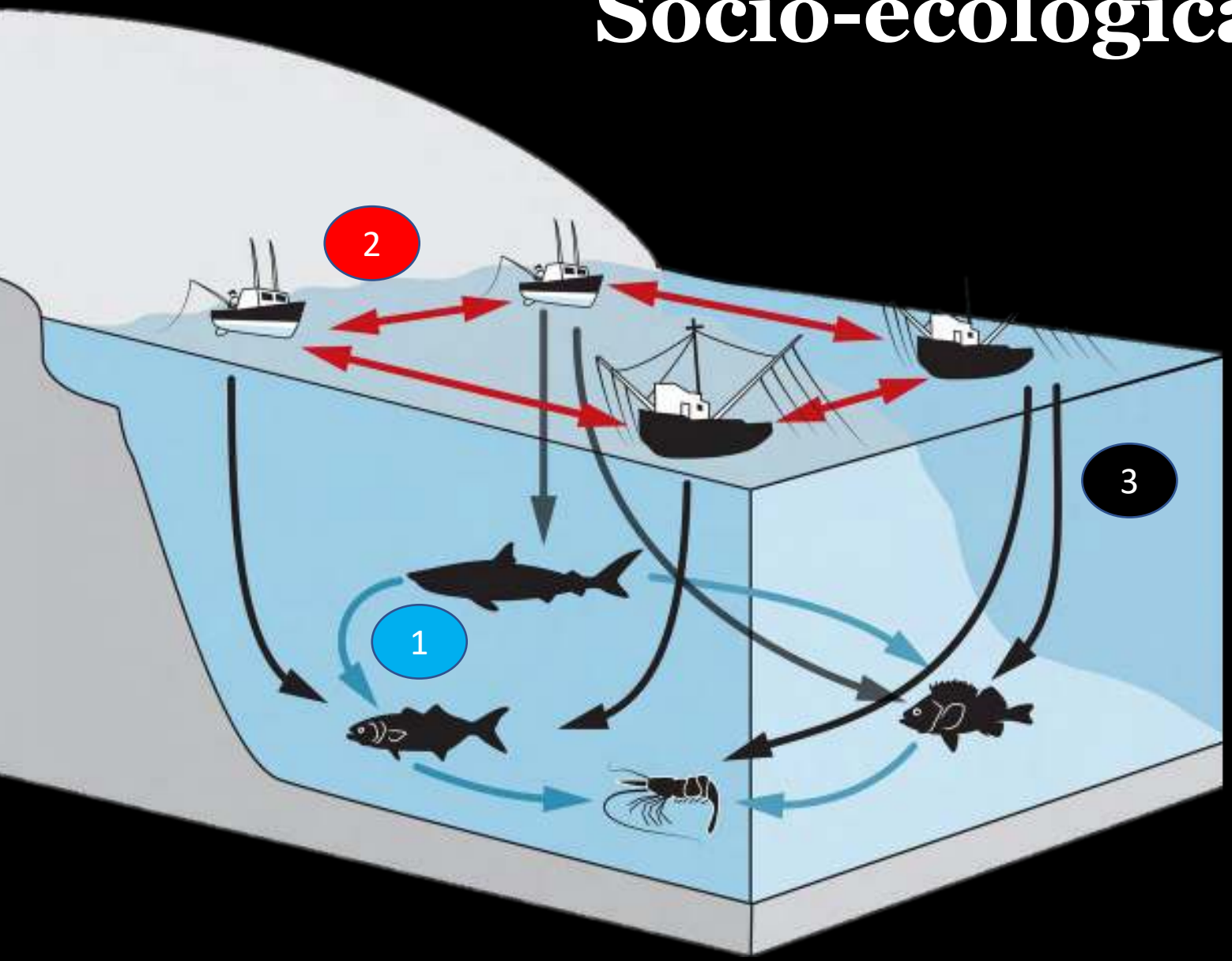
"Interdependent and linked systems of people and nature that are nested across scales"

"A system that includes societal (human) and ecological (biophysical) subsystems in mutual interactions"

"A system that includes the entities of common-pool resource, resource users, public infrastructure, infrastructure providers, institutional rules, external environment and the links between these entities"

Colding and Barthel (2019) *Ecology and Society* 24

Socio-ecological networks

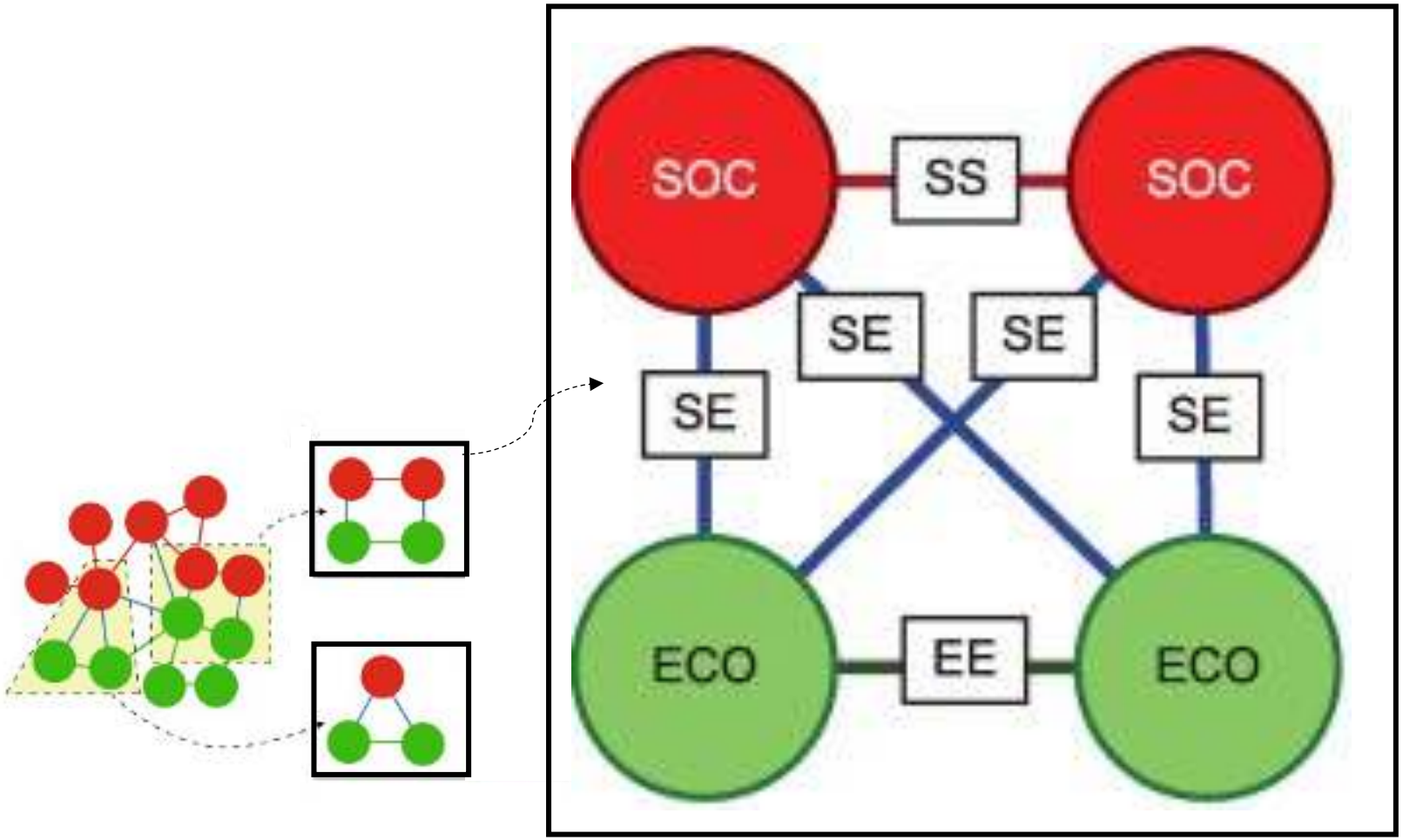


Trophic interaction
Collaboration
Harvest

How a change in local fishing policy may spread through word of mouth through the social network*, potentially changing which species fishers decide to catch. *How these changes in fishing pressure propagate through the marine food web

Bodin (2017) *Science* 357

Motifs as basic building blocks of a SES



NODES

SOC: Social Actors

ECO: Ecological resources

LINKS

SS: Social-to-Social

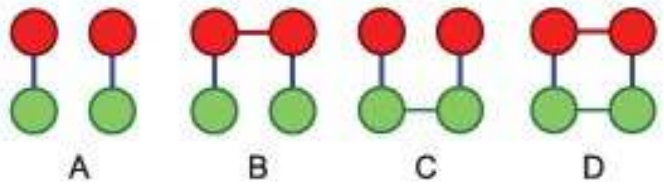
EE: Ecological-to-Ecological

SE: Socio-Ecological

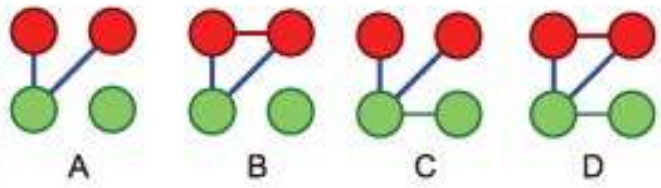
Bodin & Tengo (2012) *Glob Environ. Change*

Symmetric resource access

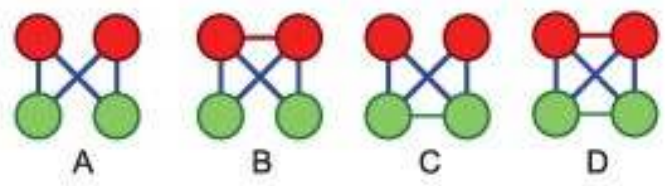
I. One-to-one resource access



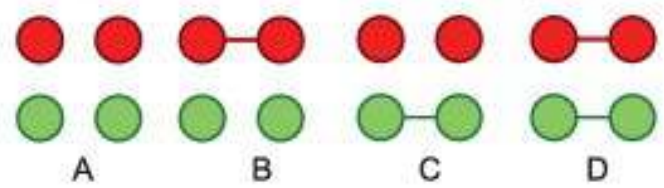
II. Shared resource access



III. Multiple shared resources

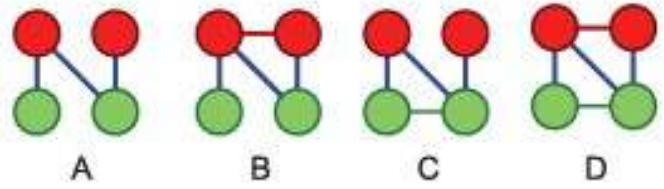


IV. Separated social and ecological systems

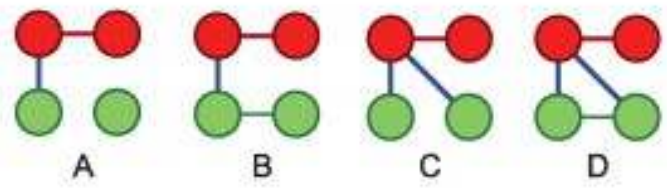


Asymmetric resource access

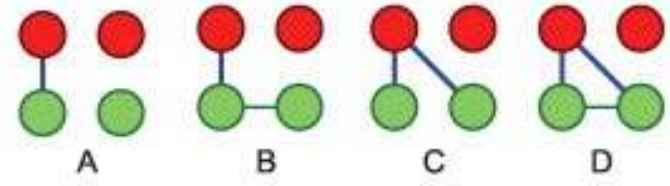
V. One exclusive, one shared resource



VI. Mediated resource access

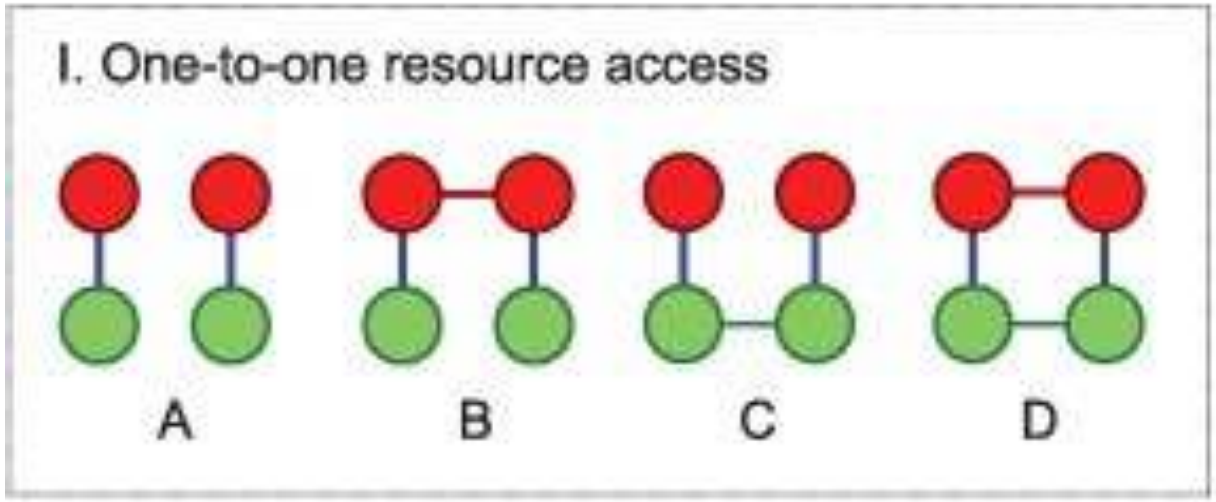


VII. Isolated social actor



Symmetric access to ecological resources

I. One-to-one resource access



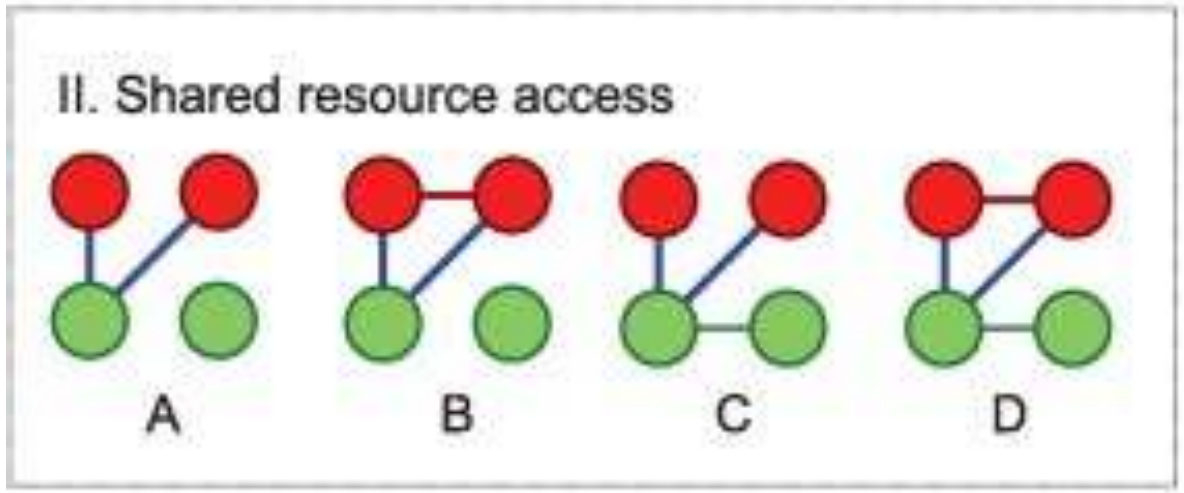
Each actor has exclusive access to one ecological resource

No direct resource sharing between actors

No actor can substitute one resource with another

Symmetric access to ecological resources

II. Shared resource access

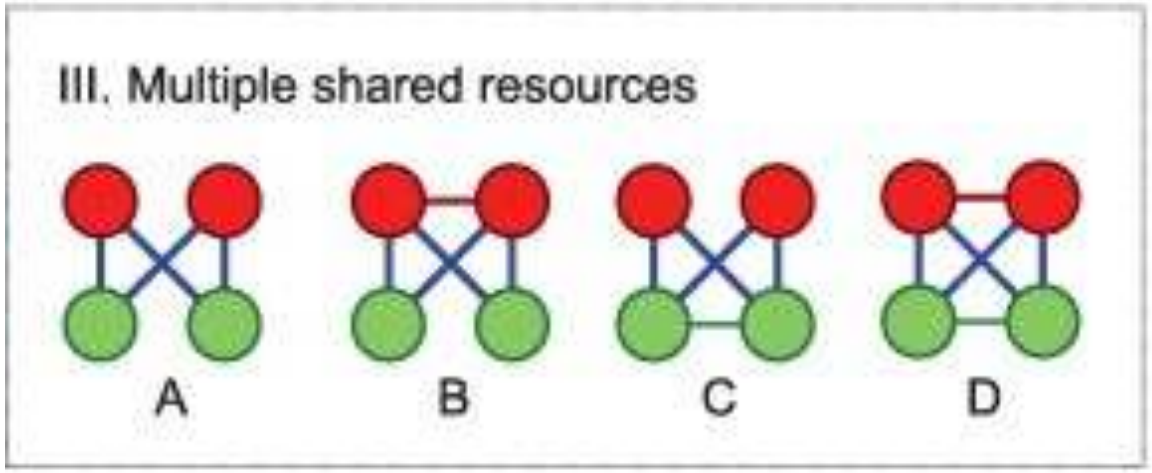


Both social actors have access to one single ecological resource

All configurations within this family are characterized by resource sharing/competition, with no possibilities for substitution

Symmetric access to ecological resources

III. Multiple shared resources

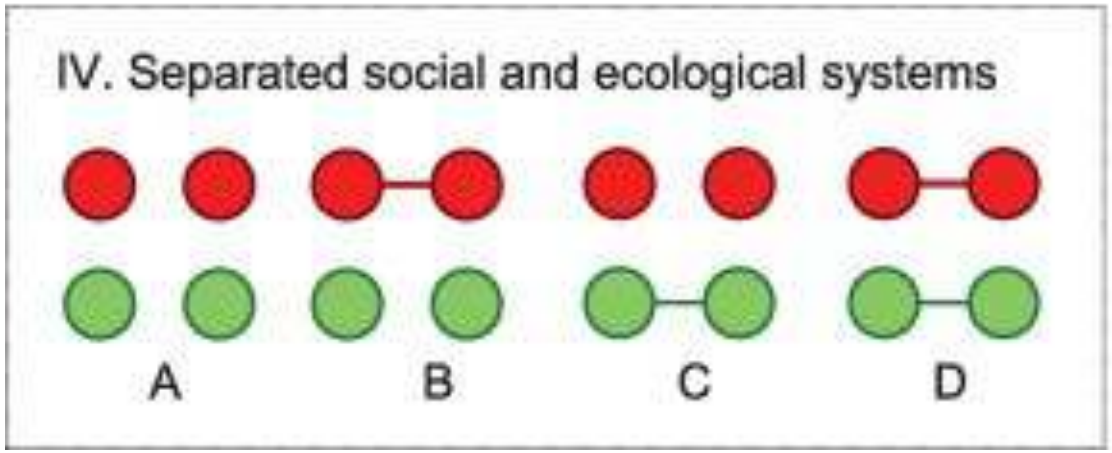


Both social actors have access to both ecological resources

This implies substitutability of resource utilization for both actors, but also sharing/competition between them

Symmetric access to ecological resources

IV. Separated social and ecological systems



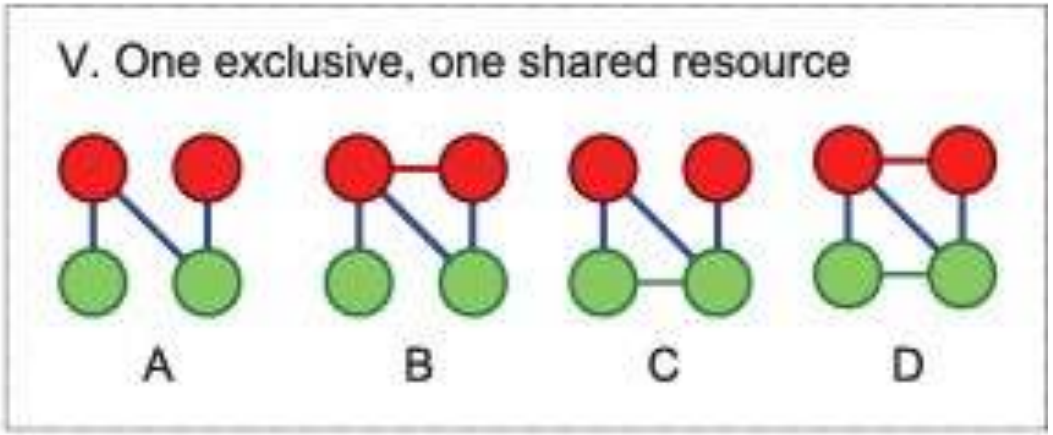
Lack of links between the social-ecological nodes

Family is of limited interest from a SES point of view,

Existence of such motifs in a larger SES system informs the extent to which actors are disconnected from resources.

Asymmetric access to ecological resources

V. One exclusive, one shared resource

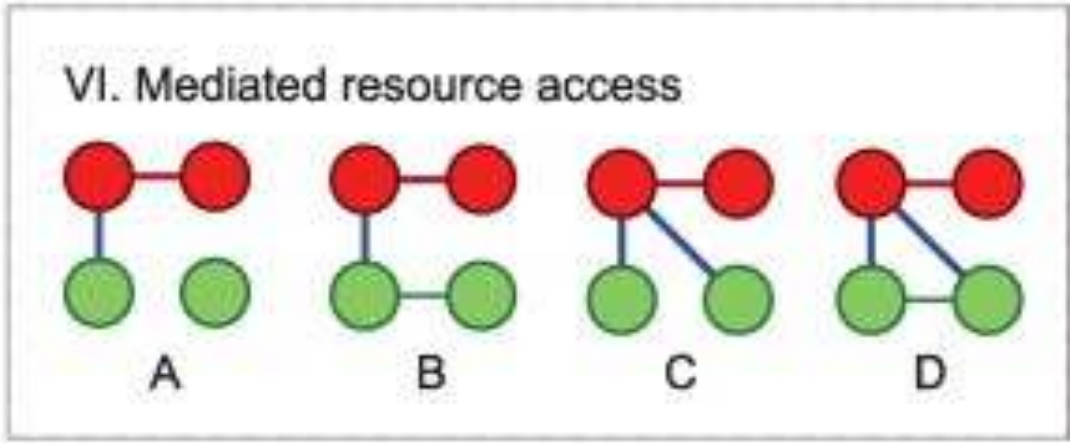


One social actor has access to both ecological resources
The other can only directly access one.

One actor experiences ecological substitutability, while the other does not and sharing/competition is relevant for one ecological resource but not for the other.

Asymmetric access to ecological resources

VI. Mediated resource access



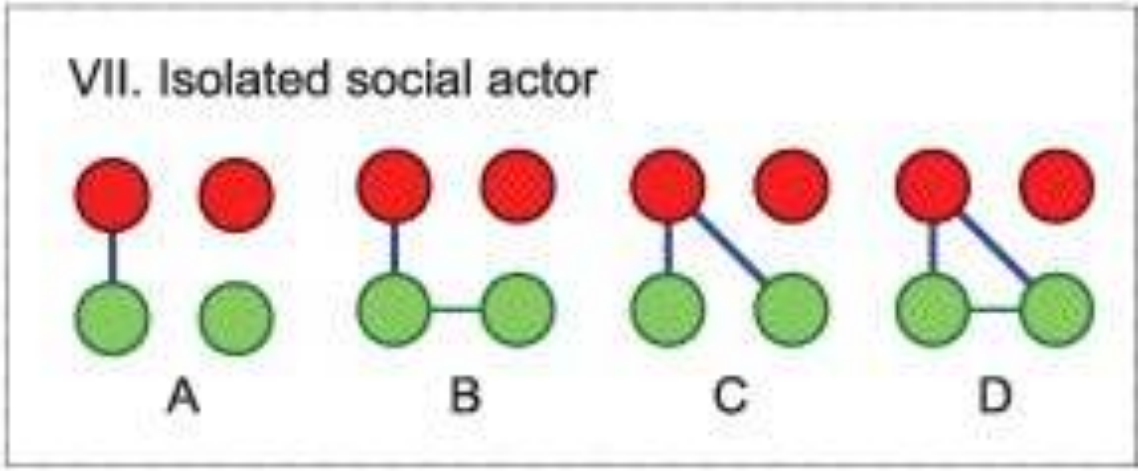
Only way for one social actor to access an ecological resource is through the other. This suggests power asymmetries in resource access. It is plausible to assume that actor with direct resource access is typically in a more favourable position than the other

Alternatively, the social actor harvesting the resources is dependent on the other actor to get access to appropriate gear and capital.

Which of these scenarios applies for any given system depends on the context and on what types of relationships are being studied.

Asymmetric access to ecological resources

VII. Isolated social actor



One of the social actors is decoupled from the other actor and the ecological resources.

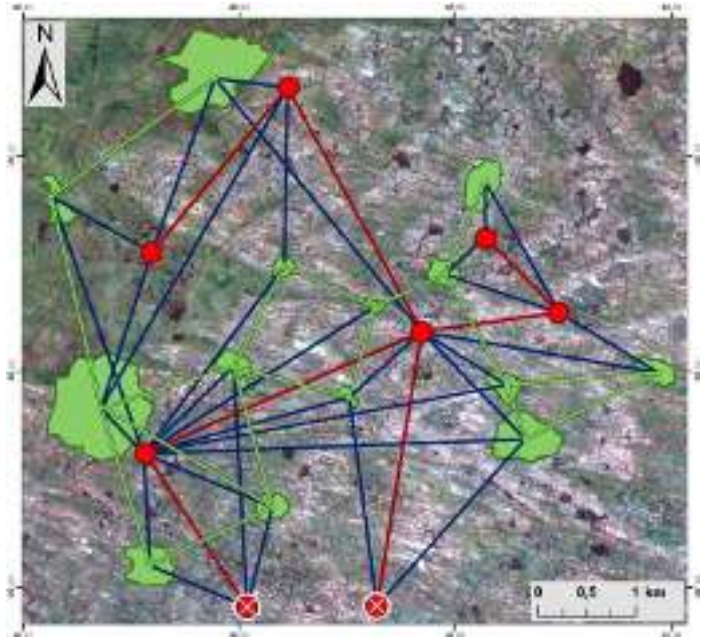
Family is of limited interest, although its prevalence can inform the level of social isolation in the larger SES.

Small-scale forest governance in Madagascar

1 **Define social-ecological linkages** —
(**control and use of ecosystem services**)

2 **Define appropriate social actors** (**clans**) ●
and ecological resources (**forest patches**) ▭

3 **Define appropriate social-to-social** (**kinship**) —
and ecological-to-ecological links (**seed dispersal**) —



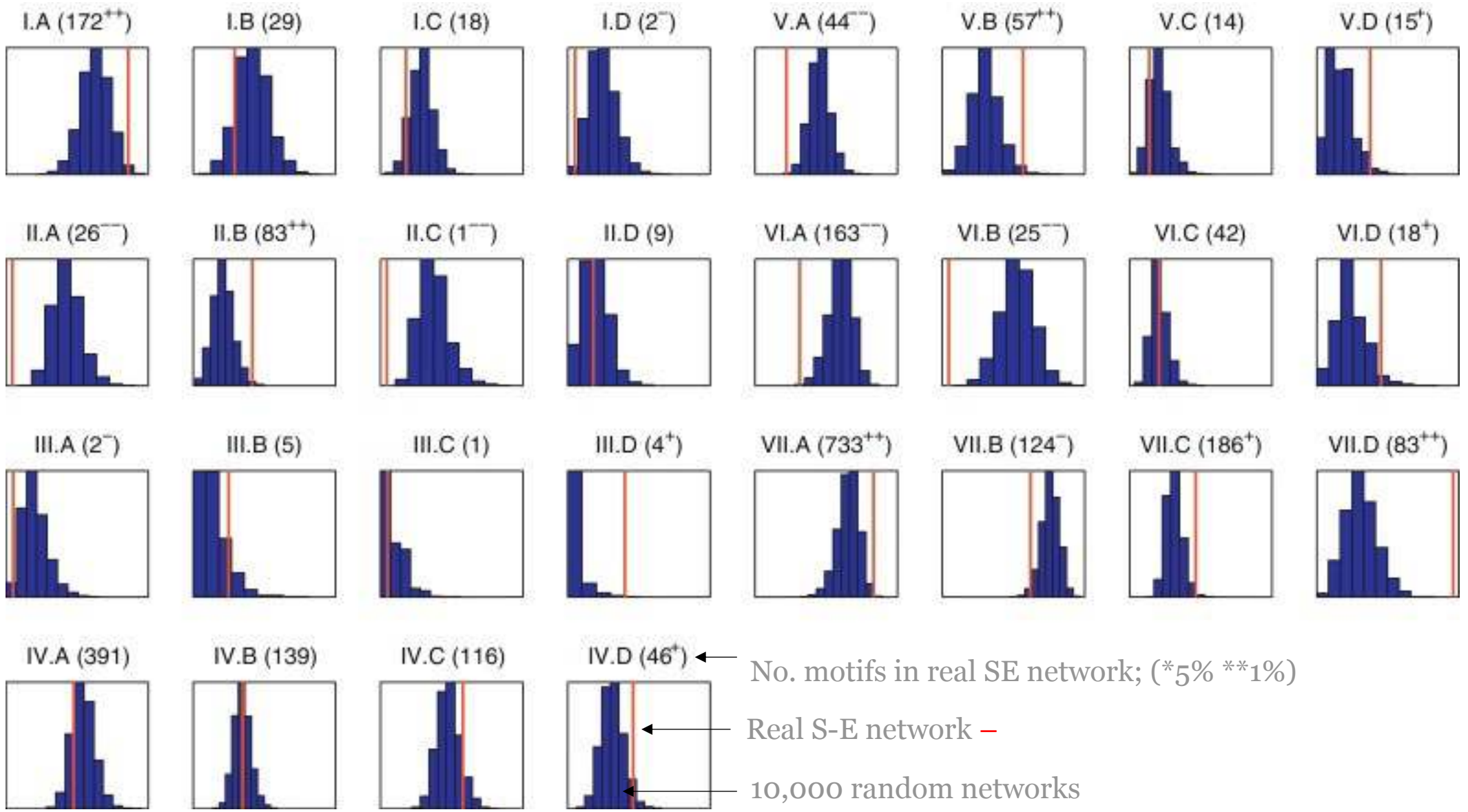
4 **Evaluate social-ecological network** (two key criteria)**:**

1. Scale matching: the interdependent social actors and the ecological resources should both be defined at such scales that their ability to impact on each other is comparable in strength.

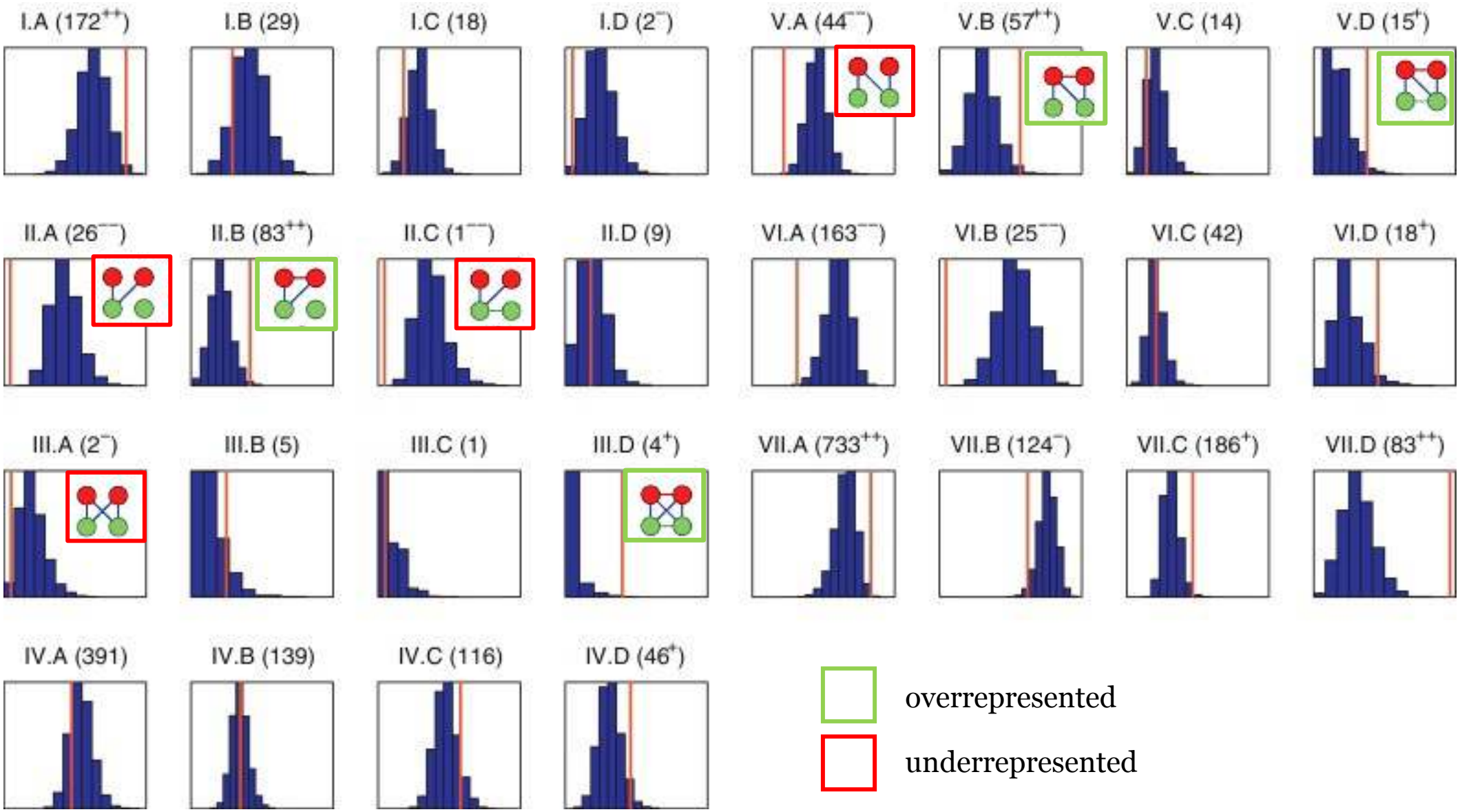
2. Patterns of links: ensure that S-S, E-E and S-E links can in theory occur across all or most of the nodes in the network.

5 **Assess which SES motifs occur more or less frequently than by chance** (null models)

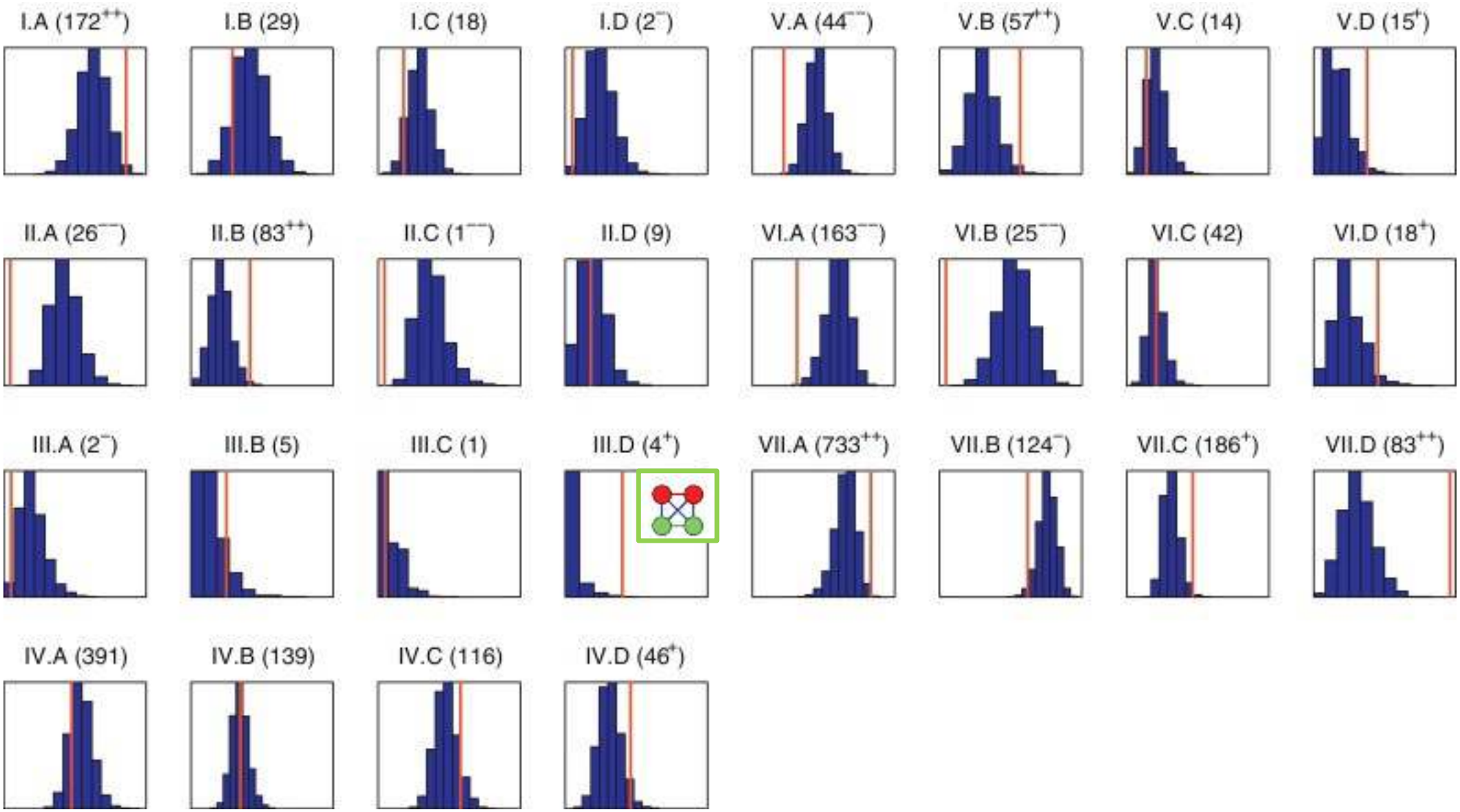
Some SES motifs are more frequent than others



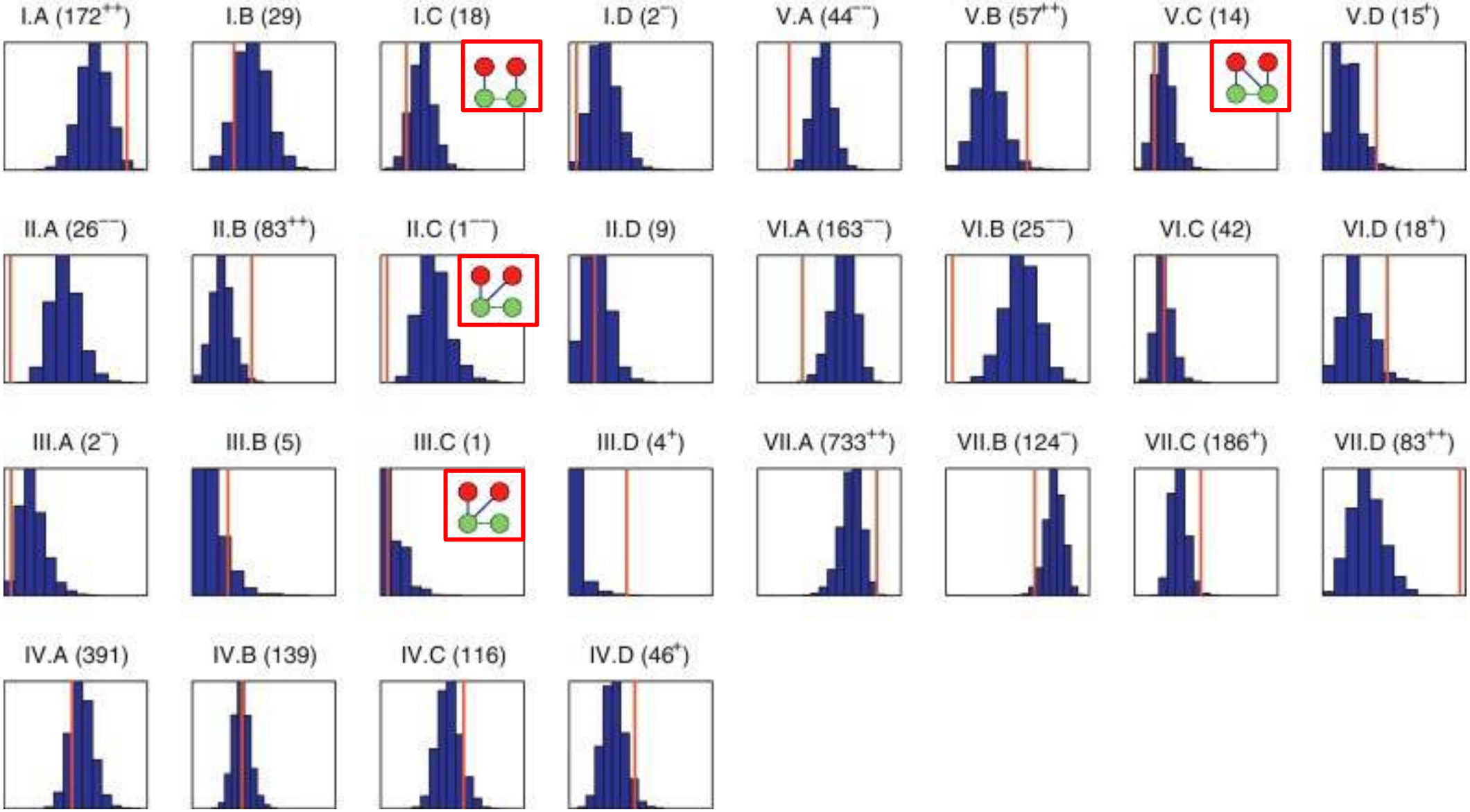
Shared forest access generally implies social connectivity



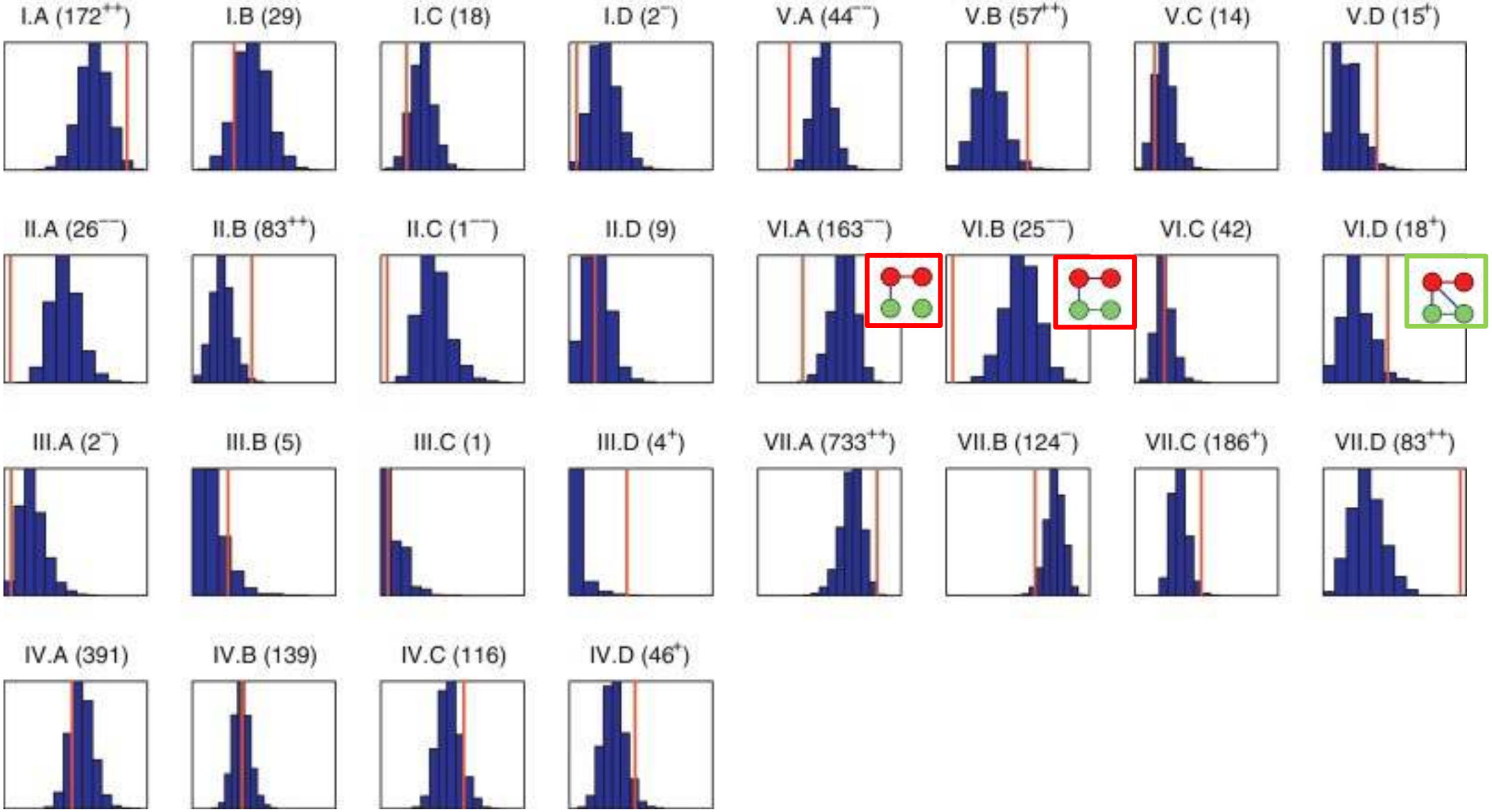
Highly interconnected clans and forest patches are common



Motifs with ecological but no social connectivity are underrepresented or neutral



Mediated access occurs rarely (VI A-B.) ***unless*** **clan with access to resources have links to both forest patches** (VI.D)



"The clans either divide access to patches among each other, or, if a patch is shared, the clans are also socially linked to each other. All these configurations are likely to contribute to the successful resource governance in this area."

Bodin & Tengo (2012) *Glob Environ. Change*

https://www.youtube.com/watch?v=0XE2uo0ZZ44

Photos: Sergio Bartelsman, ACAIPI, Fundación Gaia Amazonas










ETHNOSPHERE

"JUST AS THERE IS A BIOSPHERE, A BIOLOGICAL WEB OF LIFE, SO TOO THERE IS A CULTURAL FABRIC THAT ENVELOPS THE EARTH, A CULTURAL WEB OF LIFE. YOU MIGHT THINK OF THE ETHNOSPHERE AS BEING THE SUM TOTAL OF ALL THOUGHTS AND DREAMS, MYTHS, INTUITIONS AND INSPIRATIONS BROUGHT INTO BEING BY THE HUMAN IMAGINATION SINCE THE DAWN OF CONSCIOUSNESS."

-Wade Davis







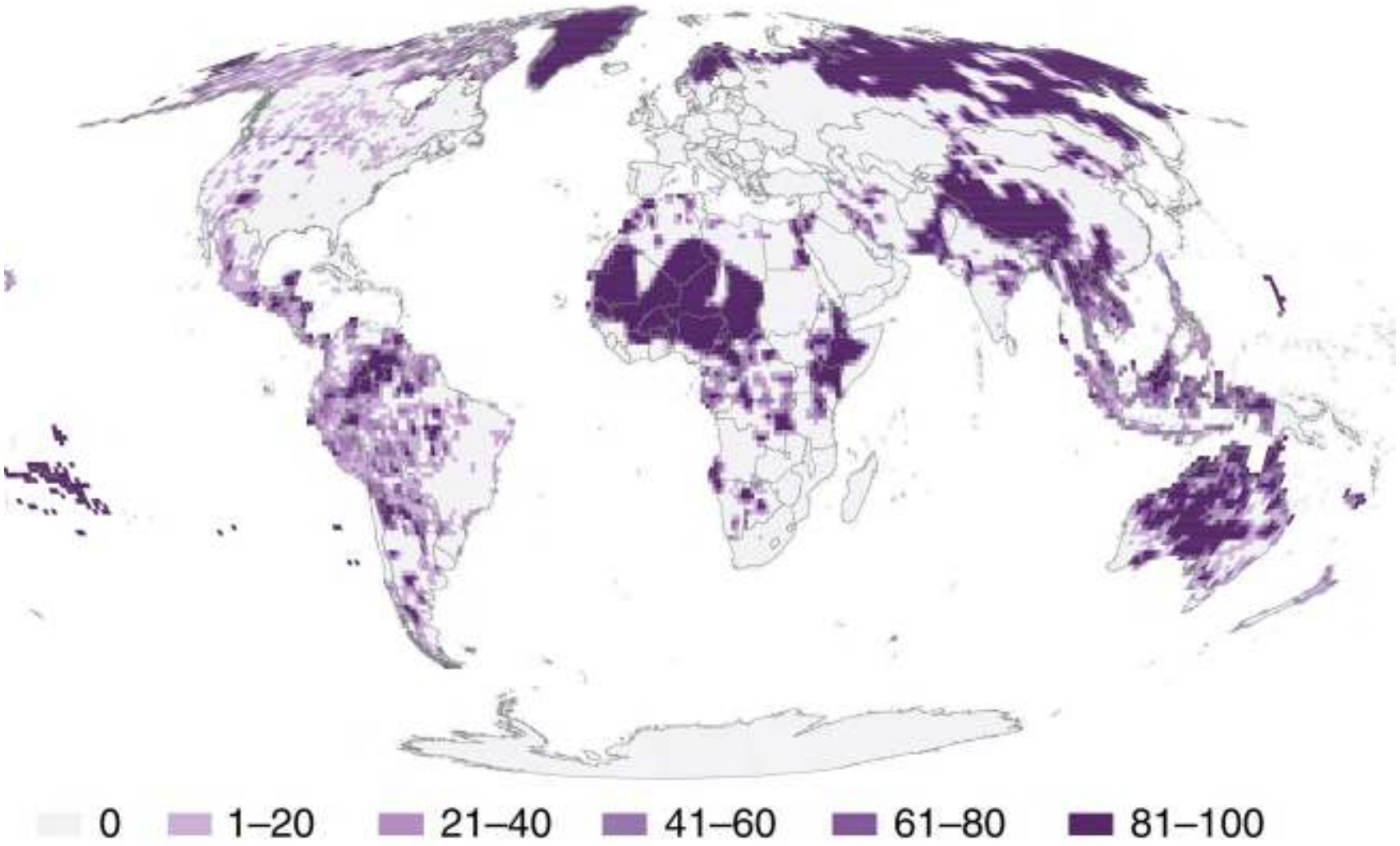









Indigenous Peoples inhabit >25% of the world's land surface



% of each degree square mapped as Indigenous

Garnett *et al.* (2018) *Nature Sustainability*

Indigenous Lands: 36% of the world's Intact Forest Landscapes

Fa *et al.* (2020) *Front. Ecol. Environ.*

Photo: R. Cámara-Leret
Colombian Amazonia

Studies of indigenous knowledge on plant services have been affected by two sets of limitations:

1. Based on aggregate indicators such as the number of uses, useful species, or uses per species known within a community, **leaving out essential information on the *identity* of species and uses and their *relationships***

Studies of indigenous knowledge on plant services have been affected by two sets of limitations:

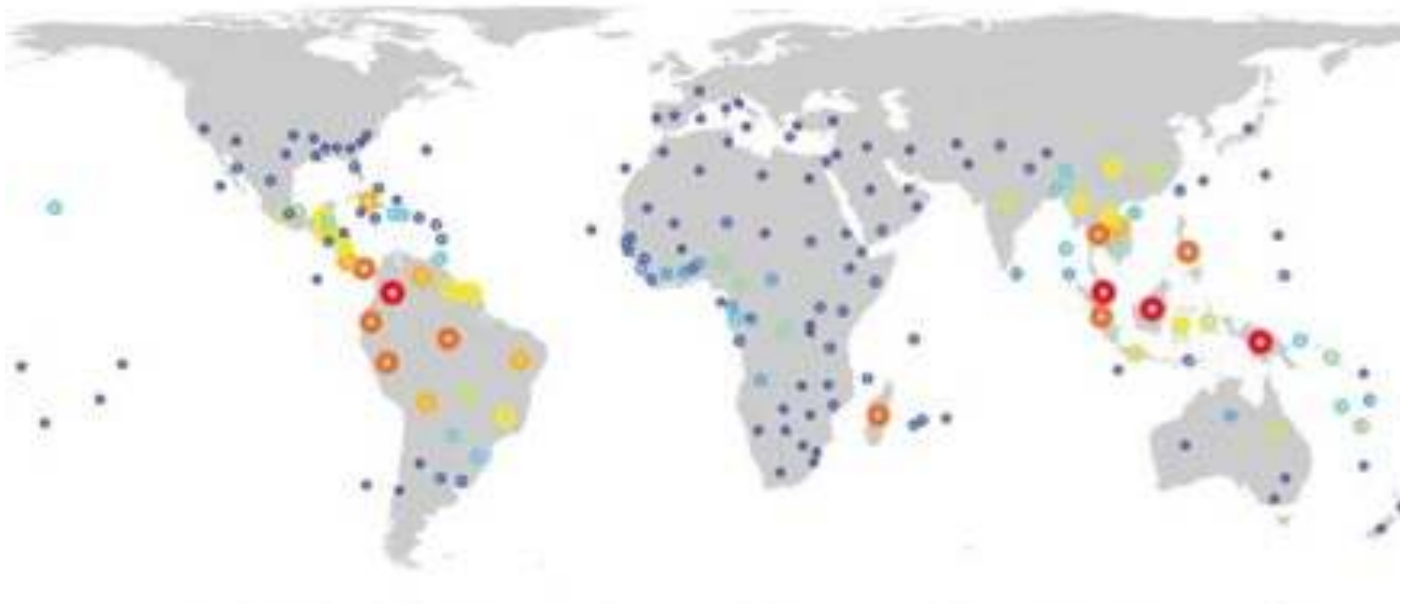
1. Based on aggregate indicators such as the number of uses, useful species, or uses per species known within a community, **leaving out essential information on the *identity* of species and uses and their *relationships***

2. Documented knowledge at **small scales or with few cultures**

Cámara-Leret, Fortuna, and Bascompte (2019) *PNAS*

Palms

Wide distribution



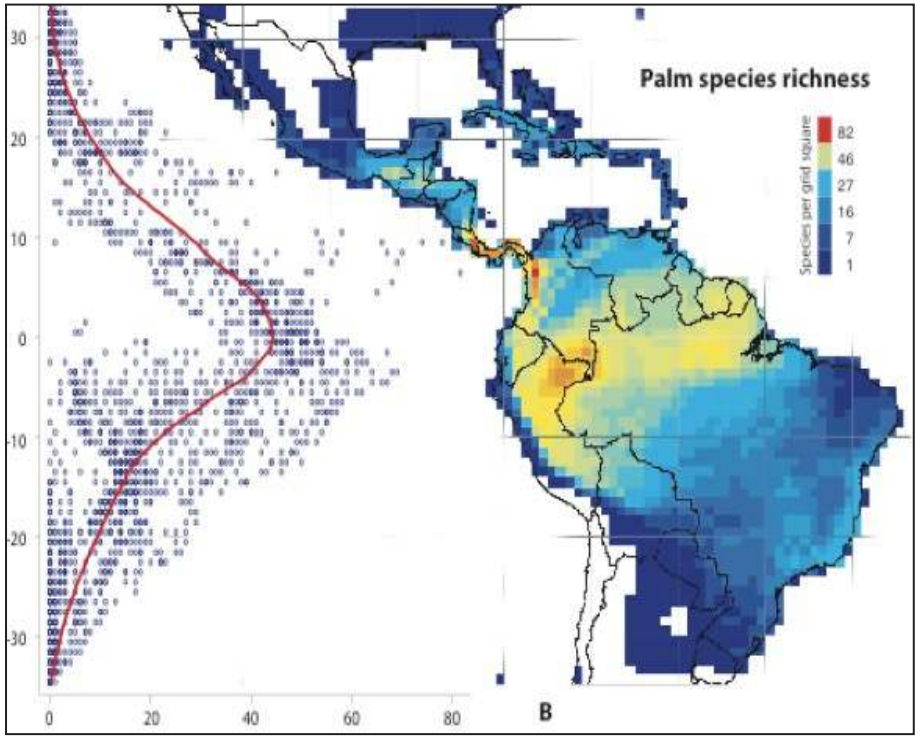
Eiserhardt et al. (2011) Annals of Botany 108

Palms

Wide distribution

High species richness

	# species	# endemic	% endemic
Continental	514		
CEPB	332	143	43
Colombia	247	50	20
Ecuador	140	13	9
Peru	148	24	16
Bolivia	87	7	8



Bjorholm et al. (2003) Global Ecol. Biogeogr. 14

Palms

Wide distribution

High species richness

Easy to recognize

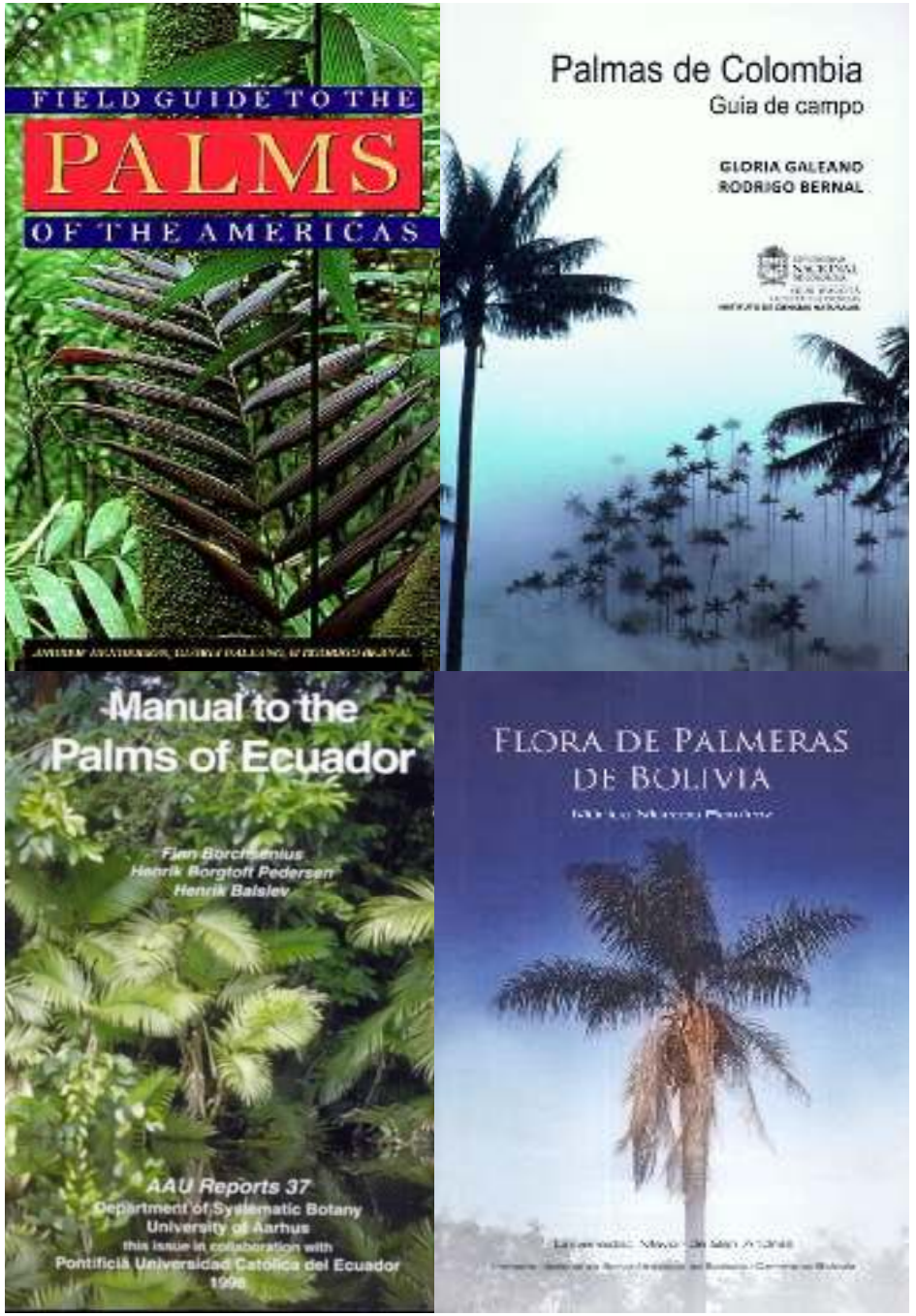
Palms

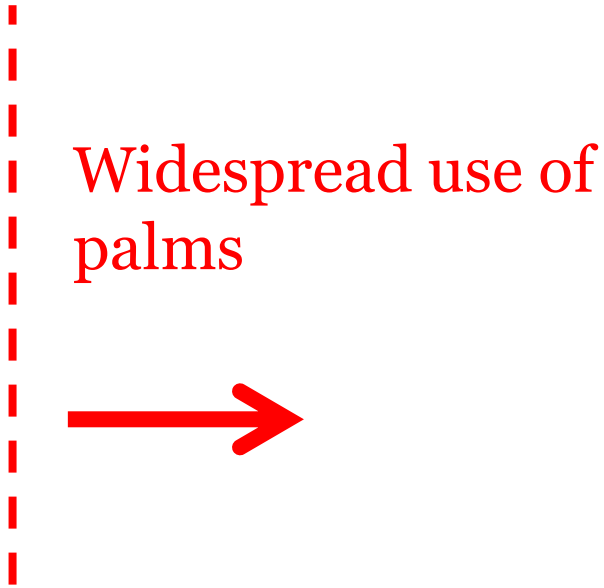
Wide distribution

High species richness

Easy to recognize

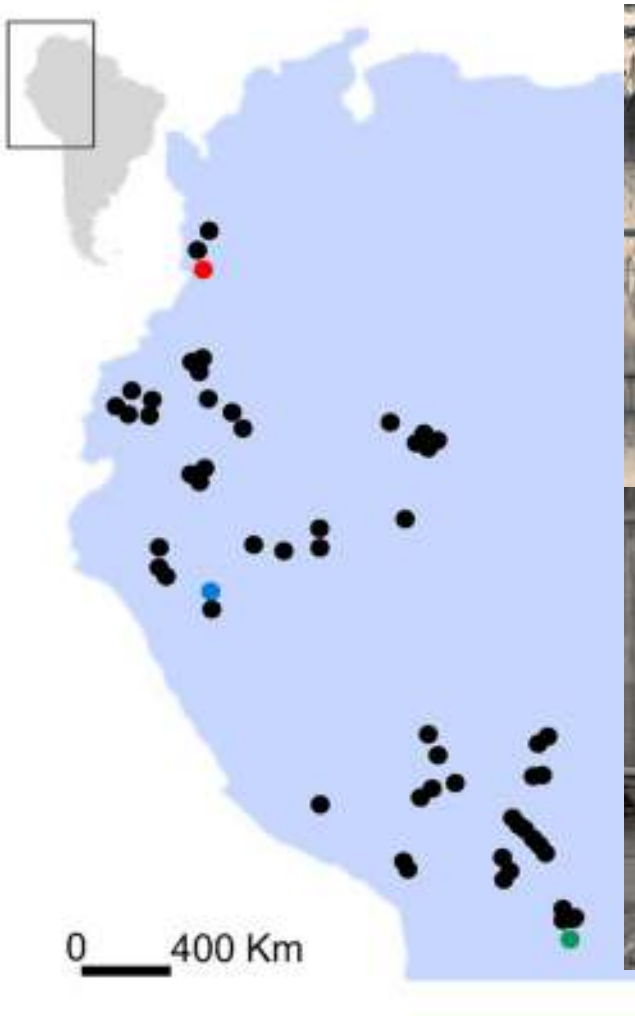
Resolved taxonomy





Morcote & Bernal (2001) *Bot Rev* 67

57 communities: 2,137 informants



Protocol: Cámara-Leret et al. 2012. In: *Medicinal Plants and the Legacy of R.E. Schultes*, 41-71.

Selection of informants

EXPERTS/GENERAL

Informant's gender	No. experts	No. general informants	Total informants	Percentage
Men	7	40	47	54
Women	0	40	40	46
Total	**7**	**80**	**87**	

Field (1 day)

Vernacular names

Botanical collections

Selection of informants

AGE

EXPERTS/GENERAL

18-30; 31-40; 41-50; 51-60; >60

Informant's gender	No. experts	No. general informants	Total informants	Percentage
Men	7	40	47	54
Women	0	40	40	46
Total	**7**	**80**	**87**	

Household interviews

Selection of informants

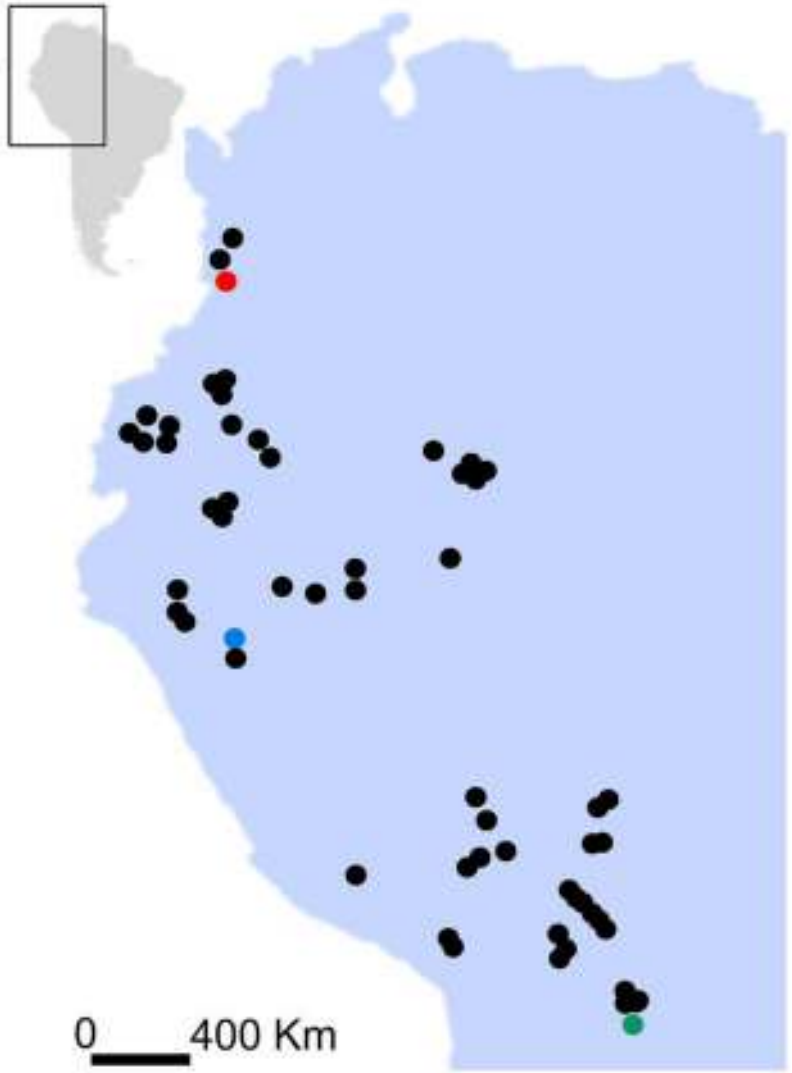
AGE

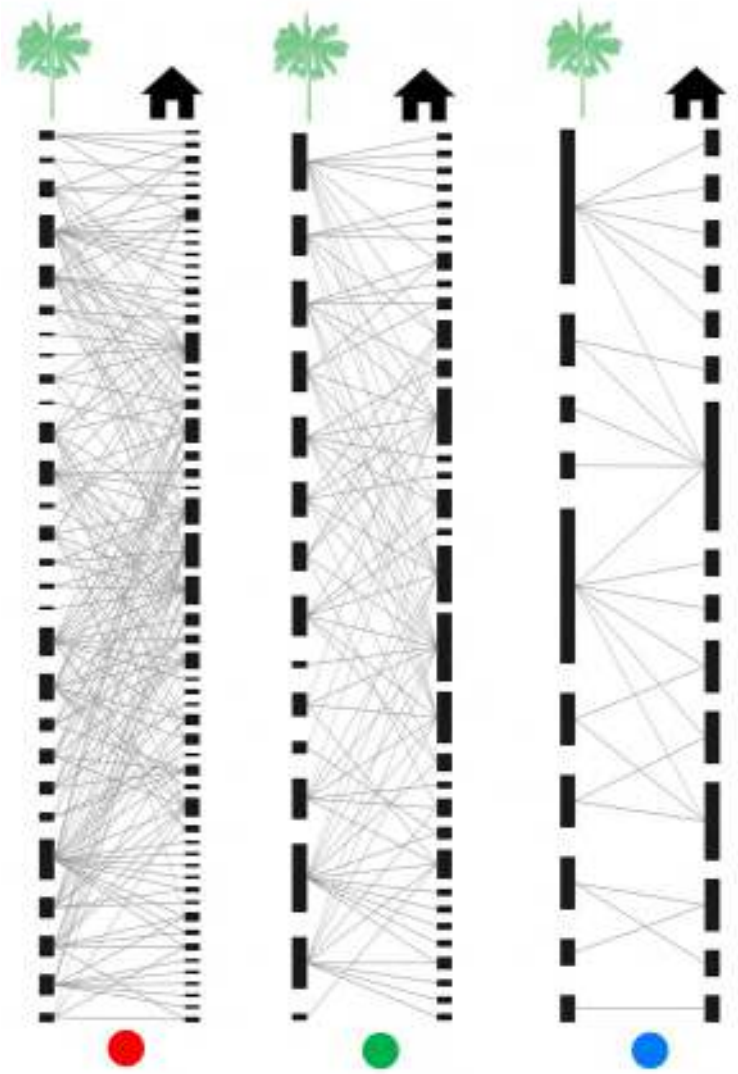
EXPERTS/GENERAL 18-30; 31-40; 41-50; 51-60; >60 GENDER

Informant's gender	No. experts	No. general informants	Total informants	Percentage
Men	7	40	47	54
Women	0	40	40	46
Total	**7**	**80**	**87**	

Emberá indigenous community of Aguacate, Pacific lowlands of Colombia

Indigenous knowledge networks





Cámara-Leret, Fortuna, and Bascompte (2019) *PNAS*

The influence of cultural and biological heritage…

Community A

Community B

The influence of cultural and biological heritage…

Community A

Community B

The influence of cultural and biological heritage…

Community A

Community B

The influence of cultural and biological heritage…

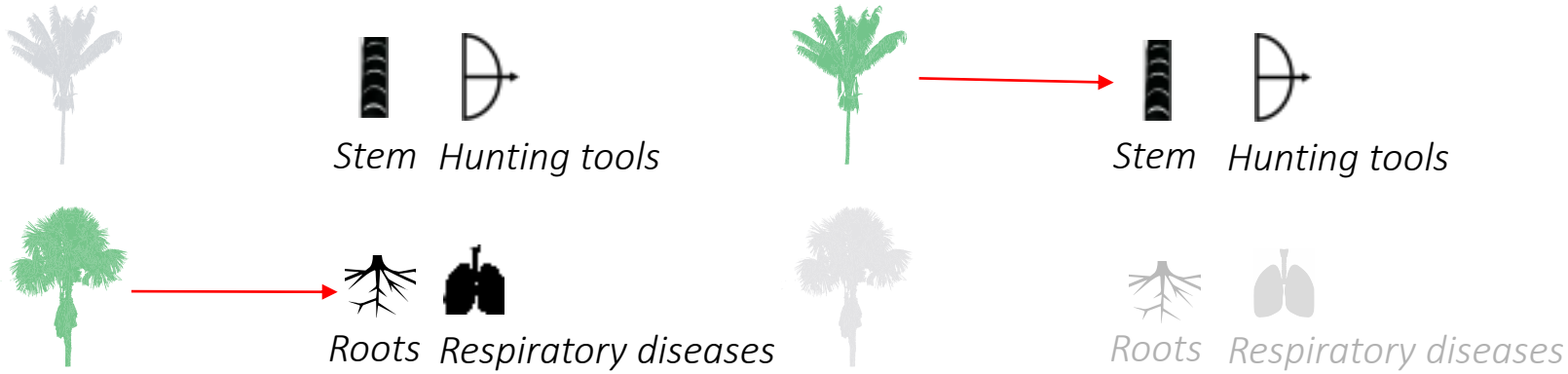
Community A

Community B

The influence of cultural and biological heritage…

Community A

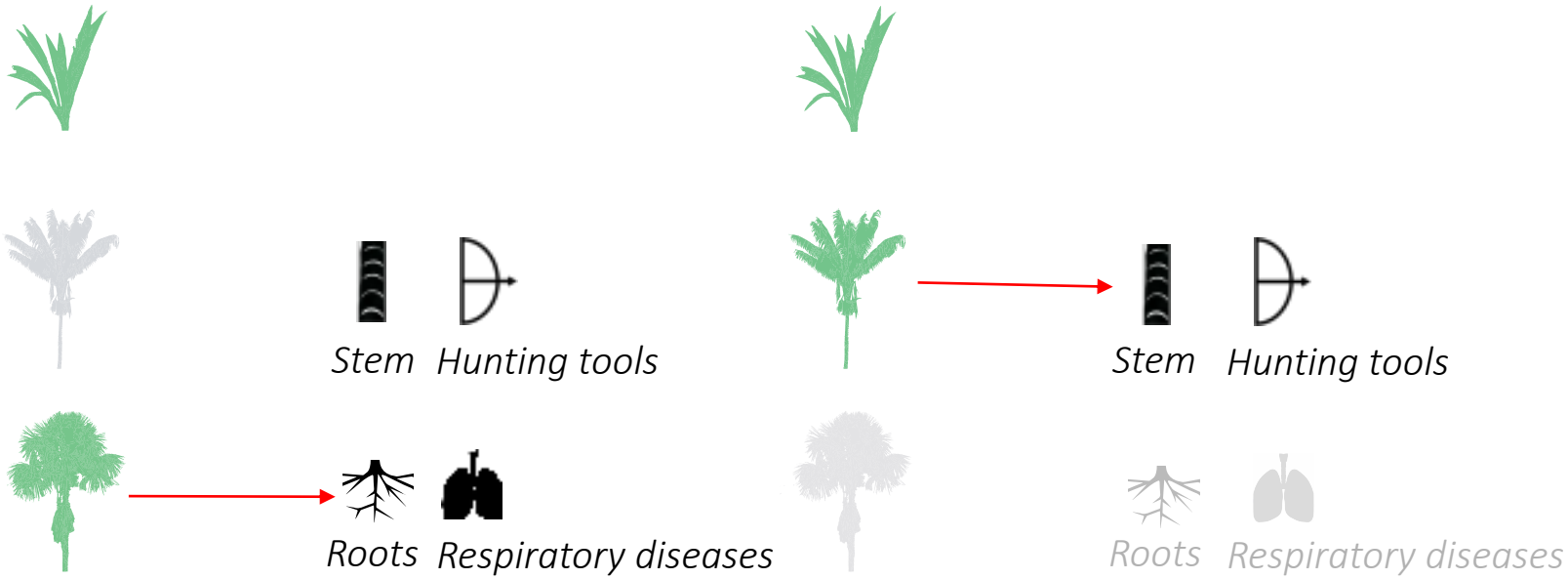
Community B



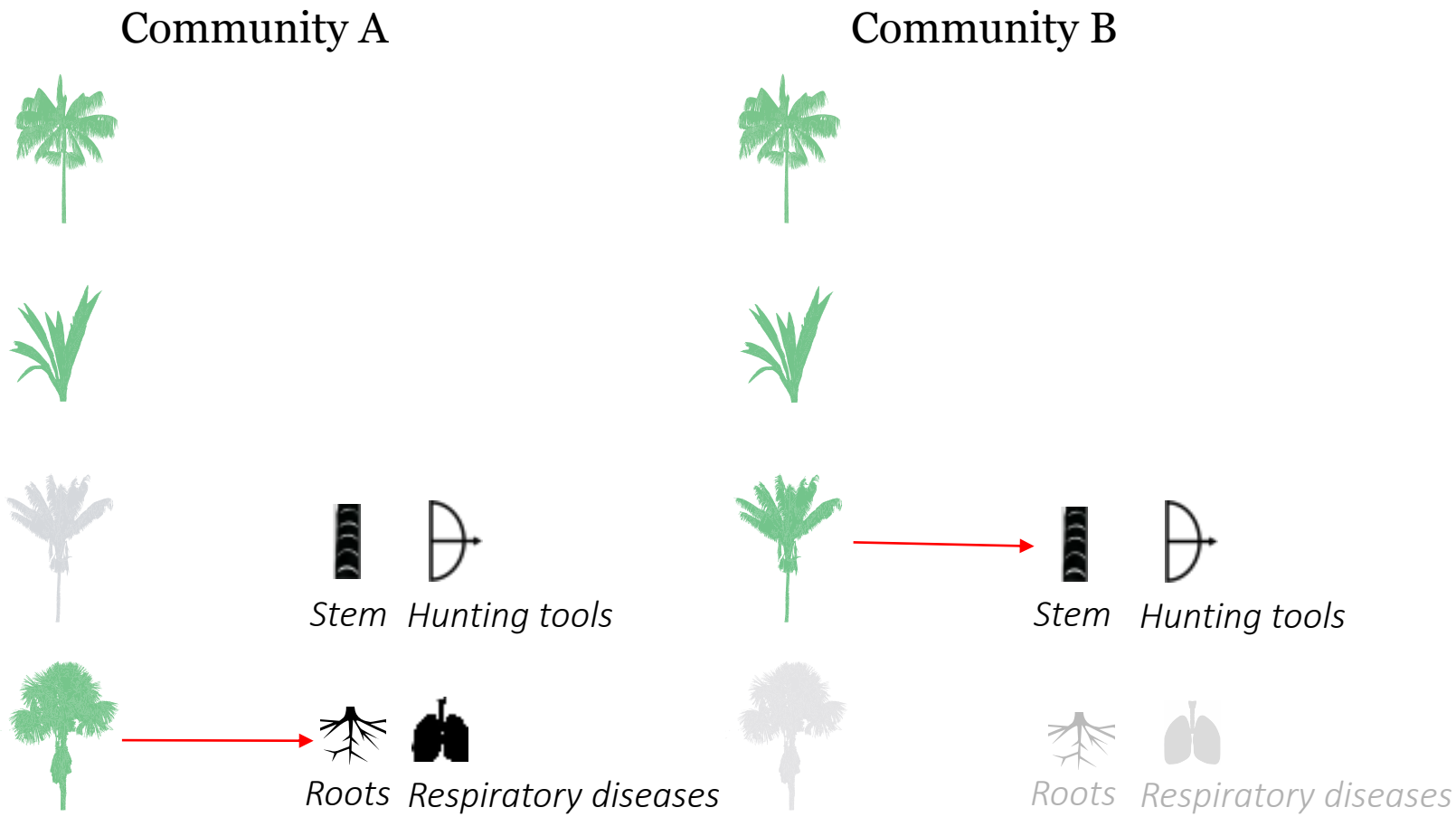
The influence of cultural and biological heritage…

Community A

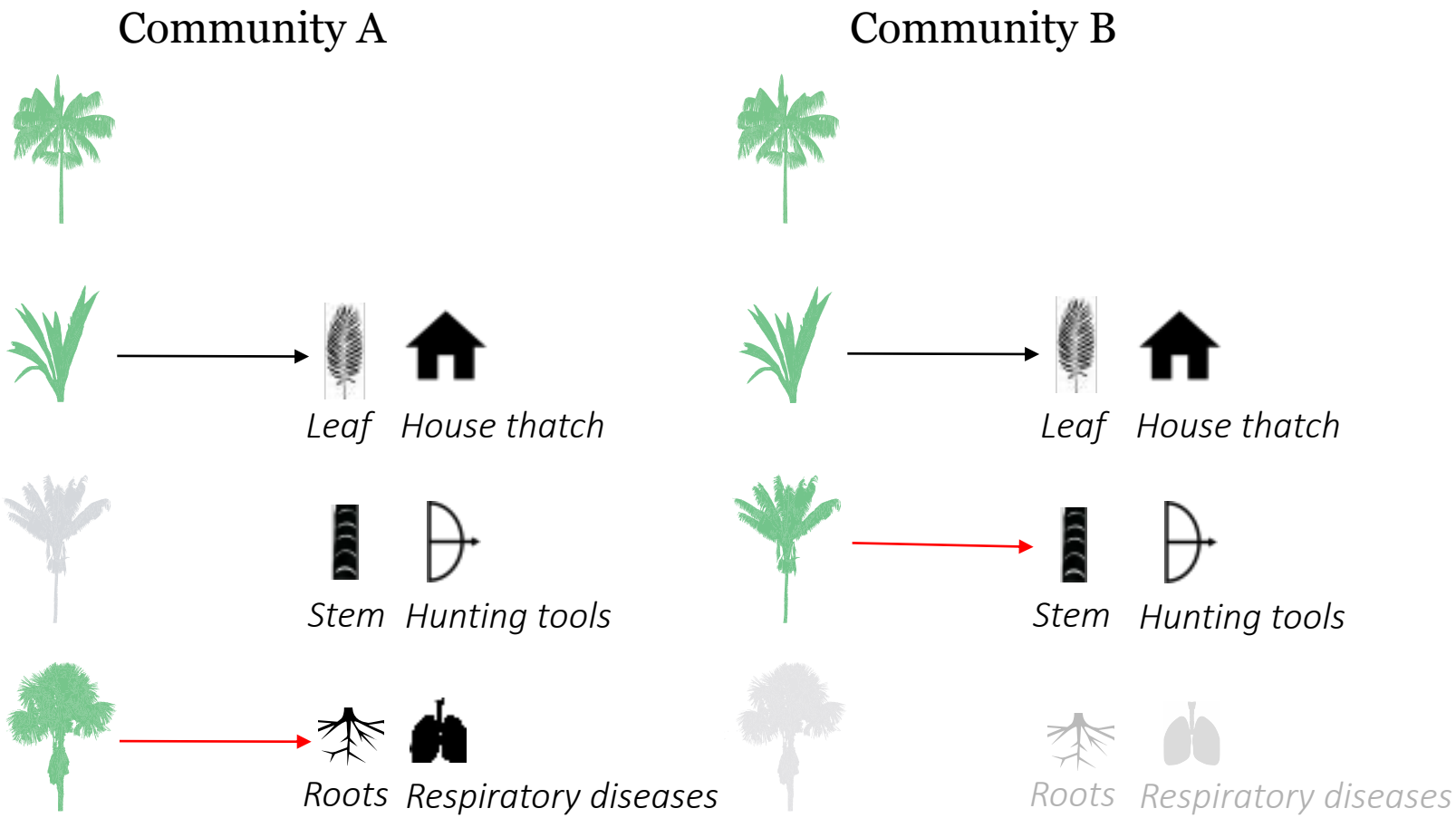
Community B



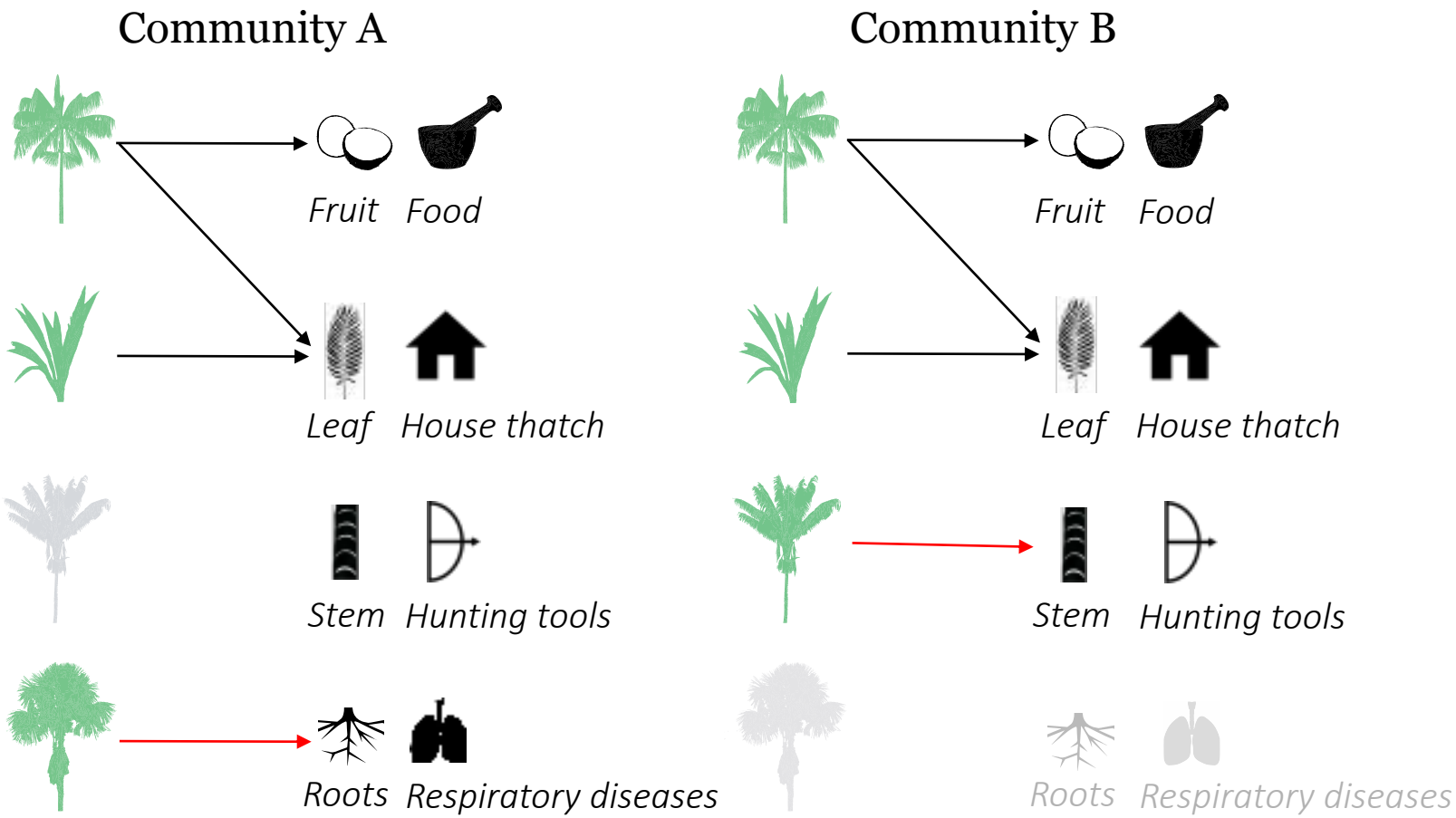
The influence of cultural and biological heritage…



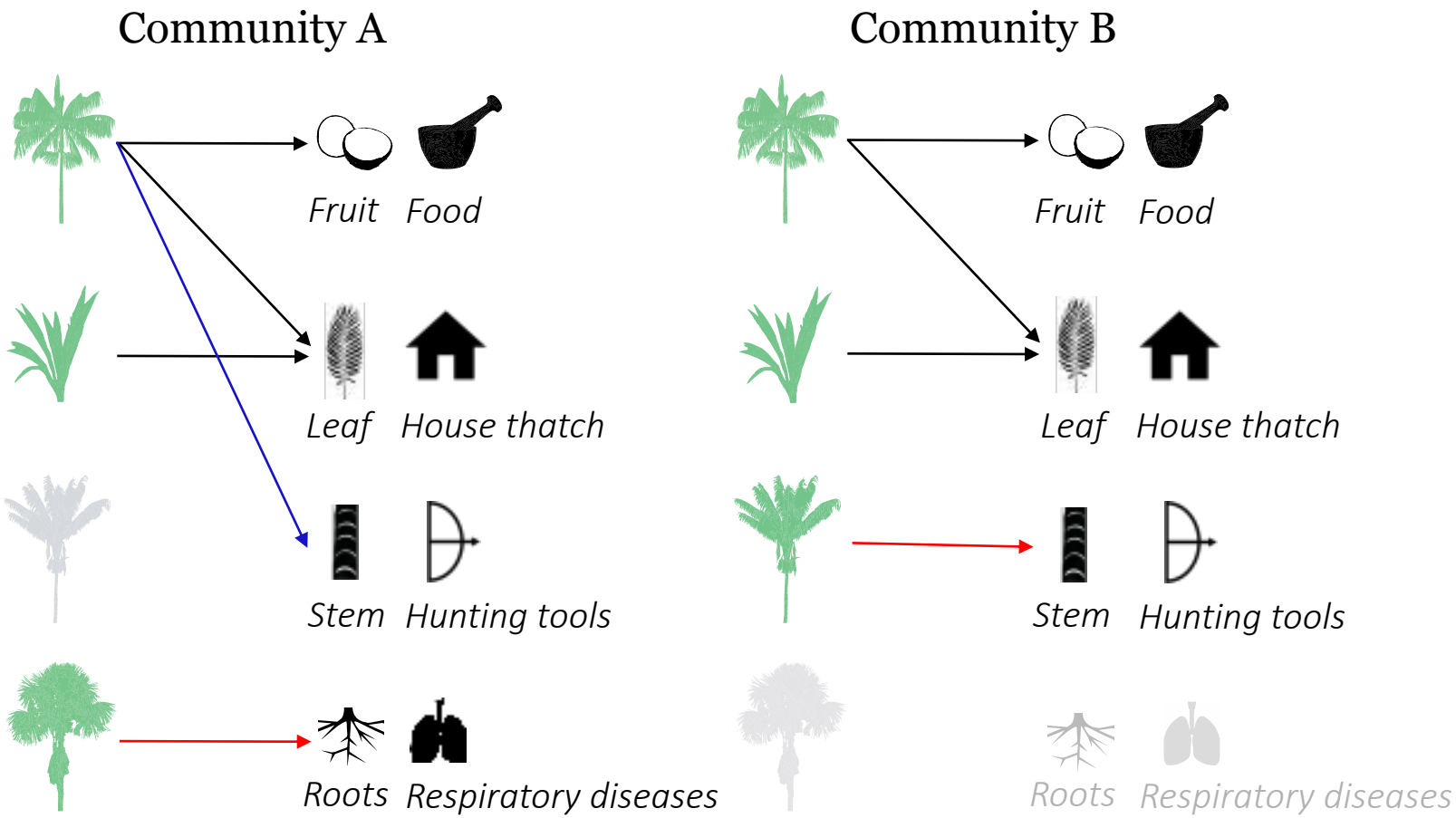
The influence of cultural and biological heritage…



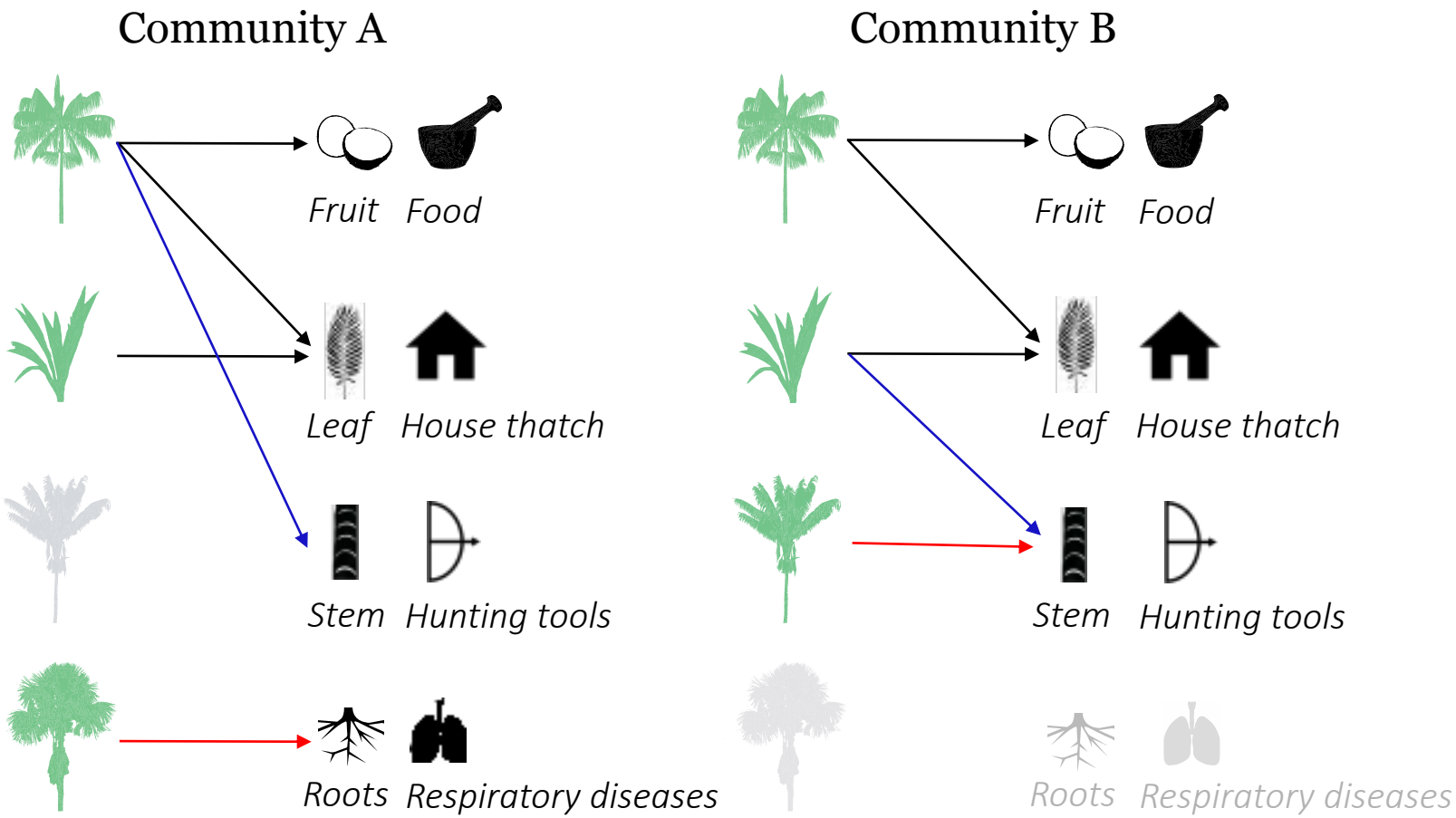
The influence of cultural and biological heritage…



The influence of cultural and biological heritage…



The influence of cultural and biological heritage…



Total dissimilarity between two indigenous knowledge networks (β) can be decomposed into:

- **Plants and services (node) turnover: β_{bio}**

  Where differences in the presence/absence of links between plants and the services they provide are the result of a plant being present in one community but not in the other.

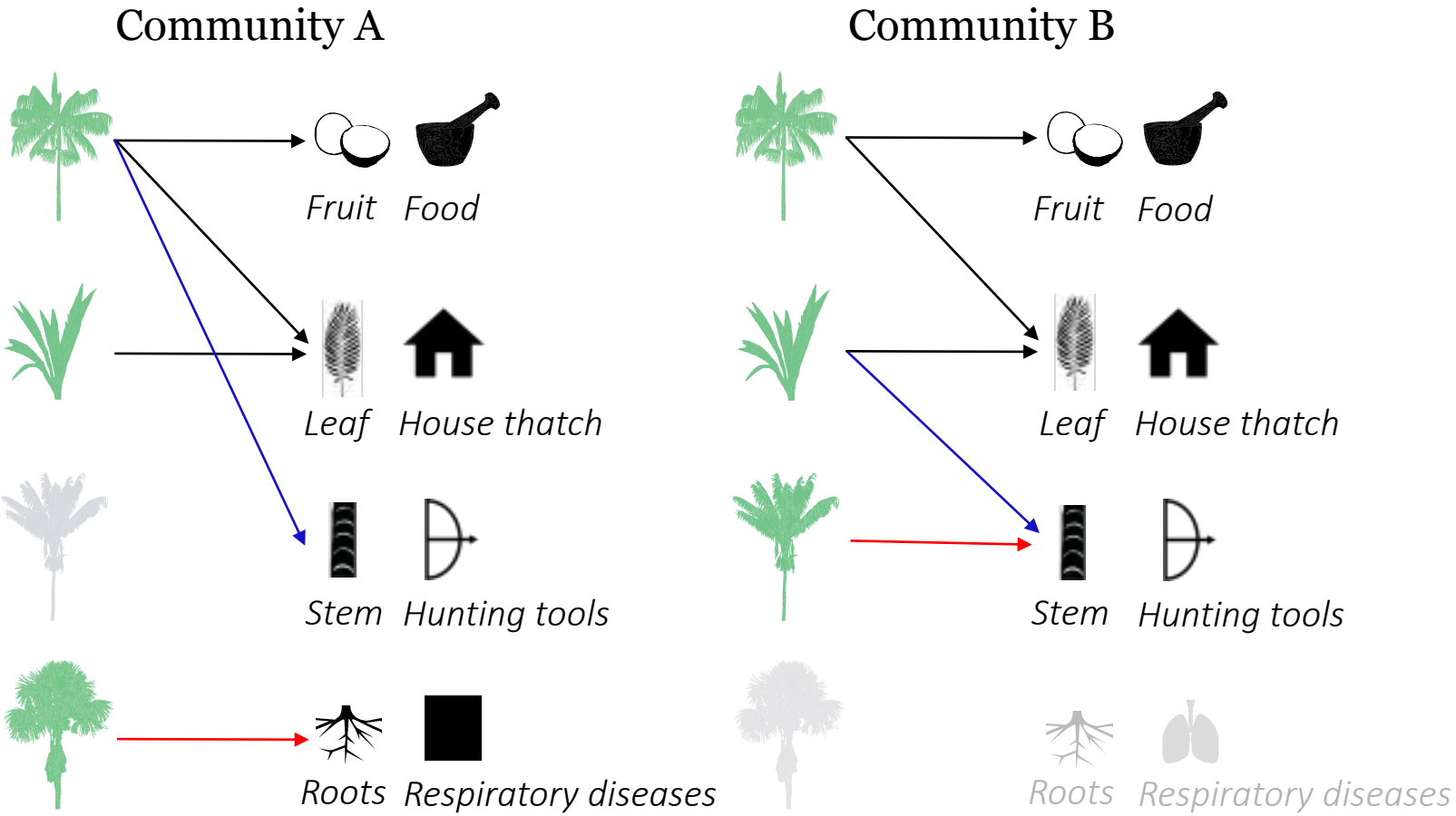
- **Indigenous knowledge (link) turnover: β_{cul}:**

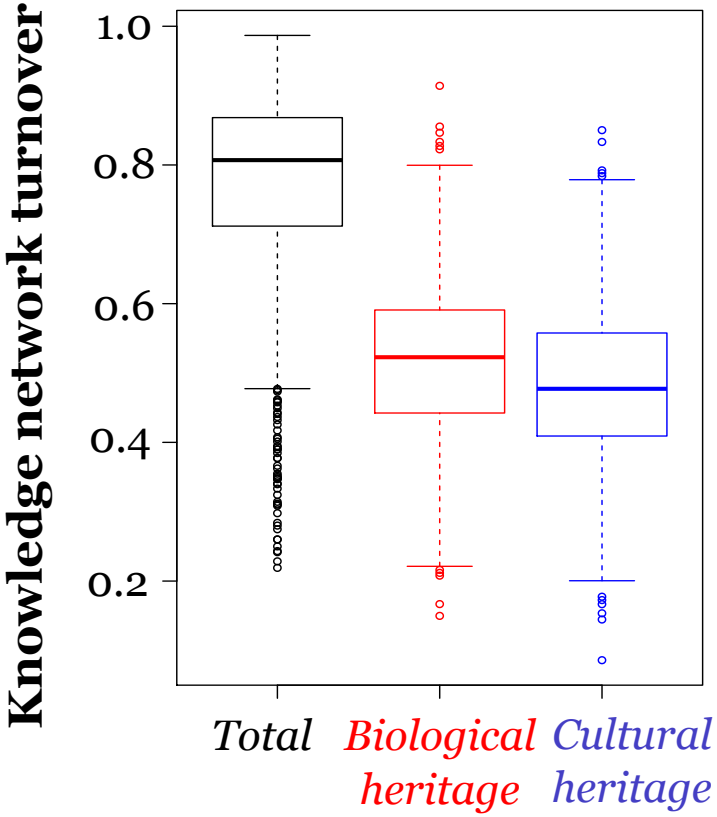
  Where differences in the presence/absence of links between plants that co-occur in both communities and the services they provide are a consequence of the cultural knowledge that one community, but not the other, has on the service that plant provides.

Relative importance of each component:

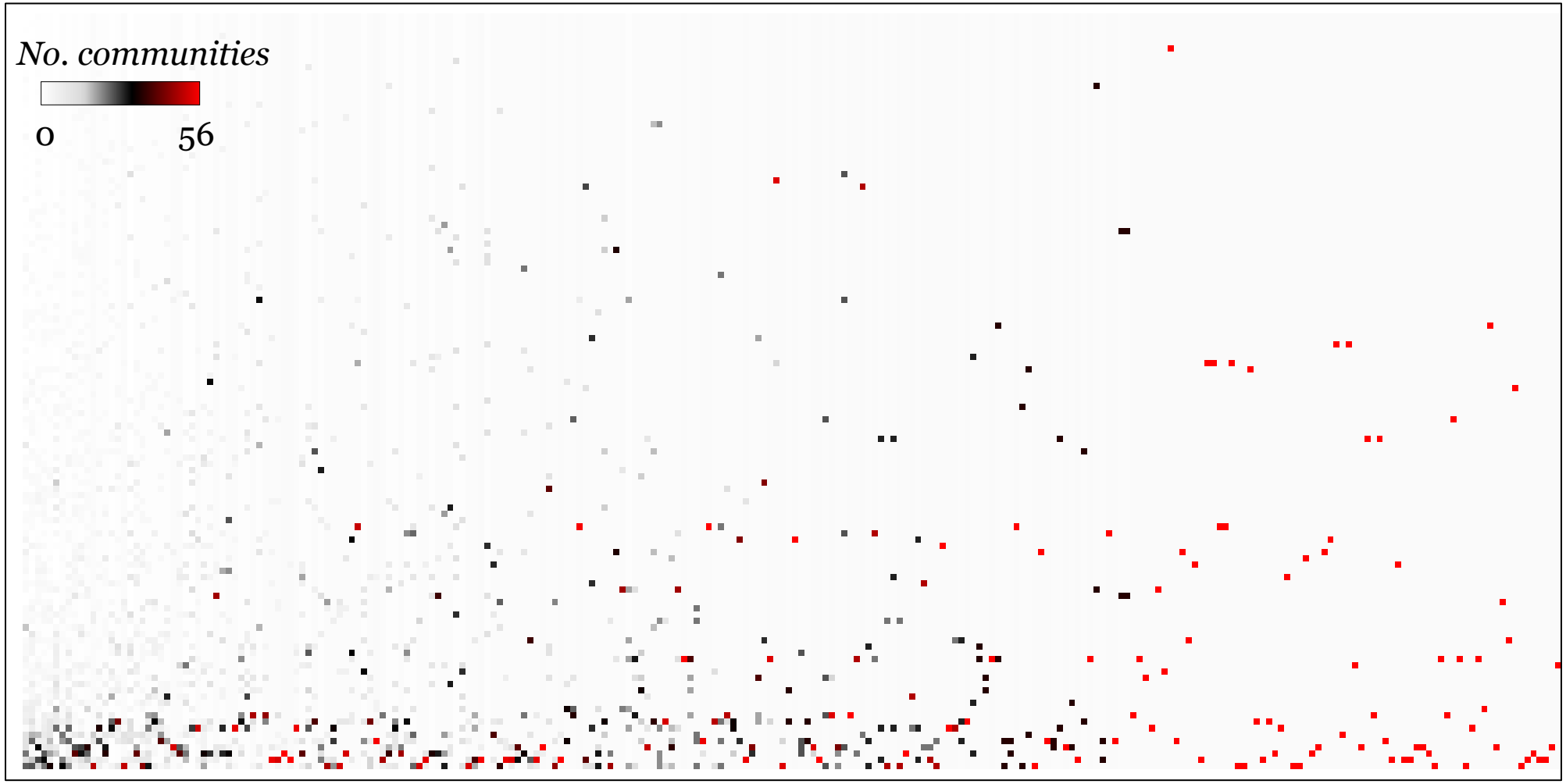
- Knowledge networks shaped by biological heritage: $\beta_{bio}/\ \beta \rightarrow 1$
- Knowledge networks shaped by cultural heritage: $\beta_{cul}/\ \beta \rightarrow 1$

The role of cultural and biological heritage

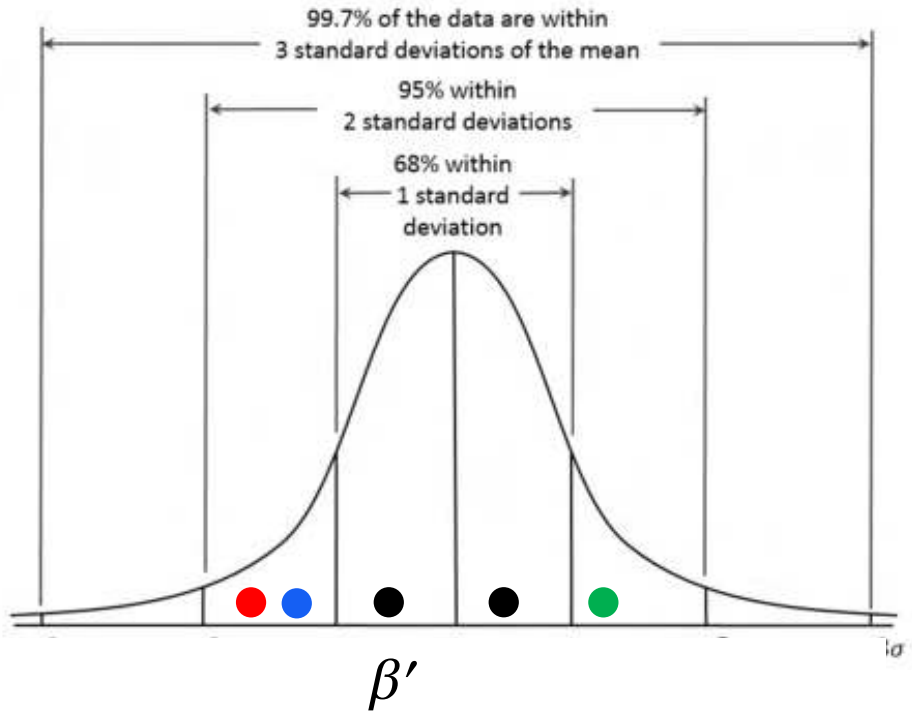


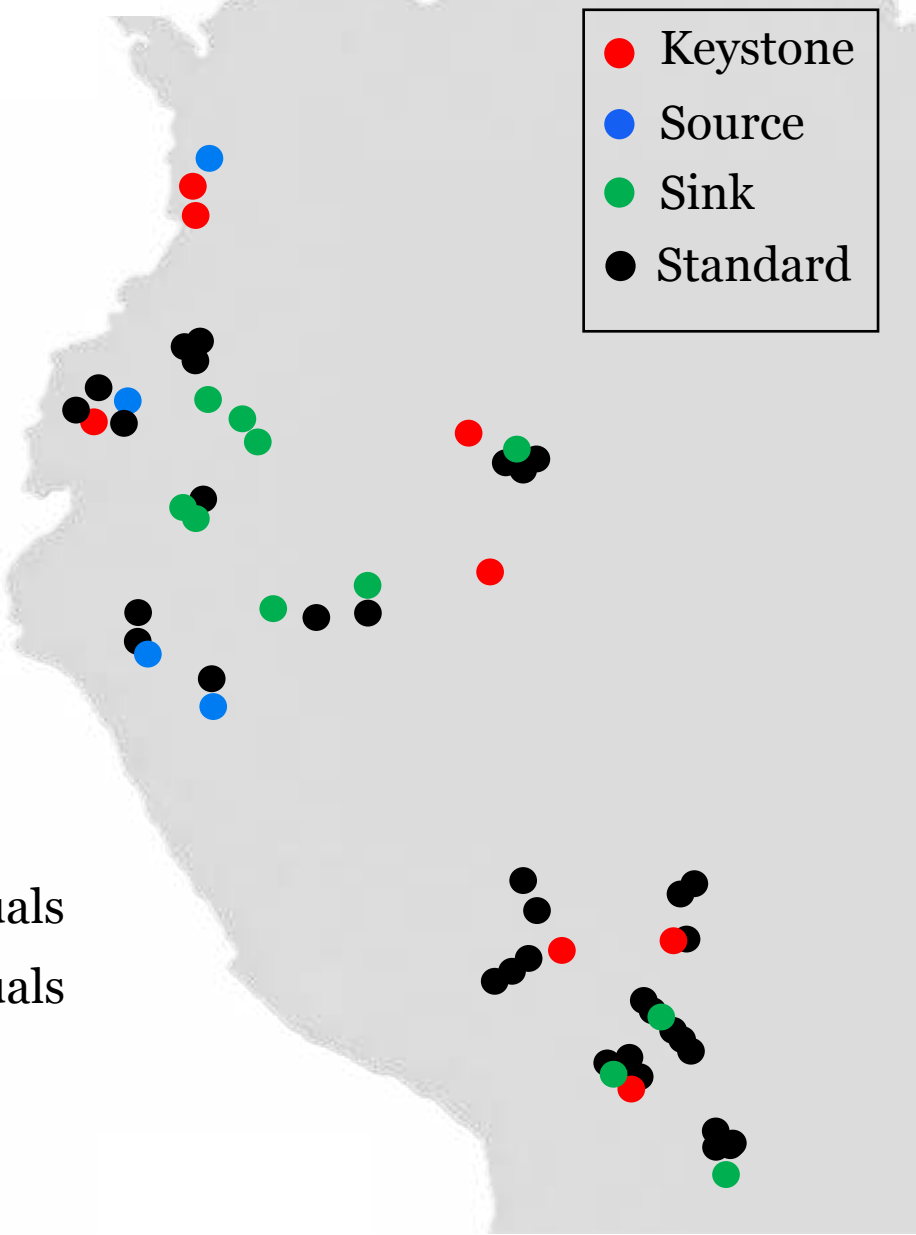


Indigenous knowledge metaweb



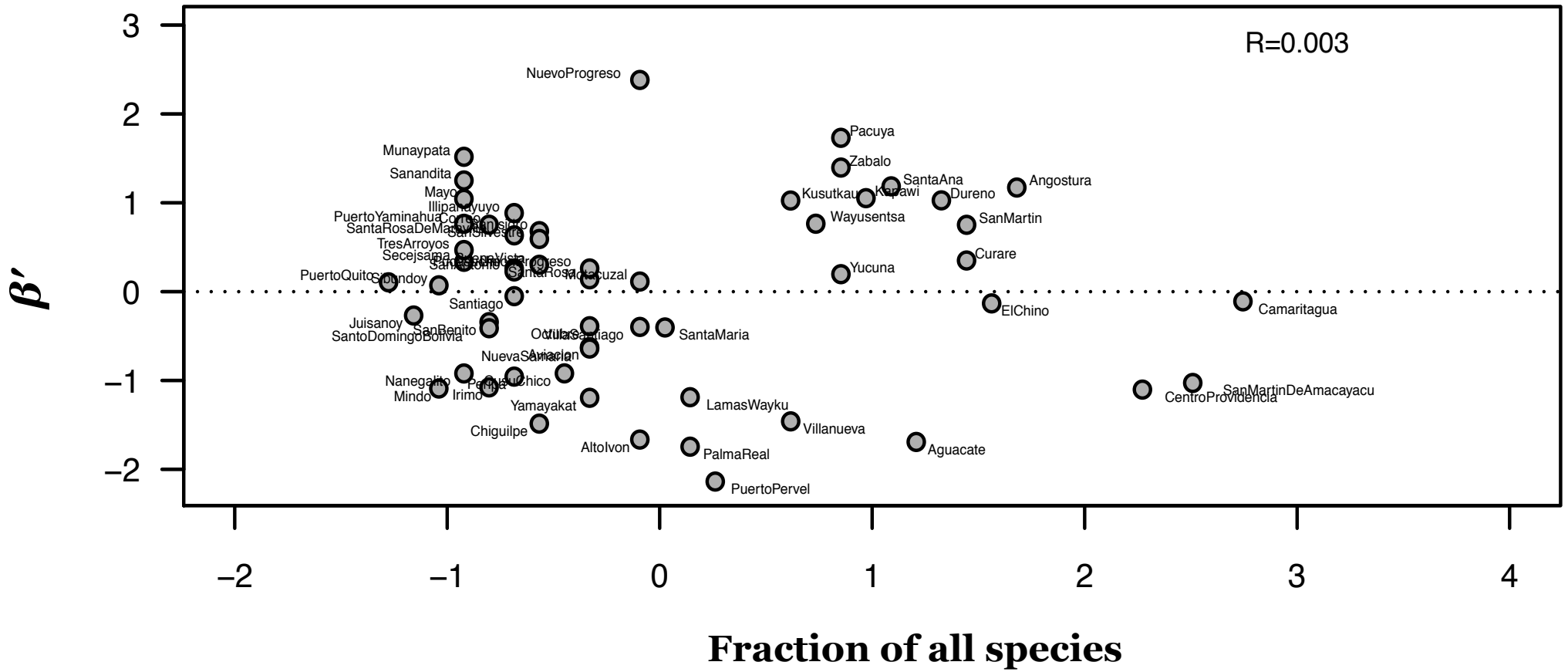
Community classification



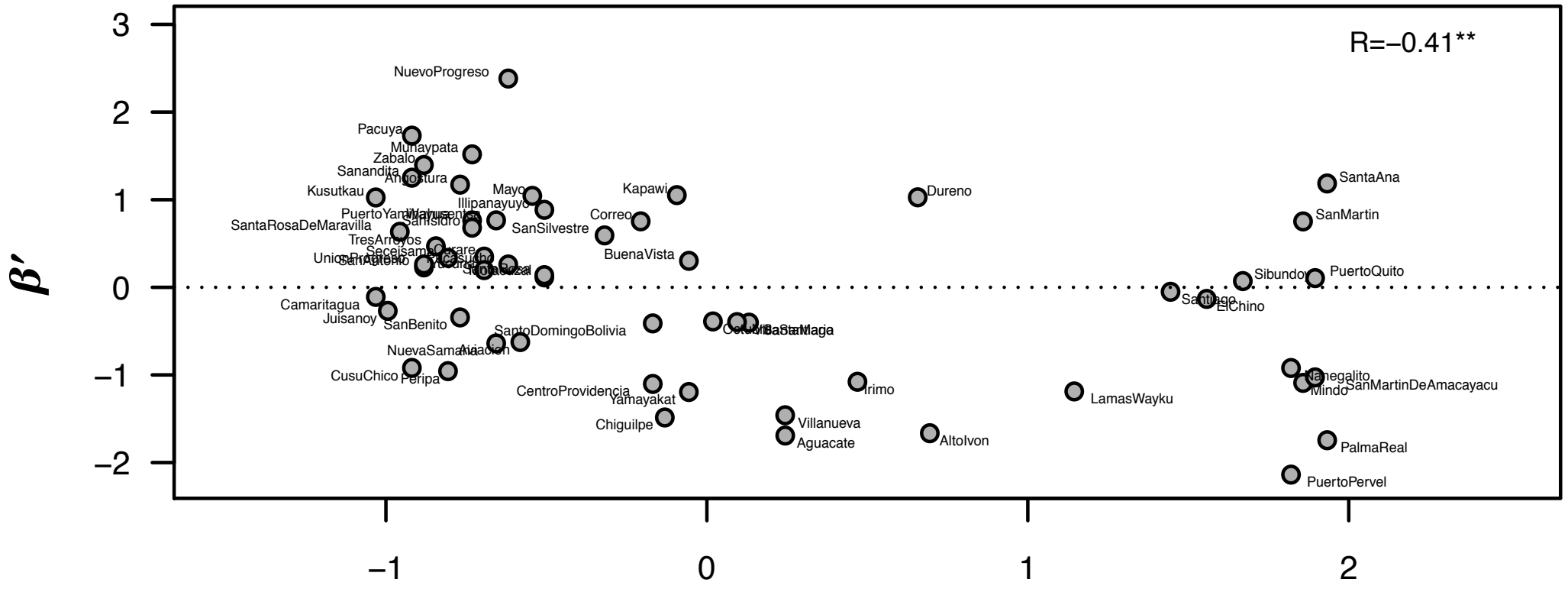


- **Keystone** βi′< 1 SD from mean β′ value & <500 individuals
- **Source** βi′< 1 SD from mean β′ value & >1,00 individuals
- **Sink** βi′> 1 SD from mean β′ value
- **Standard** βi′ within 1 SD from mean β′ value

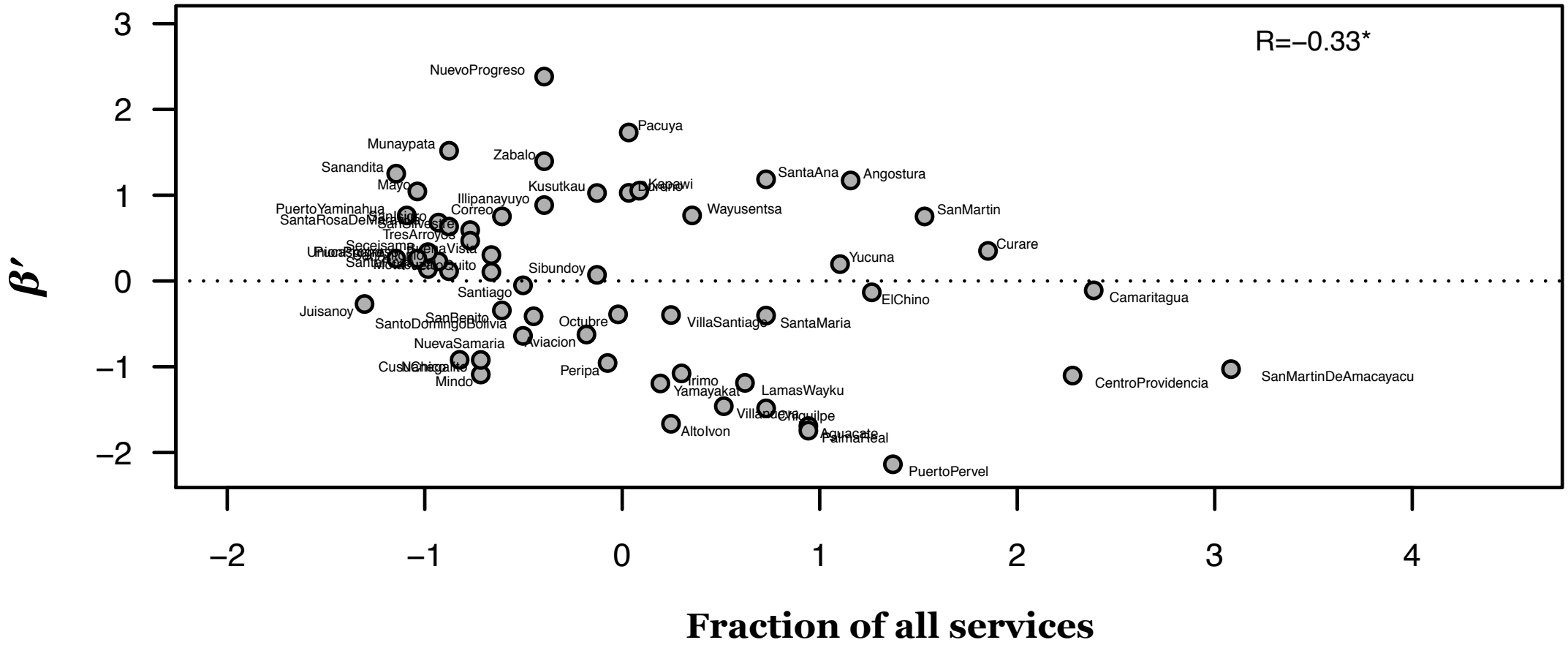
Correlates of β′



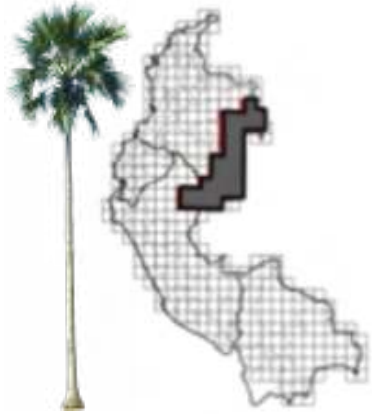
Correlates of β′

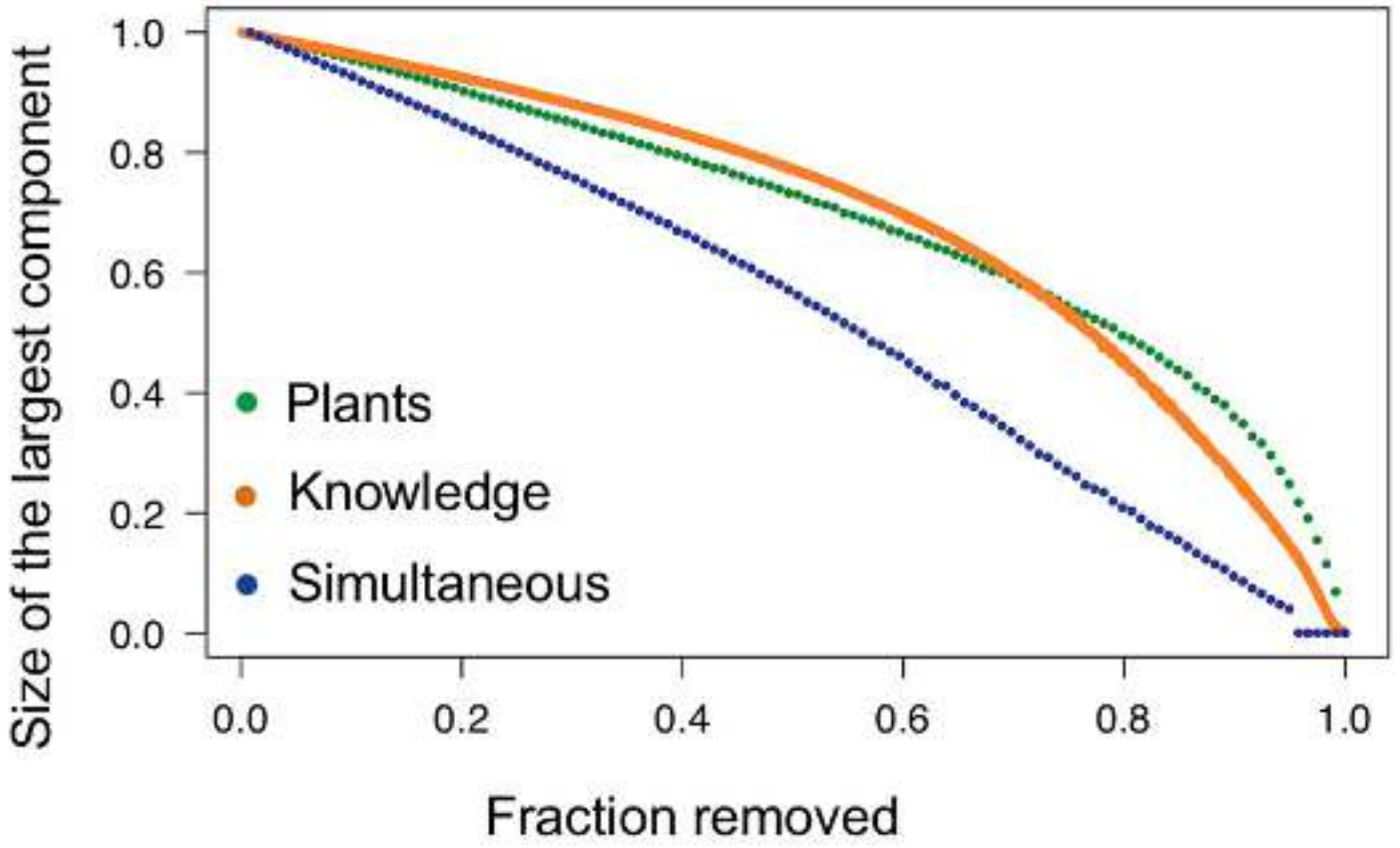


Correlates of β′



The loss of knowledge about nature's services





“Given the joint effects of plants and cultural heritage on the robustness of the indigenous knowledge metaweb, further studies linking both factors are important to maximize the conservation of nature’s contributions to people”

Multiplex social ecological network analysis reveals how social changes affect community robustness more than resource depletion

Jacopo A. Baggio[a], Shauna B. BurnSilver[b], Alex Arenas[c], James S. Magdanz[d], Gary P. Kofinas[d,e], and Manlio De Domenico[c,1]

Hypotheses:

1. Loss of specific households, social relations, core species, or entire species complexes will have similar effects on network robustness.
2. Targeted removals will have stronger negative effects than random removal on network robustness.

Baggio et al. (2016) *PNAS*

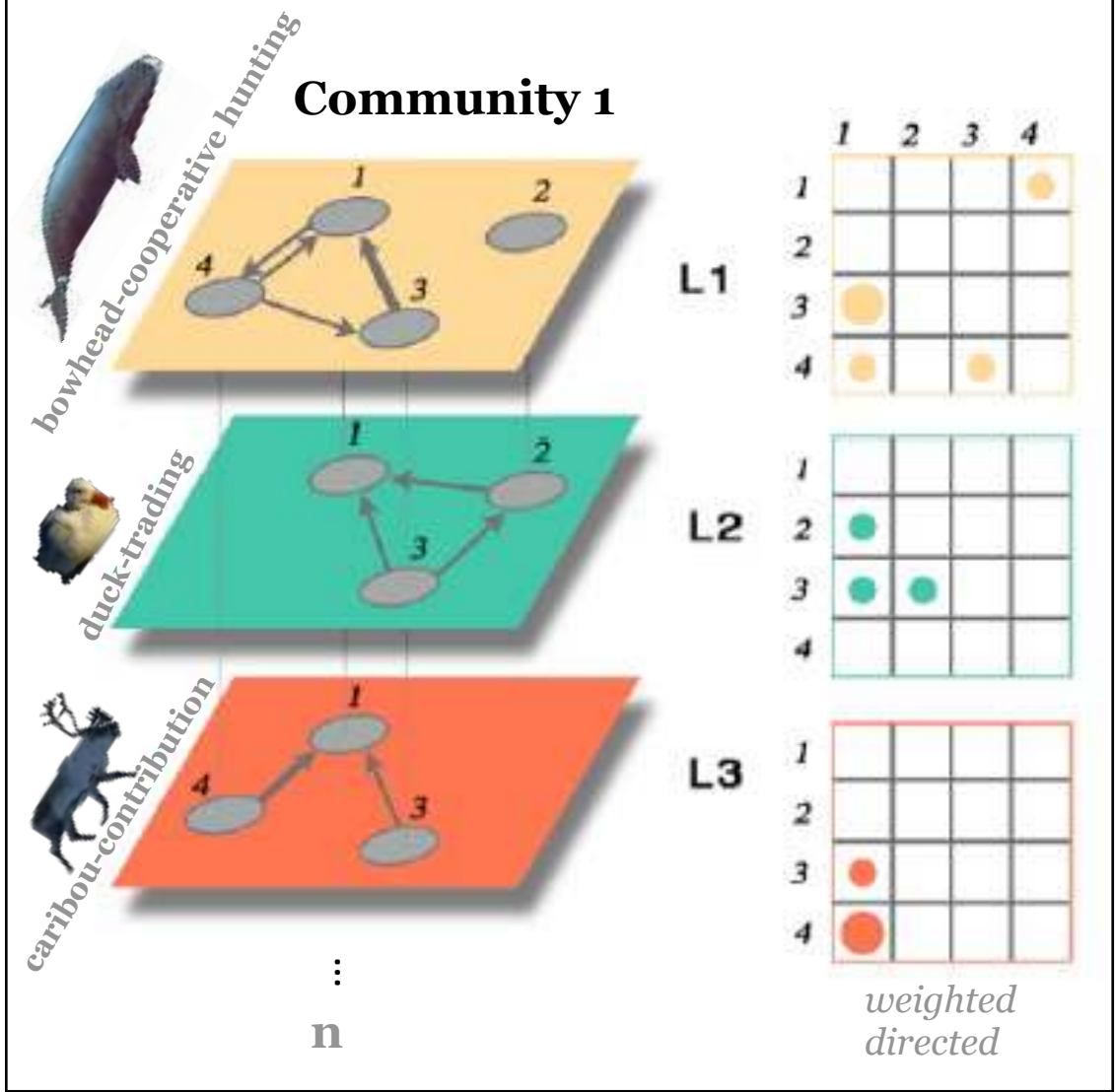
Multiplex networks

Households (n=218, 206, 164)

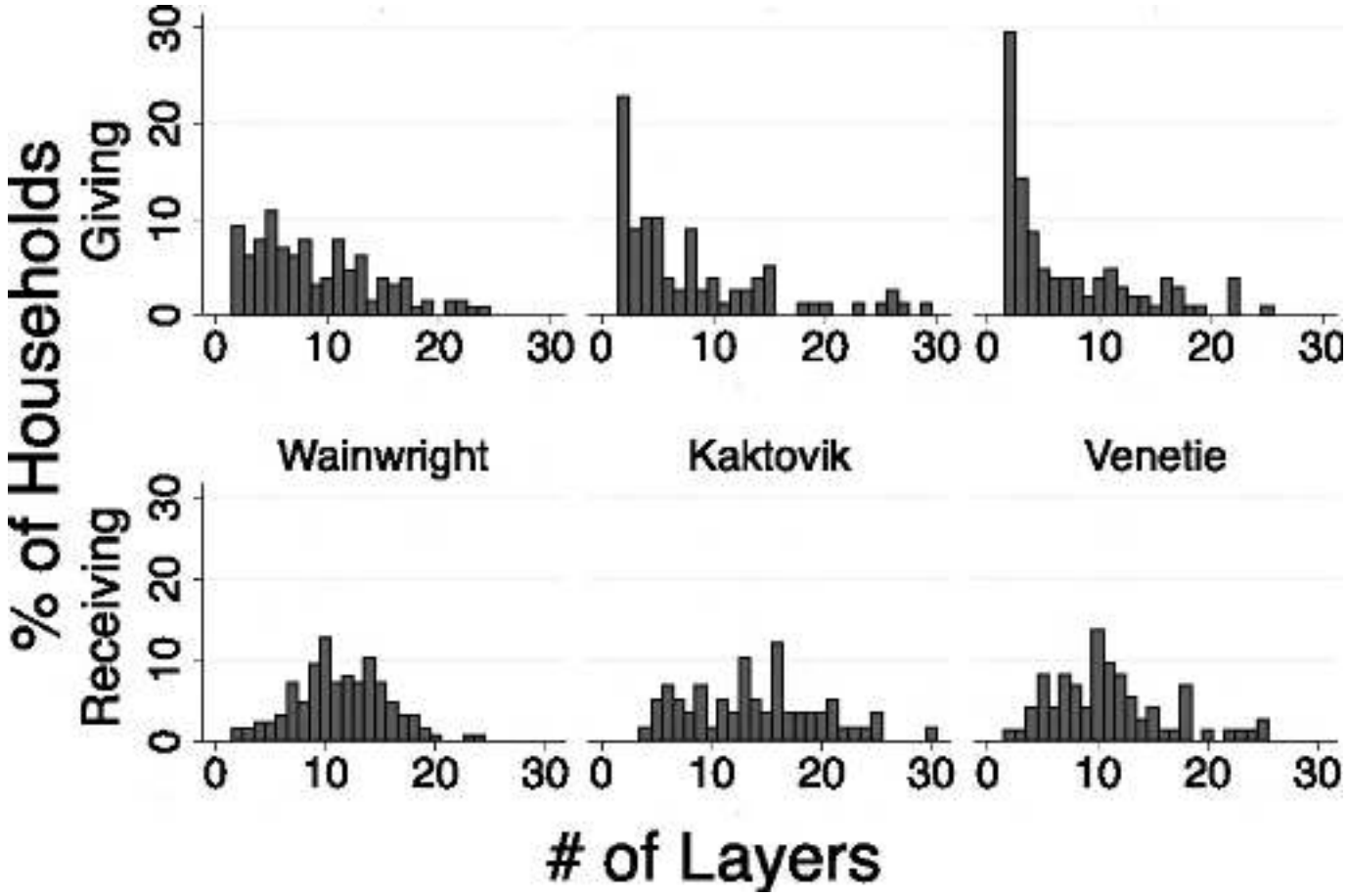
Various links show the weighted value of flows of an ecological resource obtained through a social relation:

Bowhead	+	Cooperative hunting
Duck		Trading
Caribou		Contribution
… (n=8)		…(n=12)

Unique combination of ecological resource and social relation (n=36, 37, 43)



Household's engagement in Giving-Receiving



Strongly Skewed

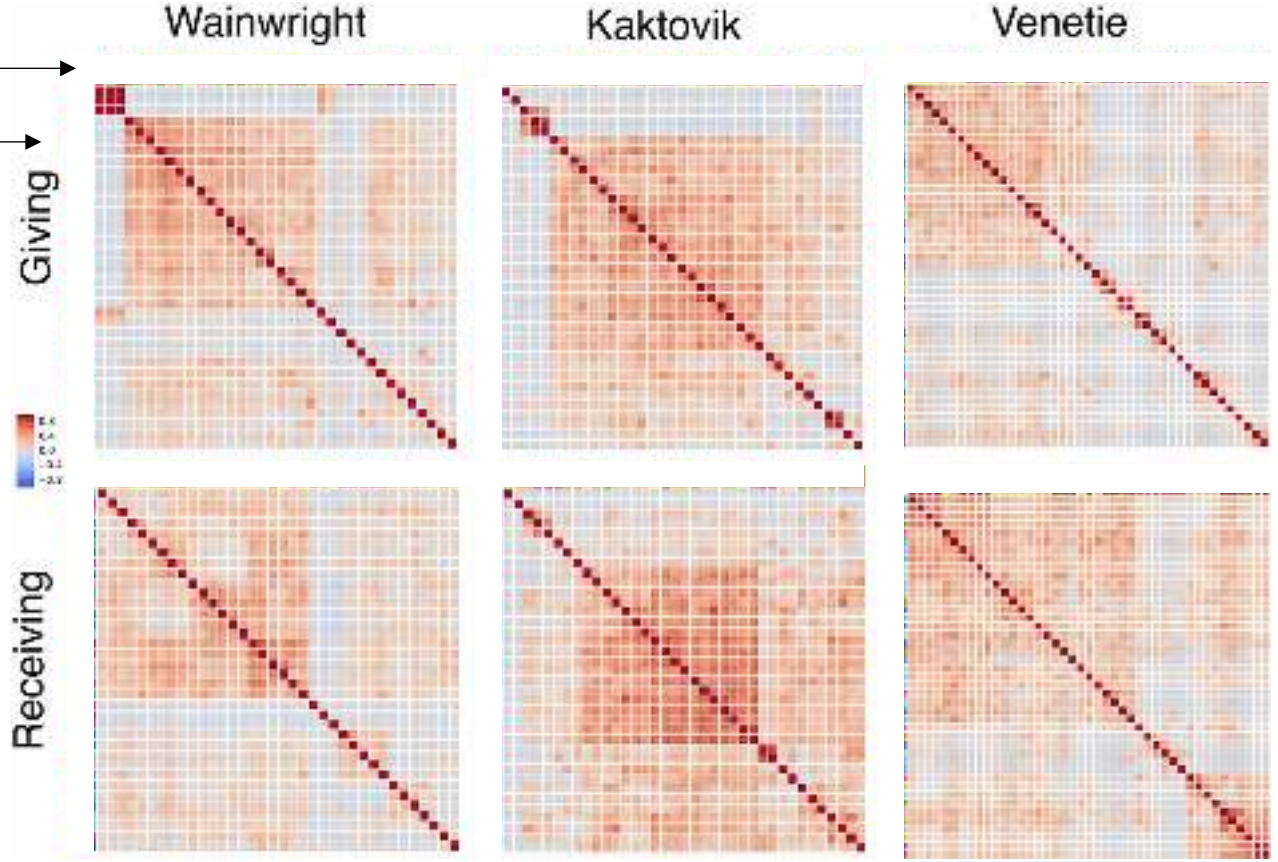
Normal or Uniform

Some households have less productive capacity (e.g., elder, disabled families), but all households may receive

Relations between different layers

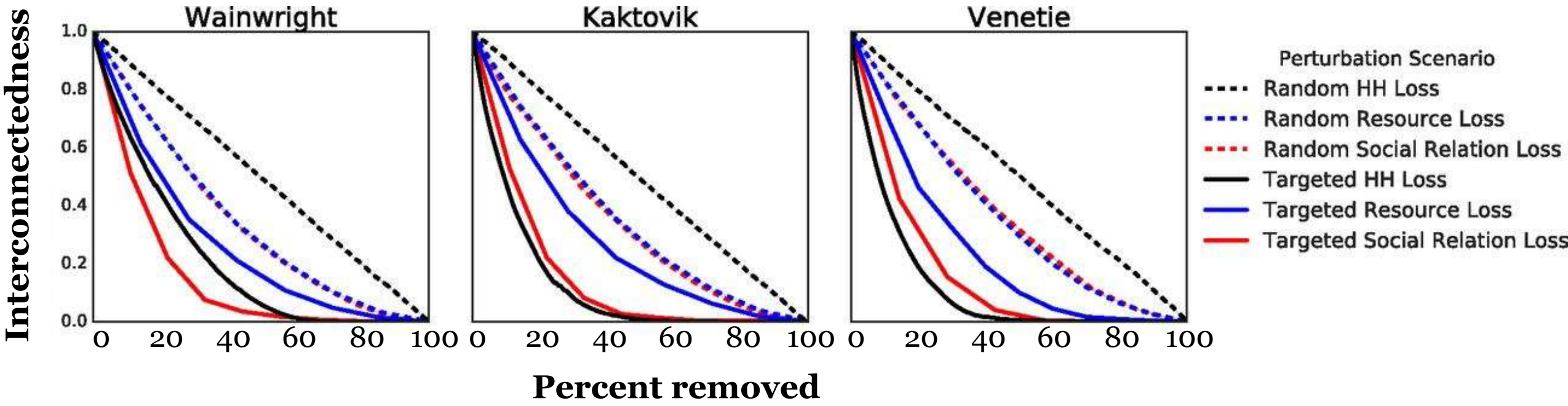
Social relations layers →

Species layers →



Layer	Giving %	Receiving %	Giving %	Receiving %	Giving %	Receiving %
Resources	28	29	11	20	39	37
Relations	**72**	**71**	**89**	**80**	**61**	**63**

Robustness of Arctic multiplex social networks



“Contrary to much of the focus on climate change, the loss of important social relations or of key households has greater effects on community interconnectedness than loss of core subsistence species”

Challenges for socio-ecological networks:

1. Incorporate nuanced environmental relationships (beyond presence/absence)
2. Explore multiple relationships and how they interact
3. Link SEN structures to environmental outcomes
4. Engage other human-environment issues beyond fit and collaboration, e.g., ecosystem services
5. Incorporate individual plants or animals as ecological nodes
6. Data on the strength of links

Sayles et al. *Environ. Res. Lett.* 14 (2019)

1 Socio-ecological networks

Rodrigo Cámara-Leret

session 6/04/2022

1.1 Indigenous knowledge networks

Today we will apply some of the network analyses used in the paper: R. Cámara-Leret, M. Fortuna & J. Bascompte (2019). Indigenous knowledge networks in the face of global change. PNAS: 116 (20) 9913-9918.

In contrast with previous exercises, today each network will be an indigenous knowledge network and we will use a dataset of 57 indigenous communities of South America. We can depict indigenous knowledge networks as bipartite graphs: nodes on one set represent plant species (in this case, of the palm family Arecaceae), nodes on the other set represent plant services, and a link connecting a plant species to a service indicates that the indigenous community knows that the plant provides them that service.

Let's begin by loading all the `R` packages we need for today:

rodrigo.camaraleret@ieu.uzh.ch

www.rcamaraleret.com

References

- Baggio, J. A *et al.* (2016). Multiplex social ecological network analysis reveals how social changes affect community robustness more than resource depletion. *PNAS 113*(48), 13708-13713.
- Bodin, Ö. & Tengö, M. (2012). Disentangling intangible social–ecological systems. *Global Env. Change*, *22*(2), 430-439.
- Bodin, Ö. (2017). Collaborative environmental governance: achieving collective action in social-ecological systems. *Science*, *357*(6352).
- Cámara-Leret, R., Fortuna, M. A., & Bascompte, J. (2019). Indigenous knowledge networks in the face of global change. *PNAS 116*(20), 9913-9918
- Colding, J. & Barthel, S. (2019). Exploring the social-ecological systems discourse 20 years later. *Ecology and Society*, *24*(1).
- Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325* (5939), 419-422.
- Sayles, J. S. *et al.* (2019). Social-ecological network analysis for sustainability sciences: a systematic review and innovative research agenda for the future. *Environmental Research Letters*, 14(9), 093003.