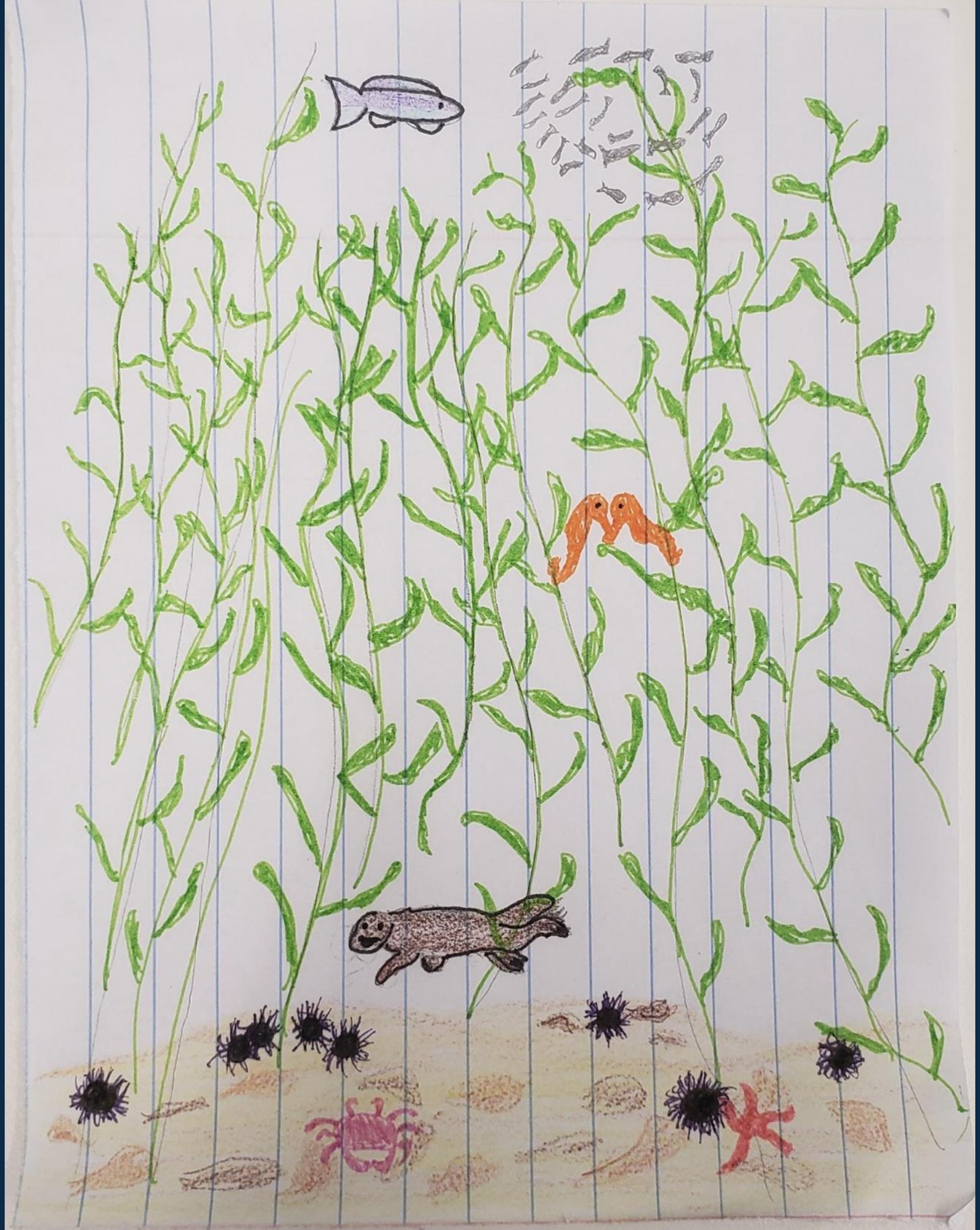
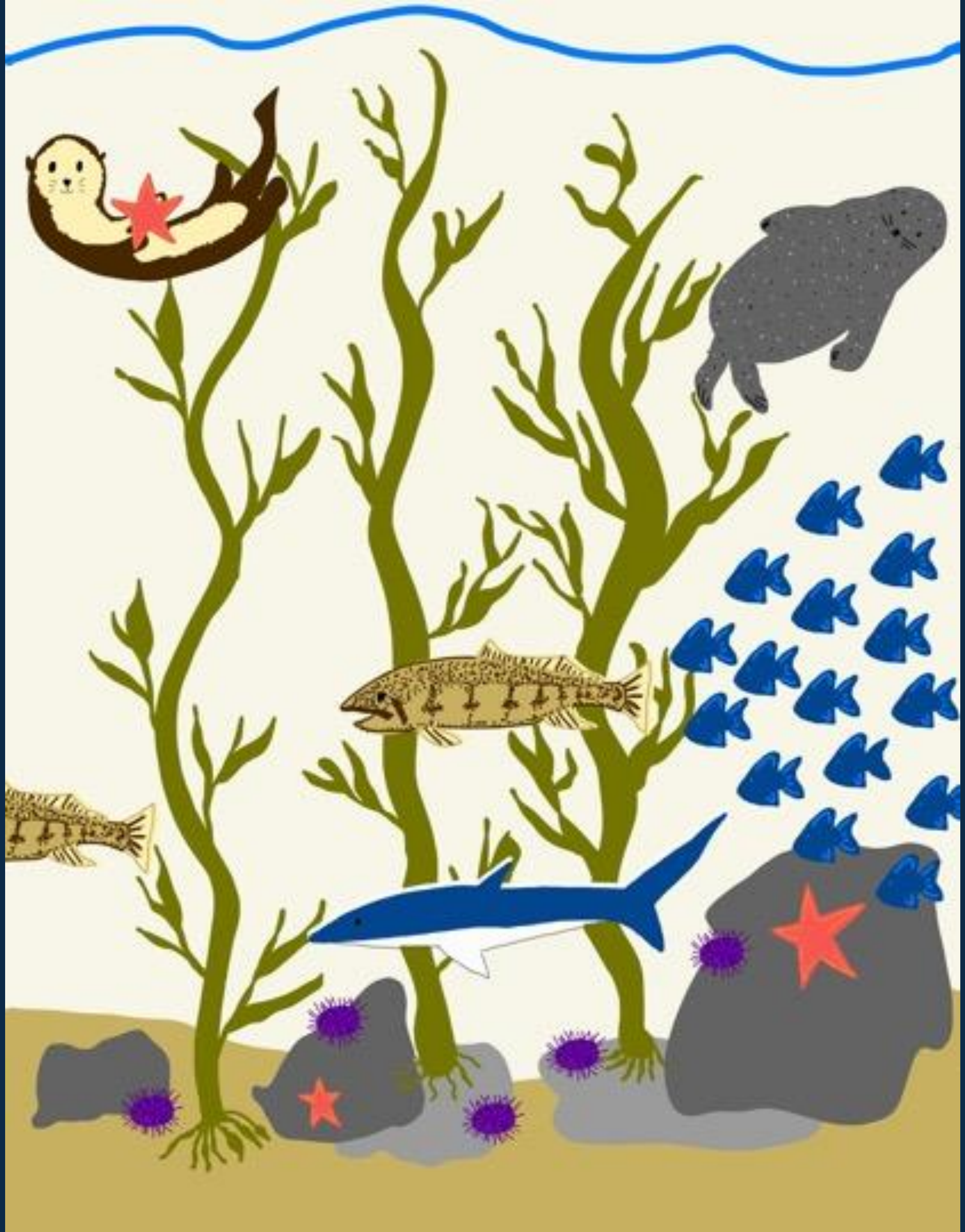
A brief overview and history of community ecology

ART GALLERY

Natalie



Daniel



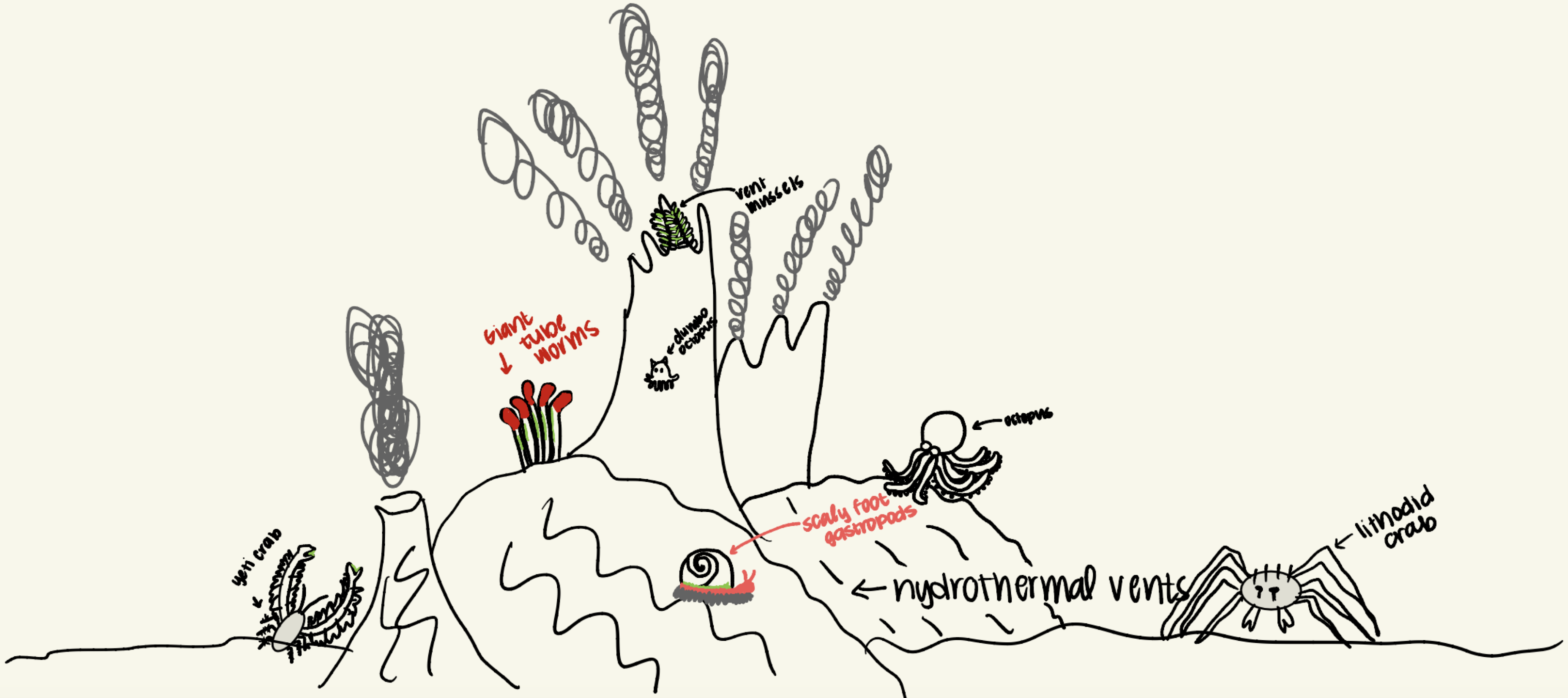
Claire

Bailey

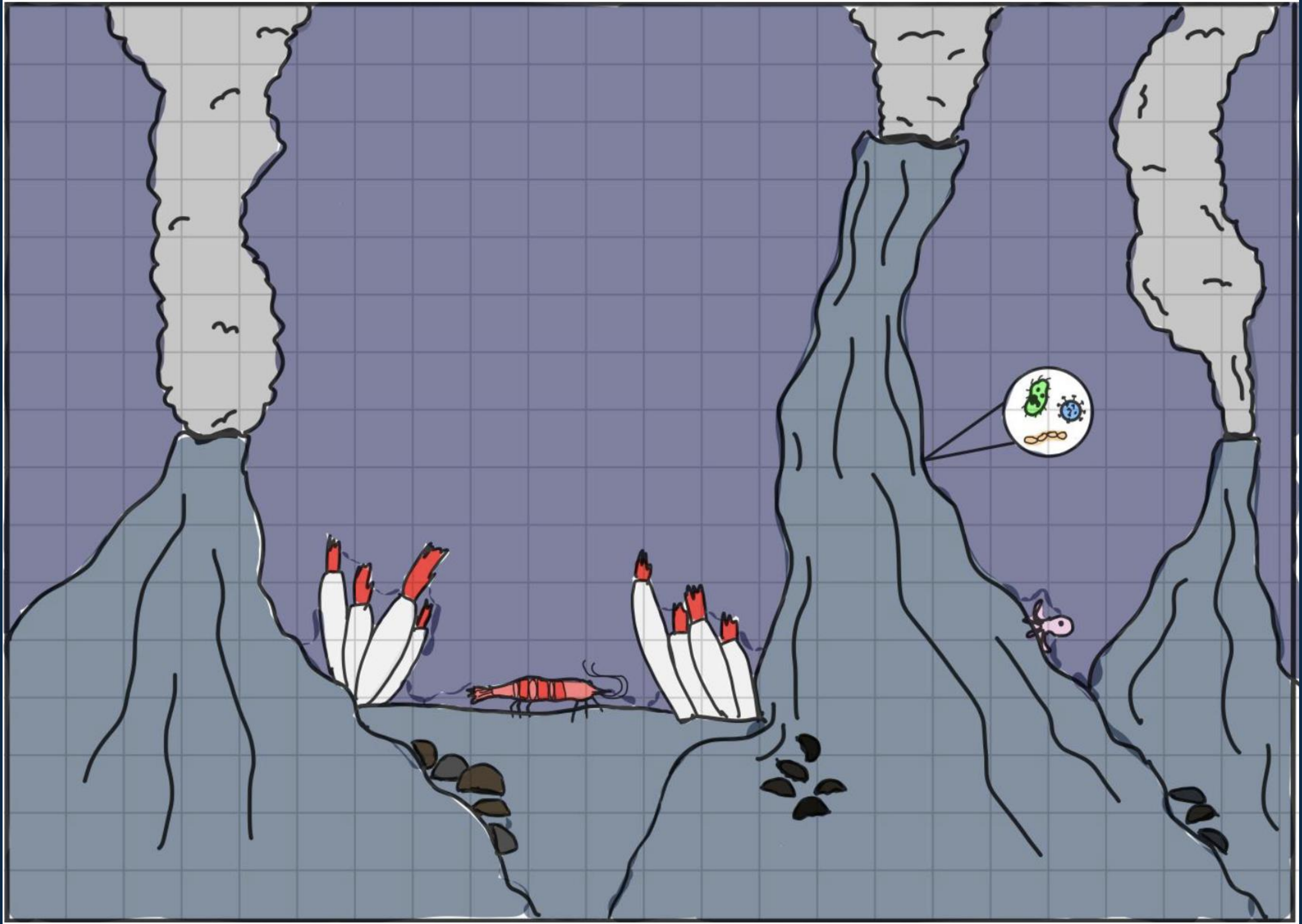
Izzy

mns 352 Jessica Urias-Quiroz Jau443

Deep Sea Vents Community

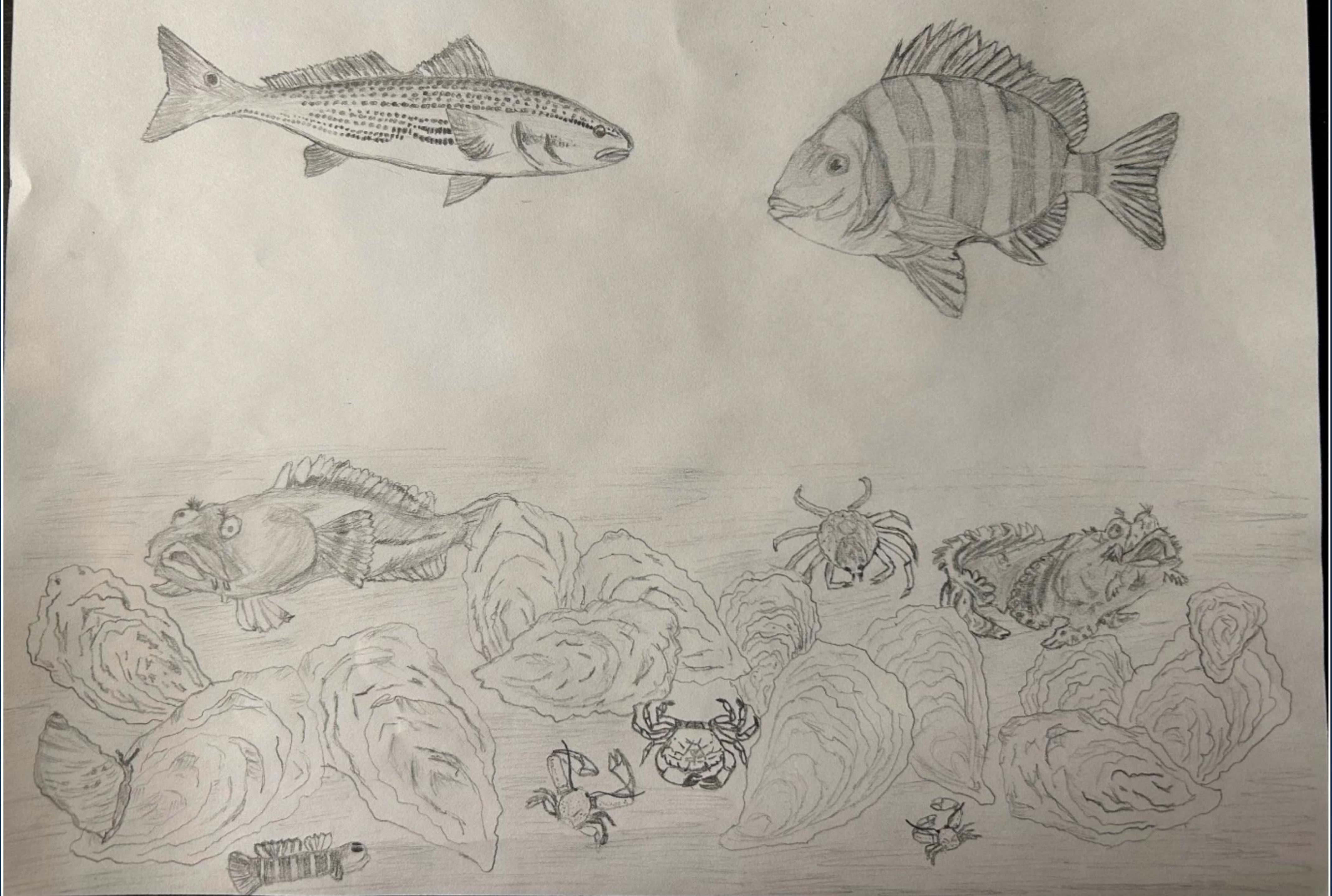


Jessica

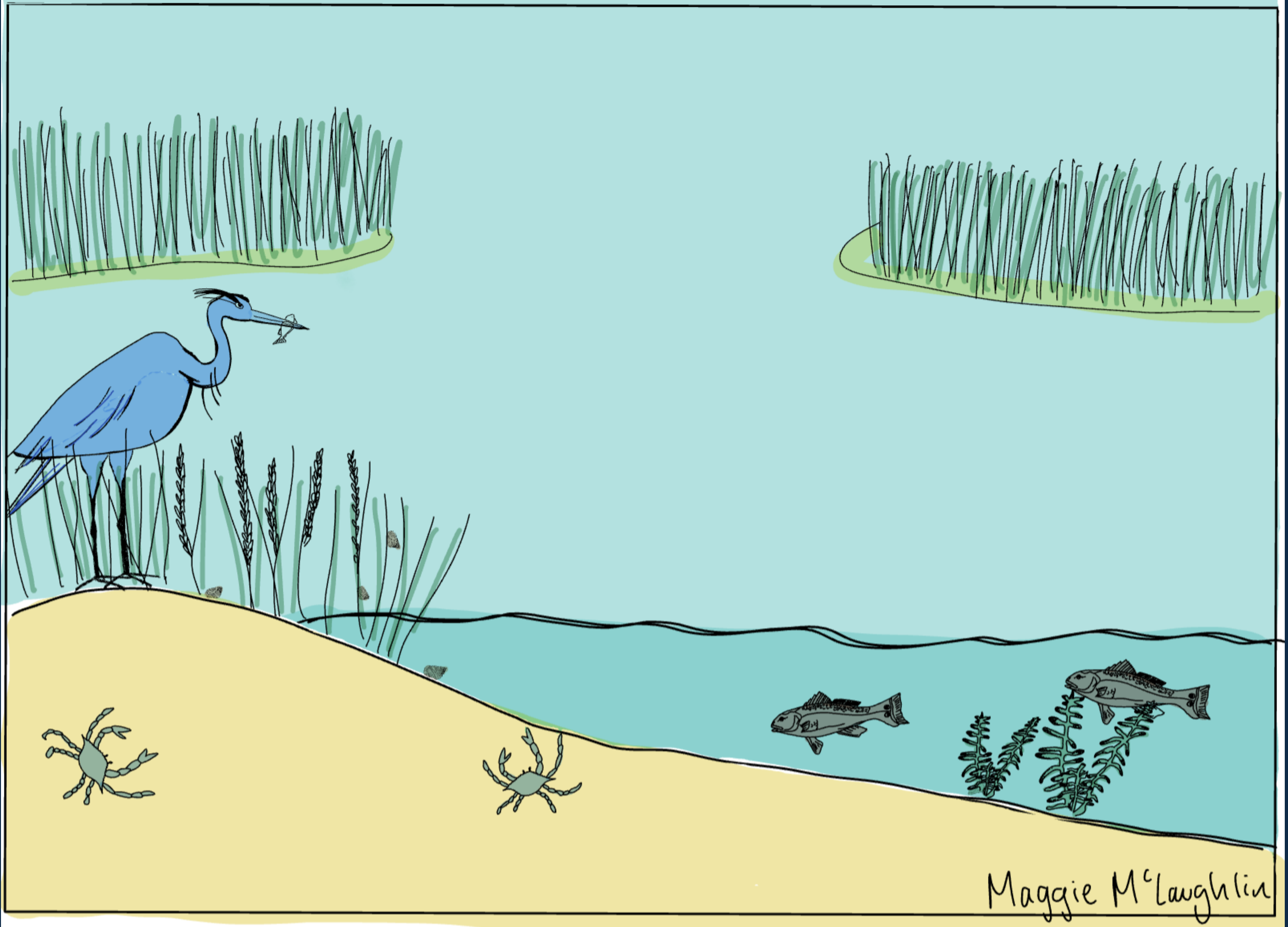


Payton

Lauren

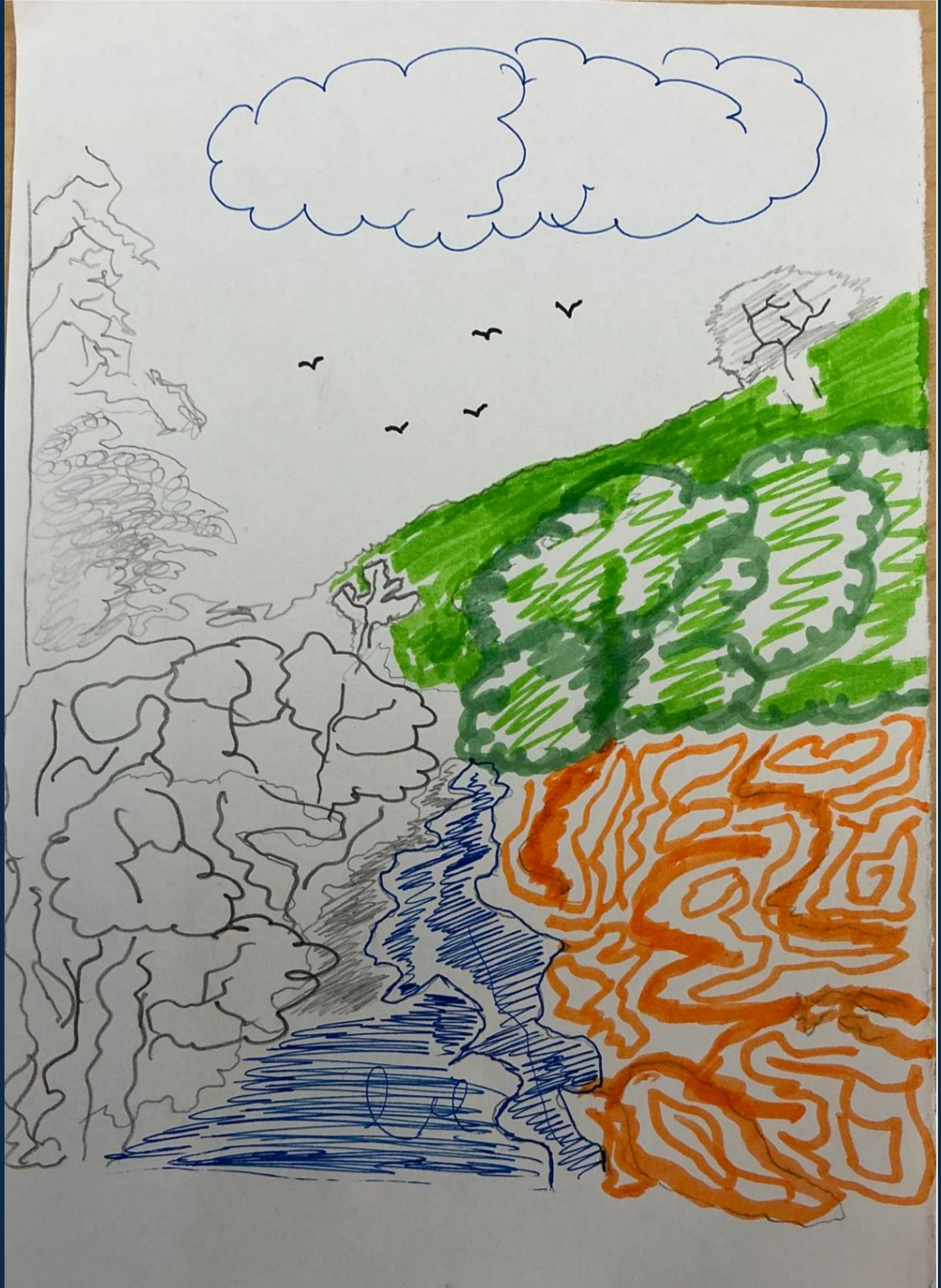


Marissa



Maggie

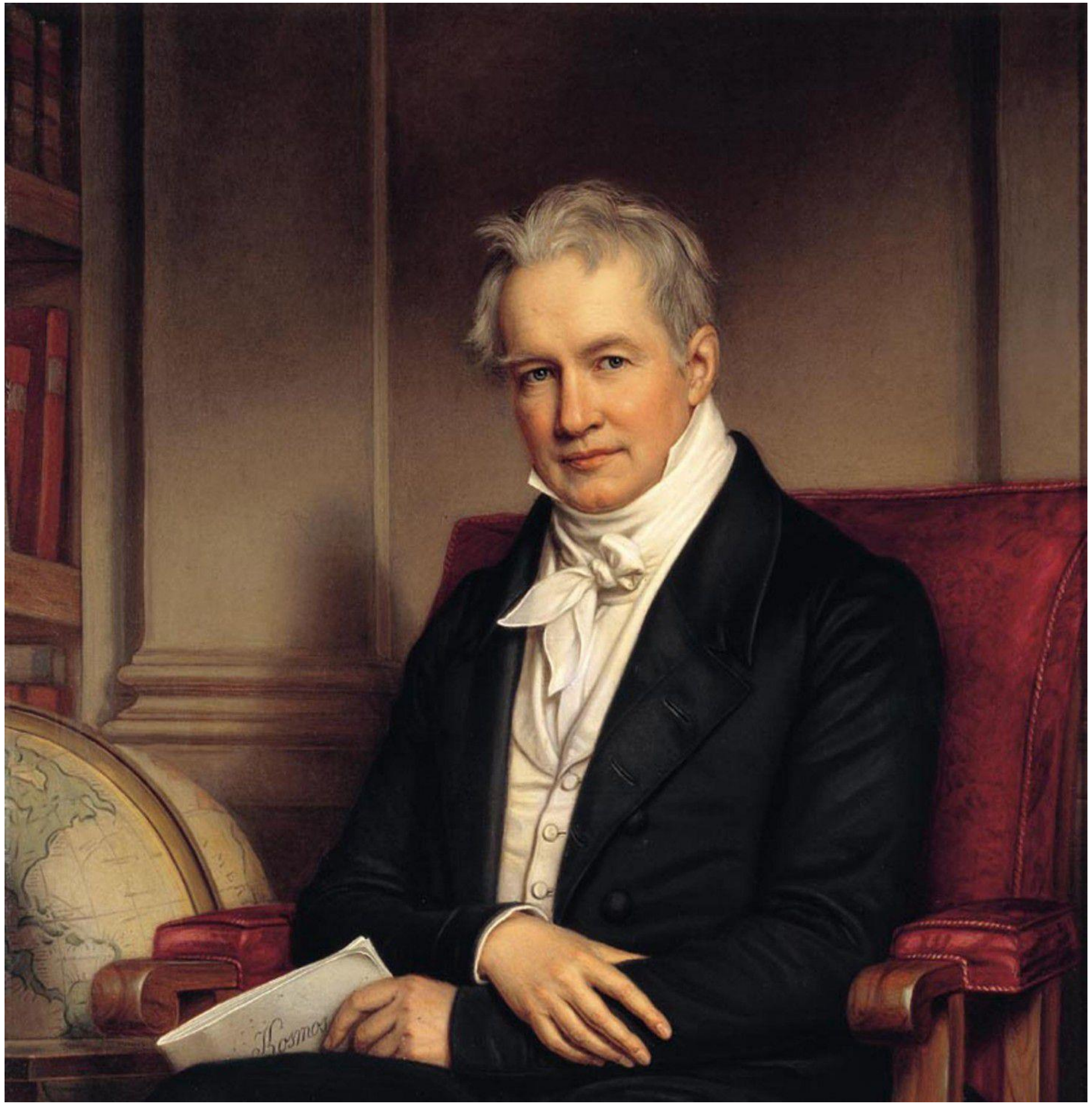
Fiorella

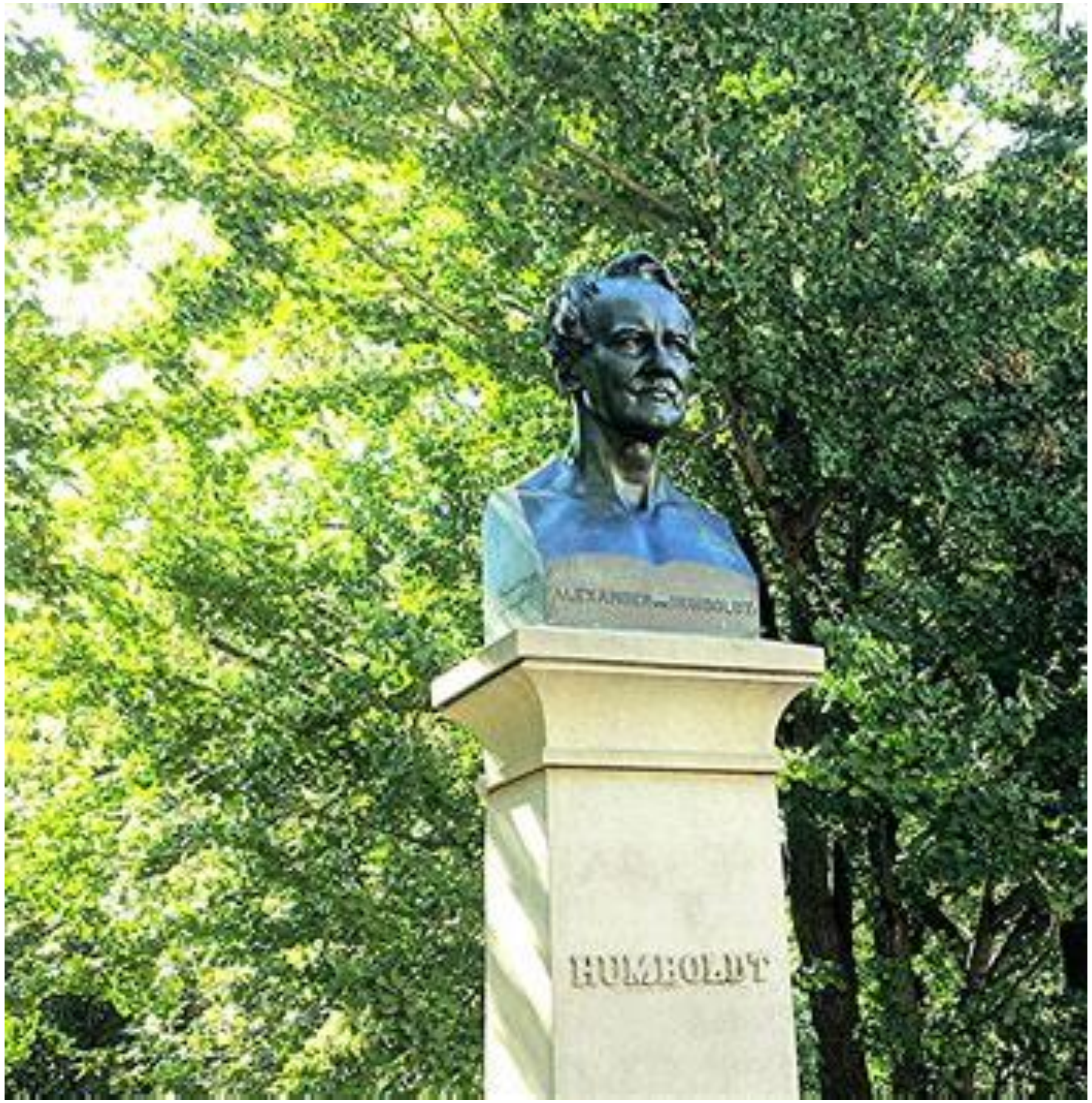


JP

Kathryn

Alexander




HUMBOLDT

Geographie der Pflanzen in den Tropen-Ländern;

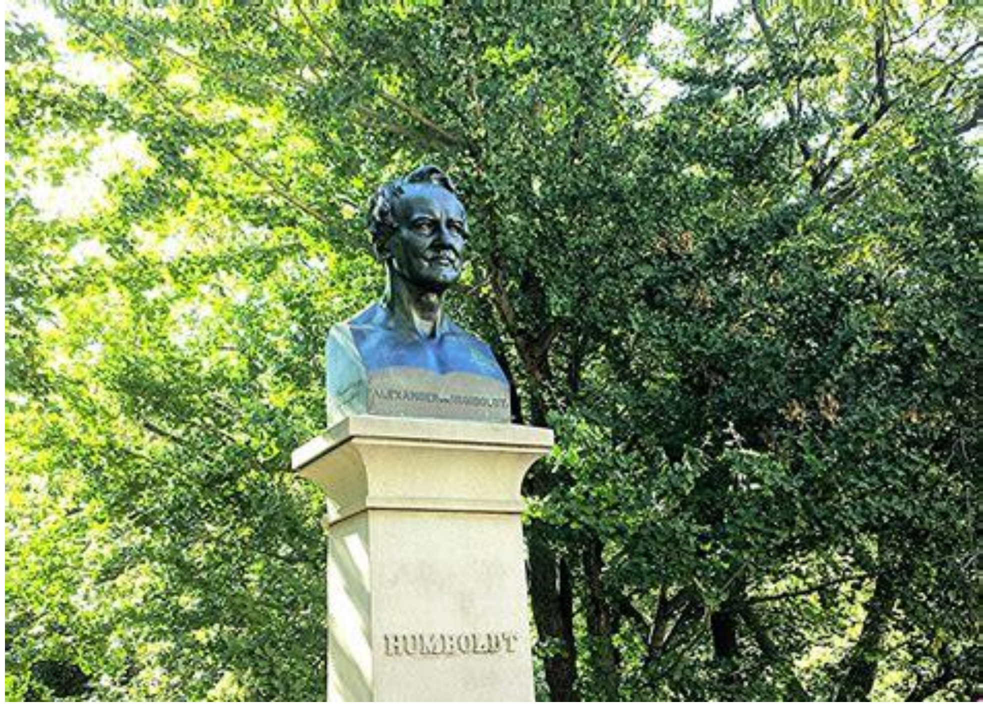
ein Naturgemälde der Anden,

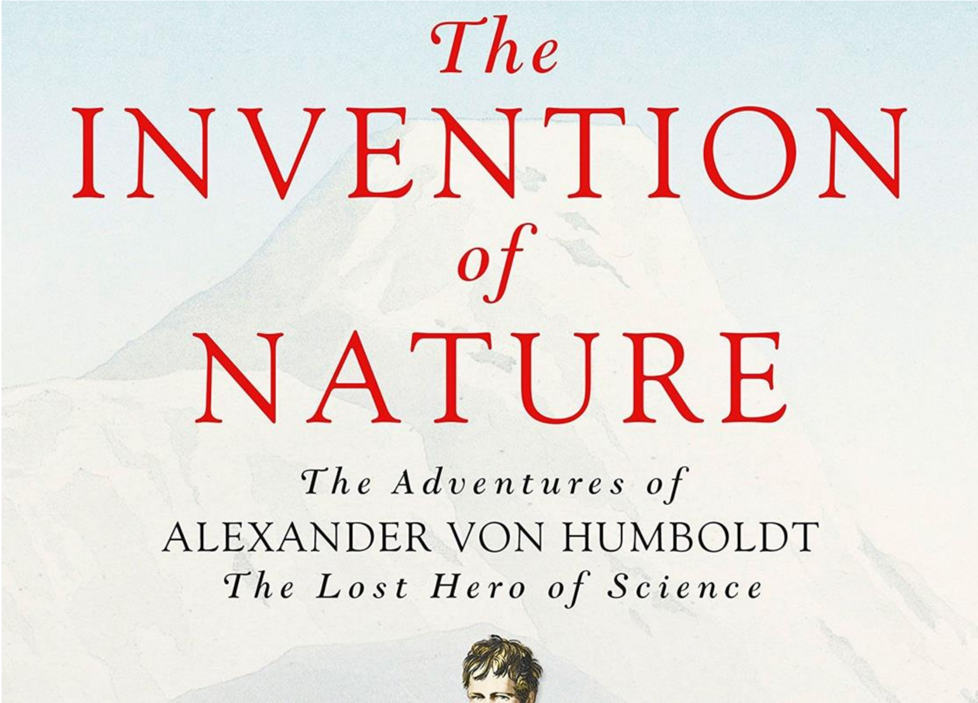
gegründet auf Beobachtungen und Messungen, welche vom 10^ten Grade nördlicher bis zum 10^ten Grade südlicher Breite angestellt worden sind, in den Jahren 1799 bis 1803.

von ALEXANDER VON HUMBOLDT und A. G. BONPLAND.



4000m bis 4900m
Dactylis
Agrostis
Region der Gräser (Pajonal)
von 4100m bis 4600m
Avena nival
Juncus
Bromus
Panicum
Lobelia nana
Stipa
Melica
Gentiana
Valeriana quit
Potentilla and
Jarava
Sida glac
Plantago pygm
Espeletia fraılexon
Saxifraga
Oenothera
Lupinus
Region der Chuquiraga, der Gentianen u. der
Frailexon, von 2000m bis 4100m
Ranunculus Gusmani
Azorella
Gruppen von baumar-
tigen Syngenesen
am Pichincha
Tussilago
Molina
Swertia quadric
Sida pichinch
Basella niv
Grenze der letzten baumartigen Pflan
Stellaria
Weissia
Melast
Geranium
Pourretia
Baccharis
Aster Mutisii
Wintera granat
Espeletia frailex
Melast. u. viel. Blumen
Wintera u. der
(Paramo)
Perdicium
Acæna elongata
Weinmannæ
Swertia quadr
Pitcarnia
emarginatum


HUMBOLDT


The
INVENTION
of
NATURE
The Adventures of
ALEXANDER VON HUMBOLDT
The Lost Hero of Science

"…physics, geology, earth science, botany, geography, zoology, climatology, oceanography, and astronomy"

"Everything is connected"

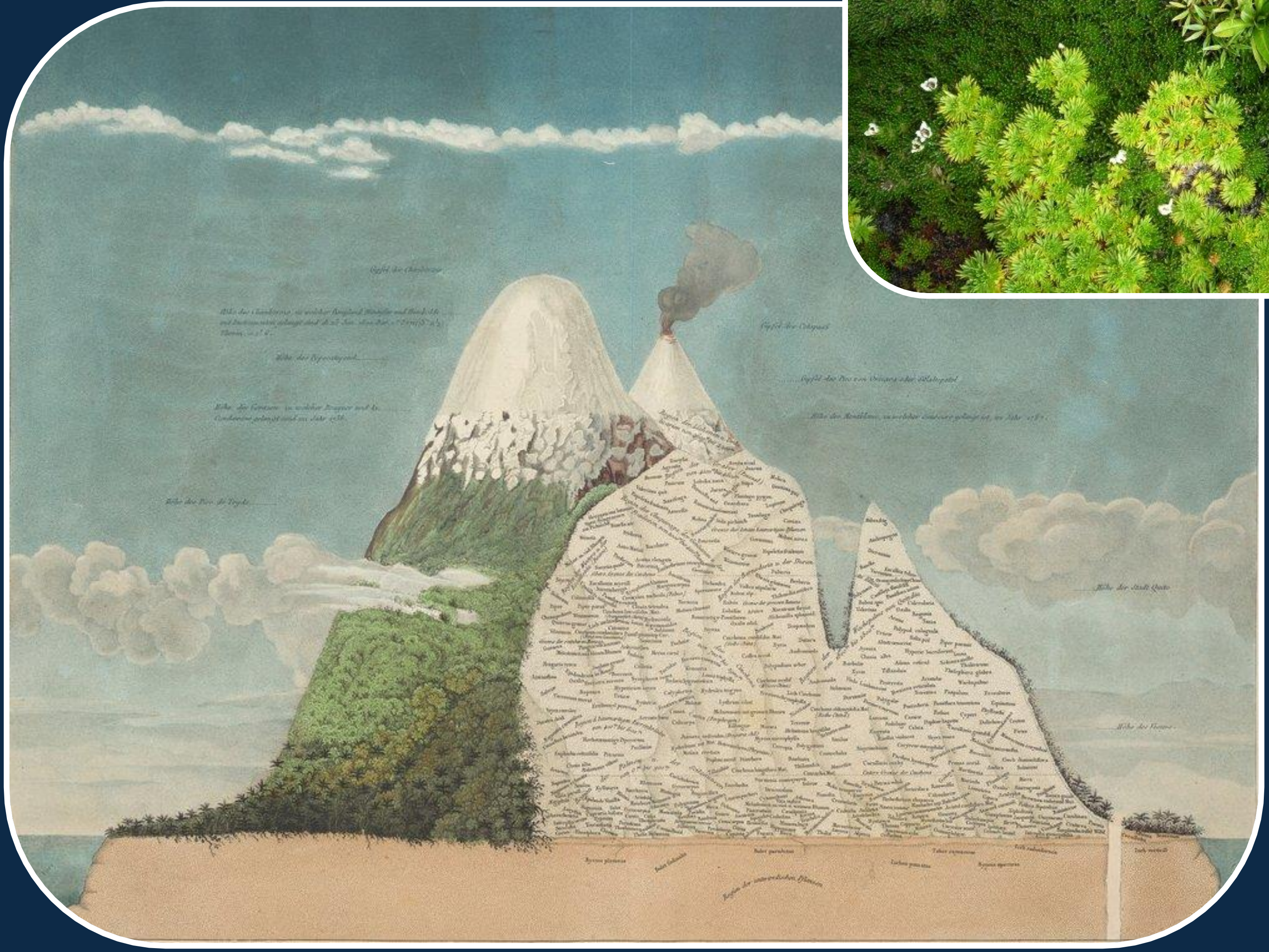
What is a community?

Plant01 Plant02 Plant03

Plant04 Plant05 Plant06

Plant07 Plant08 Plant09

Plant10 Plant11 Plan12



Local

Regional

Global

QUANTIFYING ECOLOGICAL COMMUNITIES

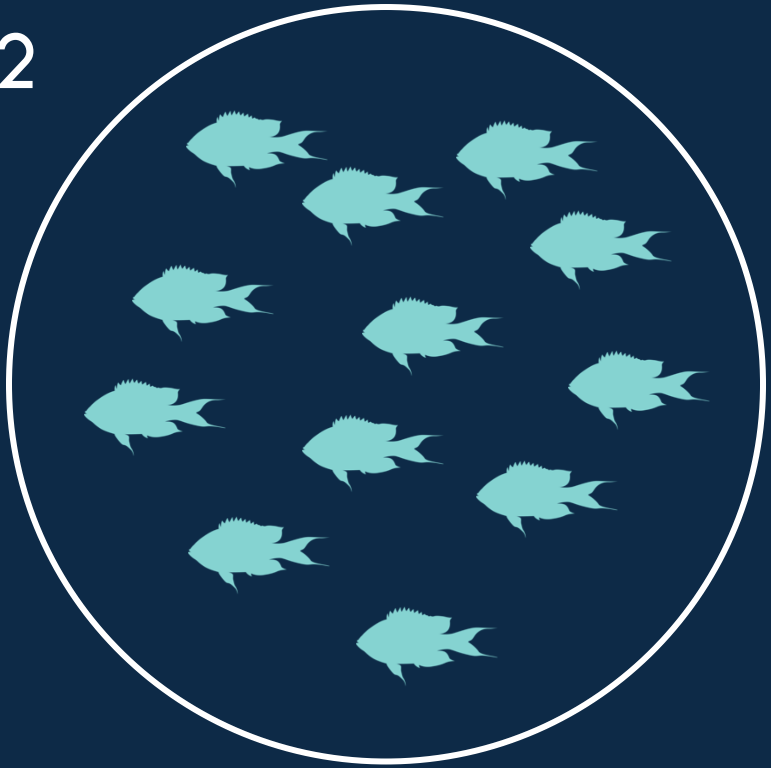

Tāne Sinclair-Taylor
Expedition Photographer


Tāne Sinclair-Taylor
Expedition Photographer

First order properties: single communities

Community 1

12

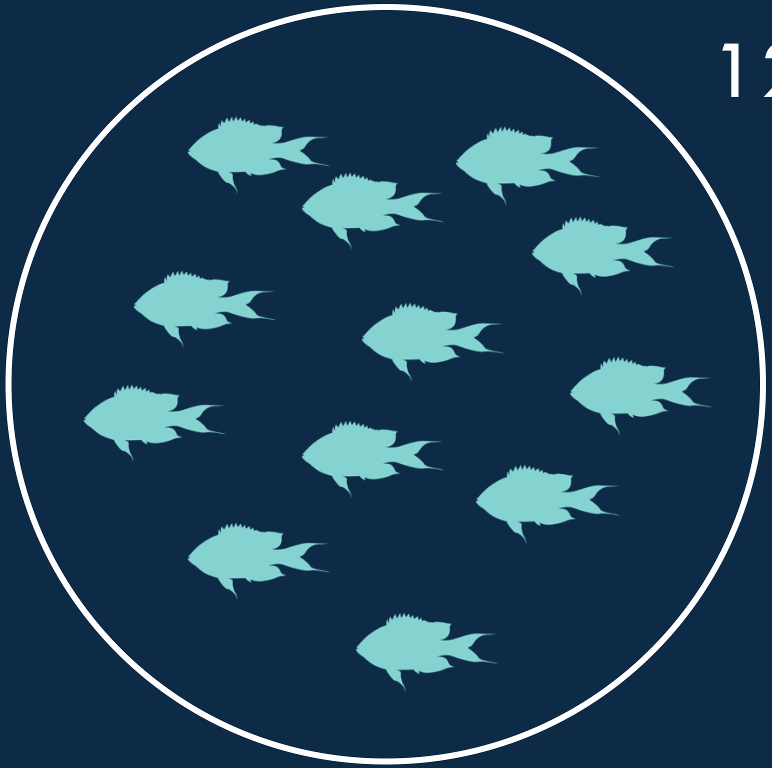


ABUNDANCE

ALWAYS integers

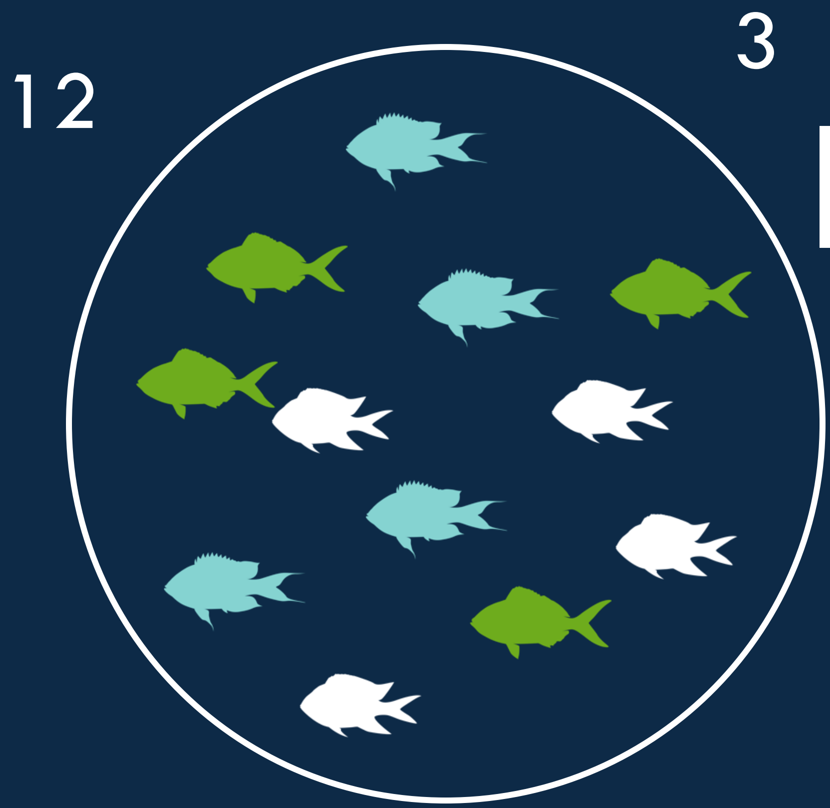
Community 2

12



First order properties: single communities

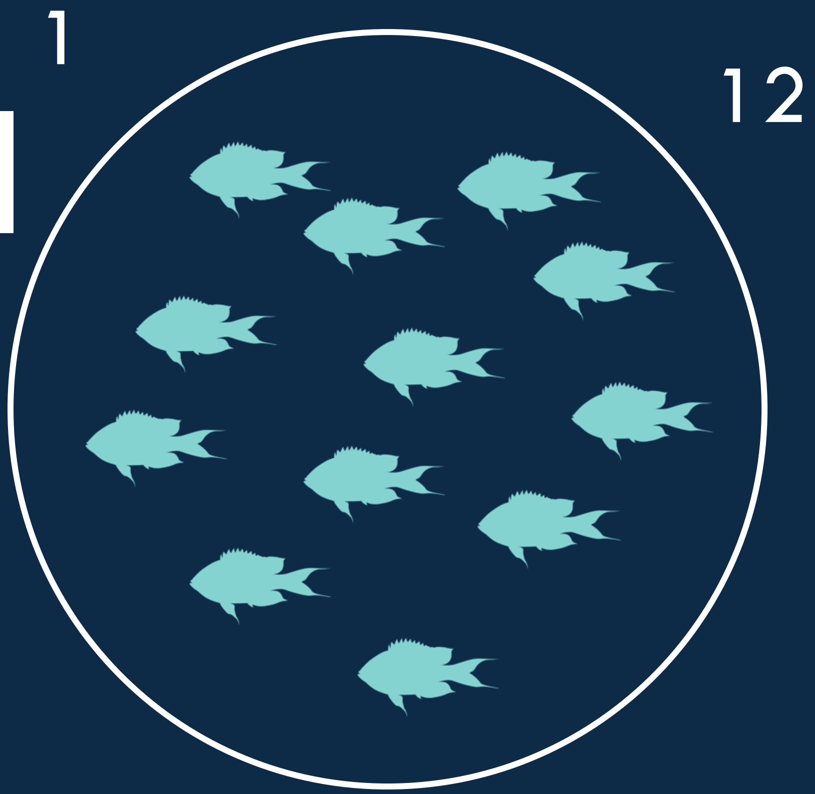
Community 1



SPECIES RICHNESS

ALWAYS integers

Community 2

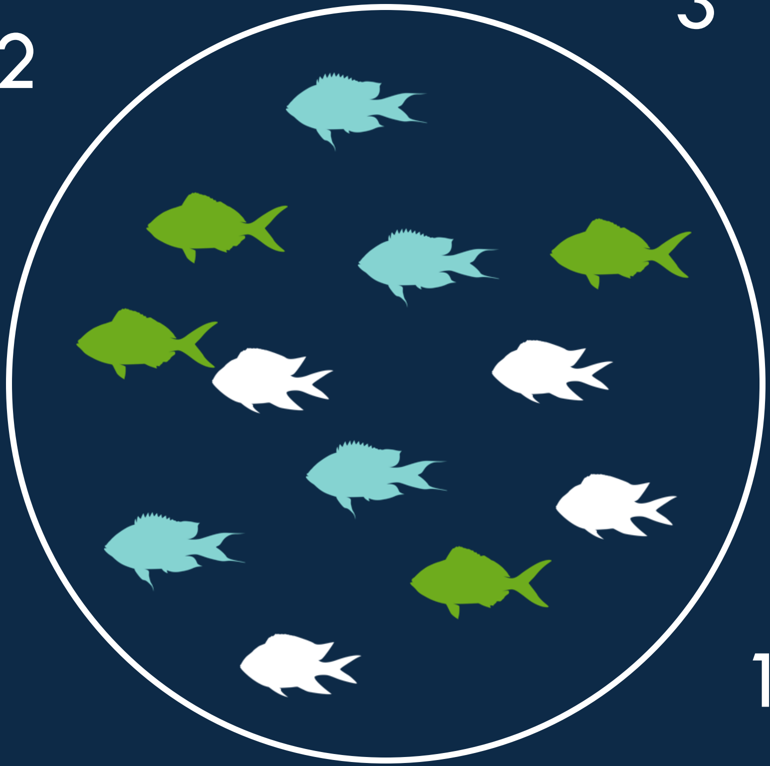


First order properties: single communities

Community 1

12

3



1.0986

DIVERSITY

Community 2

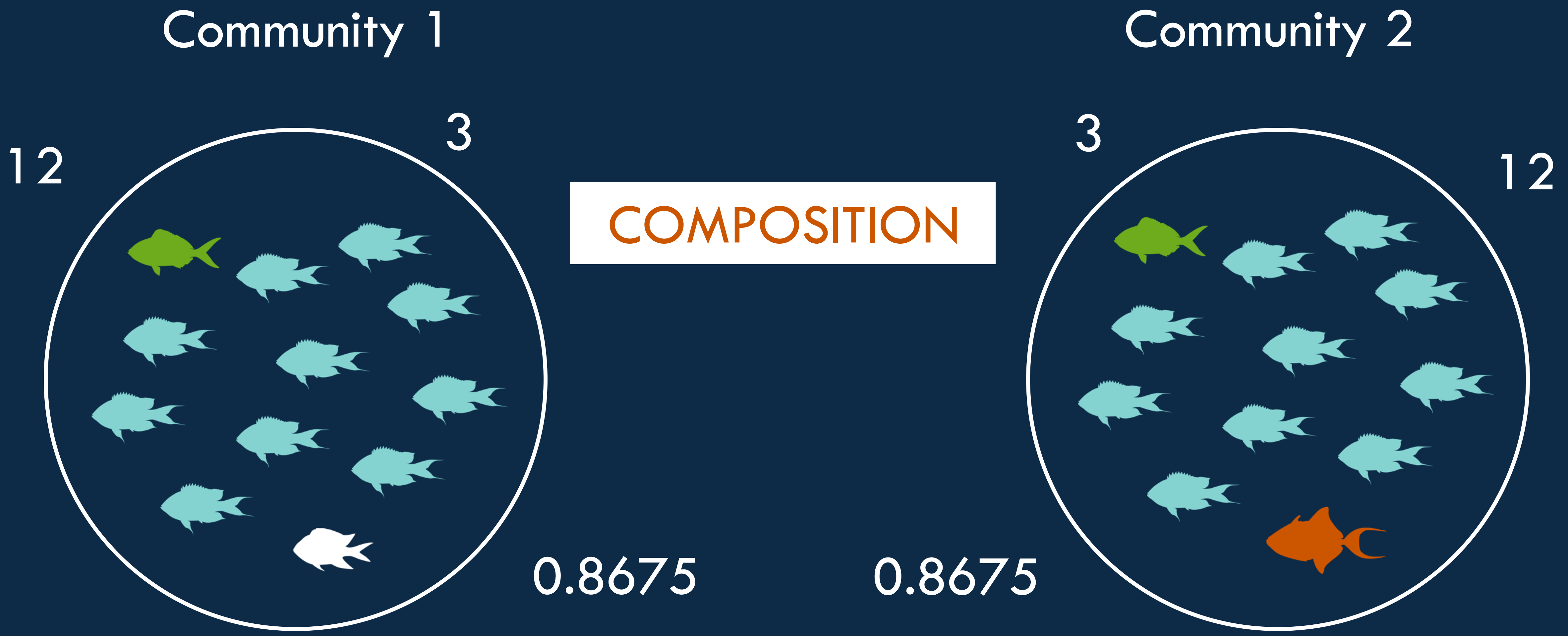
3

12

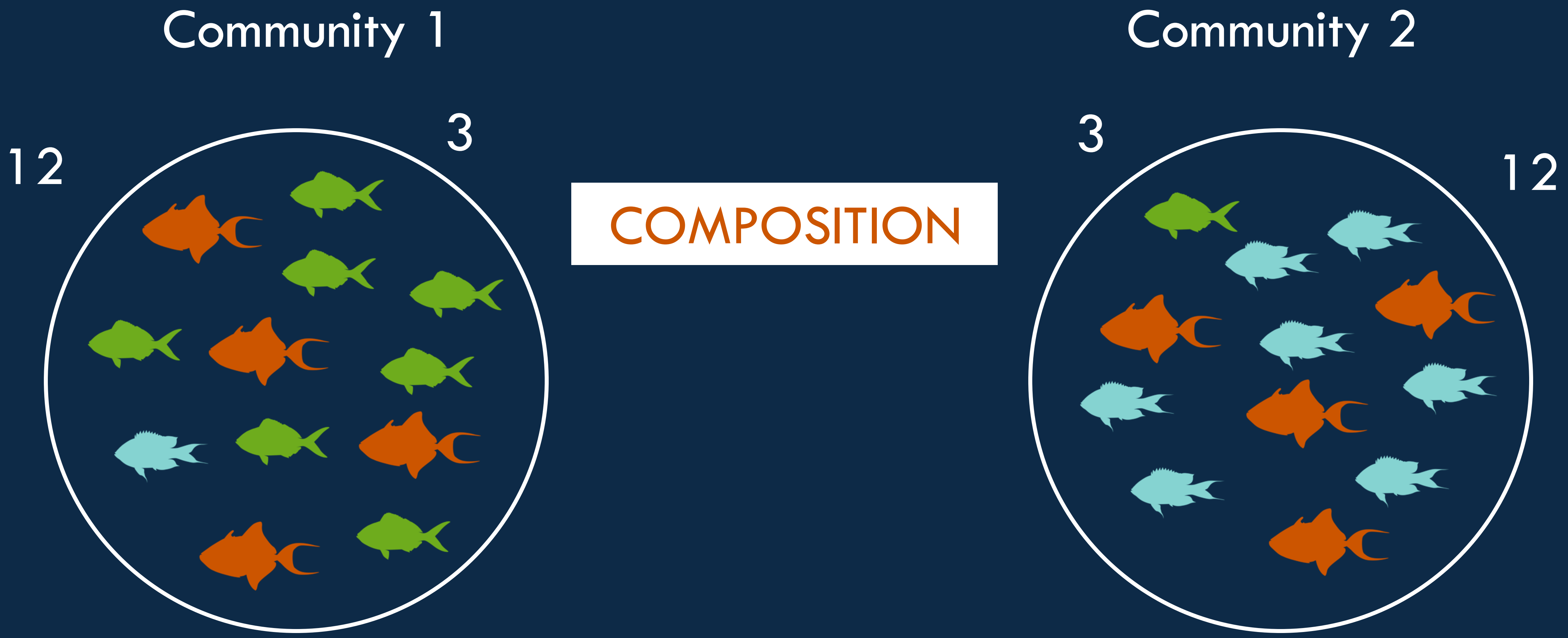
0.8675

Shannon Diversity Index: $H = -\sum[(p_i) * \log(p_i)] \mid p_i = n / N$

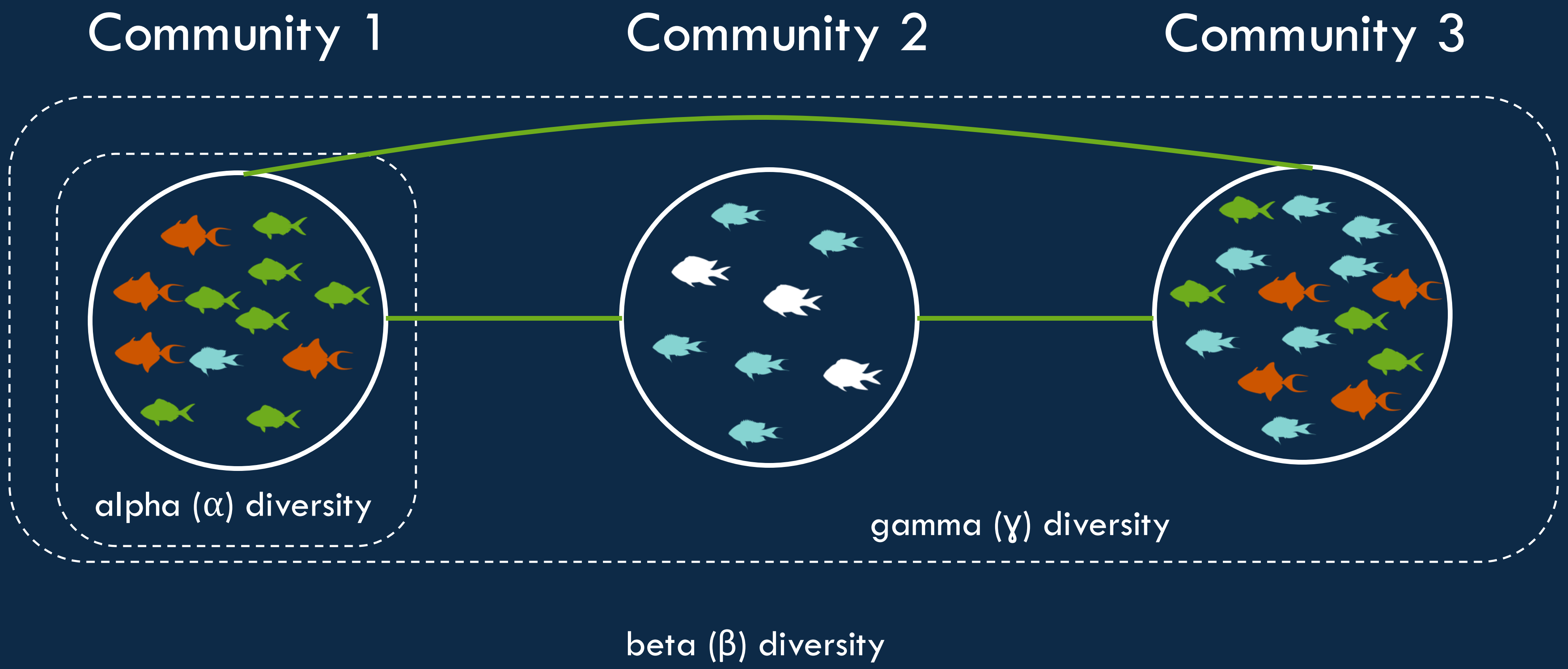
First order properties: multiple communities



First order properties: multiple communities

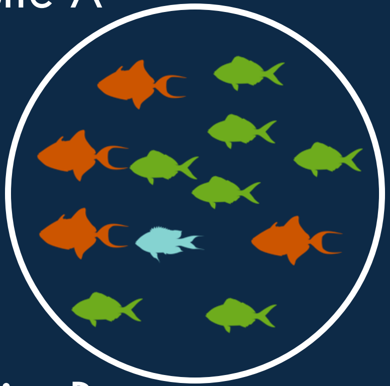


First order properties: multiple communities

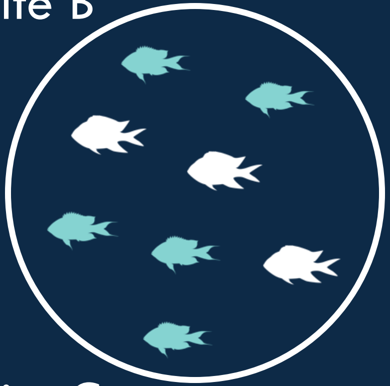


First order properties: multiple communities

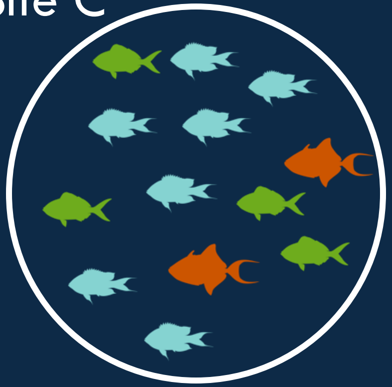
Site A



Site B



Site C



Site	Species 1	Species 2	Species 3	Species 4
A	1	1	1	0
B	0	1	0	1
C	1	1	1	0

Site	Species 1	Species 2	Species 3	Species 4
A	7	1	4	0
B	0	4	0	3
C	4	7	2	0


Tāne Sinclair-Taylor
Expedition Photographer


Tāne Sinclair-Taylor
Expedition Photographer

Second order properties: trait diversity and composition

Community A: tiny and colorful

Community B: large and plain

Trait based ecology combines basic community structure with organismal information


Second order properties: species-environment relationship

Community A: live coral

Community B: dead coral

Species environment relationships describe links between communities and environmental properties

Cheat sheet

1st order variables, one community:

1) Abundance (integer, non-negative)
2) Species richness (integer, non-negative)
3) Diversity or evenness (decimal, non-negative)
4) Species-abundance distribution (distribution)

COMMUNITY STRUCTURE

1st order variables, many communities:

1) Community composition (no value)
2) Beta-diversity (decimal, non-negative)

COMMUNITY COMPOSITION

2nd order variables:

1) Trait diversity and composition (requires species characteristics)
2) Species-environment relationships (requires site characteristics)

So many options…

1. Species richness, species density (area-standardized), or rarefied species richness

2. Diversity & evenness: Shannon index, Rényi entropy, Simpson's diversity, Simpson-Gini index, Berger Parker Index, Pielou's evenness

3. Composition: PCA, CCA, DCA, PCoA, MDS, nMDS, RDA, Cluster analysis (k-means, hierarchical, fuzzy)

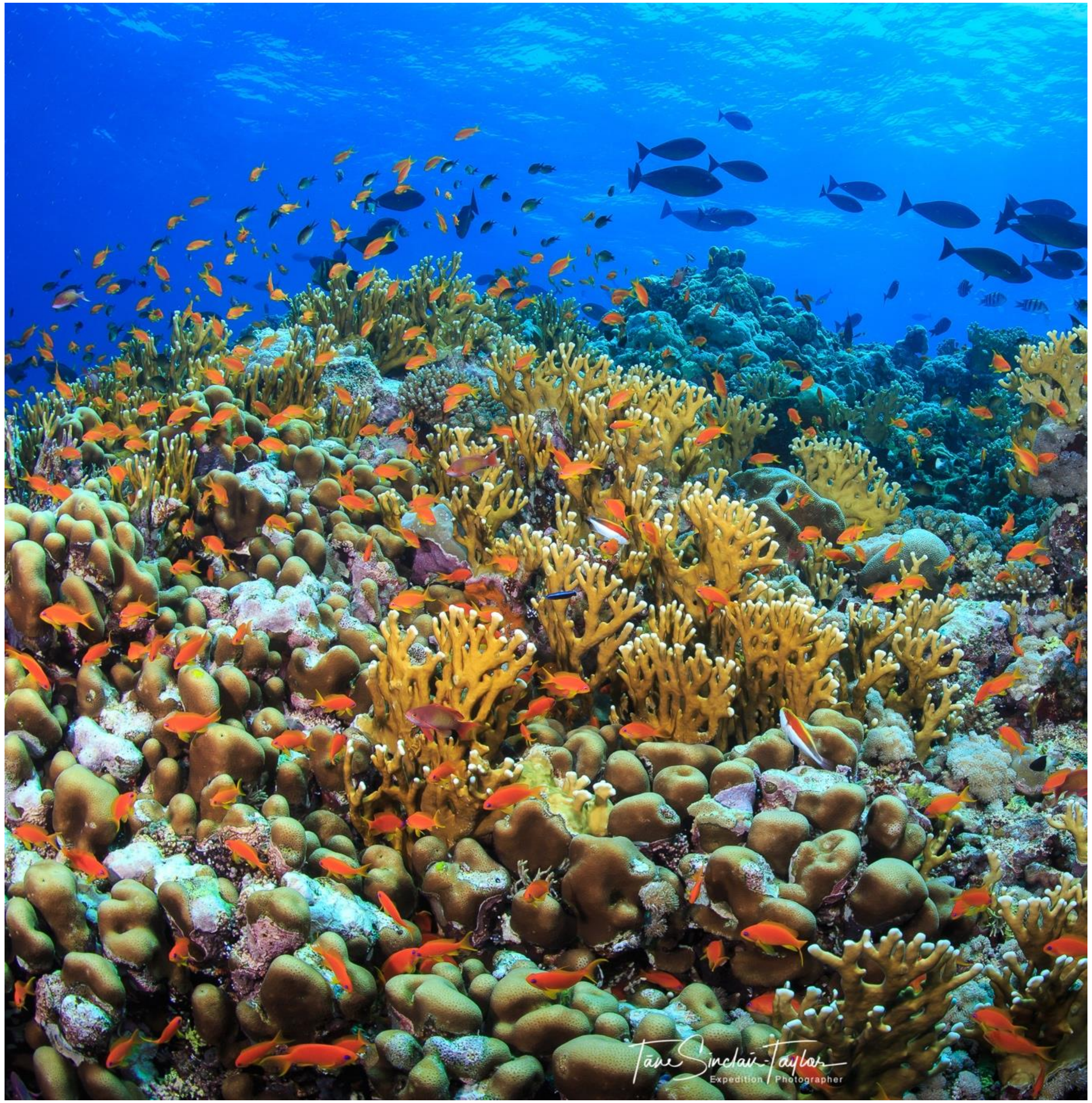
4. Beta diversity: Whittaker's index, Simpson's index, Sørensen index

5. Trait based analyses: functional richness, functional evenness, Rao's Q, functional divergence, functional diversity, functional originality

6. Species-environment relationships: redundancy analyses, canonical discriminant analysis, Mantel's test


Method 1
Method 2, yielding the exact same results
COMMUNITY ECOLOGISTS
JAKE-CLARK.TUMBLR

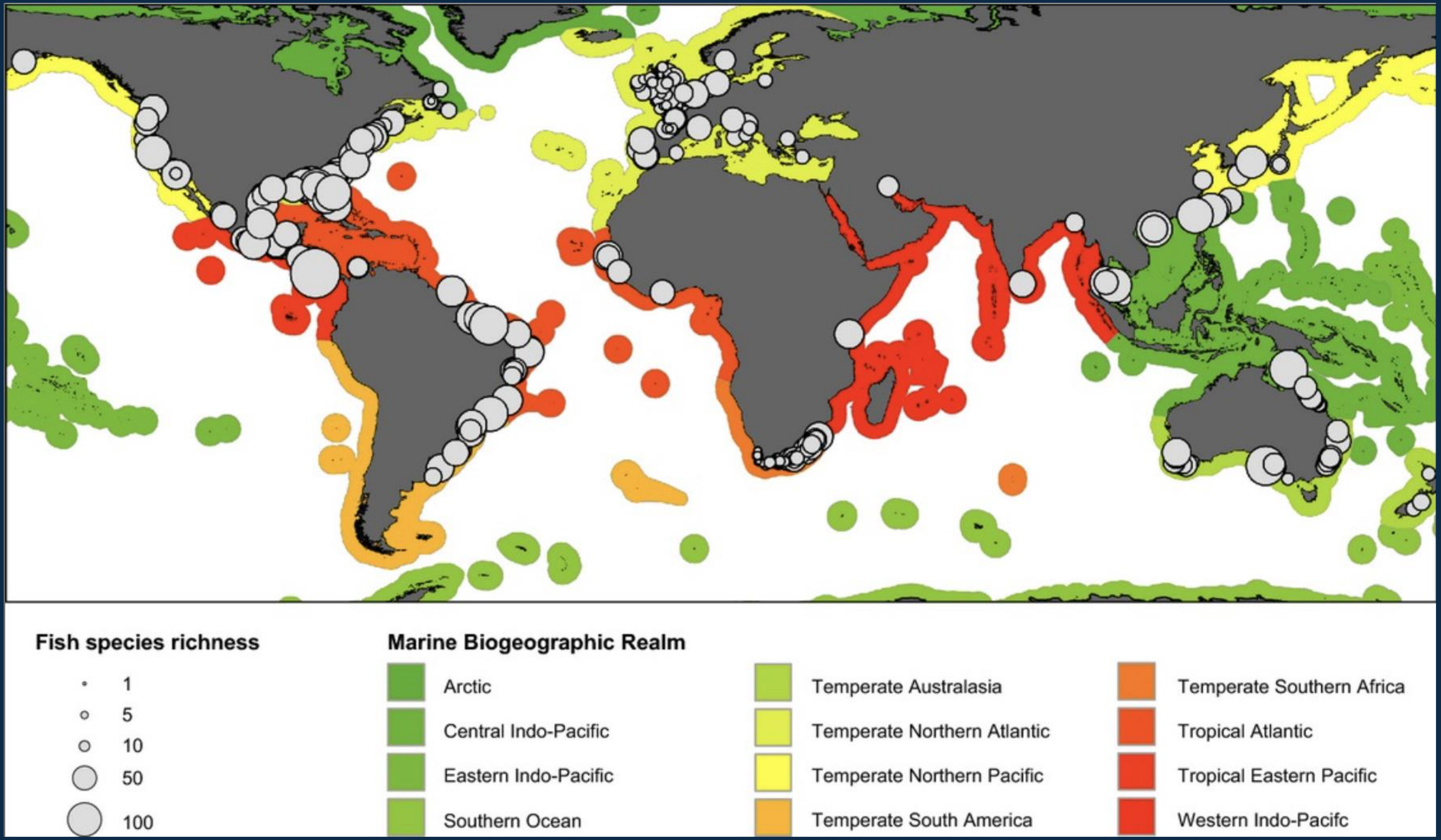

Expedition Photographer


Expedition Photographer

Patterns and predictors of global marine species richness

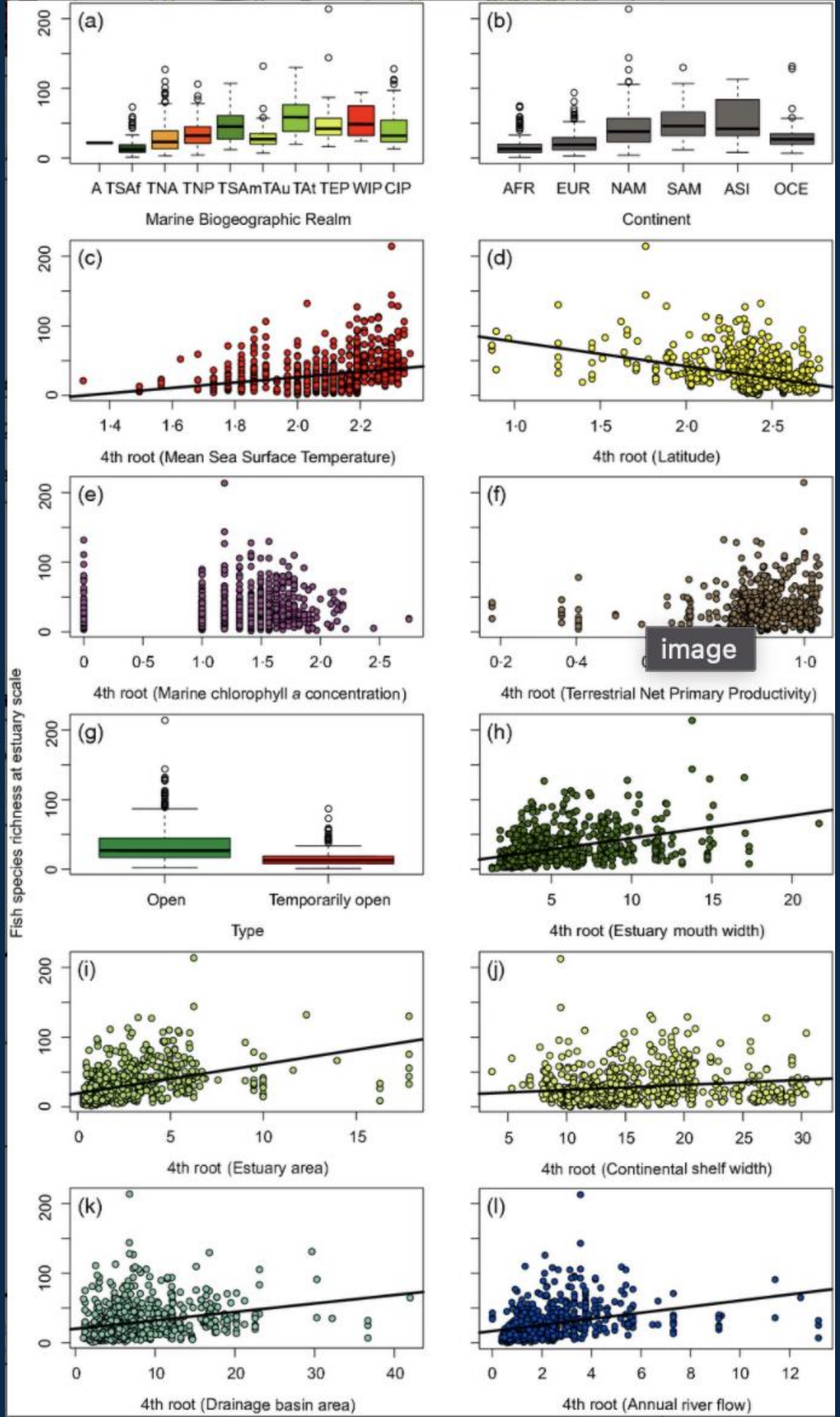
What do you think influences species richness patterns at a global scale?


Estuarine fishes



Vasconcelos et al. 2015

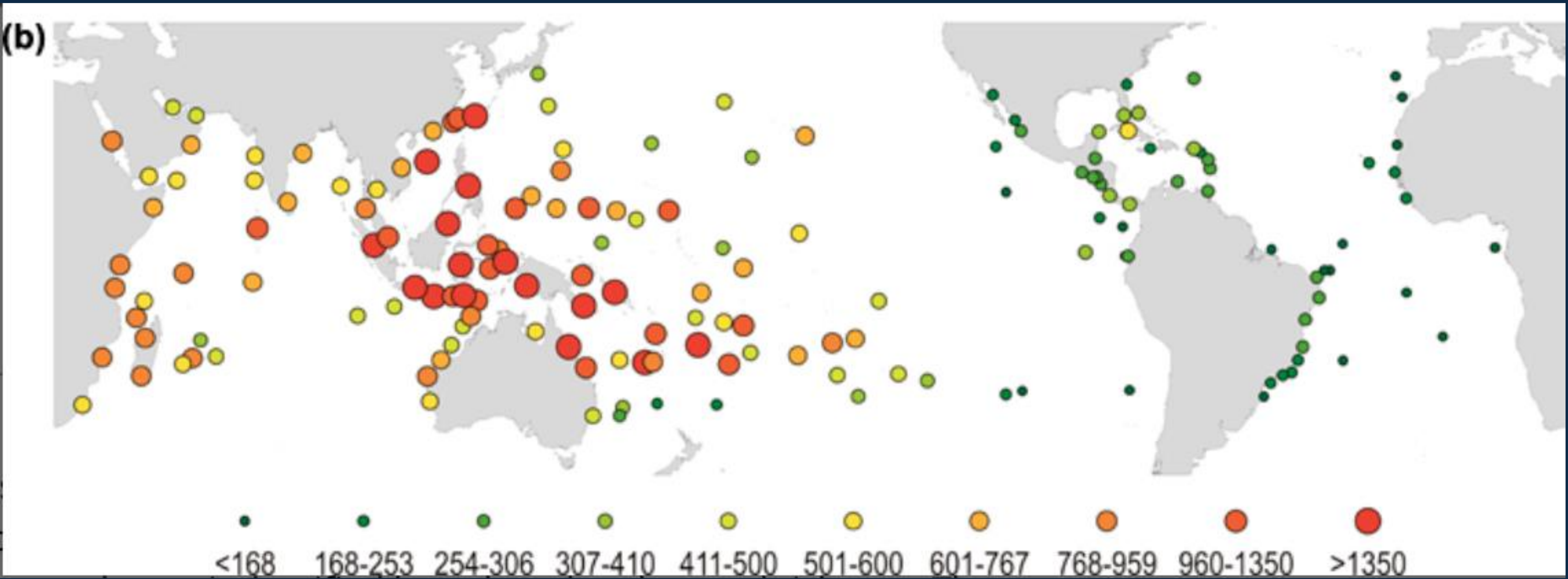
Estuarine fishes



- biogeographic realm
- sea surface temperature
- estuarine area
- connectivity

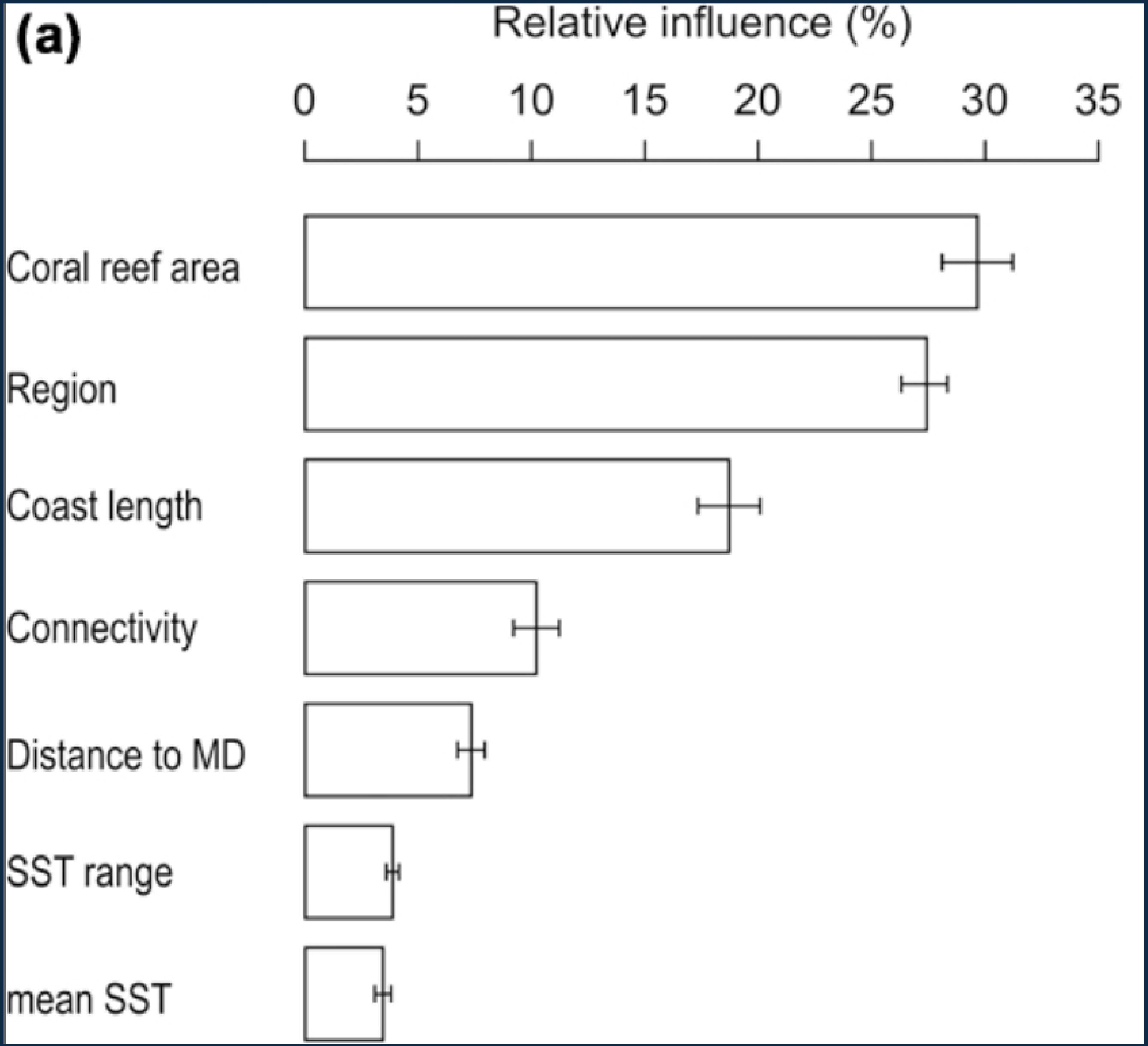
Vasconcelos et al. 2015


Coral reef fishes



Parravicini et al. 2015

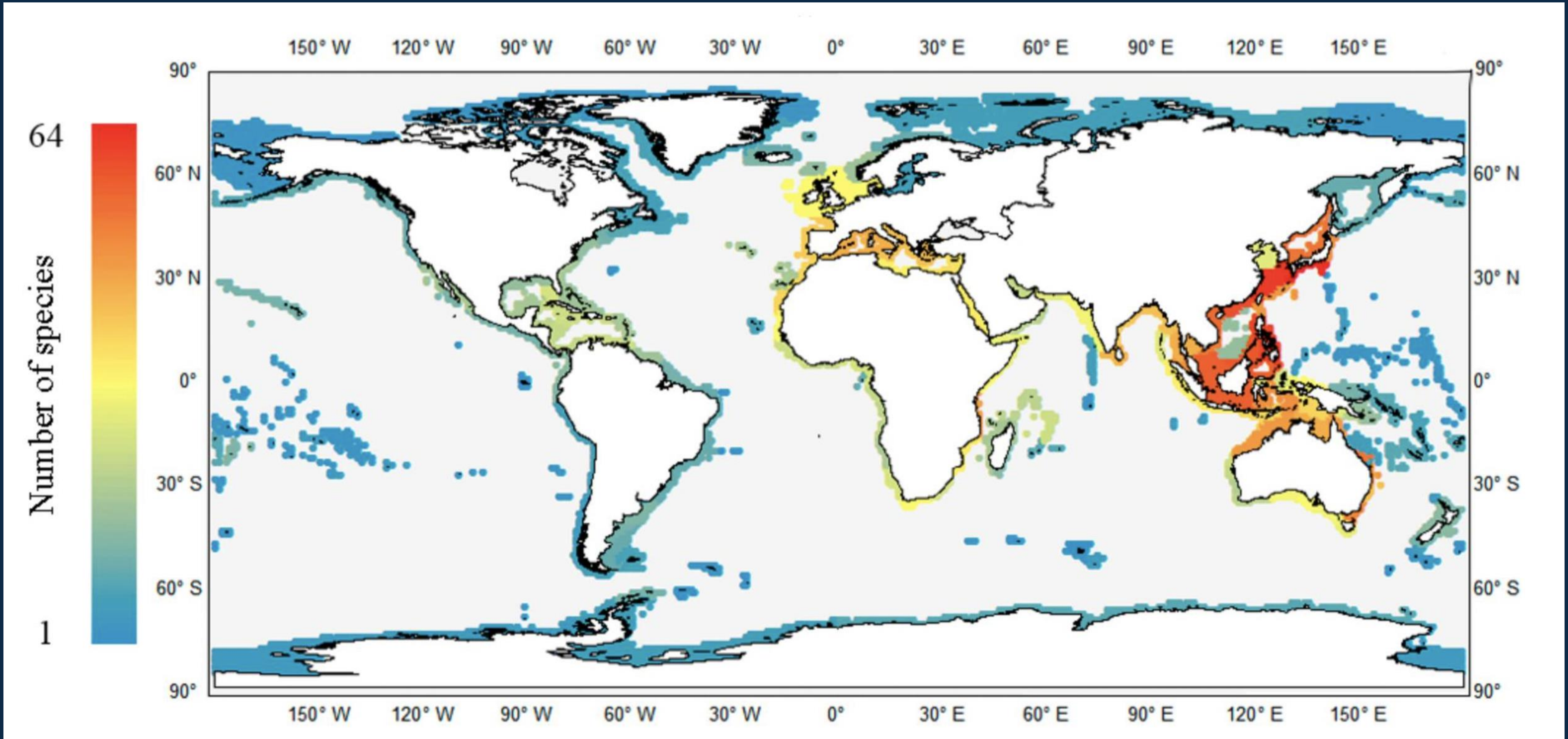
Coral reef fishes



- coral reef area
- biogeographic realm
- sea surface temperature
- connectivity

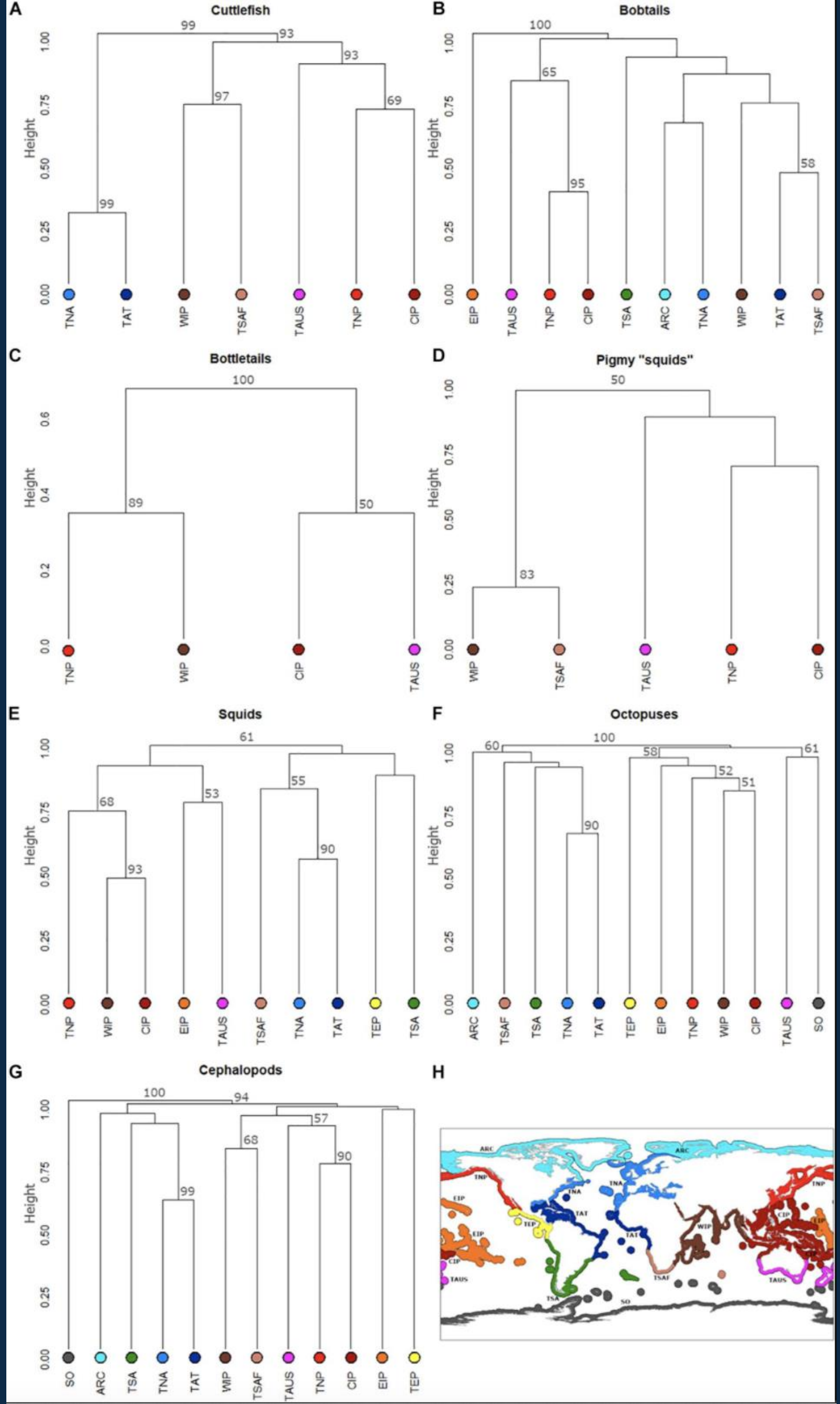
Parravicini et al. 2015


Coastal cephalopods



Rosa et al. 2019

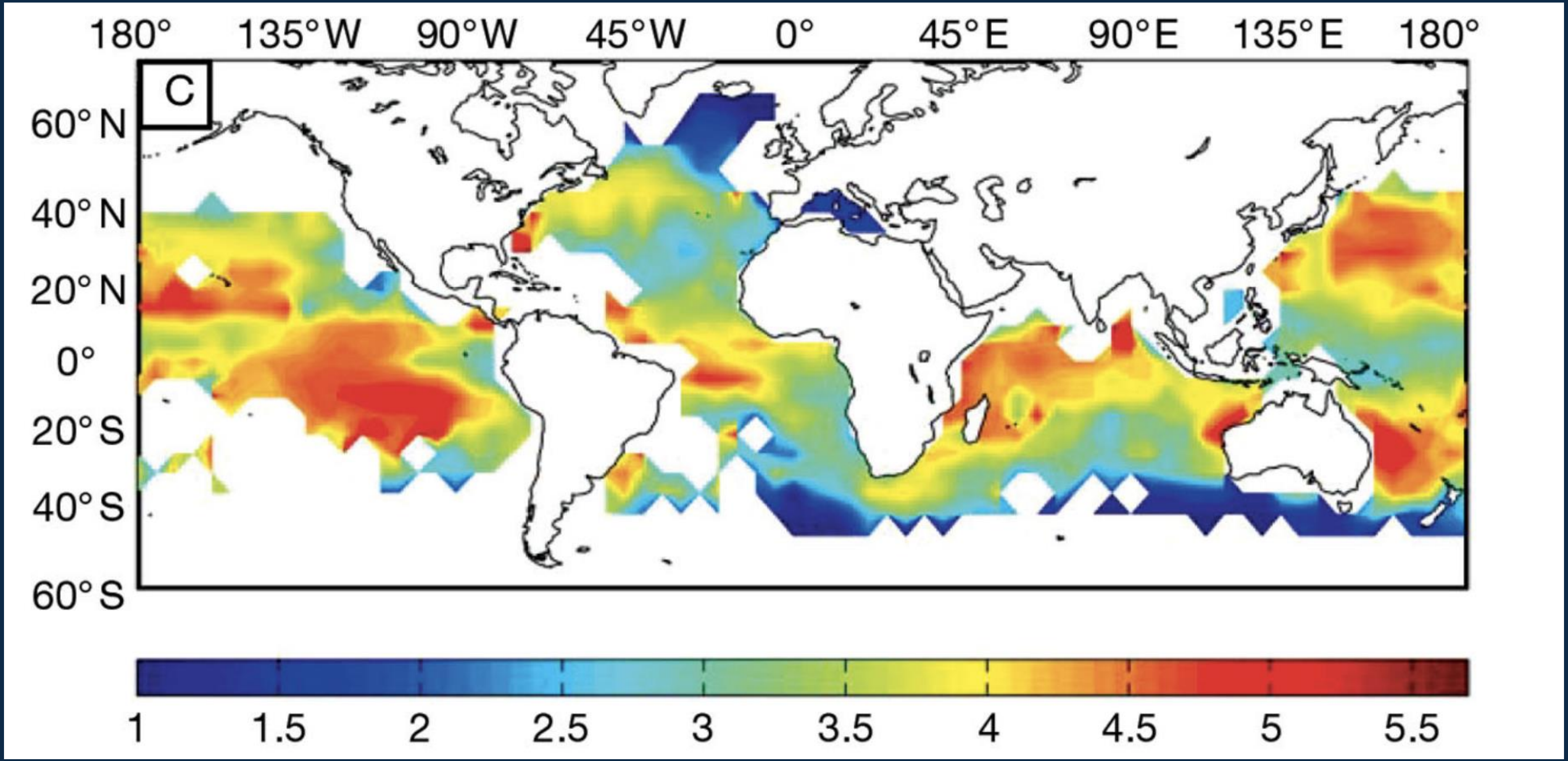
Coastal cephalopods



- phylogenetic history
- region

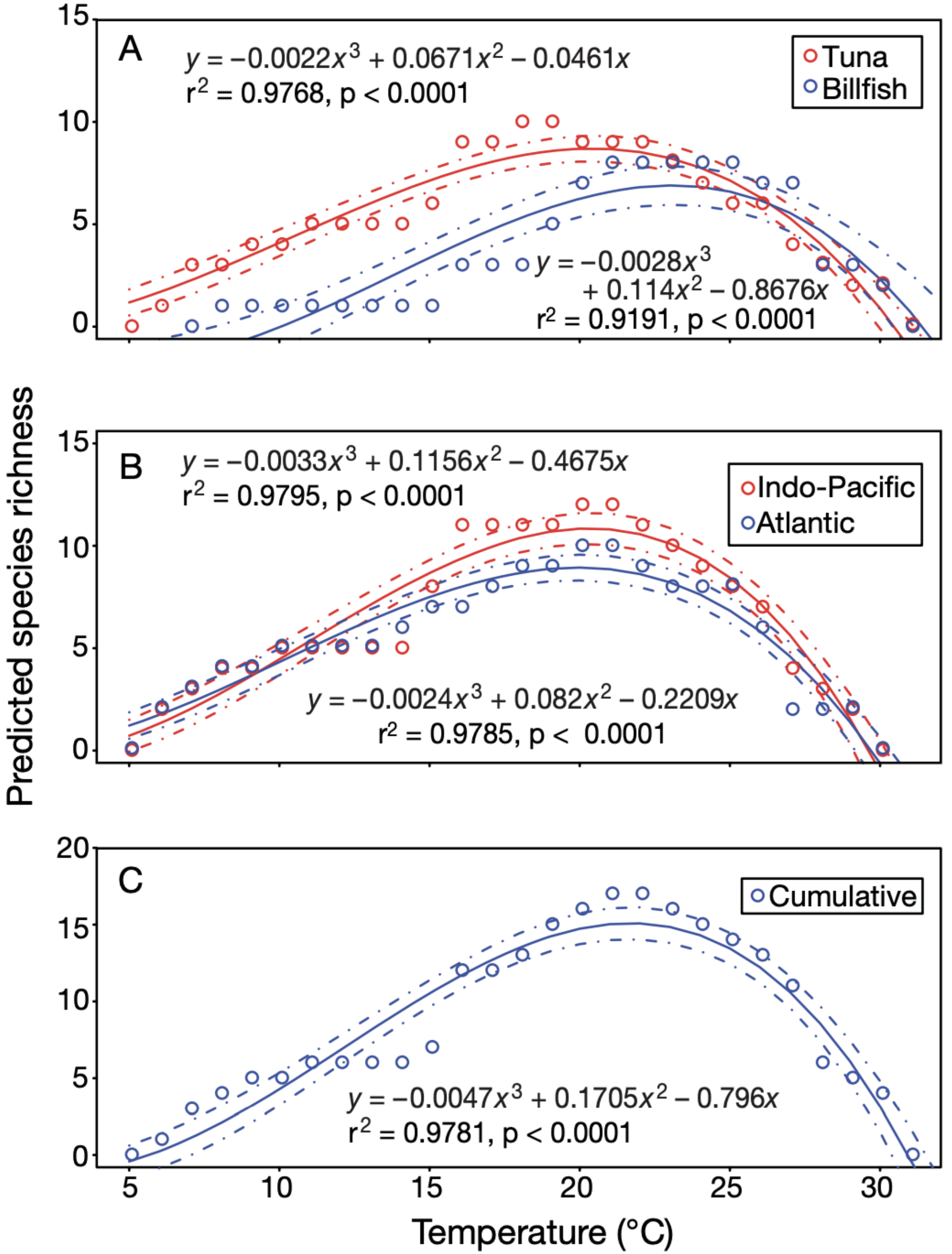
Rosa et al. 2019


Tunas and billfishes



Boyce et al. 2008

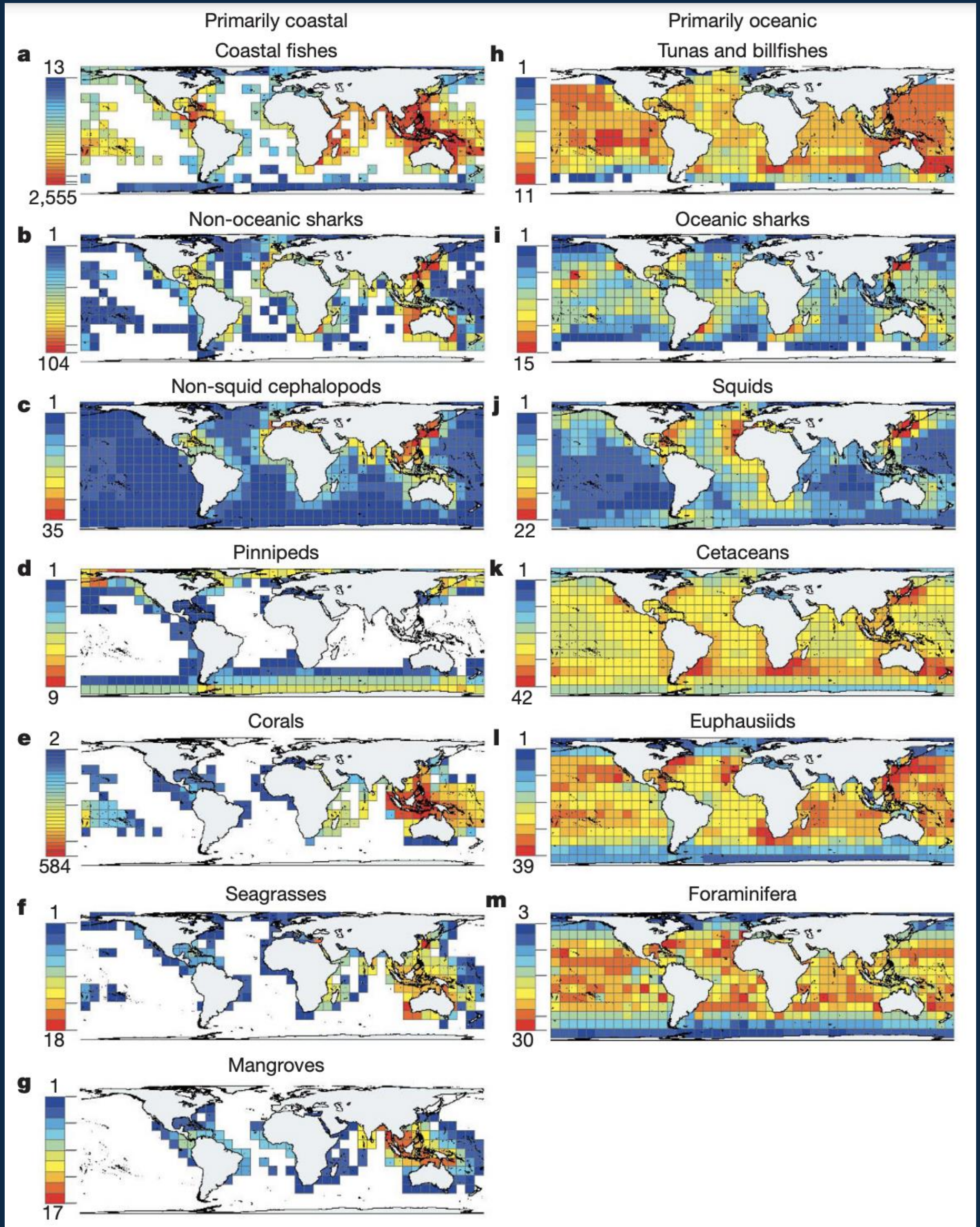
Tunas and billfishes

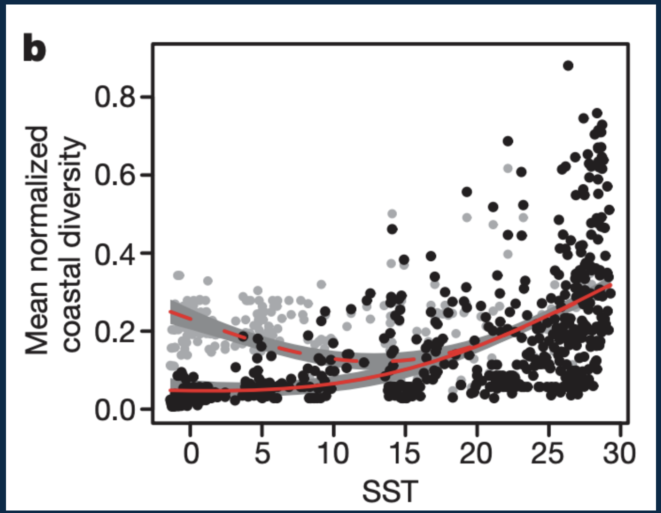


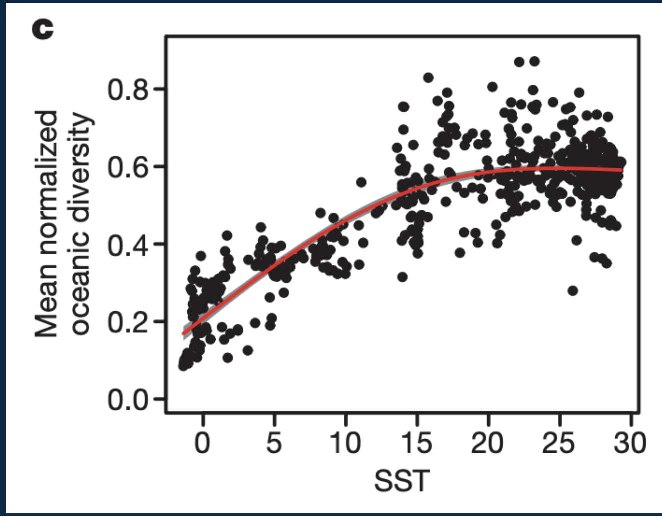
- temperature

Boyce et al. 2008

Everything?

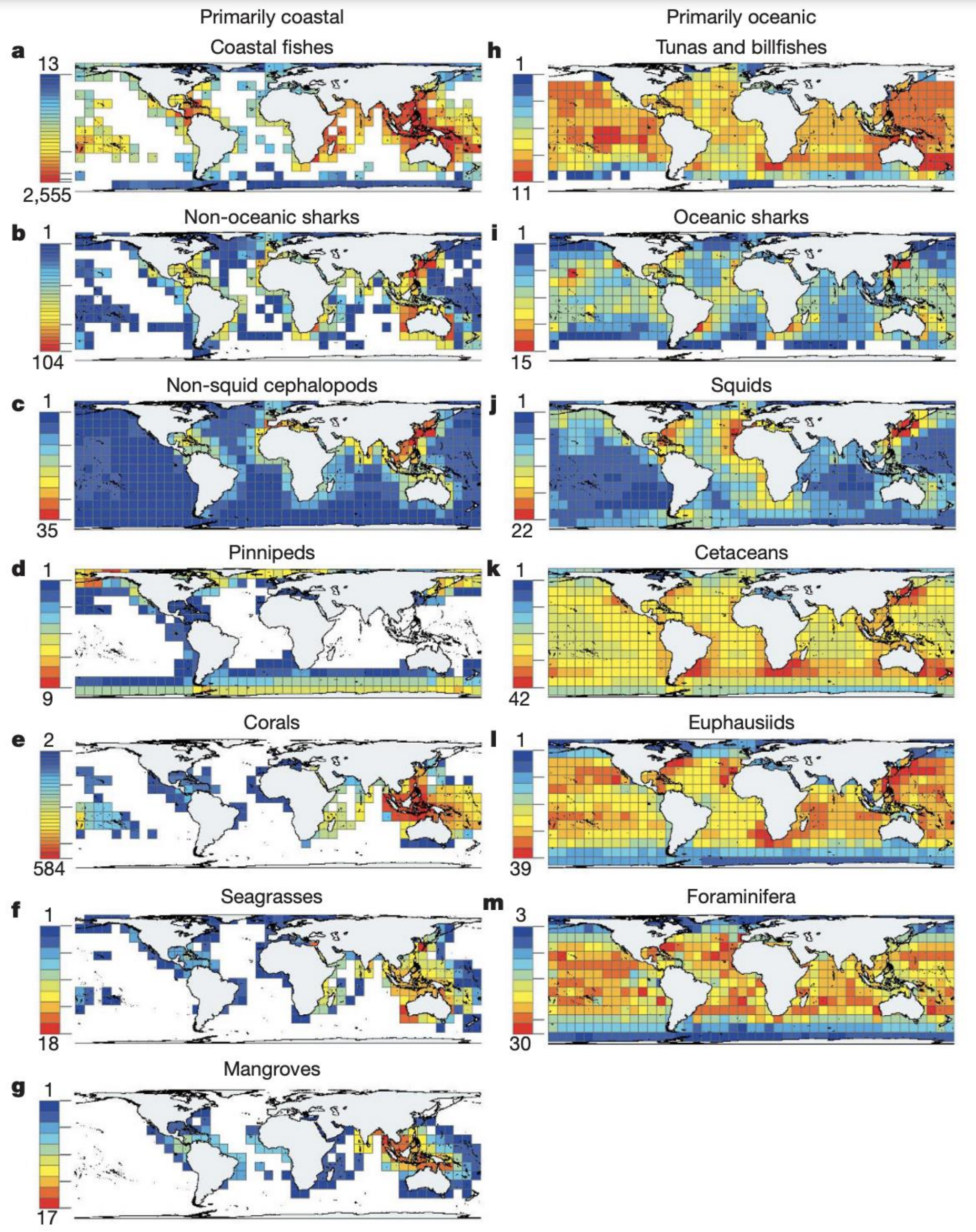






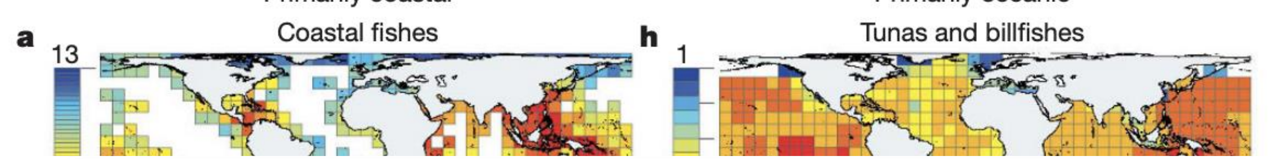
Tittensor et al. 2010

Why do species richness patterns differ between pelagic and coastal ecosystems?

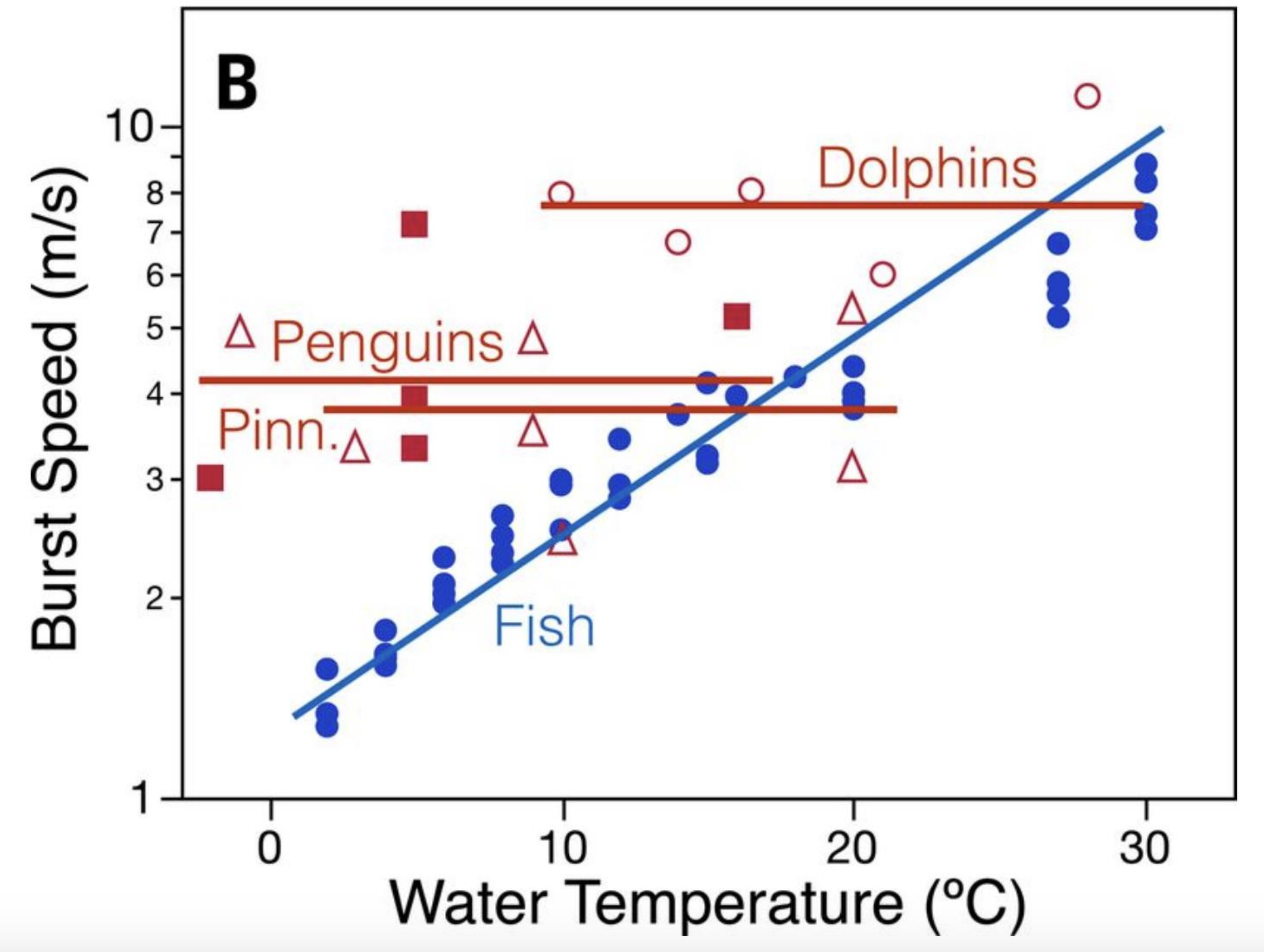


Tittensor et al. 2010

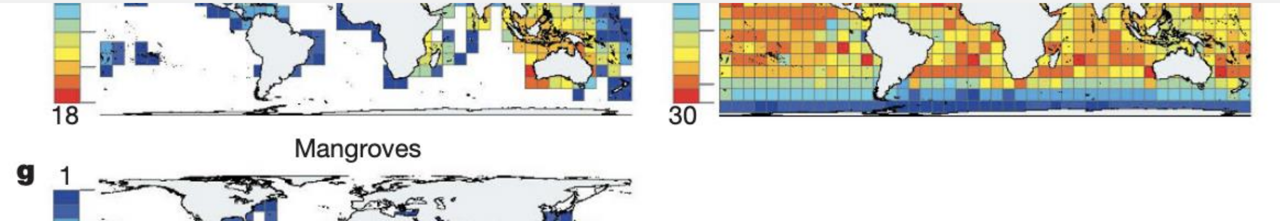
Why are pinnipeds most diverse in temperate and polar regions?



a
Coastal fishes
13
h
Tunas and billfishes
1

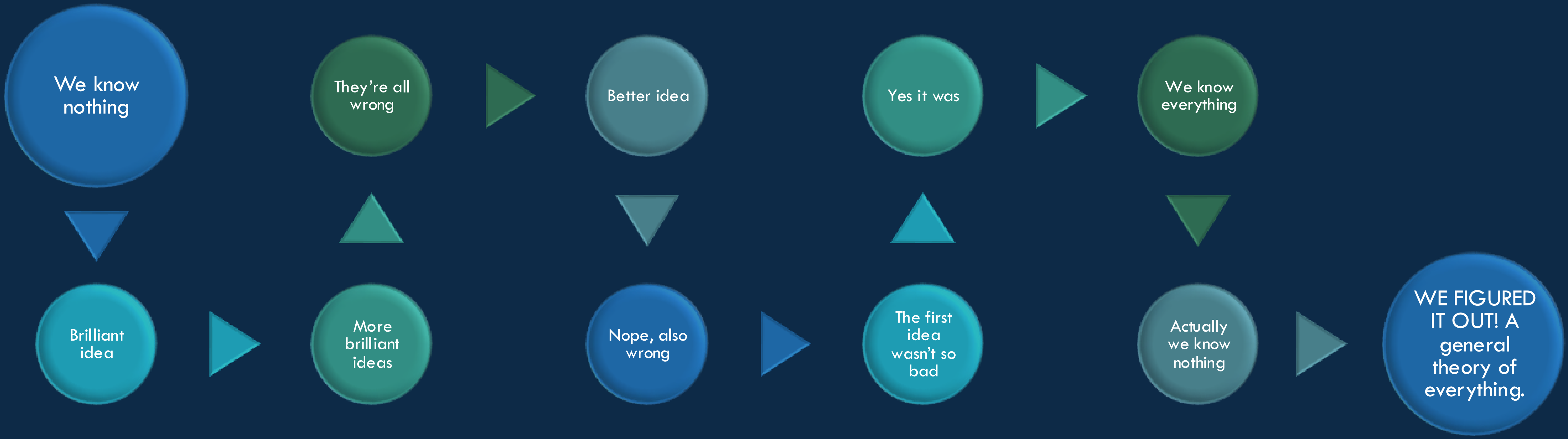


B
Burst Speed (m/s)
10
8
7
6
5
4
3
2
1
0
10
20
30
Water Temperature (ºC)
Dolphins
Penguins
Pinn.
Fish

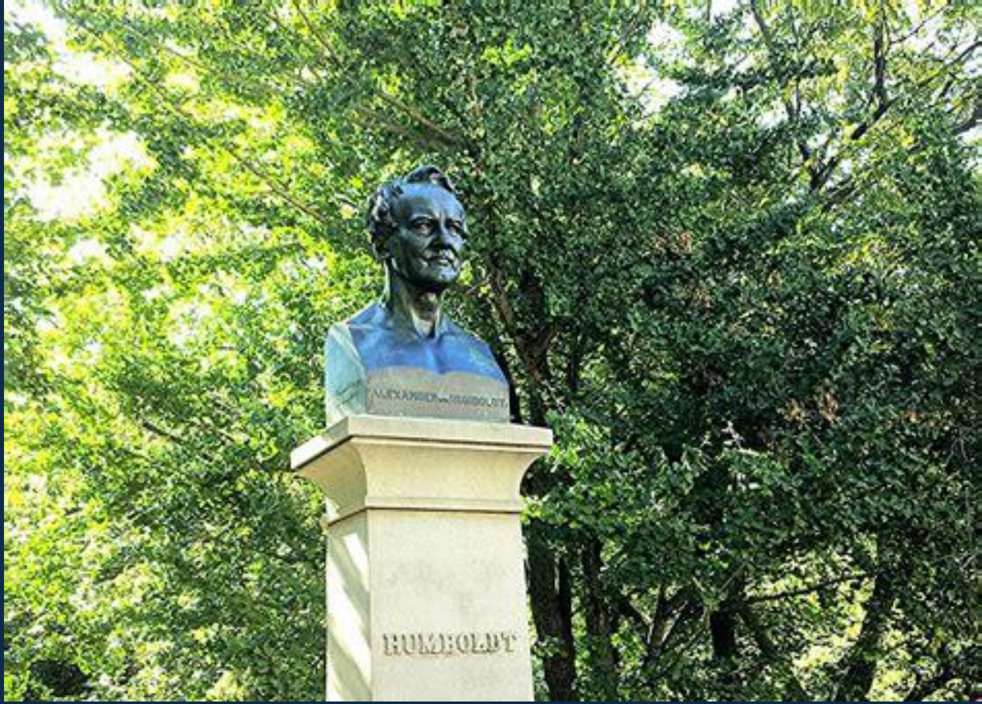


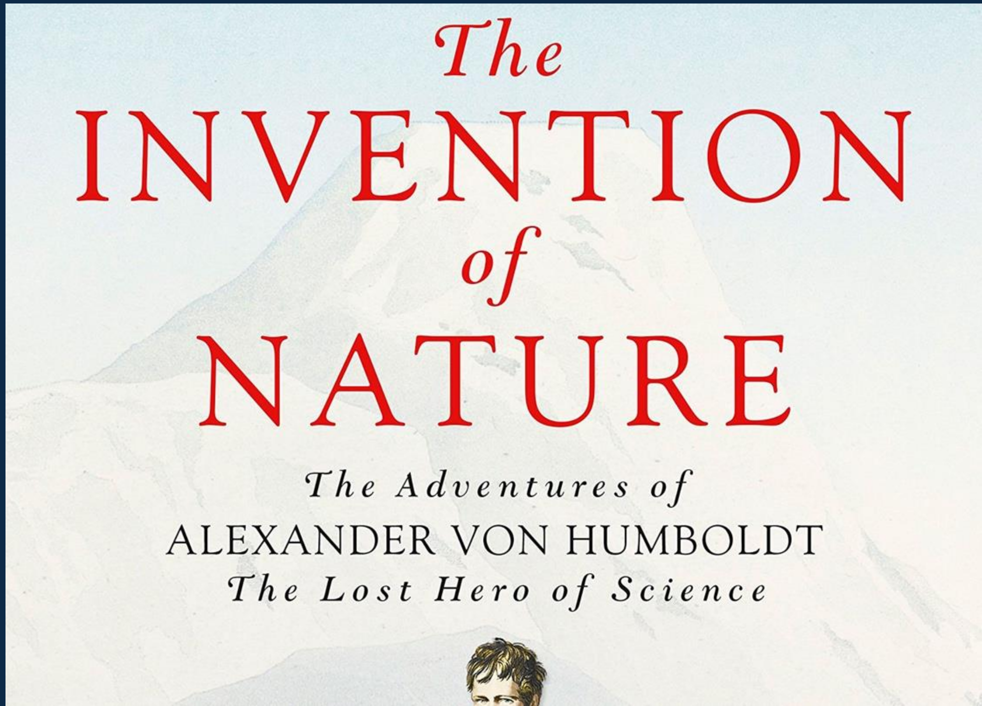
18
30
Mangroves
g
1

IDEAS AND CONCEPTS IN COMMUNITY ECOLOGY



Observing patterns


HUMBOLDT


The
INVENTION
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The Adventures of
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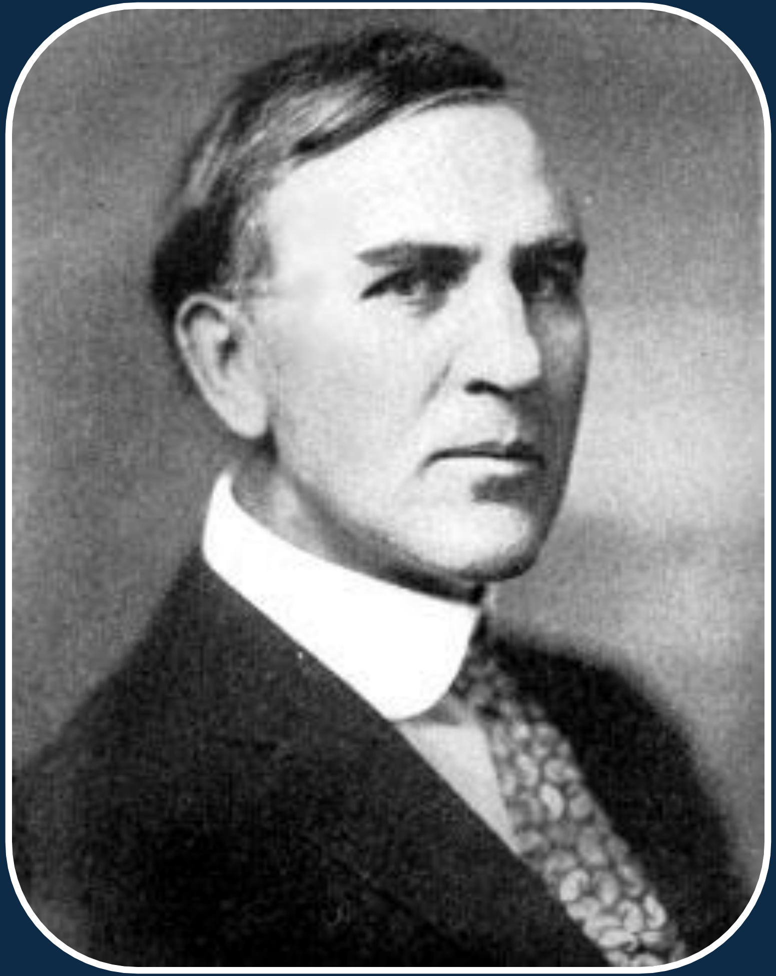
The Lost Hero of Science

Observing Patterns : Frederic Clement



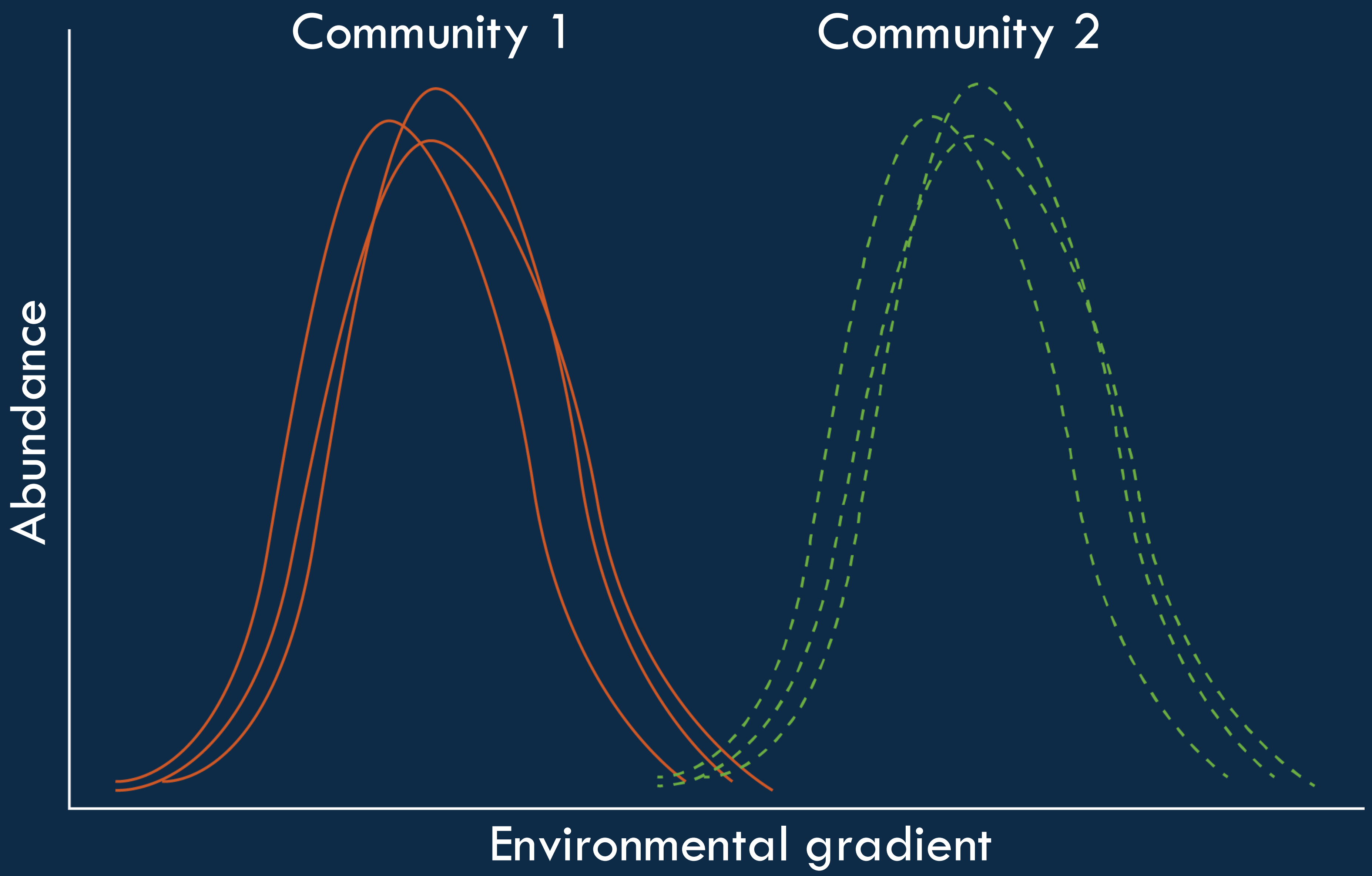
Frederic Clement (1916)

The Phytogeography of Nebraska

Plant Succession: An Analysis of the Development of Vegetation

Ecological communities as “superorganisms”

Observing Patterns : Frederic Clement



Observing Patterns : Frederic Clement

Observing Patterns : Henry Gleason

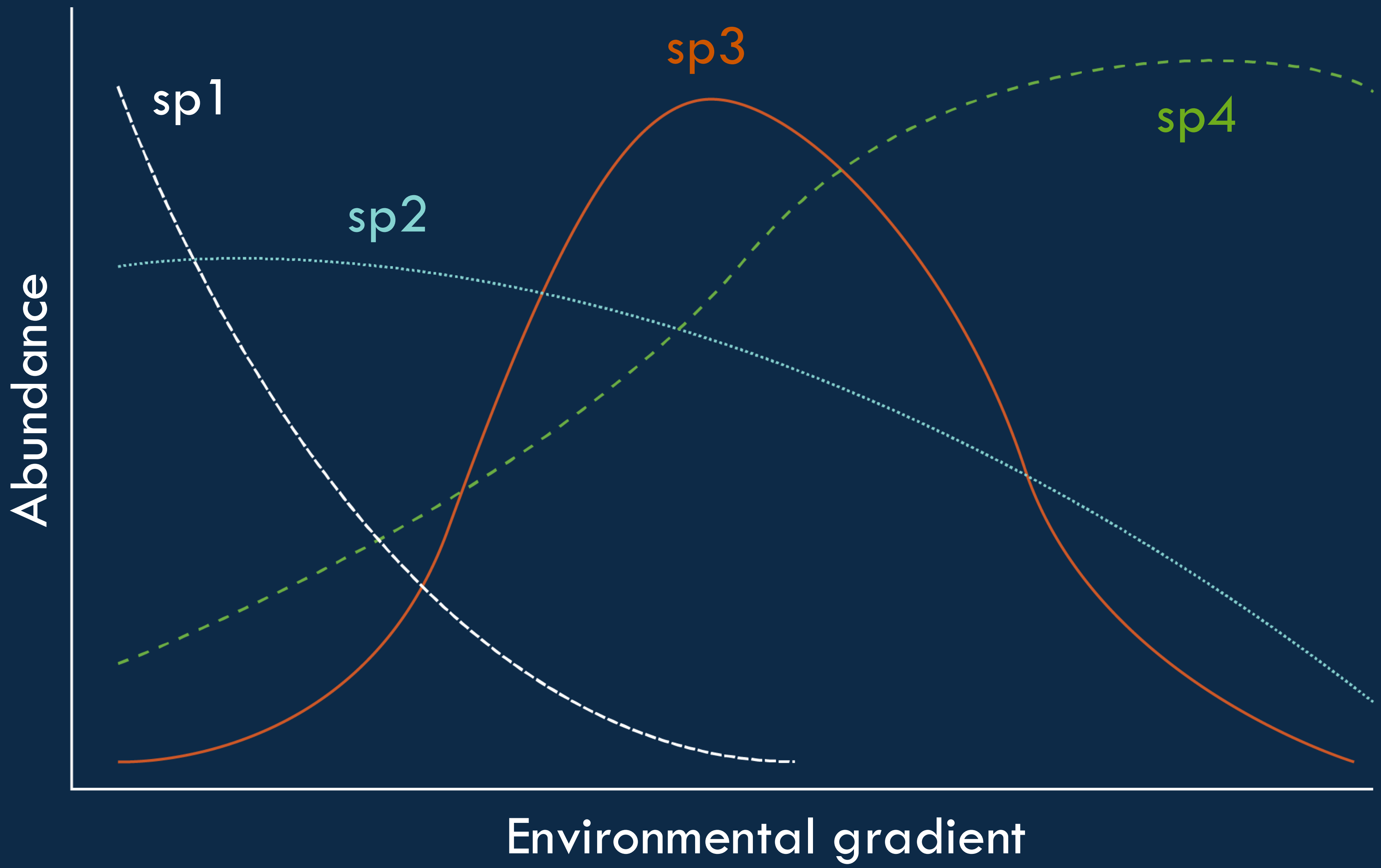
Henry Gleason (1926)

The Individualistic Concept of the Plant Association

Species and area

Ecological communities as conglomerates of species with individual tolerances

Observing Patterns : Henry Gleason



Observing Patterns : Henry Gleason

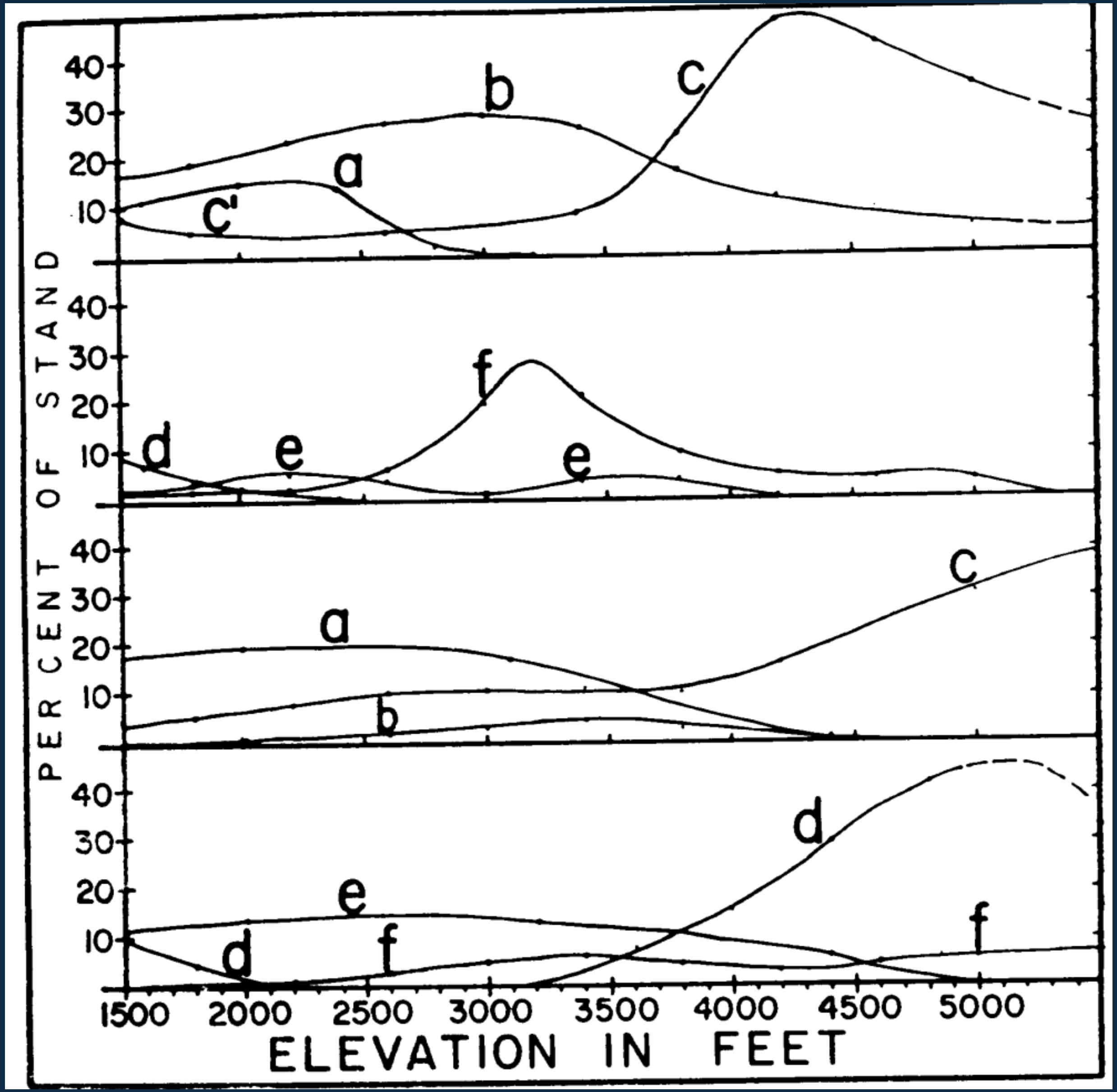
Observing Patterns: Robert H. Whittaker

Whittaker 1956

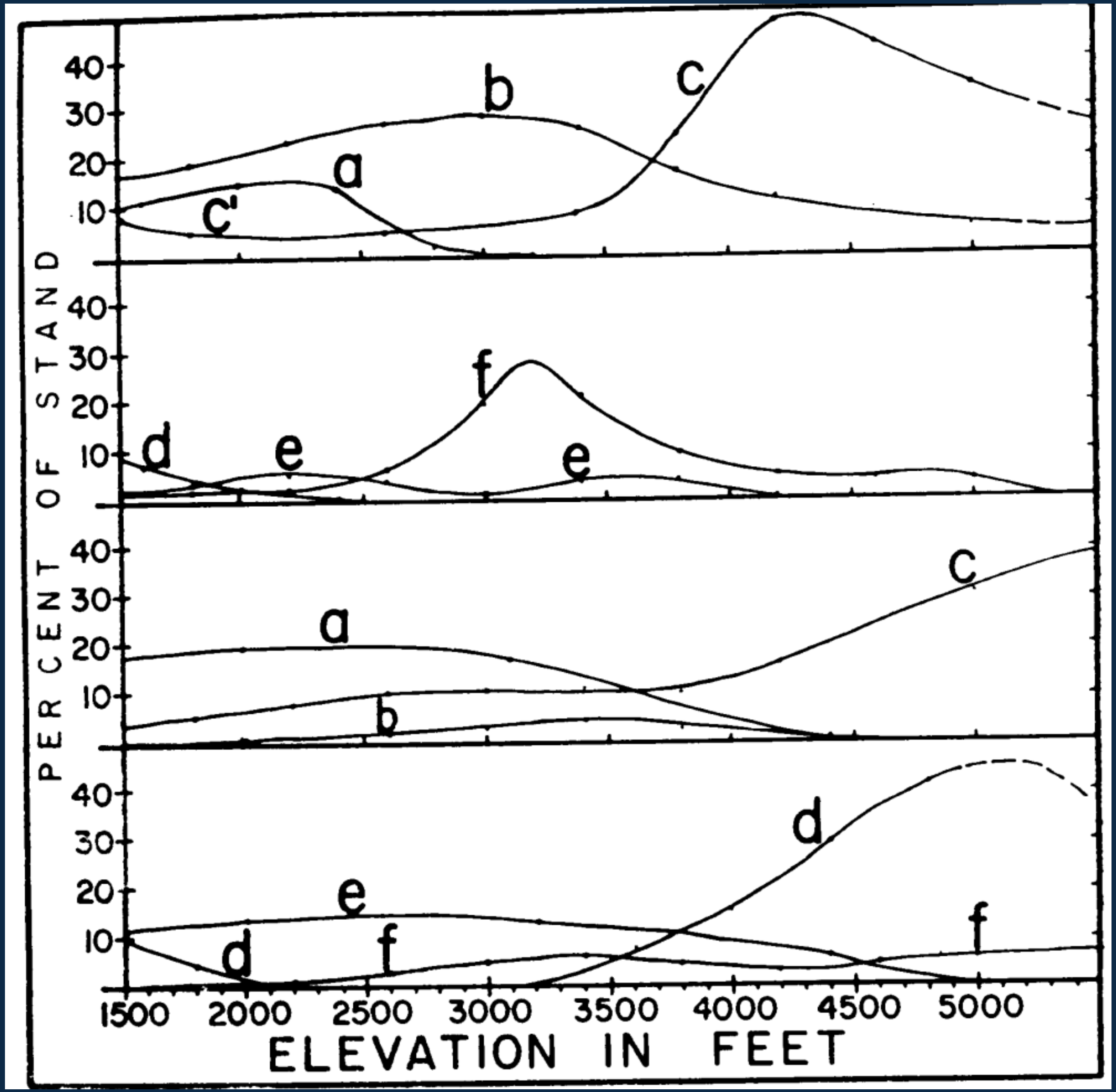
Table 3. Composite transect of moisture gradient between 3500 and 4500 ft, distribution of trees along gradient. Transect along the moisture gradient from mesic valley sites (Sta. 1) to xeric southwest slope sites (Sta. 12), based on 46 site counts including 4906 stems from elevations between 3500 ft and 4500 ft. All figures are percentages of total stems in station from 1-in. diameter class up.

Tree species	Station Number											
	1	2	3	4	5	6	7	8	9	10	11	12
Fagus grandifolia	10	5	1	1	1	..	..	..	..	..	..	..
Ilex opaca	..	1	..	x	..	..	..	..	..	..	..	..
Picea rubens	..	x	..	x	x	..	..	..	..	..	..	..
Cornus alternifolia	1	1	..	x	x	..	..	..	..	..	..	..
Aesculus octandra	8	9	4	2	6	1	..	..	..	..	..	..
Tilia heterophylla	29	11	9	1	14	3	..	..	..	..	..	..
Acer spicatum	..	16	11	..	17	1	..	..	..	..	..	..
Acer saccharum	17	7	1	1	5	1	..	..	..	..	..	..
Prunus serotina	2	1	..	1	x	2	..	..	..	..	..	..
Fraxinus americana	1	1	..	1	1	x	..	..	..	..	..	..
Betula allegheniensis	5	17	10	15	4	1	x	..	..	..	..	..
Magnolia acuminata	..	x	..	..	x	..	1	..	..	..	..	..
Magnolia fraseri	..	..	20	4	1	..	1	..	..	..	..	..
Tsuga canadensis	20	22	34	62	18	x	x	1	..	..	..	..
Halesia monticola	5	8	4	1	9	13	3	1	1	..	..	..
Ilex montana	1	x	..	1	1	1	2	..	..	..	..	..
Acer pensylvanicum	1	x	1	3	8	3	x	1	..	..	..	..
Amelanchier laevis	..	x	..	x	x	..	..	..	..	..	..	..
Quercus borealis	..	1	..	..	2	40	10	4	15	11	2	1
Acer rubrum	..	1	..	..	1	6	37	21	13	10	8	1
Prunus pensylvanica	..	..	2	..	..	..	1	..	..	..	..	..
Betula lenta	..	..	1	4	4	1	2	2	..	..	..	..
Clethra acuminata	..	..	..	1	x	..	..	..	..	..	..	..
Hamamelis virginiana	..	..	..	..	2	5	17	7	1	..	2	..
Cornus florida	..	..	..	..	1	..	x	4	..	..	..	..
Liriodendron tulipifera	..	..	..	..	2	..	..	1	..	x	..	..
Rhododendron calendulaceum	..	..	..	..	..	1	..	1	4	..	..	..
Carya glabra	..	..	..	..	..	4	x	2	6	5	..	..
Carya tomentosa	..	..	..	..	..	..	..	2	..	..	..	..
Carya ovalis	..	..	..	..	..	..	..	x	..	..	..	..
Nyssa sylvatica	..	..	1	..	..	..	2	4	1	2	7	..
Oxydendrum arboreum	..	..	x	1	..	1	3	8	14	16	1	1
Castanea dentata (dead)	..	..	..	..	2	5	7	9	10	12	1	..
Sassafras albidum	..	..	..	..	..	1	1	1	1	4	x	..
Quercus alba	..	..	..	..	..	2	1	8	24	10	x	..
Robinia pseudoacacia	..	..	..	..	..	4	5	1	3	8	3	x
Quercus prinus	..	..	..	..	..	3	4	15	4	16	11	1
Quercus velutina	..	..	..	..	..	..	x	x	1	1	..	..
Quercus coccinea	..	..	..	..	..	..	1	..	..	..	..	1
Pinus rigida	..	..	..	..	..	..	..	7	1	1	11	46
Pinus pungens	..	..	..	..	..	..	..	..	1	4	54	49
Percents by classes												
Mesic	98	98	95	90	78	22	5	3	1	..	..	..
Submesic	2	2	4	9	19	62	70	44	39	26	12	2
Subxeric	..	..	1	1	2	16	23	46	58	69	23	2
Xeric	..	..	..	..	..	..	1	7	2	5	65	96
Trees in stations	377	597	520	232	449	594	472	266	369	378	297	355
Site-samples used	1	7	4	3	4	4	4	4	4	4	3	4

Observing Patterns : Robert H. Whittaker



Whittaker 1956



Is this a good, quantitative analysis of the community?

Quantifying Patterns

Ordinations

AN ORDINATION OF THE UPLAND FOREST COMMUNITIES OF SOUTHERN WISCONSIN*

J. ROGER BRAY† AND J. T. CURTIS

Department of Botany, University of Minnesota, Minneapolis, Minnesota
Department of Botany, University of Wisconsin, Madison, Wisconsin

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Bray & Curtis 1957

TABLE 3. Composite transect of moisture gradient between 3500 and 4500 ft, distribution of trees along gradient. Transect along the moisture gradient from mesic valley sites (Sta. 1) to xeric southwest slope sites (Sta. 12), based on 46 site counts including 4906 stems from elevations between 3500 ft and 4500 ft. All figures are percentages of total stems in station from 1-in. diameter class up.

Tree species	Station Number											
	1	2	3	4	5	6	7	8	9	10	11	12
Fagus grandifolia	10	5	1	1	1	..	..	..	..	..	..	..
Ilex opaca	..	1	..	x	..	..	..	..	..	..	..	..
Picea rubens	..	x	..	x	x	..	..	..	..	..	..	..
Cornus alternifolia	1	1	..	x	x	..	..	..	..	..	..	..
Aesculus octandra	8	9	4	2	6	1	..	..	..	..	..	..
Tilia heterophylla	29	11	9	1	14	3	..	..	..	..	..	..
Acer spicatum	..	16	11	..	17	1	..	..	..	..	..	..
Acer saccharum	17	7	1	1	5	1	..	..	..	..	..	..
Prunus serotina	2	1	..	1	x	2	..	..	..	..	..	..
Fraxinus americana	1	1	..	1	1	x	..	..	..	..	..	..
Betula allegheniensis	5	17	10	15	4	1	x	..	..	..	..	..
Magnolia acuminata	..	x	..	..	x	..	1	..	..	..	..	..
Magnolia fraseri	..	..	20	4	1	..	1	..	..	..	..	..
Tsuga canadensis	20	22	34	62	18	x	x	1	..	..	..	..
Halesia monticola	5	8	4	1	9	13	3	1	1	..	..	..
Ilex montana	1	x	..	1	1	1	2	..	..	..	..	..
Acer pensylvanicum	1	x	1	3	8	3	x	1	..	..	..	..
Amelanchier laevis	..	x	..	x	x	..	..	..	..	..	..	..
Quercus borealis	..	1	..	..	2	40	10	4	15	11	2	1
Acer rubrum	..	1	..	..	1	6	37	21	13	10	8	1
Prunus pensylvanica	..	..	2	..	..	..	1	..	..	..	..	..
Betula lenta	..	..	1	4	4	1	2	2	..	..	..	..
Clethra acuminata	..	..	..	1	x	..	..	..	..	..	..	..
Hamamelis virginiana	..	..	..	..	2	5	17	7	1	..	2	..
Cornus florida	..	..	..	..	1	..	x	4	..	..	..	..
Liriodendron tulipifera	..	..	..	..	2	..	..	1	..	x	..	..
Rhododendron calendulaceum	..	..	..	..	..	1	..	1	4	..	..	..
Carya glabra	..	..	..	..	..	4	x	2	6	5	..	..
Carya tomentosa	..	..	..	..	..	..	..	2	..	..	..	..
Carya ovalis	..	..	..	..	..	..	..	x	..	..	..	..
Nyssa sylvatica	..	..	1	..	..	..	2	4	1	2	7	..
Oxydendrum arboreum	..	..	x	1	..	1	3	8	14	16	1	1
Castanea dentata (dead)	..	..	..	..	2	5	7	9	10	12	1	..
Sassafras albidum	..	..	..	..	..	1	1	1	1	4	x	..
Quercus alba	..	..	..	..	..	2	1	8	24	10	x	..
Robinia pseudoacacia	..	..	..	..	..	4	5	1	3	8	3	x
Quercus prinus	..	..	..	..	..	3	4	15	4	16	11	1
Quercus velutina	..	..	..	..	..	..	x	x	1	1	..	..
Quercus coccinea	..	..	..	..	..	..	1	..	..	..	..	1
Pinus rigida	..	..	..	..	..	..	..	7	1	1	11	46
Pinus pungens	..	..	..	..	..	..	..	..	1	4	54	49
Percents by classes												
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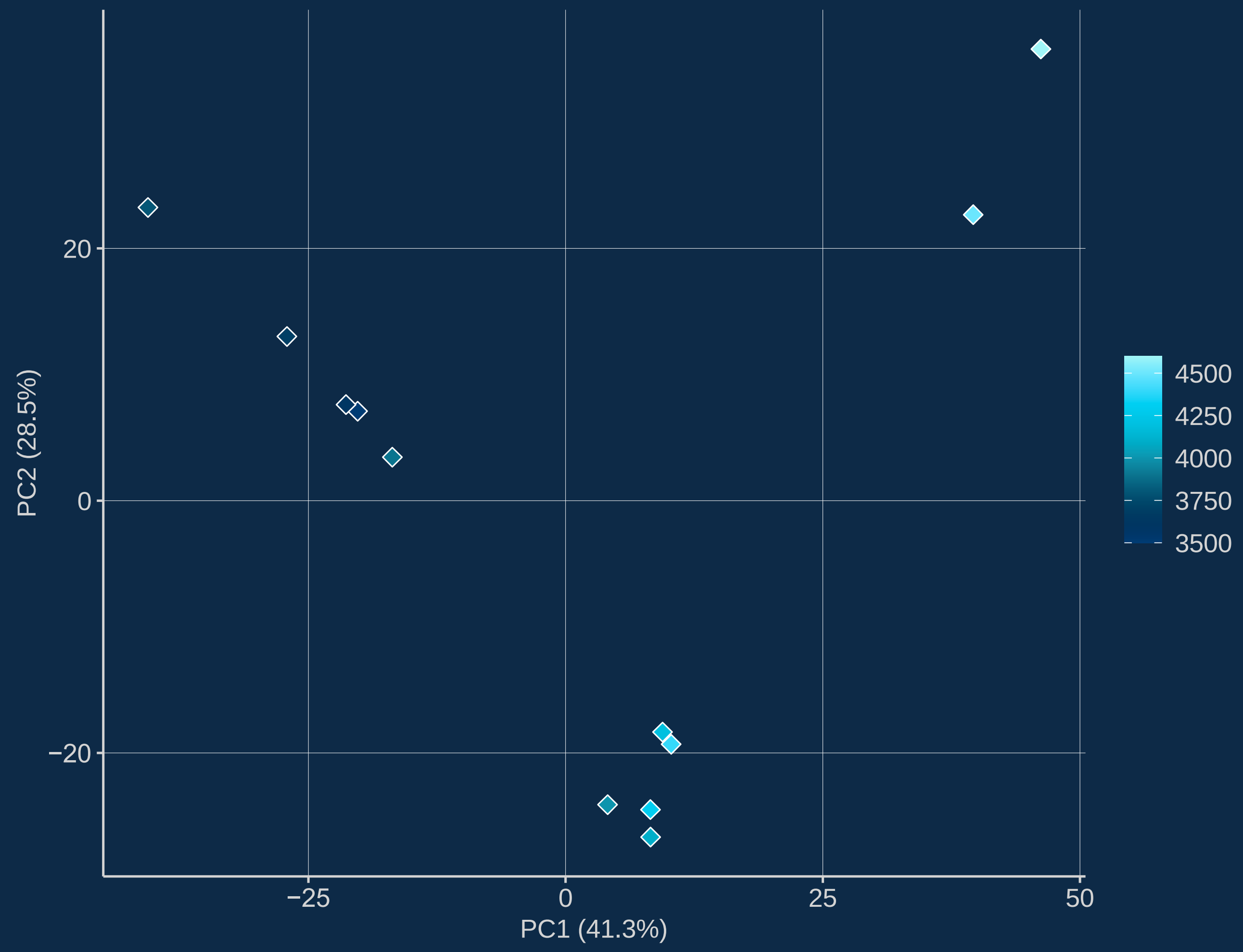
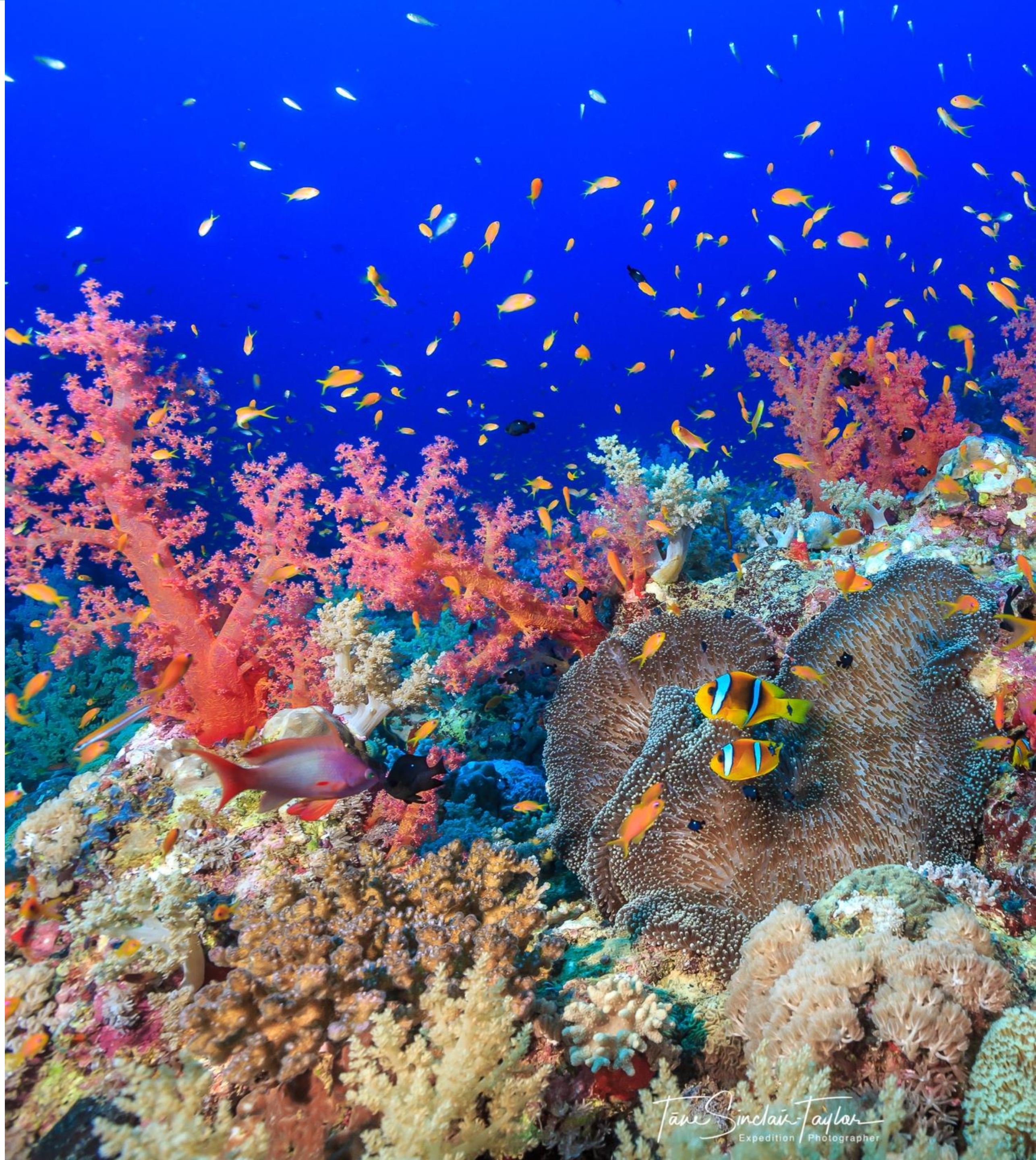



Tane Sinclair-Taylor
Expedition Photographer

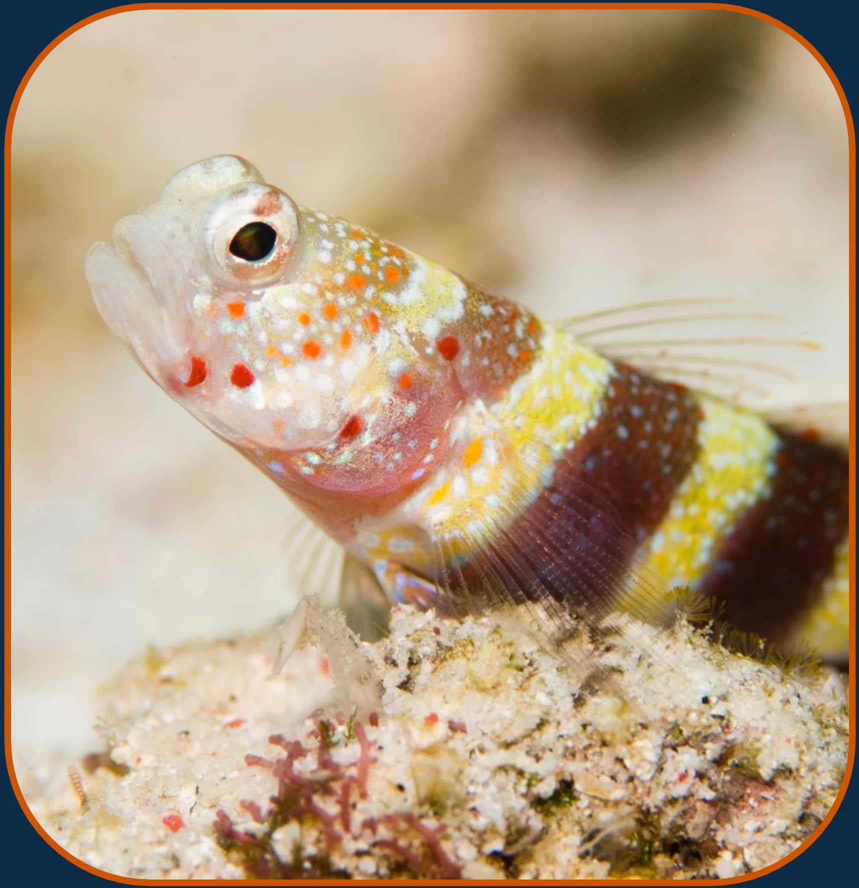

Gobies (Family Gobiidae)

Modeling dynamics

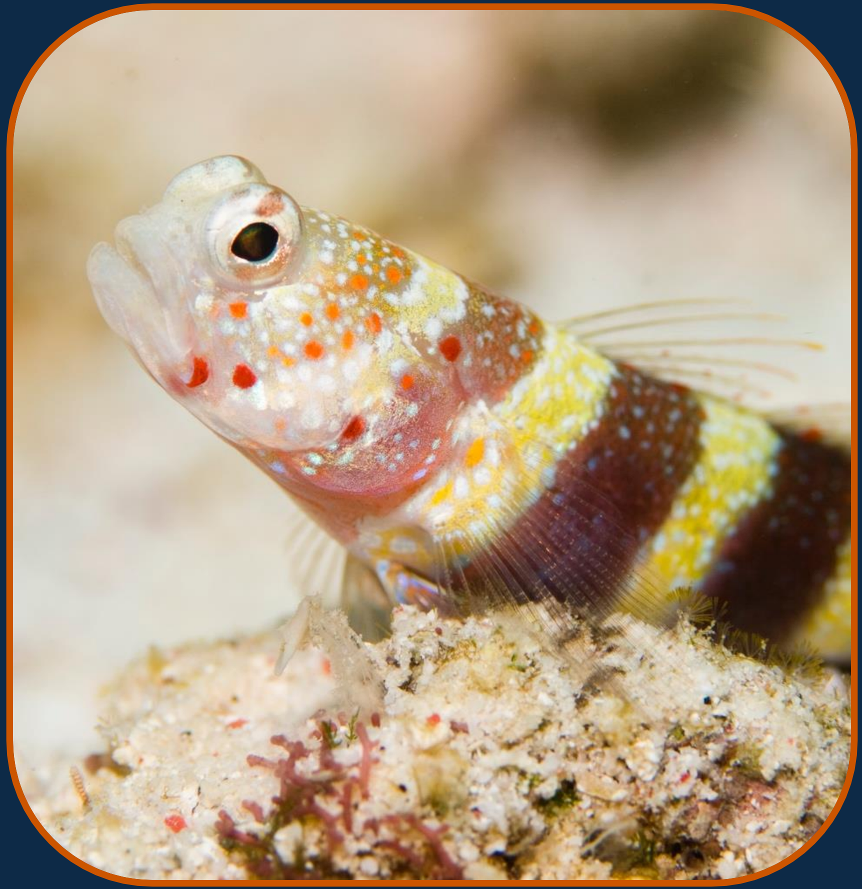
Amblyeleotris guttata

Competition!

Amblyeleotris wheeleri



Modeling dynamics



Models: Mathematical basis for population dynamics (e.g. Lotka-Volterra)

Modeling dynamics

N = population size

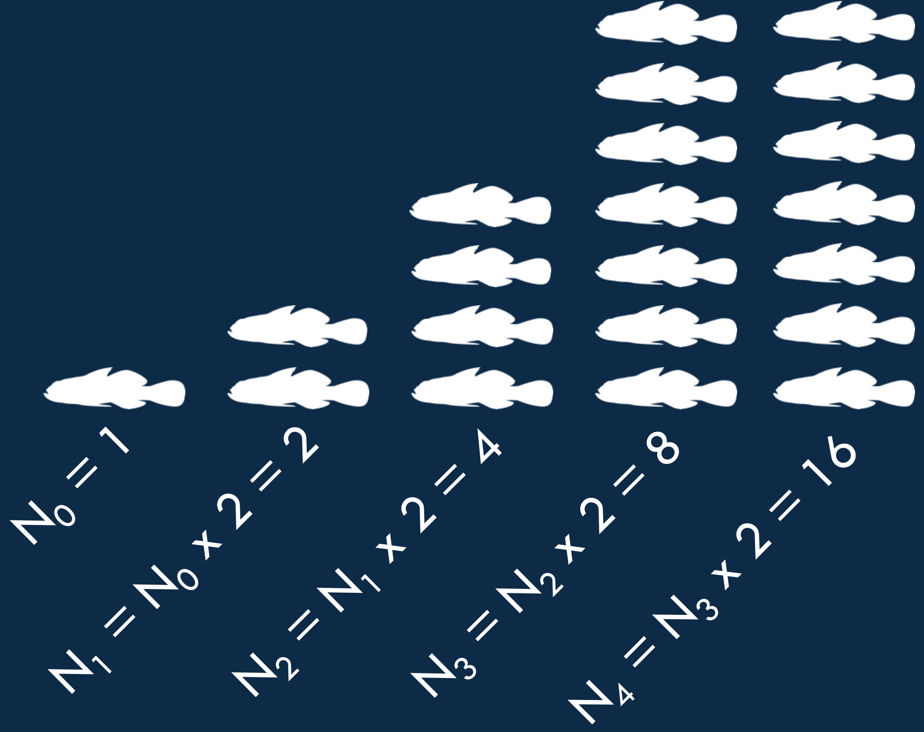
subscript = time

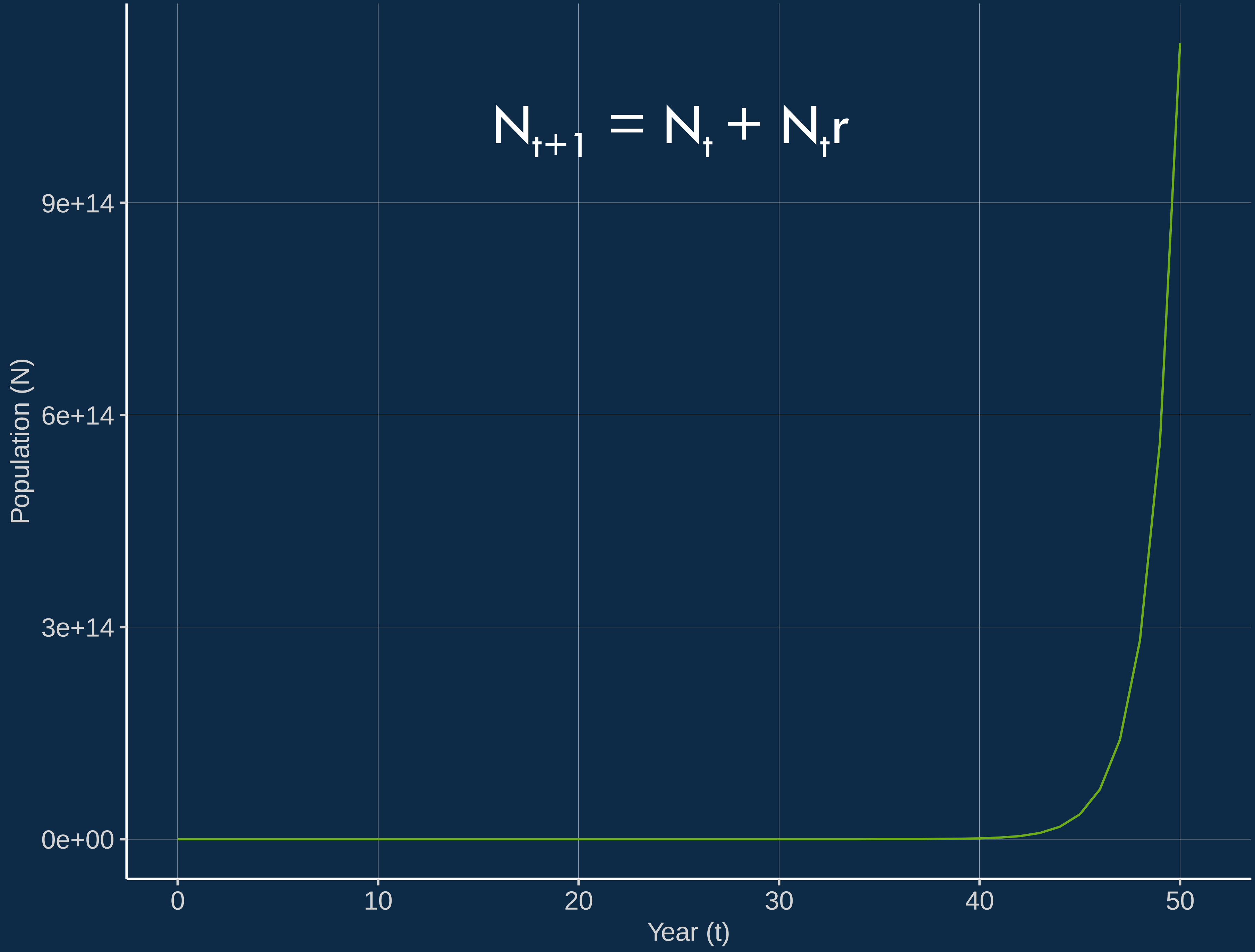
N_t = population at time t

r = population growth rate

$N_{t+1} = N_t + N_t r$

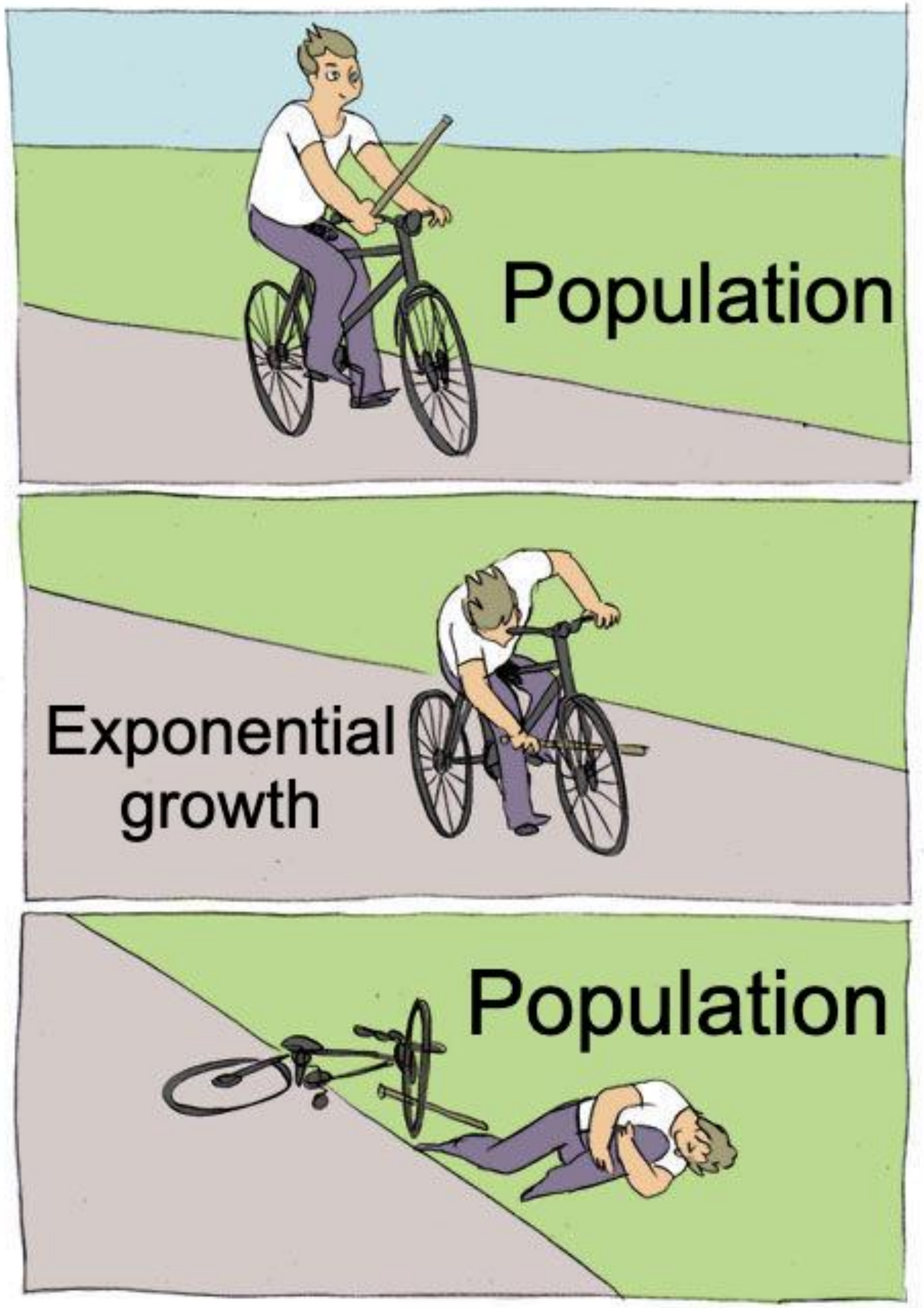
→ exponential equation





$N_{t+1} = N_t + N_t r$
9e+14
6e+14
3e+14
0e+00
Population (N)
0
10
20
30
40
50
Year (t)


900 trillion gobies


Population
Exponential growth
Population

Modeling dynamics

N = population size

subscript = time

N_t = population at time t

r = population growth rate

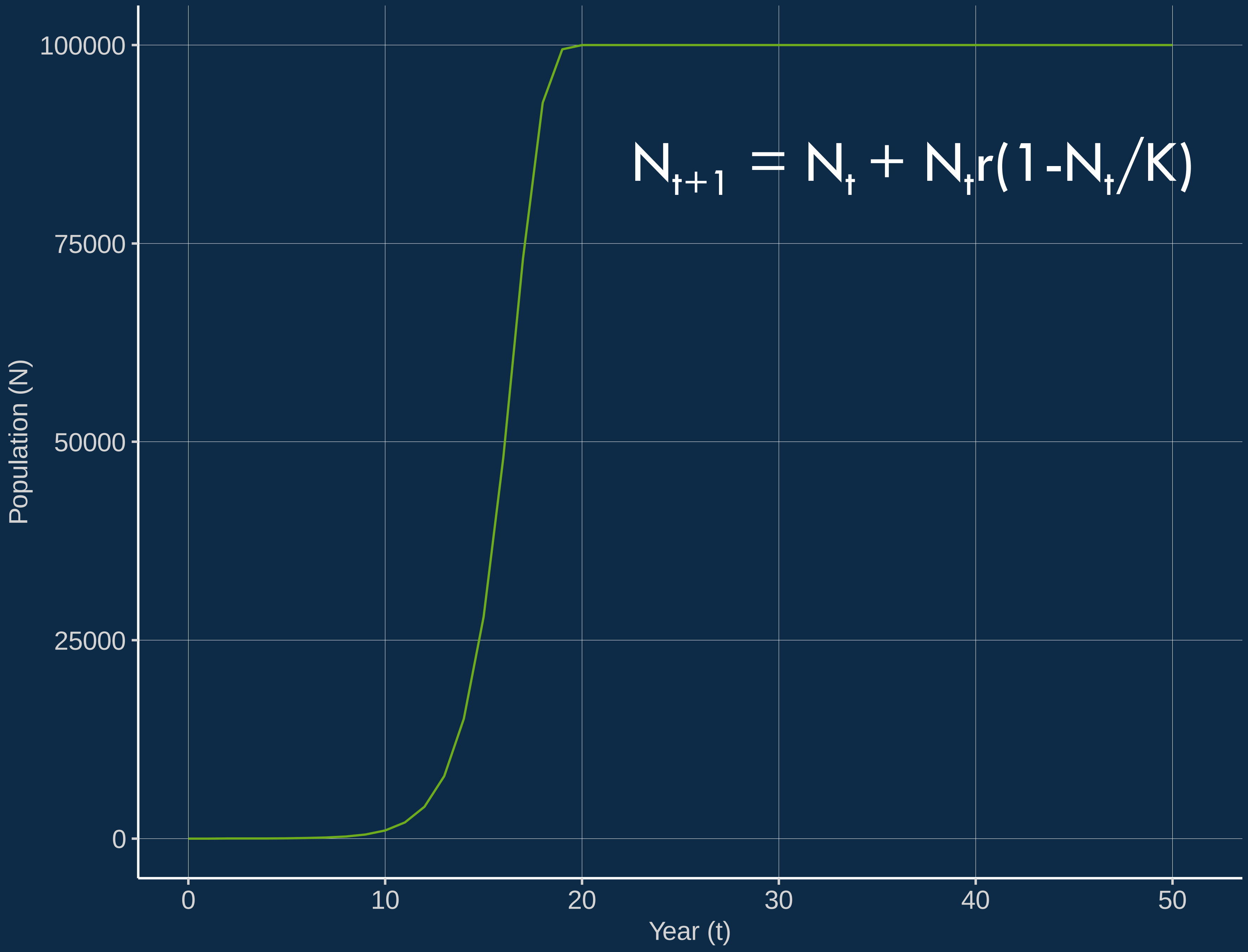
K = carrying capacity

$1 - N_t/K$ = how far from carrying capacity

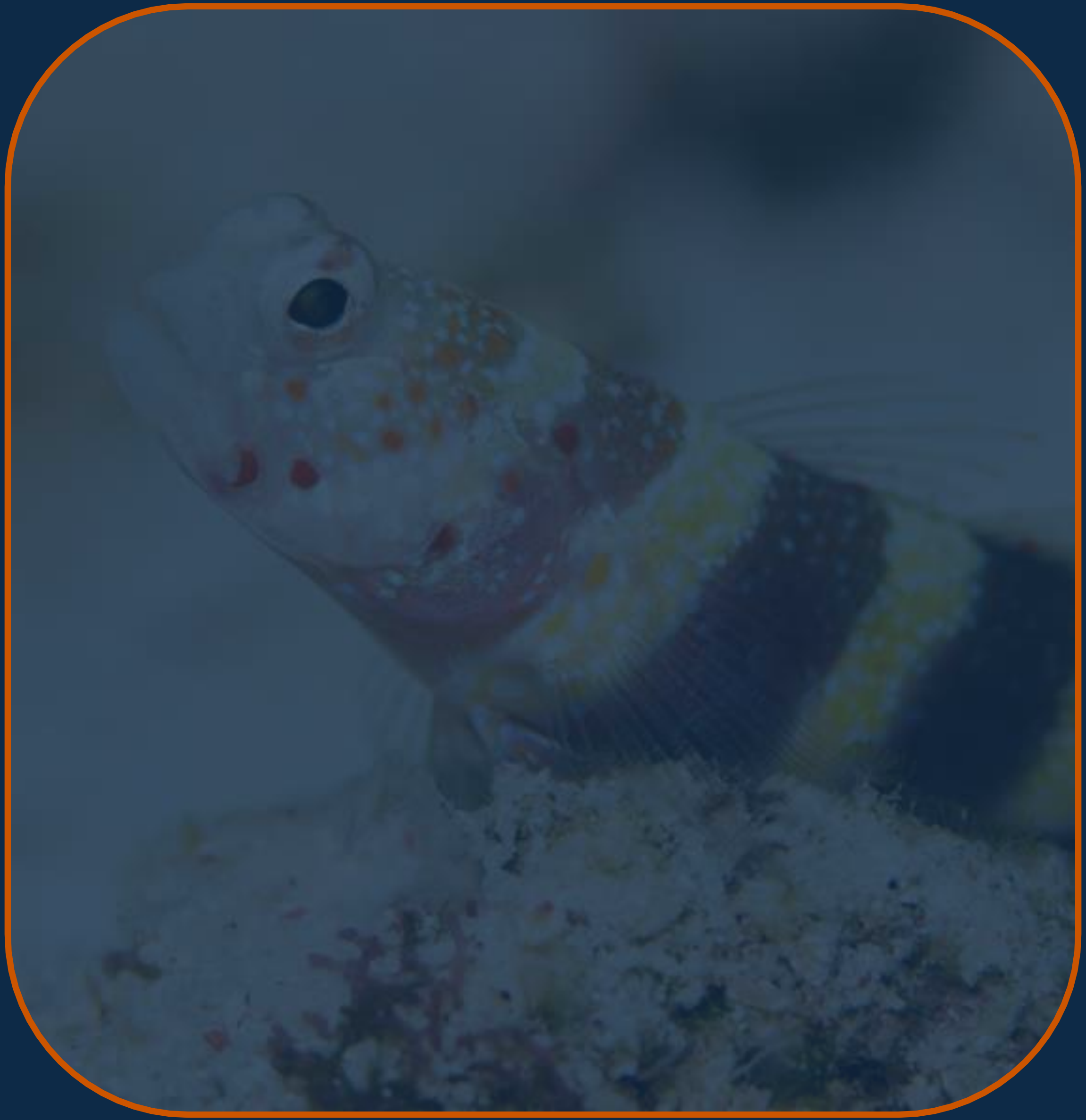
$r(1 - N_t/K)$ = real population growth

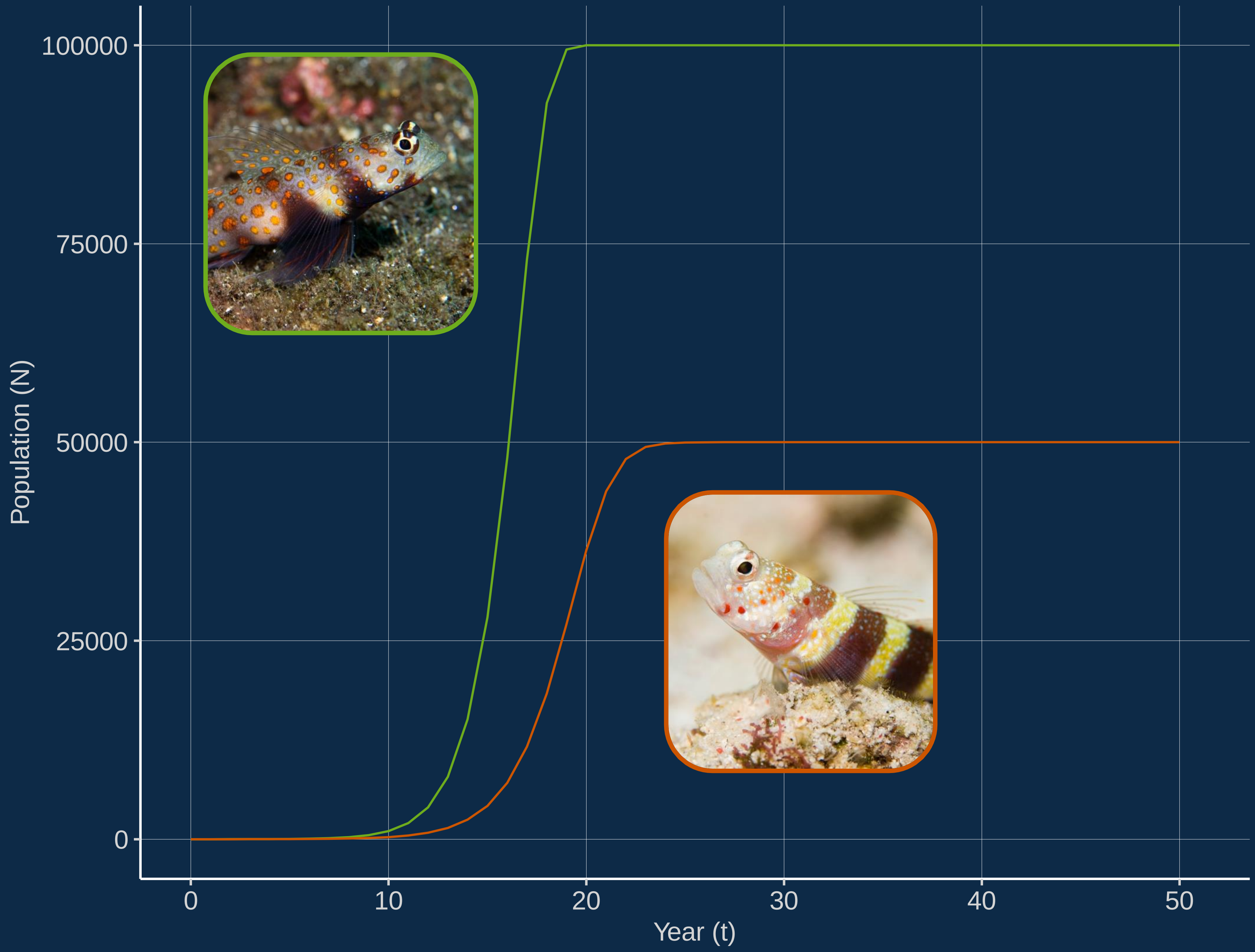
$$N_{t+1} = N_t + N_t r(1 - N_t/K)$$

→ logistic equation



$$N_{t+1} = N_t + N_t r(1 - N_t/K)$$





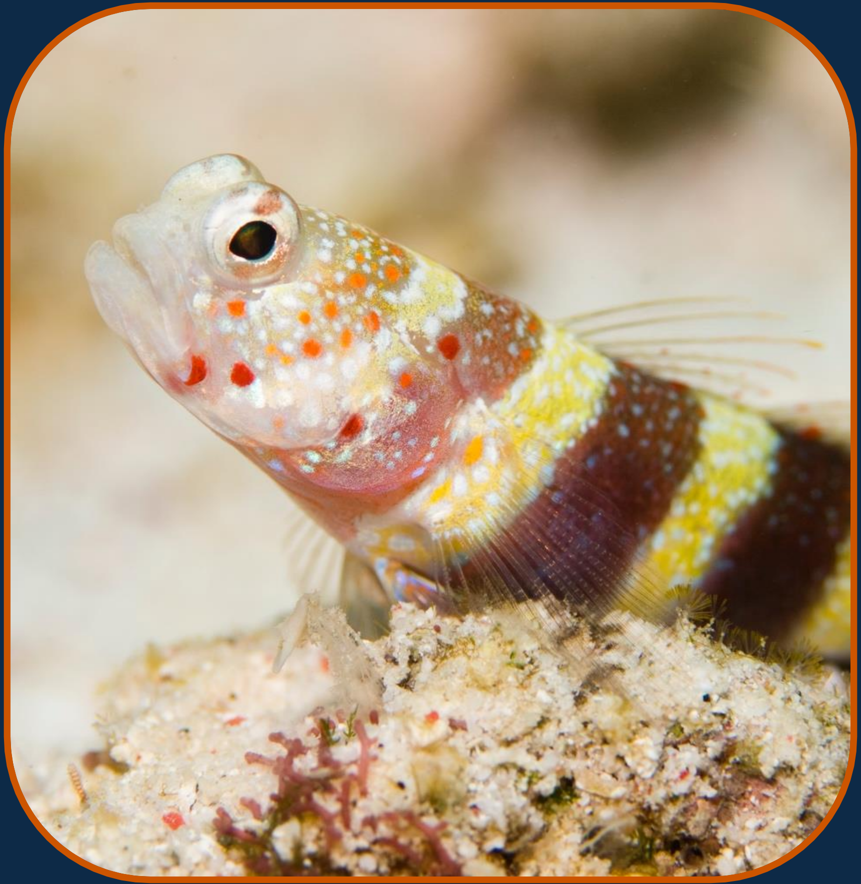
100000
75000
50000
25000
0
Population (N)
0
10
20
30
40
50
Year (t)

Modeling dynamics

α_{12}

←

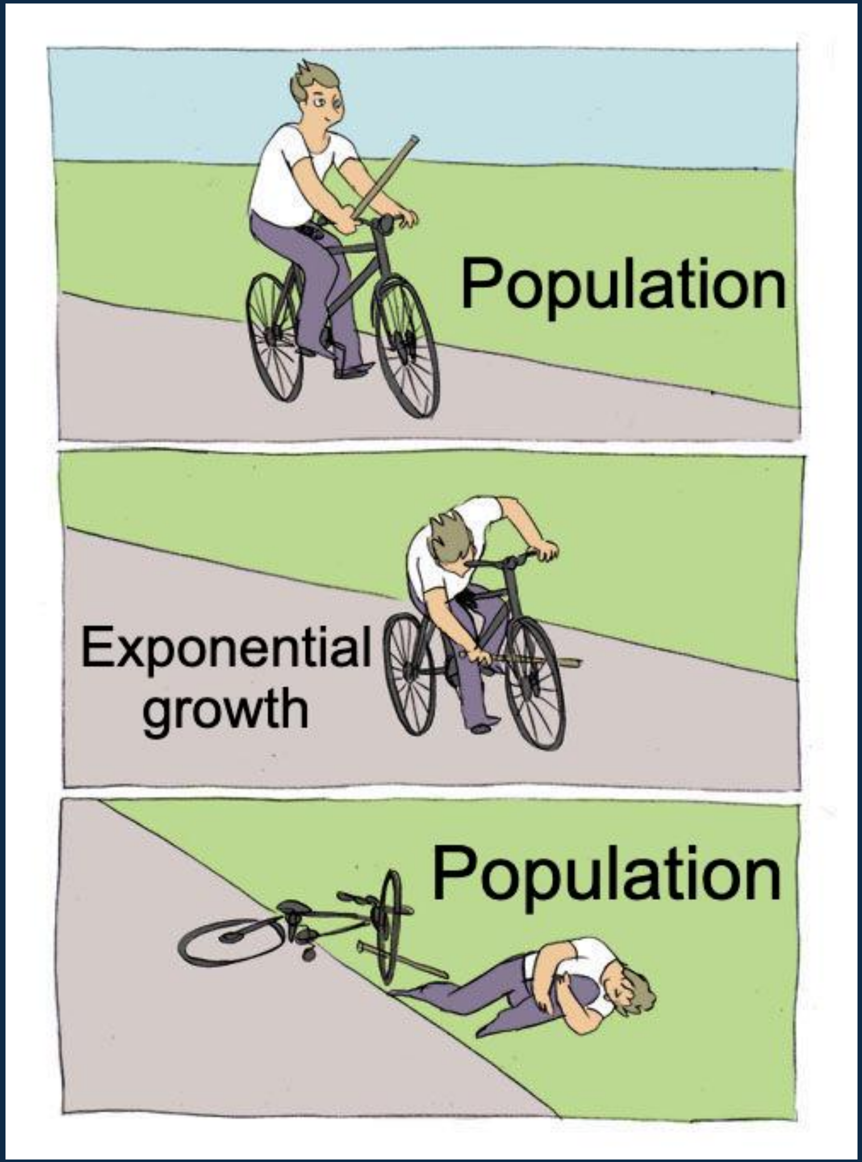
competition coefficient

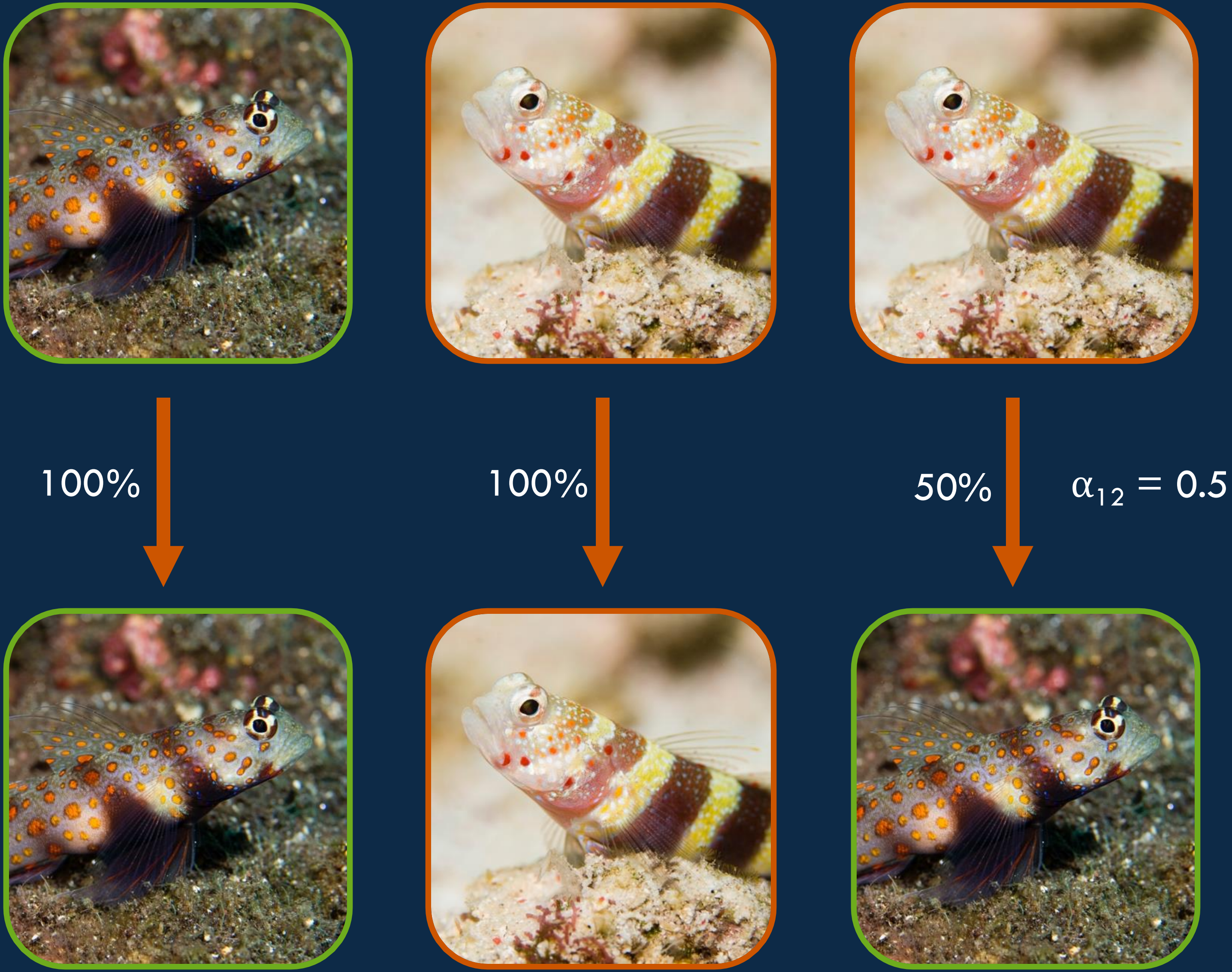


N_1

N_2

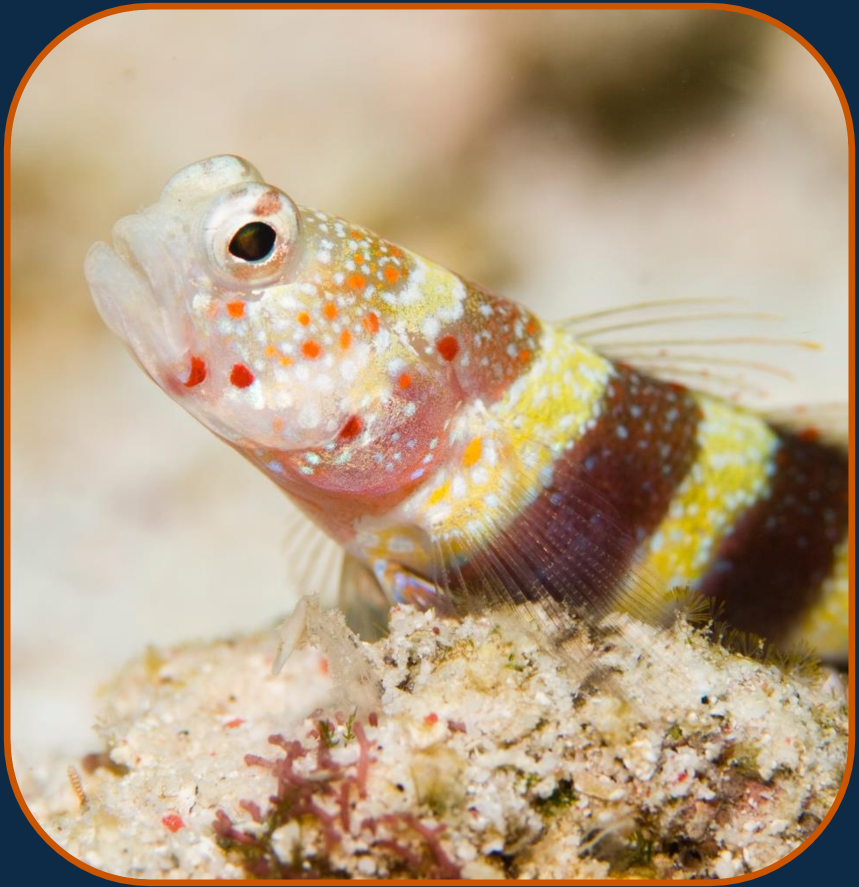
Modeling dynamics





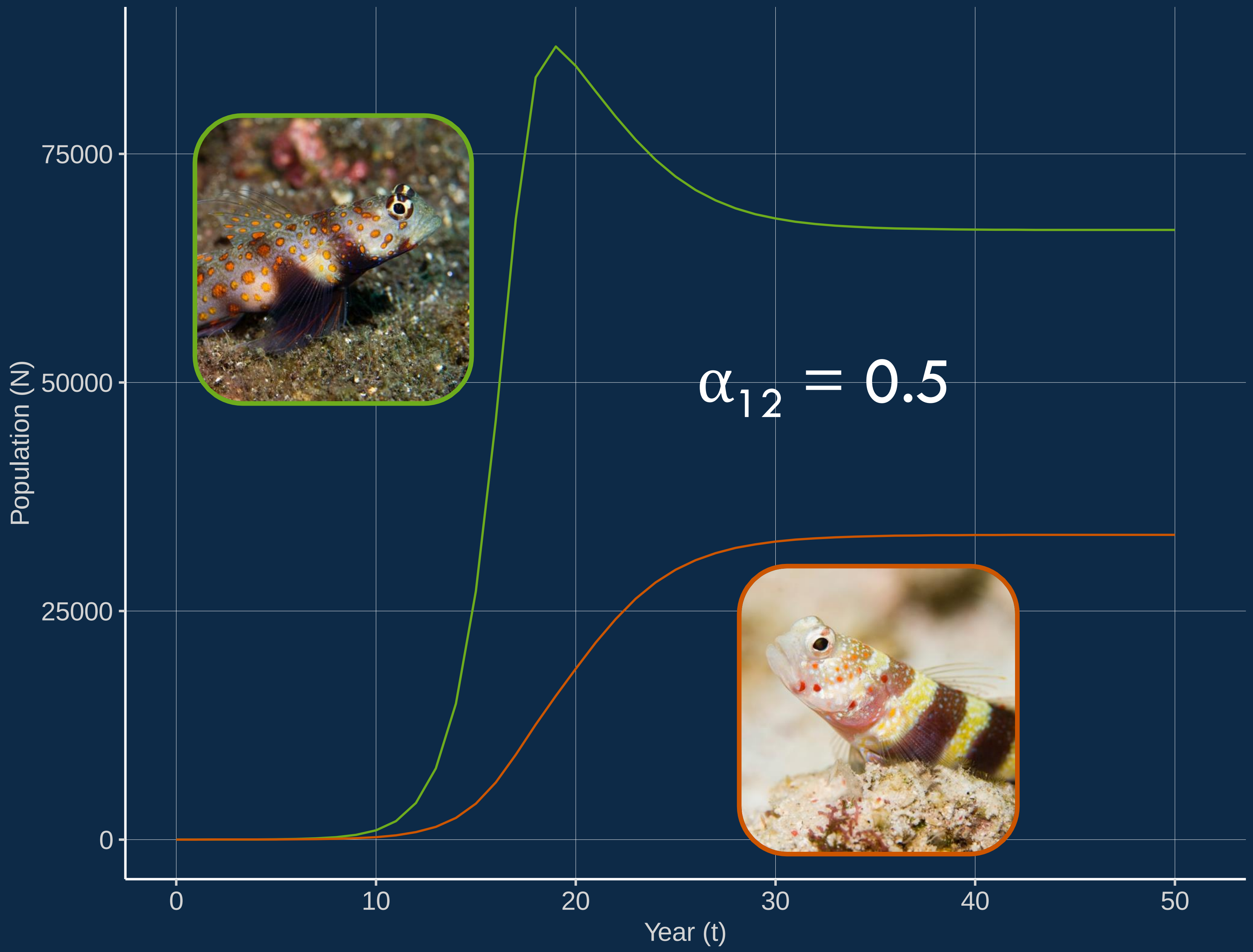
Modeling dynamics

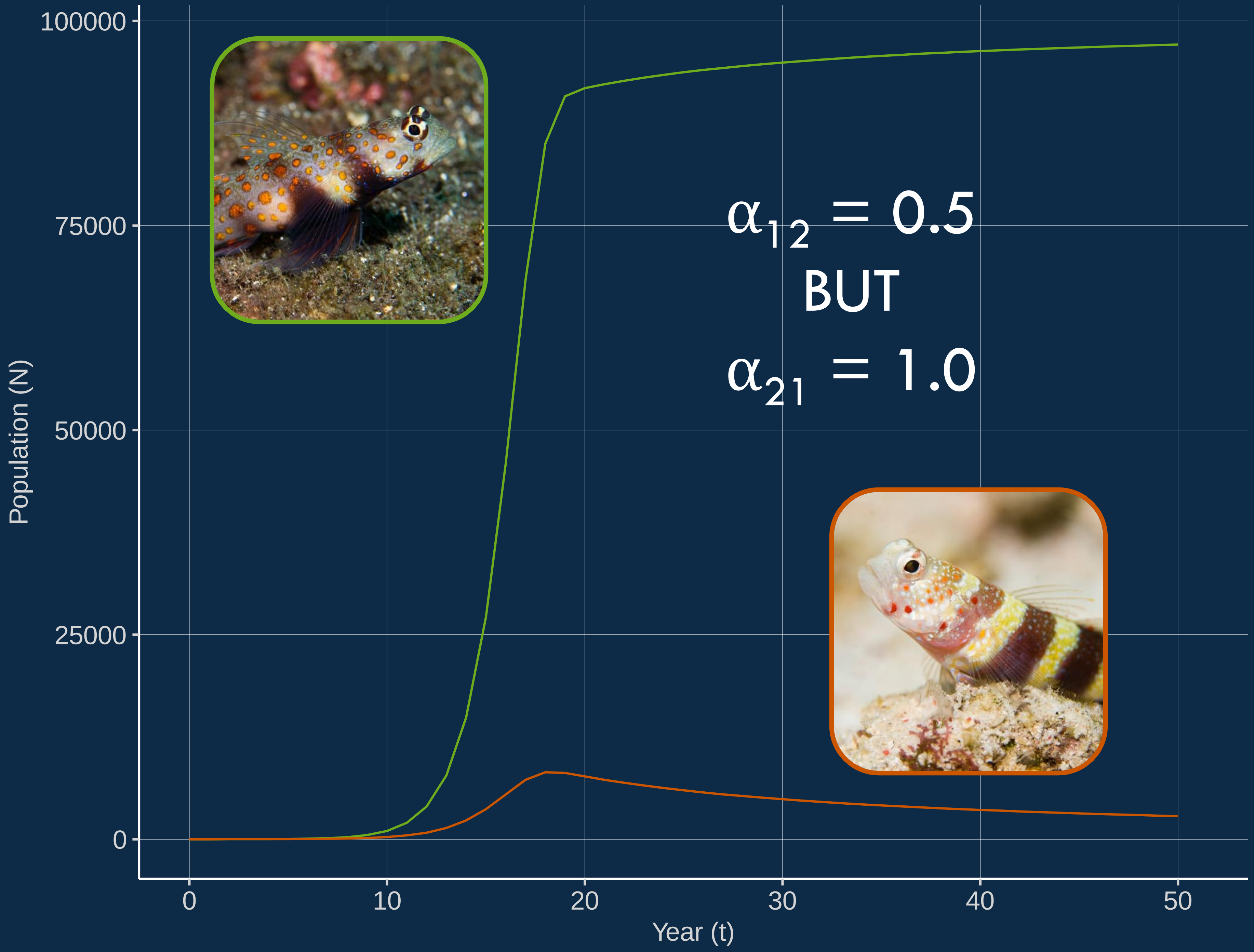
$\alpha_{12} = 0.5$ ←



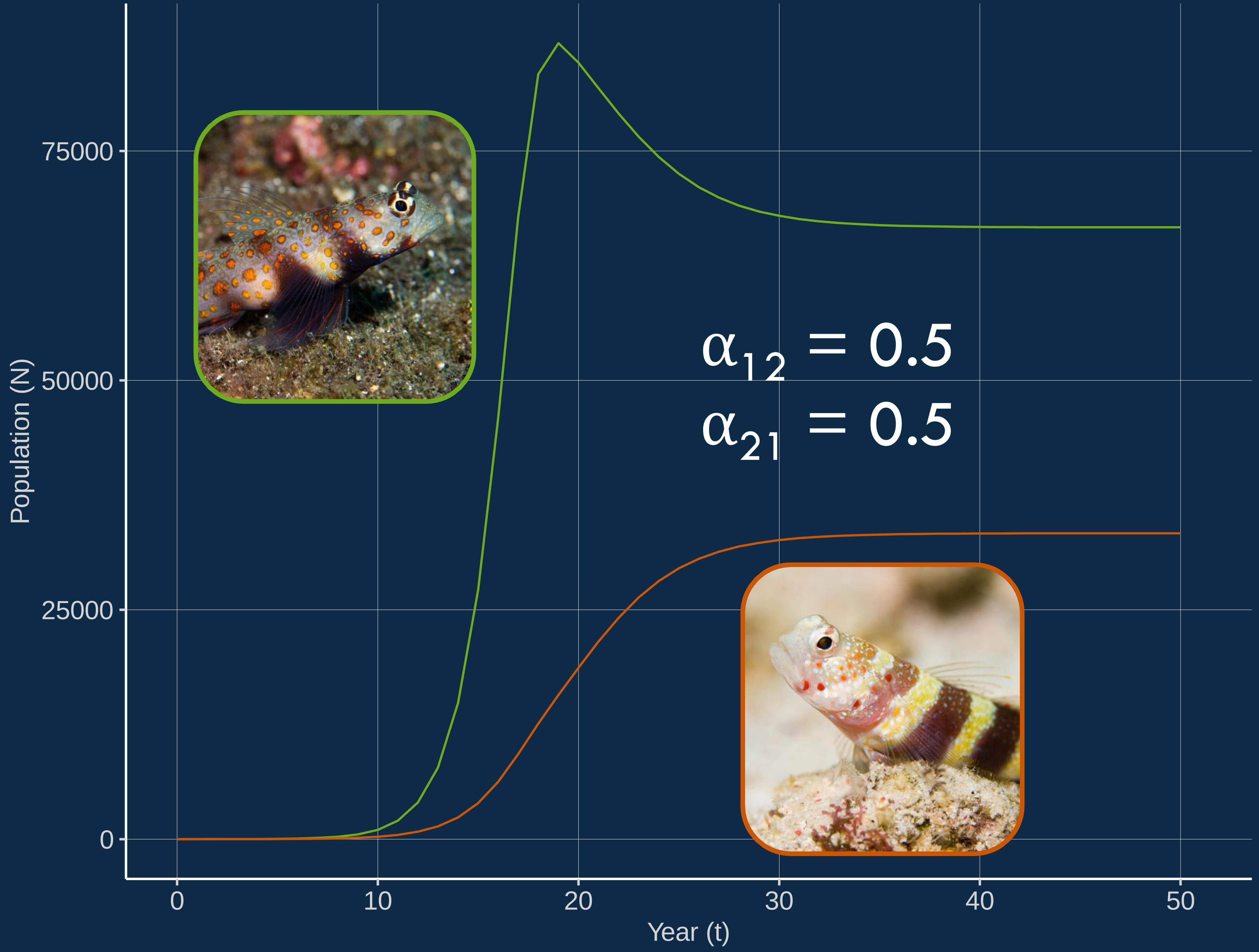
N_1 N_2

$$N_{1(t+1)} = N_{1(t)} + N_{1(t)}\, r(1 - N_{1(t)}/K_1 - \alpha_{12} N_{2(t)}/K_1)$$


Population (N)
75000
50000
25000
0
0
10
20
30
40
50
Year (t)
α12 = 0.5



100000
75000
50000
25000
0
Population (N)
0
10
20
30
40
50
Year (t)
α12 = 0.5
BUT
α21 = 1.0



75000
50000
25000
0
Population (N)
0
10
20
30
40
50
Year (t)
α12 = 0.5
α21 = 0.5

Modeling dynamics

Niche differences

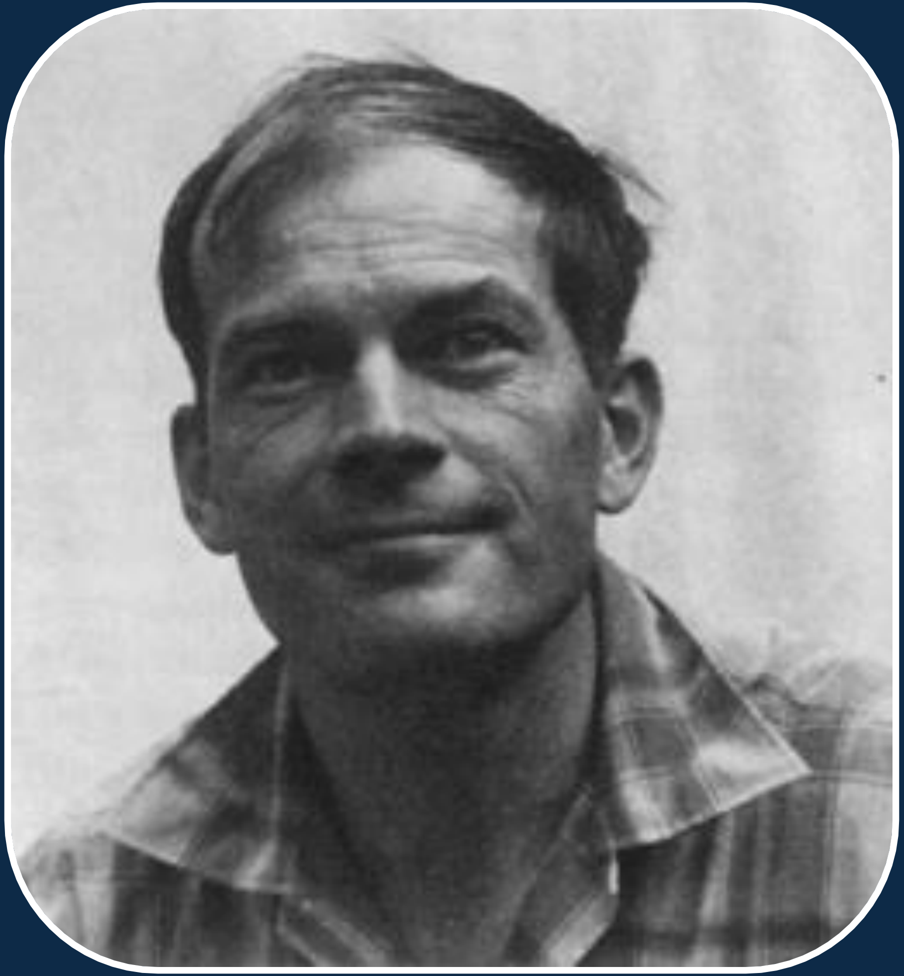
- diet
- habitat
- space
- time

intraspecific competition vs. interspecific competition

Chesson 2000; HilleRisLambers et al. 2012

Modeling dynamics

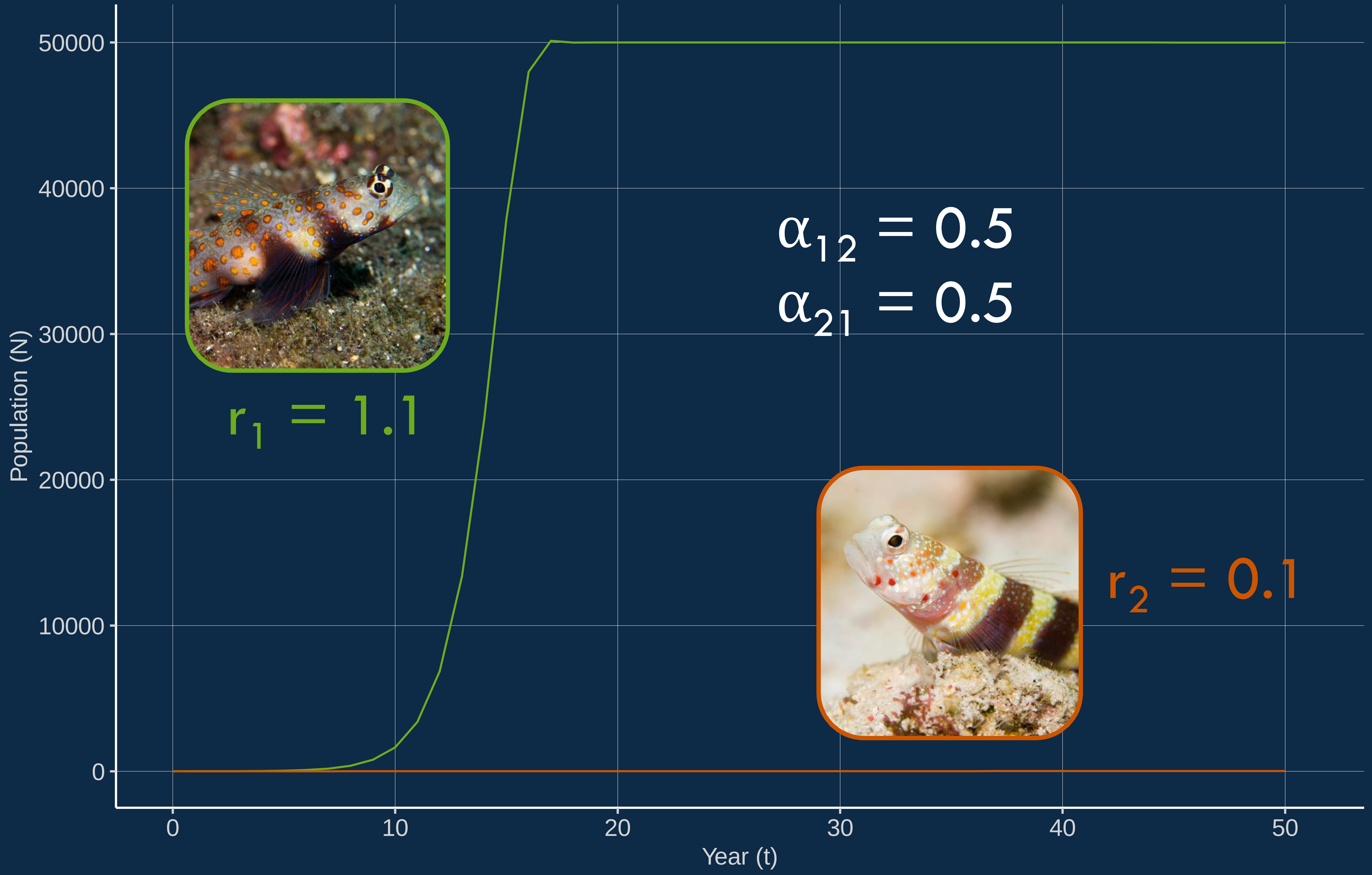
Robert MacArthur



Limiting similarity theory

David Tilman

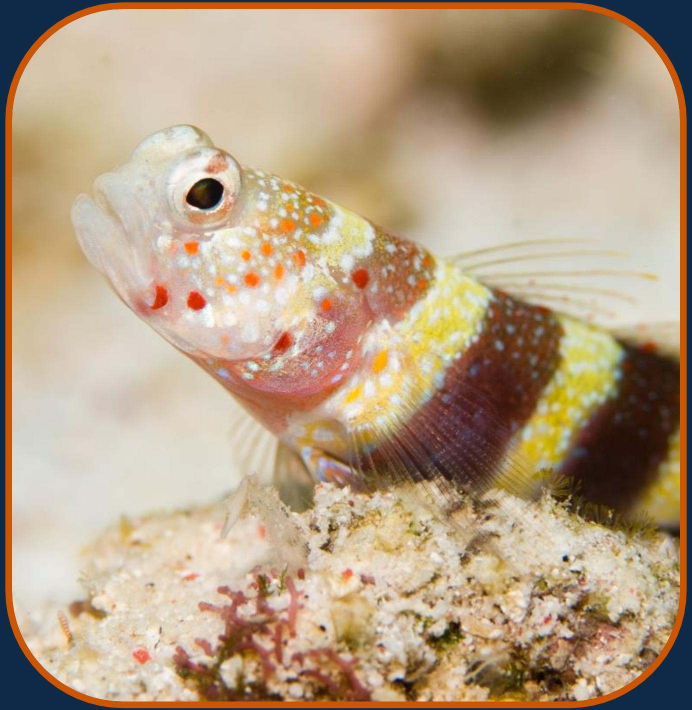
Resource competition theory


50000
40000
30000
20000
10000
0
Population (N)
0
10
20
30
40
50
Year (t)
$r_1 = 1.1$
$\alpha_{12} = 0.5$
$\alpha_{21} = 0.5$
$r_2 = 0.1$

Modeling dynamics

Fitness differences

- growth rate
- fecundity
- mortality
- energy use



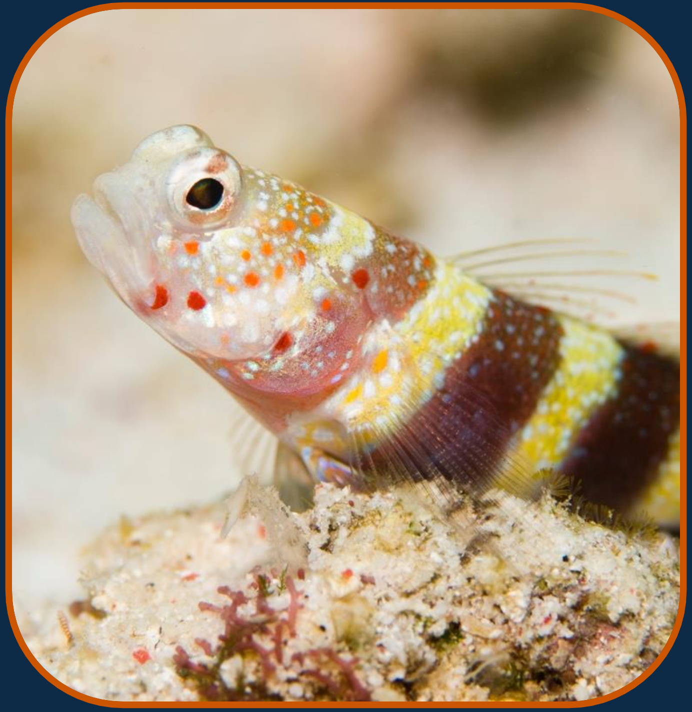
Increased fitness when rare:
Negative frequency dependence

Modeling dynamics

Niche differences

>

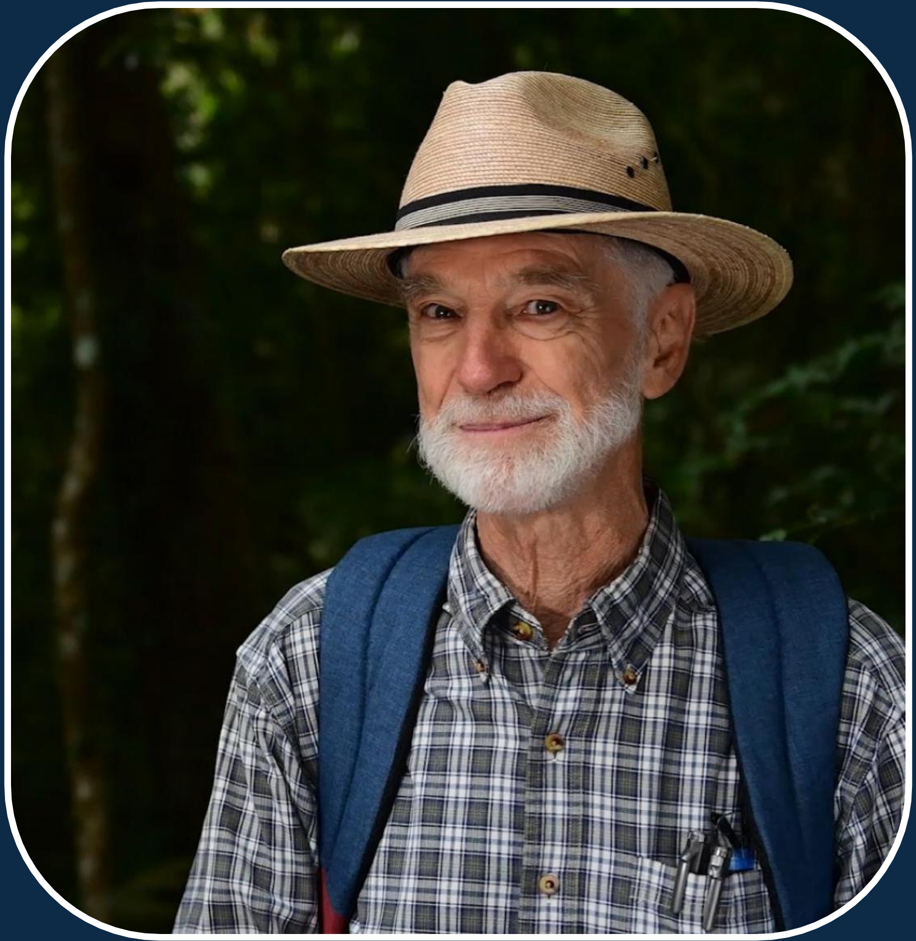
Fitness differences



Chesson 2000; HilleRisLambers et al. 2012

Modeling dynamics

Peter Chesson



Janneke HilleRisLambers

Modern coexistence theory


VALERIANO


Niches & fitness are the deterministic drivers of community assembly

Large Scale Patterns & Processes

$$\alpha_{12} = 0.5$$
$$\alpha_{21} = 0.5$$
$$r_1 = 1$$
$$r_2 = 1$$
$$K = 50{,}000$$

What happened? 😢

Large Scale Patterns & Processes

Local

Regional

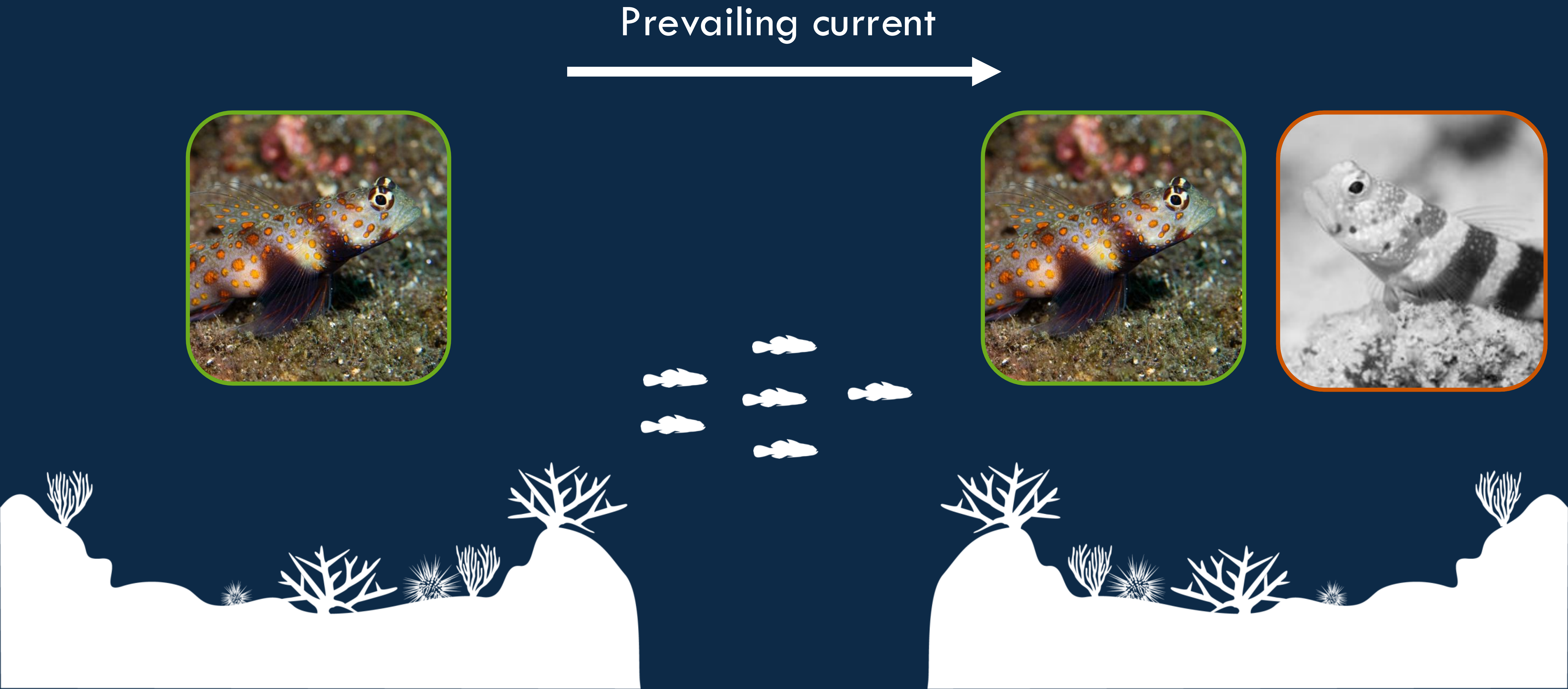
Global

Large Scale Patterns & Processes

Emigration

Immigration

Large Scale Patterns & Processes



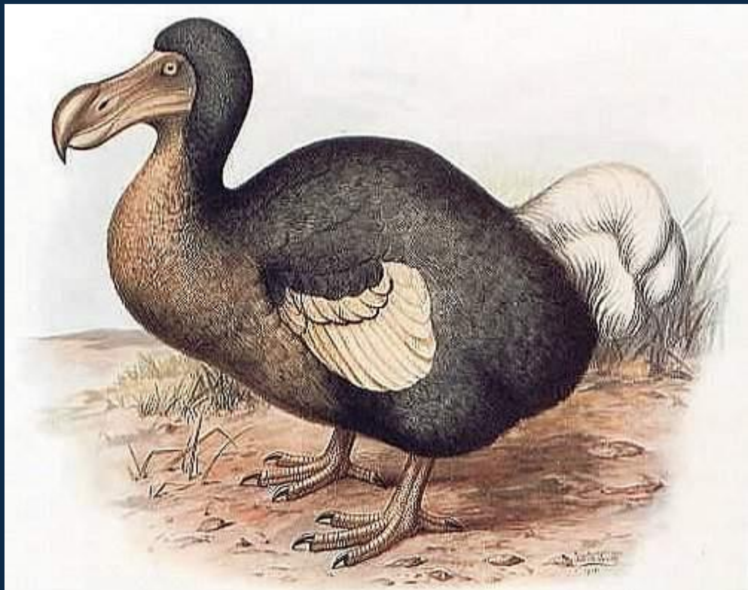
Large Scale Patterns & Processes

Extinction


Oh shit! The economy!!





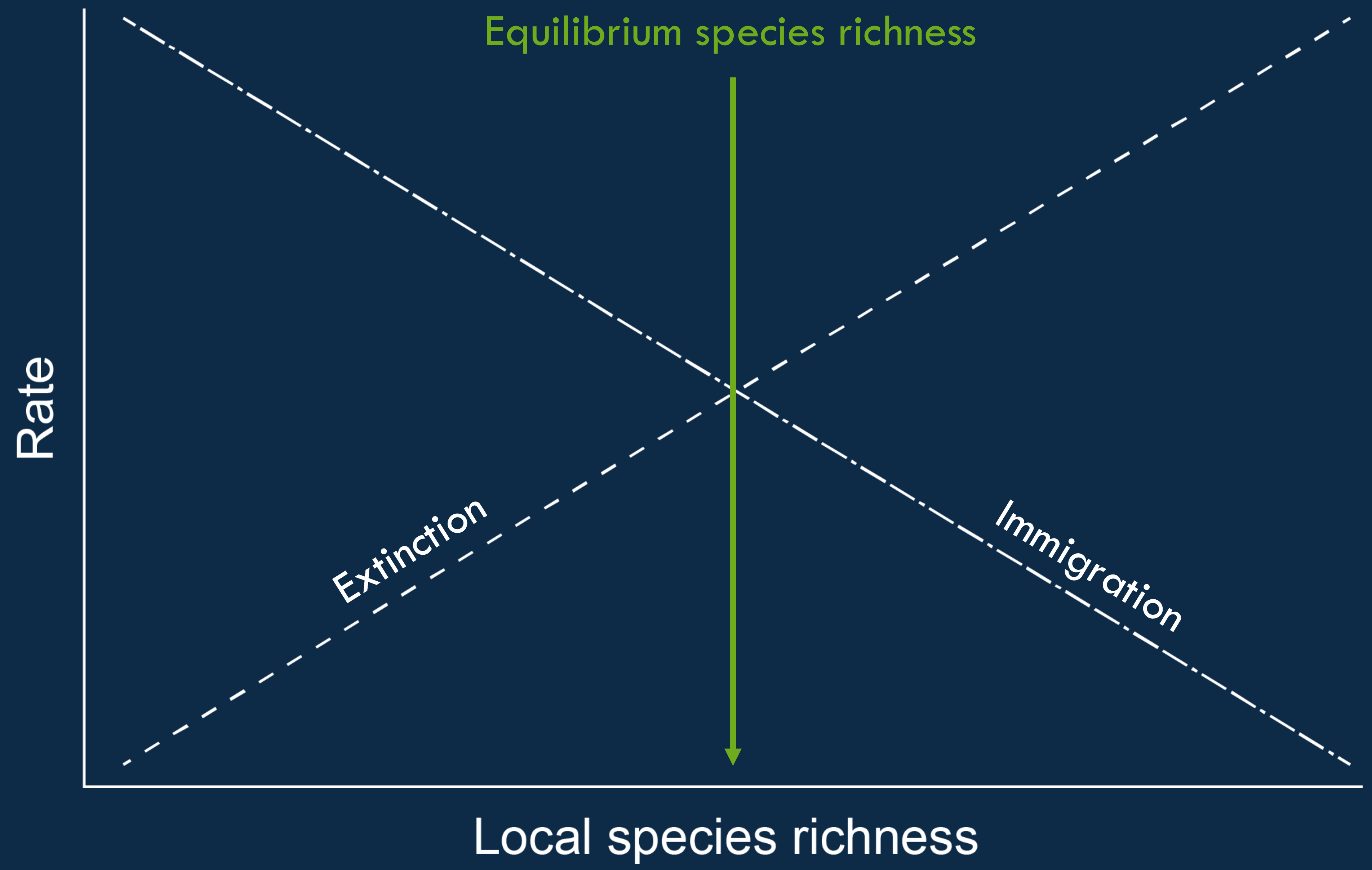


Large Scale Patterns & Processes

(Local) Extinction

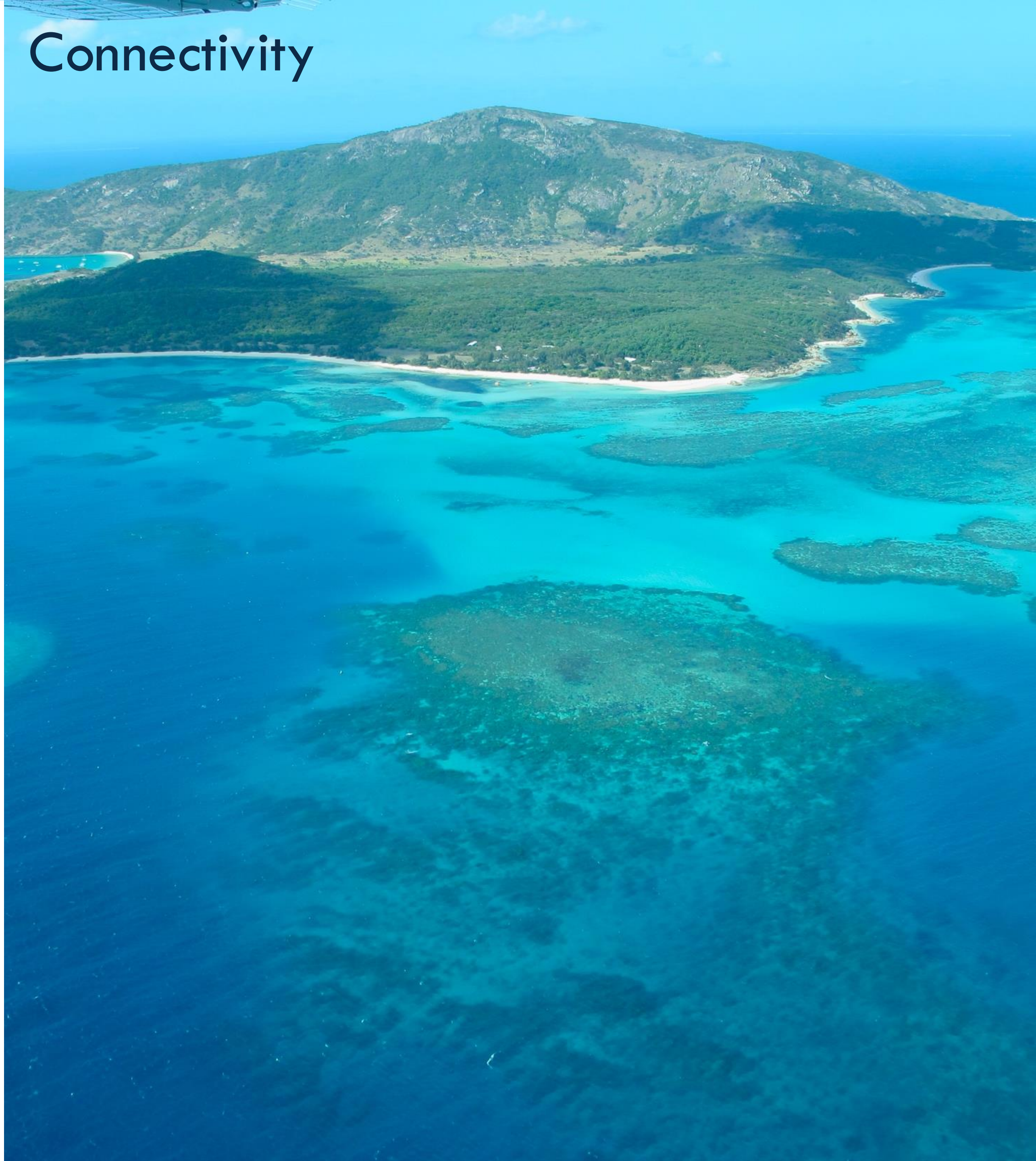

CUBAPRO

Large Scale Patterns & Processes

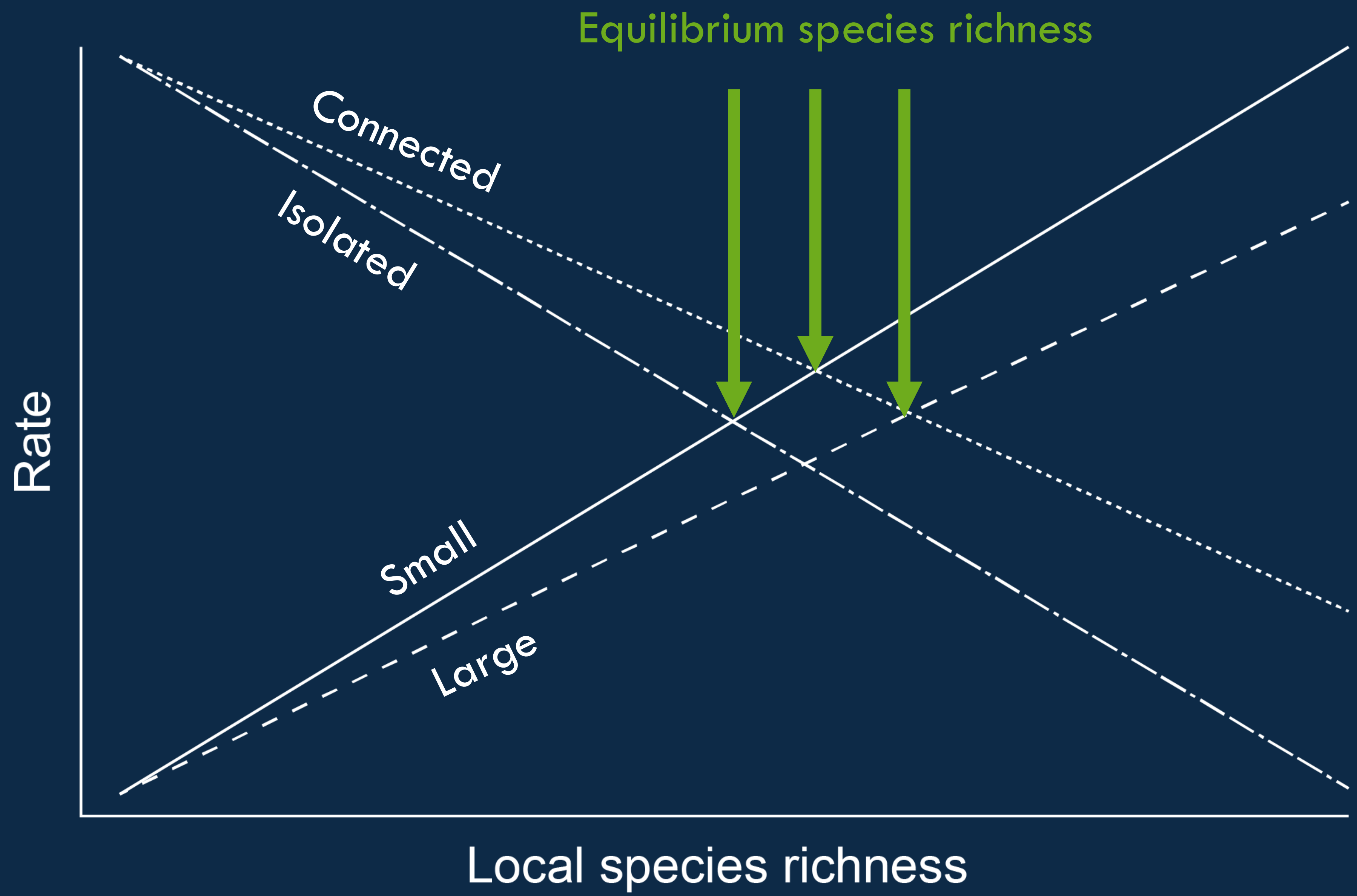


Area

Connectivity

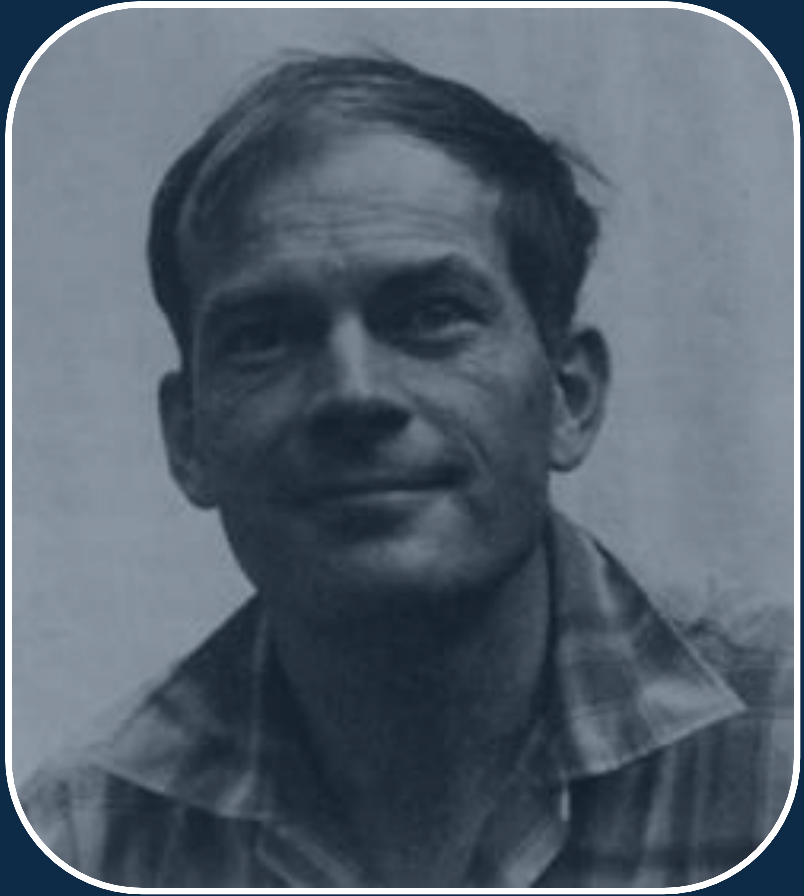


Large Scale Patterns & Processes



Large Scale Patterns & Processes

Robert MacArthur

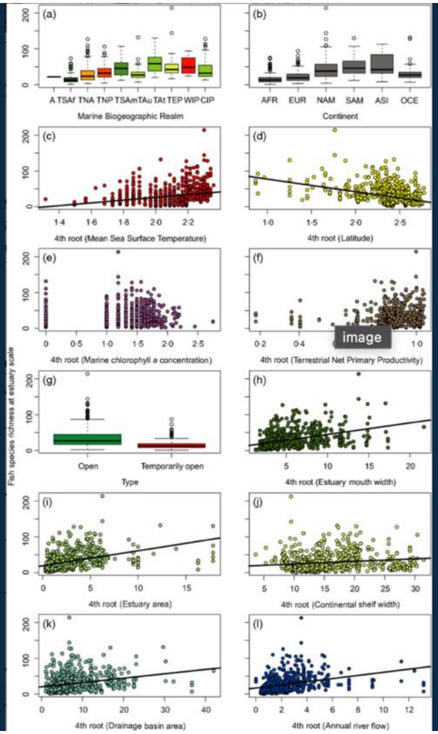


E.O. Wilson

Theory of Island Biogeography

Large Scale Patterns & Processes

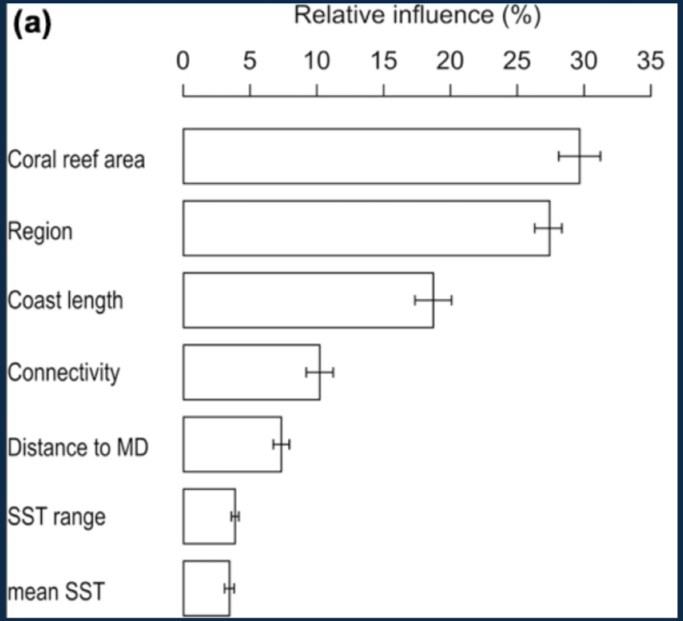
Estuarine fishes



- biogeographic realm
- sea surface temperature
- estuarine area
- connectivity

Vasconcelos et al. 2015

Coral reef fishes

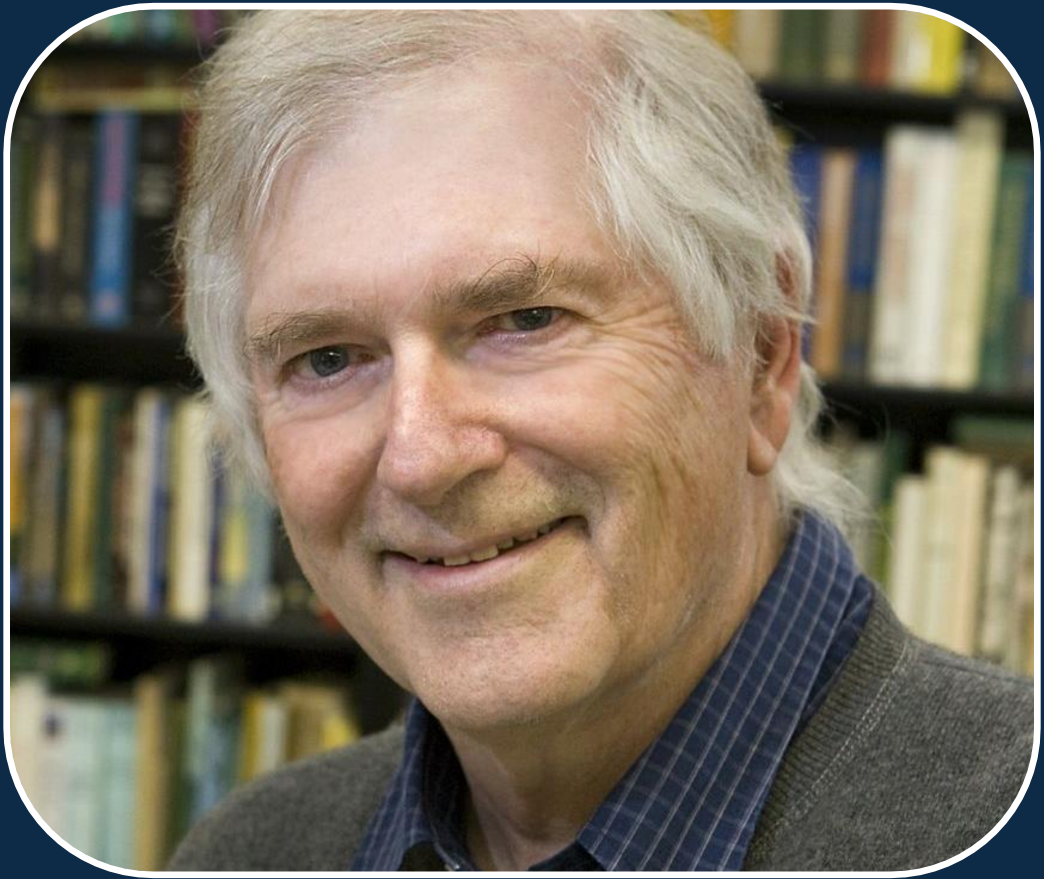


- coral reef area
- biogeographic realm
- sea surface temperature
- connectivity

Parravicini et al. 2015

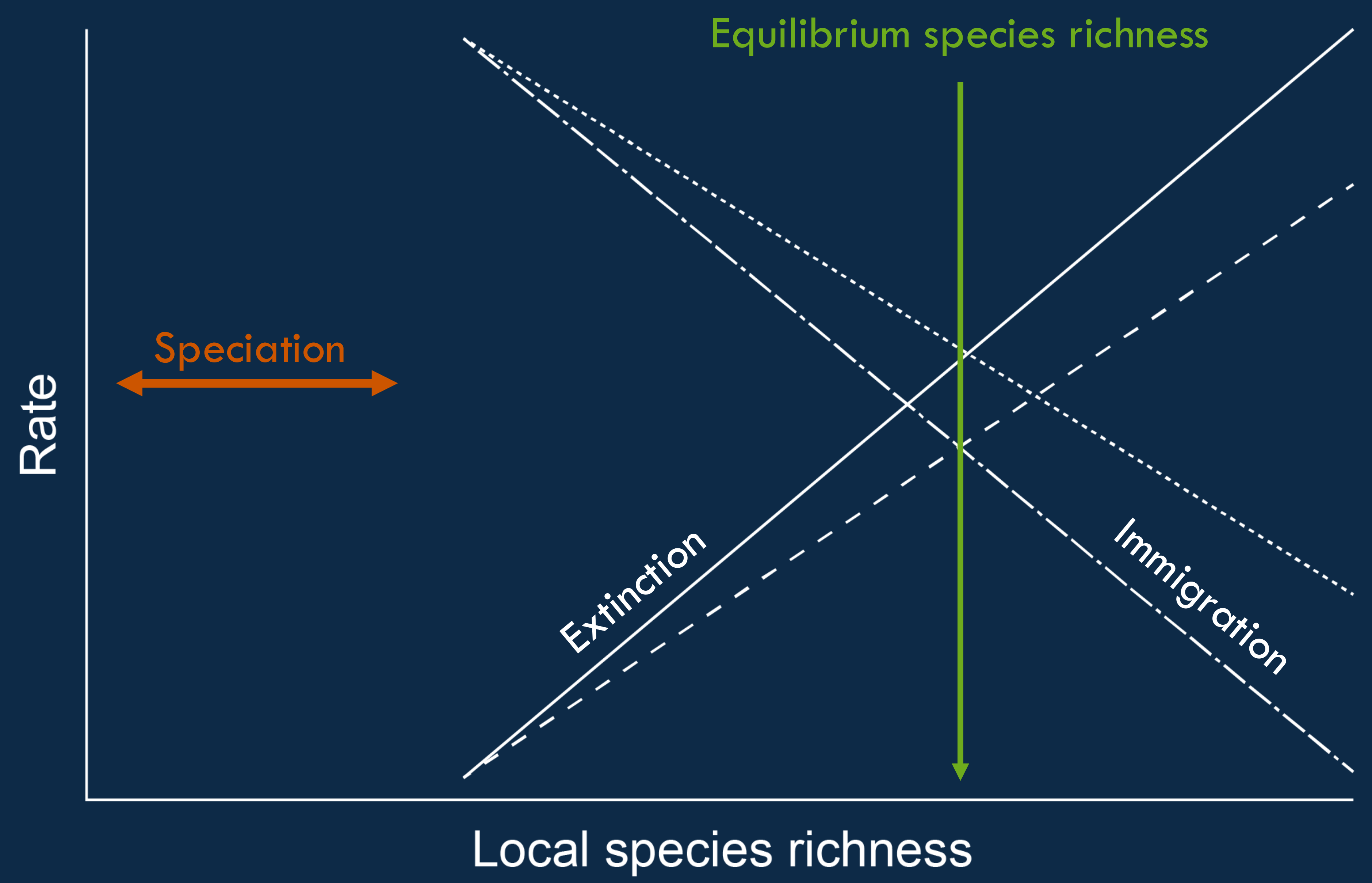
Do ecological differences matter?

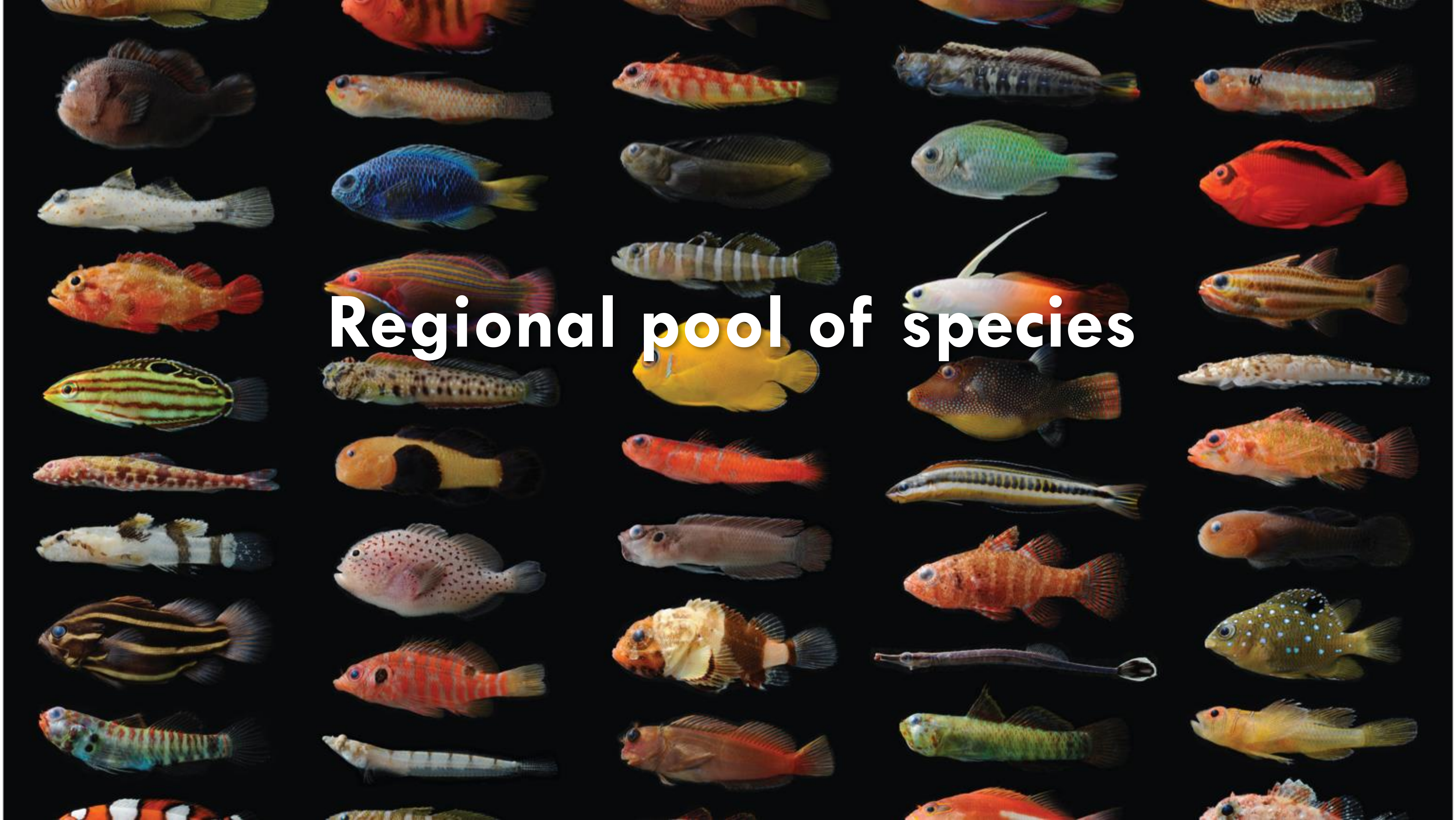
Steve Hubbell



Neutral theory of biodiversity

Large Scale Patterns & Processes

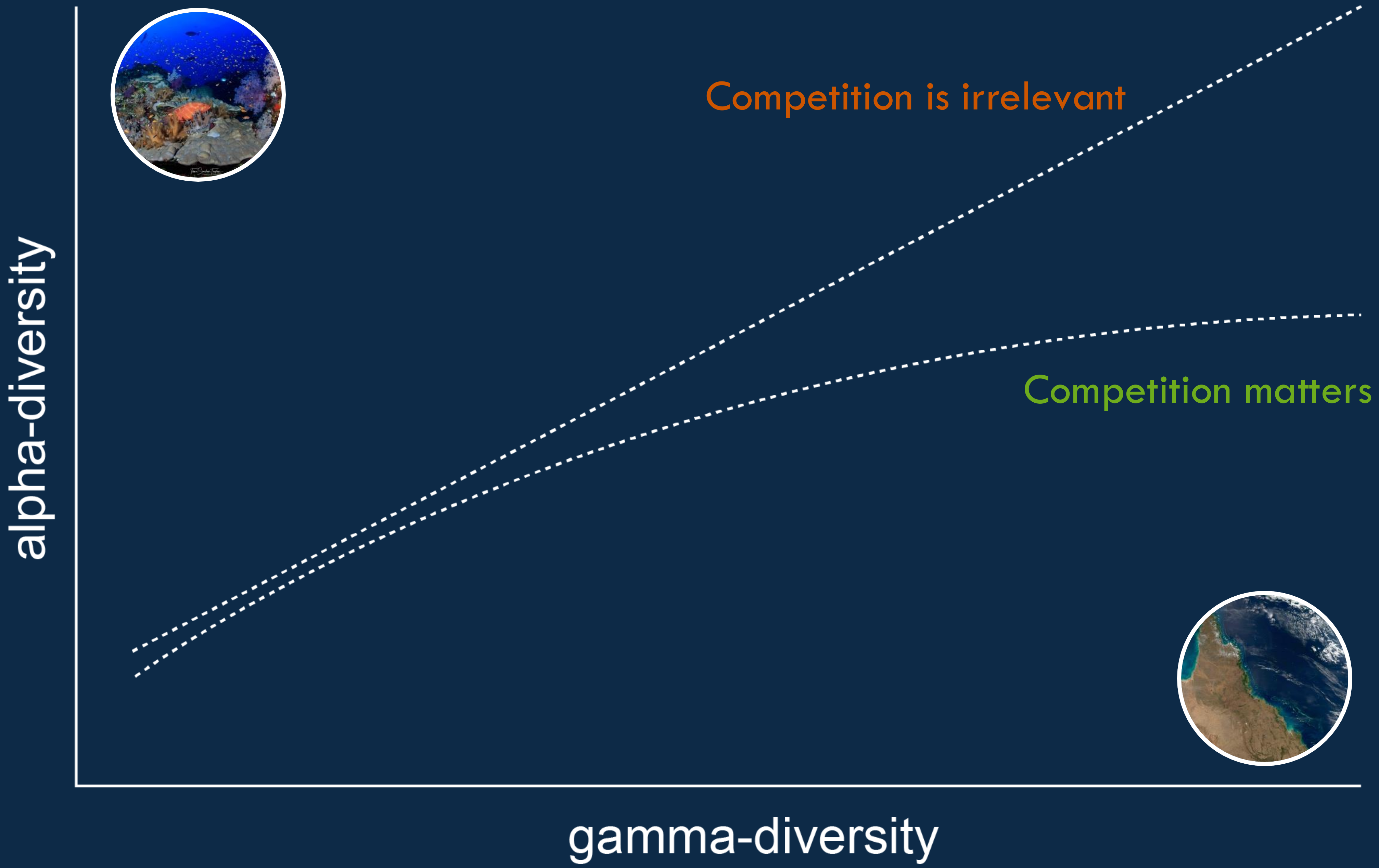



Regional pool of species

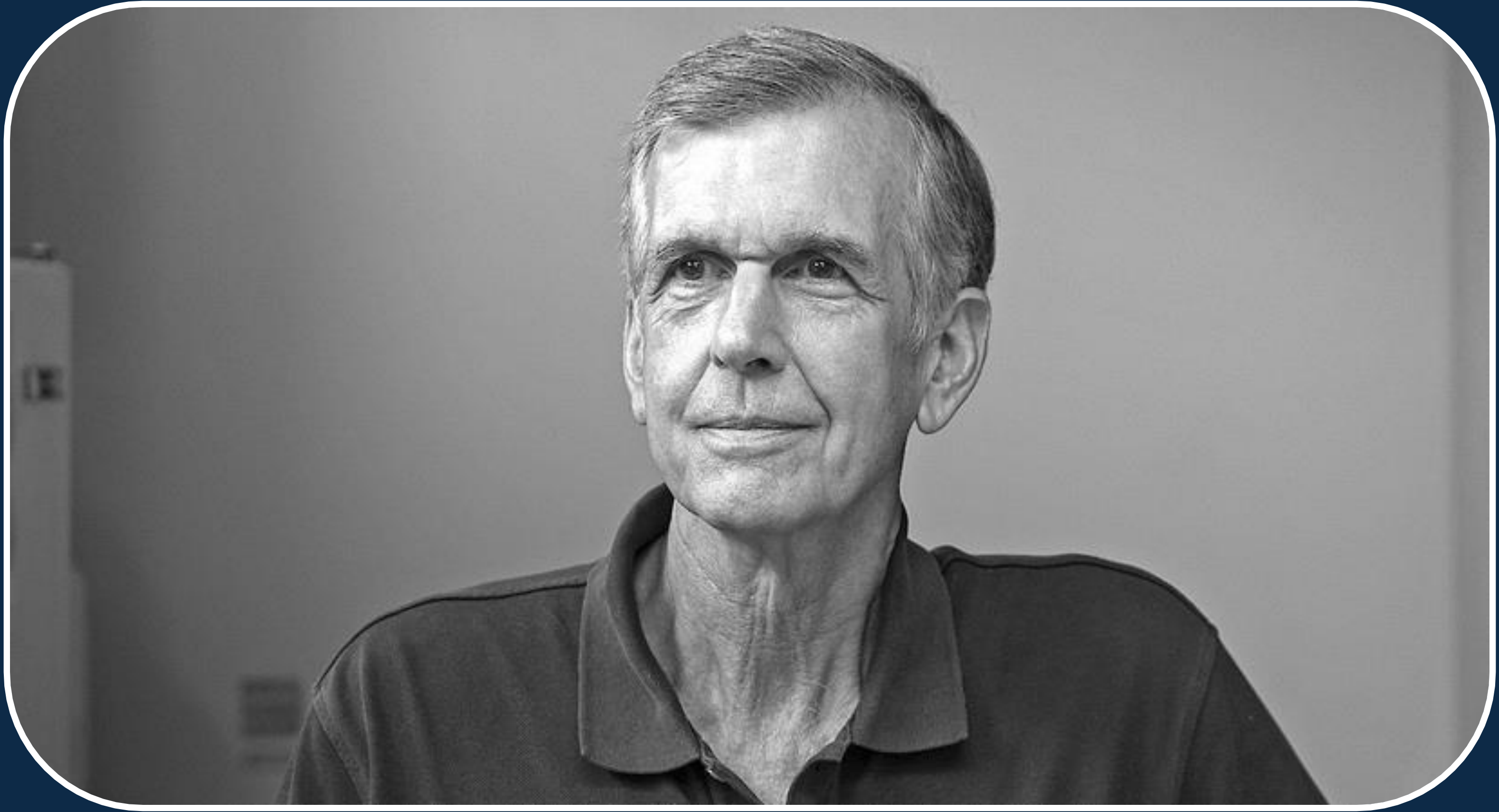
Local

Regional

Large Scale Patterns & Processes



Robert Ricklefs



Regional biodiversity hypothesis

- Early 1900s: observation of patterns
  - 1960s: competition, limiting similarity
    - 1980s: Resource competition theory
      - 2000s: modern coexistence theory
  - 1960s: theory of island biogeography
    - 1990s: neutral theory of biodiversity
      - 2010s: equal fitness paradigm
    - 1990s: regional biodiversity hypothesis
      - 2000s: global ecology and biogeography

Homework

Read *Lawton (1999). Are there general laws in ecology? (Oikos)* and submit a 250-word statement as to whether or not you agree with the main message of the paper and why.

Hint: it's in Canvas under "Files"

NEXT CLASS

Monday, Feb 3rd