# Biodiversity change in island ecosystems

Anne Magurran


In memory of Dawn A.T. Phillip 1965-2017

# BIODIVERSITY OF FRESHWATER FISHES OF TRINIDAD AND TOBAGO, WEST INDIES

Dawn Arlene Teresa Phillip

Thesis submitted for the degree of Doctor of Philosophy

University of St Andrews

October 1998

# An Illustrated Guide to the Freshwater Fishes of Trinidad and Tobago

blind cave catfish *Rhamdia quelen*

Dawn A. T. Phillip
&
Indar W. Ramnarine

April 2001

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# ZOOTAXA

**3711**

## Annotated list and key to the stream fishes of Trinidad & Tobago

DAWN A.T. PHILLIP[1], DONALD C. TAPHORN[2], ERLING HOLM[3], JAMES F. GILLIAM[4], BRADLEY A. LAMPHERE[4] & HERNÁN LÓPEZ-FERNÁNDEZ[3,5]

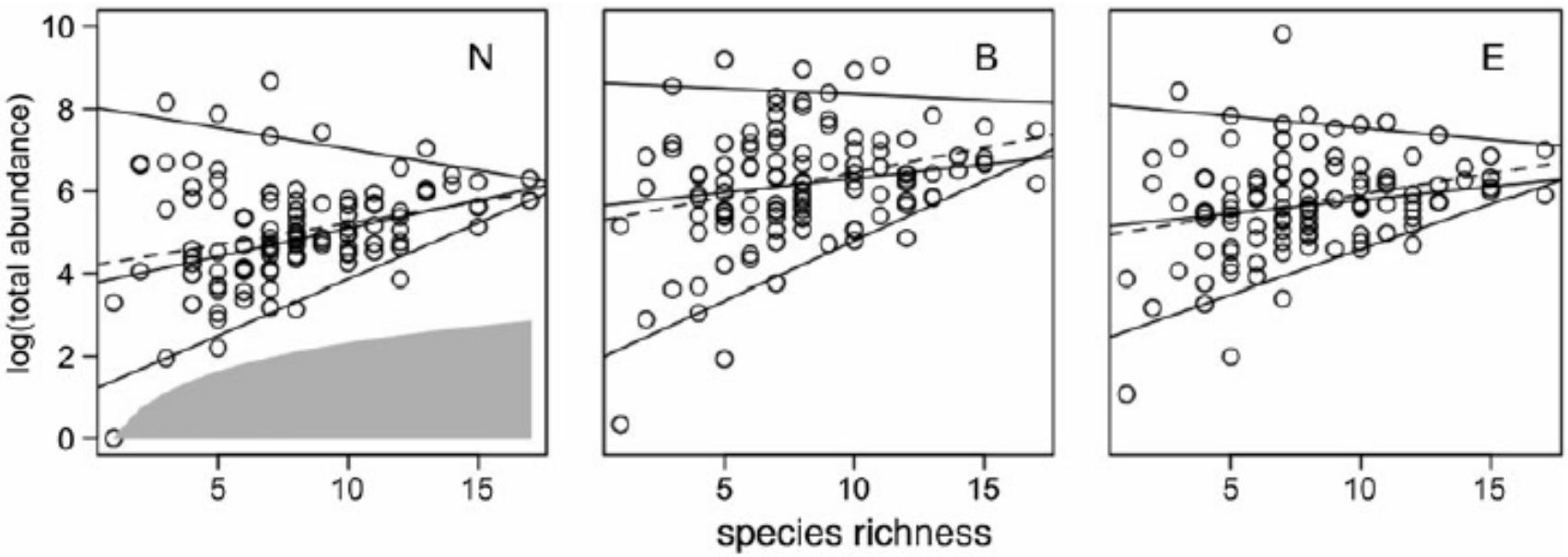
[1]*Department of Life Sciences, The University of the West Indies, St Augustine, Trinidad & Tobago, W.I.*
[2]*1822 North Charles Street, Belleville, IL 62221, USA*
[3]*Department of Natural History, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6, Canada*
[4]*Department of Biological Sciences, North Carolina State University, Raleigh, NC 27695-7617, USA*
[5]*Department of Ecology and Evolutionary Biology, University of Toronto, 25 Willcocks Street, Toronto, Ontario M5S 3B2, Canada*

*Global Ecology and Biogeography, (Global Ecol. Biogeogr.)* (2011)

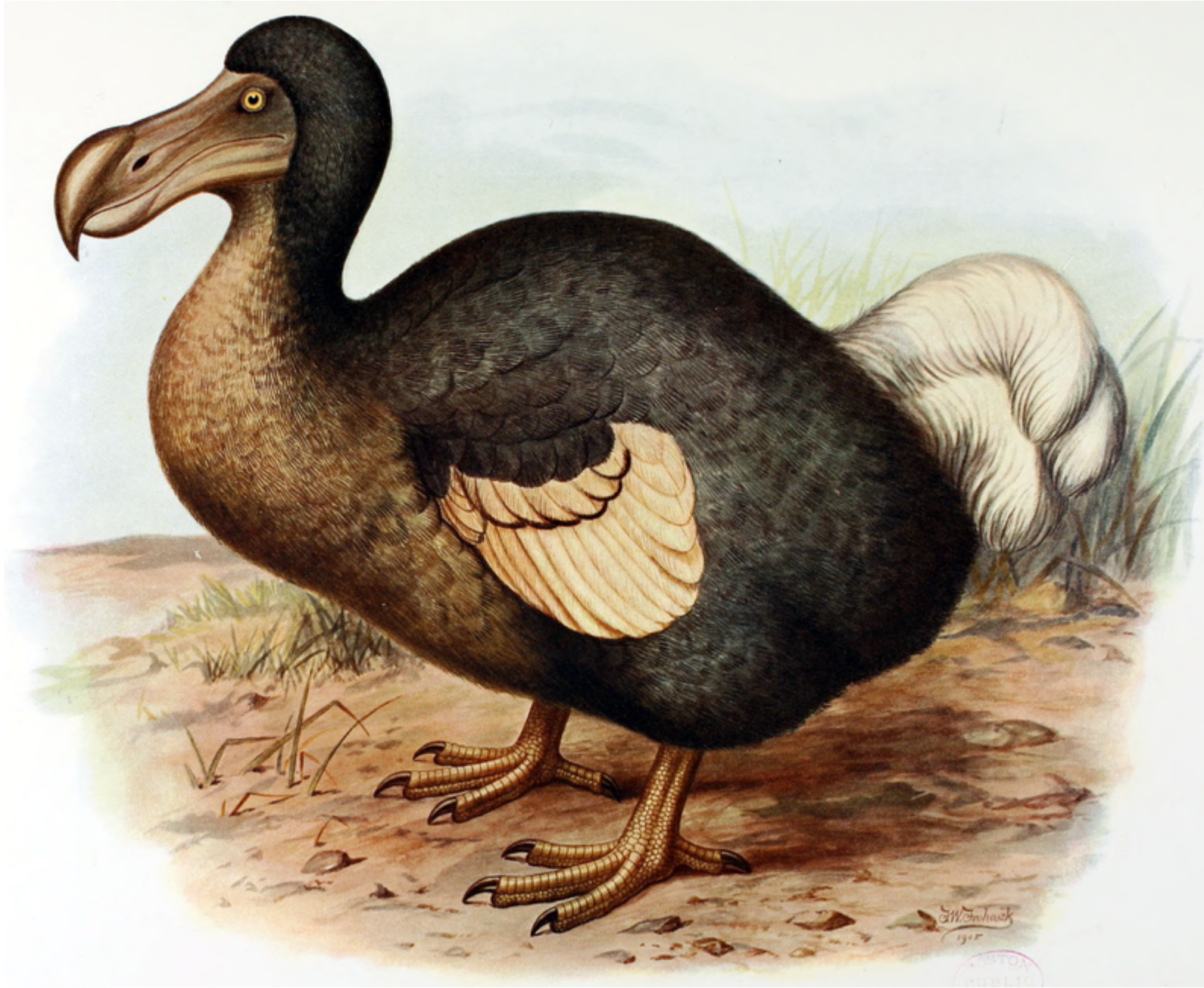
RESEARCH PAPER

# Abundance and dominance become less predictable as species richness decreases

Maria Dornelas[1*], Dawn A. T. Phillip[2] and Anne E. Magurran[3]

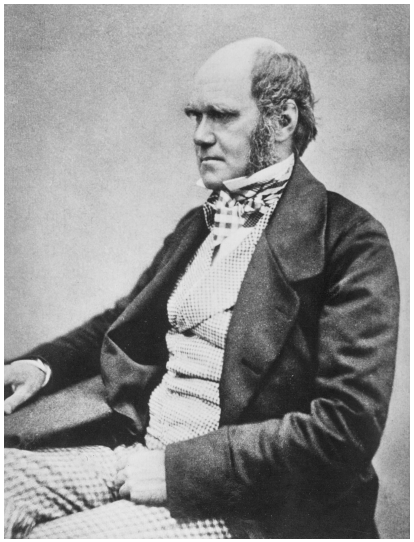


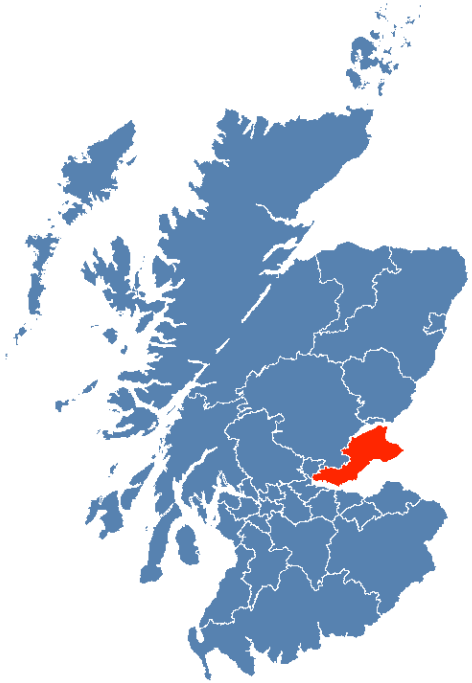

fegso

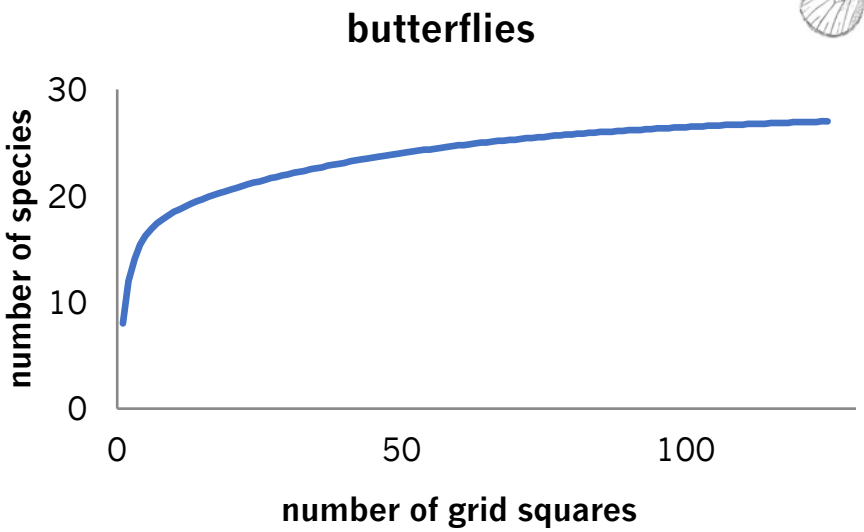


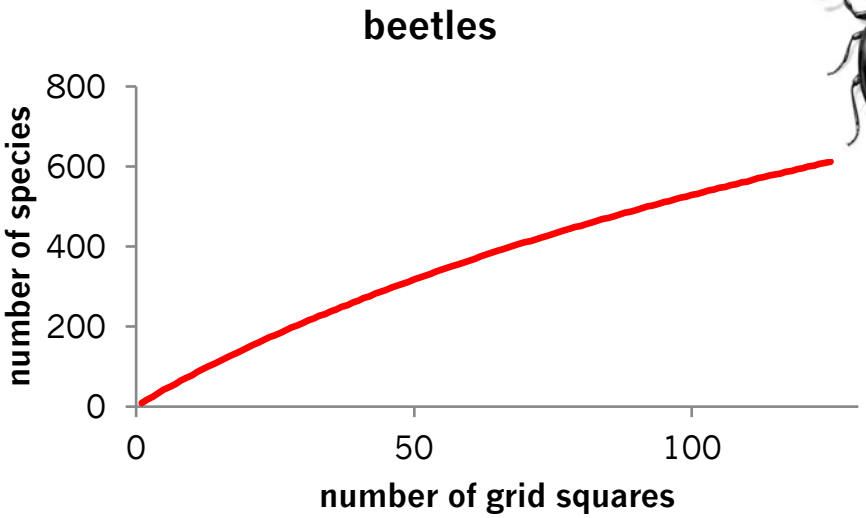
In 1855 Darwin recorded all 142 plant species in the meadow, Great Pucklands, next to his family home at Downe in England.

This appears to be the first systematic survey of species richness.






butterflies
number of species
30
20
10
0
0
50
100
number of grid squares


beetles
number of species
800
600
400
200
0
0
50
100
number of grid squares


Trinidad & Tobago 513,000 ha.

How many species of freshwater fish?

# 1. Dawn's PhD data

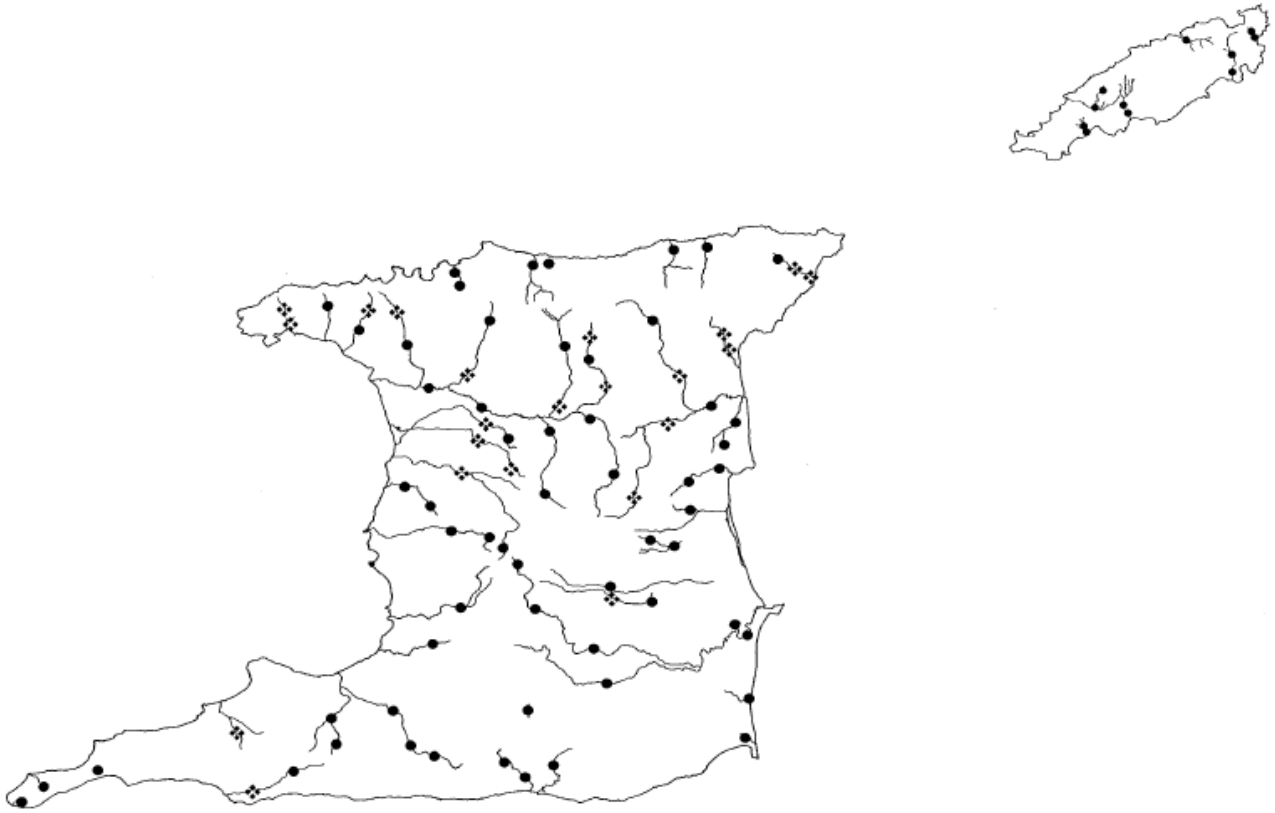


Figure 2.3. Sample sites in Trinidad and Tobago. Sites that were sampled once are indicated by ● and those sampled twice by ❖. Maps not to scale.

# 2. Museum records at University of the West Indies Trinidad & Tobago

*Zootaxa* 3711 (1): 001–064
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## Annotated list and key to the stream fishes of Trinidad & Tobago

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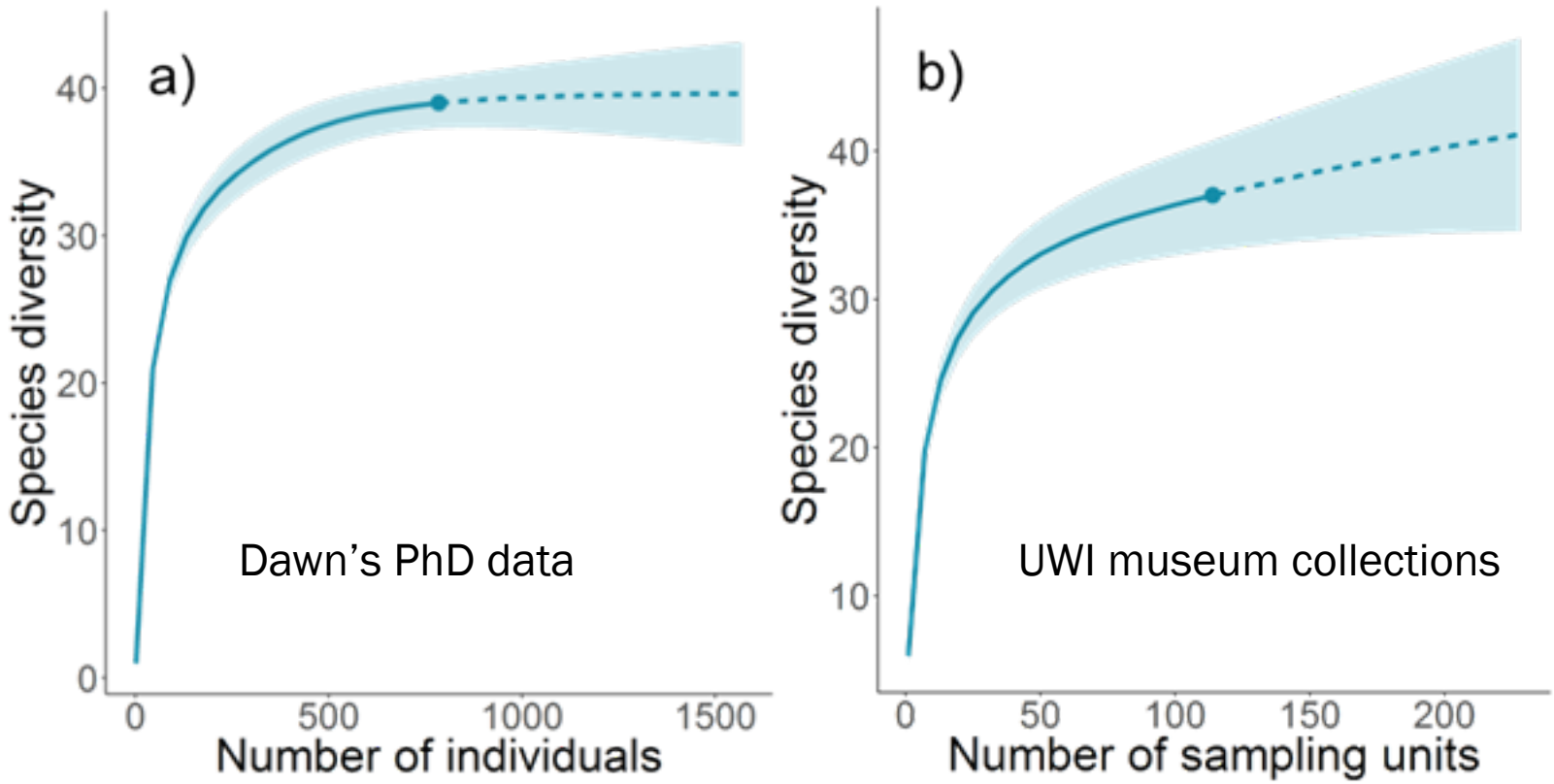
# How many freshwater fish species in Trinidad & Tobago?




iNEXT package R

Jones et al. in prep

| Species status | Museum | Dawn's PhD data | Phillip et al. *Zootaxa* |
|---|---|---|---|
| uncertain | 0 | 0 | 3 |
| introduced | 2 | 2 | 5 |
| native | 34 | 33 | 52 |
| recent colonist | 3 | 3 | 4 |
| transient | 0 | 0 | 8 |
| *total* | *39* | *38* | *72* |

Jones et al., in prep

# 85% overlap between PhD data and Museum data

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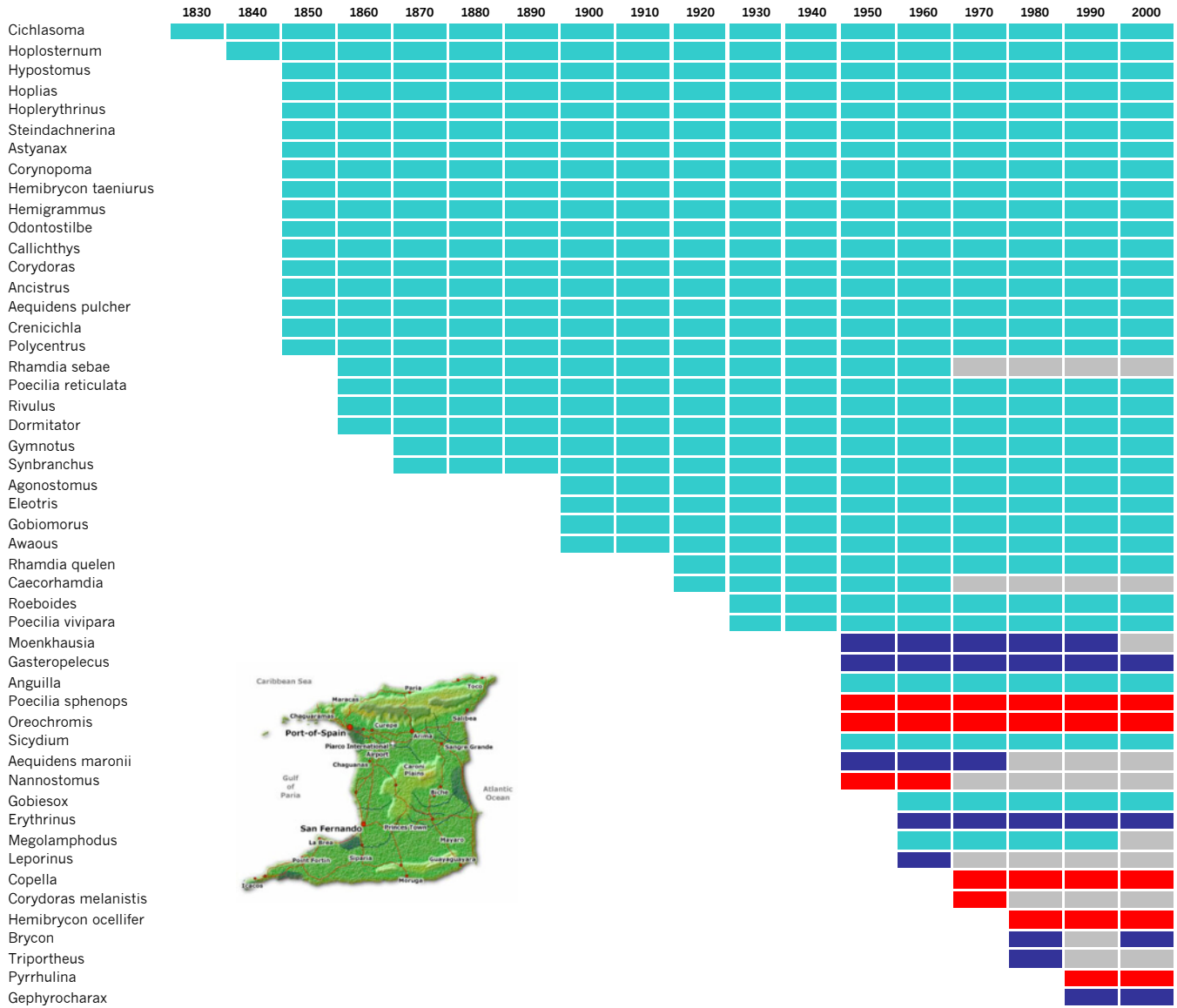
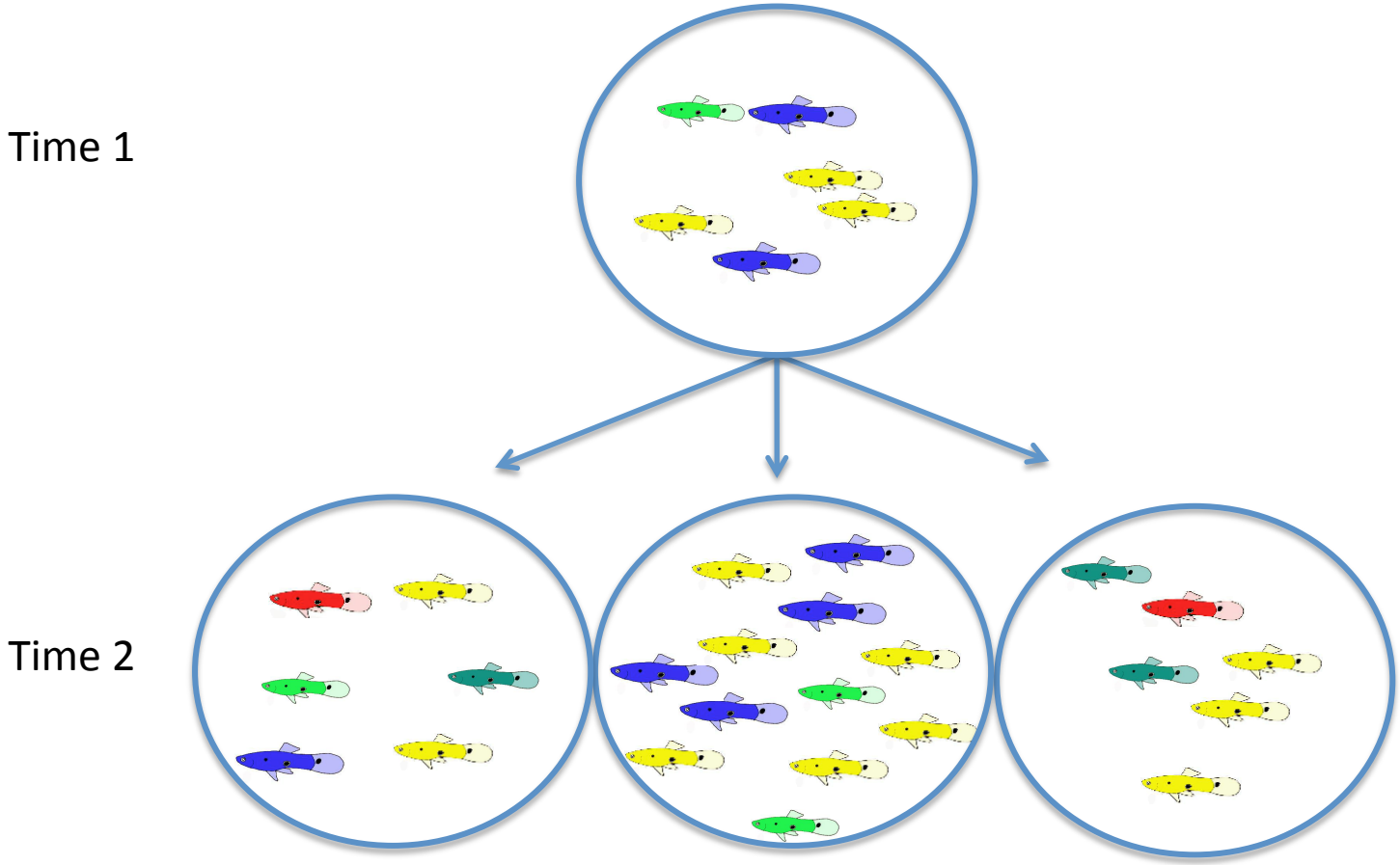



**native fauna**, **natural colonist**, **introduced exotic**, **possibly extinct**

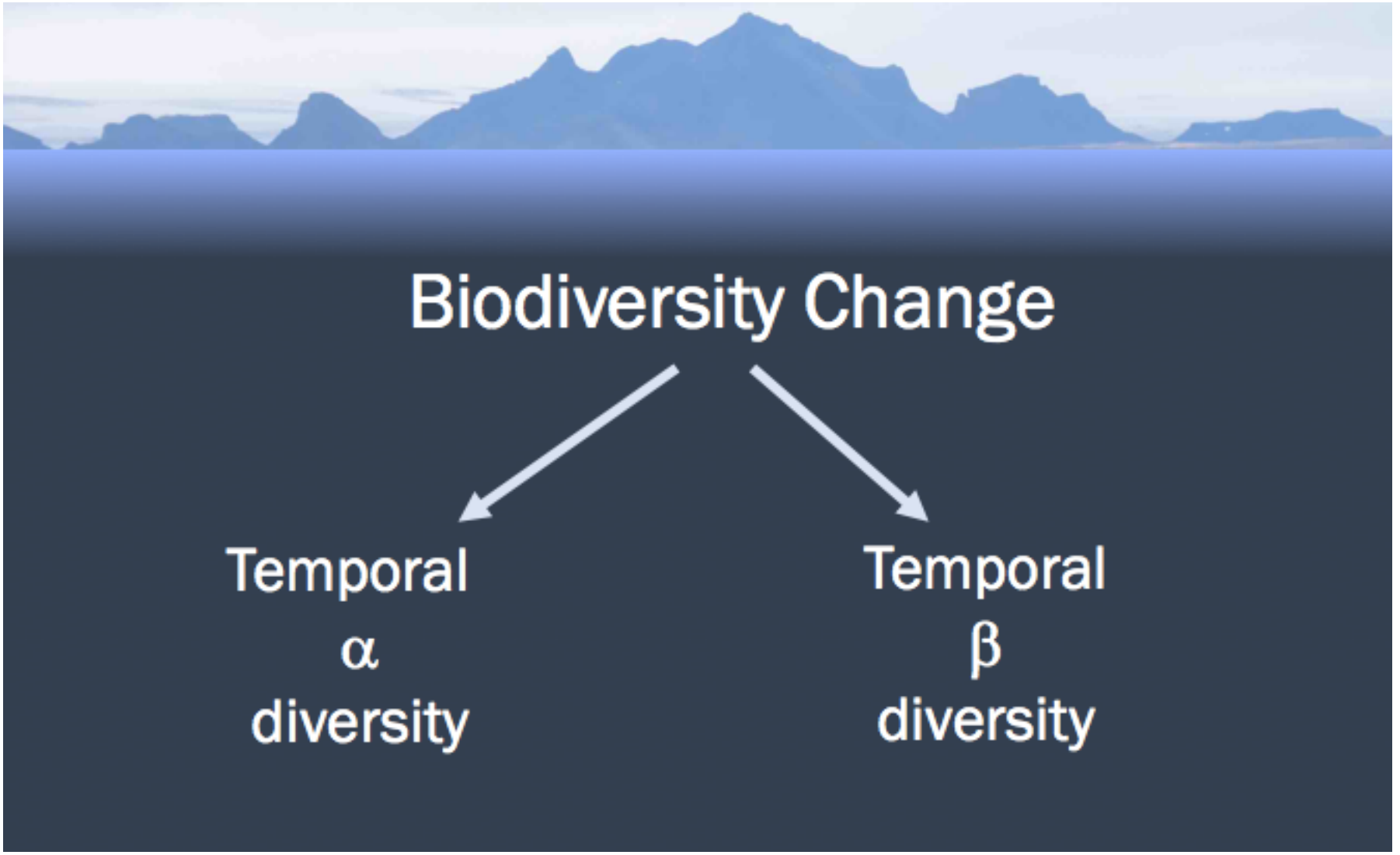
# Change through time

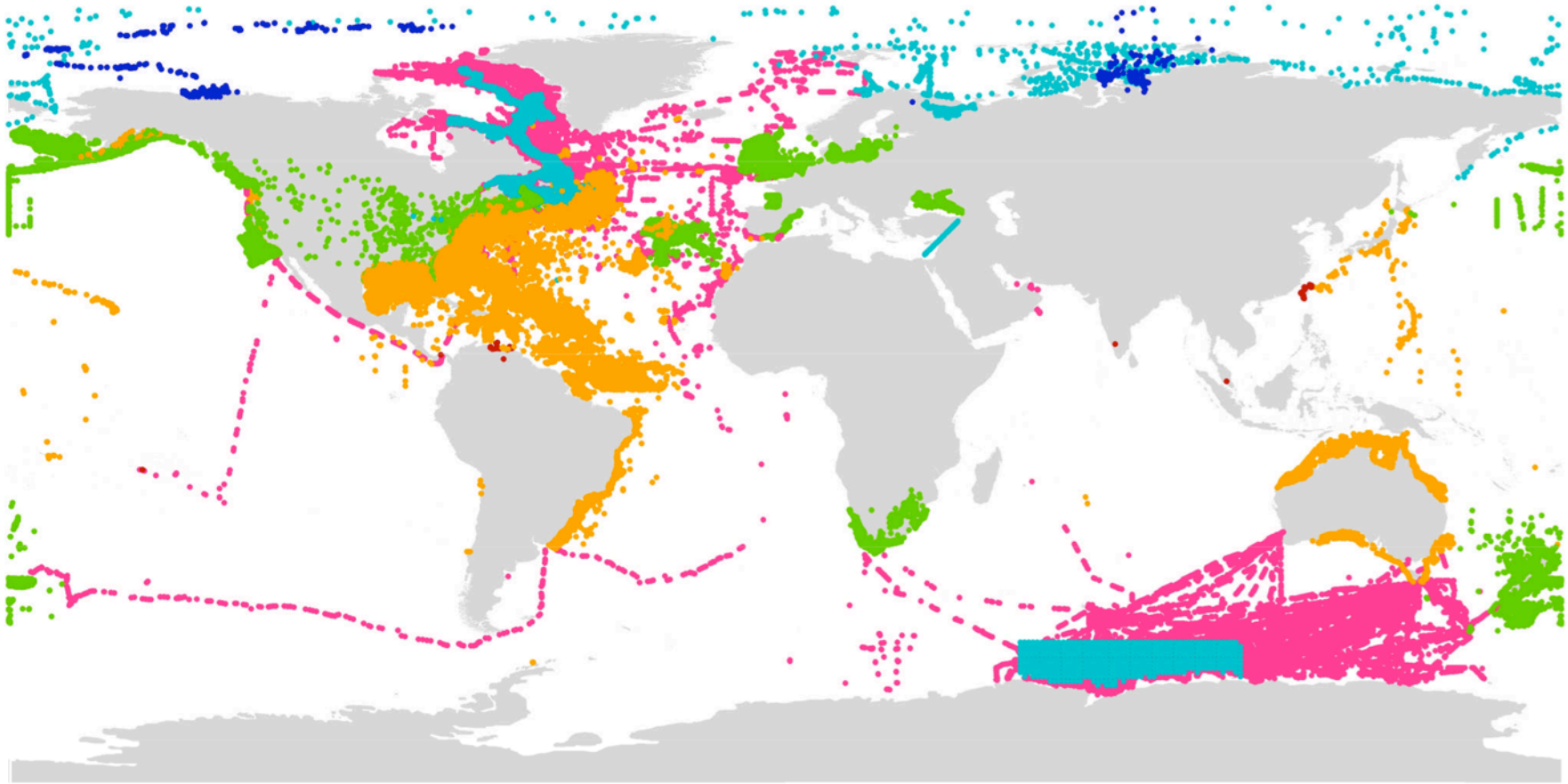
*'....we forget that each species, even where it most abounds, is constantly suffering enormous destruction at some period of its life, from enemies or from competitors for the same place and food; and if these enemies or competitors be in the least degree favoured by any slight change of climate, they will increase in numbers; and as each area is already fully stocked with inhabitants, the other species must decrease*.'

Charles Darwin, Origin of Species




| | **Scenario 1** | **Scenario 2** | **Scenario 3** |
|---|---|---|---|
| Species richness | change | no change | no change |
| Abundance | no change | change | no change |
| Composition | change | no change | change |


Biodiversity Change
Temporal
α
diversity
Temporal
β
diversity



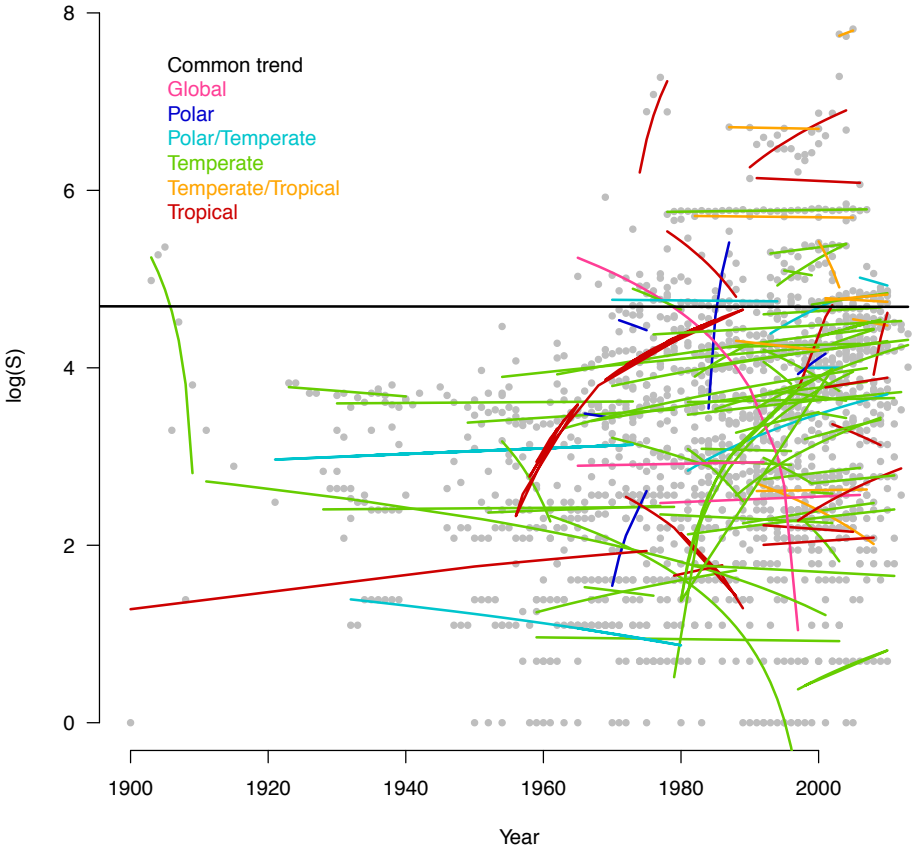
100 time series

35,613 species

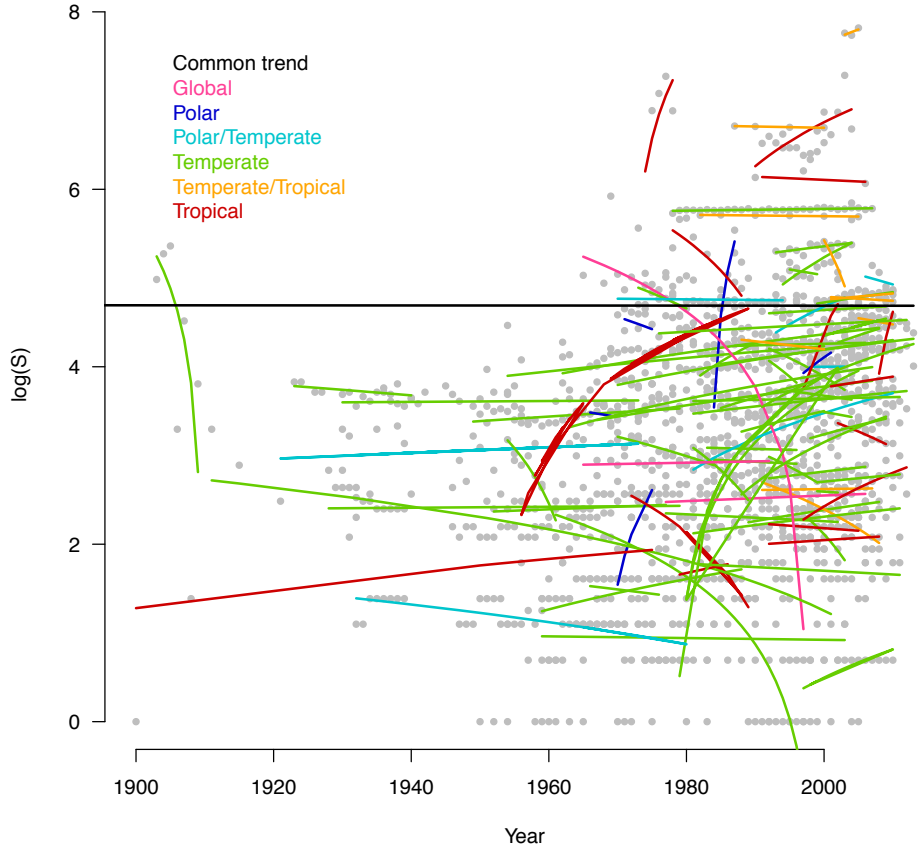
6.1 million species occurrence records

Dornelas, Gotelli, McGill, Shimadzu, Moyes, Sievers, Magurran. 2014 **Science**

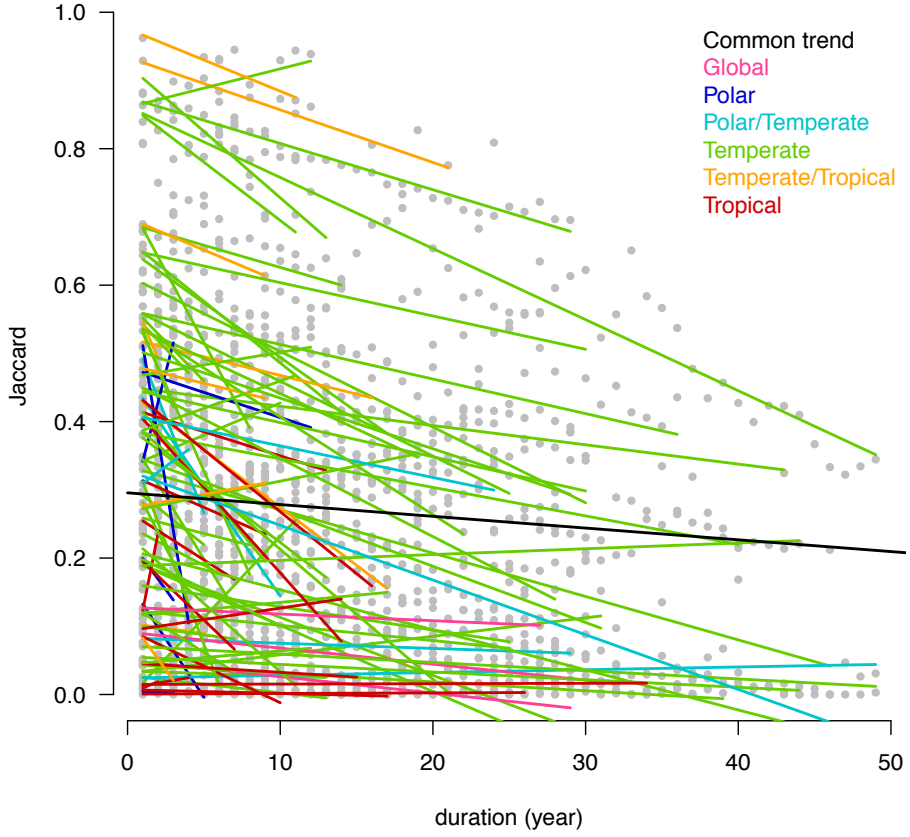
# Temporal α diversity



# Temporal α diversity




# Temporal β diversity



1. $\alpha$ diversity: there was neither a systematic loss nor a systematic gain in the number of species recorded through time. 59 communities showed an increase in species richness through time and 41 communities showed a decrease

1. $\alpha$ diversity: there was neither a systematic loss nor a systematic gain in the number of species recorded through time. 59 communities showed an increase in species richness through time and 41 communities showed a decrease

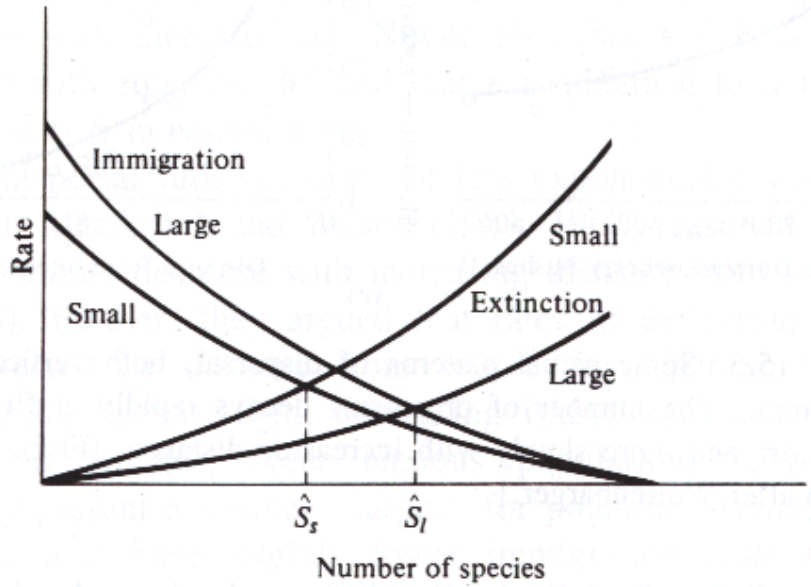
2. $\beta$ diversity: 79 of the 100 communities showed substantial changes in species composition, measured relative to the baseline of the first available survey of the community, and greater than predicted by two null models of turnover

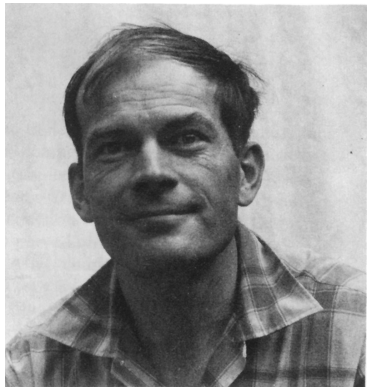
Climate change

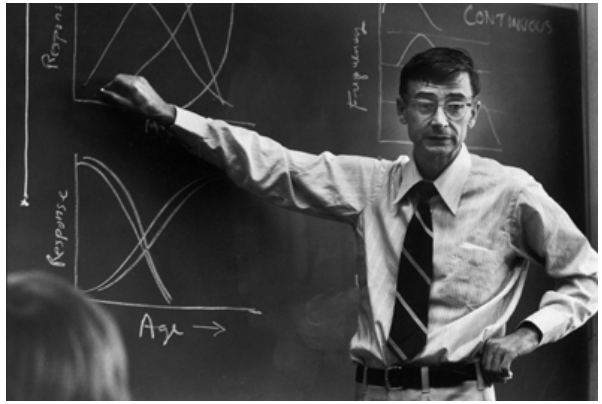
Invasive species

Habitat transformation

# Are ecological assemblages regulated?

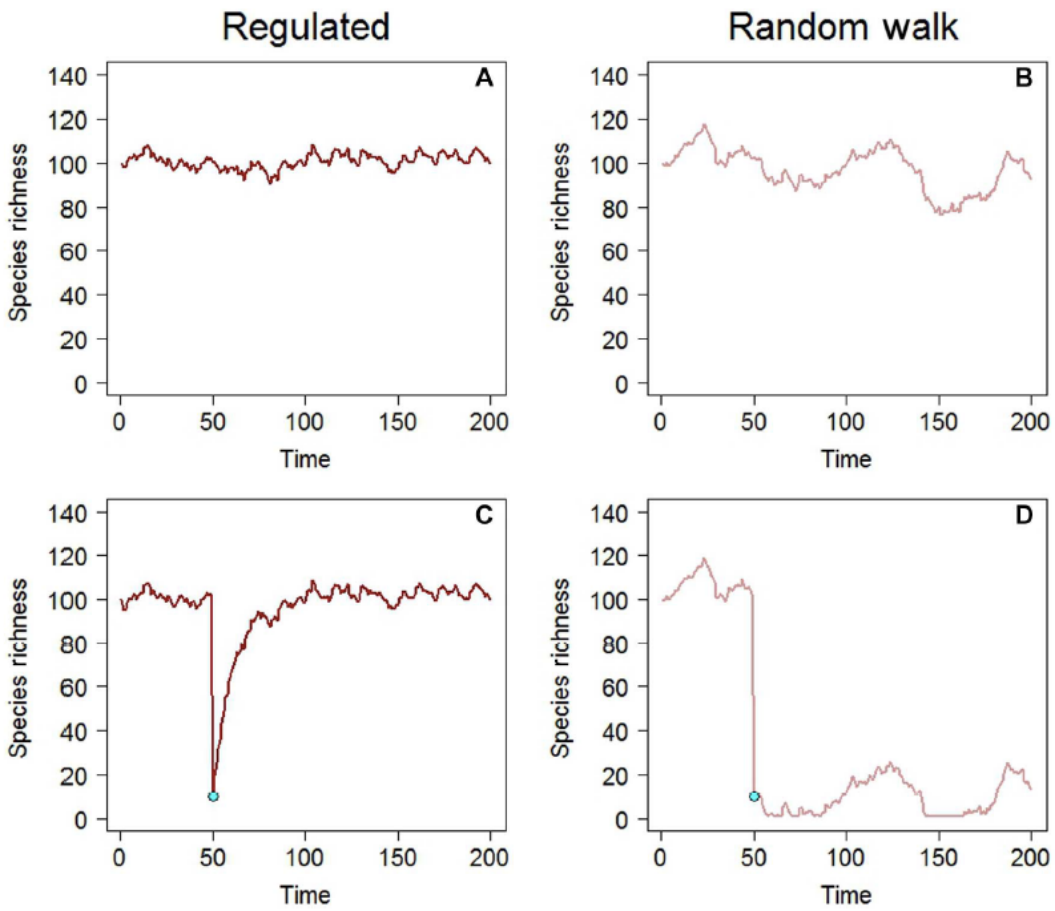


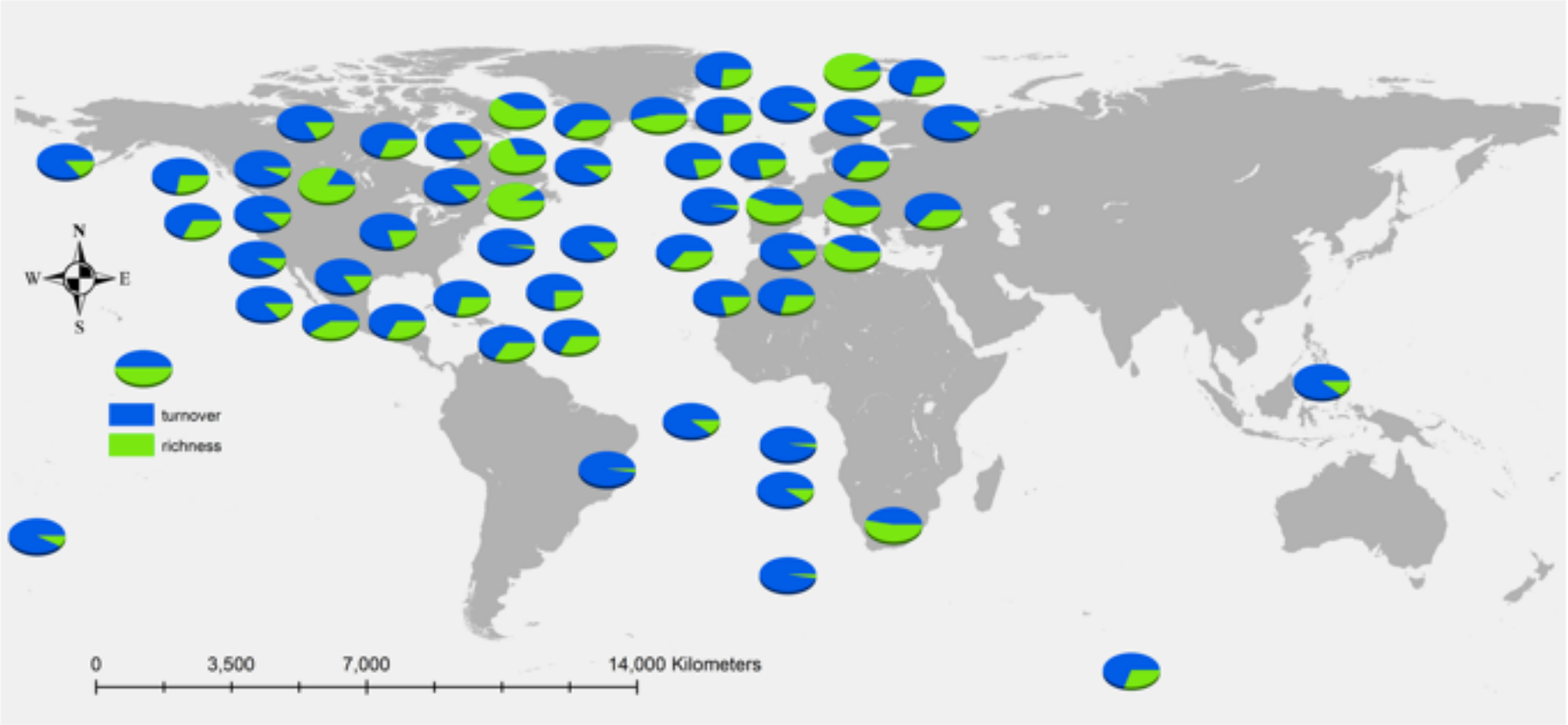



**Community-level regulation** means that biodiversity has a tendency to return to a central level following a perturbation

In 90% of the (59) communities analyzed, the pattern was in the direction of a regulated trajectory, as revealed by an Augmented Dickey-Fuller test

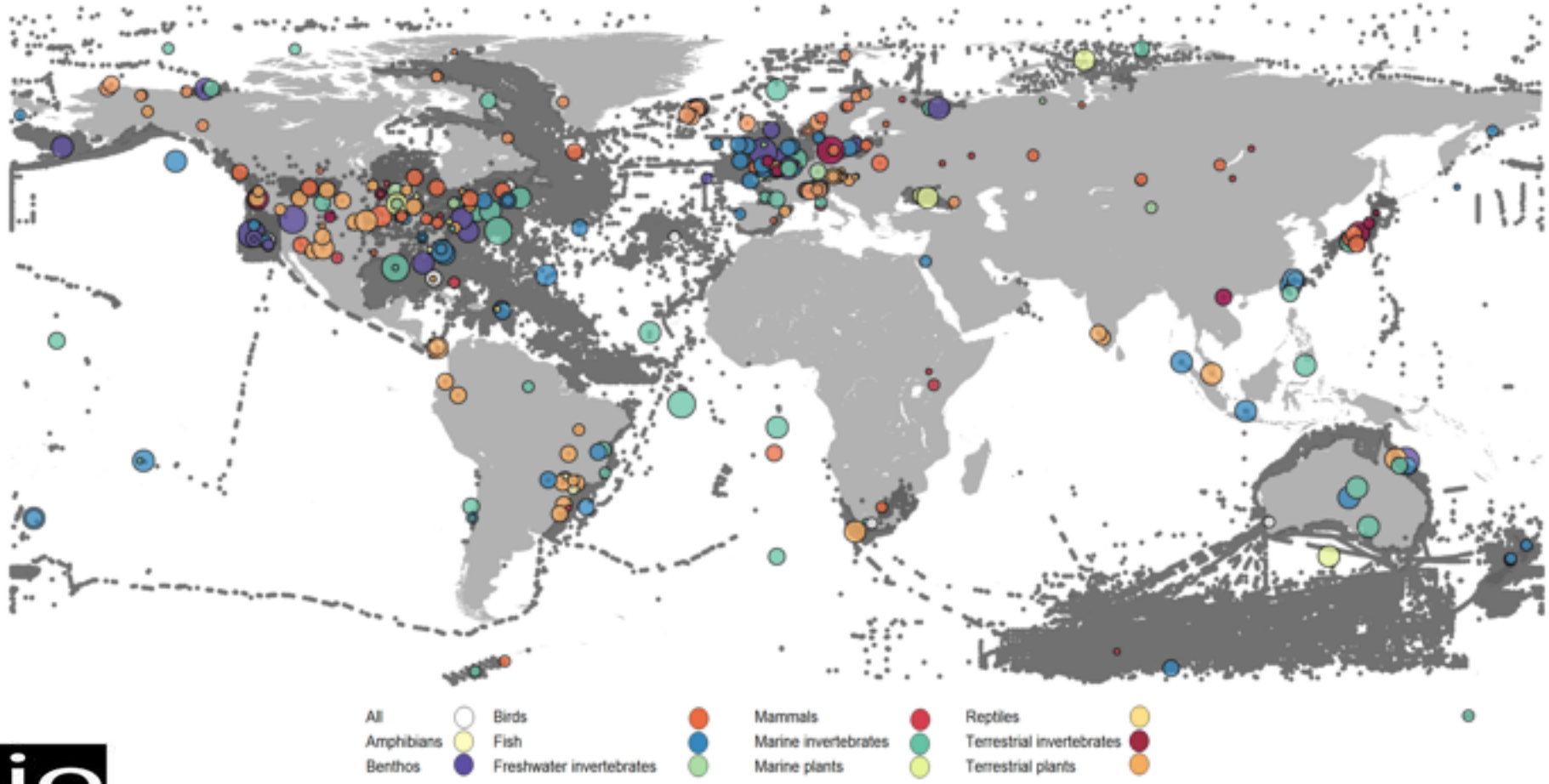



Gotelli, Shimadzu, Dornelas, McGill, Moyes, Magurran 2017 *Science Advances*




Evidence for widespread temporal regulation of S and N.....
..... underpinned by marked temporal turnover in composition in excess of levels predicted by ecological theory

Gotelli, Shimadzu, Dornelas, McGill, Moyes, Magurran 2017 *Science Advances*

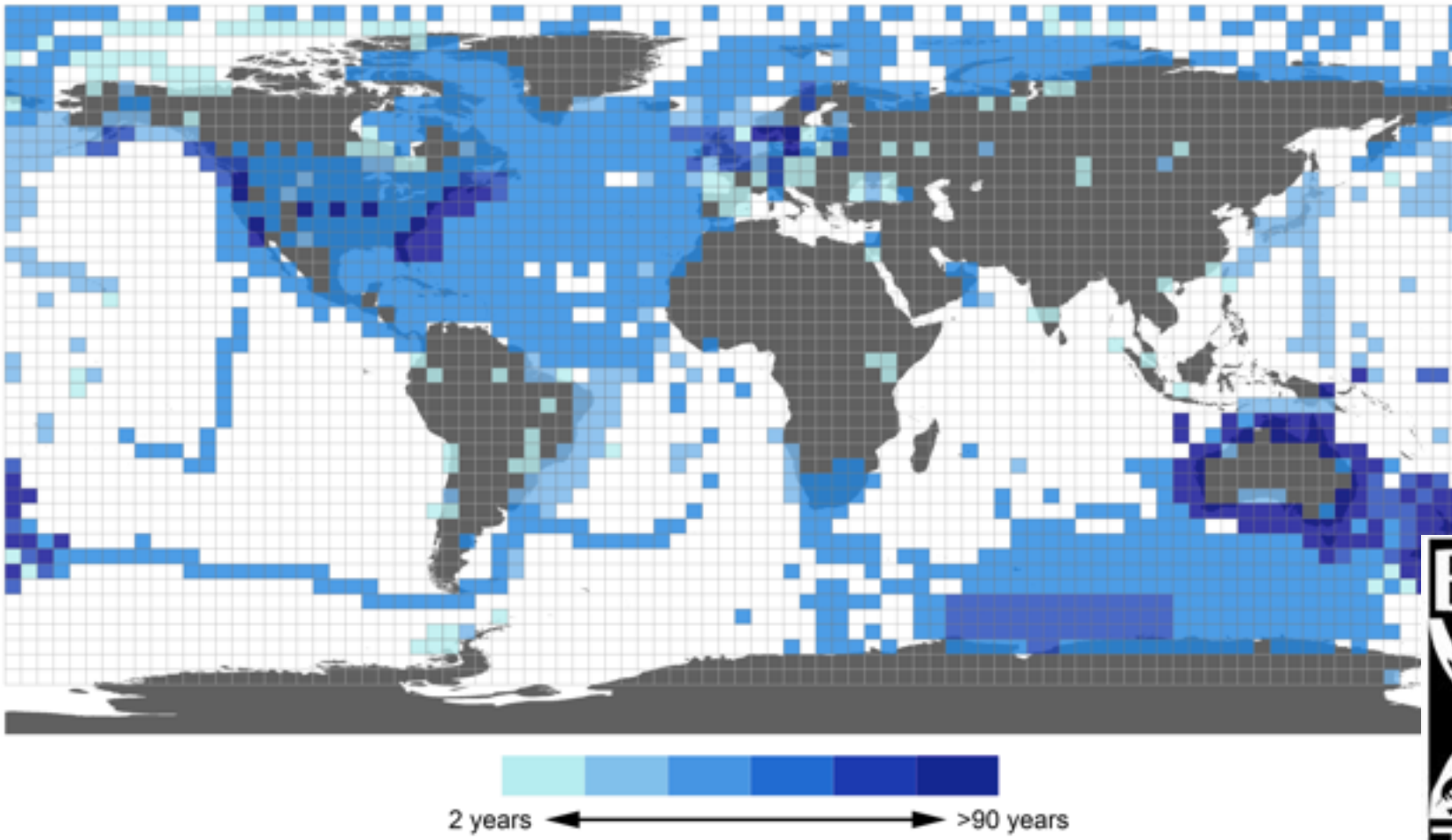



387 time series (Marine & Terrestrial)
44,884 species
12,618,393 species occurrence records

biotime.st-andrews.ac.uk

Free to anyone, anywhere in the world, to use for education, research or conservation

Dornelas M, Antão LH, Moyes F, Bates AE, Magurran AE & >>200 authors 2018 BioTIME: a database of biodiversity time series for the anthropocene. *Global Ecology and Biogeography*, in press



# Biodiversity change varies across scales

| Scale | Temporal β diversity | α diversity | Spatial β diversity | N or Biomass |
|---|---|---|---|---|
| Global | Tβ-G | α-G | Sβ-GB | ? N-G |
| Biogeographic | ? Tβ-B | α-B | Sβ-BM | ? N-B |
| Metapopulation | ? Tβ-M | α-M | Sβ-ML | N-S |
| Local | Tβ-L | α-L | | N-L |

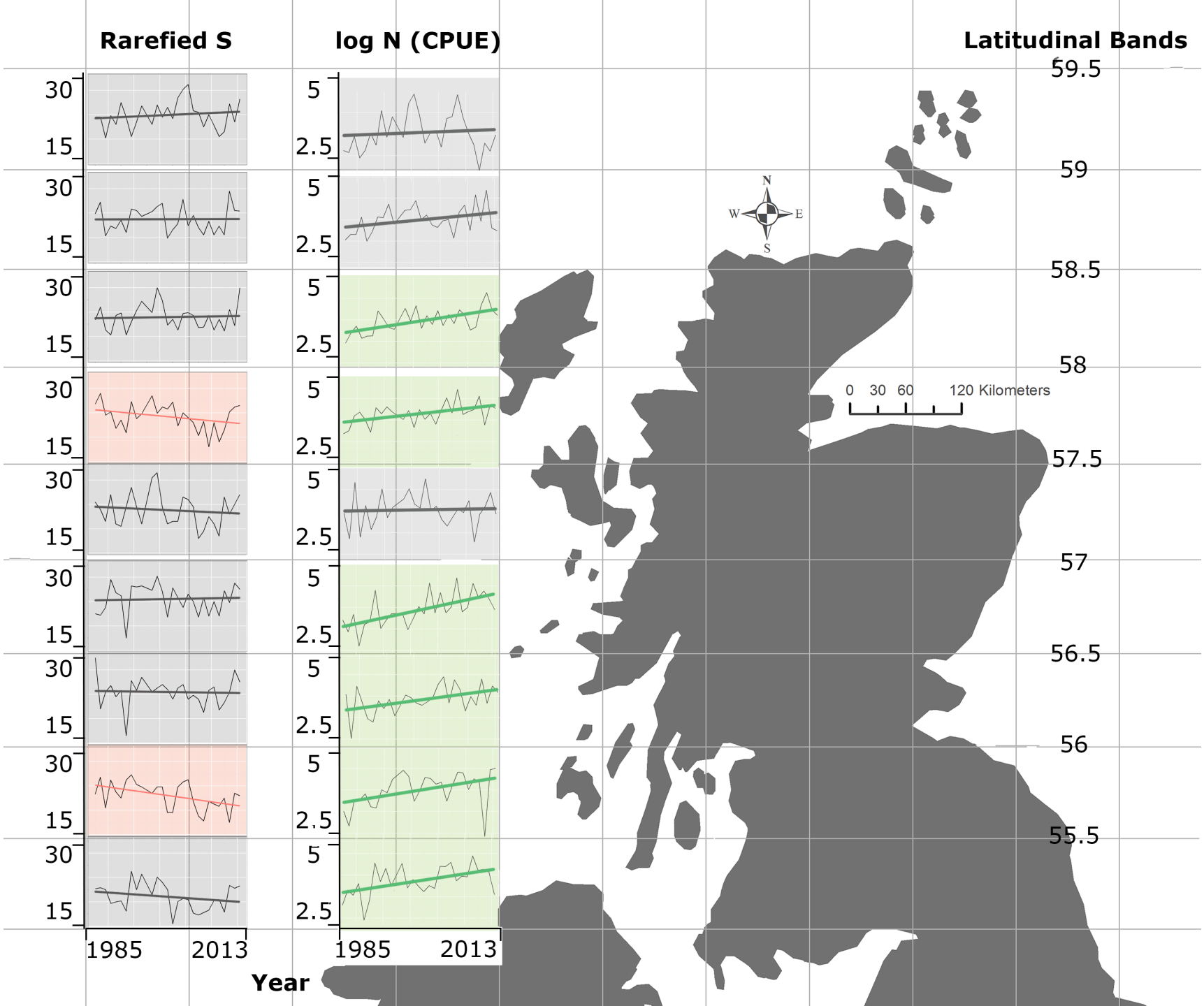
McGill, Dornelas, Gotelli, Magurran 2015 TREE

# Annual survey in first quarter, since 1980

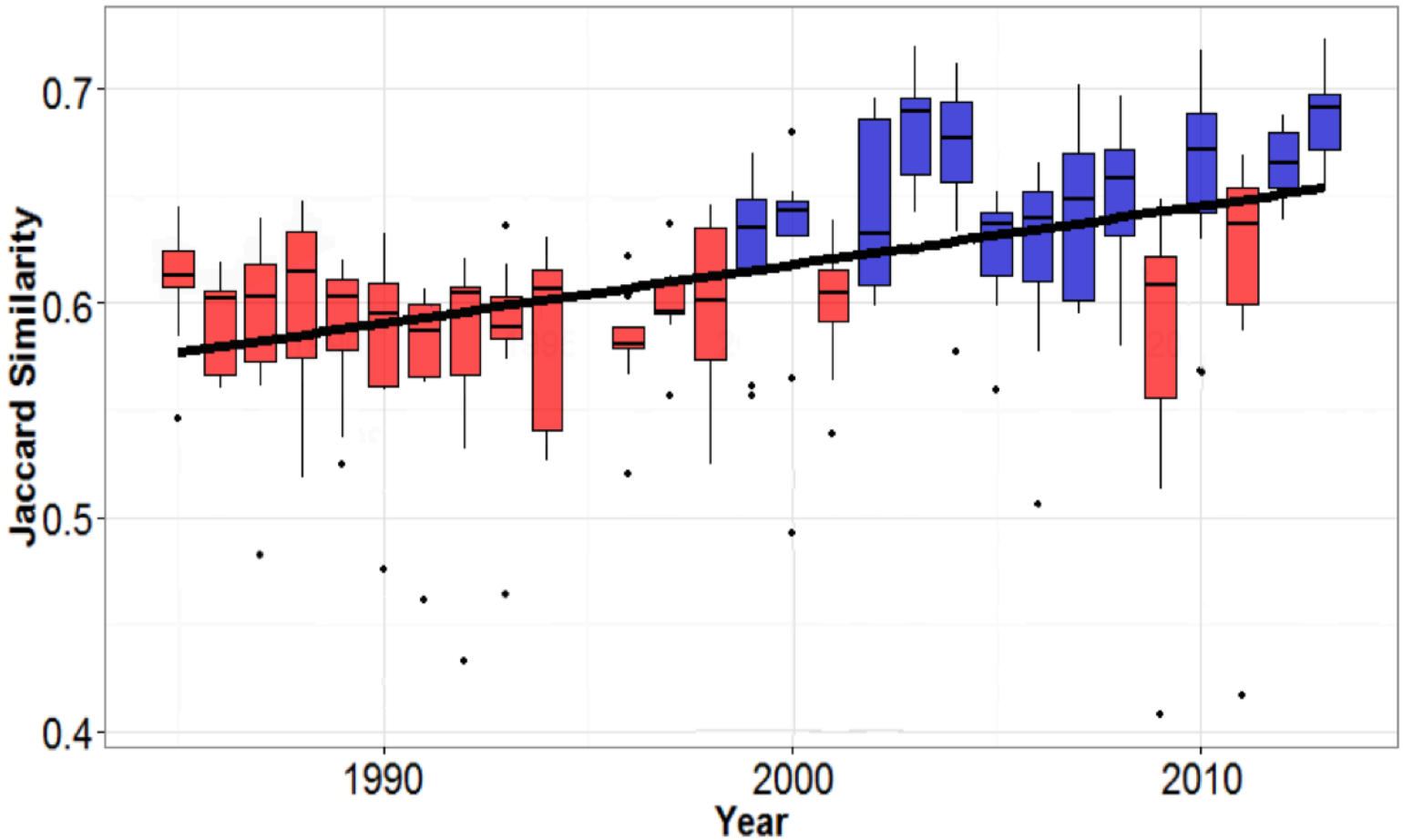

Data from
ICES portal

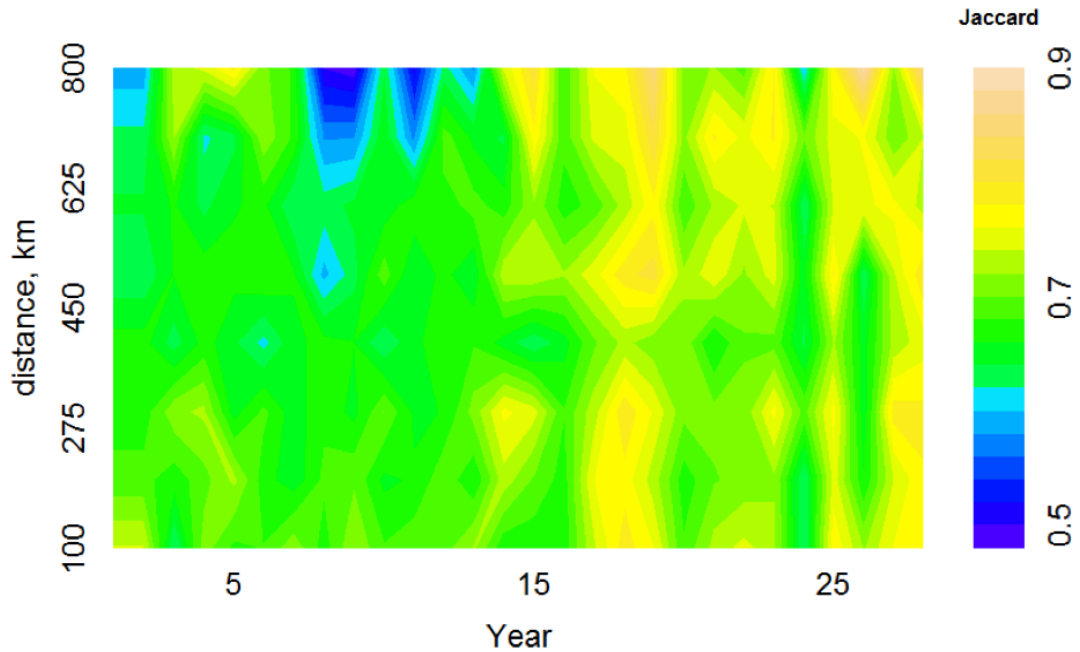
Sample-based
rarefaction

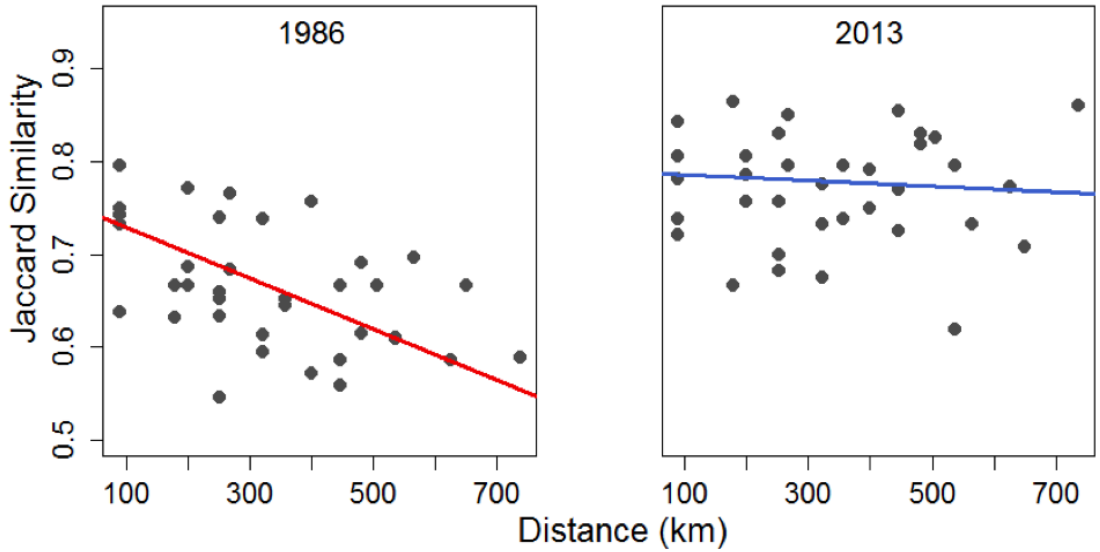
Magurran, Dornelas, Moyes, Gotelli, McGill 2015 *Nature Communications*


Rarefied S
log N (CPUE)
Latitudinal Bands
30
15
5
2.5
1985
2013
Year
59.5
59
58.5
58
57.5
57
56.5
56
55.5
N
W
E
S
0 30 60 120 Kilometers

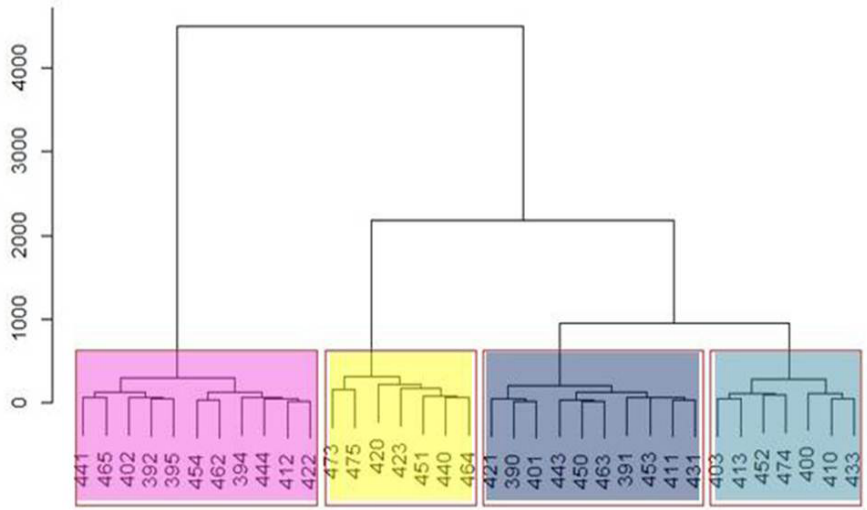
# Pairwise similarity across latitudinal bands

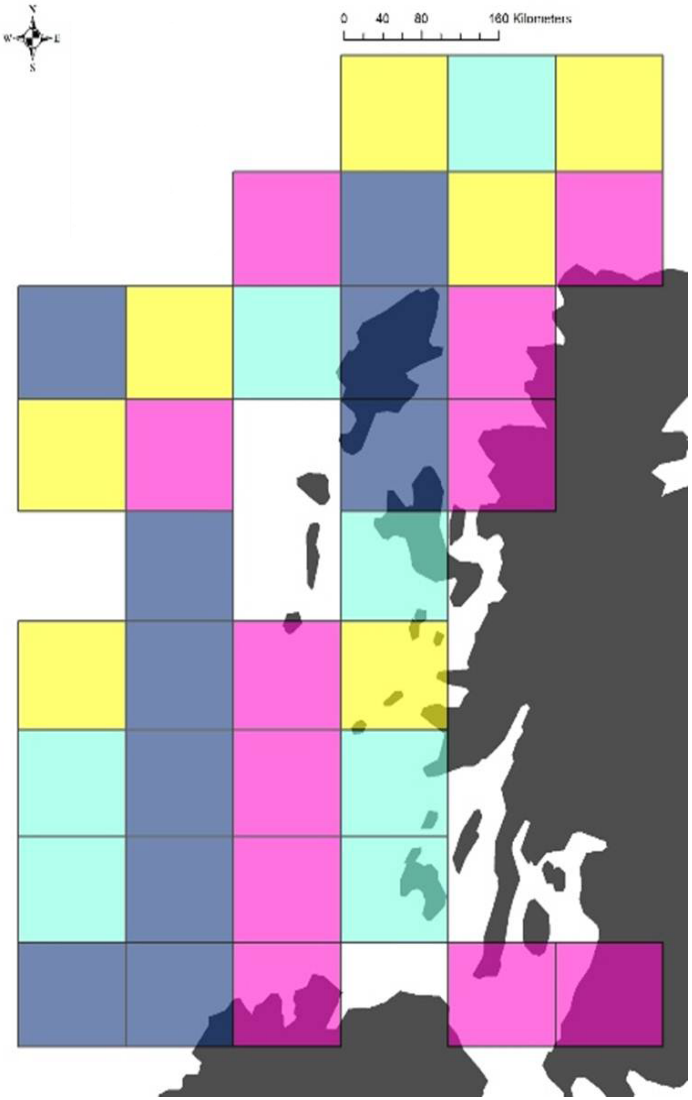



Jaccard
0.9
0.7
0.5
distance, km
800
625
450
275
100
5
15
25
Year

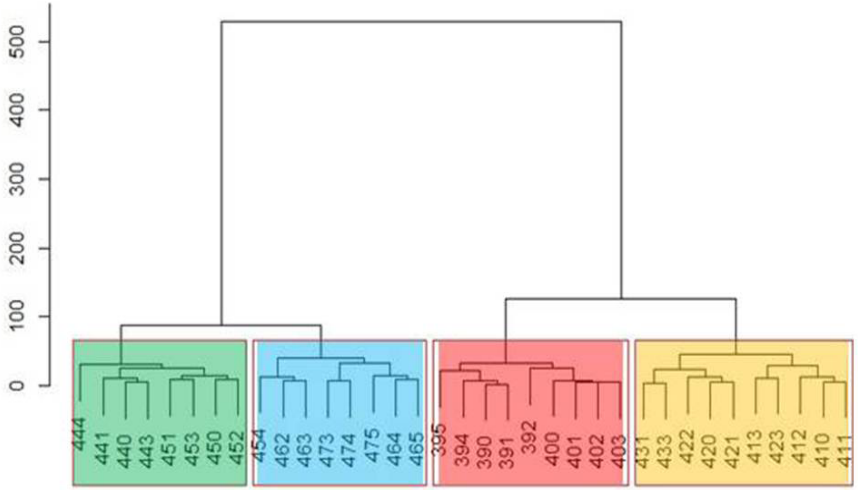

1986
2013
Jaccard Similarity
0.5
0.6
0.7
0.8
0.9
100
300
500
700
Distance (km)

# α diversity


0
1000
2000
3000
4000
441
465
402
392
395
454
462
394
444
412
422
473
475
420
423
451
440
464
421
390
401
443
450
463
391
453
411
431
403
413
452
474
400
410
433


0 40 80 160 Kilometers

# β diversity


0
100
200
300
400
500
444
441
440
443
451
453
450
452
454
462
463
473
474
475
464
465
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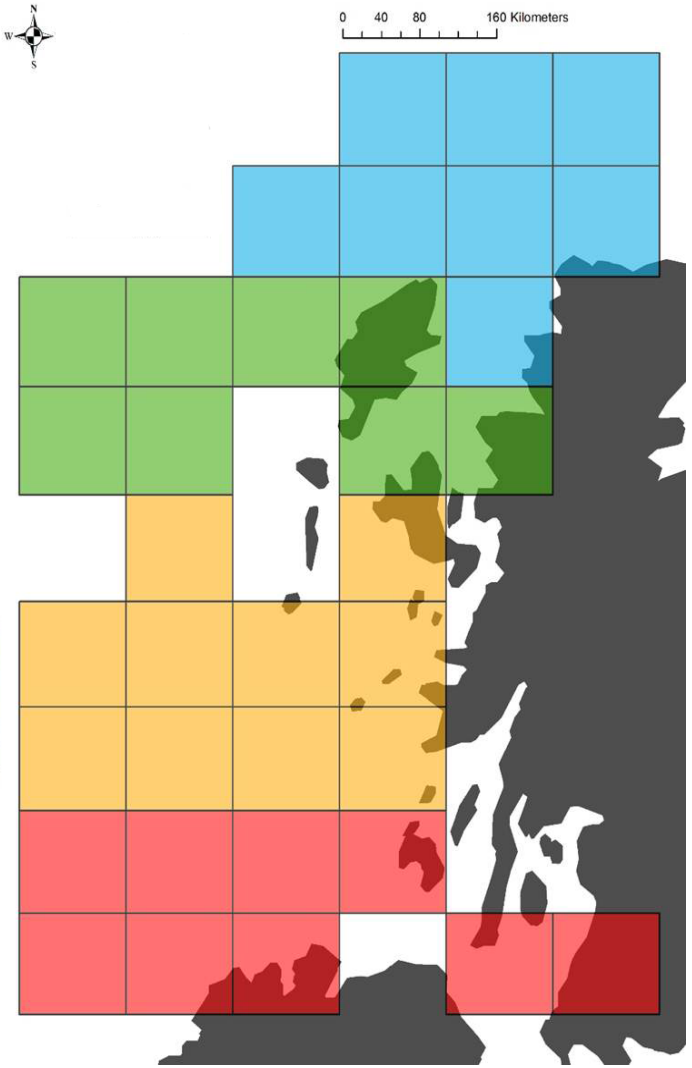
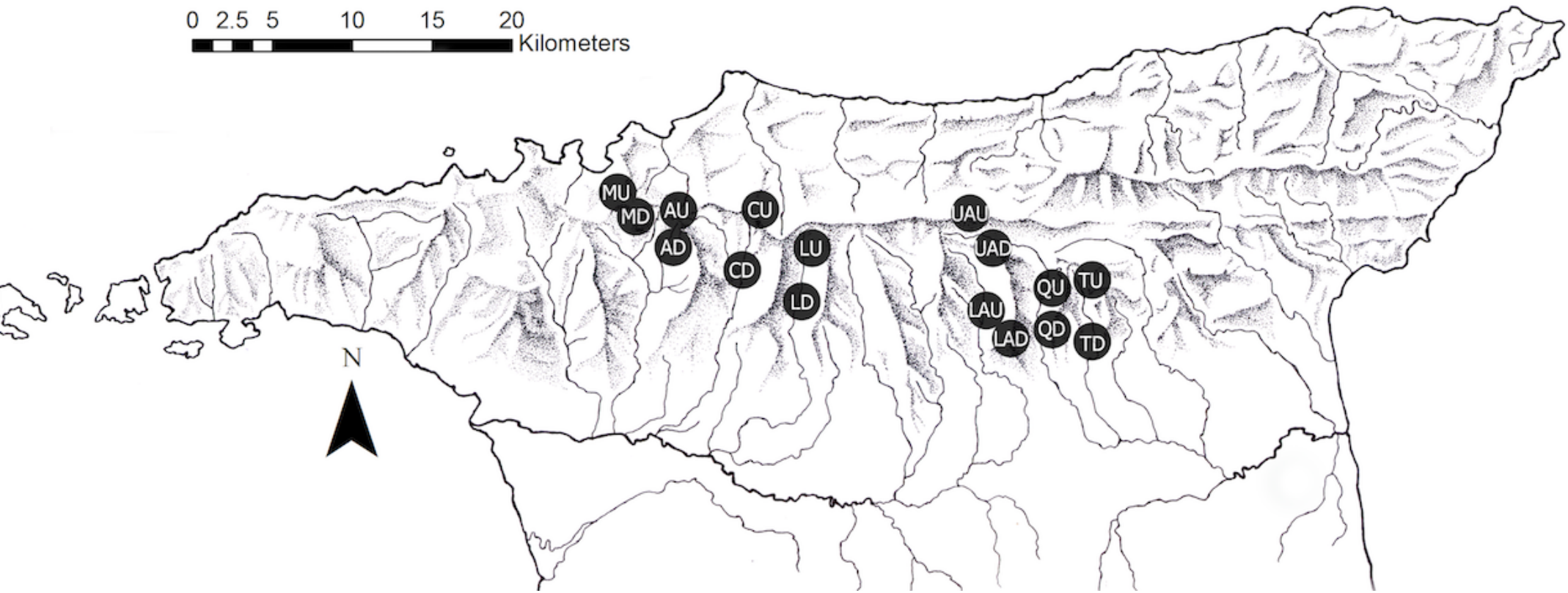
423
412
410
411


N
W
S
0 40 80 160 Kilometers


0 2.5 5 10 15 20
Kilometers
N
MU
MD
AU
AD
CU
CD
LU
LD
UAU
UAD
LAU
LAD
QU
QD
TU
TD

Environmental variables

Fish

16 localities

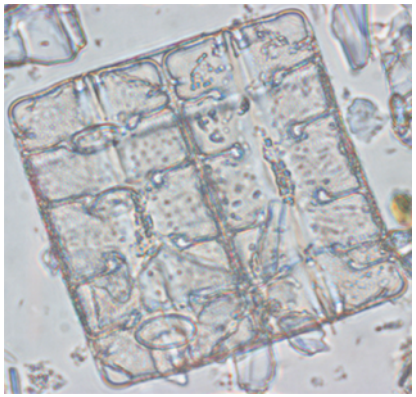
3 assemblages

Environmental variables

Sampled 4x year for

5 years

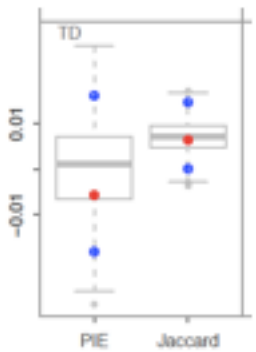
Benthic invertebrates



Diatoms

How can we tell whether any changes we detect in $\alpha$ or $\beta$ diversity are greater than what would be expected, given baseline turnover?

# NULL Model of Biodiversity Change




Calculate metric for each time step

Fit OLS slope to observed data

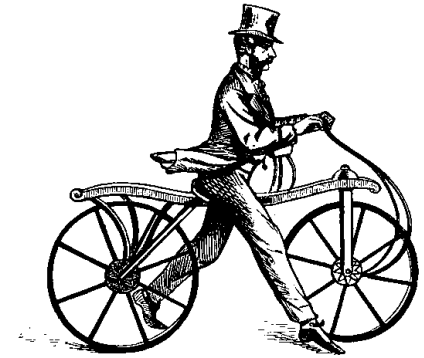
Cyclic shift observed data x1000

Fit OLS slope to each cyclic shifted assemblage

Compute Z score for observed slope relative to null distribution

Cyclic shift preserves within species temporal autocorrelation but breaks cross correlations

# Cyclic-shift permutation

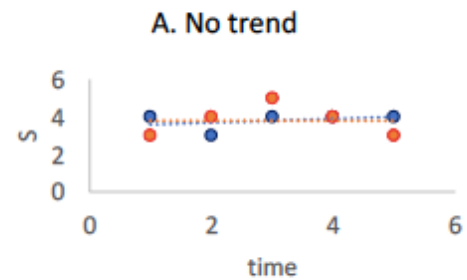


**A observed (no trend)**

| | t1 | t2 | t3 | t4 | t5 |
|---|---|---|---|---|---|
| Sp. A | 16 | 19 | 21 | 24 | 20 |
| Sp. B | 0 | 0 | 1 | 3 | 3 |
| Sp. C | 7 | 8 | 4 | 0 | 0 |
| Sp. D | 1 | 0 | 0 | 1 | 1 |
| Sp. E | 89 | 96 | 101 | 98 | 87 |
| **S** | **4** | **3** | **4** | **4** | **4** |

**cyclic-shift**

| | t1 | t2 | t3 | t4 | t5 |
|---|---|---|---|---|---|
| Sp. A | 24 | 20 | 16 | 19 | 21 |
| Sp. B | 0 | 0 | 1 | 3 | 3 |
| Sp. C | 0 | 7 | 8 | 4 | 0 |
| Sp. D | 1 | 1 | 1 | 0 | 0 |
| Sp. E | 96 | 101 | 98 | 87 | 89 |
| **S** | **3** | **4** | **5** | **4** | **3** |

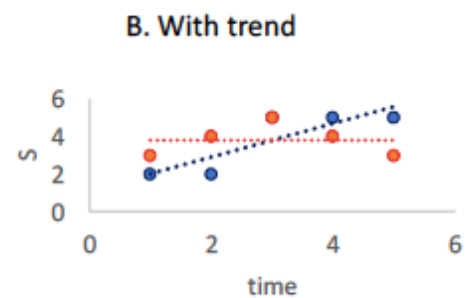


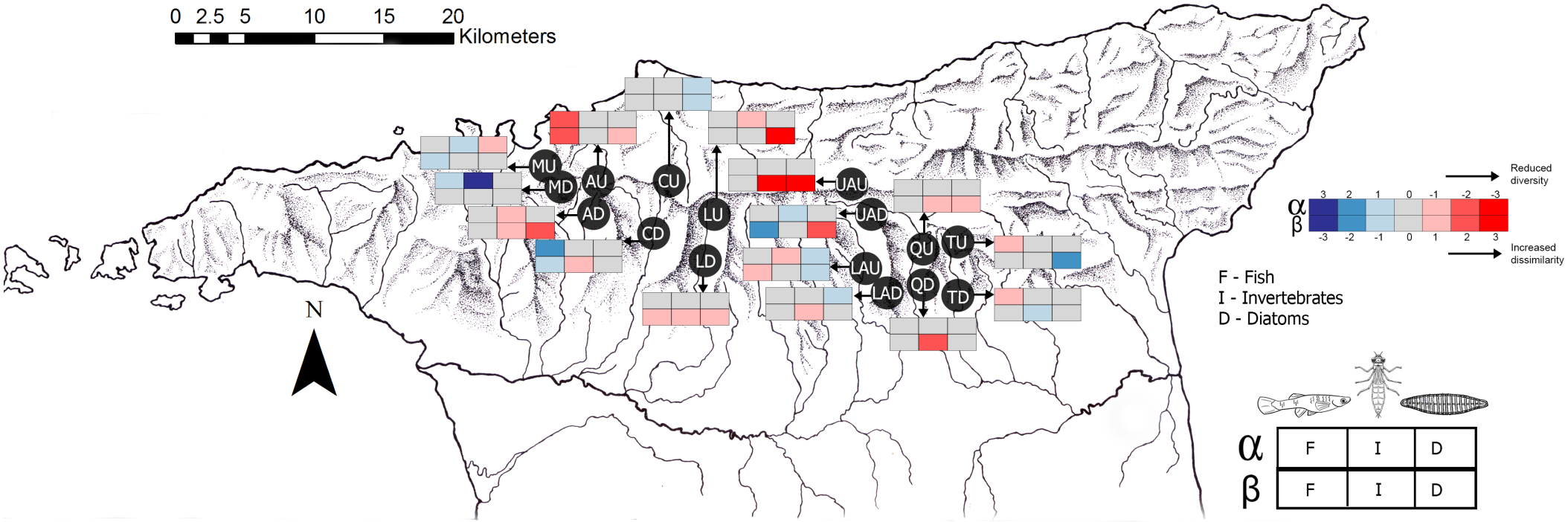

**B observed (trend)**

| | t1 | t2 | t3 | t4 | t5 |
|---|---|---|---|---|---|
| Sp. A | 16 | 19 | 21 | 24 | 20 |
| Sp. B | 0 | 0 | 1 | 3 | 3 |
| Sp. C | 0 | 0 | 4 | 7 | 8 |
| Sp. D | 0 | 0 | 1 | 1 | 1 |
| Sp. E | 89 | 96 | 101 | 98 | 87 |
| **S** | **2** | **2** | **5** | **5** | **5** |

**cyclic-shift**

| | t1 | t2 | t3 | t4 | t5 |
|---|---|---|---|---|---|
| Sp. A | 24 | 20 | 16 | 19 | 21 |
| Sp. B | 0 | 0 | 1 | 3 | 3 |
| Sp. C | 0 | 7 | 8 | 4 | 0 |
| Sp. D | 1 | 1 | 1 | 0 | 0 |
| Sp. E | 96 | 101 | 98 | 87 | 89 |
| **S** | **3** | **4** | **5** | **4** | **3** |




0 2.5 5 10 15 20
Kilometers
N
MU
MD
AU
AD
CU
CD
LU
LD
UAU
UAD
LAU
LAD
QU
QD
TU
TD
Reduced diversity
Increased dissimilarity
α
β
3 2 1 0 -1 -2 -3
-3 -2 -1 0 1 2 3
F - Fish
I - Invertebrates
D - Diatoms
α F I D
β F I D

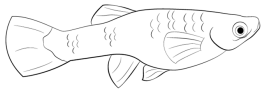
More change in $\beta$ diversity than in $\alpha$ diversity in all taxa, but,

no correlation in pattern of change across taxa, and,

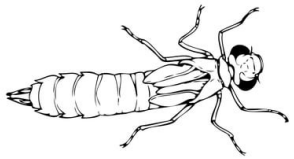
$\alpha$ and $\beta$ diversity changed independently of one another

# site compositional change over time

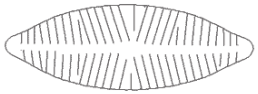
fish homogenization



invertebrates homogenization



diatoms differentiation

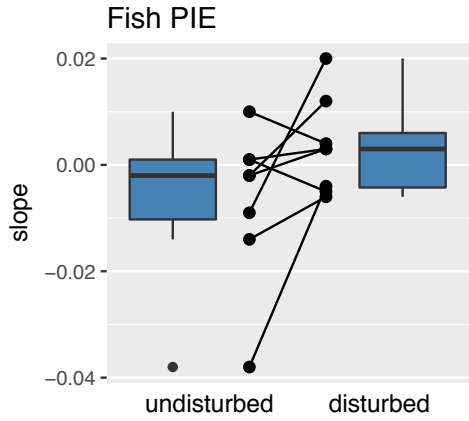


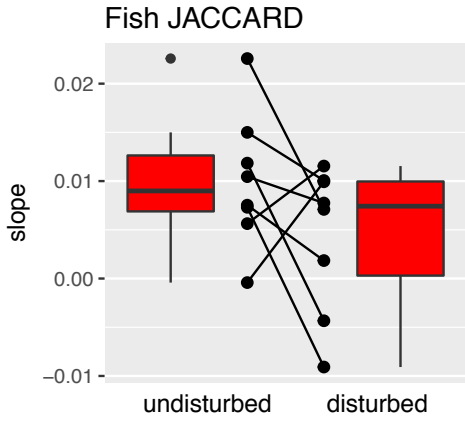
Recreational Sites (Liming)

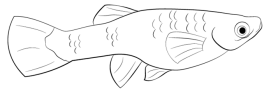
Undisturbed Sites

α diversity β diversity

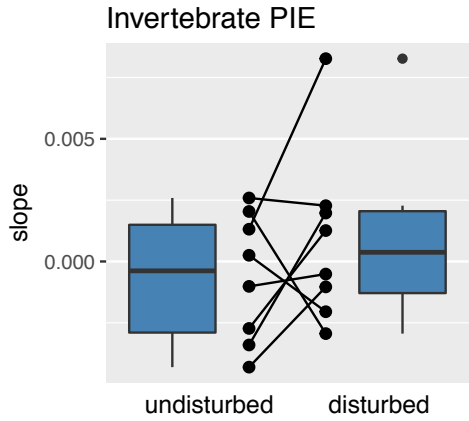
fish

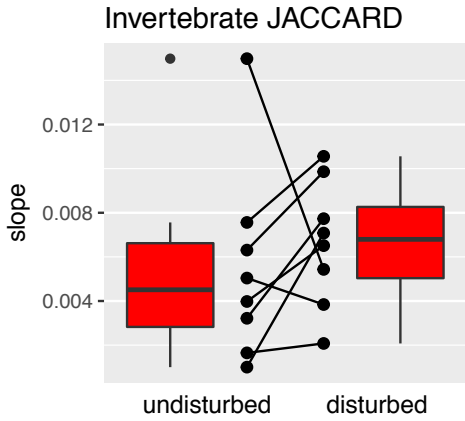


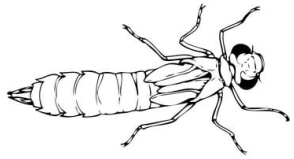



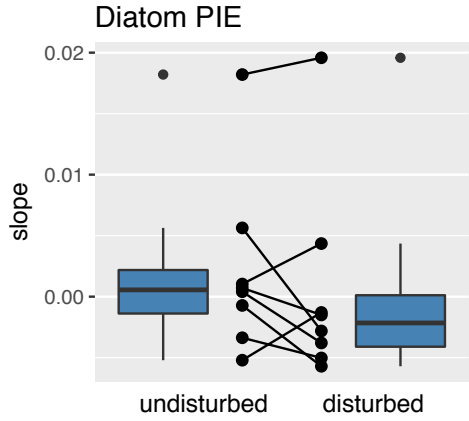
invertebrates

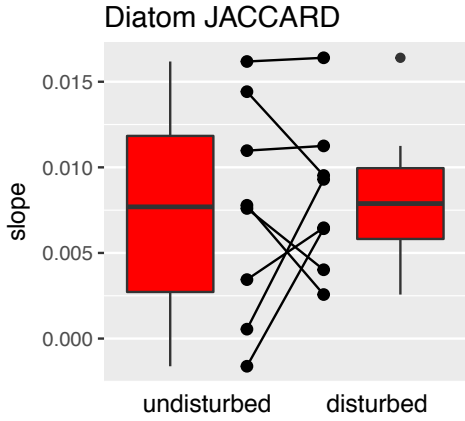


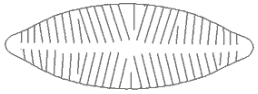



diatoms



# Divergent biodiversity change within ecosystems

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**The Earth's ecosystems are under unprecedented pressure, yet the nature of contemporary biodiversity change is not well understood. Growing evidence that community size is regulated high-**

levels anticipated by two different null models, even though temporal α-diversity metrics detected no systematic change (7).

The contrasting conclusions emerging from the growing

Ecosystems that have not been massively transformed tend to support similar numbers of species over time – and provide evidence for regulation of community size

Ecosystems
are not museums –
species composition
changes over time,
at rates that are
greater than
ecological theory
predicts

We do not understand the consequences for ecosystem function of elevated biodiversity change in the contemporary world

Effective conservation and resource management needs high-quality data on the distributions and abundances of species

# Biodiversity change and biodiversity policy

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