Scaling and spatial patterns of species co-occurrence in a rocky intertidal meta-community

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Collaborators

S. Hacker, B. Menge

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Data Wrangling/Computing

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Thanks to the GRS & GRC chairs & co-chairs!

Determinants of species distributions

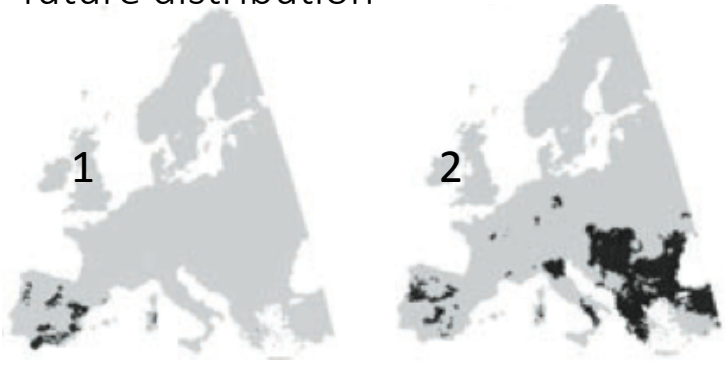
Scale & hierarchical filters

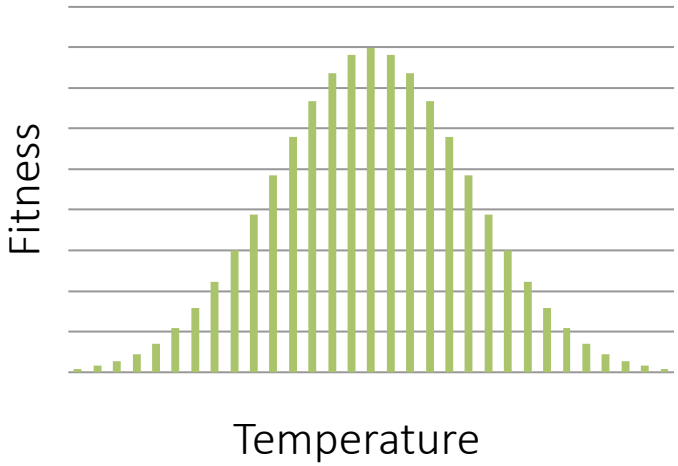
Photo: David Gonzales

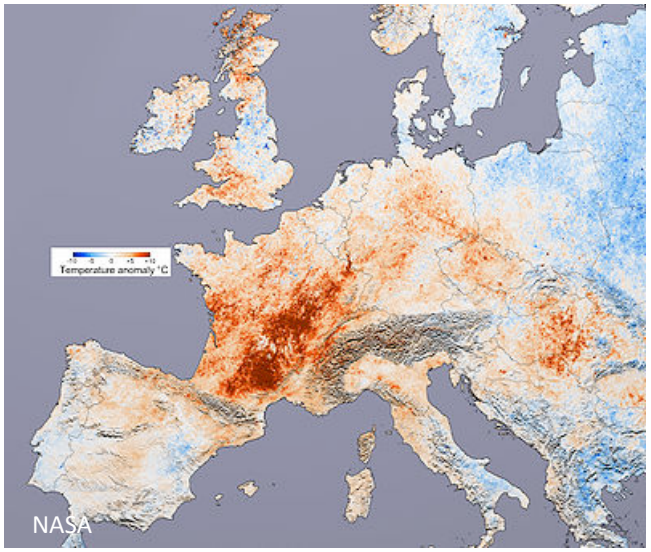
Predictability of species distributions

present distribution

future distribution







Adapted from Araújo et al. 2006

Where do species interactions fit in?

Large & small scale evidence for importance of biotic interactions

Macroecological signals of species interactions in the Danish avifauna

Nicholas J. Gotelli[a,1], Gary R. Graves[b], and Carsten Rahbek[c]

[a]Department of Biology, University of Vermont, Burlington, VT 05405; [b]Department of Vertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, DC 20013; and [c]Center for Macroecology, Evolution and Climate, Department of Biology, University of Copenhagen, DK-2100 Copenhagen Ø, Denmark

Communicated by Thomas W. Schoener, University of California, Davis, CA, December 21, 2009 (received for review August 6, 2009)

The role of intraspecific and interspecific interactions in structuring biotic communities at fine spatial scales is well documented, but the signature of species interactions at coarser spatial scales is unclear. We present evidence that species interactions may be a significant factor in mediating the regional assembly of the Danish avifauna.

continental mainland regions (23). Inferences of community assembly rules from statistical analyses of presence/absence data are controversial. Even with the use of sophisticated null-model analyses, it is not possible in most systems to discriminate spatial patterns generated by species interactions from those caused by historical

Gotelli et al. 2010 *PNAS*

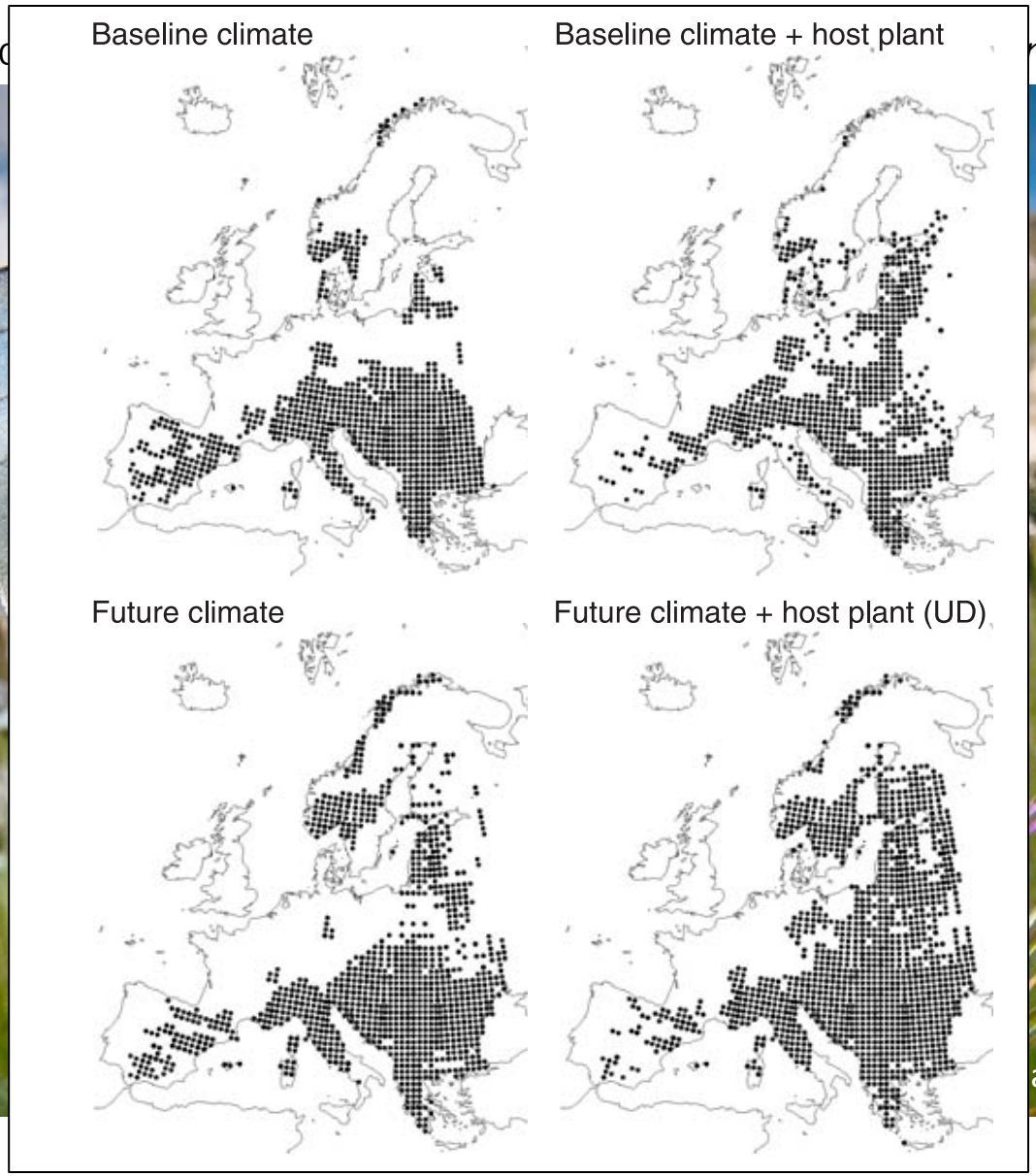
Incorporating species interactions into SDMs

Clouded Apollo butterfly, *Parnassius mnemosyne*, and host *Corydalis* plants

Araújo & Luoto 2007 *GEB*

Incorporating species interactions into SDMs

Clouded

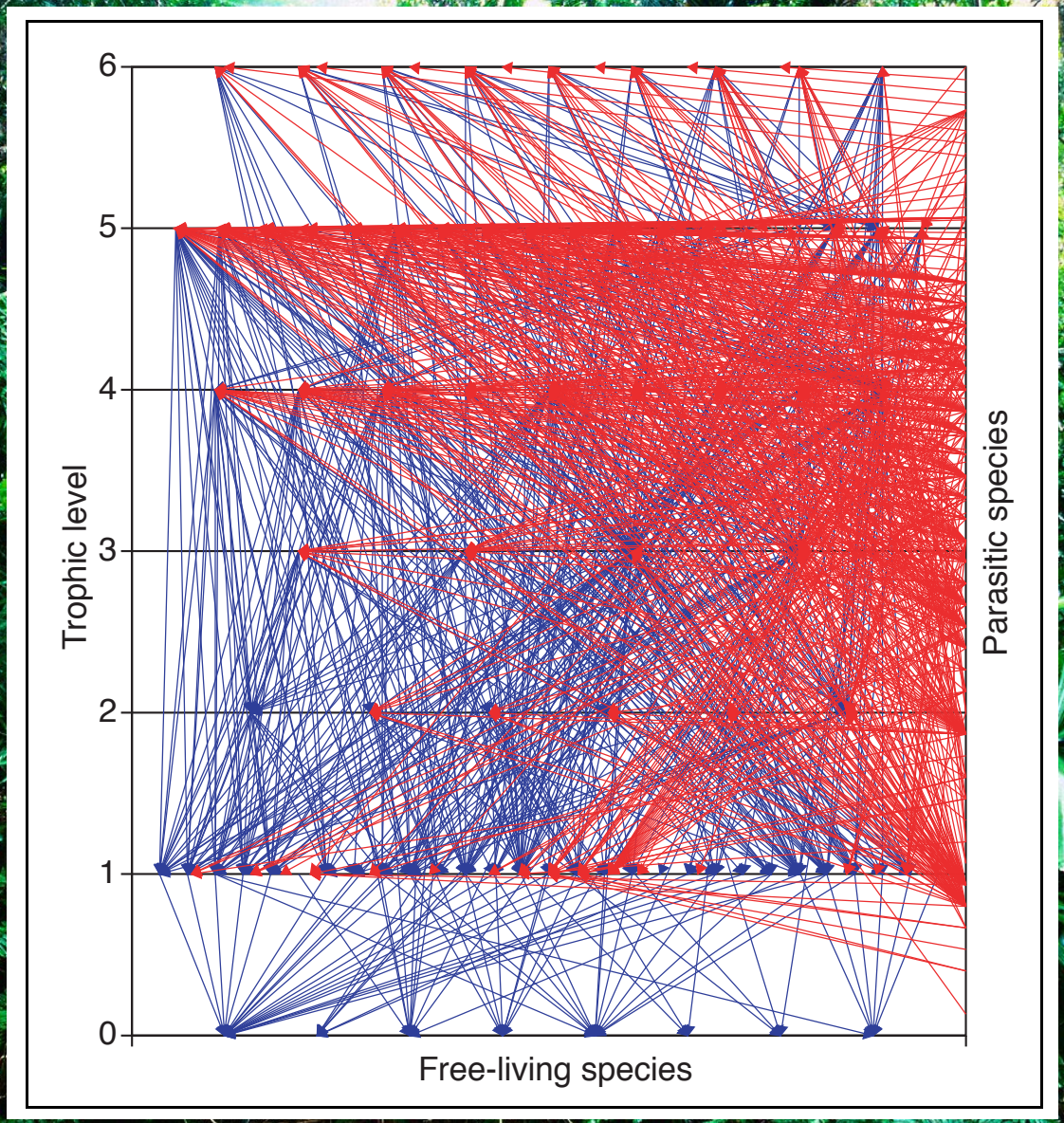


rydalis plants

Araújo & Luoto 2007 *GEB*

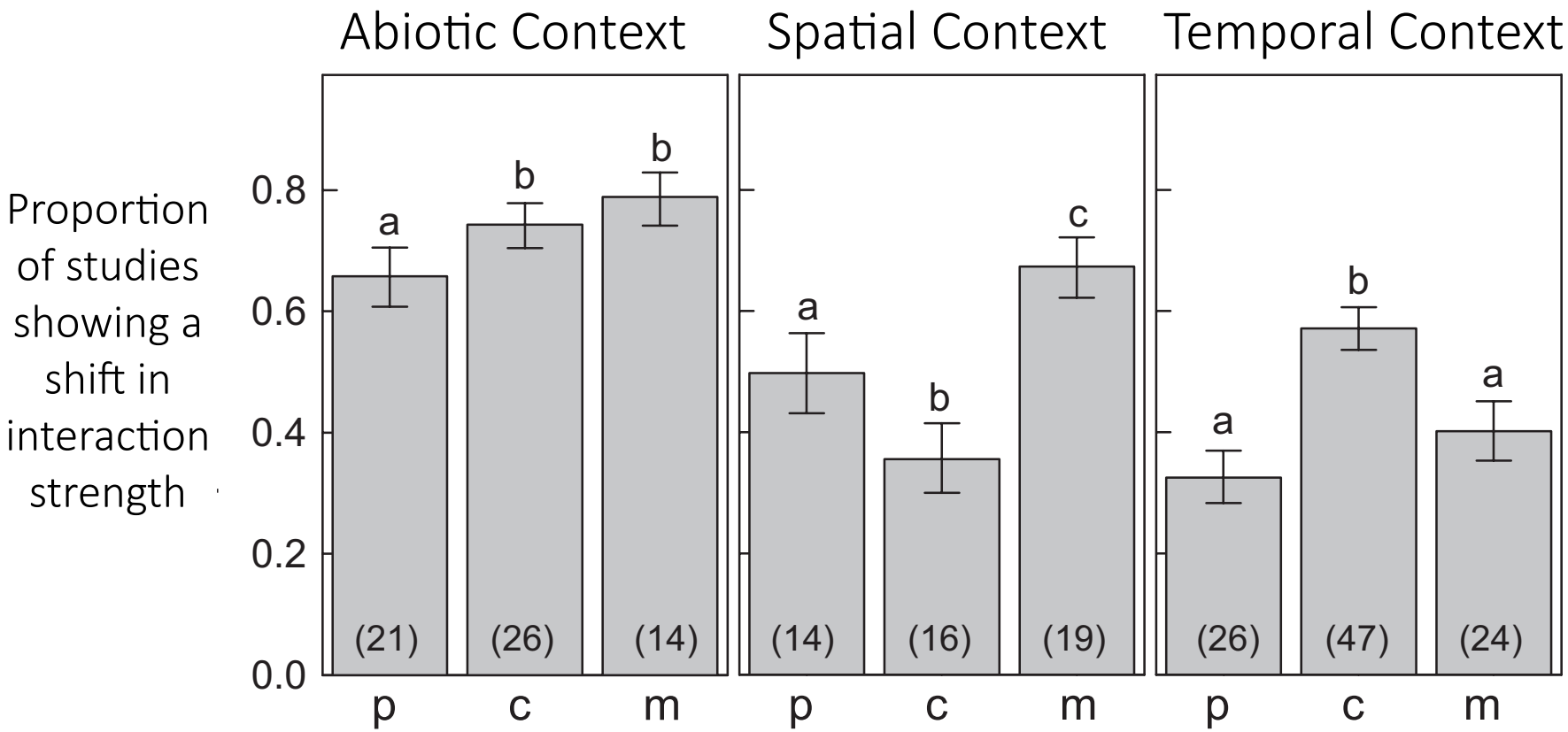
How to determine species interactions in diverse ecosystems?

How to determine species interactions in diverse ecosystems?



Carpinteria salt marsh food web, Lafferty et al. 2006

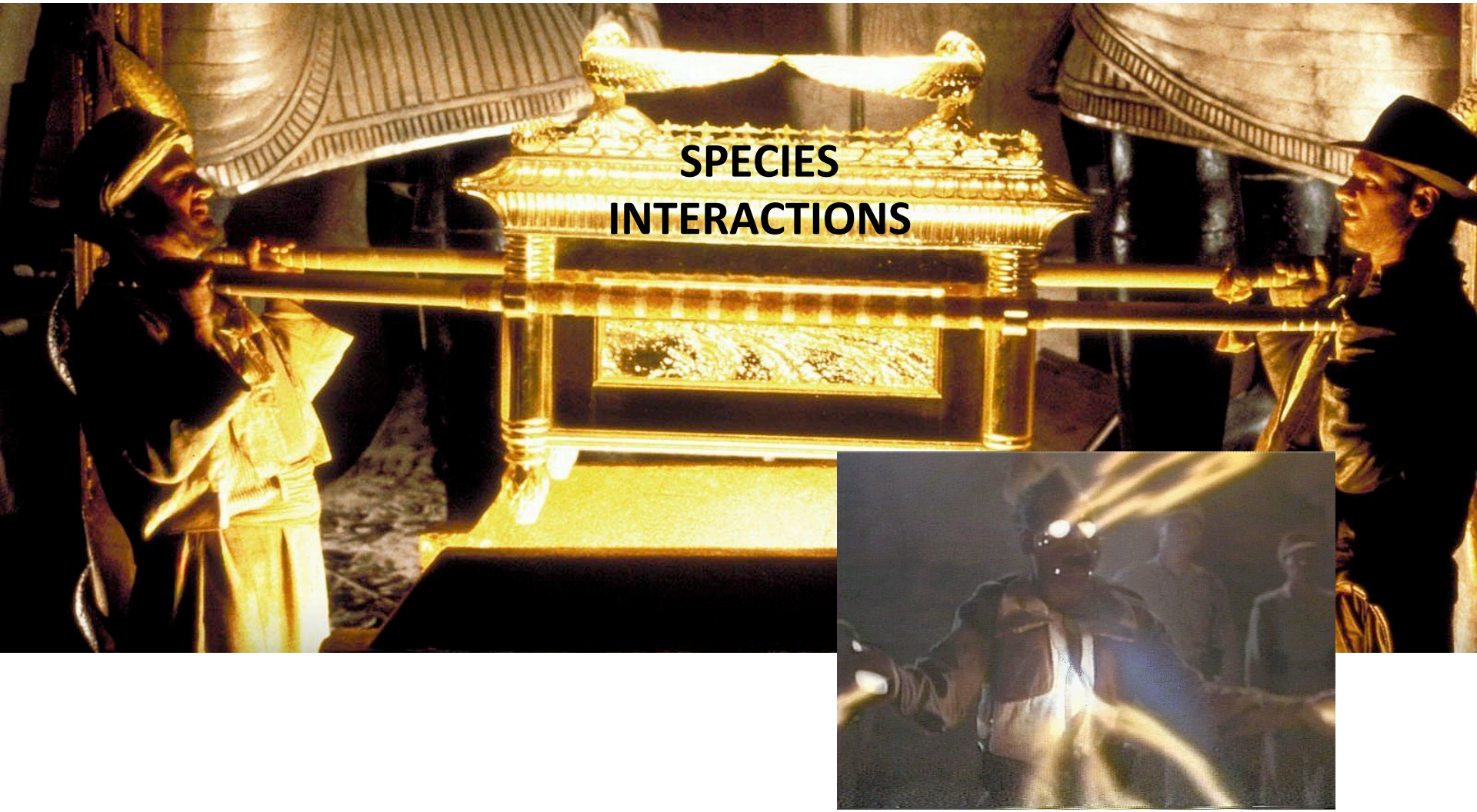
Context-dependency of species interactions



p=predation, c=competition, m=mutualism

Modified Fig. 2 in Chamberlain et al. 2014 *Ecol. Lett.*

Should we ignore this complexity?
What ecological theories do we have to make predictions?



What is the "theory of climate change"?

- Chris Harley

2013 WSN Presidential Symposium

How to identify hypotheses for how climate change affects communities?

I. Environment-Process Theories

Metabolic Theory of Ecology

Macrophysiology

Environmental Stress Models

II. Process-Persistence Theories

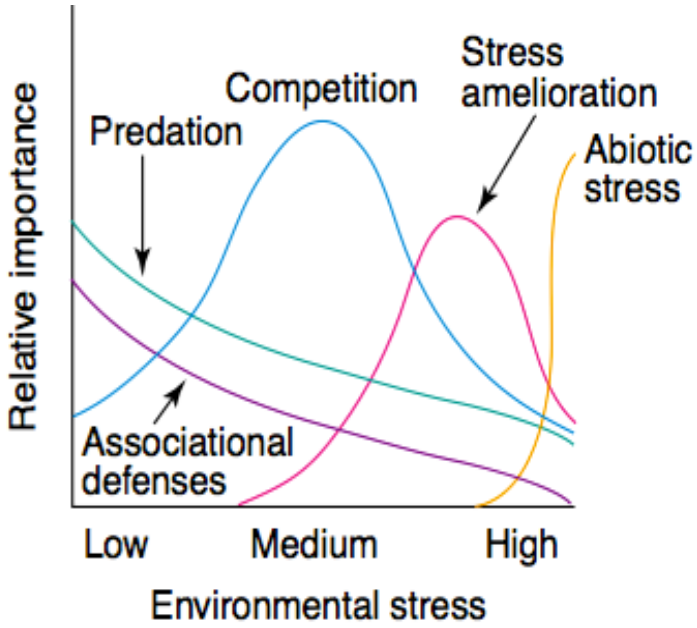
Metapopulation Theory

Evolutionary Theory

Population Ecology

Fig. 1 from O'Connor et al. 2012 *GEB*

Environmental Stress Models and the Stress Gradient Hypothesis

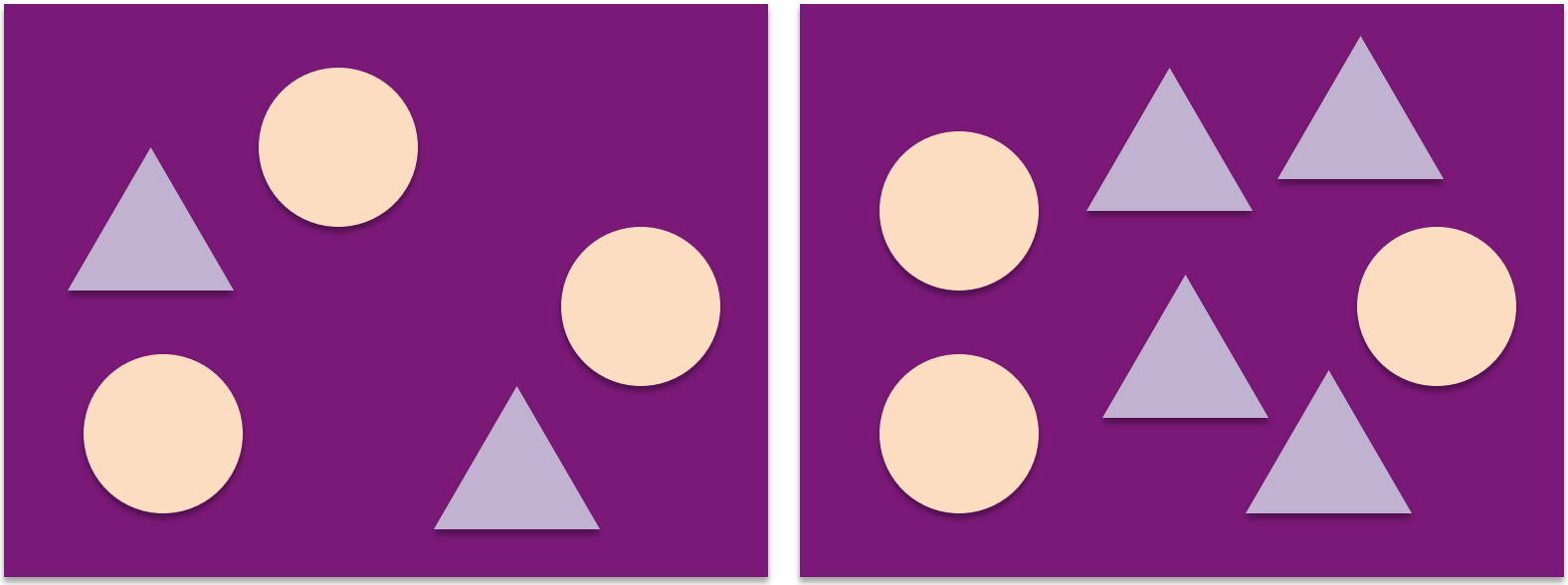


ESM: Modified Menge-Sutherland model (1987 *AmNat*) from Bruno et al. 2003 *TREE*

SGH: Bertness & Callaway 1994 *TREE*, review in Maestre et al. 2009 *J. Ecol.*

Back to: identifying species interactions in diverse systems

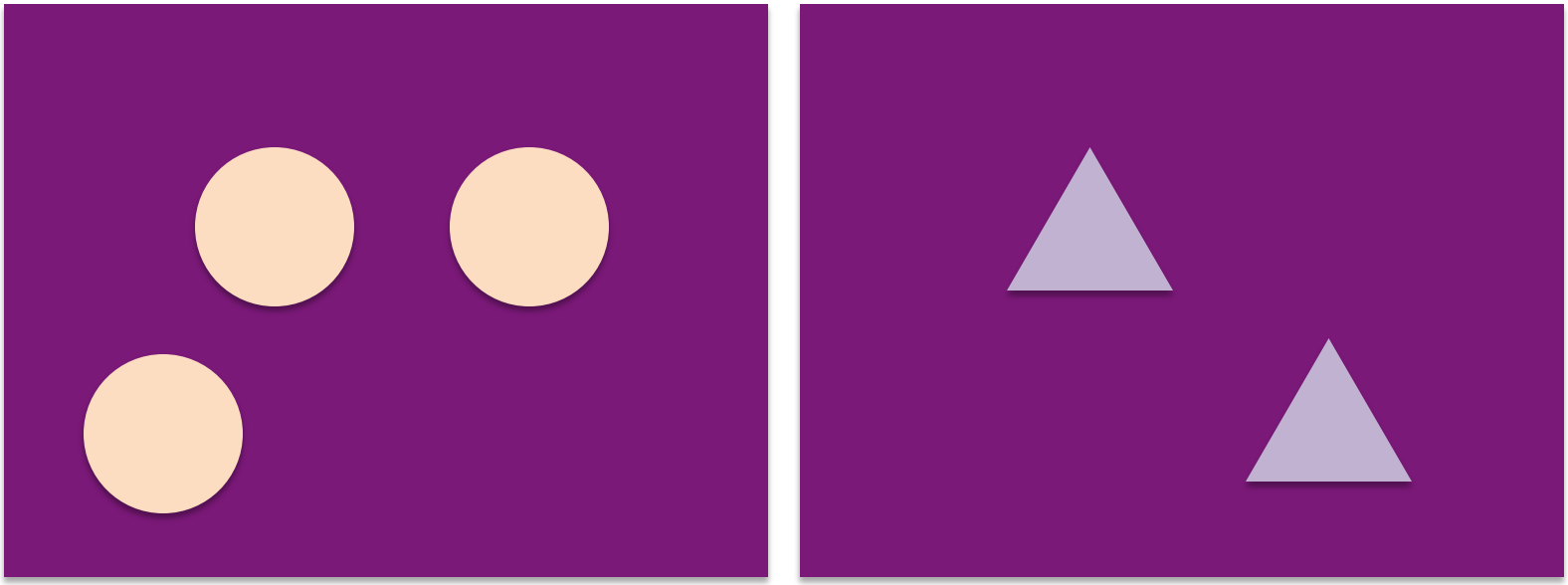
Patterns in species co-occurrence as signals of species interactions



Signal of positive co-occurrence after accounting for habitat preference

Diamond 1975, Connor & Simberloff 1979, Gotelli 2000, Peres-Neto et al. 2001, Ovaskainen et al. 2010

Patterns in species co-occurrence as signals of species interactions



Signal of negative co-occurrence after accounting for habitat preference

Diamond 1975, Connor & Simberloff 1979, Gotelli 2000, Peres-Neto et al. 2001, Ovaskainen et al. 2010

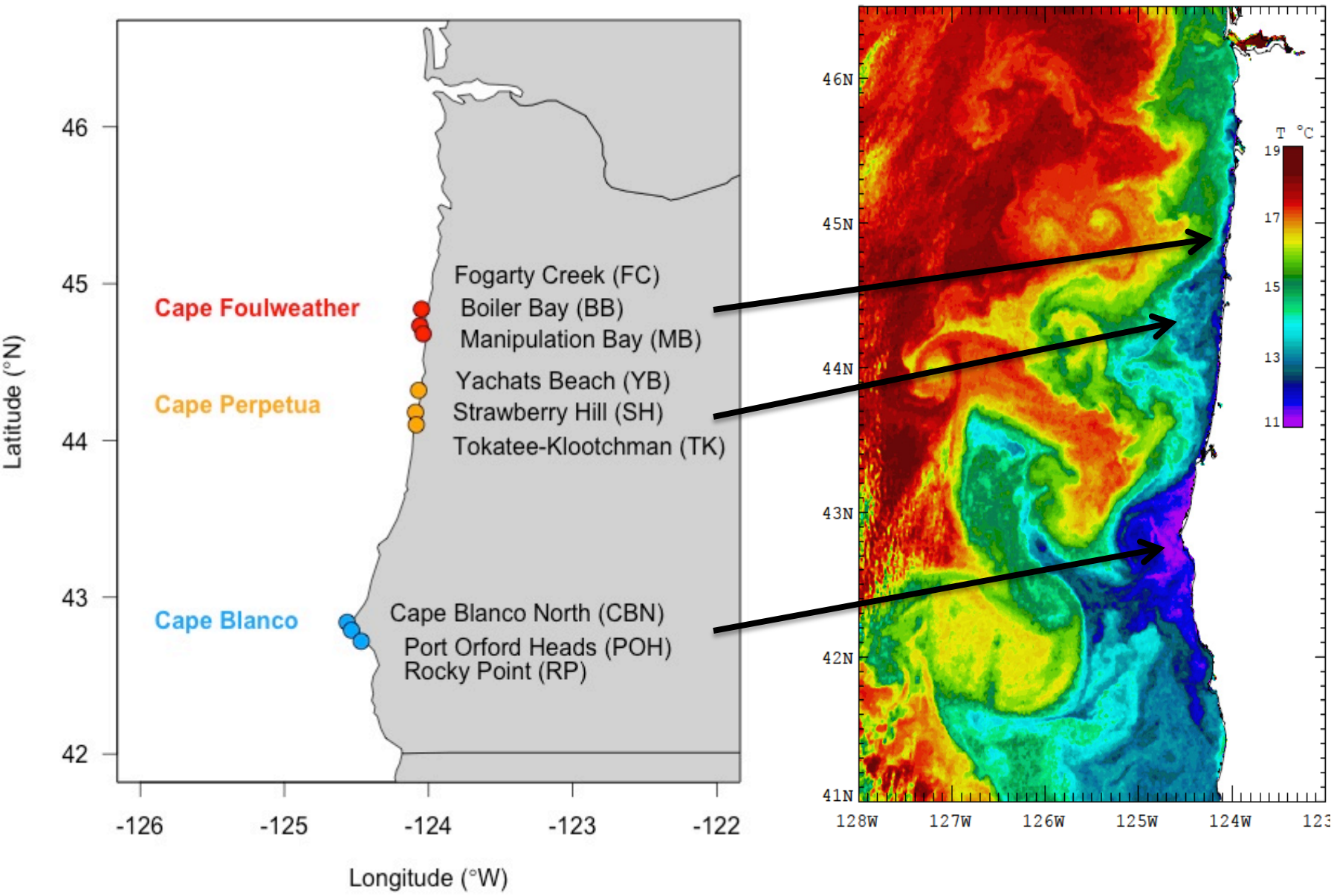
Do patterns in species co-occurrence change…

In different environmental contexts?

Across environmental stress gradients?

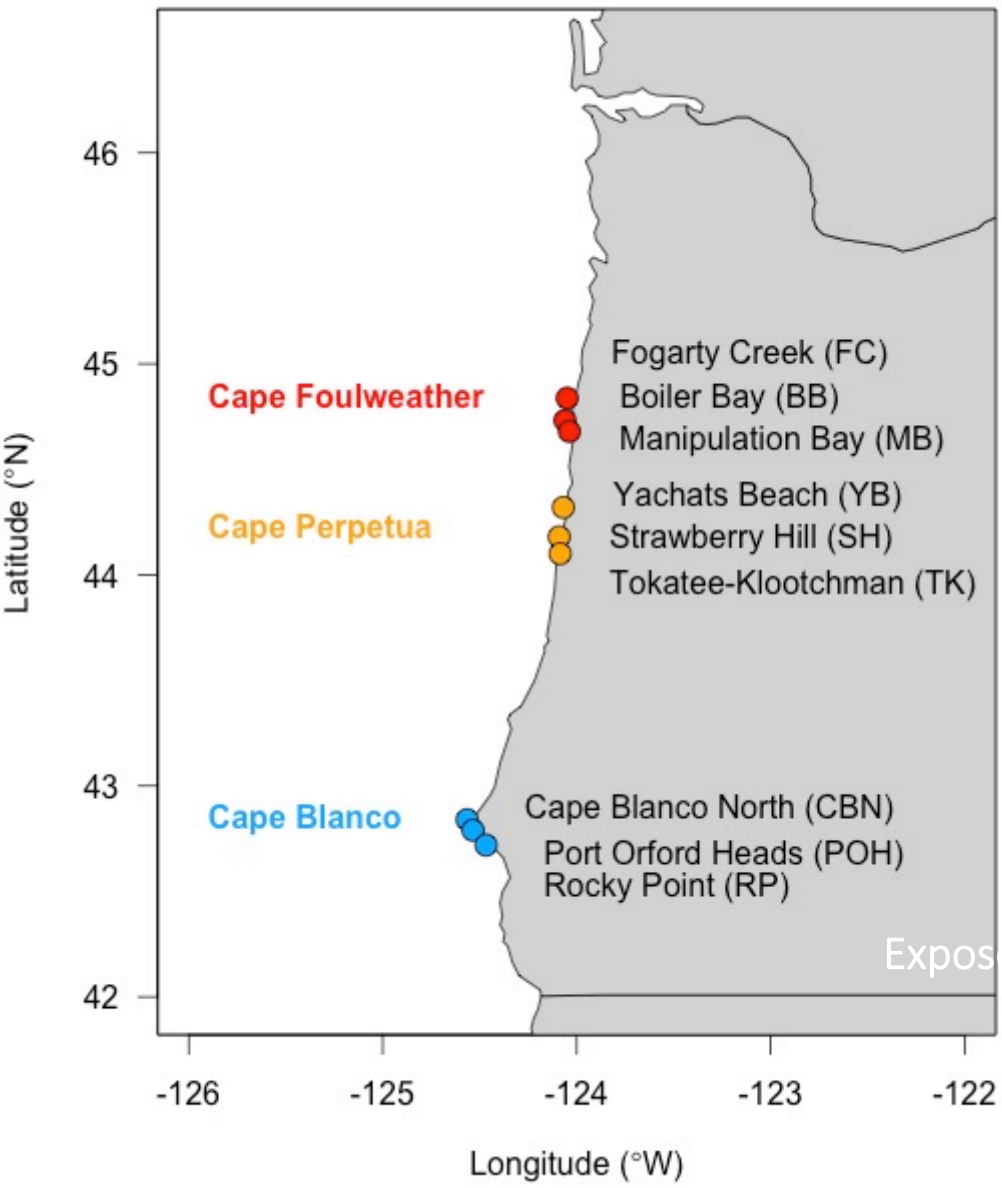
Are patterns detectable at different spatial scales?

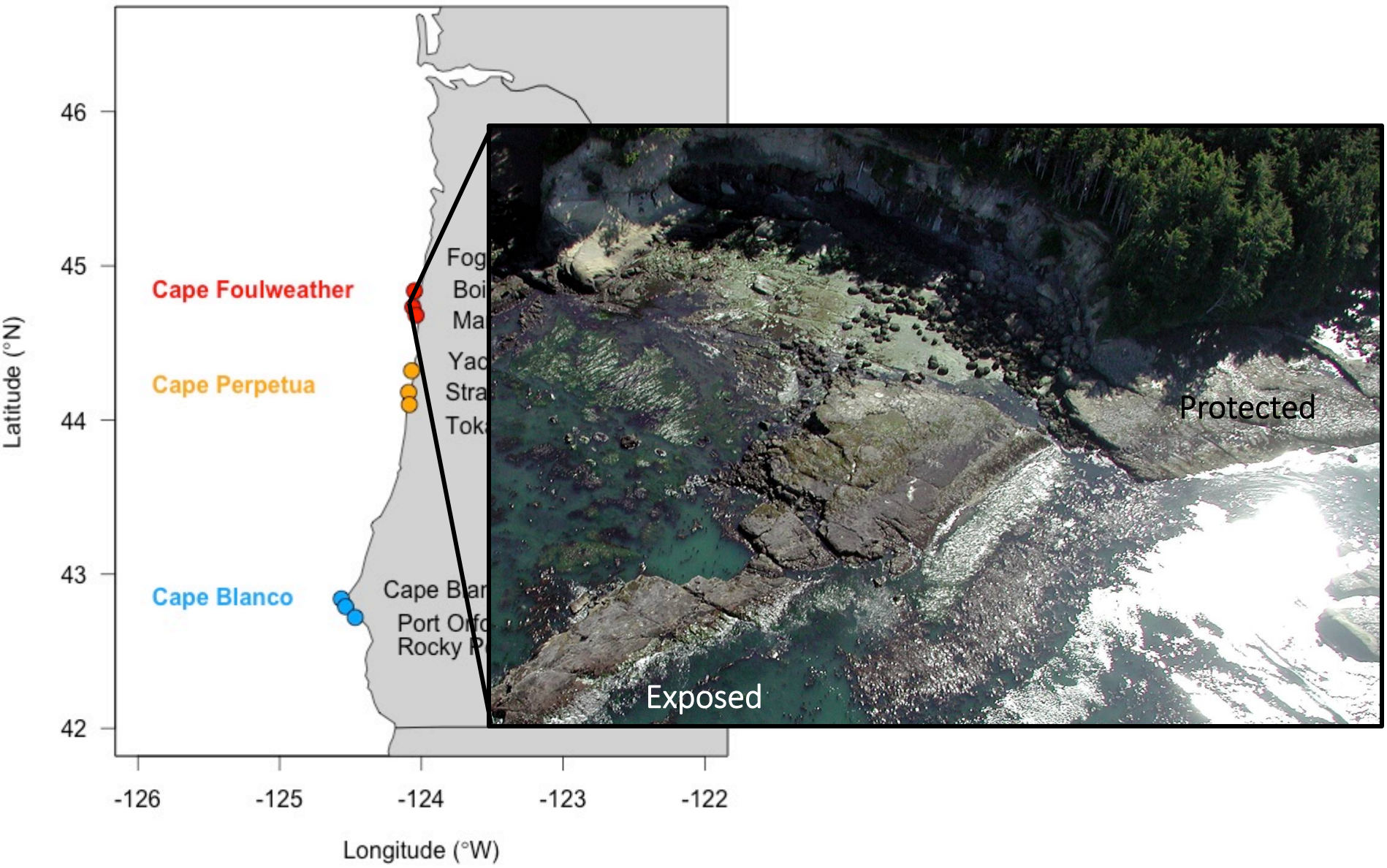
Study system: species mosaic in rocky intertidal low zone


Cape Foulweather
Fogarty Creek (FC)
Boiler Bay (BB)
Manipulation Bay (MB)
Cape Perpetua
Yachats Beach (YB)
Strawberry Hill (SH)
Tokatee-Klootchman (TK)
Cape Blanco
Cape Blanco North (CBN)
Port Orford Heads (POH)
Rocky Point (RP)
Latitude (°N)
Longitude (°W)
46
45
44
43
42
-126
-125
-124
-123
-122
46N
45N
44N
43N
42N
41N
128W
127W
126W
125W
124W
T °C
19
17
15
13
11

Yachats Beach
Cape Perpetua Region

Fogarty Creek
Cape Foulweather Region


Latitude (°N)
46
45
44
43
42
-126
-125
-124
-123
-122
Longitude (°W)
Cape Foulweather
Cape Perpetua
Cape Blanco
Fogarty Creek (FC)
Boiler Bay (BB)
Manipulation Bay (MB)
Yachats Beach (YB)
Strawberry Hill (SH)
Tokatee-Klootchman (TK)
Cape Blanco North (CBN)
Port Orford Heads (POH)
Rocky Point (RP)


Cape Foulweather
Cape Perpetua
Cape Blanco
Fog
Boi
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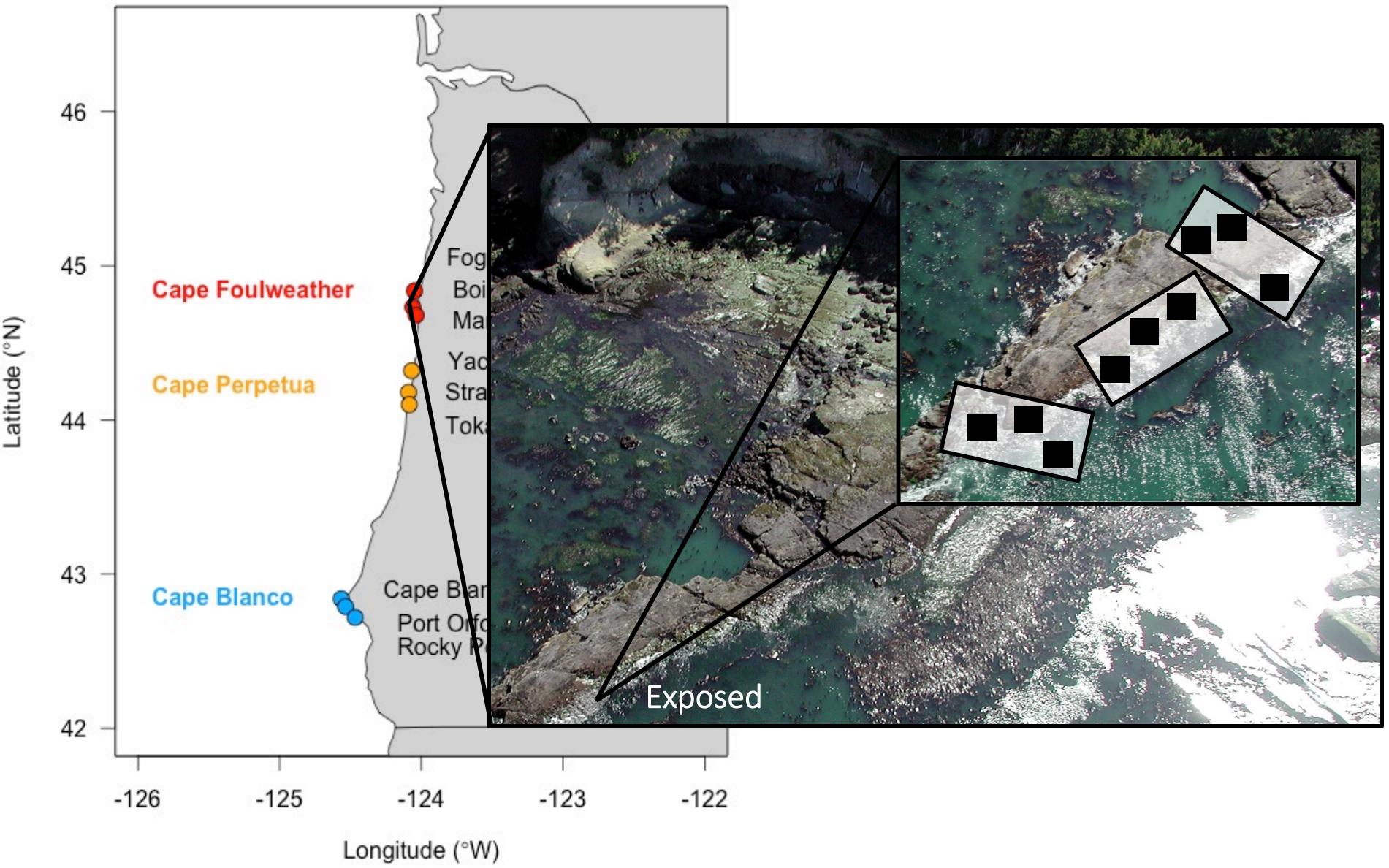
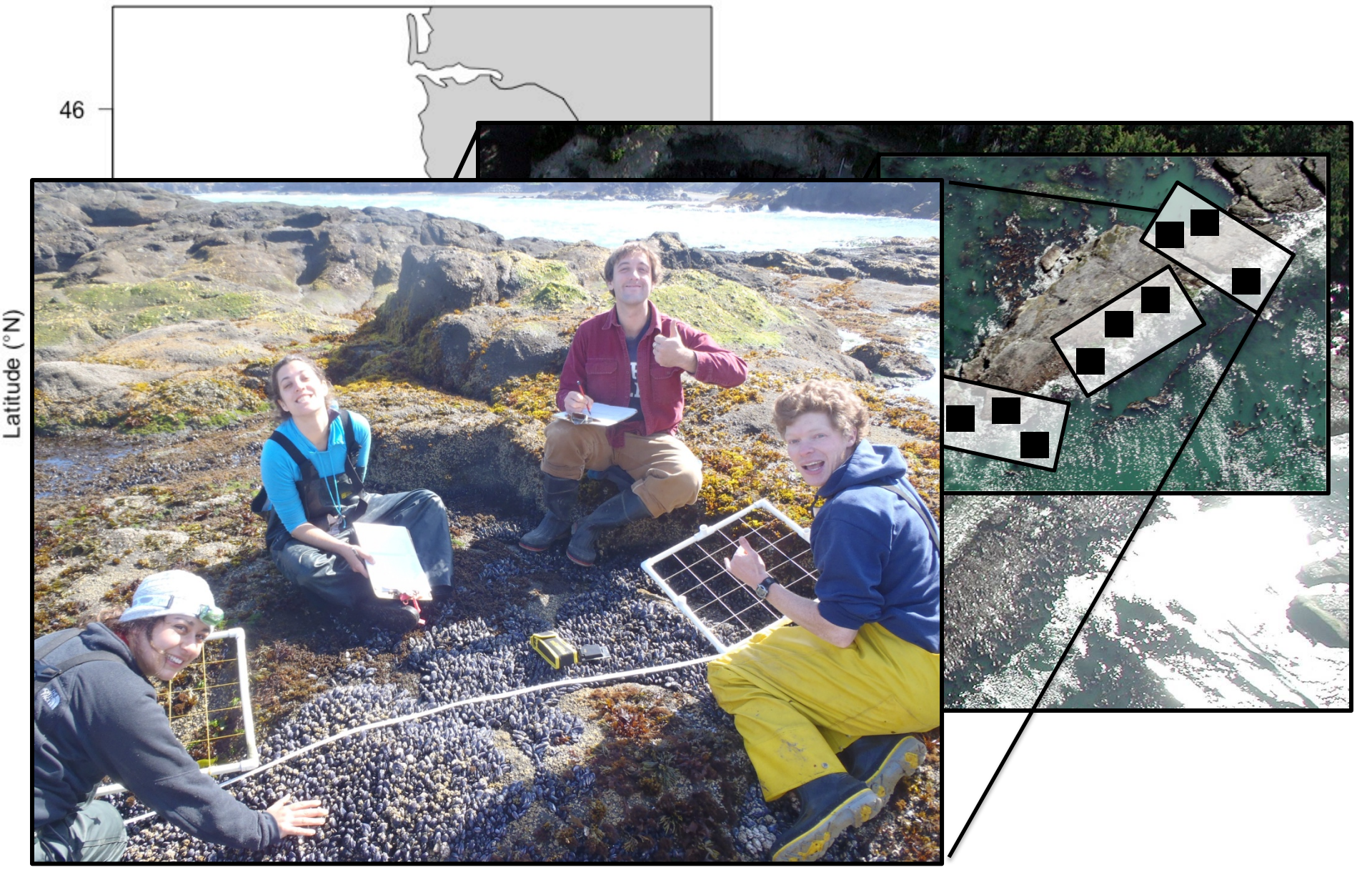
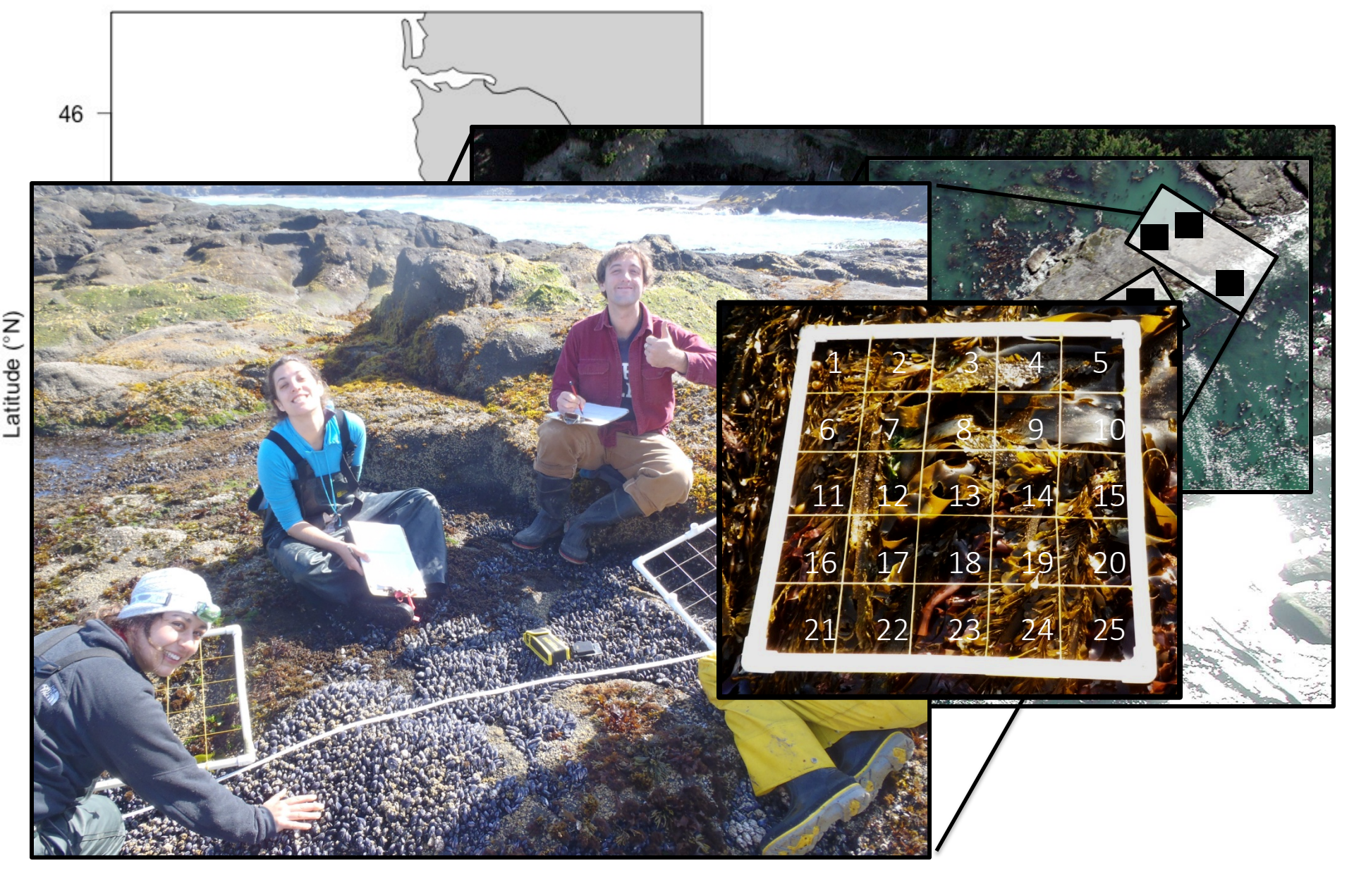
Yac
Stra
Tok
Cape Blan
Port Orfo
Rocky P
Protected
Exposed
46
45
44
43
42
-126
-125
-124
-123
-122
Latitude (°N)
Longitude (°W)


Cape Foulweather
Cape Perpetua
Cape Blanco
Exposed
46
45
44
43
42
-126
-125
-124
-123
-122
Latitude (°N)
Longitude (°W)


46
Latitude (°N)


46
Latitude (°N)
1 2 3 4 5
6 7 8 9 10
11 12 13 14 15
16 17 18 19 20
21 22 23 24 25

Intertidal Stress Gradients

wave regime
(relative wave acceleration)

heat load index
(calculated from slope, aspect*)

~~desiccation stress~~
~~(max. air temperature)~~

*McCune & Keon 2002

Need to account for habitat preferences

- currents: upwelling index, along- and cross-shelf
- temperature: water
- water retention: shelf width (distance to 100 and 200m depth)
- phytoplankton abundance: chlorophyll-*a*
- nutrient availability: PON, nitrate
- substrate heterogeneity

Multivariate regression approach

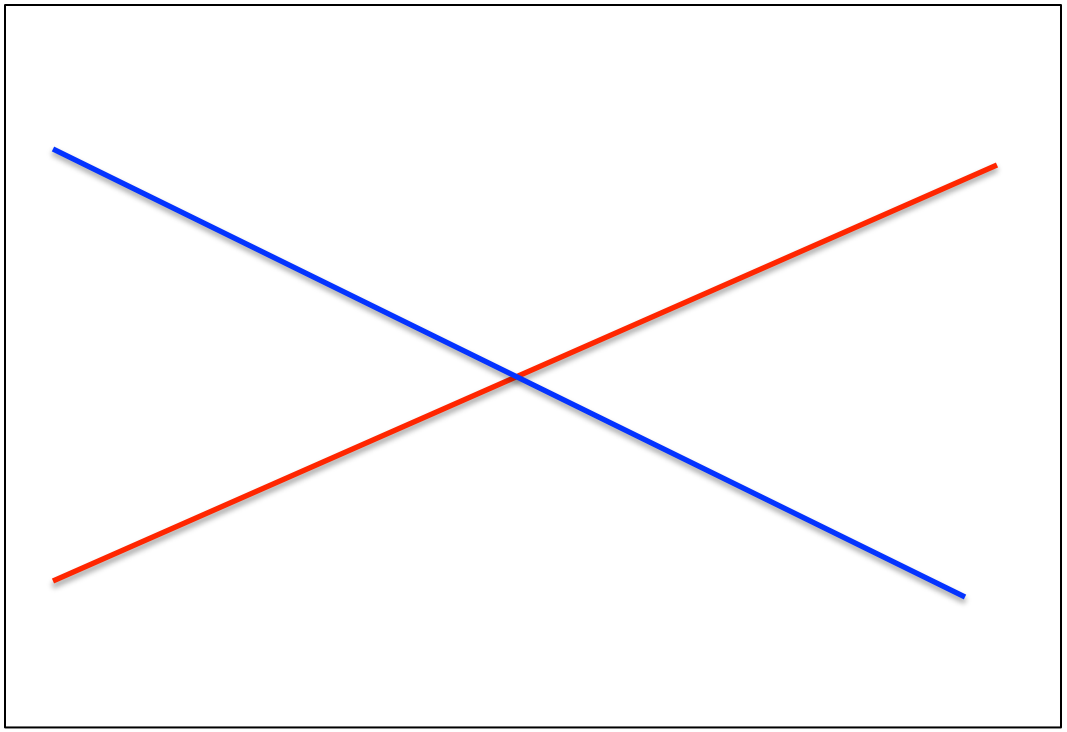
- Input:
  - presence/absence matrix of species
  - environmental matrix
- *Account for similarities/differences in habitat preferences (fundamental niche)*
- Output:
  - matrix of residual correlations among species

    (a measure of non-random co-occurrences)

Ovaskainen et al. 2010 *Ecology,* Golding 2013 PhD Thesis – R package BayesComm

What might this look like?

relative/ absolute frequency of positive co-occurrences

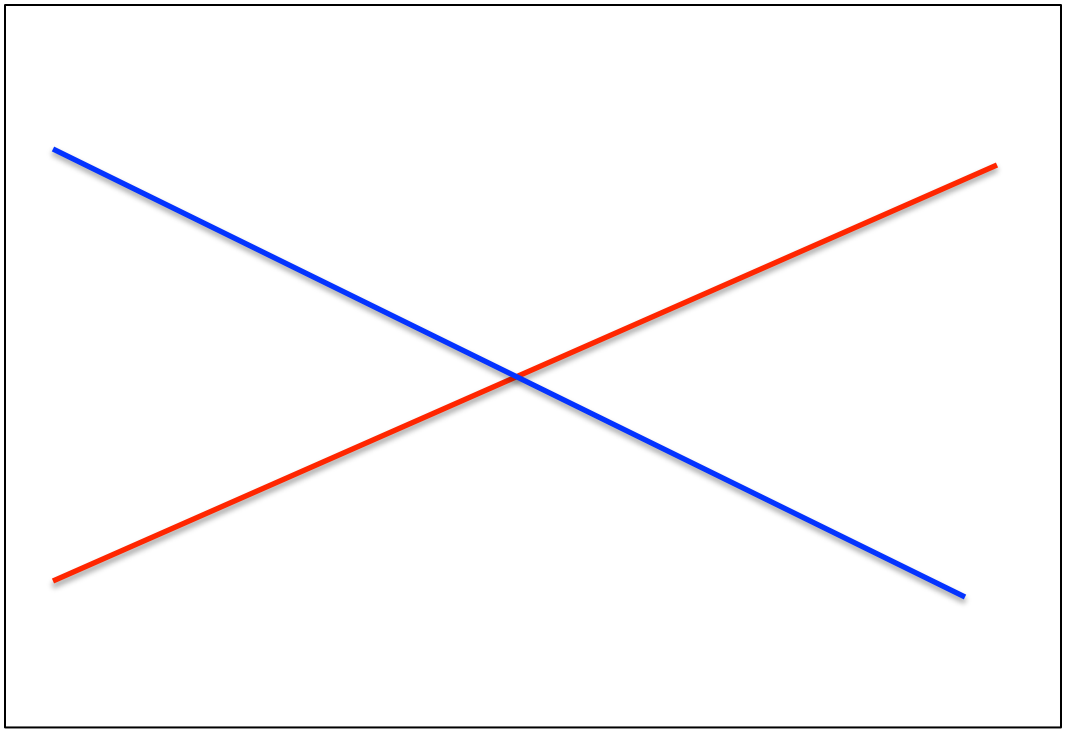


relative/ absolute frequency of negative co-occurrences

stress gradient

What might this look like?

relative/ absolute frequency of positive co-occurrences



relative/ absolute frequency of negative co-occurrences

scale

Araújo & Rozenfeld 2014 *Ecography*

Do patterns in species co-occurrence change…

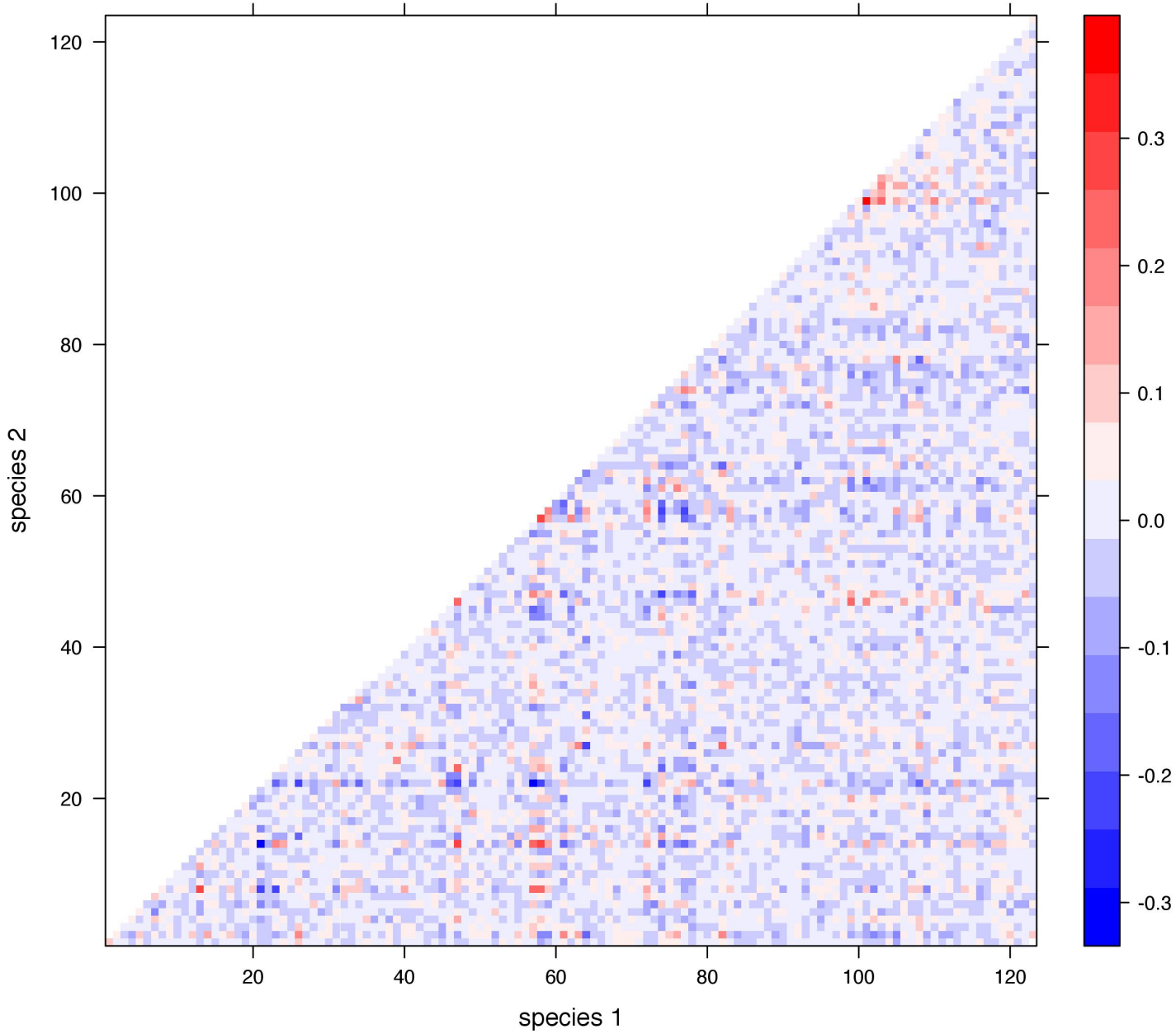
In different environmental contexts?

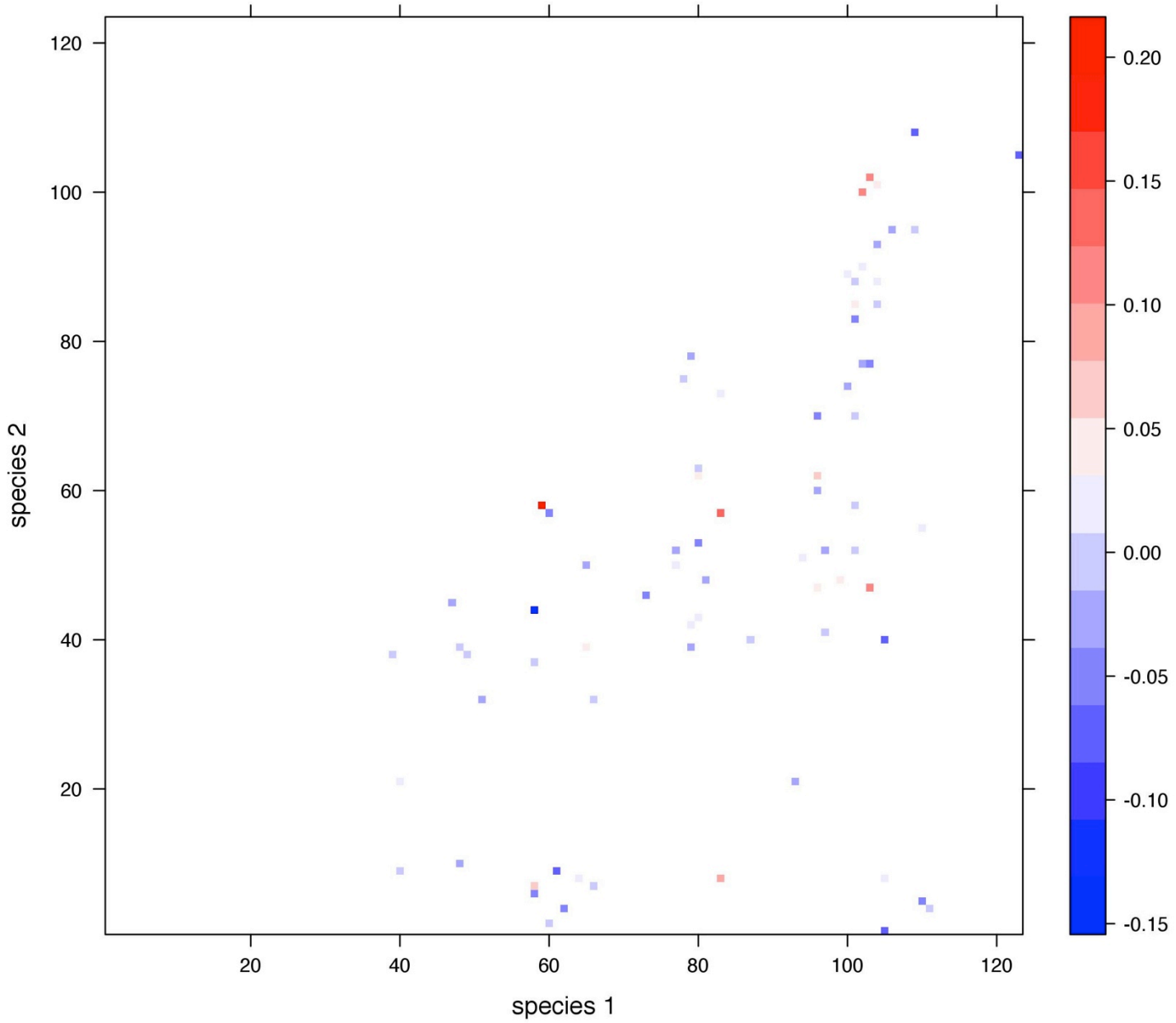
Across environmental stress gradients?

Are patterns detectable at different spatial scales?

Are there non-random co-occurrences overall?

Yes, do see residual co-occurrences at all scales and at all sites!


species 2
120
100
80
60
40
20
species 1
20
40
60
80
100
120
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3


species 2
120
100
80
60
40
20
species 1
20
40
60
80
100
120
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15

Strong negative co-occurrences

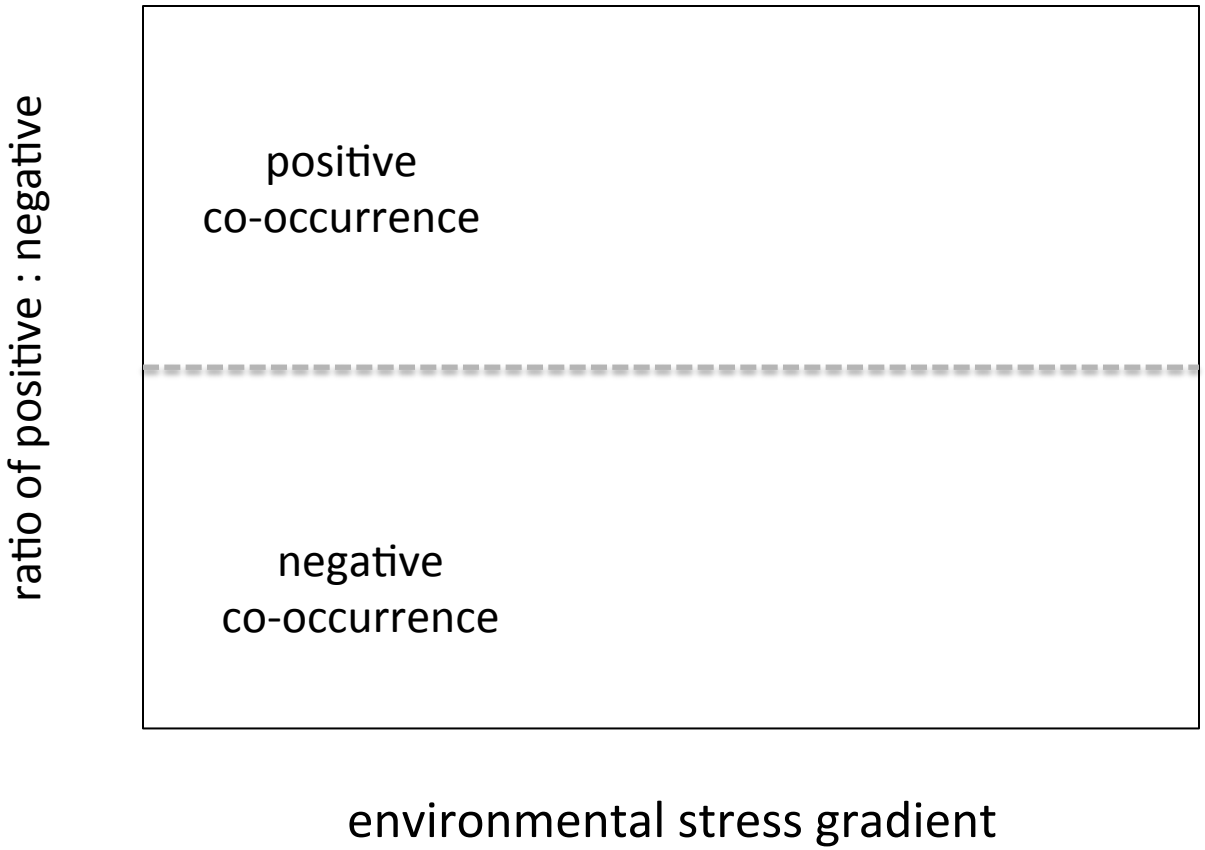
Laminaria setchellii and *Laminaria sinclairii*
(-0.24, -0.014)

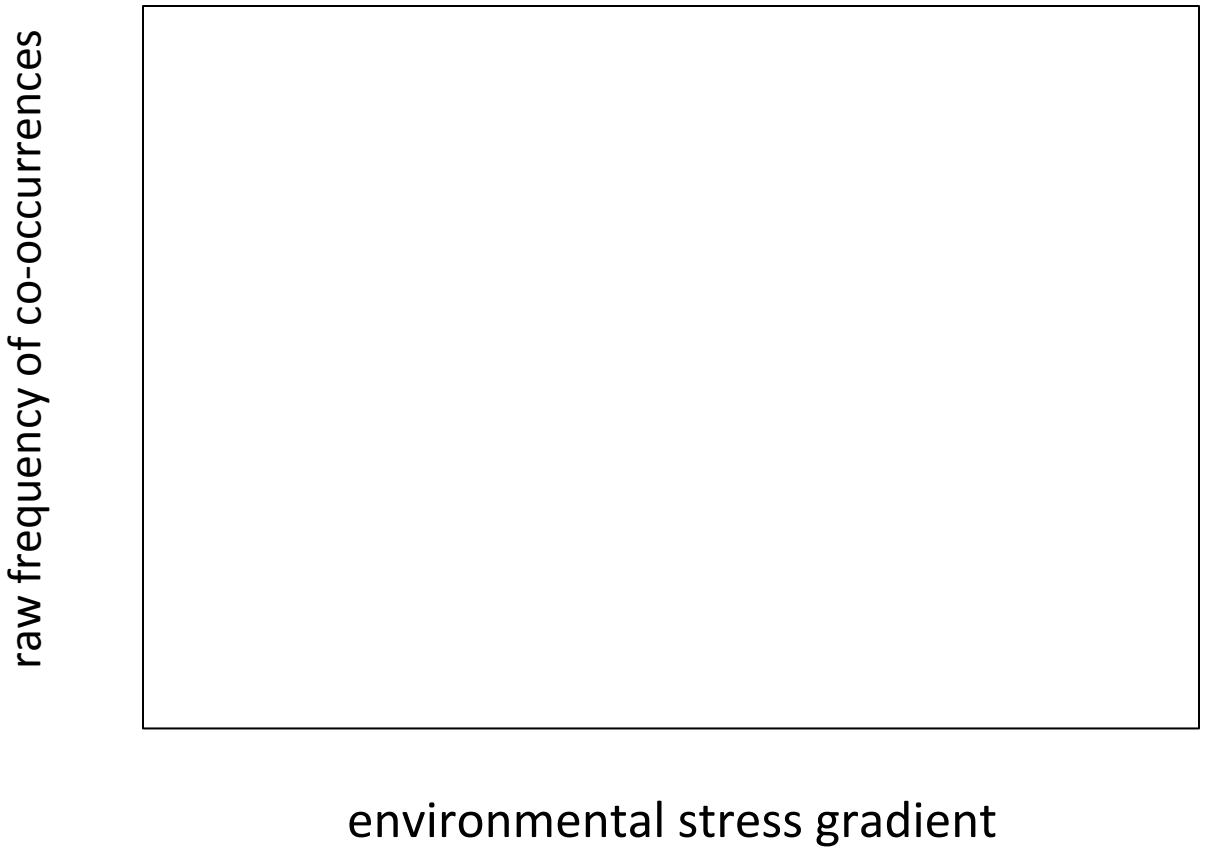
Strong negative co-occurrences

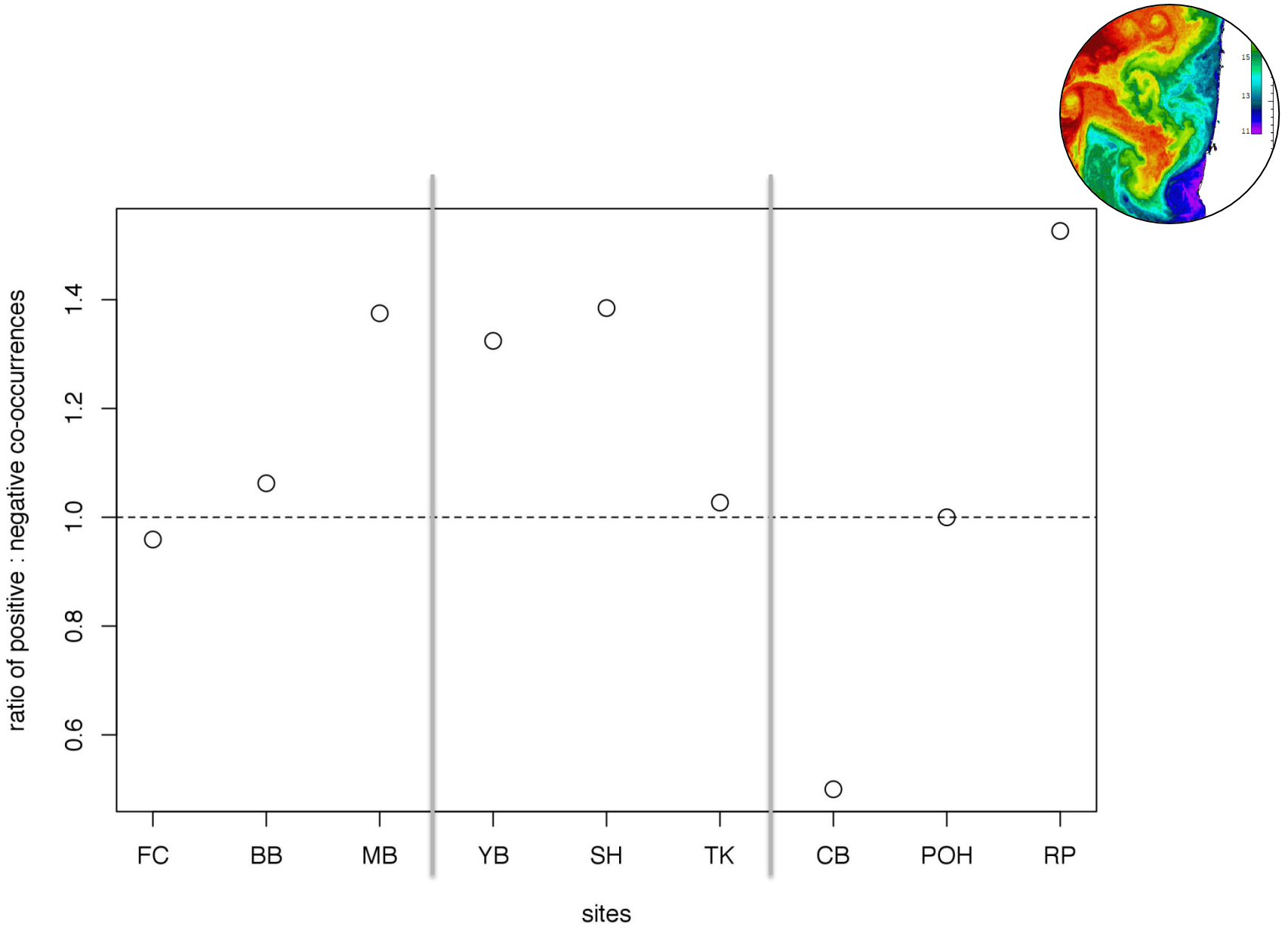
Coralline crust and *Erythrophyllum* (-0.25, -0.027)

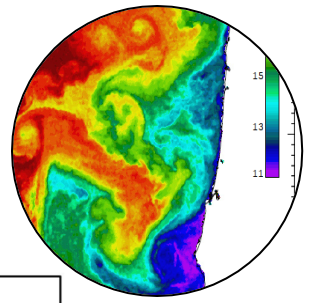
Strong positive co-occurrences

Saccharina recruits with: *Schizymenia, Neodilsea, Odonthalia floccosa*


positive
co-occurrence
negative
co-occurrence
ratio of positive : negative
environmental stress gradient


raw frequency of co-occurrences
environmental stress gradient


ratio of positive : negative co-occurrences
0.6
0.8
1.0
1.2
1.4
FC
BB
MB
YB
SH
TK
CB
POH
RP
sites
15
13
11



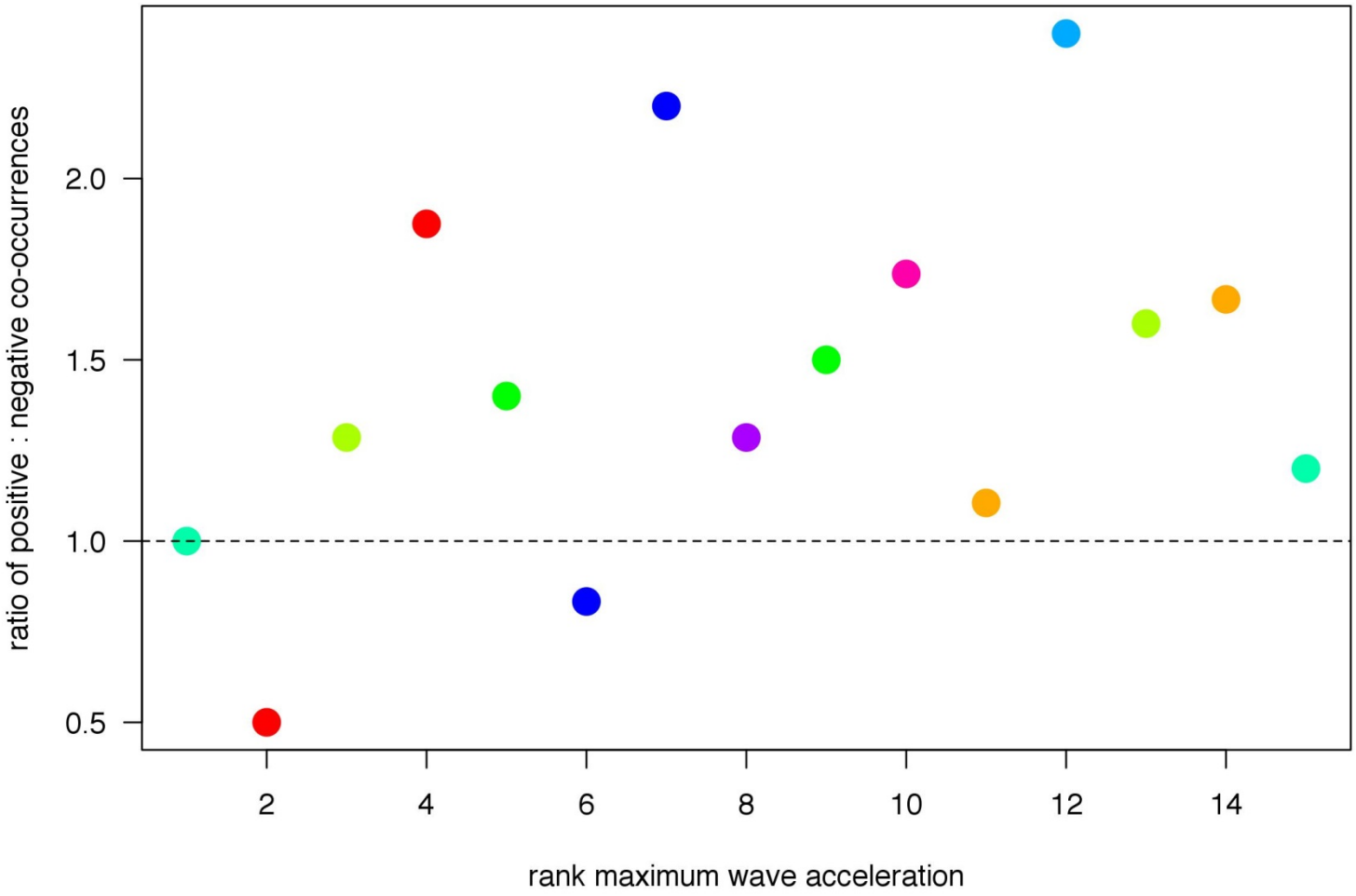
positive
negative

nubmer of residual co-occurrences

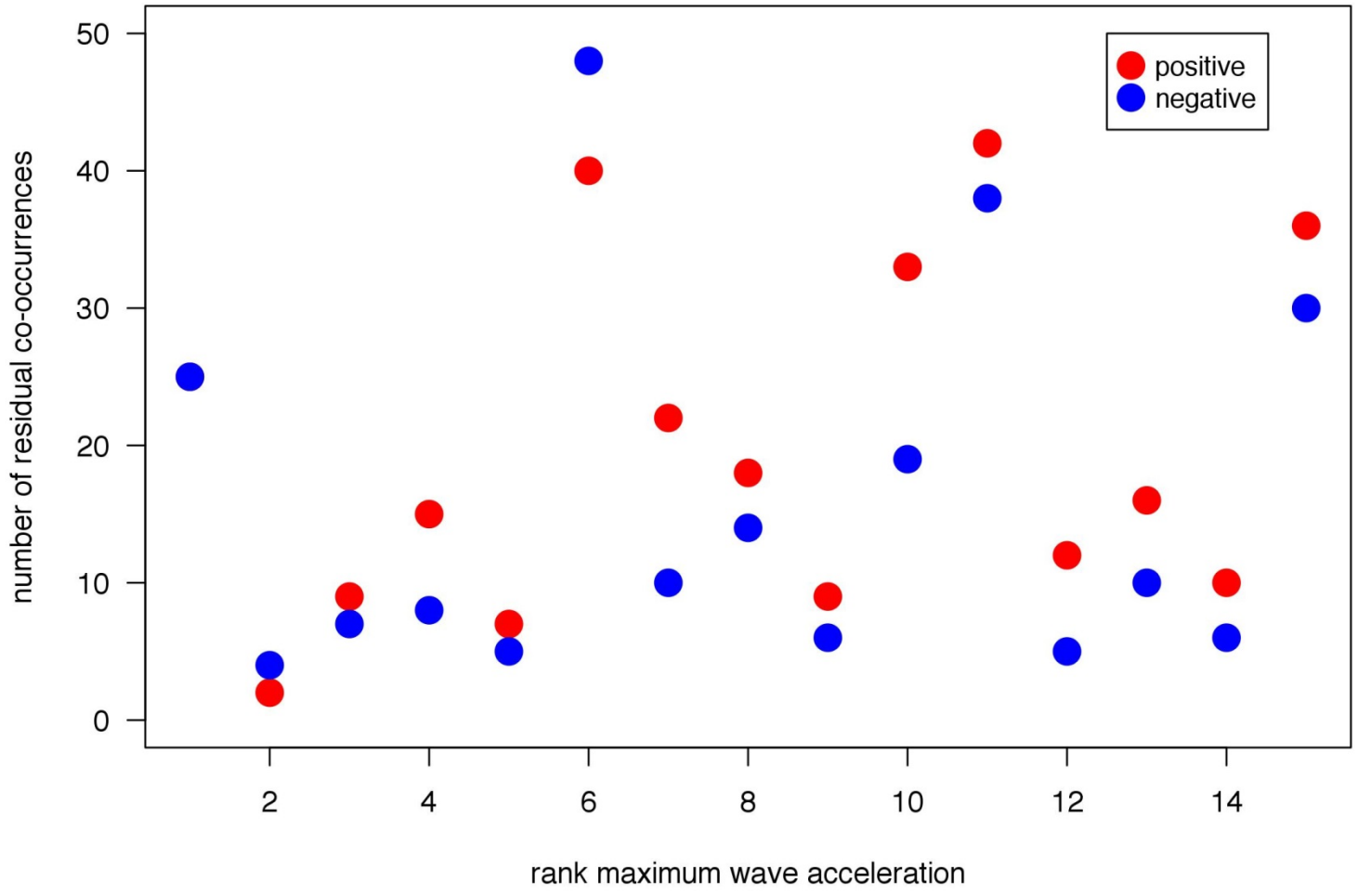
50
40
30
20
10

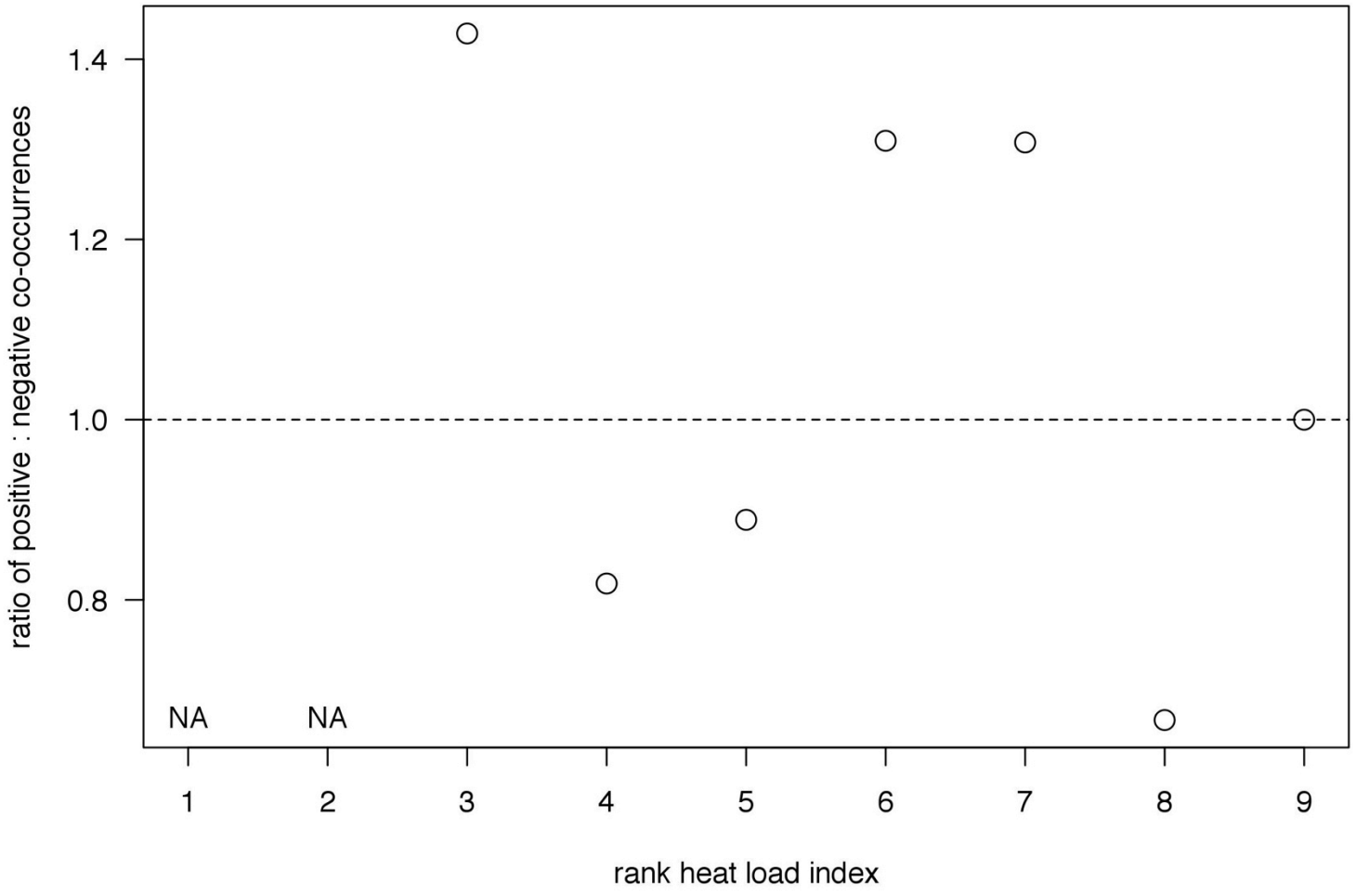
FC BB MB YB SH TK CB POH RP

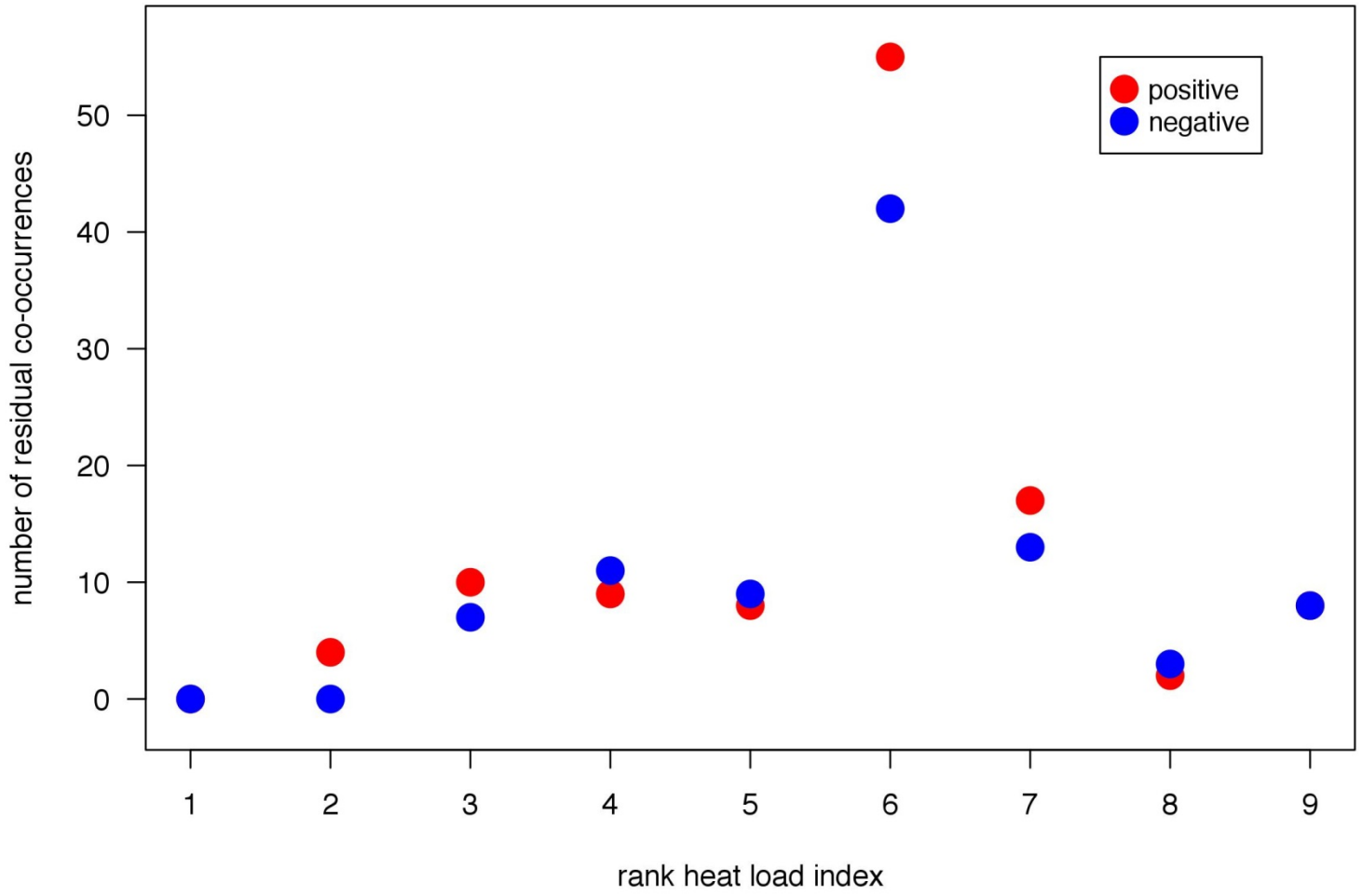
sites

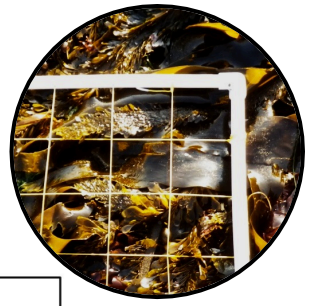


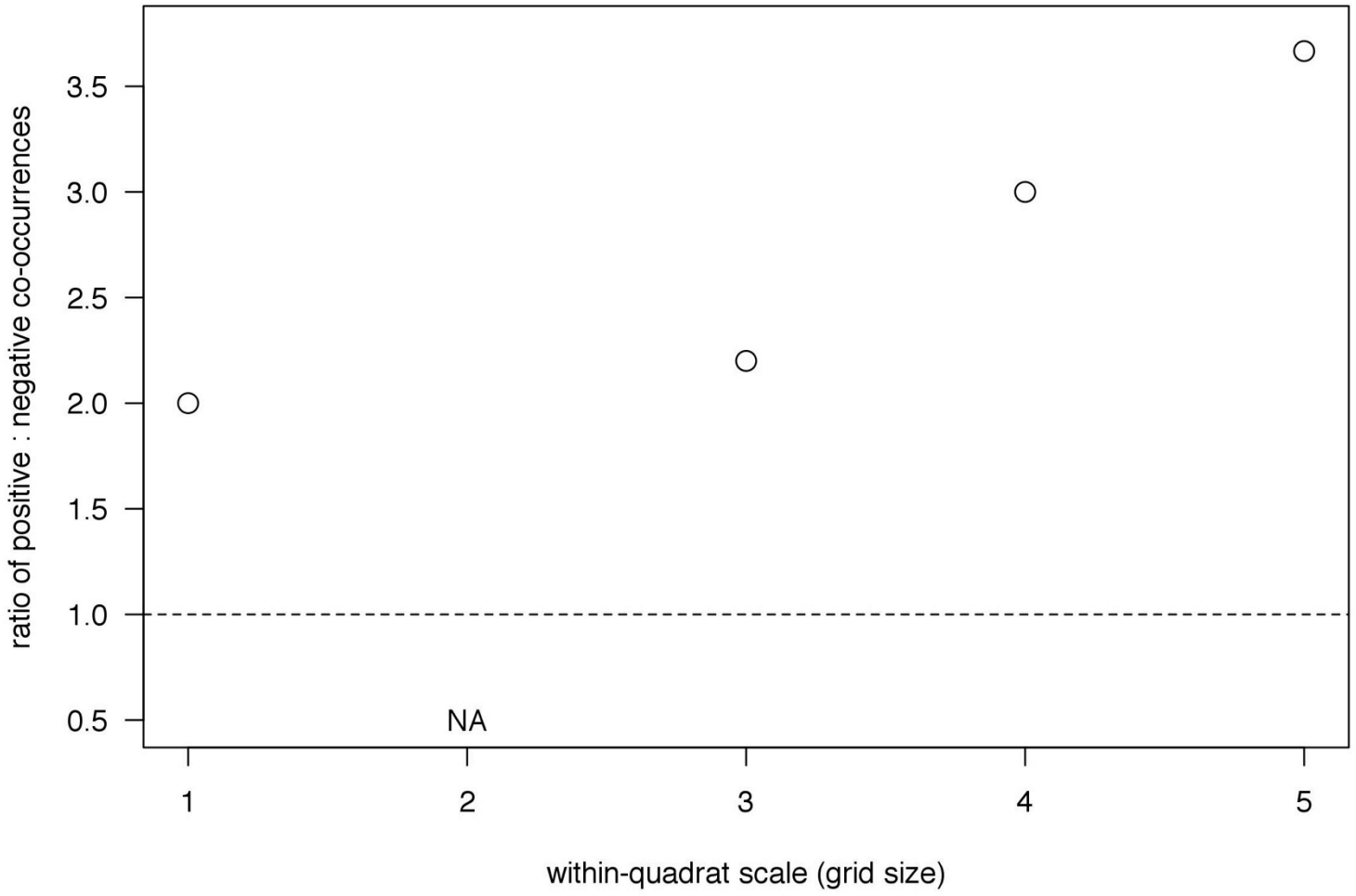
Note: same color = same site

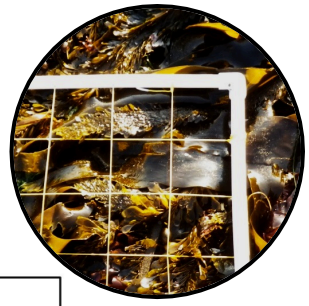

positive
negative
number of residual co-occurrences
rank maximum wave acceleration
0
10
20
30
40
50
2
4
6
8
10
12
14

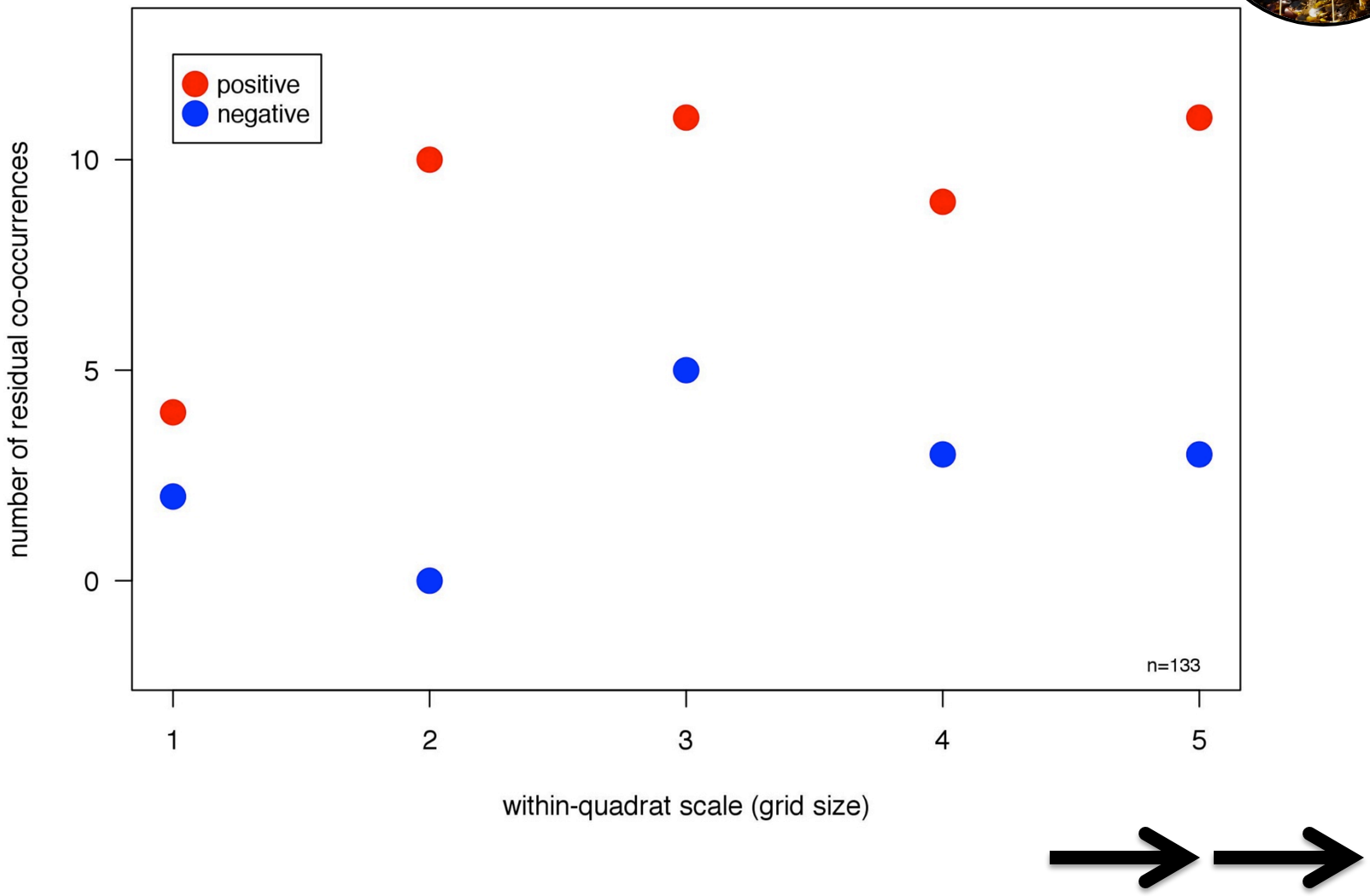

ratio of positive : negative co-occurrences
1.4
1.2
1.0
0.8
NA
NA
1
2
3
4
5
6
7
8
9
rank heat load index


positive
negative
number of residual co-occurrences
0
10
20
30
40
50
1
2
3
4
5
6
7
8
9
rank heat load index



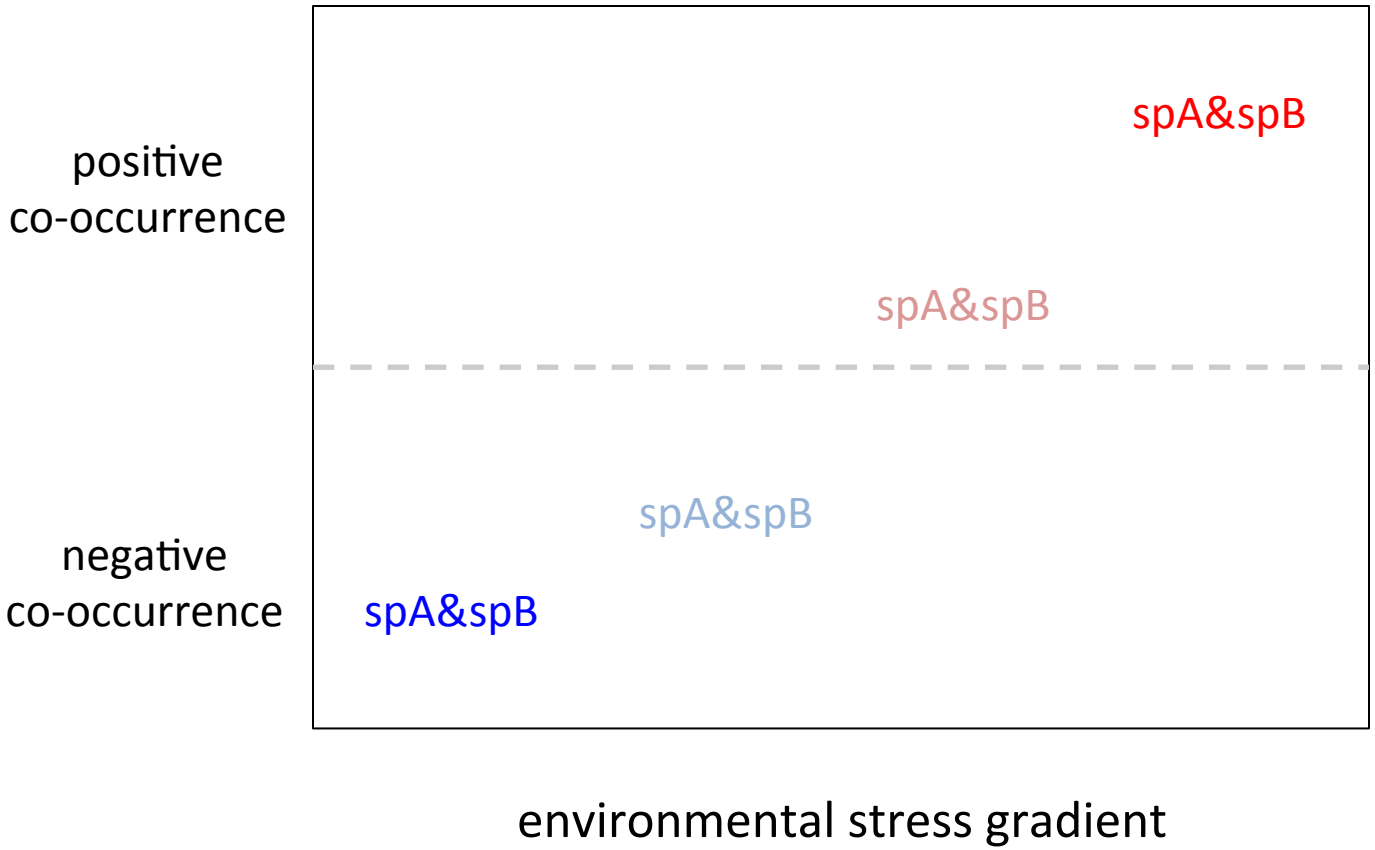

ratio of positive : negative co-occurrences
3.5
3.0
2.5
2.0
1.5
1.0
0.5
NA
1
2
3
4
5
within-quadrat scale (grid size)




positive
negative
number of residual co-occurrences
10
5
0
n=133
1
2
3
4
5
within-quadrat scale (grid size)

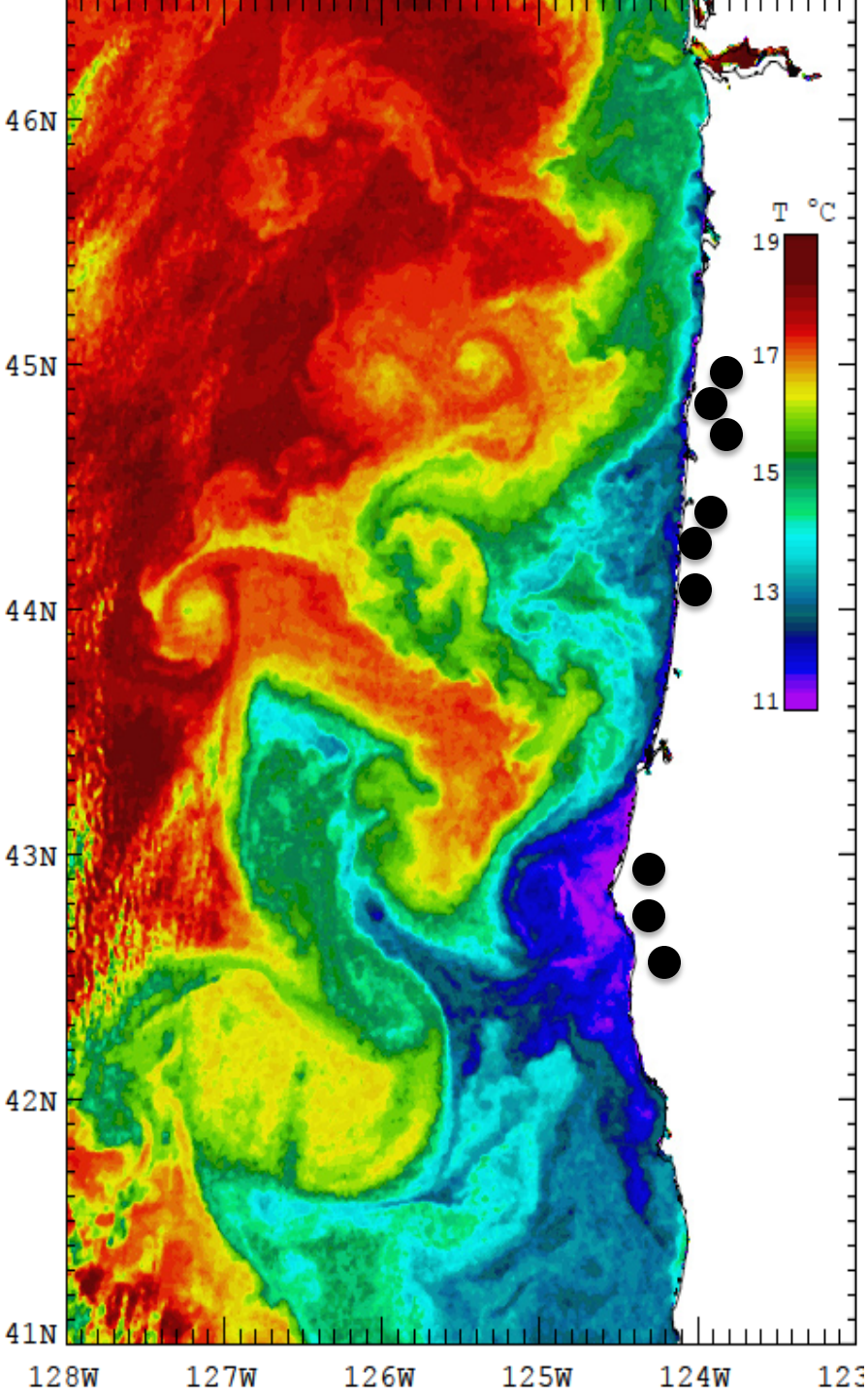
Work-in-progress

Days away: patterns of pairwise co-occurrences across gradients



See you at ESA? Wednesday, 9:50am, Ballroom A

Need to account for spatial structure in the model




Incorporating mobile species (consumer-resource dynamics)


@algaebarnacle