Thermal tolerance and the global redistribution of animals

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The world is going to change

But what are the details?

What will change, when?

Species will probably move towards the poles

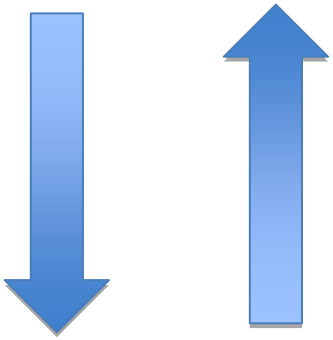
But, why were they there in the first place?

Understanding the factors that determine species distributions has been a central goal of ecology for many years

Darwin, 1859

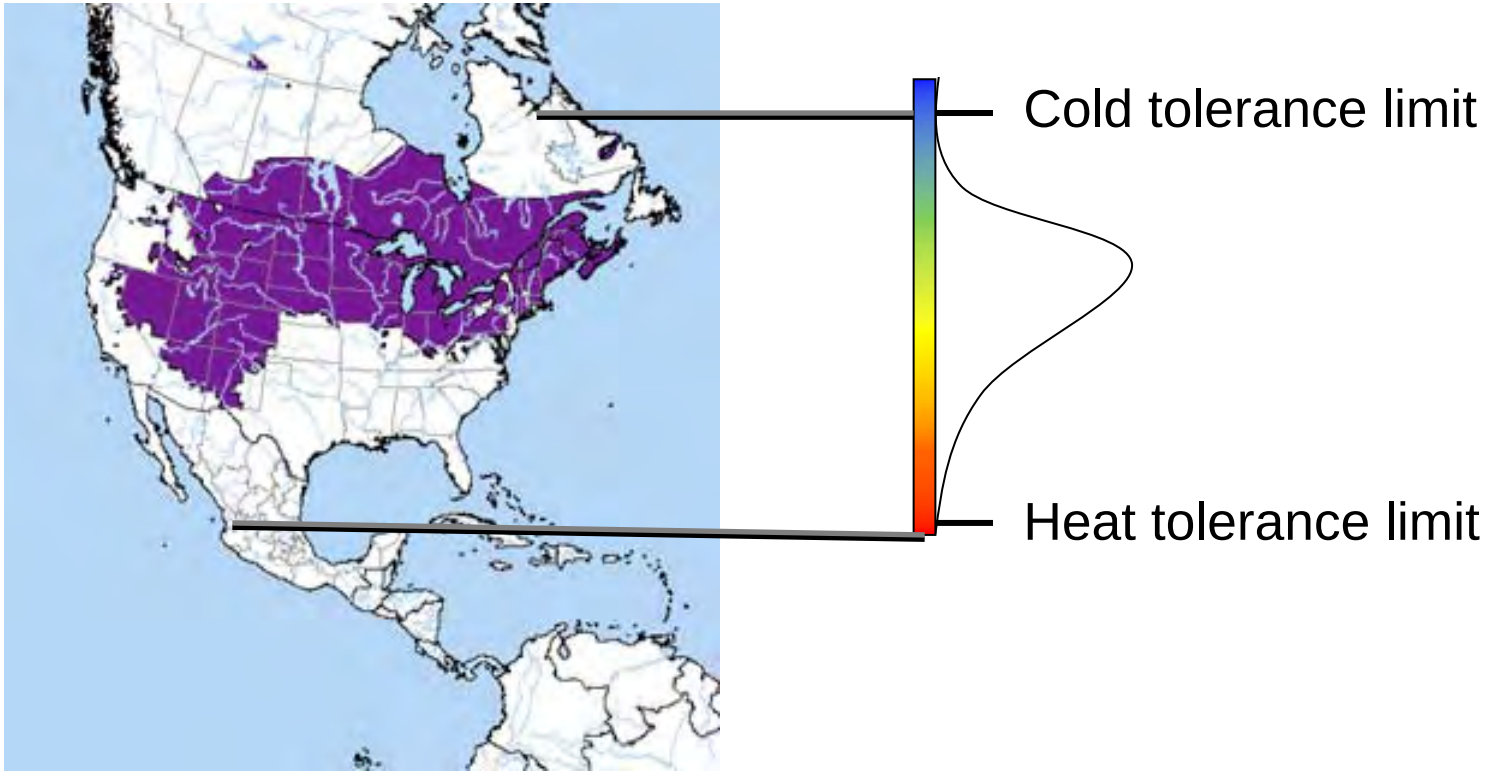
Andrewartha and Birch, 1957

MacArthur, 1970



Responses to climate change

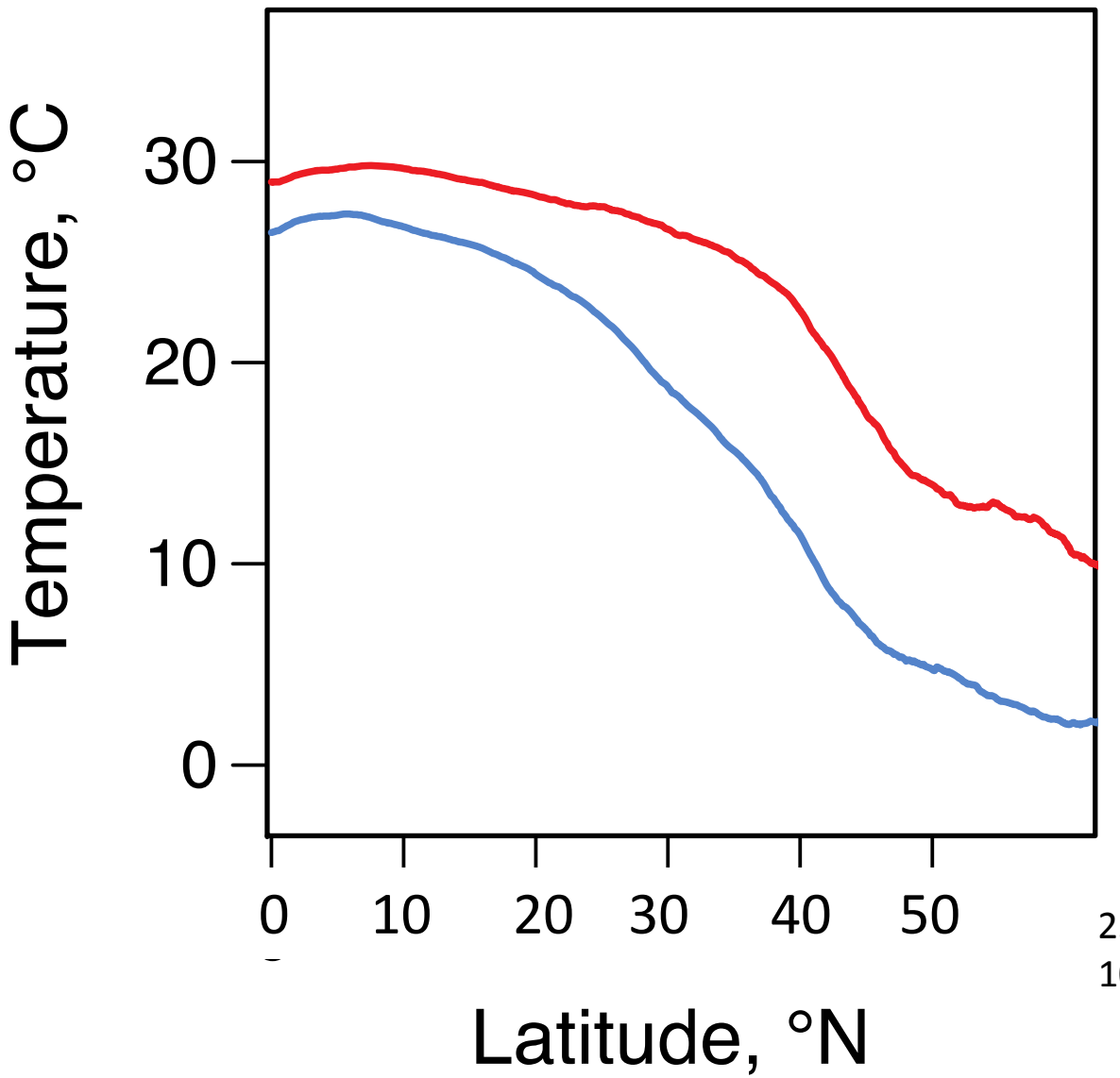
How does thermal tolerance relate to latitudinal range distributions?

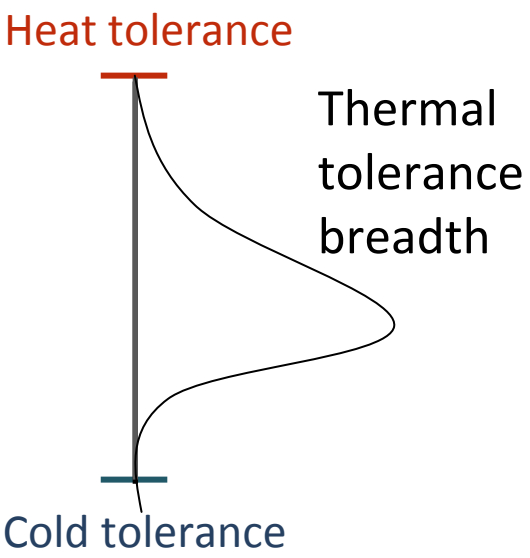


species

global

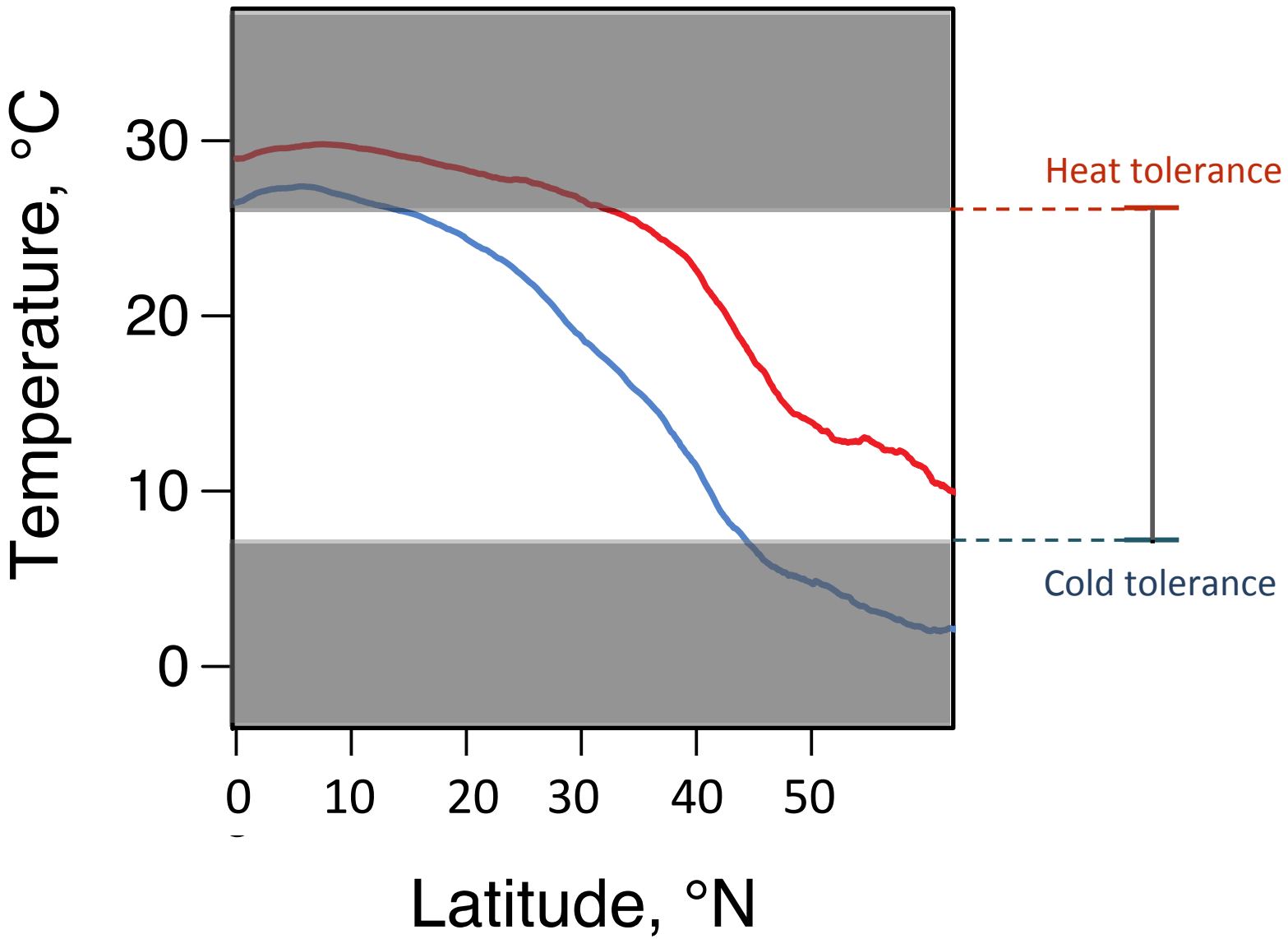
Macroecology

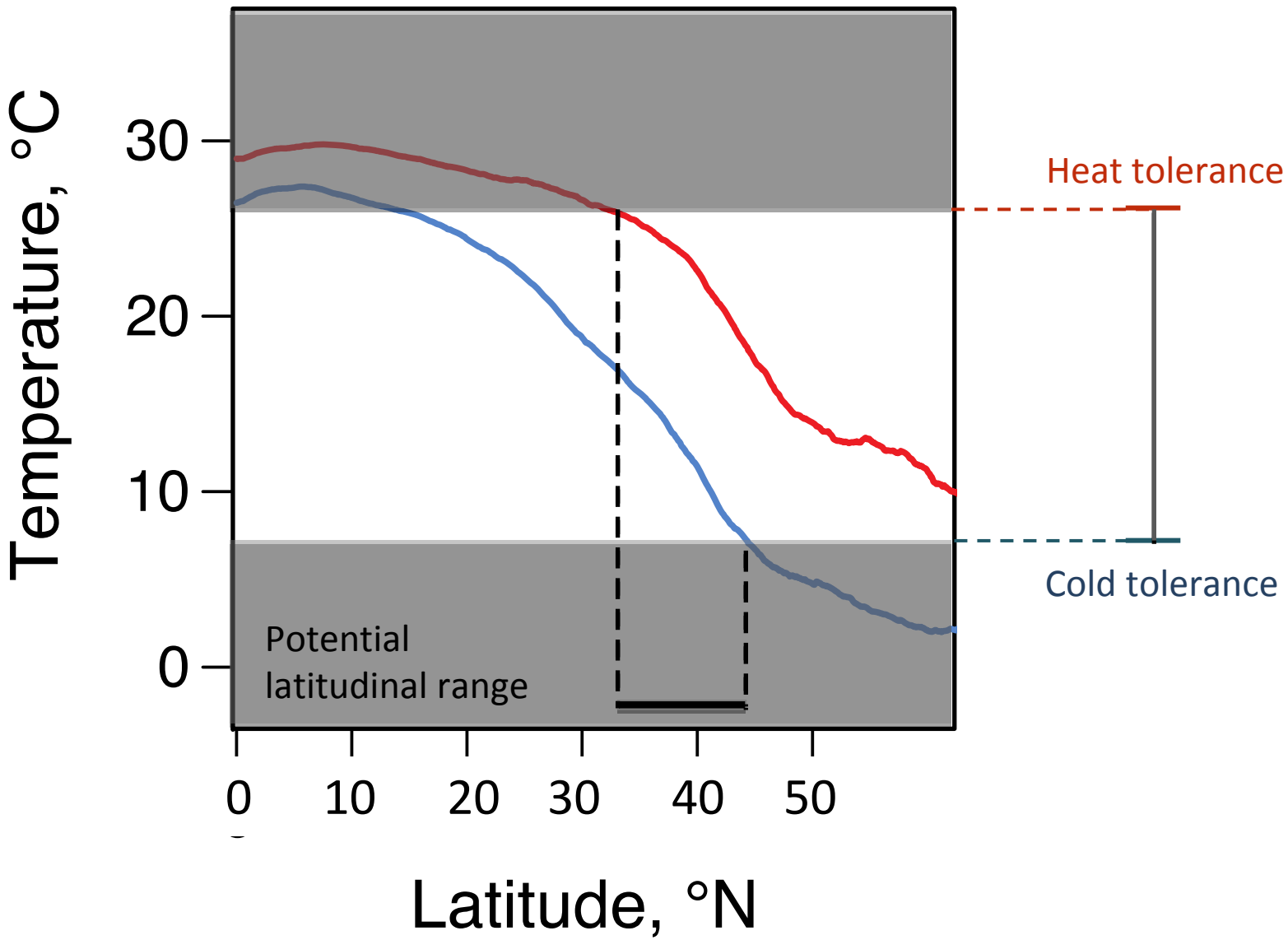


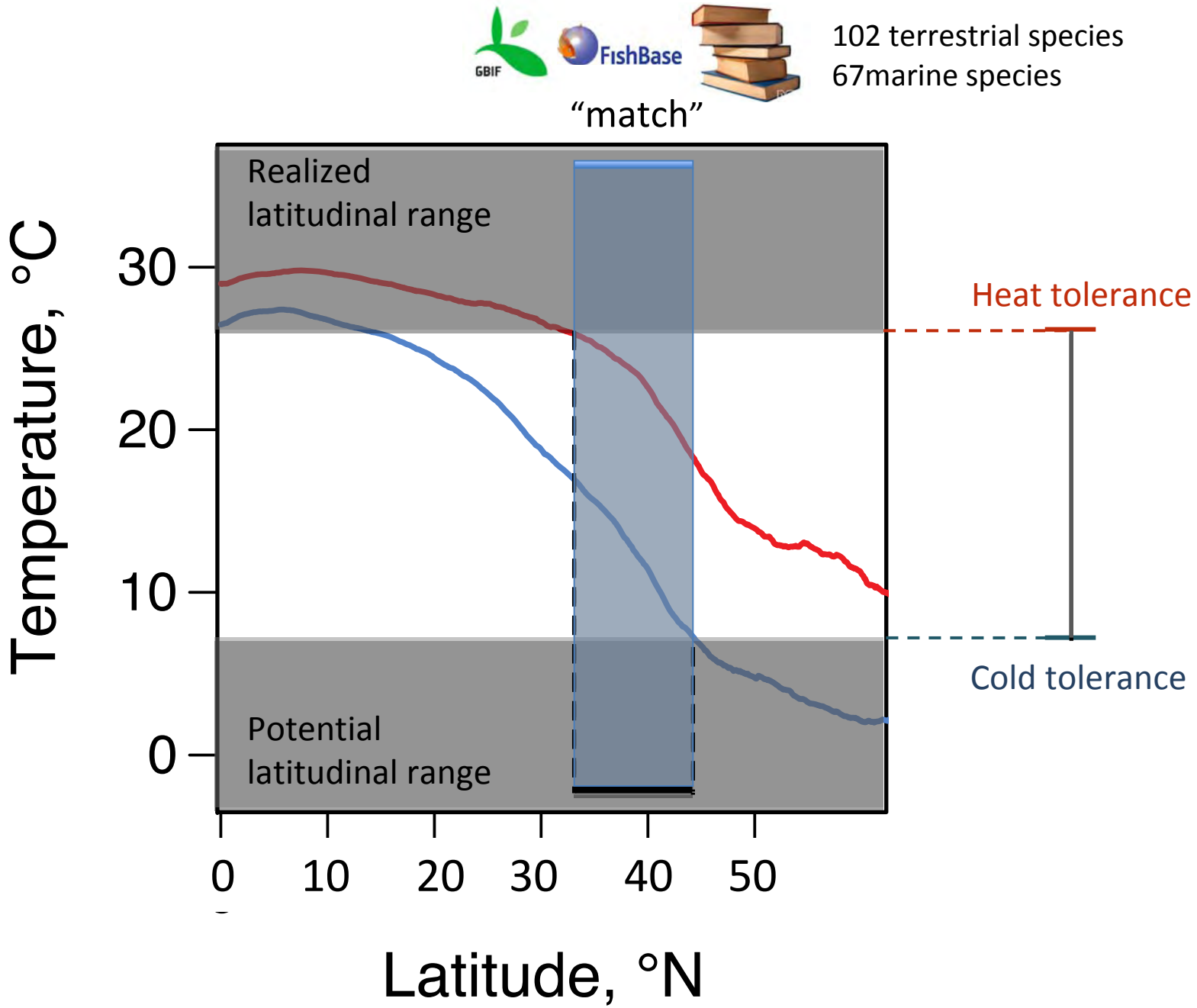


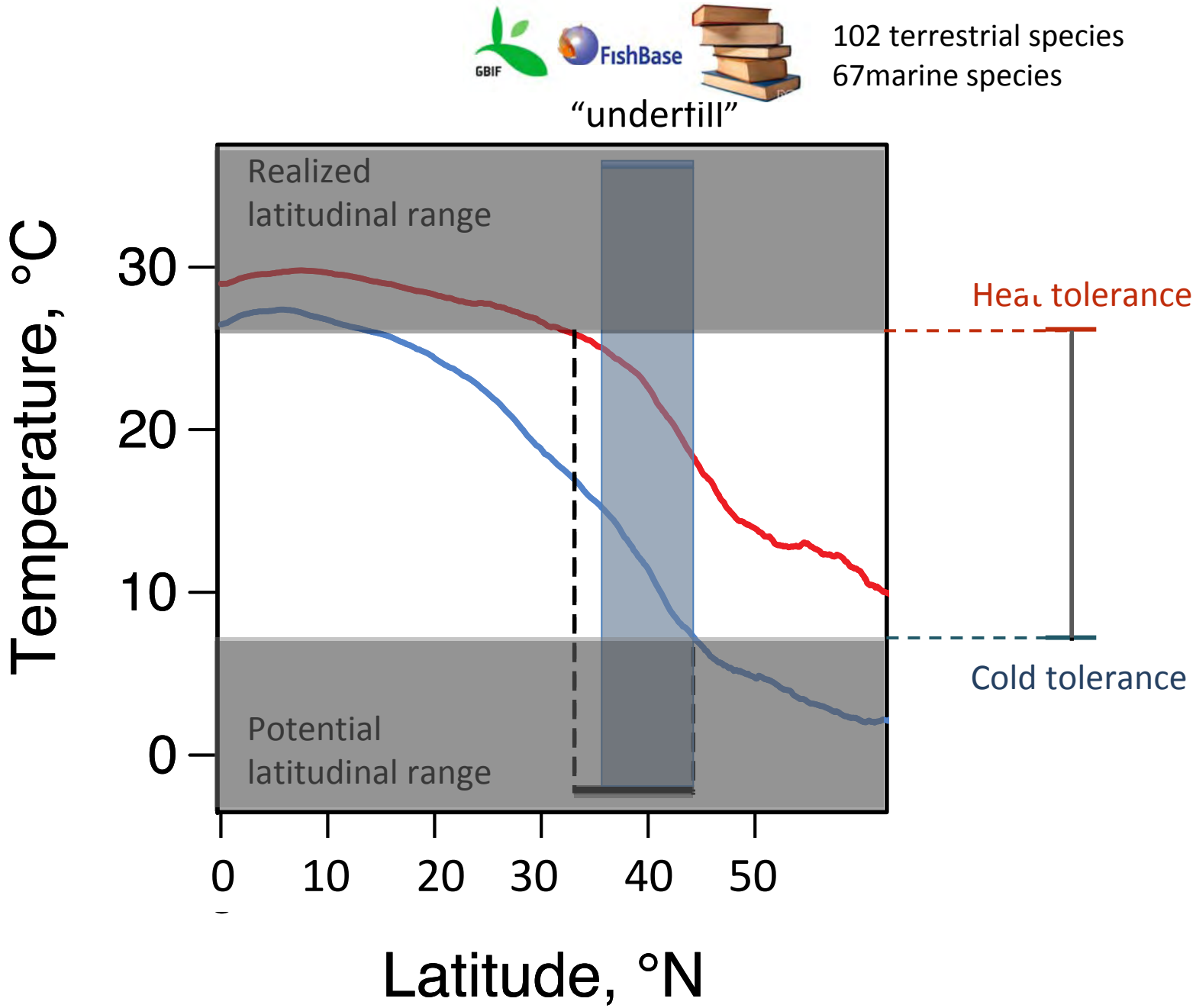
239 terrestrial species
102 marine species

Sunday, *et. al*, 2011. Proc. Roy. Soc. B.


Temperature, °C
30
20
10
0
0
10
20
30
40
50
Latitude, °N
Heat tolerance
Cold tolerance


Temperature, °C
30
20
10
0
Heat tolerance
Cold tolerance
Potential
latitudinal range
0
10
20
30
40
50
Latitude, °N


GBIF
FishBase
102 terrestrial species
67marine species
"match"
Realized
latitudinal range
Potential
latitudinal range
Heat tolerance
Cold tolerance
Temperature, °C
30
20
10
0
0
10
20
30
40
50
Latitude, °N


GBIF
FishBase
102 terrestrial species
67marine species
"undertill"
Realized
latitudinal range
Potential
latitudinal range
Heat tolerance
Cold tolerance
Temperature, °C
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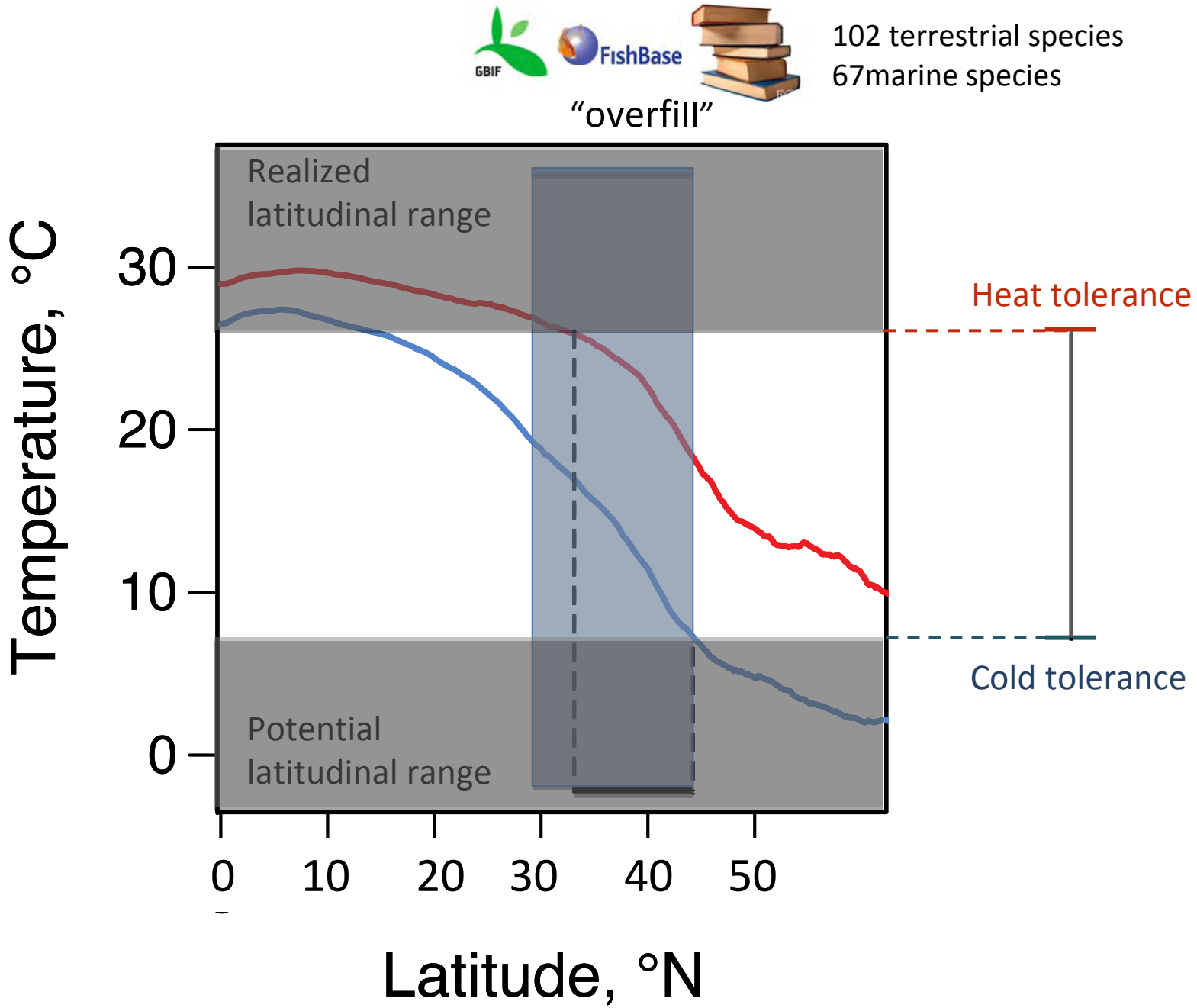
Latitude, °N


GBIF
FishBase
102 terrestrial species
67marine species
"overfill"
Realized
latitudinal range
Potential
latitudinal range
Heat tolerance
Cold tolerance
Temperature, °C
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10
0
0
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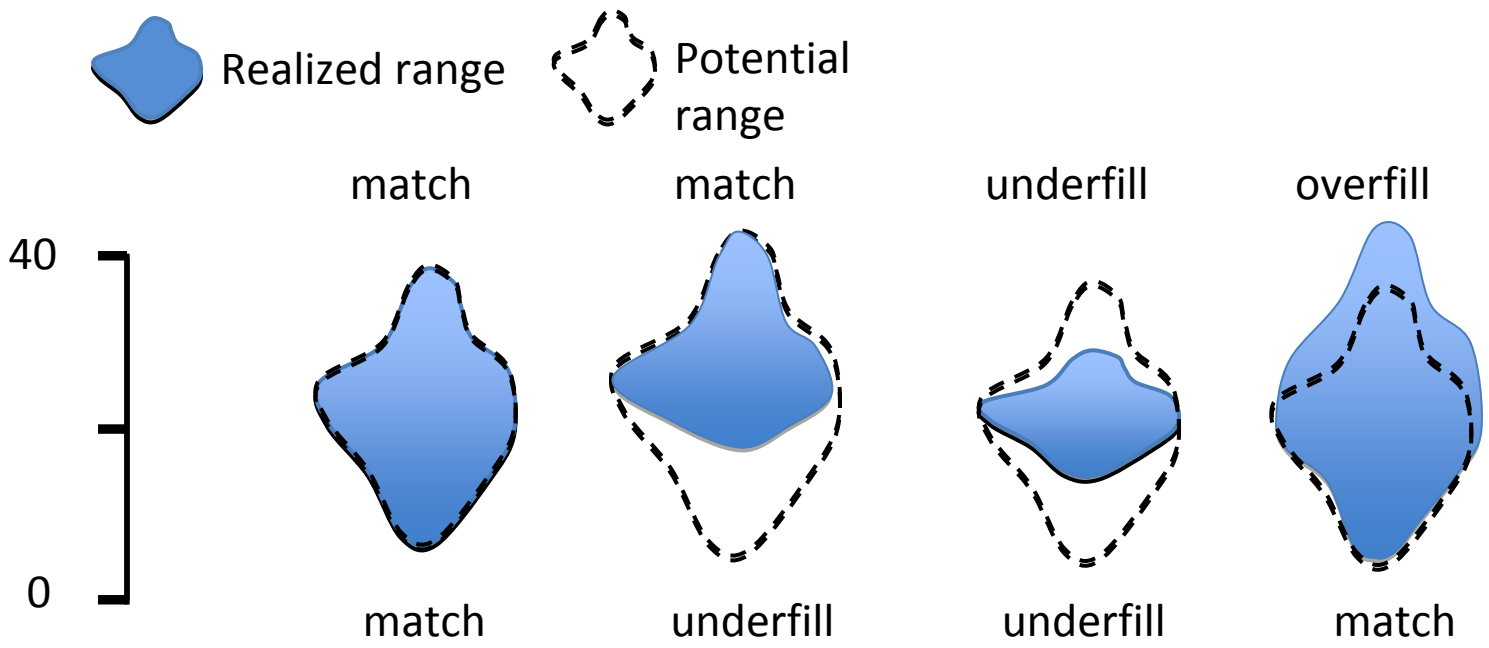
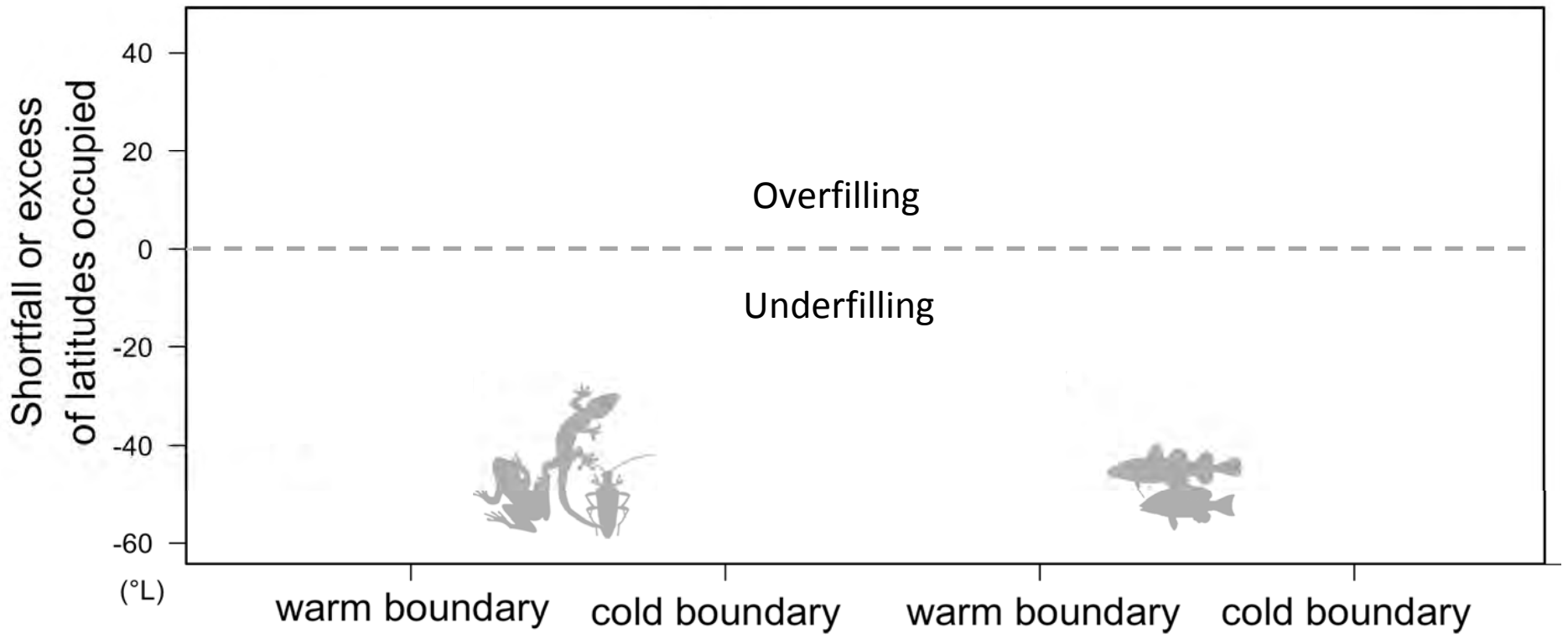
20
30
40
50
Latitude, °N

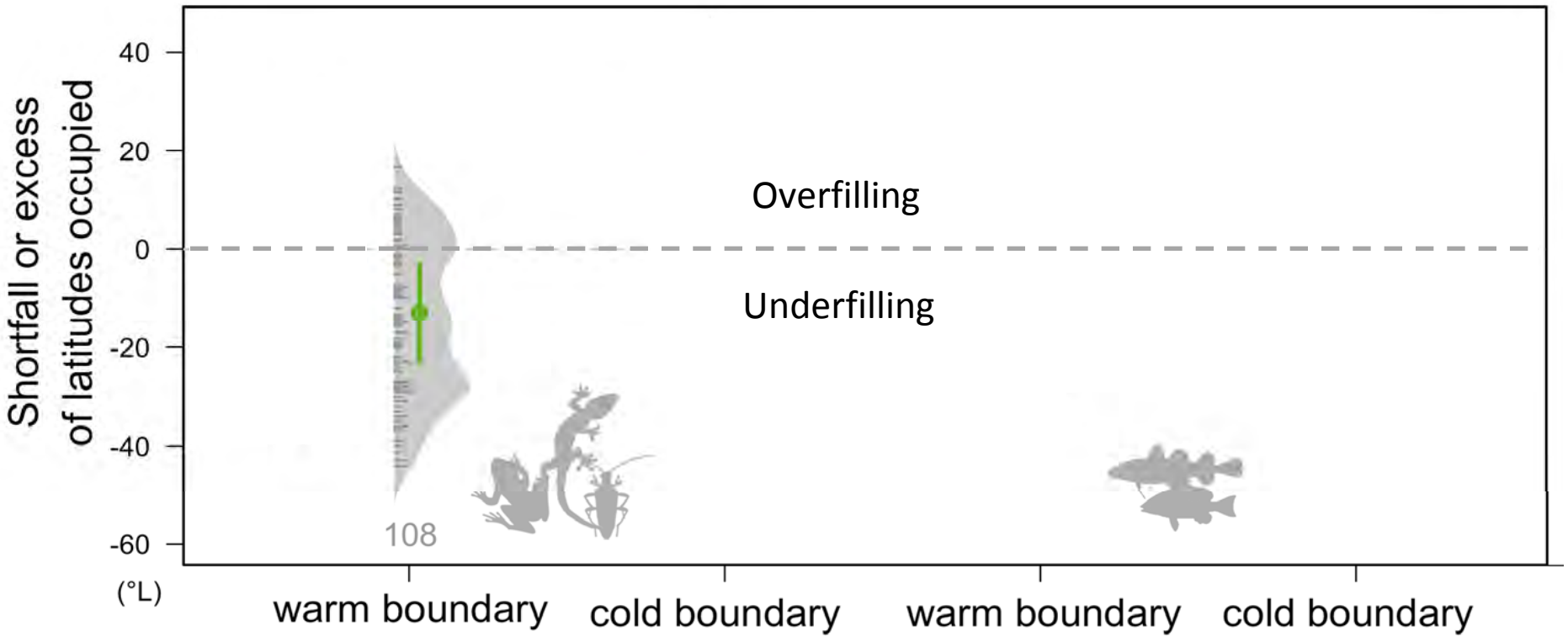

Realized range
Potential range
match
match
underfill
overfill
40
0
match
underfill
underfill
match

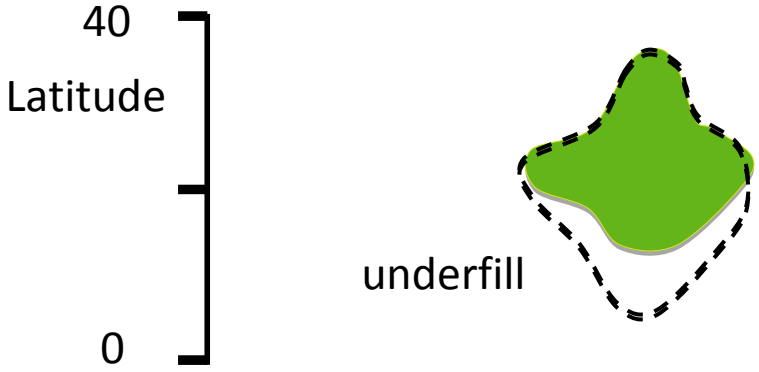
Overfilling and underfilling of latitudinal ranges



Sunday, Bates, Dulvy. *In press*. Nature Climate Change

Overfilling and underfilling of latitudinal ranges





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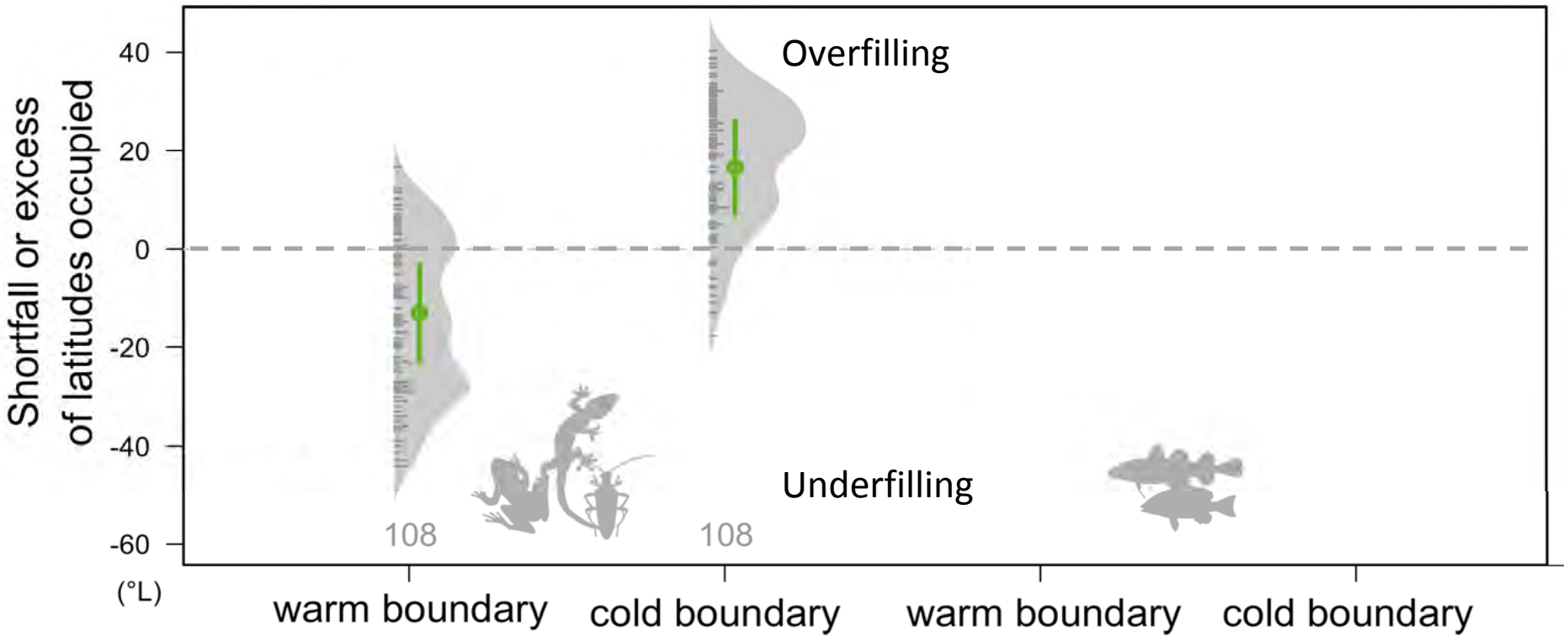
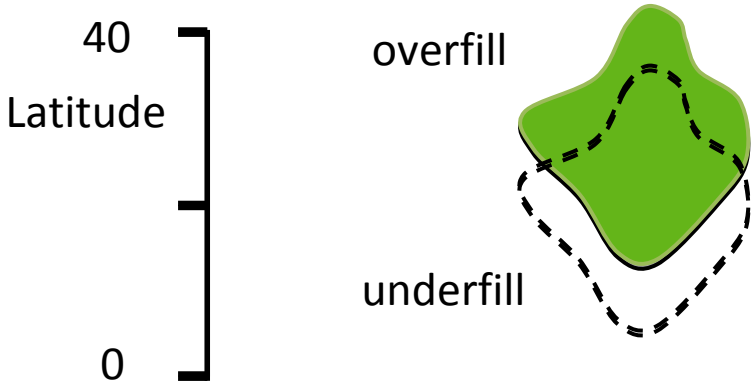
Overfilling and underfilling of latitudinal ranges





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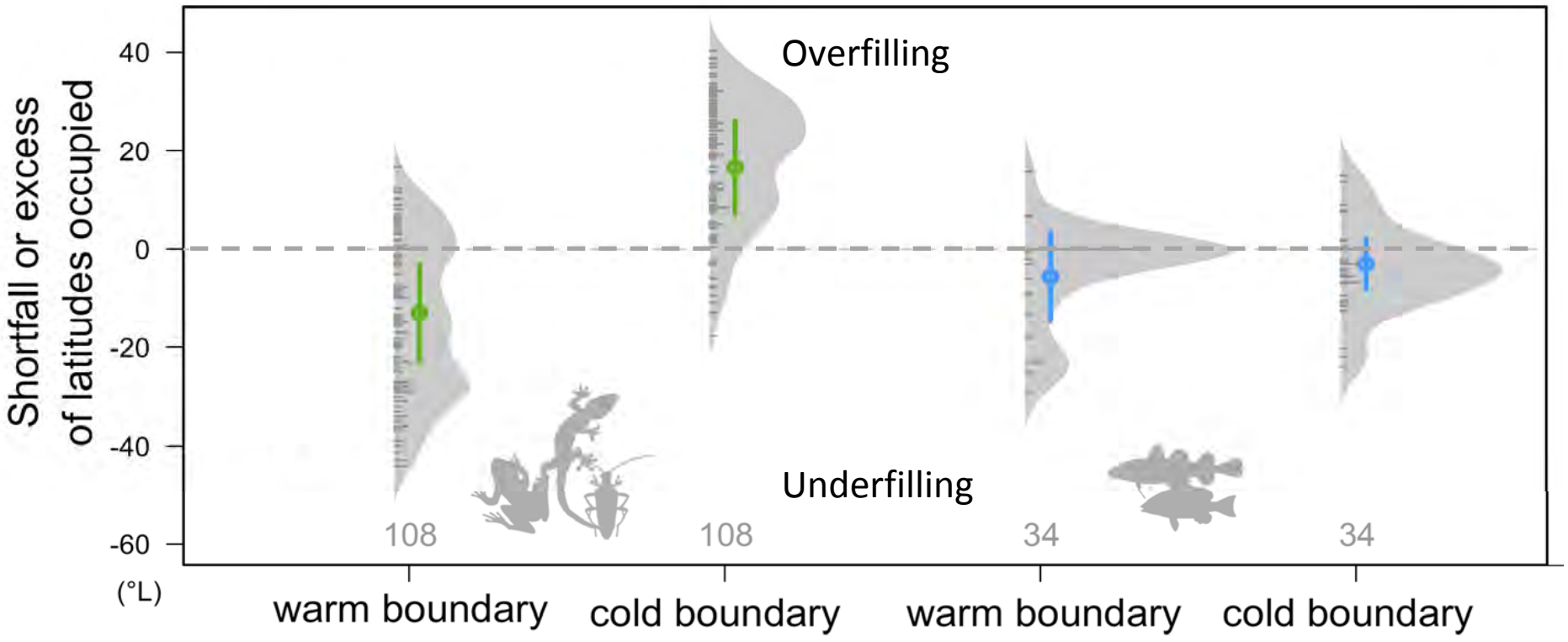
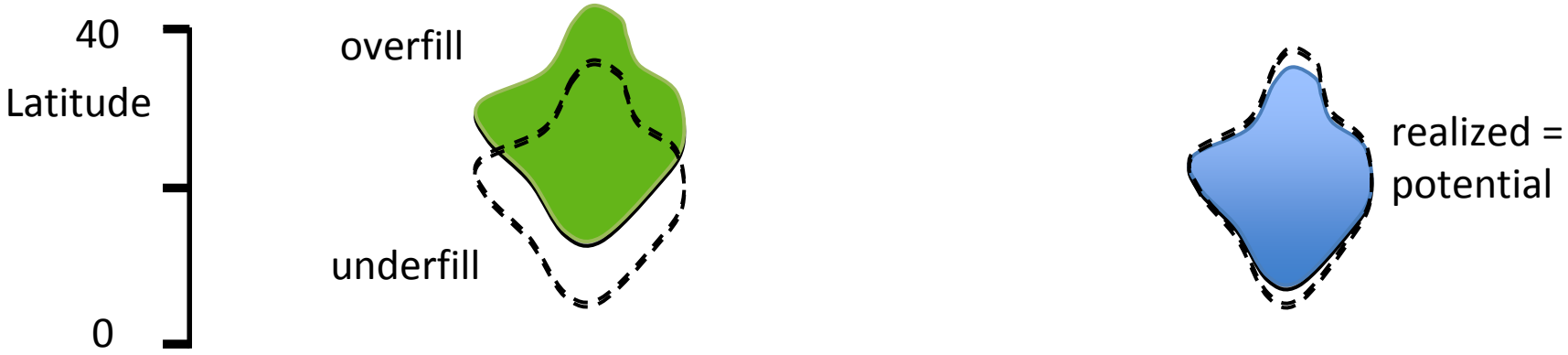
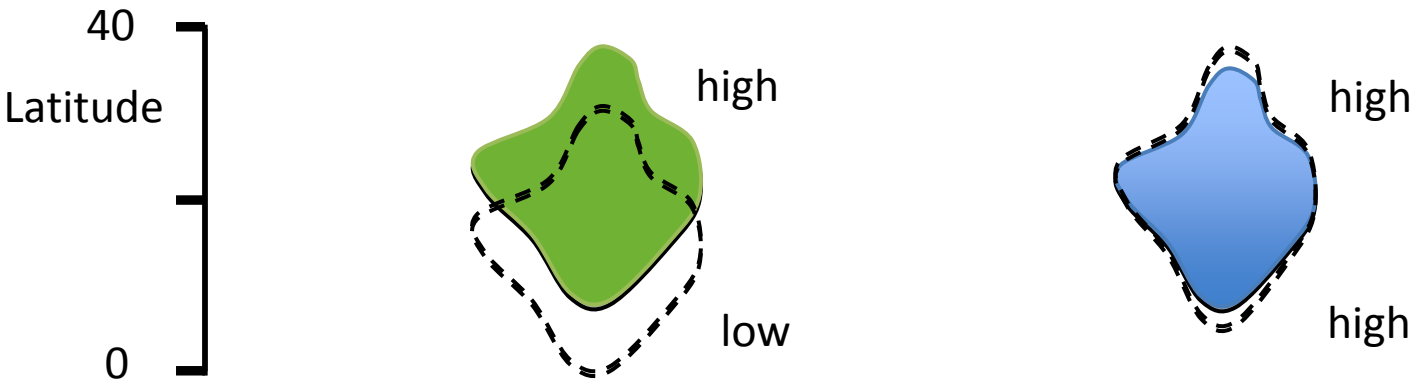
Overfilling and underfilling of latitudinal ranges





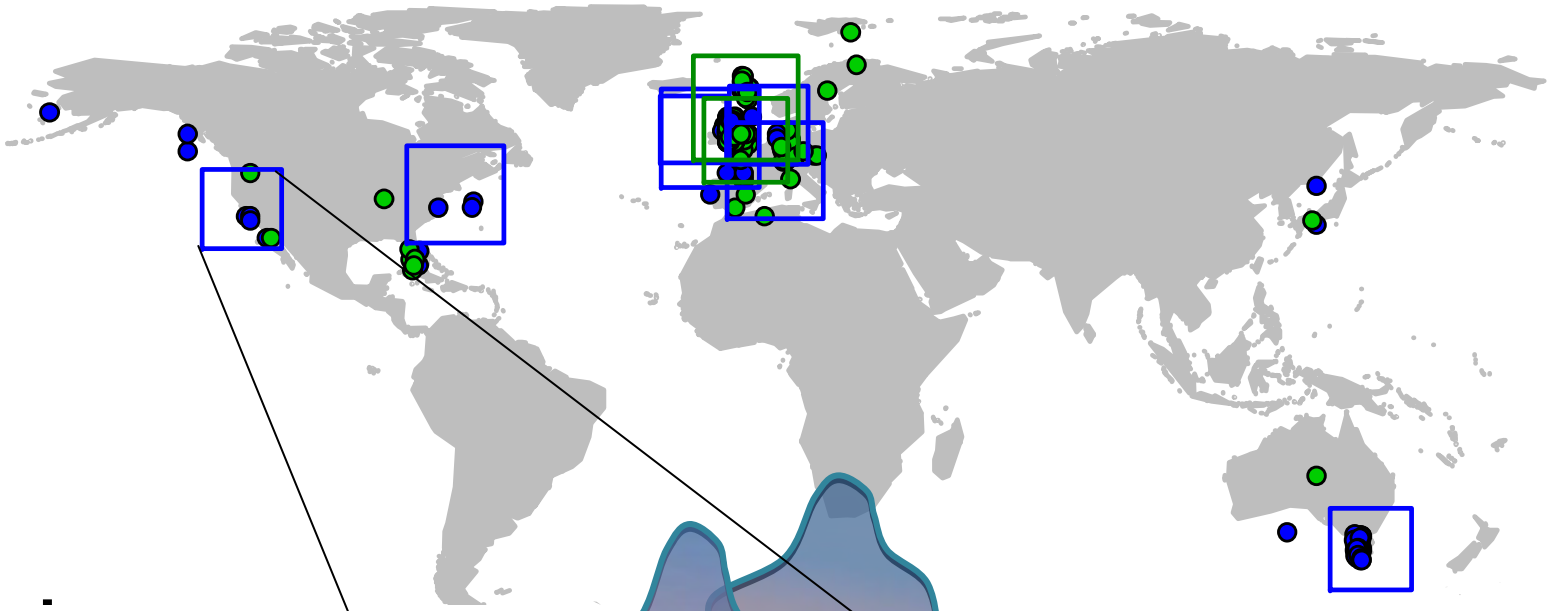
Sunday, Bates, Dulvy. *In press*. Nature Climate Change

Do terrestrial and marine species have different sensitivities to climate warming?



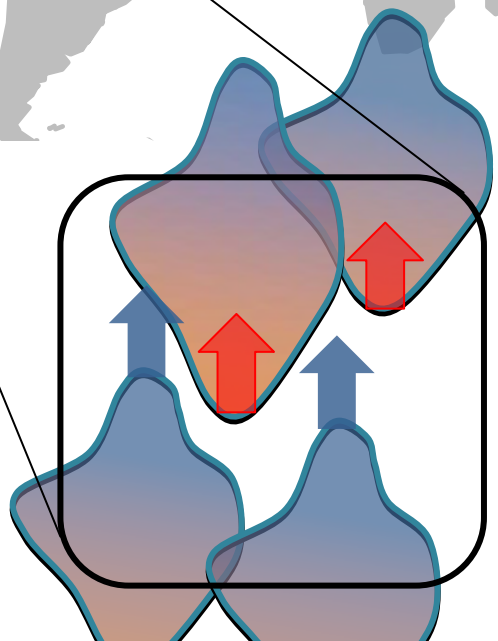
… to the lab

Reports of climate-related range shifts in ectotherms



assemblage studies

single range limits



Poleward limits

vs.

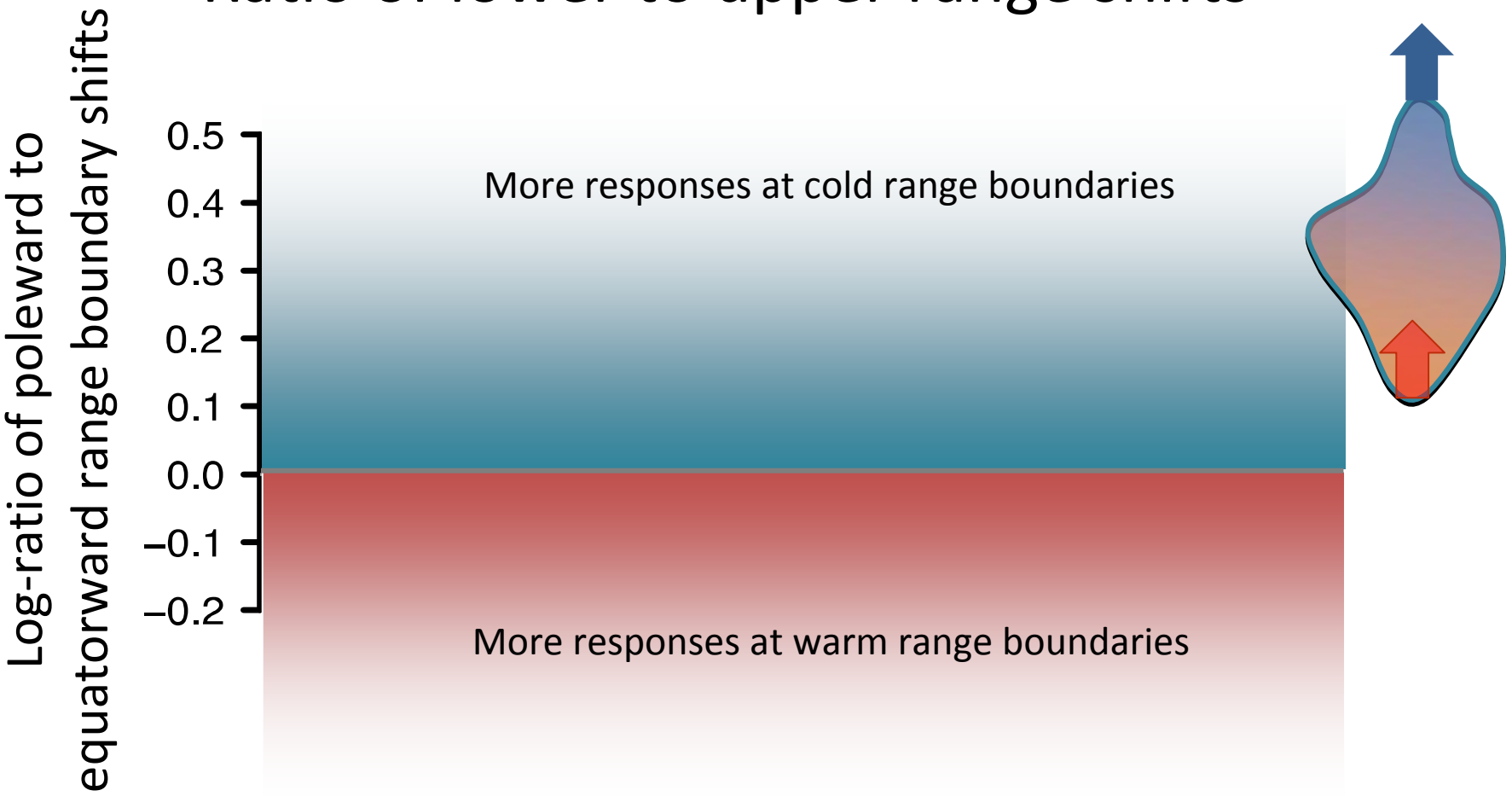
Equatorward limits

a priori expectation 1:1

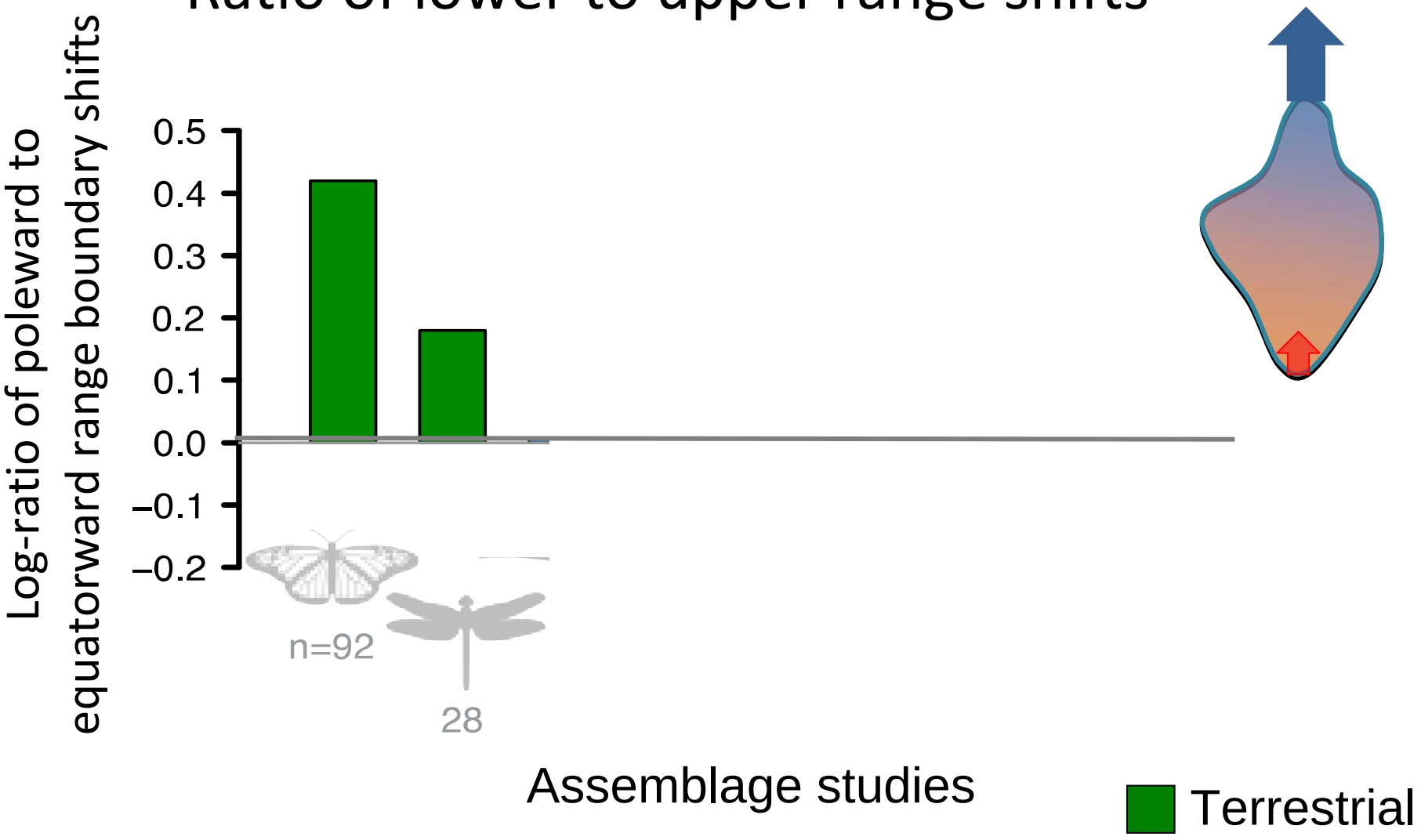
Ratio of lower to upper range shifts

Ratio of lower to upper range shifts

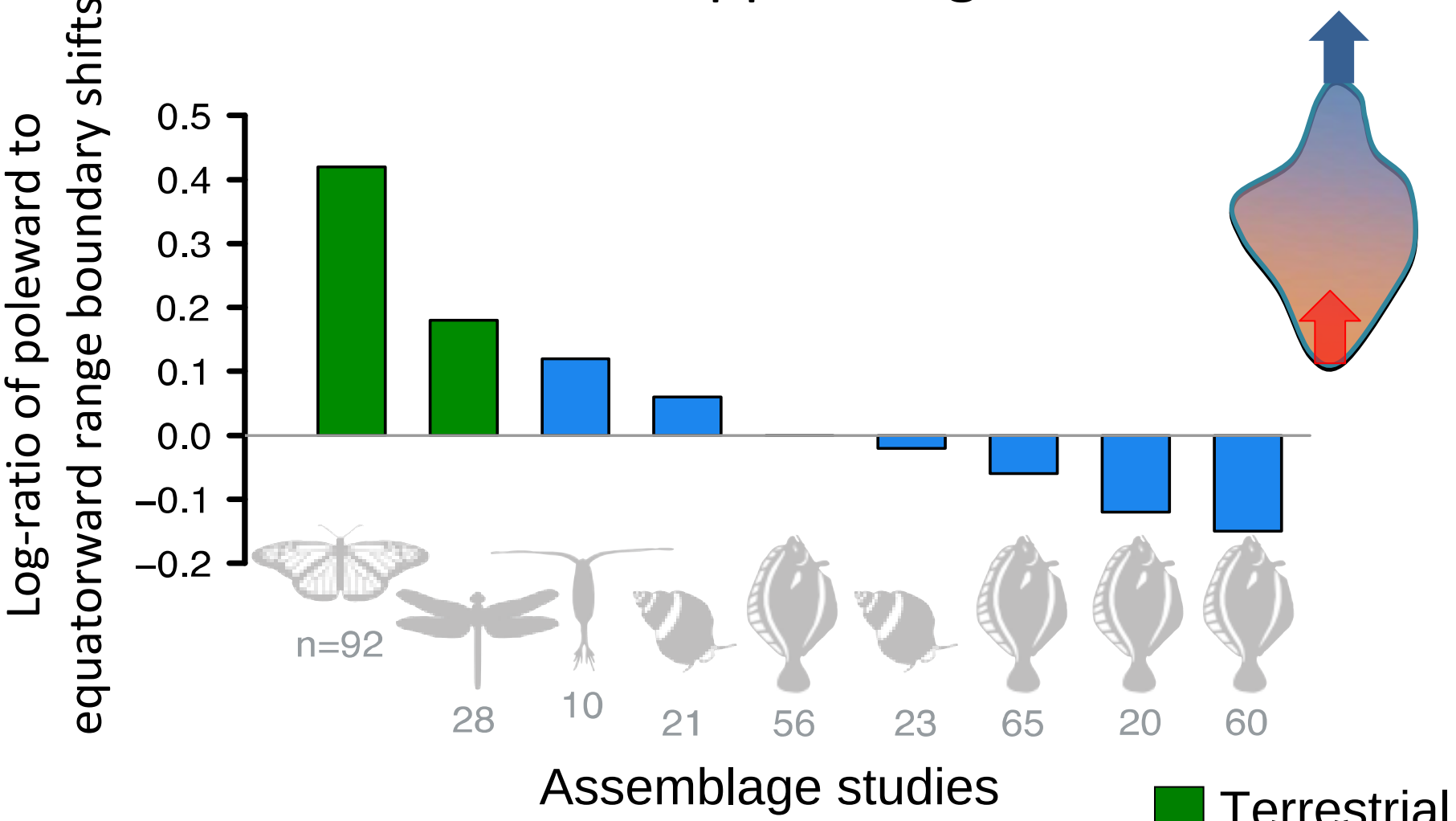
Ratio of lower to upper range shifts



Ratio of lower to upper range shifts

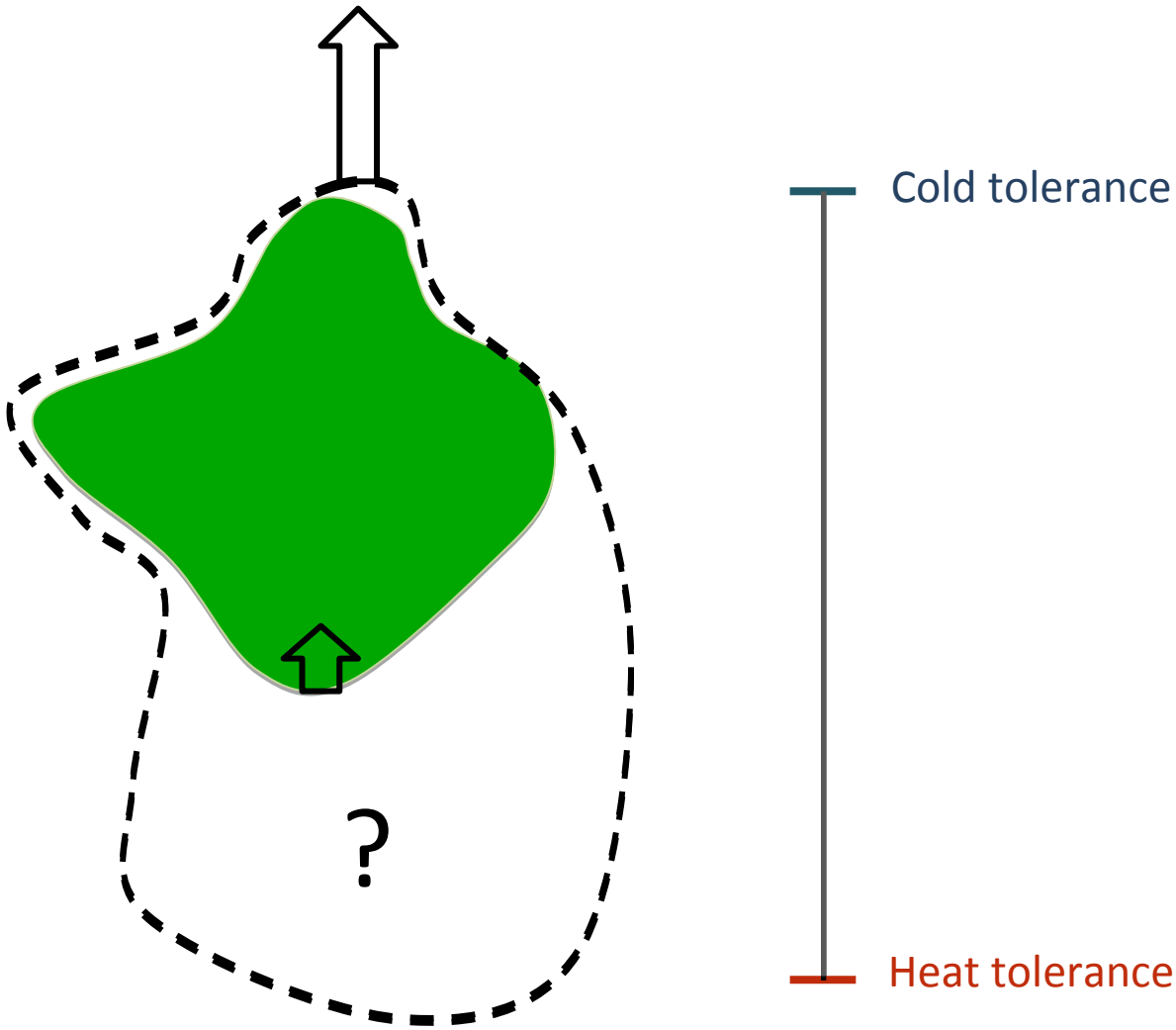


Ratio of lower to upper range shifts

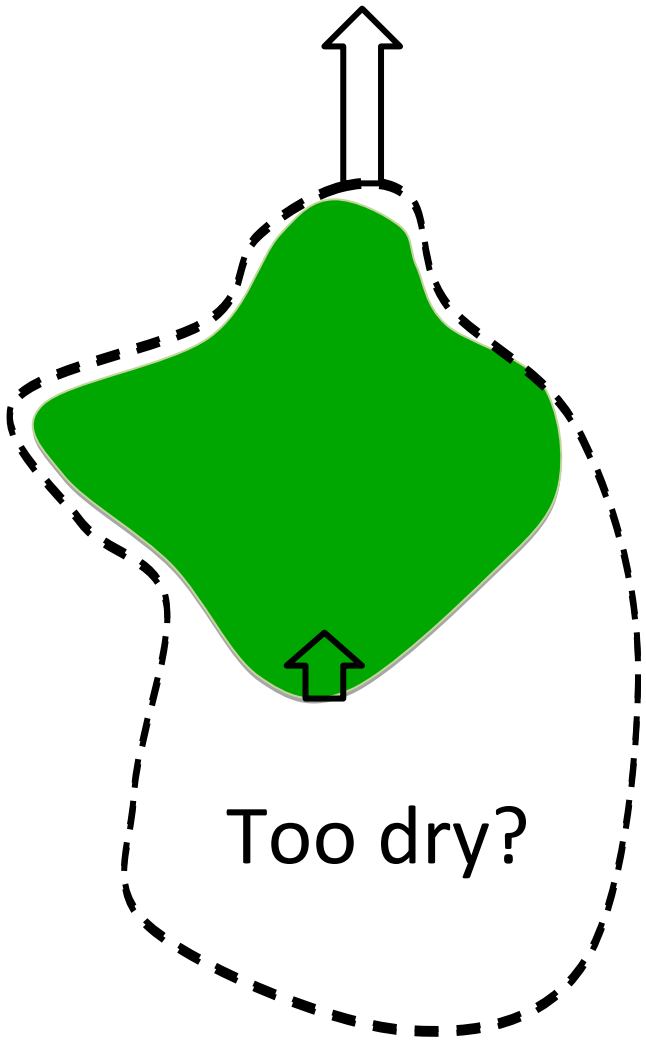


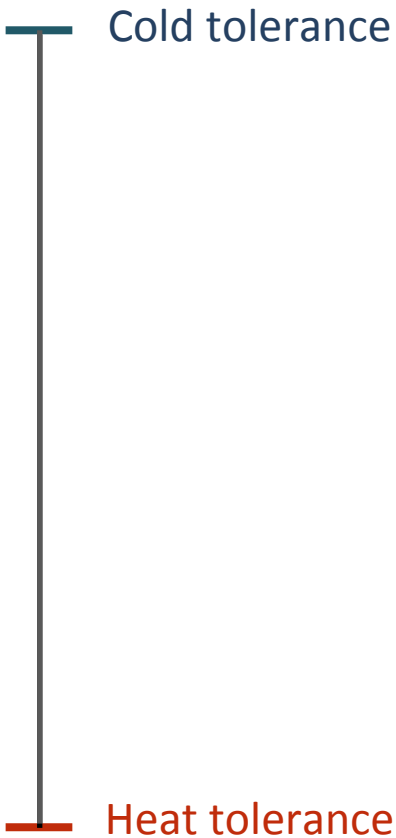
Also found in birds, and in elevational patterns of herpetiles

Terrestrial species are not responding as much at their warm range boundaries



Mechanisms





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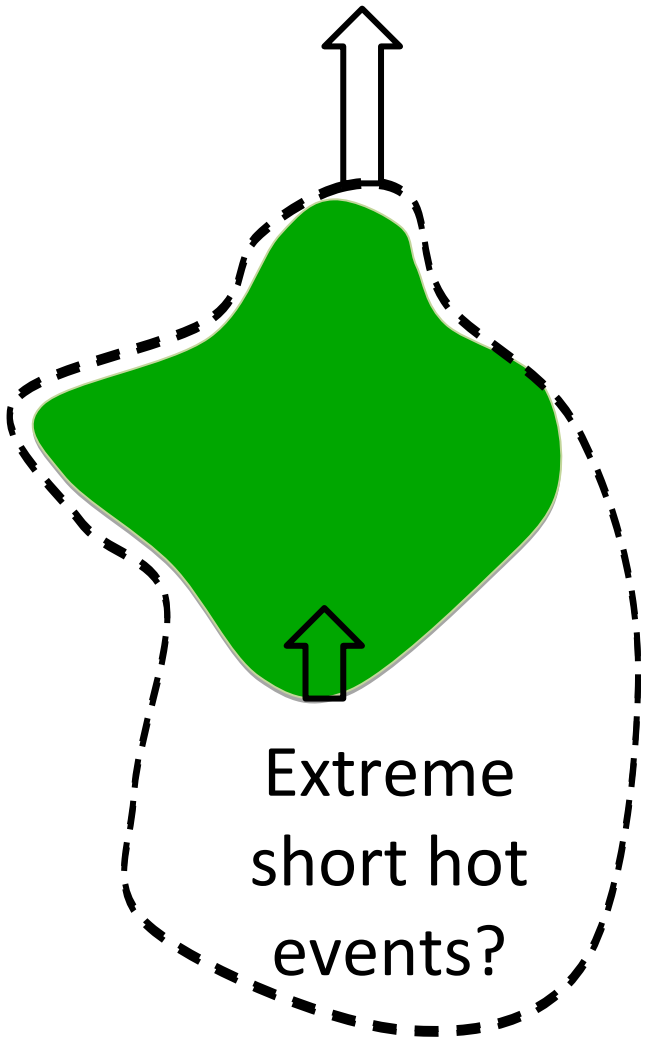

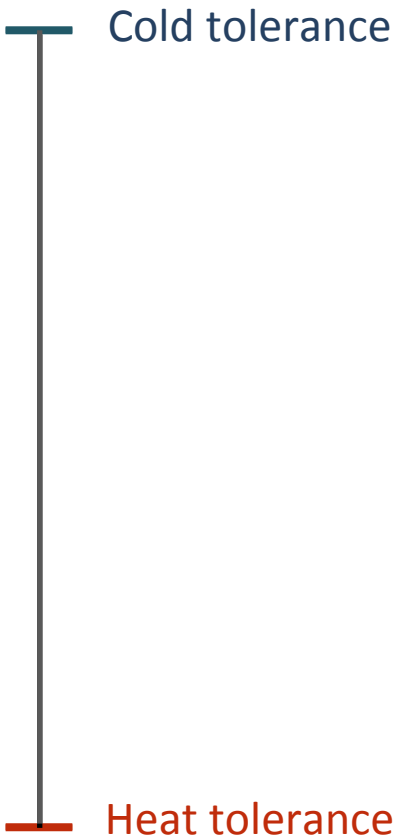

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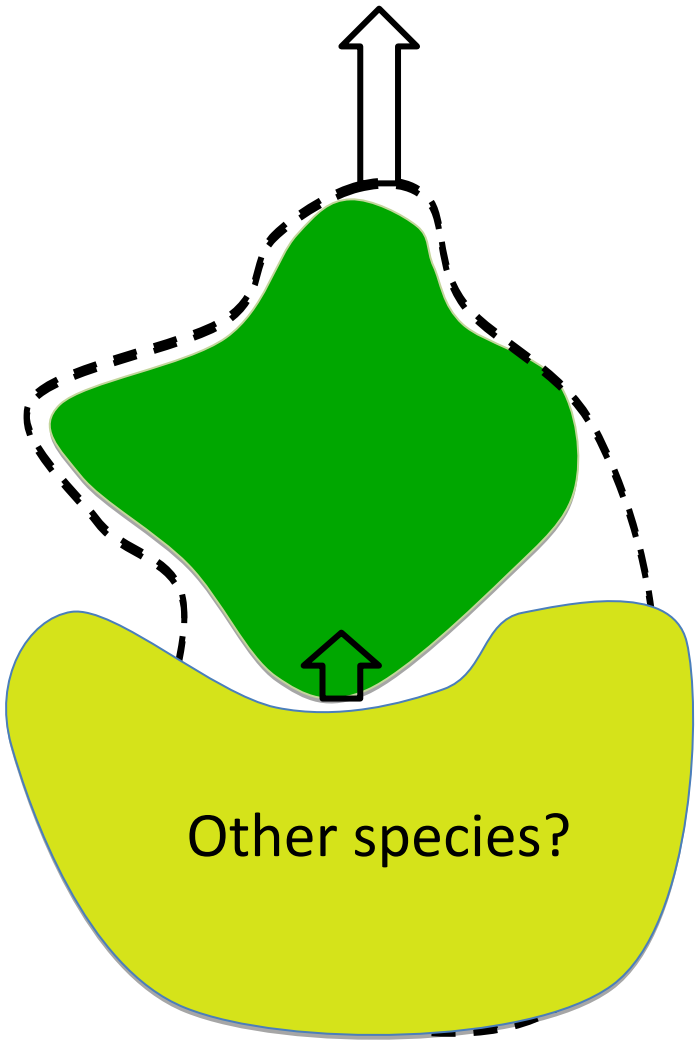
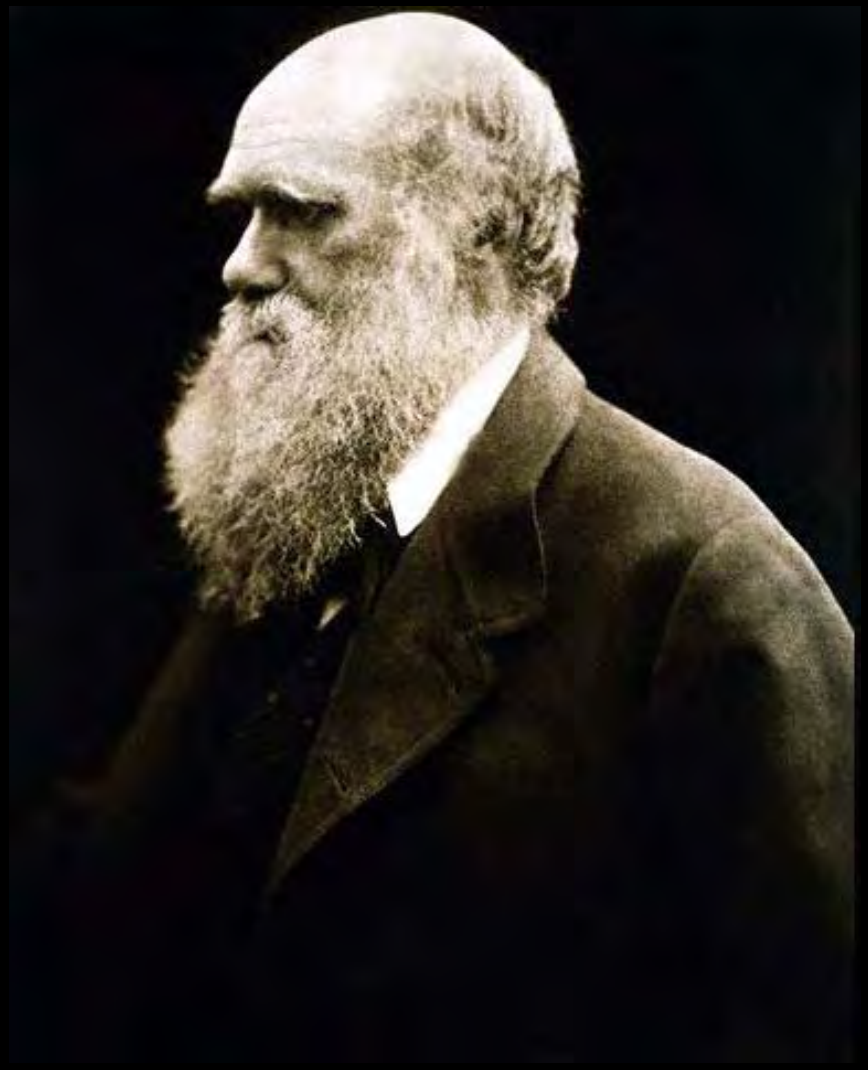


Cold tolerance

Heat tolerance

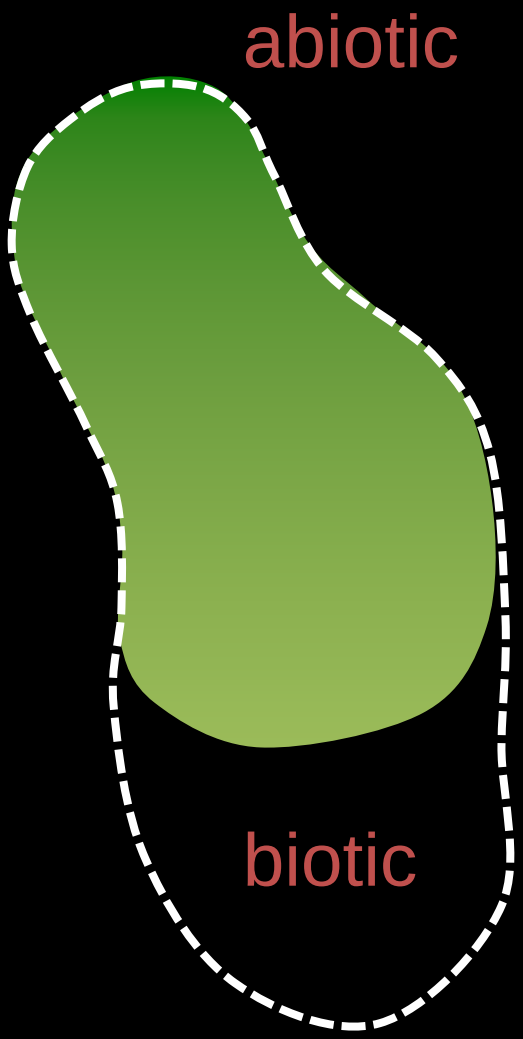
Lower latitudinal range and biotic interactions

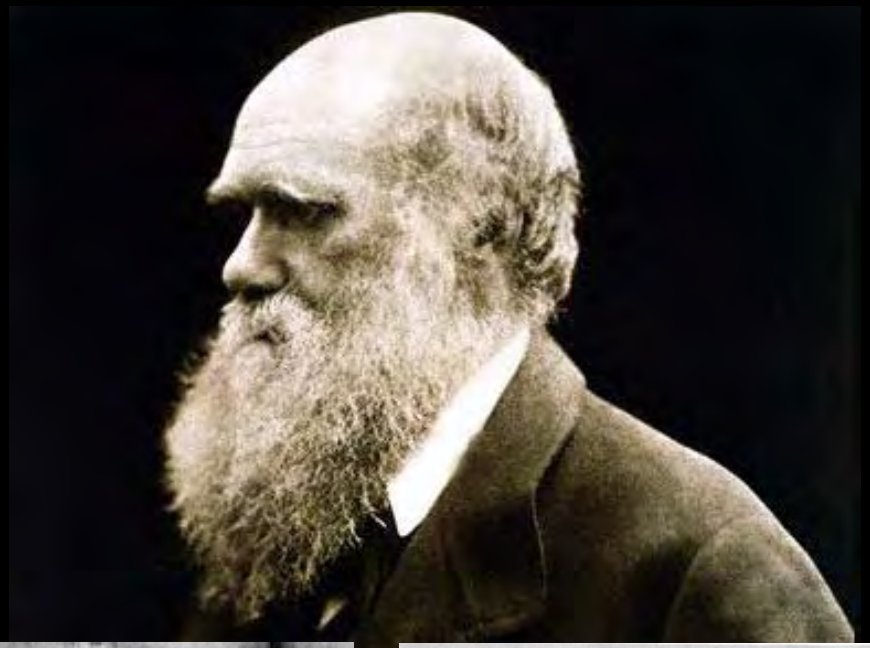
Referring to the northern hemisphere: "*When we travel southwards and see a species decreasing in numbers we may feel sure that the cause lies quite as much in other species being favoured, as in this one being hurt. So it is when we travel northwards... the number of species of all kinds, and therefore competitors, decreases… the struggle for life is almost exclusively with the elements*".

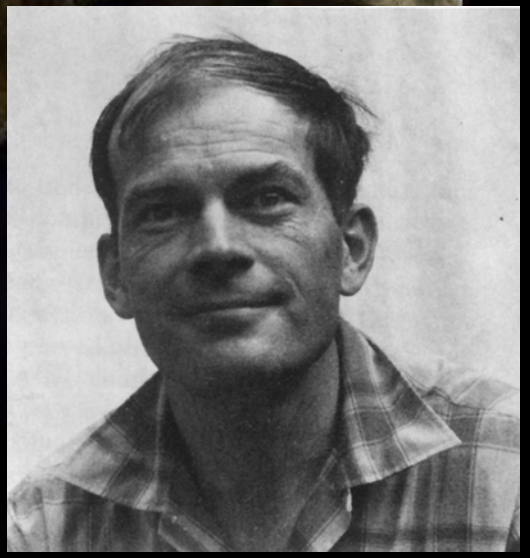


Charles Darwin

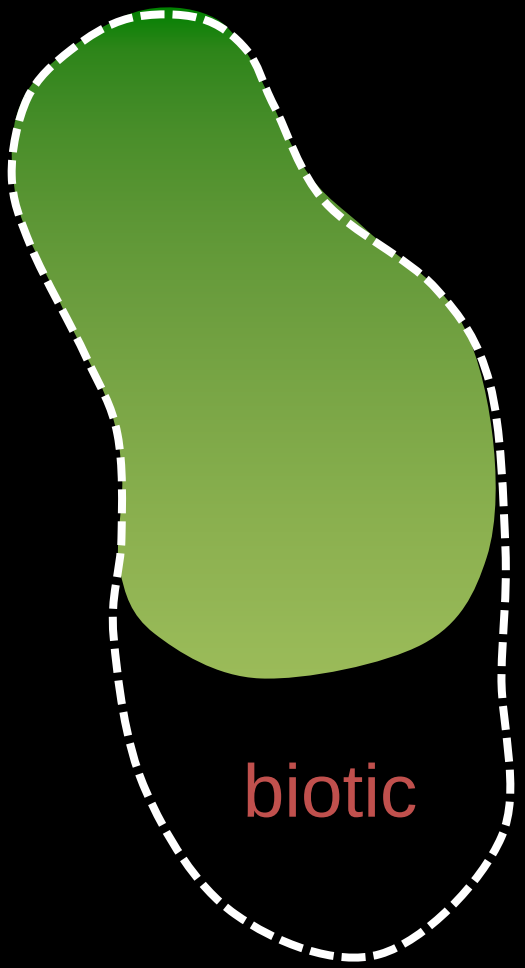
Lower latitudinal range and biotic interactions







Lower latitudinal range and biotic interactions



Why different?

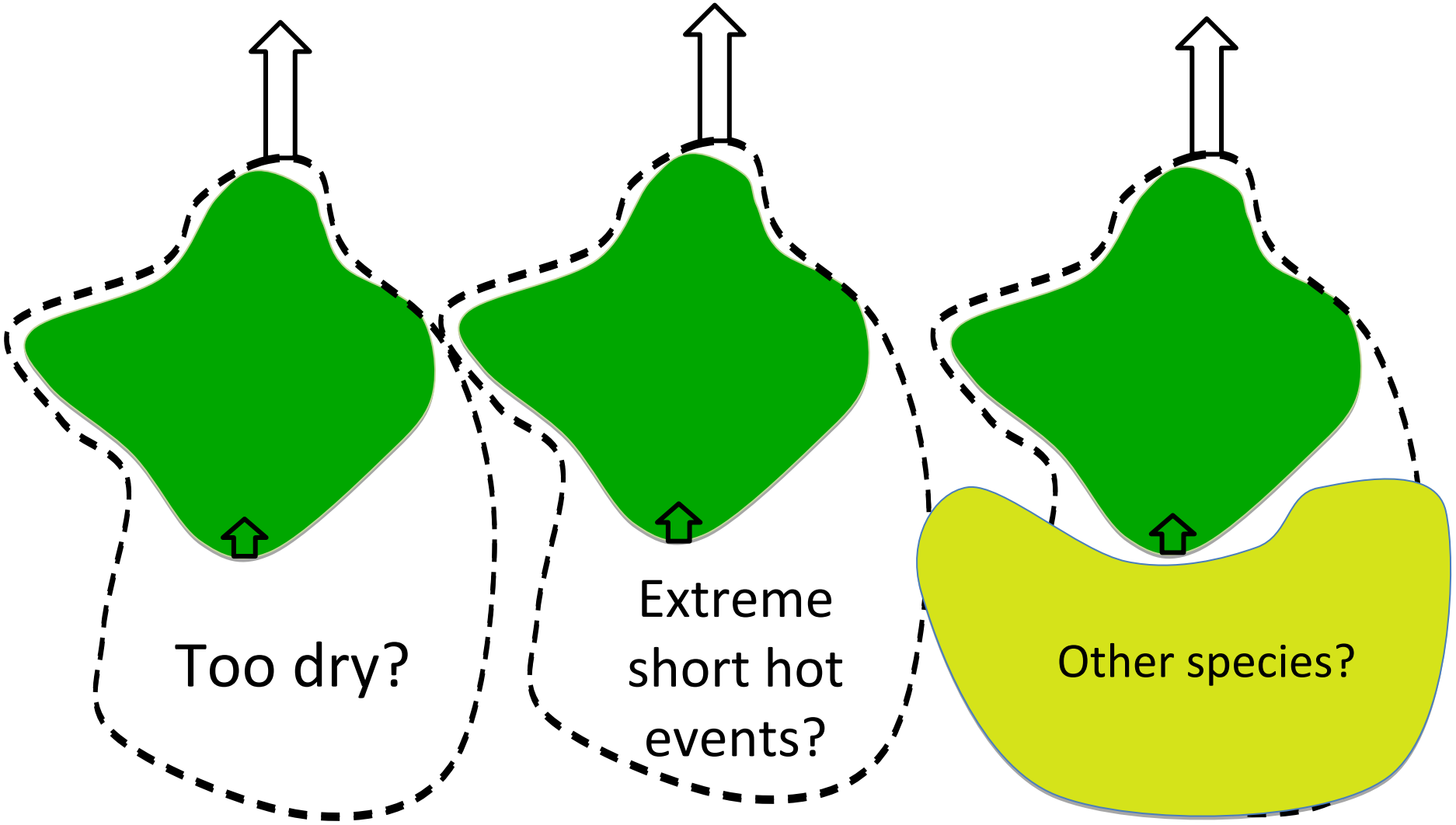
1. interactions are predominantly size-based, not species-based

fewer natural enemies

2. species diversity gradient is less pronounced

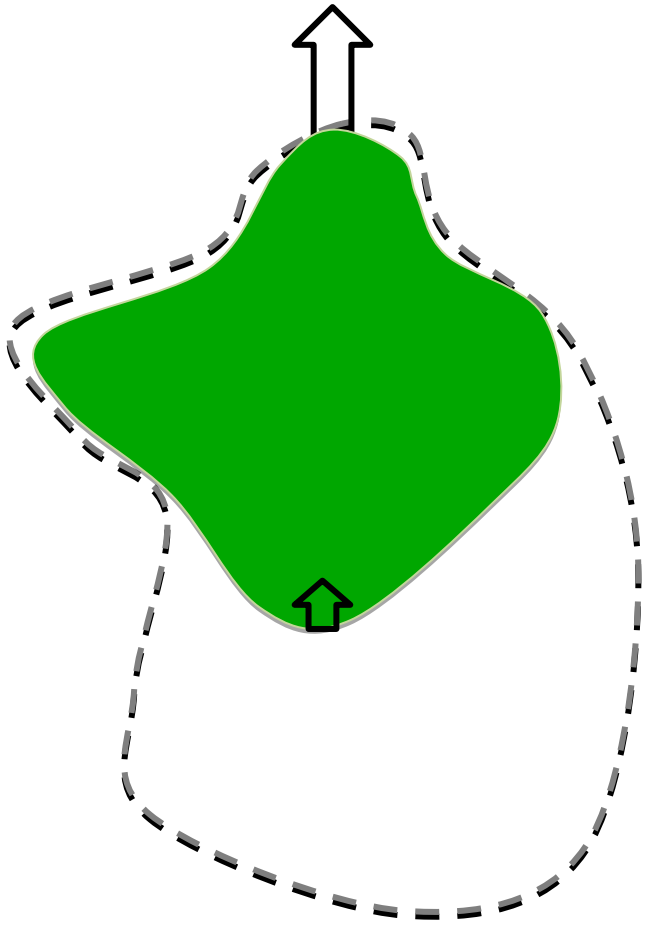
less diffuse competition

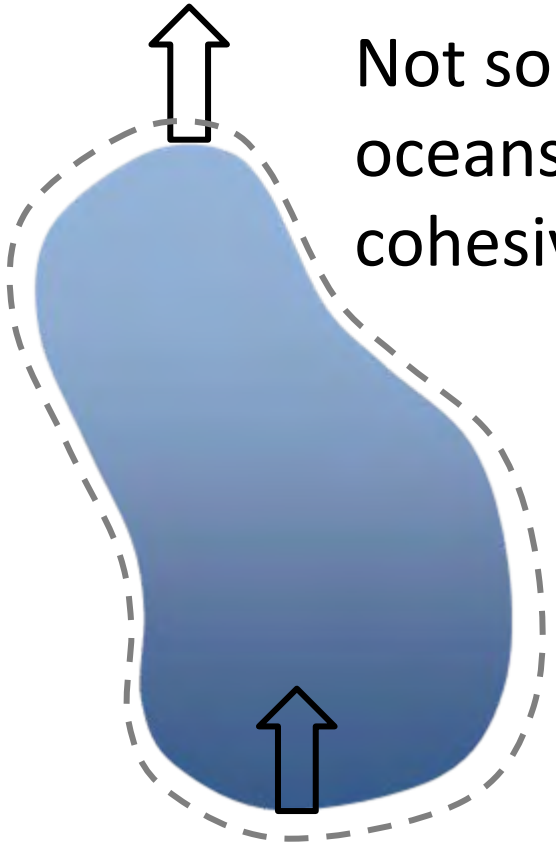
Range shifts will be less predictable on land



Range shifts will be less predictable on land compared to the ocean

On land, ranges appear to be “stretching” towards the poles, with more new species interactions





Not so in the oceans, more cohesive

Ecological theory

Climate responses

Terrestrial ≠ Marine

Thanks to:

Robert Colwell
Raymond Huey
Wendy Palen
Andy Cooper
John Reynolds
Gerry Quinn
Arne Mooers
Phillip Molloy
Maria Jose Juan Jorda
David Redding
Rowan Trebilco
Michael Hart
Carson Keever
Earth2Ocean lab
Statsbeers

Amanda Bates

Nicholas Dulvy

Natural Sciences and Engineering Research Council of Canada

Conseil de recherches en sciences naturelles et en génie du Canada

Canada