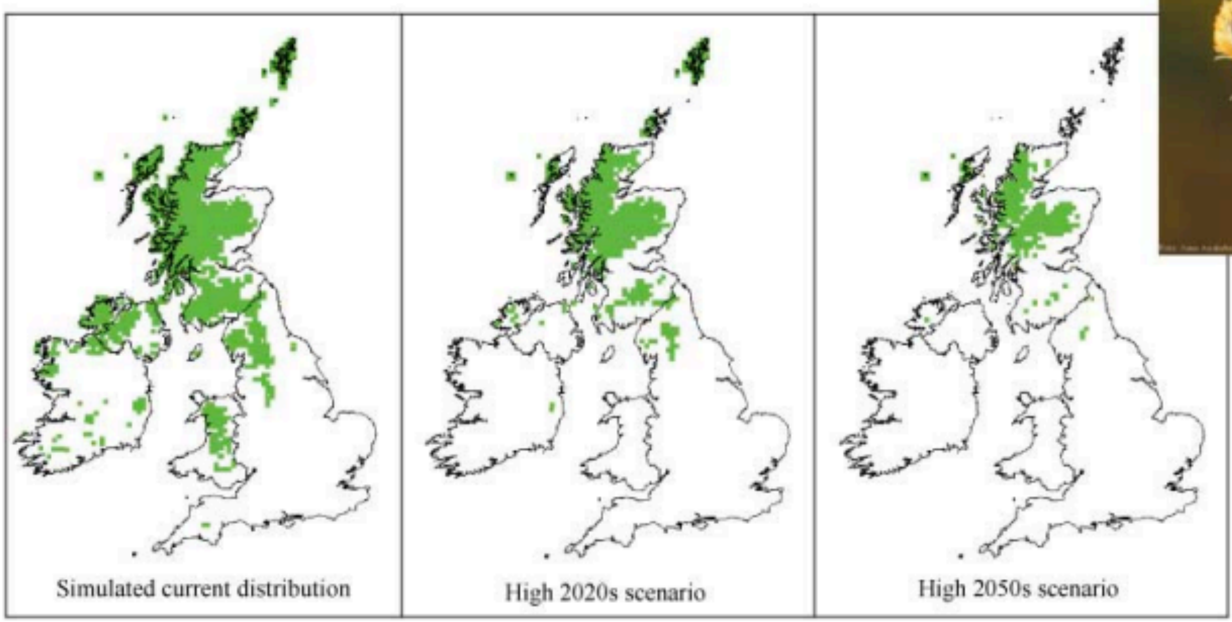
Niche Conservatism, and Common Distributions

Paleobiology

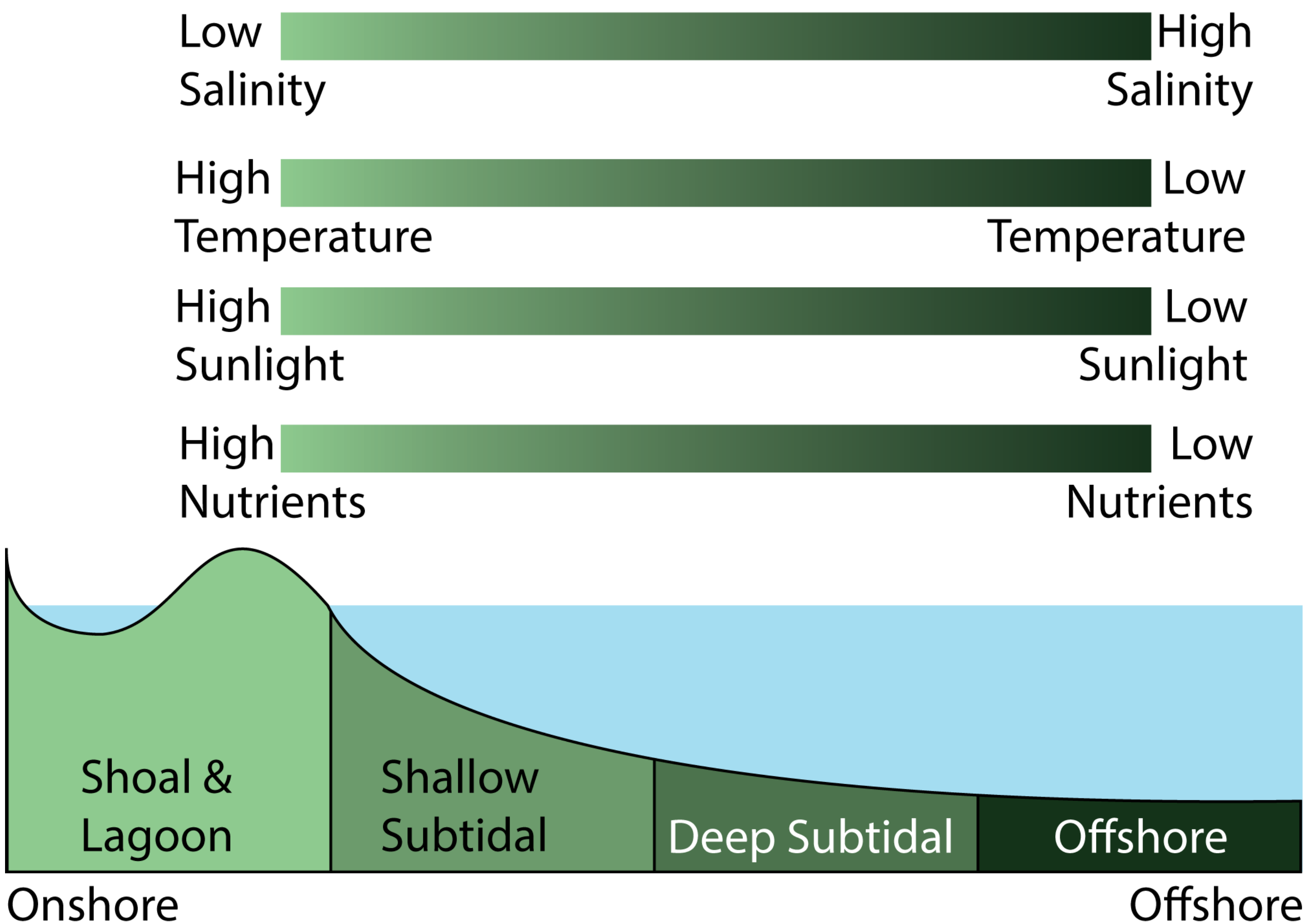
February 10, 2016

Bioclimatic envelopes

- Measure the fundamental “climatic” niche of a species.
- Generate a mathematical model that predicts future climate.
- Assume that the species will occupy all areas where that climate will be.

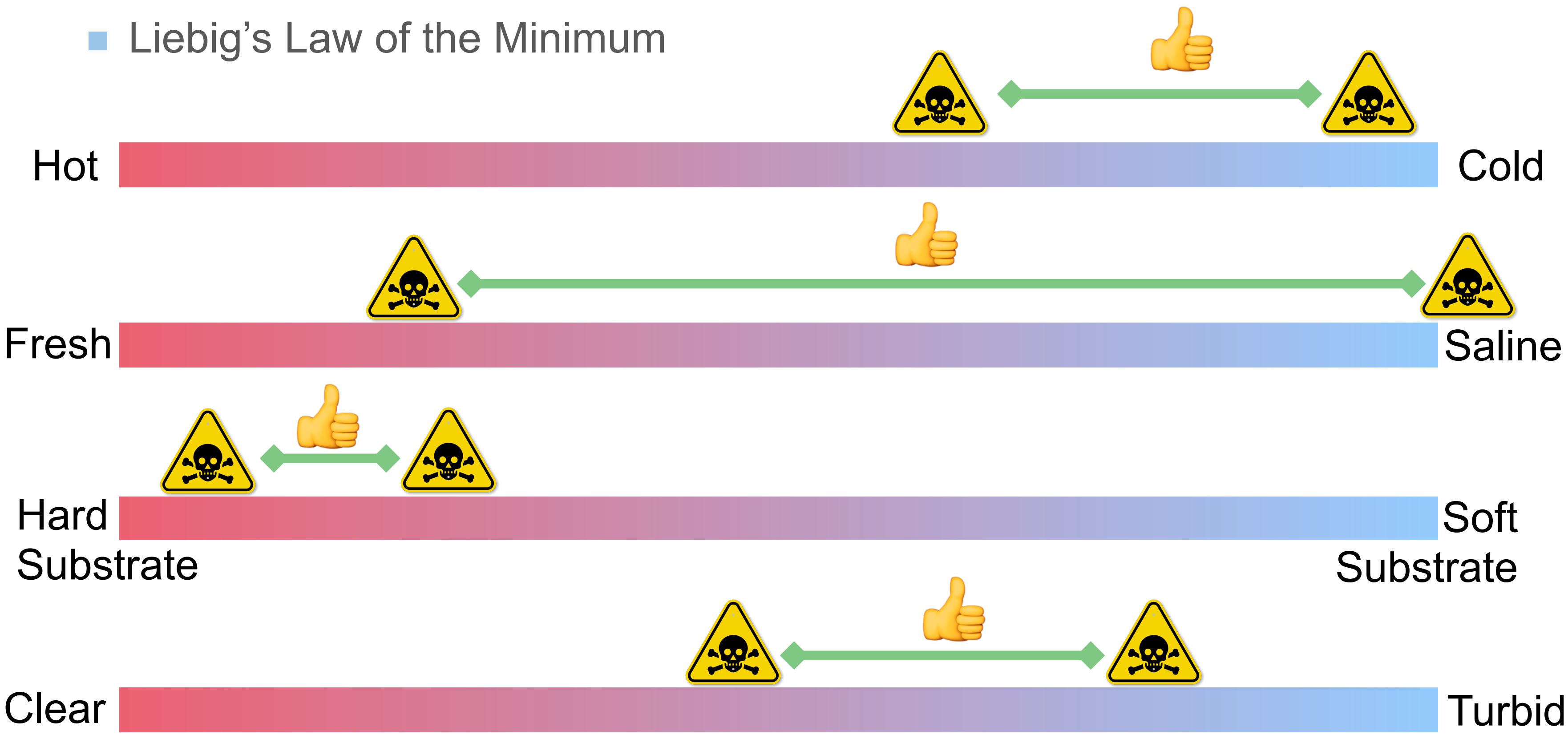


Environmental gradients



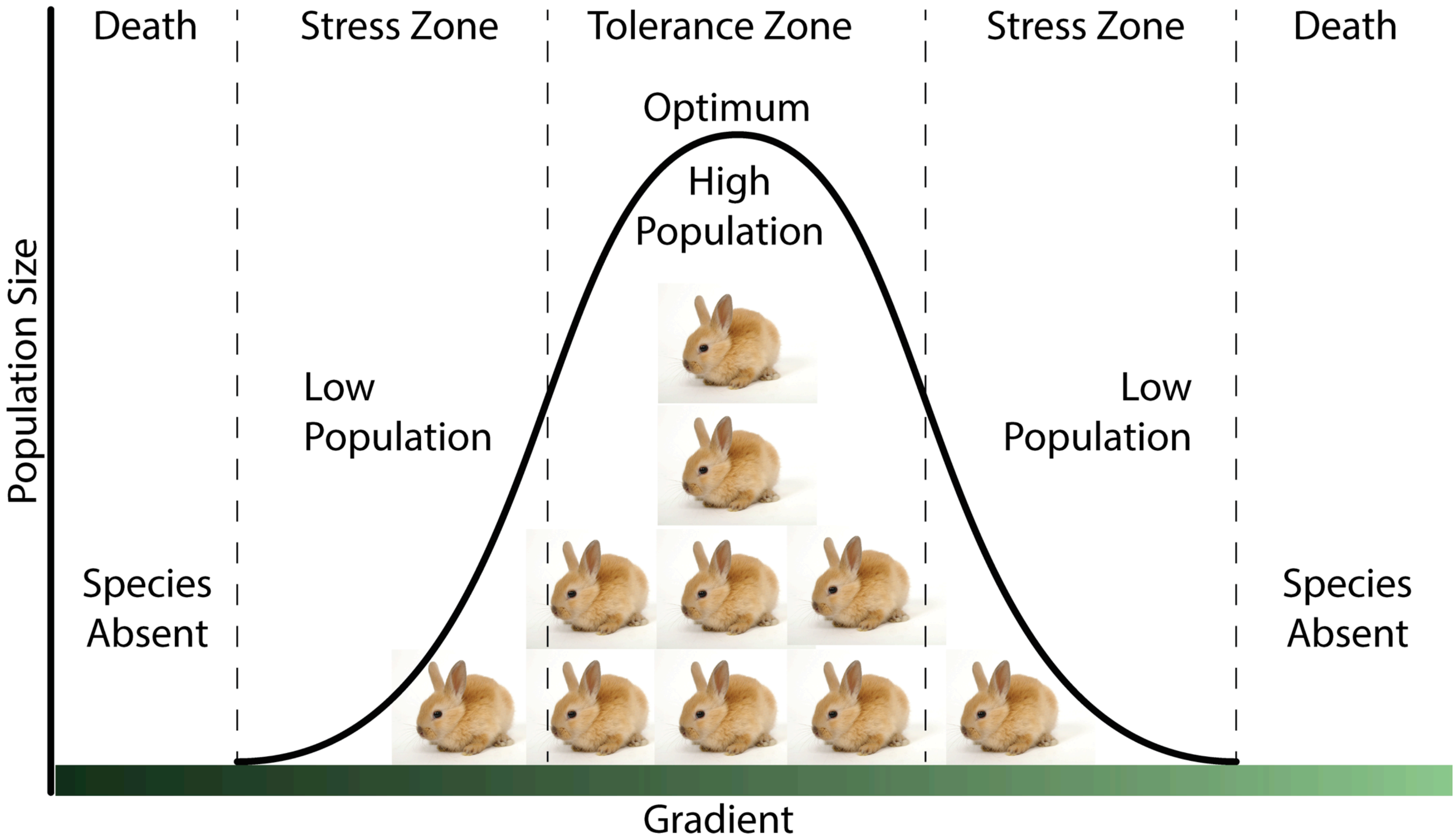
Gradient ecology

- Robert Whittaker 1967
  - Shelford's Law of Tolerance
  - Liebig's Law of the Minimum



Gradient response curve

- How a species responds in population size to different gradient values



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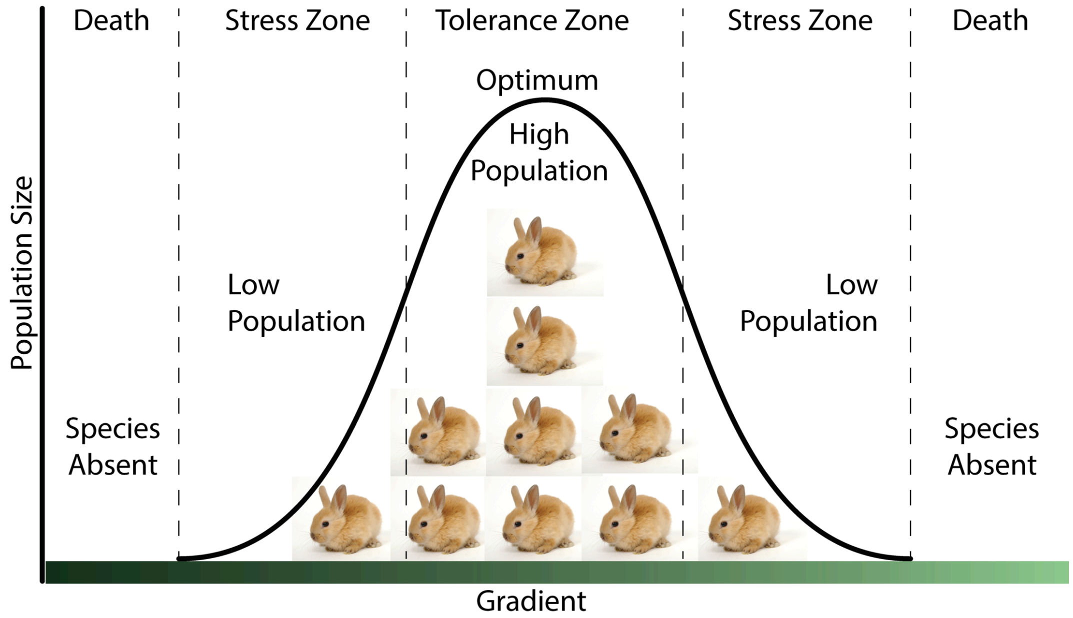

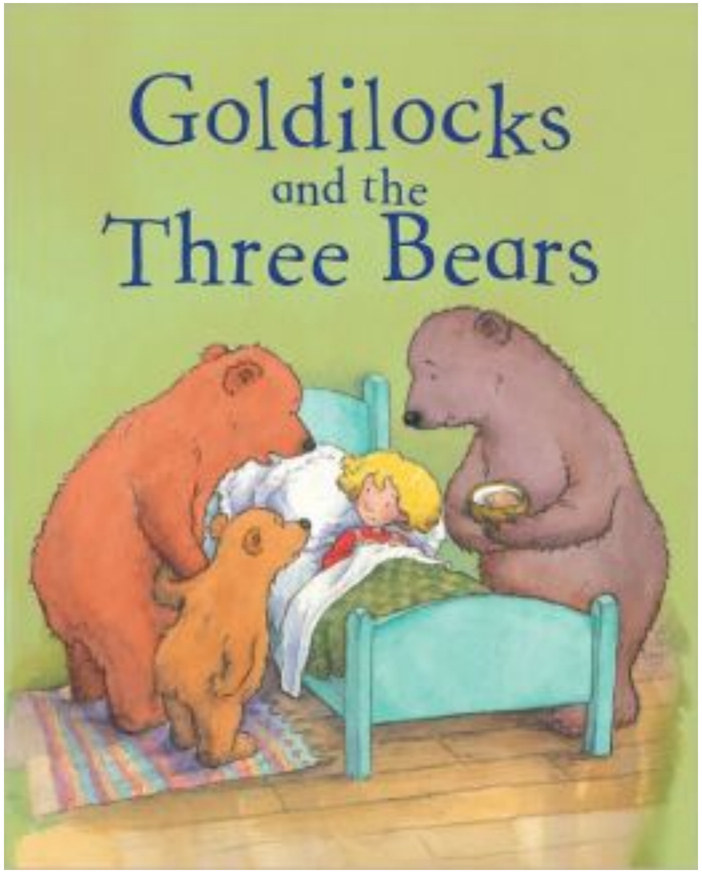

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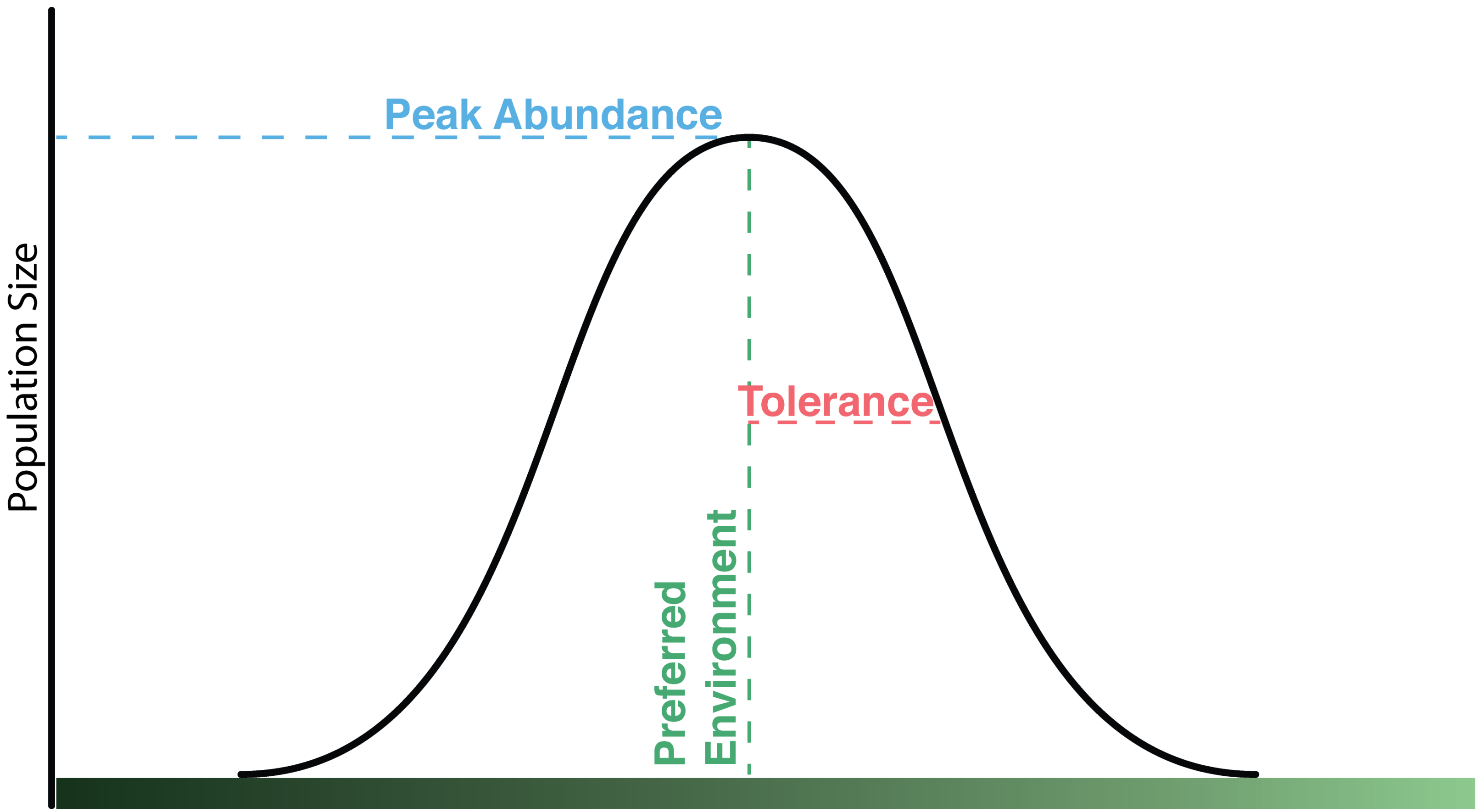

How to calculate a response curve

- Weighted Averaging
  - Find all positions along a gradient where you observe a species – i.e., take samples.
  - Count the number of individuals of that species you observe at that position – i.e., find the abundance of samples.
  - Average the sample gradient scores together weighted by abundance.

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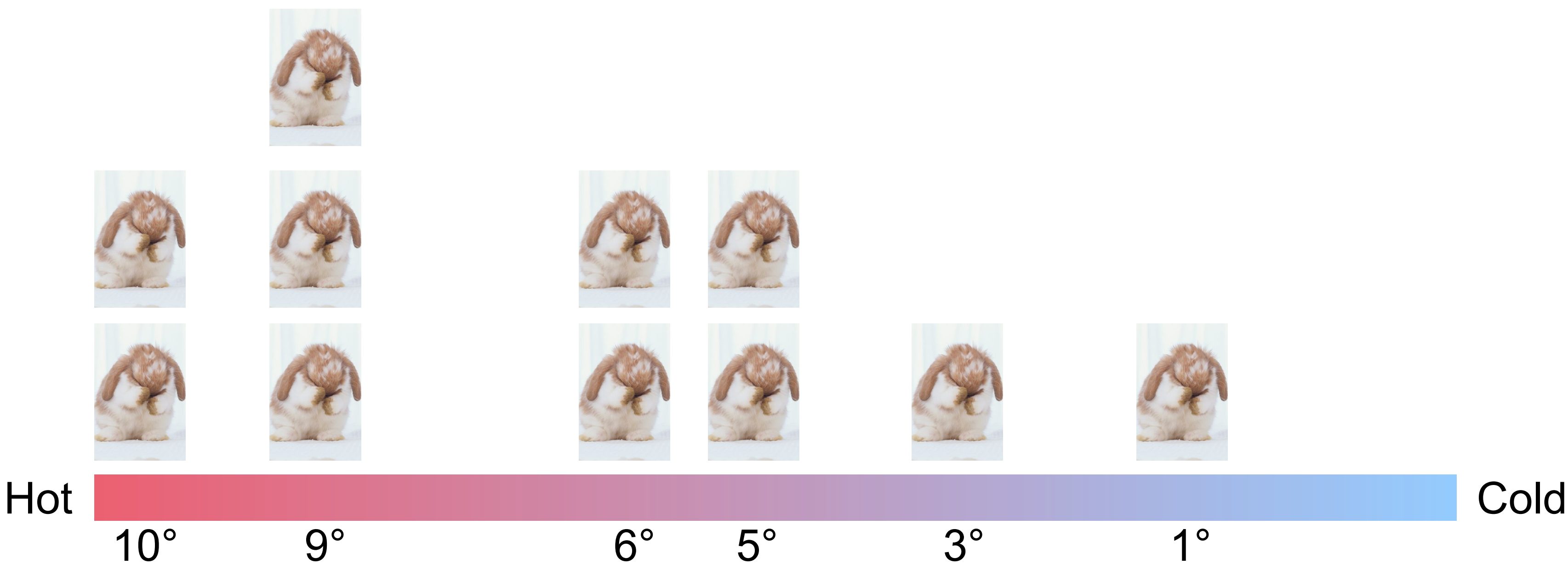
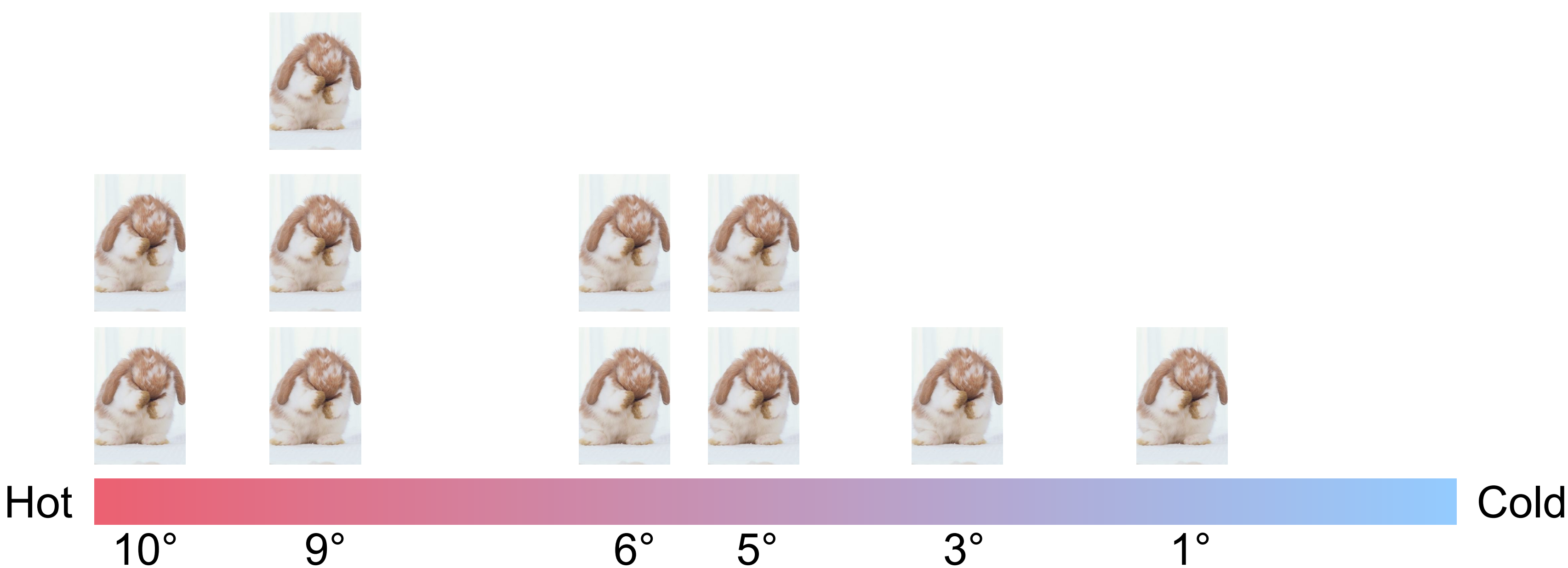


How to calculate a response curve

- Regular Average

$$\frac{10°+9°+6°+5°+3°+1°}{6} = 5.6°$$

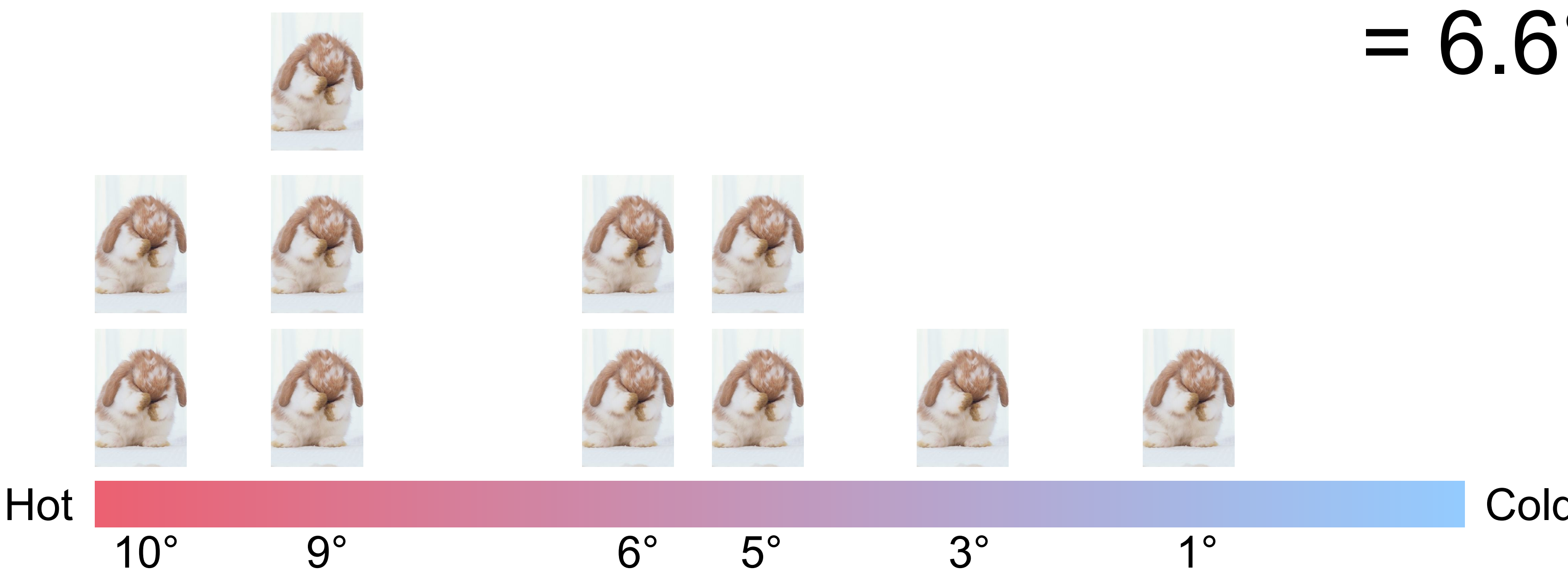


How to calculate a response curve

- Weighted Average
  - Find the total number of individuals $2+3+2+2+1+1=11$
  - Multiply each temperature by its number of individuals divided by the total.

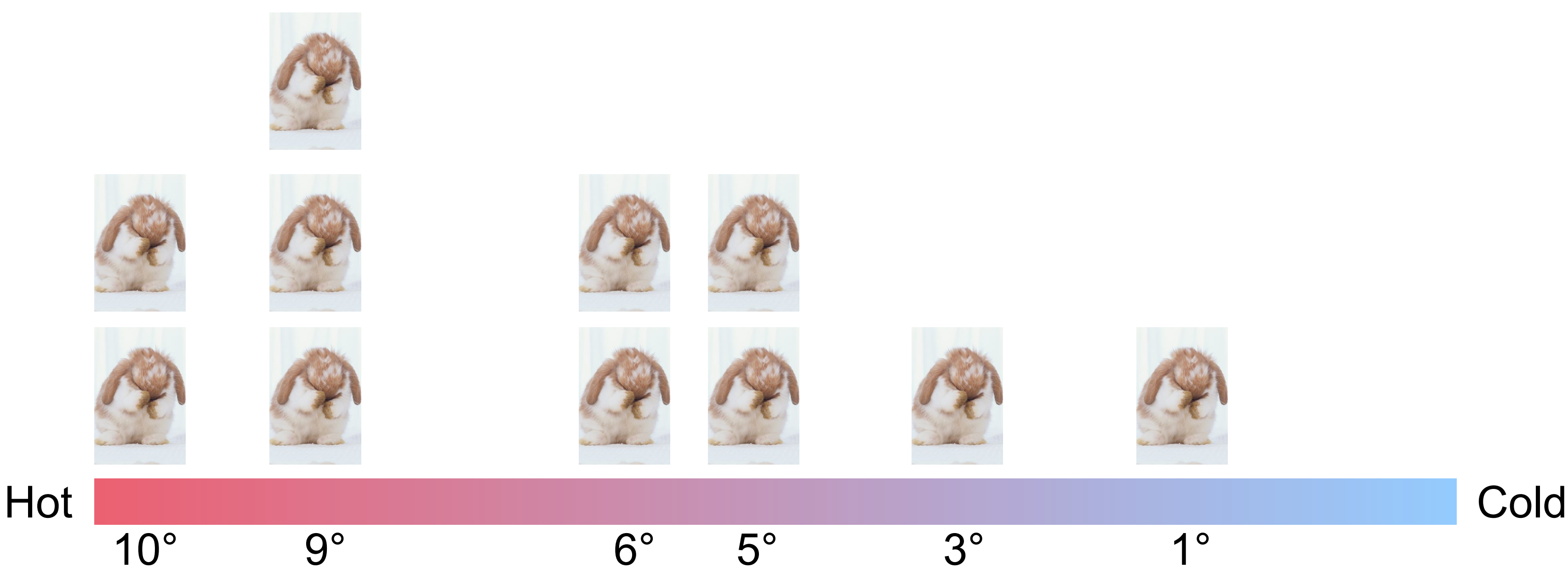
$$(10^\circ \text{x}\tfrac{2}{11})+(9^\circ \text{x}\tfrac{3}{11})+(6^\circ \text{x}\tfrac{2}{11})+(5^\circ \text{x}\tfrac{2}{11})+(3^\circ \text{x}\tfrac{1}{11})+(1^\circ \text{x}\tfrac{1}{11})$$

$$= 6.6^\circ$$

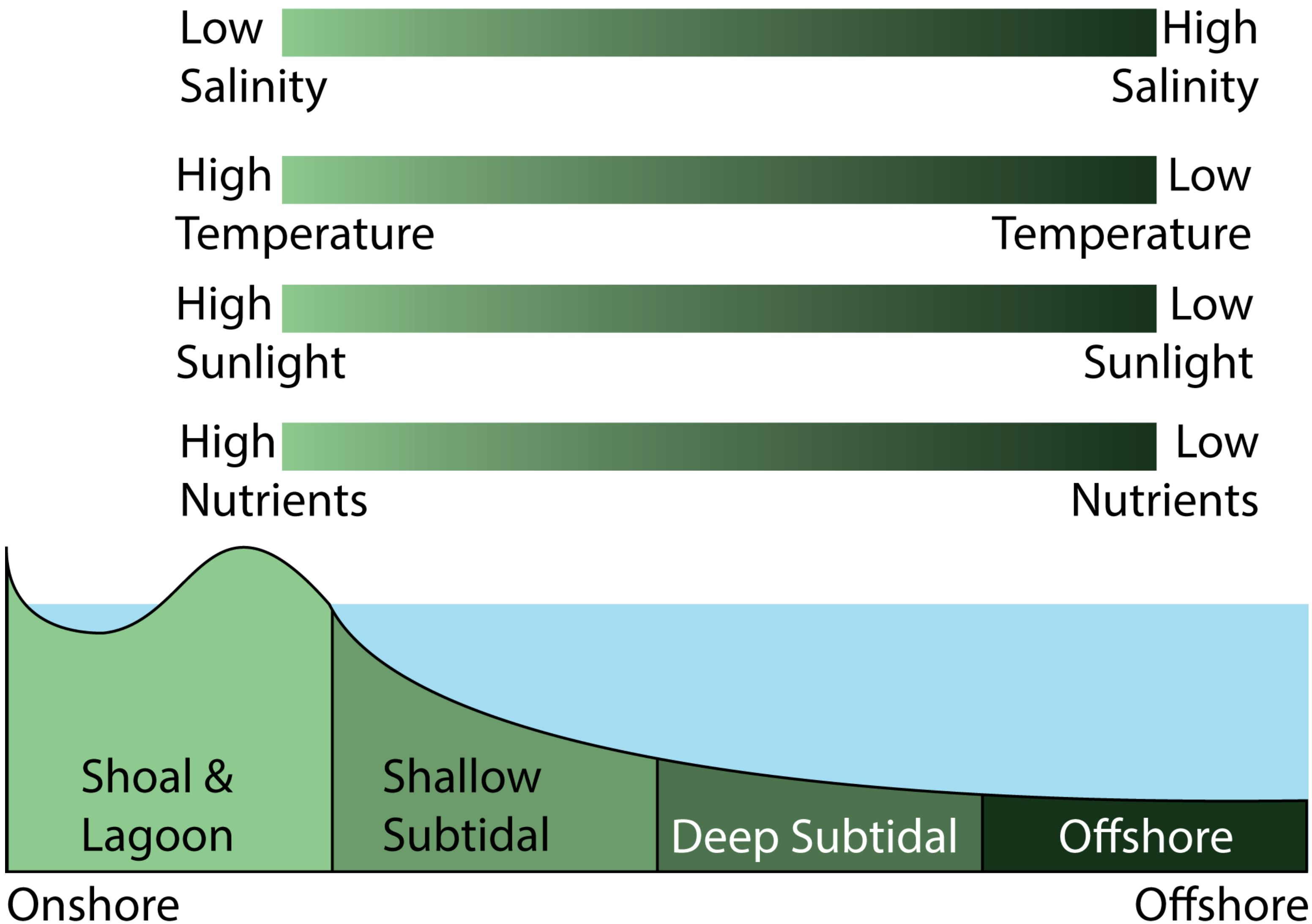


How to calculate a response curve

- Problems with Weighted Averaging and the Response Curve Model
  - Edge Effects
  - Irregular sampling
  - Assumes strict bell shaped response

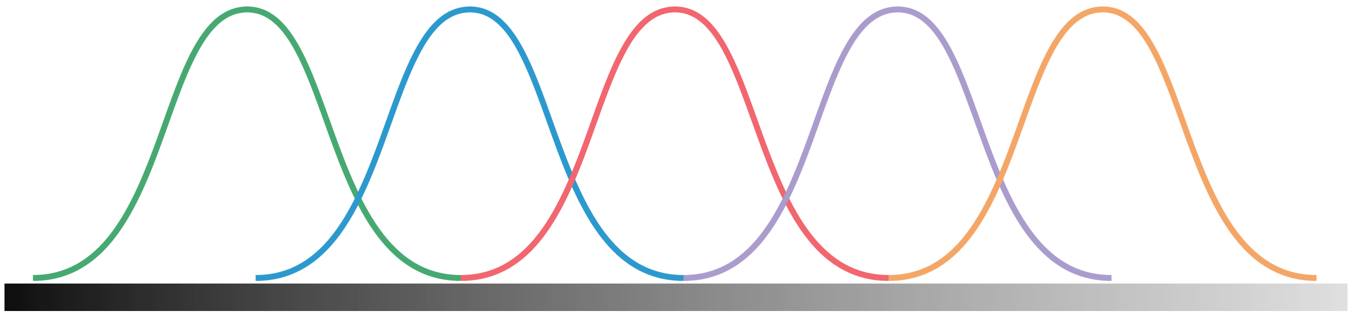


How does this help with gradients?



Inferring gradients from response curves

- The gradient response curve paradigm allows us to go *backwards* and infer the gradient from response curves (*plural*).



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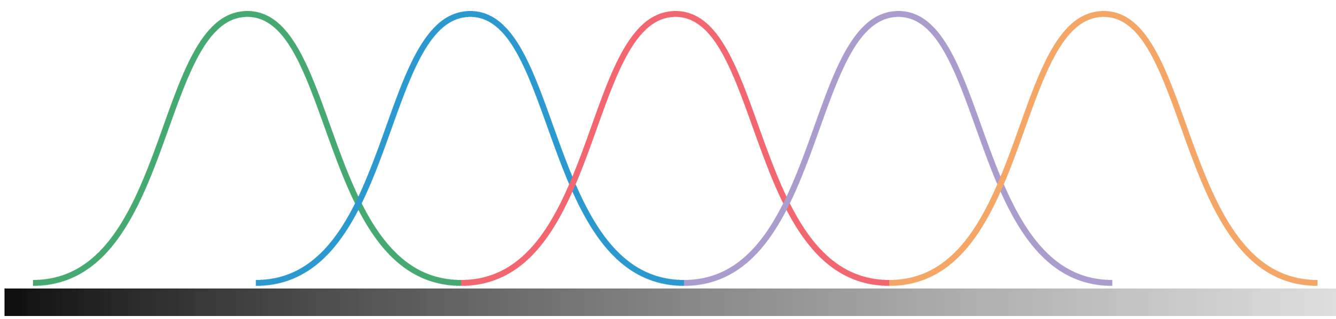

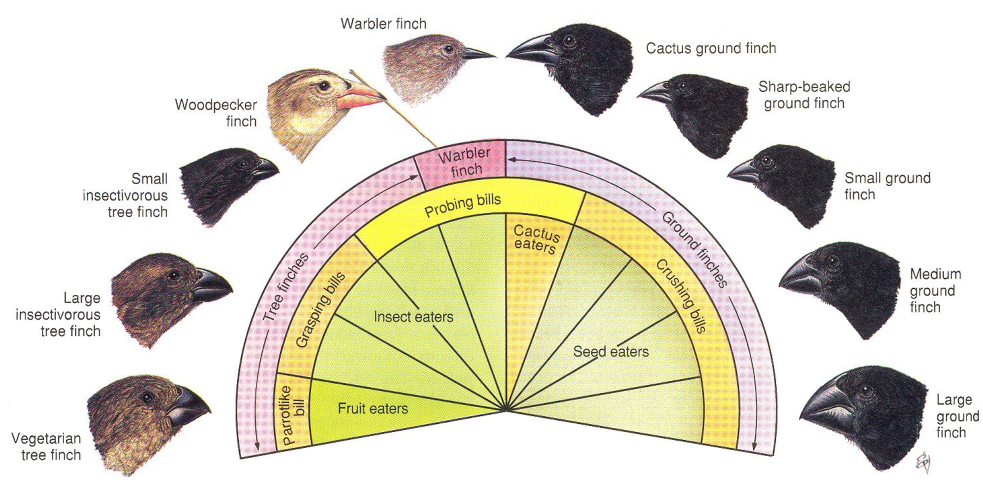

Inferring gradients with ordination

- Ordination puts species and samples in order along an inferred gradient.
  - Order samples based on shared species.

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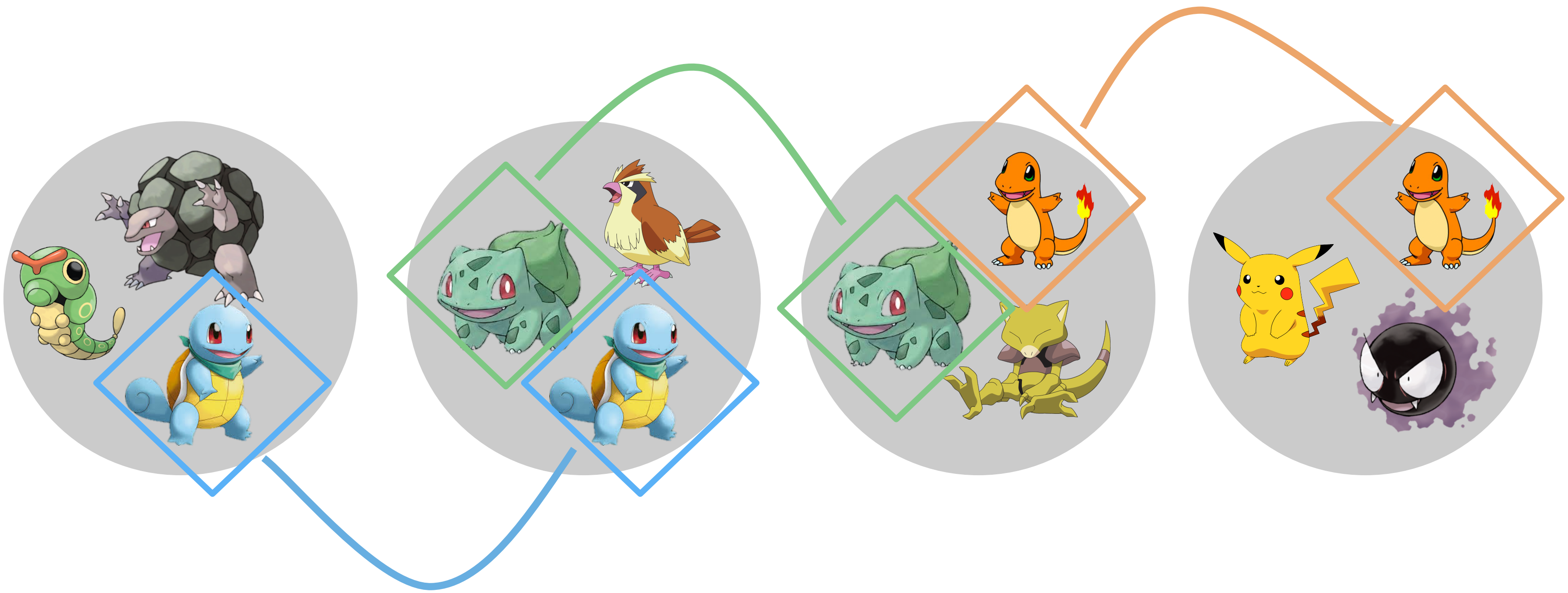
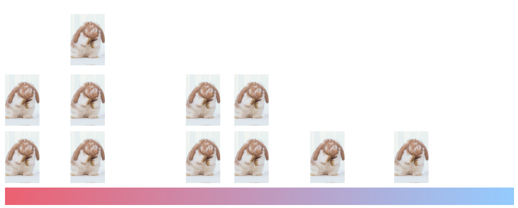


Inferring gradients with ordination

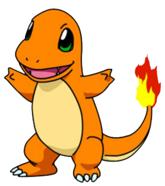
- Reciprocal Averaging is the simplest form of ordination

	A	B	C	D	E
	15	2	0	2	1
	9	6	15	0	0
	1	7	5	8	29



Inferring gradients with ordination

- Reciprocal Averaging is the simplest form of ordination

Random Values	17	12	11	55	72	Species Average
	15	2	0	2	1	23.05
	9	6	15	0	0	13
	1	7	5	8	29	53.68

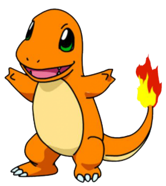
Inferring gradients with ordination

- Reciprocal Averaging is the simplest form of ordination

						Species Average
	15	2	0	2	1	23.05
	9	6	15	0	0	13
	1	7	5	8	29	53.68
Sample Average	5.75	5.57	5.16	5.29	17.6	

Inferring gradients with ordination

- Reciprocal Averaging is the simplest form of ordination

						Old Species Averages	New Species Averages
New Average	5.75	5.57	5.16	5.29	17.6		
	15	2	0	2	1	23.05	6.27
	9	6	15	0	0	13	5.42
	1	7	5	8	29	53.68	12.46
Old Average	5.75	5.57	5.16	5.29	17.6		

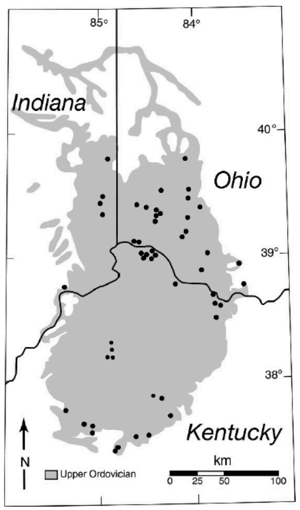
Inferring gradients with ordination

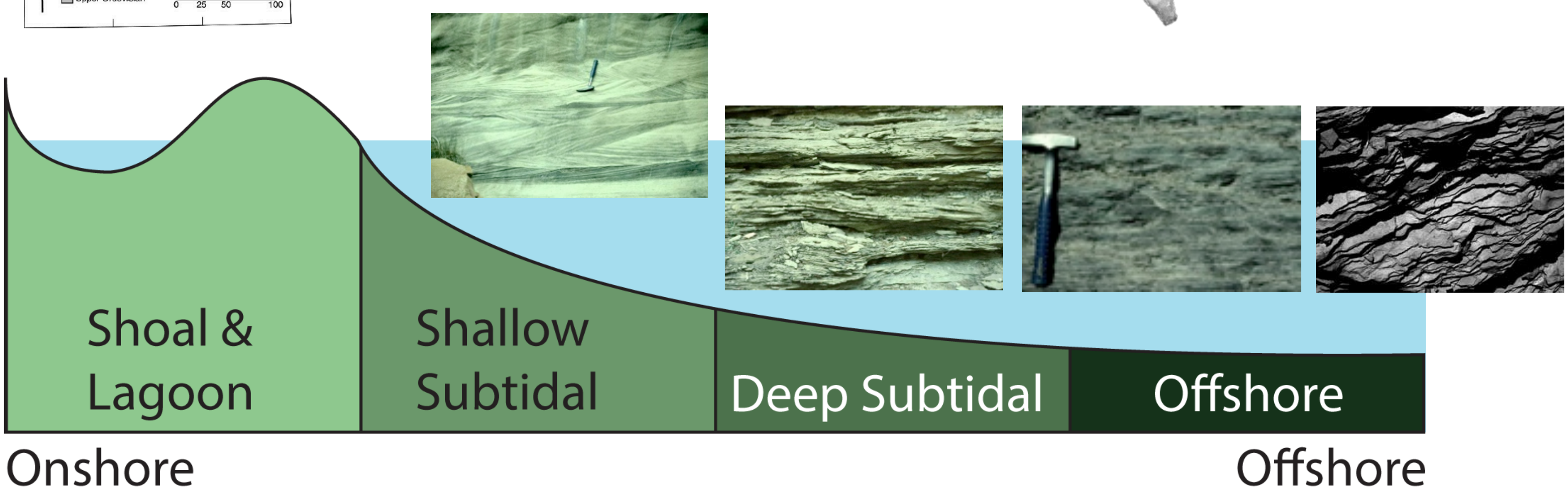
- Reciprocal Averaging is the simplest form of ordination

Old Average	5.75	5.57	5.16	5.29	17.6	Old Species Averages	New Species Averages
	15	2	0	2	1	23.05	6.27
	9	6	15	0	0	13	5.42
	1	7	5	8	29	53.68	12.46
New Average							

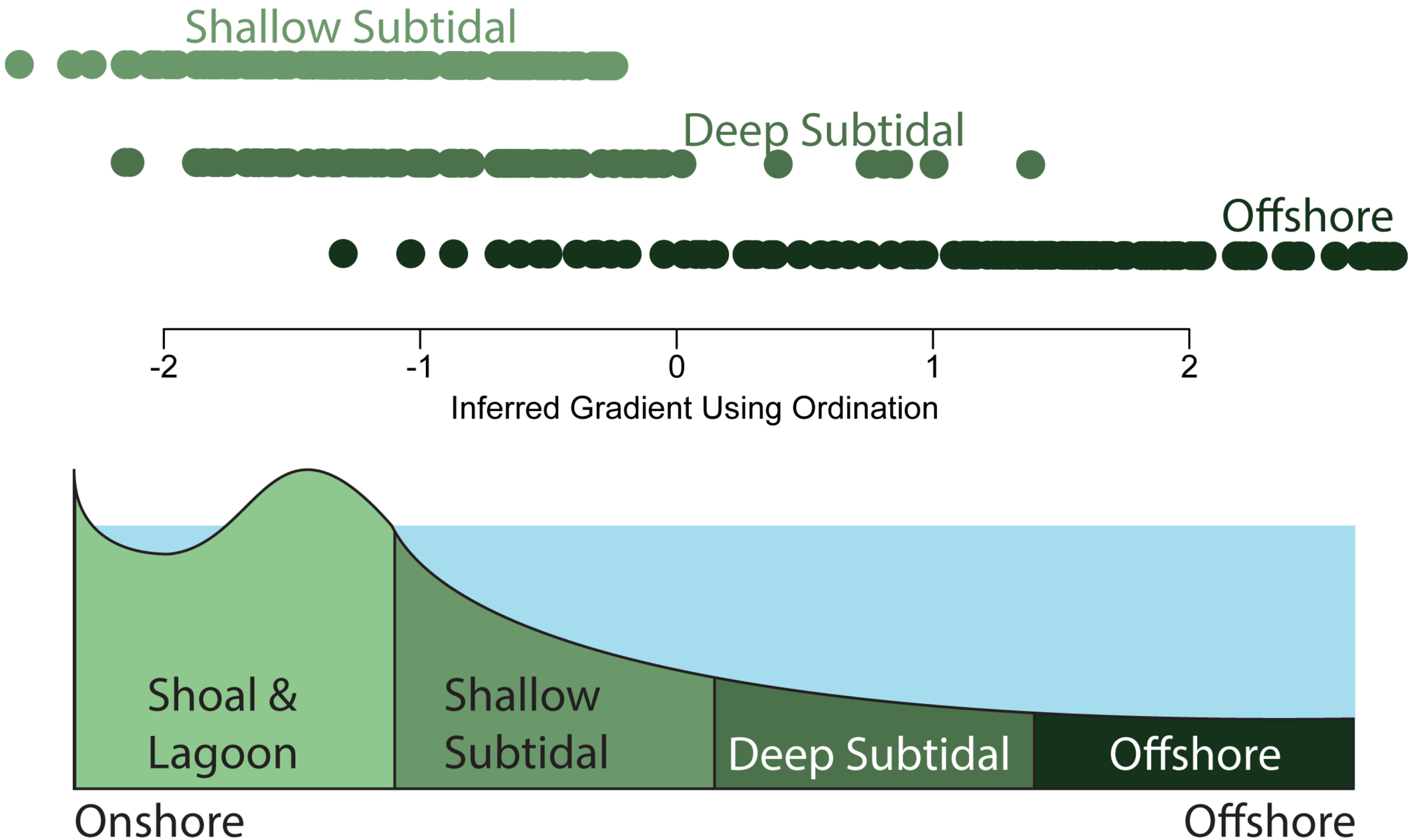
RINSE AND REPEAT!!

Applying ordination in the fossil record

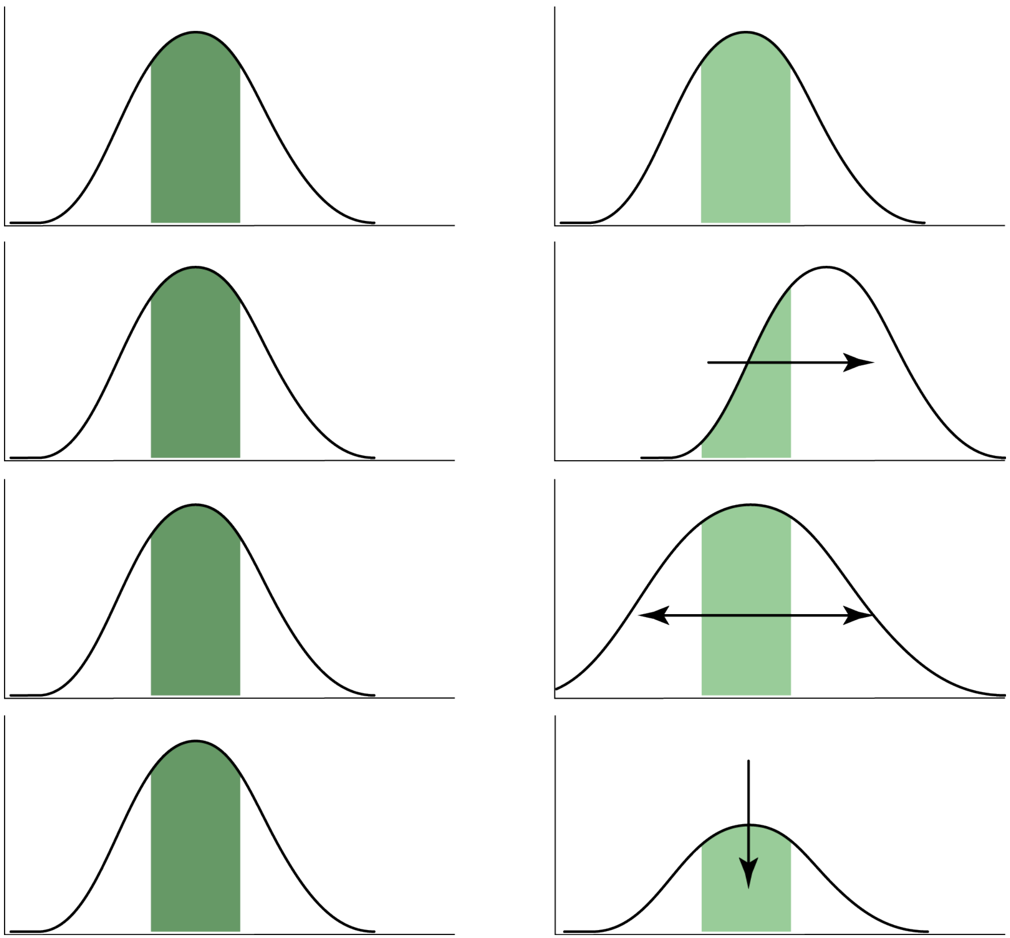




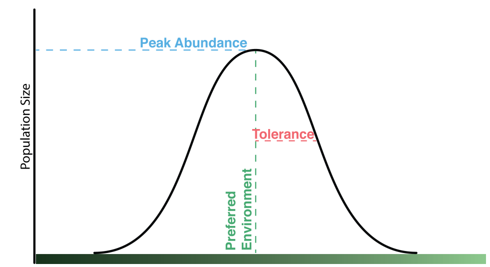
Applying ordination in the fossil record



Assessing niche conservatism

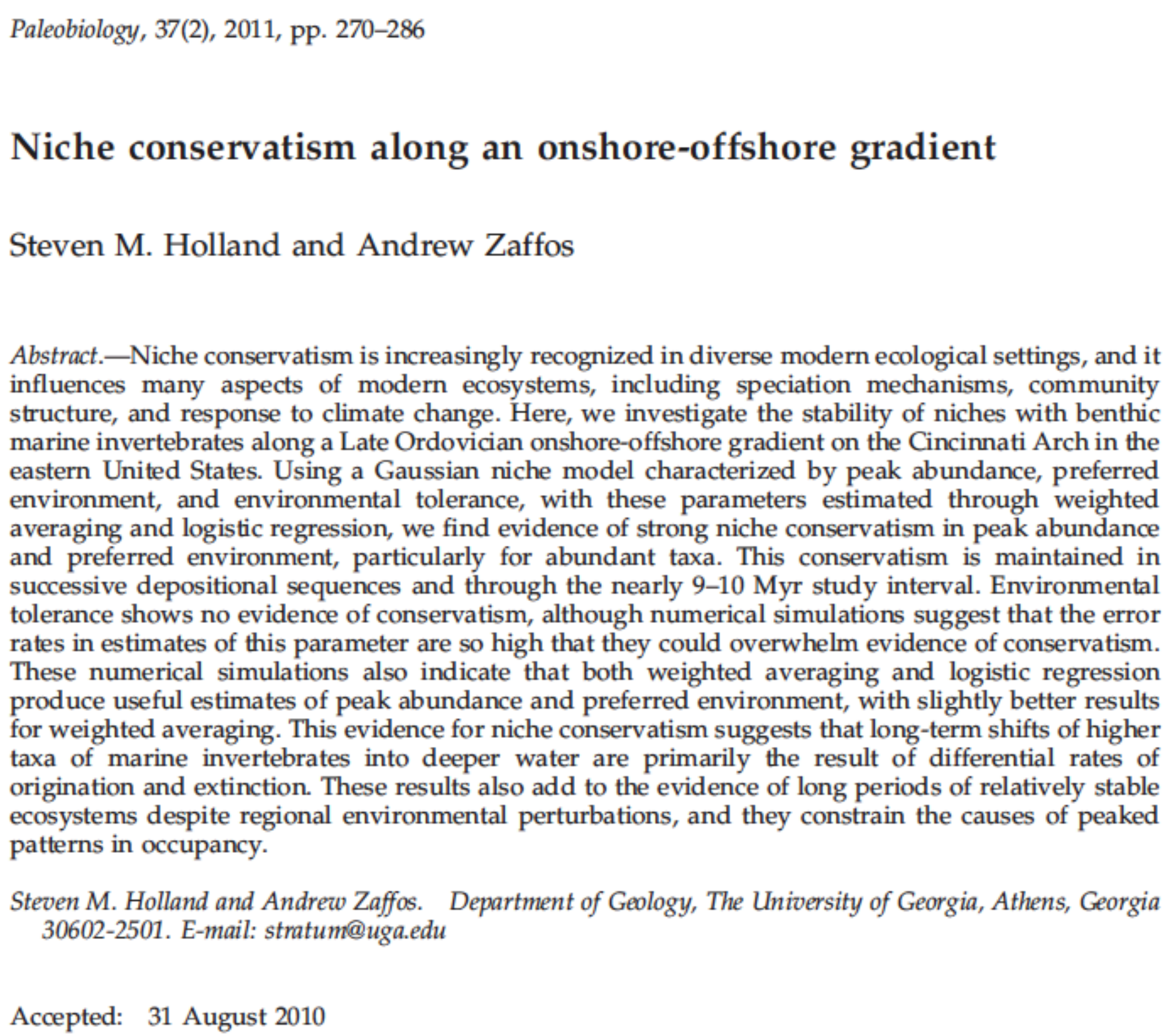


Time 1 Time 2



- Has the preferred environment changed.
- Has the tolerance changed.
- Has the peak abundance changed.

Assessing niche conservatism


Paleobiology, 37(2), 2011, pp. 270–286

Niche conservatism along an onshore-offshore gradient

Steven M. Holland and Andrew Zaffos

Abstract.—Niche conservatism is increasingly recognized in diverse modern ecological settings, and it influences many aspects of modern ecosystems, including speciation mechanisms, community structure, and response to climate change. Here, we investigate the stability of niches with benthic marine invertebrates along a Late Ordovician onshore-offshore gradient on the Cincinnati Arch in the eastern United States. Using a Gaussian niche model characterized by peak abundance, preferred environment, and environmental tolerance, with these parameters estimated through weighted averaging and logistic regression, we find evidence of strong niche conservatism in peak abundance and preferred environment, particularly for abundant taxa. This conservatism is maintained in successive depositional sequences and through the nearly 9–10 Myr study interval. Environmental tolerance shows no evidence of conservatism, although numerical simulations suggest that the error rates in estimates of this parameter are so high that they could overwhelm evidence of conservatism. These numerical simulations also indicate that both weighted averaging and logistic regression produce useful estimates of peak abundance and preferred environment, with slightly better results for weighted averaging. This evidence for niche conservatism suggests that long-term shifts of higher taxa of marine invertebrates into deeper water are primarily the result of differential rates of origination and extinction. These results also add to the evidence of long periods of relatively stable ecosystems despite regional environmental perturbations, and they constrain the causes of peaked patterns in occupancy.

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Accepted: 31 August 2010

- Preferred environment is moderately conserved.
- Peak abundance is strongly conserved.
- It is unknown if tolerance is conserved.
- Over a period of 9-10 Myrs

Assessing niche conservatism

Stratigraphic paleoecology: Bathymetric signatures and sequence overprint of mollusk associations from upper Quaternary sequences of the Po Plain, Italy

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Michal Kowalewski* Department of Geosciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, USA

ABSTRACT

Upper Quaternary sequences of the Po Plain (Italy) were used to assess the informative strength and sequence-stratigraphic overprint of quantitative paleoecological patterns. Three densely sampled cores (89 samples, 98 genera, 23,280 specimens), dominated by extant mollusk species with known environmental distributions, were analyzed with detrended correspondence analysis (DCA). The DCA scores, calibrated using extant genera, provided outstanding estimates of bathymetry (±3 m) and related environmental parameters. Depth-related successions of mollusk associations delineated by using DCA were consistent with independent sequence-stratigraphic interpretations and yielded insights inaccessible via routine techniques (e.g., depth estimates for maximum flooding surfaces). The DCA ordination demonstrates the severity of the sequence-stratigraphic overprint: samples are highly uniform taxonomically during late transgressive systems tracts and highly variable during the following highstand systems tracts. When analyzed across comparable systems tracts, similar species associations repeat during the last and current interglacial cycles, suggesting that Po Plain mollusk associations have remained remarkably stable over the past 125 k.y. The results are consistent with the bathymetric interpretation of the DC axis 1 postulated previously for the Paleozoic fossil record, demonstrate the sequence-stratigraphic overprint of paleoecological patterns predicted by computer modeling, and illustrate the utility of quantitative paleoecological patterns in augmenting sequence-stratigraphic interpretations.

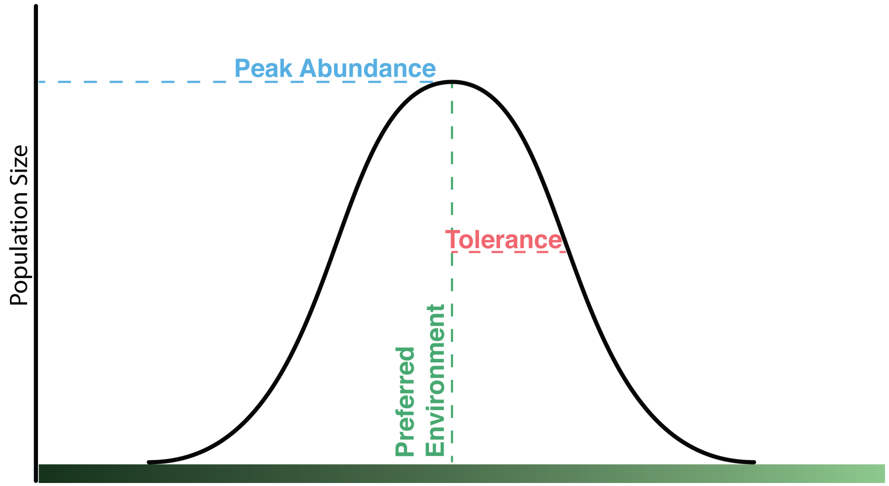
Keywords: paleoecology, sequence stratigraphy, Quaternary, mollusks, Po Plain, Italy.

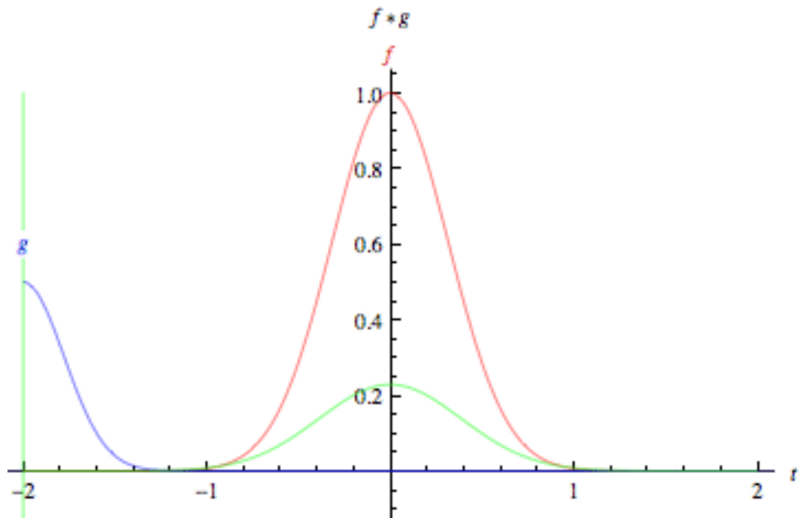
sequence-stratigraphic overprints that affect paleobiological patterns. Also, the fossil record dominated by extant species allows us to test the hypothesis—derived using long-extinct Paleozoic organisms (e.g., Holland et al., 2001; Miller et al., 2001)—that multivariate ordination gradients of marine fossil samples are driven primarily by bathymetry-related factors. The rich mollusk associations of the Po Plain should allow us to explore ecological dynamics of marginal-marine settings during high-frequency sea-level fluctuations that shaped the Quaternary history of many coastal areas of the world.

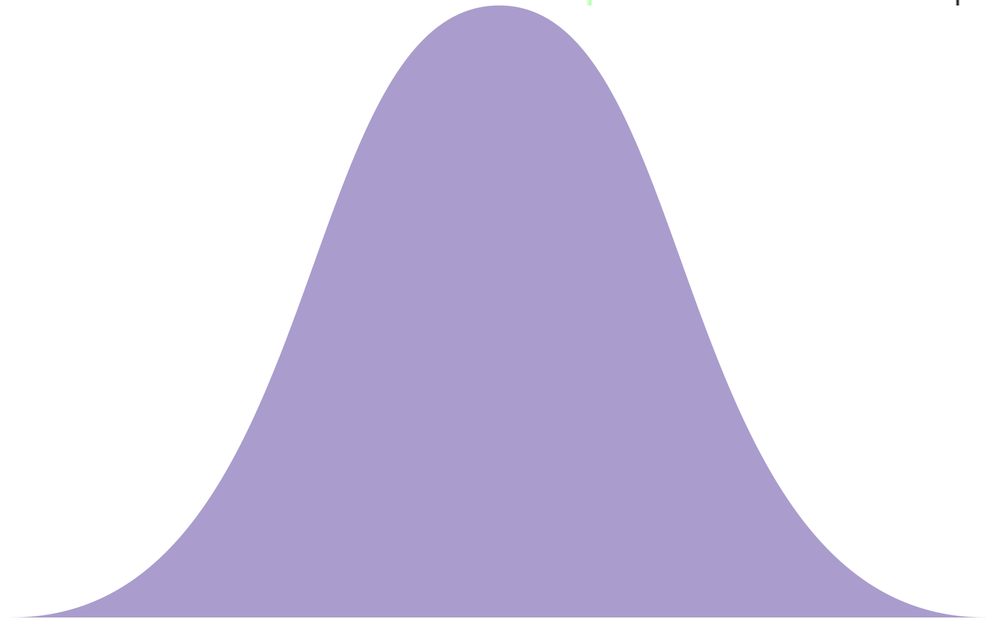
GEOLOGIC SETTING, MATERIALS, AND METHODS

The Po Plain (Fig. 1) is a large (~38,000 km^2) perisutural basin that contains a thick (up to 1000 m) succession of Pliocene–Quaternary sediments (Pieri and Groppi, 1981). Two major Quaternary depositional cycles (Qm and

Common ecological distributions

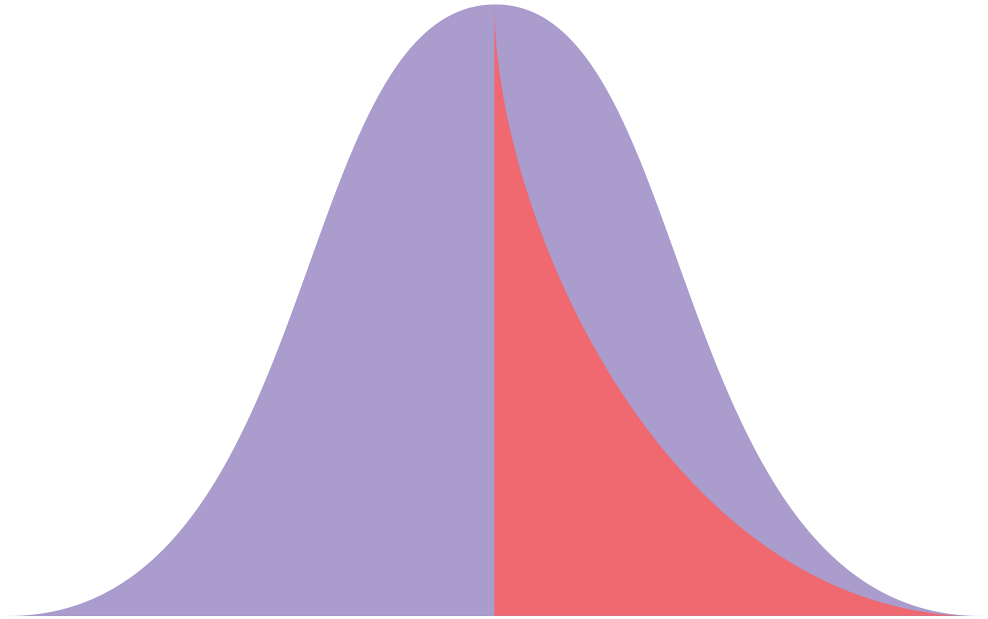






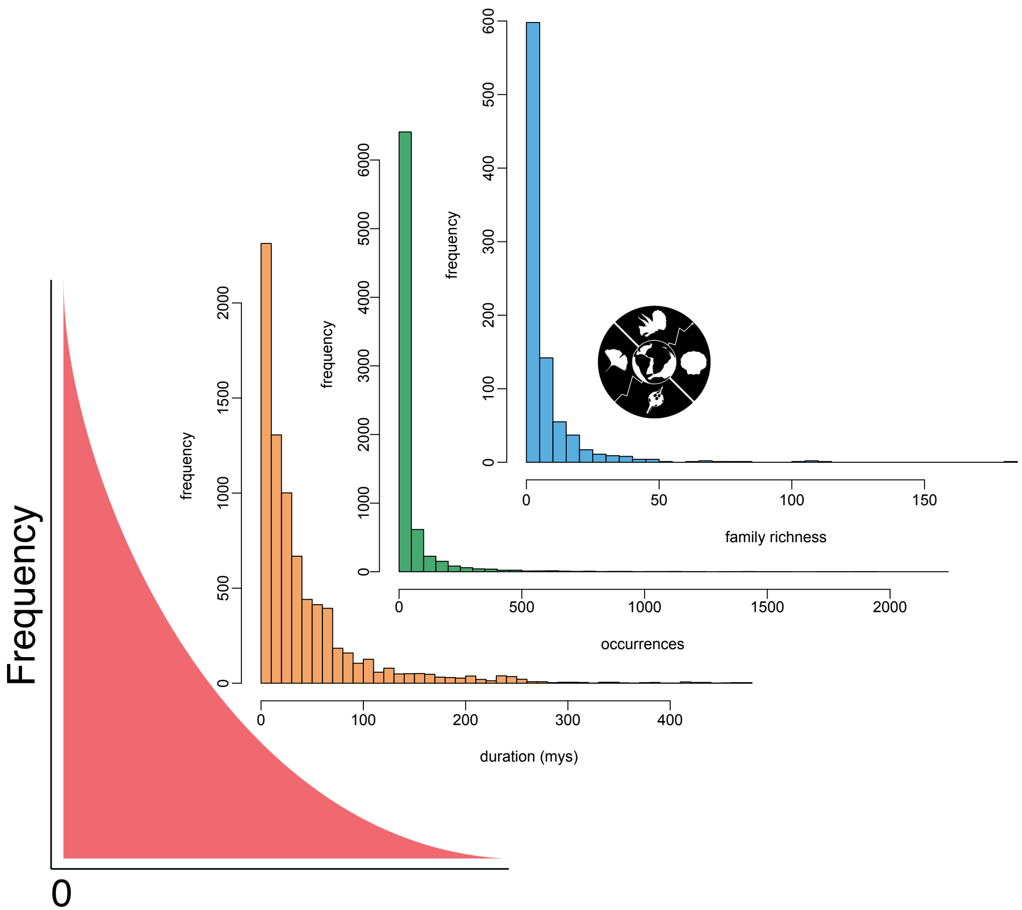
Hollow curves are the expectation

- In ecological, most things are small/short
  - Small body size
  - Small geographic range size
  - Small population size
  - Low taxonomic richness
  - Short taxonomic duration



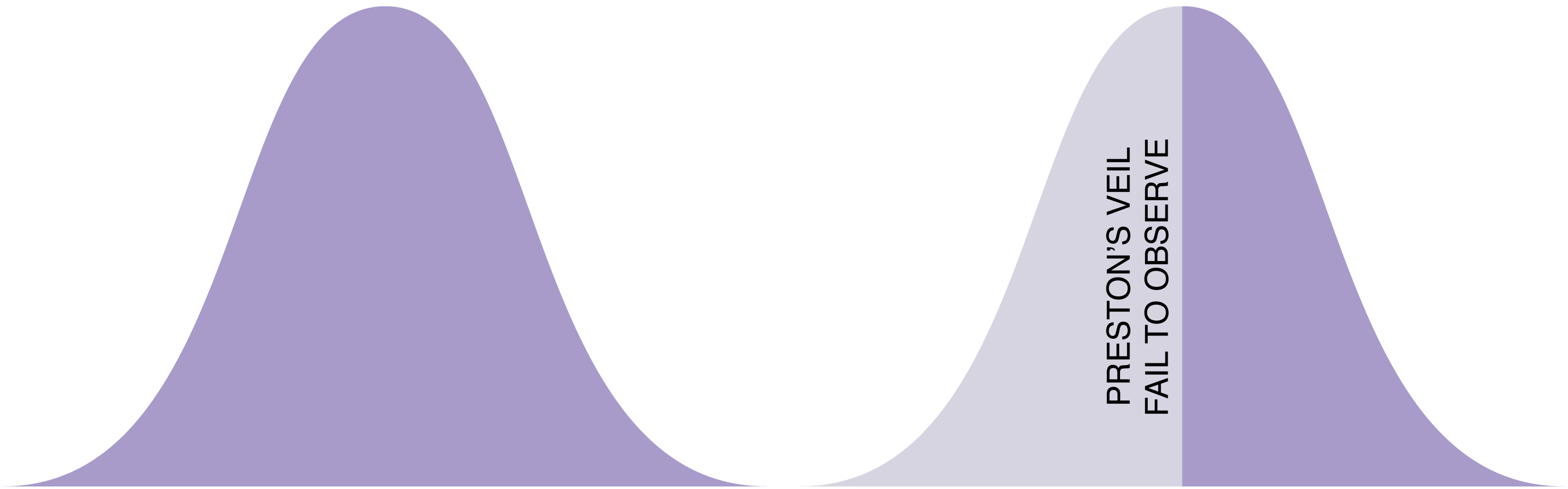
Hollow curves are the expectation

- In general, if an ecological variable is bounded by zero at the base, it will show a hollow curved shape.
  - The steepness or “hollowness” of the curve varies.



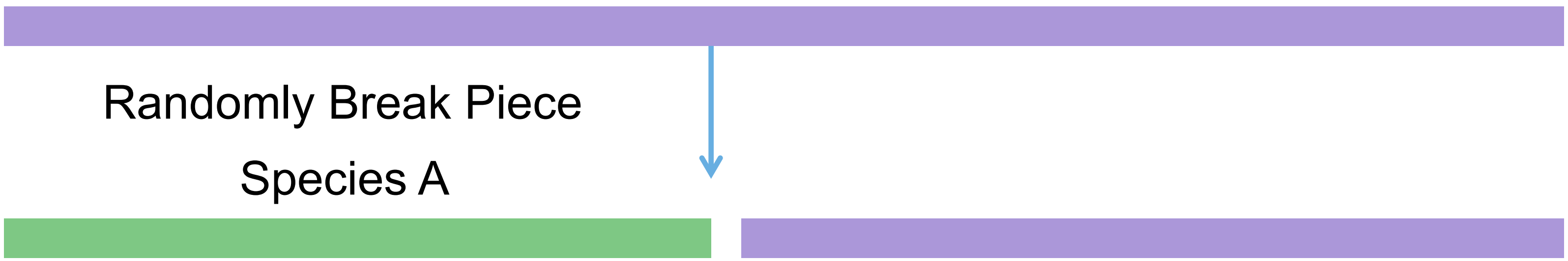
Preston's sampling veil

- Some things are so rare that that we do not observe them
  - Makes sense for certain datasets – particularly abundance data.
  - Does not make as much sense for other types of data.



Broken sticks and plates

- "Niche" apportionment models



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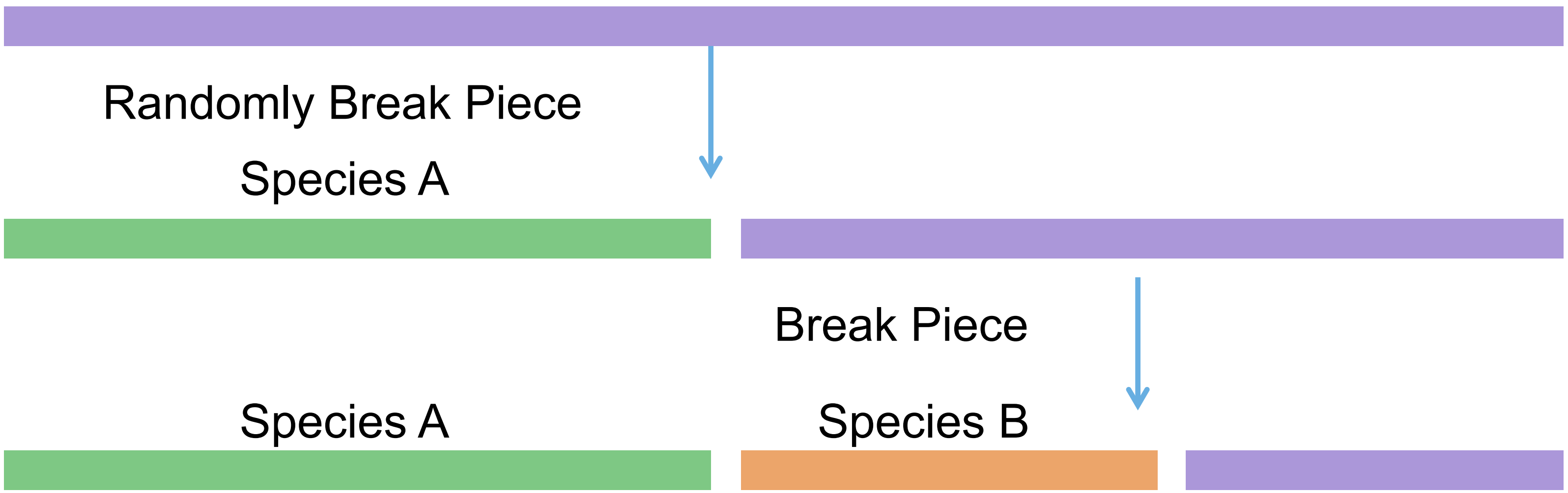
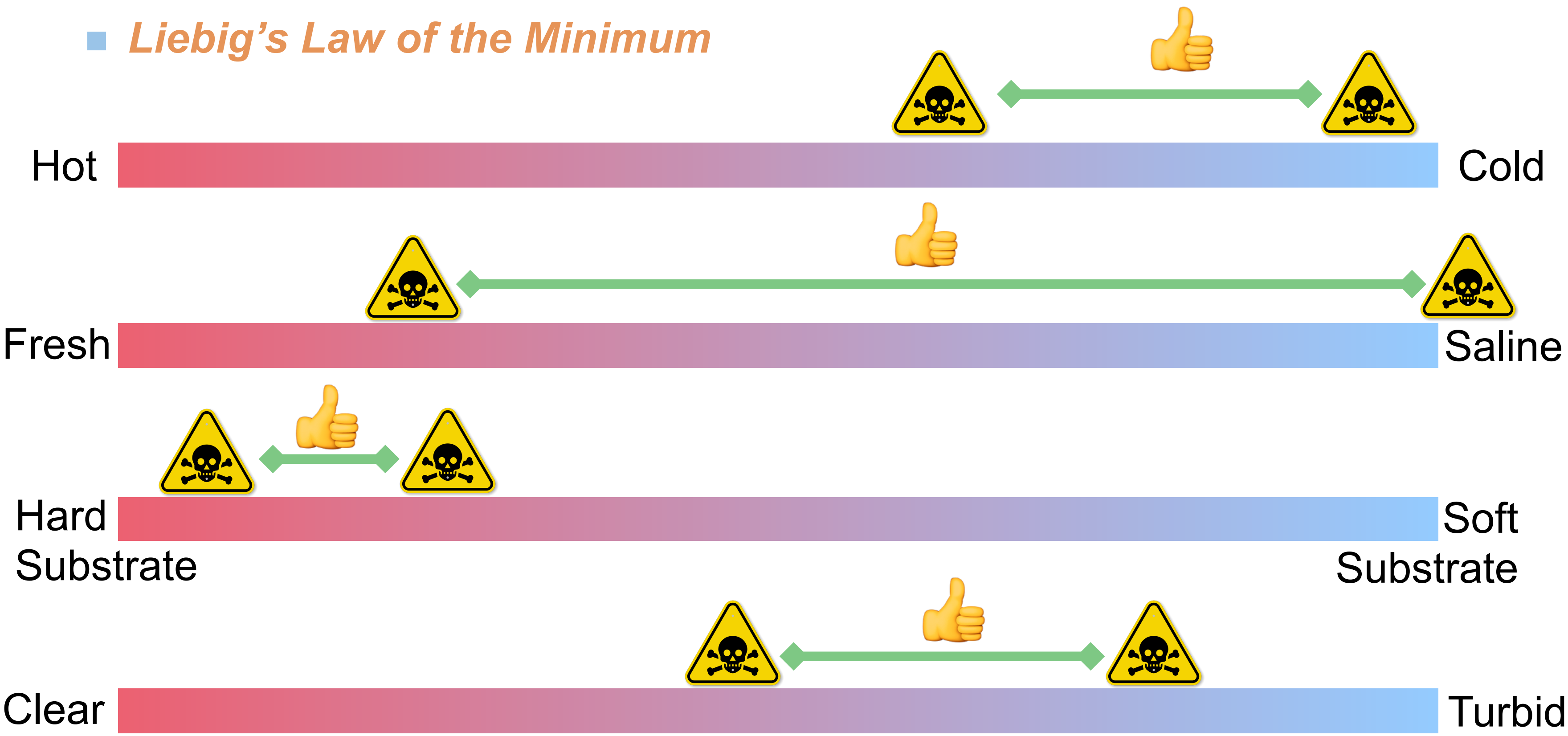


Broken sticks and plates

- “Niche” apportionment models
  - Assumes strong competitive exclusion

The one true answer

- Robert Whittaker 1967
  - Shelford's Law of Tolerance
  - ***Liebig's Law of the Minimum***



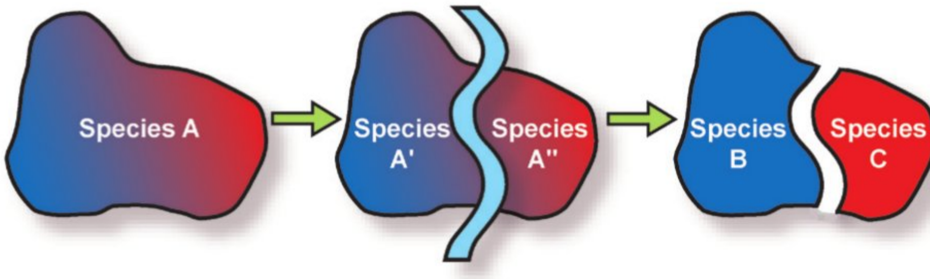
Liebig implies multiplicative systems

SUCCESS FAILURE

Temperature		Salinity		Substrate		Light		Acidity
$\frac{1}{2}$	x	$\frac{1}{2}$	x	$\frac{1}{2}$	x	$\frac{1}{2}$	x	$\frac{1}{2}$

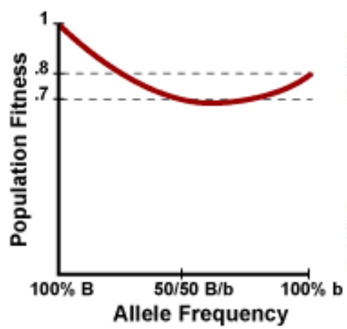
$= \frac{3}{100}$ Is the probability of success

A single failure stops everything



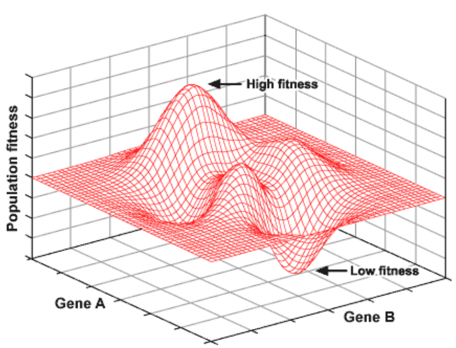
VICARIANCE SUCCESS

Genotype	Phenotype	Fitness
BB		1
Bb		.7
bb		.8



MORPHOLOGICAL DIVERISTY

FITNESS DIFFERENTIAL



NO DRIFT
STUCK IN VALLEY

All phenomena are connected