The Ecological Niche Part 1: Competition

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Biol 417: Evolutionary Ecology

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Review

Meteorology and biogeography

Over the past week we have covered how meteorology, climate, and geography govern the physical properties of any given place on Earth. This dictates which strategies are effective/not in any environment, in turn dictating the structures of ecosystems, a phenomenon termed 'Biogeography'.

Meteorology and biogeography form the backdrop against which any evolutionary/ecological phenomenon must be considered.

Today we will continue along this line of thought and talk about the ecological 'niche'.

Niche History

The Ecological Niche

The field of biogeography focuses on understanding spatial patterns of ecological communities.

Source: Wikipedia

Biogeographers quickly realised that some species are abundant in certain locations but non-existent in others.

I.e., there are conditions where they do well, and others there they can't survive and reproduce.

The Grinnellian Niche

In 1917, Grinnell (1917) used the word ‘niche’ as an umbrella term to describe the range of environments and conditions that the California Thrasher inhabits.

Source: https://birdsoftheworld.org/

The Grinnellian Niche cont.

Grinnell was interested primarily in describing the abiotic factors underpinning where a species could occur.

A species' 'Grinnellian' niche is defined by abiotic variables (e.g., temperature, precipitation, solar radiation, soil conditions, etc...).

But what about species interactions (e.g., predation, competition, symbiosis, etc...)?

The Grinnellian niche provides no framework for understanding a species' place in the environment in relation to **biotic** factors. (major limitation)

The Eltonian Niche

Ten years later, Elton (2001) extended the definition of the niche to mean a species' "... place in the biotic environment, its relations to food and enemies."

Conceptually, the Eltonian niche introduces the idea of a species' response to and effect on the environment.

Elton emphasised that species not only grow and respond to environmental conditions, but that they also change the availability and behavior of those factors as they grow. (!)

The Eltonian Niche cont.

The Eltonian niche helped (evolutionary) ecologists conceptualise complicated ecological relationships that have been playing out over evolutionary timescales.

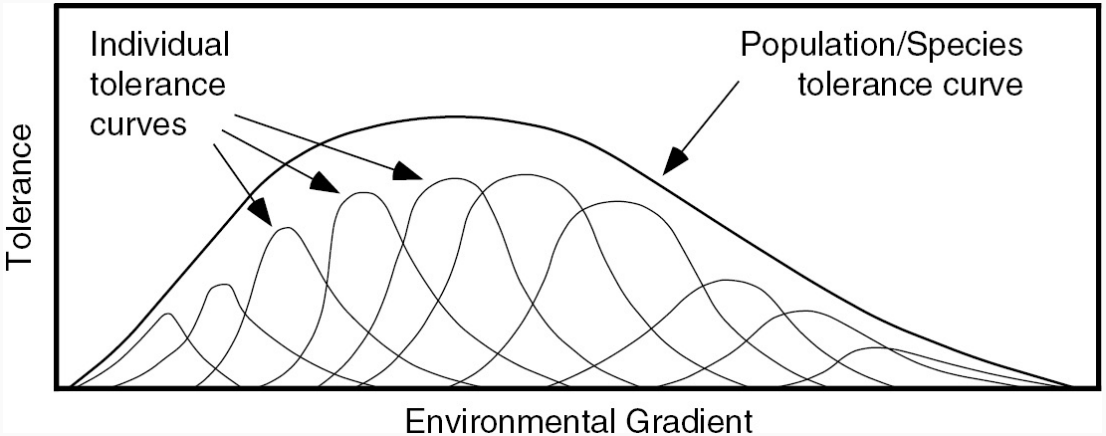
It has (and continues to) served ecologists well for nearly a century, but it has a major shortcoming:

How do we quantify a niche?

The Hutchinsonian niche

At the 1957 Cold Spring Harbor Symposia on Quantitative Biology there was a debate around the niche concept. After the conference Hutchinson (1957) wrote a paper called "Concluding Remarks".

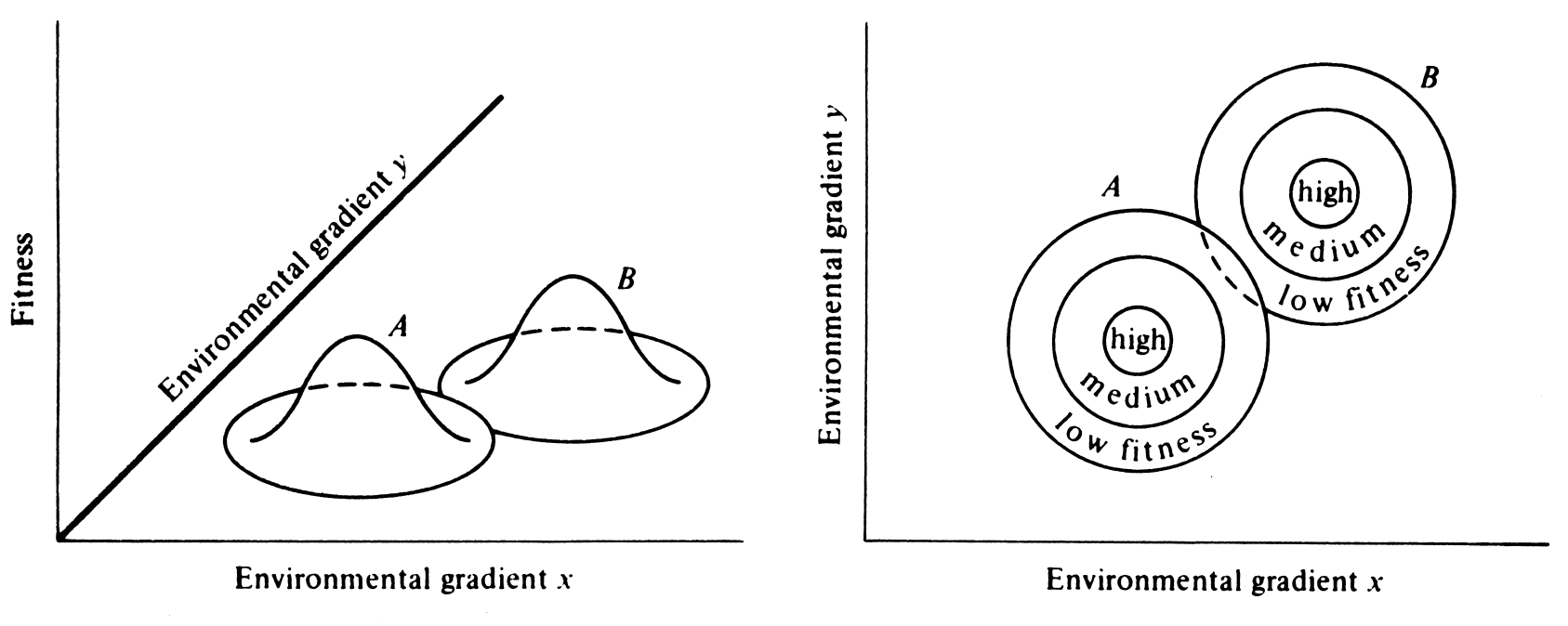
He started with the idea that plots of fitness versus a single environmental gradient usually look like bell-shaped curves



Source: Pianka (2000)

The Hutchinsonian niche cont.

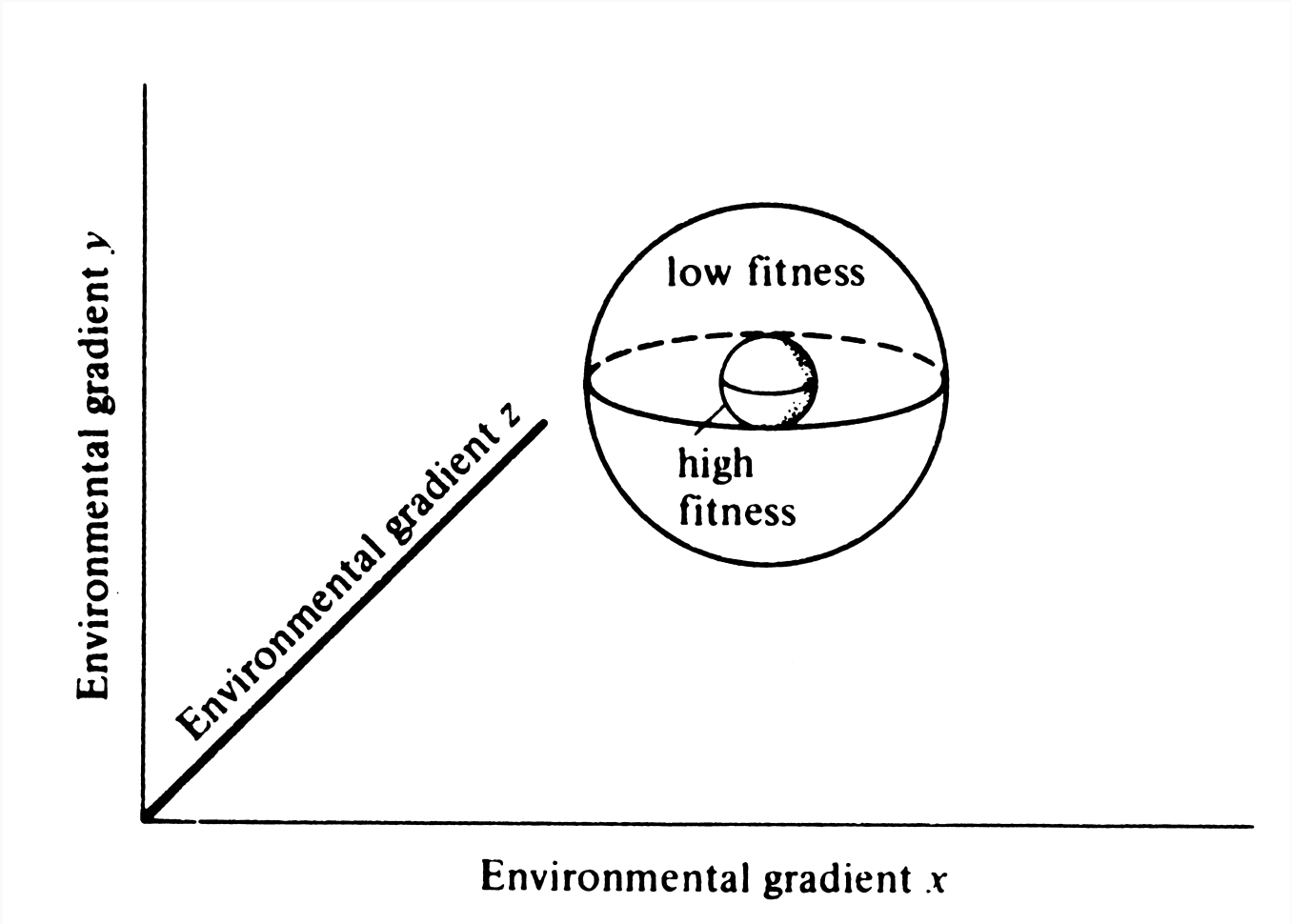
You can easily extend the idea to two different environmental variables



Source: Pianka (2000)

The Hutchinsonian niche cont.

... and to three different environmental variables

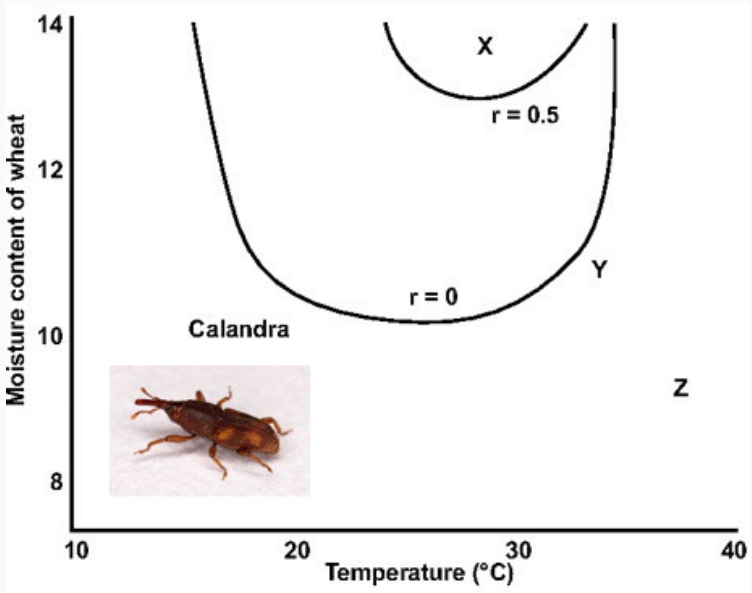


Source: Pianka (2000)

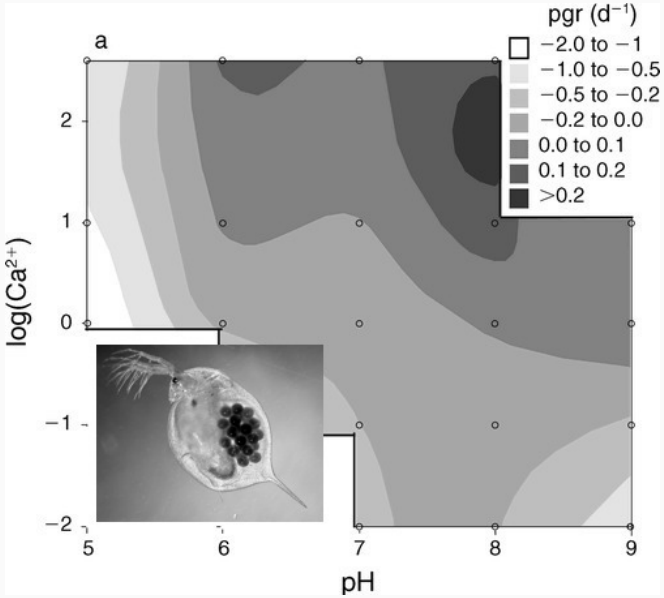
The Hutchinsonian niche cont.

... and so on for any number of axes generating an **n-dimensional hypervolume** enclosing the complete range of conditions under which it can successfully replace itself.

Volume where a species' growth rate, r_0, is ≥ 0 are inside the niche, volume with $r_0 < 0$ are outside the niche.



Calandra oryzae, source: Birch (1953)



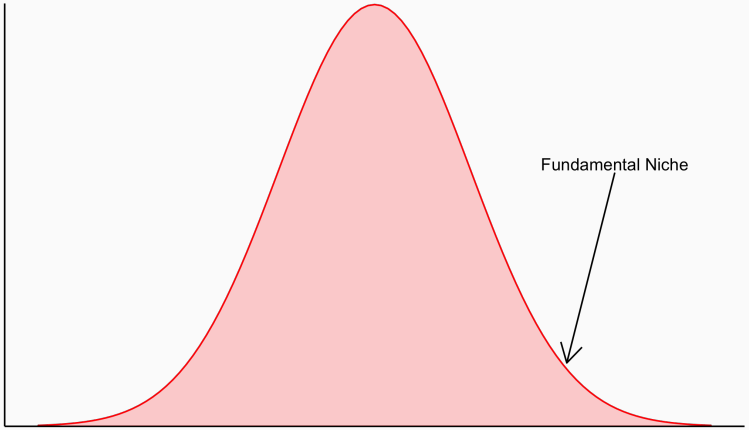
Daphnia magna, source: Hooper *et al.* (2008)

Niche Overlap and Competition

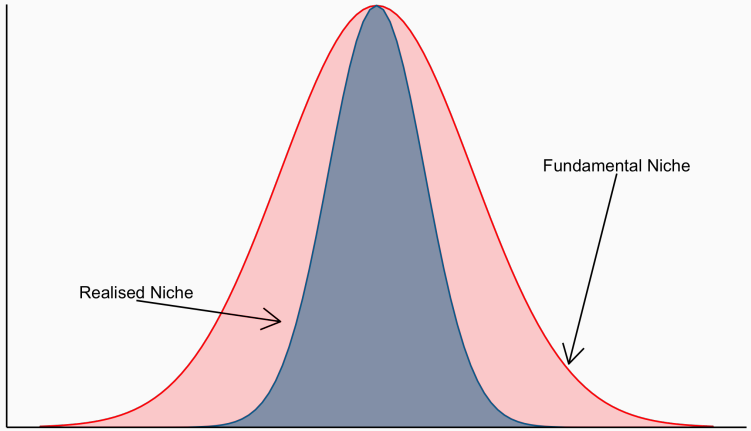
Fundamental vs. realised niches

Hutchinson's n-dimensional hypervolume niche identifies all the conditions under which a species can live, grow, and replace itself.

This space is called the **fundamental** niche



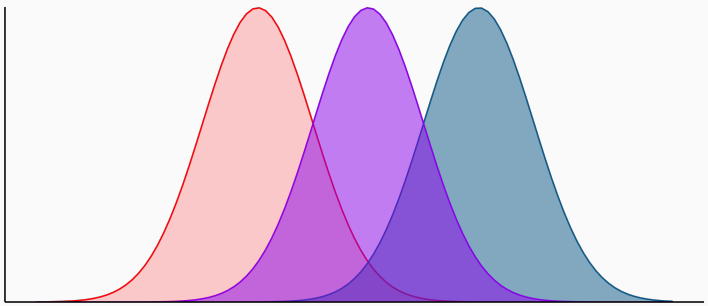
Most species only occupy a fraction of their fundamental niche: i.e., the **realised** niche

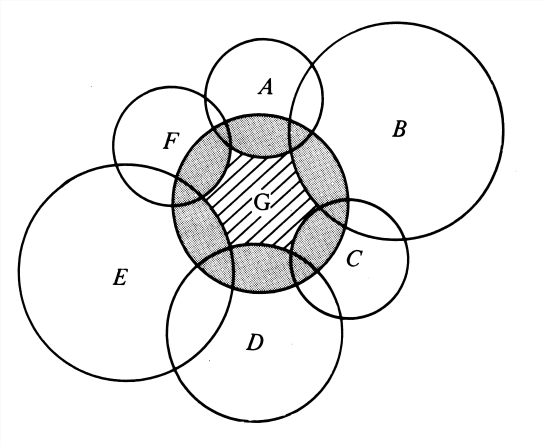


Niche Overlap

In trying to explain discrepancies between fundamental and realised niches Hutchinson focused on the concept of niche overlap and competition.

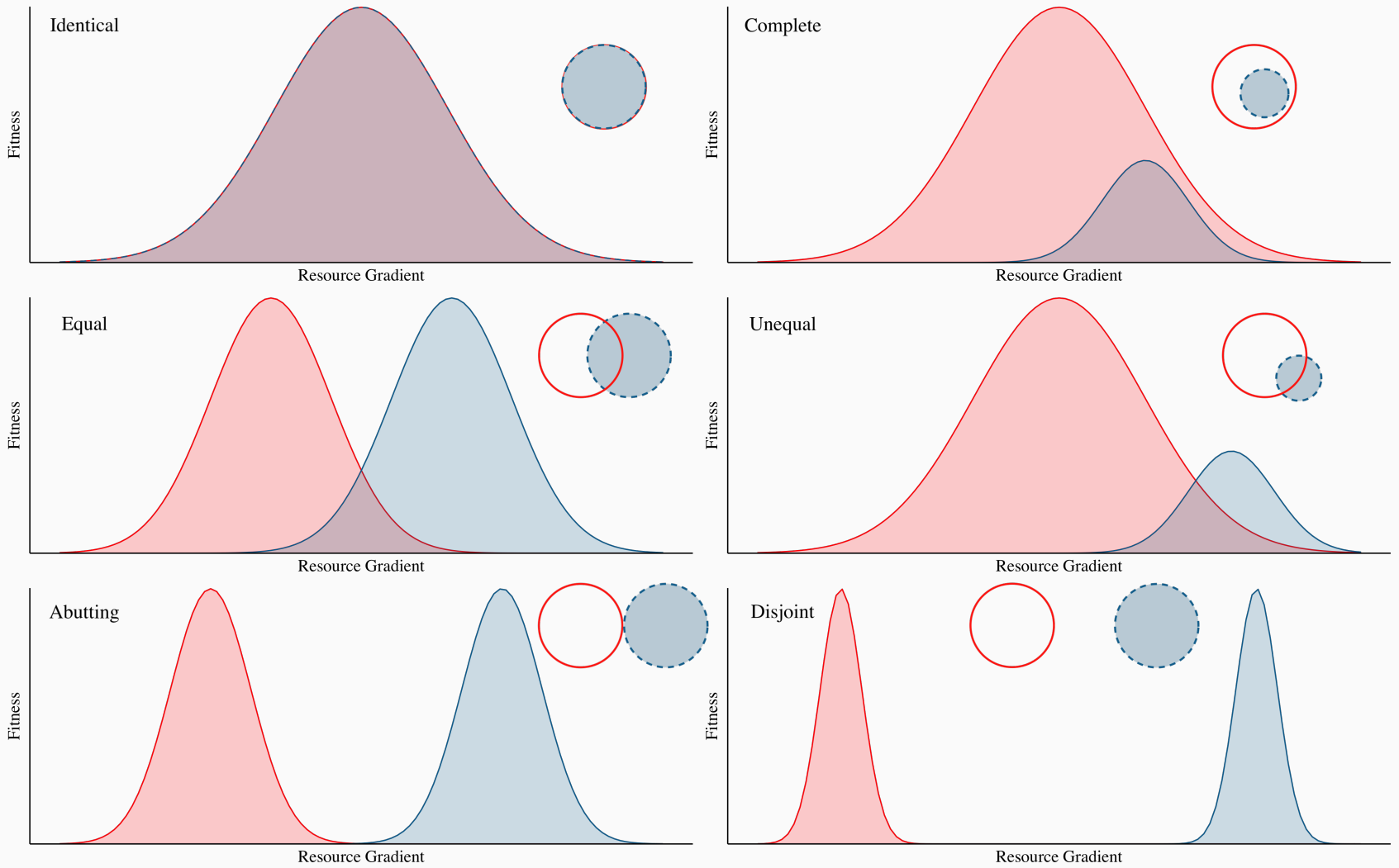
He argued that habitats should be fully saturated and niche overlap should not be permitted (i.e., overlap $\rightarrow$ competitive exclusion).





Niche overlap cont.

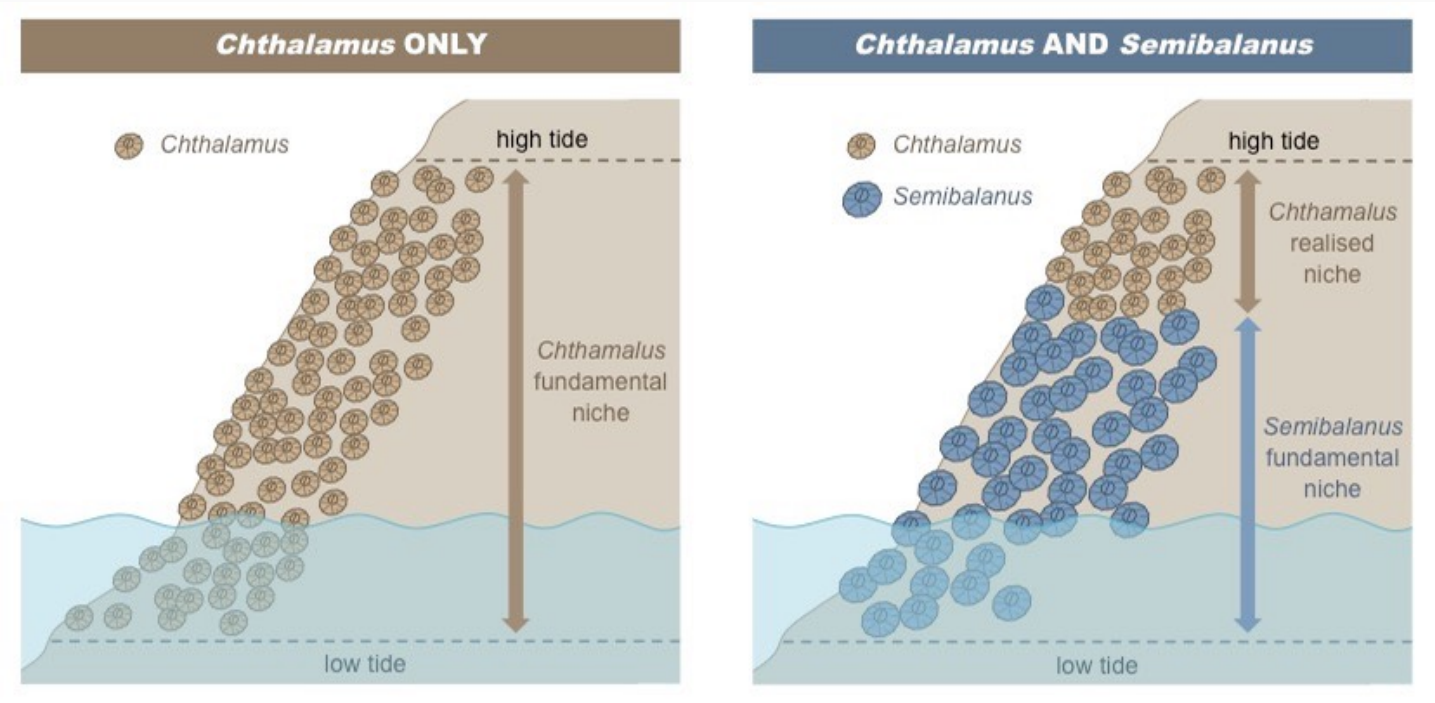
Potential scenarios:



Based on: Pianka (2000)

Competitive exclusion

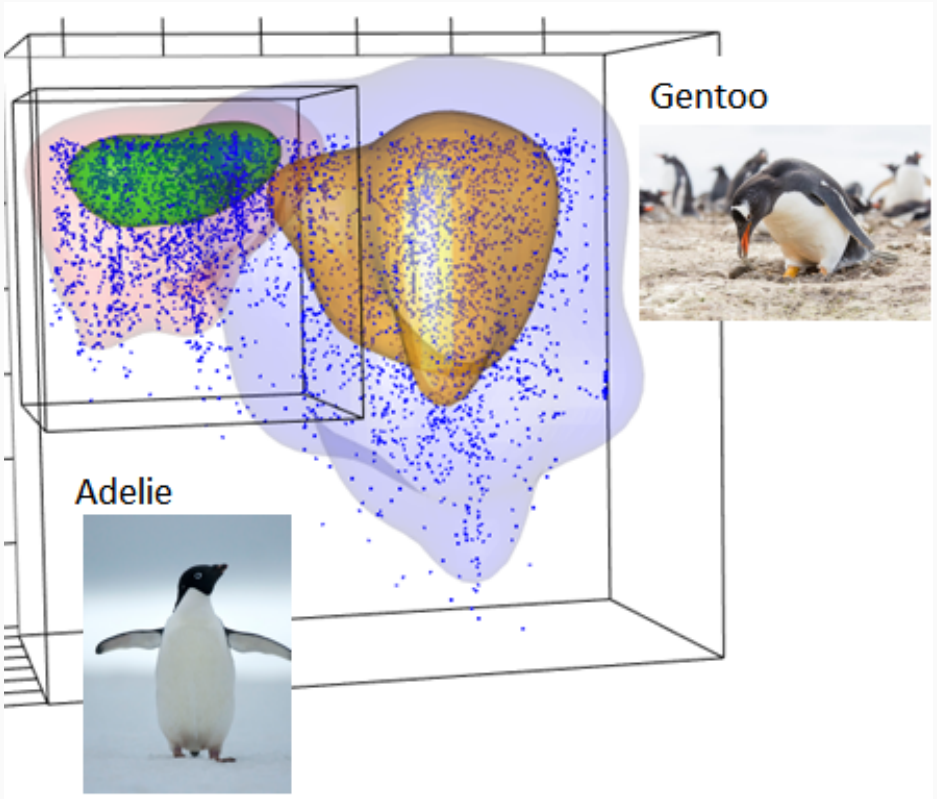
Finding: discrepancies between fundamental and realised niches were the direct result of competitive exclusion.



Based on: Connell (1961)

Niche partitioning

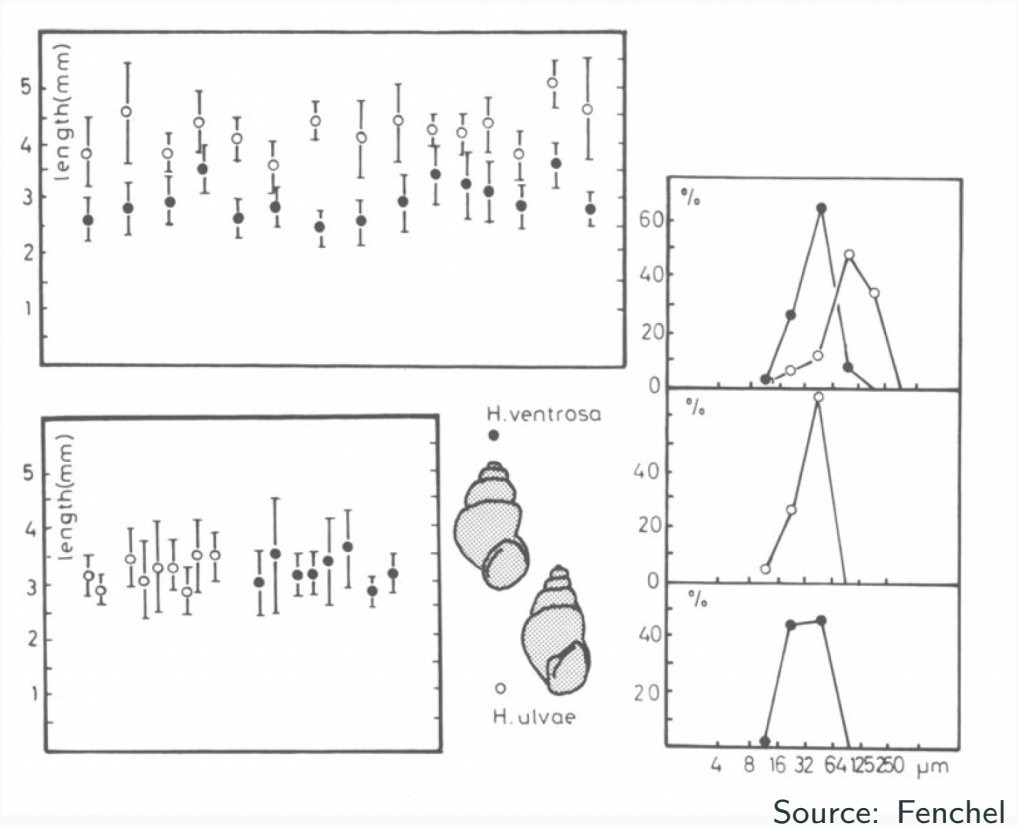
Gentoo (*P. papua*) and Adélie (*P. adeliae*) penguins are ecologically similar and feed primarily on Antarctic krill (*E. superba*). Spatially distinct foraging niches permit co-existence.



Source: Pickett *et al.* (2018)

Niche partitioning 2

When two species of mud snails (*Hydrobia spp.*) occupy different habitats, their shell sizes are identical and they specialise on food of the same size. When they occupy the same habitat they each specialise on food of different sizes and their shell sizes differ.



Source: Fenchel & Christiansen (1977)

Overlap without competition

Problem: No explanation for niche overlap without competition.

Source: http://www.clydesideimages.co.uk/

Overlap without competition cont.

Hutchinson (1957) laid out assumptions to translate the **qualitative** concept of a niche into a **quantitative** concept. Making these assumptions introduced three important limitations/properties into his framework:

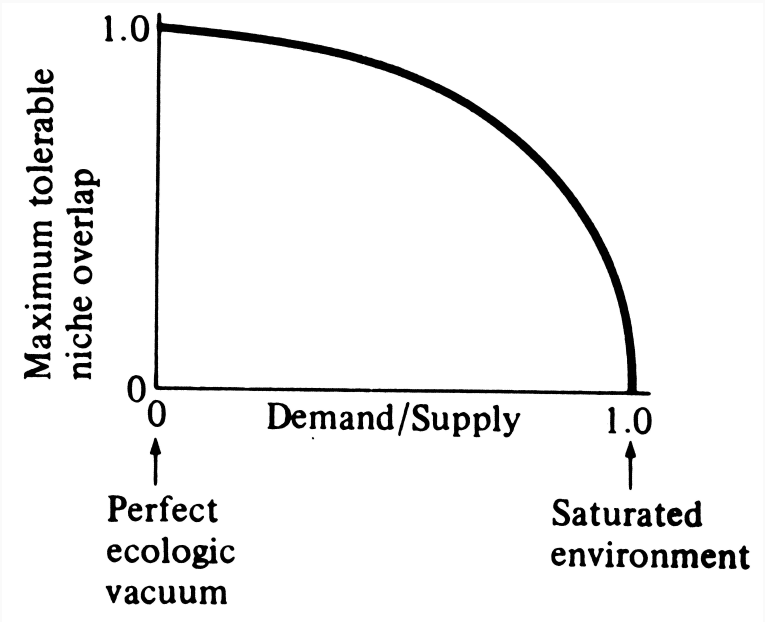
1. Saturation
2. Dimensionality
3. Non-competitive interactions

Saturation

Hutchinson (1957) assumed that the world is completely saturated.

Under this scenario, any niche space given is niche space lost, so competition is fierce. Are we prepared to make that assumption?

The amount of tolerable overlap will depend on resource availability.

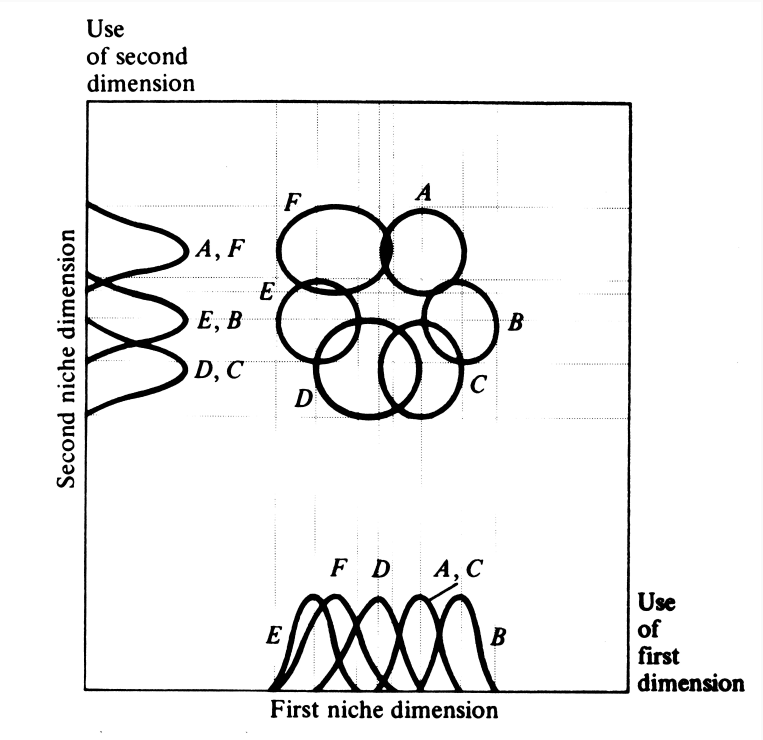


Source: Pianka (2000)

Dimensionality

Hutchinson (1957) defined an n-dimensional hypervolume.

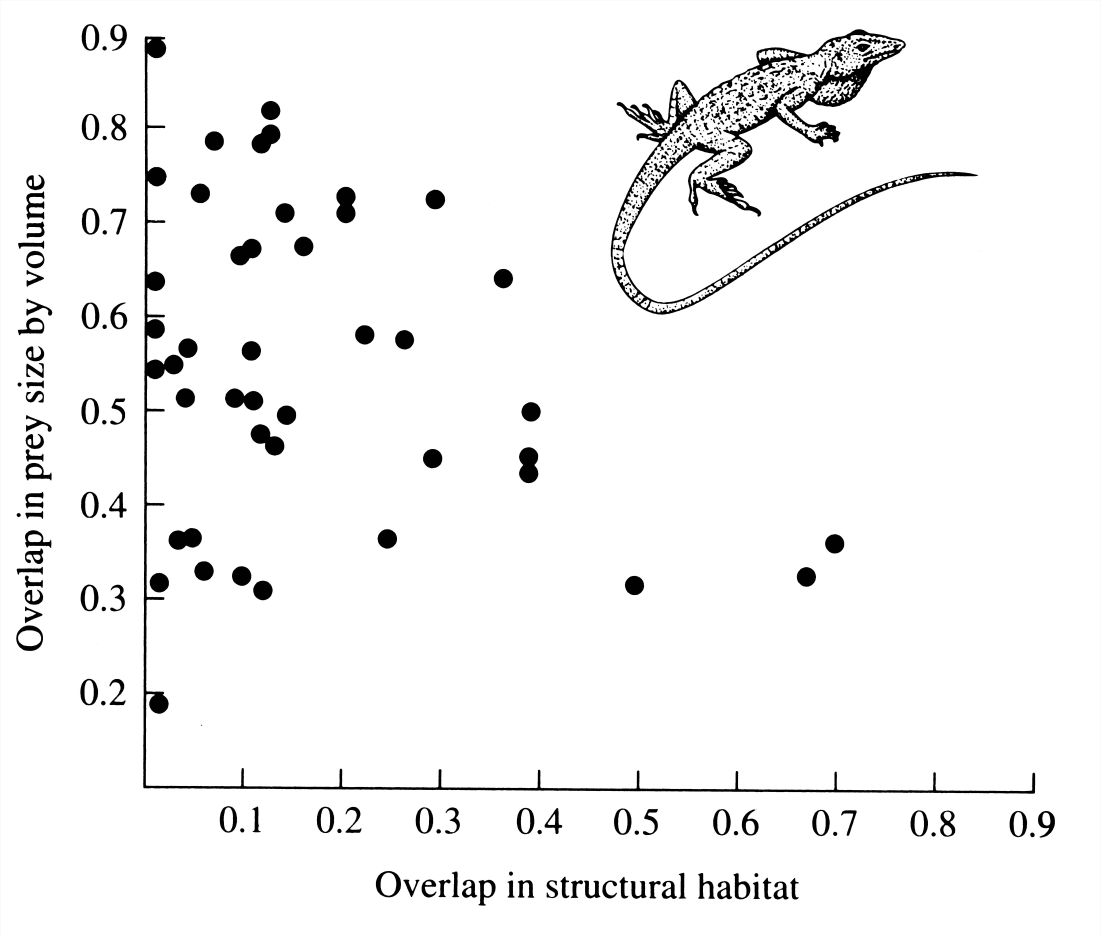
Niches are usually evaluated across 1-2 axes, but overlap on one dimension doesn't mean overlap across the entire hypervolume.



Source: Pianka (2000)

Dimensionality cont.

In *Anolis spp.* lizards, pairs of species with high dietary overlap often exploit different structural microhabitats.



Source: Schoener (1968)

Non-competitive interactions

Hutchinson (1957) focused on competitive interactions and assumed any niche overlap decreased r_0

... but there are many conditions where niche overlap can increase r_0 (e.g., predator saturation, many eyes, etc...).

Source: http://www.clydesideimages.co.uk/

Take home messages

The concept of the niche is central to evolutionary ecology (understand a species' fundamental vs. realised niche and you can understand much of its evolutionary ecology).

Quantifying a species' entire niche space is borderline impossible, but quantifying too few dimensions can ignore important separation.

There is no perfect framework for studying niches, but in doing so we have learned a lot about how species exist and co-exist.

We will continue along this train of thought next lecture...

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