The Ecological Niche Part 4: Environmental Adaptation

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Biol 417: Evolutionary Ecology

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Review

Review

Last week we saw how the concept of the ecological niche provided us with a framework for understanding competition, competitive exclusion, and generalist vs. specialist strategies.

Today we will focus on how the niche concept can help us understand responses to environmental change.

Adaptation and Environmental Change

Environmental tracking

Everything we have been talking about last week relies on the assumption that organisms track environmental change (biotic and abiotic), and that this is reflected in their niche.

But niche changes over **evolutionary** time are extremely difficult to document.

Most of our experimental evidence comes from microorganisms with short generation times.

Dallinger (1887)

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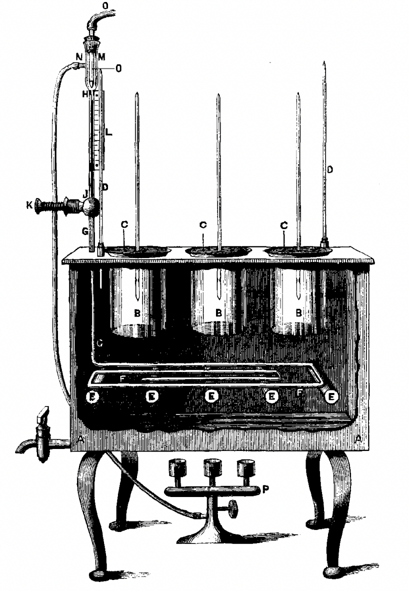


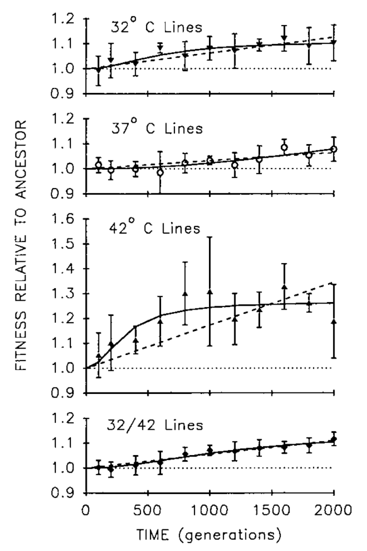
Source: Dallinger (1887)

Dallinger (1887) took a founding population of bacteria that grew between 15.5-18.3°C and reared them at steadily increasing temperatures.

Adaptation: After 7 years the population thrived at 70°C.

Cost: The founding pop. died at 70°C and the evolved pop died at 15.5°C.

Bennett et al. (1992)



Source: Bennett *et al.* (1992)

Bennett *et al.* (1992) took a founding population of *E. coli* and reared them under fixed or variable temperatures.

After 2,000 generations the populations all exhibited better fitness under the novel conditions.

Not all populations evolved at the same rate (37°C = slow, 42°C = fast).

A note on environmental change

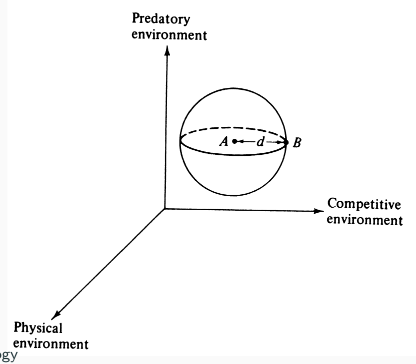
Environmental change doesn't necessarily mean abiotic change (e.g., temperature, rainfall, solar radiation, etc...).

Competition, predation, lack of symbionts/mutualists, parasites, disease, etc... all impact the suitability of any given habitat in space and time.

Environmental adaptation

Organism track environmental change, are never perfectly adapted to their environment.

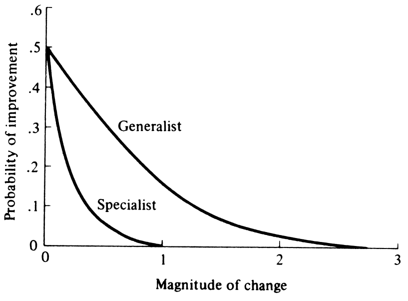
Assuming perfect adaptation lies at a particular point (A), any real organism will be at another point (B), and some distance (d), away from the point of perfect adaptation (Fisher, 1958).



Source: Pianka (2000)

Environmental adaptation cont.

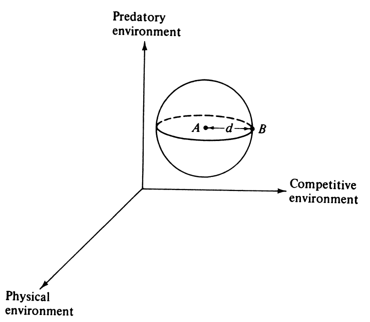
Small random changes in the 'location' of A or B have a 50:50 chance of reducing d, but large changes are *always* maladaptive because large changes in the right direction will overshoot the point of perfect adaptation (think of focusing a microscope or pair of binoculars).



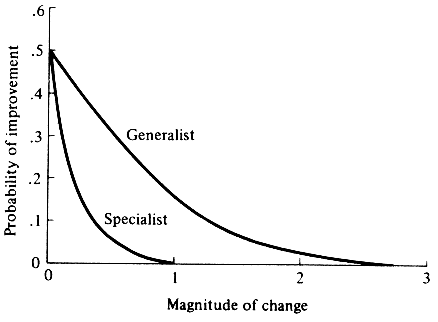
Source: Pianka (2000)

Environmental adaptation cont.

Organisms (A) track their environment (B) over evolutionary timescales, but anything that causes a fast, large change in d will seriously challenge survival and fitness (we will revisit this concept again when we start thinking about evolutionary conservation).



Source: Pianka (2000)



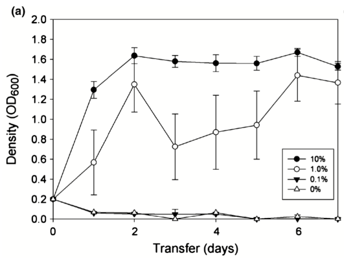
Source: Pianka (2000)

P. aeruginosa is a species of bacteria that causes serious illness in humans.

Source: cdc.gov

Perron *et al.* (2008) reared *P. aeruginosa* under quick vs. gradual antibiotic exposures and also varied immigration rates.

Under rapid environmental change pops. without immigration went extinct.



Perron *et al.* (2008)

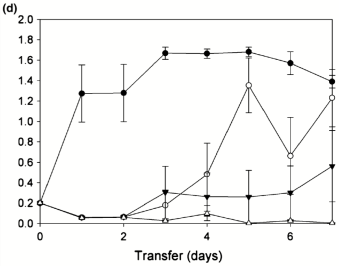
Pseudomonas aeruginosa

P. aeruginosa is a species of bacteria that causes serious illness in humans.

Source: cdc.gov

Perron *et al.* (2008) reared *P. aeruginosa* under quick vs. gradual antibiotic exposures and also varied immigration rates.

Under gradual environmental change, fewer pops. went extinct.



Perron *et al.* (2008)

Organisms can track gradual environmental change (e.g., Dallinger, 1887; Bennett *et al.*, 1992), but fast/large changes are always maladaptive (e.g., Fisher, 1958; Perron *et al.*, 2008).

What constitutes a fast/large change?

Reproduction and Environmental Change

Southwood (1977)

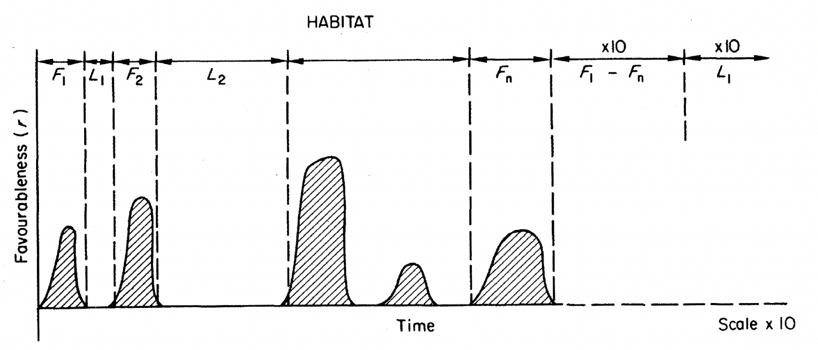
Southwood (1977) argued that organisms should base the decision on reproductive strategies according to a 2x2 space/time matrix:

		Time	
		Now	Later
Space	Here	$r_a \pm \sigma_a^2$	$r_b \pm \sigma_b^2$
	Elsewhere	$r_c \pm \sigma_c^2$	$r_d \pm \sigma_d^2$

The option(s) with the largest r values and lowest variances (σ^2) should be favoured.

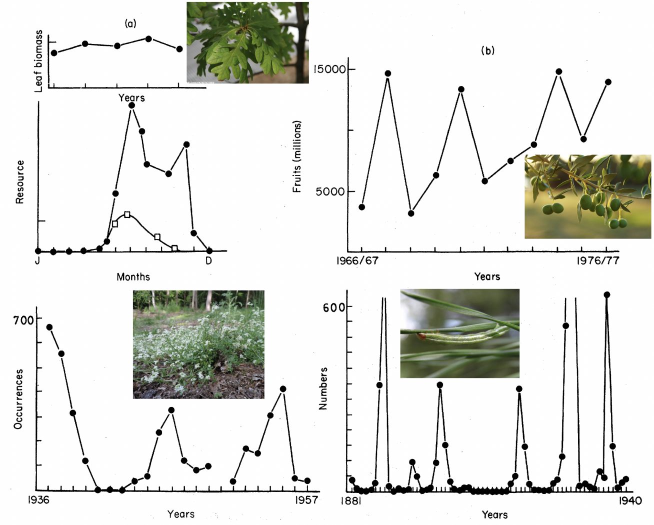
The question then is how do changes in habitat quality influence reproductive outcomes?

Let's assume any given habitat has periods of time favourable to reproduction (F_i), and unfavourable periods (L_i)



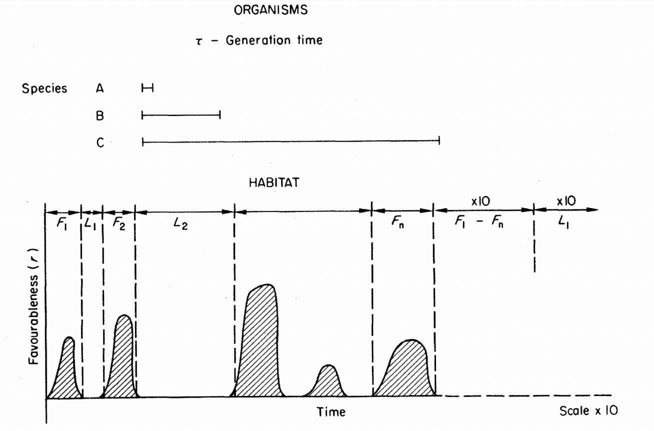
Southwood (1977)

Southwood (1977) cont.



Southwood (1977)

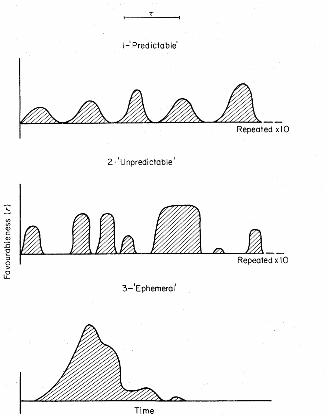
The duration of the (un)favourable periods relative to organisms' lifespans (τ) will be critical in determining whether a population can persist in an environment.



Southwood (1977)

Southwood (1977) cont.

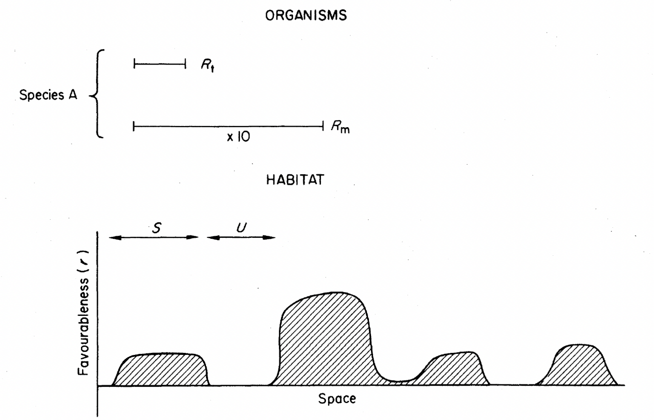
The predictabiliity of the (un)favourable periods is also critical (again relative to organisms' lifespans τ).



Southwood (1977)

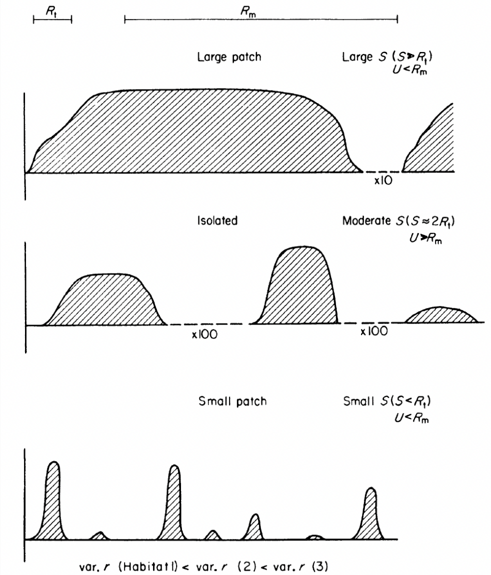
Southwood (1977) cont.

Organisms' 'day-to-day' R_t, and migratory R_m vagility will determine the extent of spatial patterns in (un)favourability they can cope with.



Southwood (1977)

Southwood (1977) cont.



Southwood (1977)

Southwood (1977) cont.

Stable habitats where $F \geq \tau$ will favour population growth.

Stochasticity or environmental change that cause $F < \tau$ and/or $L \geq \tau$ will challenge survival and reproductive capacities.

Short-term temporal stochasticity can be overcome by moving to favourable patches when $U \leq R_t$.

Long-term temporal stochasticity can be overcome by moving to favourable patches when $U \leq R_m$.

When $F < \tau$, $L \geq \tau$, and $U > R_t$ and R_m population sizes will decline.

Take home messages

Organisms track environmental change over evolutionary timescales but fast/large environmental change will always challenge survival and fitness.

The magnitude and duration of the change need to be put in the context of the species' biology.

Over ecological timescales, long-lived species with poor mobility are more susceptible to environmental change, short-lived, mobile species can cope with more environmental change.

As a corollary, short-lived species are more likely to evolve adaptations to counter environmental change.

References

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