Lecture 2

Organism/Environmental Interactions

Patterns of distribution and abundance of a species are a product of:

1. geological history of a species - plate tectonics.
2. the resources required to make a living.
3. Rates of births, deaths and migration (i.e. abundance).
4. interactions with other species (may be excluded by the presence or absence of other species).
5. Effects of the abiotic (physical) environment.

Over evolutionary time physical (abiotic) forces can be overcome via natural selection for traits that can overcome physical limitations.

Physical limitation is more likely to be a proximate explanation rather than an ultimate. That is "how" a species range is restricted rather than "why".

e.g. range of species may be limited by a temperature isotherm – but the ultimate explanation is that competition with other species restricts its range. It has simply acclimated to a specific set of conditions better than its competitor.

This lecture is concerned with the abiotic conditions that can effect distribution and abundance. Common examples include temperature, humidity, pH, salinity, current velocity, etc.

Environmental conditions are usually expressed as a gradient and the performance of individuals in a population will generally vary over this gradient.

Imagine a multi-dimensional array of factors -> Limiting factor(s) will define range of distribution.

As an example we’ll consider temperature since it is perhaps the single most important physical factor affecting all organisms, particularly in terrestrial environments.

Contrast:

**endotherms** (homeotherms), species that regulate their temperature by production of heat within their body.

vs.

**ectotherms** (poikilotherms), species who gain or loss of heat through their behavior – organisms generally restricted to warm or moderate climate (or either adapted for prolonged hibernation, or state change, e.g. overwintering egg stage).

Basically birds and mammals vs. plants, insects and cold-blooded vertebrates.

Ectotherms modify their gain and loss of heat through their behavior.

Costs – associated with being ectothermic is that the activity period is dependent on climate. This imposes limitation on developmental time.

For example, emergence in insects depends on number of suitable degree-days above some threshold.

Benefits – less energy required during lifetime, very efficient.

When costs > benefits, ectothermy will be selected against.

For ectotherms:

@ high temperatures, death due to enzyme inactivation, metabolic inbalance, dehydration.

@ low temperatures, generally able to withstand as long as not freezing.
As a rule –metabolic efficiency increases 2.5x with every 10°C. Reproduction only occurs at high temperatures. If ectotherms experience conditions beyond the normal range of tolerance they:

1. Die
2. One stage of life-cycle dies but persists as asexual or sexual eggs, cysts, seeds, etc. (e.g. invertebrates and plants).
3. Move to protected microhabitat- hibernate, reduce metabolic rate to save energy (e.g., reptiles, fish).
4. Migrate (insects – e.g. monarch butterfly).
5. Acclimate

Acclimation refers to the ability to function beyond the normal range of tolerance.

Ability to acclimate evolved in situations where environmental is predictable. In doing so organisms can extend their range (e.g. fire ants -> since introduction in 1950’s have increased range of tolerance).

Acclimation involves production or activation of different enzymes, not immediate, requires slow change. Examples, include corals acclimated to ultraviolet light levels. Show differences in survivorship based on depth of origin.

Differences in range of tolerance may not always be a function of acclimation (phenotypic plasticity) but rather genetic differences.

Can perform simply "garden experiment" to test whether tolerance is determined by one or the other. How?

Transplant individuals between environments. Potential outcomes are:

1. individuals do not change degree of tolerance (limited acclimation) -> genetic.
2. Individuals change to match new environment -> phenotypic plasticity.
3. If both genetic and phenotypic plasticity occur the change will be intermediate (acclimation potential genetically determined).

**Endotherms**

Can regulate temperature effectively at 30-40°C, but spend lots of energy doing so. Like ectotherms they have optimum body temperature but unlike ectotherms where temperature maximizes body heat production, temperature for endotherms minimizes heat production, i.e., lower energetic costs.

Contrast: ectotherms and endotherms as:

**Ectos** - low cost/low benefit strategy (ok if environment is moderate, e.g. fish or reptiles in aquatic environments).

Fact: diversity of reptiles and amphibians and aquatic vertebrates such as fish highest in tropics.

**Endos** - high benefit/high cost but constancy in performance. Tend to have wider distribution than ectos both temporally and spatial.

Evolved patterns in endothermic organisms:

**Allen’s rule** -> shorter extremities with increasing (higher) latitude.

**Bergman’s rule** -> overall larger body size increases with higher latitudes

Allen’s and Bergman’s rule describe reduction in surface area resulting in reduce loss of body heat.
In addition, **Insulation** is an adaptation. e.g. feathers, fur, etc. (conserves heat loss).

**General patterns:**

**Aquatic organisms**: ectotherms

**Terrestrial organisms:**

1. Low latitude – ectos and endos
2. High latitudes – endo, ectos with overwintering stage.

Other examples of physical forces: **Light**

Light is particularly important to plants since they rely on photosynthesis for most of their energy.

**Effects on morphology as a function of depth and light regime** (Hay 1986).

Sargassum (brown algae) – species with differences in thalli (=leaves/stems) width and degree of branching as a function of depth:

- **Shallow**: thalli are multi-layer and narrow.
- **Deep**: thalli are few, blade like and wide.
- **High light regime in shallow water**: Narrow thalli are multilayered and collect light most efficiently.
- **Low light regime thalli** are few and broad, minimize overlay between thalli to maximize light capture.
- **Direct relationship between blade width and depth**: (high light narrow, low light wide).

**Conclusion**: light levels shape morphology and can determine distribution of a species.

Other examples include effects of light on distribution of corals.

Here corals in deep water are more susceptible to high levels of ultraviolet light compared to those in shallow water.

**Why?** because deeper-dwelling corals have lower levels of uv blocking pigments.

**Salinity effects**: species of amphipod crustaceans show variability in tolerance to salinity.

Some species are **stenohaline**, others **euryhaline**.

**Summary of environmental effects:**

1. Lethal conditions limit distribution, need only occur occasionally.
2. Distribution most often limited by suboptimal conditions – below reproductive threshold.
3. Sub-lethal conditions expose individuals to negative interactions with other organisms.
4. Negative effects can be moderated by evolutionary, physiological, and behavioral responses.
5. Physical forces are important in determining patterns of distribution and abundance but may not be the ultimate factor.

**Applied considerations**: Application of concepts to environmental studies, i.e. pollution and bioremediation.

For example: Acidification of lakes and streams due to "acid rain" (emission of CO₂ causing lowering of pH in freshwater rivers and streams.

Other parameters – O₂, heavy metals, temperature, etc.

To develop guidelines limiting pollution one needs to know what levels of pollutants are tolerable. Need to develop ‘tolerance curves’ for various organisms.

Not only need know "single" pollutant effects but possible interactions between pollutants – could be additive or synergistic.