Organisms in Ecosystems

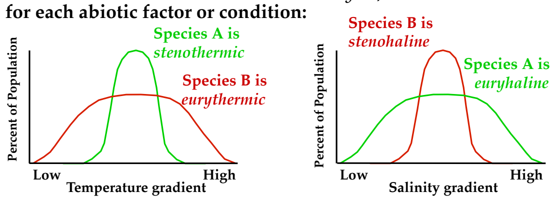
- **Organisms must reconcile their needs with what the environment provides**
  - **Organisms need a fairly constant internal environment. Because of entropy, organisms must acquire and use energy to maintain *homeostasis***
  - **Maintenance of homeostasis is possible only under a certain range of conditions (*tolerance limits*). These tolerance limits vary with the individual and over time and space**
  - **Organisms cannot do equally well in different environments (habitats). Distribution of organisms in habitats reflects environmental variation and evolutionary history**
- **Environmental challenges are countered by *adaptations*: inheritable traits that influence fitness**
  - **Adaptations are the product of *natural selection***
  - **Organisms must be adapted to abiotic conditions within the habitat, e.g., temperature, moisture, light, radiation, salinity, pH, and gravity**
  - **Organisms generally live in habitats together with organisms with similar requirements. Must be adapted to these *competitors***
  - **Organisms must also be adapted to *diseases, predators, parasites*, etc.**

Limiting Factors

- **When limits for one or a few factors that affect homeostasis are approached, those factors generally become most important in determining survival, that is, they become *limiting factors***
  - **Proposed by Liebig (1840) as " The Law of the Minimum": the growth and/or distribution of a species is dependent on the one environmental factor that is in shortest supply**
  - **Important in understanding physiological limits on animal distribution and abundance**
- **The exception is when one factor changes the tolerance for limitation of another (e.g., temperature and salinity), or when a second substance can substitute for another when availability of the first is limited (e.g., Sr for Ca in coral skeletons)**

Tolerance Range

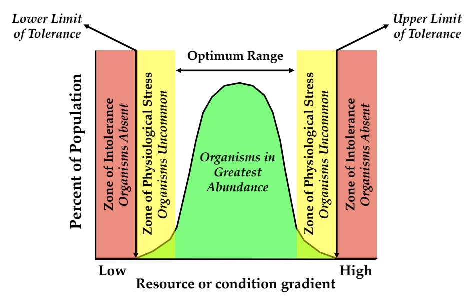
Can be narrow ('*steno-*') or broad ('*eury-*'), and is different for each abiotic factor or condition:



- **Tolerance ranges differ both within and between populations (populations with fixed and genetically-determined tolerances are called *ecotypes*)**
- **The tolerance range for one factor may affect tolerance ranges for others**
- **Tolerance ranges can change with different seasons, lifestyle stages, condition, age, etc.**

Tolerance Range

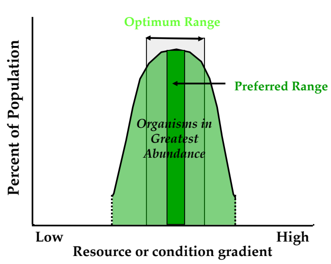
Shelford (1940) *Law of Tolerance* - For each abiotic factor or condition, there is a range within which an organism can survive and reproduce



Zones of Tolerance Range

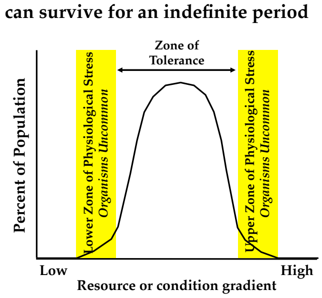
***Zone of tolerance* - central range at which the animal is most comfortable**

- **Within this range, there is often a narrower *optimal range* where the population does very well, and sometimes a *preferred range* that is actively sought out/and or competed for by individual organisms**



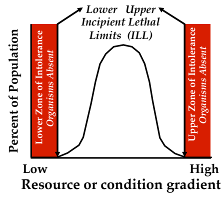
Zones of Tolerance Range

Zone of tolerance is bounded by an *upper* and *lower zone of physiological stress* (or *resistance*), within which the organism can survive for an indefinite period



Zones of Tolerance Range

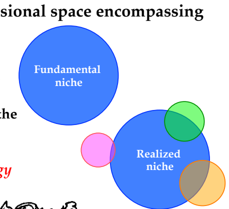
The bounds of the *upper* and *lower zone of intolerance* are determined by the *upper* and *lower* *incipient lethal limits* (*ILL*), respectively:



- ILL is the level where a stated fraction of individuals in a population (usually 50%) when brought rapidly to this level from a different level, will die within an indefinitely prolonged exposure
- ILL is not fixed, determined by previous acclimation history of the organism
- Acclimation has limits, however, and eventually the upper and lower *ultimate incipient lethal limits* are reached

Niches

- A 'living space' encompassing all of an organism's tolerance ranges defines the organism's 'profession' or *niche*
- G.E. Hutchinson described the niche as an "*n*-dimensional hypervolume": an imaginary, multi-dimensional space encompassing all of an organism's required resources and conditions
  - *Fundamental niche*: the full range of conditions to which the organism is or can be adapted
  - *Realized niche*: the (always) *smaller* portion of the fundamental niche that the organism actually gets to use

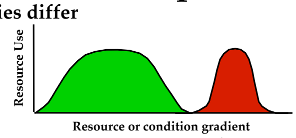


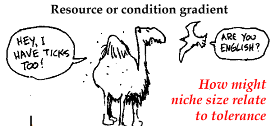
Humans are unique in that their use of technology has allowed then to hugely expand their niche

- Different species (*must*) occupy different niches
  - For example, some plants grow only on shady, moist, poorly-drained sites, while others live only on sunny, well-drained hillsides

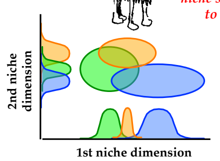
Niche Size and Overlap

- Niche sizes of different species differ
  - Species with wide (broad) niches are *generalists*
  - Species with narrow niches are *specialists*, e.g., starlings in England eat only the ticks off of sheep and deer
- *Niche overlap* occurs whenever two or more organisms use the same resource. May result in:
  - *Intraspecific competition* if organisms are the same species
  - *Interspecific competition* if organisms are different species



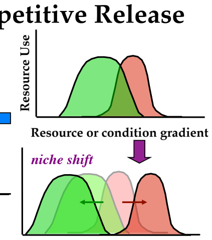


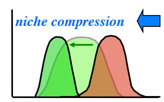
How might niche size relate to tolerance ranges?

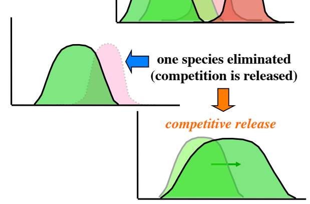


Niche Reduction and Competitive Release

- Competition may force some or all organisms with overlapping niches to:
  - Decrease the size of their realized niches (*niche compression*)
  - Alter their realized niches (*niche shift*)
- In contrast, if competition is released (e.g., if a species colonizes a new habitat with no competitors), then niche size may expand (*competitive release*)







"Normal" Physiology

- When environment is such that the organism is within tolerance limits for all factors, *"normal" physiology* occurs and the organism is free of *stress*

"Everybody knows what stress is and nobody knows what it is" – Hans Selye (1973)

- Often measured along a continuum from the molecular (e.g., induced proteins) to the ecosystem level (e.g., shifts in respiration:production or nutrient cycling)
- Most often, a measurement of "stress" is implied for any significant shift in a quality regardless of the level examined
  - *Direct indicators* (e.g., change in hormone levels)
  - *Indirect indicators* (e.g., increased intensity of parasite infection)

Four common qualities of stress at any level of ecological organization:

1) *Stress* is a response to or effect of an external factor (*stressor*) that is detrimental and disorganizing
2) The detrimental and disorganizing factor is atypical or present at atypical levels of intensity
3) The system responds by or is characterized by a modification in energy flow or system structure
4) Temporal qualities are central to the concept of stress: stress is a response to a *recent* stressor

Determining Effects of Stress

Follows the 'hierarchical organization of life':

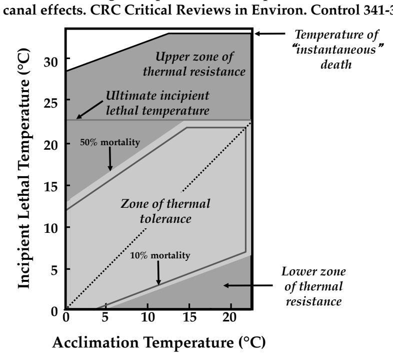
- *Subcellular*: molecular effects and biomarkers
- *Cellular*: cytotoxicological, histopathological, and genetic effects
- *Individual*: sublethal, acute, and chronic lethal effects
- *Population*: epidemiology, population genetics, population dynamics and demography
- *Community* and *ecosystem* (e.g, changes in biodiversity, P/R ratios)
- *Landscape*, *regional/ecoregional*, and *biosphere* (e.g., watershed pollution, changes in atmospheric chemistry)

Stress Effects on Individuals

- *Hormesis*: a stimulatory effect in response to exposures to low ("subinhibatory") levels of toxicants or physical agents
  - In ecology, this is associated with the so-called "*subsidy-stress*" hypothesis
  - In some animals, exposure to low-level ionizing radiation or other stressors causes an increase in lifetime reproductive output with no decrease in maternal lifespan
  - In humans, it forms the basis for homeopathic medicine
- Physiological *acclimation* and *acclimatization*: adaptive changes in an individual in response to a change in environmental conditions
  - More specifically, *acclimatization* refers to adaptive shifts taking place under *natural* conditions
  - *Acclimation* refers to shifts taking place under controlled laboratory conditions, *or* the time spent in the experimental setup before beginning measurements

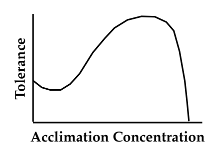
Hypothetical Thermal Tolerance in Fishes

(based on Coutant, C. 1970. Biological aspects of thermal pollution: 1. Entrainment and discharge canal effects. CRC Critical Reviews in Environ. Control 341-381)



Quantifying Acclimation

Chapman (1985) described a general toxic response model for acclimation to metals, based primarily on LC50 data:

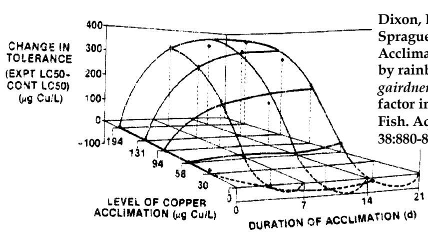


Redrawn from: Chapman, G.A. 1985. Acclimation as a factor influencing metal criteria. Pages 119-136 in R.C. Bahner and D.J. Hansen (eds). Aquatic toxicology and hazard assessment: Eighth Symposium. Philadelphia, PA, American Society for Testing and Materials.

- Zone of roughly linearly increasing tolerance with increased acclimation concentration producing increased LC50
  Explanation: induced response to metal that enhances tolerance
- Maximum acclimation concentration above which tolerance decreases
  Explanation: damaging effects exceed capacity of induced response
- Lower limit on acclimation, below which tolerance decreases
  Explanation: no induced response, but damaging effects still occur

Effects of Acclimation Time

Dixon and Sprague (1981) change in ILL for Cu with acclimation level *and* acclimation time in rainbow trout:

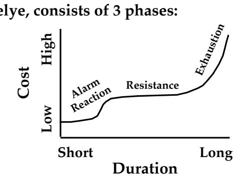


Dixon, D.G., and J.B. Sprague. 1981. Acclimation to copper by rainbow trout (*Salmo gairdneri*) – a modifying factor in toxicity. Can. J. Fish. Aquat. Sci. 38:880-888.

- Response surface is essentially a "3-D" version of Chapman (1985) results: the "ski-jump" shape is formed by the lower limit on induced response

Stress Effects on Individuals: General Adaptation Syndrome (GAS)

Also developed by Selye, consists of 3 phases:



- *Alarm reaction* involves immediate reactions, e.g., increased pulse rate, blood pressure, or respiration ("fight or flight" response)
- If stressor continues to exert effect on organism, *resistance* responses that "stimulate tissue-defense" (e.g., enlargements of the adrenal cortex, induction of metal-binding proteins occur)
- After a characteristic period of exposure, the organism enters an *exhaustion* phase indicating the that "finite adaptive energy" of individual has been reached. With continued exposure, the organism is unable to maintain itself and dies