Hibernation and Estivation in Amphibians

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Lecture Goals

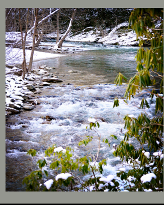
- To familiarize students with the basics of hibernation and estivation in amphibians.
- To introduce students to the on-going research.
- To high-light the areas where more research is needed.
- Required Reading: Wells pp. 148-155, The Journal of Experimental Biology p. 3

Let's talk about.....

Hibernation .... then .... Estivation

- What is hibernation/estivation?
- Where do the amphibians go?
- What physiological changes do they experience?
- What are the costs/benefits?
- What's the newest research?
- What still needs to be studied?

Hibernation
Response to short term or periodic exposure to cold



- No amphibian can remain active at subfreezing temperatures. Most spend the winters in an inactive state (depending on stored fat reserves)[1]
- They retreat to a warmer microhabitat (hibernaculum)[2] and remain inactive until warm temperatures return.
- Can last 8-9 months for northern latitude or high altitude frogs.

1. Wells, 2007 2. Scientific American, Rick Emmer

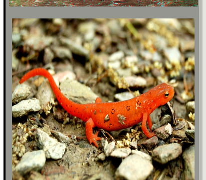
Where do they hibernate?

- Amphibians that are aquatic as adults tend to overwinter in water.
- Amphibians that are terrestrial tend to overwinter on land.
- There are always exceptions and considerable plasticity.

Wells, 2007

Urodeles

- Necturus and cryptobranchus never leave the water so they spend the winter underwater where they continue to feed (fly nymphs), but at a slower rate than in summer.
- Larvae usually spend at least one winter in streams before metamorphosing, but show little growth in the winter.



- Terrestrial plethodontids always hibernate on land and use root holes and other natural cavities in the soil and sometimes eat insects underground.
- Salamanders have been found to winter in mouse holes, under logs, gravel piles, drain pipes, under vegetative mats, cellars, mines, piles of timber and even in aggregations of up to 25 individuals.
- Salamanderella keyserlingii, found above the arctic circle, is the only salamander that is freeze tolerant to -20 degrees Celsius.
- In mild climate, Newts remain in water all winter if water is available.

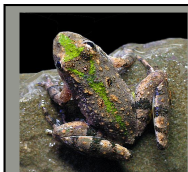
Wells, 2007

Where do they hibernate?

Choose a site to minimize desiccation (drying out) and freezing.

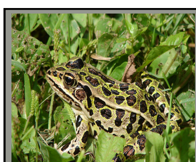
Anurans

- Toads like Bufo and spadefoot bury themselves in sand or loose soil a meter or more deep.
- Can also use natural cavities, cellars, mouse holes, mole tunnels, mammal burrows, mine tunnels.
- Most bufos can tolerate flooding of their site, natterjack toads cannot and have high mortality.
- In Russia and Siberia B. gargarizans hibernate in aggregates of 60+ in burrows 2 meters deep. Some have adapted to hibernating near hot springs (24 degrees Celsius) and remain active.



Wells, 2007

- North American Cricket Frogs hibernate in cracks in the soil near breeding ponds, crayfish burrows, cavities under rocks and gravel near streams. They prefer moist sites near water that does not freeze.
- The hibernation sites of North American tree frogs have NOT been reported, but Hyla chrysoscelis (freeze tolerant species) has been found in loose soil at the base of trees.
- Most aquatic ranid frogs all hibernate in ponds, lakes, swamps and rivers although occasional terrestrial hibernation has been reported.



Wells, 2007

- Leopard frogs hibernate in ponds and streams.
- Wood frogs hibernate in upland forested habitats where the soil is NOT saturated in water. (Only North American Ranid frog known to tolerate freezing.)
- In Europe, common frogs hibernate mostly in running water but can winter on land. In Finland, even found in the dens of poisonous adders.
- Some found moving about in mild winter weather shifting their hibernation site.
- In Eurasia, ranid frogs can be found in groups of 1,000 to 2,000 individuals.

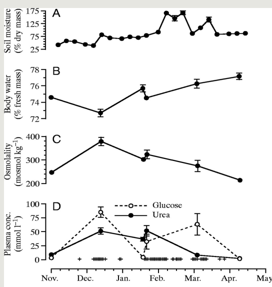
Physiology of Freeze Tolerance

http://www.youtube.com/watch?v=xI2VSxeYTQE

- Freeze-tolerant amphibians use cryoprotectants to depress the freezing point of their intracellular fluids. (Like anti-freeze decreases the freezing point of water in your car.)
- In most species, the main cryoprotectant is glucose and sometimes glycerol (urea)
- As freezing begins, water is drawn out of the cells into extra cellular spaces, particularly in the abdomen and between the skin and muscle.
- Most can only have 60% of their body fluids freeze without ill effects.
- As the frog cools, internal organs (including the heart) continue to function, allowing the glucose to be distributed to vital organs through the blood stream.

Wells, 2007 and Muir, 2008

- 2005 study by Costanzo and Lee
- In the lab, Urea's efficacy as a cryoprotectant was comparable to glycerol and as good or better than glucose in protection against freeze/thaw damage .

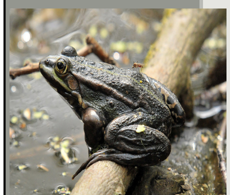


Benefits of Hibernating in Water

- Can follow the Oxygen gradient as they move around under the ice.
- No danger of desiccation.
- Little danger of freezing to death, unless the water is very shallow.
- The cold water lowers their metabolic rate by 70%, reducing their energy costs and Oxygen demands.

Wells, 2007

Costs of Hibernating in Water



- Mud at the bottom of a pond can become anoxic.
- Snow on the ice at the top of a pond can block sunlight and plants can't photosynthesize and Oxygen levels drop.
- Shallow ponds can freeze and result in mass kills.
- Predators like otters, water shrews, pole cats, trout and mergansers feed on the sluggish amphibians

Wells, 2007

Benefits of Hibernating on Land

- No shortage of Oxygen.
- Most burrows offer sufficient insulation to keep from freezing.
- If you are opportunistic you can use another animal's burrow. (less energy exerted)

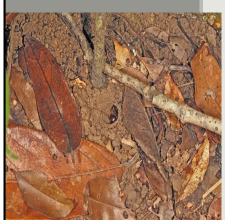
Wells, 2007

Costs of Hibernating on Land

- More susceptible to desiccation and freezing.
- More susceptible to predators, but NOT as well documented as hibernation in water.
- Unusually cold winters (like this year) can result in mass kills as well as flooding of hibernation site.
- 1979 several populations of terrestrial salamanders virtually disappeared from sites in Kentucky after a severely cold winter.

Wells, 2007

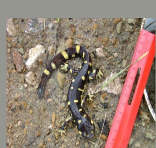
Estivation



- State of torpor that is usually associated with an amphibian's response to a hot/dry environment.
- Characterized by: Cessation of feeding, lack of movement, decrease in tissue metabolism, decrease in cardiac activity, increase in Carbon Dioxide, decrease in Oxygen, decrease in gut activity and an increase in urea.
- Period of aphagia (inactivity or dormancy).

Secor, 2005 and Glass, 2009 and Muir, 2009

Estivation



http://www.youtube.com/watch?v=tuWo_kWMihs

- California Tiger Salamander estivates up to 9 months.
- California Red-legged Frog stores energy in fat sacs that is slowly expended during estivation.
- Some anurans shed their skin that acts as a "baggie" to protect from moisture loss.
- Usually appears in explosive or opportunistic breeders.

Boone, 2009 and Glass, 2009

Future Research

- Cues for hibernation and estivation: light, temperature, moisture
- Urea (for moisture loss)
- Cryoprotectent (anti-freeze)
- Cues for emerging from hibernation and estivation
- Caecilians
- Hibernation sites for tree frogs.
- The distribution of freeze tolerance among anurans has appeared independently at least three times and possibly more (evolution)

References

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