PREDATOR DEFENSE ADAPTATIONS OF AMPHIBIANS

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WFS 533

LECTURE GOAL

- To provide students with an understanding of the different types of defense adaptations frogs and salamanders have developed.
  - What?
  - When?
  - Why?
  - How?

Photo Credit: Smithsonian Science

LECTURE SUMMARY

- Amphibian Predators
  - Everything eats amphibians
- Life cycle breakdown
  - Embryonic stage
  - Larval stage
  - Metamorphic stage
  - Adults
- Conclusion
  - Developmental trade-off

Who Eats an Amphibian?

Photo Credit: Sullivan Elementary School

- All Animalian classes
- Including themselves
- Cannibalism exists
- Invasive species problem

Who Eats an Amphibian?

INVERTEBRATES

VERTEBRATES

Photo Credit: aquaticinsect.net

Photo Credit: Rob McCormick

Photo Credit: virginiafishes.blogspot.com

Photo Credit: knoxnew.com

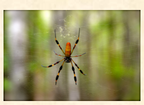


Photo Credit: Elisa Lewis

✓Parasitic Larvae

NON-NATIVE PREDATORS

Photo Credit: Ken Stanek

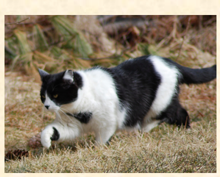
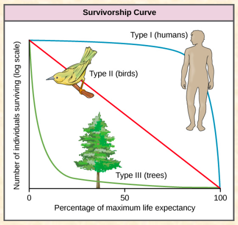


Photo Credit: Bob Maccines

Woods, Mcdonald, and Harris 2003
•375,000 to 400,000 frogs/yr brought home by domestic cats
•Underestimates total mortality

PREDATOR RESPONSE



What type of survivorship best describes amphibians?

WELLS 2007

- Entire life span
  - Type III
- Larval period
  - Type II
  - Age specific mortality remains constant
- 4 Life History Stages

PREDATOR RESPONSE:
Embryonic Stage

- Mortality is variable
  - Ecosystem conditional
- Petranka et al. 1998
  - 2% to 100% in *Ambystoma Maculatum*
  - Severe increases in mortality with presence of certain predators
  - 91% in ponds containing *Lithobates sylvatica* tadpoles
- Egg Protection
  - Chemical/Mechanical Defenses
  - Choice of Oviposition Sites
  - Timing of Reproduction
  - Adaptive Plasticity in Hatching

EGG PROTECTION

CHEMICAL DEFENSE

- Contain toxic or distasteful compounds
- Not affecting all predators
  - *L. clamitans* eggs readily consumed by leeches (R. D Howard 1978)
  - *Bufo marinus* eggs can kill native tadpoles but do not affect many invertebrates. (Axelsson et al. 1997)

MECHANICAL DEFENSE

- Protection by egg capsules and surrounding jelly
- Reliant on predator presence
- Grubb 1972
  - *Acris crepitans*
  - Larger egg capsules in permanent water breeders
- Morin 1983
  - Thick jelly does not protect against adult newts

EGG PROTECTION

OVIPOSITION SITE SELECTION

- Alford 1999
  - Many species limited to temporary ponds
  - Eggs highly palatable to fish predators
- Crump 1991
  - *Hyla pseudopuma*
  - Females can detect conspecific tadpole predators

TIMING OF REPRODUCTION

- Explosive breeders
- Petranka and Thomas 1995
  - *L. sylvatica* eggs
  - Cannabalism occurred when exposed to earlier hatchling conspecific tadpoles
- Alford 1999
  - *Bufo alatus*
  - Early breeding to surpass embryonic stage before heterospecific predators

EGG PROTECTION

ADAPTIVE PLASTICITY OF HATCHING

- Warkentin (1995)
  - *Agalychnis callidryas*
  - Predator = cat-eyed snakes
  - Eggs can survive independently in water after ~day 5
  - Will hatch prematurely if attached by snake

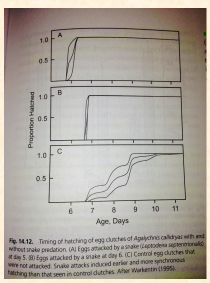


Fig. 14.12. Timing of hatching of egg clutches of *Agalychnis callidryas* with and without snake predation. (A) Eggs attacked by a snake (*Leptodeira septentrionalis*) at day 5. (B) Eggs attacked by a snake at day 6. (C) Control egg clutches that were not attacked. Snake attacks induced earlier and more synchronous hatching than that seen in control clutches. After Warkentin (1995).

http://smithsonianscience.org/2009/12/researchers-discover-treefrog-embryos-can-evaluate-different-features-of-vibrations/

PREDATOR RESPONSE:

Larval Stage

- Highest mortality rates
  - Embryonic stage is 2nd
- Why?
  - Larval period much longer
  - Mobility increases predator attraction
- 2 types of response
  - Avoid detection
  - Escape capture
- Chemical Defense
- Sensory Cues
- Alarm Responses
- Rapid Development
- Color Patterns

Photo Credit: Jim Jung

LARVAL DEFENSE

SENSORY CUES

- Tactile, Visual, or Chemical?
  - McCollum and Leimberger (1997)
    - Chemical necessary and efficient
- Multiple predators
  - Eklöv and Werner (2000)
    - Responded to bluegill
    - Bluegills reduced activity of dragonfly naiads

ALARM RESPONSES

- Hews (1988)
  - Chemical cues of injured conspecifics
- Petranka (1989)
  - *Anaxyrus americanus*
  - Food patch abandonment
  - Increased activity

Photo Credit: Animal Planet

LARVAL DEFENSE

CHEMICAL DEFENSE

- Distasteful or toxic
- Brodie and Formanowicz 1987
  - *Bufo* tadpoles
  - Palatability dependent on predator hunger
  - May vary at different developmental stages
- Why not all amphibian larvae?
  - Skin secretion expensive
  - Developmental trade-off

Photo Credit: Tanja Kessels

✓Aposematic coloration used in combination with chemical defenses

LARVAL DEFENSE: COLOR PATTERNS

- Cryptic coloration
  - Altig and Channing (1993)
    - Break up outline
    - Obscure key features
  - Storfer et al. (1999)
    - *Ambystoma barbouri*
    - Fish could detect dark larvae more easily
- Deflection marks
  - Van Buskirk et al. (2004)
    - Redirect attacks away from vital areas
  - Semlitsch (1990)
    - Considerable damage to tails
    - Did not affect survivorship

✓Aposematic coloration used in combination with chemical defenses

Photo Credit: Vernalpool.org

Photo Credit: John P. Clare

PREDATOR RESPONSE:
Metamorphic Stage

GROWTH & DEVELOPMENT

- Probably best defense mechanism (Travis 1983)
- Become less vulnerable with growth (Alford 1999)
- Swimming speed increases (Huey 1980)
- Chivers et al. (1999)
  - *Bufo boreas*
  - Reached metamorphosis quicker in response to predator cues

METAMORPH VS. LARVAE

- Defenses similar
- Examined separately
- Large size excludes many predators
  - Kehr and Schnack (1991)

PREDATOR DEFENSE:
Adult Stage

- Endler (1986)
  - Reduce detection
    - Prevent encounter
  - Reduce chance of consumption
    - During encounter
- Active vs. Passive defenses

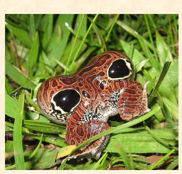


Photo Credit: Wild—facts.org

http://www.newsy.com/videos/bats-use-water-ripples-to-detect-and-hunt-frogs/

PREDATOR DEFENSE:
Adult Stage

PASSIVE

- Color Patterns
  - Cryptic
  - Color Polymorphism
- Behavioral Avoidance
  - Chemical cues
  - Woody and Mathis (1998)
    - Newts avoided predators with newt skin extract

ACTIVE

- Flight
  - Plethodontid flipping behavior (Brodie 1983)
- Attack
  - Startling vocalizations (Brodie 1978)
- Chemical Defense
  - Mimicry
- Posturing
  - Tail displays
  - http://www.youtube.com/watch?v=z0yHXz_2Lsw
  - “unken reflex”

Posturing

Photo Credit: Gary Nafis

Mimicry

Batesian Mimicry
- Wells (2007)
- “edible species can benefit by evolving a pseudoaposematic pattern resembling that of the distasteful model”

Müllerian Mimicry
- Brandon and Huheey (1981)
- “system in which several distasteful species mutually benefit from a similar color pattern”

Photo Credit: Brad Wilson

Photo Credit: Faculty.bsc.edu

Photo Credit: Marietta.edu

CONCLUSION

- Eaten by all types of wildlife
- Larval Stages
  - Biological trade-off
    - Red-eyed tree frog
- Adult stage
  - Active or Passive?
- Management
  - Focus on habitat restoration
  - Invasive predator management
    - House cats not outdoor cats
    - Strict regulation of exotic pet trade

CITATIONS

Alford, R. A. 1999. Ecology. In *Tadpoles. The biology of anuran larvae*, ed. R. W. McDiarmid and R. Altig, 240-78. Chicago: University of Chicago Press.

Altig, R., and A. Channing. 1993. Hypotheses: functional significance of colour and pattern of anuran tadpoles. *Herpetol. J.* 3:73-75.

Axelsson, E., P. Nÿstrom, J. Sidenmark, and C. Brönmark. 1997. Crayfish predation on amphibian eggs and larvae. *Amphibia-Reptilla* 18:217-28.

Brandon, R. A., and J. E. Huheey. 1981. Toxicity in the plethodontid salamanders *Pseudotriton ruber* and *Pseudotriton montanus* (Amphibia, Caudata). *Toxicon* 19:25-31.

Brodie, E. D., Jr. 1978. Biting and vocalization as antipredator mechanisms in terrestrial salamanders. *Copeia* 1978:127-29.

Brodie, E. D., Jr. 1983. Antipredator adaptations of salamanders: Evolution and convergence among terrestrial species. In *Plant, animal, and microbial adaptations to terrestrial environment*, ed. N. S. Margaris, M. Arianoutsou-Faraggitaki, and R. J. Reiter, 109-33. New York: Plenum.

Brodie, E. D., Jr., and D. R. Formanowicz, Jr. 1987. Antipredator mechanisms of larval anurans: Protection of palatable individuals. *Herpetologica* 43:369-73.

Chivers, D. P., J. M. Kiesecker, A. Marco, E. L. Wildy, and A. R. Blaustein. 1999. Shifts in life history as a response to predation in western toads (*Bufo boreas*). *J. Chem. Ecol.* 25:2455-63.

Crump, M. L. 1991. Choice of oviposition site and egg load assessment by a treefrog. *Herpetologica* 47:308-15.

Eklöv, P., and E. E. Werner. 2000. Multiple predator effects on size-dependent behavior and mortality of two species of anuran larvae. *Oikos* 88:250-58.

Ender, J. A. 1986. Defense against predators. In *Predator-prey relationships*, ed. M. E. Feder and G. V. Lauder, 109-34. Chicago: University of Chicago Press.

Grubb, J. C. 1972. Differential predation by *Gambusia affinis* on the eggs of seven species of anuran amphibians. *Am. Midl. Natur.* 88:102-8

Hews, D. K. 1988. Alarm response in larval western toads, *Bufo boreas:* Release of larval chemicals by a natural predator and its effect on predator capture efficiency. *Anim. Behav.* 36:125-33.

Howard, R. D. 1978. The influence of male-defended oviposition sites on early embryo mortality in bullfrogs. *Ecology* 59:789-98.

Huey, R. B. 1980. Sprint velocity of tadpoles (*Bufo boreas*) through metamorphosis. *Copeia* 1980:537-40.

Kehr, A. I., and J. A. Schnack. 1991. Predator-prey relationship between giant water bugs (*Belostoma oxyurum*) and larval anurans (*Bufo arenarum*). *Alytes* 9:61-69.

McCollum, S. A., and J. D. Leimberger. 1997. Predator-induced morphological changes in an amphibian: Predation by dragonflies affects tadpoles shape and color. *Oecologia* 109:615-21.

Morin, P. J. 1983. Predation, competition, and the composition of larval anuran guilds. *Ecol. Monogr.* 53:119-38.

Petranka, J. W. 1989. Response of toad tadpoles to conflicting chemical stimuli: Predator avoidance versus "optimal" foraging. *Herpetologica* 45:283-92.

Petranka, J. W., A. W. Rushlow, and M. E. Hopey. 1998. Predation by tadpoles of *Rana sylvatica* on embryos of *Ampbystoma maculatum*: Implications of ecological role reversals by *Rana* (predtor) and *Ambystoma* (prey). *Herpetologica* 54:1-13

Petranka, J. W., and D. A. G. Thomas. 1995. Explosive breeding reduces egg and tadpole cannibalism in the wood frog, *Rana sylvatica*. *Anim. Behav.* 50:731-39.

Semlitsch, R. D. 1990. Paedomorphosis in *Ambystoma talpoideum*: Maintenance of population variation and alternative life-history pathways. *Evolution* 44: 1604-13.

Storfer, A., J. Cross, V. Rush, and J. Caruso. 1999. Adaptive coloration and gene flow as a constraint to local adaptation in the streamside salamander, *Ambystoma barbouri*. *Evolution* 53:889-98.

Travis, J. 1983. Variation in growth and survival of *Hyla gratiosa* larvae in experimental enclosures. *Copeia* 1983:232-37.

Van Buskirk, J., J. Aschwanden, I. Buckelmüller, S. Reolon, and S. Rüttiman. 2004. Bold tail coloration protects tadpoles from dragonfly strikes. *Copeia* 2004:599-602.

Warkentin, K. M. 1995. Adaptive plasticity in hatching age: A response to predation risk trade-offs. *Proc. Natl. Acad. Sci. USA* 92:3507-10.

Wells, E. D. 2007. The ecology and behavior of amphibians. 645-728. Chicago: University of Chicago Press.

Woods, M., R. A. McDonald, and S. Harris. 2003. Predation of wildlife by domestic cats *Felis catus* in Great Britain. *Mammal Rev.* 33:174-88.

Woody, D. R., and A. Mathis. 1998. Acquired recognition of chemical stimuli from an unfamiliar predator: Associative learning by adult newts, *Notophthalmus viridescens*. *Copeia* 1998:1027-31.