Amphibian Predation and Defense

By: Katie Harris

"Each stage of development from egg to adult faces its own particular dangers, and at no time of day or night are frogs and their offspring safe from attack." – Tyler 1976

“almost anything will eat an amphibian.” – Porter 1972
Why Eat Amphibians?

- Amphibian Predators
  - Evolutionary Response
    - 1. Egg
    - 2. Larvae
    - 3. Adult
  - Future Directions
  - Summary

Why eat an amphibian?

- Small, slow-moving, defenseless?
- High population densities
- Good source of protein
- Lack indigestible material
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Common Predators?
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• Invertebrates
  • eggs and larvae
  • temporary ponds
  • caddisfly larvae
  • parasites
  • trophic loop

Lethocerus americanus

Pseudacris regilla

Common Predators?

• Invertebrates
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Trichoptera

Ambystoma maculatum

Common Predators?

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Macrobdella

Lithobates sylvaticus
Common Predators?

- Invertebrates
  - eggs and larvae
  - temporary ponds
  - caddisfly larvae
  - parasites
  - trophic loop

- Fish
  - Eggs, larvae, adults

- Reptiles
Common Predators?

- Invertebrates
- Fish
- Reptiles
- Birds
- Amphibians
- Mammals
Option 1: Reduce the likelihood of being detected

Option 2: Reduce the chances of being consumed once detected

Behavioral
Physiological
Morphological
Chemical
Phenological

Ambystoma maculatum
Option 1: Reduce the likelihood of being detected

Option 2: Reduce the changes of being consumed once detected

Behavioral
- Physiological
- Morphological
- Chemical
- Phenological

Eggs: Mechanical and Chemical

- Egg capsule and jelly
- Toxic and distasteful compounds
- Effectiveness depends on predator
  - Eggs of *R. californianus* & *R. catesbeianus*
    - Distasteful to newts and larval ambystomatids (Parker 1979)
    - Readily consumed by leeches (Howard 1978)
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Eggs: Oviposition Site

- Areas without fish
  - Temporary ponds
  - On land
- Areas void of predators
  - *Anaxyrus americanus* avoid oviposition in areas that contained *Lithobates sylvaticus* eggs (Petranka et al. 1994)
  - *L. sylvaticus* didn’t lay eggs in ponds with predatory sunfish (Hopey and Petranka 1994)

Lithobates sylvaticus
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Eggs: Timing of Reproduction

- Early spring
  - before predatory species reach peak densities
- Synchronized reproduction
  - earlier hatchlings consume eggs deposited later
  - swamp predators increasing individual survival
Eggs: Adaptive Plasticity

- **Red-eyed tree frog** (*Agalychnis callidryas*)
  - Egg mass hatches immediately if clutch is attacked (Warkentin 1995, Warkentin 2000, Warkentin et al. 2001)
  - Survive by dropping in water
  - Trade off! → small, not very mobile
- Wasp predation – single hatching (Warkentin 2000)
- Fungus – eggs closest to fungus hatch first

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Eggs: Adaptive Plasticity

• Hatching is delayed in the presence of predators (Sih and Moore 1993, Moore et al. 1996)
  - Allows larvae to hatch at a more advanced stage

Larval Defense:
Larval Defense: Color Patterns

- First line of defense
- Drab colors
- Countershading
- Disruptive coloration
- Reflective or transparent
- Deflection marks

Lithobates clamitans

Lithobates catesbiana

Storfer et al. 1999
Larval Defense: Color Patterns

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Larval Defense: Phenotypic Plasticity

- *Acris*
  - tail tip coloration (Caldwell 1982)

- *Hyla chrysoscelis*
  - dragonfly naiads present
  - dark orange, deep tail fins, dark
  - predators absent
  - shallow, unmarked tail fins
  - early age exposure = gradual development (LaFiandra & Babbitt 2004)
  - direct contact not necessary

Present

Absent
Larval Defense: Phenotypic Plasticity

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  - tail tip coloration (Caldwell 1982)

- **Hyla chrysoscelis**
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  - predators absent
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  - direct contact not necessary

Larval Defense: Behavioral

- **Schooling** (Rodel and Linsenmair 1997)
  - decreases chance of individual capture

- **Time of day**
  - shift active when predators are not active (Sih et al. 1992)
  - *Ambystoma barbouri* – tend to be nocturnal in presence of fish (Taylor 1983)

- **Refuge habitats: less food**
  - water column – *Ambystoma talpoideum* (Miller et al. 2005)
  - trade-offs → vulnerability versus foraging efficiency

- **Limit activity** (Altewegg 2003)
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- **Limit activity** (Altwegg 2003)
Larval Defense: Sensory Cues

- Tactile
- Visual
- Chemical
  - discrimination between dangerous and less dangerous genetic response—previous exposure is not required
  - discrimination between predators of conspecific larvae (Chivers and Mirza 2001)
  - not always present, can develop rapidly (Kiesecker and Blaustein 1997)
Larval Defense: Sensory Cues

• Tactile
• Visual
• Chemical
  • discrimination between dangerous and less dangerous genetic response—previous exposure is not required
  • not always present, can develop rapidly (Hewson and Blaustein 1997)

Larval Defense: Alarm Responses

• Cues from injured conspecifics (Hews and Blaustein 1985)
  • use these cues to avoid areas where predators are likely
  • increase activity (different than most)
    • beneficial if predator has already been detected (Hews 1998)

Larval Defense: Growth & Development

• Rapid growth
• Predators have limited prey size
• Sprint speed increases with size (Richards and Bull 1990)
• Higher growth rate = higher survivorships (Travis 1983)
• Growth and predator exposure
  • *Bufo boreas* – increased growth rate (Chivers et al. 1999)
  • *Ambystoma macrodactylum* – decreased growth rate
    • foraging decreased (Wildy et al. 1999)
Larval Defense: Growth & Development

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  • *Ambystoma macrourum* – decreased growth rate
  • Foraging decreased (Wildy et al. 1999)

Larvae Defense: Chemical Defenses

• Distasteful and toxic; particularly anuran tadpoles
  • *Bufo* - palatability varies among predators
• Why not in all species?
• Why not in all species?
  • Expensive to produce
  • Temporary ponds: too costly, rapid growth
  • Permanent ponds: worth the energy costs, slow growth
Adult Defense: Cryptic Coloration

- Matching dorsal coloration to environment (Edmunds 1974)
- Reflect light in visible and infrared spectrum (Schalm et al. 1977, Emerson et al. 1990)
- Color change (Iga and Bagnara 1975)
- Cryptic patterning (Cott 1940)

Hyla chrysoscelis

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Hyalinobatrachium taylori

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Hyla cinerea
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Adult Defense: Color Polymorphism

- Polymorphism = different forms
- Genetically controlled
  - can be environmentally influenced (Brown and Travis, 1965, Harvey and Travis, 1966)
- Pacific tree frog
  - slow → not effective to immediate predation
  - adaptive → seasonal shifts
  - light intensity and temperature → thermoregulation (Stegen et al., 2004)
Adult Defense: Color Polymorphism

- Polymorphism = different forms
- Genetically controlled • can be environmentally influenced (Merrell 1965, Fogelman et al. 1980)

Pacific tree frog • color-changing morph (brown/green) • slow → not effective to immediate predation • adaptive → seasonal shifts • light intensity and temperature → thermoregulation (Travis and Trexler 1984, Harkey and Semlitch 1988)

- Adult Defense: Predator Avoidance

- Avoid locations where predators present
- Chemical cues • predators • injured conspecifics
- Newts (Woody and Mathis 1998) • did not avoid chemical stimuli from fish (Woody and Mathis 1998, Marvin and Hutchinson 1995, Woody and Mathis 1997) • avoided chemical stimuli from fish if associated with injured conspecific (Woody and Mathis 1998)

- Adult Defense: Predator Avoidance

- Avoid locations where predators present
- Chemical cues • predators • injured conspecifics
- Newts (Plethodon vandykei) • avoided chemical stimuli from fish if associated with injured conspecific (Woody and Mathis 1998)
**Adult Defense: Predator Avoidance**

- Avoid locations where predators present
- Chemical cues
  - predators
  - injured conspecifics
- Newts
  - did not avoid chemical stimuli from fish (Marvin and Hutchinson 1995, Woody and Mathis 1998)
  - avoided chemical stimuli from fish if associated with injured conspecific (Woody and Mathis 1998)

**Adult Defense: Behavioral**

- Jumping – slender bodies (Heinen and Hammond 1997)
- Coiling – Mount Lyell salamander *Hydromantes playcephalus* (Jones and Wiens 1979)
  - Vocalization
  - Biting (Taylor and Ludlam 2013)
- Tail display – Plethodontidae, Salamandridae (Wake and Dresner 1967)
- Unken reflex (Kuchta 2005)
Adult Defense: Behavioral

- **Jumping** – slender bodies (Heinen and Hammond 1997)
- **Flipping** – Plethodontids (Whiteman and Wissinger 1991, Azizi and Landberg 2000)
- **Coiling** – Mount Lyell salamander *Hydromantes playcephalus* (Garcia-Paris and Deban 1995)
- **Death feigning** – leaf litter frog *Ischnocnema aff. henselii* (Váz-Silva et al. 2004)
- **Vocalization** (Weber 1978)
- **Biting** (Taylor and Ludlam 2013)
- **Tail display** – Plethodontidae, Salamandridae (Wake and Dresner 1967)
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Adult Defense: Chemical

- Granular glands
  - Found in all amphibians, relatively similar structure
  - Distributed throughout the skin or concentrated
- Defensive secretions
  1. Widespread, naturally occurring compounds.
     - Can serve other functions → microbes and fungi
     - Defensive when secreted in large quantities
  2. Evolved for defense → toxic
- Origin
  - Synthesized within the animal (Smith et al. 2002)
  - Derived from chemicals of other organisms (Daly et al. 1994)
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**Origin**

- Synthesized within the animal: Smith et al. (2002)
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**Adult Defense: Aposematic Coloring**

- Coloration to warn or deter predators
- Only beneficial when predator can see colors
- Dendrobatidae
  - Color brightness correlates to toxicity: Summers and Clough (2001)

**Adult Defense: Mimicry**

- Predators learn to avoid the aposematic patterns
- Batesian mimicry: edible species benefit by evolving pseudoaposematic colors
- *Pseudotriton ruber* & *Notophthalmus viridescens*
  - readily eaten before exposure to red efts: Brodie & Howard (1972)
  - less palatable than *Desmognathus* species: Brodie et al. (1978)
  - produce toxins: Mullerian
- Mullerian mimicry: toxic species share a common warning coloration

**Mullerian mimicry**

- Toxic species share a common warning coloration

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Future Directions

- Impact on populations
  - demographic impact of predation
  - impact of specific predators
  - invasive predators
- Genetics
- Relationships between toxicity and predators
- Caecilians and salamanders

Summary

- Subject to vast array of predators
- Predation is greatest on egg and larval stages
- Most predators are generalists
- Protection against predators is varied
- Predation lessened by:
  - reduce the change of detection
  - reduce the changes of being consumed once detected
  - chemical, phenological, behavioral, physiological, morphological

References

- Carpenter, C., and P. M. Wissinger. 1994. Restriction of wood frogs to fish free habitats: how important is adult choice? Herpetologica 50, 663.