Amphibian Foraging Ecology (Part I)

Goal of Lecture
To familiarize students with the basic principles and evolution of amphibian foraging ecology

To familiarize students with the different foraging strategies, resource selection, prey detection, and feeding mechanisms of terrestrial amphibians

Reading Assignments
Zug: pp. 249-256
Pough: pp. 395-397, 400-405
Duellman: pp. 238-240

Supplemental Reading
Toft Foraging Ecology

Lecture Road Map
I. Evolution of Foraging Techniques
II. Energetics
III. Foraging Movement and Habitat Selection
IV. Foraging Modes
V. Prey Selection & Diet
VI. Prey Detection
VII. Feeding Mechanisms
Foraging vs. Feeding?

**Feeding:** A physiological and morphological process that involves consuming and digesting food.

**Foraging:** A behavioral process which includes searching for resources and the decision-making involved in how, when and where to search. (Toft 2002)

Foraging Ecology in the Light of Evolution

- Foraging behavior is evolutionarily plastic
  - feeding strategies and mechanisms have evolved in response to natural selection
- If different strategies lead to a difference in fitness, then natural selection occurs
  - Difference in energy gain
  - Quality of shelter

Optimal Foraging Theory

Explains the evolution of foraging strategies

“Animals that harvest resources the best are at a selective advantage. Thus natural selection should favor the fine tuning of resource acquisition (optimal foraging)” – Zug

Obtain the most from available resources while expending the least amount of energy
Factors that Influence Foraging Behavior

External
- Resource availability, predation risk, social interactions, etc.

Evolutionary history
- Morphological (size of mouth)
- Physiological (bursts of movement)
- Anatomy (shape)
- Very noticeable in tadpoles

Internal
- Hunger, age, reproductive state, etc.

Example: Morphological Constraint
Size of Gape in ant-eating specialists vs. generalist feeders

(Pough et al. 2004)
Energetics

“There’s no such thing as a free lunch.” – Barry Commoner

- What determines how an animal acquires its resources?
- Cost-benefit analysis
  - Cost – use of energy in searching and obtaining resources (such as food)
  - Benefit – energy acquired to survive, grow, and reproduce
- Energy Budget: the balance of energy income against energy outcome
Optimal Diet

Diet which maintains positive energy budget

What does an amphibian consider when making it’s shopping list?

1.) Prey abundance
2.) Energy spent handling prey
3.) How often predator eats

Plethodon cinereus switches from generalist to specialist as prey abundance increases

Habitat and Home Range

Habitat
• Population level
• Series of resource patches
  – Depletable resource: Food
  – Nondepletable resource: Shelter

Home Range
• Individual level
• Area within habitat occupied by animal during normal activities (foraging)
• Most amphibians have small home ranges
• High fidelity

What determines size of home range?

Movement

Homing Behavior

Daily movements for amphibians are short and brief (usually)

Sit and wait predators move from refuge to feeding station (*Hyla chrysoscelis*)

Active predators move from refuge and alternate between bouts of searching to rest (*Plethodon cinereus*)
Foraging Modes

Sit-and-wait
- Most anurans
- Energetically conservative, low capture rate
- Short bursts of movement
- Well developed vision
- Cryptic coloration
- Specialists

Active
- Some anurans (Dendrobatids), most salamanders, caecilians
- Energetically expensive, high capture rate
- Well developed chemical senses
- Sustained amounts of activity
- Generalists

*Foraging modes usually exist as a continuum

How Did Foraging Modes Evolve?

Two hypotheses of evolution of foraging modes:
- Selection-based
- Phylogeny-based

Diet and Prey Selection
- In general, adult anurans, salamanders, and caecilians are opportunistic carnivores
- Eat insects and small invertebrates (and anything else that fits in mouth)
- Eat prey whole, do not chew
Prey Detection

Three main sensory cues used by terrestrial amphibians for prey detection

1.) Visual
2.) Auditory
3.) Chemosensory

These are often combined during foraging

Visual Prey Detection

- Sit-and-Wait Predators
- Anurans and caudates
- Use vision to determine, size, speed, and location of prey
- Large, well-developed eyes

Auditory Prey Detection

Use of airborne sounds to detect prey poorly documented

- *Bufo marinus* moves towards calling *Physalaemus postulosus*

Active foragers (mostly caudates and caecilians)

Opercularis system transmits seismic vibrations (as low as ~200Hz) to inner ear
Opercularis System
• Transmits vibrations from forelimb to inner ear through opercularis muscle
• Creates fluid movement in inner ear cavity
• Vibrations stimulate neuroreceptors
• These low frequencies are usually made by digging insects
• Caecilians use mechanoreceptors

Chemosensory Prey Detection
• Three main chemical senses:
  – Olfactory – airborne odors
  – Vomeronasal – surface odors
  – Gustation – tasting
• Olfaction and vomeronasal function used in prey location and identification, gustation used to accept or reject prey once captured

Olfaction
• Airborne odors
• Long-distance detection
• Olfactory epithelium sensitive to volatile compounds
• Buccal pumping – lunged amphibians
Vomerolfaction

- Surface odors – high molecular weight compounds
- Short-range odor detection
- Picked up by tongue or snout and transported to vomeroolfactory organ (Jacobson’s organ)
- Common in active foragers (salamanders)

Gustation

- Not used to locate prey
- Accepts or rejects based on chemical (taste) or mechanical (spines) stimuli

Terrestrial Feeding Mechanisms

- Two broad classes of terrestrial feeding mechanisms in amphibians
  1.) Akinetic – move lower jaw only
  2.) Projectile – use tongue to capture prey
### Akinetic Feeding Mechanism

- Simplest tetrapod feeding system
- Caecilians
- Rigid skull and hinged lower jaw
- Many lineages with akinetic skulls have evolved projectile feeding mechanisms

![Image of caecilian](image_url)

(Pough et al. 2002)

### Projectile Feeding Mechanisms in Caudates

- Lingual Prehension
- Less derived salamanders - large fleshy tongue
- Evolved independently in several lineages multiple times (Plethodontids)
- Absence of lungs critical to evolution of tongue projection

![Image of tongue projection](image_url)

Different tongue projections in Plethodontidae (Pough et al. 2002)

### Projectile Feeding Mechanisms in Anurans

**Mechanical pulling**
- Basal frogs (Ascaphidae and Discoglossidae)
- Muscles attached to front of mandible draws tongue slightly forward
- Accompanied by lunging

**Inertial elongation**
- Tongue “flipped” out of mouth
- Smaller prey

![Image of Bufo marinus](image_url)

Inertial elongation in *Bufo marinus* (Pough et al. 2002)
Overview

• Be able to differentiate feeding and foraging
• Know the evolutionary process of foraging ecology
• Be able to explain the Optimal Foraging Theory
• Know which factors influence foraging behavior
• Know the different types of terrestrial foraging modes among amphibians
• Know how terrestrial amphibians detect their prey
• Know the different terrestrial feeding mechanisms of amphibians

Texts Used


Foraging ecology

Part II

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Road map

I. Adaptations of amphibians to foraging on water
   i. Caecilians
   ii. Caudata
   iii. Anura

II. Foraging ecology of tadpoles

Amphibians that feed under water

- Several amphibian families have adapted to aquatic life
- Mostly opportunistic
- Both active hunters or sit and wait

Caecilians

- Genus Thyphlonectes
  - Active hunters
  - Poor vision
  - Smell and tact
- Opportunistic
- Generalists
Typhlonectes compressicauda diet

Caudata

- Several families adapted to aquatic life
  - Salamandridae
  - Cryptobranchidae
  - Sirenidae
  - Amphiumidae
  - Proteidae

- Hyobranchial apparatus
  - Support and move gills
  - Expand and contract the buccal cavity during feeding

Caudata

- Use suction to capture the prey
  - Just with buccal expansion
  - Rapid strike
  - Manipulate prey with teeth

- Diet
  - Fish
  - Aquatic invertebrates
  - Worms
  - Crustaceans

- Aquatic salamanders respond to odor, movement or touch; terrestrial ones respond to movement
Diet of *Hynobius retardatus* larvae

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Kohmatsu and Yukihiro (2001)

Predators

- Salamanders prey on other salamanders
- Can be cannibals
- Scavengers

Salamander larvae

- Same as adults: opportunistic predators
  - Aquatic invertebrates
  - Tadpoles
  - Other salamanders
Aquatic Frogs

- Predators
- Sit and wait
- Use camouflage or hiding places

Xenopus borealis diet

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(Browning and Moseley, 2010)

Tadpoles

- Most have:
  - Keratinized jaw
  - Rows of labial teeth
  - Papillae
- Food transport by buccal pumping
- Food particles catch by branchial filaments and branchial mucus
Adults and tadpoles have different diets:
- Carnivorous
- Insectivorous
- Little selection
- Herbivores
- Scapers
- Filters
- Grazers
- Carnivores
- Oophagous

Classical stream ecosystem:

Multiple functional roles of tadpoles:
Tadpoles

• Tadpoles mouth structures are specialized for their diet
• Filters: feed on small particles on surface
• Grazers: feed on biofilm or algae

Tadpoles

• Stream grazers: feed from algae in fast moving streams
• Oophagus: feed eggs
• Detritivorous: Fine particles from substrate

Tadpoles

• Carnivores: Feed on animals
• Cannibals: Feed on their own species
Algae Bloom

What is going to happened in the Forest

Reduction in amphibians as prey
Trophic cascades caused by ranavirus

• Decline in number of individuals resulted in an increased in the abundance of the zooplankton community

\[ Y = 0.077X + 8.406 \]

\[ R^2 = 0.78 \]

Trophic cascades caused by ranavirus

• Decline in number of individuals resulted in an increased in the biofilm layer of the pools

\[ Y = 0.0021X + 0.02 \]

\[ R^2 = 0.84 \]
**Trophic cascades caused by ranavirus**

- Decline in number of individuals resulted in an increased of phytoplankton

**Summary**

- Aquatic amphibians are mostly predators
  - Opportunistic
  - Non selective
- Salamander larvae and caecilians can be active hunters
- Aquatic anurans are ambush predators
- Tadpoles have mouth parts adapted to the niche they inhabit
- Tadpoles are an important part of the ecosystem

**Questions**

- What is the function of the hyobranchial apparatus in caecilians and aquatic salamanders
- What is/are the major difference/s on foraging strategies between aquatic anurans, Caecilians, and aquatic salamanders
- What is/are the major difference/s on foraging strategies between adult anurans and its larvae
- What is the ecological role of tadpoles. What happened if they are removed?