

Tadpole Development, Ecology, and Metamorphosis



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Goal of the Lecture

To familiarize students with tadpole development and ecology, including metamorphosis.

Reading Assignments:

- 1) See Website: Wells (2007)
- 2) Altig et al. (2007): *Freshwater Biology* 52:386-395 (Req: website)
- 3) Petranksa and Kennedy: *Oecologia* 120:621-631 (Suppl: website)

Lecture Structure

- I. Embryonic Development
- II. Hatchling Development
- III. Larval Development & Ecology
- IV. Metamorphosis

Embryonic Development

Gosner (1960) Stages Stages 1-19

Nutrition

- Egg Yolk
- Oviducts

External Gills

- Heart Beats

Hatching

- Frontal Glands
- Egg Tooth

Eleutherodactylus

12 hrs – 27 days

Vascularized Tissues

- Tail
- Abdominal Walls

↑ O₂

Development ↓

Embryonic Development

Temperature Influences *B. valliceps*

Survival Maximized at Ideal Range of Temperatures

Adaptations

1. Breeding Behavior
2. Tolerance Plasticity

Tropical vs. Temperate

Development Faster at Warmer Temperatures

Adaptive Temps:

Across Species: 15-20 C

- Cool Adapted: 10-15 C
- Warm Adapted: 20-25 C

50-59F

6 hrs: 40 C

68-77F

Across Species: 5-35 C

- Cool Adapted: 5-25 C
- Warm Adapted: 15-35 C

41-77F

59-95F

Hatchling Development

Gosner (1960) Stages Stages 20-25

2 Pairs of Gills

3rd and 4th Branchial Arch

Direct Development & Viviparous

Absent

Operculum

- Grows Posterior
- Distal "Transient" Gills Atrophy

Ready to Swim & Eat!

Stage 25

Oral Disc

Branchial Arches

Adhesive Organ

Stabilization

Larval Development

Gosner (1960) Stages

Pre-Metamorphosis
Body Growth

Forelimbs develop about 1 stage behind hind limbs

Stages 26-41

NH₃ Production
(ammonotelly)

Pro-Metamorphosis
Limb Growth
Skin: Vascularized

Respiratory and Digestive Systems

Respiration

Rana catesbeiana

- Skin: Vascularization Sparse
- Lungs: Few Capillaries, Small Surface Area, Low Ventilation Capacity

Importance ↑ Development

Digestion

- Filter Plates & Ciliary Grooves
- Intestines: 1.4 – 8X BL (1 – 7 in.; nutrients)
- Microphagus vs. Macrophagus

↑ BC Volume ↓ Filtering Apparatuses

Low DO or GC blocked (Buoyancy)

Larval Growth

Sigmoidal Relation

American Naturalist
141:717-728

Fowler's Toad

Spea multiplicata

Carnivore Omnivore


Body Plan:

30%


Tail

Bilateral Myotomic Muscles

Tadpole Feeding Ecology



Richard Wassersug
American Zoologist 15:405-417, Oecologia 120:621-631



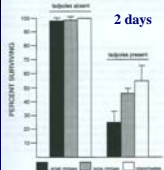
Jim Petranka

Microphagus Filter Feeders:

- Herbivores (algae, detritus)
- Scrape and Filter
- Assimilation: 25-75%

- Cannot digest cellulose
- Animal: 1.5X shorter
- Clearance: 1-5 hrs

Macrophagus Predators:




2 days

Lab Experiments:

- 24-54% Invert Survival

Pond Experiments:

- 49% Less than Controls
- 1288 chironomids / m²
- Thrust forward and bite
- Keystone predators?
- Ephemeral Ponds



S. multiplicata

Diet Studies: Digestibility

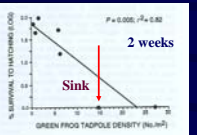
Tadpole Feeding Ecology

Carnivorous & Cannibalistic Morphs

SCAVENGE
 dead
 Conspecifics

Eggs:


Wood Frog Survival



2 weeks


Sink

- 43 masses (43,258 embryos)
- 15 masses (15,090 embryos)
- No larvae captured
- Early Breeders



Overwintering *R. clamitans*

Larvae: Animal Behaviour 46:87-94; Behavioral Ecology 10:436-443




D. Pfenning

Animal vs. Plant Matter

- Protein and Lipids
- Accelerate Growth
- Size at metamorphosis ↑

→ Kin Recognition

- Association (Om vs. Car)



Carnivore

Environmental Relations

Temperature:

34-42 C
93-104 F

Highest:
Shallow Ponds and Tropics

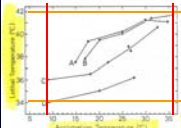
10-35 C
50-94 F

Phototaxis:

- Positive: Ponds: Tadpoles; Streams: Salamander Larvae
- Negative: Ponds: Salamander Larvae; Streams: Tadpoles

Salinity:

- Intolerant of >0.5 ppt
- Bufo viridis*: 6 ppt (15%)



DO: <1 mg/L pH: <4

Nitrogenous Waste


NH₃: >0.5 mg/L

NO₂: >2 mg/L

NO₃: >30 mg/L

NOTE: ↑ pH ↑ Temp ↑ NH₃

Temp (F)	Percent NH ₃ of total ammonia				
	pH 6.5	pH 7.0	pH 7.5	pH 8.0	pH 8.5
68	.13	.40	1.24	8.82	11.2
77	.18	.57	1.77	5.38	15.3
82	.22	.70	2.17	6.56	18.2
86	.26	.80	2.48	7.46	20.3



Tadpole Community Ecology

Tadpole Densities

Fishless
•700/m²

Fish
•5/m²

Competitors:

- Invertebrates (algae)
- Fish (inverts)
- Conspecifics/Congeners (both)

Predators:

- Eggs: Inverts, Fish,
- Larvae: Amphibians

Gape-limited: Fast Growth

Fecal Input

5 mg/day
•3.5g/m²
35 kg/ha
31 lb/ac

Role of Tadpoles?

Predatory Defense

Palatability

Activity

Schooling

Metamorph Development

Gosner (1960) Stages

Forelimbs Emerge through Opercular Wall

ureotely

Stages 42-46

Duration of Larval Development

Temperate: 2-3 Months
Tropical: 1-2 Months
Spea: 10-14 days

(Overwintering: Permanent Ponds)

Metamorphosis

Hormone Regulation

T₃: Triiodothyronine

T₄: Thyroxine

T₃ & T₄: Peak at Gosner 39

Organism Effects:

- Intestines: Shorten
- Tail & Gills: Degeneration
- Skin: Vascularization/Chromatophores/Thickens

- Lungs: Functional (44)
- Kidneys: Urea
- Mandibles & Eyelids: Develop

Immune System: Dismantled

Factors Triggering Metamorphosis

Factors: •Density of Conspecifics and Congeners

- Competition
- Cannibalism/Predation

Ecology 63:905-911,
Ecology 71:2313-2322,
Ecology 79:1859-1872

•Density of Predators

- Growth rate increases
- Activity decreases in presence



•Water Characteristics

- Water quality
- Water volume vs. temperature vs. concentration
- Volume and Proximity to Water Surface

Adaptive Plasticity:

BioScience 42(9):671-678

Evolutionary capability to exhibit different phenotypes depending on environmental conditions.

- Developmental Plasticity
- Polyphenism (carnivorous vs omnivorous)
