Monitoring Amphibians in Great Smoky Mountains National Park

By C. Kenneth Dodd, Jr.

— Abstract —

Amphibian species have inexplicably declined or disappeared in many regions of the world, and in some instances, serious malformations have been observed. In the United States, amphibian declines frequently have occurred even in protected areas. Causes for the declines and malformations probably are varied and may not even be related. The seemingly sudden declines in widely separated areas, however, suggests a need to monitor amphibian populations as well as identify the causes when declines or malformations are discovered.

In 2000, the President of the United States and Congress directed Department of the Interior (DOI) agencies to develop a plan to monitor the trends in amphibian populations on DOI lands and to conduct research into possible causes of declines. The DOI has stewardship responsibilities over vast land holdings in the United States, much of it occupied by, or potential habitat for, amphibians. The U.S. Geological Survey (USGS) was given lead responsibility for planning and organizing this program, named the Amphibian Research and Monitoring Initiative (ARMI). Authorization carried the mandate to set up a national amphibian monitoring program on Federal lands, to develop the sampling techniques and biometrical analyses necessary to determine status and trends, and to identify possible causes of amphibian declines and malformations.

The biological importance of Great Smoky Mountains National Park has been recognized by its designation as an International Biosphere Reserve. As such, it is clearly the leading region of significance for amphibian research. Although no other region shares the wealth of amphibians as found in the Great Smokies (31 species of salamanders, and 13 of frogs), the entire southern and mid-section of the Appalachian Mountain chain is characterized by a high diversity of amphibians, and inventories and monitoring protocols developed in the Smokies likely will be applicable to other Appalachian National Park Service properties.

From 1998 to 2001, USGS biologists carried out a pilot inventory and monitoring research project in Great Smoky Mountains National Park. A variety of inventory, sampling, and monitoring techniques were employed and tested. These included wide-scale visual encounter surveys of amphibians at terrestrial and aquatic sites, intensive monitoring of selected

plots, randomly placed small-grid plot sampling, litterbag sampling in streams, monitoring nesting females of selected species, call surveys, and monitoring specialized habitats, such as caves. Coupled with information derived from amphibian surveys on Federal lands using various other techniques (automated frog call data loggers, PVC pipes, drift fences, terrestrial and aquatic traps), an amphibian monitoring program was designed to best meet the needs of biologists and natural resource managers after taking into consideration the logistics, terrain, and life histories of the species found within Great Smoky Mountains National Park.

This report provides an overview of the Park's amphibians, the factors affecting their distribution, a review of important areas of biodiversity, and a summary of amphibian life history in the Southern Appalachians. In addition, survey techniques are described as well as examples of how the techniques are set up, a critique of what the results tell the observer, and a discussion of the limitations of the techniques and the data. The report reviews considerations for site selection, outlines steps for biosecurity and for processing diseased or dying animals, and provides resource managers with a decision tree on how to monitor the Park's amphibians based on different levels of available resources. It concludes with an extensive list of references for inventorying and monitoring amphibians. USGS and Great Smoky Mountains National Park biologists need to establish cooperative efforts and training to ensure that congressionally mandated amphibian surveys are performed in a statistically rigorous and biologically meaningful manner, and that amphibian populations on Federal lands are monitored to ensure their long-term survival. The research detailed in this report will aid these cooperative efforts.

Introduction

The Florida Caribbean Science Center (now Florida Integrated Science Center) received funding in 1997 from the U.S. Geological Survey (USGS) Inventory and Monitoring (I&M) Program to conduct a pilot project for amphibians in the southeastern United States. After considering several locations, Great Smoky Mountains National Park (fig. 1) was selected for the survey because of its amphibian diversity and the large number of potential threats to its varied ecosystems (Brown, 2000). During the course of the next 4 years, a field research team of enthusiastic young biologists was assembled to collect information on the species richness and distribution of the Park's amphibians. Researchers used a variety of sampling techniques, including 10 x 10-meter survey plots, "permanent" 30 x 40-meter plots, coverboards, litter-bag surveys, and a great number of time-constrained litter and stream searches. The team looked for previously reported rare species, sampled historic locations, investigated unique habitats (such as caves), and examined museum records and published literature. Survey activities and techniques were designed to optimize the use of available personnel within budget and logistic constraints. Survey teams sampled more than 500 sites (fig. 2) and recorded data on more than 10,000 amphibians. All parts of the Park were visited in all seasons and in all weather conditions.

The objectives of the Great Smoky Mountains National Park I&M program were to: (1) provide a geographically referenced inventory of the amphibian resources of the Great Smoky Mountains National Park; (2) provide indices of abundance of Park selected amphibian species, referenced to locations and habitat types; (3) develop and transfer to the Great Smoky Mountains National Park and National Park Service a series of protocols suitable for long-term monitoring of amphibian populations in the "Smokies" and other Appalachian parks; (4) evaluate current distributions and abundance of amphibian species as possible in the Park with literature reports of past investigations. This manual fulfills the third objective of the I&M program. Additional information on amphibian natural history, distribution, landscape ecology, trends analysis, and protocol development are published in Dodd and others, (2001), Waldron and others, (2003); Dodd, (2004), or is under development.

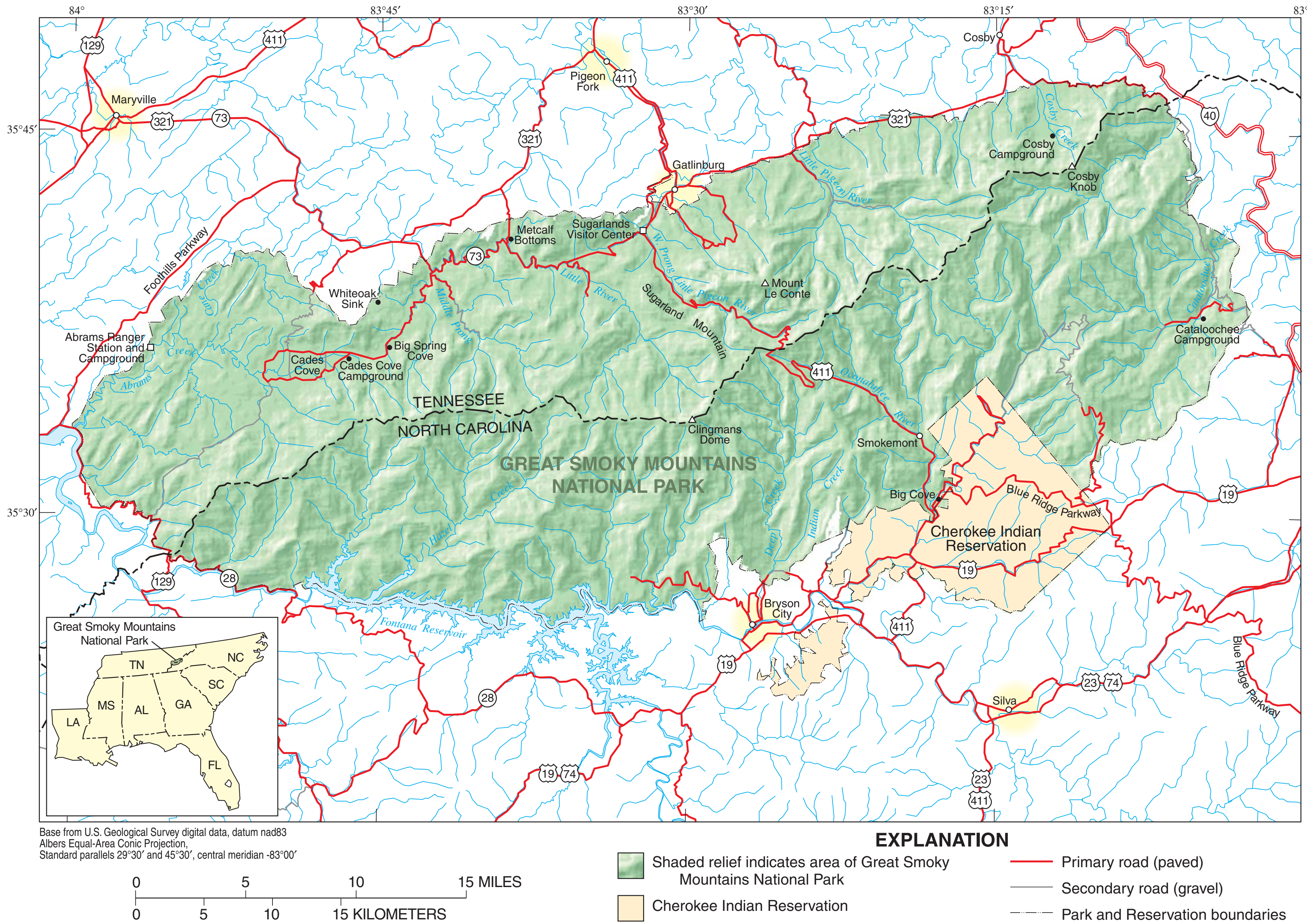


Figure 1. Great Smoky Mountains National Park, North Carolina and Tennessee.

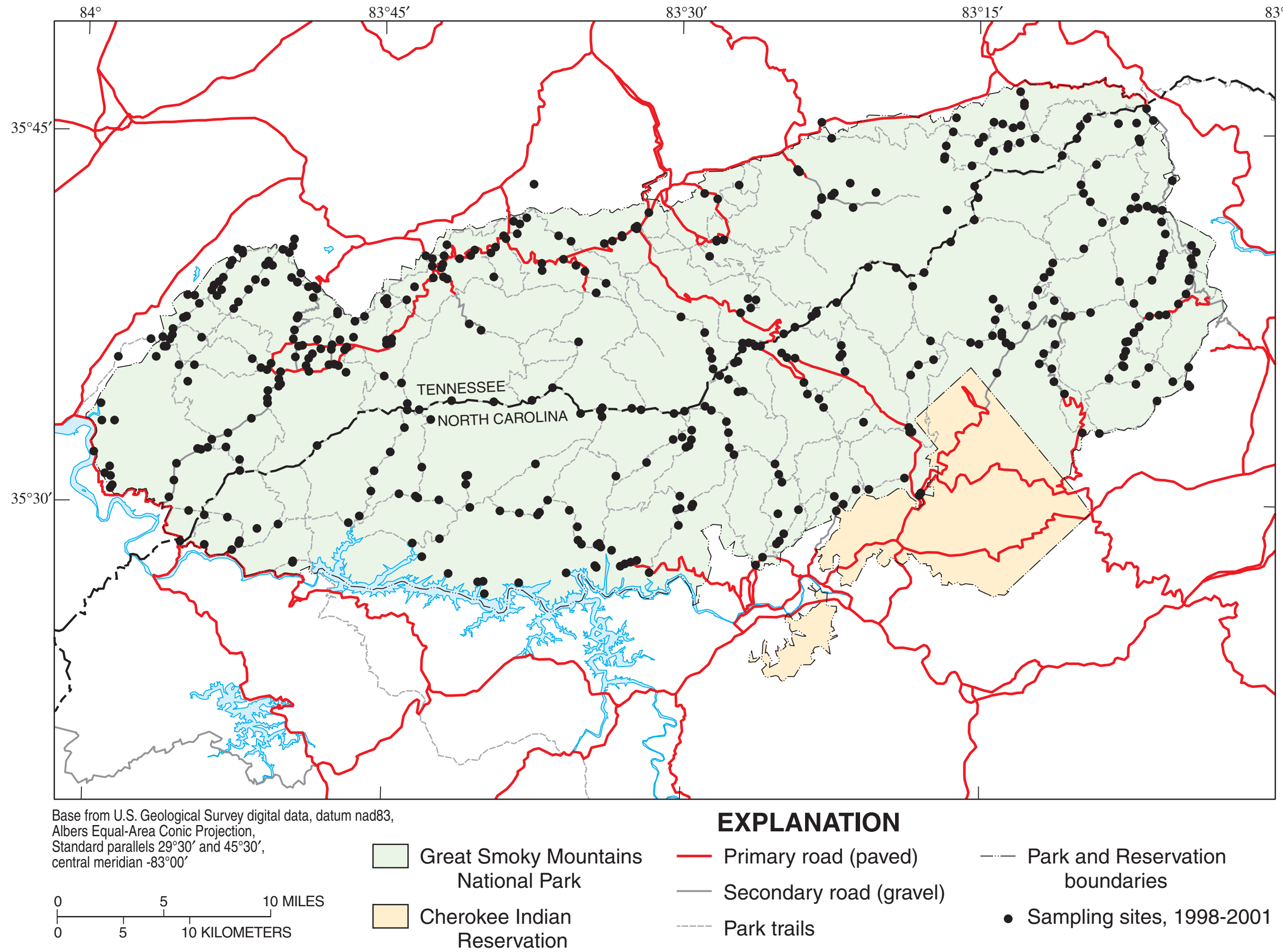


Figure 2. Location of U.S. Geological Survey sampling sites in Great Smoky Mountains National Park, 1998 to 2001.

Acknowledgments

This manual is the result of collaborative survey efforts during 4 years of hard field work between 1998 and 2001 in the Great Smoky Mountains. The author would like to thank the following individuals for their support, assistance, dedication, and companionship:

For their field collecting skill, expertise, and general good humor during all kinds of weather conditions, the USGS field crew from 1998 to 2001 (in alphabetical order): Jamie Barichivich, Jeff Corser, Elizabeth Domingue, Marian Griffey, Kelly Irwin, Christy Morgan, Rick 'Bubba' Owen, Kevin G. Smith, and Jayme Waldron. For figure 7: Todd Campbell. For advice: James Petranka and Chuck Smith.

For their support and assistance: the National Park Service personnel at Great Smoky Mountains National Park, particularly Keith Langdon, Dana Soehn, and Jack Piepenbring.

For providing funding: Norita Chaney (USGS Inventory and Monitoring Program, Reston, Virginia), Russell Hall (Florida Integrated Science Center), and the USGS Amphibian Research and Monitoring Initiative (ARMI).

For providing research permits: National Park Service (Great Smoky Mountains National Park), North Carolina Wildlife Resources Commission, Tennessee Wildlife Resources Agency.

For providing the beautiful illustrations of larval amphibians: Jacqualine Grant.

For reading the manuscript and making valuable comments: Jamie Barichivich, Marian Griffey, Russell Hall, Steve Johnson, Keith Langdon, and Jennifer Staiger.

HOW TO USE THIS GUIDE

Monitoring Amphibians in Great Smoky Mountains National Park is meant to help National Park Service natural resource biologists, university researchers, nongovernmental biologists, and the interested public understand and overcome some of the biological and nonbiological constraints to setting up a large-scale inventory and monitoring program for amphibians inhabiting the Great Smoky Mountains. Some of the information applies only to amphibians within the Great Smokies, whereas information on setting up inventory and monitoring programs may have more broad applications with regard to Appalachian amphibians. Many persons who use this guide will be familiar with basic amphibian biology, but others will require a refresher course or will be unfamiliar with amphibian life histories.

This guide serves as a companion volume to Dodd (2004) and, for that reason, information in that work has not been duplicated except when absolutely necessary. There is usually an exception to every generalization discussed below, and biologists should expect to encounter species outside of their "normal" habitat, that often do not fit identification information, or that have unusual behavioral patterns. Extensive information is not included on threats to amphibians (for example, habitat loss and alteration, disease, nonindigenous species, climate change, toxic chemicals, UVB, malformations) or the various reasons why amphibians are vulnerable to environmental problems (including their biphasic life cycle, skin permeability, and the complex morphological and biochemical transformations which accompany metamorphosis). These topics are dealt with in more detail elsewhere (Dodd, 1997, 2004; Alford and Richards, 1999; Corn, 2000; Houlahan and others, 2000).

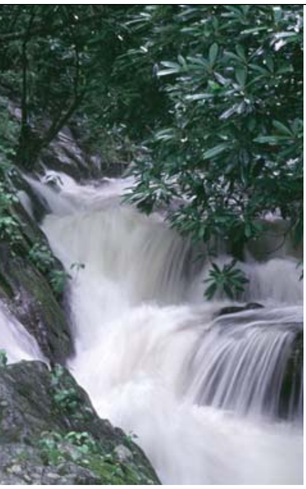
All of the potential sampling protocols, techniques, and methods of data analysis that may accompany, or be required for, a large-scale amphibian inventory and monitoring program cannot be discussed within one short guide. For this reason, many specialized techniques are not discussed, instructions are not provided for making traps, and statistical programs are not considered in detail. However, references are provided at the end of this guide (see **References on Inventorying and Monitoring Amphibians**).

Future amphibian monitoring within Great Smoky Mountains National Park will be linked to the U.S. Department of Interior (DOI) Amphibian Research and Monitoring Initiative (ARMI). Standardized methods of data collection, entry, and analysis currently are being developed by ARMI researchers for all DOI lands. Pertinent information will be made available to Federal agencies and ARMI partners through ARMI's web site:

edc2.usgs.gov/armi/

A cautionary note: There is always the danger that site information will be misused by criminal elements to find amphibians in order to collect them. This is true in National Parks and on other Federal lands, as well as on private lands. None of the amphibians found in Great Smoky Mountains National Park are endangered or threatened under the Federal Endangered Species Act of 1973, as amended, although several species, such as Hellbenders, are protected by state law. Locations of many of the Park's amphibians, including its endemic salamanders, are well known via the published scientific literature and on records attached to museum specimens. Therefore, it seems unlikely that mentioning Park locations in this guide will increase the probability of collection, especially when these species are found readily, and often in greater abundance, outside the Park. For example, the Mole Salamander, Southern Zigzag Salamander, and Mud Salamander might be considered "rare" or "isolated" within Great Smoky Mountains National Park, yet very large and widespread populations of these species are found in the Tennessee Valley and elsewhere. Still, Park Service employees and research scientists working within the Park, including field survey teams, must be observant for illegal collectors and immediately report suspicious activities to law enforcement personnel.

Amphibians of the Great Smoky Mountains



Species Richness

A total of 31 salamanders and 13 frogs have been recorded from the Great Smoky Mountains National Park. Note that common names are capitalized, and that species names (consisting of a genus and specific epithet) are italicized. Species codes allow data to be entered in shorthand format. To minimize data entry errors, species codes should be either all capitalized or all in lower case letters. Capitals and lower-case letters should not be intermixed. Using accepted and standardized common and scientific names (Crother, 2000), the amphibians are:

Common name	Scientific name	Suggested species code
	Salamanders	
Spotted Salamander	*Ambystoma maculatum*	AMA
Marbled Salamander	*Ambystoma opacum*	AOP
Mole Salamander	*Ambystoma talpoideum*	ATA
Green Salamander	*Aneides aeneus*	AAE
Hellbender	*Cryptobranchus alleganiensis*	CAL
Seepage Salamander	*Desmognathus aeneus*	DAE
Spotted Dusky Salamander	*Desmognathus conanti*	DCO
Imitator Salamander	*Desmognathus imitator*	DIM
Shovel-nosed Salamander	*Desmognathus marmoratus*	DMA
Seal Salamander	*Desmognathus monticola*	DMO
Ocoee Salamander	*Desmognathus ocoee*	DOC
Black-bellied Salamander	*Desmognathus quadramaculatus*	DQU
Santeetlah Salamander	*Desmognathus santeetlah*	DSA
Pigmy Salamander	*Desmognathus wrighti*	DWR
Three-lined Salamander	*Eurycea guttolineata*	EGU
Junaluska Salamander	*Eurycea junaluska*	EJU
Long-tailed Salamander	*Eurycea longicauda*	ELO
Cave Salamander	*Eurycea lucifuga*	ELU
Blue Ridge Two-lined Salamander	*Eurycea wilderae*	EWI
Spring Salamander	*Gyrinophilus porphyriticus*	GPO
Four-toed Salamander	*Hemidactylium scutatum*	HSC
Common Mudpuppy	*Necturus maculosus*	NMA
Eastern Red-spotted Newt	*Notophthalmus viridescens*	NVI
Northern Slimy Salamander	*Plethodon glutinosus*	PGL
Jordan's Salamander	*Plethodon jordani*	PJO
Southern Gray-cheeked Salamander	*Plethodon metcalfi*	PME
Southern Appalachian Salamander	*Plethodon oconaluftee*	POC
Southern Red-backed Salamander	*Plethodon serratus*	PSE
Southern Zigzag Salamander	*Plethodon ventralis*	PVE
Mud Salamander	*Pseudotriton montanus*	PMO
Black-chinned Red Salamander	*Pseudotriton ruber*	PRU
	Frogs	
Northern Cricket Frog	*Acris crepitans*	ACR
American Toad	*Bufo americanus*	BAM
Fowler's Toad	*Bufo fowleri*	BFO
Eastern Narrow-mouthed Toad	*Gastrophryne carolinensis*	GCA
Cope's Gray Treefrog	*Hyla chrysoscelis*	HCH
Spring Peeper	*Pseudacris crucifer*	PCR
Upland Chorus Frog	*Pseudacris feriarum*	PFE
American Bullfrog	*Rana catesbeiana*	RCA
Northern Green Frog	*Rana clamitans*	RCL
Pickerel Frog	*Rana palustris*	RPA
Northern Leopard Frog	*Rana pipiens*	RPI
Wood Frog	*Rana sylvatica*	RSL
Eastern Spadefoot	*Scaphiopus holbrooki*	SHO

Amphibian taxonomy and systematics within the southern Appalachians are topics of intense debate among biologists. Rationale for using the listed names is provided by Dodd (2004).

Habitats and Distribution

Five major forest communities are recognized within the Great Smoky Mountains National Park, although 80 percent of the Park falls within the Eastern Deciduous Forest Ecosystem (Houk, 1993). Some botanists have further subdivided the vegetation into as many as 67 florally distinct communities. No one species of amphibian is associated entirely with a single forest community, although some of the high-elevation salamanders (*Plethodon jordani, Desmognathus ocoee, D. wrighti*) are more often found in the spruce-fir community than in other community types. Habitat structure, particularly one that retains moisture and high humidity, is important in shaping salamander distribution. The high-elevation coniferous forest appears ideal in providing shade, cover (in the form of coarse woody debris), and abundant surfaces for moisture condensation.

Five major forest communities are recognized within the Great Smoky Mountains National Park....

The ***spruce-fir forest*** (fig. 3) is dominated by Red Spruce (*Picea rubens*) and Fraser Fir *(Abies fraseri*), and is found generally above 1,676 m (5,500 ft), although the community descends to 1,372 m (4,500 ft) in some locations and individual Red Spruce are found at even lower elevations. This is the Canadian Zone boreal forest of high moisture, cool or cold temperatures, and high humidity (Houk, 1993). Ground surface is often dense with fallen tree branches and trunks, and carpeted by thick layers of tree needles. Wet, rotten, woody debris and dense needle mats provide ideal hiding places for terrestrial salamanders. Streams originate in this habitat, usually beginning as small seeps and springs. As streams trickle through

Figure 3. Spruce-fir forest at Indian Gap.

the dark-green forest, they gather momentum. Even at higher elevations, aquatic salamanders, particularly duskies (*Desmognathus*) and Blue Ridge Two-lined Salamanders (*Eurycea wilderae*), may be plentiful within the headwater streams.

At somewhat lower elevations (1,067-1,524 m; 3,500-5,000 ft), ***deciduous northern hardwoods*** (fig. 4) predominate, such as Sugar Maples (*Acer saccharum*), American Beech (*Fagus grandifolia*), and Yellow Birch (*Betula alleghaniensis*). Many terrestrial and aquatic salamanders reach their lower or upper distributional range within this community; frogs are scarce. ***Cove hardwoods***, the third community, comprise the most diverse forest community in the Smokies, one that is endemic to the southern Appalachian Mountains. It occurs generally below 1,372 m (4,500 ft) in sheltered valleys, and is dominated by Tulip Poplar (*Liriodendron tulipifera*), Dogwood (*Cornus florida*), Red Maple (*Acer rubrum*), Sweetgum (*Liquidamber styraciflua*), White Basswood (*Tilia americana* var. *heterophylla*), Yellow Buckeye (*Aesculus flava*), and Black Birch (*Betula lenta*). Both hardwood communities have complex understory vegetation, often with much coarse woody debris, which provides cover for terrestrial salamanders. The streams through these hardwood forests are rocky and fast paced, and salamanders are very common along streamsides and in the water.

Two somewhat specialized forest communities are found in the Smokies. The ***hemlock*** community (fig. 5) is dominated by Eastern Hemlocks (*Tsuga canadensis*), commonly

Figure 4. Deciduous forest at Lynn Hollow.

Hemlocks are massive with tall, straight trunks. When they fall, they provide excellent habitat for salamanders....

Figure 5. Hemlock forest at Chinquapin Knob.

called "spruce-pines" by natives of the southern mountains, and is common between 1,067-1,524 m (3,500-5,000 ft) in elevation. Hemlocks descend to much lower elevations along cold mountain stream valleys, and overlap considerably with both hardwood forests and the spruce-fir forest of the higher elevations. Hemlocks are massive with tall, straight trunks. When they fall, they provide excellent habitat for salamanders, both in the rotting wood and under exfoliating bark (fig. 6).

The ***pine-oak forest*** (fig. 7) occupies the drier areas of the Park, particularly the area west of Cades Cove and at mid-elevations on the North Carolina side of the Park. This forest is dominated by Southern Red (*Quercus falcata*),

Figure 6. Coarse woody debris in Cove forest at Roaring Fork. Note the pink survey flags marking the position of transects.

Northern Red (*Q. rubra*), Scarlet (*Q. coccinea*), Black (*Q. velutina*), and Chestnut (*Q. prinus*) Oaks, and by Pitch (*Pinus rigida*), White (*P. strobus*), and Table Mountain (*P. pungens*) Pines. Soils are dry, as is the leaf litter. Prior to human intervention, this community burned frequently in the western regions of the Park, and a fire-adapted vegetation community resulted. Terrestrial salamanders are few, and usually found only during cool, wet times of the year. Aquatic-breeding salamanders and frogs are found along streamsides, where they likely remain close to water. The bottomlands along Cane Creek and Abrams Creek likely formed a corridor from the Tennessee Valley into Cades Cove. As a result, amphibian species richness is surprisingly high, particularly for frogs.

Amphibians are not uniformly distributed throughout the Great Smoky Mountains National Park. There are wide-ranging species, species restricted to specialized habitats, and species found in only one area of the Park.

Monitoring programs will need to take the distribution of species into account to optimize time and financial resources. A few generalizations can be made about amphibian distribution and habitats within the Park.

SALAMANDERS

Terrestrial salamanders (see **Life History**) include species that are: restricted in distribution in the Great Smokies; wide ranging but not common species; and wide ranging in higher or lower elevations, and generally common. Because they do not have larvae, they must be sampled where they carry out their entire life cycle, usually on the forest floor and under leaf litter and other debris.

Amphibians are not uniformly distributed throughout the Great Smoky Mountains National Park.


Photographer: Todd Campbell, University of Tampa

Figure 7. Oak-pine forest.

Table 1. Identification and life history of the nonpermanently aquatic salamanders of Great Smoky Mountains National Park

[mos, months; yr, year; mm, millimeter; TL, total length; SVL, snout-vent length; ~, approximately; <, less than; >, greater than]

Species	Egg deposition	Hatching	Larval period	Hatching size	Size and time of Metamorphosis	Spots on dorsum	Dorsal pattern	Belly pattern	Tail attributes	Notes
Ambystoma maculatum	Jan. to late Mar. (mountains-late Feb. to early Mar.); 4-7 weeks incubation	April-May	2-4 mos	12-17 mm TL	29-32 mm SVL; 43-60 mm TL (to 75 mm TL if overwinter); mid-June to August		dull olive green, no conspicuous markings	white or light	tail fin lightly mottled or finely stippled; dark at tip	Breeding occurs in 2-3 bouts following rain; pond type larvae
A. opacum	Oct-Nov (in pond by Sept.); 9-15 days incubation, but must be flooded 1-2 days	winter	5-7 mos	10-14 mm TL	~33 mm SVL; 49-58 mm TL; late March mid-June		blackish, drab; older larvae have mottling on body	throat stippled; scattered melanophores on lateral sides	dorsal fin extends almost to front limbs	Pond type larvae; series of ventrolateral light spots forming a line below limb insertions
A. talpoideum	Sept. to Mar. (winter)	winter to early spring	3-4 mos, but variable	~10 mm SVL	32 to 50 mm SVL; May to Sept.		black and yellow blotches along midline of back	dark band on midline (poor in some specimens)	yellow and black on tail fin	Pond type larvae; variable life histories with regard to timing of events
Desmognathus conanti	early May to early July, perhaps to mid-August; 45-60 days incubation	July to early fall	<1 yr	8-12 mm SVL; 12-20 mm TL	9-12 mm SVL, to 20 mm SVL; July to early fall?	5-8 pairs of even or alternating spots or blotches	sides with dorsolateral stripe; dorsum variable		spot pattern continues on tail	In older larvae, spots or blotches may fuse
D. imitator	late spring to early summer?									
D. marmoratus	late spring to early summer?; 10-12 weeks incubation	mid-Aug to mid-Sept.	3 yrs (10-20 mos)	11 mm SVL	26-38 mm SVL; May to Oct.	2 rows light spots	dark, conspicuous light flecks on sides		spatulate	more slender, with longer legs than DQ
D. monticola	mid-June to mid-August; 2 mos incubation	early summer to fall; Sept.	10-11 mos	11-12 mm SVL	June-July	4-5 pairs light dorsal spots between limbs				
D. ocoee	July to early Aug. to Sept.; 52-74 days incubation	Aug to late Sept.	9-10 mos	13-18 mm TL	11-15 mm SVL; May to June	4-6 pairs of alternating light spots on dorsum				round snouts
D. quadramaculatus	May to June	July to Sept.	3-4 yrs	11-16 mm SVL	35-42, to 54 mm SVL; mid-summer	6-8 pairs light spots between limbs	light brown			much larger than all other Desmogs; lots of yolk 1-2 mos after hatching
D. santeetlah	early May to early July, perhaps to mid-August; 45-60 days incubation	July to early fall	<1 yr	8-12 mm SVL; 12-20 mm TL	9-12 mm SVL, to 20 mm SVL; July to early fall?	4-5 pairs of even or alternating spots or blotches				

Table 1. Identification and life history of the nonpermanently aquatic salamanders of Great Smoky Mountains National Park (Continued)

[mos, months; yr, year; mm, millimeter; TL, total length; SVL, snout-vent length; ~, approximately; <, less than; >, greater than]

Species	Egg deposition	Hatching	Larval period	Hatching size	Size and time of Metamorphosis	Spots on dorsum	Dorsal pattern	Belly pattern	Tail attributes	Notes
Eurycea guttolineata	winter	early to mid-Mar?	3.5-5.5 mos (< 1 yr), but may over-winter	11-12.5 mm SVL	22-27 mm SVL, to 32 mm SVL; June to August	no paired light spots	cream; uniformly stippled; then dark broad dorsolateral stripe; narrow mid-dorsal stripe	immaculate	dorsal fin does not extend forward of rear legs	stream type
E. junaluska	at least by mid-May	early June?	1-2 yr	7-9 mm SVL; 11-13 mm TL	34-42 mm SVL; mid-May to August		deep olive green to brown	no iridophores		dense, well-defined cheek patches; lower margin of dark pigmentation straight
E. longicauda	late autumn to early spring	Nov-March after 4-12 weeks	normally <1 yr (4-7 mos)	18-21 mm SVL; 40 mm TL;	23-28 mm SVL; > 50 mm TL if over-wintering; mid-June-July		cream colored; then uniformly dark, similar to adults; no paired spots	immaculate		
E. lucifuga	Sept. to Feb.		6-18 mos; most 12-15 mos	9-12 mm SVL; to 17.5 mm TL	31-37 mm SVL; to 70 mm TL; spring		sparse pigmentation with 3 longitudinal series of spots on the side			
E. wilderae	Feb. to May; 4-10 weeks incubation	May to August	1-2 yr	7-9 mm SVL; 11-14 mm TL	18-19 mm SVL in 1 yr, to 32 mm SVL in 2 yr; April to July	6-9 pairs light dorsolateral	dusky	light with iridophores		stream type; tail fin stops near insertion of rear limbs; reddish gills; square snouts
Gyrinophilus porphyriticus	summer	late summer to autumn	to 4 yr	18-22 mm TL	55-65 mm SVL, to 70 mm high elevation; late June to August		light yellow brown to gray with fine flecking			long truncated snouts with small eyes
Hemidactylium scutatum	Feb to May	May-June?	21 to 61 days		11-15 mm SVL; 17-25 mm TL; July?		nondescript, yellow brown; dorsal fin extends to head			pond type larvae; joint nesting occurs; brooding
Pseudotriton montanus	autumn to early winter	winter	15-17 mos to 29-30 mos	<13 mm SVL	35-44 mm SVL; mid-May to Sept.		light brown; older with widely scattered spots	immaculate		stream type; over-wintering occurs; larvae can be very large
P. ruber	autumn to early winter; 3 mos incubation	mid-Dec to mid-Feb	1.5 to 3.5 yr (27-31 mos)	11-14 mm TL	34-46 mm SVL; 62-86 mm TL; May to July		light brown; weakly mottled or streaked	dull white		stream type; no black chins or dorsal spots

Monitoring programs can target each type of distributional pattern or habitat listed below, depending upon the objectives of the researchers and the funds and personnel available. For example, whereas a few people can easily monitor the status of the Southern Zigzag Salamander, a much more elaborate protocol will be necessary to monitor populations of the Southern Red-backed Salamander. A number of these species are syntopic, making multispecies monitoring a realistic objective. As much as possible, single species sampling and monitoring should be avoided in favor of multispecies sampling and data recording. Some examples of typical distribution patterns follow:

Species restricted in distribution

Southern Zigzag Salamander (*Plethodon ventralis*).

Wide ranging, but not common, species

Southern Appalachian Salamander (*Plethodon oconaluftee*).

Species that are common and wide ranging at higher elevations

Pigmy Salamander (*Desmognathus wrighti*); Jordan's Salamander (*Plethodon jordani*); Southern Gray-cheeked Salamander (*Plethodon metcalfi*).

Species that are common and wide ranging at lower elevations

Northern Slimy Salamander (*Plethodon glutinosus*); Southern Red-backed Salamander (*Plethodon serratus*).

River-dwelling salamanders inhabit only the largest of the Smokies' rivers (fig. 8), including Little River, Middle Prong, Oconaluftee River, Little Pigeon River, Abrams Creek, the lower reaches of Deep Creek and, perhaps, Hazel Creek. There are only two true river-dwelling salamanders in the Great Smokies, the Hellbender (*Cryptobranchus alleganiensis*), known presently only from Little River, Oconaluftee River, and Deep Creek

Figure 8. Middle Prong at Tremont.

Figure 9. Ideal habitat for Hellbenders in Lower Abrams Creek.

(Nickerson and others, 2002; Dodd, 2004) (fig. 9), and the Common Mudpuppy (*Necturus maculosus*), known only from Little River and Abrams Creek. One additional salamander, the Junaluska Salamander (*Eurycea junaluska*), tends to be associated with some of the Park's larger western and northwestern streams and rivers on the Tennessee side of the Smokies. Larvae are found near the shore, and the adults inhabit streambanks for at least part of the year. However, this species also inhabits some smaller streams, and it is by no means a "river-dwelling" species.

Creek and stream salamanders have larvae that develop in the creeks and streams of the Park (figs. 10-12), whereas the adults may be

Figure 10. Small stream in unnamed tributary to Falls Branch.

Figure 11. Medium-sized stream in normal flow at Roaring Fork.

aquatic, semi-aquatic, or even terrestrial to a greater or lesser degree. Many of these species are widespread in the Park because of the large number of creeks and streams available for colonization. A few species are found only at higher mountain elevations (for example, the Ocoee and Imitator Salamanders), whereas others are lowland species (Spotted Dusky, Three-lined, and Long-tailed Salamanders). Instead of a circumscribed area, their habitat is often linear, following the streams and streamsides. The dusky salamanders (*Desmognathus*) are prominent in this group, but there are many exceptions to each habitat categorization listed below. Even Black-bellied Salamanders have been found well above the forest floor in rock crevices among boulders at considerable distances from water. Monitoring adults and larvae of these species requires very different techniques, and may require sampling very different types of habitats.

Nearly aquatic species

Shovel-nosed Salamander (*Desmognathus marmoratus*).

Predominantly aquatic and streamside species

Spotted Dusky Salamander (*Desmognathus conanti*); Seal Salamander (*Desmognathus monticola*); Black-bellied Salamander (*Desmognathus quadramaculatus*); Santeetlah Salamander (*Desmognathus santeetlah*);

Many of these species are widespread in the Park because of the large number of creeks and streams available for colonization.

Figure 12. Medium-sized stream in high water at Whiteoak Flats Branch.

Junaluska Salamander (*Eurycea junaluska*). The extremely high elevation areas where some streams first appear may be devoid of salamanders if the water emanates from the Anakeesta rock formation (Dodd, 2004).

Species with aquatic larvae but are largely terrestrial as adults

Imitator Salamander (*Desmognathus imitator*); Ocoee Salamander (*Desmognathus ocoee*); Three-lined Salamander (*Eurycea guttolineata*); Long-tailed Salamander (*Eurycea longicauda*); Blue Ridge Two-lined Salamander (*Eurycea wilderae*).

A few ***salamanders*** require very ***specialized habitats*** in the Great Smokies, or at least are usually found in these habitats. Some of these species have larvae which are found in the same streams and creeks as the preceding species, although the adults prefer to leave the streams. Whereas the larvae may be relatively easy to survey, adults often can be quite difficult to find with any regularity. One species, the Seepage Salamander, does not have a larval stage, and the adults are only found in wet seeps.

Cave inhabitants (fig. 13)

Cave Salamander (*Eurycea lucifuga*).

Known only from Stupkas Cave, the Calf caves, and one record from Whiteoak Sink. Other salamanders in the Smokies may live in caves, especially around the entrances (Dodd and others, 2001). The larvae of some salamanders (for example, *E. longicauda* in Gregorys Cave) develop in pools well inside cave passages (fig. 14).

Rock face inhabitants (fig. 15)

Spotted Dusky Salamander (*Desmognathus conanti*); Seal Salamander (*Desmognathus monticola*).

Permanent to near permanent wet rock walls with hiding places, particularly along trails, road cuts, and in the vicinity of waterfalls, especially at lower elevations.

Figure 13. Entrance to Gregorys Cave.

Figure 14. Rimstone pools and cave pool at Gregorys Cave. Salamander larvae develop in the pools, although they are unlikely to complete metamorphosis.

A few salamanders require very specialized habitats in the Great Smokies, or at least are usually found in these habitats.

Figure 15. Rock face near Double Gap.

Spring Inhabitants

Spring Salamander (*Gyrinophilus porphyriticus*); Black-chinned Red Salamander (*Pseudotriton ruber*).

Inhabitants of swampy and mucky habitats (fig. 16)

Mud Salamander (*Pseudotriton montanus*).

Known only from a few scattered locations in the lowlands of the northern side of the Park.

Inhabitants of wet seepages (fig. 17)

Seepage Salamander (*Desmognathus aeneus*).

Known only from drainages on the southwestern side of the Park.

Figure 17. Seep at Big Spring Cove.

Finally, there are ***salamanders that breed in ponds***, and it is virtually only at this time that these species can be censused. Five species fall into this category: the Spotted Salamander *(Ambystoma maculatum*); Marbled Salamander (*A. opacum*); the rare Mole Salamander (*A. talpoideum*); Four-toed Salamander (*Hemidactylium scutatum)*; and Eastern Red-spotted Newt (*Notophthalmus viridescens)*. Breeding ponds are limited within the Park, being concentrated in Cades Cove and nearby Big Spring Cove (the four Finley-Cane sinkhole ponds), the Cane Creek drainage, and at scattered localities between Sugarlands and Cades Cove along Little River (at the Sinks and ditches along the road to Tremont). These locations are on the Tennessee side of the Park. Although beaver ponds are found in Bone Valley and Big Cove in North Carolina, and small scattered ditches and wetlands occur in Cataloochee Valley, no pond salamanders are known to breed in them.

Figure 16. Former trout pond mucky habitat in Cataloochee.

Mud Salamanders are known only from a few scattered locations in the lowlands of the northern side of the Park.

FROGS

Frogs in the Great Smoky Mountains National Park require water for breeding and for tadpole development. As such, the diversity and distribution of frogs are not as great in the mountains as in the adjacent lowlands of the Tennessee Valley and Atlantic Coastal Plain. In the Smokies, four major types of breeding sites are used by frogs and toads: ponds (natural, as well as of beaver or human origin); woodland pools; grassy ditches, pools, and rivulets; and larger streams and rivers.

Ponds

Pond distribution is limited in the Smokies, being confined mostly to Cades Cove, Big Spring Cove, and two beaver ponds. The

Figure 18. Gum Swamp at Cades Cove in high water.

Figure 19. Gum Swamp at Cades Cove when dry.

most important frog-breeding ponds are Gum Swamp (figs. 18, 19), Gourley Pond (figs. 20, 21), Methodist Church Pond (fig. 22), and the sewage-treatment pond (all in Cades Cove); the four sinkhole ponds in Big Spring Cove (also known as the Finley-Cane ponds); and the beaver ponds in Bone Valley and Big Cove (fig. 23). Species that commonly use these ponds are the American Toad (*Bufo americanus*), Cope's Gray Treefrog (*Hyla chrysoscelis*), Northern Green Frog (*Rana clamitans*), Pickerel Frog (*R. palustris*), Wood Frog (*R. sylvatica*), and Eastern Spadefoot (*Scaphiopus holbrooki*), known only from Gum Swamp. American Bullfrogs (*R. catesbeiana*) also have been heard at the beaver pond in Big Cove. Some of these ponds dry completely as the summer progresses, particularly Gum Swamp (fig. 19), Gourley Pond (fig. 21), and the Finley-Cane sinkhole ponds.

Figure 20. Gourley Pond at Cades Cove in high water.

Figure 21. Gourley Pond at Cades Cove when dry.

Figure 22. Methodist Church Pond at Cades Cove.

Figure 23. Beaver pond at Big Cove.

Woodland Pools

Woodland pools are scattered at various areas within the Park. They range from a few centimeters deep to about 0.5 m, and they usually dry as summer progresses. Woodland pools are located in level ground at Cosby, Sugarlands, Metcalf Bottoms, Big Spring Cove, Little Cataloochee Valley, throughout the Cane Creek drainage (fig. 24), Cades Cove (especially along Abrams Creek at the western edge of the cove), and doubtless in other areas of the Park. Amphibians that use these small pools for breeding include the Eastern Red-spotted Newt (*Notophthalmus viridescens*), American Toad (*Bufo americanus*), Cope's Gray Treefrog (*Hyla chrysoscelis*), Northern Green Frog (*Rana clamitans*), Pickerel Frog (*R. palustris*), and Wood Frog (*R. sylvatica*).

Figure 24. Woodland drainage pool at Cane Creek.

Grassy Ditches, Pools, and Rivulets

Grassy ditches, pools, and rivulets are generally shallow, open-canopied habitats, with a grassy vegetation where concealment and breeding sites are available (fig. 25). Only two places in the Park contain much of this habitat: Cades Cove and Cataloochee Valley. Frogs found here include the American Toad (*B. americanus*); Eastern Narrow-mouthed Toad (*Gastrophryne carolinensis*), known only from grassy pools at the Abrams Creek Ranger Station and at Shields Pond in Cades Cove; Spring Peeper (*Pseudacris crucifer*); Upland Chorus Frog (*Pseudacris feriarum*); and the ubiquitous Wood Frog (*R. sylvatica*). These habitats normally dry rapidly with the warm weather, although the rivulets and some pools in Cades Cove may persist well into summer.

Streams and Rivers

A few species of frogs breed in the shallows of rivers and larger streams. In the Great Smokies, the American Bullfrog's (*R. catesbeiana*) large tadpoles are conspicuous in Abrams Creek near the Abrams Creek Ranger Station. Additional species, such as Fowler's Toad (*B. fowleri*), breed in the backwaters formed from flooding along streams and rivers. Other frogs, such as Northern Green Frogs (*R. clamitans*), are found along streambanks during the nonbreeding seasons.

Table 2. Identification and Life History of the Frogs of Great Smoky Mountains National Park

[<, less than; >, greater than; mm, millimeter; cm, centimeter; m, meter; m^2, square meters]

Species	Eggs	Tadpole description	Breeding times	Larval period	Metamorph size
Acris crepitans	eggs deposited singly; 1 gelatinous envelope, >2.3 mm in diameter; deposited in shallow water among stems of grass or on bottom; 250 eggs per complement	a medium-sized light to medium-gray tadpole; throat light; tail musculature mottled or reticulated; usually a very distinctive "black flag" on the tail tip; tail long and narrow; anus dextral (to the right); oral disk emarginate; most 30-36 mm total length, rarely to 46 mm	April to June, possibly into July	35-70 days, based on *Acris crepitans blanchardi*	10-15 mm
Bufo americanus	eggs in strings with gelatinous casings; 2 envelopes present; strings long, to 60 m; 15-17 eggs per 25 mm; 4,000-12,000 eggs on bottom of quiet pools	body round or oval in dorsal view; eyes dorsal (looks cross-eyed); nostrils large; color dark brown to black; dorsal portion of the body unicolored; venter with aggregate silvery or copper spots; snout sloping in lateral view; tail musculature distinctly bicolored; anus medial (in the center); spiracle is distinctly on left side of body	spring (March-April)	50-65 days	7-12 mm
B. fowleri	eggs in strings with gelatinous casings; 1 envelope present and <5 mm in diameter; strings 2.4-3 m with 17-25 eggs per 25 mm; 5,000-10,000 eggs; in tangled mass around vegetation	body round or oval in dorsal view; eyes dorsal (looks cross-eyed); nostrils large; color dark; dorsal portion of body slightly mottled; snout rounded in lateral view; tail musculature often not distinctly bicolored; anus medial (in the center); spiracle is distinctly on left side of body	April to July	40-60 days	7.5-11.5 mm
Gastrophryne carolinensis	eggs in small surface film that has a mosaic structure; envelope a truncated sphere; mass round or square; 10-150 eggs per mass; in any depression with water, but not deep pools	a small jet-black tadpole with lateral white to pink stripes on posterior portion of body extending to the tail musculature. Viewed from the side, the head comes to a point; body round in dorsal view; eyes wide set and lateral; anus median; jaws do not have keratinized sheaths, and the oral disc and labial teeth are absent	mid-May to mid-August	20-70 days	8.5-12 mm
Hyla chrysoscelis	eggs in small surface film, but envelope not in truncated sphere; no mosaic structure; 5-40 eggs per mass; in shallow ponds attached loosely to vegetation, or free. Air bubbles present.	small to medium-sized grayish tadpole with a high dorsal tail fin; dorsal tail fin height equal to or greater than musculature height; tail long, with black blotches; background color of mature tail orange to scarlet; throat rarely pigmented; dorsal fin never extends anterior to midway between the spiracle and eye; anus dextral (to the right); oral disk not emarginate	April to June, but calls occasionally heard at other times of the year	45-65 days	13-20 mm
Pseudacris crucifer	eggs deposited singly in shallow water near bottom among vegetation; one gelatinous envelope.	a small-sized deep-bodied tadpole with a medium-sized tail; tail musculature mottled; fins clear or with blotches; no dots on body; snout square when viewed dorsally; anus dextral (to the right); oral disk not emarginate	late winter to early spring (February to April); calls occasionally heard at other times of the year	90-100 days	9-14 mm
P. feriarum	egg mass in lump, but loose irregular cluster; 1 envelope, 3.6-4.0 mm; deposited in marshy areas and pools in matted vegetation	small olive to black tadpole with a bronze belly; tail medium; anus dextral (to the right); oral disk not emarginate; tadpoles develop rapidly	February to April.	50-60 days	8-12 mm

Table 2. Identification and Life History of the Frogs of Great Smoky Mountains National Park (Continued)

[<, less than; >, greater than; mm, millimeter; cm, centimeter; m, meter; m^2, square meters]

Species	Eggs	Tadpole description	Breeding times	Larval period	Metamorph size
Rana catesbeiana	eggs in large surface film in form of a disc; 10,000-12,000 eggs per disc; deposited among water plants or brush; 1 gelatinous envelope	large olive to grayish green tadpole with small widely spaced small spots (dots) covering the body and tail; venter straw; eyes bronze; body oval and round in dorsal view; eyes dorsal or dorsolateral; nostrils small compared with eyes; lower jaw wide; anus dextral (to the right); oral disk emarginate	late spring and throughout the summer. Calls may be heard at other times of the year	1-2 years	31-59 mm
R. clamitans	eggs in surface film; mass <0.09 m^2; 1,000-5,000 per mass; attached to vegetation or free; 2 gelatinous envelopes	large (but not deep bodied) olive green tadpole with large dark spots, generally with a white throat; belly deep cream without iridescence; body oval and round in dorsal view; eyes dorsal or dorsolateral; nostrils small compared with eyes; tail green mottled with brown; lower jaw wide; anus dextral (to the right); oral disk emarginate	late April to late July or even early August. Calls may be heard at other times of the year	to 1 year	23-38 mm
R. palustris	eggs in firm regular cluster; brown above and yellow below; mass a sphere 38-100 mm in diameter; 2 envelopes present; 2,000-4,000 eggs; mass deposited 75-100 mm to 91 cm under water; attached to debris and vegetation	large, full, deep-bodied tadpole; olive green shading through yellow on sides; venter cream, back marked with fine black and yellow spots; belly with blotches of white; venter iridescent, viscera visible; tail very dark, black blotches can aggregate to purple-black; body oval and round in dorsal view; eyes dorsal or dorsolateral; nostrils small compared with eyes; lower jaw narrow; anus dextral (to the right); oral disk emarginate	late winter to spring (mid-March-April)	70-80 days	19-27 mm
R. pipiens	mass a firm regular cluster; 3,500-6,500 eggs close together in mass; 2 envelopes present; outer envelope 5 mm; eggs black above and white below; deposited near surface, usually attached to grasses and vegetation, sometimes free	large, deep-bodied tadpole; dorsally dark brown, covered with small gold spots; belly deep cream, with bronze iridescence; viscera visible; throat translucent and more extensive than Pickerel Frog; similar in appearance to Green Frog, but darker; body oval and round in dorsal view; eyes dorsal or dorsolateral; nostrils small compared with eyes; lower jaw narrow; anus dextral (to the right); oral disk emarginate	probably early March to early May	60-80 days	18-31 mm
R. sylvatica	eggs in firm regular cluster; black above and white below; mass a sphere 38-100 mm in diameter; 2 envelopes present; 2,000-4,000 eggs; mass deposited 75-100 mm to 91 cm under water; attached to debris and vegetation	medium-sized tadpole with usually very dark to gray coloration, and with a faint light stripe of cream, white or gold along the upper jaw (like a mustache); venter cream with belly slightly pigmented at sides; body oval and round in dorsal view; eyes dorsal or dorsolateral; nostrils small compared with eyes; anus dextral (to the right); oral disk emarginate; tail quite long; dorsal crest high extending on to body	winter and early spring (mid-December to March)	45-85 days	16-18 mm
Scaphiopus holbrooki	eggs in loose irregular cylinder or band; mass 25-75 mm wide and 25-305 mm long; deposited on stems of plants/grass; 1 gelatinous envelope; 200 per packet	a small dark tadpole, bronze to brown with close-set tiny orange spots; body round or oval in dorsal view; eyes close-set and dorsal, iris black; head wide relative to body width; tail short, with tip blunt and rounded; anus medial (in the center); spiracle is ventrolateral. Often found in "schools" of hundreds of tadpoles	only heard calling once (July 12, 1999). Probably any time from March to October	14-60 days	8.5-12 mm

Figure 25. Grassy pool at Cades Cove.

Other Breeding Sites

Four minor types of wetlands and aquatic sites are used occasionally by frogs for breeding in the Great Smokies. American toads (*B. americanus*) breed in the backwaters along the north shore of Fontana Reservoir, although **reservoirs** (fig. 26) are generally depauperate of amphibians. Small, usually closed-canopied, **swampy and mucky wetlands** (for example, those found along Indian Creek, at Smokemont, and at the old trout pond in Cataloochee; see fig. 16) are used by Wood Frogs (*R. sylvatica*). Wood Frogs are quite variable in their choice of breeding sites, even to depositing eggs in human-enlarged **spring pools** and **roadside ditches**. Indeed, virtually any pool in late winter to early spring is likely to be colonized by breeding Wood Frogs.

Life History

*Terrestrial Salamanders (*Plethodontidae*).* The life cycle of terrestrial plethodontids takes place in a multidimensional space. Naturalists tend to think of salamanders as surface-dwelling, but surface activity is only a small part of the life cycle of a terrestrial salamander. Most terrestrial species probably do not have a very large home range on the ground surface, including beneath debris and litter. They spend a considerable part of their lives underground, and biologists really know very little about their life history, especially their time spent underground and the depth and range of underground lateral movement. In addition, terrestrial species occasionally become arboreal during the night or under rainy conditions; salamanders often take refuge under loose bark. Salamanders at different life stages may remain nearly

Figure 26. Chilhowee Lake at mouth of Abrams Creek.

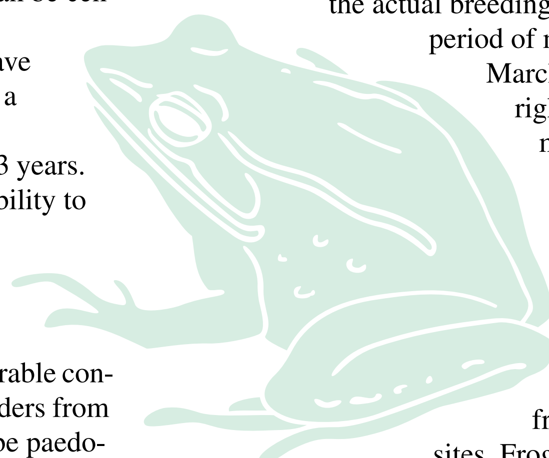
entirely underground (tiny juveniles perhaps; adults during egg deposition and mating) or on the surface (adult feeding and territoriality, environmental conditions permitting). It is by no means clear that space is used similarly by different life stages. Thus, detection probabilities may change with life stage within a habitat. The eggs of some terrestrial species have never been seen, and nests have been located only with extreme infrequency. Some plethodontids may be long-lived (5-10 years).

*Semi-Aquatic Salamanders (*Ambystomatidae, Plethodontidae, Salamandridae*).* All attributes that apply to terrestrial salamanders apply to semi-aquatic salamanders in terms of surface and underground habitat use. Semi-aquatic salamanders, however, require water for reproduction. For mole salamanders (*Ambystoma*) and newts (*Notophthalmus*), breeding sites are usually standing water (ponds, ditches) free of fishes. For semi-aquatic plethodontids, breeding sites include seeps and streams from little trickle trails to sizeable streams or rivers. Adults (mole salamanders and newts) may migrate synchronously to breeding sites in a quite orderly fashion, although temporally constrained to one or a few nights during the breeding season. Breeding adults and egg masses can be censused, but herpetologists know little about what proportion of a population breeds annually, and from what area they are drawn. Males and females may not stay for equal amounts of time during the breeding season, even when the breeding season is extended.

Stream-breeding species may live permanently in the streams (*Desmognathus marmoratus*), streamsides (many other *Desmognathus*), or at various distances from the stream (*D. imitator*, *Gyrinophilus, Pseudotriton*). Distances may range from a few meters to hundreds of meters away, and breeding migrations are not synchronized. Little is known about spatial distribution during terrestrial nonbreeding times. For some species (for example, *Hemidactylium scutatum*) virtually nothing is known about their lives away from woodland pools and streams/ ditches outside of the breeding season. For certain species (*D. quadramaculatus*) adults can be censused streamside, whereas adults of other species (*D. imitator*) can be readily found in terrestrial habitats; some species (*Pseudotriton*) can be found terrestrially as adults usually only by luck, and the adults of a few species (egg-brooding adult female *Hemidactylium*) are observed only during the breeding season.

All eggs of semi-aquatic salamanders are deposited in water, and the egg masses of some species (*Ambystoma*) can be censused easily. All semi-aquatic species have larvae which remain in a larval stage from a few months to as long as 2-3 years. Paedomorphosis (the ability to breed while maintaining a larval appearance) occurs in a few species (*Ambystoma talpoideum*) under favorable conditions, but no salamanders from the Park are known to be paedomorphic. Larvae metamorphose and presumably take up adult habits, but nothing is known concerning dispersion for most species. Maturation can range from one to many years, depending on species. Individuals of some species (*Ambystoma, Notophthalmus*, large *Desmognathus*) may live 10-15 or more years.

*Aquatic salamanders (*Cryptobranchidae, Proteidae*)*. Little is known about the life history of most of these species, except for *Cryptobranchus*. Species within these families are entirely aquatic. The spatial use of habitat is largely unstudied except for Hellbenders, which are known to have home ranges and to guard nesting sites. Fully aquatic species (*Cryptobranchus, Necturus*) inhabit medium to large streams and rivers in the southern Appalachians. Hellbenders may live 25 or more years. Nothing, however, is known about longevity of the Common Mudpuppy (Proteidae: *Necturus*), because the larvae are little known and, for the most part, rarely seen.



Frogs. All of the frogs in the southern Appalachians have a “typical” amphibian life cycle. Adults move to a breeding site, deposit eggs that hatch into larvae (tadpoles), metamorphose to juveniles, disperse, and grow until they are ready to repeat the cycle. For most species, however, many questions about the life cycle remain unanswered (what percentage is breeding in any one year, where do juveniles go, how far do adults disperse). Larval periods may be extremely brief (days in *Scaphiopus*) to extremely long (years in some *Rana*). Breeding may be synchronous (spadefoots, many ranids) or extended (*Rana catesbeiana*). Even when synchronous and explosive (*Rana sylvatica*), the actual breeding date may extend over a period of months (December to March) as adults wait for the right combination of environmental conditions. Adults (and perhaps juveniles) of many frog species spend most of their lives away from the breeding sites. Individuals have been found hundreds (or even thousands) of meters from the nearest breeding sites. Frogs are often exceptionally hard to locate outside the breeding season, much less to sample them. However, the terrestrial sites are extremely important to survival since individuals spend most of their lives as terrestrial predators.

Although most species of frogs call during the breeding season, some species do not or they have only weak voices that do not carry far. Calling times are variable among species; some call during the day, some call at dusk and during the early evening, and some call only between midnight and early dawn. Some species call only during rains, whereas others will call most evenings of the breeding season. Some frogs breed in winter (even in the mountains of the South), others breed in the spring or summer, whereas others call during an extended breeding season. Calling times and seasons also vary latitudinally and perhaps with elevation.

Areas of Particular Amphibian Species Richness

Three areas within Great Smoky Mountains National Park are particularly rich in amphibians. Two (Cades Cove, Cane Creek drainage) are lowland sites, whereas the third is the high-elevation spruce-fir forest. The lowland sites are similar in amphibian species composition; they are rich in species because they are the only two sizeable lowland areas within the Park with a large variety of wetlands. As such, they contain most of the frogs and pond-breeding salamanders. Both areas share species affinities with the herpetofauna of the Tennessee Valley, from whence lowland amphibians colonized Cane Creek and Cades Cove (via Abrams Creek). On the other hand, the high-elevation amphibians are composed entirely of salamanders, and two species (*Plethodon jordani, Desmognathus imitator*) are virtually endemic to the Park (*D. imitator* is found also in the Plott Balsams). Other high-elevation species in the spruce-fir forest (for example, *D. ocoee, D. wrighti, P. metcalfi*) are found in other restricted regions of the Southern Appalachians. These three areas should be the special focus of amphibian monitoring activities.

Identification

Most biologists working at Great Smoky Mountains National Park should be able to identify the majority of the amphibians that they observe by using a combination of the color photographs, species descriptions, and identification/life history tables found in this manual and in Dodd (2004). Some individual animals may be impossible to identify with certainty. Larvae, especially small salamander larvae and tadpoles, often cannot be distinguished without microscopic examination. Adult salamanders, especially the duskies (*Desmognathus*), are notoriously variable with overlapping phenotypic and genotypic characters. Field biologists have found it increasingly difficult to place some individual animals into a species category because of the range of genetic and color variation observed in natural populations. As a result, sometimes an animal must be recorded to genus, species complex, or as “unknown” in field notes.

One of the best ways to identify salamander and frog larvae, in addition to color and morphology, is to examine their habitats and the times of year they are found. This can most easily be done through a comparative table. Morphological and life history characteristics are listed in tables 1 and 2 to help field biologists identify the species that are being examined. These data can be used in conjunction with the information in Dodd (2004).

SALAMANDERS

All salamanders in the Great Smoky Mountains have four limbs with four (*Necturus, Hemidactylium*) or five (all others) toes on each hind foot. They all have tails, lack dry scales covering the body (lizards have dry scales), and have skins that are moist or wet to the touch. The skins of a few species, such as Jordan’s Salamander (*Plethodon jordani*), are sticky because of glandular secretions, but only the Hellbender and Common Mudpuppy are truly slimy.

Biologists take two standard measurements with regard to length. The total length (TL) is the length of an animal from the tip of the snout to the tip of the tail. Because some salamanders lose their tails (or parts thereof) to predation, another common measurement recorded is the snout-vent length (SVL). SVL is measured from the tip of the snout to the posterior portion of the vent (the opening of the cloaca, the common receptacle for the digestive, excretory, and reproductive tracts). All scientific measurements are recorded in metric units, usually millimeters.

Salamander larvae sometimes are divided into two general groups, depending on morphology and the type of wetland in which they develop. The pond form (fig. 27A) is stout bodied, with long filamentous gills and a wide dorsal fin which extends well onto the body. Mole salamanders (*Ambystoma*), for example, have this type of larva. Pond larvae develop in still water, and use the extra surface area of the body and fin as aids in swimming. Stream larvae (*Eurycea*, *Pseudotriton*) are slimmer than pond larvae, with more streamlined bodies, shorter gills, and a narrower tail fin that does not extend onto the body (fig. 27B). These larvae usually live in swift flowing water, where extra surface area on the body would be a distinct disadvantage.

A number of useful characters are available which can be used to identify salamanders to genus or family. A few illustrative examples are provided, but more detailed comparisons are found in Dodd (2004) under the heading "Similar Species."

Desmognathus: All dusky salamanders have a light line which extends from the back of the eye to the angle of the jaw. The duskies also have well-developed muscles on the sides of their heads. They need these muscles to raise the upper jaw in order to open their mouths, since the lower jaw is fused to the skull.

Gyrinophilus versus *Pseudotriton*: Although these colorful salamanders are superficially similar in appearance, Spring Salamanders (*Gyrinophilus*) have a canthus rostralis, a large white line bordered by black lines, that runs from in front of each eye to the nostrils. Salamanders of the genus *Pseudotriton* do not have this line. Spring Salamanders use the canthus rostralis as a "gunsight" to zero in on prey.

Plethodontidae versus all other salamander families: All lungless salamanders have a nasolabial groove that extends from each nostril to the upper jaw. The nasolabial groove transmits chemicals to the salamander from the substrate; no other salamander family has this groove.

FROGS

Like most salamanders, frogs have four legs with four toes on the front limbs and five toes on the rear limbs. The hind limbs are much larger than the front limbs, and are used to propel the body when walking, hopping, or jumping. Frogs are measured in TL, that is, from the tip of the snout to the end of the body between the hind limbs (that is, at the end of the

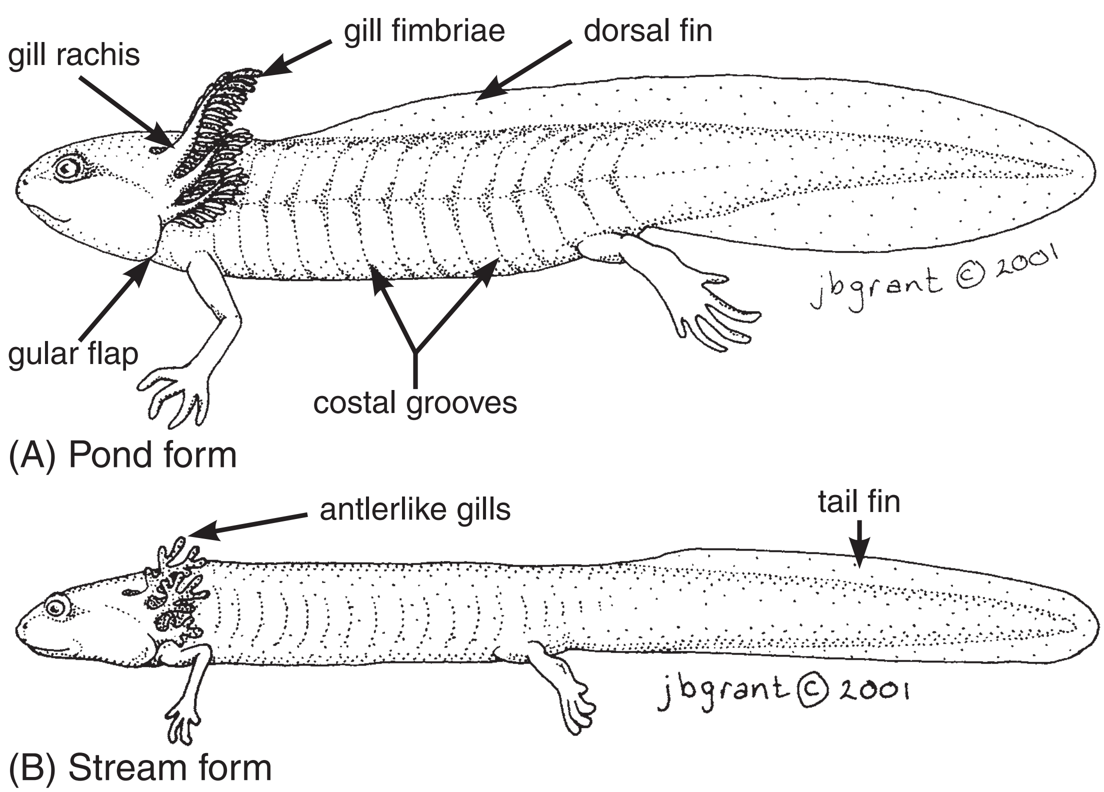


Figure 27. Body morphology of a salamander larva: (A) pond form; (B) stream form.

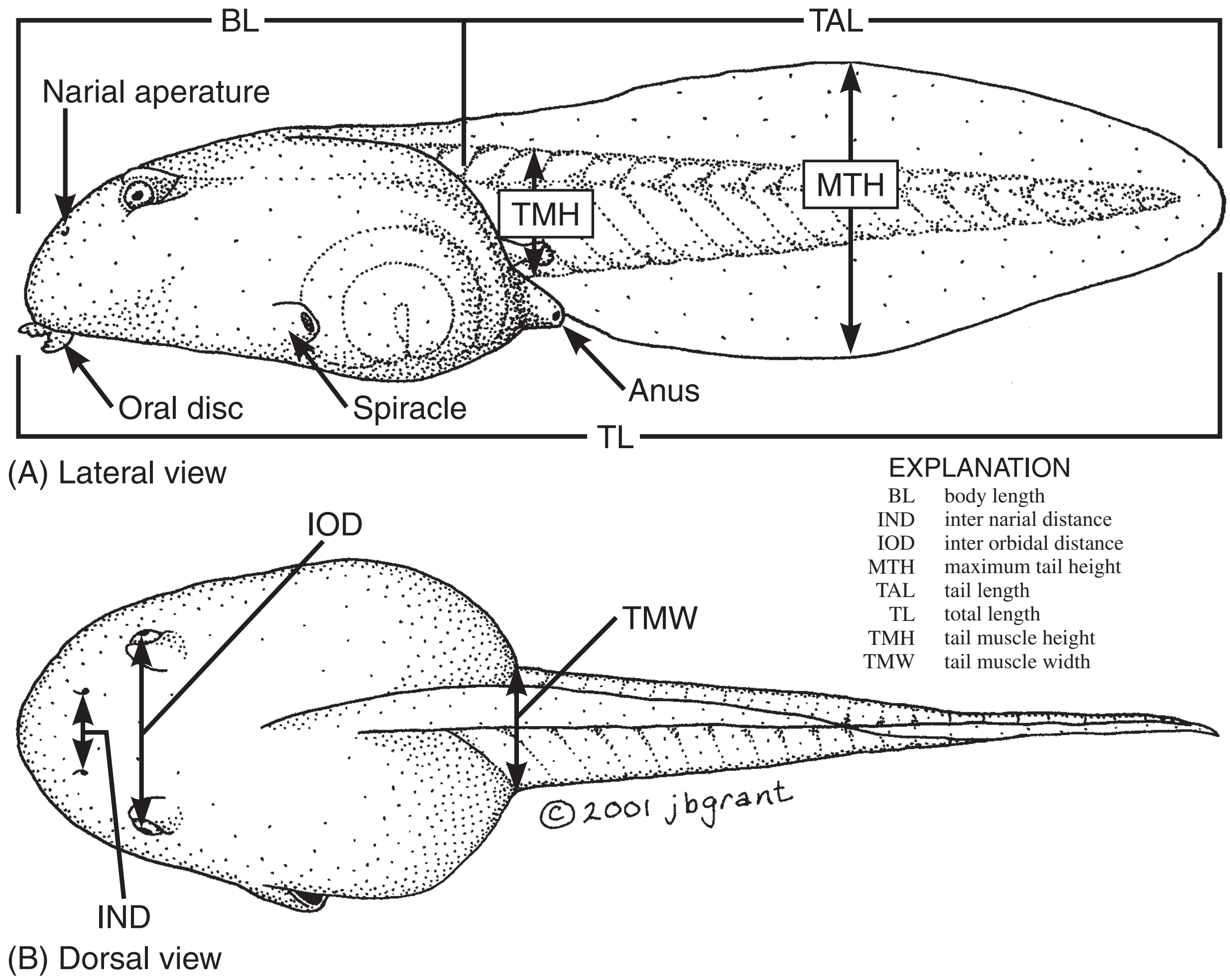
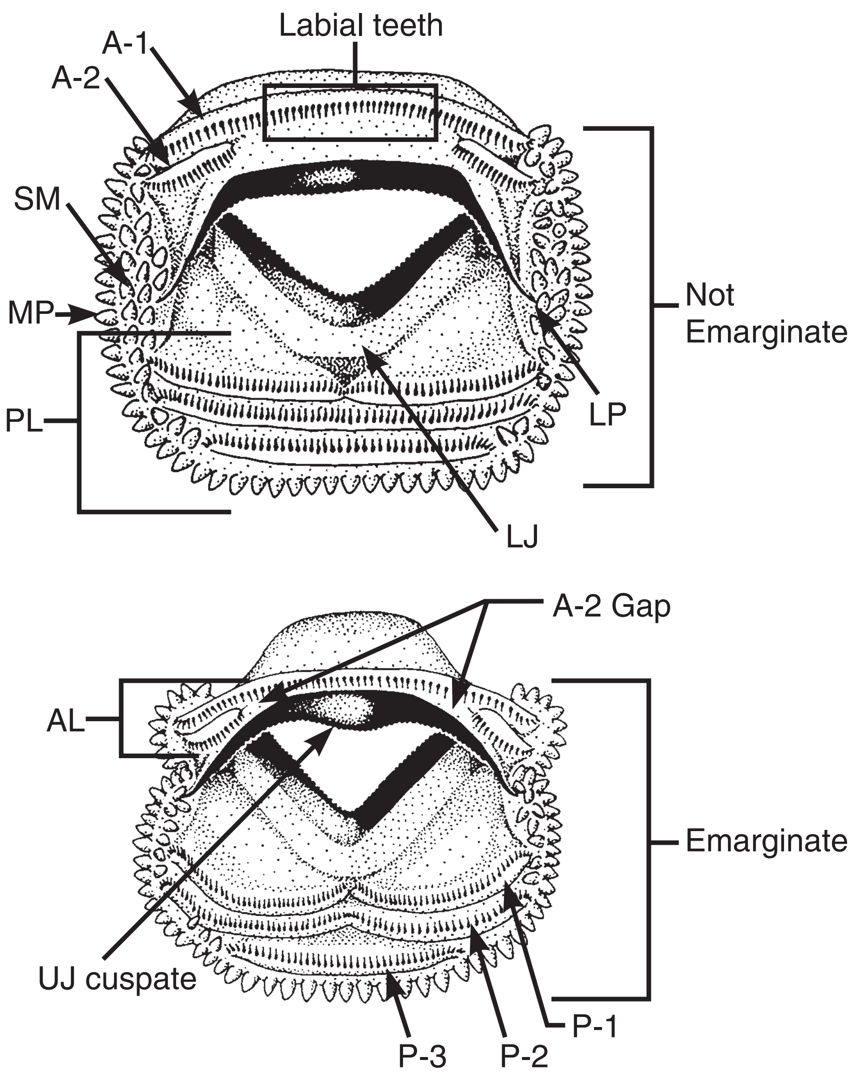


Figure 28. Body morphology of a tadpole.

urostyle). Of course, there are many other measurements which could be made, such as the length of the various sections of the hind limb, but these data generally are not important in amphibian monitoring-programs except in studies of fluctuating asymmetry (Alford and others, 1999, but see McCoy and Harris, 2003).

Tadpoles are morphologically complex. As with salamander larvae, there are two general tadpole body types, the pond type and the stream type. Pond-type tadpoles have deeper bodies and higher tail fins than do stream-type tadpoles. Structures important in the identification of tadpoles are labeled on figure 28. The oral disk consists of the mouth parts; the narial aperture is the opening to the nostrils; the spiracle is the opening from the gills (water is taken in through the mouth, passes over the gills, and is expelled via the spiracle); the anus is the opening from the digestive tract. The total length (TL) consists of the body length (BL) and tail length (TAL). Sometimes additional morphological measurements are taken, such as the maximum width of the tail musculature (TMH) or the maximum tail depth (MTH). The location and size of these characters, or their ratios in relation to one another, are useful in identifying what otherwise appears to be just another drab, olive-green, or black tadpole.

The tadpoles of different species of frogs often appear identical to one another, but the structure of their mouthparts readily separate them. Biologists may need to examine mouthparts to determine which species is in hand. For this reason, a diagram has been included of tadpole mouthparts is provided in figure 29. The nomenclature follows Altig and McDiarmid (1999). The location, number, and degree of separation among labial teeth and papillae are important characters for identifying tadpoles. Examining tadpole oral disks (sometimes incorrectly termed “teeth”) also gives researchers an opportunity to check the health of the tadpole. For example, the horny jaw sheaths drop out when the tadpole is exposed to certain toxic compounds and to the dangerous disease, chytridiomycosis. However, tadpoles should not be



EXPLANATION

AL	anterior (upper) labium
A-1 and A-2	first and second upper tooth rows
A-2 GAP	medial gap in second anterior tooth row
LJ	lower jaw sheath
LP	lateral process of upper jaw sheath
M	mouth
MP	marginal papilla
OD	oral disk
PL	posterior (lower) labium
P-1, P-2, P-3	first, second, and third posterior (lower) tooth rows
SM	submarginal papilla
UJ	upper jaw sheath

Figure 29. Oral disc (mouthparts) of a tadpole.

held too long before examination or preservation, since some tadpoles may shed denticles in the laboratory.

As with salamanders, there are certain useful defining characteristics that help to identify certain superficially similar animals. Some of these are listed below (also see "Similar Species" in Dodd, 2004).

Bufonidae versus Pelobatidae: Frogs in both of these families are terrestrial. However, the true toads (*Bufo*) are dry-skinned and "warty," and have prominent cranial crests and parotoid glands. The spadefoot toads (*Scaphiopus*) are smooth-skinned, lack cranial crests and parotoids, and have a sharp digging spade on their hind feet.

Hylidae versus other frog families: all hylid frogs (*Acris, Pseudacris, Hyla*) in the Great Smokies have slightly to completely expanded toepads, but only in the treefrogs (*Hyla*) are these greatly expanded for climbing; the other hylids are mostly ground-dwelling (however, note that Spring Peepers, *Pseudacris crucifer*, often call from the trees from late fall to early spring before descending to breeding ponds).

Rana palustris versus *R. pipiens*: these very similar frogs are both green and spotted. In *R. palustris*, the spots are squarish, paired and of nearly equal size, whereas in *R. pipiens* they are smaller, rounded, and more randomly scattered on the frog's back.

Additional Information

Information on the etymology, identification of adults, larvae, and eggs, similar species and how to differentiate them, taxonomic problems, distribution both within the Park and elsewhere in North America, life history, abundance and status, and remarks on interesting aspects of the biology of the species are found in Dodd (2004). Data on 44 amphibians are presented, including information on species no longer thought present (for example, *Aneides aeneus*) or which were reported historically from the Park, but whose actual occurrence may be doubtful (*Acris crepitans*). Distribution maps, color photographs of amphibians from the Park, and original color illustrations accompany each account.