

Issues and Perspectives

A Guide to Sexing Salamanders in Central Appalachia, United States

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Abstract

Documenting the sex of individuals encountered during wildlife research and monitoring activities is important for understanding and tracking changes in populations. However, sexing salamanders can be particularly difficult because secondary sex characters are often subtle or only visible during the breeding season, and guidance on species-specific sex determination is lacking from most field guides. The purpose of this guide is to provide a reference to assist biologists in the Central Appalachian region with identifying sex of live adult salamanders. In the main text we provide summary tables and figures to serve as concise references in the field. In Text S1 (*Supplemental Material*) we provide individual species accounts that contain concise yet comprehensive information for each species based on the published literature, as well as many images depicting sexually dimorphic characters. Our focal region encompasses partial or entire distributions for 56 species of salamanders in 5 families (Ambystomidae, Cryptobranchidae, Plethodontidae, Proteidae, and Salamandridae). We identified seven morphological characters that are strongly sexually dimorphic and useful for sexing live, nonanesthetized, adult salamanders in the field, with males of individual species exhibiting one to five of the characters. We identified more than 20 additional characters that are weakly sexually dimorphic, difficult to distinguish in the field, or species-specific. Our guide serves as a synthesis of sexually dimorphic characters for salamanders in Central Appalachia, and we anticipate it will have broad value for researchers, monitoring programs, and salamander enthusiasts in eastern and central North America.

Keywords: *Ambystoma*; *Aneides*; *Cryptobranchus*; *Desmognathus*; *Eurycea*; *Gyrinophilus*; *Plethodon*; *Pseudotriton*

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Introduction

Quantifying aspects of population structure, such as sex ratio and age class, is important for studying and managing wildlife (Skalski et al. 2005). Data at the individual level can provide insight into spatial and temporal dynamics of populations, resulting in more robust assessments of population health than abundance estimates alone (Kurose et al. 2005; Koons et al. 2006; Reid et al. 2006). For example, it is common that environmental changes affect ages and sexes differently because of differences in physiology, size, behavior, and space use (Steen et al. 2006; Popescu and Hunter 2011; Cayuela et al. 2016). Improved understanding of these differential effects broadens the ecological understanding of species and the ability to manage them.

Determining the sex of animals in the field depends on the presence of distinguishable primary or secondary sex characters at the time of observation, and observer awareness of them. For many salamander species, sexing

individuals is inherently difficult because secondary sex characters are often subtle or only visible during the breeding season (e.g., Sever 1975; Marvin 2009; Morgan et al. 2014). This challenge is compounded by a lack of widely available guidance for sexing salamanders. Most field guides for salamanders in the United States provide little or no information on distinguishing between sexes (e.g., Dodd 2004; Powell et al. 2016). Although several natural history books (e.g., Bishop 1943; Petranks 1998; Pflingsten et al. 2013) and internet sites (e.g., AmphibiaWeb [<https://amphibiaweb.org/>]) provide useful information on sexual dimorphism, none are comprehensive and all are lacking in visual examples, a critical tool for training in identification (Branson et al. 2010; Tirkaz et al. 2015). Thus, determining all the sexually dimorphic characters for a particular salamander species or group of species may require renting or purchasing books, having access to scientific literature databases, and spending a substantial amount of time searching for and compiling the information.

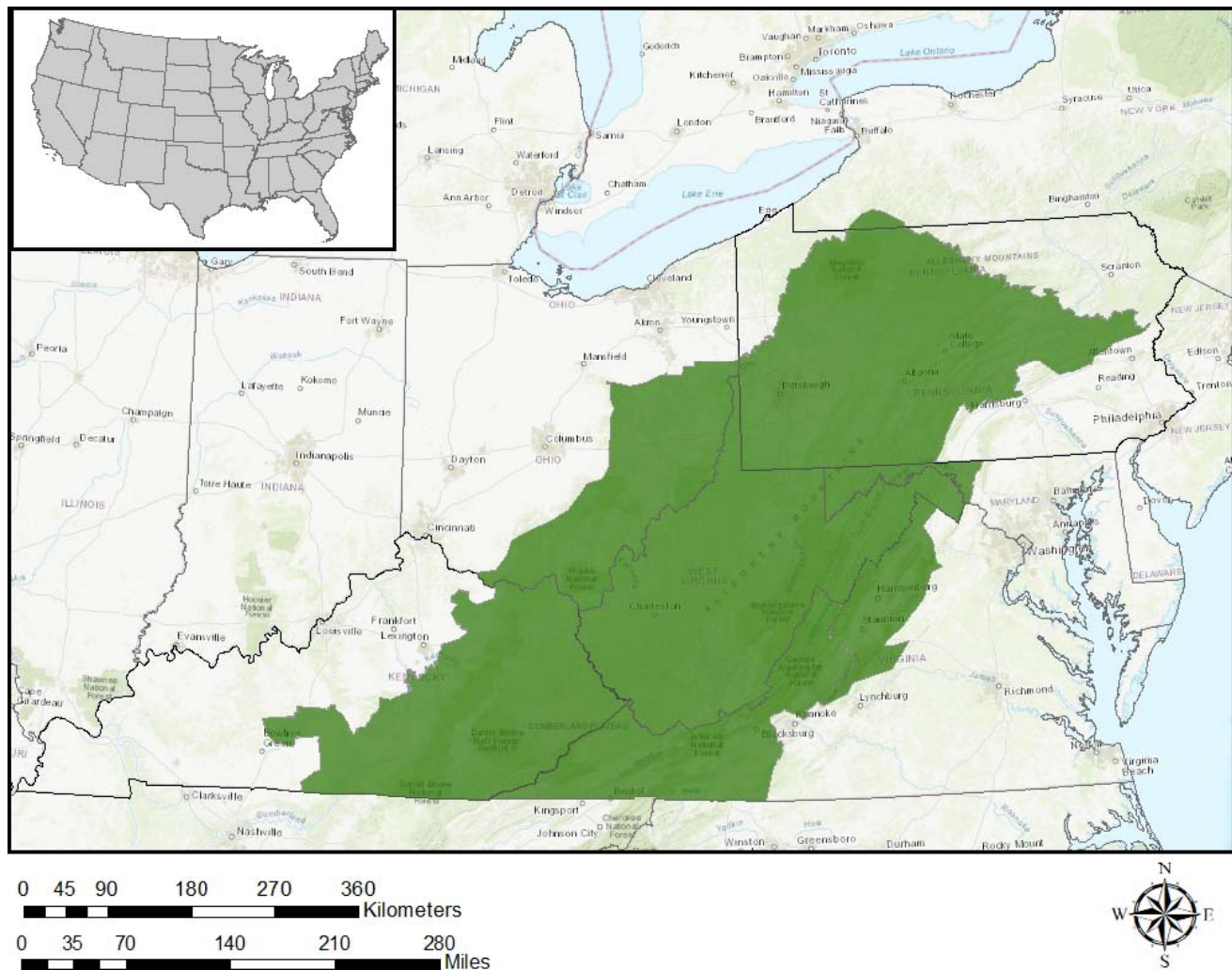


Figure 1. The Central Appalachian region, United States, as defined by Stephenson (2013). The northern boundary is defined by the last glacial maximum, which occurred throughout the central and western part of Pennsylvania and a small section of southern New York. The southern part of the range is considered to terminate at the Tennessee and North Carolina state lines. The boundary to the east and west is delineated by the Blue Ridge Mountains and the Ohio River valley, respectively.

Table 1. Sexually dimorphic characters with generally strong diagnostic value for determining sex of live, nonanesthetized, adult salamanders in the field in Central Appalachia, United States. For each species, 'V' denotes characters that are typically visible in the field, and 'LP' denotes characters that are less prominent and thus can be difficult to see in the field. All characters except visible eggs refer to males, and most characters are only visible or prominent during the breeding season; see the *Supplemental Material* for additional species-specific information. We note that lack of documentation for a character does not imply that it is definitively absent for a given species, but to our knowledge it has not been reported.

Species	Swollen nasolabial grooves and cirri	Mental gland	Squared snout	Swollen jaw musculature	Swollen cloaca	Cloacal papillae	Visible eggs (candling)	Visible testes (candling)	References
Streamside salamander <i>Ambystoma barbouri</i>					V				Petranka 1998
Jefferson salamander <i>Ambystoma jeffersonianum</i>					V		V		Bishop 1941; Minton 1954; Myers 2003
Blue-spotted salamander <i>Ambystoma laterale</i>					V				Bishop 1941; Pfingsten 1989c
Spotted salamander <i>Ambystoma maculatum</i>					V		V		Bishop 1941; Husting 1965; Myers 2003
Marbled salamander <i>Ambystoma opacum</i>					V		V		Pechmann 1995
Mole salamander <i>Ambystoma talpoideum</i>					V		V		Shoop 1960; Scott 1993; Pechmann 1995
Small-mouthed salamander <i>Ambystoma texanum</i>					V				Wyman 1971
Eastern tiger salamander <i>Ambystoma tigrinum</i>					V				Bishop 1941; Sever and Dineen 1978
Green salamander <i>Aneides aeneus</i>	V	V					V		Bishop 1943; Waldron and Pauley 2007; Sever et al. 2016; personal observation (Text S1, <i>Supplemental Material</i>)
Eastern hellbender <i>Cryptobranchus alleganiensis alleganiensis</i>					V				Bishop 1941; Taber et al. 1975
Spotted dusky salamander <i>Desmognathus conanti</i>		LP							Rossman 1958; Verrell 1995; Rupp and Sever 2018
Northern dusky salamander <i>Desmognathus fuscus</i>		LP					V	V	Juterbock 1978; Jones 1986; Hom 1987; Keyser et al. 2011; Sever et al. 2016
Shovelnose salamander <i>Desmognathus marmoratus</i>		LP					V		Martof 1962
Seal salamander <i>Desmognathus monticola</i>		LP					V	V	Sever 1976; Bruce and Hairston 1990; Keyser et al. 2011; Sever et al. 2016
Allegheny Mountain dusky salamander <i>Desmognathus ochrophaeus</i>		LP					V	V	Sever 1976; Verrell 1988; Evans et al. 1997; Verrell and Mabry 2003; Sever et al. 2016
Blue Ridge dusky salamander <i>Desmognathus orestes</i>		V		V					Petranka 1998
Northern pygmy salamander <i>Desmognathus organi</i>		LP	LP						Crespi et al. 2010
Flat-headed salamander <i>Desmognathus planiceps</i>		V							Newman 1955
Blackbelly salamander <i>Desmognathus quadramaculatus</i>		LP					V		Sever 1976; Bruce 1988a; Sever et al. 2016
Black mountain salamander <i>Desmognathus welteri</i>		V					V		Verrell and Mabry 2003; Sever et al. 2016
Pygmy salamander <i>Desmognathus wrighti</i>		V						V	Valentine 1963; Hining and Bruce 2005; Peterman et al. 2016; Sever et al. 2016
Northern two-lined salamander <i>Eurycea bislineata</i> (Lineage B)	V	V	V	V			V		Noble 1929; Bishop 1941; Sever et al. 2016; Siegel et al. 2020; personal observation (Text S1, <i>Supplemental Material</i>)

Table 1. Continued.

Species	Swollen nasolabial grooves and cirri	Mental gland	Squared snout	Swollen jaw musculature	Swollen cloaca	Cloacal papillae	Visible eggs (candling)	Visible testes (candling)	References
Southern two-lined salamander <i>Eurycea cirrigera</i> (Lineage E)		V*		LP			V		Brophy and Pauley 2002
Three-lined salamander <i>Eurycea guttolineata</i>	V								Dawley 1992
Eastern long-tailed salamander <i>Eurycea longicauda longicauda</i>	V								Bishop 1941; Cooper 1960; Guttman 1989; Trauth et al. 1993; Carlin 1997
Cave salamander <i>Eurycea lucifuga</i>	V	V					V		Bishop 1943; Sever et al. 2016; Bradley 2018
Blue Ridge two-lined salamander <i>Eurycea wilderae</i>	V*	V*		V*			V	V	Sever 1979; Bruce 1988b; Kozak 2003; Sever et al. 2016
Spring salamander <i>Gyrinophilus porphyriticus</i>							V		Bruce 1972a; Niemiller et al. 2010
West Virginia spring salamander <i>Gyrinophilus subterraneus</i>							V		Niemiller et al. 2010
Four-toed salamander <i>Hemidactylium scutatum</i>	V	LP	V						Blanchard and Blanchard 1931; Bishop 1941
Common mudpuppy <i>Necturus maculosus</i>						V			Bishop 1926, 1932
Red-spotted newt <i>Notophthalmus viridescens</i> <i>viridescens</i>					V				Sever 1981
Eastern red-backed salamander <i>Plethodon cinereus</i>	V	LP	V				V	V	Dunn 1926; Dodd and Brodie 1976; Dawley and Crowder 1995; Gillette and Peterson 2001; Sever et al. 2016
White-spotted slimy salamander <i>Plethodon cylindraceus</i>		V	V	V					Downer 2009
Dixie Cavern salamander <i>Plethodon dixi</i>									
Northern zigzag salamander <i>Plethodon dorsalis</i>		V							Dodd and Brodie 1976
Northern ravine salamander <i>Plethodon electromorphus</i>		V							Highton 1962
Northern slimy salamander <i>Plethodon glutinosus</i>	V	V	V					LP	Bishop 1941; Organ 1960b; Dodd and Brodie 1976; Price and Secki Shields 2002
Valley and ridge salamander <i>Plethodon hoffmani</i>		V							Dodd and Brodie 1976
Peaks of Otter salamander <i>Plethodon hubrichti</i>	V	V	V				V	V	Thurrow 1957; Dodd and Brodie 1976; Fredrickson et al. 2007; Reichenbach and Brophy 2017
Blacksburg salamander <i>Plethodon jacksoni</i>	V	V							Newman 1954
Cumberland Plateau salamander <i>Plethodon kentucki</i>	V	V	V	V					Dodd and Brodie 1976; Marvin 2009
Northern gray-cheeked salamander <i>Plethodon montanus</i>	V	V		V					Hairston and Pope 1948; Dodd and Brodie 1976; Caruso and Rissler 2017
Cheat Mountain salamander <i>Plethodon nettingi</i>	V	LP	V				V		Personal observations (Text S1, <i>Supplemental Material</i>)
Yellow-spotted woodland salamander <i>Plethodon pauleyi</i>		V					V		Felix et al. 2019
Cow Knob salamander <i>Plethodon punctatus</i>	V	V	V						Tucker 1998; personal observation (Text S1, <i>Supplemental Material</i>)

Table 1. Continued.

Species	Swollen nasolabial grooves and cirri	Mental gland	Squared snout	Swollen jaw musculature	Swollen cloaca	Cloacal papillae	Visible eggs (candling)	Visible testes (candling)	References
Southern ravine Salamander <i>Plethodon richmondi</i>	V	V	V					V	Wallace 1969; Dodd and Brodie 1976; Dyal 2006; personal observation (Text S1)
Shenandoah salamander <i>Plethodon shenandoah</i>	V	LP	V				V	V	Dodd and Brodie 1976; personal communication (Text S1, <i>Supplemental Material</i>)
Big Levels salamander <i>Plethodon sherando</i>									
Southern zigzag salamander <i>Plethodon ventralis</i>		V							Highton 1997
Shenandoah Mountain salamander <i>Plethodon virginia</i>		V							Highton 1997
Wehrle's salamander <i>Plethodon wehrlei</i>		LP							Bishop 1941, 1943
Weller's salamander <i>Plethodon welleri</i>	V	LP			V				Bishop 1943, Organ 1960a; Dodd and Brodie 1976
Yonahlossee salamander <i>Plethodon yonahlossee</i>	V	V							Pope 1950; Dodd and Brodie 1976
Mud salamander <i>Pseudotriton montanus</i>					V				Bruce 1975
Northern red salamander <i>Pseudotriton ruber ruber</i>					V		V		Bishop 1941; Bruce 1978b

* Denotes characters that may not be exhibited by all males in the region. See *Supplemental Material* for more information.

The lack of easily available resources and guidance for identifying sex of salamanders creates a barrier for inclusion of this information in research projects and monitoring programs. Although many wildlife biologists and student researchers are likely familiar with some prominent sexually dimorphic characters (e.g., mental glands, cirri), it is unlikely that the majority of nonprofessional herpetologists are knowledgeable about the characters that are useful for every species they could encounter in their projects, or when the characters are likely to be visible. In addition, it is likely that most biologists and nonsalamander experts would benefit from visual examples of sexually dimorphic characters to assist with identification in the field.

The purpose of this guide is to provide a reference to assist nonprofessional herpetologists with identifying sex of adult salamanders in the field. Species coverage is constrained to the Central Appalachian region, including portions of southern New York, Pennsylvania, eastern Ohio, eastern Kentucky, western Maryland and Virginia, and all of West Virginia (Stephenson 2013; Figure 1). This region is a global biodiversity hotspot for salamanders (Buckley and Jetz 2007; Rissler and Smith 2010), and contains many endemic species of conservation concern, such as Cheat Mountain salamander *Plethodon nettingi*, Shenandoah salamander *Plethodon shenandoah*, Cow Knob salamander *Plethodon punctatus*, and Peaks of Otter salamander *Plethodon hubrichti*. Many of the species covered in this guide also occur in other geographic regions. Thus, while our species coverage is

restricted to Central Appalachia, this guide has broad value for biologists in eastern and central North America.

Methods

We used distribution boundaries in Powell et al. (2016) to delineate salamander species occurring in the Central Appalachian region. For each species, we compiled and reviewed published literature and graduate theses that investigated sex identification. We attempted to include all primary literature and avoided citing gray literature when feasible. We also reviewed literature on size-at-maturity and breeding season because many characters that distinguish sexes of adults are only visible during the breeding season. Data for size-at-maturity and breeding season provided here should be considered approximations because they are spatially and temporally variable. We created tables to serve as quick references in the field, and included illustrations and images to show examples of sexually dimorphic characters. The Text S1 (*Supplemental Material*) file contains individual species accounts with additional information and images.

Results

We identified seven morphological characters that are broadly useful for sexing live, nonanesthetized, adult salamanders in the field (Table 1). These characters include presence or prominence of swollen nasolabial



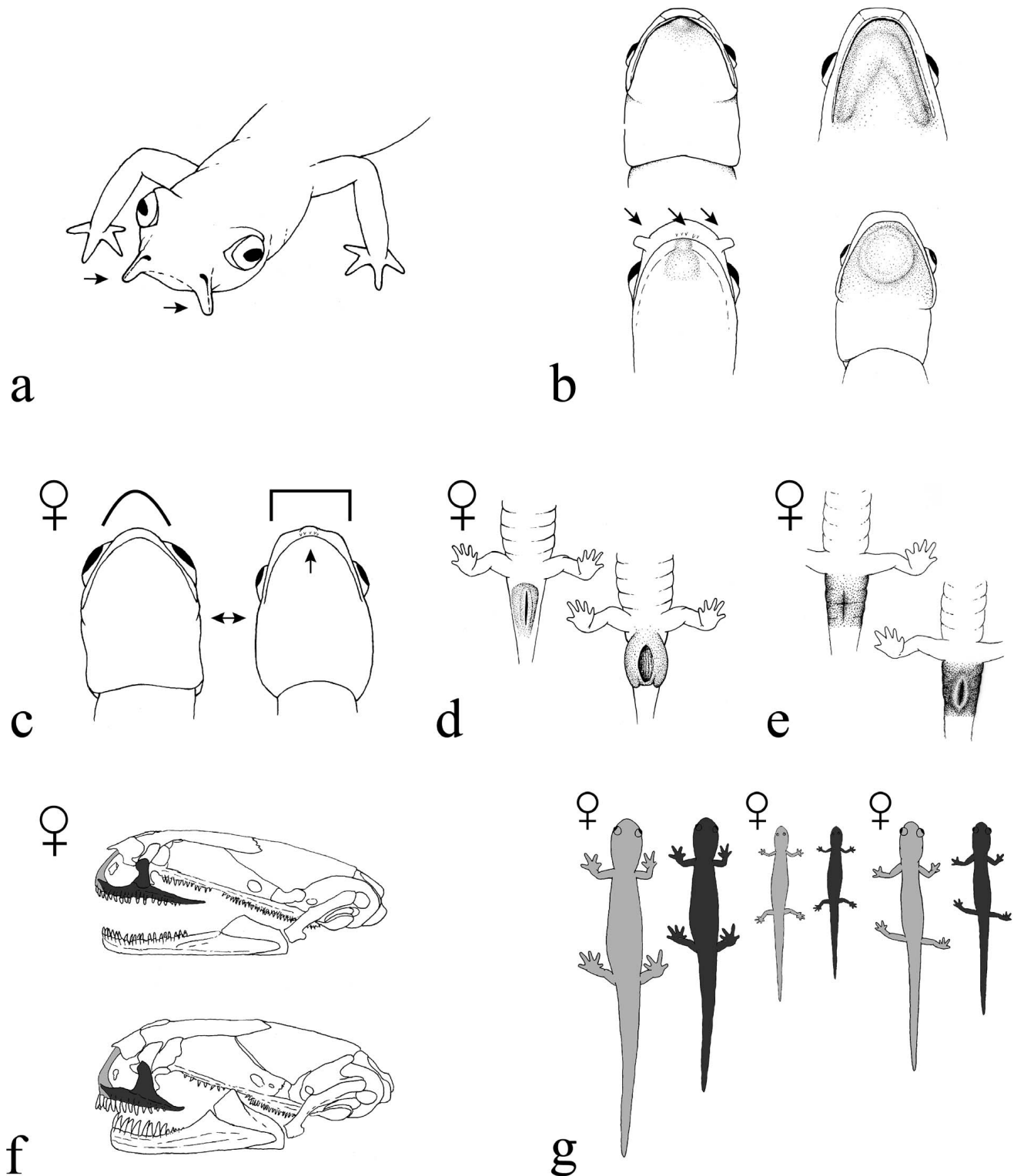


Figure 2. Illustrations of sexually dimorphic characters of adult salamanders in the Central Appalachian region, United States. Illustrations are males except where denoted by ♀. Species-specific presence of these characteristics is provided in Table 1: **(a)** cirri (from a photograph of the two-lined salamander *Eurycea bislineata* species complex by Wayne Van Devender); **(b)** mental glands, Allegheny Mountain dusky Salamander *Desmognathus ochrophaeus* (top left; after Bishop 1941), pygmy salamander *Desmognathus wrighti* (top right; after Valentine 1963), a member of the two-lined salamander species complex (bottom left; also note the premaxillary teeth piercing the upper lip and the cirri; after Arnold 1977), Yonahlossee salamander *Plethodon yonahlossee* (bottom right); **(c)** squared snout, four-toed salamander *Hemidactylium scutatum* (after Bishop 1941), also note the premaxillary teeth piercing the upper lip; **(d)** swollen cloaca and cloacal papillae of *Ambystoma* (spotted salamander *Ambystoma maculatum*; after Duellman and Trueb 1986); **(e)** swollen cloaca of Plethodontidae (slimy salamander); **(f)** enlarged premaxillary teeth (light gray bone) and maxillary teeth (dark gray bone), northern two-lined salamander *Eurycea bislineata* (after Noble 1927); **(g)** adult size dimorphism, spotted salamander (left), northern dusky salamander *Desmognathus fuscus* (middle), and slimy salamander (right).





Figure 3. Photographic examples of morphological characters useful for distinguishing sex of adult salamanders in the Central Appalachian region, United States (all photographs are males). Species-specific presence of these characters is provided in Table 1: **(a)** mental gland, male slimy salamander *Plethodon glutinosus* (Randolph County, West Virginia; photograph courtesy of Brett Skelly); **(b)** squared snout and swollen nasolabial grooves, male Cumberland Plateau salamander *Plethodon kentucki* (Wayne County, West Virginia); **(c)** swollen cloaca, male streamside salamander *Ambystoma barbouri* (Wayne County, West Virginia); **(d)** eggs visible through the abdominal wall, female northern dusky salamander *Desmognathus fuscus* (Pocahontas County, West Virginia); **(e)** swollen cloaca, male slimy salamander (Randolph County, West Virginia); **(f)** lack of swollen cloaca, female slimy salamander (Randolph County, West Virginia). Additional photographs are available in Text S1 (Supplemental Material).

Table 2. Life-history characteristics for the 56 salamander species present in Central Appalachia, United States. Size at maturity, breeding season, and time of oviposition is listed for each species. Size at sexual maturity represents the snout–vent length (SVL) of each sex where sexual maturity or breeding activity has been confirmed; estimates where total length, but not SVL, were provided are shown as (TL). Breeding season corresponds to the period of time when sexual dimorphism is likely to be exhibited. Oviposition times represent when candling is no longer an effective method to identify females. Additional species-specific information can be found in the *Supplemental material*.

Species	Size at maturity, SVL (mm)	Breeding season	Oviposition	References
Streamside salamander <i>Ambystoma barbouri</i>	70–89 *	Late December–Early April	At time of breeding	Kraus and Petranka 1989; Kats and Sih 1992; Kraus 2013
Jefferson salamander <i>Ambystoma jeffersonianum</i>	M: 62 F: 76	December–March	At time of breeding	Uzzell 1964, 1967a; Williams 1973; Brodman 1995
Blue-spotted salamander <i>Ambystoma laterale</i>	M: 42–45 F: 51–52	Late March–April	At time of breeding	Uzzell 1967b; Minton 1972; Gilhen 1974; Downs 1989
Spotted salamander <i>Ambystoma maculatum</i>	M: 63 F: 78	Mid-March–April	At time of breeding	Bishop 1941; Flageole and Leclair 1992; Brodman 1995
Marbled salamander <i>Ambystoma opacum</i>	45	September–early October	At time of breeding	Dunn 1917; Seibert 1989; personal observation (Text S1, <i>Supplemental Material</i>)
Mole salamander <i>Ambystoma talpoideum</i>	M: 51.4–54.8 F: 50.5–53.3 Paedomorphs: 25	November–January (paedomorphs breed earlier)	At time of breeding	Semlitsch 1985; Semlitsch et al. 1988; Krenz and Sever 1995
Small-mouthed salamander <i>Ambystoma texanum</i>	M: 60 F: 69	December–mid-April	At time of breeding	Plummer 1977; Petranka 1984; Keen 1975
Eastern tiger salamander <i>Ambystoma tigrinum</i>	81 *	February–March	At time of breeding	Cooper 1955; Semlitsch 1983; Downs 1989
Green salamander <i>Aneides aeneus</i>	46	May–June and September–October	June	Cupp 1971; Canterbury and Pauley 1994; Waldron and Pauley 2007
Eastern hellbender <i>Cryptobranchus alleganiensis alleganiensis</i>	M: 300 (TL) F: 380 (TL)	Late August–early October	At time of breeding	Smith 1907; Bishop 1941; Taber et al. 1975; Humphries and Pauley 2000
Spotted dusky salamander <i>Desmognathus conanti</i>	M: 48 F: 50	April–November	Mid-July–mid-October	Rossman 1958; Mount 1975; Rupp and Sever 2018
Northern dusky salamander <i>Desmognathus fuscus</i>	M: 35 F: 40	April–June and September–October	June–August	Wilder 1913; Danstedt 1975; Juterbock 1978; Davic 2013
Shovelnose salamander <i>Desmognathus marmoratus</i>	M: 50 F: 55–59		Late Spring and Summer	Martof 1962; Bruce 1985
Seal salamander <i>Desmognathus monticola</i>	M: 42 F: 50	September–April	June–September	Bishop 1941; Organ 1961a; Juterbock 1978; Marcum 1994
Allegheny Mountain dusky salamander <i>Desmognathus ochrophaeus</i>	M: 37 F: 27–30	September–June	June–July	Forester 1979; Keen and Orr 1980; Verrell 1988; Orr 1989
Blue Ridge dusky salamander <i>Desmognathus orestes</i>		Spring, late Summer, and Fall	June–October	Organ 1961a
Northern pygmy salamander <i>Desmognathus organi</i>			Late Summer	Crespi et al. 2010
Flat-headed salamander <i>Desmognathus planiceps</i>				
Blackbelly salamander <i>Desmognathus quadramaculatus</i>	M: 57–61 F: 73–75	Summer and Fall	June–September	Organ 1961a; Bruce 1988a; Camp et al. 2000
Black mountain salamander <i>Desmognathus welteri</i>	50	April–late June	July–August	Juterbock 1978, 1984; Smith et al. 1996; Felix 2001; Verrell and Mabry 2003
Pygmy salamander <i>Desmognathus wrighti</i>	25	September–October and April–May		Organ 1961a,b; Tilley and Bernardo 1993
Northern two-lined salamander <i>Eurycea bislineata</i> (Lineage B)	M: 67 F: 61	October–May	April–August	Noble 1929; Bishop 1941; Pawlik 2008
Southern two-lined salamander <i>Eurycea cirrigera</i> (Lineage E)	43 *	September–May	mid-March–early April	Sever 1979; Brophy and Pauley 2002
Three-lined salamander <i>Eurycea guttolineata</i>	50	July–December	November–December	Marshall 1999
Eastern long-tailed salamander <i>Eurycea longicauda longicauda</i>	M: 45 F: 49	Mid-October	Late Fall–early Spring	Hutchison 1956; Cooper 1960
Cave salamander <i>Eurycea lucifuga</i>	M: average 60 F: 49–58	Summer and early Fall**	September–February	Hutchison 1956; Green et al. 1967; Organ 1968; Rudolph 1978; Carlyle et al. 1998; Petranka 1998
Blue Ridge two-lined salamander <i>Eurycea wilderae</i>	M: 28 F: 25	October–March	February–April	Sever 1979; Reagan 1984; Bruce 1988b; Kozak 2003

Table 2. Continued.

Species	Size at maturity, SVL (mm)	Breeding season	Oviposition	References
Spring salamander <i>Gyrinophilus porphyriticus</i>	60–70	October–June	Summer	Organ 1961c; Bruce 1972a, 1978a
West Virginia spring salamander <i>Gyrinophilus subterraneus</i>	100			Besharse and Holsinger 1977; Niemiller et al. 2010
Four-toed salamander <i>Hemidactylium scutatum</i>	M: 50 F: 60	September–November	February–April	Blanchard and Blanchard 1931; Blanchard 1933, 1934; Branin 1935; Wood 1955
Common mudpuppy <i>Necturus maculosus</i>	200 (TL)	September–October	April–June	Bishop 1926, 1932, 1941; Fitch 1959; Harris 1961; Petranksa 1998
Red-spotted newt <i>Notophthalmus viridescens viridescens</i>	Highly variable	March–June	Late March–early July	Pope 1924; Noble 1929; Brandon and Bremer 1966; Healy 1973; Harris et al. 1988; Massey 1988; Petranksa 1998; Sever 2006
Eastern red-backed salamander <i>Plethodon cinereus</i>	M: 32 F: 34	October–December	June–July	Bishop 1943; Sayler 1966; Pfingsten 1989a; Lang and Jaeger 2000
White-spotted slimy salamander <i>Plethodon cylindraceus</i>		April–September	Summer and early Fall	Organ 1960a; Wells 1980
Dixie Cavern salamander <i>Plethodon dixi</i>	M: 55			Pope and Fowler 1949
Northern zigzag salamander <i>Plethodon dorsalis</i>	35	November–April	April–June	Sever 1978a,b; Wilkinson et al. 1993; Minton 2001
Northern ravine salamander <i>Plethodon electromorphus</i>	M: 48 F: 51	Late Winter	April–May	Wood 1945; Minton 1972, 2001; Pfingsten 1989b, 2013
Northern slimy salamander <i>Plethodon glutinosus</i>	M: 45 F: 57	Fall	Late July–early August	Bishop 1941; Pope and Pope 1949
Valley and ridge salamander <i>Plethodon hoffmani</i>	M: 40 F: 43	Spring; secondary breeding season in Fall	Late April–mid-May	Angle 1969
Peaks of Otter salamander <i>Plethodon hubrichti</i>	M: 39 F: 46	September–October	June	Pague 1989; Wicknick 1995; Mitchell and Wicknick 1996; Reichenbach and Brophy 2017
Blacksburg salamander <i>Plethodon jacksoni</i>	M: 116 (TL) F: 124 (TL)			Newman 1954
Cumberland Plateau salamander <i>Plethodon kentucki</i>	M: 48 F: 52	Late July–October	September	Mittleman 1951; Marvin 1996
Northern gray-cheeked salamander <i>Plethodon montanus</i>		Late July or August		Organ 1958
Cheat Mountain salamander <i>Plethodon nettingi</i>	M: 36 F: 38	Spring and Fall	Summer	Brooks 1948; Green and Pauley 1987; personal observation (Text S1, Supplemental Material)
Yellow-spotted woodland salamander <i>Plethodon pauleyi</i>	M: 63 F: 52			Felix et al. 2019
Cow Knob salamander <i>Plethodon punctatus</i>	M: 49 F: 59	Early August–May	February–April	Tucker 1998
Southern ravine salamander <i>Plethodon richmondi</i>	M: 34 F: 35	November–March	May	Barbour 1953, Wallace 1969; Nagel 1979
Shenandoah salamander <i>Plethodon shenandoah</i>	M: 34 * F: 35 *	Spring and Fall		Wynn 1991; personal communication (Text S1, Supplemental Material)
Big Levels salamander <i>Plethodon sherando</i>				
Southern zigzag salamander <i>Plethodon ventralis</i>				
Shenandoah Mountain salamander <i>Plethodon virginia</i>				
Wehrle's salamander <i>Plethodon wehrlei</i>	M: 57 F: 60	Spring and Fall	January–April	Johnson 1961; Pauley and England 1969; Hall and Stafford 1972; Bruce 2000
Weller's salamander <i>Plethodon welleri</i>	M: 30 F: 35	Spring and Fall	Mid-August–September	Hoffman and Kleinpeter 1948; Highton 1962; Thurow 1963
Yonahlossee salamander <i>Plethodon yonahlossee</i>	M: 56 F: NA	Spring and Fall; peaks in August and September		Pope 1950
Mud salamander <i>Pseudotriton montanus</i>	M: 45 F: 65	July–November	Fall–early Winter	Fowler 1946; Robinson and Reichard 1965; Bruce 1974, 1975, 1978b
Northern red salamander <i>Pseudotriton ruber ruber</i>	M: 50 F: 60	mid-June–September	Fall	Bishop 1941; Bruce 1972b, 1974, 1978a, b

* Size at maturity was not listed for this species. These values represent sizes of adult individuals captured in the field.

** Breeding season is poorly studied for this species. The time of breeding is based on expert opinion from the authors.



Table 3. Sexually dimorphic characters with generally weak diagnostic value (W) for determining sex of live, nonanesthetized, adult salamanders in the field in Central Appalachia, United States. See the *Supplemental Material* for species-specific information on differences between sexes for these characters. The “Other” category denotes species with sexually dimorphic characters not described in Tables 1 or 2 (Y), which are provided in Table 4. We note that lack of documentation for a character does not imply that it is definitively absent for a given species, but to our knowledge it has not been reported.

Species	Enlarged premaxillary teeth	Enlarged maxillary teeth	Size dimorphism	Swollen cloaca	Other	References
Streamside salamander						
<i>Ambystoma barbouri</i>						
Jefferson salamander					Y	
<i>Ambystoma jeffersonianum</i>						
Blue-spotted salamander			W		Y	Pfingsten 1989c
<i>Ambystoma laterale</i>						
Spotted salamander			W		Y	Bishop 1941
<i>Ambystoma maculatum</i>						
Marbled salamander					Y	
<i>Ambystoma opacum</i>						
Mole salamander			W		Y	Raymond and Hardy 1990
<i>Ambystoma talpoideum</i>						
Small-mouthed salamander			W		Y	Williams et al. 2009
<i>Ambystoma texanum</i>						
Eastern tiger salamander			W		Y	Bishop 1941, 1943; Williams et al. 2009
<i>Ambystoma tigrinum</i>						
Green salamander						
<i>Aneides aeneus</i>						
Eastern hellbender					Y	
<i>Cryptobranchus alleganiensis alleganiensis</i>						
Spotted dusky salamander	W			W	Y	Rossman 1958
<i>Desmognathus conanti</i>						
Northern dusky salamander	W			W	Y	Juterbock 1978
<i>Desmognathus fuscus</i>						
Shovelnose salamander	W		W	W	Y	Martof 1962
<i>Desmognathus marmoratus</i>						
Seal salamander	W		W	W		Organ 1961a; Castanet et al. 1996, Wyckoff and Niemiller 2011
<i>Desmognathus monticola</i>						
Allegheny Mountain dusky	W			W	Y	Sever 1976
<i>Desmognathus ochrophaeus</i>						
Blue Ridge dusky salamander						
<i>Desmognathus orestes</i>						
Northern pygmy salamander	W		W		Y	Crespi et al. 2010
<i>Desmognathus organi</i>						
Flat-headed salamander	W					Newman 1955
<i>Desmognathus planiceps</i>						
Blackbelly salamander	W		W			Organ 1961a; Petranka 1998
<i>Desmognathus quadramaculatus</i>						
Black mountain salamander	W				Y	Verrell and Mabry 2003
<i>Desmognathus welteri</i>						
Pygmy salamander	W			W	Y	Valentine 1963
<i>Desmognathus wrighti</i>						
Northern two-lined salamander	W				Y	Noble 1929
<i>Eurycea bislineata</i> (Lineage B)						
Southern two-lined salamander			W		Y	Brophy and Pauley 2002
<i>Eurycea cirrigera</i> (Lineage E)						
Three-lined salamander		W				Noble 1927
<i>Eurycea guttolineata</i>						
Eastern long-tailed salamander			W	W	Y	Bishop 1941; Guttman 1989
<i>Eurycea longicauda longicauda</i>						
Cave salamander		W		W	Y	Noble 1927; Hutchison 1956
<i>Eurycea lucifuga</i>						
Blue Ridge two-lined salamander	W				Y	Kozak 2003
<i>Eurycea wilderae</i>						
Spring salamander						
<i>Gyrinophilus porphyriticus</i>						
West Virginia spring salamander						
<i>Gyrinophilus subterraneus</i>						

Table 3. Continued.

Species	Enlarged premaxillary teeth	Enlarged maxillary teeth	Size dimorphism	Swollen cloaca	Other	References
Four-toed salamander <i>Hemidactylium scutatum</i>	W		W			Blanchard and Blanchard 1931; Bishop 1941
Common mudpuppy <i>Necturus maculosus</i>			W			Bishop 1941
Red-spotted newt <i>Notophthalmus viridescens viridescens</i>			W		Y	Bishop 1941
Eastern red-backed salamander <i>Plethodon cinereus</i>	W		W		Y	Dunn 1926; Hood 1934; Bishop 1943
White-spotted slimy salamander <i>Plethodon cylindraceus</i>						
Dixie Cavern salamander <i>Plethodon dixi</i>						
Northern zigzag salamander <i>Plethodon dorsalis</i>						
Northern ravine salamander <i>Plethodon electromorphus</i>						
Northern slimy salamander <i>Plethodon glutinosus</i>						
Valley and ridge salamander <i>Plethodon hoffmani</i>						
Peaks of Otter salamander <i>Plethodon hubrichti</i>					Y	
Blacksburg salamander <i>Plethodon jacksoni</i>					Y	
Cumberland Plateau salamander <i>Plethodon kentucki</i>			W			Marvin 2009
Northern gray-cheeked salamander <i>Plethodon montanus</i>			W			Hairston and Pope 1948
Cheat Mountain salamander <i>Plethodon nettingi</i>					Y	
Yellow-spotted woodland salamander <i>Plethodon pauleyi</i>						
Cow Knob salamander <i>Plethodon punctatus</i>						
Southern ravine salamander <i>Plethodon richmondi</i>						
Shenandoah salamander <i>Plethodon shenandoah</i>						
Big Levels salamander <i>Plethodon sherando</i>						
Southern zigzag salamander <i>Plethodon ventralis</i>						
Shenandoah Mountain salamander <i>Plethodon virginia</i>						
Wehrle's salamander <i>Plethodon wehrlei</i>						
Weller's salamander <i>Plethodon welleri</i>						
Yonahlossee salamander <i>Plethodon yonahlossee</i>			W			Pope 1950
Mud salamander <i>Pseudotriton montanus</i>						
Northern red salamander <i>Pseudotriton ruber ruber</i>						

grooves or cirri in males (Figures 2a, 2b, 3b), presence of a visible mental gland in males (Figures 2b, 3a), squared snout in males (Figures 2c, 3b), swollen jaw musculature in males, swollen cloaca in males (Figures 2d, 2e, 3c, 3e, 3f), cloacal papillae, and visibility of testes (males) or eggs (females) through the abdominal wall. Individual

species exhibited one to five of these characters (Table 1). For many species, eggs and testes can be seen by pressing the dorsal surface of the abdomen against a light, referred to as “candling.” In addition, eggs often are visible through the abdominal wall even without a light (Figure 3d). Most characters are only visible or

Table 4. Species-specific sexually dimorphic characters for salamander species in Central Appalachia, United States. These characters are in addition to the characters summarized in Tables 1 and 2. Additional species-specific information can be found in the *Supplemental Material*.

Species	Additional characters	References
Jefferson salamander <i>Ambystoma jeffersonianum</i>	Males have a more compressed tail during the breeding season. The toes of appressed limbs of males overlap 1.5 to 2 costal grooves, while those of females usually at least touch. The head tends to be flatter and broader in males than females.	Bishop 1941; Minton 1954
Blue-spotted salamander <i>Ambystoma laterale</i>	Males have toes of appressed limbs that usually overlap, touch, or nearly touch, while toes of females do not touch and may have a gap of up to three costal folds. Males have keeled tails that are compressed for the distal half during the breeding season. Average gap distance between external nares is smaller for males than females.	Bishop 1941; Gilhen 1974; Uzzell 1967b
Spotted salamander <i>Ambystoma maculatum</i>	Males have more of the dorsum covered by spots. Males have more chromatic, but less bright, yellow spots in western North Carolina. The toes of appressed limbs of females are separated by 2 to 3 costal folds, whereas those of males may touch or be separated by a single costal interspace. Gravid females have a relatively slender tail and lighter cloaca compared with males, and a distinctly swollen midsection.	Bishop 1941; Husting 1965; Morgan et al. 2014
Marbled salamander <i>Ambystoma opacum</i>	Males have silvery-white crossbands, while females have silvery-gray crossbands.	Todd and Davis 2007
Mole salamander <i>Ambystoma talpoideum</i>	Males have a longer cloaca than females. Males have a prominent glandular area dorsolaterally on the tail as well as a large tail fin. Females also exhibit cloacal swelling, a glandular area on their tail, and a tail fin during the breeding season, but these characters are much less pronounced than they are in males.	Shoop 1960; Raymond and Hardy 1990
Small-mouthed salamander <i>Ambystoma texanum</i>	Average tail length of males is longer than females. Gravid females have a swollen abdomen.	Wyman 1971; Williams et al. 2009
Eastern tiger salamander <i>Ambystoma tigrinum</i>	Males tend to have longer and taller tails than females. Average snout-vent length of males is shorter than females in some populations.	Bishop 1941, 1943; Williams et al. 2009
Eastern hellbender <i>Cryptobranchus alleganiensis alleganiensis</i>	Gravid females have a swollen abdomen.	Smith 1907
Spotted dusky salamander <i>Desmognathus conanti</i>	Sexually mature males lack vomerine teeth.	Rossman 1958
Northern dusky salamander <i>Desmognathus fuscus</i>	Females have more vomerine teeth than males.	Juterbock 1978
Shovelnose salamander <i>Desmognathus marmoratus</i>	For large males, the posterior section of the cloaca is lined with black pigment.	Martof 1962
Allegheny Mountain dusky salamander <i>Desmognathus ochrophaeus</i>	The tip of the lower jaw of males is obliquely truncated and males lack vomerine teeth.	Bishop 1941
Northern pygmy salamander <i>Desmognathus organi</i>	Average tail length is greater for females than males, and average head width is greater for males than females.	Crespi et al. 2010
Black mountain salamander <i>Desmognathus welteri</i>	Males possess enlarged cloacal glands.	Verrell and Mabry 2003
Northern two-lined salamander <i>Eurycea bislineata</i> (Lineage B)	During the breeding season, males exhibit yellowish or whitish courtship glands on the posterior area of the jaws and eyelid and white and opaque nasal glands.	Noble 1929; Siegel et al. 2020
Southern two-lined salamander <i>Eurycea cirrigera</i> (Lineage E)	Males exhibit caudal glands during the breeding season.	Sever 1989
Eastern long-tailed salamander <i>Eurycea longicauda longicauda</i>	Males exhibit caudal glands during the breeding season.	Trauth et al. 1993
Blue ridge two-lined salamander <i>Eurycea wilderae</i>	Males exhibit caudal glands during the breeding season.	Sever 1989
Four-toed salamander <i>Hemidactylium scutatum</i>	Gravid females have a swollen abdomen.	Blanchard and Blanchard 1931
Common mudpuppy <i>Necturus maculosus</i>	Average tail length of females is slightly larger than males	Bishop 1941
Red-spotted newt <i>Notophthalmus viridescens viridescens</i>	During the breeding season, males have tails that are keeled and twice as wide as females. Males exhibit nuptial pads on the inner thighs and digits of the hind feet.	Pope 1924; Singhas and Dent 1975
Eastern red-backed salamander <i>Plethodon cinereus</i>	Males develop a whitish, swollen region around the cloaca during the breeding season. Distance between nares is a fairly reliable determinant of sex, with male and female mean distance being 0.27 mm and 0.19 mm, respectively.	Quinn and Graves 1999; Gillette and Peterson 2001

Table 4. Continued.

Species	Additional characters	References
Peaks of Otter salamander <i>Plethodon hubrichti</i>	Males develop a whitish, swollen region around the cloaca during the breeding season.	Fredrickson et al. 2007
Blacksburg salamander <i>Plethodon jacksoni</i>	During the breeding season, males exhibit courtship swelling anterior to the base of the tail.	Newman 1954
Cumberland Plateau salamander <i>Plethodon kentucki</i>	Females typically have wider tails than males	Marvin 2009
Cheat Mountain salamander <i>Plethodon nettingi</i>	Males develop a whitish, swollen region around the cloaca during the breeding season.	Figure S17 (Text S1, Supplemental Material)

prominent during the breeding season. Information on species-specific size at maturity and breeding season is provided in Table 2. Additional species-specific information is available in Text S1 (*Supplemental Material*).

Two characters, enlarged premaxillary and maxillary teeth (Figure 2f), are strongly sexually dimorphic for some species (Table 3), but these characters are difficult to distinguish in the field unless animals are first anesthetized. For some species, males and females can be distinguished by their size (Table 3), with females typically being larger (Figure 2f; see *Supplemental Material* for species-specific information). However, male and female size distributions overlap, so size is only a reliable character when females exceed the maximum size of males. Additional species-specific sexually dimorphic characters have been reported in the literature for many Central Appalachian species, which are summarized in Table 4 and discussed in the individual species accounts (*Supplemental Material*).

Salamanders in Central Appalachia display a wide variety of sexually dimorphic characters, but no characters are present in all species and most species can only reliably be sexed in the field during the breeding season. Our guide serves as the most robust synthesis of sexually dimorphic characters available for salamanders in Central Appalachia to-date, and provides helpful guidance for the periods when species may display sexual dimorphism. However, we emphasize that size at maturity and breeding season can vary across the distribution of species, and recommend that additional research on local populations be consulted when available. Unfortunately, information needed for reliable sex determination is lacking or unpublished for many species, and we encourage researchers to address these biological and natural history information gaps.

Supplemental Material

Please note: *The Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Text S1. Individual species accounts with information on size at maturity, breeding season, and sexually dimorphic characters for salamanders in Central Appalachia, United States.

Available: <https://doi.org/10.3996/JFWM-20-042.S1> (13.547 MB PDF)

Reference S1. Marcum C Jr. 1994. Ecology and natural history of four plethodontid species in the Fernow Experimental Forest, Tucker County, West Virginia. Master's thesis. Huntington, West Virginia: Marshall University.

Available: <https://doi.org/10.3996/JFWM-20-042.S2> (17.296 MB PDF)

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