Herpetological Review

Gape Width: An Alternative to Snout–Vent Length for Characterizing Anuran Size

KEVIN B. ROGERS
Aquatic Research Group, Colorado Division of Wildlife
P.O. Box 775777, Steamboat Springs, Colorado 80477, USA
e-mail: kevin.rogers@state.co.us

Herpetological Review, 2009, 40(4), 416–418.
© 2009 by Society for the Study of Amphibians and Reptiles

Gape Width: An Alternative to Snout–Vent Length for Characterizing Anuran Size

KEVIN B. ROGERS
Aquatic Research Group, Colorado Division of Wildlife
P.O. Box 775777, Steamboat Springs, Colorado 80477, USA
e-mail: kevin.rogers@state.co.us

Snout–vent length (SVL) is the most frequently used metric to describe the size of anurans captured in the field (Hammerson 1999; Stebbins 2003). In addition to taxonomy and systematics, SVL has been commonly used in a wide variety of studies including those on age (e.g., Kellner and Green 1995; Schroeder and Baskett 1968), growth (e.g., Quinn and Mengden 1984; Ritke et al. 1991), demography (e.g., Miller 1977; Van Gelder and Rijsdijk 1987), fecundity (e.g., Quinn and Mengden 1984; Reading 1986; Tejedo 1992), mate selection (e.g., Arak 1988; Marco et al. 1998; Olson et al. 1986; Reading 1991), and locomotion (e.g., Daugherty and Sheldon 1982; Navas et al. 1999). Despite the pervasive use of SVL, little has been published on the precision and accuracy of this metric (Blouin-Demers 2003). Users may have recognized the limitations of SVL, but continued to acquire this metric presumably because of its ease of use and lack of a robust alternative. Measuring mass has become increasingly popular as a metric to describe size (Alvarez and Nicieza 2002; Carey 1978), but its properties have also not been well studied and can be more difficult to obtain in the field. Inadequacies in SVL are a direct result of the inherent malleability in the anurans being studied, as amphibian vertebral columns are somewhat flexible (Fellers et al. 1994). Unlike fish where measurements between researchers on the same individual yield functionally equivalent results (Anderson and Neumann 1996), measurements on frogs appear to be highly variable (K. Rogers, personal observation). Perhaps measurement of more rigid structures that are still clearly defined and easy to isolate would provide more consistent results. This study seeks to quantify variation in SVL measurement as well as that in some alternative metrics expected to be more reproducible between researchers.

Methods.—This study examined 100 animals representing three different year classes from nine lots of the Boreal Toad (*Anaxyrus boreas boreas*) brood stock housed at the Colorado Division of Wildlife's Native Aquatic Species Restoration Facility (NASRF) in Alamosa, Colorado. Husbandry practices at NASRF sought to emulate conditions found in the wild where possible and generally followed Scherf-Norris et al. (2002). Brood stock was reared in captivity from eggs collected in the wild. Animals were maintained on a normal circadian pattern with photoperiod matching ambient conditions. Tanks were maintained at a minimum temperature of 20°C, ranging up to 26°C on hot summer afternoons, with a UVA basking light available in each tank. Boreal Toads were fed 3-week old crickets powdered with nutrient supplements (Scherf-Norris et al. 2002) and hibernated from October 1 through May 1 at 5°C in four environmental chambers subdivided into hibernacula that could house up to five individuals each (Scherf-Norris et al. 2002).

Metrics used in this study were obtained by passing animals down an assembly line of six biologists who each measured the SVL, length of the tibiofibula (TF), width of the gape (GW; Fig. 1), and mass for every toad. Lengths were measured in mm with digital calipers, while mass (g) was obtained with digital balances tared before each measurement. An ANOVA was used to evaluate differences between readers. The coefficient of variation (CV) between readers for each Boreal Toad was also calculated, and a mean CV for all 100 toads for each body metric was determined. Differences between mean CVs were also evaluated with an ANOVA followed by Bonferroni's multiple comparison test with simultaneous 95% confidence intervals.

Fig. 1. Gape width measurements were taken with a digital caliper from the corners of each Boreal Toad's mouth.

Results.—There was considerable variation between readers ($P = 0.029$) in the average SVL calculated for all 100 toads measured (Fig. 2). In fact, measurements varied by as much as 30% of the calculated mean SVL for a given toad, with a mean of 12% (95% CI from 11–13%). Significant variation occurred between readers measuring TF as well ($P = 0.035$). Differences between biologists were not evident for GW ($P = 0.081$) or mass ($P > 0.999$).

Coefficients of variation were greatest for SVL and TF and least for mass (Fig. 3). Gape width did provide significantly more precision than SVL and TF, but not mass. As captive Boreal Toads used in this study were of known age, correlation of the various metrics with age was possible. Animal age ranged from 16–40 months. All metrics were positively correlated with age, with highly significant regressions ($P < 0.001$). However, mass was least predictive with an $r^2 = 0.76$. SVL and TF were intermediate, while GW showed the highest correlation with age ($r^2 = 0.85$; Fig. 4)

Discussion.—Variation in mean SVL measurements was considerable, and potentially a function of how aggressively Boreal Toads were handled during the measurement process. Body parts easily isolated for measurement produced consistent results, while those that required holding the animal in uncomfortable positions induced movement, and therefore more measurement error. It was expected that measurements of body parts less flexible than the anuran vertebral column would be more reproducible between readers. It was surprising therefore that the TF measurement was no better than SVL for repeatability as the tibiofibula bone is rigid and should have yielded more consistent results. Perhaps subject movement induced by the awkward holding position required to measure TF played a role in the relatively large mean coefficient of variation seen for this metric (Fig. 3). GW was significantly less variable between readers. In fact this assessment is probably conservative, as much of the variation observed was due to contributions from only one of six biologists (Fig. 2). Consistency in GW measurement was facilitated by mouth corners being well defined and easily located by most readers. In addition, Boreal Toads could be held in a comfortable position while acquiring this

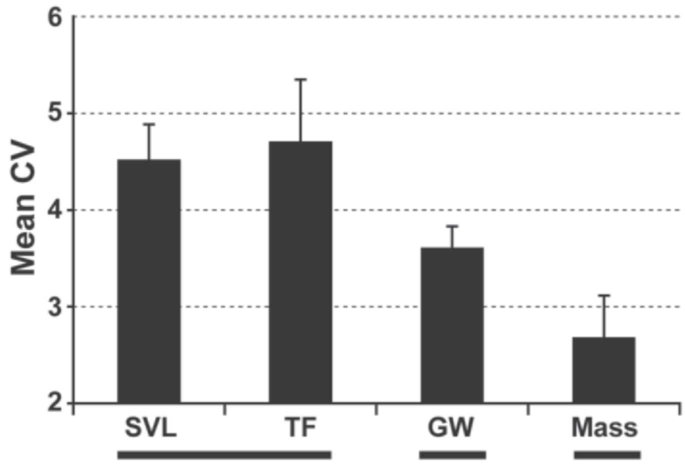

FIG. 3. Mean coefficient of variation (CV) calculated from 100 CVs generated across six biologists for snout–vent length (SVL), tibiofibula length (TF), gape width (GW), and mass with associated 95% confidence intervals. Bars sharing the same bold line below the x-axis are not significantly different ($\alpha = 0.05$).

dimension; reducing writhing that can complicate measurement of SVL and TF. This benefit was also conferred to measurement of mass. It was also not surprising that mass was the most repeatable measure used in this study, as it is the least subject to interpretation as implemented here with top-loading digital scales. Mechanical tube scales commonly used in field surveys might introduce additional measurement variation, but mass will remain a valuable metric for describing Boreal Toad size.

Perhaps the most useful aspect of measuring the width of the gape is that in addition to being very repeatable between measurers, it gave the tightest correlation with age over the size ranges examined here—a function that mass was not able to consistently achieve. While condition or plumpness of an individual can greatly affect the mass of a Boreal Toad, it often

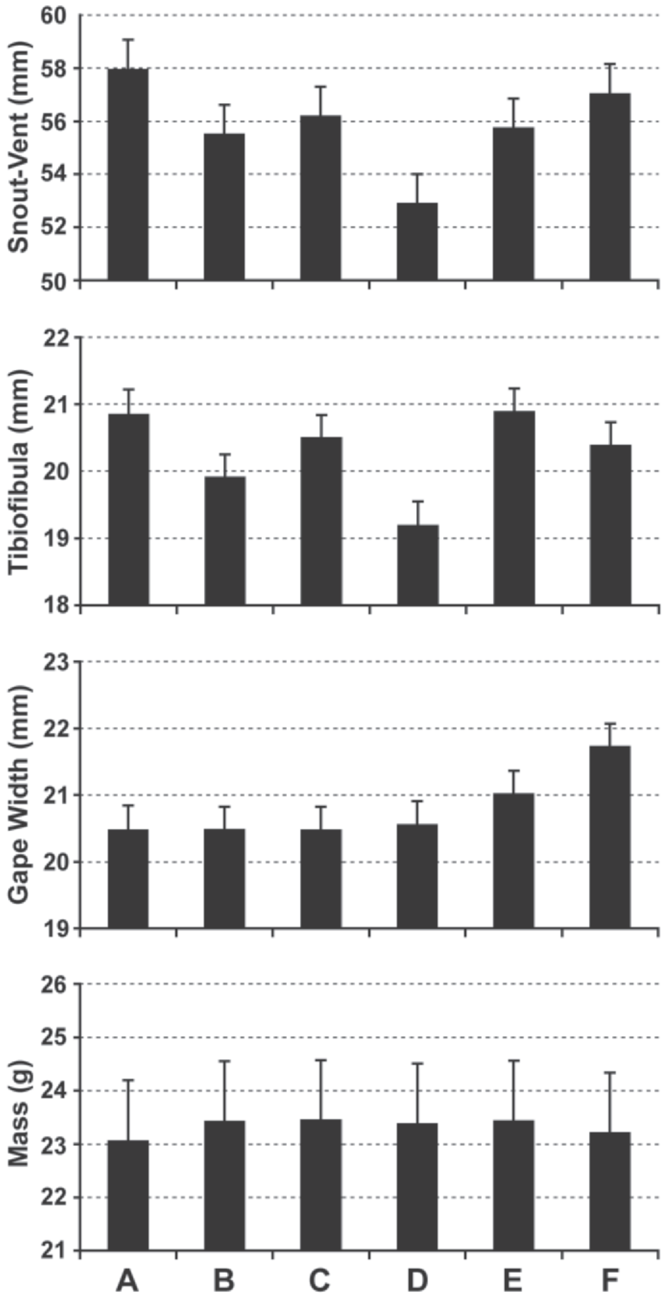

FIG. 2. Average snout–vent length (mm), average tibiofibula length (mm), average gape width (mm), and average body mass (g) for 100 Boreal Toads measured by each of six biologists (A–F) with associated standard errors.

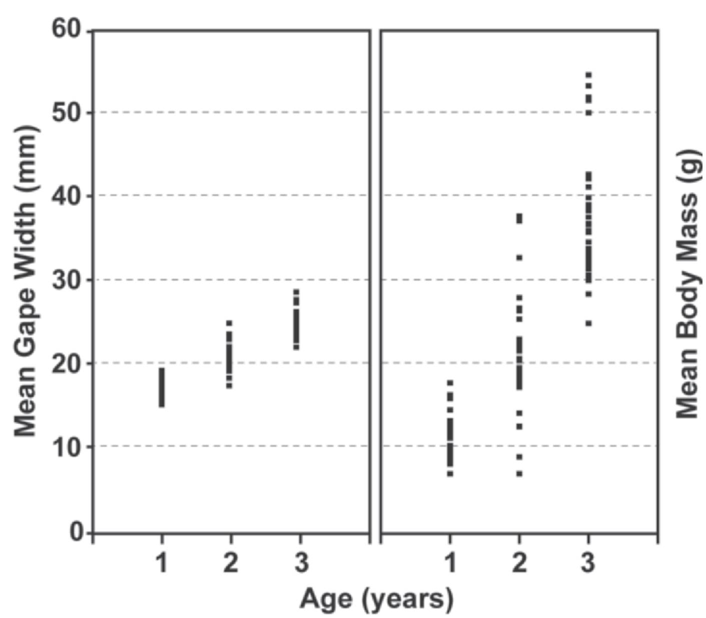

FIG. 4. Mean values for gape width (mm) and mass (g) calculated across biologists as a function of toad age.

has little to do with age. GW on the other hand is intimately tied to the animal's more rigid cranial dimensions. Though others have documented a poor relationship of SVL or mass to age in sexually mature amphibians (Halliday and Verrell 1988; Reading 1991; Wake and Castanet 1995), cranial dimensions in the first several years of a Boreal Toads life appear to more closely reflect age of the individual than mass, at least in the captive Boreal Toads used in this study. Although environmental conditions at NASRF were matched to ambient conditions, the steady diet furnished to these captive Boreal Toads might have provided for more consistent growth than would be realized in the wild. An additional study on known age wild Boreal Toads would be required to confirm the tight link between gape width and age in natural populations.

Indeed, for many analyses where only a rough index of size is required, SVL is probably adequate even with variation between readers. Certainly some of this variation can be mitigated if the same biologist acquires all of the readings. However, if precision is critical to the outcome of the study, or if a metric that is more closely correlated with age is required, then using GW is recommended.

Acknowledgments.—My gratitude is extended to J. Logan (B), T. Banulis (C), J. Eichler (D), T. Jungwirth (E), and C. Fetkavich (F) who indulged my desire to explore an alternative, and took a day to measure toad parts along with D. Schnoor for shuttling toads to the assembly line. The staff at NASRF is thanked for maintaining the population of adult toads that make this sort of study possible. M. Mahoney provided a thorough review that greatly improved the manuscript. All applicable institutional animal care guidelines were followed during the implementation of this project.

Literature Cited

Alvarez, D., and A. G. Nicieza. 2002. Effects of temperature and food quality on anuran larval growth and metamorphosis. Ecology 16:640–648.

Anderson, R. O., and R. M. Neumann. 1996. Length, weight, and associated structural indices. *In* B. R. Murphy and D. W. Willis (eds.) Fisheries Techniques, 2nd ed., pp. 447–482. American Fisheries Society, Bethesda, Maryland.

Arak, A. 1988. Female mate selection in the natterjack toad: active choice or passive attraction? Behav. Ecol. Sociobiol. 22:317–327.

Blouin-Demers, G. 2003. Precision and accuracy of body-size measurements in a constricting, large-bodied snake (*Elaphe obsolete*). Herpetol. Rev. 34:320–323.

Carey, C. 1978. Factors affecting body temperatures of toads. Oecologia 35:197–219.

Daugherty, C. H., and A. L. Sheldon. 1982. Age-specific movement patterns of the frog *Ascaphus truei*. Herpetologica 38:468–474.

Fellers, G. M., C. A. Drost, and W. R. Heyer. 1994. Handling live amphibians. *In* W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster (eds.), Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians, pp. 275–276. Smithsonian Institution Press, Washington, DC.

Halliday, T. R., and P. A. Verrell. 1988. Body size and age in amphibians and reptiles. J. Herpetol. 22:253–265.

Hammerson, G. A. 1999. Amphibians and Reptiles in Colorado. 2nd ed. University Press of Colorado and Colorado Division of Wildlife, Niwot, Colorado. 484 pp.

Kellner, A., and D. M. Green. 1995. Age structure and age at maturity in Fowler's toads, *Bufo woodhousii fowleri*, at their northern range limit. J. Herpetol. 29:485–489.

Marco, A., J. M. Kiesecker, D. P. Chivers, and A. R. Blaustein. 1998. Sex recognition and mate choice by male western toads, *Bufo boreas*. Anim. Behav. 55:1631–1635.

Miller, P. H. 1977. A demographic study of the chorus frog, *Pseudacris triseriata*. Master's thesis. Colorado State University, Fort Collins.

Navas, C. A., R. S. James, J. M. Wakeling, K. M. Kemp, and I. A. Johnston. 1999. An integrative study of the temperature dependence of whole animal and muscle performance during jumping and swimming in the frog *Rana temporaria*. J. Comp. Physiol., B. 169:588–596.

Olson, D. H., A. R. Blaustein, and R. K. O'hara. 1986. Mating pattern variability among western toad (*Bufo boreas*) populations. Oecologia 70:351–356.

Quinn, H. R., and G. Mengden. 1984. Reproduction and growth of *Bufo houstonensis* (Bufonidae). Southwest. Nat. 29:189–195.

Reading, C. J. 1986. Egg production in the common toad, *Bufo bufo*. J. Zool. 208:99–107.

———. 1991. The relationship between body length, age and sexual maturity in the common toad, *Bufo bufo*. Holarctic Ecol. 12:245–249.

Ritke, M. E., J. G. Babb, and M. K. Ritke. 1991. Annual growth rates of adult gray treefrogs (*Hyla chrysoscelis*). J. Herpetol. 25:382–385.

Scherf-Norris, K. L., L. J. Livo, A. Pessier, C. Fetkavich, M. Jones, M. Kombert, A. Goebel, and B. Spencer. 2002. Boreal Toad Husbandry Manual. Colorado Division of Wildlife, Fort Collins, Colorado. 78 pp. http://wildlife.state.co.us/Research/Aquatic/BorealToad/.

Schroeder, E. E., and T. S. Baskett. 1968. Age estimation, growth rates, and population structure in Missouri bullfrogs. Copeia 1968:583–592.

Stebbins, R. C. 2003. A Field Guide to Western Reptiles and Amphibians. 3rd ed. Houghton Mifflin Co., New York. 560 pp.

Tejedo, M. 1992. Absence of the trade-off between the size and number of offspring in the natterjack toad (*Bufo calamita*). Oecologia 90:294–296.

Van Gelder, J. J., and G. Rijsdijk. 1987. Unequal catchability of male *Bufo bufo* within breeding populations. Holarctic Ecol. 10:90–94.

Wake, D. B., and J. Castanet. 1995. A skeletochronological study of growth and age in relation to adult size in *Batrachoseps attenuatus*. J. Herpetol. 29:60–65.