



STATE BASED ON FOOT MORPHOLOGY



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Introduction

Species identification of amphibians based on their dismembered or partly digested parts is a basic aspect of dietary studies on amphibian-consuming organisms. In the course of attempting to identify amphibian limbs obtained from river otter (*Lontra canadensis*) gastrointestinal tracts, we became aware of the lack of data to systematically identify amphibian limbs. Hence, we have developed a dichotomous key to amphibians based on foot morphology (both front and hind) for all 27 species of amphibians in Washington State (14 salamanders and 13 frogs). One cannot distinguish selected closely related species unambiguously depending on which foot (front or hind) is available, so genetic or, less satisfactorily, geographic data may be needed to distinguish some species. Here, we present a sub-finalized version of the dichotomous key to the feet of all 27 amphibian species in Washington State based on morphology. We anticipate that use of this key will enable selected refinements that may assist in distinguishing at least a few of the species that currently cannot be separated based either on their front or hind feet alone.



Method

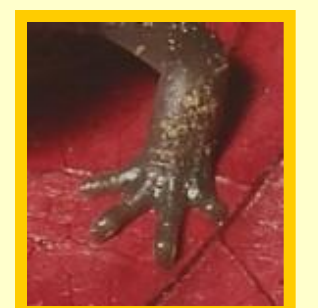
Foot Morphology Key

We extracted data on amphibian foot morphology for the 27 species of amphibians known to occur in Washington State from published literature. We verified those data through examination of museum specimens from the University of Washington Burke Museum and the University of Puget Sound Slater Museum, photographs of amphibian feet from several sources, and to a lesser degree, live animals. We also examined specimens and photographs for characteristics of amphibian feet not addressed in the literature. Collectively, we used these data to develop a verification table for all features of foot morphology that might be useful to distinguish either different groups or species of amphibians. Using this table, we constructed this sub-finalized version of the dichotomous key.

Results

Foot Morphology Key to Washington State Amphibians (beta version)

1. Four digits on limb, representing a front foot (manus).....2
Five digits on limb, representing a hind foot (pes).....24
2. Digit 2 is shorter than digit 13
Digit 2 longer than digit 112
3. Skin covered with tubercles4
Skin lacking tubercles.....6
4. No palmar or thenar tubercles; subarticular tubercles reduced
.....Great Basin Spadefoot (*Spea intermontana*)
Prominent palmar, thenar, and subarticular tubercles5
5. If aligned together digit 4 extends to distal end of phalange 2 on digit 3
.....Western Toad (*Bufo boreas*)
If aligned together digit 4 reaches phalange 2 on digit 3, but never to its distal endWoodhouse Toad (*Bufo woodhousii*)
6. Subarticular tubercle between phalanges 1 and 2 reduced or absent on both digits 3 and 47
Subarticular tubercles between phalanges 1 and 2 on digits 3 and 4 pronounced9
7. Thenar and palmar tubercles similar size and shape; if present, accessory palmar tubercles reducedColumbia Spotted Frog (*Rana luteiventris*)
Thenar and palmar tubercles differ in size and shape8
8. A large thenar tubercle covering most of palm and, if present, smaller elongate palmar tubercleAmerican Bullfrog (*Rana catesbeiana*)
Two tubercles always present; a small thenar is circular or ovoid, a larger palmar is elongated.....Green Frog (*Rana clamitans*)



9. Subarticular tubercles between phalanges 1 and 2 on digits 1, 3 and 4; pronounced accessory palmar tubercles may be present
.....Cascade Frog (*Rana cascadae*)
Subarticular tubercles between phalange 1 and 2 present only on digits 3 and 4.....10
10. Accessory palmar tubercles present.....11
Accessory palmar tubercles absent.....Northern Leopard Frog (*Rana pipiens*)
11. Thenar tubercle round with an irregular margin; palmar tubercle elongateOregon Spotted Frog (*Rana pretiosa*)
Thenar tubercle oval to elongate; palmar tubercle elongate
.....Northern Red-legged Frog (*Rana aurora*)
12. Digit 2 ≤ 75 percent of length of digit 313
Digit 2 > 75 percent of length of digit 314
13. Digits with expanded tips (possessing toe disks), prominent on digits 3 and 4 (i.e., width of toe tip at least 1.4 times width of middle of the first phalange (Fig. a); an intercalary cartilage present that makes the toe tip appear to have a buckle in side view.....
.....Pacific Chorus Frog (*Pseudacris regilla*)
Digits lacking expanded tips (toe disks) or intercalary cartilagesTailed Frogs (*Ascaphus*)
14. All digits with cornified tips; 2 large palmar tubercle.....
.....Giant Salamanders (*Dicamptodon*)
Digits not cornified15
15. Digits significantly wider at the base and taper to the tip16
Digits more symmetric, not significantly wider at the base than the tips.....17
16. Tips of digits tapered to a point, may have keratinized tips; skin lacking tubercles.....Tiger Salamander (*Ambystoma tigrinum*)
Tips of digits taper to a rounded end; skin well tubercled, distinctly bicolored, brown on top, and yellow beneath.....
.....Rough-skinned Newt (*Taricha granulosa*)
17. Digit 1 $\geq 1/2$ length of digit 218
Digit 1 $< 1/2$ length of digit 220
18. Digit 4 $\geq 1/2$ length of digit 3, ventral side of foot not brightly colored19
Digit 4 $< 1/2$ length of digit 3, ventral side of foot yellow or orange
.....Torrent Salamanders (*Rhyacotriton*)
19. Digits do not taper to tip
.....Northwestern Salamander (*Ambystoma gracile*)
Digits taper slightly to tip.....
.....Long-toed Salamander (*Ambystoma macrodactylum*)
20. All digits webbed21
Digits not webbedEnsatina (*Ensatina eschscholtzii*)
21. Viewed dorsally, webbing reaches distal end of digit 122
Viewed dorsally, webbing does not reach distal end of digit 123
22. Dorsal pigmentation visible, ventral may be red-orange with varying intensityLarch Mountain salamander (*Plethodon larselli*)
Dorsal and ventral surfaces largely unpigmented.....
.....Van Dyke's salamander (*Plethodon vandykei*)
23. Lateral side of digit 3 webbing extends to boundary of metatarsal-phalange 1, Western Red-backed Salamander (*Plethodon vehiculum*)
Lateral side of digit 3 webbing extends into phalange 1.....
.....Dunn's salamander (*Plethodon dunnii*)
24. Digits clearly webbed ; digits highly asymmetric in length, length of digit 4 at least twice the length of digit 125
Digits unwebbed or not clearly webbed ; digits of subequal length, length of digit 4 considerably less than the twice the length of digit 136
25. Digits 4 and/or 5 broader or more flattened than digits 1, 2, and 3
.....Tailed Frogs (*Ascaphus*)
Digits 4 and 5 similar to digits 1, 2, and 3, but not broader or more flattened26
26. Digits with expanded tips, possessing toe disks; in particular digits 3 and 4 (i.e., width of toe tip usually at least 1.4 times the width of the middle of the first phalange; an intercalary cartilage present that makes the toe tip appear to have a buckle in side view.....
.....Pacific Chorus Frog (*Pseudacris regilla*)
Digits without expanded tips, toe disks or intercalary cartilages.....27
27. Cornified cutting, typically black or dark brown, inner metatarsal tubercles28
If present, inner metatarsal tubercles not cornified.....30
28. One cornified cutting black or dark brown inner metatarsal tubercles, tips of digits also often cornified light brown or black to varying degreesGreat Basin Spadefoot (*Spea intermontana*)
Two cornified cutting metatarsal tubercles, may be black or dark brown29
29. Webbing extends to distal end of digit 4; inner metatarsal tubercle at most 2x the size of outer metatarsal tubercle.....
.....Western Toad (*Bufo boreas*)
Webbing distal to phalange 2 on digit 4 exists only as a fringe to the end of the digit; inner metatarsal tubercle at least 3x the size of outer metatarsal tubercleWoodhouse Toad (*Bufo woodhousii*)
30. Digits essentially fully webbed, reaching to toe tips or nearly so.....31
Digits not fully webbed, reduced or incised on either side of digit 4 to at least level of most distal subarticular tubercle.....34
31. Digits 1, 2, and 3 largely unpigmented dorsally, unlike digits 4 and 532
All digits similarly pigmented dorsally.....33

32. Full webbing extends to distal end of digit 3
.....American Bullfrog (*Rana catesbeiana*)
Incomplete webbing such that webbing only fringes the last two phalanges (3 and 4) on digit 3Green Frog (*Rana clamitans*)
33. One prominent elongated tubercle on the inner metatarsal.....
.....Columbia spotted frog (*Rana luteiventris*)
One prominent elongated tubercle on the inner metatarsal and a less prominent outer metatarsal tubercle.....Oregon spotted frog (*Rana pretiosa*)
34. Digits 4 and 5 have sharp-edged large dark spots dorsally.....
.....Northern Leopard Frog (*Rana pipiens*)
Digits 4 and 5 lacking sharp-edged dark spots, but may have paler diffuse spots35
35. Digits 1, 2 and 3 are dorsally pigmented with red/pink hues.....
.....Northern Red-legged Frog (*Rana aurora*)
Digits 1, 2 and 3 are dorsally pigmented with yellow hues
.....Cascade frog (*Rana cascadae*)
36. Tips of all digits cornified, 2 large plantar tubercles.....
.....Giant Salamanders (*Dicamptodon*)
Digits not cornified37
37. Digit 4 is equal to or longer than the sole of the foot
.....Long-toed Salamander (*Ambystoma macrodactylum*)
Digit 4 is not equal to or longer than the sole of foot38
38. Digits significantly wider at the base and taper to the tip.....39
Digits not significantly wider at the base than the tips, more symmetrical40
39. Tips of digits tapered to a point, may have keratinized tips; skin lacking tuberclesTiger Salamander (*Ambystoma tigrinum*)
Tips of digits taper to rounded end, skin covered with tubercles, distinctly bicolored, brown on top, yellow or orange beneath.....
.....Rough-skinned Newt (*Taricha granulosa*)
40. Digit 1 is less than two-thirds the length of digit 241
Digit 1 is more than two-thirds the length of digit 2
.....Northwestern Salamander (*Ambystoma gracile*)
41. Digit 1 greater than $1/3$ length of digit 2
.....Torrent Salamanders (*Rhyacotriton*)
Digit 1 less than $1/3$ length of digit 242
42. Some webbing between digits even if limitedEnsatina (*Ensatina eschscholtzii*)
No visible webbing between digitsEnsatina (*Ensatina eschscholtzii*)
43. Digit 5 has only 1 phalange, ventral side of feet usually reddish.....
.....Larch Mountain salamander (*Plethodon larselli*)
Digit 5 has 2 phalanges, ventral side not usually reddish44
44. Webbing on digit 1 extends to toe tip, webbing on digits 2-5 extends to beyond the boundary of metatarsal-phalange 1, foot largely unpigmentedVan Dyke's salamander (*Plethodon vandykei*)
Webbing on digit 1 does not extend to toe tip, webbing on digits 2-5 extends at most to boundary of metatarsal-phalange 1, foot has some pigment45
45. Webbing attached mostly perpendicular to digits 2-4
.....Western Red-backed Salamander (*Plethodon vehiculum*)
Webbing incised on all digitsDunn's salamander (*Plethodon dunnii*)



Conclusion

We anticipate that this key will have practical uses beyond dietary studies. For example, it may be useful in studies assessing road-kills, where typically but a fraction of animals are whole, requiring alternatives routes for identification.

Literature Cited

See handout below.

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