ERRATUM

Due to a printers error the last sentence of couplet 1b in the key to species on page 617 is incorrect. It should be replaced with the following two sentences. "In males, ratio of PH/PL falls between 0.25-0.28 and ratio of FL/PL between 0.39-0.42. In females, PH/PL falls between 0.24-0.28 and FL/PL between 0.36-0.39_____ K. subrubrum"

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Morphometric Validation of the Striped Mud Turtle (*Kinosternon baurii*) in the Carolinas and Virginia

TRIP LAMB AND JEFF LOVICH

***Kinosternon baurii* has been traditionally viewed as an inhabitant of peninsular Florida. The variable expression of "diagnostic" striping patterns in this species has complicated the precise demarkation of its northern range, where specimens are often misidentified as *K. subrubrum subrubrum*. Lamb (1983) confirmed reports of *K. baurii* in Georgia and South Carolina through the multivariate analysis of morphometric characters. Here we expand his treatment, by comparing additional *Kinosternon* of questionable status with 189 *K. baurii* from throughout Florida and 191 *K. s. subrubrum* from Georgia north to New York.**

Discriminant analysis of 15 shell characters clearly separated *K. baurii* and *K. s. subrubrum*. Discriminant scores, calculated a posteriori for 39 *baurii*-like *Kinosternon* from Georgia, the Carolinas, and Virginia, demonstrated complete overlap with the canonical scores of *K. baurii*. Thus, on the basis of both pigmentation patterns and morphometrics, we assign these 39 questionable forms to *K. baurii*. A key and set of discriminant functions that distinguish the species of *Kinosternon* along the Atlantic Coastal Plain are provided.

THROUGHOUT most of peninsular Florida, the striped mud turtle, *Kinosternon baurii*, exhibits the head and carapace stripes that characterize this species. Nonetheless, these diagnostic features demonstrate considerable variation in their degree of expression, and head and/or carapace patterns (white to cream in color) can be greatly obscured if not completely obliterated. Reduced pigmentation, a fairly common condition in older individuals, appears to typify populations from certain regions in the state. For example, turtles from the Gulf Hammock (Levy and Taylor counties) and the Lower Keys show greatly reduced carapace striping, and some specimens lack carapace stripes altogether (Iverson, 1978; Uzzell and Schwartz, 1955).

The variable expression of striping patterns in *K. baurii* has complicated identification of this species in the northern portion of its range, where it has often been misidentified as *K. subrubrum subrubrum*. As in the Gulf Hammock region, specimens of *K. baurii* from Georgia and South Carolina demonstrate a great reduction or absence of carapace markings, though head stripes are generally present. These unusual patterns, coupled with the perception that *K. baurii* is largely a peninsular form, have fostered debate about the species' presence outside of Florida (Duever, 1972; Ernst, 1974; Gibbons et al., 1979).

Lamb (1983) employed discriminant analysis of shell and cranial traits to assess the taxonomic status of a suspect population of *Kinosternon* near Aiken, South Carolina. Morphometrically, the turtles demonstrated distinct separation from Georgia and South Carolina *K. s. subrubrum*, but exhibited extensive overlap with *K. baurii* from northern Florida. Thus, the South Carolina specimens were assigned to *K. baurii*, as were several Georgia specimens with similar pigmentation patterns.

Recently other researchers have employed the discriminant functions provided by Lamb (1983) to classify (*Kinosternon* specimens with *baurii*-like pigment patterns from southwest Georgia (Camp et al., 1988), northeast South Carolina (W. Seyle, pers. comm.), North Carolina (A.

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Braswell, pers. comm.; W. Palmer, pers. comm.), and Virginia (J. Mitchell, pers. comm.). In each case, these functions yielded discriminant scores that fall within the *K. baurii* range of values. However, the discriminant functions derived from the Lamb (1983) survey may not be appropriate for identifying questionable forms that occur beyond the geographic region demarcated by specimens employed in the original analysis. The predictive power of the discriminant analysis could be seriously compromised, especially if genetic and/or environmental factors have induced extensive morphometric variation.

To adequately address the possibility of geographic differentiation in the two species, and its potential influence on the diagnostic value of shell characters, we conducted a second, more extensive survey. Sample sizes were greatly increased, as was the geographic scope of these samples. The discriminant functions generated from this enlarged data base are used to classify turtles of questionable status from new localities in Georgia, the Carolinas, and Virginia.

Materials and Methods

One hundred ninety-one *K. s. subrubrum* from Georgia northeast to New York and 189 *K. baurii* from throughout peninsular Florida were examined for shell analysis. Specimens selected for the *K. s. subrubrum* sample were characteristic of the subspecies (each without any semblance of distinct head stripes, though some individuals exhibited head patterns consisting of spots or light reticulations). Specimens composing the *K. baurii* sample were from Florida and represented localities outside the range of *K. s. subrubrum.* A total of 39 specimens exhibiting various degrees of head and/or carapace striping were critically compared to the reference samples above. These questionable forms were either brought to our attention by other researchers, or were found by one of us during examinations of various museum collections. All of the specimens examined are listed by state and county locales in the Appendix.

Fifteen shell characters were measured to the nearest 0.1 mm with digital calipers. The characters (and designated abbreviations) are as follows: carapace length (CL); carapace width (CW); plastron length (PL); plastral widths at the gular-anterior humeral (PA), anterior humeral-posterior humeral (PB), posterior humeral-femoral (PC), and femoral-anal (PD) seams; midline seam lengths for the intergular (I), gular (G), anterior humeral (AH), posterior humeral (PH), femoral (F), and anal (A) scutes; plastral forelobe length (FL); plastral hindlobe length (HL). Character descriptions and measurement landmarks are detailed in Iverson (1977); plastral scute terminology follows Hutchison and Bramble (1981). Due to pronounced sexual dimorphism in plastral features (Gibbons, 1983), the sexes were analyzed separately. All specimens were >70 mm CL and had a complete set of character measurements.

A two-group comparison of the *K. s. subrubrum* and *K. baurii* samples was conducted using stepwise discriminant analysis (the DISCRIMINANT program package of SPSS-X). Initially, analysis was conducted using the raw data as input variables. For comparison, subsequent analyses were run on the following transformed data sets: 1) natural logs; 2) residuals generated from regression analysis of each character on CL; and 3) ratios of each character to CL.

Discriminant scores were calculated a posteriori for the questionable forms by multiplying their character values by the unstandardized canonical coefficients and summing these products. As a result, a questionable specimen's relative position along the axis providing maximal separation of the reference groups was determined. Moreover, discriminant scores were calculated for the Georgia and South Carolina specimens reported by Lamb (1983), in order to test their previous assignment to *K. baurii.*

Results

Results from the discriminant analysis of the nontransformed data set provided effective separation for the two species. Histograms of discriminant scores demonstrated complete separation for female *Kinosternon* (Fig. 1A), whereas slight overlap between species was observed for the males (Fig. 2A). Discriminant scores computed for the questionable specimens were plotted on the two-group canonical axis corresponding to their appropriate sex (Figs. 1B, 2B). Scores of all 39 specimens fall within the range of their respective *K. baurii* sample. Characters that were most influential in discriminating the two species included the following, in order of importance: for males: FL, PH, PA, and PC; for females: PH, CW, PC, and FL. It should be noted that the same variables were identified as the most influential discriminating characters in Lamb (1983). Results for the transformed

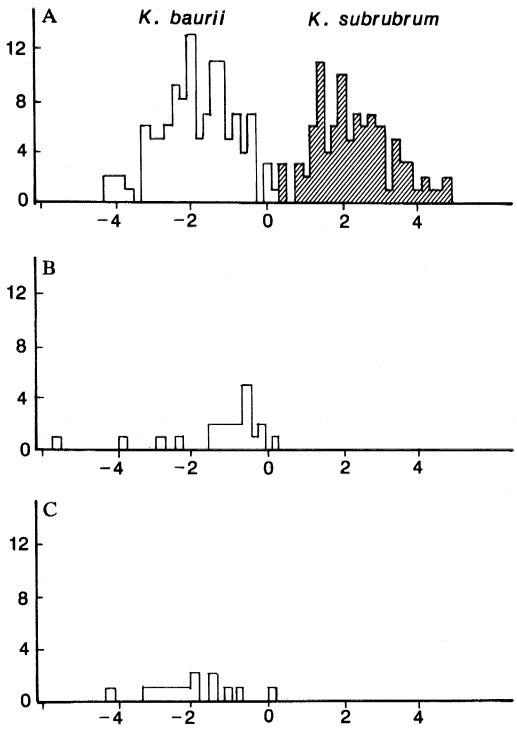

Fig. 1. A) Histogram of canonical variates for female *Kinosternon* generated from the two-group analysis. B) Discriminant scores for the questionable *Kinosternon* specimens. C) Discriminant scores for the Georgia and South Carolina *K. baurii* identified by Lamb (1983). Scores for the questionable forms were derived from the function 0.32989(CW) − 0.18114(PL) + 0.05534(PA) − 0.41545(PC) + 0.21335(I) + 0.09978(G) + 0.11516(AH) − 0.29116(PH) + 0.40144(FL) − 1.33202, where values <0.3 = *K. baurii.*

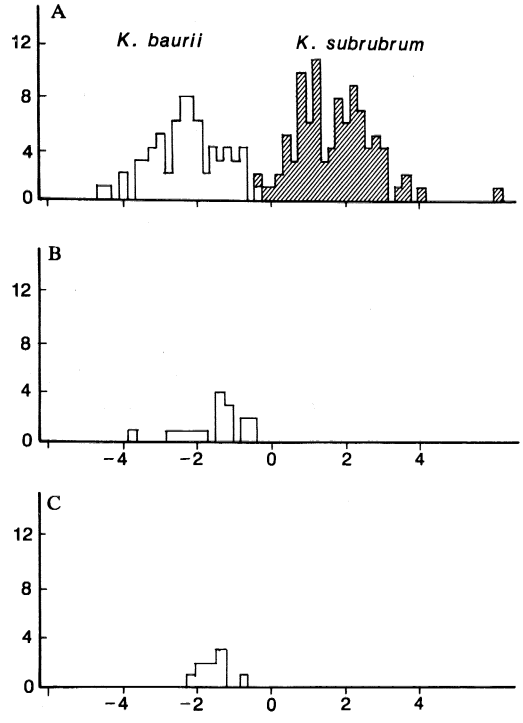

Fig. 2. A) Histogram of canonical variates for male *Kinosternon* generated from the two-group analysis. B) Discriminant scores for the questionable *Kinosternon* specimens. C) Discriminant scores for the Georgia and South Carolina *K. baurii* identified by Lamb (1983). Scores for the questionable forms were derived from the function 0.19979(CW) − 0.30907(PL) + 0.18596(PA) − 0.45300(PC) + 0.09885(I) − 0.12075(PH) + 0.08270(F) + 0.48112(A) + 0.53173(FL) − 3.47756, where values <−0.5 = *K. baurii.*

data sets, i.e., natural logs, residuals, and ratios, were practically identical to those for the raw data; effective separation between species was achieved in each analysis, and discriminant scores for the questionable specimens demonstrated complete overlap with those of *K. baurii.* Scores for the Georgia and South Carolina *Kinosternon* surveyed by Lamb (1983) also overlap with the *K. baurii* sample (Figs. 1C, 2C), corroborating their previous assignment to this species.

Discussion

Field identification of *K. baurii* in the northern portion of its range has been problematic due to: 1) the incomplete expression of diagnostic pigment characters, often involving the reduction or absence of carapace stripes; and 2) sympatry with *K. s. subrubrum,* which can display head and neck patterns that resemble the head stripe patterns of *K. baurii.* For example, only 12 of the 39 specimens that we examined possessed three carapace stripes. Thus there has been a tendency for researchers to dismiss *Kinosternon* with head stripes from Georgia and further north as *K. s. subrubrum.*

Lamb (1983) demonstrated the reliability of morphological traits in distinguishing *K. baurii* and *K. s. subrubrum* within a region encompassing northern Florida and portions of Georgia and South Carolina. The results presented herein effectively expand this treatment. Our

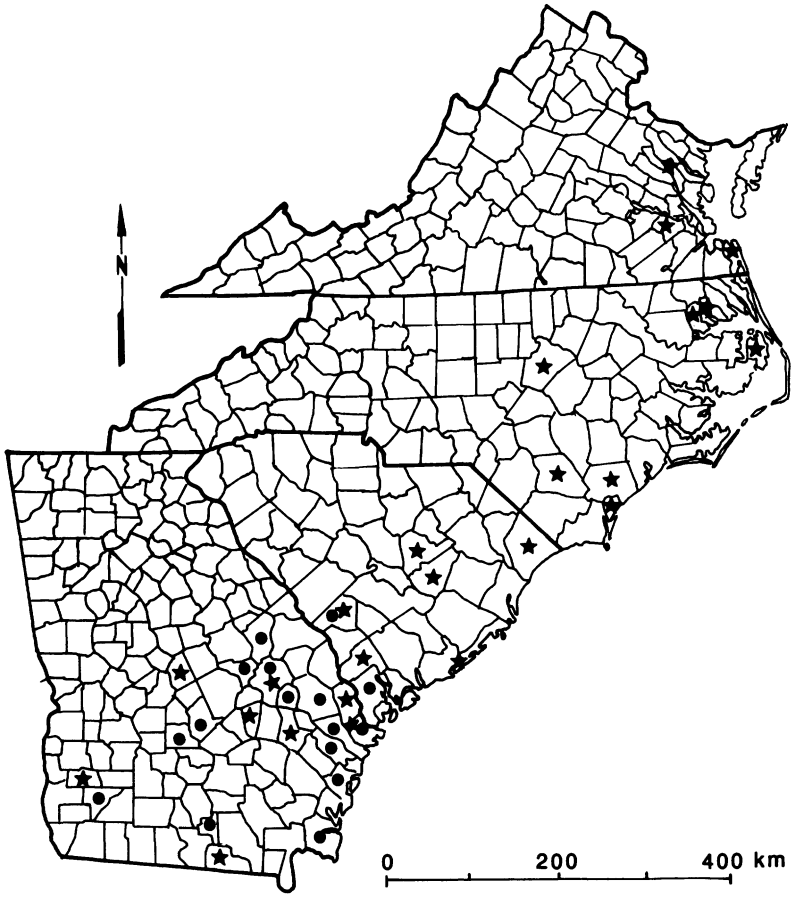

Fig. 3. Map of localities for *Kinosternon baurii* north of Florida. The new localities are represented by stars and previously established localities by circles.

morphometric comparison of *K. baurii* throughout Florida vs *K. s. subrubrum* from coastal plain and piedmont localities along the Atlantic seaboard revealed that the two species can be readily and consistently distinguished over a much broader geographic scale. Lamb (1983) also presented a case for assigning certain specimens from Georgia and South Carolina with strong facial striping (and in some cases, weak carapace striping) to *K. baurii.* We have documented the occurrence of similarly pigmented turtles from numerous localities north along the Atlantic Coastal Plain to Virginia and have demonstrated their morphometric affinities with *K. baurii.* Thus, on the basis of both pigmentation patterns and morphometrics, we assign the 39 questionable forms examined in this study to *K. baurii.*

Additional, independent support for our interpretation is provided from reproductive data on a specimen from Perquimans County, North Carolina. An adult female NCSM 29582 with head stripes, had oviducal eggs when captured on 2 Oct. 1988 (W. Palmer, pers. comm.). Whereas *K. baurii* females typically possess oviducal eggs in the fall (Iverson, 1979), female *K. s. subrubrum* do not (Gibbons, 1983).

In summary, we conclude that 39 *baurii*-like *Kinosternon* from outside the presently accepted range of *K. baurii* should be assigned to this taxon. Preliminary clues based on pigmentation patterns were confirmed through multivariate character analysis. The new localities extend the species' range over 600 km northeast to Virginia and indicate a continuous distribution along the Atlantic Coastal Plain (Fig. 3). In light

of these results, we are presently undertaking a broader survey of the polytypic *K. subrubrum* in an attempt to ascertain evolutionary relationships among its designated subspecies and *K. baurii*.

Key to Species of *Kinosternon* Inhabiting the Atlantic Coastal Plain

Although this key reliably distinguishes *K. baurii* from *K. s. subrubrum*, we strongly encourage confirming identification with the discriminant functions provided in the legends of Figures 1 and 2.

1a. Carapace stripes present, greatly reduced, or absent. Side of head bearing a pair of stripes, either continuous or broken. Canthal stripe typically extends anterior of eye to tip of snout. In males, ratio of PH/PL falls between 0.29–0.33 and ratio of FL/PL between 0.35–0.38. In females, PH/PL falls between 0.28–0.35 and FL/PL between 0.32–0.35 ..... *K. baurii*

1b. Carapace stripes absent. Side of head variable, from no markings to extensive spotting or stripe-like patterning, but seldom involving a pair of stripes. If side of head is patterned, then canthal stripe, if present, does not extend anterior of eye. In males, ratio of PH/PL falls between 0.25–0.28 and ratio of PL falls between 0.24–0.28 and FL/PL between 0.36–0.39 ..... *K. subrubrum*

Material Examined

Institution acronyms follow Leviton et al. (1985), plus the nonstandard abbreviations: CMFS (Carnegie Museum field series), SREL (Savannah River Ecology Laboratory Museum), and USNMFS (U.S. National Museum field series).

Kinosternon baurii.—**Florida**, Alachua County (Co.): AMNH 93197; UF 265, 326, 766–7, 771, 1417, 1657 (2), 2723, 9206, 9213, 9654 (4), 9822, 12020, 14640–41, 54701, 60900, 60901, 62924–25, 69557, 69588, DB3283, DRJ188, JBI241, JBI244–45, JBI248, JBI250, JBI252, JBI262, JBI266, JBI268–70, JBI775, SRT1416, T1008, two uncatalogued specimens; Baker Co.: UF 44315, 50749–51; Bradford Co.: UF 7198; Brevard Co.: AMNH 6978, UF 6618, 7069, 32637, 46033–40, 46042–43, one uncatalogued specimen; Broward Co.: UF 54704; Citrus Co.: UF 32630; Clay Co.: one uncatalogued specimen; Collier Co.: UF 587, 17667; Columbia Co.: UF 62074; Dade Co.: UF 597, 1305, 2889, 32641, 32643, 54183–84, 54703, 56363–65, UGA 3788, 4272, USNM 249565, 249567, 249569–71, 249573, 249582, 249586; Dixie Co.: UF two uncatalogued specimens; Duval Co.: UF 12019, 32849, five uncatalogued specimens; Gilchrist Co.: UF 54702, one uncatalogued specimen; Glades Co.: UF 4095–96; Hernando Co.: UF 32631, UGA 3794; Highlands Co.: AMNH 65619, UF RAS166; Hillsborough Co.: UF 32632, SREL 1797; Indian River Co.: UF 43784, 45728, 56388; Jefferson Co.: UF 28313, 62423; Lafayette Co.: UF 14642; Lake Co.: UF 32634, UGA 3791; Levy Co.: UF 12017–18, 12021–22, 14643, 32652–54; Manatee Co.: 32645–51; Marion Co.: UF 17669–70, 32638–39, 36939–41, 56926, JBI264, one uncatalogued specimen; Monroe Co.: UF 2386, 7105–06, 32642, JBI255, JBI684, UGA 4271; Pinellas Co.: AMNH 5189, USNM 64222–23; Polk Co.: UF 1923 (2), 2861, 6616, 9597, 56924–25, 60899, JBI 535–38; Putnam Co.: UF 32640, JBI253, one uncatalogued specimen, USNM 192777; St. Johns Co.: UF 1726, 1927, 50289, 50337, 50640, 50756, 50777, SJ171; Taylor Co.: UF 28311, 32635; Volusia Co.: UF 4884, 56927, JBI541, one uncatalogued specimen; Wakulla Co.: AMNH 14164, UF 54698, 62422, one uncatalogued specimen.

Kinosternon s. subrubrum.—**District of Columbia**, USNM 8383, 11604, 45562, 139626, 213745. **Delaware**, New Castle Co.: AMNH 66179, 70731, 129338; Sussex Co.: 121528. **Georgia**, Baker Co.: UGANHM 3295, 3297, 3757, 3775, 3780–81; Bibb Co.: UGANHM 3727–28; Charlton Co.: UGANHM 4268; Clarke Co.: UGANHM 3264, 3266, 3287, 3300; Clinch Co.: UGANHM 4269, 19034, 19044; Colquitt Co.: UGANHM 19039, 19483; Columbia Co.: SREL 3078–82; Dooly Co.: UGANHM 3748; Early Co.: UGANHM 3778–79; Fulton Co.: UGANHM 3733; Glynn Co.: UGANHM 3709; Hancock Co.: UGANHM 19484; Irwin Co.: UGANHM 3265, 3715-16; Jones Co.: UGANHM 19031; Lowndes Co.: UGANHM 3725; McIntosh Co.: UGANHM 3731, 3744; Morgan Co.: UGANHM 3262, 3736–37; Newton Co.: UGANHM 3735; Oconee Co.: UGANHM 3282–84; Screven Co.: UGANHM 3702; Talbot Co.: UGANHM 3739; Telfair Co.: UGANHM 3274; Ware Co.: UGANHM 4267, 4270, 19037; Wilkinson Co.: UGANHM 17178; **Indiana**, Knox Co.: USNM 13377. **Maryland**, Anne Arundel Co.: USNM 202968–69; Cecil Co.: DU R2361; Charles Co.: USNM 32047, 139627; Dorchester Co.: AMNH 66178; Harford Co.: USNM 9021; Montgomery Co.: USNM 139628; Prince Georges Co.: USNM 139624; Talbot Co.: AMNH 66176, USNM 121526–27. **North Carolina**, Alamance Co.: NCSM 12577; Bertie Co.: NCSM 11788; Camden Co.: NCSM 11949, 15247, 28717; Carteret Co.: NCSM 6604, 20021–22, 29411–14; Chatham Co.: NCSM 11345–46, 23657; Columbus Co.: NCSM 2585, 29415; Currituck Co.: NCSM 19394, 28984; Dare Co.: NCSM 3290, 22967, 28432, 29283; Gaston Co.: NCSM 24882; Granville Co.: NCSM 7547, 25239; Harnett Co.: NCSM 7503, 21697; Hoke Co.: NCSM 23147, 25624; Hyde Co.: NCSM 11749, 12524, 25409; Johnston Co.: NCSM 19945; Jones Co.: NCSM 9204; Lee Co.: NCSM 21620; Moore Co.: NCSM 21013; New Hanover Co.: NCSM 11238–39; Onslow Co.: NCSM 7736, 29416; Pamlico Co.: NCSM 21287; Pender Co.: NCSM 2560, 14165; Pitt Co.: NCSM 5371; Randolph Co.: NCSM 28294; Sampson Co.: NCSM 13762, 25256, 26474; Scotland Co.: NCSM 12226, 16455, 17572, 18974; Stanley Co.: NCSM 8678, 16956; Surry Co.: NCSM 15730; Tyrell Co.: NCSM 11689, 25410; Union Co.: NCSM 9173, 20914, 21084, 23142; Vance Co.: NCSM 15149; Wake Co.: NCSM 2557–58, 23889; Washington Co.: NCSM 11948, 15107; Wayne Co.: NCSM 2581. **New Jersey**, Burlington Co.: AMNH 67651; Cape May Co.: AMNH 111146, USNM 3; Middlesex Co.: AMNH 43889, 49903; Ocean Co.: USNM 55703. **New York**, AMNH 2433; Suffolk Co.: AMNH 16948. **South Carolina**, Aiken Co.: NCSM 8408, 8410, SREL 3223, UGANHM 3278, 4259–60, 4262–63, 4265; Barnwell Co.: UGANHM 4261, 4264, 4266; Oconee Co.: DU R2910. **Virginia**, USNM 23131; Accomack Co.: USNM 166950; Chesapeake Co.: USNM 124856; Fairfax Co.: USNM 59965, 136648, 139630; Halifax Co.: USNM 158588; Hampton Co.: USNM 3165–49; Hanover Co.: USNM 198697; Northampton Co.: USNM 40225–26, 67412–15, 67417, 73256–57, 73259, 207093; Pittsylvania Co.: USNM 144128; Prince George Co.: USNM 139625; Southampton Co.: USNM 245884.

Questionable *Kinosternon.*—**Georgia**, Calhoun Co. (UGANHM 3776); Echols Co. (SSM 11781); Effingham Co. (SSM 8655, 10782, 10785, 11003); Emanuel Co. (SSM 11702); Montgomery Co. (SSM 10506); Tattnall Co. (SSM 11780); Twiggs Co. (UGANHM 3749). **South Carolina**, Charleston Co. (AUM 14131); Clarendon Co. (four individuals maintained alive at SREL); Hampton Co. (SREL 3064, SSM 10558); Horry Co. (AMNH 128571, UMMZ 94175); Sumter Co. (AUM 13800, 18371). **North Carolina**, Bladen Co. (DU R2384); Chowan Co. (NCSM 29332–3); Dare Co. (NCSM 29280–1, 28633); New Hanover Co. (NCSM 12807, 13763); Pender Co. (NCSM 4780); Perquimans Co. (DU R1673, NCSM 29582, 29820); Wake Co. (NCSM 17909). **Virginia**, King and Queen Co. (USNMFS 14009); Surry Co. (USNMFS 17604–5); City of Virginia Beach (CMFS 54347, 54349).

Georgia and South Carolina *K. baurii* identified by Lamb (1983): SREL 2270, 2525, 2527–9, 2531; SSM 5763, 5922, 6039, 8509, 9528; UGANHM 3258–9, 3280, 3285–6, 3706, 3708, 3745, 3786, 3796.

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