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A new species of freshwater crab (Brachyura: Potamoidea: Potamonautidae) from the Ruwenzori region of western Uganda, East Africa

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Abstract.—We report here on a collection of freshwater crabs of the family Potamonautidae Bott, 1970 from Uganda, East Africa, as part of a study on the relationships between freshwater crabs and river blindness (onchocerciasis). The collection comprised more than a hundred specimens belonging to two species of *Potamonautes* MacLeay, 1838, *P. aloysiisabaudiae* Nobili, 1905, and *P. rukwanzi,* new species. The new species described here was collected from an isolated crater lake in the Ruwenzori Mountain region of western Uganda. The species is distinguished by a combination of characters of the carapace, abdomen, sternum, chelipeds, and the first gonopod. Intraspecific comparisons between adults, subadults and juveniles, and between males and females, are also presented. The addition of *P. rukwanzi,* brings to twelve the number of species of freshwater crabs reported from Uganda.

The freshwater crabs reported on here were obtained during a long-term study of onchocerciasis (river blindness) in Uganda carried out by scientists from the Bernhard Nocht Institute for Topical Medicine, Hamburg, Germany. The survey aimed to identify associations between freshwater crabs and the aquatic larval stages of the biting blackflies of the genus *Simulium* Latreille, 1802 that serve as vectors for the parasite *Onchocerca volvulus* Leuckart, 1893. The immature stages of *Simulium* need to develop in fast-flowing rivers and streams, and must attach themselves to supports (e.g., floating vegetation or rocks). An interesting exception are those few species (including those that function as vectors of onchocerciasis in East and Central Africa) that develop in an obligate phoretic association with river crabs in order to complete their development into adult flies (McMahon 1951, Barnley & Prentice 1958, Williams et al. 1964, Warner 1977, Katz et al. 1982).

Control measures for the vectors of onchocerciasis depend (in part) on the understanding of the relationships between *Simulium* larvae and freshwater crabs (McMahon et al. 1958, Rodger 1977, Williams 1991). This close ecological association between the blackfly vectors of onchocerciasis and freshwater crabs in this part of Africa means that researchers need to be able to distinguish between different species of freshwater crabs and to understand the composition of the crab fauna of this region. However, identification of African freshwater crabs has long been problematic (Williams 1991, Cumberlidge 1999) and misidentification of species is common in many studies. Furthermore, the freshwater crab fauna of East and Central Africa is poorly known and it is likely that there are still a large number of species still to be

discovered. This situation further contributes to the confusion that surrounds studies involving the freshwater crabs of this region of Uganda.

The freshwater crabs used were collected in the Ruwenzori Mountain region of western Uganda. Fast-flowing mountain streams, major rivers and a series of small crater lakes associated with the Western Rift Valley characterize the region. The vegetation includes moist tropical forest on the mountain slopes and dry savanna in the lowland areas.

The specimens of the new species from Rukwanzi Crater Lake have a number of important characters that do not conform to the descriptions of any known species (Bott 1955, Cumberlidge 1999). This new species is described from an adult male, and the taxonomically important characters of the gonopods, abdomen, mouthparts, carapace, sternum, and chelipeds are illustrated. This is the 55th species of *Potamonautes* MacLeay, 1838 to be described (Bott 1955, Williams 1991, Cumberlidge 1999).

Materials and Methods

In 1993 a total of 86 crab specimens were collected from Rukwanzi Crater Lake in the Ruwenzori Mountains of western Uganda (0°28′41″N, 30°16′44″E) by one of the authors (RG). Air and water temperature data were collected and the ecological conditions of each locality in the lake were noted. Each freshly collected crab was immediately examined in the field for attached blackfly larvae or pupae, and this information was used by the onchocerciasis research team. Specimens were preserved in formalin in the field and sent to Northern Michigan University (NMU) for identification. Upon arrival at NMU, the specimens where transferred to 70% alcohol and added to the collection. Next, the gender and stage of development of each freshwater crab specimen was noted (whether juvenile, subadult, or adult) and features of the carapace, cheliped, pereiopods, sternum, abdomen, and gonopods of the largest adult male and female specimens were examined and drawn to scale. The terminology used to describe the anatomical features is that proposed by Cumberlidge (1999).

Four dimensions of the carapace were recorded from all available specimens: length, width, height, and front width. Measurements of carapace width (cw), carapace length (cl), carapace height (ch), and front width (fw) were made with digital vernier callipers (Mitutoyo Digimatic Model CD-6″P), and are given correct to at least 0.1 mm. Carapace proportions were calculated according to fw or cl. The ratios of carapace width, carapace length and carapace height to front width (cw/fw, cl/fw and ch/fw) and front width relative to carapace length (fw/cl) were examined using linear regression analysis, and were each found to provide a useful index for making intraspecific and interspecific comparisons. Two-tailed t-tests were used to test for differences between the mean values of carapace proportions between males and females, and between adults and non-adults.

Crabs carrying eggs or hatchlings were assumed to be sexually mature. Sexual maturity in females was otherwise determined by the extent of the development of the female abdomen (which is broad enough to cover the entire sternum and to touch the bases of the coxae of the walking legs in adults) and of the female pleopods (which are noticeably broader and more hair-fringed than those of juvenile and sub-adult females) (Cumberlidge 1999). This permitted the separation of adult females from juveniles and subadults, and allowed an estimate of the molt of puberty for the species. Because male and female freshwater crabs of the same species grow at similar rates and reach a comparable range of body sizes as adults, this measurement also allows an estimate of the stage of development of male crabs of the same species.

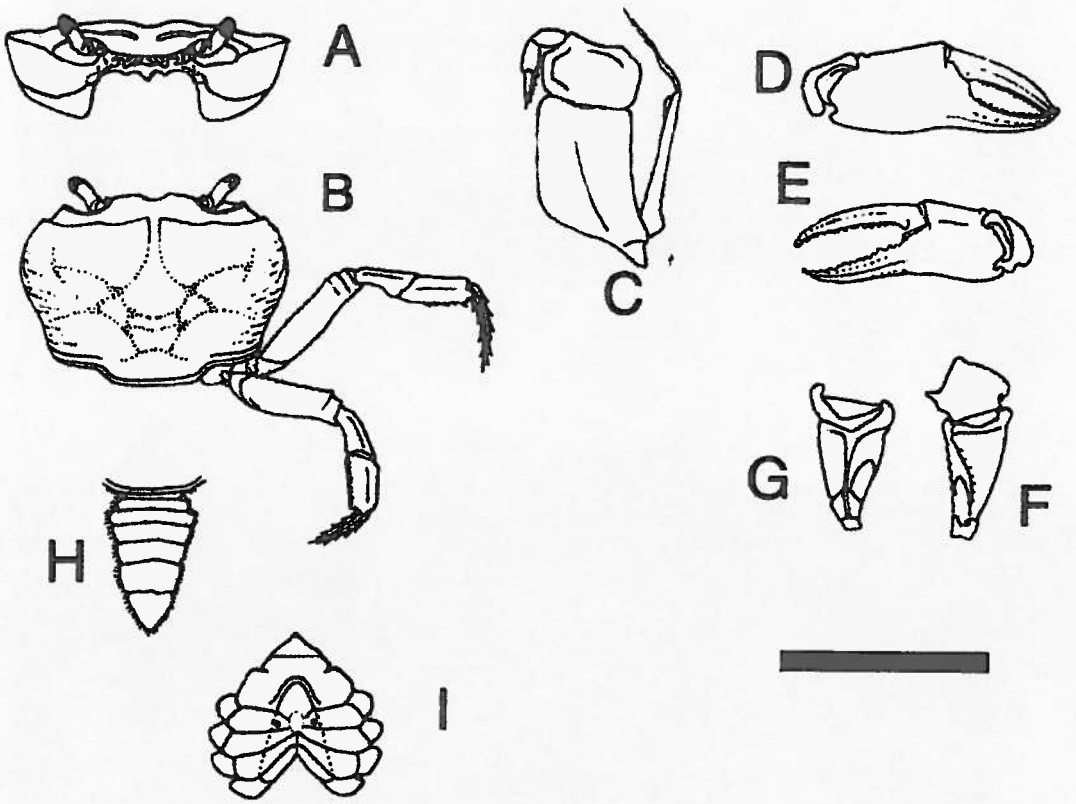

Fig. 1. *Potamonautes rukwanzi,* new species, adult male holotype from Rukwanzi Crater Lake, Uganda (cw 23 mm), NMU. A, cephalothorax, frontal aspect; B, whole animal, dorsal aspect; C, left third maxilliped; D, male right cheliped; E, male left cheliped; F, merus of cheliped, superior view; G, merus of cheliped, ventral view; H, male abdomen; I, male sternum. Scale bar equals 20 mm (a, b, d–i), and 7 mm (c).

Systematic Account

Potamonautes rukwanzi, new species
Figs. 1, 2

Type material and type locality.—Holotype NMU 16.07.1993, adult male, cw 23.0 mm, paratype adult female, Rukwanzi Crater Lake, Uganda (0°28′41″N, 30°16′44″E) 16 Jul 1993. Paratypes: same locality as holotype, 1 female, NMU; 1 female, 4 males, Zoologisches Museum Hamburg, Germany.

Material examined.—Including holotype and paratypes: 46 males cw 28.10–30.80 mm, 41 females cw 28.02–31.67 mm, same locality as types.

Diagnosis.—Vertical suture on carapace sidewall present. Carapace flat (ch/fw = 0.95), dorsal surface texture of carapace smooth, conspicuously sculpted by deep cervical, cardiac, semi-circular, urogastric, transverse branchial grooves. Exorbital tooth small, low, blunt. Epibranchial tooth low, small, not distinguishable from rest of anterolateral margin. Anterolateral margin posterior to epibranchial tooth smooth, distinctly raised, posterior end curving inward slightly in branchial region, not continuous with posterolateral margin.

Description of holotype.—Carapace outline transversely oval, 1.36 times as wide as long, widest on anterior third (cw/fw = 3.15), flattened (ch/fw = 0.95); dorsal surface texture smooth, conspicuously sculpted by deep cervical, cardiac, semi-circular, urogastric, transverse branchial grooves. Front slightly bilobed, relatively wide,

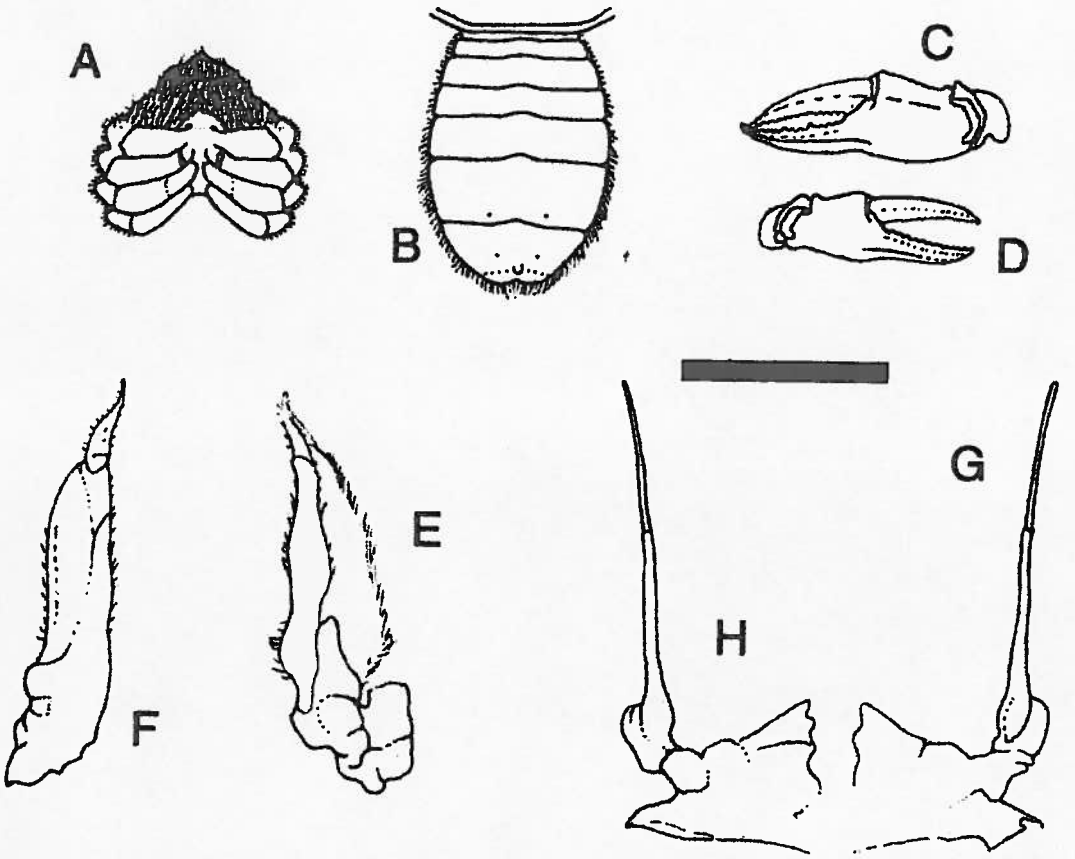

Fig. 2. *Potamonautes rukwanzi,* new species, features of a selected female and reproductive characters of adult male holotype from Rukwanzi Crater Lake, Uganda (cw 23 mm), NMU. A, female sternum; B, female abdomen; C, female left cheliped; D, female right cheliped; E, male right gonopod 1, ventral view; F, male right gonopod 1, dorsal view; G, male right gonopod 2, ventral view; H, male right gonopod 2, dorsal view. Scale bar equals 20 mm (a–d), and 5 mm (e–h).

about one-third cw (fw/cw = 0.31), front moderately deflexed, not meeting inferior margins of antennulular fossae. Postfrontal crest spanning entire carapace, consisting of fused epigastric, postorbital crests, meeting anterolateral margins at epibranchial teeth. Anterolateral margin between exorbital angle and epibranchial tooth lacking intermediate tooth; anterolateral margin posterior to epibranchial tooth smooth, distinctly raised, posterior end curving inward slightly in branchial region, not continuous with posterolateral margin. Exorbital tooth small, low, blunt, epibranchial tooth extremely reduced, not distinguishable from granules on rest of anterolateral margin. Carapace sidewalls completely smooth, each sidewall divided into 2 parts by longitudinal (epimeral) suture, beginning medially at lower margin of orbit, curving backward across sidewall; vertical suture absent.

Mandibular palp 2-segmented; terminal segment single, undivided, with hair but no hardened process at junction between segments. Epistomial tooth triangular, pointed downward, lined by granules. Third maxillipeds filling entire oral field, except for transversely oval efferent respiratory openings at superior lateral corners; long flagellum on exopod of third maxilliped; ischium of third maxilliped smooth, vertical groove

Table 1.—The ratio of carapace width (cw), carapace length (cl), and carapace height (ch) to front width (fw) in male and female *Potamonautes rukwanzi*, new species from Uganda (n.s. = not significant).

Sex	cw/fw Mean ± *SD*	cl/fw Mean ± *SD*	ch/fw Mean ± *SD*
Male	3.17 ± 0.10 (n = 46)	2.36 ± 0.06 (n = 46)	0.95 ± 0.05 (n = 46)
Female	3.14 ± 0.13 (n = 41)	2.37 ± 0.09 (n = 41)	0.94 ± 0.05 (n = 41)
	(p > 0.05, n.s.)	(p > 0.05, n.s.)	(p > 0.05, n.s.)

present. First thoracic sternal sulcus, between sternite one (s1) and sternite two (s2), short; second sulcus (s2/s3) deep, running horizontally across sternum; third sternal sulcus (s3/s4) consisting of 2 short notches at edges of sternum, but continuing as shallow, barely visible, v-shaped groove; anterior margin of sterno-abdominal cavity raised, in advanced position on sternite four (s4), almost meeting s3/s4. All episternal sulci (i.e., s4/e4, s5/e5, s6/e6 and s7/e7) distinct. Fifth sternite (s5) with pair of sternal knobs. Fourth to sixth sternites (s4/s5, s5/s6, s6/s7) within sterno-abdominal cavity discontinuous (i.e., separated medially), seventh sternite (s7/s8) continuous; short median line running perpendicular to s6/s7 and s7/s8. Adult male abdomen segment three (a3) to abdomen segment seven (a7) tapering inward to form long triangle, a3 widest, telson (a7) narrowest. Telson sides straight, triangular, not bell-shaped; abdomen segment six (a6) long, almost as long as width of distal margin of a6. Sternal suture s4/s5 meeting margin of telson close to (but not at) junction between a7/a6; s5/s6 meeting margin of a6 in middle of segment, s6/s7 meeting a5 just short of a5/a6 junction.

Terminal article of gonopod 1 (go1) short (ratio of length of terminal article to subterminal segment 0.30), longitudinal groove on terminal article narrow along entire length, clearly visible on ventral, superior sides, but not visible on dorsal side; lateral, medial folds of ventral side of terminal article equal in height, width; terminal article slim, cone-shaped, almost straight, directed slightly outward; tapering to upcurved tip with clear apical opening. Junction between terminal article and subterminal segment of go1 marked by deep sulcus ventrally and dorsally; go1 with broad dorsal membrane. Gonopod 2 (go2) longer than go1; terminal article of go2 with long flagellum, slightly shorter than subterminal segment (ratio of length of terminal article to subterminal segment 0.70).

Dactylus of right cheliped arched, curving downward, relatively slim (0.33 height of palm); upper margin of dactylus smooth; finger of propodus slim (0.33 height of palm), lower margin of propodus of cheliped slightly indented. Fingers of propodus, dactylus each with row of small, even-sized teeth, closed fingers leaving wide oval interspace. Inner margin of inferior face of merus of pereiopod one (P1) lined by row of small uneven teeth, outer margin lined

Table 2.—The ratio of carapace width (cw), carapace length (cl), and carapace height (ch) to front width (fw) in adult and non-adult (combined juveniles and sub-adults) of *Potamonautes rukwanzi*, new species from Uganda (n.s. = not significant, s. = significant).

Age class	cw/fw Mean ± *SD*	cl/fw Mean ± *SD*	ch/fw Mean ± *SD*
Adult	3.17 ± 0.10 (n = 78)	2.38 ± 0.06 (n = 78)	0.95 ± 0.05 (n = 78)
Non-adult	3.00 ± 0.15 (n = 8)	2.28 ± 0.12 (n = 8)	0.88 ± 0.00 (n = 8)
	(p < 0.05, s.)	(p > 0.05, n.s.)	(p > 0.05, n.s.)

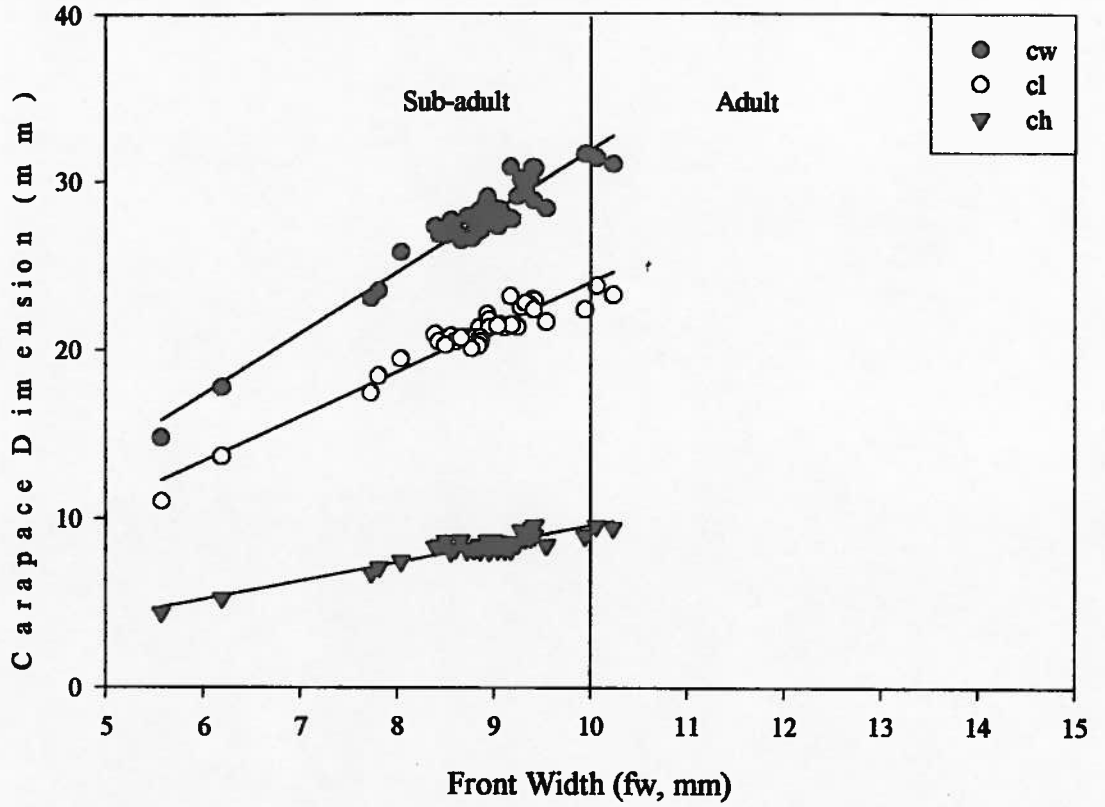

Fig. 3. Comparison of the dimensions of the carapace relative to body size for 40 female specimens of *Potamonautes rukwanzi,* new species. R-values (all at df = 39) indicate very highly significant ($P < 0.001$) correlation between size classes. cw = 3.63 + 4.44, R = 0.97; cl = 2.70–2.827, R = 0.97; ch = 1.10–1.35, R = 0.94. cw = carapace width at the widest point; cl = carapace length, measured along the median line; ch = cephalothorax height, the maximum depth of the cephalothorax; fw = front width, the width of the front measured along the anterior margin; r = correlation coefficient.

by small even teeth; tooth on distal merus small but detectable; superior surface of merus smooth. Inner margin of carpus of P1 with two teeth, second much smaller than first; first carpal tooth broad, triangular, pointed, second carpal tooth low, blunt, with several granules on raised margin behind it. Merus, carpus, propodus, dactylus of pereiopods 2 to 5 (P2 to P5) all shortened: P3 longest, P5 shortest, inner margin of propodus of P5 with broad, raised ridge along length, dactyli of P2-5 tapering to point, each bearing 4 rows of downward-pointing sharp bristles; dactylus of P5 shortest.

Size.—Dimensions of largest available adult male measured in millimeters are: cw 31.12, cl 22.9, ch 9.42, fw 9.60. Mean carapace proportions (n = 86) are: cw/fw = 3.15, cl/fw = 2.39, cw/cl = 1.36, ch/fw = 0.95, fw/cl = 0.42 and fw/cw = 0.31.

Pubertal molt.—A female with hatchlings (cw 22.9 mm) and three other ovigerous females (cws 29.7, 31.0, 36.3 mm) indicate an adult size range of cw from approximately 22 to 37 mm. The largest immature female with a slim abdomen that did not overlap the coxae of walking leg measured cw 17.80 mm. The pubertal molt, from sub-adult to sexually mature adult, was estimated to occur between cw 22 to 25 mm.

Etymology.—The species is named for the Rukwanzi Crater Lake, the only known

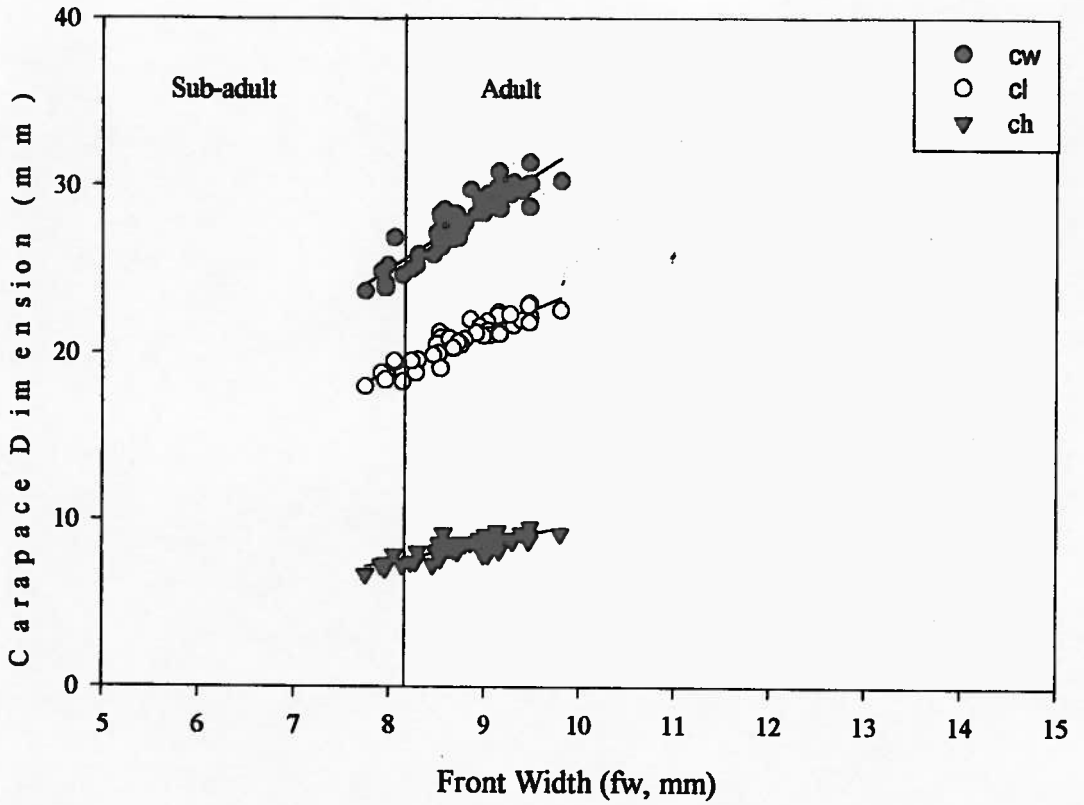

Fig. 4. Comparison of the dimensions of the carapace relative to body size for 46 male specimens of *Potamonautes rukwanzi*, new species. R-values (all at df = 45) indicate very highly significant ($P < 0.001$) correlation between size classes. cw = 3.65 + 4.20, r = 0.91; cl = 2.45–0.76, r = 0.92; ch = 1.14–1.62, r = 0.83. cw = carapace width at the widest point; cl = carapace length, measured along the median line; ch = cephalothorax height, the maximum depth of the cephalothorax; fw = front width, the width of the front measured along the anterior margin; r = correlation coefficient.

locality where it occurs. The specific name *rukwanzi* is a noun in apposition.

Remarks.—The new species is assigned to the family Potamonautidae Bott, 1970 because it conforms with the diagnosis provided by Bott (1955) and Cumberlidge (1999). These characters include a two-segmented mandibular palp, antennules folding horizontally, anterior respiratory openings that are simple holes, and a male abdomen with seven visible segments, where abdominal segment 1 is clearly visible. The new species is assigned here to *Potamonautes* because it has a number of characters that conform to the revised diagnosis of the genus provided by Cumberlidge (1999). These characters include a postfrontal crest that completely crosses the carapace to meet the anterolateral margins at the epibranchial teeth; an anterolateral margin lacking an intermediate tooth between the exorbital angle and the epibranchial tooth; a two-segmented mandibular palp with terminal segment single, undivided, and with hair at junction between segments; a third maxilliped with exopod having a long flagellum; a first gonopod with terminal article short, about one-third as long as the subterminal segment of gonopod 1; and a second gonopod with the terminal article a long flagellum about 0.75 times as long as the subterminal segment of gonopod 2.

Ecology.—Rukwanzi Crater Lake (altitude 1340 m) has a diameter of approxi-

mately 300m. When crabs were caught and abiotic features of Rukwanzi Crater Lake were measured, the lake was warm (mean water surface temperature 25.1°C), highly saline (mean conductivity 393 μS/cm) and highly alkaline (pH 9.5).

Distribution.—Uganda. Known only from Rukwanzi Crater Lake, which is a steep-walled crater lake that was probably formed during the Pleistocene (Beadle 1981).

Comparisons.—Other freshwater crabs found in lakes associated with the East African rift valley include species belonging to two families, the Potamonautidae and the Platythelphusidae Colosi, 1920 (Bott 1955, Cumberlidge 1999). *Potamonautes rukwanzi* is clearly distinguished from any of the six species in the Platythelphusidae by clear differences in the characters of the carapace, mandible, third maxilliped, sternum, gonopods 1 and 2, pereiopods and chelipeds (Cumberlidge 1999). Preliminary cladistic studies (Cumberlidge 1999) indicate that these six species form a monophyletic group that is distinct from the clade that includes members of *Potamonautes* (Potamonautidae).

Potamonautes rukwanzi is most likely to be confused with other small species of freshwater crabs occurring in East Africa because all have a weak postfrontal crest, a distinct vertical sulcus on the ischium of the third maxilliped, and a reduced or absent epibranchial tooth (Cumberlidge 1999). However, all of these taxa can be distinguished from *P. rukwanzi* by examination of the carapace sidewall: they all possess a distinct vertical sulcus in the subhepatic region that divides the sidewalls into three parts, while this vertical sulcus is completely absent in *P. rukwanzi* so that the carapace sidewalls are divided into only two parts.

Morphometric Analysis

In general, the carapace proportions of *P. rukwanzi* are typical of those found in species of lake-living or river-living freshwater crabs in Africa (Cumberlidge 1999). For example, the mean cw/fw ratio in *P. rukwanzi* = 3.15 ± 0.11 (n = 86) falls within the range of species with a carapace of medium width (cw/fw = 3.1–3.5) defined by Cumberlidge (1999). In West Africa, where there are few lakes, a moderately widened carapace is commonly associated with stream-living species (Cumberlidge 1993a, 1993b, 1993c; Cumberlidge 1994a, 1994b). Moreover, the mean ch/fw ratio in *P. rukwanzi* = 0.95 ± 0.05 (n = 86), falls within the range of species with a flat carapace (ch/fw = 0.8–1.0) also identified by Cumberlidge (1999). A flattened carapace is commonly associated with completely aquatic species in West Africa (Cumberlidge 1999). Finally, the mean fw/cl ratio in *P. rukwanzi* = 0.42 ± 0.07 (n = 86) falls within the range of species with a relatively wide front (fw/cl = 0.4–0.5) identified by Cumberlidge (1999). A wide frontal margin is associated with aquatic freshwater crabs and is found in all species of West African *Potamonautes* (fw/cl = 0.46–0.5) (Cumberlidge 1999).

The relative proportions of the carapace of juvenile and subadult males of *P. rukwanzi* differ from adult male crabs in that the carapace of juveniles is significantly more narrow than that of adults (cw/fw = 0.059fw + 2.65, df = 85, R = 0.3, $P < 0.05$). In contrast, the carapace length (cw/fw) and carapace thickness (ch/fw) do not show any real increases as crabs grow. These relationships are described by cl/fw = 0.01fw + 2.26, df = 85, R = 0.104 (indicating no significant correlation, $P > 0.05$) and by ch/fw = 0.02fw + 0.75, df = 85, R = 0.25 (indicating no significant correlation, $P > 0.05$) between size groups. In summary, the carapace of adult male *P. rukwanzi* is relatively wider than that of juvenile crabs, but the carapace length and carapace height are similar in all age groups.

The relative proportions of the carapace of juvenile and subadult female *P. rukwanzi* were not found to differ from adult female

crabs. The relative carapace width (cw/fw), relative carapace length (cl/fw) and relative carapace height (ch/fw) of juveniles were all found to be different from those of adults. These relationships are described by cw/fw = 0.08fw + 2.38, df = 85, R = 0.58 (indicating a significant correlation, $P < 0.001$) between size groups; cl/fw = 0.06fw + 1.861, df = 85, R = 0.55 (indicating a significant correlation, $P > 0.001$) between size groups; ch/fw = 0.03fw + 0.7, df = 85, R = 0.50 (indicating a significant correlation, $P > 0.001$) between size groups. In summary, the carapace of adult female *P. rukwanzi* is significantly wider, longer and higher than that of juvenile females. The finding that the carapace height of female *P. rukwanzi* increases significantly as a crab grows agrees with the assertion by Warner (1977) that the carapace of adult female freshwater crabs become "thicker" (i.e., higher) than those of non-adult females. The positively allometric increase in branchial chamber volume may reflect the increased oxygen demands placed on females by the developing ova.

Comparisons of the mean carapace proportions of male and female crabs, and between adult and non-adult crabs (juveniles and sub-adults grouped together) are shown in Tables 1 and 2. No significant difference ($P > 0.05$) was found between adult male and female *P. rukwanzi* for any of the three carapace proportions (cw/fw, cl/fw, and ch/fw) so morphometric data for adult crabs of both sexes was pooled.

A significant difference ($P < 0.05$) was found between the carapace width (cl/fw) of adult and non-adult crabs indicating positive allometric growth, but no significant difference ($P > 0.05$) was found between the carapace length (cl/fw) or carapace height (ch/fw) of adults and non-adults, indicating isometric growth. This means that valid comparisons of carapace proportions such as length (cl/fw) and height (ch/fw) can be made between crabs of any size and age, but comparisons of carapace width (cw/fw) should be restricted to adult specimens only. Characters for which isometric (relatively equal) growth was found to occur can be used for identification of the species and for interspecific comparisons, because these proportions do not differ between adult, sub-adult and juvenile crabs. For male *P. rukwanzi,* the characters for which isometric growth occurs include cl/fw and ch/fw. Because the growth rate of these characters does not vary between age classes, these two proportions may prove to be useful descriptive morphometric characters for making interspecific comparisons.

The abiotic conditions of Rukwanzi Lake such as water temperature and conductivity were typical of the values recorded from other lakes that make up the chain of late Pleistocene volcanic crater lakes in the Western Rift Valley (Beadle 1981). Further studies of the ecology and distribution of *P. rukwanzi* are warranted because this species may be endemic to this lake, making a determination of its conservation status important. No specimens of *P. rukwanzi* were found to harbour *Simulium* larvae and pupae. This is not surprising because the blackfly vector of onchocerciasis depends on well shaded streams in forest environments and is not adapted to the conditions in an open and stagnate crater lake (Williams 1991).

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