

Scientific Papers

Natural History Museum The University of Kansas

21 December 2015

Number 47:1–9

A new possibly parthenogenic species of *Lynceus* from Canada (Crustacea: Branchiopoda: Laevicaudata), with key to the Nearctic female Laevicaudata

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ABSTRACT A new species of laevicaudatan branchiopod, *Lynceus grandirostris*, is described. This new species is so far known only from a single locality near Yellowknife, Canada, and is morphologically distinguished from all other known *Lynceus* species by the elongated form of the female rostrum, which would appear to preclude copulation. Three collections made over several years have yielded 55 females, but only three males. Males of this species are thus far extremely rare. The large size of the female rostrum coupled with the relative rarity of males suggests that this species may be parthenogenic. A key to the female Laevicaudata of North America is presented.

KEY WORDS: clam shrimp; *Lynceus grandirostris*; ephemeral wetlands; mating systems.

INTRODUCTION

The Lynceidae Baird, 1845, the only family in the branchiopod order Laevicaudata, is a small family of clam shrimp comprising three genera and approximately 41 species worldwide (Martin and Belk, 1988; Pessacq et al., 2011; Timms, 2013). The Laevicaudata are characterized by having a bivalved and hinged carapace that lacks growth lines, male first thoracopods modified into claspers (second thoracopods slightly modified in *Lynceiopsis* Daday, 1912 and *Paralimnetis* Gurney, 1931; see Martin and Belk, 1988), a large head and rostrum, first antennae that are short and club shaped, a reduced number of thoracic somites and limbs (compared to other clam shrimp), and no caudal furcae (hence the name Laevicaudata for the order). Contrary to Tasch (1969), Pennak (1989), Smith (2001) and Dumont and Negrea (2002), the head as well as the body are encompassed by the carapace (Martin et al., 1986; Martin and Belk, 1988). However, the head can be projected outside the carapace and withdrawn again, unlike in the Onychocaudata.

The Laevicaudata as a distinct taxon of clam shrimp was first recognized and named by Linder (1945), later defined in more detail by Fryer (1987), and its classificatory status within the Branchiopoda treated in more detail by various authors (e.g., Olesen, 2007, 2009, Pessacq et al.,

2011, Olesen and Richter, 2013). Most known species are temperate to boreal in distribution, and like the majority of "large branchiopods" (the Anostraca, Notostraca, Laevicaudata, Spinicaudata, and Cyclestherida) they are known almost entirely from seasonally astatic pools. The Lynceidae contains three genera, only two of which, *Lynceus* Müller, 1776 and *Paralimnetis*, occur in North America. *Lynceus* is the most speciose laevicaudatan genus, both in North America and worldwide. Four *Lynceus* species (*L. gracilicornis*, *L. mucronatus*, *L. brevifrons*, and *L. brachyurus* Müller, 1776) are reported from North America (Martin and Belk, 1988).

Between 2000 and 2005, K. A. L. Reading collected 58 specimens of lynceid clam shrimp from a pool near Yellowknife, Canada, and sent them to the first author. The specimens proved to be an undescribed species of *Lynceus*, the fifth known member of the genus from North America, which we describe below.

ACKNOWLEDGMENTS

We wish to express our sincere gratitude to Ken Reading for collecting this new species.

MATERIALS AND METHODS

Live animals were collected from the wild using a dip net. Adult clam shrimp were fixed in 10% formalin solution for several months, transferred to 70% ethyl alcohol, and examined, dissected, and drawn under a stereo dissection microscope. A female and a male specimen were photographed with a Nikon D800 fitted to a dissecting scope with an 'LM Scope' adapter. To increase the depth of focus several photos (about 10) were taken at different focal planes and combined in Zerene Stacker 1.04. One male and several female specimens were prepared for SEM, which involved critical point drying in a graded alcohol series, mounting on stubs, and coating with a mixture of palladium and platinum; the SEM used was a JEOL JSM-6335-F (FE).

The new species was compared to the original descriptions of, as well as preserved material of, all other North American *Lynceus* species from a variety of locations and to selected species of the genus (see below).

COMPARATIVE MATERIALS

DCR refers to catalog numbers of specimens in the collection of D. C. Rogers.

Lynceus bififormis (Ishikawa, 1895)

JAPAN: SHIGA PREFECTURE: Kusatsu – Shi, Kataoka-Cho, rice paddy, 26 May 2004, M. J. Grygier, DCR-611.

Lynceus brachyurus Müller, 1776

CANADA: ONTARIO: King Township, 79° 38' 02" W, 43° 55' 96" N, 22 April 2000, K. A. L. Reading, Det. D. C. Rogers, DCR-364. SAKATCHEWAN: On road from Prince Albert to La Ronge to Yellow Knife, 28 June 1994, K. A. L. Reading, Det. D. C. Rogers, DCR-345. USA: CALIFORNIA: Modoc County: Rail-road bed pool at intersection of rail-road and Clear Lake Road, east of Highway 139, south of Tule Lake City, 27 March 1998, D. C. Rogers, R. E. Hill. Lassen County: Sage flat pool, ~13 km north of Termo, on west side of Highway 395, D. C. Rogers. San Joaquin County: Large vernal pool south of Buena Vista Road, D. C. Rogers, DCR-103. Shasta County: Redding, Shasta Bible College Pond, a winter lake between HWY 44 and Hartnell Avenue, March 1987, D. C. Rogers, DCR-13. MONTANA: Deer Lodge County: Pinter Lake pool, 23 July 1995, D. L. Gustafson, Det. D. C. Rogers, DCR-574. Glacier County: Cut Bank Creek Road, Pond #9, 7 July 1956, R. Brunson. OREGON: Lake County: Squaw Buttes

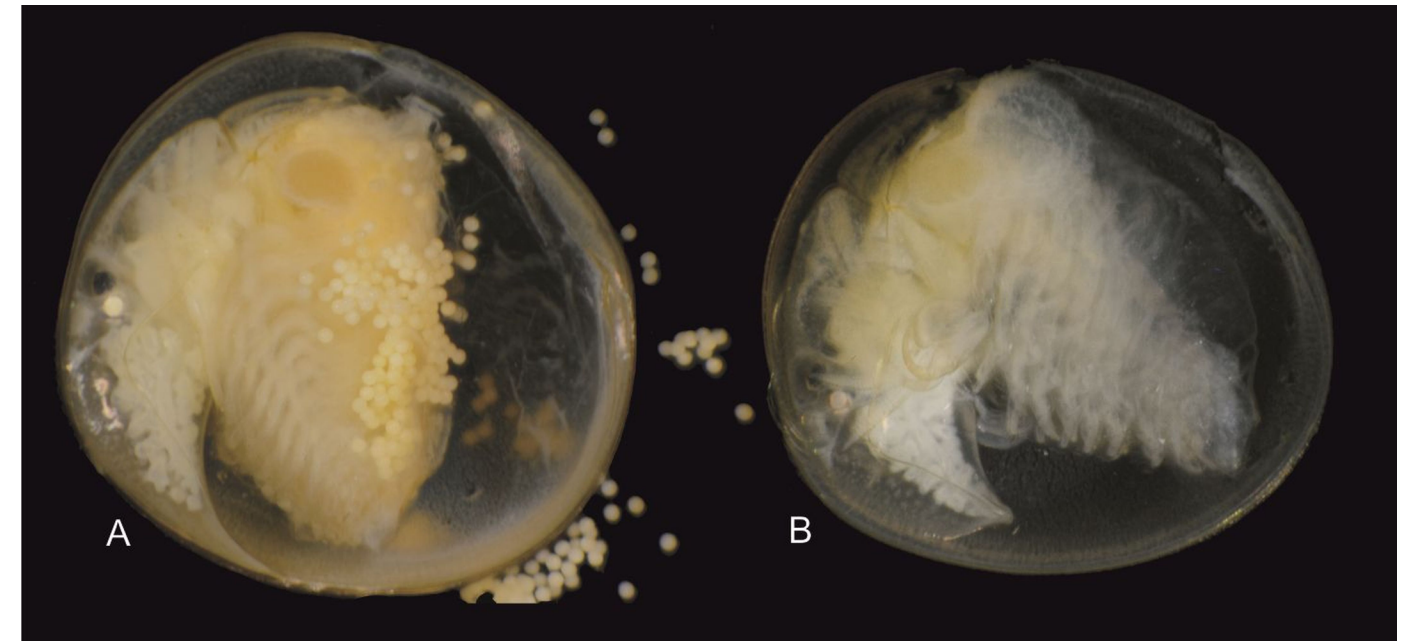


Fig 1. *Lynceus grandirostris*, new species. A. Female, left lateral view. B. Male, left lateral view.

Lake, 24 May 1999, D. C. Rogers, DCR-175. Sycan Marsh, 23 June 2001, W. Fields, Det. D. C. Rogers, DCR-416.

Lynceus brevifrons (Packard, 1877)

USA: NEW MEXICO: Cibola County: 35° 03' 06.70" N, 107° 59' 48.96" W, B. K. Lang, DCR-459. Harding County: Rock Lake Playa, D. Garcia de la Cadena, Det. D. C. Rogers, DCR-618. Hidalgo County: Schoolhouse Tank, Gray Ranch, Animas Valley, 21 September 2000, D. C. Rogers, B. K. Lang, DCR-238.

Lynceus gracilicornis (Packard, 1871)

USA: FLORIDA: Leon County: Leon City, Lake Manson area, past intersection of Road 305 and 303, in

small pool, 28 August 2001, T. Spears, Det. D. C. Rogers, DCR-393. GEORGIA: Baker County: Ichauway Plantation, George Sand Pond, 20 March 2003, J. Jensen, Det. D. C. Rogers, DCR-521. Early County: Shackelford-William's Bluff Preserve (TNC), 21 March 2003, J. Jensen and T. Floyd, Det. D. C. Rogers, DCR-516. Newton County: 2 April 1998, J. Battle, Det. D. C. Rogers, DCR-389. NORTH CAROLINA: Craven County: Cherry Point Marine Air Station, 20 April 1993, A. L. Broswell, Det. D. Belk, DCR-415.

Lynceus mucronatus (Packard, 1875)

USA: MONTANA: Madison County: Hidden Lake pool, 30 June 1990, D. L. Gustafson, Det. D. C. Rogers, DCR-576.

SYSTEMATICS

Branchiopoda Latreille, 1817**Laevicaudata Linder, 1945****Lynceidae Baird, 1845*****Lynceus grandirostris*, new species**

(Figs. 1–4)

Types.—Holotype (female, LACM CR 2000-031.1) and paratypes (females, LACM CR 2000-031.2) in the Natural History Museum of Los Angeles County, Los Angeles, USA. Allotype (male, ZMUC CRU 4780) and paratypes (females, ZMUC CRU 4781 and 4782) in the Natural History Museum of Denmark.

Material examined.—CANADA: NORTHWEST TERRITORIES: 20 km west of Yellowknife, 3 July 2000,

18 females, K. A. L. Reading, Det. D. C. Rogers, DCR-370. Same locality data, 10 August 2002, 22 females, 1 male, K. A. L. Reading, Det. D. C. Rogers, DCR-733. Same locality data, 27 July 2005, 15 females, 2 males, K. A. L. Reading, Det. D. C. Rogers, DCR-734.

Female.—(Figs. 1A, 2A, B, and 3). Length range: 6.0–7.5mm. Head 1.25 to 2 times larger than body. Fornices broad, angulated. Setal fields elongated, closely spaced, subequal in size to compound eye. Dorsal organ narrowly oval, elongate. Rostrum elongate, extending beyond telson, either straight or curving along the interior anterior margin of the carapace. Rostrum 4–5 times longer than greatest rostral width. Rostral carina simple,

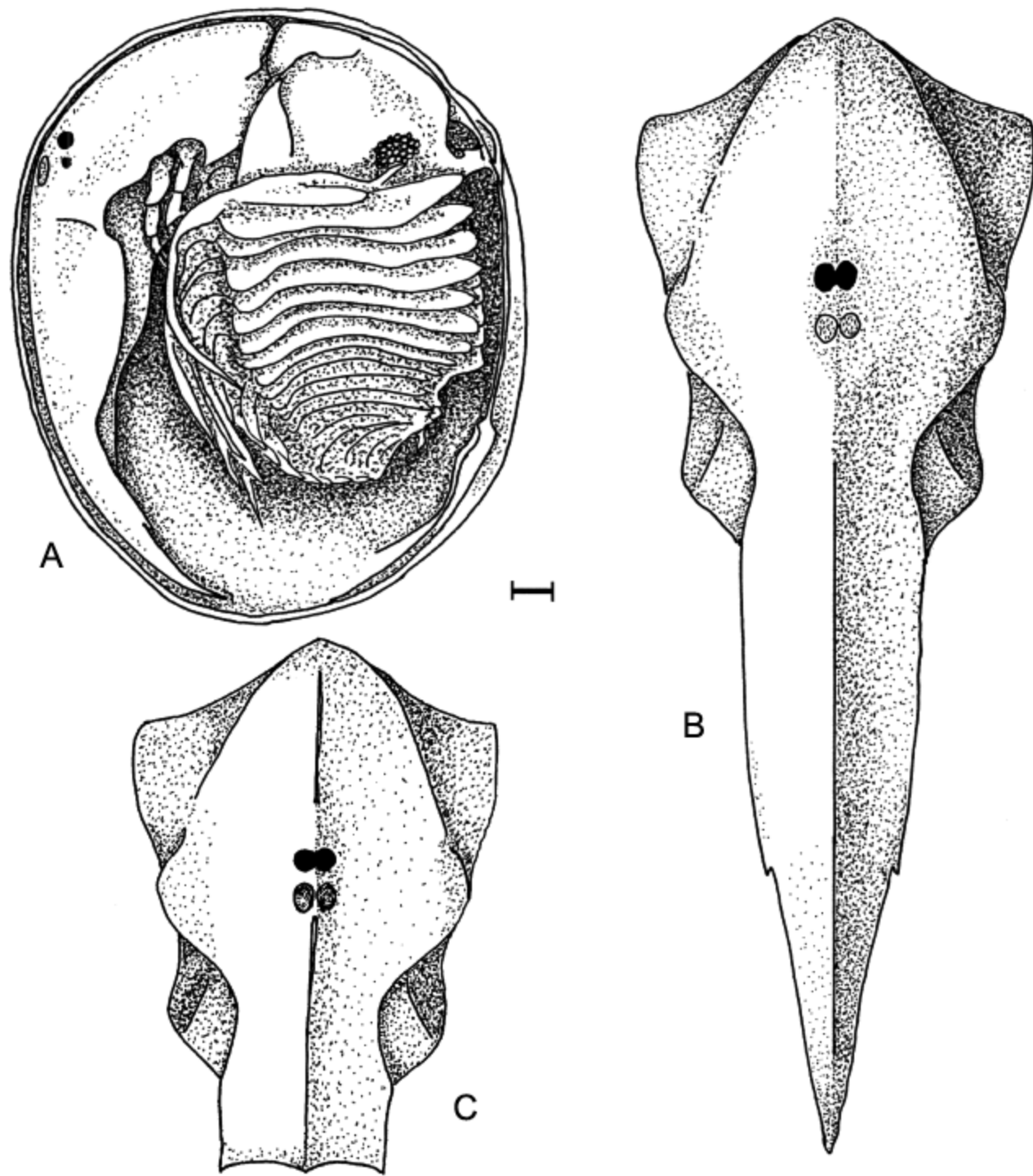


Fig 2. *Lynceus grandirostris*, new species. A. Female, left lateral view. B. Female, head, anterior view. C. Male, head anterior view.

more pronounced posterior to setal fields. Rostrum with posteriolateral margins densely fringed with fine setae, with setal row extending to lateral spine. Rostrum with proximal portion less than half width of head. Rostrum with single, subparallel, short, lateral spine, situated at

approximately three fifths of way along rostrum towards apex. Acumen (rostrum portion distal to lateral spines) gradually tapering to form acute apex.

First antennae with two antennomeres. Proximal antennomere cylindrical, 1.5 times as long as broad.

Distal antennomere cylindrical, 4 times as long as broad, with apex rounded, and bearing numerous short sensory setae (olfactory papillae) (sensu Martin et al., 1986).

Second antenna peduncle with proximal coxa bearing three to nine posteriodistal aciculate setae. Peduncle basis with ring of short, acute setae around base of the endopod and exopod (flagellae). Endopod (anterior flagellum) with 22 flagellomeres, each bearing dorsal, pectinate, natatory seta bearing numerous setulae. Exopod (posterior flagellum) with 16 flagellomeres, with dorsal, pectinate, natatory seta bearing numerous setulae.

Labrum large, well developed, and clothed apically and posteriorly in fine setae. Mandible broadly spatulate, molar surface with 12 to 16 transverse ridges becoming larger in size posteriorly. Posterior most three ridges more broadly spaced than other ridges, with posterior most ridge separated by three times its basal width and prolonged into a spine. First maxilla typical for genus (see Martin et al., 1986; Martin and Belk, 1988). Second maxilla absent.

Carapace globose, subspherical, smooth and without ornamentation, 8–10 mm in length.

Thoracopods, body, and telson typical for females of genus (see Martin and Belk, 1988). Eleven pairs of serially homologous thoracopods.

Endites I–V margined with two rows of setae, each seta angled posteriorly in distal third, and margined on distal and proximal sides with smaller setulae. Setal apicies with dense brush of fine setules. Scraping setae and spines absent. Endites I–III with setae on distal margin. Endites IV and V with marginal setae more robust than on other endites, and limited to dorsal margins. Anterior row of setae shorter than posterior row by one third to one fourth. Endite I broadly triangular. Endite II broad. Distal margins of endites I and II coequal. Endite III elongate and lobiform distally. Endite IV projecting, triangular. Endite V elongate, digitiform, gently curving dorsally. Endopod elongate, digitiform, gently curving dorsally, with stout setae along dorsal margin and apically, similar in form to setae of endite V. Endopod distal margin with scattered, fine, filiform setae. Scraping setae and spines absent.

Lamina abdominalis present, broad, directed anteriorly, and bearing three triangular marginal extensions: one dorsally directed, one anteriorly directed, and one anteroventrally directed (Fig. 2E).

Telson smooth, lacking spines or pilosity. Telsonal setae set in shallow, circular recesses with rugulose surface. Telsonal setae filiform, elongate, longer than the telson, and slightly tumid at base.

Male.—(Figs. 1B, 2C and 4). Length 4.5mm and 6mm. Generally similar to female in appearance. Male rostrum abbreviated, subequal in length to distance between

compound eyes and rostral constriction. Apex of rostrum with lateral corners and medial keel projecting slightly. Intervening margins slightly sulcate. Rostrum with posteriolateral margins fringed with fine, short setae, with setal row extending to rostral apex, and across rostrum anterior margin.

First antennae with an anterior, longitudinal, dense fringe of short, stout setae.

Right and left claspers equal in size and shape, of typical *Lynceus* form. Clasper terminology follows Sigvardt and Olesen (2014) and Kaji et al. (2014). Endite I clasper limb typical for genus, lobiform, and margined with recurved short setae. Endite II margined with stout, close set spines. Endite III broad, oval, and flattened, with lateral margins armed with setae. Medial marginal setae in single row, stout, closely set, and spiniform. Lateral marginal setae in two rows, with inner row short, stout, closely set, and peg shaped. Outer row with stout bases, closely set, tapering to long setaform tips, again closely set. Small palp (endite IV) clavate, widest at midlength, roughly twice as long as broad, apically truncate, with row of stout, closely set, spiniform setae. Large palp (endite V) 10% longer than small palp, subcylindrical, straight in proximal half, distal half arcing posteriorly about 45° from normal. Anterior margin with row of small filiform setae and bearing stout spiniform seta at apical fourth. Apex rounded, with six elongate spiniform setae.

Endopod (movable finger, sometimes termed endite VI) narrow, strongly arcuate in proximal fifty percent, with distal fifty percent slightly decurved, and tapering to subacute apex. Endopod apex extending to just beyond middle of endite III.

Remaining limbs as in female. Telson as in female, although lamina abdominalis is lacking.

Etymology.—The name '*grandirostris*' is in reference to the elongated rostrum that serves to separate the species from others in the genus.

Type locality.—A temporary tundra pool 20 km west of Yellowknife, Canada: 62° 30' 32" N, 114° 48' 25" W, 183 m asl.

Habitat.—Temporary pool in tundra.

Range.—This species is only known from the type locality.

Activity Period.—Observed between June and August.

IUCN Red List status.—This species currently meets the red list definition (IUCN, 2001) as a Critically Endangered Species (CR B2ab). Its known extent of occurrence is estimated to be less than ten square kilometers, and at present it is known to exist only at a single location. Additional surveys need to be conducted to determine and establish the distribution and status of this species.

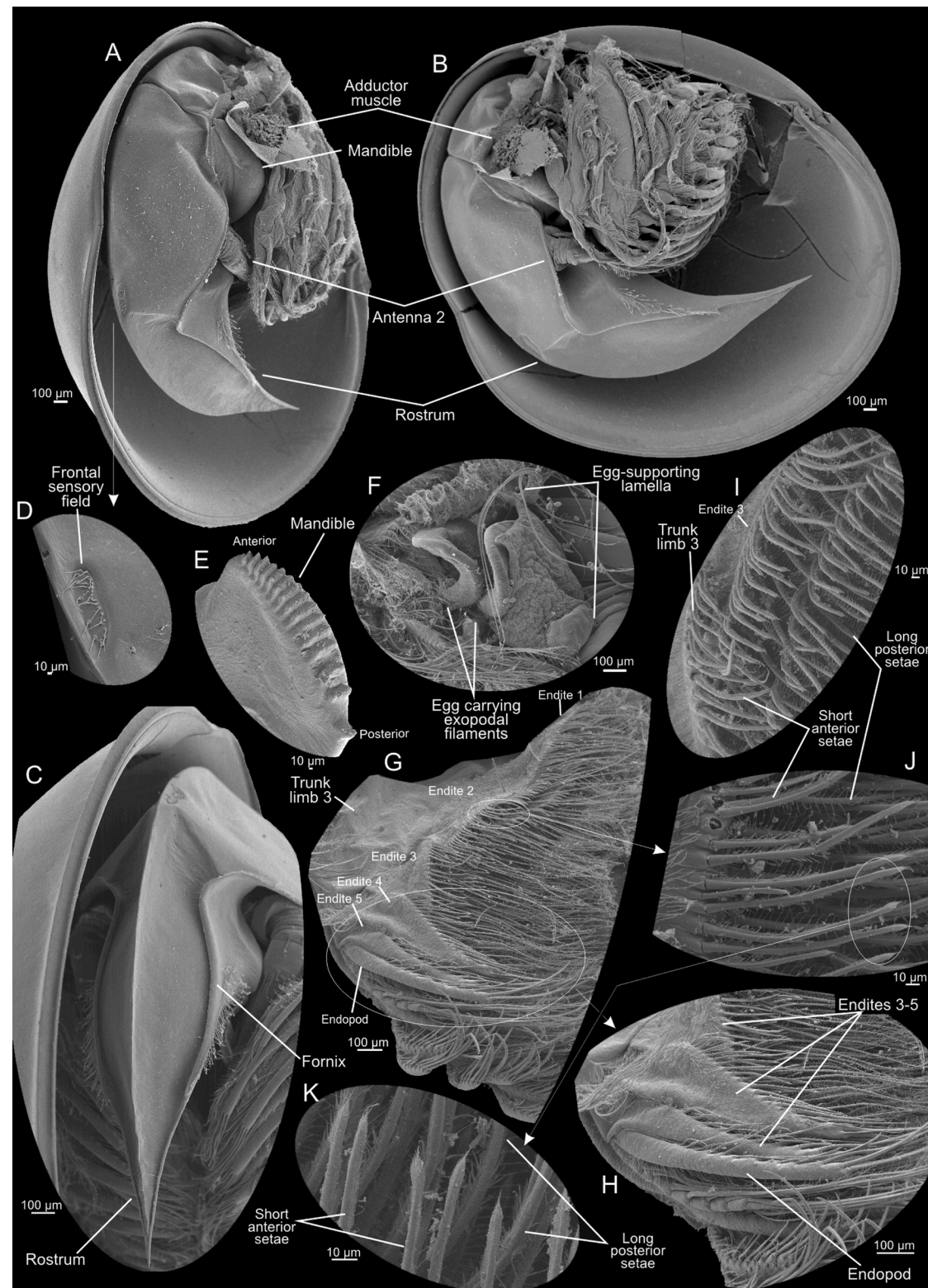


Fig 3. Scanning electron micrographs of female of *Lynceus grandirostris*, new species. All of same specimen. A. Dorsal view with left carapace valve removed. B. Left lateral view. C. Frontal view with left carapace valve removed. D. Frontal sensory field of rostrum. E. Mandible, gnathal edge, right side. F. Egg carrying exopodal filaments and egg-supporting lamella. G. Trunk limb 3, right side, seen from anterior. H. Endites 3-5 and endopod of trunk limb 3. I. Setae of endite 3 of trunk limb 3. J. Detail of anterior and posterior setae of endite 3 of trunk limb 3. K. Greater detail of anterior and posterior setae of endite 3 of trunk limb 3.

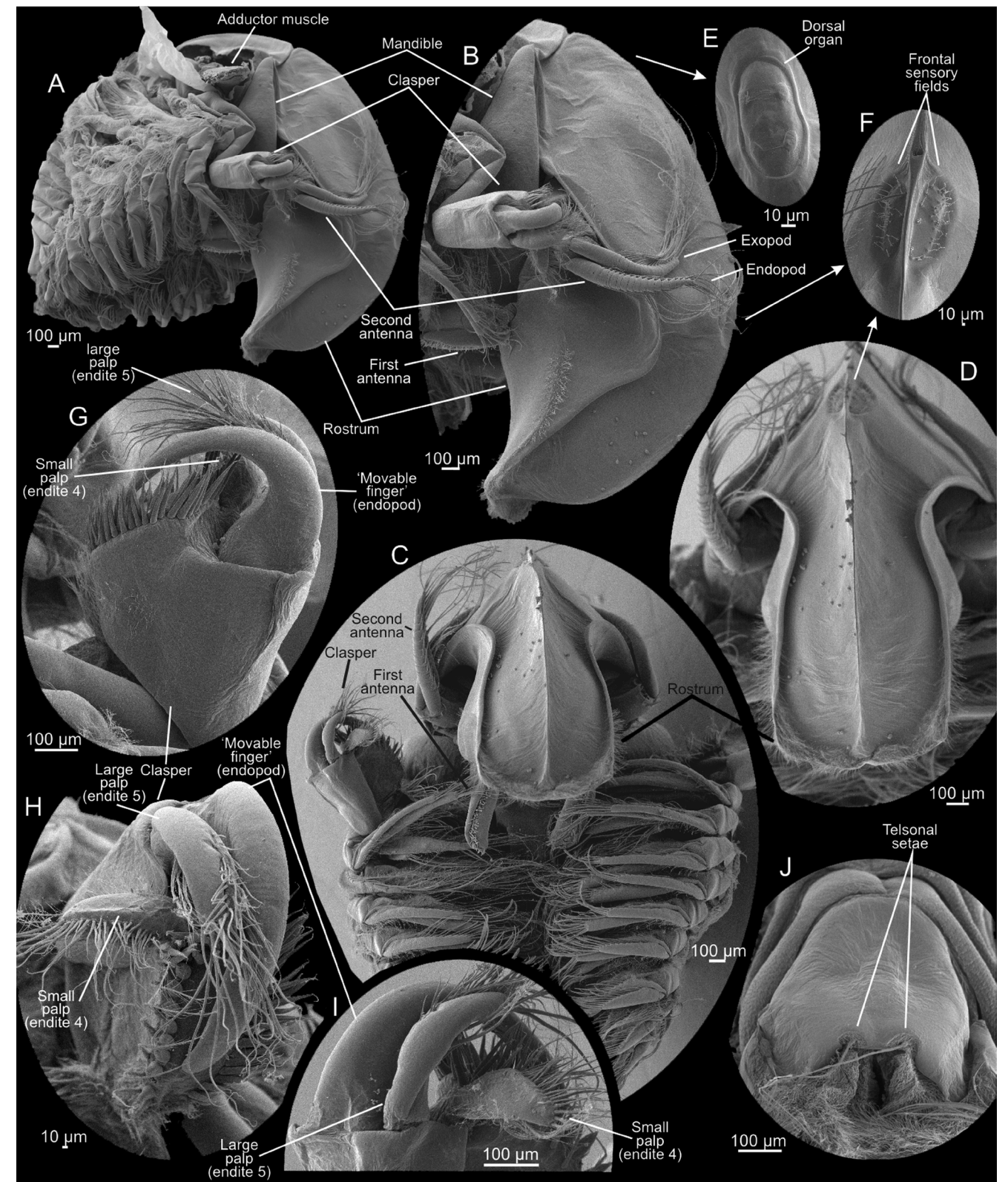


Fig 4. Scanning electron micrographs of male of *Lynceus grandirostris*, new species. All of same specimen. A. Right lateral view, carapace removed. B. Head, right lateral view. C. Ventral view, carapace removed. D. Rostrum, anterior view. E. Dorsal organ. F. Frontal sensory fields. G. Right clasper, lateral view. H. Right clasper, distal view. I. Right clasper, distal portion, medial view. J. Telson, posterior view.

DISCUSSION

Most *Lynceus* species are defined based upon characters of the male first thoracopods, which are modified as claspers to amplex the female prior to mating (Martin and Belk, 1988). Only three males of *L. grandirostris*, new species were collected, and with the elongated rostrum of the female, it is difficult to even envision how mating would be possible. Because of the large number of specimens collected, the fact that males are rare, and the fact that the rostrum would seem to complicate mating (because it blocks access to the entire ventral surface of the female), we speculate that this species is parthenogenetic or at least that the females may be hermaphrodites as has been observed in many spinicaudatan genera (Rogers et al., 2012). If so, this would be the first reported parthenogen or hermaphrodite in the Laevicaudata.

Another possible effect of the elongated rostrum is that the female may be unable to scrape detritus from the substrate. In other species of *Lynceus* it has been shown that the endopod and some of the distal endites bear characteristic and robust setae modified for scraping (Fryer and Boxshall, 2009). Such distinct scraper setae are not present in *L. grandirostris*, new species, where the setae in this position are more soft and slender and therefore probably incapable of scraping as suggested by Fryer and Boxshall (2009) for other *Lynceus*. Therefore it is possible that *L. grandirostris*, new species (at least females) are limited to filter feeding, although mouthparts do not differ appreciably from those of other species of *Lynceus*. The mandibles are large but do not possess corneous transverse ridges as large as in *L. gracilicornis* (figure 4d in Martin et al., 1986).

Male *L. grandirostris*, new species appear to be identical to male *L. brachyurus*, differing only in having a slightly (<5%) shorter large palp (endite V) than North American *L. brachyurus* populations and a more clavate large palp than Eurasian *L. brachyurus*. These differences are very minor and may be of no consequence. Male *L. grandirostris*, new species are separated from all other New World *Lynceus* species by the form of the claspers, which have a narrow large palp, and the small palp (endite IV) broadly expanded medially, twice as long as broad. *Lynceus gracilicornis* also has the small palp expanded distally on the right clasper, but it is roughly as long as broad and the small palp is extremely broad (see figure 8d in Martin and Belk, 1988). *Lynceus gracilicornis* claspers are asymmetrical, as opposed to *L. grandirostris*, new species which are symmetrical.

Lynceus grandirostris, new species females are distinguished from all other described females of species of *Lynceus* by the elongated rostrum, which extends one fourth to one third of the length around the carapace. The

female *L. grandirostris*, new species is most similar to *L. brachyurus*. Females of the two species are easily separated by the length of the rostrum and the form of the rostral acumen. In *L. brachyurus* the acumen is subequal in length to the width of the rostrum at the lateral spines (see Sigvardt and Olesen, 2014, figure 1G; Martin and Belk, 1988, figures 4C and 6B), whereas in *L. grandirostris*, new species the acumen is two to three times as long as the rostral width at the lateral spines. Both species share the form of the second antennae.

The first antennae and labrum of *L. grandirostris*, new species are similar in form to the same structures in *L. mucronatus* (figure 7a in Martin and Belk, 1988).

It is interesting that the females would be so remarkably different from all other species, but the males are not. Typically, in other branchiopods where there are separate sexes, it is the males that are morphologically unique, and the females are much more uniform (Rogers, 2002). Typically this means that the females are selecting the mates (Rogers, 2002). The only other instance among the so called "large branchiopods" where the females are different and the males are nearly identical is in certain species of *Parartemia*, where the males of a few species are difficult to tell apart, but the females are radically different (*Parartemia informis* Linder, 1941, *P. serventyi* Linder, 1941, and *P. contracta* Linder, 1941). In these instances, the similar species are separated ecologically, and would never occur in the same habitats (Timms, 2004, 2012).

KEY TO FEMALE NEARCTIC LYNCEIDAE

Martin and Belk (1988) provided a key to the known species of Laevicaudata occurring in the Americas based upon male characters. Male *L. grandirostris* n. sp. would key out to *L. brachyurus* in that key. We provide a key here for the female species of Laevicaudata known from North America. Female Laevicaudata are easily separated from the males in that they have unmodified first thoracopods.

- 1 Rostral carina not bifurcate anteriorly 2
- 1' Rostral carina bifurcate anteriorly 6
- 2 Rostral lateral margin with distally directed spine, apex acute 3
- 2' Rostral lateral margin without spine, apex rounded *Lynceus gracilicornis* (Packard, 1971)
- 3 Acumen (rostrum beyond the lateral spines) margin straight or concave 4
- 3' Acumen margin convex *Lynceus mucronatus* (Packard, 1975)

- 4 Acumen margin straight 5
- 4' Acumen margin concave *Lynceus brachyurus* Müller, 1776
- 5 Rostrum length subequal to 1.5 times longer than greatest rostral width *Lynceus brevifrons* (Packard, 1877)
- 5' Rostrum length three times longer than greatest rostral width *Lynceus grandirostris*, new species
- 6 Distal branches of rostral carina as long as unbranched portion of carina; apex of rostrum slightly emarginate *Paralimnetis texana* Martin and Belk, 1988
- 6' Distal branches of rostral carina shorter than unbranched portion of carina; apex of rostrum slightly truncate *Paralimnetis mapimi* Maeda-Martinez, 1987

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