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Illustration of type material of Cretaceous *Linuparus* spp. (Decapoda: Achelata: Palinuridae) from British Columbia, Canada, and reevaluation of American occurrences of *Linuparus*

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Abstract

The type material of *Linuparus canadensis* (Whiteaves, 1885a) and *Linuparus vancouverensis* (Whiteaves, 1895) from British Columbia, Canada, are re-illustrated. Key features not originally mentioned are indicated. Many eastern North American occurrences previously referred to *L. canadensis* should be placed within *L. keyesi* Kornecki et al., 2017. Thus, the geographic range of *L. canadensis* is modified and restricted to Western and Central North America.

Key words: Palinuridae, holotype, Cretaceous, North America, lobster

1. Introduction

The genus *Linuparus* White, 1847, is among the long ranging, speciose genera in the Decapoda, first appearing in the Early Cretaceous (Lower Greensand – Aptian/Albian [Woods, 1925]) in England and ranging into the Holocene in the Indo-Pacific. To date, thirty-six extinct species have been named (Schweitzer et al., 2010; Feldmann et al., 2021), of which fourteen are known from North America. Of these, *Linuparus canadensis* (Whiteaves, 1885a) and *Linuparus vancouverensis* (Whiteaves, 1895) from Alberta and British Columbia, Canada, respectively, were the first to be described. For this reason as well as because both were represented by well-preserved and relatively complete specimens, the two species have become common standard comparative taxa for many subsequently named extinct species described in Canada and the United States. However, to our knowledge, the type specimens have been illustrated photographically only once (Feldmann and McPherson, 1980, plate 4). Although those illustration were sharply in focus, they are overexposed and relatively low contrast either as a result of the original photographic preparation or the printing process. Thus, we re-examined and photographed the type specimens in order to make comparisons with recently named species more precise. Additionally, the current re-examination of the specimens permits focusing on morphological details not discussed previously.

2. Materials and Methods

Specimens of *Linuparus canadensis* and *Linuparus vancouverensis* are deposited in the Geological Survey of Canada, Eastern Paleontology collection. Specimens of *Linuparus canadensis* (Whiteaves, 1885a) include the holotype, GSC 5057, and hypotype, GSC 61413. *Linuparus vancouverensis* (Whiteaves, 1895) is represented by

the holotype, GSC 5964, part and counterpart, and the holotype of *Hoploparia bennetti* Woodward, 1900, part and counterpart, now recognized as a junior synonym of *L. vancouverensis*.

The specimens were coated with ammonium chloride and photographed with a Nikon D7200 with AF Nikkor 28–105 lens. Brightness and contrast were adjusted using Adobe Photoshop CC2018.

Abbreviations: GAB, Gale A. Bishop Collection, probably now deposited in the South Dakota School of Mines and Technology, Rapid City, South Dakota, USA; GSC, Geological Survey of Canada, Eastern Paleontology Division, Ottawa, Ontario, Canada; ZRC, Zoological Reference Collection, Department of Zoology, National University of Singapore.

3. Systematic palaeontology

Order Decapoda Latreille, 1802
Infraorder Achelata Scholtz and Richter, 1995
Superfamily Palinuroidea Latreille, 1802
Family Palinuridae Latreille, 1802

Genus *Linuparus* White, 1847

Type species: *Palinurus trigonus* von Siebold, 1824, by original designation.

Included species: as in Feldmann et al. (2021).

Diagnosis: as in Schweitzer et al. (2015).

Linuparus canadensis (Whiteaves, 1885a)

(Figs. 1, 2)

Hoploparia (?) *canadensis* Whiteaves, 1885a, p. 237; Whiteaves, 1885b, p. 87, pl. 11.

Podocrates canadensis (Whiteaves); Whiteaves, 1895, p. 132.

Linuparus atavus Ortmann, 1897, p. 239, figs. 1–4; Woodward, 1900, p. 396.

Linuparus (*Podocrates*) *canadensis* (Whiteaves); Woodward, 1900, p. 396, pl. 16, fig. 1.

Linuparus canadensis (Whiteaves); Whiteaves, 1903, p. 325, pl. 41, fig. 1; Rathbun, 1935, p. 36; Feldmann and McPherson, 1980, p. 12, pl. 4, figs. 1, 3, 5, pl. 5, figs. 4, 9, 10; Bishop and Williams, 1986, figs. 4, 8D, 9B, C; Cope et al., 2005, fig. 6.1.

Podocratus canadensis (Whiteaves); Rathbun, 1926a, p. 134, pl. 35, fig. 2, pl. 36; Rathbun, 1926b, p. 185, p. 63, figs. 12, 16.

Linuparus (*Thenops*) *canadensis* (Whiteaves); Mertin, 1941, p. 215; Schweitzer et al., 2003, p. 16, fig. 8.1.

Remarks: *Linuparus canadensis* is a large, robust, and coarsely ornamented species (Fig. 1) that has been recognized in the Upper Midwest, Gulf Coastal Plain, and the Atlantic Coastal Plain of North America subsequent to its naming from specimens from Bow River, Alberta, Canada. The present re-examination of the holotype suggests that several records of the species do not exhibit key characters that are diagnostic of the species. Their disposition is discussed below.

The axial ridge on the cephalic region bears a small number of coarse nodes anteriorly and bifurcates into coarsely nodose ridges as it approaches the deep cervical groove forming a chevron-shaped pattern. The overall field of the cephalic region is relatively smooth. The thoracic region bears a strong, coarsely nodose axial ridge broadening posteriorly and terminating posteriorly as a triangular structure. The lateral ridges are, by contrast, narrow, well defined, and carrying closely spaced small nodes. The dorsal surface between the ridges is coarsely granular. This plexus of features may be taken as diagnostic of *Linuparus canadensis.*

Several other morphological features are present on the holotype (Fig. 2) that have not been illustrated or discussed previously. One of the hallmarks of *Linuparus* spp. is the presence of stridulating structures. Careful examination of the frontal region (Fig. 2.3) and the lateral margin of the thoracic region (Fig. 2.4) provide evidence of stridulating structures in both areas. The axial margin of the antennal base on the left side of the animal exhibits a swollen region (Fig. 2.3) analogous to that seen on extant *Linuparus somniosus* Berry and George, 1972, ZRC 1999.0001, although the rugose surface responsible for producing the sound when contacting the counterpart on the right antennal base is not visible. The anterior-most flank of the thoracic region is inflated to serve as a roughened surface producing a sound when contacted by the merus of the second pereiopod as in *L. somniosus* (Fig. 2.4). This feature was first noticed in fossil *Linuparus* by Secretan (1964, p. 123) and was named the *appreil stridulant*.

Fig. 1. ***Linuparus canadensis*** **(Whiteaves, 1885a)**. ***1–2***, GSC 5057, holotype, dorsal (*1*) and ventral (*2*) surfaces; ***3***, GSC 61413, hypotype, posterior dorsal surface. Scale bars = 1 cm.

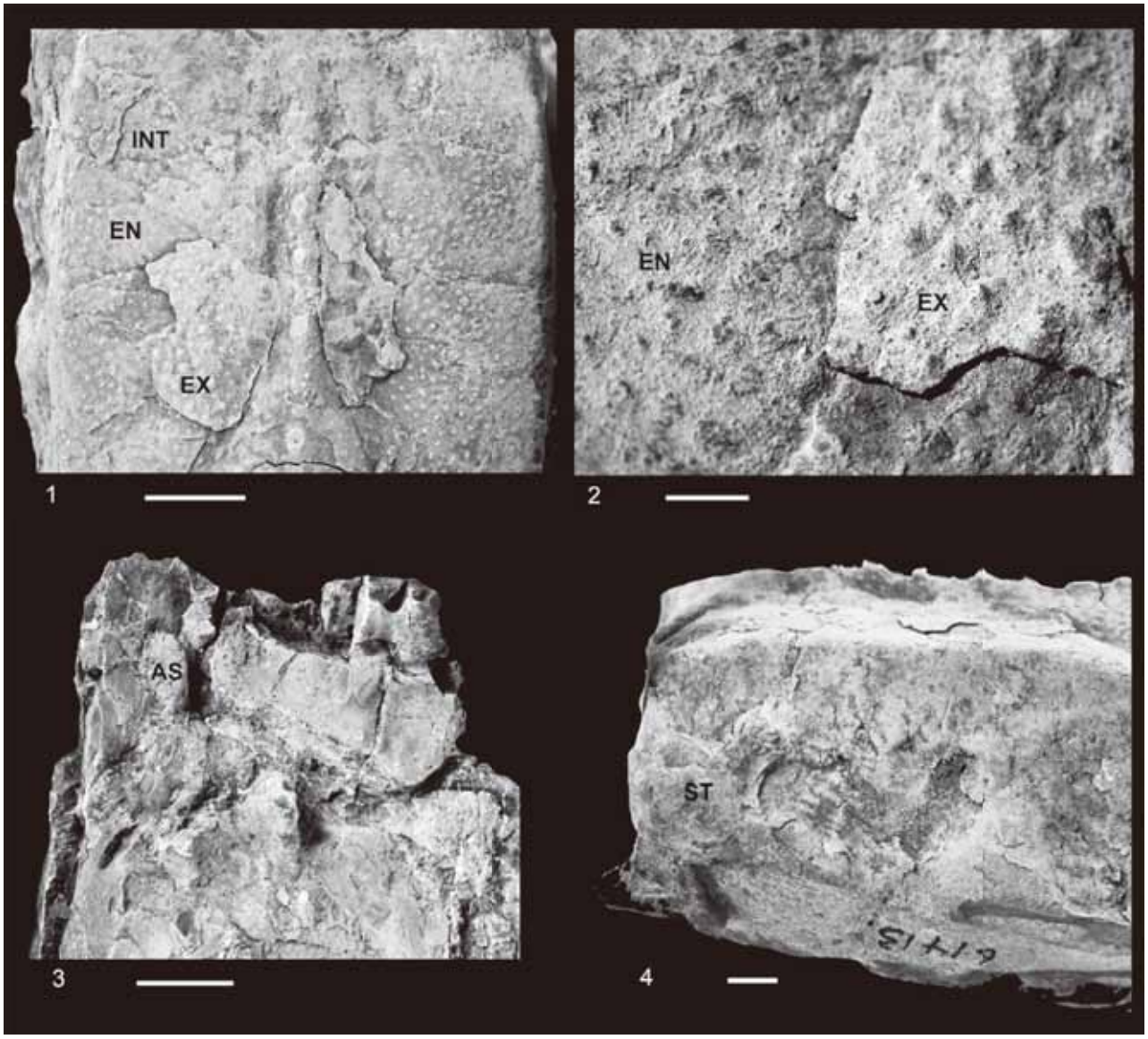

Fig. 2. *Linuparus canadensis* (Whiteaves, 1885a). ***1***, ***2***, GSC 61413, hypotype, dorsal surface, mold of the interior of the cuticle (INT), surface if endocuticle (EN), and surface of exocuticle (EX) (*1*, *2*). ***3***, GSC 5057, holotype, anterior view with antennal stridulating structure (AS). ***4***, GSC 61413, hypotype, left lateral view of stridulating structure (ST). Scale bars 1, 3 = 1 cm; scale bar 2 = 2 mm; scale bar 4 = 5 mm.

The cuticle on the thoracic section of the holotype of *Linuparus canadensis* has exfoliated to the extent that it is possible to differentiate the surfaces of the mold of the interior of the cuticle, the surface of the endocuticle, and the surface of the exocuticle (Figs. 2.1, 2.2). It is important to recognize the specific surface when describing ornamentation. The cuticle of the holotype is developed with a nodose structure which is reflected as a finely granular mold of the interior surface, a nodose surface on the endocuticle, and a more coarsely nodose surface on the exocuticle.

Linuparus keyesi Kornecki, Feldmann, and Schweitzer, 2017 (p. 285, fig. 7A–G) was recently named based upon several key differences between specimens from the southeastern United States and *L. canadensis* from Alberta, Canada, and the upper Midwestern USA. Thus, references to *L. canadensis* (in: Bishop, 1981, fig. 1D; Bishop, 1983, fig. A; Bishop, 1991, p. 8–17; Cope et al., 2005, fig. 6.1; Bishop 2016, pl. 2, figs. 9, 10) from Illinois, Mississippi, and Tennessee, USA, are better assigned to *L. keyesi*. All of the specimens in these references possess a narrow axial ridge that does not

widen posteriorly, a smooth to finely granular surface, and all one of the specimens have finely nodose lateral keels. Specimen GAB 37-1141 (Bishop, 1983, fig. 3) has larger nodes than typical of *L. keyesi* on the lateral keels.

***Linuparus vancouverensis* (Whiteaves, 1895)**

(Fig. 3)

Podocrates vancouverensis Whiteaves, 1895, p. 132.

Podocratus vancouverensis Whiteaves, 1895; Rathbun, 1926a, p. 135, pl. 37, figs. 1–3.

Linuparus (Podocrates) vancouverensis (Whiteaves); Woodward, 1900, p. 394, pl. 15, figs. 1–3.

Hoploparia bennetti Woodward, 1900, p. 433; Whiteaves, 1903, p. 320; Rathbun, 1926a, p. 129; Feldmann and McPherson, 1980, p. 14, pl. 4, fig. 2.

Linuparus vancouverensis (Whiteaves); Whiteaves, 1903, p. 323, pl. 40, figs. 1–3; Feldmann and McPherson, 1980, p. 14, pl. 4, figs. 2, 4, 6, 7, pl. 5, figs. 5, 8.

Linuparus (Eolinuparus) vancouverensis (Whiteaves, 1895); Mertin, 1941, p. 215; Schweitzer et al., 2003, figs. 8.2, 3.

Remarks: *Linuparus vancouverensis* is a more gracile species that is readily distinguished from *L. canadensis*. The cephalic region is finely granular with narrow lateral carinae and an axial ridge bifurcating posteriorly into an oblanceolate structure terminating at the weakly convex-forward cervical groove. The cephalic carinae as well as those on the thoracic region are less pronounced than those on *L. canadensis* and are granular rather than nodose. The thoracic axial ridge is narrow throughout and does not widen posteriorly.

4. Discussion

Re-examination and re-illustration of the type material of the first named species of *Linuparus* from North America establishes landmarks against which subsequently studied specimens within the genus can be tested. This work is intended to provide key morphological features that can anchor the identifications of other specimens assigned to the genus. This strictly typological approach is essential in recognition of species-level taxa, and it serves as a starting point for considerations of intraspecific range of morphological variation, recognition of dimorphic or polymorphic conditions, and definition of congeneric species. *Linuparus canadensis* is restricted to the Pacific coast and upper Midwest of North America, and Atlantic and Gulf Coastal plain occurrences in North America should be referred to *L. keyesi*.

Attempts have been made previously to subdivide *Linuparus* into subgenera (e.g. Mertin, 1941); however, advances in phylogenetic analyses have made it possible to analyze relationships in a less subjective manner. Thus, a multivariate analysis of defined species should be undertaken to re-evaluate species groupings with the goal of testing the subgeneric alignment within *Linuparus* as currently understood and assure that species groupings are monophyletic. That project is beyond the scope of this contribution.

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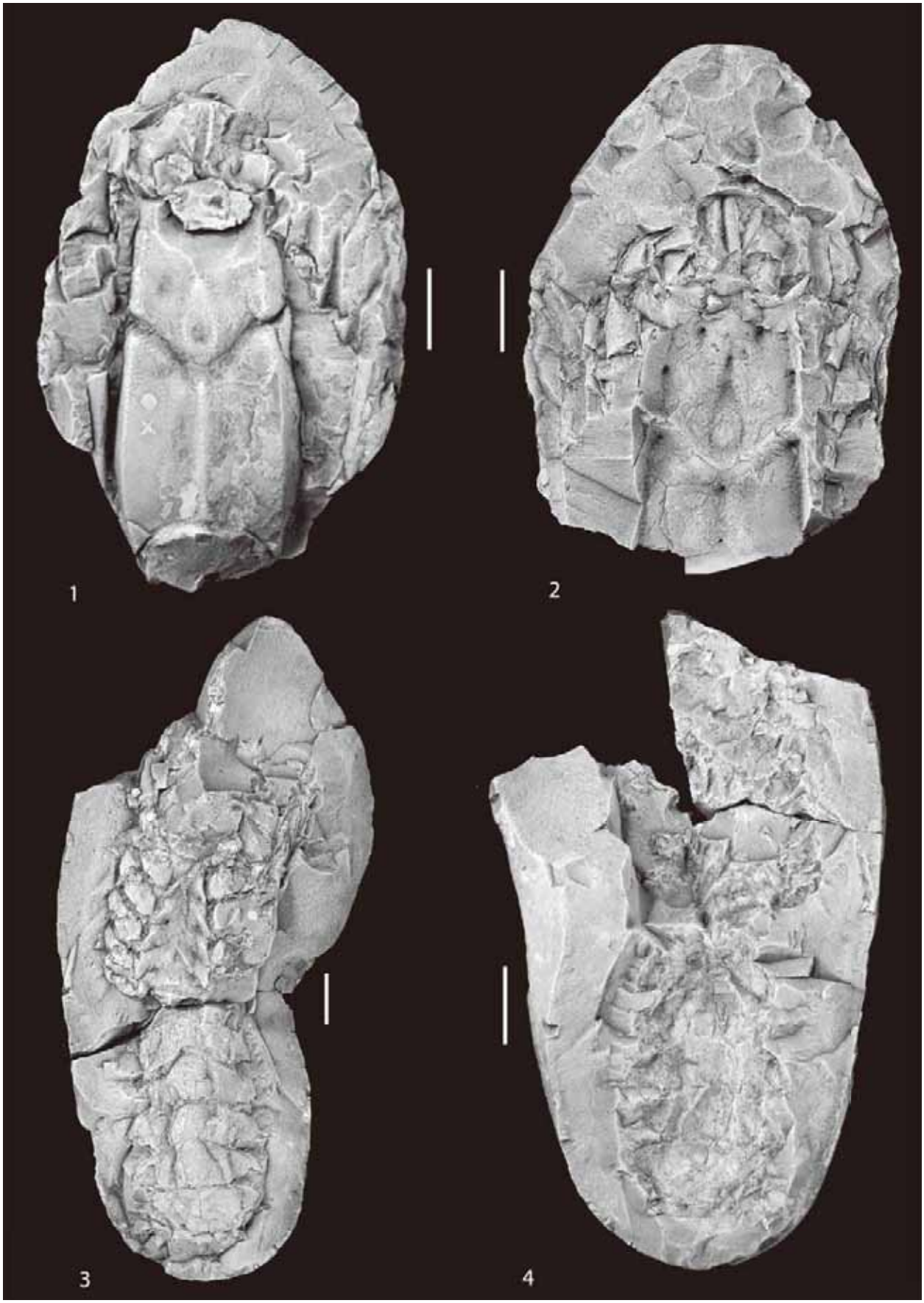

Fig. 3. ***Linuparus vancouverensis*** **(Whiteaves, 1895)**. ***1***, GSC 5964, holotype, dorsal surface on part. ***2***, GSC 5964a, holotype, counterpart. ***3***, GSC 5972, part, holotype of *Hoploparia bennetti* now referred to *L. vancouverensis*, ventral view of sternum and dorsal view of pleonites. ***4***, GSC 5972a, counterpart, holotype of *Hoploparia bennetti* now referred to *L. vancouverensis*, ventral view of sternum and dorsal view of pleonites. Scale bars = 1 cm.

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