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# Redescription of *Cathaica pyrrhozona montana* (Möllendorff, 1875) and description of *C. zoui* Wu, n. sp., from eastern China (Eupulmonata: Camaenidae)

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**Abstract.** Two species of *Cathaica* Möllendorff, 1884 are described from eastern China, *C. pyrrhozona montana* (Möllendorff, 1875) from Beijing and a new species, *C. zoui* Wu, n. sp., from Jinan, Shandong Province. The new species is conchologically similar to *Cathaica fasciola* (Draparnaud, 1801). The new species and *C. p. montana*, a subspecies of *C. pyrrhozona* (Philippi, 1845), the type species of *Cathaica*, share a similar structure of the dart-sac apparatus, in having one proximal accessory sac on the right side of dart sac, both mucous glands and the proximal accessory sac entering the dart-sac chamber. However, the distance between the dart-sac septum and the entrance of the mucous glands is distinctly shorter in the new species than that in *C. p. montana*. The genital anatomy of these two taxa suggests that the structure of the inside of the dart-sac apparatus deserves special attention of understanding systematics of the bradybaenine snails. In addition, the presence of dense cilia on the septum of the dart sac in the new species is newly reported for the subfamily Bradybaeninae.

**Key words.** Bradybaeninae, new species, dart-sac apparatus

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## Introduction

*Cathaica* Möllendorff, 1884 was established based on shell morphology. Andreae (1900) refined the species from Möllendorff's inventory (1884) and assigned them to *Eucathaica* [=*Cathaica* (*Cathaica*), type species *Helix pyrrhozona* Philippi, 1845], *Pliocathaica* [type species *Helix pulveratrix* E. von Martens, 1879], *Xerocathaica* [type species *Helix kreitneri* Hilber, 1882, not *Cathaica nanschanensis* (Möllendorff, 1899) in Richardson 1983], *Campylocathaica* [type species *Helix przewalskii* E. von Martens, 1882], and *Pseudiberus* Ancey, 1887 [type species *Helix tectumsinense* E. von Martens, 1873] as well. This system was followed, or partially followed, by many authors (e.g. Thiele 1931; Richardson 1983; Schileyko 2004). However, in relying solely on shell morphology, some unrelated species are included in this concept of *Cathaica*. *Bradybaena brevispira* (H. Adams, 1870) is an example of one such species, which was included by Möllendorff (1884), Pilsbry (1893 in 1892–1893, 1894 in 1894–1895), and Gude (1902a) in *Cathaica*.

*Cathaica* is among the most diverse genus of the family Camaenidae, subfamily Bradybaeninae (Richardson 1983). However, our current knowledge of *Cathaica*, which is crucial for establishing a more natural classification, remains very insufficient. The assignment of *Cathaica* species into subgenera, which was challenged by some recent work (Wu *et al.* 2023; Zhang and Wade 2023), requires more support from both anatomical and molecular evidence. In this work, we describe two *Cathaica* species each of which has a proximal accessory sac on the right side of dart sac, including one that is new to science, with a particular focus on the internal structure of dart sac apparatus that is believed to be important for defining *Cathaica*.

## Materials and methods

The specimens were relaxed by drowning in water before being transferred to 70% ethanol for fixation, which was replaced with ethanol of the same concentration after three days. The shell and genitalia were measured using digital

vernier callipers (genitalia from a photograph) to the nearest 0.1 mm. The number of whorls was recorded following the method described by Kerney and Cameron (1979) with ⅛ whorl accuracy. Genitalia was measured after the specimens were sufficiently fixed in 70% ethanol. The dart sac was opened to observe the internal morphology, and the proximal accessory sac was opened apically to observe the opening leading to the dart sac and other internal structures. Directions used in descriptions of genitalia: proximal, towards the genital atrium; distal, away from the genital atrium; left and right side of dart sac (see Wu *et al.* 2023: fig. 1A).

Abbreviations: a.s.l., above sea level; At, atrium; BC, bursa copulatrix; BCD, bursa copulatrix duct; NHMUK, materials in collections of The Natural History Museum, London, United Kingdom; DS, dart sac; DSC, dart sac chamber, the internal space incompletely closed by the distal dart sac and the SD (see below) (Fig. 11); Dt, love dart; DtC, love-dart chamber, the chamber secreting and containing the love dart; FO, free oviduct; HBUMM, mollusc collection of Museum of Hebei University, Hebei, China; MG, mucous glands; MGE, entrance(s) of mucous glands; P, penis; PAS, proximal accessory sac, a blind sac on proximal dart sac and opening into dart sac chamber or elsewhere; PO, opening of proximal accessory sac; PR, penial-retractor muscle; PS, penis sheath; SD, dart-sac septum, a fleshy septum between the atrial opening and the opening of the DtC (Fig. 11); SMF, Forschungsinstitut und Naturmuseum Senckenberg, Frankfurt am Main, Germany; VD, vas deferens.

## Systematics

### Superfamily Helicoidea Rafinesque, 1815

### Family Camaenidae Pilsbry, 1895

### Subfamily Bradybaeninae Pilsbry, 1898

#### Genus *Cathaica* Möllendorff, 1884

*Helix* (*Cathaica*) Möllendorff 1884: 339 (without subdivisions, most species now assigned to *Cathaica*, *Bradybaena*, *Laeocathaica*, and *Pseudiberus*)—Pilsbry 1893 in 1892–1893: 204.

*Eulota* (*Cathaica*)—Pilsbry 1894 in 1894–1895: 200, 202, 205. Andreae 1900: 2 (with five genera: *Eucathaica* Andreae, 1900; *Pliocathaica* Andreae, 1900; *Xerocathaica* Andreae, 1900; *Campylocathaica* Andreae, 1900; *Pseudiberus* Ancey, 1887). Gude 1902a: 8. Gude 1902b: 52. Thiele 1931: 692 (= *Cathaica* (*sensu stricto*), = *Eucathaica* + *Pliocathaica* + *Xerocathaica* + *Campylocathaica* + *Kaznakoviella* Lindholm, 1922). Yen 1939: 137 (type species not *Helix fasciola* Draparnaud, 1801). Schileyko 2004: 1690 (= *Cathaica* (*sensu stricto*) + *Pliocathaica* + *Xerocathaica*).

**Type species.** *Helix pyrrhozona* Philippi, 1845, by original designation.

**Diagnosis.** Protoconch granulate. Penial sheath present. Proximal accessory sac one or two. Mucous glands more than two. Epiphallic papilla present in *Cathaica* (*Pliocathaica*), or absent in *Cathaica* (*sensu stricto*). Penial caecum, flagellum, accessory sac, and poly-layered structure in dart-sac apparatus absent (updated from Wu 2019).

**Taxonomic remarks.** The poly-layered structure (PLS), which is a poly-layered structure in much, or a limited portion, of the dart sac and/or accessory sac; it is formed by wavy and spongy connective tissue that connects tightly with neighbouring tissue (Wu 2004, 2019). *Cathaica fasciola*, however, does not have the PLS observed in, for example, *Bradybaena* and *Aegista*, in which the PLS is only present inside the trunk of dart sac (Wu 2004). Mistaking the septa or folds inside the proximal accessory sac for the PLS (e.g. Wu 2004: fig. 22D, 2023: table 1) undoubtedly results from regarding the proximal accessory sac (PAS) as the accessory sac (in Wu 2004: fig. 22C, "AS" should be PAS), although in the PAS, the septa that are parallelly arranged and never connect to each other (Fig. 4D) look slightly like real PLS which are regularly interweaved to be sponge-like (e.g. in *Aegista* (*Plectotropis*) *gerlachi* (E. von Martens, 1881); Wu 2004: fig. 14B–D).

To precisely describe the structure of dart-sac apparatus, it is crucial to distinguish the accessory sac from the proximal accessory sac. However, the internal structure of the dart-sac apparatus has usually been neglected in the studies on Bradybaeninae. An accessory sac can be clearly defined as a sac both inserted by mucous glands and opening into the chamber containing the love dart (DtC) or opening into the dart-sac chamber (DSC) (Wu *et al.* 2019), which means the accessory sac is virtually an expanded tube of varying volume connecting the mucous glands and the dart-sac chamber or love-dart chamber. In comparison to the accessory sac, the proximal accessory sac is a caecum located on and only opens into the dart-sac chamber (Fig. 11). As revealed here, and earlier by Wu *et al.* (2023), *Cathaica* species have one or two pieces of distinguishable sac-shaped structure associated with the dart sac.

#### *Cathaica pyrrhozona montana* (Möllendorff, 1875)

Figures 1–4, 11A

*Helix* (*Camena*) *pyrrhozona* var. *montana* Möllendorff 1875: 217.

*Cathaica* (*Cathaica*) *fasciola montana*—Richardson 1983: 48.

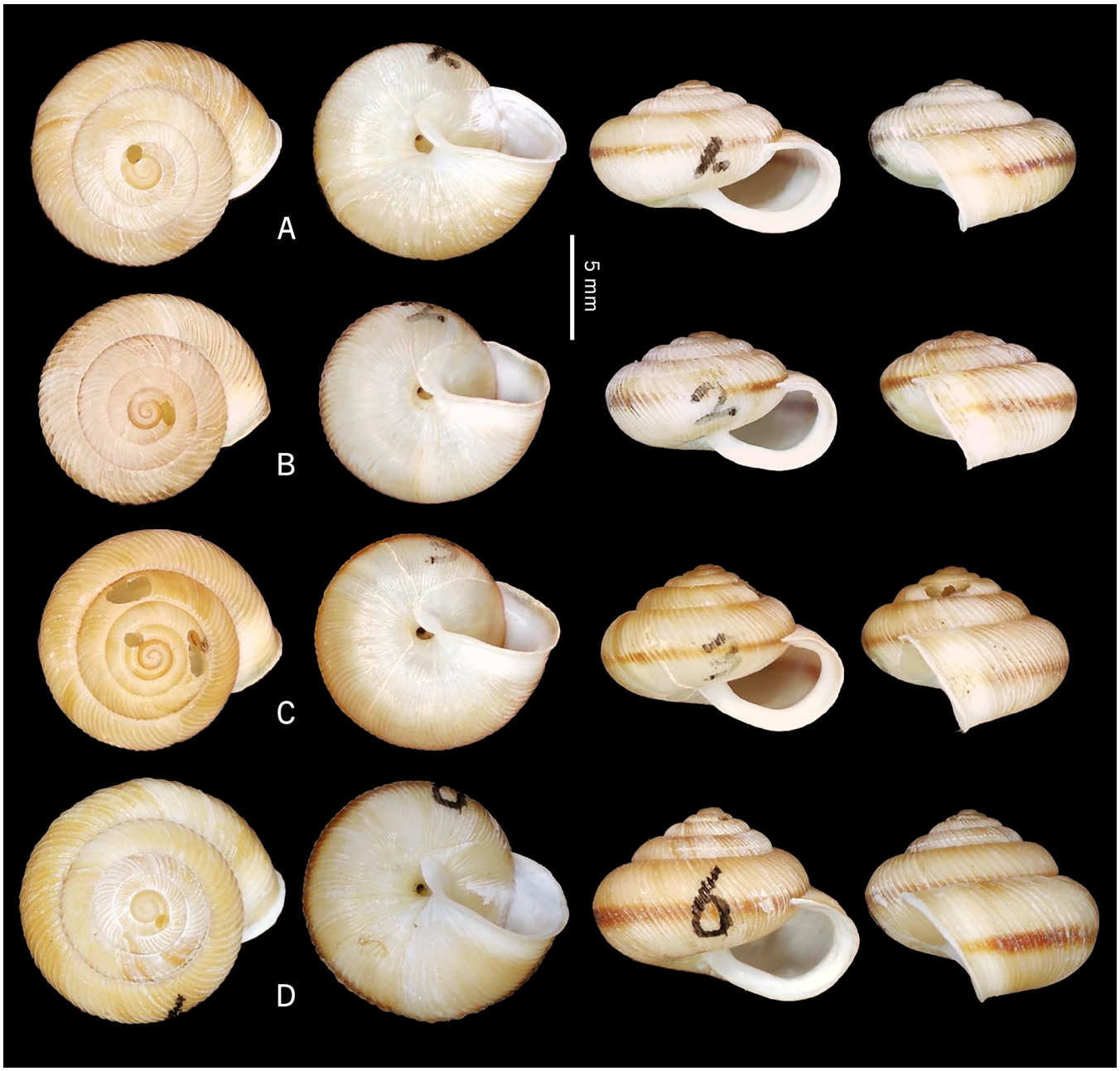


**Figure 1.** *Cathaica pyrrhozona montana* (Möllendorff, 1875), HBUMM 08229, specimens 1–3, 6.

**Diagnosis.** Shell ovate-conic. Spire with fine ribs. Umbilicus narrow. Mucous glands numerous, separated from vagina, seldom branched, opening to dart-sac chamber. One proximal accessory sac, on right side of dart sac, opening to dart-sac chamber. Vagina opening to atrium.

**Material examined.** HBUMM 08229: 14 mature animals; mountains at Fangshan [房山], Beijing; 36.45° N 116.95° E; leg. Heng-Tao Zhang [张恒韬], July 2018 (HBUMM 08229, specimens 1–10 measured, and specimens 1 and 3 dissected).

**Redescription.** Shell (Fig. 1) ovate-conic, thin, dextral. Spire conoid, high. Whorls convex. Suture deep. Umbilicus very narrow; shell base gently transitioning into umbilicus. Columella rather oblique; columellar lip dilated, slightly covering umbilicus. Protoconch radially granulate. Spiral furrows absent or sparse on spire, but variably dense near umbilicus. Last whorl not descending in front. Shell surface with ribs that do not form clear crenulations at periphery. Growth lines between ribs indistinct. Young shell rough with scales. Adult shell smooth. Young shell angulate at periphery. Last

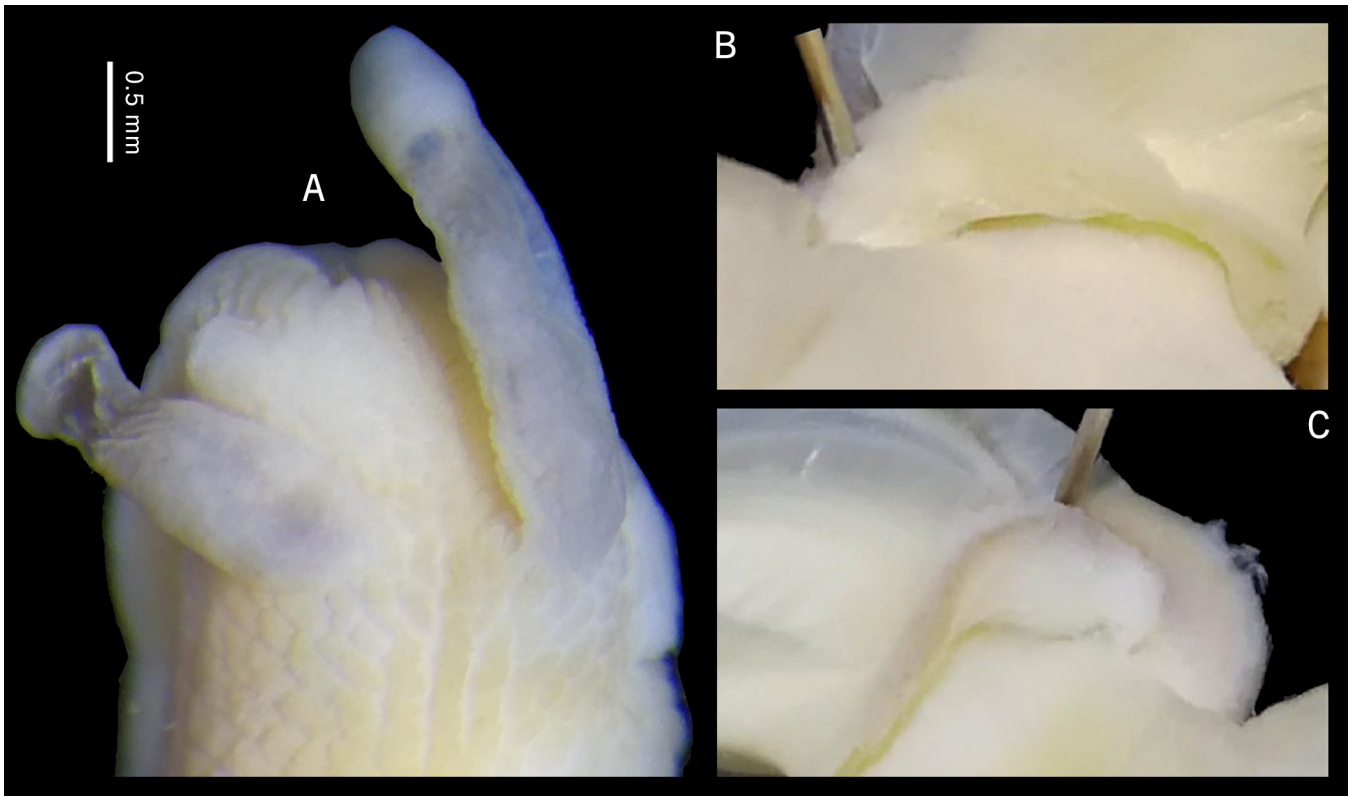


**Figure 2.** *Cathaica pyrrhozona montana* (Möllendorff, 1875), HBUMM 08229, specimen 2. **A**, anterior part of animal, dorsal view. **B**, left margin of mantle. C, right margin of mantle.

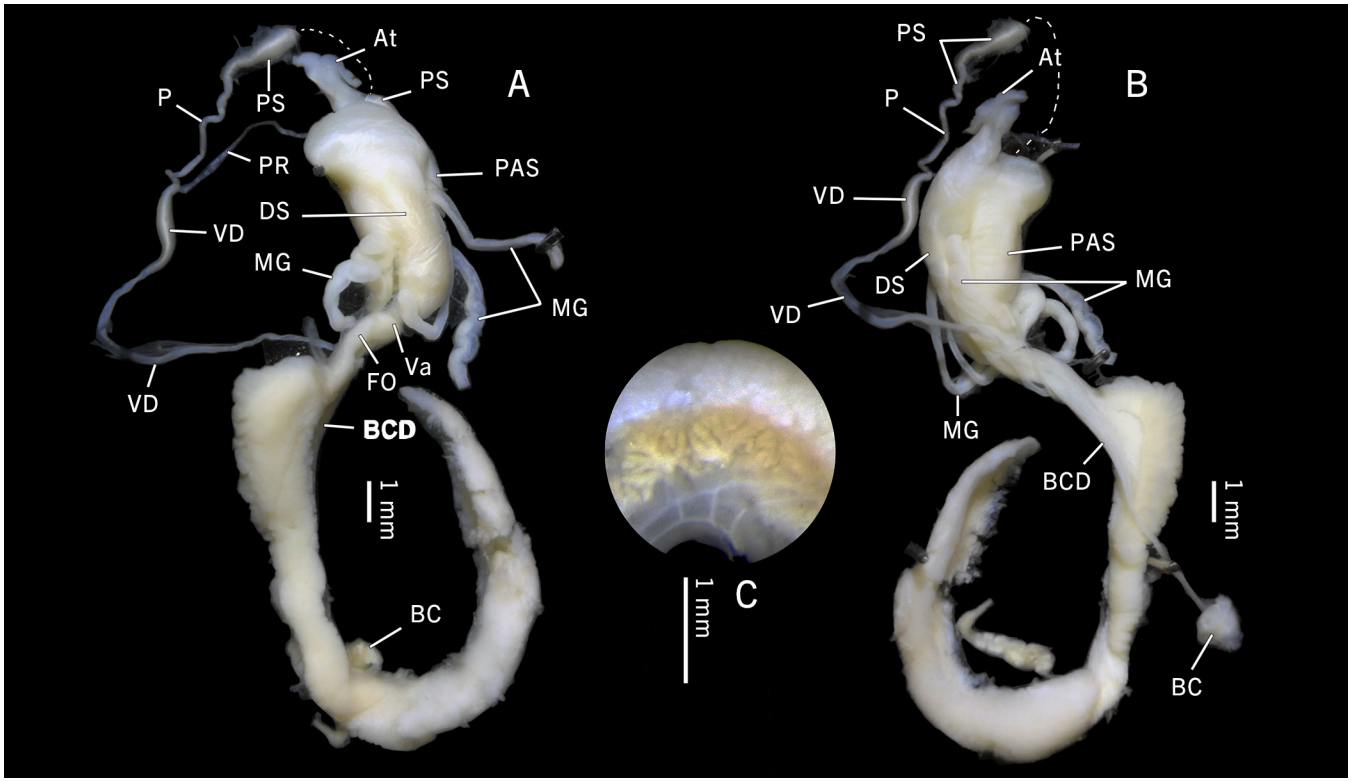


**Figure 3.** *Cathaica pyrrhozona montana* (Möllendorff, 1875), HBUMM 08229, specimen 3. **A**, **B**, both sides of genitalia. **C**, gonad.

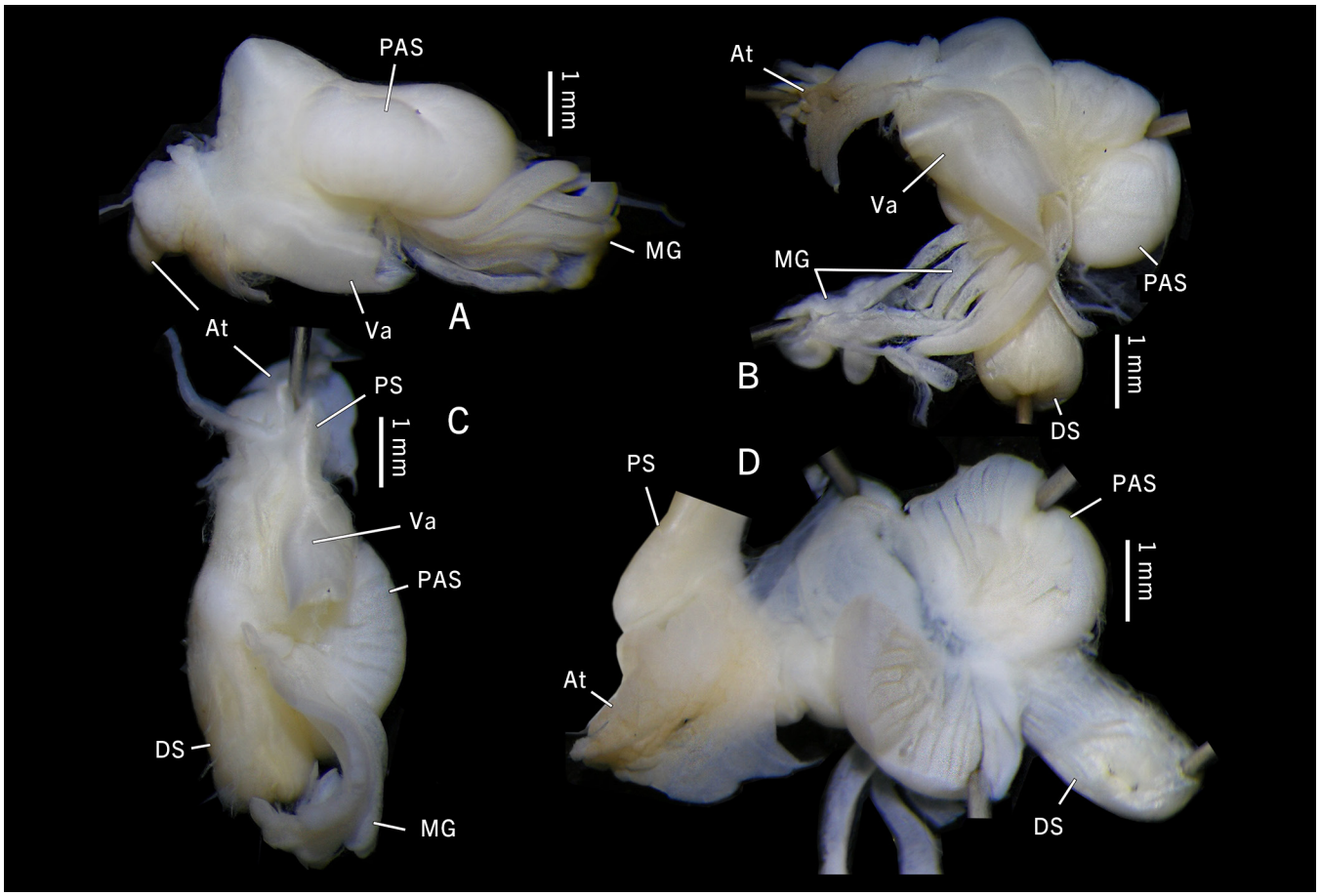


**Figure 4.** *Cathaica pyrrhozona montana* (Möllendorff, 1875). **A**, right side of dart sac apparatus. **B**, bottom view of dart sac apparatus. **C**, bottom view of dart sac apparatus, showing insertion of mucous glands. **D**, exposed proximal accessory sac, showing internal parallel septa. **A**, **B**, **D**, HBUMM 08229, specimen 1; **C**, HBUMM 08229, specimen 2.

whorl rounded at periphery in adults, with base convex. Aperture roundedly quadrate, slightly expanded below. Ring-like thickening present within aperture. Aperture with a very low, broad basal tooth near columella. Peristome oblique, somewhat sinuate, not continuous, thin. Parietal callus indistinct. Shell dull, brownish yellow, with a chestnut-brown band slightly below periphery. Measurements (with mean ± SD of HBUMM 08229, specimens 1–10): shell height 6.9–9.3 mm (8.0 ± 0.8 mm), shell breadth 11.0–13.0 mm (12.0 ± 0.6 mm), aperture height 4.6–5.4 mm (4.9 ± 0.3 mm), aperture breadth 6.5–7.4 mm (7.1 ± 0.3 mm); number of whorls (with mean): protoconch 1¼–1⅝ (~1½); teleoconch and protoconch 4¾–5⅝ (~5¼).

General anatomy (Fig. 2). Eversible head wart between ommatophore insertions indistinct. Tentacles leaden-black. Mantle edge without any lobed appendage. Remaining body creamy white. Jaw arcuate, with 8 projecting ribs (in two dissected specimens).

Genitalia (Figs 3, 4, 11A). Membranate sac surrounding terminal genitalia absent. Penial sheath long, approximately ½ penis length. Penis short, slender, simple outside. Flagellum absent. Vas deferens thickened near penial-retractor muscle. Mucous glands 8 or 9 single tubules, subequal to dart sac in length, each with distinct peduncle, not attached to vagina by connective tissue, opening to dart sac chamber. Proximal part of dart sac not elongated (not forming a neck-structure). Dart sac containing 1 piece of dart. Proximal accessory sac on right side of dart sac, internally with numerous parallel septa (Fig. 4D), opening into dart sac chamber. Vagina entering atrium. Measurements (specimen 3): DS 5.7 mm long, 2.0 mm broad; MG 6.4 mm; PS 2.8 mm; P 7.9 mm; Ep 2.6 mm; VD 9.0 mm; PR 4.0 mm; Va 3.7 mm; FO 1.0 mm; combined BC and BCD 11.4 mm.

**Distribution.** Only known from the type locality: western Beijing.

**Taxonomic remarks.** The described specimens were found on the limestone outcrops at Fangshan, western region of

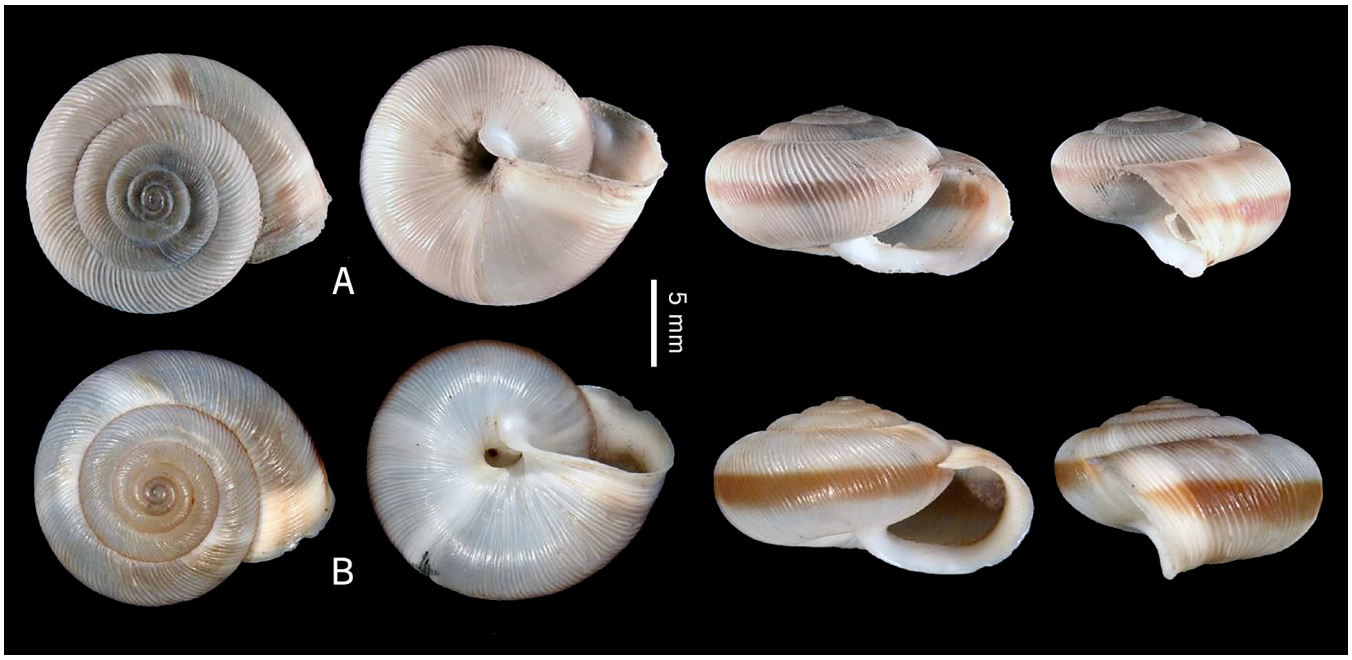


**Figure 5.** *Cathaica fasciola* (Draparnaud, 1801). **A**, NHMUK 1912.6.27.45. **B**, SMF22861a.

Beijing, the type locality of *C. pyrrhozona montana*. In this subspecies the structure of the dart-sac apparatus is the same as that of *C. p. pyrrhozona* (HBUMM 08290, from Dezhou [德州], Shandong Province, 11 mature animals, 37.43° N 116.33° E, leg. Y.-F. Zou, 2018-X) (Zhang and Wade 2023). However, *C. p. pyrrhozona* has a relatively shorter penis sheath than *C. p. montana*. The sympatric congener *Cathaica pekinensis conoidea* (Deshayes, 1873) is like *C. pyrrhozona montana* in having a higher spire (Deshayes 1873: pl. 3, figs 16, 17) but it has a distinctly broader umbilicus (Deshayes 1873: pl. 3 figs 13–15) and an ovate aperture.

The obvious difference between *C. pyrrhozona* and *Cathaica fasciola* (Draparnaud, 1801) (Wu *et al.* 2023: fig. 52A) in the anatomy of dart sac apparatus suggests the former species is valid.

***Cathaica zoui* Wu, n. sp.**

Figures 6–10, 11B

*Cathaica* sp. 2 of Zhang and Wade 2023.

**ZooBank identifier.** urn:lsid:zoobank.org:act:ED831ED9-3367-4767-BA6B-99D82ACA913B

**Diagnosis.** Shell depressed. Spire with fine ribs. Umbilicus broad. Mucous glands numerous, opening into dart-sac chamber and tightly associated with dart-sac septum. Proximal accessory sac 1, on right side of dart sac. Proximal accessory sac opening into dart-sac chamber. Vagina opening to atrium.

**Type material.** Holotype, a mature animal, HBUMM 08288, specimen 1: Liantaishan Mount [莲台山], Jinan, Shandong Province, China; 36.45° N 116.95° E; coll. Yi-Fan Zou [邹轶帆] and Heng-Tao Zhang; October, 2018; shell height 9.8 mm, shell breadth 18.1 mm, aperture height 5.6 mm, aperture width 8.7 mm; protoconch 1⅝ whorls, teleoconch and protoconch whorls 5⅝. Paratypes, 6 mature animals, HUBMM 08288, specimens 2–7, same collection data as holotype. Two juvenile specimens of HBUMM 08288 are excluded from the types. DNA-voucher, HBUMM 08289, the same collection data as types.

**Description.** Shell (Figs 6, 7D) depressed, thin, dextral. Spire low. Whorls convex. Suture deep. Umbilicus broad, approximately ⅓ of diameter. Shell gently transitioning into umbilicus. Columella oblique. Columellar lip slightly dilated, scarcely overhanging umbilicus. Protoconch radially granulate (Fig. 7D). Spiral furrows sparse throughout teleoconch. Final part of last whorl scarcely ascending or descending. Shell surface with ribs but not forming clear crenulations at periphery. Growth lines between ribs indistinct. Young shell roughened by scales. Adult shell not scaly or hairy. Adult last whorl rounded at periphery, with base convex. Aperture roundedly quadrate, slightly expanded below. Ring-like thickening present within aperture. Aperture with a low, broad basal tooth near columella. Peristome oblique, thin, somewhat sinuate, not continuous. Parietal callus indistinct. Shell dull, dirty white, with a chestnut-brown peripheral band. Measurements (all type specimens): shell height 8.2–

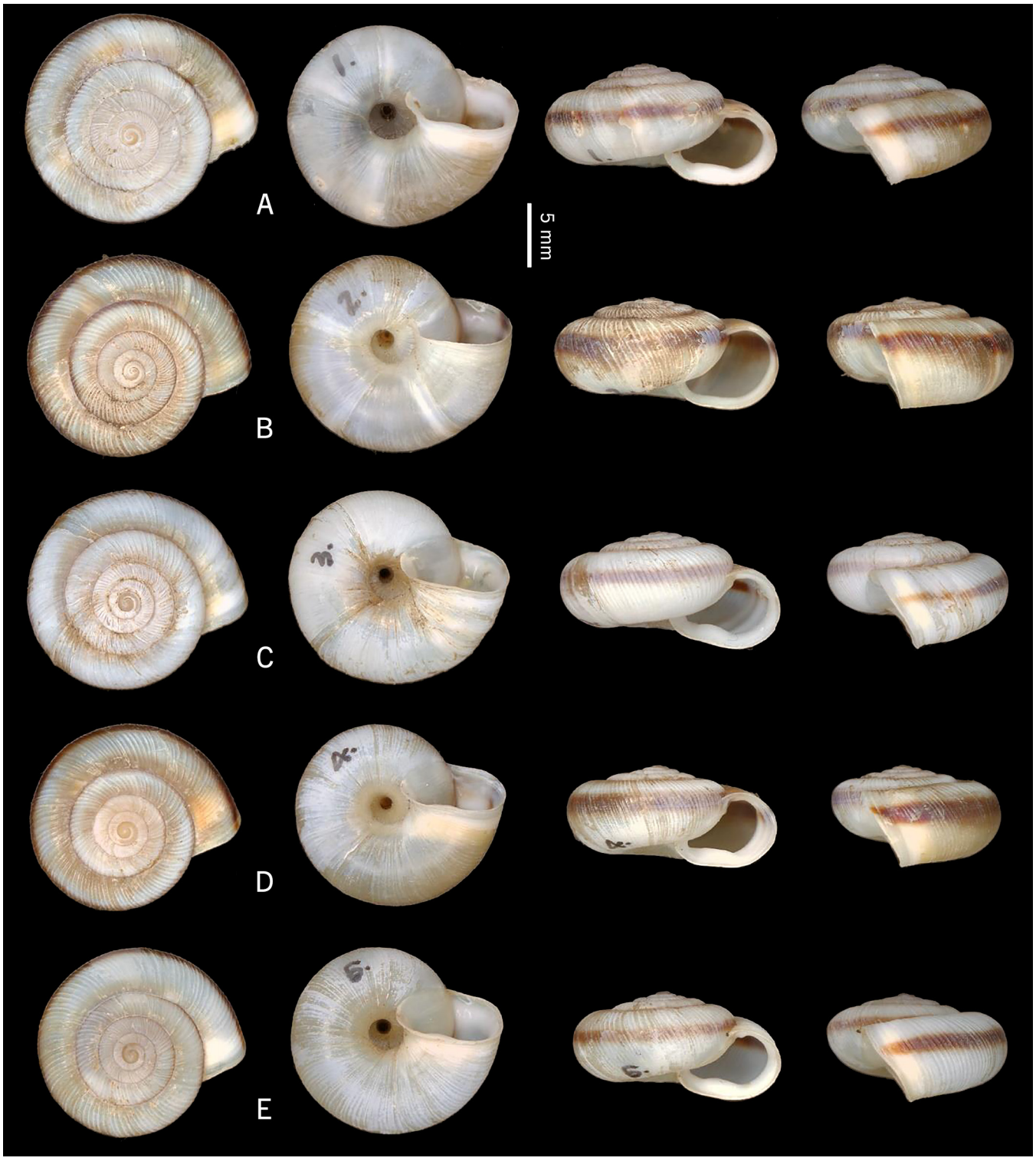


**Figure 6.** *Cathaica zoui* Wu, n. sp. **A**, HBUMM 08288, specimen 1, holotype. **B**–**E**, paratypes, HBUMM08288, specimens 2–4, 6.

9.8 mm (9.0 ± 0.6 mm), shell breadth 16.3–18.1 mm (17.2 ± 0.7 mm), aperture height 7.7–8.7 mm (8.4 ± 0.37 mm), aperture width 5.6–6.8 mm (6.1 ± 0.46 mm), diameter of umbilicus 2.8–3.9 mm (3.4 ± 0.4 mm); number of whorls (with mean): protoconch 1⅜–1⅝ (~1½); teleoconch and protoconch: 5⅝–6¼ (~1⅜).

General anatomy (Fig. 7A–C). Eversible head wart between ommatophore insertions indistinct. Tentacles lead-


**Figure 7.** *Cathaica zoui* Wu, n. sp. **A**, anterior part of animal, dorsal view. **B**, left margin of mantle. **C**, magnified protoconch. **D**, right margin of mantle. **A**, **C**, HBUMM 08288, specimen 1, holotype. **B**, **D**, HBUMM 08288, specimen 2, paratype.

en-black. Mantle edge without any lobed appendage. Remaining body creamy white. Jaw arcuate, with 6 or 7 projecting ribs.

Genitalia (Figs 8–10, 11B). Membranate sac surrounding terminal genitalia absent. Penial sheath long, approximately ¼ penis length. Penis long, slender, simple outside. Flagellum absent. Vas deferens thickened near penial-retractor muscle. Mucous glands with 9–11 tubules, usually not branched, or if so, then simply; mucous glands longer than dart sac, each with a distinct peduncle, not attached to vagina by connective tissue, opening into dart-sac chamber and tightly associated with dart-sac septum. Proximal part of dart sac neither elongate nor forming a neck-structure. Dart sac containing one piece of love dart. Love dart curved, with cross section diamond to four-bladed, approximately 6 mm long. Mucous glands apically entering papilla, and with dense cilia (approximately 0.1 mm long), near opening of love-dart chamber on septum between atrial opening and opening of DtC. Proximal accessory sac 1, on right side of dart sac, internally with numerous parallel septa, opening into dart-sac chamber near mucous-gland insertion. Vagina entering atrium. Measurements (specimen 2): DS 5.7 mm long, 1.8 mm broad (proximal accessory sac not included); MG 6.3 mm; PS 8.4 mm; P 17.6 mm; Ep 6.9 mm; VD 7.9 mm; PR 6.1 mm; Va 4.4 mm; FO 1.0 mm; combined BC and BCD 13.2 mm.

**Etymology.** This species is named after the collector, Mr Yi-Fan Zou.

**Distribution.** Only known from the type locality.

**Taxonomic remarks.** The new species belongs to *Cathaica* (*sensu lato*) according to the most recent understanding of generic divisions within Chinese Bradybaeninae (Wu 2019, 2023; Zhang and Wade 2023). The new species conchologically resembles *Cathaica fasciola* (Fig. 5), but it has a broader umbilicus and a distinct basal tooth. These species differ in the structure of their dart-sac apparatus, especially in the number and position of the proximal accessory sac. *Cathaica leei* Yen, 1935 (see Zhang *et al.* 2020: fig. 5D–F for a figure of the types), which is distributed in Taishan [泰山], Shandong, differs from the new species in its more rounded

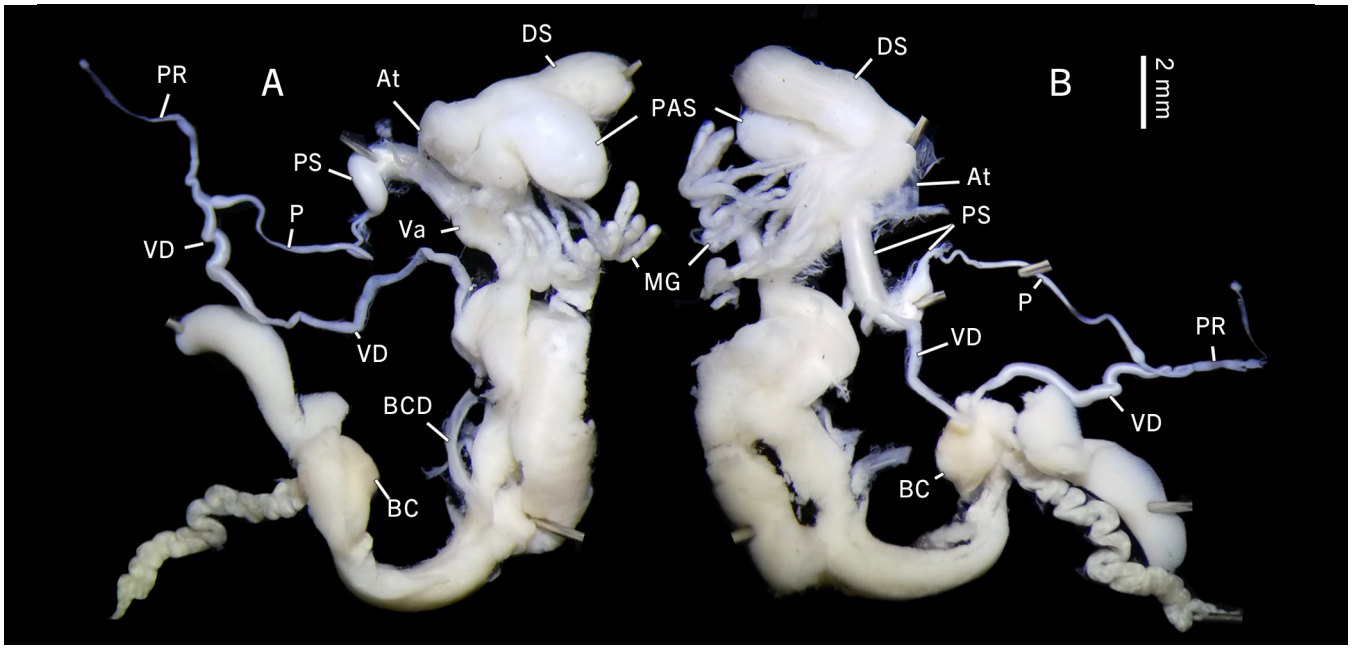


**Figure 8.** *Cathaica zoui* Wu, n. sp., HBUMM 08288, specimen 2, paratype. Both sides of genitalia.

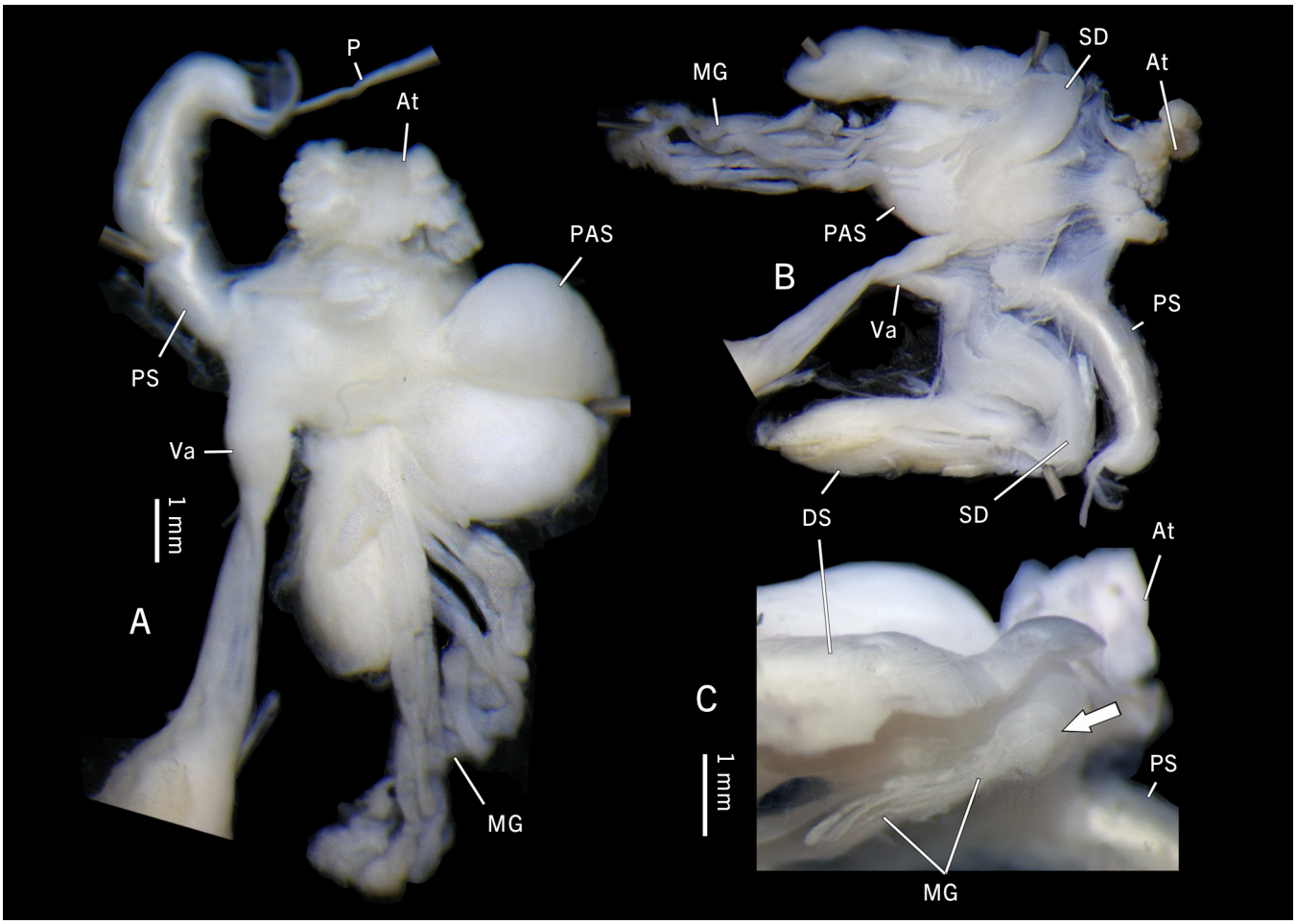


**Figure 9.** *Cathaica zoui* Wu, n. sp., HBUMM 08288, specimen 1, holotype. **A**, bottom view of dart sac apparatus. **B**, exposed dart sac apparatus. **C**, magnified part of exposed dart sac apparatus. Arrow indicates papilla/entrance of mucous glands on dart sac septum.

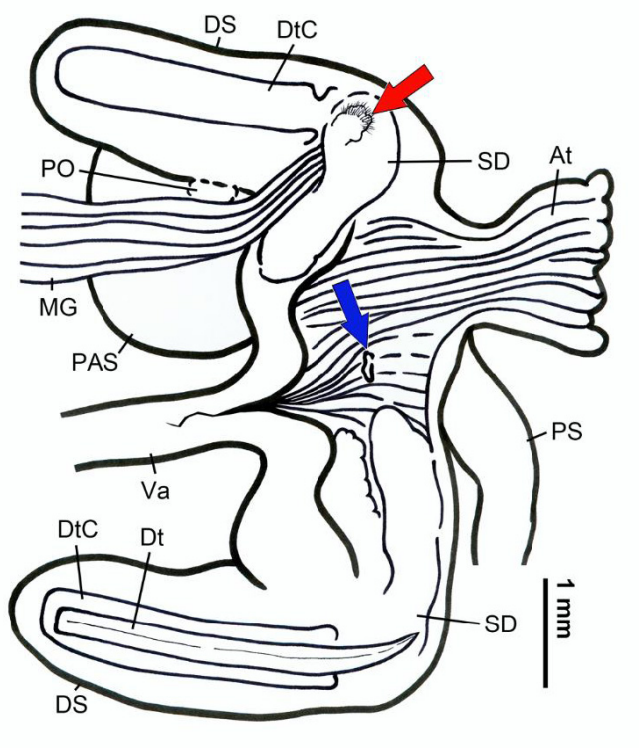


**Figure 10.** *Cathaica zoui* Wu, n. sp., HBUMM 08288, specimen 1, holotype; exposed dart sac apparatus. Red arrow shows the papilla of mucous glands tightly associated with the dart sac septum; blue arrow shows the entrance of penis.

aperture, the absence of basal tooth, and the absence of distinct, regularly distributed ribs. The new species shares with *C. pyrrhozona montana*, *C. pyrrhozona pyrrhozona*, *C. fohuiensis* Zhang, 2023 and *C. multicostata* Zhang, 2023 a single right proximal accessory sac on the dart sac and most of the internal structure of the dart-sac apparatus.

The presence of cilia on the septum between the atrium and the opening of the dart chamber is unknown in other bradybaenine genera. The ciliate dart-sac septum, which is tightly associated with the entrance of the mucous glands, supposedly aids in smearing mucus on the love dart or in keeping the dart steady during dart shooting.

## Discussion

In comparison to *Cathaica fasciola*, which has two proximal accessory sacs, and *Cathaica pulveratricula* (E. von Martens, 1882), which has only one PAS on the left side of the dart sac (Wu *et al.* 2023: fig. 52A, B), *C. pyrrhozona* and *C. zoui* Wu, n. sp., has only one PAS on the right side of the dart sac. In respect to the systematics of the genus *Cathaica* (*sensu lato*), it can no longer be treated as monophyletic (Wu *et al.* 2023), and its subgenera cannot be considered valid until their type species have been studied and their systematic position proven. Furthermore, knowledge of the genital morphology of bradybaenine genera is still dismayingly poor. For example, in most genera in the central Chinese Clade C of Wu *et al.* (2023), the presence of a PAS among the terminal taxa remains unknown, although the significance of PAS is preliminarily understood.

The molecular phylogenetic analysis based on partial *16S* and partial *CO1* genes suggests that the phylogenetic relationship within the clade composed of *C. zoui* Wu, n. sp. (= *Cathaica* sp. 2 of Zhang and Wade 2023) and the other species with geographic proximity, namely *Cathaica leei* Yen, 1935, *Cathaica* sp. 1, *Cathaica fohuiensis* Zhang, 2023,

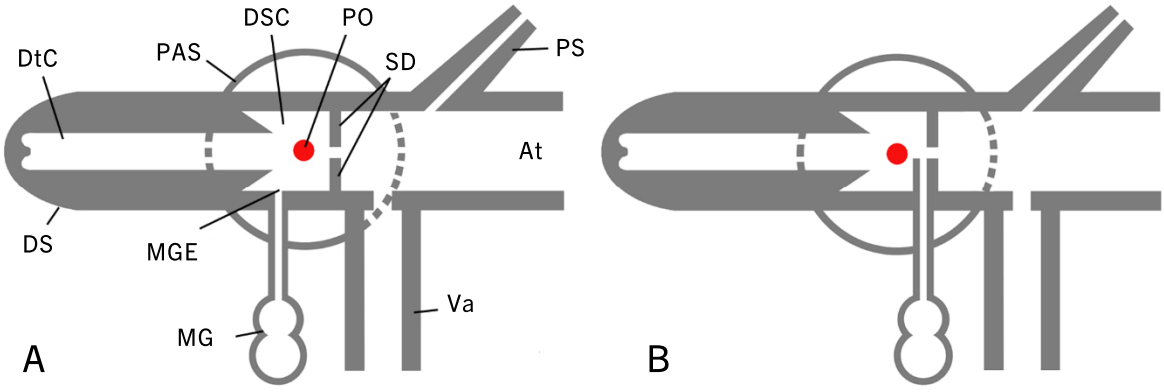


**Figure 11.** Diagrams of dart sac apparatus with love dart removed. **A**, *Cathaica pyrrhozona montana* (Möllendorff, 1875). Proximal accessory sac on the right side of dart sac; vagina opening into atrium; entrance of mucous glands leading to dart sac chamber, not associated with dart sac septum (compare with the same structure in *Cathaica p. pyrrhozona*; Zhang and Wade 2023: fig. 4B). **B**, *Cathaica zoui* Wu, n. sp. Proximal accessory sac on the right side of dart sac; vagina opening into atrium; entrance of mucous glands leading to dart sac chamber, tightly associated with dart sac septum. Red dot, the opening of proximal accessory sac.

*Cathaica fasciola* (Draparnaud, 1801), and *Cathaica pyrrhozona pyrrhozona* (Philippi, 1845), are not clear because of low support for the clades (Zhang and Wade 2023: fig. 6). Considering this and the presence of two proximal accessory sacs in *C. fasciola*, further investigation is needed to determine if *C. fasciola* truly belongs to *Cathaica* (*sensu stricto*).

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