

## RESEARCH PAPER

# *Pterostichus izurusanus* sp. nov., an isolated and specialized species of the *macrogenys* species group (Coleoptera: Carabidae) discovered on a mountain on the edge of the Kanto Plain, Honshu, Japan

Kôji SASAKAWA<sup>1,\*</sup>, Yôichi SUZUKI<sup>2</sup> & Hirotarô ITÔ<sup>3</sup>

<sup>1</sup>Laboratory of Zoology, Department of Science Education, Faculty of Education, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba-shi, Chiba, 263-8522 Japan; e-mail: ksasa@chiba-u.jp

<sup>2</sup>Tochigi Prefecture, Japan [Unaffiliated]

<sup>3</sup>Niigata Prefecture, Japan [Unaffiliated]

\*corresponding author

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**Abstract.** A new species, *Pterostichus izurusanus* sp. nov., belonging to the *macrogenys* species group of the subgenus *Nialoe* Tanaka, 1958 (s. lat.), is described. This species is currently known only from Mt. Izuru-san (Tochigi Prefecture, Japan), which is located on a narrow ridge that protrudes from a mountainous area towards the Kanto Plain; the mountainous area other than the ridge is occupied by *P. macrogenys* Bates, 1883, another member of the same species group. The origin and differentiation process of this new species are discussed, based on its distribution pattern, morphological characteristics, and morphology-based phylogeny. An updated key to species of the *macrogenys* species group is provided.

**Key words.** Coleoptera, Carabidae, *Nialoe*, biogeography, comparative morphology, endophallus, ground beetle, identification key, isolated distribution, male genitalia, morphological phylogeny, new distribution record, Japan, Palaearctic Region

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## Introduction

The *macrogenys* species group is a member of the East Asian endemic subgenus *Nialoe* Tanaka, 1958 (s. lato, i.e., *Nialoe* sensu SASAKAWA 2021) of the ground beetle genus *Pterostichus* Bonelli, 1810. It occurs in mountainous areas north of central Honshu in the Japanese archipelago (SASAKAWA & MITSUDUKA 2023). Members have atrophied metathoracic wings, resulting in low dispersal ability, and the group shows remarkable geographic differentiation. Currently, 43 species-group taxa are known, most of which have limited distribution ranges (SASAKAWA & MITSUDUKA 2023). However, the validity of these taxa as distinct species, their distribution ranges, and within-group phylogenetic relationships remain incompletely understood and further studies are needed.

Here, we describe a new species of this group discovered on a mountain at the edge of the Kanto Plain. Its distribution is peculiar. It was collected from a narrow ridge that protrudes from a mountainous area surrounded by environments that are unsuitable for this species group (Fig. 1). The larger mountainous area excluding the ridge is occupied by *P.*

*macrogenys* Bates, 1883, another member of this group with a similar body size. Given that within this species group, individuals of similar body size are typically distributed in mutually exclusive habitats (SASAKAWA 2009, SASAKAWA et al. 2020, SASAKAWA & MITSUDUKA 2023), the observed distribution pattern implies that the new species may have been displaced from the mountainous area by *P. macrogenys* and consequently restricted to the ridge. That is, the new species appears to be restricted to the ridge through biotic (the presence of a similar relative) and abiotic (surrounding plains unsuitable for habitat) factors. In this study, we report the morphological peculiarities of the new species and its phylogenetic position within the species group based on morphology-based phylogenetic analysis, and discuss its differentiation process as inferred from the results.

## Materials and methods

The present study is based mainly on specimens described as the new species here. However, considering the proximity of their type localities, the following four species



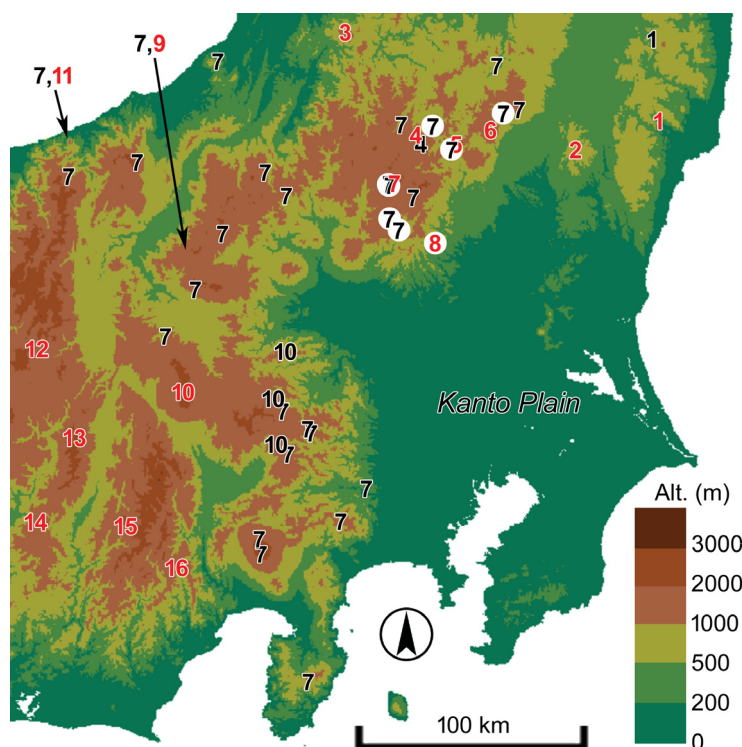


Fig. 1. Distribution of the *Pterostichus macrogenys* species group in southern Tohoku, Kanto, and eastern Chubu districts, compiled from SASAKAWA & MITSUDUKA (2023), MITSUDUKA (2023), SASAKAWA (2024), and new records (white circles). Only records with unambiguous species identity (i.e., collection sites of type specimens and records based on specimens identified by the endophallus) are presented. Red numbers denote the type locality of each species. 1 – *P. iwakiensis* Sasakawa, 2009; 2 – *P. yamizosanus* Sasakawa, 2005; 3 – *P. sumondakensis* Sasakawa, 2005; 4 – *P. isolatus* Sasakawa, 2005; 5 – *P. nakamiyorinus* Morita, Ohkawa & Kurihara, 2013; 6 – *P. momuranus* Morita, Ohkawa & Kurihara, 2013; 7 – *P. macrogenys* Bates, 1883; 8 – *P. izurusanus* sp. nov.; 9 – *P. nagasawai* Ito & Ogai, 2015; 10 – *P. koheii* Nakane, 1963; 11 – *P. omissis* Sekine & Nakase, 2022; 12 – *P. shikatai* Toda, 2012; 13 – *P. todai toyoshimai* Sugimura, 2002; 14 – *P. todai todai* Morita & Kanie, 1997; 15 – *P. miyazawai* Morita & Ohkawa, 2009; 16 – *P. toyodai* Morita & Kurosa, 1998.

of the *macrogenys* species group were studied for comparison: *P. macrogenys* (see Material listed below under that species); *P. isolatus* Sasakawa, 2005, from Mt. Tashiro-san, Minamiaizu-machi; *P. momuranus* Morita, Ohkawa & Kurihara, 2013, from Enna rindô, Nasushiobara-shi; and *P. nakamiyorinus* Morita, Ohkawa & Kurihara, 2013, from Naka-miyori, Nikkô-shi (Fig. 1). Information on the morphology of the above-mentioned species was obtained from the original descriptions and subsequent redescrptions of each species, which describe key morphological characters (BATES 1883; SASAKAWA 2005, 2024; MORITA et al. 2013). *Pterostichus ixion* (Tschitschérine, 1902), described from “montagnes de Nikko” (= the Nikkô Mountains), was also treated as a member of the species group by some authors. However, based on the original description (TSCHITSCHÉRINE 1902) and a subsequent redescription (JEDLIČKA 1962), this species lacks the elytral setigerous puncture pattern that serves as a reliable synapomorphy of this group (specifically, the absence of the anterior puncture on interval 3; this puncture is absent in the *macrogenys* species group but present in *P. ixion*), and therefore was not included in the species group in the most recent study (SASAKAWA 2025a); indeed, *P. ixion* and the new species differ in body coloration and in the sexual characteristics of male sternum 7 (TSCHITSCHÉRINE 1902; this study), which are key taxonomic characters of *Nialoe* (s. lat.).

Male specimens of the new species were identified according to the morphology of the endophallus, which was inflated by injecting toothpaste from the base of the aedeagus. The utility of this structure in species-level taxonomy has been demonstrated in many groups of *Pterostichus* (e.g., MAKAROV & SUNDUKOV 2022, YIN et al. 2023, SASAKAWA 2025b). Females were identified by matching their external morphological features with those of identified

males from the same collection site. The terminology of the endophallus and body length (BL) measurements follows SASAKAWA et al. (2020). BLs were taken from the mandible apices (BLm), the anterior margin of the labrum (BLl), and the clypeal apex (BLc) to the elytral end. The values are presented as ranges (minimum–maximum) and mean  $\pm$  standard deviation for each sex. To capture differences in the morphology of the pronotum, pronotal anterior margin width (PAW), pronotum width at the widest part (PW), and pronotal posterior margin width (PPW) were measured, and the value of  $(PAW + PPW) / PW$  was calculated. In general, an individual with a smaller  $(PAW + PPW) / PW$  has a more cordate pronotum, that is, one that is more constricted anteriorly and posteriorly. Measurements were performed for all examined specimens.

The specimens examined are housed in the collections of the Laboratory of Zoology, Department of Science Education, Faculty of Education, Chiba University, Chiba, Japan (CHUJ); Tochigi Prefectural Museum, Tochigi, Japan (TPM); the private collection of H. Itô, Niigata, Japan (cHIT); and the private collection of Y. Suzuki, Tochigi, Japan (cYSZK).

To investigate the phylogenetic position of the new species, phylogenetic trees were constructed using maximum parsimony analysis with TNT version 1.6 (GOLOBOFF & MORALES 2023). Twelve adult characters of the new species were coded according to SASAKAWA & MITSUDUKA (2023) and added to their dataset. Procedures for phylogenetic analysis, the evaluation of nodal support, and mapping of character state changes on the trees also followed SASAKAWA & MITSUDUKA (2023). Specifically, the phylogenetic analysis was performed with the following parameter settings: Analyze > “Traditional search”; Starting trees > “Wagner trees” with “random seed” = 1 and 100 replicates; Swapping algorithm > “tree bisection reconnection (TBR)”

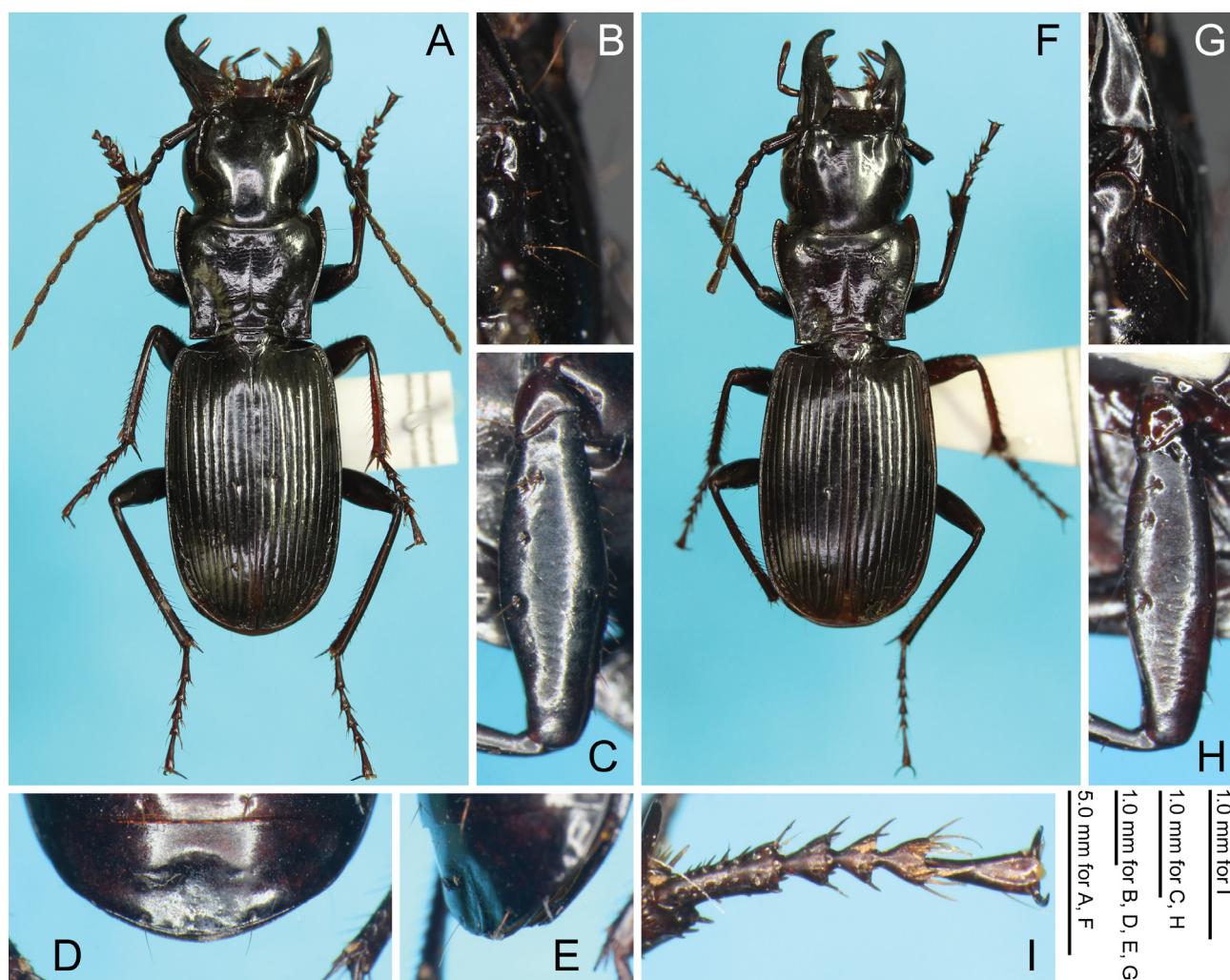


Fig. 2. External structures of *Pterostichus izurusanus* sp. nov.: A–E – holotype, male (A – habitus in dorsal view; B – head (part) in left dorsolateral view; C – left mesofemur in ventral view; D – sternum 7 in ventral view; E – sternum 7 in left ventrolateral view). F–I – paratype, female (F – habitus in dorsal view; G – head (part) in left dorsolateral view; H – left mesofemur in ventral view; I – left foretarsomeres in ventral view).

with 10 trees saved per replication; default parameter settings for all other factors. All characters were treated as “non-additive” and given equal weight. Bootstrap values were calculated using “standard” and “absolute frequencies” options with 1,000 replicates. Synapomorphies and autapomorphies were mapped on the strict consensus tree derived from the obtained trees, based on the list of character state changes (found under Optimize > Synapomorphies > List common synapomorphies in the TNT output). Apomorphies designated as “some trees” and “all trees” in the TNT output were referred to as “possible” and “unambiguous” apomorphies, respectively.

### Taxonomy

#### *Pterostichus (Nialoe) izurusanus* sp. nov.

(Figs 2, 3)

**Type material.** HOLOTYPE: ♂ (CHUJ), Japan, Tochigi Prefecture, Tochigi City, Izuru-machi, Mt. Izuru-san, alt. 500 m, 17-XI-2024, Y. Suzuki leg. PARATYPES: 2 ♂♂ 3 ♀♀, same locality: 1 ♂ (TPM), 15-X-2024, Y. Suzuki leg.; 1 ♀ (CHUJ), 25-X-2024, Y. Suzuki leg.; 1 ♀ (TPM), 30-X-2024, Y. Suzuki leg.; 1 ♂ (CHUJ), 24-XI-2024, Y. Suzuki leg.; 1 ♀ (CHIT), 36.495358°N, 139.570964°E, 3-VII-2025, H. Itô leg.

**Description. Male** (holotype). *Measurements.* BLm 18.82 mm, BLl 16.79 mm, BLc 16.26 mm, (PAW + PPW) / PW 1.70.

*Dorsal habitus.* Macrocephalic species (Fig. 2A). Surface black to dark brown, glossy, not opaque. Metathoracic wings completely atrophied. Chaetotaxy as in other species of *macrogenys* species group, except for setae of supraorbital area (Fig. 2B) and mesofemur (Fig. 2C).

*Head* large, widest at tempora (Fig. 2A). Mandibles long, hooked at apex, with left one larger and more hooked than right one; surface smooth. Frontal grooves shallow. Anterior supraorbital setae two on right side, one on left; posterior supraorbital setae three on right side, two on left (Figs 2B, G). Eyes small, less convex. Tempora developed, their maximum length twice that of eyes.

*Pronotum* inverted trapezoid-shaped, less convex (Fig. 2A). Lateral margin less arcuate at apical 2/3. Anterior angles strongly produced. Marginal setae in two pairs, anterior at widest pronotal point and posterior near posterior angles. Surface almost smooth.

*Elytra* almost parallel-sided, less convex (Fig. 2A). Two setigerous punctures on interval 3, anterior one

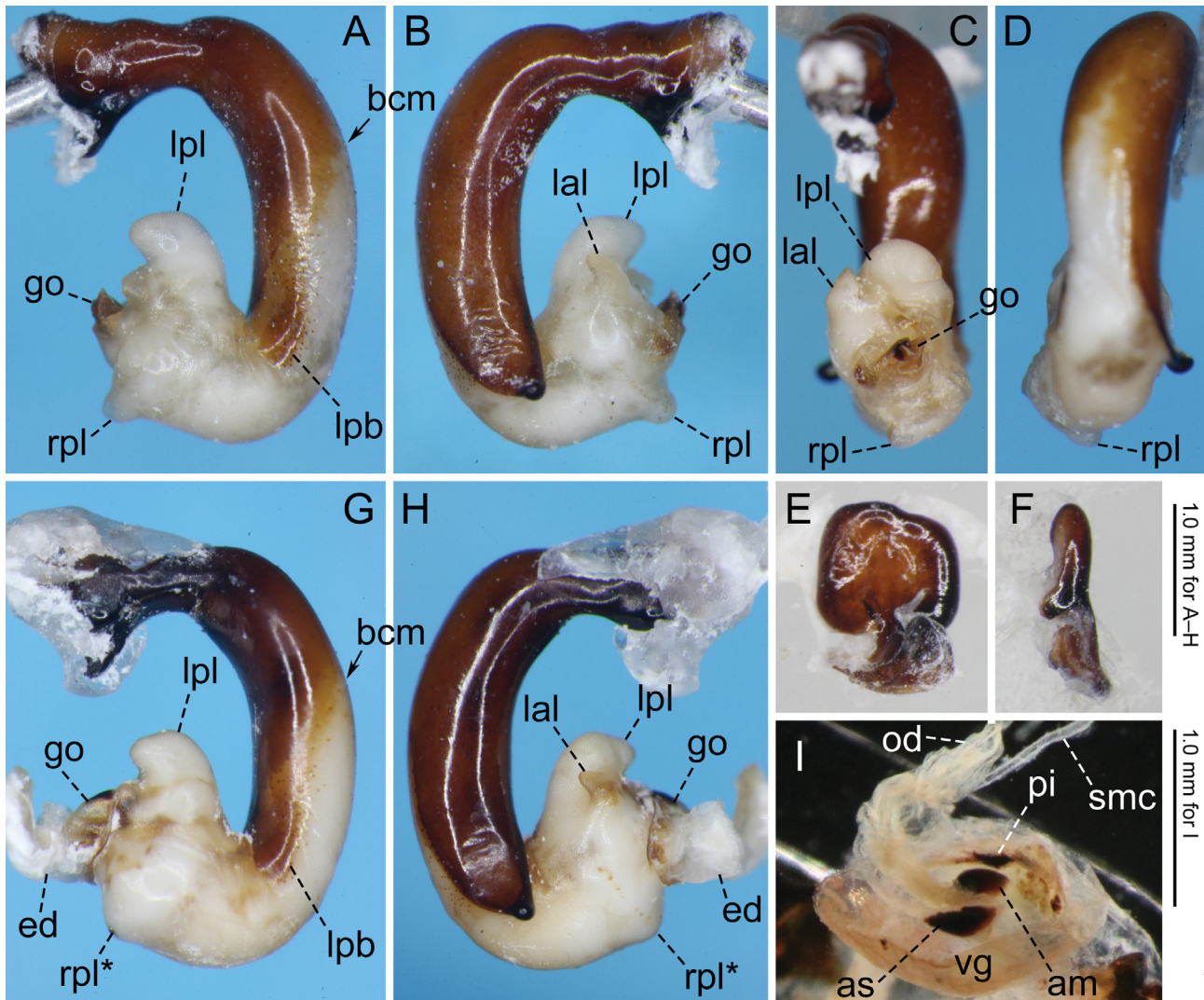


Fig. 3. Genitalia of *Pterostichus izurusanus* sp. nov.: A–F – holotype male (A – aedeagus with everted endophallus in left lateral view; B – aedeagus with everted endophallus in right lateral view; C – aedeagus with everted endophallus in ventral view; D – aedeagus with everted endophallus in dorsal view; E – left paramere in left lateral view; F – right paramere in left lateral view). G–H – paratype male (G – aedeagus with everted endophallus in left lateral view; H – aedeagus with everted endophallus in right lateral view). I – paratype female, vagina and surrounding parts in anterodorsal view. Abbreviations: am – apophysis of median oviduct; as – apophysis of seminal canal; bcm – border between the chitinized and membranous parts at the dorsum of the aedeagus; ed – ejaculatory duct; go – gonopore; lal – left apical lobe; lpb – left pigmented band; lpl – left preapical lobe; od – oviduct; pi – pigmentation on the innermost part of the vagina; rpl – right preapical lobe; smc – seminal canal; vg – vagina. Asterisk indicates that the lobes are not fully inflated.

almost in middle, posterior one almost in posterior 1/6, both adjoining stria 2.

**Abdomen (ventral sclerites).** Sterna 4–6 with pair of setae; sternum 7 with pair of setae. Sternum 7 shallowly concave, with portion corresponding to midline of concavity slightly raised (Figs 2D, E). Surface almost smooth.

**Legs.** Mesofemur with four setae along posterior margin. Meso- and metatarsomere 5 without setae on ventral side.

**Genitalia.** Aedeagus without conspicuous tubercle; apical part not bent, with tip broadly rounded; membranous part near ostium broader than related species, with its basal end (border between chitinized and membranous parts) reaching closer to base of aedeagus than middle of arcuate section (apical 3/4) of aedeagus (Figs 3A–D). Endophallus with gonopore directed basal-ventrally (Figs 3A–D). Left pigmented band distinctly sclerotized; apical half sclerotized to same degree as chitinous part of aedeagus (lpl in Fig. 3A). Right preapical

lobe semi-ellipsoid (rpl in Figs 3A–D). Left preapical lobe largely protruding, with apex bifurcated (lpl in Figs 3A–C). Left apical lobe small, weakly curved, conical in shape; apex not bifurcated (lal in Figs 3B, C). Relative size of lobes: left preapical lobe  $\gg$  right preapical lobe  $>$  left preapical lobe. Left paramere square (Fig. 3E). Right paramere short, straight, with rounded apex (Fig. 3F).

**Female.** Protarsomere 1 without adhesive setae on ventral side (Fig. 2I). Abdominal sternum 7 not concave; posterior margin with two pairs of setae. Genitalia: Vagina almost spherical. Innermost part of vagina with pigmentations (pi in Fig. 3I). Maximum width of largest pigmentations about 3/4 that of apophysis of median oviduct (am in Fig. 3I) and about 1/2 that of apophysis of seminal canal (as in Fig. 3I).

**Variability.** *Dorsal surface.* Mandibular surface with two or three shallow short wrinkles in middle in two female

specimens. Pronotal laterobasal impressions sparsely punctate in some specimens.

**Chaetotaxy.** In paratypes, anterior supraorbital setae one on each side, except for left side of one female specimen, which has two. Posterior supraorbital setae two on each side, except for left side of one male specimen, which has one seta. Mesofemoral setae three, except for one female specimen and left side of one male specimen, which have two setae.

**Measurements.** Male body length (mm) ( $n = 3$ ): BLm 17.08–18.82,  $17.78 \pm 0.92$ ; BLl 15.54–16.79,  $16.02 \pm 0.68$ ; BLc 14.99–16.26,  $15.48 \pm 0.68$ . Female body length (mm) ( $n = 3$ ): BLm 17.71–18.11,  $17.94 \pm 0.21$ ; BLl 15.79–16.45,  $16.18 \pm 0.35$ ; BLc 15.19–15.89,  $15.59 \pm 0.36$ . (PAW + PPW) / PW 1.65–1.73, mean 1.69 ( $n = 6$ ).

**Differential diagnosis.** Among the four locally adjacent species of the same species group, the new species is the most similar to *P. macrogenys* in general external appearance but can be distinguished from it by the following character states: less cordate pronotum with higher (PAW + PPW) / PW value (1.57–1.63, mean 1.60 in *P. macrogenys*), broader membranous part near the ostium of the male aedeagus, and the shape of the male endophallus. From the remaining three species, *P. isolatus*, *P. maomuranus*, and *P. nakamiyorinus*, it is readily distinguished by its darker body coloration, less produced pronotal anterior angles, and wider apex of the aedeagus in the male genitalia. The presence of additional setae on the supraorbital area and the mesofemur is also characteristic of this species; however, because some individuals lack these additional setae, they cannot serve as definitive diagnostic characters at the species level.

**Etymology.** The specific name is an adjective derived from Mt. Izuru-san, the type locality of the new species.

### *Pterostichus (Nialoe) macrogenys* Bates, 1883

(Fig. 4)

**Material examined.** JAPAN: FUKUSHIMA PREFECTURE: 4 ♂♂ 1 ♀ (cYSZK), Minamiaizu Town, Yunohana, near Mt. Tashiro-yama, 3-X-2023, Y. Suzuki leg. (Figs 4A–C). TOCHIGI PREFECTURE: 4 ♂♂ 1 ♀ (cYSZK), Nasu Town, Yumoto, Y. Suzuki leg. (1 ♂, 9-IX-2022; 1 ♀, 16-IX-2022; 2 ♂♂, 30-IX-2022; 1 ♂, 5-X-2022); 2 ♂♂ (cYSZK), Nasushiobara City, Itamuro, near Miyama Dam, 2-VIII-2023, Y. Suzuki leg. (Figs 4D–F); 1 ♂ 1 ♀ (cYSZK), Nikko City, Yumoto, Y. Suzuki leg. (1 ♂, 21-IX-2016; 1 ♀, 12-VIII-2021); 3 ♂♂ (cHIT), Nikko City, Serizawa, alt. 733 m (36.988800°N, 139.646337°E), 24-IX–9-XI-2024, H. & R. Itô leg.; 1 ♂ (TPM), Nikko City, Ashiomachi, Mt. Kôshin-zan, Nanataki, 20-VIII-1986, K. Satoh leg.; 1 ♂ (TPM), Nikko City, Ashiomachi, Riv. Mochigase-gawa (Riv. Karahuro-gawa), 24-VIII-1986, K. Satoh leg. (Figs 4G–I). GUNMA PREFECTURE: 1 ♂ 2 ♀♀ (cYSZK), Katashina Village, Higashiogawa, near Suganuma Lake, 26-VI-2023, Y. Suzuki leg. (1 ♀, 28-VI-2022; 1 ♀, 12-VII-2022; 1 ♂, 26-VI-2023).

**Notes.** The identification of these specimens is based on the observation that their endophallus structure is identical to that of the lectotype of the species (SASAKAWA 2024).

### Revised key of the *P. macrogenys* species group

The key to the species in SASAKAWA & MITSUDUKA (2023) is updated to include *P. izurusanus* sp. nov. with the following revised (30 and 31) and additional (31a) couplets:

- 30 BLc  $\geq 15.0$  mm. .... 31  
 – BLc  $< 15.0$  mm. .... 32  
 31 Left apical lobe of endophallus gradually narrowed towards apex and moderately bent (lal in Fig. 3). .... 31a  
 – Left apical lobe of endophallus cylindrical, not narrowed towards apex and strongly bent (SASAKAWA et al. 2020: lal in figs 6A, B). BLc 16.4–17.6 mm. Mt. Gassan and Azuma Mountains. .... *P. gassanus* Sasakawa, 2009  
 31a Border between chitinized and membranous parts on dorsal side of aedeagus reaching closer to the base than the middle of arcuate section (bcm in Fig. 3). BLc 15.0–16.3 mm. Mt. Izuru-san. .... *P. izurusanus* sp. nov.  
 – Border between chitinized and membranous parts on dorsal side of aedeagus reaching only to the middle of arcuate section (SASAKAWA 2005: fig. 10A). BLc 15.5 mm. Mt. Sumon-dake. .... *P. sumondakensis* Sasakawa, 2005

### Morphological phylogeny

The coding of the character states of *P. izurusanus* is as follows (character ID/coding; see SASAKAWA & MITSUDUKA 2023, Table 1): 1/0; 2/0; 3/0; 4/2; 5/1; 6/0; 7/2; 8/0; 9/0; 10/0; 11/1; 12/0 (1–10, male genitalia; 11, female genitalia; 12, female external structure). The 50 most-parsimonious trees with a score of 40 were obtained. In the strict consensus tree (Fig. 5), *P. izurusanus* was placed at the basal clades as a branch of polytomy, with no autapomorphy. Except for the addition of *P. izurusanus*, the topology of the strict consensus tree was identical to that of SASAKAWA & MITSUDUKA (2023), although the character-state change reconstructions and nodal statistical supports differed slightly.

### Discussion

Among the morphological characters of *P. izurusanus*, the most notable are the additional setae on some body parts. These were observed among the supraorbital setae and the setae of the posterior margin of mesofemur in most individuals. In *Pterostichus*, the supraorbital setae are normally composed of one anterior and one posterior seta (BOUSQUET 1999). In *P. izurusanus*, however, there are one or two anterior setae and two or three posterior setae. Regarding the mesofemoral setae, *Pterostichus* normally has two setae on the posterior margin (BOUSQUET 1999). An exception is found in the *Platysma* Bonelli, 1810 group (subgenera *Adelosia* Stephens, 1835, *Metallophilus* Chaudoir, 1838, *Myosodus* Fischer von Waldheim, 1823, *Platysma*, *Plectes* Fischer von Waldheim, 1822, and *Sino-reophilus* Sciaky, 1996) in which two additional setae are present, resulting in a total of four setae on the posterior margin (DORJDEREM et al. 2020). In *P. izurusanus*, one or two additional setae were present, resulting in three or four setae on the posterior margin. As additional setae occur as a rare variation in Carabidae (e.g., MORITA 1995, ČURČIĆ et al. 2006, SASAKAWA 2023), it is considered that the additional setae in *P. izurusanus* originated from this. Because it is unlikely that differences in the numbers of a few setae on a part of the body have a significant effect on fitness, these additional setae are presumed to be neutral in terms of natural selection. In general, the fixation of neutral

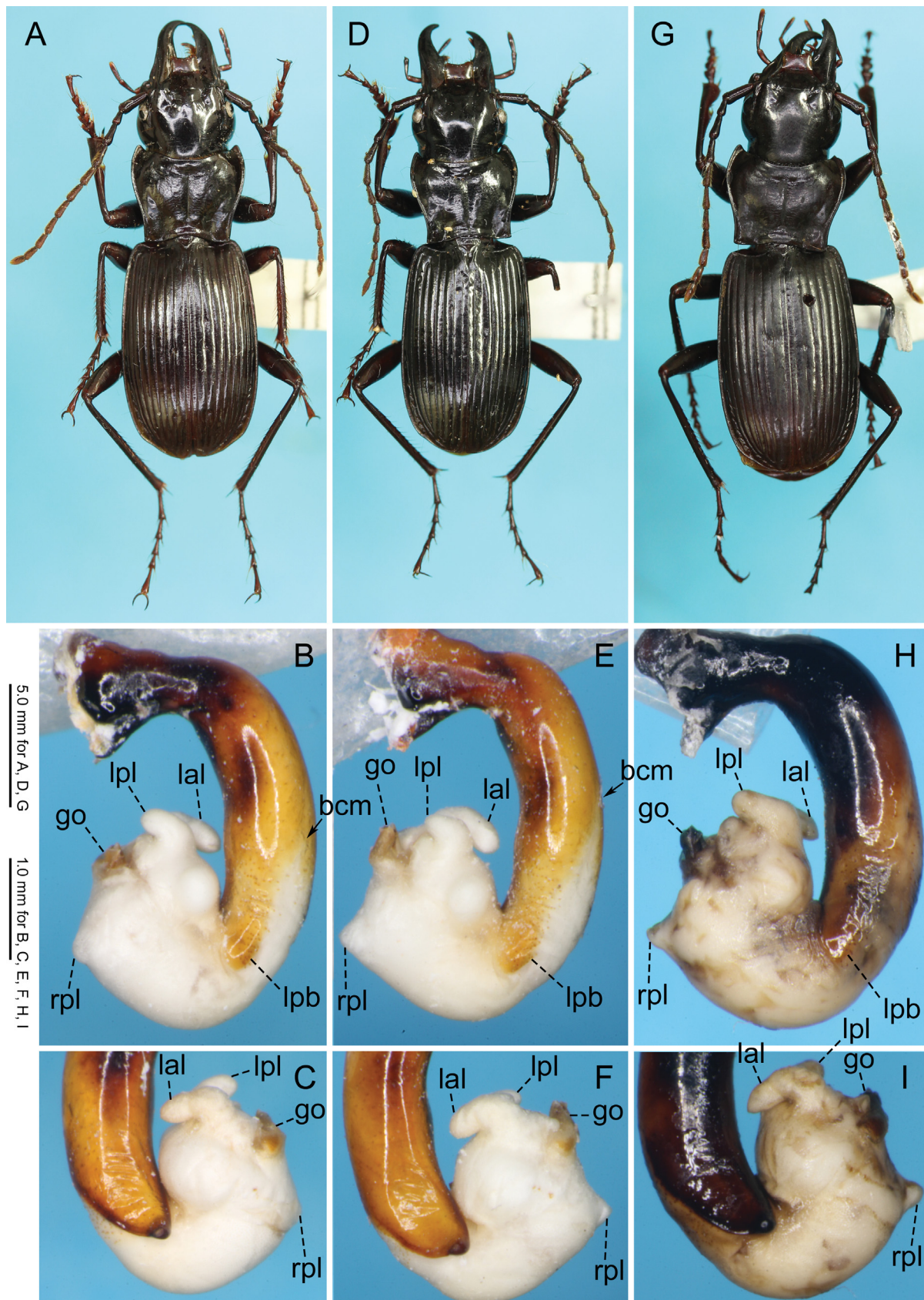


Fig. 4. *Pterostichus macrogenys* Bates, 1883, non-types: A–C – male from Yunohana (A – habitus in dorsal view; B – aedeagus with everted endophallus in left lateral view; C – aedeagus with everted endophallus (part) in right lateral view). D–F – male from Itamuro (D – habitus in dorsal view; E – aedeagus with everted endophallus in left lateral view; F – aedeagus with everted endophallus (part) in right lateral view). G–I – male from Riv. Mochigase-gawa (G – habitus in dorsal view; H – aedeagus with everted endophallus in left lateral view; I – aedeagus with everted endophallus (part) in right lateral view). Abbreviations: bcm – border between the chitinized and membranous parts at the dorsum of the aedeagus; go – gonopore; lal – left apical lobe; lpb – left pigmented band; lpl – left preapical lobe; rpl – right preapical lobe. In the male from Riv. Mochigase-gawa, the bcm could not be identified due to discoloration caused by potassium hydroxide treatment during dissection (H).

variation is more likely in small populations (genetic drift). Therefore, the presence of additional setae in *P. izurusanus* may be associated with its narrow distribution range and presumably small population size.

The obtained species phylogeny contained many polytomies, and the statistical support for the nodes was not sufficient. Nevertheless, as discussed below, together with the distribution pattern, it provides insights into the differentiation process of the new species. In the consensus phylogenetic tree, all species in the basal polytomy, including *P. izurusanus*, are distributed north of the Kanto District. Among these species, *P. izurusanus* has the southernmost and isolated distribution, and its distribution range is apparently narrow. Regarding the morphological characters used in the phylogenetic analysis, *P. izurusanus* does not possess apomorphies, implying that it retains character states similar to those of the ancestor of the *macrogenys* species group. These results contrast with those for *P. macrogenys*, which has a similar external appearance and the closest distribution to *P. izurusanus*. *Pterostichus macrogenys* is not phylogenetically related to *P. izurusanus*; it forms a polytomy with *P. gassanus* and *P. sumodakensis*, and this polytomic clade is sister to *P. ohsawacavus*. In terms of the morphological characters used in the phylogenetic analysis, *P. macrogenys* possesses three apomorphies. Considering that in the *macrogenys-gassanus-sumodakensis-ohsawacavus* clade, the distributions of the three species other than *P. macrogenys* are clustered on the Sea of Japan side around the southern Tohoku District (SASAKAWA & MITSUDUKA 2023), it is assumed that the initial differentiation of the clade occurred in that area. It is likely that the derived species *P. macrogenys* dispersed southward and came to occupy a wide distribution. Given that within this species group, species of similar body size are mutually distributed (SASAKAWA 2009, SASAKAWA et al. 2020, SASAKAWA & MITSUDUKA 2023), our results regarding species phylogeny, character evolution, and distribution patterns are consistent with the hypothesis that *P. izurusanus* originated from an ancestral species that was isolated on the ridge by the more derived, similar-sized *P. macrogenys*.

### Acknowledgements

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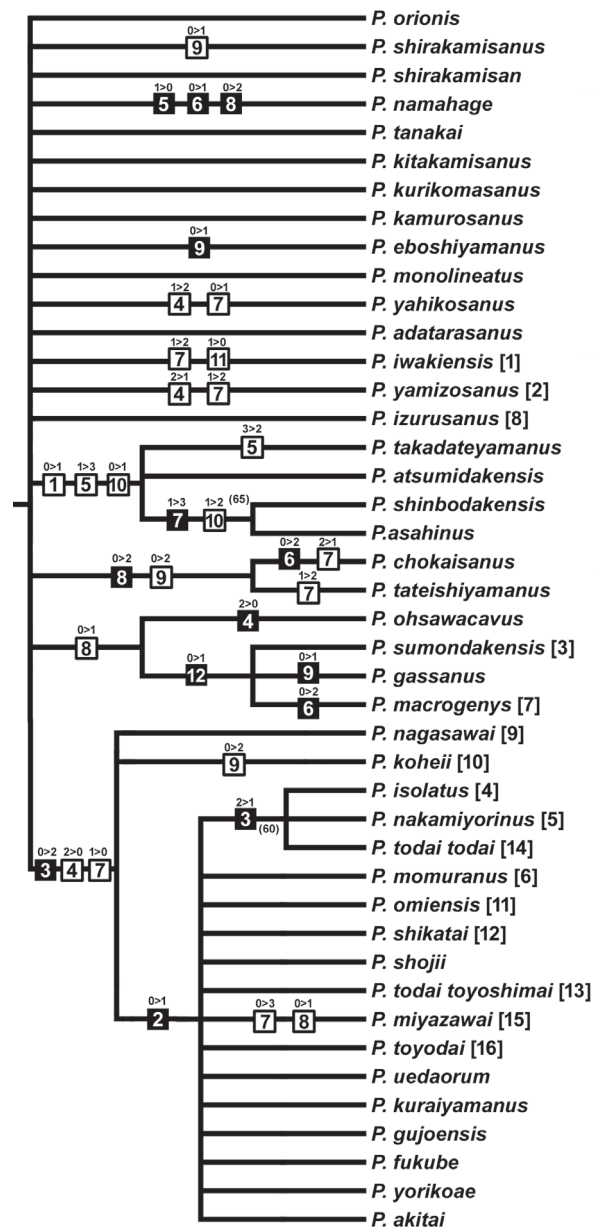


Fig. 5. The strict consensus tree of the 50 most parsimonious trees. Synapomorphies and autapomorphies are indicated by the squares on branches, where the numbers in the squares indicate character ID and numbers above the squares indicate character-state change. Black and white squares indicate “unambiguous” and “possible” apomorphies, respectively. Numbers in parentheses below the branches indicate bootstrap values (where > 50%). Numbers in square brackets after the species names indicate that the species were collected at the sites coded with the same numbers in Fig. 1.

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