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Two New Pseudoscorpion Species of the Coastal Genus *Garypus* L. Koch, 1873 (Garypidae) and an Updated Checklist of the Pseudoscorpiones of Taiwan

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Pseudoscorpions are predatory microarthropods that feed on even smaller animals, such as mites and springtails. While these organisms are generally considered terrestrial and live in the leaf litter or under barks or rocks, some pseudoscorpions live in the intertidal area, including species in the genera *Anagarypus*, *Anchigarypus*, and *Garypus* in the family Garypidae. This study describes two new species of the genus *Garypus* L. Koch from Southern Taiwan, *Garypus wilsoni* Lin & Chang sp. nov. and *Garypus sanasai* Lin, Huang & Chang sp. nov., reviews the pseudoscorpion fauna of Taiwan, and provides an updated checklist of the country. Specimens of the two new species were collected in seashore habitats and their status as new species were supported by both morphology and molecular phylogenetic analysis. Our discovery marks the first new species of pseudoscorpions reported in Taiwan since 1937, as well as the first records of the family Garypidae in Taiwan and of *Garypus* in East Asia. Moreover, the discovery of these two new species in Taiwan fills the regional distribution gap between *Garypus* in Thailand and southward and its closely related genus *Anchigarypus* in South Korea and Japan. The location where *Garypus sanasai* Lin, Huang & Chang sp. nov. was found also represents the northernmost distribution of the genus *Garypus* in the West Pacific.

Key words: Pseudoscorpion, *Garypus*, New species, Taiwan, Checklist.

BACKGROUND

Pseudoscorpions are small arachnids with a body length of about 0.1–1.0 cm (Beccaloni 2009). They feed on even smaller animals, such as springtails and mites, and prefer habitats that are warm, dark, and humid. These microscopic predators are often found under rocks and bark, or in leaf litter and soil (Weygoldt 1969; Červená et al. 2021). Additionally, a small group of species may also be found in intertidal and supratidal areas (Weygoldt 1969). Similar to species living in more terrestrial habitats, the species inhabiting the littoral area live in shaded microhabitats, which help them avoid direct sunlight, and are often recorded within rock crevices, as well as under rocks, driftwood, wrack, and fish bones (Lee 1979).

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In the pseudoscorpion family Garypidae Simon, three genera have been found inhabiting the littoral area, including *Garypus* L. Koch, *Anagarypus* Chamberlin, and *Anchigarypus* Harvey. *Anagarypus* occurs in Australia and various islands in the Indian Ocean. *Anchigarypus* used to be part of *Garypus*. Lee (1979) first divided Western America *Garypus* into the *giganteus* and *californicus* groups using morphological characters. Recently, based on the morphology and molecular phylogeny of Garypidae, Harvey et al. (2020) proposed a new genus, *Anchigarypus*, to include species formerly in the *californicus* group and one species native to Northeast Asia. The two genera are distinguished by the junction between the metatarsi and tarsi of all legs (transverse in *Garypus*, oblique in *Anchigarypus*), the absence or presence of setae within the pleural membrane (absent in *Garypus*, present in *Anchigarypus*), lateral spinules on the blades of rallum on chelicera (present in *Garypus*, absent in *Anchigarypus*), and microsetae near trichobothrium *b* (present in *Garypus*, absent in *Anchigarypus*). Currently, the genus *Anchigarypus* occurs in Japan, South Korea, southern California, and Baja California, Mexico, whereas *Garypus* has a worldwide distribution.

Pseudoscorpions rely on three mechanisms for dispersal: self-locomotion, phoresy, and rafting. Among maritime garypids, *Garypus titanius* Beier, has been reported in the guano deposits of nesting birds, and *Anchigarypus californicus* (Banks) has been found in an island with sea-bird colony. Both suggested the possibility that these species were avian dispersed (Lee 1979). Additionally, Lee (1979) found fresh driftwood with several *Anchigaypus californicus* (Banks) on a beach where the species had never been found before, and further proposed that oceanic currents play a crucial role in the dispersal of these intertidal organisms.

Composed of 35 species (Harvey 2021), the genus *Garypus* L. Koch is widespread in the tropical, subtropical, and the Northern temperate regions with a discontinuous distribution (Harvey et al. 2020). Except for *Garypus armeniacus* Redikorzev, which lives along river banks in Armenia, most of the *Garypus* species live in coastal habitats (Harvey et al. 2020; World Pseudoscorpiones Catalog 2022). In a recent review of *Garypus*, Harvey et al. (2020) revised several species in the genus, reconstructed the phylogeny of garypid genera, and provided a key to the Indo-West Pacific species of *Garypus*. They also emphasized the importance of the color pattern on the carapace in *Garypus* taxonomy. In the West Pacific, *Anchigarypus* and *Garypus* have an allopatric distribution: the former is found in the north, *i.e.*, in Japan and in South Korea, and the latter is found in the south, with Thailand being its northernmost range (Harvey et al. 2020; Harvey 2021). So far, a large gap exists in the Philippines, China, and Taiwan, as there has been no record of either genus in these countries.

Pseudoscorpion studies in Taiwan can be traced back to 1906–1907 when German entomologist Hans Sauter, who moved to Taiwan in 1905, collected specimens in Koroton, Takao, and Gyamma (current Taichung and Kaohsiung). His specimens were later deposited in the Natural History Museum in Berlin, Germany and examined by Norwegian zoologist Edvard Ellingsen. Ellingsen (1912) reported 10 species of pseudoscorpions belonging to seven genera in Taiwan, including a new species, *Cheiridiuni formosanum* (*Cryptocheiridium formosanum*), and a new "variety", *Microcreagris granulata* var. *formosana*. Kishida (1920, as cited in Kishida 1928) changed the variety to a full specific status, *Microcreagris formosana*, based on Ellingsen's description and, possibly, three female specimens he collected from Keelung and Alishan. After re-examining Sauter's specimens, Beier (1931) described a new species, *Geogarypus formosanus*. Later, Beier (1937) described a new subspecies, *Withius australasiae formosansus*, and reported that specimens of *Ideobisium formosanum* in Ellingsen (1912) were mis-identified *Microcreagris pusilla*.

After examining Taiwanese specimens deposited in Berlin, Harvey (1988) synonymized *Geogarypus formosanus* with *Geogarypus javanus*, which was later synonymized with *Geogarypus longidigitatus* (Harvey 2000). Additionally, specimens of *Chelifer brevidigitatus* in Ellingsen (1912) were reported to be mis-identified, but their true identity is unknown (Harvey 1991). Recently, Lin and Liu (2020) reported the phoretic behavior of the pseudoscorpion *Lophochernes bicarinatus* on the longhorn beetle *Batocera davidis* in Taiwan. These articles represent the only studies about the pseudoscorpion fauna of Taiwan after Beier (1937). Currently, 10 species of pseudoscorpions belonging to eight genera and eight families have been recorded (World Pseudoscorpiones Catalog 2022). These numbers are relatively low compared to those in neighboring countries, such as 68 species in Japan (World Pseudoscorpiones Catalog 2022). However, rather than low diversity, the low species richness in Taiwan, as currently documented, likely reflects the lack of research in the last 85 years.

In this study, we report two specimens of *Garypus* recently collected in seashore habitats in southern Taiwan and compile the first comprehensive checklist of the pseudoscorpion fauna of Taiwan. After comparing these specimens with similar species using both morphology and DNA barcodes, we conclude that these specimens belong to two species new to science. We describe the two new species, *Garypus wilsoni* Lin

& Chang, sp. nov. and *Garypus sanasai* Lin, Huang & Chang, sp. nov., provide detailed descriptions, photos and illustrations of the holotypes, and make the DNA barcodes of the holotypes available in GenBank.

MATERIALS AND METHODS

The specimens were collected by hand and preserved in 95% ethanol. The four legs on the left side were removed for DNA extraction. The holotype specimens are deposited in the pseudoscorpion collection of the National Taiwan University Museum of Zoology (NTUM-PSC). The specimens were examined under a Nikon SMZ800N stereo microscope equipped with a plan Apo 1x objective lens. Detailed examination was conducted under a Nikon eclipse E200 optical microscope. Photos were taken using a TOUPCAM E3ISPM12300KPA digital camera. To observe the genitalia area, the specimens were boiled in 20% proteinase K at 60°C overnight or until the genitalia area was clearly visible.

Genomic DNA was extracted from two legs of the specimens using the EasyPure Genomic DNA Spin Kit (Bioman, New Taipei City, Taiwan) or the QIAamp DNA Micro kit (Qiagen, Hilden, Germany) following the manufacturers' instructions and eluted in 50 µL elution buffer. For QIAamp DNA Micro kit, 1 µL of carrier RNA was added to buffer AL.

Polymerase chain reaction (PCR) for the mitochondrial cytochrome *c* oxidase subunit 1 (*COI*) gene was conducted using the primers LCO1490 (Folmer et al. 1994) and Chelicerate_R2 (Barrett and Hebert 2005). Amplification was carried out in 20-µL reactions under the following conditions: preheat at 95°C for 1 min; 5 cycles of 94°C for 40 sec, 45°C for 40 sec, and 72°C for 1 min; 35 cycles of 94°C for 40 sec, 51°C for 40 sec, and 72°C for 1 min; and a final extension at 72°C for 5 min (Vidergar et al. 2014). PCR products were visualized using 1.5% agarose gel electrophoresis and sequenced by Genomics (Taipei, Taiwan) using an ABI 3730X Genetic Analyzer. The sequences were assembled in Sequencher 5.4.6 and double-checked by eye. The resulting sequences were deposited into GenBank under accession numbers OL514113 and OL514114.

All *COI* sequences of *Garypus* available in GenBank were retrieved for DNA barcode analysis. Sequences of *Anagarypus australianus* and *Anchigarypus japonicus* were also retrieved and used as outgroups. Sequences were aligned using Clustal X2 (Larkin et al. 2007). The maximum likelihood tree was constructed using RAxML-HPC2 (Stamatakis 2006) with the GTR+G+I model and 1,000 bootstraps as implemented in the CIPRES Science Gateway V3.3 (Miller et al. 2010). The uncorrected *p*-distances were calculated using MEGA X (Kumar et al. 2018).

For morphological descriptions, we followed Chamberlin (1931) and Harvey (1992) for terminology and measurements. The following abbreviations were used to describe trichobothria on chela. Fixed finger: *eb*, external-basal trichobothrium; *esb*, external-subbasal trichobothrium; *est*, external-subterminal trichobothrium; *et*, external-terminal trichobohirum; *ib*, internal-basal trichobothrium; *isb*, internal-subbasal trichobothrium; *ist*, internal-subterminal trichobothrium; *it*, internal-terminal trichobothrium. Movable finger: *b*, basal trichobothrium; *sb*, subbasal trichobothrium; *st*, subterminal trichobothrium; *t*, terminal trichobothrium.

RESULTS

Checklist of the order Pseudoscorpiones of Taiwan

Family Garypidae Simon
Subfamily Garypinae Simon
Genus *Garypus* L. Koch

Garypus wilsoni Lin & Chang, sp. nov.

(Figs. 1A, 2, 3, 4A, B)
urn:lsid:zoobank.org:act:83FD87FD-B660-43F5-85AF-E00A0BB2809A

Material examined: Holotype: ♂; Checheng Township, Pingtung County, Taiwan; 22°04'59.5"N 120°42'03.4"E; coll. Bo-Xin Guo & Yi-Ting Chung; 15 Dec. 2020; GenBank: OL514114; NTUM-PSC-0001.

Etymology: The species is named after the late American biologist and naturalist Edward Osborne Wilson (1929–2021) for his dedication to island biogeography and biodiversity.

Diagnosis: The species shares some common characters with *G. necopinus* Harvey and *G. marmoratus* Mahnert with trichobothrium *st* situated midway between *sb* and *t* or slightly closer to *sb*, tooth rows not touching each other when fingers of palps are closed, tergites mostly pale yellow in color with some brown spots. The three species can be differentiated by the color pattern of carapace and the shape of the galea and rallum.

Description: Color in ethanol (Fig. 2). Chela finger red-brown, chelal hand brown, carapace and abdomen pale yellow, femur and patella of palp dark yellow, legs white, tergites VI–X mainly with 4 brown spots, 2 at lateral, 2 middle spot, tergites I–V with more brown color area near the middle spots.

Chelicera: Hand with 5 setae, movable finger with 1 distal setae; 1 lyrifissure present between interior setae and basal setae, another lyrifissure situated at the base of ventral side fixed finger; fixed finger with 7 teeth, first and 7th smaller than others, 1 tooth situated near galea on movable finger; galea (Fig. 3E) with 4 rami; serrula exterior with 29 blades, serrula interior with 20 blades; rallum with 3 blades, the basal one shortest, each blades with small lateral spinules (Fig. 3F).

Pedipalp (Fig. 3A): Mostly lightly granulated, dorsal and ventral side of fingers smooth; 2 lyrifissure situated at basal part of patella; fingers slightly curved in lateral view (Fig. 3D); *ib* and *esb* almost on the same horizontal plane, *ist* and *isb* also on the same horizontal plane, *est* to *et* as long as 1/2 distance of *est* to *isb*; *et* without adjacent patch of microsetae, with 8 microsetae near *t*, 4 microsetae clustered near both *sb* and *b*; venom apparatus present on both fingers; gaps present while fingers closed; fixed finger with 101 straight, triangular teeth, and movable finger with 85 round teeth.

Cephalothorax: Carapace triangular (Fig. 4A, B); 2 pairs of eyes, anterior eyes larger than lateral eyes; anterior and posterior furrow present; median maxillary lyrifissure situated at the 1/3 part from the apical of the

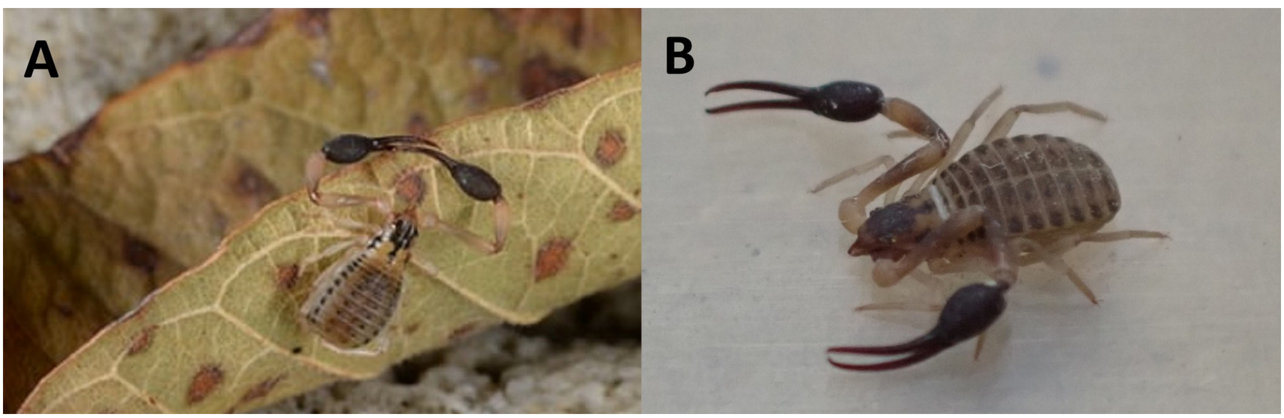

Fig. 1. Photos of the holotypes of the two new species of *Garypus*. The photos were taken when the individuals were still alive. (A) *Garypus wilsoni* sp. nov. Lin & Chang (Photo by Bo-Xin Guo and Yi-Ting Chung with permission). (B) *Garypus sanasai* sp. nov. Lin, Huang & Chang.

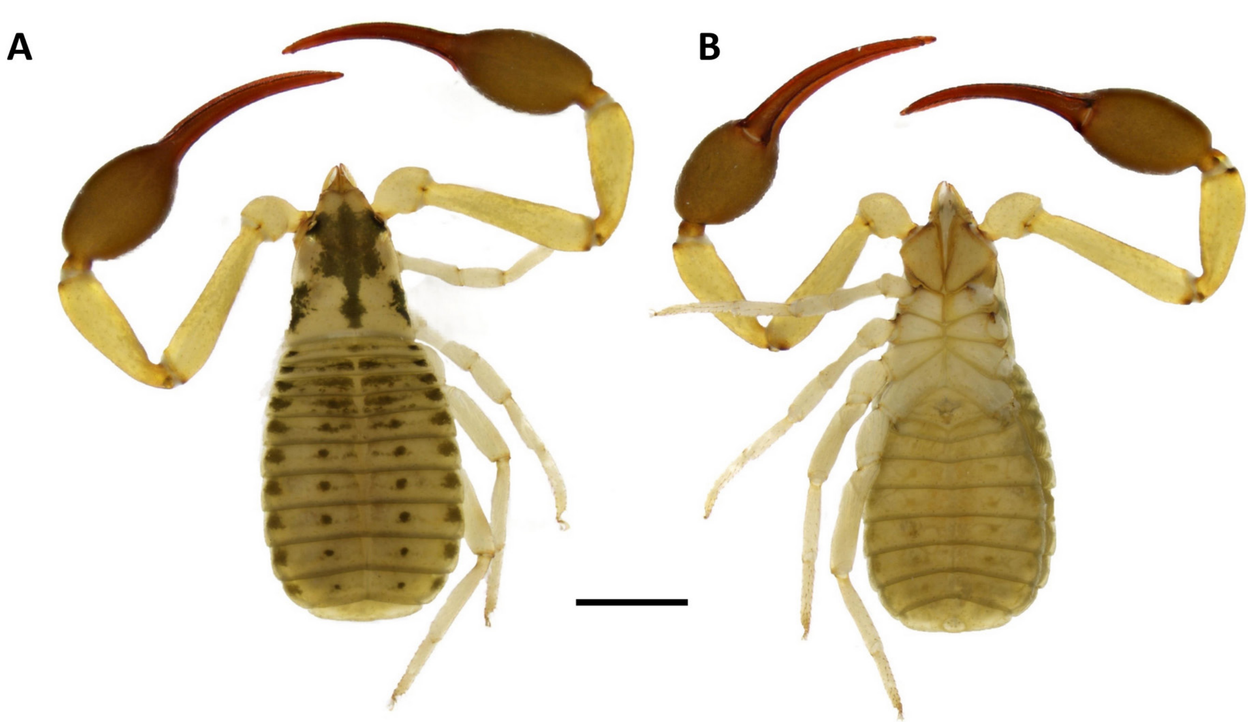

Fig. 2. *Garypus wilsoni* Lin & Chang sp. nov. (A) dorsal view, (B) ventral view. Scale bar = 1 mm.

palp coxa area; manducatory process with 5 setae, 18 setae on palp coxa; coxa setae arranged 6: 7: 12: 16.

Legs (Fig. 3B, C): Metatarsi and tarsi not fused together in all legs, transverse structure present between metatarsi and tarsi; arolium shorter than claws; leg IV femur + patella 3.91× longer than deep.

Abdomen: Tergites I–X and sternites IV–X with median suture; setal row situated at bottom of tergites and sternites, tergites V–X and sternites III–IX with many lyrifissure upon the setae row; tergites I–XII

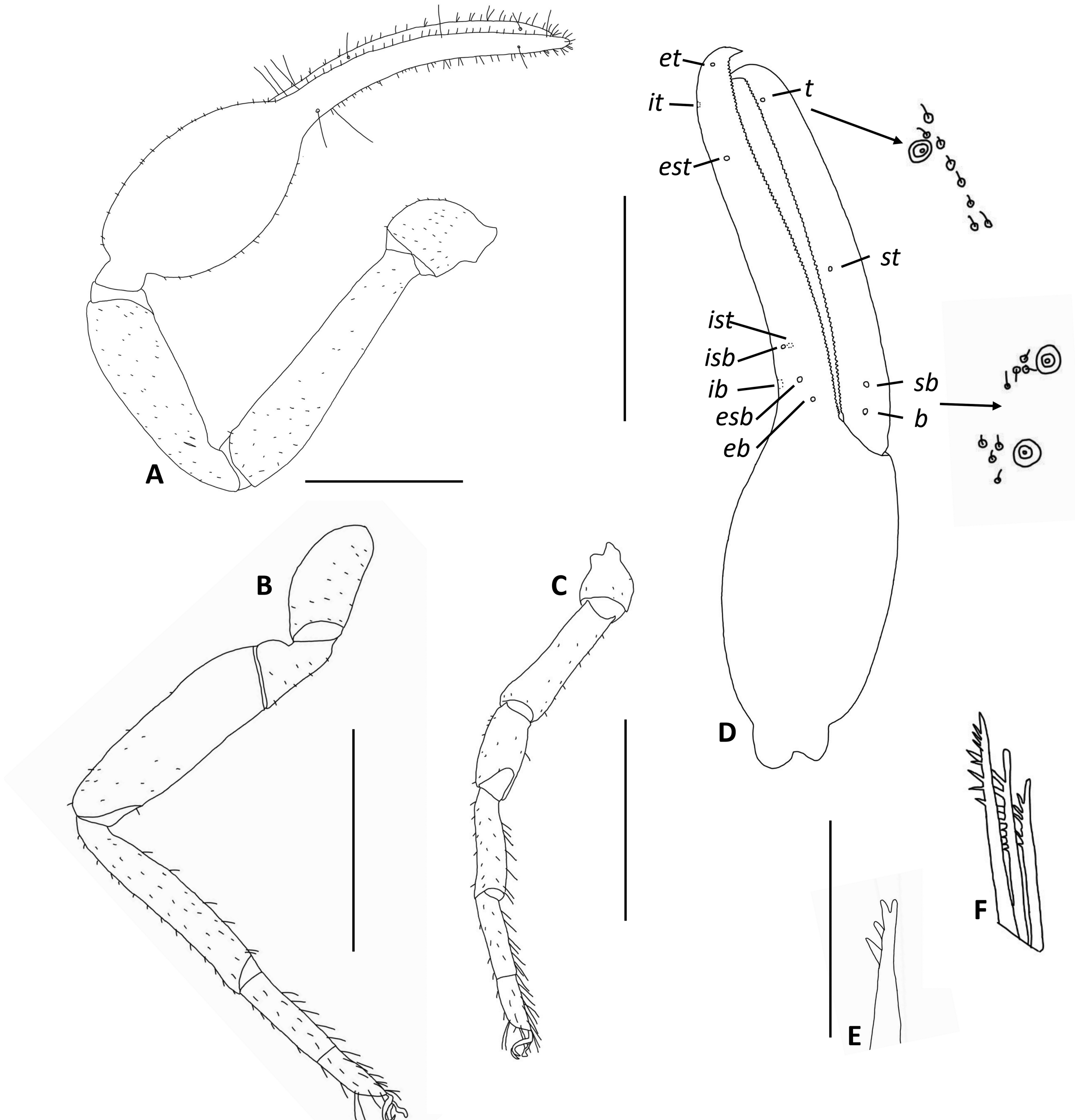

Fig. 3. *Garypus wilsoni* Lin & Chang sp. nov. (A) Dorsal view of left palp; (B) left leg IV; (C) left leg I; (D) lateral view of right palp; (E) galea of left chelicera; (F) rallum of left chelicera. Scale bars: A–D = 1 mm; E, F = 0.05 mm.

setae arranged 8: 8: 9: 9: 12: 12: 10: 14: 12: 11: 12: 2, sternites IV–XII setae arranged 9: 11: 12: 11: 12: 11: 10: 5: 2, setae on genitalia (sternite II) smaller than the setae on other sternites; pleural membrane without setae.

Genitalia: Ejaculatory duct atrium large and oval; duct of posterior dorsal gland long and bifurcate at distal with clavated shape ends; lateral genital sac long and slender; anterior genital operculum with 30 setae, posterior with 9 setae, not in a row.

Dimensions (in mm): Body length (excluding chelicerae) 4.31. Chelicera 0.34/ 0.17; movable finger length 0.31. Pedipalp: trochanter 0.68/0.44; femur 1.59/0.43; patella1.53/0.48; chela with pedicel 3.40/0.88; chela without pedicel long 3.27; hand without pedicel long 1.36; movable finger length 2.03. Carapace 1.43/1.34; anterior eye 0.16; posterior eye 0.10. Leg I: femur 0.67/0.23; patella 0.42/0.22; tibia 0.56/0.16; metatarsus 0.45/0.14; tarsus 0.31/0.11. Leg IV: femur + patella 1.29/0.33; tibia 1.09/0.18; metatarsus 0.48/0.14; tarsus 0.30/0.13.

Remarks: The specimen, a single male, was collected on the reef of the seashore area during ebb tide in the evening.

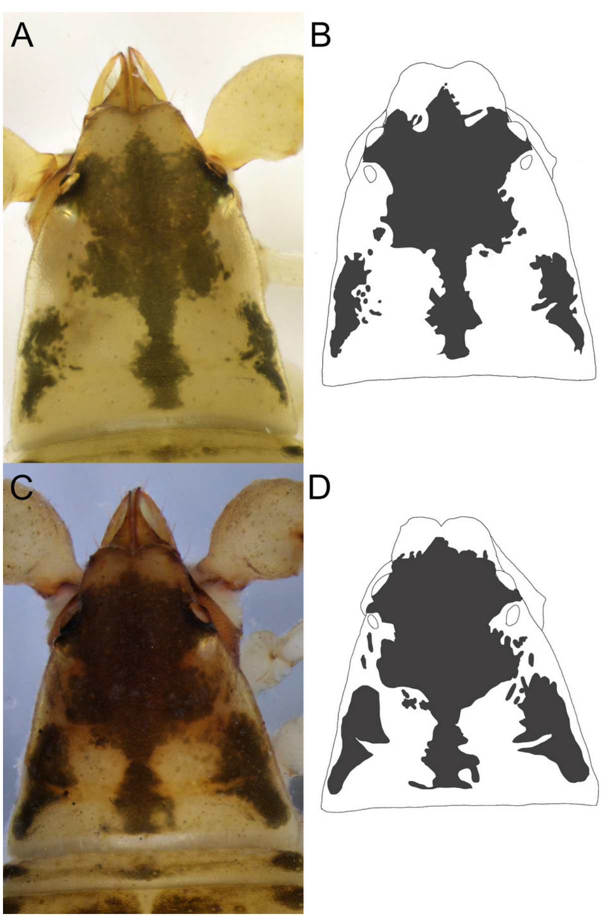

Fig. 4. Dorsal view of carapace and the comparison of color patterns of the two species. (A, B) *Garypus wilsoni* Lin & Chang sp. nov.; (C, D) *Garypus sanasai* Lin, Huang & Chang sp. nov.

Distribution: Type locality (Checheng Township, Pingtung County, Taiwan).

Garypus sanasai Lin, Huang & Chang, sp. nov.

(Figs. 1B, 4C, D, 5, 6)
urn:lsid:zoobank.org:act:3617DC34-9275-440B-AB17-B388A6E14F9E

Materials examined: Holotype: ♂; Lüdao Township, Taitung County, Taiwan; 22°38'08.1"N 121°29'55.8"E; coll. Jun-Xuan Huang; 01 Sep. 2020; GenBank: OL514113; NTUM-PSC-0002.

Etymology: The species is named after “sanasai”, a legendary name of the type locality. In the legends of many Taiwanese indigenous tribes, which are part of the Austronesian peoples, their ancestors arrived Taiwan through a way station called “sanasai”, which, some tribes believe, is Green Island (Lüdao Township). The specific epithet is a noun in apposition.

Diagnosis: The color pattern on carapace and tergites of the new species is most similar to that of *G. schwendingeri* Harvey. The new species can be differentiated from *G. schwendingeri* by the pattern of trichobothria on chela (*ist* and *isb* on the same horizontal plane in the new species, but not in *G. schwendingeri*). The species shares some common characters with *G. necopinus* Harvey and *G. marmoratus* Mahnert, with trichobothrium *st* midway between *sb* and *t* or slightly closer to *sb*, tooth rows not touching each other when fingers of palps are closed, tergites mostly pale yellow in color with some brown spots. The three species can be differentiated by the color pattern of carapace and the shape of galea and rallum. Compared to *G. wilsoni*, the color is darker than *G. wilsoni* and the color pattern of carapace is quite different on both lateral sides, also the color pattern of tergites, *G. wilsoni* with less brown color, the setae of poseterior genital operculum, *G. wilsoni* is not in a row, *ib* is situated between *isb* and *esb* in *G. sanasai*, *ib* and *esb* on the same horizontal pane in *G. wilsoni*.

Description: Color in ethanol (Fig. 5). Mostly pale yellow; pedipalp dark yellow with dark brown chela, anterior, posterolateral, and posteromedial carapace dark brown, legs pale white, tergites mostly light yellow with 4 brown spots at lateral and middle side, and with some brown color at the middle of tergites I–V.

Chelicera: Hand with 5 setae, movable finger with 1 distal setae; 1 dorsal and 1 ventral lyrifissure on the basal of fixed finger; fixed finger with 3 teeth and 4 smaller teeth, movable finger with 1 apical tooth; galea present (Fig. 6E), with 4 rami, 3 rami at distal and 1 at lateral; rallum (Fig. 6D) with 3 blades, each blade with several small lateral spinules; serrula exterior with 33 blades, serrula interior with 21 blades.

Pedipalp (Fig. 6A): Granulated in whole chela including the pedicel; Femur slender, 4.15 times longer than broad, patella 3.19 longer than broad; 2 lyrifissure situated at basal part of patella; both fingers slightly curved in lateral view (Fig. 6F), fixed finger more curved than movable; fixed finger with 8 trichobothria, movable finger with 4; *isb*, *ib*, *esb*, *eb* in a row, *ist* and *ib* in a different row, *st* much closer to *sb* than to *t*, *est* closer to *et* than *isb*, *ist* and *isb* on the same horizontal plane, *ib* between *isb* and *esb*; *et* without adjacent patch of microsetae, with 18 microsetae near *t*, and 7 microsetae between *sb* and *b*; venom apparatus present on both fingers; gaps present while fingers closed; Fixed finger with 116 straight round teeth, movable finger with 89 teeth, 37 round and small teeth at the basal part, 52 retrose triangular teeth at the distal part, a gap present between 37th and 38th tooth.

Cephalothorax: Triangular carapace (Fig. 4C, D); 2 pairs of eyes; anterior and posterior furrow present, posterior furrow clearer than the anterior; the manducatory process with 5 apical setae, 10 setae on palp coxa; coxa I–IV setae arranged: 5:8:10:17.

Legs (Fig. 6B, C): Metatarsi and tarsi not fused together in all legs, metatarsi slightly longer than tarsus in Leg I, but same length in Leg IV, transverse structure present between metatarsi and tarsi.

Abdomen. Tergites I–X and sternites I–X with median structure; setae at the bottom of each tergites; color pattern of tergites related to the presence of the setae; tergites I–XII setae arranged 6: 12: 11: 13: 9: 11: 11: 6: 7: 11: 8: 2, sternite IV–XII setae arranged 9: 10: 11: 12: 14: 12: 12: 4: 2; setae on genitalia (sternite II) smaller than the setae on other sternites, the setae at bottom - middle of sternite largest; Pleural membrane without setae.

Genitalia: Not visible after incubation in Proteinase K for two days, 36 setae and 2 lyrifissure on anterior genital operculum, posterior with 9 setae in a row.

Dimensions (in mm): Body length (excluding chelicerae) 4.71. Chelicera 0.47/0.26; movable finger length 0.38. Pedipalp: trochanter 0.70/0.505; femur 1.66/0.40; patella 1.47/0.46; chela with pedicel 3.21/0.83; chela without pedicel 3.07 long; hand without pedicel 1.22 long; movable finger length 2.02. Carapace 1.36/1.40; anterior eye 0.14; posterior eye 0.12. Leg I: femur 0.80/0.23; patella 0.46/0.23; tibia 0.63/0.17; metatarsus 0.38/0.12; tarsus 0.32/0.10. Leg IV: femur + patella 1.40/0.32; tibia 1.10/0.16; metatarsus 0.45/0.15; tarsus 0.45/0.15.

Remarks: Green Island is a volcanic island located about 33 km east of Taiwan and covers an area of about 16 km^2. The coasts on the island are mostly formed by coral reef and are scattered with stretches of sandy beaches. The specimen of *Garypus sanasai* was found in Ziping. Located in the southernmost part of the island, Ziping is a tidal pool and the most complete lagoon on Green Island. The beach of the lagoon is formed by

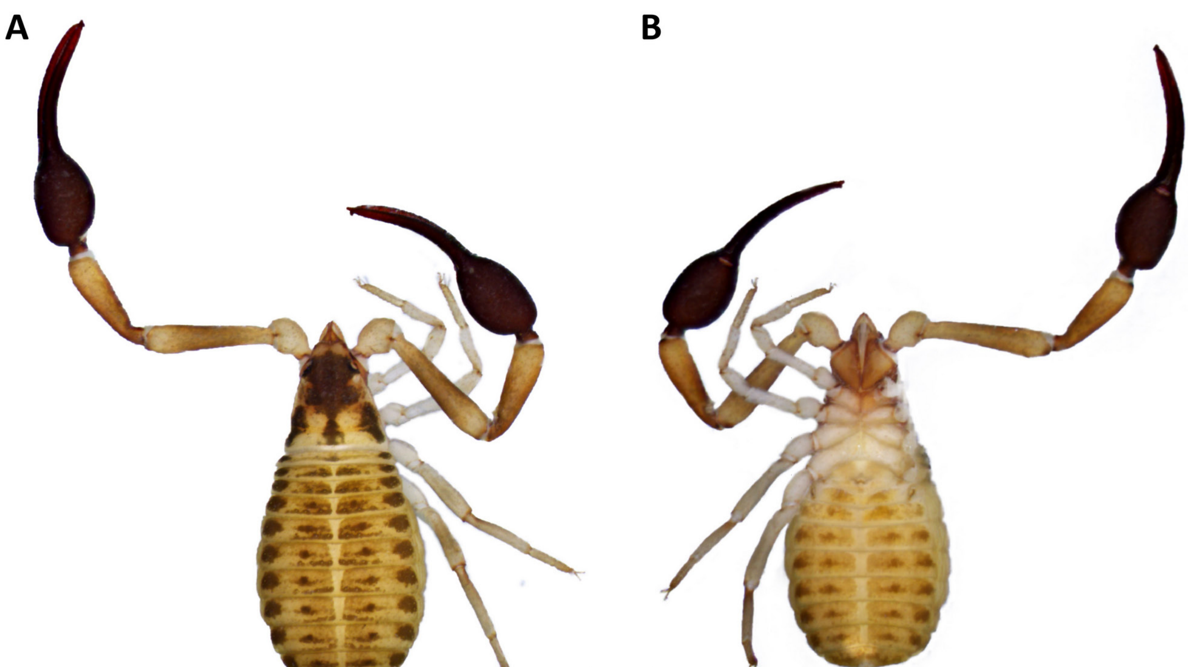

Fig. 5. *Garypus sanasai* Lin, Huang & Chang sp. nov. (A) dorsal view; (B) ventral view. Scale bar = 1 mm.

finely divided coral reefs, on which are small patches of the low-growing plant "Reef Pemphis" (*Pemphis acidula* JR Forst and G Forst). The coral reef beach was scattered with stones about 7 cm in radius. The new species was found hiding under one of them. The individual kept its palps and legs close to its body and did not move when the stone was removed, probably to avoid being detected. No other animals were found under the same stone. After searching for other similar-sized stones nearby, no other pseudoscorpions were

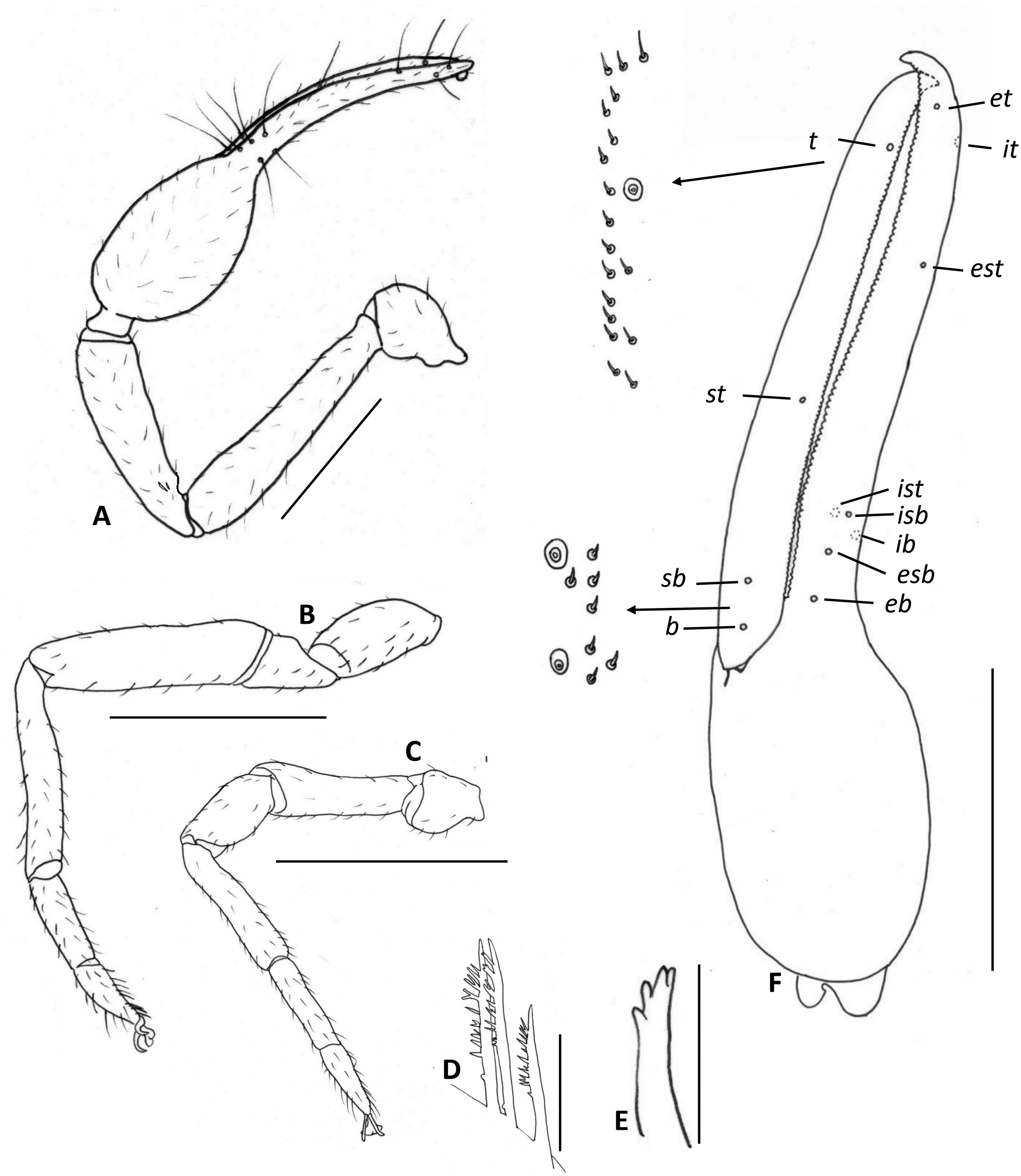

Fig. 6. *Garypus sanasai* Lin, Huang & Chang sp. nov. (A) dorsal view of left palp; (B) left leg IV; (C) left leg I; (D) rallum of left chelicera; (E) galea of left chelicera; (F) lateral view of right palp. Scale bars: A–D = 1 mm; E, F = 0.05 mm.

found.

Distribution: Type locality (Green Island, Taitung County, Taiwan).

Family Cheiridiidae Hansen
Genus *Cryptocheiridium* Chamberlin

Cryptocheiridium formosanum (Ellingsen, 1912)

Cheiridiuni formosanum Ellingsen 1912: 123–125.
Cryptocheiridium formosanum (Ellingsen 1912): Chamberlin 1931: 238.

Remarks: Endemic to Taiwan. The type locality of the species is Kaohsiung (Takao).

Family Cheliferidae Risso
Genus *Lophochernes* Simon

Lophochernes bicarinatus Simon, 1878
(Fig. 7C)

Chelifer bicarinatus (Simon 1878): Ellingsen 1912: 122.
Lophochernes bicarinatus Simon 1878: Beier 1932: 243–244, figs. 250–251.

Remarks: The first record was in Kaohsiung (Takao). The species is common under the bark. This species has been reported to be phoretic on the longhorn beetle *Batocera davidis* in Taiwan (Lin and Liu 2020).

Family Chernetidae Menge
Genus *Ochrochernes* Beier

Ochrochernes galatheae (With, 1906)

Chelifer galatheae With 1906: Ellingsen 1912: 122.
Ochrochernes galatheae (With 1906): Beier 1932: 127–128.

Remarks: The first record of the species in Taiwan was in Taichung (Karoton) with 1 specimen (Ellingsen 1912), after being first recorded from India.

Family Chthoniidae Daday
Genus *Tyrannochthonius* Chamberlin

Tyrannochthonius japonicus (Ellingsen, 1907)
(Fig. 7D)

Chthonius japonicus Ellingsen 1907: Ellingsen 1912: 128.
Tyrannochthonius japonicus (Ellingsen 1907): Beier 1932: 66.

Remarks: The species was first recorded in Kaohsiung (Takao) and Taichung (Koroton), common in the leaf litter. It was originally described from Japan.

Family Geogarypidae Chamberlin
Genus *Geogarypus* Chamberlin

Geogarypus longidigitatus (Rainbow, 1897)
(Fig. 7A, B)

Garypus javanus Tullgren 1905: Ellingsen 1912: 122.
Geogarypus formosanus Beier 1931: 315–316, fig. 10.
Geogarypus longidigitatus (Rainbow 1897): Harvey 2000: 377–383.

Remarks: Harvey first synonymized *Geogarypus formosanus* with *Geogarypus javanus* after examining Taiwanese specimens deposited in Berlin (Harvey 1988) and later synonymized *Geogarypus javanus* with *Geogarypus longidigitatus* (Harvey 2000). The species was first recorded in Kaohsiung (Takao), and can be found under the bark and in leaf litter.

Family Neobisiidae Chamberlin
Genus *Microcreagris* Balzan

Microcreagris pusilla Beier, 1937

Ideobisium formosanum Ellingsen 1912: 125–127.
Microcreagris pusilla Beier 1937: 268–269.

Remarks: The type locality of the species is in Feng-yuan (Karoton), Taichung City. Common in the leaf litter.

Microcreagris formosana Ellingsen, 1912

Microcreagris granulata formosana Ellingsen 1912: 127–128.
Microcreagris formosana Kishida 1928: 411–412.

Remarks: Common in the leaf litter. The type locality of the species was in Kaohsiung (Takao and Gyamma). Ćurčić (1983) and Harvey (1999) revised the Asian species of *Microcreagris* and transferred some species into *Bisetocreagris* Ćurčić, 1983. However, their revisions did not include the two Taiwanese species, *M. pusilla* and *M. formosana*. Whether these species belong to *Microcreagris* or *Bisetocreagris* still needs further research. *M. formosana* was first described as a variety of *Microcreagris granulata*. Kishida (1920, as cited in Kishida 1928) later erected the specimens from Taiwan to a full specific status, *Microcreagris formosana.*

Family Olpiidae Banks
Genus *Olpium* L. Koch

Olpium jacobsoni Tullgren, 1908

Olpium longiventer L. Koch and Keyserling 1885: Ellingsen 1912: 125 (misidentification).

Olpium jacobsoni Tullgren 1908: Beier 1932: 183–184.

Remarks: The species was first recorded in Kaohsiung (Takao), after being first recorded from Indonesia.

Family Withiidae Chamberlin
Genus *Withius* Kew

Withius australasiae formosanus (Beier, 1937)

Allowithius australasiae formosanus Beier 1937: 275–276, fig. 6.
Withius australasiae formosanus (Beier 1937): Harvey 1991: 659.

Remarks: The type locality of the subspecies is in Kaoshiung (Takao).

Withius piger (Simon, 1878)

Chelifer subruber Simon 1878: Ellingsen 1912: 122.

Remarks: The species was first recorded in Kaohsiung (Takao) (Ellingsen 1912). It is a cosmopolitan species.

Phylogenetic analysis of *Garypus*

The maximum likelihood analysis based on the *COI* gene suggested that the two new species are closely related (Fig. 8). The *COI* *p*-distance is 7.2% between the two new species, *G. wilsoni* and *G. sanasai* (Table 1). This value is comparable to the interspecific distances between *G. latens* and *G. malgaryungu* (6.9–7.2%) and between *G. dissitus* and *G. malgaryungu* (7.9–8.1%). The values are 12.7–16.9% between Taiwanese species and Australian species, and 15.6–17.3% between Taiwanese species and species in the Mediterranean region.

DISCUSSION

This study represents the first addition to the pseudoscorpion fauna of Taiwan since 1937 (Beier 1937) and the first report of *Garypus* in East Asia. It extends the known distribution of the genus northward in the West Pacific region, and fills a gap regarding the distribution of *Garypus* and *Anchigarypus*. In

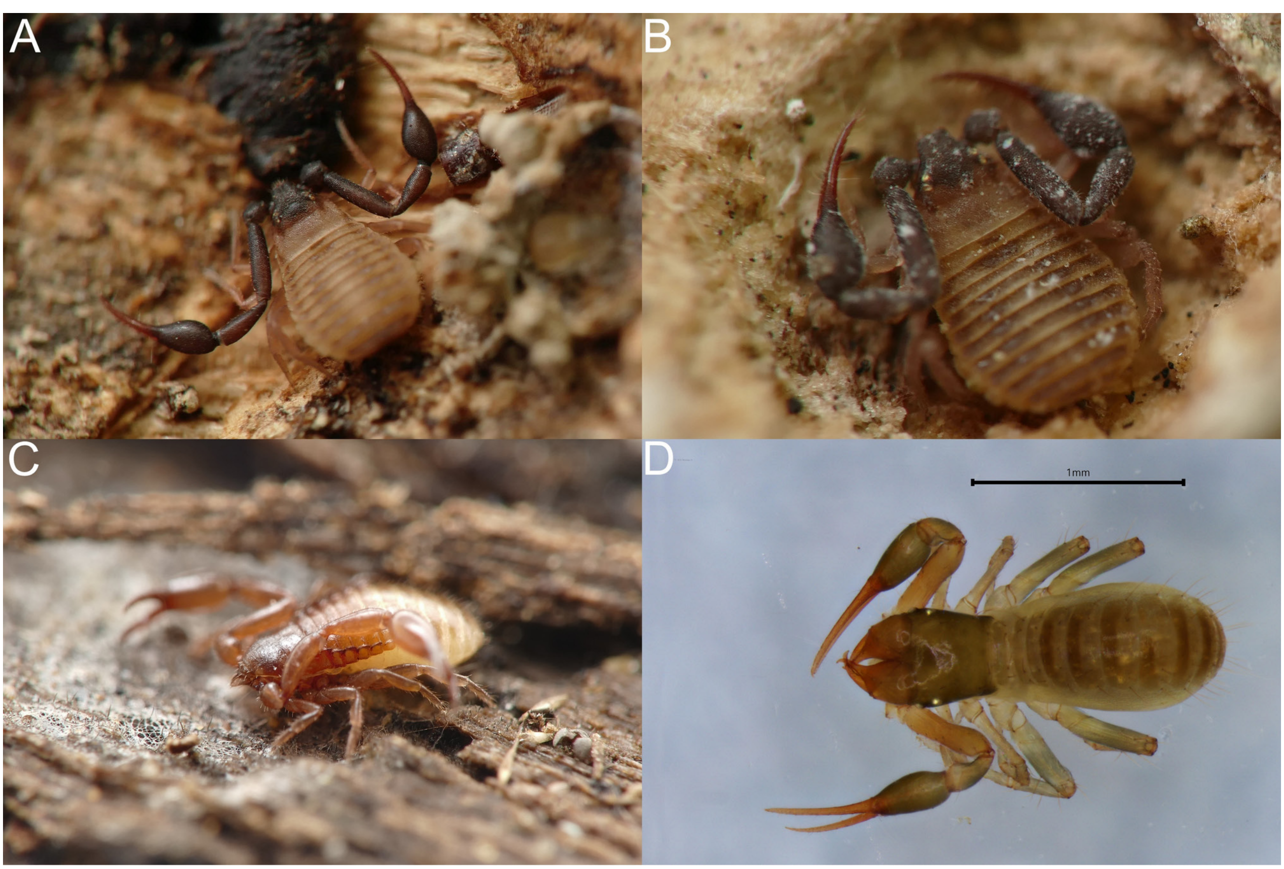

Fig. 7. Pseudoscorpions of Taiwan. (A) and (B) *Geogarypus longidigitatus* (Rainbow), Dec. 13, 2019, Beitou, Taipei, Taiwan; (C) *Lophochernes bicarinatus* Simon, Dec. 21, 2020, Beitou, Taipei, Taiwan; (D) *Tyrannochthonius japonicus*, Oct. 21, 2020, Taman Mt. Taoyuang, Taiwan.

Western America, the distributions of the two genera overlap in Baja California, Mexico. However, they do not co-occur in the same habitat (Lee 1979). In East Asia, *Anchigarypus* is found in South Korea and Japan. Further south in Taiwan, only *Garypus* has been reported. It is intriguing whether the distributions of the two genera would overlap in Taiwan as they do in Baja California.

Harvey et al. (2020) underscored the importance of the color patterns of carapace and tergites in distinguishing *Garypus* species and suggested that illustrations, photos, and/or descriptions of these characters need to be provided when describing new species (Harvey et al. 2020). In our study, both morphological characters and molecular data support the two new species. In accordance with Harvey et al.'s (2020) suggestions, the two new species can be unambiguously distinguished by the aforementioned color patterns. Moreover, the *COI* *p*-distance between the two species is within the range of interspecific distances in *Garypus* estimated in Harvey et al. (2020) and in our study. As in several recent studies (Ohira et al. 2018; Muster et al. 2021), our results highlight the importance of explicitly reporting DNA barcodes (*COI* sequences) from type specimens in facilitating the discovery of new species and, potentially, in expediting the biodiversity research of Pseudoscorpiones.

CONCLUSIONS

Pseudoscorpions are a poorly studied group of arachnids in Taiwan and globally. The description of two new maritime species of the genus *Garypus* in this study marks the first record of the family Garypidae in Taiwan and the first record of the genus *Garypus* in East Asia. The discovery makes Taiwan the northernmost known distribution of the genus, and a potential contact zone between *Garypus* and *Anchigarypus* in the West Pacific region. The detailed checklist of pseudoscorpions of Taiwan and the description of two new species, the first addition to the pseudoscorpion fauna of Taiwan in 85 years, serve as a starting point for future taxonomic, biodiversity, and biogeographical research in and concerning the country.

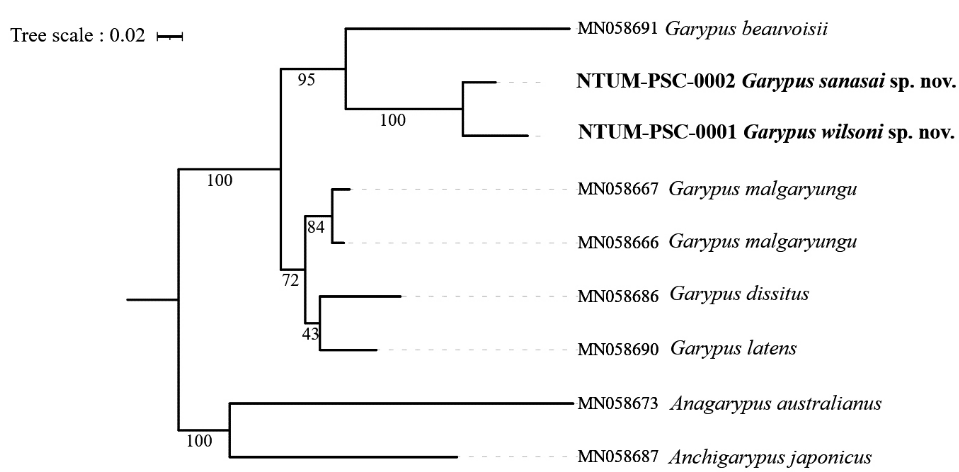

Fig. 8. Maximum likelihood tree of the genus *Garypus*. The tree was based on all mitochondrial *COI* sequences available in GenBank and newly acquired sequences from the two new species, and was rooted using *Anagarypus* and *Anchigarypus*. Numbers around nodes are bootstrap values.

Table 1. Uncorrected *p*-distance between *Garypus* specimens based on the *COI* gene

	MN058686 *G. dissitus*	MN058691 *G. beauvoisii*	MN058690 *G. latens*	MN058667 *G. malgaryungu*	MN058666 *G. malgaryungu*	NTUM-PSC-0002 *G. sanasai*
MN058691 *G. beauvoisii*	0.173					
MN058690 *G. latens*	0.087	0.159				
MN058667 *G. malgaryungu*	0.079	0.143	0.069			
MN058666 *G. malgaryungu*	0.081	0.152	0.072	0.021		
NTUM-PSC-0002 *G. sanasai*	0.147	0.156	0.135	0.133	0.127	
NTUM-PSC-0001*G. wilsoni*	0.157	0.173	0.169	0.151	0.148	0.072

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Availability of data and materials: Type specimens are deposited in the pseudoscorpion collection of the National Taiwan University Museum of Zoology (NTUM-PSC). DNA sequences are available in GenBank under accession numbers OL514113 (*Garypus sanasai* sp. nov.) and OL514114 (*Garypus wilsoni* sp. nov.).

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