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**Redescription of five *Parasteatoda* species and one
Campanicola (Araneae: Theridiidae) species from
Taiwan**
**臺灣產五種擬肥腹蛛屬 (*Parasteatoda*)
和一種吊鐘姬蛛屬 (*Campanicola*)
之重新描述**

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Abstract

This paper redescribes five species of *Parasteatoda* Archer, 1946 and one species of *Campanicola* Yoshida, 2015 from Taiwan. Among these species, four *Parasteatoda* species are reported in Taiwan for the first time, namely *P. asiatica* (Bösenberg and Strand 1906), *P. culicivora* (Bösenberg and Strand 1906), *P. ducta* (Zhu 1998), and *P. transipora* (Zhu and Zhang 1992). Furthermore, the male of *P. quadrimaculata* (Yoshida *et al.* 2000) is described for the first time. On the other hand, we report the rediscovery of *Campanicola ferrumequina* (Bösenberg and Strand 1906). Both sexes of the aforementioned species are redescribed and photographed in order to facilitate future taxonomic studies of Taiwanese spiders.

Key words: *Parasteatoda*, *Campanicola*, Theridiidae, new record, Taiwan

摘要

本文重新描述臺灣產五種擬肥腹蛛 (*Parasteatoda*) 和一種吊鐘姬蛛 (*Campanicola*)。其中，四種擬肥腹蛛屬為臺灣的新紀錄種：*Parasteatoda asiatica* (Bösenberg and Strand 1906)、*Parasteatoda culicivora* (Bösenberg and Strand 1906)、*Parasteatoda ducta* (Zhu 1998) 和 *Parasteatoda transipora* (Zhu and Zhang 1992)。另外，我們提供了四斑擬肥腹蛛 *Parasteatoda quadrimaculata* (Yoshida *et al.* 2000) 的雄性個體的首次形態描述。而另外一方面，我們重新紀錄 *Campanicola ferrumequina* (Bösenberg and Strand 1906) 存在於臺灣。上述所有物種之雄性與雌性皆重新描述及提供標本影像以促進未來臺灣產蜘蛛之分類學研究。

關鍵詞：擬肥腹蛛屬、吊鐘姬蛛屬、姬蛛科、新紀錄、臺灣

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Introduction

The genus *Parasteatoda* Archer, 1946 represents a group of comb-footed spiders with 43 species distributed across Asia, Europe, and New Guinea (World Spider Catalog 2023). Yoshida (2015) reclassified some species from *Parasteatoda* into a new genus, *Campanicola*, predominantly occurring in Taiwan and China (World Spider Catalog 2023). Currently, six *Parasteatoda* species and three *Campanicola* species are recorded in Taiwan (Yoshida 2015). Through our collection and examination of specimens of these genera, we discovered four new records of *Parasteatoda* in Taiwan, namely *P. asiatica* (Bösenberg and Strand 1906), *P. culicivora* (Bösenberg and Strand 1906), *P. ducta* (Zhu 1998), and *P. transipora* (Zhu and Zhang 1992). Additionally, the male of *P. quadrimac-*

ulata (Yoshida *et al.* 2000) is described for the first time. Chu and Okuma (1974) and Chen (1996) documented the occurrence of *C. ferrumequina* (Bösenberg and Strand 1906) in Taiwan, but Yoshida (2015) contended that these records were cases of misidentification, thus dismissing the species' existence on the island. Recently, we managed to re-discover Taiwanese populations of *C. ferrumequina*, confirming its occurrence in Taiwan. In summary, five *Parasteatoda* species and one *Campanicola* species from Taiwan are discussed, and both sexes of the aforementioned species were redescribed in this paper.

Materials and methods

The specimens were collected by sweep nets or through visual searches in their habitats (rock walls, trees, grasses

and artificial structures) in Taiwan. All specimens were preserved in 70% ethanol and deposited at National Chung Hsing University. Specimens were examined, measured, and photographed using a Nikon SMZ800N microscope with SAGE VISION SGview (SAGE VISION Co., Ltd.). Genital photos of the specimens were taken by a Leica M205C microscope with the Focus Stacking Automatic Microphotograph System (TORI FOCUS). Multifocal plane images were stacked using Helicon Focus version 7.5.1 (Helicon Soft Ltd.). The epigynum of females was dissected and cleaned in a warm 10% KOH solution to examine its inner genital structure.

All measurements are given in millimeters (mm). The measurements of the legs were shown as: total length (femur, patella and tibia, metatarsus, tarsus). Abbreviations used in this paper were: ALE, anterior lateral eye; AME, anterior median eye; PLE, posterior lateral eye; PME, posterior median eye; C, conductor; CD,

copulatory duct; CP, copulatory pore; Cy, cymbium; E, embolus; FD, fertilization duct; S, spermatheca; St, subtegulum; T, tegulum; Ti, tibia.

Results

Campanicola ferrumequina (Bösenberg and Strand 1906)

(Fig. 1)

Theridion ferrum-equinum: Bösenberg and Strand, 1906, p. 139, pl. 12, f. 261.

Theridion ferrumequinum: Saito, 1959, p. 70, f. 65A–C; Chu and Okuma, 1974, p. 39.

Achaeearanea ferrumequina: Yoshida, 1983, p. 40 (Transferred from *Theridion*); Yaginuma, 1986, p. 34, f. 19.8; Chen, 1996, p. 126; Zhu, 1998, p. 99, f. 56A–C; Song, Zhu and Chen, 1999, p. 90, f. 39G–H; Yoshida, 2000, p. 140, f. 4–7; Namkung, 2003, p. 87, f. 13.3a–b; Yoshida, 2003, p. 102, f. 250–253, 574; Yin *et al.*, 2012, p. 255, f. 84a–e.

Parasteatoda ferrumequina: Yoshida, 2008, p. 39 (Transferred from *Achaeara-*

nea); Yoshida, 2009, p. 382, f. 258–259.

Campanicola ferrumequina: Yoshida, 2015, p. 33 (Transferred from *Parastematoda*); Li *et al.*, 2021, p. 101, f. 4A–H, 5A–F, 6A–C. Kim, 2021, p. 29.

Specimens examined. 1♂, 2♀♀ (ABARA_03587–03589), 20 Jan. 2022, Chang-Lin Chung leg., Nanan Waterfall, Zhuoxi Township, Hualien County; 4♀♀ (ABARA_04310–04313), 23 Jul. 2022, Kuang-Ping Yu leg., Fuyuan National Forest Recreation Area, Ruisui Township, Hualien County.

Diagnosis. This species is similar to *C. tanakai* Yoshida, 2015 in body shape, coloration and shape of palp organ. *C. ferrumequina* can be distinguished from the latter by a horseshoe-shaped epigynum (in contrast to the two brackets-like structures in *C. tanakai*), shorter and doubly twisted copulatory ducts (longer and twisted four times in *C. tanakai*), and conductor of male palp organ moderately

curved (largely curved in *C. tanakai*).

Description Female (ABARA_04310). Body length 2.32. Carapace length 1.04, width 0.87. Abdomen length 1.47, width 1.30, height 1.19. Leg formula: I, IV, II, III. Leg I 4.16 (1.33, 1.29, 0.96, 0.58). Leg II 3.12 (1.02, 0.96, 0.63, 0.51). Leg III 2.42 (0.78, 0.72, 0.50, 0.42). Leg IV 3.54 (1.11, 1.07, 0.81, 0.55). Diameters of eyes: AME 0.10, ALE 0.10, PME 0.10, PLE 0.10. Interdistances of eyes: AME-AME 0.02, AME-ALE 0.04, PME-PME 0.08, PME-PLE 0.03. Clypeus height 0.16. Carapace oval, yellowish brown, with a circular thoracic groove. Chelicerae, maxillae and labium yellowish brown. Sternum yellowish brown with marginal black flecks. Legs yellowish brown with indistinct dusky rings. Dorsum of abdomen black with circular and lineate white pigments. Venter of abdomen grayish brown with blackish flecks and white pigments. Spinnerets surrounded with blackish ring (Fig. 1a–c).

Epigynum horseshoe-shaped. Copulatory ducts thin and long, twisted twice (Fig. 1d–e).

Male (ABARA_03589). Body length 2.30. Carapace length 1.10, width 1.01. Abdomen length 1.54, width 1.15, height 1.19. Leg formula: I, II, IV, III. Leg I 5.06 (1.62, 1.60, 1.16, 0.68). Leg II 3.69 (1.20, 1.17, 0.78, 0.54). Leg III 2.62 (0.86, 0.78, 0.54, 0.44). Leg IV 3.60 (1.26, 1.23, 0.70, 0.41). Diameters of eyes: AME 0.10, ALE 0.10, PME 0.10, PLE 0.10. Interdistances of eyes: AME-AME 0.03, AME-ALE 0.04, PME-PME 0.07, PME-PLE 0.04. Clypeus height 0.17. Coloration similar to female (Fig. 1f–h). Conductor tip long and curved, with helical lines (Fig. 1i–k).

Distribution. Taiwan (Hualien), China, Japan, Korea.

Remarks. *C. ferrumequina* was previously recorded in Taiwan by Chu and

Okuma (1974) and Chen (1996). However, Yoshida (2015) suggested that these records seem to be cases of misidentification. He regarded specimens from Taiwan as belonging to other *Campanicola* species, leading to the conclusion that *C. ferrumequina* is not distributed in Taiwan. Contrary to this, we rediscovered this species in Hualien County.

Parasteatoda asiatica (Bösenberg and Strand 1906)

(Fig. 2)

Achaea asiatica: Bösenberg and Strand, 1906, p. 148, pl. 12, f. 278.

Achaeearanea asiatica: Yaginuma, 1986, p. 33, f. 19.7; Zhu, 1998, p. 96, f. 56A–E; Yoshida, 2000, p. 143, f. 14–16; Namkung, 2003, p. 92, f. 13.8a–b; Yoshida, 2003, p. 105, f. 260–262; Yin *et al.*, 2012, p. 246, f. 77a–g.

Achaeearanea asiaticus: Song, Zhu and Chen, 1999, p. 86, f. 38C–D, K–L.

Parasteatoda asiatica: Yoshida, 2008, p. 39 (Transferred from *Achaeearanea*);

Yoshida, 2009, p. 382, f. 250–251; Kim, 2021, p. 99, f. 41A–I.

Specimens examined. 1 ♀ (ABARA_04653), 02 Sep. 2022, 2 ♂♂, 2 ♀♀ (ABARA_04701–04704), 01 Nov. 2022, Yu-Ming Huang leg., Tianzi Village, Zhushan Township, Nantou County.

Diagnosis. This species is similar to males of *Nihonhimea japonica* (Bösenberg and Strand 1906) in body shape and coloration. *P. asiatica* can be distinguished from the latter by the S-shaped copulatory ducts of females (larger copulatory pore and curved copulatory ducts in *N. japonica*), and the conductor tip of the male palp organ has a twist (without a twist in *N. japonica*).

Description. Female (ABARA_04653). Body length 2.06. Carapace length 0.84, width 0.71. Abdomen length 1.35, width 1.19, height 1.25. Leg formula: I, IV, II, III. Leg I 3.35 (1.01, 0.99, 0.86, 0.49).

Leg II 2.91 (1.03, 0.82, 0.64, 0.42). Leg III 2.09 (0.63, 0.56, 0.50, 0.40). Leg IV 3.19 (0.98, 0.96, 0.78, 0.47). Diameters of eyes: AME 0.08, ALE 0.08, PME 0.08, PLE 0.08. Interdistances of eyes: AME-AME 0.08, AME-ALE 0.03, PME-PME 0.09, PME-PLE 0.03. Clypeus height 0.11. Carapace oval, orange; eye region black. Chelicerae, maxillae, labium and sternum orange. Pedipalps orange; tibia, metatarsi and tarsi brown. Legs orange; patella, tibia, metatarsi and tarsi brown. Abdomen yellow, with blackish and whitish flecks. Spinnerets surrounded with two blackish spots (Fig. a–c). Epigynum orange. Copulatory ducts S-shaped (Fig. 2d–e).

Male (ABARA_04701). Body length 1.69. Carapace length 0.85, width 0.69. Abdomen length 0.98, width 0.72, height 0.77. Leg formula: I, II, IV, III. Leg I 3.93 (1.22, 1.19, 1.01, 0.51). Leg II 2.64 (0.82, 0.80, 0.62, 0.40). Leg III 1.98 (0.65, 0.55, 0.42, 0.36). Leg IV 2.71

(0.87, 0.81, 0.63, 0.40). Diameters of eyes: AME 0.08, ALE 0.08, PME 0.08, PLE 0.08. Interdistances of eyes: AME-AME 0.07, AME-ALE 0.03, PME-PME 0.08, PME-PLE 0.04. Clypeus height 0.11. Coloration similar to female (Fig. 2f–h). Conductor tapering to tip (Fig. 2i–k).

Distribution. Taiwan (Nantou), China, Japan, Korea.

Parasteatoda culicivora (Bösenberg and Strand 1906)

(Fig. 3)

Theridion culicivorum: Bösenberg and Strand, 1906, p. 143, pl. 12, f. 297.

Achaearanea culicivorum: Yoshida, 1983, p. 40 (Transferred male from *Theridion*).

Achaearanea culicivora: Yaginuma, 1986, p. 33, f. 19.4; Yoshida, 2000, p. 146, f. 32–36; Yoshida, 2003, p. 111, f. 278–282, 580.

Parasteatoda culicivora: Yoshida, 2008,

p. 39 (Transferred from *Achaearanea*); Yoshida, 2009, p. 380, f. 234–235; Yoshida, 2016, p. 18; Kim, 2021, p. 101, f. 42A–F, pl. 19

Specimens examined. 2 ♀♀ (ABARA_00609, 00617), 22 Jul. 2019, Wei-Zhe Tseng leg., 1 ♂, 2 ♀♀ (ABARA_03579–03580, 03592), 11 Dec. 2011, Yu-Ming Huang leg., Cingtonglin, Wufeng District, Taichung City; 1 ♀ (ABARA_00660), 11 Jul. 2019, Anansi Brigade leg., Lovers Lake Park, Anle District, Keelung City; 1 ♂ (ABARA_00663), 25 Jul. 2019, 1 ♂, 1 ♀ (ABARA_01235, 01243), 19–20 Oct. 2019, Anansi Brigade leg., Bogongkeng, Sanyi Township, Miaoli County; 1 ♀ (ABARA_01681), 15 Aug. 2019, Hsiu-Chou Chung leg., Chinan National Forest Recreation Area, Shoufeng Township, Hualien County; 1 ♂, 1 ♀ (ABARA_03607, 03675), 03 Feb. 2022, Pin-Huang Hsu leg., Denggong Road, Tamsui District, New Taipei City; 1 ♀ (ABARA_03619),

28 Feb. 2022, Yu-Ming Huang leg., Dacun 5-1 trail, Peitung District, Taichung City; 1♂, 1♀ (ABARA_03621, 04513), 19 Feb. 2022, Yu-Ming Huang leg., Xinhua Experimental Forest Station, Xinhua District, Tainan City; 1♂ (ABARA_3868), 07 May 2022, Ting-Kuan Lin leg., Duona, Liouguei District, Kaohsiung City; 2♂, 4♀♀ (ABARA_03751–03752, 03897–03900), 25 Mar. 2022, Anansi Brigade leg., Beipu Village, Beipu Township, Hsinchu County; 2♀♀ (ABARA_03939–03940), 25 Mar. 2022, Anansi Brigade leg., Matai trail, Jianshi Township, Hsinchu County; 5♂♂, 7♀♀ (ABARA_04177, 04250–04251, 04287–04291, 04298–04301), 06–07 Jul. 2022, Anansi Brigade leg., 2♀♀ (ABARA_04775–04776), 12 Jan. 2023, Yu-Chun Hsiao leg., Shuangliu Forest Recreation Area, Shizi Township, Pingtung County; 1♂, 1♀ (ABARA_04294–04295), 25 Jan. 2018, Kuang-Ping Yu leg., Changshou Road, Gushan District, Kaohsiung City; 1♂

(ABARA_04351), 03 Aug. 2022, 1♂, 2♀♀ (ABARA_04678–04679, 04693), 28 Sep. 2022, Yu-Ming Huang leg., Metropolitan Park, Xitung District, Taichung City; 2♀♀ (TESRI_Ar1411–1412), 22 Jul. 2015, Ying-Yuan Lo leg., Paoma trail, Jiaoxi Township, Yilan County; 5♀♀ (TESRI_LT042–046), 17 Mar 2018, Ying-Yuan Lo leg., Lantan trail, East District, Chiayi County.

Diagnosis. This species is similar to *P. kentingensis* (Yoshida 2015) and *P. ryukyu* (Yoshida 2000) in body shape and coloration. *P. culicivora* and *P. kentingensis* have longer copulatory ducts and larger copulatory pores in females, while *P. ryukyu* with shorter copulatory ducts and smaller copulatory pores. The turning of copulatory ducts is angular in *P. culicivora* and *P. kentingensis*, while a round and large curve is in *P. ryukyu*. The ducts of *P. kentingensis* are more curved under the posterior edge than *P. culicivora*. The basal part of the male

embolus is not segmented in *P. culicivora* (segmented in *P. kentingensis* and *P. ryukyu*).

Description. Female (ABARA_04693). Body length 4.80. Carapace length 1.78, width 1.41. Abdomen length 3.51, width 2.96, height 3.21. Leg formula: I, IV, II, III. Leg I 9.06 (2.80, 2.51, 2.76, 0.99). Leg II 5.89 (1.84, 1.72, 1.63, 0.70). Leg III 4.04 (1.26, 1.17, 1.00, 0.61). Leg IV 6.58 (2.33, 1.88, 1.64, 0.73). Diameters of eyes: AME 0.12, ALE 0.11, PME 0.12, PLE 0.12. Interdistances of eyes: AME-AME 0.05, AME-ALE 0.04, PME-PME 1.00, PME-PLE 0.05. Clypeus height 0.29. Carapace oval, with a circular thoracic groove, dusky brown. Chelicerae, maxillae and labium brown with dusky flecks. Sternum yellowish brown. Legs brown with distal dusky rings. Abdomen dusky brown with white pigments, black flecks. Spinnerets surrounded with a circular blackish ring (Fig. 3a–c). Epigynum brown with large copulatory

pore and conspicuous sclerotized posterior edge. Copulatory ducts with largely curved under the posterior edge, the turning of copulatory ducts angular (Fig. 3d–e).

Male (ABARA_04679). Body length 2.44. Carapace length 1.25, width 1.04. Abdomen length 1.23, width 1.19, height 1.36. Leg formula: I, II, IV, III. Leg I 5.38 (1.58, 1.55, 1.62, 0.63). Leg II 3.50 (1.02, 1.01, 0.96, 0.51). Leg III 2.56 (0.80, 0.70, 0.66, 0.40). Leg IV 3.21 (1.02, 0.99, 0.77, 0.43). Diameters of eyes: AME 0.10, ALE 0.09, PME 0.10, PLE 0.10. Interdistances of eyes: AME-AME 0.06, AME-ALE 0.03, PME-PME 1.00, PME-PLE 0.05. Clypeus height 0.19. Coloration similar to female (Fig. 3f–h). The upper part of conductor bulging and bending into nearly right angle form in retrolateral view (Fig. 3k). Embolus thin and long, the basal part of embolus not segmented (Fig. 3i–k).

Distribution. Taiwan (widespread in low-altitude mountains), China, Japan, Korea.

Parasteatoda ducta (Zhu 1998)

(Fig. 4)

Achaearana ducta: Zhu, 1998, p. 107, f. 64A–C; Song, Zhu and Chen, 1999, p. 90, f. 39E–F.

Parasteatoda ducta: Yoshida, 2008, p. 39 (Transferred from *Achaearana*); Li *et al.*, 2021, p. 112, f. 12–14, 15C, D.

Specimens examined. 2♀♀ (ABARA_03437, 03454), 31 Jan. 2021, 2♀♀ (ABARA_03608–03609), 08 Nov. 2021, Chang-Lin Chung leg., 2♂♂ (ABARA_04178, 04249), 07 Jul. 2022, Yu-Ming Huang, Li Liu and Li-Ping Wang leg., Shuangliu Forest Recreation Area, Shizi Township, Pingtung County; 2♀♀ (ABARA_03893–03894), 16 Mar. 2022, Li Liu leg., Lover’s Gorge Waterfall, Maolin District, Kaohsiung City; 1♀ (ABARA_04093), 20 Jun. 2022, Yu-

Ming Huang leg., Dingbenzai, Zhuqi Township, Chiayi County; 3♀♀ (ABARA_04507–04509), 23 Aug. 2022, Ting-Kuan Lin leg., Wujie reservoir, Renai Township, Nantou County; 2♀♀ (ABARA_04768–04769), 22 Jan. 2023, Yu-Ming Huang leg., White Deer Suspension Bridge, Heping District, Taichung City; 2♀♀ (ABARA_04833–04834), 13 Apr. 2023, Yu-Ming Huang leg., Fenqihu, Zhuqi Township, Chiayi County.

Diagnosis. This species is similar to *P. transipora* in the body shape and shape of the palp organ. *P. ducta* can be distinguished from the latter by the twisted-roll-shaped copulatory ducts (two copulatory ducts overlapping in *P. transipora*), and the conductor of the male palp organ slender with a sharp tip (wider in *P. transipora*).

Description. Female (ABARA_04709). Body length 2.01. Carapace length 0.82, width 0.69. Abdomen length 1.23, width

1.17, height 1.09. Leg formula: I, IV, II, III. Leg I 2.71 (0.91, 0.80, 0.58, 0.42). Leg II 2.01 (0.62, 0.61, 0.40, 0.38). Leg III 1.62 (0.50, 0.45, 0.37, 0.30). Leg IV 2.47 (0.83, 0.74, 0.48, 0.42). Diameters of eyes: AME 0.08, ALE 0.08, PME 0.08, PLE 0.08. Interdistances of eyes: AME-AME 0.04, AME-ALE 0.03, PME-PME 0.05, PME-PLE 0.04. Clypeus height 0.12. Carapace oval, yellowish brown. Chelicerae, maxillae, labium and sternum yellowish brown. Leg white to light yellow, patella, tibia, metatarsus and tarsus yellow with dark brown ring. Abdomen brownish black, dorsum of abdomen with a discontinuous white band near the midpoint and contains occasional white spots. Spinnerets yellow surrounded with blackish ring (Fig. 4a–c). Copulatory ducts long, twisted-roll-shaped, surround spermathecae. Fertilization ducts long and thin (Fig. 4d–e).

Male (ABARA_04178). Body length 1.32. Carapace length 0.73, width

0.61. Abdomen length 0.91, width 0.63, height 0.61. Leg formula: I, IV, II, III. Leg I 2.65 (0.87, 0.83, 0.59, 0.36). Leg II 1.90 (0.59, 0.57, 0.44, 0.30). Leg III 1.52 (0.51, 0.45, 0.29, 0.27). Leg IV 2.03 (0.67, 0.65, 0.40, 0.31). Diameters of eyes: AME 0.08, ALE 0.08, PME 0.08, PLE 0.08. Interdistances of eyes: AME-AME 0.05, AME-ALE 0.03, PME-PME 0.07, PME-PLE 0.04. Clypeus height 0.12. Coloration of males is lighter than females. Other characteristics are similar to female (Fig. 4f–h). Palps scoop-shaped, embolus long and bends more than one round, distal part thin. Conductor long and tapering (Fig. 4i–k).

Distribution. Taiwan (Taichung, Nantou, Chiayi, Kaohsiung and Pingtung), China.

Parasteatoda transipora (Zhu and Zhang 1992)

(Fig. 5)

Theridion transiporum: Zhu and Zhang, 1992, p. 27, f. 7A–C.

Achaearanea transipora: Zhu, 1998, p. 91, f. 52A–E (Transferred from *Theridion*); Song, Zhu and Chen, 1999, p. 95, f. 44A–D.

Parasteatoda transipora: Yoshida, 2008, p. 39 (Transferred from *Achaearanea*).

Specimens examined. 3♀♀ (ABARA_03473, 03477–03478), 15 Nov. 2021, Yu-Ming Huang and Pin-Huang Hsu leg., Shichuan Village, Caotun Township, Nantou County; 1♀ (ABARA_03575), 29 Oct. 2021, Yu-Ming Huang and Pin-Huang Hsu leg., Giaokeng, Taiping District, Taichung City; 1♀ (ABARA_03590), 03 Oct. 2020, Li-Jing Huang leg., Sapodang, Xiulin Township, Hualien County; 1♀ (ABARA_04675), 08 Nov. 2021, Chang-Lin Chung leg., 2♀♀ (ABARA_03617–03618), 23 Dec. 2021, Yu-Ming Huang leg., 1♀ (ABARA_04292), 06 Jul. 2022, Yu-Ming Huang, Li Liu and Li-Ping Wang leg., 1♀ (ABARA_04777), 12 Jan. 2022, Yu-Chun

Hsiao leg., Shuangliu Forest Recreation Area, Shizi Township, Pingtung County; 1♀ (ABARA_03622), 19 Feb. 2022, Yu-Ming Huang leg., Xinhua Experimental Forest Station, Xinhua District, Tainan City; 1♀ (ABARA_03629), 09 Jul. 2020, Pin-Huang Hsu leg., Shixiangshan Farm, Wufeng District, Taichung city; 3♀♀ (ABARA_03748–03750), 25 Mar. 2022, Anansi Brigade leg., Beipu Village, Beipu Township, Hsinchu County; 1♀ (ABARA_04176), 08 Apr. 2022, Yu-Ming Huang leg., Dabaisha, Lyudao Township, Taitung County; 2♀♀ (ABARA_04500–04501), 09 Apr. 2022, Yu-Ming Huang leg., Lyudao Lighthouse, Lyudao Township, Taitung County; 1♂, 1♀ (ABARA_04709–04710), 19 Sep. 2022, Yu-Ming Huang leg., Toushe Reservoir, Yuchi Township, Nantou County; 1♀ (TESRI_Ar2378), 23 Jun. 2017, Chung-Sheng Huang leg., Jufenershan, Guoxing Township, Nantou County; 1♂ (TESRI_Ar5174), 13 May 2020, Chi-Chun Liao leg., Sun Moon Lake Antique

Assam Tea Farm, Yuchi Township, Nantou County; 1♂ (TESRI_Ar8101), 11 Aug. 2021, Chi Wei leg., Dongyue, Nanao Township, Yilan County.

Diagnosis. This species is similar to *P. cingulata* (Zhu 1998) in body shape and coloration. *P. transipora* can be distinguished from the latter by the overlap of two copulatory ducts in females (separated in *P. cingulata*). The shape of male palp organs of *P. transipora* are oval (round in *P. cingulata*), and conductor wide and long (longer in *P. cingulata*).

Description. Female (ABARA_04709). Body length 2.85. Carapace length 1.24, width 0.98. Abdomen length 2.24, width 1.99, height 1.73. Leg formula: I, IV, II, III. Leg I 5.31 (1.75, 1.57, 1.38, 0.61). Leg II 3.44 (1.10, 1.00, 0.84, 0.50). Leg III 2.44 (0.72, 0.71, 0.58, 0.43). Leg IV 4.07 (1.44, 1.26, 0.93, 0.44). Diameters of eyes: AME 0.09, ALE 0.09, PME 0.09, PLE 0.09. Interdistances of eyes: AME-

AME 0.07, AME-ALE 0.03, PME-PME 0.09, PME-PLA 0.06. Clypeus height 0.20. Carapace oval, with a circular thoracic groove; clypeus concave. Carapace, chelicerae, maxillae, labium and sternum blackish brown. Legs white to yellow with black rings. Abdomen yellowish brown to blackish brown, with white pigments. Spinnerets brown surrounded with black ring (Fig. 5a–c). Epigynum yellowish brown, copulatory pore large, with a protrusion at the posterior middle of copulatory pore. Copulatory ducts from wide to narrow, curved as circular shape at the base, circular part of two copulatory ducts overlap together (Fig. 5d–e).

Male (ABARA_04710). Body length 0.93. Carapace length 0.73, width 0.39. Abdomen length 0.89, width 0.41, height 0.47. Leg formula: I, II, IV, III. Leg I 2.42 (0.76, 0.75, 0.54, 0.37). Leg II 1.68 (0.52, 0.52, 0.33, 0.31). Leg III 1.29 (0.44, 0.35, 0.26, 0.24). Leg IV 1.64

(0.52, 0.51, 0.32, 0.29). Diameters of eyes: AME 0.08, ALE 0.08, PME 0.08, PLE 0.08. Interdistances of eyes: AME-AME 0.03, AME-ALE 0.02, PME-PME 0.07, PME-PLE 0.04. Clypeus height 0.19. Coloration similar to female (Fig. 5f–h). Embolus long and bends more than one round, distal part thin. Conductor long, distal part flat (Fig. 5i–k).

Distribution. Taiwan (Hsinchu, Taichung, Nantou, Tainan, Pingtung, Yilan, Hualien and Taitung), China.

Parasteatoda quadrimaculata

(Yoshida *et al.* 2000)

(Fig. 6)

Achaearanea quadrimaculata: Yoshida *et al.* 2000, p. 130, f. 32–35.

Parasteatoda quadrimaculata: Yoshida, 2008, p. 39 (Transferred from *Achaearanea*); Yoshida, 2015, p. 33

Specimens examined. 1 ♀ (ABARA_03476), 16 Nov. 2021, Yu-Ming

Huang and Pin-Huang Hsu leg., Kengkou Village, Wufeng District, Taichung City; 1 ♀ (ABARA_03824), 06 Apr. 2022, Yu-Ming Hung leg., Chunghai Bridge, Lanyu Island, Taitung County; 1 ♂ (ABARA_04187), 03 Apr. 2021, Chang-Lin Chung leg., Matai trail, Ji-an-shi Township, Hsinchu County; 1 ♀ (ABARA_04341), 06 Jul. 2022, Yu-Ming Huang, Li Liu and Li-Ping Wang leg., Shuangliu Forest Recreation Area, Shizi Township, Pingtung County; 1 ♂, 1 ♀ (ABARA_04612–04613), 02 Dec. 2017, Han-Po Chang leg., Zhishan Yan, Shilin District, Taipei City; 1 ♀ (ABARA_04614), 18 Feb. 2018, Kuang-Ping Yu leg., Tzaishan, Gushan District, Kaohsiung City; 2 ♀♀ (TESRI_Ar0047–0048), 12 Jul. 2012, Yin-Yuan Lo leg., Wushikeng, Heping District, Taichung City.

Diagnosis. This species is similar to other *Parasteatoda* species in body shape. *P. quadrimaculata* can be distinguished

from congeneric species by the thick and short female copulatory ducts (longer in other *Parasteatoda* species) and male embolus embedded within the conductor (embolus embedded within the conductor in other *Parasteatoda* species).

Description. Female (ABARA_04341). Body length 3.26. Carapace length 1.46, width 1.28. Abdomen length 2.08, width 1.87, height 1.72. Leg formula: I, IV, II, III. Leg I 7.02 (2.11, 2.32, 1.84, 0.75). Leg II 5.16 (1.67, 1.66, 1.22, 0.61). Leg III 3.82 (1.24, 1.09, 0.99, 0.50). Leg IV 5.26 (1.69, 1.73, 1.23, 0.61). Diameters of eyes: AME 0.09, ALE 0.09, PME 0.10, PLE 0.10. Interdistances of eyes: AME-AME 0.08, AME-ALE 0.05, PME-PME 0.10, PME-PLE 0.07. Clypeus height 0.23. Carapace oval, with a circular thoracic groove; clypeus concave. Carapace, chelicerae, maxillae, labium and sternum yellowish brown. Legs yellowish brown; patella, tibia, metatarsi and tarsi dusky brown. Dorsum of abdomen blackish

brown, with four white spots in the front, back, left, and right; Venter of abdomen yellowish white (Fig. 6a–c). Epigynum brown. Copulatory ducts thick and short. Spermathecae relatively large, ellipse shaped (Fig. 6d–e).

Male (ABARA_04187). Body length 2.52. Carapace length 1.10, width 1.02. Abdomen length 1.57, width 1.16, height 1.22. Leg formula: I, II, IV, III. Leg I 7.16 (2.18, 2.30, 1.93, 0.75). Leg II 5.60 (1.75, 1.72, 1.43, 0.70). Leg III 3.7 (1.18, 1.07, 0.93, 0.52). Leg IV 4.73 (1.49, 1.41, 1.13, 0.54). Diameters of eyes: AME 0.11, ALE 0.11, PME 0.11, PLE 0.11. Interdistances of eyes: AME-AME 0.05, AME-ALE 0.03, PME-PME 0.07, PME-PLE 0.05. Clypeus height 0.15. Coloration similar to female (Fig. 6f–h). Embolus black, short, with sharp tip. Conductor translucent, spoon shaped. Embolus not embedded within conductor (Fig. 6i–k).

Distribution. Taiwan (Taipei, Hsinchu, Taichung, Kaohsiung and Pingtung, Lanyu Island)

Remarks. This species differs from other *Parasteatoda* species in terms of coloration and genital organs. Our molecular data (unpublished) confirmed that the female and male specimens belong to the same species and also suggest that it may not belong to the genus *Parasteatoda*. However, given the uncertainty surrounding its accurate generic classification, we have chosen to retain its current taxonomic status to maintain stability.

Discussion

In this study, we redescribe six theridiid species from Taiwan, including four newly recorded *Parasteatoda* species, the first morphological description of male *P. quadrimaculata*, as well as the rediscovered *Campanicola ferrumequina*. Detailed morphological descriptions and photographs are provided for each

species.

C. ferrumequina and *P. asiatica* have been recorded in China, Japan, and Korea, while *P. ducta* and *P. transipora* are only known from China. Although we did not examine specimens from other countries, the specimens from Taiwan can be easily identified based on previous morphological descriptions (Zhu and Zhang 1992; Zhu 1998; Song *et al.* 1999; Namkung 2003; Yoshida 2000, 2003, 2009; Yin *et al.* 2012; Kim 2021; Li *et al.* 2021). Furthermore, their ecological behaviors are consistent with previous studies. *P. asiatica* is typically found inhabiting the undersides of leaves, where it constructs irregular webs (Zhu 1998; Namkung 2003; Yin *et al.* 2012). Meanwhile, *C. ferrumequina*, *P. ducta*, and *P. transipora*, are known to inhabit rock walls, where they construct bell-shaped retreats on their webs (Bösenberg and Strand 1906; Zhu 1998; Namkung 2003; Yoshida 1983, 2015; Li *et al.* 2021).

The specimens of *P. culicivora* from

Taiwan correspond well with the descriptions in previous literature. However, another species in Taiwan, *P. kentingensis*, could be confused with *P. culicivora*. *P. kentingensis* is differentiated from *P. culicivora* by the female copulatory ducts largely curved under the posterior edge, and the male palpus conductor is relatively thin, lacking a downward swelling (Yoshida 2015). From our observations, it is difficult to distinguish between the females of *P. culicivora* and *P. kentingensis* based on Yoshida's description. When examining the genital organs, they can be easily misjudged depending on the viewing angle.

Nevertheless, the distinction between these two species is attainable through the characteristics of the male palp organs. However, the male of *P. kentingensis* is similar to the *P. tepidariorum* (C. L. Koch, 1841) based on Yoshida's illustration. Apparently, it's quite difficult to distinguish these species based on morphological characteristics.

Resolving the problems of these species may require a detailed comparison with type specimens and conducting the DNA-based species delimitation.

This paper provides the first description of male *P. quadrimaculata*. Based on our examination, we believe that *P. quadrimaculata* is very different from other *Parasteatoda* species in its morphological characteristics, suggesting *P. quadrimaculata* may not belong to *Parasteatoda*. However, we are currently uncertain about the appropriate genus for *P. quadrimaculata*. Therefore, we have decided to temporarily retain its current genus name without change.

This study identified four new record species and one re-discovered species in Taiwan. Additionally, it provided the first description of male *P. quadrimaculata*. These findings would serve as a valuable reference for future research on the taxonomy of the family Theridiidae.

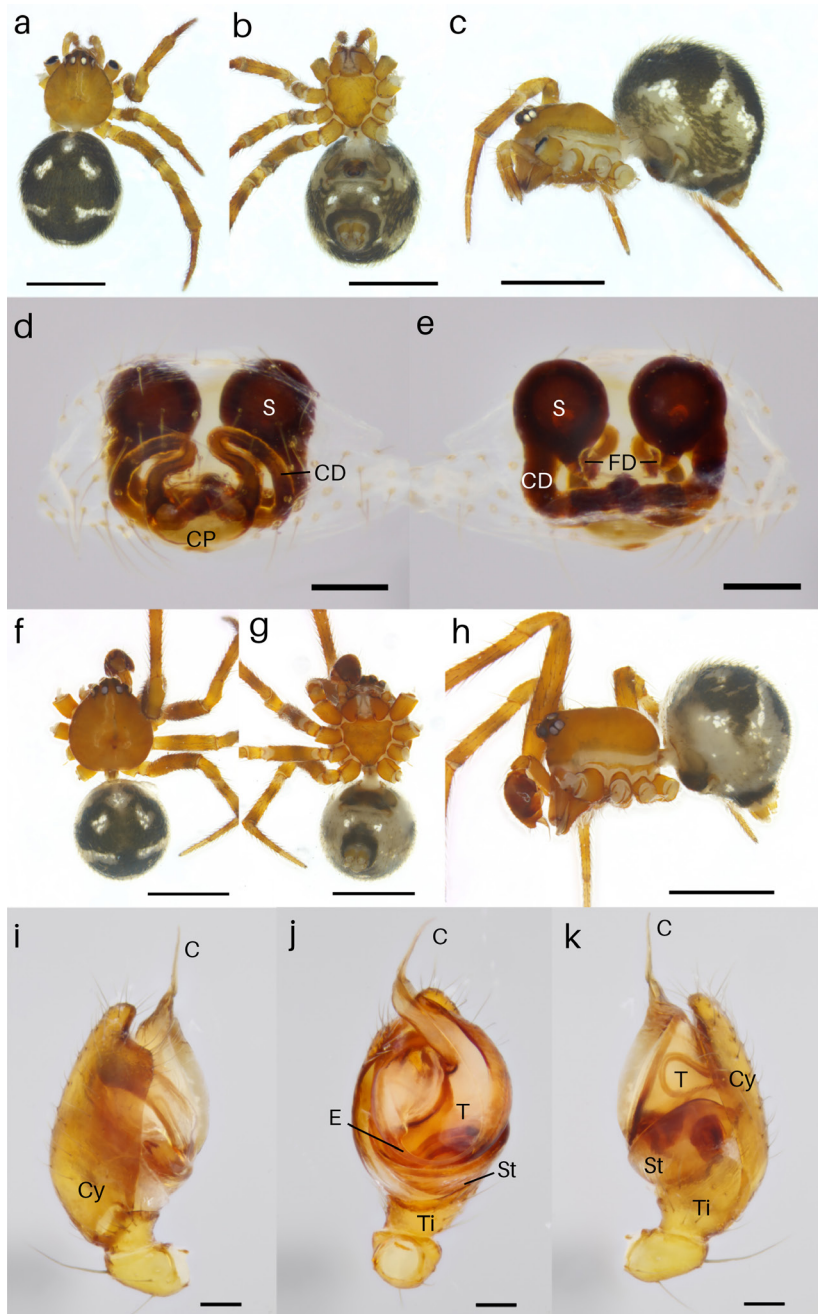


Fig. 1 *Campanicola ferrumequina* a–c, female habitus (a: dorsal view, b: ventral view, c: lateral view); d: female epigynum, e: vulva. f–h, male habitus (f: dorsal view, g: ventral view, h: lateral view). i–k, male left palp (i: prolateral view, j: ventral view, k: retrolateral view). Scale bars: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

圖 1 *Campanicola ferrumequina* a–c, 雌蛛 (a: 背面觀, b: 腹面觀, c: 側面觀); d: 外雌器腹面觀, e: 外雌器背面觀. f–h, 雄蛛 (f: 背面觀, g: 腹面觀, h: 側面觀). i–k, 雄蛛左觸肢 (i: 前側面觀, j: 腹面觀, k: 後側面觀). 比例尺: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

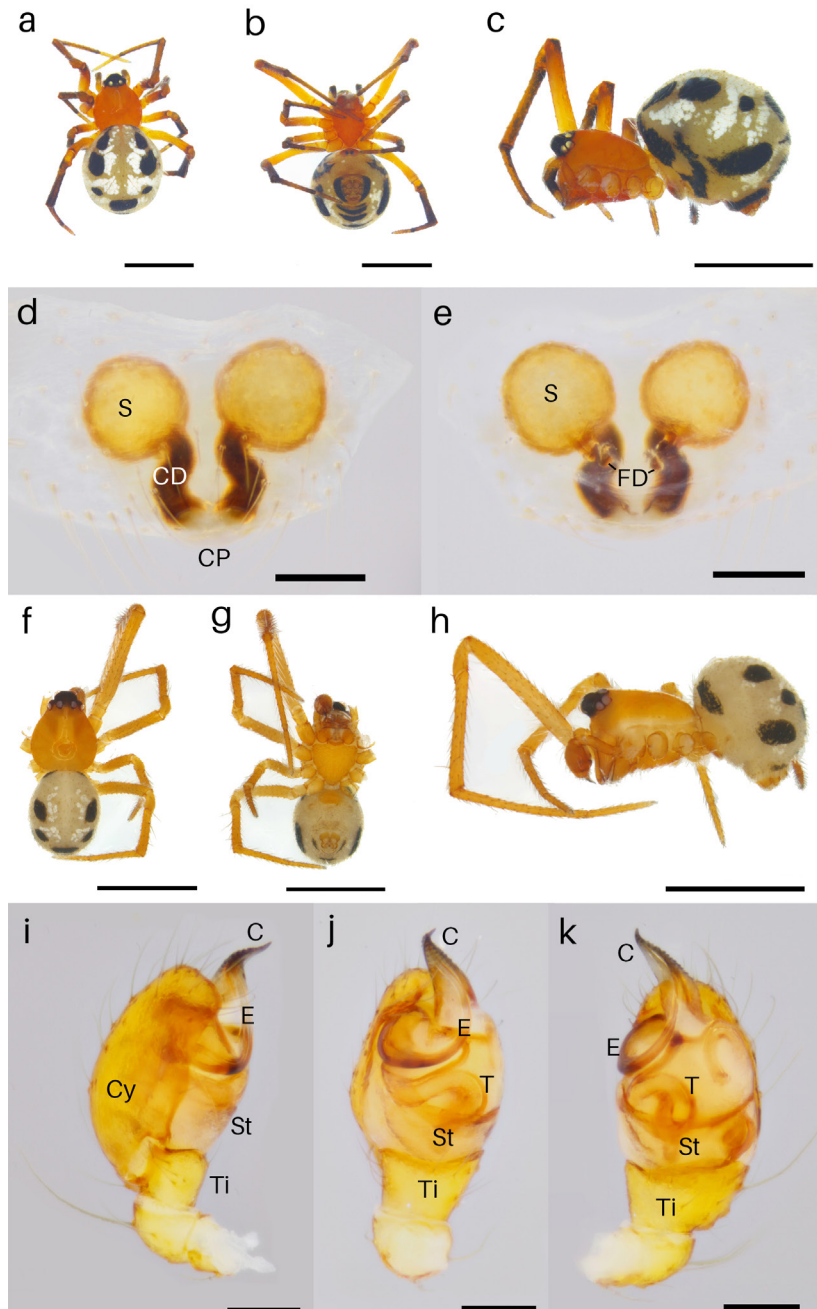


Fig. 2 *Parasteatoda asiatica* a–c, female habitus (a: dorsal view, b: ventral view, c: lateral view); d: female epigynum, e: vulva. f–h, male habitus (f: dorsal view, g: ventral view, h: lateral view). i–k, male left palp (i: prolateral view, j: ventral view, k: retrolateral view). Scale bars: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

圖 2 *Parasteatoda asiatica* a–c, 雌蛛 (a: 背面觀, b: 腹面觀, c: 側面觀); d: 外雌器腹面觀, e: 外雌器背面觀. f–h, 雄蛛 (f: 背面觀, g: 腹面觀, h: 側面觀). i–k, 雄蛛左觸肢 (i: 前側面觀, j: 腹面觀, k: 後側面觀). 比例尺: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

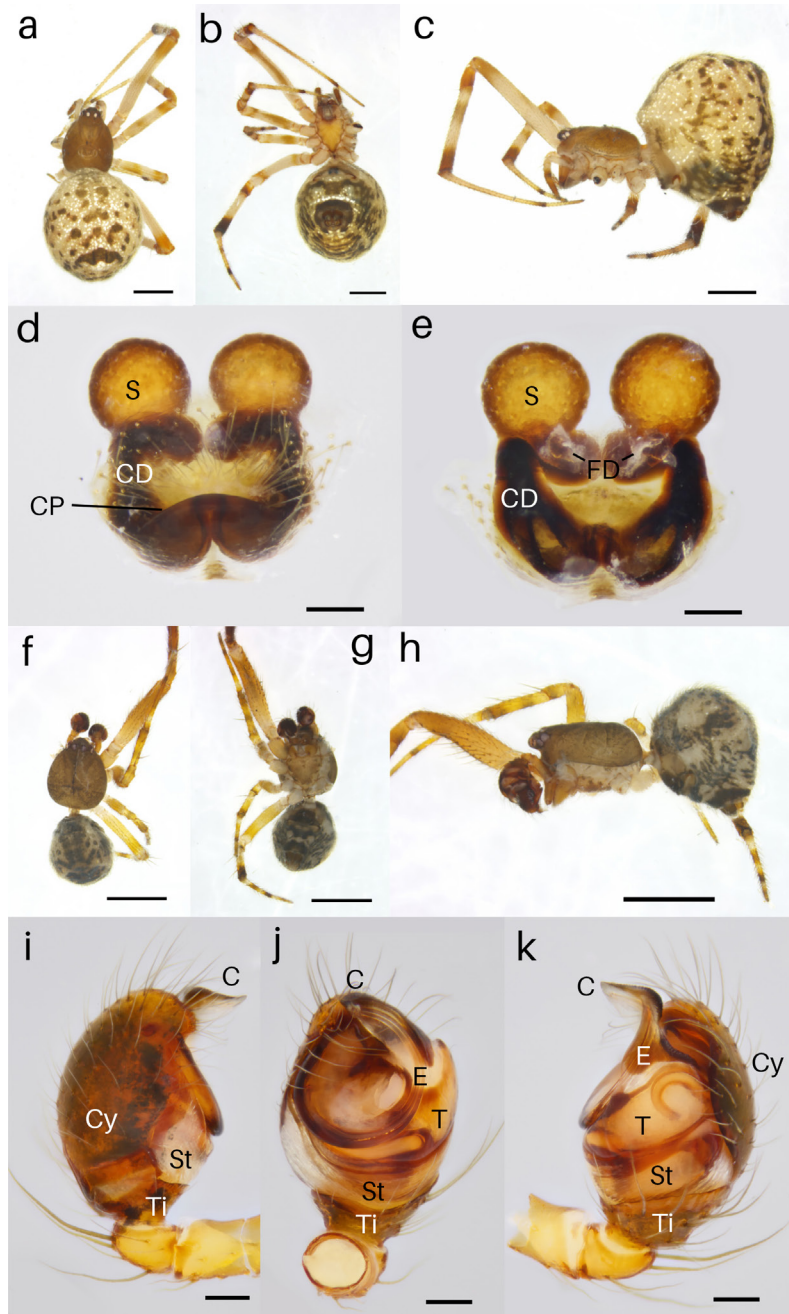


Fig. 3 *Parasteatoda culicivora* a–c, female habitus (a: dorsal view, b: ventral view, c: lateral view); d: female epigynum, e: vulva. f–h, male habitus (f: dorsal view, g: ventral view, h: lateral view). i–k, male left palp (i: prolateral view, j: ventral view, k: retrolateral view). Scale bars: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

圖 3 *Parasteatoda culicivora* a–c, 雌蛛 (a: 背面觀, b: 腹面觀, c: 側面觀); d: 外雌器腹面觀, e: 外雌器背面觀. f–h, 雄蛛 (f: 背面觀, g: 腹面觀, h: 側面觀). i–k, 雄蛛左觸肢 (i: 前側面觀, j: 腹面觀, k: 後側面觀). 比例尺: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

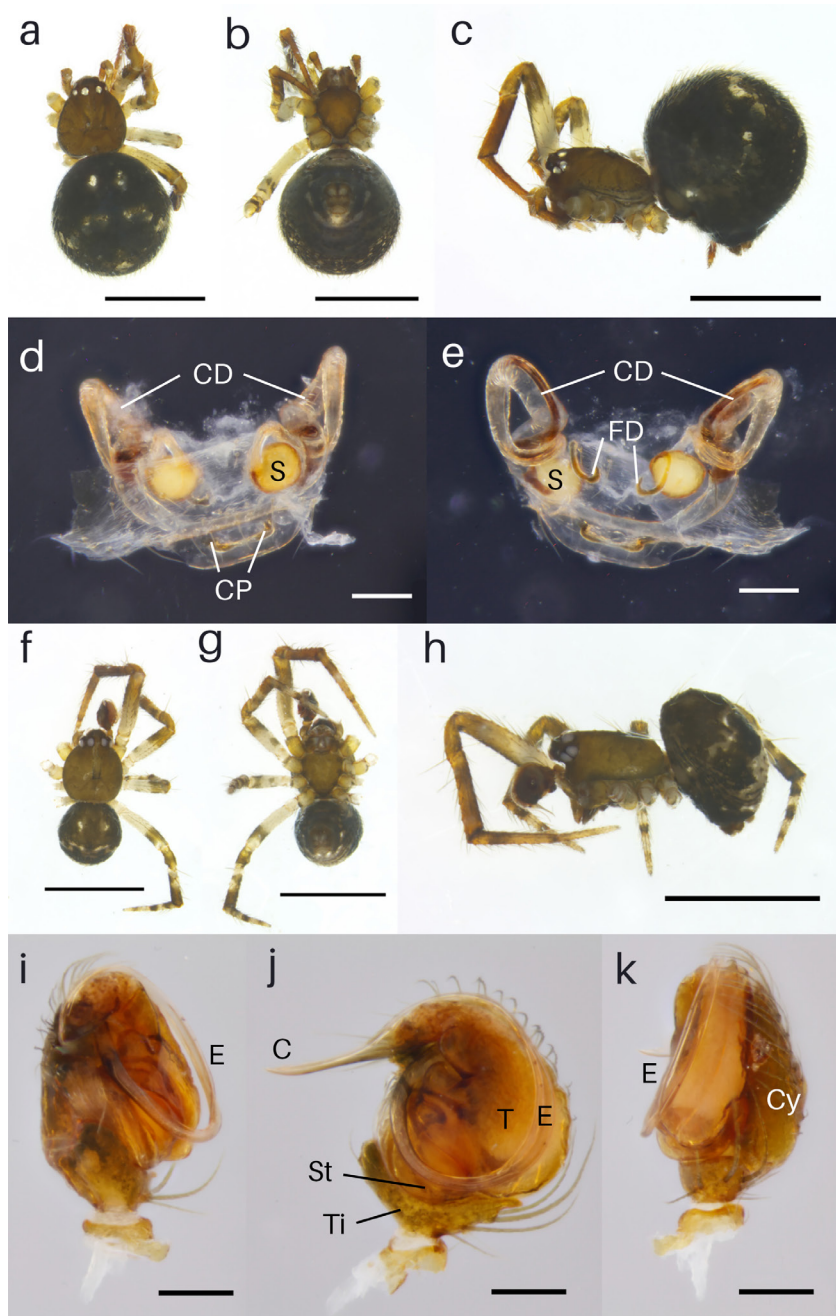


Fig. 4 *Parasteatoda ducta* a–c, female habitus (a: dorsal view, b: ventral view, c: lateral view); d: female epigynum, e: vulva. f–h, male habitus (f: dorsal view, g: ventral view, h: lateral view). i–k, male left palp (i: prolateral view, j: ventral view, k: retrolateral view). Scale bars: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

圖 4 *Parasteatoda ducta* a–c, 雌蛛 (a: 背面觀, b: 腹面觀, c: 側面觀); d: 外雌器腹面觀, e: 外雌器背面觀. f–h, 雄蛛 (f: 背面觀, g: 腹面觀, h: 側面觀). i–k, 雄蛛左觸肢 (i: 前側面觀, j: 腹面觀, k: 後側面觀). 比例尺: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

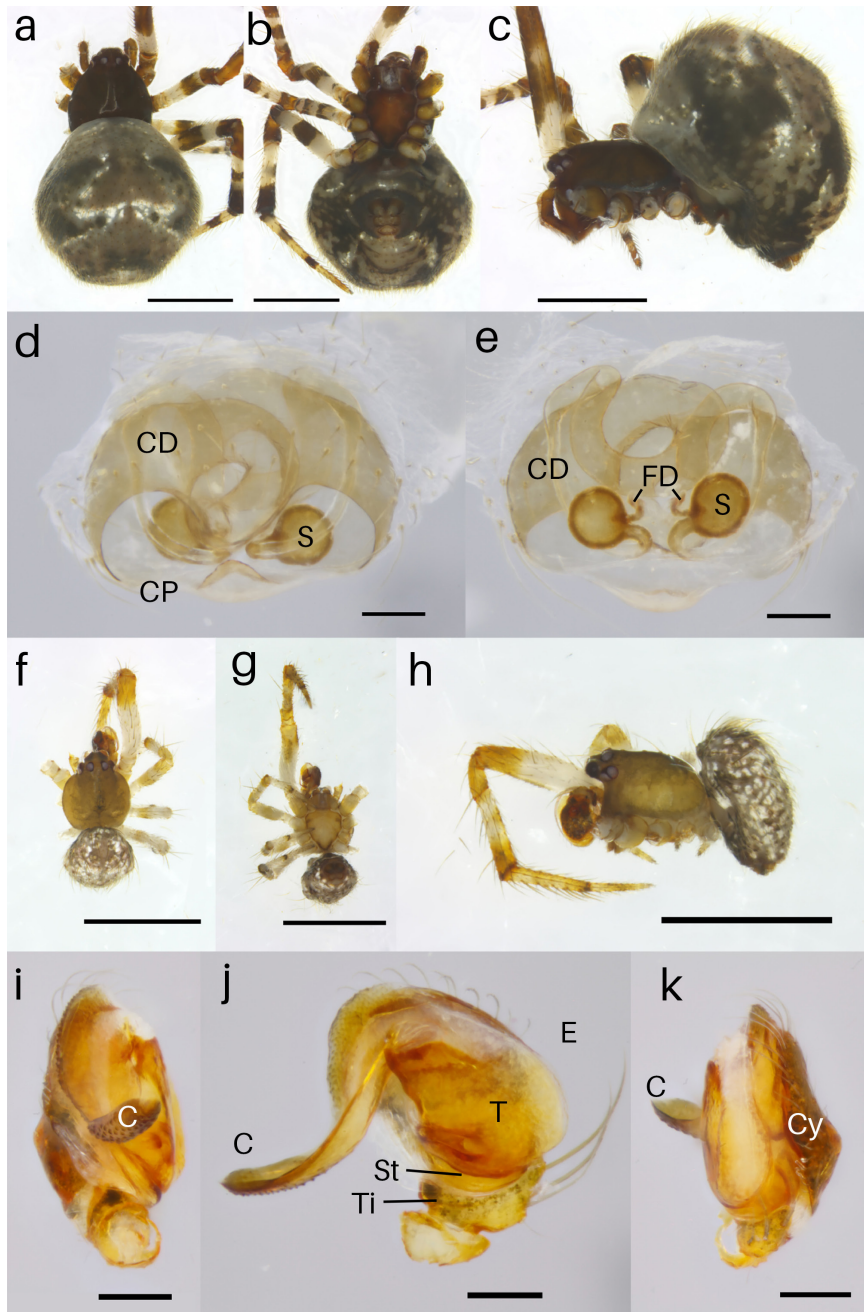


Fig. 5 *Parasteatoda transipora* a–c, female habitus (a: dorsal view, b: ventral view, c: lateral view); d: female epigynum, e: vulva. f–h, male habitus (f: dorsal view, g: ventral view, h: lateral view). i–k, male left palp (i: prolateral view, j: ventral view, k: retrolateral view). Scale bars: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

圖 5 *Parasteatoda transipora* a–c, 雌蛛 (a: 背面觀, b: 腹面觀, c: 側面觀); d: 外雌器腹面觀, e: 外雌器背面觀. f–h, 雄蛛 (f: 背面觀, g: 腹面觀, h: 側面觀). i–k, 雄蛛左觸肢 (i: 前側面觀, j: 腹面觀, k: 後側面觀). 比例尺: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

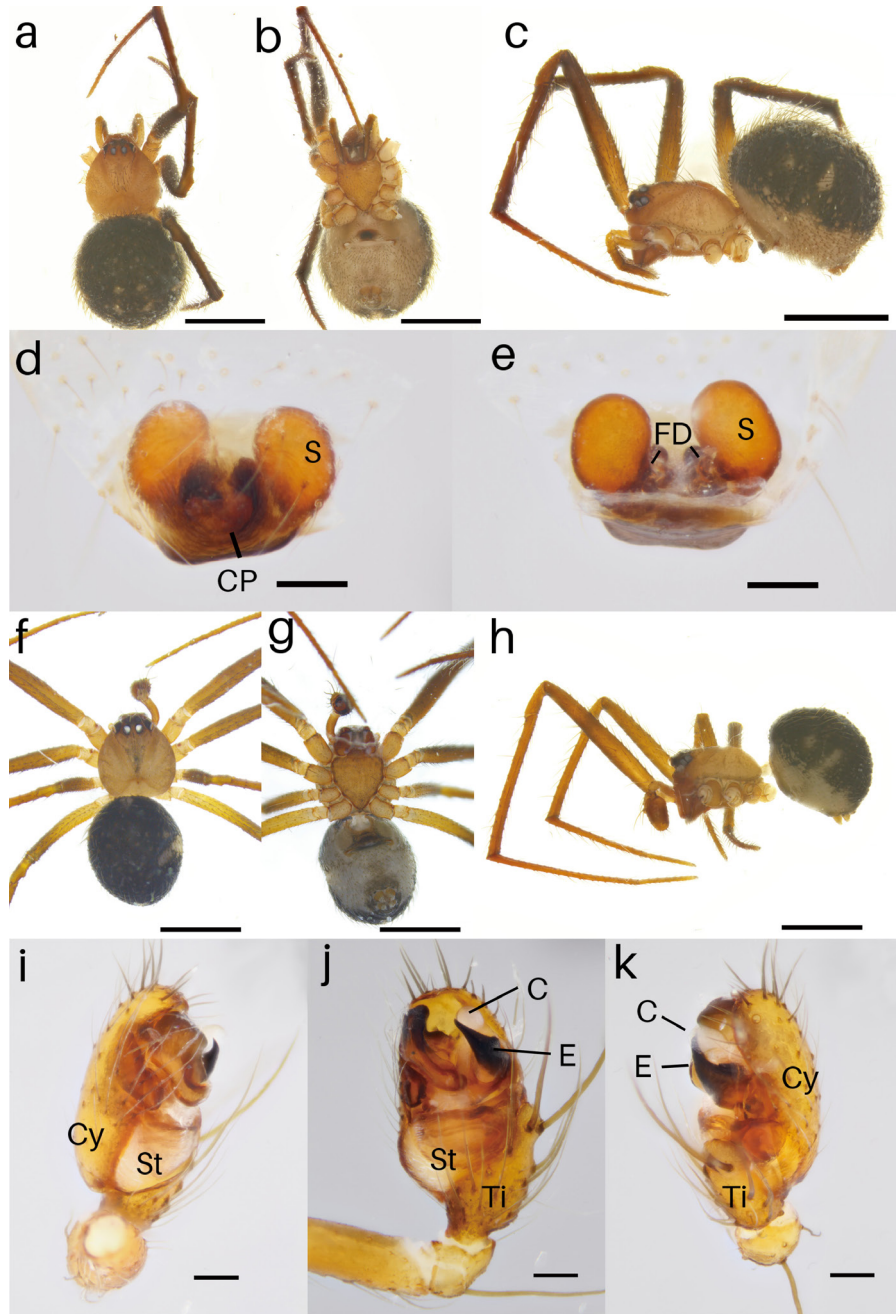


Fig. 6 *Parasteatoda quadrimaculata* a–c, female habitus (a: dorsal view, b: ventral view, c: lateral view); d: female epigynum, e: vulva. f–h, male habitus (f: dorsal view, g: ventral view, h: lateral view). i–k, male left palp (i: prolateral view, j: ventral view, k: retrolateral view). Scale bars: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

圖 6 *Parasteatoda quadrimaculata* a–c, 雌蛛 (a: 背面觀, b: 腹面觀, c: 側面觀); d: 外雌器腹面觀, e: 外雌器背面觀. f–h, 雄蛛 (f: 背面觀, g: 腹面觀, h: 側面觀). i–k, 雄蛛左觸肢 (i: 前側面觀, j: 腹面觀, k: 後側面觀). 比例尺: 1 mm (a–c, f–h); 0.1 mm (d–e, i–k).

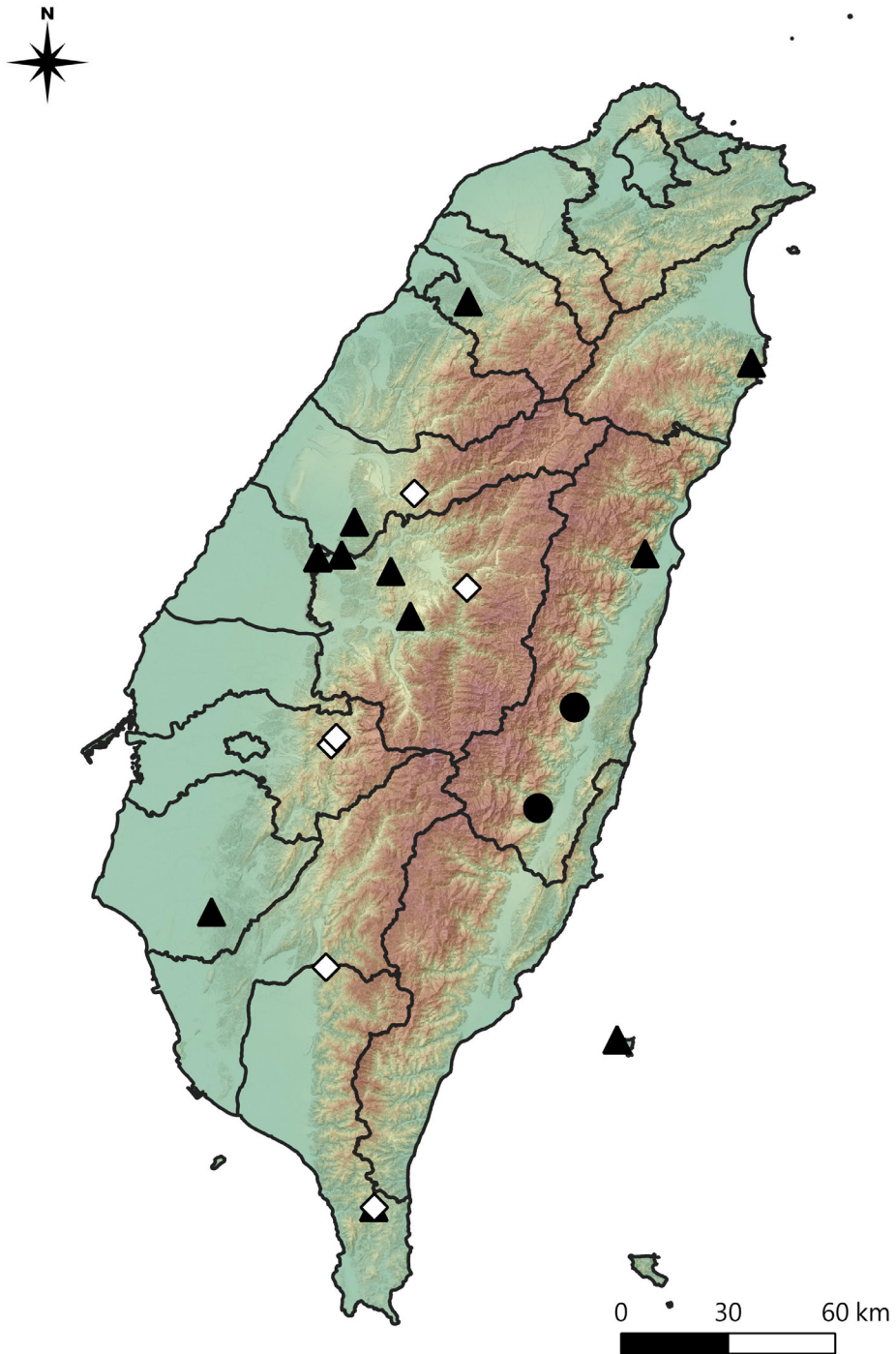


Fig. 7 Distribution of *Campanicola ferrumequina*, *Parasteatoda ducta*, and *Parasteatoda transipora* in Taiwan. ●: *Campanicola ferrumequina*; ◇: *Parasteatoda ducta*; ▲: *Parasteatoda transipora*.

圖 7 *Campanicola ferrumequina*, *Parasteatoda ducta* 以及 *Parasteatoda transipora* 在臺灣之分布 ●: *Campanicola ferrumequina*; ◇: *Parasteatoda ducta*; ▲: *Parasteatoda transipora*.

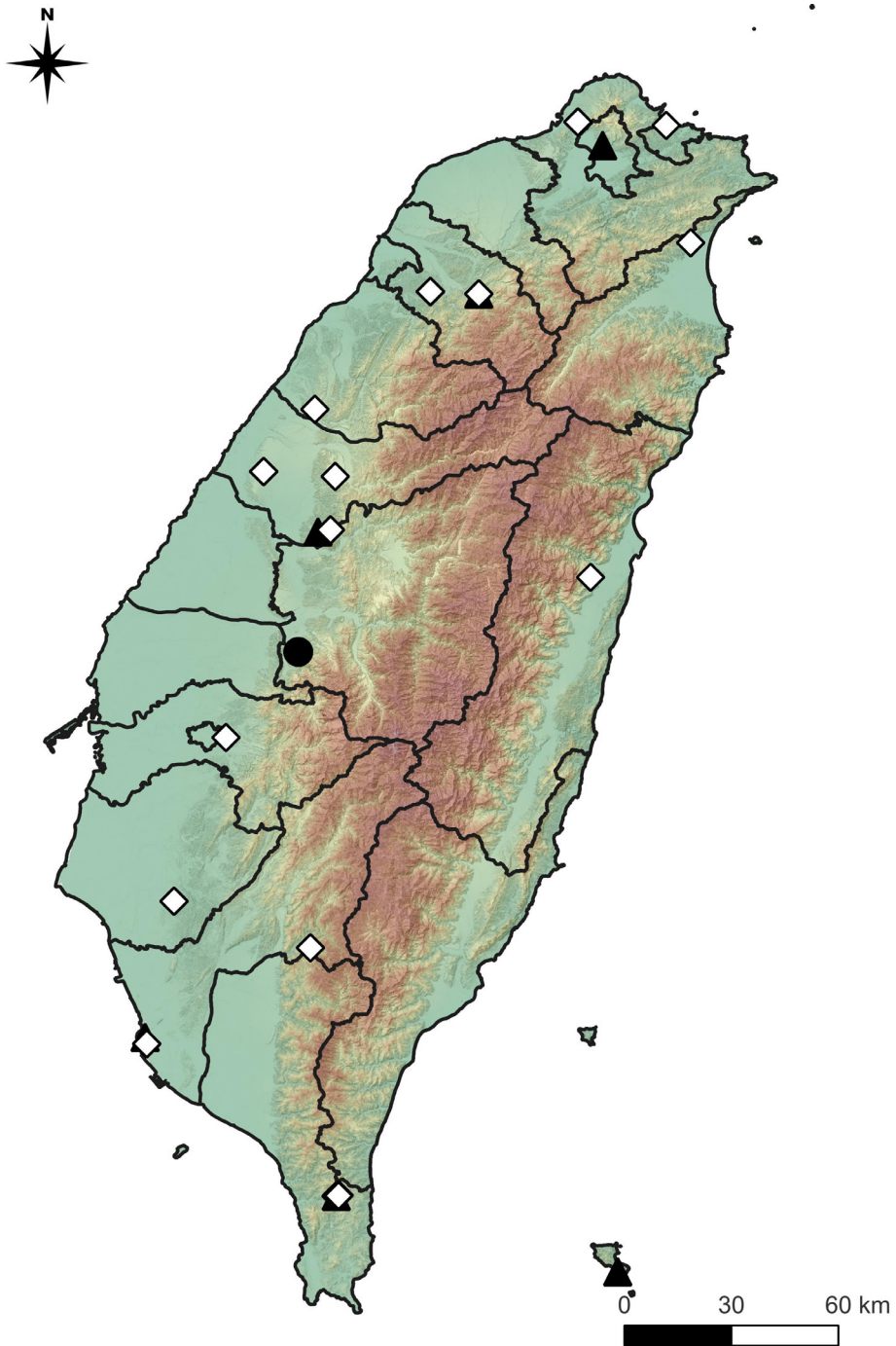


Fig. 8 Distribution of *Parasteatoda asiatica*, *Parasteatoda culicivora*, and *Parasteatoda quadrimaculata* in Taiwan. ●: *Parasteatoda asiatica*; ◇: *Parasteatoda culicivora*; ▲: *Parasteatoda quadrimaculata*.

圖 8 *Parasteatoda asiatica*, *Parasteatoda culicivora* 以及 *Parasteatoda quadrimaculata* 在臺灣之分布 ●: *Parasteatoda asiatica*; ◇: *Parasteatoda culicivora*; ▲: *Parasteatoda quadrimaculata*.

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澎湖鎮海海草床大型無脊椎動物之組成 分析

Composition analysis of macroinvertebrates in the seagrass beds of Chenhai, Penghu County, Taiwan

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摘要

澎湖縣白沙鄉鎮海灣海草床係澎湖縣內面積最大的海草床，擁有豐富的生態資源。近年來，由於航道開發的影響，海草床面積有所減少。因此，各單位近年亦執行多項海草床評估計畫，以瞭解海草床現況並制定相應的保育措施。過去澎湖縣內的海草床調查研究多集中在魚類方面，而對無脊椎動物的調查資料則相對較少，因此，本研究於 2022 年 3 月至 2023 年 4 月，每月至鎮海海草床進行無脊椎動物之生物相調查，旨在瞭解海草床中無脊椎動物的組成，以提供後續保育工作之參考依據。調查期間，共發現 107 種無脊椎動物，其中以軟體動物門 53 種最多，其次為節肢動物門 41 種。在鎮海海草床的螺貝類物種中，海蜷科物種為第一優勢種。螺貝類物種之多樣性指數顯示，種類豐度介於 0.29-1.31；優勢度介於 0.94-1.00；歧異度介於 0.10-0.65；均勻度介於 0.07-0.41，根據 ANOVA 分析，種類豐度無明顯季節變化；優勢度、歧異度及均勻度等 3 項指數則呈現季節變化。未來須透過持續的基礎生態調查，以更全面評估保護區的可行性。

關鍵詞：澎湖、海草床、無脊椎動物、組成分析

Abstract

The seagrass bed in Chenhai Bay, Baisha Township, Penghu County, is the largest within Penghu County and possesses abundant ecological resources. In recent years, the area of the seagrass bed has decreased due to the impact of channel development.

Consequently, various organizations have implemented several seagrass bed assessment projects to understand the current status and formulate corresponding conservation measures. Previous research on seagrass beds in Penghu County has mainly focused on fish, with relatively limited data on invertebrates. Therefore, in this study monthly surveys of invertebrate biodiversity in the Chenhai seagrass bed were conducted from March 2022 to April 2023, aiming to comprehend the composition of invertebrates in the seagrass bed and provide a reference basis for subsequent conservation efforts. During the survey period, a total of 107 species of invertebrates were identified, with the phylum Mollusca being the most abundant with 53 species, followed by the phylum Arthropoda with 41 species. Among the gastropod species in the Chenhai seagrass bed, species of the family Batillariidae emerged as the most dominant. Diversity indices for gastropod species indicated a range of species richness from 0.29 to 1.31, dominance from 0.94 to 1.00, diversity from 0.10 to 0.65, and evenness from 0.07 to 0.41. According to ANOVA analysis, species richness showed no significant seasonal variation, while dominance, diversity, and evenness indices exhibited seasonal changes. In the future, continuous foundational ecological surveys are necessary for a more comprehensive assessment of the feasibility of the conservation area.

Key words: Penghu, seagrass bed, invertebrates, composition analysis

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緒言

海草 (Seagrass) 係生長於海洋環境中之開花植物，全世界約 60 種 (Orth *et al.* 2006; Sachithanandam *et al.* 2022; Sudo *et al.* 2021)，廣泛分布於世界溫帶及熱帶海岸線，包含溫帶北大西洋、北太平洋、地中海與南大洋，以及熱帶大西洋與印度-西太平洋 (Short *et al.* 2007)。結構複雜的海草床不僅提供魚類及無脊椎動物等海洋生物豐富的食物來源，也是生物產卵、成長與避敵的重要棲息地 (邱與謝 2012；趙 2018；Jiang *et al.* 2020; Pogoreutz *et al.* 2012)，此外，海草不僅具穩定沉積物的作用，亦產生大量有機碳，提供重要的生態系服務 (Ecosystem services)，也因此坐擁相當豐富的生物多樣性 (冼等 2011；Orth *et al.* 2006；Rodil *et al.* 2022)。

臺灣的海草主要分布在西岸、恆春半島及離島之泥灘地或礁岩底質之淺水海域 (林 2019)。回顧臺灣海草分類和分布的研究，Yang *et al.* (2002) 曾對臺灣的海草分布進行調查，共發表 7 種海草，且主要分布

於西南海岸及澎湖群島；柯 (2004) 則針對當時已記錄之 10 種海草進行詳細觀察與描述；而目前臺灣有紀錄的海草則有 12 種 (林 2019)。根據冼等 (2011) 的調查，澎湖縣已記錄 3 科 5 屬 7 種海草，其中又以白沙鄉鎮海村鎮海灣潮間帶的海草床面積最大。

近年來，林 (2019) 之研究已對鎮海海草床之生態系進行調查，然而，有關此處之生態系及生物相組成方面等研究，目前仍相對不足。根據冼等 (2011) 與林 (2019) 之調查，鎮海海草床大致由卵葉鹽草 (*Halophila ovalis*)、單脈二藥草 (*Halodule uninervis*)、甘草 (*Nanozostera japonica*)、線葉二藥草 (*Halodule pinifolia*) 以及毛葉鹽草 (*Halophila decipiens*) 組成，其中，卵葉鹽草為澎湖潮間帶的優勢海草 (趙 2018)，同時也是構成鎮海海草床的主要海草。然而，由於港子及講美漁港之航道開發，原有的海草床面積已大幅縮減，對當地生態系之影響逐漸加劇。

在海草床生態系中，海草之生物

固定化作用 (Immobilization) 提供無脊椎動物等初級消費者無機營養物質；無脊椎動物則為大多數魚類的食物來源 (林與蕭 2011；林 2019)，為使食物鏈維持穩定，應先瞭解鎮海灣潮間帶之生態多樣性及生物量之時空變化，方能探討後續保育之作為，因此，本研究以徒手徒步方式並搭配穿越線及方框，進行初步潮間帶調查，目前已掌握無脊椎物種生物相以及螺貝類生物之多樣性指數，期望透過對鎮海

海草床之基礎調查結果，提供未來評估海草床復育計畫或建立保護區之可行性參考依據。

材料與方法

大型無脊椎動物調查

本研究之調查期間為 2022 年 3 月至 2023 年 4 月，於鎮海灣潮間帶 ($23^{\circ}38'54.0''\text{N}$, $119^{\circ}36'18.4''\text{E}$) (圖 1) 進行採集，採集頻率為每月一次，並依據中央氣象局全球資訊網公告之

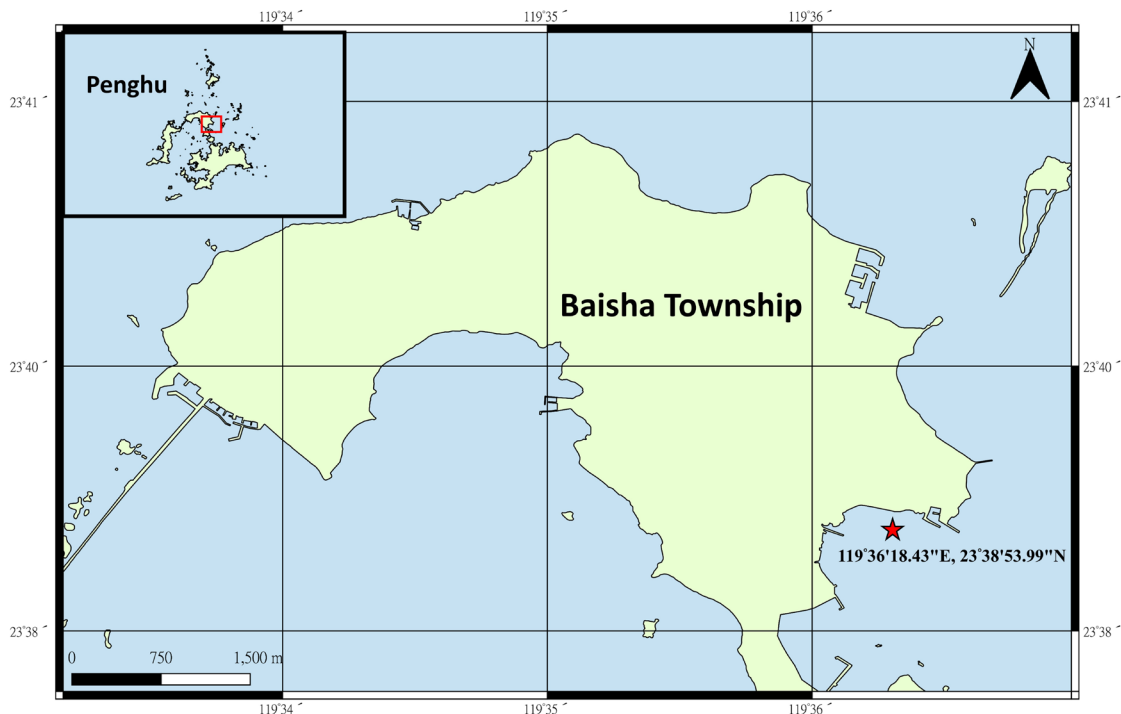


圖 1 鎮海海草床樣點位置圖 (星號處)。

Fig. 1 Map of Chenhai seagrass bed sampling location (marked with asterisks).

潮汐表，於每月大退潮時進行作業。調查方式則參考國家海洋研究院 2020 年《我國海洋生態調查監測網與監測規範建立之整體規劃》成果報告書—軟底質海域底棲生物採樣通則進行調查。

無脊椎動物之調查方式係以營釘固定長 25 m 之穿越線，並以穿越線左右兩側垂直延伸 5 m 為採集區域，共進行 5 重複；另外，本研究針對軟體動物門中的螺貝類生物進行後續多樣性指數分析，此部分以方框法進行調查，調查方式係在海草床上放置自製方框（ $1 \times 1 \text{ m}^2$ ，共 100 小格，每小格之長、寬各 10 cm），隨機取其中 20 小格計算單位面積內之螺貝類生物，並依物種進行分類，作業完畢後再換下一個點進行調查，以上作業共進行 5 重複，即可得出範圍內之螺貝類物種類別及數量。

1. 多樣性指數分析

本研究所使用之各項指數及計算方式均參照《我國海洋生態調查監測網與監測規範建立之整體規劃》成果報告書（2020），並使用 Microsoft

Excel 2021 進行計算，分析項目依序如下：

(1) 種類豐度（Richness）：

種類豐度（Richness）表示某地生物群集中種類豐富程度的指數，常用的指數如馬格列夫指數（Margalef's diversity index, D_{mg} ），其計算公式如下：

$$D_{mg} = (S - 1) / \ln N$$

式中，S 為物種數；N 為物種之總個體數。

(2) 優勢度（Dominance）：

優勢度用於評估不同物種或生物群體在一個生態系統中的相對優勢程度，其計算公式如下：

$$D_2 = (N_1 + N_2) / N$$

式中， N_1 為第一優勢種的個體數； N_2 為第二優勢種的個體數；N 為總個體數。

(3) 歧異度指數（Diversity）：

夏農韋納歧異度指數（Shannon-Wiener's diversity index, H' ）是一個廣泛使用的多樣性指數，用來評估生物群集的物種豐富度和均勻度。它的計算基於逢機採樣假設，以確保準確性。

其計算方式為：

$$H' = -\sum_{i=1}^S P_i \times \ln(P_i)$$

式中，S 為物種數； P_i 為第 i 種物種所佔的比例。

(4) 均勻度指數 (Evenness)：

均勻度指數用於評估生態系統或群集中不同物種的相對均勻度或均一性。本研究採用皮耶諾均勻度指數 (Pielou's evenness index)，計算方式為：

$$J = H' / (H'_{\max})$$

式中， H' 為多樣性指數； H'_{\max} 為 $\log_2 S$ ，表示多樣性指數的最大值，S 則為物種數。

所有計算得出的值均四捨五入至小數點後 2 位。

結果與討論

大型底棲無脊椎動物調查結果

本研究於鎮海海草床觀察到的無脊椎動物可分為刺胞動物門 (Cnidaria)、軟體動物門 (Mollusca)、環節動物門 (Annelida)、節肢動物門 (Arthropoda) 及棘皮動物門

(Echinodermata) 五大類，物種名錄表詳如表 1，共記錄到 5 門 15 綱 26 目 62 科 82 屬 107 種無脊椎動物，其中以軟體動物門的物種數最多 (53 種)；節肢動物門 (41 種) 次之。根據本研究之調查結果，鎮海海草床中最優勢的物種為海蜷科物種 (Batillariidae) (圖 2)，包含多型海蜷 (*Batillaria multiformis*)、黑瘤海蜷 (*Batillaria sordida*) 及燒酒海蜷 (*Batillaria zonalis*)。此外，根據林 (2019) 進行之鎮海海草床生態系調查，其調查結果亦顯示軟體動物門的物種數最多 (37 種)；節肢動物門 (31 種) 次之，與本研究結果相符。

在海草床生態系中，海草扮演著初級生產者的角色，其生物固定化作用所固定之無機質，與其地上部及地下部產生之碎屑與有機質，皆為底棲無脊椎動物等初級消費者的重要食物來源 (鍾 2012；林 2019)。此外，由海草葉片所構成之立體空間，提供許多小型底棲生物棲息及避敵，進而吸引更高階消費者前來覓食，並增加海草床之生物多樣性，突顯無脊椎動

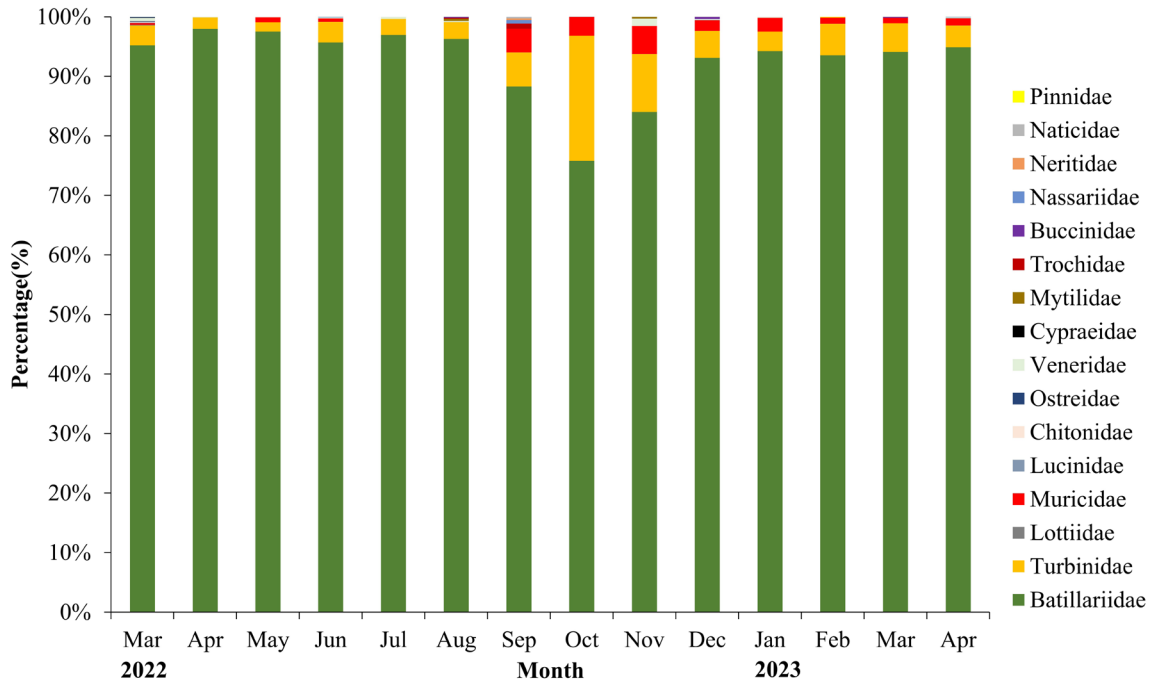


圖 2 鎮海海草床螺貝類生物月別群集組成。

Fig. 2 Monthly composition of gastropod and bivalve assemblages in Chenhai seagrass bed.

表 1 鎮海海草床無脊椎物種名錄表 (常見種以 * 表示)

Table 1 Species catalogue of invertebrates in Chenhai seagrass bed (common species marked with *)

Phylum	Class	Order	Family	Scientific name	Chinese name
Cnidaria	Anthozoa	Actiniaria	Actiniidae	<i>Paracondylactis hertwigi</i> *	-
Cnidaria	Hexacorallia	Ceriantharia	Cerianthidae	<i>Cerianthus filiformis</i> *	-
Cnidaria	Octocorallia	Scleralcyonacea	Virgulariidae	<i>Virgularia juncea</i> *	燈芯箸海綿
Mollusca	Polyplacophora	Chitonida	Chitonidae	<i>Liolophura japonica</i> *	大駝石鰐
Mollusca	Polyplacophora	Chitonida	Ischnochitonidae	<i>Ischnochiton comptus</i>	薄石鰐
Mollusca	Scaphopoda	Dentaliida	Dentaliidae	<i>Dentalium</i> sp.	象牙貝未知種
Mollusca	Gastropoda	Trochida	Turbinidae	<i>Turbo stenogyrus</i> *	高腰蝾螺
Mollusca	Gastropoda	Trochida	Turbinidae	<i>Lunella coronata</i> *	珠螺
Mollusca	Gastropoda	Trochida	Turbinidae	<i>Lunella granulata</i> *	瘤珠螺
Mollusca	Gastropoda	-	Lottiidae	<i>Nipponacmea schrenckii</i>	花青螺
Mollusca	Gastropoda	Trochida	Trochidae	<i>Monodonta labio</i>	草蓆鐘螺
Mollusca	Gastropoda	Trochida	Trochidae	<i>Trochus sacellum</i>	齒輪鐘螺
Mollusca	Gastropoda	Trochida	Trochidae	<i>Umbonium vestiarium</i>	彩虹蝸螺
Mollusca	Gastropoda	Cycloneritida	Neritidae	<i>Nerita albicilla</i> *	漁舟蜆螺
Mollusca	Gastropoda	Cycloneritida	Neritidae	<i>Nerita polita</i> *	玉女蜆螺
Mollusca	Gastropoda	Cycloneritida	Neritidae	<i>Nerita undata</i> *	粗紋蜆螺
Mollusca	Gastropoda	Littorinimorpha	Littorinidae	<i>Littoraria lutea</i>	芝麻玉黍螺
Mollusca	Gastropoda	Littorinimorpha	Littorinidae	<i>Littoraria pallescens</i>	多彩玉黍螺
Mollusca	Gastropoda	Littorinimorpha	Littorinidae	<i>Littoraria scabra</i>	粗紋玉黍螺
Mollusca	Gastropoda	Littorinimorpha	Littorinidae	<i>Littoraria undulata</i> *	波紋玉黍螺
Mollusca	Gastropoda	Caenogastropoda <i>incertae sedis</i>	Batillariidae	<i>Batillaria multiformis</i> *	多型海蝓
Mollusca	Gastropoda	Caenogastropoda <i>incertae sedis</i>	Batillariidae	<i>Batillaria sordida</i> *	黑瘤海蝓
Mollusca	Gastropoda	Caenogastropoda <i>incertae sedis</i>	Batillariidae	<i>Batillaria zonalis</i> *	燒酒海蝓
Mollusca	Gastropoda	Littorinimorpha	Vermetidae	<i>Thylacodes adamsii</i> *	大蛇螺
Mollusca	Gastropoda	Littorinimorpha	Cypraeidae	<i>Mauritia arabica</i> *	阿拉伯寶螺
Mollusca	Gastropoda	Littorinimorpha	Cypraeidae	<i>Erronea erronea</i> *	愛龍寶螺
Mollusca	Gastropoda	Littorinimorpha	Naticidae	<i>Notocochlis gualteriana</i> *	小灰玉螺
Mollusca	Gastropoda	Littorinimorpha	Naticidae	<i>Natica vitellus</i>	腰帶玉螺
Mollusca	Gastropoda	Neogastropoda	Muricidae	<i>Menathais tuberosa</i> *	角岩螺
Mollusca	Gastropoda	Neogastropoda	Muricidae	<i>Reishia clavigera</i> *	蚵岩螺
Mollusca	Gastropoda	Neogastropoda	Muricidae	<i>Tenguella granulata</i> *	結螺

Mollusca	Bivalvia	Venerida	Veneridae	<i>Marcia hiantina</i>	臺灣環簾蛤
Mollusca	Bivalvia	Venerida	Veneridae	<i>Periglypta corbis</i>	-
Mollusca	Bivalvia	Venerida	Veneridae	<i>Venerupis aspera</i> *	小眼花簾蛤
Mollusca	Bivalvia	Venerida	Veneridae	<i>Tapes platyptycha</i> *	花斑淺蜆
Mollusca	Bivalvia	Cardiida	Cardiidae	<i>Vasticardium flavum</i> *	黃邊烏尾蛤
Mollusca	Bivalvia	Lucinida	Lucinidae	<i>Codakia punctata</i>	胭脂滿月蛤
Mollusca	Bivalvia	Lucinida	Lucinidae	<i>Ctena bella</i>	美姬滿月蛤
Mollusca	Bivalvia	Cardiida	Tellinidae	<i>Scutarcopagia scobinata</i>	銼紋櫻蛤
Annelida	Polychaeta	Amphinomida	Amphinomidae	<i>Eurythoe complanata</i> *	扁猶帝蟲
Annelida	Polychaeta	Sabellida	Sabellidae	<i>Sabellastarte spectabilis</i>	華麗光纓蟲
Arthropoda	Merostomata	Xiphosurida	Limulidae	<i>Tachypleus tridentatus</i>	三棘鬣
Arthropoda	Malacostraca	Amphipoda	Talitridae	<i>Platorchestia</i> sp.*	扁跳蝦未知種
Arthropoda	Malacostraca	Stomatopoda	Pseudosquillidae	<i>Pseudosquilla ciliata</i>	多毛假蝦姑
Arthropoda	Malacostraca	Decapoda	Stenopodidae	<i>Stenopus hispidus</i>	猊蝦
Arthropoda	Malacostraca	Decapoda	Penaeidae	<i>Metapenaeopsis barbata</i>	鬚赤蝦
Arthropoda	Malacostraca	Decapoda	Penaeidae	<i>Penaeus canaliculatus</i>	深溝對蝦
Arthropoda	Malacostraca	Decapoda	Penaeidae	<i>Penaeus latisulcatus</i>	寬溝對蝦
Arthropoda	Malacostraca	Decapoda	Penaeidae	<i>Penaeus semisulcatus</i>	短溝對蝦
Arthropoda	Malacostraca	Decapoda	Solenoceridae	Solenoceridae sp.	管鞭蝦科未知種
Arthropoda	Malacostraca	Decapoda	Palaemonidae	Palaemonidae sp.	長臂蝦科未知種
Arthropoda	Malacostraca	Decapoda	Palaemonidae	<i>Conchodytes</i> sp.	江瑤蝦未知種
Arthropoda	Malacostraca	Decapoda	Palaemonidae	<i>Palaemon serrifer</i>	鋸齒長臂蝦
Arthropoda	Malacostraca	Decapoda	Alpheidae	<i>Alpheus lobidens</i> *	葉齒鼓蝦
Arthropoda	Malacostraca	Decapoda	Diogenidae	<i>Calcinus latens</i> *	隱伏硬殼寄居蟹
Arthropoda	Malacostraca	Decapoda	Diogenidae	<i>Clibanarius eurysternus</i>	寬胸細螯寄居蟹
Arthropoda	Malacostraca	Decapoda	Diogenidae	<i>Clibanarius infraspinus</i>	下棘細螯寄居蟹
Arthropoda	Malacostraca	Decapoda	Paguridae	<i>Pagurus benedicti</i> *	小形寄居蟹
Arthropoda	Malacostraca	Decapoda	Dromiidae	<i>Alcockdromia fallax</i>	-
Arthropoda	Malacostraca	Decapoda	Leucosiidae	<i>Pyrhila pisum</i>	豆形拳蟹
Arthropoda	Malacostraca	Decapoda	Majidae	<i>Micippa philyra</i>	拳折額蟹
Arthropoda	Malacostraca	Decapoda	Calappidae	<i>Calappa philargius</i> *	逍遙饅頭蟹
Arthropoda	Malacostraca	Decapoda	Parthenopidae	<i>Cryptopodia fornicata</i>	圓拱隱足蟹
Arthropoda	Malacostraca	Decapoda	Portunidae	<i>Scylla serrata</i>	鋸緣青蟬
Arthropoda	Malacostraca	Decapoda	Portunidae	<i>Thalamita crenata</i> *	鈍齒短槳蟹

Arthropoda	Malacostraca	Decapoda	Portunidae	<i>Thalamita prynna</i> *	底棲短樂蟹
Arthropoda	Malacostraca	Decapoda	Portunidae	<i>Thalamita sima</i>	雙額短樂蟹
Arthropoda	Malacostraca	Decapoda	Xanthidae	<i>Atergatis integerrimus</i>	正直愛潔蟹
Arthropoda	Malacostraca	Decapoda	Xanthidae	<i>Leptodius affinis</i> *	溝痕皺蟹
Arthropoda	Malacostraca	Decapoda	Xanthidae	<i>Leptodius gracilis</i> *	細巧皺蟹
Arthropoda	Malacostraca	Decapoda	Varunidae	<i>Gaetice depressus</i>	平背蜞
Arthropoda	Malacostraca	Decapoda	Sesarmidae	<i>Nanosesarma minutum</i>	小型小相手蟹
Arthropoda	Malacostraca	Decapoda	Sesarmidae	<i>Parasesarma pictum</i>	斑點擬相手蟹
Arthropoda	Malacostraca	Decapoda	Macrophthalmidae	<i>Chaenostoma crassimanus</i>	粗掌開口蟹
Arthropoda	Malacostraca	Decapoda	Macrophthalmidae	<i>Chaenostoma orientale</i>	東方開口蟹
Arthropoda	Malacostraca	Decapoda	Mictyridae	<i>Mictyris brevidactylus</i> *	短指和尚蟹
Arthropoda	Malacostraca	Decapoda	Ocypodidae	<i>Ocypode ceratophthalmus</i>	角眼沙蟹
Arthropoda	Malacostraca	Decapoda	Ocypodidae	<i>Gelasimus borealis</i>	北方丑招潮蟹
Arthropoda	Malacostraca	Decapoda	Ocypodidae	<i>Gelasimus jocelynae</i>	賈瑟琳丑招潮
Arthropoda	Malacostraca	Isopoda	Ligiidae	<i>Ligia exotica</i> *	奇異海蟑螂
Arthropoda	Thecostraca	Balanomorpha	Balanidae	<i>Amphibalanus amphitrite</i> *	紋藤壺
Arthropoda	Thecostraca	Balanomorpha	Balanidae	<i>Tetraclitella multicosata</i> *	多肋小笠藤壺
Echinodermata	Asteroidea	Valvatida	Archasteridae	<i>Archaster typicus</i> *	飛白楓海星
Echinodermata	Asteroidea	Valvatida	Oreasteridae	<i>Protoreaster nodosus</i>	-
Echinodermata	Echinoidea	Diadematoida	Diadematidae	<i>Diadema savignyi</i>	沙氏冠海膽
Echinodermata	Echinoidea	Camarodonta	Toxopneustidae	<i>Tripneustes gratilla</i>	白棘三列海膽
Echinodermata	Echinoidea	Camarodonta	Temnopleuridae	<i>Salmacis sphaeroides</i>	雜色角孔海膽
Echinodermata	Holothuroidea	Holothuriida	Holothuriidae	<i>Holothuria atra</i> *	黑海參
Echinodermata	Holothuroidea	Holothuriida	Holothuriidae	<i>Holothuria fuscocinerea</i>	棕環參
Echinodermata	Holothuroidea	Holothuriida	Holothuriidae	<i>Holothuria hilla</i> *	黃疣海參

物在海草床中之重要性（鍾 2012；林 2019；Short *et al.* 2007）。鎮海潮間帶之海草組成以卵葉鹽草為主，冼等（2011）指出，卵形葉海草剝落的葉片所產生的有機碎屑，是許多貝類或濾食性生物的食物來源之一。這些貝類和濾食性生物在海草床生態系中扮演初級消費者的角色，除了是許多海洋生物的食物來源（林與蕭 2011），其濾食行為亦有助穩定海草床生態系的水質（黃與邱 2016），故監測此類生物的族群量對研擬未來生態保育政策具有重要性。

螺貝類生物之多樣性指數分析

本研究於鎮海海草床共記錄 16 種螺貝類物種，各月份之多樣性指數如表 2 所示。由分析結果得知，第一優勢種為海蜷科（*Batillariidae*）物種；第二優勢種為蝾螺科（*Turbinidae*）物種。經計算，鎮海海草床之種類豐度介於 0.29-1.31；優勢度介於 0.94-1.00；歧異度介於 0.10-0.65；均勻度則介於 0.07-0.41。以下針對各項多樣性指數進行討論：

(1) 鎮海海草床螺貝類之種類豐度

本研究之計算結果顯示，鎮海海草床在 2022 年 4 月及 7 月的豐度最低（0.29）；2022 年 3 月最高（1.31）。進一步以單因子變異數分析（以下簡稱 ANOVA）進行季節間之分析，發現無顯著差異（ $p > 0.05$ ），顯示種類豐度方面無明顯季節變化。根據每月調查結果，於鎮海海草床所發現之螺貝類大致介於 3-5 種，皆以海蜷科物種為大宗；蝾螺科物種居次，雖 2022 年 3 月發現多達 10 種螺貝類物種，但除海蜷科及蝾螺科物種之外，其餘種類皆僅發現零星個體，故種類豐度無明顯季節變化。

(2) 鎮海海草床螺貝類之優勢度

優勢度顯示第一與第二優勢種在總個體數中的相對比例，若優勢度接近 1，代表第一優勢種在群體中佔多數；由分析結果得知，鎮海海草床各月份之優勢度以 2022 年 9 月及 11 月為最低（0.94）；2022 年 4 月及 6 月為最高（1.00），顯示第一優勢種的海蜷科物種在群集組成中為多數，與實際觀察結果相符。而 ANOVA 之結

果則可發現季節間有顯著差異 ($p < 0.05$)，呈春夏高於秋冬之季節變化，係因海蜷科物種在春夏時的族群數較秋冬多所致。

(3) 鎮海海草床螺貝類之歧異度

經計算結果可發現，鎮海海草床在 2022 年 4 月的歧異度最低 (0.10)；2022 年 10 月最高 (0.65)。ANOVA 之分析結果顯示季節間有顯著差異 ($p < 0.05$)，呈秋冬高於春夏的季節變化，此結果係因海蜷科物種在秋冬時的族群數較春夏季少所致。

(4) 鎮海海草床螺貝類之均勻度

均勻度介於 0 至 1 之間，數值越接近 1 時，顯示種間個體數分布較均勻。由計算結果可知，鎮海海草床在 2022 年 4、5、8 月的均勻度最低 (0.07)；2022 年 10 月最高 (0.41)，可發現各月份之均勻度偏低，顯示鎮海海草床之種間個體數分布較不均勻。根據 ANOVA 的分析結果，發現季節間亦具顯著差異 ($p < 0.05$)，呈秋冬高於春夏的季節變化，其原因亦為海蜷科物種秋冬時的族群數較春夏季少所致。

綜整上述分析結果可知，因海蜷科物種為鎮海海草床螺貝類生物中的第一優勢種，故其族群數的變化為左右各項多樣性指數之主因。Kamimura and Tsuchiya (2008) 的研究指出，燒酒海蜷 (*Batillaria zonalis*) 為沖繩縣豐見城市與根 (Yone, Tomigusuku, Okinawa) 潮間帶的優勢種，其族群變化與孔石蓴 (*Ulva pertusa*) 之覆蓋率相關。該研究結果顯示，燒酒海蜷之族群大小有明顯的季節變化，於 1 至 4 月時的生物量較高，可能與其食物來源 — 孔石蓴在 1 至 5 月時的高覆蓋率有關，由該項研究可推測鎮海海草床海蜷科物種之族群量亦與海草床消長有關。

根據本研究調查結果，鎮海海草床的海蜷科物種數於春夏兩季達到高峰；秋末 (約 10 月時) 則最低 (圖 3)，而鎮海潮間帶於 4 月時有較高的海草覆蓋率；至 9 月時則明顯消失 (圖 4)，可推測海蜷科物種之族群數受海草床之消長而產生季節性變化，與趙 (2018) 於岐頭灣進行的調查結果相符，該研究指出，生物量高峰與卵葉

表 2 鎮海海草床各月份螺貝類生物之個體數及多樣性指數

Table 2 Monthly individual counts and diversity indices of gastropod and bivalve species in Chenhai seagrass bed

Family	Chinese name	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Batillariidae	海蠔科	907	960	1,168	1,599	1,013	540	309	191	268	472	491	637	1,047	1,089
Turbinidae	蝾螺科	32	19	19	58	28	16	20	53	31	23	17	36	54	42
Lottiidae	蓮花青螺科	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Muricidae	骨螺科	3	0	10	9	0	0	14	8	15	9	12	7	10	14
Lucinidae	滿月蛤科	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Chitonidae	石蟹科	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostreidae	牡蠣科	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Veneridae	簾蛤科	5	1	1	3	4	1	0	0	4	1	1	0	0	2
Cypraeidae	寶螺科	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilidae	殼菜蛤科	0	0	0	0	0	2	0	0	1	0	0	0	0	0
Trochidae	鐘螺科	0	0	0	0	0	1	3	0	0	0	0	0	0	0
Buccinidae	峨螺科	0	0	0	0	0	1	0	0	0	2	0	0	2	0
Nassariidae	織紋螺科	1	0	0	2	0	0	2	0	0	0	0	0	0	1
Neritidae	蜆螺科	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Naticidae	玉螺科	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Pinnidae	江珧蛤科	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Total number of individuals		953	980	1,198	1,671	1,045	561	350	252	319	507	521	681	1,113	1,148
Taxa count		10	3	4	5	3	6	7	3	5	5	4	4	4	5
Richness		1.31	0.29	0.42	0.54	0.29	0.79	1.02	0.36	0.69	0.64	0.48	0.46	0.43	0.57
Dominance		0.99	1.00	0.99	0.99	1.00	0.99	0.94	0.97	0.94	0.98	0.98	0.99	0.99	0.99
Diversity		0.25	0.10	0.14	0.21	0.15	0.19	0.51	0.65	0.59	0.31	0.27	0.27	0.26	0.24
Evenness		0.08	0.07	0.07	0.09	0.09	0.07	0.18	0.41	0.25	0.13	0.13	0.14	0.13	0.10

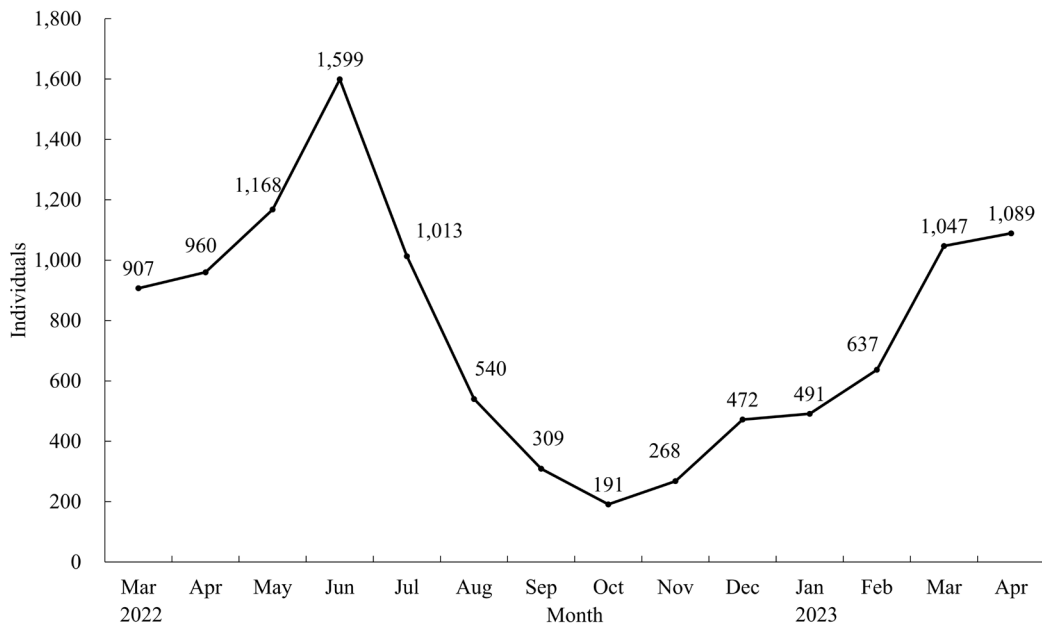


圖 3 鎮海海草床各月份海蜷科物種個體數。

Fig. 3 The individual counts of Batillariidae species in Chenhai seagrass bed for each month.

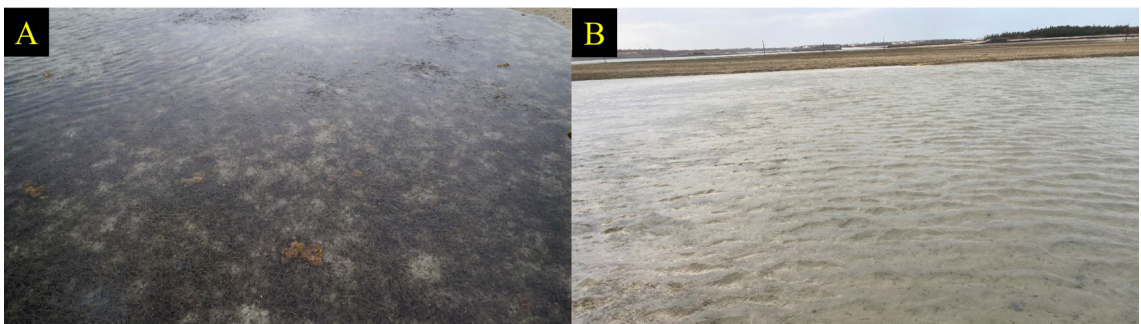


圖 4 鎮海潮間帶海草覆蓋情形 (A: 2022 年 4 月調查時拍攝, 海草茂密; B: 2022 年 9 月調查時拍攝, 海草床已明顯消失)。

Fig. 4 Chenhai intertidal seagrass coverage (A: Captured in April 2022 during the survey, showing dense seagrass; B: Captured in September 2022 during the survey, indicating a noticeable disappearance of the seagrass bed).

鹽草之花果期相伴出現，由此可知，生物量與花果期息息相關。

本研究已初步瞭解鎮海海草床的無脊椎動物種類，由調查結果可見，鎮海海草床具豐富的生態，然而，因巷子及講美漁港的航道開發，使鎮海潮間帶的海草床面積大幅縮減，因此澎湖水產試驗所於近年舉辦海草移植活動（林 2019），透過讓當地民眾親身參與復育海草床之行動，使民眾能更加瞭解海草床的重要性，未來亦可考慮規劃「鎮海海草復育區」，並制定相關海草床保護政策，及持續推動社區參與活動與落實環境教育；未來研究應持續監測無脊椎動物甚至是脊椎動物的族群量，並分析海草移植的成效，作為永續管理之重要參考依據。

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臺灣中部臺灣山茶 (*Camellia formosensis*) 兒茶素及咖啡因含量分析

Analysis of catechins and caffeine content of *Camellia formosensis* in Central Taiwan

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摘要

臺灣山茶 (*Camellia formosensis*) 為臺灣特有的山茶科植物，零星分布於臺灣中部以南的中低海拔山區，並在臺灣中部形成其天然分布的最北邊界，具有穩定的野外族群。本研究選定南投縣仁愛鄉眉原山、鹿谷鄉鳳凰山、鹿谷鄉樟湖山及信義鄉雙龍的臺灣山茶族群，進行兒茶素和咖啡因含量分析。研究結果顯示，鳳凰山地區的總兒茶素 (TC) 含量最高，平均為 $103.70 \text{ mg}\cdot\text{g}^{-1}$ ，其中主要兒茶素成分包括表沒食子兒茶酚沒食子酸 (EGCG)、表沒食子兒茶酚 (EGC) 和沒食子兒茶素 (GC)，其中又以 EGCG 含量最高，平均達 $44.81 \text{ mg}\cdot\text{g}^{-1}$ 。咖啡因平均含量為 $25.68 \text{ mg}\cdot\text{g}^{-1}$ ，以樟湖山地區最高，雙龍地區最低。此外，不同個體的臺灣山茶在酯型、非酯型兒茶素含量與兒茶素品質指數、苦澀味指數方面具有明顯差異。利用二階段集群分析將中部地區臺灣山茶分為高總兒茶素型、低總兒茶素型、高 EGCG 型和低 EGCG 型等四大類型，顯示臺灣中部地區的臺灣山茶具有高度的基因多樣性。本研究結果對於臺灣山茶的優良品系選育和保育提供了重要參考依據。

關鍵詞：臺灣山茶、兒茶素、咖啡因、兒茶素苦澀味指數

Abstract

Camellia formosensis, endemic to Taiwan, is a unique species of the Theaceae family, sparsely distributed in the mid to low-altitude mountainous regions of central to southern Taiwan, forming its natural northern boundary in central Taiwan. It maintains stable populations in the wild. This study selected populations of *Camellia formosensis* from Meiyuan Mountain in Renai Township, Fenghuang Mountain and Zhanghu Mountain in Lugu Township, and Shuanglong in Xinyi Township, Nantou County, Taiwan, for analysis of catechin and caffeine content. The results showed that the total

catechin (TC) content was highest in the Fenghuang Mountain area, averaging 103.70 mg.g^{-1} , with major catechin components including epigallocatechin gallate (EGCG), epigallocatechin (EGC), and galocatechin (GC). Among them, EGCG content was the highest, averaging 44.81 mg.g^{-1} . The average caffeine content was 25.68 mg.g^{-1} , with the highest in the Zhanghu Mountain area and the lowest in the Shuanglong area. Furthermore, differences were observed among different individuals of *Camellia formosensis* in terms of esterified and non-esterified catechin contents, as well as catechin quality and bitterness indices. Using two-stage cluster analysis, *Camellia formosensis* in central Taiwan was classified into four major types: high total catechin type, low total catechin type, high EGCG type, and low EGCG type, indicating a high degree of genetic diversity. These findings provide important references for the breeding and conservation of superior strains of *Camellia formosensis*.

Key words: *Camellia formosensis*, catechin, caffeine, catechin bitterness index

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緒言

茶，是世界上消費量最大的飲料之一 (Chan *et al.* 2011)，主要原因在於其獨特風味和眾多健康益處 (Cooper 2012)。而茶的風味及健康益處是來自茶葉中豐富的植化素，如兒茶素 (catechin)、咖啡因 (caffeine)、游離胺基酸 (free amino acid) 及多酚類 (polyphenol) 等，它們不僅賦予茶的健康機能性外，也影響茶葉的品質 (曾雯郁 2021; Borse *et al.* 2002; Senanayake 2013; Xia *et al.* 2020)。其中，兒茶素是茶葉中的重要成分，佔茶葉乾重的 12-24%，具有強烈的抗氧化及生理活性。茶樹中兒茶素類化合物主要有表沒食子兒茶酚沒食子酸 (epigallocatechin gallate, EGCG)、表兒茶酚沒食子酸 (epicatechin gallate, ECG)、表沒食子兒茶酚 (epigallocatechin, EGC)、兒茶素 (catechin, C)、表兒茶酚 (epicatechin, EC)、沒食子兒茶素沒食子酸酯 (gallocatechin gallate, GCG)、沒食子兒茶素 (gallocatechin, GC)、兒茶素沒食子酸酯 (catechin

gallate, CG) 等八大類 (吳白玟等 2011; Yang *et al.* 2007; Wan *et al.* 2023; Wen *et al.* 2024)。然而，茶具有自交不親和 (self-incompatibility) 的特性，因此其不同群落間或族群內的基因型有著高度異質化 (Yao *et al.* 2012; Jahangirzadeh Khiavi *et al.* 2021)。兒茶素的含量因茶樹品種、葉齡和產區的環境條件等而有很大差異 (Wei *et al.* 2011; Sabhapondit *et al.* 2012; Anand *et al.* 2015)。

根據文獻記載，於清康熙 56 年 (1717 年) 完成的諸羅縣志，即有提及先民會利用臺灣山茶來製茶，並指出水沙連一帶分布甚廣 (周鍾瑄 1993)。現今臺灣山茶科 (Theaceae) 山茶屬 (*Camellia*) 植物總計有 12 種，其中具有潛力可製成茶飲的僅有臺灣山茶 (*Camellia formosensis*) 及垢果山茶 (*Camellia furfuracea*) (沈揮勝 2019; 蘇夢淮 2024)。臺灣山茶是臺灣的特有植物，主要分布在臺灣中部、南部中低海拔 (700-1,650 m) 山區及東部臺東延平鄉永康山 (蘇夢淮 2007; 龔冠寧等 2021;

汪澤宏 2024)。過去臺灣山茶曾被認為是茶樹 (*Camellia sinensis*) 的亞種 (subspecies)、變種 (variety) 或變型 (form) (翁世豪 2022; 胡智益 2024); 直至 Su 等人 (2009) 利用核基因 RPB2 分析, 確認將臺灣山茶重新定義為種 (species) 的地位。臺灣山茶的野外族群及數量, 因環境開發及破壞, 已日趨減少, 被臺灣維管束植物紅皮書名錄評定為接近受威脅 (near threatened, NT) 等級的物種 (臺灣植物紅皮書編輯委員會 2017)。但因其獨特風味, 頗具有開發及研究價值 (翁世豪 2022; 汪澤宏 2024), 目前臺灣山茶已在南投縣魚池鄉、高雄六龜等地區形成地方特色產業 (蘇夢淮 2015)。

近年來農業部茶及飲料作物改良場廣泛蒐集全臺的臺灣山茶, 建立多個種原品系, 包括南投縣的眉原山茶、德化社山茶、鳳凰山茶, 嘉義縣的樂野山茶、龍頭山茶, 高雄縣的鳴海山茶、南鳳山山茶及臺東縣的永康山茶等 (蘇夢淮 2015; 翁世豪 2022)。農業部茶及飲料作物改良場除利用臺灣

山茶作為父本, 緬甸大葉種作為母本, 成功雜交出適合製作紅茶的臺茶 18 號之外; 更利用永康山茶進行優良品系選育, 於 2019 年正式命名為臺茶 24 號 (沈勇強等 2015; 蕭建興 2023)。由此可知臺灣山茶資源的重要性, 可作為後續茶樹育種或特色茶品開發之用。

農業部林業及自然保育署自 2019 年起推動施行「林業永續多元輔導方案」, 開放林業用地可經營林下經濟, 並頒布「林下經濟經營使用審查作業要點」, 目前開放項目有金線連 (*Anoectochilus formosanus*)、段木香菇及木耳、林下養蜂、臺灣山茶、馬蘭 (*Strobilanthes cusia*) 及臺灣天仙果 (*Ficus formosana*) 等 6 種 (邱祈榮 2019; 農業部 2023)。林下經濟是森林的多元經營利用, 除林木主產物經營收穫外, 另於森林冠層下經營森林副產物, 在以森林永續經營與不超限利用原則下, 應用林地資源和林下空間的複合生產模式, 著重於林下空間的配置規劃與使用, 達成森林資源共享與協調發展的生態農林業 (陳

芬蕙和何政坤 2018；黃裕星 2018）。林下經濟的推動，除可提高林地資源利用，並可增加林農的短期收入，提高林農營林的意願，以確保木材資源數量、品質的穩定性（陳芬蕙和何政坤 2018；黃裕星 2018；巫建成等 2020）。臺灣山茶為森林下層的植物，耐蔭性佳，極適合林下栽植且經濟價值高，十分具備發展潛力。

臺灣中部的臺灣山茶族群為臺灣山茶天然分布緯度最高的族群（蘇夢淮 2007；胡智益 2024），且過去文獻指出，臺灣中部的臺灣山茶基因多樣性高於南部及東部的族群（汪澤宏 2024）。然而，臺灣中部地區的臺灣山茶研究仍然較為缺乏，故本研究選擇中部地區不同族群的野生臺灣山茶進行成分分析之研究，探討中部地區臺灣山茶的兒茶素及咖啡因組成之差異，以提供未來優良單株選拔及資源保育的重要基礎資料。

材料與方法

一、試驗材料

本研究於 2022 年 10 月在南投縣鹿谷鄉鳳凰山（Fenghuang Mountain, FHM）及樟湖山（Zhanghu Mountain, ZHM）、信義鄉雙龍地區（Shuanglong, SL）、仁愛鄉眉原山（Meiyuan Mountain, MYM），共四個區域，進行臺灣山茶茶芽採樣，共選定 20 株樣木，分別為鳳凰山 4 株、樟湖山 10 株、雙龍 3 株、眉原山 3 株。研究區域位置如附錄 1，採樣座標、海拔高度及現況如附錄 2 所示。本研究區域鄰近之日月潭氣象站資料顯示，該區域之年均溫約為 19.3°C，最冷月為 1 月份，其月均溫為 14.4°C，最暖月則為 7 月份，月均溫為 22.9°C；年均降雨量為 2,343 mm，降雨主要集中在 3 月至 9 月（交通部中央氣象署 2024）。

二、試驗方法

本研究於臺灣山茶樣木中，採摘 1 芽 2 葉之新梢，鮮重各 100 g，以烘箱設定 60°C 進行乾燥 10 hr 備用。隨後取 0.25 g 乾重，磨碎後利用 75% 酒精定量至 10 ml，萃取時間 1 hr，前後各

以超音波震盪 1 min，萃取液以純水稀釋 10 倍後過濾，然後採用高效能液相層析儀系統 (high performance liquid chromatography, HPLC) (Shimadzu, Japan)，分離管柱採用 C6H5 (phenyl) 管柱 (250 mm × 4.6 mm × 5 μm)，樣品注射量 10 μL，移動相 (mobile phase) 流速為 0.8 ml/min，檢測波長 280 nm，藉以分析咖啡因與 8 種主要的兒茶素，即 EGCG、ECG、EGC、C、EC、GCG、GC、CG，標準品藥劑購自 Sigma 公司 (黃志煜等 2003；胡正恆和陳芬蕙 2020；Song *et al.* 2012)。總兒茶素 (total catechins, TC) 則是將上述兒茶素進行加總。兒茶素苦澀味指數 (catechin bitterness index, CBI) 及兒茶素品質指數 (catechin quality index, CQI) 均是代表茶葉品質的指數 (Tan *et al.* 2020; Lu *et al.* 2023)；兒茶素苦澀味指數數值越大，苦澀味越重；兒茶素品質指數越高，則代表茶菁嫩度和品質愈好，所製成綠茶品質愈高；隨著茶菁老化和品質不佳，兒茶素品質指數也降低，CBI 及 CQI 分別按照公式 (1)

及 (2) 計算。

$$CBI = \frac{EGCG+EGC+ECG+GC}{EC+C} \quad (1)$$

$$CQI = \frac{EGCG+EGC}{EGC} \times 100 \quad (2)$$

三、統計分析

本研究使用 SPSS 統計套裝軟體 (statistical product and service solutions, version 26.0)，進行單因子變異數分析 (one-way ANOVA) 比較不同地區與不同品系之兒茶素及咖啡因含量之差異，再以 Tukey' HSD 檢定方法進行顯著性差異之比較，分析時所使用之信賴區間為 95 %。並以二階段集群分析法 (two steps cluster) 進行集群分析 (cluster analysis)，研析臺灣山茶兒茶素之化學品系，當不同來源單株間的距離愈小，表示兩者的相似度愈高，即兒茶素成分的組成與含量愈趨於一致 (鄭森松等 2008)，最後依各集群共同表徵 (即 TC 及 EGCG 含量多寡)，將其區分為高總兒茶素型、低總兒茶素型、高 EGCG 型和低 EGCG 型等四大類型。

結果與討論

一、兒茶素含量之分析

臺灣中部地區之臺灣山茶總兒茶素含量，經 HPLC 分析結果，如表 1 所示。本研究區域的臺灣山茶總兒茶素以鳳凰山地區為最高，總兒茶素含量為 $103.70 \pm 21.61 \text{ mg.g}^{-1}$ （平均值 \pm 標準差 standard deviation），眉原山 $78.63 \pm 13.35 \text{ mg.g}^{-1}$ 、樟湖山 $76.09 \pm 27.91 \text{ mg.g}^{-1}$ 次之，最低的則是雙龍地區的 $63.67 \pm 13.88 \text{ mg.g}^{-1}$ ，而四個區域的臺灣山茶總兒茶素之間未有顯著差異。前人研究指出，六龜地區臺灣山茶，總兒茶素以多納 $149.40 \pm 15.90 \text{ mg.g}^{-1}$ 最高，而扇平綠心芽 $122.40 \pm 2.20 \text{ mg.g}^{-1}$ 總兒茶素含量較低；相較之下，臺灣中部地區的臺灣山茶總兒茶素略低於六龜地區的臺灣山茶（陳盈如等 2019）。另以小葉種茶樹的青心烏龍及臺茶 12 號的新鮮茶芽進行分析，其總兒茶素含量則分別是 $33.57\text{-}33.42 \text{ mg.g}^{-1}$ 及 $35.62\text{-}36.44 \text{ mg.g}^{-1}$ （林佳妮 2009），但另一試驗青心烏龍及臺茶 12 號新鮮茶芽總兒茶素分析結果，兩者則有顯著差異，臺茶 12 號

比青心烏龍之平均含量多 16.41 mg.g^{-1} （石榆鳳 2007），推測其可能是受到基因、氣候（如溫度、日照時間和降雨量等）、土壤、生長海拔和採摘季節等因素影響所致（Wei *et al.* 2011; Anand *et al.* 2015）。

臺灣中部不同地區的臺灣山茶，8 種兒茶素組成分析，結果如表 1 所示，鳳凰山跟樟湖山的 C 之間有顯著差異（ $p < 0.01$ ），而鳳凰山跟樟湖山間的 CG 及鳳凰山跟樟湖山、鳳凰山跟雙龍的 ECG 有顯著差異（ $p < 0.05$ ）；EC、EGC、EGCG、GC、GCG 等五種兒茶素皆無顯著差異性。臺灣中部地區臺灣山茶兒茶素，兒茶素含量主要是以 EGCG、EGC 及 GC 等 3 種居多，其中又以 EGCG 為主，平均含量達 $44.81 \pm 18.61 \text{ mg.g}^{-1}$ ，以鳳凰山地區含量 $62.23 \pm 16.36 \text{ mg.g}^{-1}$ 為最高，而雙龍地區含量最低僅 $36.90 \pm 14.96 \text{ mg.g}^{-1}$ ，皆明顯高於臺灣主要栽培大葉種茶樹品種臺茶 8 號的 7.34 mg.g^{-1} 、臺茶 18 號 10.52 mg.g^{-1} 及小葉種茶樹品種青心烏龍 7.26 mg.g^{-1} 及臺茶 12 號 10.90 mg.g^{-1} （石榆鳳 2007）。而 EGC

兒茶素含量部分，臺灣中部地區臺灣山茶的平均含量達 $12.54 \pm 9.66 \text{ mg.g}^{-1}$ ，以眉原山地區含量 $16.33 \pm 3.73 \text{ mg.g}^{-1}$ 為最高，雙龍地區含量 $6.40 \pm 3.95 \text{ mg.g}^{-1}$ 最低；而小葉種茶樹品種 EGC 含量部分，青心烏龍 $3.78\text{-}23.99 \text{ mg.g}^{-1}$ 及臺茶 12 號 $5.06\text{-}26.63 \text{ mg.g}^{-1}$ （石榆鳳 2007；林佳妮 2009），兒茶素的含量攸關著茶湯的回甘程度，其回甘的強度主要會隨 EGC 和 EC 濃度的增加而提高，但亦會受 EGCG、咖啡因和茶胺酸影響（Zhang *et al.* 2020），若要製作回甘度高的茶品，建議可選擇高 EGC 和 EC 的品系。此外茶芽中 EGC 的含量與製成紅茶中茶黃素（theaflavin）的含量呈正相關，故茶黃素被認為是衡量紅茶品質的重要指標，由此可知，EGC 亦是影響紅茶品質的重要兒茶素種類（Roberts 1958; Yao *et al.* 2005）。本研究 GC 的部分，平均含量達 $10.11 \pm 7.26 \text{ mg.g}^{-1}$ ，以樟湖山含量 $12.25 \pm 8.76 \text{ mg.g}^{-1}$ 為最高，眉原山則是最低含量為 $5.47 \pm 3.52 \text{ mg.g}^{-1}$ 。鳳凰山 ECG 含量最高為 $9.13 \pm 2.89 \text{ mg.g}^{-1}$ ，而雙龍則最

低為 $3.93 \pm 0.72 \text{ mg.g}^{-1}$ ；而青心烏龍及臺茶 12 號茶樹品種的 ECG 則分別為 1.11 mg.g^{-1} 及 1.43 mg.g^{-1} （石榆鳳 2007），ECG 是兒茶素中苦澀味最明顯的兒茶素種類，若要製作高品質的綠茶，建議以低 ECG 的茶樹品種來製作（Jin *et al.* 2018），但 ECG 和 EGCG 則是與紅茶的品質呈正相關（Yao *et al.* 2005）；故雙龍地區低 ECG 的臺灣山茶可嘗試製作綠茶，而鳳凰山高 ECG 的臺灣山茶則適宜作紅茶。而 8 種兒茶素中以 CG 含量為最低，平均含量僅達 $0.27 \pm 0.20 \text{ mg.g}^{-1}$ 。

影響兒茶素類含量的因素，主要有品種、季節、生長部位、栽培管理、氣候、光照及製茶過程等（Wei *et al.* 2011; Anand *et al.* 2015; Zheng *et al.* 2018; Yu *et al.* 2020）。總兒茶素、兒茶素組成分及兒茶素被多元酚氧化酶（polyphenol oxidase）催化之茶紅素（thearubigins）、茶黃素等，為決定茶葉品質的重要影響因子，故常被作為茶葉品質評比的參考指標（Roberts 1958; Yao *et al.* 2005; Yu *et al.* 2020）。

二、咖啡因含量之分析

茶葉中的生物鹼 (alkaloids) 化合物包含咖啡因 (caffeine)、可可鹼 (theobromine) 及茶鹼 (theophylline) (Gramza-Michałowska 2014)，其中咖啡因為茶葉中最主要的生物鹼，種子及嫩葉中含量較高，佔乾物重的 2-5%，為茶葉苦味的主要來源之一 (戴佳如 2016；Zhu *et al.* 2019；Deka *et al.* 2021)。茶葉中的咖啡因，除不同茶樹品種間含量差異甚大外，亦會受到採摘部位、季節、氣候和栽培條件等因子的影響 (戴佳如 2016；郭芷君和楊美珠 2022；Zhu *et al.* 2019)。以 Zhu 等人 (2019) 進行山茶屬植物的新鮮幼葉進行成分分析結果為例，小葉種茶樹 (*Camellia sinensis*) 四季春 (Shuchazao) 品種的咖啡因含量為 $34.17 \pm 3.70 \text{ mg.g}^{-1}$ ，而大葉種茶樹阿薩姆 (*Camellia sinensis* var. *assamica*) 雲康 43 號 (Yunkang 43) 品種的咖啡因含量則為 $42.85 \pm 0.85 \text{ mg.g}^{-1}$ ，可知大葉種茶樹咖啡因含量高於小葉種茶樹。本研究臺灣山茶咖啡因平均含量為 $25.68 \pm 5.49 \text{ mg.g}^{-1}$ ，

以樟湖山地區 $27.57 \pm 4.04 \text{ mg.g}^{-1}$ 為最高，雙龍地區則是最低為 $23.10 \pm 3.21 \text{ mg.g}^{-1}$ ，然不同地區間差異並不顯著 (表 2)。而永康山地區 4 種不同品系臺灣山茶的咖啡因含量則是在 $24.43\text{-}31.80 \text{ mg.g}^{-1}$ ，與本研究結果相當 (林亞弘 2019)。六龜試驗林的野生臺灣山茶咖啡因含量則高達 $70.70\text{-}123.50 \text{ mg.g}^{-1}$ ，明顯高於臺灣中部及東部地區臺灣山茶咖啡因含量，尤其是南鳳山地區的野生臺灣山茶 (陳盈如等 2019)。而本研究結果與臺灣常見栽培茶樹品種的咖啡因含量相比，略低於大葉種茶樹品種臺茶 8 號的 28.40 mg.g^{-1} 、臺茶 18 號 26.31 mg.g^{-1} ，但略高於小葉種茶樹品種青心烏龍 23.42 mg.g^{-1} 及臺茶 12 號 22.37 mg.g^{-1} (林宜昕 2008)。

三、酯型兒茶素與非酯型兒茶素之分析

兒茶素又可分為酯型兒茶素 (gallate type catechins) 和非酯型兒茶素 (non-gallate type catechins)，其中，酯型兒茶素所占比例最大，包括

EGCG、ECG、GCG 及 CG 等；非酯型兒茶素則有 C、EC、EGC 及 GC 等。另酯型兒茶素具有較高之抗氧化活性，被認為會影響茶葉的品質（林金科等 2005；Liu and Tzen 2022）。本研究不同來源之臺灣山茶，除 ZHM-7、ZHM-8、SL-1 及 MYM-2 等 4 個單株的非酯型兒茶素高於酯型兒茶素外，其餘單株酯型兒茶素總量均高於非酯型兒茶素，與過去六龜及永康山地區之臺灣山茶酯型兒茶素和非酯型兒茶素含量研究結果相仿（林亞弘 2019；陳盈如等 2019）。然鳳凰山、樟湖山、雙龍及眉原山等不同群體間非酯型兒茶素及酯型兒茶素總量並無顯著差異（表 3、圖 1），但不同單株間之酯型兒茶素、非酯型兒茶素含量仍具一定程度的變異；例如非酯型兒茶素總量以鳳凰山地區為最高達 31.65 mg.g^{-1} ，眉原山地區次之，達 30.03 mg.g^{-1} ，雙龍地區則為 21.70 mg.g^{-1} 為最低。酯型兒茶素總量部分鳳凰山地區臺灣山茶的總量達 72.05 mg.g^{-1} ，最低則為雙龍地區的 41.97 mg.g^{-1} 。顯示臺灣中部地區的臺灣山茶具有豐富的

遺傳多樣性。

四、兒茶素品質指數和苦澀味指數之分析

利用臺灣中部地區臺灣山茶兒茶素資料，進行兒茶素品質指數和苦澀味指數計算，結果顯示（表 3），臺灣中部地區的臺灣山茶兒茶素品質指數在 152.91-2503.70 之間，同一地區，但不同單株間之差異頗大，以鳳凰山為例，FHM-3 其兒茶素品質指數為 233.49，但 FHM-4 卻高達 2503.70。而臺灣中部地區的臺灣山茶兒茶素苦澀味指數則介於 4.95-51.54 之間，同一地區，但不同單株間指數亦有所差異，以樟湖山為例，ZHM-7 其兒茶素苦澀味指數為 6.94，但 ZHM-10 則是 51.54。由此可知，臺灣中部地區臺灣山茶兒茶素含量及組成差異甚大，其中，不乏優良單株，可提供後續栽培、育種、推廣之用。譬如，高兒茶素品質指數和低苦澀味指數，則可製成品質優良之茶葉；而兒茶素含量最高，但品質指數最低者，則適宜作為兒茶素醫療、保健食品等開發利用。

五、臺灣山茶的化學多態性

植物產生各種二次代謝物 (secondary metabolites)，使它們能夠對抗不同逆境，從而增加它們的適應性 (Kliebenstein 2004)。然而種群內和種群之間的二次代謝物普遍存在顯著差異 (Leur *et al.* 2006)，而此即為植物二次代謝物的化學多態性 (chemical polymorphism)。為瞭解臺灣中部地區不同來源間臺灣山茶化學多態性的關係，本研究利用臺灣中部地區的 20 株野生臺灣山茶樣品，以 8 種兒茶素成分對樣品進行二階段集群分析，當距離為 5 時，可將其分為 4 大類群 (表 4、圖 2)。第 1 類型為高總兒茶素型，其總兒茶素含量在 $68.90-108.60 \text{ mg.g}^{-1}$ 之間，此類型包含位於鹿谷鄉的 FHM-2 (105.10 mg.g^{-1})、FHM-3 (87.40 mg.g^{-1})、FHM-4 (91.90 mg.g^{-1})、ZHM-1 (88.10 mg.g^{-1})、ZHM-2 (81.50 mg.g^{-1})、ZHM-9 (108.60 mg.g^{-1})、ZHM-10 (68.90 mg.g^{-1})，信義鄉的 SL-2 (78.30 mg.g^{-1})，仁愛鄉的 MYM-1 (79.00 mg.g^{-1}) 及 MYM-3 (91.80 mg.g^{-1})

等；第二類型則為低總兒茶素型，其總兒茶素含量在 $47.50-65.10 \text{ mg.g}^{-1}$ 之間，包含位於鹿谷鄉的 ZHM-3 (47.50 mg.g^{-1})、ZHM-5 (61.30 mg.g^{-1})、ZHM-6 (52.40 mg.g^{-1})、SL-3 (62.00 mg.g^{-1})，仁愛鄉的 MYM-2 (65.10 mg.g^{-1})；第 3 類型的高 EGCG 型，其 EGCG 含量在 $71.70-84.50 \text{ mg.g}^{-1}$ 之間，包含位於鹿谷鄉的 FHM-1 (84.50 mg.g^{-1}) 及 ZHM-4 (71.70 mg.g^{-1})；第 4 類型的低 EGCG 型，其 EGCG 含量在 $13.80-20.70 \text{ mg.g}^{-1}$ 之間，包含位於鹿谷鄉的 ZHM-7 (13.80 mg.g^{-1})、ZHM-8 (18.50 mg.g^{-1}) 及信義鄉的 SL-1 (20.70 mg.g^{-1})。結果顯示高總兒茶素型臺灣山茶在臺灣中部地區四個族群中皆有分布，低總兒茶素型則是除鳳凰山無分佈外其餘則皆有分佈，高 EGCG 型臺灣山茶僅分布在鹿谷鄉的鳳凰山及樟湖山，而低 EGCG 型臺灣山茶則是分布在鹿谷鄉的樟湖山及信義鄉的雙龍。可知臺灣山茶 8 種兒茶素含量與組成，與地理分布較無關聯；但在不同臺灣山茶個體間可發現，其兒茶素含量及成分組成差異

性高。此結果與汪澤宏（2024）的研究結果相符，顯示臺灣中部的臺灣山茶具有高度的遺傳多樣性。

結論

本研究指出，臺灣山茶作為臺灣特有茶品具有巨大的發展潛力，然而，在發展過程中必須重視生物多樣性及保育。為了充分挖掘這一潛力，我們建議採取多項策略。首先，進行優良品系的選育，以開發出更具特色和優質的茶品種，提高競爭力和附加價值。其次，深入研究日照、溫度、水分、土壤等氣候環境因素對臺灣山茶生長和二次代謝物生合成的影響，以提供栽培指南和管理建議。政府相關單位可透過相關研究結果，制定支持臺灣山茶產業發展的政策，包括推廣、輔導、管理規範等方面的支持措施。同時，建立完整的臺灣山茶產業鏈，從種植、加工到市場推廣，滿足市場需求，提供高品質的臺灣特色茶品。這些策略的實施將有助於推動臺灣山茶產業的發展，提升其在國內外市場上

的地位和競爭力，同時促進臺灣山茶的林下經濟產業發展，實現產業和環境的雙贏。

此外臺灣山茶目前野外族群零星分布於臺灣中、南部及東部山區，族群數量稀少，加上人為干擾嚴重，多處族群已受威脅，應積極透過無性繁殖的方式，保存臺灣山茶種源，並建立完整的基因庫，確保其遺傳多樣性得以保存。野外天然的臺灣山茶族群，未來可考慮劃設保護區，並加強監測及巡視，減少人為干擾，以維護臺灣山茶野生族群能穩健生長。

綜合上述，在合理利用與開發臺灣山茶野生資源來發展臺灣山茶產業時，亦應加強保護臺灣山茶野生族群，以保護物種遺傳多樣性，並維護生態系統的完整性，以達永續多元經營之目標。

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表 1 臺灣中部地區臺灣山茶 (*Camellia formosensis*) 兒茶素成分分析Table 1 Analysis of Catechin Composition in *Camellia formosensis* from the Central Taiwan Region

Sample name	C (mg.g ⁻¹)	CG (mg.g ⁻¹)	EC (mg.g ⁻¹)	ECG (mg.g ⁻¹)	EGC (mg.g ⁻¹)	EGCG (mg.g ⁻¹)	GC (mg.g ⁻¹)	GCG (mg.g ⁻¹)	TC (mg.g ⁻¹)
FHM (n = 4)	8.38 ± 5.98 ^a	0.48 ± 0.31 ^a	2.95 ± 1.47 ^a	9.13 ± 2.89 ^a	12.83 ± 7.86 ^a	62.23 ± 16.36 ^a	7.50 ± 4.50 ^a	0.23 ± 0.29 ^a	103.70 ± 21.61 ^a
ZHM (n = 10)	1.09 ± 1.79 ^b	0.17 ± 0.11 ^b	3.36 ± 2.07 ^a	4.52 ± 2.30 ^b	13.12 ± 12.33 ^a	40.66 ± 19.29 ^a	12.25 ± 8.76 ^a	0.92 ± 0.98 ^a	76.09 ± 27.91 ^a
SL (n = 3)	2.10 ± 1.15 ^{ab}	0.40 ± 0.10 ^{ab}	2.10 ± 1.21 ^a	3.93 ± 0.72 ^b	6.40 ± 3.95 ^a	36.90 ± 14.96 ^a	11.10 ± 6.51 ^a	0.73 ± 0.40 ^a	63.67 ± 13.88 ^a
MYM (n = 3)	5.87 ± 4.05 ^{ab}	0.17 ± 0.12 ^{ab}	2.37 ± 0.86 ^a	4.87 ± 0.86 ^{ab}	16.33 ± 3.73 ^a	43.33 ± 14.16 ^a	5.47 ± 3.52 ^a	0.23 ± 0.12 ^a	78.63 ± 13.35 ^a

註 1：FHM (鳳凰山)、ZHM (樟湖山)、SL (雙龍)、MYM (眉原山)。

註 2：表中數值為平均值 ± 標準差。以 one-way ANOVA 比較不同地區兒茶素含量差異，並利用 Tukey's HSD 檢定法比較顯著性差異，不同字母表示存在顯著差異 ($p < 0.05$)。

註 3：C (兒茶素)、CG (兒茶素沒食子酸酯)、EC (表兒茶酚)、ECG (表兒茶酚沒食子酸)、EGC (表沒食子兒茶酚)、EGCG (表沒食子兒茶酚沒食子酸)、GC (沒食子兒茶素)、GCG (沒食子兒茶素沒食子酸酯)、TC (總兒茶素)。

Note 1: FHM (Fenghuang Mountain), ZHM (Zhanghu Mountain), SL (Shuanglong), MYM (Meiyuan Mountain).

Note 2: The values in the table are Mean ± SD. The differences in catechin content among different regions were compared using one-way ANOVA. Tukey's HSD test was employed to assess the significance of these differences. Different letters indicate significant differences ($p < 0.05$).

Note 3: C (catechin), CG (catechin gallate), EC (epicatechin), ECG (epicatechin gallate), EGC (epigallocatechin), EGCG (epigallocatechin gallate), GC (gallocatechin), GCG (gallocatechin gallate), TC (total catechins).

表 2 臺灣中部地區臺灣山茶 (*Camellia formosensis*) 咖啡因含量分析
 Table 2 Analysis of Caffeine Content in *Camellia formosensis* from the Central Taiwan Region

Sample name	N	Caffeine (mg.g ⁻¹)
FHM	4	23.63 ± 7.76 ^a
ZHM	10	27.57 ± 4.04 ^a
SL	3	23.1 ± 3.21 ^a
MYM	3	24.7 ± 8.63 ^a
Total	20	25.68 ± 5.49

註 1：FHM（鳳凰山）、ZHM（樟湖山）、SL（雙龍）、MYM（眉原山）。

註 2：表中數值為平均值 ± 標準差。以 one-way ANOVA 比較不同地區間咖啡因含量差異，並利用 Tukey's HSD 檢定法比較顯著性差異，同行相同字母表示無顯著差異。

Note 1: FHM (Fenghuang Mountain), ZHM (Zhanghu Mountain), SL (Shuanglong), MYM (Meiyuan Mountain).

Note 2: The values in the table are Mean ± SD. The differences in caffeine content among different regions were compared using one-way ANOVA. Tukey's HSD test was employed to assess the significance of these differences. Means sharing the same letter in the same column are not significantly different.

表 3 臺灣中部地區臺灣山茶 (*Camellia formosensis*) 兒茶素類型與品質之比較Table 3 Comparison of Catechin Types and Quality in *Camellia formosensis* from the Central Taiwan Region

Sample name	Non-gallate type catechins (mg.g ⁻¹)	Gallate type catechins (mg.g ⁻¹)	Catechin quality index	Catechin bitterness index
FHM-1	32.70	97.70	675.52	28.39
FHM-2	34.20	70.90	562.40	6.01
FHM-3	36.30	51.10	233.49	7.15
FHM-4	23.40	68.50	2,503.70	4.95
ZHM-1	27.10	61.00	423.08	21.46
ZHM-2	21.00	60.50	536.61	20.34
ZHM-3	17.30	30.20	625.53	22.35
ZHM-4	54.20	81.20	193.48	22.56
ZHM-5	20.90	40.40	582.35	26.50
ZHM-6	23.90	28.50	250.89	19.00
ZHM-7	38.80	19.10	695.65	6.94
ZHM-8	35.70	23.58	953.64	7.72
ZHM-9	42.80	65.80	238.83	10.25
ZHM-10	16.50	52.40	528.57	51.54
SL-1	25.40	25.30	991.67	10.18
SL-2	22.70	55.60	530.10	15.80
SL-3	17.00	45.00	678.46	15.97
MYM-1	25.80	53.20	385.40	26.10
MYM-2	33.40	31.70	152.91	5.12
MYM-3	30.90	60.90	410.20	7.14

註：FHM（鳳凰山）、ZHM（樟湖山）、SL（雙龍）、MYM（眉原山）。

Note: FHM (Fenghuang Mountain), ZHM (Zhanghu Mountain), SL (Shuanglong), MYM (Meiyuan Mountain).

表 4 臺灣中部地區臺灣山茶 (*Camellia formosensis*) 之化學多態性分析
 Table 4 Chemical Polymorphism Analysis of *Camellia formosensis* from the Central Taiwan Region

Type	Sample name	EGCG (mg.g ⁻¹)	TC (mg.g ⁻¹)
High TC	FHM-2	59.40	105.10
	FHM-3	45.10	87.40
	FHM-4	59.90	91.90
	ZHM-1	55.70	88.10
	ZHM-2	52.50	81.50
	ZHM-9	58.50	108.60
	ZHM-10	47.30	68.90
	SL-2	50.20	78.30
	MYM-1	48.10	79.00
	MYM-3	54.50	91.80
Low TC	ZHM-3	26.70	47.50
	ZHM-5	36.40	61.30
	ZHM-6	25.50	52.40
	SL-3	39.80	62.00
	MYM-2	27.40	65.10
High EGCG	FHM-1	84.50	130.40
	ZHM-4	71.70	135.40
Low EGCG	ZHM-7	13.80	57.90
	ZHM-8	18.50	59.28
	SL-1	20.70	50.70

註 1：FHM（鳳凰山）、ZHM（樟湖山）、SL（雙龍）、MYM（眉原山）。

註 2：EGCG（表沒食子兒茶酚沒食子酸）、TC（總兒茶素）、High TC（高總兒茶素型）、Low TC（低總兒茶素型）、High EGCG（高表沒食子兒茶酚沒食子酸型）、Low EGCG（低表沒食子兒茶酚沒食子酸型）。

Note 1: FHM (Fenghuang Mountain), ZHM (Zhanghu Mountain), SL (Shuanglong), MYM (Meiyuan Mountain).

Note 2: EGCG (epigallocatechin gallate), TC (total catechins), High TC (high total catechins type), Low TC (low total catechins type), High EGCG (high epigallocatechin gallate type), Low EGCG (low epigallocatechin gallate type).

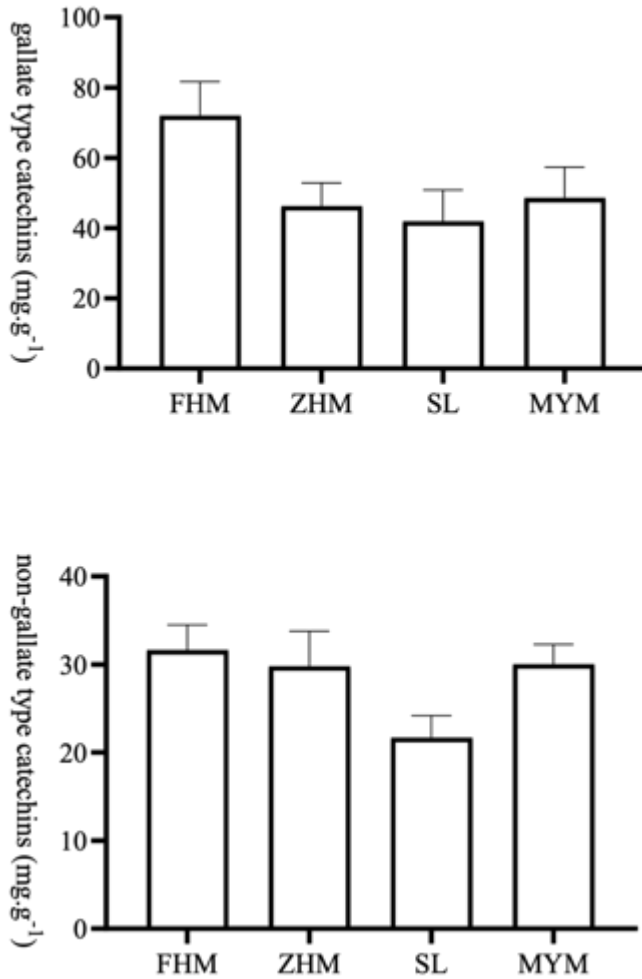


圖 1 以單因子變異數分析進行中部地區臺灣山茶 (*Camellia formosensis*) 兒茶素類型差異分析結果。

Fig. 1 Results of one-way ANOVA on the differences in catechin types of *Camellia formosensis* from the central region of Taiwan.

註：鳳凰山 (FHM, n = 4)，樟湖山 (ZHM, n = 10)，雙龍 (SL, n = 3) 和眉原山 (MYM, n = 3)。圖中數值為平均值 ± 標準差。

Note: Fenghuang Mountain (FHM, n = 4), Zhanghu Mountain (ZHM, n = 10), Shuanglong (SL, n = 3) and Meiyuan Mountain (MYM, n = 3). The values in the figure are the Mean ± SD.

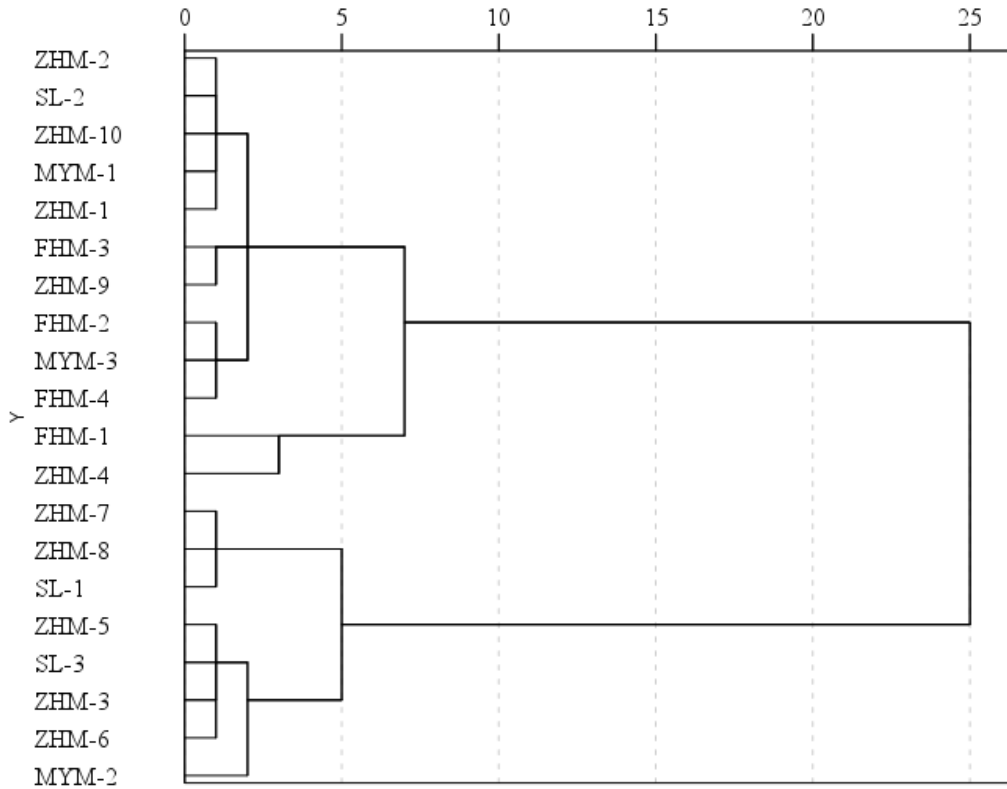


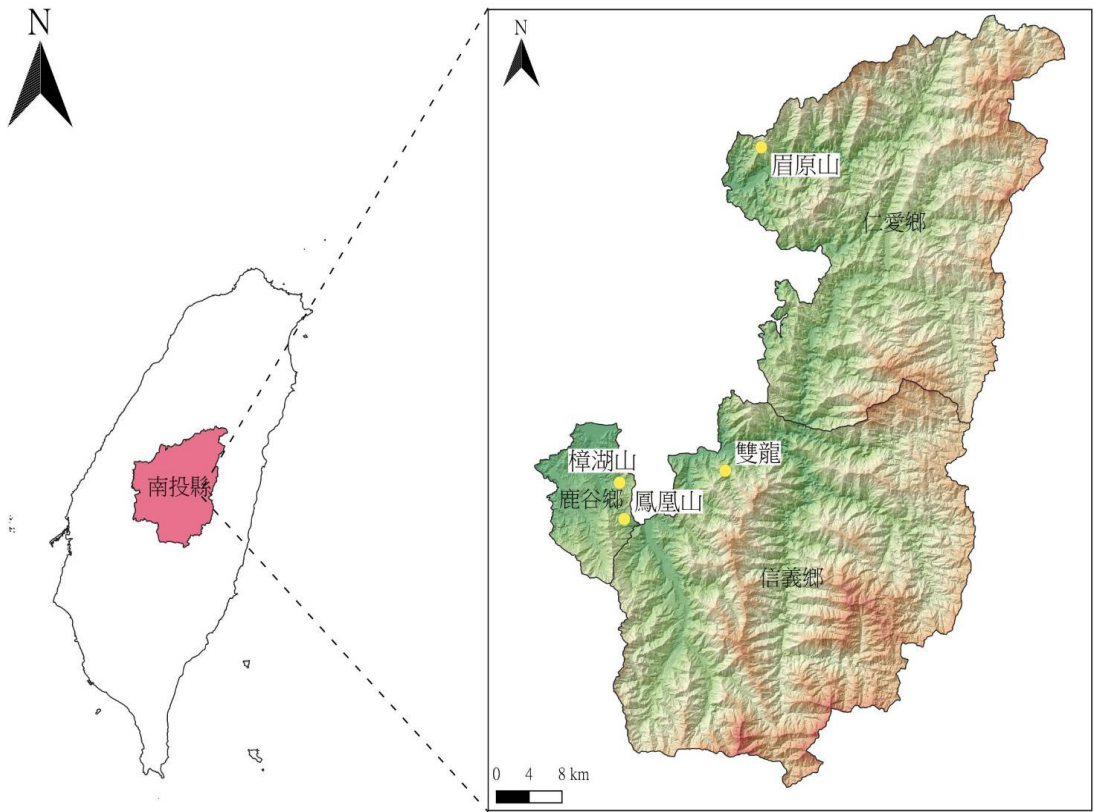
圖 2 臺灣中部地區臺灣山茶 (*Camellia formosensis*) 兒茶素含量階層式集群分析圖。

Fig. 2 Hierarchical Cluster Analysis of Catechin Content in *Camellia formosensis* from the Central Taiwan Region.

註：FHM (鳳凰山)、ZHM (樟湖山)、SL (雙龍)、MYM (眉原山)。

Note: FHM (Fenghuang Mountain), ZHM (Zhanghu Mountain), SL (Shuanglong), MYM (Meiyuan Mountain).

附錄 1 研究區域位置圖。
Appendix 1 Location of the study area.



附錄 2 採樣區域地理環境。

Appendix 2 Geographical environment of sampling sites.

Sites	Coordinate	Altitude (m)	Slope (°)	Aspect
FHM	23°43'07.0"N 120°49'19.3"E	806	10	NE
ZHM	23°43'39.3"N 120°49'19.2"E	940	15	E
SL	23°45'54.5"N 120°56'19.7"E	1,439	20	E
MYM	24°06'10.3"N 120°58'52.3"E	1,396	30	NE

註：FHM（鳳凰山）、ZHM（樟湖山）、SL（雙龍）、MYM（眉原山）。

Note: FHM (Fenghuang Mountain), ZHM (Zhanghu Mountain), SL (Shuanglong), MYM (Meiyuan Mountain).

橙花破布子（紫草科）：

臺灣海漂植物新紀錄

Cordia subcordata Lamarck (Boraginaceae): A newly recorded sea drift plant in Taiwan

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摘要

本文報導臺灣產紫草科 (Boraginaceae) 一新紀錄種：橙花破布子 (*Cordia subcordata* Lamarck)。本種產於非洲 (東岸)、南亞、東南亞、澳洲北部和太平洋島嶼。2023 年在臺灣恆春半島岬灣海岸發現一新紀錄植物。本文提供橙花破布子的形態描述及相片以辨別。

關鍵詞：破布子屬、橙花破布子、新紀錄、海漂植物、臺灣、分類學

Abstract

This article presents information about a newly recorded species of Boraginaceae discovered in Taiwan: *Cordia subcordata* Lamarck. This species is native to Africa (east coast), South Asia, Southeast Asia, northern Australia, and the Pacific Islands. In 2023, a newly recorded plant of this species was identified on the coastline of the promontory in the Hengchun Peninsula, Taiwan. The article includes morphological descriptions and photos of *Cordia subcordata* Lamarck to aid identification.

Key words: *Cordia*, *Cordia subcordata*, new record, sea drift plants, Taiwan, Taxonomy

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緒言

破布子屬 (*Cordia*) 植物大約有 225-271 種，(POWO 2024; WFO 2023)，主要分布在北美洲和南美洲的熱帶地區，非洲及亞洲分布較少 (Zhu *et al.* 1995)。

Flora of Taiwan (Hsiao and Liu 1998) 僅記錄金平氏破布木 (*Cordia aspera* subsp. *kanehirae* (Hayata) H.Y. Liu) 和破布子 (*Cordia dichotoma* G. Forst.) 等二種；東沙島的紀錄有橙花破布子 (*Cordia subcordata* Lamarck) (伍等 2017)。2023 年恆春生態解說員顏士傑先生於屏東縣恆春鎮大光里附近海岸發現破布子屬之橙花破布子植株；經作者二年的觀察，此株順利開花及結果，已經立足於該生育地。此地區海岸有許多的海漂植物如棋盤腳 (*Barringtonia asiatica* (L.) Kurz)、瓊崖海棠 (*Calophyllum inophyllum* L.)、海欖果 (*Cerbera manghas* L.)、蓮葉桐 (*Hernandia nymphiifolia* (Presl) Kubitzki)、欖仁樹 (*Terminalia catappa* L.)、水黃皮 (*Pongamia pinnata* (L.) Pierre)、草海桐 (*Scaevola taccada*

(Gaertn.) Roxb.)、葛塔德木 (*Guettarda speciosa* L.) 等樹木，而橙花破布子的果實有浮力，可隨洋流漂流到很遠的地方，也是一種海漂植物 (Barker and Telford 1993; Claussen 2005; Smith 1990; Smith *et al.* 1990; Green 1999; 高等 2023)。在恆春海岸區域也有撿拾橙花破布子之果實的紀錄，甚至在沙灘上萌芽，惟橙花破布子並非是可長久生長在沙灘上的植物，沙灘上所發現的小苗皆夭折，然我們發現的這一植株是循著海溝被大浪送到高處有積土的珊瑚礁岩凹穴裡，因而能生存多年，並且開花結果。本文報導橙花破布子為臺灣植物誌新增之類群，並提供它的形態描述及相片供參。

分類處理

Cordia subcordata Lamarck, Tabl. Encycl. 1: 421. 1792. 橙花破布子 Fig. 1.

Type: Papua New Guinea, Port Praslin, Commerson P. s.n. (Type: P, Photo!)

小喬木，高約 4 m，幼枝四稜，

光滑或近光滑。樹皮黃褐色。小枝無毛。葉紙質，側脈 5-7 對，互生；葉柄長 3-6 cm，光滑；卵形或狹卵形，長 8-18 cm，寬 6-13 cm，先端尖或急尖，基部鈍或近圓形，稀心形，全緣或微波狀，葉表具貼伏毛，葉背葉脈或脈腋間具毛狀物。頂生圓錐花序，二歧分枝，花序鬆散，花冠橙紅色，光滑或近光滑，漏斗形，花徑 3.5-4.0 cm，裂片 5-7，寬圓，平展；花萼革質，合生成圓筒狀，長 12-16 mm，先端具短小而不整齊的裂片；雄蕊與花冠筒齊平或略微伸出，花絲長度 3-8 mm，附著於花冠筒上半部。堅果卵球形或倒卵球形，2-3 cm，果實被硬化且增大的花萼包被，內具 1-2 粒種子。花期 9-10 月。果 11-12 月。

引證標本：臺灣，屏東縣恆春鎮大光里海岸，04 Oct. 2023，S. W. Chung 15606 (TAIF)。

檢索表

- 1. 花萼筒杯狀，花白色
- 2. 葉披針至長卵形，長尾尖；花萼筒有稜 金平氏破布子

- 2. 葉卵形至寬卵形，短尾尖；花萼筒光滑 破布子
 - 1. 花萼筒長管狀，花橘色 橙花破布子

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由於顏士傑、郭明裕及呂順泉先生在野外採集及調查的協助，致使本文更加完備，謹此致上誠摯的謝意。

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伍淑惠、陳建文、陳佳玉、蔡雅如、陳建帆。2017。東沙島植物相變化與復育物種選擇。國家公園學報 27(2): 10-26

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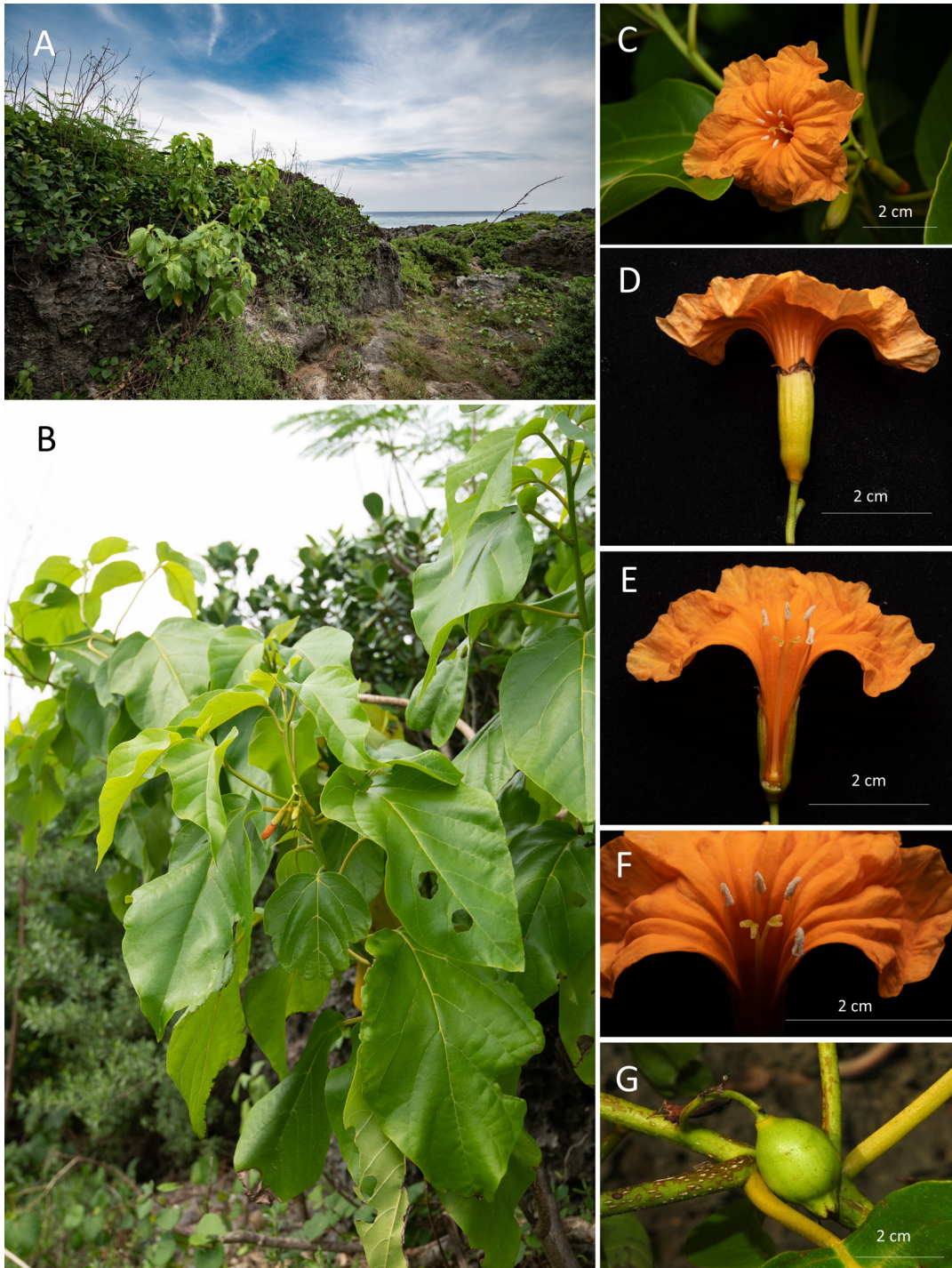


圖 1 橙花破布子 (*Cordia subcordata* Lamarck) A. 生育地; B. 植株; C. 花枝; D. 花冠側面; E-F. 花冠、雄蕊和雌蕊 G. 果枝。

Fig. 1 *Cordia subcordata* Lamarck. A. Habitat; B. Plant; C. Flowering branch; D. Side view of corolla; E-F. Corolla, stamens and pistil; G. Fruiting branch.

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8. 英文彙編書籍：Jinchu, H. and W. Fuwen. 1990. Development and progress of breeding and rearing giant pandas in captivity within China. pp. 322-325. *In*: H. Jinchu (ed.). *Research and progress in biology of the giant panda*. Sichuan Publishing House of Science and Technology, Sichuan, People's Republic of China.

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