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台灣特有種盤古蟾蜍(*Bufo bankorensis*)的蝌蚪，可生長棲息於
流水域與靜水域等不同環境。 (陳琬婷　攝)。

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# Contents

# Four New Species of Freshwater Harpacticoid Copepods (Canthocamptidae: Copepoda) from Mountain Lakes of Taiwan

# 台灣高山湖泊四種淡水生猛水溞 (Canthocamptidae: Copepoda)新種

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## Abstract

This paper describes four new species of harpacticoid copepods (Canthocamptidae: Copepoda) from freshwater ponds and lakes in the Central Mountain Range of Taiwan. They are *Bryocamptus nenggaoensis* sp. nov., *Elaphoidella formosanus* sp. nov., *E. hirsutus* sp. nov., and *Echinocamptus shihi* sp. nov. *B. nenggaoensis* was found in abundance in Bai-Shi-Chi and a small puddle near Mt. Neng-Gao, *E. formosanus* was collected from Tun-Lu-Chi, a small pond with bottom rich in detritus from decayed plants and grazer's droppings, and *E. hirsutus* and *E. shihi* were collected from a wetland with muddy sediment near grassy pad adjacent to Yuan-Yan-Hu.

## 摘　要

本文描述 4 種棲息在台灣高山湖泊的新種淡水猛水溞(Canthocamptidae: Copepoda)，其分別爲 *Bryocamptus nenggaoensis* sp. nov.、*Elaphoidella formosanus* sp. nov.、*E. hirsutus* sp. nov.及

*Echinocamptus shihi* sp. nov.。*B. nenggaoensis* 棲息在能高山附近的白石池及附近草坡的積水小水窪內，數量相當豐富。*Elaphoidella formosanus* 的採集地爲屯鹿池，池底有豐富的植物碎屑及偶蹄類排遺。*E. hirsutus* and *Echinocamptus shihi* 的採集地爲鴛鴦湖邊緣的草澤溼地。

**Key words:** taxonomy, Copepoda, *Bryocamptus*, *Elaphoidella*, *Echinocamptus*

**關鍵詞：**分類、淡水橈足類、*Bryocamptus*、*Elaphoidella*、*Echinocamptus*

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## Introduction

Inland waters such as rivers and lakes are parts of the landscape mosaic separated from one another by geological formations and geographical structures. They have often evolved to have unique and diverse fauna after a long period of the isolation. In the Central Mountain Range of Taiwan, there are many such isolated lakes and ponds that have no fish but plankton and aquatic insects. Some of them are shallow, and the surface water often freezes in winter for a period of time.

Small cyclopod and harpacticoid copepods always find suitable niche in inland waters. Most of the freshwater harpacticoids are smaller than 0.5 mm in length, and are easily missed in sampling with large mesh nets. Ishida (1992) described a new species *Bryocamptus pacificus* from Taichung, Taiwan. This is the only paper on the freshwater harpacticoid copepod that has been reported so far from the island (Wang 1998).

In past few years we conducted a survey of freshwater copepods of Taiwan, and some harpacticoids were collected from pools and lakes in the Central Mountain Range. This paper describes four new species, *Bryocamptus nenggaoensis* sp. nov., *Elaphoidella formosanus* sp. nov., *E. hirsutus* sp. nov., and *Echinocamptus shihi* sp. nov., belonging to the family Canthocamptidae (Copepoda). They were collected with a plankton net with a mesh size of 55 $\mu$m, 30 cm in length, 15 cm in diameter at the opening, and equipped with a small collecting bottle at the cod end. Some specimens were collected with a scoop in a puddle at night.

The samples were fixed with 5% formalin-water solution in the field, sorted and preliminarily identified under a stereomicroscope in the laboratory, and preserved in 70% ethanol-water solution. Appendages were dissected and mounted on microscopic slides with polyvinyl lactophenol tinted with lignin pink. Images were made with a camera Lucida. All specimens and samples are deposited at the Systematics and Biodiversity Laboratory of the National Hsinchu University of Education (SBNHCUE), Hsinchu, Taiwan.

## ***Bryocamptus nenggaoensis* sp. nov.**

Figs. 1 and 2

### **Type material**

Holotype: A female (dissected and mounted on slide) collected from Bai-Shi-Chi (White-Stone Pool) (23°55´40″N, 121°16´00″E) located near Mt. Neng-Gao at an elevation of 2,900m on 4 May 1997 by Shuh-Sen Young (SBNHCUE 001). Collection site water temperature was 11°C and pH 6.0.

Paratypes: A female (dissected and mounted on slide, SBNHCUE 002); a male (dissected and mounted on a slide, SBNHCUE 003); and 5 males and 5 females preserved in the 70% alcohol-water solution (SBNHCUE 004). Same collection data as holotype.

### **Description**

Female (holotype): Body length (excluding caudal setae) 0.44 mm. Rostrum short. Prosome with cephalosome and 4 free pedigerous somites; urosome 4-segmented; posterior margin of pedigerous and urosomal somites smooth. First urosomal somite with two transverse rows of spinules from lateral to ventral, one along the anterior margin and the other along the posterior margin: the former longer than the latter. Second urosomal somite with a transverse row of spinules along the posterior margin from lateral to ventral surface. Third urosomal somite with a row of spinules along the posterior margin of dorsal surface. Fourth urosomal somite with a row of spinules along the posterior margin of lateral surface. Anal operculum convex, armed with a crescent row of spinules. Caudal ramus length about equal to the width; terminal accessory seta short; inner and outer terminal setae with fracture plane at base; outer seta about a half of the length of the inner seta. Antennule 8-segmented; segment 4 with a long esthetasc, reaching the last segment. Antenna 3-segmented, exopod 2-segmented with 1 seta and 3 setae. Swimming legs 1-3 with 3-segmented exopod and 3-segmented endopod; leg 4 with 3-segmented exopod and 2-segmented endopod. Spine and seta formula of legs 1-4 as follows:

| | Coxa | Basis | Exopod | Endopod |
|---|---|---|---|---|
| Leg 1 | 0-0 | I-1 | I-0; I-1; I- (I+2) -0 | 0-1; 0-1; 0- (I+2) -0 |
| Leg 2 | 0-0 | I-0 | I-0; I-1; II- (I+2) -1 | 0-1; 0-1; 0- (I+2) -1 |
| Leg 3 | 0-0 | I-0 | I-0; I-1; II- (I+2) -2 | 0-1; 0-0; 0-2-2 |
| Leg 4 | 0-0 | I-0 | I-0; I-1; II- (I+2) -2 | 0-1; 1- (II+1) -2 |

Basipod of leg 5 with an expansion on the inner side with 6 setae, middle depressed, saddle-shaped, and the outer corner with 2 setae; exopod 1-segmented, its length longer than basipod, with 5 setae, order of length short to long from inner to outer seta: 1, 5, 3, 4, 2.

Male (paratype): Body length (excluding caudal setae) 0.42 mm. Rostrum short. Prosome with cephalosome and 4 free pedigerous somites; urosome 6-segmented, the posterior margin of pedigerous and urosomal somites smooth. Second to fourth urosomal somites, each with a row of spinules along the posterior margin of lateral and ventral surfaces. Fifth urosomal somite with a row of spinules along the posterior margin. Posterior margin of anal operculum crescent-shaped, armed with spinules. Length of caudal ramus almost equal to the width with two terminal setae that have fracture plane at base, and outer seta about half length of inner seta. Antennule 7-segmented. Antenna 3-segmented and exopod 2-segmented with 1 seta and 3 setae, respectively. Swimming legs 1-4, fairly similar to those of female but with some differences: leg 2, endopod 2-segmented, segment 2 with 4 setae; leg 3, exopod without inner seta on segment 2, and endopod 3-segmented, its segment 2 with a long inner apophysis extending pass the setae of segment 3; leg 4, endopod without inner setae on segment 2; basipod of leg 5 not expanded on inner side with 2 setae; and exopod 1-segmented with 6 setae.

Etymology: The name "*nenggaoensis*" derived from the type locality, Neng-Gao Mountain.

Habitat: Bai-Shi-Chi, the type locality of *B. nenggaoensis* sp. nov., was a small pool with a surface area of 0.6 ha, and the maximum depth of 6m. Its bottom was covered with coarse sand. Water temperature was 4-15°C and pH 5.0-6.0 (Cheng and Wang 1997). *B. nenggaoensis* was also found in another pool Neng-Gao-Chi (23° 59´30″N, 121°15´10″E), a small pool located near Neng-Gao Mountain at an elevation of 2,900m, and had the surface area of 0.1 ha, maximum depth of 0.5m, and bottom covered with coarse sand.

Remarks: Female *B. nenggaoensis* sp. nov. is fairly similar in characters to *Bryocamptus vejdovsky* (Mrazek, 1893) and *Bryocamptus intercalaris* Shen and Tai, 1973. However, *B. nenggaoensis* has a continuous row of spinules along both lateral and dorsal posterior margins on the third urosomal somite, whereas *B. vejdovsky* and *B. intercalaris* have a discontinuous row on the dorsal surface (Borutsky 1952; Shen *et al*. 1979). Also, *B. nenggaoensis* has a small inner seta on segment 1 and no seta on segment 2 of the leg 3 endopod, whereas *B. vejdovsky* and *B. intercalaris* have both segments 1 and 2 of leg 3 endopod with a full grown inner seta (Bourstkii 1952; Shen *et al*. 1979).

## ***Elaphoidella formosanus* sp. nov.**

Figs. 3 and 4

### Type material

Holotype: A female (dissected and mounted on slide) collected from Tun-Lu-Chi (Dear Pool) (23°53´30″N, 121°15´10″E) at an elevation of 2,850m on 5 May 1997 by Shuh-Sen Young (SBNHCUE 005). Collection site water temperature 10°C, pH 6.5.

Paratypes: A male (dissected and mounted on slide) (SBNHCUE 006); 5 males and 5 females preserved in 70% ethanol-water solution (SBNHCUE 007). Same collection data as holotype.

### Description

Female (holotype): Body length (excluding caudal setae) 0.55 mm. Rostrum short. Prosome with cephalosome and 4 free pedigerous somites; urosome 4-segmented; posterior margins of pedigerous and urosomal somites smooth. Each of the first to fourth urosomal somites with a row of spinules along the posterior margins on the lateral and ventral surfaces. Anal operculum convex without spinules. Caudal ramus length and width subequal; terminal accessory outer setae short; inner terminal seta long and strong without fracture plane at base. Antennule with 8-segments; segment 4 with long esthetasc, reaching the end of terminal segment. Antenna with 3-segments; exopod with a single segment and 4 setae. Swimming legs 1-4 with expod of 3 segments

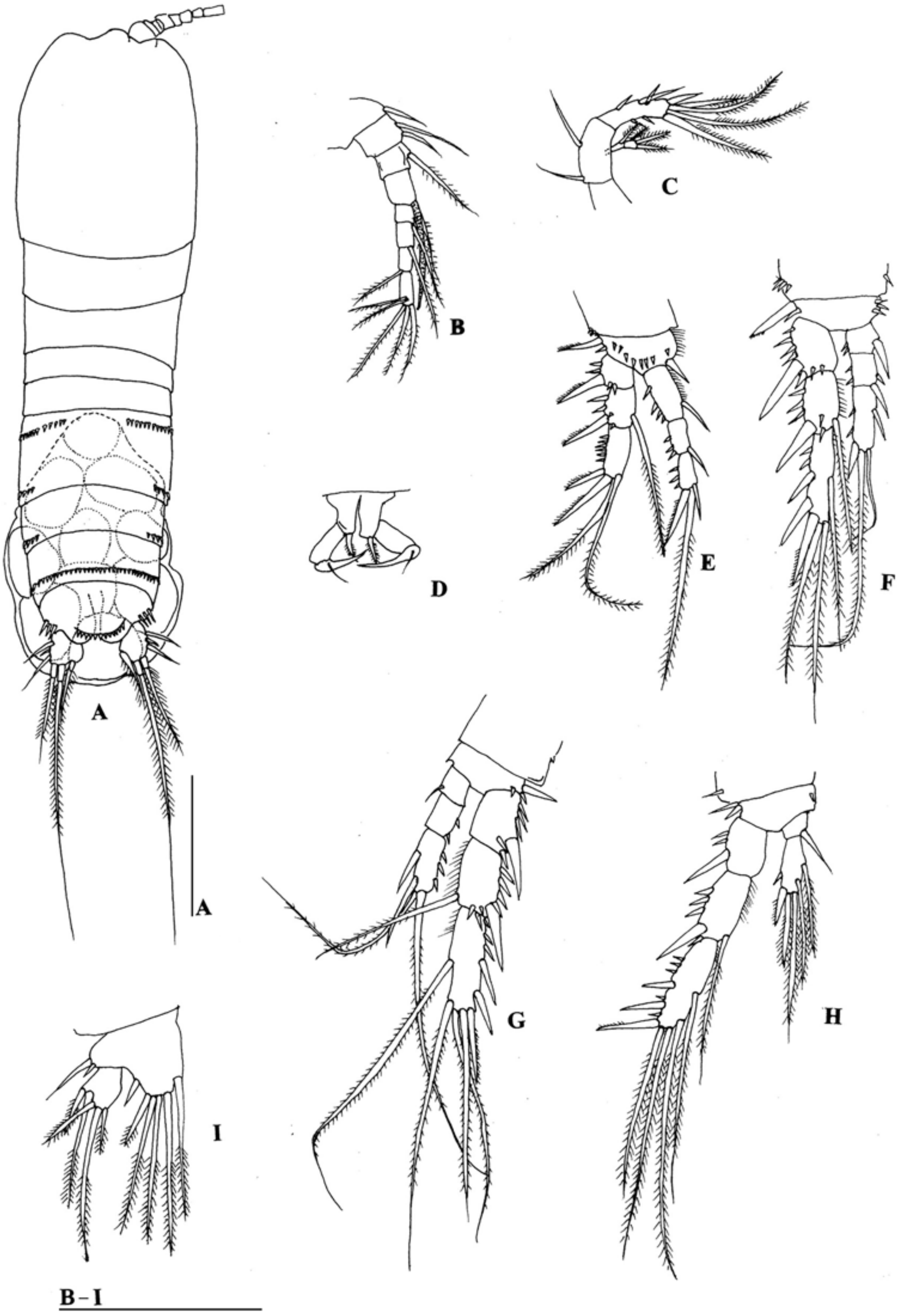

**Fig. 1.** *Bryocamptus nenggaoensis* sp. nov. female (holotype): A, dorsal view of habitus; B, antennule; C, antenna; D, maxilliped; E, left leg 1; F, left leg 2; G, right leg 3; H, left leg 4; I, left leg 5; posterior views of legs 1-5; scales = 0.1 mm.

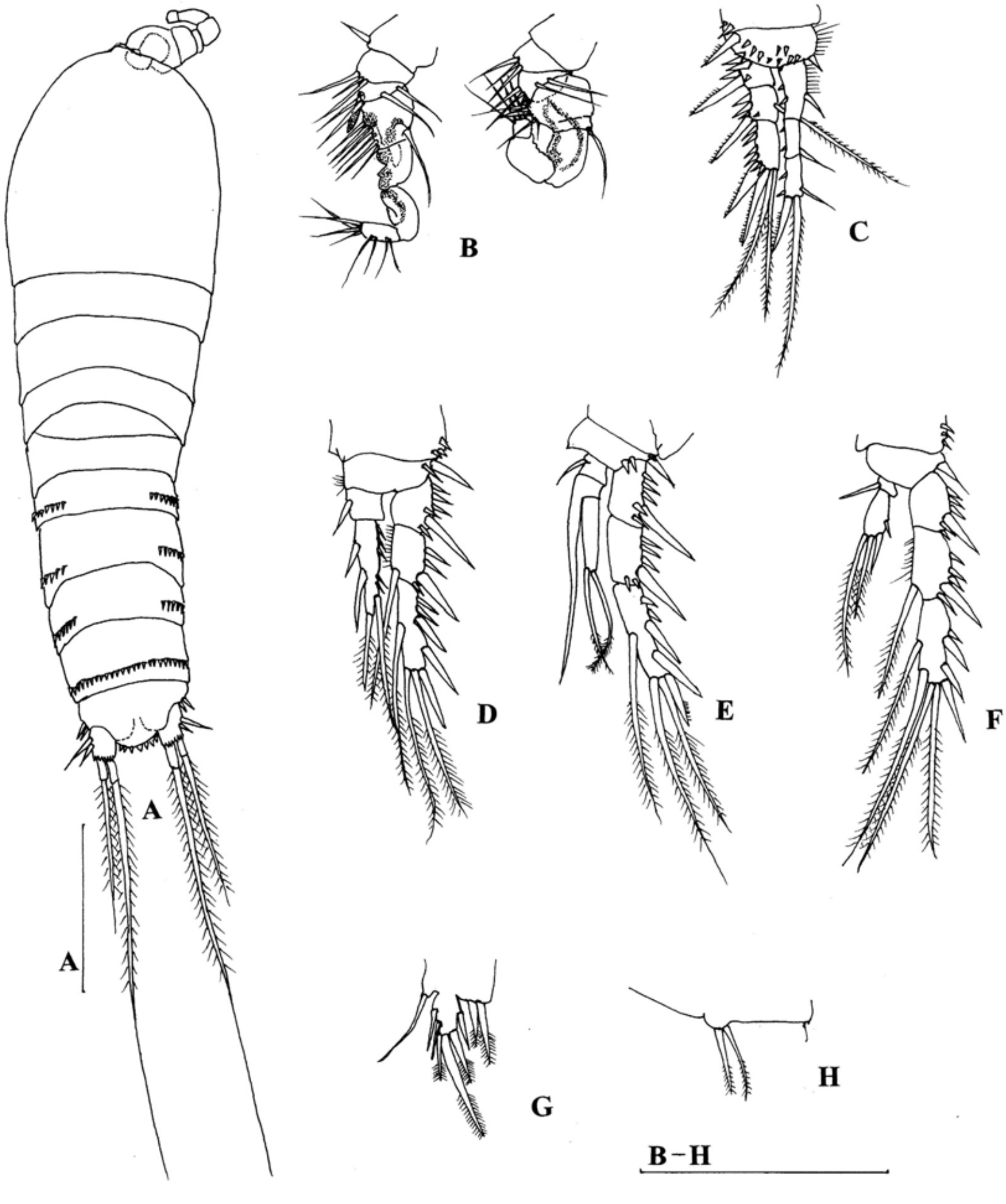

**Fig. 2.** *Bryocamptus nenggaoensis* sp. nov. male (paratype): A, dorsal view of habitus; B, antennule; C, left leg 1; D, right leg 2; E, right leg 3; F, right leg 4; G, left leg 5; H, leg 6; posterior views of legs 1-5; scales = 0.1 mm.

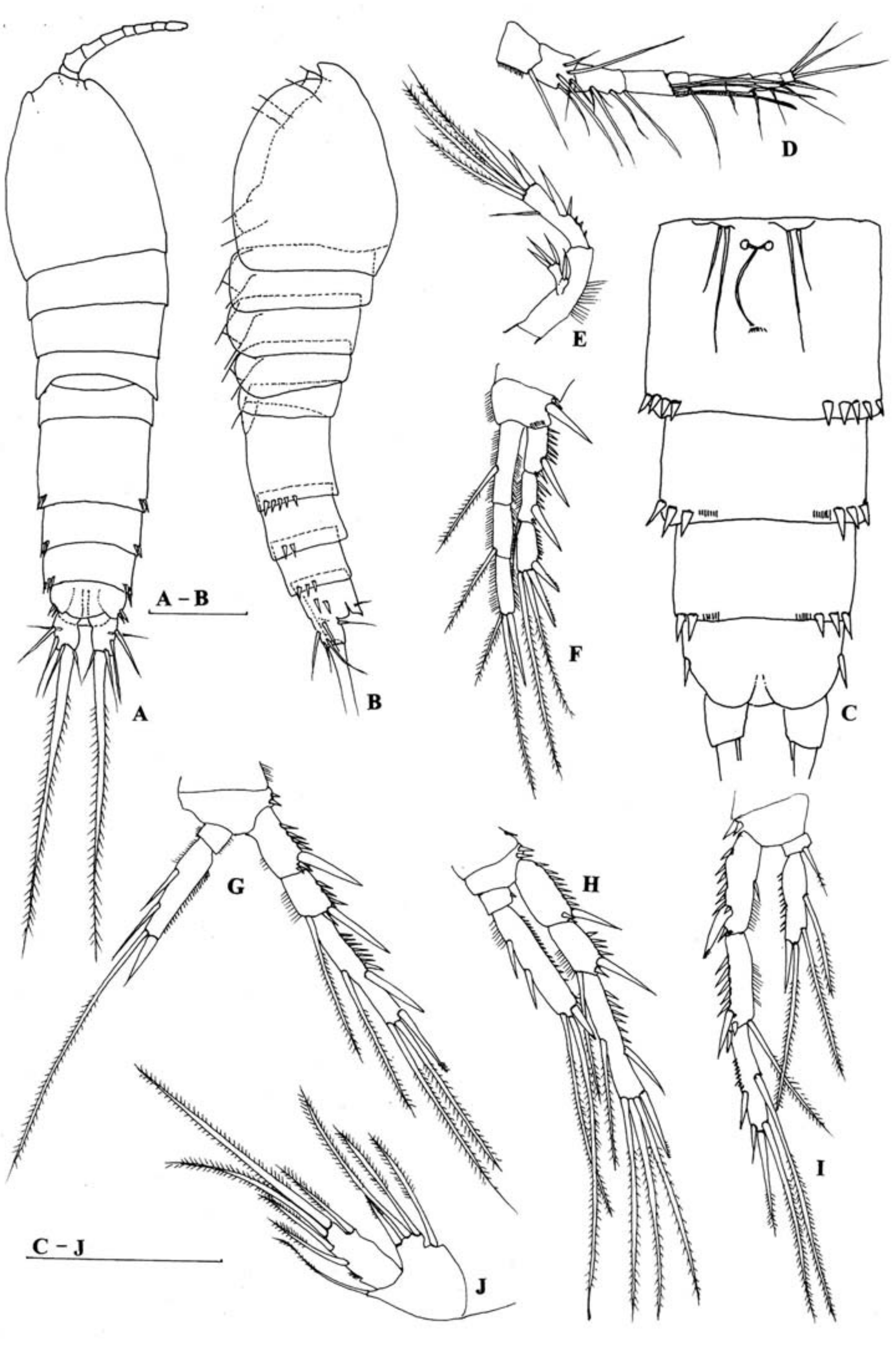

**Fig. 3.** *Elaphoidella formosanus* sp. nov. female (holotype): A, dorsal view of habitus; B, lateral view of habitus; C, ventral view of urosome; D, antennule; E, antenna; F, right leg 1; G, right leg 2; H, right leg 3; I, left leg 4; J, left leg 5; posterior views of legs 1-5; scales = 0.1 mm.

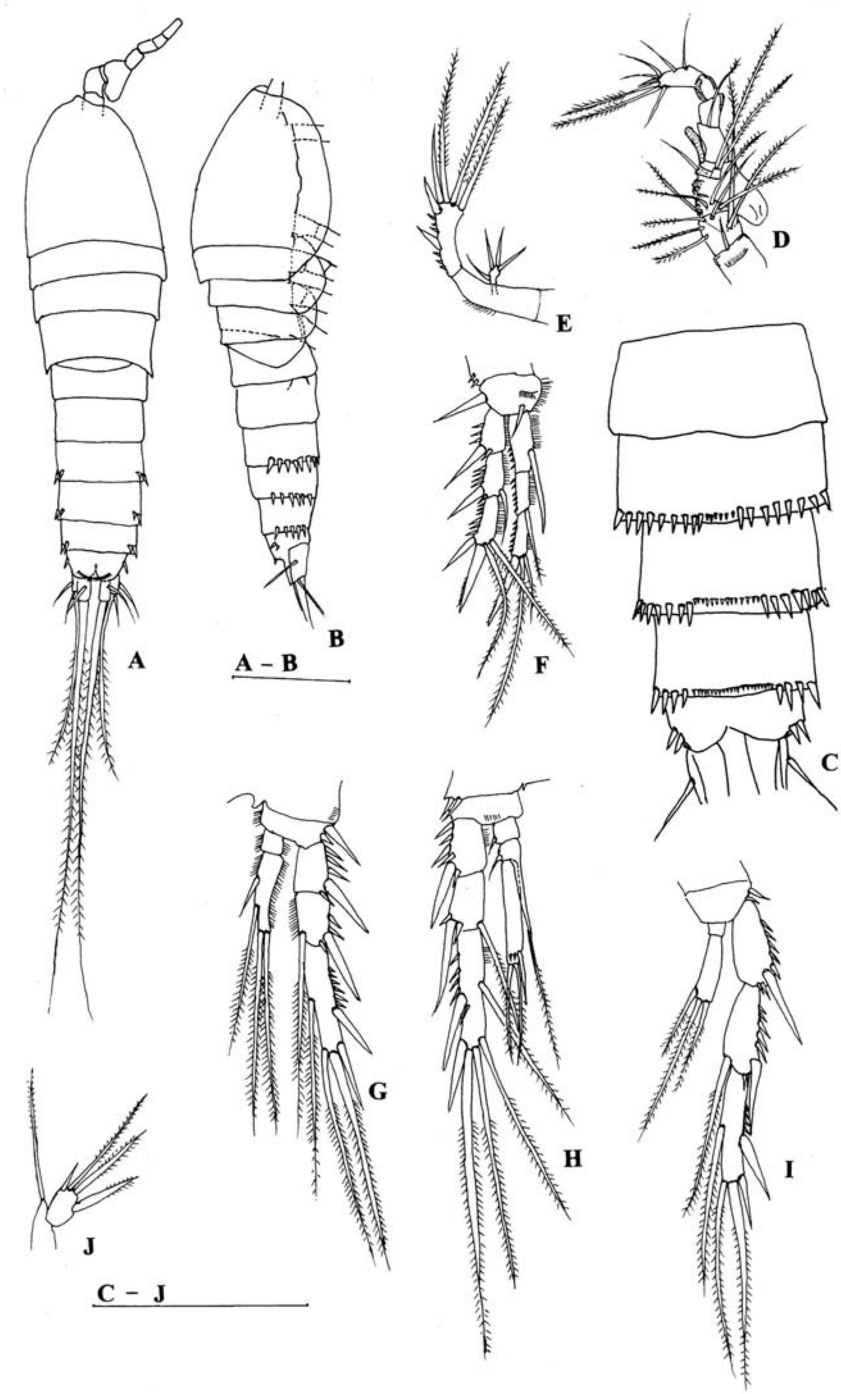

**Fig. 4.** *Elaphoidella formosanus* sp. nov. male (paratype): A, dorsal view of habitus; B, lateral view of habitus; C, ventral view of urosome; D, antennule; E, antenna; F, left leg 1; G, right leg 2; H, left leg 3; I, right leg 4; J, left leg 5; posterior views of legs 1-5; scales = 0.1 mm.

and endopod of 3 segments for leg 1 and 2 segments for legs 2-4. Spine and seta formula of legs 1-4 as follows:

| | Coxa | Basis | Exopod | Endopod |
|---|---|---|---|---|
| Leg 1 | 0-0 | I-0 | I-0; I-1; I- (I+2) -0 | 0-1; 0-1; 0-I+2-0 |
| Leg 2 | 0-0 | 0-0 | I-0; I-1; I- (I+2) -1 | 0-0; 0- (I+1) -2 |
| Leg 3 | 0-0 | 0-0 | I-0; I-1; I- (I+3) -1 | 0-0; 0- (I+2) -2 |
| Leg 4 | 0-0 | 0-0 | I-0; I-1; I- (I+2) -1 | 0-1; 0- (I+1) -2 |

Basipod of leg 5 with large inner expansion with 4 setae and narrow outer expansion with a terminal seta; exopod 1-segmented with 5 setae, order of length short to long from inner to outer seta: 3, 5, 4, 2, 1; outer margin with hair-like small spinules.

Male (Paratype): Body length (excluding caudal setae) 0.45 mm. Rostrum short. Prosome with cephalosome and 4 free pedigerous somites; urosome 5-segmented, posterior margin of pedigerous and urosomal somites smooth. Each of the second to fifth urosomal somites with a row of spinules along posterior margins of lateral and ventral surfaces. Posterior margin of anal operculum crescent-shaped, armed with spinules. Caudal ramus length and width subequal with two terminal setae; terminal setae without fracture plane at base; outer seta an half length to that of inner seta. Antennule 8-segmented; Antenna 3-segmented; exopod 1-segmented with 4 setae. Exopod of legs 1-4 similar to that of female. Leg 3 with endopod 3-segmented; segment 2 with a long inner apophysis, extending beyond the setae of segment 3. Basipod of leg 5 small with an outer seta; exopod 1-segmented with 4 setae.

Etymology: The name “*formosanus*” derived from Formosa (Taiwan).

Habitat: Tun-Lu-Chi (Deer pond), the type locality of *E. formosanus* sp. nov. is a small water pond with a surface area of about 1 ha. Its depth is 2m and bottom covered with thick layer of detritus from decayed plants and deer droppings. Water temperatures are 4-18°C and pH 6.0-6.6 (Chen and Wang 1997).

Remarks: *E. formosanus* sp. nov. is closely related to *Elaphoidella superpedalis* Shen and Tai, 1964 and *Elaphoidella longipedis* Chappuis, 1931. However, *E. formosanus* has the exopod length/width ratio of 2.4 for leg 5 that is smaller than 4.6 of *E. superpedalis* and 3.3 of *E. longipedis*. The third segment of exopod of leg 4 has the spine and seta formula of I- (I+2) -1 (total 5) for *E. formosanus* that differs from I- (I+2) -2 (total 6) of *E. superpedalis* and *E. longipedis* (Shen *et al*. 1979; Ishida and Kikuchi 2000).

### ***Elaphoidella hirsutus* sp. nov.**

Fig. 5

**Type material**

Holotype: A female (dissected and mounted on slide) collected from Yuan-Yang-Hu (Mandarin duck lake) (24°34´50″N, 121°23´50″E) in the northern Taiwan at an elevation of 1,670m on 19 August 1996 by Shuh-Sen Young (SBNHCUE 008). Collection site water temperature 14°C, pH 6.5.

Paratype: A female (dissected and mounted on slide) (SBNHCUE 009); 5 females preserved in 70% ethanol-water solution (SBNHCUE 010). Same collection data as holotype.

## Description

Female (holotype): Rostrum short. Body length (excluding caudal setae) 0.67 mm. Prosome with cephalosome and 4 free pedigerous somites; urosome 4-segmented, all somites coarsely serrated posteriorly. Dorsal surface of pedigerous and urosomal somites armed with numerous transverse rows of minute spinules. First to third urosomal somites with a row of spines along posterior margins of lateral and ventral surfaces, a row of spines on the third urosomal somite that is broken into three sections on ventral surface. Anal operculum convex, armed with comb like spinules on the posterior margin. Caudal ramus length about twice the width; dorsal surface bulging and bearing a spine; terminal accessory seta short; inner and outer terminal setae without fracture plane at base; outer seta an half the length of the inner seta. Antennule 8-segmented, segment 4 with long esthetasc, reaching beyond the end of terminal segment. Antenna 3-segmented, exopod 1-segmented with 4 setae. Exopod 3-segmented for swimming legs 1-4 and endopod 3-segmented for leg 1 and 2-segmented for legs 2-4. Spine and seta formula of legs 1-4 as follows:

| | Coxa | Basis | Exopod | Endopod |
|---|---|---|---|---|
| Leg 1 | 0-0 | I-1 | I-0; I-1; I- (I+2) -0 | 0-1; 0-1; 0- (I+2) -0 |
| Leg 2 | 0-0 | I-0 | I-0; I-1; I- (I+2) -1 | 0-1; 0- (I+2) -2 |
| Leg 3 | 0-0 | 0-0 | I-0; I-1; I- (I+2) -2 | 0-1; 0- (I+2) -3 |
| Leg 4 | 0-0 | 1-0 | I-0; I-1; I- (I+2) -2 | 0-0; 0-2-2 |

Basipod of leg 5 with a large inner expansion with 4 setae and a narrow outer expansion with a terminal seta; exopod 1-segmented with 5 setae, order of length from short to long from the inner to outer seta, 1, 2, 4, 5, 3; both outer and inner margins with 2 small spines.

Male: Unknown.

Etymology: The name ‘‘*hirsutus*” derived from Latin ‘‘hairs”, referring to small spinules on somites.

Habitat: Yuan-Yang-Hu (Mandarin duck lake), the type locality of *E. hirsutus* sp. nov., is a small lake with a surface area of 3.6 ha, depth of 4.3m, and bottom covered with thick layer of mud and detritus, water temperatures are 8-20°C and pH 6.5 (Chen and Wang 1997).

Remarks: Female *E. hirsutus* sp. nov. is fairly similar in characters to those of *E. grandidieri* (Guerne and Richard, 1893), *E. coronata* (Sars, 1904), *E. decorata* (Daday, 1904), and *E. nepalensis* (Ishida, 1994). However, *E. hirsutus* is distinguishable from *E. grandidieri* by having minute spinules on posterior margins of all somites, dorsal surface of pedigerous somites and urosomal somites, instead of smooth without spinules for *E. grandidieri* (Borutsky 1952; Shen *et al*.1979). Kikuchi (1985) reported, based on SEM examination, that *E. grandidieri* also has spinulated somites, but these spinules were not shown by Ishida and Kikuchi (2000). *E. decorate*, *E. coronata* and *E. nepalensis* have no transverse rows of minute spinules on dorsal and ventral surfaces of all somites (Ishida

1994; Shen *et al*. 1979).

### Family Canthocamptidae Brady, 1880

### Genus *Echinocamptus* Chappuis, 1929

### ***Echinocamptus shihi* sp. nov.**

Fig. 6

**Type material**

Holotype: A female (dissected and mounted on slide, SBNHCUE 011) collected from Yuan-Yang-Hu in the northern Taiwan (24°34´50″N, 121°23´50″E) on 19 August 1996 by Shuh-Sen Young. Collection site water temperature 14°C, pH 6.5.

Paratypes: 3 females preserved in 70% ethanol-water solution (SBNHCUE 012). Same collection data as holotype.

**Description**

Female (holotype): Body length excluding caudal setae 0.40 mm. Rostrum short. Prosome comprising cephalosome and 4 free pedigerous somites; urosome 4-segmented; posterior margin of pedigerous and urosomal somites smooth. A row of spinules along the posterior margins on both lateral surfaces of first and second urosomites, and on both lateral and ventral surfaces of third urosomite. Anal somite with a row of spinules along the posterior margins on lateral sides, and four spinules on ventral side. Anal operculum convex, armed with 4 spinules on the posterior margin. Caudal ramus, length subequal to width; terminal accessory seta short; inner and outer terminal setae with fracture plane at base; outer seta about half as long as inner seta. Antennule 8-segmented; segment 4 with long esthetasc, reaching distal border of the terminal segment. Antenna 3-segmented; exopod 1-segmented with 4 setae. Swimming legs 1-4 with 3-segmented exopod and 2- (leg 1) or 3-segmented (legs 2-4) endopod. Spines and setae formula of legs 1-4 as follows:

| | Coxa | Basis | Exopod | Endopod |
|---|---|---|---|---|
| Leg 1 | 0-0 | I-1 | I-0; I-1; I- (I+2) -0 | 0-I; 0- (I+1) -0 |
| Leg 2 | 0-0 | I-0 | I-0; I-1; II- (II+1) -1 | 0-1; 0- (I+1) -1 |
| Leg 3 | 0-0 | I-0 | I-0; I-1; II- (I+3) -1 | 0-1; 0-2-2 |
| Leg 4 | 0-0 | I-0 | I-0; I-1; I- (I+3) -1 | 0-1; I- (I+1) -2 |

Basipod of leg 5: inner expansion with 6 setae, inner 4 longer than outer 2, outer expansion with distal outer margin saddle shape, distal corner bearing a terminal seta exopod one segmented with 5 setae, order of length short to long from inner to outer seta: 1, 5, 2, 4, 3.

Male: Unknown.

Etymology: The name ‘‘*shihi*” derived in honor of Dr. Chang-tai Shih, who encouraged the author to study freshwater copepods of Taiwan.

Habitat: Yuan-Yang-Hu (Mandarin duck lake), the type locality of *E. shihi* sp. nov. is a small lake with a surface area of 3.6 ha, depth of 4.3m, and bottom covered with thick layer of mud and detritus, temperatures are 8-20°C and pH 6.5 (Chen and Wang 1997).

Remarks: *E. shihi* sp. nov. is closely related to *Echinocamptus parvus* Borutskii, 1952, with 2-segmented endopod on leg 1. They differ in number of spines and setae on the third exopodite

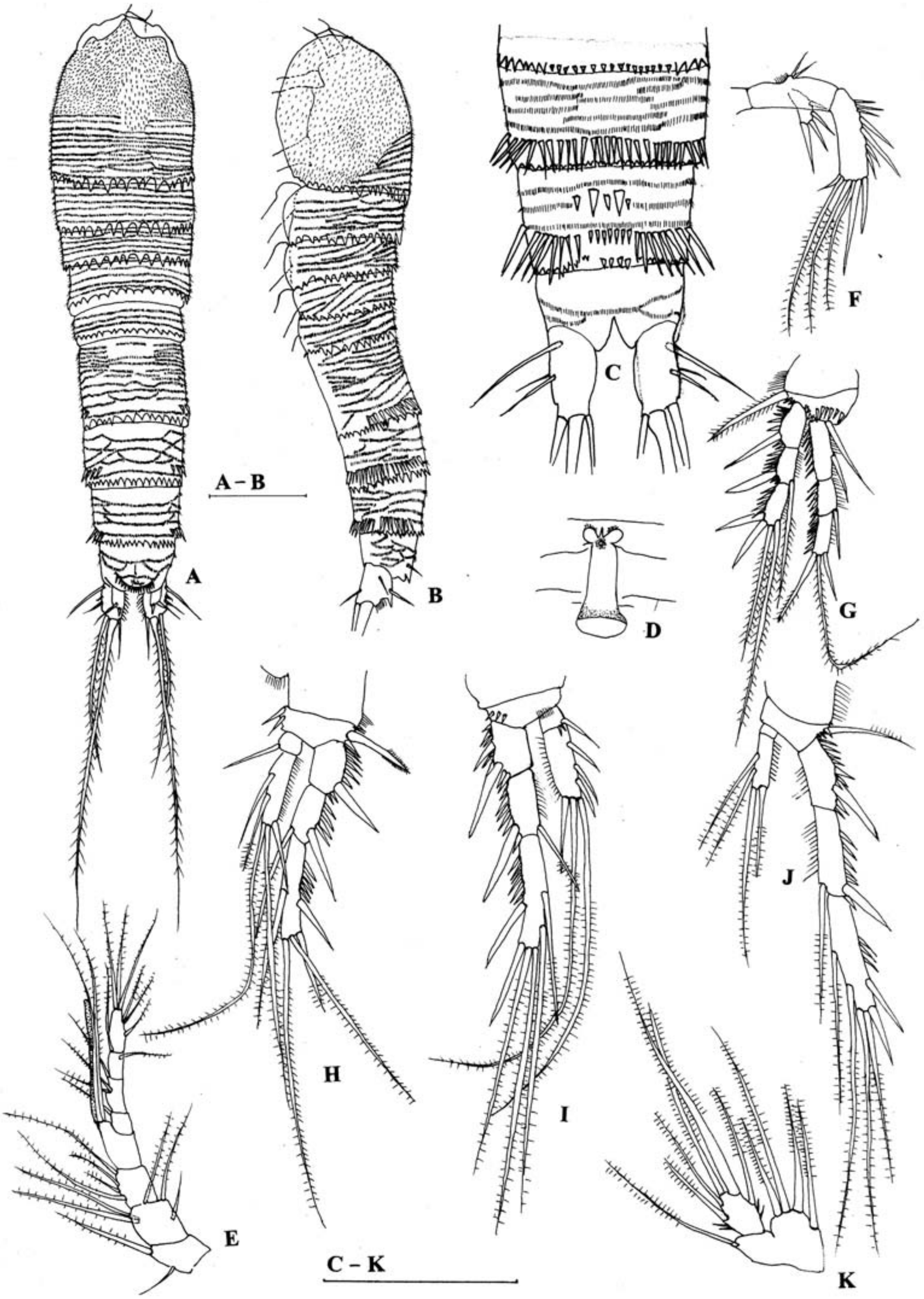

**Fig. 5.** *Elaphoidella hirsutus* sp. nov. female (holotype): A, dorsal view of habitus; B, lateral view of habitus; C, ventral view of Urosome; D, genital duct; E, antennule; F, antenna; G, left leg 1; H, right leg 2; I, left leg 3; J, right leg 4; K, right leg 5; posterior views of legs 1-5; scales = 0.1 mm.

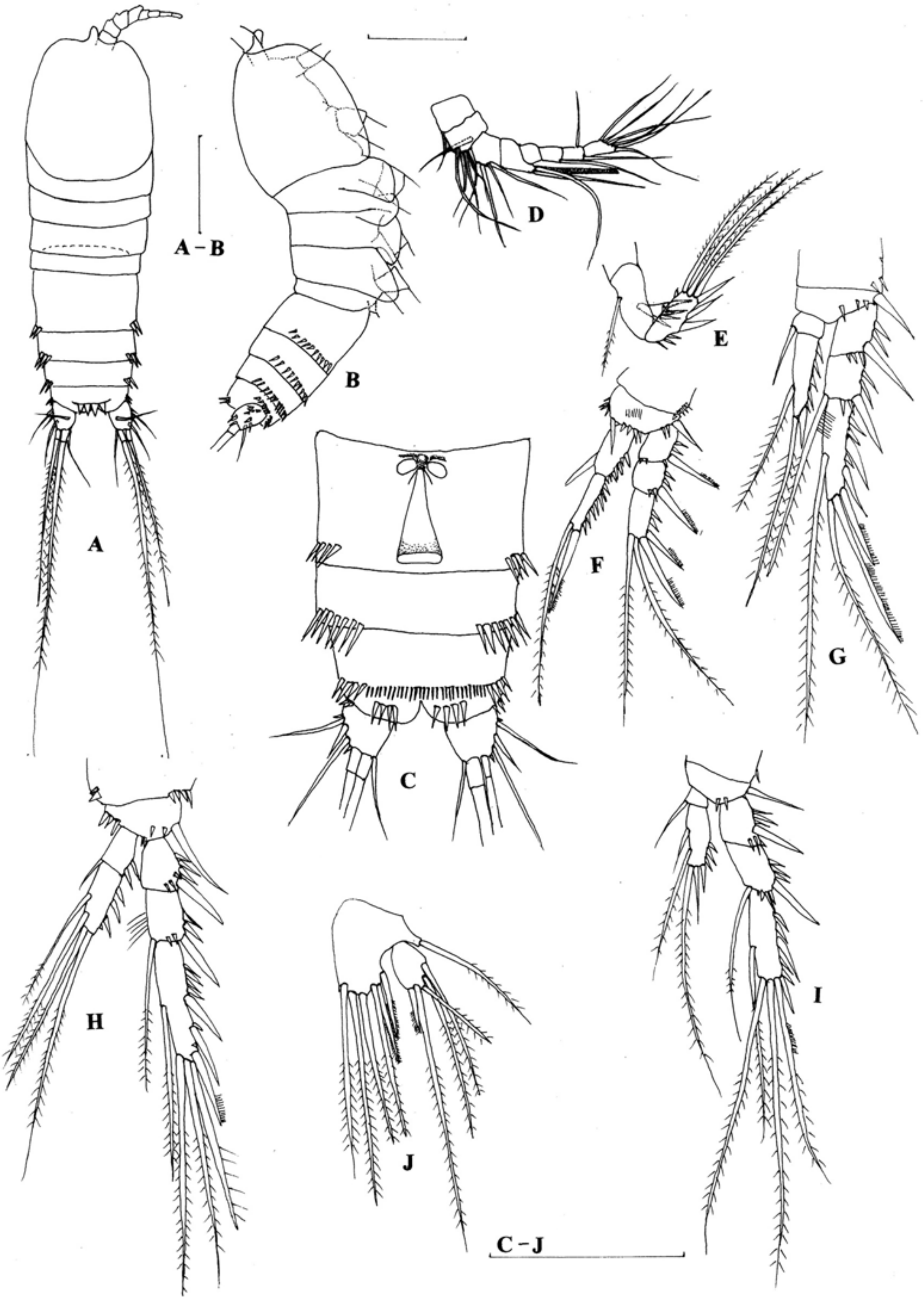

**Fig. 6.** *Echinocamptus shihi* sp. nov. female: A, dorsal view of habitus; B, lateral view of habitus; C, ventral view of urosome; D, antennule; E, antenna; F, right leg 1; G, right leg 2; H, right leg 3; I, right leg 4; J, right leg 5; posterior views of legs 1-5; scales = 0.1 mm.

segment of leg 2-4. The spine and seta formulae for *E. parvus* are leg 2: 1, 2, 2 (total 5); leg 3: 1 (2), 2, 2 (total 6); leg 4: 2, 2, 2. (total 6).

## Acknowledgements

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台灣生物多樣性研究(TW J. of Biodivers.) 12(4): 341-350, 2010

# 蝙蝠性別與體重對於外寄生蝠蠅豐富度的相關性探討

# Relationships of Sex and Body Weight of the Bat (*Miniopterus schreibersii*) with Abundance of Its Ectoparasitic Flies

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## 摘　要

本研究針對南投縣地利地區的摺翅蝠(*Miniopterus schreibersii*)群集進行寄生於蝙蝠體外之蝠蠅種類鑑定，並檢驗蝙蝠的體重與性別對於寄生蝠蠅豐富度之影響情形。2007 年 9 月至 2008 年 8 月共採樣了 570 隻摺翅蝠成蝠，從牠們身上共採集到 2,698 隻蝠蠅。蝠蠅皆隸屬於蛛蠅科(Nycteribiidae)，共 2 屬，其中屬於毛刷蛛蠅屬的姜宜蛛蠅(*Pencillidia jenynsii*) 1 種(310 隻)，而蛛蠅屬有 2 種，分別爲短鋏蛛蠅 (*Nycteribia parvula*) (1,425 隻)及長鋏蛛蠅(*N. allotopa mikado*) (963 隻)。蝙蝠的體重與性別對蝠蠅豐富度影響的結果顯示，僅有短鋏蛛蠅的豐富度在體重較輕或較重二類群宿主間出現顯著性差異。

## Abstract

We investigated ectoparasitic flies of the bat *Miniopterus schreibersii* and determined the effects of sex and body weight of the bat on the fly abundance. About 30 adult males and 30 adult females of the bat was collected monthly at a predawn with a harp trap at the outlet of the water tunnel in Di-Li, Nantou County, Taiwan, September 2007 to August 2008. A total of 2,698 individuals of the bat flies were collected from 570 individuals of the bat. Three species of the bat flies were identified. They were *Pencillidia jenynsii*, *Nycteribia parvula* and *Nycteribia allotopa mikado*, belonging to the family Nycteribiidae. Only the abundance of *N. parvula* was found to correlate significantly with body weight of the bat.

**關鍵詞：**外寄生蟲、姜宜蛛蠅、短鋏蛛蠅、長鋏蛛蠅、摺翅蝠

**Key words:** ectoparasite, *Pencillidia jenynsii*, *Nycteribia parvula*, *Nycteribia allotopa mikado*, *Miniopterus schreibersii*

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# 緒言

物種的繁殖成功與存活皆需依靠其棲息的環境條件，尤其是棲地品質與食物資源。對寄生蟲而言，宿主可視爲寄生蟲之棲地環境(Giorgi *et al*. 2004; Presley 2004; Patterson *et al*. 2007)，因此宿主的特性包括身體大小、性別與營養程度等都是影響寄生蟲族群數量的因素(Christe *et al*. 2003; Presley 2007)。透過探討宿主特性對於寄生蟲族群數量的影響，提供一個釐清「寄生關係」這類複雜共生系統之探討重點。宿主在研究上是容易界定的單位，每一宿主個體皆提供了外寄生蟲(ectoparasite) 群落寄生的棲地，宿主物種若普遍常見，則因容易取得足夠樣本數，故可提供重複實驗操作的進行，因此宿主與外寄生蟲的群集關係(assemblages)在群落生態學(community ecology)或群集組成(assemblage composition)的研究上提供了一個非常可行的系統(Presley 2007)。相較於其他哺乳類，翼手目(Chiroptera) (蝙蝠)具有飛行能力、特殊的棲息行爲以及不易與其他哺乳類群共棲等特性，讓蝙蝠擁有類似於獨立演化單位(如島嶼)的特質與機制(Presley 2004)，使得其外寄生蟲也各自跟隨著宿主進入不一樣的演化途徑，因此蝙蝠的外寄生蟲大部分呈現出高度的宿主專一性(ter Hofstede *et al*. 2004; Dick and Gettinger 2005; Dick and Patterson 2007)。此外，對具有飛行能力的蝙蝠而言，其外寄生蟲的傳播只能透過宿主的棲所，或棲息時個體間的接觸來達成(Mashall 1982)，其外寄生蟲感染源也相對地單純，因此，蝙蝠的飛行能力及其外寄生蟲具高宿主專一性這兩個特點，有利於探討宿主特性對於寄生蟲豐富度影響的相關議題。

一般而言，棲息於洞穴的蝙蝠(cavity roosters)其外寄生蟲的數量都顯著地高於棲息在葉叢中的蝙蝠(foliage roosters) (ter Hofstede and Fenton 2005)。摺翅蝠(*Miniopterus schreibersii*)分類上屬於蝙蝠科(Vespertilionidae)、長指蝠屬(*Miniopterus*)，爲洞穴型棲息(cave-dwelling)

的物種，常以高密度的個體群聚。該物種於台灣的分布甚廣，由低海拔至高海拔皆有發現紀錄(林等 2004)，牠們身上經常可發現有大量的外寄生蟲(Lourenço and Palmeirim 2007)，但卻不包括蝨子(lice: Anoplura)。陸棲型的哺乳動物通常會被蝨子所感染，蝙蝠卻是其中的例外，牠們的外寄生蟲種類並不包括蝨目的種類(Whitaker 1988; Gullan and Cranston 1994; Kim 2006)。蝙蝠身上有一群具有類似於蝨子生態棲位(niche)的外寄生性昆蟲，這些物種並不會在其他哺乳類動物身上發現，這群昆蟲稱爲蝠蠅(bat fly)。蝠蠅是指一群只專屬(obligate)寄生於蝙蝠體外的吸血性昆蟲的俗稱，分類上隸屬於雙翅目(Diptera)的蝨蠅首科(Hippoboscoidea)，包括蝙蝠蠅科(Streblidae)與蛛蠅科(Nycteribiidae) (于 2001; Dick and Patterson 2006; Petersen *et al*. 2007)。關於蝠蠅宿主專一性程度，長期以來一直爭論不定，但透過近期新熱帶地區(美洲)嚴謹的調查結果顯示，蝠蠅具有非常高的宿主專一性(ter Hofstede *et al*. 2004; Dick and Gettinger 2005; Dick and Patterson 2007)。

台灣蝙蝠的種類目前已達 30 餘種，超越囓齒目(Rodentia)與食蟲目(Insectivora) 的總種數，而且近年來不斷有新的種類被發現，但其外寄生蝠蠅種類目前卻僅知 6 個物種(Maa 1962, 1967; 林及陳 1999)，其中屬於蛛蠅科毛刷蛛蠅屬(*Penicillidia*)的有杜孚蛛蠅(*P. dufourii tainanii*)以及姜宜蛛蠅(*P. jenynsii*)等 2 種；屬於蛛蠅科蛛蠅屬(*Nycteribia*)的有短鋏蛛蠅(*N. parvula*)、長鋏蛛蠅(*N. allotopa mikado*)以及福懋蛛蠅(*N. formosana*)共 3 種；隸屬於蝙蝠蠅科則有短跗蝙蝠蠅屬(*Brachytarsina*)的安邦蝙蝠蠅(*B. amboinensis*)。有關台灣地區蝠蠅的研究，除了 Maa (1962, 1967)對上述蝠蠅物種有所記錄與描述，以及楊(1977)對於蛛蠅科各屬的形態比較和演化趨向研究外，一概闕如，更遑論台灣的蝠蠅宿主專一性程度及蝙蝠特性的影響。

對於生物而言，越大範圍的棲地可容納之物種數(richness)與各物種之豐富度 (abundance) 相對會較高，也因此，體型較大的宿主就可能會比體型較小的宿主藏匿更多的寄生蟲。此外，宿主的性別也是一個影響寄生蟲豐富度的關鍵因子，在許多的哺乳類物種中，都可以觀察到雄性比雌性具有較高的寄生蟲感染率 (prevalence)及感染強度(intensity) (Poulin 1996; Morand *et al*. 2004; Cattadori *et al*. 2006)，解釋這樣的現象常聚焦於宿主二性間的免疫力及活動範圍的差異，因雄性的睪固酮濃度會抑制本身的免疫能力而造成寄生蟲豐富度的上升(Folstad and Karter 1992; Roberts *et al*. 2004)，且通常雄性動物有較大的活動範圍及散布至更遠距離的現象，相對的也有更多的機會感染寄生蟲(Morand *et al*. 2004)。因此，本研究將針對一棲居在南投縣地利地區的摺翅蝠群集進行爲期 1 年的捕捉調查，並採集其身上的蝠蠅，除確立所寄生之蝠蠅種類外，並將宿主(蝙蝠)視爲寄生蟲之棲地環境，探討與檢驗宿主特性(如體表面積、性別等)對寄生蟲的豐富度之影響情形。而體表面積與體重二者之間呈現高度正相關，體表面積之大小大約等於體重的 2/3 次方(Presley and Willig 2008)，所以本研究假設體重較重的宿主應當有數量較多的寄生蟲寄生，且基於哺乳類動物的雄性個體一般都比雌性個體具有更多的外寄生蟲的觀點，本研究也假設雄蝠被蝠蠅的寄生率應高於雌蝠的被寄生率。

## 材料與方法

### 一、研究時間、地點及物種

本研究自 2007 年 9 月至 2008 年 8 月爲止，進行 1 年的野外調查工作，爲避免對洞穴中棲息的蝙蝠造成過度干擾，採集頻度爲每月 1 次，每次 1 個採集夜。

採樣地點位於南投縣信義鄉地利村之引水

涵洞(23°47'36"N, 120°55'53"E)，海拔高度約390m (圖 1)。洞穴內終年有水流動，蝙蝠的出入口僅有一處爲涵洞之出水口端。本研究捕捉棲息於此涵洞之摺翅蝠族群，並採集其身上之蝠蠅。此洞穴內棲息的蝙蝠物種平均以摺翅蝠數量最多(估計最多超過 1,000 隻)，台灣小蹄鼻蝠(*Rhinolophus monoceros*)次之(估計最多超過 500 隻)，台灣鼠耳蝠(*Myotis taiwanensis*)與台灣葉鼻蝠(*Hipposideros terasensis*)則曾零星出現。

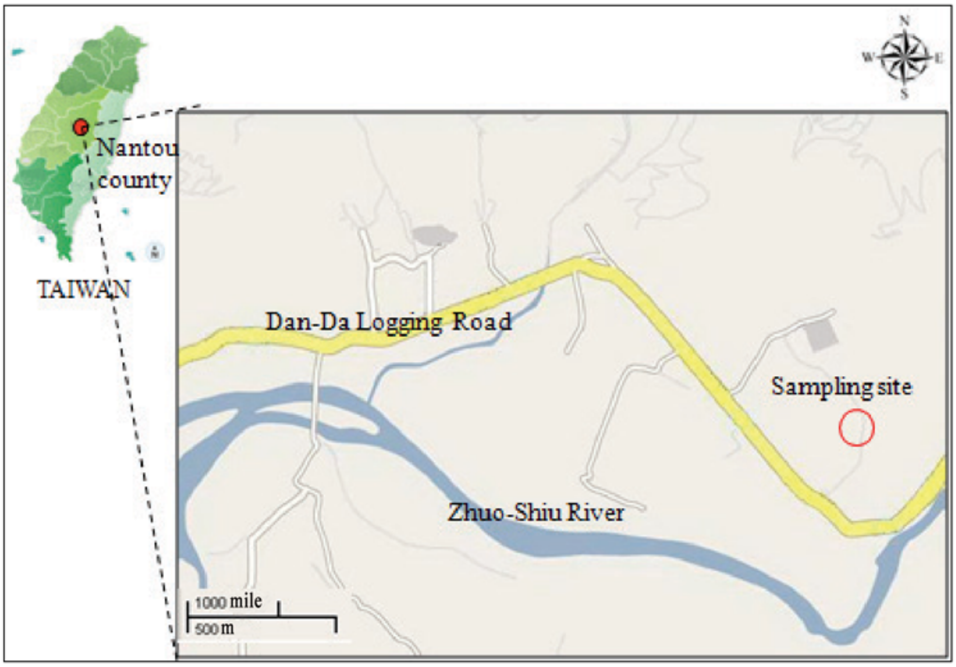

**圖 1.** 南投地利地區摺翅蝠採集樣區示意圖。

**Fig. 1.** The Sampling site of *Miniopterus schreibersii* in Di-Li, Nantou County, Taiwan.

二、蝙蝠的採集與測量

本研究自 2007 年 9 月至 2008 年 8 月爲止，每月進行 1 次採集，月間間隔超過 28 天，每次採集在天亮前約 2 hr，於引水涵洞出水口架設豎琴網(harp trap)，捕捉清晨時大量回巢之摺翅蝠。爲了確認雌、雄蝠對此洞穴的利用屬性，並避免因雌蝠提早返回棲所哺育幼蝠，造成雌、雄蝠在採樣上公母數量的偏差，因此在 2008 年 5-8 月蝙蝠生殖、育幼季節時，將採集的時間改爲傍晚蝙蝠出洞後約 2 hr 始架設豎琴網。收網後，僅留置摺翅蝠成蝠(adult)，個體區分雌雄，平均分配放置於透氣式昆蟲飼養箱中。每次月採集檢驗的摺翅蝠成蝠數量儘量達到雌雄各 30 隻，合計總數 60 隻。捕獲的蝙蝠會進行體重測量與性別確認。

三、蝠蠅的採集、保存與鑑定

蝠蠅採集以 2 人爲一組，由 1 人雙手固定蝙蝠，另 1 人使用金屬鑷子由尾部至頭部翻開毛皮逐一檢視，如發現蝠蠅便使用沾有 75%酒精之軟毛刷或毛筆迅速將其壓制，等約 5-10 sec 使得蝠蠅昏厥並立即夾起置入標本瓶中，酒精須小心避開蝙蝠的眼、鼻、口、耳等部位，接著由蝙蝠腹面尾部往上再次逐一檢視毛皮有無

蝠蠅，重複相同動作 1-3 次，儘可能完整採集每 1 隻蝙蝠身上之蝠蠅個體(Acher and Cardinal 2001; ter Hofstede *et al*. 2004; Dick 2005)。直到確認體表無蝠蠅後，使用吸水性良好的棉布(或紙巾)拭乾蝙蝠毛皮，確認狀態良好後隨即放飛。爲避免蝙蝠因人爲操作壓力過大而傷亡，因此每 1 隻的檢視採樣流程儘量控制在 10 min 內。

採集之蝠蠅蟲體則置入內含 75%酒精及採集紀錄防水紙片(登錄採集地點、日期與宿主編號)的標本瓶內，留待日後於實驗室進行種類鑑定，並同時登錄蝠蠅相關資料(蟲體數量、寄生蟲有無交配行爲等)。測量蝙蝠與採集蝠蠅等動作，皆在蝙蝠洞穴入口前之水泥平台上操作完成。採集之蝠蠅依 Maa (1967)之描述鑑定至種，並記錄物種、雌雄、懷孕與否，以及新羽化成蟲的數量。

四、統計、分析方法

爲了解雌、雄摺翅蝠在體重上是否有顯著的差異現象，須先排除蝙蝠採樣數合計不足 30 隻(n<30)的月份及懷孕雌蝠的體重資料後，使用 Student’s *t*-test 檢驗雌雄二性全年的體重是否具有差異。

針對蝙蝠性別與體重對於外寄生蟲豐富度的相關性，爲確保分析的資料在統計上具有足夠的樣本數，因此僅將宿主樣本數大(等)於 30 隻(n≧30)的月份納入分析。儘管對野生動物的體表面積進行實際的量測非常不容易，但依據 Presley and Willig (2008)的報告指出，體重與體表面積二者之間呈現高度正相關，二數值的換算關係爲：體重(body weight)的 2/3 次方等於體表面積之大小。因此，本研究皆使用體重資料代表體表面積進行統計分析，同時體重的資料須排除懷孕雌蝠的資料，以避免對於體重數據上的干擾。

體重與性別對於蝠蠅豐富度間的關係，則使用二因子變異數分析(Two-way ANOVA)進行分析比較，其中蝠蠅數量的資料使用 $\log_{10}$ 進行轉換，體重資料則以蝙蝠(不分雌雄)的平均重量爲基準，區分成體重較輕及體重較重的二類群，以符合 ANOVA 的假設需求。

本研究使用 SPSS 12 進行資料統計分析，並使用 Excel 2007 繪圖，如摺翅蝠採樣數不足 30 隻的月份，將不列入統計分析。

## 結　果

一、感染摺翅蝠的蝠蠅物種

研究期間共採樣了 570 隻摺翅蝠成蝠，從其身上共採集 2,698 隻蝠蠅，經鑑定後這些蝠蠅皆隸屬於蛛蠅科，共 2 屬，爲毛刷蛛蠅屬與蛛蠅屬，屬於毛刷蛛蠅屬的僅有姜宜蛛蠅 1 種(310 隻)，屬於蛛蠅屬的有 2 種，分別爲短鋏蛛蠅 1,425 隻及長鋏蛛蠅 963 隻(表 1)。上述 3 種蛛蠅皆採自蝙蝠之軀幹，並無採集自翼膜或股間膜之紀錄。

**表 1.** 2007 年 9 月至 2008 年 8 月於南投地利地區摺翅蝠身上所採集之蝠蠅種類與數量

**Table 1.** Species and numbers of bat flies collected from *Miniopterus schreibersii* in Di-Li, Nantou County, September 2007 to August 2008

| Family | Species | Sample size |
|---|---|---|
| Nycteribiidae | *Penicillidia jenynsii* | 310 |
| | *Nycteribia parvula* | 1,425 |
| | *Nycteribia allotopa mikado* | 963 |

二、雌、雄摺翅蝠的體重差異

爲了解雌、雄摺翅蝠在體重上是否有顯著的差異現象，首先排除蝙蝠採樣數合計不足 30 隻(n<30)的月份(2008 年 1 月與 7 月)及 2008 年 5 月份 4 筆懷孕雌蝠的資料後，總共分析了 296 隻雄蝠(體重 8-14g, 11.22 ± 0.07g)及 245 隻雌蝠(體重 8-14g, 10.86 ± 0.07g)，合計共 541 筆的摺翅蝠體重資料，使用 Student’s *t*-test 檢驗雌雄二性全年的體重結果發現，雄蝠的體重顯著地高於雌蝠的體重($p$<0.001)。

三、蝙蝠特性與蝠蠅豐富度的關係

摺翅蝠的平均體重(不區分雌雄)爲 11.04 ± 0.04g (n=541)，依平均值將體重資料區分成體重較輕與較重二類群，並使用 Two-way ANOVA 分析結果顯示，性別因子與體重因子二者間並無顯著的交互作用(F=0.147, $p$=0.702)，雌雄二性間的總寄生蟲豐富度亦無顯著差異(F=3.375, $p$=0.067)，體重較重的蝙蝠群其總蝠蠅豐富度顯著地高於體重較輕的蝙蝠群(F=7.430, $p$=0.007)，但蝠蠅豐富度與體重的相關性並不高($y=1.7 + 0.456X_1 + 1.003X_2$, $R^2$=0.023; $X_1$, bat sex, $X_2$, bat body weight)。

針對姜宜蛛蠅寄生數量與宿主性別及體重相關性的 Two-way ANOVA 分析結果顯示，性別因子與體重因子二者間並無顯著的交互作用(F=0.184, $p$=0.668)，蝙蝠雌雄二性之間的姜宜蛛蠅豐富度並無顯著差異(F=0.005, $p$=0.944)，寄生於體重較輕及體重較重二類群蝙蝠的姜宜蛛蠅豐富度也無顯著性的差異(F=3.402, $p$=0.066) (表 2)。

**表 2.** 蝙蝠性別及體重對蝠蠅豐富度影響之二因子變異數分析 (Two-way ANOVA) *P* 値表 (**, $p$<0.01)
**Table 2.** *P*-values of Two-way ANOVA on the relationships of the bat sex and body weight with the bat fly abundance (**, $p$<0.01)

| Total batfly<br>Bat species | Sex | Body weight | Sex × Body weight |
|---|---|---|---|
| Total batfly | 0.067 | 0.007** | 0.702 |
| *Penicillidia jenynsii* | 0.944 | 0.066 | 0.668 |
| *Nycteribia parvula* | 0.306 | 0.005** | 0.172 |
| *Nycteribia allotopa mikado* | 0.113 | 0.099 | 0.97 |

針對短鋏蛛蠅寄生數量與宿主性別及體重相關性的 Two-way ANOVA 分析結果顯示，性別因子與體重因子二者間並無顯著的交互作用(F=1.873, $p$=0.172)，蝙蝠雌、雄二性之間的短鋏蛛蠅豐富度並無顯著差異(F=1.050, $p$=0.306)，寄生於體重較輕及體重較重二類群蝙蝠的短鋏蛛蠅豐富度出現顯著差異，體重較重蝙蝠類群的短鋏蛛蠅豐富度顯著的高於體重較輕的蝙蝠類群，但短鋏蛛蠅豐富度(F=7.891, $p$=0.005)與體重之間則無顯著性相關($y=1.245 + 0.111X_1 + 0.832X_2$, $R^2$=0.022; $X_1$, bat sex, $X_2$, bat body weight) (表 2)。

針對長鋏蛛蠅寄生數量與宿主性別及體重相關性的 Two-way ANOVA 分析結果顯示，性別因子與體重因子二者間並無顯著的交互作用(F=0.001, $p$=0.970)，雌、雄宿主二性之間的長鋏蛛蠅豐富度並無顯著差異(F=2.526, $p$=0.113)，寄生於體重較輕及體重較重二類群蝙蝠的長鋏蛛蠅豐富度也無顯著性的差異(F=2.728, $p$=0.099) (表 2)。

# 討論

體重除了與體表面積有關外，也意涵著宿主營養程度的不同(Christe *et al*. 2003)。一般而言，寄生蟲對於選擇宿主的策略會有二種極端不同的類型，第一類型爲選擇衰弱易攻擊的宿主(Christe *et al*. 2000)，第二類型則偏好營養條件佳的宿主(Christe *et al*. 2003)。依據本研究結果顯示：體重較輕與體重較重的二群摺翅蝠，所感染的蝠蠅豐富度在總蝠蠅豐富度的層級具有顯著性差異，在各別蝠蠅物種的層級則有短鋏蛛蠅出現豐富度上的差異，此結果符合外寄生蟲對宿主的選擇會明顯朝向營養狀況較佳宿主的策略模式，因此推論短鋏蛛蠅可能偏好體重較重(營養好或棲地大)的宿主。但在本研究中則宿主體重與性別因子對於姜宜蛛蠅及長鋏蛛蠅二物種的豐富度並無顯著性影響。

雖然較輕及較重二類群宿主的短鋏蛛蠅豐富度有差異，但是宿主體重與短鋏蛛蠅數量之間的相關係數卻不顯著，推論可能有其他因素影響了蝠蠅的寄生數量，諸如蝙蝠性別、蝙蝠個體間梳理(grooming)行爲的差異、年齡或者群落結構組成等。因爲性別上的差異包括免疫能力、自由遷徙(vagility)的能力以及活動範圍不同等(Krasnov *et al*. 2005)，而宿主的梳理行爲常是外寄生蟲死亡率的主因 (Funakoshi 1977; Marshall 1981)。ter Hofstede *et al*. (2004)的研究也指出梳理行爲應該是蝠蠅宿主寄生部位隔離的形成因素，至於年齡上的差異或許也會影響蝙蝠梳理行爲的能力(Presley and Willig 2008)，這些因素都可能在統計上減低了體重與蝠蠅數量的相關性。

短鋏蛛蠅的豐富度在宿主體重較重及較輕二分群上出現顯著差異，理論上體重具有顯著差異的雌蝠與雄蝠(雄>雌)，所寄生之短鋏蛛蠅豐富度的差異也應會出現顯著性差異，但結果並非如此，雌蝠與雄蝠的短鋏蛛蠅豐富度卻是無顯著差異。因此，推論短鋏蛛蠅數量的多寡，除了受到蝙蝠體重因素的影響外，對特定蝙蝠性別因素(雌性)的偏好減弱了體重(代表體表面積或營養資源)因素的影響，形成雌、雄蝠的蝠蠅豐富度相似的結果。雖然在許多的哺乳類物種中，都可以觀察到雄性比雌性具有較高的寄生蟲感染率及感染強度的現象(Poulin 1996; Morand *et al*. 2004; Cattadori *et al*. 2006)，而且 Moore and Wilson (2002)的研究也提出了「哺乳類動物的雄性個體一般都比雌性個體具有更多的外寄生蟲」的觀點，但是這些研究中有關翼手目的資料不充足，其中Moore and Wilson (2002)的報告中指出一些例子，外寄生蟲的豐富度與蝙蝠體型大小呈現負相關，因此Presley and Willig (2008)使用 22 種在巴拉圭採集的蝙蝠物種，探討外寄生蟲豐富度與宿主體型及性別因子之間的模式，結果顯示 16 種蝙蝠中有 14 種的蝙蝠雌性具有較高的外寄生蟲豐富度，而蝙蝠體型大小與外寄生蟲豐富度的關係則有 12 個例子顯示正相關，另有 11 個例子出現負相關，結果並無法支持「雄性的哺乳類比雌性藏匿了更大量的外寄生蟲」的看法。除此之外，Christe *et al*. (2007)也利用歐洲的*Myotis myotis* (大鼠耳蝠)及*M. blythii* (中鼠耳蝠)的蟎屬外寄生蟲 *Spinturnix* spp.進行外寄生蟲對於社會性或空間性聚集宿主的感染策略研究，其野外研究指出*Spinturnix* spp.這類外寄生蟎屬具有顯著偏好雌性宿主的現象，而在實驗室利用*M. daubentoni*與寄生蟎進行寄生蟲對宿主的偏好及其存活度的研究，結果則指出寄生蟲在雌性蝙蝠身上存活的數量顯著地高於雄性蝙蝠，該研究並認爲寄生蟲對於宿主的選擇是積極主動的傾向於尋找更佳(profitable)的宿主。

儘管本研究的結果顯示了重量可能是短鋏蛛蠅選擇宿主的偏好因素之一，除此之外，其他包括二性別間自由遷徙的能力、活動範圍以及免疫能力等的資料都是缺乏的，加上宿主的

體溫高低、毛皮濃密程度及宿主個體本身修飾或躲避寄生蟲的行爲差異的不同，這些已知或未知的相關因子共同作用下，將左右了蝠蠅對摺翅蝠的選擇偏好，因此「性別」這個因素，在未來研究中應需細分成更多的生物影響因子進行探討。

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# 不同海拔和棲地類型之盤古蟾蜍蝌蚪的形態變異

# Variation in Morphological Characters of *Bufo bankorensis* Tadpoles among Different Elevations and Habitats

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## 摘　要

盤古蟾蜍(*Bufo bankorensis*)廣泛分布於台灣海拔 100-3,000m的山區，經常於溪流或池塘進行繁殖。本研究分析不同海拔區域間之盤古蟾蜍蝌蚪的體型變異，並比較生長在池塘與溪流棲地的蝌蚪形態。自 2005 年 3 月至 2008 年 2 月，於阿里山地區 100- 2,300m的海拔範圍內設置不同海拔高度的樣地，捕捉發育期在 Gosner stages 30-32 期的盤古蟾蜍蝌蚪進行形態測量及形態差異的分析。結果發現，蝌蚪的全長、尾長與尾肌寬有隨著海拔升高而增加的趨勢，但體長、體高、體寬、尾高及尾肌高則以生長在中海拔池塘棲地者較大；而相對尾長則以高海拔池塘棲地的蝌蚪最大，中海拔池塘棲地的蝌蚪最小。生長在中海拔溪流棲地的蝌蚪，除了具有較大的相對尾長，以及尾長不具差異外，其他測量形質均比中海拔池塘棲地的蝌蚪小。

## Abstract

The Central Formosan toad (*Bufo bankorensis* Barbour) is widely distributed in hills and mountains at elevations from 100-3,000m in Taiwan. Its tadpoles occur in lotic and lentic habitats. We collected the tadpoles at 19 sampling sites at the elevations from 100-2,320m in the Ali Mountain Range from March 2005 to February 2008. Seven morphometric characters at the Gosner stages 30-32 were measured and compared among different elevations and between stream and pond habitats. The results showed that the means of total length (TTL), tail length (TL) and caudal tail muscle width (CMW) increased with the elevation. The means of head and body length (HBL), body height (BH), body width (BW), tail height (TH), and caudal tail muscle height (CMH) from pond habitat were larger than those from the other sites at mid-elevations. The mean of relative tail length (RTL) was the largest for tadpoles from the pond habitat at high elevations, while it was the smallest for those from pond habitat at mid-elevations. All of the morphometric characters of the tadpoles from stream habitat were smaller than those from pond habitat at mid-elevations, but the mean RTL from stream habitat was larger than that from pond habitat.

**關鍵詞：**盤古蟾蜍、蝌蚪、形態、海拔、棲地

**Key words:** *Bufo bankorensis*, tadpole, morphology, elevation, habitat

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## 緒　言

生物的體型會受生理、生態和社會結構的影響(Schäuble 2004)。在生態環境變異的影響之下，許多物種具有區域性適應(local adaptation)或地理形態變異(geographical morphological variation)的現象(Miaud and Merilä 2001; Sommer and Pearman 2003)；而生存於不同棲地環境的兩棲類，也經常存在生理、生活史、形態及行爲特徵上的差異(Miaud and Merilä 2001)。

氣候是限制兩棲類分布的主要環境因素之一。海拔分布廣泛的兩棲類，受到不同海拔高度之溫度變異的影響，會在生殖特徵(Beattie 1987)及發育特徵(Bervern 1987)上產生變異。Merilä *et al*. (2004)對廣泛分布於歐洲的林蛙(*Rana temporaria*)蝌蚪進行低溫及食物限制實驗，發現在環境溫度較低和食物供應不足時，其蝌蚪具有較大的相對尾長(relative tail length, RTL)，進一步分析時發現，林蛙蝌蚪的相對尾長增大主要是受到軀體部位生長減緩的影響，其實際尾長並無增長的現象。有些學者則認爲具有較大相對尾長的蝌蚪，可能具有較強之移動能力來躲避天敵的效用(Stahlberg *et al*. 2001)。因此，蝌蚪的相對尾長在面對不同的

環境條件時，如溫度、食物或天敵壓力，經常會產生不同程度的變異，但不排除可能因不同地區的遺傳變異導致差異。

不同的棲地類型會影響蝌蚪之形態特徵的發育。生長在溪流與池塘環境的蝌蚪，其外觀形態具有明顯的差異(Altig and Johnston 1989)。在池塘環境中的棲地穩定性及個體競爭，會使蝌蚪的體型產生變異。生長在族群密度較高之池塘的蝌蚪，具有體型小、生長快、變態較早且變態體型較小的現象(Loman 2003)。生長在靜水域的 *Litoria ewingii* 蝌蚪，池塘水體的穩定性也會影響其生長及發育(Lauck *et al.* 2005)。Boone *et al.* (2002)發現棲息於暫時性水域的 *Ambystoma talpoideum* 幼體具有發育期短、存活率低及變態體型較小的現象。另一方面，生長於溪流環境的蝌蚪，水流速度經常是影響其形態構造變異的重要環境因子。Richards (2002)利用棲息於北昆士蘭雨林之溪流緩流中的 *L. genimaculata*、*Mixophyes schevilli* 及生活在急流中的 *L. nannotis* 與 *Nyctimystes dayi* 蝌蚪進行流速箱與人造溪流實驗，發現生長在急流環境中的 *L. nannotis* 與 *N. dayi* 蝌蚪具有較大的口器及腹部吸盤等形態特質，能在急流的環境中吸附岩石；而具有較低尾鰭者可以在遭遇激流時到避難所躲避。

盤古蟾蜍(*Bufo bankorensis*)廣泛分布在台灣本島低山丘陵至海拔 3,000m 左右的山區(潘 1997)，以往曾被認爲是分布於中國大陸各地的中華大蟾(*B. gargarizans*)，1986 年經日本學者松井正文鑑定爲台灣特有種(Matsui 1986)。盤古蟾蜍的蝌蚪棲息在流水域或靜水域中，在水流較爲平緩的溪流平瀨、潭區或溝渠、水潭、池塘都有其活動蹤跡(Chou and Lin 1997)。其蝌蚪的體型屬於流水攀附型(lotic and clasping type)，眼小位於頭側上方，口器比一般靜水型的黑眶蟾蜍(*B. melanostictus*)蝌蚪大，且具有較多的次邊突(submarginal papilla)，可攀附在岩石表面(Chou and Lin 1997)。此外，盤古蟾蜍的蝌蚪體型一般較爲扁平，尾部上下的皮質鰭小，尾後緣通常呈圓鈍狀(周 1997)。由於盤古蟾蜍的海拔分布廣泛，且蝌蚪可生長棲息於流水域與靜水域的不同環境，本研究乃利用阿里山地區不同海拔之溪流及池塘樣地，來調查比較盤古蟾蜍蝌蚪的形態是否存在變異。

## 材料與方法

### 一、採集地點

自 2005 年 3 月至 2008 年 2 月，我們將阿里山地區劃分爲低海拔(100-400m)、中海拔(800-1,200m)及高海拔(2,100-2,320m)等 3 個海拔區域，在各區域內尋找有盤古蟾蜍蝌蚪棲息的樣地，總共設立有 19 個調查樣地(圖 1)。調查期間，並未在低海拔的靜水域及高海拔的流水域發現盤古蟾蜍蝌蚪。故本研究分別在低海拔設置有 5 個溪流樣地，中海拔設置有 5 個溪流及 5 個池塘樣地，而高海拔則設立 4 個池塘樣地。所設置之溪流樣地共有 10 個，樣地的河寬介於 1.5-88m 不等，海拔由低至高分別爲新五虎寮(WHL)、觸口(CK)、159 甲出水溪(CSS)、內腦寮(NNL)、159 甲石腳桶(SJT)、驛馬溪(YM)、崁仔溪(CS)、巴沙娜(BSN)、特富野(TFY)、拉拉吾雅(LLWY)等地。池塘樣地多爲人造池塘、灌溉用蓄水池及道路邊臨時性水域，分別爲湘泉休閒農場(HC)、樂野(LY)、隙頂(隙頂 1，SD 1；隙頂 2，SD 2；隙頂 3，SD 3)、阿里山受鎮宮(SJ)、姊潭(ES)、沼平 7 號橋(JP)，以及台 18 線 92K (92K)等 9 個池塘樣地(表 1 與圖 1)，其水體面積介於 13-1,760 m$^2$ 之間，池塘四周的植被組成差異頗大。研究期間，中、高海拔區域以阿里山氣象站(120°48'18"E，23°30'37"N，海拔 2,413m)的氣候資料做爲參考，而低海拔區域則參考嘉義氣象站(120°25'28"E，23°29'52"N，海拔 27m)的氣溫和雨量資料。總合 2005 年 3 月至 2008 年 2 月的氣

象資料，可發現 6-8 月爲研究區域的雨季，11 月至隔年 2 月爲乾季(圖 2)，其中阿里山氣象站之月平均雨量爲 446.5 mm，月平均氣溫爲 11.7°C；而嘉義氣象站的月平均雨量則爲 207.7 mm，月平均氣溫爲 23.6°C。

**表 1.** 盤古蟾蜍蝌蚪 19 個調查樣地的基本資料

**Table 1.** Coordinations, elevations and habitats of the 19 sampling sites of *Bufo bankorensis* tadpoles in this study

| Code | Sites | Latitude | Longitude | Elevation (m) | Habitat |
|---|---|---|---|---|---|
| WHL | Wuhuliao | 208000 | 2593264 | 190 | Stream |
| CK | Chukou | 209745 | 2592901 | 230 | Stream |
| CSS | Chushueisi | 210896 | 2595020 | 326 | Stream |
| NNL | Neinaoliao | 209516 | 2591968 | 330 | Stream |
| SJT | Shihjiaotong | 210448 | 2594981 | 378 | Stream |
| YM | Yima | 217248 | 2597571 | 832 | Stream |
| CS | CiSi | 217905 | 2597927 | 911 | Stream |
| BSN | Bashana | 225536 | 2596674 | 970 | Stream |
| TFY | Tefuye | 225825 | 2592442 | 981 | Stream |
| LLWY | Lalawuya | 219451 | 2595913 | 1,152 | Stream |
| HC | Hsiangchuan | 217385 | 2598032 | 883 | Pond |
| LY | Leya | 219054 | 2594668 | 908 | Pond |
| SD 1 | Siding 1 | 214907 | 2590388 | 1,063 | Pond |
| SD 2 | Siding 2 | 214643 | 2590174 | 1,131 | Pond |
| SD 3 | Siding 3 | 214389 | 2590373 | 1,190 | Pond |
| SJ | Shoujhen Temple | 230647 | 2601611 | 2,155 | Pond |
| ES | Elder sister | 231016 | 2601762 | 2,200 | Pond |
| JP | Jhaoping | 230930 | 2601359 | 2,265 | Pond |
| 92K | 92K | 231385 | 2600469 | 2,320 | Pond |

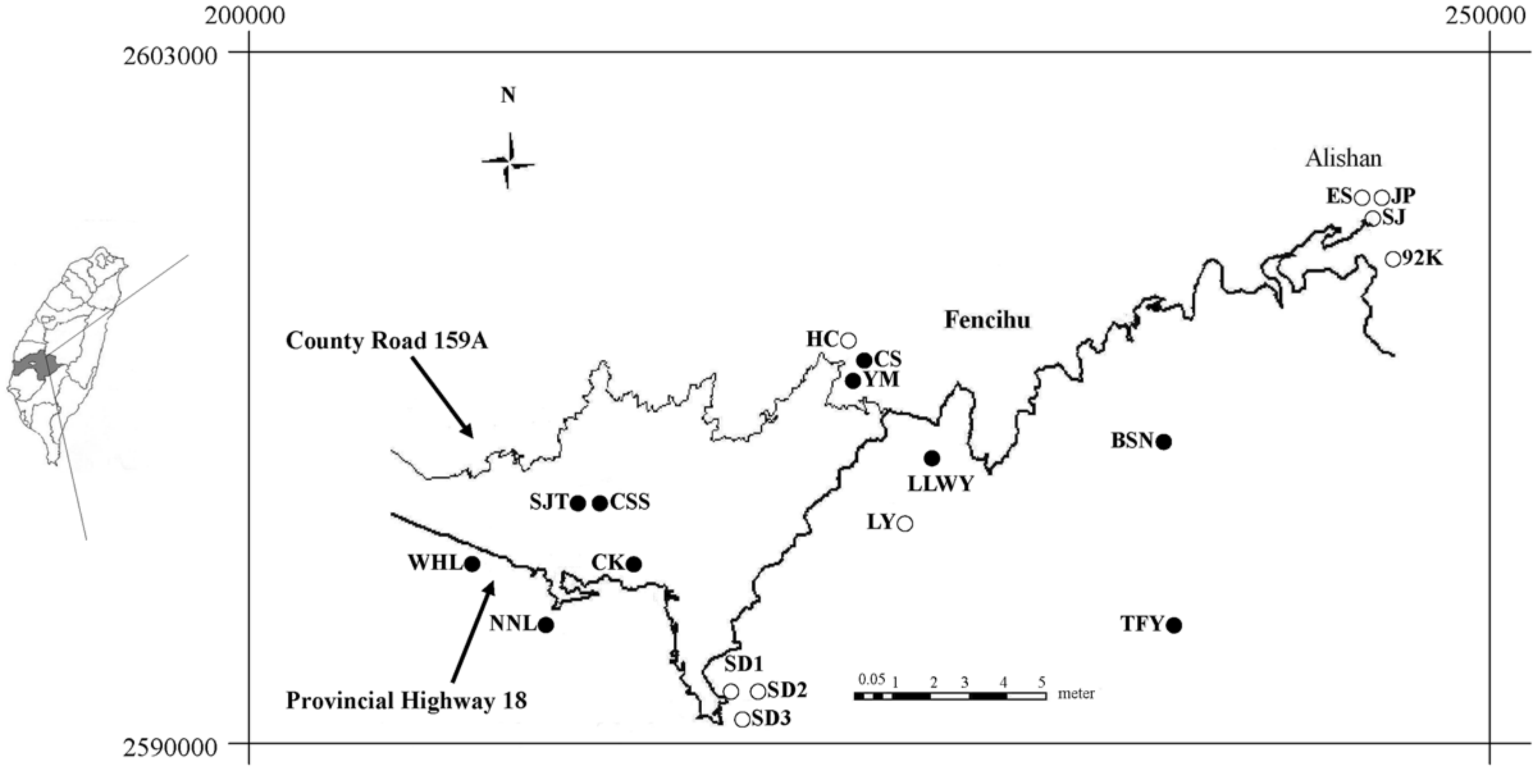

**圖 1.** 本研究盤古蟾蜍蝌蚪之採集地點的地理相關位置圖(實心代表溪流樣地，空心代表池塘樣地)。圖中樣地代號分別爲WHL (新五虎寮)、CK (觸口)、CSS (出水溪)、NNL (內腦寮)、SJT (石腳桶)、YM (驛馬溪)、CS (崁仔溪)、BSN (巴沙娜)、TFY (特富野)、 LLWY (拉拉吾雅)、HC (湘泉)、LY (樂野)、SD 1 (隙頂 1)、SD 2 (隙頂 2)、SD 3 (隙頂 3)、SJ (受鎮宮)、ES (姊潭)、JP (沼平 7 號橋)，以及 92K (台 18 線 92K)。

**Fig. 1.** Sampling sites (solid circles, stream sites; open circles, pond sites) of *Bufo bankorensis* tadpoles in the Ali Mountain Range, Chiayi County, Taiwan (WHL, Wuhuliao; CK, Chukou; CSS, Chushueisi; NNL, Neinaoliao; SJT, Shihjiaotong; YM, Yima; CS, CiSi; BSN, Bashana; TFY, Tefuye; LLWY, Lalawuya; HC, Hsiangchuan; LY, Leya; SD 1-3, Siding 1-3; SJ, Shoujhen Temple; ES, Elder sister; JP, Jhaoping; 92K, Provincial Highway 92K).

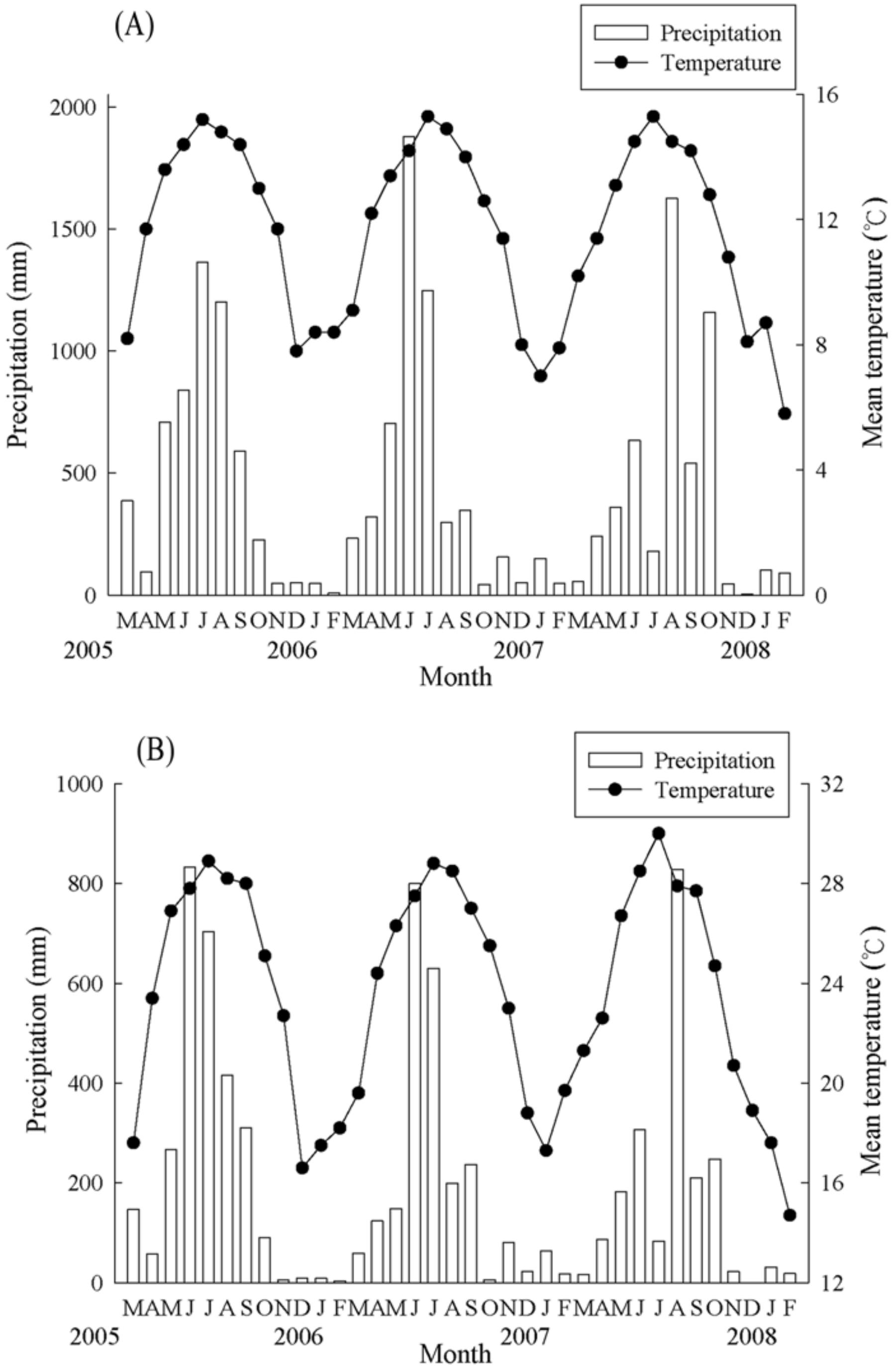

**圖 2.** 2005 年 3 月至 2008 年 2 月研究期間，採集地區每月平均氣溫和累積雨量資料。圖(A)來自阿里山氣象站，圖(B)來自嘉義氣象站。

**Fig. 2.** Monthly precipitations and mean temperatures at the Ali Mountain Weather Station (A) and the Chiayi Weather Station (B), March 2005 to February 2008.

### 二、野外採集及實驗室標本測量

在所設置的 19 個樣地中，以 10×25×15 cm 撈網來撈取蝌蚪。在撈取蝌蚪時，每個蝌蚪聚集群隨意撈取 10-20 隻，然後在溪流樣地移動 5m 以上的距離再進行撈取，而在池塘樣地則視池塘的大小來移動撈取的位置，每個樣地以撈取 100-200 隻蝌蚪爲原則。所有採集的蝌蚪均以 10%福馬林固定保存，帶回實驗室進行形態測量(Vences *et al*. 2002; Laugen 2003)。由於蝌蚪會隨著成長發育而改變體型，爲了避免受到異速生長(allometry)的影響(Hammer 2002)，本研究利用先前在阿里山姊潭所採集的 3,911 隻蝌蚪，以解剖顯微鏡觀察 Gosner stages 25-45 期的蝌蚪(Gosner 1960)，並測量其體重、體長及全長，結果發現在 Gosner stages 30-32 期的生長發育較爲平緩(圖 3)，故本研究後續的分析，均以發育期在 Gosner stages 30-32 期的個體來進行測量。每隻蝌蚪均利用準確度達 0.01 mm 的數位游標尺(Mitutoyo: 500-196)來測量全長(total length, TTL—吻端至尾端)、體長(head to body length, HBL—吻端至泄殖孔)、體寬(body width, BW—俯視頭部最寬處)、體高(body height, BH—側觀身體最高處)、尾長(tail lenght, TL—泄殖孔至尾端)、尾高(tail height, TH—側觀尾部最高處)、尾肌高(caudal muscle height, CMH—側觀尾肌最高處)、尾肌寬(caudal muscle width, CMW—俯視尾肌最寬處) (周 1997; Buskirk and Saxer 2001)等 8 個測量形質(圖 4)及計算相對尾長：RTL = TL/TTL，同時以電子秤(Sartorius BJ310，精確度至 0.01g)測量其體重(body weight)。

### 三、資料分析

對不同海拔區域與棲地類型之蝌蚪進行單變量分析，所有的蝌蚪樣本區分爲高海拔靜水域、中海拔靜水域、中海拔流水域及低海拔流水域等 4 個 OTUs (operational taxonomic unit)。以 Kolmogorov-Smirnov test 檢驗各測量形質符合常態分布後，利用 ANOVA 來比較各 OTU 間之 TTL、HBL、BW、BH、TL、TH、CMH、CMW 及 RTL 等形質是否存在差異，若具有顯著性的差異，再以 Fisher’s PLSD 進行事後兩兩比較，上述分析均以 $p<0.05$ 爲顯著水準。此外，各形質經自然對數(*ln*)轉換後，利用判別分析(discriminant function analysis, DFA) (Gvozdik *et al*. 2008)將各變數重新組合成線性的判別函數(discriminant function)，進行事後判別分群並記錄各 OTU 的判別正確率，同時也利用各蝌蚪樣本在判別軸的分布來檢視其分群狀況(陳 2005; 張 2006)。上述的統計分析均利用 STATISTICA 7.0 統計軟體進行(StatSoft Inc. 2004)。

## 結　果

### 一、不同海拔與棲地之蝌蚪形態的單變量分析

本研究在 19 個調查樣地共採集測量有 1,072 隻 Gosner stages 30-32 期的盤古蟾蜍蝌蚪，包含低海拔溪流棲地 328 隻(OTU 1)、中海拔溪流棲地 335 隻(OTU 2)、中海拔池塘棲地 202 隻(OTU 3)及高海拔池塘棲地 207 隻(OTU 4)。以 ANOVA 檢測發現所有形質在 4 個 OTUs 之間均具有顯著性的差異($p<0.01$) (表 2)。其中，高海拔池塘棲地之盤古蟾蜍蝌蚪具有最大的 TTL (mean=24.66 mm, SE=0.20)，低海拔溪流棲地之蝌蚪的 TTL 最小(mean=21.56 mm, SE=0.17)，而中海拔池塘棲地之蝌蚪也比中海拔溪流棲地的個體具有較大的 TTL (Fisher’s PLSD test, $p<0.05$) (表 2)。各形質利用 Fisher’s PLSD 進行事後兩兩比較發現，低海拔與中海拔溪流棲地之盤古蟾蜍蝌蚪(OTU 1 與 OTU 2)的 TTL、HBL、BH、TL、CMH 及 CMW 具顯著性差異($p<0.05$)，但 BW、TH 與 RTL 則無差異存在(表 2)，顯示在相似的溪流棲地中，中海拔之盤古蟾蜍蝌蚪具有較大的全長、體長、體高、尾長、尾肌高及尾肌寬。在池塘棲地中，高海

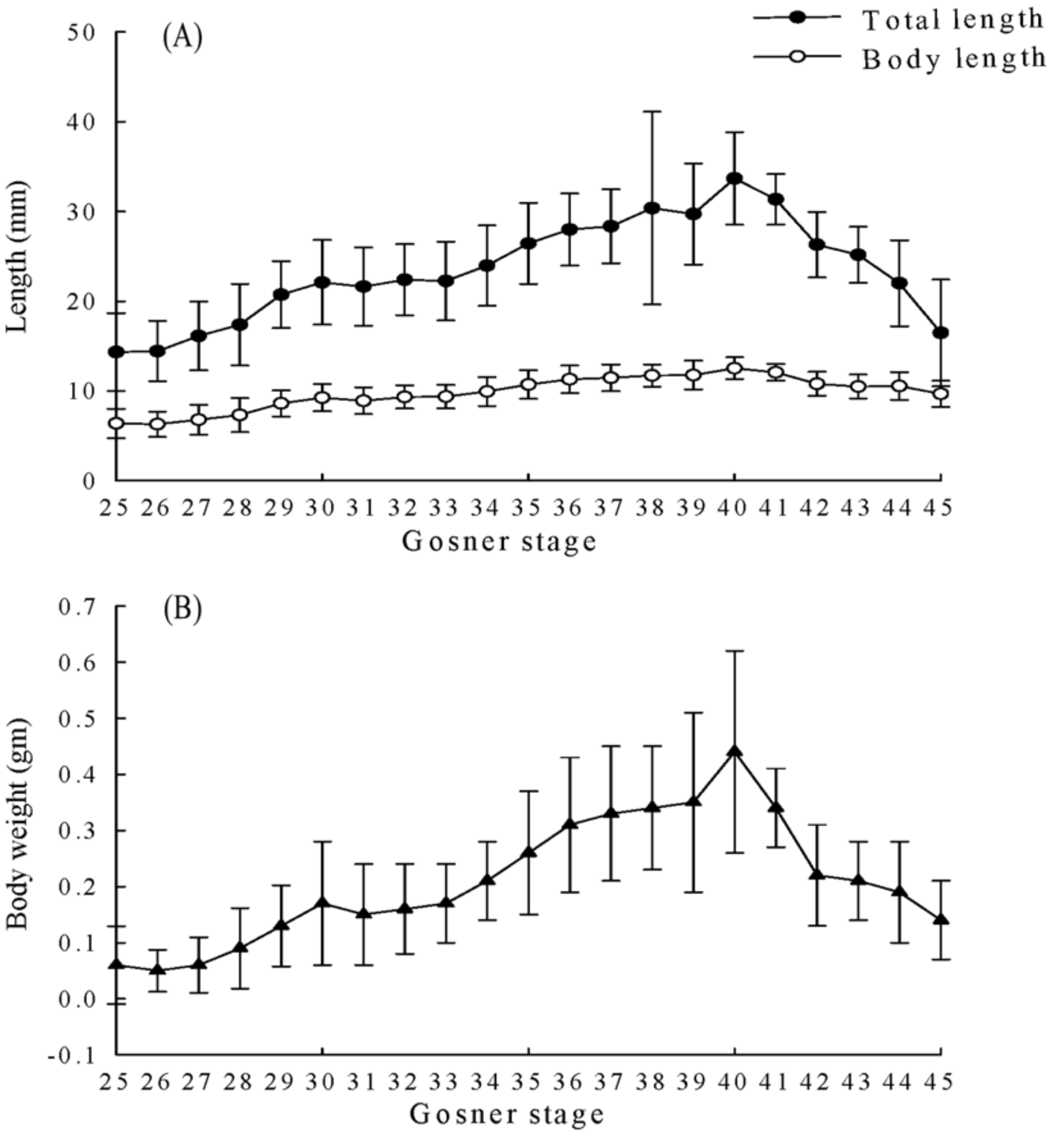

**圖 3.** 在阿里山姊潭所採得不同Gosner生長期之盤古蟾蜍蝌蚪的平均體長、全長(A)與平均體重(B)的變化圖(垂直線段表示標準誤差)。

**Fig. 3.** Mean body lengths, total lengths (A), and body weights (B) of *Bufo bankorensis* tadpoles at Gosner stages 23 to 43 collected from Elder Sister Lake of Alishan (vertical bars, standard errors).

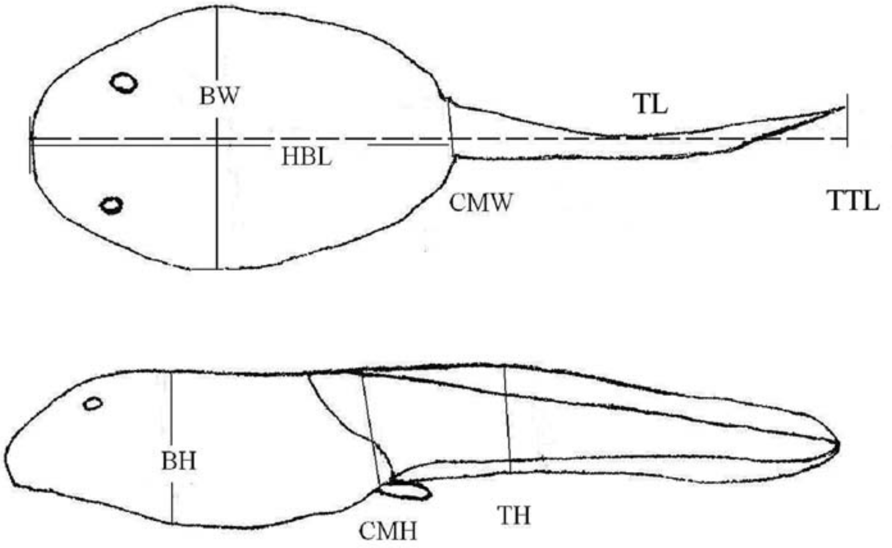

**圖 4.** 盤古蟾蜍蝌蚪所測得之身體及尾部形態特徵：體長(HBL)、全長(TTL)、體寬(BW)、體高(BH)、尾長(TL)、尾高(TH)、尾肌高(CMH)及尾肌寬(CMW)。

**Fig. 4.** Eight morphological characters of *Bufo bankorensis* tadpole measured for this study (HBL, head and body length; TTL, total length; BW, body width; BH, body height; TL, tail length; TH, tail height; CMH, caudal tail muscle height; CMW, caudal tail muscle width).

**表 2.** 不同海拔流水域與靜水域棲地之盤古蟾蜍蝌蚪形態的比較。(OTU 1，低海拔溪流；OTU 2，中海拔溪流；OTU 3，中海拔池塘；OTU 4，高海拔池塘)

**Table 2.** Comparison of morphometric measurements (mean ± standard errors) of *Bufo bankorensis* tadpoles among different habitat types (OTU 1, low-elevation streams; OTU 2, mid-elevation streams; OTU 3, mid-elevation ponds; OTU 4, high-elevation ponds)

| Characters* | OTU1 (n=328) | OTU2 (n=335) | OTU3 (n=202) | OTU4 (n=207) |
|---|---|---|---|---|
| TTL (mm) | 21.56 ± 0.17$^{a}$ | 22.36 ± 0.16$^{b}$ | 23.09 ± 0.21$^{c}$ | 24.66 ± 0.2$^{d}$ |
| HBL (mm) | 9.45 ± 0.06$^{a}$ | 9.66 ± 0.06$^{b}$ | 10.49 ± 0.08$^{c}$ | 10.32 ± 0.08$^{c}$ |
| BH (mm) | 4.28 ± 0.05$^{a}$ | 4.47 ± 0.05$^{b}$ | 4.69 ± 0.06$^{c}$ | 4.44 ± 0.06$^{b}$ |
| BW (mm) | 5.22 ± 0.07$^{a}$ | 5.37 ± 0.07$^{a}$ | 5.94 ± 0.08$^{b}$ | 5.19 ± 0.08$^{a}$ |
| TL (mm) | 12.12 ± 0.12$^{a}$ | 12.70 ± 0.12$^{b}$ | 12.60 ± 0.15$^{b}$ | 14.35 ± 0.15$^{c}$ |
| TH (mm) | 3.85 ± 0.04$^{a}$ | 3.94 ± 0.04$^{a}$ | 4.30 ± 0.05$^{b}$ | 3.96 ± 0.05$^{a}$ |
| CMH (mm) | 3.14 ± 0.03$^{a}$ | 3.45 ± 0.03$^{b}$ | 3.66 ± 0.04$^{c}$ | 3.59 ± 0.04$^{c}$ |
| CMW (mm) | 0.92 ± 0.01$^{a}$ | 1.10 ± 0.01$^{b}$ | 1.21 ± 0.02$^{c}$ | 1.29 ± 0.02$^{d}$ |
| RTL: TL/TTL | 0.56 ± 0.002$^{b}$ | 0.56 ± 0.002$^{b}$ | 0.55 ± 0.002$^{a}$ | 0.57 ± 0.002$^{c}$ |

* Significant difference in character among habitat types with different superscripts a, b, c and d with Fisher's PLSD test at the 5% level ($p<0.05$).

拔蝌蚪(OTU 4)具有較大的 TTL、TL、CMW 和 RTL ($p<0.05$)，然而 BH、BW、TH 則顯著小於中海拔池塘棲地的個體(OTU 3) ($p<0.05$)，顯示在池塘棲地中，高海拔的盤古蟾蜍蝌蚪雖然比中海拔個體具有較大的全長、尾長、尾肌寬及相對尾長，但身體則相對較小。另外，比較同樣位於中海拔之溪流與池塘棲地的盤古蟾蜍蝌蚪(OTU 2 與 OTU 3)則發現，池塘棲地的蝌蚪具有較大的TTL、HBL、BH、BW、TH、CMH 及 CMW，僅 RTL 小於溪流棲地的個體($p<0.05$)，而 TL 則無差異存在(表 2)，即中海拔池塘棲地之盤古蟾蜍蝌蚪具有較大的全長，其身體各部分相對較大，但尾長則不具差異。

### 二、不同海拔及棲地之蝌蚪的分群關係

將所有的蝌蚪樣品測量值帶入 DFA 所建構的判別函數，發現整體的正確率爲 61.6%。各個 OTU 的判別正確率以 OTU 3 的 44.1%爲最低，其他 3 個 OTUs 的正確率則介於 56.5%至 70.1%之間。其中的OTU 1 的主要錯分群體爲OTU 2， OTU 2 的主要錯分群體爲OTU 1，而 OTU 3 的錯分群體則以 OTU 1 與 OTU 2 爲主，至於OTU 4 則分別有 11.1%至 17.4%不等的個體被錯分其他 3 個 OTUs (表 3)。在進一步的典型分析(canonical analysis)中共可建立 3 個判別軸，經 Wilk’s Lambda，$\chi^2$ 檢定皆達顯著水準($p<0.001$)，表示這些判別軸具有解釋變異的意義。這 3 個軸分別可以解釋 70.9%、20.1%及 9.0%的整體變異量，其中 Root 1 主要受到 TTL 及 TH 的影響(表 4)，而利用 Root 1 及 Root 2 所繪製的樣品散布圖(圖 5)則可發現 OTU 1、OTU 2 與 OTU 3 之間有較大的重疊，而 OTU 4 的散布大且包覆其他 3 個 OTUs 的密集區。

## 討　論

在探討蛙類蝌蚪體型與海拔梯度變異之關係時，除考慮全長的變化之外，也必須考慮身體與尾部之不同形質的改變模式，如此才能獲致更詳盡的生態訊息。在本研究所測量的 8 個形質中，盤古蟾蜍蝌蚪的 TTL 與 CMW 呈現 OTU 4 > OTU 3 > OTU 2 > OTU 1 的變異，而 TL 則呈現 OTU 4 > OTU 3 = OTU 2 > OTU 1 的變異，即存在隨海拔升高而增大的趨勢。但其他 HBL、BH、BW、TH 與 CMH 等 5 個形質則都以棲息在中海拔池塘棲地之蝌蚪族群(OTU 3)爲最大，且在事後的兩兩檢測中大都具有統計上的差異(PLSD test, $p<0.05$)。這 8 個形質在不同OTUs之間的改變模式並不完全相同。高海拔池塘棲地的蝌蚪(OTU 4)具有最大的尾長 14.4 mm (SE = 0.15)，中海拔池塘與溪流棲地蝌蚪的尾長分別爲 12.6 mm (SE = 0.15)與 12.7 mm (SE = 0.12)，而低海拔溪流棲地的蝌蚪尾長則僅有 12.1 mm (SE = 0.12)。這結果與 Merilä *et al.* (2004)發現低溫環境並不會造成林蛙蝌蚪尾長增長的結果並不相同，因此溫度對蝌蚪尾巴之影響仍有待後續研究的進一步探討。另一方面，Laugen *et al.* ( 2005)發現廣泛棲息在歐洲不同緯度的林蛙，其體型大小會隨著緯度變化而呈現駝峰型(hump-shaped)的改變，並推論這可能與緯度梯度所產生的溫度變異有關。本研究發現盤古蟾蜍蝌蚪的 HBL 等 5 個形質都是以中海拔池塘棲地的蝌蚪(OTU 3)爲最大，且中海拔池塘棲地蝌蚪(OTU 3)的所有測量形質，除 TL 外均顯著的大於中海拔溪流棲地的蝌蚪(OTU 2) (PLSD test, $p<0.05$)。盤古蟾蜍主要分布於台灣海拔 100-3,000m 的山區(呂等 1990; 潘 1997)，且多數在靜水域或水流較爲平緩的溪流平瀨、潭區或溝渠進行繁殖(Chou and Lin 1997)。因此，溪流的流動水域環境及低海拔的夏季高溫與高海拔的冬季低溫環境有可能成爲影響盤古蟾蜍蝌蚪生長的環境因子，使其體型的發育在不同的海拔與棲地間產生改變。

在 DFA 的事後判別分群中發現，中海拔

**表 3.** 不同海拔與棲地分群之盤古蟾蜍蝌蚪形態判別分析的錯分表

**Table 3.** The classification matrix of *Bufo bankorensis* tadpoles from different habitat types with the discriminant function analysis (percentages in parentheses; bold numbers along the diagonal, number of tadpoles correctly classified to the habitat type groups; *N*, total number of tadpoles classified to the habitat type groups; OTU 1, low-altitude stream group; OTU 2, mid-elevation stream group; OTU 3, mid-elevation pond group; OTU 4, high-elevation pond group)

| Group | OTU 1 | OTU 2 | OTU 3 | OUT 4 | *N* |
|---|---|---|---|---|---|
| OTU 1 | **230 (70.1)** | 86 (26.2) | 5 (1.5) | 7 (2.1) | 328 |
| OTU 2 | 75 (22.4) | **224 (66.9)** | 24 (7.2) | 12 (3.6) | 335 |
| OTU 3 | 37 (18.3) | 65 (32.2) | **89 (44.1)** | 11 (5.5) | 202 |
| OTU 4 | 23 (11.1) | 36 (17.4) | 31 (15.0) | **117 (56.5)** | 207 |

**表 4.** 不同海拔與棲地分群之盤古蟾蜍蝌蚪形態判別分析，第 1、2、3 軸各變數之標準化正典係數值。粗體之數值表示該變數對判別有較大貢獻

**Table 4.** Standardized coefficients of the first three canonical variables for *Bufo bankorensis* tadpoles among different elevations and habitats (boldface numbers, canonical variables better describing the variance)

| Variables | Root 1 | Root 2 | Root 3 |
|---|---|---|---|
| **TTL** | **1.12** | -2.32 | -0.63 |
| HBL | 0.16 | 1.30 | -1.17 |
| BH | -0.66 | -0.06 | 0.76 |
| BW | -0.26 | 0.12 | 0.09 |
| TL | -0.09 | 0.64 | 0.48 |
| **TH** | **-0.97** | 0.35 | -0.54 |
| CMH | 0.55 | 0.54 | 0.92 |
| CMW | 0.66 | 0.27 | 0.34 |
| RTL | -0.26 | 0.01 | 0.13 |
| Eigenvalue | 0.66 | 0.19 | 0.08 |
| Cumulative % of variance | 70.9 | 91.0 | 100 |

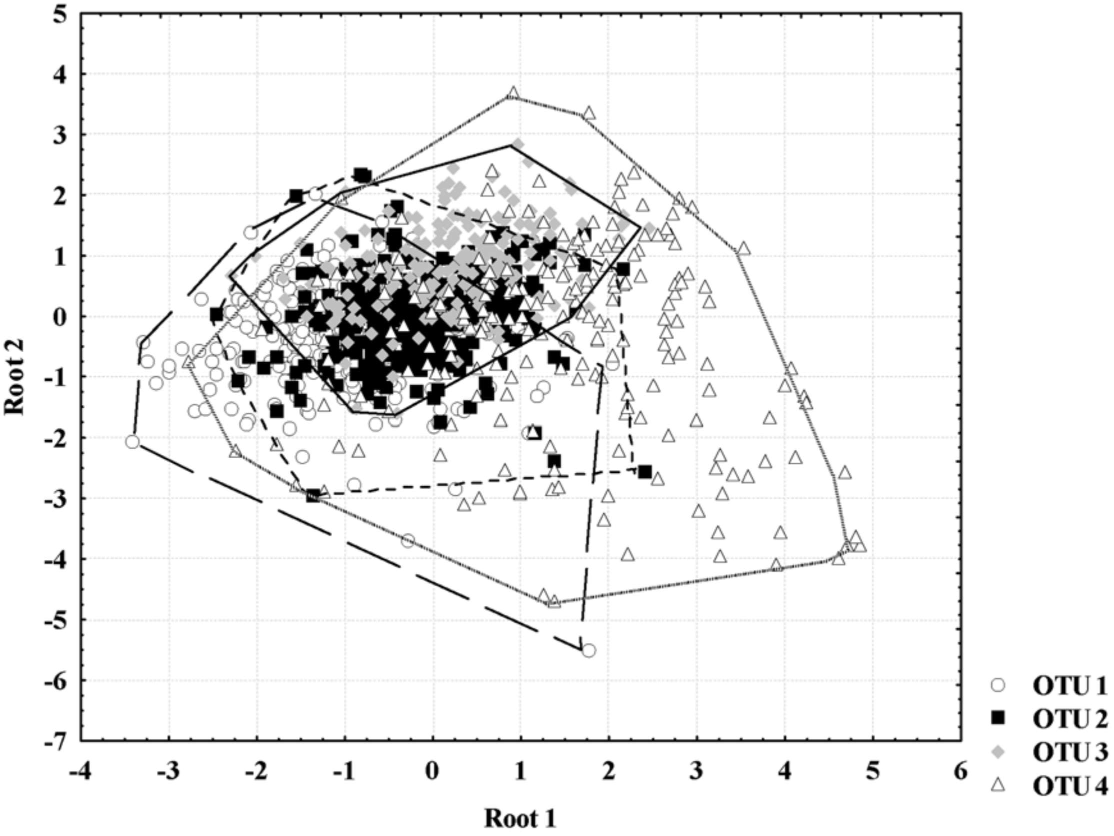

**圖 5.** 不同海拔與棲地類型盤古蟾蜍蝌蚪之測量形質的前兩軸典型分析散布圖。OTU 1，低海拔溪流；OTU 2，中海拔溪流；OTU 3，中海拔池塘；OTU 4，高海拔池塘。

**Fig. 5.** Canonical plots of the first two axes for *Bufo bankorensis* tadpoles from four habitat types (OTU 1, low-elevation streams; OTU 2, mid-elevation streams; OTU 3, mid-elevation ponds; OTU 4, high-elevation ponds).

及低海拔溪流棲地的蝌蚪(OTU 1 與 OTU 2)，在兩個群體間存有較高的錯分率，但較少被錯分至中、高海拔池塘棲地的蝌蚪群體中；反之，中、高海拔池塘棲地之蝌蚪(OTU 3 與 OTU 4)被錯分至溪流棲地群體則相對較多。在DFA的事後判別分群中，如果兩組資料有重疊則可能產生錯分的情況，而其分配錯誤的機會則視兩組資料的重疊大小而定(McGarigal *et al*. 2000)，池塘棲地之盤古蟾蜍蝌蚪具有較高的形態變異，也可能使其存在較高的錯分率。此外，池塘的水域大小及水深也可能對蝌蚪的成長造成影響(Vences *et al*. 2002)，Loman (2003)發現棲息在小池塘的蝌蚪，具有存活率低、成長速率快及變態體型較小的現象，並推論這可能是棲息於小池塘的蝌蚪易遭受到食物競爭、空間競爭及水域乾枯等壓力有關。本研究並未就各池塘的深度作完整測量，難以進一步探討水域大小及深度對盤古蟾蜍蝌蚪之生長的影響。

此外，我們比較 4 個OTUs的RTL發現，高海拔池塘棲地蝌蚪(OUT 4)具有最大的RTL，而中海拔池塘棲地蝌蚪(OUT 3)的 RTL 最小，

但中、低海拔之溪流棲地蝌蚪(OUT 1 及 OUT 2)的RTL則無差異存在。進一步比較發現，高海拔池塘棲地蝌蚪(OTU 4)的 RTL 較中海拔池塘棲地蝌蚪(OUT 3)大，且其 TTL 及 TL 也顯著大於中海拔蝌蚪(PLSD test, $p<0.05$)，但HBL則無差異存在(表 2)。中、高海拔池塘棲地蝌蚪之 RTL 的差異，主要是因爲高海拔族群具有較長的尾長所致。另一方面，如果比較同樣位於中海拔之溪流棲地與池塘棲地蝌蚪(OUT 2 及 OUT 3)的 RTL，則可發現溪流棲地蝌蚪(OUT 2)的 RTL 較大，但其 TTL 及 HBL 則顯著小於池塘棲地蝌蚪(PLSD test, $p<0.05$)，而TL則無差異存在(OTU 2 及OTU 3 分別爲 12.7 mm及 12.6 mm)，所以TTL變異應該是導致兩個OTUs間之RTL差異的主要因素。至於低海拔及中海拔溪流棲地蝌蚪(OUT 1 及 OUT 2)的 RTL 雖然沒有差異，但中海拔族群的 TTL、HBL 及 TL 均較低海拔族群大(PLSD test, $p<0.05$)。雖然本研究發現各 OTUs 的 TTL 存在 OTU 4 > OTU 3 > OTU 2 > OTU 1 的變異，但 HBL 在相同海拔不同棲地間(即 OUT 2、OUT 3)存在較大的差異，而 TL 則在相同棲地不同海拔間(即OUT 1、OUT 2 與OUT 3、OUT 4)具有較大的差異(表 2)。其 HBL 與 TL 的改變模式與 TTL 不盡相同，這也是導致 RTL 在各OTUs產生變化的主要因素。生長在溪流環境之蝌蚪具有較大的RTL，可能與其棲息環境之水流速度有關，較大的 RTL 有助於蝌蚪移動潛藏於避難所(Stahlberg *et al*. 2001)，且溪流型的蝌蚪體型大都較爲瘦長(Richards 2002)。較高大的身體及尾鰭可能阻礙蝌蚪在狹隘的避難所躲避而降低存活率，而瘦長的身體也可減少蝌蚪在移動時碰撞到岩石的機率。至於生長在池塘棲地的蝌蚪，體型則多呈橢圓形且尾鰭較高(楊等 2006)。此外，蝌蚪的尾巴長度也會受到天敵的影響，在具有天敵壓力的棲息環境下，蝌蚪的 RTL 往往較小，且尾巴也比較容易受傷(Buskirk and Relyea 1998)；低溫與食物缺乏等環境因素也會減緩蝌蚪身體的發育，使其具有較大的 RTL (Merilä *et al*. 2004)。阿里山地區之盤古蟾蜍蝌蚪在溫度較低的池塘棲地具有較大的體型，而其形態與 RTL 在不同海拔區域與棲地間的差異，可能受到溫度、天敵、食物量及水域環境，如流水域、靜水域、水體大小與深度等多種不同環境因子的影響。

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# 清水溪台灣特有種明潭吻鰕虎 (*Rhinogobius candidianus*)攝食生態

# Feeding Ecology of the Endemic Goby (*Rhinogobius candidianus*) in Chinshui Creek, Taiwan

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## 摘　要

本研究爲了解台灣特有種明潭吻鰕虎攝食習性，自 2008 年 11 月至 2009 年 10 月間，每月於濁水溪支流的清水溪流域以 12 伏特電魚器進行樣本採集，並檢測其胃內容物組成。期間共捕獲明潭吻鰕虎 1,103 尾，最小與最大個體體長分別爲 1.70 cm 及 7.73 cm。結果顯示，該流域於乾季水流量低且穩定，故食物種類豐富，致使乾季空胃率(3.83%)低於雨季的空胃率(16.24%)。明潭吻鰕虎屬於雜食性魚類，各月份間胃內容物種類相對重要指數(RI)之群聚分析結果顯示，主要以水生昆蟲、有機碎屑與絲藻片段爲主，各季節攝食食物種類相似度達 40%以上。該魚攝食習性會隨著不同成長階段而改變，其主要攝食種類由水生昆蟲轉變爲絲藻片段，且攝食種類會因乾季、雨季和颱風的影響而有明顯的差異，提供明潭吻鰕虎攝食生態，做爲保育溪流生態之參考。

## Abstract

In order to examine the feeding ecology of the endemic goby *Rhinogobius candidianus* in Chinshui Creek, a tributary to Choushui River in Taiwan, the fish was sampled monthly with a 12-volt electric fishing gear from November 2008 to October 2009. A total of 1,103 individuals of the fish with the body sizes ranging between 1.70 cm and 7.73 cm were collected, and their stomach contents were examined. Number of fish with empty stomach was 3.83% in the winter dry season while 16.24% in the summer monsoon season. Apparently, the winter dry season of low stream flow provided a stable stream environment with abundance of food for the fish. *R. candidianus* is omnivorous fish consuming primarily filamentous algae, insects, and detritus. Relative frequency occurrence and abundance of these three food items varied with time, and composed more than 40% of the similarity relative indices. The diet composition varied significantly with fish sizes, showing a shift of diet from aquatic insects to filamentous algae with the growth. The composition also varied significantly between the summer monsoon season and winter dry season, and strongly affected by typhoon events.

**關鍵詞：**鰕虎、明潭吻鰕虎、攝食習性、清水溪、台灣

**Key words:** goby, *Rhinogobius candidianus*, feeding habit, Chinshui Creek, Taiwan

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## 緒　言

台灣屬於多山川的島嶼生態系，大大小小的河川溪流密布於全台各地，提供各種淡水魚類所需的水源和棲地。生長於這些河川、湖泊及河口的魚類高達 257 種以上，若扣除外來種，原生淡水魚類至少可達 232 種，其中淡水魚類歧異度最大的類群，爲鰕虎科(Gobiidae)魚類，高達 75 種之多，占全台灣之原生魚種的 32% (陳 2008)。

在淡水魚類中，目前統計有 42 種本土演化出的台灣特有種(endemic species)魚類，其中鰕虎科魚類有 10 種居次(陳 2008)。明潭吻鰕虎 *Rhinogobius candidianus* 爲台灣特有種魚類(邵 2006)，最早由 Regan (1908)在日月潭及南部地區的魚類標本中發現，原發表學名爲 *Ctenogobius candidianus*，後來由陳及方(1999)修正學名爲 *Rhinogobius candidianus*，分布於台灣東北部、北部及中部的溪流上中下游水域中(陶 2006)，在清水溪流域魚類調查中發現明潭吻鰕虎爲清水溪的優勢魚種，占全部魚種之 21% (陳 2008)。然而長期以來的任意墾伐森林、攔砂壩、水庫的建立、廢水污染、外來種引入、非法毒、電魚等人爲因素，威脅到河川中原生魚類之生存空間，甚至已有許多種類完全滅絕的情況發生(陳及方 1999)。

至今對於明潭吻鰕虎食性說法不一，有肉食性(顏 1995, 1997; 陳及方 1999; 詹及陳 2002; 陶 2006)及雜食性(曾 1990)說法，皆僅有初步探討，尚無其他完整明確的食性分析。故本研究主要目的是根據清水溪流域中明潭吻鰕虎不同季節及體長間所攝食之食物種類的變化進行分析，進一步了解其攝食習性資料，並藉以做爲未來保育的參考依據。

## 材料與方法

### 一、採樣時間與方法

本研究自 2008 年 11 月至 2009 年 10 月，期間除因莫拉克颱風災情嚴重，導致無法進行 8 月樣本採集外，每月至嘉義縣阿里山山脈之西支嶺線的清水溪流域(圖 1)以 12V 電魚器間接放電方式採樣，隨機採獲 100 尾的明潭吻鰕虎，立即以 10%中性福馬林溶液固定並進行編號，攜回實驗室 7 天後，以流動式清水沖洗 24 hr，利用游標卡尺測量體全長(total length, TL)，使用電子磅秤記錄體重(g)，再進行解剖，剪開魚之腹部，取出胃部秤重(g)後以 75%酒精保存，以方便後續胃內容物的鑑定。

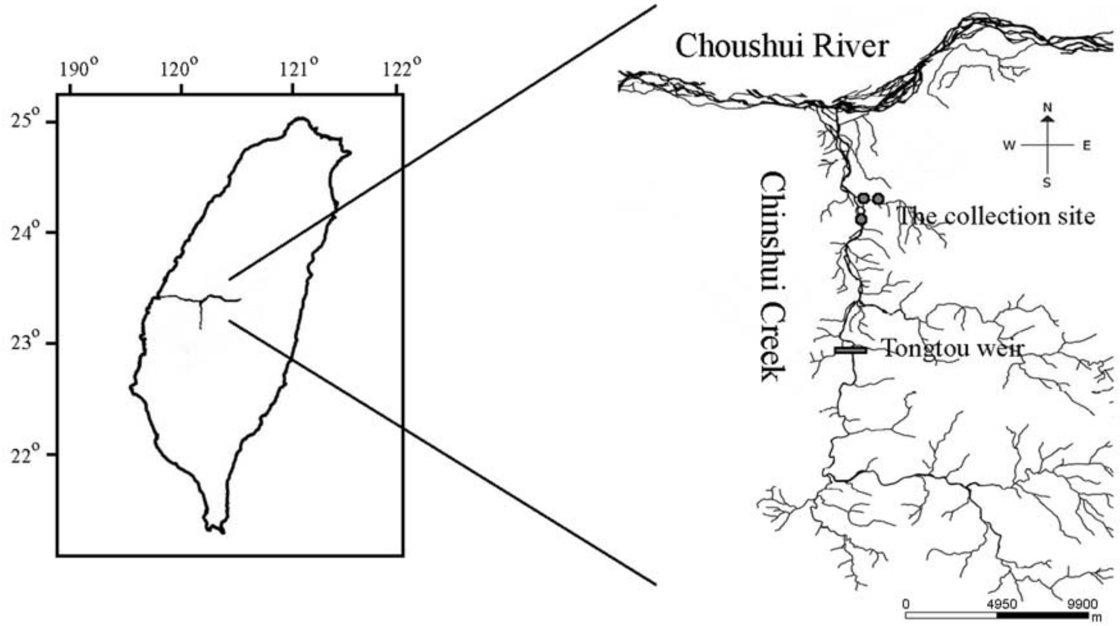

**圖 1.** 明潭吻鰕虎採樣的地點—清水溪。

**Fig. 1.** The fish sampling sites (solid circles) at Chinshui Creek in Taiwan.

### 二、空胃率

當明潭吻鰕虎胃中無殘留食物時判定爲空胃，空胃率以下列公式計算之：

$$N\% = \frac{N_0}{N} \times 100 \qquad (1)$$

$N_0$，胃無內容物之魚尾數；N，總魚尾數(陳及郭 2009)。

### 三、胃內總容物鑑定及分析

胃內容物的分析先將胃內含物挑出，放置在培養皿中，培養皿下方墊一張方格紙(每格長寬爲 1 mm)，以利估算內含物大小，再移至

解剖顯微鏡下以尖鑷小心分離內含物；將食物項目分 10 種類如下：絲藻片段(filamentous algae)、水生昆蟲(Insecta)、水蚤(Cladocera)、輪蟲(Rotifera)、線蟲(Nematoda)、魚卵(fish eggs)、魚鱗片(fish scales)、斧足類(bivalves)、腹足類(Gastropoda)及有機碎屑(detritus)，並以定性法和定量法分析之。

定量法估計胃內食物種類對胃內總種類之豐富度百分比(percentage abundance of food item)。

$$Fi\% = \frac{Fi}{\sum_{i=1}^{n} Fi} \times 100 \qquad (2)$$

Fi 爲胃內食物 i 種類，i = 1, 2,…n 種類(Hyslop 1980; 林 2006; 陳及郭 2009)。

定性法估計胃內某食物種類出現頻率百分比(percentage frequency occurrence of food item)以$Ni\% = \frac{Ni}{N} \times 100$ (Ni，爲胃內容物中 i 類食物種類之魚尾數；N，胃內容物食物之總魚尾數)(殷 1998; 林 2006; 陳及郭 2009)估計，但$\sum_{i=1}^{n}$ $Ni \neq 100\%$，爲了求出 i 食物類魚尾數的總出現頻率百分比，故增加$\sum_{i=1}^{n} Ni$除之，如下：

$$Ni\% = \frac{Ni/N}{\sum_{i=1}^{n} Ni} \times 100 \qquad (3)$$

按照上面定量和定性法所得之結果，求出相對食物指數(relative index)計算公式如下：

$$Ri = Fi\% \times Ni\% \qquad (4)$$

利用 RI 值分析判別明潭吻鰕虎胃內容物的優勢食物項目種類(林 2006; 陳及郭 2009)。

### 四、動物性胃含物的判定

另將胃內動物性生物項目，移至另一培養皿中，以解剖顯微鏡進行數量計數和種類鑑定，當鑑定到水生昆蟲殘骸時，以觀察到其頭部爲一單位數，魚卵與魚鱗則以一顆和片爲一單位數計數。明潭吻鰕虎胃內含物中所分析的食物種類，以定性法(Equation 3)引算其食物種類之豐富度百分比。

### 五、微藻(periphyton)相對豐富度等級之表示

將解剖出之胃內含物以二次水(distilled deionized water)定量 1 ml 後移至浮游生物計數盤(Sedgewick-Rafter cell)中，以光學顯微鏡進行數量估算及藻種鑑定，並以下列相對豐富度之等級(rank of relative abundance)表示，A：觀察 1 ml 樣本中出現個體數量大於 1,000 (dominant)；B：在 50-1,000 之間(abundant)；C：在 10-50 (common)；D：小於 10 (rare) (方等 1996)。

### 六、統計分析

本研究主要以 PRIMER 6.0 統計軟體進行非介量多尺度空間排序分析(non-metric multidimensional scaling, MDS)、相似度百分率(similarity percentage, SIMPER)及單項相似度分析(one-way ANOSIM)之方法，以 2008 年 11 月至 2009 年 10 月之食性資料，分析各月份攝食食物種類之變化及不同體長等級(<3.5、3.5-4.4、4.5-5.4、5.5-6.4 及>6.4 cm)間攝食物種的差異，與了解造成攝食食物種類差異的主要關鍵攝食物種，當其計算出之 Global Test R 值等於 0 時表完全相同；R 值小於 0.25 表差異不明顯；R 值大於 0.5 表雖有重疊但能清楚分開；R 值大於 0.75 表有顯著差異；R 值等於 1 表完全不同。Significance level 值 $p<0.05$，才有顯著差異。

## 結果與討論

### 一、各月份魚體採樣其體全長、體重及乾、雨季空胃率之變化

本研究所採的魚體數量，共採樣 1,103 尾，最小體全長、體重爲 1.70 cm、0.04g，最大體全長、體重爲 7.73 cm、6.18g (表 1)，並發現有 151 尾呈現空胃狀態。依據中央氣象局 2008-2009 年間降雨量結果發現雨季爲 3-11 月，平均降

雨量 233.91 mm，空胃率 16.24%；乾季為 12、1 和 2 月，平均降雨量 9.53 mm，空胃率 3.83%，雨季空胃率較高。

水域中餌料生物的數量消長(季節和環境變化)，以及其他理化因子(包括降雨量、風力、溶氧、光照等)的影響對魚類的生長起間接作用(殷 1998)。葉(2008)在湖山水庫工程計畫生態保育措施成果報告書中指出，清水溪水生昆蟲族群量高密度分布於平均水深 5-20 cm 及平均流速為 0-40 cm/sec 間。由於清水溪高密度的水生昆蟲出現於水流較平緩區域，因此推測雨季空胃率較乾季高，可能是受到雨季雨量充沛水流湍急，水域混濁及水流量大增，導致魚行攝食動物性生物較為不足，而造成雨季空胃率提高的原因之一。

**表 1.** 清水溪各月份採集明潭吻鰕虎之平均體長、體重及數量之變化

**Table 1.** Total lengths and total weights (mean±standard deviations; ranges in parentheses) of *Rhinogobius candidianus* collected from Chinshui Creek over the time from November 2008 to October 2009

| Month | Sampling number of fish | Total length (cm) | Body weight (g) |
|---|---|---|---|
| 2008 | | | |
| Nov | 103 | 5.33 ± 1.06 (2.28-7.73) | 2.27 ± 1.25 (0.11-6.18) |
| Dec | 100 | 4.83 ± 0.85 (2.65-6.59) | 1.66 ± 0.76 (0.21-4.89) |
| 2009 | | | |
| Jan | 100 | 4.41 ± 1.16 (1.70-6.40) | 1.36 ± 0.91 (0.04-3.55) |
| Feb | 100 | 3.92 ± 0.98 (2.16-6.66) | 1.00 ± 1.02 (0.11-4.53) |
| Mar | 100 | 3.84 ± 0.90 (2.14-6.28) | 0.81 ± 0.62 (0.05-3.10) |
| Apr | 100 | 4.17 ± 1.08 (2.28-7.49) | 1.12 ± 1.03 (0.09-5.08) |
| May | 100 | 4.13 ± 0.97 (2.68-6.60) | 1.02 ± 0.78 (0.17-3.62) |
| Jun | 100 | 4.25 ± 1.00 (2.33-6.60) | 1.17 ± 0.89 (0.11-4.38) |
| Jul | 100 | 4.16 ± 0.86 (2.77-6.53) | 0.99 ± 0.76 (0.23-4.01) |
| Sep | 100 | 4.65 ± 0.66 (2.75-6.33) | 1.28 ± 0.58 (0.21-3.08) |
| Oct | 100 | 4.73 ± 0.51 (3.65-6.37) | 1.49 ± 0.51 (0.58-2.89) |
| Average | 100 | 4.50 ± 0.99 (1.70-7.73) | 1.36 ± 0.95 (0.04-6.18) |

### 二、不同月份胃內含物種類組成之變化和相對重要指數之相似性比較

各月份間胃內食物種類豐度的變化(圖 2)與胃內食物種類出現頻率之變化(圖 3)顯示，各個月份皆以絲藻片段、水生昆蟲與有機碎屑為最主要攝食物種；胃內容物中出現頻率較少的有水蚤、輪蟲、線蟲、魚卵、魚鱗片、斧足類及腹足類。

以各月份間明潭吻鰕虎胃內容物種類相對重要指數(RI)之群聚分析結果顯示(圖 4)，各季節攝食食物種類相似度達 40%以上；將數值轉化成非介量多度空間(MDS) (圖 5)，並以相似 60%和 80%作為群聚的依據，結果顯示分為 3 群，為乾季、雨季及颱風月份(2009 年 6 月輕度蓮花、8 月中度莫拉克及 10 月中度芭瑪颱風)。再利用單項相似度分析(one-way ANOSIM)檢測在各月份間其攝食食物種類差異性，結果顯示各月份間有顯著的差異(Global Test, R 值 = 0.204; $p<0.05$)。

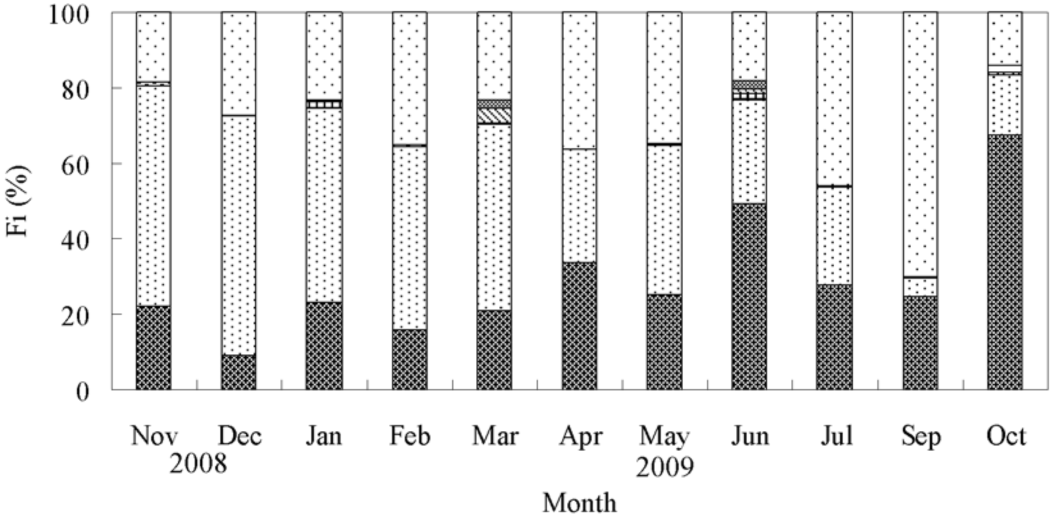

**圖 2.** 清水溪明潭吻鰕虎在 2008 年 11 月至 2009 年 10 月間攝食食物種類豐度百分比之月份變化。

**Fig. 2.** Percentage composition of monthly abundance (Fi) of food items in stomach contents of *Rhinogobius candidianus* collected from Chinshui Creek, November 2008 to October 2009 (▩, filamentous algae; ⬚, Insecta; ▦, Cladocera; ⁙, Rotifera; ≋, Nematoda; ▧, fish eggs; ▥, fish scales; ▨, bivalves; ▓, Gastropoda; ⊡, detritus).

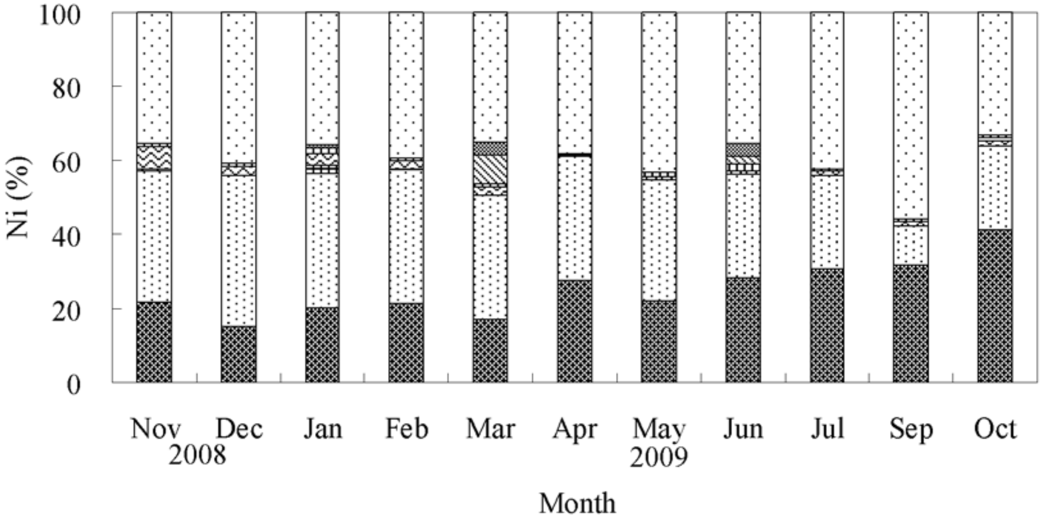

**圖 3.** 清水溪明潭吻鰕虎在 2008 年 11 月至 2009 年 10 月間攝食食物種類頻率百分比之月份變化。

**Fig. 3.** Percentage composition of monthly frequency occurrence (Ni) of food items in stomach contents of *Rhinogobius candidianus* collected from Chinshui Creek, November 2008 to October 2009 (▩, filamentous algae; ⬚, Insecta; ▦, Cladocera; ⁙, Rotifera; ≋, Nematoda; ▧, fish eggs; ▥, fish scales; ▨, bivalves; ▓, Gastropoda; ⊡, detritus).

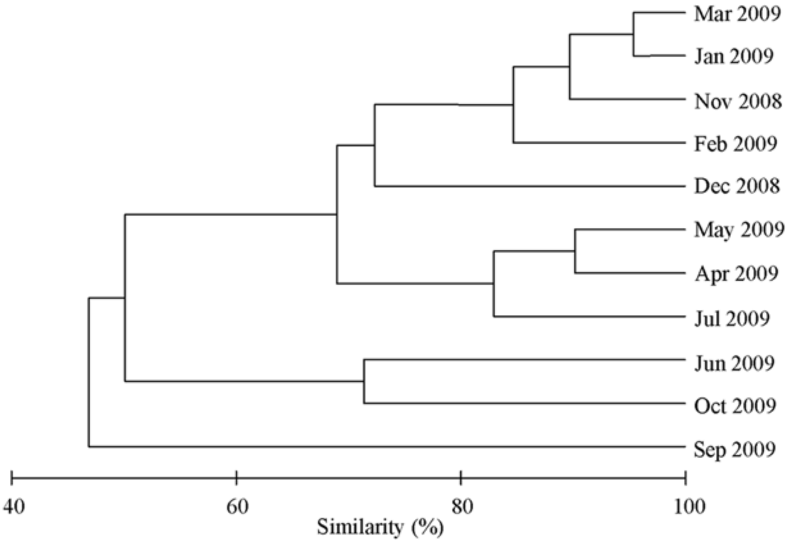

**圖 4.** 清水溪明潭吻鰕虎在 2008 年 11 月至 2009 年 10 月間不同月份攝食食物種類之相對重要指數(RI)相似度樹狀圖。

**Fig. 4.** A cluster dendrogram showing similarity in monthly relative indices (RI) of food items in stomach contents of *Rhinogobius candidianus* collected from Chinshui Creek, November 2008 to October 2009.

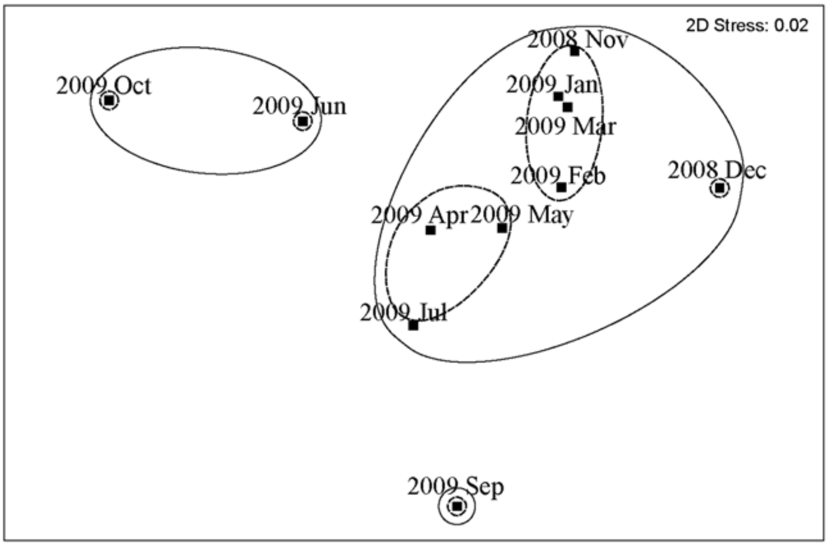

**圖 5.** 清水溪明潭吻鰕虎在 2008 年 11 月至 2009 年 10 月間不同月份之食物相對重要指數(RI)非介量 MDS 空間分布圖。

**Fig. 5.** Non-metric multi-dimentional scaling (MDS) showing similarity (solid line circles, 60%; dashed line circles, 80%) in monthly relative indices (RI) of food items in stomach contents of *Rhinogobius candidianus* collected from Chinshui Creek, November 2008 to October 2009.

魚類攝食行爲和水域環境中餌料生物的改變，會影響魚類的食物組成和攝食強度，當食物組成中某一喜好食物種類大量出現的時候，此食物便成爲該物種的主要食物(殷 1998)。溫(2002)指出鰕虎科黑鰕虎屬(*Bathygobius* sp.)魚類會爲選擇食物而隨著食物資源豐度轉移，有季節性的移動。清水溪的明潭吻鰕虎攝食水生昆蟲數量乾季時 54.21%、雨季 31.68%和颱風月份 16.1%，乾季攝食水生昆蟲較多；攝食絲藻片段則乾季 18.28%、雨季 29.08%及颱風的月份 47.15%，食絲藻片段以雨季和颱風月份較高。由此推論乾季水流平緩較適合水生昆蟲生長，雨季和颱風月份水流湍急，較不適合水生昆蟲生長，而雨量充沛適合絲藻生長，亦使明潭吻鰕虎乾季攝食動物性餌料生物，雨季攝食絲藻片段較多，因此推論乾季、雨季和颱風月份會導致明潭吻鰕虎所攝食的食物種類有所差異。

明潭吻鰕虎各月份所攝食動物性生物種類之變化(圖 6)總計有 10 種動物性生物，以蜉蝣目(Ephemeroptera)的蜉蝣 40.14%、雙翅目(Diptera)的搖蚊 29.32%及毛翅目(Trichoptera)的石蠶 20.66%爲主要攝食的動物性生物。各月份所攝食的微細藻類組成(表 2)共計兩門，爲綠藻植物門 3 屬、矽藻植物門 17 屬，主要攝食以矽藻類爲主，其中又以橋彎藻屬(*Cymbella* sp.)、等片藻屬(*Diatoma* sp.)、異極藻屬(*Gomphonema* sp.)和針桿藻屬(*Synedra* sp.)居多。

陳(2008)調查清水溪流域中的水生昆蟲，以蜉蝣目的四節蜉蝣科(Baetidae)、雙翅目的搖蚊科(Chironomidae)及毛翅目的網石蠶科(Hydropsychidae)，爲清水溪流域水生昆蟲的主要優勢種，而與明潭吻鰕虎胃內容物中，所攝食的水生昆蟲蜉蝣目、雙翅目及毛翅目爲主要攝食種類相符合，推測明潭吻鰕虎以清水溪水域中數量最多的餌料生物爲主要食物，顯示明潭吻鰕虎食性與棲息水域中的食物資源豐度有關。

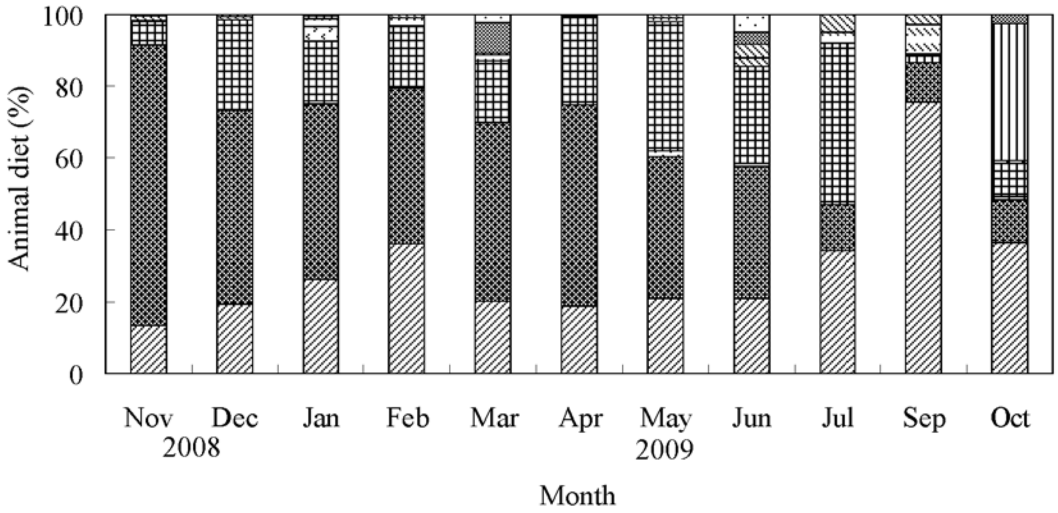

**圖 6.** 清水溪明潭吻鰕虎於 2008 年 11 月至 2009 年 10 月間攝食動物性生物種類豐度百分比之月份變化。

**Fig. 6.** Percentage composition of animal diet in stomach contents of *Rhinogobius candidianus* collected from Chinshui Creek, November 2008 to October 2009 (▨, Diptera; ▩, Ephemeroptera; ⬚, Lepidoptera; ▦, Trichoptera; ⬚, Cladocera; ▒, Rotifera; ▭, Nematoda; ▥, fish eggs; ▧, fish scales; ▩, bivalves; ⬚, Gastropoda).

**表 2.** 清水溪明潭吻鰕虎在 2008 年 11 月至 2009 年 10 月間不同月份之胃內含物微細藻類的組成變化
**Table 2.** Monthly variation in the microalgal composition of stomach contents of *Rhinogobius candidianus* collected from Chinshui Creek, November 2008 to October 2009 (A, average cells number of algae in 1 ml >1,000; B, 50-1,000; C, 10-50; D, <10)

| Species | 2008 | | 2009 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Sep | Oct |
| **Chlorophyta** | | | | | | | | | | | |
| *Closterium* | | C | | | | | | | | | |
| *Cosmarium* | C | C | D | C | D | A | B | B | B | C | D |
| *Scenedesmus* | D | D | D | B | D | | D | | | C | |
| **Bacillariophyta** | | | | | | | | | | | |
| *Achnanthes* | | D | D | C | | | C | C | C | C | |
| *Amphiprora* | D | | D | | D | D | | | C | B | D |
| *Biddulphia* | | D | D | D | C | | D | C | | | D |
| *Cocconeis* | B | B | B | B | C | C | C | D | D | | D |
| *Cyclotella* | C | D | D | B | D | | B | | C | | |
| *Cymatopleura* | | | D | | | | | | | | |
| *Cymbella* | A | A | B | A | C | A | A | A | A | A | B |
| *Diatoma* | | | D | A | C | A | A | A | A | D | |
| *Fragilaria* | D | D | D | | | A | B | D | B | | |
| *Gomphonema* | B | B | B | A | B | A | B | A | A | A | C |
| *Gyrosigma* | D | | | | | | | D | C | | |
| *Melosira* | A | B | B | A | D | B | B | B | A | B | B |
| *Navicula* | B | B | B | B | B | B | A | B | B | A | B |
| *Nitzschia* | B | B | B | A | B | B | A | B | A | A | C |
| *Stauroneis* | | | | | | | | D | C | | |
| *Surirella* | | | D | | | | | D | D | | |
| *Synedra* | A | A | B | A | B | A | A | A | A | A | B |

胃內含物中所攝食的微細藻類以矽藻類爲主，此結果與清水溪底藻群聚組成調查相符(陳 2008)。矽藻類有多種不同的生長形式，主要分爲 3 種生態群，分別爲底層、高層和具有移動能力的種類(Wellnitz and Ward 1998; Holomuzki and Biggs 2006)。一般認定在上層的藻比較容易被掠食(Steinman 1996)，明潭吻鰕虎胃內容物中所攝食的微矽藻類以表層藻的橋彎藻屬、等片藻屬、異極藻屬與針桿藻屬爲主。明潭吻鰕虎形態特徵吻略尖突，口大、斜裂，腹鰭癒合成吸盤狀(曾 1990; 顏 1995; 顏 1997; 詹及陳 2002; 陶 2006)，貼於岩石壁上捕食水生昆蟲，隨著攝食隨機地刮取岩石上之薄層底藻爲食，因此推論明潭吻鰕虎在微細藻類的利用上，並沒有特別之專一性，以表層矽藻類爲易被攝食的藻種。

許多研究都發現魚類食性與季節的改變和食物資源豐度的變化有很大的關聯(Stoner and Zimmerman 1988; Clements and Choat 1993; Blay 1995; Labropoulou *et al*. 1997; Garcia and Amich 2000; Xie *et al*. 2000)，本研究明潭吻鰕虎的食性與季節變化和清水溪食物資源豐度

有關，顯示季節的變化造成明潭吻鰕虎攝食食物種類有很大的差異。

### 三、不同體長別胃內含物種類組成變化和相對重要指數之相似性比較

明潭吻鰕虎在不同體長等級間攝食物種的變化，在體全長<3.5 cm (魚尾數，163)和3.5-4.4 cm (魚尾數，315)等級，以水生昆蟲爲主要攝食種類；體全長 4.5-5.4 cm (魚尾數，306)等級，以絲藻片段、水生昆蟲和有機碎屑爲主；體全長 5.5-6.4 cm (魚尾數，143)和體全長>6.4 cm (魚尾數，25)等級，則以絲藻片段爲主要攝食種類(表 3)。在各體長間明潭吻鰕虎胃內容物種類相對重要指數(RI)之群聚分析結果顯示(圖 7)，其各體長等級所攝食食物種類相似度爲 50%以上。將數值轉化成非介量多度空間(MDS) (圖 8)，並以相似 60%作爲群聚的依據，結果顯示分爲兩群，僅體全長<3.5 cm等級與其他等級不同。再利用單項相似度分析(one-way ANOSIM)檢測在各等級間其攝食食物種類差異性，結果顯示體全長<3.5 cm等級與其他 4 個等級有顯著的差異(Global Test, R 值 = 0.025; $p<0.05$)。

魚類在成長至幼魚階段後，會各自轉向固有的不同食性類型，食性轉化會隨著體長的不同，攝食器官的發育完善，其所攝食的食物種類和組成仍會不斷的發生不同程度的變化(Schmitt and Holbrook 1984; Holbrook *et al*. 1985; Copp and Mann 1993; McCormick 1998; 殷 1998)。本研究結果顯示：體全長<4.5 cm的明潭吻鰕虎以水生昆蟲爲主要攝食種類，體全長>5.4 cm 者則以攝食絲狀藻類爲主。

殷(1998)提出草食性的草魚仔魚，尙未形成切割水草的咽齒和咽磨，仔魚階段是依靠呑吸與口裂大小相符合的微小食料生物，等口裂增大，咽齒和咽磨開始發育，攝食能力增強，才開始攝取水生植物，攝食器官發育更加完善，食性分化更明顯。明潭吻鰕虎在幼魚階段的攝食器官和攝食方式尙未發育完善，因此會隨著成長發育完善而增加食絲藻片段，攝食習性會因體型不同而有所差異。溫(2002)指出鰕

**表 3.** 清水溪明潭吻鰕虎在 2008 年 11 月至 2009 年 10 月間攝食食物種類豐度百分比之體全長等級變化
**Table 3.** Percentage composition of monthly abunadance (Fi) of food items in stomach contents of five size classes of *Rhinogobius candidianus* collected from Chinshui Creek, November 2008 to October 2009

| Food items | Size classes (total length, cm) | | | | |
|---|---|---|---|---|---|
| | <3.5 | 3.5-4.4 | 4.5-5.4 | 5.5-6.4 | >6.4 |
| Filamentous algae | 4.68 | 25.80 | 33.56 | 47.49 | 44.47 |
| Insecta | 68.11 | 39.28 | 32.79 | 23.36 | 32.15 |
| Rotifera | 0 | 0.03 | 0 | 0 | 0 |
| Cladocera | 0.01 | 0.30 | 0.16 | 0 | 0 |
| Nematoda | 0.10 | 0.38 | 0.23 | 0.34 | 0.29 |
| Fish eggs | 0 | 0 | 3.37 | 0 | 0 |
| Fish scales | 0.09 | 0.14 | 0.14 | 0.71 | 0 |
| Gastropoda | 0.23 | 0.32 | 0.55 | 0.58 | 0 |
| Bivalves | 0.47 | 0.54 | 0.07 | 0.04 | 0.00 |
| Detritus | 26.31 | 33.21 | 32.18 | 27.48 | 23.10 |

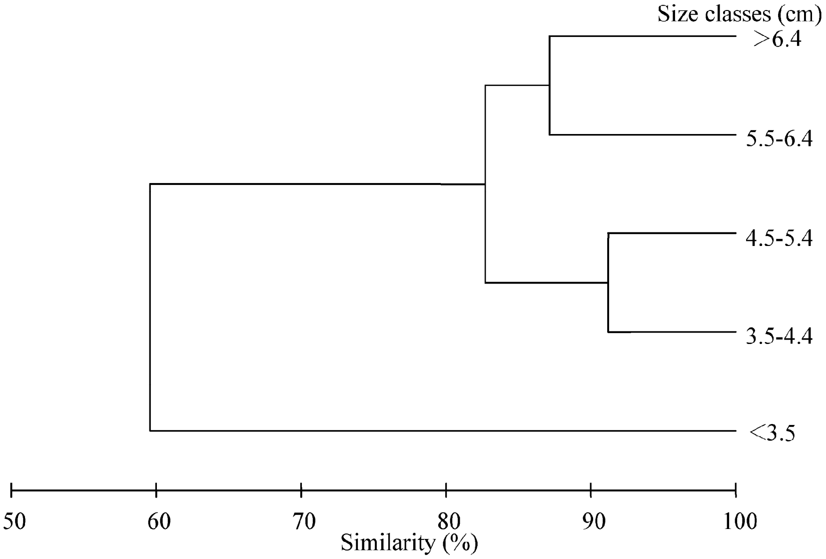

**圖 7.** 清水溪明潭吻鰕虎在 2008 年 11 月至 2009 年 10 月間胃內容物之食物相對重要指數(RI)的體全長間相似度樹狀圖。

**Fig. 7.** A cluster dendrogram showing similarity in relative indices (RI) of the food items in the stomach contents among five size classes of *Rhinogobius candidianus* collected from Chinshui Creek, November 2008 to October 2009.

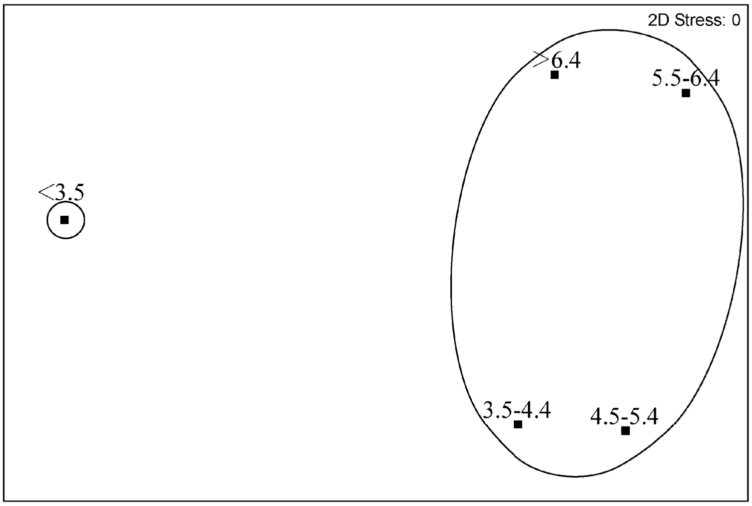

**圖 8.** 清水溪明潭吻鰕虎在 2008 年 11 月至 2009 年 10 月間胃內容物之食物相對重要指數(RI)的體全長間非介量 MDS 空間分布圖。

**Fig. 8.** Non-metric multi-dimentional scaling (MDS) showing similarity (solid line circles, 60%) in relative indices (RI) of food items in stomach contents among five size classes (solid squares, individuals with total length in cm) of *Rhinogobius candidianus* collected from Chinshui Creek, November 2008 to October 2009.

虎科黑鰕虎屬的黑鰕虎(*Bathygobius fuscus*)、椰子黑鰕虎(*B. cocosensis*)、巴東黑鰕虎(*B. padangensis*)都是隨著成長而增加攝食片狀藻類的比例。此結果亦與本研究明潭吻鰕虎攝食食性相符合，顯示其攝食習性和食物種類會隨成長而改變。

本研究結果顯示，不同季節變化影響清水溪中明潭吻鰕虎空胃率和胃內容物的種類組成，食性會隨著不同成長階段而改變，由此推測明潭吻鰕虎屬雜食性魚類(omnivores)。郭(1996)指出清水溪魚類群聚結構及數量因豐、枯水期而有明顯的變化；本研究區域目前已成爲建置湖山水庫水源引入河段的所在地，一旦設立，清水溪流量將會減少，可能會影響中、下游魚類之棲息。棲地變化及食物可利用率的改變將造成魚類食性變化(Lukoschek and McCormick 2001; Hajisamae *et al*. 2004)，因此在興建桶頭攔河堰後，若水流量減少無法維持各種水生生物基礎生存所需之最低流量，將造成棲地的改變，進而可能影響雜食性明潭吻鰕虎對食物的可利用率，因此研究清水溪特有優勢種明潭吻鰕虎攝食生態，盼能做爲保育溪流生態之參考依據。

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# 七種非褶菌目眞菌(擔子菌門)的台灣新紀錄

# Seven Species of Aphyllophorales (Basidiomycotina) Newly Recorded to Taiwan

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## 摘　要

本文描述 7 種非褶菌目(非孔狀)的台灣新紀錄種。它們分別屬於珊瑚菌科的星孢珊瑚菌及舌狀棒瑚菌、鎖瑚菌科的皺鎖瑚菌、皺孔菌科的肉紅膠韌革菌、釘菇科的富士山釘菇、枝瑚菌科的擬粉紅枝瑚菌，以及革菌科的地生綿革菌。

## Abstract

Seven species of non-poroid aphyllophorales belonging to the families Clavariaceae, Clavulinaceae, Gomphaceae, Meruliaceae, Ramariaceae and Thelephoraceae, are described and illustrated as new records to Taiwan. They are *Clavaria asterospora* Pat., *Clavariadelphus ligula* (Schaeff.: Fr.) Donk, *Clavulina rugosa* (Fr.) Schroet., *Gloeostereum incarnatum* S. Ito & S. Imai., *Gomphus fujisanensis* (Imai) Parmasto, *Ramaria neoformosa* Petersen and *Tomentella terrestris* (Berk. & Br.) Larsen.

**關鍵詞：**珊瑚菌類、釘菇科、革菌科、皺孔菌科

**Key words:** Clavarioid fungi, Gomphaceae, Meruliaceae, Thelephoraceae

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## 緒　言

非褶菌目眞菌外形歧異度非常高，多爲腐生，少數爲共生。多數具菌蓋或棒狀至珊瑚狀，子實層多孔狀，少數爲褶狀或光滑，菌肉木質(稱爲硬菇)或革質，鮮爲肉質。

在台灣已發表有關非孔狀非褶菌目的種類很多，其中屬於珊瑚菌科的 7 種爲：紫珊瑚菌(*Clavaria purpurea* Muell.: Fr.)、紡錘形擬鎖瑚菌【*Clavulinopsis fusiformis* (Sow.: Fr.) Corner】、亮色擬鎖瑚菌【*C. laeticolor* (Berk. & Curt.) Petersen】、紅擬鎖瑚菌【*C. miyabeana* (S. Ito) S. Ito】、亮多珊瑚菌【*Multiclavula clara* (Berk. & Curt.) Petersen】、原生多珊瑚菌【*M. vernalis* (Schw.) Petersen】及白擬叢枝瑚【*Ramariopsis kunzei* (Fr.) Donk】；屬於鎖瑚菌科有 2 種爲：灰色鎖瑚菌【*Clavulina cinerea* (Bull.: Fr.) Schroet.】及冠鎖瑚菌【*C. cristata* (Holmsk.: Fr.) Schroet.】；屬於枝瑚菌科有 4 種爲：金黃枝瑚菌【*Ramaria aurea* (Schaeff.: Fr.) Quèl.】、葡萄色枝瑚菌【*R. botrytis* (Pers.: Fr.) Ricken】、軟垂枝瑚菌【*R. flaccida* (Fr.) Ricken】及黃枝瑚菌【*R. flave* (Fr.) Quel.】；屬於釘菇科有 1 種爲：毛釘菇【*Gomphus floccosus* (Schw.) Sing.】；屬於革菌科有 3 種爲：皺皮革菌(*Thelephora caperata* B. & Mont.)、棕色革菌【*T. fuscella* (Cesati) Lloyd】及多瓣革菌(*T. multipartita* Schw.) (澤田 1931, 1959; 陳等 1994; 王等 1999; 周 2000; 張等 2001; 周及張 2005)。

## 性狀描述

**星孢珊瑚菌**(圖 1; 圖 8A)

***Clavaria asterospora*** Pat., Tabl. Analyt. Fung. France (Paris) 6: 568, 1887.

*Clavaria acuta* Sowerby, Col. Fig. Engl. Fung. Mushr. 3: 138, 1803.

*Clavulinopsis asterospora* (Pat.) Corner, Annals of Botany Memoirs No. 1: 357, 1950.

子實體扁平單枝狀，高 2-3 cm，直徑 0.1-0.15 cm，肉質脆，表面淡白褐色，子實層平滑。擔孢子近球形，表面具長刺狀突起物，透明無色，非類澱粉質反應，8-12 × 7-8 $\mu$m；擔子棒形，4 孢型，30-50 × 7-10 $\mu$m；囊狀體無；菌絲無扣子體。

**棲 息 地：**在平地公園地上聚生。

**研究標本：**台中市國立自然科學博物館植物園，海拔 80m，2006 年 4 月 27 日，周文能 CWN 07087。

**世界分布：**歐洲。

**附　　記：**此種最大特徵是孢子有刺狀突起物似星芒狀，在野外只憑外觀比較難辨認(Breitenbach and Kränzlin 1986)。

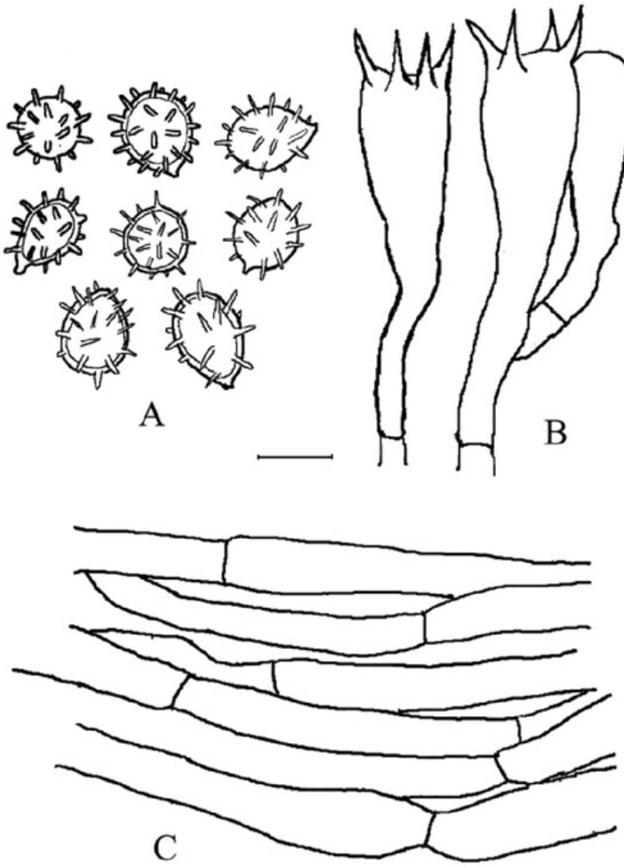

**圖 1.** 星孢珊瑚菌。A, 擔孢子; B, 擔子; C, 菌絲無扣子體。比例尺＝10 μm。

**Fig. 1.** *Clavaria asterospora.* A, baisidiospores; B, basidia; C, hyphae without clamps (bar = 10 μm).

**舌狀棒瑚菌**(圖 2; 圖 8B)

***Clavariadelphus ligula*** (Schaeff.: Fr.) Donk, Rev. Niederl. Homob. Aphyll. 2: 73, 1933.

*Clavaria ligula* Schaeff., Fung. Bavar. Palat. 4: 116, 1774.

*Clavaria ophioglossoides* Batsch, Elench. Fung. (Halle): 135, 1783.

子實體棒形至扁柱狀，高 6-7 cm，寬 0.8-1 cm，肉質脆，表面灰紅色，子實層平滑。擔孢子橢圓形，表面平滑，透明無色，非類澱粉質反應，9-12 × 5-6 μm；擔子長棒形，4 孢型，50-80 × 6-8 μm；囊狀體無；菌絲有扣子體。

**棲息地：**在中海拔森林內地上聚生。

**研究標本：**嘉義縣竹崎鄉石桌霹靂山，海拔 1,775m，2008 年 5 月 16 日，周文能 CWN 07895。

**世界分布：**亞洲、北美、歐洲、非洲。

**附　記：**此標本是棒瑚菌 *Clavariadelphus pistillaris* (Fr.) Donk的迷你個體，子實體、孢子的寬度及擔子的長度皆較小，棒瑚菌一般紀錄高 10-30 cm (Corner 1950; Coker 1974; Breitenbach and Kränzlin 1986; 今関及本郷 1989; Methvin 1990; 卯 2000)。

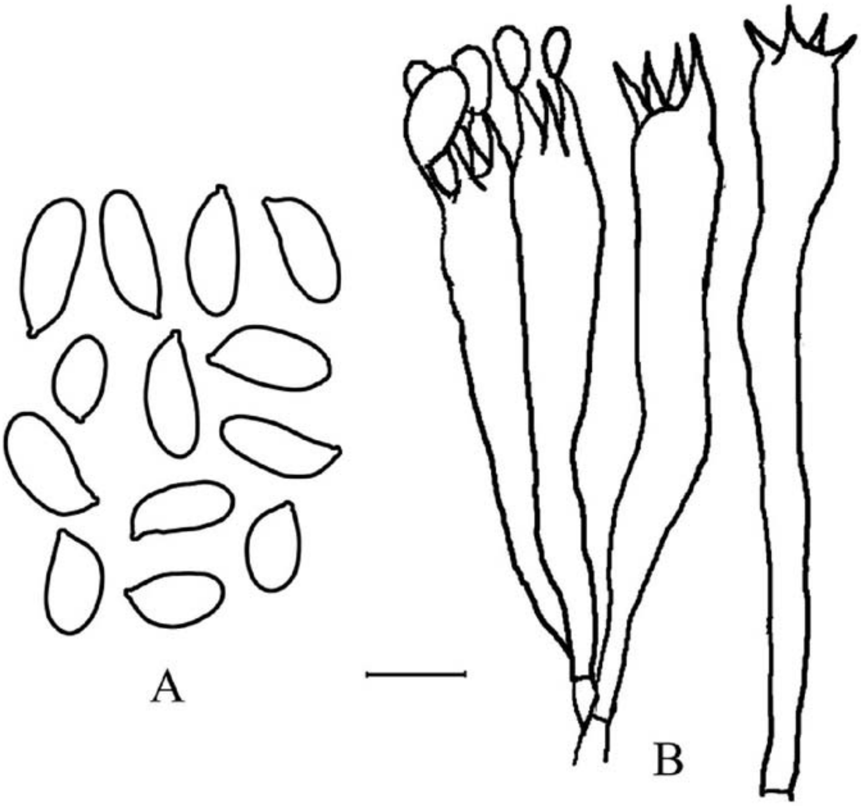

**圖 2.** 舌狀棒瑚菌。A, 擔孢子; B, 擔子。比例尺＝ 10 $\mu$m。

**Fig. 2.** *Clavariadelphus ligula.* A, baisidiospores; B, basidia (bar = 10 $\mu$m).

**皺鎖瑚菌**(圖 3; 圖 8C)

***Clavulina rugosa*** (Fr.) Schroet., in Cohn, Krypt.-Fl. Schlesien (Breslau) 3.1 (25-32): 442, 1888.

*Clavaria rugosa* Bull., Herb. Fr. 10: tab. 448, fig. 2, 1790.

*Ramaria rugosa* (Bull.) Gray, Nat. Arr. Brit. Pl. (London) 1: 655, 1821.

子實體扁柱狀，不分枝或不規則分枝，高 2-4 cm，寬 0.1-0.3 cm，肉質脆，表面白色，子實層平滑或有皺紋。擔孢子寬橢圓形至近球形，表面平滑，透明無色，非類澱粉質反應，9-10 × 7-9 $\mu$m；擔子棒形，2 孢型，40-50 × 6-8 $\mu$m；囊狀體無；菌絲有扣子體。

**棲 息 地：**在中海拔森林內及平地公園殼斗科樹下地上散生至群生。

**研究標本：**苗栗縣泰安鄉觀霧，海拔 2,000m，2004 年 6 月 15 日，周文能 CWN 06649；台中市國立自然科學博物館植物園，海拔 80m，2005 年 9 月 29 日，周文能 CWN 06974。

**世界分布：**亞洲、北美、歐洲、澳洲。

**附　　記：**此種與冠鎖瑚菌 *Clavulina cristata* (Holmsk.: Fr.) Schroet.容易混淆，而且常同時相伴發生，但冠鎖瑚菌子實體頂端樹枝狀不規則分枝，較灰白色至淡褐色，子實層光滑，且孢子較小，6-9 × 5-7.5 $\mu$m (Corner 1950; Breitenbach and Kränzlin 1986; 今関及本郷 1989; 卯 2000)。

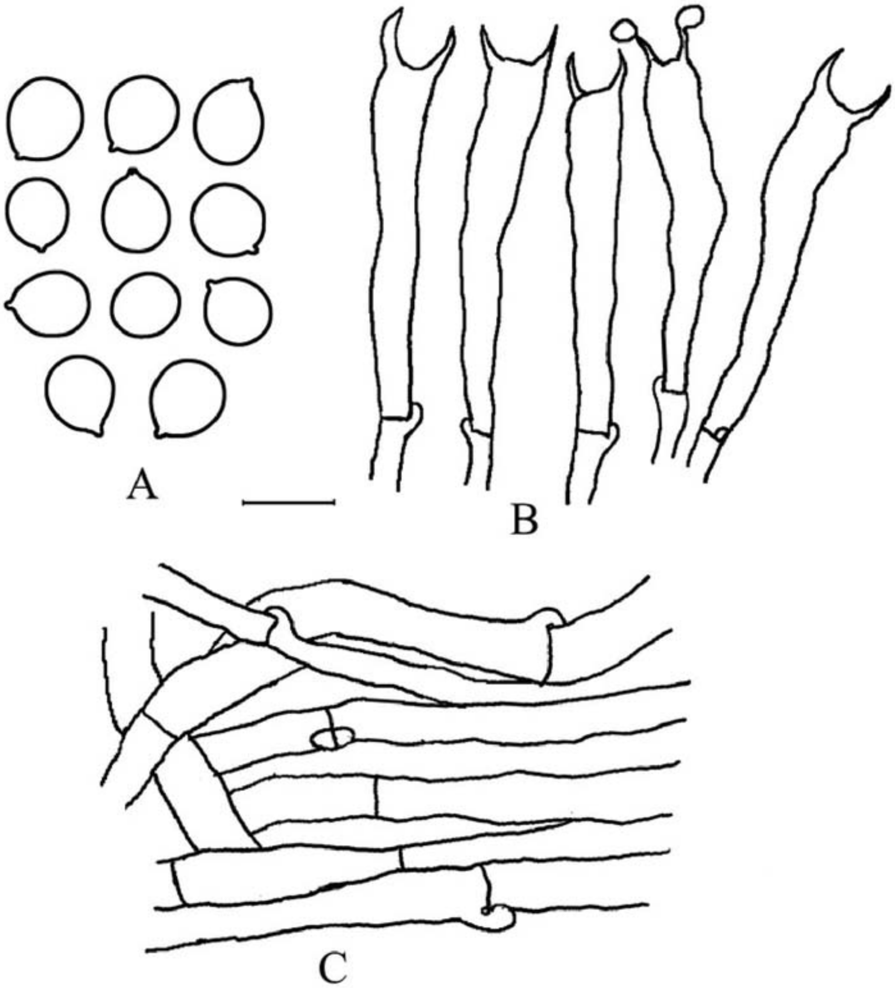

**圖 3.** 皺鎖瑚菌 (CWN 06974) 。A, 擔孢子; B, 擔子; C, 菌絲有扣子體。比例尺＝ 10 $\mu$m。

**Fig. 3.** *Clavulina rugosa* (CWN 06974). A, baisidiospores; B, basidia; C, hyphae with clamps (bar = 10 $\mu$m).

**擬粉紅枝瑚菌**(圖 4; 圖 8D)

***Ramaria neoformosa*** Petersen, Am. J. Bot. 63: 314, 1976.

子實體繖狀分叉成珊瑚狀，高 7-10 cm，寬達 10 cm，基部柄狀有污紫斑點，表面鮭粉紅色至粉肉紅色，子實層平滑。擔孢子橢圓形，表面粗糙具疣，透明無色，非類澱粉質反應，8-10 × 4-5 $\mu$m；擔子棒形，4 孢型，40-60 × 7-9 $\mu$m；囊狀體無；菌絲無扣子體。

**棲 息 地：**在中海拔森林內地上散生。

**研究標本：**嘉義縣竹崎鄉石桌霹靂山，海拔 1,775m，2003 年 8 月 13 日，周文能 CWN 06328。

**世界分布：**中國、歐洲。

**附　　記：**此種與葡萄狀枝瑚菌 *Ramaria botrytis* (Pers.: Fr.) Ricken 外觀類似，容易混淆，但葡萄狀枝瑚菌表面灰白色頂端帶暗紅色，且菌絲有扣子體 (Breitenbach and Kränzlin 1986; 卯 2000)。

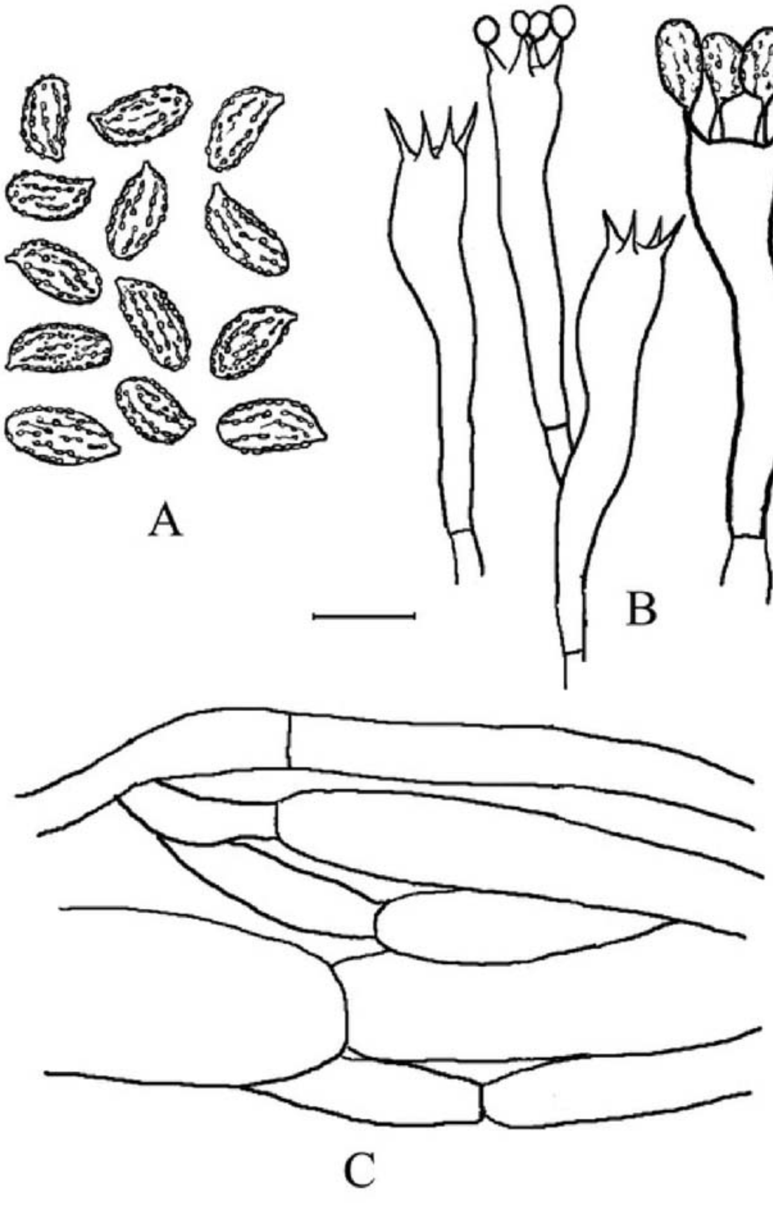

**圖 4.** 擬粉紅枝瑚菌。A, 擔孢子; B, 擔子; C, 菌絲無扣子體。比例尺＝ 10 $\mu$m。

**Fig. 4.** *Ramaria neoformosa*. A, baisidiospores; B, basidia; C, hyphae without clamps (bar= 10 $\mu$m).

**富士山釘菇**(圖 5; 圖 8E)

***Gomphus fujisanensis*** (Imai) Parmasto, Identification of URSS Clavariaceae: 28, 1965.

*Cantharellus fujisanensis* S. Imai, Bot. Mag., Tokyo 60: 519, 1941.

子實體喇叭狀，高 7-10 cm，菌蓋直徑 4-6 cm，表面土黃色，具翹起鱗片，蓋緣全緣。子實層呈分叉交錯，皺折隆起，厚質，乳白色。菌柄中生，與菌蓋無明顯界線，管狀，中實，淡白黃色，粗 0.7-1 cm。擔孢子近橢圓

形，淡紅黃色，表面粗糙突起，非類澱粉質反應，10-13 × 5.5-6.5 μm；擔子柄長棒形，4孢型，70-80 × 8-10 μm；囊狀體無；菌絲無扣子體。

**棲息地：**在中高海拔雲杉林內地上散生。

**研究標本：**南投縣仁愛鄉鳶峰，海拔2,700m，2003年7月30日，周文能 CWN 06278。

**世界分布：**中國、日本。

**附　記：**此種與毛釘菇 *Gomphus floccosus* 的區別在無鮮艷橙紅顏色；在中國雲南當地人會採食此菌，並於市場販售。但日本圖鑑記載有毒，食後出現腹瀉嘔吐症狀(今関及本郷 1989; 卯 2000)。

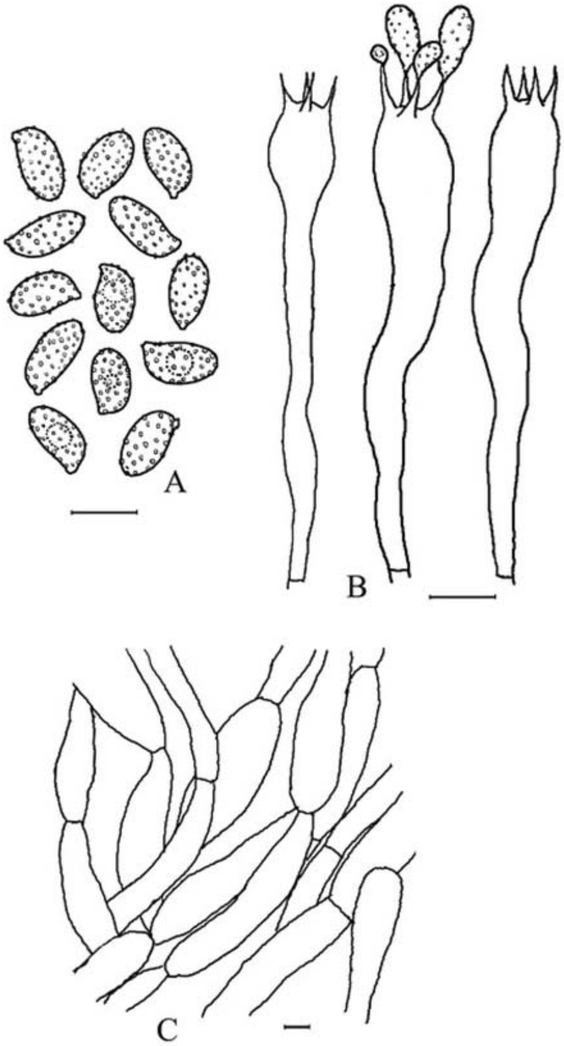

**圖5.** 富士山釘菇。A, 擔孢子; B, 擔子; C, 菌蓋外皮菌絲無扣子體。比例尺＝10 μm。

**Fig. 5.** *Gomphus fujisanensis*. A, baisidiospores; B, basidia; C, Hyphae of pileipellis without clamps (bars = 10 μm).

### **地生綿革菌**(圖 6; 圖 8F)

***Tomentella terrestris*** (Berk. & Br.) Larsen, Mycol. Mem. 4: 105, 1974.

*Zygodesmus terrestris* Berk. & Broome, Ann. Mag. Nat. Hist., Ser. 57: 130, 1881.

子實體平伏或稍隆起呈不規則小瘤狀，厚達 1 cm以下，寬 2-10 cm，表面紅棕色至暗褐色，硬質，子實層平滑。擔孢子不規則近球形，表面粗糙具刺，褐色，非類澱粉質反應，7.5-10 $\mu$m；擔子，4 孢型，60-80 × 9-12 $\mu$m；囊狀體未觀察到；菌絲有扣子體。

**棲息地：**在平地公園殼斗科樹下地上散生至群生。

**研究標本：**台中市國立自然科學博物館植物園，海拔 80m，2005 年 9 月 15 日，周文能 CWN 06962。

**世界分布：**亞洲、北美、歐洲。

**附　　記：**此種在野外常被誤以爲是子囊菌門炭角菌目(Xylariales)中的炭皮菌類(Hypoxylon)，但顯微鏡下可見有擔子及菌絲有扣子體等構造，明顯屬擔子菌門；記載常生長在非常腐朽的木頭上，也可以生長在地上(Breitenbach and Kränzlin 1986)。

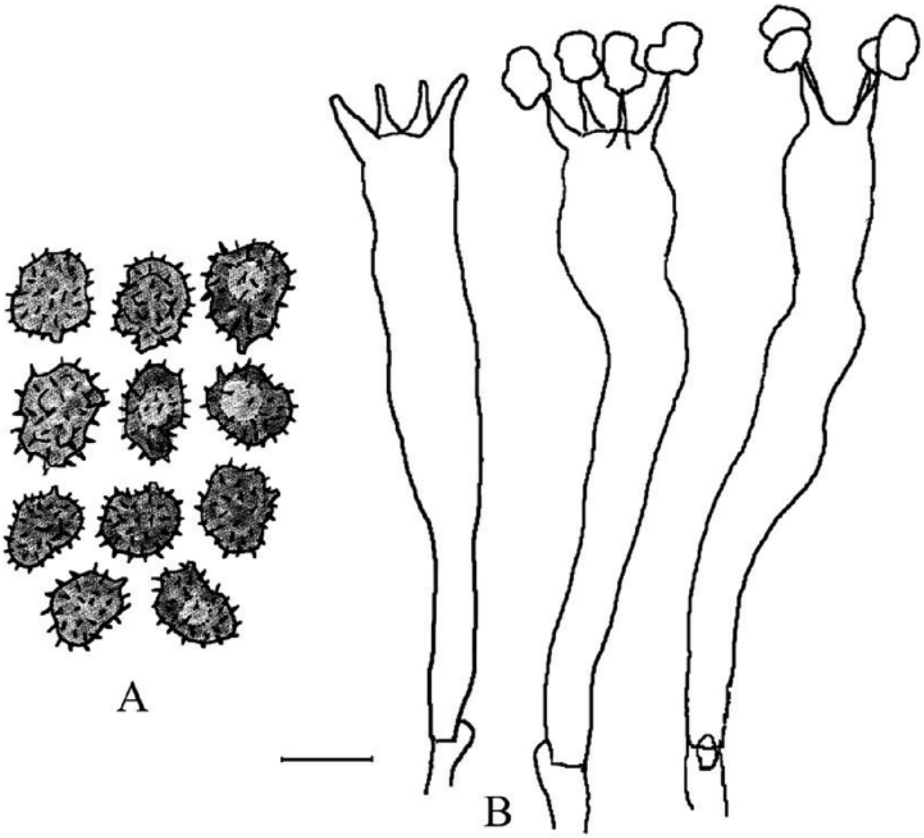

**圖 6.** 地生綿革菌。A, 擔孢子; B, 擔子。比例尺＝ 10 $\mu$m。

**Fig. 6.** *Tomentella terrestris*. A, baisidiospores; B, basidia (bar = 10 $\mu$m).

**肉紅膠韌革菌**(圖 7; 圖 8G)

***Gloeostereum incarnatum*** S. Ito & S. Imai, Trans. Sapporo Nat. Hist. Soc. 13: 11, 1933.

*Merulius incarnatus* (S. Ito & S. Imai) Spirin & Zmitr., Nov. Sist. Niz. Rast. 37: 182, 2004.

子實體耳狀或扇形，直徑 6-12 cm，厚 0.3-0.5 cm，膠質有彈性，表面淡黃褐色至黃褐色，邊緣有齒狀毛附著，子實層平滑。擔孢子卵圓形至橢圓形，表面平滑，透明無色，非類澱粉質反應，7-10 × 5.5-7.5 $\mu$m；擔子長棒形，4 孢型，50-80 × 8-10 $\mu$m；囊狀體棒狀或近柱狀，30-80 × 5-9 $\mu$m；菌絲有扣子體。

**棲息地：**在中海拔森林內腐木上聚生。

**研究標本：**台中縣東勢雪山坑，海拔 1,500m，2001 年 6 月 1 日，周文能 CWN 05069。

**世界分布：**中國、日本。

**附　　記：**在野外此種常被誤認爲是木耳類，但顯微構造中的擔子截然不同，木耳類擔子橫隔成 4 個細胞，屬於異擔子菌綱，而非褶菌目是屬於同擔子菌綱，擔子不分隔。此種原發現於日本，1 屬 1 種，歸於皺孔菌科 (Meruliaceae)，在中國則爲著名食藥用菌，稱爲榆耳，並歸於革菌科 (今関及本郷 1989; 卯 2000)。

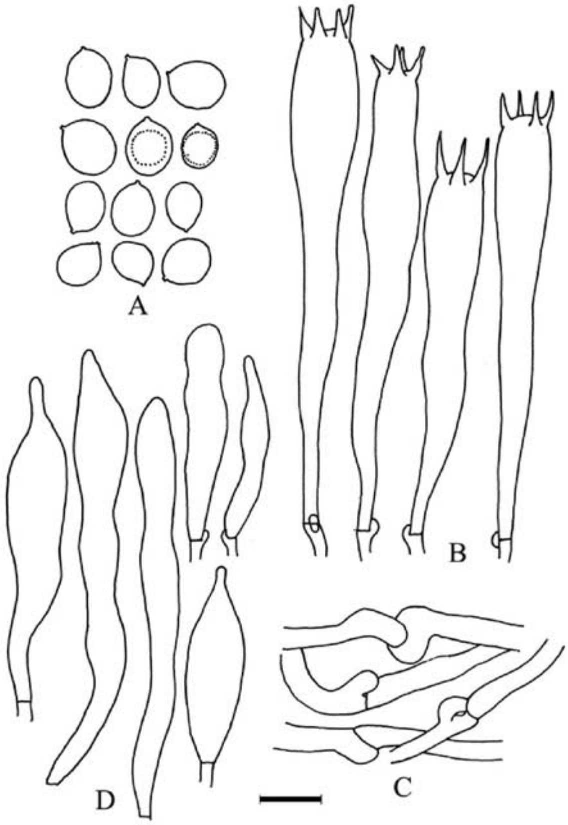

**圖 7.** 肉紅膠韌革菌。A, 擔孢子; B, 擔子; C, 菌絲無扣子體; D, 囊狀體。比例尺＝ 10 $\mu$m。

**Fig. 7.** *Gloeostereum incarnatum*. A, baisidiospores; B, basidia; C, hyphae with clamps; D, cystidia (bar = 10 $\mu$m).

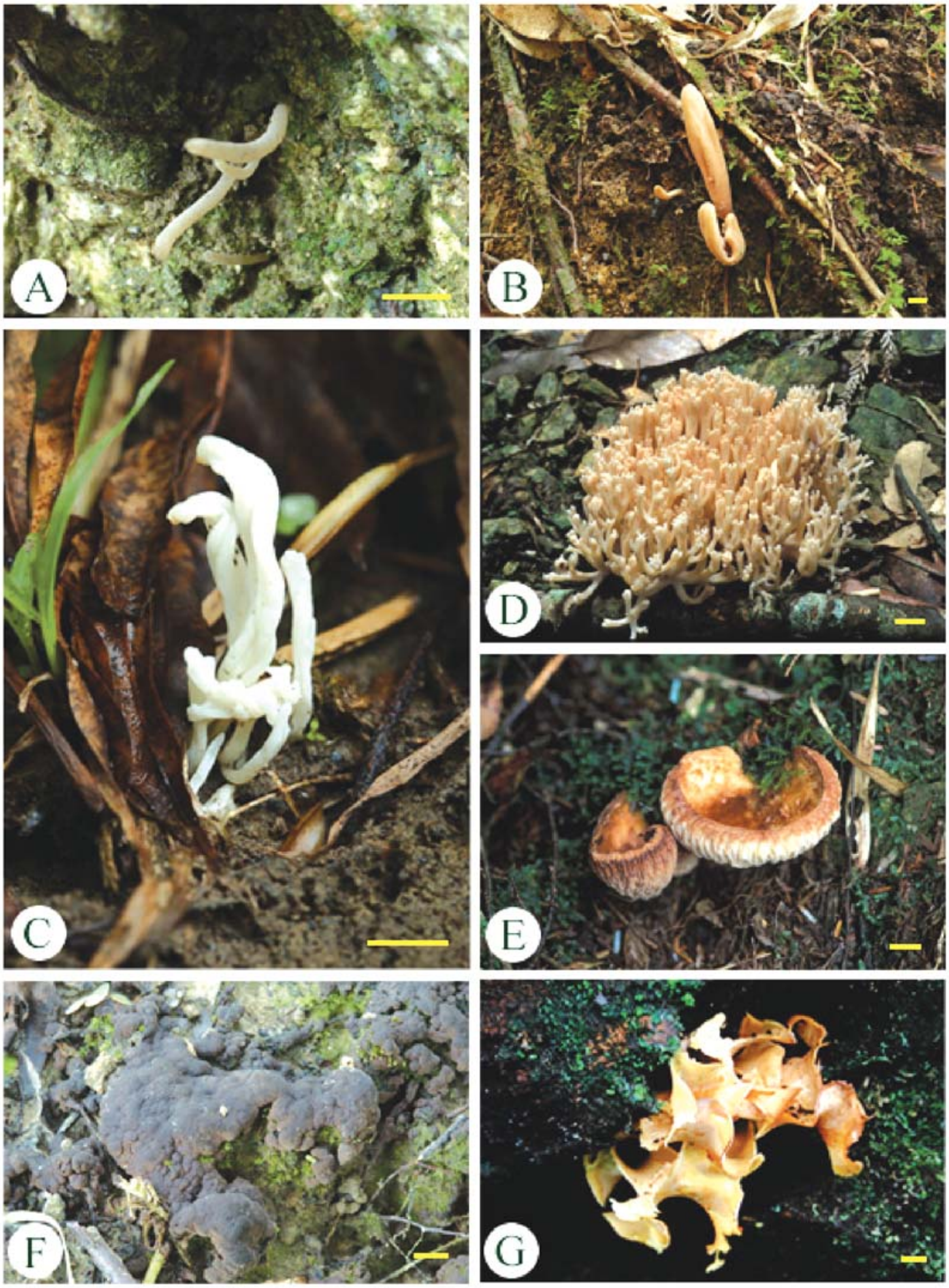

**圖 8.** 子實體：A, 星孢珊瑚菌; B, 舌狀棒瑚菌; C, 皺鎖瑚菌; D, 擬粉紅枝瑚菌; E, 富士山釘菇; F, 地生綿革菌; G, 肉紅膠韌革菌。比例尺＝ 1 cm。

**Fig. 8.** Fruit bodies: A, *Clavaria asterospora*; B, *Clavariadelphus ligula*; C, *Clavulina rugosa*; D, *Ramaria neoformosa*; E, *Gomphus fujisanensis*; F, *Tomentella terrestris*; G, *Gloeostereum incarnatum* (bars = 1 cm).

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# A Review of the Family Tessaratomidae (Hemiptera: Pentatomoidea) of Taiwan with Descriptions of Newly Recorded Two Genera and Five Species

# 台灣荔蝽科昆蟲二新紀錄屬及五新紀錄種

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## Abstract

This paper reviews the family Tessaratomidae from Taiwan which are consisted of five genera and ten species. Of them five species and two genera are newly recorded to the island. They are *Eusthenes femoralis* Zia, 1957, *Eusthenes robustus* (Lepeletier and Serville, 1825), *Eusthenes saevus* Stål, 1863, *Eusthenimorpha jungi* Yang, 1935, and *Mattiphus splendidus* Distant, 1921. They are described and illustrated with living adult color pictures, and provided with a check list of host plants and a key to the genera and the species of Tessaratomidae of Taiwan.

## 摘　要

本文整理台灣產荔蝽科 (Tessaratomidae) 舊有紀錄種類 3 屬 5 種及 2 新紀錄屬 5 新紀錄種，所有新紀錄種均有詳細形態特徵描述及形態繪圖，分別爲 *Eusthenes femoralis* Zia、*E. robustus*

(Lepeletier and Serville)、*E. saevus* Stål、*Eusthenimorpha jungi* Yang 及 *Mattiphus splendidus* Distant 等 5 種。文末並附有生態照片及寄主植物名錄。

**Key words:** Tessaratomidae, *Eusthenimorpha*, *Mattiphus*, host plant, Taiwan

**關鍵詞：**荔蝽科、*Eusthenimorpha* 屬、*Mattiphus* 屬、寄主植物、台灣

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## Introduction

The family Tessaratomidae (Hemiptera: Pentatomoidea) are large bugs usually with metallic colors. Adults and nymphs are phytophagus, and thus, most of the species spend their lives on tree leaves and stems. They are found mainly in the tropics of the Eastern Hemisphere but a few in the Western Hemisphere. Tessaratomidae are a small family closely related to the family Pentatomidae. Except for large size and flatted edge nymph, all members of Tessaratomidae look like those of Pentatomidae with robust body and very small head. Sometimes, the former was considered as the subfamily Tessaratominae of the latter. Tessaratomidae comprises 49 genera and about 235 species worldwide (Rolston *et al*. 1993). Some species are pests, such as *Tessaratoma papillosa,* the pest of litchi (*Litchi chinesis*), which injures the fruiter (Drury 1770).

Stål (1865) first established supergeneric groups of tessaratomid bugs at a subfamily level under Pentatomidae. Horváth (1900) recognized nine tribes and established a key to the genera. Kirkaldy (1909) catalogued the world fauna, recognizing 11 tribes of Tessaratomidae. Leston (1955) followed Kirkaldy's classification system, but reducing some of the tribes to subtribes, and describing two new subtribes. The modern tessaratomid taxonomy follows Kumar's (1969) classification system. He divided Tessaratomidae into three subfamilies: Natalicolinae, Oncomerinae and Tessaratominae. The Tessaratominae are subdivided further into three tribes: Prionogastrini, Sepinini and Tessaratomini. This classification system was adopted by Rolston *et al*. (1993) and followed by this study. Schuh and Slater (1995) reviewed the systematics and biology of the family.

There were five known species of Tessaratomidae from Taiwan (Rolston *et al*. 1993), three species recorded by Esaki (1926) and two species by Hsiao (1977) and Zia (1957). This paper adds two newly recorded genera and five newly recorded species to the tribe Tessaratomini of Tessaratomidae of Taiwan. They are described and illustrated, and provided with a key to the genera and the species, and the information of their host-plants (Table 1). All specimens used in this study are preserved in the Endemic Species Research Institute.

**Table 1.** Host plants of ten Tessaratomidae species

| Tessaratomids | Host plants | | |
|---|---|---|---|
| | Family | Species | References |
| *Eurostus validus* | Fagaceae | *Castanea mollissima** | Ren and Chen 2009 |
| | | *Castanea* sp. | Zhang 1985 |
| | | *Castanea seguinii** | Lin *et al*. 1999 |
| | | *Castnopsis sclerophylla* | Zhang 1985 |
| | | *Cyclobalanopsis glauca** | Ho and Chen |
| | | *Quercus acutissima** | Zhang 1985 |
| | | *Quercus fabri* | Zhang 1985 |
| | Juglandaceae | *Juglans sigillata* | Ji *et al*. 2001 |
| | Piperaceae | *Piper nigrum* | Yang 1962; Zhang 1985 |
| | Scrophulariaceae | *Paulownia tomentosa** | Lei and Zhou 1998 |
| | Euphorbiaceae | *Sapium sebiferum** | Zhang 1985 |
| | Rosaceae | *Pyrus* sp. | Yang 1962; Zhang 1985 |
| | Sterculiaceae | *Firmiana simplex** | Yang 1962; Zhang 1985 |
| | | *Vernicia fordii** | Yang 1962; Zhang 1985 |
| *Eusthenes cupreus* | Fagaceae | *Cyclobalanopsis glauca** | Zhang 1985 |
| | | *Castanopsis indica** | Ho and Chen |
| | | *Quercus acutissima** | Lin *et al*. 1999 |
| | Theaceae | *Camellia oleifera** | Lin *et al*. 1999 |
| | Sterculiaceae | *Vernicia fordii** | Lin *et al*. 1999 |
| | Verbenaceae | *Tectona* sp. | Schaefer and Ahmad 1987 |
| *Eusthenes femoralis* | Aquifoliaceae | *Ilex* sp. | Zhang 1985; Lin *et al*. 1999 |
| | Fagaceae | *Castanea mollissima** | Zhang 1985; Lin *et al*. 1999; Ren and Chen 2009 |
| | Sabiaceae | *Meliosma pinnata** | Ho and Chen |
| | Theaceae | *Camellia oleifera** | Zhang 1985; Lin *et al*. 1999 |
| *Eusthenes robustus* | Araliaceae | *Schefflera octophylla** | Zhang 1985; Lin *et al*. 1999 |
| | Fagaceae | *Quercus* spp. | Lin *et al*. 1999 |
| | | *Castanopsis indica** | Ho and Chen |
| | Juglandaceae | *Juglans sigillata* | Ji *et al*. 2001 |
| *Eusthenes rubefactus* | Fagaceae | *Cyclobalanopsis glauca** | Ho and Chen |
| *Eusthenes saevus* | Betulaceae | *Alnus formosana** | Ho and Chen |
| | Fagaceae | *Quercus* spp. | Lin *et al*. 1999 |
| | Juglandaceae | *Juglans sigillata* | Ji *et al*. 2001 |
| *Eusthenes theseus* | Fagaceae | *Cyclobalanopsis glauca** | Lin *et al*. 1999 |
| *Eusthenimorpha jungi* | Fagaceae | *Castanopsis indica* | Ho and Chen |
| *Mattiphus splendidus* | Euphorbiaceae | *Mallotus* sp. | Lin *et al*. 1999 |

| | | | |
|---|---|---|---|
| | Fagaceae | *Castanopsis indica** | Ho and Chen |
| | | *Cyclobalanopsis glauca** | Lin *et al.* 1999 |
| | | *Quercus acutissima** | Zhang 1995 |
| | Rosaceae | *Prunus* sp. | Zhang 1995 |
| | Scrophulariaceae | *Paulownia* sp. | Zhang 1995; Lin *et al.* 1999 |
| *Tessaratoma papillosa* | Burseraceae | *Canarium album** | Yang 1962 |
| | Caricaceae | *Carica papaya** | Yang 1962 |
| | Euphorbiaceae | *Ricinus communis** | Yang 1962 |
| | Fabaceae | *Canavalia* spp. | Yang 1962 |
| | Moraceae | *Ficus* spp. | Yang 1962 |
| | Musaceae | *Musa sapientum** | Yang 1962 |
| | Pinaceae | *Pinus* spp. | Yang 1962 |
| | Poaceae | *Saccharum sinense** | Yang 1962 |
| | Rosaceae | *Prunus mume** | Yang 1962 |
| | | *Prunus persica** | Yang 1962 |
| | | *Prunus salicina** | Yang 1962 |
| | Rubiaceae | *Coffea* spp. | Yang 1962 |
| | Rutaceae | *Citrus* spp. | Yang 1962 |
| | | *Citrus maxima** | Yang 1962 |
| | | *Citrus limon** | Yang 1962 |
| | | *Fortunella* spp. | Yang 1962 |
| | Sapindaceae | *Euphoria longana** | Hoffmann 1931 |
| | | *Koelreuteria formosana** | Ho and Chen |
| | | *Litchi chinensis** | Hoffmann 1931 |
| | | *Litchi* sp. | Schaefer and Ahmad 1987 |
| | | *Nephelium* sp. | Schaefer and Ahmad 1987 |
| | Solanaceae | *Nicotiana tabacum** | Yang 1962 |
| | | *Solanum melongena** | Yang 1962 |

* The species remarked in this table are also exist in Taiwan.

## Family TESSARATOMIDAE Stål, 1865

Body large, and shape ovoid to elliptical. Head laterally keeled, very small relative to body size. Bucculae short. Antennae four or five segmented. Ocelli nearer to eyes than to each other. Labium short, reaching apices of fore coxae. Rostrum with 4 joints, reaching the middle of mesosternum; second joint long; last two joints short. Scutellum triangular, reaching the base of membranes without covering corium. Veins of the membrane not reticulate. Hind wings with a hamus. External efferent system of metathoracic gland reduced. Tarsi two or three segmented. The first pair of abdominal spiracles entirely exposed, not hidden by metasternum, easily distinguishable from those of the species of Pentatomidae. Aedeagus with upto four pairs of conjunctival processes. Nymphs with dorsal abdominal glands between terga III/IV, IV/V and V/VI (Yang 1935; Slater 1982; Schuh and Slater 1995; Sinclair 2000).

# Key to the genera and the species of Tessaratomidae from Taiwan

**1(2)** Postmargin of pronotum strongly protrudented backward and covered basal mesoscutellum; head and basal prothorax extended downward; lateral margin of pronotum prominent but smooth........ ......................................................................................................... *Tessaratoma papillosa* (Drury)

**2(1)** Postmargin of pronotum slightly protrudented backward, not covered basal mesoscutellum;

**3(17)** Metasternum bulged, equal to stature of coax;

**4(5)** Metasternum bulged strongly, elevated plate, cross-shaped; metatibia crooked inwardly for male adult.......................................................................................... *Eusthenimorpha jungi* Yang

**5(4)** Metasternum bulged weakly, like rhombus or pentagon; if crucifix, lateral margin of abdominal sternites VII acute; metatibia not crooked on male adult;

**6(18)** Posterior femora strongly incrassated, with a long and strong spine from the base of male adult;

**7(8)** Yellow brindle on lateral margin of tergites more than 1/3 of the tergites length; angle between distal spur and postfemur not greater than 45 degree.............................. *Eusthenes femoralis* Zia

**8(7)** Yellow brindle on lateral margin of tergites less than 1/3 of the tergites length; angle between distal spur and posfemur greater than 45 degree;

**9(10)** Basal of 4th antennal segment primrose yellow; metasternum bulged slightly, like a crucifix; lateral margin of 7th abdominal segment pointed; metatibia not crooked inwardly on male; 8th ventral abdominal segment with a triangular indentation in middle area.................................................. ......................................................................................................... *Eusthenes saevus* Stål

**10(9)** Basal of 4th antennal segment black; metasternum bulged, like a rhombus, postmarginal spacious and smooth; 8th ventral abdominal segment without a triangular indentation in middle area;

**11(12)** Ventrum and legs chestnut brown, with gloss but no dark twills; lateral margin of tergites olivaceous, with sorrel stripes on basal area, about 25-35 mm in length......................................................... ......................................................................................................... *Eusthenes rubefactus* Distant

**12(11)** Ventrum and legs blackness; if not, dark twills presented; stripes on lateral margin of abdominal segments small or absent;

**13(16)** Small body, less than 30 mm in length; an indentation in the middle area on male genital segment;

**14(15)** Body color glossy with sparse wrinkle and ornamentation........................ *Eusthenes theseus* Stål

**15(14)** Body color dim with obvious wrinkle and ornamentation, mush rugged, verdigris-green; ventral surface glossy, purple-brown or verdigris-green without dark twills............................................ ......................................................................................... *Eusthenes cupreus* (Westwood)

**16(13)** Large body, longer than 30 mm in length; 3 small lobs on male genital segment................................... ..................................................................................... *Eusthenes robustus* (Lepeletier and Serville)

**17(3)** Metasternum not bulged, sank into the area between meso-coxa and meta-coxa; posterior femur strongly incrassated with a long and strong spine in male adult but smaller in female; 4th antennal segment yellowish-brown but blackness in basal area; 8th abdominal segment equal between width and length........................................................................................... *Eurostus varidus* Dallas

**18(6)** Posterior femora of male not incrassated, without a long and strong spine from the base; metasternum contact with 3rd sternum; antenna black; anterior margin of compound eye with a spine................................................................................................................ *Mattiphus splendidus* Distan

### Genus *Eurostus* Dallas, 1851

Type species: *Eurostus validus* Dallas, 1851. designated by Distant, 1902.

**1. *Eurostus validus* Dallas, 1851 (Fig. 2A)**

*Eurostus validus* Dallas, 1851. List Hem. 1: 343, pl. 11, figs. 2a-c.

Distribution: China (Anhui, Fujian, Guangdong, Guangxi, Guizhou, Hubei, Hunan, Jiangsu, Jiangxi, Shandong, Shanxi, Sichuan, Yunnan, Zhejiang), India, Hong Kong, Laos, Taiwan, Vietnam (Rolston *et al*. 1993).

### Genus *Eusthenes* Laporte, 1833

Type species: *Tessaratoma robusta* Lepeletier and Severin, 1828. by monotype.

**2. *Eusthenes cupreus* (Westwood, 1837) (Fig. 2B)**

*Tessaratoma* (sic) *cuprea* Westwood, 1837. Cat. Hope 1: 27.

*Eusthenes cupreus* Dallas, 1851. List. Hem. 1: 342.

Distribution: Bhutan, Burma, China (Anhui, Fujian, Guangdong, Guangxi, Guizhou, Jiangxi, Sichuan, Xizang, Yunnan, Zhejiang), India (Assam, Sikkim), Laos, Malay Penninsula, Malaysia, Nepal, Sri Lanka, Taiwan, Thailand (Rolston *et al*. 1993).

**3. *Eusthenes femoralis* Zia, 1957 (Figs. 1A, 1B, 2C)**

*Eusthenes femoralis* Zia, 1957. Acta Ent. Sin. 7: 430, 431-432, 447.

Material examined: TAIWAN, Urai, on *Meliosma pinnata* (Sabiaceae), 1. X. 2009, 1 male, by J. Z. Ho.

Characters: Male, 30 mm in length and 18 mm in width. Female, 29-30 mm in length and 16-18 mm in width (Zia 1957). Head wrinkled, the lateral lobes rather strongly reflex on each side; antennae fairly closely pubescent. Pronotum broad, anterior margin thickened; sides oblique, much narrowed towards the anterior; posterior angles subprominent, rounded. Scutellum transversely wrinkled; connexivum rather broad. Apical teeth of posterior femora directing towards the apex and marking each with the femur an angle not greater than 45 degrees; apex of genital segment rather convex when viewed caudally.

Coloration: A colorful bug but color highly variable. Dorsum castaneous or purplish castaneous, occasionally olivaceous. Ventrum brown or yellow-brown, Knees and apex of claws black; connexivum dark green or greenish-black, spotted with ochraceous or yellow at segmental bases which occupying 1/3-1/2 area of each segment; apex of scutellum yellow; membrane dark brassy-ocraceous; antennae black but red-brown the basal stained, the extreme apex brown.

Distribution: Southern China (Fujian, Guangdong, Guangxi, Guizhou, Yunnan, Zhejiang), Taiwan (new record) (Rolston *et al*. 1993).

### 4. *Eusthenes robustus* (Lepeletier and Serville, 1825) (Figs. 1C, 1D, 2D )

*Tessaratoma robusta* Lepeletier and Serville, 1825. Enc. Meth. 10: 591.
*Dinidor* (*Eusthenes*) *robustus* Laporte, 1833. Mag. Zool. (Guérin) 2: 64.
*Dinidor robustus* Spinola, 1837. Essai, 304.
*Eusthenes elephas* Dohrn, 1863. Stett. Ent. Ztg. 24: 351. (syn. by Vollenhoven, 1868)
*Eusthenes polyphemus* Stål, 1863. T. E. S. London. 598.
*Eusthenes scutellaris* Vollehoven, 1868. Faun. Arch. Indo-Néerl., 28.
*Eusthenes elephas* Walker, 1868. Cat. Het. 3: 468.
*Eusthenes jason* Stål, 1870. Svensk. Vet. Ak. Hsandl. 9: 232.
*Eusthenes touchei* Fallou, 1887. Naturaliste, 413.
*Eusthenes thoracicus* Distant, 1990. A. M. N. H. (7), 6: 61; Id., 1902. Faun., Br. Ind. Rh.: 266.

Material examined: TAIWAN, Shouka, on *Castanopsis indica* (Fagaceae), 15. X. 2009, 1 female, by J. Z. Ho.

Characters: Body size usually large and robustus, like the other species that very complexly variable in color, forms and sizes (Yang 1935). Pronotum broader than the bases of hemelytra, with anterior and lateral margins emarginate slightly and the lateral areas more or less rugulose. Connexivum moderately or broadly exposed. Basal spine of posterior femora of male strong and curved. Abdomen slightly or much broader than the pronotal angles. Apical margin of genital segment of male entire, but convex at middle to form a〝W〞shape. Terminal abdominal segments of female with pleurite X longer than the pleurite IX. Apexes of terminal abdominal segments of female as variable as those of *E. cupreus*. Posterior tibiae of male curved or rather strait (Yang 1935). Body sizes: Male, 30-38 mm long in length and 17-25 mm long in body width; Female, 32-36 mm long in length and 18-23 mm long in width.

Coloration: Body above generally blackish-brown, or reddish-cupreus, sometimes becoming piceous, dark-green, or olivaceous-green; much brown or paler on the corious portions; sometimes more or less tinted with olivaceous-green on the head above. Antennae black, with the base of basal joint rather ochraceous, extreme apex of apical joint rather ferruginous. Antero-lateral areas of pronotum, scutellum, basal or apical areas of corium and connexivum. Scutellum, sometimes, much darker or greenish-darker than other surfaces of body above. Apex of scutellum, basal spot of each abdominal segment in the connexivum distinctly or obscurely ochraceous or concolour with the other areas of connexivum. Body beneath also very variable pale or dark brownish-green, ochraceous, or reddish-cupreus. Rostrum and legs blackish or ocraceous. Tarsi more or less brown, sometimes becoming blackish or concolour to the other portions of legs.

Distribution: Bhutan, Borneo, China (Fujian, Guangdong, Guangxi, Guizhou, Hainan Island, Jiangxi, Sichuan, Yunnan), E. Indies, India (Assam, Bengal, Sikkim), Indo-China, Java, Macao, Malay Penninsula, Sumatra, Suwalesi (Celebes), Thailand, Taiwan (new record), Vietnam (Rolston *et al.* 1993).

### 5. *Eusthenes rubefactus* Distant, 1901 (Fig. 2E)

*Eusthenes rubefactus* Distant, 1901. Trans. Ent. Soc. London p. 111.

*Eusthenes diomedes* Breddin, 1904. Wien. Ent. Ztg. 23: 15-16. syn. by Distant, 1921.

Distribution: Myanmar, India (Assam), Indo-China, Sri Lanka, Taiwan, Vietnam (Rolston *et al.* 1993).

### 6. *Eusthenes saevus* Stål, 1863 (Figs. 1E, 1F, 1G, 2F)

*Eusthenes saevus* Stål, 1863. Trans. Ent. Soc. Lond. 1: 597-598.

*Eusthenes philoctetes* China, 1925. Ann. Mag. N. His. 16: 455.

*Eusthenes philoctetes* Tang, 1935. Cat. Ins. Sin. 2: 364.

*Eusthenes saevus obsoletus* Young, 1935. Bull. Fan Mem. Inst. Biol. 6: 114-115.

Material examined: TAIWAN, Auoneda, 29-30. X. 1992, 11 males and 2 females, by J. Z. Ho; Puli, 16. V. 1956, 1 female, by K. S. Lin; Lushan, 14. XI. 1992, 1 female, by J. Z. Ho; Oneda, 4. XI. 1993, 2 females, by J. Z. Ho; Shitou, 6. IX. 1993, 1 male, by C. K. Sunekang; 17. III. 1991, 1 male, by Lo; Taichung, 18. X. 1961, 1 female, by S. C. Chiu; Taihiyan, 23. XII. 1932, 1 male, by J. Z. Ho; Taoyuan, 9. VII. 1993, 1 female, by Lo; Wushinkeng, 22. VII. 1993, by J. Z. Ho.

Characters: Head wrinkled, the lateral lobes not strongly reflex on each side; antennae not pubescent. Pronotum broad, anterior margin not thickened; sides oblique, much narrowed towards the anterior; posterior angle subprominent, rounded. Scutellum transversely wrinkled; connexivum not broad. Basal spine on postfemur of male not as strong as that of *E. cupreus* and apical teeth of posterior femora directing towards the apex and marking each with the femur an angle not greater than 45 degrees. Genital segment of male scarcely sinuate at posterior margin; apex of genital segment rather convex when viewed caudally. Body sizes: Male, 24-28 mm long in length and 12-15 mm long in width; Female, 26-30 mm long in length and 14-16 mm long in width.

Coloration: Above purplish-green, and sometimes is olivaceous-green especially in head, thorax, and connexivum. Body beneath castaneous or purplish castaneous, usually with golden-greenish reflection. Antennae black but apical joint with the base and apex ochraceous (these ochraceous portion variable, narrow or broad), sometimes the apex of third joint is also ochraceous. Legs are red or reddish-brown. Connexvium olivaceous-green, spotted with purplish castaneous at segmental base. Apex of scutellum yellow-brown. Membrane dark brassy-ocraceous.

Distribution: Bhutan, Borneo, China (Anhui, Guangdong, Guizhou, Jiangxi, Shanxi, Sichuan, Yangtze, Yunnan, Zhejiang), India (Assam, Sikkim), Indo-China, Malay Penninsula, Taiwan (new record) (Rolston *et al.* 1993).

### 7. *Eusthenes theseus* Stål, 1870

*Eusthenes theseus* Stål, 1870. Sv. Vet. Akad. Handl. 9: 231.

Distribution: China (Fujain, Guizhou, Sichuan, Xizang, Yunnan, Zhejiang), India (Sikkim, W. Bengal), Indo-China, Laos, Nepal, Taiwan, Vietnam (Rolston *et al.* 1993).

## Genus *Eusthenimorpha* Yang, 1935

Type species: *Eusthenimorpha jungi* Yang, by original designation.

### 8. *Eusthenimorpha jungi* Yang, 1935 (Figs. 1H, 1I, 2G)

*Eusthenimorpha jungi* Yang, 1935. Bull. Fan Mem. Inst. Biol. 6: 118-119.

Material examined: TAIWAN, Shouka, on *Castanopsis indica* (Fagaceae), 15. X. 2009, 1 male, by J. Z. Ho.

Characters: Compared to *Eusthenes* and *Eurostus* species, the body shape of this species is more ovate. Antenna with the base of basal joint, second joint longer than third but shorter than the fourth. Connexivum well-exposed. Metasternal elevated plate much lower and transversely cross-shaped, mesosternum rather uniformly and longitudinally sulcated. Anterior femora with a very small spine on the anterior side near the apex, intermediate and posterior femora with two spines near apex; posterior femora also with a stronger spine near the base, but without two rows of small spines or tubercles at the underside, all these spines are black. Abdomen not elevated at base. Body sizes: Male, 24-26 mm long in length and 16-17 mm long in width; Female, 24-27 mm long in length and 16-17 mm long in width.

Coloration: Body above uniformly dark-green, beneath uniformly ochraceous. Antennae piceous and the apical area of the apical joint rather ochraceous. Apex of scutellum ochraceous, lateral margins of pronotum brownish-black, membrane bronze, sternum with pale golden-greenish reflection; femora ochraceous; tibiae, tarsi, and rostrum fuscous.

Distribution: China (Zhejiang, Hainan Island), Taiwan (new record) (Rolston *et al*. 1993).

### Genus *Mattiphus* Amyot and Serville, 1843

Type species: *Mattiphus carrenoi* Amyot and Serille by monotype

### 9. *Mattiphus splendidus* Distant, 1921 (Figs. 1J, 1K, 2H)

*Mattiphus splendidus* Distant, 1921. Entomol. 54: (698) 166.

Material examined: TAIWAN, Shouka, on *Castanopsis indica* (Fagaceae), 15. X. 2009, 1 male, by J. Z. Ho.

Characters: This species is smaller than other tessaratomid species in Taiwan. Second joint of antennae is the longest, third a little shorter than the fourth. Pronotum and scutellum more or less finely transversely wrinkled. Lateral margins of pronotum uniformly rounded and reflexed. Corium thick but very finely punctate. Body sizes: Male, 20 mm long in length and 13 mm long in width; Female, 22-27 mm long in length and 13-16 mm long in width (Zia 1957); breadth between pronotal angles in male about 11-15 mm, in female about 13-16 mm.

Coloration: Head, pronotum and scutellum resplendent green, but darkish-ochraceous in central lobe of head and sometimes the lateral margins being irregularly darkish-ochraceous, and ochraceous or darkish in the apex of scutellum. Corium pale castaneous with greenish reflexions at costal and apical areas; membrane very pale castaneous. Connexivum greenish-black, ochraceous (distinct or obscure), spotted at the base of each abdominal segments. Body beneath resplendent-green or golden-green or pale-ochraceous (discoloured). Head beneath, rostrum and legs pale castaneous; antennae castaneous, becoming darker towards apex.

Distribution: China (Fujian, Guangxi, Guizhou, Sichuan, Yunnan), Indo-China, Laos, Taiwan (new record) (Rolston *et al*. 1993).

### Genus *Tessaratoma* Berthold, 1827

Type species: *Tessaratoma papillosa* Drury, 1770 (= *Cimex papillosa* Drury, 1770). disignated by Distant, 1902.

**10. *Tessaratoma papillosa* (Drury, 1770) (Fig. 2I)**

*Cimex papillosus* Drury, 1770. III. Nat. Hist. 1: 96-97, pl. 43 fig. 2. (species name in index)

*Cimex chinese* Thunberg, 1783. Nov. Ins. Sp. 2: 45, pl. 2 fig. 59. syn. by Wolff, 1880.

*Cimex sinensis* (sic) Gmelin, 1790. Syst. Nat. ed. 13, 1: 2158.

*Edessa papillosus* Fabricius, 1803. Syst. Rh.: 150.

*Tessaratoma sonneratii* Lepeletier and Serville, 1825. Enc. Meth. 10: 590-591. syn. with *Cimex chinesis* Thunberg, 1783 by Mayr, 1866.

*Tessaratoma ossacruenta* Gray, 1832. Griffith's Anim. Kingd. 15: 239.

*Tessaratoma javana* Burmeister, 1834. Nov. Act. Leop. Carol 16 Suppl.: 293.

Distribution: Australia, Borneo, Burma, China (Fujian, Guangdong, Guangxi, Guizhou, Hainan Island, Jiangxi, Kiangsi, Kweichow, Kwangtung, Manchuria, Sichuan, Yunnan), E. Indies, India (Assam, Hindustan), Indo-China, Indonesia (Lombok Island), Japan, Java, Laos, Lesser Sunda Island (Timor Island), Malaysia, Philippines, Sierra Leone, S.E. Asia, Sri Lanka, Sumatra, Taiwan, Thailand, Vietnam (Rolston *et al*. 1993).

## Discussion

Many Tessaratomidae species are colorful and polished when alive, and the characteristics of body color are used for description in previous references. However, the body color of these species are variable and sometimes with high similarity among relative species and the body color of living bugs and dried specimens are quite different. Thus, it might be difficult to identify these species with these characters. Generally, the living tessaratomids in Taiwan are emerald-green, olive-green, or purplish green, but evolve into dark-green or purple bronze immediately after abiosis and become ochraceous or caramel to darkish-ochraceous in several days later. Therefore, the body color is not a reliable character for the taxonomy of Tessaratomidae. In addition, the nymphs of tessaratomids are also colorful and particular in flat body size, and it is also not easy to be identified. However, only a few notices on these nymph character states were shown. It is suggested that more importance should be placed on these nymph character states when consider the systematic relationships between these species. It could be more suitable than what has been done hitherto, for Tessaratomidae species classifying and nymphal morphological characteristics is also need to be taken into consideration in studies on taxonomy.

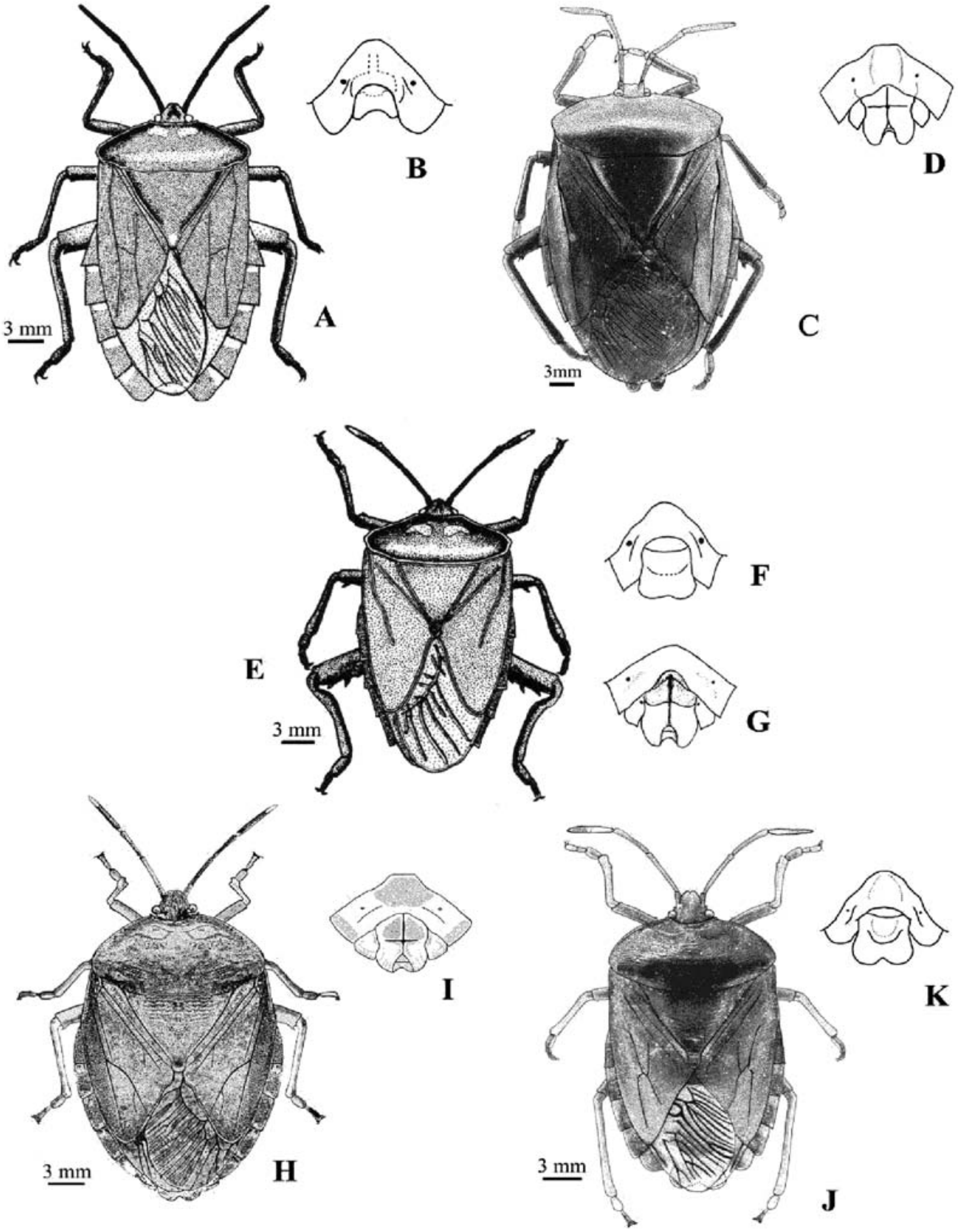

**Fig. 1.** New record species of Tessaratomidae in Taiwan. A-B, *Eusthenes femoralis* Zia and genital segments of male; C-D, *Eusthenes robustus* (Lepeletier and Serville) and genital segments of female; E-G, *Eusthenes saevus* Stål and genital segments of male (F) and female (G); H-I, *Eusthenimorpha jungi* Yang and genital segments of female; J-K, *Mattiphus splendidus* Distant and genital segments of male.

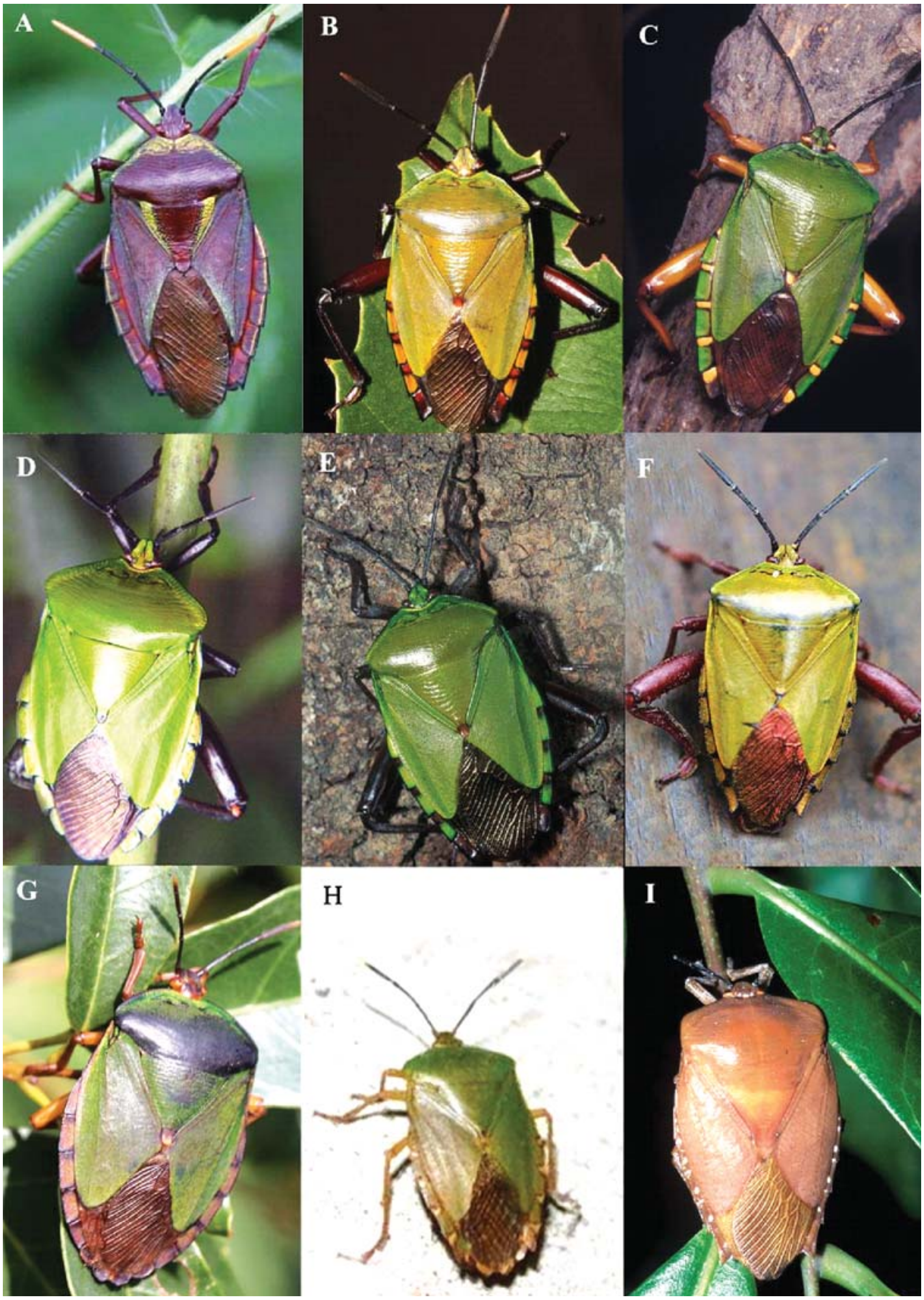

**Fig. 2.** Tessaratomidae of Taiwan. A, *Eurostus validus* Dallas; B, *Eusthenes cupreus* (Westwood); C, *Eusthenes femoralis* Zia; D, *Eusthenes robustus* (Lepeletier and Serville); E, *Eusthenes rubefactus* Distant; F, *Eusthenes saevus* Stål; G, *Eusthenimorpha jungi* Yang; H, *Mattiphus splendidus* Distant; I, *Tessaratoma papillosa* (Drury).

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# 應用 ISSR 分子標誌研究台灣檫樹之族群遺傳變異

# Genetic Diversity in *Sassafras randaiense* (Hay.) Rehder (Lauraceae) Based on ISSR Fingerprinting

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## 摘 要

台灣檫樹 *Sassafras randaiense* (Hay.) Rehder 爲台灣特有種樟科(Lauraceae)植物，本研究運用簡單序列重複區間(inter-simple sequence repeat, ISSR)分子標誌分析族群之遺傳結構與多樣性。採集自 7 處之自然分布區域共 137 株樣木，使用 8 個 ISSR 引子進行 PCR 擴增試驗獲得 39 個條帶，多型性條帶有 38 條(97.44%)。族群遺傳變異分析結果顯示台灣檫樹具有高歧異度(H=0.3438)與遺傳分化(Gst=0.2788)，分子變異分析(AMOVA)結果顯示族群間變異成分 16.47% ($p<0.0001$)，族群內爲 83.53% ($p<0.0001$)，族群遺傳變異主要成分來自於族群內；依遺傳變異矩陣與地理距離矩陣之相關性測驗(Mantel test)無顯著關聯(r=0.1542)，歸群與主座標分析所顯示遺傳變異與地理親緣不具分布關係。本研究顯示族群遺傳變異主要來自地區族群內，爲維持族群遺傳多樣性，在保育策略上建議在自然生育地區實施就地保育措施，避免濫伐等人爲干擾。同時可選擇移地保育，進行各地區族群引種育林之遺傳交流，擴大種原資源保育。

# Abstract

*Sassafras randaiense* (Hay.) Rehder (Lauraceae) is an endemic species of Taiwan. We collected 137 individuals from 7 natural populations and examined ISSR fingerprintings of the DNA sequences. PCR amplification with 8 ISSR primers yielded 39 DNA fragments, of which 38 were polymorphic (97.44%). AMOVA revealed that variance component among the populations was 16.47% ($p$<0.0001), while within population was 83.53% ($p$<0.0001). Mantel test exhibited low correlation (r = 0.2830, $p$ = 0.1542) between the genetic variation and the spatial distribution. Popgene analysis revealed high genetic diversity (H= 0.3438) of the species and also high genetic differentiation among the populations (Gst = 0.2788). Cluster analysis and the principal coordinate analysis (PCOA) revealed no significant correlation (r = 0.6635 $p$ = 0.9995) between the genetic differentiation and the spatial distribution. The conservation strategy for the species is to maintain in situ biodiversity and further to raise its gene diversity by hybridization among the populations in ex situ conservation.

**關鍵詞：**台灣檫樹、簡單序列重複區間、基因歧異度、遺傳分化

**Key words:** *Sassafras randaiense*, ISSR, genetic diversity, genetic differentiation

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## 緒　言

台灣檫樹 *Sassafras randaiense* (Hay.) Rehder 是世界上珍貴的闊葉樹種，曾繁茂於新生代第三紀之上新世(距今約 180 萬年)，目前全球檫樹屬(*Sassafras*)植物僅存 3 種，台灣檫樹係台灣特有種，另尚有檫樹(*S. tsumu* Hemsl)、北美檫樹(*S. albidum* Nees) (劉等 1994)。檫樹屬植物目前因分布稀少，有絕滅之危險。台灣檫樹在本地母樹甚少，每年無法採得足量種子，種子發芽率又極低，因而在育苗瓶頸亦難於突破，致使無法供應大量造林。

近年來，分子標誌廣泛應用在物種遺傳變異的研究，甚至用於生態學、分類學、遺傳學及生物地理學的研究。Zietkiewicz 等人(1994)所發展以聚合酶連鎖反應技術爲基礎之簡單序列重複區間(inter-simple sequence repeat, ISSR)分子指紋標誌，具操作方便、實驗花費較少及所需DNA樣本數少，具有多型性(polymorphism)高及再現性(reproducibility)高等優點，因此廣泛應用於遺傳連鎖分析及建構遺傳圖譜，研究物種族群遺傳變異，區分種內、亞種，或品系及栽培種及研究自然族群的雜交現象等(Adams *et al*. 2003; Barth *et al*. 2003; Christoph *et al*. 2003; Ge *et al*. 2003; 侯等 2007; 張等 2009)。素有「國蝶」之稱的寬尾鳳蝶喜歡在台灣檫樹

的新芽及嫩葉上產卵，當台灣檫樹開始發芽時，剛孵化之幼蟲即取食新葉。其幼蟲屬單食性，唯一寄主植物爲台灣檫樹，也因此突顯台灣檫樹在寬尾鳳蝶生態保育工作上不可或缺的生態地位。

就物種保育而言，了解族群各種特徵爲最首要工作，探討族群遺傳結構、基因庫規模、遺傳變異及分化程度，爲保育族群之策略規劃重要依據。台灣檫樹相關研究資料缺乏，若能深入探討族群遺傳結構，有助於了解其基因庫規模及分化程度，同時，分析族群多樣性將利於資源保育與利用的策略規劃。有鑑於此，本研究廣泛採集各生育地族群，應用ISSR分子標誌探討遺傳結構與族群多樣性，以了解族群之遺傳變異，對保育族群提供參考。

## 材料與方法

### 一、材料

廣泛採集自台灣北、中、南及東部地區等7個自然分布地區(圖1)；每區取11-21個樣株，共採得137株樣株，每株選取表面無病蟲害葉片5-10枚，並以矽膠乾燥劑脫水乾燥，其相關位置資料如圖1及表1。

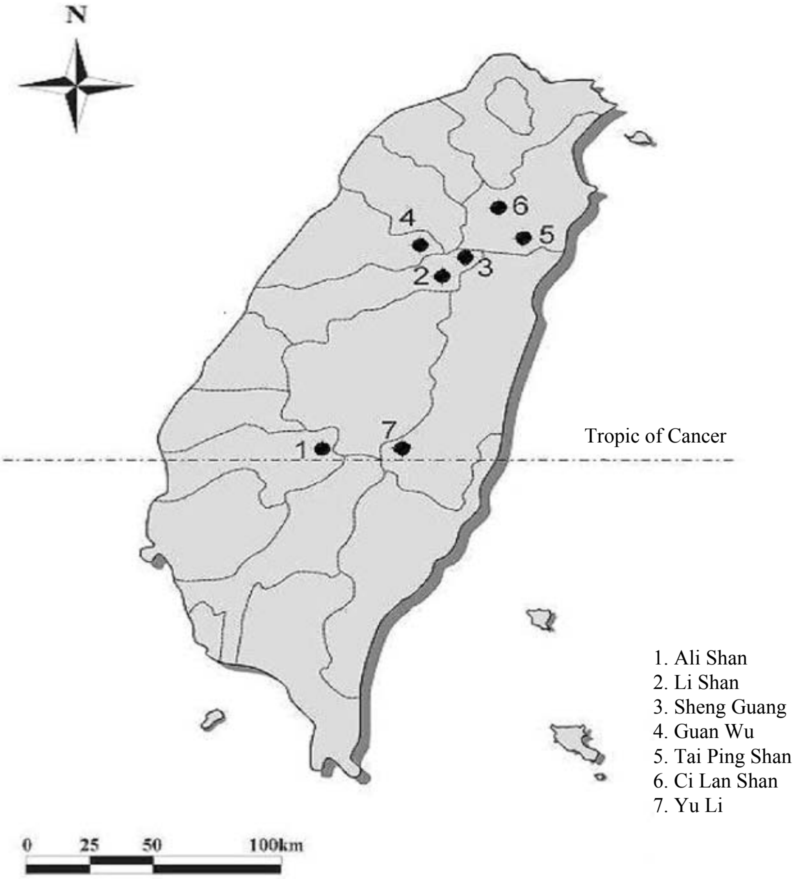

**圖 1.** 台灣檫樹之採集地理位置圖。

**Fig. 1.** Collection sites (solid circles) of *Sassafras randaiense* in Taiwan.

**表 1.** 台灣檫樹採集地區之位置資料

**Table 1.** Collection sites, elevations, and sample sizes of *Sassafras randaiense* collected from Taiwan

| Collected site | Latitude/Longitude | Elevation (m) | Sample size |
|---|---|---|---|
| 1. Ali Shan | 23°31'09"N/120°48'32"E | 2,309 | 15 |
| 2. Li Shan | 24°15'23" N/121°14'59"E | 1,902 | 15 |
| 3. Sheng Guang | 24°22'15" N/121°20'17"E | 1,862 | 23 |
| 4. Guan Wu | 24°30'24"N/121°06'55"E | 2,102 | 21 |
| 5. Tai Ping Shan | 24°29'40"N/121°32'02"E | 1,729 | 20 |
| 6. Ci Lan Shan | 24°40'51"N/121°30'10"E | 1,495 | 25 |
| 7. Yu Li | 23°23'24"N/121°22'37"E | 1,032 | 18 |
| Total | | | 137 |

二、方法

本試驗之Genomic DNA萃取主要參考Kobayashi *et al*. (1998) 之改良CTAB (cetyl trimethyl ammonium bromide)方法進行萃取。參考Ziekiewicz *et al*. (1994)的方法加以修改，其反應溶液總體積爲 25 $\mu$L，試劑濃度爲：10 mM Tris-HCl, 50 mM KCl, 1.0 mM MgCl, 0.1% gelatin (w/v), 1%Triton X-100 (w/v), 10 ng template DNA, 100 $\mu$M dNTPs, 0.2 $\mu$M primer, 以及 0.5 units Taq polymerase (HT Biotechnology, England)。ISSR 試驗引子取自 UBC (University of British Columbia) Biotechnology Laboratory 之 100 組隨機引子，共篩選出 8 組最合適之引子(表 2)進行放大。PCR經溫度梯度與引子篩選之最佳化(optimization)測試後，ISSR 分子標誌擴增之引子、最佳黏合溫度與循環參數，分別如下：

**表 2.** 台灣檫樹 ISSR 分析之 8 組引子序列與黏合溫度

**Table2.** Primers and annealing temperatures used for the extraction of ISSR DNA sequences of *Sassafras randaiense*

| Primer No. | Sequence (5’ - 3’) | Annealing temperature |
|---|---|---|
| UBC 825 | ACA CAC ACA CAC ACA CT | 57°C |
| UBC 855 | ACA CAC ACA CAC ACA CYT | 57°C |
| UBC 857 | ACA CAC ACA CAC ACA CYG | 57°C |
| UBC 864 | ATG ATG ATG ATG ATG ATG | 55°C |
| UBC 866 | CTC CTC CTC CTC CTC CTC | 58°C |
| UBC 888 | BDB[1] CAC ACA CAC ACA CA | 58°C |
| UBC 889 | DBD[1] ACA CAC ACA CAC AC | 58°C |
| UBC 891 | HVH[1] TGT GTG TGT GTG TG | 58°C |

[1] B=(G/T/C), D=(G/A/T), H=(A/T/C), V=(G/A/C).

以溫度循環儀(mastercycler gradient)進行PCR 反應，其反應溫度與循環參數爲：DNA前期變性(94℃, 6 min)，39 個循環之 DNA 變性(94℃, 30 sec)、引子黏合(52-56℃, 50 sec)、延伸反應(72℃, 2 min)，最後維持在 72℃, 7 min完成反應。PCR擴增之產物以 1.5%之Agarose 膠片電泳分離。電泳緩衝液爲 0.5×TBE buffer，大片膠(200 mL)以電壓 200V 分離 100 min，將擴增的DNA產物進行電泳。電泳分離後之膠片以溴化乙錠(ethidium bromide)溶液進行染色，於暗房中以紫外燈觀察條帶，並以Polaroid 667 照相記錄。

讀取清晰、亮度大具多型性之條帶，以代碼 1 (出現)和 0 (不出現)記錄條帶出現狀況。再利用NTSYS套裝軟體(Rohlf 1993)，以Simple Matching 公式計算兩兩樣本間之相似度矩陣(SSM)。以Dice公式(Dice 1945)計算兩兩樣本間之相似度(SAB)矩陣。將SSM相似度矩陣轉換成Excoffier *et al*. (1992)發表的D距離矩陣。求出遺傳距離矩陣後，以 Popgene (Yeh *et al*. 1997)軟體分析族群間遺傳變異，計算Nei's遺傳歧異度指數(Nei 1973)，以及計算族群間遺傳分化係數Gst (Nei 1973)，再利用Gst估算基因流傳值Nm〔Nm=0.5 × (l-Gst)/Gst)〕(Slatkin and Barton 1989)。以 Simple Matching 公式計算遺傳變異矩陣，再以Biom軟體之Mantel test公式(Mantel 1967)，進行地理矩陣之關聯分析檢定。其中，地區族群間之距離矩陣係以兩地區族群間之所在位置之地理距離求得。

以AMOVA vl.55 程式(Excoffier *et al*. 1992)分析各地區族群遺傳變異成分，包括屬於地理位置之中南部、北部族群，分別就二大地理範圍、地理範圍內族群間及族群內等三級變異影響；地區族群所分屬之中央山脈、雪山山脈及玉山山脈之三級變異影響；及僅就所有族群間、族群內個體間之二級變異影響，計算各層級之變異成分值及所占總變異成分之百分比，並以 9,999 次隨機重排測驗各變異成分的顯著性。

將NTSYS-pc ver 2.0 所計算出之各樣本間Dice相似度矩陣及AMOVA所算出之地區間距離(Φst)矩陣，以NTSYS-pc v.2.0 的SAHN (sequential, agglomerative, hierarchial, and nested clustering method)程式、UPGMA (unweighted pair-group method using arithmetic averages)方法進行各地區族群的歸群分析，並建立其關係樹狀圖(dendrogram)，以及進行主座標分析，以二、三維所占變異最大主要軸繪成平面圖及立體圖，求出各地區族群的變異關係。

## 結果

經聚合酶連鎖反應得到 39 個條帶，其中多型性條帶有 38 個(97.44%)，以Popgene計算族群 Nei's 基因歧異度值爲 0.3438，各地區族群介於 0.0877-0.4038，以棲蘭山地區最高，阿里山地區最低，遺傳分化分析結果遺傳分化係數(Gst)爲 0.2788 (表 3)。

**表3.** 台灣檫樹之遺傳歧異度、遺傳分化及遺傳流

**Table 3.** Popgene analysis of genetic diversity (H) and genetic differentiations (Gst) based on ISSR DNA sequences of *Sassafras randaiense* from the 7 collection sites of Taiwan

| Collection sites | H | Gst |
|---|---|---|
| 1. Tai Ping Shan | 0.1403 | |
| 2. Yu Li | 0.3372 | |
| 3. Ci Lan Shan | 0.4038 | |
| 4. Ali Shan | 0.0877 | |
| 5. Guan Wu | 0.2546 | |
| 6. Li Shan | 0.2966 | |
| 7. Sheng Guang | 0.1251 | |
| | 0.3438 | 0.2788 |

將樣區間遺傳距離矩陣(表 4)與海拔距離(表 5)進行關聯測驗(Mantel test)之相關係數爲 0.2830，經 1,000 次隨機排列測驗未達顯著相關($p$=0.1542)。

若將分布於台灣中南、北部地理位置，進行三級變異分析結果，地理區間之變方成分是-3.07% ($p$<0.722)，族群間地理位置之變方成分是 17.92% ($p$<0.01)，族群內地理位置的變方成分是 85.15% ($p$<0.01) (表 6)。

**表 4.** 台灣檫樹之 ISSR 分析之遺傳距離(Φst)矩陣

**Table 4.** A matrix of Nei’s genetic distances (Φst), based on ISSR DNA sequences of *Sassafras randaiense*, among 7 collection sites (1, Tai Ping Shan; 2, Yu Li; 3, Ci Lan Shan; 4, Ali Shan; 5, Guan Wu; 6, Li Shan; 7, Sheng Guang)

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 2 | 0.0473 | | | | | |
| 3 | 0.1482 | 0.0726 | | | | |
| 4 | 0.3236 | 0.1881 | 0.1844 | | | |
| 5 | 0.3407 | 0.2470 | 0.1993 | 0.1751 | | |
| 6 | 0.0586 | 0.0249 | 0.0781 | 0.2190 | 0.2612 | |
| 7 | 0.2714 | 0.1001 | 0.1030 | 0.1955 | 0.0855 | 0.1493 |

**表 5.** 台灣檫樹樣區族群之海拔距離矩陣

**Table 5.** A matrix of elevation distances of *Sassafras randaiense* among 7 collection sites (1, Tai Ping Shan; 2, Yu Li; 3, Ci Lan Shan; 4, Ali Shan; 5, Guan Wu; 6, Li Shan; 7, Sheng Guang)

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 2 | 57.2 | | | | | |
| 3 | 12.2 | 69.4 | | | | |
| 4 | 131.0 | 95.8 | 140.0 | | | |
| 5 | 42.3 | 76.3 | 41.8 | 113 | | |
| 6 | 38.7 | 47.0 | 46.5 | 93.3 | 30.7 | |
| 7 | 24.3 | 50.8 | 31.5 | 108.0 | 27.0 | 15.1 |

**表 6.** 台灣檫樹 ISSR 分析之分子變方成分分析表

**Table 6.** Analysis of molecular variance based on ISSR DNA sequences of *Sassafras randaiense*

| Source of variation | | df[1] | SSD[2] | MSD[3] | Variation component | Total var. (%) | *p*-value |
|---|---|---|---|---|---|---|---|
| Nested Analysis | | | | | | | |
| Exposure group | Variance among groups | 1 | 8.87 | 8.87 | -0.01 | -3.07% | <0.722 |
| | Variance among populations within groups | 5 | 68.39 | 13.68 | 0.57 | 17.92% | <0.01 |
| | Variance within populations | 130 | 351.07 | 2.70 | 2.70 | 85.15% | <0.01 |
| Mountains group | Variance among groups | 2 | 29.64 | 14.82 | 0.02 | 0.55% | <0.237 |
| | Variance among populations within groups | 4 | 47.62 | 11.91 | 0.52 | 16.02% | <0.01 |
| | Variance within populations | 130 | 351.07 | 2.70 | 2.70 | 83.43% | <0.01 |
| Analysis among populations | | | | | | | |
| Populations | Variance among populations | 6 | 77.26 | 12.88 | 0.53 | 16.47% | <0.001 |
| | Variance within populations | 130 | 351.07 | 2.70 | 2.70 | 83.53% | <0.001 |

[1] df: degree of freedom.
[2] SSD: sum of square.
[3] MSD: mean square.

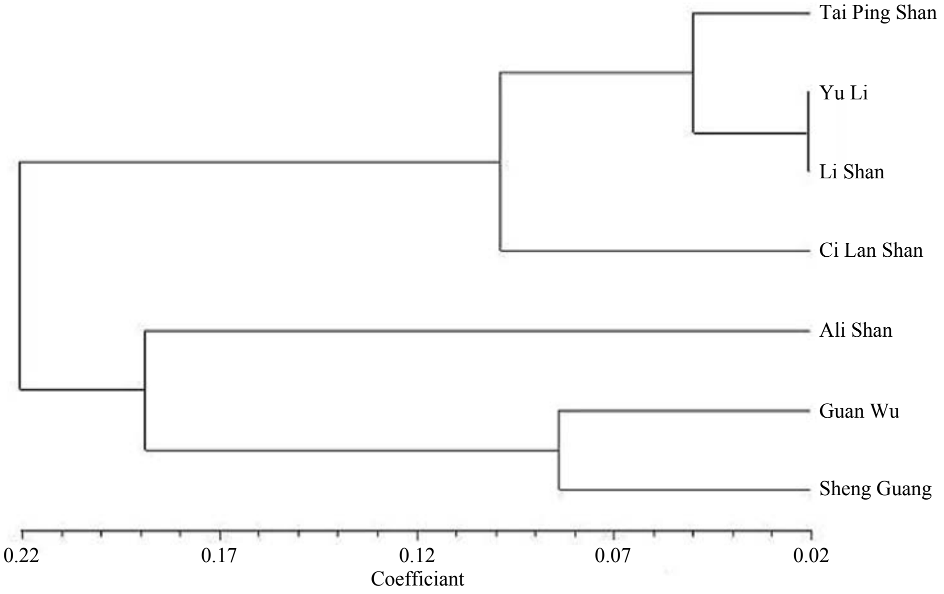

**圖 2.** 台灣檫樹歸群分析(UPGMA)之樹狀圖。

**Fig. 2.** UPGMA dendrogram of 7 populations of *Sassafras randaiense* based on ISSR DNA sequences.

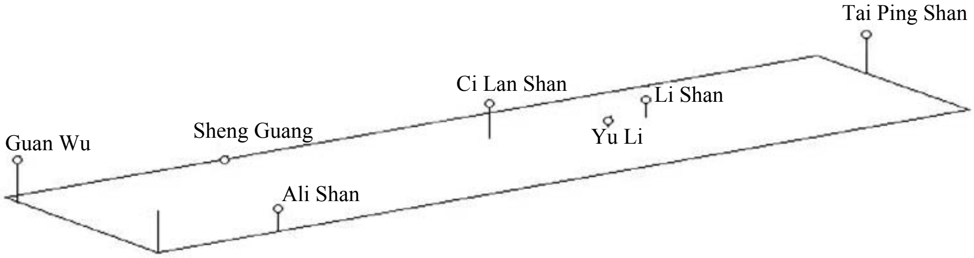

**圖 3.** 台灣檫樹主座標分析之三維座標圖。

**Fig. 3.** Three-dimensional principal coordinate analysis among 7 populations of *Sassafras randaiense* based on the ISSR DNA sequences.

若以地區族群所分布之山系進行三級變異分析結果，則山系變異成分是 0.55% ($p<0.237$)，族群山系間之變異成分是 16.02% ($p<0.01$)，山系內的變異成分是 83.43% ($p<0.01$)。若僅就所有地區族群間、族群內個體間之二級變異影響，則族群間之變異成分是 16.47% ($p<0.0001$)，族群內的變異成分是 83.53% ($p<0.0001$)，顯示族群大部分變異仍存在於各地區之族群內(表 4)。

地區族群歸群分析建立樹狀圖，經比對遺傳距離矩陣與相似度矩陣所得之協表相關係數(cophenetic correlation coefficient, r)爲 0.76008，顯示此歸群圖尚未扭曲表現眞實群團關係，歸群圖(圖 2)遺傳距離座標值介於 0.02 到 0.22 之間，在距離 0.14 的地方可以大致將族群間呈現出 3 群團，顯示無地理分布關聯，第一群包括太平山、花蓮、棲蘭山及梨山共 4 個族群；第二群僅有阿里山族群；第三群觀霧、勝光 2 個族群。再由主座標分析結果來比較族群間之關係，座標圖族群間之地理關係亦不明顯(圖 3)。

## 討論

台灣檫樹各地區天然林之族群經遺傳變異分析結果(Popgene)，族群 Nei's 基因歧異度(H=0.3438)與同樣應用 ISSR 分析研究之台灣特有種玉山杜鵑 (*Rhododendron pseudochrysanthum* Hayata) 基因歧異度爲 0.3371 (鄭 2003)、刺柏(*Juniperus formosana* Hayata)基因歧異度爲 0.3536 (蔡 2004)、及唐杜鵑(*R. simsii* Planch.)族群基因歧異度爲 0.3423 (陳 2005)等相當，亦與大陸瀕危二色胡枝子(*Lespedeza bicolor*)之基因歧異度 0.392 (趙等 2007)相當，推測本種與上述原生植物等同具高度之遺傳歧異度現象。台灣檫樹各地區天然林族群之歧異度值從 0.0877 至 0.4038 間，以棲蘭山族群具有最高之歧異度(0.4038)，而阿里山族群最低(0.0877)，顯示各地區族群具高度遺傳歧異度現象。本種分布於中低海拔區域之崩塌地，爲次生演替先驅種之生態特性，隨著人爲森林開發，各族群受干擾之影響使其遺傳變異發生，一如 Li *et al*. (2002)研究所指出特有種、瀕危植物具較高之遺傳多樣性一般；同時，其受環境變異、繁殖限制、先驅者效應或冰河期殘存等因素(Ranker 1994; Li and Ge 2002)，亦促使族群具有較高之遺傳多樣性。

此外，台灣檫樹族群的遺傳分化係數(Gst)爲 0.2788，族群間的遺傳變異占總變異量的 27.88%，其族群間遺傳分化高於 Hamrick *et al*. (1992)在 220 屬中之 662 種林木中所研究之遺傳分化平均水平(Gst=0.129)。Buso *et al*. (1987)認爲分化指數介於 0-0.05 代表種間分化弱，0.05-0.15 表示中等分化，大於 0.25 則分化明

顯；同時與其他應用 ISSR 研究族群遺傳分化相比，如水柳族群之遺傳分化(Gst)爲 0.1820 (蔡 2001)，玉山杜鵑遺傳分化(Gst)爲 0.2659 (鄭 2003)，顯見台灣檫樹在族群的遺傳分化相當明顯。

階層性遺傳變異分析顯示各地區族群不因分布於中南、北部地理位置之影響，主要變異仍存在於地理位置內的各地區族群內。同時，地區族群所分布之山系關係，顯示族群變異受山系影響不大，大部分變異仍存在於各地區族群內。因此，就所有地區族群間、族群內個體間之變異影響，則族群變異成分大都存在於各地區族群內，顯示其族群變異主要來自於各地區族群內。鄭 (2003)研究台灣特有的玉山杜鵑其族群間的變異成分占 24.92%，族群內個體間爲 75.08%；Ge *et al.* (2003)以 ISSR 研究稀有植物四合木(*Tetraena mongolica* Maxim.)其變異成分 15.2%存在於族群間，84.8%存在於各地區族群內；刺柏遺傳變異之變異成分 22.79%存在於族群間，77.03%存在於各地區族群內(蔡 2004)。上述族群遺傳變異之變異成分顯示其族群分化之傾向，即本種如玉山杜鵑、四合木及與刺柏等族群自然分布之族群，大部分變異存在各地區族群內，此印證了台灣檫樹各地區族群之遺傳變異分析結果，族群具有較高之遺傳多樣性與分化明顯之現象。

一般植物之族群分化起源有多種模式，如隨環境梯度變化而形成漸變模式，或者是不同生態環境造成分化，或地理距離的隔離，或者不同族群發育歷程所造成分化等(Sokal and Oden 1978)；由台灣檫樹族群遺傳變異矩陣與各地區族群地理距離矩陣之關聯測驗結果未達顯著相關，反映其遺傳變異可能不隨環境梯度變化而變異，即本種天然分布於中、高海拔區域內，可見於砍伐跡地、火燒跡地、造林地初期及次生林先驅角色，即各地族群間適應生育地之表現，推測其族群變異非連續性變異，而是來自生育地各別適應影響，即生育地環境差異所產生分化趨勢。此現象亦符合其歸群分析結果，所顯示各地區族群間並無地理分布之關聯，同時主座標分析之座標圖亦顯示族群間地理關係亦不明顯(圖 3)。目前台灣檫樹分布於中高海拔區域，隨著人爲森林開發破壞，加上其崩塌地先驅種之生態特性，使其遺傳變異持續發生，維持了較高遺傳多樣性與分化明顯之現象。本研究顯示族群遺傳變異主要來自地區族群內，然而各地區族群受植群自然演替後，生育環境之不利其天然更新影響，又因本種與台灣特有種蝶類－寬尾鳳蝶之生活史息息相關，在保育策略上建議在自然生育地實施就地保育措施，避免濫伐等人爲干擾，以維持各地區族群之遺傳多樣性。同時，亦可選擇適合生長之崩塌或裸露林地用於移地保育，各族群進行引種育林，以增加族群遺傳交流，擴大種原資源保育。

## 結　論

台灣檫樹族群遺傳變異分析具高度遺傳歧異度與族群分化的遺傳多樣性，族群大部分變異存在於各地區族群內，族群遺傳歸群分析顯示無地理歸群現象，Mantel 測驗結果推演族群變異非連續性變異，而是來自生育環境各別適應之關聯，由於本種天然分布於砍伐跡地、火燒跡地、造林地初期及次生林整理後之林地，適應於林緣或孔隙氣候，各地區族群受植群自然演替後即不利其天然更新影響，顯然生育地環境差異產生族群分化趨勢。

本研究顯示族群遺傳變異主要來自地區族群內，然而，又因本種與台灣特有種蝶類－寬尾鳳蝶之生活史息息相關，在保育策略上建議在自然生育地實施就地保育措施，避免濫伐等人爲干擾，以維持族群遺傳多樣性。同時可選擇移地保育，進行各地區族群引種育林之遺傳交流，擴大種原資源保育。

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# 台灣四種鱧科魚類的檢索與一隻腹鰭變異的線鱧

# A Key to the Species of the Genus *Channa* (Channidae: Teleostei) of Taiwan with Description of a Ventral Fin Abnormal Specimen of *Channa striata* (Bloch, 1793)

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## 摘　要

我們詳細的檢視目前保存在國立自然科學博物館(NMNS)及農委會特有生物研究保育中心(ESRI)的鱧科鱧屬 *Channa* (Channidae: Teleostei)魚類標本，並提出台灣現生 4 種鱧科鱧屬魚類檢索表以供參考。根據標本，台灣現生的 4 種鱧屬魚類分別爲 *Channa asiatica* (Linnaeus, 1758)、*Channa maculata* (Lacepede, 1802)、*Channa striata* (Bloch, 1793)及 *Channa micropeltes* (Cuvier, 1831)。其中 1 隻採集於花蓮縣，目前保存於特生中心，外部缺乏腹鰭的標本(HABF-00545, 179 mm SL)，經重新檢視後判定是腹鰭缺陷且背鰭鰭條數變異的 *C. striata*，並非早先被鑑定的 *C. asiatica*。

## Abstract

We examined the specimens of the snakeheads belonging to the genus *Channa* (Channidae: Teleostei) deposited at the National Museum of Natural Science (NMNS) and Endemic Species Research Institute (ESRI). Four species were identified. They were *Channa asiatica* (Linnaeus, 1758), *Channa maculata*

(Lacepede, 1802), *Channa striata* (Bloch, 1793) and *Channa micropeltes* (Cuvier, 1831), representing all currently known snakehead fishes in Taiwan, Also, we found a snakehead specimen (standard length, 179 mm) collected from Hualien in the ESRI collections (HABF-00545), whose taxonomic status was uncertain but it is more closely resemble to *C. striata* that has pelvic fins than *C. asiatica* that has no pelvic fins. This paper briefly describes this abnormal specimen, compared it with the known species, and presents a key to the species of the genus *Channa* of Taiwan for further investigation.

**關鍵詞：**線鱧、七星鱧、斑鱧、小盾鱧、鱧科

**Key words:** *Channa striata, C. asiatica, C. maculata, C. micropeltes*, Channidae

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## 緒言

根據研究報告、專書或網路上的資料庫等，台灣的鱧科魚類在種類鑑定上顯得相當紊亂。台灣第 1 次的鱧科魚類報導在 1902 年，當時依據腹鰭的有無被分爲具有腹鰭的 *Ophicephalus* 及不具有腹鰭的 *Channa* 兩個屬，3 個種 *Ophicephalus maculata* (Lacepede, 1802)、*O. tadianus* (Jordan and Evermann, 1902)及 *Channa formosana* (Jordan and Evermann, 1902)。後來 *O. tadianus* 被認爲是 *C. maculata* 的同種異名。

Myers and Shapovalov (1931)根據 1 隻採集於台灣且沒有腹鰭的鱧科魚類，而認爲腹鰭的有無可能只是變異，*Ophicephalus* 應該被併入到 *Channa*，並將這 1 隻沒有腹鰭的鱧科魚類鑑定爲 *Channa gachua* (Hamilton, 1822)，不過並沒有留下標本，*C. gachua* 在台灣出現的紀錄也只有 1931 年這一次。同時他們也根據一些特徵認爲 *C. formosana* (Jordan and Evermann, 1902)是 *C. asiatica* 的同種異名。

目前在台灣野外紀錄有 4 種鱧科魚類，分別爲 *C. asiatica*、*C. maculata*、*C. striata* 及 *C. micropeltes*。其中的 *C. asiatica* 及 *C. maculata* 是 1902 年就出現在台灣的鱧科魚類；*C. micropeltes* 在台灣被發現的年代約爲 1995 年(張及蔡 2004)；另外，根據標本(HABF-1652, 178.2 mm SL)，*C. striata* 出現在台灣的紀錄至少可追溯至 1983 年。

我們認爲台灣的鱧科魚類在鑑種時發生困擾的原因如下：一、中文俗名與學名的不當連結，例如中文俗名「Kotai」，其實泛指 *C. asiatica* 及 *C. striata*；「魚虎」泛指 *C. maculata*、*C. striata* 或 *C. micropeltes*。二、腹鰭的有無是否爲鱧科魚類鑑種上的穩定形質，未能受到重視。三、早期學術界對於台灣已出現 *C. striata* 的敏銳度不足，許多的 *C. striata* 被鑑定爲 *C. maculata*。基於上述幾點原因，本文經詳細檢視目前保存在國立自然科學博物館及行政院農業委員會特有生物研究保育中心(以下簡稱特生中心)的鱧科魚類標本後，提出台灣產鱧科鱧屬魚類檢索表以供後續之研究，並訂正 1

隻目前保存在特生中心，缺乏腹鰭的鱧科魚類標本。

## 材料與方法

本文所計數及進行形質測量的鱧科魚類標本共 15 隻，其中 5 隻現存於國立自然科學博物館，7 隻現存於特生中心，包括主要的研究標本HABF-00545；另外 3 隻標本分別保存於國立北門高級中學及嘉義縣自然史教育館。標本測量形質(morphometric characters)使用游標卡尺精確測量至 0.1 mm，並以標準體長(standard length, SL)的百分比表示。詳細的標本資料見表 1。

## 結果與討論

本研究所檢視的鱧科魚類標本形質結果如表2所示。*C. striata*、*C. maculata* 或 *C. micropeltes* 均具有 1 對腹鰭，而 *C. asiatica* 不具有腹鰭；*C. asiatica* 的喉膜(opercula stretched)呈 U 字形，而 *C. striata*、*C. maculata* 或 *C. micropeltes* 則呈現 V 字型(圖 1)，Vishwanath and Geetakumari (2009)也認為喉膜的型式是鑑別鱧科魚類的重要依據，特別是應用在鑑別 *C. striata* 及 *C. gachua* 上；*C. micropeltes* 的喉部(gular portion)具有鱗片，而 *C. asiatica*、*C. striata* 及 *C. maculata* 沒有鱗片(圖 1)。Musikasinthorn and Taki (2001)的報告指出喉部具有鱗片的鱧科魚類共有 7 種，包括 *C. micropeltes*，並據此訂正 *Channa siamensis* (Gunther, 1861)應該是屬於 *Channa lucius* (Cuvier and Valenciennes, 1831)的同種異名。側線鱗的部分，*C. striata*、*C. asiatica* 或 *C. maculata* 的側線鱗數介於 54-61 個，明顯少於 *C. micropeltes* 的 92 個；*C. maculata* 的側線屬於完全但是不連續，其側線鱗列於臀鰭起點上方中斷，由中斷處下兩行鱗片再出現並延伸至尾柄末端。依據上述外部形質及特徵，建立台灣產鱧科鱧屬魚類檢索表如下：

### *Channa micropeltes* (Cuvier, 1831)

**Synonyms:** *Ophicephalus micropeltes* Cuvier, 1831; *Ophicephalus bivittatus* Bleeker, 1845; *Ophiocephalus stevensii* Bleeker, 1853; *Ophiocephalus diplogramma* Day, 1865; *Ophicoephalius studeri* Volz, 1903

### *Channa maculata* (Lacepede, 1802)

**Synonyms:** *Bostrychus maculates* Lacepede, 1801; *Ophicephalus guentheri* Sauvage and Dabry de Thiersant, 1874; *Ophicephalus lucius* Koller, 1927; *Ophicephalus tadianus* Jordan and Evermann 1902; *Ophiocephaus marmoratus* Brind, 1914

### *Channa asiatica* (Linnaeus, 1758)

**Synonyms:** *Gymnotus asiaticus* Linnaeus, 1758; *Channa ocellata* Peters, 1864; *Channa fasciata* Steindachner, 1866; *Channa sinensis* Sauvage, 1880; *Channa orientalis* Karoli, 1882; *Channa formosana* Jordan and Evermann 1902

### *Channa striata* (Bloch, 1793)

**Synonyms:** *Ophicephalus striatus* Bloch, 1793; *Ophiocephalus wrahl* Lacepede, 1801; *Ophiocephalus chena* Hamilton, 1822; *Ophiocephalus vagus* Peters, 1868; *Ophiocephalus philippinus* Peters, 1868

## 台灣產鱧科鱧屬魚類檢索表

## A key to the species of *Channa* (Channidae) from Taiwan

**1a.** 喉部具有鱗片.......... 小盾鱧 *C. micropeltes*
(Gular portion with small scales.......... *C. micropeltes*)
**1b.** 喉部沒有鱗片.......... 2
(Gular portion without small scales.......... 2)
**2a.** 側線鱗不連續.......... 鱧魚 *C. maculata*
(Lateral line scales discontinuous.......... *C. maculata*)
**2b.** 側線鱗連續.......... 3
(Lateral line scales continuous.......... 3)
**3a.** 缺乏腹鰭，喉膜呈U字形，臀鰭鰭條數 27-33.......... 七星鱧 *C. asiatica*
(Pelvic fin absent, U-shaped sharp isthmus, anal fin rays 27-33.......... *C. asiatica*)
**3b.** 具腹鰭一對，喉膜呈V字形，臀鰭鰭條數 25-27.......... 線鱧 *C. striata*
(Pelvic fin present, V-shaped sharp isthmus, anal fin rays 25-27.......... *C. striata*)

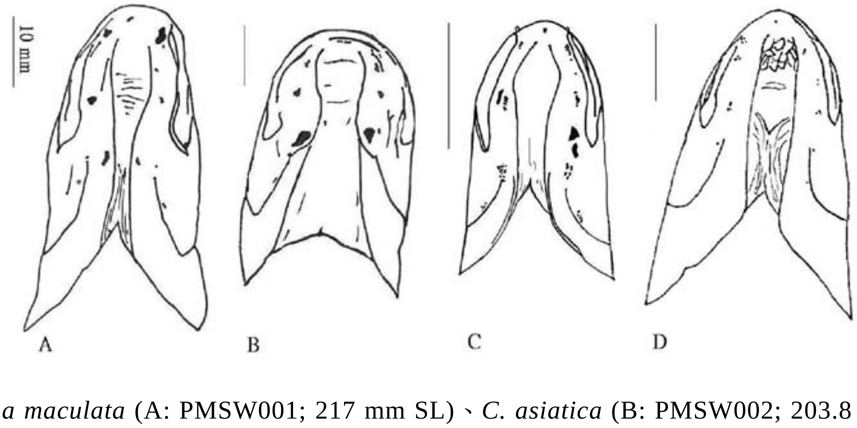

**圖 1.** *Channa maculata* (A: PMSW001; 217 mm SL)、*C. asiatica* (B: PMSW002; 203.8 mm SL)、*C. striata* (C: F000693; 107.5 mm SL) 及 *C. micropeltes* (D: HABF-2217; 199.3 mm SL)的喉部圖示。*C. asiatica* 的喉膜呈現 U 字形；*C. micropeltes* 的喉部可見鱗片。

**Fig. 1.** Ventral views of the heads of *Channa maculata* (A: PMSW001; 217 mm SL), *C. asiatica* (B: PMSW002; 203.8 mm SL) showing U-shaped isthmus between opercula, *C. striata* (C: F000693; 107.5 mm SL), and *C. micropeltes* (D: HABF-2217; 199.3 mm SL) showing small scales on the gular area.

**表 1.** 鱧屬(genus *Channa*)魚類引證標本

**Table 1**. Specimens of the genus *Channa* examined

| Specimen no. | Locality | Deposited | Standard length (mm) | Collected data | Original named | Checked |
|---|---|---|---|---|---|---|
| HABF-00545 | Matai-an River, Hualien, Taiwan | Endemic Species Research Institute | 179 | 2001/10/16 | *C. asiatica* | *C. striata* |
| HABF-1652 | Heng River, Taipei, Taiwan | Endemic Species Research Institute | 178.2 | 1983/10/ | *Channa* sp. 泰國鱧魚 | *C. striata* |
| HABF-00315 | Puzi River, Chiayi, Taiwan | Endemic Species Research Institute | 151.1 | 2001/2/22 | *C. maculata* | *C. striata* |
| HABF-00387 | Bazhang River, Chiayi, Taiwan | Endemic Species Research Institute | 233 | 2001/12/27 | *C. maculata* | *C. striata* |
| F00693 | Wu River, Taichung, Taiwan | National Museum of Natural Science | 107.5 | 2004/8/26 | *C. striata* | *C. striata* |
| F00760 | Jinshan, Taipei, Taiwan | National Museum of Natural Science | 96.1 | 2004/9/5 | *C. striata* | *C. striata* |
| PMSW001 | Tainan, Taiwan | National Pei-men Senior High School | 203.8 | >1967 | * | *C. asiatica* |
| HABF-1642 | Danshui River, Taipei, Taiwan | Endemic Species Research Institute | 178 | 1983/10/ | *C. asiatica* | *C. asiatica* |
| F00003 | Dajia River, Taichung, Taiwan | National Museum of Natural Science | 215.2 | 1990/2/21 | *C. asiatica* | *C. asiatica* |
| F00066 | Dou-an, Guangxi, China | National Museum of Natural Science | 196.8 | 2002/10/8 | *C. asiatica* | *C. asiatica* |
| HABF-2164 | Dawo River, Miaoli, Taiwan | Endemic Species Research Institute | 154.5 | 2005/9/15 | *C. asiatica* | *C. asiatica* |
| PMSW002 | Jiali, Tainan, Taiwan | National Pei-men Senior High School | 217 | 1963/5/6 | *Ophiocephalus tadianus* | *C. maculata* |
| NMNSCY005 | Chiayi, Taiwan | Chiayi Natural History Education Museum | 114.2 | 1985-1987 | * | *C. maculata* |
| F00062 | Dou-an, Guangxi, China | National Museum of Natural Science | 153.5 | 2002/10/8 | *C. maculata* | *C. maculata* |
| HABF-2217 | Cengwen Reservoir, Taiwan | Endemic Species Research Institute | 199.3 | 2006/1/1 | *C. maculata* 小盾鱧 | *C. micropeltes* |

* no data.

**表 2.** 標本 HABF-00545 與 4 種鱧科魚類的形質比較

**Table 2.** A comparison of morphological characters among *Channa striata*, *C. asiatica*, *C. maculata* and *C. micropeltes*

| Characters | HABF-00545<br>179 mm SL | *C. striata* n=5<br>96.1-233 mm SL | *C. asiatica* n=5<br>154.5-215.2 mm SL | *C. maculata* n=3<br>114.2-217.0 mm SL | *C. micropeltes* n=1<br>199.3 mm SL |
|---|---|---|---|---|---|
| Dorsal fin rays | 39 | 43-45 | 43-47 | 44-45 | 44 |
| Pectoral fin rays | 16 | 15-17 | 15-17 | 17-18 | 18 |
| Anal fin rays | 26 | 25-27 | 27-33 | 29 | 29 |
| Pelvic fin rays | * | 6 | * | 6 | 6 |
| Lateral scale rows | 63 | 56-61 | 54-61 | 55-58 | 92 |
| Scale row on cheek | 9 | 9-10 | 9-10 | 14-16 | 22 |
| In % of standard length: | | | | | |
| Body depth | 14.19 | 15.71 - 17.70 | 15.33 - 19.21 | 18.76 - 20.37 | 29.40 |
| Head depth | 31.68 | 29.91 - 32.94 | 24.88 - 27.44 | 32.81 - 34.27 | 41.19 |
| Snout length | 5.41 | 5.20 - 6.14 | 4.98 - 5.50 | 5.21 - 5.85 | 7.38 |
| Orbit diameter | 4.22 | 3.48 - 5.67 | 3.24 - 3.95 | 3.55 - 5.25 | 5.02 |
| Interorbital width | 7.73 | 6.95 - 7.68 | 6.87 - 7.98 | 6.41 - 7.09 | 10.94 |
| Upper jaw length | 13.26 | 10.30 - 12.93 | 9.19 - 11.25 | 12.31 - 13.05 | 13.85 |
| Dorsal fin base length | 60.70 | 57.17 - 60.61 | 63.48 - 71.24 | 55.50 - 60.28 | 63.67 |
| Anal fin base length | 34.62 | 32.99 - 38.80 | 43.09 - 45.19 | 36.73 - 39.58 | 43.85 |
| Pectoral fin base length | 5.15 | 4.16 - 4.74 | 4.85 - 5.22 | 4.50 - 4.73 | 5.12 |
| Pelvic fin base length | * | 2.29 - 3.18 | * | 1.84 - 2.35 | 8.78 |
| Caudal peduncle depth | 10.34 | 7.28 - 9.83 | 9.90 - 11.76 | 10.81 - 12.12 | 13.55 |

* lacks both pelvic fins.

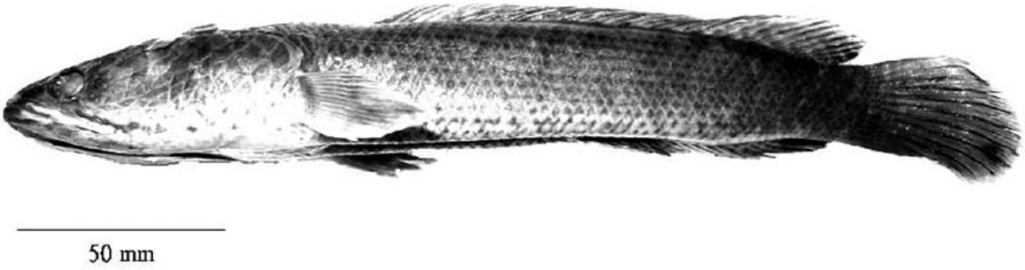

**圖 2.** HABF-00545 (179 mm SL)的標本照。缺乏腹鰭的 *Channa striata*，2001 年 10 月 16 日採集於花蓮縣。

**Fig. 2.** A specimen (HABF-00545; 179 mm SL) of *Channa striata* without pelvic fins, collected from Hualien on 16 October 2001.

我們在建立台灣產鱧科鱧屬魚類檢索表的過程中，發現1隻目前保存於特生中心，2001年採集於花蓮縣的鱧科魚類標本 (HABF-00545; 圖2)，其喉部不具有鱗片，側線鱗列完全且連續，缺乏腹鰭，而其背鰭鰭條數少於本研究所檢視的 *C. striata* 或 *C. asiatica*，形質請參照表2。雖然這隻標本在腹鰭的相對位置無任何鰭條狀的構造，但腹鰭基部呈現對狀突起且無鱗片覆蓋，顯然與 *C. asiatica* 腹面由鱗片緊密覆蓋而光滑的類型有所不同，而HABF-00545的喉膜呈V字形，此亦與 *C. asiatica* 的喉膜呈U字形的類型不同，因此判定這隻標本應爲 *C. striata* 的變異。

近年來，在野外採集人力及頻度大幅增加的情況下，1931 年採集於台灣且被鑑定爲缺乏腹鰭的 *C. gachua* 已近80年沒有再被採獲的紀錄。另外，*C. gachua* 具有腹鰭(Courtenay *et al*. 2004; Froese and Pauly 2009)，因此可以推論，1931年出現在台灣而沒有腹鰭的 *C. gachua* 可能只是 *C. maculata* 或 *C. striata* 的變異型，而 *C. striata* 也確實有被誤認爲 *C. gachua* 的報導(Ng and Lim 1990)。

台灣的 *C. asiatica* 及 *C. maculata* 被認爲僅分布於台灣西部及東北部的宜蘭縣，東部的花蓮及台東兩縣並沒有採集紀錄(陳及方1999)。目前，花蓮縣及台東縣所發現的鱧科魚類至少有3筆紀錄，且種類均爲 *C. striata*，其中1筆爲本研究所使用，採集於花蓮縣的標本(HABF-00545)；另2筆紀錄皆位於台東縣，分別爲1996-2001年採集於台東縣馬武窟溪(蔡 2006)及1994年採集於台東縣成功鎭的標本(FRIP20322)，該標本目前保存於水產試驗所東部海洋生物研究中心。

由本研究所建立的台灣產鱧科鱧屬魚類檢索，對於台灣鱧科魚類在分類及種之鑑別提供良好依據，然而對於個別之變異應更詳加判別。鱧科魚類外部形質的變異不僅發生在腹鰭，背鰭、胸鰭或脊椎骨均曾發現變異的情形，發生變異的種類亦呈多樣化，Ng and Lim (1990)認爲許多鱧科魚類鰭部的變異可能是因爲外傷或疾病所導致，並非遺傳，這個部分可以經由繁殖試驗得到証實。另外，Ng and Lim (1990)舉 *Channa orientalis* Schneider, 1801 (缺乏腹鰭)及 *C. gachua* 爲例，認爲早期的報告因爲對於種類的不熟悉，導致同一種被認爲有兩型。Yazdani and Chanda (1971)報導了2隻變異的 *Channa stewartii* (Playfair, 1867)，其背鰭分別缺少第6及第8鰭條，而造成背鰭的缺刻，而背鰭缺少第8鰭條的標本，同時也缺少腹鰭。另外，Arockiaraj *et al*. (2004)也曾報導可能受到環境污染而導致脊椎骨數有變異的 *Channa punctata* (Bloch, 1793)及 *C. striata*。根據一些既有的標本，台灣的高屏溪也曾採獲右側胸鰭缺乏的 *C. maculata*；中國大陸的廣西省也採獲缺乏單側腹鰭的 *C. maculata*。鱧科魚類變異的發生原因，實有待進一步探討。

## 謝誌

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   Baker, C. S., F. Cipriano and S. R. Palumbi. 1996. Molecular genetic identification of whale and dolphin products from commercial markets in Korea and Japan. Molecular Ecology 5: 671-685.

   For books and symposiums:

   Soule, M. E. and B. A. Wilco. 1980. Conservation biology: An evolutionary-ecological approach. Sinauer Associates, Sunderand, Massachusetts.

   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, China.
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