# 目 錄



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台灣生物多樣性研究
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# 台灣生物多樣性研究

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**封面圖說／**
赤背松柏根(Oligodon formosanus)利用特化的上頷齒劃開鳥蛋，留下像開罐器開過的缺口蛋殼，是判定鳥巢天敵的重要線索。（池文傑 攝）


# 台灣生物多樣性研究

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## 摘　要

「2010 愛知生物多樣性目標」確立之後，可快速瞭解廣時空尺度生物多樣性現況的「公民科學」應運而生。我國雖然已對繁殖鳥設計妥善的監測系統，全國冬季鳥類的監測仍相當缺乏。爲此，本研究參考美國聖誕節鳥類調查，設計「台灣新年數鳥嘉年華」監測我國冬季的鳥類相。2013 年底至 2014 年初的 16 天內，由 598 名志工於全國 122 個半徑 3 km 的樣區圓內執行鳥類調查，共記

錄 292 種鳥。就鳥種豐富度及鳥類豐度而言，龍鑾潭、南澳、西南沿海及蘭陽平原爲重要的熱點。顯示常見的冬候鳥種類不多但族群量相當龐大。緯度遷徙的候鳥，大多以濕地、草原及淺山爲主要棲地，可能使此類環境成爲我國冬季的鳥類熱點。首年的資料尚無法瞭解族群變化，但是可先瞭解我國冬季鳥類的分布及群聚組成。未來將持續執行冬季鳥類監測，並嘗試與東亞各國共同監測東亞-澳洲遷徙線的候鳥。

# Abstract

After Aichi Biodiversity Targets was released in 2010, citizen science projects that reveal the status of biodiversity in broader spatial-temporal scale increased rapidly. In Taiwan, there are some monitoring systems for breeding bird, but not for wintering avifauna. Based on the principles of Christmas Bird Count, we designed a "New Year Bird Count, Taiwan" to monitor the wintering avifauna. From Dec 28$^{th}$, 2013, to Jan 12$^{th}$, 2014, 598 volunteers contributed to this survey in 122 circle sample areas (3 km in diameter). Two hundred and ninety-two species were recorded. For bird species richness and abundance, Longluan Lake, Nan'ao, Southwest coastal and Lanyang plain were the important hotspots, indicating low diversity but high abundance of common wintering specie. Major habitats of these wintering species were wetlands, grasslands and lowland forests, which may be avifauna hotspots in winter. We were unable to elaborate on the population trend from the first-year data alone. However, the data provides valuable information about the distribution and the community composition of the avifauna in winter. This project will continue to be conducted with an attempt to cooperate with countries in East Asia to monitor migrants in East Asia-Australia Flyways.

**關鍵詞**：聖誕節鳥類調查、公民科學、遷徙、台灣、冬候鳥

**Key words:** Christmas Bird Count, citizen science, migration, Taiwan, wintering bird species

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## 緒 言

2010 年，生物多樣性公約(Convention on Biological Diversity, CBD)第 10 屆締約國大會(10$^{th}$ Conference of the Parties, COP10)檢視「2010 生物多樣性目標(2010 Biodiversity Targets; Secretariat of the Convention on

Biological Diversity 2006)」的執行成效。會後，全球生物多樣性展望第三版(Global Biodiversity Outlook 3) 指出，大多數締約國並未達成 2010 生物多樣性目標 (Secretariat of the Convention on Biological Diversity 2010a)。雖然國際上對於生物多樣性保育的態度日漸積極，部分保育成效呈正向發展，但是生物多樣性的流失仍未減緩，仍需全球共同努力(Butchart *et al.* 2010)。

爲此，生物多樣性公約秘書處設定更嚴格的新十年目標「愛知生物多樣性目標(Aichi Biodiversity Targets)」作爲 2010 年至 2020 年的保育工作審視標準(Secretariat of the Convention on Biological Diversity 2010b)，要求各締約國至遲於 2020 年之前達成。生物多樣性公約秘書處與聯合國環境規劃署(United Nations Environment Programme, UNEP)結合各國相關組織，組成「生物多樣性指標夥伴關係(Biodiversity Indicators Partnership, BIP)」。主要針對愛知生物多樣性目標的內容，設計適當的指標，作爲評估政策、經營管理策略以及長期監測的主要客體(2010 Biodiversity Indicators Partnership 2010)。

許多調查指出，東亞-澳洲遷徙路線(East Asia-Australia flyways)上，候鳥的數量大致呈現下降的趨勢(Delany and Scott 2006; Goriup and Tucker 2007; Kirby *et al.* 2008; Nebel *et al.* 2008)。東亞-澳洲遷徙路線的候鳥共有 728 種，其中 98 種爲受脅物種(threatened)和近危物種(near threatened)，約占 14% (Kirby *et al.* 2008)。其中，水鳥中約有 62%的物種的族群量顯著下降，僅有 10%呈現增加的趨勢(Delany and Scott 2006)。Nebel *et al.* (2008)於長達 24 年間的長期水鳥監測成果指出，水鳥的遷徙族群大幅下降 79%。51 種遷徙性猛禽中，17 種(33%)的族群量呈現下降的趨勢(Goriup and Tucker 2007)。

瞭解一個地區的生物多樣性現況及變化，往往需要大空間尺度及長時間的監測，蒐集並有效整合、運用大量的資料(Hochachka *et al.* 2012)。此類研究需投入大量的人力、時間及財援，不易由研究人員獨立完成，於是公民科學(citizen science)研究便應運而生(Irwin 1995; Bonney *et al.* 2009; Sullivan *et al.* 2009; Dickinson *et al.* 2010)。公民科學是指以參與民眾爲主要的資料蒐集者，與研究人員共同蒐集可供分析的資料。以公民科學機制容易獲得廣時空尺度及同步性高的資料，同時提昇參與民眾的科學知識，兼具研究及教育價值(Bonney *et al.* 2009; Dickinson *et al.* 2010)。以公民科學爲機制所執行的計畫已經廣泛應用於天文學(Lintott *et al.* 2008)及環境及生物多樣性監測(如聖誕節鳥類調查 Christmas Bird Count; Smith 2012；英國繁殖鳥類調查 United Kingdom’s Breeding Bird Survey; Risely *et al.* 2008)。

我國目前長期執行的公民科學研究中，「台灣繁殖鳥類大調查(Breeding Bird Survey, Taiwan; BBS Taiwan; 柯等 2013)」及「台灣鳥類繁殖力及存活率監測(The Monitoring Avian Productivity and Survivorship program, Taiwan; MAPS Taiwan; 宋等 2012 )」皆以繁殖鳥爲主要的監測對象。關於我國的鳥類海拔分布研究，也大多以繁殖鳥類爲主要對象 (丁 1993; Ding 2001; 許 2004; Lee *et al.* 2004; 黃 2010)，全國性的冬季鳥類相調查及候鳥的海拔分布相關研究較缺乏。以國家保育責任(national responsibility of conservation; Schmeller *et al.* 2014)的觀點來看，就鳥類而言，我國保育責任最重要的是特有種和特有亞

種，接著依序繁殖鳥、冬候鳥、過境鳥及迷鳥。目前我國對鳥類的研究及監測已經步上軌道，應著手建立冬候鳥及冬季鳥類相的監測系統。

本研究參考美國聖誕節鳥類調查的執行原則，以冬季鳥類為監測對象，設計公民科學活動「台灣新年數鳥嘉年華」。於 2013 年末至 2014 年初的 16 天內，以公民科學方式於 122 個面積相同樣區圓內執行同步性高的鳥類調查。藉此瞭解：(一)我國冬季時留鳥及冬候鳥的群聚組成；(二)冬季時留鳥及冬候鳥的鳥種豐富度及豐度的分布。

## 材料與方法

### 調查範圍

台灣新年數鳥嘉年華以公民科學為主要的調查原則，由自願者擔任調查樣區負責人，(活動中稱為「鳥老大」)。樣區負責人於我國所轄行政區域內，自由選擇一定點，調查範圍以此點之座標為圓心，以半徑 3 km 畫圓所得之範圍，稱為樣區圓。樣區負責人須於調查活動開始前向中華民國野鳥學會登記，並充分瞭解台灣新年數鳥嘉年華的操作方法與注意事項，始可成為納入分析之樣區圓。若遇樣區圓範圍重疊的狀況，中華民國野鳥學會將協助調整圓心位置。2014 年共計有 122 個樣區圓，如圖 1。

### 調查期間

調查期間為國曆 1 月 1 日前 1 個星期六至 1 月 1 日後的第 2 個星期日。依此原則，2014 年的活動期間為 2013 年 12 月 28 日至 2014 年 1 月 12 日，共 16 天，其中包含 7 天假日。樣區負責人於 16 天中任擇一日調查，調查時間須於當日凌晨 0 時至午夜 0 時之間完成，共 24 小時。調查時間至少須涵蓋一天當中的 6 小時。未來各年間的調查日期亦應盡可能接近。

### 調查人員

各樣區圓之調查人員由樣區負責人招募，參與人數無限制。除樣區負責人之外，可獨立執行鳥類調查者稱為「鳥夥伴」，可與樣區負責人分別於樣區圓內的不同地點執行鳥類調查。無法單獨執行鳥類調查者稱為「鳥鄉民」，跟隨樣區負責人或鳥夥伴參與鳥類調查。

### 調查方法

執行調查之前，必須記錄樣區圓名稱、調查日期、調查起始時間、調查結束時間、天氣狀況、風速及參與人數。

天氣狀況分為以下類別：

A：沒有雲或零星幾朵雲

B：部分有雲或雲層多變

C：雲層滿佈或陰天

D：濃霧； E：毛毛雨; F：陣雨

風速則分為以下幾類：

0：無風、樹葉草莖不動，參考風速為 0-0.5 m/s；

1：樹葉、草莖及小枝擺動，參考風速為 1.6-5.4 m/s；

2：塵沙飛揚，小樹幹搖動，參考風速為 5.5-10.7 m/s；

3：大樹搖動，雜物可能被吹倒，參考風速為 >10.8 m/s。

樣區負責人須盡可能完整記錄樣區圓內的鳥類種類及數量。各樣區圓內的地景結構及棲地組成不盡相同，因此，不同的環境及現場狀況分別適用不同的鳥類調查方法。

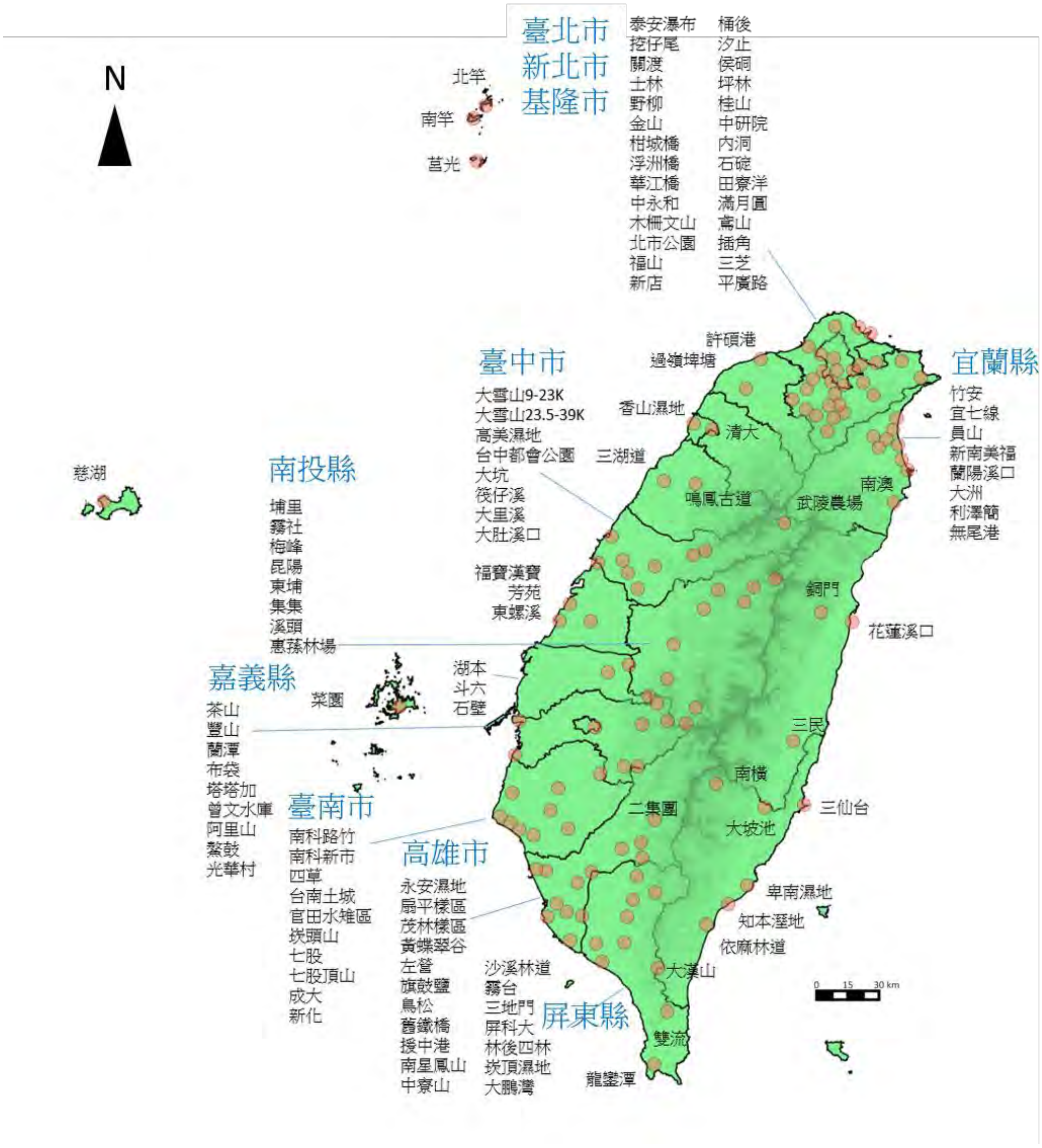


**圖 1.** 2014 台灣新年數鳥嘉年華所有樣區圓分布圖。

**Fig. 1.** Distribution of all circle sample areas in 2014 New Year Bird Count, Taiwan.

一、穿越線法(line transect, Burnham *et al.* 1980)

選定一條固定方向的路線，以固定的速度(約 1-2 km/hr)步行前進，記錄路線兩側目擊與聽見之所有鳥類種類及數量。此方法適用於山區或其他道路系統不密集之處。調查員須記錄調查路線起點及終點之座標。

二、群集計數法(counting flocks)：

樣區圓內視野良好且觀察方向順光的觀察點，以望遠鏡掃視，記錄目視可及範圍內的所有鳥類種類及數量。觀察點之間的距離，約爲調查者輔以望遠鏡可正確辨識鳥種之兩倍距離。例如調查者輔以單筒望遠鏡可正確記錄之距離爲 100 m，則兩觀察點之間的距離略小於 200 m，以避免遺漏鳥類個體。爲避免重複計數，觀察點之間以明顯的標的物作爲界線。此方法適用於河口、溼地、海岸、魚塭等開闊環境，以及鳥類大量聚集之夜棲地。由於群集計數法的紀錄容易受鳥類移動影響，觀察時應特別留意鳥類的移動狀況。若於河口或海岸，水鳥的群聚狀況容易受潮汐的影響，須在滿潮前後兩小時內，水鳥聚集於離岸近處時執行調查(Bibby *et al.* 1992)。若已掌握水鳥避潮的停棲地點，則在停棲地點計數。調查員須記錄調查人員計數時所在位置之座標。

三、地區搜尋法(area search, Ambroses 1989)

在設定的調查範圍區內，調查員可於一定時間內，清查區域內的鳥類種類及數量。由於此方法操作自由度高，容易發現一些隱密性較高之鳥種。此方法適用於範圍界線明確、道路系統發達、範圍涵蓋面積步行可及之處，例如校園、公園及農田等。調查員須回報執行地區搜尋之範圍。

四、附加紀錄

在上述三種方法規劃之區域及時間以外所觀察到的鳥類個體，均歸屬於附加紀錄。

**資料彙算與統計分析**

對於各鳥種分類歸屬的認定、台灣族群的特有性及遷留狀況皆以中華民國野鳥學會鳥類紀錄委員會所發布之「2014 台灣鳥類名錄」爲主要參考依據(蔡等 2014)，未列於該名錄之鳥種，則參考 Clements 世界鳥類名錄 6.7 版所列之分布範圍判斷(Clements *et al.* 2012)。於各鳥種保育等級的認定，則以行政院農業委員會林務局出版之「台灣地區保育類野生動物圖鑑」爲主要參考依據(行政院農業委員會林務局 2010)。地圖採用 Quantum GIS 2.4.0 版製作，分布點分類採 Jenks natural breaks optimization 法分類，使組內差異同質性最高，組間的異質性最高。繪圖軟體則採用 Sigma Plot 12.3 版繪製。

## 結　果

2014 年台灣新年數鳥嘉年華於 16 天內，由 89 位樣區負責人，509 位自願參與者，在涵蓋我國台澎金馬地區的 122 個樣區圓內執行，覆蓋面積將近國土的 1/10。所有樣區圓的分布涵蓋我國的保護區包括：5 個國家公園、1 個國家自然公園、2 個都會公園、2 個自然保留區、9 個野生動物保護區、12 個野生動物重要棲息環境、38 個國家重要溼地及 31 個重要野鳥區域(important bird area, IBA)。活動期間共記錄 292 種鳥，包含 24 種特有種、54 種特有亞種；139 種留鳥、128 種冬候鳥、59 種過境鳥、6 種迷鳥、14 種引進種；包含瀕臨絕種保育類 6 種、珍貴稀有保育類 40 種、其他應予保育類 12 種(附錄 1)。

鳥種豐富度(bird species richness)方面，所有樣區圓的鳥種豐富度的分布如圖 2 (mean = 45.22 , SD = 16.46, n = 122)，其中以龍鑾潭(104 種)、南澳(90 種)及鰲鼓(81 種)爲前三高者。留鳥的鳥種豐富度分布如圖 3a (mean=32.42 , SD = 10.93, n =122)，前三高的樣區圓分別爲曾文水庫(59 種)、龍鑾潭(57 種)及南澳(56 種)。冬

候鳥的鳥種豐富度分布如圖 3b (mean = 13.80 , SD = 11.49, n = 122)，以龍鑾潭最高(50 種)，接著依序爲鰲鼓(47 種)及竹安(41 種)。

豐度(abundance)方面，所有樣區圓的豐度的分布如圖 4 (mean = 1546.51, SD = 2029.88, n = 122)，其中以布袋最高(9,696 隻次)，接著爲竹安(9,260 隻次)和茄萣(7,720 隻次)。留鳥的豐度分布如圖 5a (mean = 900.94, SD = 976.74, n = 122)，前三高的樣區圓依序爲三民(6,505 隻次)、關渡(4,835 隻次)和埔里(3,829 隻次)。冬候鳥的豐度分布如圖 5b (mean = 811.04, SD = 1772.78, n = 122)，前三高的樣區圓依序爲布袋(8,865 隻次)、宜七線(7,287 隻次)和竹安(7,209 隻次)。

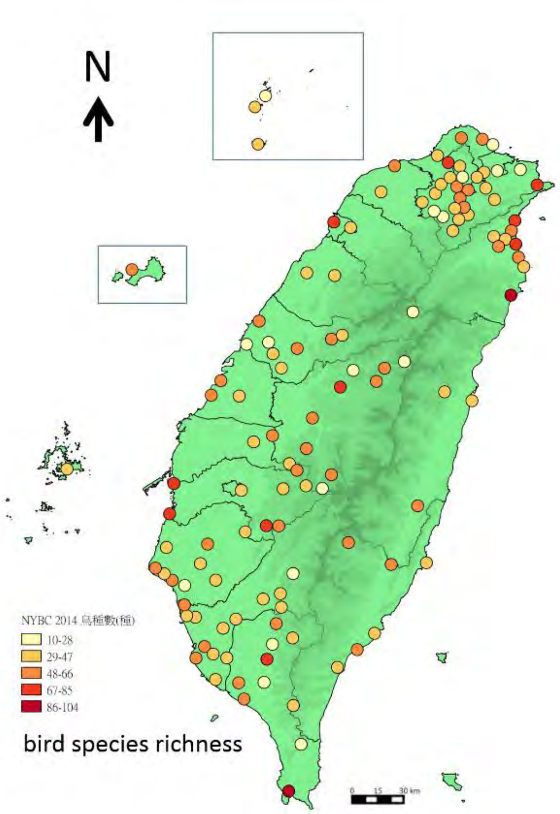


**圖 2.** 2014 台灣新年數鳥嘉年華所有樣區圓鳥種豐富度分布圖，以 Jenk 臨界值法分類。

**Fig. 2.** Distribution of bird species richness of the all circle sample areas in 2014 New Year Bird Count, Taiwan. (classified by Jenk natural break method)

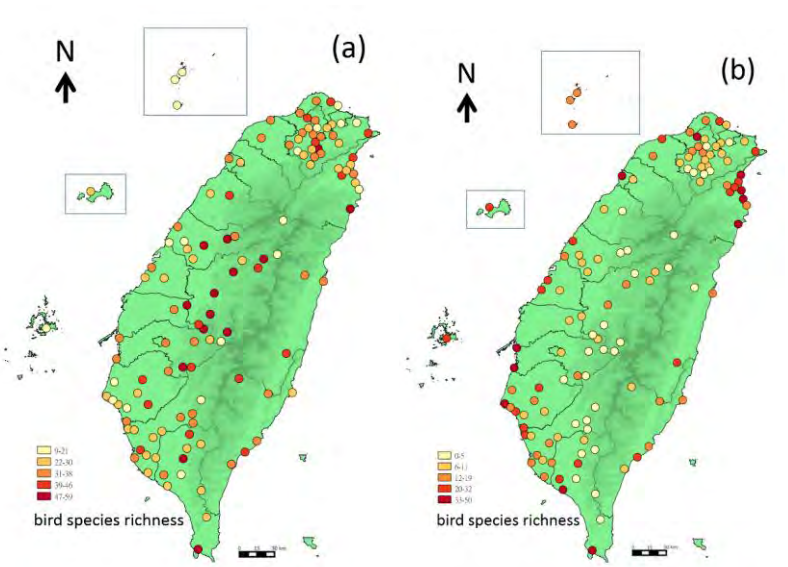


**圖 3.** 2014 台灣新年數鳥嘉年華繁殖鳥(a)及冬候鳥(b)的鳥種豐富度分布圖，以 Jenk 臨界值法分類。

**Fig. 3.** Distribution of bird species richness of breeding bird species (a) and wintering species (b) in 2014 New Year Bird Count, Taiwan. (classified by Jenk natural break method)

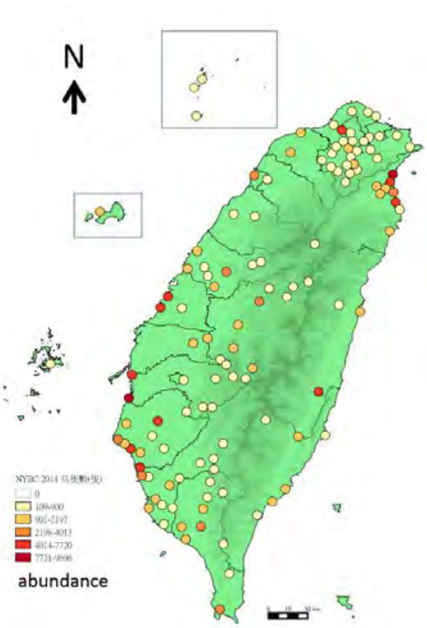


**圖 4.** 2014 台灣新年數鳥嘉年華所有樣區圓的鳥類豐度分布圖，以 Jenk 臨界值法分類。

**Fig. 4.** Distribution of bird abundance of the all circle sample areas in 2014 New Year Bird Count, Taiwan. (classified by Jenk natural break method)

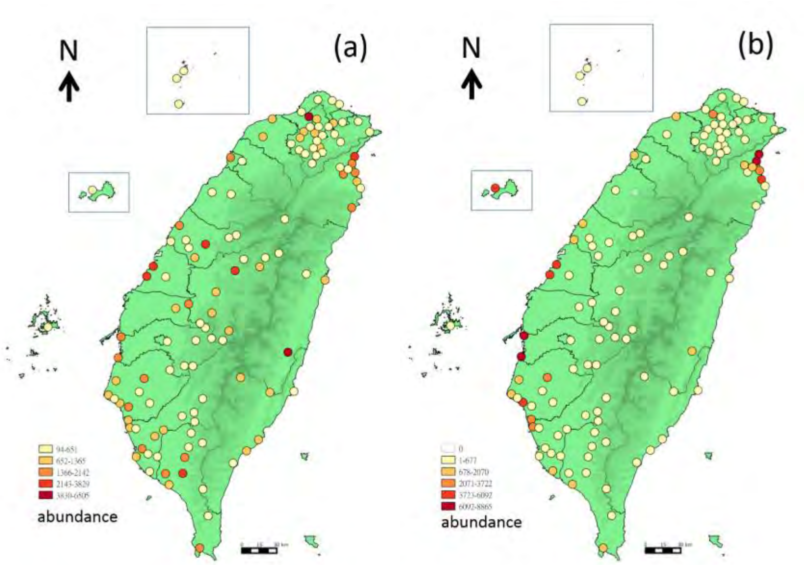


**圖 5.** 2014 台灣新年數鳥嘉年華繁殖鳥(a)及冬候鳥(b)的豐度分布圖，以 Jenk 臨界值法分類。

**Fig. 5.** Distribution of abundance of breeding bird species (a) and wintering species (b) in 2014 New Year Bird Count, Taiwan. (classified by Jenk natural break method)

## 討　論

與「2014 台灣鳥類名錄」相較，所有的普遍及不普遍留鳥和冬候鳥中，僅未記錄到東方澤鵟(*Circus spilonotus*)、灰胸秧雞(*Gallirallus striatus*)、長尾鳩(*Macropygia tenuirostris*)、短耳鴞(*Asio flammeus*)及低地繡眼(*Zosterops meyeni*)，另無任何海鳥的紀錄。長尾鳩和低地繡眼於我國行政區域內僅分布於蘭嶼及綠島地區(劉等 2012b; 2012c; 蔡等 2014)，顯示未來應於離島地區劃設樣區圓以求完善。雖然本次調查範圍包括澎湖、金門及馬祖等離島，但澎湖及金門僅各有一個樣區圓，東引、蘭嶼、綠島、龜山島、小琉球、北方三島及東沙群島則無任何樣區圓的設置。未來應重視離島的鳥類現況並積極地嘗試尋求任何於離島設置樣區圓的可能。本次調查亦無任何海鳥的紀錄，主要是因爲海鳥不易於陸上觀察，需仰賴船隻出海觀察，或許針對海鳥另行設計適用的監測系統較爲恰當(Camphuysen *et al.* 2004)。然而，若於離島設置樣區圓，或許有助於冬季時台灣與離島間近海地區觀察海鳥。另外，本次調查雖然記錄到不少稀有鳥種，但是筆數不多，監測成效有限。就稀有鳥種而言，或許應另行建立以稀有鳥種爲主要對象的監測系統，如水雉繁殖狀況監測(水雉生態教育園區 2013)、山麻雀普查(蔡若詩 個人通訊)和八色鳥大調查(林等 2008)。

冬季時期，無論從鳥種豐富度或豐度來看，濕地(如龍鑾潭、鰲鼓及蘭陽平原)和淺山地區(如南澳及曾文水庫)皆爲冬季時期的重要鳥類熱點。Kou *et al.* (2013)認爲溫度是影響鳥類緯度遷徙的重要因子。我國位於低緯度地區，溫度雖然有季節變化但差異遠小於高緯度地區，往熱帶遷徙的夏候鳥(17 種)遠少於來自高緯度地區的冬候鳥(179 種) (蔡等 2014)。因

此，冬候鳥的加入，大幅改變我國的鳥類群聚組成，提高鳥種豐富度及豐度。由於台灣的冬候鳥大多由雁鴨科(Anatidae)、鷺科(Ardeidae)、鷸科(Scolopacidae)、鴴科(Charadriidae)、長腳鷸科(Recurvirostridae)及鷗科(Laridae)等以濕地爲主要棲地的鳥類，以及鶯類(Warbler)、鶇科(Turdiae)、鶺鴒科(Motacillidae)及鵐科(Emberizidae)等以草原、農田及淺山森林爲主要棲地的鳥類所組成(劉等 2012a; 2012b; 2012c)，再加上從中高海拔地區降遷至低海拔山區的鳥類，可能因而使淺山及沿海濕地成爲冬季時的鳥類熱點。冬候鳥的族群量通常相當龐大，需要大量的食物資源，可能是使龍鑾潭地區、西南沿海及蘭陽平原等大面積的溼地環境成爲冬候鳥熱點的主要原因。

本次調查以美國聖誕節鳥類調查的方法爲原則，經適合我國現況調整之後，設計爲「台灣新年數鳥嘉年華」，以公民科學方式執行。首年的調查原先設定爲試辦性質，然而，有效的樣區圓數量(122 處)遠高於當初預設的數量(30 處)，可見我國鳥類觀察者相當踴躍參與公民科學活動。首年資料雖然無法建立變化趨勢的資訊，但是樣區數多且高同步性的調查，使首年成果可適當反映我國冬季鳥類相的群聚組成及分布。未來將持續執行，建立完善的冬季鳥類監測系統，並嘗試與東亞各國合作，共同監測東亞-澳洲遷徙線的候鳥變化。

## 謝　誌

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**附錄 1.** 2014 年台灣新年數鳥嘉年華所紀錄之鳥類名錄。I：瀕臨絕種野生動物，II：珍貴稀有野生動物，III：其他應予保育之野生動物

**Appendix 1.** Bird species list from 2014 New Year Bird Count, Taiwan. I: Endangered species; II: Rare and Valuable Species; III: Other Conservation Deserving Wildlife

| Chinese vernacular name | Scientific name | Abundance | Status | Endemic species | Endemic subspecies | Introduced species |
|---|---|---|---|---|---|---|
| 鴻雁 | *Anser cygnoides* | 1 | | | | |
| 凍原豆雁 | *Anser serrirostris* | 4 | | | | |
| 凍原/寒林豆雁 | *Anser serrirostris/fabalis* | 2 | | | | |
| 花鳧 | *Tadorna tadorna* | 1 | | | | |
| 鴛鴦 | *Aix galericulata* | 15 | II | | | |
| 赤膀鴨 | *Anas strepera* | 59 | | | | |
| 羅文鴨 | *Anas falcata* | 6 | | | | |
| 赤頸鴨 | *Anas penelope* | 3147 | | | | |
| 綠頭鴨 | *Anas platyrhynchos* | 193 | | | | |
| 花嘴鴨 | *Anas zonorhyncha* | 2442 | | | | |
| 呂宋鴨 | *Anas luzonica* | 1 | | | | |
| 琵嘴鴨 | *Anas clypeata* | 6365 | | | | |
| 尖尾鴨 | *Anas acuta* | 3116 | | | | |
| 白眉鴨 | *Anas querquedula* | 54 | | | | |
| 小水鴨 | *Anas crecca* | 8452 | | | | |
| 紅頭潛鴨 | *Aythya ferina* | 13 | | | | |
| 鳳頭潛鴨 | *Aythya fuligula* | 1747 | | | | |
| 斑背潛鴨 | *Aythya marila* | 11 | | | | |
| 長尾鴨 | *Clangula hyemalis* | 1 | | | | |
| 白秋沙 | *Mergellus albellus* | 1 | | | | |
| 鵪鶉 | *Coturnix japonica* | 1 | | | | |
| 台灣山鷓鴣 | *Arborophila crudigularis* | 32 | III | ● | | |
| 竹雞 | *Bambusicola thoracicus* | 170 | | | ● | |
| 藍腹鷴 | *Lophura swinhoii* | 33 | II | ● | | |
| 環頸雉 | *Phasianus colchicus* | 72 | II | | ● | |
| 小鸊鷉 | *Tachybaptus ruficollis* | 863 | | | | |

| Chinese vernacular name | Scientific name | Abundance | Status | Endemic species | Endemic subspecies | Introduced species |
|---|---|---|---|---|---|---|
| 冠鸊鷉 | *Podiceps cristatus* | 10 | | | | |
| 黑頸鸊鷉 | *Podiceps nigricollis* | 2 | | | | |
| 鸕鷀 | *Phalacrocorax carbo* | 8326 | | | | |
| 黃小鷺 | *Ixobrychus sinensis* | 53 | | | | |
| 栗小鷺 | *Ixobrychus cinnamomeus* | 17 | | | | |
| 蒼鷺 | *Ardea cinerea* | 4381 | | | | |
| 紫鷺 | *Ardea purpurea* | 15 | | | | |
| 大白鷺 | *Ardea alba* | 2611 | | | | |
| 中白鷺 | *Mesophoyx intermedia* | 227 | | | | |
| 小白鷺 | *Egretta garzetta* | 3544 | | | | |
| 岩鷺 | *Egretta sacra* | 5 | | | | |
| 黃頭鷺 | *Bubulcus ibis* | 3361 | | | | |
| 池鷺 | *Ardeola bacchus* | 22 | | | | |
| 綠簑鷺 | *Butorides striata* | 16 | | | | |
| 夜鷺 | *Nycticorax nycticorax* | 2157 | | | | |
| 黑冠麻鷺 | *Gorsachius melanolophus* | 38 | | | | |
| 埃及聖 | *Threskiornis aethiopicus* | 389 | | | | ● |
| 白琵鷺 | *Platalea leucorodia* | 6 | II | | | |
| 黑面琵鷺 | *Platalea minor* | 812 | I | | | |
| 魚鷹 | *Pandion haliaetus* | 103 | II | | | |
| 黑翅鳶 | *Elanus caeruleus* | 35 | II | | | |
| 東方蜂鷹 | *Pernis ptilorhynchus* | 31 | II | | | |
| 大冠鷲 | *Spilornis cheela* | 198 | II | | ● | |
| 熊鷹 | *Nisaetus nipalensis* | 1 | I | | | |
| 林鵰 | *Ictinaetus malayensis* | 34 | I | | | |
| 花鵰 | *Clanga clanga* | 1 | II | | | |
| 灰面鵟鷹 | *Butastur indicus* | 8 | II | | | |
| 鳳頭蒼鷹 | *Accipiter trivirgatus* | 89 | II | | ● | |
| 松雀鷹 | *Accipiter virgatus* | 15 | II | | ● | |
| 北雀鷹 | *Accipiter nisus* | 2 | II | | | |
| 蒼鷹 | *Accipiter gentilis* | 1 | II | | | |
| 黑鳶 | *Milvus migrans* | 138 | II | | | |
| 白腹海鵰 | *Haliaeetus leucogaster* | 2 | II | | | |
| 白尾海鵰 | *Haliaeetus albicilla* | 1 | I | | | |
| 鵟 | *Buteo buteo* | 15 | II | | | |
| 灰腳秧雞 | *Rallina eurizonoides* | 1 | | | ● | |
| 白腹秧雞 | *Amaurornis phoenicurus* | 73 | | | | |
| 緋秧雞 | *Porzana fusca* | 8 | | | | |
| 紅冠水雞 | *Gallinula chloropus* | 3025 | | | | |

| Chinese vernacular name | Scientific name | Abundance | Status | Endemic species | Endemic subspecies | Introduced species |
|---|---|---|---|---|---|---|
| 白冠雞 | *Fulica atra* | 437 | | | | |
| 高蹺鴴 | *Himantopus himantopus* | 9125 | | | | |
| 反嘴鴴 | *Recurvirostra avosetta* | 842 | | | | |
| 太平洋金斑鴴 | *Pluvialis fulva* | 5447 | | | | |
| 灰斑鴴 | *Pluvialis squatarola* | 495 | | | | |
| 小辮鴴 | *Vanellus vanellus* | 209 | | | | |
| 跳鴴 | *Vanellus cinereus* | 1 | | | | |
| 蒙古鴴 | *Charadrius mongolus* | 98 | | | | |
| 鐵嘴鴴 | *Charadrius leschenaultii* | 225 | | | | |
| 東方環頸鴴 | *Charadrius alexandrinus* | 12044 | | | | |
| 劍鴴 | *Charadrius placidus* | 1 | | | | |
| 小環頸鴴 | *Charadrius dubius* | 1152 | | | | |
| 彩鷸 | *Rostratula benghalensis* | 100 | II | | | |
| 水雉 | *Hydrophasianus chirurgus* | 285 | II | | | |
| 磯鷸 | *Actitis hypoleucos* | 374 | | | | |
| 白腰草鷸 | *Tringa ochropus* | 57 | | | | |
| 黃足鷸 | *Tringa brevipes* | 2 | | | | |
| 鶴鷸 | *Tringa erythropus* | 3 | | | | |
| 青足鷸 | *Tringa nebularia* | 2110 | | | | |
| 小青足鷸 | *Tringa stagnatilis* | 405 | | | | |
| 鷹斑鷸 | *Tringa glareola* | 2017 | | | | |
| 赤足鷸 | *Tringa totanus* | 249 | | | | |
| 中杓鷸 | *Numenius phaeopus* | 1 | | | | |
| 大杓鷸 | *Numenius arquata* | 779 | III | | | |
| 黑尾鷸 | *Limosa limosa* | 25 | | | | |
| 斑尾鷸 | *Limosa lapponica* | 3 | | | | |
| 翻石鷸 | *Arenaria interpres* | 806 | | | | |
| 流蘇鷸 | *Calidris pugnax* | 3 | | | | |
| 寬嘴鷸 | *Calidris falcinellus* | 47 | | | | |
| 丹氏濱鷸 | *Calidris temminckii* | 4 | | | | |
| 長趾濱鷸 | *Calidris subminuta* | 586 | | | | |
| 紅胸濱鷸 | *Calidris ruficollis* | 504 | | | | |
| 三趾濱鷸 | *Calidris alba* | 311 | | | | |
| 黑腹濱鷸 | *Calidris alpina* | 12789 | | | | |
| 長嘴半蹼鷸 | *Limnodromus scolopaceus* | 3 | | | | |
| 田鷸 | *Gallinago gallinago* | 1037 | | | | |
| 針尾鷸 | *Gallinago stenura* | 2 | | | | |
| 中地鷸 | *Gallinago megala* | 1 | | | | |
| 灰瓣足鷸 | *Phalaropus fulicarius* | 2 | | | | |

| Chinese vernacular name | Scientific name | Abundance | Status | Endemic species | Endemic subspecies | Introduced species |
|---|---|---|---|---|---|---|
| 棕三趾鶉 | *Turnix suscitator* | 1 | | | ● | |
| 黑嘴鷗 | *Saundersilarus saundersi* | 80 | II | | | |
| 紅嘴鷗 | *Chroicocephalus ridibundus* | 2179 | | | | |
| 黑尾鷗 | *Larus crassirostris* | 6 | | | | |
| 銀鷗 | *Larus argentatus* | 52 | | | | |
| 裏海銀鷗 | *Larus cachinnans* | 17 | | | | |
| 小黑背鷗 | *Larus fuscus* | 1 | | | | |
| 小燕鷗 | *Sternula albifrons* | 18 | II | | | |
| 裏海燕鷗 | *Hydroprogne caspia* | 659 | | | | |
| 白翅黑燕鷗 | *Chlidonias leucopterus* | 45 | | | | |
| 黑腹燕鷗 | *Chlidonias hybrida* | 733 | | | | |
| 野鴿 | *Columba livia* | 1655 | | | | ● |
| 灰林鴿 | *Columba pulchricollis* | 215 | | | | |
| 金背鳩 | *Streptopelia orientalis* | 638 | | | ● | |
| 紅鳩 | *Streptopelia tranquebarica* | 4409 | | | | |
| 珠頸斑鳩 | *Streptopelia chinensis* | 1081 | | | | |
| 翠翼鳩 | *Chalcophaps indica* | 21 | | | | |
| 綠鳩 | *Treron sieboldii* | 157 | | | | |
| 紅頭綠鳩 | *Treron formosae* | 6 | II | | ● | |
| 褐翅鴉鵑 | *Centropus sinensis* | 1 | | | | |
| 番鵑 | *Centropus bengalensis* | 12 | | | | |
| 黃嘴角鴞 | *Otus spilocephalus* | 10 | II | | ● | |
| 領角鴞 | *Otus lettia* | 20 | II | | ● | |
| 鵂鶹 | *Glaucidium brodiei* | 5 | II | | ● | |
| 東方灰林鴞 | *Strix nivicola* | 2 | II | | ● | |
| 褐鷹鴞 | *Ninox japonica* | 1 | II | | | |
| 台灣夜鷹 | *Caprimulgus affinis* | 12 | | | ● | |
| 叉尾雨燕 | *Apus pacificus* | 23 | | | | |
| 小雨燕 | *Apus nipalensis* | 2319 | | | ● | |
| 翠鳥 | *Alcedo atthis* | 232 | | | | |
| 蒼翡翠 | *Halcyon smyrnensis* | 3 | | | | |
| 斑翡翠 | *Ceryle rudis* | 4 | | | | |
| 戴勝 | *Upupa epops* | 3 | | | | |
| 五色鳥 | *Megalaima nuchalis* | 353 | | ● | | |
| 小啄木 | *Dendrocopos canicapillus* | 190 | | | | |
| 大赤啄木 | *Dendrocopos leucotos* | 9 | II | | ● | |
| 紅隼 | *Falco tinnunculus* | 197 | II | | | |
| 燕隼 | *Falco subbuteo* | 2 | II | | | |
| 遊隼 | *Falco peregrinus* | 19 | I | | | |

| Chinese vernacular name | Scientific name | Abundance | Status | Endemic species | Endemic subspecies | Introduced species |
|---|---|---|---|---|---|---|
| 灰喉山椒鳥 | *Pericrocotus solaris* | 567 | | | | |
| 紅尾伯勞 | *Lanius cristatus* | 676 | III | | | |
| 棕背伯勞 | *Lanius schach* | 174 | | | | |
| 綠畫眉 | *Erpornis zantholeuca* | 235 | | | | |
| 黃鸝 | *Oriolus chinensis* | 8 | I | | | |
| 朱鸝 | *Oriolus traillii* | 48 | II | | ● | |
| 大卷尾 | *Dicrurus macrocercus* | 923 | | | ● | |
| 灰卷尾 | *Dicrurus leucophaeus* | 2 | | | | |
| 小卷尾 | *Dicrurus aeneus* | 223 | | | ● | |
| 黑枕藍鶲 | *Hypothymis azurea* | 408 | | | ● | |
| 松鴉 | *Garrulus glandarius* | 75 | | | ● | |
| 灰喜鵲 | *Cyanopica cyanus* | 1 | | | | ● |
| 台灣藍鵲 | *Urocissa caerulea* | 238 | III | ● | | |
| 紅嘴藍鵲 | *Urocissa erythrorhyncha* | 1 | | | | ● |
| 樹鵲 | *Dendrocitta formosae* | 833 | | | ● | |
| 喜鵲 | *Pica pica* | 566 | | | | |
| 星鴉 | *Nucifraga caryocatactes* | 35 | | | ● | |
| 禿鼻鴉 | *Corvus frugilegus* | 4 | | | | |
| 巨嘴鴉 | *Corvus macrorhynchos* | 201 | | | | |
| 玉頸鴉 | *Corvus torquatus* | 2 | | | | |
| 歐亞雲雀 | *Alauda arvensis* | 22 | | | | |
| 小雲雀 | *Alauda gulgula* | 212 | | | | |
| 棕沙燕 | *Riparia chinensis* | 2634 | | | | |
| 灰沙燕 | *Riparia riparia* | 2 | | | | |
| 家燕 | *Hirundo rustica* | 2567 | | | | |
| 洋燕 | *Hirundo tahitica* | 2310 | | | | |
| 金腰燕 | *Cecropis daurica* | 8 | | | | |
| 赤腰燕 | *Cecropis striolata* | 1210 | | | | |
| 東方毛腳燕 | *Delichon dasypus* | 531 | | | | |
| 赤腹山雀 | *Poecile varius* | 45 | II | | ● | |
| 煤山雀 | *Periparus ater* | 14 | III | | ● | |
| 青背山雀 | *Parus monticolus* | 156 | III | | ● | |
| 黃山雀 | *Parus holsti* | 60 | II | ● | | |
| 紅頭山雀 | *Aegithalos concinnus* | 981 | | | | |
| 茶腹鳾 | *Sitta europaea* | 46 | | | | |
| 鷦鷯 | *Troglodytes troglodytes* | 7 | | | ● | |
| 河烏 | *Cinclus pallasii* | 20 | | | | |
| 白環鸚嘴鵯 | *Spizixos semitorques* | 199 | | | ● | |
| 烏頭翁 | *Pycnonotus taivanus* | 1045 | II | ● | | |

| Chinese vernacular name | Scientific name | Abundance | Status | Endemic species | Endemic subspecies | Introduced species |
|---|---|---|---|---|---|---|
| 白頭翁 | *Pycnonotus sinensis* | 7626 | | | ● | |
| 紅嘴黑鵯 | *Hypsipetes leucocephalus* | 2790 | | | ● | |
| 棕耳鵯 | *Hypsipetes amaurotis* | 10 | | | ● | |
| 火冠戴菊鳥 | *Regulus goodfellowi* | 14 | III | ● | | |
| 台灣鷦眉 | *Pnoepyga formosana* | 24 | | ● | | |
| 短尾鶯 | *Urosphena squameiceps* | 1 | | | | |
| 棕面鶯 | *Abroscopus albogularis* | 246 | | | | |
| 日本樹鶯 | *Horornis diphone* | 2 | | | | |
| 遠東樹鶯 | *Horornis canturians* | 24 | | | | |
| 小鶯 | *Horornis fortipes* | 8 | | | ● | |
| 深山鶯 | *Horornis acanthizoides* | 14 | | | ● | |
| 褐色柳鶯 | *Phylloscopus fuscatus* | 31 | | | | |
| 黃腰柳鶯 | *Phylloscopus proregulus* | 4 | | | | |
| 黃眉柳鶯 | *Phylloscopus inornatus* | 67 | | | | |
| 極北柳鶯 | *Phylloscopus borealis* | 119 | | | | |
| 冠羽柳鶯 | *Phylloscopus coronatus* | 1 | | | | |
| 東方大葦鶯 | *Acrocephalus orientalis* | 17 | | | | |
| 台灣叢樹鶯 | *Locustella alishanensis* | 1 | | ● | | |
| 棕扇尾鶯 | *Cisticola juncidis* | 44 | | | | |
| 黃頭扇尾鶯 | *Cisticola exilis* | 6 | | | ● | |
| 斑紋鷦鶯 | *Prinia crinigera* | 3 | | | ● | |
| 灰頭鷦鶯 | *Prinia flaviventris* | 229 | | | | |
| 褐頭鷦鶯 | *Prinia inornata* | 827 | | | ● | |
| 褐頭花翼 | *Fulvetta formosana* | 38 | | ● | | |
| 粉紅鸚嘴 | *Sinosuthora webbiana* | 218 | | | ● | |
| 黃羽鸚嘴 | *Suthora verreauxi* | 40 | | | ● | |
| 冠羽畫眉 | *Yuhina brunneiceps* | 1379 | | ● | | |
| 綠繡眼 | *Zosterops japonicus* | 5076 | | | | |
| 山紅頭 | *Cyanoderma ruficeps* | 792 | | | ● | |
| 小彎嘴 | *Pomatorhinus musicus* | 610 | | ● | | |
| 大彎嘴 | *Megapomatorhinus erythrocnemis* | 143 | | ● | | |
| 頭烏線 | *Schoeniparus brunneus* | 137 | | | ● | |
| 繡眼畫眉 | *Alcippe morrisonia* | 2147 | | ● | | |
| 台灣畫眉 | *Garrulax taewanus* | 85 | II | ● | | |
| 台灣白喉噪眉 | *Ianthocincla ruficeps* | 10 | II | ● | | ● |
| 黑喉噪眉 | *Ianthocincla chinensis* | 6 | | | | ● |
| 棕噪眉 | *Ianthocincla poecilorhyncha* | 46 | II | ● | | |
| 台灣噪眉 | *Trochalopteron morrisonianum* | 65 | | ● | | |
| 白耳畫眉 | *Heterophasia auricularis* | 725 | | ● | | |

| Chinese vernacular name | Scientific name | Abundance | Status | Endemic species | Endemic subspecies | Introduced species |
|---|---|---|---|---|---|---|
| 黃胸藪眉 | *Liocichla steerii* | 332 | | ● | | |
| 紋翼畫眉 | *Actinodura morrisoniana* | 106 | III | ● | | |
| 寬嘴鶲 | *Muscicapa latirostris* | 7 | | | | |
| 紅尾鶲 | *Muscicapa ferruginea* | 3 | | | | |
| 鵲鴝 | *Copsychus saularis* | 14 | | | | (註) |
| 白腰鵲鴝 | *Copsychus malabaricus* | 5 | | | | ● |
| 黃腹琉璃 | *Niltava vivida* | 77 | III | | ● | |
| 小翼鶇 | *Brachypteryx montana* | 15 | | | ● | |
| 台灣紫嘯鶇 | *Myophonus insularis* | 87 | | ● | | |
| 白斑紫嘯鶇 | *Myophonus caeruleus* | 6 | | | | |
| 小剪尾 | *Enicurus scouleri* | 17 | II | | ● | |
| 野鴝 | *Calliope calliope* | 58 | | | | |
| 白尾鴝 | *Cinclidium leucurum* | 38 | III | | ● | |
| 藍尾鴝 | *Tarsiger cyanurus* | 17 | | | | |
| 白眉林鴝 | *Tarsiger indicus* | 2 | III | | ● | |
| 栗背林鴝 | *Tarsiger johnstoniae* | 56 | | ● | | |
| 紅喉鶲 | *Ficedula albicilla* | 26 | | | | |
| 白眉鶲 | *Ficedula zanthopygia* | 2 | | | | |
| 黃胸青鶲 | *Ficedula hyperythra* | 14 | | | ● | |
| 紅胸鶲 | *Ficedula parva* | 1 | | | | |
| 鉛色水鶇 | *Phoenicurus fuliginosus* | 178 | III | | ● | |
| 黃尾鴝 | *Phoenicurus auroreus* | 285 | | | | |
| 藍磯鶇 | *Monticola solitarius* | 99 | | | | |
| 黑喉鴝 | *Saxicola maurus* | 10 | | | | |
| 虎鶇 | *Zoothera dauma* | 44 | | | | |
| 灰背鶇 | *Turdus hortulorum* | 1 | | | | |
| 黑鶇 | *Turdus merula* | 9 | | | | |
| 白頭鶇 | *Turdus poliocephalus* | 7 | II | | ● | |
| 白眉鶇 | *Turdus obscurus* | 34 | | | | |
| 白腹鶇 | *Turdus pallidus* | 255 | | | | |
| 赤腹鶇 | *Turdus chrysolaus* | 272 | | | | |
| 斑點鶇 | *Turdus eunomus* | 36 | | | | |
| 紅尾鶇 | *Turdus naumanni* | 6 | | | | |
| 輝椋鳥 | *Aplonis panayensis* | 75 | | | | ● |
| 泰國八哥 | *Acridotheres grandis* | 11 | | | | ● |
| 八哥 | *Acridotheres cristatellus* | 415 | II | | ● | |
| 白尾八哥 | *Acridotheres javanicus* | 3090 | | | | ● |
| 林八哥 | *Acridotheres fuscus* | 10 | | | | ● |
| 家八哥 | *Acridotheres tristis* | 1507 | | | | ● |

| Chinese vernacular name | Scientific name | Abundance | Status | Endemic species | Endemic subspecies | Introduced species |
|---|---|---|---|---|---|---|
| 黑領椋鳥 | *Gracupica nigricollis* | 198 | | | | ● |
| 小椋鳥 | *Sturnia philippensis* | 6 | | | | |
| 灰背椋鳥 | *Sturnia sinensis* | 122 | | | | |
| 灰頭椋鳥 | *Sturnia malabarica* | 29 | | | | ● |
| 粉紅椋鳥 | *Pastor roseus* | 1 | | | | |
| 絲光椋鳥 | *Sturnus sericeus* | 276 | | | | |
| 灰椋鳥 | *Sturnus cineraceus* | 74 | | | | |
| 綠啄花 | *Dicaeum minullum* | 9 | | | ● | |
| 紅胸啄花 | *Dicaeum ignipectus* | 56 | | | ● | |
| 岩鷚 | *Prunella collaris* | 2 | | | ● | |
| 東方黃鶺鴒 | *Motacilla tschutschensis* | 1835 | | | | |
| 灰鶺鴒 | *Motacilla cinerea* | 332 | | | | |
| 白鶺鴒 | *Motacilla alba* | 404 | | | | |
| 大花鷚 | *Anthus richardi* | 53 | | | | |
| 樹鷚 | *Anthus hodgsoni* | 161 | | | | |
| 白背鷚 | *Anthus gustavi* | 1 | | | | |
| 赤喉鷚 | *Anthus cervinus* | 181 | | | | |
| 黃腹鷚 | *Anthus rubescens* | 2 | | | | |
| 白眉鵐 | *Emberiza tristrami* | 9 | | | | |
| 小鵐 | *Emberiza pusilla* | 9 | | | | |
| 黑臉鵐 | *Emberiza spodocephala* | 162 | | | | |
| 花雀 | *Fringilla montifringilla* | 45 | | | | |
| 褐鷽 | *Pyrrhula nipalensis* | 36 | | | ● | |
| 灰鷽 | *Pyrrhula erythaca* | 1 | | | ● | |
| 台灣朱雀 | *Carpodacus formosanus* | 11 | | ● | | |
| 金翅雀 | *Chloris sinica* | 1 | | | | |
| 臘嘴雀 | *Coccothraustes coccothraustes* | 2 | | | | |
| 麻雀 | *Passer montanus* | 18212 | | | | |
| 白喉文鳥 | *Euodice malabarica* | 30 | | | | ● |
| 白腰文鳥 | *Lonchura striata* | 382 | | | | |
| 斑文鳥 | *Lonchura punctulata* | 1630 | | | | |
| 黑頭文鳥 | *Lonchura atricapilla* | 27 | | | | |

註：鵲鴝於金門為留鳥，於台灣為引進種。

# Identifying predators of passerine shrub and ground nests in a lowland forest of Taiwan

# 台灣低海拔森林燕雀目鳥類灌叢巢與地面巢的天敵判別

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## Abstract

Predation is one of primary causes of nest failure for passerines. We applied an infrared time-lapse video system to continually monitor ground and shrub nests of six small passerine species in a disturbed lowland forest in central Taiwan from 2006 to 2007. The daily predation rate of shrub nests (0.059 ± 0.006) was higher than that of ground nests (0.034 ± 0.005, $\chi^2 = 5.84$, $p = 0.016$). We recorded 17 species of nest predators that were classified into five predation types: snakes (8 species), birds (4 species), macaques (*Macaca cyclopsis*) (1 species), other mammals (4 species), and ants (one unidentified species). Snakes were major predators of both shrub and ground nests. Macaques preyed on shrub and ground nests equally. Avian predators were more focused on shrub than ground nests while other mammalian predators preferred ground nests. Predators such as snakes and ants left no traces but only an empty nest. Therefore, identifying these predators without video surveillance was almost impossible. Each other type of predator would leave characteristic marks that could be identified later. Raptors usually caught the parents in the nest and left the feathers on the rim of the nest while ignoring the unhatched eggs. Macaques always left a

distinctive mess around the nest. Other mammalian predators would usually leave footprints and a loosened nest. We established guidelines for identifying predator types based on the marks around the preyed nests.

## 摘　要

天敵掠食是造成小型燕雀目鳥類繁殖失敗的主因之一。2006-2007 年繁殖期間，在中台灣一處受擾動的低海拔森林中，監測 6 種小型燕雀目鳥類的地面巢與灌叢巢，並利用紅外線縮時錄影系統持續記錄，作爲輔助。其中，灌叢巢（0.059 ± 0.006）面臨的每日被掠食率高於地面巢（0.034 ± 0.005, $\chi^2 = 5.84$, $p = 0.016$）。研究期間共記錄到 17 種鳥巢掠食者，分爲蛇類（8 種）、鳥類（4 種）、台灣獼猴（1 種）、其他哺乳類（4 種）以及螞蟻（不知名種）等五種掠食者類型。無論是灌叢巢或地面巢，蛇類都是最主要的天敵，台灣獼猴沒有特別偏好的巢型，鳥類天敵傾向掠食灌叢巢，而其他哺乳類天敵則偏好地面巢。大多數的蛇類和螞蟻在掠食後只會留下一個空的鳥巢，不留有其他痕跡，若沒有鳥巢的錄影資料將幾乎無法判定天敵種類，除此之外，不同類型的天敵在掠食後，會留下獨特的痕跡可供辨識。猛禽通常會將巢中的親鳥抓走，並留下親鳥的羽毛在巢的邊緣和未孵化的蛋。台灣獼猴常常在巢邊留下容易辨識的混亂痕跡。而其他哺乳類天敵通常會留有腳印並造成被掠食的鳥巢鬆落。因此，我們將被掠食的鳥巢痕跡及其周圍環境遺跡歸納出一些可供判定其天敵類型的準則。

**Key words:** infrared time-lapse video photography, nest fate, predator determination, predation risk, subtropical region

**關鍵詞**：紅外線縮時錄影系統、鳥巢命運、天敵判定、掠食風險、亞熱帶地區

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## Introduction

Nest predation is the primary cause of nest failure for many passerines (Ricklefs 1969; Martin 1993), and the rate of successful breeding is an important factor influencing bird populations. Identifying the causes of nest failure helps to determine factors affecting nesting success. A “nest predator” is any species that removes or damages eggs or nestlings

(Thompson III *et al.* 1999; Thompson III and Burhans 2004). To fully understand nest predation pattern, it is critical to investigate local nest predator composition and predators' densities, searching tactics and spacing behavior as well as densities of alternative preys (Hanski *et al.* 1996). And the spacing behavior means the activity pattern of predators such as macaques could climb trees while most rodents stay on the ground. Among these factors, predator identification is the first step to clarify nest predation pattern.

There were numerous studies on nest predation in temperate and tropical regions, especially in Central and South America (Wikelski *et al.* 2003; Rader *et al.* 2007; Brawn *et al.* 2011). However, only a few nest predation researches for tropical and subtropical Asia have been published, partially due to the different patterns in predator shifts among biogeographical regions and landscapes. Predation risk is related to the composition and density of predators. The nest predation risk in tropical and subtropical regions appear to be higher than the temperate region for a variety of reasons such as the diversity and density of predators may be much higher in the low latitudes, but some are still barely understood (Gibbs 1991; Martin 1996; Auer *et al.* 2007).

The studies of nest predator using artificial and real nests showed different results. A few nest predation studies in tropical Asia experimented with artificial nests (Cooper and Francis 1998; Wong *et al.* 1998; Sodhi *et al.* 2003; Pangau-Adam *et al.* 2006). In the tropical lowland forest of Singapore, artificial ground nests were found preyed by lizards, crows, squirrels, wild pigs, feral dogs, banded leaf monkeys, and long-tailed macaques with video monitoring (Wong *et al.* 1998). Rodents were the most common predators of both ground and shrub artificial nests, and the shrub nests were more susceptible to dwarf cuscus, squirrels, and tree snakes in Sulawesi (Pangau-Adam *et al.* 2006). However, a recent real nest study in Thailand found that macaques and snakes were the main predators (Pierce and Pobprasert 2013).

Because natural nests are difficult to find, working with artificial nests baited with quail and plasticine eggs is an easier way to study nest predators. Plasticine eggs often allow a clear separation of predator types (Söderström *et al.* 1998; Pangau-Adam *et al.* 2006) as some mammalian and avian predators may leave marks on these eggs, though not allowing identification to the species level. However, these artificial nests cannot simulate the whole breeding stage without incubating parents and chicks in the nest (Melville *et al.* 2014). In addition, lacking live animals to produce natural sounds and smells induces biases. For example, no snakes predate these artificial nests (Part and Wretenberg 2002; Thompson III and Burhans 2004).

To identify the nest predator to the species level is challenging. Depending on the remnants found in and around the nests, such as nest lining disruption, eggshell fragments, remains of eaten chicks left at nests, footprints around nests, predator types and species may be identified (Brown *et al.* 1998). However, these remnants also do not always allow unambiguous identification of predator type or species. Moreover, parent birds sometimes might alter the remnants after the predation event (Brown *et al.* 1998).

While direct observation would be ideal, direct human observations of nest predation events are rare and may also bias results because the presence of the human may deter potential predators. Therefore, a new technical nest monitoring system that applied time-lapse video photography was developed in recent decades to provide an effective tool to identify nest predators (Williams and Wood 2002; Renfrew and Ribic 2003; Stake and Cimprich 2003; Peterson *et al.* 2004; Stake *et al*. 2004; Sabine *et al.* 2005; Rader *et al.* 2007). This technique used on real nests is definitely the most reliable method because it helps to eliminate all the biases mentioned above and usually allows accurate species identification of the predator (Cutler and Don 1999).

In this study, we identified and compared the nest predator species or types between ground and shrub passerine nests using video photography in subtropical lowland forests of Taiwan. We linked them to the typical remnants left after the predation event and established guideline for identifying predator types. Finally, we compared the predation risk between videoed and non-videoed nests.

# Methods

**Study area**

This study was conducted in Huben Village, Linnei Township, Yunlin County in west-central Taiwan (120˚37.1’E, 23˚44.5’N) (Fig. 1.). Huben Village was designated as an Important Bird Area (IBA) mainly for the conservation of the Fairy Pitta (*Pitta nympha*) by the Chinese Wild Bird Federation (2001) which was later endorsed by BirdLife International. The study area is about 250 ha with elevation ranging from 50 to 500 m, and more than 50 % of the area is covered by Ma Bamboo (*Dendrocalamus latiflorus* Munro). Secondary broadleaf trees are common on the sides of ravines and ridges. Orange orchards and betel nut (*Areca catechu*) plantations are sparsely distributed in the area.

**Nest searching and monitoring**

Nests were searched during the breeding seasons from early March until late August in 2006 and 2007 based on parental behavior cues, systematic searches, and parent flushes. Located nests were not higher than 2 m from the ground. Nests built directly on the ground were categorized as ground nests, while those built within small trees or low stems were classified as shrub nests.

Once a nest was found, we recorded the nesting stage (building, laying, incubation or nestling stage) and the coordinates using GPS (GPSMAP 60CSx, Garmin Corporation, Hsi-Chih, Taipei, Taiwan), and filled out a nest card (Martin *et al.* 1997) to describe the nest characteristics and location for later revisits.

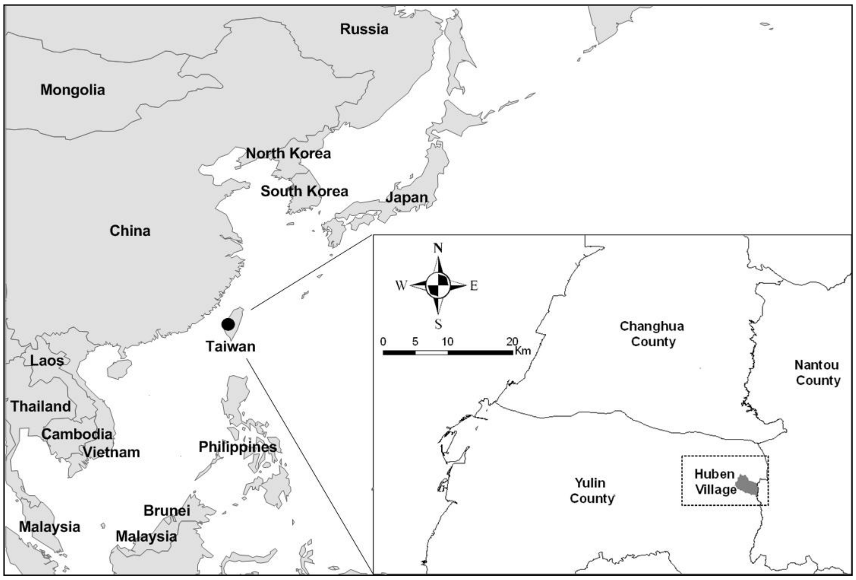


**Fig. 1.** Map of the Huben Village study area in west-central Taiwan.

Each nest was checked every three to four days to determine its status. When the nest appeared preyed upon (eggs or young removed), we recorded the nest structure and searched the area immediate surrounding the nest for evidence of predation, such as eggshells, bodies, animal footprints, animal route and broken nests (Martin and Geupel 1993).

**Video photography and predator identification**

The video system was only set on active nests that had eggs or young in the nest to record nest predators and breeding behavior. To record as much nest breeding data as possible, nests that were in the laying and incubation stages had priority. We also attempted to video ground and shrub nests equally to compare their predators.

We monitored the active nests by a time-lapse video photography system which consisted of an infrared camera with 850 nm infrared wavelength (EZ230, EverFocus Electronics Corporation, Hsi-Chih, Taipei, Taiwan), digital recorder (ESDR400H, EverFocus Electronics Corporation, Hsi-Chih, Taipei, Taiwan) and a cable powered by three rechargeable, 12-volt, deep-cycle batteries. The video system was placed in a 56×56×76 mm waterproof housing and we precluded setting the system on ravines to avoid the system being washed away in a storm. A tripod with a mounted camera was placed 1.5 m from the nest and was connected with a 50-100 m cable with the video recording system set up 20-50 m away to reduce the disturbance by human activities. The video system continuously recorded the nesting activity for 24 hours a day at a speed of 5 frames/sec. A 250 GB hard disk allowed 24-hour of monitoring for 14 days. The video photography was colored in the light and black and white in the dark. We visited the recorder and replaced the batteries every other day until the chicks fledged or the nest failed. We used a hand-held monitor to check the status of nests without approaching them directly.

If a nest was preyed upon, we reviewed the digital videos thoroughly to confirm the predators and the predation process.

**Statistical analysis**

Nest survival data were obtained by locating and monitoring nests following the field protocol (Martin *et al.* 1997). We also used Mayfield logistic regression modeling to estimate the daily predation rate (Aebischer 1999; Hazler 2004; Hazler 2006). Mayfield logistic regression is based on the Mayfield estimator (Mayfield 1961; 1975). We compared daily predation rates at monitored nests with and without video and tested the effect of the photographic system on nest predation rates in program CONTRAST (Hensler and Nichols 1981; Hines and Sauer 1989) which is based on establishing variance covariance matrices that contrast two or more nest survival rates and then comparing their differences with a chi-square distribution.

# Results

In the breeding seasons of 2006 and 2007, we monitored 234 nests (143 shrub nests and 91 ground nests) of six species: Grey-cheeked Fulvetta (GF, *Alcippe morrisonia*), Black-naped Monarch (BM, *Hypothymis azurea*), Light-vented Bulbul (LB, *Pycnonotus sinensis*), Dusky Fulvetta (DF, *Schoeniparus brunneus*), Fairy Pitta (FP, *Pitta nympha*) and Taiwan Scimitar-Babbler (SB, *Pomatorhinus musicus*) (Table 1).

**Table 1.** Daily predation rates (±SD) at shrub and ground nests in Huben village from March to July 2006 and 2007

| Type | No. of nests | No. of depredated nests | Observation days | Daily predation rate |
|---|---|---|---|---|
| **Shrub nests** | **143** | **93** | **1,625** | **0.062±0.006** |
| Grey-cheeked Fulvetta (*Alcippe morrisonia*) | 110 | 73 | 1,286.5 | 0.061±0.007 |
| Black-naped Monarch (*Hypothymis azurea*) | 11 | 7 | 122 | 0.057±0.021 |
| Light-vented Bulbul (*Pycnonotus sinensis*) | 16 | 11 | 146.5 | 0.082±0.023 |
| Fairy Pitta (*Pitta nympha*) | 4 | 1 | 27 | 0.037±0.036 |
| Dusky Fulvetta (*Schoeniparus brunneus*) | 2 | 1 | 43 | 0.023±0.023 |
| **Ground nests** | **91** | **45** | **1,343.5** | **0.038±0.005** |
| Fairy Pitta (*Pitta nympha*) | 53 | 21 | 888.5 | 0.029±0.007 |
| Dusky Fulvetta (*Schoeniparus brunneus*) | 17 | 13 | 184.5 | 0.076±0.019 |
| Taiwan Scimitar-Babbler (*Pomatorhinus musicus*) | 21 | 11 | 270.5 | 0.041±0.012 |

Among the ground nests, 45 nests (49.5%) were preyed, and the daily predation rate was 0.038±0.005 (1,343.5 observed days). Three nests (3.3%) were destroyed by rain, one nest (1.1%) was destroyed by humans, three nests failed for unknown reasons, and 39 nests (42.9%) were successful (i.e. fledged one or more young).

For the shrub nests, 93 nests (65.0%) were preyed, and the daily predation rate was 0.062±0.006 (1,625 observed days) which was higher than the rate for ground nests ($\chi^2 = 8.89$, $p = 0.003$). Six nests (4.2%) were destroyed by rain, two nests (1.4%) were destroyed by humans, one nest (0.7%) failed due to unknown reasons, and 41 nests (28.7%) were successful.

**Nest predators**

We monitored 117 out of a total of 234 nests using video photography. Among them, 70 predation events were recorded that included 64 nests which each was preyed by one predator and six nests (Grey-cheeked Fulvetta (n=3), Fairy Pitta (n=2), and Light-vented Bulbul (n=1)) which each was recorded predation events twice. Of these, 44.3% (n=31) and 55.7% (n=39) were diurnal and nocturnal predators, respectively. Most snakes were nocturnal (79.6%, n=35), while macaques (08:19 to 17:33) and avian predators (06:36 to 18:00) were exclusively diurnal, and other mammals appeared in both day and night times (Fig. 2).

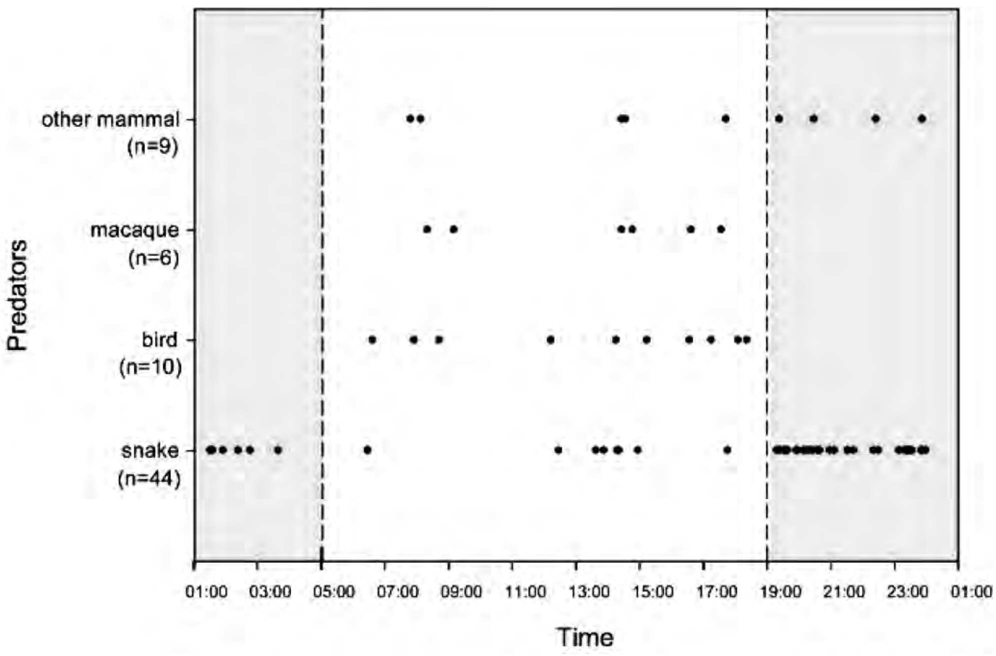


**Fig. 2.** Occurrence times of four predator groups visiting song bird nests in Huben Village from March to July in 2006 and 2007. We did not display the occurrence time of ants in this figure because they were too small in the video photography to identify their first predation time.

We identified eight species of snakes, four species of birds, macaques (1 species, Taiwan only) and four species of other mammals (Table 2). Macaques and other mammals were separated in two groups due to their different activity pattern. Macaques would move between ground and trees while other mammals usually stayed on the ground.

**Table 2.** Ground and shrub nest predators for Fairy Pitta (FP), Taiwan Scimitar-Babbler (SB), Dusky Fulvetta (DF), Light-vented Bulbul (LB), Black-naped Monarch (BM) and Grey-cheeked Fulvetta (GF) recorded by video in Huben village from March to July 2006 and 2007 during the laying, incubation, or nestling stages

| Predator Type | Species | Ground nests | | | | | | | Shrub nests | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Laying | Incubation | | | Nestling | | | Incubation | | | | Nestling | | | |
| | | FP | FP | SB | DF | FP | SB | DF | LB | BM | GF | FP | BM | GF | FP | DF |
| Snake | Tree snake | | | | | | | | | | | | | | | |
| | *Boiga kraepelini* | | 2 | 1 | 1 | 1 | | | 2 | | 5 | | 1 | 5 | | |
| | Ground snake | | | | | | | | | | | | | | | |
| | *Oligodon formosanus* | | | 1 | | | | | | | | | | 1 | | |
| | *Ptyas mucosus* | | 3 | | | | | | | | | | | | | |
| | *Lycodon rufozonatus* | | | | | 1 | | 1 | | | | | | | | |
| | *Elaphe carinata* | 1 | | | | | | | | | 1 | | | | | 1 |
| | *Psammodynastes pulverulentus* | | | | | 1 | | | | | | | | | | |
| | *Orthriophis taeniura friesi* | | | | | | | | | | | 1 | | 1 | | |
| | *Protobothrops mucrosquamatus* | | | | | | 1 | 1 | | | | | 1 | 2 | | |
| | Unidentified snake | | | 1 | | 1 | 1 | | | | 4 | | | | 1 | |
| Bird | Raptor | | | | | | | | | | | | | | | |
| | *Spilornis cheela* | | | | | 1 | | | | | | | | 1 | | |
| | *Accipiter trivirgatus* | | | | | | | | | | | | | 4 | | |
| | Corvid bird | | | | | | | | | | | | | | | |
| | *Dendrocitta formosae* | | | | | | | | | 2 | | | 1 | | | |
| | Cuckoo | | | | | | | | | | | | | | | |
| | *Cuculus optatus** | | | | | | | | | | | | | 1 | | |
| Macaque | *Macaca cyclopsis* | | | | | 1 | | 1 | | 1 | 1 | | | 2 | | |
| Other Mammal | Carnivore | | | | | | | | | | | | | | | |
| | *Paguma larvata taivana* | | | | | 2 | | | | | | | | 1 | | |
| | *Herpestes urva* | | | 1 | | 1 | | 1 | | | | | | 1 | | |
| | Rodent | | | | | | | | | | | | | | | |
| | *Callosciurus erythraeus* | | 1 | | | | | | | | | | | | | |
| | *Niviventer coningi* | | | | | | | | | | | | | 1 | | |
| Ant | - | | | | | | | 1 | | | | | | | | |
| Total | | 1 | 6 | 4 | 1 | 9 | 2 | 5 | 2 | 3 | 11 | 1 | 3 | 20 | 1 | 1 |

*According to Ding *et al*. (2013), we treated the *Cuculus saturatus* described in Chen *et al*. (2009) as *Cuculus optatus*.

Snakes were the major predators for both shrub (61.9%) and ground (64.3%) nests (Table 2, Fig. 3). Avian predators (21.4%, *Z*=2.94) focused on shrub nests while mammalian predators (21.4%, *Z*=0.71) preferred ground nests. Macaques preyed on ground (7.1%) and shrub nests (9.5%, Fig. 3) equally. Snakes and macaques did not have preference between eggs or young while the raptors and other mammals focused on the young in the nests (Table 2).

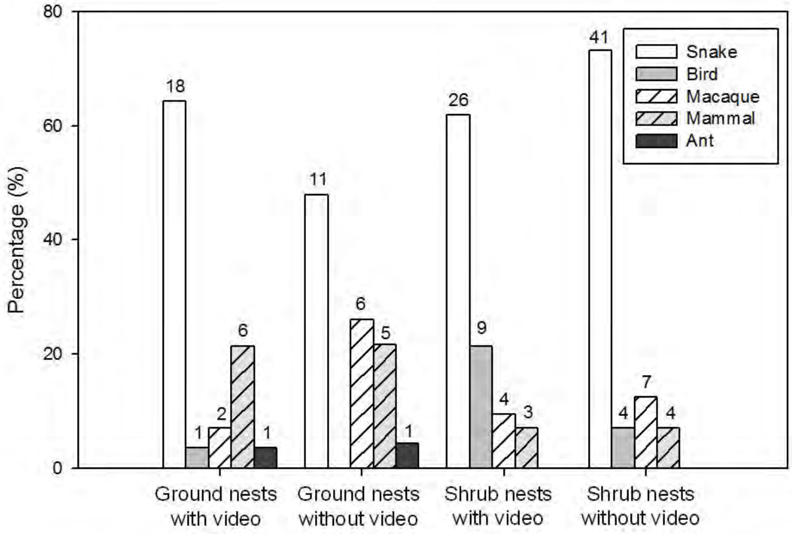


**Fig. 3.** Percentage of ground and shrub nests prey by the five predator groups. The actual number of nests in each category is shown at the top of the bars.

In the shrub nests, the daily predation rate (0.052±0.008, 38 depredated nests, 767 observed days) at 58 nests with video observation was similar to that at 85 regularly visited nests without video observation (0.070±0.009, 55 depredated nests, 858 observed days; $\chi^2 = 2.273$, $p = 0.132$). In contrast, the daily predation rate (0.023±0.005, 26 depredated nests, 1091 observed days) at 61 ground nests with video observation was significantly lower than that at 30 ground nests without video observation (0.079±0.017, 19 depredated nests, 252.5 observed days; $\chi^2 = 8.523$, $p = 0.004$).

**The predator identification guidelines**

We generalized the predator identification guidelines using video photography and field experience (Fig. 4). First, we observed the surrounding area of the nest preyed to determine if it was clean or messy. If the environment was disturbed or there were some animal footprints and tracks, we would categorize them as a mammalian predator. Mammal footprints and the remnants they left in the nests also helped to know what had happened. The location and breeding stage of nests would also help to classify the predators. Carnivores hunted nestlings in ground nests (57%), but raptors preferred nestlings in shrub nests (83%, Table 2). Then, we recorded the nest remnants to classify the potential predator type.

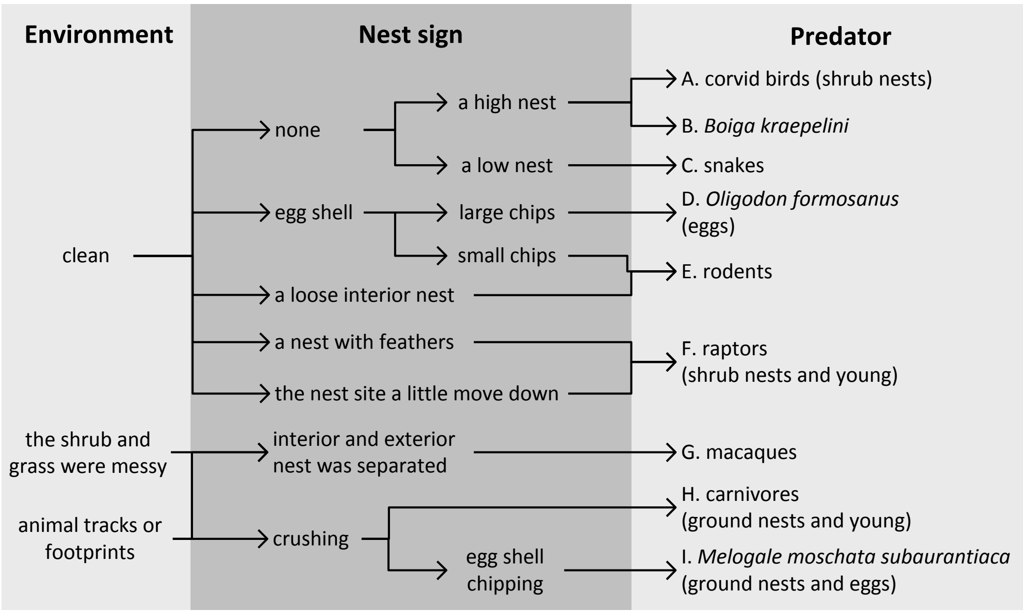


**Fig. 4.** Guidelines to identify the shrub and ground nest predators by the signs left in the environment and in and around the nest. The characteristics in parentheses were the preferences of predators for the prey. The video and nest photographs were given in Appendix A.

Snakes were both the major predators of the shrub and ground nests. *Boiga kraepelini*, a typical tree snake capable of climbing trees, was the most frequent predator (n=18). *O. formosanus* would leave a special remnant after eating eggs which consisted of tooth marks made by its specialization maxillary teeth left on the eggshell as if it had used a can-opener. Other snakes would usually swallow all the eggs or chicks in the nest, and did not leave any signs around the nest and also kept the empty nest unperturbed. Sometimes, the chicks were too large to swallow so that the suffocated bodies would be left near nests. Although most remnants left by snakes were not obvious, we would classify snake predation events by a clean and complete nest in the same surroundings as before.

Avian predators usually preyed on shrub nests and did not leave obvious evidence. After predation, the site of the shrub nest would be slightly moved downward. Three avian predator types were raptors, Corvidae and cuckoos. Raptors focused on the young and parents in the nests but ignored eggs. Feathers of the abdominal stuck on the rim of the nest after the raptor caught the parent bird incubating in the nest. Eggs and young both were preyed on by

Corvidae. A cuckoo (*Cuculus optatus*) was found to kill two nestlings but not eat them in a nest (Chen *et al*. 2009). The nestlings' bodies were left under the shrub nest. The only case of an avian predator preying on a ground nest was *Spilornis cheela* preying on a Fairy Pitta nest with five nestlings.

*Macaca cyclopis* is the only endemic species of macaques in Taiwan. In this study, they preyed on both shrub and ground nests in incubating and nestling stages. Macaques pulled down nests with their hands and casually threw them away onto the ground. The two layers (interior and exterior) of shrub nests would be separated by the macaques with hands. It was also easy to realize that macaques had visited the nest, because they would make messy shrubs and grasses after passing the surrounding area and usually pulled down the nests with their hands and casually threw nests away onto the ground near the original nest site.

Other mammalian predators included carnivores and rodents. Most carnivores preferred ground nests and nestlings. Carnivores would leave animal tracks and footprints that helped the identification. For example, *Melogale moschata subaurantiaca* searched prey with its nose and made a clear footpath by digging the soil. It would leave fragmented eggshells as a dominative sign after predation, and also pressed the nests or dug a hole on the bottom of ground nests. Rodents in Taiwan are much smaller than carnivores, so they would loosen the interior nest and leave chippings of egg shells.

We also recorded that ants preyed on a Dusky Fulvetta nest. However, we could not identify the species as the ants only appeared as tiny black dots on the monitor. The nest predation by ants might continue for several days, and could be observed directly that we had met the event once.

Considering the prey preference of each predator as well as the signs and remnants around the nests, we identified the shrub and ground nest predators in nests that were not monitored by video. Ninety-four shrub and 47 ground nests were classified into five predator types that included snakes, birds, macaques, other mammals and ants. The composition of predator groups was not different between the nests with and without video observation ($\chi^2$ = 4.33, $p$ = 0.363). Snakes were still the major predators, macaques equally preyed on shrub and ground nests, and birds and other mammals had similar preferences in their prey. Birds preferred shrub nests while other mammals attacked to ground nests (Fig. 3).

## Discussion

In this study, we summarized environmental signs and nest remnants to construct a guideline that can help in identifying predator type in nest predation. These evidences can be applied to determine nest predators in similar environments and regions.

We found predation the major cause of nest failure in a Taiwan's lowland forest, although typhoons and rain storms also destroyed nests (3.7%). Occasionally, farmers (1.2%) carelessly broke the nests when managing their bamboo farmlands. Overall, predators hazarded the survival of passerines' nests in the forest. In Taiwan, snakes are the dominant nest predators, followed by other mammals, macaques and raptors. Our results are similar as those researches that snakes were more frequent nest predators at low latitudes (Pierce and Pobprasert 2013; DeGregorio *et al.* 2014). Our results are different from the temperate region where mammals, snakes, corvid birds are major predators, and nest parasitism by cowbirds and cuckoos are also common (Renfrew and Ribic 2003; Pietz and Granfors 2005; Benson 2010). Since regional predators depend on the local fauna, a complete list of local fauna is the first step to estimate the predation risk of nests. Using infrared cameras, we determined the nest predators that included Formosan macaques (*Macaca cyclopis*), Formosan ferret-badgers (*Melogale moschata subaurantiaca*), Formosan gem-faced civets (*Paguma larvata taivana*), Formosan crab-eating mongooses (*Herpestes urva*), Formosan wild boars (*Sus scrofa taivanus*), and rodents. These species are common in the Hushan reservoir near our study area (Cheng 2008).

The fact that the daily predation rate of shrub nests was higher than that of ground nests may be a reflection in such open habitat with scattered trees, dense shrubs and open canopy. In this habitat type, predators can easily detect the nests from above.

We found that the daily predation rate in ground nests was significantly different between those observed by the video system and the human while those in shrub nests showed no difference, that was similar to the results of Williams and Wood (2002), and Stake and Cimprich (2003). Using the video system underestimated the daily predation rate in ground nests and it suggests that using the video system alone may not be sufficient to understand the daily predation pattern and it is necessary to conduct direct field observation.

We monitored the real nests in the field that could reflect a real nest predation situation. Although the daily predation estimates maybe similar between artificial and real nests, predators differed substantially in their predation of artificial versus real nests. In addition, artificial nests also presented the biological bias in the predator assemblage that could not detect the existence of snakes (Thompson III and Burhans 2004). Several studies on artificial nests' studies did not detect snakes in the tropical and subtropical region (Wong *et al.* 1998; Hausmann *et al.* 2005; Pangau-Adam *et al.* 2006). Snakes were the most important predators of many real nests of tropical forests (Stake and Cimprich 2003; Stake *et al.* 2004; Staller *et al.* 2005). Ignoring snakes might cause serious bias when estimating nest predation risks.

**Nest preferences in predator faunas**

Although snakes were the major predators in both shrub and ground nests, we found differences between shrub and ground nests in the predator assemblage. Avian predators focused on shrub nests and rarely plundered eggs and young in the ground nests (Söderström *et al.* 1998; Hausmann *et al.* 2005). We only recorded raptors preying on nestlings and parent birds, and left eggs in the nests, but Gray Treepies (*Dendrocitta formosae*) which belongs to Corvidae would also prey on eggs and chicks. These visual hunters took mainly the conspicuous shrub nests (Weidinger 2002) and ignored the more cryptic ground nests. Other mammals preyed on the young in ground nests and shrub nests that were close to the ground.

Each type of predator searches for prey in a different manner. Avian predators locate nests using visual cues, and macaques also search for prey by visual cues. Other mammals apply olfactorial cues when locating prey (Hausmann *et al.* 2005). Thermoreceptors are present in snakes, which help to detect their prey (De Cock Buning 1983; Campbell *et al.* 2002). Thermoreceptors may be the reason of the detecting bias in artificial nests, because snakes could not detect those nests without living beings inside.

Applying the video system to detect predation pattern did not increase the daily predation rate (Brown *et al.* 1998; Thompson III *et al.* 1999) and also did not affect the composition of the predator faunas. Similar to Stake and Cimprich (2003), we also found no evidence that the video system would be used by predators as a cue to search the nests, and predators did not notice the video camera while they preyed on nests. The lower predation risk of video-taped nests could be explained that we only used video for the active nests and avoided those nests which failed in the early stages (i.e., laying and incubation) (Stake and Cimprich 2003).

The video system monitored the predatory situation of nests effectively. Using the video photography, we identified 17 species of nest predators, yielding a unique predator assemblage and showing the high nest predation risk in Taiwan. One limitation of this type of predator identification was the growth of plants that blocked the nest. In these cases we only obtained shadows and obscure photographs while predators were visiting nests. We could only identify to the predator types by the patterns and shapes, but not to species.

**Signs left at nests by predators**

After a nest predation event, predators would leave their characteristic traces around the nest, and rarely did the bird parents come back to the nest and move these remnants. The evident signs could be kept in the nests and used to determine the nest’s fate. The evident sign we used to identify the snake species is serrated eggshells left by *O. formosanus*. Otherwise most other snakes left no evidence as they usually left only an empty nest that could be classified as snake predation events. The adult’s feathers left on the rim of the nest were also a clear sign that a raptor caught a parent bird from a breeding nest. Macaques would leave a mess around the nests and usually pulled down nests by their hands and casually threw nests away on the ground near the original nest site. Mammalian footprints and the remnants they left in the nests also helped us to surmise what happened.

The actions of ants were rare events especially it is hard to identify them. Ants moved eggs or nestlings piece by piece and left nests clean with no remnants after their predation. To identify the ant species was impossible unless we visited the nests. *Crematogaster* sp. was found to prey on broken eggs of Grey-cheeked Fulvetta (W. J. Chen 2007, *personal observation*). In the videos, we saw many small black spots covering the nest and realized that they were ants, but we could not identify the species. Similar to snakes, ants also left nothing but an empty nest, but the predatory action would continue several days.

The video photography recorded clear evidence of nest predators and obtained stronger data than field identification. However, some minimum fieldwork is still necessary. The monitor can be used to check the stage of nests and reduced the frequency to revisit the active nest. The system causes hardly any nest failure with minimal disruption to nest site or adults (Thompson III *et al.* 1999; Renfrew and Ribic 2003; Stake and Cimprich 2003; Sabine *et al.* 2005). The disadvantage of applying the video-monitoring is its cost.

Based on fieldwork, we could identify the type of predator based on the remnants of the nests after the predation events. However, to make a sound link between the nest remnants and the predator, we needed the video system to fully understand the relationship between predators and prey. Thus, just using the signs to determine predator type was not reliable.

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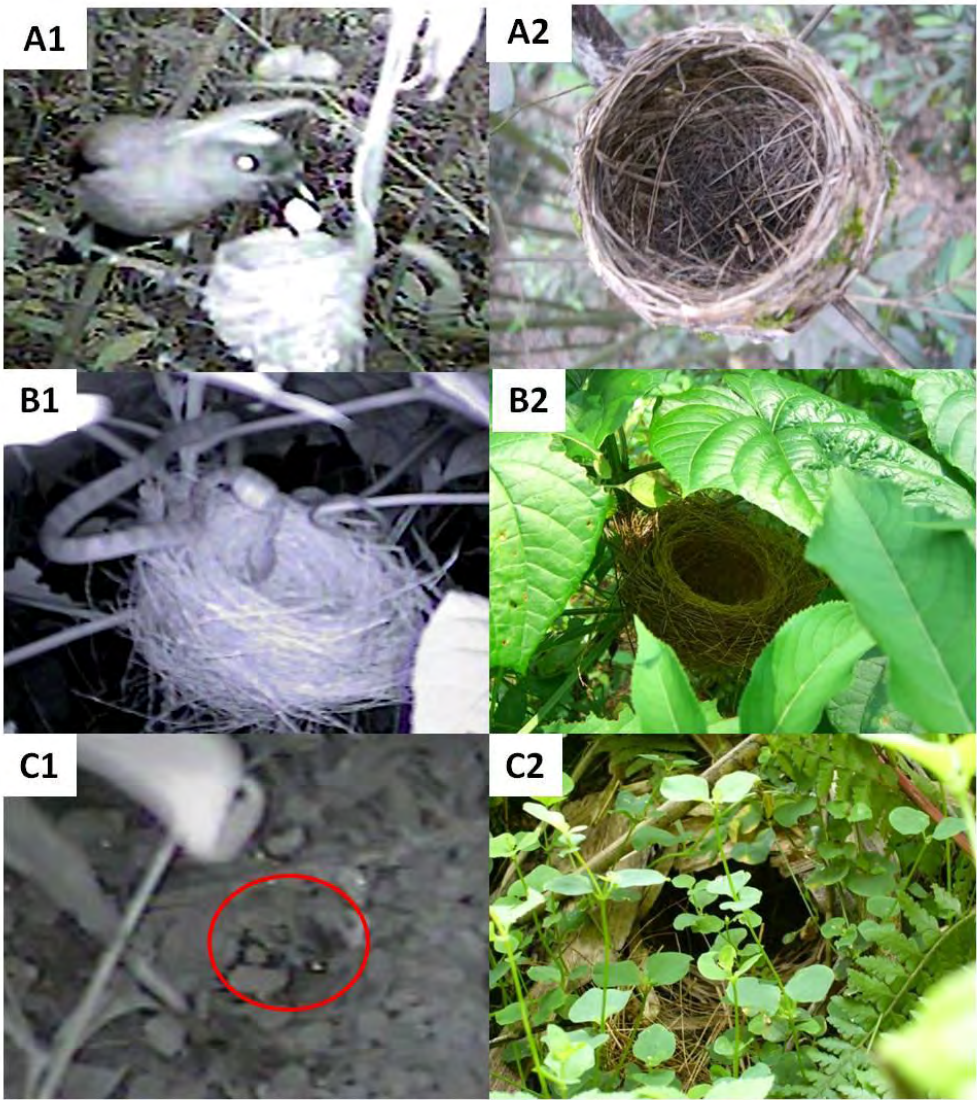
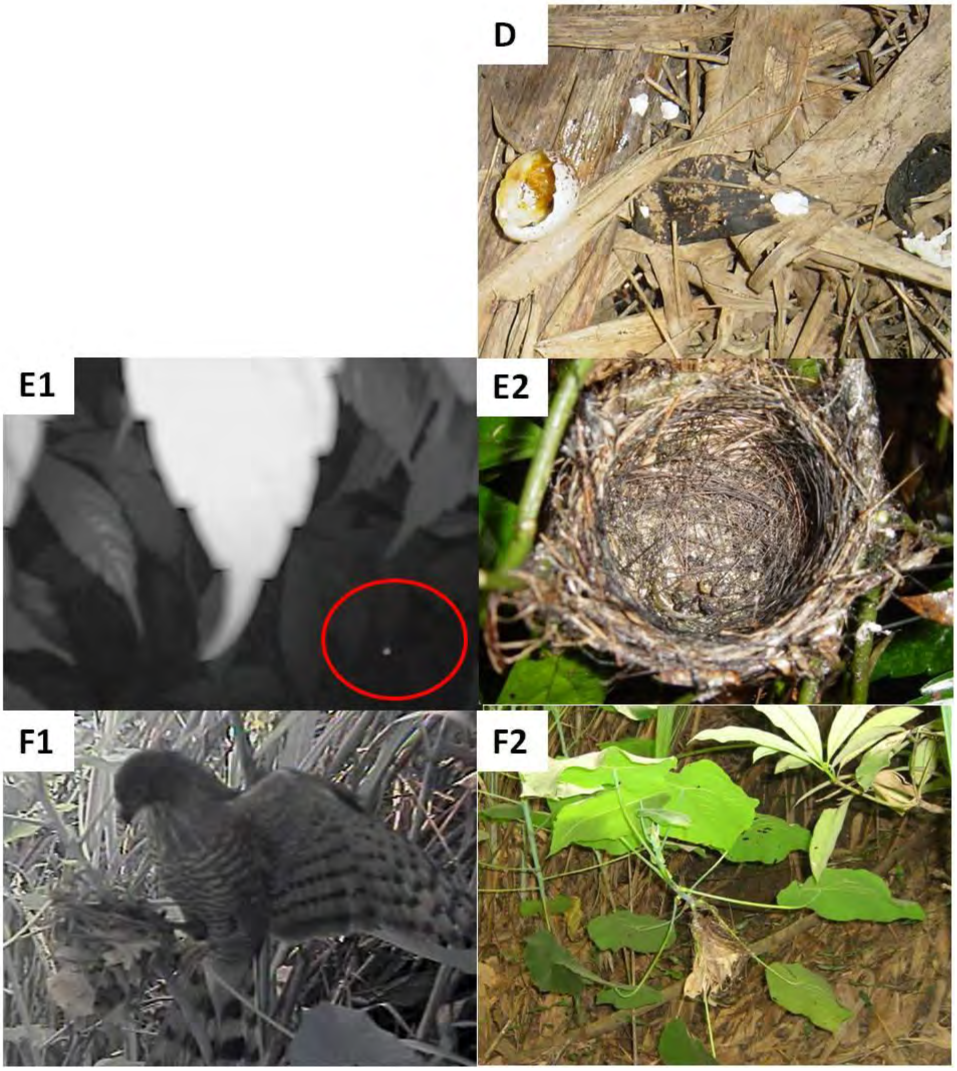
**Appendix A.** The video photography and nest photographs showing various predation type present:




**A1.** *Dendrocitta formosae* swallowed eggs of Black-naped Monarch (*Hypothymis azurea*) and left a clean nest (**A2**).

**B1.** *Boiga kraepelini* swallowed eggs of Light-vented Bulbul (*Pycnonotus sinensis*) and left a clean nest (B2).

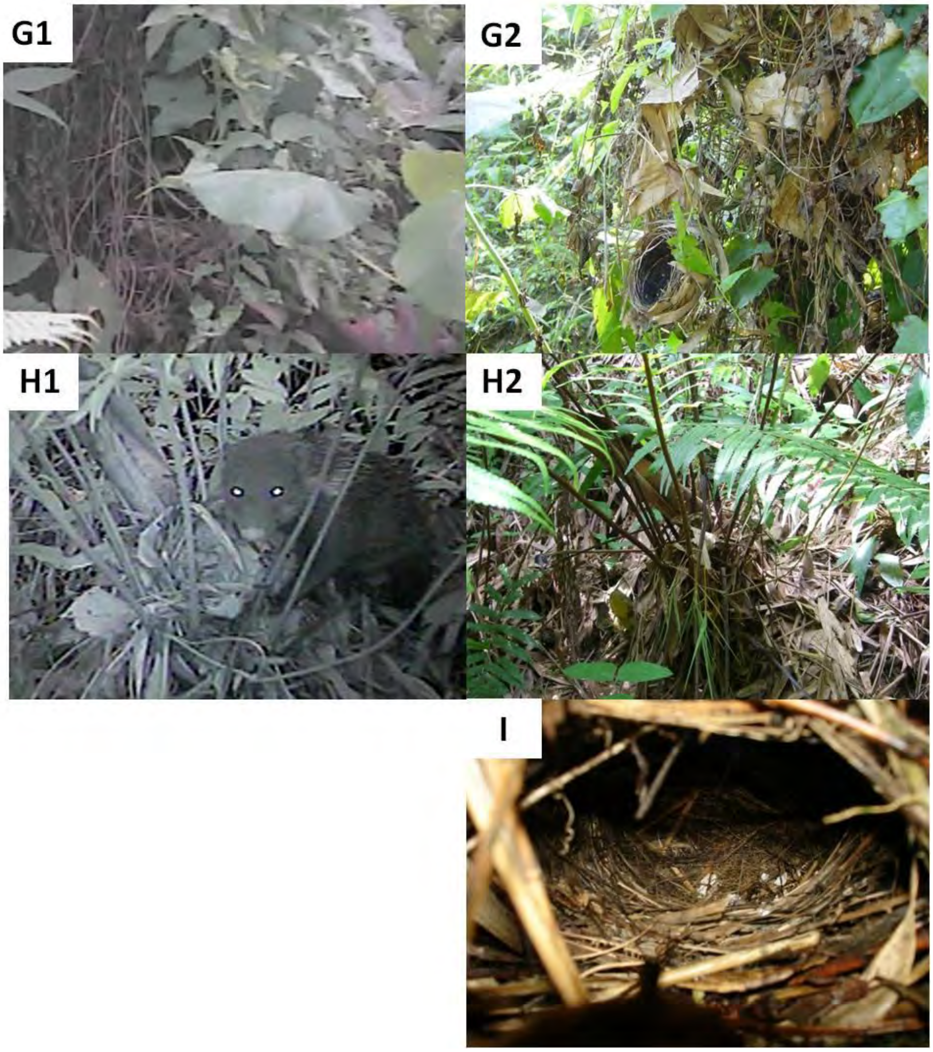
**C1.** *Protobothrops mucrosquamatus* preyed on the young of Taiwan Scimitar-Babbler (*Pomatorhinus musicus*) and left a clean nest (**C2**).




**D.** *Oligodon formosanus* preyed on eggs of Fairy Pitta (*Pitta nympha*) and left serrated eggshells around nests.

**E1**. A rodent preyed on the young of Grey-cheeked Fulvetta (*Alcippe morrisonia*) and left a loose interior nest (E2).

**F1**. *Accipiter trivirgatus* preyed on the young of Grey-cheeked Fulvetta (*Alcippe morrisonia*) and shifted the nest location a little downward (**F2**).




**G1.** *Macaca cyclopsis* preyed on the young of Grey-cheeked Fulvetta (*Alcippe morrisonia*) and messed up the shrub and the nest site (**G2**).

**H1.** *Herpestes urva* preyed on the young of Dusky Fulvetta (*Schoeniparus brunneus*) and crushed the nest (**H2**).

**I.** *Melogale moschata subaurantiaca* preyed on the eggs of Taiwan Scimitar-Babbler (*Pomatorhinus musicus*) and left chipped egg shell.

# 溫度與水量對於澤蛙(*Fejervarya limnocharis*)蝌蚪體長及變態的影響

# Effects of temperature and water volume on body length and metamorphosis of Indian rice frog (*Fejervarya limnocharis*) tadpoles

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## 摘　要

本研究以台灣平地至低海拔地區常見的澤蛙(*Fejervarya limnocharis*)蝌蚪為對象，觀察在實驗室操作不同環境溫度及水量狀況下的蝌蚪存活及變態率，探討這些因子對於無尾兩棲類蝌蚪的影響。澤蛙蝌蚪在 20℃、25℃、30℃下置於 100ml、200ml、400ml 水量飼養，於蝌蚪開始變態的第 58 天及結束實驗的第 125 天比較體長數據。結果 20℃存活率最高但體長較小且無法變態，顯示低溫環境雖有利蝌蚪生存但不利其成長。水量多的環境中蝌蚪體長明顯較大，且溫度與水量對蝌蚪體長的影響有交互作用，顯示不同環境因子除了其個別效果外，彼此也會相互影響；依本研究結果推

測，暖化可能造成棲地環境升溫而影響澤蛙幼體之存活。


## Abstract

To investigate the impacts of environmental temperature and water volume on metamorphosis and survival rates of anuran amphibians, *Fejervarya limnocharis* tadpoles were incubated at 20℃, 25℃, 30℃ with different water volumes. Survival rates of *Fejervarya limnocharis* tadpoles were highest under 20℃. Average body size was smaller at lower environmental temperature and lower water volume on Day 58 and Day 125 under the 20℃ treatment. Tadpoles in high water volume treatments reached significantly larger body size. This suggests that lower temperature is favorable to the survival of tadpoles, but harmful to their growth. In spite of singular effects on growth, there was also remarkable correlation between environmental temperature and water volume factors on the body length of the tadpoles.



**關鍵詞**：變態、蝌蚪、溫度、水量

**Key words:** metamorphosis, tadpole, temperature, water volume,

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## 緒　言

隨著長期氣候資料的蒐集與研究，科學家們近年陸續提出世界正面臨暖化與氣候變遷的現象。政府間氣候變遷專門委員會(IPCC)長期關注暖化現象，在其第四次評估報告中指出 1906 至 2005 年全球均溫上升 0.74℃，且以 1980 年以來的氣溫上升最為明顯(IPCC 2007)；第五次評估報告亦指出氣候系統暖化很明確，1983 至 2012 年可能為 1400 年來北半球最暖的 30 年，更預測在 2100 年全球均溫上升可能達到 1.5℃以上(IPCC 2013)。暖化狀況使得劇烈氣候事件更加明顯，例如 2013 年侵襲菲律賓的海燕(Haiyan)颱風，便是有氣象記錄以來登上陸地的最強熱帶氣旋(Blunden and Arndt 2014)。科學家們也透過電腦模擬氣候狀況作出預測，認為溫室效應引起的暖化現象將會增加聖嬰現象的頻率及強度，進而嚴重影響全球氣候(Cai *et al.* 2014)。

台灣地區近期的報告指出，百年來(1911 至 2009 年)台灣的年平均溫度上升 1.4℃，約為全球平均值(0.74℃)的 2 倍(許等 2011)。在降雨方面，台灣各地 6 個測站(台北、台中、台南、恆春、花蓮及台東)平均降雨量的線性變化幅度雖然不明顯，但是降雨日數卻有減少的趨勢。百年來(1911 至 2009 年)下降幅度平均每 10 年

減少 4 天，但近 30 年(1980 年以後)卻增爲每 10 年減少 6 天。豪雨(日雨量 ≥100mm)及大豪雨(日雨量 ≥200mm)在近 50 年及近 30 年均有明顯增多趨勢；而小雨日數(日雨量 ≤ 1mm)則百年來每 10 年減少 2 天，近 30 年每 10 年減少 4 天(許等 2011)。足見台灣地區氣候朝著降雨天數減少、間隔延長及雨量集中化的方向變動。

在各類脊椎動物中，兩棲動物是最容易因爲環境變動而族群受影響的動物類群之一(Foden *et al.* 2013)。舉例而言，中美洲哥斯大黎加 Monteverde 地區的金蟾蜍(*Bufo periglenes*)族群在 1980 年代末期消失，就被認爲是 1986 至 1987 年間聖嬰現象造成當地氣候及生態系的改變有關(Anchukaitis and Evans 2010)。而近期研究亦歸納出：已名列 IUCN 紅皮書中有滅絕危機兩棲類當中，有 670 至 933 個物種的族群高度容易受到氣候變遷危害，其比例約爲全球現生兩棲類物種的 11%至 15% (Foden *et al.* 2013)。

蝌蚪及幼蛙的存活率以及變態時間早晚可能會間接影響兩棲類生殖族群波動，國外科學家發現變態時間較早以及變態時體型較大的幼蛙除了存活率較高外，尙有性成熟時間較早、體型較大等特點(Berven 1990)，這可能讓牠們在生殖季獲得一些優勢。低溫環境下，兩棲類幼體的甲狀腺發育、甲狀腺素分泌與相關受器的功能皆會受到溫度的影響而產生缺陷，造成幼體成長緩慢、體型較小且無法進入變態期(Frieden *et al.* 1965; Moriya 1983)。高溫除了增加蝌蚪代謝率、改變水中含氮廢物濃度與水質外，也可能會透過對甲狀腺功能的作用而間接影響蝌蚪變態過程(Ashley *et al.* 1968)，可見溫度對於蝌蚪變態的影響不容忽視。此外，由於暫時性靜水域水量與其中生活的蝌蚪密度呈反比關係，當水量減少時，蝌蚪密度即相對增加。國外學者曾指出當生長環境的水量減少時，其中的蝌蚪會提早以較小體型進入變態(Crump 1989; Denver *et al.* 1998)成爲幼蛙；亦有人證實這個現象與蝌蚪的密度增加有關(Richter *et al.* 2009)，但上述現象是否會另外受到溫度影響則不得而知，値得再加以探討。

台灣地區有許多無尾兩棲類利用野外暫時性靜水域進行繁殖，而這些水域的存續時間長短、積蓄水量多寡、水體溫度高低等物理條件則容易受到當地降雨日數、雨量、氣溫等天氣因素的影響。若台灣地區氣候變動眞如氣象學家所言，有氣溫升高、小雨日數減少、豪大雨頻率增加的趨勢，則這些暫時性水域中繁殖的蛙類蝌蚪除了容易因爲高溫與降雨間隔延長造成生存空間狹小、乾涸死亡外，亦有可能因豪雨帶來洪水被沖走而無法存活。

國內以往對於靜水域繁殖之兩棲類受精卵發育及蝌蚪成長過程是否受水體表面積、深度、水量、存續時間、水中環境因子影響之研究成果較少，大部分僅針對單一環境因子進行探討，例如水溫(張 2002; 吳 2004)及水量變化(陳 2005)對蝌蚪的影響等。但對於水中不同的物理因子之間是否有存在著交互作用，甚至在水量不足、族群密度過高時對兩棲類個體本身之生長情形、存活率或變態後的體形大小等關乎未來族群量，以及個體競爭力的狀況會造成多大的影響？在現有研究中則尙未加以探討。

本研究以澤蛙(*Fejervarya limnocharis*)蝌蚪爲實驗對象，觀察在實驗室中操作溫度及水量因子狀況下蝌蚪的存活、成長及變態情形，來探討這些因子對於兩棲類蝌蚪成長狀況是否有影響，以及不同因子對其成長是否存在交

互作用。澤蛙主要產於中國、日本、東南亞與台灣地區，普遍出現於 1,000 公尺以下低海拔平原、丘陵及農村環境，多在水深 5~15cm 的稻田、水池、草澤及雨後臨時水坑中產卵，繁殖期為 2 月至 10 月(費 1999; 呂等 2002)。雌蛙每次產卵數約 30 至 1800 顆；依前人研究所述，台灣地區澤蛙的蝌蚪期大約 20 至 60 天(Alexander *et al.* 1963; Kuan and Lin 2011)。

## 材料與方法

我們於 2010 年 7 月 14 日在雲林縣斗六市湖山水庫自然生態保留及復育區菜園內，採集產於低窪積水之 3 片漂浮性澤蛙卵團，每團採集 200 至 250 顆卵；蛙卵來自同一族群但並非同一對澤蛙所生。為確保所有蛙卵在孵化過程中環境條件一致，卵在攜回實驗室充分混合後一起放入裝有 3000ml 人工軟水(Artificial soft water, ASW; Freda and Dunson 1984)，L40cm x W25cm 方型塑膠水盆中，再置於控制日/夜各 12 小時光週期的 25℃生長箱。人工軟水成分為每 1000ml 逆滲透水加入 $NaHCO_3$(48mg)、$CaSO_4$(24mg)、 $MgSO_4$(30mg)及 KCl(2mg)以維持一定滲透壓。2 天後換水並除去雜質與未受精卵，再放回生長箱等待其完全孵化。依據 2009 年研究人員於當地所設溫濕度記錄器(型號 HOBO H08-003-02)資料，該地區 1 至 3 月、4 至 6 月、7 至 9 月和 10 至 12 月之平均氣溫各為 19.83℃、25.43℃、29.57℃及 25.17℃，全年平均相對濕度則是 80.22%。本實驗飼養蝌蚪的生長箱依野外狀況取整數值，設定溫度 20℃、25℃及 30℃(上下波動控制在 2℃內)及相對濕度 80%，並以日/夜各 12 小時進行光週期的調控。

蝌蚪孵化後，將發育至 Stage25(Gosner 1960)蝌蚪分裝至不同水量燒杯開始進行實驗，以 20 隻蝌蚪為一組放入控制 20℃、25℃及 30℃三種溫度生長箱；生長箱內部空間為 150 公升。蝌蚪置於 100ml、200ml、400ml 水量燒杯中飼養；各處理 3 重複，共使用 540 隻蝌蚪；其餘蝌蚪則於 7 月下旬放回同一菜園。每 2 或 3 天換水並餵食足夠的顆粒飼料並隨機自每個燒杯中取樣 5 隻蝌蚪測量體長至 0.1mm，若前次飼料被蝌蚪食盡，則換水時按照存活蝌蚪數增放飼料，至蝌蚪開始變態(Stage42; Gosner 1960)為止。進入變態期後蝌蚪體長會因尾部被吸收而縮短，在實驗第 58 天 25℃及 30℃處理組開始出現變態個體時，由各燒杯取樣 5 隻蝌蚪測量此時期的體長並將已變態蝌蚪移除。此後每次換水及餵食時皆移除已變態個體、記錄變態所需天數並保留其餘未變態蝌蚪。部分蝌蚪在長期飼養下並未全數變態，我們在實驗開始後第 125 天結束實驗，計算存活及變態蝌蚪數並取樣量測蝌蚪體長。遇燒杯中剩餘蝌蚪不足 5 隻時，則測量並記錄所有蝌蚪的體長。

統計方法上，本研究以 Chi-square($\chi^2$)來比較第 125 天的蝌蚪存活率及變態率，並以 Two-way ANOVA 比較第 58 天與 125 天蝌蚪的平均體長是否有受到不同水量、溫度處理的影響，以及不同因子之間有無交互作用(溫度 x 水量)；並用 Fisher's Least Significant Difference (LSD)進行事後比較。所使用的統計軟體為 SYSTAT 12。

## 結　果

在實驗結束(第 125 天)時，蝌蚪總存活率為 29.6%(表 1)；各水量處理下溫度對存活率均有顯著影響(水量 100ml: $\chi^2_2$=7.5, $p$=0.023；

水量 200ml: $\chi^2{}_2$=16.5, $p$<0.001；水量 400ml: $\chi^2{}_2$=13.1, $p$=0.001)，以 20℃處理組平均存活率 35.0%最高、30℃處理組 24.5%最低；水量對蝌蚪存活率影響則不顯著($\chi^2{}_2$=1.4, $p$=0.495)。

**表 1.** 澤蛙蝌蚪在各處理下的存活率及初始體長(平均值±標準差)

**Table 1.** Survival rates and initial body length (mean±sd) of *Fejervarya limnocharis* tadpoles under all treatments

| Water volume | Survival rate (%) | | | Initial bodylength (mm) | | |
|---|---|---|---|---|---|---|
| | 20℃ | 25℃ | 30℃ | 20℃ | 25℃ | 30℃ |
| 100 ml | 30.0±1.0 | 10.0±3.5 | 20.0±1.0 | 8.3±0.8 | 8.3±0.8 | 7.7±0.8 |
| 200 ml | 36.7±0.6 | 11.7±2.8 | 15.0±2.6 | 8.3±0.8 | 8.5±1.1 | 8.1±1.1 |
| 400 ml | 38.3±2.5 | 25.0±0 | 10.0±3.5 | 8.6±0.9 | 8.3±0.9 | 8.5±0.7 |
| average | 35.0±1.6 | 15.6±2.8 | 15.0±2.4 | 8.4±0.8 | 8.4±0.9 | 8.1±0.9 |

實驗開始時平均體長爲 8.3±0.9mm(表 1)；因各處理的蝌蚪初始體長無差異(p>0.05)，我們認爲可直接比較第 58 天(開始有蝌蚪進入變態)及 125 天(結束實驗)的數據來探討溫度及水量對蝌蚪體長之影響。排除未出現變態個體的 20℃處理組後，第 58 天出現變態個體的 25℃及 30℃處理組平均體長各爲 16.9±4.3 及 17.8±3.6mm(表 2)，顯示澤蛙蝌蚪在本實驗條件下開始進入變態的平均體長約爲 16.9±4.3mm。出現變態個體的 25℃及 30℃處理組在第 125 天平均體長各爲 25.6±3.8 及 25.4±2.5mm；此時蝌蚪雖未全部變態，我們仍可判斷在本實驗條件下，澤蛙蝌蚪最大可變態的平均體長應當在 25.6±3.8mm 以上(表 2)。

第 58 天各水量處理下蝌蚪體長具有顯著差異(two-way ANOVA, $F_{2,99}$=5.381, $p$=0.006)：400ml 處理組平均體長(17.8±3.6mm)大於 100ml(16.0±2.7mm)及 200ml(16.1±2.9mm)。蝌蚪在第 125 天結束實驗時，各水量處理的蝌蚪體長亦有顯著差異(two-way ANOVA, 水量 $F_{2,102}$=5.097, $p$=0.008)，100ml 處理下蝌蚪平均體長(23.3±3.6mm)顯著小於 400ml(25.8±3.4mm)及 200ml(26.0±3.2mm)處理組，可見長時間處於水量不足的情況下，對蝌蚪的成長存在著不利的影響；而在相同飼養期間內，水量多則可讓蝌蚪成長至較大的體型。而 30℃下 400ml 水量蝌蚪變態率最高且平均變態時間最短，顯示高溫與大水量有助蝌蚪變態(表 3)。

溫度對第 125 天蝌蚪體長的影響達到顯著水準(two-way ANOVA, $F_{2,102}$=3.503, $p$=0.034；表 2)，20℃處理下的體長小於 25℃及 30℃處理組。此外，two-way ANOVA 結果亦顯示溫度及水量對體長的影響有顯著交互作用(溫度×水量: $F_{2,99}$=2.806, $p$=0.030)。

在 125 天實驗期間不同溫度處理下蝌蚪變態率有顯著差異($p$<0.05)，其中 20℃處理組蝌蚪均無變態(表 3)。不同水量處理間的變態率則無顯著差異($\chi^2{}_2$=1.59, $p$=0.452)。所需的變態日數平均爲 100.2±18.7 天，但此兩種溫度變態日數差異不顯著(two-way ANOVA, 溫度、水量、溫度×水量: $p$>0.05 ；表 3)。因僅有 25℃及 30℃處理組有蝌蚪進入變態期，故只針對 25℃及 30℃溫度處理組進行變態日數的比較及討論而排除 20℃處理組。

**表 2.** 第 58 天及 125 天在各處理下的澤蛙蝌蚪體長(平均值±標準差)

**Table 2.** Body length (mean±sd) of *Fejervarya limnocharis* tadpoles under all treatments on Day 58 and Day 125

| Water volume | Day 58 length (mm) | | | Day 125 length (mm) | | |
|---|---|---|---|---|---|---|
| | 20℃ | 25℃ | 30℃ | 20℃ | 25℃ | 30℃ |
| 100ml | 15.0±1.9 (n=15) | 16.6±3.0 (n=15) | 16.3±3.3 (n=15) | 23.2±3.3 (n=15) | 22.8±4.9 (n=6) | 23.8±2.6 (n=12) |
| 200ml | 15.2±1.6 (n=15) | 17.2±4.5 (n=15) | 15.8±2.5 (n=15) | 24.1±4.4 (n=15) | 27.6±2.3 (n=7) | 26.3±2.8 (n=9) |
| 400ml | 15.1±2.4 (n=15) | 17.0±5.4 (n=15) | 21.2±5.0 (n=15) | 25.0±3.6 (n=15) | 26.3±4.3 (n=15) | 26.2±2.2 (n=6) |
| Average | 15.1±2.0 | 16.9±4.3 | 17.8±3.6 | 24.1±3.8 | 25.6±3.8 | 25.4±2.5 |

**表 3.** 澤蛙蝌蚪在各處理下的變態率與變態日數(平均值±標準差)

**Table 3.** Metamorphosis rates and metamorphosis days (mean±sd) of *Fejervarya limnocharis* tadpoles under all treatments

| Water volume | Temperature | Number of metamorphosis | Metamorphosis rate (%) | Metamorphosis days |
|---|---|---|---|---|
| 100ml | 25℃ | 6 | 10.0±5.0 | 110.2±7.1 |
| | 30℃ | 4 | 6.7±2.9 | 101.8±17.7 |
| 200ml | 25℃ | 8 | 13.3±5.8 | 95.3±19.4 |
| | 30℃ | 4 | 6.7±2.9 | 104.5±16.8 |
| 400ml | 25℃ | 7 | 11.7±2.9 | 107.4±23.6 |
| | 30℃ | 9 | 15.0±5.0 | 89.1±18.3 |
| Total | | 38 | 7.0±5.2 | 100.2±18.7 |

*No tadpoles underwent metamorphosis under 20℃ treatment.

## 討　論

環境溫度可能影響兩棲類的變態過程，日本研究曾指出在低溫環境下會因爲甲狀腺素及泌乳激素的影響而使兩棲類變態時間延長(Moriya 1998)。前人研究結果顯示台灣北部春、夏季澤蛙蝌蚪有表現出成長模式的差異，出生季節及溫度對於蝌蚪體長影響有顯著的交互作用：春季蝌蚪在低溫(22℃)下成長時間較久但變態時體長較大；夏季蝌蚪在高溫(29℃)下雖長得較快但變態時體長較小(Kuan and Lin 2011)。該研究與本研究的結果有些出入，但依其實驗方法所述，蝌蚪飼養於方型淺塑膠盒且餵食煮熟菠菜(未說明有無控制濕度)，是否因爲飼養容器較易蒸發水分及所餵食物種類不同造成蝌蚪在變態上的差異，日後應可再進行研究加以探討。

科學家普遍接受無尾兩棲類蝌蚪的成長至變態過程具表型可塑性(phenotypic plasticity)，若環境條件較差且蝌蚪達到最小可變態體長時，蝌蚪會儘快變態成爲小蛙以早日脫離惡劣環境。若環境條件良好則蝌蚪會留在該水域成長，待體長較大再進入變態，如此對小蛙生存率及競爭力將有正面幫助(Wilbur and Collins 1973)。已知北美洲鏟足蟾科(Pelobatidae)兩棲類的蝌蚪會因溫度升高、族群密度增加與食物量改變而加快變態時間(Newman 1998)；其作用機制爲身體感受到環境中水量減少及食物受限等逆境，間接促使甲狀腺素等內分泌激素加速產生而提前進入變態期(Boorse and Denver 2003)。在本研究採取固定水量及供應充足食物的穩定環境飼養下，無法得知澤蛙蝌蚪是否有類似的生理反應，但由平均變態時間長達 100 天以上的結果看來，如此穩定環境下的澤蛙蝌蚪應是採取緩慢成長、等待體長夠大後才開始變態的策略。至少，我們可確定本實驗所操作的最低水量(100ml)雖然影響蝌蚪體長大小，尚不會對蝌蚪造成壓力促使牠們儘速變態。

而在環境條件不佳的水域中，部分蝌蚪雖可加快其生長速率以達最小變態體長以避免乾旱死亡，但取而代之的可能是勉強變態後的小蛙背負著體長過小、行動力差、免疫較弱等另類風險(Gervasi and Foufopoulos 2008)。我們參考與澤蛙同樣在春至秋季繁殖，且產卵於雨後積水等暫時水域的諸羅樹蛙(*Rhacophorus arvalis*)的例子來看，其蝌蚪需要達到特定體長才會開始變態，若環境狀況不佳(如食物或空間不足)則會造成生長遲滯、變態時程延長(陳 2005)。本研究中澤蛙蝌蚪最小可變態體長爲 16.9±4.3mm 而最大變態體長超過 25.6±3.8mm，在此體長範圍內若不考慮溫度對於內分泌等生理功能的影響，第 125 天時各處理下蝌蚪應當都達到可變態體長且正常進入變態。然而結果不如預期的原因，有可能是我們所操作實驗條件並非蝌蚪難以忍受之逆境，無法迫使其早日進入變態期逃離此等環境的緣故。未來可進行水量及食物量減少的操作實驗，以探討澤蛙蝌蚪在惡劣環境下是否會因此提前進入變態過程。

由於同一卵團無法滿足實驗所需蝌蚪數量，本研究僅能以充分混合再隨機取樣的方式降低處理間蝌蚪的遺傳差異。而實驗過程中亦觀察到部份燒杯中蝌蚪大小出現明顯差異而使得平均體長標準差(SD 值)較大，例如第 58 天 25℃的 200ml 處理組和 400ml 處理組。但在前人研究會出現如此體型差異，推測可能是蝌蚪們對空間及食物資源出現種內競爭的結果(Semlitsch and Caldwell 1982)。在野外，處於競爭弱勢的個體可能因資源持續短缺，直到

優勢蝌蚪變態離開水池之後才能獲取到較為足夠的資源，從而延長其變態所需時間。此現象在水量穩定的環境下尚不會對蝌蚪存活造成顯著影響，倘若其所生活之暫時性水域因久未降雨而乾涸，則可能造成競爭弱勢蝌蚪來不及變態離開而死亡。但科學家亦曾觀察到蝌蚪會在低溫下主動往較水溫較高之處移動(Bradford 1984)，甚至進行聚集以其行為維持一定溫度來抵抗寒冷環境(Beiswenger 1977)，此類行為應當會相對減少蝌蚪個體間的競爭，或許可以作為本實驗中 20℃低溫處理下蝌蚪體型較為一致的原因。且因蝌蚪呈現聚集行為時所需的活動空間相對較小，故水量對此溫度下蝌蚪的影響效應亦較不顯著，使得各水量處理蝌蚪體長差異不大。

在第 125 天結束實驗時，不同溫度處理下的蝌蚪變態率具有顯著差異，但不同水量處理間的變態率則無顯著差異($\chi^2_2$=1.59, $p$=0.452；含完全無蝌蚪進入的 20℃處理組)。蝌蚪進入變態所需日數(不含 20℃處理組)平均為 100.2±18.7 天，由其標準差數值大小可知變態日數的變動幅度頗大；但由水量、溫度(不含 20℃處理組)均未顯著影響蝌蚪變態日數的結果來看，影響其變態日數另有其他原因。依據前人研究過程中減少水量及降低深度可使蝌蚪提早進入變態期(Denver *et al.* 1998)的結果看來，或許實驗過程中的水量動態減少較可能是刺激蝌蚪變態的因子，此論點尚需未來有進一步的研究來驗證。本實驗所操作的各溫度處理下僅 25℃及 30℃組有蝌蚪進入變態，但此兩種溫度變態率差異不顯著(表 3)；依此推測只要到達一定的溫度以上，蝌蚪便可正常進入變態期。而在本研究各操作組中唯獨 20℃處理下無任何蝌蚪進入變態狀態，顯示低溫對於澤蛙蝌蚪變態有負面影響，可能是因為低溫影響甲狀腺正常功能(Frieden *et al* 1965; Moriya 1983)並使蝌蚪生理代謝率下降的緣故。

本研究的澤蛙蝌蚪於 20℃處理組在 125 天實驗結束時，其平均體長(24.1±3.8mm)雖已達到本實驗操作下的 16.9±4.3mm 最小可變態平均體長但卻完全未進入變態，推測是低溫抑制其內分泌系統功能而間接造成的影響。而較高溫度(25℃、30℃)處理下蝌蚪雖然可正常變態，但我們生長箱溫度上下波動僅控制在操作溫度的±2℃以內，而野外水體實際上會因陽光曝曬而出現較 30℃更高的水溫，加上日夜溫差亦可能對生理功能產生效應；未來可進一步用控制 24 小時溫度起伏變動的方式，來探討日周期性溫度變化對蝌蚪是否會有其他程度的影響。

綜合本研究結果，我們可初步得知較高水溫不利於澤蛙蝌蚪生存，且澤蛙蝌蚪的體長會在高溫環境下受到生存環境中水量多寡影響。但實驗室內所操作的環境條件畢竟不若野外狀況多變及規模劇烈，其中有許多因素被簡化，是否能代表野外狀況仍有待商榷。但針對溫度與水量的議題上，暖化效應更明顯是否會造成棲地升溫而影響蝌蚪存活？氣候變遷導致降雨間隔時間延長是否會造成水量減少而使蝌蚪體長較小？若野外狀況真是如此，不能排除將會造成蝌蚪無法變態或小蛙因體長小而減低其競爭力與逃避天敵能力。未來可設計野外實驗、監測環境變動情形，或在類似研究中增加溫度日夜變化、水量隨時間減少等操作變因，以了解日夜溫差劇烈與降水間隔延長對兩棲類可能造成之衝擊。

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# The complete mitochondrial genome of the Formosan ferret-badger (*Melogale moschata subaurantiaca*)

# 台灣鼬獾整體粒線體基因組序列

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## Abstract

A complete mitochondrial genome of the Formosan ferret-badger (*Melogale moschata subaurantiaca*) was obtained by PCR amplification and DNA sequencing. The genome spans 16,497 bp that includes 13 protein-coding genes, 22 tRNA genes, and two rRNA genes. Nucleotide sequence divergence (K2P distance) of mitochondrial genome was 3.57% with that of Chinese ferret-badger (*Melogale moschata*).

## 摘　要

台灣鼬獾整體粒線體基因組序列以聚合脢連鎖反應及核酸定序獲得，全長共 16,497 bp，包含 13 個蛋白基因、22 個 tRNA 基因與 2 個 rRNA 基因，與大陸鼬獾整體粒線體核酸序列歧異度為 3.57%。

**Key words:** mitochondrial genome, *Melogale moschata subaurantiaca*, Taiwan

**關鍵詞**：粒線體基因組、鼬獾、台灣

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## Introduction

The Chinese ferret-badger (*Melogale moschata*, Mustelidae, Carnivora, Mammalia) comprises six subspecies and is distributed in China, India, Myanmar, Laos, Vietnam and Taiwan (Wozencraft 2005; Lariviere and Jennings 2009). It adapts well to tropical and subtropical forests, grasslands, and cultivated areas, and often lives near villages (Storz and Wozencraft 1999). Since 2008, *M. moschata* is confirmed as a rabies virus carrier and regarded as an important source of rabies transmission in southeastern China (Lei *et al.* 2008; Liu *et al.* 2010). Yu *et al.* (2011) had reported a complete mitochondrial genome of *M. moschata* from China, but without referring to its subspecies status.

The Formosan ferret-badger (*Melogale moschata subaurantiaca*) is an endemic and the only *Melogale* species in Taiwan Island (Wozencraft 2005; Lariviere and Jennings 2009). It is common and widely distributed across the whole island at low to high elevations (Lin 2008; Chiang *et al.* 2012). First case of rabies in ferret-badgers of Taiwan was detected in 2013 (Wu *et al.* 2014; Chiou *et al.* 2014). Because Taiwan Island had been free from canine rabies for 52 years (Wu *et al.* 2014), the cause of rabies re-emergence aroused the concern for relationship of ferret-badgers from Taiwan and China.

The genetic distance of mitochondrial genes between *M. moschata subaurantiaca* from Taiwan and *M. m. taxilla* from Vietnam reaches the interspecific level within the mustelid lineages, implying deep divergence among subspecies of *M. moschata* (Hosoda *et al.* 2011). We hereby report the complete mitochondrial genome of *M. moschata subaurantiaca* from Taiwan and compare it with that of *M. moschata* from China in divergence of sequences.

## Materials and methods

### Sampling and DNA extraction

Muscle tissue of Formosan ferret-badger (*Melogale moschata subaurantiaca*) was collected from a roadkill specimen near Yuan-Ton Temple in Fangshan Township, Pingtung County, southern Taiwan in 2012. Genomic DNA was extracted by using the Puregene DNA purification kit (Gentra) according to the manufacturer’s instructions.

**Primer design, PCR amplification and DNA sequencing**

To amplify the complete Formosan ferret-badger mitochondrial genome, 17 sets of primers were designed based on an alignment of ferret-badger mitochondrial genome sequences taken from GenBank with accession numbers HM106328 (*Melogale moschata*; Table 1). The PCR reactions were run on a GeneAmp 9700 PCR system (Applied Biosystems, Inc) and consisted of 1μl of template DNA (10–100ng), 2.5 μM of each primer, 0.4 mM of each dNTP, 1 unit of Taq polymerase and 1x buffer with 1.5mM $MgCl_2$, toally 25 μl. The PCR conditions were as follows: 5 minutes at 94℃, 35 cycles of 94℃ for 30 seconds, 45–50℃ for 30 seconds, and 72℃ for 1 minute, and a final 7 minutes extension at 72℃. PCR products were sequenced using an ABI Prism 3730 DNA automated sequencer (Applied Biosystems, Inc).

**Table 1.** Primers used in amplifying and sequencing the complete mitochondrial genome of *Melogale moschata subaurantiaca* from Taiwan

| Primer name | Sequence (5’ → 3’) | Location | Product length (bp) |
|---|---|---|---|
| MMAF | GCCAGAGAACTACTAGCAAC | 558-577 | 1200 |
| MMAR | GGAGAAGTATTTCTTGTTACTCAT | 1734-1757 | |
| MMBF | CAACTCCTAATATTTTACTGGG | 1677-1698 | 1059 |
| MMBR | GAAGAGGATTTGAACCTCTGG | 2715-2735 | |
| MMCF | ATCTAGCCAGTCCCCTTCCT | 2624-2643 | 1143 |
| MMCR | GAAACAAGAGGGCTTGAACC | 3745-3766 | |
| MMDF | CCTATTATAACAGCAAGCATTC | 3665-3686 | 1111 |
| MMDR | TCAGTAGGGCCGTGATTGCC | 4756-4775 | |
| MMEF | TATCGCTATCACACACATGAAA | 4593-4614 | 1181 |
| MMER | AGGTCTACGGATGCTCCCGCATG | 5751-5773 | |
| MMFF | ATAATTGGGGGCTTTGGAAACTGA | 5559-5582 | 1651 |
| MMFR | ACTGCTTGGGCATCCATAGTACT | 7187-7209 | |
| MMGF | CAAAGTCAAATTATAGGTGGA | 6991-7011 | 820 |
| MMGR | ATCATGTTGAGGTATCTAGTTG | 7789-7810 | |
| MMHF | ACTTTGAGAAATGATCTGCCTC | 7680-7701 | 891 |
| MMHR | AATAAGGGCTACTGCAAATTCT | 8549-8570 | |
| MMIF | GATTGGAGGAGCTACCCTAGC | 8462-8482 | 1037 |
| MMIR | GTAAGGTTAGTGCTATGTTTAT | 9477-9498 | |
| MMJF | TGACACTTCGTAGACGTCGTCTG | 9347-9369 | 1443 |
| MMJR | ACGCTATTATGCATGCTAGTCA | 10768-10789 | |
| MMKF | CTATTCTACACCCTAGTAGGCTC | 10630-10652 | 941 |
| MMKR | CTATATTTACAGTAAATGGG | 11551-11570 | |
| MMLF | CACTACACAACGCGGAAAATAC | 11418-11439 | 1009 |
| MMLR | GTGGCAGCCAGTAGCAGGCCT | 12406-12426 | |
| MMMF | AACACATGGGACTTCCAACAAAT | 12344-12366 | 1716 |
| MMMR | TTAGCTTTGTAGGGTTTTCTTC | 14038-14059 | |
| MMNF | CCTAATCAAACTTTACTTCATA | 13510-13531 | 976 |
| MMNR | AGTATAATCCTCGTCCTACG | 14466-14485 | |
| MMOF | ACAGCCTTCTCGTCAGTCAC | 14356-14375 | 1087 |
| MMOR | ATAGTTAAATTAGAATGCCAGC | 15421-15442 | |
| MMPF | CCTATTAAAATGAAGAGTCTTTGT | 15300-15323 | 984 |
| MMPR | ACGTTGCATGTGCTTAGTTCTG | 16262-16283 | |
| MMQF | CCGTAACTTCAAAAGTATACAA | 16208-16229 | 934 |
| MMQR | TATCGATTATAGAACAGGCTC | 624-644 | |

**Sequence analysis**

Forward and reverse sequences for the same section of mtDNA were edited using SeqMan (DNASTAR, LaserGene, Madison, WI, USA). The boundaries of each gene in the mitochondrial genome of *Melogale moschata subaurantiaca* were identified by sequence alignment of published Carnivora mitochondrial genome. Start and stop codons were used to define the protein-coding genes. Sequences were aligned and similarity analysis performed using the software BIOEDIT version 7.0.4 (Hall 1999). Numbers of tandem repeats were calculated using the program Tandem Repeats Finder (Benson 1999).

## Results and discussion

**General features of the *Melogale moschata subaurantiaca* mitochondrial genome**

The complete mitochondrial genome of *Melogale moschata subaurantiaca* (Genbank accession no. KP726273) is 16,497 bp in length, shorter than *Melogale moschata* (Genbank accession no. HM106328) which is 16,587 bp (Table 2). The differences result from different lengths of the control region between two species. The genome contains 13 protein-coding genes, 22 tRNA genes, and two rRNA genes. Eight tRNA genes and one protein-coding gene are located on the light strand, with the remaining genes located on the heavy strand. The overall base composition of the heavy strand is 31.95% A; 26.62% C; 14.72% G; 26.71% T. Guanine (G) is the rarest nucleotide and the GC content is 41.43%.

**Protein-coding genes**

The mtDNA contains 13 protein-coding genes. One of these (ND6) is located on the light strand (Boore 2004), with the others all on the heavy strand. This arrangement is typical for vertebrates (Table 2). Among 13 protein-coding genes of *Melogale moschata subaurantiaca* and *M. moschata*, the common Met start codon (ATG) could be assigned as the start codon for all protein-coding genes except for ND2, ND3 and ND5, which begin with ATC, ATA and ATA respectively. Common stop codons (TAA or TAG) could be assigned to most of the putative protein-coding sequences. ND1, ND2, COIII and ND4 are terminated with incomplete stop codons (T--) (Table 2), which are accommodated post-transcriptionally in the mRNA maturation process by polyadenylation (Ojala *et al.* 1981; Broughton *et al.* 2001). Two protein-coding regions (ATP8/ATP6 and ND4L/ND4) overlap and in each case both genes are translated from the same cistronic mRNA.

Nucleotide and amino acid sequences divergence (K2P distance) of the 13 protein-coding genes between the two whole mitochondrial genome were 1.99–4.61% and 0.00–2.88% (Table 2). Among the 13 protein-coding genes, ATP8 is most conserved, followed by Cytb, COI and COIII, whereas ND2 has evolved most rapidly.

**Table 2.** Characteristics and comparison of gene length, GC content, the number of codons, start codon, stop codon, and nucleotide and/or amino acid sequence divergences (% Kimura two-parameter distance) between the two complete mitochondrial genomes of *Melogale moschata subaurantiaca* from Taiwan and *M. moschata* from China (*M. moschata subaurantiaca* / *M. moschata*)

| Gene | From | To | Length (bp) | Codon | | | Intergenic nucleotides* | Strand† | Nucleotide divergence (%) | Amino acid divergence (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No. of codons | Start | Stop | | | | |
| tRNA Phe | 1/1 | 69/69 | 69/69 | – | – | – | – | H/H | 0 | – |
| 12SrRNA | 70/70 | 1030/1029 | 961/960 | – | – | – | 0/0 | H/H | 1.25 | – |
| tRNAVal | 1031/1030 | 1097/1096 | 67/67 | – | – | – | 0/0 | H/H | 0 | – |
| 16SrRNA | 1097/1096 | 2666/2664 | 1570/1569 | – | – | – | -1/-1 | H/H | 1.78 | – |
| tRNA Leu(UUR) | 2667/2665 | 2741/2739 | 75/75 | – | – | – | 0/0 | H/H | 0 | |
| ND1 | 2744/2742 | 3698/3696 | 955/955 | 318/318 | ATG/ATG | T– –/T– – | 2/2 | H/H | 3.14 | 0.00 |
| tRNA Ile | 3699/3697 | 3768/3766 | 70/70 | – | – | – | 0/0 | H/H | 1.43 | – |
| tRNA Gln | 3766/3764 | 3839/3837 | 74/74 | – | – | – | -2/-2 | L/L | 4.05 | – |
| tRNA Met | 3841/3839 | 3910/3908 | 70/70 | – | – | – | 1/1 | H/H | 0 | – |
| ND2 | 3911/3909 | 4952/4950 | 1042/1042 | 347/347 | ATC/ATC | T– –/ T– – | 0/0 | H/H | 4.61 | 2.88 |
| tRNA Trp | 4953/4951 | 5019/5017 | 67/67 | – | – | – | 0/0 | H/H | 0 | – |
| tRNA Ala | 5029/5027 | 5097/5095 | 69/69 | – | – | – | 9/9 | L/L | 0 | – |
| tRNA Asn | 5099/5097 | 5171/5169 | 73/73 | – | – | – | 1/1 | L/L | 1.36 | – |
| OL | 5172/5170 | 5207/5205 | 36/36 | – | – | – | 0/0 | –/– | 0 | – |
| tRNA Cys | 5205/5203 | 5271/5269 | 67/67 | – | – | – | -2/-2 | L/L | 0 | – |
| tRNA Tyr | 5271/5269 | 5338/5336 | 68/68 | – | – | – | -1/-1 | L/L | 0 | – |
| COI | 5340/5338 | 6884/6882 | 1545/1545 | 515/515 | ATG/ATG | TAA/TAA | 1/1 | H/H | 2.91 | 0.49 |
| tRNA Ser(UCN) | 6881/6879 | 6956/6954 | 76/76 | – | – | – | -3/-3 | L/L | 1.32 | – |
| tRNA Asp | 6961/6959 | 7027/7025 | 67/67 | – | – | – | 4/4 | H/H | 1.49 | – |
| COII | 7028/7026 | 7711/7709 | 684/684 | 228/228 | ATG/ATG | TAA/TAA | 0/0 | H/H | 3.51 | 0 |
| tRNA Lys | 7715/7713 | 7781/7779 | 67/67 | – | – | – | 3/3 | H/H | 0 | – |
| ATP8 | 7783/7781 | 7986/7984 | 204/204 | 68/68 | ATG/ATG | TAA/TAA | 1/1 | H/H | 1.99 | 1.49 |
| ATP6 | 7944/7942 | 8624/8622 | 681/681 | 227/227 | ATG/ATG | TAA/TAA | -43/-43 | H/H | 3.08 | 0.88 |
| COIII | 8624/8622 | 9407/9405 | 784/784 | 261/261 | ATG/ATG | T– –/T– – | -1/-1 | H/H | 2.93 | 0 |
| tRNA Gly | 9408/9406 | 9476/9474 | 69/69 | – | – | – | 0/0 | H/H | 1.45 | – |
| ND3 | 9477/9475 | 9824/9822 | 348/348 | 116/116 | ATA/ATA | TAG/TAA | 0/0 | H/H | 4.31 | 0 |
| tRNA Arg | 9825/9823 | 9892/9890 | 68/68 | – | – | – | 0/0 | H/H | 2.94 | – |
| ND4L | 9893/9891 | 10189/10187 | 297/297 | 99/99 | ATG/ATG | TAA/TAA | 0/0 | H/H | 4.04 | 0 |
| ND4 | 10183/10181 | 11560/11558 | 1378/1378 | 459/459 | ATG/ATG | T– –/T– – | -7/-7 | H/H | 4.06 | 1.53 |
| tRNA His | 11561/11559 | 11629/11627 | 69/69 | – | – | – | 0/0 | H/H | 0 | – |
| tRNA Ser(AGY) | 11630/11628 | 11691/11689 | 62/62 | – | – | – | 0/0 | H/H | 1.61 | – |
| tRNA Leu(CUN) | 11692/11690 | 11761/11759 | 70/70 | – | – | – | 0/0 | H/H | 0 | – |
| ND5 | 11753/11751 | 13585/13580 | 1833/1830 | 611/610 | ATA/ATA | TAA/TAA | -9/-9 | H/H | 3.11 | 1.80 |
| ND6 | 13569/13564 | 14102/14097 | 526/526 | 175/175 | ATG/ATG | TAA/TAA | -17/-17 | L/L | 3.99 | 1.14 |
| tRNA Glu | 14103/14098 | 14171/14166 | 61/61 | – | – | – | 0/0 | L/L | 0 | – |
| Cytb | 14176/14171 | 15315/15310 | 1140/1140 | 378/378 | ATG/ATG | TAA/TAA | 4/4 | H/H | 2.82 | 1.06 |
| tRNA Thr | 15316/15311 | 15383/15378 | 68/68 | – | – | – | 0/0 | H/H | 2.94 | – |
| tRNA Pro | 15384/15379 | 15448/15443 | 65/65 | – | – | – | 0/0 | L/L | 3.08 | – |
| Control region | 15449/15444 | 16497/16587 | 1048/1144 | – | – | – | 0/0 | – | 12.63 | – |
| PCG‡ | – | – | 11413/11410 | 3794/3793 | – | – | – | – | 3.40 | 1.01 |
| Entire genome | – | – | 16497/16587 | – | – | – | – | – | 3.57 | 1.01 |

Notes: Bold letters indicate different lengths of genes between the two taxa. * Numbers correspond to the nucleotides separating different genes. Negative numbers indicate overlapping nucleotides between adjacent genes; † H and L denote heavy and light; ‡ Combined sequences of 13 protein-coding genes (PCGs).

**RNA genes**

There are 22 tRNA genes identified in the *Melogale moschata subaurantiaca* mitochondrial genome, with lengths ranging from 61bp (tRNA-Glu) to 76 bp (tRNA-Ser). The 12S rRNA and 16S rRNA genes are 961 bp and 1,570 bp respectively. tRNA-Ile and tRNA-Gln are overlapping with separate transcripts in opposite directions. This arrangement is typical for mammalian mitochondrial genomes (Anderson *et al*. 1981; Parma *et al*. 2003, Tsai *et al*. 2009). (Table 2).

**Control region**

The origin of L-strand replication ($O_L$) of *Melogale moschata subaurantiaca* was located between tRNA-Asn and tRNA-Cys, which is 36bp in size and similar to those of other vertebrates (Hou *et al*. 2007; Delisle and Strobeck 2002; Yue *et al*. 2006). The sequence of the control region (CR) of *M. moschata subaurantiaca* located between tRNA-Pro and tRNA-Phe is 1,048 bp in size and contains three sets of repeats in position 569-616, 568-726 and 568-726 by online software TANDEM REPEATS FINDER (Benson 1999).

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# 瑟尼良苔蛾—台灣新紀錄種蛾類

# *Eugoa cernyi* Bucsek, 2012 (Erebidae, Arctiinae) - a newly recorded moth from Taiwan

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## 摘　要

原產於泰國、印度、馬來西亞的瑟尼良苔蛾(*Eugoa cernyi*)首次記錄於臺灣。本種前翅內線爲鋸齒狀，此特徵可與臺灣產良苔蛾屬其他已知種區分。本報告提供本種雄性與雌性個體與生殖器照片供參考比較。

## Abstract

*Eugoa cernyi* Bucsek (2012), a moth distributed in Thailand, Malaysia, and India, was recorded for the first time in Taiwan. This species can be distinguished from the others in the same genus in Taiwan by the serrate antemedial band on its forewings. Pictures of male and female bodies are provided in this paper, including their genitalia.

**關鍵詞**：裳蛾科、苔蛾族、新紀錄種

**Key words:** Erebidae, Lithosiini, newly recorded species

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## 緒 言

良苔蛾屬 *Eugoa* 是 Walker 在 1857 年建立的（Walker 1857）。當時指定的模式種爲產於婆羅洲的 *Eugoa aequalis* Walker 1857。本屬多爲中、小型蛾類，顏色多爲不顯眼的灰色、褐色、黑色，也有部分爲白色。觸角絲狀，部分種類的雄蟲觸角爲雙櫛齒狀。前翅多爲長橢圓形，中室處常有一至二個斜向的黑褐色斑點。後翅長度超過腹部，通常沒有明顯的斑紋。本屬種類主要分布於印澳區，北至日本，南至新幾內亞和澳洲，西至中國，甚至非洲也有分佈（Holloway 2001）。

臺灣良苔蛾屬的種類，在張保信先生的「臺灣蛾類圖說（二）」（1989）中描述了 3 種：臺雙點良苔蛾 *E. formosicola* Matsumura 1927、雙點良苔蛾 *E. bipunctata*（Walker 1862）和暗良苔蛾 *E. obscura* Hampson 1900；後來 Inoue 和 Kishida （1992）在「臺灣鱗翅目昆蟲誌 Part1」名錄中也記錄 5 種：*E. bipunctata*（在本名錄中可能根據 Hampson（1900）的意見，將前述 *E. formosicola* 視爲 *E. bipunctata* 的同物異名）、*E. brunnea* Hampson 1914、*E. grisea* Butler 1877、*E. obscura formosibia* Strand 1917 和 *E. sinuata* Wileman 1914；王效岳先生 (1994)於「認識臺灣的昆蟲 7 燈蛾科」則進一步加入這 5 種的中文名稱（中點良苔蛾 *E. bipunctata*、暗良苔蛾 *E. brunnea*、雙點良苔蛾 *E. grisea*、小良苔蛾 *E. obscura formosibia* 和三角斑良苔蛾 *E. sinuata*）和標本圖示。因爲 Hampson（1900）將產於日本的 *E. obscura* Leech 1888 移至 *Siccia* 屬，卻又同時將產於婆羅洲的良苔蛾新種命名爲 *E. obscura*，所以 Holloway（2001）把後命名的 *E. obscura* 改名爲 *E. hampsoni*，並將 *E. obscura* var. *formosibia* Strand 1917 視爲其同物異名。現在加上本種，臺灣產良苔蛾屬共有 6 種。

本研究重新檢視採於苗栗縣泰安鄉象鼻村及士林村的苔蛾標本，進行生殖器解剖，並檢視存放於國立自然科學博物館的標本，同時參考國外近年 *Eugoa* 屬的相關文獻，並與發表該物種的學者 K. Bucsek 討論並比較外生殖器形態後，確認該標本爲臺灣新紀錄種「瑟尼良苔蛾 *Eugoa cernyi* Bucsek 2012」。

## 材料與方法

生殖器解剖用的標本均於苗栗縣泰安鄉象鼻村用水銀燈於夜間採獲。成蟲展翅針插乾燥。取下腹部，浸泡於 10% KOH 中，兩天後取出，置於雙眼解剖顯微鏡下，取出並清理生殖器上多餘組織、鱗毛，以 95%酒精固定後，

轉置二甲苯（Xylene）中脫水，最後以封片膠（Assistant-Histokitt, Germary）封片並拍照。

## 結　果

**瑟尼良苔蛾 *Eugoa cernyi* Bucsek 2012** (圖 1-8)

*Eugoa cernyi* Bucsek 2012: 8. (圖 1、2)


**圖 1.** *Eugoa cernyi* 瑟尼良苔蛾模式種(Karol Bucsek 提供)。

**Fig. 1.** *Eugoa cernyi* Holotype. (Karol Bucsek)

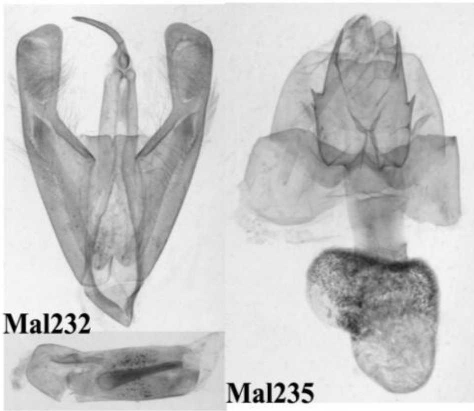


**圖 2.** *Eugoa cernyi* 瑟尼良苔蛾模式種生殖器(Karol Bucsek 提供)。

**Fig. 2.** *Eugoa cernyi* Holotype. Male and female genitalia. (Karol Bucsek)

**形態描述：**雄蟲（圖 3、4）翅展 19-28mm，雌蟲（圖 5、6）21-29mm。觸角黃褐色，雄蟲觸角雙櫛齒狀，櫛齒長度比觸角寬二倍以上，各櫛齒端具有針狀毛，雌蟲觸角雙櫛齒狀，但櫛齒甚短。雄蟲頭部灰色無紋。胸部灰色，在頭部後方有兩個黑點，肩板灰色，有一個黑褐色斑。腹部乳白色無紋。前翅灰色，翅基前緣和中央各有一個黑點，內線黑褐色，鋸齒狀曲折，於後緣處向外彎（此鋸齒狀內線特徵可與臺灣產本屬已知其他種類明顯區分），內側散佈黑褐色鱗，外側黑褐色向中線漸淺，中室端有斜向兩個黑點，有時只有一個，中線曲折，大致與外緣平行，於中室和後緣處外突，中線外側黑褐色，向外緣漸淺，亞外緣線黑褐色，波狀曲折。緣毛顏色由頂角起深淺相間。後翅乳白色無紋，頂角附近顏色較深。雌蟲翅色花紋同雄蟲。


**圖 3.** *Eugoa cernyi* 瑟尼良苔蛾雄蟲。

**Fig. 3.** Male *Eugoa cernyi*.


**圖 4.** *Eugoa cernyi* 瑟尼良苔蛾雄蟲腹面。

**Fig. 4.** Male *Eugoa cernyi* underside.


**圖 5.** *Eugoa cernyi* 瑟尼良苔蛾雌蟲。

**Fig. 5.** Female *Eugoa cernyi*.


**圖 6.** *Eugoa cernyi* 瑟尼良苔蛾雌蟲腹面。

**Fig. 6.** Female *Eugoa cernyi* underside.

**外生殖器：**Bucsek(2012)書中僅附外生殖器圖片，並未有文字描述，在此對其外生殖器進行描述。雄蟲（圖 7）鉤形突（uncus）弧狀細長；無顎形突（gnathos）；背兜（tegumen）細長；抱器（valva）略呈三角形，邊緣骨化程度較高，末端平直，向背側微突；陰莖（aedeagus）細長，具有一個細長椎狀的角狀器（cornuti）。雌蟲（圖 8）交配囊（corpus burse）密佈絨毛狀突起，近末端的那一半部分較稀疏；後陰片（lamella postvaginalis）骨化明顯，略成梯型，兩側及末端具尖銳突起；肛乳突（papillae analis）具有稀疏剛毛。

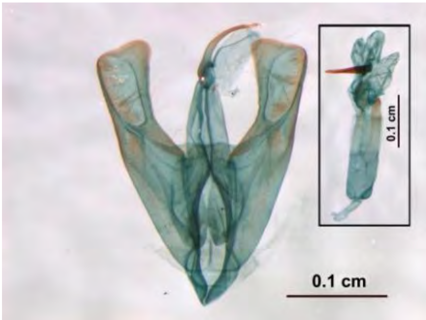


**圖 7.** *Eugoa cernyi* 瑟尼良苔蛾雄蟲生殖器(徐歷鵬攝)。

**Fig. 7.** Male *Eugoa cernyi* genitalia. (Li-Peng Hsu)

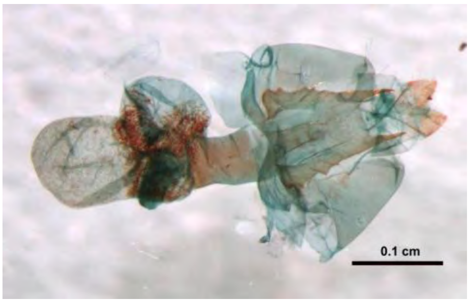


**圖 8.** *Eugoa cernyi* 瑟尼良苔蛾雌蟲生殖器。

**Fig. 8.** Female *Eugoa cernyi* genitalia.

**標本檢查：**1♂, 1994.III.30, 苗栗縣泰安鄉象鼻村。1♂, 1994.IV.11, 苗栗縣泰安鄉象鼻村。1♂, 1994.VI.14, 苗栗縣泰安鄉象鼻村。1♀, 1994.VI.28, 苗栗縣泰安鄉象鼻村。1♂1♀, 2014.VIII.7, 南投縣雲龍橋。1♂2♀, 2014.VIII.29, 南投縣屯原。1♀, 2014.VII.5, 高雄市扇平, leg. 廖文泉。1♀,2014.VII.19,屏東縣大漢林道, leg. 廖文泉。1♀, 2014.VIII.29, 南投縣丹大林道, leg. 謝祚元。以上標本筆者私人收藏。1♂ ,1996.X.14-17, 宜蘭縣福山, leg. C. S. Lin & M. L. Chan。1♂, 1984.III.9, 南投縣惠蓀林場, leg. B. S. Chang。1♂, 1983.V.21, 苗栗縣橫龍, leg. B. S. Chang。1♂, 1986.VIII.9, 新竹縣北埔, leg. B. S. Chang。1♂, 1990.VII.18-20, 南投縣霧社, leg. C. S. Lin。1♂, 1992.VII.23, 南投縣春陽, leg. C. S. Lin。1♂1♀, 1984.VIII.2, 桃園縣下巴陵, leg. B. S. Chang。1♀, 1985.VI.16, 南投縣東埔, leg. B. S. Chang。1♀, 1985.VIII.28, 南投縣惠蓀林場, leg. B. S. Chang。1♀, 1985.V.18, 南投縣盧山, leg. B. S. Chang。1♀, 1988.IX.19-23, 苗栗縣泰安, leg. C. S. Lin。1♀, 1991.VI.18-19, 南投縣蓮華池, leg. C. S. Lin。1♀, 1991.IX.25, 南投縣霧社, leg. C. S. Lin。2♀, 2002.VIII.14-16, 南投縣合望, leg. W. T. Yang。以上標本存放於國立自然科學博物館。

**世界分布：**泰國、馬來西亞、印度、臺灣。

**臺灣產良苔蛾的檢索表**

1. 體型甚小，展翅小於 1 公分。------------------------------------------ *Eugoa. hampsoni* 小良苔蛾
   體型大於 1 公分。-----------------------------------------------------------------------------------2
2. 前翅暗褐色，無明顯斑紋。-----------------------------------------------------*E. brunnea* 暗良苔蛾
   前翅非暗褐色，具明顯斑紋。-----------------------------------------------------------------------3
3. 前翅灰白色。-----------------------------------------------------------------*E. sinuata* 三角斑良苔蛾
   前翅非灰白色。-----------------------------------------------------------------------------------------4
4. 前翅內線中間常消失，呈雙點狀。---------------------------------------------*E. grisea* 雙點良苔蛾
   前翅內線不成雙點狀。-----------------------------------------------------------------------------------5
5. 前翅內線呈鋸齒狀。---------------------------------------------------------------*E. cernyi* 瑟尼良苔蛾
   前翅內線不呈鋸齒狀。-------------------------------------------------------*E. bipunctata* 中點良苔蛾


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# A New Record of the Earthworm *Ocnerodrilus occidentalis* Eisen, 1878 from Matsu

# 馬祖新紀錄種蚯蚓西土寒蠕蚓

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## Abstract

This paper describes the exotic ocnerodrilid earthworm *Ocnerodrilus occidentalis* Eisen, 1878 as a new record from Matsu. Now distributed globally, the species is a small earthworm whose native home is likely in Central or South America.

## 摘　要

本文描述一採自馬祖南竿、北竿及東引之新紀錄外來種蚯蚓西土寒蠕蚓 *Ocnerodrilus occidentalis* Eisen, 1878。其爲小型蚯蚓，屬於寒蠕蚓科(Ocnerodrilidae)，可能原產於中美洲或南美洲。此種蚯蚓目前廣泛分布於全球。

**Key words:** *Ocnerodrilus occidentalis*, earthworm, Matsu

**關鍵詞**：西土寒 蠕蚓、蚯蚓、馬祖

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## Introduction

*Ocnerodrilus occidentalis* Eisen, 1878 was first described by Eisen based on specimens found in an irrigation box from his vineyard at Fresno County, California (Eisen 1878; Gates 1972). Eisen (1900) redefined this species with specimens collected from the original locality as well as those from the city parks of Durango, Mexico. Eisen (1900) also described two varieties, var. *sinensis* and var. *arizonae*, of this species. The description of the former was based on specimens from pots containing plants brought from China, while specimens of the latter were obtained near irrigation ditches in Phoenix, Arizona (Eisen 1900). Both Michaelsen (1910) and Stephenson (1914) doubted the validity of var. *arizonae*, and Chen (1933) considered var. *sinensis* as invalid since intermediate forms were observed among var. *typicus*, var. *arizonae* and var. *sinensis*. The distribution range of *O. occidentalis* includes Central Asia, India, Ceylon, Myanmar, Singapore, Hainan, China, Japan, Philippines, Solomons and New Hebrides, California, Arizona, Mexico, Cuba, and Australia and Tasmania (Gates 1972; Blakemore 2010). According to Gates (1972), plant quarantine interceptions show that the species still is being carried around the world by man, and the original home of this species may be somewhere between the United States and South America.

Gates (1972) stated that *O. occidentalis* is known only from parthenogenetic morphs without seminal vesicles and spermathecae. Currently only seven nominal species have been reported for the genus *Ocnerodrilus* and all of them are native to Central and/or South America (Brown and Fragoso 2007).

The following description is based on 19 preserved specimens deposited at the Taiwan Endemic Species Research Institute, Jiji, Nantou, Taiwan.

### *Ocnerodrilus occidentalis* Eisen, 1878

*Ocnerodrilus occidentalis* Eisen, 1878: 10; 1900: 113. – Michaelsen, 1900: 377; 1910: 100; 1931: 1. – Stephenson, 1914: 361; 1916: 348. – Chen, 1933: 224; 1938: 426. – Gates, 1935: 93; 1942: 99; 1961: 57; 1972: 273; 1982: 16. – Lee, 1981: 567. – Blakemore, 2010: 183.

*Ocnerodrilus tenellulus* Gates, 1945: 223.

**Materials examined.** － Three mature (clitellate) specimens collected 31 May 2012 from a roadside ditch near the weather station (elevation 48 m), Nangan by H. P. Chen and T. L. Ai (coll. no. 2012-54); six specimens collected 26 June 2012 near a trash treatment field (elevation 64 m), Tangchi Village, Beigan by H. P. Chen and W. J. Chih (coll. no. 2012-61); five mature and five immature specimens collected 31 August 2012 near Zhongling Temple (elevation 76 m), Dongyin by H. P. Chen and H. H. Huang (coll. no. 2012-130).

**Description.** － Length (clitellates) 20–28 mm, diameter 1.0–1.2 mm. Segment number 75–89. Prostomium epilobous. Dorsal pores absent. Clitellum XIV–XIX or XIII–XX, annular, setae present (Fig. 1A). Setae lumbricine (eight setae per segment), closely paired, aa: ab: bc: cd = 4: 1: 4: 1. Spermathecal pores absent. Male pores one pair in XVII, faint, each slightly lateral to seta b. Female pores one pair in XIV, each anterior to seta b (Fig. 1A). Specimens unpigmented.

Septa present from 4/5, 4/5 thin, 5/6/7 thick, 7/8–11/12 thickened, and 12/13 to posterior end thin and membranous. Gizzard absent. Intestine enlarged from XII. Hearts two pairs in X–XI. Calciferous glands one pair in IX, shiny, thick-walled, yellowish brown in color. Nephridia holoic.

Spermathecae absent. Accessory glands absent. Testes two pairs in X and XI. Seminal vesicles absent. Prostate glands one pair, each coiled, tubular and lying under intestine (Fig. 1B). Ovaries in XIII, racemose.

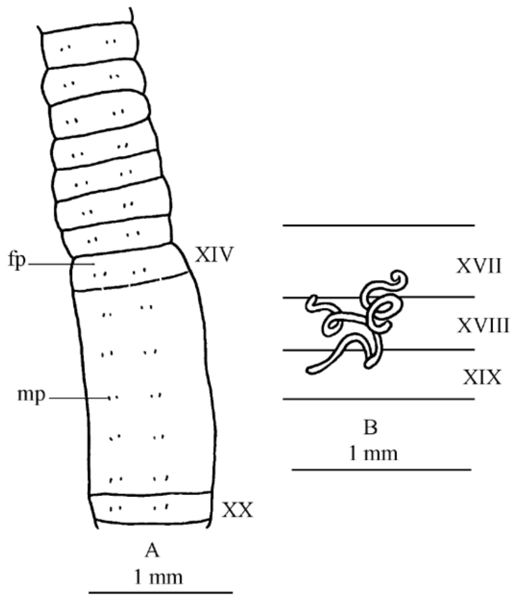


**Fig. 1.** *Ocnerodrilus occidentalis* Eisen: A, ventral view of preclitellar and clitellar regions (fp, female pore; mp, male pore); B, dorsal view of prostate glands.

## Acknowledgments

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# *Crotalaria goreensis* Guill. & Perr. (**Leguminosae**), a newly naturalized species plant in Taiwan

# 台灣新歸化植物：西非豬屎豆

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## Abstract

*Crotalaria goreensis* Guill. & Perr. (Legumiosae) was recently discovered in Hengchun Peninsula, Taiwan, as a newly naturalized and potentially aggressive weed. A detailed description, photographs and geographic distribution are provided for identification of the species.

## 摘　要

近年作者於台灣恆春半島發現之新歸化植物：西非豬屎豆。此植物爲具有潛在危害的農田雜草，本文提供該種歸化植物的描述、彩色照片及地理分布以供鑑定用。

**Key words:** *Crotalaria goreensis*, flora, Leguminosae, naturalized plant, Taiwan.

**關鍵詞**：西非豬屎豆、植物誌、豆科、歸化植物、臺灣

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## Introduction

*Crotalaria goreensis* Guill. & Perr. (Legumiosae) is a newly naturalized species that belongs to **Leguminosae**, a major contributor to the naturalized flora in Taiwan (Wu et al., 2004; Chen, 2008). Naturalization events of several other **Leguminosae** species, such as *Aeschynomene americana* L. var. *glandulosa* (Pior.) Rudd, *Indigofera pseudo-tinctoria* Matsum., *Mimosa pigra* L., and *Trigonella hamosa* Forsk., were reported after the second edition of *Flora of Taiwan* was published (Wu and Huang, 1999; Yang and Peng, 2001; Chen, 2008; Jung et al. 2009). After publishing the latest checklist of alien plant in Taiwan (Ku et al., 2011), we report *Crotalaria goreensis* Guill. & Perr as one more newly naturalized **Legumiosae** plant in Taiwan. Descriptions and photographs of *Crotalaria goreensis* Guill. & Perr. are presented in this paper.

## Taxonomic Treatments

*Crotalaria goreensis* Guill. & Perr., Fl. Seneg. Tent. 1: 165. 1832. 西非豬屎豆 Fig 1.

Type: Senegal, *Perrottet 170* (syntypes: P!); *Perrottet s.n.* (syntypes: P!).

An erect annual or perennial herb, about 80 cm high, with many branches, finely pubescent throughout. Leaves trifoliolate, obovate to elliptic, 2.5–8 cm long, 0.5–2.5 cm wide, mucronate or rounded at apex, the upper surface glabrous, the lower surface pubescent; stipules lanceolate-falcate, 0.6–2 cm long; petioles erecto-patent, slightly silky, 2.5–3.5 cm long. Racemes terminal, up to 25 cm long, 12–20-flowere; pedicels ca. 3 mm long; calyx 4–5 mm long, 2–3 mm wide, pubescent; clefts lanceolate, covered with hairs; corolla yellow but often with orange or red-brown, twice as long as the calyx, not twisted. Pod 15–20 mm long, half as thick, oblong, when young densely silky, 10–12-seeded. Seeds 2.5–4 mm long, orange.

**Distribution:** Native in tropical Africa; naturalized in Australia and Taiwan.

**Habitat and phenology:** Open wasteland, ca. 20 m. Flowering and fruiting from October to February.

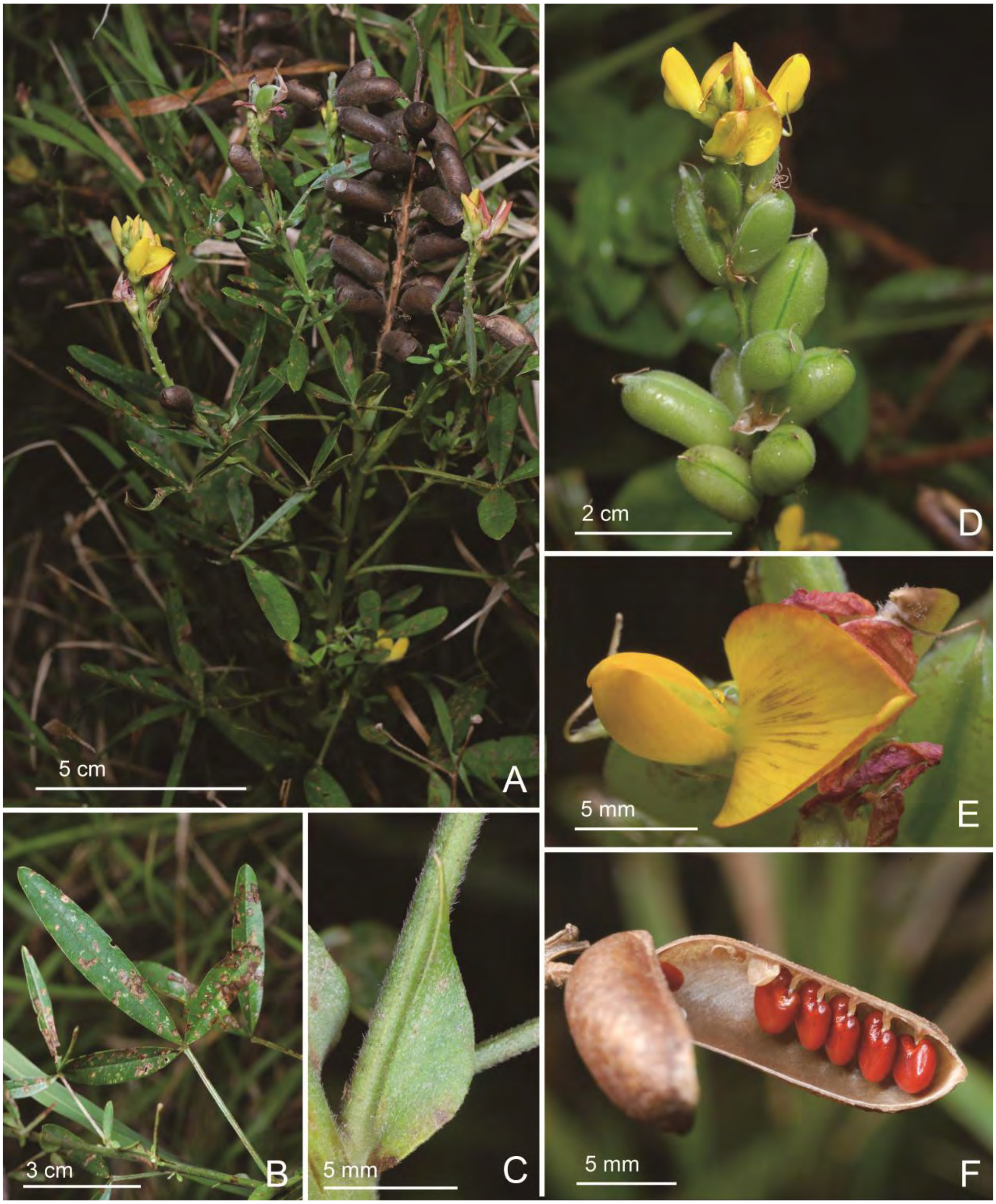


**Fig 1.** *Crotalaria goreensis* Guill. & Perr. A. habit; B. leaf; C. stipule; D. fruiting and flowering branch; E. flower; F. pod with seeds.

**Voucher specimens:** Pingtung: Houpi Lake, *T. C. Hsu 5310* (TAIF); Hengchun, *P. F. Lu 23600* (TAIF).

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   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.
8. Table should be typed on a separate sheet and be headed by a title of dual languages (Chinese and English). It consists of only horizontal lines and typed with English terms (if possible) and Arabic numerals. If foot notes are required, mark with superscripts $^{1}$, $^{2}$, $*$, $^{\#}$, etc.
9. Figure should be drawn with black ink on a separate white tracing paper with a figure legend of the dual languages below. Computer graph made from laser printer is acceptable.
10. Photograph should be a glossy black and white shot with sufficient resolution to be clearly legible after reduction. When multiple photos are employed, the author should arrange them in plates. Micrographs should include bars indicating scales of magnification. Photos should be pasted on white A4 paper loosely with the figure legend below.