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封面圖說／

叫聲有如鳥鳴的斯文豪氏赤蛙，常出現於山區溪澗環境。

(楊育昌 攝)

## 台灣生物多樣性研究

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# 烏石坑地區森林與溪流環境兩棲類群聚受地震影響之研究

## Study of Earthquake Effects on the Forest and Stream Amphibian Communities in Wushykeng Area

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### 摘 要

本研究分析 1997 至 2008 年春、秋季烏石坑地區無尾目兩棲類固定穿越線監測調查資料。調查路線包含屬於森林與溪流棲地環境各 2 條穿越線；依 921 地震發生及調查路線調整等因素分為 4 個時期。共記錄 13 種兩棲類動物，其中 2 種為地震後的新紀錄種。森林環境地震後一期種數明顯減少可能因植被破壞之故；而地震後二期、三期兩棲類種類數回升，且數量上明顯夏季多而秋季少。溪流環境地震前和地震後一期兩棲類數量同森林棲地般無明顯季節變化，地震後的種數增加則可能是森林性兩棲類另覓生殖場所的結果；且地震後二期、三期因秋季梭德氏赤蛙大量出現，在數量上有明顯的季節性變化，但為夏季少、秋季多的狀況。地震後二、三期秋季溪流環境之各項指數明顯較低，主要因為梭德氏赤蛙單一種數量大增。烏石坑地區斯文豪氏赤蛙族群在地震後一期便已回復到地震前水準，和關刀溪地區的研究結果相符；其族群波動雖然甚不穩定，但大致有森林與溪流棲

地環境彼此消長現象，推測個體會在不同棲地間移動交流。至於梭德氏赤蛙直至地震後二、三期才發生的秋季生殖高峰現象，初步推測可能是溪流環境改變合適梭德氏赤蛙繁殖，加上附近植群回復之結果。

## Abstract

Summer and autumn anuran line-transect survey of two forest and two stream transects at Wushykeng area before and after the 921 earthquake (1997 to 2008) was analyzed in this research. We found 13 amphibian species with two new species records after the earthquake. No distinct seasonal variation was found in the number of frogs between pre-quake and the first post-quake periods in forest habitats, but the number of species reduced in the post-quake periods. It might be a result of the destruction of forest vegetation due to the quake. In the second and the third post-quake periods, amphibian abundance recovered but showed seasonal fluctuation with high in the summer and low in the autumn. There was no seasonal population variation in stream habitats in pre-quake and early-post-quake periods. Increase of species numbers might be a result of frogs seeking new breeding sites after forest habitats destruction. The total frog abundance fluctuated conspicuously from low in the summer to high in the autumn due to the explosive increase of *Rana sauteri* individuals in the autumns in the latter post-quake periods. Biodiversity indexes were lower in stream habitats in the latter post-quake periods, resulting from the increase of *Rana sauteri* abundance. The *Odorrana swinhoana* population in Wushykeng recovered in the first post-quake period, probably as a result of the frogs moving between forest and stream habitats. In addition, the autumn *Rana sauteri* population bursts in the latter post-quake periods were presumably due to the stream habitats becoming appropriate for breeding and the recovery of nearby vegetations.

**關鍵詞：**兩棲類、長期監測、地震、低海拔

**Key words :** amphibian, long-term monitoring, earthquake, low altitude

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## 前 言

位於臺中市和平區自由里烏石坑地區的行政院農業委員會特有生物研究保育中心低海拔試驗站在成立期間曾爲了提供規劃及未來經營管理依據，自 1992 年 10 月至 1994 年 6 月在此地完整詳細的動物資源先期調查工作(方等 1994；何等 2004)。當時共發現 13 種無尾目兩棲類動物，占台灣 29 種原生無尾目兩棲動物的 40% 以上，足見這個地區兩棲類動物資源相當豐富。

發生於 1999 年的 921 地震重創了中部山林環境及溪流生態，並造成烏石坑山區部份邊坡崩塌、土石裸露，遇到豪雨往往容易發生土石流。2001 年桃芝、娜莉等颱風挾帶風雨更造成後續災害，衝擊山區森林及溪流生態環境。例如烏石坑吊橋原本距溪面約 20 m 深，在多次沖下土石流後僅剩約 7 m；下游烏石坑分校附近跨烏石坑溪的長榮橋原爲雙線道水泥橋，也被沖走兩截橋面並將其餘橋面埋沒(何等 2004)。這些強度干擾對野生動物影響很大，況且兩棲動物相對而言遷移能力較低且皮膚保水能力不佳須依賴水域生活及繁殖(Pough 2007)，對於前述的地震、颱風等劇烈天災事件之應變能力亦相對較弱，棲息地若遭破壞可能導致當地族群的大幅波動。本地區乾溪溪谷原來水量及林相穩定，地震前可以發現此地區大部份兩棲類物種(楊及林 2000)，但地震後乾溪水流時常枯竭而烏石坑溪段亦多遭土石填塞，對兩棲類所造成的影響程度如何，以及需時多久才可回復原本狀態？雖然曾有學者探討過人工林經營如何干擾森林生態系的兩棲類(關等 2007)，或 921 地震的劇烈擾動對於單一溪流性蛙類族群的影響(賴等 2002, 關及賴 2002)，但地震對於兩棲類群聚在森林與溪流環

境之間的消長情形造成何種效應則尚未釐清；這些疑問則有待地震後持續調查研究方可確認。有鑑於此，本研究取烏石坑地區兩棲類監測資料加以分析，藉以評估地震前後該地區森林及溪流棲息環境內兩棲類群聚的變動情況。

由於地震屬於偶發性的天然災害，不易藉著控制實驗及系統性取樣來探討其對於兩棲類的影響程度。但若有長期生態監測地點恰巧位於地震發生區域內，如在 921 地震影響範圍內的關刀溪流域(關 1999)以及本研究的烏石坑溪流域，則可根據地震前後的生物族群及群聚組成調查結果，來進一步推斷地震對生態系之影響範圍、影響時間長度及受到影響的種類。

爲了對照地震發生之前與之後的生態環境狀況，我們在地震後持續調查兩棲類群聚。希望除了瞭解兩棲動物遭受 921 地震干擾的程度，也能提供經營管理及棲地復育措施參考。根據在關刀溪斯文豪氏赤蛙(*Odorrana swinhoana*)研究結果顯示，兩棲類族群在地震後的變化主要受到當地水域改變的直接影響。水域環境變化不但改變族群量，亦影響族群在時間、空間上的分布，甚至干擾了兩棲類的繁殖週期(賴等 2002)。至於此種現象是否亦發生在同樣位於台灣中部且海拔高相當的烏石坑地區，我們將在此研究中作更進一步的探討。

## 材料與方法

### 一、研究地點

研究地點爲行政院農業委員會特有生物研究保育中心低海拔試驗站，位於臺中市和平區烏石坑地區，涵蓋國有林大安溪事業區第 122 林班整體。區內以東南方之山椒山(海拔

1834m)為最高點，區域中心一帶坡度較緩和。東邊以乾溪、西邊以烏石坑溪為界，兩溪會合後向西北流經烏石坑社區並注入大安溪。南方則以山嶺與其它林班毗鄰，地形上呈現南北走向，南方地勢高且北偏西方地勢低。林地面積共 353.17ha，含天然林、人工林及苗圃，其中除 107ha 左右為造林地及苗圃外，其餘為楠、櫟林帶樹種為主之原生林，提供多樣化的環境。區內海拔高度 680 m~1834 m，年均溫約為 18°C，年均雨量約 2600mm。烏石坑地區氣候乾、濕季明顯，雨量多集中於 4~9 月；相對濕度高，年平均值約 85.9%，而全年平均有霧日數約為 100 天(試驗站監測資料，未發表)。

## 二、調查方法

在烏石坑地區的森林棲地環境及溪流棲地環境中各選定兩條固定調查穿越線，包括低海拔試驗站辦公室至南方水源段之右線林道(穿越線 A)、山椒山段之左線林道(穿越線 B)、乾溪段(穿越線 C)及烏石坑溪段(穿越線 D)等 4 條調查路線(圖 1)。各棲地環境之穿越線長約 1 公里。其中森林棲地環境為 A、B 線，屬於坡度陡峭之森林林道，A 線前半段為台灣杉(*Taiwania cryptomerioides*)人工林，後半段為天然低海拔闊葉林；B 線則全線皆為台灣杉人工林；屬於溪流棲地環境的 C、D 線則為水勢湍急的流水域，屬典型台灣上游河川景況，溪中間雜著大小石塊。其中 C 線是乾溪河道，在雨季時水量豐沛，洪水期流水寬度可達 2m，但冬季時上游河段只剩伏流存在；D 線為烏石坑溪主流，水量較 C 線豐沛，全年有水，且溪床石塊所造成之孔隙較多、狀況穩定。

由於烏石坑地區地質脆弱，棲地環境極易受到山區暴雨沖刷及土石崩落的影響，加上 1999 年~2000 年期間因地震、颱風、暴雨等

天然災害造成地質不穩、道路中斷、落石嚴重，在調查路線狀況不良及人員安全考量等因素下，暫時停止固定路線調查。而在 2001 年之後，由於地形地貌的改變，受到邊坡崩塌及地形上有部分路徑中斷，無法依先前調查路線行進，故各棲地環境下調查路徑均稍作調整(圖 1)。本研究中稱 921 地震前為「第一階段」，時間包括 1997 年及 1998 年；而大地震以後則為「第二階段」，涵蓋時間為 2001 年~2008 年。

調查時，以 2~3 人為一組採用目視遇測法調查，並輔以穿越帶鳴叫計數法(呂等 1996)，記錄沿穿越線兩側 2 m 內兩棲動物種類、數量、棲地環境、微棲地狀況。每次選擇無降雨夜晚的 19:00 至 22:00 之間調查，在森林、溪流兩種棲地環境下所使用的總調查時間各約 60 至 90 min。

## 三、調查時期

由於低海拔試驗站地區的兩棲類長期監測研究經歷了研究人員組成改變、重新規劃調查路線、調整年度調查頻率等各種因素，地震前、後固定穿越線調查之月份亦不盡相同，本研究將其分為下列 4 個時期：

- (一) 地震前：921 地震發生之前 2 年。自 1997 年 1 月起至 1998 年 11 月，每年單數月份依第一階段路線調查 1 次。
- (二) 地震後一期：921 地震發生後重新調查的前 2 年。在 2001 年 6 月、11 月及 2002 年 6 月、9 月，依第二階段路線進行調查 1 次。
- (三) 地震後二期：自 2003 年 6 月起至 2005 年 9 月止，在每年 6 及 9 月份各調查 1 次；依第二階段路線調查各穿越線。
- (四) 地震後三期：自 2006 年 1 月起，目前仍然正在進行中。每月均調查 1 次兩棲類；依第二階段路線調查各穿越線。

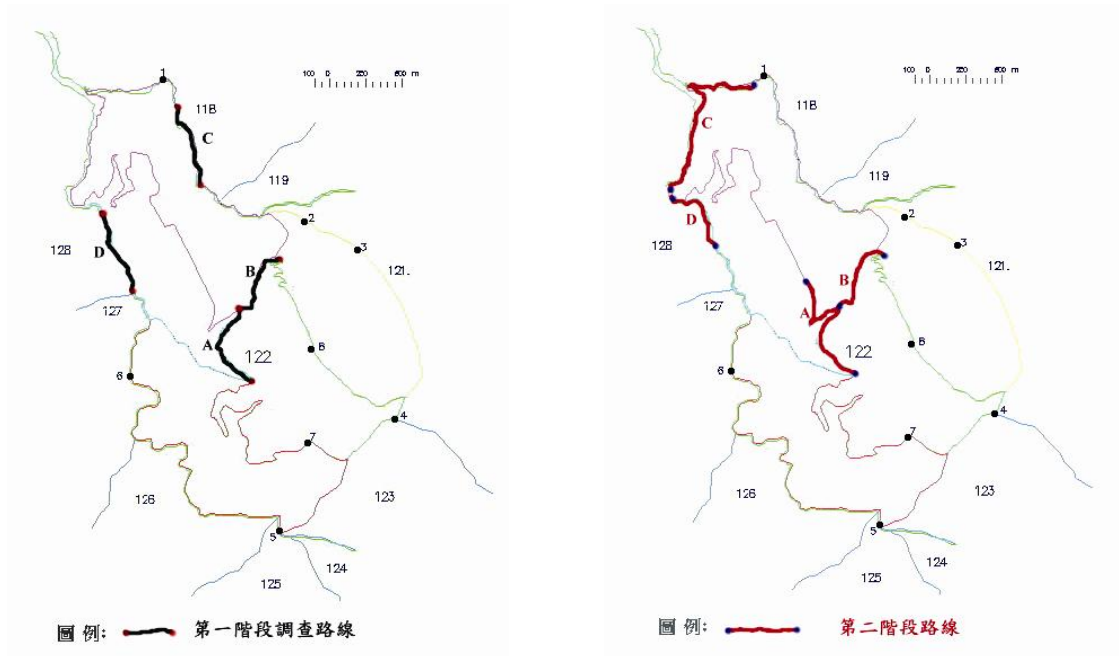


圖 1. 烏石坑地區兩棲類調查穿越線。第一階段為地震發生前的 1997 至 1998 年；第二階段為 2001 年以後。受地震影響，兩階段之間調查路線稍有差異。

Fig. 1 Transects of amphibian survey at Wushykeng area. Stage 1 was from 1997 to 1998 before the earthquake, and stage 2 was after 2001. There was little difference on routes between both stages because of the earthquake.

#### 四、資料分析

在各年度的調查資料中以夏、秋兩季最齊全，此兩季又以 6 月份及 9 月份較完整。故原則上夏季採用 6 月、秋季採用 9 月份數據來統計和比較；當缺乏這兩月份資料時，則以同一季節的其他月份資料代替。在本研究中夏季使用 7 月(1997、1998 年)資料，而秋季則使用 11 月(2001 年)資料來取代。

為瞭解烏石坑地區的兩棲類動物多樣性，除了統計兩棲類種數與族群數量外，並採

用物種豐富度(Species richness)、辛浦森多樣性指數(Simpson's index of diversity)、夏農多樣性指數(Shannon's index of diversity) 以及均勻度指數(Evenness index)來分析兩棲類多樣性。並以 Bray-Curtis similarity 計算各次調查間的物種組成相似度指數(先開根號轉換)，再以 ANOSIM 比較各時期之間的物種組成相似度，以 SIMPER 分析各物種在相似度上所貢獻的百分比，上述方法由 PRIMER 5.2 軟體分析。單因子的比較若資料符合常態分布，採用

變異數分析(ANOVA)，若不符合常態分布，則採用克－瓦二氏(Kruskal-Wallis)變異數等級分析。

## 結 果

921 地震之後在烏石坑地區共記錄了 13 種兩棲類動物，連同地震前的調查資料，本地區的無尾兩棲類共有 15 種，其中包括兩種地震後才發現的新紀錄種：樹蟾科的中國樹蟾(*Hyla chinensis*)以及狹口蛙科的黑蒙西氏小雨蛙(*Microhyla heymonsi*)。而另外兩種早期有記錄的蛙種，包括赤蛙科的長腳赤蛙(*Rana longicrus*)及樹蛙科的橙腹樹蛙(*Rhacophorus aurantiventris*)，則自 1997 年起未曾再度發現。在所記錄的 15 種無尾兩棲類中，蟾蜍科的盤古蟾蜍(*Bufo bankorensis*)，樹蛙科的莫氏樹蛙(*Rhacophorus moltrechti*)、橙腹樹蛙、褐樹蛙(*Buergeria robusta*)、面天樹蛙(*Kurixalus idiootocus*)，以及赤蛙科的斯文豪氏赤蛙、梭德氏赤蛙(*Rana sauteri*)為台灣特有種，特有蛙類比例超過烏石坑所有蛙類的 40 %。

依據調查成果資料，溪流環境蛙類數量在地震後二期開始顯著增加(ANOVA,  $F_{3,16}=3.88$ ,  $p=0.029$ )，但森林樣區的蛙類數量在地震前與地震後未觀察到特定的變動模式(ANOVA,  $F_{3,16}=1.32$ ,  $p=0.302$ )。另外，在地震後二期起，各棲地環境皆開始呈現明顯的季節性波動。森林棲地環境的蛙類數量夏季多、秋季少；而溪流棲地環境蛙類數量卻呈現秋季多、夏季少的狀況(圖 2)。

森林棲地環境下所記錄兩棲類共有 13 種，711 隻次。占總數 80%以上的常見種為盤古蟾蜍、布氏樹蛙(*Polypedates braueri*)，中文俗名原為白額樹蛙)、莫氏樹蛙、艾氏樹蛙

(*Kurixalus eiffingeri*)、面天樹蛙、斯文豪氏赤蛙、梭德氏赤蛙和拉都希氏赤蛙(*Hylarana latouchii*)。其中地震前的兩棲類共 9 種，數量以莫氏樹蛙、拉都希氏赤蛙和盤古蟾蜍為主。地震後一期蛙種數雖然一度降為 6 種，但地震後二期、三期則增至 10 種；數量上以拉都希氏赤蛙、盤古蟾蜍和斯文豪氏赤蛙為主(圖 3)。常見種類在地震前後數量並無顯著波動(Kruskal-Wallis test,  $p>0.05$ )，但其中較為特別的是莫氏樹蛙在地震後一期所占百分比明顯降低( $\chi^2_3=129.1$ ,  $p<0.001$ )，拉都希氏赤蛙則明顯升高( $\chi^2_3=97.3$ ,  $p<0.001$  圖 3)。

在溪流棲地環境下共記錄了 12 種 6786 隻次兩棲類，常見種為盤古蟾蜍、日本樹蛙(*Buergeria japonica*)、褐樹蛙、福建大頭蛙(*Limnonectes fujianensis*)、斯文豪氏赤蛙、梭德氏赤蛙和拉都希氏赤蛙。其中地震前共發現 7 種兩棲類，數量以盤古蟾蜍、褐樹蛙和斯文豪氏赤蛙為主；地震後則增加至 9 種，數量以梭德氏赤蛙、盤古蟾蜍和褐樹蛙為主(圖 4)。其中斯文豪氏赤蛙族群除在森林中的少量族群在地震後二期起有夏季多、秋季少的波動外，只能大致看出有森林與溪流棲地族群彼此消長的現象(圖 5)。而梭德氏赤蛙在地震前和地震後一期數量不多，卻在地震後二期開始有明顯變化，特別是在秋季，地震後二期及三期的數量顯著增加( $H=12.89$ ,  $p=0.005$ )，所占的數量百分比增加至 80 % 以上(圖 6)。在夏季，褐樹蛙亦在地震後二期及三期數量顯著增加(圖 7,  $H=8.79$ ,  $p=0.032$ )，而面天樹蛙則是在地震後一期出現較多的數量(圖 7,  $H=8.77$ ,  $p=0.032$ )。

而在兩棲類多樣性的分析結果，物種豐富度、辛浦森多樣性指數、夏農多樣性指數、均勻度等 4 種指數在地震前(1997-1998 年)和地

震後一期(2001-2002 年)無論是在季節上或是棲地環境類型上的差異均不明顯。但因梭德氏赤蛙大量出現的緣故，2003 年起每年秋季溪流棲地環境之各項指數均明顯較低(表 1)。而物種組成相似度在震前後只有秋季的溪流樣區有顯著差異(ANOSIM, Global R= 0.507,

$p=0.004$ )，地震前與地震後一期物種組成相似度高，地震後二期及三期的相似度高，而這兩組間的群聚組成有顯著差異，組間的相似度差異主要由梭德氏赤蛙及盤古蟾蜍所貢獻(SIMPER, 兩物種貢獻的百分比和達 63 %至 76 %)，夏季及森林樣區則無此現象(圖 8)。

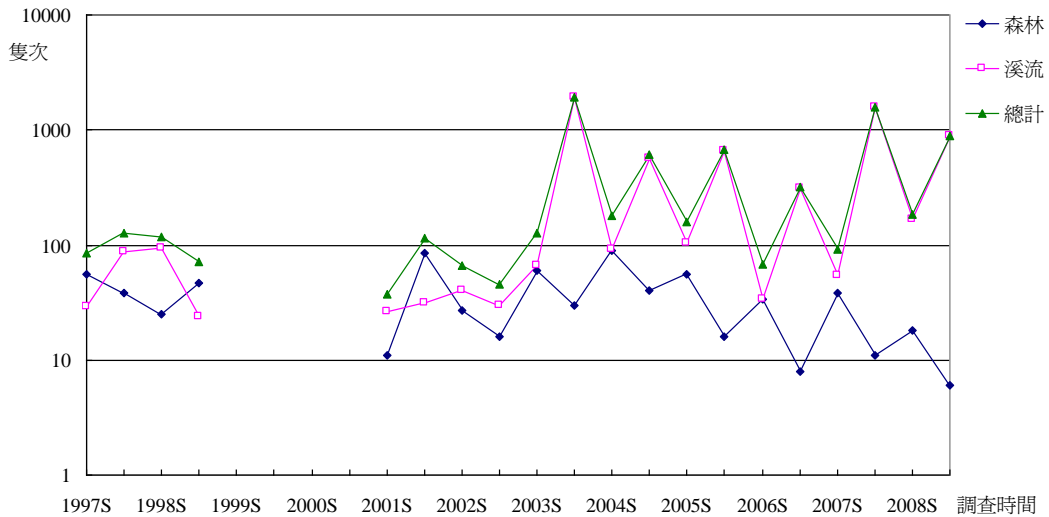


圖 2. 各年夏(S)、秋(A)季烏石坑地區兩棲類總數量；2003 年(地震後二期)起呈現劇烈季節性波動。(Y 軸為 log<sub>10</sub> 對數刻度)

Fig. 2 Total number of Wushyrkeng amphibians in the summer and autumn. There were dramatically seasonal fluctuations since 2003 (second post-earthquake) from the beginning to show significant seasonal fluctuations. (Y axis was log<sub>10</sub> logarithmic scale)

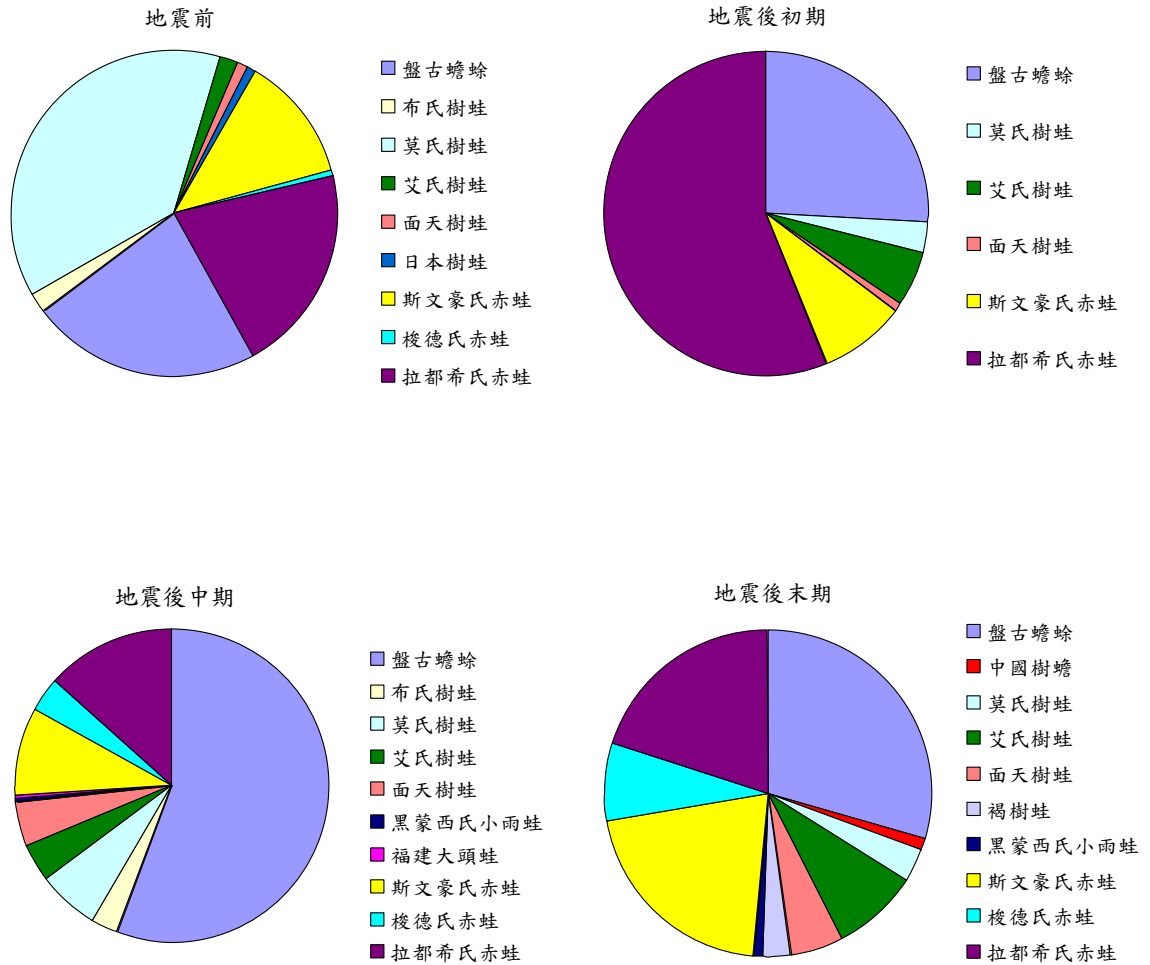


圖 3. 烏石坑地區森林棲地環境在地震前後各時期兩棲類組成。地震後種數顯著減少，且地震前數量最優勢的莫氏樹蛙所占比例亦明顯降低。

Fig. 3 Amphibian assemblages of forest habitats around the earthquake. Species number decreased after the earthquake. The ratio of *Rhacophorus moltrechti*, the most abundant species before the earthquake, also decreased significantly.

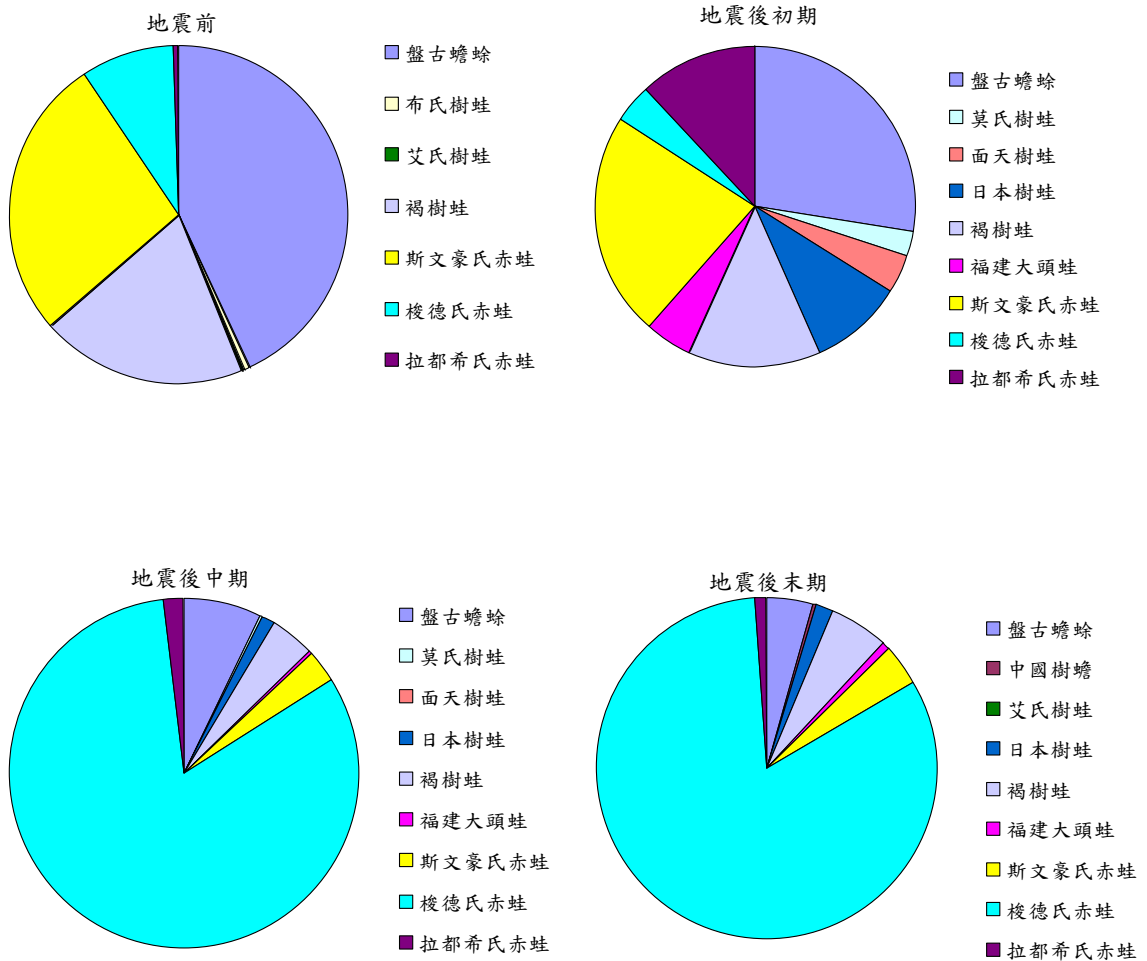


圖 4. 烏石坑地區溪流棲地環境在地震前後各時期兩棲類組成。地震後兩棲類種類數升高，且地震中、後期梭德氏赤蛙所占比例大為增加。

Fig. 4 Amphibian assemblages of stream habitats around the earthquake. Species number increased after the earthquake. The ratio of *Rana sauteri* rose dramatically at mid- and late- post-earthquake periods.

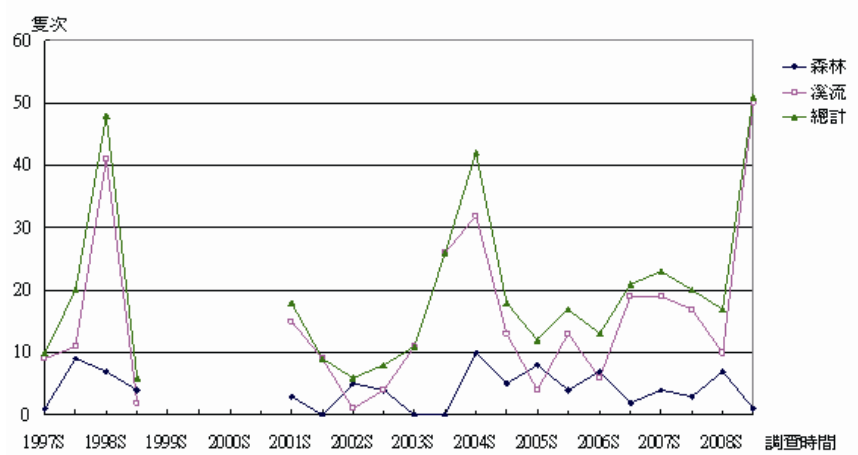


圖 5. 烏石坑地區斯文豪氏赤蛙族群變動狀況。大致上，有森林棲地族群與溪流族群間彼此消長的現象。(S: 夏季)

Fig. 5 Population fluctuation of *Odorrana swinhoana* at Wushykeng area. Roughly, there was an alternation between forest and stream populations. (S: summer)

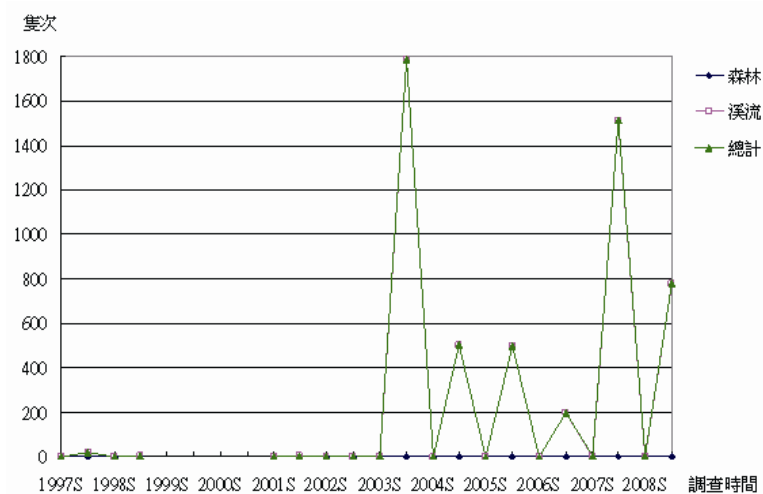


圖 6. 烏石坑地區梭德氏赤蛙族群變動狀況。至 2002 年為止，梭德氏赤蛙總數均在 20 隻以下，但 2003 年(地震後二期)起秋季溪流棲地環境之族群量大幅增加，約在 200 至 2,000 隻之間。(S: 夏季)

Fig. 6 Population fluctuation of *Rana sauteri* at Wushykeng area. Total numbers were under 20 until 2002. However, population at stream habitat increased dramatically between 200 to 2,000 since autumn, 2003. (S: summer)

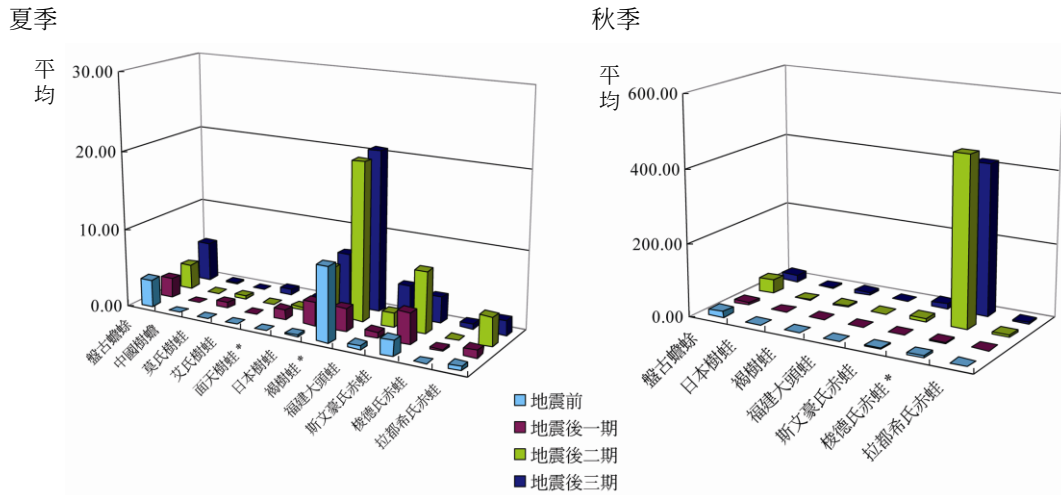


圖 7. 在地震後二、三期溪流環境，夏季面天樹蛙、褐樹蛙及秋季梭德氏赤蛙數量顯著增加。(\*表示該物種數量在各時期有顯著差異)

Fig. 7 Abundances of *Kurixalus idiootocus*, *Buergeria robusta* in summer and *Rana sauteri* in autumn increased distinctly in the periods of second- and third-post-earthquake periods. (\* represents there was distinct difference of the species.)

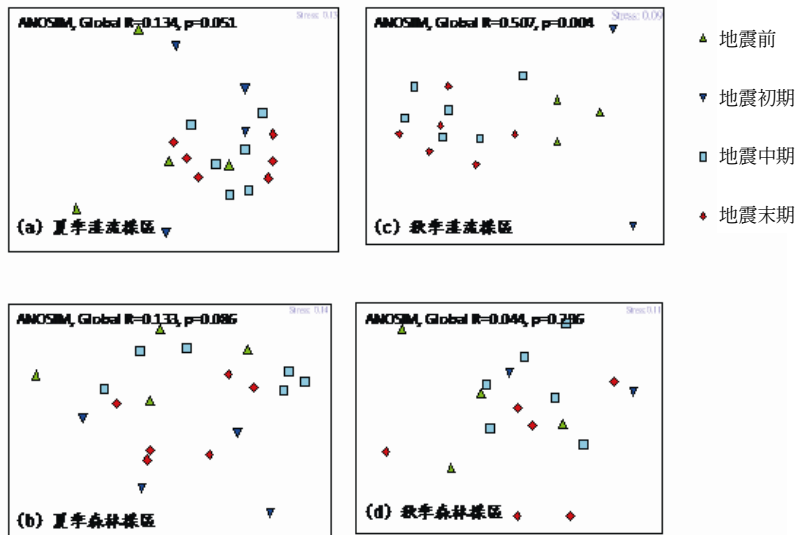


圖 8. 以 ANOSIM 分析各時期兩棲類物種組成相似度，僅秋季溪流樣區的物種相似度有顯著差異。(各點表示各樣線單一次調查的群聚組成，距離越近表示越相似。)

Fig. 8 Similarity of amphibian assemblage was analyzed by ANOSIM. There's only one distinct difference at stream habitat in the autumn. (Each point represents the community composition from a single survey. The shorter the distance between two points the more similarities between them.)

**Table 1.** 烏石坑地區兩棲類多樣性分析結果。地震前和地震後一期差異不明顯；地震後二期起秋季溪流棲地部份指數明顯較低(粗體字表示有差異但未達顯著，\*表示該數值有顯著差異。S: 夏季；A: 秋季)

**Table1.** Results of diversity analysis of amphibian fauna at Wushykeng area. There is no significant difference between Pre- and first-post-earthquake periods. There were differences of some indexes after second-post-earthquake period (Bold font represents there is a difference but not distinct; \* represents there was a distinct difference; S: Summer, A: Autumn)

	1997		1998		2001		2002		2003		2004		2005		2006		2007		2008		
	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	
Species Number	Forest	6	3	6	6	5	3	6	4	7	4	8	6	8	6	7	4	7	4	5	4
	Stream	5	4	3	3	5	4	8	4	6	6	6	5	6	6	6	5	5	6	5	5
Species Abundance	Forest	0.11	0.08	0.24	0.13	0.45	0.04	0.22	0.25	0.12	0.13	0.09	0.15	0.15	0.38	0.21	0.50	0.18	0.36	0.28	0.67
	Stream	0.17	0.05	0.03	0.13	0.19	0.13	0.20	0.13	0.09	0.00*	0.07	0.01*	0.06	0.01*	0.18	0.02*	0.09	0.00*	0.03	0.01*
Simpson's Index	Forest	0.62	0.60	0.83	0.62	0.85	0.36	0.81	0.64	0.56	0.19	0.67	0.68	0.74	0.83	0.82	0.82	0.78	0.67	0.78	0.80
	Stream	0.73	0.61	0.65	0.37	0.61	0.71	0.82	0.75	0.71	0.13*	0.73	0.22*	0.62	0.38*	0.80	<b>0.54</b>	0.76	0.09*	0.59	0.21*
Shannon's Index	Forest	0.51	0.45	0.73	0.53	0.67	0.25	0.70	0.48	0.54	0.19	0.66	0.58	0.68	0.71	0.75	0.57	0.70	0.49	0.63	0.39
	Stream	0.57	0.50	0.46	0.28	0.51	0.57	0.81	0.61	0.63	0.15*	0.64	0.22*	0.56	0.29*	0.71	<b>0.45</b>	0.65	0.11*	0.54	0.21*
Evenness	Forest	0.66	0.95	0.94	0.69	0.96	0.53	0.90	0.80	0.64	0.31	0.73	0.75	0.76	0.91	0.88	0.95	0.83	0.81	0.91	0.65
	Stream	0.82	0.83	0.97	0.59	0.73	0.95	0.90	1.02	0.82	0.19*	0.82	0.32*	0.72	0.38*	0.91	<b>0.65</b>	0.92	0.14*	0.77	0.30*

## 討 論

烏石坑地區的 15 種兩棲類中，主要分布於苗栗以北的長腳赤蛙(龔及楊 2010)在 1992 至 1994 年間僅有 2 筆調查紀錄且每次僅 1 隻個體；而零星分布於低海拔原始林，但中部地區尚未有正式紀錄(龔及楊 2010)的橙腹樹蛙亦僅有 1 隻個體的紀錄。由於此 2 種在台中低海拔山區數量原本稀少，在後續調查中亦未能再度發現，未來宜繼續長期追蹤並著重生殖季及其生殖水域棲地調查，才能確認其族群狀況。至於在 921 地震後才開始記錄到的中國樹蟾和黑蒙西氏小雨蛙，由於發現頻度及族群數量仍相對較低，其後續族群變動情形亦值得持續加以觀察。

在森林棲地環境下，地震不但造成布氏樹蛙、日本樹蛙、梭德氏赤蛙暫時由森林中消失，莫氏樹蛙所占的百分比亦由 37.95 % 遽降至 2.88 %；但盤古蟾蜍、拉都希氏赤蛙所占比例卻增加，顯示地震對於不同種類的影響有差異。其原因可能因地震造成坡面崩塌、樹木傾倒、土壤岩盤破碎、地下水位變動，使原本鬱閉潮溼的森林變為開闊且乾燥所導致。在植群及微氣候條件未復原的地震後一期，盤古蟾蜍等耐旱種類成為主要組成蛙種；直到地震後二、三期植群逐漸回復(震央九份二山處在地震後二期的 2004 年之植生恢復率已可達 70.1 %，林等 2006)，兩棲類種數才能慢慢地回升。至於莫氏樹蛙數量至今無法回復至地震前規模，則可能是因為森林尚未恢復至鬱閉、易積水狀態，以致其缺乏生活與繁殖場所之故。

和森林棲地相當不同的是，地震造成溪流棲地環境的蛙種從地震前的 7 種，增加到在地震後每個階段皆記錄到 9 種。地震後新出現於溪流棲地環境的蛙種包括主要在森林及靜水

域繁殖的莫氏樹蛙、面天樹蛙，以及在緩流水域繁殖的日本樹蛙及福建大頭蛙。這些種類會出現在烏石坑溪和乾溪中，除了因森林及積水環境改變，迫使利用這些棲地的兩棲類另覓生殖場所外，原本較深、水流較急的溪谷因土石崩坍和雨水沖刷使溪床平坦，開始在溪谷中出現緩流、水潭等合適環境，亦是可能的原因。但近年來由於長期氣候變遷，在降雨日數減少及單次降雨量增加的趨勢下，溪流附近易有偶發性的洪流出現。原本在緩流及靜水域生殖的蛙種，要如何因應這樣大且急的水流，可能需要更進一步的研究觀察。

在南投縣關刀溪流域的長期生態研究結果顯示，斯文豪氏赤蛙族群在地震後數量、存活率均一度明顯下降，在 2000 年 6 月後族群數量雖逐漸恢復，但在體長、體重、年齡結構上皆較地震前為小。可能是由於長年待在溪流中的大型個體因地震而死亡或遷出而消失，被原本在岸上及森林中活動、體型較小的年輕個體取代，建立地震後新族群的結果(賴等 2002)。本研究中並未特別針對斯文豪氏赤蛙探討體型及族群結構，但由 2001 年夏季的資料顯示，烏石坑地區的族群量在 921 地震後一期便可回復到地震前水準，這點則和關刀溪地區的研究結果相符。而烏石坑地區斯文豪氏赤蛙族群波動雖然甚不穩定，但大致有森林與溪流棲地環境彼此消長的現象，推測當地斯文豪氏赤蛙個體在不同棲地環境間移動交流，亦可間接支持關刀溪流域的研究結果(圖 5)。

此外，烏石坑地區溪流棲地環境下的斯文豪氏赤蛙族群達高峰的季節變異很大，這和關刀溪地區族群高峰每年穩定出現在夏、秋季之間的情形略有不同。推測因關刀溪流域研究環境為鬱閉森林中的小山澗及附近數個人工蓄水池，雨季時溪水流量不致過大，而旱季仍有

水池及森林中潮溼的環境供棲息，因此斯文豪氏赤蛙族群可以穩定存在(關及賴 2002)。烏石坑的調查區域則為空曠溪床，不但平時缺乏植群遮蔽，雨後也容易因洪流破壞、砂石沖刷而改變，時有久旱造成溪水枯竭，棲地的劇烈變化可能是斯文豪氏赤蛙族群無法維持穩定的原因。

就單一物種在地震後的族群變動而言，較特殊者為在溪流中繁殖的梭德氏赤蛙。自 1994 年即發現烏石坑地區梭德氏赤蛙開始聚集至溪邊為夏末秋初，最高峰則為冬季(方等 1994；何等 1998；Lin and Lue 2004)，而蝌蚪變態成為小蛙的時間約為次年春季。再根據地震前及地震後一期資料，本種地震前之秋季數量皆不及百隻，2003 年 9 月起卻暴增至 2000 隻左右，之後每年秋季皆維持在 200 至 2000 隻之間(圖 6)。本研究的調查結果雖然初步證實地震後的梭德氏赤蛙繁殖季節與地震前相符合，但其繁殖族群數量呈戲劇性變化之狀況卻值得未來更深入研究。

由於梭德氏赤蛙蝌蚪受到環境溫度的影響甚大，高海拔地區的冬季低溫與低海拔地區的夏季高溫都可能造成生殖失敗。而低海拔地區族群在秋、冬季生殖，可能是因為這段期間的溪水溫度較適合其蝌蚪成長的緣故(賴 2002)。例如 11 月至隔年 3 月是南投縣溪頭地區梭德氏赤蛙繁殖及蝌蚪成長時期，此時該地溪水溫度介於 11.2 °C 至 18.4 °C 之間(Lai *et al.* 2002)；故推測在與溪頭海拔高度相仿的烏石坑，梭德氏赤蛙生殖季溪流水溫應該與溪頭相差不大。而依據 921 地震後烏石坑溪與乾溪匯流口上游段的記錄資料，而 2000 年 3 月至 2001 年 2 月間平均水溫為 20.2 °C，2001 年 3 月至 2002 年 2 月間平均水溫為 18.2 °C(林 2002)；此外，2007 年 3 月至 2008 年 2 月平均水溫為

18.8 °C，而梭德氏赤蛙蝌蚪成長的 9 月至翌年 2 月則為 17.8 °C(李等 2008)，顯見地震後溪水溫度有逐漸變為適合梭德氏赤蛙蝌蚪生長之趨勢。雖然本研究缺乏烏石坑當地的植生恢復狀況之數據，但由 2003 年後 921 地震影響地區河流輸砂濃度開始逐年下降(陳及林 2009)及 2004 年九份二山崩塌地之植生復育狀況可達 70.1%(林等 2006)等前人研究成果來看，不排除烏石坑地區溪流邊坡植群於地震後二期的 2003 至 2004 年亦已逐漸回復，唯其跡象在此階段僅能自溪流蛙類相略見端倪，且與森林內非屬同步而無法擴大解釋至森林性蛙種的族群回復狀況。

相對於森林棲地環境，池塘及溪流等水域環境的兩棲類群聚組成相對較為多變。除了不同蛙種對於水域的利用目的不一，例如因為繁殖、成長、覓食、棲息及躲避天敵而出現水域附近，其出現的數量與時間長度亦各有不同。有些種類是長期生活於其中的居留者(residents)，有些是生殖季出現的種類，更有為了保持體內水份平衡才前往水域的短期過客(關 1999)。在烏石坑地區的長期監測過程中，若需選擇不同棲地類型下的蛙種作為監測指標，則建議選用在該棲地環境中出現時間較長、對棲地忠誠度高、族群達一定程度、對環境變動敏感，且族群波動易於觀察的物種，例如在森林環境的盤古蟾蜍、莫氏樹蛙、艾氏樹蛙、拉都希氏赤蛙，以及溪流環境的褐樹蛙、盤古蟾蜍、斯文豪氏赤蛙、梭德氏赤蛙等。藉著這些指標物種的種類組成及族群變動，或許可以建構出烏石坑地區棲地環境的變動模式，進而瞭解環境變遷對當地生態系的影響。

## 引用文獻

- 方懷聖、洪典戊、李德旺、陳立禎、盧堅富、何健鎔、林雲龍、林華慶、林春富。1994。臺中烏石坑地區野生動物之調查。台灣省特有生物研究保育中心(動物組)。134-188頁。
- 呂光洋、陳添喜、高善、孫承矩、朱哲民、蔡添順、何一先、鄭正寬。1996。台灣野生動物資源調查—兩棲類動物資源調查手冊。行政院農業委員會。144頁。
- 何東輯、楊吉宗、彭仁傑、黃獻文、方懷聖、林旭宏、薛美莉、張仕緯、張簡琳玟、楊耀隆、鄭錫奇、林斯正、林春富、賴肅如、何健鎔、沈明雅、翁韶良、陳元龍。1998。烏石坑地區生態系長期監測。行政院農業委員會特有生物研究保育中心八十七年度烏石坑地區生態系長期監測試驗研究計畫執行成果。11-18頁。
- 何東輯、劉敏慧、程忠智。2004。烏石坑地區蛙類資源介紹。自然保育季刊 46:36-40。
- 李訓煌、張世倉、薛美莉、朱恩良。2008。烏石坑溪棲地變遷與生物多樣性之研究成果報告書。行政院農業委員會林務局東勢林區管理處。129頁。
- 林昭遠、王祥帆、莊智瑋。2006。應用生態指標探討九份二山崩塌地植生復育變遷之研究。水土保持學報 38(3): 279-286。
- 林斯正。2002。烏石坑溪水生昆蟲長期監測與地震後組成變動。2002年生物多樣性保育研討會論文集。156-175頁。
- 陳宏宇、林冠瑋。2009。山崩、土石流在 921 地震後的演變。921 地震對生態影響與回復論文集。行政院農業委員會。1-10頁。
- 楊吉宗、林春富。2000。烏石坑地區永久樣區兩棲類長期監測(3/3)。行政院農業委員會特有生物研究保育中心八十七年度烏石坑地區生態系長期監測試驗研究計畫執行成果。14-18頁。
- 賴勇志、關永才、謝寶森、李宗翰。2002。地震對斯文豪氏赤蛙(*Rana swinhoana*)族群的影響。2002年動物行為暨生態研討會論文集。第16頁。
- 賴肅如。2002。海拔對臺灣山區梭德氏赤蛙生活史變異之影響。國立臺灣大學動物學研究所博士論文。80頁。
- 關永才。1999。關刀溪森林生態系兩棲動物群聚之研究。林業研究季刊 21(2):33-40。
- 關永才、莊銘豐、劉俊良。2007。人工林經營對兩棲類動物族群及群聚組成之影響。林業研究專訊 14(1):17-19。
- 關永才、賴勇志。2002。地震對斯文豪氏赤蛙族群在時間與空間分佈的影響。全球變遷通訊雜誌 34:21-30。
- 龔文斌、楊懿如。2010。運用志工調查資料進行臺灣蛙類分佈預測。2010數位典藏地理資訊學術研討會論文集。
- Lai, S. J., Y. C. Kam, F. H. Hsu and Y. S. Lin. 2002. Elevational Effects on the Growth and Development of Tadpoles of Sauter Frog, *Rana sauteri* Boulenger in Taiwan. *Acta Zoologica Taiwanica* 13(1): 11-20.
- Lin, C. F. and K. Y. Lue. 2004. Altitudinal Differences in Temporal Distribution, Spatial Preference and Timing of Breeding Climax of Frogs and Toads in Central Taiwan. *Endemic Species Research* 6(1): 39-50.
- Pough, F. H. 2007. Amphibian Biology and Husbandry. *ILAR Journal* 48(3): 203-213



## 七股沿海地區地覆變遷分析

# Analyses of Land-cover Changes in the Qigu Coastal Zone

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### 摘要

本研究以台南市之七股沿海地區 1994 年、2004 年及 2010 年等 3 期 SPOT 衛星影像資料進行影像變遷分析，探討該地區之地覆變遷情況。綜合 1994 年與 2010 年衛星影像變遷分析，七股沿海該 16 年間主要變化如下，七股鹽田與魚塭部分區域原為水域轉變為荒地，部分區域原為乾涸之後海水流入；網子寮、頂頭額及新浮崙等離岸沙洲朝東與朝南漂移；另位於頂頭額沙洲南段之防風林與沙地大幅消失；黑面琵鷺保護區之東南與南側，原為沙地被開挖為養殖魚塭；曾文溪口河床則有遭洪水沖刷現象。此外，該期間七股沿海植被消長情形分析如下，七股溪口生長之紅樹林原先主要有 3 塊，面積合計 6.2 ha，2010 年僅剩 1 塊紅樹林面積減為 5.1 ha；網子寮沙洲北段原有 14.4 ha 植被消失，網子寮沙洲南段防風林造林面積由 4.2 ha 增為 14.8 ha；頂頭額沙洲北段防風林面積由 8.5 ha 降為 3.7 ha，殆此期間沙洲遭侵蝕所致；另頂頭額沙洲南段之防風林則遭侵蝕而消失，1994 年面積高達 87.8 ha，至 2010 年僅剩 7.3 ha。由影像變遷分析結果顯示，七股沿海離岸沙洲有朝東南方向漂移趨勢，殆與沙源補充、沿岸流、波浪及東北季風等因子有關，造成海岸嚴重侵蝕，尤其頂頭額沙洲南段之防風林面積不斷地縮減，甚至可能完全消失，亟需積極進行各種固堤與護沙措施。

## Abstract

Remote sensing images taken by French SPOT satellites showed that there were changes in land covers in the coastal zone of Qigu in 1994, 2004 and 2010. Specifically, an analysis of images taken over the past 16 years revealed a number of changes. Firstly, sediments had eroded and were deposited in Wangziliao, Dingtou'e and Xinfulun offshore sandbars, which drifted east and/or south. Secondly, the southeast and southern areas of the Black-faced Spoonbill Refuge had been replaced by fish ponds. Finally, the riverbed was shown seriously eroded at Cengwen estuary. In addition to these changes in land covers, losses in coastal vegetation were also documented. In 1994, there were three mangrove swaths with a total area of 6.2 ha in the Qigu estuary. However, two of these were excavated in 2008, and in 2010 only an area of 5.1 ha remained. While the windbreak forest increased from 4.2 ha to 14.8 ha at the southern Wangziliao sandbar, its area reduced from 8.5 to 3.7 ha at the northern Dingtou'e sandbar. Another windbreak forest eroded and disappeared at the southern Dingtou'e sandbar, an area of approximately 87.8 ha in 1994 that diminished to only 7.3 ha in 2010. The windbreak forests have seriously eroded and may even disappear completely at the southern Dingtou'e sandbar. Therefore, urgent stabilization of the sand bank of this region is recommended in order to protect the greater Qigu area from further deterioration.

**關鍵詞：**七股、地覆、變遷

**Key words :** Qigu, land cover, change

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## 緒 言

台南七股沿海地區擁有沙洲、鹽田、潟湖、河口、紅樹林、魚塭等多樣之濕地生態景觀，生態環境豐富且棲地多樣化，蘊育豐富之生物資源，為重要野鳥棲地。然由於河川輸砂量減少、地盤下陷、海岸開發、構築海堤及防護措施等諸多因素，以致海岸地形重大改變。

近些年來，七股海岸卻有嚴重侵蝕現象，致使海岸林消失，生態環境嚴重破壞問題。

遙感探測(remote sensing)利用裝置不需要與研究物體、地區或現象直接接觸便能取得資料(Lillesand and Kiefer 1994)，遙測技術可經常且正確提供地球上之自然資源與人文資料，以及人類在空中、水中及陸地上活動情況，所獲得資料可供資源開發與土地利用政策上之有

效依據(謝 1992)，應用遙測資料於觀測大面積與長時間地貌變遷動態，是一項重要技術(周等 1992)。遙測資料具有綜觀覽要、多時攝像、大面積涵蓋及快速分析等優點，並可與舊有影像比對，得知遞變過程，並根據資料追蹤變遷因素，以及推估將來可能發生之事件，做事先之規劃與防範(蕭等 1994)。近些年來，台灣使用遙測資料愈趨普遍，應用領域亦相當廣泛，包括土地利用／覆蓋、海洋探測、海岸環境監測、農作物調查監測、環境保護監測、氣候預測、防救災、地質調查、礦產探勘、工程應用、數位影像製圖、資源資訊系統建立等。

沿海生態系於空間複雜度與時間變異度有極大差異，故監測與研究沿海生態系之生物物理特性與控制過程相當具有挑戰性。再者，沿海生態系之影響遠遠超過區域尺度，於如此大區域中，透過遙測獲取數據是唯一實際可行之方法(Klemas 2009)。近年來有關衛星影像應用於沿海地區變遷之研究，如 Liu *et al.*(2008)探討過去 10 年中國沿海地區耕地流失與建設用地佔用之機制，指出土地利用轉變之主要驅動力，為人口成長與技術進步，推動快速工業化、公共運輸設施建造、鄉村都市化及東部沿海地區農村聚落擴展。Ahmed *et al.*(2009)以 Landsat 衛星影像確認 3 個北非近海瀉湖過去 30 年(1972-2004)期間之重要環境特徵，並分析主要環境變遷原因，認為遙測於偵測與定量近海瀉湖與其鄰近地景之地表覆蓋變遷，為一種極具有潛力之應用方法。Ardli and Wolff(2009)以印尼爪哇之塞加拉阿納克瀉湖(Segara Anakan lagoon)1987 年～2006 年間之 4 幅 SPOT 衛星影像，量化土地利用與覆蓋空間變遷特性，主要變遷原因為來自於內陸河流沉積物淤塞瀉湖，以及紅樹林轉變與資源開發。Kurt *et al.*(2010)以 1987 年與 2007 年之 2 幅 Landsat

衛星影像分析土耳其伊斯坦堡(Istanbul)沿海地區海岸線變遷，指出該期間伊斯坦堡海岸線之長度擴增 32 km。El-Asmar and Hereher(2011)以多光譜掃描儀、Landsat 及 SPOT 感測器獲取之 4 幅衛星影像，評估 1973 年～2007 年間尼羅河三角洲(Nile Delta)沿海地區之時空變遷，結果顯示大約 50% 沿海地帶受到侵蝕，13% 為淤積，而曼扎拉瀉湖(Manzala lagoon)面積估計明顯削減 34.5%，變遷主要為尼羅河洪水之管控與人類活動改變土地利用型態所致。

有關七股海岸變遷之相關研究報告，如簡等(2006)曾針對青山漁港西南航道至頂頭額汕間約 10 km 海岸，進行地形水深測量、潮流流及漂砂調查與分析，探討七股瀉湖沙洲變遷之物理機制與消退原因，並以數值模式與現場試驗方法進行防護工法成效評估，研擬七股瀉湖沙洲保護之對策與方案。林等(2007)曾藉由歷史地圖、航照、衛星影像及地面斷面調查等資料，研究外傘頂洲與網子寮沙洲之地形變遷。方與楊(2007)曾探討臺南地區海岸沙洲之變遷，針對其變遷因素，研擬永續發展策略。洪與林(2008)以網子寮沙洲附近海氣象資料與福衛二號衛星影像，配合地形剖面實測，探討濱線變動與地形變動之動力機制。本研究目的主要以七股沿海地區遙測影像為材料，配合相關圖檔及地面調查資料，進行影像變遷分析，探討該地區沙洲、植被及瀉湖等棲地變遷情況與因素，提供保育決策、規劃與經營管理之參考。

## 材料與方法

### 一、研究區環境概況

七股區位在台南市西側之沿海地區，北以將軍溪為界，南至曾文溪(圖 1)，早期為台江內海之一部分，後來因曾文溪改道，內海逐漸



圖 1.七股沿海地區研究範圍圖。

Fig. 1. The study area in the Qigu coastal zone.

陸化而形成陸地。七股沿海主要有網子寮、頂頭額及新浮崙等沙洲屏障，沙洲為抵抗波浪與潮流之第一道防線，避免外海強風大浪直接侵襲內陸。七股瀉湖為台灣最大瀉湖，具高生產力與多樣性之生態環境，漁民們在瀉湖中從事養殖牡蠣與文蛤，以及設置定置網捕魚等行為。七股鹽田已全面廢曬，之後興建台灣鹽業博物館與七股鹽山，當地又有大量魚塭，養殖虱目魚，也形成當地特色，部分成功轉型發展觀光漁村，七股已成爲著名觀光景點。此外，七股之紅樹林分布，許多是生長在魚塭堤岸、排水溝堤岸或大排水溝河床中，紅樹林周遭也蘊藏著豐富生機如彈塗魚、各種招潮蟹及貝類等，成爲鳥類覓食、築巢或休憩場所。

曾文溪口每年冬季全球瀕臨絕種黑面琵鷺便會從北方飛至該區域附近避寒度冬，成爲全世界黑面琵鷺最重要之棲息地，在 2002 年農委會劃定 634 ha「台南縣曾文溪口野生動物重要棲息環境」，其中 300 ha 劃爲「台南縣曾文溪口北岸黑面琵鷺野生動物保護區」，以保護其生態資源。尤其，近些年來度冬黑面琵鷺已超過千隻，甚至占全世界一半以上數量，可見其重要性。

## 二、材料與設備

### (一) 衛星影像資料

本研究所使用之法國 SPOT 衛星影像資料是向中央大學太空及遙測研究中心價購，爲定

量離岸沙洲之完整地形與植被之考量，故挑選低潮位影像。影像皆爲等級 3 處理之多波段影像，由於影像時間上差異，影像爲不同感測器所拍攝，影像之解像力亦不同，SPOT2 爲 20 m，而 SPOT5 爲 10 m，3 期影像雖然解像力有差異，惟影像皆已作系統改正，且使用地面控制點及林務局農航所 40m 網格數值地形模型資料完成精密幾何糾正，並以最鄰近法(nearest neighborhood, NN)之重新取樣方式投影套合在台灣二度橫麥卡脫地圖投影座標系統上，並將 1994 年影像像元大小重新取樣改以 10 m x 10 m，以套合其它 2 期影像。

### (二) 其它圖籍資料

其它圖檔資料包括行政院主計處所提供之村里行政界線資料庫、康訊科技掃描之內政部 1/25,000 地形圖影像。

### (三) 主要研究工具

主要研究分析軟體爲 ERDAS IMAGINE 遙測影像處理系統軟體與 ESRI ArcView 地理資訊系統軟體。

## 三、研究方法

### (一) 影像資料獲取與前處理

向中央大學太空及遙測研究中心購得 1994 年、2004 年及 2010 年等 3 期之法國 SPOT 衛星多波段影像資料，原爲文字檔，須先以 ERDAS IMAGINE 進行轉檔、定位、重取樣、鑲嵌及切取等前處理，影像屬性資料詳見表 1。

表 1. 七股沿海地區 SPOT XS 影像之屬性表

Table 1. Sources of SPOT XS imageries for the Qigu coastal zone

Date	Time (a.m.)	Satellite number	Incidence (°)	Orientation (°)	Azimuth (°)	Elevation (°)
3 Jan. 1994	10:55:54	SPOT2	23.7	10.6	159.6	40.6
14 Jan. 2004	11:00:13	SPOT5	29.3	14.4	158.7	41.9
17 Jan. 2010	10:45:00	SPOT5	8.3	13.4	153.5	41.3

## (二) 影像套疊分析

將已前處理之前後期影像以 IMAGINE 軟體進行影像重疊分析，將前期影像之第 3 波段(紅外光波段)以藍色與綠色顯示，後期影像以紅色顯示，3 種色調重疊後得到重疊影像，再以 ArcView 軟體進行比對分析判釋地物之變化，繪製變遷區域。所得之重疊影像，基於 Young (1802)提出三原色說之加色混合原理，地覆無變化，顏色呈灰色或黑白調，變遷區域顏色為後期光譜反射值較強之紅色調，或是前期光譜反射值較強之青色調(藍色加綠色混合)。於近紅外光波段，植被、建物與荒地之波譜反射值較高，沙灘與水體較低，紅色調與青色調顏色愈深表示 2 期影像波譜反射值之變化愈大。

## (三) 沙洲植被消長分析

分別將 1994 年、2004 年及 2010 年等 3 期影像之第 1、2 及 3 波段以藍色、綠色及紅色顯示，以 ArcView 軟體針對七股溪口、網子寮及頂頭額沙洲上之植被分別進行螢幕數化、計算面積及比對分析。

## (四) 七股潟湖面積消長分析

就 1994 年與 2010 年此 2 期影像，以 ArcView 軟體分別進行螢幕數化、計算面積及比對分析。

# 結果與討論

## 一、地覆變遷

於 1925 年前曾文海埔地尚未開發，河川上游未興建大型水工構造物，七股沙洲地區獲得充沛漂砂補給，其灘線變遷幅度相當大，沙洲多有向海側方向展延現象；而隨著海埔地開發，以及曾文溪上游水庫與攔河堰興建，沙洲灘線則有往陸側方向後退之情形，由

1966~1989 年期間，沙洲整體之灘線平均共後退約 280 m；而 1994 年青山漁港西南航道防波堤建造完成後，沙洲灘線後退變遷情形相當劇烈，其中於 2000~2005 年期間離岸沙洲之灘線後退約 50~140 m(簡等 2006)。網子寮沙洲原細長狹窄，卻有多次新潮口的形成與閉合，尤其北段前沙丘消失，整個高程下降形成一潮汐灘地，而南段的海岸線也後退百公尺以上，海灘消失，主要為海岸工程結構物建構導致沙洲砂量收支嚴重失衡有關(林等 2007)。網子寮沙洲冬季受由北往南沿岸輸砂、風砂搬運影響往南移動；夏季則受颱風波浪越洗作用影響往東移動，這兩股分力使網子寮沙洲長期以來呈現往東南遷移之現象(洪與林 2008)。綜合以上前人研究，顯示七股沿海之離岸沙洲有逐漸朝內陸方向漂移之趨勢。

本研究由 1994 年與 2004 年此 2 期 SPOT 衛星影像變遷分析，結果發現七股沿海該 10 年間主要變化如下，結果亦顯示離岸沙洲大致朝內陸方向漂移，其中網子寮離岸沙洲朝東與朝南漂移，且新增 1 處潮口(圖 2)，而頂頭額沙洲北段朝南漂移，新浮崙沙洲朝東與朝南漂移變化，原為水域轉變為沙地，呈現紅色調，而原為沙地轉變為水域，則呈現青色調。七股鹽田及魚塢部分區域，原為水域轉變為荒地，呈現紅色調，部分區域原為乾涸引進海水，則呈現青色調。另位於頂頭額沙洲南端即七股西堤堤防西側之防風林消失，轉變為水域，波譜反射值降低，呈現帶狀之青色調。台南縣曾文溪口北岸黑面琵鷺動物保護區之東南與南側，原為沙地被開挖為養殖魚塢，轉變為水域，波譜反射值降低，呈現塊狀之青色調。曾文溪口河床沖刷與堆積變化，呈現青色調與紅色調。

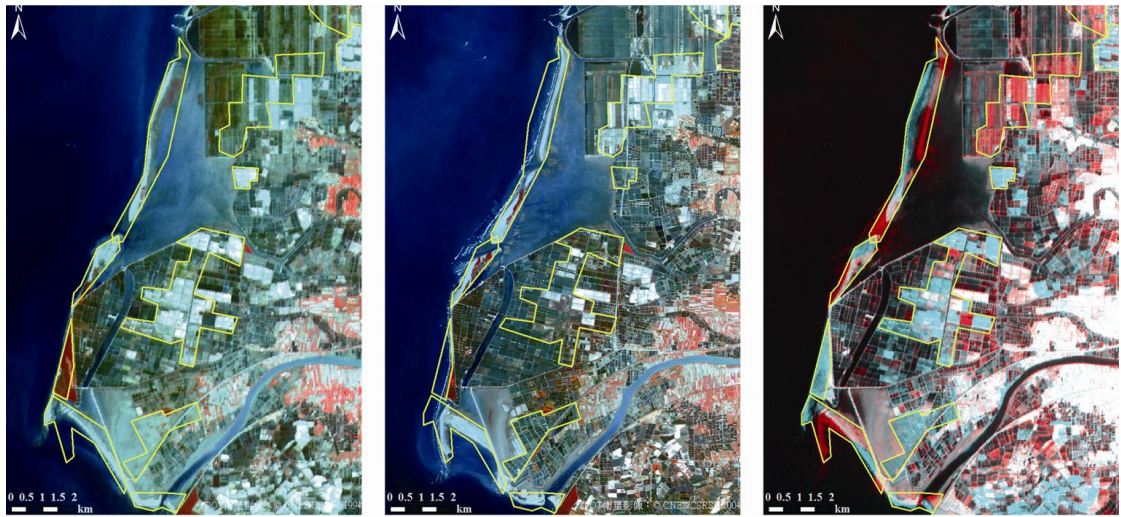


圖 2. 七股沿海地區 1994~2004 年 SPOT 衛星影像。(左：1994 年，中：2004 年，右：重疊)

Fig. 2. Satellite images of the Qigu coastal zone by SPOT 3/2/1 in 1994 (left), 2004 (middle) and the two images overlapped (right).

另由 2004 年與 2010 年此 2 期影像變遷分析，顯示該近 6 年間離岸沙洲仍持續朝內陸方向漂移，其中網子寮離岸沙洲仍朝東與朝南

漂移，潮口位置產生變化，而頂頭額沙洲北段持續朝南漂移，新浮崙沙洲朝東南漂移變化(圖 3)。七股部分鹽田及魚塢由於受降雨及

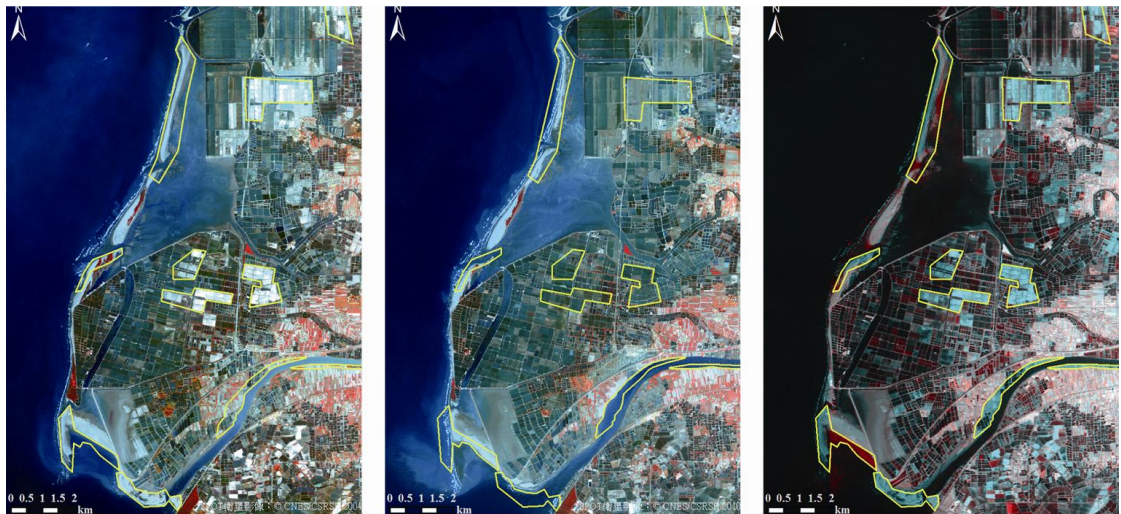


圖 3. 七股沿海地區 2004~2010 年 SPOT 衛星影像。(左：2004 年，中：2010 年，右：重疊)

Fig. 3. Satellite images of the Qigu coastal zone by SPOT 3/2/1 in 2004 (left), 2010 (middle) and the two images overlapped (right).

其作業過程而呈現變化。至於曾文溪口應是受莫拉克颱風帶來豪雨，造成河床多處有沖刷現象，原為沙地或旱作地轉變為水域，呈現青色調。

陳與張(2003)曾以經過率定曲線法之統計分析與檢定修正，推估曾文溪主流下游與主要支流後崛溪、菜寮溪歷年輸沙量，結果顯示曾文水庫興建前，主流下游年平均輸沙量為 1,480 萬噸，建庫後降為 965 萬噸，較建庫前減少 515 萬噸，約減少 35%。其中，除水庫年平均淤積量 570 萬噸外，菜寮溪年平均減少 360 萬噸，亦是造成主流下游輸沙量減少之主要原因，輸沙量減少勢必影響離岸沙洲沙量收支之動態平衡，故離岸沙洲消失應與上游河川輸沙量減少有關。由於海岸地區海埔地開發、海岸結構物興建，改變近岸潮波流特性及海岸漂沙平衡機制，加上海岸沙源供給量短缺情形下，西南海岸多處已呈現侵蝕現象。

## 二、沙洲植被消長

由於所挑選 1994 年、2004 年及 2010 年等 3 期影像之拍攝時間間隔較長，分別為 10 年與 6 年，且沙洲植被為獨立區塊，種類簡單，易清楚看出其間之變化，再者將影像之第 1、2 及 3 波段分別以藍色、綠色及紅色顯示，影像上植被呈現紅色調，乾燥沙地呈現淡青色調，而潮濕沙地呈現灰

綠色調，三者以肉眼即可區分，故直接進行螢幕數化。

七股沿海沙洲植被之消長情形分析區域如圖 4，各區域面積變化結果如表 2，七股溪



圖 4. 七股沿海重要區域植被消長情形分析區域。(V1：七股溪口，V2：網子寮沙洲北段，V3：網子寮沙洲南段，V4：頂頭額沙洲北段，V5：頂頭額沙洲南段)

Fig. 4. Satellite images showing the areas of vegetation change analysis in the Qigu coastal zone. V1: Qigu Estuary, V2: northern Wangziliao sandbar, V3:southern Wangziliao sandbar, V4:northern Dingtou'e sandbar and V5:southern Dingtou'e sandbar.

表 2. 七股沿海地區 1994~2010 年植被面積變化矩陣表

Table 2. A change matrix of vegetation areas (ha) in the Qigu coastal zone from 1994 to 2010

Vegetation	1994	2004	2010
V1	6.2	6.2	5.1
V2	14.4	0.0	0.0
V3	4.2	8.2	14.8
V4	8.5	12.8	3.7
V5	87.8	22.6	7.3

口生長於河道之紅樹林原先主要有 3 塊，1994 年面積合計有 6.2 ha，於 2008 年時被認為會影響七股溪排水順暢之虞，挖除上游段 2 塊紅樹林，2010 年僅剩 1 塊紅樹林之面積為 5.1 ha (圖 5-V1)。網子寮沙洲北段於 1994 年時原生長有 14.4 ha 植被，於 2004 年影像即消失(圖 5-V2)；南段沙洲上防風林則持續進行造林，防風林面積逐漸增加，1994 年為 4.2 ha，2004 年增為 8.2 ha，至 2010 年則增為 14.8 ha(圖 5-V3)。頂頭額沙洲北段之防風林面積，1994 年時有 8.5 ha，2004 年增為 12.8 ha，至 2010 年卻降為 3.7 ha(圖 5-V4)，殆此期間沙洲遭侵蝕所致。另位於頂頭額沙洲南段即七股西堤堤防西側之防風林則不斷地遭侵蝕而消失，1994 年面積高達 87.8 ha，2004 年降為 22.6 ha，至 2010 年僅剩 7.3 ha(圖 5-V5)。

### 三、七股潟湖面積消長

七股潟湖除於網子寮汕東側、潟湖南北 2 個潮口、七股溪口與大寮大排水溝附近水域較深外，其餘水域之水深大致皆小於 1 m (簡等 2006)。關於七股潟湖邊界之界定，其東側與南側可明確以堤防為界，西側為離岸沙洲較不易

界定，一般應以滿潮時水體所覆蓋區域為界，惟配合滿潮潮位之清晰影像攝取不易，且本研究當初考量以能見到離岸沙洲之完整地形與植被之定量，故挑選低潮位影像，遂以通常不為水體所浸潤，而於影像上呈現亮色調之乾燥沙地為界。七股潟湖面積消長分析結果如圖 6，由 1994 年影像潟湖面積量測約為 1,300 ha，至 2010 年潟湖面積為 1,050 ha，面積減少 250 ha(19%)，主要是由於網子寮沙洲北段朝內陸方向漂移所形成，結果顯示離岸沙洲逐漸朝內陸靠近，加上潟湖泥沙經年累月淤積，造成潟湖水域逐漸消失。

北門與七股潟湖外海沙洲，近年來更由於颱風侵襲西海岸頻繁，沙洲規模有變遷消退加快之趨勢，多處沙洲之脊線高度明顯降低，沙灘急遽向內陸消退，且部分段幾近於平均海水面，更使得防風林地受浸海水而死亡(蘇與彭 2010)。台南海岸地區之變遷，除象徵地理變化，同時意味人為影響生態環境改變，人類活動不僅造成河流改道縮減，同時造成沙洲消退(方與楊 2007)。綜合以上前人與本研究結果，影響本研究區地景變遷之自然驅動力主要包括沿岸流、波浪、東北季風及颱風等，主要藉

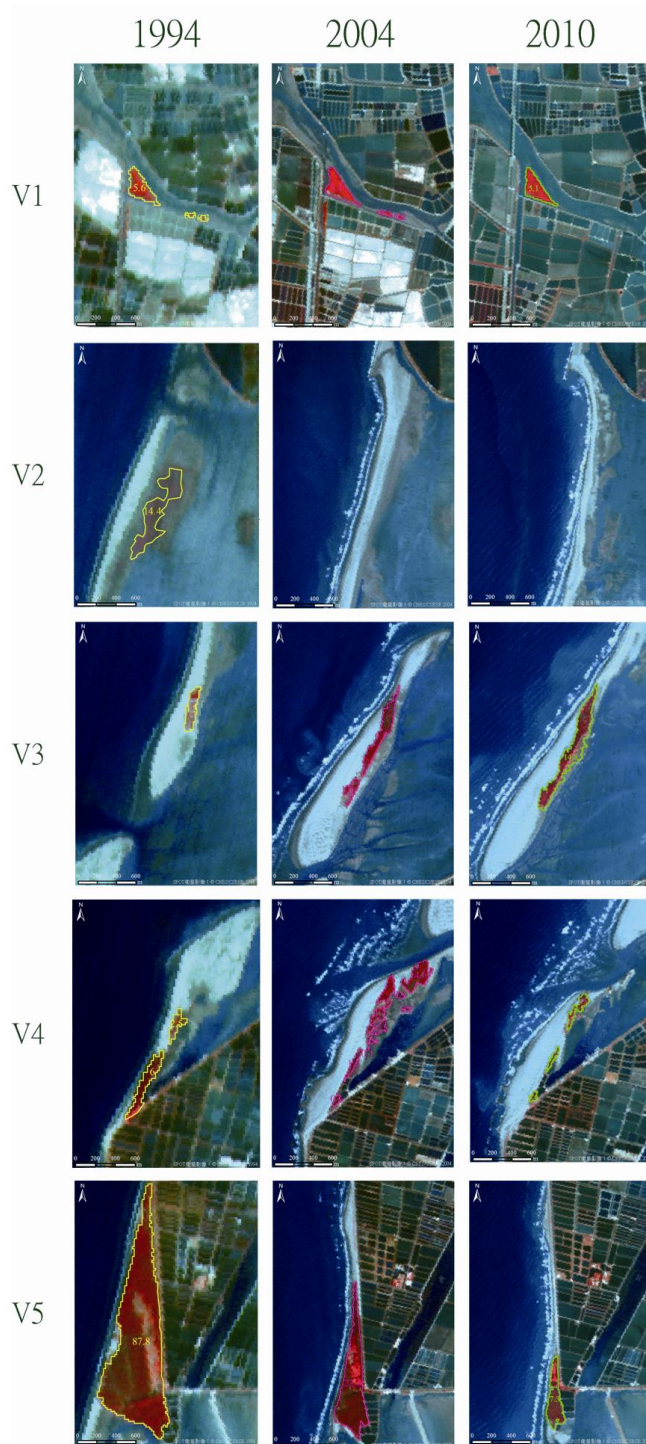


圖 5. 七股沿海重要區域植被消長情形。

Fig. 5. Satellite images showing the changes in coastal vegetation in the Qigu coastal zone.

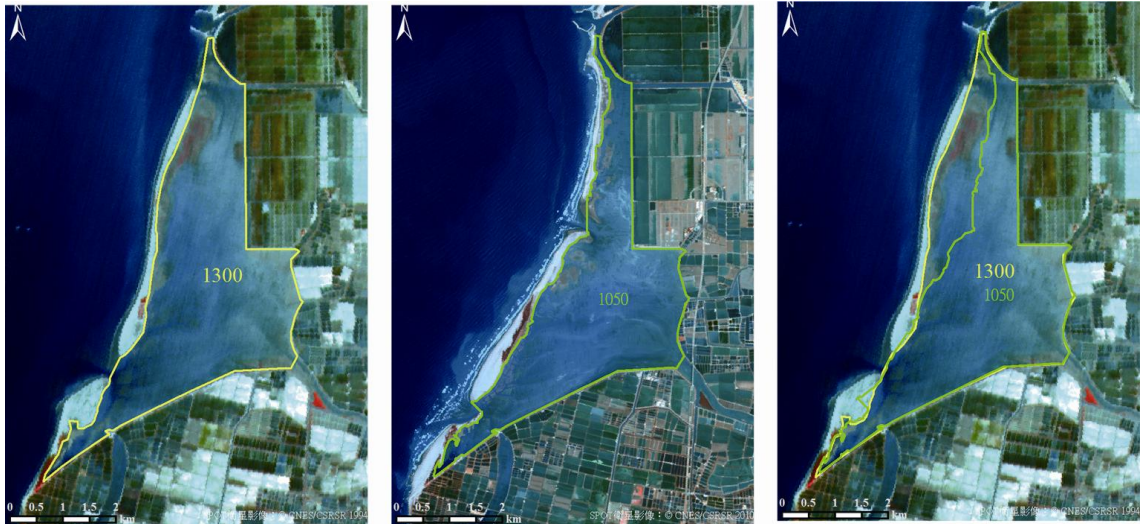


圖 6. 七股潟湖面積變化（左：1994 年，中：2010 年，右：重疊。）

**Fig. 6.** Satellite images showing the changes of the area at the Qigu lagoon by SPOT 3/2/1 in 1994 (left), 2010 (middle) and the two area shapes overlapped (right).

由輸沙、風沙搬運、越洗等作用，影響沙洲漂移、海岸沖淤、防風林及潟湖消長之變化趨勢；人爲驅動則包括河海工程結構物影響沙洲砂量收支平衡，造林則與植被之消長有關。離岸沙洲朝內陸漂移，使得沙洲靠海側產生侵蝕，原有防風林傾倒枯死，而原護堤植被遭沙埋覆蓋，棲地型態改變，會導致生物死亡或遷移，改變原來生物相，造成物種組成與結構產生變化。此外潟湖淤積變淺面積縮減，其生物承載量勢必降低，影響食物鏈，生物族群消長變化，進而影響整個生態系。

### 結論與建議

由前人與本研究衛星影像變遷分析結果顯示，七股沿海離岸沙洲有朝東南方向漂移趨

勢，殆與沙源補充、沿岸流、波浪及東北季風等因子有關，造成海岸嚴重侵蝕，而七股潟湖則由於離岸沙洲朝內陸方向漂移，加上潟湖泥沙淤積，造成潟湖水域面積減少，至於七股西堤堤防西側之防風林面積亦不斷地縮減，甚至可能完全消失，亟需積極進行各種固堤與護沙措施，而固堤與護沙之措施不應一味仰賴剛性之工程結構物作為防堵，不但破壞美觀，有時反而適得其反，加劇侵蝕作用，除考量適地植被進行固沙與造林外，更有必要思考配合疏導方式如兼具滯洪與保育之多功能溼地。此外，更重要應考量如何補充沙源，解決下游河段輸沙量減少問題，台灣河川輸沙多淤積於中上游河段，多到甚至欲開放外銷，宜設法輸運至下游河段，以解決海岸侵蝕問題。

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## 引用文獻

- 蘇煥智、彭紹博。2010。治水新思維--台南縣治水政策白皮書。余紀忠文教基金會及台南縣政府。
- 方偉達、楊孟潭。2007。臺南地區海岸變遷與永續發展策略。2007。土地研究學術研討會-城鄉治理與永續發展論文集。臺北大學不動產與城鄉環境學系編印。
- 林宗儀、羅毓芳、洪敬媛。2007。台灣西南部海岸沙洲島的地形變遷：第二十九屆海洋工程研討會論文集 433-438。
- 周天穎、杜昌柏、白金城。1992。地理資訊系統及遙測技術應用於空間分析之研究。遙感探測 17: 50-67。
- 洪敬媛、林宗儀。2008。台南網子寮沙洲近期地形變動：第三十屆海洋工程研討會論文集 505-510。
- 陳翰霖、張瑞津。2003。曾文水庫對流量和輸沙量的影響。地理研究報告 39：37-53。
- 簡仲和、郭晉安、黃建維、蔡宗利、陳嘉君、廖彩文、葉美蘭、黃俊維、曾鈺蘋。2006。七股潟湖保護對策研究(2/2)。經濟部水利署第六河川局。
- 蕭國鑫、劉治中、李惠容。1994。遙測與 GIS 結合應用於德基水庫集水區土地利用／覆蓋監測。遙感探測 21: 21-54。
- 謝仁馨。1992。航照判讀與遙感探測。中華民國航空測量與遙感探測學會出版。
- Ahmed, M. H., B. M. El Leithy, J. R. Thompson, R. J. Flower, M. Ramdani, F. Ayache and S. M. Hassan. 2009. Application of remote sensing to site characterization and environmental change analysis of North African coastal lagoons. *Hydrobiologia* 622:147-171.
- Ardli, E. R. and M. Wolff. 2009. Land use and land cover change affecting habitat distribution in the Segara Anakan lagoon, Java, Indonesia. *Regional Environmental Change* 9:235-243.
- El-Asmar, H. M. and M. E. Hereher. 2011. Change detection of the coastal zone east of the Nile Delta using remote sensing. *Environmental Earth Sciences* 62(4):769-777. doi:10.1007/s12665-010-0564-9.
- Klemas, V. 2009. Sensors and Techniques for Observing Coastal Ecosystems. *In: Remote Sensing and Geospatial Technologies for Coastal Ecosystem Assessment and Management*, X. Yang (Editor). Springer-Verlag, Berlin.
- Kurt, S., A. Karaburun and A. Demirci. 2010. Coastline changes in Istanbul between 1987 and 2007. *Scientific Research and Essays* 5(19):3009-3017.
- Lillesand, T. M. and R. W. Kiefer. 1994. Remote sensing and image interpretation. 3rd ed., John Wiley and Sons, New York.
- Liu, Y. S., L. J. Wang and H. L. Long. 2008. Spatio-temporal analysis of land-use conversion in the eastern coastal China during 1996-2005.

Journal of Geographical Sciences 18(3):  
274–282. doi:10.1007/s11442-008-0274-3.

Young, T. 1802. The Bakerian lecture: On the  
theory of light and colours. Phil. Trans. R.  
Soc. Lond. 92, 12–48. doi:10.1098/rstl.  
1802.0004.



# A Review and Status of Fossil Cetacean Research in Taiwan

## 台灣鯨豚化石研究回顧與現況

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## Abstract

This study reviews the status of known fossil cetaceans and reported fossil cetacean-bearing localities in Taiwan, including published and formerly un-reported specimens and localities from field investigations, national and private collections. There are 15 known localities of cetacean fossils, spanning Late Pleistocene (~0.01 Ma) to Late Miocene (~5.4 Ma), and four cetacean families are recognized: Delphinidae, Balaenopteridae, Balaenidae, and Eschrichtiidae. The occurrences indicate the potential to discover more cetacean-bearing localities and specimens in Taiwan. In particular, the cetacean fossils of Quaternary age can provide valuable information on the origins of the modern cetacean fauna around Taiwan.

## 摘 要

此研究回顧先前台灣已知的鯨豚化石，並整理了台灣已發表及此研究在野外、博物館及私人收藏中所調查發現的鯨豚化石產地。共有 15 個地點有鯨魚化石的紀錄，年代涵蓋了中新世晚期(約 540 萬年前)到更新世晚期(約 1 萬多年前)，包含了海豚科、鬚鯨科、露脊鯨科及灰鯨科的化石。從此研究可以看出台灣的鯨豚化石產地及數量在目前可能都被低估了，原因可能包含了缺乏系統性的研究，而一部分的化石材料也在野外沒有被適當的挖掘而造成不可彌補的損失。此外，本研究所紀錄在第四紀時期的鯨豚化石對於解釋台灣現生鯨豚的多樣性提供了根本的資訊。

**Key words :** paleodiversity, whale, dolphin, Pleistocene, Quaternary

**關鍵詞：**古生物、鯨魚、海豚、更新世、第四紀

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## Introduction

Fossils of Cetacea (whales, dolphins, and porpoises) have been discovered and reported worldwide (Fordyce 2009), with hundreds of fossil species described on the basis of well-preserved skeletons as well as single elements (such as skull or ear bones). Fossil cetaceans are crucial for understanding cetacean phylogeny and evolutionary history. In particular, Quaternary fossils could help understand the origins of living cetacean species, while late Miocene-Pliocene fossils could elucidate patterns in rapidly-evolving groups such as the ocean dolphins, Delphinidae. Furthermore, cetacean fossils could help refine

the geological age and depositional settings of sedimentary rocks.

Given the abundance and diversity of fossil Cetacea in Japan (Oishi and Hasegawa 1995b), it is surprising that relatively few fossils of cetaceans have been recognized and reported in Taiwan in spite of the closeness of the two regions in the western North Pacific. Taiwanese localities of published specimens and newly-discovered localities with cetacean fossils are shown in Fig. 1. The oldest fossil cetaceans reported in Taiwan in the literature are from the latest Miocene to the earliest Pliocene (Kueichulin Formation; Chiu 1972). Figure 2A shows an example of an odontocete from the Kueichulin Formation of

Guoshing Township in the field. Several factors could explain the limited knowledge of cetacean fossils in Taiwan: few fossil cetaceans have been discovered (possibly relating to the amount of available marine sedimentary rock outcrop or the previous lack of direct research on fossil Cetacea), and most fossil cetaceans from Taiwan are unpublished specimens that have been found accidentally or recovered by amateur paleontologists. Examples of occurrences include fossil specimens trawled from the sea bottom of Penghu Channel by fishing boats (Chang 1996), fossils recovered during construction (Chang and Cheng 1998), and fossils recovered during drilling for petroleum (Meng 1961; Huang 1965, 1976; Chiu 1972). In Taiwan, cetacean-bearing rocks include alternating beds of sandstone and shale (Erchungchi, Liuchungchi, Kueichulin and Erjiou Formations), and massive conglomerate with a few layers of sandstone (Toukoushan Formation). Figure 3 gives examples of cetacean-bearing formations and fossils.

The scope of advanced research on cetacean fossils in Taiwan could include the following (based on Fitzgerald 2004): 1) to locate where fossil cetaceans have previously been discovered; 2) to recognize the faunal compositions of these localities from national institution or private collections; 3) to understand the sedimentary geology of these cetacean-bearing localities; and 4) to resolve the geological age of these fossil-bearing localities. The purpose of this study is to review the status of known fossil cetaceans, to summarize the published fossil cetacean-bearing localities in Taiwan, to record

formerly unknown specimens from field investigations, and to report on cetacean fossils in national museums and private collections.

## Materials and Methods

Most specimens discovered remain in the field because it is imprudent to recover them without systematic excavation due to risk of damage. Also, some specimens are in the care of private collectors, such as fossil balaenids reported by Tsai *et al.* 2012; such specimens could be described formally once the specimens go to national institutions. Two eschrichtiid fossils, NMNS-F051728 and LFMM-W-001, are deposited at National Museum of Natural Science, Taichung, Taiwan (NMNS) and Land Fossil and Mineral Museum, Tainan, Taiwan (LFMM) respectively.

### **Mysticeti (baleen whale)**

Fossil mysticetes from Taiwan were discovered during petroleum exploration by the Taiwan Petroleum Exploration Division of the Chinese Petroleum Corporation in the 1950's. Following a series of excavations, a few articles on fossil whales were published (Meng 1961; Huang 1965, 1976; Chiu 1972) and several fossil cetacean localities were reported (Fig. 1). These discoveries produced many mysticete fossils, though mainly they were non-diagnostic elements such as broken vertebrae and incomplete ribs. As no skulls were discovered, the fossils could not be identified with confidence. However, a new species, *Balaenoptera taiwanica*, was

established based on an isolated tympanic bulla (Huang 1965). Huang argued that morphological characters of the bulla (including an abrupt limbation (sic) and distinct deep furrow of the involucre, gentle depression and very weak grooves on the middle part of the inner lip, and narrow tympanic cavity) were sufficient to define a new species following criteria used by Kellogg (1924). However, Kellogg did offer a caution (Kellogg 1924) which states: “the tympanic bones are sufficiently diagnostic to be used as a guide in the determination of species... but no definite allocation will be made until more material is available for study”. More recently, Steeman (2010) concluded that ear bones may show sufficient diagnostic characters to allow identification at species level, but isolated ear bones or other isolated skeletal material should not be used to establish new scientific names (also see Barnes 1977; Oishi and Hasegawa 1995a). With that provision, if isolated specimens are used for taxonomical identification purposes, they may dramatically enhance our knowledge of cetacean paleo-diversity and paleo-distribution (Steeman 2010). The taxonomic status of *Balaenoptera taiwanica* Huang, 1965, will be treated in depth by Tsai separately.

Field research and examination of national and private collections identified the localities shown in Fig. 1. Newly-recognized specimens that are currently under study include two fossil eschrichtiid specimens (NMNS-F051728 and LFMM-W-001), comprising partial posterior crania (Tsai *et al.* 2011) and fossil balaenids, with cervical vertebrae and tympanic bulla

(Tsai *et al.* 2012). In spite of their incomplete preservation, these specimens show key diagnostic features, such as the presence of paired tuberosities on the supraoccipital shield for eschrichtiids (Ichishima *et al.* 2006) and the fused cervical vertebrae for balaenids (Kellogg 1928). These specimens should elucidate the evolutionary history and paleo-distribution of Eschrichtiidae and Balaenidae in the northwestern Pacific.

### **Odontoceti (toothed whale, dolphin, and porpoise)**

Only four odontocete bearing-localities have been documented in three publications (Fig. 1; Tan 1937; Chang 1996; Chang and Cheng 1998) and just one family, Delphinidae, has been reported to date. Eight vertebrae were discovered (seven in Houlong Township, Miaoli County and one in Chochen Township, Tainan City) and identified as posterior lumbar vertebrae based on the position of transverse processes and lack of ventral processes for chevron bones (Tan 1937). An isolated tooth (Fig. 2B) probably represents a species of Delphinidae from Liuchungchi Formation of Yujing Township. Two well-preserved skulls include one identified as the extant shortfinned pilot whale, *Globicephala macrorhynchus* Gray (Chang 1996), and the other proposed by Chang and Cheng (1998) as a new species, *Pseudorca yuanliensis*. The former specimen shows no major difference from extant *Globicephala macrorhynchus*, but does show minor differences that probably reflect postmortem erosion, for example, destruction of the globose and robust antorbital processes (therefore

obliterating the deep and wide antorbital notch) or to continuous wear which caused the maxillary alveoli to be absent from ventral view. The similarities to extant *Globicephala macrorhynchus* include a short and wide rostrum, posterior extension of the maxillae compressing the occipital shield which is not visible in dorsal view, and rugosities on the dorsal surface of the premaxillae near the anterior tip of the rostrum. The Late Pliocene or Early Pleistocene holotype specimen of *Pseudorca yuanliensis* is well-preserved, including a nearly-complete skull, cervical and thoracic vertebrae and ribs, but its morphology, paleoecology and phylogenetic relationships need to be reevaluated. Furthermore, the name, *Pseudorca yuanliensis*, is a *nomen nudum* because publication of the name does not fulfill requirements of availability (ICZN 1999: Art. 13). For now, the name is best used in quotes, thus: “*Pseudorca yuanliensis*”.

Few well-preserved fossil odontocetes were encountered during this study. However, the quantity of fossil odontocetes seems higher than previously thought. For example, according to an amateur paleontologist (L. C. Wang, pers. comm. ), a fossil odontocete with a nearly complete skeleton was discovered, but without financial support and human resource, the fossil had to be excavated quickly before a typhoon and only fragments were recovered. Though few diagnostic bones (such as skulls) were recognized during this study, other bones could also be useful for studying the paleo-diversity of fossil odontocetes in Taiwan (ear bones, see Bianucci 1996; limb bones, see Kazár and Bohaska 2008).

## Discussion

The known published fossil localities, in addition to newly-recognized specimens in national museums and private collections and those remaining in the field (Fig. 1), indicate clearly the scope of fossil whale studies in Taiwan as well as the potential to improve knowledge of the natural history, paleontology, and geological context of Cetacea in this region. Until recently, the published fossil record of Cetacea in Taiwan represented only two families, Balaenopteridae and Delphinidae. However, recent findings of geologically young eschrichtiids (gray whales) and balaenids (right whales) (Tsai *et al.* 2011, 2012) reveal a higher paleo-diversity at the family level than at present (eschrichtiids and balaenids do not now live in Taiwanese waters). In Taiwan, the limited fossil record of Cetacea could be attributed to a combination of the biases outlined by Uhen and Pyenson (2007): taxonomic, time scale, collection effort, available rock area, research effort, and taphonomic biases. Among these seven biases, the previously limited research effort is probably significant in Taiwan. Few papers that mention fossil Cetacea have been published since the first report that recorded fossil cetaceans from Houlong and Chochen Township by Tan (1937).

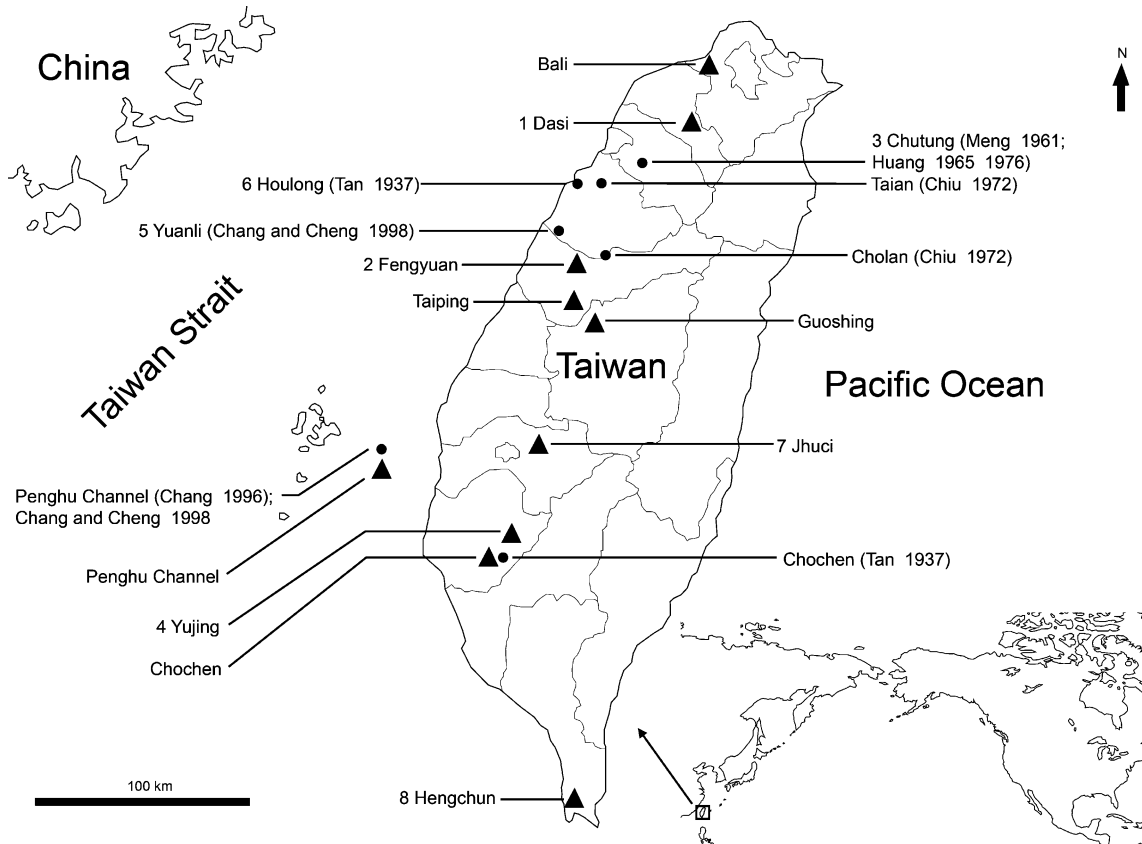
The seven localities (Fig. 1) identified from previous publications have expanded to 15 by recent field work. The new localities expand the regions yielding fossil cetaceans northwards (Bali) and southwards (Hengchun). All the fossil cetacean-bearing localities are restricted to

western Taiwan, partly because sedimentary rocks in eastern Taiwan are often metamorphosed or volcanoclastic sediments, which are unlikely to yield vertebrate fossils. However, these new localities reveal that more cetacean-bearing localities could be discovered. Considering the extant cetacean diversity around Taiwan (Yang 1976; Chou 2004) and diverse cetacean fossil assemblages discovered in Japan (Oishi and Hasegawa 1995b), a more diverse fossil record of Taiwanese Cetacea could be expected. Fossil specimens dredged from sea bottom are occasionally reported from other countries (Fordyce 1984; Whitmore *et al.* 1986; Post and Kompanje 1995), but this happens frequently in Taiwan (Chang 1996; Tsai *et al.* 2011, 2012).

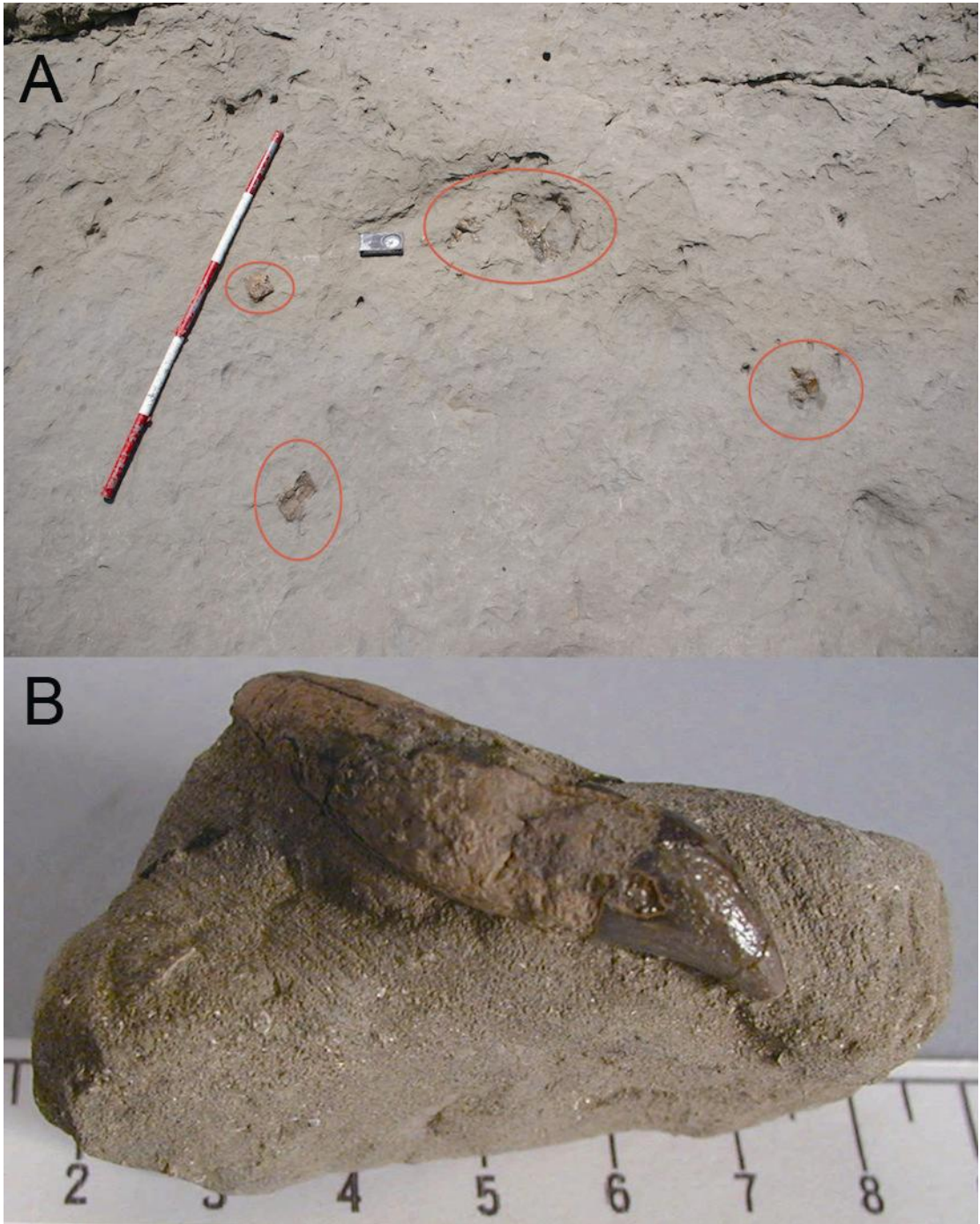
Long-term changes in geography could be a driving force of cetacean evolution, such as the opening of the Drake Passage and the initiation of the Antarctic Circumpolar Current (Steeman *et al.* 2009). Pleistocene alternations between glacial and interglacial affected the geography between continental Asia and Taiwan: interglacial high sea levels precluded migration of terrestrial mammals, and allowed passage of Cetacea, while glacial low sea levels linked landmasses and allowed terrestrial movement while limiting cetaceans. Fossils from the sea bottom of Penghu Channel (elephants - Takahashi *et al.* 2001; gray whales-Tsai *et al.* 2012) are consistent with the notion of alternating terrestrial and marine migration routes. Fluctuating conditions from shallow marine and lagoon to terrestrial settings around Taiwan, especially Taiwan Strait (Ku *et al.* 2005), also changed cetacean habitat

on a local scale. Such temporal variation in habitats may have affected the migration route, mating and calving regions of gray whales, *Eschrichtius robustus*, but the behavior of the modern western population of gray whales is too inadequately understood to predict the nature of possible change (Jones and Swartz 2009). For other gray whale populations, glacial and interglacial changes in Pleistocene sea level may have forced them to change their feeding mode from benthic feeders to generalists (Pyenson and Lindberg 2011).

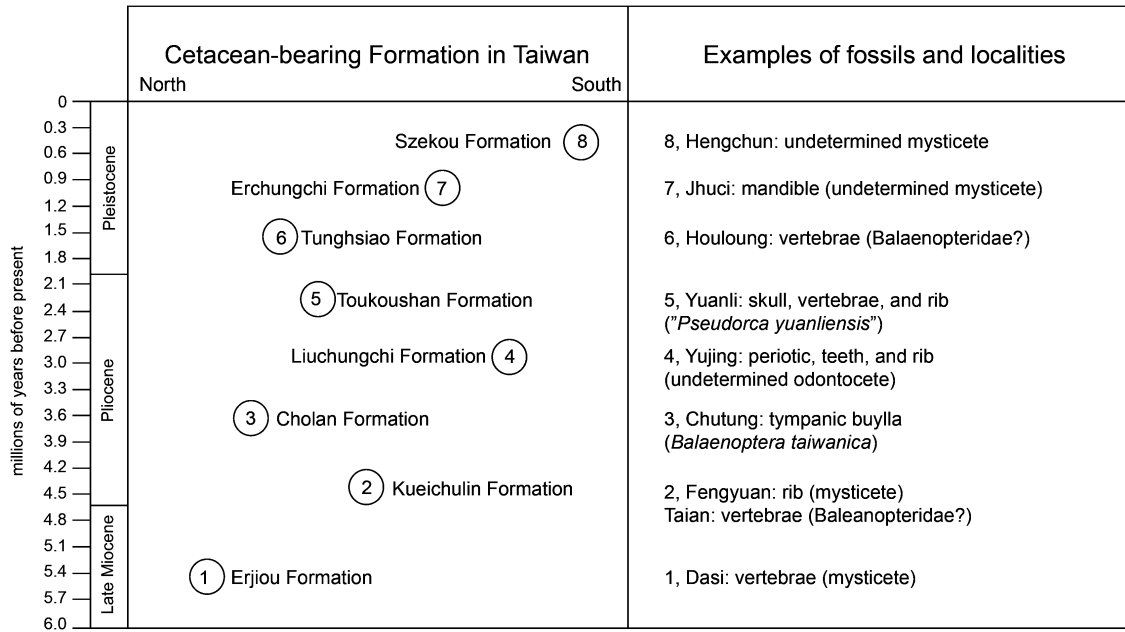
The identification of more cetacean-bearing localities, and the (re)identification of published and newly-discovered cetacean fossils (Fig.1) both suggest that Taiwan could be a high-yielding region for future discoveries and could improve the knowledge of the cetacean fossil record along the western Pacific rim. The fossil record of Cetacea in Japan could be an analogue for Taiwan; Japan is stratigraphically well-sampled, yielding an extremely diverse assemblage of extinct cetaceans, such as *Aetiocetus*, *Chonecetus*, *Herpetocetus*, and *Balaenula* (Mysticeti) and *Kentriodon*, *Scaldicetus*, and *Eurhinodelphis* (Odontoceti) (Oishi and Hasegawa 1995b). This review concludes that comparable taxonomic and stratigraphic diversity could be developed for fossil marine mammals in Taiwan.



**Figure 1.** Localities of cetacean fossils in Taiwan. ● represents the fossil sites in the literature and ▲ stands for the new localities reported in this study. Of note, there are two localities overlapping with fossils found in the past and newly-discovered material, Chochen and Penghu Channel. The number beside the locality corresponds to Figure 3. The miniature at the bottom right shows the relative position of Taiwan in the northern Pacific.



**Figure 2.** An odontocete fossil in the field, Kueichulin Formation of Guoshing Township (A). Red circles indicate the positions of the fossil material; an fossil odontocete tooth with matrix, Liuchungchi Formation of Yujing Township (B).



**Figure 3.** Comparison between cetacean-bearing formations and fossil specimens and localities in Taiwan. Holo., Holocene; L. Mio., Late Miocene.

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## Literature Cited

- Barnes, L. G. 1977. Outline of eastern North Pacific fossil cetacean assemblages. *Systematic Zoology* 25: 321-343.
- Bianucci, G. 1996. The Odontoceti (Mammalia, Cetacea) from Italian Pliocene. Systematics and phylogenesis of Delphinidae. *Palaeontographia Italica* 83: 73-167.
- Chang, C. H. 1996. The first fossil record of a short-finned pilot whale (*Globicephala macrorhynchus*) from the Penghu Channel. *Bulletin of the National Museum of Natural Science* 8: 73-80.
- Chang, C. H. and Y. N. Cheng. 1998. Extraordinary fossil records of Cetacea from Pleistocene in Taiwan. p. 85. *In*: H. Otsuka and K. D. Rigakubu (eds.). *The Ryukyu Islands: The arena of adaptive radiation and extinction of island fauna*. Kagoshima University, Department of Earth and Environmental Sciences.
- Chiu, H. T. 1972. Occurrence of whale bone fossils in Taiwan. *Acta Geologica Taiwan* 15: 23-26.
- Chou, L. S. 2004. History of the marine mammal study in Taiwan. pp. 129-138. *In*: S. Akiyama, R. Miyawaki, T. Kubodera, and M. Higuchi (eds.). *Proceedings of the Fifth and Sixth Symposia on Collection Building and Natural History Studies in Asia and the Pacific Rim*. National Science Museum Monographs, Tokyo.
- Fitzgerald, E. M. G. 2004. A review of the Tertiary fossil Cetacea (Mammalia) localities in Australia. *Memoirs of the Museum Victoria* 61: 183-208.
- Fordyce, R. E. 1984. Preliminary report on cetacean bones from Chatham Rise (New Zealand). *Geologisches Jahrbuch* 65: 117-120.
- Fordyce, R. E. 2009. Fossil sites, Noted. pp. 459-466. *In*: W. F. Perrin, B. G. Würsig, and J. G. M. Thewissen (eds.). *Encyclopedia of Marine Mammals*. Academic Press.
- Huang, T. Y. 1965. A new species of a whale tympanic bone from Taiwan, China. *Transactions and Proceedings of the Palaeontological Society of Japan* 61: 183-187.
- Huang, T. Y. 1976. Second discovery of a whale tympanic bone from Taiwan, China. *Petroleum Geology of Taiwan* 13: 193-199.
- Ichishima, H., E. Sato, T. Sagayama and M. Kimura. 2006. The oldest record of Eschrichtiidae (Cetacea: Mysticeti) from the Late Pliocene, Hokkaido, Japan. *Journal of Paleontology* 80: 367-379.

- International Commission on Zoological Nomenclature. 1999. International code of zoological nomenclature. The Natural History Museum, London. (Online version - <http://www.nhm.ac.uk/hosted-sites/iczn/code/>)
- Jones, M. L. and S. L. Swartz. 2009. Gray whale (*Eschrichtius robustus*). pp. 503-511. In: W. F. Perrin, B. G. Würsig, and J. G. M. Thewissen (eds.). Encyclopedia of Marine Mammals. Academic Press.
- Kazár, E. and D. J. Bohaska. 2008. Toothed whale (Mammalia: Cetacea: Odontoceti) limb bones of the Lee Creek Mine, North Carolina. pp. 271-324. In: C. E. Ray, D. J. Bohaska, I. A. Koretsky, L. W. Ward, and L. G. Barnes (eds.). Geology and Paleontology of the Lee Creek Mine, North Carolina, IV. Virginia Museum of Natural History Special Publication 14.
- Kellogg, R. 1924. Description of a new genus and species of whalebone whale from the Calvert Cliffs, Maryland. Proceedings of the United States National Museum 63: 1-14.
- Kellogg, R. 1928. The history of whales – Their adaptation to life in the water. The Quarterly Review of Biology 3: 174-208.
- Ku, H. W., Y. G. Chen and T. K. Liu. 2005. Environmental change in the southwestern coastal plain of Taiwan since Late Pleistocene: Using multiple proxies of sedimentary organic matter. Terrestrial Atmospheric and Oceanic Sciences 16: 1079-1096.
- Meng, C. Y. 1961. The well preserved fossil bones first discovered from Taiwan. Shih Yu Tung Hsin 120: 2-4. (in Chinese)
- Oishi, M. and Y. Hasegawa. 1995a. Diversity of Pliocene mysticetes from eastern Japan. The Island Arc 3: 436-452.
- Oishi, M. and Y. Hasegawa. 1995b. A list of fossil cetaceans in Japan. The Island Arc 3: 493-505.
- Post, K. and E. J. O. Kompanje. 1995. Late Pleistocene white whales *Delphinapterus leucas* from Dutch coastal waters. Lutra 38: 67-76.
- Pyenson, N. D. and D. R. Lindberg. 2011. What happened to gray whales during the Pleistocene? The ecological impact of sea-level change on benthic feeding areas in the North Pacific region. PloS ONE 6 (7): 1-14. (DOI: 10.1371/journal.pone.0021295)
- Steehan, M. E. 2010. The extinct baleen whale fauna from the Miocene-Pliocene of Belgium and the diagnostic cetacean ear bones. Journal of Systematic Palaeontology 8: 63-80.
- Steehan, M. E., M. B. Hebsgaard, R. E. Fordyce, S. Y. W. Ho, D. L. Rabosky, R. Nielsen, C. Rahbek, H. Glenner, M. V. Sorensen and E. Willerslev. 2009. Radiation of extant cetaceans driven by restructuring of the oceans. Systematic Biology 58: 1-13.
- Takahashi, K., C. H. Chang and Y. N. Cheng. 2001. Proboscidean fossils from the Japanese Archipelago and Taiwan Islands and their relationship with the Chinese Mainland. pp. 148-151. In: G. Cavaretta, P. Gioia, M. Mussi, and M. R. Palombo (eds.). The World of Elephants: Proceedings of the 1st

International Congress. Consiglio Nazionale delle Ricerche.

- Tan, K. 1937. Notes on the remains of fossil Delphinidae from two different localities in Taiwan. *Taiwan Tigaku Kizi* 8: 92-95.
- Tsai, C. H., C. H. Chang and L. K. Lin. 2011. Morphology and phylogenetic relationships of gray whale-like fossils from Taiwan. *Chinese Bioscience* 53: 41. (Abstract)
- Tsai, C. H., C. H. Chang and L. K. Lin. 2012. Occurrence of fossil balaenids in Taiwan and its implications for climate change. *Chinese Bioscience* 54: 60. (Abstract)
- Uhen, M. D. and N. D. Pyenson. 2007. Diversity estimates, biases, and historiographic effects: Resolving cetacean diversity in the Tertiary. *Palaeontologia Electronica* 10: 1-22.
- Whitmore, F. C., G. V. Morejohn and H. T. Mullins. 1986. Fossil beaked whales - *Mesoplodon longirostris* dredged from the ocean bottom. *National Geographic Research* 2: 47-56.
- Yang, H. C. 1976. Studies on the whales, porpoises and dolphins of Taiwan. Annual Report of Science, Taiwan Museum 19: 131-178. (in Chinese with English abstract)

# Towards an Understanding of Butterfly Diversity and Composition in an Artificial Habitat: A Case Study of the Ecology Education Park in the Endemic Species Research Institute

## 了解蝴蝶群聚於人工棲地的多樣性及組成：以特有生物研究保育中心之生態教育園區為例

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## Abstract

Habitat destruction by human activity is a severe issue around the world. The growing number of semi-natural habitats and artificial habitats should be further studied owing to their potential functions in conservation and education. A one-year survey of butterflies in an artificial habitat, Ecology Education Park (EEP) in the Endemic Species Research Institute, was conducted to understand the composition and monthly variation of the butterfly community there. In total 96 butterfly species and 1754 individuals

were recorded during 12 investigations. Among them, 9, 16, 13, 18, and 40 recorded species came from families Hesperiiidae, Papilionidae, Pieridae, Lycaenidae, and Nymphalidae, respectively. Species richness peaked in July and October, and a similar pattern showed in all five butterfly families in EEP. During the 12-months period, large variation of butterfly abundance happened in Lycaenidae and Nymphalidae owing to one or two apparent peak(s); but no apparent peak resulted in relatively small abundance variation in Pieridae. For different families, the peak could have occurred due to outbreak of one or two species, or multiple species maintaining a certain level of population during the same period. Among the results from four diversity indices, a similar pattern was found when considering the number of individuals in the total sample. The apparent drop of values of indices occurred in December owing to a population outbreak of a small number of species. The preliminary results from this study can give light to the importance of monitoring community structure in artificial habitats by manipulating proper sampling methods and by adopting adequate diversity indices.

## 摘 要

人類活動造成的棲地破壞為全球性嚴重議題。隨之增加的半天然棲地和人工棲地因具備保育及教育的潛在功能，值得加以重視。特有生物研究保育中心的生態教育園區為人工營造的棲地，為了解棲息於該地之蝴蝶群聚的組成及月間變化，進行為期一年的蝶相調查。每月一次共計 12 次調查，記錄到 96 種蝶類共計 1754 隻次，其中弄蝶科(Hesperiiidae) 9 種、鳳蝶科(Papilionidae) 16 種、粉蝶科(Pieridae) 13 種、灰蝶科(Lycaenidae) 18 種、蛺蝶科(Nymphalidae) 40 種。分屬五科的蝶類在 7 月及 10 月達種數高峰。灰蝶科和蛺蝶科在數量分布上有較大的月間變異，肇因於一至二次的數量高峰；月間變異較小的粉蝶科在數量上則無明顯高峰。不同科別的蝶類，其數量高峰的複因可能為一或二個物種的族群擴張，或是多個物種在同一期間維持一定的數量。採用四種多樣性指數計算的結果指出，在考量物種個體數於總個體數中比例時，數值於月間呈現出相似模式，均於 12 月驟降至最低數值，原因為該月份少數物種在個體數量上有族群擴張現象。本研究的初步結果旨在強調：透過適當的採樣方法及採用適當的多樣性指數，將有助於提供人工棲地中物種群聚組成監測上的重要訊息。

**Key words :** artificial habitat, Ecology Education Park, butterfly community structure, population outbreak, diversity index

**關鍵詞：**人工棲地、生態教育園區、蝴蝶群聚組成、族群擴張、多樣性指數

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## Introduction

Almost all the habitats around the world have been influenced by human directly or indirectly in different scales and in many aspects (Bishop *et al.* 1981; Naeem *et al.* 1994; Vitousek *et al.* 1997; Chapin III *et al.* 2000). Since natural habitats are diminishing, semi-natural and artificial habitats, which are both increasing in number, have become important study plots as with natural ones (Hietala-Koivu *et al.* 2004). A well-designed management of those habitats can generate meaningful insights in conservation biology(e.g., protect and conserve plants and animals) or for educational purposes(Pratt 1994; Fernández-Juricic and Jokimäki 2001; Li 2005). Therefore, in addition to conserving natural habitats, it is critical to direct attention to the management of semi-natural or artificial habitats.

Previously a log-storage pool, Ecology Education Park(simplified as EEP thereafter) is an artificial habitat constructed in 1993 in the Endemic Species Research Institute(simplified as ESRI thereafter). After undergoing habitat reconstruction and systematical planting for several years, EEP is now composed of diverse microhabitats with abundant endemic plant species and has attracted many animals ever since. At least 697 plant species, 60 birds, 20 reptiles, 16 amphibians, 105 butterfly species, and 144 moths have been recorded in EEP. Previous studies have focused on the diversity of organisms inhabiting in natural sampling plots, and the correlation between the biodiversity and

ecosystem functioning were also held(Chapin III *et al.* 2000; Loreau *et al.* 2001). However, little is known about the species diversity of artificial habitats, regardless of the benefits that monitoring changes in species composition in such habitats may provide useful information for improving the management protocols. The EEP, has been constructed and managed, thus becomes an ideal sampling plot for studying such important issues.

Butterflies are adequate indicators of habitat changes(Kunte 1997), especially when comparing to the other terrestrial insect groups with limited baseline knowledge(Thomas 2005). In this study, we underwent surveys of butterfly communities in EEP by recording the number of individuals in each species once every month. Assessment of species richness, evenness, and other diversity indices were conducted to understand the patterns of community composition and monthly variation. Based on the preliminary results, sampling methods and monitoring protocols for an artificial habitat are expected to be improved and reconstructed.

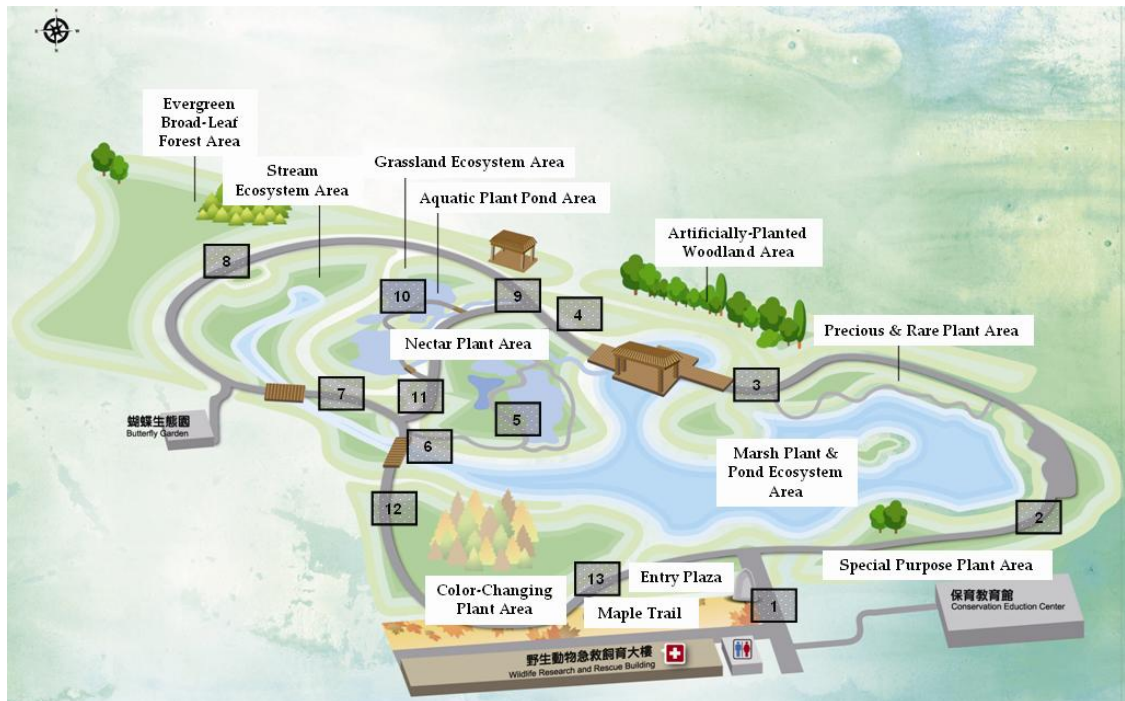
## Materials and Methods

### Study area

Butterfly community survey took place during 2011 in EEP in ESRI, located in Jiji Township, Nantou County, Taiwan(N23° 49' 36", E120° 48' 4.56"). The altitude of the study location was 301 m. The 3.5-hectare area contains several habitat types, including forests, grasslands, and ponds. Around the park, plant species clustered in areas such as nectar plant area, evergreen

broad-leaf forest area, precious and rare plant area, special purpose plant area, and color-changing plant area(Fig. 1). Information about

food plants of butterfly adults(i.e., nectar plants) and larvae(i.e., host plants) in EEP are listed in **Appendix 1**.



**Fig.1.** A map of EEP with distinctive areas. Shaded squares with number represent the order of transect line from 1 to 13, formed as a circular route. That is, after passing the 13<sup>th</sup> spot, the recorder kept walking to the 1<sup>st</sup> spot to finish the investigation.

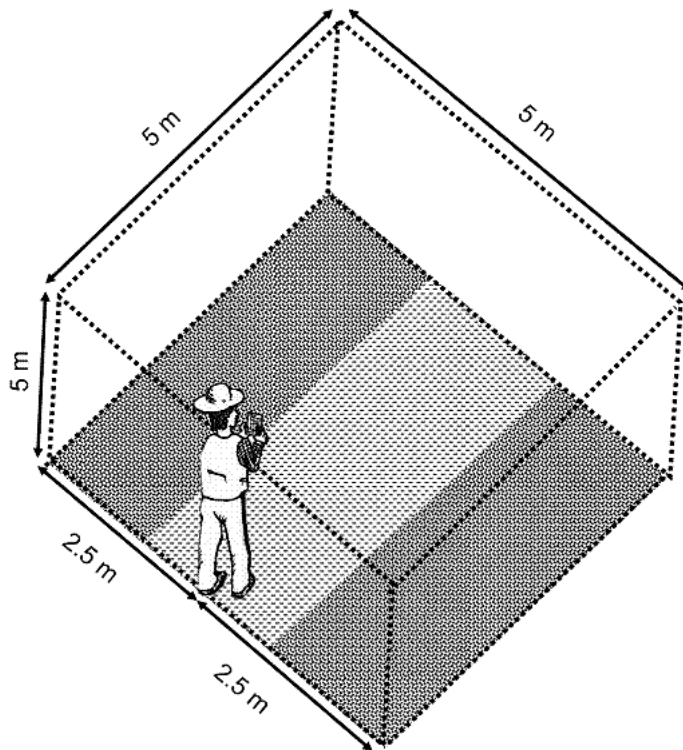
### Sampling methods

The transect was a one-km route across each habitat type in EEP(Fig. 1). The investigation was made under good weather condition(except for raining) once every month from 09:00 to 12:00 when the highest species richness and the number of individuals could be observed during the day(Yan 2011). The recorders walked at a

uniform pace forward and recorded the species name and number of individuals of butterflies found within a space formed by a 5-m range cube(i.e., a method which is similar to Pollard Walk by Pollard(1977, 1982), Pollard and Yates(1993), and descriptions by Pollard(1991); see Fig. 2). Most butterflies were identifiable in flight, while some smaller and indistinguishable

individuals(usually butterflies belonging to the family Hesperidae) were captured by butterfly net for further identifications. Additional investigations during each month were made for

the supplement of butterfly species(asterisk symbol in **Table 1**), and data of which(both the number of species and individuals) were not included for further analyses.



**Fig. 2.** The detection range when sampling in EEP. The space was formed as a 125 m<sup>3</sup> cube where the recorder kept track of the species and the number of butterflies passing by.

### Diversity indices

We regarded EEP as a relatively small sampling plot, where the recording of butterfly species has been made for more than 3 years(i.e., assuming nearly all of butterfly species in the butterfly community were recorded and identified). The sampling frequency was also assumed to be

enough in order to ensure the probability for each individual in each population being chosen is equal. With the above assumptions, the diversity indices can be adopted for interpretations. Four commonly used indices were adopted to make comparisons of the pattern of diversity and composition of butterflies.

## (1) Species richness

Species richness indicates the number of species in the community (McIntosh 1967). In this study, we adopted the complete count of the number of butterfly species in order to make comparisons with other diversity indices considering the number of individuals.

## (2) Evenness

Based on the Shannon index, which will be described in the next section, Pielou's evenness index (referred to as Pielou index thereafter) represents the ratio of observed diversity to the maximum possible diversity of a community with the same species richness (van Dyke 2008). The formula for calculating species evenness are

$$H_{max} = \ln S$$

$$J = H/H_{max} \quad (\text{Pielou 1966})$$

where  $H_{max}$  is the Shannon index when all the species in the community had an equal number of individuals,  $S$  the species richness (i.e., the number of species),  $\ln S$  the natural logarithm of  $S$ ;  $J$  is the measure of species evenness (i.e., Pielou index),  $H$  the measure of species diversity (from Shannon index).

## (3) Shannon index

The Shannon-Wiener index is a commonly used nonparametric measurement of heterogeneity (uncertainty) based on information theory (Margalef 1957, 1958). The name of the Shannon-Wiener index derived from Shannon's (1948) admiration for Norbert Wiener for his contribution

of basic philosophy and theory to communication theory (also clarified by Spellerberg and Fedor (2002)). The Shannon-Wiener index (as Shannon index thereafter) can be used with both large and small sample sizes (van Dyke 2008). The formula for the Shannon index is

$$H = - \sum_{i=1}^S (p_i) (\ln p_i) \quad (\text{Shannon 1948})$$

where  $H$  is the measure of species diversity (i.e., Shannon index),  $S$  the species richness,  $p_i$  the proportion of individuals in the total sample which belongs to the  $i$ th species, and  $\ln p_i$  the natural logarithm of  $p_i$ .

## (4) Simpson's index

Simpson (1949) presented a nonparametric measurement of heterogeneity derived from the probability that two individuals chosen at random and independently from the population belonging to the same group (i.e., species). Since we regarded the sample as a finite collection (i.e., collection as a complete population, Pielou (1966, 1969), the complement of Simpson's diversity (simplified to Simpson's index thereafter) was used to estimate the heterogeneity of butterfly community in EEP. The formula for the Simpson's index is

$$1 - D = 1 - \sum_{i=1}^S \left[ \frac{n_i(n_i - 1)}{N(N - 1)} \right] = 1 - \frac{\sum_{i=1}^S n_i(n_i - 1)}{N(N - 1)} \quad (\text{Pielou 1969})$$

where  $1 - D$  is the Simpson's index of diversity

for a finite population,  $S$  the species richness,  $n_i$  the number of individuals in the total sample which belongs to the  $i$ th species,  $N$  the number of individuals in the total sample.

### Statistical Analyses

Chi-square goodness of fit test was used to check if the proportion of butterfly families in EEP fit the known proportion of butterfly families of Taiwan. Pearson's chi-squared test of independence was used to see if there was any correlation between total species number and species number in each family across months. Bartlett's test of homogeneity of variance was used to compare the pattern of butterfly abundance across months in the three families which took up the majority of total butterfly abundance.

## Results

### Composition of butterfly species

Scientific names of butterfly species being

recorded during 2011 are listed in **Appendix 2**. As shown in **Table 1**, 104 butterfly species were found in EEP, accounting for 24.07% of the species in Taiwan. Among them, the family Papilionidae accounted for the largest proportion (41.46%) while the family Lycaenidae took up the smallest proportion (15.32%). The species distribution by families in EEP was different from the distribution of Taiwan (Chi-square goodness of fit test:  $p = 0.013$ ). The butterfly family Nymphalidae contributed the most to all of butterfly species recorded during 2011 (**Table 2**), and the similar pattern occurred in most of time periods (10 months during a year, **Fig. 3**). July and October were two peaks of the number of butterfly species during 2011 (**Fig. 3**). The distribution of species number in each family was similar to an overall pattern regardless of the separation by butterfly families (Pearson's chi-squared test of independence:  $p = 0.719$  in Hesperidae;  $p = 0.413$  in Papilionidae;  $p = 0.321$  in Pieridae;  $p = 0.87$  in Lycaenidae;  $p = 0.994$  in Nymphalidae).

**Table 1.** Number of butterfly species in EEP and in Taiwan

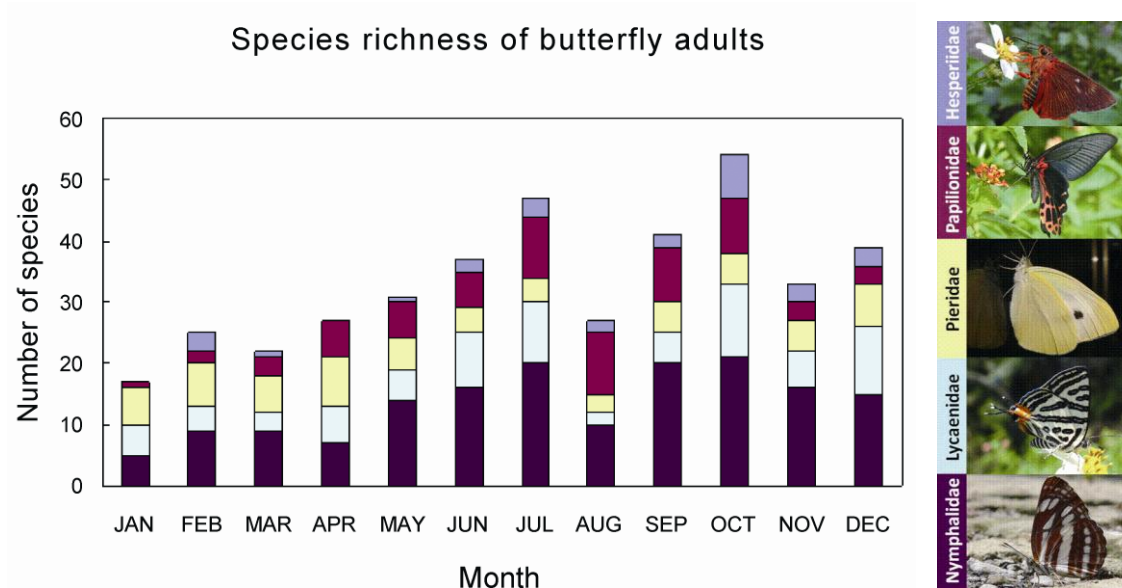
Family	Number of species		Percentage(%)
	EEP*	Taiwan**	
Hesperidae	13	69	18.84
Papilionidae	17	41	41.46
Pieridae	14	38	36.84
Lycaenidae	19	124	15.32
Nymphalidae	41	160	25.63
Total	104	432	24.07

\* represent the number of species including the supplied records

\*\* The number of species in Taiwan is the most recent record from TaiBNET (Catalogue of Life in Taiwan: <http://taibnet.sinica.edu.tw/>)

**Table 2.** Records of the number of butterfly species and individuals in EEP during 2011

Family	Species		Individuals	
	Number	Percentage(%)	Number	Percentage(%)
Hesperiidae	9	9.37	34	1.94
Papilionidae	16	16.67	149	8.49
Pieridae	13	13.54	456	26.00
Lycaenidae	18	18.75	534	30.45
Nymphalidae	40	41.67	581	33.12
<b>Total</b>	<b>96</b>	<b>100.00</b>	<b>1754</b>	<b>100.00</b>

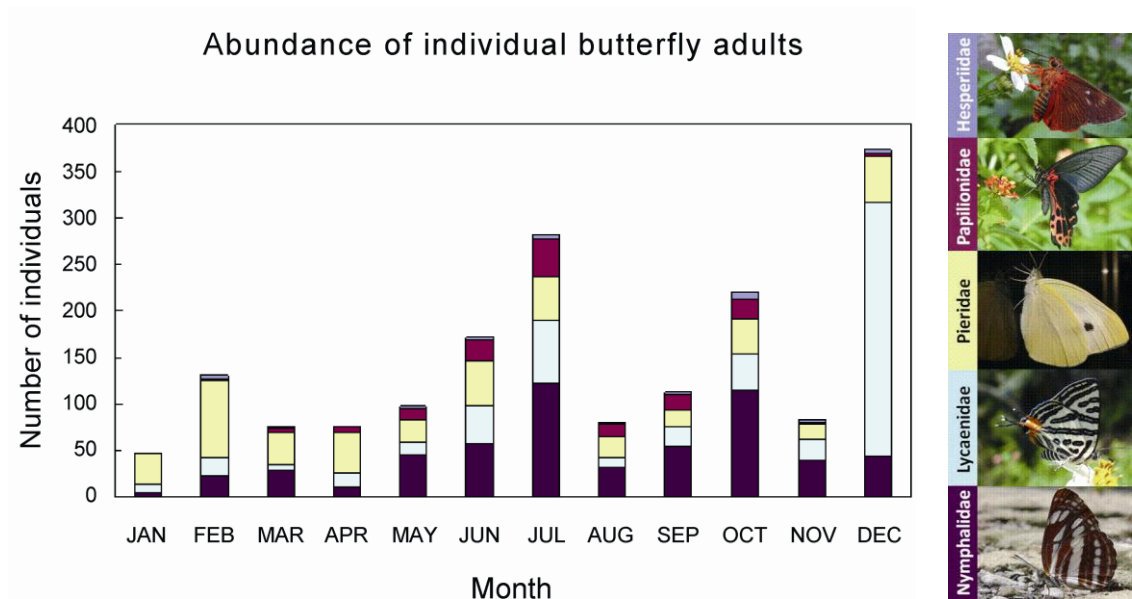


**Fig. 3.** Number of butterfly species in EEP during 2011(see **Appendix 3** for details).

**Composition of individual butterflies**

The combination of individual butterflies (populations of different species) recorded in every survey was considered as a butterfly community in EEP. The family Nymphalidae contributed the most to all of the individuals recorded during 2011, and the families Pieridae and Lycaenidae also took up relatively large proportions(**Table 2**). However, the distribution of individual butterflies during a year in each of the three families was different significantly(Bartlett's test

of homogeneity of variance:  $p < 0.001$ )(**Fig.4**). The family Lycaenidae had the largest variance 5476.6, followed by Nymphalidae at 1346.4 and Pieridae at 339.3. Outbreaks occurred once in Lycaenidae in December and twice in Nymphalidae in July and October, respectively; the abundance of Pieridae was highest in February while in the families which contributed less to total abundance: Hesperidae peaked in October and Papilionidae peaked in July(**Fig. 4**).



**Fig. 4.** Number of individual butterflies in EEP during 2011(see **Appendix 4** for details).

**Information from diversity indices**

Species richness increased from January to the first peak in July, and the second peak occurred in October after a sudden drop in August(**Fig. 5**).

The maximum and minimum values of species richness were 54 and 17 in October and January, respectively. Once considering the number of individuals, the distribution pattern during 2011

changed obviously. Values from the Pielou index showed that species evenness was relatively stable until the smallest value occurred in December (Fig. 5). Results of the Shannon index and the Simpson's index shared a similar pattern to species evenness

(Fig. 5 and 6). The maximum and minimum values of the three indices across months were both found in September and December, respectively (Pielou index = 0.926 and 0.607; Shannon index = 3.440 and 2.223; Simpson's index = 0.968 and 0.788).

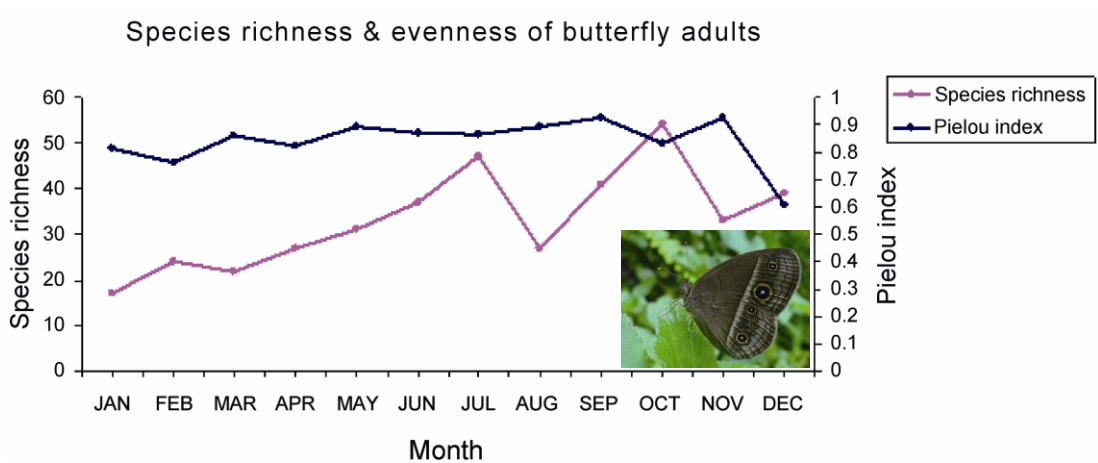


Fig. 5. Species richness and evenness of butterfly adults in EEP during 2011.

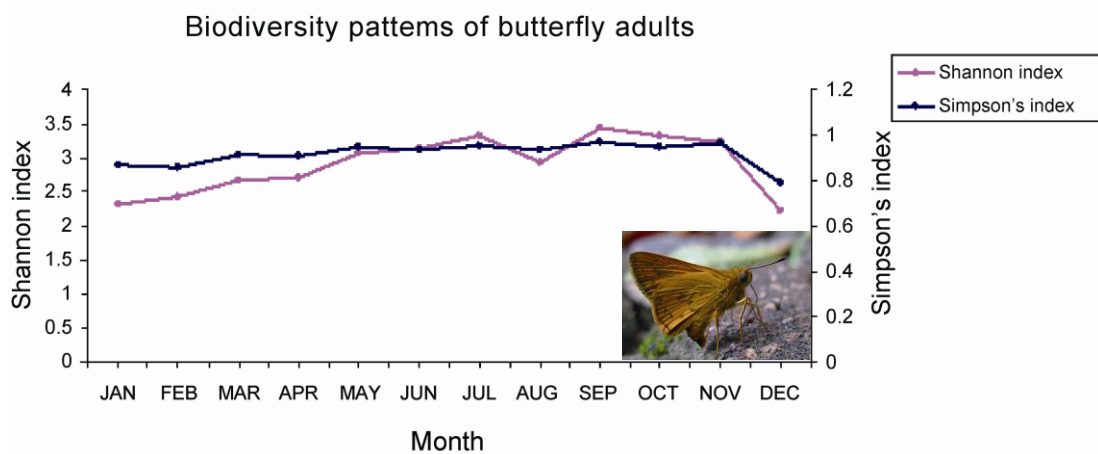


Fig. 6. Biodiversity patterns of butterfly adults indicated by two diversity indices in EEP during 2011.

## Discussion

### Composition of butterfly species

Slightly less than quarter of the butterfly species in Taiwan were found in EEP(**Table 1**). However, nearly half of Papilionidae species of Taiwan were found in EEP during 2011. Besides various nectar plants and host plants(**Appendix 1**), shoals and small ponds are scattered in EEP. Adults of Papilionidae species, for example, *Graphium sarpedon connectens*, *Papilio bianor thrasymedes*, and *Papilio taiwanus*, used to have water in such microhabitats(Hsu 1999). By studying the life history strategies and behaviors of butterfly species, the connection of habitat diversity to their growth, survival, and reproduction, might be informed. On the other hand, since the surveys were always held from 09:00 to 12:00, some butterfly species, such as *Ravenna nivea* (belonging to the family Lycaenidae) that is usually active at dawn and dusk(Hsu 1999), were possibly neglected when counting. In addition, many species were active inside the bush or the forest, making them hard to discover if surveying along the transect route. In addition, the Pollard Walk method(mainly followed in this study) was constructed and advocated in countries in the temperate zone, thus the investigation method was suggested to be modified according to regional characters in countries that lie in the subtropics and the torrid zones(Lyu 2011). In conclusion, additional investigations in different time periods, by various routes, and with adjustment based on regional difference can increase the relevance of specie richness

monitoring in an artificial plot.

Species composition by family in EEP did not coincide with species composition in Taiwan, although the family Nymphalidae made up the largest proportion in both cases(**Table 2** and **Fig. 3**). However, the checklist from TaiBNET may possibly overestimate the number of butterfly species in Taiwan, since some species were rarely discovered and even considered as “vagrant” butterfly species. As a result, the comparison of species number between EEP and Taiwan will only be more meaningful if integrated with checklists of butterfly species made by as many other survey groups as possible. The pattern of species number in each family across months was similar; Papilionidae, Lycaenidae, and Nymphalidae butterflies mainly peaked in July and October(**Table 2** and **Fig. 3**). In our records, monthly rainfall in July and October differed significantly(July: 309 mm; October: 74 mm; unpublished data); however, with limited environmental information, no convincing explanation could be made. Species abundance can correlate closely with the weather(Roy and Sparks 2000), the growth of nectar plants (Warren 1987; Peterson 1997), and many other extrinsic or intrinsic factors(e.g., Cushman *et al.* 1994). Therefore, studies on life history characters of butterfly species and their interactions with plants, combining with long-term environmental factors, should all help to explain the occurrence of the population outbreak.

### Composition of individual butterflies

The abundance peak(i.e., the highest number

of individual butterflies) in each butterfly family during 2011 was February in Pieridae, July in Papilionidae and Nymphalidae, October in Hesperidae, and December in Lycaenidae(**Fig. 4**). In February, *Pieris rapae crucivora* and *P. canidia* contributed the most to Pieridae's abundance(unpublished data). Similar to the description from previous investigation, these two Pieridae species were active from December to February even when cold currents came(Li 2011). In July, *Cupha erymanthis*, *Euploea tulliolus koxinga*, *Tirumala limniace limniace*, and *E. mulciber barsine* were frequently seen in the Nectar Plant area, visiting plants such as *Bidens pilosa radiata*, *Lantana camara*, *Asclepias curassavica*, and *Eupatorium clematideum gracillimum*. The abundance peak of Nymphalidae did not owe to the outbreak of certain species but was influenced by different species(**Fig. 3** and **4**). Many Papilionidae species were active in July as well(**Fig. 3**). Among them, *Graphium sarpedon connectens* and *Papilio protenor protenor* usually flew near shoals, drinking water occasionally. Records of Hesperidae were scarce in both number of species and individuals(**Fig. 3** and **4**). In October, there were only 8 Hesperidae individuals belonging to 7 species(unpublished data). Owing to not only the relatively small size but high flying speed of Hesperidae butterflies, more efforts should be made for discovering them and counting their number. In December, outbreaks of the two Lycaenidae species, *Jamides bochus formosanus* and *Zizula hylax*(the smallest butterflies in size in Taiwan indicated by

Li(2011)) resulted in the abundance peak of the family(unpublished data). In sum, large variance in abundance across months indicated that there was one apparent peak of abundance in the family(e.g., Lycaenidae); on the other hand, small variance represented no clear abundance peak during a year. Among the peak in certain family, there may be outbreaks of one or two species(e.g., Lycaenidae), or relatively equal individuals contributed from several species(e.g., Papilionidae). The above scenarios will be more apparent after incorporating diversity indices.

#### Information from diversity indices

When the pattern comparison was made between species richness and species evenness across 12 months, fluctuations were more obvious in species richness than evenness(**Fig. 5**). Results of species richness indicated that there were numerous butterfly species coming out in specific months while results of species evenness showed that there was only one odd event occurring in December. From November to December, species richness of butterflies in EEP was increasing while outbreaks of certain species(in family Lycaenidae) caused species evenness to decrease. The Shannon index and the Simpson's index both consider the number of individual butterflies when estimating the heterogeneity of butterfly community. Though underlying mechanisms of the two indices are different, the patterns were similar in this case. Many diversity indices have been proposed based on different concepts and for different applications; each diversity index has its derived characters as well. For example, the sensitivity is different

between the two indices we adopted in this study. The Simpson's index is more sensitive to changes in dominant species in the community while the Shannon index is more sensitive to changes in rare species (Peet 1974). To choose diversity indices for biological applications, the following considerations should be made. First, diversity indices should be conducted in adequate spatial scales (i.e.,  $\alpha$ ,  $\beta$ , or  $\gamma$  diversity by Whittaker (1960)); local, landscape, or macro-scale by Whittaker *et al.* (2001). Second, the adoption of adequate indices depends on the understanding of studying organisms' life history strategies, of the sampling methods we design, and of concepts underlying the indices (summarized by Krebs (1989)). Without thorough consideration, many interpretations and further examinations based on diversity indices would be inconvincible (see examples reviewed by Chi *et al.* (2003)). Were species recorded in EEP close to completeness? Was the sampling frequency enough to ensure the equal probability for each individual in each chosen population? Only if the above assumptions can be confirmed by more evidence would the results from diversity indices be reliable.

### Future studies

For the improvement of sampling methods and monitoring protocols, butterfly diversity and composition in an artificial habitat was examined. However, data gathered once a month over a year provided limited information because of the lack of long-term monitoring and comparative studies across years. By long-term monitoring of butterfly populations or communities, more information

can be obtained. For example, records of butterfly populations or communities by years can reflect the butterflies' phenology (Brakefield 1987; Pollard 1988; Kunte 1997), the effects of habitat changes (Krauss *et al.* 2010; Krämer *et al.* 2012), climate changes (Parmesan *et al.* 1999; Roy and Sparks 2000; van Swaay *et al.* 2010), and human disturbances (Kitahara and Fujii 1994; Blair and Launer 1997; Kitahara *et al.* 2000; Tiple *et al.* 2007; White and Kerr 2007; Chen *et al.* 2009).

In EEP, park managers prune and renew vegetation routinely to prevent possible danger and for the convenience of guided tours offered to tourists. As indicated by previous studies just mentioned above, there are some directions for future studies in EEP. A comparison of the butterfly community's structure before and after vegetation changes, or under different degree of human disturbances (e.g., mowing, pruning, and plantation), may help us measure the impact of artificial managements. In addition, though the transect route across microhabitats in EEP was set to avoid nonrandom sampling from observations in certain habitat types, the comparison of butterfly communities' structures between different microhabitats may provide information about butterflies' life history characteristics (Lyu 2011). Since EEP is an artificial park planted with various plant species, the comparison of community compositions of animal species and abundance between this artificial-planted environment and other natural or semi-natural environments may help us examine the relationship between the characters of habitats and organisms biodiversity. In addition, the

relationships of community compositions between plants and animals may also be informed. The butterfly is a good model for examining the relationship between plants and animals, since previous studies have examined the coevolution between food plants and butterflies (Ehrlich and Raven 1964; Janz *et al.* 2001). In our case, the plantation of food plants for butterflies (see **Appendix I**), including the control of their quality (Culin 1997) and quantity (Tiple *et al.* 2011), their distribution (Grossmueller and Lederhouse 1987) and further interactions with butterflies should all help to improve the managing protocol in an artificial park.

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### Literature Cited

- Bishop, N., S. B. Hrdy, J. Teas and J. Moore. 1981. Measures of human influence in habitats of South Asian monkeys. *International Journal of Primatology* 2: 153-167.
- Blair, R.B. and A. E. Launer. 1997. Butterfly diversity and human land use: Species assemblages along an urban gradient. *Biological Conservation* 80: 113-125.
- Brakefield, P. M. 1987. Tropical dry and wet season polyphenism in the butterfly *Melanitis leda* (Satyrinae): Phenotypic plasticity and climatic correlates. *Biological Journal of the Linnean Society* 31: 175-191.
- Chao, R.-F. and H.-S. Fang. 2002. The butterflies of Taitung. Endemic Species Research Institute, Jiji, Nantou, Taiwan (R.O.C.). (in Chinese)
- Chapin III, F.S., E. S. Zavaleta, V. T. Eviner, R. L. Naylor, P. M. Vitousek, H. L. Reynolds, D. U. Hooper, S. Lavorel, O. E. Sala, S. E. Hobbie, M. C. Mack and S. Diaz. 2000. Consequences of changing biodiversity. *Nature* 405: 234-242.
- Chen, C.-C., L.-C. Huang, Y.-C. Lin, Y.-S. Liu, H.-K. Peng and K.-H. Lo. 2009. Studies on the population structure of moving Danaidae of Yushan National park and surrounding area (Research Grant 9806). Yushan National Park Headquarters, Nantou, Taiwan (R.O.C.). (in Chinese)
- Chi, H., Y.-B. Huang, Y.-T. Tai, Y.-Y. Wu and R.-W. Liu. 2003. A discussion about the biodiversity research from domestic biodiversity articles. pp. 335-360. *In: Ecosystem management-Conference on theoretical and practical studies of the permanent plot*. Forestry Bureau, Council of Agriculture, Executive

- Yuan, Taiwan(R.O.C.).(in Chinese)
- Culin, J. D. 1997. Relationship of butterfly visitation with nectar qualities and flower color in Butterfly Bush, *Buddleia davidii*. News of the Lepidopterists' Society 39: 35-39.
- Cushman, J. H., C. L. Boggs, S. B. Weiss, D. D. Murphy, A. W. Harvey and P. R. Ehrlich. 1994. Estimating female reproductive success of a threatened butterfly: Influence of emergence time and host plant phenology. *Oecologia* 99: 194-200.
- Ehrlich, P. R. and P. H. Raven. 1964. Butterflies and plants: A study in coevolution. *Evolution* 18: 586-608.
- Fernández-Juricic, E. and J. Jokimäki. 2001. A habitat island approach to conserving birds in urban landscapes: Case studies from southern and northern Europe. *Biodiversity and Conservation* 10: 2023-2043.
- Grossmueller, D. W. and R. C. Lederhouse. 1987. The role of nectar source distribution in habitat use and oviposition by the tiger swallowtail butterfly. *Journal of the Lepidopterists' Society* 41: 159-165.
- Hietala-Koivu, R., T. Järvenpää and J. Helenius. 2004. Value of semi-natural areas as biodiversity indicators in agricultural landscapes. *Agriculture Ecosystem and Environment* 101: 9-19.
- Ho, J.-Z. and L.-H. Chang. 1998. The butterflies of Tainan. Endemic Species Research Institute, Jiji, Nantou, Taiwan(R.O.C.).(in Chinese)
- Hsu, Y.-F. 1999. Butterflies of Taiwan(I). National Fenghuanggu Bird Park, Nantou, Taiwan.(in Chinese)
- Janz, N., K. Nyblom, S. Nylin. 2001. Evolutionary dynamics of host-plant specialization: A case study of the tribe Nymphalini. *Evolution* 55: 783-796.
- Kitahara, M., K. Fujii. 1994. Biodiversity and community structure of temperate butterfly species within a gradient of human disturbance: An analysis based on the concept of generalist vs. Specialist strategies. *Researches on Population Ecology* 36: 187-199.
- Kitahara, M., K. Sei and K. Fujii. 2000. Patterns in the structure of grassland butterfly communities along a gradient of human disturbance: Further analysis based on the generalist/specialist concept. *Population Ecology* 42: 135-144.
- Krauss, J., R. Bommarco, M. Guardiola, R. K. Heikkinen, A. Helm, M. Kuussaari, R. Lindborg, E. Ockinger, M. Pärtel, J. Pino, J. Pöyry, K. M. Raatikainen, A. Sang, C. Stefanescu, T. Teder, M. Zobel and I. Steffan-Dewenter. 2010. Habitat fragmentation causes immediate and time-delayed biodiversity loss at different trophic levels. *Ecology Letters* 13: 597-605.
- Krämer, B., D. Poniatowski and T. Fartmann. 2012. Effects of landscape and habitat quality on butterfly communities in pre-alpine calcareous grasslands. *Biological Conservation* 152: 253-261.
- Krebs, C. J. 1989. Species diversity measures. pp. 328-368. *In*: C. M. Wilson and S. Pisano(ed.) *Ecological methodology*. Harper Collins Publishers, New York, USA.

- Kunte, K. J. 1997. Seasonal patterns in butterfly abundance and species diversity in four tropical habitats in the northern Western Ghats. *Journal of Biosciences* 22: 593-603.
- Li, J.-H. 2004. The legend of Jou-Jou Mountain: Commentary manual of Ecology interpretation. Endemic Species Research Institute, Jiji, Nantou, Taiwan(R.O.C.).(in Chinese)
- Li, D.-W. 2005. The occurrence and ecology of Danaidae(Lepidoptera) in Dakeng Butterfly Education area. *Science Education Monthly* 227: 2-9.(in Chinese)
- Li, D.-W. 2011. Butterfly resources in Dakeng area in Taichung. Vedan Enterprise Corporation, Taichung, Taiwan.(in Chinese)
- Lyu, C.-J. 2011. Studies on structure of butterfly community in Dongpu, Yushan National Park. Unpublished master's thesis, Taipei Municipal University of Education, Taipei, Taiwan.(in Chinese)
- Loreau, M., S. Naeem, P. Inchausti, J. Bengtsson, J. P. Grime, A. Hector, D. U. Hooper, M. A. Huston, D. Raffaelli, B. Schmid, D. Tilman and D. A. Wardle. 2001. Biodiversity and ecosystem functioning: Current knowledge and future challenges. *Science* 294: 804-808.
- Margalef, D. R. 1957. Information theory in ecology(in Spanish). *Memorias de la Real Academia de Ciencias y Artes de Barcelona* 23: 373-449. [Seen in English version translated by Wendell Hall]
- Margalef, D. R. 1958. Information theory in Ecology. *General Systematics* 3: 36-71.
- McIntosh, R. P. 1967. An index of diversity and the relation of certain concepts to diversity. *Ecology* 48: 392-404.
- Moore, S.-J., J.-M. Yu, Y.-C. Chiu, T.-W. Hsu, F.-H. Hsu, L.-H. Chang, L.-W. Zhang-Jian, Y.-L. Chen, R.-J. Peng, Y.-L. Yang, Y.-C. Liu, H.-C. Cheng, C.-C. Han and C.-F. Lin. 2002." Kananavu" local records— Commentary manual of natural resources of Nanzihian River in Kaohsiung County. Endemic Species Research Institute, Jiji, Nantou, Taiwan(R.O.C.).(in Chinese)
- Naeem, S., L. J. Thompson, S. P. Lawler, J. H. Lawton and R. M. Woodfin. 1994. Declining biodiversity can alter the performance of ecosystems. *Nature* 368: 734-737.
- Parmesan, C., N. Ryrholm, C. Stefanescu, J. K. Hill, C. D. Thomas, H. Descimon, B. Huntley, L. Kaila, J. Kullberg, T. Tammaru, W. J. Tennent, J. A. Thomas and M. Warren. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature* 399: 579-583.
- Peet, R. K. 1974. The measurement of species diversity. *Annual Review of Ecology and Systematics* 5: 285-307.
- Peterson, M. A. 1997. Host plant phenology and butterfly dispersal: Causes and consequences of uphill movement. *Ecology* 78: 167-180.
- Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* 13: 131-144.
- Pielou, E. C. 1969. *An Introduction to mathematical ecology*. pp. 223, 286. Wiley-Interscience, New York, USA.
- Pollard, E. 1977. A method for assessing changes in the abundance of butterflies. *Biological*

- Conservation 12: 115-134.
- Pollard, E. 1982. Monitoring butterfly abundance in relation to the management of a nature reserve. *Biological Conservation* 24: 317-328.
- Pollard, E. 1988. Temperature, rainfall and butterfly numbers. *Journal of Applied Ecology* 25: 819-828.
- Pollard, E. 1991. Monitoring butterfly numbers. pp. 89-95. *In*: F. B. Goldsmith(ed.). *Monitoring for Conservation and Ecology*. Chapman and Hall, New York, USA.
- Pollard, E. and T. J. Yates. 1993. Monitoring butterflies for ecology and conservation. The British butterfly monitoring scheme. pp. 274. *In*: Institute of terrestrial ecology and joint nature conservation committee. Chapman and Hall, London.
- Pratt, J. R. 1994. Artificial habitats and ecosystem restoration: Managing for the future. *Bulletin of Marine Science* 55: 268-275.
- Roy, D. B. and T. H. Sparks. 2000. Phenology of British butterflies and climate change. *Global Change Biology* 6: 407-416.
- Shannon, C. E. 1948. A mathematical theory of communication. *The Bell System Technical Journal* 27: 379-423. [in addition to "reprinted with corrections of pp. 379-423, 623-656"]
- Simpson, E. H. 1949. Measurement of diversity. *Nature* 163: 688.
- Spellerberg, I. F. and P. J. Fedor. 2002. A tribute to Claude Shannon(1916-2001) and a plea for more rigorous use of species richness, species diversity and the 'Shannon-Wiener' Index. *Global Ecology and Biogeography* 12: 177-179.
- Thomas, J. A. 2005. Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. *Philosophical Transactions of the Royal Society B: Biological Sciences* 360: 339-357.
- Tiple, A. D., A. M. Khurad and R. L. H. Dennis. 2007. Butterfly diversity in relation to a human-impact gradient on an Indian university campus. *Nota Lepidopterologica* 30: 179-188.
- Tiple, A. D., A. M. Khurad and R. L. H. Dennis. 2011. Butterfly larval host plant use in a tropical urban context: Life history associations, herbivory, and landscape factors. *Journal of Insect Science* 11: 1-21.
- Tsai, Y.-F., L.-W. Zhang-Jian, R.-S. Lin, Y.-L. Chen, C.-F. Lin, X.-H. Cai, H.-S. Fang and Y.-C. Chiu. 2005. *Wildlife of Taoyuan. Endemic Species Research Institute, Jiji, Nantou, Taiwan(R.O.C.).(in Chinese)*
- van Dyke, F. 2008. Measuring biodiversity. pp. 89-95. *In*: J. Ebihara(ed.). *Conservation biology: Foundations, concepts, applications*, 2nd edition. Springer-Verlag New York, USA.
- van Swaay, C., A. Harpke, A. van Strien, B. Fontaine, C. Stefanescu, D. Roy, D. Maes, E. Kühn, E. Öunap, E. Regan, G. Švitra, J. Heliölä, J. Settele, M. Musche, M. Warren, M. Plattner, M. Kuussaari, N. Cornish, O. Schweiger, R. Feldmann, R. Julliard, R. Verovnik, T. Roth, T. Brereton and V. Devictor. 2010. The impact of climate change

- on butterfly communities 1990-2009. Report to the EEA. Butterfly Conservation Europe & De Vlinderstichting, Wageningen.
- Vitousek, P. M., H. A. Mooney, J. Lubchenco and J. M. Melillo. 1997. Human domination of earth's ecosystems. *Science* 277: 494-499.
- Warren, M. S. 1987. The ecology and conservation of the health fritillary butterfly, *Mellicta athalia*. I. Host selection and phenology. *Journal of Applied Ecology* 24: 467-482.
- White, P. J. T. and J. T. Kerr. 2007. Human impacts on environment–diversity relationships: Evidence for biotic homogenization from butterfly species richness patterns. *Global Ecology and Biogeography* 16: 290-299.
- Whittaker, R. H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. *Ecological Monographs* 30: 279-338.
- Whittaker, R. J., K. J. Willis and R. Field. 2001. Scale and species richness: Towards a general, hierarchical theory of species diversity. *Journal of Biogeography* 28: 453-470.
- Yan, J.-H. 2011. The Influence of daily rhythm and weather factors on butterfly monitoring criteria in subtropical zone: A case study in lowland Taiwan. Unpublished master's thesis, National Taiwan Normal University, Taipei, Taiwan.(in Chinese)
- Yang, J.-Z. 2009. Wildlife of Taitung. Endemic Species Research Institute, Jiji, Nantou, Taiwan(R.O.C.).(in Chinese)
- Yang, Y.-L. 1995. Common butterflies of Nantou. Endemic Species Research Institute, Jiji, Nantou, Taiwan(R.O.C.).(in Chinese)
- Zhang-Jian, L.-W., F.-H. Hsu, Y.-L. Chen, C.-F. Lin, X.-H. Cai and H.-S. Fang. 2002. Wildlife of Hsinchu. Endemic Species Research Institute, Jiji, Nantou, Taiwan(R.O.C.).(in Chinese)
- Zhang-Jian, L.-W., R.-S. Lin, Y.-L. Chen, Y.-F. Tsai, D.-W. Li, Y.-C. Chiu and H.-S. Fang. 2005. Wildlife of Yilan. Endemic Species Research Institute, Jiji, Nantou, Taiwan (R.O.C.).(in Chinese)

**Appendix 1.** List of food plant species of adults(nectar plants) and larvae(host plants) of butterflies in EEP.

<b>Nectar Plants</b>		
Species name	Endemic species	
<b>Family Acanthaceae</b>		
<i>Strobilanthes formosanus</i> Moore		
<b>Family Asteraceae</b>		
<i>Ageratum houstonianum</i> Mill.		
<i>Bidens pilosa</i> L. var. <i>radiata</i> Sch.		
<i>Eupatorium clematideum</i> (Wall. ex DC.) Sch. Bip. var. <i>gracillimum</i> (Hayata) C. I Peng & S. W. Chung	Y	
<b>Family Capparidaceae</b>		
<i>Crateva adansonii</i> DC. subsp. <i>formosensis</i> Jacobs	Y	
<b>Family Iridaceae</b>		
<i>Belamcanda chinensis</i> (L.) DC.	Y	
<b>Family Leeaceae</b>		
<i>Leea guineensis</i> G. Don		
<b>Family Plumbaginaceae</b>		
<i>Plumbago zeylanica</i> L.		
<b>Family Verbenaceae</b>		
<i>Callicarpa japonica</i> Thunb. var. <i>luxurians</i> Rehder		
<i>Clerodendrum cyrtophyllum</i> Turcz.		
<i>Clerodendrum inerme</i> (L.) Gaertn.		
<i>Clerodendrum kaempferi</i> (Jacq.) Siebold ex Steud.		
<i>Clerodendrum trichotomum</i> Thunb.		
<i>Duranta repens</i> L.		
<i>Lantana camara</i> L.		
<i>Premna hengchunensis</i> Lu & Yang	Y	
<i>Premna serratifolia</i> Linn.		
<i>Stachytarpheta urticaefolia</i> (Salisb.) Sims.		
<i>Tectona grandis</i> L. f.		
<i>Vitex negundo</i> L.		
<i>Vitex trifolia</i> L.		
<b>Host Plants</b>		
Species name	Endemic species	Species recorded
<b>Family Acanthaceae</b>		
<i>Hygrophila pogonocalyx</i> Hayata	Y	<i>Junonia almana</i> (Linnaeus, 1758) <i>Zizula hylax</i> (Fabricius, 1775)
<i>Lepidagathis formosensis</i> Clarke ex Hayata		<i>Kallima inachus formosana</i> (Fruhstorfer, 1912)
<i>Strobilanthes formosanus</i> Moore		<i>Kallima inachus formosana</i> (Fruhstorfer, 1912)
<b>Family Annonaceae</b>		
<i>Goniothalamus amuyon</i> (Blanco) Merr.		<i>Graphium agamemnon</i> (Linnaeus, 1758)

**Family Aristolochiaceae***Aristolochia zollingeriana* Miq.*Byasa polyeuctes termessus*(Fruhstorfer, 1908)*Aristolochia heterophylla* Hemsl.*Pachliopta aristolochiae interposita*(Fruhstorfer, 1904)*Aristolochia cucurbitifolia* Hayata

Y

*Byasa polyeuctes termessus*(Fruhstorfer, 1908)*Pachliopta aristolochiae interposita*(Fruhstorfer, 1904)*Byasa polyeuctes termessus*(Fruhstorfer, 1908)*Pachliopta aristolochiae interposita*(Fruhstorfer, 1904)**Family Asclepiadaceae***Asclepias curassavica* L.*Danaus chrysippus*(Linnaeus, 1758)*Tylophora ovata*(Lindl.) Hook. ex Steud.*Parantica aglea maghaba*(Fruhstorfer, 1909)*Dregea volubilis*(L. f.) Benth.*Parantica sita niphonica*(Moore, 1883)*Hoya carnosa*(L. f.) R. Br.*Tirumala limniace limniace*(Cramer, 1775)*Parantica sita niphonica*(Moore, 1883)**Family Cycadaceae***Cycas taitungensis* C. F. Shen, K. D. Hill, C.

Y

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*Chilades pandava peripatria*(Hsu, 1989)**Family Fabaceae***Archideneron lucidum* (Benth.) I.Nielse*Eurema blanda arsakia*(Fruhstorfer, 1910)*Cassia fistula* L.*Eurema blanda arsakia*(Fruhstorfer, 1910)*Senna siamea*(Lamarck) Irwin & Barneby*Catopsilia pomona*(Fabricius, 1755)*Indigofera spicata* Forsk.*Catopsilia pomona*(Fabricius, 1755)*Freyeria putli formosanus*(Matsumura, 1919)**Family Flacourtiaceae***Scolopia oldhamii* Hance*Cupha erymanthis*(Drury, 1773)**Family Lauraceae***Cinnamomum camphora*(L.) Presl.*Graphium sarpedon connectens*(Fruhstorfer, 1906)*Cinnamomum verum* J. S. Presl.*Graphium sarpedon connectens*(Fruhstorfer, 1906)*Machilus japonica* Sieb. & Zucc. var.

Y

*kusanoi*(Hayata) Liao*Graphium sarpedon connectens*(Fruhstorfer, 1906)*Machilus thunbergii* Sieb. & Zucc.*Graphium sarpedon connectens*(Fruhstorfer, 1906)**Family Magnoliaceae***Michelia compressa*(Maxim.) Sargent

Y

*Graphium doson postianus*(Fruhstorfer, 1908)**Family Moraceae***Malaisia scandens*(Lour.) Planch.*Euploea tulliolus koxinga*(Fruhstorfer, 1908)*Ficus microcarpa* L. f. var. *microcarpa*.*Euploea mulciber barsine*(Fruhstorfer, 1904)*Ficus virgata* Reinw. ex Blume*Euploea eunice hobsoni*(Butler, 1877)*Euploea mulciber barsine*(Fruhstorfer, 1904)*Ficus formosana* Maxim.*Euploea eunice hobsoni*(Butler, 1877)*Euploea mulciber barsine*(Fruhstorfer, 1904)*Euploea eunice hobsoni*(Butler, 1877)**Family Oxalidaceae**

*Oxalis corniculata* L.

*Zizeeria maha okinawana*(Matsumura, 1929)

**Family Piperaceae**

*Piper betle* L.

*Graphium agamemnon*(Linnaeus, 1758)

**Family Plantaginaceae**

*Plantago major* L.

*Junonia almana*(Linnaeus, 1758)

**Family Poaceae**

*Miscanthus floridulus*(Labill.) Warb. ex  
Schum. & Laut.

*Parnara bada*(Moore, 1878)

*Setaria palmifolia*(J. Konig) Stapf

*Melanitis leda*(Linnaeus, 1758)

*Telicota bambusae horisha*(Evans, 1934)

**Family Rutaceae**

Genus *Citrus*

*Papilio demoleus*(Linnaeus, 1758)

**Family Salicaceae**

*Salix babylonica* L.

*Cupha erymanthis*(Drury, 1773)

*Salix warburgii* O. Seem

Y

*Cupha erymanthis*(Drury, 1773)

**Family Scrophulariaceae**

*Lindernia ciliata*(Colsm.) Pennel

*Junonia almana*(Linnaeus, 1758)

*Lindernia anagallis*(Burm. f.)

*Junonia almana*(Linnaeus, 1758)

**Family Zingiberaceae**

*Hedychium coronarium* Koenig

*Jamides alecto dromicus*(Fruhstorfer, 1910)

*Alpinia zerumbet*(Persoon) B. L. Burt & R.  
M. Smith

*Jamides alecto dromicus*(Fruhstorfer, 1910)

\*Generalization from Chao and Fang(2002), Ho and Chang(1998), Li(2004), Moore *et al.*(2002), Tsai *et al.*(2005), Yang(1995), Yang(2009), and Zhang-Jian *et al.*(2002, 2005)

**Appendix 2.** Species list of butterflies recorded in EEP during 2011.

Species name	Endemic species
<b>Family Hesperiiidae</b>	
<i>Borbo cinnara</i> (Wallace, 1866)	
<i>Burara jaina formosana</i> (Fruhstorfer, 1911)	
<i>Caltoris cahira austeni</i> (Moore, 1883)	
<i>Daimio tethys niitakana</i> (Matsumura, 1907)	
<i>Hasora bada</i> (Moore, 1858)	
<i>Parnara bada</i> (Moore, 1878)	
<i>Pelopidas agna</i> (Moore, 1886)	
<i>Potanthus confucius angustatus</i> (Matsumura, 1910)	
<i>Potanthus motzui</i> (Hsu, Li, & Li, 1990)	Y
<i>Seseria formosana</i> (Fruhstorfer, 1909)	Y

*Suastus gremius*(Fabricius, 1798)  
*Telicota bambusae horisha*(Evans, 1934)  
*Telicota ohara formosana*(Fruhstorfer, 1911)

#### Family Papilionidae

*Byasa impediens febanus*(Fruhstorfer, 1908)  
*Byasa polyeuctes termessus*(Fruhstorfer, 1908)  
*Graphium agamemnon*(Linnaeus, 1758)  
*Graphium doson postianus*(Fruhstorfer, 1908)  
*Graphium sarpedon connectens*(Fruhstorfer, 1906)  
*Pachliopta aristolochiae interposita*(Fruhstorfer, 1904)  
*Papilio bianor thrasymedes*(Fruhstorfer, 1909)  
*Papilio castor formosanus*(Rothschild, 1896)  
*Papilio demoleus*(Linnaeus, 1758)  
*Papilio helenus fortunius*(Fruhstorfer, 1908)  
*Papilio hermosanus*(Rebel, 1906) Y  
*Papilio memnon heronus*(Fruhstorfer, 1929)  
*Papilio nephelus chaonulus*(Fruhstorfer, 1908)  
*Papilio polytes polytes*(Linnaeus, 1758)  
*Papilio protenor protenor*(Cramer, 1775)  
*Papilio thaiwanus*(Rothschild, 1898) Y  
*Papilio xuthus*(Linnaeus, 1767)

#### Family Pieridae

*Appias indra aristoxemus*(Fruhstorfer, 1908)  
*Appias lyncida eleonora*(Boisduval, 1836)  
*Catopsilia pomona*(Fabricius, 1755)  
*Catopsilia pyranthe*(Linnaeus, 1758)  
*Cepora nadina eunama*(Fruhstorfer, 1903)  
*Eurema blanda arsakia*(Fruhstorfer, 1910)  
*Eurema hecabe*(Linnaeus, 1758)  
*Eurema brigitta hainana*(Moore, 1878)  
*Hebomoia glaucippe formosana*(Fruhstorfer, 1908)  
*Ixias pyrene insignis*(Butler, 1879)  
*Leptosia nina niobe*(Wallace, 1866)  
*Pieris canidia*(Sparrman, 1768)  
*Pieris rapae crucivora*(Boisduval, 1836)

#### Family Lycaenidae

*Acytoleptis puspa myla*(Fruhstorfer, 1909)  
*Arhopala birmana asakurae*(Matsumura, 1910)  
*Artipe eryx horiella*(Matsumura, 1929)  
*Celastrina lavendularis himilcon*(Fruhstorfer, 1909)  
*Chilades pandava peripatria*(Hsu, 1989)

*Deudorix epijarbas menesicles*(Fruhstorfer, 1912)  
*Freyeria putli formosanus*(Matsumura, 1919)  
*Heliophorus ila matsumurae*(Fruhstorfer, 1908)  
*Jamides alecto dromicus*(Fruhstorfer, 1910)  
*Jamides bochus formosanus*(Fruhstorfer, 1909)  
*Lampides boeticus*(Linnaeus, 1767)  
*Leptotes plinius*(Fabricius, 1793)  
*Megisba malaya sikkima*(Moore, 1884)  
*Nacaduba kurava therasia*(Fruhstorfer, 1916)  
*Prosotas nora formosana*(Fruhstorfer, 1916)  
*Rapala varuna formosana*(Fruhstorfer, 1912)  
*Spindasis syama*(Horsfield, 1829)  
*Zizeeria maha okinawana*(Matsumura, 1929)  
*Zizula hylax*(Fabricius, 1775)

**Family Nymphalidae**

*Athyma cama zoroastes*(Bulter, 1877)  
*Athyma perius*(Linnaeus, 1758)  
*Athyma selenophora laela*(Fruhstorfer, 1908)  
*Cupha erymanthis*(Drury, 1773)  
*Cyrestis thyodamas formosana*(Fruhstorfer, 1898)  
*Danaus chrysippus*(Linnaeus, 1758)  
*Danaus genutia*(Cramer, 1779)  
*Discophora sondaica tulliana*(Stichel, 1905)  
*Euploea eunice hobsoni*(Butler, 1877)  
*Elymnias hypermnestra hainana*(Moore, 1878)  
*Euploea mulciber barsine*(Fruhstorfer, 1904)  
*Euploea sylvester swinhoei*(Wallace & Moore, 1866)  
*Euploea tulliolus koxinga*(Fruhstorfer, 1908)  
*Hestina assimilis formosana*(Moore, 1895)  
*Hypolimnas bolina kezia*(Bulter, 1877)  
*Junonia almana*(Linnaeus, 1758)  
*Junonia iphita*(Cramer, 1779)  
*Junonia lemonias aenaria*(Fruhstorfer, 1912)  
*Kallima inachus formosana*(Fruhstorfer, 1912)  
*Lethe chandica ratnacri*(Fruhstorfer, 1908)  
*Lethe verma cintamani*(Fruhstorfer, 1909)  
*Limenitis sulphitia tricola*(Fruhstorfer, 1908)  
*Melanitis leda*(Linnaeus, 1758)  
*Melanitis phedima polishana*(Fruhstorfer, 1908)  
*Mycalesis francisca formosana*(Fruhstorfer, 1908)  
*Mycalesis gotama nanda*(Fruhstorfer, 1908)

<i>Mycalesis zonata</i> (Matsumura, 1909)	
<i>Neptis hylas luculenta</i> (Fruhstorfer, 1898)	
<i>Neptis nata lutatia</i> (Fruhstorfer, 1913)	
<i>Neptis sappho formosana</i> (Fruhstorfer, 1908)	
<i>Neptis taiwana</i> (Fruhstorfer, 1908)	Y
<i>Parantica aglea maghaba</i> (Fruhstorfer, 1909)	
<i>Parantica sita nipponica</i> (Moore, 1883)	
<i>Parantica swinhoei</i> (Moore, 1883)	
<i>Penthema formosanum</i> (Rothschild, 1898)	
<i>Phalanta phalantha</i> (Drury, 1773)	
<i>Polygonia c-aureum lunulata</i> (Esaki & Nakahara, 1923)	
<i>Tirumala limniace limniace</i> (Cramer, 1775)	
<i>Tirumala septentrionis</i> (Butler, 1874)	
<i>Ypthima baldus zodina</i> (Fruhstorfer, 1911)	
<i>Ypthima multistriata</i> (Butler, 1883)	

\*Based on the most recent records from TaiBNET(Catalogue of Life in Taiwan: <http://taibnet.sinica.edu.tw/>) and Name Lists of Butterflies of Taiwan(updated on 2011/05/15) by Butterfly Conservation Society of Taiwan(<http://www.butterfly.org.tw/home.php>)

### Appendix 3. Number of butterfly species recorded during 2011.

Family	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Hesperiidae	0	3	1	0	1	2	3	2	2	7	3	3
Papilionidae	1	2	3	6	6	6	10	10	9	9	3	3
Pieridae	6	7	6	8	5	4	4	3	5	5	5	7
Lycaenidae	5	4	3	6	5	9	10	2	5	12	6	11
Nymphalidae	5	9	9	7	14	16	20	10	20	21	16	15
Total	17	25	22	27	31	37	47	27	41	54	33	39

### Appendix 4. Number of individual butterfly adults recorded during 2011.

Family	Month												Total
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Hesperiidae	0	3	1	0	2	4	5	2	2	8	3	4	34
Papilionidae	1	2	5	7	13	21	41	14	17	21	3	4	149
Pieridae	33	83	35	43	23	50	46	23	19	38	15	48	456
Lycaenidae	9	20	4	15	15	38	67	10	20	39	24	273	534
Nymphalidae	5	23	30	11	45	59	123	32	55	115	39	44	581
Total	48	131	75	76	98	172	282	81	113	221	84	373	1754

First Record of Pelagic Aeolid Nudibranch *Glaucus atlanticus*  
Forster, 1777 (Gastropoda: Glaucidae) in the Intertidal Zone  
of SiaoLiouciou off Southwestern Taiwan Island

臺灣新記錄種海洋性裸鰓類動物—大西洋海神海蛞蝓  
在小琉球潮間帶的出現

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## Abstract

*Glaucus atlanticus* Forster, 1777, a pelagic aeolid nudibranch which has been found in temperate and tropical oceans throughout the world, is reported herein as a newly recorded species to inhabit the intertidal zone of SiaoLiouciou, Taiwan. The morphological differences to its related congeneric species, its geographical distribution as well as the environmental conditions of its occurrence are discussed.

## 摘要

大西洋海神海蛞蝓(*Glaucus atlanticus* Forster, 1777)是一種原分布於全球熱帶至溫帶海域漂浮的海洋性裸鰓類動物，是臺灣的新紀錄物種，首次在臺灣的琉球嶼潮間帶出現。有關本種與同屬近似種間之形態差異、地理分布和出現的環境條件，將在本文中加以討論。

**Key words :** new record, nudibranch, *Glaucus atlanticus*, SiaoLiouciou, Taiwan

**關鍵詞：**臺灣新紀錄、裸鰓類、*Glaucus atlanticus*、小琉球、臺灣

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## Introduction

There are two groups of pelagic aeolid nudibranchs. The Fionidae Gray, 1857 has only one species, which is not a zooplankton and lives on floating objects. The other group is of the subfamily, Glaucinae Gray, 1827, a true pelagic form, which has the ability to swim, and is the subject fauna of this paper. Members of Glaucinae are the blue sea slugs and are found in tropical and temperate oceans throughout the world (Miller 1974). They float upside down and use their long cerata and a gas bubble in their stomach to maintain buoyancy. The colonial floating cnidarians are their main food (Valdés and Campillo 2004).

Two genera were erected in the subfamily Glaucinae: *Glaucus* Forster, 1777 and *Glaucilla* Bergh, 1860, each with one species, *Glaucus atlanticus* Forster, 1777 and *Glaucilla marginata* Bergh, 1860, respectively. However, some authors recognize *Glaucilla* as a synonym of *Glaucus*, because these two sister monotypic genera are related and provide the same information. *Glaucus* is regarded as the single valid genus within the family Glaucidae, and with two species *Glaucus atlanticus* Forster, 1777 and *Glaucus marginatus*

(Bergh 1860) (Keen 1971; Gofas *et al.* 2001; Valdés and Campillo 2004; Burn 2006).

In our recent intertidal monitoring study in the near-shore waters of SiaoLiouciou on 24 January 2012, 55 individuals of *G. atlanticus*, a newly recorded species of pelagic aeolid nudibranch from Taiwan, were observed and photo-vouchered, but no specimen was preserved. This species is a well-known circumtropical species. Finding this species in SiaoLiouciou, particularly in the intertidal zone as compared to open oceanic environments, provides interesting information on the zoogeographic distribution of this species.

*Glaucus atlanticus* has a flattened, slender and elongate body, of which both sides have three groups of wing-like cerata (Fig. 1). The first group of cerata is larger with a short stalk. The other two groups are smaller and sessile. The most dorsal ceras is largest in size with the others decreasing ventrally in each group. The cerata are conical, tapering and fragile. There are about 81 papillae of cerata in total. The species' head is short and not distinctly separated from the body. Oral tentacles and rhinophores are short and smooth. Its foot is broad with rounded anterior

corners, extending to the posterior end of the body. The anus and renal pore lie between the second and third groups of cerata, with the renal pore more proximate to the second group. The reproductive organs open on the right side of the body near the first group of cerata (Fig. 3).

The body hue of *G. atlanticus* is silver gray, with the lower edge of the cerata electric-blue (Fig. 1). The dorsum is silver but dark blue on its ventral surface. The central portion of the foot is silver in color, with border bands of bright blue that join together at the head and near the posterior end of the foot (Fig. 2, 3).

The sister species—*G. marginatus* which is closely related to *G. atlanticus* has not yet been found in Taiwan. The differences between them are thus: (1) the body size of *G. marginatus* is smaller (approximately 0.5 in adults) than that of *G. atlanticus* (Ross and Quetin 1990), (2) *G. marginatus* has up to four groups of cerata on both sides. The first two groups of cerata are pedunculate with a long stalk, while the last two groups are sessile and partially fused. A clearly distinguishable feature is that the body of *G. marginatus* is shorter, with the cerata arranged in uneven lines, one over the other, whereas they are arranged as a single series in *G. atlanticus* (Valdés and Campillo 2004).

*Glaucus atlanticus* is seldom seen in intertidal zones or near shore as it is pelagic except during periods of on-shore winds when they can be found floating in coastal waters, sometimes being washed into the intertidal zone. They float partially by means of an air bubble that they have swallowed and stored in their

stomach and can move toward prey or mates with their cerata, making slow swimming movements. They eat various drifting prey including the toxic siphonophore *Physalia utriculus*, as well as the chondrophores, *Veleva veleva* and *Propita pacifica* (Bayer 1963; Thompson and Bennett 1970; Lalli and Gilmer 1989).

Individuals of *G. atlanticus* were found in the Duzeiping intertidal zone located in the northwestern part of SiaoLiouciou Island during the period from 24 to 27 January 2012. The water temperature (0-5 meters deep) and air temperature were 24.3°C, 18.8°C (24/1); 24.4°C, 17.9°C (25/1); 24.8°C, 18.4°C (26/1) and 24.6°C, 20.4°C (27/1). The wind speed and direction from 24 to 27 January were 4.2 m/sec., NW; 4.9 m/sec., NW; 3.5 m/sec., N and 3.0 m/sec., N, respectively. They were washed into the intertidal zone with their prey, *Physalia physalis* and *Propita pacifica*. Some were found with egg strings excreted from the opening of their reproductive organs (Fig. 3). This suggests that they had abundant food supply (Ross and Quetin 1990).

The find of this extremely rare species in SiaoLiouciou suggests that the populations of this species have dispersed from the circumtropical area by the central Kuroshio Current further into the Taiwan Strait.

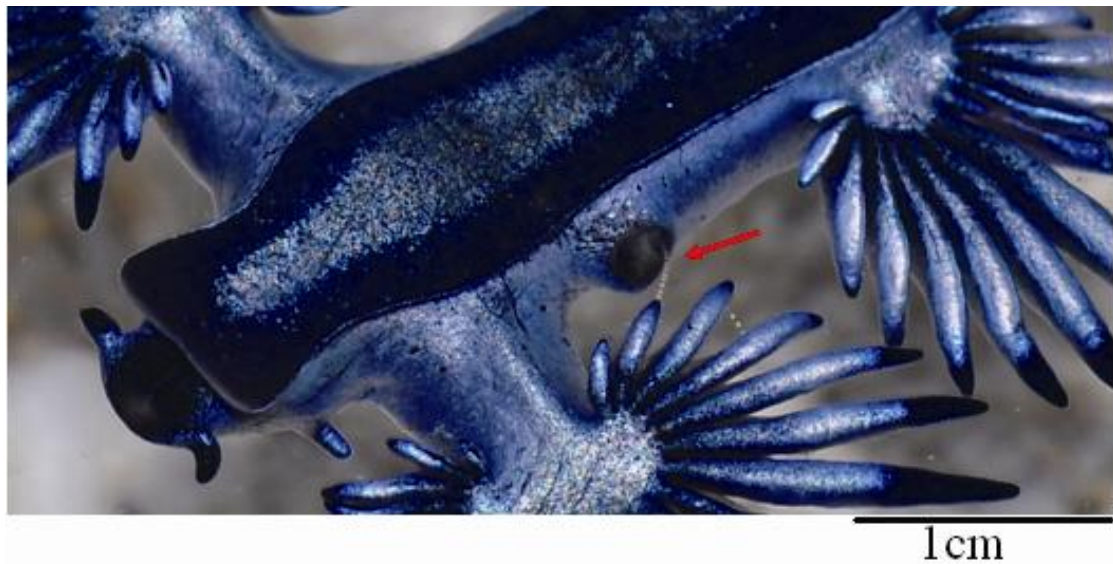
We thank the government of Pingtung County, Taiwan, for providing us with the requisite research grants.



**Fig. 1.** *Glaucus atlanticus* floats upside down; its foot is always dorsal.



**Fig. 2.** *Glaucus atlanticus*, the back of the animal, being silver, may provide a way of hiding from undersea predators as it floats upside down.



**Fig. 3.** *Glaucus atlanticus* is hermaphrodite; the red arrow designates the opening of its reproductive organs which can receive a partner's sperm, or release fertilized eggs (egg strings).

### Literature Cited

- Bayer, F. M. 1963. Observations on the pelagic mollusks associated with the siphonophores *Velella* and *Physalia*. *Bulletin of Marine Science of the Gulf & Caribbean* 13: 454-466.
- Bergh, R. 1860. Om forekomsten at neldefim hos mollusker. *Videnskabelige Meddelelser fra Naturhistorisk Forening Kjobenhavn* 61: 309-31, plate 8.
- Burn, R. 2006. A checklist and bibliography of the Opisthobranchia (Mollusca: Gastropoda) of Victoria and the Bass Strait area, south-eastern Australia. *Museum Victoria Science Reports* 10: 1-42.
- Forster, J. G. A. 1777. A voyage round the world, in his Britannic Majesty's sloop, resolution, commanded by Capt. James Cook, during the years 1772, 3, 4, and 5, Vol. 1. White, London. 53 p.
- Gofas, S. J., L. Renard and P. Bouchet. 2001. Mollusca. In: M. J. Costello, *et al.* (ed.). (2001). European register of marine species: A check-list of the marine species in Europe and a bibliography of guides to their identification. *Collection Patrimoines Naturels* 50: 180-213.
- Keen, A. M. 1971. Sea shells of tropical west America. Marine mollusks from Baja California to Peru. Stanford University Press, Stanford, California. 1064 p.

- Lalli, C. M. and R. W. Gilmer. 1989. Pelagic snails: The biology of holoplanktonic gastropod mollusks. Stanford University Press, California: 259.
- Miller, M. C. 1974. Aeolid nudibranchs (Gastropoda: Opisthobranchia) of the family Glaucidae from New Zealand waters. *Zoological Journal of the Linnean Society of London* 54: 31-61.
- Ross, R. M. and L. B. Quetin. 1990. Mating behavior and spawning in two neustonic nudibranchs in the family Glaucidae. *American Malacological Society* 8: 61-66.
- Thompson, T. E. and I. Bennett. 1970. Observations on Australian Glaucidae (Mollusca: Opisthobranchia). *Zoological Journal of the Linnean Society of London* 49: 187-197.
- Valdés, A. and O. A. Campillo. 2004. Systematics of pelagic aeolid nudibranchs of the family Glaucidae (Mollusca, Gastropoda). *Bulletin of Marine Science* 75(3): 381-389.

# *Mitracarpus hirtus* (L.) DC. (Rubiaceae), a Newly Naturalized Plant in Taiwan

## 臺灣新歸化茜草科植物－蓋裂果

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### Abstract

*Mitracarpus hirtus* (L.) DC. (Rubiaceae), native to the tropical Americas, has recently been found in low elevation, central Taiwan. This represents a newly recorded genus and naturalized species in Taiwan. A detailed morphology description, line-drawings, photographs and geographic distribution of the plant are provided in this paper to aid identification.

### 摘要

本文報導一種原產於熱帶美洲之茜草科植物－蓋裂果 (*Mitracarpus hirtus* (L.) DC. )，最近發現已歸化於臺灣中部低海拔地區。其所屬之蓋裂果屬(*Mitracarpus* Zucc.)亦為臺灣新紀錄屬，本文提供形態特徵描述、地理分布及生育地環境，並提供彩色圖片與手繪圖以資辨識。

**Key words :** *Mitracarpus hirtus*, naturalized plant, Rubiaceae, Taiwan.

**關鍵詞：** 蓋裂果、歸化植物、茜草科、臺灣

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## Introduction

蓋裂果屬

In recent decades, frequent global trade activities, transportation, and travels have aided the distribution of organisms or propagules, and thus the process of species dispersal. Plants could travel beyond natural barriers and colonize a different environment more than ever before. In Taiwan, hundreds of plants have been introduced (Wu *et al.* 2004), some of which have become newly recorded genus, eg. *Clidemia* D. Don (Yang, 2001), *Cyphomandra* Sendt. (Tseng *et al.* 2008a), *Flaveria* Juss. (Tseng *et al.* 2000), *Pectis* L. (Jung *et al.* 2011), *Rivina* L. (Tseng *et al.* 2008b). In this study we report a newly recorded species, *Mitracarpus hirtus*, as well as a newly recorded genus, *Mitracarpus* Zucc. ex Schult. & Schult. f., in Taiwan. Also provided is a brief description of the genus and a morphology description, line drawing illustrations, habitat and morphology photographs of the species.

Annual or perennial herbs, or sometimes shrubs. Young stems 4-angled. Leaves opposite and decussate, subsessile to short-petiolate. Inflorescences terminal or axillary, glomerulate, with densely crowded flowers, the glomerules subtended by bracts. Flowers bisexual and monomorphic, hypanthium turbinate to subglobose. Calyx persistent, 4-lobed; lobes opposite, two longer and two shorter. Corolla hypocrateriform, 4-lobes, white, tube usually with a ring of moniliform hairs within. Stamens 4; style filiform, bifid. Ovary 2-locular. Fruit capsular with transversal dehiscence. Seeds planoconvex, with square-shaped or X-shaped depression on the ventral face; depressions covered by strophiole.

About 30 species are distributed in Mexico, Central America, West Indies, South America, and are introduced to Africa, Madagascar, and Asia (Andersson 1992, Taylor and Steyermark 2004).

## Taxonomy Treatment

*Mitracarpus* Zucc. ex Schult. & Schult. f., Syst. Veg., Mant. 3: 210, 399. 1827.

*Mitracarpus hirtus* (L.) DC., Prodr. 4: 572.1830.

Basionym: *Spermacoce hirta* L., Sp. Pl., ed. 2, 1: 148. 1762. TYPE: *Browne s.n.* s.d., Herb.

Linn. No. 125.8 (Lectotype: LINN photo!).

蓋裂果 Fig. 1-3

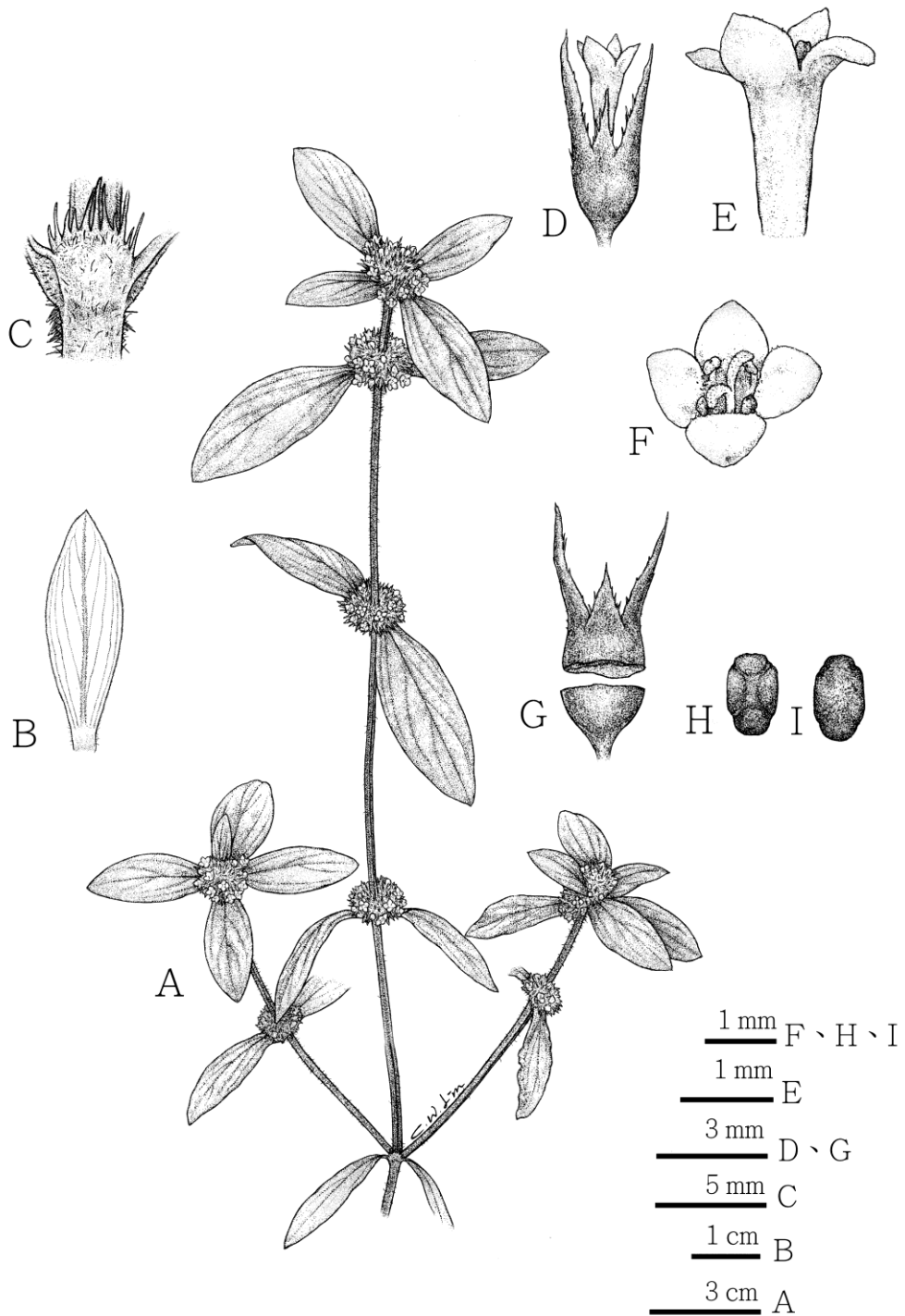
Annual herbs 30-50 cm high, stems spreading-ascending, simple or sparingly branched; branches subterete or 4-angled, sparsely hirsute to villous. Leaves sessile; blade thinly papery, elliptic-oblong or lanceolate, 3–5 cm long, 0.7–1.5 cm wide, adaxially scaberulous and sparsely villosulous or pilosulous, abaxially villous or pilose, base acute to obtuse or rounded, apex acute; secondary veins 3–6 pairs; stipule sheaths 2–4 mm long, villosulous or pilosulous to glabrescent, with 6–9 linear setae, 2–4 mm long. Flowers small, very dense. Calyx sparsely to densely puberulent or strigillose; ovary portion subglobose to ellipsoid, ca. 0.5 mm long; limb deeply lobed; lobes unequal, triangular to lanceolate, 2 larger 1.8–2 mm long, 2 smaller 0.8–1.2 mm long, ciliate. Corolla white, funnellform, outside puberulent to glabrous; tube 1.3–1.8 mm long, glabrous inside; lobes triangular to ovate, 0.5–1 mm long. Capsules subglobose, ca. 1.5 mm in diam., scaberulous or sparsely puberulent; seeds dark brown, oblate-suboblong, ca. 1 mm long, with a X-shaped sulcus on the adaxial face. Chromosome number:  $n=42$  (Walter 1962).

**Specimen examined:** TAIWAN: Taichung City, Longjing Dist. (龍井區), Nanliao Village (南寮里), Dadushan, elev. ca. 213 m, 24°10'18.54" N, 120°33'25.50" E, 17 Jan. 2013, *Lin C.J.* 750 (TAIE).

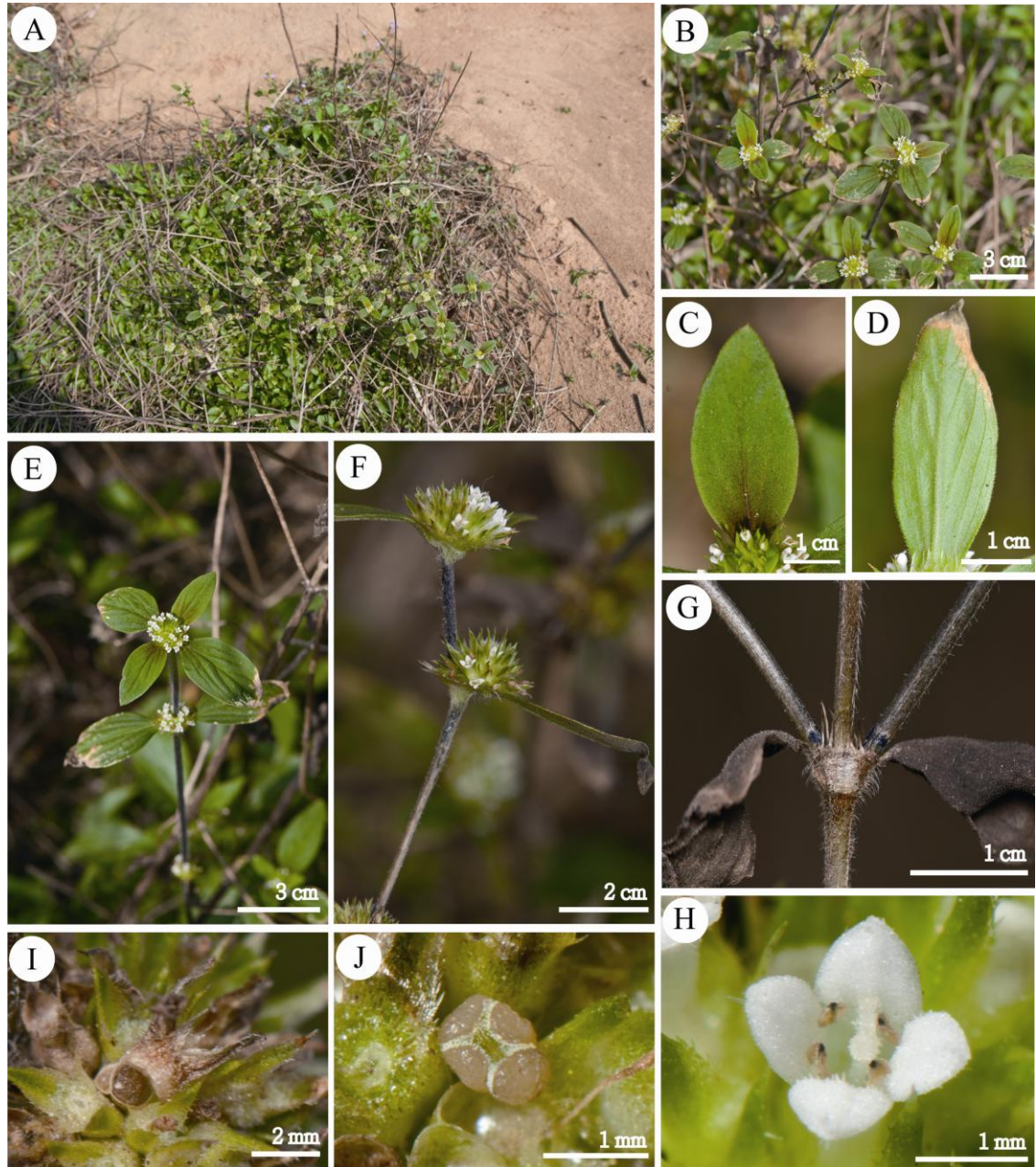
**Distribution and phenology:** *Mitracarpus hirtus* is native to the Antilles and Central, North, and South America; and is naturalized in tropical Africa, Asia, Australia, and Pacific islands (Chen

*et al.* 2011; Nicolson 1977; Fosberg *et al.* 1993). In Taiwan, this species is found in open areas. In the Dadu tableland in the western part of central Taiwan (Fig. 3), the species is found along roadsides and mixed with low grasses and weeds. Field observations have found that the populations in Taiwan are stable and have even somewhat expanded since 2011. The species flower all year round, but principally from April to November.

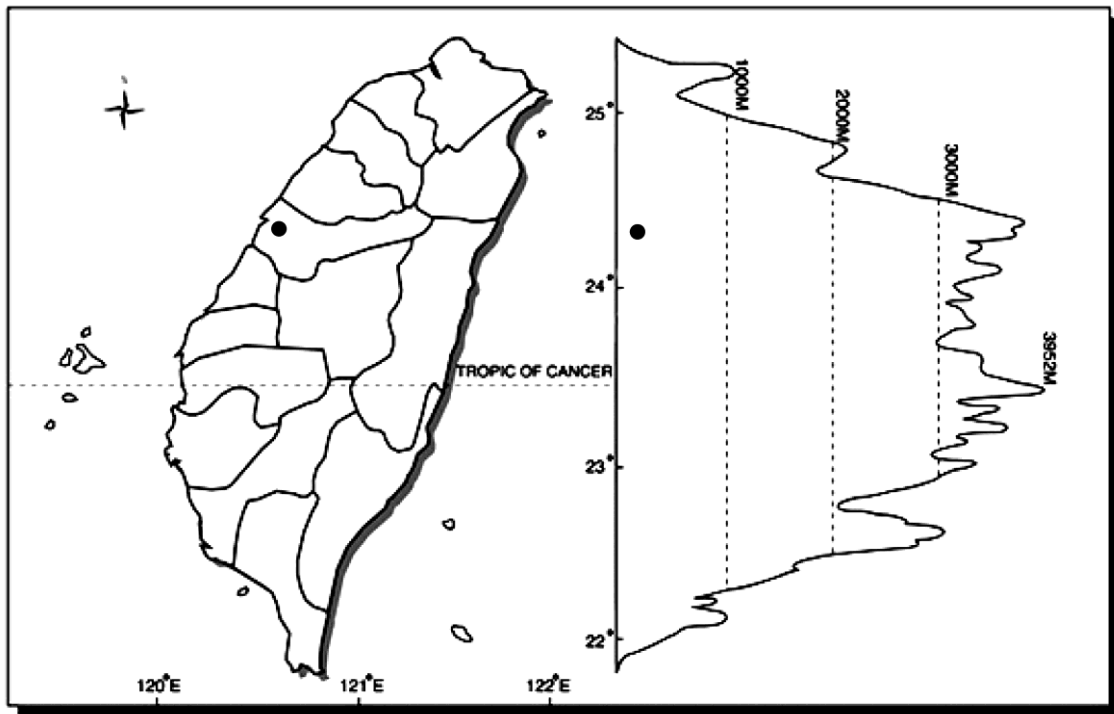
**Note:** The morphological character of this genus resembles that of *Spermacoce* L. in Taiwan, though it is characterized by circumscissile fruits and seeds with a X-shaped sulcus on the adaxial face (Taylor and Steyermark 2004).



**Fig. 1.** *Mitracarpus hirtus* (L.) DC. A: habit; B: abaxial view of leaf; C: stipule; D: flower; E: corolla; F: showing the stigma and style; G: mature fruit; H: adaxial view of seed; I: abaxial view of seed.



**Fig. 2.** *Mitracarpus hirtus* (L.) DC. A: habitat (On the roadside); B: habit; C: adaxial view of leaf; D: abaxial view of leaf; E: flowering shoot; F: stem; G: stipule; H: flower; I: mature fruit, showing the circumscissile dehiscence; J: adaxial view of seed.



**Fig. 3.** Distribution map of *Mitracarpus hirtus* (L.) DC. in Taiwan.

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## Literature Cited

- Andersson, L. 1992. A provisional checklist of neotropical Rubiaceae. Scripta Botanica Belgica Volume 1. National Botanic Garden of Belgium.
- Chen, T. and C. M. Taylor. 2011. *Mitracarpus* (Rubiaceae). In: Wu, Z.-Y., P. H. Raven and D. Y. Hong (eds), Flora of China 19: 217. Science Press, Beijing, and Missouri Botanical Garden Press, St. Louis.
- Fosberg, F. R., M. H. Sachet and R. L. Oliver. 1993. Rubiaceae. Flora of Micronesia 5: Bignoniaceae-Rubiaceae. Smithsonian Contributions To Botany 81: 44-135.
- Jung, M. J., C. W. Hsien, Y. C. Kao and C. L. Yeh. 2011. *Pectis* L. (Asteraceae), a newly recorded genus to the Flora of Taiwan. *Taiwania* 56(2): 173-176.
- Nicolson, D. H. 1977. Typification of names vs. typification of taxa: Proposals on article 48

- and reconsideration of *Mitracarpus hirtus* vs. *M. villosus* (Rubiaceae). *Taxon* 26: 573.
- Taylor, C. M. and J. A. Steyermark. 2004. *Mitracarpus* (Rubiaceae). In: Berry, P. E., K. Yatskievych and B. K. Holst (eds), *Flora of the Venezuelan Guayana* 8: 653-655. Missouri Botanical Garden Press, St. Louis. U.S.A.
- Tseng, Y. H., C. C. Wang and Y. T. Chen. 2008b. *Rivina humilis* L. (Phytolaccaceae), a newly naturalized plant in Taiwan. *Taiwania* 53(4): 417-419.
- Tseng, Y. H., C. Y. Liou, H. F. Yen and C. I. Peng. 2000. *Flaveria bidentis* (L.) Kuntze (Asteraceae), a newly naturalized plant in Taiwan. *Quarterly Journal of Forest Research* 30(4): 23-28.
- Tseng, Y. H., C. Y. Liu, S. C. Liu and C. H. Ou. 2008a. *Cyphomandra betacea* (Cav.) Sendt. (Solanaceae), a newly naturalized plant in Taiwan. *Quarterly Journal of Chinese Forestry* 41(3): 425-429.
- Walter, H. L. 1962. Chromosome Numbers in North American Rubiaceae. *Brittonia* 14(3): 285-290.
- Wu, S. H., C. F. Hsieh and M. Rejmánek. 2004. Catalogue of the Naturalized Flora of Taiwan. *Taiwania* 49: 16-31.
- Yang, S. Z. 2001. A new record and invasive species in Taiwan-*Clidemia hirta* (L.) D. Don. *Taiwania* 46(3): 232-237.



## Errata

Vol.	No.	Page	Table 2.	Error	Correction
13	3	231	$\chi^2$ value	83.1	15.3
				385.5	32.1
				285.5	35.6
				131.1	26.9



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