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行政院農業委員會特有生物研究保育中心 編印
Published by Endemic Species Research Institute,
Council of Agriculture, Taiwan, R. O. C.



GPN : 2009900002

台灣生物多樣性研究

Taiwan Journal of Biodiversity

20卷
4期

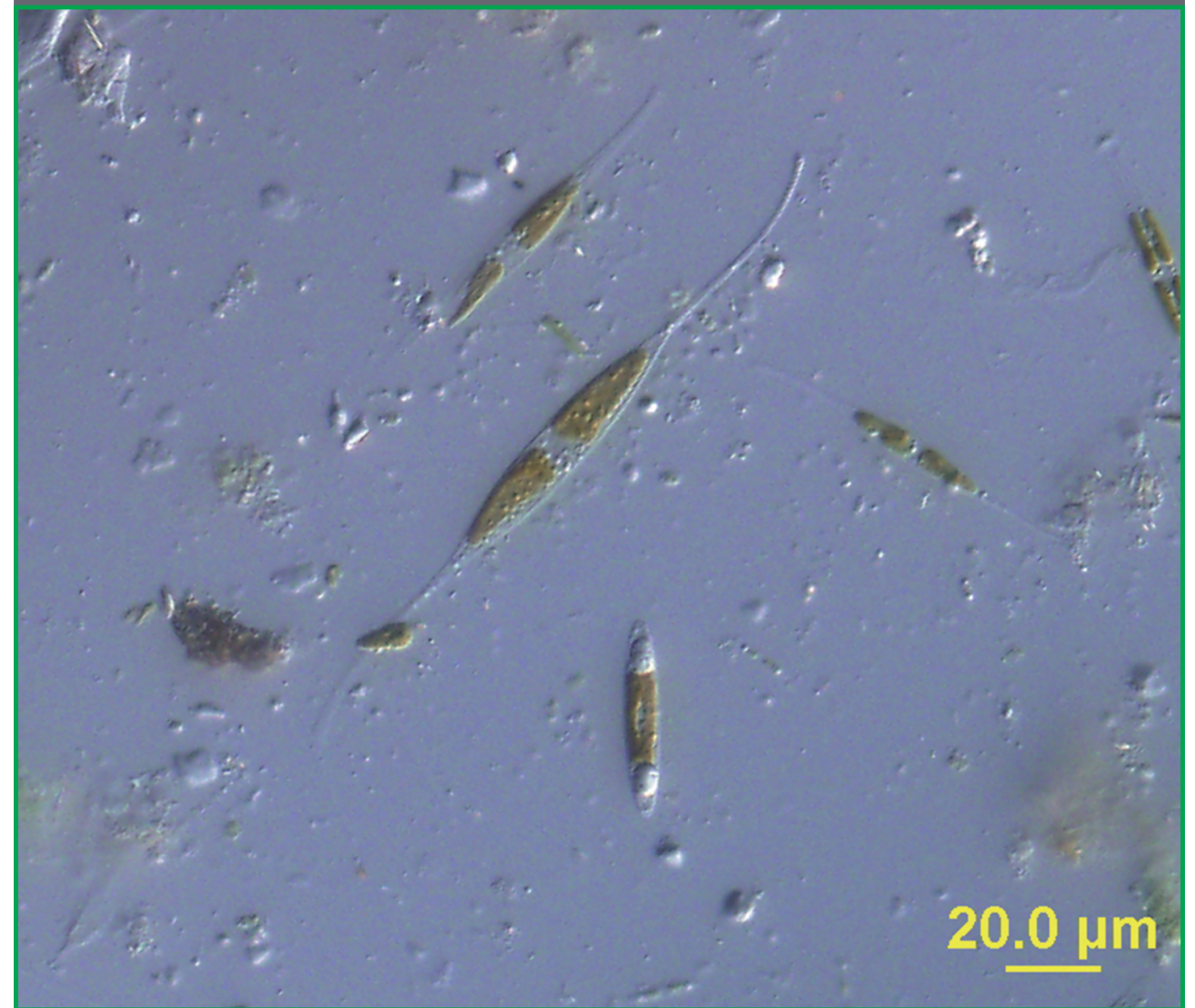
台灣生物多樣性研究 Taiwan Journal of Biodiversity

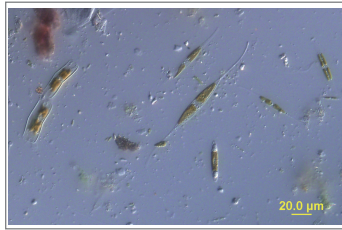
第 20 卷第 4 期

中華民國 107 年 10 月

Vol. 20, No. 4

October 2018





封面圖說 /
在海水人工浮島水域常見到Achnanthes屬及Nitzschia屬矽藻(李麗華 攝)

台灣生物多樣性研究

(原為《特有生物研究》半年刊，2010年元月起更名，並以季刊發行)

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英文編輯 / 金恆鏞、華博諾
出版編輯 / 黃智男、黃書彥

出版 / 農委會特有生物研究保育中心
住址 / 南投縣集集鎮55244民生東路1號
電話 / 049-2761331 轉 254
網址 / <http://www.tesri.gov.tw>
印刷 / 綠凌興業社
出版日期 / 中華民國 107 年 10 月
創刊日期 / 中華民國 88 年元月
出版登記 / 局版台誌第 10207 號

Taiwan Journal of Biodiversity

(Continuation of former journal of "Endemic Species Research", 1999-2009)

Publisher / Jia-Dong Yang
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Published by Endemic Species Research Institute
1 Min-Sheng E. Road, Jiji, Nantou 55244,
Taiwan, R.O.C.
Tel: 886-49-2761331 ext. 254
<http://tesri.tesri.gov.tw>

Published Date: October 2018

GPN: 2009900002
ISSN: 2076-6971

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Taxonomic reappraisal of *Solanum biflorum* var. *kotoense* (Solanaceae)

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Received: June 1, 2018; Accepted: October 16, 2018

Abstract

The identity of *Solanum biflorum* Lour. var. *kotoensis* Y. C. Liu & C. H. Ou is reappraised as its type specimen was rediscovered in TCF. Based on comparative study of related fresh and herbaria materials, *S. biflorum* var. *kotoensis* is treated as a synonym of *Lycianthes boninensis* Bitter. *L. boninensis* could be readily distinguished from closely related *L. biflora* by its glabrous habits and distinct morphology of calyx teeth. *L. boninensis* was regarded as endemic to the Bonin Islands, but presently its distribution range extends to the Ryukyu Islands and Lanyu, forming a remarkable phytogeographic pattern.

Key words: Lanyu, *Lycianthes biflora*, *Lycianthes boninensis*, *Solanum biflorum* var. *kotoense*, Taiwan, taxonomy.

紅頭耳鉤草之分類再議

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收件日期: 2018 年 6 月 1 日; 接受日期: 2018 年 10 月 16 日

摘要

伴隨模式標本重現於 TCF 標本館, 本研究探討紅頭耳鉤草 (*Solanum biflorum* Lour. var. *kotoensis* Y. C. Liu & C. H. Ou) 之分類地位。基於新鮮及乾燥標本之觀察比對, 我們將 *S. biflorum* var. *kotoensis* 處理為 *Lycianthes boninensis* 之異名。紅頭耳鉤草與近似種紅絲線 (*Lycianthes biflora* (Lour.) Bitter) 可藉由光滑之植物體及相異的萼齒形態區分。*L. boninensis* 過往被認定為小笠原群島之特有種, 但目前其地理分布延伸至琉球群島及蘭嶼, 形成一獨特之植物地理模式。

關鍵詞: 蘭嶼、紅絲線、紅頭耳鉤草、臺灣、分類學

Introduction

Lycianthes (Dunal) Hassl. is a large genus of Solanaceae comprising 150–200 species (Dean *et al.* 2017), with the majority distributed in the New World from Mexico to Argentina, and only approximately 30 species are found in the Old World between Asia and Australia (Dean 2004). Although sometimes included within *Solanum* by earlier authors (e.g. Hatusima 1969; Liu and Ou 1974, 1978), *Lycianthes* is commonly recognized as a distinct genus in modern studies (e.g. Yamazaki 1993b; Zhang *et al.* 1994; D' Arcy and Peng 1998) as it could be well characterized in morphology by the combination of cup-shaped, 10-veined, mostly 5–10 toothed calyx and poricidal anther dehiscence (D' Arcy 1986; Dean 2004; Olmstead *et al.* 2008; Dean *et al.* 2017). Molecular data has shown that *Lycianthes* is distant from *Solanum* but closely related to the chili pepper genus *Capiscum*, and some recent analyses have revealed that *Lycianthes* is paraphyletic with *Capiscum* nested within (Olmstead *et al.* 2008; Särkinen *et al.* 2013). A systematic recircumscription of *Lycianthes* and/or *Capiscum* is thus ultimately necessary.

In Taiwan, two *Lycianthes* species, *L. biflora* (Lour.) Bitter and *L. lysimachioides* (Wall.) Bitter, are commonly accepted (Zhang *et al.* 1994; D' Arcy and Peng 1998; Yang and Liu 2002; Boufford *et al.* 2003; Editorial Committee of the Red List of Taiwan Plants 2017). An additional taxon, described as *Solanum biflorum* Lour. var. *kotoensis* Y. C. Liu & C. H. Ou (Liu and Ou 1974) from Lanyu island, underwent a more intricate taxonomic history. This variety was accepted in the first edition of the Flora of Taiwan (Liu and Ou 1978) but later reduced by

Liao (1987) as a synonym of *S. biflorum* var. *glabrum* Koidz. ex Hatus. described from the Bonin Islands. Yamazaki (1993b), on the other hand, recombined this taxon under *Lycianthes laevis* (Dunal) Bitter described from Java [as *L. laevis* var. *kotoensis* (Y.C.Liu & C.H.Ou) T.Yamaz.] and simultaneously recorded it from the Ryukyu Islands. Meanwhile, *S. biflorum* var. *kotoense* was sunken into *L. biflorum* in other studies (Zhang *et al.* 1994; D' Arcy and Peng 1998; Yang and Liu 2002).

During a field trip to Lanyu in November, 2006, we met a fruiting *Lycianthes* sp. (Fig. 1A) along the trail to Mt. Hungtou, the highest peak of the islet. The plant was first linked to *L. biflora* due to its erect habit, though it showed somewhat distinct characters such as glabrous habit and shorter, spine-like calyx teeth. After preliminary study, it soon revealed that this taxon might match *Solanum biflorum* var. *kotoensis* and is also very close to *L. boninensis* described from the Bonin Islands of Japan (Liu and Ou 1974, 1978; Toyoda 2003; Yahara and Nagata 2003). To clarify its exact taxonomic position, we planned to examine the type specimen of *Solanum biflorum* var. *kotoense*, which was recorded as being collected by T. Sata from Botel Tobago (an alternative name of Lanyu) on 7 August, 1932, and preserved in the Herbarium of the Department of Botany, National Taiwan University ("Herb. Dept. Bot. Coll. Sci. National Taiwan University") (Liu and Ou 1974), currently the Herbarium of National Taiwan University (herbarium code: TAI). However, we failed to locate any specimen matching Liu and Ou's (1974) record in TAI, and the identity of the Mt. Hungtou *Lycianthes* thus remained uncertain.

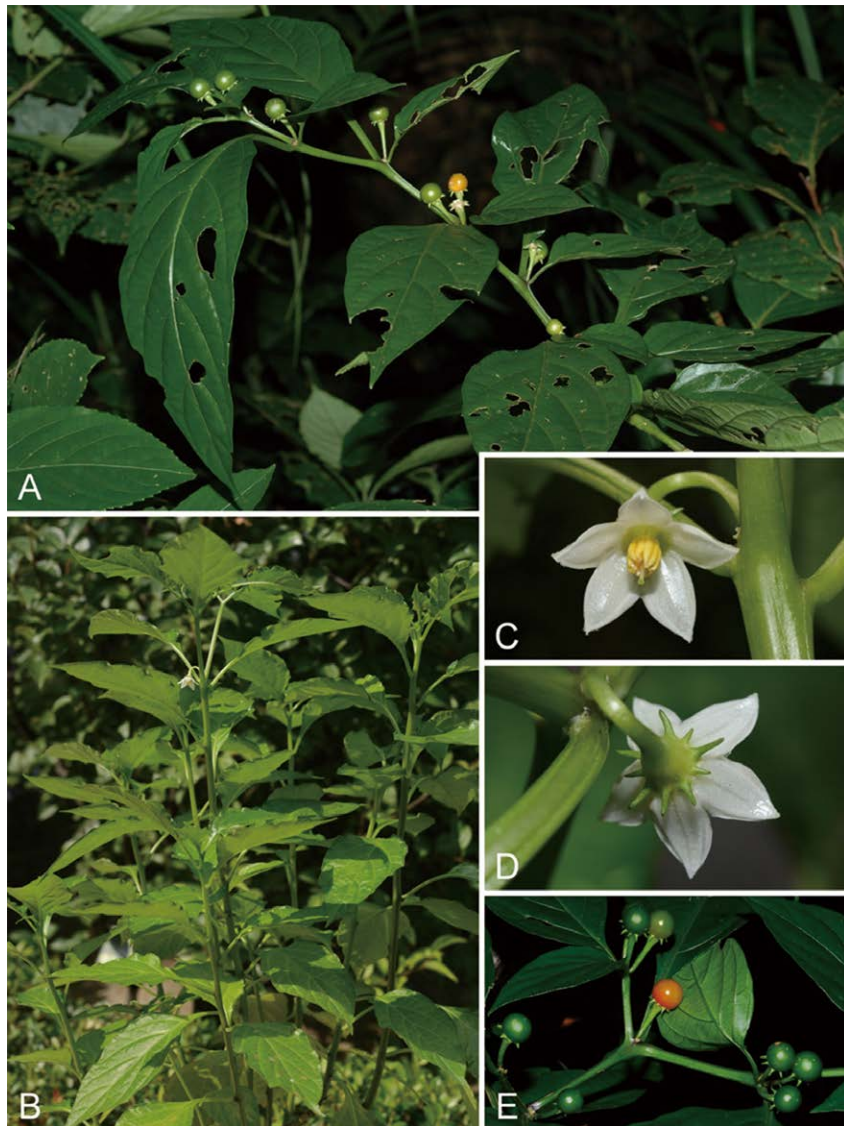


Fig 1. Morphology of *Lycianthes boninense* found in Lanyu (A & E from *Chung 8427*; B–D from *Chung 12223*). A. Fruiting habit. B. Flowering habits. C. Flower, front view. D. Flower, back view, showing calyx teeth. E. Fruits.

After a critical study of the rediscovered holotype of *S. biflorum* var. *kotoense* and related fresh and herbaria materials, we are convinced that the unknown *Lycianthes* we encountered at Mt. Hungtou in 2006 along with several *Lycianthes* collections from Lanyu match *S. biflorum* var. *kotoense*, and all these specimens also correspond to *Lycianthes boninensis*. As *L. boninensis* takes priority at species rank, we treated *Solanum biflorum* var. *kotoensis* as a synonym of *L. boninensis* for the first time. The global distribution of *L. boninensis*, previously considered endemic to the Bonin Islands (Yamazaki 1993b; Yahara and Nagata 2003), then extends to the Ryukyu Islands and Lanyu (Fig. 3). To aid identification, the full synonymy, morphological description, voucher specimens and color plates of *L. boninensis* is presented in this study. Its taxonomic identity, phytogeography and conservation status are also discussed.

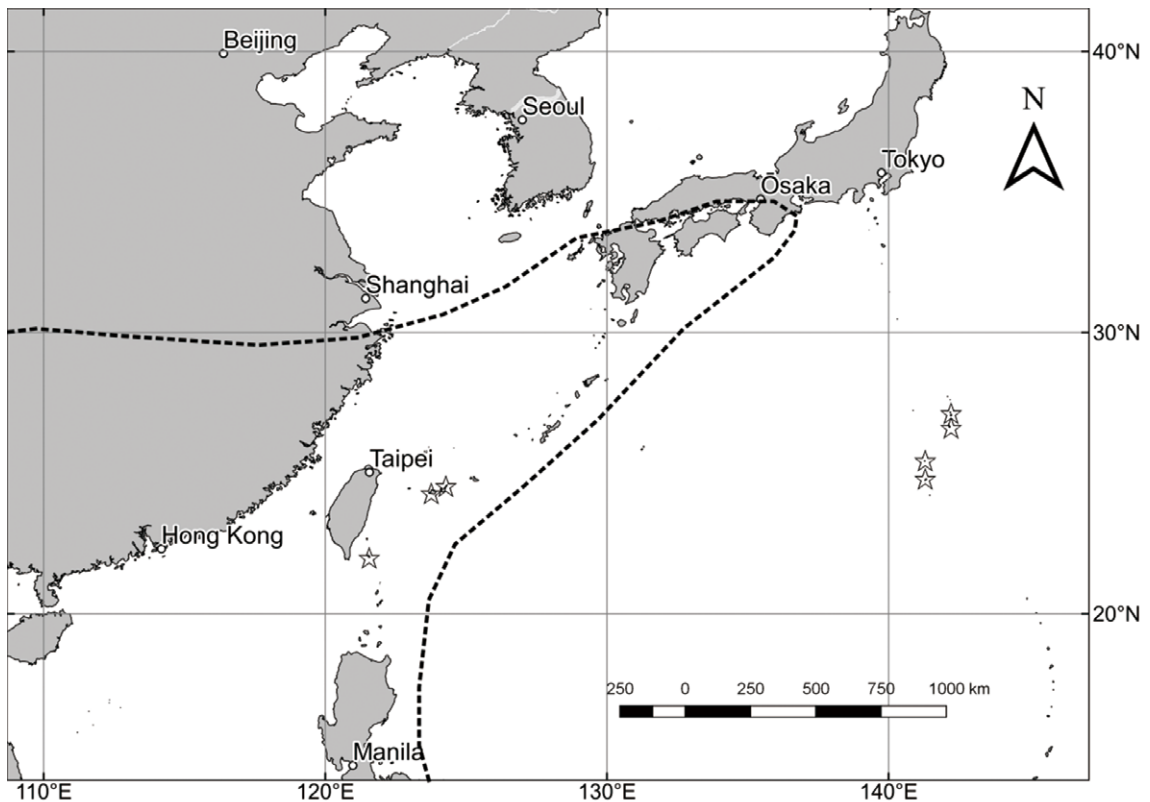


Fig 3. Distribution ranges of *Lycianthes boninensis* (stars) and *L. biflora* (dashed line) in East Asia.

TAXONOMIC TREATMENT

Lycianthes boninensis Bitter, Abh. Nat. Ver. Bremen 24:483. (1919). Figs. 1 & 2. **Type:** JAPAN. Tokyo: Bonin Islands (“Bonininseln”), *Warburg s.n.* (holotype: B, possibly destroyed).

= *Solanum biflorum* Lour. var. *kotoense* Y.C.Liu & C.H.Ou, Quart. J. Chin. For. 7: 151. 1974 [as “*kotoensis*”]. ≡ *Lycianthes laevis* (Dunal.) Bitter var. *kotoensis* (Y.C.Liu & C.H.Ou) T. Yamaz., Fl. Japan. 1993. **syn. nov.** **Type:** TAIWAN. Taitung: Lanyu (Botal Tobago), Mt. Satuja, 7 Aug 1932, *T. Sata s.n.* (holotype: TCF!).

= *Solanum boninense* Nakai ex Tuyama, Bot. Mag. Tokyo 50: 132. 1936. **Type:** JAPAN. Tokyo: Bonin Islands, Chichijima (“Ins. Titizima”), 8 July 1920, *T. Nakai s.n.*, (holotype: TI!).

= *Solanum biflorum* Lour. var. *glabrum* Koidz. ex Hatus., J. Geobot. (Kanazawa) 17:49. 1969. **Type:** JAPAN. Tokyo: Bonin Islands, 1 Oct 1912, *S. Nisimura 81* (holotype: TI!).

Morphology: Subshrubs 0.6–1.0 m tall. Branches glabrous, sometimes sparsely hairy at very young stage. Leaves solitary or unequally paired, thick membranaceous, sparsely hairy at very young stage, soon turning glabrous, petiole 1–3 cm long; major leaves ovate or ovate-oblong, 10–18 cm long, 4.0–8.5 cm wide, apex acute or acuminate, base cuneate or rounded, shortly attenuate into petiole, entire, lateral veins 5–7 pairs; minor leaves broadly ovate to oblong, 3–8 cm long, 2–4 cm wide. Inflorescences 1–6-flowered fascicles in leaf axils. Pedicel 0.5–1.0 cm long, glabrous, retrose in flowering, erect in fruiting. Calyx cup-shaped, 3–4 mm long, ca. 4 mm in diam., glabrous, 10-toothed; teeth spine-

like, attached slightly below the rim, subequal or distinctly unequal in length, 0.3–1.5(–2.0) mm long; corolla rotate-campanulate, white, deeply 5-lobed, lobes ca. 7 mm long, ovate-lanceolate, acute; stamens 5, connivent, inserted in corolla tube, filaments ca. 1 mm long, anthers oblong, ca. 3.5 mm long; style filiform, ca. 5 mm long. Berry red, globose, 0.7–0.9 cm in diam., with saucer-shaped persistent calyx at base.

Chinese name: “紅頭耳鉤草” (Liu and Ou 1978).

Global distribution: *Lycianthes boninensis* is currently reported in Japan and Taiwan (Fig. 3). In Japan, it has been recorded from Chichijima, Hahajima, Kita Iwo Jima and Minami Iwo Jima of the Bonin Islands (Ogasawara Subprefecture, Tokyo Metropolis) (Toyoda 2003) and Ishigakijima and Iriomotejima of the Ryukyu Islands (Okinawa Prefecture) (Yamazaki 1993). In Taiwan, it is currently only recorded in Lanyu (Lanyu Township, Taitung Co.). The record of *Lycianthes boninensis* in Borneo (Beaman and Anderson 2004) is currently rejected as discussed below.

Habitat and phenology: In Lanyu, *Lycianthes boninensis* was found growing under primary broadleaved forest at the elevation of 200–400 m. Flowering was recorded from May to July and fruiting from July to next March.

Conservation status: EN. See the discussion below.

Additional specimens examined: TAIWAN. Taitung: Lanyu Township, Mt. Hungtou (Mt. Hon-tou;), 12 Jul 1935, *Hosokawa 8128* (TCF); 12 Jul 1935, *Kano s.n.* (TCF); 20 Sep 1972, *Huang & Kao 6236* (TCF); 12 Nov 2006, *Chung 8427* (TAIF); 12 Oct 2013,

Lu 26059 (TAIF); 10 Jun 2015, *Chung 12223* (TAIF); Mt. Yamada, *Sata 1691*, Jul 19, 1932 (TAI); Tungching Stream, 30 Sep 2010, *Jung 5166* (TAIF); en route from Yehyu Bridge to hill peak up the Yehyu River, 27 Feb 1993, *Ho 1072* (HAST). JAPAN. Tokyo Metropolis, Ogasawara Subprefecture: Chichijima, 14 Jul 1905, *Hattori s.n.* (TI); Hahajima, 6 Aug 1905, *Hattori s.n.* (TI); 19 Jun 1920, *Nakai s.n.* (TI); 28 Jul 1930, *Tuyama s.n.* (TI); 26 Jun 1932, *Hara T215* (TI); 30 Jun 1932, *Kuwanok s.n.* (TI); 7 Apr 1934, *Tuyama s.n.* (TI); 4 Apr 1936, *Tuyama s.n.* (TI); 400 m, 16 Jul 1969, *Yamazaki s.n.* (TI); Kita Iwo Jima (“Kita-iwo-zima”), 20 Nov 1935, *Tuyama s.n.* (TI); 16 Jun 1940, *Tuyama s.n.* (TI); 300 m, 28 May 1970, *Yamazaki & Enomoto s.n.* (TI); 13 Jul 1993, *Yasui s.n.* (TI); Minami Iwo Jima, 31 Mar 1936, *Tuyama s.n.* (TI); 15 & 16 Jun 1982, *Ohba 826074* (TI).

DISCUSSION

Typification and taxonomic affinity of *Lycianthes boninensis*

All but few loaned ones of the Solanaceae types preserved in the Herbarium Berolinense were unfortunately destroyed during WWII (Hiepko 1987), and currently we could not find any surviving original materials of *Lycianthes boninensis* from online databases of B and other European herbaria. The identity of this name is therefore based on the comparison with original description (Bitter 1919), previous studies (Yamazaki 1993b; Toyoda 2003; Yahara and Nagata 2003) and specimens collected from its type locality. Neotypification would be ultimately necessary if no extant type materials could be discovered after an extensive search.

Lycianthes boninensis is closely related to

the widespread and variable *L. biflora* but readily distinguished by the hairiness of plant bodies and the morphology of calyx teeth. In *L. boninensis*, the stems and leaves are only sparsely hairy at very young stage and soon become entirely glabrous, the calyx is entirely glabrous, with conical-subulate teeth attached slightly below calyx rim, and the calyx teeth are sometimes unequal in length, up to 2 mm and generally 0.3–1.5 mm long. While in *L. biflorum*, the annual stems, leaves and calyx are always sparsely to densely pubescent, and the calyx teeth are linear-subulate, nearly equal in length, generally 2–3 mm long and attached onto the calyx rim. It should be noted that both *L. boninensis* and *L. biflorum* could be found in Lanyu, where they tend to grow allopatrically. *L. biflorum* [voucher specimens: *Sata 1687* (TAI); *Huang 10675* (TAI); *Chang 2841* (TAIF); *Jung 5030* (TAIF)] is often found in open and semi-open waste places or forest margin near sea-level, but *L. boninensis* is only discovered under moist rain forests in the northern mountainous region. All specimens currently examined are clearly separable by the characters mentioned above.

Yamazaki's (1993b) treatment of *Solanum biflorum* var. *kotoense* was somehow impractical. Firstly, he placed this taxon as a variety of Javanese *Lycianthes laevis*, but *L. laevis*, as described in Bitter's (1919) monograph and also seen on its holotype [*J.B.L.T. Leschenault de la Tour 683* (P image!)], bears shortly 5-toothed calyx which is strikingly distinct from the present taxon. Secondly, he stated that *Lycianthes laevis* var. *kotoensis* differs from *L. boninensis* in having membranaceous (vs. thick membranaceous), oblong (vs. ovate) leaves, attenuately acuminate (vs. acute) leaf apices

and irregular (vs. subequal) calyx. However, the holotype of *Solanum biflorum* var. *kotoensis* (Fig. 2) bears ovate leaves and subequal calyx teeth, both conflicting Yamazaki's observation. The distinction in leaf texture is too subtle to serve as diagnosing character, and specimens from Lanyu comprise leaves varied from ovate to oblong with acute to acuminate apices and calyx teeth varied from obviously irregular to subequal. Based on these observations, we are convinced that none of the characters mentioned by Yamazaki (1993b) are usable to distinguish *Solanum biflorum* var. *kotoense* from *L. boninensis*, and hence we agree with Liao (1987) that *S. biflorum* var. *kotoense* is identical to the Bonin taxon. However, as this taxon could be readily distinguished from *L. biflora* not only by glabrous habits but also by the morphology of calyx teeth, we believe it is better to recognize it as an independent species, namely *L. boninensis*, instead of a glabrous variety of *L. biflora*.

Conservation status of *Lycianthes boninensis*

Lycianthes boninensis was evaluated as EN (Endangered) in Japan (Ministry of the Environment, 2015). In Taiwan, *L. boninensis* is currently only recorded in the northern mountainous region of Lanyu. Although it is recorded in four locations (Mt. Hongtuo, Mt. Yamada, Tungching Stream and Yehyu River) according to specimen data, all these locations are actually closely adjacent and thus better considered as a single subpopulation. A total of ca. 100 mature individuals and ca. 10 km² area of occupancy are estimated based on our field investigation between 2006–2018. As neither population decline nor immediate threat has been observed, this species is evaluated as EN (D1) at national level based on IUCN Red List

Categories and Criteria (IUCN 2012a; 2012b; Editorial Committee of the Red List of Taiwan Plants 2017).

Phytogeography of *Lycianthes boninensis*

The Bonin-Ryukyu-Lanyu distribution pattern of *Lycianthes boninensis* is remarkable and not known from any other vascular plants (Hsieh 2003). The only similar case is *Limonium wrightii* (Hance) Kuntze (Plumbaginaceae), although it occurs in a slightly wider range including the Izu Islands, southern Taiwan and Penghu Islands (Yamazaki 1993a; Li 1998; Toyoda 2003). All other native species sharing among the Bonin Islands, the Ryukyu Islands and Lanyu are globally much more widespread.

The geographic location and flora of the Bonin Islands is rather isolated, with about 43% of vascular plants considered endemic (Kobayashi and Ono 1987). On the other hand, the floras of the Ryukyu Islands and Lanyu, each with fewer than 12% endemic species (Ohba 1996; unpublished data), are more correlative to closely adjacent areas such as southern Japan, Taiwan and northern Philippines. It could therefore be hypothesized that the speciation of *L. boninensis* more likely took place on the Bonin Islands, and its emigration to the Ryukyu Islands and Lanyu might have happened more recently. The small, bright reddish and smell-less berries of *L. boninensis* well fit the syndrome of ornithochory (Albuquerque *et al.* 2006), and it thus has the potential of long-distance dispersal among these oceanic islets. The Bonin-origin hypothesis could further demonstrate that the co-occurrence of closely related *L. boninensis* and *L. biflora* in the Ryukyu Islands and Lanyu (Fig. 3) might be a result of multiple independent

colonization, though phylogenetic and population genetic studies are eventually needed in seeking its origin and evolution history.

Besides Taiwan and Japan, *Lycianthes boninensis* was also recorded from Borneo based on a single collection from the Mount Kinabalu region (Beaman and Anderson 2004). However, the voucher specimen [Kokawa & Hotta 5609 (L image!)] differs from Japanese and Taiwanese materials in having much narrower leaves and linear-subulate calyx lobes. We thus believe that this record was a result from misidentification. Nevertheless, since *L. boninensis* could be easily confused with *L. biflorum* if not carefully studied, there is still a chance to find out additional records of *L. boninensis* within the broad distributing range of *L. biflorum* if a comprehensive re-examination of herbaria and field survey is conducted.

ACKNOWLEDGEMENTS

We are grateful of You-Ting Hsieh (謝侑廷) for taking specimen photos in TCF, the curators of HAST, TAI, TAIF, TCF and TI for herbaria access; Che-Wei Lin (林哲緯), Shen-Kun Yu (余勝焜), Pi-Fong Lu (呂碧鳳), Chiu-Mei Wang (王秋美), Chih-Hsiung Chen (陳志雄) and Hsin-Chieh Hung (洪信介) for accompanying field trips, and two anonymous reviewers for their valuable comments.

LITERATURE CITES

- Albuquerque, L. B., A. Velázquez and R. Mayorga-Saucedo. 2006. Solanaceae composition, pollination and seed dispersal syndromes in Mexican Mountain Cloud Forest. *Acta Botanica Brasilica* 20(3): 599-614.
- Beaman, J. H. And C. Anderson. 2004. The plants of Mount Kinabalu 5. Dicotyledon families Magnoliaceae to Winteraceae. Natural History Publications, Kota Kinabalu, Malaysia. 609 pp.
- Bitter, G. 1919. Die Gattung *Lycianthes*. *Abhandlungen Naturwissenschaftlichen Vereine Zu Bremen* 24: 292-520.
- Boufford, D. E., H. Ohashi, T. C. Huang, C. F. Hsieh, J. L. Tsai, K. C. Yang, C. I Peng, C. S. Kuoh and A. Hsiao. 2003. A checklist of the vascular plants of Taiwan. pp. 15-139. *In*: T. C. Huang *et al.* (eds.), *Flora of Taiwan*, 2nd ed., Vol. 6. Editorial Committee of the Flora of Taiwan, Dept. Bot., NTU, Taipei, Taiwan.
- Dean, E. A. 2004. A taxonomic revision of *Lycianthes* series *Meizonodontae* (Solanaceae). *Botanical Journal of the Linnean Society* 145: 385-424.
- Dean, E. A., M. Reyes, R. Fauré, G. K. Walden, D. Canington, D. Brandon and D. M. McNair. 2017. Identification of the species of *Lycianthes* series *Tricolores* (Capsiceae, Solanaceae). *Systematic Botany* 42(1): 191-209.
- D'Arcy, W. G. and C. I Peng. 1998. Solanaceae. pp. 552-555. *In*: T. C. Huang *et al.* (eds.), *Flora of Taiwan*, 2nd ed., Vol. 4. Editorial Committee of the Flora of Taiwan, Dept. Bot., NTU, Taipei, Taiwan.
- D'Arcy, W. G. 1986. The calyx in *Lycianthes* and some other genera. *Annals of the Missouri Botanical Garden* 73: 117-127.
- Editorial Committee of the Red List of Taiwan Plants. 2017. *The Red List of Vascular*

- Plants of Taiwan, 2017. Endemic Species Research Institute, Forestry Bureau, Council of Agriculture, Executive Yuan and Taiwan Society of Plant Systematics, Nantou, Taiwan.
- Hatusima, S. 1969. On a glabrous form of *Solanum biflorum*. *Journal of Geobotany* 17(2): 49.
- Hiepko, P. 1987. The collections of the Botanical Museum Berlin-Dahlem (B) and their history. *Englera* 7: 219-252.
- Hsieh, C. F. 2003. Composition, endemism and phytogeographical affinities of the Taiwan Flora. pp. 1-14. In: T.C. Huang *et al.* (eds.), *Flora of Taiwan*, 2nd ed., Vol. 6. Editorial Committee of the Flora of Taiwan, Dept. Bot., NTU, Taipei, Taiwan.
- IUCN. 2012a. Guidelines for application of IUCN Red List criteria at regional and national levels: Version 4.0. IUCN, Gland, Switzerland and Cambridge, UK.
- IUCN. 2012b. IUCN Red List categories and criteria: Version 3.1., 2nd edition. IUCN, Gland, Switzerland and Cambridge, UK.
- Kobayashi, S. and M. Ono. 1987. A revised list of vascular plants indigenous and introduced to the Bonin and Volcano Islands. *Ogasawara Research* 13: 1-55.
- Li, H. L. 1998. Plumbaginaceae. pp. 79-82. In: T. C. Huang *et al.* (eds.), *Flora of Taiwan*, 2nd ed., Vol. 4. Editorial Committee of the Flora of Taiwan, Dept. Bot., NTU, Taipei, Taiwan.
- Liao, J. C. 1987. The revisions and supplements of plant scientific names in Taiwan. *Quarterly Journal of Chinese Forestry* 20(4): 139-145.
- Liu, Y. C. and C. H. Ou. 1974. New additions to the Flora of Taiwan. *Quarterly Journal of Chinese Forestry* 7(4): 150-152.
- Liu, Y. C. and C. H. Ou. 1978. Solanaceae. pp. 530-550. In: H. L. Li *et al.* (eds.), *Flora of Taiwan*, Vol. 4. Epoch Publishing Co., Ltd., Taipei, Taiwan.
- McNeill, J., F. R. Barrie, W. R. Buck, V. Demoulin, D. L. Greuter, D. L. Hawksworth, P. S. Herendeen, S. Knapp, K. Marhold, J. Prado, W. F. Prud'homme van Reine, J. F. Smith and J. H. Wiersema (eds.). 2012. International Code of Nomenclature for algae, fungi and plants (Melbourne Code): Adopted by the Eighteenth International Botanical Congress, Melbourne, Australia, July 2011. *Regnum Vegetabile* 154: 1-274.
- Ministry of the Environment. 2015. Red Data Book 2014: Threatened Wildlife of Japan, Vol. 8, Vascular Plants. Gyosei Co., Tokyo, Japan. 664 pp.
- Ohba, H. 1996. The temperate elements of the Flora of the Nansei-shoto (the Ryukyu Islands) and the global climate change. pp. 185-204. In: K. Omasa, K. Kai, H. Taoda, Z. Uchijima and M. Yoshino (eds.), *Climate Change and Plants in East Asia*. Springer-Verlag Tokyo, Tokyo, Japan.
- Olmstead, R. G., L. Bohs, H. A. Migid, E. Santiago-Valentin, V. F. Garcia and S. M. Collier. 2008. A molecular phylogeny of the Solanaceae. *Taxon* 57: 1159-1181.

- Särkinen, T., L. Bohs, R. G. Olmstead and S. Knapp. 2013. A phylogenetic framework for evolutionary study of the nightshades (Solanaceae): a dated 1000-tip tree. *BMC Evolutionary Biology* 13: 214.
- Toyoda, T. 2003. *Flora of Bonin Islands (Enlarged & Revised)*. Aboc Co. Ltd., Tokyo. 522 pp. (in Japanese).
- Yahara, T. and Y. Nagata. 2003. *Red Data Plants*. Yama-Kei Publ. Co. Ltd., Tokyo (in Japanese). p.107.
- Yamazaki, T. 1993a. Plumbaginaceae. pp. 96-97. *In*: K. Iwatsuki, T. Yamazaki, D. E. Boufford and H. Ohba (eds.), *Flora of Japan*, Vol. IIIa. Angiospermae, Dicotyledoneae, Sympetalae (a)., Kodansha Ltd., Tokyo, Japan.
- Yamazaki, T. 1993b. Solanaceae. pp. 192-193. *In*: K. Iwatsuki, T. Yamazaki, D. E. Boufford and H. Ohba (eds.), *Flora of Japan*, Vol. IIIa. Angiospermae, Dicotyledoneae, Sympetalae (a). Kodansha Ltd., Tokyo, Japan.
- Yang, Y. P. and H. Y. Liu. 2002. *Manual of Taiwan vascular plants*, Vol. 6. The Council of Agriculture, the Executive Yuen, Taipei, Taiwan.
- Zhang, Z. Y., A. M. Lu and W. G. D'Arcy. 1994. *Lycianthes* (Dunal) Hassler. pp. 325-328. *In*: Z. Y. Wu and P. H. Raven (eds.), *Flora of China*, Vol. 17. Science. Press, Beijing, China and Missouri Botanical Garden, St. Louis, USA.

Survey data of diatoms on seawater artificial floating islands

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Received: August 31, 2018; Accepted: December 27, 2018

Abstract

This dataset recorded benthic diatoms attached to the diatom boards installed on the artificial floating islands (AFIs) in the seawater in Anping Historical Waterview Park, Tainan, Taiwan. Diatoms were cultured using diatom boards and sampled four times from October to December, 2017. A total of 45 diatom species belonging to 22 genera were identified. Among them, the *Navicula* genus was the highest in richness, and *Achnanthes subsessilis* and *Nitzschia longissima* dominated in number.

Key words: Artificial Floating Island, diatoms, sampling event

海水人工浮島矽藻調查資料

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收件日期：2018年8月31日；接受日期：2018年12月27日

摘要

本資料集提供2017年10月至12月於台南市安平歷史水景公園人工浮島上進行附生矽藻培養，並進行4次採集與藻種鑑定所得結果，於附著藻板之矽藻共鑑定出22屬45種，其中以菱形藻屬(*Navicula*)種類最多，*Achnanthes subsessilis*及*Nitzschia longissima*為數量優勢藻種。

關鍵詞：人工浮島、矽藻、取樣事件

Introduction

An artificial floating island (AFI) is a group of plants cultivated on artificial platforms that float on water. AFIs are typically established for various objectives such as bank erosion prevention and shoreline protection, landscape design and planning, wildlife habitat provision, and water purification and filtration (Hoeger 1988; Nakamura and Mueller 2008). Studies on the water purification and filtration function of AFIs have focused on the effects of nutrient absorption of vascular plants and the wildlife habitat provided by AFIs (Stewart *et al.* 2008; Billore 2009; Li *et al.* 2010; Zhang *et al.* 2014). However, few studies have addressed the structure of AFIs or the microorganisms attached to the underwater root systems. Diatoms constitute the main species in water bodies, and they provide a food source for primary producers and other organisms in the underwater biosphere. Additionally, the structure and plant root systems of AFIs provide surfaces for the effective attachment of diatom substrates (Nakamura *et al.* 1995). To address the research gap regarding benthic diatoms on AFIs, this study investigated benthic diatoms on AFIs established on seawater. The diatom species and related environmental data collected and established by this study can serve as reference for future investigations.

Methods and Materials

1. Sampling Location

The Anping Historical Waterview Park in Tainan, Taiwan, (120°15'21.81" E, 22°00'00.84" N) served as the sampling location for this

study (Fig. 1). The park has a water area of approximately 6 km² and water depth of 3 m. The southern portion of the park is connected to the Anping harbor area and the Tainan Canal; the northern portion comprises the Yanshui River basin and estuary. The gauge height within the park varies with the sea tide; the water salinity level is generally between 31 and 35 ppt (Lin 2017). Since 2016, seven AFIs have been established by faculty members and students of the Department of Hydraulic and Ocean Engineering of National Cheng Kung University. The established AFIs comprise plants such as *Sesuvium portulacastrum* (L.) L. and *Avicennia marina* (Forsk.) Vierh (Fig. 2). This study conducted culture, sampling, investigation, and identification processes on three of these AFIs to obtain information regarding benthic diatoms.

According to 2017 data obtained from the Tainan Anping Observation Station of the Central Weather Bureau (Table 1), the annual rainfall amount in Anping is 1,055 mm and the mean annual temperature is 25.4°C. To prevent the effects of typhoon or intense rainfall during summer, diatom boards were installed in October. The mean monthly temperatures during the investigation period were 27.4°C (October) and 24°C (November), and the rainfall measurements were 42 (October) and 3.5 (November) mm. An on-site test of the park's water quality conducted on October 28, 2017, revealed that the water pH was 8.28, water temperature was 26.5°C, salinity was 34 ppt, dissolved oxygen concentration was 7.87 mg/L, and turbidity was 1.23 FNU (Formazin Nephelometric Units). Therefore, the water had a high dissolved oxygen concentration as well as high transparency.



Fig. 1. Sampling location.



Fig. 2. AFIs established by faculty members and students of the Department of Hydraulic and Ocean Engineering of National Cheng Kung University.

Table 1. Meteorological data recorded in 2017 in the Anping Historical Waterview Park (Anping Observation Station of the Central Weather Bureau)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Ambient Temperature (°C)	19.7	18.9	21.9	5	28.1	29.7	30	30.1	30.2	27.3	24	19.3	25.4
Rainfall (mm)	0	0.5	11	63	71	217.5	438	175	33	42	3.5	0.5	1055

2. Diatom Sampling

This study includes a total of five sampling events, which is defined by the date the samples were retrieved from the field. Of the five events, four were sampling of benthic diatoms, which is gathered from the field on October 23, October 31, November 20, and November 30, 2017. The fifth is a sample of planktonic diatoms, which is sampled from the field on October 28, 2017 with a test on the park's water quality. Further details of the sampling process are given below.

(1) Culture of benthic diatoms:

Eight diatom boards (transparent acrylic boards measuring 15×15 cm²) were placed on each of the three AFIs on October 16, 2017. Subsequently, sampling processes were conducted on October 23, October 31, November 20, and November 30, 2017, with the culture period being 7, 15, 35, and 45 days, respectively.

(2) Sampling of benthic diatoms:

On each sampling date, two of the diatom boards were removed from the AFIs; specifically, a total of six boards were retrieved on each sampling session. The retrieved boards were covered with tin-foil paper for shading, after which they were sent to the laboratory under refrigeration. The benthic diatoms were then scraped off using toothbrushes.

(3) Sampling of planktonic diatoms:

For comparison with the benthic diatoms, this study sampled the water near the Historical Waterview Park regions in which the diatom boards were placed on October 28. The collected water samples were subjected to centrifugation, acid washing, and fixation in the laboratory. Subsequently, observation and identification processes were conducted on the water samples.

(4) Identification of diatoms:

All the diatom fluids were first concentrated in a centrifugal machine for 10 minutes at 3,500 rpm; the fresh diatoms were then observed using a differential interference contrast microscope (OLYMPUS, BX51; 1,000X). Subsequently, acid washing was conducted using concentrated sulfuric acid, after which observation and identification processes were performed using an electron microscope (HITACHI, TM 3000; 4,000–10,000X). The main reference items for identification were *The Diatoms: Biology and Morphology of the Genera* (Round *et al.* 1996) and *Freshwater Diatom Flora of Taiwan* (Wu *et al.* 2011).

Results

1. Diatom board fouling

During the 45 days of culture of benthic diatoms, the diatom boards were retrieved on days 7, 15, 35, and 45 and sent to the laboratory, where the benthic diatoms were then scraped off. Figure 3 presents the changes observed on the diatom boards. The organisms found on the diatom boards varied with time. On day 7 (Fig. 3a), benthic diatoms, cyanobacteria, and other algae were observed, but the coverage was not extensive. On day 15 (Fig. 3b), the diatom

boards were completely covered by various algae including *Ulva fasciata*, a type of macroalgae of the *Ulva* genus; some fouling marine organisms such as Balanidae and Sabellidae of Sabellida were also observed. On day 35 (Fig. 3c), the diatom boards were fully covered by macroalgae and fouling organisms. Finally, on day 45 (Fig. 3d), the diatom boards were mostly covered by Balanidae, whereas only a few green algae and Sabellidae were observed.

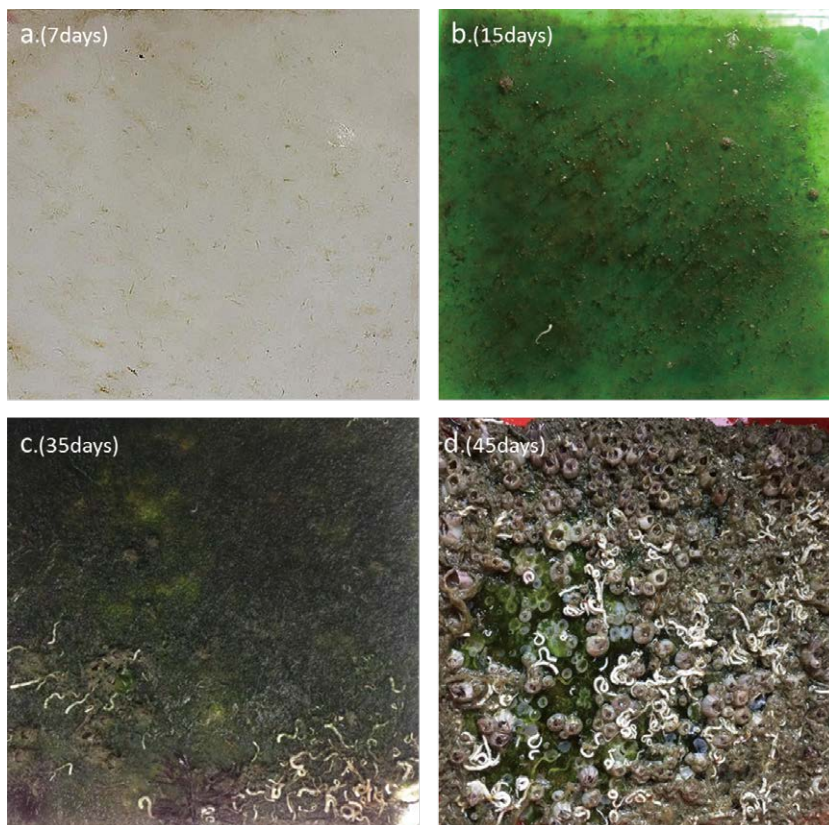


Fig. 3. Changes observed on diatom boards during different culture stages.

2. Diatom species

Among the fouling diatoms on the diatom boards and the planktonic diatoms in the water, a total of 46 diatom species belonging to 23 genera were identified after acid washing. Of the identified species, 45 were observed on the diatom boards and 24 were observed in the water. The majority of the diatoms identified belonged to *Navicula*; they were six in total and included *Achnanthes subsessilis* and *Nitzschia longissima*, which were the dominant species in number. In addition, *Haslea spicula*, *Plagiotropis lepidoptera*, and *Thalassiosira tealata* were observed on the diatom board, indicating the preceding three species belong to phytoplankton.

Table 2 lists the diatoms documented in this study. A database containing the morphological pictures of all listed diatoms and relevant environmental data was established. This database can serve as a reference for related future research.

Datasets

Dataset description

Object name: Darwin Core Archive The_Survey_Data_of_Benthic_Diatoms_in_Anping_Historical_Waterview_Park

Character encoding: UTF-8

Format name: Darwin Core Archive format

Format version: 1.0

Distribution: http://ipt.taibif.tw/archive.do?r=the_survey_data_of_benthic_diatoms_in_anping_historical_waterview_park

<https://www.gbif.org/dataset/a0998d3b-4a7f-4add-8044-299092d9c63f>

<https://doi.org/10.15468/mwzwl5>

Publication date of data: 2018-08-31

Language: Chinese

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Table 2. Diatoms recorded in Anping Historical Waterview Park

Families	Genera	Species	Niche types	
			Periphytic	Planktonic
Achnantheaceae	<i>Achnanthes</i>	<i>Achnanthes brevipes</i> C.Agardh	v	v
		<i>Achnanthes kuwaitensis</i> Hendey	v	v
		<i>Achnanthes subsessilis</i> Kützing	v	v
Achnanthidiaceae	<i>Achnantheidium</i>	<i>Achnantheidium</i> sp.	v	
Achnanthidiaceae	<i>Planothidium</i>	<i>Planothidium septentrionalis</i> (Østrup) Round & Bukhtiyarova	v	
Bacillariaceae	<i>Nitzschia</i>	<i>Nitzschia acicularis</i> (Kützing) W.Smith	v	
		<i>Nitzschia frustulum</i> (Kützing) Grunow	v	
		<i>Nitzschia inconspicua</i> Grunow	v	
		<i>Nitzschia longissima</i> (Brébisson) Ralfs	v	v
		<i>Nitzschia microcephala</i> Grunow	v	v
		<i>Nitzschia sigma</i> (Kütz.) W.Smith	v	v
Bacillariaceae	<i>Psammodyctyon</i>	<i>Psammodyctyon constrictum</i> (W.Gregory) D.G.Mann	v	
		<i>Psammodyctyon panduriforme</i> (W.Gregory) D.G.Mann	v	v
Biddulphiaceae	<i>Biddulphia</i>	<i>Biddulphia longicuris</i> Greville	v	
		<i>Biddulphia reticulata</i> Roper	v	
Catenulaceae	<i>Amphora</i>	<i>Amphora biggiba</i> Grunow	v	

Table 2. Diatoms recorded in Anping Historical Waterview Park (cont. I)

Families	Genera	Species	Niche types	
			Periphytic	Planktonic
Cocconeidaceae	<i>Cocconeis</i>	<i>Amphora coffeaeformis</i> (C.Agardh) Kützing	v	v
		<i>Amphora sublaevis</i> Hustedt	v	v
	<i>Cocconeis pellucida</i> Hantzsch	v	v	
	<i>Cocconeis placentula</i> Ehrenberg	v	v	
Cymatosiraceae	<i>Campylosira</i>	<i>Cocconeis scutellum</i> var. <i>scutellum</i> Ehrenberg	v	v
		<i>Campylosira cymbelliiformis</i> (A. W.F.Schmidt) Grunow ex Van Heurck	v	
Diploneidaceae	<i>Diploneis</i>	<i>Diploneis oblongella</i> (Nägeli ex Kützing) Cleve-Euler	v	v
Gomphonemataceae	<i>Encyonema</i>	<i>Encyonema minutum</i> (Hilse) D.G.Mann	v	
Licmophoraceae	<i>Licmophora</i>	<i>Licmophora ehrenbergii</i> var. <i>ovata</i> (W.Smith) Van Heurck	v	
Naviculaceae	<i>Gyrosigma</i>	<i>Gyrosigma tenuissimum</i> (W.Smith) J.W.Griffith & Henfrey	v	
Naviculaceae	<i>Haslea</i>	<i>Haslea nautican</i> (Cholnoky) Griffen	v	
		<i>Haslea spicula</i> (Hickie) Bukhtiyarova		v
Naviculaceae	<i>Navicula</i>	<i>Navicula gottlandica</i> Grunow in Van Heurck	v	v
		<i>Navicula perminuta</i> Grunow	v	

Table 2. Diatoms recorded in Anping Historical Waterview Park (cont. II)

Families	Genera	Species	Niche types	
			Periphytic	Planktonic
		<i>Navicula</i> sp.1	v	v
		<i>Navicula torneensis</i> Cleve	v	
		<i>Navicula tripunctata</i> (O.F.Müller) Bory	v	
		<i>Navicula symmetrica</i> R.M.Patrick	v	
Naviculaceae	<i>Seminavis</i>	<i>Seminavis strigosa</i> (Hustedt) Danieleadis & Economou-Amilli	v	v
Plagiotropidaceae	<i>Plagiotropis</i>	<i>Plagiotropis lepidoptera</i> (W.Gregory) Kuntze		v
Pleurosigmataceae	<i>Pleurosigma</i>	<i>Pleurosigma finnarchicum</i> Grunow	v	
		<i>Pleurosigma intermedium</i> W.Smith	v	
Rhoicospheniaceae	<i>Gomphonemopsis</i>	<i>Gomphonemopsis pseudexigua</i> (R.Simonsen) Medlin	v	
Skeletonemataceae	<i>Skeletonema</i>	<i>Skeletonema tropicum</i> Cleve	v	v
Stephanodiscaceae	<i>Cyclotella</i>	<i>Cyclotella meneghiniana</i> Kützing	v	v
Thalassiosiraceae	<i>Thalassiosira</i>	<i>Thalassiosira minima</i> Gaarder	v	v
		<i>Thalassiosira minuscula</i> Krasske	v	
		<i>Thalassiosira tenera</i> Proschkina-Lavrenko		v
		<i>Thalassiosira tealata</i> Takano	v	v

References

- Billore, S. K. and J. K. Sharma. 2009. Treatment performance of artificial floating reed beds in an experimental mesocosm to improve the water quality of river Kshipra. *Water Science and Technology* 60:2851-2859.
- Hoeger, S. 1988. Schwimmkampen: Germany's artificial floating islands. *Journal of Soil and Water Conservation* 43:304-306.
- Li, X., H. L. Song, W. Li, and X. W. Lu and O. Nishimura. 2010. An integrated ecological floating-bed employing plant, freshwater clam and biofilm carrier for purification of eutrophic water. *Ecological engineering* 36:382-390.
- Lin, W. U. 2017. Water quality purification and ecological functions of artificial floating. National Cheng Kung University Master's thesis.
- Nakamura, K., Y. Shimatani, O. Suzuki, S. Oguri and T. Yasumochi. 1995. The ecosystem of artificial floating island in Lake Kasumigaura. *International Conference of lakes in Kasumigaura* 1:56-58.
- Nakamura, K. and G. Mueller. 2008. Review of the performance of the artificial floating island as a restoration tool for aquatic environments. *World Environmental and Water Resources Congress*, May 13-16, 2008, Honolulu, Hawaii. United States. Round F. E., Crawford R. M. and D.D. Mann. 1996. *The diatoms, biological and morphology of the genera*. Published by Cambridge Univ. Press.
- Cunningham, B. G. Kania and M. T. Osterlund. 2008. Floating islands as an alternative to constructed wetlands for treatment of excess nutrients from agricultural and municipal wastes-results of laboratory-scale tests. *Land Contamination and Reclamation* 16:25-34.
- Wu, J. T., B. Babu, C. L. Chou and S. J. Saraswathi. 2011. *Freshwater Diatom Flora of Taiwan*. Biodiversity Research Center, Academia Sinica.
- Zhang, C. B., W. L. Liu, X. C. Pan, M. Guan, S. Y. Liu, Y. Ge and J. Chang. 2014. Comparison of effects of plant and biofilm bacterial community parameters on removal performances of pollutants in floating island systems. *Ecological Engineering* 73:58-63.
- Stewart, F. M., T. Mulholland, A. B.

應用無人機於馬祖大鳳頭燕鷗與瀕危黑嘴端鳳頭燕鷗之巢位調查

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收件日期: 2018 年 5 月 21 日; 接受日期: 2018 年 11 月 26 日

摘要

黑嘴端鳳頭燕鷗 (*Thalasseus bernsteinii*) 是台灣數量最瀕危稀有的海鳥，爲了在不對繁殖燕鷗造成過度干擾的情況下進行調查，本研究在 2017 年於馬祖列島燕鷗保護區中利用旋翼無人機收集島嶼環境資料，並定位島嶼上每一個大鳳頭燕鷗 (*T. bergii*) 與黑嘴端鳳頭燕鷗的繁殖巢位。2017 年的 6 月 8 日透過無人機調查在鐵尖島上共發現 10 個黑嘴端鳳頭燕鷗巢位與 1643 巢大鳳頭燕鷗巢位，並在 7 月 6 日發現 4 個黑嘴端鳳頭燕鷗巢位與 970 巢大鳳頭燕鷗巢位。本研究並利用 generalized linear models 分析島嶼之坡度、高度與植被覆蓋度對兩種燕鷗巢位分布之影響程度。結果發現在地勢較高 (高潮位線 13 公尺以上)、坡度較緩 (25 度以下) 且植被覆蓋率較低 (22% 以下) 的樣區中，有較高機率 (50% 以上) 的大鳳頭燕鷗巢位分布。而且，黑嘴端鳳頭燕鷗偏好在在大鳳頭燕鷗巢位密度較高的區域中繁殖。此外，在距離觀鳥屋較遠的樣區也發現有顯著較高的大鳳頭燕鷗巢位密度，島嶼上的人造物可能對燕鷗巢位偏好有負面影響。整體而言，鐵尖島尚可透過植被整理釋出更多合適空間供燕鷗繁殖，無人機的使用突破了過去在難以抵達的海島上不易調查巢區全貌的限制，可提升海鳥巢區監測的效率與準確度，未來應將無人機視作海鳥調查之重要工具。

關鍵詞: 海鳥保育、群聚繁殖、數值地表模型

Use of unmanned aerial vehicles (UAVs) to census nest site of Greater Crested Tern *Thalasseus bergii* and critically endangered Chinese Crested Tern *Thalasseus bernsteini* in Matsu, Taiwan

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Received: May 21, 2018; Accepted: November 26, 2018

Abstract

The Chinese Crested Tern, *Thalasseus bernsteini* (CCT), is the most critically endangered seabird species in Taiwan. CCT nests sympatrically with the Great Crested Tern, *T. bergii* (GCT), on seven protected islands within the Matsu Island Tern Refuge (MITR). To minimize disturbances during the breeding season, we used Unmanned Aerial Vehicles (UAVs) to locate CCT nests and built digital surface models of the protected islands in the MITR. In 2017, we found 10 CCT nests and 1643 GCT nests on Tiejien Island on 8 June, and another 4 CCT nests and 970 GCT nests on 6 July. We also used generalized linear models to distinguish the effects of elevation, slope, and vegetation coverage on the probability of CCT and GCT nest occurrence. The model indicated that GCT preferred to nest on high (>13 m above high tide line), flat (slope < 25°), and less vegetation cover (< 22%) ground, while CCT preferred to nest within higher GCT nest density areas. In addition, we found that GCT nest density significantly increased with the distance to bird blinds, which may imply a negative impact of human disturbance on the terns' nest site preferences. In conclusion, we found that the removal of more vegetation on Tiejien Island would provide more nesting areas for CCT and GCT colonies. UAVs served as an important tool in improving the accuracy and efficiency of seabird colony and habitat monitoring on hard to reach islands.

Key words: seabird conservation, colonial breeding, digital surface model

前言

遙測 (remote sensing) 技術在生態研究中一直都是個重要工具，利用人造衛星或是飛行載具對地面的觀測影像，可幫助研究人員了解大尺度的氣候變遷到小尺度的動植物分布資訊。但使用人造衛星與飛行具進行遙測研究的限制也相當明顯，一是因距離地面較遠以致影像解析度有限；二是飛行的頻度彈性有限，難以針對個別事件進行監測；另外，在操作與維護上的費用也相當高，非一般研究單位可以負荷 (Berni *et al.* 2009)。隨著科技日新月異，近十年來無人飛行載具 (unmanned aerial vehicles, UAV, 以下簡稱無人機) 的普及已提供了研究者相對較便宜、快速、安全且節省人力的遙測影像取得方式。依據 UAV 的機體設計、動力來源與承載重量, Watts *et al.* (2012) 將其分為四個等級，本研究所討論與使用的無人機主要是第四類載重能力在 5kg 以下的旋翼無人機。固定翼與旋翼無人機的主要差別便是在於飛行速度與靈活度上，固定翼無人機的飛行速度與飛行範圍較旋翼遠，較適合應用在大面積的拍攝或探索任務上。相對的，旋翼無人機雖飛行時間較短，但是在靈活度上高出許多，可垂直起降、懸停觀察為其主要特色。

在野生動物保育與生態資源研究領域中，無人機已被廣泛的利用在生物多樣性評估、群聚物種計數、重點物種偵測、野生動物棲地管理等研究上 (Anderson and Gaston 2013; Chabot and Bird 2015)。而且，可應用的研究物種從大型的哺乳類動物到小型的鳥類皆可適用 (Vermeulen *et al.* 2013; Chabot *et al.* 2015)。舉例來說，Murfit *et al.* (2017) 比較無人機與傳統人力在潮間帶的珊瑚礁調查效率，結果顯示兩種調查方式的準確率並無顯著差

異，且無人機可提供更大面積尺度的地理資訊，對需要在短暫潮汐時間內進行大範圍調查的海岸生態研究而言，無人機非常適用。Hodgson *et al.* (2017) 的研究也指出利用無人機自高空監測在地表活動的野生動物族群，較傳統在地面觀察的準確率高出約 43.96%。Koh and Wich (2012) 以自行設計的固定翼無人機在印尼的熱帶雨林中進行空拍調查，在其 25 分鐘的飛行期間可調查 15 平方公里，交通工具難以穿越的熱帶雨林樣區，並提供解析度小於 10 公分的影像供後續分析，該文作者認為這對地方保育管理機關在監測大型野生動物與森林中的盜獵、盜伐行為上，是一個革命性的新工具。然而，國內目前關於無人機的研究與應用仍著重於系統開發、地形量測與防災領域，尚未有野生動物資源領域之相關研究 (江凱偉, 2015; 饒見有等, 2014)。

台灣目前僅有兩個以海鳥為保育目標的保護區 (馬祖列島燕鷗保護區與澎湖貓嶼海鳥保護區)，過去與保護區相關的研究與計畫多以族群調查、巡護管理與教育宣導為主 (張壽華, 2008; 劉用福, 2008; 社團法人中華民國野鳥學會, 2010; 鄭謙遜, 2012; 陳思穎, 2015; 社團法人台北市野鳥學會, 2017)。馬祖列島燕鷗保護區中有多種保育類燕鷗於此區域繁殖，其中以大鳳頭燕鷗 (*Thalasseus bergii*) 數量為最多 (張壽華, 2008)，並以黑嘴端鳳頭燕鷗 (*Thalasseus bernsteini*) 最為珍稀，估計全球數量僅約 100 隻，名列 IUCN 紅皮書中的極危 (Critically Endangered) 等級物種 (Birdlife International, 2017)。社團法人台北市野鳥學會 (以下簡稱台北鳥會) 自 2008 年起便開始調查馬祖列島燕鷗保護區的燕鷗繁殖族群，每年於燕鷗繁殖季期間 (5-8 月) 每月出海 2 次進行觀察，迄今已累積 10 年的

長期族群監測資料。自 2011 年開始，台北鳥會執行「馬祖列島燕鷗保護區鳳頭燕鷗誘鳥計畫」，每年皆以假鳥模型吸引上述兩種鳳頭燕鷗進駐特定島嶼繁殖，但綜觀誘鳥計畫執行以來，歷年曾發生過數次棄巢事件，受限於不易觀察，目前仍無法判斷原因為何（社團法人台北市野鳥學會，2017）。

由於燕鷗生性敏感，繁殖期間若研究員登上島礁進入巢區，會使燕鷗驚飛離巢，為避免干擾，過去 10 年來進行燕鷗族群調查之方法都是租用漁船繞行燕鷗繁殖島嶼，以群集計數法方式估計在島上活動的燕鷗族群數量（社團法人台北市野鳥學會，2017）。然而燕鷗習性多偏好於無人島礁頂端群聚繁殖（林于凱，2007），以繞島計數的方式必定會受限於視角而有所低估，亦無法確認其繁殖族群數量或巢數。一般而言，若欲了解燕鷗繁殖族群之數量，較準確的調查方式應是進入巢區後計數地面巢數（Walsh *et al.* 1995），卻難免對鳥群造成驚擾。為了在不過度干擾燕鷗繁殖的情況下蒐集必要資料，本研究在馬祖列島燕鷗保護區中利用無人機於島嶼上空拍攝燕鷗繁殖族群，並記錄島嶼環境資料如坡度、高度與植被覆蓋度。後續透過空拍圖資計數並定位每一個大鳳頭燕鷗與黑嘴端鳳頭燕鷗的繁殖巢位，並與環境資料對比以得知其巢位分布偏好，以利未來保護區管理單位擬訂更完整的棲地經營管理策略。

研究材料與方法

1. 研究樣區與物種

馬祖列島燕鷗保護區成立於 2000 年，保護區範圍涵蓋東引鄉之雙子礁，北竿鄉之三連嶼、中島、鐵尖、白廟、進嶼，南竿鄉之瀏泉礁，與莒光鄉蛇山共 8 座島嶼（圖 1）。8 座島嶼均為孤立於各鄉外之無人島嶼，主要保護目標為於此地繁殖的大鳳頭燕鷗、白眉燕鷗（*Onychoprion anaethetus*）、紅燕鷗（*S. dougallii*）、蒼燕鷗（*S. sumatrana*）、黑尾鷗（*Larus crassirostris*）、岩鷺（*Egretta sacra*）與叉尾雨燕（*Apus pacificus*）。

大鳳頭燕鷗主要分布在熱帶與亞熱帶舊大陸的沿海地區，在台灣為夏候鳥，僅在離島地區如馬祖、澎湖與金門有繁殖紀錄，每年約在四月至五月間抵達繁殖地，結群於無人島上開始群聚生殖（colonial breeding），並在八至九月間離去（張壽華，2008；鄭謙遜，2012）。黑嘴端鳳頭燕鷗為極度瀕危之鳥種，2009 年估計其世界族群量僅 50 隻（Chen *et al.* 2009）。目前僅確認台灣馬祖、澎湖、浙江伍峙山與韭山列島與南韓為其繁殖地（Chen *et al.* 2015；Song *et al.* 2017）。自 2000 年發現以來，在馬祖的族群數量在 1-20 之間（張壽華 2008；台北市野鳥學會，2017）。

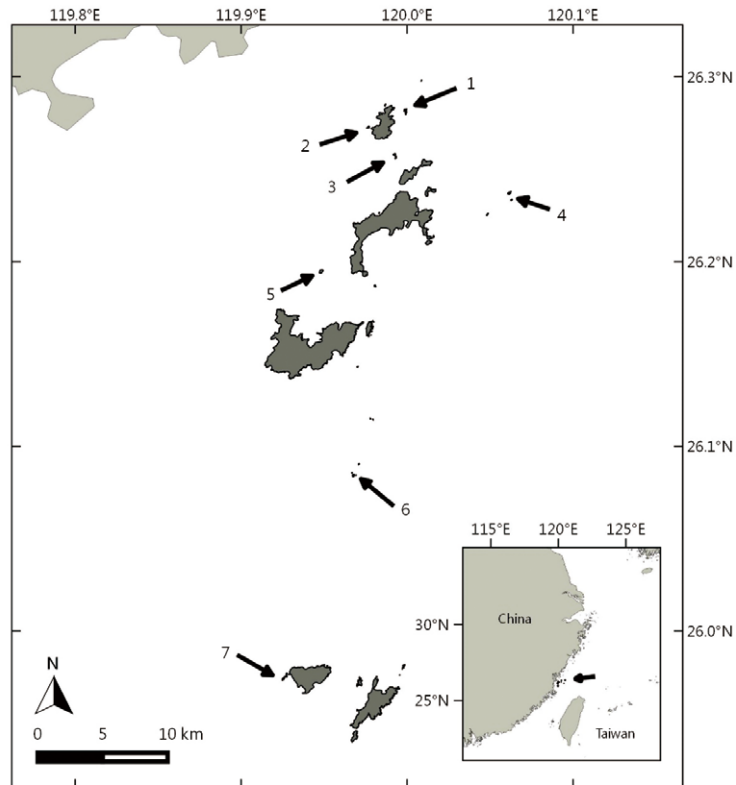


圖 1. 馬祖列島燕鷗保護區各島嶼位置 (雙子礁位於東引鄉, 未列於本圖), 7 座島嶼依序為 1. 白廟、2. 鐵尖、3. 中島、4. 三連嶼、5. 進嶼、6. 瀏泉礁、7. 蛇山。

Fig. 1. Locations of the seven protected islands in the Matsu Island Terns Refuge (The Twin reefs located in Dongyin township were not included in this figure): 1. Baimao, 2. Tiejien, 3. Zhongdao, 4. Sanlianyu, 5. Jinyu, 6. Liuquanjiao, 7. Sheshan.

2. 無人機調查

本研究所選用之無人機型號為 DJI Mavic Pro (Dà-Ji ā ng Innovations Science and Technology Co., Ltd) 摺疊型四旋翼無人機，不含旋翼與旋臂之機體大小為 83×83×198 mm。2017 年研究人員於 6 月 8 日、7 月 6 日與 9 月 22 日至馬祖列島燕鷗保護區內操作無人機進行燕鷗繁殖族群調查，在距離燕鷗繁殖巢區 100 公尺以上距離外施放無人機升空，起飛後垂直上升至海拔高度 50 公尺 (島高約 15 公尺，無人機距離巢區約 35 公尺)，再以每秒 4 公尺的速度，水平移動前往繁殖巢區上方攝影。6 月與 7 月之調查任務為建立燕鷗繁殖巢區之完整影像，僅拍攝鐵尖島頂端之燕鷗繁殖區域，9 月之調查任務為利用影像建立全島立體模型，使用手機 app 軟體 DroneDeploy 控制無人機的飛行路徑，在海拔高度 50 公尺處每 2 秒以 28mm 焦段鏡頭垂直向下拍攝一張影像，影像解析度為 4000×3000 像素，以正向 80%，側項 70% 影像重疊率拍攝整座島嶼，每次的拍攝時間因電力限制皆控制在 20 分鐘以內。

3. 資料處理與統計分析

使用軟體 ContextCapture (Bentley Systems Inc.) 判讀無人機空拍影像之坐標資訊 (WGS 84 經緯度坐標系統標示) 及相機資訊後，以 Scale-invariant feature transform 演算方法自動匹配大量特徵點，並透過攝影測量的原理，恢復各影像之間相對關係。同時，軟體也將坐標資訊及相機資訊作為幾何約制條件，使自動匹配成果之比例尺、坐標等均與真實世界之比例尺、坐標值接近，並產出島嶼之數值地表模型 (Digital Surface Model) 及真實正射影像 (True Ortho)，使用之坐標系統為 TWD97。另由於本研究並未將數值地表模型修正至真實高程系統，故模型中的高度資料為相對性的數值 (橢球高系統)。

在正射影像中可藉由燕鷗體羽顏色的差異分辨大鳳頭燕鷗與黑嘴端鳳頭燕鷗，本研究透過人工檢視的方式判斷影像中的燕鷗位置，並將拍攝期間在島嶼頂端巢區中位置未明顯移動的個體位置定義為巢位，同時也紀錄巢區中明顯無親鳥照護的棄蛋，棄蛋與巢位的位置均使用軟體 QGIS 2.18.15 (QGIS Development Team 2017) 予以定位。在燕鷗巢位偏好的分析中，考量到燕鷗不會利用島嶼上受潮汐淹沒的區域，本研究之研究樣區設定在鐵尖島上高潮位以上之區域 (由正射影像判視礁岩上無明顯浸淹痕跡之區域)，並透過 QGIS 將該區域劃分為 6,796 個 1 m×1 m 的樣區。每樣區之平均高度與坡度值均由島嶼之數值地表模型推算而來，並將高度定義為該樣區與高潮位線之垂直距離 (m)。植被覆蓋度則是透過正射影像判視植群面積在每個樣區中的比例 (%)，由於 2017 年在鐵尖島上觀察到以觀測屋為中心明顯分隔的 2 個繁殖群落 (colony)，故植被覆蓋比例是依照該繁殖群落存在的同時期影像作為判視標準，亦即北面的繁殖群落以 6 月 8 日的影像、南面的繁殖群落以 7 月 6 日的影像判視樣區內的植被覆蓋度。另外，為了解人造建築對燕鷗的影響，也透過正射影像量測每樣區中心點與島上人造觀鳥屋的直線距離。

為了解島嶼之自然地形地貌特徵 (不含人造物) 對大鳳頭燕鷗巢位分布之影響，本研究使用 Generalized linear models (GLM) 建立大鳳頭燕鷗巢位分布之預測模式，資料設定為二項分布 (binary distribution, 0 = 無巢位, 1 = 有巢位)，樣區的平均高度、坡度與植被覆蓋度為預測因子。在全島 6,796 個樣區中，有大鳳頭燕鷗巢位分布的樣區共有 461 個，另採用隨機取樣的方式在研究範圍中選取出 461 個沒有大鳳頭燕鷗巢位的樣區加入分析。另外，為了解地形特徵與人造物的位置對大鳳頭燕鷗巢位密度的影響，在 461 個有大鳳頭

燕鷗巢位出現的樣區中，採用 linear regression 分析樣區的平均地面高度、坡度、植被覆蓋度與觀鳥屋距離共四項因子，與樣區中的燕鷗巢位密度 (巢/m²) 關係。

黑嘴端鳳頭燕鷗的巢位偏好分析採用同樣方式，依據其與大鳳頭燕鷗共域繁殖的習性，在 461 個有大鳳頭燕鷗巢位出現的樣區中，隨機挑選 12 個無黑嘴端鳳頭燕鷗巢位的樣區與 12 個確認有黑嘴端鳳頭燕鷗巢位分布的樣區。採用 GLM 分析樣區內平均地面高度、坡度、植被覆蓋度、觀鳥屋距離與大鳳頭燕鷗巢密度，對樣區中黑嘴端鳳頭燕鷗巢位出現機率的影響程度，資料設定為二項分布 (binary distribution, 0 = 無巢位, 1 = 有巢位)。

在兩種燕鷗的巢位預測模式中，以預測值 0.5 作為分界，大於 0.5 為有巢位，小於 0.5 為無巢位的樣區，逐樣區比對預測結果與實際資料後，依照比對結果驗證預測模式的準確率 (正確預測數量 / 模式中全部樣區數量)。

另外，為了解黑嘴端鳳頭燕鷗巢位環境

與其是否成功孵化的關係，本研究也比較失敗與成功巢位周圍 1 公尺內的大鳳頭燕鷗巢數、平均地表高度、坡度與植被覆蓋率是否有顯著之差異。統計分析均是在軟體 R 1.0.136 (R Core Team 2017) 中操作。

結果

2017 年 6 月 8 日的無人機調查發現在鐵尖島嶼北端有 1,643 巢大鳳頭燕鷗，11 巢黑嘴端鳳頭燕鷗 (其中一巢由後續地面調查確認為誤判)；7 月 6 日的調查發現在南端有 970 巢大鳳頭燕鷗，4 巢黑嘴端鳳頭燕鷗，同時也在北端巢區地面發現有 346 顆棄蛋 (圖 2)。9 月 22 日的無人機調查也在鐵尖島南端巢區發現有 318 顆棄蛋，由於當時島上已無燕鷗活動，同日研究人員登上鐵尖島檢視巢區狀況，透過地面計數方式共發現有北端 162 顆棄蛋、南端 346 顆棄蛋。與無人機的調查結果相比，北面巢區棄蛋的計數與 7 月 6 日的無人機計數結果差距較大，但南面棄蛋的計數結果差距僅有 8%。

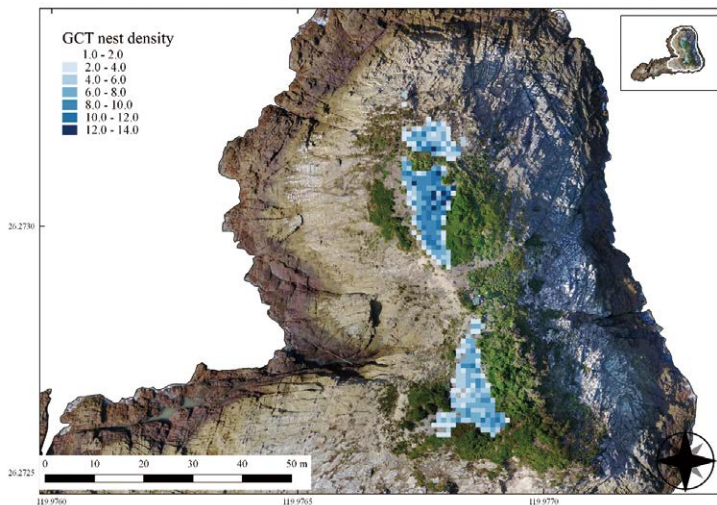


圖 2. 鐵尖島上各樣區中的大鳳頭燕鷗巢位密度 (巢/m²)，菱形圖表示觀鳥屋之位置。

Fig. 2. Nest densities (nest per m²) of Greater Crested Tern on the Tiejien Island, the rhombus indicates the location of the bird blind.

在大鳳頭燕鷗巢位分布的預測模式中，樣區之高度、植被覆蓋度與坡度都對巢位出現機率有顯著之影響，且模式的預測準確率達 93.9%(表 1)。三項因子的各別模式分析中，以地面高度對大鳳頭燕鷗巢位分布機率的預測準確率最高 (91.2%)、坡度次之 (80.9%)、植被覆蓋度最低 (51.7%)。以 50% 巢位分布機率為分水嶺，可得知高度約在 13 公尺以上、坡度約 25 度以下、植被覆蓋度 22% 以下的樣區中有較高的分布機率 (圖 3)，主要分布在島嶼北側與南側頂端且坡度較為平緩的位置 (圖 4，圖 5)。

表 1. 研究範圍內各樣區中大鳳頭燕鷗巢位的分布機率在 GLM 中與各項環境因子之關係

(n = 922, 截距 = -12.848, Cox & Snell $R^2 = 0.66$)

Table 1. The result of GLM explaining nest occurrence probabilities of the Greater Crested Tern in each site on Tiejien Island by each factor

(n = 922, intercept = -12.848, Cox & Snell $R^2 = 0.66$).

Factors	Estimate	S.E.	Odds ratio	95% CI	p value
Relative Height (m)	1.258	0.136	3.519	2.692–4.599	<0.001
Vegetation Coverage (%)	-0.046	0.020	0.956	0.946–0.966	<0.001
Slope (°)	-0.045	0.005	0.955	0.917–0.993	0.022

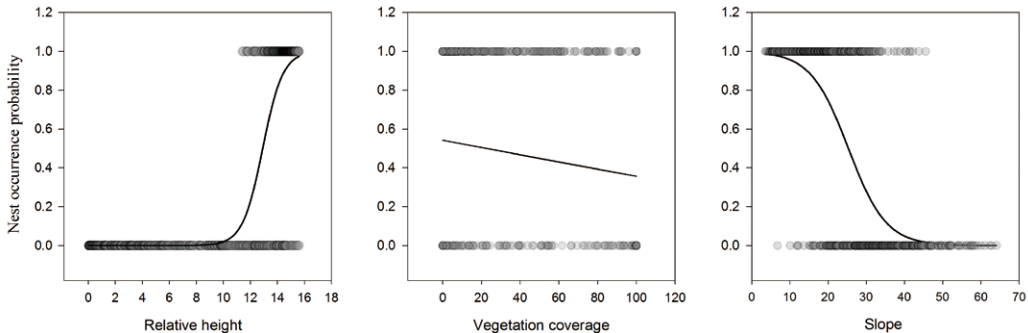


圖 3. 各樣區中的大鳳頭燕鷗巢位實際分布機率 (圓點, n = 922) 與 GLM 分析中以 (a) 相對地面高度 (m)、(b) 植被覆蓋度 (%) 與 (c) 坡度預測之大鳳頭燕鷗巢位分布機率 (曲線)。各預測模式之 Cox & Snell R^2 值與預測準確率如下: (a) 0.60, 91.2% (b) 0.16, 51.7%; (c) 0.45, 80.9%

Fig. 3. The values of Greater Crest Tern nest occurrence probability in each sample site (dots, n = 922) and predicted values by (a) relative height (m), (b) vegetation coverage (%) and (c) slope (°) in GLM (lines). The Cox & Snell R^2 and predicted accuracy for each model were as follows: (a) 0.60, 91.2% (b) 0.16, 51.7%; (c) 0.45, 80.9%

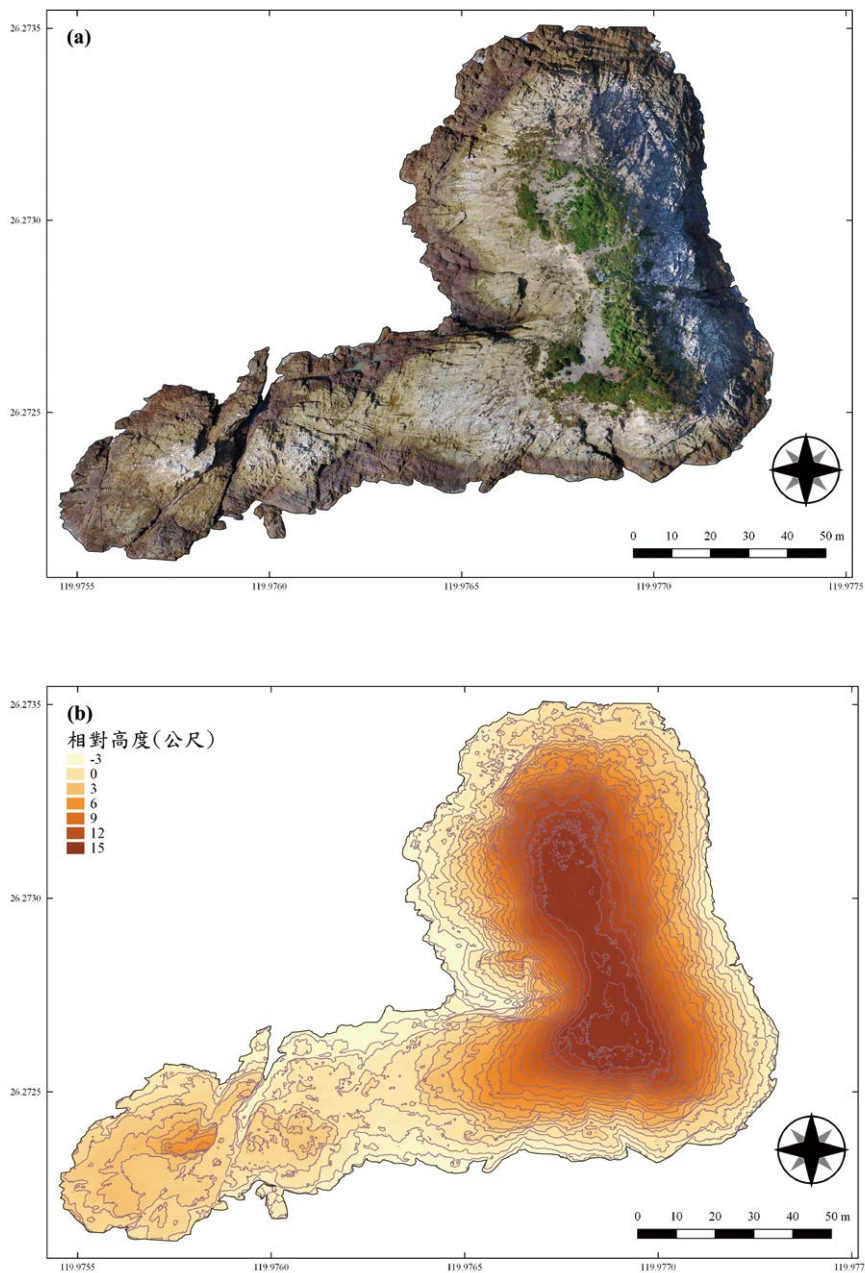


圖 4. 鐵尖島的真實正射影像 (a) 與數值地表模型及 1 公尺等高線圖 (b)。

Fig. 4. The true orthoimage (a) and digital surface model with 1 m elevation contour lines (b) of Tiejien Island.

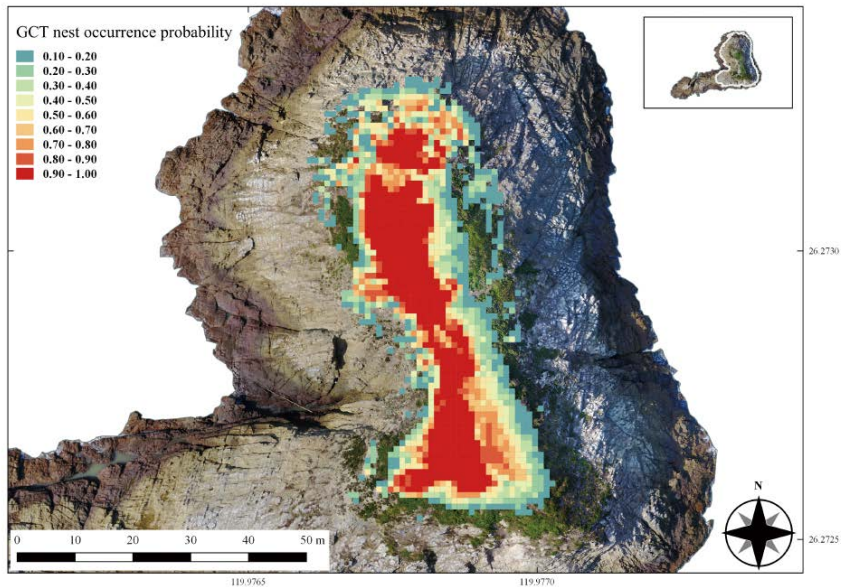


圖 5. 鐵尖島上各樣區依據大鳳頭燕鷗巢位分布機率之模式預測結果。

Fig. 5. Greater Crested Tern nest occurrence probability plot for Tiejien Island.

在大鳳頭燕鷗巢位密度的線性模式分析中，地面高度與植被覆蓋度對巢位密度都有顯著之影響 (表 2)。然而，坡度之影響程度未達顯著水準，且在模式中顯示樣區與觀鳥屋的距離對巢位密度有顯著之負面影響。此外，在黑嘴端鳳頭燕鷗的巢位分布預測模式分析中，模式之預測準確率達 75%，僅大鳳頭燕鷗的巢位密度對黑嘴端鳳頭燕鷗巢位的出現機率有正面的顯著影響 (odd ratio = 1.517, 95% CI = 1.064–2.154, $p = 0.021$)。14 巢黑嘴端鳳頭燕鷗中有 6 巢成功孵化，但在各樣環境因子的分析中並未發現對繁殖成功率有顯著影響。

表 2. 大鳳頭燕鷗巢位密度 (巢 / 平方公尺) 與各項環境因子之關係 ($n = 461$)，線性回歸式之截距 = -25.32, $R^2 = 0.352$

Table 2. Linear relationships of nest densities (nest per m^2) of Greater Crested Tern and each factor ($n = 461$), intercept = -25.32, $R^2 = 0.352$

Factors	Estimate	S.E.	p value
Relative Height (m)	2.051	0.257	< 0.001
Vegetation coverage (%)	-0.067	0.005	< 0.001
Distance to blind (m)	0.094	0.019	< 0.001
Slope (°)	0.019	0.018	0.29

討論

由於本研究中無人機並未針對停棲在巢區周圍或島嶼下方的燕鷗進行拍攝，2017年6月8日巢位計數的結果(1,643巢)與該次海面觀察結果(3,000隻個體)相較，若以每一巢有兩隻親鳥作估計(1643 \times 2=3286)，則觀察結果相近。根據Hodgson *et al.* (2016)在澳洲Macquarie Island上比較無人機與地面利用望遠鏡觀察大鳳頭燕鷗族群量的結果，作者認為兩方法的誤差比例應在10%以內，未來應再進行更完整的拍攝以比對無人機與海面觀測兩種方法在海鳥數量調查上的差異。在黑嘴端鳳頭燕鷗的調查結果中，後續登島觀察發現無人機在6月8日觀察到的11個巢位有10巢確認為繁殖中之巢位，可視作21隻個體，與海面觀察的結果(16隻)相較誤差約為23.8%，過去以海面觀察方式進行族群估計可能低估其實際族群量。海面觀察在視角上的限制對馬祖燕鷗調查一直是主要的誤差來源，藉由觀察在島嶼周圍活動的個體也無法得知實際參與繁殖的個體數量，以無人機直接進行巢位的確認應是目前干擾程度較低、準確率最高的方式。在棄蛋的計數結果中，9月22日無人機在南面巢區的計算結果與地面計數結果相近，但北面巢區的棄蛋可能在7月6日至9月22日之間因海風的吹襲或燕鷗踩踏而破碎或滾落，而與無人機計算結果有較大的差距。未來應在發現棄巢後立刻以無人機進行拍攝，以有助於了解棄蛋數量、分布與環境概況以利後續分析。

關於燕鷗驚飛距離，2017年進行拍攝時巢區中已有近千巢以上燕鷗，當時無人機可接近至10公尺左右方才有燕鷗驚飛情形。但是，2018年燕鷗選擇在另一座較小的島嶼上繁殖，巢區內僅有約100巢燕鷗，無人機在30公尺高空拍攝時便發現燕鷗有驚飛情形。Vas *et al.* (2015)建議無人機的起飛距離至少

要離鳥群100公尺以上，但接近鳥群而不造成干擾的最小距離則依鳥種而異。初步判斷本研究中的燕鷗的驚飛距離可能與其族群量或繁殖階段有關，未來應再進行相關測試以釐清此問題。

在大鳳頭燕鷗巢位分布模式中顯示，島嶼上坡度較緩、植被覆蓋度低且高度較高的位置有較高的機率被大鳳頭燕鷗使用，與林于凱(2007)在澎湖小白沙嶼上的調查結果相似。若視50%以上巢位分布機率之樣區為合適的繁殖棲地，鐵尖島上約有888平方公尺的區域適合燕鷗繁殖利用，配合巢位密度之模式推估結果，理論上可乘載約3,732巢燕鷗(可視作7,464隻個體)。除此之外，鐵尖島尚有許多低分布機率(20–50%)的樣區可透過植被移除與整地的方式提高其利用機率，參考2000年來馬祖列島燕鷗保護區中大鳳頭燕鷗的族群調查資料(介於590–4,600隻個體之間，張壽華2008；台北市野鳥學會，2017)，目前鐵尖島上的理論承載量應高於大鳳頭燕鷗的歷史最大族群量。然而，此一理論值是以燕鷗同時進駐並利用島嶼上所有合適之樣區進行估計，但2017年燕鷗的巢區明顯以觀測屋為中心分為南北兩繁殖群落，而且樣區與觀測屋的距離對大鳳頭燕鷗巢位密度也有顯著之正面影響，顯示燕鷗偏好在遠離觀測屋的位置築巢。此觀測屋興建於2017年春季，選址之依據是參考過往觀察經驗，挑選在燕鷗較少利用且適合觀察整個巢區的位置，但可能因繁殖季期間研究人員在觀測屋的進出與活動仍對燕鷗造成驚擾，而使燕鷗偏好在遠離觀測屋的位置繁殖。假設未來燕鷗之繁殖群落皆是以南北兩巢區擇一進駐繁殖的情形，參考目前模式預測之合適樣區(50%以上分布機率)中的巢位密度預測值推算並扣除觀測屋位置，北面樣區可乘載約2,189巢、南面樣區可乘載約1,538巢，則兩個巢區的理論乘載都低於歷年大鳳頭燕鷗之最大族群量，且

以南面巢區的承載量較低。針對此一現象，建議未來棲地經管對策有三：1. 將觀測屋移動至島嶼南北兩端，以避免將巢區切割為二的情形；2. 拓展南北兩巢區之合適繁殖地面積，透過修整植被或填土、覆土等方式降低地面坡度與植被覆蓋度；3. 架設掩蔽廊道將人員進出觀測屋的路線遮蔽，並加強觀測屋四周的掩蔽，避免人為活動驚擾燕鷗。

在本研究中發現黑嘴端鳳頭燕鷗偏好出現在大鳳頭燕鷗巢位密度較高的核心樣區，可能暗示黑嘴端鳳頭燕鷗將大鳳頭燕鷗視為繁殖棲地品質的參考指標，或是藉由群體禦敵行為獲得較佳的保護，在其他的海鳥、水鳥中也有許多類似的案例 (Burger, 1981; Erwin, 1979; Nuechterlein, 1981)。在許多文獻中也指出，群聚繁殖的海鳥在巢位密度較高的核心區域中，巢蛋或幼鳥被天敵捕食的機率較低 (Coulson 1968; Savoca *et al.* 2011; Kazama *et al.* 2011)，占據較好的棲地 (在群落中心或地勢較高、視野較好的位置) 築巢的個體通常能獲得較佳的繁殖成功 (Kokko *et al.*, 2004)。然而，2017 年發現的 14 巢黑嘴端鳳頭燕鷗僅有 6 巢成功孵化，在繁殖成功率與環境因子的分析中也未發現顯著之關聯性，樣本數的不足可能是主要原因，未來應持續收集巢位資料釐清影響繁殖成功率之重要因素。2017 年 7 至 8 月間馬祖當地鳥友曾多次觀察到遊隼在鐵尖嶼活動並捕食燕鷗幼鳥，對島上的燕鷗造成嚴重之驚擾。雖然沒有直接證據顯示遊隼捕食黑嘴端鳳頭燕鷗，但在 2017 發現的 14 巢黑嘴端鳳頭燕鷗中，僅有一隻幼鳥成功存活至飛行階段，繁殖成功率非常低，未來應針對每一個巢位進行嚴密之監測以釐清其繁殖失敗原因。另外，根據 Chen *et al.* (2011) 在大陸浙江五峙山與韭山列島的研究結果，6 巢黑嘴端鳳頭燕鷗中有 5 巢與大鳳頭燕鷗混群繁殖，6 巢都是位於坡度低於 30%、低植被覆蓋度的位置，與本研究結

果相似。但該研究中作者認為黑嘴端鳳頭燕鷗的巢位是隨機分布於大鳳頭燕鷗繁殖群落中，且巢位彼此並不相鄰 (距離至少 15 公尺以上)，與本研究發現有 8 巢黑嘴端鳳頭燕鷗位於鄰近樣區的結果不同。此一現象可能與繁殖地的黑嘴端鳳頭燕鷗族群量與棲地環境差異有關，在 Chen *et al.* (2011) 的研究中，2004–2009 年間在同一巢區中發現的黑嘴端鳳頭燕鷗最多僅有 2 巢，可能因族群數量太少而無法建立同種的繁殖群落。

整體而言，黑嘴端鳳頭燕鷗混群於大鳳頭燕鷗之中且偏好在大鳳頭燕鷗巢位密度較高的樣區繁殖，而樣區的高度、坡度與植被覆蓋度對大鳳頭燕鷗巢位的分部有重要影響。目前馬祖列島燕鷗保護區以模型假鳥吸引大鳳頭燕鷗與黑嘴端鳳頭燕鷗進駐人為營造棲地的經營管理方針應是正確之方向，但在黑嘴端鳳頭燕鷗數量仍處於瀕危之現況下，建議應持續進行繁殖季前的棲地營造並強化繁殖期間的監控與管理工作以改善現況。觀測屋的存在雖然對燕鷗繁殖棲地的選擇有負面影響，但在保育研究需要更具科學性的數據收集以及近距離觀察的前提下，本研究建議應維持觀測屋的位置，透過架設遮蔽廊道以及拓展更多合適繁殖棲地的方法以確保鐵尖島上的繁殖棲地足夠燕鷗繁殖。

本研究利用無人機在燕鷗繁殖季期間於馬祖列島燕鷗保護區收集相關圖資，突破過去僅能於海面上進行觀察的限制，並可獲得準確的燕鷗巢位數量與分布資訊。以本研究收集的 4K 影像而言，影像解析度已足夠在距離巢區約 35 公尺的空中計數燕鷗的數量並分辨種類，未來無人機的影像解析度若可再獲提升，應可在更遠的距離外監測島嶼上的鳥類與環境，可應用的監測範圍與研究題材將會更廣。建議未來應將把無人機作為海鳥例行調查之必備工具，在不干擾燕鷗繁殖情形下，收集足夠的影像資訊以監控海鳥繁殖概

況。但必須注意的是，2018年4月法院已通過「民用航空法」部分條文修正案，使用重量250公克以上的無人機，需向民航局辦理註冊與操作證，且不得在禁航區、限航區及航空站飛行場四周操作無人機，研究人員在使用無人機前應先辦理相關程序並注意研究樣區是否位於禁航區內。

繁殖棲地的適合度參數也可應用於評估其他島嶼適合燕鷗繁殖之棲地面積與位置，相關之研究方法也可應用於其他於海島上繁殖的海鳥，無人機之使用應有助於提升海鳥繁殖族群調查準確率與效率，並提供更多資訊於主管單位對各種保育類海鳥繁殖地的經營管理策略。

謝誌

感謝連江縣政府與科技部長年補助本研究，並感謝林務局農林航空測量所謝幸宜技士、黃宗仁技士提供之技術指導。

參考文獻

- Anderson, K., and K. J. Gaston. 2013. Lightweight unmanned aerial vehicles will revolutionize spatial ecology. *Frontiers in Ecology and the Environment* 11:138-146.
- Berni, J. A., P. J. Zarco-Tejada, L. Suárez, and E. Fereres. 2009. Thermal and narrowband multispectral remote sensing for vegetation monitoring from an unmanned aerial vehicle. *IEEE Transactions on Geoscience and Remote Sensing* 47:722-738.
- BirdLife International. 2017. *Thalasseus bernsteini* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2017: e.T22694585A118862671. Downloaded on 05 May 2018.
- Burger, J. 1981. A Model for the Evolution of Mixed-Species Colonies of Ciconiiformes. *The Quarterly Review of Biology*, 56(2), 143-167.
- Chabot, D., and D. M. Bird. 2015. Wildlife research and management methods in the 21st century: Where do unmanned aircraft fit in? *Journal of Unmanned Vehicle Systems* 3:137-155.
- Chabot, D., S. R. Craik, and D. M. Bird. 2015. Population census of a large common tern colony with a small unmanned aircraft. *PLoS One* 10:e0122588.
- Chen, S. H., Z. Y. Fan, C. S. Chen, and Y. W. Lu. 2011. The breeding biology of chinese crested terns in mixed species colonies in eastern China. *Bird Conservation International* 21:266-273.
- Chen, S., S.H. Chang, Y. Liu, S. Chan, Z. Fan, C. Chen, C.W. Yen, and D. Guo. 2009. A small population and severe threats: status of the critically endangered chinese crested tern *Sterna bernsteini*. *Oryx* 43.
- Chen, S., Z. Fan, D. D. Roby, Y. Lu, C. Chen, Q. Huang, L. Cheng, and J. Zhu. 2015. Human harvest, climate change and their synergistic effects drove the chinese crested tern to the brink of extinction. *Global Ecology and Conservation* 4:137-145.
- Coulson, J. 1968. Differences in the quality of birds nesting in the centre and on the edges of a colony. *Nature* 217:478-479.
- Croxall, J. P., S. H. M. Butchart, B. E. N. Lascelles, A. J. Stattersfield, B. E. N.

- Sullivan, A. Symes, and P. Taylor. 2012. Seabird conservation status, threats and priority actions: a global assessment. *Bird Conservation International* 22:1-34.
- Erwin, R. M. 1979. Species interactions in a mixed colony of common terns (*Sterna hirundo*) and black skimmers (*Rynchops niger*). *Animal Behaviour*, 27, 1054–1062.
- Hodgson, J. C., R. Mott, S. M. Baylis, T. T. Pham, S. Wotherspoon, A. D. Kilpatrick, R. Raja Segaran, I. Reid, A. Terauds, and L. P. Koh. 2017. Drones count wildlife more accurately and precisely than humans. *Methods in Ecology and Evolution*.
- Hodgson, J. C., S. M. Baylis, R. Mott, A. Herrod, and R. H. Clarke. 2016. Precision wildlife monitoring using unmanned aerial vehicles. *Scientific reports* 6:22574.
- Kazama, K., Y. Niizuma, K. Q. Sakamoto, and Y. Watanuki. 2011. Factors affecting individual variation in nest-defense intensity in colonially breeding black-tailed gulls (*Larus crassirostris*). *Canadian Journal of Zoology* 89:938-944.
- Kokko, H., M. P. Harris, and S. Wanless. 2004. Competition for breeding sites and site-dependent population regulation in a highly colonial seabird, the common guillemot *Uria aalge*. *Journal of Animal Ecology*, 73(2), 367–376.
- Koh, L. P., and S. A. Wich. 2012. Dawn of drone ecology: low-cost autonomous aerial vehicles for conservation. *Tropical Conservation Science* 5:121-132.
- Murfitt, S. L., B. M. Allan, A. Bellgrove, A. Rattray, M. A. Young, and D. Ierodiaconou. 2017. Applications of unmanned aerial vehicles in intertidal reef monitoring. *Scientific reports* 7:10259.
- Nuechterlein, G. L. 1981. ‘Information parasitism’ in mixed colonies of western grebes and Forster’s terns. *Animal Behaviour*, 29(4), 985–989.
- Savoca, M. S., D. N. Bonter, B. Zuckerberg, J. L. Dickinson, and J. C. Ellis. 2011. Nesting density is an important factor affecting chick growth and survival in the herring gull. *The Condor* 113:565-571.
- Song, S.K., S. W. Lee, Y. K. Lee, S. Y. Lee, C. H. Kim, S. S. Choi, H. C. Shin, J. Y. Park, J. H. Lee, and W.-Y. Kim. 2017. First report and breeding record of the chinese crested tern *Thalasseus bernsteini* on the Korean Peninsula. *Journal of Asia-Pacific Biodiversity* 10: 250-253.
- Vas, E., A. Lescroël, O. Duriez, G. Boguszewski, and D. Grémillet. 2015. Approaching birds with drones: first experiments and ethical guidelines. *Biology Letters* 11.
- Vermeulen, C., P. Lejeune, J. Lisein, P. Sawadogo, and P. Bouché. 2013. Unmanned aerial survey of elephants. *PLoS One* 8:e54700.
- Walsh, P., D. Halley, M. Harris, A. Del Nevo, I. Sim, and M. Tasker. 1995. Seabird monitoring handbook for Britain and Ireland: a compilation of methods for survey and monitoring of breeding seabirds. JNCC/RSPB/ITE/Seabird Group. Peterborough.
- Watts, A. C., V. G. Ambrosia, and E. A. Hinkley. 2012. Unmanned aircraft systems in remote sensing and scientific research: classification

and considerations of use. *Remote Sensing* 4:1671-1692.

林于凱。2007。澎湖小白沙嶼三種燕鷗巢位選擇與孵化成功之研究。國立中山大學生物科學系研究所碩士論文。

林信宇。2015。無人機於重劃區調查應用之研究。健行科技大學土木工程系空間資訊與防災科技碩士班學位論文。

社團法人中華民國野鳥學會。2010。馬祖列島燕鷗保護區內野鼠調查計畫。連江縣政府委託計畫期末報告。

社團法人台北市野鳥學會。2017。2017年馬祖列島燕鷗保護區經營管理計畫成果報告書。連江縣政府。

張壽華。2008。馬祖地區鳥類資源暨其生態旅遊之研究。臺灣海洋大學環境生物與漁業科學研究所碩士論文。

陳思穎。2015。賞鳥距離限制對遊客之影響：以馬祖列島燕鷗保護區生態賞鳥之旅為例。南華大學旅遊管理學系旅遊管理碩士論文。

劉用福。2008。馬祖列島燕鷗保護區經營管理之研究。臺灣海洋大學環境生物與漁業科學研究所碩士論文。

鄭謙遜。2012。澎湖縣貓嶼及自然保留區鳥類資源調查成果報告書。澎湖縣政府農漁局。

饒見有，陳智揚，詹鈞評，劉暹，李文慶。2014。無人機攝影測量與直接地理定位之精度分析。國土測繪與空間資訊 2:1-22。

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