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Geographic Range Shifts of Taiwan's Endemic Plant Species *Prunus transarisanensis* under Climate Change

氣候變遷下臺灣特有植物阿里山櫻花 (*Prunus transarisanensis*) 的地理分布變化

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Abstract

Climate change is driving shifts in the species distribution, and its impact is particularly pronounced on high mountain plants sensitive to warming. *Prunus transarisanensis* is an endemic species found exclusively in the high-altitude regions of Taiwan, known for its ornamental cherry tree. In this study, species survey records and environmental data were integrated, and ensemble ecological niche modeling was employed to predict the current and future suitable habitats, as well as their spatiotemporal dynamics for *P. transarisanensis* under various climate scenarios (shared socioeconomic pathways SSP126, SSP370, SSP585, 2071-2100). The model identified that a cool environment and moderate precipitation are key characteristics for suitable habitats of *P. transarisanensis*. In the analysis of the dynamics of suitable habitat distribution under three future scenarios, it was found that climate change will transform a significant portion of the currently suitable habitats into vulnerable states, regardless of the scenario. Even under the low emission scenario (SSP126), only a small portion of suitable habitat may persist as refugia. However, under the SSP370 or SSP585 scenarios, habitat degradation will be more severe, potentially leading to a high risk of extinction for the species. Based on the above results, this study proposes several suggestions to assist *P. transarisanensis* to adapt to climate change.

Key words: range dynamics, ensemble ecological niche modeling, shared socioeconomic pathways, extinction, conservation

摘要

氣候變遷正在驅使生物的地理分布發生改變，對暖化敏感的高山植物而言，其影響尤為顯著。阿里山櫻花 (*Prunus transarisanensis*) 分布於臺灣高海拔地區，是一種具觀賞價值的特有種櫻花。本研究整合物種調查及環境資料，運用集成生態棲位建模，預測當前和未來氣候情境 (共享社會經濟路徑 SSP126、SSP370、SSP585，2071-2100 年) 下，該物種之適宜生育地範圍及其時空分布動態。由所建構的集成模型可發現，冷涼環境與適度降水，是阿里山櫻花適宜生育地的關鍵特徵。未來 3 種情境下的適宜生育地分布動態分析結果顯示，無論何種情境，氣候變遷都將導致當前適宜生育地，大幅轉為脆弱狀態，即便是低碳排的 SSP126 情境下，也僅能保存少部分適宜生育地，供作避難所，而在 SSP370 或 SSP585

情境下，生育地退化情況將更顯嚴峻，最終可能導致該物種面臨高度滅絕風險。綜合上述推測結果，本研究最後也提出了幾點協助阿里山櫻花調適氣候變遷的建議。

關鍵詞：分布動態、集成生態棲位建模、共享社會經濟路徑、滅絕、保育

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Introduction

Climate change has been regarded as an unavoidable global phenomenon of this century and the most significant threat to Earth's biodiversity (Warren *et al.* 2013; Urban 2015). Within the next 50 years, approximately one-third of the world's species may face the threat of extinction due to this phenomenon (Román-Palacios and Wiens 2020). The complex terrain of high mountains fosters species diversity and endemism (Steinbauer *et al.* 2016; Noroozi *et al.* 2018). However, due to isolation effects, it also shapes the rarity, scattered distribution, and narrow habitat range of mountain species. These mountain species are often more sensitive to climate change, especially plant communities (Thuiller *et al.* 2005; Adhikari *et al.* 2018). To adapt to the impacts of climate change, most mountain plant species are shifting towards higher altitudes, tracking new suitable climate zones (Jump *et al.* 2012; Kellner *et al.* 2023). This migration allows them to thrive in environments with optimal conditions for their growth and survival. Unfortunately, under the impact of global warming, as elevation increases, not only does the temperature rise rapidly (Pepin *et al.* 2015; Lamprecht *et al.* 2018), but available areas also are significantly decreasing (Freeman *et al.* 2018). Furthermore, the natural barriers of high mountains restrict the dispersal of plants (Essl *et al.* 2011; Di Musciano *et al.* 2020; Chen *et al.* 2023), exacerbating the impact of climate change on mountain vegetation simultaneously.

Ecological niche modeling (ENM) predicts potential distribution ranges based on the correlation between species presence records and environmental variables. When combined with data on climate change scenarios, it enhances understanding of species responses to climate change and aids in the formulation of conservation strategies (Dhyani *et al.* 2021; Hoveka *et al.* 2022; Ceccarelli *et al.* 2022). ENM has developed various types of algorithms, such as general linear model (GLM) and multivariate adaptive regression splines (MARS) for regression methods, as well as machine learning methods like boosted regression tree (BRT), maximum entropy (MaxEnt), and support vector machine (SVM). Recently, the "ensemble" ecological niche modeling (EENM), which integrates predictions from multiple models, has been continuously evolving. Compared to single models, EENM achieves consensus from multiple algorithms, mitigating the uncertainties in single-model predictions and leading to improved prediction accuracy (Araújo and New 2007; Marmion *et al.* 2009).

Taiwan has many high mountains, and is characterized by complex terrain and environments that have fostered rich and unique plant diversity. Statistical data from the past century indicates that Taiwan has experienced a temperature increase of approximately 1.4°C, which is significantly higher than the global average (Lu *et al.* 2012). Moreover, the rate of warming in high mountain areas has surpassed that of plains and lowlands

(Lin *et al.* 2015). Past studies have examined the effects of climate change on mountain vegetation composition and distribution. For example, Chou *et al.* (2011) predicted that future climate warming would drive changes in Taiwan's mountainous vegetation distribution, causing many plant species to migrate to higher altitudes. Jump *et al.* (2012) observed that the rise of the forest line is consistent with the warming trend. Kuo *et al.* (2022) suggested that some vulnerable species might face the threat of extinction due to climate change.

Prunus transarisanensis is an endemic species of Taiwan, taxonomically classified in the Rosaceae family and the *Prunus* genus. It is found at an elevation of approximately 2,500 m. Its appearance is that of a small shrub tree with whitish or light pink petals (Hsieh and Ohashi 1993). Due to its highly attractive appearance, this tree species is one of the important components of cherry blossom tourism in Taiwan, significantly contributing to the income of the Alishan region each year (Liu *et al.* 2021). However, among various cherry tree species, the habitats of *P. transarisanensis* are situated at relatively higher altitudes, making them susceptible to the impacts of climate change. Consequently, this study assesses future threats to *P. transarisanensis* based on species survey data and EENM. The investigation seeks to determine: (1) what are the major factors affecting species distribution; (2) how the suitable habitat transforms under different climate change scenarios; and (3) if it is highly vulnerable to the impacts of climate change, how can we assist this species in adapting?

Materials and methods

Scope of study and species occurrence record

The geographical area covered by this study is the subtropical island of Taiwan, which has a land area of approximately 36,000 km^2. Its land is predominantly covered by forests, while urban and agricultural areas are mainly located in coastal plains. The island's terrain fluctuates greatly, consisting mostly of mountains and hills. The variation in altitude among the high mountains results in a range of complex climate types, including tropical, subtropical, temperate, and cold zones. Due to this diverse climate, a rich variety of vegetation ecosystems has formed, leading to the identification of 12 types of zonal forests and 9 types of azonal forests (Li *et al.* 2013).

The species occurrence records are derived from the ecological survey database (ecollect.forest.gov.tw). This dataset was systematically collected through island-wide surveys commissioned by the Forestry and Nature Conservation Agency (FANCA), with the collaboration of experts and scholars from various universities and research institutions. Only occurrence records of the genus *Prunus*, totaling 13,301 records and including 86 records of the target species, from the years 1981 to 2010 were extracted to match the time interval of predictors. To maintain precise geographic coordinates, data with fewer than three decimal places were removed. Furthermore, spatial thinning was performed using the "spThin" package in the R version 4.1.3 environment (Aiello-Lammens *et al.* 2015) to reduce the impact of spatial autocorrelation and geographic sampling bias. In order to achieve the spatial resolution required for predictors, a minimum neighbor distance of at least 1 km was set between each occurrence record. After processing, there were 32 occurrence records of *P. transarisanensis* (Fig. 1a), along with 1,230 records of other species.

Environment variables

Climate, soil, and topography are commonly considered factors in assessing the habitat suitability of plant species (Titeux *et al.* 2016; Hageer *et al.* 2017; Wan *et al.* 2019). Therefore, the predictors used encompass these three factors. This study did not incorporate land cover variables because all occurrence records of *P. transarisanensis* were located within forested areas according to the Ministry of the Interior's land use survey results (maps.nlsc.gov.tw). For the current climate scenario, 19 bioclimatic variables (BIO1-BIO19, Table S1) were extracted from the CHELSA V2.1 (chelsa-climate.org), with data spanning from 1981 to 2010 (Karger *et al.* 2017). Soil data were downloaded from the ISRIC-World Soil Information (isric.org) and included six soil variables: coarse fragments volumetric, soil texture fraction clay, soil texture fraction sand, soil texture fraction silt, soil pH, and cation exchange capacity. The digital elevation model was obtained from the Ministry of the Interior (data.gov.tw) and processed using the Surface Tool in ArcGIS 10.8 (ESRI Inc.) software to generate variables such as slope and aspect. The spatial resolution of all layers was re-sampled to 1 × 1 km. To avoid collinearity, a selection was conducted according to Pearson correlation coefficients (< 0.7, Dormann *et al.* 2013). When two variables were highly correlated, the variable with the greatest ecological relevance to *P. transarisanensis* was chosen. The Pearson correlation analysis for environmental variables was performed using the R package "virtualspecies" (Leroy *et al.* 2016).

For future scenarios, CHELSA V2.1 also provides future climate data. Five global circulation models (GCMs, namely GFDL-ESM4, IPSL-CM6A-LR, MPI-ESM1-2-HR, MRI-ESM2-0, and UKESM1-0-LL) and three greenhouse gas emission scenarios (SSP126, SSP370, and SSP585) were utilized. Each scenario represents radiative forcing increasing by 2.6, 7.0, and 8.5 Wm^{-2} between 1750 and 2100, respectively. The bioclimatic data under these three scenarios for the 2071-2100 period was downloaded. Table S1 shows the mean values within the study area. The future bioclimatic variables generated by each of these five GCMs were used to construct models for *P. transarisanensis*, and the average probability was calculated as the final result to evaluate habitat suitability. Moreover, due to the relative stability of soil and topographical factors, it is assumed that the relevant variables remain constant.

Ensemble ecological niche modeling

The R package “sdm” (Naimi and Araújo 2016) was used to execute EENM to predict a suitable habitat for *P. transarisanensis*. Five algorithms were applied, including BRT, GLM, MARS, MaxEnt, and SVM. Since all algorithms required background data (pseudo-absence points), pseudo-absences could only be selected from areas where other plant species had been recorded, a more objective approach to avoid considering under-sampled areas as unsuitable for *P. transarisanensis* (Ghisbain *et al.* 2020; Lu and Huang 2023). From the occurrence records of *P. transarisanensis*, 70% were randomly selected for the training dataset, while the remaining 30% were allocated to the testing dataset. The model performance of each algorithm was evaluated using bootstrap sampling on the training dataset. The 100 replicates were constructed using five algorithms, resulting in 500 models.

Model accuracy was evaluated using two metrics a threshold-independent statistic—the area under the receiver operating characteristic curve (AUC) (Fielding and Bell 1997) and a threshold-dependent statistic—the true skills statistic (TSS) (Allouche *et al.* 2006). The AUC was produced using the true positive rate (i.e., sensitivity) and the false positive rate from the classification table. The TSS was determined using the sensitivity and the true negative rate (i.e., specificity). Higher values for these two metrics indicate better prediction accuracy of the model. The standard for excellent models was set as values of AUC and TSS higher than 0.9 and 0.8, respectively (González-Ferreras *et al.* 2016). The ensemble method was performed by retaining models with high predictive accuracy (TSS＞0.8) and then calculating the weighted average based on their TSS values to generate an ensembled occurrence probability map of species. On the map, higher probabilities indicate a greater likelihood of suitable habitat for the species. The probability corresponding to the maximum TSS was considered the threshold (Liu *et al.* 2013) to convert the map into a binary map of suitable and unsuitable habitats. In addition, the importance of each predictive variable for model fitting was assessed using the "getVarImp" function of the "sdm" R package. The response curve, revealing the relationship between the species occurrence probability and the variables, was generated using the "rcurve" function from the same R package.

Spatiotemporal dynamic analysis

According to the methodology outlined by Dai *et al.* (2019), changes in suitable habitats were assessed, and the generation of dynamic ranges was performed using the Combine Tool in ArcGIS as follows:

a. Vulnerable habitat: Regions of habitat currently deemed suitable but predicted to become unsuitable under the future climate scenario.

b. Increased suitable habitat: Regions of habitat currently considered unsuitable but predicted to become suitable under the future climate scenario.

c. Climate refugia: Regions of habitat currently suitable and predicted to remain suitable under the future climate scenario.

Results

Using a criterion of Pearson correlation coefficients < 0.7, the 28 predictive variables obtained earlier were narrowed down to 11 variables for constructing the prediction models. Table 1 shows the average AUC and TSS calculated from the test dataset using five algorithms, each with 100 replicates. In general, BRT, MaxEnt and SVM had good accuracy; of these, BRT showed the best performance, indicating that these models had greater prediction power. Only 112 high-performance models (TSS>0.8) were retained for the following weighted averaging to ensure highly accurate predictions. As a result, this ensemble model was employed to predict suitable habitats for *P. transarisanensis*. The habitat distribution of the entire study area is shown in Fig. 1b. It is evident that the spatial pattern is confined to areas with relatively higher altitudes, estimated to cover a total area of 1,396 km².

Table 1 The area under the curve for the receiver operating characteristic (AUC) and true skill statistic (TSS) generated by five algorithms
表 1 5種演算法獲取之接收者操作特徵曲線下面積 (receiver operating characteristic, ROC) 與真實技能統計值 (true skill statistic, TSS)

Algorithm	AUCmean	SD	TSSmean	SD
Boosted regression	0.89	0.07	0.74	0.11
Generalized L model	0.86	0.06	0.69	0.11
Multivariate adaptive regression splines	0.84	0.10	0.67	0.13
Maximum entropy	0.89	0.06	0.72	0.10
Support vector machine	0.88	0.07	0.71	0.12

SD: standard deviation

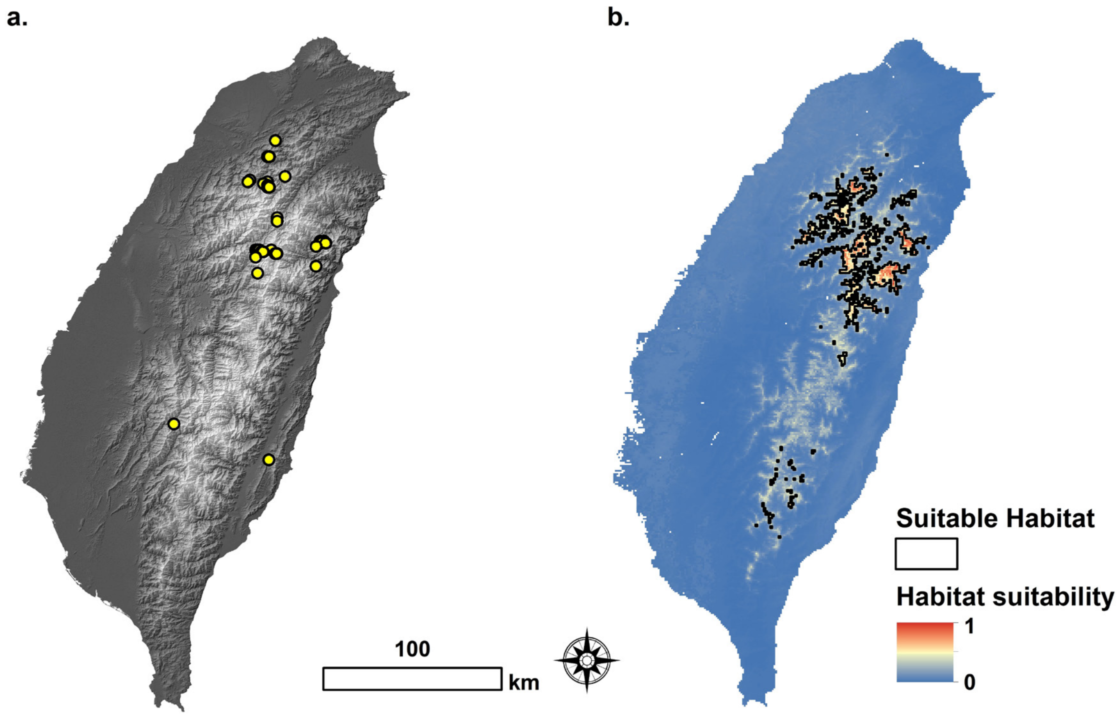

Fig. 1 (a) Occurrence records of *Prunus transarisanensis*, and a digital elevation model. Brighter colors indicate higher elevations; (b) predicted results according to the ensemble model.
圖 1 (a) 阿里山櫻花 (*Prunus transarisanensis*) 發生紀錄與研究區數值高程模型，亮度愈高代表海拔愈高；(b) 集成模型所推估之適宜生育地範圍。

Taking into consideration the importance of each variable in model fit, the variables with an importance > 10% include minimum temperature of coldest month (78.82%), precipitation of warmest quarter (22.63%), slope (10.66%) and soil texture fraction silt in percent (10.19%). The effects of the remaining variables are relatively insignificant (Table 2). The climatic variables are clearly the most dominant, with the minimum temperature of the coldest month and precipitation of the warmest quarter being the two most important variables that are related to the species' occurrence in

Table 2 Estimates of importance (%) of the predictor variables to the ensemble model
表 2 各預測變項對集成模型的重要性 (%)

Variable	Importance
Minimum temperature of coldest month	78.82
Precipitation of the warmest quarter	22.63
Slope	10.66
Soil texture fraction silt in percent	10.19
Precipitation of the coldest quarter	8.38
Cation exchange capacity	8.24
Mean diurnal range	7.51
Aspect	7.02
Temperature seasonality	5.93
Soil pH	5.82
Soil texture fraction sand in percent	4.45

ensemble prediction.

The primary contributing variables from ensemble prediction indicate that the probability of occurrence was highest at the lowest minimum temperature of the coldest month and precipitation of the warmest quarter (Fig. 2). The peak value of the former variable occurred below 1°C, while that of the latter variable occurred around 700 mm. Analysis of the response curves above indicates that *P. transarisanensis* prefers a cool

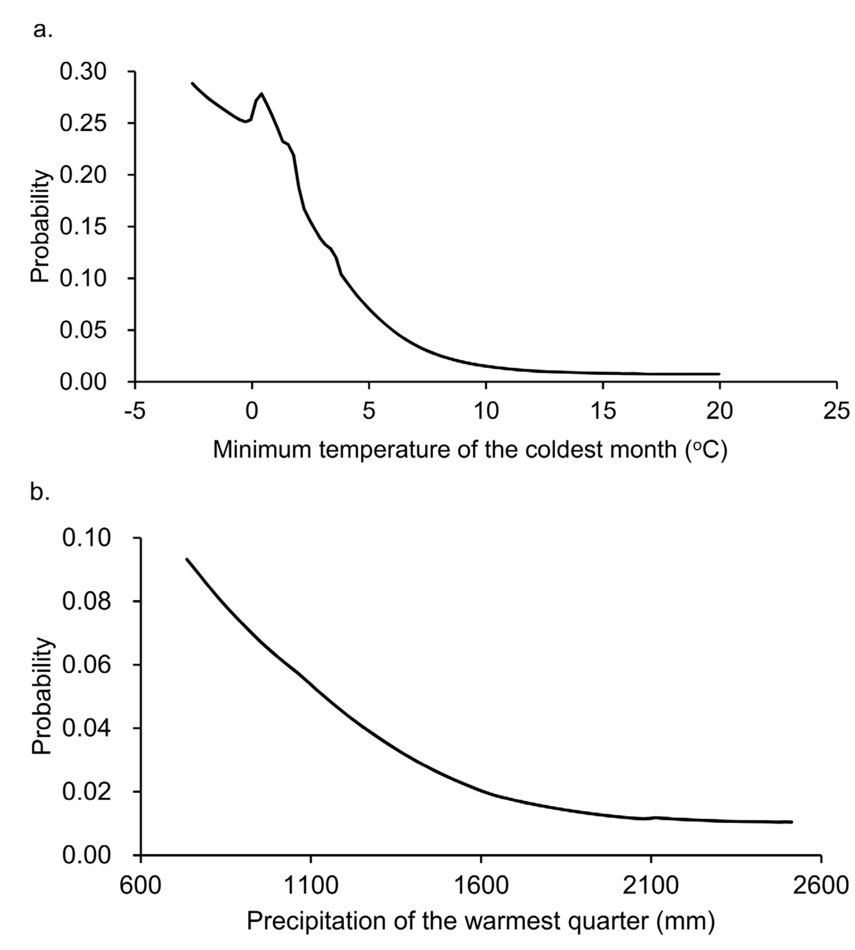

Fig. 2 Response curves of the primary contribution variables based on the ensemble prediction. (a) minimum temperature of the coldest month; (b) precipitation of the warmest quarter.

圖 2 阿里山櫻花 (*Prunus transarisanensis*) 對集成模型主要變項之反應曲線，(a) 最冷月最低溫；(b) 最暖季降水量。

environment and requires moderate precipitation.

From the current to the future, the habitat dynamic range of *P. transarisanensis* is projected. Overall, in the future, only two types of habitats will remain: climate refugia and vulnerable habitats, with the majority of the area occupied by vulnerable habitats. Under the low-emission SSP126 scenario, only a small amount of suitable habitat, estimated at approximately 355 km², can be maintained as refugia. Under the more severe warming scenarios of SSP370 and SSP585, the majority of suitable habitats are predicted to transition into vulnerable habitats, and climate refugia virtually cease to exist (Fig. 3).

Discussion

Due to its significant contribution to performance improvement, EENM is one of the most commonly used tools for predicting the impact of climate change on suitable habitats of species (Yun *et al.* 2017; Jung *et al.* 2023). The ensemble model constructed in this study was employed to predict the distribution of *P. transarisanensis*. Among the single algorithms, BRT, MaxEnt, and SVM were found to perform exceptionally well. A commonality among them is that they all belong to machine learning algorithms. Compared with the two linear models of GLM and MARS, machine learning algorithms are able to process non-linear relationships between predictors (Recknagel 2001). Therefore, this might be the reason why the models fitted by these three algorithms showed relatively better performance, as stated above. The result is similar to previous investigations on other plant species (Rahmanian *et al.* 2021; Sarma *et al.* 2022). To maintain the stability of the final model, only high-performance models are retained for the ensemble, ensuring that subsequent scenario simulations and conservation planning are built on a robust scientific foundation.

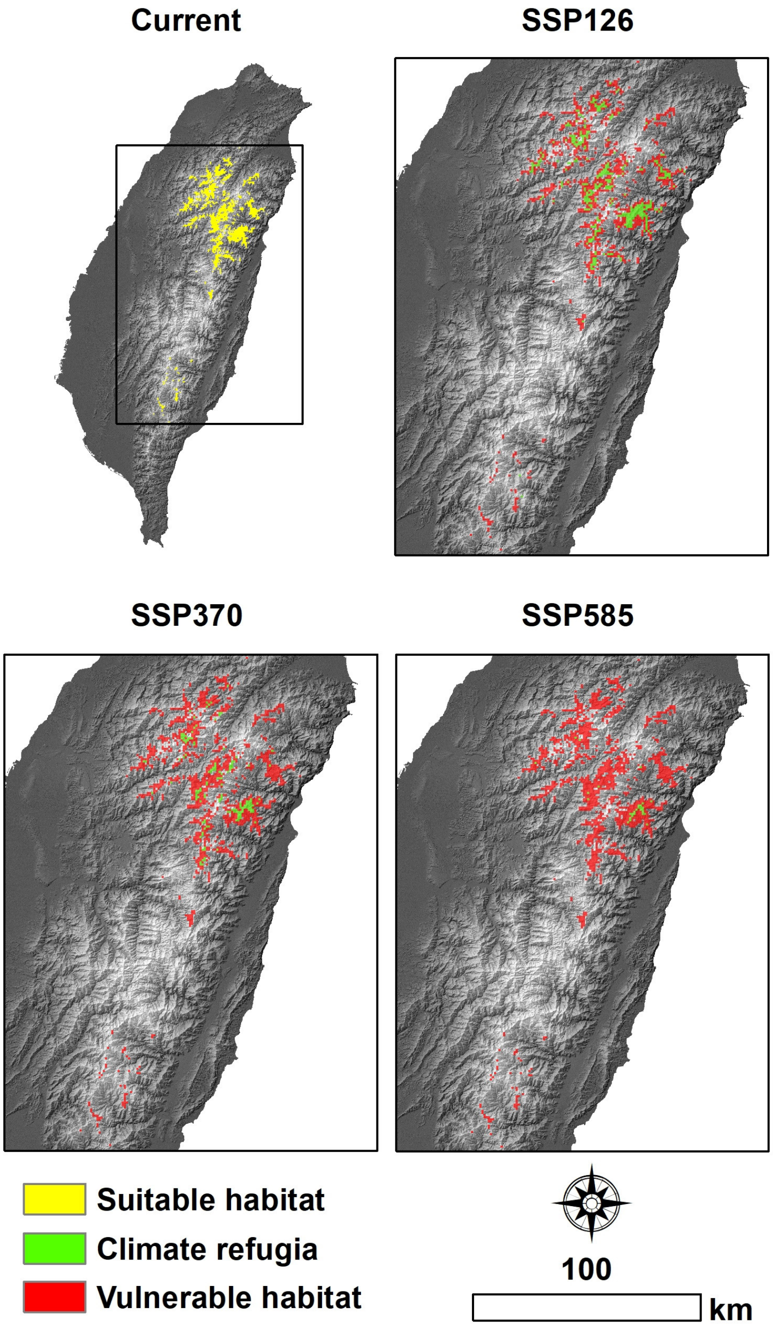

Fig. 3 The dynamic range of suitable habitat for *Prunus transarisanensis*. The upper left panel shows the current distribution, while the upper-right, bottom-left and bottom-right panels represent the SSP126, SSP370, and SSP585 emission scenarios, respectively, for the period of 2071-2100.

圖 3 阿里山櫻花 (*Prunus transarisanensis*) 的適宜生育地分布動態。左上圖為當前潛在分布，右上、左下與右下圖分別表示直至 2071~2100 年間，SSP126、SSP370 與 SSP585 情境下的潛在分布變化。

Prunus species are highly sensitive to temperature, which is one of the primary factors regulating their flowering stage. Similar to annual or biennial plants, *Prunus* species undergo a vernalization process. This involves accumulating a certain amount of chilling during endodormancy and heat during ecodormancy to ensure proper flowering in spring (Luedeling *et al.* 2013; Fadón *et al.* 2015). Therefore, maintaining a certain low-temperature level during the winter is one of the key prerequisites for their subsequent growth and development cycle (Szalay *et al.* 2010; Luedeling *et al.* 2013; Benmoussa *et al.* 2017; Zhang *et al.* 2023). The model fitting in this study indirectly supports this perspective. The ensemble model indicated that among the temperature-related variables, the minimum temperature of the coldest month strongly influenced the prediction of suitable habitat for *P. transarisanensis*. Habitats with a certain level of cold during the coldest month are relatively suitable for this species. After sufficient chill accumulation, the reproductive activity starts with inflorescence emergence as pointed out by Sakar *et al.* (2019). On the contrary, relatively high temperatures during winter may affect the tolerance limit to flowering, disrupting their phenological cycles and resulting in significant negative consequences. Additionally, a peak value is observed in the curve around 1°C, likely attributed to other variables, though it does not alter the overall trend interpretation. Besides temperature, precipitation in mountain areas is also an important factor, influencing not only plant growth but also genetic variations (Chaves *et al.* 2003; Manel *et al.* 2012). This study suggests that moderate precipitation (approximately below 1,000 mm) during the warm season is favorable for *P. transarisanensis*. Conversely, excessive precipitation may lead to adverse outcomes.

As high mountain plants have

narrow elevation tolerance, they are more exposed to a greater risk of habitat loss and local extinction due to climate change than species distributed at lower elevations (Guisan and Theurillat 2000; Engler *et al.* 2011). In this study, the species distribution predictions indicate that *P. transarisanensis* is found in the mountainous areas on the northern side of Taiwan, which have characteristics similar to temperate climate zones (Li *et al.* 2015). However, according to past climate observations, Taiwan has experienced increasing temperatures and continuous rise in extreme rainfall over the past few decades (Hsu and Chen 2002; Shiu *et al.* 2009; Jump *et al.* 2012; Tung *et al.* 2022). Therefore, the climate in Taiwan is becoming increasingly less favorable for *P. transarisanensis*, which prefers cooler and moderate precipitation environments in the mountains. This also suggests that the suitable habitat of this species is likely undergoing qualitative shifts due to climate change.

As for future projections, the results of most GCMs agree that Taiwan is highly susceptible to extreme temperatures. For instance, heatwaves are expected to intensify, becoming more frequent and prolonged. Conversely, extremely cold days are gradually disappearing (Tsai *et al.* 2023). Regarding changes in spatial patterns of temperature, the warming is more significant in high mountains than in plains, profoundly impacting ecosystems and species distributions (Lin *et al.* 2015). Additionally, precipitation distribution in various regions is significantly uneven, leading to increasing drought and flood risks (Huang *et al.* 2012). According to the analysis results of this study, the majority of suitable habitats for *P. transarisanensis* are projected to transition into vulnerable habitats due to the impact of climate change. Even under the low emission scenario (SSP126), the available area serving as climate refugia is constrained. Under the more severe emission scenarios of SSP370 and SSP585, the predicted degradation of suitable habitats is expected to be more severe, potentially leading to a high risk of extinction for this species.

In order to adapt to future climate change, this study proposes several recommendations for the conservation of *P. transarisanensis*. Firstly, in the current conservation assessment system in Taiwan at the regional level and according to the International Union for Conservation of Nature (IUCN) criteria, this species is classified as "Near Threatened," falling short of the threatened status (Editorial Committee of the Red List of Taiwan Plants 2017; IUCN 2022). However, it is important to emphasize that it is a "vulnerable species" susceptible to the impacts of climate change, which requires increased conservation efforts. Furthermore, given the potential vulnerability of habitats, immediate priority should be given to these areas for ex situ conservation. Due to the well-established conservation network in the mountainous areas of Taiwan (Tang *et al.* 2006), there is limited space available for adjusting nature reserves to maintain suitable habitats. Therefore, it is necessary to enhance long-term monitoring efforts related to climate refugia to prevent the extinction of this species. Finally, incorporating the impacts of climate change into IUCN Red List assessments could potentially alter the threat status of numerous endemic species (Trull *et al.* 2018). As a result, the research framework established in this study can be regarded as a valuable insight for evaluating other species listed in the Red List.

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Supplements to the *Paspalum* L. (Poaceae) Species in Taiwan

臺灣產雀稗屬（*Paspalum* L.，禾本科）補註

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Abstract

Herein, three naturalized *Paspalum* spp. (Poaceae): *Paspalum mandiocanum* Trin, *Paspalum plicatulum* Michx., and *Paspalum virletii* E. Fourn. in Taiwan are confirmed. Descriptions of morphological characters, their color photos and illustrations, and a taxonomic key for Taiwanese *Paspalum* spp. are documented for identification in this paper.

Key words: *Paspalum*, naturalized species, Poaceae

摘要

本文確認並描述三種臺灣的歸化雀稗屬 (*Paspalum* L.，禾本科) 成員：寬葉雀稗 (*P. mandiocanum* Trin)、皺稃雀稗 (*P. plicatulum* Michx.) 和絨葉雀稗 (*P. virletii* E. Fourn.)，提供其形態描述、彩色照片、線描圖及臺灣產雀稗屬檢索表以利鑑定。

關鍵詞：雀稗屬、歸化種、禾本科

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Introduction

Paspalum L. (Poaceae) is a large genus with about 350 species globally (Liu 2000; Chen and Stephen 2006; Sánchez-Ken 2010; Scataglini *et al.* 2014; Delfini *et al.* 2023; POWO 2023), and 13 species of this genus were recorded in the second edition, Flora of Taiwan (Liu 2000). Chen and Stephen (2006) described 16 *Paspalum* taxa in the flora of China and recorded 14 taxa distributed in Taiwan. Chen (2008) described the naturalization of *Paspalum notatum* Fleuggé in Taiwan, which is a perennial grass species used for slope stabilization. Wu *et al.* (2010) adopted the viewpoints of Chen (2008), and cataloged seven alien *Paspalum* species including *P. notatum* to the naturalized flora in Taiwan. Chen *et al.* (2014) revised the grass flora of Taiwan, adopted 11 *Paspalum* species and two varieties, and modified the key to the *Paspalum* species in Taiwan. Although Chen *et al.* (2014) adopted most taxonomic treatments in Chen and Stephen (2006), the occurrence of *Paspalum hirsutum* Retz. was excluded from the grass flora of Taiwan. However, the naturalization of *P. notatum* in Taiwan (Chen 2008;

Wu *et al.* 2010) was neglected by Chen *et al.* (2014). Chang-Yang *et al.* (2022) updated the checklist of the naturalized flora in Taiwan, and listed *P. notatum* in the checklist as a naturalized plant in Taiwan. After examining the type specimen's image of *Paspalum hirsutum* Retz. (*Bladh s.n.*, LUND), I accepted the taxonomic treatments in Chen *et al.* (2014). Based on these reports by Chen (2008), Wu *et al.* (2010), Chen *et al.* (2014), and Chang-Yang *et al.* (2022), 14 *Paspalum* taxa are recorded and described to the grass flora of Taiwan.

In my personal botanical surveys in recent years, I found three strange *Paspalum* spp. in northern Taiwan (Fig. 1). Based on comparisons between vouchers from Taiwan and relative type specimens, I confirmed these strange grasses as *Paspalum mandiocanum* Trin, *Paspalum plicatulum* Michx., and *Paspalum virletii* E. Fourn. Based on these vouchers collected by myself in recent years, I consider these three *Paspalum* taxa to have naturalized in northern Taiwan. Herein, morphological characters of these three newly naturalized *Paspalum* spp. are described in this paper, and their type speciemens' information and images (Fig. 4 and 7), color photos (Fig. 3, 6 and 9), and line-drawings (Fig. 2, 5 and 8) are attached benefit to the identification. A modified taxonomic key to these 17 *Paspalum* taxa in Taiwan is also included.

Taxonomic treatments

1. *Paspalum mandiocanum* Trin., Gram. Panic.: 113, 1826. Csurhes and Navie, Broad-leaved paspalum — Invasive plant risk assessment: 6, 2016; Simon and Alfonso, AusGrass2, 2011. 寬葉雀稗 Fig. 2 and 3

TYPE: BRAZIL. Prope Mandiocam, *G.H. von Langsdorff s.n.* (Holotype: LE-TRIN, photo; Isotype (fragm. ex LE-TRIN): MVFA, US, photo).

Perennials, weakly clumped or stoloniferous, culms prostrate to ascending,

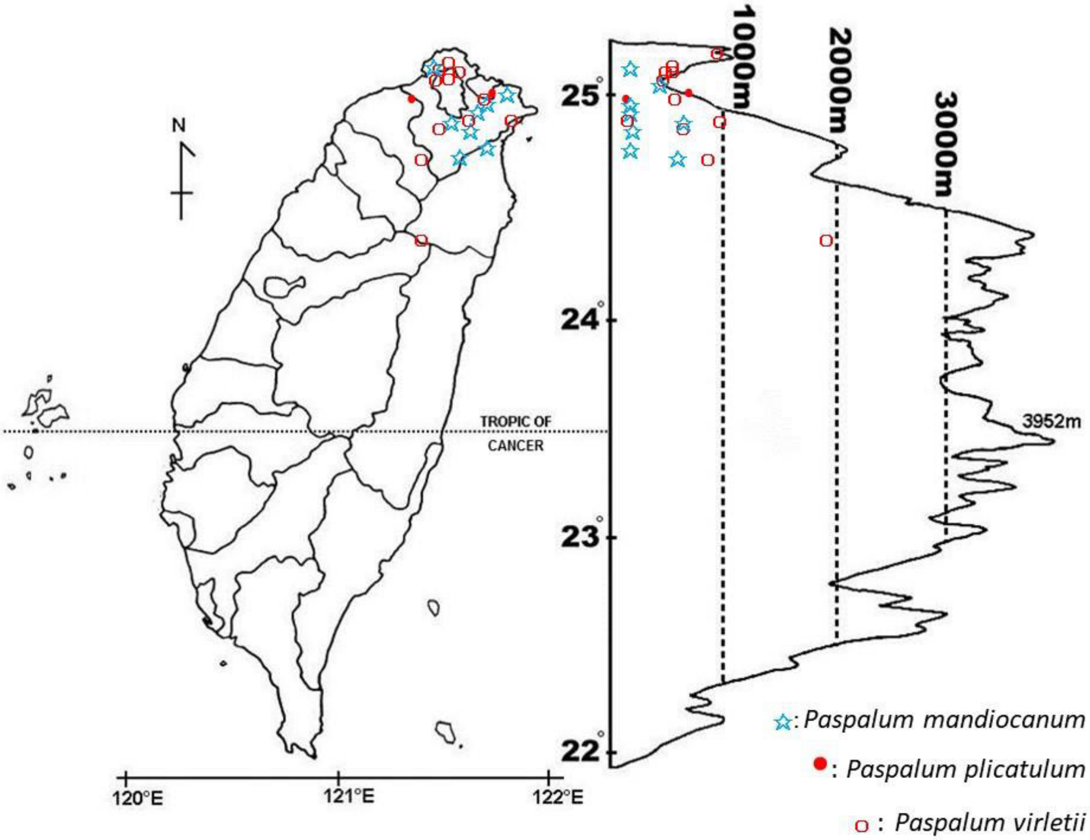

Fig. 1 Distribution map of *Paspalum mandiocanum* Trin, *P. plicatulum* Michx., and *P. virletii* E. Fourn.in Taiwan.

圖 1 寬葉雀稗 (*Paspalum mandiocanum* Trin)、皺稃雀稗 (*P. plicatulum* Michx.) 與絨葉雀稗 (*P. virletii* E. Fourn.) 在臺灣的分布圖。

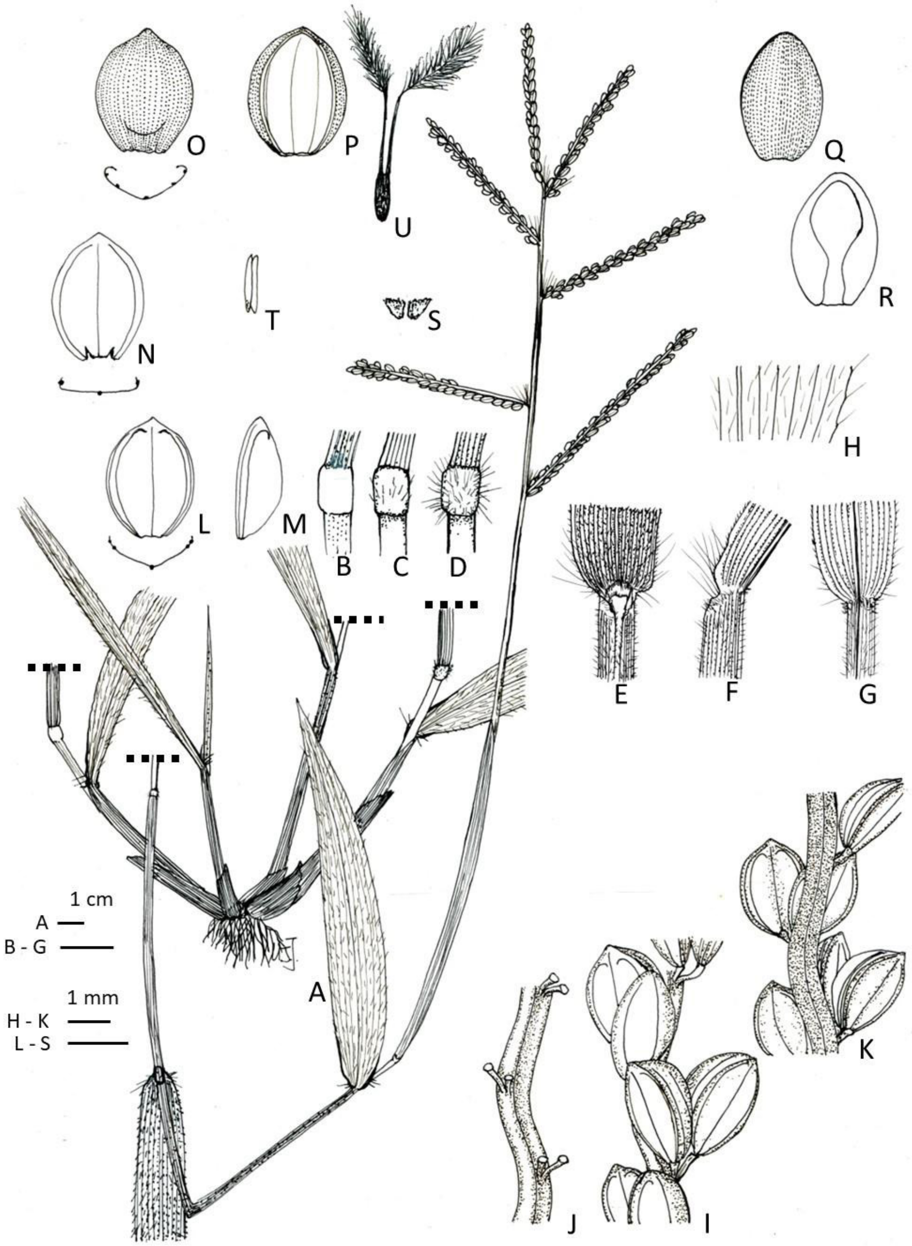

Fig. 2 *Paspalum mandiocanum* Trin. A: habit. B – D: nodes. E – G: basal part of leaf blades, E: adaxial view, F: lateral view; G: abaxial view. H: part of blade margin. I – K: parts of racemes showing their paired spikelets. L & M: upper glumes, M: lateral view. N: lower lemma. O & P: upper lemmas, O: abaxial view, P: adaxial view. Q & R: upper paleas, Q: abaxial view, R: adaxial view. S: lodicules. T: anther. U: Pistil.

圖 2 寬葉雀稗 (*Paspalum mandiocanum* Trin)。A：植株。B – D：節。E – G：葉基， E：葉面觀；F：側面觀；G：葉背觀。H：葉緣局部。I – K：總狀花序分支上的成對小穗。L & M：內穎，M：側面觀。N：第一小花外稃。O & P：第二小花外稃，O：背側觀，P：腹側觀。Q & R：第二小花內稃，Q：背側觀，R：腹側觀。S：鱗被。T：花藥。U：雌蕊。

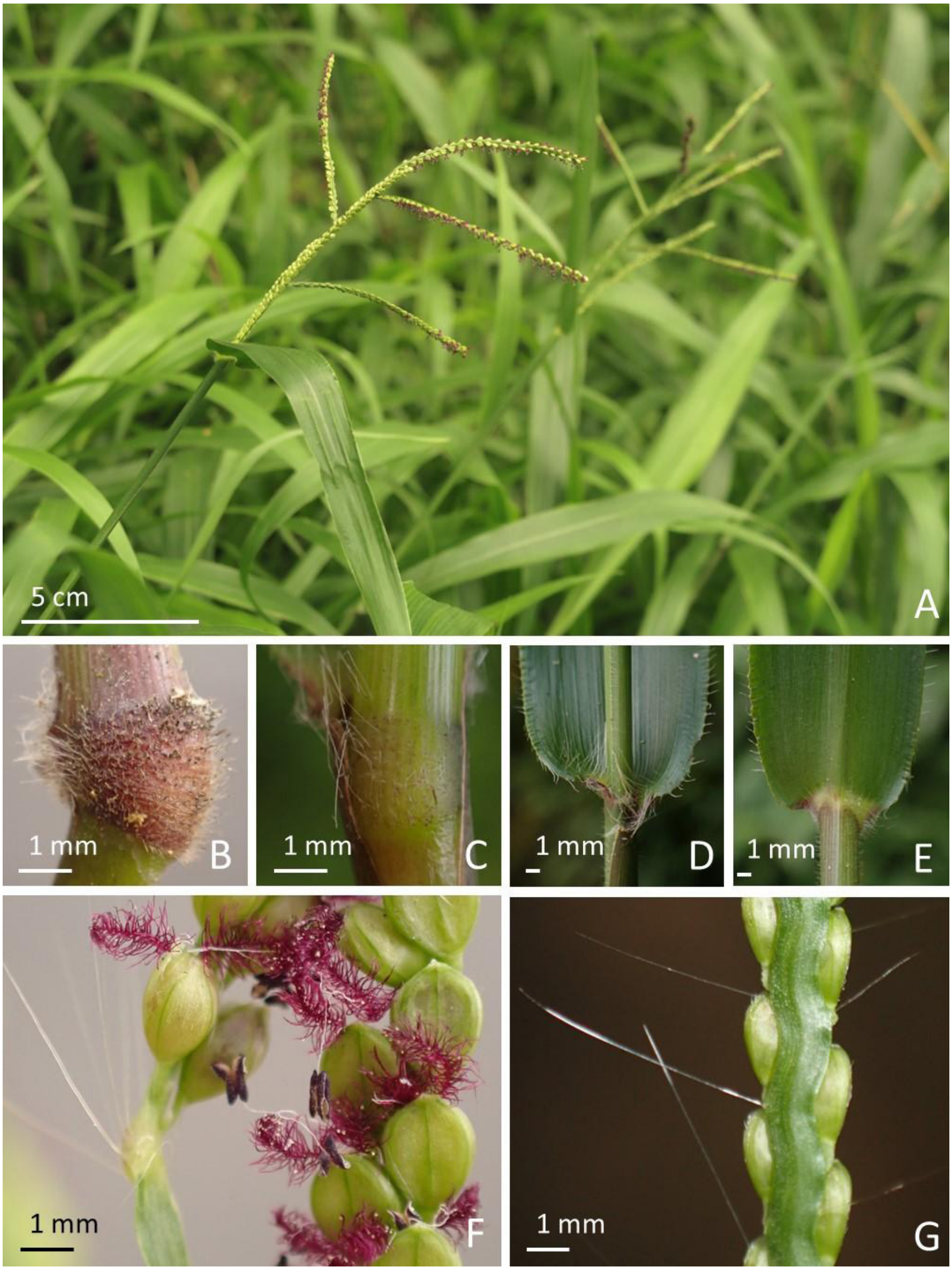

Fig. 3 *Paspalum mandiocanum* Trin. A: habit. B & C: nodes. D & E: basal parts of leaf blades, D: adaxial view, E: abaxial view. F & G: parts of racemes, F: with anthers and spreading stigmas.

圖 3 寬葉雀稗 (*Paspalum mandiocanum* Trin)。A：植株。B & C：節。D & E：葉基， D：葉面觀，E：葉背觀。F & G：總狀花序分支局部，F：具花藥與盛開柱頭。

to 50 cm in height; nodes with antrorse to spreading hairs or glabrous, rooting at basal nodes or not, internodes glabrous; leaf sheaths compressed and one-keeled, sparsely hairy on surfaces and margins; collar whitish, long-pilose on adaxial sides around ligules, short-hairy on abaxials; ligules membranous, to 1 mm long, apex truncate; blades linear, to 3 cm wide, bases obtuse to broadly round, apices acute, glabrous to sparsely hispidulate, 1-keeled at abaxial surfaces. Racemose racemes apical, axis to 30 cm long, with three-six branches, racemose branches to 6 cm long, arils sparsely long-pilose as whiskers or not. Spikelets paired, rachis to 1 mm long, glabrous or sparsely long-pilose; spikelets ellipsoids, upper glumes, and lower lemmas similar, elliptic to rounded, glabrous or sparsely hairy at intercostal regions, apex acute; upper glumes three- or five-nerved, lower lemma three-nerved. Upper lemmas and paleas rounded, coriaceous, whitish to pale-greenish; upper lemmas five-nerved, surfaces of intercostal regions with finely engraved spots, apexs acute, margin rewinded; upper paleas ovate, two-nerved, surfaces of intercostal regions with finely engraved spots, apexs rounded, margins rewinded but not overlapped. Lodicules two, apex truncate, hyaline, to 0.3 mm long. Anthers three, to 1.5 mm long, purplish; pistil one, ovary ellipsoid, glabrous, surface brownish when dried, stigma purplish.

Specimens examined: TAIWAN. New Taipei City, Pengxi District, Wanku, 15 Jun 2023, *Ming-Jer Jung 6668* (TAIF), Pinglin District, Pinglin, 30 Sep 2023, *Ming-Jer Jung 6713* (TAIF), Sanchi District, Sanchi, 24 Oct 2022, *Ming-Jer Jung 6596* (TAIF), Sherdin District, Sherdin, 16 Jun 2023, *Ming-Jer Jung 6670* (TAIF), Wulai District, Fushan Botanical Garden, 14 Dec 2007, *Ming-Jer Jung 2063* (TAIF), same loc., 9 Mar 2008, *Ming-Jer Jung 2440* (TAIF), same loc., 2 Sep 2020, *Ming-Jer Jung 6261* (TAIF), Xintien District, Xintien, 23 Sep

2023, *Ming-Jer Jung 6705* (TAIF); Ilan Hsien, Jiaosi Hsiang, Jiaosi, 18 Jul 2023, *Ming-Jer Jung 6687* (TAIF).

Notes: The vernacular name of *Paspalum mandiocanum* Trin. are broad-leaved paspalum, broad-leaf paspalum, broad-leafed paspalum, and warrel grass (Csurhes and Navie 2016). This grass species is native to subtropical areas, in southern America, and naturalized in south-eastern China and Australia (Simon and Alfonso 2011; Csurhes and Navie 2016; Delfini *et al.* 2023; POWO 2023). In Taiwan, it was found on roadsides and disturbed forest edges at low elevations in northern Taiwan. Several vouchers (*Ming-Jer Jung 2063, 2440, 6261* [TAIF]) of this alien species had been previously misidentified by me as *Paspalum virgatum* L., but can be distinguished based on the taxonomic key provided in this document.

2. *Paspalum plicatulum* Michx., Fl. Bor.-Amer. (Michaux) 1: 45, 1803. Chen and Stephen, In: Wu and Raven (eds.) Fl. China, 22: 570, 2006; Allen and Hall, In: Barkworth *et al.* (eds.) Fl. N. Amer., vol. 25. electronic version, 2022. 皺稃雀稗 Fig. 4, 5, and 6

TYPE: USA. Georgia et Florida, *Michaux s.n.* (P, photo)

Plants perennial; shortly rhizomatous but often indistinctly. Culms 30-110 cm, stout, erect, branched at basal nodes; nodes glabrous or sparsely appressed hairy. Leaf sheaths glabrous; collars whitish, sparsely pilose at adaxial sides, ligules 2-3 mm, apex truncate; basal blades to 35 cm long, cauline blades to 10 cm long, 2-8 mm wide, conduplicate to flat. Racemose racemes terminal, with two to five alternate branches; branches 3-5 cm, usually divergent, rarely merely ascending; branch axes 0.6-1.1 mm wide, glabrous. Spikelets paired, 2.5-3 mm long, 1.5-2.2 mm wide, elliptic-ovate; upper glumes elliptic-round, glabrous or shortly appressed pubescence

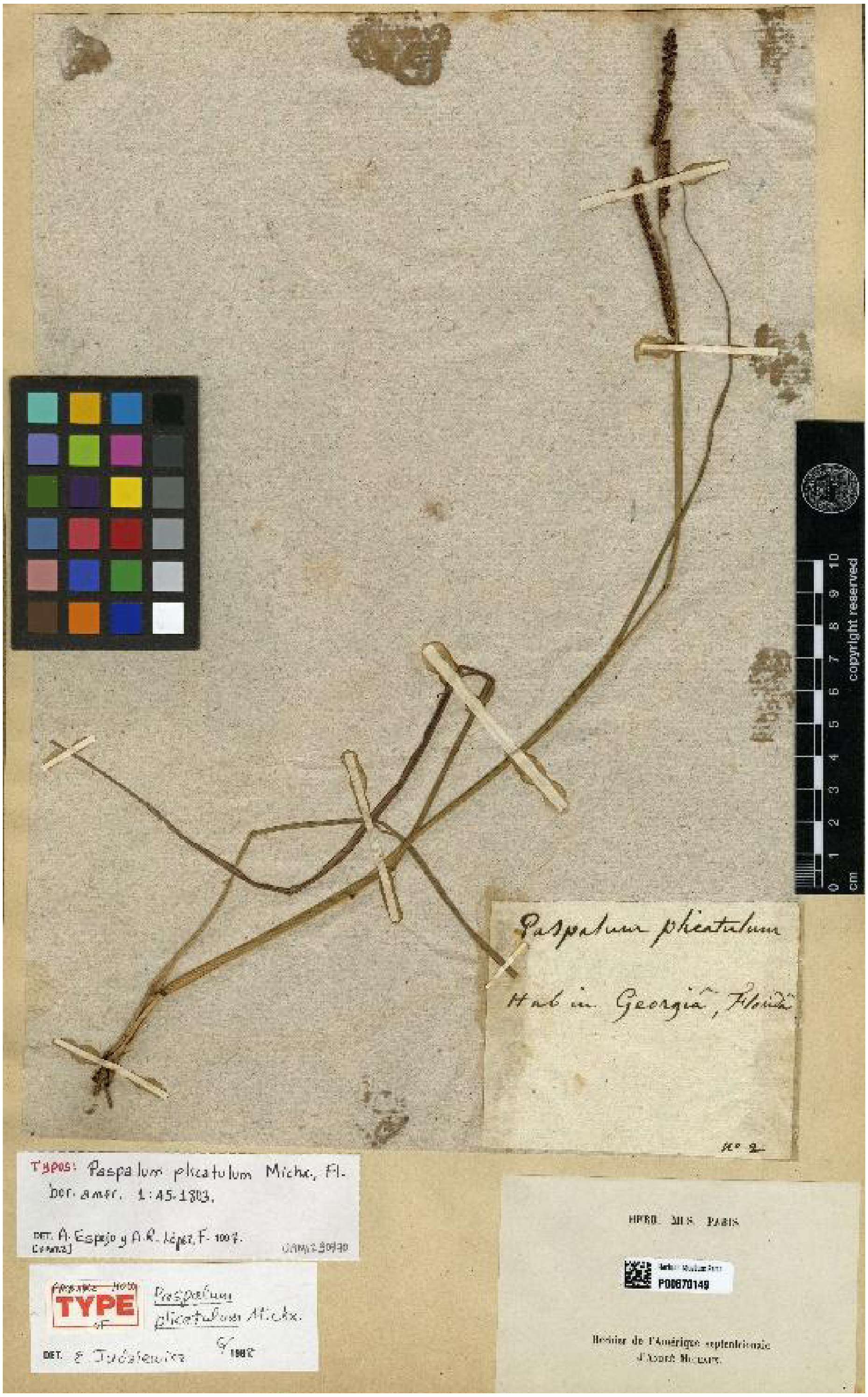

Fig. 4 Type specimens' image of *Paspalum plicatulum* Michx. (*Michaux s.n.*, P).
圖 4 皺稃雀稗 (*Paspalum plicatulum* Michx.) 模式標本影像 (*Michaux s.n.*, P)。

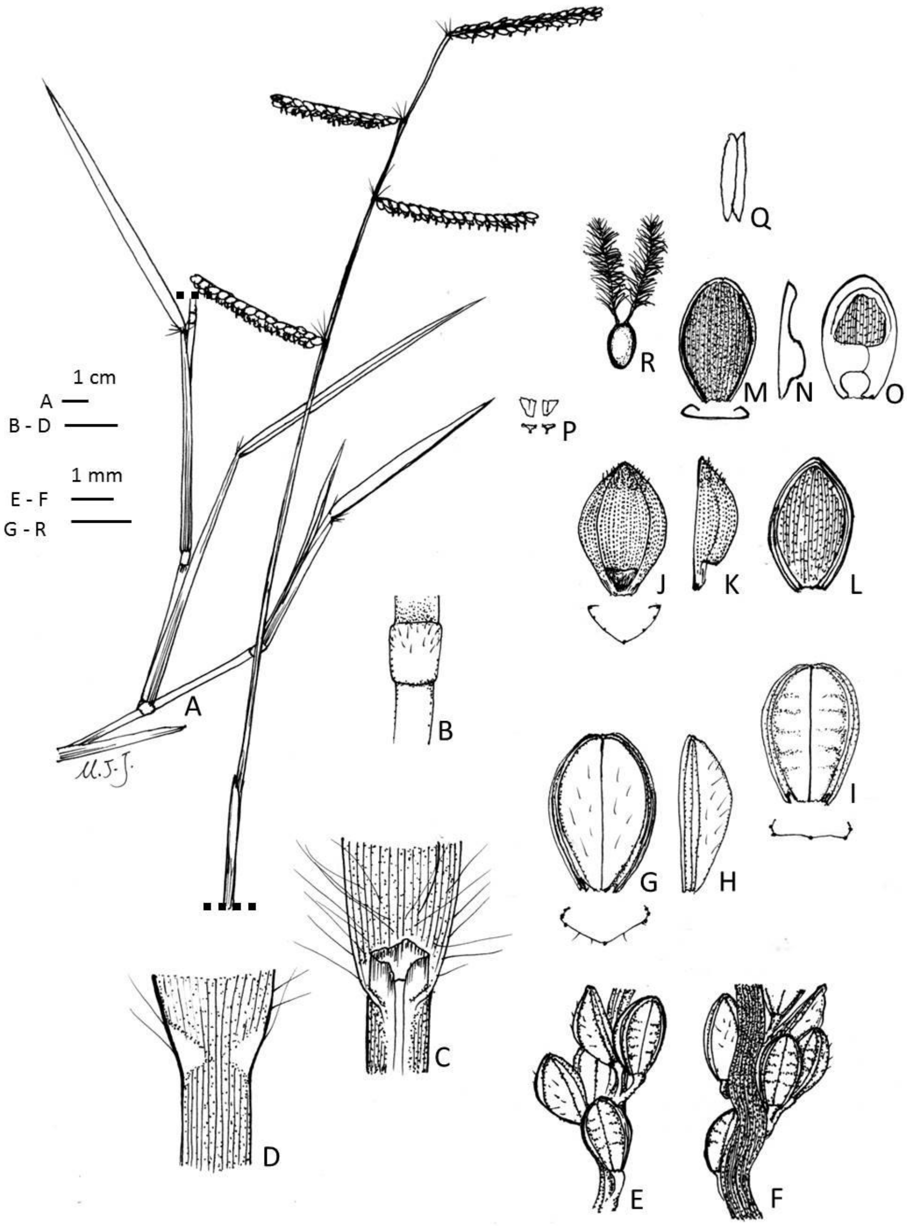

Fig. 5 *Paspalum plicatulum* Michx. A: habit. B: node. C & D: basal parts of leaf blade, C: adaxial view showing ligule, D: abaxial view. E & F: parts of racemes showing their paired spikelets. G & H: upper glumes, H: lateral view. I: lower lemma. J – L: upper lemmas, J: abaxial view, K: lateral view; L: adaxial view. M – O: upper paleas, M: abaxial view, N: lateral view, O: adaxial view. P: lodicules. Q: anther. R: pistil.

圖 5 皺稃雀稗 (*Paspalum plicatulum* Michx.)。A：植株。B：節。C & D：葉基；C：葉面觀與葉舌，D：葉背觀。E & F：總狀花序分支與成對小穗。G & H：內穎， H：側面觀。I：第一小花外稃。 J – L：第二小花外稃，J：腋側觀，K：側面觀； L：腹側觀。M – O：第二小花內稃， M: 背面觀，N：側面觀，O：腋側觀。 P：鱗被。Q：花藥。R：雌蕊。

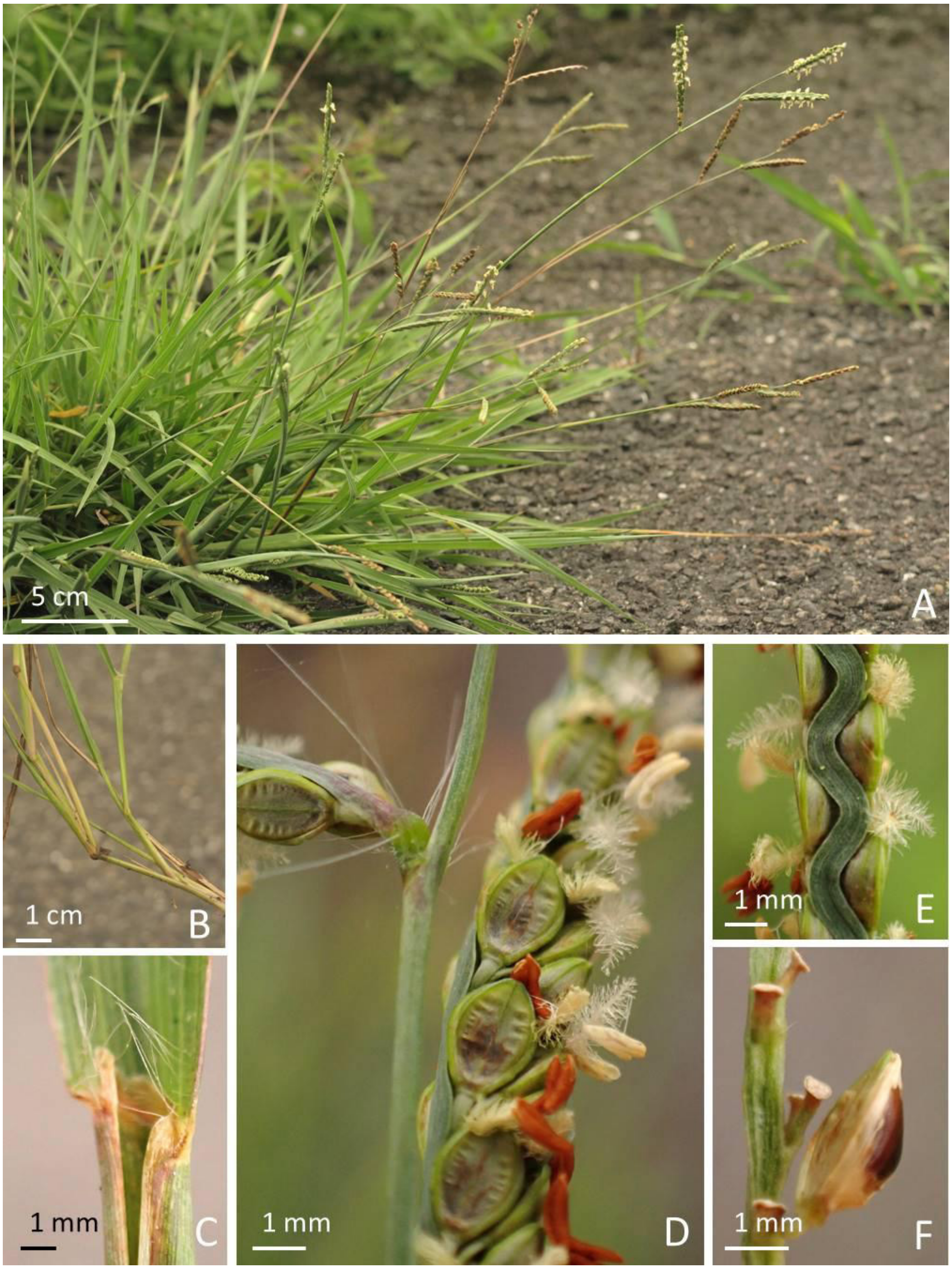

Fig. 6 *Paspalum plicatulum* Michx. A: habit. B: basal part of culm with branches. C: basal part of the leaf blade. D: part of inflorescence, showing the axe and lateral view of raceme, anthers, and spreading stigmas. E: part of raceme and axe, with spreading stigmas. F: rachis and spikelet, lateral view.

圖 6 皺稃雀稗 (*Paspalum plicatulum* Michx.)。A：外觀。B：稈基部具分支。C：葉基。D：總狀花序分支部分，呈現分支軸與分支側面觀、花藥與盛開柱頭。E：花序分支片段，呈現盛開柱頭。F：穗柄與小穗，側面觀。

at intercostal regions, five- or seven-veined, margin reflexed, apex rounded or with inconspicuous notch; lower lemmas elliptic, usually glabrous or shortly appressed pubescence, five-veined, apex rounded; upper florets dark glossy brown, upper lemma rounded, inconspicuously five-veined, abaxial surfaces of intercostal regions with finely engraved spots, one-notched at central-lower parts, margins reflexed, apex acute, finely hispidulate at apical parts of intercostal regions; upper paleas broadly ovate, two-keeled, abaxial surfaces of intercostal regions with finely engraved spots, margins reflexed with two rounded and overlapped appendages; lodicules two, apex truncate, to 0.3 mm long; anthers three, bicolor, pale yellow or orange, ca. 1.5 mm long.

Specimens examined: TAIWAN. New Taipei City, Tzefang District, Tzefang, 15 Jun 2023, *Ming-Jer Jung 6669* (TAIF), same loc., 30 Sep 2023, *Ming-Jer Jung 6714* (TAIF); Taoyuan City, Gueishan District, Gueishan, 16 Apr 2023, *Ming-Jer Jung 6667* (TAIF).

Notes: The vernacular name of *Paspalum plicatulum* Michx. is brownseed paspalum (Allen and Hall 2022). This grass is native to southern North America and northern South America, and naturalized in western Africa, northern China, India, and New Guinea (Chen and Stephen 2006; Scataglini *et al.* 2014; Allen and Hall 2022; POWO 2023). In Taiwan, this grass is locally naturalized at roadsides and full-sunny grassland, low-elevation, northern Taiwan.

3. *Paspalum virletii* E. Fourn., Mexic. Pl. 2: 12, 1886. Allen and Hall, In: Barkworth *et al.* (eds) Fl. N. Amer., vol. 25. electronic version, 2022. 絨葉雀稗 Fig. 7, 8, and 9

TYPE: MEXICO. San Luis Potosí, *Virlet 1329* (P, photo)

Perennials; cespitose. Culms 40-75 cm, erect, not swollen at the base; nodes

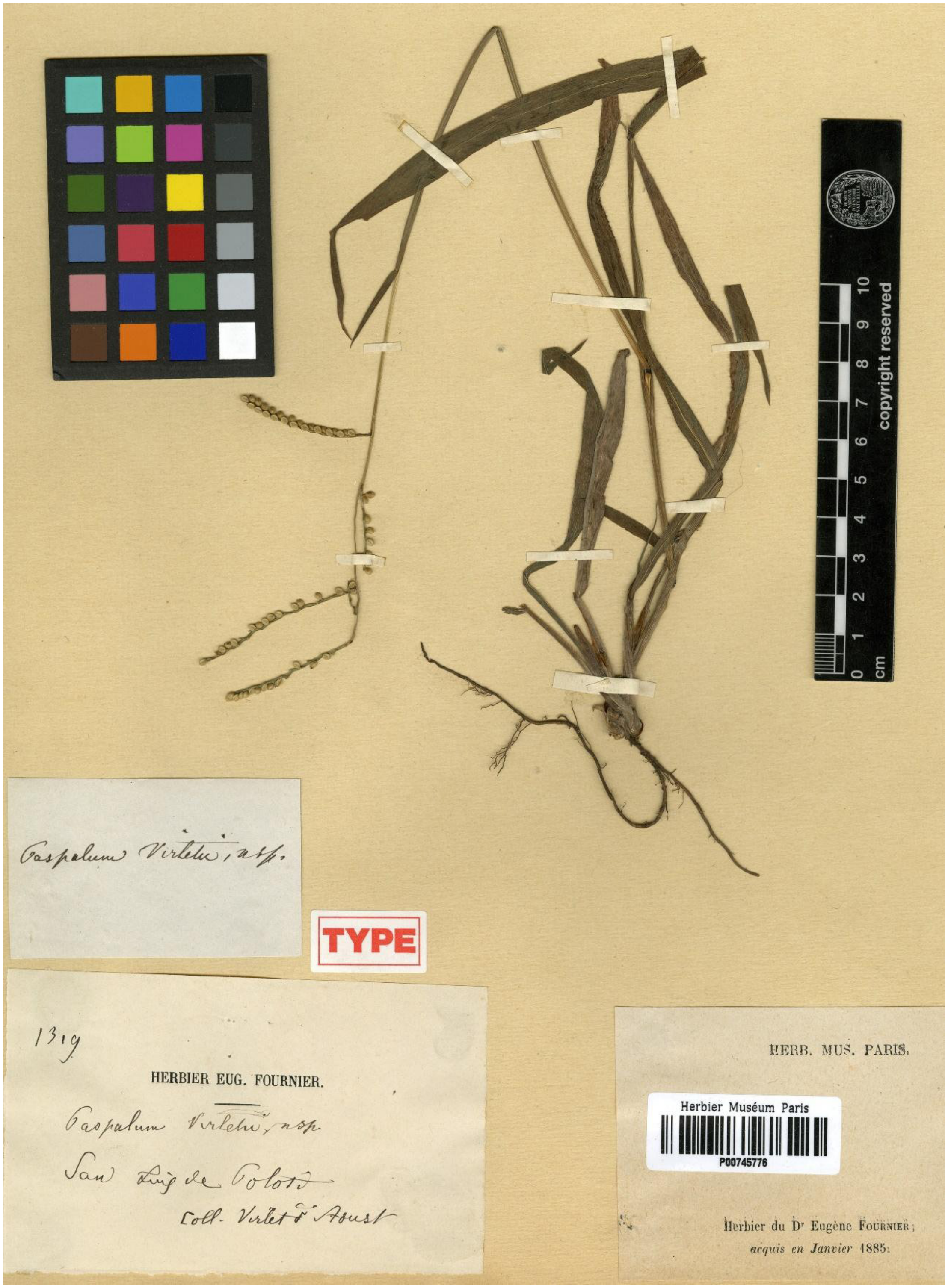

Fig. 7 Type specimens' image of *Paspalum virletii* E. Fourn. (*Virlet 1329*, P).
圖 7 絨葉雀稗 (*Paspalum virletii* E. Fourn.) 模式標本影像 (*Virlet 1329*, P)。

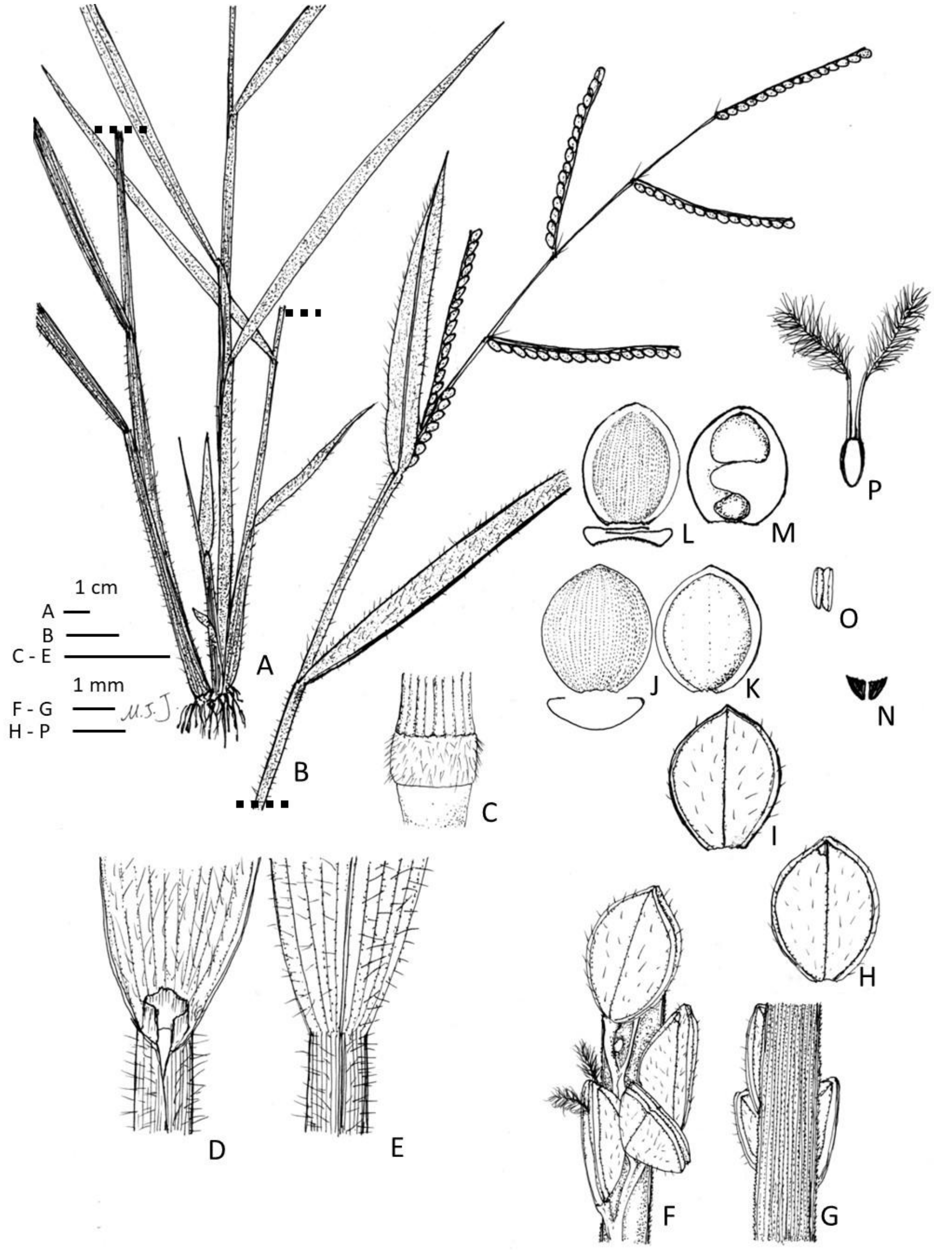

Fig. 8 *Paspalum virletii* E. Fourn. A: habit. B: inflorescence with upper leaves. C: node. D & E: basal part of leaf blades, D: adaxial view showing its ligule, E: abaxial view. F & G: part of racemes, F: showing the paired spikelets and solitary spikelet with vestigial bud. H: upper glume. I: lower lemma. J & K: upper lemmas, J: abaxial side, K: adaxial side. L & M: upper paleas, L: abaxial side, M: adaxial side. N: lodicules. O: anther. P: pistil.

圖 8 絨葉雀稗 (*Paspalum virletii* E. Fourn.)。A：外觀。B：花序與上部葉片。C：節。D & E：葉基，D：葉面側與葉舌，E：葉背觀。F & G：總狀花序分支片段， F：成對小穗與單生小穗和其旁芽痕。H：內穎。I：第一小花外稃。J & K：第二小花外稃，J：背側觀，K：腹側觀。L & M：第二小花內稃，L：背側觀，M：腹側觀。N：鱗被。O：花藥。P：雌蕊。

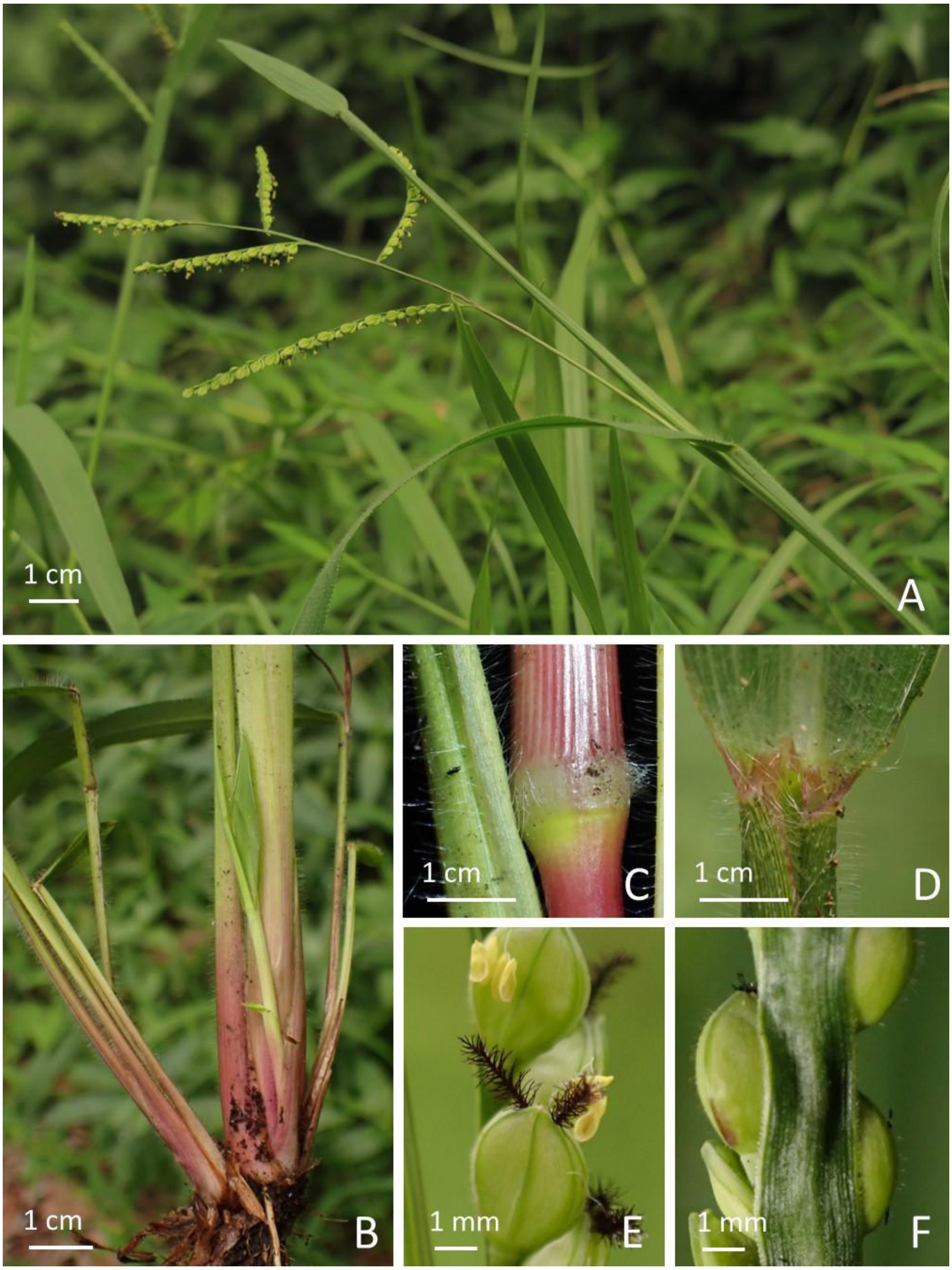

Fig. 9 *Paspalum virletii* E. Fourn. A: Habit. B: culms, showing its cespitose habit. C: node and part of leaf sheath. D: basal part of leaf base with ligule. E: part of racemes, showing the anthers and spreading stigmas. F: part of racemes, showing the paired spikelets.

圖 9 絨葉雀稗 (*Paspalum virletii* E. Fourn.)。A：外觀。B：稈叢生。C：節與局部葉鞘。D：葉基與葉舌。E：總狀花序分支局部，具花藥與盛開雌蕊。F：總狀花序分支局部，具成對小穗。

spreading to reversed pubescent. Sheaths pubescent, upper part keeled, collar inconspicuous; blades to 15 cm long, to 1 cm wide, flat, pubescent at both surfaces totally. Panicles terminal, with 3-8 racemosely arranged branches; branches 2-7 cm, spreading; branch axes narrow, sparsely pubescent. Spikelets 2-2.5 mm long, 1.4-1.6 mm wide, paired or not, with vestigial bud when solitary, imbricate, appressed to the branch axes, ovate to rounded. Upper glumes sparsely shortly pubescent, three-veined, margins entire; lower lemmas glabrous or sparsely shortly pubescent, three-veined, margins entire; upper florets pale to stramineous or golden brown, upper lemmas ovate to rounded, margins reflexed, apex acute, abaxial surfaces of intercostal regions with finely engraved spots; upper paleas broadly ovate, margins reflexed with two protruding lobes, lobes overlapped, apex round, intercoastal regions with finely engraved spots; lodicules 2, to 0.4 mm long, apex truncate, brownish when dried; anther three, yellowish, to 1 mm long; pistil one, ovary ellipsoid, to 0.7 mm long, stigma purplish.

Specimens examined: TAIWAN. New Taipei City, Chingshan District, Dayoukeng, 8 Jun 2023, *Ming-Jer Jung 6666* (TAIF), Pingshi District, Jingtong, 24 Jun 2023, *Ming-Jer Jung 6682* (TAIF), Wangu, 30 Sep 2023, *Ming-Jer Jung 6711* (TAIF), Ruifang District, Ruifang, 18 Jun 2023, *Ming-Jer Jung 6672* (TAIF), same loc., 30 Sep 2023, *Ming-Jer Jung 6709* (TAIF), Tamshui District, Mt. Datun, 2 Jul 2008, *Ming-Jer Jung 3032* (TAIF), Xintien District, Xintien, 23 Sep 2023, *Ming-Jer Jung 6706* (TAIF); Taipei City, Beitou District, Mt. Chungcheng, 24 Jul 2009, *Ming-Jer Jung 4247* (TAIF), same loc., *Ming-Jer Jung 4248* (TAIF), Mt. Hsiangtien to Mt. Mientien, 7 Aug 2008, *Ming-Jer Jung 3152* (TAIF), Mt. Hsiangtien to Chingtien Temple, 7 Aug 2008, *Ming-Jer Jung 3159* (TAIF); Taoyuan City, Fushin District, Mt. Dongyien, 30 Jun

2023, *Ming-Jer Jung 6683* (TAIF); Ilan Hsien, Tatong Hsiang, Ssuyuanyakou, 2 Sep 2020, *Ming-Jer Jung 6260* (TAIF), Toucheng Hsiang, Situ, 19 Jun 2023, *Ming-Jer Jung 6675* (TAIF).

Notes: The vernacular name of *Paspalum virletii* E. Fourn. is Virlet's paspalum (Allen and Hall 2022). This grass is native to subtropics, southern North America (Sánchez-Ken 2010; Allen and Hall 2022; POWO 2023), and naturalized at roadsides and half-shaded forest edges at low to middle elevation, northern Taiwan. I had misidentified several vouchers (*Ming-Jer Jung 3032, 3152*, *3159*, *4247, 4248*, TAIF) of this alien species as *Paspalum scrobiculatum* L. var. *bispicatum* Hackel (as *Paspalum commersonii* Lam.) or *Paspalum thunbergii* Kunth ex Steud., but they can be distinguished based on the taxonomic key provided in this paper.

Key to the species of *Paspalum* L. in Taiwan

1. Spikelets with a marginal fringe of silky hairs, hairs 1~2 mm long.

2. Racemes two or three, apical two opposite; habits stoloniferous. ……..*P. conjugatum*

2. Racemes usually more than four.

3. Racemes alternate arranged, spikelets 3~4 mm. ……………..….*P. dilatatum*

3. Racemes alternate or spiral arranged, spikelets 2~3 mm.……..…....*P. urvillei*

1. Spikelets without a marginal fringe of silky hairs.

4. Upper glume and lower lemma broadly winged along margins. *P. fimbriatum*

4. Upper glume and lower lemma not winged.

5. Plants rhizomatous, decumbent or stoloniferous, not tufted.

6. Plants rhizomatous, racemes two or three, apical two opposite. ……….......... *P. notatum*

6. Plants decumbent or stoloniferous;

7. Racemes more than four4, alternate.

8. Spikelets ovoid, 3~4 mm long. …………………….....…....*P. dilatatum*

8. Spikelets ellipsoid, 2.5~3 mm long. ……….………. ......*P. mandiocanum*

7. Racemes two (rarely three), apical two opposite or subopposite.

9. Upper glume sparsely pubescent. ……………….…………...... *P. distichum*

9. Upper glume glabrous. ……………..……………...*P. vaginatum*

5. Plants tufted, culms bases occasionally ascending.

10. Fertile floret dark glossy brown at maturity.

11. Racemes 10- or more, arranged as an apical panicle……….............*P. virgatum*

11. racemes three-eight, alternate.

12. Upper glumes transversely rugose; stigma whitish. ……..... *P. plicatulum*

12. Upper glumes smooth, not transversely rugose; stigma violate to blackish. …………...*P. scrobiculatum*

13. Leaf blades pilose totally on adaxial surface. ……......................var. *bispicatum*

13. Leaf blades usually glabrous.

14. Spikelets ca. 2 mm long, orbicular. ……………….................var. *orbiculare*

14. Spikelets 2~3 mm long, broadly elliptic. ……… ....var. *scrobiculatum*

10. Fertile floret yellow-green to pale brown at maturity.

15. Spikelets 1~1.5mm..…....*P. paniculatum*

15. Spikelets 2~3 mm.

16. Leaf blades pubescence on both surfaces totally. ………………....... *P. virletii*

16. Leaf blades glabrous in upper part of both surfaces.

17. Rachis 2~4 mm wide; spikelets 2~2.5 mm. ………..…............... *P. longifolium*

17. Rachis 1~1.5 mm wide; spikelets 2.5~3 mm. ……….…....... *P. thunbergii*

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從手機照片得知岸際垂釣魚種組成與體長可行性分析

Analysis of the Species Composition and Body Length of Shore Fishing from Mobile Phone Photos by Anglers

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摘要

國際研究指出休閒漁業對特定族群移除量高於以往認知，運用手機拍照可能是立即掌握休閒垂釣漁獲現況的可行方式。本調查利用手機拍攝以路亞釣獲魚隻照片並記錄詮釋資料，分析發現岸際常釣獲魚隻體長多在 30 cm 以下，在墾丁和成功釣獲魚種類別與麟山鼻和灰窯子不同，八斗子與龍洞海域的玳瑁石斑在春夏交際體型較小、秋冬之際較大。

關鍵詞：釣客、公民科學、休閒漁業、路亞釣魚

Abstract

International studies have indicated that the removal of particular fish stocks by recreational fisheries are higher than commonly perceived. Smartphone is an immediate and potential tool to collect useful recreational fisheries data. This research uses a smartphone to take photos of the fish caught by lure fishing and the accompanying metadata. The results show that most of the fish caught along the coast are less than 30 cm in length. The benthic fish species assemblage in Kenting and Chenggong are different from the species in Linshanbi and Huayozhi. Compared to other months, the body length of groupers, *Epinephelus quoyanus*, caught from April to June in Keelung, were smaller.

Key words: angler, citizen science, recreational fishing, lure fishing

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緒言

海洋休閒漁業 (Marine Recreational Fishing) 是指主要用於休閒和 / 或個人食用，所進行捕獲或嘗試捕獲水生生物資源的行為，以娛樂或運動等非商業性心態來利用水生生物資源，包括岸際潮間帶水域或坐船出海 (ICES 2021, 2023)。從漁業法所定義娛樂漁業係指 : 娛樂漁船搭載乘客在船上或登島嶼、礁岩從事採捕水產動植物、觀賞漁撈作業、觀賞生態及生物、賞鯨等活動。周 (2019) 則建議將休閒垂釣定義為 " 以休閒為目的，使用之漁具、漁法，以竿釣為限之垂釣活動，所得漁獲不得出售 "，強調非營利性行為。

以往普遍認為休閒漁業對魚類種群的影響微乎其微，大部分地區不會統計休閒漁業數據 (Hyder *et al*. 2018)。 但 Cooke and Cowx (2004) 使用加拿大資料推估出休閒漁業約移除了全球 12% 的漁業資源；Hyder *et al*. (2018) 指出休閒漁業大約移除了 27% 歐洲海鱸 (*Dicentrarchus labrax*) 與大西洋鱈 (*Gadus morhua*) 資源；Radford *et al*. (2018) 指出休閒漁業移除的歐洲海鱸、褐鱒 (*Salmo trutta*)、大西洋鱈、青鱈 (*Pollachius pollachius*) 資源量可達商業捕魚的一半以上。因為這些驚人的統計數據出現，International Council for the Exploration of the Sea (ICES) 開始要求加盟國以固定的方式定期取得統計上可靠的休閒漁業漁獲數據並納入資源評估中。

過往臺灣休閒漁業研究多偏向經濟面向。海洋委員會海洋保育署 (以下簡稱海保署) 估計臺灣釣魚人口約 116 萬人 (黃 2022)，推算約佔 5% 臺灣總人口數。估算東北角與北海岸釣客佔遊客比例依季節在 1.3-4.5% 間變動，每日釣遊支出約 446-458 元臺幣 (不含釣具)，從全年釣遊 56,438-70,652 人次估計年總花費約為 2,500-3,200 萬臺幣左右 (王 2005; 林 2006)。有關休閒漁業能釣獲的魚種、魚種棲地或魚隻體型多以問卷、漁獲日誌或訪查方式進行，例如孟 (2004) 指出墾丁潛水打魚每人每月可以捕獲 492 尾漁獲；劉 (2022) 推估 2017-2018 年臺灣周邊各海域娛樂海釣船全年釣獲約 5,500

公噸漁獲物，以白帶魚 (*Trichiurus lepturus*) 最多；葛 (2015) 統計 2000-2013 年間深澳漁港海釣船，每船每年平均釣獲 31 公噸漁獲。其他研究則著重在付費釣魚意願方面。顯示臺灣係屬認為休閒漁業不致於影響魚類種群永續利用，且未曾詳實調查和統計休閒漁業數據的國家。

岸際垂釣是人類社會殘存的合法狩獵行為之一，可供民眾取得亞潮帶或潮間帶水域的魚類資源以供食用。以潛水或浮潛觀察進行學術調查，除覆蓋率低且受能見度影響外，魚隻也會有閃避掠食者、晝夜出沒習性或匿礁等行為，另外岸際魚類分布並不均勻 (即有優良釣場)，以有限次數垂釣進行調查其時間與空間涵蓋率偏低。岸際漁業資源豐寡一向難以掌握，卻可能影響漁村家計與社區安定不應忽視，亦是達成里海願景需面對的議題，今天去海邊能不能釣到魚、能釣到幾尾魚，可能是民眾對海洋資源變化最直接的感受。

公民科學是社會民眾與專業科學家之間的合作，藉由吸引對研究項目有興趣的參與者，從而達成教育推廣目的，在進行大範圍空間與長時間尺度研究時能節省成本效益而具有優勢，休閒釣魚者參與公民科學項目，除能提供所需數據外，並能通報當地新物種入侵等問題 (Skov *et al*. 2021)，鼓勵釣客使用手機 app 回報釣遊資訊雖有誤差，但對於資訊缺乏的休閒漁業仍是低成本且足以收集基本資訊的方式 (Gundelund *et al*. 2020)。海保署自 2020 年鼓勵釣友成為釣訊情報員，參與海洋公民科學家計畫，積極建構 iOCEAN 垂釣資料庫。

本調查即本人嘗試從一般民眾角度，探討現地使用手機拍攝釣獲魚隻可行性，並初步分析統計部分的釣魚照片與附帶資訊後，了解此公民科學調查所能提供岸際魚類生態資訊，並期結果有助增進對岸際魚類生態了解。故本報告尚仍持續進行中，但在實際啟動公民科學計劃之前，須先初步分析以了解現有資料收集方式的缺點，以便後續改善而增加未來結果面相與可信度。

材料與方法

本研究擷取本人 2020 年 8 月 ~ 2023 年 7 月在臺灣本島、澎湖及東引使用路亞擬餌釣法所釣獲魚種資料，作釣時開啟手機定位，釣獲當下以本人手機拍攝釣獲魚隻，照片即會同時記錄釣獲日期、時間、地點與所使用路亞種類，後續依照片判斷至魚種層級，若不易判斷或種類繁多者則歸屬至科以便後續分析。作釣環境許可時則擺放固定比例物在魚隻身旁一起拍攝，固定比例物可能是 30 cm 直尺 (圖 1A) 或電子魚尺 (DRESS アプリ)，電子魚尺可在 DRESS 專用 app 程式中直接量測長度並顯示在照片上 (圖 1B)。若該魚種有顯著尾叉時選用尾叉長，若無則量測全長。有固定比例物時量至 cm，若在手上拍照則依魚體佔手掌比例概估至最接近 5 cm 長度區間。後續分析體長時會優先選用由電子魚尺進行量測者，以求統計時有相同量測基準。

路亞釣法 (Lure Fishing) 是相對於真餌釣法的統稱，真餌釣法用來捕抓魚隻的方式是鉤上對象魚喜愛且可吞入食用的生物性餌料。路亞釣法則以視覺為主聽覺為輔來吸引魚隻咬食的策略，需由釣者操弄釣竿舞線使假餌在水中正確地游動、跳動或漂移下沈，致使對象魚誤以為是餌魚而進行捕食，此其 lure 誘騙之意。

路亞釣法常用假餌可概分軟餌與硬餌。軟餌多稱為軟蟲，主要以軟性橡膠鑄模製成，各廠牌形狀繁多主要可分為魚型或異型，魚型外觀為小魚模樣 (圖 1D)，異型則多有諸多突起物以模仿節肢動物，軟蟲需搭配鉛錘以便拋甩並將軟蟲帶至目標水深。本調查使用軟蟲 2-3 寸，鉛錘重量 7-40 g，主要手法則為跳底與平收小跳為主。

硬餌可概分為湯匙 (Spoon)、米諾 (Minnow)、水表系 (Topwater)、鐵板 (Jig) 等，各自適用在不同的水深場域。湯匙外觀類似無柄湯匙 (圖 1C)，主要使用在淺水區，是最簡單又有效的硬餌；米諾泛指外觀為魚型的路亞，利用弧度不同的舌板來使假餌下沉與擺動；水表系多以製造水花聲響或波紋光影方式吸引下方獵食者捕食；鐵板

(圖 1B) 外觀由不規則的斜面 / 凸角 / 凹刻結構組成，舞弄時模擬小魚快速逃竄或者瀕死掙扎飄落動作，對於掠食性魚種吸引力極高。本調查主要使用湯匙快速搜尋淺水釣場，重量 3-15 g，而以鐵板應對水表至底棲各掠食魚種，重量 10-40 g，同時使用米諾。

以手機拍照會自動記錄經緯度，但地點過細，為便於文章中呈現，茲將基隆八斗子海域統歸為 Badouzi，東北角南雅海域為 Nanya，東北角鼻頭角海域統歸為 Bitou，龍洞灣為 Longdung，東北角和美村為 Homei，東北角福隆為 Fulong，東北角馬崗海域為 Magang，宜蘭縣南方澳為 Nanfanao，花蓮縣豐濱為 Fengbin，臺東縣成功為 Chengong，墾丁國家公園釣魚區皆為 KTNP，澎湖馬公市為 Magong，新北市淡水河口為 Tamshui，北海岸灰窯子為 Huayozhi，北海岸麟山鼻為 Linshanbi，連江縣東引島為 Dongyin。相關位置請參見圖 2 所示。

本調查僅由一人使用一支釣竿搭配單一假餌進行，日別名目單位努力漁獲量 (Nominal Catch Per Effort Unit, NCPUE) 定義為各地點一日內捕獲之各魚種數量 (尾數 / 天)，每天作釣時間約在 1-3 hrs，使用路亞種類則依當地地形與環境特徵挑選適合者，選擇邏輯請參閱前文所述。將各調查地點與 NCPUE 利用主成分分析 (Principal Component Analysis, PCA)，以探討各地點捕獲之魚種相似情形。分析前將 NCPUE 進行 Hellinger 轉換，即對各地點各魚種 NCPUE 取平方根，以降低特定魚種大量出現時導致偏離模式分析假設，並刪除釣獲尾數少於 5 尾之魚種，最終套入模式分析魚種為 :*Sebastiscus marmoratus*; *Sebastiscus tertius*; *Cephalopholis boenak*; *Epinephelus hexagonatus*; *Epinephelus quoyanus*; *Epinephelus akaara*; *Epinephelus coioides*; *Caranx sexfasciatus*; *Lutjanus fulviflamma*; *Lutjanus monostigma*; *Lutjanus vitta*; *Terapon jarbua*; *Cirrhitus pinnulatus*; *Cheilinus trilobatus*。Scorpaeninae gen. spp. 類魚種則將石狗公屬以外同科魚種併入，至於 *Synodus* spp.、 *Thalassoma* ssp. 與 *Sphyraena* ssp. 則將同屬魚種全數併入以利分析。

本調查遵循妥善釋放原則 (Cooke and Suski 2005)。魚鉤以無倒鉤者優先，或將倒鉤壓平或折斷以降低解鉤時對魚隻傷害，並將釣獲魚隻放置在潮濕表面進行拍照，或以手部輕觸方式拍照，拍照後小心解鉤放回流通水域中，不棄置在潮池內，整體過程不超過 30 秒。眼斑擬石首魚 (*Sciaenops ocellatus*) 與龍虎斑 (*Epinephelus fuscoguttatus* x *Epinephelus lanceolatus*) 皆不進行釣後釋放。

本研究統計分析以 R 軟體 (R Core Team 2020) 處理。並使用 Bartlett test 進行均質性檢定，以 $p < 0.05$ 視為否定樣本均質假設，使用 Shairo-Wilk test 進行常態性檢定，以 $p < 0.05$ 視為否定樣本常態分佈假設，符合上述前提後，始以變方分析 (ANOVA) 進行樣本均值檢定，以 $p < 0.05$ 視為否定樣本間均值相等假定。

結果

路亞釣法主要是以有捕食行為的魚種為主要目標，越具攻擊性的魚種越容易被路亞釣獲，偏藻食性且嘴小魚種如雀鯛類 (Pomacentridae gen. ssp.) 與臭肚類 (Siganidae gen. spp.) 等較難被路亞釣獲。本調查期間計釣獲 27 科 729 尾魚隻，其 NCPUE 如表 1 所示。主要以石斑屬 (*Epinephelus* spp.)、九刺鮨屬 (*Cephalopholis* spp.)、鮋科 (Scorpaenidae gen. spp.)、狗母屬 (*Synodus* spp.) 等底棲魚類為主，其餘則為中泳層巡游魚種如笛鯛屬 (*Lutjanus* spp.)、鯵科 (Carangidae gen. spp.)、鯛科 (Sparidae gen. spp.)、花身鯻 (*Terapon jarbua*)、康氏馬鞭魚 (*Fistularia commersonii*)、隆頭魚科 (Labridae gen. spp.) 等，再來則是表層快速泳動魚種如鬼頭刀 (*Coryphaena hippurus*)、金梭魚科 (Sphyraenidae gen. spp.)、鶴鱵科 (Belonida gen. spp.) 等等。當中以玳瑁石斑 (*Epinephelus quoyanus*, 圖 1C) 釣獲數量最多達 176 次，其次是橫紋九刺鮨 (*Cephalopholis boenak*, 圖 1D)、花身鯻與鮋科。本研究亦曾釣獲放生之龍虎斑與其他雜交石斑種類，以及眼斑擬石首魚。

從表 1 可以看出，玳瑁石斑與橫紋九刺鮨可在同一地點被釣獲，包括八斗子、灰窯子、麟山鼻、龍洞、南雅與馬公都有，且兩者皆未曾在墾丁、豐濱、成功、南方澳、馬崗、福隆與淡水被釣過；淡水以點帶石斑 (*Epinephelus coioides*) 與馬拉巴石斑 (*Epinephelus malabaricus*) 為主；六角石斑 (*Epinephelus hexagonatus*) 僅在墾丁、成功與豐濱被釣獲，且為主要鮨科魚種；赤點石斑 (*Epinephelus akaara*) 則為東引主要石斑屬魚種，與三色石狗公 (*Sebastiscus tertius*) 同為東引島最常釣獲的底棲魚種；石狗公 (*Sebastiscus marmoratus*) 則主要在八斗子與鼻頭被釣獲；翼鰤 (*Cirrhitus pinnulatus*) 可在墾丁、成功、南方澳與馬崗被釣獲，卻未曾在龍洞至淡水海域被釣獲。

接著使用 PCA 以便了解各地釣獲魚種組成相似情形，結果如圖 3 所示。PC1 可以解釋 27.5%，PC2 可以解釋 15.4% 數據散布情形。在魚種分布上以翼鰤 (s14) 與六角石斑 (s5) 解釋度最高，其釣獲地點與玳瑁石斑 (s6) 或橫紋九刺鮨 (s4) 相反，前 2 魚種主要在墾丁、成功、豐濱與南方澳釣獲，後二魚種則以麟山鼻與灰窯子為主；和美為花身鯻 (s13) 最常釣獲地點。其餘魚種因靠近中心解釋度較差。因此在墾丁、成功、豐濱與南方澳所能釣獲魚種與麟山鼻、灰窯子、南雅、龍洞與八斗子不同，馬崗與馬公釣獲的魚種組成亦不同。同時龍洞與八斗子能釣獲的魚種組成十分相近。

從表 1 表 2 可看出多數魚種釣獲次數甚少，且 NCPUE 為 1，顯示一日內多僅釣獲 1 尾魚。出現較高 NCPUE 魚種有三色石狗公、六角石斑與翼鰤，單日內可釣獲 8 尾。5 月與 6 月平均 NCPUE 最高，其次是 2 月，但其主要貢獻魚種並不相同。3 月與 12 月因海況較差皆少於 30 筆記錄且平均 NCPUE 亦最低。玳瑁石斑終年可見，平均每日可釣獲 2 尾以上，在 5 月 NCPUE 最高；橫紋九刺鮨僅 12 月未曾釣過，平均 NCPUE 可達 2.8 尾 / 日。

軟蟲是能釣獲最多魚種的路亞類型，同時也是 NCPUE 最高的路亞種

類，平均一日內可釣獲 3.6 尾魚，釣獲魚種多是底棲性的鮨科、石狗公屬、狗母屬與翼鰯等附礁魚類為主，笛鯛屬與隆頭魚科也會追咬掠過礁石的軟蟲 (表 3)。湯匙是 NCPUE 第二高的路亞種類，主要釣獲翼鰯與橫紋九刺鮨。

在臺灣岸際能釣獲的魚種大致以 10-30 cm 為主要體型範圍 (圖 4)。在岸際能釣到超過 25 cm 的魚隻並不容易。石斑屬以赤點石斑最大，點帶石斑次之，此兩種石斑才有超過 30 cm 個體出現，放生之龍虎斑亦為大型石斑魚種，常見之玳瑁石斑與橫紋九刺鮨體長超過 20 cm 個體並不易見，六角石斑與其他九刺鮨屬在岸際都只能釣到小型個體，鯻科與笛鯛屬魚類體型亦多在 20 cm 以下。金梭魚屬與鶴鱵、鬼頭刀、康氏馬鞭魚與七星鱸 (*Lateolabrax japonicus*) 都屬於岸際能釣獲的大體型魚種。從圖 4 中亦可以看出隆頭魚科會追咬路亞的多為大型個體，尤其是管唇魚 (*Cheilio inermis*) 與紫錦魚 (*Thalassoma purpureum*) 常出現超過 30 cm 個體。

因本研究釣獲魚種以玳瑁石斑尾數最多，後續即針對玳瑁石斑進一步分析。經以 Shapiro-Wilk test 檢視使用電子魚尺量測玳瑁石斑之體長分布顯示符合常態性分布假說 ($n = 59$, $p = 0.180$)，經 Bartless test 檢定後顯示不同路亞類型間玳瑁石斑體長均質性相等 ($df = 2$, $p = 0.894$)。經變方分析檢定以湯匙 ($n = 5$)、鐵板 ($n = 4$) 或軟蟲 ($n = 50$) 捕獲玳瑁石斑平均體長並無顯著差異 (圖 5, ANOVA, $p = 0.051$)。但軟蟲捕獲之玳瑁石斑體長區間較另二路亞種類廣，最大為 26.2 cm 而最小為 9.2 cm。

因 PCA 結果顯示龍洞與八斗子能釣獲的魚種組成近似，故將兩地玳瑁石斑釣獲資料合併以增加分析樣本數。從圖 6 中可以看出八斗子與龍洞在 4/5/6 月與 11 月能釣獲小型玳瑁石斑 (< 15 cm) ，中大型個體 (15-20 cm) 除 2 月外終年皆產，大於 25 cm 大型個體則在 3/5/9 與 11 月曾釣過。11 月與 5 月同時能釣獲大型與小型玳瑁石斑，其餘各月多以中大型個體為主。

討論

有鑒於ICES對於休閒漁業的重視，Skov *et al*. (2021) 訪問了參與WGRFS會議中負責各國休閒漁業研究的學者或管理者，在20個國家中有12個認為智慧型手機app具備提供休閒漁業管理所需資料潛能，對具備多樣性與分散性而難以收集資料的休閒漁業，這可能是唯一的資料來源，特別是app有助於管理者與釣客間即時溝通回饋，可以迅速收集特定時/空間漁獲量、漁獲物種與努力量的分佈狀況，後續即可挑選熱點進行現地調查訪視。陳 (2017) 使用拍照法進行休閒漁業調查時指出，釣客並不願意提供漁獲給研究人員量測，若能累積不易取得之磯釣魚種組成與體長大小，將有助於健全澎湖南方四島海域生態資料庫與休閒漁業發展。

潛水調查是了解水深30 m內海域魚種名錄與數量常用方式 (陳 2017)，但潛水調查中魚隻體長估計是憑藉潛水員的經驗與環境中如珊瑚等對比後概估 (Hodgson *et al*. 2006; 陳 2017)，排除有經驗的潛水員需長時間訓練，不同潛水員之間推算的數據也難以整併比對 (Hodgson *et al*. 2006)。 但概估魚隻體長除可用體長 - 體重關係式來轉換成重量以便推估資源量外，若目標魚種已曾有生殖生物學研究成果，還可以用來了解調查海域主要是成魚、亞成魚或仔稚魚棲息地，進而推估該海域是哺育場還是繁殖交配場，進而調整保育措施，也可用來了解成魚出沒的可能繁殖期。例如星雞魚 (*Pomadasys kaakan*) 雌魚之50%性成熟尾叉長為41 cm (吳等 2021)，而本研究在淡水釣獲者最大僅25 cm，可推論應尚未達成熟體長。

近年來臺灣已將岸際垂釣漸次導入管理，以期永續利用資源，例如墾丁國家公園海域一般管制區垂釣許可管理要點，與基隆市娛樂漁業島礁磯釣自治條例，當中皆有可攜回魚種與該魚種體長規定，例如基隆市娛樂漁業島礁磯釣自治條例明定20 cm以下必須釋放，同時基隆市島礁磯釣證管理及收費辦法亦規定：“從事島礁磯釣活動人員，應檢視漁獲體長，提供娛樂漁業漁船船長登錄於該航次之磯

釣活動日誌”。可知了解常見魚種與其體長範圍是經營管理釣魚管制區必備之數據，更是後續滾動檢討所需。藉由釣客自主回報可能僅提供俗名、魚種判斷錯誤或僅回報目測概估體長等缺點，若能改以擺放比例尺後以固定 app 拍照，除能減少疲憊釣客文字作業疏漏外，更能保存魚隻照片與其詮釋資料供後續追溯佐證。

願意參與回報的釣客可能沒有辦法代表所有垂釣族群 (Gundelund *et al*. 2020)。釣魚是一種技藝，經過長時間練習的老手，會比新手釣到更多或更大的魚。在使用釣客回報資訊時應考量回報者特質，分析回報資料品質對研究主題影響程度，尋求特定釣客全程參與標準化資料收集是校正公民科學資料的方法之一 (Gundelund *et al*. 2020, Skov *et al*. 2022)。因此未來應考慮導入願意參與回報且經過訓練的釣魚老手，類似陳 (2017) 調查澎湖南方四島漁業活動。經訓練的公民科學家可協助提供所有釣獲魚隻體長與種類，而非經挑選要攜回食用的較大型魚隻，以避免釣客自主上傳照片可能高估魚類體型分佈的情形。此為本研究後續努力方向。

路亞釣法以掠食性魚種為目標，可協助監控與移除不當放生之外來種或非當地生態魚種。本調查顯示岸際魚種常見體長多小於 30 cm (圖 4)，而許多放生魚隻體型比當地常見食物鏈頂端個體更大，例如本研究在淡水釣獲之龍虎斑 (圖 1A) 與基隆長潭里釣獲之眼斑擬石首魚皆大於 30 cm，又屬掠食性魚種，可能對生態系造成危害，漁政主管機關除限制放生魚種外，亦應規範適合放生體型。釣獲移除非當地或外來魚種以保護原生水域生態已在臺灣執行，如墾丁國家公園管理處委託嘉南藥理大學移除龍鑾潭重要濕地外來種魚類 (黃 2021)，海保署亦向所有釣客宣導切勿釋放釣獲之龍虎斑與眼斑擬石首魚 (黃 2022)。路亞釣法造成魚隻死亡率最低，有助避免移除過程傷及其他非目標魚種 (黃 2021)，而 Lewin (2018) 與 Skov *et al*. (2022) 亦提及以路亞釣獲之歐洲海鱸或褐鱒較不易死亡。若能藉由手機 app 讓釣客即時通報大量放生魚種出

現，除可協助主管機關掌握出沒熱點，並能以對原生魚種最小傷害方式協助移除掠食性放生魚種。

本調查顯示，底棲性六角石斑與翼鰶主要出現在墾丁、成功、豐濱與南方澳，玳瑁石斑與橫紋九刺鮨則出現在八斗子、龍洞、麟山鼻、灰窯子與馬公，在淡水河口是以點帶石斑與馬拉巴石斑為主 (圖 3)，顯示各地能釣獲的底棲魚種不同。岸際垂釣雖無法代表所有岸際漁業行為，但因手機定位準確度大幅提升，未來若能架接至資料庫中，將可大幅增加各魚種空間分布解析度。以本調查最常見之玳瑁石斑為例，臺灣魚類資料庫對其分布簡述為東部、西部、南部、北部、東北部、澎湖、綠島、東沙與南沙，但資料庫中同時對玳瑁石斑生態棲地特徵描述為 " 近岸碎屑的珊瑚礁區 "，可推論玳瑁石斑並不會出現在以沙地環境為主之整個西部海岸。後續若能持續將釣獲魚種經緯度導入地理資訊系統，應有助於學術界後續設計採樣調查以探討造成魚種空間分布差異的環境因子為何。此亦是 ICES 為何重視手機 app 能協助累積此一數據原因。

本調查顯示常見岸際魚種體長多小於 30 cm，目前臺灣對於岸際魚種之體長頻度尚無充足之文獻，無法得知造成本研究所見現象原因為何，而臺灣魚類資料庫中僅有曾記錄之最大體長。岸際魚類調查最常使用之潛水調查，係由訓練有素之潛水員自行概估長度，以致概估之體長難以比較，這也是珊瑚體檢中通常僅特別記錄石斑魚長度是否大於 30 cm (Hodgson *et al*. 2006)，或印度 - 西太平洋海域是否有大於 20 cm 鸚哥魚類出沒，視為當地過漁指標 (Hodgson *et al*. 2006)，當調查海域從未見過大型魚體時表示該地潛水打魚行為盛行。本研究之岸際垂釣海域與部分潛水或浮潛調查海域重疊，所得之魚種分布與組成可與水中調查互相比對，彌補在打魚行為盛行海域難以見到大魚的情形，並能提供相對上更可信且可比較之魚隻體長。

從休閒漁業收集魚類相對數量與體長可能因特定漁法而有偏差，但潛水魚類調查亦受到當地是否有高強度

打魚活動影響，在打魚行為盛行點魚隻會不敢靠近潛水員，也不適合在河口或沙地等環境操作。例如陳 (2017) 研究指出，澎湖南方四島海域石斑魚屬魚種計有 9 種，潛水調查只有看到 3 種，漁業調查有 7 種，其中僅玳瑁石斑同時在兩種調查被記錄到。另横紋九刺鮨在南方四島調查 28 個測站中，僅西吉島 1 個測站豐度為偶見 (3-6 尾)，其餘 7 個測站多屬於稀少 (1-2 尾)，剩下 20 個測站則沒有記錄到。但本研究在馬公市平均一日可釣獲 4.5 尾横紋九刺鮨，為當地主要釣獲魚種。借助公民調查累積垂釣資料作為學術研究參酌，應不失為可行的方法，像是横紋九刺鮨因無充分資料可評估受威脅程度，而被國際自然保育聯盟列入紅皮書中之數據缺乏 (Data Deficient) 類別，更應該從各種角度了解其分佈面積與數量是否減少。

結論

借助公民調查累積魚類資料可增進魚類資料庫中魚種分佈空間解析度，並了解各地常見魚種與體型。以手機拍照除能取得魚隻照片外，會同時記錄經緯度、日期、時間與體型等詮釋資料，現地調查時即可前往熱門釣點進行，並能累積罕見魚種相關生物資訊。若能在使用者同意下讓 app 在拍照時直接擷取相關資訊會是最簡便的，且魚隻與固定比例尺須一起拍照保存，並將詮釋資料如經緯度與時間刻印在相片上，以避免未來資料庫發生詮釋資料錯植或遺失等問題。

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表 1 各地區釣獲魚種之名目單位努力漁獲量 (隻數 / 天)
Table 1 The NCPUE (number/day) of fish caught in different locations

Family	Species	Ba do uzi	Bitou	Chengong	Dongyin	Fengbin	Fu long	Ho mei	Hua yozhi	KTNP	Lin shanbi	Longdung	Ma gang	Ma gong	Nan fanao	Nan ya	ND	Tam shui	average
F187 Synodontidae	*Synodus* spp.	1.1		1						1		1.5	1.6				1		1.3
	Trachinocephalus myops	1.8																	1.8
F245 Mugilidae	*Mugilidae gen.* spp.												1					1	1.0
F255 Belonidae	*Strongylura anastomella*															1			1.0
	Tylosurus acus melanotus												2						2.0
	Tylosurus crocodilus crocodilus												1						1.0
F297 Fistulariidae	*Fistularia commersonii*	2	1																1.5
F304 Scorpaenidae	*Scorpaeninae gen.* spp.	1.2	2						1		2				1				1.3
	Sebastiscus marmoratus	1.5	3.3																1.8
	Sebastiscus tertius				5.3														5.3
F332 Moronidae	*Lateolabrax japonicus*				1														1.0
F338 Serranidae	*Cephalopholis argus*	1		1						1.2									1.1
	Cephalopholis boenak	1.5							3		7	1.5		4.5		1	1		2.8
	Cephalopholis urodeta									1									1.0
	Epinephelus hexagonatus			1		2				3									2.6
	Epinephelus merra			1						1									1.0
	Epinephelus quoyanus	2.2	1		1			1.5	3.2		2.5	1.3		2.5		1.7			2.3
	Epinephelus akaara				3.8														3.8
	Epinephelus awoara																	1.5	1.5
	Epinephelus bleekeri																	1	1.0
	Epinephelus coioides	1.5																2.4	2.3
	Epinephelus fuscoguttatus x Epinephelus lanceolatus																	1	1.0
	Epinephelus macrospilos											1							1.0
	Epinephelus malabaricus																	1.7	1.7
F342 Pseudochromidae	*Labracinus cyclophthalmus*			1						1				1					1.0
F352 Apogonidae	*Ostorhinchus* spp.	1																	1.0
F361 Coryphaenidae	*Coryphaena hippurus*											2							2.0
F364 Carangidae	*Alectis indica*										2								2.0
	Caranx melampygus		1																1.0
	Caranx papuensis						1												1.0
	Caranx sexfasciatus	1						1	1			1	1					1	1.0
	Trachinotus blochii	1																	1.0
F366 Leiognathidae	*Nuchequula nuchalis*																	1	1.0

F370 Lutjanidae	*Lutjanus argentimaculatus*																	1	1.0
	Lutjanus fulviflamma	1						1	2							1		1	1.1
	Lutjanus fulvus							1				1							1.0
	Lutjanus monostigma	1.3						1			3		1						1.4
	Lutjanus rivulatus								1										1.0
	Lutjanus russellii																	1	1.0
	Lutjanus vitta	1.3										2						1	1.5
F374 Haemulidae	*Pomadasys kaakan*																	1.5	1.5
F377 Lethrinidae	*Lethrinus lentjan*									1									1.0
	Lethrinus nebulosus	1										1				1			1.0
F378 Sparidae	*Acanthopagrus latus*	1																	1.0
	Acanthopagrus schlegelii																	1	1.0
	Pagrus major	1.5																	1.5
F380 Polynemidae	*Polynemidae gen.* spp.	1																	1.0
F381 Sciaenidae	*Sciaenops ocellatus*	1																	1.0
F382 Mullidae	*Parupeneus ciliatus*	1											1						1.0
	Parupeneus indicus															1			1.0
	Parupeneus multifasciatus												1						1.0
	Parupeneus pleurostigma	1																	1.0
	Upeneus tragula	1																	1.0
F399 Terapontidae	*Terapon jarbua*	1.9					1	1.4	1		2	1.5	1.5			1.8		1	1.9
F402 Cirrhitidae	*Cirrhitus pinnulatus*			2						3			2		1				2.6
	Paracirrhites forsteri					1				1					1				1.0
F411 Pomacentridae	*Abudefduf bengalensi*							1											1.0
F412 Labridae	*Cheilio inermis*							1				1	1						1.0
	Cheilinus trilobatus	1		1				1				1							1.0
	Pseudolabrus eoethinus	1			1														1.0
	Thalassoma jansenii	1																	1.0
	Thalassoma purpureum	1								1			1.5			1.5			1.3
	Thalassoma quinquevittatum									1									1.0
	Thalassoma trilobatum									1			1		1	1			1.0
F435 Pinguipedidae	*Parapercis pacifica*									1									1.0
F467 Siganidae	*Siganus* sp.	1																	1.0
F472 Sphyraenidae	*Sphyraena barracuda*															1			1.0
	Sphyraena flavicauda	1									1	3		1					1.5
	Sphyraena jello										1								1.0
F510 Diodontidae	*Diodon holocanthus*	1.3											1						1.2
	average	1.2	1.7	1.1	2.4	1.5	1.0	1.1	1.7	1.3	2.6	1.4	1.3	2.3	1.0	1.2	1.0	1.2	1.4

表 2 每個月釣獲各魚種名目單位努力漁獲量 (尾數 / 天)
Table 2 The NCPUE (number/day) of fish caught each month

Family	Species Month:	1	2	3	4	5	6	7	8	9	10	11	12	average
F187 Synodontidae	*Synodus* spp.	1	2.5	1.5	1		1	1	1	1	1	1	1	1.3
	Trachinocephalus myops	2							2	3	1			1.8
F245 Mugilidae	*Mugilidae gen.* spp.	1	1											1.0
F255 Belonidae	*Strongylura anastomella*										1			1.0
	Tylosurus acus melanotus					2								2.0
	Tylosurus crocodilus crocodilus										1			1.0
F297 Fistulariidae	*Fistularia commersonii*					2	1							1.5
F304 Scorpaenidae	*Scorpaeninae gen.* spp.	1		1	1.3	2	1.5	1	1	1	1	1		1.3
	Sebastiscus marmoratus	2	2	2	2		1		1	1			1	1.8
	Sebastiscus tertius	1	8				4.5			3				5.3
F332 Moronidae	*Lateolabrax japonicus*									1				1.0
F338 Serranidae	*Cephalopholis argus*	1	1		1		1			2	1			1.1
	Cephalopholis boenak	1	1.5	1	6	3	2	1	1.5	1.3	1	1		2.8
	Cephalopholis urodeta		1							1				1.0
	Epinephelus hexagonatus						8	2		1.8	1			2.6
	Epinephelus merra				1						1			1.0
	Epinephelus quoyanus	2	2	1.3	2.2	2.7	1.9	1.3	1.6	1.8	2.3	2.1	1.2	2.3
	Epinephelus akaara						4.5			1				3.8
	Epinephelus awoara										1.5			1.5
	Epinephelus bleekeri											1		1.0
	Epinephelus coioides	2				1		3	2.8	1	3	1.3		2.4
	Epinephelus fuscoguttatus x Epinephelus lanceolatus										1			1.0
	Epinephelus macrospilos		1											1.0
	Epinephelus malabaricus								2			2	1	1.7
F342 Pseudochromidae	*Labracinus cyclophthalmus*				1					1	1			1.0
F352 Apogonidae	*Ostorhinchus* spp.								1	1				1.0
F361 Coryphaenidae	*Coryphaena hippurus*	2	2											2.0
F364 Carangidae	*Alectis indica*		2											2.0
	Caranx melampygus								1					1.0
	Caranx papuensis										1			1.0
	Caranx sexfasciatus	1							1	1		1	1	1.0
	Trachinotus blochii								1					1.0
F366 Leiognathidae	*Nuchequula nuchalis*								1					1.0
F370 Lutjanidae	*Lutjanus argentimaculatus*										1			1.0
	Lutjanus fulviflamma				1		1	1	1	1	1.2		1	1.1
	Lutjanus fulvus						1				1			1.0

	Lutjanus monostigma						1.3	1	2	1				1.4
	Lutjanus rivulatus												1	1.0
	Lutjanus russellii	1							1	1	1			1.0
	Lutjanus vitta	1							1	2	1	2		1.5
F374 Haemulidae	*Pomadasys kaakan*								1.5					1.5
F377 Lethrinidae	*Lethrinus lentjan*									1				1.0
	Lethrinus nebulosus							1		1		1		1.0
F378 Sparidae	*Acanthopagrus latus*								1					1.0
	Acanthopagrus schlegelii							1						1.0
	Pagrus major											1	2	1.5
F380 Polynemidae	*Polynemidae gen.* spp.												1	1.0
F381 Sciaenidae	*Sciaenops ocellatus*								1	1				1.0
F382 Mullidae	*Parupeneus ciliatus*												1	1.0
	Parupeneus indicus										1			1.0
	Parupeneus multifasciatus	1												1.0
	Parupeneus pleurostigma								1					1.0
	Upeneus tragula											1		1.0
F399 Terapontidae	*Terapon jarbua*	1				1.5	2.5	1.1	2.5	1.2	2	1.3	1	1.9
F402 Cirrhitidae	*Cirrhitus pinnulatus*				1.5	2	5.5	8		1.6	2		1	2.6
	Paracirrhites forsteri		1	1	1					1				1.0
F411 Pomacentridae	*Abudefduf bengalensi*									1				1.0
F412 Labridae	*Cheilio inermis*		1					1	1			1		1.0
	Cheilinus trilobatus	1					1				1	1		1.0
	Pseudolabrus eoethinus			1			1	1		1			1	1.0
	Thalassoma jansenii												1	1.0
	Thalassoma purpureum					2	1	1	1		2			1.3
	Thalassoma quinquevittatum						1							1.0
	Thalassoma trilobatum			1			1	1						1.0
F435 Pinguipedidae	*Parapercis pacifica*		1											1.0
F467 Siganidae	*Siganus* sp.	1												1.0
F472 Sphyraenidae	*Sphyraena barracuda*								1					1.0
	Sphyraena flavicauda		1		1						2			1.5
	Sphyraena jello	1												1.0
F510 Diodontidae	*Diodon holocanthus*						1	1	1	1				1.2
	average	1.3	1.9	1.2	1.7	2.0	2.0	1.6	1.3	1.3	1.3	1.3	1.1	1.4

表 3 不同路亞種類釣獲魚種名目單位努力漁獲量 (尾數 / 天)
Table 3 The NCPUE (number/day) of each fish species by different lure types

Family	Species	jig	minnow	soft bait	spoon	average
F187 Synodontidae	*Synodus* spp.	1.5	1.0	1.2	1.0	1.2
	Trachinocephalus myops	1.3		2.5		1.8
F245 Mugilidae	*Mugilidae gen.* spp.			1.0	1.0	1.0
F255 Belonidae	*Strongylura anastomella*				1.0	1.0
	Tylosurus acus melanotus	2.0				2.0
	Tylosurus crocodilus crocodilus			1.0		1.0
F297 Fistulariidae	*Fistularia commersonii*			1.5		1.5
F304 Scorpaenidae	*Scorpaeninae gen.* spp.			1.3	1.0	1.3
	Sebastiscus marmoratus			2.2	1.0	2.1
	Sebastiscus tertius	1.0		5.1		4.6
F332 Moronidae	*Lateolabrax japonicus*			1.0		1.0
F338 Serranidae	*Cephalopholis argus*	1.0		1.2		1.1
	Cephalopholis boenak	1.0		2.6	3.3	2.7
	Cephalopholis urodeta			1.0		1.0
	Epinephelus hexagonatus	1.0		2.4	1.7	2.0
	Epinephelus merra			1.0		1.0
	Epinephelus quoyanus	2.0	1.0	2.0	1.8	1.9
	Epinephelus akaara			3.8		3.8
	Epinephelus awoara			1.5		1.5
	Epinephelus bleekeri			1.0		1.0
	Epinephelus coioides			2.3	1.3	2.1
	Epinephelus fuscoguttatus x Epinephelus lanceolatus		1.0			1.0
	Epinephelus macrospilos			1.0		1.0
	Epinephelus malabaricus			1.7		1.7
F342 Pseudochromidae	*Labracinus cyclophthalmus*			1.0		1.0
F352 Apogonidae	*Ostorhinchus* spp.			1.0		1.0
F361 Coryphaenidae	*Coryphaena hippurus*	2.0				2.0
F364 Carangidae	*Alectis indica*			2.0		2.0
	Caranx melampygus	1.0				1.0
	Caranx papuensis					0.0
	Caranx sexfasciatus	1.0		1.0	1.0	1.0
	Trachinotus blochii				1.0	1.0

F366 Leiognathidae	*Nuchequula nuchalis*				1.0	1.0
F370 Lutjanidae	*Lutjanus argentimaculatus*			1.0		1.0
	Lutjanus fulviflamma			1.0	1.1	1.1
	Lutjanus fulvus			1.0	1.0	1.0
	Lutjanus monostigma				1.4	1.4
F377 Lethrinidae	*Lethrinus lentjan*			1.0		1.0
	Lethrinus nebulosus			1.0	1.0	1.0
F378 Sparidae	*Acanthopagrus latus*				1.0	1.0
	Acanthopagrus schlegelii			1.0		1.0
	Pagrus major	1.0		1.0		1.0
F380 Polynemidae	*Polynemidae gen.* spp.			1.0		1.0
F381 Sciaenidae	*Sciaenops ocellatus*				1.0	1.0
F382 Mullidae	*Parupeneus ciliatus*	1.0		1.0		1.0
	Parupeneus indicus				1.0	1.0
	Parupeneus multifasciatus			1.0		1.0
	Parupeneus pleurostigma				1.0	1.0
	Upeneus tragula			1.0		1.0
F399 Terapontidae	*Terapon jarbua*	1.0		1.0	1.9	1.8
F402 Cirrhitidae	*Cirrhitus pinnulatus*	1.0		2.1	4.0	2.1
	Paracirrhites forsteri			1.0	1.0	1.0
F411 Pomacentridae	*Abudefduf bengalensi*				1.0	1.0
F412 Labridae	*Cheilio inermis*			1.0	1.0	1.0
	Cheilinus trilobatus			1.0	1.0	1.0
	Pseudolabrus eoethinus			1.0		1.0
	Thalassoma jansenii			1.0		1.0
	Thalassoma purpureum			1.5	1.0	1.3
	Thalassoma quinquevittatum			1.0		1.0
	Thalassoma trilobatum			1.0	1.0	1.0
F435 Pinguipedidae	*Parapercis pacifica*			1.0		1.0
F467 Siganidae	*Siganus* sp.	1.0				1.0
F472 Sphyraenidae	*Sphyraena barracuda*				1.0	1.0
	Sphyraena flavicauda	3.0		1.0		1.5
	Sphyraena jello			1.0		1.0
F510 Diodontidae	*Diodon holocanthus*	1.0	1.0		1.0	1.0
	average	1.8	1.0	3.6	3.0	1.3

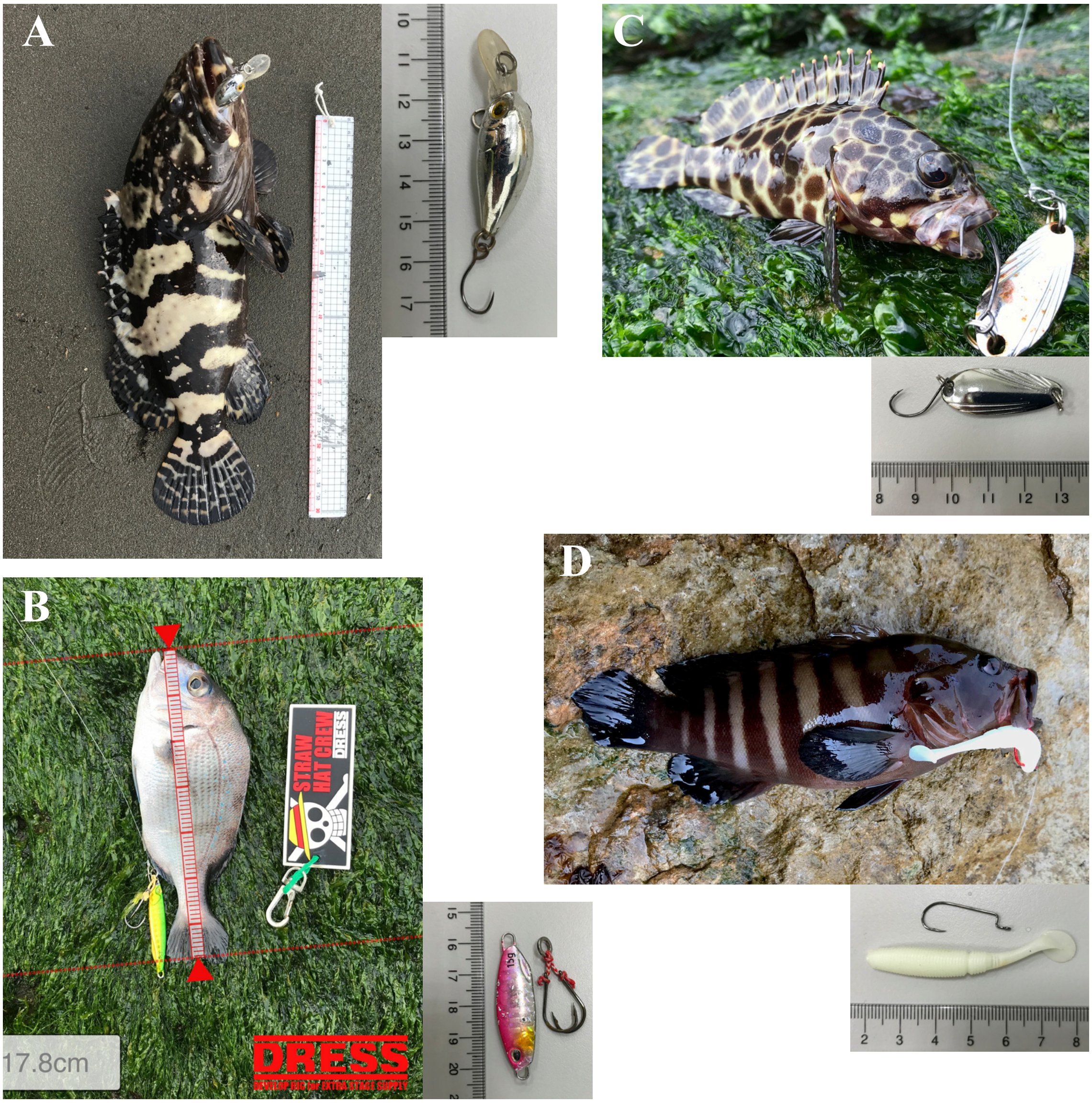

圖 1 本研究使用路亞與魚隻照片範例：(A) 以米諾釣獲之龍虎斑 (*Epinephelus fuscoguttatus* x *Epinephelus lanceolatus*)；(B) 以鐵板釣獲之真鯛 (*Pagrus major*)，右側為電子魚尺；(C) 以湯匙釣獲之玳瑁石斑 (*Epinephelus quoyanus*)；(D) 以軟蟲釣獲之橫紋九刺鮨 (*Cephalopholis boenak*)。

Fig. 1 The example of lure types and fish photos used in this research: (A) the hybrid grouper caught by a minnow; (B) the *Pagrus major* caught by a jig, the e-ruler was put on its right-hand side; (C) the *Epinephelus quoyanus* caught by a spoon; (D) the *Cephalopholis boenak* caught by a soft bait.

圖 2 本研究調查地點示意圖。
Fig. 2 The sampling location of this research.

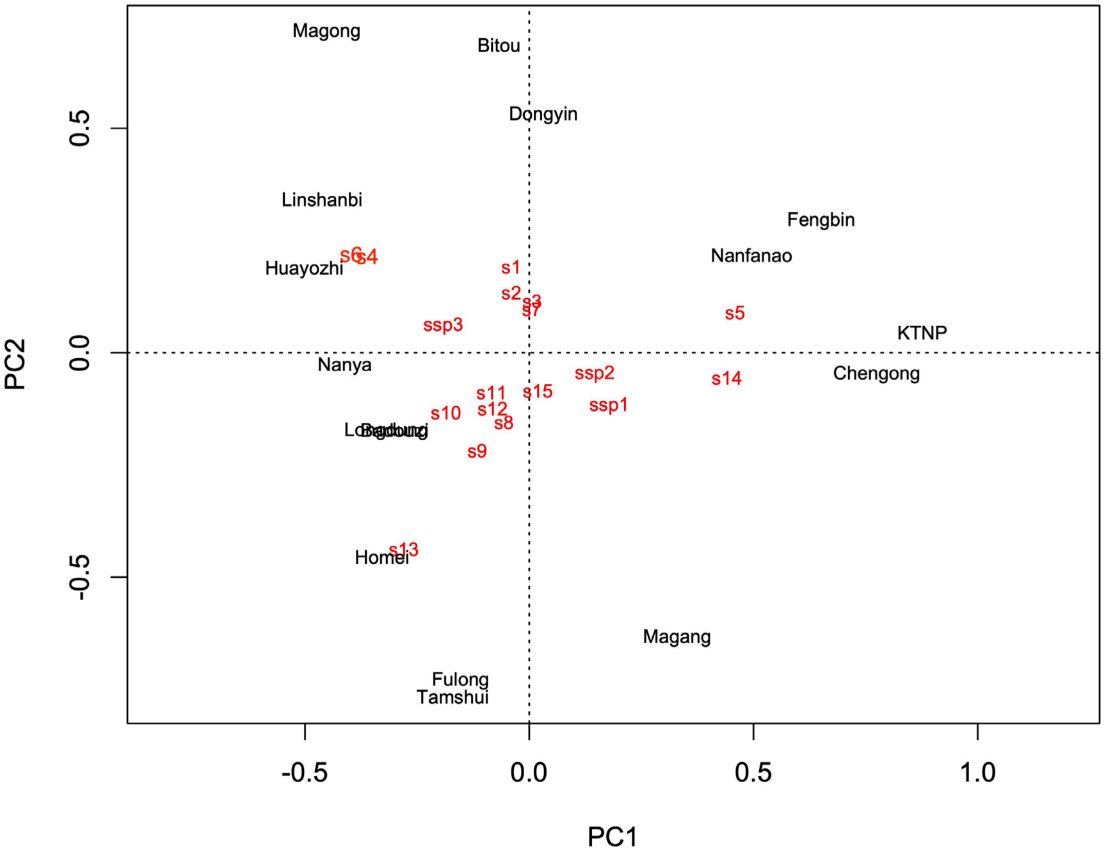

圖 3 各地點釣獲魚種經主成分分析結果。

Fig. 3 The result of principal component analysis about fish species and location.

s1:Scorpaeninae gen. spp.; s2:*Sebastiscus marmoratus*; s3:*Sebastiscus tertius*; s4:*Cephalopholis boenak*; s5:*Epinephelus hexagonatus*; s6:*Epinephelus quoyanus*; s7:*Epinephelus akaara*; s8:*Epinephelus coioides*; s9:*Caranx sexfasciatus*; s10:*Lutjanus fulviflamma*; s11:*Lutjanus monostigma*; s12:*Lutjanus vitta*; s13:*Terapon jarbua*; s14:*Cirrhitus pinnulatus*; s15:*Cheilinus trilobatus*; ssp1:*Synodus* spp.; ssp2:*Thalassoma* ssp.; ssp3:*Sphyraena* ssp.

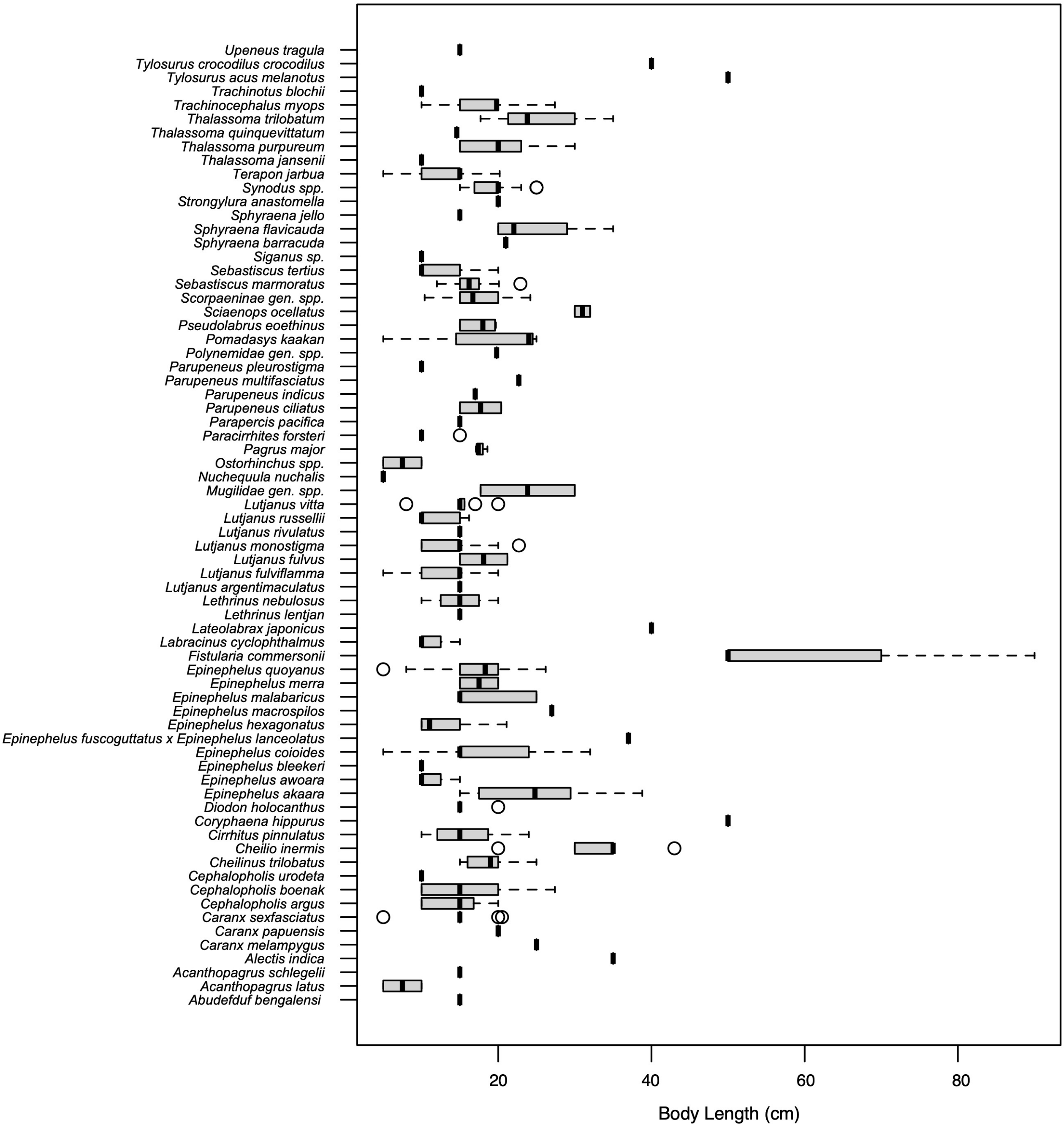

圖 4 各釣獲魚類體長範圍。本處所指體長，在具尾叉魚種為尾叉長，無明顯尾叉魚種則為全長。

Fig. 4 The body length distribution of fish caught in this research. For fish with a forked tail, the body length means fork length; for fish without a clearly forked tail, the body length means total length.

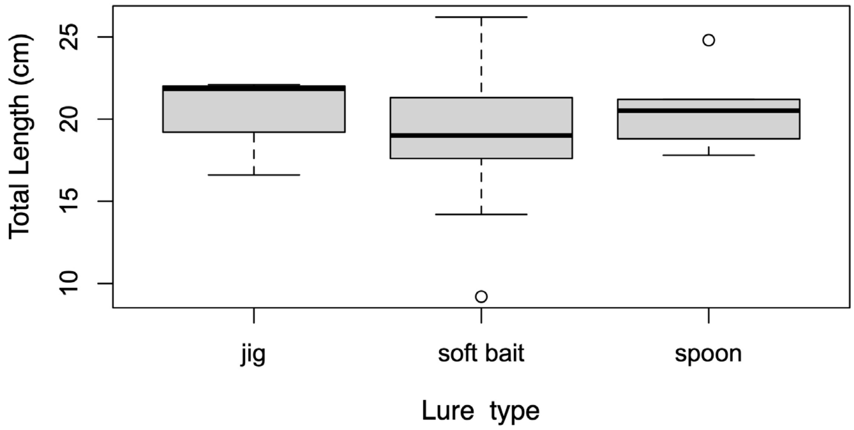

圖 5 經電子魚尺量測不同路亞類型所釣獲玳瑁石斑 (*Epinephelus quoyanus*) 其體長無明顯差異。
Fig. 5 Measurements by e-ruler show no significant body length difference between *Epinephelus quoyanus* caught by different lure types.

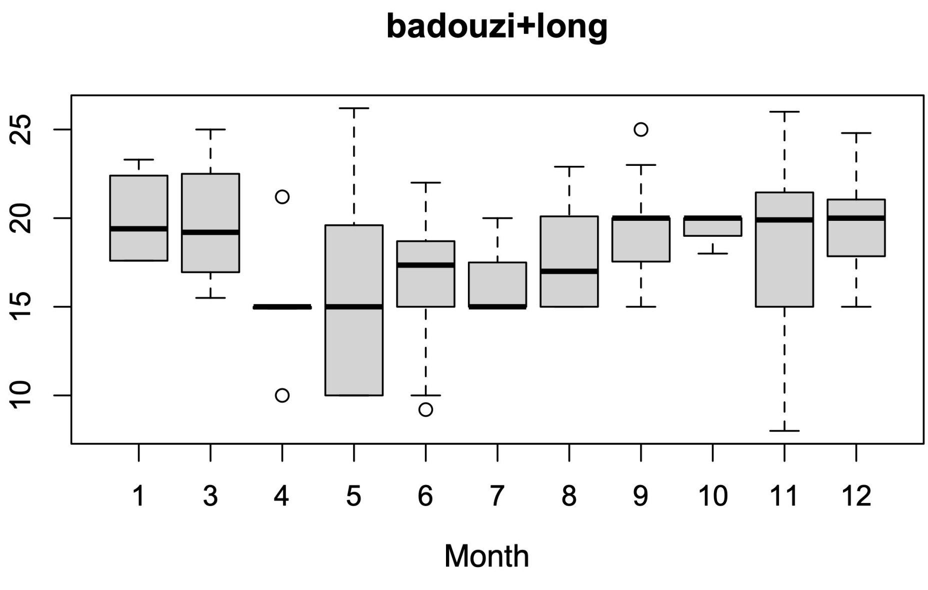

圖 6 八斗子與龍洞海域小體型玳瑁石斑 (*Epinephelus quoyanus*) 主要在 4-6 月和 11 月間釣獲。
Fig. 6 Compared to other months, the length of *Epinephelus quoyanus* caught from April to June and November in Badouzi and Longdung was smaller.

資料論文 **Data Paper**

Survey on Diversity of Planktonic Diatoms in Sinfong Mangrove, Taiwan

新豐紅樹林浮游矽藻多樣性調查

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Abstract

There has yet to be a study that has specifically explored the diatom species population in Taiwanese mangrove forests. The present study investigates the diversity of planktonic diatom species and water quality environmental factor parameters from the Sinfong Mangrove forest in Sinfong Township, Hsinchu County, Taiwan. Furthermore, we established a dataset for diatom and related environmental data to serve as a reference for future monitoring research. In this study, 65 genera and 136 species of planktonic diatoms were identified, among which 15 species of *Nitzschia* were the most diverse taxon group.

Key words: plankton, diatom, Sinfong Mangrove

摘要

國內有關紅樹林矽藻相關研究甚少，本調查係針對新竹縣新豐紅樹林的浮游矽藻進行採集鑑定，並建立了矽藻名錄及環境因子資料庫，做為未來的監測研究參考。已鑑定出矽藻 65 屬 136 種，其中以 *Nitzschia* 屬 15 種多樣性最高。

關鍵詞：浮游生物、矽藻、新豐紅樹林

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Introduction

Coastal mangrove forests are crucial ecosystems that provide natural habitats for wildlife, prevent coastal erosion, digest pollutants, enhance water quality, and exhibit high ecological productivity (Kuo *et al.* 2012). Moreover, mangrove ecosystems are important breeding grounds for fish and are therefore crucial fishery areas. The maintenance of fishery resources relies on plankton communities, including phytoplankton (Robertson and Blaber 1992). Phytoplankton including chlorella, cyanobacteria, diatoms, and haptophyceae are the primary producers in mangrove ecosystems (Jeffrey and Vask 1997). Most diatoms are sensitive to and respond rapidly to environmental changes because they have a short life cycle and reproduce rapidly. In addition, they are easy to sample, prepare, and identify, entailing low sampling and analysis costs (Dixit *et al.* 2001; Gell *et al.* 2007; Reid and Ogen 2009; Soeprobowati *et al.* 2012), making them the ideal biological indicators of environmental changes.

The mangrove forests in Taiwan are mainly distributed along the west coast of Taiwan from Tamsui (Taipei City) to Donggang and Linbian (Pingtung County), and the main mangrove species found here are *Kandelia obovata*, *Avicennia marina*, *Lumnitzera racemosa*, and *Rhizophora stylosa* (Hsueh 1995). Sinfong Mangrove forest is located at the estuary of Sinfong River, Sinfong Township, Hsinchu County, and was formerly known as "Hongmaogang (紅毛港)." According to previous studies, the mangrove forests of "Hongmaogang" are believed to have been imported from Guangdong Province in the 1790s, and by the time when Taiwan was under Japanese rule, they were already thriving (Chao 2005). Currently, the main mangrove species found in the Sinfong Mangrove forest are *K. obovata* and *A. marina* (Wang *et al.* 2015).

Taiwanese studies have mainly focused on the identification of diatom species or taxa (Shen 1956; Chang 1966; Li 1976; Li and Chiang 1979; Huang 1981). The community composition of algae is closely related to water quality and can serve as powerful biological indicators of environmental changes. Therefore, to understand the relationship between algae and water quality, a series of studies have been conducted on planktonic algae found in reservoirs (Chang *et al.* 1995; Chi *et al.* 1988). Thereafter, several studies have explored the role of epiphytic diatoms in rivers as water quality indicators (Wu 1984; Yu *et al.* 1995; Huang 1992; Chen and Lai 1984, 1985; Lai 1997). Studies related to aquaculture along Taiwanese coasts have primarily investigated the distribution of planktonic diatom populations (Wang 2002; Chou 2001; Chen 1998; Tsai 2008). In particular, these studies have separated and purified diatoms from the southwestern coast of Taiwan and investigated the phylogeny of these species. Pen (2015) investigated the productivity of planktonic algae. Chen (2003) studied the clustering of diatoms in estuarine flats in central Taiwan. Hsu (2009) analyzed the spatiotemporal changes in benthic diatom coenosium in Gaomei Wetland. Some studies have also explored the use of bait in aquaculture (Chen 2007). There has yet to be a study that has specifically explored the diatom species population in Taiwanese mangrove forests.

Project description

Survey on Diversity of Planktonic Diatoms in Sinfong Mangrove.

Study area description:

The two sampling points were St1 and St2, as shown in Fig. 1. St1, was located within the mangrove forest and St2 was located by the riverbank of Sinfong River on the edge of the mangrove forest. Both sampling points were tidal sections.

Sampling methods

Sampling description:

Water quality

To measure the quality of water in Sinfong Mangrove, we used a portable water quality sensor (HANNA, Multiparameter Meter, HI9829) to determine the water temperature, conductivity, dissolved oxygen, and pH value. Collected water samples underwent ethanol extraction to determine the concentration of chlorophyll a in the water body according to the Environmental Protection Administration. A total of four sampling events were performed in May, August, October, and December, 2017.

Data on the water quality in the study region are presented in Table 3. Data on the water temperature in May was unavailable. For the other months, the maximum water temperature was recorded at St1 in August (26.5°C), whereas the minimum water temperature was recorded at St2 in December (16.3°C). In general, the water temperature in areas within the

Fig. 1 The sampling stations in Sinfong Mangrove.
圖 1 新豐紅樹林及各樣點位置圖。

mangrove was higher than that in areas outside the mangrove. The maximum dissolved oxygen was found at St1 in October (11.8 mg/L), whereas the minimum dissolved oxygen was recorded at St1 in August (0.7 mg/L). The maximum electrical conductivity was recorded at St1 in May (26.9 μmS/cm), whereas the minimum electrical conductivity was recorded at St2 in August (6.2 μmS/cm). In general, the electrical conductivity of water was higher in areas within the mangrove than in those outside the mangrove. The soil pH at St2 in October was 6.0, indicating slightly acidic conditions, whereas the soil pH at St1 in May was 8.1, indicating slightly basic soil conditions. In general, the pH of the water within the mangrove forest was slightly basic, whereas that outside the mangrove forest was slightly acidic. The maximum salinity was recorded at St1 in May (16.3 psu), whereas the minimum salinity was recorded at St2 in August (3.4 psu). In general, the salinity of water within the mangrove forest was higher than that of water outside the mangrove forest during the same season. The maximum chlorophyll a concentration in water was observed at St1 in October (162.7 μg/L), whereas the minimum chlorophyll a concentration was observed at St1 in December (1.5 μg/L). In general, the chlorophyll a concentration in water within the mangrove forest was higher than that in water in regions outside the mangrove forest, indicating that the algal biomass within the mangrove forest was higher than that outside the mangrove forest.

Plankton diatoms

During each sampling event, 500 ml of water samples were collected from each sampling point and taken back to the laboratory for observation and identification (Hsieh *et al.* 2019).

Quality control:

For diatom identification, some manuals were used (Round *et al.* 1990). Scientific names of diatom taxon names were according to Guiry and Guiry (2022).

Step description:

1. Samples were collected from habitat. The sampling locations are the same habitat type. Each sample was collected in the same type of tidal flat habitat, regardless of whether it was at St1 within the mangrove forest or at St2 along the mangrove forest's edge.
2. The samples were acid-wash treatment for identification.
3. Photograph the samples with an electron microscope.
4. Conversion of paper-based records from the field and laboratory into an electronic data format (Excel spreadsheets).
5. Organizing the datasets into a standardized format.
6. Export of data as a Darwin Core Archive.
7. Generation of dataset-level metadata.

Geographic coverage

Description:

The Sinfong Mangrove forest is located at the estuary of Sinfong River, Sinfong Township, Hsinchu County.

Coordinates:

St1 (24.908387, 120.97173); St2 (24.908907, 120.971857).

Taxonomic coverage

Description:

All diatoms were identified to genus or species level. In total, 136 species taxa were identified belonging to three classes, 22 orders, 38 families, and 65 genera. The taxonomic coverage of the diatoms found in the studied material is given in Table 1. A list of diatom species found in sample stations is in Table 3.

Temporal coverage

Notes:

Sample in May, August, October, and December, 2017.

Usage license

Usage license:

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Data resources

Data package title:

Darwin Core Archive Survey Data of Planktonic Diatoms in Sinfong Mangrove

Resource link:

https://www.gbif.org/dataset/6bd0551c-f4e9-4e85-9cec-6cefae343234

Alternative identifiers:

https://doi.org/10.15468/d23vg3

https://ipt.taibif.tw/resource?r=survey_data_of_diatoms_in_hsinfong_mangrove

Data set name:

Survey Data of Planktonic Diatoms in Sinfong Mangrove

Data format:

Darwin Core Archive

Data format version:

1.8 published on December 4, 2023

Table 1 Taxonomic coverage of diatoms from studied samples
表 1 調查樣本中矽藻各目下分類群數目

Orders	Families	Genera	Species
Achnanthales	4	4	11
Aulacoseirales	1	1	2
Bacillariales	1	7	26
Chaetocerotales	1	1	1
Coscinodiscales	2	3	3
Cyclophorales	1	1	1
Cymatosirales	1	1	1
Cymbellales	2	4	10
Eupodiscales	1	2	2
Fragilariales	1	2	2
Hemiaulales	1	1	1
Licmophorales	1	2	2
Melosirales	1	1	2
Naviculales	11	19	44
Plagiogrammales	1	1	1
Rhaphoneidales	1	2	2
Rhizosoleniales	1	1	1
Stephanodiscales	1	3	5
Surirellales	2	4	6
Thalassionematales	1	1	2
Thalassiophysales	1	1	2
Thalassiosirales	2	3	9

Table 2 List of diatom species found in sample stations (*presence)
表 2 各樣站調查矽藻名錄

		St1				St2			
	Abbreviation	May	Aug	Oct	Dec	May	Aug	Oct	Dec
Achnanthes brevips C. Agardh	Achbre			*		*	*		*
Achnanthes rupestoides Hohn	Achrup	*							
Achnanthes subconstricta (Meister) Toyoda	Achsub							*	
Achnanthidium convergens (Kobayasi) Kobayasi	Achiucon	*							
Achnanthidium exiguum (Grunow) Czarn	Achiuexi	*			*	*	*	*	*
Actinocyclus normanii (Gregory) Hustedt	Actnor	*		*	*				
Amphora libyca Ehrenberg	Amplib					*			
Amphora sp.	Amp sp.						*		
Aulacoseira ambigua (Grunow) Simonsen	Aulamb								*
Aulacoseira granulata (Ehrenberg) Simonsen	Aulgran	*	*		*	*	*	*	*
Azpeitia nodulifera (A.W.F. Schmidt) G.A. Fryxell & P.A. Sims	Azpnod					*			
Bacillaria paxillifera (O.F. Müller) T. Marsson	Bacpax	*	*	*	*	*			*
Berkeleya rutilans (Trentepohl ex Roth) Grunow	Berrut	*		*					
Biremis lucens (Hustedt) Sabbe, Witkowski et vyverman	Birluc	*							
Campylosira cymbelliformis (A. Schmidt) Grunow ex van Heurck	Camcym				*		*	*	*
Chaetoceros decipiens Cleve	Chadec	*	*	*	*	*	*		
Cocconeis placentula var. euglypta (Ehrenberg) Cleve	Coceug					*			
Cocconeis molesta Kützing	Cocmol						*		
Cocconeis placentula var. *placentula* Ehrenberg	Cocpla					*			
Coscinodiscus radiatus Ehrenberg	Cosrad							*	
Cosmioneis hawaiiensis R.L. Lowe & A.R. Sherwood	Coshaw		*						
Craticula cuspidata (Kützing) D.G. Mann	Cracus					*			
Cyclotella cryptica Reimann, Lewin & Guillard	Cyccry	*							
Cyclotella meneghiniana Kützing	Cycmen	*		*	*	*	*	*	*
Cyclotella baltica (Grunow) H. Håkansson	Cycbal	*	*	*	*				
Cyclophora tenuis Castracane	Cycten				*				
Cylindrotheca closterium (Ehrenberg) Reimann & J.C. Lewin	Cylclo								*
Cymbella affinis Kützing	Cymaff					*			
Delphineis minutissima (Hustedt) Simonsen	Delmin				*	*		*	*
Denticula hyalina (Schrader) Simonsen	Denhya	*			*				
Diadesmis confervacea Kützing	Diacon	*				*	*	*	
Dimeregramma fulvum (Gregory) Ralfs in Pritchard	Dimful	*							
Diploneis caffra (Giffen) A. Witkowski, H. Lange-Bertalot & D. Metzeltin	Dipcaf	*	*		*				
Diploneis oblongella (Nägeli ex Kützing) Cleve-Euler	Dipobl	*					*	*	
Diploneis smithii (Brébisson) Cleve	Dipsmi	*	*	*	*		*		
Discostella sp.	Dis sp.	*							

Encyonopsis leei K. Krammer	Enclee				*				
Entomoneis alata (Ehrenberg) Ehrenberg	Entala	*	*	*	*	*	*	*	*
Entomoneis ornata (Bailey) Reimer	Entorn	*	*						
Eucampia cornuta (Cleve) Grunow	Euccor								*
Fallacia nicobarica	Fallnic	*	*	*	*				
Fallacia pseudosemilyrata (R. Simonsen) D.G. Mann	Fallpse	*	*		*		*		*
Fallacia sp.	Fall sp.				*				
Fragilaria capucina Desmazières	Fracap							*	
Gomphoneis sp.	Gom sp.					*			
Gomphonema augur Ehrenberg	Gomaug								*
Gomphonema gracile Ehrenberg	Gomgra							*	
Gomphoneis clevei (Fricke) Gil	Gomcle					*			*
Gomphonema insigne Gregory	Gomins							*	
Gomphonma minutum (C. Agardh) C. Agardh	Gommin					*			
Gomphonema parvulum (Kützing) Kützing	Gompar	*	*	*	*	*	*	*	*
Gomphonema sp.	Gom sp.						*		
Gyrosigma acuminatum (Kützing) Rabenhorst	Gyracu		*						
Gyrosigma attenuatum (Kützing) Rabenh	Gyratt	*	*						*
Gyrosigma balticum (Ehrenberg) Rabenhorst	Gybal							*	*
Gyrosigma eximium (Thwaites) Boyer	Gyrexi	*							
Halamphora bistriata Stepanek & Kociolek	Halbis				*				
Halamphora coffeiformis (C.Agardh) Mereschkowsky	Halcof		*	*		*			
Halamphora holsatica (Hustedt) Levkov	Halhol	*					*	*	
Hantzschia amphioxy (Ehrenberg) Grunow	Hanamp	*		*	*	*	*	*	
Hippodonta neglecta Lange-Bertalot, Metzeltin & Witkowski	Hipneg	*							
Hippodonta sp.	Hip sp.		*		*				
Hobaniella longicruris (Greville) P.A. Sims & D.M. Willioms	Hoblon							*	
Humidophila biscutella (Gerd Moser, Lange-Bertalot & Metzeltin) Lowe, Kociolek, Johansen, van de vijver, Lange-Bertalot & Kopalová	Humbis	*							
Luticola intermedia (Hustedt) Levkov, Metzeltin & A. Pavlov	Lutint						*		
Luticola goeppertiana (Bleisch) D.G. Mann ex J. Rarick, S. Wu, S.S. Lee & Edlund	Lutgoe	*			*	*			
Luticola ventriconfusa Lange-Bertalot	Lutven							*	
Melosira nummuloides C. Agardh	Melnum	*	*						
Melosira varians C. Agardh	Melvar					*			*
Minidiscus comicus Takano	Mincom	*		*					*
Navicula antonii Lange-Bertalot	Navant					*			
Navicula capitatoradiata Germain	Navcap					*	*		*
Navicula gregaria Donkin	Navgre	*	*		*			*	
Navicula longa (Gregory) Ralfs ex Pritchard	Navlon					*			
Navicula perminuta Grunow	Navperm				*				
Navicula seminuloides Hustedt	Navsem						*		
Navicula symmetrica Patrick	Navsym					*		*	
Navicula taraxa M.H. Hohn & J. Hellerman	Navtar					*		*	
Navicula tripunctata (O.F. Müller) Bory	Navtri	*		*					
Navicula veneta Kützing	Navven						*	*	

Nitzschia amabilis Suzuki	Nitama				*				
Nitzschia bilobata W. Smith	Nitbil	*							
Nitzschia capitellata Hustedt	Nitcap			*					
Nitzschia clausii Hantzsch	Nitcla					*			
Nitzschia dissipata (Kützing) Rabenhorst	Nitdis	*	*						
Nitzschia fasciculata (Grunow) Grunow	Nitfas								*
Nitzschia frustulum (Kützing) Grunow	Nitfru	*			*	*	*	*	*
Nitzschia gracilis Hantzsch	Nitgra	*			*	*	*	*	*
Nitzschia hybrida Grunow	Nithyb					*	*		*
Nitzschia intermedia Hantzsch ex Cleve & Grunow	Nitint	*	*						*
Nitzschia longissima (Brébisson) Ralfs	Nitlon	*	*		*				
Nitzschia nana Grunow	Nitnan							*	*
Nitzschia palea (Kützing) W. Smith	Nitpal	*	*		*	*	*		*
Nitzschia scalpelliformis Grunow	Nitsca	*			*				*
Nitzschia sigma (Kützing) W. Smith	Nitsig	*							*
Odontella aurita (Lyngbye) C. Agardh	Odolon					*			*
Petrodictyon gemma (Ehrenberg) D.G. Mann	Petrgem		*						
Pinnularia sp.	Pin sp.	*	*	*	*	*	*	*	*
Planothidium delicatulum (Kützing) Round & Bukhtiyarova	Pladel				*	*			*
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	Plafre					*			
Planothidium rostratoholarcticum Lange-Bertalot & Bąk in Bąk & Lange-Bertalot	Plaros	*					*	*	
Pleurosigma acuminatum (Kützing) W. Smith	Pleacu			*	*				
Pleurosigma angulatum (Queckett) W. Smith	Pleang	*			*				
Pleurosigma patagonicum (Ferrario & Sar) Sterrenburg & Sar	Plepat				*				
Pleurosigma salinarum (Grunow) Grunow	Plesal					*			
Pseudofrustulia lancea Y. Sawai & T. Nagumo in Sawai & al	Pselan	*							
Pseudo-nitzschia australis Frenguelli	Pseaus				*				
Pseudo-nitzschia subpacifica (Hasle) Hasle	Psesub					*			
Punctastriata linearis D.M. Williams & Round	Punlin					*			*
Rhaphoneis amphiceros (Ehrenberg) Ehrenberg	Rhaamp	*			*			*	*
Rhizosolenia imbricate Brightwell	Rhiimb					*			
Sellaphora pupula (Kützing) Mereschkovsky	Selpup	*			*		*	*	*
Seminavis strigosa (Hustedt) Danieledis & Economou-Amilli	Semstr	*		*	*	*	*	*	*
Skeletonema tropicum Cleve	Sketro	*	*	*	*			*	
Stauroneis gracilis Ehrenberg	Stagra	*							
Stauroneis sp.	Sta sp.					*			
Stephanodiscus minutulus (Kützing) Cleve & Möller	Stemin								*
Surirella angusta Kützing	Surang	*							
Surirella ovata Kutzing	Surova	*					*		
Tabularia tabulata (C.Agardh) Snoeijs	Tabtab				*				
Thalassionema nitzschioides (Grunow) Mereschkowsky	Thanit					*	*	*	*
Thalassionema pseudonitzschioides (Schuette & Schrader) Hasle in Hasle & Syvertsen	Thapse			*	*				

Thalassiosira angulata (W. Gregory) Hasle	Thaang	*							
Thalassiosira cedarkeyensis A.K.S.K. Prasad	Thaced			*	*				
Thalassiosira duostra C. Pienaar	Thaduo						*		
Thalassiosira minuscula Krasske	Thamin					*			
Thalassiosira nanolineata (A.Mann) Fryxell & Hasle	Thanan				*		*	*	*
Thalassiosira weissflogii (Grunow) G.Fryxell & Hasle	Thawei		*	*	*	*	*	*	
Thalassiosira sp.	Tha sp.					*			
Tryblionella coarctata (Grunow) D.G. Mann	Tryper						*		
Tryblionella compressa (J.W. Bailey) M. Poulin	Trycoa	*		*	*	*			
Tryblionrlla hungarica (Grunow) Frenguelli	Trycom							*	*
Tryblionella persuadens (Cholnoki) K.P. Cavalcante. P.I. Tremarin &T.A.V. Ludwig	Tryhun	*	*	*	*				
Tryblionella perversa (Grunow) D.G. Mann	Tryper	*	*		*			*	
Tryblioptychus cocconeiformis (Grunow) Hendey	Trycoc					*			
Ulnaria ulna (Nitzsch) P. Compère	Ulnuln					*	*	*	*
Number of species		59	28	25	49	50	36	38	41

Table 3 The water quality results for Sinfong Mangrove in 2017
表 3 新豐紅樹林各樣區水質監測數值

	St1				St2			
	May	Aug	Oct	Dec	May	Aug	Oct	Dec
Water temperature (℃)	_	26.5	22.2	17.5	_	24.7	21.7	16.3
Dissolved oxygen (mg/L)	4.5	0.7	11.8	3.7	6.3	3.3	7.7	5.4
Conductivity (μmS/cm)	26.9	20.4	23.2	17.0	11.1	6.2	19.3	15.2
pH	8.1	7.7	7.0	7.5	7.7	7.3	6.0	7.4
Salinity (psu)	16.3	12.2	14.1	10.1	6.2	3.4	11.5	8.9
Chlorophyll a (μg/L)	38.8	24.3	162.7	1.5	8.3	5.1	5.3	7.8

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「台灣生物多樣性研究」稿約

壹、一般說明

一、《台灣生物多樣性研究》為農業部生物多樣性研究所出版之學術期刊，歡迎國內外學者發表有關生物多樣性或自然保育之學術論文與有關物種出現資料之資料論文，但以未曾在其他刊物發表之原創研究及資料為限。

二、本刊為網路期刊，隨時接受投稿，並於每年 1 月、4 月、7 月及 10 月在本所網站 (https://www.tbri.gov.tw/A15_2/content/31503) 刊登發行。

三、撰稿中、英文均可，來稿以完整微軟 WORD 格式文稿電子檔傳送至「台灣生物多樣性研究」期刊編輯委員會電子信箱 (email: tjbd@tbri.gov.tw)。

四、經本刊接受刊登之稿件，投稿著作所有列名作者皆同意授權本刊單位以非專屬授權之方式再授權，並得為重製、公開傳輸、授權用戶下載、列印等行為。為符合資料庫之需求，並得進行格式之變更。

五、稿件無稿酬，但經刊登之文稿將提供 PDF 檔給作者，不另贈送抽印本。

六、來稿由本刊送請相關學者專家審查、簽註意見或修改，如需修改者再送請作者自行補充修正，作者應於收稿 2 週內完成修正，如於收稿 2 個月後仍未將修正稿件寄回者，視同放棄投稿。稿件付印前作者應負責校對。

七、通訊作者需在期刊出版前簽署文稿版權轉移同意書給期刊編輯室。

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一、學術論文部份

依照 1. 題目，2. 作者姓名、服務單位、地址，3. 通訊作者之 e-mail，4. 摘要，5. 關鍵詞，6. 緒言，7. 材料與方法，8. 結果與討論 (可分列)，9. 結論 (可省略)，10. 謝誌 (可省略)，11. 引用文獻等順序撰寫；其中 1 至 5 項請中英文並列，本文為中文撰寫者，依先中文後英文順序；本文為英文撰寫者，則先英文後中文。文章若屬於研究短報 (Note) 者可不分章節。

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三、另附標題頁 (cover page)，註明簡題 (short running title) 及作者或聯絡人之姓名、電話、傳真、住址、e-mail 位址。

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一、題目以 30 字為限。

二、作者中英文姓名之右上角以縮小數字標示服務單位註記。作者的英文姓名需列全名，名在前姓在後；複姓複名者，二字間用 “-” 相連；作者若為兩人，姓名間以 “and” 連接；若為三人或以上，除最後一人與其前一人間以 “and” 連接外，其餘之間以半形逗號連接。

三、中英文摘要以 500 字為限，摘要內容應以結果及結論為主，目的及方法可簡潔敘述或省略。避免使用條列式的摘要。

四、中英文關鍵詞以 5 個為限。

肆、文稿書寫應注意事項

一、文稿須以 Microsoft Word 可讀取之軟體編輯，以 A4 (30 cm × 21 cm) 白紙單面雙空行 (double spaces) 列印，文稿之天、地、左、右須留白 3 cm，於每頁正下方註記頁碼。

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例：1. 中、日文期刊：柳榗、徐國士。1971。台灣稀有及有絕滅危機之動植物種類。中華林學季刊 4(4): 89-96。

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4. 英 文 期 刊：Clough, B. 1998. Mangrove forest productivity and biomass accumulation in Hinchinbrook Channel, Australia. Mangroves and Salt Marshes 2: 191-198.

5. 英文期刊：Pimm, S. L. and J. L. Gittleman. 1992. Biodiversity : Where is it ? Science 255: 940.

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

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

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

9. 網 站 資 料：POWO. 2023. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet. Retrieved on 29 September 2023 from http://www.plantsoftheworldonline.org/

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