Modelling Spatial Patterns of Rare Orchids for Conservation Priority in Taiwan

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ABSTRACT

Twenty four rare orchid species (including 11 endemic species) were selected form the red lists of vascular plants in Taiwan for this study. Using species locality information and 26 independent environmental variables, the potential distribution of each species was generated by ecological niche-based models. Based on modelled species distributions, an orchid richness map was created. We first applied a threshold to convert the modelled probability distribution to a predicted presence map for each species. Then, every single-species map was overlaid to produce a species richness map for rare orchids. The result showed that large areas of high orchid richness fell beyond present conservation reserves, and were insufficiently investigated. This study demonstrates a modelling approach to identify potentially refuges for rare species, and to evaluate the effectiveness of the present conservation reserves.

INTRODUCTION

Taiwan (formerly known as Formosa) is a continental island, situated at the transition from tropics to subtropics (21˚45'~25˚56'N, 119˚18'E~124˚34'E) with an area of 36,000 km^2. Taiwan is a mountainous island; about 70% of its total area is covered by mountains which comprise over 200 peaks higher than 3000 meters above sea level (asl). The island's climate is characterized with high rainfall (annual mean 2,515 mm) and constantly high humidity. Owing to the special geographical location and great habitat heterogeneity, Taiwan floristic diversity is high, along with several subsidiary islands, comprising ca. 4077 species, including near 400 orchid species (Hsieh, 2003). However, many species are becoming rare because of habitat change and over collecting. In the Taiwan red lists based on IUCN criteria, there are 129 orchids out of 788 threatened vascular plants (unpublished report). Many species occur in remote regions that are difficult to sample, and their distribution information is limited. The lack of knowledge about species distributions would certainly hamper conservation planning for these extinction-prone taxa. Recently, species distribution models (SDMs) based on ecological-niche theory have prompted conservation-biology studies, especially for rare species, with robust analytical methods (Guisan & Zimmermann, 2000; Papeş & Gaubert, 2007). In this study, we demonstrated using SDMs to model potential suitable habitats of rare orchid species, and the result could assist estimation of species conservation status, and of reserves effectiveness.

METHODS

Species studied

Twenty-four orchid species (including 11 endemic species) were selected for this study from red lists of vascular plants in Taiwan (Table 1). Most species have small and fragmented populations, and some species can only be found in a very restricted areas (e.g. *Appendicula reflexa, Dendrobium linawianum, Gastrochilus hoii*). Even those species formerly common to the island (e.g. *Pleione bulbocodioides*) are under long-term pressure of over collection, and decreasing in population sizes.

Species occurrences were georeferenced from herbarium records, published plant inventories and our own botanical observations. We assigned species occurrences to 1 km^2 grid cells; multiple occurrences within the same cell were considered as one ‘unique’ record. Samples collected for species are listed in Table 1, and localities are displayed in Figure 1.

Species distribution model

The species distributions were modelled with the maximum entropy method (MaxEnt, version 3.3.3; http://www.cs.princeton.edu/~schapire/maxent/). This programme was developed for modelling species’ geographic distributions with presence-only data, and has been shown to outperform the majority of other modelling applications, especially when sample sizes are small. MaxEnt calculates a probability distribution over the grid, which may be interpreted as an index of habitat suitability for a species (Elith *et al.,* 2011).

We used all presence records of 24 orchid species together with 26 independent environmental variables (e.g. monthly rainfall [abiotic], vegetation types [biotic]; Table 2) for model building. (For the correlation test procedure to select independent factors, please refer to (Hsu *et al.,* 2012) The programme gave a value of the area under the receiver operating characteristic curve (AUC), an estimate of model performance (Table 1). The model results are illustrated in Figure 2 with warmer colours indicate high probability of suitable conditions in terms of environmental predictors.

Orchid richness map

To create a species richness map, we first applied a threshold of sensitivity-specificity sum maximization (obtained in model outputs) to convert the MaxEnt probability distribution to a predicted presence map for each species. Next, every single-species map was overlaid to produce a species richness map for epiphytes. The richness map was corrected for present land-use change to eliminate species distributions in urbanized regions. Finally, the richness map was compared with current conservation areas (i.e. national parks and reserves) to assess the conservation status of the studied species.

RESULTS AND DISCUSSIONS

Figure 3 demonstrates the richness level of studied orchid species and current conservation area in Taiwan. In average, only 31% of predicted suitable habitats for the 24 rare orchids are protected by present reserves (Table 1). However, large areas of high orchid richness, especially in mid-altitudes (1,000－2,000 asl), fall outside conservation reserves. In western Taiwan, most unprotected areas with high orchid diversity are located close to populated villages or farmlands, whereas in eastern Taiwan, rare orchids are often found in remote areas with low human populations. It is obvious that populations of rare orchids in the west of the island would face higher risk of extinction through land use and anthropogenic activities. Based on this conjecture, we propose a conservation strategy for rare orchid species in Taiwan. We recommend 1. To establish long-term plots for monitoring rare orchid populations in western Taiwan, and 2. To carry out more thorough studies of the orchid population in eastern Taiwan to define the conservation status of these orchids.

In this study, we demonstrated a modelling approach to allow the identification of suitable habitats for rare species, and to provide framework data for the definition of conservation status, and for conservation strategies. Moreover, the application of SDMs also helps conservation authorities to evaluate the effectiveness of the present conservation reserves.

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Table 1. The 24 orchid species studied.

Species	IUCN Category[2)]	Samples[3)]	AUC[4)] value	Fractional protected area (%)[5)]
Appendicula reflexa	NE	9	0.99	19
*Ascocentrum pumilum**[1)]	NT	48	0.93	27
*Bulbophyllum aureolabellum**	NT	14	0.92	29
Bulbophyllum hirundinis	NT	12	0.94	25
*Bulbophyllum tokioi**	EN	17	0.96	31
*Chiloschista segawai**	NT	9	0.92	42
Cypripedium debile	NT	9	0.97	89
*Cypripedium formosana**	EN	12	0.96	62
Dendrobium catenatum	VU	11	0.89	21
Dendrobium falconeri	NE	17	0.99	3
Dendrobium linawianum	CR	6	0.98	33
*Flickingeria tairukounia**	CR	6	0.99	11
*Gastrochilus hoii**	CR	11	0.99	54
*Gastrochilus raraensis**	NT	16	0.98	50
Haraella retrocalla	VU	66	0.87	19
Liparis cordifolia	LC	26	0.92	33
*Luisia cordata**	CR	7	0.97	17
*Oberonia pumila**	VU	9	0.95	27
Phreatia formosana	NE	15	0.96	27
Phreatia taiwaniana	NE	8	0.90	19
Pleione bulbocodioides	VU	46	0.95	47
*Taeniophyllum complanatum**	NT	7	0.94	28
Thrixspermum pensile	VU	11	0.96	16
Trichoglottis rosea	NT	12	0.98	13

1) Asterisks indicate endemic species in Taiwan.

2) IUCN categories: CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern, NE: Not Evaluated.

3) Samples denotes the number of occurrences used in SDMs.

4) The area under the curve (AUC) was obtained in model results.

5) Fractional protected area is the fraction of predicted suitable habitats for species being protected by present reserves.

Table 2. Factors used for model building.

NO	Variable (Abbrev.)	Unit
1	Annual precipitation (Pannual)	Millimetre
2	Precipitation seasonality (Pcv)	Decimal fraction
3	Total water deficiency (Pdef)	Millimetre minus ˚C
4	January rainfall (P01)	Millimetre
5	April rainfall (P04)	Millimetre
6	May rainfall (P05)	Millimetre
7	June rainfall (P06)	Millimetre
8	July rainfall (P07)	Millimetre
9	October rainfall (P10)	Millimetre
10	Annual mean temperature (Tmean)	˚C
11	Temperature seasonality (Tsd)	Millimetre
12	Soil category (Soilcode)	Cardinal numbers: 0~9
13	Soil acidity (SoilPH)	Ordinal numbers: 0~9
14	Inclination (Slope)	Degree
15	Eastness	Ordinal numbers: 0~8
16	Northness	Ordinal numbers: 0~8
17	The distance to the nearest location above 3000 m asl (Dto3000)	Metre
18	The distance to the nearest river (D2river)	Metre
19	*Abies* habitat suitability (Abies)	Decimal (0~1)
20	*Tsuga* habitat suitability (Tsuga)	Decimal (0~1)
21	*Picea* habitat suitability (Picea)	Decimal (0~1)
22	*Pinus* habitat suitability (Pinus)	Decimal (0~1)
23	Cypress habitat suitability (Cypress)	Decimal (0~1)
24	The habitat suitability of lowland broad-leaved forest (BLL)	Decimal (0~1)
25	The habitat suitability of midland broad-leaved forest (BLM)	Decimal (0~1)
26	The habitat suitability of highland broad-leaved forest (BLH)	Decimal (0~1)

For the calculation of variables, please refer to the (Hsu *et al.*, 2012)

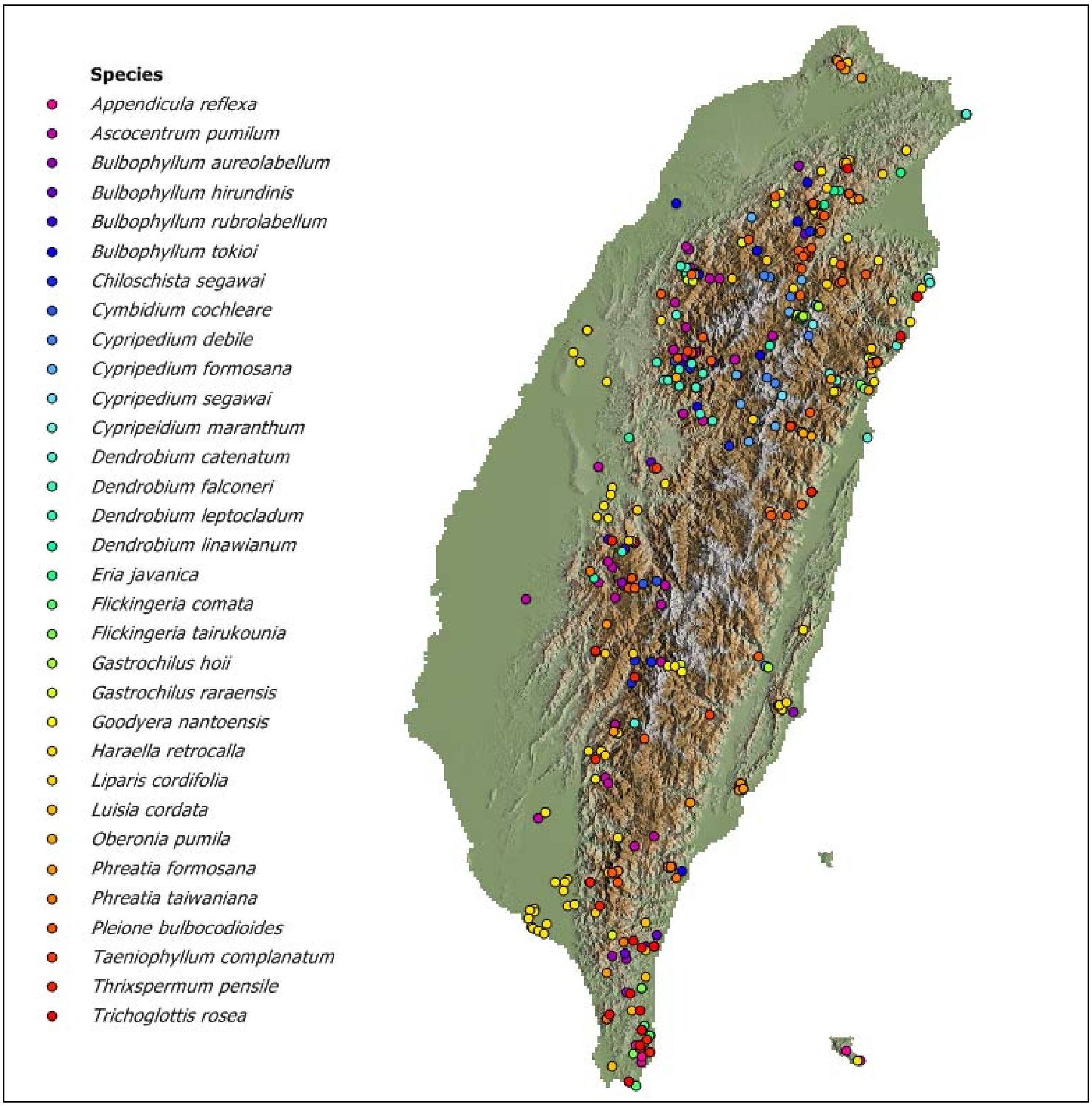
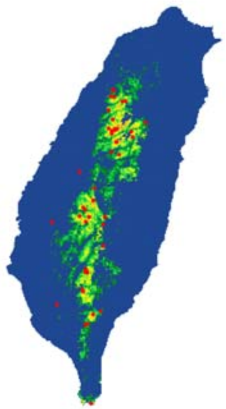
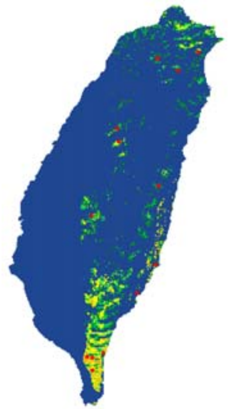
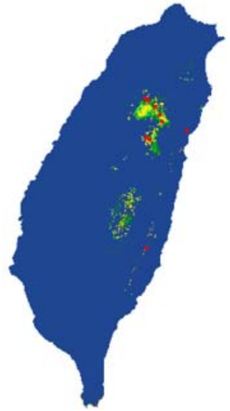
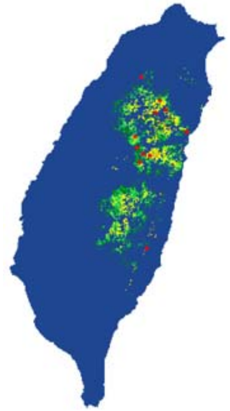
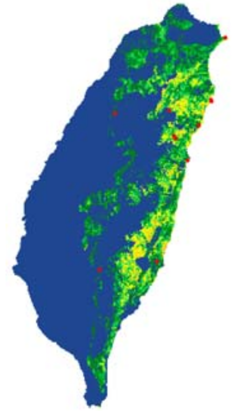
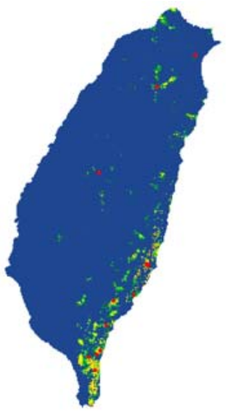
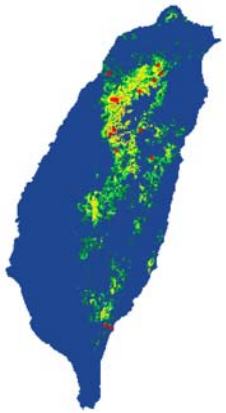
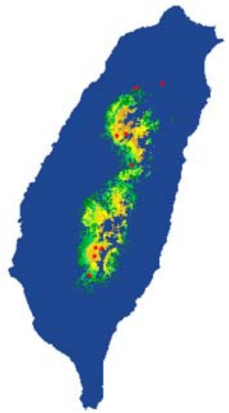
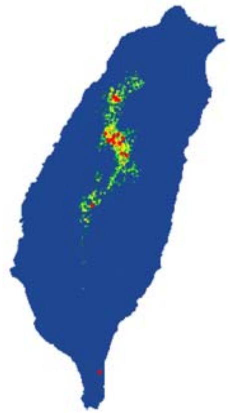


Fig. 1. The occurrences of 24 orchid species in Taiwan.

					
Appendicula reflexa	*Ascocentrum pumilum*	*Bulbophyllum aureolabellum*	*Cypripedium debile*	*Cypripedium formosana*	*Dendrobium catenatum*
					
Bulbophyllum hirundinis	*Bulbophyllum tokioi*	*Chiloschista segawai*	*Dendrobium falconeri*	*Dendrobium linawianum*	*Flickingeria tairukounia*

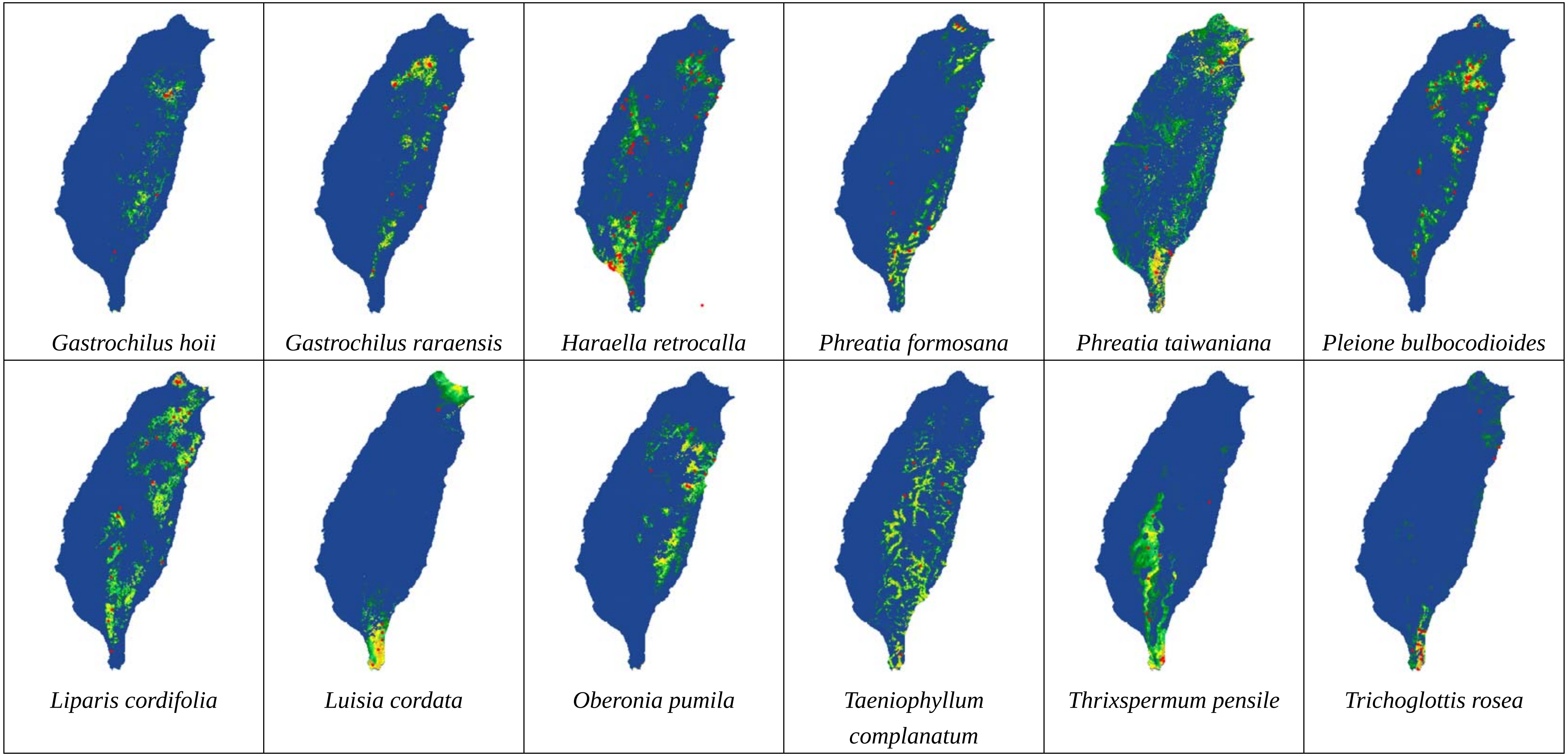


Fig. 2. The model results of 24 species. Colours (yellow and light green) indicate high probability of suitable conditions in terms of predictors for species. Red dots indicate species occurrence.

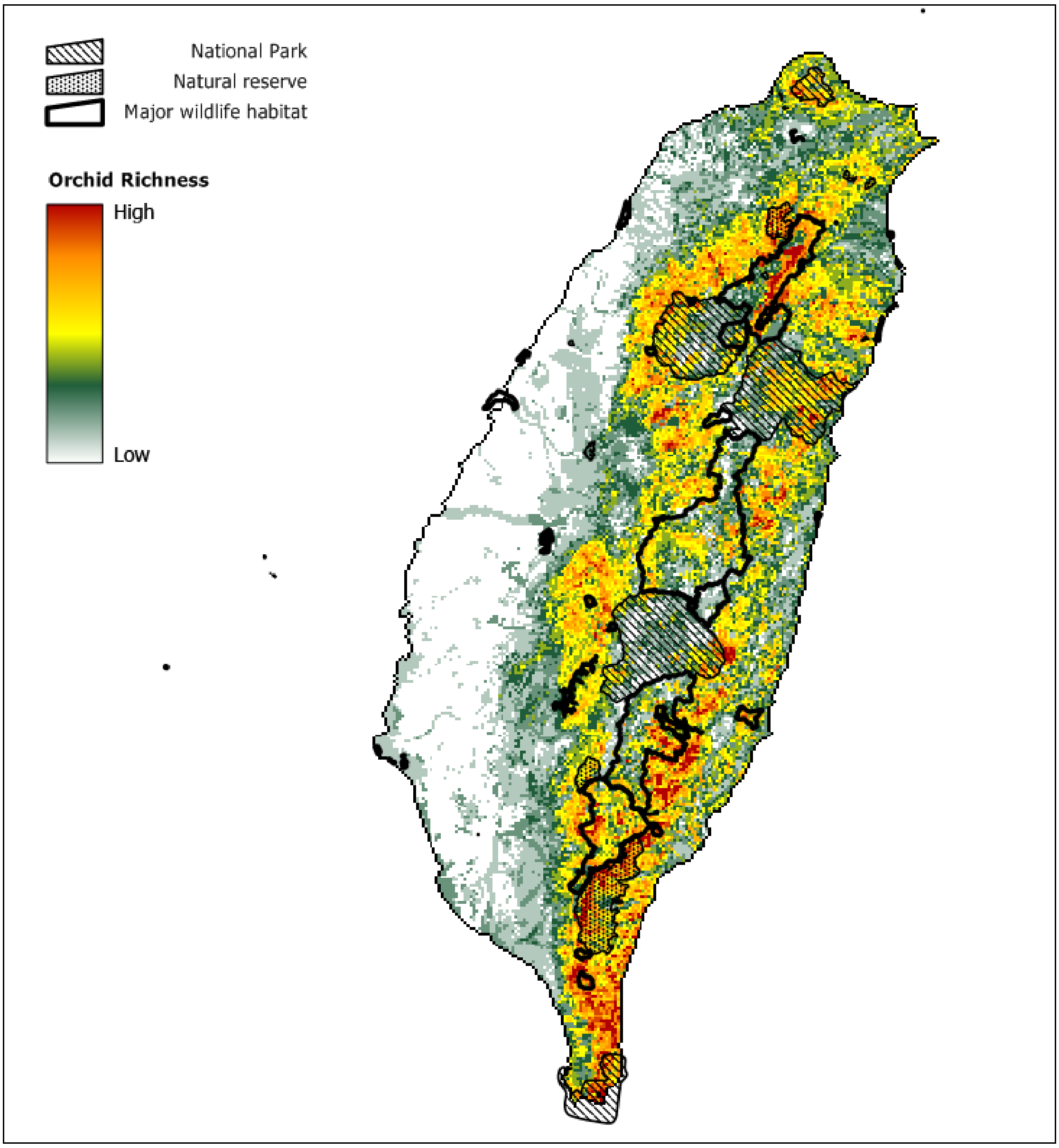


Fig. 3. The richness map of 24 studied orchid species based on model results. Bordered areas indicate current reserves in Taiwan.