

# Using Species Distribution Models to Assess the Rarity and Conservation Status of Taiwanese Birds

## 運用物種分布預測模式評估臺灣繁殖鳥類的稀有度及保育現狀

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### Abstract

Taiwan's unique biodiversity is threatened by regional and global change. Therefore, there is an urgent need for improved monitoring and assessment of its flora and fauna. Here, we used a recently established database (1) to build distribution models of most of Taiwan's breeding birds, (2) to use these models to establish a measure of each species' coverage of the study area (called quartile rarity) and (3) to compare this new measure to two already established measures of species' status: namely, recorded rarity as scored by the Chinese Wild Bird Federation (2010) and Taiwanese conservation status as determined by the Council of Agriculture of Executive Yuan (2009). We found that there is a correlation between each species' coverage of the study area, recorded rarity and Taiwanese conservation status.

However, much variation remains unexplained. We focused on those species where there are discrepancies in status assessments between these three measures to be able to better assess the status of each bird species as well as to better monitor these species in the future. We also investigated the relationship of endemic status to the three species status measures: endemic status was not significantly related to the two measures of rarity, but had a significant association with conservation status. We recommend further studies exploring the wealth of biodiversity data now available on Taiwan's avifauna.

## 摘 要

由於臺灣的生物多樣性受到地區性與全球變遷的威脅，改善評估臺灣動植物現況的方式為當務之急。本文以近期建立的臺灣繁殖鳥類分布資料庫(1)建構臺灣繁殖鳥類的分布預測模式，(2)由模式預測結果建立新的評估標準「四分位數稀有度」，(3)比較「四分位數稀有度」與現存評估標準(包括由中華民國野鳥學會提供之「紀錄稀有度」與行政院農業委員會野生動物保育名錄之「保育等級」)。我們發現各鳥種在臺灣分布面積與紀錄稀有度、保育等級相關，然而三者間仍存在部分變異，因此進一步檢視在此三項標準間存在變異的鳥種。本研究並非意圖批評現存的標準，而是希望藉由檢視三項標準間的異同以評估物種狀態，並在未來提供更好的監測方式。此外，本文亦評估了特有狀態與前述三項標準的關係，但特有性與三者皆無顯著相關。我們建議未來可有更多研究善加利用已經建置且數量豐富的臺灣鳥類生物多樣性資料。

**Key words:** biodiversity, conservation priorities, GIS, sampling effort, endemism

**關鍵詞：**生物多樣性、保育優先性、地理資訊系統、調查努力量、特有性

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## Introduction

The conservation of biodiversity has gained increasing attention from both the public and decision-makers because biodiversity is the basis for functioning ecosystems and the life-support system of the earth.

Ecosystem services have increasingly been

recognized as important to society both for the inherent value of the continuing existence of species and for their functional and economic value, such as to filter out pollution or to foster ecotourism (Millennium Ecosystem Assessment 2005). However, all levels of biodiversity have been rapidly eroding, despite repeated international and national pledges and efforts to halt the global,

regional and local decline of biodiversity (Butchart *et al.* 2010).

Taiwan is an important biodiversity hotspot of endemism for many taxa, including birds. Although Taiwan has a network of relatively well-protected areas, it also faces multiple challenges to its biodiversity due to unsustainable economic growth and its environmental consequences. Therefore, efforts to increase biodiversity monitoring and assessment of Taiwan's flora and fauna are urgently needed.

One of the most visible and well-documented taxa of Taiwan's fauna is its avifauna, with 589 bird species having been recorded in all of Taiwan, including its outlying islands (Chinese Wild Bird Federation 2011) of which 145 species are breeding birds from the island of Taiwan alone (Fang 2008). Recently, the first comprehensive avifauna of Taiwan was published (Severinghaus *et al.* 2010). Constant-effort monitoring schemes have also been set up, such as the Taiwan breeding bird survey (BBS Taiwan) (Lee *et al.* 2010), the monitoring avian productivity and survivorship in Taiwan (MAPS Taiwan) project which maintains constant effort mist-netting and banding sites (Lin and Chen 2011), and species-specific monitoring programs for the black-faced spoonbill *Platalea minor* (Yu 2010), Ryukyu scops-owl *Otus elegans* (Severinghaus 2007) and fairy pitta *Pitta nympha* (Lin 2011). As a consequence, more and more information is now available to assess the status of Taiwan's bird species pertaining to their rarity and threat of extinction (Council of Agriculture of Executive Yuan 2009; Chinese Wild Bird Federation 2010; Severinghaus *et al.* 2010).

With the growing availability of locational databases on Taiwanese birds, there is also a growing need to analyze this information. Previous

studies focused on species richness patterns in a specific local region (Hsu *et al.* 2004; Ko 2004; Peng 2008), Taiwan's mountains (Shiu and Lee 2003), or all of Taiwan (Lee *et al.* 2004). Species distribution models were used to study bird distributions only in a local region (Huang 2001; Koh *et al.* 2006a; Koh *et al.* 2006b) or of a single species or subfamily (Liao 1997; Ko *et al.* 2009a). Ho (2005) and Ding *et al.* (2006) selected avian biodiversity hotspots and studied bird species richness patterns in East Asia but did not focus on Taiwan. A hotspot analysis using Taiwan's birds was restricted to 14 out of the 17 endemic bird species (Ko *et al.* 2009b). We recently build distribution models for most of Taiwan's breeding birds to reassess the conservation status of Taiwanese birds and to calculate how well their distributions are covered by Taiwan's protected areas network (Wu *et al.*, In preparation). As rarity is one of the important categories for determining the conservation status of a species (Mace and Lande 1991), we use these distribution models to calculate a new measure of rarity (called quartile rarity) and compare it to two other already established measures used to assess the status of Taiwan's bird species.

## Methods

### Study area

The study area was the island of Taiwan that is situated at latitudes 21°54'N to 25°18'N and longitudes 120°27'E to 122°E with the maximum elevation of 3,952m. Its climate ranges from tropical in the south to subtropical in the north and alpine in the high mountains. The mean annual temperature is 18.0°C which decreases by -5.43°C/km in elevation (Su 1984). The average annual

precipitation is 2510 mm. The natural vegetation is almost exclusively forest, with great variation due to variable topography and human influences which have dramatically changed many of Taiwan's landscapes. We divided the study area into a total of 36,022 grid pixels, each in size of 1 km x 1 km.

### Data collection and compilation

For this study, we selected the 145 bird species that are listed as breeding species on the island of Taiwan (Fang 2008). To determine the status of each species regarding its endemism, rarity, and global and Taiwanese conservation status, a variety of sources were consulted (Appendix 1). Distributional data for these bird species were derived from the following sources to build the first comprehensive distributional dataset of the breeding birds of Taiwan:

- (1) Data collected from 1993 to 2004 from each of Taiwan's counties collected by the Endemic Species Research Institute (ESRI) and local wild bird societies during a series of research projects. Data were collected along road segments of 2 to 3 km length that were covered during a 2-hour walk in the morning within 3 to 4 hours after sunrise and sampled once a season to once a month.
- (2) Data collected from 1999 to 2003 by the biological resources survey of Taiwan which was organized by the Spatial Ecology Lab of National Taiwan University (Koh *et al.* 2006a). Data were collected during 6 minutes point counts at a distance of 150 meters from each other along road segments of 1 to 2 km length (with 5 to 10 points as replications in each road segment) that were covered during a 3-hour walk after sunrise. Each segment was surveyed once.
- (3) Data collected by P.-F. Lee during the investigation of the current status of the Lanyang River system for the Water Resources Planning Institute which is part of the Ministry of Economic Affairs (MOEA). Data were collected by professional researchers once during each of the four seasons using the point count method. Seven sites were covered in 2002, and another seven in 2003. At each site, an observer walked along a river road and made 6 minute point counts at 200-meter intervals, and then, on the return walk, repeated each count. The counts were done once in the morning and once in the afternoon.
- (4) Data collected by P.-F. Lee and Chie-Jen Ko in Shei-Pa National Park, including the Kuanwu Recreation Area (Ko 2004), and the Xuejian Recreation Area. 47 sites in Shei-Pa and Kuanwu were censused three times during the 2003 breeding season, and 46 sites in Xuejian were censused three times during the 2004 breeding season.
- (5) Data collected in Taroko National Park by Peng (2008) using the point count method twice a month from April 2006 to March 2007 at 74 sites.
- (6) Data collected by Wen-Jay Chih, Chie-Jen Ko and Man-Yu Yang from the Szu-Tsao area for the Ecological Monitoring of Tainan Technology Industrial Park research project in 2008. Data were collected by making total counts of birds resting and feeding on a large number of salt pans and fish ponds.

For each record, the following information was entered by T.-Y. Wu into a database: (1) Latin binomial name; (2) number of individuals recorded if available, otherwise only presence recorded; (3) collection time (day, month and year); (4) ge-

ographical coordinates of collection localities; and (5) data sources.

We restricted records to those from the months of March to July, as this period corresponds to the main breeding season of most species. We excluded those species for which < 30 grid cells had been coded as present because distribution models usually do not perform well at low sample sizes (Stockwell and Peterson 2002; Wisz *et al.* 2008). Excluding those species with small sample sizes left us with 116 species (Appendix 1) with a total of 33,785 presence records within the 1 x 1 km grid and 2,455 grid cells containing one or more species.

### **Building distribution models**

For each of the 116 selected species, we used its presence records to build a distribution model, which is a probabilistic map of the likelihood of the species' presence or absence within the study area. To build the models, 120 environmental data layers compiled by the Spatial Ecology Laboratory of National Taiwan University were used (for details, Lee *et al.* 1997) which were updated in 2008 by the same lab. These environmental data layers fell into 8 categories and covered the entire island of Taiwan with 36,022 1x1 km grid pixels, with all the layers overlaying perfectly.

We used a two-tailed *t-test* to test each of the selected environmental variables for significant association ( $p < 0.05$ ) with the presence or absence of the species. Only significantly associated variables were retained. An Unweighted Pair Group Method with Arithmetic Mean (UPGMA) Tree in Ecological Niche Factor Analysis (ENFA) was run to avoid autocorrelation between the remaining variables. If two variables were correlated at a correlation coefficient  $> 0.9$ , one of them was

randomly chosen and used for building the distribution model. The variables remaining after this selection were used to build the distribution models for each species.

The following five methods were used to build distribution models for each species: multiple discriminant analysis (Johnson and Wichern 1998), ecological niche factor analysis (Hirzel *et al.* 2002; Hirzel *et al.* 2004), genetic algorithm for rule-set production (Stockwell and Noble 1992; Stockwell 2005), logistic regression (Guisan and Zimmermann 2000; Austin 2002) and maximum-entropy (Phillips *et al.* 2006; Phillips *et al.* 2009). The three best performing models for each species based on their respective AUC (area under an ROC curve) scores (which is a generally accepted method of ranking model performance) were chosen. These three selected models were then summed up to derive one distribution model for each species (see Appendix 1 for the models selected for each species).

Finally, we deleted overpredicted areas for 11 of the 116 species by comparing our modelled distributions with published distribution maps (Severinghaus *et al.* 2010). Any region of Taiwan where the species had never been observed was converted into absence by using a variety of appropriate shape files (elevation, ecoregions, counties). These 'final maps' were used for all further analyses.

We categorized each species into one of four quartile categories whereby first, second, third and fourth quartile species correspond to the modeled distribution of the respective species covering 0-25%, 25-50%, 50-75% and 75-100% of all pixels of our study area, respectively (corresponding to almost 9,006 pixels or 9,006 km<sup>2</sup> per quartile). Appendix 1 gives the exact percentage

coverage for each species; note that none of the species fell exactly on the 25%, 50% and 75% dividing line. This categorical measure is called ‘quartile rarity’ from hereupon, in contrast with ‘recorded rarity’ which is a categorical measure established by the Chinese Wild Bird Federation (2010) where each species is categorized as rare (the respective bird species was recorded in < 20% of suitable habitats), uncommon (the respective bird species was recorded 20-70% of suitable habitats) or common (the respective bird species was recorded in > 70% of suitable habitats). Scores of recorded rarity were published by Severinghaus *et al.* (2010) and the Chinese Wild Bird Federation (2010), but the latter used more recent information (T.-S. Ding, personal communication 2011). Differences between these two assessments were minimal: the slaty-legged crane *Rallina eurizonoides* and the collared owlet *Glaucidium brodiei* were scored uncommon by the Chinese Wild Bird Federation (2010), but rare and common, respectively, by Severinghaus *et al.* (2010). As we did not model the slaty-legged crane due to its insufficient sample size (Appendix 1), the only difference relevant to our study is the different scores for the collared owlet. Therefore, we decided to use only the more recent assessment of recorded rarity (Chinese Wild Bird Federation 2010) for all 116 species.

The conservation status of each of Taiwan’s bird species was categorized by the Council of Agriculture of Executive Yuan (2009). The three measures of each species’ status, namely, quartile rarity, recorded rarity and conservation status, are given for each bird species in Appendix 1.

## Results

### Status of Taiwanese breeding birds

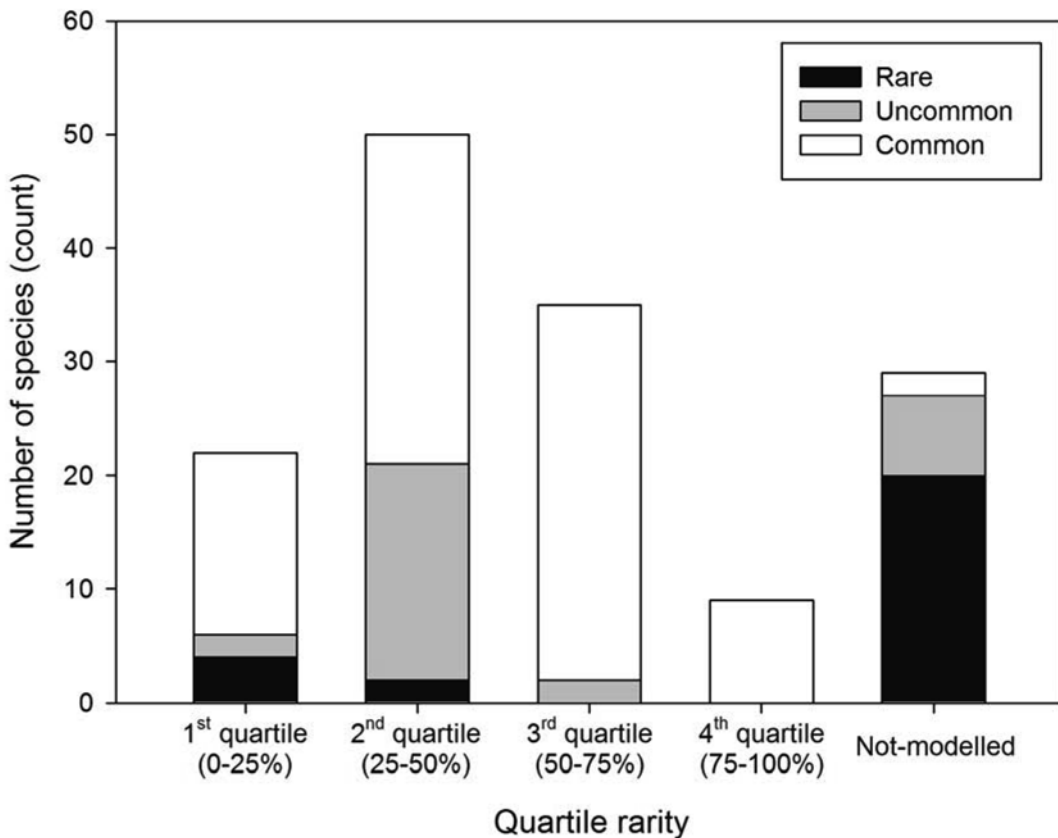
Appendix 1 lists the 145 known breeding bird species of Taiwan, but it does not include the > 30 invasive species which now regularly breed in Taiwan (Fang 2008; Chinese Wild Bird Federation 2010, 2011; Walther 2011). 17 species have full endemic status, 62 species are recognized endemic subspecies, and the remaining 66 species are not endemics. Only 7 out of the 145 species are listed as globally threatened: 5 as near-threatened, and the fairy pitta and Styan’s bulbul *Pycnonotus taivanus* as vulnerable. However, more species are considered threatened within Taiwan: 5 are listed as endangered (Australasian grass-owl *Tyto longimembris*, black eagle *Ictinaetus malayensis*, mountain hawk-eagle *Nisaetus nipalensis*, black-naped oriole *Oriolus chinensis*, russet sparrow *Passer rutilans*), 33 as rare and valuable, and 11 as other conservation-dependent species, with the remaining 96 species not considered threatened within Taiwan. 26, 30 and 89 species were recorded as rare, uncommon and common, respectively. Considering quartile rarity, 22, 50, 35 and 9 species fell into the first, second, third and fourth quartile, respectively (note that the remaining 29 species were not modeled and therefore not categorized for ‘quartile rarity’).

### Comparison among the species status measures

We used quartile rarity as one of the measures to reassess the conservation status of Taiwanese birds and to calculate how well their distributions are covered by Taiwan’s protected areas network (Wu *et al.*, In preparation). In this paper, we explored where there are inconsistencies between the three species status measures.

We first compared quartile rarity with recorded rarity, and then compared them with the birds' conservation status. Species recorded as rare fell only into the first or second quartile (Fig. 1) whereby the two bird species falling into the second quartile were the little forktail *Enicurus scouleri* and the yellow tit *Macholophus holsti*. Uncommon species fell only into the first, second and third quartile whereby the two species falling

into the first quartile were the cinnamon bittern *Ixobrychus cinnamomeus* and the crested myna *Acridotheres cristatellus* and the two species falling into the third quartile were the Taiwan partridge *Arborophila crudigularis* and the white-tailed robin *Cinclidium leucurum*. Common species fell into all four quartiles, with 16 species falling into the first quartile and 29 species falling into the second quartile.



**Fig. 1.** Comparison of quartile rarity versus recorded rarity of 116 Taiwanese bird species (likelihood ratio chi-square,  $G^2 = 28.59$ ,  $n = 116$ ,  $df = 6$ ,  $p < 0.0001$ ). Quartiles 1-4 correspond to the percentage coverage of the study area by each species; 'Not-modelled' means the sample size was insufficient to model the species' distribution (Methods and Appendix 1).

Substituting categorical scores (rare = 1, uncommon = 2, common = 3) for recorded rarity and percent coverage of study area (Appendix 1) for quartile rarity, recorded rarity and percent coverage of study area were also significantly correlated, but with much unexplained variation remaining (Spearman-Rank test,  $n = 116$ ,  $Z = 4.57$ , Rho corrected for ties = 0.28,  $p < 0.0001$ ).

Comparing recorded rarity with Taiwanese conservation status (Fig. 2), we found that the distribution of conservation status categories were not distributed randomly amongst the three categories of recorded rarity. Endangered species only fell into the rare category, and rare and valuable species were least prevalent in the common category. However, other conservation-dependent species increased in prevalence from rare to common, as did the non-threatened species. Surprisingly, some rare and valuable species fell into the common category.

Comparing quartile rarity with Taiwanese conservation status (Fig. 3), we found that endangered species were found only in the first quartile, while other conservation-dependent species appeared in all quartiles except the fourth quartile. Rare and valuable species, meanwhile, appeared in all quartiles, but at a much higher percentage in the first and second quartile. The distribution of these categories was not significantly different from random.

Plotting the number of recorded pixels versus recorded rarity showed an overall positive relationship (Fig. 4 A), but it was also evident that many of the species recorded as uncommon or common were only recorded in relatively few pixels in our database. Plotting the number of predicted pixels versus recorded rarity showed a similar positive relationship (Fig. 4 B) but with

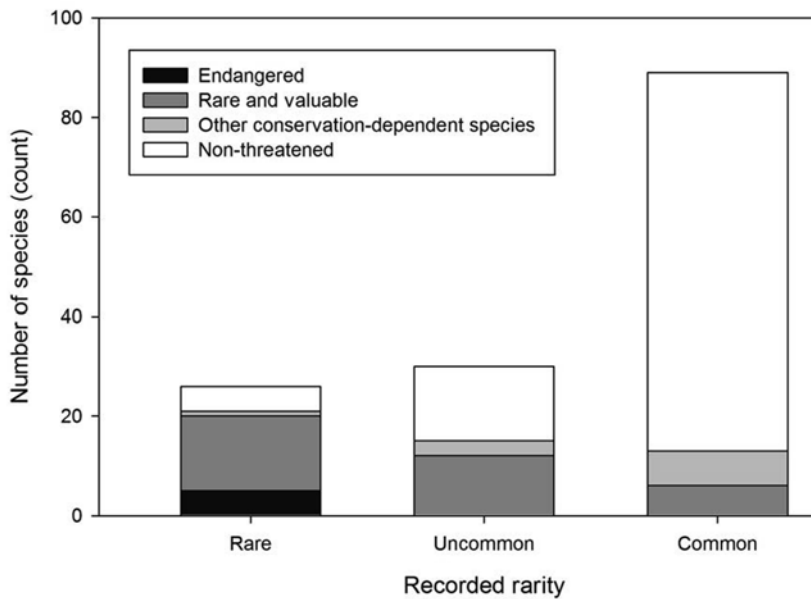
even more unexplained variation.

We finally compared endemic species status with the two categories of rarity and Taiwanese conservation status. Neither measure of rarity was significantly associated with endemic species status (Figs 5-6). All three categories of endemism were found within the three categories of recorded rarity (Fig. 5). For quartile rarity, however, there were no endemic species in the fourth quartile (Fig. 6). Endemism was not distributed randomly amongst the four categories of Taiwanese conservation status (Fig. 7). Endemic species were found in all categories except the endangered category, while endemic subspecies and non-endemic species were found in all four categories of threatened status.

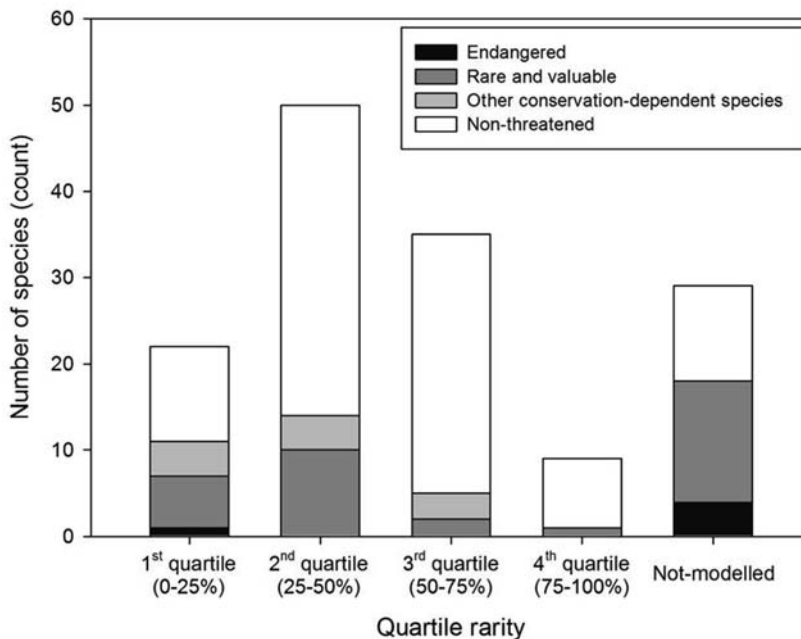
## Discussion

Recently, species distribution models have become an important tool in conservation biology because they usually allow a much better approximation of the true species distribution than the old-fashioned dot or range maps. These models have another advantage because they provide a more realistic estimate of the extent of occurrence, which is “the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon” (IUCN Standards and Petitions Subcommittee 2010).

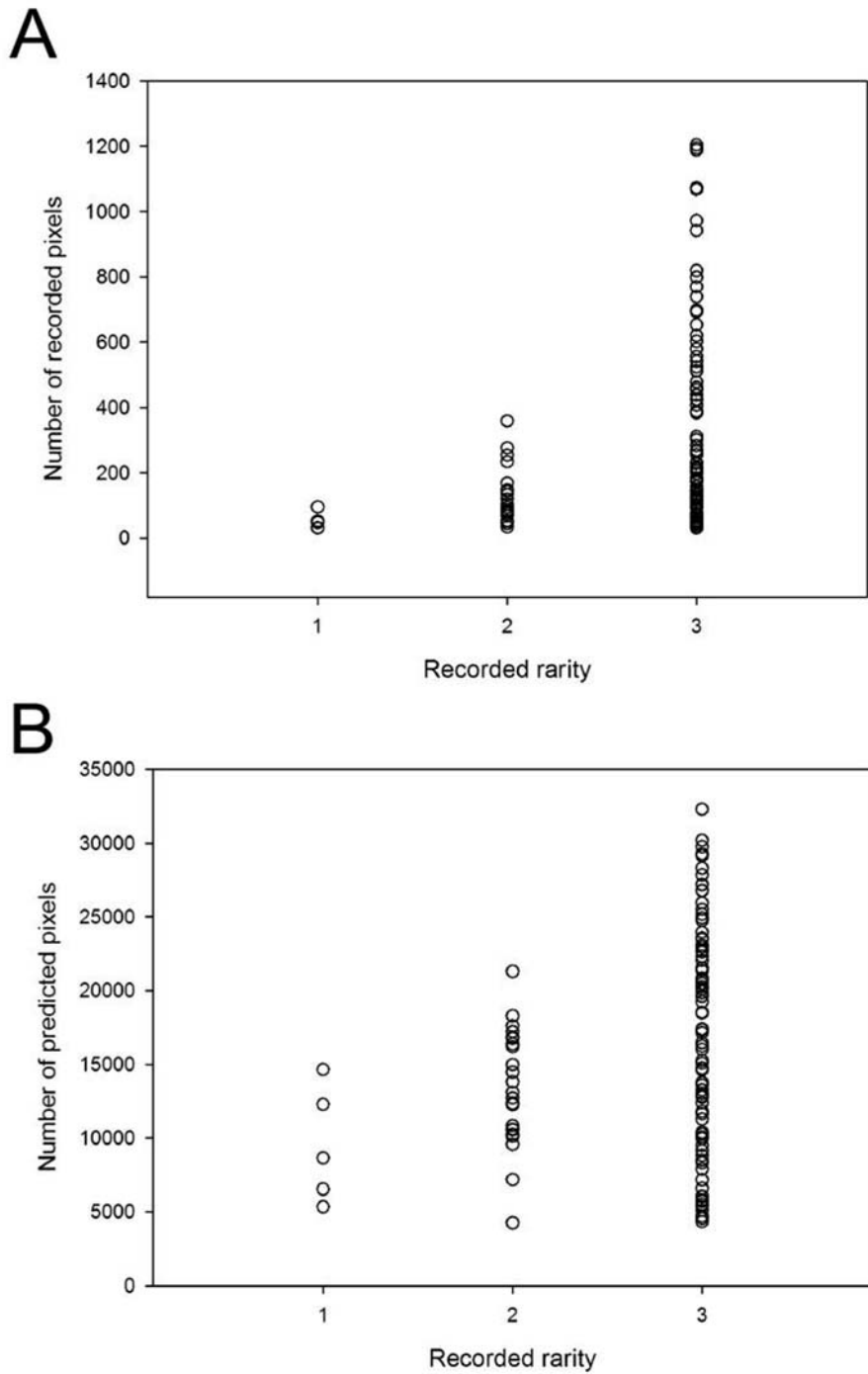
In this study, we estimated the extent of occurrence based on our distributional models for 116 species of Taiwanese breeding birds. As the models were based on a 1 x 1 km grid, the number of predicted pixels (Appendix 1) equals the number of square kilometers which equals the size of that



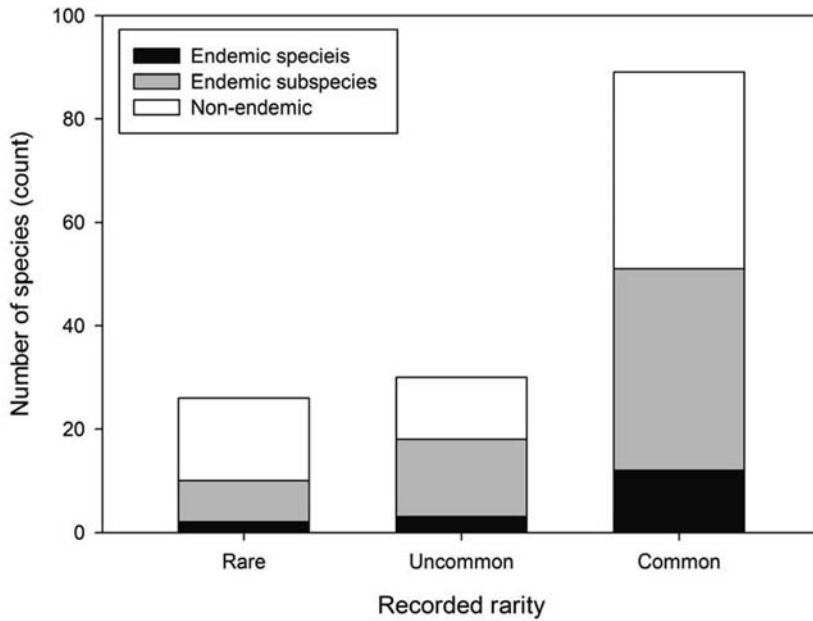
**Fig. 2.** Comparison of recorded rarity versus Taiwanese conservation status of 145 Taiwanese bird species (likelihood ratio chi-square  $G^2 = 61.17$ ,  $n = 145$ ,  $df = 6$ ,  $p < 0.0001$ ).



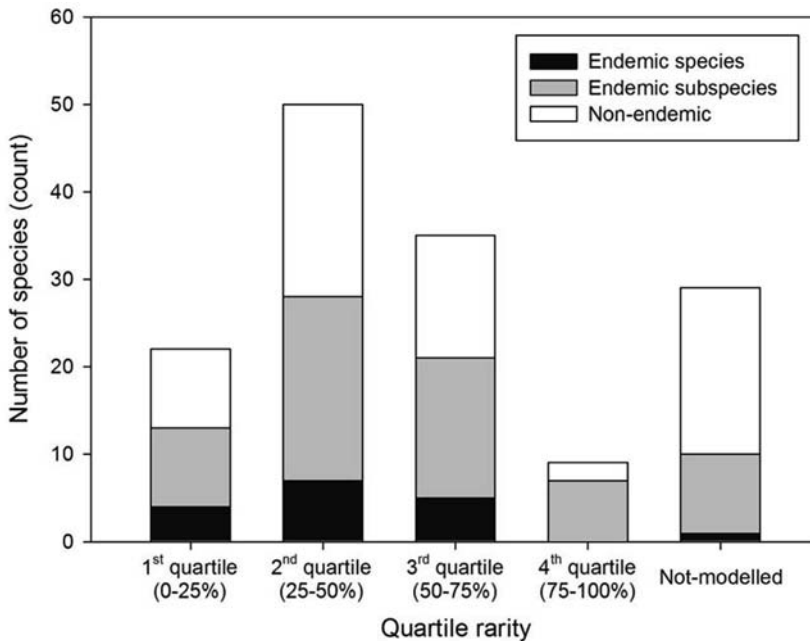
**Fig. 3.** Comparison of quartile rarity versus Taiwanese conservation status of 116 Taiwanese bird species (likelihood ratio chi-square  $G^2 = 12.74$ ,  $n = 116$ ,  $df = 9$ ,  $p = 0.17$ ). Quartiles 1-4 correspond to the percentage coverage of the study area by each species; 'Not-modelled' means the sample size was insufficient to model the species' distribution (Methods and Appendix 1).



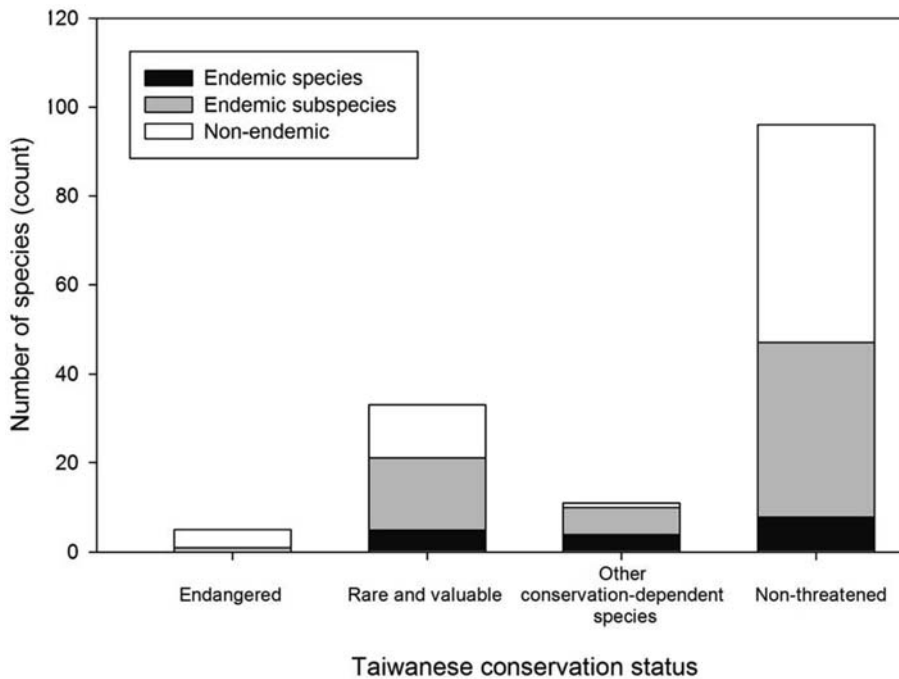
**Fig. 4.** Relationship between recorded rarity (rare = 1, uncommon = 2, common = 3) and: (A) the number of recorded pixels within our database (Spearman-Rank,  $n = 116$ ,  $Z = 8.77$ , Rho corrected for ties = 0.70,  $p < 0.0001$ ); (B) the number of predicted pixels within our database (Spearman-Rank,  $n = 116$ ,  $Z = 4.57$ , Rho corrected for ties = 0.28,  $p = 0.003$ ) of 116 Taiwanese bird species.



**Fig. 5.** Comparison of recorded rarity versus Taiwanese endemic status of 145 Taiwanese bird species (likelihood ratio chi-square  $G^2 = 3.74$ ,  $n = 145$ ,  $df = 4$ ,  $p = 0.44$ ).



**Fig. 6.** Comparison of quartile rarity versus Taiwanese endemic status of 116 Taiwanese bird species (likelihood ratio chi-square  $G^2 = 5.04$ ,  $n = 116$ ,  $df = 6$ ,  $p = 0.54$ ). Quartiles 1-4 correspond to the percentage coverage of the study area by each species; 'Not-modelled' means the sample size was insufficient to model the species' distribution (Methods and Appendix 1).



**Fig. 7.** Comparison of Taiwanese conservation status versus endemic species status of 145 Taiwanese bird species (likelihood ratio chi-square  $G^2 = 14.16$ ,  $df = 6$ ,  $n = 145$ ,  $p = 0.03$ ).

species' extent of occurrence. This continuous measure was transformed into a categorical measure called quartile rarity in order to compare it with two previously established measures, recorded rarity and Taiwanese conservation status. The reason for doing so is not to criticize these two already established measures, but rather to highlight where these measures agree and where they differ in assessing a species' status. Such comparisons should help us to better determine the status of each bird species as well as to better monitor these species in the future.

The general impression from our results is that the extent of occurrence (measured continuously as the number of predicted pixels and the percentage coverage of the study area or categorically as quartile rarity), recording frequency (measured

as both recorded rarity or recorded pixels) and Taiwanese conservation status are all correlated to some extent, but often which much variation left unexplained. As this overall result is to be expected, what we should focus on is the remaining unexplained variation.

For example, it should be worthwhile to look closer at species which are first-quartile species but which were recorded as common (Fig. 1) or as non-threatened (Fig. 3). In Wu *et al.* (In preparation), all those species were listed which are first quartile species as well as those species that are not well covered by protected areas in order to draw more attention to them.

Here, we want to draw attention to those 16 species (yellow bittern *Ixobrychus sinensis*, Malayan night-heron *Gorsachius melanolophus*,

ruddy-breasted crane *Porzana fusca*, greater painted-snipe *Rostratula benghalensis*, Oriental pratincole *Glareola maldivarum*, collared scops-owl *Otus lettia*, Eurasian magpie *Pica pica*, Eurasian nutcracker *Nucifraga caryocatactes*, coal tit *Periparus ater*, Styan's bulbul, Taiwan bush-warbler *Bradypterus alishanensis*, streak-throated fulvetta *Alcippe cinereiceps*, flamecrest *Regulus goodfellowi*, winter wren *Troglodytes troglodytes*, collared bush-robin *Tarsiger johnstoniae*, vinaceous rosefinch *Carpodacus vinaceus*) which are first quartile species but were recorded as common (Fig. 1). As the definition of common is "the respective bird species was recorded in > 70% of suitable habitats" (Appendix 1), we suggest that these suitable habitats may be relatively rare within the entire study area (i.e. mainland Taiwan) but relatively common within their respective ecoregions (e.g., high elevation species such as Eurasian nutcracker, coal tit, Taiwan bush-warbler, streak-throated fulvetta, flamecrest, winter wren, collared bush-robin and vinaceous rosefinch).

An alternative explanation is that some of our modeled distributions or underlying data sources are in need of improvement. For example, the Malayan night-heron and collared scops-owl are common in Taiwan's lowland areas within suitable habitats. However, the distribution model shows the Malayan night-heron to be common only in the central lowlands (Wu *et al.*, In preparation). Therefore, this species may be under-predicted by our distribution model because this species has recently become accustomed to human habitations. The Malayan night-heron was, until recently, only found in lowland forests where it was rare (Wang 1991) and secretive (Fang 2008). Recently, however, it has invaded all sorts of

urban parks, gardens and even small traffic islands in the middle of busy roads in Taipei (Lin *et al.* 2008; personal observations). As our database does not include such recent records, the Malayan night-heron's rapid expansion into human-dominated landscapes has not yet been included in our distribution maps.

A likely reason for underestimating the collared scops-owl's distribution could simply be that it is a nocturnal species, and since most of our data was collected during daylight, the collared scops-owl was most likely under-recorded. In Wu *et al.* (In preparation), we further suggest that the modeled distributions of four of the wetland species (specifically, yellow bittern, ruddy-breasted crane, greater painted-snipe, Oriental pratincole) may have been underestimated because of the lack of variables related to rivers or wetlands in our environmental data. Therefore, such variables should be added to the analysis, although additional locational data for these species are also needed.

The Eurasian magpie poses an interesting example of a species now common in urbanized areas, which was modeled to be mostly present in the urbanized areas of northwestern and southwestern Taiwan (Wu *et al.*, In preparation). Apparently, this species was originally only common in southern Taiwan (Swinhoe 1863) and later spread to the central-western and northwestern regions where it is now common in urban areas, especially in park-like landscapes (Lin 1997). Meanwhile, its abundance apparently declined in the southern parts (Severinghaus *et al.* 2010; personal observations). Therefore, the Eurasian magpie can be considered common in its limited urban habitat, but rare within the entire study area. Likewise, the Styan's bulbul is very common in the eastern region of Taiwan, but is

also considered to be rare within all of Taiwan, possibly due to competition with the light-vented bulbul.

The usefulness of our distribution models is to throw up the question of whether the model's database, assumptions and methodology need to be improved, or whether other assessments of the species' status need to be reassessed (this study, Wu *et al.*, In preparation). This evaluation needs to be done on a species-by-species basis.

Of the 16 species mentioned above, six are categorized as threatened in Taiwan, but the other 10 species are considered non-threatened; given their restricted distributions, their status may also need to be reassessed. Furthermore, 10 of these species are endemic species or subspecies, further emphasizing their conservation value. On the other hand, the Taiwan partridge and the white-tailed robin were recorded as uncommon but are third quartile species (Fig. 1). As the definition of uncommon is "the respective bird species was recorded 20-70% of suitable habitats" (Appendix 1), we suggest that these suitable habitats are relatively widespread but that the species only infrequently occupies it or is recorded in it (Discussion below).

Similarly, there are five species (water rail *Rallus aquaticus*, watercock *Gallicrex cinerea*, small buttonquail *Turnix sylvaticus*, golden parrotbill *Paradoxornis verreauxi*, chestnut munia *Lonchura atricapilla*) which were recorded as rare but are considered non-threatened and 13 species (crested serpent-eagle *Spilornis cheela*, crested goshawk *Accipiter trivirgatus*, greater painted-snipe, Oriental pratincole, mountain scops-owl *Otus spilocephalus*, collared scops-owl, Formosan magpie *Urocissa caerulea*, green-backed tit *Parus monticolus*, coal tit, Styan's bulbul, Taiwan barwing *Actinodura morrisoniana*,

flamecrest, plumbeous redstart *Rhyacornis fuliginosa*) recorded as common but considered either rare and valuable or conservation-dependent species (Fig. 2).

Finally, there are 11 species (yellow bittern, cinnamon bittern, Malayan night-heron, ruddy-breasted crake, Eurasian Magpie, Eurasian nutcracker, Taiwan bush-warbler, streak-throated fulvetta, winter wren, collared bush-robin, vinaceous rosefinch) which are first quartile species but are considered non-threatened (Fig. 3). On the other hand, there are five third quartile species (Taiwan partridge, crested goshawk, mountain scops-owl, plumbeous redstart, white-tailed robin) and one fourth quartile species (crested serpent-eagle) which are considered threatened (Fig. 3). The reasons for their threatened status despite being widespread are various, although the particular reasons are not specified within the relevant document (Council of Agriculture of Executive Yuan 2009). Here, we briefly discuss these six species.

The Taiwan partridge is an endemic species, but little research has been done concerning the effects of hunting pressure or habitat loss (Severinghaus *et al.* 2010). Fang (2008) suggested the main pressure is habitat loss while tourism in forests and pesticides could also negatively influence this species. It may also be under-recorded because of its secretive behavior.

The crested goshawk is an endemic subspecies. Although it has adapted to human-influenced areas and has become the only diurnal raptor which can survive in urban areas in Taiwan (Severinghaus *et al.* 2010), the entire order Falconiformes is listed in the Appendix 2 of CITES (2011). Therefore, this species is listed as threatened in the COA schedule (Council of Agriculture of Executive Yuan 2009) but not listed in the IUCN

red list (International Union for Conservation of Nature and Natural Resources 2011).

The mountain scops-owl is also an endemic subspecies, is common in Taiwan and does not face severe threats (Severinghaus *et al.* 2010). The entire order Strigiformes is listed in the Appendix 2 of CITES (2011), but this species is not listed in the IUCN red list (International Union for Conservation of Nature and Natural Resources 2011).

The plumbeous redstart is also an endemic subspecies and is commonly found in suitable habitats (rivers of low to mid elevation areas), but faces high hunting pressure because of the cage bird trade which may be the reason why it is not found in all suitable habitats (Severinghaus *et al.* 2010).

The white-tailed robin is an endemic subspecies and faces no immediate threats to its population (Severinghaus *et al.* 2010).

The crested serpent-eagle lives in lowland forests and has even adapted to fragmented forests around urban areas (Severinghaus *et al.* 2010). This species is also listed in the Appendix 2 of CITES (2011) but not listed in the IUCN red list (International Union for Conservation of Nature and Natural Resources 2011).

These discrepancies in status assessments when using different criteria are to be expected. For example, widespread species may have low population densities, as may be the case for the Taiwan partridge and white-tailed robin. When assessing a species' status, we should include as many relevant categories as possible, which is why we recommended including quartile rarity and protected areas coverage into future assessments of the conservation status of Taiwanese birds (this study, Wu *et al.*, In preparation). However, these

comparisons also draw our attention to cases that do not seem to make much sense: for example, how can the crested serpent-eagle be a fourth-quartile species, be recorded as common within its suitable habitats which include fragmented forests near urban areas, but still considered to be a rare and valuable species? Such obvious discrepancies as the ones discussed above should alert us to reassess a species' status.

The assessments of each species' recorded rarity (Chinese Wild Bird Federation 2010) and conservation status (Council of Agriculture of Executive Yuan 2009) as detailed in Appendix 1 are based on expert opinions and scoring procedures detailed in the Council of Agriculture of Executive Yuan schedule (2008). This scoring procedure involves adding scores for five conservation-related categories, which are: population distribution, dominance in habitat, population trend, endemic status, and other threats (e.g., hunting, habitat loss). Here, we simply suggest that our new measures, percent coverage of study area, quartile rarity (both in Appendix 1) and percent coverage of protected areas (Wu *et al.*, In preparation) should be included in whatever scoring system is used to evaluate each species' conservation status in the future. Such an exercise would also prove very valuable for other taxa.

Our Fig. 4 highlights a further potential problem. Plotting the number of recorded and predicted pixels versus recorded rarity using categorical scores also shows that there remains considerable unexplained variation, especially among the common category (Fig. 4). Evidently, species recorded as common by the Chinese Wild Bird Federation (2010) range from being rarely to commonly recorded in our database and also had widely different extent of occurrences. Again,

this discrepancy justifies further investigation.

We also investigated the relationship of endemic status to these other three measures (Fig. 5-Fig. 7). As may be expected, endemic status is not obviously related to recorded rarity, quartile rarity or Taiwanese conservation status. However, it is important to point out those species which are endemic species or subspecies and also have low recorded and quartile rarity (of those species that were modeled, only ring-necked pheasant (*Phasianus colchicus*) and white-browed bush-robin (*Tarsiger indicus*) qualify; Wu *et al.*, In preparation).

One of the few drawbacks of modeling species distributions is that the rarest species, which are also often the most important for conservation efforts, cannot be reliably modeled because of insufficient sample size (Methods). For this reason, we were unable to model the distributions of 28 rare or cryptic species (Appendix 1). While some species are so localized that modeling is not necessary (e.g., the Australasian grass-owl only occurs in one severely restricted area in southern Taiwan, Severinghaus *et al.* 2010), other species are most likely under-recorded because they are cryptic (e.g., several of the wetland species) or nocturnal (e.g., several of the other owl species). For these species, special efforts must be made to increase the number of observations.

If sample sizes remain insufficient despite these efforts, there remain two possibilities to map these species: either simply map the occurrences without any modeling (e.g., using a dot map or a grid system) or, better, using expert-derived models in which the environmental preferences are not calculated statistically (as in the inductive models used in this study) but derived from expert knowledge (called deductive models, Corsi *et al.*

2000). The modeling of rare species is one of the frontiers of current research (for recent studies for birds, Guisan *et al.* 2006, Walther *et al.* 2007, Jiguet *et al.* 2010, Marini *et al.* 2010a, 2010b) which will help in modeling the distributions of Taiwan's rare and cryptic birds.

The ability provided by Geographic Information Systems to calculate each species' extent of occurrence and its coverage provided by the protected areas network (this study; Wu *et al.*, In preparation) are major improvements in assessing each species' conservation status as well as the overall performance of the protected areas network in maintaining the long-term survival of Taiwan's avifauna. These studies highlight the usefulness of large distributional databases and modern analytical methods such as species distribution modeling and Geographic Information Systems to help us with the monitoring and assessment of a large number of taxa.

Recent efforts by the Endemic Species Research Institute (ESRI) in collaboration with the Chinese Wild Bird Federation and the Institute of Ecology and Evolutionary Biology at National Taiwan University to expand citizen participation in the Taiwan Breeding Bird Survey (BBS Taiwan) (Lee *et al.* 2010) and the Monitoring Avian Productivity and Survivorship in Taiwan (MAPS Taiwan) project (Lin and Chen 2011) should be welcomed and supported as they supply the important baseline data for our assessment efforts within Taiwan, but should also be seen as important in the efforts to monitor biodiversity on a global scale (Walther *et al.* 2007; Scholes *et al.* 2008; Ash 2009)

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**Appendix 1.** The percentage coverage of the study area, quartile rarity, recorded rarity and Taiwanese conservation status of the 145 species of Taiwanese breeding birds as listed in Fang *et al.* (2008). Latin and English names were taken from the Chinese Wild Bird Federation (2010) as well as their endemic species status; endemic = full endemic species status; name of subspecies' trinomial = recognized as endemic subspecies; all other species are listed as non-endemic. Global conservation status is given according to BirdLife International (2010): \* = vulnerable; \$ = near-threatened; all other species are listed as least concern. The fourth column gives the number of 1 x 1 km grid pixels in which the respective species was recorded to be breeding  $\geq 1$  times during the months March to July. The fifth column gives the number of grid pixels in which the respective species was predicted to be present using our distribution models (Methods). Note that the White Wagtail was excluded a *priori* from distribution modeling because it was not possible to visually distinguish breeding individuals and wintering visitors, some of which extend their stay in Taiwan into the breeding season. The superscript letters indicate which three of the following five methods for building distribution models were chosen as the best performing models based on their AUC scores to derive at a final distribution model (Methods): multiple discriminant analysis (D), ecological niche factor analysis (E), genetic algorithm for rule-set production (G), logistic regression (L), and maximum-entropy (M). The sixth column gives the percentage coverage of the study area which is the number of predicted pixels (fifth column) divided by the total number of grid pixels of the study area (36,022) and multiplied by 100. The seventh column gives quartile rarity which was derived from the number in the sixth column (see Methods for details). The eighth column gives the recorded rarity scored by the Chinese Wild Bird Federation (2010) as follows: R = rare (the respective bird species was recorded in < 20% of suitable habitats), UC = uncommon (the respective bird species was recorded 20-70% of suitable habitats), C = common (the respective bird species was recorded in > 70% of suitable habitats). The ninth column gives the Taiwanese conservation status scored by the Council of Agriculture of Executive Yuan (2009) as follows: EN = endangered; RV = rare and valuable; CD = other conservation-dependent species; all other species are non-threatened.

Latin Name	Endemic species status	English Name	Number of grid pixels recorded	Number of grid pixels predicted	% coverage of study area	Quartile rarity	Recorded rarity	Taiwanese conservation status
<i>Coturnix chinensis</i>		blue-breasted quail	5	-	-	-	R	RV
<i>Arborophila crudigularis</i> <sup>\$</sup>	endemic	Taiwan partridge	234	2127 <sup>D,E,L</sup>	59.07	3	UC	CD
<i>Bambusicola thoracicus</i>	<i>sonorivox</i>	Chinese bamboo-partridge	769	2830 <sup>D,E,L</sup>	78.57	4	C	-
<i>Lophura swinhoii</i> <sup>\$</sup>	endemic	Swinhoe's Pheasant	43	13099 <sup>G,L,M</sup>	36.36	2	UC	RV
<i>Syrnaticus mikado</i> <sup>\$</sup>	endemic	mikado pheasant	12	-	-	-	R	RV

Latin Name	Endemic species status	English Name	Number of grid pixels recorded	Number of grid pixels predicted	% coverage of study area	Quartile rarity	Recorded rarity	Taiwanese conservation status
<i>Phasianus colchicus</i>	<i>formosanus</i>	ring-necked pheasant	51	6534 <sup>D,L,M</sup>	18.14	1	R	RV
<i>Aix galericulata</i>		mandarin duck	19	-	-	-	UC	RV
<i>Tachybaptus ruficollis</i>		little grebe	96	9137 <sup>D,E,L</sup>	25.37	2	C	-
<i>Ixobrychus sinensis</i>		yellow bittern	48	5103 <sup>D,L,M</sup>	14.17	1	C	-
<i>Ixobrychus cinnamomeus</i>		cinnamon bittern	74	4229 <sup>D,E,L</sup>	11.74	1	UC	-
<i>Gorsachius melanolophus</i>		malayan night-heron	51	5686 <sup>D,E,L</sup>	15.78	1	C	-
<i>Nycticorax nycticorax</i>		black-crowned night-heron	255	13754 <sup>D,E,L</sup>	38.18	2	C	-
<i>Butorides striata</i>		striated heron	28	-	-	-	UC	-
<i>Bubulcus ibis</i>		cattle egret	383	16443 <sup>D,E,L</sup>	45.65	2	C	-
<i>Egretta garzetta</i>		little egret	602	20673 <sup>D,E,L</sup>	57.39	3	C	-
<i>Elanus caeruleus</i>		black-shouldered kite	1	-	-	-	R	RV
<i>Mitvus migrans</i>		black kite	27	-	-	-	R	RV
<i>Spilornis cheela</i>	<i>hoya</i>	crested serpent-eagle	555	27166 <sup>D,E,L</sup>	75.42	4	C	RV
<i>Accipiter trivirgatus</i>	<i>formosae</i>	crested goshawk	185	23554 <sup>D,E,L</sup>	65.39	3	C	RV
<i>Accipiter virgatus</i>	<i>fuscipectus</i>	besra	67	10082 <sup>D,L,M</sup>	27.99	2	UC	RV
<i>Ictinaetus malayensis</i>		black eagle	30	6516 <sup>D,G,L</sup>	18.09	1	R	EN
<i>Nisaetus nipalensis</i>		mountain hawk-eagle	14	-	-	-	R	EN
<i>Rallina eurizonoides</i>	<i>formosana</i>	slaty-legged crane	20	-	-	-	UC	-
<i>Gallinallus striatus</i>	<i>taiwanus</i>	slaty-breasted rail	10	-	-	-	UC	-
<i>Rallus aquaticus</i>		water rail	0	-	-	-	R	-

Latin Name	Endemic species status	English Name	Number of grid pixels recorded	Number of grid pixels predicted	% coverage of study area	Quartile rarity	Recorded rarity	Taiwanese conservation status
<i>Amaurornis phoenicurus</i>		white-breasted waterhen	197	13006 <sup>D,G,L</sup>	36.11	2	C	-
<i>Porzana fusca</i>		ruddy-breasted crane	34	5790 <sup>D,E,L</sup>	16.07	1	C	-
<i>Gallinix cinerea</i>		watercock	3	-	-	-	R	-
<i>Gallinula chloropus</i>		common moorhen	217	13734 <sup>D,E,L</sup>	38.13	2	C	-
<i>Turnix sylvaticus</i>		small buttonquail	1	-	-	-	R	-
<i>Turnix suscitator</i>	<i>rostratus</i>	barred buttonquail	71	11259 <sup>D,G,L</sup>	31.26	2	C	-
<i>Rostratula benghalensis</i>		greater painted-snipe	30	6571 <sup>D,L,M</sup>	18.24	1	C	RV
<i>Hydrophasianus chirurgus</i>		pheasant-tailed jacana	5	-	-	-	R	RV
<i>Glareola maldivarum</i>		oriental pratincole	60	5352 <sup>E,L,M</sup>	14.86	1	C	CD
<i>Columba pulchricollis</i>		ashy wood-pigeon	85	12249 <sup>D,E,L</sup>	34.00	2	UC	-
<i>Streptopelia orientalis</i>	<i>orii</i>	Oriental turtle-dove	122	21334 <sup>D,L,M</sup>	59.22	3	C	-
<i>Streptopelia tranquebarica</i>		red collared-dove	620	22015 <sup>D,E,L</sup>	61.12	3	C	-
<i>Streptopelia chinensis</i>		spotted dove	510	19241 <sup>D,G,L</sup>	53.41	3	C	-
<i>Chalcophaps indica</i>		emerald dove	102	12685 <sup>D,L,M</sup>	35.21	2	UC	-
<i>Treron sieboldii</i>		white-bellied pigeon	142	16843 <sup>D,G,L</sup>	46.76	2	UC	-
<i>Cuculus sparverioides</i>		large hawk-cuckoo	185	15245 <sup>D,G,L</sup>	42.32	2	C	-
<i>Cuculus saturatus</i>		Himalayan cuckoo	477	27195 <sup>D,E,L</sup>	75.50	4	C	-
<i>Centropus bengalensis</i>		lesser coucal	302	15999 <sup>D,G,L</sup>	44.41	2	C	-
<i>Tyto longimembris</i>	<i>pithecopis</i>	Australasian grass-owl	3	-	-	-	R	EN
<i>Otus spilocephalus</i>	<i>hambroeki</i>	mountain scops-owl	178	19863 <sup>D,E,G</sup>	55.14	3	C	RV

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<i>Otus leiffia</i>	<i>glabripes</i>	collared scops-owl	68	7134 <sup>D,G,L</sup>	19.80	1	C	RV
<i>Ketupa flavipes</i>		tawny fish-owl	3	-	-	-	R	RV
<i>Strix leptogrammica</i>		brown wood-owl	7	-	-	-	R	RV
<i>Strix aluco</i>	<i>yamadae</i>	tawny owl	8	-	-	-	R	RV
<i>Glaucidium brodiei</i>	<i>pardalotum</i>	collared owl	119	16183 <sup>D,E,L</sup>	44.93	2	UC	RV
<i>Ninox japonica</i>		northern boobook	17	-	-	-	UC	RV
<i>Caprimulgus affinis</i>	<i>stictomus</i>	savanna nightjar	33	10047 <sup>D,G,M</sup>	27.89	2	C	-
<i>Apus pacificus</i>		fork-tailed swift	93	16364 <sup>D,E,L</sup>	45.43	2	UC	-
<i>Apus nipalensis</i>	<i>kuntzi</i>	house swift	541	29737 <sup>D,E,L</sup>	82.55	4	C	-
<i>Alcedo atthis</i>		common kingfisher	206	20466 <sup>D,L,M</sup>	56.82	3	C	-
<i>Megalaima nuchalis</i>	endemic	Taiwan barbet	1194	26744 <sup>D,G,L</sup>	74.24	3	C	-
<i>Dendrocopos canicapillus</i>		gray-capped woodpecker	213	22724 <sup>D,E,L</sup>	63.08	3	C	-
<i>Dendrocopos leucotos</i>	<i>insularis</i>	white-backed woodpecker	52	10537 <sup>D,E,L</sup>	29.25	2	UC	RV
<i>Picus canus</i>		gray-faced woodpecker	52	8621 <sup>D,E,L</sup>	23.93	1	R	RV
<i>Pitta nympha</i> *		fairy pitta	21	-	-	-	UC	RV
<i>Coracina macei</i>		large cuckoo-shrike	15	-	-	-	R	RV
<i>Pericrocotus solaris</i>		gray-chinned minivet	454	22924 <sup>D,E,L</sup>	63.64	3	C	-
<i>Lanius schach</i>		long-tailed shrike	144	9117 <sup>D,G,L</sup>	25.31	2	C	-
<i>Oriolus chinensis</i>		black-naped oriole	4	-	-	-	R	EN
<i>Oriolus trailii</i>	<i>ardens</i>	maroon oriole	86	14976 <sup>D,L,M</sup>	41.57	2	UC	RV

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<i>Dicrurus macrocerus</i>	<i>harterti</i>	black drongo	523	19574 <sup>D,G,L</sup>	54.34	3	C	-
<i>Dicrurus aeneus</i>	<i>braunianus</i>	bronzed drongo	389	23935 <sup>D,E,L</sup>	66.45	3	C	-
<i>Hypothymis azurea</i>	<i>oberholseri</i>	black-naped monarch	739	22595 <sup>D,G,L</sup>	62.73	3	C	-
<i>Garrulus glandarius</i>	<i>taiwanus</i>	Eurasian jay	116	20246 <sup>D,L,M</sup>	56.20	3	C	-
<i>Urocissa caerulea</i>	endemic	Formosan magpie	103	12350 <sup>D,L,M</sup>	34.28	2	C	CD
<i>Dendrocitta formosae</i>	<i>formosae</i>	gray treepie	697	29269 <sup>D,G,L</sup>	81.25	4	C	-
<i>Pica pica</i>		Eurasian magpie	53	4319 <sup>E,L,M</sup>	11.99	1	C	-
<i>Nucifraga caryocatactes</i>	<i>owstoni</i>	Eurasian nutcracker	71	6010 <sup>D,E,L</sup>	16.68	1	C	-
<i>Corvus macrorhynchos</i>		large-billed crow	386	22705 <sup>D,E,L</sup>	63.03	3	C	-
<i>Parus monticolus</i>	<i>insperatus</i>	green-backed tit	283	13576 <sup>D,E,L</sup>	37.69	2	C	CD
<i>Macholophus holstis</i>	endemic	yellow tit	95	12262 <sup>D,E,L</sup>	34.04	2	R	RV
<i>Periparus ater</i>	<i>pilosus</i>	coal tit	124	7862 <sup>E,L,M</sup>	21.83	1	C	CD
<i>Sittiparus varius</i>	<i>castaneiventris</i>	varied tit	50	10217 <sup>D,L,M</sup>	28.36	2	UC	RV
<i>Riparia paludicola</i>		plain martin	205	17320 <sup>D,G,L</sup>	48.08	2	C	-
<i>Hirundo rustica</i>		barn swallow	423	17377 <sup>D,E,L</sup>	48.24	2	C	-
<i>Hirundo tahitica</i>		Pacific swallow	653	21515 <sup>D,G,L</sup>	59.73	3	C	-
<i>Delichon dasypus</i>		Asian house-martin	84	13798 <sup>D,E,L</sup>	38.30	2	UC	-
<i>Cecropis striolata</i>		striated swallow	388	14720 <sup>D,G,L</sup>	40.86	2	C	-
<i>Aegithalos concinnus</i>		black-throated tit	207	16240 <sup>D,L,M</sup>	45.08	2	C	-
<i>Alauda gulgula</i>		Oriental skylark	177	10371 <sup>D,E,L</sup>	28.79	2	C	-

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<i>Cisticola juncidis</i>		zitting cisticola	228	13247 <sup>D,G,L</sup>	36.77	2	C	-
<i>Cisticola exilis</i>	<i>volitans</i>	golden-headed cisticola	147	10810 <sup>D,G,L</sup>	30.01	2	UC	-
<i>Prinia erinigera</i>	<i>striata</i>	striated prinia	91	10234 <sup>E,G,L</sup>	28.41	2	C	-
<i>Prinia flaviventris</i>		yellow-bellied prinia	579	23446 <sup>D,E,L</sup>	65.09	3	C	-
<i>Prinia inornata</i>	<i>flavirostris</i>	plain prinia	693	25167 <sup>E,G,L</sup>	69.87	3	C	-
<i>Spizixos semitorques</i>	<i>cinereicapillus</i>	collared finchbill	438	23527 <sup>D,E,L</sup>	65.31	3	C	-
<i>Pycnonotus sinensis</i>	<i>formosae</i>	light-vented bulbul	1067	24897 <sup>D,L,M</sup>	69.12	3	C	-
<i>Pycnonotus taiwanus</i> *	endemic	styan's bulbul	269	5500 <sup>D,G,M</sup>	15.27	1	C	RV
<i>Hypsipetes leucocephalus</i>	<i>nigerrimus</i>	black bulbul	1187	30185 <sup>D,G,L</sup>	83.80	4	C	-
<i>Cettia fortipes</i>	<i>robustipes</i>	brownish-flanked bush-warbler	230	19635 <sup>D,G,L</sup>	54.51	3	C	-
<i>Cettia acanthizoides</i>	<i>concolor</i>	yellowish-bellied bush-warbler	126	11621 <sup>D,L,M</sup>	32.26	2	C	-
<i>Bradypterus alishanensis</i>	endemic	Taiwan bush-warbler	122	8474 <sup>E,L,M</sup>	23.52	1	C	-
<i>Abroscopus albogularis</i>		rufous-faced warbler	512	23076 <sup>G,L,M</sup>	64.06	3	C	-
<i>Pomatorhinus erythrocnemis</i>	<i>erythrocnemis</i>	spot-breasted scimitar-babbler	692	25945 <sup>D,G,L</sup>	72.03	3	C	-
<i>Pomatorhinus ruficollis</i>	<i>musicus</i>	streak-breasted scimitar-babbler	942	29139 <sup>D,G,L</sup>	80.89	4	C	-
<i>Proeopysa albiventer</i>	<i>formosana</i>	scaly-breasted wren-babbler	176	12839 <sup>D,E,M</sup>	35.64	2	C	-
<i>Stachyris ruficeps</i>	<i>praecognita</i>	rufous-capped babbler	1204	27835 <sup>D,G,L</sup>	77.27	4	C	-
<i>Garrulax albogularis</i>	<i>ruficeps</i>	white-throated laughingthrush	17	-	-	-	R	RV
<i>Garrulax poeilorhynchus</i>	<i>poeilorhynchus</i>	rusty laughingthrush	133	17199 <sup>D,G,L</sup>	47.75	2	UC	RV
<i>Garrulax taewanus</i> <sup>§</sup>	endemic	Taiwan hwamei	276	17604 <sup>D,L,M</sup>	48.87	2	UC	RV

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<i>Garrulax morrisonianus</i>	endemic	white-whiskered laughingthrush	135	9938 <sup>D,L,M</sup>	27.59	2	C	-
<i>Lioicichla steerii</i>	endemic	Steere's liocichla	407	18459 <sup>G,L,M</sup>	51.24	3	C	-
<i>Actinodura morrisoniana</i>	endemic	Taiwan barwing	54	9478 <sup>D,E,L</sup>	26.31	2	C	CD
<i>Alcippe cinereiceps</i>	<i>formosana</i>	streak-throated fulvetta	101	8783 <sup>E,L,M</sup>	24.38	1	C	-
<i>Alcippe brunnea</i>	<i>brunnea</i>	dusky fulvetta	798	25504 <sup>D,G,L</sup>	70.80	3	C	-
<i>Alcippe morrisonia</i>	<i>morrisonia</i>	gray-cheeked fulvetta	1072	26777 <sup>D,E,L</sup>	74.34	3	C	-
<i>Heterophasia auricularis</i>	endemic	white-eared sibia	425	18530 <sup>E,G,L</sup>	51.44	3	C	-
<i>Yuhina brunneiceps</i>	endemic	Taiwan yuhina	438	17147 <sup>E,G,L</sup>	47.60	2	C	-
<i>Yuhina zantholenca</i>		white-bellied yuhina	461	20088 <sup>D,G,L</sup>	55.77	3	C	-
<i>Paradoxornis webbianus</i>	<i>bulomachus</i>	vinous-throated parrotbill	158	15059 <sup>D,G,M</sup>	41.81	2	C	-
<i>Paradoxornis verreauxi</i>	<i>morrisonianus</i>	golden parrotbill	7	-	-	-	R	-
<i>Zosterops japonicus</i>		Japanese white-eye	972	32308 <sup>D,E,L</sup>	89.69	4	C	-
<i>Regulus goodfellowi</i>	endemic	flamecrest	77	6071 <sup>E,G,M</sup>	16.85	1	C	CD
<i>Troglodytes troglodytes</i>	<i>taivanus</i>	winter wren	43	4535 <sup>D,G,L</sup>	12.59	1	C	-
<i>Sitta europaea</i>		Eurasian nuthatch	121	11793 <sup>D,G,L</sup>	32.74	2	C	-
<i>Acridotheres cristatellus</i>	<i>formosanus</i>	crested myna	168	7143 <sup>D,G,L</sup>	19.83	1	UC	RV
<i>Myophonus insularis</i>	endemic	Formosan whistling-thrush	311	20812 <sup>D,G,L</sup>	57.78	3	C	-
<i>Turdus poliocephalus</i>	<i>niveiceps</i>	island thrush	17	-	-	-	R	RV
<i>Brachypteryx montana</i>	<i>goodfellowi</i>	white-browed shortwing	171	12749 <sup>D,L,M</sup>	35.39	2	C	-
<i>Tarsiger indicus</i>	<i>formosanus</i>	white-browed bush-robin	47	5333 <sup>D,E,L</sup>	14.80	1	R	CD

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<i>Tarsiger johnstoniae</i>	endemic	collared bush-robin	110	8289 <sup>E,L,M</sup>	23.01	1	C	-
<i>Rhyacornis fuliginosa</i>	<i>affinis</i>	plumbeous redstart	148	20714 <sup>D,G,L</sup>	57.50	3	C	CD
<i>Cinclidium leucurum</i>	<i>montium</i>	white-tailed robin	359	18274 <sup>E,G,L</sup>	50.73	3	UC	CD
<i>Enicurus scouleri</i>	<i>fortis</i>	little forktail	31	14639 <sup>B,E,M</sup>	40.64	2	R	RV
<i>Muscicapa ferruginea</i>		ferruginous flycatcher	83	10589 <sup>D,G,L</sup>	29.40	2	UC	-
<i>Ficedula hyperythra</i>	<i>innexa</i>	snowy-browed flycatcher	132	12833 <sup>D,E,L</sup>	35.63	2	C	-
<i>Niltava vivida</i>	<i>vivida</i>	vivid niltava	254	16738 <sup>D,E,L</sup>	46.47	2	UC	CD
<i>Cinclus pallasi</i>		brown dipper	43	14451 <sup>D,G,L</sup>	40.12	2	UC	-
<i>Dicaeum concolor</i>	<i>uchidai</i>	plain flowerpecker	26	-	-	-	UC	-
<i>Dicaeum ignipectum</i>	<i>formosum</i>	fire-breasted flowerpecker	134	14595 <sup>E,G,L</sup>	40.52	2	C	-
<i>Passer rutilans</i>		russet sparrow	9	-	-	-	R	EN
<i>Passer montanus</i>		Eurasian tree sparrow	819	21341 <sup>D,G,L</sup>	59.24	3	C	-
<i>Lonchura striata</i>		white-rumped munia	265	22299 <sup>D,G,L</sup>	61.90	3	C	-
<i>Lonchura punctulata</i>		nutmeg mannikin	388	24737 <sup>D,G,L</sup>	68.67	3	C	-
<i>Lonchura atricapilla</i>		chestnut munia	26	-	-	-	R	-
<i>Prunella collaris</i>	<i>fennelli</i>	alpine accentor	11	-	-	-	C	-
<i>Motacilla alba</i>		white wagtail	not used	-	-	-	C	-
<i>Carpodacus vinaceus</i>	<i>formosanus</i>	vinaceous rosefinch	39	4683 <sup>D,E,L</sup>	13.00	1	C	-
<i>Pyrrhula nipalensis</i>	<i>uchidae</i>	brown bullfinch	79	12344 <sup>E,L,M</sup>	34.27	2	UC	-
<i>Pyrrhula erythaca</i>	<i>owstoni</i>	gray-headed bullfinch	34	9544 <sup>D,L,M</sup>	26.49	2	UC	-