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# Does the Distribution of Breeding Bird Species Richness in Taiwan Follow the Mid-Domain Effect?

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**ABSTRACT:** In this paper, we examined the breeding bird species richness along an elevational gradient in northern Taiwan. These data obtained from 144 sites were used to test the mid-domain model. We compared the species richness with expectations from the mid-domain models, and identified elevational ranges at which the species richness was excessive or depauperate in species, relative to expectations. In addition, we compared the observed spatial distributions of geographic ranges with those predicted by mid-domain models to explore how species richness deviations were produced. Along the entire elevational gradient, observed species richness in most sites obviously deviated from those predicted by mid-domain models. We hypothesize that asymmetrical hump-shaped curve of the species richness may come from the combination of the favorableness hypothesis, the productivity hypothesis, and the mid-domain effect. Comparisons between observed and predicted spatial distributions of geographic ranges indicated that the nonrandomness of the distributions of endpoints or midpoints was highly congruent with vegetation transitions along the elevational gradient. The time hypothesis may account for the nonrandomness below 500 m.

**KEY WORDS: Bird species richness, Elevational gradient, Mid-domain effect, Taiwan.**

## INTRODUCTION

Describing and explaining spatial patterns of species diversity has been one of the main themes in ecology. The best-known pattern is the latitudinal gradient in species richness which states that species richness peaks within tropical latitudes, decreasing toward the poles (Rosenzweig, 1995). Previously, patterns of species richness along elevational gradients were considered as mirrors of species richness along the latitudinal gradients (Stevens, 1992). However, Rahbek's review (1995) of elevational diversity patterns from a variety of taxa showed that only 20% of the studies supported a monotonically decreasing curve, 49% exhibited hump-shaped curves with the highest richness at mid-elevations; and 24% had a plateau of high richness across the lower elevations.

As the diversity theory has progressed and more empirical data have been generated, it has become clear that many factors underlie large-scale diversity gradients (Brown, 2001; Lomolino, 2001), among them the mid-domain effect (Colwell and Lees, 2000). A mid-domain effect occurs when landmass boundaries, such as oceans and mountaintops, limit species ranges, and the simple overlap of many, variously sized ranges creates a peak in species richness at mid-elevation (Colwell and Hurtt, 1994; Colwell and Lees, 2000). This prediction is based solely on geographical constraints and offers a null model against which empirical patterns can be compared. Although there are some critics of the mid-domain effect (see Zapata et al., 2003), many empirical studies support the predicted pattern (Colwell et al., 2004). In recent years, comparisons of observed biodiversity patterns with predictions based on randomizations of geographic range have become common (see review of Colwell et al., 2004).

Many local-scale studies in Taiwan found hump-shaped relationship between bird species richness (BSR) and elevation (Kano, 1940; Jai, 1977; Shiu and Lee, 2003; Ding et al., 2005). Using compiled data from all of Taiwan, Lee et al. (2004) examined distributions of BSR on a regional scale and also found a hump-shaped relationship. They hypothesized that urbanization might have decreased the BSR and changed the inverse relationship between BSR and elevation into a hump-shaped relationship. They also proposed a time hypothesis which stated that the biotic communities in the mid-elevation zone of Taiwan

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had relatively longer periods of existence during the Pleistocene glacial cycles. The diversity patterns of birds along elevational gradients have not been tested using mid-domain null models.

The objectives of this study were to (1) examine the species richness pattern in breeding birds along an elevational gradient in northern Taiwan, (2) evaluate the support for a mid-domain model by comparing the observed distribution of BSR to mid-domain predictions, and (3) compare observed spatial distributions of elevation ranges with those predicted by a mid-domain model, and identify the BSR deviations using the spatial distribution of geographic ranges.

## METHODS

### Study area

Taiwan is a continental island off the southeast coast of the Asian mainland. It is separated from the mainland by the Taiwan Strait, which is about 150 km wide. The lofty mountains of Taiwan include more than 200 peaks higher than 3000 m (Wang, 1980). The climate is generally subtropical at lowlands. Temperature decreases as elevation increases at a lapse rate of -5.43°C km$^{-1}$ (Su, 1984a). Precipitation is heaviest during the summer, but rain falls year-round in northern region. Due to the high precipitation, forests are the primary type of natural vegetation in Taiwan. Broadleaf forests are dominant at lower elevations (generally under 2500 m), whereas coniferous forests are more prominent at higher elevations.

This study was conducted in northern Taiwan over an area of 11388.6 km$^2$ (Fig. 1). The area lies between latitudes 24°00’N and 25°18’N, and longitudes 120°27’E and 122°00’E. The greatest N-S distance is 144.9 km, and the greatest E-W distance is 150.85 km. In general, the elevation gradient increases from north to south, with mountains higher than 3000 m located primarily in the southern portion. The temperature averages 21.5°C (range: 16.7-23.0°C) and the total precipitation averages 2976.4 mm (range: 1283.0-4892.4 mm) at sea level (Taiwan Central Weather Bureau, http://www.cwb.gov.tw). Vegetation types occurring along the elevational gradient are *Ficus-Machilus*, *Machilus-Castanopsis*, *Quercus*, *Tsuga-picea*, *Abies*, and alpine (Su, 1992).

### Bird data

BSR data were sampled from 144 sites during early March to the end of June in 2001-2003. Sites were chosen based on four GIS layers: ecoregion (Su, 1992), elevation, vegetation, and road distribution. The number of the sampling sites in each ecoregion was determined by the relative area of each ecoregion. The same criterion was used to determine the number of sites placed in each of the three elevation classes: low (0-1000 m), mid (1000-2000 m), and high (above 2000 m), and in each of vegetation type. All sites were placed in areas within the reach of road systems to make sure easy accessibility.

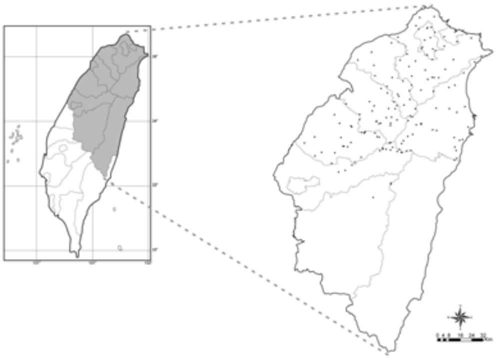

Fig. 1. Map of sampling locations in northern Taiwan.

At each site, we established one transect with 5-10 point counts located at least 150 m apart. At each station, we recorded the bird species that were seen or heard during a six-minute sample period. We applied the variable circular plot method in these point counts (Reynolds et al., 1980). Each site was sampled one time. Sampling was conducted during sunny, windless days from sunrise to no more than 3 hours later. Geographic coordinates and elevations for each station were taken with a handheld Global Positioning System receiver (Garmin, Taipei, Taiwan).

### Data analysis

BSR for each site were calculated as the cumulative species number across all the point counts at that site. Exotic species, migrants, and individuals of breeding species that were passing through the area were excluded from analyses. To evaluate potential variations in sampling effort among sites, we adjusted species richness using nonparametric randomization estimators, Chao2 and Jack2, the least biased estimates for small numbers of samples (Colwell and Coddington, 1994). The species richness was logarithmically transformed to stabilize the variances and improve the normality of the residuals. We used the lowest and highest elevations where a species occurred in this study as the lower and higher range endpoints of the species, respectively. The range extent and midpoint for a species were the difference and the mean of its higher and lower endpoints, respectively.

To test the influence of geographic boundaries, observed diversity patterns were compared to null model predictions generated by a Monte Carlo simulation procedure (Mid-Domain Null, McCain, 2004). This procedure generates species richness curves by sampling either empirical range sizes or range midpoints, and then randomizing the other within a bounded domain, based on analytical stochastic models (Colwell and Hurtt, 1994; Colwell and Lees, 2000). We model range locations as uniformly distributed among geometrically feasible values given observed range sizes, that is, we randomized the range locations within a bounded domain, but not the range sizes. Simulation boundaries were the elevations of mountain summit (i.e. 3900 m in our study site) and sea level. Richness data were generated at 100-m increments of elevation, based on 1000 simulations sampled without replacement from empirical ranges (Colwell et al., 2004; McCain, 2004). Regressions of the empirical values on predicted values, provided $r^2$ estimates to the fit of the null model. The Komogorov-Smirnov goodness of fit test was also applied to test the fit to the null model.

From these randomizations, we proceeded systematically from a formal statistical comparison of observed species richness patterns versus a mid-domain prediction, towards a quantitative characterization of what was responsible for the differences between the observed and predicted species richness. That is, we directly analyzed the empirical and simulated distributions of range endpoints and midpoints to understand how deviations between the observed and predicted species richness arose. This comparison indicates regions where there is a paucity or an accumulation of range endpoints or midpoints relative to the patterns expected under a mid-domain effect alone. Additionally, species range locations and sizes were jointly examined for each species.

## RESULTS

### BSR distribution in the elevatitonal gradient

Ninety-two breeding bird species (listed in the Appendix) were recorded over the survey period. The minimum and maximum species richness at 144 sites was 6 and 42, respectively. Species richness estimators adjusted by Chao2 and Jack2 gave similar patterns along the elevational gradient. Therefore, we used the Chao2 estimator to evaluate the support for the mid-domain null model.

Generally, the observed species richness showed a hump-shaped pattern. However, the curve was asymmetrical, and thus differed from mid-domain predictions (Fig. 2). The weak fit to the null model predictions was demonstrated by a low $r^2$ value (0.242), although the hump-shaped pattern was statistically significant ($p < 0.001$). In addition, the Komogorov-Smirnov goodness of fit test indicated that the two distribution curves significantly differed ($p < 0.001$). Differences between observed species richness and that predicted by the mid-domain model revealed that the highest deviation, a positive residual, occurred in low-elevation areas (Fig. 3). Positive residuals declined sharply from sea level to about 300 m. Both positive and negative anomalies appeared between 300 and 800 m, followed by mostly negative values above 800 m.

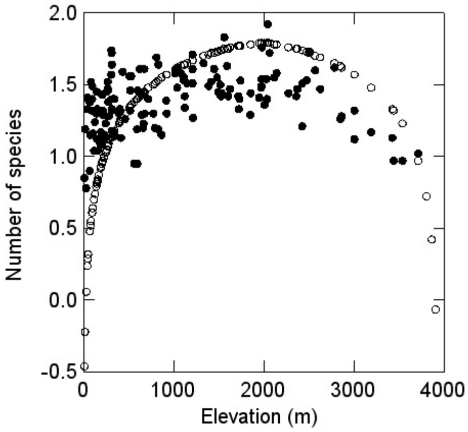

Fig. 2. Observed breeding bird species richness (black dots) along an elevational gradient in northern Taiwan, plotted with predicted values (white dots) under the mid-domain model ($y = -0.00x^2 + 0.06x-3.56$). Species richness was log-transformed. The observed values were weakly fitted to the null model ($r^2 = 0.242$, $p < 0.001$).

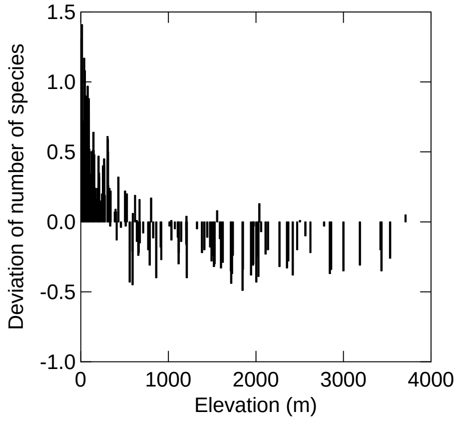

Fig. 3. Deviations of observed breeding bird species richness from that predicted by the mid-domain model. The species richness was log-transformed.

### Bird elevational range endpoints and midpoints

The largest discrepancy in the lower range endpoint distributions between the observed and the expected occurred at 0-499 m (Fig. 4A). More species than expected appeared in the foothills and low-elevation mountains. A comparison of higher range endpoint distributions between observed and expected values showed that the largest excess appeared at 500-999 m (Fig. 4B). Another excess peak appeared at 2000-2499 m. In other words, more species than expected reached their upper extents at 500-999 m and 2000-2499 m. The observed midpoint distribution showed that the largest excess occurred at 0-499 m, compared to the expected distribution (Fig. 4C). Another apparent excess occurred at 1000-1499 m. A marked paucity in the observed and expected midpoint distributions existed at 2000-2999 m. Generally, positive and negative anomalies appeared below and above 1500 m, respectively.

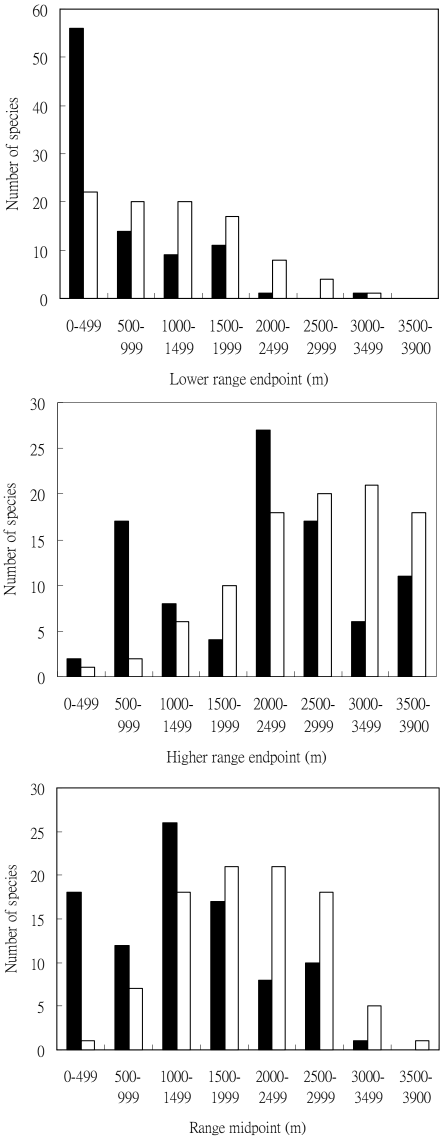

Fig. 4. Observed distribution of range locations of 92 breeding bird species (black bars), and expected distribution based on the mid-domain model (white bars). A: lower range endpoints. B: higher range endpoints, and C: range midpoint along an elevational gradient in northern Taiwan.

## Bird elevational range extents

Because the total elevational range extent of mountains in northern Taiwan is around 3900 m, we classified the species into 3 groups by their extent sizes: small-ranged (smaller than 1000 m, 22.8%, 21 sp.), medium-ranged (1000-1999 m, 45.7%, 42 sp.), and large-ranged species (≥ 2000 m, 31.5%, 29 sp.) (Fig. 5). A high percentage (90.5%, 19/21) of small-ranged species occurred entirely below 1000 m. In contrast, 62.1% (18/29) of large-ranged species extended from below 100 m to mid or high elevations. Compared to small- or large-ranged species, medium-ranged species occurred rather evenly from sea level to high elevations. The midpoints of most (85.7%, 18/21) of the small-ranged species were below 500 m. The midpoints of 65.5% (19/29) of large-ranged species were at 1000-1499 m, and those of 66.7% (28/42) of medium-ranged species were below 2000 m.

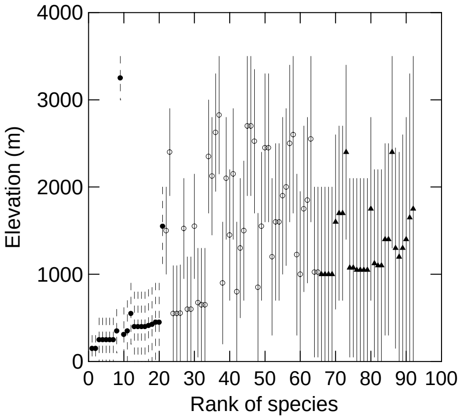

Fig. 5. Elevational range extents and midpoints of species in northern Taiwan, ranked by the size of the range extent. Dashed lines with black dots, continuous lines with white dots, and continuous lines with black triangles represent range extents of small-ranged, medium-ranged, and large-ranged species, respectively.

# DISCUSSION

## Deviations of the BSR curve from the mid- domain effect

The BSR demonstrated a hump-shaped curve along an elevational gradient in northern Taiwan. This pattern is consistent with previous studies in Taiwan (Kano, 1940; Jai, 197; Shiu and Lee, 2003; Lee et al., 2004; Ding et al., 2005). Despite the significant correlation between observed species richness and that predicted by the mid-domain model, the correlation is weak and many discrepancies exist. Negative anomalies in species richness appeared in the elevational ranges greater than 300 m, while positive values principally occurred at 0-300 m. The greatest excess of the empirical lower range endpoints relative

To the expected lay in the same range (Fig. 4A). An evaluation of environmental factors may explain this discrepancy.

The temperature on Taiwan's mountains generally decreases with elevation, with a lapse rate of -5.43 °C km$^{-1}$ (Su, 1984a). Based on the favorableness hypothesis (Terborgh, 1973; Brown, 1981), an increase in air temperature should increase the physiological performance and efficiency of a bird's energy use and thus be more favorable for birds. Additionally, species in areas of higher temperature tend to have a shorter life span, and this may increase rates of speciation (Rohde, 1992). Collectively, BSR in Taiwan may be higher at lower elevations.

Primary productivity plays an important role in distribution of BSR in East Asia (Ding et al., in press). Productivity hypothesis states that species richness increases with productivity (see reviews of Rahbek, 1997). NDVI (normalized difference vegetation index), a surrogate for primary productivity (Box et al., 1989; Ustin et al., 1991), increase from low to mid elevations, followed by a decreasing trend from mid to high elevations in areas of northern Taiwan (Koh et al., in press). Therefore, BSR may have a hump-shaped curve along the elevational gradient in northern Taiwan.

As combining the favorableness hypothesis, the productivity hypothesis, and the mid-domain model, the BSR distribution in northern Taiwan will probably be an asymmetrical hump-shaped curve, which increases slowly from low to mid elevations and decreases more quickly from mid to high elevations. Our data suggest that the prediction of the favorableness hypothesis, the productivity hypothesis, and the mid-domain effect may need to be combined to yield a better fit to the empirical data.

## Distributions of bird range endpoints and vegetation transitions

Comparisons of the empirical higher range endpoints to the expected revealed a great excess at 500-999 m (Fig. 4B). More species (17 species) than expected end their ranges at 500-999 m (Fig. 5).

The distribution limitation for birds may be related to a transition of vegetation types in northern Taiwan. Koh and Lee (2003) investigated the patterns of breeding birds in northern Taiwan, and proposed that a low-elevational community was restricted to areas under 1000 m. Those authors argued that a bird community's transition from low- to mid-elevation was consistent with a vegetation transition from the *Machilus-Castanopsis* zone to the *Quercus* zone. The transition zone of *Machilus-Castanopsis* to the *Quercus* in northern Taiwan generally extends from 500 to 1200 m (Su, 1984b). Birds living in the *Machilus-Castanopsis* forests may gradually disappear in this range. The vegetation transition may explain why more species than expected end their range at 500-1499 m, especially 500-999 m. Therefore, species richness at 500-999 m is not consistently higher than those at 0-499 m, and contradicts the predictions of the mid-domain model. A secondary excess of higher range endpoints clustered at 2000-2499 m. Species range midpoints and extents revealed that 27 species reached their upper extents at 2000-2499 m (Fig. 5). Again, this may have been due to a vegetation transition from the *Quercus* zone to the *Tsuga-Picea* zone (i.e., 2000-2200 m, Su, 1984b). Jai (1977) also demonstrated that a transition from a mid- (1000-2300 m) to a high- (above 2300 m) elevation bird community is consistent with the vegetation transition.

## A cluster of the small-ranged species and the time hypothesis

Greatest excess in midpoints exist at 0-499 m, which is in accordance with a cluster of the small-ranged species (85.7%) in this range (Fig. 4C). The time hypothesis in which the biotic communities in the mid-elevation zone of Taiwan had relatively longer periods of existence during the Pleistocene glacial cycles (Lee et al., 2004) may offer a potential explanation for accumulations of small-ranged species below 500 m. Dramatic climatic fluctuations might have caused the biotic communities to shift up and down along the elevational gradient (Tsukada, 1967). Therefore, they might have had more opportunities to adapt to wider elevational ranges. By contrast, the biotic communities that adapted to the lower end of the elevational gradient might have been totally eliminated by the extreme climates during the Pleistocene glacial period. Thus, they might not have had a long history like mid-elevational communities and would have only been able to extend into smaller ranges. In our view, the cluster of midpoints of the small-ranged species below 500 m is congruent with the prediction of the time hypothesis.

For breeding birds in northern Taiwan, large and statistically significant differences exist between the observed species richness and those predicted by the mid-domain models. Therefore, BSR in northern Taiwan does not conform to the mid-model effect. Interestingly, the asymmetrical hump-shaped curve of BSR may come from a synthesis of the favorableness hypothesis, the productivity hypothesis, and the mid-domain effect.

Comparisons between observed and predicted spatial distributions of range endpoints and midpoints indicated a pattern of nonrandomness that was highly congruent with vegetation transitions along the elevational gradient. In addition, the nonrandomness below 500 m may be explained by the time hypothesis.

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Appendix 1. Lowest elevations, highest elevations, midpoints, and elevational ranges of species of terrestrial breeding birds surveyed in northern Taiwan from 2001 to 2003. Scientific names of species follow Monroe and Sibley (1993).

| Species | | Lowest elevation (m) | Highest elevation (m) | Midpoint (m) | Elevational range (m) |
|---|---|---|---|---|---|
| **Family Accipitridae** | 鷲鷹科 | | | | |
| *Accipiter virgatus* | 松雀鷹 | 0 | 2100 | 1050 | 2100 |
| *Accipiter trivirgatus* | 鳳頭蒼鷹 | 50 | 2000 | 1025 | 1950 |
| *Spilornis cheela* | 大冠鷲 | 0 | 2000 | 1000 | 2000 |
| **Family Phasianidae** | 雉科 | | | | |
| *Arborophila crudigularis* | 深山竹雞 | 50 | 2100 | 1075 | 2050 |
| *Bambusicola thoracica* | 竹雞 | 0 | 2000 | 1000 | 2000 |
| *Syrmaticus mikado* | 帝雉 | 1700 | 3000 | 2350 | 1300 |
| **Family Turnicidae** | 三趾鶉科 | | | | |
| *Turnix suscitator* | 棕三趾鶉 | 0 | 500 | 250 | 250 |
| **Family Columbidae** | 鳩鴿科 | | | | |
| *Chalcophaps indica* | 翠翼鳩 | 0 | 620 | 310 | 620 |
| *Columba pulchricollis* | 灰林鴿 | 700 | 2300 | 1500 | 1600 |
| *Treron sieboldii* | 綠鳩 | 0 | 2100 | 1050 | 2100 |
| *Streptopelia chinensis* | 斑頸鳩 | 0 | 900 | 450 | 900 |
| *Streptopelia orientalis* | 金背鳩 | 0 | 1100 | 550 | 1100 |
| *Streptopelia tranquebarica* | 紅鳩 | 0 | 500 | 250 | 500 |
| **Family Cuculidae** | 杜鵑科 | | | | |
| *Cuculus saturatus* | 筒鳥 | 0 | 3300 | 1650 | 3300 |
| *Cuculus sparverioides* | 鷹鵑 | 700 | 2200 | 1450 | 1500 |
| **Family Centropidae** | 鴉鵑科 | | | | |
| *Centropus bengalensis* | 番鵑 | 0 | 800 | 400 | 800 |
| **Family Strigidae** | 鴟鴞科 | | | | |
| *Glaucidium brodiei* | 鵂鶹 | 300 | 2100 | 1200 | 1800 |
| **Family Megalaimidae** | 鬚鴷科 | | | | |
| *Megalaima oorti* | 五色鳥 | 0 | 1700 | 850 | 1700 |
| **Family Picidae** | 啄木鳥科 | | | | |
| *Dendrocopos canicapillus* | 小啄木 | 0 | 2100 | 1050 | 2100 |
| *Dendrocopos leucotos* | 大赤啄木 | 700 | 2400 | 1550 | 1700 |
| *Picus canus* | 綠啄木 | 900 | 2800 | 1850 | 1900 |
| **Family Alaudidae** | 雲雀科 | | | | |
| *Alauda gulgula* | 小雲雀 | 0 | 800 | 400 | 800 |
| **Family Pycnonotidae** | 鵯科 | | | | |
| *Hypsipetes leucocephalus* | 紅嘴黑鵯 | 0 | 1600 | 800 | 1600 |
| *Pycnonotus sinensis* | 白頭翁 | 0 | 1200 | 600 | 1200 |
| *Spizixos semitorques* | 白環鸚嘴鵯 | 50 | 1300 | 675 | 1250 |
| **Family Laniidae** | 伯勞科 | | | | |
| *Lanius schach* | 棕背伯勞 | 0 | 300 | 150 | 300 |
| **Family Certhiidae** | 旋木雀科 | | | | |
| Subfamily Troglodytinae | 鷦鷯亞科 | | | | |
| *Troglodytes troglodytes* | 鷦鷯 | 2150 | 3700 | 2925 | 1550 |

Appendix 1. (*Continued*)

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|---|---|---|---|---|---|
| **Family Muscicapidae** | 鶲科 | | | | |
| Subfamily Turdinae | 鶇亞科 | | | | |
| *Brachypteryx montana* | 小翼鶇 | 1100 | 2900 | 2000 | 1800 |
| *Cinclidium leucurum* | 白尾鴝 | 300 | 2500 | 1400 | 2200 |
| *Tarsiger johnstoniae* | 栗背林鴝 | 1700 | 3700 | 2700 | 2000 |
| *Tarsiger indicus* | 白眉林鴝 | 1600 | 3400 | 2500 | 1800 |
| *Myiophoneus insularis* | 紫嘯鶇 | 50 | 1950 | 1000 | 1900 |
| *Turdus Poliocephalus* | 白頭鶇 | 1000 | 2000 | 1500 | 1000 |
| **Family Sylviidae** | 鶯科 | | | | |
| Subfamily Sylviinae | 鶯亞科 | | | | |
| *Actinodura morrisoniana* | 紋翼畫眉 | 1450 | 2800 | 2125 | 1350 |
| *Alcippe brunnea* | 頭烏線 | 0 | 2000 | 1000 | 2000 |
| *Alcippe cinereiceps* | 灰頭花翼 | 1600 | 3300 | 2450 | 1700 |
| *Alcippe morrisonia* | 繡眼畫眉 | 0 | 2600 | 1300 | 2600 |
| *Garrulax albogularis* | 白喉笑鶇 | 1100 | 2000 | 1550 | 900 |
| *Garrulax poecilorhynchus* | 竹鳥 | 50 | 2100 | 1075 | 2050 |
| *Garrulax canorus* | 畫眉 | 0 | 850 | 425 | 850 |
| *Garrulax morrisonianus* | 金翼白眉 | 1600 | 3700 | 2650 | 2100 |
| *Heterophasia auricularis* | 白耳畫眉 | 600 | 2600 | 1600 | 2000 |
| *Liocichla steerii* | 藪鳥 | 700 | 2700 | 1700 | 2000 |
| *Pnoepyga pusilla* | 鱗胸鷦鶥 | 1400 | 2800 | 2100 | 1400 |
| *Pomatorhinus erythrocnemis* | 大彎嘴畫眉 | 0 | 2200 | 1100 | 2200 |
| *Pomatorhinus ruficollis* | 小彎嘴畫眉 | 0 | 2100 | 1050 | 2100 |
| *Stachyris ruficeps* | 山紅頭 | 0 | 2800 | 1400 | 2800 |
| *Yuhina brunneiceps* | 冠羽畫眉 | 700 | 2800 | 1750 | 2100 |
| *Yuhina zantholeuca* | 綠畫眉 | 0 | 2000 | 1000 | 2000 |
| *Abroscopus albogularis* | 棕面鶯 | 150 | 2450 | 1300 | 2300 |
| *Bradypterus alishanensis* | 褐色叢樹鶯 | 1300 | 3500 | 2400 | 2200 |
| *Cettia acanthizoides* | 深山鶯 | 1700 | 3500 | 2600 | 1800 |
| *Cettia fortipes* | 小鶯 | 300 | 2500 | 1400 | 2200 |
| *Cisticola exilis* | 黃頭扇尾鶯 | 0 | 300 | 150 | 300 |
| *Cisticola juncidis* | 棕扇尾鶯 | 0 | 828 | 414 | 828 |
| *Prinia flaviventris* | 灰頭鷦鶯 | 0 | 800 | 400 | 800 |
| *Prinia criniger* | 斑紋鷦鶯 | 0 | 2200 | 1100 | 2200 |
| *Prinia inornata* | 褐頭鷦鶯 | 0 | 800 | 400 | 800 |
| *Paradoxornis webbianus* | 粉紅鸚嘴 | 0 | 2400 | 1200 | 2400 |
| Subfamily Muscicapinae | 鶲亞科 | | | | |
| *Ficedula hyperythra* | 黃胸青鶲 | 700 | 2500 | 1600 | 1800 |
| *Muscicapa ferruginea* | 紅尾鶲 | 1000 | 2800 | 1900 | 1800 |
| *Niltava vivida* | 黃腹琉璃 | 300 | 2150 | 1225 | 1850 |
| **Family Regulidae** | 戴菊科 | | | | |
| *Regulus goodfellowi* | 火冠戴菊鳥 | 1900 | 3500 | 2700 | 1600 |
| **Family Aegithalidae** | 長尾山雀科 | | | | |
| *Aegithalos concinnus* | 紅頭山雀 | 700 | 2700 | 1700 | 2000 |
| **Family Paridae** | 山雀科 | | | | |
| *Parus ater* | 煤山雀 | 1400 | 3700 | 2550 | 2300 |
| *Parus holsti* | 黃山雀 | 950 | 2100 | 1525 | 1150 |
| *Parus monticolus* | 青背山雀 | 800 | 2700 | 1750 | 1900 |
| *Parus varius* | 赤腹山雀 | 200 | 1600 | 900 | 1400 |
| **Family Sittidae** | 鳾科 | | | | |
| *Sitta europaea* | 茶腹鳾 | 1400 | 2900 | 2150 | 1500 |
| **Family Nectariniidae** | 吸蜜鳥科 | | | | |
| *Dicaeum concolor* | 綠啄花鳥 | 200 | 900 | 550 | 700 |
| *Dicaeum ignipectus* | 紅胸啄花鳥 | 700 | 2500 | 1600 | 1800 |
| **Family Zosteropidae** | 繡眼科 | | | | |
| *Zosterops japonica* | 綠繡眼 | 0 | 1200 | 600 | 1200 |
| **Family Fringillidae** | 雀科 | | | | |
| *Carpodacus vinaceus* | 朱雀 | 1900 | 3700 | 2800 | 1800 |
| *Pyrrhula erythaca* | 灰鷽 | 1950 | 3500 | 2725 | 1550 |
| *Pyrrhula nipalensis* | 褐鷽 | 950 | 2150 | 1550 | 1200 |

Appendix 1. (*Continued*)

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|---|---|---|---|---|---|
| **Family Passeridae** | 文鳥科 | | | | |
| Subfamily Passerinae | 文鳥亞科 | | | | |
| *Lonchura punctulata* | 斑文鳥 | 0 | 500 | 250 | 500 |
| *Lonchura striata* | 白腰文鳥 | 0 | 1100 | 550 | 1100 |
| *Passer montanus* | 麻雀 | 0 | 500 | 250 | 500 |
| Subfamily Prunellinae | 岩鷚亞科 | | | | |
| *Prunella collaris* | 岩鷚 | 3000 | 3700 | 3350 | 700 |
| Subfamily Motacillidae | 鶺鴒亞科 | | | | |
| *Motacilla alba* | 白鶺鴒 | 0 | 1110 | 555 | 1110 |
| **Family Sturnidae** | 椋鳥科 | | | | |
| *Acridotheres cristatellus* | 八哥 | 0 | 500 | 250 | 500 |
| **Family Corvidae** | 鴉科 | | | | |
| Subfamily Corvinae | 鴉亞科 | | | | |
| *Corvus macrorhynchos* | 巨嘴鴉 | 0 | 3500 | 1750 | 3500 |
| *Dendrocitta formosae* | 樹鵲 | 0 | 1300 | 650 | 1300 |
| *Garrulus glandarius* | 松鴉 | 500 | 2100 | 1300 | 1600 |
| *Nucifraga caryocatactes* | 星鴉 | 1600 | 3300 | 2450 | 1700 |
| *Oriolus traillii* | 朱鸝 | 100 | 600 | 350 | 500 |
| *Pericrocotus solaris* | 紅山椒 | 50 | 2200 | 1125 | 2150 |
| *Urocissa caerulea* | 台灣藍鵲 | 0 | 900 | 450 | 900 |
| Subfamily Dicrurinae | 卷尾亞科 | | | | |
| *Dicrurus aeneus* | 小卷尾 | 50 | 2000 | 1025 | 1950 |
| *Dicrurus macrocercus* | 大卷尾 | 0 | 700 | 350 | 700 |
| *Hypothymis azurea* | 黑枕藍鶲 | 0 | 1300 | 650 | 1300 |

# 臺灣繁殖鳥類種豐富度的分布是否具有中間區域效應?

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## 摘　　要

本報告係調查臺灣北部海拔梯度上的繁殖鳥類種豐富度。我們用調查所得 144 筆資料來檢驗其是否支持中間區域模式。首先我們比較鳥種豐富度的觀察值與中間區域模式的預測值，並且指出觀察值多於或少於預測值的海拔區段。再比較鳥種海拔分布範圍的所在位置，其觀察值與預測值的差異，以探究鳥種豐富度觀察值偏離預測值的原因。結果發現大部份的鳥種豐富度觀察值明顯偏離中間區域模式的預測值，並且觀察值在海拔梯度上呈現出不對稱駝型分布，可能是由喜好假說、生產力假說及中間區域效應的合成效應所產生。鳥種海拔分布範圍之上下限及中點，其觀察值偏離預測值之所在，與海拔梯度上的植被變換帶有高度的一致性。海拔分布範圍較小的鳥種多聚集於海拔 500 公尺以下，則可能歸因於歷史因素。

關鍵詞：鳥種豐富度、海拔梯度、中間區域效應、臺灣。

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