

Seasonal Variation in Bird Species Richness along Elevational Gradients in Taiwan

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ABSTRACT

Seasonal variations in the distribution of bird species richness and community composition along elevational gradients in Taiwan were studied. We compiled bird species richness data through an extensive literature review, and classified the data into breeding season, non-breeding season, and year-round sets. We then examined the avifaunal-environmental relationships using presence/absence data by principle components analysis (PCA), cluster analysis, and detrended correspondence analysis (DCA). With the year-round dataset, species richness appeared roughly constant from sea level to about 1500 m, then declined with increasing elevation; while the richness during the breeding season was non-linearly related to elevation, with a hump-shaped curve which peaked at around 1500 m. By separating migratory landbirds from residents during the non-breeding season, however, we found that the two groups had different patterns along the gradient: residents showed a hump-shaped pattern similar to that of the breeding season, whereas migratory landbirds showed a negative exponential pattern. The results of PCA and cluster analysis demonstrated that the resident assemblages were classified into three major categories: lowlands, mid-elevation domain, and highlands, separated roughly by the elevations of 300 and 2300 m. DCAs indicated that elevation and human disturbance are the major environmental factors contributing to variations in the trend of resident assemblages. The seasonality of data collection strongly influences bird species richness distribution patterns and should be clearly defined to obtain a meaningful result in bird species richness studies.

Key words: bird community, elevational gradient, seasonal variation, species richness, Taiwan

INTRODUCTION

Species richness generally decreases with increasing elevation (Begon *et al.*, 1996). Although some research has shown that the relationship between species richness and elevation is monotonic (e.g., Wolda, 1987; Navarro S., 1992; Patterson *et al.*, 1998), recent studies (e.g., Rahbek, 1997; Samson *et al.*, 1997; Fleishman *et al.*, 1998; Lees *et al.*, 1999) and reviews (e.g., McCoy, 1990; Rahbek, 1995) have demonstrated that species richness peaks toward the middle

elevation and is hump-shaped.

When studying species richness patterns, the exact number of a sample species must be determined. For example, Wolda (1987) investigated the distributions of insect species richness along elevational gradients in Panama, and suggested that surveying with different sampling regimes (short-term vs. long-term) might produce different richness distribution patterns. McCoy (1990) recommended that if species turnover rates differed between lower and higher elevations, then the temporal scale

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employed would strongly influence the evaluation of these patterns. Many bird species have obvious annual migratory cycles. Therefore, differences in the season surveyed might also influence the evaluation of the distribution patterns of bird species richness.

Studies have shown the distributions of migratory landbirds in wintering habitats tend to occur at middle elevations in Africa and the Neotropics (e.g., reviewed in Karr, 1976). However, others (e.g., Petit *et al.*, 1995) have found the wintering habitat use of Neotropical migratory landbirds to be well-represented in lowland (< 1000 m) habitats. Karr (1976) also reported that wintering migrants were more abundant in lowland forests of India and Malaysia. The annual autumn arrivals of migratory birds can even double the number of species in a given tropical or subtropical habitat, especially on islands (e.g., Leck, 1972). If species richness distribution patterns differ between migratory and sedentary birds, as suggested above, the overall patterns in these habitats might vary among seasons. Therefore, distribution patterns need to be separated by seasons, and their explanations or mechanisms need to be reconsidered. Some studies have investigated seasonal variations in bird species richness or bird community composition at a given place (e.g., Karr, 1976; Karr and Freemark, 1983; Blake, 1984; Braithwaite *et al.*, 1989; Loiselle and Blake, 1991). Nevertheless, few studies have assessed variations along elevational gradients in tropical or subtropical regions.

In this paper, we studied the temporal bird community pattern along elevational gradients in Taiwan using a meta-analysis. We examined seasonal variations in avian species richness by investigating relationships between bird communities and environmental factors. In particular, we determined the distribution patterns of species richness during the breeding season, non-breeding season, and year-round through compiling a species database from an intensive literature review, and by comparing these patterns and estimating the influence of migratory landbirds on the richness pattern during the non-breeding

season. We then classified the sampling sites in accordance with their bird compositions by principal components analysis (PCA) and cluster analysis. Finally, we used detrended correspondence analysis (DCA) to explore the relationships between bird communities and environmental factors.

STUDY AREA

Taiwan is located some 90 km off the southeastern Chinese coast in a subtropical climate zone between 22°N and 25°N latitude and 120°E and 122°E longitude. It is a small (roughly 36,000 km²), mountainous island, with approximately one-third of its land area higher than 1000 m above sea level and more than 200 peaks that exceed 3000 m. The Central Mountain Range, which generally runs north to south, reaches a maximum height of nearly 4000 m and forms steep elevational gradients. The climate of Taiwan is warm (average annual temperature of the lowlands is about 23 °C) and humid (average annual precipitation is above 2500 mm).

Forests predominate the landscape in Taiwan, covering 58% of the land area. From sea level to the highest peaks, the vegetation can be distinguished into seven spectra of forest types (Su, 1984; Table 1). This variety of environments in turn supports a rich fauna. Indeed, more than 400 species of birds (about 40% resident) are known to occur on this small island.

METHODS

Species database

We completed an extensive literature review on the distribution of birds on Taiwan. A database of species and localities was established. Since there are many candidates of published records, we selected literature based on the following four guidelines: (1) the avifauna was the main objective of the study (for example, we excluded literature for which the fauna was surveyed as part of an environmental impact assessment); (2) the survey frequency of the study was at least once per month; (3) the

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elevation of the study site was clearly documented; and (4) the elevational extent of the study site did not exceed 300 m. Using these criteria, our database contained 35 localities (Fig. 1) from 21 publications (see Appendix 1). Except in the lowlands (< 250 m) or near high mountain peaks (> 3650 m), the physiognomies of these sites were dominated by forests, especially mature forests. Most sites (24 of 35) had data from bird surveys conducted for at least one full year, while the rest had data only for the breeding season. Most sites (15 of 24) had bird records separated by breeding and non-breeding seasons, but some (9 of 24) had only a complete listing of the bird species present during the entire survey period.

Only landbirds were analyzed in this study. Landbirds are defined as birds that occur mostly in terrestrial habitats (such as grasslands, brush, forests, farmlands, orchards, and urban regions) for nesting, foraging, and roosting (for the taxa of landbirds covered in this study, see Appendix 2). In addition, Taiwan is located along major Asian migratory routes (McClure, 1974), and most wintering migrants recorded in Taiwan are transients, with only a few species of migrants remaining for the entire season (e.g., Chih, 2000). Because most transients pass through Taiwan between mid-August and mid-October during fall migration and between mid-March and mid-May during spring migration (e.g., Lu, 1997; Pan, 1998; Chih, 2000), we therefore excluded migrant data during these periods. We also excluded the Apodidae (three species found here) and the Hirundinidae (six species found here), which continuously fly and forage in the air. When the data permitted, we attempted to separate the data for breeding and non-breeding season, and distinguish resident birds from migrants. As a result, the database contained 175 species (see Appendix 2) and included 67 wintering migratory landbirds and 3 summer visitors.

Although birds are well-studied taxonomically and relatively easy to survey, population densities in a habitat are difficult to accurately estimate due to various sources of bias attributed to the observer, census method, weather, and level of effort (Bibby

et al., 2000). This is particularly true in a metadata analysis that collects data from different papers with different sampling methods. For this reason, we used presence/absence data to analyze the community-environment relationships.

We extracted environmental characteristics of each locality from an environmental GIS database compiled by Lee *et al.* (1997). The database was in a grid formation with a 1 × 1-km resolution. These variables are naturalness index (0-10, an index generated by assigning the land cover types to appropriate categories with those highly undisturbed types, such as mature forests, being 10 while those highly developed ones, such as concrete buildings, being 0), mean elevation, mean temperatures in January and July, total precipitation in January and July, and mean annual humidity as the environmental variables.

Data analyses

We studied species richness patterns by plotting the pattern along an elevational gradient using a distance-weighted least-squares smoothing in SYSTAT (Wilkinson, 1999).

We used classification and ordination techniques to examine the relationship between birds and environments. Because rare birds observed in a focal locality by chance rather than by determinate might interfere with the examinations, we used PCA to extract the principal variation in the bird data before conducting the classifications. We then calculated Euclidean distances between localities according their PC scores and used an average-linkage method to construct a dendrogram of the localities. We also used DCA to order the localities based on their bird compositions and then examined the relationships between the DCA axes and environmental factors.

RESULTS

Species richness patterns

The year-round bird species richness declined with elevation above about 1500 m (Fig. 2). Below this elevation, species richness remained roughly constant. In contrast, in the breeding season, the richness reached a maximum at mid elevations (about 1500 m) and showed an obvious hump-shaped pattern. By separating the non-breeding season data into residents and migrants, these two groups showed very distinct patterns (Fig. 2). The pattern for residents in the non-breeding season was similar to that of the breeding season, but the number of species presented at a given site was generally higher (Wilcoxon signed-rank test; $T = 20.5$, $n = 14$, $p < 0.05$), particularly at mid elevations (Fig. 2).

In contrast, the richness of wintering migratory landbirds reached a maximum at sea level and declined with increasing elevation (Spearman's correlation coefficient; $r_s = -0.918$, $n = 24$, $p < 0.001$). It was roughly constant between 1000 and 3000 m (Spearman's correlation coefficient; $r_s = -0.018$, $n = 7$, $p > 0.5$) and overall showed a negative exponential-like pattern. Wintering migratory landbirds tended to occur in the lowlands. They represented a high proportion of the avifauna in the plains (46%–62%) and hills (22%–48%), but only a small proportion in mid to high elevations (<20%).

Species-environment relationships

To explore the species-environment relationship, several PCAs were performed. The proportions of variance explained by the first three PC axes were 32.7%, 21.5%, and 7.9%, respectively, for the bird distributions in the breeding season. Since the proportions of the variance explained by each axis obviously decreased after the third axis, we used the first two axes in the cluster analysis. These localities were classified mainly by elevation into three major categories: lowlands, mid-elevation domain, and highlands (Fig. 3). Similarly, most variance was explained by the first two PC axes (33.3% in PC1, 19.9% in PC2, and only 7.8% in PC3) for the resident distribution in the non-breeding season. Again, through cluster analysis using the

first two PC axes, we obtained a dendrogram (Fig. 4) with a highly similar pattern to that of the breeding season.

The DCA results for birds in the breeding season indicated that the eigenvalue for the first DCA axis was 0.69, and the length of the gradient of the axis was 5.4 SDs (standard deviations), but those parameters for the second axis were only 0.08 and 1.5 SDs, respectively (Fig. 5). Apparently, the first DCA axis contained the major variation trend of the breeding bird communities. Only the first axis was significantly correlated with elevation ($r_s = -0.96$, $p < 0.001$; Table 2), mean July temperature ($r_s = 0.92$, $p < 0.001$; Table 2), and the naturalness index ($r_s = -0.86$, $p < 0.001$; Table 2). Note that the mean July temperature decreased linearly with increasing elevation, and the correlation coefficient was -0.97 ($p < 0.001$). That is to say, the major variation trend of the breeding bird communities was dependent on elevation and human disturbance (i.e., the naturalness index).

For resident birds in the non-breeding season, DCA results were similar to those of the breeding season. The first DCA axis was the major source of variation with an eigenvalue of 0.59 and length of gradient of 4.2 SDs (Table 2, Fig. 5) and was significantly correlated with elevation ($r_s = -0.93$, $p < 0.001$; Table 2), mean January temperature ($r_s = 0.93$, $p < 0.001$; Table 2), and the naturalness index ($r_s = -0.85$, $p < 0.001$; Table 2). The elevation and mean January temperature were also closely related ($r_s = -0.94$, $p < 0.001$).

The results of DCA for wintering migratory landbirds showed that the variation gradients were not as obvious as were those for breeding birds. The lengths of the gradients of the first two axes were similar (3.0 and 2.9 SDs, Table 2). The correlation was not as strong as in the previous cases.

DISCUSSION

The seasonality of bird occurrence strongly influences species richness patterns.

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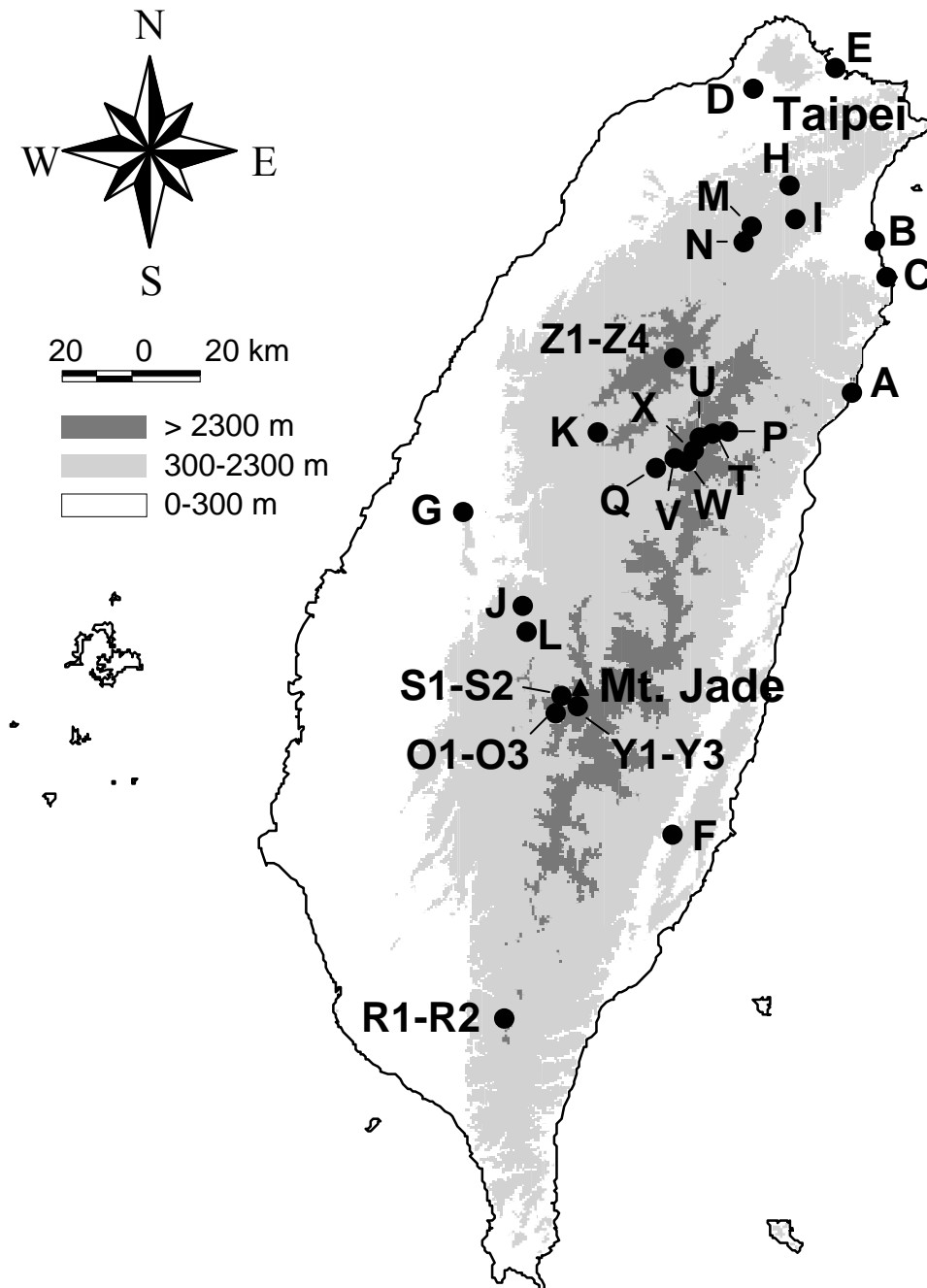


Fig. 1. Locations of the avian study localities in Taiwan compiled by this study.

Resident species richness in Taiwan was non-linearly related to elevation during the breeding and non-breeding seasons, and exhibited a hump-shaped curve with a peak at around 1500 m. In contrast, the richness pattern of wintering migratory landbirds showed a negative exponential form.

In our study, the richness patterns between residents in breeding and non-breeding

seasons were similar. The minor differences were due to the three summer visitors (*Cuculus sparverioides*, *C. saturatus*, and *Glareola maldivarum*; Appendix 2) that occurred during the breeding season. In addition, the resident species richness in the non-breeding season was always higher than in the breeding season at a given site, particularly at mid elevations. This is

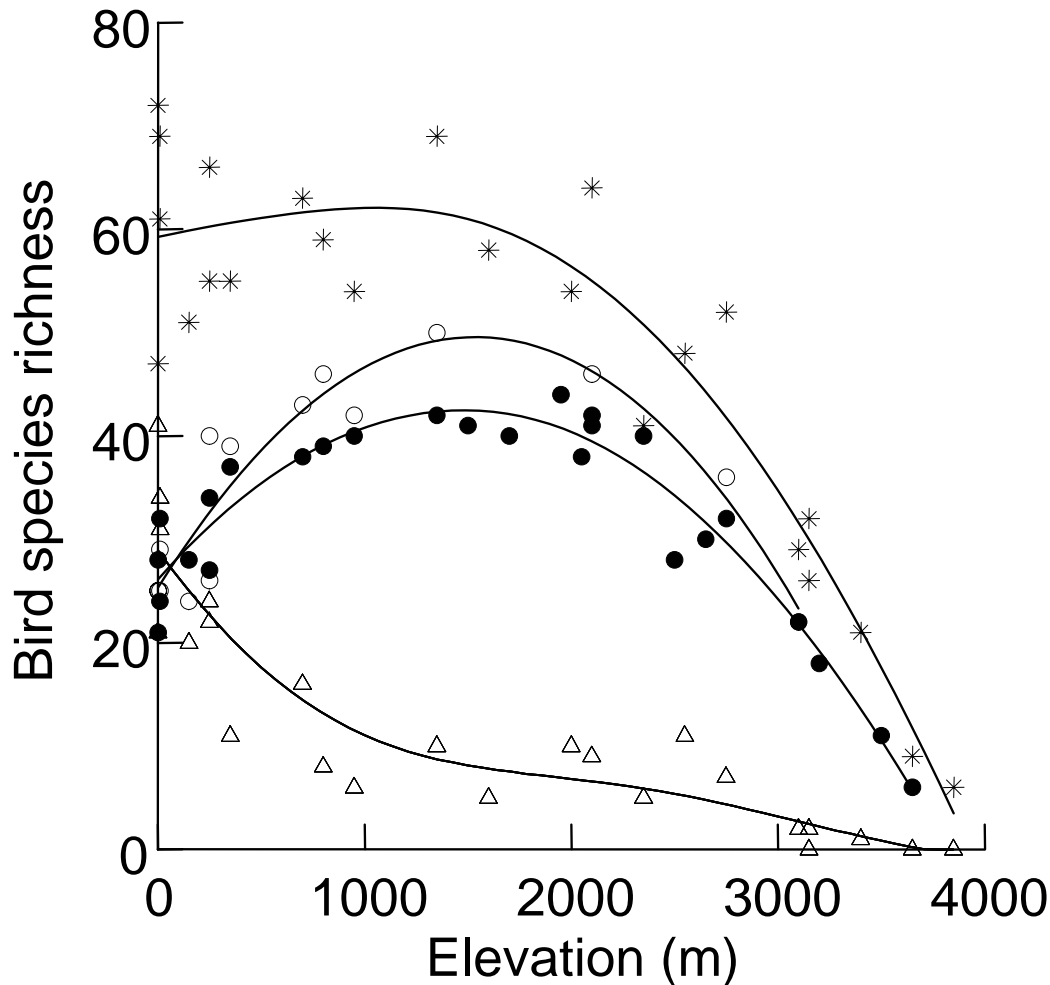


Fig. 2. Patterns of bird species richness along elevational gradients in Taiwan: *: year-round, ●: resident species richness in the breeding season, ○: resident species richness in the non-breeding season, and Δ: migrant species richness in the non-breeding season. All lines were fit by distance-weighted least squares smoothing.

largely due to the seasonal elevational migration undertaken by some resident species during winter.

Two types of patterns have been observed for the relationship between species richness and elevation, each with several supporters: monotonic (Terborgh, 1977; Navarro, 1992; Patterson *et al.*, 1998) and hump-shaped (McCoy, 1990; Rahbek, 1995, 1997; Samson *et al.*, 1997; Fleishman *et al.*, 1998). The methods used in these studies, however, were not consistent, especially when the seasonality of the survey data was considered. We suggest that this temporal factor should be considered as we have shown that the pattern of bird species

richness distribution along elevational gradients varies with season.

Obviously, wintering migratory landbirds cause this variation. To acquire enough food is the most important constraint in habitat selection for migratory birds during migration. Migratory birds, especially long-distance migrants that must overcome geographic barriers, need to acquire enough food to meet their energetic requirements for movements (Moore *et al.*, 1995). In Taiwan, wintering migratory landbirds tend to occur in the lowlands. This pattern is similar to those of areas in the Neotropics and in Southeast Asia (e.g., Karr, 1976; Petit *et al.*, 1995). We suspect that this distribution pattern may be a result

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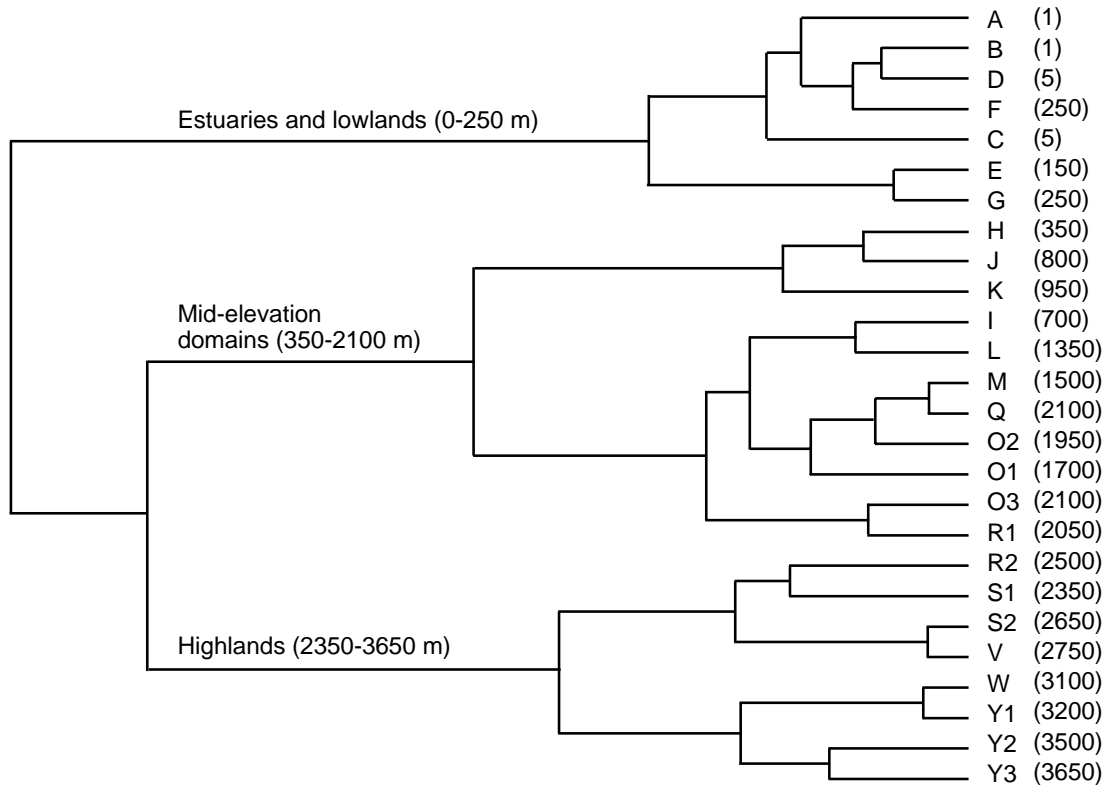


Fig. 3. Cluster analysis using principal component scores for resident birds in the breeding season. The localities were classified into three major categories roughly by 300 and 2300 m elevations. The letters are the codes of the study localities shown in Fig. 1. The number in parentheses after each locality code shows the mean elevation (m) of the locality.

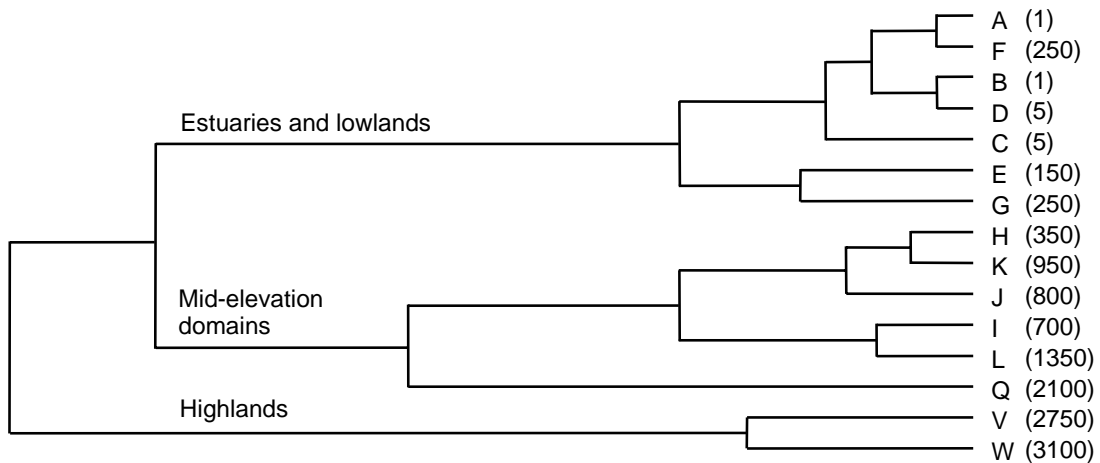


Fig. 4. Cluster analysis using principal component scores for resident birds in the non-breeding season. The localities were classified into three major categories by elevations. The letters are the codes of the study localities shown in Fig. 1. The number in parentheses after each locality code shows the mean elevation (m) of the locality.

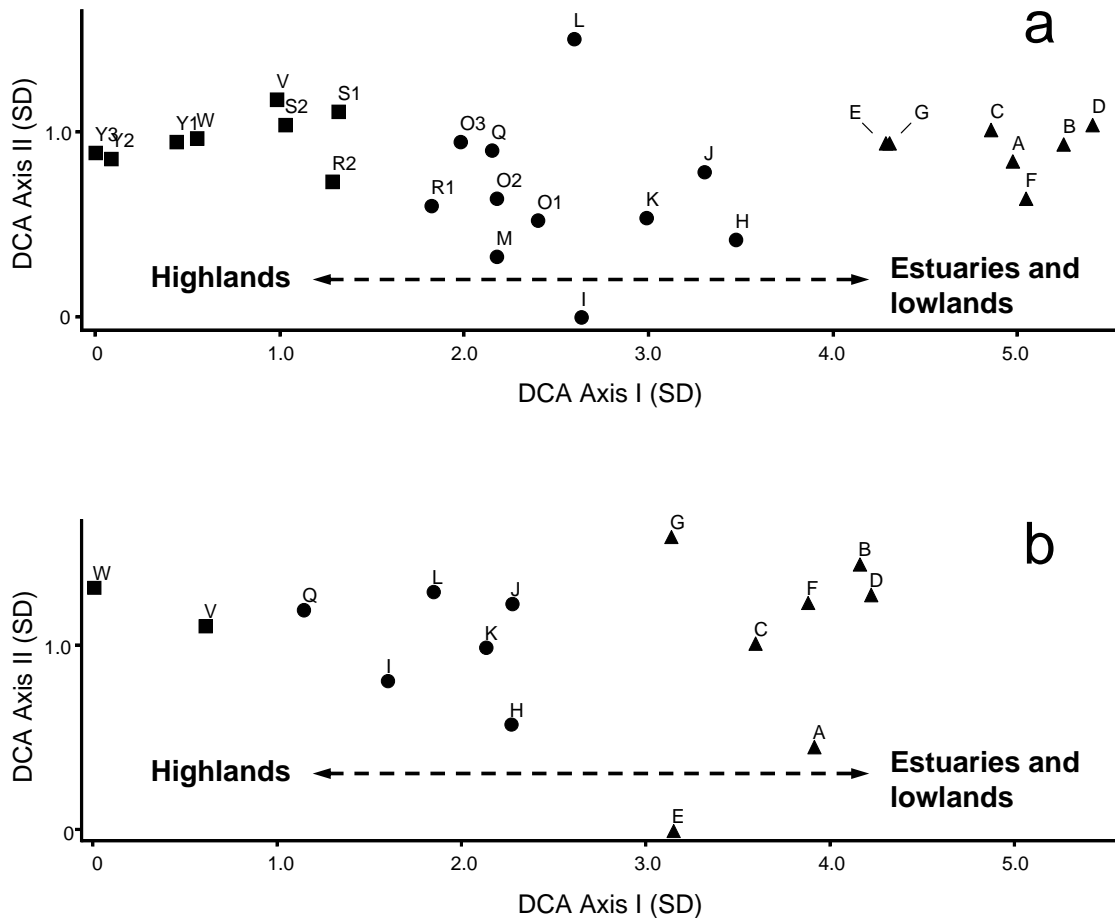


Fig. 5. Detrended correspondence analysis of localities using presence/absence data for resident birds in the (a) breeding and (b) non-breeding seasons. ▲ = lowlands (below 300 m), ● = mid-elevation domains (between 300 and 2300 m), ■ = highlands (above 2300 m).

of food availability, especially arthropods. Distributions of ectothermic arthropods are strongly affected by temperature, thus, they are abundant in lowlands during the winter period. In our study, most wintering insectivorous migrants (e.g., *Locustella ochotensis* and *Phylloscopus* spp.) were recorded in the lowlands, and this is an indication that these birds select preferable habitat with good food resources. On the other hand, the richness pattern for frugivorous and omnivorous migrants (e.g., *Turdus* spp.) showed an equal distribution from sea level to near 3000 m. In Taiwan, most broadleaf plants occur below about 3000 m (Su, 1992, 1994). Most of these plants fructify in summer and mature in autumn and winter (e.g., Kuo, 1997). The distributions of frugivorous and omnivorous

migrants are less constrained by food, and thus they have broader ranges.

The study sites with resident bird compositions were classified into three clusters mainly by the elevation factor in both breeding and non-breeding seasons. DCA indicated that elevation and mean temperature were the major environmental gradients that were significantly correlated with the main variation trend of the resident assemblages. The avifaunal-environmental relationships observed in this study were generally in agreement with those of previous studies conducted in different geographical regions (e.g., Sabo, 1980; Blake, 1984; Brown and Stillman, 1993; Neave *et al.*, 1996).

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Table 1. Main vegetation zones along elevational gradients in central Taiwan (adapted from Su 1984).

Vegetation zone	Physiognomy	Approximate elevation range (m)	Mean annual temperature (°C)	Climatic zone
Alpine vegetation	Scrub	> 3600	< 5	Subarctic
<i>Abies</i> zone	Coniferous forest	3100-3600	5-8	Cold-temperate
<i>Tsuga-Picea</i> zone	Coniferous forest	2500-3100	8-11	Cool-temperate
Upper <i>Quercus</i> zone	Broadleaf-coniferous forest	200 -2500	11-14	Temperate
Lower <i>Quercus</i> zone	Broadleaf forest	1500-2000	14-17	Warm-temperate
<i>Machilus-Castanopsis</i> zone	Broadleaf forest	500-1500	17-23	Subtropical
<i>Ficus-Machilus</i> zone	Broadleaf forest	< 500	> 23	Tropical

Physical environments (e.g., Kirk *et al.*, 1996; Welsh and Loughheed, 1996; Cueto and de Casenave, 1999; Hawkins, 1999; Venier *et al.*, 1999), vegetation composition (e.g., Loiselle and Blake, 1991; Estades, 1997), and vegetation structure (e.g., Lescourret and Genard, 1994) have frequently been considered the major factors influencing avian distribution and community organization. Temperature is important as it strongly influences species distributions either directly through physiological effects (e.g., Root, 1988a; Repasky, 1991), or indirectly through its influence on the distribution of vegetation (e.g., Su, 1984, 1992) and availability of food (e.g., Root, 1988b). For a given physiographic region or specific landform, elevation is usually regarded as a rough indicator of climatic factors, being especially close to mean temperature (either annual or monthly). In general, mean temperature extremely monotonically declines with increasing elevation (e.g., Terborgh, 1971) and is commonly used as an indicator. It is not surprising that both elevation and mean temperature contributed significantly in explaining the resident assemblages along the elevational gradients in our study.

Vegetation is often considered an important habitat component for birds because it provides foraging opportunities, diversity of food, shelter, or nesting substrate, and other conditions suitable for

successful reproduction (Wiens and Rotenberry, 1981). The three major clusters were separated roughly by elevations of 300 and 2300 m in this study. Below 300 m, the major habitats are grasslands and scrub. Between 300 and 2300 m, mature broadleaf forests are dominant. Above 2300 m, conifers excel. Because vegetation types parallel the elevation gradient in Taiwan, it is not easy to discriminate the contributions of these two factors. Further study on these aspects may provide a more-satisfactory answer.

We found that the relationship between migrant assemblages and environments was not clear. Neither cluster analysis nor DCA revealed a clear pattern. Most migrants of this study were rare and were recorded at only a few sites. Although 46% (31 of 67) of migrant species occurred in one or two sites, only 15% (10 of 67) species were recorded in more than half of the sites where migrants were found. This situation resulted in a unique assemblage at a given site. Since most sites were characterized by some specific assemblages, we could find no good explanation for the variation trend in the migrant assemblages.

The temporal scale used in the survey strongly influenced the evaluation of the bird species richness pattern in our study. McCoy (1990) demonstrated that a one-time sample would miss a larger proportion of the total yearly complement of insect species. A long-term study can evaluate the

Table 2. Correlation coefficient matrix between the axes scores of the bird DCA and the environmental factors for the resident bird communities ($n = 26$) in the breeding season, and the resident bird communities ($n = 15$) and migratory landbirds ($n = 21$) in the non-breeding season.

Bird community	DCA	
	Axis I	Axis II
Resident bird in breeding season		
Eigenvalue	0.69	0.08
Length of gradient (SD)	5.40	1.51
Elevation	-0.96**	0.21
Mean July temperature	0.92**	-0.15
Total July precipitation	0.15	0.26
Mean annual humidity	-0.31	-0.11
Naturalness index	-0.86**	-0.35
Resident birds in non-breeding season		
Eigenvalue	0.59	0.12
Length of gradient (SD)	4.21	1.59
Elevation	-0.93**	-0.26
Mean January temperature	0.93**	0.15
Total January precipitation	0.12	0.58*
Mean annual humidity	-0.17	-0.01
Naturalness index	-0.85**	0.02
Migratory landbirds in non-breeding season		
Eigenvalue	0.43	0.16
Length of gradient (SD)	3.02	2.91
Elevation	-0.54*	0.02
Mean January temperature	0.54*	-0.03
Total January precipitation	0.08	0.18
Mean annual humidity	-0.32	0.03
Naturalness index	-0.57*	-0.22

* $p < 0.05$; ** $p < 0.001$.

“true” species richness. However, in bird species richness studies, an excessively long survey period might obtain an assemblage whose members do not live together during the entire survey period. Then, a “pseudo” richness pattern might result. Therefore, the survey time and temporal scale should be carefully considered against the characteristics of the taxa when an assemblage undergoes massive species turnover in a subtropical area.

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Appendix 2. Species list compiled in this study. Nomenclature of birds follows Monroe and Sibley (1993).

Scientific name	Common name	Status†
Phasianidae		
<i>Arborophila crudigularis</i>	Taiwan Partridge	R
<i>Bambusicola thoracica</i>	Chinese Bamboo-Partridge	R
<i>Lophura swinhoii</i>	Swinhoe's Pheasant	R
<i>Syrmaticus Mikado</i>	Mikado Pheasant	R
<i>Phasianus colchicus</i>	Common Pheasant	R
Turnicidae		
<i>Turnix suscitator</i>	Barred Buttonquail	R
Picidae		
<i>Dendrocopos canicapillus</i>	Grey-capped Woodpecker	R
<i>Dendrocopos leucotos</i>	White-backed Woodpecker	R
<i>Picus canus</i>	Grey-faced Woodpecker	R
Megalaimidae		
<i>Megalaima oorti</i>	Black-browed Barbet	R
Coraciidae		
<i>Eurystomus orientalis</i>	Dollarbird	M
Cuculidae		
<i>Cuculus sparverioides</i>	Large Hawk-Cuckoo	SV
<i>Cuculus saturatus</i>	Oriental Cuckoo	SV
<i>Centropus bengalensis</i>	Lesser Coucal	R
Strigidae		
<i>Otus spilocephalus</i>	Mountain Scops-Owl	R
<i>Otus bakkamoena</i>	Collard Scops-Owl	R
<i>Strix leptogrammica</i>	Brown Wood-Owl	R
<i>Strix aluco</i>	Tawny Owl	R
<i>Glaucidium brodiei</i>	Collared Owlet	R
<i>Ninox scutulata</i>	Brown Hawk-Owl	R
<i>Asio flammeus</i>	Short-eared Owl	M
Columbidae		
<i>Columba pulchricollis</i>	Ashy Wood-Pigeon	R
<i>Streptopelia orientalis</i>	Oriental Turtle-Dove	R
<i>Streptopelia chinensis</i>	Spotted Dove	R
<i>Streptopelia tranquebarica</i>	Red Collared-Dove	R
<i>Chalcophaps indica</i>	Emerald Dove	R
<i>Treron sieboldii</i>	White-bellied Green-Pigeon	R
Glareolidae		
<i>Glareola maldivarum</i>	Oriental Pratincole	SV
Accipitridae		
<i>Pernis ptilorhyncus</i>	Oriental Honey-buzzard	M
<i>Milvus migrans</i>	Black Kite	R

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<i>Spilornis cheela</i>	Crested Serpent-Eagle	R
<i>Circus spilonotus</i>	Eastern Marsh-Harrier	M
<i>Circus cyaneus</i>	Northern Harrier	M
<i>Accipiter trivirgatus</i>	Crested Goshawk	R
<i>Accipiter soloensis</i>	Chinese Goshawk	M
<i>Accipiter gularis</i>	Japanese Sparrowhawk	M
<i>Accipiter virgatus</i>	Besra	M
<i>Accipiter nisus</i>	Eurasian Sparrowhawk	M
<i>Butastur indicus</i>	Grey-faced Buzzard	M
<i>Buteo buteo</i>	Common Buzzard	M
<i>Ictinaetus malayensis</i>	Black Eagle	R
<i>Aquila clanga</i>	Greater Spotted Eagle	M
Falconidae		
<i>Falco tinnunculus</i>	Common Kestrel	M
<i>Falco subbuteo</i>	Eurasian Hobby	M
<i>Falco peregrinus</i>	Peregrine Falcon	M
Ardeidae		
<i>Gorsachius melanolophus</i>	Malay Night-Heron	R
<i>Ixobrychus sinensis</i>	Yellow Bittern	R
<i>Ixobrychus cinnamomeus</i>	Cinnamon Bittern	R
Laniidae		
<i>Lanius cristatus</i>	Brown Shrike	M
<i>Lanius schach</i>	Long-tailed Shrike	R
Corvidae		
<i>Garrulus glandarius</i>	Eurasian Jay	R
<i>Urocissa caerulea</i>	Formosan Magpie	R
<i>Dendrocitta formosae</i>	Grey Treepie	R
<i>Pica pica</i>	Black-billed Magpie	R
<i>Nucifraga caryocatactes</i>	Spotted Nutcracker	R
<i>Corvus frugilegus</i>	Rook	M
<i>Corvus macrorhynchos</i>	Large-billed Crow	R
<i>Oriolus traillii</i>	Maroon Oriole	R
<i>Coracina macei</i>	Large Cuckooshrike	R
<i>Pericrocotus solaris</i>	Grey-chinned Minivet	R
<i>Dicrurus macrocercus</i>	Black Drongo	R
<i>Dicrurus aeneus</i>	Bronzed Drongo	R
<i>Hypothymis azurea</i>	Black-naped Monarch	R
<i>Terpsiphone atrocaudata</i>	Japanese Paradise-Flycatcher	M
Muscicapidae		
<i>Monticola solitarius</i>	Blue Rock-Thrush	M
<i>Myiophoneus insularis</i>	Formosan Whistling-Thrush	R
<i>Zoothera dauma</i>	Scaly Thrush	M
<i>Turdus poliocephalus</i>	Island Thrush	R
<i>Turdus obscurus</i>	Eyebrowed Thrush	M
<i>Turdus pallidus</i>	Pale Thrush	M
<i>Turdus chrysolaus</i>	Brown-headed Thrush	M

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<i>Turdus naumanni</i>	Dusky Thrush	M
<i>Brachypteryx Montana</i>	White-browed Shortwing	R
<i>Muscicapa griseisticta</i>	Grey-streaked Flycatcher	M
<i>Muscicapa dauurica</i>	Asian Brown Flycatcher	M
<i>Muscicapa ferruginea</i>	Ferruginous Flycatcher	R
<i>Ficedula hyperythra</i>	Snowy-browed Flycatcher	R
<i>Niltava vivida</i>	Vivid Niltava	R
<i>Erithacus akahige</i>	Japanese Robin	M
<i>Luscinia calliope</i>	Siberian Rubythroat	M
<i>Luscinia svecica</i>	Bluethroat	M
<i>Luscinia cyane</i>	Siberian Blue Robin	M
<i>Tarsiger cyanurus</i>	Orange-flanked Bush-Robin	M
<i>Tarsiger indicus</i>	White-browed Bush-Robin	R
<i>Tarsiger johnstoniae</i>	Collared Bush-Robin	R
<i>Phoenicurus aureoreus</i>	Daurian Redstart	M
<i>Cinclidium leucurum</i>	White-tailed Robin	R
<i>Saxicola torquata</i>	Common Stonechat	M
Sturnidae		
<i>Sturnus philippensis</i>	Chestnut-cheeked Starling	M
<i>Sturnus sinensis</i>	White-shouldered Starling	M
<i>Sturnus vulgaris</i>	Common Starling	M
<i>Sturnus cineraceus</i>	White-cheeked Starling	M
<i>Acridotheres cristatellus</i>	Crested Myna	R
Sittidae		
<i>Sitta europaea</i>	Wood Nuthatch	R
Certhiidae		
<i>Troglodytes troglodytes</i>	Winter Wren	R
Paridae		
<i>Remiz consobrinus</i>	Chinese Penduline-Tit	M
<i>Parus ater</i>	Coal Tit	R
<i>Parus monticolus</i>	Green-backed Tit	R
<i>Parus holsti</i>	Yellow Tit	R
<i>Parus varius</i>	Varied Tit	R
Aegithalidae		
<i>Aegithalos concinnus</i>	Black-throated Tit	R
Regulidae		
<i>Regulus goodfellowi</i>	Flamecrest	R
Pycnonotidae		
<i>Spizixos semitorques</i>	Collared Finchbill	R
<i>Pycnonotus sinensis</i>	Light-vented Bulbul	R
<i>Pycnonotus taivanus</i>	Styan's Bulbul	R
<i>Ixos amaurotis</i>	Brown-eared Bulbul	M
<i>Hypsipetes leucocephalus</i>	Black Bulbul	R

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Cisticolidae		
<i>Cisticola juncidis</i>	Zitting Cisticola	R
<i>Cisticola exilis</i>	Golden-headed Cisticola	R
<i>Prinia criniger</i>	Striated Prinia	R
<i>Prinia flaviventris</i>	Yellow-bellied Prinia	R
<i>Prinia inornata</i>	Plain Prinia	R
Zosteropidae		
<i>Zosterops japonicus</i>	Japanese White-eye	R
Sylviidae		
<i>Urosphena squameiceps</i>	Asian Stubtail	M
<i>Cettia canturians</i>	Manchurian Bush-Warbler	M
<i>Cettia fortipes</i>	Brownish-flanked Bush-Warbler	R
<i>Cettia acanthizoides</i>	Yellow-bellied Bush-Warbler	R
<i>Bradypterus seebohmi</i>	Russet Bush-Warbler	R
<i>Locustella ochotensis</i>	Middendorff's Grasshopper-Warbler	M
<i>Acrocephalus bistrigiceps</i>	Black-browed Reed-Warbler	M
<i>Acrocephalus arundinaceus</i>	Great Reed-Warbler	M
<i>Phylloscopus inornatus</i>	Inornate Warbler	M
<i>Phylloscopus borealis</i>	Arctic Warbler	M
<i>Abroscopus albogularis</i>	Rufous-faced Warbler	R
<i>Garrulax albogularis</i>	White-throated Laughingthrush	R
<i>Garrulax poecilorhynchus</i>	Rusty Laughingthrush	R
<i>Garrulax canorus</i>	Hwamei	R
<i>Garrulax morrisonianus</i>	White-whiskered Laughingthrush	R
<i>Liocichla steerii</i>	Steere's Liocichla	R
<i>Pomatorhinus erythrocnemis</i>	Spot-breasted Scimitar-Babbler	R
<i>Pomatorhinus ruficollis</i>	Streak-breasted Scimitar-Babbler	R
<i>Pnoepyga pusilla</i>	Pygmy Wren Babbler	R
<i>Stachyris ruficeps</i>	Rufous-capped Babbler	R
<i>Actinodura morrisoniana</i>	Formosan Barwing	R
<i>Alcippe cinereiceps</i>	Streak-throated Fulvetta	R
<i>Alcippe brunnea</i>	Dusky Fulvetta	R
<i>Alcippe morrisonia</i>	Grey-cheeked Fulvetta	R
<i>Heterophasia auricularis</i>	White-eared Sibia	R
<i>Yuhina brunneiceps</i>	Formosan Yuhina	R
<i>Yuhina zantholeuca</i>	White-bellied Yuhina	R
<i>Paradoxornis webbianus</i>	Vinous-throated Parrotbill	R
<i>Paradoxornis verreauxi</i>	Golden Parrotbill	R
Alaudidae		
<i>Alauda gulgula</i>	Oriental Skylark	R
Nectariniidae		
<i>Dicaeum concolor</i>	Plain Flowerpecker	R
<i>Dicaeum ignipectus</i>	Fire-breasted Flowerpecker	R
Passeridae		
<i>Passer rutilans</i>	Russet Sparrow	R
<i>Passer montanus</i>	Eurasian Tree Sparrow	R

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<i>Motacilla alba</i>	White Wagtail	M
<i>Motacilla flava</i>	Yellow Wagtail	M
<i>Motacilla cinerea</i>	Grey Wagtail	M
<i>Anthus richardi</i>	Richard's Pipit	M
<i>Anthus hodgsoni</i>	Olive-backed Pipit	M
<i>Anthus gustavi</i>	Petchora Pipit	M
<i>Anthus cervinus</i>	Red-throated Pipit	M
<i>Anthus spinoletta</i>	Water Pipit	M
<i>Prunella collaris</i>	Alpine Accentor	R
<i>Lonchura striata</i>	White-rumped Munia	R
<i>Lonchura punctulata</i>	Scaly-breasted Munia	R
<i>Lonchura Malacca</i>	Black-headed Munia	R
Fringillidae		
<i>Fringilla montifringilla</i>	Brambling	M
<i>Carduelis sinica</i>	Grey-capped Greenfinch	M
<i>Carduelis spinus</i>	Eurasian Siskin	M
<i>Carpodacus vinaceus</i>	Vinaceous Rosefinch	R
<i>Pyrrhula nipalensis</i>	Brown Bullfinch	R
<i>Pyrrhula erythaca</i>	Grey-headed Bullfinch	R
<i>Eophona migratoria</i>	Yellow-billed Grosbeak	M
<i>Emberiza fucata</i>	Chestnut-eared Bunting	M
<i>Emberiza pusilla</i>	Little Bunting	M
<i>Emberiza rustica</i>	Rustic Bunting	M
<i>Emberiza elegans</i>	Yellow-throated Bunting	M
<i>Emberiza aureola</i>	Yellow-breasted Bunting	M
<i>Emberiza sulphurata</i>	Yellow Bunting	M
<i>Emberiza spodocephala</i>	Black-faced Bunting	M
<i>Emberiza pallasii</i>	Pallas's Bunting	M
<i>Emberiza schoeniclus</i>	Reed Bunting	M

† M, migrant; R, resident; SV, summer visitor.

台灣鳥類種豐富度分布與群聚組成之季節變異

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本研究探討台灣鳥類種豐富度沿海拔梯度分布之型態，以及鳥類群聚組成與環境之關係。我們蒐集過去研究及資源調查報告，建立資料庫。依據鳥類出現情形，將季節區分為全年、繁殖季與非繁殖季。使用主成分分析、群團分析與降趨對應分析探討這三種類型鳥類分布與環境之關係。結果顯示種豐富度沿海拔分布模式有季節變異，以全年資料來看，鳥種數從平地至海拔 1500 公尺均維持相似值，往高海拔則有下降情形。若僅以特定季節來看，繁殖季鳥種數在海拔 1500 公尺附近最高，呈鐘形分布曲線；非繁殖季種豐富度由平地至海拔 1500 公尺則維持一致的高峰，之後隨海拔遞升而遞減。將非繁殖季區分為留鳥與候鳥，留鳥的模式與繁殖季類似，冬候鳥則呈現負指數曲線。主成分分析及群團分析結果發現，可將留鳥組成依海拔 300 及 2300 公尺為界，劃分為三個類群。降趨對應分析則顯示不論在繁殖季或非繁殖季，留鳥群聚變異與海拔及人為干擾均有極顯著之關係。本研究認為季節對鳥類種豐富度估算有顯著影響，進行鳥類群聚研究的取樣應考慮季節效應。

關鍵詞：鳥類群聚、海拔梯度、季節變異、種豐富度、台灣