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Bird guild loss and its determinants on subtropical land-bridge islands, China

Zhifeng Ding[1,2], Kenneth James Feeley[3,4], Huijian Hu[2] and Ping Ding[1*]

Abstract

Background: The guild concept is useful for understanding the community structure in a land-bridge island system, but most fragmentation studies have focused only on the importance of island area and isolation, other island attributes such as perimeter-area ratio (*PAR*) were overlooked or understudied.

Methods: We have adopted a guild approach to investigate the impacts of island attributes on bird guild richness on a set of 41 recently isolated land-bridge islands in the Thousand Island Lake (TIL), China.

Results: We found insectivores had the largest number of species (34 species), followed by understory foraging guilds (28 species), omnivores (27 species) and canopy guilds (25 species). Furthermore, our data showed that migrants and residents responded equally to island area, insectivores and understory guilds were sensitive to island area but omnivores and canopy guilds were not very sensitive. Most guild richness was determined by island area, except for omnivores and canopy guilds.

Conclusions: Although *PAR* or habitat diversity found to be important for bird species richness, our results highlight the importance of island area in maintaining bird diversity in fragmented island systems.

Keywords: Bird guilds, Island area, Land-bridge islands, *PAR*, Thousand Island Lake, *z* values

Background

Fragmentation is considered the most important cause of biodiversity loss in the world (Brooks et al. 2002; Stockwell et al. 2003; Reed 2004). Declines in species diversity due to fragmentation have been documented for birds, mammals, insects and plants from small-scale experimental studies to continental-scale analyses (reviews in Fahrig 2003; Ewers and Didham 2006). Yet, most fragmentation studies have focused only on the importance of patch area, which may not adequately explain the effects of fragmentation on habitat occupancy by birds (Helzer and Jelinski 1999). Indeed, patches of equal area may also vary significantly in the amount of their area exposed to edges, which can have significant impacts on bird communities. For example, studies by Helzer and Jelinski (1999) found that perimeter–area ratio (*PAR*) was a more effective measure of habitat patch quality than patch area. Therefore, while the maintenance of large patches is important to the conservation of bird communities, patch characteristics such as patch shape should also be recognized and taken into account.

The guild concept (where guilds are groups of species that exploit the same class of environmental resources in a similar way, Root 1967, 2001) is very popular among ecologists (Terborgh and Robinson 1986; Hawkins and MacMahon 1989; Simberloff and Dayan 1991), and is useful for understanding community structure and the process of community organization. In addition, guilds are also often used to evaluate the collective responses of multiple species to changes in resources or ecological conditions (Block et al. 1995). For example, Canterbury et al. (2000) and O'Connell et al. (2000) used guilds to assess ecological condition. Thus, it is important to relate bird guilds to changed habitats because such relationships are useful in understanding bird community structures and species variations across different vegetation types (Wiens and Rotenberry 1981).

Previous studies have documented many general patterns from the studies of bird guilds. For example, migrants and residents seemed equally sensitive to

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* Correspondence: dingping@zju.edu.cn
[1] The Key Laboratory of Conservation Biology for Endangered Wildlife of the Ministry of Education, College of Life Sciences, Zhejiang University, Zijin'gang Campus, Hangzhou 310058, China
Full list of author information is available at the end of the article

fragmentation based on limited experimental studies (reviews in Lampila et al. 2004). Guilds such as insectivores appeared to be more sensitive to disturbance due to their dispersal ability or specific food requirements or specific habitat requirements (Anjos and Boçon 1999; Şekercioğlu et al. 2002; Chettri et al. 2005; Stouffer et al. 2006; Gray et al. 2007). Granivores were found to be positively affected by forest fragmentation (Marini 2001; Şekercioğlu and Sodhi 2007; Giraudo et al. 2008), and their abundance increased significantly following disturbance (Gray et al. 2007). Compared to insectivores and granivores, omnivores and carnivores were less sensitive to fragmentation (Bierregaard and Stouffer 1997; Anjos and Boçon 1999; Ribon et al. 2003).

Likewise, species that forage in certain forest strata are highly sensitive to fragmented areas. For instance, understory birds are particularly sensitive to forest fragmentation (Stouffer and Bierregaard 1995; Stratford and Stouffer 1999; Ribon et al. 2003), partly due to their low dispersal ability (Stouffer and Bierregaard 1995). Canopy birds may view a relatively fragmented landscape as one continuous cluster of forest habitat because of their large gap-crossing ability, making them relatively insensitive to remnant area (Dale et al. 1994).

However, most of these studies have been conducted in forest fragments, which are quite different from the land-bridge islands in our system. Indeed, land-bridge islands have been characterized as having several potential advantages over other study systems, such as having a common biogeographic history, well-delineated boundaries and an inhospitable matrix (Wang et al. 2010; Hu et al. 2011; Ding et al. 2013). Thus, land-bridge islands are considered as ideal systems for studying habitat fragmentation. Applying the guild approach in such systems has also been important for understanding ecological theory (MacArthur and Wilson 1967; Gilpin and Hanski 1991; Opdam 1991; Rosenzweig 1995), and for the management and conservation of biodiversity (Fahrig and Merriam 1994).

In this study, we have adopted a guild approach to investigate the impacts of island attributes on bird guilds. We first investigated the effects of fragment area on the richness of bird guilds, and had three null hypotheses. (1) Migrants and residents showed an equal response to island area; (2) insectivorous guilds were the most sensitive to island area; (3) understory guilds were the most sensitive to island area. We next considered four factors other than island area and isolation that might influence the number of coexisting bird species: *PAR*, *SI* (shape index), plant species richness, habitat diversity. Specifically, we addressed the following question: what factors drive the richness of bird guilds in island fragments?

Methods

Study sites

The study islands were located in the TIL (29°22′–29°50′N, 118°34′–119°15′E), which was formed by the Xin'anjiang dam in 1959. The TIL covers around 580 km^2 of water area and contains 1078 islands (0.25–1320 ha) since the water reached its final level of 108 m. The TIL is in a subtropical monsoon climate zone, with four distinct seasons, abundant rainfall and a mild climate. The mean daily temperature is 17°C, with a low of −7.6°C in January and a high of 41.8°C in July. The approximate annual rainfall is 1430 mm. The landscape is dominated by the naturally secondary forest (mainly *Pinus massoniana* Lamb.) and is mixed with lots of broad-leaved trees and shrubs.

We conducted our research on 41 islands across an area and isolation gradient. Island areas were measured using digital maps with a scale of 1:10000. We used the distance from the nearest mainland beach as a measure of isolation (Meyer and Kalko 2008; Wang et al. 2009). PAR was estimated as $PAR = P/A$ and SI was calculated as $SI = P/[2 \times (\pi \times A)^{0.5}]$ where P was the island perimeter (m) and A was the corresponding island area (ha).

Bird censuses

We conducted bird censuses following a line transect method (Bibby et al. 2000) on each of the study islands during breeding seasons (April–June) and winter seasons (November–January) from 2006 to 2009. The number of transects selected on each island was roughly proportional to the island area (Wang et al. 2010). A total of 15 censuses were taken on each island per season to increase the probability of detecting elusive or rare birds (Ralph et al. 1993). We recorded bird species richness and abundance during each census but used only species richness for our analyses (See Additional file 1: Table S1). Censuses were made between 0.5 h after dawn through to 11:00 h (local time) in the mornings and between 15:00 and 0.5 h before sunset in the afternoons, when bird activity is at its maximum, and were not made during inclement weather (rain or strong winds). To minimize potential bias, the observers alternated the order in which islands were surveyed (MacNally et al. 2002).

Guild classifications

We assigned all bird species to guilds based on their migratory status, dietary categories and foraging strata (Canterbury et al. 2000; O'Connell et al. 2000; Lampila et al. 2004; Lim and Sodhi 2004). For each ecological characteristic, the different categories were mutually exclusive and a species could only be assigned to one category (See Additional file 1: Table S2; Lim and Sodhi 2004).

We determined migratory status based on Zhuge et al. (1990) and divided species into two broad categories, migrants and residents. We classified species into one of four mutually exclusive dietary guilds (i.e. carnivores, insectivores, omnivores and granivores) according to their predominant diet as reported by authors. Carnivores were defined as species that feed on mainly non-insect animals. Insectivores were set as birds that feed predominantly on insects and small arthropods. Omnivores eat different combinations of animal and plant materials, and granivores mainly feed on grains and seeds. Foraging strata was classified as ground, understory, midstory, canopy and air.

Information on dietary categories and foraging strata was gathered from published species accounts and primarily from Zhuge et al. (1990). Specifically, guilds with fewer than three species were excluded from the analysis due to their lower statistical power. In other words, only guilds with more than three species in each of the 41 studied islands were used for our analysis (Weiher et al. 1998). In the present study, we used residents, migrants, insectivores, omnivores, canopy guilds and understory guilds for subsequent analyses.

Island habitat variables

We classified the habitats on the study islands into seven main types: (1) coniferous forests, (2) broadleaf forests, (3) coniferous-broad mixed forests, (4) bamboo groves, (5) shrubs, (6) grasses and (7) farmlands (Zhang et al. 2008). Habitat diversity per island was estimated by visually tallying the number of habitat types on each island (Wang et al. 2010). To determine plant species richness, we conducted detailed surveys of all vascular plant species occurring on the 41 study islands during the 2007 growing season (April to November). During the surveys, we determined the presence or absence of plant species (abundance data were not collected) through multiple visits to all islands, following traditional field methods designed to record the highest possible number of species. On all islands < 100 ha (39 islands), islands were circumnavigated and 4–16 transects were established (number and length of transects were dependent on the shape and length or width of the island). Each transect was walked a minimum of three times by trained observers. For the two islands > 100 ha in area, surveys were conducted as above but centered on each prominent hill. Most plant species were identified and recorded in the field. We collected voucher specimen for all species, which were then identified, or their identities confirmed, in the lab according to *Flora of Zhejiang* (Editorial Committee of Flora of Zhejiang 1993) and *Keys of Seed Plants in Zhejiang* (Zheng 2005).

Data analysis

Prior to the analysis, we discarded *SI* and habitat diversity because of its high Pearson's correlations (higher or equal than 0.8, Torras et al. 2008) with other variables (Table 1). For testing the multicollinearity, the VIF (variance inflation factors) of all variables did not exceed 4 ($\text{VIF}_{\text{Area}} = 1.55$, $\text{VIF}_{PAR} = 1.60$, $\text{VIF}_{\text{Plant}} = 1.27$, $\text{VIF}_{\text{Isolation}} = 1.07$), which is below the maximum threshold of 10 suggested by Neter et al. (1996). Based on previous analyses (Yu et al. 2012), only isolation had significant spatial autocorrelation (Global Moran's I, Moran 1950) but there was no effect of spatial structure of islands on species richness (Mantel test, Mantel 1967).

Table 1 Correlation matrix among island area, isolation, *SI*, *PAR*, habitat diversity and plant richness

	Isolation	*SI*	*PAR*	Habitat diversity	Plant richness
Area	−0.04	0.83***	−0.56***	0.82***	0.38*
Isolation		−0.02	0.20	0.04	−0.19
SI			−0.51***	0.86***	0.17
PAR				−0.65***	−0.40*
Habitat diversity					0.21

*$p < 0.05$, ***$p < 0.001$.

We related species richness of each guild to island area using the log-log transformed power model ($\log S = \log c + z \times \log A$, where S is richness of bird guilds, A is area, and c and z represent the intercept and slope of the species-area relationship), as this model was the most common used in the literature and had higher explanatory power compared to others (Watling and Donnelly 2006). The z values indicated how rapidly species richness increased with island area and are considered a measure of community's vulnerability to fragmentation. Then, we used the methodology described in Zar (1996) to compare the z values of each regression. This method uses a t-test in a fashion analogous to that of testing for differences between two populations. The test statistic is calculated as $t = (b_1 - b_2) / S_{b1,b2}$, where the variables b_1 and b_2 are the regression coefficients and $S_{b1,\,b2}$ is the standard error of the difference between the regression coefficients.

In addition, we used a stepwise linear regression analysis, which included four island attributes (island area, isolation, *PAR* and plant richness), to find the best fit models for richness of each guild. Goodness-of-fit was assessed using AIC*c* values (modification of AIC for small *n*) (Burnham and Anderson 2002; Johnson and Omland 2004) for each of the candidate regression models. Variation partitioning was also used to estimate the relative contribution of each island attribute to richness of each guild.

All calculations and analyses were performed in R 2.13.1 (R Development Core Team 2011).

Results

Species-area relationships

We recorded a total of 77 bird species across the 41 study islands in TIL: 49 residents and 28 migrants. Insectivores were the best represented guild in TIL (34

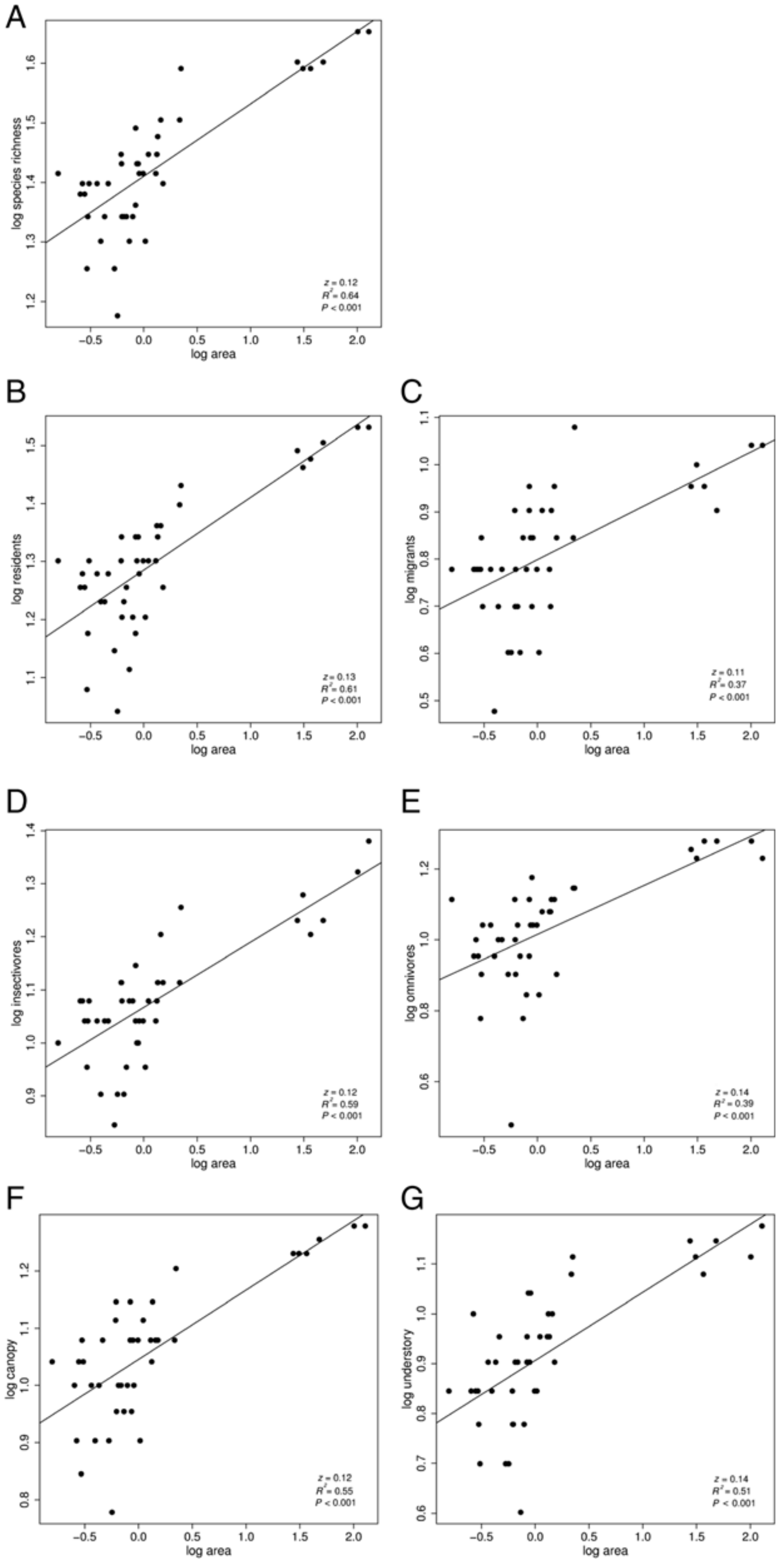

Figure 1 Response of bird guilds to island area. **(A)** total species richness, **(B)** residents, **(C)** migrants, **(D)** insectivores, **(E)** omnivores, **(F)** canopy guilds and **(G)** understory guilds.

species), followed by omnivores (27 species), granivores (11 species) and carnivores (5 species). Understory foraging guilds were the most common (28 species), followed by canopy (25 species), ground (13 species), midstory (8 species) and air (3 species).

The *z* value of total species richness and island area was 0.12. The regression coefficient for the relationship between residents and island area was 0.13, and was 0.11 for the relationship between migrants and island area (Figure 1). These slopes were not significantly different ($p > 0.05$). In dietary guilds, the fitted *z* values were 0.12 (insectivores) and 0.14 (omnivores), and there were no significant differences between them ($p > 0.05$). In foraging guilds, the fitted *z* values were 0.14 (understory) and 0.12 (canopy), and there were also no significant differences between them. Taken together, all *z* values were not significantly different from each other ($p > 0.05$).

Effects of island attributes on guild richness

In the backward stepwise analysis, island area and *PAR* all had significant relationships with the richness of all bird guilds, but only island area had a significant relationship with migrants (Table 2). Island area and *PAR* explained 65% of total species richness, 65% of residents, 37% of migrants, 67% of insectivores, 49% of omnivores, 62% of canopy guilds and 47% of understory guilds, while their joint effects explained nearly 30% (Figure 2). Specifically, island area had the greatest pure explanatory power for most guilds (five out of seven guilds), larger than the pure effect of *PAR*. For omnivorous and canopy guilds, both island area and *PAR* explained a similar amount of variation (Figure 2E, F).

Discussion

Species-area relationships

Previous analyses showed that the *z* values of birds in fragmented ecosystems were within the range 0.10-0.16 (Begon et al. 1986; Watling and Donnelly 2006). In our case, we found that the *z* values for all bird guilds ranged from 0.11 to 0.14 and were similar to the average slopes reported for birds. Contrary to other predictions across a variety of systems and species groups (Preston 1962; Rosenzweig 1995; May and Stumpf 2000; Panitsa et al. 2006), the relatively low *z* values in the present study may suggest higher inter-island immigration rates of birds (Connor and McCoy 1979; Rosenzweig 1995; Krauss et al. 2003). This is particularly possible for birds because they are generally regarded as good dispersers (Lampila et al. 2004). In addition, low *z* values could also be a result of low extinction rates or a combination of high immigration and low extinction (Johnson and Simberloff 1974).

Specifically, residents and migrants showed no significant responses to island area. This was consistent with previous analyses (Brotons et al. 2003; Lampila et al. 2004), but contrary to Mönkkönen and Welsh's (1994) predications, who indicated that forest fragmentation should affect residents more than migrants. One possible explanation is that heterospecific attraction occurs (positive interactions between migrants and residents, Mönkkönen et al. 1990), so that migrants use the presence of residents as a cue for profitable sites. In the case of dietary and foraging guilds, all of their *z* values were similar to each other, and there were no significant differences between them. Also, these *z* values were not significantly different from the *z* values of total species richness. This indicated that all guilds had weaker sensitivity to area loss when compared to other insularized/bird guilds, possibly due to the relatively homogeneous habitat diversity on these islands, leading to a slower rate of guild loss with decreasing island area (Hu et al. 2011; Yu et al. 2012).

Effects of island attributes on guild richness

Island area was the first variable to enter in the linear regression model, positively influencing guild richness (Table 2). It is a common trend that species richness is positively correlated to fragment area for birds on islands

Table 2 Results of stepwise linear regression for each bird guild

Guilds	Best fitted model	R^2	*F*	*p*
All guilds	$SR = 32.44 + 0.14 \times \text{Area} - 109.48 \times PAR$	0.65	38.38	<0.001
Migration strategy				
Residents	$R = 24.63 + 0.11 \times \text{Area} - (-86.53) \times PAR$	0.65	38.81	<0.001
Migrants	$M = 6.31 + 0.05 \times \text{Area}$	0.32	20.00	<0.001
Dietary guild				
Insectivores	$In = 13.85 + 0.09 \times \text{Area} - 37.71 \times PAR$	0.67	41.57	<0.001
Omnivores	$Om = 14.28 + 0.05 \times \text{Area} - 58.43 \times PAR$	0.49	19.87	<0.001
Foraging guild				
Canopy	$Ca = 14.51 + 0.05 \times \text{Area} - 54.09 \times PAR$	0.62	33.63	<0.001
Understory	$Un = 10.44 + 0.05 \times \text{Area} - 36.33 \times PAR$	0.47	18.93	<0.001

SR means richness of all birds, *R* residents, *M* migrants, *In* insectivores, *Om* omnivores, *Ca* canopy, and *Un* understory.

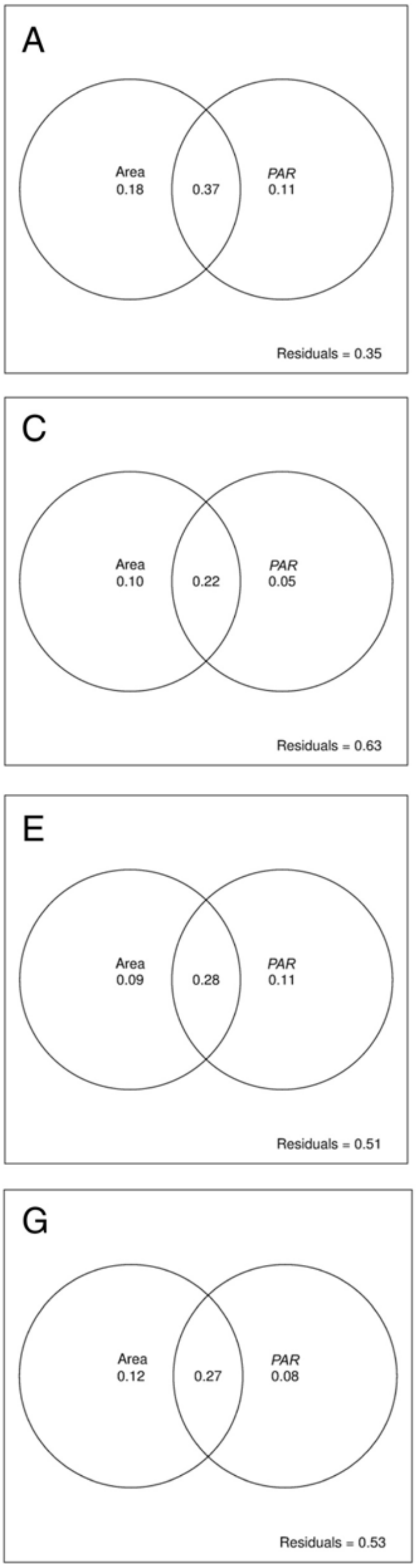

Figure 2 Venn diagram showing the effects of island attributes on guild richness. **(A)** total species richness, **(B)** residents, **(C)** migrants, **(D)** insectivores, **(E)** omnivores, **(F)** canopy guilds and **(G)** understory guilds.

or fragments (reviews in Ricklefs and Lovette 1999; Watling and Donnelly 2006; Benassi et al. 2007), and also for other animals (reviews in Watling and Donnelly 2006) or plants (Hu et al. 2011). Additionally, *PAR* had significantly negative effects on guild richness, possibly because the islands with less relative interior habitat (high *PAR*) increased the risk of local extinction and thereby decreased guild richness. Indeed, Helzer and Jelinski (1999) also found that bird species richness decreased with increased *PAR* in wet meadow grasslands. Contrary to general expectations, isolation had little effect on the richness of all guilds. The lack of an isolation effect might be due to the high mobility of birds and/or the narrow range of isolation values included in this study (Watling and Donnelly 2006). Likewise, plant richness was also not correlated with guild richness. This might indicate that some plant species retain higher bird species richness than other plant species did. For example, MacGregor-Fors (2008) found that bird species richness was not related to tree species richness, but was instead related to specific tree taxa.

The results of variation partitioning indicated that island area was of prime importance for the distribution of total species richness, residents, migrants, insectivores and understory guilds. This is not surprising because large areas may have more habitats (higher habitat diversity, and hence more species, Williams 1964) and/or lower extinction rates than small areas (MacArthur and Wilson 1967). In the case of omnivores and canopy guilds, both island area and *PAR* contributed equally in explaining guild richness (Figure 2E, F). This indicated that omnivores and canopy guilds were not very sensitive to fragments, as also indicated by previous analyses (Dale et al. 1994; Bierregaard and Stouffer 1997; Anjos and Boçon 1999; Ribon et al. 2003).

Conclusions

Our findings showed insectivores had the largest number of species (34 species), followed by understory foraging guilds (28 species), omnivores (27 species) and canopy guilds (25 species). The low richness of other guilds might be due to the characteristics of the study site and/or food resources (Gray et al. 2007; Ding et al. 2013). That is, the relatively homogeneous habitat diversity and/or the lack of specific food resources at TIL might account for the low richness of such guilds. Furthermore, our data showed that migrants and residents responded equally to island area, insectivores and understory guilds were sensitive to island area but omnivores and canopy guilds were not very sensitive. Most guild richness was determined by island area, except for omnivores and canopy guilds. Although *PAR* or habitat diversity (plant species richness) or isolation has been found to be important for bird species richness (Helzer and Jelinski 1999; Ricklefs and Lovette 1999; Watling and Donnelly 2006), our results highlight the importance of island area in maintaining bird diversity in fragmented island systems.

Additional file

Additional file 1: Table S1. Island × species abundance matrix for birds on 41 islands in the Thousand Island Lake, China. **Table S2.** Species × trait data matrix for birds on 41 islands in the Thousand Island Lake, China.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

ZD, KJF and PD conceived and designed the experiments, and ZD and PD performed the experiments. All the authors participated in the data analysis and paper writing. All the authors read and approved the final version of the manuscript.

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Author details

[1]The Key Laboratory of Conservation Biology for Endangered Wildlife of the Ministry of Education, College of Life Sciences, Zhejiang University, Zijin'gang Campus, Hangzhou 310058, China. [2]Guangdong Entomological Institute & South China Institute of Endangered Animals, Guangzhou 510260, China. [3]Department of Biological Sciences, Florida International University, Miami, FL 33199, USA. [4]Center for Tropical Plant Conservation, Fairchild Tropical Botanic Garden, Coral Gables, FL 33156, USA.

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References

Anjos LD, Boçon R (1999) Bird communities in natural forest patches in southern Brazil. Wilson Bull 111:397–414

Begon M, Harper JL, Townsend CR (1986) Ecology. Individuals, populations, communities. Blackwell, London

Benassi G, Battisti C, Luiselli L (2007) Area effect on bird species richness of an archipelago of wetland fragments in Central Italy. Community Ecol 8:229–237

Bibby CJ, Burgess ND, Hill DA, Mustoe S (2000) Bird census techniques. Academic Press, London

Bierregaard RO Jr, Stouffer PC (1997) Understory birds and dynamic habitat mosaics in Amazonian rainforests. In: Laurance WF, Bierregaard RO (eds) Tropical forest remnants. ecology, management, and conservation of fragmented communities. University of Chicago Press, Illinois, pp 138–155

Block WM, Finch DM, Brennam LA (1995) Single-species versus multiple-species approaches for management. In: Martin TE, Finch DM (eds) Ecology and management of neotropical migrant birds: a review and synthesis of critical issues. Oxford University Press, New York, pp 461–476

Brooks TM, Mittermeier RA, Mittermeier CG, Da Fonseca GAB, Rylands AB, Konstant WR, Flick P, Pilgrim J, Oldfield S, Magin G, Hilton-Taylor C (2002) Habitat loss and extinction in the hotspots of biodiversity. Conserv Biol 16:909–923

Brotons L, Mönkkönen M, Martin JL (2003) Are fragments islands? Landscape context and density-area relationships in boreal forest birds. Am Nat 162:343–357

Burnham KP, Anderson DR (2002) Model selection and multimodel inference: a practical information-theoretic approach, 3rd edn. Springer-Verlag, New York

Canterbury GE, Martin TE, Petit DR, Petit LJ, Bradford DF (2000) Bird communities and habitat as ecological indicators of forest condition in regional monitoring. Conserv Biol 14:544–558

Chettri N, Deb DC, Sharma E, Jackson R (2005) The relationship between bird communities and habitat. Mt Res Dev 25:235–243

Connor EF, McCoy ED (1979) The statistics and biology of the species-area relationship. Am Nat 113:791–833

Dale VH, Pearson SM, Offerman HL, O'Neill RV (1994) Relating patterns of land-use change to faunal biodiversity in the central Amazon. Conserv Biol 8:1027–1036

Ding ZF, Feeley KJ, Wang YP, Pakeman RJ, Ding P (2013) Patterns of bird functional diversity on land-bridge island fragments. J Anim Ecol 82:781–790

Editorial Committee of Flora of Zhejiang (1993) Flora of Zhejiang. Zhejiang Science and Technology Press, Hangzhou

Ewers RM, Didham RK (2006) Confounding factors in the detection of species responses to habitat fragmentation. Biol Rev 81:117–142

Fahrig L (2003) Effects of habitat fragmentation on biodiversity. Annu Rev Ecol Evol 34:487–515

Fahrig L, Merriam G (1994) Conservation of fragmented populations. Conserv Biol 8:50–59

Gilpin ME, Hanski I (1991) Metapopulation dynamics: empirical and theoretical investigations. Academic Press, London

Giraudo AR, Matteucci SD, Alonso J, Herrera J, Abramson RR (2008) Comparing bird assemblages in large and small fragments of the Atlantic Forest hotspots. Biodivers Conserv 17:1251–1265

Gray MA, Baldauf SL, Mayhew PJ, Hill JK (2007) The response of avian feeding guilds to tropical forest disturbance. Conserv Biol 21:133–141

Hawkins CP, MacMahon JA (1989) Guilds: the multiple meanings of a concept. Annu Rev Entomol 34:423–451

Helzer CJ, Jelinski DE (1999) The relative importance of patch area and perimeter-area ratio to grassland breeding birds. Ecol Appl 9:1448–1458

Hu G, Feeley KJ, Wu JG, Xu GF, Yu MJ (2011) Determinants of plant species richness and patterns of nestedness in fragmented landscapes: evidence from land-bridge islands. Landscape Ecol 26:1405–1417

Johnson JB, Omland KS (2004) Model selection in ecology and evolution. Trends Ecol Evol 19:101–108

Johnson MP, Simberloff DS (1974) Environmental determinants of island species number in the British Isles. J Biogeogr 1:149–154

Krauss J, Steffan-Dewenter I, Tscharntke T (2003) How does landscape context contribute to effects of habitat fragmentation on diversity and population density of butterflies? J Biogeogr 30:889–900

Lampila P, Mönkkönen M, Desrochers A (2004) Demographic responses by birds to forest fragmentation. Conserv Biol 19:1537–1546

Lim HC, Sodhi NS (2004) Responses of avian guilds to urbanization in a tropical city. Landscape Urban Plan 66:199–215

MacArthur RH, Wilson EO (1967) The theory of island biogeography. Princeton University Press, Princeton

MacGregor-Fors I (2008) Relation between habitat attributes and bird richness in a western Mexico suburb. Landscape Urban Plan 84:92–98

MacNally R, Horrocks G, Bennett AF (2002) Nestedness in fragmented landscapes: birds of the box-ironbark forests of south-eastern Australia. Ecography 25:651–660

Mantel N (1967) The detection of disease clustering and a generalized regression approach. Cancer Res 27:209–220

Marini MÂ (2001) Effects of forest fragmentation on birds of the cerrado region, Brazil. Bird Conserv Int 11:13–25

May RM, Stumpf MPH (2000) Ecology-species-area relations in tropical forests. Science 290:2084–2086

Meyer CFJ, Kalko EKV (2008) Bat assemblages on Neotropical land-bridge islands: nested subsets and null model analyses of species co-occurence patterns. Divers Distrib 14:644–654

Mönkkönen M, Welsh DA (1994) A biogeographical hypothesis on the effects of human caused habitat changes on the forest bird communities of Europe and North America. Ann Zool Fennici 31:61–70

Mönkkönen M, Helle P, Soppela K (1990) Numerical and behavioural responses of migrant passerines to experimental manipulation of resident tits (*Parus* spp.): heterospecific attraction in northern breeding bird communities? Oecologia 85:218–225

Moran PAP (1950) Notes on continuous stochastic phenomena. Biometrika 37:17–33

Neter J, Kutner MH, Nachtsheim CJ, Wasserman W (1996) Applied linear statistical model: regression, analysis of variance, and experimental design. Irwin Professional Publishing, Chicago

O'Connell TJ, Jackson LE, Brooks RP (2000) Bird guilds as indicators of ecological condition in the central Appalachians. Ecol Appl 10:1706–1721

Opdam P (1991) Metapopulation theory and habitat fragmentation: a review of holarctic breeding bird studies. Landscape Ecol 5:93–106

Panitsa M, Tzanoudakis D, Triantis KA, Sfenthourakis S (2006) Patterns of species richness on very small islands: the plants of the Aegean archipelago. J Biogeogr 33:1223–1234

Preston FW (1962) The canonical distribution of commonness and rarity. Ecology 43(185–215):410–432

R Development Core Team (2011) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, [http://www.R-project.org/]

Ralph CJ, Geupel GR, Pyle P, Martin TE, Desante DF (1993) Handbook of field methods for monitoring landbirds. USDA Forest Service / UNL Faculty Publications, Albany

Reed DH (2004) Extinction risk in fragmented habitats. Anim Conserv 7:181–191

Ribon R, Simon JE, De Mattos GT (2003) Bird extinctions in Atlantic forest fragments of the Viçosa region, southeastern Brazil. Conserv Biol 17:1827–1839

Ricklefs RE, Lovette IJ (1999) The roles of island area *per se* and habitat diversity in the species-area relationships of four Lesser Antillean faunal groups. J Anim Ecol 68:1142–1160

Root RB (1967) The niche exploitation pattern of the blue-gray gnatcatcher. Ecol Monogr 37:317–350

Root RB (2001) Guilds. In: Levin SA (ed) Encyclopedia of biodiversity. Academic Press, San Diego, pp 295–302

Rosenzweig ML (1995) Species diversity in space and time. Cambridge University Press, Cambridge

Şekercioğlu CH, Sodhi NS (2007) Conservation biology: predicting birds' responses to forest fragmentation. Curr Biol 17:838–840

Şekercioğlu CH, Ehrlich RP, Daily GC, Aygen D, Goghring D, Sandi RF (2002) Disappearance of insectivorous birds from tropical forest fragments. Proc Natl Acad Sci 99:263–267

Simberloff D, Dayan T (1991) The guild concept and the structure of ecological communities. Annu Rev Ecol Syst 22:115–143

Stockwell CA, Hendry AP, Kinnison MT (2003) Contemporary evolution meets conservation biology. Trends Ecol Evol 18:94–101

Stouffer PC, Bierregaard RO (1995) Use of Amazonian forest fragments by understory insectivorous birds. Ecology 76:2429–2445

Stouffer PC, Bierregaard RO, Strong C, Lovejoy TE (2006) Long-term landscape change and bird abundance in Amazonian rainforest fragments. Conserv Biol 20:1212–1223

Stratford JA, Stouffer PC (1999) Local extinctions of terrestrial insectivorous birds in a fragmented landscape near Manaus, Brazil. Conserv Biol 13:1416–1423

Terborgh J, Robinson S (1986) Guilds and their utility in ecology. In: Kikkawa J, Anderson DJ (eds) Community ecology: pattern and process. Blackwell, Palo Alto, pp 65–90

Torras O, Gil-Tena A, Saura S (2008) How does forest landscape structure explain tree species richness in a Mediterranean context? Biodivers Conserv 17:1227–1240

Wang Y, Li Y, Wu Z, Murray BR (2009) Insular shifts and trade-offs in life-history traits in pond frogs in the Zhoushan Archipelago, China. J Zoo 278:65–73

Wang YP, Bao YX, Yu MJ, Xu GF, Ding P (2010) Nestedness for different reasons: the distributions of birds, lizards and small mammals on islands of an inundated Lake. Divers Distrib 16:862–873

Watling JI, Donnelly MA (2006) Fragments as islands: a synthesis of faunal responses to habitat patchiness. Conserv Biol 20:1016–1025

Weiher E, Paul Clarke GD, Keddy PA (1998) Community assembly rules, morphological dispersion, and the coexistence of plant species. Oikos 81:309–322

Wiens JA, Rotenberry JT (1981) Censusing and the habitat evaluation of avian habitat occupancy. Stud Avian Biol 6:522–532

Williams CB (1964) Patterns in the balance of nature. Academic Press, London

Yu M, Hu G, Feeley KJ, Wu J, Ding P (2012) Richness and composition of plants and birds on land-bridge islands: effects of island attributes and differential responses of species groups. J Biogeogr 39:1124–1133

Zar JH (1996) Biostatistical analysis. Prentice Hall Upper Saddle River, New Jersey

Zhang JC, Wang YP, Jiang PP, Li P, Yu MJ, Ding P (2008) Nested analysis of passeriform bird assemblages in the Thousand Island Lake region. Biodivers Sci 16:321–331

Zheng CZ (2005) Keys of seed plants in Zhejiang. Zhejiang Science and Technology Publishing House, Hangzhou

Zhuge Y, Gu HQ, Cai CM (1990) Fauna of Zhejiang: Aves. Zhejiang Science and Technology Publishing House, Hangzhou