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Habitat fragmentation in north Thailand: a case study

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Summary

We surveyed birds in two remnant patches of montane evergreen forest landscapes differing in intensity of habitat fragmentation, land use patterns and development. Present landscape configurations in Mae Tuen and Om Koi show that both became heavily fragmented (Table 1, see also Figure 1) between 1954 and 1996. The low abundance at Om Koi of large frugivores, such as Brown Hornbills *Ptilolaemus tickelli* and Great Hornbills *Buceros bicornis*, and their lack at Mae Tuen, are probably effects of prolonged fragmentation.

Introduction

Fragmentation changes intact forest to small patches of native vegetation, mutually isolated by a matrix of agricultural or other developed lands (Wilcove *et al.* 1986, Saunders *et al.* 1991). Changes in structure, spatial relationships and function among ecosystem elements (Forman and Godron 1986) affect plant and animal species and their interactions (Bierregaard and Dale 1996). Patch size has been found to be an important factor determining bird diversity (e.g. Ambuel and Temple 1983). Isolation resulting from fragmentation can affect species distribution and reduce the productivity or survival of nesting birds (e.g. Donovan *et al.* 1995). In the case of small birds, edge-effects have been found, including increased nest predation and brood parasitism (Paton 1994).

In northern Thailand, slash-and-burn shifting cultivation, together with hunting and development of roads and human settlements, caused major declines in biodiversity in montane forest (Dearden 1995, Fox *et al.* 1995, Dearden *et al.* 1996). Many areas were first fragmented over 50 years ago (Fox *et al.* 1995, this study). However, the effects of habitat fragmentation on wildlife and the use of remnant patches in this region have never been systematically studied.

This study examined responses of bird communities to habitat fragmentation and other human disturbances. We surveyed birds in two remnant sample patches of montane evergreen forest landscapes differing in fragmentation pattern and intensity of human disturbance. Because fragmentation is a landscape-scale process (Harris 1984), we also examined the structures, configurations, and changes of montane evergreen forest landscapes by use of remote sensing and GIS technology.

Study areas

Two montane evergreen forest landscapes, located within Om Koi (20,481.08 ha) and Mae Tuen (18,530.79 ha) Wildlife Sanctuaries, were selected for this study

Table 1. Structure and patterns for montane evergreen forest landscapes at Om Koi and Mae Tuen, measured by FRAGSTATS (McGarigal and Marks 1995) from 1996 forest types and landuse maps.

Indices	Landscape	
	Mae Tuen	Om Koi
Total landscape area (ha)	18,530.79	20,481.08
Total area of remaining montane evergreen forest (ha)	2,475.33	3,403.79
Percentage of landscape	13.36	16.62
Largest patch index (%)	3.94	16.62
Number of patches	43.00	44.00
Mean patch size (ha)	57.57	77.36
Patch size SD (ha)	132.02	377.77
Total core area (ha)	890.88	1,623.26
Mean core area (ha)	20.72	36.89
Core area SD (ha)	61.59	209.73

(Table 1). Elevations at the Om Koi site were 1,400–1,800 m and, at Mae Tuen, 850–1,250 m. Average annual rainfall for each site is over 1,000 mm. Indigenous vegetation is mainly lower montane evergreen forest, dominated by tree families including Fagaceae, Lauraceae and Dipterocarpaceae (Thailand Forest Research Center 1991, 1992, Whitmore 1984). The sites differ in intensity of habitat fragmentation, land-use patterns and development (Figure 1).

Methods

Landscape structure and change

Visual interpretation of LANDSAT TM imagery, taken on 15 February 1996 at a scale of 1:50,000, was conducted for the study area. Digital maps of forest type and land use were built by digitizing resulting hardcopy maps and photomosaics for each landscape were created. Ground checks were conducted during field surveys from November 1996 to June 1998. We recognized five classes of forest types and land use: montane evergreen forest, open and disturbed montane forest, mixed deciduous forest, dry dipterocarp forest, old clearings/crop fields. The software FRAGSTAT version 2.0 (McGarigal and Marks 1995) was used to analyse spatial configurations of landscapes and sample patches. To analyse landscape change within the selected sites, FRAGSTAT was used to analyse maps of montane evergreen forest derived from aerial photographs taken between 1954 and 1996.

Bird diversity and abundance

Four montane forest patches were sampled in each of the two landscapes. A total of 1,000 m of transect lines were set up in each patch, 500 m in the interior zone and 500 m in the edge zone. Edge zone was defined as within 100 m from the forest edge (McGarigal and McComb 1995). Edge zone transects consisted of five, 100 m lines located perpendicular to the edge at 200–300 m intervals. Seven bird surveys along each of these transects were conducted between September 1997 and June 1998. Species name, number of individuals, and their perpendicular distance from the transect lines were recorded. The software DISTANCE version 2.0 (Laake *et al.* 1993) was used for analysis of bird density

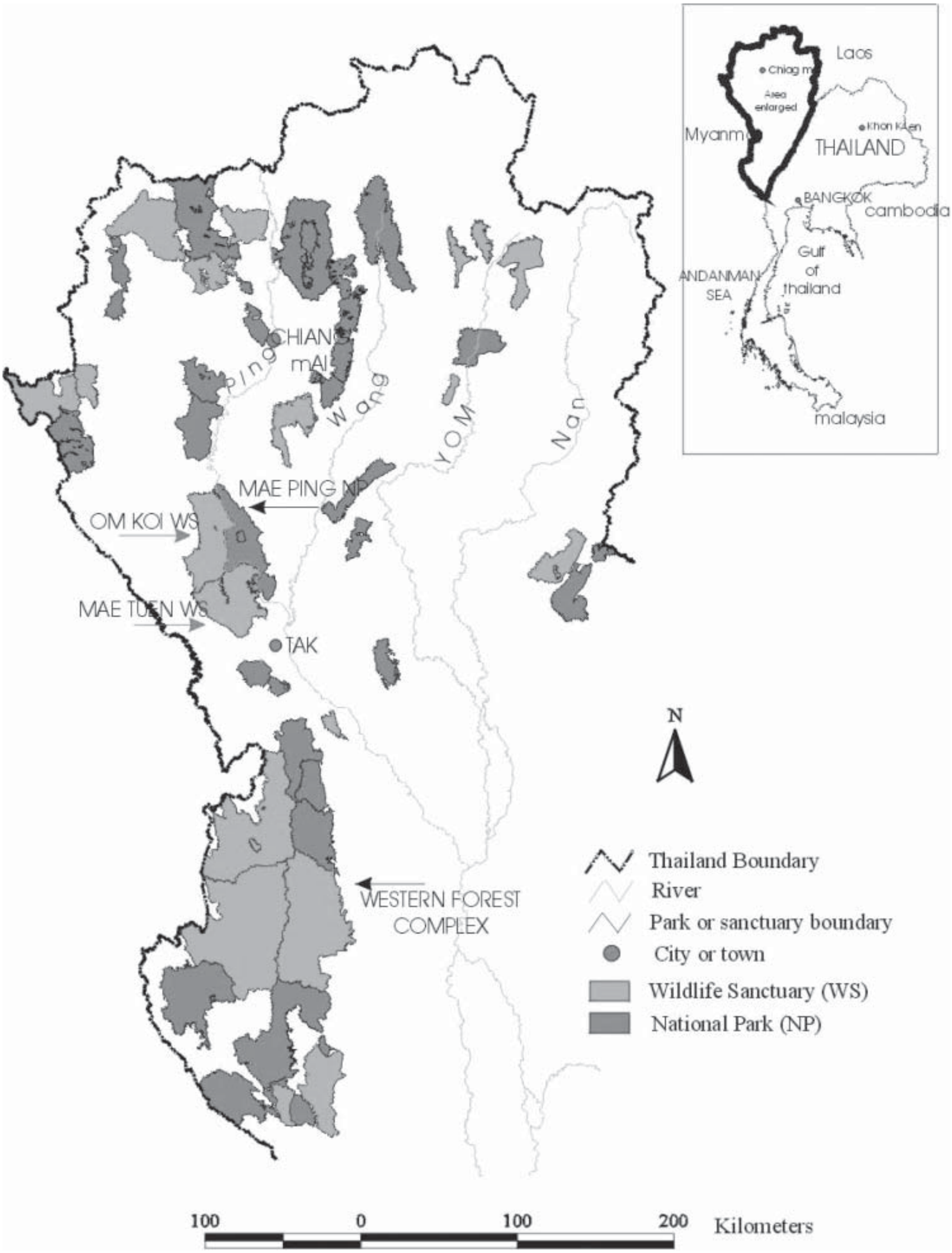

Figure 1. Locations of Om Koi and Mae Tuen Wildlife Sanctuaries in northern Thailand.

(birds/ha). Species abundance was calculated as "species/site visit". The amount of data for individual species was insufficient for DISTANCE to produce reliable results. *T*-tests therefore were used to evaluate the hypotheses that species diversity and density were equal between: (1) forest patches with high and low levels of fragmentation/human disturbances, (2) forest edges next to old clearings or crop fields and (3) edges and interior zones.

Results

Landscape structure and change

Present landscape configurations in Mae Tuen and Om Koi show that both became heavily fragmented (Table 1, see also Figure 1), between 1954 and 1996 (Tables 2 and 3). Fragmentation was measured in terms of forest patches, defined as unconnected remnants of forest environments situated within the overall landscape. More severe fragmentation at Mae Tuen is indicated by the largest patch index (LPI), the area (m^2) of the largest patch in the landscape divided by total landscape area (m^2), then multiplied by 100 to convert to a percentage. The LPI comprises almost 17% of the landscape in Om Koi but only 4% in Mae Tuen. Mean patch size (MPS) at Om Koi (77 ha) was greater than at Mae Tuen (57 ha) and patch size variability (SD) was also greater at Om Koi. Core area is the area (m^2) within a patch calculated by eliminating a 100 m wide buffer along the perimeter and then dividing by 10,000 (to convert to hectares). Total core area (TCA) is the sum of the core areas of each patch (m^2) in a landscape. TCA in Om Koi is almost twice that of Mae Tuen and mean core area (MCA) values are also

Table 2. Comparisons of changes in montane evergreen forest between 1954 and 1999 at Om Koi Wildlife Sanctuary, Chiang Mai and Tak province, northern Thailand, from interpretation of aerial photographs with a scale of 1:50,000.

Indices	Year		Difference
	1954	1996	
Total landscape area (ha)	21,559.75	21,559.75	0
Total area of remaining montane evergreen forest (ha)	3,567.04	2,678.62	888.42
Largest patch index (%)	15.35	8.77	6.58
Number of patches	20.00	36.00	–16.00
Mean patch size (ha)	178.35	74.41	103.94
Patch size SD (ha)	718.28	313.23	405.05
Total core area (ha)	1,884.01	1,135.25	748.76
Mean core area (ha)	94.20	31.54	62.66
Core area SD (ha)	408.62	155.81	252.81

Table 3. Comparisons of changes in montane evergreen forest between 1954 and 1999 at Mae Tuen Wildlife Sanctuary, Tak province, northern Thailand, from interpretation of aerial photographs with a scale of 1:50,000.

Indices	Year		Difference
	1954	1996	
Total landscape area (ha)	21,182.33	21,182.33	0
Total area of remaining montane evergreen forest (ha)	4,974.92	2,334.19	2,640.73
Largest patch index (%)	23.14	3.33	13.86
Number of patches	6.00	43.00	–37.00
Mean patch size (ha)	829.15	54.28	774.87
Patch size SD (ha)	1,821.18	130.71	1,690.47
Total core area (ha)	2,545.90	826.67	1,719.23
Mean core area (ha)	424.32	19.23	405.09
Core area SD (ha)	948.38	58.33	890.05

higher in Om Koi. The lower core area variability (SD) at Mae Tuen indicates a more uniformly fragmented landscape.

Bird diversity, density and abundance

A total of 149 bird species (2,433 detections) were recorded: 89 species (1,238 detections) at Mae Tuen and 119 species (1,192 detections) at Om Koi. Bird diversity and density were compared between the two study sites (Table 4) and between the edge and interior zones at each site (Table 5).

The index of abundance, mean number of birds/site visit, was calculated from the sample of seven visits per site. The four most abundant species at Om Koi, Gray-cheeked Fulvetta *Alcippe morrisonia*, Mountain Bulbul *Hypsipetes mcclellandii*, Golden-throated Barbet *Megalaima franklinii* and White-tailed Leaf-warbler *Phylloscopus davisoni*, were montane evergreen forest obligates (Lekagul and Round, 1991). At Mae Tuen, however, two species of more disturbed habitats, Black Bulbul *Hypsipetes madagascariensis* and Streaked Spiderhunter *Arachnothera magna,* were among the five most abundant species. Large frugivores, such as Brown Hornbill *Ptilolaemus tickelli* and Great Hornbill *Buceros bicornis,* still existed with low abundance (1.43 and 0.43 birds/site visit respectively) at Om Koi but none were found at Mae Tuen. Species that utilize clearings, such as Flavescent Bulbul *Pycnonotus flavescens* and Red-whiskered Bulbul *Pycnonotus jocosus,* were found along the forest edges in low abundance (1.43 and 0.71 birds/site visit respectively).

Bird diversity and density were calculated for each patch and the patches were arranged from small to large (Figure 2). Although there was no significant relationship between patch size and bird diversity or density, there was a trend

Table 4. Comparison by *t*-test of bird diversity and density in montane evergreen forest patches at Om Koi and Mae Tuen Wildlife Sanctuaries, Chiang Mai and Tak provinces, northern Thailand, from seven surveys made at each site during September 1997 to June 1998.

Comparison	Om Koi		Mae Tuen		*t*	df	*P*	Power[a]
	Mean	SE	Mean	SE				
Diversity								
Patch								
Species number	63.25	3.20	54.00	2.48	2.28	6	0.062	0.62
Species number[b] (without P7)	66.33	1.20	54.00	2.48	3.97	5	0.011*	–
Interior zone								
Species number	32.75	2.43	29.50	2.22	0.99	6	0.361	0.17
Edge zone								
Species number	38.00	0.91	37.25	3.28	0.22	6	0.830	0.06
Density (no. birds/ha)								
Patch	6.91	0.97	8.80	0.29	–	–	0.200[c]	–
Interior zone	8.96	0.85	10.60	1.49	0.74	6	0.485	0.12
Edge zone	10.91	1.94	8.68	1.47	0.92	6	0.395	0.15

*Significant difference.
[a]Statistical power at $\alpha = 0.05$.
[b]Data from the smallest fragment were left out of the analysis.
[c]Mann–Whitney test was used due to the non-normal distribution of data (Zar 1984).

Table 5. Comparison by *t*-test of bird diversity and density between edge and interior zones within montane evergreen forest patches at Om Koi and Mae Tuen, Om Koi and Mae Tuen Wildlife Sanctuary, Chiang Mai and Tak provinces, northern Thailand, from a sample of seven surveys made at each site during September 1997 to June 1998.

Comparisons	Edge zone		Interior zone		*t*	df	*P*	Power[a]
	Mean	SE	Mean	SE				
Diversity								
Om Koi								
Species number	38.00	1.83	32.75	2.43	2.02	6	0.089	0.53
Mae Tuen								
Species number	37.25	3.28	29.50	2.22	1.96	6	0.098	0.50
Overall								
Species number	37.63	1.58	31.13	1.64	2.85	14	0.013*	–
Density (no. birds/ha)								
Om Koi	10.91	1.94	8.96	0.85	0.92	6	0.391	0.45
Mae Tuen	8.68	1.47	10.47	1.55	0.83	6	0.437	0.39
Overall	9.79	3.40	8.79	2.41	0.01	14	0.991	0.05

*Significant difference.
[a]Statistical power at $\alpha = 0.05$.

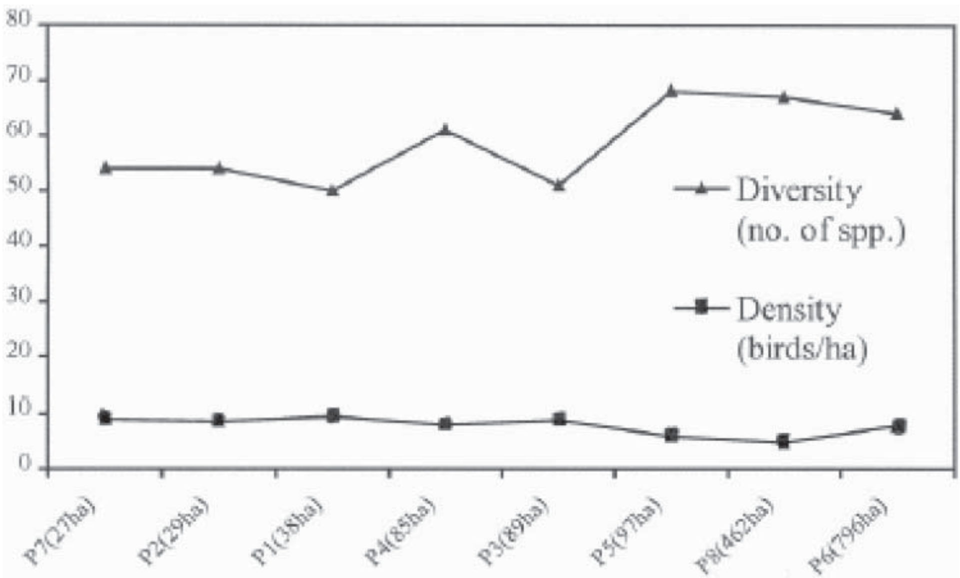

Figure 2. Bird diversity (number of bird species) and density (birds/ha) in different-sized patches (ha) in montane evergreen forests at Om Koi Wildlife Sanctuary, Chiang Mai and Tak provinces, northern Thailand. Patches are arranged from small to large. Figures are means from seven transects per patch, surveyed from September 1997 to June 1998.

for increased diversity in medium (P5) and large patches (P8, P9). There was a significant relationship between species numbers and patch size when the smallest patch in the sample (P7 in Om Koi) was removed from the analysis (Table 4). Patch P7 was removed because its boundaries are partly defined by a cliff habitat, rather than the old cleared fields of the other patches.

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Discussion

Landscape and patch configuration

The severe fragmentation at Mae Tuen, compared with Om Koi, is mainly due to increased market farming, primarily of cabbage, exacerbated by the development of a paved road. Dearden (1995) and Fox *et al.* (1995) have reported improvement in socioeconomic conditions among local people after road construction, with subsequent degradation of forest areas.

Om Koi contained more large patches and larger core areas than Mae Tuen. While both forest landscapes have been heavily fragmented larger patch size may promote the survival of more species. Furthermore, slash-and-burn activities on the Om Koi landscape have virtually halted, but continue in Mae Tuen. The faster pace of forest loss in Mae Tuen from 1954 to 1996 may have already led to local extinctions.

Bird responses

Bird species currently in the area may be able to adjust to the modified habitats or could be small remnant populations with a high risk of local extinction. Studies of old forest fragments in Singapore and Hong Kong revealed the extinction of many forest birds (Corlett and Turner 1997). Warburton (1997) found that species composition tended to converge in small forest remnants since locally common species often survive well in modified habitats. The long-term survival of much of the tropical biota will depend on the ability of species to persist in highly modified habitats and on human capacity to manage and conserve degraded landscapes (Laurance and Bierregaard, 1997). Furthermore, the appearance of species persistence may be concealing the largely invisible erosion of genetic diversity as population numbers decline (Whitmore 1997).

The configuration of the forest patches at Om Koi may be a key factor in maintaining higher numbers of bird species. Natural forest corridors connect large remnant patches to patches of the same forest types. Within Om Koi, the low bird diversity in the small and isolated patch P7 may indicate the effects of fragmentation (Figure 2), since reduced patch size and increased isolation adversely affect bird diversity (e.g. Bierregaard *et al.* 1992, Kattan and Alvarez-Lopez 1996).

Although we did not find a relationship between type of clearing and bird diversity and abundance along patch edges, the smaller contrast between habitat types in patches at Om Koi may have helped to maintain avian diversity. Bierregaard and Stouffer (1997) describe a number of primary rainforest birds in an Amazonian forest that forage in adjacent secondary forest and use it to recolonize small primary forest fragments nearby. Some primary forest specialists avoided modified habitats while others adapted to the changed landscape (Laurance and Bierregaard 1997). We found some evergreen forest species, such as Yellow-cheeked Tit *Parus spilonotus* and Black-headed Sibia *Heterophasia melanoleuca*, used regrowth along patch edges in Om Koi. However, we found no primary forest birds that use cabbages fields next to Mae Tuen forest patches.

Species that favour clearings, such as Flavescent and Red-whiskered Bulbuls, were in low abundance within 100 m of the forest edge, in both sites. Lovejoy *et al.* (1986) also found that very few species of secondary growth invaded tropical forest patches in the Amazon. In contrast, de Casenave *et al.* (1998), studying bird communities in semi-arid forest in Argentina, found species assemblages along forest edge that were similar to those of secondary growth and so avian responses to forest edges may differ between habitats.

Significantly greater bird diversity along edge zones compared with the forest interior (Table 4) agrees with some studies in other habitat types (e.g. Leopold 1933, de Casenave *et al.* 1998). Gates and Gysel (1978) suggested that birds might be drawn to edges because of greater food availability, but bird species richness was depressed along newly created edges of a tropical forest in the Amazon (Lovejoy *et al.* 1986). Birds were abundant within 100 m of the old edges of forest patches at Om Koi and Mae Tuen but species composition differed. Abundant species along forest edge at Om Koi were strictly evergreen forest birds, while along the more disturbed edges at Mae Tuen these obligate evergreen forest species were joined by species that occupy both forest and disturbed habitats.

The low abundance at Om Koi of large frugivores, such as Brown and Great Hornbills, and their lack at Mae Tuen, are probably effects of prolonged fragmentation. Large frugivorous birds require continuous habitat along altitudinal gradients because fruit availability is variable in time and space, and tracking these resources involves seasonal movements that cover large areas. Forest fragmentation separates foraging areas and may severely restrict year-round access to food (Guindon 1996). Fragmentation also reduces the large trees in which hornbills select nesting cavities and reduction of sites can lead to changes in nest competition and reproductive success (Poonswad and Kemp 1993). Large frugivorous birds, including three species of hornbills, were eliminated from Hong Kong and Singapore by fragmentation and hunting (Corlett and Turner 1997). Hornbills in the study area may also have suffered from hunting pressure. Large birds are a favoured target for local hunters (Redford 1992) and local people have been seen using a Great Hornbill head as a trophy. Bennett and Dahaban (1995) witnessed many bird species in Sarawak that were taken for their feathers and bills for use in traditional decorations and ceremonies.

No significant difference was found in bird density between edge and interior zones, overall or within each site. This differs from studies where abundance was higher in both natural (de Casenave *et al.* 1998) and anthropogenic (e.g. Yahner 1988) edges. The sample sizes in this study may have been too small to detect any differences in density.

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