Comparison of Structure and Bird Diversity of Mixed Fruit Orchards and Natural Forest at Ban Khiriwong, Nakhon Sri Thammarat

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Abstract

The canopy characteristics and bird diversity were measured in mixed fruit orchard (suan som rom) and natural forest in Ban Khiriwong, Nakhon Si Thammarat Province. The orchard canopy was half as high and only half as dense as that of the forest, and had less cover over the ground (85% vs. 100%). The lower understory layer was much less dense than that of the forest. The major fruit species contributing to the canopy volume were *Durio zibethinus* (34.2%), *Parkia speciosa* (16.3%), *Garcinia mangostana* (12.9%), *Artocarpus integer* (6%), *Lasium domesticum* (4.7%), *Areca catechu* (4.6%), *Musa acuminata* (3.6%), and *Nephelium lappaceum* (2.7%). A total of 20 species of plants were planted, some of them shrubs. It is recommended that more understory plants be used in the orchard to improve canopy cover and increase commercial value. Bird diversity in the orchard was surprisingly high, with 59 species recorded on the standardized 10 census lists, in comparison with 51 species in the 4.5 ha forest patch surveyed. The orchard bird diversity included a large number of disturbed and secondary forest species and was still lower than that in undisturbed forest in the national park (79 species) The orchard lacked primary forest species such as hornbills and broadbills and also the suite of understory babblers typical of peninsular Thai and Malayan lowland forest.

บทคัดย่อ

งานวิจัยนี้ได้ศึกษาลักษณะของชั้นเรือนยอดและความหลากหลายของนกในป่าสวนผสมผลไม้ (สวนสมรม) และป่าธรรมชาติ ณ บ้านคีรีวงศ์ จังหวัดนครศรีธรรมราช พบว่า สวนสมรมมีความสูงและความหนาแน่นของชั้นเรือนยอดเพียงครึ่งหนึ่งของป่าธรรมชาติ ทำให้มีร่มเงาปกคลุมพื้นล่างน้อยกว่าในป่าธรรมชาติ (85% และ 100%) และเรือนยอดชั้นล่างมีความหนาแน่นน้อยกว่าป่าธรรมชาติ โดยไม้ผลชนิดหลักๆที่ให้ร่มเงาก็คือ ทุเรียน (*Durio zibethinus*) 34.2 %, สะตอ (*Parkia speciosa*) 16.3 %, มังคุด (*Garcinia mangostana*) 12.9%, จำปาดะ (*Arthocarpus intege*) 6 %, ลางสาด, ลองกอง (*Lasium domesticum*) 4.7 %, หมาก (*Areca catechu*) 4.6%, กล้วยป่า (*Musa acuminata*) 3.6 % และ เงาะ (*Nephilium lappaceum*) 2.7 % โดยมีไม้ปลูกทั้งหมด 20 ชนิด ซึ่งบางส่วนจะเป็นไม้พุ่ม จากผลการวิจัยมีข้อเสนอแนะคือ จะต้องมีการปลูกพรรณไม้ชั้นล่างเพื่อเพิ่มร่มเงาปกคลุมและเพิ่มมูลค่าของสวนสมรม เมื่อเปรียบเทียบในป่าธรรมชาติแล้ว ความหลากหลายของนกในสวนสมรมมีค่าสูงมาก โดยพบนกทั้งหมด 59 ชนิดในวิธีเก็บข้อมูลรายชนิดมาตรฐาน ซึ่งในหย่อมป่าธรรมชาติ 4.5 เฮกแตร์พบนกเพียง 51 ชนิดเท่านั้น ความหลากหลายของนกที่พบในสวนสมรม จะรวมไปถึงนกในบริเวณป่าเสื่อมโทรมและป่าทุติยภูมิ แต่พบว่ามีจำนวนน้อยชนิดกว่านกในป่าปฐมภูมิหรือในเขตอุทยานแห่งชาติ (79 ชนิด) ชนิดนกที่ไม่พบในสวนสมรม ก็คือ นกเงือก, นกปากกว้าง, และกลุ่มนกกระจิ๊ด ที่เป็นนกประจำถิ่นแถบคาบสมุทรประเทศไทยและบริเวณป่าที่ราบต่ำมลายัน

Introduction

The village of Ban Kiriwong, Nakhon Sri Thammarat Province, became the focus of national attention after a disastrous flood in November of 1988 swept away houses and roads in the center of the village, and killed several people. Ban Kiriwong is at the junction of two streams that descend in steep valleys from upper elevations which are in Khao Luang National Park; the main stream is the Khlong Tha Di. Other villages fared worse and lost more lives, as mountainsides covered with rubber orchards were particularly prone to land slips (Rao 1988). Ban Kiriwong villagers for at least 100 years have mostly engaged in a kind of agroforestry called "suan som rom", or mixed fruit orchards, that from a distance resemble natural forest These orchards are created by replacing the natural forest (except for a few useful native trees which are left standing) with a dozen or so kinds of fruit trees which are spaced irregularly over the hillsides. The understory is maintained clear and lianas and any wildlife which may threaten the crops or the safety of the villagers are eliminated. No pesticides or fertilizer are used. The income from the suan som rom is said to be greater over the year than that from monoculture orchards that are less productive on an area basis and require more economic subsidies than a mixed orchard which has several stories of foliage cover.

The project investigators became interested in studying the ecological characteristics of the mixed fruit orchards in July 8–9, 2000, on a trip sponsored by BIOTEC aimed at studying the way of life of the villagers and exploring ways of using the expertise of BIOTEC researchers to improve the welfare of the villagers. We were taken into the orchard by a local guide who explained the uses of the various plants and techniques of management. It is clear that the orchards extended far up the mountainsides, and as we observed later, are still slowly expanding upwards into the national park. Forest Department officials have an agreement with the villagers that they will observe the boundary of the park, but some villagers are not complying with it. The villagers maintain, however, that the mixed orchard is a kind of "forest" and maintains cover and other ecological attributes of natural vegetation.

The ecological group from BIOTEC then decided to formulate a plan to determine through objective and quantitative measurements to what extent the mixed orchard mimics natural forest. It seemed clear that mixed fruit orchard should be superior to monocultures of fruit trees in a number of attributes such as foliage density, productivity, and lack of harmful chemicals (although this has not been demonstrated quantitatively). It is less clear, however, whether the mixed orchard is comparable to natural forest in its ecology. The team decided to carry out relatively brief but quantitative comparisons of vegetation structure and bird diversity. The vegetation comparison would include measures of canopy height, density, and cover over the ground. The comparison of bird communities would employ a standardized method of comparing species diversity and frequency of observation in defined areas. The village areas were studied during 25–30 October 2000 and 19–24 November 2001. In addition, a study of bird diversity in undisturbed low elevation forest near the headquarters of the national park was carried out in 7–10 April of 2001.

This part of the report deals with the vegetation study. A second part deals with bird diversity, also included here but separate.

Objectives of Project

The major objectives of the project were as follows:

1. To compare the structural features of the mixed orchard "forest" with the natural forest in Khao Luang National Park nearby, with respect to: average height, tree density and basal area, percent canopy cover, and canopy density at all levels of the forest;
2. To compare the diversity and cover of ground vegetation in the mixed orchard with that in natural forest;
3. To compare bird diversity in the mixed orchard with that in natural forest nearby;
4. To educate villagers, especially children, about the natural diversity of plants and animals in the natural forest.

Study Site

The two vegetation study sites were located near the village of Ban Khiriwong, Nakhon Si Thammarat Province, on the southeastern slopes of Khao Luang National Park, at approximately 8° 26.5' N, 99°45.5' E. An orchard area of approximately 25 ha was selected near the Khlong Tha Di stream between 150 and 320 m elevation above msl. A forest patch 4.5 ha in area surrounded by orchard was selected 2.5 km up the valley to the west at an elevation of 500–600 m elevation on a hillside. this was the only suitable forest that could be located within the orchard area below 700 m elevation; all other non-orchard areas had been reduced to scrub vegetation.

Methods of Vegetation Study

Establishment of transects, points and plots

In both habitats, approximately 12 transects were laid out and points were established in a regular grid within the bounds of the areas selected. Points, 100 in each habitat, were spaced 50 m apart in the orchard area and 20 m apart in the forest patch (which was too small to allow wider spacing). Hand compasses and tape measures were used for laying out the grid. Ten points that lay on bedrock in a ravine and hence had no forest trees, and 2 points lying near large cut stumps in gaps, were discarded in the forest patch. Each point was used for canopy measurements, and served as the center of a circular plot 0.01 ha in area for inventory of all stems > 1 cm dbh. In addition, a square plot 4 m^2 in area was placed around the point for estimation of ground vegetation cover.

Canopy measurements

The point intercept method of Brockelman (1997) for measuring upper canopy surface height was employed, with additional measurements made for the purpose of determining total canopy volume as well as height. A Suunto clinometer (Forestry Suppliers, Inc., Jackson, MS, U.S.A.) was used to determine the vertical line running through the canopy and zenith point, while the viewer stood over the point. The heights to the nearest meter of all canopies intersecting the line were measured with an optical

Ranging Rangefinder® (Forestry Suppliers, Inc.), and recorded. "Canopy" here consists of any leaves or living branches; spaces between leaves are ignored, but spaces greater than about 30 cm between branches are considered as gaps. In the forest patch no attempt was made to determine limits of individual tree canopies, but in the orchard the species of each tree canopy was noted.

Plot measurements

All stems ≥1 cm dbh were measured and recorded in the 0.01 ha circular plots. Diameters were later converted to stem basal areas. Attempts were made to identify the most common species in the forest, and all species were recorded in the orchard. We estimated ground cover by eye to the nearest 5 % in the 4-m^2 quadrats for each of the following plant categories: grasses, dicotyledonous herbs (forbs), vines, woody seedlings, ferns and allies, and absence (bare ground). At least 3 persons made independent estimates for each type and these were averaged, or reduced to a single estimate by consensus. After some practice estimates usually did not differ by more than 10% between persons.

Analysis of canopy cover

Cover of vegetation was analyzed by plotting the heights at which the vertical intercepts hit foliage for all points as columns in a Microsoft Excel worksheet, and then summing the columns horizontally across the points and then vertically. This allowed determination of the foliage characteristics defined below. A distinction is observed between "total canopy" as representing the whole column of foliage above each point, and the "canopy surface" which is the uppermost canopy foliage recorded (cf. Parker 1995).

Percent surface cover.—This represents the estimated percent of the area (as determined from the percent of the points) which have forest cover above the ground vegetation (1 m height). For the orchard, the percent canopy surface area cover was divided among the individual fruit tree species.

Percent surface cover in relation to height.—The highest foliage (or canopy surface) over each point is distributed over height above ground, which gives the frequency distribution of forest height. This can be plotted as a simple frequency distribution (grouped into 5-m height intervals in Figures 2 and 4, right side), and as a cumulative distribution from the top down to the ground (Figure 1). The latter provides a picture of the total surface canopy (as a percentage of the points) *above* each 1-m height class. The distribution of canopy surface height is summarized by a mean height and its standard deviation, which provides an estimate of "surface canopy roughness."

Maximum height.—This is simply the maximum surface canopy height, which can be determined for the whole sample of points and for each species (orchard). This does not necessarily represent the maximum tree height unless a point happened to lie under the highest point of the highest tree.

Total canopy volume.—This statistic is derived from the sum of all canopy "hits" above all points. Divided by 100, it gives the average amount of foliage (number of 1-m intervals with foliage) above each point.

Mean canopy height.—This represents the mean height of the canopy volume as described above, and is the weighted average of canopy height using all heights intersecting canopy. The mean canopy height is necessarily lower than the mean surface canopy height.

Results

The orchard species

A total of 34 species of woody plants were identified in the orchard plots (Table 1) as compared with at least 122 species in 46 families provisionally identified in the forest patch. The total for the orchard includes at least 15 wild species. The species found in the orchard are listed in Table 2, which gives their uses and the numbers of stems found in the 1-ha sample. Some of the wild species represent large trees left standing (such as some large *Hopea pierrei* and *Michelia champaca* trees harvested for wood) and other smaller trees represent successional species found mainly in the ravines, such as *Macaranga* spp., *Vitex, Oroxylum, Memecylon*, and *Caryota* palms which are ravine-loving forest species.

A total of about 20 species counted were planted for household or commercial use; 7 of these did not occur frequently enough or were not tall enough to be recorded in the point intercepts. One species, *Hibiscus rosa-sinensis*, which has colorful red flowers, was planted as a boundary marker between different villagers' property holdings.

Canopy surface cover

Canopy surface covers 100% of the area of the forest plot, but only 85% of the orchard area (Table 1) The mean canopy surface height in the forest patch (26.3 m; SD = 11.5) was twice as high as that of the orchard (12.8 m; SD = 8.7). The standard deviation (SD) of both canopies was rather high, reflecting the removal of many of the largest trees in the patch, and the amount of gap area in the orchard (which is scored as 1 or 0 m canopy height). Approximately 12 large stumps of trees cut at least 10 years previously were found in the forest patch. This is reflected in the scarcity of canopy measurements exceeding 50 m. The surface canopy distribution histograms (Figures 2 and 4, right side) show that in the forest patch most (76%) of the surface lay above 20 m height, whereas in the orchard, relatively little of the canopy surface (22%) lay above 20 m. The cumulative distribution curves (Figure 1) clearly indicate the difference in height; in the forest patch the 50% canopy cover occurs at about 27 m, whereas in the orchard it occurs near 15 m. In the orchard, the highest percent of canopy cover is provided by the tallest fruit tree species, the durian (*Durio zibithinus* L.), with 30 percent of points (though *Michelia champaca* L. trees may sometimes achieve greater heights).

Canopy volume

Canopy volume (Table 1) is twice as great in the forest patch as in the orchard. It also has a somewhat different vertical distribution (Figures 2 and 4, left side). In the forest, ground cover was 65%, and cover in the understory (1–5 m) averaged over 50%. In the orchard, ground cover was 96% but understory cover was much lower, only 10%

between 1 and 2 m, and less than 30% up to 5 m. Middle canopy cover averaged around 30% or less in the forest up to about 27 m, and in the orchard to about 15 m. Above these heights canopy volume generally tapered off to 0 at about 52 m in the forest and 33 m in the orchard.

In the orchard, the highest canopy volume was contributed by *Durio*, with 34% of the total, with *Parkia* and *Garcinia* ranked next with about 16% and 13%, respectively (Table 2). The contributions of understory species such as *Lasium, Nephelium* and *Bouea* will probably increase in time as they are planted between the existing larger trees. We noted that the upper parts of the orchard above 250 m had lower canopy height and volume than the lower parts, which were older. Upon inspecting orchards at higher elevations of 600–700 m, near and above the forest patch, we noted that villagers were planting mostly the betelnut palm, *Areca catechu*, and we observed villagers cutting open the fruits in their temporary houses.

Ground cover

There are marked differences in the composition of the ground vegetation between orchard and forest (Table 2) Villagers cut back the ground vegetation with gasoline-powered blades every year or two, and often plant the ground with a species of bamboo grass to suppress more aggressive wild species. Cover in the orchard comprised mostly grasses (28%) forbs (20%) and vines (13%), and totaled an average of 83%. In the forest patch, there was no grass but seedlings, vines and herbs were represented almost equally, and bare areas averaged 57% due to shading by the dense understory and middle canopy.

Number, Size, and basal area of stems

The dbh and basal area data have not been completely summarized, and have to be entered into an Excel spreadsheet to be analyzed. However, the total numbers of stems ≥1 cm dbh has been summarized: 733 per ha for the orchard and 2889 for the forest patch. In addition, the forest patch had 616 woody climber stems per ha, whereas the orchard had none because they are removed by the villagers.

Discussion

The orchard has approximately half the height and foliage mass of the patch of selectively logged natural forest left at slightly higher elevation. Its species diversity is of course much lower, and it has only about 21% as many woody stems. This is because the forest has many more natural understory plants which are cut away in the orchard. The orchard has a total cover of woody plants of 85% vs. 100% for the forest patch. The absence of a dense lower understory of woody plants in the orchard is perhaps the major structural difference between orchard and natural forest. Because the orchard tends to be more open, the ground cover is more dense there than in natural forest, consisting mostly of grasses, herbs and vines. In the forest, ground cover is only dense in gaps; it is often absent under tall dense tree canopy.

Mixed fruit orchards are highly diverse agroforestry ecosystems. They are superior to monoculture orchards or rubber plantations in maintaining vegetative cover and biodiversity. "They are certainly superior to oil and coconut palm plantations which do not provide adequate cover or soil-holding ability. Rubber orchards are also not able to hold the soil and friable rocks effectively with their sparse roots on steep slopes, as evidenced by the disastrous landslides in many mountainous areas during the 1988 flood. The fruit orchards apparently effectively held the soil on the hills around Ban Khiriwong during this flood. However, they did not prevent the rapid runoff of water during the deluge. The smaller vegetation mass, especially in the understory, may have contributed the speed of water runoff that wreaked so much havoc in the village. The water-absorption capacity of orchard vegetation and soil as compared with that of monoculture orchard or natural forest could be assessed by conducting controlled watershed studies if suitable small experimental watersheds could be found. That would be worthwhile to do, but would entail far more time and expense that the present rather preliminary study. One would have to measure rainfall each day and compare it with runoff in the ravines; even hour-by-hour comparisons would be desirable.

Is the mixed fruit orchard an adequate substitute for natural forest? The answer to this question has to be no, from both the structural and biodiversity standpoints. The floods would probably have been less sudden and worse if undisturbed natural vegetation had covered the hillsides instead of orchard. Today the threat of flooding is worse because orchards are ascending the mountainsides little by little each year, and are, according to forestry maps available to the field teams, well into the national park. It seems apparent that the park personnel do not check the upper orchard boundaries, now reaching 800 m above msl in places that are not too steep to plant, or else Forestry officials have ceded more degraded forest area to the village.

How can the mixed orchards be "improved" to increase their cover value? The tree cover will gradually improve as the fruit trees increase in size, especially those with dense foliage such as *Durio*, *Garcinia*, and *Nephelium* and the lower story fruit trees. Species such as *Areca* palm and *Parkia* have rather thin foliage with less cover value. We would also suggest leaving more native hardwood species standing, and leaving suboptimal areas such as ravines with their natural tree cover. This would also help to maintain bird and other animal diversity. A final suggestion is to plant more understory crops to make up for the loss of natural understory vegetation. "Such crops might considerably add to the commercial value of the orchard if high-value plants such as flowers, medicinal plants and ornamentals were planted. Shade-tolerant species would be particularly welcome. These would be planted primarily in gaps between fruit trees where they do not interfere with fruit harvest (durians are allowed to fall and are caught in large nets spread on the ground).

By adding to the commercial value of the orchard, more income could be generated and further forest encroachment might be prevented. However, this appears to be mainly or partly a problem of increase in the number of families or villagers without property holdings in the existing orchard area. Such a problem must be attacked by creating new sources of income and new kinds of occupations, as well as more conscientious enforcement by the Forest Department. Without enforcement of the boundary by regular patrolling and aerial observation, no strategies will succeed in saving the natural forest (Brockelman et al. 2002.

One objective that the project did not achieve well enough was education of young local villagers in the value of natural vegetation and biodiversity. Little time and budget were available to carry our education activities while on survey trips, and the field team found virtually no good canopy forest within easy walking distance of the village. In addition, the rather negative findings with regard to ecological conditions in the fruit orchard, and the obvious continuing encroachment into the upland forest, created an awkward personal relations problem that the team was not up to solving at the time. The lowland villagers themselves, like those around protected areas elsewhere throughout Thailand, did not admit to encroaching and always pointed to the park boundary higher up above the orchards. The question was not raised with villagers higher up at the forest edge, in order not to create a confrontational mood. The park boundary in fact is neither marked nor known at all by the Forest Department itself. The boundary copied on 1:50,000 maps several years ago from the Forest Department's own maps consists of ridiculous pencil squiggles drawn with no regard to terrain features.

As Robert Frost affirmed in his famous poem, "Good fences make good neighbors." The Forest Department has no good boundaries nor good fences, and will not have good neighbors unless it cedes the entire southern and eastern flanks of the national park to orchard planters.

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'able 1. Plant species in the Ban Khiriwong orchard area. P = planted species, W = wild, T = tree, S = shrub, VC = woody climber.

o.	Name and use	Local name	Habit	DBH (cm)		No. stems	%
				range	mean		
	ANACARDIACEAE						
1	*Bouea macrophylla* Griff. (P, fruit)	มะปราง	T	30.0-36.0	33	2	0.27
2	*Mangifera* sp. (W)	มะม่วงป่า	T	4.5	-	1	0.14
	ARALIACEAE						
3	*Polyscias fruticosa* (L.) Harms (W)	เล็บครุฑ	S	2-6.5	3.5	3	0.41
	BIGNONIACEAE						
4	*Oroxylum indicum* (L.) Kurz (W)	เพกา	T	1.0-39.2	18.4	3	0.41
	BOMBACACEAE						
5	*Durio zibethinus* Merr. (P, fruit)	ทุเรียน	T	1.4-71.5	19.38	137	18.69
	CARICACEAE						
6	*Carica papaya* L. (P, fruit)	มะละกอ	ST	5.6-15.2	9.35	4	0.54
	DIPTEROCARPACEAE						
7	*Hopea pierrei* Hance (W, wood)	ตะเคียน	T	87.1-112.0	99.55	2	0.27
	EUPHORBIACEAE						
8	*Hevea brasiliensis* (Willd. ex A.Juss) Mull.Arg. (P, rub	ยางพารา	T	23.6-60.8	40.68	5	0.68
9	*Macaranga indica* Wight (W)	ปอหูช้าง	T	4.1-20.7	8.02	9	1.23
	GUTTIFERAE						
10	*Garcinia mangostana* Linn. (P, fruit)	มังคุด	T	1.0-45.0	11.64	86	11.73
	LABIATAE						
11	*Vitex pinnata* L. (W)	ตีนนก	T	16.6	-	1	0.14
	LEGUMINOSAE-MIMOSOIDEAE						
12	*Archidendron jiringa* (Jack) I. C. Nielsen (P, beans)	เนียง	T	3.5-34.0	11.95	25	3.41
13	*Parkia speciosa* Hassk. (P, beans)	สะตอ	T	3.2-48.1	22.32	58	7.91
	LEGUMINOSAE-PAPILIONOIDEAE						
14	*Dalbergia migrescens* Kurz (W)	ไม้ฉนวน	T	29.9	-	1	0.14
	MAGNOLIACEAE						
15	*Michelia champaca* L. (W, wood)	จำปาป่า	T	3.4-5.2	4.52	4	0.54
	MALVACEAE						
16	*Hibiscus rosa-sinensis* Linn. (P, boundary fence)	ชบา	ST	1.0-4.7	3.27	13	1.77
	MELASTOMATACEAE						
17	*Memecylon oleifolium* Blume (W)	ไม้พลอง	S/T	1.9-2.3	2.03	3	0.41
	MELIACEAE						
18	*Lansium domesticum* Correa (P, fruit)	ลางสาด, ลองกอง	T	1.0-30.0	8.18	93	12.68
19	*Sandoricum koetjape* (Burm.f.) Merr. (P, fruit)	กระท้อน	T	13.2	-	1	0.14
	MORACEAE						
20	*Artocarpus heterophyllus* Lam. (P, fruit)	ขนุน	T	42.3	-	1	0.14
21	*Artocarpus integer* (Thunb.) Merr. (P, wood)	จำปาดะ	T	4.0-69.0	25.31	20	2.73
22	*Ficus* spp. (W)	มะเดื่อ	T	1.0-31.0	5.34	7	0.95
	MUSACEAE						
23	*Musa acuminata* Colla (P, bananas)	กล้วยป่า	H	1.6-23.2	10.35	102	13.91
	MYRTACEAE						
24	*Syzygium malaccense* (L.) Merr. & L.M. Perry (P, fru	ชมพู่	T	4.5	-	1	0.14

No.	Name and use	Local Name	Habit	DBH (cm)		No. stems	%
				range	mean		
	PALMAE						
25	*Areca catechu* Linn. (P, betelnut)	หมาก	P	1.5-35.0	12.3	121	16.51
26	*Caryota bacsonensis* Magalon (W)	เต่าร้าง	P	9.9	-	1	0.14
27	*Cocos nucifera* Linn. var. *nucifera* (P, coconut)	มะพร้าว	P	27.0-32.1	29.55	2	0.27
	PIPERACEAE						
28	*Piper betle* L. (P, leaves chewed with betel)	พลู	WC	4.5	-	1	0.14
	RUBIACEAE						
29	*Coffea canephora* Pierre ex A.Froehner (P, coffee)	กาแฟ	S	6	-	1	0.14
30	*Ixora ebarbata* Craib (P, ornamental)	เข็มขาว	S	4.7-9.7	7.15	2	0.27
	RUTACEAE						
31	*Citrus hystrix* DC. (P, spice)	มะกรูด	ST	11.2	-	1	0.14
	SAPINDACEAE						
32	*Nephelium lappaceum* Linn. (P, fruit)	เงาะ	T	9.4-44.2	23.55	8	1.09
33	*Pometia ridleyi* King ex Radlk. (W)	สาย	T	3.3-30.5	12.53	3	0.41
	STERCULIACEAE						
34	*Sterculia villosa* Roxb. (W)	ปอสำโรง	T	74.4	-	1	0.14
	UNKNOWN (W)	ไม่รู้จัก	T	2.5-34.0	13.56	10	1.36

Table 2. Vegetative cover statistics for forest patch and orchard area.

Category	% surface cover >1 m	Maximum height	Total canopy volume		
			Sum	%	Mean h
Forest patch	100	52	1187	100	16.7
Orchard, total	85	33	590	100	12.2
Durio zibethinus	30	31	202	34.2	15.0
Parkia speciosa	16	27	96	16.3	14.9
Garcinia mangostana	5	24	76	12.9	6.4
Artocarpus integer	2	23	36	6.1	1.4
Lasium domesticum	1	13	28	4.7	6.6
Areca catechu	11	23	27	4.6	12.1
Musa acuminata	6	8	21	3.6	3.7
Nephelium lappaceum	1	14	16	2.7	8.1
Michelia champaca	1	25	11	1.9	19.3
Bouea macrophylla	1	7	9	1.5	1.7
Cocos nucifera	1	7	3	0.5	6.0
Archidendron jiringa	1	5	2	0.3	3.5
Hibiscus rosa-sinensis	0	3	2	0.3	2.5
Wild plants	9	33	61	10.3	13.9

Table 3. Percent ground cover of different plant categories in orchard and in the natural forest patch.

Type of ground plants	Percent cover	
	Orchard	Forest patch
Grasses	28.4	0
Forbs	19.6	11.8
Vines	16.7	12.7
Ferns and allies	11.2	5.6
Woody seedlings	7.1	13.2
Bare ground	17.0	56.6

Figure 1. Cumulative percent canopy surface cover in relation to height

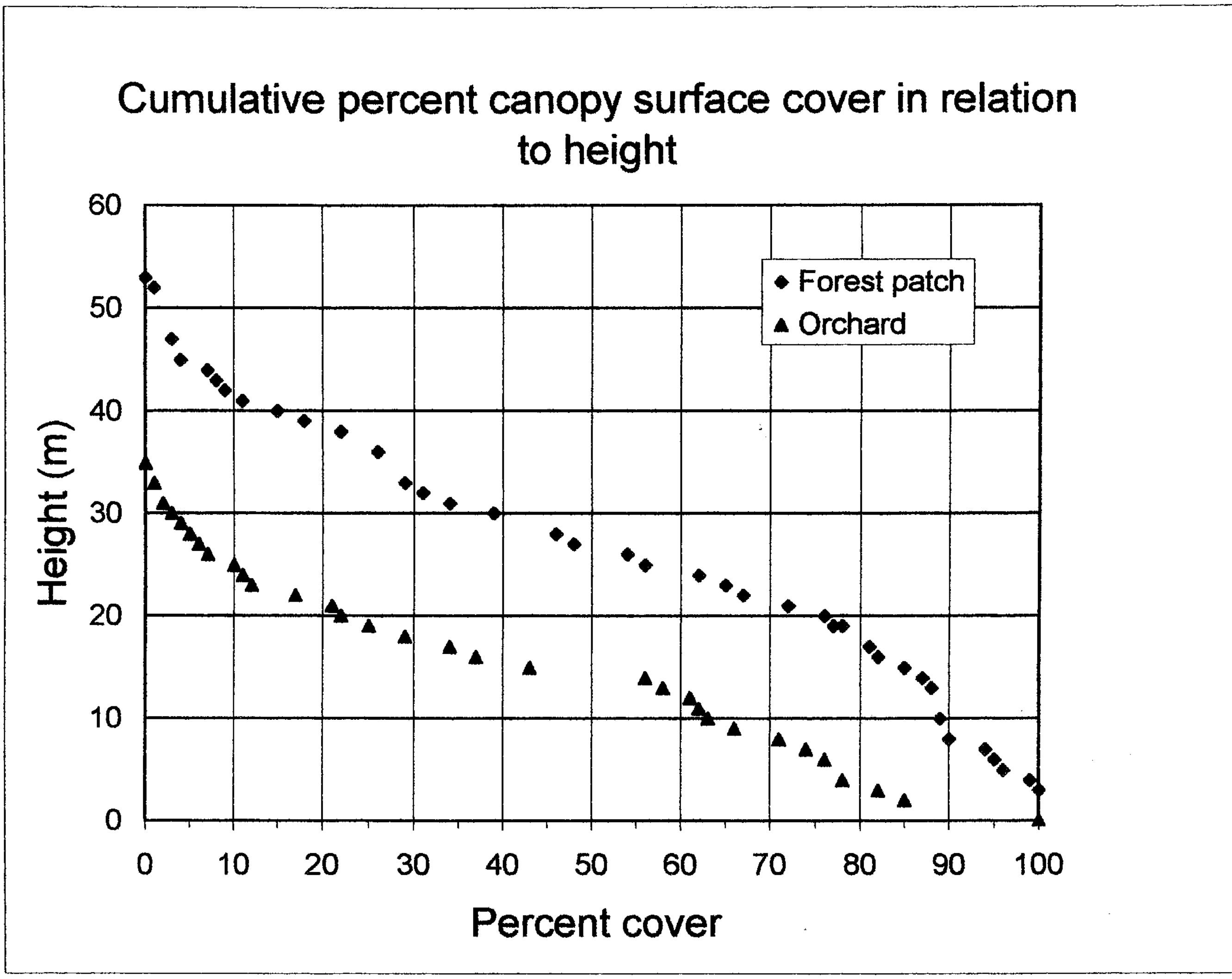


Figure 2. Canopy volume and distribution of canopy surface-height for the orchard in Ban Khiriwong. Canopy volume is the sum of horizontal area covered over height.

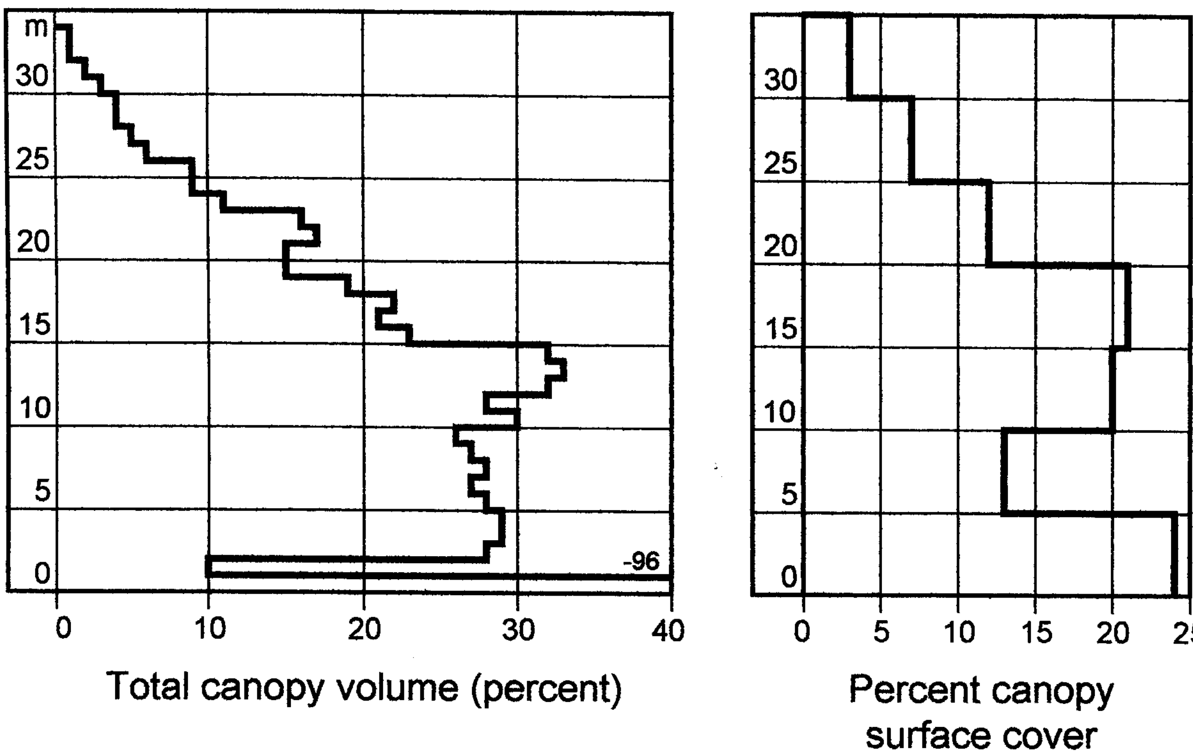


Figure 3. Canopy volume of fruit species in the Ban Khiriwong orchard.

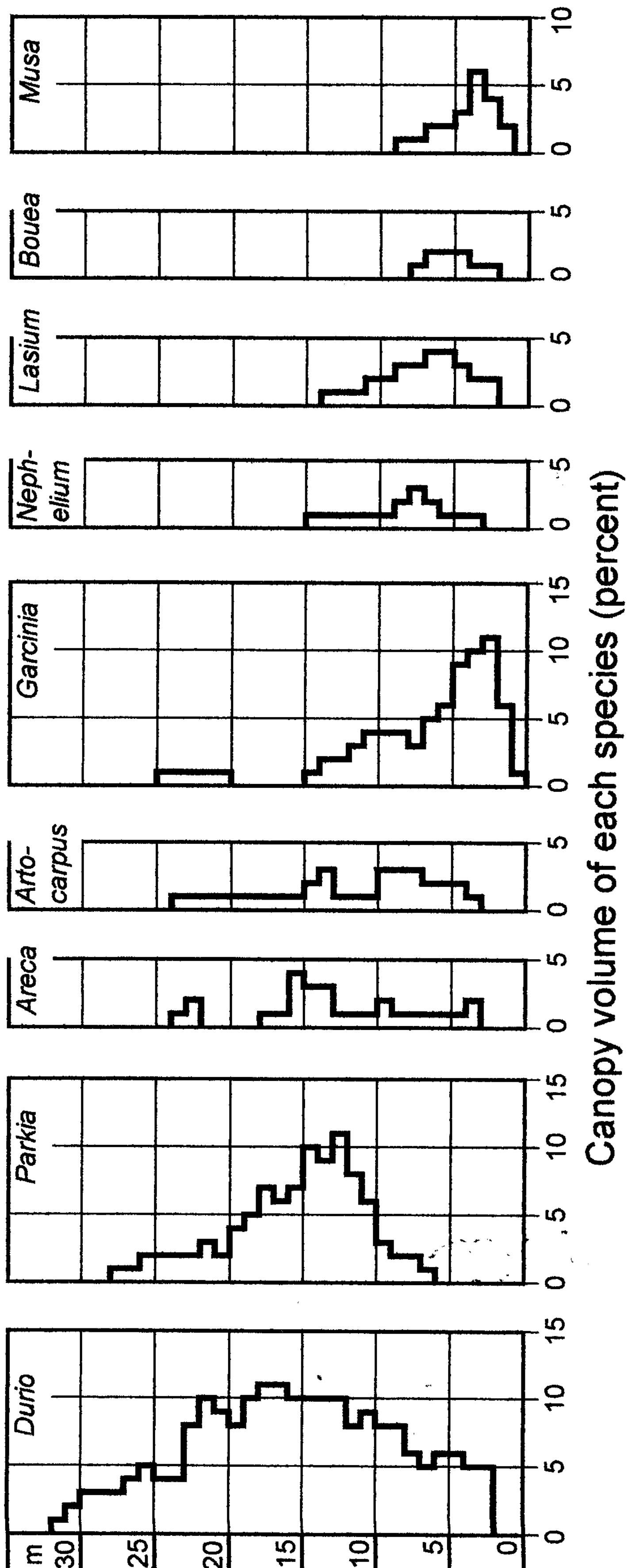
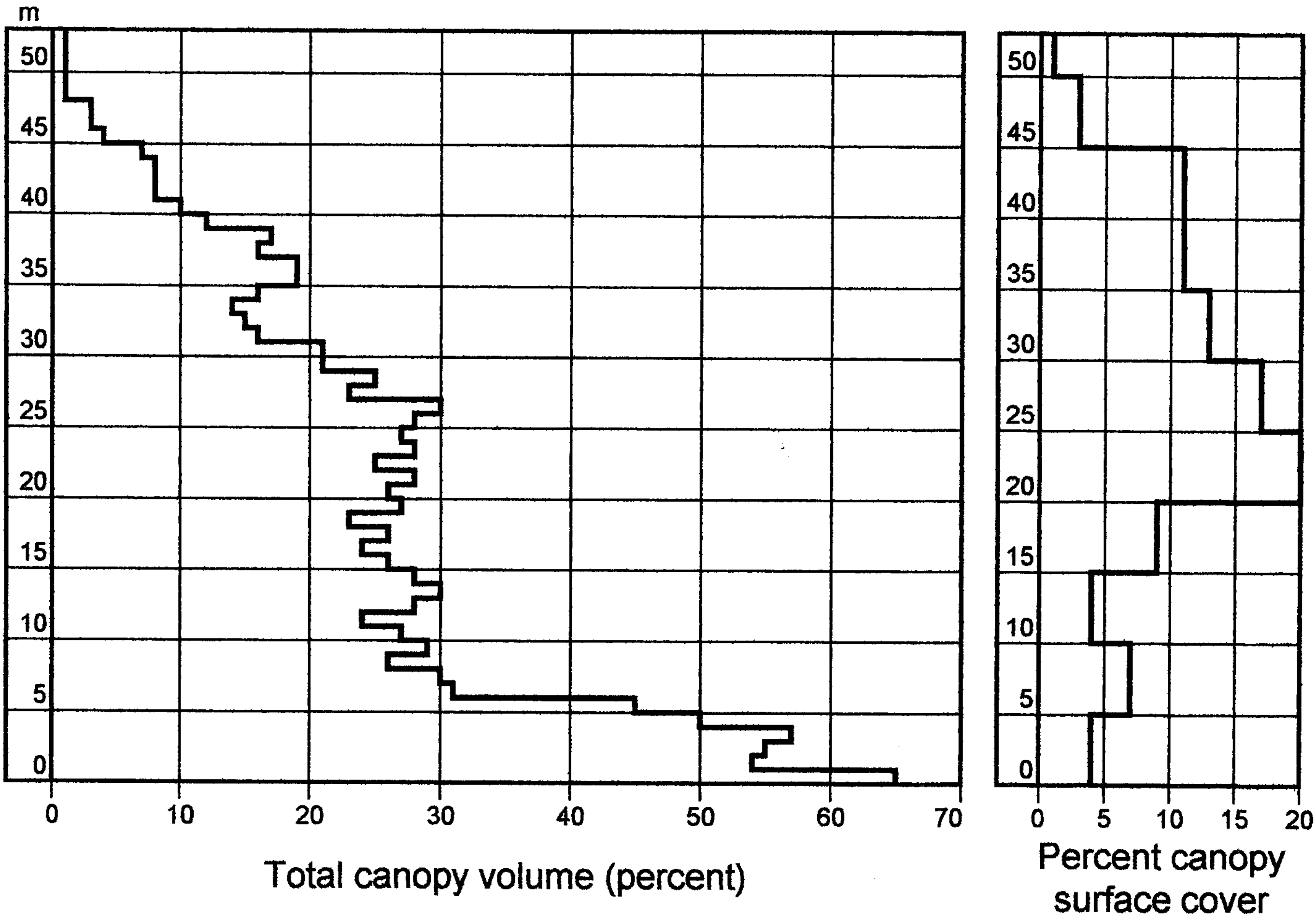


Figure 4. Canopy volume and distribution of canopy surface-height for the Forest Patch at Ban Khiriwong (compare with Figure 2).



A Comparison of Bird Communities in Managed Orchards and Natural Forest, outside and inside Khao Luang National Park, Nakhon Si Thammarat, South Thailand

Philip D. Round, George A. Gale, and Warren Y. Brockelman

(DRAFT)

INTRODUCTION

Many early assessments of the contribution of protected areas to national, regional and local economies, have focused on evaluating the benefits which accrue to society from maintaining large areas of forest, such as provision of critical services (*e.g.*, water cycling; maintenance of ecological processes, *etc.*) and also on equitable sharing of benefits from non-consumptive uses, such as ecotourism (*e.g.*, Brockelman and Dearden 1990; Dixon and Sherman 1991; McNeely and Dobias 1991). However, in recent years increased emphasis has been placed on the rights of local communities to both manage and utilise the resources of forests, including those inside protected areas. Social scientists have argued, primarily from the point of view of social justice, that the forests should be "returned to the people" (*e.g.*, Ramitanondh 1989). Some resource managers and community foresters, without objective data, have argued that parks and sanctuaries have failed to conserve biodiversity as intended, and that conservation would be better served if local people were involved in harvesting, and managing, their resources (Ghimire and Pimbert 1997; Makarabhirom 1998). This latter view is still widely held even though Bruner *et al.* (2001), during a wide survey of tropical protected areas, concluded that conventional protection, usually through exclusion or strict regulation of human use, was highly effective in protecting biodiversity through reducing land-clearance. Parks were also somewhat effective in mitigating other destructive uses such as logging, hunting, burning, grazing, *etc.* Satellite images, taken continuously since the 1960s, show the near total devastation wrought in lowland forests outside protected areas throughout SE Asia, due to a combination of logging, agriculture, and the spread of human settlements.

This debate between outright exclusion and opening protected areas for sustainable use has particular relevance in Thailand where a Community Forestry Bill is presently being considered by parliament. This would give communities the right to manage land inside national parks and wildlife sanctuaries, provided they can demonstrate that their occupation of these areas pre-dated their designation, and subject to them drawing up management plans and demonstrating sustainability of proposed activities (Makarabhirom *loc. cit.*). However, it is difficult to judge sustainability, as there are few cases where replicable and widespread monitoring of human uses or wildlife diversity and abundance inside protected areas has been carried out. The loss of larger, more sensitive species of birds and mammals from areas with heavy human use, yet which retain forest cover, is well documented (Round 1984, 1988; Robinson and Bennett 2000).

It is important that baseline studies are conducted to assess actual and potential human impacts of human use, and modification of vegetation, upon biodiversity before any changes in protected area policy are made. Although claims are often made of the historic role of communities in protecting forest and biodiversity, the capacity of communities to self-govern their natural resources cannot be assumed. Comparative work focusing on conditions under which communities can successfully manage their natural resources is scarce and biased, in part because social scientists and community forestry activists generally focus on institutions that persist, rather than those that have failed and disappeared (Barrett *et al.* 2001). In one of the few scientifically-based comparisons conducted, Salafsky *et al.* (2001) in a review of 39 project sites in Asia and the Pacific, found that community-based management strategies only worked under a limited set of circumstances, in which a mix of strategies including direct protection, management and restoration, policy and advocacy, as well as education and awareness was used.

There is a surprising scarcity (and, in Thailand, a near-complete absence) of studies, carried out by biologists, which have quantified the biodiversity values of existing community forests or intensively man-managed forests compared with "natural forest". For example, none of 29 papers in the 346-page proceedings of an international seminar "Biodiversity Conservation and Community Development" (Wood *et al.* 1995) attempted to quantify biodiversity in either managed or unmanaged habitats. Steinmetz and Mather (1996) measured wildlife abundance near Karen villages in Thung Yai Naresuan Wildlife Sanctuary, part of Thailand's ca. 20,000 sq. km Western Forest Complex, through line-transect methods. While they found moderate densities of small herbivores and some primates, their results concerning human impacts were inconclusive, partly due to lack of appropriate control areas. The United Nations Food and Agriculture Organization (FAO) misleadingly-titled *Community Forestry Note 13* "What about the wild animals?" (Redford *et. al.* 1995) concerned itself not with the abundance or diversity of wildlife in community forests, but rather with the opportunities for humans to harvest and eat wildlife, without considering sustainability.

One of very few studies on biodiversity in managed forests indicated that bird species richness in various Indonesian agroforests was about one-third to slightly more than one-half that in primary forest (Thiollay 1995). Fully 41% of birds encountered in forest were never found in the agro-forest, while 25% of the bird species in agro-forest did not enter forest. Disturbance of natural vegetation did not merely cause a reduction in number of bird species, therefore, but also involved replacements of the more sensitive forest-living species by others more tolerant of disturbance.

The Indonesian agro-forestry model, where native timber trees and fruit-trees and spices are grown, sometimes in association with durian (*Durio sp.*) and other native or near-native fruit trees in often highly complex and species-rich associations, is relatively well-studied (de Foresta and Michon 1990, 1991; Michon and Bompard 1987; Michon and de Foresta 1995). A similar agro-forestry system has operated around a few older settlements in southern Thailand, of which one of the best-known is Ban Khiriwong, Lan Saka District, Nakhon Si Thammarat Province on the steep slopes of the mountain of Khao Luang (Juiprik 1997). The "forest orchards" or *suan somrom* retain a dense woody cover of tall trees, mainly tall durian (*Durio zibethana* Murray) interspersed with several other species of fruit trees, and a few species used for wood such as *Michelia champaca* Linn. The durian planted is a local variety, in which the trees are allowed to grow to 30 m or more, and the fruits are harvested ripe as they drop from the tree. The Khiriwong orchards are often cited as a good example of peoples' coexistence with forest by the villagers who enthusiastically promote themselves as forest managers (Tourism Authority of Thailand 2000).

The age of the Khiriwong orchards is not reliably recorded, but local people claim that the area has been utilised in the same manner for ca. 100 years. The orchards are said to have many attributes of natural forest, and hence provide a useful substitute for it. It is certainly true that, because of its nearly closed canopy, the mixed orchards from some distance resemble natural forest. Although torrential rain and disastrous floods of November 1988 caused loss of life and property in Khiriwong village, this was largely due to log-slides and mud-slides from further up-slope, where newly-established rubber plantations had exposed much topsoil (Rao, 1988). Erosion and damage to trees in the immediate Khiriwong area was much less, suggesting that these old mixed orchards may mimic the watershed and soil stabilisation properties of forest.

The aim of this survey was to compare the ecological attributes of the Khiriwong mixed orchards with those of "natural forest" nearby, in Khao Luang National Park. The impetus for this study came from a visit to Ban Khiriwong by staff of the National Center for Genetic Engineering and Biotechnology (BIOTEC) during July 2000. The study consisted of two parts. The first was an analysis of the structural characteristics and plant diversity of mixed orchards in comparison with nearby natural forest. The second was a comparison of bird diversity between orchard and natural forest using standardised sample methods.

This paper presents the findings from the bird surveys. Birds were selected for study because they are diverse, with (in most cases) well known habitat requirements and general bionomics (*e.g.*, Round 1988; Lekagul and Round 1991), and they are relatively easily surveyed and detected, especially given familiarity with their vocalisations. They are therefore especially useful as indicators of biodiversity.

AIMS

This study was aimed at determining how closely the Khiriwong mixed orchards resembled natural or semi-natural forest in terms of their biodiversity, as measured by the composition of their bird communities.

Initially, it was assumed that representative examples of lowland or foothill forest, which could be compared with orchards, would be found at Khiriwong. In October 2000, when bird studies were commenced, the observers hiked up-slope in search of remaining forest patches, reaching an elevation of ca. 500 m, finding only a few very small and disturbed fragments of forest. One 4.5 ha fragment, surrounded by, and near the upper limit of, the fruit orchards was selected for survey. Because of its elevation and limited area it was intuitively felt that this site, which had been selectively logged, would have lost much of the diversity that would likely have existed in the Khriwong foothills before any settlements in the area. Almost no intact canopy forest of any significant extent remains at Khiriwong below about 500 or 600 m elevation, as was confirmed both by interviews with local people and by surveys on foot in October of 2000 and 2001. As demonstrated by Wells (1976, 1985) the diversity of lowland bird species in the Sunda subregion attenuates markedly with progression up the hill slopes, with the steepest distributional "break" occurring around the hill-foot boundary, placed by Wells (1976) at around 150 m in Malaysia. Sampling forest fragments on the upper hill slopes at >500 m would not, therefore, be expected to yield a bird fauna that was most comparable to that which would have been found in the orchard areas on the lower hill slopes around Khiriwong village when the area was still forested. Accordingly, a third study area in which the lowland and foothills forest avifauna of Khao Luang could be examined was required. After discussing this with birdwatchers familiar with Khao Luang National Park, and with National Parks Division staff, an area of mature forest at Krung Ching, Nop Phitam District, in the north of the park, was selected. These three study sites are henceforth referred to as Khiriwong Orchards; forest fragment (or forest patch) and Krung Ching forest.

STUDY AREAS

Khiriwong orchards

The area lay on foothills and lower submontane slopes on the south-eastern flank of Khao Luang at ca. 8° 26.5'N; 99° 45.5'E (Fig. 1). Areas covered by the survey ranged in elevation from approximately 160 m (valley bottom) to 320 m on the flanks of a steep-sided valley. Vegetation was predominantly orchard, formed mostly by durian trees, 20–30 m in height. Other canopy trees, included kathorn *Sandoricum koetkjape* Merr., sataw bean *Parkia speciosa* Hassle., betel nut *Areca catechu* Linn., planted for their fruits, together with *Michelia champaca* Linn., planted for timber. Trees comprising the middle storey include mangosteen *Garcina mangostana* Linn., langsat/longong *Lansium domesticum* Correa, and gandaria *Bouea macrophylla* Griff. The understorey was sparse, formed by a few *Salacca* palms and the ground layer was predominantly of grasses, 1 m high, with some tapioca. A few native trees remained, especially in ravines and along the banks of the stream. A detailed description of the vegetation is in preparation.

Khiriwong forest patch

This forest fragment lay at 8° 26.3'N; 99 44.5'E at 510–600 m elevation, approximately three hours walk up-slope from the lowest Khiriwong orchards near the village. The fragment was estimated to be 4.5 ha and contained a mix of disturbed and selectively logged forest with some trees exceeding 40 m in height. The fragment was completely encircled by orchards and or banana plantations. A small brook ran through its centre.

Krung Ching forest

Krung Ching lay on the northern flank of Khao Luang along the catchment of the Khlong Krung Ching, at roughly 8° 43'N; 99° 41'E (Fig. 1). This area was selected for study because it represented continuous, tall forest which was either unlogged, or had only been lightly logged in the past. It covered a range of elevation similar to that at the Khiriwong orchards, 180 m to 340 m, and was therefore appropriate for comparison. It differed from Khiriwong somewhat in that the topography in some areas, (notably along the valley of the Khlong Krung Ching) was less steep and encompassed a plateau of ca. 15 sq. km at roughly 300 m elevation. Data collection was limited to the northern and eastern margins of the plateau, up against the foothills, so as to cover an area as similar in topography as possible to Khiriwong, an area of c. 1.0 sq. km. The vegetation was tall and multi-storied, and rich in palms and lianas. It was relatively well-watered, with a number of small damp patches and forest streams. Areas of parkland and disturbed vegetation around the Krung Ching substation, in the extreme lowlands (<150 m) were somewhat similar to valley bottom habitat at Khiriwong in having already been cleared.

METHODS

Khiriwong lowland patch was visited during 28–30 October 2000; the Khiriwong hill-slope patch during 20–23 November 2001 and Krung Ching during 7–10 April 2001. At each site the observer walked slowly through each area, recording all birds seen or heard on "MacKinnnon Lists" (Bibby *et al.* 1998, MacKinnon and Phillips 1993). In this method, a list of each new species encountered is made, up to a predetermined number, when a new list is started. Each species therefore only appears once per list, regardless of whether the encounter is with a single individual or with a flock of several individuals. In this case, ca. 10 lists of 20 species were used because experience elsewhere in Thailand and SE Asia have shown this to be manageable and efficient (Round 1998, 1999). At both Khiriwong patches data collection was made partly along transects, spaced 100 m apart, used to collect vegetation data, although in order to obtain a sample of suitable size, data collection was not limited to the transects alone. Both the Khiriwong orchards survey and the Krung Ching survey were carried out by PDR, while the Khiriwong hill-slope patch survey was implemented by GG. The observers had a high familiarity with calls and songs of most species. Birds identified by sound were only counted if estimated to be within 30 m of the observer, in order to avoid over-counting species with loud, obtrusive calls, such as barbets.

Although for reasons given elsewhere (Round 1998, 1999), aerial-feeding birds are often excluded from lists, in this case, they were included in the tally since the number of individuals and species was small, and most were closely associated with, and fed over, the forest canopy. Both migrant and resident species were tallied, since surveys of the three sites took place when a reasonably complete complement of migrant species could be expected to be present. Efforts were made to spread coverage throughout the areas, in order to avoid bias from repeated observations of the same individual birds.

A species accumulation curve was drawn for each site. An average curve was fitted, by rotating the position of each list (so that first list and all subsequent lists became the last list in turn, and tallying anew each time). An average value for each list could then be obtained and a smooth curve fitted. The percentage of observations contributed by each species was also calculated as a means of objectively estimating relative abundance.

Nomenclature follows Round (2000).

RESULTS

A total of 130 species of birds was recorded at the three sites combined (Table 1). Fifty-nine species were recorded on ten lists (average 56.6 species on nine lists) in the Khiriwong orchards; 51 species on nine lists in the Khiriwong forest patch, and 82 species on 11 lists (average 75.8 species on nine lists) at Krung Ching (Fig. 2). Fifteen species were shared among all three sites; 18 species were found in the Khiriwong orchards but not at the other two sites, 12 species were found only in the Khiriwong forest patch, while 41 species, exactly half of all those found, were unique to Krung Ching. The two natural forest sites had 13 species in common that were not found in the orchards, while the forest patch and the orchard shared 13 species in common, which were not found in Krung Ching (Table 1).

The three sites had rather different bird communities, the two Khiriwong sites having slightly less than half their species in common ($C_S = 0.483$: Table 3). The most distinct site was the lowland forest at Krung Ching ($C_S = 0.383$ compared with the orchard, and 0.403 with the Khiriwong forest patch: Table 3).

The species accumulation curves for all sites were relatively steep, in no case reaching the asymptote, although the forest patch curve appeared to be flattening (Fig. 2). However, the list for Krung Ching climbed much more steeply than at either of the Khiriwong sites, reflecting the much greater species richness of this site.

Using a range of diversity indices, the lowland forest site (Krung Ching) was demonstrably more diverse than either of the two Khiriwong sites. A Fisher's Index (α)

value of 47.4 was obtained for the lowland forest site, compared with 28.2 for the orchard and 23.7 for the forest patch (Table 2).

Although the frequency distribution data from Krung Ching and the Khiriwong Forest Patch both fitted the log series ($\chi^2 = 4.66$ and $\chi^2 = 4.68$, respectively; for 3 degrees of freedom, $p > 0.10$), that for Khiriwong orchards appeared significantly different ($\chi^2 = 11.36$; for 3 degrees of freedom, $p < 0.01$). However, Leigh *et al.* (2000) make persuasive arguments for using Fisher's Index for diversity comparisons, even when the data does not necessarily fit a log-series. Further comments are made with respect to each site below.

Khiriwong Orchards

The most abundant species in the orchards were the bulbuls *Pycnonotus finlaysoni* and *Iole olivacea* (each recorded on 100% of lists); *Loriculus vernalis, Arachnothera longirostra* (90% of lists); *Muscicapa dauurica, Prinia rufescens* and *Anthreptes malacensis* (80% of lists); *Gerygone sulphurea* and *Dicaeum trigonostigma* (70%); *Megalaima australis, Pycnonotus melanicterus, Orthotomus atrogularis, Pellorneum ruficeps* and *Macronous gularis* (60%); *Cypsiurus balasiensis, Chloropsis cochinchinensis, Dicaeum cruentatum* and *Arachnothera chrysogenys* (50%); and *Phaenicophaeus tristis* and *Aegithina tiphia* (40%).

Of the total of 59 species, only 18 species (and only three of the 20 most abundant species listed above, *Iole olivacea, Dicaeum trigonostigma* and *Arachnothera chrysogenys*) were more or less strictly Sundaic forest birds, which together accounted for only 44 of 200 bird registrations (22%), the remainder being species that are widespread in the Indochinese subregion.

Babblers (Timaliinae) are generally good indicators of biodiversity, since all are short-winged forms with rather limited dispersal capabilities. The larger, least disturbed forests are rich in babblers. For example, Khao Nor Chuchi, possibly the single richest lowland forest site remaining in southern Thailand, possesses at least 22 species of babblers among the 318 bird species recorded there (Round and Treesucon, 1998). Only four species of babblers were recorded in the orchards, and together accounted for only 8% of all bird registrations. None of these species (*Macronous gularis, Pellorneum ruficeps, Stachyris nigriceps* and *Yuhina zantholeuca*) was of strictly Sundaic affinity, all being more or less common and widely distributed throughout the country.

The bird community at Khiriwong was heavily biased towards edge-inhabiting species, and species with a wide distributional range throughout Thailand, occurring in a variety of habitats. Nonetheless, Khiriwong possessed a number of interesting attributes. Three species of woodpeckers, Rufous Woodpecker *Celeus brachyurus*, Banded Woodpecker *Picus miniaceus* and Buff-rumped Woodpecker *Meiglyptes tristis*, were present. While two out of three are of Sundaic affinity, all are among the more ecologically tolerant of woodpeckers and are known elsewhere to enter plantations and orchards to some degree, although they would probably not be expected in monocultures such as rubber. Some nectarivores (*e.g., Arachnothera chrysogenys*, found on 50% of lists); small frugivores (*Megalaima australis*, found on 60% of lists); or frugivores/nectarivores, (*e.g., Loriculus vernalis*, on 90% of lists) were relatively well represented. *Loriculus* was regarded as being indicative of better quality forest by Round and Brockelman (1998) but the present results suggest they may be surprisingly tolerant, and perhaps do well in fruit orchards. However, another expected frugivore/nectarivore, Asian Fairy Bluebird *Irena puella*, which is normally abundant in mature forest, was completely absent from the orchards. It is not surprising that two ecologically tolerant flowerpecker species, the Sundaic Orange-bellied Flowerpecker *Dicaeum trigonostigma* (70% of lists) and widespread Scarlet-backed Flowerpecker *D. cruentatum* (50% of lists) should be common, but the absence of another species, Thick-billed Flowerpecker *D. agile*, more closely associated with forest, is telling.

Both White-rumped Shama and Asian Fairy Bluebird were detected further up-slope in small forest fragments. It is unlikely, therefore, that their absence from the orchards was due solely to capture for use as cagebirds, especially since Asian Fairy Bluebird was common in the forest patch (Table 1). The absence of the latter species from the orchards may reflect the lack of some important resource for this species, perhaps "keystone" fruiting species such as *Ficus*. Capture for use as a cagebird has impacted very strongly on White-rumped Shama, which was apparently so scarce in the forest fragment that it was not detected during the formal survey.

Only one species recorded at Khiriwong, Jerdon's Baza *Aviceda jerdoni*, was considered as nationally near-threatened (Round 2000).

Khiriwong Forest Patch

The most abundant species, *Alophoixus ochraceus*, *Arachnothera longirostra*, *Irena puella*, and *Pellorneum tickelli*, occurred on 100% of the lists. Other common species included *Macronous gularis*, *Pycnonotus melanicterus*, and *Yuhina zantholeuca* (88.9% of the lists); *Hypothymis azurea* and *Orthotomus sutorius* (66.7% of lists); *Chloropsis cyanopogon*, *Dicrurus leucophaeus*, *Orthotomus atrogularis* and *Tephrodornis virgatus* (55.6% of lists); *Arachnothera affinis*, *Dicrurus annectans*, *Eurylaimus ochromalus*, *Megalaima australis*, *Megalaima chrysopogon*, *Phylloscopus inornatus* and *Terpsiphone paradisi* (44.4% of lists).

The Khiriwong forest patch was less diverse than Krung Ching and somewhat similar in diversity and dominance to the Khiriwong orchards (Table 2).

Although the Asian Fairy Bluebird was quite common in the forest, the White-rumped Shama was not recorded during the survey, its abundance almost certainly being depressed due to trapping and collection of nestlings by local villagers. The species was heard in this patch in October 2000, while at least ten shamas were observed in cages in the nearest village.

While the Khiriwong forest patch held some forest species that were absent from the orchards, such as the Asian Fairy Bluebird, Moustached Babbler *Malacopteron magnirostre*, Brown Fulvetta *Alcippe brunneicauda* and Asian Paradise-flycatcher *Terpsiphone paradisi*, not surprisingly in view of its elevation it lacked the suite of lowland forest species recorded from Krung Ching. Seven species of babblers contributed 17.2 % of registrations. Although this exceeded the 8 % of registrations involving four species in the orchards, and also the 14.5 % of registrations contributed by babblers at Krung Ching (below), there were 13 babbler species, nearly twice as many, at the latter site. The only babbler species added by the Khiriwong forest patch that was not found elsewhere, and incidentally also the commonest, was Buff-breasted Babbler *Pellorneum tickelli*, which is a submontane and montane species. In fact, more than 75% of all babbler registrations in the Khiriwong forest patch were contributed by this species, together with the very tolerant and wide-ranging Striped Tit Babbler and White-bellied Yuhina. Overall, the proportion of registrations contributed by Sundaic bird species was 25.7 %, slightly greater than in the orchards, but still only half that in the Krung Ching lowland forest (below).

No hornbills, nor any other nationally rare or threatened species were detected in the Khiriwong forest patch.

Krung Ching

The most frequently recorded species were *Copsychus malabaricus* (90.9 % of lists); *Irena puella* (81.8% of lists); *Megalaima mystacophanos* (72.7 % of lists); *Alophoixus bres, Hypogramma hypogrammicum* (63.6% of lists), *Orthotomus atrogularis, Stachyris erythroptera* and *Arachnothera longirostra* (54.6 % of lists), *Megalaima australis, Aegithina viridissima, Oriolus xanthonotus, Rhinomyias olivacea, Pellorneum capistratum*, (45.5 % of lists); *Blythipicus rubiginosus, Megalaima chrysopogon, Calorhamphus fuliginosus, Phaenicophaeus javanicus, Aerodramus fuciphagus, Calyptomena viridis, Aegithina lafresnayei, Philentoma pyrhopterum, Pycnonotus brunneus* and *Malacopteron cinereum* (36.4 % of lists).

In comparison with both Khiriwong plots, the commonest species at Krung Ching showed less overall predominance, as would be expected of a more diverse habitat. Neither of the commonest species at Krung Ching, White-rumped Shama, an understorey-inhabiting insectivore, and Asian Fairy Bluebird, an arboreal frugivore, was detected in the Khiriwong orchards, though *Irena* was very abundant in the Khiriwong forest patch. The commonest bulbul found at Krung Ching, *Alophoixus bres*, is characteristic of forest at lower elevations and was recorded in neither of the Khiriwong plots but was replaced by Ochraceous Bulbul, *A. ochraceus* in the forest patch (Table 1). Ecotone-inhabiting bulbuls, and those feeding on the small fruits of pioneer tree species (*e.g.*, most *Pycnonotus* spp., *Iole olivacea*), which predominated in the Khiriwong orchards were scarcer at Krung Ching. In contrast to the Khiriwong orchards, where just one species of barbet was recorded, Krung Ching held four species, all of which were in the first twenty most abundant species and together accounted for 9.5% of sightings. In the Khiriwong forest patch three species of barbets were recorded, and accounted for only 5.5% of registrations.

Krung Ching held 13 species of babblers, which accounted for 32 of 220 bird registrations (14.5%), compared with only three species in the Khiriwong orchards and seven in the forest patch. None of the three commonest babblers at Krung Ching, *Stachyris erythroptera, Pellorneum capistratum* and *Malacopteron cinereum*, was recorded at the other two sites.

Altogether, species of Sundaic affinity, and more or less obligate forest birds, contributed 122 of 220 bird registrations at Krung Ching (55.5%), more than twice the proportion in the Khiriwong orchards. Approximately 19 species recorded at Krung Chung (23%) would probably not be expected to occur at >500 m elevation, based on their (lowland forest) habitat requirements. Even so, the Krung Ching sample should not be taken as fully representative of a lowland-forest community since, even there, the plains were already devoid of forest cover, and many extreme lowland specialists were not detected.

The presence of four species of hornbills at Krung Ching, and their complete absence from the other two sites was especially noteworthy. Eight species of bird found at Krung Ching were listed as nationally threatened /near-threatened by Round (2000): in addition to the hornbills mentioned above, these were Malaysian Honeyguide *Indicator archipelagicus*, Dark-throated Oriole *Oriolus xanthonotus*, Ferruginous Babbler *Trichastoma bicolor* and Chestnut-rumped Babbler *Stachyris maculata*. The Krung Ching area also still supported a few primates. Both White-handed Gibbon *Hylobates lar* and Dusky Leaf Monkey *Trachypithecus obscurus* were heard, while a few Black Giant Squirrels *Ratufa bicolor* were seen. None of these species was recorded at either of the Khiriwong sites.

Effects of human disturbance

Although this survey did not attempt a detailed examination of use of forest and forest products by local people, this is clearly an aspect of crucial importance in understanding local avifaunas and other aspects of biodiversity. The effects of human use are varied, impacting on the avifauna through both directly (hunting and persecution) and indirectly (through habitat loss and fragmentation).

Hunting and trapping

The local people at Khiriwong were still trapping wild birds in violation of wildlife protection laws. On 22 November 2001 while walking back from surveying the forest fragment, a group of men were observed walking downslope towards Khiriwong village with two cages, each of which contained a Blue-winged Leafbird. It was not clear whether the live birds were decoys or newly trapped birds, though this nonetheless provided direct evidence that local people were still actively involved in trapping wild birds. In addition to the ten White-rumped Shamas (already mentioned), 11 Asian Fairy Bluebirds, one Vernal Hanging Parrot, one Red-whiskered Bulbul *Pycnonotus jocosus*, one Verditer Flycatcher *Eumyias thalassina*, and one *Cyornis* flycatcher were observed in cages in Khiriwong village. The great scarcity of White-rumped Shamas in both orchards and in the forest fragment was almost certainly due to such pressures.

Larger species such as hornbills are particularly vulnerable to direct disturbance, by shooting of adults, and by collection of nestlings for the pet trade. However, it is likely that most hornbills would have disappeared from Khiriwong many years earlier due to a combination of direct disturbance and habitat loss.

Removal of natural forest cover

The most obvious effect of high levels of human use at Khiriwong was the loss of natural forest cover from most areas below 600–700 m elevation. As we have shown, this has removed habitat for a wide range of more ecologically sensitive, lowland forest species. The Khiriwong forest patch lay well above the normal upper altitudinal limits for some species found at Krung Ching , such as *Oriolus xanthonotus, Trichastoma bicolor*, and *Stachyris maculata*

Contra assertions about the stability of the agroforestry systems at Khiriwong, the replacement of forest by plantation was still in progress, even in areas lying inside Khao Luang National Park. During the survey in November 2001 we observed new orchards in the process of being established within the park boundary at elevations of 700 m upwards to at least 800 m. Gradual enlargement of cultivated areas is a persistent problem in situations where local people are farming land in close proximity to forest, and is very difficult to monitor. Since the boundary between forest and cultivated land is seldom demarcated by permanent markers, the temptation for local people to expand their clearings will always exist, especially in the absence of any realistic social sanction applied to offenders by *tambol* administrative organisations (TAOs), or other local, democratically-elected, institutions. This was one of the key problems identified by Round and Hobart (1994) associated with community forestry initiatives elsewhere in S. Thailand, at Khao Nor Chuchi.

Fragmentation of habitat

Many hornbills, including all four species found at Krung Ching, are still present elsewhere in southern Thailand at elevations similar to that of the Khiriwong forest patch. Such a small fragment as the 4.5 ha Khiriwong forest patch was clearly too small to hold hornbills or other large birds which occur at low density. However, it is not easy to disentangle the effects of fragmentation from other factors (McGarigal and Cushman 2002). Hornbills will also have been impacted by hunting, the effects of which are liable to be more severe in small forest patches, where there is little, or reduced, possibility of recolonisation from elsewhere. Habitat fragmentation also impacts on smaller birds. The forest interior frugivore, Green Broadbill *Calyptomena viridis* was not detected in the forest patch. Ford and Davison (1995) also noted a marked reduction in babblers and other understory birds even from patches as large as 500–800 ha.

DISCUSSION

All three sites surveyed showed a moderate to high diversity of birds. At another site in S. Thailand, Khao Nor Chuchi, Krabi, Round and Brockelman (1998) obtained Fisher's Index values of 31.0 and 32.8 for mature forest; 22.6 and 27.0 for secondary forest and 19.2 for regenerating clearing. These were lower than that obtained for forest at Krung Ching but comparable with that obtained for the Khiriwong orchards (28.2). However, a sampling method other than MacKinnon Lists was used at Khao Nor Chuchi, in which all individuals of a species were counted. This would lead to a lower S/N ratio, and hence seemingly lower diversity, than would be obtained under MacKinnon lists. Where MacKinnon Lists were used for another habitat in S Laos, species-rich, plains dry dipterocarp forest, a value almost as high as Krung Ching (41.7, compared with 47.4; Round 1998) was obtained. Calculation of Fisher's Index for a wider sample of bird communities in different habitats, and using a range of sampling methods, and sample sizes would be instructive. Nonetheless, it is already clear that diversity at both Khiriwong sites was much depressed in relation to a range of less disturbed forest habitats.

Other than for vegetation type, the two lowland/foothills sites, Khiriwong orchards and Krung Ching, were judged to be comparable in their environmental features and location. Both covered a roughly similar range of elevations (though Krung Ching was of marginally less steep topography than Khiriwong), and included major streams. Greater concern is given by the fact that Khiriwong was surveyed during October, after the end of the breeding season, when bird vocalising was generally at a lower level, whereas Krung Ching was censused in April, at a time when most forest birds were breeding and probably vocalised more. However, it is not thought that this was a significant source of error, since birds were detected both by sight and by sound. It probably takes longer to amass a sample when birds are calling less, but there should be little bias over differential detectability among species (MacKinnon and Phillips 1993). The main exception for this are the parasitic cuckoos, *Cuculus micropterus*, *Cacomantis* spp., *Chrysococcyx* spp., and *Surniculus lugubris*, which are more or less always difficult to observe, but have loud vocalisations during the breeding season, and are therefore much more detectable at such times. However parasitic cuckoos contributed only three of 220 registrations at Krung Ching. This was too small a proportion to pose any significant bias.

Differences arising from coverage of one of the sites (the Khiriwong forest patch by a different observer (GG) are likely to be minimal, since the MacKinnon lists method is relatively robust and little affected by difference in observer skills (Bibby, *et al.*, 1998). Even though a small proportion of individual birds were not identified with certainty in the forest patch, they could still be included in the analysis (Tables 1, 2) because they were recognisable as distinct species.

The three sites were strongly dissimilar, with rather limited overlap among their avifaunas. The Khiriwong orchards differed markedly in the structure and composition of their bird community in comparison to the lowland forest, exemplified by Krung Ching. In particular, the orchards lacked most of those species characteristic of the Sundaic lowland forest bird community, and the majority of species recorded were widespread and ecologically tolerant birds, found in a range of habitats, including forest, forest edge, plantations or open cultivated land throughout Thailand. The Khiriwong orchards were especially depauperate in understorey-inhabiting insectivores, such as babblers, and even the relatively ecologically tolerant White-rumped Shama, while a great many other species of obligate forest bird found at Krung Ching were also absent. Although smaller frugivores and nectarivores fared better, they were heavily biased in favour of edge-inhabiting species, and other, small to medium frugivores which were abundant in forest, such as Asian Fairy Bluebird, were absent. Our results closely parallel those of Thiollay (1995) for Indonesian traditional agro-forests. He, too, found that larger frugivores, larger insectivores of both canopy and understorey, and terrestrial insectivores of the forest interior, were absent from, or much reduced in, agro-forests. Species persisting included small frugivores, smaller, foliage-gleaning insectivores, nectarivores and edge species.

Although the Khiriwong forest patch was only a short distance from the orchards, it differed markedly in the composition of its avifauna, possessing a few more forest species, and a few "new" species characteristic of higher elevations. Nonetheless, it bore considerably more similarity to the orchards than it did to the other, closed canopy forest site, Krung Ching. This may, at first site, seem surprising, but it illustrates the outstanding richness of the lowland avifauna in comparison with the relatively depauperate hill-slope and submontane avifaunas in the Sunda subregion (Wells 1985, 1999). Some edge-inhabiting species may move between the orchards and the forest patch, while many forest-interior species will have been lost due to area effect. The smallness of the forest patch may cause it to "mirror" (after Diamond *et al.* 1987) the attributes of surrounding cultivated areas to some degree.

Mixed-species forest orchards, such as those at Khiriwong, offer food resources for a number of smaller nectarivorous and frugivorous birds, such as *Megalaima australis*, *Loriculus vernalis*, *Dicaeum trigonostigma* and *Arachnothera chrysogenys*, which would not be found in monoculture plantations such as rubber. The species accumulation curve for rubber plantation surveyed at Khao Nor Chuchi, Krabi, S. Thailand by Gro-Nielsen (1997) reached an asymptote at ≤ 25 species, less than half that for Khiriwong.

It could therefore be argued that Khiriwong is relatively well-off in comparison with other agricultural areas, for example, in rubber plantations that have been allowed to ascend hill slopes to 600 m or even higher. The Khiriwong model might, therefore, be appropriate for habitat diversification, and restoration of modest levels of biodiversity in sites that have already been heavily impacted by man, and in which continued human agricultural use is a major imperative. However, it should certainly not be seen as a satisfactory alternative to conservation forest in protected areas, as exclusion of human use is the best means of maintaining biodiversity.

It is assumed that plant species richness will impact upon bird diversity. A plant community which is poorer in species will, other things being equal, offer fewer foraging niches for birds (Wiens and Rotenberry 1981; Hansen *et al.* 1995). Clearly, the Khiriwong orchards had many fewer species of large tree than forest, and it would be expected that orchards would offer a smaller range of fruit and other food resources than forest. However, it is unclear to what extent the poor representation of understorey and middle storey insectivores is a function of reduced structural complexity, as opposed to biotic complexity, of the vegetation. A forest would have a large number of tree seedlings, rattans and other vegetation occupying the lower strata, whereas the understorey in the Khiriwong orchards was sparse or absent. It is possible that if more varied undergrowth was allowed to grow beneath the fruit trees, populations of some understorey birds might eventually recover.

By default, the model for conservation followed in southern Thailand and elsewhere throughout the Sunda subregion, has been one in which rural populations have been allowed to expand cultivation to occupy virtually the entire lowland area, with forest being allowed to remain, if at all, on hill-slopes only. While this may be appropriate for watershed conservation, it is a very poor strategy for biodiversity conservation. As this study has shown, neither patches of closed canopy, multi-storied forest on hill slopes nor tall, mature orchards of the valley bottom and foothills were an adequate substitute for original, closed canopy forest of lowlands and foothills which clearly surpassed the former areas in avian richness.

This study conclusively demonstrates that in no sense can the kind of agro-forestry or community forestry practised by the local community at Khiriwong be regarded as a substitute for conventional protection of biodiversity through establishing protected areas, and conserving original vegetation cover. The bird community of the orchards was heavily skewed towards ecologically tolerant edge species, and widespread Indo-Malayan birds of drier and disturbed habitats. The boundary of the remaining forest lay at too high an elevation to support more than a highly attenuated lowland avifauna, completely lacking in the kind of lowland forest specialists found in mature forest of the foothills. Even where original vegetation remained, the forest patches were too small to support larger birds such as hornbills, or even some sensitive forest-interior insectivores that might otherwise persist at that elevation. Additionally, we found a high level of human disturbance of the remaining forest patches. Hunting or theft of nestlings probably also contributed to the absence of hornbills and the great scarcity of even such small birds as White-rumped Shama, while new and continuing clearance of forest was observed during the survey. It appears that orchards were still being expanded at the expense of the forest.

In fact, even Krung Ching, which lay in the foothills rather than in the plains, did not truly exemplify the outstanding richness of the (now almost vanished) lowland forest that once covered Thailand's lowlands. Lowland specialists such as Black Hornbill *Anthracoceros malayanus*, Red-crowned Barbet *Megalaima rafflesii*, Sooty-headed Babbler *Malacopteron affine*, Large Wren Babbler *Napothera macrodactyla*, Striped Wren Babbler *Kenopia striata*, and many other species, some of which are still today found in small numbers elsewhere, at Khao Nor Chuchi (Round and Treesucon 1998), were absent or undetected at Krung Ching due to the absence of any extreme lowland or plains forest. We believe that our findings are highly significant for pursuing biodiversity conservation in man-modified landscapes. We should not be seeking, as a general principle, to extend or legitimise extractive human use in national parks and other protected areas, as many Thai NGOs, and some international conservation agencies (IUCN 2002), have suggested, since this would further reduce biodiversity. A more appropriate strategy would be to encourage agricultural diversification in existing plantations, while seeking to restore original forest cover in selected areas around the lowland margins of existing protected areas, perhaps through "buy-back" or financial compensation to farmers or landowners, such as in Florida, USA (Main *et al.* 1999). The active engagement of local people on park management boards should also be sought to help further these goals.

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Table 1 Numbers and species of birds recorded in orchard and forest habitats, Khao Luang National Park

Numbers represent no. of occurrences on 20-species MacKinnon Lists. (Khiriwong orchard, 10 lists; Khiriwong forest patch, 9 lists; Krung Ching, 11 lists,)

Species	Common name	Khiriwong (orchard)	Khiriwong (forest patch)	Krung Ching (forest)
Accipiter badius	Shikra	1	1	0
Aceros undulatus	Wreathed Hornbill	0	0	1
Aegithina lafresnayei	Great Iora	1	0	4
Aegithina tiphia	Common Iora	4	0	0
Aegithina viridissima	Green Iora	1	0	5
Aerodramus fuciphagus	Edible-nest swiftlet	0	0	4
Aethopyga siparaja	Crimson Sunbird	2	0	0
Aethopyga temminckii	Scarlet Sunbird	0	3	0
Alcippe brunneicauda	Brown Fulvetta	0	2	1
Alophoixus bres	Grey-cheeked Bulbul	0	0	7
Alophoixus ochraceus	Ochraceous Bulbul	1	9	3
Alophoixus phaeocephalus	Yellow-bellied Bulbul	0	0	2
Anorrhinus galeritus	Bushy-crested Hornbill	0	0	1
Anthreptes malacensis	Brown-throated Sunbird	8	0	0
Anthreptes simplex	Plain Sunbird	1	1	0
Anthreptes singalensis	Ruby-cheeked Sunbird	4	0	1
Arachnothera affinis	Grey-breasted Spiderhunter	0	4	1
Arachnothera chrysogenys	Yellow-eared Spiderhunter	5	2	1
Arachnothera flavigaster	Spectacled Spiderhunter	1	0	0
Arachnothera longirostra	Little Spiderhunter	9	9	6
Aviceda jerdoni	Jerdon's Baza	1	0	0
Berenicornis comatus	White-crowned Hornbill	0	0	3
Blythipicus rubiginosus	Maroon Woodpecker	0	0	4
Buceros vigil	Helmeted Hornbill	0	0	1
Cacomantis merulinus	Plaintive Cuckoo	0	2	0
Cacomantis sonneratii	Banded Bay Cuckoo	0	0	1
Calorhamphus fuliginosus	Brown Barbet	0	0	4
Calyptomena viridis	Green Broadbill	0	0	4
Celeus brachyurus	Rufous Woodpecker	2	0	0
Centropus sinensis	Greater Coucal	1	0	0
Ceyx erithacus	Rufous-backed Kingfisher	0	0	2
Chalcophaps indica	Emerald Dove	1	0	0
Chloropsis cochinchinensis	Blue-winged Leafbird	5	2	2
Chloropsis cyanopogon	Lesser Green Leafbird	1	5	3
Copsychus malabaricus	White-rumped Shama	0	0	10
Copsychus saularis	Oriental Magpie Robin	1	0	0

Species	Common name	Khiriwong (orchard)	Khiriwong (forest patch)	Krung Ching (forest)
Corydon sumatranus	Dusky Broadbill	0	0	1
Cuculus micropterus	Indian Cuckoo	0	0	1
Culicicapa ceylonensis	Grey-headed Flycatcher	0	3	3
Cypsiurus balasiensis	Asian Palm Swift	5	2	0
Dendronanthus indicus	Forest Wagtail	1	0	0
Dicaeum cruentatum	Scarlet-backed Flowerpecker	5	0	1
Dicaeum trigonostigma	Orange-bellied Flowerpecker	7	0	1
Dicrurus annectans	Crow-billed Drongo	0	4	0
*Dicrurus hottentottus**	Hair-crested Drongo	0	2	0
Dicrurus leucophaeus	Ashy Drongo	0	5	0
Enicurus leschenaulti	White-crowned Forktail	0	0	2
Eurylaimus ochromalus	Black-and-yellow Broadbill	1	4	3
Gerygone sulphurea	Golden-bellied Gerygone	7	0	0
Harpactes diardii	Diard's Trogon	0	0	1
Harpactes oreskios	Orange-breasted Trogon	0	1	0
Hemiprocne comata	Whiskered Treeswift	1	0	0
Hemiprocne longipennis	Grey-rumped Treeswift	5	0	0
Hemipus picatus	Bar-winged Flycatcher-shrike	6	0	1
Hirundo rustica	Barn Swallow	0	0	1
Hypogramma hypogrammicum	Purple-naped Sunbird	0	0	7
Hypothymis azurea	Black-naped Monarch	0	6	3
Indicator archipelagicus	Malaysian Honeyguide	0	0	1
Iole olivacea	Buff-vented Bulbul	10	0	1
Irena puella	Asian Fairy Bluebird	0	9	9
Lacedo pulchella	Banded Kingfisher	0	0	1
Loriculus vernalis	Vernal Hanging Parrot	9	3	0
Luscinia cyane	Siberian Blue Robin	2	0	1
Macronous gularis	Striped Tit Babbler	6	8	3
Malacocincla abbotti	Abbott's Babbler	0	0	1
Malacocincla malaccensis	Short-tailed Babbler	0	0	3
Malacopteron cinereum	Scaly-crowned Babbler	0	0	4
Malacopteron magnirostre	Moustached Babbler	0	2	2
Megalaima australis	Blue-eared Barbet	6	4	5
Megalaima chrysopogon	Gold-whiskered Barbet	0	4	4
Megalaima mystacophanos	Red-throated Barbet	0	2	8
Meiglyptes tristis	Buff-rumped Woodpecker	2	0	1
Muscicapa dauurica	Asian Brown Flycatcher	8	2	1
Muscicapa sibirica	Dark-sided Flycatcher	0	0	1
Myiophoneus caeruleus	Blue Whistling Thrush	0	1	0
Nectarinia jugularis	Olive-backed Sunbird	1	1	0
Nyctyornis amictus	Red-bearded Bee-eater	0	0	2
Oriolus xanthonotus	Dark-throated Oriole	0	0	5

Species	Common name	Khiriwong (orchard)	Khiriwong (forest patch)	Krung Ching (forest)
Orthotomus atrogularis	Dark-necked Tailorbird	6	5	6
Orthotomus sutorius	Common Tailorbird	3	6	1
Pellorneum capistratum	Black-capped Babbler	0	0	5
Pellorneum ruficeps	Puff-throated Babbler	6	1	0
Pellorneum tickelli	Buff-breasted Babler	0	9	0
Pericrocotus divaricatus	Ashy Minivet	2	1	0
Pericrocotus flammeus	Scarlet Minivet	2	2	0
Pericrocotus roseus	Rosy Minivet	0	1	0
Phaenicophaeus chlorophaeus	Raffles's Malkoha	0	0	2
Phaenicophaeus curvirostris	Chestnut-breasted Malkoha	1	2	1
Phaenicophaeus javanicus	Red-billed Malkoha	0	0	4
Phaenicophaeus tristis	Green-billed Malkoha	4	0	0
Philentoma pyrhopterum	Rufous-winged Flycatcher	0	0	4
Phylloscopus borealis	Arctic Warbler	1	0	3
Phylloscopus coronatus	Eastern Crowned Warbler	3	0	2
Phylloscopus inornatus	Yellow-browed Warbler	1	4	0
Phylloscopus tenellipes	Pale-legged Leaf Warbler	1	2	0
Picus miniaceus	Banded Woodpecker	2	0	0
Pitta guajana	Banded Pitta	0	0	2
Platylophus galericulatus	Crested Jay	0	0	1
Prinia rufescens	Rufescent Prinia	8	0	0
Prionochilus maculatus	Yellow-breasted Flowerpecker	0	2	3
Prionochilus percussus	Crimson-breasted Flowerpecker	0	0	1
Pycnonotus atriceps	Black-headed Bulbul	0	2	1
Pycnonotus brunneus	Red-eyed Bulbul	1	2	4
Pycnonotus erythrophthalmos	Spectacled Bulbul	1	0	1
Pycnonotus finlaysoni	Stripe-throated Bulbul	10	1	0
Pycnonotus melanicterus	Black-crested Bulbul	6	8	2
Rhaphidura leucopygialis	Silver-rumped Swift	3	0	0
Rhinomyias olivacea	Fulvous-chested Flycatcher	0	3	5
Spilornis cheela	Crested Serpent-Eagle	1	3	0
Spizaetus alboniger	Blyth's Hawk-Eagle	1	0	0
Stachyris erythroptera	Chestnut-winged Babbler	0	0	6
Stachyris maculata	Chestnut-rumped Babbler	0	0	1
Stachyris nigriceps	Grey-throated Babbler	2	3	2
Stachyris poliocephala	Grey-headed Babbler	0	0	2
Stachyris striolata	Spot-necked Babbler	0	0	1
Surniculus lugubris	Drongo Cuckoo	0	0	1
Tephrodornis virgatus	Large Woodshrike	0	5	1
Terpsiphone paradisi	Asian Paradise-flycatcher	0	4	2
Treron (curvirostra)	Thick-billed Pigeon	1	0	2
Trichastoma bicolor	Ferruginous Babbler	0	0	2

Species	Common name	Khiriwong (orchard)	Khiriwong (forest patch)	Krung Ching (forest)
Tricholestes criniger	Hairy-backed Bulbul	0	0	3
Yuhina zantholeuca	White-bellied Yuhina	2	8	0
Zoothera citrina	Orange-headed Thrush	0	3	0
Total number of individuals		200	180	220

(* There appear to be no previous records of *D. hottentottus* for the Thai-Malay Peninsula. This record is provisionally retained for the purposes of this analysis, while recognising that further evidence would be necessary before adding it to the faunal list. *D. h. brevirostris* is a common winter visitor to a range of woodland habiatts, including close canopy evergreen forest in continental Thailand and its occasional occurrence in peninsular Thailand seems likely.)

Table 2. A comparison of bird diversity among three study sites

	Khiriwong	Krung Ching	Khiriwong (forest patch)
N	200	220	180
S	59	82	51
Fisher's α	28.23	47.39	23.72
Shannon-Wiener	3.77	4.16	3.58
Simpson (reciprocal)	42.89	68.05	42.85
McIntosh	0.895	0.924	0.897
Berger-Parker (reciprocal)	20	22	20

Table 3. Coefficients of similarity among the three sites

	Similarity index	Khiriwong orchard	Khiriwong forest patch
Krung Ching	Sorensen (qualitative	0.383	0.403
	Sorensen (quantitative)	0.111	0.175
Khiriwong forest patch	Sorensen (qualitative	0.483	-
	Sorensen (quantitative)	0.166	

Fig. 2. Species accumulation curves for forest orchards, forest patch and forest, Khao Luang National Park