Research paper

Applying a Territory Mapping Method to Census the Breeding Bird Community Composition in a Montane Forest of Taiwan

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【Summary】

Territory mapping is considered one of the most accurate methods for estimating forest bird densities and studying the subtle relationships between birds and their habitats. Nevertheless, the territory mapping method has rarely been applied to estimate entire bird communities in tropical and subtropical regions of Asia. We conducted territory mappings in an area of around 40 ha at a mid-elevation site in Taiwan for a period of 20 consecutive weeks (40 census days in total) from early March to late July 2005 to establish field protocols of territory mapping and examine the effectiveness of this method in detecting the avian community composition. Fifty-seven bird species from 5719 registrations were recorded during the 40 field censuses. The results suggested that the optimal period for territory mapping at the study site was during 10~12 wk from early April to late June, because during this period, the prevalences of most breeding species were highest. Within this period of time, we registered 88% of the breeding species recorded historically. Repeatedly playing 2 repetitions of the territorial songs of the 14 commonest species did not significantly affect the total number of breeding species or registrations recorded on each census. These results indicate that with a good trail system, the territory mapping method is suitable for censusing bird communities in forests of Taiwan and similar habitats in Asia. However, due to the non-territorial behavior, asynchronous breeding season, and multiple broodings of birds in tropical and subtropical regions, the efficiency of territory mapping method is not as good as that in temperate regions.

Key words: census efficacy, community composition, optimal census time, playback effect, spot mapping.

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研究報告

以領域描圖法調查台灣山區森林繁殖鳥類群聚組成

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摘　要

領域描圖法被視為能準確估計森林繁殖鳥類密度，並適合於探討鳥類與棲地間的細微關聯。然而，領域描圖法甚少被用來估計熱帶及亞熱帶亞洲的鳥類群聚組成。我們於2005年3月上旬至7月下旬對台灣中海拔地區約40公頃範圍之鳥類群聚，進行連續20週、共40天次之領域描圖法。研究目的為建立領域描圖法操作方法及探討此方法對鳥類群聚組成的察覺效率。研究期間紀錄到57種鳥，共5719筆紀錄。研究結果顯示，4月上旬至6月上旬是以領域描圖法調查台灣中海拔繁殖鳥類群聚的最佳時間。在這段時間內，本方法可以察覺到88%過去曾經紀錄到的繁殖鳥種。在進行領域描圖法時伴隨錄音回播，以當地最普遍14種鳥類的領域性鳴唱聲重複兩次的方式，對於所調查到之繁殖鳥類種數及數量並無顯著影響。因此，若有完善的步道系統，領域描圖法應該可以適合用於調查台灣森林及亞洲類似棲地的鳥類群聚組成。然而，由於熱帶及亞熱帶部分鳥類領域行為並不明顯，繁殖季節常不同步，且常一季多巢，領域描圖法的效率並不如在溫帶地區進行的結果。

關鍵詞：覺察效率、群聚組成、最適調查時間、回播效應、領域描圖法。

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INTRODUCTION

Birds usually occupy high levels in ecological food webs, and are both more easily recognizable and more comprehensively taxonomically studied than other animal groups. Therefore, birds are frequently employed as a model taxon to empirically test ecological theories in community ecology and to serve as surrogate biological indicators of environmental quality (Bibby et al. 2000). Among the census methods applied to bird communities, territory mapping is viewed as the most accurate method for estimating the abundances of terrestrial breeding birds (e.g., Howell et al. 2004, Simms et al. 2009) and evaluating their use of habitats (e.g., Moorman and Guynn 2001, Anich et al. 2009). This has led to territory mapping being used as a standard method to calibrate other avian census methods (e.g., Raman 2003, Buckland 2006).

During breeding seasons, most male birds perform obvious behaviors (notably singing and chasing) to advertise and claim territories. The territory mapping method takes advantage of these behaviors by counting all males in a given area and depicting them on a map (Williams 1936, Kendeigh 1944). This method has been adapted by some long-term ecological monitoring programs, including the Common Bird Census of the United Kingdom, which has provided reliable information on the population abundance of about 60 bird species over 36 yr (Saether et al. 2009, Thaxter et al. 2010). Comparing annual population abundances reveals temporal changes in avian populations, which can be used to evaluate possible impacts of environmental changes (Siriwardena et al. 1998, Simms et al. 2009, Thaxter et al. 2010).

The territory mapping method was originally developed in the temperate zone (Williams 1936). Birds in the temperate zones generally have shorter breeding seasons than those in the tropics or subtropics, which implies that territory establishment and advertising are in relative synchrony (Ricklefs 1966, Stutchbury and Morton 1995). Breeding seasons of birds in the tropics or subtropics are also usually less conspicuous and more unstable and inconsistent (Wyndham 1986, Stutchbury and Morton 2008). This usually results in tropical bird censuses taking longer; for example, Raman (2003) took 4 mo to estimate bird densities in a tropical rainforest region in India. Moreover, the avifauna is generally richer and more diverse in the tropics and subtropics than in temperate regions (Orme et al. 2005, Ding et al. 2006), which increases the complexity and difficulty of applying territory mapping.

Taiwan lies on the Tropic of Cancer, and its avifauna and avian breeding ecology are much more diverse and complex than those in temperate regions. To the best of our knowledge, very few published studies have applied the territory mapping method in censuses of forest bird communities in Taiwan or in neighboring southeastern Asian countries (but see Sodhi et al. 1997, who conducted censuses on bird communities in a mangrove forest of Singapore). This prompted us to apply the territory mapping method to the avian community in a montane forest of Taiwan and by comparing the obtained data with a historical avifauna checklist, check its effectiveness in detecting local breeding species. In total, 40 territory mappings were conducted over 20 consecutive weeks to determine the optimal census period, defined as covering the greatest singing activities of most local breeding species. Playback of conspecific songs increases the chance of detecting secretive birds (Lor and Malecki 2002) and has been widely used in bird censuses in North America (e.g., Johnson et al. 1981, Marion et al. 1981) and the Neotropics (e.g., Terborgh et al. 1990, Robinson and Terborgh 1995). Using a paired design of territory mappings, we therefore also examined the effects of playback to determine whether it is useful when conducting territory mapping in censusing avian communities.

The specific objectives of this study were to determine (1) the efficacy of the territory mapping method by comparing it with a historical avifauna checklist, (2) the optimal census time of territory mapping at the study site, and (3) the usefulness of applying the playback technique in territory mapping.

MATERIALS AND METHODS

This study was conducted in an area of around 40 ha at the Meifeng Highland Experimental Farm of National Taiwan University (24°05´N, 121°10´E), which is approximately 2150 m above sea level. Areas at this elevation exhibit the highest species richness of breeding bird species in Taiwan (Lee et al. 2004, Ding et al. 2005), and the Meifeng area is well-known for its rich and diverse avifauna and is within an Important Bird Area as designated by Birdlife International (2004). According to the weather data of the on-site Meifeng Meteorological Station, the annual precipitation was 2383 mm and the average air temperature was 12.2℃ in 2003~2005. The monthly average temperature was highest in July (16.5℃) and lowest in January (5.8℃). The study site was originally established for conducting horticultural research, and contains a well-developed path system and various landscape types (such as primary broadleaf forests, Japanese cryptomeria (*Cryptomeria japonica*) plantations, orchards, greenhouses, and plowed fields) (Lee et al. 2005). The vegetation surrounding the study site comprises primary broadleaf forests dominated by species of the Fagaceae and Lauraceae.

In order to obtain precise mappings of birds, the boundary of all landscape patches at the study site, as identified from an aerial photograph, and other conspicuous features such as wire poles, single trees, and large rocks were all drawn on a visit map. This map was printed at a scale of 1: 1000 on A3 paper, which was a convenient size to carry in the field while remaining sufficiently precise to map bird locations.

We conducted territory mappings from early March to late July 2005, for a period of 20 consecutive weeks, to give 40 census days in total. All 40 censuses were undertaken by the first author (CWL) on days with fine weather, and 2 censuses were conducted each week: 1 d with playback and the other day without playback. Considering possible effects of dialects, most of the songs used in the playback censuses were collected at the study area using a directional microphone (ME67, Sennheiser, Old Lyme, CT, USA) and a digital recorder (PMD670, Marantz, Mahwah, NJ, USA). The playbacks included songs of the following 14 most common bird species at the study site: Chinese Bamboo Partridge, White-tailed Blue Robin, Taiwan Sibia, Steere's Liocichla, Grey-cheeked Fulvetta, Formosan Yuhina, Red-headed Tree Babbler, Vinous-throated Parrotbill, Strong-footed Bush Warbler, Rufous-faced Flycatcher Warbler, Vivid Niltava, Red-headed Tit, Green-backed Tit, and Brown Bullfinch (scientific names are given in Table 1). Two repetitions of identical syllables of the territorial song of each species were played repeatedly at an interval of 100~200 m through a speaker (WPA-66B, Kaotek, Kaohsiung, Taiwan) carried by the investigator.

Activities of most bird species at the study site were greatest early in the morning (Yuan et al. 2004), and hence each census began within 30 min before sunrise and ended within 3 h after sunrise. Four census routes (each of which covered within a 50-m distance any location of the study site) were laid out to produce territory mappings. In order to reduce bias caused by the mapping being conducted at the same time of day (Hayes et al. 1986), the censuses conducted in each month involved different combinations of routes and directions (Fig. 1). The study site was walked at 1 km/h, and the locations of all birds seen or heard were recorded throughout each census. The locations and movements of all birds seen or heard were closely monitored as much as possible to avoid double counting. To save space on the map and speed up the recording process, we used a 1- or 2-letter code for each bird species that was related to its scientific or English name. All activities of territorial display (e.g., fighting, singing, and calling) as well as the age, sex, number of birds, movements, and color rings were also noted on the visit maps as special symbols, following the system of the International Bird Census Committee (Robbins 1970). The nomenclature of birds followed Severinghaus et al. (2010).

All registrations collected from field censuses were transcribed into species maps (one for each species) using ArcGIS (vers. 9.1, ESRI 2005). Locations of territorial local breeding species were analyzed to determine their territories and population densities. Species of the Hirundinidae and Apodidae were excluded since they show insignificant territorial behavior. Others with territories that were larger than the entire study site were also excluded, such as species of the Accipitridae

Table 1. List of recorded bird species and their status at the study site. –, species on the historical checklist but not recorded in this study; +, species spotted at the study site but not recorded during the censuses; ++, recorded during the censuses; +++, species not listed on the historical checklist but recorded during the censuses

Family name	Scientific name	English name	Status at the study site	Recorded during censuses	Consecutive observation weeks
Ardeidae	*Bubulcus ibis*	Cattle Egret	Transient	-	-
Anatidae	*Anas crecca*	Eurasian Teal	Vagrant	-	-
Pandionidae	*Pandion haliaetus*	Osprey	Transient	-	-
Accipitridae	*Pernis ptilorhynchus*	Oriental Honey-buzzard	Transient	-	-
	Milvus migrans	Black Kite	Vagrant	-	-
	Spilornis cheela	Crested Serpent-Eagle	Resident	+	-
	Butastur indicus	Grey-faced Buzzard	Transient	-	-
	Circus spilonotus	Eastern Marsh-Harrier	Transient	-	-
	Accipiter trivirgatus	Crested Goshawk	Resident	-	-
	Accipiter soloensis	Chinese Goshawk	Transient	-	-
	Accipiter gularis	Japanese Sparrowhawk	Transient	-	-
	Accipiter virgatus	Besra	Resident	++	1
	Accipiter nisus	Eurasian Sparrowhawk	Transient	-	-
	Accipiter gentilis	Northern Goshawk	Transient	-	-
	Buteo buteo	Eurasian Buzzard	Transient	-	-
	Buteo lagopus	Rough-legged Hawk	Transient	-	-
	Ictinateus malayensis	Black Eagle	Resident	-	-
	Aquila clanga	Greater Spotted Eagle	Transient	-	-
	Spizaetus nipalensis	Mountain Hawk-Eagle	Resident	-	-
Falconidae	*Falco tinnunculus*	Eurasian Kestrel	Wintering	-	-
	Falco peregrinus	Peregrine Falcon	Transient	-	-
Phasianidae	*Arborophila crudigularis*	Taiwan Partridge	Transient	+++	1
	Bambusicola thoracica	Chinese Bamboo-Partridge	Resident*	++	20
	Lophura swinhoii	Swinhoe's Pheasant	Resident	++	1
Charadriidae	*Pluvialis fulva*	Pacific Golden-Plover	Vagrant	-	-
Scolopacidae	*Scolopax rusticola*	Eurasian Woodcock	Vagrant	+++	2
Phalaropodidae	*Phalaropus lobatus*	Red-necked Phalarope	Vagrant	-	-
Columbidae	*Columba pulchricollis*	Ashy Wood-Pigeon	Transient	++	1
	Streptopelia orientalis	Eastern Turtle-Dove	Resident	++	20
	Treron sieboldii	White-bellied Pigeon	Resident	+	-
Cuculidae	*Cuculus sparverioides*	Large Hawk-Cuckoo	Summering	++	3
	Cuculus saturatus	Himalayan Cuckoo	Summering	++	4
	Cuculus poliocephalus	Lesser Cuckoo	Transient	-	-
Strigidae	*Otus spilocephalus*	Mountain Scops Owl	Resident	-	-
	Strix leptogrammica	Brown Wood Owl	Resident	-	-
	Strix aluco	Tawny Owl	Resident	++	1
	Glaucidium brodiei	Collared Owlet	Resident	+	-
Apodidae	*Hirundapus caudacutus*	White-throated Needletail	Transient	-	-
	Hirundapus cochinchinensis	Silver-backed Needletail	Transient	-	-
	Apus pacificus	Fork-tailed Swift	Transient	++	2
	Apus nipalensis	House Swift	Resident	+	-

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Capitonidae	*Megalaima nuchalis*	Taiwan Barbet	Transient	++	2
Picidae	*Dendrocopos leucotos*	White-backed Woodpecker	Resident	++	1
Hirundinidae	*Hirundo rustica*	Barn Swallow	Transient	-	-
	Hirundo tahitica	Pacific Swallow	Resident*	++	2
	Cecropis striolata	Striated Swallow	Transient	-	-
	Delichon dasypus	Asian House Martin	Resident	+	-
Motacillidae	*Motacilla cinerea*	Grey Wagtail	Wintering	-	-
	Motacilla alba	White Wagtail	Transient	++	1
	Anthus hodgsoni	Olive-backed Pipit	Wintering	++	4
	Anthus rubescens	Buff-bellied Pipit	Transient	+++	4
Campephagidae	*Pericrocotus solaris*	Grey-chinned Minivet	Resident	++	7
Pycnonotidae	*Spizixos semitorques*	Collared Finchbill	Transient	+	-
	Pycnonotus sinensis	Light-vented Bulbul	Transient	++	1
	Hypsipetes leucocephalus	Black Bulbul	Transient	++	1
Troglodytidae	*Troglodytes troglodytes*	Winter Wren	Wintering	-	-
Sylviidae	*Cettia diphone*	Japanese Bush Warbler	Wintering	-	-
	Cettia fortipes	Strong-footed Bush Warbler	Resident*	++	20
	Cettia acanthizoides	Yellowish-bellied Bush Warbler	Wintering	++	5
	Bradypterus alishanensis	Taiwan Bush Warbler	Wintering	++	3
	Locustella lanceolata	Lanceolated Warbler	Transient	-	-
	Phylloscopus borealis	Arctic Warbler	Wintering	-	-
	Abroscopus albogularis	Rufous-faced Flycatcher Warbler	Resident*	++	20
Reguliidae	*Regulus goodfellowi*	Flamecrest	Wintering	++	1
Cisticolidae	*Prinia criniger*	Striated Prinia	Resident	+	-
	Prinia inornata	Plain Prinia	Resident	++	1
Timaliidae	*Pomatorhinus erythrogenys*	Rusty-cheeked Scimitar Babbler	Resident	++	2
	Pomatorhinus ruficollis	Streak-breasted Scimitar Babbler	Resident	++	10
	Pnoepyga albiventer	Scaly-breasted Wren Babbler	Transient	+++	2
	Stachyris ruficeps	Red-headed Tree Babbler	Resident*	++	20
	Garrulax albogularis	White-throated Laughingthrush	Resident	+	-
	Garrulax poecilorhynchus	Rusty Laughingthrush	Resident	++	-
	Garrulax morrisonianus	White-whiskered Laughingthrush	Wintering	++	7
	Liocichla steerii	Steere's Liocichla	Resident*	++	20
	Actinodura morrisoniana	Taiwan Barwing	Resident	++	1
	Alcippe cinereiceps	Streak-throated Fulvetta	Wintering	+	-
	Alcippe morrisonia	Grey-cheeked Fulvetta	Resident	++	18
	Heterophasia auricularis	Taiwan Sibia	Resident*	++	20
	Yuhina brunneiceps	Formosan Yuhina	Resident*	++	20
	Yuhina zantholeuca	White-bellied Yuhina	Transient	-	-
	Paradoxornis webbianus	Vinous-throated Parrotbill	Resident*	++	19
	Paradoxornis verreauxi	Golden Parrotbill	Wintering	-	-
Turdidae	*Monticola solitarius*	Blue Rock Thrush	Wintering	-	-
	Myophonus insularis	Taiwan Whistling Thrush	Wintering	-	-
	Zoothera dauma	Scaly Thrush	Wintering	-	-
	Turdus chrysolaus	Brown-headed Thrush	Wintering	-	-
	Turdus poliocephalus	Island Thrush	Transient	+++	1
	Turdus pallidus	Pale Thrush	Wintering	++	6

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	Turdus obscurus	Eye-browed Thrush	Wintering	-	-
	Turdus naumanni	Dusky Thrush	Transient	-	-
Muscicapidae	*Luscinia calliope*	Siberian Rubythroat	Wintering	-	-
	Luscinia johnstoniae	Collared Bush Robin	Wintering	++	4
	Luscinia cyanura	Orange-flanked Bush Robin	Wintering	++	5
	Phoenicurus auroreus	Daurian Redstart	Wintering	++	1
	Myiomela leucura	White-tailed Blue Robin	Summering*	++	20
	Muscicapa ferruginea	Ferruginous Flycatcher	Summering*	++	12
	Ficedula hyperythra	Snowy-browed Flycatcher	Resident	++	12
	Niltava vivida	Vivid Niltava	Resident	++	9
Aegithalidae	*Aegithalos concinnus*	Red-headed Tit	Resident*	++	20
Paridae	*Parus ater*	Coal Tit	Wintering	+	-
	Parus monticolus	Green-backed Tit	Resident*	++	20
	Parus holsti	Yellow Tit	Resident*	++	3
Sittidae	*Sitta europaea*	Eurasian Nuthatch	Resident	-	-
Diceaidae	*Dicaeum ignipectum*	Fire-breasted Flowerpecker	Resident	++	1
Zosteropidae	*Zosterops japonicus*	Japanese White-eye	Transient	-	-
Laniidae	*Lanius cristatus*	Brown Shrike	Wintering	-	-
Emberizidae	*Emberiza pusilla*	Little Bunting	Vagrant	+++	1
	Emberiza chrysophrys	Yellow-browed Bunting	Vagrant	-	-
	Emberiza elegans	Yellow-throated Bunting	Vagrant	+	-
	Emberiza spodocephala	Black-faced Bunting	Wintering	++	5
Fringillidae	*Fringilla montifringilla*	Brambling	Vagrant	+++	1
	Carduelis spinus	Eurasian Siskin	Wintering	-	-
	Carpodacus vinaceus	Vinaceous Rosefinch	Wintering	-	-
	Pyrrhula nipalensis	Brown Bullfinch	Resident*	++	20
Passeridae	*Passer montanus*	Eurasian Tree Sparrow	Transient	-	-
Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	Transient	-	-
Dicruridae	*Dicrurus aeneus*	Bronzed Drongo	Vagrant	++	1
Corividae	*Garrulus glandarius*	Eurasian Jay	Resident*	++	4
	Dendrocitta formosae	Grey Treepie	Transient	-	-
	Nucifraga caryocatactes	Eurasian Nutcracker	Transient	-	-
	Corvus macrorhynchos	Large-billed Crow	Transient	+	-

* With confirmed evidence of breeding activities (carrying nest materials, nest witnessed, or fledgling witnessed) at the study site.

and Falconidae. Nocturnal species of the Strigidae were generally silent during the daytime and were therefore also excluded. To assess the census efficacy of the territory mapping method, a complete checklist of bird species present within the study site (see Table 1) was provided by a local expert, Mu-Chi Tsai, who is a former vice-executive of the Meifeng Highland Experimental Farm and an eminent bird watcher with more than 20 yr of birding experience in the Meifeng area. He has compiled the checklist for the Meifeng Highland Experimental Farm based on his personal observations from 1990 to 2004. According to its migratory status within the study site, each species on the checklist was categorized into 5 groups: local resident, summer breeder, transient, vagrant, and wintering species. The efficacy of territory mappings of this study was assessed by comparing our

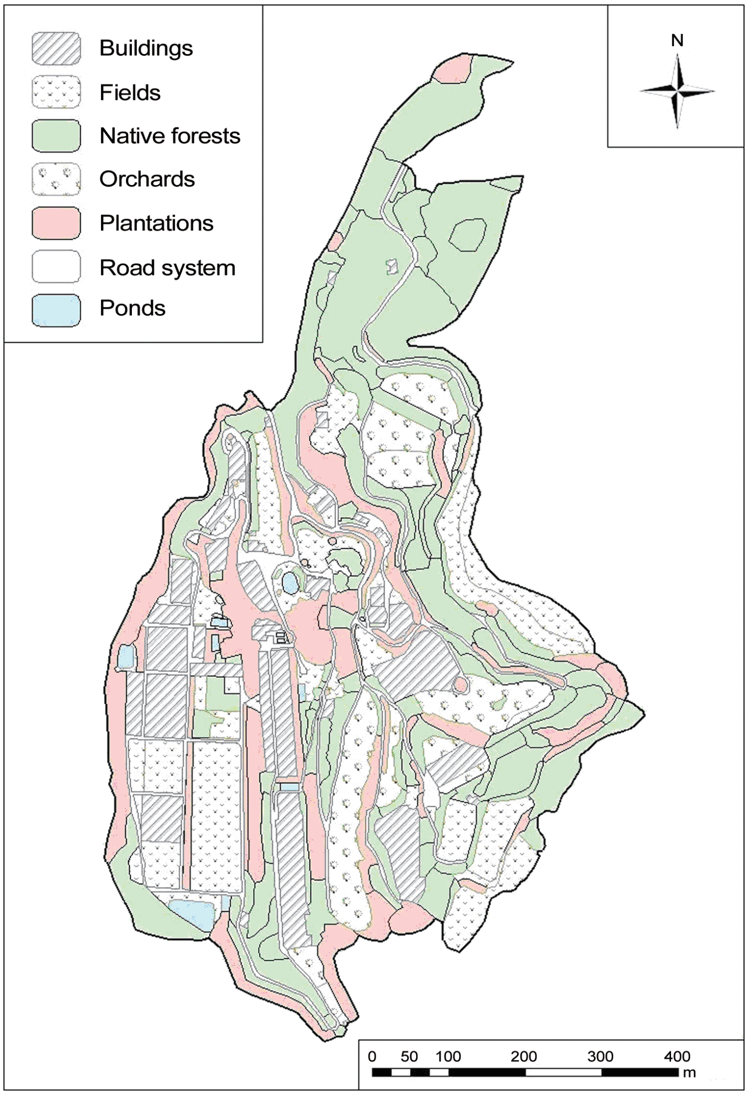

Fig. 1. Landscape structure and trail system of the study site.

recorded species with those on the historical checklist.

In the territory mapping method, each male registration in a single visit was considered a possible territorial male. Traditionally, the presence of at least 3 valid spots (at least 2 of which were confirmed as a male based on song or plumage) in a certain area from over 8 valid visits falling into a group was assumed to indicate a territory that was occupied by a breeding pair or an established territorial male (e.g., Robbins 1970, Svensson 1978). In this study, we adopted a similar criterion of using at least 3 male registrations to determine a territory. Those registrations with only 1 or 2 valid spots were still mapped but not considered to be an established territory. Boundary aggression or contemporary visual or acoustic registrations that confirmed the presence of at least 2 males was used to discriminate distinct territories occupied by adjacent individuals and thus avoid double counting.

The period of territory determination for each species was chosen by temporal registration trends. First, the week with the most registrations during the 20 wk was selected, from which the period of territory determination was extended to the previous or subsequent week that had more registrations. This procedure was repeated until the 20 wk were all chosen.

Five visits per study site are considered sufficient for open fields of temperate zones, while 10 visits per study site are considered sufficient for woodlands with high bird densities (Gibbons et al. 1996). To determine the optimal census time for each species and a suitable duration of territory mapping in the Meifeng area, which comprises a mixture of forests and open fields, the present study lasted 20 wk in order to cover the entire breeding seasons of most species. We assumed that, after 20 wk of conducting the census, the cumulatively detected species territories reached 100%. Moreover, stacking the optimal census period for each species revealed the best census time of territory mapping for the study site. When at least 75% of the overall territories of a species were detected within 10 wk, a period of 10 wk was chosen as the optimal census time for this species. The optimal census time for each other species was determined as the period of time when 75% of its territories had been detected.

All registrations were transcribed onto the ArcGIS platform and to identify contemporary registrations, registrations of the maps obtained during different visits were denoted by different colors. We used a minimum convex polygon (Hawths Analysis Tools 3.23 for ARC/GIS) (Beyer 2004) of all registrations in each territory to illustrate the relative location of each territory. To calculate bird densities, territories with partial areas outside the study boundary were also included, which is in accordance with the recommendations of the Common Bird Census (Marchant 1981, Bibby et al. 2000).

RESULTS

Community composition

In total, 57 bird species from 5719 registrations were recorded during the field censuses (Table 1). Among these, 48 species have breeding records in Taiwan (including residents and summer breeders), and 33 species are local breeding species at the study site. The recorded breeding activities revealed 16 species with definite breeding records at the study site (Table 1). We also recorded 9 wintering species, 11 transient species, and 4 vagrant species during the census period (Table 1).

The historical bird checklist of Meifeng listed 113 species, comprising 41 local resident species, 4 summer breeders, 27 wintering species, 34 transient species, and 7 vagrant species (Table 1).

After deleting species that exhibited insignificant territorial behavior (i.e., members of the Hirundinidae and Apodidae), had large territories (i.e., members of the Accipitridae and Falconidae), or were nocturnal (i.e., members of the Strigidae), the detection rate of local resident species of this study approached 86.2%, with summer breeders reaching 100% (Table 2). Three of the 4 known local resident species that we missed (White-bellied Pigeon, White-throated Laughing-Thrush, and Striated Prinia) were actually detected during the census time but only (just) outside the study area. The fourth known local resident species, Eurasian Nuthatch, was not recorded at the study site during the study period. Detection

Table 2. Detection ratio of local resident and summer breeding species was higher than that of wintering, transient, and vagrant species. Species with insignificant territorial behavior (the Apodidae and Hirundinidae), large territories (the Accipitridae and Falconidae), or nocturnal (the Strigidae) were excluded

Category	No. of species recorded in this study	No. of species on the historical checklist	No. of shared species	Detection ratio (%)
Local resident	26	29	25	86.2
Summer breeding	4	4	4	100.0
Wintering	9	26	9	34.6
Transient	10	18	6	33.3
Vagrant	4	6	0	0.0

rates of wintering and transient species of this study were 34.6 and 33.3%, respectively (Table 2). Among those wintering or transient species we missed in this study, Collared Finchbill, Streak-throated Fulvetta, Coal Tit, and Large-billed Crow were spotted within the study site but not during the field censuses. None of the 6 vagrant species on the historical checklist were detected during the 40 field censuses. However, the following 8 species that were not listed on the checklist were recorded during the field censuses of this study: Taiwan Partridge, Eurasian Woodcock, Buff-bellied Pipit, Island Thrush, Scaly-Breasted Wren Babbler, Little Bunting, Brambling, and Bronzed Drongo (see Table 1).

Effect of playback

The number of registered individuals of breeding species did not significantly differ between censuses conducted with and without playback (means of 143.90 and 142.05 registrations per census, respectively; paired t-test, $p = 0.79$, $n = 20$ each) (Fig. 2). The total number of breeding species recorded also did not differ between the censuses with and without playback (19.10 and 19.75 species per census, respectively; paired t-test, $p = 0.33$) (Fig. 3). The use of playback elicitation had no significant effects on the registrations of the 14 commonest bird species during the 40 censuses (14 paired t-tests, all $p > 0.05$) or in each month (70 unpaired t-tests, all $p > 0.05$).

Optimal census time

The number of registered individuals of breeding species of the 40 censuses was higher from early April to late June (Fig. 3). The number of registered breeding species of the 40 censuses peaked in April (Fig. 4). Neither the number of registered breeding individuals nor that of registered species fluctuated much over the 20-wk study period.

The absence of a playback effect on either the number of species or the number of individuals recorded in this study meant that the bird registration data from the 40 field censuses could be combined. Despite there being ample registrations for the Brown Bullfinch, this species showed no signs of territorial behaviors, and it was very difficult to define stable groupings due to the larger number of individuals and their complicated flight paths. Similarly, the small number of simultaneous registrations and vague information on movements also made it difficult to determine the number of territories at the study site for the Rusty-cheeked Scimitar Babbler and Yellow Tit. Therefore, data for these 3 species were not used when determining territory densities.

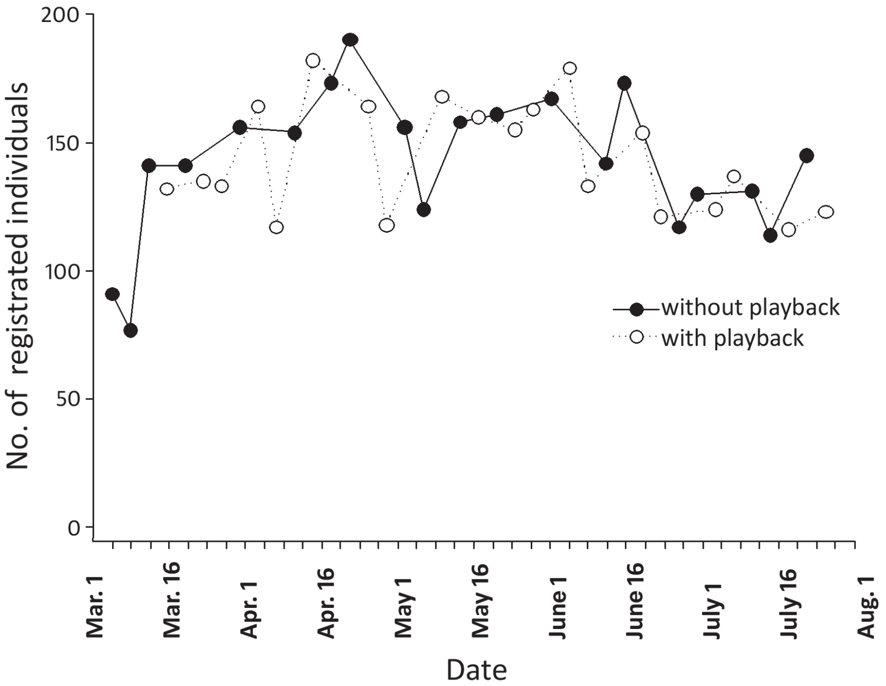

Fig. 2. Number of registered individuals of the breeding species of the 40 censuses during the study period.

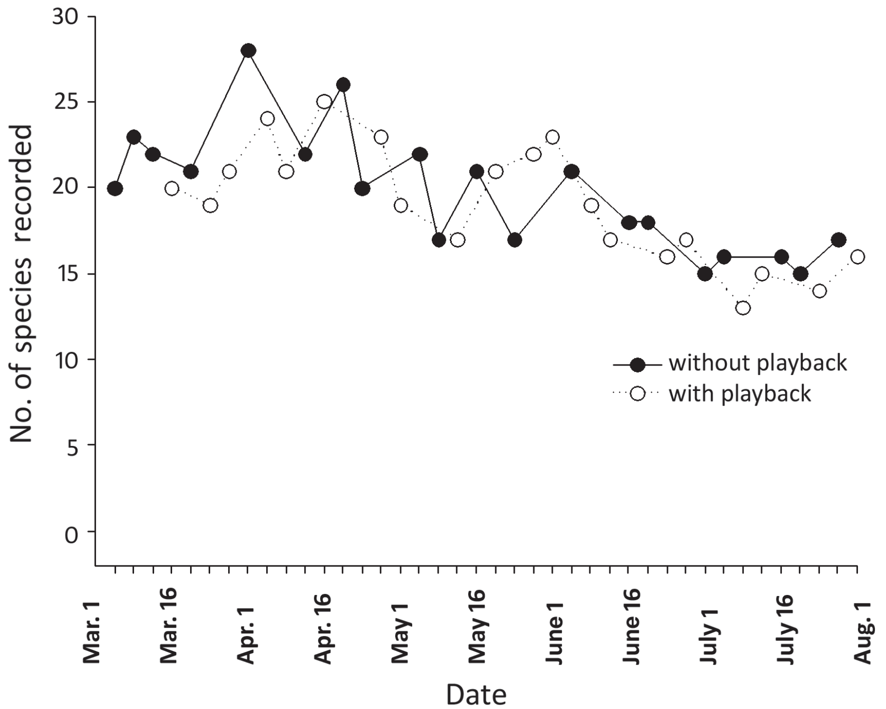

Fig. 3. Number of recorded breeding species of the 40 censuses during the study period.

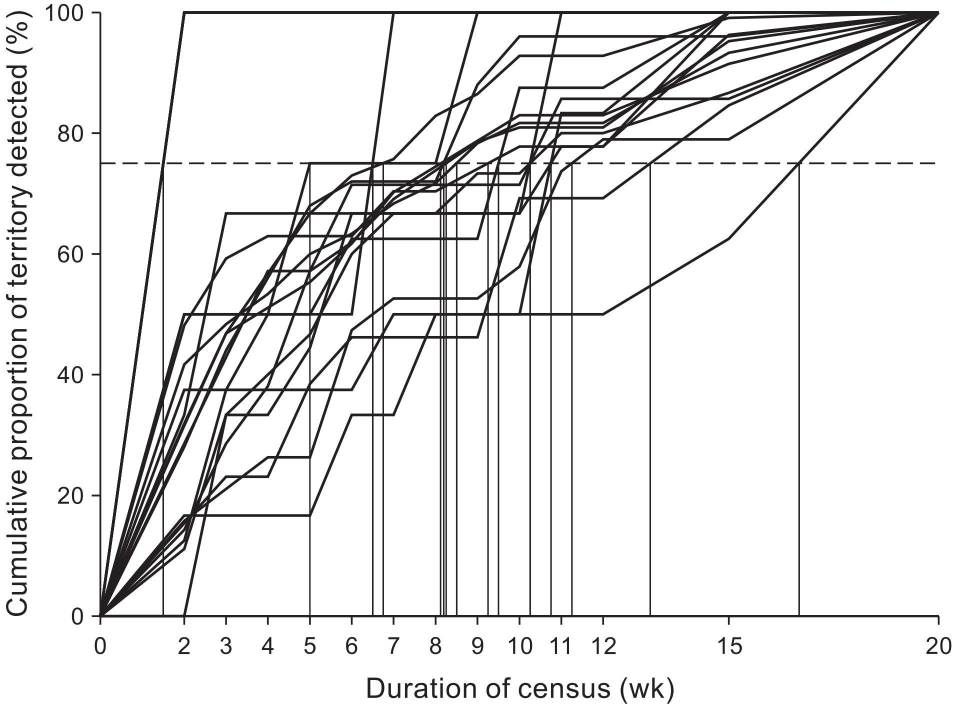

Fig. 4. In most breeding species, 75% of the territories were detected within 12 wk. The cumulative measured times to detect 75% of the territories of each species are interpolated by straight lines.

The cumulative detection ratios of the territories of each bird over 20 consecutive weeks reached 75% within 8, 8~10, and 10~12 weeks in 6, 12, and 18 of 20 species, respectively (Fig. 4). For the 20 breeding species with registrations of more than 3 wk, the optimal censusing time of species (defined as the weeks that had at least 30% of the maximum registrations in a week) lasted from early March to late July, with an overlapping period from late April to mid-May (Fig. 5). The registrations were highest in April, May, March June, and July in 6, 6, 4, 3, and 1 of the 20 species, respectively (Fig. 5).

Territories and densities

The territory mapping method revealed that the dominant species in this study site were Steere's Liocichla (2.58 territories per hectare [terr./ha]) (Fig. 6) and Formosan Yuhina (1.23 terr./ha). Other subdominant species (with territory densities of 0.25~1 terr./ha) were the White-tailed Blue Robin (0.98 terr./ha) (Fig. 7), Red-headed Tree Babbler (0.85 terr./ha), Taiwan Sibia (0.60 terr./ha), Strong-footed Bush Warbler (0.53 terr./ha), Chinese Bamboo Partridge (0.38 terr./ha), Red-headed Tit (0.30 terr./ha), and Grey-cheeked Fulvetta (0.28 terr./ha). Species that were sparsely distributed at the study site (territory densities of < 0.25 terr./ha) were the Rufous-faced Flycatcher Warbler (0.18 terr./ha) (Fig. 8), Vinous-throated Parrotbill (0.18 terr./ha), Green-backed Tit (0.18 terr./ha), Streak-breasted Scimitar Babbler (0.15 terr./ha), Eurasian Jay (0.13 terr./ha), Vivid Niltava (0.10 terr./ha), Ferruginous Flycatcher (0.10 terr./ha), Snowy-browed Flycatcher

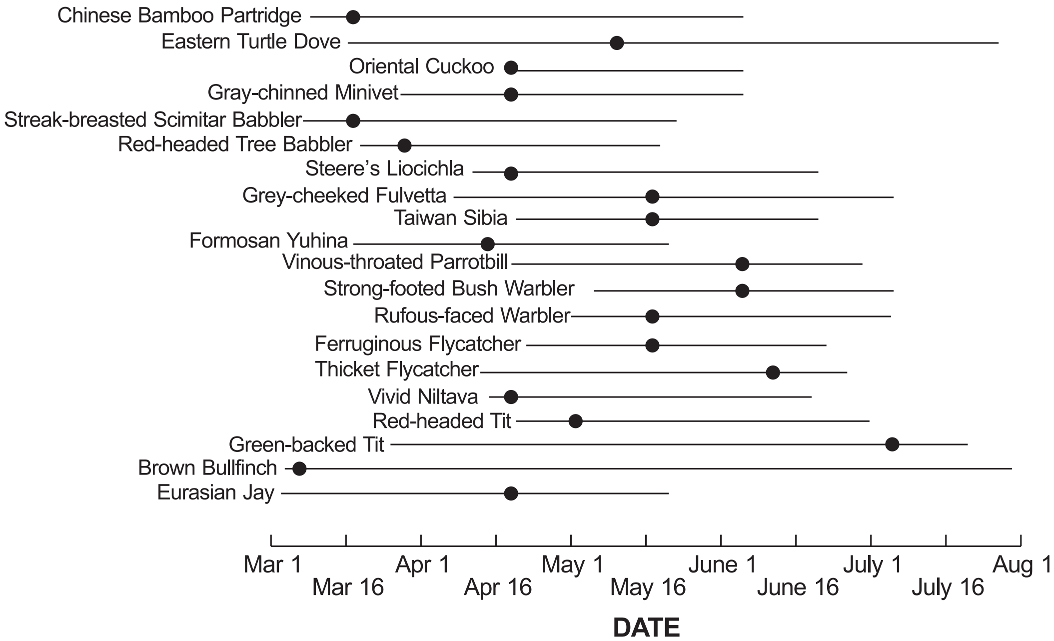

Fig. 5. The best census time for breeding species in this study was from early April to late June. Each horizontal line represents the optimal census time for a species with the circle indicating the time at which the highest number of registrations were recorded for that species. Only those breeding species with more than 3 wk of registrations are listed.

(0.08 terr./ha), Grey-chinned Minivet (0.05 terr./ha), Large Hawk Cuckoo (0.03 terr./ha), and Oriental Cuckoo (0.03 terr./ha). Territory maps (minimum convex polygons) of Steere's Liocichla (Fig. 6), White-tailed Blue Robin (Fig. 7), and Rufous-faced Flycatcher Warbler (Fig. 8) are provided as examples.

DISCUSSION

Detection rate with the territory mapping method

Application of the territory mapping method in this study resulted in a high overall detection rate (87.9%) of local resident and summer breeding species. Among the 4 breeding species that were listed as missed in field censuses of this study, the Eurasian Nuthatch was probably either present at a very low density or exhibited a low detection rate because it rarely displays territorial songs. The detection of the other 3 breeding species that were listed as missed in this study (White-bellied Pigeon, White-throated Laughing Thrush, and Striated Prinia) but were found just outside the study area might have been due to they have previously bred within the study site, but not during 2005. Therefore, territory mapping should be an efficient method for surveying breeding bird species at the study site. However, the efficiency of the territory mapping method in this study was not as good as similar studies conducted in temperate regions (e.g., Johnson et al. 1981, Marion et al. 1981, Siriwardena et al. 1998, Thaxter et al. 2010), which usually reach this level of detection rate within 10 censuses. We suggest that this was due to the non-territorial behavior, asynchronous breeding season, and multiple broods of birds at the study site.

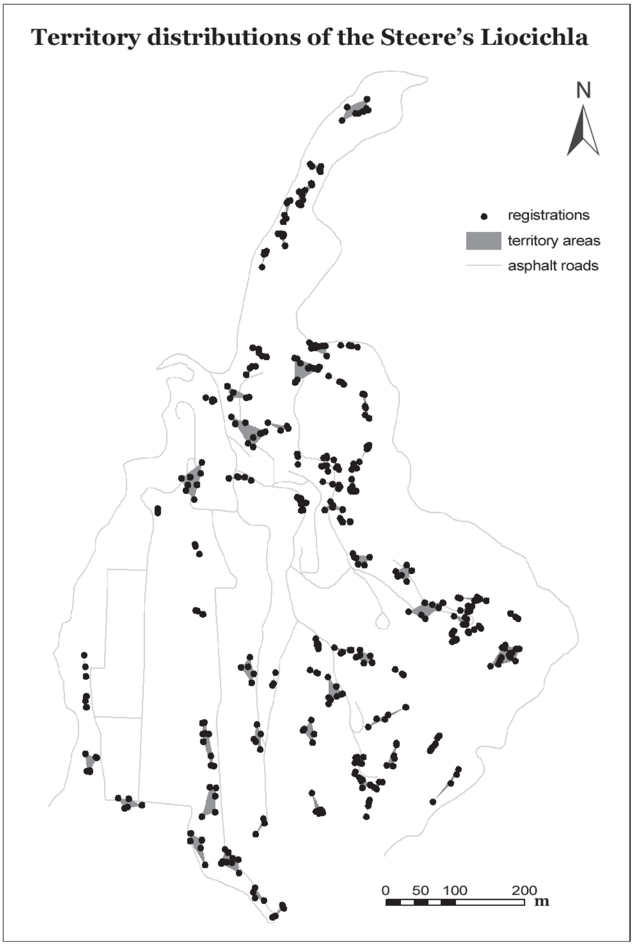

Fig. 6. Registration points and determined territories (minimum convex polygon) of the Steere's Liocichla at the study area.

The detection rates of transient and wintering species were relatively low. Some transient species passed the study site mostly in autumn (Mu-Chi Tsai, pers. commun.). Since our census was conducted from March to July to target breeding species, it could have missed those autumn-transient species and only recorded a small portion of wintering species and some transient species that had not returned to their breeding grounds. Moreover, vagrant species are those that do not appear regularly in a specific region, and hence usually have a very low abundance and are very unlikely to be encountered. The checklist used in this study was compiled from records spanning many years (1990~2004), and hence a zero detection rate for vagrant species is understandable given that this study lasted only 5 mo. Moreover, 4 vagrant species recorded during the census time (Eurasian Woodcock, Little Bunting, Brambling, and Bronzed Drongo) were not listed on the historical checklist. Both of these results show that vagrant species are rare, unstable, and difficult to record. The compilation of an accurate checklist of vagrant species requires

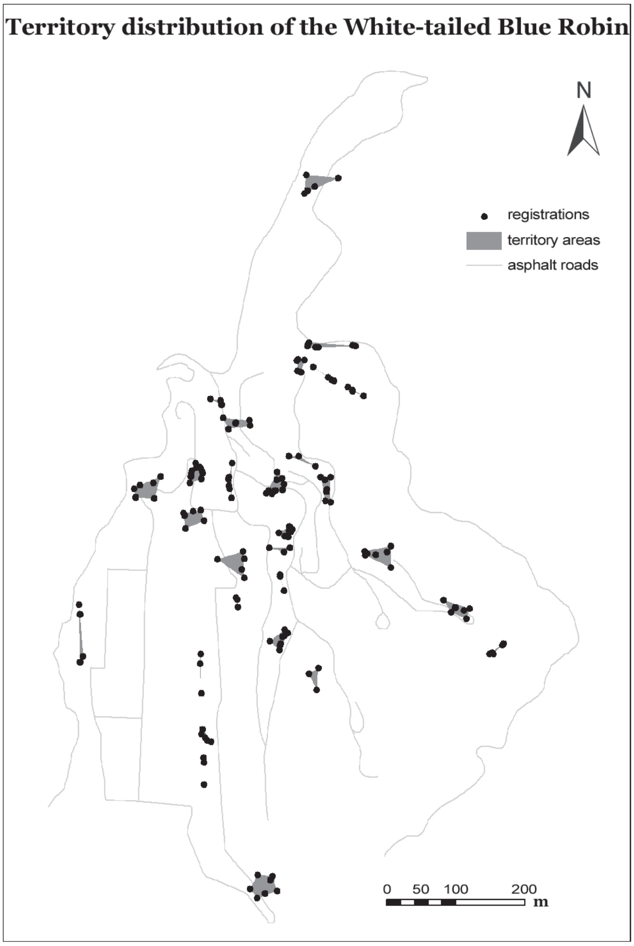

Fig. 7. Registration points and determined territories (minimum convex polygon) of the White-tailed Blue Robin at the study area.

the accumulation of long-term census data.

Optimal census time

One of the major factors that needs to be taken into consideration when planning a census timetable is the length of the breeding season, since some species produce only 1 brood per season whereas others may rear 2 or more broods per season (Best 1981, Yuan et al. 2006). Therefore, a longer census period will increase the probability of community fluxes confounding the results and overestimating the number of territories. Taking the lack of breeding synchrony into account, the duration should be as short as possible while still covering the conspicuous breeding activities of most species (Robbins 1970).

In this study, in order to determine the most suitable time for using territory mapping to accurately estimate the bird density at the study site, the census period of 20 wk was spread over the entire breeding season of most local breeding species. Combining data of local residents and summer breeders, we concluded that the best period to census the bird community at the study site is from early

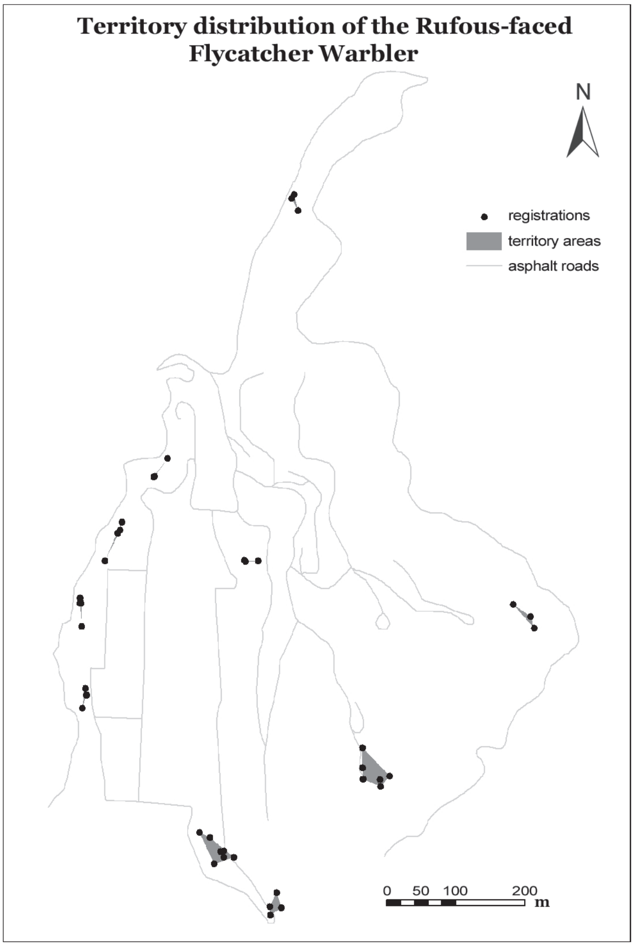

Fig. 8. Registration points and determined territories (minimum convex polygon) of the Rufous-faced Flycatcher Warbler at the study area.

April to late June since high numbers of recorded registrations would be maintained for 80% of breeding species during this period. Moreover, since 75% of the territories could be identified in 90% of species within 10~12 wk of conducting the census, we recommend that 10~12 wk from early April to late June is the best census time for conducting territory mapping at the study site and other similar sites.

The time course of registration recordings can vary for species exhibiting multiple broods, which is probably related to different stages of the nesting cycle that are repeatedly iterated throughout a single breeding season (Best 1981). Hence, some studies only focused on the first-brood breeding territories in territory mapping to avoid bias (e.g., DeSante 1981). In the present study, although high registrations could be maintained for most species from early April to late June, this period of 3 mo probably contains 2 to 3 nesting cycles (including incomplete cycles) for multiple-brooding species. Therefore, to determine the first-brood breeding territories and take the breeding strategies of birds and weather conditions into account, we suggest that 4~6 wk starting from early April is the best census time for the present study site and similar sites.

Playback effect

Playback is used to evoke responses of territory holders and thereby determine boundaries between neighbors, but mostly it can be applied to only 1 species at a time (Falls 1981). Ideally, the playback should be sufficiently loud to be heard by birds within a 50-m distance from the census route, while still allowing the observer to hear the responses (Johnson et al. 1981). We found that the use of playback did not increase the overall detection rate for breeding birds. This was probably due to the high volume of the playback which masked the responding songs by males within earshot and also impaired the detection and hearing ability of the observer. In addition, most previous studies have employed playing durations of 1~15 min for each species (e.g., Gibbs and Wenny 1993, Robinson and Terborgh 1995, Roberts and Norment 1999, Young et al. 2005). The present study included the 14 most common bird species at the study site, and time constraints resulted in only 2 syllables (usually < 10 s) of the territorial song of each species being played. This short playback for each species might not have been adequate to prompt the responses of male birds. Some birds might have been attracted by the playback and approached closer to the investigator without making any vocal response to this short playback. Moreover, the songs played were the most common bird species at the study site and probably had little effect on increasing detection rates of these common species because most of them had been singing actively during the time period of the censuses. If we used songs of some species that are rare and seldom sing (e.g., Eurasian Nuthatch), the effect of playbacks might have been more obvious.

CONCLUSIONS

Based on the results of the present study, we concluded that territory mapping is a census method that can be applied for breeding bird communities in montane subtropical forests with a well-developed path system. However, its efficiency is not as good as in temperate regions. The best period to conduct territory mapping method at mid-elevations in central Taiwan is during a 10~12-wk period from early April to late June, since this would maintain high numbers of recorded registrations for most breeding species. The census time can be reduced to 4~6 wk starting from early April if the focus is on the first brood of the breeding season. Playbacks of bird songs do not help much when conducting a census on an entire breeding bird community in this period of time. Few previous studies deployed the territory mapping method in tropical and subtropical regions, and hence this study provides useful guidelines for further studies in these regions.

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