

The spread and relative abundance of the non-native White-crested Laughingthrush *Garrulax leucolophus* and Lineated Barbet *Megalaima lineata* in Singapore

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The non-native species White-crested Laughingthrush *Garrulax leucolophus* and Lineated Barbet *Megalaima lineata* are now firmly established in various parts of Singapore. This study chronicles their spread over the past two decades and verifies their persistence in areas where they had previously been seen or heard. The relative abundance of these birds at 16 sites reported in the literature was evaluated by means of field visits whereby intra- and inter-species ecological interactions with native avian species were observed. Both species have spread and become established in the west, south and central parts of Singapore and field visits confirmed the persistence of populations in most of these areas, with evidence of breeding in some cases. The highest White-crested Laughingthrush count was at Kent Ridge Park followed by Bukit Batok Nature Park and Bukit Batok West/Brickland Road, while for Lineated Barbet the highest count was at Bukit Batok Nature Park followed by Fairways Drive and Bukit Brown. Further field studies across all parts of Singapore and the satellite islands are needed to determine accurate populations of these species and observe any adverse ecological interactions with native avian species. Appropriate intervention conservation measures may be proposed if there is evidence of detrimental effects of the increasing population of these alien species on native birds that occupy similar ecological/foraging niches and nesting sites.

INTRODUCTION

An invasive species is an organism that is not native (alien) and is known to have negative effects on native biodiversity and ecosystems (Carrete & Tella 2008). Invasive plants and animals are the second greatest threat to biodiversity after habitat loss. However, not all introduced species are invasive.

Most invasions are a direct result of human activities. For example, deforestation for agriculture indirectly creates suitable habitats for the establishment of exotic species that possess intrinsic characteristics and biological factors that favour their success (Yap & Sodhi 2004). Avian species demonstrating social behaviour, colonial nesting, high fecundity, varied diet, foraging innovations, locomotive efficiency, habitat flexibility, low neophobia, human commensalism, sedentary behaviour and ecological plasticity have been shown to be successful invaders (Sol *et al.* 2002, Yap & Sodhi 2004, Carrete & Tella 2008). Other factors such as introduction effort and propagule pressure are also directly related to invasion success (Carrete & Tella 2008). A clear understanding of the contributing environmental and intrinsic factors would bode well in the development of effective management strategies in tackling invasive populations.

This study focuses on the White-crested Laughingthrush *Garrulax leucolophus* and Lineated Barbet *Megalaima lineata*, two alien species in Singapore whose populations have ballooned in the past two decades; both are now relatively common in secondary forests and many green spaces.

Until recently, the White-crested Laughingthrush had a large native range from north and north-east India, south-east Tibet, Sumatra, Myanmar, Thailand, Indochina to south-west China, but was absent from central and south Thailand, Peninsular Malaysia and Singapore. Today it is a rare to locally common feral resident in central Thailand (Bangkok area), Peninsular Malaysia (Penang Island and Kuala Lumpur area) as well as Singapore (Robson 2008). It is easily recognisable by its distinctive broad whitish crest, black mask, whitish underparts, rufous-chestnut upperparts and rufous flanks and undertail-coverts. It is usually seen in flocks which produce song bursts of rapid chattering and repetitive double-note phrases. It is found in a wide range of habitats, including broadleaved evergreen, semi-evergreen and dry deciduous forest, secondary growth and bamboo up to about 1,600 m (Robson 2008). Its varied diet includes berries, seeds, nectar, insects and small

reptiles. It is a co-operative breeder and is multi-brooded, laying 2–6 eggs per brood (Yap & Sodhi 2004).

The Lineated Barbet has a similar large native range from north-west, north and north-east India, Nepal, Bangladesh, south Myanmar, Thailand, south and central Vietnam to south-west China (south Yunnan), Java and Bali (Robson 2008), but is limited to northern Peninsular Malaysia although Wells (1999) has plotted its southward movement particularly down the east coast of the peninsula. With its broad yellow orbital skin, beige to pinkish bill and broad creamy-white streaked head and breast, it is unlikely to be mistaken for any of the native barbet species of Singapore. Only one other barbet, the somewhat smaller Green-eared Barbet *Megalaima faiostricta* of south China, Thailand and Indochina is generally similar in appearance but lacks the bright yellow orbital skin and is characterised by a red eye and rather obvious green cheeks and ear-coverts; the calls of the two species are also distinctive. The presence of Lineated Barbet is often betrayed by its far reaching territorial loud *poo-poh* calls uttered every second, as well as a rapid bubbling *koh-koh-koh-koh-koh* call. This bird has been found in habitats ranging from deciduous forest, scattered trees in open areas, coastal scrub and plantations up to 1,220 m, but is confined to the lowlands in northern Peninsular Malaysia (Robson 2008). A frugivore with a varied diet consisting of fruits, in particular figs, nectar as well as flower petals, it also takes insects, eggs and nestlings particularly when feeding young; it nests in tree holes and is double-brooded, with the second brood started within days of the fledging of the first (Shorts & Horne 2002).

The White-crested Laughingthrush (hereafter the laughingthrush) and the Lineated Barbet (hereafter the barbet) are believed to have been introduced into Singapore, possibly through the bird trade as accidental escapes (Wang & Hails 2007) as well as through deliberate release known as *fang sheng*, literally meaning 'freeing life' by devout Buddhists on Vesak Day. In the late 1980s, the laughingthrush was sporadically seen in southern Singapore and the Central Catchment Area. By the early 1990s, the species was regularly seen in Bukit Batok Nature Park and the western catchment area. The barbet was first seen in Bukit Batok Nature Park in the mid-1990s and by the early 2000s had spread to the fringes of Bukit Timah Nature Reserve and other areas (Lim 2009).

Although over the last two decades, sightings and nesting records were submitted to the Bird Group of the Nature Society (Singapore) and appeared in *Singapore Avifauna*, no systematic

study of the chronology and extent of spread, relative abundance, etc., of these aliens in secondary forests, wooded areas and green spaces of Singapore has been made. Therefore the objectives of this study were:

- (1) To document the chronology and extent of spread of these two aliens in Singapore through extensive review of bird sighting information and scientific literature.
- (2) To verify the persistence of these birds in areas where they have been seen and heard over recent years through systematic visits to these areas.
- (3) To perform a rough preliminary density estimate of these birds in areas where they were previously seen or heard and compare the relative abundance of these birds in these areas.
- (4) To observe the foraging behaviour, food and habitat preferences as well as any ecological interactions with native species through field observations.

METHODS

Determination of range expansion

Singapore Avifauna issues were reviewed for records of both species to document the chronology and extent of their spread in Singapore. *Singapore Avifauna* was a publication of the Bird Group of the Nature Society (Singapore) which documented local sightings submitted by birdwatchers, and is the only such record available in the public domain today. The inaugural issue was published in April 1987 and it was available online from 2008 to 2010, the final issue covering the period July–September 2010. I was able to review volumes covering the following periods: April 1987–December 1989, April–June 1990, January 1994–March 1995, May 1997–September 2010. Missing issues were not retrievable despite efforts to source them.

Field surveys

Sixteen sites were surveyed over a three-month period in areas where the laughingthrush and barbet had previously been seen or heard, in order to confirm the persistence of these species and make a rough estimate of their abundance. These sites (Table 1) were selected

following the review of *Singapore Avifauna* and discussion with local birdwatchers about their recent sightings of the species; the site selection was made on the basis that it appeared that naturalisation had occurred and that there was a greater likelihood of an encounter.

Field observations were made by walking the main trails (transects) at these locations. Binoculars and a camcorder were used for observations and recordings. Surveys were carried out from 07h30 when bird activity is at its highest and usually completed by 10h00, depending on the length of the transect. Every effort was made to cover the full length of each trail; however, the sites vary greatly in size and consequently the length of individual transects was very variable.

A 'visual search and listen' method was adopted every 10 m on the trails to detect the two target species. The time of observation was noted and numbers counted; habitat type, foraging behaviour, diet, intra- and inter-species behaviour (feeding, resting, preening, duetting, mating and aggression) were also documented.

If birds were not visible, numbers were estimated from the calls heard. For the laughingthrush, a conservative three birds were counted for every burst of singing heard, as this is a sociable bird and typically occurs in groups of three or more birds. For the barbet, every call detected was counted as a single bird. The loudness of the call was used to estimate the distance of a bird that could not be seen. To avoid double counting, birds heard or seen were not counted if detected in close proximity and in the same direction. Counts were not made on the return journey on the same trail.

RESULTS

Chronology and extent of the spread of the species in Singapore

The locations and spread of the laughingthrush and the barbet are plotted in Figures 1 and 2 respectively.

According to *Singapore Avifauna*, three laughingthrushes were first observed at Gilman Park on 17 May 1987; one was a juvenile seen begging for food. In the late 1980s, the species was also seen sporadically at Jalan Loyang Besar (north-east), Sime Road (central)

Table 1. Details of survey sites.

Date	Site	Habitat type	Distance covered	Weather conditions
29 December 2012	MacRitchie Reservoir	Regenerating secondary forest with open parkland	3,000 m	Sunny; fair cloud cover
5 January 2013	Bukit Batok Nature Park	Hilly secondary forest	1,460 m	Sunny; fair cloud cover
6 January 2013	Neo Tiew Lane 2	Dense wooded habitat with vast open grassland	800 m	Sunny; little cloud cover
12 January 2013	Lorong Danau	Extensive dense forest flanking restricted military area	50 m	Overcast & cloudy
12 January 2013	Nanyang Crescent	Extensive dense forest flanking restricted military area	1,500 m	Overcast & cloudy
13 January 2013	Bukit Batok West & Brickland Road	Pockets of secondary forest interspersed with grassland	1,220 m	Overcast; dense cloud cover
27 January 2013	Goldhill Avenue	Sparsely wooded garden parkland	300 m	Sunny; fair cloud cover
3 February 2013	Kent Ridge Park	Hilly secondary forest	900 m	Sunny; fair cloud cover
9 February 2013	Pasir Ris Park	Open parkland flanked by riverine mangroves	1,000 m	Sunny; little cloud cover
11 February 2013	Jurong Lake Park & Japanese Garden	Manicured park with sparse patches of woods	1,700 m	Overcast and cloudy
12 February 2013	Bukit Timah Nature Reserve – Mountain Cycle Track	Primary forest	1,600 m	Sunny; little cloud cover
17 February 2013	Fairways Drive	Golf course flanked by strips of secondary forest	1,000 m	Overcast; dense cloud cover
23 February 2013	Telok Blangah Hill Park	Hilly secondary forest	1,050 m	Sunny; no cloud cover
24 February 2013	Singapore Botanic Gardens	Manicured park with remnant primary forest	1,800 m	Sunny; fair cloud cover
3 March 2013	Mount Faber Park	Hill forest and parkland	1,140 m	Sunny; fair cloud cover
10 March 2013	Bukit Brown	Undisturbed woodland – old cemetery	1,200 m	Sunny; fair cloud cover

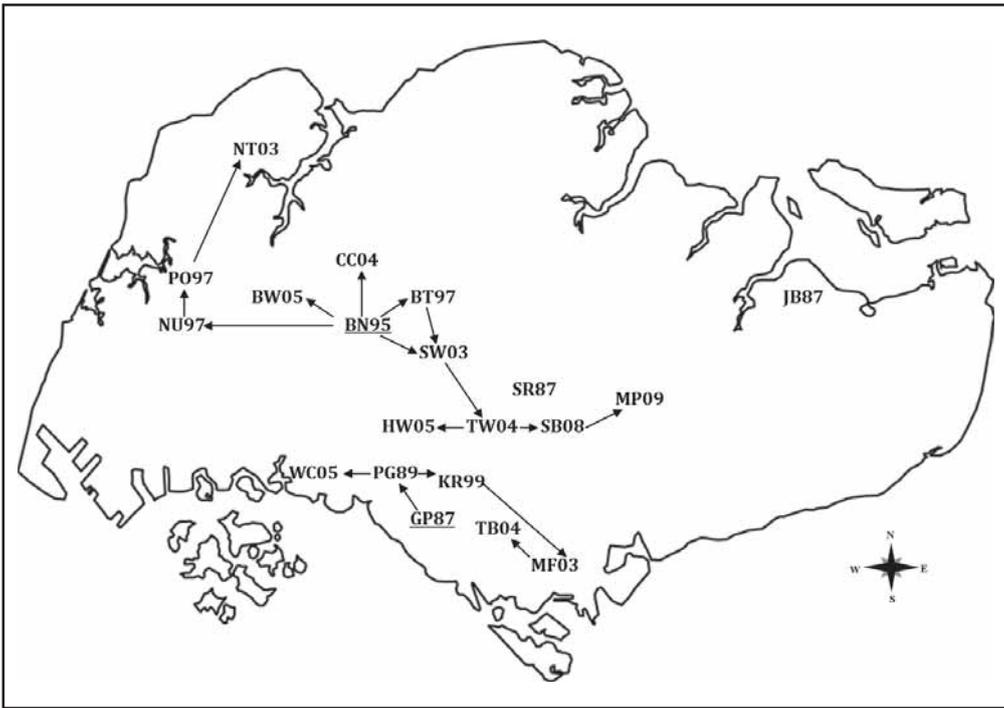


Figure 1. Chronological spread of White-crested Laughingthrush.

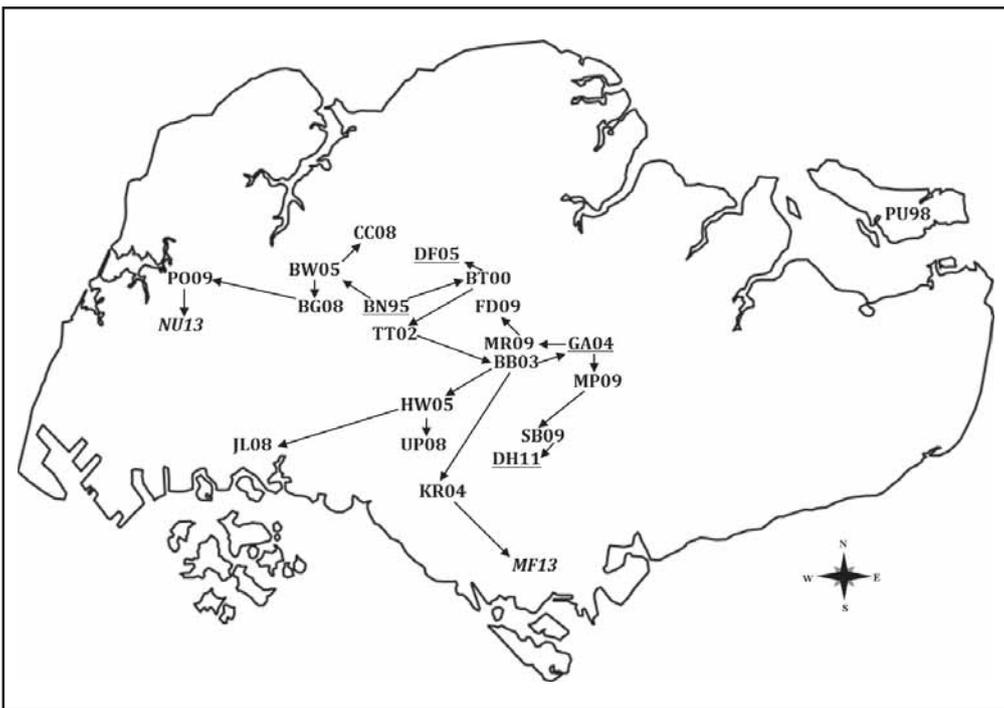


Figure 2. Chronological spread of Lined Barbet

Legend for Figures 1 & 2

Two digit numbers indicate year first recorded at a location.

Underlined locations indicate areas with breeding records.

Italicised locations are new sites discovered during field surveys.

Directional arrows indicate probable direction of spread from one site to another based on chronology and site proximity.

Location abbreviations used

- BB:** Bukit Brown
- BG:** Bukit Gombak
- BN:** Bukit Batok Nature Park
- BT:** Bukit Timah Nature Reserve
- BW:** Bukit Batok West
- CC:** Choa Chu Kang Road
- DF:** Dairy Farm Road
- DH:** Dempsey Hill
- FD:** Fairways Drive
- GA:** Gymkhana Avenue
- GP:** Gilman Park

- HW:** Holland Woods
- JB:** Jalan Loyang Besar
- JL:** Jurong Lake Park
- KR:** Kent Ridge Park
- MF:** Mount Faber
- MP:** Malcolm Park
- MR:** MacRitchie Reservoir
- NT:** Neo Tiew Lane 2
- NU:** Nanyang Technological University
- PG:** Prince George's Park

- PO:** Poyan
- PU:** Pulau Ubin
- SB:** Singapore Botanic Gardens
- SR:** Sime Road
- SW:** Sunset Way
- TB:** Telok Blangah Hill Park
- TT:** Toh Tuck Road Woods
- TW:** Tyersall Woods
- UP:** Ulu Pandan Park Connector
- WC:** West Coast Park
- YC:** Yio Chu Kang Woods

and Prince George's Park (south-west). From 1995 onwards, it established strongholds in the west, particularly in Bukit Batok Nature Park where it was often encountered, mostly in flocks—highest count 19 birds on 28 March 2004, whilst juveniles seen on 29 May 2000 indicated successful breeding here. The literature indicates that by 1997 the Bukit Batok population had started to spread north-west into the forest at Nanyang Technological University and Poyan; also east to Bukit Timah Nature Reserve; south to Sunset Way by 2003; Tyersall Woods by 2004; Holland Woods by 2005; Singapore Botanic Gardens by 2008 and north to Choa Chu Kang by 2004. From Poyan, birds may have moved north-east and become established in Neo Tiew Lane 2 by 2005. In the south the species was established at Kent Ridge Park in early 1992 (Lamont 1998) and Gilman Park in 1997, spreading east into Mount Faber by 2003, Telok Blangah Hill Park by 2004 and west into West Coast Park by 2005. The laughingthrush is now firmly established in west and south Singapore.

According to the literature and based on personal observations, three barbets were first seen in Bukit Batok Nature Park on 25 March 1995 and the species has been frequently seen in the park ever since. From 2000 it spread north-west into Choa Chu Kang and Poyan, west to Jurong Lake Park and east to Bukit Timah Nature Reserve, Dairy Farm Road to the Central Catchment Area including Bukit Brown and MacRitchie Reservoir. The spread continued south along the Ulu Pandan Connector, Holland Woods and Singapore Botanic Gardens. Breeding has been reported in Bukit Batok Nature Park (2002), Dairy Farm (2009), Jurong Lake Park (2009) and Dempsey Hill (2011). The field visits in January and March 2013 showed further movement west into Lorong Danau/Nanyang Crescent and further south into Mount Faber. The barbet is now firmly established in west and central Singapore.

Persistence of populations, population estimates and relative abundance

The numbers of laughingthrushes and barbets seen or heard at the 16 survey sites are summarised in Table 2 whilst the relative abundance of the two species at the survey sites is compared in Figure 3.

The laughingthrush was most common at Kent Ridge Park—34 birds counted, followed by Bukit Batok Nature Park with 25 birds. These hilly forested sites with dense leaf-litter provide suitable habitat for the birds to thrive, which is a key factor favouring invasion (Williamson & Fitter 1996). At Bukit Batok West/Brickland Rd, 18 birds were counted, while fewer than 10 birds were counted at all other sites. Eleven barbets were counted at Bukit Batok Nature Park, followed by Fairways Drive and Bukit Brown with 10 and 9 respectively.

DISCUSSION

The number and location of the original releases/escapes and the number of individuals involved on each occasion are unknown, but evidently the number of events and number of individuals involved had an important bearing on the subsequent success of the species in the wild. The introduction in the 1990s of green corridors linking parks and existing green areas in Singapore may have also been a springboard for the two species to move rapidly around the island, aiding their spread and establishment in west, south and central Singapore.

Literature reviews and field observations show that both species are only found in low numbers in primary forest and tend to favour secondary growth, indicating their tolerance of degraded forest and woodland habitat conditions. The massive destruction of primary

Table 2. Records of White-crested Laughingthrush (L) and Lineated Barbet (B) seen/heard during field visits.

Survey site	Total no.	Detailed observations including behaviours/remarks on habitat, etc.
MacRitchie Reservoir	L: 0 B: 2	Laughingthrush: No records. Barbet: Singles heard at 1,260 m & 2,620–2,870 m.
Bukit Batok Nature Park	L: 25 B: 11	Laughingthrush: A single bird heard at 380 m and 4 flocks heard at 530 m, 760 m, 1,120 m & 1,420 m. At 40–70 m, 5 adults and 3 juveniles were feeding on biscuits left on the ground by park-goers and foraging in the leaf-litter in dense understorey. The birds were not afraid of human presence. Singles were also seen at 380 m, 670 m (feeding on a forest cockroach), 680 m (feeding on a caterpillar) and 920 m. Barbet: 2 birds were heard each at 60–70 m, 190–370 m & 490–500 m. Singles heard at 610–640 m, 680 m, 820 m, 870 m & 1,250 m.
Neo Tiew Lane 2	L: 6 B: 0	Laughingthrush: 6 birds foraging 20 m above ground on albizia tree and also feeding on small berries of a shrub at trail edge at 500–560 m. Barbet: No records.
Lorong Danau	L: 3 B: 4	Laughingthrush: An unseen flock heard at 40 m. Barbet: Singles heard at 1 m, 40 m & 50 m. One seen at 50 m feeding on berries and uttering soft calls.
Nanyang Crescent	L: 9 B: 3	Laughingthrush: 6 birds seen in thickets with dense undergrowth at 400 m and a flock heard in albizia forest by the canal at 450 m. Barbet: Singles heard at 1 m, 410 m & 500 m.
Bukit Batok West & Brickland Rd	L: 18 B: 7	Laughingthrush: 5 flocks heard at 20 m, 180 m, 280–290 m, 450 m & 510 m. A flock of 3 birds seen calling at mid-storey level in albizia. Barbet: Singles heard at 210–220 m, 510 m & 1,140 m; 2 birds heard at 300 m & 1,000 m.
Goldhill Avenue	L: 3 B: 5	Laughingthrush: A single seen at 110 m; 2 birds seen at 220 m. Barbet: Singles heard at 20 m, 130–170 m, 220 m, 280–300 m; 1 bird seen perched in mid-storey of albizia at 220 m.
Kent Ridge Park	L: 34 B: 2	Laughingthrush: 6 flocks calling at 10 m, 80–90 m, 130 m, 240 m, 260 m & 860 m; 3 birds foraging in leaf litter at 150 m; 5 birds feeding on an opened fruit husk at 210–220 m; 2 birds, 5 birds and a single seen at 260 m, 320 m & 590 m respectively. Barbet: Singles heard at 1 m & 150 m.
Pasir Ris Park	L: 0 B: 0	Laughingthrush: No records. Barbet: No records.
Jurong Lake Park & Japanese Garden	L: 0 B: 3	Laughingthrush: No records. Barbet: A single feeding on small fruits at 180 m, singles heard at 710 m & 950 m.
Bukit Timah Nature Reserve – Mountain Cycle Track	L: 0 B: 2	Laughingthrush: No records. Barbet: Singles heard at 280 m & between 1,270–1,360 m.
Fairways Drive	L: 0 B: 10	Laughingthrush: No records. Barbet: Singles seen at 1 m, 110 m & 340 m. Singles heard at 1 m, 230 m, 380 m, 570 m & 700 m; 2 birds heard at 200 m.
Telok Blangah Hill Park	L: 9 B: 0	Laughingthrush: A flock heard at 200 m and 6 birds seen at close range at 1,050 m preening/allo-preening in a pine tree & feeding on bread on the ground. Barbet: No records.
Singapore Botanic Gardens	L: 0 B: 1	Laughingthrush: No records. Barbet: A single heard on repeat visit on 3 March 2013 (no record when site was first surveyed on 24 February 2013).
Mount Faber Park	L: 0 B: 1	Laughingthrush: No records. Barbet: A single heard at 940 m.
Bukit Brown	L: 3 B: 9	Laughingthrush: A flock heard at 800 m. Barbet: Singles heard at 1 m, 300 m, 430 m, 800 m, 970 m & 1,190 m; 2 birds heard at 360 m. A single seen in mid-storey of a tree at 780 m.

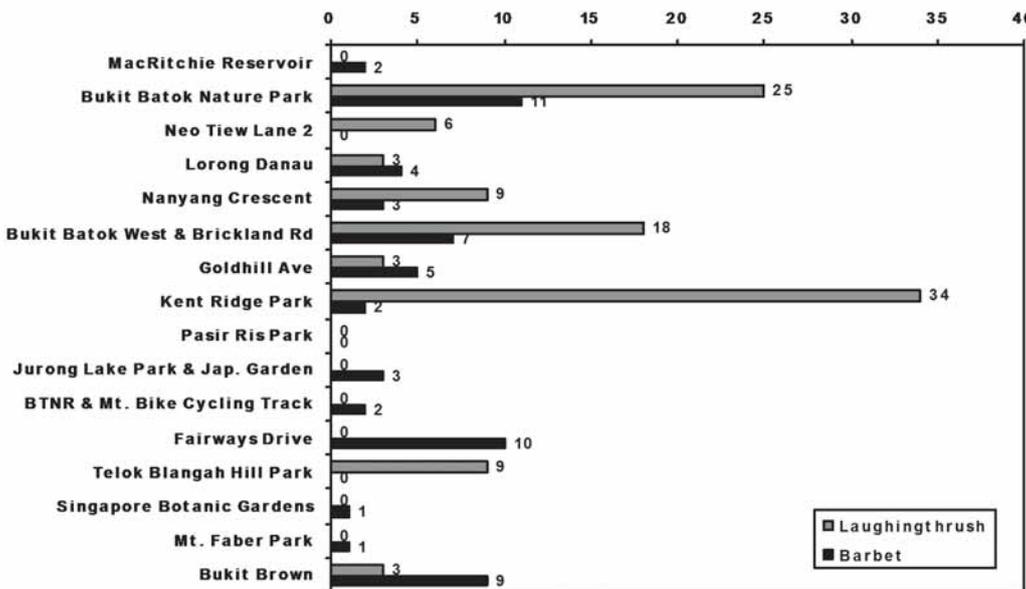


Figure 3. Relative abundance of White-crested Laughingthrush and Lineated Barbet at the field sites.

forest in Singapore during the eighteenth century changed the landscape to secondary forests and woodlands—habitats suitable for these adaptable species (Brook *et al.* 2003, Sodhi *et al.* 2004). Most of the barbet nest holes were cavities excavated in branches of albizia trees *Falcataria moluccana*—a common, fast-growing species of secondary forests and self-seeded woodlands growing on abandoned land.

The success of the laughingthrush as an invasive species is attributable to the fact that it is a sociable bird living in groups, benefiting from the improved protection from predators, better foraging and reproductive efficiency afforded by the group (Yap & Sodhi 2004). It is a multi-brooded cooperative breeder with adults assisting each other to care for the young (Round 2006)—during the visit to Bukit Batok Nature Park, five adults and three juveniles were seen together. During site visits, its varied diet was observed to include forest cockroaches, caterpillars, small berries and human waste food including bread and biscuits. The ability to exploit varied food sources is another important factor in its successful exploitation of many different green spaces in Singapore. The fact that it is sedentary with a relatively high body mass and that it appears to be relatively aggressive also contributes to its invasive spread in Singapore (Kolar & Lodge 2001); it is believed to have displaced a population of another non-native, the Greater Necklaced Laughingthrush *Garrulax pectoralis* from Kent Ridge Park (Lamont 1998). It may have also occupied ecological niches vacated by babblers; for example, Abbott's Babbler *Malacocincla abbotti*, which was formerly common but now in decline, has disappeared from Bukit Batok Nature Park—the decline is thought to be due to direct competition with the laughingthrush coupled with forest degradation and fragmentation isolating unsustainable non-viable populations (Yong 2009).

However, the laughingthrush was not detected in seven of the 16 sites surveyed; four of these, Mount Faber, Singapore Botanic Gardens, Bukit Timah Nature Reserve and MacRitchie Reservoir previously held individuals/populations, and repeat visits will need to be made to confirm whether isolated populations are still present or are truly extirpated.

The canopy-dwelling barbet was more often heard than seen. It is a stronger flyer than the laughingthrush—given that it is a frugivore, it needs to fly across forest patches to search for and visit scattered fruiting trees. During breeding periods, the bird also searches for trees with suitable dead wood for nest excavation. Hole-nesting species experience lesser stress than open-nesting species when faced with micro-climatic changes, and also suffer less mortality in terms of individual or whole nest losses (Yap & Sodhi

2004). The barbet is also reported to be double-brooded, the second brood being started within days of the fledging of the first brood (Short & Horne 2002). All these factors are possible explanations why it is more widespread than the laughingthrush and was detected at 13 of the 16 study sites.

The alien Lineated Barbet and the native resident Red-crowned Barbet *Megalaima rafflesii* are closely related species of similar size; both are frugivores, nesting in tree cavities, and might be expected to be in direct competition. However, based on Wells (1999), personal observations and sightings in *Singapore Avifauna*, the Red-crowned Barbet is always recorded and breeds in primary forest, whilst the Lineated Barbet is usually recorded in secondary forest and open areas (Wells 1999), and there are no breeding records from primary forest; in fact there may be no competition between these species for nest sites. It may be that those cavity-nesting woodpeckers which favour secondary forest habitats are more adversely affected by the alien barbet, as local birdwatchers have seen the barbet showing aggression towards woodpeckers. An important non-avian consideration is the potential detrimental impact on native forest flora by the dispersal of seeds of non-native flora, thereby extending the range of alien flora, since the barbet is a versatile frugivore, feeding on exotic species like MacArthur's palm *Ptychosperma macarthurii*, *Cecropia* species and albizia *Falcataria moluccana*. In the not-too-distant future, it is also plausible that populations of the barbet in Singapore may be augmented by natural range expansion from Malaysia—it has been recorded spreading down the coasts of the peninsula during the last century where it is found in coastal habitats due to deforestation (Wells 1999).

During field visits, neither laughingthrush nor barbet was seen or heard in Pasir Ris Park, suggesting they have not spread to east Singapore, possibly due to lack of a green corridor linking the central catchment forest to the isolated patchy forests in the east. However, these visits confirmed the spread and persistence of populations of laughingthrush and barbet in west, south and central Singapore. This invasive transition from introduced to naturalised populations is presumably a result of a combination of many factors—climatic matching (Duncan *et al.* 2003, Hayes & Barry 2008), presence of suitable habitats (Williamson & Fitter 1996), existence of empty niches, varied diets and inherent attributes of the birds (Kolar & Lodge 2001), social behaviour, cooperative breeding (Round 2006) and aggressive nature.

On the other hand, over the past decades, loss of non-protected green areas holding native habitats has led to the fragmentation and isolation of populations of sensitive resident birds, some of

which gradually died out leading to the current depauperate state of Singapore's avifauna (Castelletta *et al.* 2000, Brook *et al.* 2003, Sodhi *et al.* 2004, Yong 2009, Sodhi *et al.* 2010). Ecological niches previously occupied by native species are now being taken over by more tolerant and invasive species such as the laughingthrush and the barbet.

Given that the laughingthrush competes directly with native ground-dwelling and foraging birds and that the barbet competes directly with native frugivores and some of the native tree-cavity nesters, it is important that further field studies are carried out on these alien species in the north and east of Singapore and the offshore islands which have not been well surveyed. Population assignment methods or phylogeography (Alacs *et al.* 2009) would be useful to determine the geographic origins and the genetic relatedness of the populations in different parts of Singapore. Data from these studies could potentially be used to infer the pattern and extent of invasive spread as well as to determine whether their populations are potentially detrimental to native birds occupying similar ecological/foraging niches and nesting sites.

Evaluation of other potential invasive species in the bird trade should be carried out, given the country's role in the international bird trade (Nijman 2010), the significant number of bird shops, the widespread popularity of birds as pets and the thriving songbird and exotic bird culture in Singapore. This will help determine the need for appropriate interventions, for example the culling of naturalised and other exotic species to prevent further and future invasions in order to protect vulnerable native species from extirpation.

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