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Changes in the Status of *Lophura* Pheasants in Khao Yai National Park, Thailand: A Response to Warming Climate?

Philip D. Round[1]

Department of Biology, Faculty of Science, Mahidol University, Rama 6 Road, Bangkok 10400, Thailand

and

George A. Gale

King Mongkut's University of Technology Thonburi, School of Bioresources & Technology, 83 Mu 8 Thakham, Bangkhuntien, Bangkok 10150, Thailand

ABSTRACT

Long-term bird population changes in response to natural or anthropogenic factors have been relatively well documented in the temperate zone, but rarely in the tropics, where there are few long-term data sets. Here, we analyze a 25-yr sequence of records of two species of *Lophura* pheasants, Siamese Fireback *L. diardi* and Silver Pheasant *L. nycthemera* in Khao Yai, Thailand's oldest national park. These data suggest that the number and proportion of detections of the lowlands-inhabiting *L. diardi* have increased significantly in relation to those of the higher elevation inhabitant *L. nycthemera*. Environmental factors mediated by changing climate are the most plausible explanation for the changing proportions of sightings of the two species. Further work is needed to explore in detail microhabitat selection of these birds and whether changes in microsite conditions on the forest floor or other factors are driving the observed distribution. Long-term monitoring of the avifauna along an elevational gradient is also recommended in tandem with increased monitoring of local climatic conditions.

Abstract in Thai is available at http://www.blackwell-synergy.com/loi/btp.

Key words: climate change; *Lophura diardi; Lophura nycthemera;* tropical forest.

Over the past 100 years, the global average temperature has increased by approximately 0.6°C and is expected to continue to rise rapidly (Houghton *et al.* 2001). Although species have responded to climatic changes on an evolutionary timescale, a critical question for wild species is how they cope with the current rate of change (Root *et al.* 2003). Among birds, climate change is linked with earlier breeding (Crick *et al.* 1997, Forcchammer *et al.* 1998, McCleery & Perrins 1998, Crick & Sparks 1999, Schaefer *et al.* 2006), earlier arrival dates, and later departure dates in breeding visitors (Mason 1995, Butler 2003, Lehikoinen *et al.* 2004, Beaumont *et al.* 2006, Jonzén *et al.* 2006). Poleward and altitudinal range expansions have been documented in birds and in many other taxa (Thomas & Lennon 1999, Hickling *et al.* 2006). Typically, studies of responses of birds and other species to climate change have focused on organisms occurring in the temperate zone and climatic zones closer to the poles (Root *et al.* 2003). However, since the mid-1970s all tropical rain forest regions have experienced a significant warming at a mean rate of 0.26 ± 0.05°C per decade, in synchrony with the global increase (Malhi & Wright 2005). In one of the few tropical studies on birds, Pounds *et al.* (1999) documented rapid change in the avifauna (the colonization of montane habitats by nonmontane species) linked to declining mist frequency (itself induced by rising air temperatures) in cloud forest in Costa Rica.

Here, we investigate whether the incidence of two species of *Lophura* pheasants that occur syntopically in a mid-elevation forest in Khao Yai National Park, northeastern Thailand has changed in the past two to three decades, and speculate on the possible causes.

The Silver Pheasant *Lophura nycthemera* and Siamese Fireback *L. diardi* occur sympatrically over much of their SE Asian ranges encompassing north and east Myanmar, northern and eastern Thailand, and Indochina (King *et al.* 1975, Delacour 1977, Dickinson 2003). The race of Silver Pheasant occurring in northern Thailand, south to Khao Yai, *L. n. jonesi*, is mainly montane and submontane in distribution, inhabiting elevations of 700 m and above in Thailand, though other races are occasionally found lower, down to 200 m in some parts of Laos and Vietnam, (J. W. Duckworth, pers. comm., J. C. Eames, pers. comm., R. Timmins, pers. comm.). The monotypic *L. diardi* is a lowland species, in Thailand mainly inhabiting forest in plains and foothills to a maximum elevation of 700–800 m (King *et al.* 1975, Lekagul & Round 1991, Robson 2000), though usually found below 500 m in Laos (J. W. Duckworth, pers. comm.). Although there is substantial local variation in altitudinal range in both species across their ranges, the two are only rarely found alongside each other in Laos and Vietnam (J. W. Duckworth, pers. comm., J. C. Eames, pers. comm.). In their relatively wide zone of geographical overlap, the two species are thus largely segregated by habitat and elevation.

METHODS

Study area.—Khao Yai is Thailand's oldest park, established in 1962, and is occupied mainly by evergreen or semi-evergreen forest,

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[1]Corresponding author; e-mail: frpdr@mahidol.ac.th

with small areas of mixed deciduous forest around the northern margins. Much of this forest is tall and mature, with large trees, and is roughly evenly divided between foothills (< 600 m) and submontane elevations (600–1000 m). However, significant areas in the foothills zone, such as along the southern access road from the headquarters descending to the town of Prachinburi, have been logged.

Observations were collected within a radius of 5 km of the park headquarters. Most of the area was evergreen forest alternating with patches of *Imperata*-dominated grassland, left over from former cultivation, the area having supported a small human population before the park was established. Parts of this grassland area are maintained as grazing habitat for large herbivores by annual burning or mowing. The topography is an undulating plateau, at elevations 600–890 m, with over 80 percent of the area lying > 750 m. The plateau is transected by a major stream, the Lam Takhong, and there are many smaller streams, most of which dry up seasonally during February to April. The area has been regarded as lying in an altitudinal transition zone between lowland forest and hillslope (or even lower montane) forest (*e.g.*, Smitinand 1968). The highest summit in the park, Khao Rom (1350 m), lies only 8.5 km SE of the study area.

RECORDS OF *LOPHURA* PHEASANTS IN KHAO YAI.—Dickinson (1963) was the first to record *L. nycthemera* in Khao Yai National Park, though Deignan (1963) was presumably aware of its occurrence there, since he listed the species 'south as far as Nakhon Ratchasima,' the province in which a major part of Khao Yai lies. McClure (1974) listed both *L. nycthemera* and *L. diardi* for Khao Yai but described both as rare, and his seasonal distribution table provides only one monthly entry for each species, indicating that he made, or knew of, very few sightings, perhaps as few as one of each species, during the period of his coverage (1967–1973).

Notwithstanding the scarcity of early records, both *L. nycthemera* and *L. diardi* are now known to be relatively common, and are frequently observed in the headquarters area of Khao Yai.

SOURCES AND ANALYSES OF DATA.—Sightings of both *Lophura* pheasants were usually reported in the written accounts of birdwatchers, filed at the (now defunct) Association for the Conservation of Wildlife, Bangkok, during 1978–1986, and at either the Center for Conservation Biology, Mahidol University, Bangkok, or the Bird Conservation Society of Thailand from 1986 onwards up to the present, and this constituted our primary data source. Further, an appeal for all sightings of either *L. nycthemera* or *L. diardi* in Khao Yai was posted on the Oriental Birding Newsgroup in January 2000. The data supplied were usually numbers and sexes of pheasants sighted, date and duration of visits, and approximate location (by trail), and were therefore amenable to analysis, even though the search effort was not standardized. In addition, we incorporated all our own sightings, made both while birdwatching in the park, and implementing standardized surveys (below). The extensive trail and road network allowed more or less even access across the limited range of elevations within the park headquarters area. We noted all records of *Lophura* pheasants, and recorded search effort as number of days per trip, regardless of the number of observers. Negative records were also included.

Simple linear correlations were used to assess changes in pheasant encounter rates and changes in rainfall and temperature through time. Distance data from line transects conducted on a mapped 30-ha plot, the Mo-Singto Long-term Biodiversity Study Plot, lying 800 m from the park headquarters, during May 2003 to August 2005, analyzed using DISTANCE 5.0 software (Thomas *et al.* 2004), were employed to estimate densities and probability of detections of both species.

RESULTS

Records (not including those from transect sampling) of a total of 354 individual pheasants were available for the period of analysis. This comprised 84 sightings (177 individuals) of *L. diardi* and 87 sightings of 177 individuals of *L. nycthemera.* Eighty-six individuals of both species combined were seen during the 15-yr period from 1979 to 1993 compared with 268 individuals during 1994–2004 inclusive (Fig. 1). The approximate detection rates for these two periods, for both pheasants combined, were 0.21 pheasants per day and 0.67 pheasants per day, respectively.

The proportions of sightings contributed by each species varied markedly through time. Up to 1993, *L. diardi* contributed only 16 of 86 individual pheasants seen (18.6%) with only two sightings of single individuals being made before 1987. In the period from 1994 to the present, *L. diardi* contributed more than half of all pheasants observed (60.1%; 161 out of 268 observations). *Lophura diardi* contributed a significantly higher proportion, and *L. nycthemera* a significantly lower proportion, of pheasants observed in the second period than in the first ($\chi^2 = 43.1$; $P < 0.01$, df $= 1$).

There was a significant increase in the detection rate of *L. diardi* during the survey period, both as measured by the number

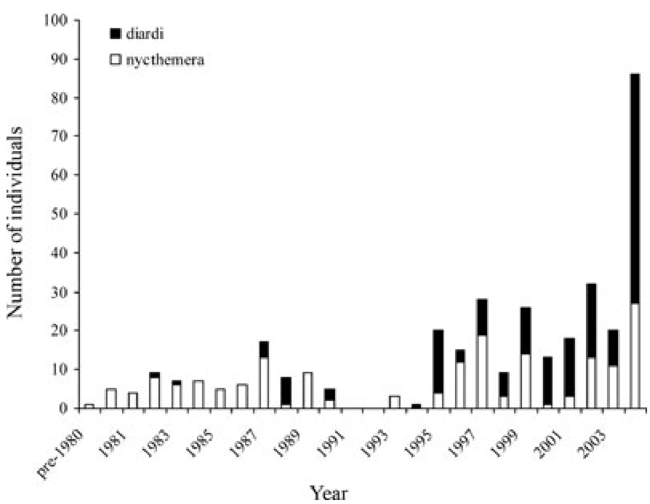

FIGURE 1. Numbers of *Lophura* pheasants detected in Khao Yai National Park, *ca* 1978–2004.

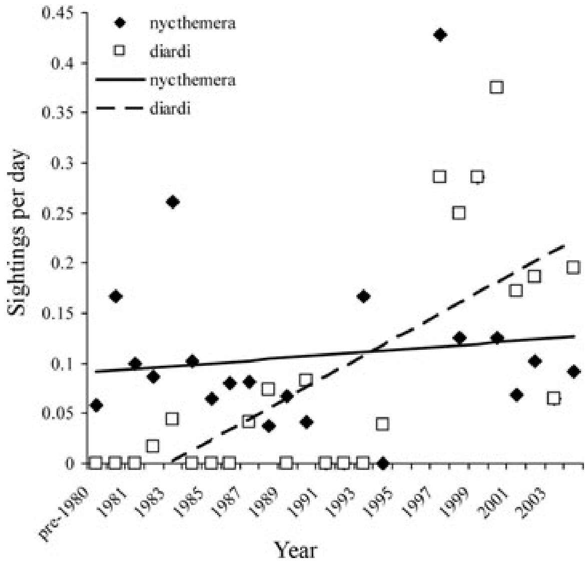

FIGURE 2. Detection rates of *Lophura* pheasants, 1980–2004.

of individuals per day ($r = 0.607$; $P = 0.002$), and the number of sightings per day ($r = 0.686$; $P < 0.001$; Fig. 2). In contrast, neither the number of individuals detected nor the number of sightings per day increased significantly in *L. nycthemera* ($r = 0.164$, $P = 0.45$ and $r = 0.265$, $P = 0.708$, respectively). There was no significant increase in flock size in either species during the study period (*L. nycthemera* mean flock size: 1.98 ± SD 1.42; $r = 0.095$, $P = 0.669$; *L. diardi* mean flock-size: 2.22 ± 1.44; $r = 0.376$, $P = 0.152$).

The disparity between the detection patterns of *L. nycthemera* and *L. diardi* was very striking. One of us (PDR) spent many hours in 1982–1985 walking trails on the 30-ha Mo-Singto study plot, with access routes to and from the plot probably adding another 50 ha in total. Though *L. nycthemera* was seen eight times during that period there were no sightings of *L. diardi*. A colleague spent approximately 20 d/mo during the period November 1981 to March 1983 studying White-handed Gibbons *Hylobates lar* on the same plot, encountering *L. nycthemera* at least six times during that period, but never once seeing *L. diardi* (U. Treesucon, pers. comm.).

At the present time, the majority of pheasant encounters on and around the Mo-Singto plot are with *L. diardi*. During 2001–2004 we recorded 23 sightings of 48 individual *L. nycthemera*, compared with 49 sightings of 84 *L. diardi* on, or in the immediate vicinity of, the study plot. Camera-trapping, conducted beneath fruiting *Prunus* trees during 2004 recorded ca. eight *L. diardi* compared with only one *L. nycthemera* (W.Y. Brockelman, pers. comm.). The latter observer, who has worked in the park for nearly 30 yr, commented that *L. nycthemera* 'used to be much more common' (W.Y. Brockelman, pers. obs.).

During line transect surveys, we recorded 13 sightings of 23 adult *L. nycthemera* and 15 sightings of 34 adult *L. diardi*. Only six records of *L. nycthemera* (46.1%) were on lower, flatter areas below the 770-m contour, while the 11 of 15 *L. diardi* records (73.3%) were below this contour. However this difference was not statistically significant ($\chi^2 = 2.23$, $P = 0.142$) and there was much overlap.

For density estimation, due to the small sample size, and as detection distances between species appeared to be similar, data from both species were pooled to generate a single detection function following Buckland *et al.* (2001). The density estimate for *L. diardi* was greater (10.0 groups or 22.8 individuals/km^2, vs. 8.0 groups or 14.7 individuals/km^2) However, due to the small sample size, the variances of the estimates were large (95% CI: 4.7–21.5 groups/km^2 for *L. diardi* and 2.6–24.5 groups/km^2 for *L. nycthemera*) suggesting that the estimates should be treated with caution (Buckland *et al.* 2001).

DISCUSSION

Both *Lophura* pheasants presently co-exist in the headquarters of Khao Yai, though their relative abundance has changed markedly over the past two decades. The proportion of sightings contributed by *L. diardi* changed from 18.6 percent during 1980–1993 (all but two of these sightings coming from 1987 to 1993) to 60.1 percent during 1994 to 2004. There was a significant increase in the rate of detections (sightings/unit effort) of *L. diardi* throughout the study period, whereas the detection rate of *L. nycthemera* remained unchanged.

Although observers identified most sightings by trail, most sightings could not be related to point locations. Data collection was not standardized, though there was no bias toward data collection from higher or lower elevations, or from differential spatial coverage during any period of the study that could account for the observed change in incidence of the two species through time. While it is likely that some of the same individuals were observed in the same locations repeatedly by different observers, the change in the relative proportion of observations of one species to another would not be expected to show a strong bias over time. Some of the increase in sightings may have been due to pheasants becoming tamer and easier to observe than formerly, following the cessation of hunting in the 40 yr since the park was established. The improved skills and more detailed knowledge of birdwatchers on where to find pheasants within the park may also have contributed. Much less information was available pre-1990. Neither increased habituation nor differences in coverage can account for the changing proportions of the two species, however.

If one or the other species had been more adversely affected by, or less able to rapidly recover from, predation, this might lead to differential detectability though time. However, there is no evidence that either was the case. Both species are equally targeted by hunters. Clutch sizes are also similar (reported as 6–8 eggs for *L. n. jonesi* and 4–8 eggs for *L. diardi*; A. Hennache, pers. comm. to P. Garson) suggesting no major difference in intrinsic rates of increase. Captive *L. nycthemera* maintained in (Thai) Department of National Parks breeding stations produced slightly more eggs than did *L. diardi* (average 19.4 eggs/female/yr in *L. nycthemera* compared with 18.4 eggs in *L. diardi*; P. Sanpote, pers. comm.). There are no data on juvenile survival, which is likely to be more important than clutch size in affecting recruitment, but again is unlikely to have created such an obvious change in detections.

There has been no major change in habitat, such as the breakdown in a former physical or vegetational barrier, which could account for a rapid colonization of the headquarters area by a species that was formerly absent. The southern parts of Khao Yai slope down gently from > 1000 m to the park boundary to *ca* 100 m, and in most of the area the forest cover is unbroken. Although a northern access road into the park road was constructed during the late 1950s and early 1960s, and a connecting road to the southern park boundary was built in 1982, this low level of habitat perturbation would not have affected the distribution of forest interior species such as pheasants. A few open-country or deciduous woodland birds that have apparently benefited, and have recently colonized the headquarters area of the park (*e.g.*, Asian koel *Eudynamys scolopaceus*, plaintive cuckoo *Cacomantis merulinus*, red-wattled lapwing *Vanellus indicus*, racket-tailed treepie *Crypsirina temia*, common myna *Acridotheres tristis* and olive-backed sunbird *Nectarinia jugularis*; Lynam *et al.* 2006) are all confined to forest edge or grassland, and their numbers have remained small. Nor is it likely that loss of habitat in the lowlands has displaced *L. diardi* and caused more individuals to move upslope into suboptimal habitat formerly occupied solely by *L. nycthemera*. If this was the case, it would be likely that, after some initial increase in numbers in that habitat, the population would gradually dwindle as senescent birds, unable to sustain their numbers through recruitment, died off.

SYNTOPY AMONG *LOPHURA* PHEASANTS.—Why has *L. diardi* recently become more detectable in relation to *L. nycthemera*? One should first consider how usual is the co-existence of two *Lophura* species in the same habitat.

In the few cases where *Lophura* pheasants occur in sympatry, they are usually ecologically segregated by habitat or elevation (Davison 1981; Thewlis *et al.* 1998; BirdLife International 2000, 2001). The co-occurrence of two *Lophura* in lowland mixed dipterocarp forest of Malaysia (Davison 1981) occurs in the context of an exceedingly rich avifauna and a high level of endemism at the Sunda subregional level. The avifauna of Khao Yai, by contrast, is relatively species-poor. It supports, for example, only ten species of babblers and laughingthrushes (Timaliiinae and Garrulacinae) compared with roughly 25 species of babblers in lowland Sundaic rain forest (Wells 1985). This makes it all the more surprising that two *Lophura* pheasants should both be relatively common in the same habitat.

The present syntopy of two congeneric pheasants in Khao Yai's relatively depauperate avifauna is unlikely to reflect a stable situation, but instead indicates a dynamic interaction, in which the lowland species, *L. diardi*, is increasingly moving into the habitat of the higher elevation species, *L. nycthemera*. Even though both species seemingly take a wide range of plant matter and invertebrates, the two overlap greatly in feeding ecology, and an increase in one species might be expected to affect the numbers of the other.

POSSIBLE EFFECTS OF CHANGING CLIMATE.—The most likely reason for an increase in numbers of *L. diardi* is the operation of an environmental factor that favors this species. We suggest that factors mediated by changing climate are the most plausible explanation for the increased frequency of sightings of *L. diardi*.

Ecological changes caused directly by rising temperature, or mediated through increased evapotranspiration, would be expected to benefit plants and animals of drier lowland habitats at the expense of montane species. Logically, one might assume that animals would track vegetational changes. However, changes in distributions might be detected more easily in animals than in plants due to their greater conspicuousness. Moreover, animals could be responding to minor vegetational changes such as those demonstrated by Karr and Freemark (1983) in the understory of a Panamanian forest including changes in leaf litter depth, soil humidity or other microclimatic features.

Detailed mapping of the forest tree flora on the Mo-Singto permanent plot, carried out over several years (Brockelman *et al.* 2002), provides indications that changes in seedling recruitment among forest trees are taking place. Seedlings of the third most common tree on the plot (*Nephelium melliferum* Fam. Sapindaceae) are failing to survive on south and west-facing slopes, while adult trees are distributed throughout the plot. This has tentatively been attributed to rising temperatures (Brockelman *et al.* 2005).

The direct evidence for temperature change at Khao Yai is equivocal, however. Temperature graphs for the two largest provinces abutting Khao Yai, Nakhon Ratchasima to the north and Prachinburi to the south, show a significant rising trend in two of three measurements. The mean minimum and mean temperature for Nakhon Ratchasima, ($r = 0.855$, $P < 0.001$ and $r = 0.840$, $P < 0.001$, respectively) and the mean minimum and mean maximum for Prachinburi ($r = 0.713$, $P < 0.001$ and $r = 0.706$, $P < 0.001$, respectively) increased by 1.5–2.0°C over a 50-yr period (data supplied by Meteorology Department, Bangkok). Although the trends differ between the two stations for mean maximum and mean temperatures, the trend of increase for mean minimum temperature was very similar in both. However, the rise documented (~2°C) was larger than has been recorded elsewhere where the climate is warming, and the effects of increased urbanization or other 'heat-island' effects around the recording stations have almost certainly contributed. Temperature records from a recording station in Sakaerat Biosphere Reserve, which lies to the north-east of Khao Yai, at *ca* 400 m elevation, do not show any increase over the past 35 yr, however (data supplied by Sakaerat Environmental Research Station). Rainfall also showed no consistent pattern among the stations. There was a statistically significant decrease in rainfall at Sakaerat during the years 1969–2004 (mean annual rainfall 1059 mm ± SD 239 mm; $r = 0.706$; $P < 0.0001$) and for Prachinburi during 1951–2003 (mean annual rainfall 1929 mm ± SD 297; $r = 0.321$; $P = 0.019$). However, the annual rainfall at third site, Pak Chong, to the north of the park, showed no significant trend (mean annual rainfall during 1972–2004: 1113 mm ± SD 178; $r = 0.173$; $P = 0.337$). Temperatures elsewhere in the region (southwestern China) have significantly increased, while rainfall has significantly declined or increased depending on the station. In particular, temperatures most notably increased and rainfall decreased in the lower reaches of the Lancang (Mekong) river (Yunling & Yiping 2005).

CONCLUSIONS: FUTURE WORK.—The most plausible explanation is that there has been a real increase in the size and viability of the *L. diardi* population in the park headquarters area in response to changes in an environmental variable. *Lophura nycthemera*, in contrast, has not increased, and, allowing for likely increased detectability in both pheasant species, may have actually declined during the study period. The most plausible explanation for the observed trend is climate change.

Global climate change may not be the only factor implicated, however. Khao Yai was formerly part of a much larger area of surrounding forest, most of which has since been cleared for farmland. Forest cover in the provinces surrounding Khao Yai was reduced by 25–50 percent during 1973–1995 (Kermel-Torrès 2004). Fragmentation and associated edge effects such as reported in Pasoh, Malaysia, can negatively affect a wide range of wildlife, including insects, birds, and mammals (Okuda *et al.* 2003). The more than 2000 km^2 area of Khao Yai is a relatively large fragment. However, the impact of large-scale deforestation on regional climate has been demonstrated for Amazonia where, during the dry season, higher temperatures and higher rainfall were observed over deforested areas compared to forested areas (Negri *et al.* 2004). Loss of forest from areas surrounding Khao Yai might be expected to induce drying and increased temperatures in the forest interior that might also benefit lowland species.

Two other species-pairs that might respond similarly to any habitat changes, whose habitat relations are apparently similar to those of the pheasants and whose numbers might be more easily tracked, are orange-breasted trogon *Harpactes oreskios* (lowland) and red-headed trogon *H. erythrocephalus* (submontane/montane); and Hainan blue flycatcher *Cyornis hainanus* (lowland) and hill blue flycatcher *C. banyumas* (submontane/montane). Both trogons occur on the Mo-Singto permanent plot, in roughly similar numbers (there were 198 orange-breasted trogons detections during May 2003–August 2005 compared with 243 red-headed trogon detections; Khao Yai Avian Diversity Project, unpub. data). They are presumably ecologically segregated, and their co-existence is not surprising, given that as many as four *Harpactes* spp. may co-exist in lowland Sundaic rain forest (Wells 1999). We have a strong suspicion that *C. hainanus* has become more common in the past couple of decades. While both *C. hainanus* and *C. banyumas* were previously known from the headquarters area of Khao Yai, *C. hainanus* was usually found in the lower-lying areas, 600–700 m. Only *C. banyumas* was present on the Mo-Singto Plot during 1982–1983, and again during 2000–2002, when intensive observations were recommenced there. However, at least two *C. hainanus* appeared on the plot for the first time during 2003. This is too little information on which to base any conclusions, especially as *C. hainanus* may tend to favor, and move into, small natural clearings and tangles occasioned by treefalls, but it suggests that further monitoring of these species-pairs, in addition to the *Lophura* pheasants, might be instructive.

We cannot yet prove that *L. nycthemera* has declined as *L. diardi* has increased in numbers. If climate change is inducing vegetational or other changes that favor the lowland species (*L. diardi*), this is likely to be at the expense of the upland species, (*L. nycthemera*) and we should eventually be able to demonstrate an increase in the altitudinal range occupied by *L. diardi*, and an upslope retreat of *L. nycthemera*. Up to now, though, there have been few surveys outside of the narrow elevational range around the Khao Yai headquarters in which our studies were conducted. In addition to investigating the detailed ecology and interactions between the two pheasants, future studies should concentrate upon conducting standardized sampling of a wider range of bird species, including, but not limited to, the other species-pairs mentioned, along altitudinal gradients in the park. It would also be necessary to increase the number of meteorological stations in and around the park in order to monitor climatic changes.

Most protected areas in the tropics are small fragments of former large expanses of forest. It may take many decades before the full effects of isolation and fragmentation, and edge effects on the communities of plants and animals that live within their boundaries, become fully evident. However, the deleterious impacts of these factors are likely to be exacerbated due to climate change. There is an urgent need for more widespread monitoring of population trends among potentially sensitive species, and also for the monitoring of habitat change in tropical forest fragments.

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SUPPLEMENTARY MATERIAL

The following supplementary material for this article is available online at: www.blackwell-synergy.com/loi/btp.
Acknowledgments S1.

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