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Short Communication

Flight initiation distance as behavioral indicator of hunting pressure: a case study of the Sooty-headed Bulbul (*Pycnonotus aurigaster*) in Xishuangbanna, SW China

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Abstract
Traditional assessments of anthropogenic impacts on biodiversity often ignore hunting pressure or use subjective categories (e.g. high, medium or low) that cannot be readily understood by readers or replicated in other studies. Although animals often appear tame in habitats without hunting compared to habitats with hunting, few studies have demonstrated such effects. We determined the flight initiation distance (FID; i.e. human-animal distance when the animal begins to flee) of a common frugivorous bird of Southeast Asia, Sooty-headed Bulbul (*Pycnonotus aurigaster*) across a gradient of hunting pressures in Xishuangbanna, Yunnan, SW China. Controlling for confounding effects, we show that FID increased with hunting pressure, which was quantitatively measured through encounters with hunters. As FIDs respond more specifically to hunting than other defaunation metrics, we suggest they can be used as behavioral indicators of hunting pressure in developing conservation strategies.

Key words: Anti-predator behavior; bushmeat; fear; overexploitation; tameness.

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Introduction

Assessing anthropogenic impacts on native ecosystems is an urgent priority for biodiversity conservation. Aspects of behavior have been advocated as indicators of anthropogenic disturbance [1], although the feasibility and practicality of using behavior in conservation science has been questioned [2]. Here we address the question of how to measure hunting pressure objectively and efficiently, especially over a network of research sites or reserves, using behavioral information.

Although over-hunting, introduced species, trophic cascades and climate change are all likely to drive extinctions in the future [3], conservation biologists have often focused their attention on more visible threats, such as habitat destruction [4]. Typically biodiversity assessments ignore hunting pressure, even when conservation biologists may be aware of the presence of hunting in an area, or use subjective categories (e.g. high, medium or low) that are difficult or impossible to standardize for other studies [4]. Depending on local norms, one researcher's 'heavily hunted' forest may be equivalent to another's forest with 'low hunting' pressure. Terms such as defaunation or empty forest suffer from similar problems [5]. Yet knowledge about hunting is needed to determine its effects on ecosystems, and, at the marginal level, to compare its threat to other threats and plan more effective conservation strategies.

Flight initiation distance (FID) is the distance between the prey and the predator or hunter at the point when an animal begins to flee. If the prey behaves optimally, one would expect the FID to increase with predation or hunting pressure [6,7]. For example, FIDs of fishes, ungulates and birds to humans were higher in areas with hunting than in areas without hunting [8-15]. In an environment with at least some predation or hunting pressure, individuals that flee too late are more likely to be killed, whereas individuals that flee too soon unnecessarily increase energy expenditure through locomotion, potentially reducing food intake and social activity. For these reasons, individuals should optimize their FID by weighing the risk of predation against the costs of flight [6,7].

Hence, in principle FID may be used to measure hunting pressure in a landscape and use it to compare hunting levels at different sites. In this study, we compared FIDs of a common, open-habitat frugivorous bird, Sooty-headed Bulbul (*Pycnonotus aurigaster*; IUCN Red List Category – Least Concern) [16], which are targeted by hunters, over an increasing gradient of known hunting pressures in Xishuangbanna Prefecture, Yunnan, SW China (Fig. 1). Controlling for confounding effects, we show that FIDs clearly increased with hunting pressure. We discuss the potential and limitations of this approach for assessing hunting pressure.

Methods

Study site and species

We conducted this study in Xishuangbanna Prefecture, Yunnan, an area of tropical forests in SW China (Fig. 1). In this area, hunting has extirpated several vertebrate species, and hunters even target small birds (8-25cm) [5,17,18]. Sooty-headed Bulbul (*Pycnonotus aurigaster*; beak to tail length: 20cm) is a common open habitat species [19], which hunters often shoot in this region. We conducted fieldwork from October 2013 to March 2014 (non-breeding season). Three field sites of varying hunting pressure were selected for the study: 1) Xishuangbanna Tropical Botanical Garden (XTBG), where birds were not hunted, 2) around Menglun town where there was little to moderate hunting pressure, and 3) around Mengsong town where hunting pressure was severe (see Fig. 1).

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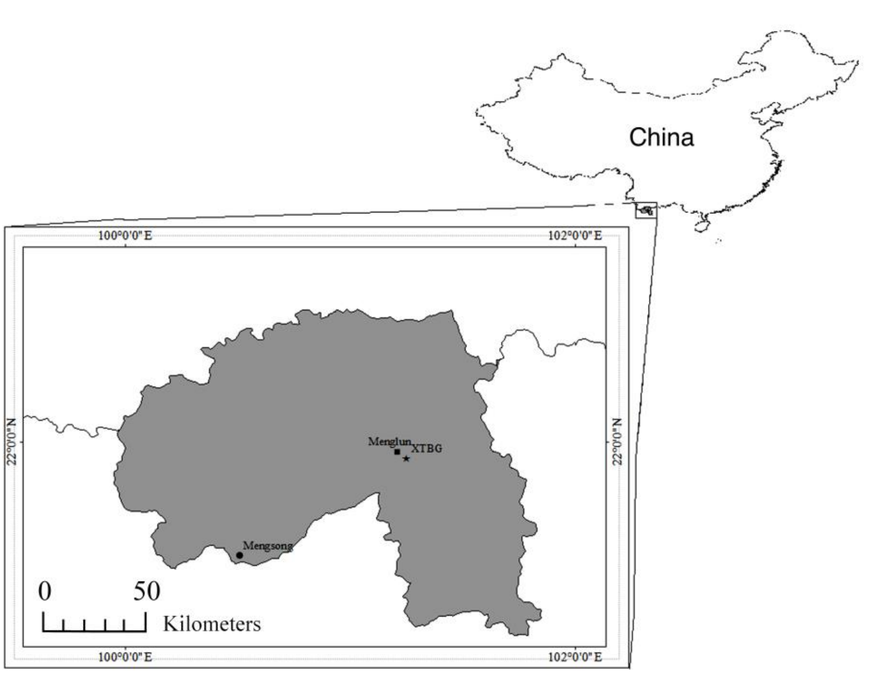

Fig. 1. Map of the study sites in Xishuangbanna Prefecture, Yunnan Province, China. Star indicates Xishuangbanna Tropical Botanical Garden (0 hunters/hr), square indicates Menglun township (0.06 hunters/hr), and circle indicates Mengsong township (0.55 hunters/hr).

Estimating hunting pressure

We estimated the hunting pressure in the three sites used in the study by counting the number of bird hunters encountered on trails. Bird hunters were mainly active in the day and used long homemade shotguns (~2m in length), which have been illegal in China since 1996 [5,17]. Most medium to large sized vertebrates (>1 kg), barring a few hunting-tolerant species (e.g. Common Muntjac, Silver Pheasant, Leopard Cat, Small Indian Civet), have been hunted out from the study area [5,17,18]. Shotguns used by these hunters can fire up to 15 pellets in a single shot, allowing them to harvest flocks of small birds for bush-meat [17]. Bulbul (~21 cm) or even smaller sized birds make up more than half of the individuals recorded in hunters' bags (see [5,17,18] for details). Nets were also used to trap birds in and around fruiting trees, but the use of nets was comparatively rare, and we did not encounter nets during our transect walks. We spent a minimum of 100 hours per site to count the abundance of hunters. As hunter encounters were made visually, we were able to identify the hunter if he was encountered multiple times on a single trail on the same day, and not recount him. We standardized the number of hunters sighted by the effort (number of hours per site).

Study design

To examine the effects of flight initiation distance (FID) of bulbuls, we first observed the birds from a distance (c. 60 m) with binoculars. The flocks generally make conspicuous contact calls while foraging, which makes it easy to spot them from a long distance. We conducted all trials in open habitats within the study sites, as FID may vary with habitat type [20]. We only selected birds that were below 3 m in perch height (height from ground), as FID of birds might vary with perch height at the time of human approach [21]. We measured perch height (0-3m) of the flock as the mean perch height of all birds in the flock. We also only selected foraging birds with flock sizes of three or four birds, as FID might vary with flock size and between foraging

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and non-foraging birds [20]. Then, the observer (RS) walked towards the flock from a standardized starting point, 40 m away. The observer would stop walking when the first bird in the flock fled. We measured the FID and perch height using a range finder (Nikon coolshot AS). Four flocks in Mengsong and none in other sites fled before RS reached the 40 m start point. We did not measure the FID of these mistrials. Each trial involved walking directly towards the selected bird flock from the starting point, with gaze oriented directly towards the subject flock, as orientation and approach are conspicuous cues of predation risk [7,20]. The approach towards the flock was always in a straight line, with no vegetation preventing the observer and bird flock from seeing one another. The same observer (RS), wearing the same clothes and walking at c. 1.6 km hr^{-1}, approached all the flocks (n = 90). We measured the FID of 30 flocks in each of the three field sites. We sampled each flock only once in Menglun and Mengsong, and because these flocks appear to be territorial, we shifted trial-sites (>500m) after sampling a flock. However, in XTBG, we sampled some flocks twice because of the relatively small study area (1125 ha). These repeat trials were at least four months apart, and the re-sampled flocks did not differ in their FIDs from the flocks that we sampled only once (W = 72, P = 0.67).

Data analyses

We carried out the analyses using R v3.01 [22]. We used a linear regression model to investigate the effects of perch height, flock size and hunting pressure on the FID of Sooty-headed Bulbul. We entered perch height and flock size first in the model as controlling covariates.

Results

The hunter encounters per hour in XTBG, Menglun and Mengsong were 0 (0 hunters in 100 hours), 0.06 (19 hunters in 311 hours), and 0.55 (59 hunters in 107.5 hours), respectively. Consistent with expectations, there was a highly significant decrease in the flight initiation distance (FID) of Sooty-headed Bulbuls from Menglun to XTBG (β = -3.58 ± 1.160, P = 0.01; Fig. 2) and a significant increase from Menglun to Mengsong (β = 11.51 ± 1.165, P < 0.001; Fig. 2). Moreover, we found no significant effect of the partially controlled variables, perch height (0-3m; β = 0.78 ± 0.78, P = 0.32) and flock size (3-4 individuals; β = -0.15 ± 0.96, P = 0.87) on the FID.

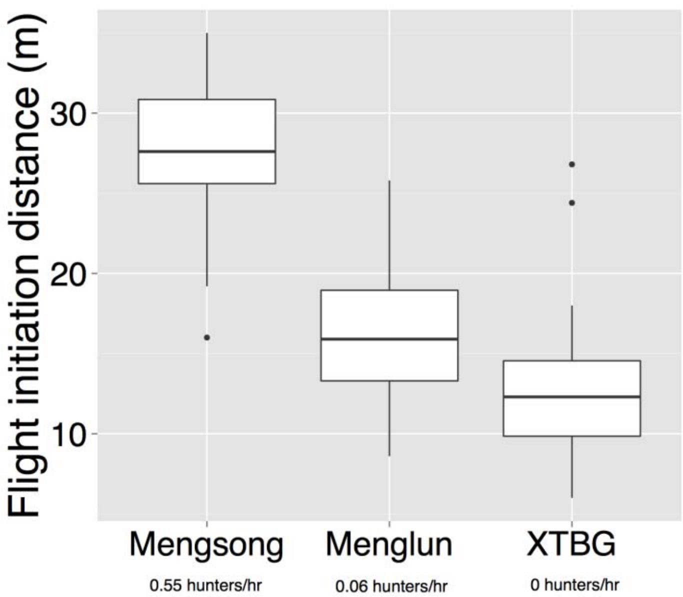

Fig. 2. Boxplot showing the flight initiation distances (FID) in Sooty-headed Bulbul flocks in sites with different hunting pressure. Medians, first and third quartile, and outliers are presented for each site. Whiskers present 5 and 95 percentiles. The FIDs were significantly different among all three sites.

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Discussion

Our results suggest that Sooty-headed Bulbuls (Fig. 3) changed their FID in response to hunting pressure. Animals' sense of predation risk is affected by habitat density and resource availability [23-25], but measurements can be made in similar habitats, as in this study, and replication at different points within sites can reduce the influence of differences in resources, which are likely to vary at finer spatial scales. We carefully controlled for other potential confounding variables, including differences among individuals in their activity levels, perch height and group sizes, both through the sampling design and the statistical analysis. FIDs were lowest in the botanical garden (XTBG) where there was no hunting. In XTBG, it is possible that there is a confounding effect of habituation as a consequence of the large number of visitors to the garden [20]. However, Menglun and Mengsong had similar human densities, 48 persons/km^2 and 45 persons/km^2, respectively (http://www.agri.com.cn/), suggesting the much higher hunting in Mengsong was responsible for birds' higher FIDs there, and evidence from studies of other taxa also demonstrates that FID increases with hunting pressure [8-15,20]. We suggest the measurement of FIDs can be used as an efficient and replicable method to estimate hunting pressure.

One might ask, why not use the number of hunter encounters or market surveys as a proxy for hunting pressure? However, the rate of hunter encounters might not accurately estimate hunting pressure, because of differences in the behavior of hunters towards outsiders. For example, hunters may be much more discrete if their activities are illegal, and especially if the penalties for being caught are severe. Similarly, the amount of bushmeat observed in a local market may not correlate well with the number of animals hunted in the surrounding region. For example, in the Assam state of NE India, an estimated 10,000 roosting Amur falcons were killed every night during the peak migration season. However, none of these birds were openly sold in the markets [26].

Some caveats concerning the use of FIDs as a behavior indicator (*sensu* [1]) should be considered. The nature of the relationship between FID and hunting pressure is not precisely known and is likely to be non-linear and to vary among species. As we have shown from Xishuangbanna, FIDs may be used to measure the relative hunting pressure among sites without further development, but local ground-truthing of FIDs over a gradient of known hunting pressures will improve their utility, and even allow the estimation of the absolute value of hunting in another area. The technique requires the use of species that are targeted by hunters throughout the region, and are relatively easily observed; open-landscape species such as Sooty-headed Bulbul seem most suitable because their flights can be readily detected at long distances. However, previous studies have also showed that behavior is not an indicator of hunting in all animals [14,15,27,28]. Therefore, robustness of results could be enhanced by simultaneously measuring the FIDs of two or three species because different species may be sensitive to different ranges of hunting pressure, and the use of multiple species could reduce the stochastic variation [27]. Moreover, information on multiple species could be useful for studies over larger areas, so that even if not all species were present at a particular site, there would be enough information to compare that site with others. Where hunting is opportunistic, which is typical of bushmeat hunting in many tropical forests [29], FIDs may be taken as a measure of general hunting pressure on the environment. However, where hunters may be targeting selected high-value species such as elephants or rhinos, additional information specific to these species would be required.

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Fig. 3. Sooty-headed Bulbul (*Pycnonotus aurigaster*) at Xishuangbanna Tropical Botanical Garden (XTBG), Yunnan, China; photo credit: Rachakonda Sreekar.

Implications for conservation

We encourage researchers working at multiple sites in the same region, such as the managers of a reserve network, to use FID measurements as a way of assessing relative hunting pressures among sites. The technique is relatively inexpensive and requires very little observer training. Any species that experiences human exploitation where the presence of humans is obvious and some individuals escape (e.g. shooting, mist-netting, some sorts of trapping) is expected to regulate its FIDs in response to the frequency of this exploitation. FID measurement is more specific to hunting than the use of defaunation indices [30], which also are affected by other drivers of defaunation such as fragmentation, climate change, co-extinctions and invasive species. Indeed, in any situation where hunting is correlated with other human activities, such as when logging makes areas more accessible to hunting [31], FIDs could potentially determine what proportion of the defaunation is attributable to hunting, and to determine how best to protect animals.

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