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The potential impacts of the songbird trade on mixed-species flocking

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ABSTRACT

Mixed-species flocking is an important avian social system that supports a large number of species. Current reviews of threats to mixed flocks have only examined two types of anthropogenic pressures: different land use intensity and fragmentation. We highlight the bird trade as another major potential threat for many mixed-species flocking species in Southeast Asia. We examine the potential indirect impact of the bird trade by comparing social networks of flocking data collected over two periods nearly 20 years apart (1997 and 2016) from the same site in Sumatra, Indonesia. We find that the structure of the two networks was significantly correlated. However, of the 90 species observed, 49 had previously been identified as part of the bird trade. These species experienced a significantly greater decrease in network centrality over time compared to the non-traded species, resulting in a loss of structure in the mixed-species flocking network. Simulating further disturbances suggests that flocks may not be resilient to the complete loss of two or more traded species. Our results suggest that trapping is likely to be contributing to the degradation of flocks, and ultimately could lead to the widespread declines in those other species that also rely on mixed-species flocking.

1. Introduction

There is increasing awareness of the need to conserve ecological networks. Interactions between species, such as pollinator-plant networks (Burkle et al., 2013) and predator-prey food webs (Dunne et al., 2002), are widespread and form an essential part of ecosystem functioning. One very common, but often overlooked system of interactions are mixed-species groups. For example, mixed-species bird flocks (‘mixed flocks’ hereafter) have been reported in many parts of the world (Munn, 1985; Hutto, 1994; Develey and Peres, 2000; Lee et al., 2005; Sridhar and Shanker, 2014). They can represent a significant proportion of the avifauna (e.g. over 50% of species reported in Madagascar, Eguchi et al., 1993; in Australia, Bell, 1983; and in the Dominican Republic, Latta and Wunderle, 1996) and many species are obligate flock members. In mixed flocks, participants (two or more species) travel together in search of dispersed food (Buskirk, 1976; Bell, 1983), actively maintaining group cohesion with both conspecifics and heterospecifics (Farine et al., 2014). Doing so can bring important fitness benefits for participants (Dolby and Grubb, 1998), and the survival rates of obligate mixed flock members has been shown to be significantly higher than for species feeding alone or in pairs (Jullien and Clobert, 2000). Thus, conserving mixed-species flocks is likely to be important for maintaining the presence and abundance of many species.

Mixed flock formation can be highly sensitive to environmental change (Mokross et al., 2014), and, in particular, the loss of key species can fundamentally alter the dynamics of mixed flock composition (e.g., Maldonado-Coelho and Marini, 2000). This could be because flocking can facilitate transfer of information about food resources among individuals (Aplin et al., 2012), with some species playing a keystone role in spreading information about new food resources (Suzuki, 2012; Farine et al., 2015). Flocking can also confer anti-predator benefits (e.g., Thiollay, 1999), with certain species providing significant vigilance benefits (Goodale and Kotagama, 2005; Martinez and Zenil, 2012; Martinez et al., 2016). Species in mixed flocks are typically thought to take on one of two different roles: nuclear species (the initiator of mixed flocks) and attendant species (Moynihan, 1962); and nuclear species have been shown to provide important benefits for attendant species that cannot be gained in their absence (Dolby and Grubb, 1998). However, in terms of ecosystem function, the loss of a common attendant species could be equally severe if these bring survival benefits to nuclear species via group augmentation or by providing foraging

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benefits (e.g. Satischandra et al., 2007). Thus, identifying species that are central in their communities, both nuclear or attendant, and identifying key threats they face is an important goal for conservation biologists (Goodale et al., 2017).

Human disturbances are a major source of threats for ecosystems worldwide. Two main anthropogenic disturbance impacts to mixed flocks have been studied: forest fragmentation and different land-use intensity (see review by Goodale et al., 2015). Across studies, evidence suggests that disturbed areas typically contain smaller flocks with reduced species richness (Goodale et al., 2015). A few recent studies have also suggested that community structure (i.e. the network of interactions among species) can also be affected (Mokross et al., 2014), with the changing composition of species in the landscape impacting how species interact with one-another (Mammides et al., 2015). This community-centric approach is important because it more directly links anthropogenic disturbances to functional change in the communities involved. Such an approach is likely to be particularly important for disturbances in which the impacts may be as severe as those caused by habitat disturbances, but where the cues much less noticeable. One such potential threat, that has yet to be examined in the context of conservation of avian communities, is bird trapping.

The wild bird trade is widespread in South-east Asia. Thousands of birds are sold to fulfill various purposes: as pets or household ornaments, for food, religious release, traditional medicine (Jepson and Ladle, 2009; Shepherd, 2012), or for bird singing competitions (where bird owners use species such as White-rumped Shama *Kittacincla malabarica* and compete for the best song; Eaton et al., 2015). Birds are sourced both locally and more widely. A recent assessment in the three largest bird markets in Jakarta shows that 98% of the total volume of birds traded (182 species) are native to Indonesia (Chng et al., 2015). However, the enormous demand for birds (the wildlife trade is worth an estimated US$2.5 billion/year in East Asia and the Pacific, and perhaps up to USD$1 billion/year in Indonesia alone; UNODC, 2013) has severely depleted animal populations in local forests. For example, many of the wild bird species that are sold in the markets of Jakarta (on Java) are becoming very rare and now being sourced from neighbouring Sumatra (Jepson and Ladle, 2009; Shepherd, 2012; Chng and Eaton, 2016). If the same species that are being trapped and traded are also species that are central in mixed flocks, for example drongos are among the most commonly traded species (Shepherd, 2012, Chng and Eaton, 2016) and often considered as being nuclear in mixed flocks (Satischandra et al., 2007), then the loss of these species could alter the entire structure of communities. Subsequently, this could have significant repercussions on the behaviour of remaining species in the community (Dolby and Grubb, 1999), with potential carry-over effects into foraging and reproductive success.

In this study, we investigate the potential indirect effects of bird trapping to have an impact on the formation and maintenance of mixed-species flocks. We conducted two surveys (1997 and 2016) in Lampung Province, in southwest Sumatra, Indonesia, where birds are actively being targeted for the bird trade (see Fig. 1 for example). We use social network analysis to investigate changes in the community structure over time. Social network analysis provides a powerful toolbox for quantifying structural properties of multi-species communities, thus moving beyond simple descriptors of flocking propensity. Specifically, it provides quantitative measures of the importance of each species (i.e. its centrality, determined by the extent of co-occurrences in flocks with other species) as well as modelling tools (i.e. null models similar to those used in community ecology, Gotelli and Graves, 1996, Miller et al., 2017) to evaluate whether mixed flock communities show non-random structural patterns. The latter question is particularly important for determining the presence of interspecific relationships that are important for the ongoing functioning of the system.

The aim of our study is to assess the changes in flocking structure in a protected area that has experienced ongoing illegal bird trapping. Specifically, we use mixed flock networks generated from our two surveys to test (i) whether networks in the two years are more structured than expected under indiscriminate flocking (showing preferred associations between certain species), (ii) whether the propensities for species to flock together (and thus the resulting network structure) are correlated over the two survey periods spanning 19 years, (iii) whether traded species and non-traded species differ in their social network centrality, (iv) whether the centrality of traded and non-traded species changed over time, and (v) whether the mixed flock networks are resilient to the complete removal of traded species. Our study also represents the first major dataset on mixed flocks from Sumatra.

2. Study area

The Way Canguk Research Station (Lat. −5.658643, Long. 104.407098; Fig. 2) is located inside the Bukit Barisan Selatan National Park (325,000 ha) and was established in 1997. The national park is the third largest protected area in Sumatra, and contains some of the last intact areas of lowland rainforest on this island (O'Brien and Kinnaird, 1996). Our study was conducted along a trail system covering an area of approximately 380-ha of intact lowland forest contained within the Way Canguk Research Station area. The study area, and the research station, are surrounded by a larger contiguous primary forest (the national park), while the national park is surrounded by matrix of intact forest, burned forest, areas disturbed by illegal logging, and agricultural lands. Illegal logging and encroachment for agricultural expansion are the main threats to the national park, but this is not a threat inside the research station itself (Gaveau et al., 2007). Two main anthropogenic disturbances occur in the Way Canguk Research Station: forest fires and bird trapping. Forest fires occurred twice: 165 ha were burned in 1997/1998 (Kinnaird and O'Brien, 1998) and in 2015, 7 ha of this previously damaged forest was burned a second time (William Marthy pers. obs.). However, we conducted all surveys in areas > 600 m (beyond the impact of fire in this community, Adeney et al., 2006) and buffered by a river from areas affected by fire, and thus do not believe it has a confounding effect. By contrast, trapping of birds for trade has persisted on Way Canguk Research Station, and in our specific study area, since the late 1990's (O'Brien and Kinnaird, 1996; Harris et al., 2017), and continues to occur despite the presence of the research station staff and increased patrolling efforts in the larger Bukit Barisan Selatan National Park (unpublished data based on interviews of research station and national parks staff). For example, between 2014 and early 2017, the research station staff recorded 13 incidents of bird trapping: in 10 instances the staff found evidence that bird trapping had occurred (i.e. dead birds, camps, poles for nets), and in three instances the staff met directly with the perpetrators (in two instances the perpetrators were arrested). As a consequence of trapping, two of targeted species, the White-rumped shama and the Grey-cheeked bulbul *Alophoixus bres* are now extremely rare, although a recent study by Harris et al. (2017) suggests that abundances of birds in the study area have remained relatively stable. Trappers active in the research station area typically use a lure (e.g. a male Blue-winged Leafbird Chloropsis moluccensis; Fig. 1) to attract and capture target birds in mist-nets or with bird-lime (an adhesive made from tree sap; Shepherd et al., 2004). During the capture process, other species can also be caught (i.e. as "bycatch"). Individuals of these species can be released, die or be killed (e.g. Fig. 1), or kept by trappers.

3. Data collection

3.1. Field observations

We conducted two surveys, the first between July and October 1997 for a total of 24 observation days, and the second between August and November 2016 for a total of 18 observation days. Observations were made by the same observer (WM) and along the same trail system, which had been cut and mapped through the forest in order to facilitate