Seasonal Migration Within Aseasonal Tropical Rainforests: A Phenomenon With Immense Implications

INTRODUCTION: Tropical rainforests (**TRF**) are often considered aseasonal, however every TRF studied shows seasonal phenological variations corresponding to precipitation and solar irradiance[1]. Flushing, flowering, fruiting, and invertebrate biomass have general community-wide peaks during a region's wet season, with large-fruited trees exhibiting the strongest phenological clumping[1,2]. Due to local precipitation regimes, phenology peaks vary in different geographical locations, creating spatio-temporal resource shifts[1,3,4]. Migration, the large-scale seasonal range shifts that occur in response to disparities in regional resources, has not been studied as a faunal survival adaptation within tropical rainforests[1].

Uncovering how animals move in response to seasonal resource shifts is critical to the conservation of migrating species and the ecological processes they perform[5,6,7,8]. Furthermore, species dependent on variable resources are the first to face local extinction after forest fragmentation. Moreover, migrating species are particularly threatened by current global climatic changes[5,6]. *I will create a spatio-temporal model of fruiting shifts in SE Asia, then track hornbill movements to test my hypothesis that migration exists in TRF to follow resource shifts.*

BACKGROUND: Current research on migration as a response to seasonal resource shifts is focused on temperate and highly seasonal tropical regions[5]. While altitudinal migration that follows seasonal phenological changes does exist in TRF, large-scale seasonal migration that follows regional climatic differences is completely unreported[2,6,7]. Newton's comprehensive textbook on migration argues that the increased movements required to cross climatic gradients and the limited resource inequalities between TRF negate the returns for intra-TRF migration[7]. However, highly mobile TRF frugivores like hornbills can traverse hundreds of kilometers per week, and in SE Asia, seasonality is sufficient to create resource disparities[4,8,9].

<u>SE Asia</u> is the optimal location to test for migration because monsoons create localized weather patterns in lowland TRF. Variations in wet seasons form a matrix of adjacent landscapes with offset phenologies[1,4]. Consumers depend on these spatio-temporal rhythms in the food supply[1,2,3,8]. Local seasonal resource disparities are extreme, exceeding six fold increases in fruiting species during months of peak rainfall. This provides incentive for migration[6].

<u>Hornbills</u> are large frugivorous birds that are highly mobile and capable of migration. They favor large, ripe, oily fruits in rare canopy/emergent tree species that fruit seasonally[2,3,8,10]. Hornbills are keystone seed dispersers and the SE Asian equivalent of toucans[8,9]. Hornbills track resources throughout their home ranges and juveniles are known to roam until they obtain territories, however *hornbills are not known to migrate*[8].

<u>A seasonal flock of 3000+ plain pouched hornbills, *Aceros subruficollis*, has recently been discovered around Lake Tasek Temengor in Peninsular Malaysia[11].</u> The hornbills fly north after staying in the region during the two month period of peak rainfall and fruiting[3,11]. *The destination of* A. subruficollis *is unknown*, however, it has never been recorded as a breeding in Malaysia[8,11]. The seasonal presence of this flock in Malaysia for purposes other than breeding suggests that *A. subruficollis* is migrating outside of Malaysia, most likely into Thailand.

If *A. subruficollis* is migrating, it would constitute the first documented migration by a TRF species[7]. Altitudinal migration can be refuted because *A. subruficollis* vacates from the Lake Tasek Temengor region where elevation changes exceed 1000m within a 30km zone[11]. *A. subruficollis*is is currently listed as a vulnerable species due to the rapid decline in small total population. In addition, the details of its range, life history and ecology are unknown[8,12].

HYPOTHESIS: i) Rainfall-driven local phenology differences have resulted in significant seasonal resource disparities across space within TRF. **ii)** *A. subruficollis* will migrate in order to exploit seasonal resources. **Null**: **i)** Resources are homogeneously distributed in time and **ii)** *A. subruficollis* movements do not correlate with resource abundance.

OBJECTIVE 1: Create a spatio-temporal resource model using GIS mapping techniques to test the relationship between rainfall and phenology of fruiting trees. Then, model optimal migration paths for *A. subruficollis* based on distance and temporal resource abundances.
METHODS: 1) Create regional monthly rainfall/fruiting species database. Precipitation data is available from the Malaysian and Thai Hydrological departments, phenological data is available from the literature[1]. **2)** Model month-by-month rainfall and fruit abundance by region in ArcGIS. **3)** Use large-scale layered models to quantify resource disparities across time and space. **4)** Model *A. subruficollis* optimal movements to exploit spatio-temporal resource peaks.
OBJECTIVE 2: Test if *A. subruficollis* migrates to exploit spatio-temporal resource abundances.
METHODS: 1) Radio-track 15 *A. subruficollis* individuals for two years[9]. Capture birds with pulley-mounted canopy mist-nets at roost in Malaysia and attach satellite-transmitters at the base of the tail feathers[9]. Monitor their movements with a receiver[9]. **2)** Input *A. subruficollis* movement data into a GIS spatio-temporal resource model. **3)** Determine if there is causal relationship (using spatial auto-correlation) between movements and spatio-temporal resources.

CONSEQUENCES: Migrants and species dependent on seasonal resources are particularly vulnerable to climatic changes and forest fragmentation[5,7,8]. Moreover, concerns about climate change stress the importance of keystone seed dispersers, like hornbills, to help move the trees to more suitable climates[8,9]. A positive feedback response could develop where keystone migrants disappear from disturbed forests, decreasing ecosystem functioning and future forest resilience. TRF migration also directly challenges Rapaport's Rule of decreasing animal range size with latitude, a theory based on decreased resource variability in the tropics. The seasonal resource models I will create will bring the degree of variability into question. Migrating frugivores also provide rapid long-range seed dispersal along distinctive corridors and back to roosts, shaping the spatial regeneration patterns and diversity of forest trees[3,10].

BROADER IMPACTS: I will partner with the Forestry Research Institute of Malaysia (FRIM). Malaysian researchers will aid in all aspects of this project including anticipated co-authorships on publications, and becoming fully trained in the methods and analyses. FRIM helps to manage Malaysia's natural resources, making it optimal to immediately bridge my research with policy and action. Additionally, this research will locate movement corridors that are critical to conservation efforts for this vulnerable species, which benefits future human generations of all nations[12]. *A. subruficollis* is also a charismatic species and important tourism draw in the region[8].

Finally, Dr. Poonswad at the Mahidol University in Bangkok has enlisted master's students working on Thailand Hornbill Project (THP) to help track *A. subruficollis* in Thailand. Working with FRIM and THP will bring together an international team and facilitate the local and broad dissemination of results in English, Malay and Thai.

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