Migration Stopover Selection for Hair-Crested Drongos

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ABSTRACT

Stopover sites for bird migrations serve important roles in refueling and rest. Hair-crested drongos (*Dicrurus hottentottus*) are migratory birds that migrate to Thailand during winter and back to China during summer, but there have been no previous studies that have done on their migratory patterns. This study analyzed the characteristics of migration stopover sites for hair-crested drongos. By analyzing the relationship between environmental variables and stopover site location using ArcGIS and Maxent, I identified that the three most important variables for hair-crested drongo stopover site selection were mean annual air temperature, mean diurnal air temperature range, and elevation. Hair-crested drongos prefered sites with temperature higher than 17 degree Celsius in general. Female and male drongos showed differences in site selection, especially with respect to elevation. Male tended to migrate along eastern routes with lower elevation. Female tended to migrate along western routes which form straight lines between the breeding sites and wintering grounds. Understanding the criteria for drongo migration stopover selection will assist future conservation efforts and improve migration success rate for more migratory birds.

KEYWORDS

hair-crested drongos, migration, stopover, site selection, migratory behaviors, species distribution modeling

INTRODUCTION

Migration is known to be the biggest cause of death for migratory birds. Concentrated mortality can occurr during migration (Sergio et al., 2019). Migrations entail higher costs and risks than more static stages because of metabolic exhaustion, navigation errors and unpredictable exposure to predation, anthropogenic threats and adverse weather (Newton 2008). The success of migration can be greatly influenced by the availability and quality of stopover sites. Stopovers along the migration routes can help replenish energy needed (Nathan et al. 2008, as cited in Cohen et al. 2021). However, a shortage of available stopovers can exacerbate the mortality rate during migration. The quality of the habitat can also influence the subsequent flight range (Bayly et al., 2013; Gomez et al., 2017, as cited in Cohen et al. 2021).

Current studies show that migratory birds adapt to seasonal variability by having slightly different stopover selection criteria in different seasons, since migration in different seasons means change in available vegetation cover, and food sources. (Petit 2000, Zuckerberg et al. 2016, as cited in Stanley 2021). In addition, migratory birds' preferences for stopovers resemble their nest site selection more than other external factors (Petit 2000). It is critical for us to understand how habitat selection criteria change in different seasons and differences in selection criteria between stopovers and breeding sites. Understanding what habitats could be potential stopover sites and preserving those habitats can help minimize human-related death during migration.

The Hair-crested Drongo (*Dicrurus hottentottus*) is a common bird throughout much of east and southeast Asia. The species is a summer breeder in central and northern China (Cantrell et al. 2016). Hair-crested Drongos started migrating south for wintering grounds since mid-October, reaching the China-Indochina Peninsula. They started migrating north to breeding sites starting in late April, reaching central China. Hair-crested Drongos migrate individually. It takes about twenty days to complete the migration for both the north and south migration routes. The population of Hair-crested Drongo has decreased in recent years. Currently, most existing the literature has focused on their breeding sites (Cantrell et al. 2016; Gao et al. 2016); but few studies have focused on their migration pattern, or especially the habitat selection of their stopovers. Understanding the selection criteria for stopovers will be helpful in preserving this species and by targeting those habitats for better conservation.

In order to investigate the characteristics of Hair-crested Drongo migration stopovers, I asked the following questions: (1) Did different sex of hair-crested drongos show different preferences for stopovers? (2) As mentioned above, habitat selection varied when the season changed. How did stopover selections differ when traveling north compared to south? I used data from the tracking devices installed on the back of Hair-crested Drongos since 2020 and analyzed the data along with environmental factors. I hoped to identify habitats that will be used as future stopover sites and gain a better understanding of Hair-crested Drongo migration patterns.

METHODOLOGY

Study Site Description

The full study area encompassed southeast China, northern Vietnam, Laos, and Thailand. The main study site was located in Henan Dongzhai National Nature Reserve, China (114°18′～114°30′E ,31°28′～32°09′N). The reserve was built in June, 2001.The reserve is located in the transitional area of subtropical and temperate zones. The first study site was at Baiyun Management Station, which was one of management stations distributed across the reserve (Figure 1). All drongos captured here wore bluetooth trackers. The second study site was Tianqiao village, about 18.9 km from Baiyun Management Station. All drongos captured here wore satellite trackers. Both study sites showed similar vegetation covers. Forest composition was dominated by oaks, Quercus spp., Masson pine (*Pinus massoniana*), dyetree (*Platycarya strobilacea*), beautiful sweetgum (*Liquidambar formosana*), and hupeh rosewood (*Dalbergia hupeana*) with major shrub species including young oriental oak (*Quercus variabilis*), glaucous allspice (*Lindera glauca*), and bamboos (*Pleioblastus spp.*) (Song and Qu 1996, as cited in Cantrell et al. 2016). The natural habitats within the reserve, mostly near the edge of the forests, serve as breeding sites for drongos during summer.

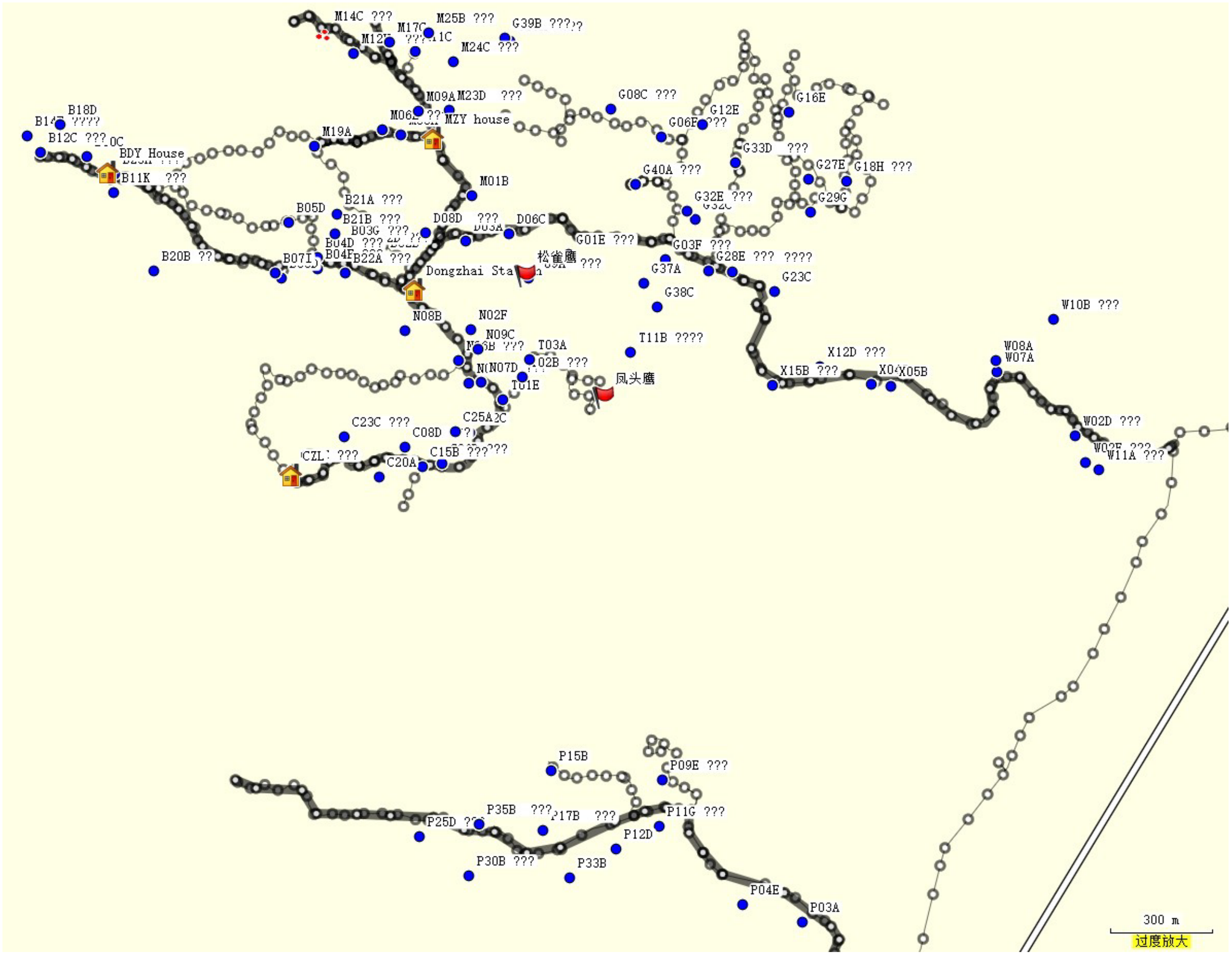

Figure 1. Identified nest sites in the study areas. The drongos that have installed tracking devices were captured from these sites.

Drongos utilized other natural areas as stopovers during both northward and southward migration. Drongos also stopped at northern Vietnam, Laos, and Thailand before they reached their destination. Areas in northern Vietnam, Laos, and Thailand have higher annual temperature and precipitation compared to mainland China. I collected environmental factors of each stopover for the purpose this research.

Data Collection

I collected two different sets of data. The first set of data included exact stopover location coordinates. All data from tracking devices was organized by Dr. Lei Lv, who is a senior researcher at Sun Yat-sen University. The second set of data included climatic factors, geographic features and vegetation composition.

Location Data & Tracking Devices

The exact stopover locations were recorded by tracking devices (Figure 2). We used two types of tracking devices. The first one was Global Messenger Backpack Tracker HQBG0804. Data was processed through satellites, enabling me to directly retrieve information online at any time. The trackers marked a checkpoint every 2 to 3 days, and information was updated online every 5 checkpoints. The second one was Druid Technology Backpack Tracker Nano. Data was processed through bluetooth, so data from drongos that wore bluetooth tracker can only be retrieved when the drongos are nearby. We retrieved this location data once per year when the drongos returned to the reserve. There was one female that started wearing a satellite-based tracker and one male started wearing a bluetooth tracker since 2020. We captured 20 new drongos near Baiyun station and tied bluetooth trackers to them in 2021. We also captured 20 more drongos near Tianqiao Village and tied satellite-based trackers to them in 2021.

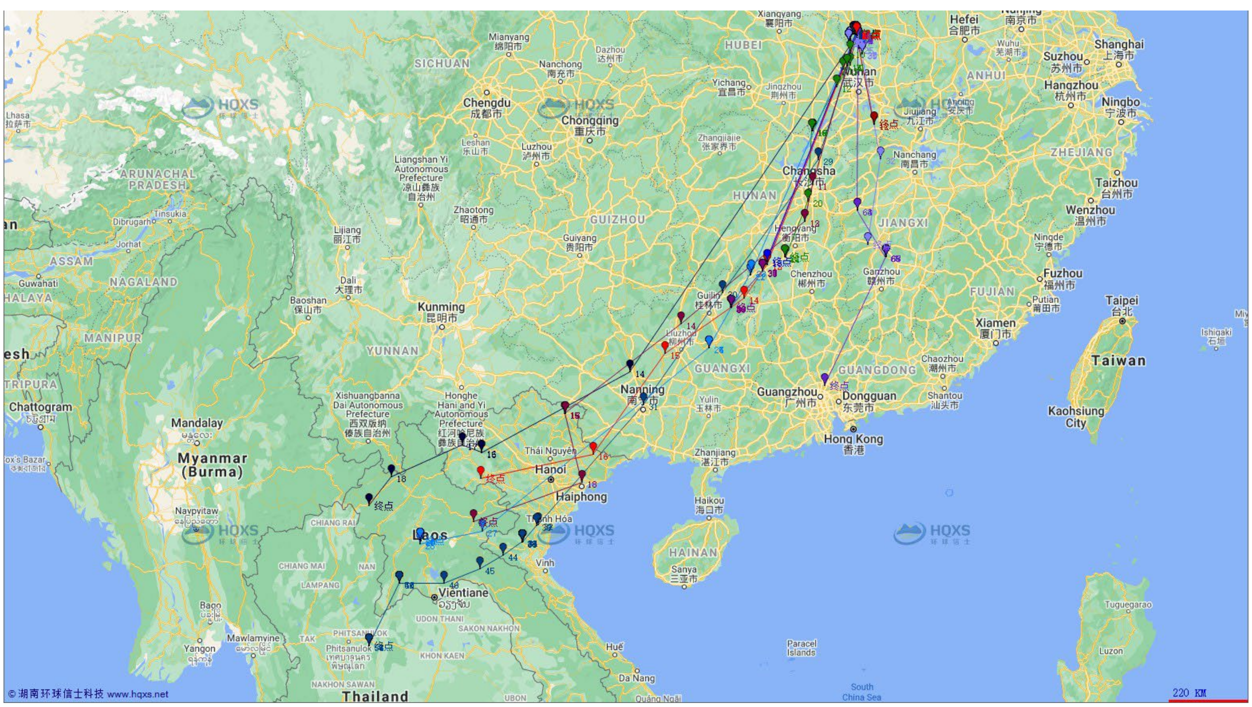

Figure 2. The migration overview for the two drongos that started to wear tracking devices since 2020. The map depicts their migration stopover locations during their northward migration in May 2021.

Environmental Variables

I collected 6 different environmental variables, including mean annual air temperature, mean diurnal air temperature range, annual precipitation amount, NDVI(Normalized difference vegetation index), land use, and elevation (Table 1). The temperature and precipitation data were all downloaded from Chelsa (*Climatologies at high resolution for the earth's land surface areas)* Bioclim Dataset, projected for the year 2011-2040 under the SSP 585 scenario (which resembled our current carbon dioxide emission trajectory) (Karger et al., 2017). NDVI values were extracted from MODIS13Q1 (Moderate Resolution Imaging Spectroradiometer) at the resolution of 250m, produced at 16 days interval (Didan, 2015). The land use data was downloaded from Sentinel-2, an annual 10-meter resolution map of Earth's land surface from 2017-2021. The elevation data was provided by ESRI, which is collected from SRTM (The Shuttle Radar Topography Mission) at 30 meters resolution (Karra et al., 2021).

Bio1	mean annual air temperature	Chelsa for the year 2011-2040 under the SSP 585
Bio2	mean diurnal air temperature range	Chelsa for the year 2011-2040 under the SSP 585
Bio12	annual precipitation amount	Chelsa for the year 2011-2040 under the SSP 585
NDVI	NDVI(Normalized difference vegetation index)	MODIS(NASA) 13Q1
ndvi1_oct1	NDVI values for study area from 10/01/2021-10/15/2021	
ndvi1_oct2	NDVI values for study area from 10/16/2021-11/01/2021	
ndvi_nov1	NDVI values for study area from 11/02/2021-11/15/2021	
ndvi_nov2	NDVI values for study area from 11/16/2021-12/01/2021	
ndvi_dec1	NDVI values for study area from 12/02/2021-12/15/2021	
ndvi_dec2	NDVI values for study area from 12/16/2021-01/01/2022	
	land use	ESRI Sentinel-2
asia_dem	elevation	SRTM(ESRI)

Table 1. Sources of selected environmental variables.

I only adopted the annual mean temperature and precipitation because these factors reflected the longer annual trend of local climate. Narrowing the temporal scale of these climatic factors would only distract us by daily fluctuations of temperature and precipitation. Having long-term climatic factors reflect the ecological conditions around the stopover sites, which was suitable for answering what characteristics led drongos to prefer such stopover sites over other different ecological environments.

Analysis

I prepared all environmental variables via Arcmap and then exported them to Maxent. I downloaded the MODIS data using USGS earth explorer. I extracted, processed, and then mosaiced all data to accommodate the vast span of the study area. Maxent (Maximum Entropy Model) is one of the most widely used species distribution models (SDMs) (Wang et al., 2022). Maxent enables scholars to model species' geographic distributions with presence-only data, which serves the need of my study perfectly (Phillips et al., 2006). Maxent operates based on the concept that among all probability distributions satisfying the constraints, the user chooses the one of maximum entropy (Phillips and Dudík, 2008). I separated the occurrences data into three categories. I first created a separate dataset for nestlings, since we were not able to identify sex directly on these young drongos. For the rest of the adult drongos, I separated them into male and female groups. I also recategorized the adult drongos' occurrence points based on the direction of migration, which can be thought of interchangeably as the season. The first run of Maxent included all adult drongos. They were sub-categorized as northward female drongos, northward male drongos, southward female drongos, and southward male drongos.

I used the following settings the first run of Maxent: random seed was true (meaning points that randomly picked for testing will change each time), and random test points were set to 20%. Model performance was evaluated by the area under the curve (AUC) of the receiver operator characteristic (ROC), which is a threshold-independent measurement for assessing the discrimination ability between presence and random points (Phillips et al., 2006). Although the value ranged from 0 (random) to 1.0 (perfect distinction) in theory (Khanum et al., 2013), the actual maximum testing AUC of the presence-only model is always lower than 1.0 (Phillips et al., 2006). Higher AUC values indicate models with better distinctive capacity, while AUC values lower than 0.5 indicate models that cannot discriminate between preferred habitat and environmental background. An AUC value is higher than 0.75 indicates a good model (Elith et al., 2006). Models with the lowest training and test omission rates and with the highest AUC were chosen, both served as a metric of the models' predictive performance (Redon and Luque, 2010).

RESULTS

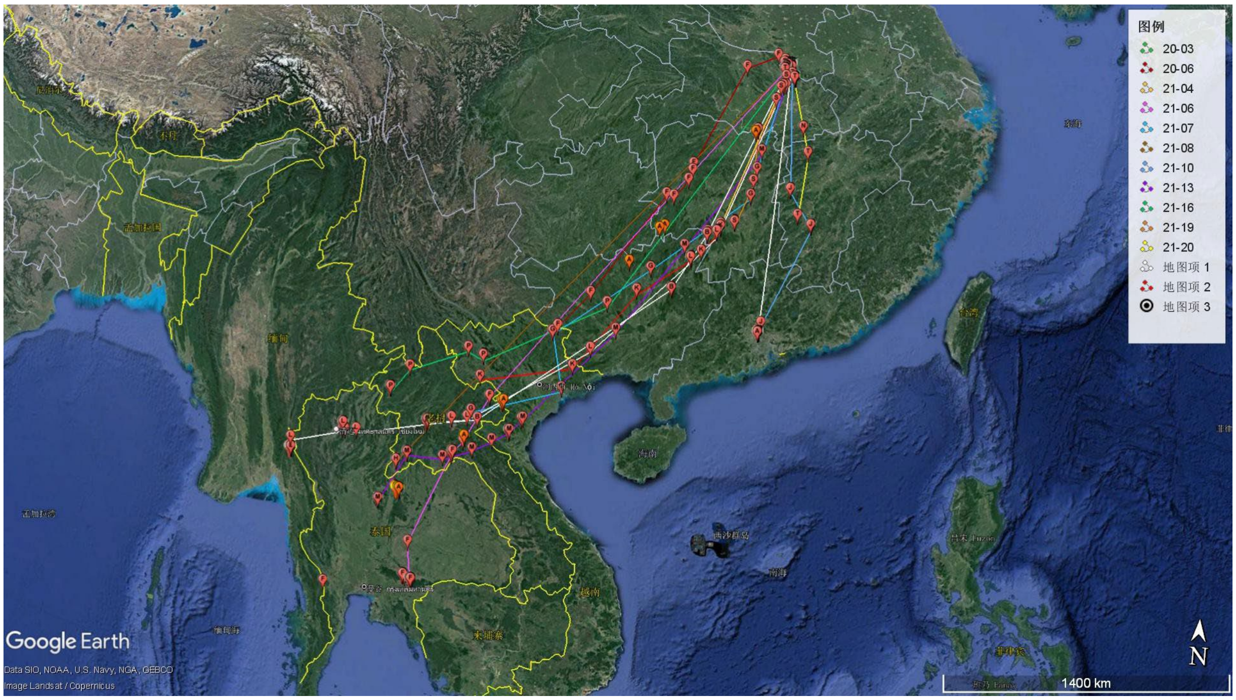

Figure 3. Migration routes for hair-crested drongos. Samples included both that have complete data and those that don't have complete data points yet.

Currently (as of May 15 2022) only 4 female and 3 male drongos have returned their complete migration data. For those individuals, the migration routes were similar and their locations were close to each other. Based on the map (Figure 3), the migration routes formed a narrow band. There were two males and one female that seem to migrate along eastern routes, but full data points were not available for the first run in Maxent.

Model Performance (First Run)

For the first run, all outputs showed training AUC values larger than 0.75, which meant all outputs were ecologically relevant. The AUC values for northward female drongos was 0.871, northward male drongos was 0.955, southward female drongos was 0.899, southward male drongos was 0.876 (see Figure 4a-4d).

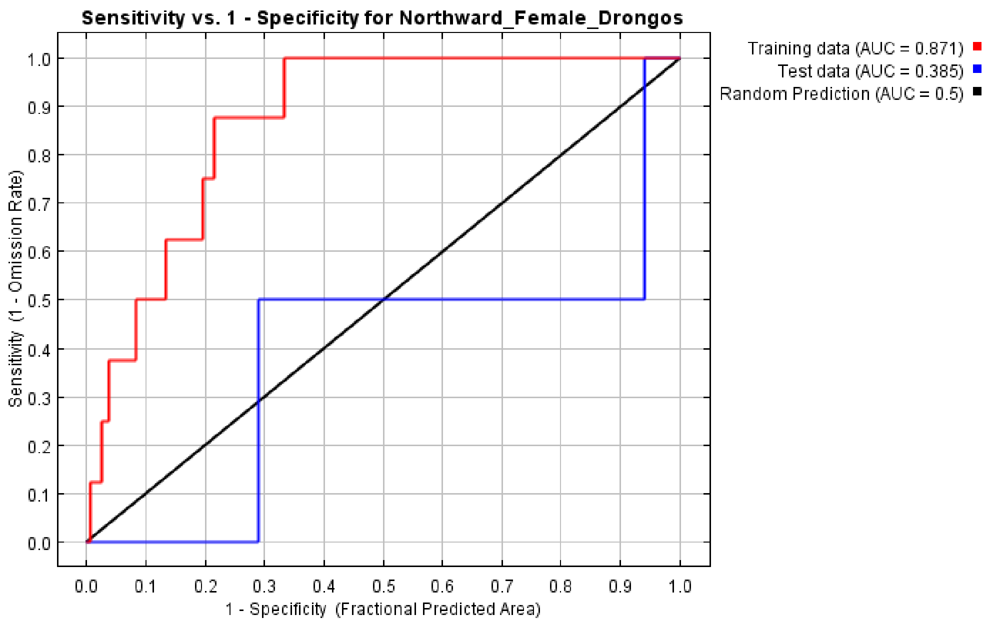

Figure 4a. AUC of Northward Female Drongos.

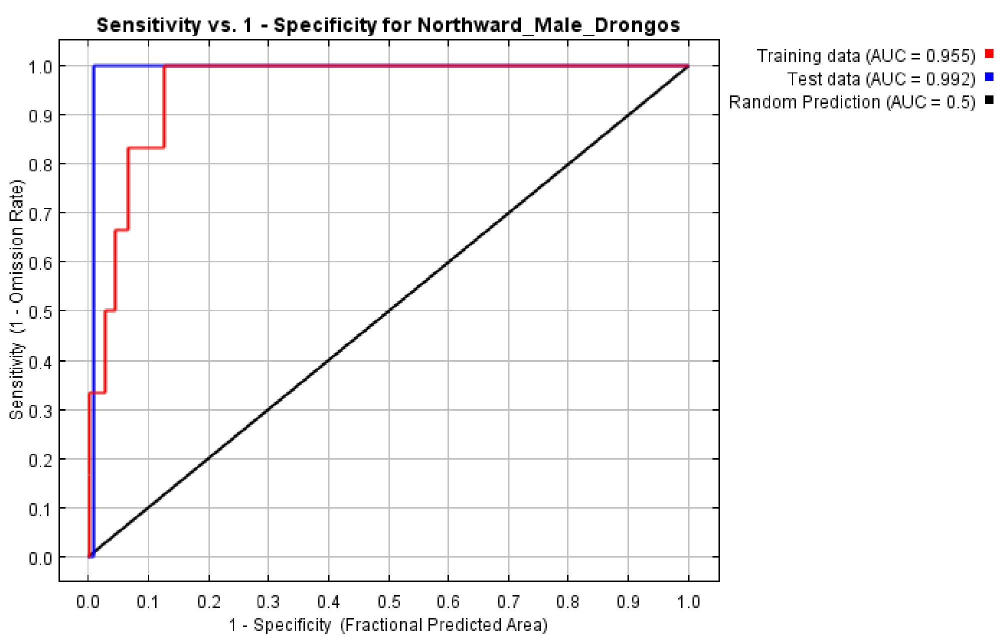

Figure 4b. AUC of Northward Male Drongos.

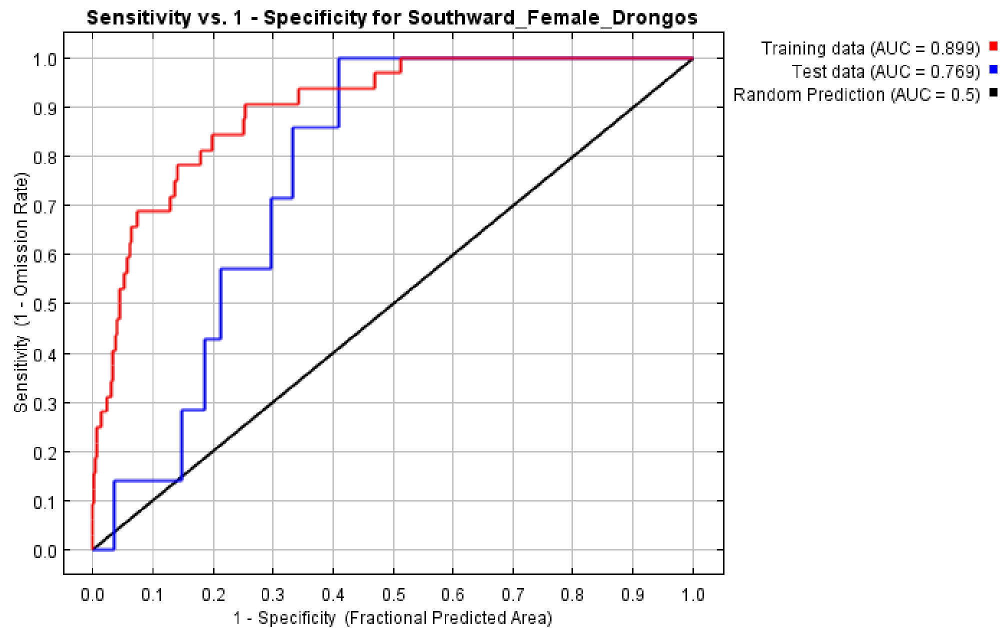

Figure 4c – AUC of Southward Female Drongos.

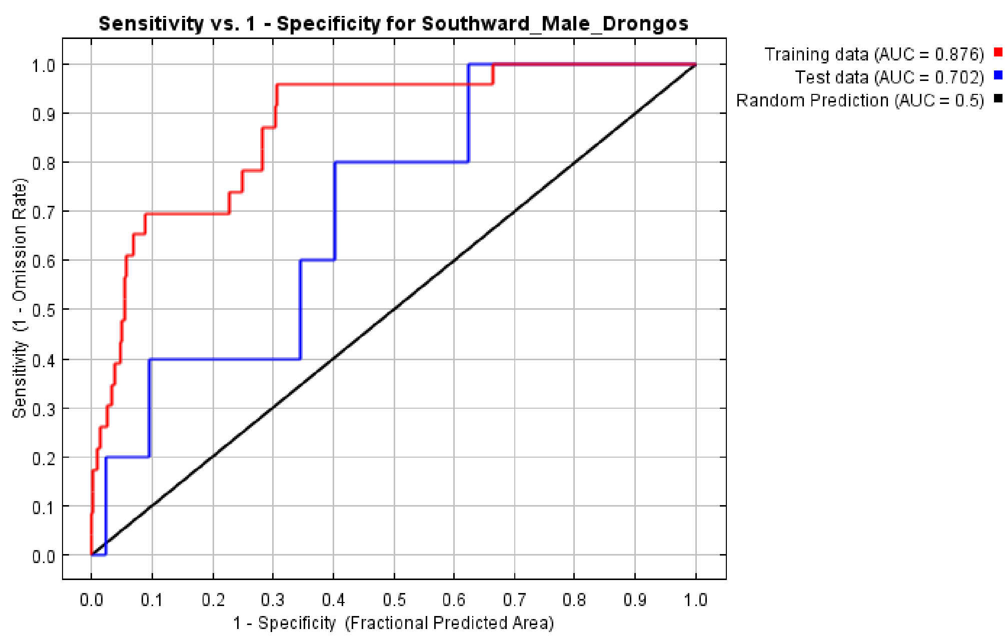

Figure 4d. AUC of Southward Male Drongos.

The percent contribution generated by Maxent was used to rank the importance of each variable. When comparing the environmental contribution, the primary contributing factors varied substantially across the four groups. Northward male drongos have a closer ranking of variable contribution with southward male drongos rather than northward female drongos, and the same trend applies to the female. In other words, variable contributions were similar among the same sex rather than the same migration direction. Mean annual air temperature and mean diurnal air temperature range variables were among the top of the list for both northward and southward male drongos, while elevation showed consistently higher value of contribution for both northward and southward female drongos. Mean annual air temperature also contributed significantly for female drongos in general, but elevation showed trivial contribution for male drongos.

Table 2. Names of abbreviated environmental variables.

Bio1	mean annual air temperature
Bio2	mean diurnal air temperature range
Bio12	annual precipitation amount
NDVI	NDVI(Normalized difference vegetation index)
ndvi1_oct1	NDVI values for study area from 10/01/2021-10/15/2021
ndvi1_oct2	NDVI values for study area from 10/16/2021-11/01/2021
ndvi_nov1	NDVI values for study area from 11/02/2021-11/15/2021
ndvi_nov2	NDVI values for study area from 11/16/2021-12/01/2021
ndvi_dec1	NDVI values for study area from 12/02/2021-12/15/2021
ndvi_dec2	NDVI values for study area from 12/16/2021-01/01/2022
	land use
asia_dem	elevation

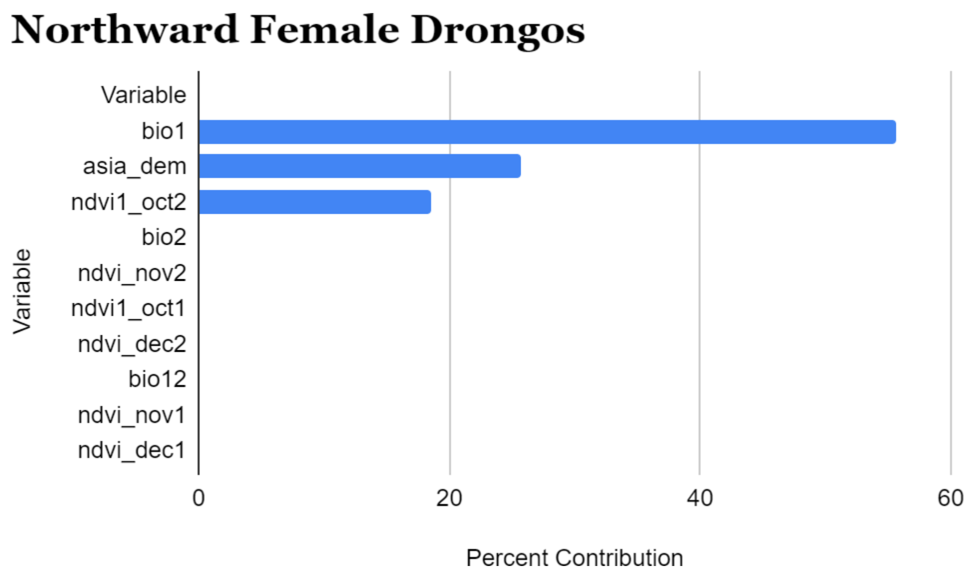

Figure 5a. Percent of variable contribution for northward female drongos. See table 2 for each variable's description.

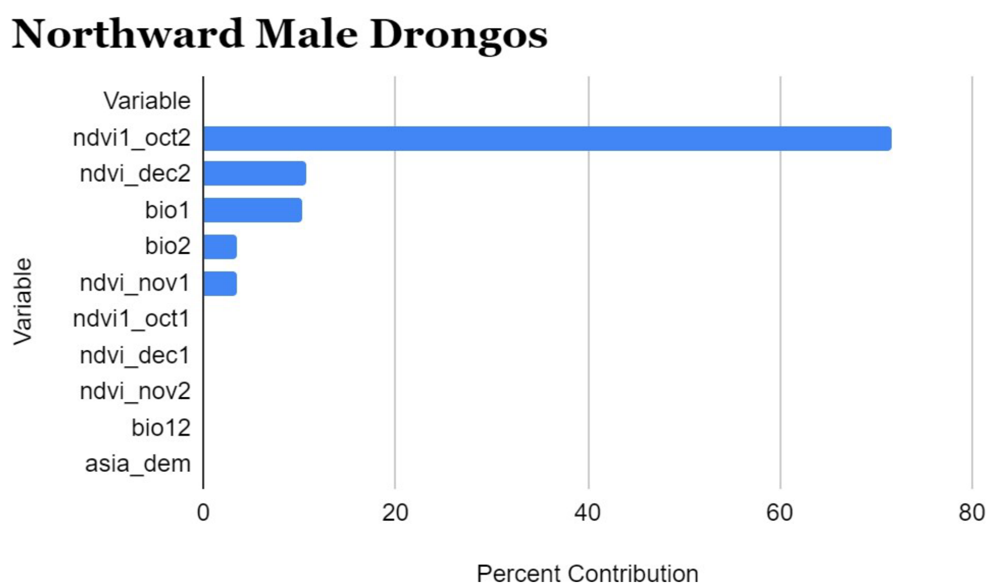

Figure 5b. Percent of variable contribution for northward male drongos. See table 2 for each variable's description.

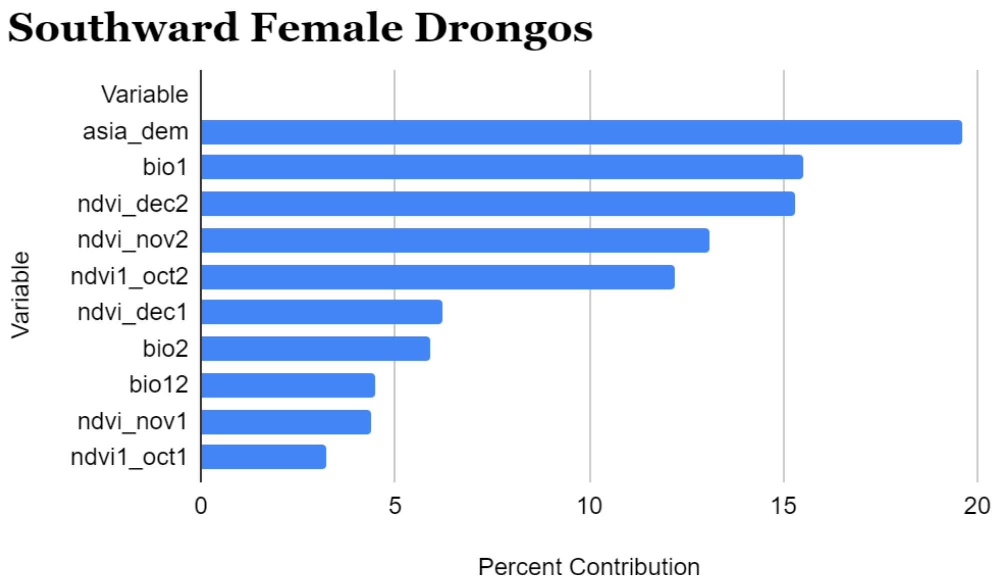

Figure 5c. Percent of variable contribution for southward female drongos. See table 2 for each variable's description.

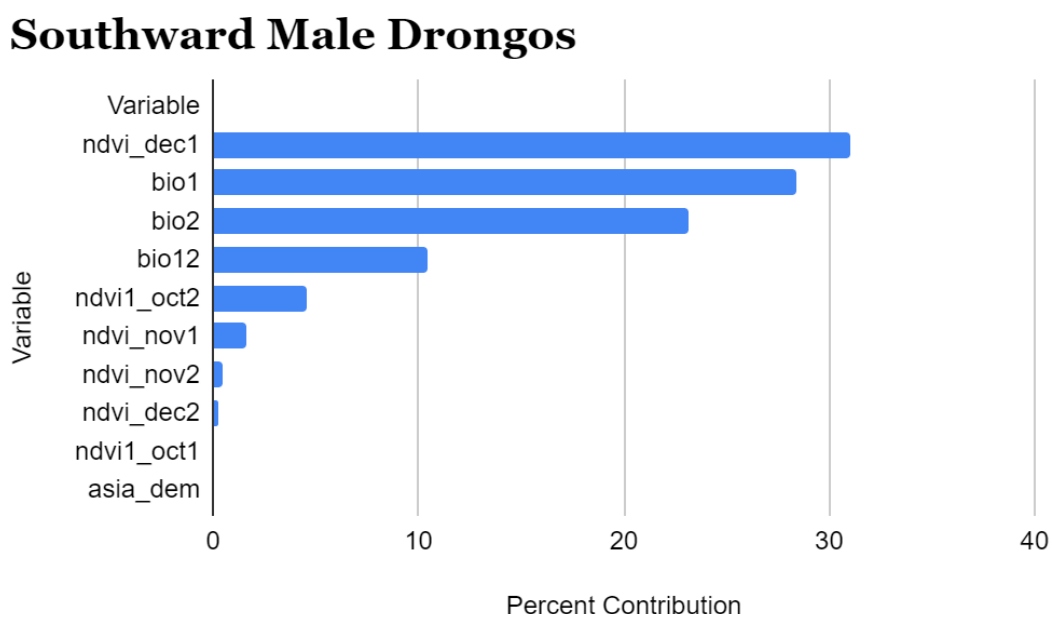

Figure 5d. Percent of variable contribution for southward male drongos. See table 2 for each variable's description.

DISCUSSION

The aim of this study was to understand what were shared in common between all stopover sites during hair-crested drongos' migration. I wanted to know if different sex of hair-crested drongos show different preferences for stopovers. I also wanted to understand how stopover selections differed when traveling north compared to south. I expected female and male to show different preferences for stopovers, especially with regards to vegetation cover at the stopover sites.

Results confirmed that female and male do show different preferences, but they were different with respect to elevation. Both sexes were sensitive to mean annual air temperature and mean diurnal air temperature range. Male tended to migrate along routes with lower elevation. Migration was a critical life-cycle stage for migratory birds, and this study should help improve our understanding regarding the characteristics of selected habitats.

Temperature

Based on the variable contribution, mean annual air temperature, mean diurnal air temperature range, and elevation constituted the three most important variables during drongos' migration. For female drongos, the mean annual air temperature and elevation contributed the most. For male drongos, the mean annual air temperature and mean diurnal air temperature range contributed the highest. I expected that hair-crested drongos would be sensitive to the temperature. Based on Petit's theory, migratory birds' preferences for stopovers resemble their nest site selection more than other external factors (2000). During the breeding season, I have observed that the more days that have temperature lower than 17 degree Celsius at the Dongzhai national reserve, the later drongos laid their eggs. I assumed hair-crested drongos should exhibit higher tolerance for the most environmental variables during migration compared to breeding season. Our data (unpublished) indicates that the lowest temperature of wintering grounds with successful egg laying was higher than 17 degree Celsius. Therefore, I concluded that drongos may be tolerant to few days of extreme temperature, but in general they preferred areas with higher temperature, which aligned with our results from the migration study.

Elevation

Surprisingly, elevation contributed 0% for both southward and northward male drongos. Based on migration routes shown in figure 3, male tended to migrate along the east, and female tended to migrate along the west. Because the general elevation of southeast China has a trend of decreasing elevation from west to east, that means male drongos migrate along routes with lower elevations. Recalling Petit's theory that migration behaviors resemble breeding sites choices, in this study I saw that drongos preferred stopover sites at lower elevations, which aligned with their nest sites choices at lower elevation as well. Female drongos have a smaller body size than the male, thus they were less defendable or competitive if male has occupied the more advantageous, or easy to reach places at low elevation. They were forced to start migration earlier and their routes tend to be straight lines. Therefore, they lacked ambient time to migrate along the eastern routes, which had lower elevation. Female drongos also migrated further. At their winter grounds, male tended to stop at the northern Vietnam and Laos, while female willcontinue to migrate until they reached the south end of Thailand. All points that were located at the far south part of the map belonged to the female.

There are two hypotheses that may explain the above findings. The arrival-time hypothesis predicts that the sex whose fitness is more limited by intra-sexual competition for mates will be more likely to forego food-related benefits of migration and remain on breeding grounds instead (Ketterson & Nolan, 1976). The body-size hypothesis states that inclement weather makes year-round residency a risky strategy, regardless of food availability (Ketterson & Nolan, 1976). These two hypotheses suggested that female made different preferences than male can be the result of need to arrive further wintering grounds on time and the result of outcompeted by male, but these two hypotheses stressed the importance of intra-sex competition and whether or not the species decide to migrate or stay at breeding sites. No other studies have proposed related hypotheses that explained inter-sex differences in preference for stopover sites during the fall migration towards wintering grounds. This study showed that female and male drongos exhibited different preferences in stopover site selection, but that did not necessarily imply the two sexes were in competition during migration. Further studies are needed to support the idea that female drongos migrate along western routes is the result of need to arrive on time and unable to compete with male.

Synthesis

In conclusion, based on the results from Maxent, hair-crested drongos selected their stopover sites based on temperature and elevation. Drongos selected stopover sites that had average temperature higher than 17 degree Celsius. The only difference in stopover site preference between two sexes was elevation. Female seemed to be more sensitive to elevation than male, and male tend to migrate along routes with lower elevation. I expected that both sexes should have similar preference on temperature, but different with regards to elevation, distance to human disturbance (expected to be studied in second run of Maxent), etc. The current results supported my hypothesis.

Limitations & Further Implications

Sample size was the biggest limitation of this study. Sample size was limited because attempts to install tracking devices in previous years have all failed. The two drongos that were captured in summer 2020 were the first successful time that Dr. Lei obtained full tracking data sets. Sample size was also limited due to the high death rate during migration. Thus, out of 40 drongos that were captured and wore tracking devices in year 2021, only half survived and returned to Dongzhai national reserve in year 2022. Higher sample size would improve the accuracy of the results. Future studies can continue to monitor this migratory population of drongos and also combine the findings with other migratory behaviors of drongos, such as the migration time frames of female to yield a holistic picture of drongos' migration patterns.

Understanding what were the contributing factors in hair-crested drongos' migration plays a vital role for future conservation efforts. Hair-crested drongos are currently experiencing population decrease, and yet I was not able to identify the precise reasons behind this decline. Scholars have also shown that migratory birds will be impacted due to climate change. Results suggest that the ability to colonize newly suitable areas may make resident species resilient to future climate change, but that climate-induced range contractions may make neotropical migrants vulnerable to these changes (Rushing et al., 2020). In addition, female drongos and male drongos clearly have different migratory patterns. I should provide extra conservation measures for both female and male drongos, and expand existing reserves to incorporate more diverse habitats.

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