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Density estimate and habitat preference of the globally endangered Giant Nuthatch (*Sitta magna*) in Mt. Ashae Myin Anauk Myin, Pindaya, Southern Shan State, Myanmar

Thura Soe Min Htike[1,3] *, Philip D. Round[2], Tommaso Savini[1] and Naruemon Tantipisanuh[1], Dusit Ngoprasert[1], George A. Gale[1]

1. Conservation Ecology Program, School of Bioresources & Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand
2. Department of Biology, Faculty of Science, Mahidol University, Bangkok, Thailand
3. Dry Zone Greening Department Ministry of Natural Resources and Environmental Conservation, Myanmar

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Thura Soe Min Htike, Range Officer
Dry Zone Greening Department

Abstract

The globally endangered Giant Nuthatch is restricted to submontane forests of southern China, eastern Myanmar and northern Thailand, but recent verified records of the species in Myanmar are absent. We aimed to update information regarding the distribution, abundance and habitat use of Giant Nuthatch in eastern Myanmar. We surveyed four sites with either previous records or likely habitat. We used playback with adaptive cluster sampling to map Giant Nuthatch locations and associated habitat at the 1800 ha Mt. Ashae Myin Anauk Myin (AMAM), the only site we confirmed the species. One to five surveys were conducted at 48 points during January to March 2019. Giant Nuthatch was found at 19 points between 1594 m and 2098 m elevation. N-mixture models were applied to estimate abundance and identify habitat variables correlated with abundance and detection probability. Abundance was positively associated with larger diameter trees, a higher proportion of pine and oak combined based on their total basal area, and negatively correlated with elevation. Foraging data suggested that Giant Nuthatch preferred to feed on trunks and large branches of larger diameter pines and Fagaceae trees. The total population in the sampled area was estimated at 56 birds (25-128, 95% CI) perhaps representing 1-3% of the global population highlighting the need for urgent protection of this area.

ပင်းတယမြို့နယ်၊ ဇော်ဂျီကြိုးဝိုင်း၊ အရှေ့မြင်အနောက်မြင်တောင်ဒေသတွင် တွေ့ရသည့် ကမ္ဘာလုံးဆိုင်ရာမျိုးသုဉ်းရန်အန္တရာယ်ရှိသော ငှက်ပြာခြောက်ကြီးမျိုးစိတ်၏ အကောင်ရေနှင့်နေထိုင်ကျက်စားရာဒေသဆက်စပ်မှုများအားလေ့လာခြင်း

ဦးသူရစိုးမင်းထိုက်၊ တောအုပ်ကြီး
အပူပိုင်းဒေသစိမ်းလန်းစိုပြည်ရေးဦးစီးဌာန

စာတမ်းအကျဉ်း

ကမ္ဘာလုံးဆိုင်ရာ မျိုးသုဉ်းရန်အန္တရာယ်ရှိသော ငှက်ပြာခြောက်ကြီးမျိုးစိတ် (Giant Nuthatch) သည် တရုတ်ပြည်တောင်ပိုင်း၊ မြန်မာနိုင်ငံအရှေ့ပိုင်းနှင့် ထိုင်းနိုင်ငံ မြောက်ပိုင်း ရှိ တောင်ပေါ်သစ်တောများတွင်သာ ကန့်သတ်ကျက်စား နေထိုင်သည့် ငှက်မျိုးစိတ်တစ်ခု ဖြစ်ပြီး မကြာသေးမီက မြန်မာနိုင်ငံရှိငှက်မျိုးစိတ်များ လေ့လာမှုမှတ်တမ်းတွင်မတွေ့ရပါ။ဤသုတေသန သည် မြန်မာနိုင်ငံအရှေ့ပိုင်း၊ ရှမ်းပြည်နယ် တောင်ပိုင်းတွင် Giant Nuthatch ၏ ပျံ့နှံ့ကျက်စားနေထိုင်မှု၊ အကောင်ရေကြွယ်ဝမှု၊ နေရင်းဒေသနေရာများ အသုံးပြုခြင်းနှင့် ပတ်သက်သော သုတေသနအခြေခံအချက် အလက်များကို ရှာဖွေဖြည့်ဆည်းရန် ရည်ရွယ်ပါသည်။ ငှက်ပြာခြောက်ကြီးမျိုးစိတ် ရှာဖွေရန်အတွက် တောင်ကြီးမြို့နယ်၊ ကလောမြို့နယ်၊ ရွာငံ မြို့နယ်နှင့် ပင်းတယယ မြို့နယ်များအတွင်း သမိုင်းမှတ်တမ်းတွင် တွေ့ရှိခဲ့ရသော နေရာများနှင့် ဖြစ်နိုင်ချေရှိသောနေရာများ စုစုပေါင်း(၄)နေရာတွင် ရက်ပေါင်း(၃၀) ကျော်ခန့်ကြာ ရှာဖွေခဲ့ပါ သည်။ ငှက်ပြာခြောက်ကြီးမျိုးစိတ် ရှာဖွေတွေ့ ရှိခဲ့သော တစ်ခုတည်းသော နေရာ ဖြစ်သည့် ပင်းတယ မြို့နယ်၊ ဇော်ဂျီကြိုးဝိုင်း၊ အရှေ့မြင် အနောက်မြင်တောင်ဒေသတွင် နမူနာအမှတ်ပေါင်း (၄၈)ခု ချမှတ်၍ စာရင်းကောက်ယူခြင်း ဆောင်ရွက်ခဲ့ပါသည်။ ငှက် အကောင်ရေပေါကြွယ်ဝမှု၊ တွေ့မြင် နိုင်မှု ဖြစ်တန်စွမ်းနှင့် နေရင်းဒေသ၏ လက္ခဏာများ ဆက်စပ်မှုကိုသိရှိနိုင်ရန် N-mixture models ကိုအသုံးပြု၍ ကိန်းဂဏန်း အချက် အလက်များကို စိစစ်လေ့လာခဲ့ပါသည်။ ငှက်ပြာခြောက်ကြီးမျိုးစိတ် ပေါကြွယ်ဝမှုသည် ပင်စည်လုံးပတ်ကြီးမားသော ထင်းရှူး၊ သစ်ချ၊ သစ်အယ်ပင်ကြီး များပေါကြွယ်ဝသော တောအမျိုးအစားနှင့် တိုက်ရိုက်အချိုးကျ ၍ ပင်လယ် ရေမျက်နှာပြင် ထက်အမြင့်နှင့်မူ ပြောင်းပြန်အချိုးကျကြောင်း တွေ့ရှိရပါသည်။ အစာစားသုံးမှု လေ့လာချက်များအရ ငှက်ပြာခြောက်ကြီးသည် ထင်းရှူး၊ သစ်ချ၊ သစ်အယ်ပင်ကြီးများ၏ ပင်စည်နှင့် သစ်ကိုင်းကြီးများပေါ်တွင် ကျက်စားလေ့ရှိသည်ကို တွေ့ရှိရပါသည်။ နမူနာ ကောက်ယူသည့်ဧရိယာ၃.၂၅ စတုရန်းကီလိုမီတာတွင် ငှက်ပြာခြောက်ကြီး အကောင်ရေပေါင်း (၅၆)ကောင်ခန့် (၂၅-၁၂၈, ၉၅% CI) ရှိသည်ဟု ခန့်မှန်းရပြီး ယင်းပမာဏသည် တစ်ကမ္ဘာလုံးရှိ ငှက်ပြာ

ခြောက်ကြီးဦးရေစုစုပေါင်း၏ (၁-၃)ရာခိုင်နှုန်းခန့်ရှိပြီး ဇော်ဂျီကြိုးဝိုင်း၊ အရှေ့မြင် အနောက်မြင်တောင်ဒေသသည် ကမ္ဘာလုံးဆိုင်ရာမျိုးသုဉ်းရန် အန္တရာယ်ရှိသော ငှက်ပြာခြောက် ကြီးမျိုးစိတ်အား ထိန်းသိမ်းရန် အရေးကြီးသော နေရာဒေသတစ်ခု ဖြစ်ကြောင်းတင်ပြ အပ်ပါ သည်။

Density Estimate And Habitat Preferences Of The Globally Endangered Giant Nuthatch *Sitta Magna* In Mt. Ashae Myim Anauk Myim, Pindaya, Southern Shan State Myanmar

1. Introduction

The Giant Nuthatch *Sitta magna* is a globally endangered species restricted to submontane forests (1192- 3400 m) in southern China (mostly restricted to Yunnan), eastern Myanmar (principally Shan State) and northern Thailand (BirdLife International 2001). It has a small population, which is inferred to be declining and severely fragmented as a result of loss of its conifer and mixed forest habitats to logging, fuelwood collection, shifting cultivation and fire (Birdlife International 2016). These factors are the main reason why it was uplisted from vulnerable (VU) to globally endangered (EN) in 2012. The global population is estimated 1,000-2,499 mature individuals, roughly equivalent to 1,500-3,800 individuals in total (Birdlife International 2016). The population trend is likely decreasing, and the main threat is possibly the destruction of pine forests although this is largely undocumented.

Recent data about the Giant Nuthatch is rare or absent except unpublished records by local bird guides due to poor accessibility, the large potential habitat area and some insurgent activity near national boundaries. Historical records suggest that the Giant Nuthatch’s habitat range within Myanmar covered nearly one-third of its global habitat range, south from the Mogok Hills, Mandalay Region, east from the Menetaung Range and Kalaw, Shan State, to Mt Nattaung, in Northern Karen State (BirdLife International 2016, Harrap 2018, Smythies 1953). According to Birdlife International Red Data Book (2001), there were 13 locations with historical records of the Giant Nuthatch in the Shan State and surrounding areas. Most of the locations are near or around Kalaw and Taunggyi because these areas were more accessible compared with key border areas and more remote areas. Moreover, most of the remaining habitat falls in areas under the complete or partial control of various ethnic armed groups in Shan State which, in addition to extremely limited budgets, greatly constrains the central government’s ability to establish and maintain national protected areas (MCRB 2018).

Only three post-1950 records have been discovered for Myanmar (BirdLife International 2001), while recent surveys in Shan State were unsuccessful in locating the species (BirdLife International 2016). The most recent historical record shows that Giant Nuthatch was last found near Taunggyi, Shan State, in the mid-1980s (BirdLife International 2001). According to unpublished information, the last time when local birdwatchers saw the Giant Nuthatch was in 2016 in Mount Ashae Myin Anauk Myin (Ko Pan Kalaw, Tin Ko Oo and S. Gidean verbally 2017). However, it has probably been locally extirpated from some historical sites since several watershed areas have been subjected to forest clearance and burning for decades (Htwe et al. 2015). At Kalaw, where the last sightings were in 2008 (Ko Pan Kalaw verbally 2017), the pine forests have been extensively cleared and burned and Giant Nuthatch is thought to have been locally extirpated (Bezuijen et al. 2010).

More broadly, the annual deforestation rate of Shan State was high (0.93%) during the past decade, with a net forest loss between 2001 and 2010 (~5,648 km2) being the largest among other regions and states in Myanmar (Wang et al. 2016). Forest clearance in Shan State was mainly driven by agricultural expansion, shifting cultivation, overexploitation of timber, fuelwood consumption (including charcoal), infrastructure development, mining, and fire (Myint 2018). The ongoing change in land use practices especially the transformation of forest to agriculture in conjunction with rapid development will probably have an increased impact on this species in its habitat range in Myanmar (Barlow et al. 2016; Cosset et al. 2019). Since the remaining habitats of the Giant Nuthatch in Myanmar are not protected and might lack proper management in the future due to the current political situation, there is an urgent need to begin to assess the current status of Giant Nuthatch in Myanmar and begin the process of identifying and managing remaining habitat for the species.

This research was conducted to provide observation and habitat use data to assess the current status and distribution of the Giant Nuthatch in Myanmar focusing on mostly Shan State. A brief quantitative assessment of tree and other substrate use as well as foraging behavior was also conducted during this study as this basic information is also lacking for the species and would likely be useful in assessing habitat use.

2. Objectives

The main goals of this study were to assess the distribution of the Giant Nuthatch in Myanmar mainly in Southern Shan state. My specific objectives were to: (1) collate the most recent records of Giant Nuthatch within the past 10 years (2008-2017) in Myanmar and assess their reliability, (2) assess the probability of detection and habitat associated with detection of the Giant Nuthatch in at two historical sites and two potential sites with recent observations(<6 years) by local bird watchers within Myanmar (3) estimate the abundance of the Giant Nuthatch in the areas the species was detected, (4) understand the foraging behavior of the Giant Nuthatch in the three selected sites, and (5) assess the amount and distribution of remaining forest habitat in the Shan State that is at least potentially suitable for the Giant Nuthatch.

3. Materials and Mehtods

3.1 Selection of potential study areas

3.1.1 GIS mapping

Since the habitat associations of Giant Nuthatch are still not well understood, I specified the basic parameters roughly based on my literature review to assess the possible habitat patches of Giant Nuthatch in Shan State, Myanmar. The first parameter was that the land use type should be hill evergreen forest that included both broad-leaved forest and coniferous forest and I excluded tropical seasonally deciduous forest and other land use types from the consideration of possible habitat patches. The second parameter was an elevation range of 1,200 - 1,800 m because all previous Giant Nuthatch records were found within this altitudinal range in Myanmar. The third one was the minimum habitat patch size which was considered to be 20 ha based on telemetry data which reported a home range size of 12.2 ha (Techachoochert 2018) of one male Giant Nuthatch, the only known telemetry record.

Preliminary image classification was conducted from April to May 2018 to assess the remaining habitat of Giant Nuthatch in Myanmar. Landsat 8 ETM+ images taken during the dry season (01 January 2018 – 31 March 2018) and data from Google Earth were used to classify land use types and to identify evergreen and deciduous forests. We assumed that all deciduous forests will be excluded from this image classification because most deciduous trees shed their leaves during the late autumn and spring (here January - May in Myanmar). Acquiring the satellite images during this season could also avoid the interference of clouds. Path-Rows of the 13 Landsat scenes that covered the whole Shan State included 130-045, 130-46, 131-044, 131-045, 131-046, 132-043, 132-044, 132-045, 132-046, 132-047, 133-044, 133-045 and 133-046. All data used WGS 1984, Universal Transverse Mercator (UTM) coordinates in zone 47 N. All images were selected based on the percentage (<10%) of cloud presence.

As above noted, image classification was focused on higher elevations (1200-1800 m) based on the historical records of the Giant Nuthatch in Myanmar (BirdLife International 2001), pine and broad-leaved evergreen vegetation type and forest patches ≥ 20 ha.

Firstly, 13 Landsat 8 OLI images were acquired from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov/) on 11 April 2018. Each scene was clipped to the extent of the Shan State boundary layer. Digital image preprocessing included layer stacking that was conducted for each scene by use of the tool "Composite Bands". Each raster file was also clipped by using a DEM (Digital elevation model) SRTM (Shuttle Radar Topographic Mission) layer that are also acquired from USGS website to the extent of the desired elevation range (1200-1800 m). For image classification, signature files were developed for identifying forest (evergreen forest) and non-forest (all other land use types) based on band combination 5-6-4 and 5-4-3 and a Google Earth images. Supervised classification by implementing maximum likelihood classification was used to classify the image and all 13 scenes were classified in ArcGIS 10.3. All images were mapped one by one because images acquired on different dates have different reflections. After image classification, I combined all scenes and extracted the desired area and converted these areas to a shape file of polygons.

The results from image classification showed that the Shan State includes over 300,000 polygons of possible habitat areas. The total possible habitat area was approximately about 16,344 km2 and covered about 10.49% of the total area of Shan State. The total number of polygons larger than 20 ha was about 5,000 patches. The number of polygons larger than 2000 ha was just over 100 patches.

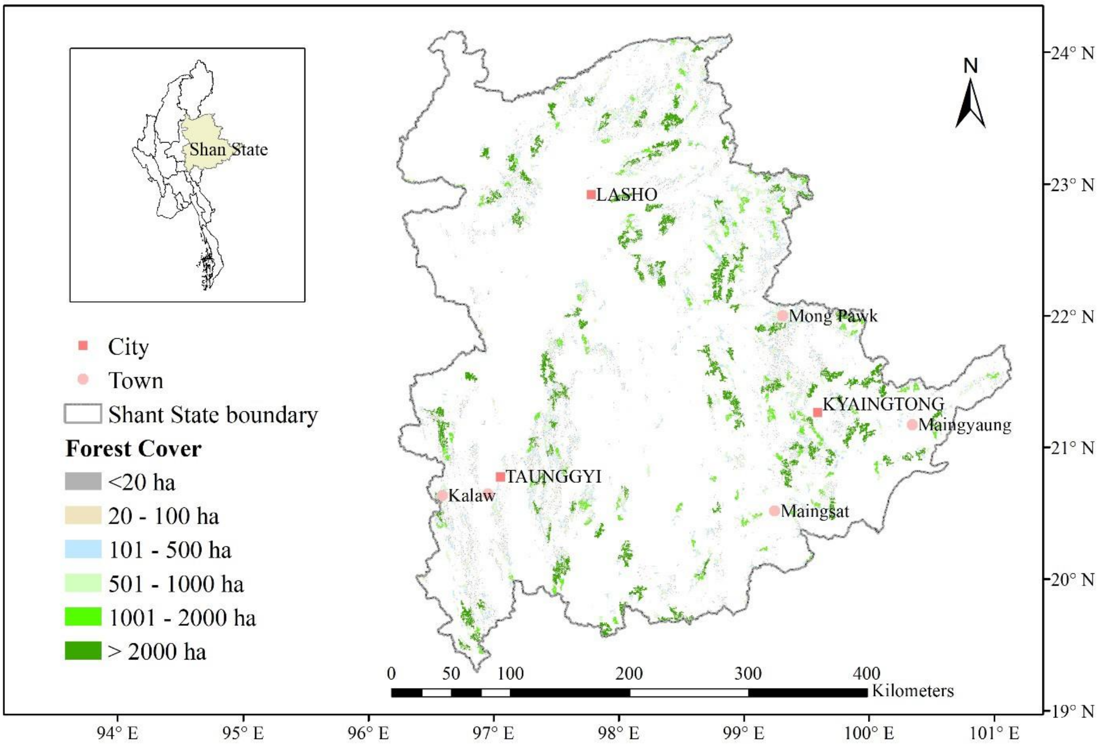

Figure 3.1. A preliminary map showing the possible habitat patches of Giant Nuthatch in Shan State, Myanmar. All colored areas within the Shan State represents hill evergreen broadleaf and coniferous forests between an elevational range of 1200 – 1800 m.

3.1.2 Historical records and unpublished records

I also considered the historical locations from the literature and the most recent unpublished records to find possible Giant Nuthatch locations. Only three post-1950 records have been discovered for Myanmar (BirdLife International 2001), while recent surveys in Shan State were unsuccessful in locating the species (BirdLife International 2016). The study areas were selected focusing primarily on the thirteen historical locations of the Giant Nuthatch (BirdLife International 2001), most of which were near or around Kalaw and Taunggyi and therefore relatively accessible compared with remote border areas (Figure 2.1). However, I could not georeference exact historical locations, most of which were >70 years old, and referred only broadly to geographically distinct features like rivers and towns.

Moreover, I also selected potential study areas from more recent unpublished records of Giant Nuthatch obtained through bird watching tours. There were only two locations where the Giant Nuthatch have been recorded less than 10 years ago. The most recent sighting was in Mt. Ashae Myin Anauk Myin in 2016 where a bird watching group got a single detection at one location (21˚ 1.549' and 96˚ 37.182'). The species was also recorded at Yay Aye Kan Reserved Forest in 2008 (Ko Pan Kalaw verbally 2017).

I selected four forest patches that I considered had the highest potential to support the species based on historical records from BirdLife International 2001 and information from interviews of local bird guides. The four forest patches were (1) Mt Ashae Myin

Anauk Myin (Pindaya Township), (2) Ye Aye Kan Reserve Forest (Kalaw Township), (3) Taunggyi Bird Sanctuary (Taungyi Township) and (4) Mt Myin Ma Hti (Kalaw Townhsip) (Figure 3.2).

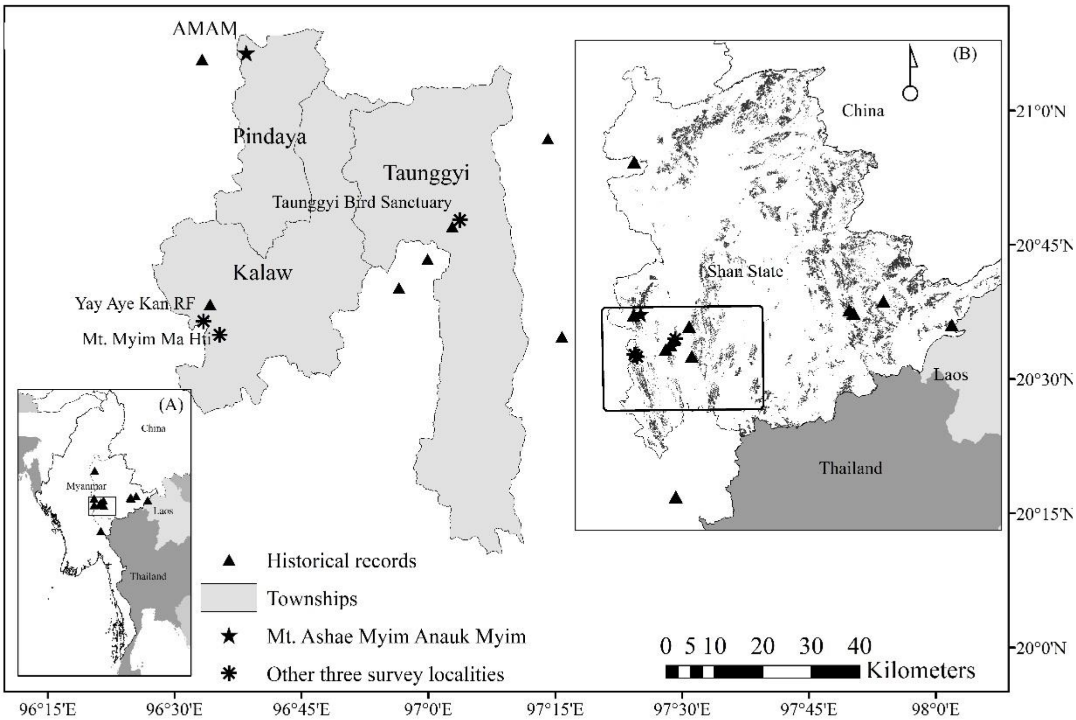

Figure 3.2. Map showing the localities of historical records and the four forest patches that were selected for initial surveys (including Mt. Ashae Myim Anauk Myim [AMAM]) for the presence/absence of Giant Nuthatch. The dark areas in inset Map (B) show approximately 3,660 potential forest habitat patches greater than 30 ha in Shan State resulting from our preliminary image classification

3.2 Study areas

3.2.1 Mt Ashae Myin Anauk Myin

Mt Ashae Myin Anauk Myin (AMAM) is located in Zaw Gyi Reserve Forest in Pindaya and Ywaksauk Townships, southern Shan State at 21°05.446' N and 96°38.136"E. The estimated area of the forested portion of the reserve forest in Pindaya and Ywaksauk Townships is approximately 1,800 ha based on my image classification. The highest point of the area is 2,257 m above sea level (second highest peak in Shan State) and is part of the Shan plateau. The vegetation is characterized by the presence of both broad-leaved forests and coniferous forests (Kurz 1877, Kress et al. 2003) and trees species of both forest types especially pines and oaks are found together in some places. *Pinus kesiya* is dominant in pine forests and various Fagaceae species are widely found in both forest types. Rhododendron forests and mountain grassland cover the highest elevations while hill deciduous forests mixed with pines are found at some parts of the lower elevations (Kress et al. 2003). Cattle ranching along with the cultivation of garden peas occurs along the mountain ridges. Orchid collection by local peoples from the villages around the reserve forest occurs during the winter as an alternative livelihood. There is an exclusion zone inside the reserve forest for village land including tea and orange plantations. There are no published historical records of the occurrence of the Giant Nuthatch in this area but a recent sighting of one nuthatch was photographed in 2016 during a bird watching trip to this area (Ko Pan Kalaw, Tin Ko Oo and S. Gidean verbally 2017).

3.2.2 Yay Aye Kan Reserved Forest

The second forest patch, Yay Aye Kan Reserve Forest, was located at 20˙35.718ˈ N 96˙ 31.668ˈ E, 2 km south-west of Kalaw city and was established in 1912 to preserve the watershed of Yay Aye Reservoir. This reservoir is the main water reserve for the city of Kalaw (Forest Department, Myanmar) and is well-known among bird watchers and trekkers because of its diverse avifauna and suitable conditions for trekking. The forested area of this reserve is 790 ha. Hill evergreen broad-leaved forest is the dominant forest type and coniferous forests are dispersed around the reserved forest (Kress et al. 2003). This hill evergreen forest encloses two reservoirs and many streamlets making this reserve forest wetter than my other study areas. Mixed coniferous forest habitat around the reserve forest was cleared for charcoal making during the previous decades. Fuelwood collection occurs frequently inside the reserve forest while the secondary pine trees are hacked for resin extraction. Giant Nuthatch was last recorded time in this reserved forest in 2008 (Ko Pan Kalaw verbally 2017). Although many visits to this forest, local bird guides haven’t seen the Giant Nuthatch after 2008, and they also reported that they have never seen the Giant Nuthatch in secondary pine forests and pine plantations dispersed around this reserved forest.

3.2.3 Mt. Myin Ma Hti

Mt. Myin Ma Hti, the third forest patch, a site of cultural importance, was located at 20˙35.183ˈ N 96˙ 35.928ˈ E about 10 km south-east of Kalaw City. Mixed coniferous forest covered a small isolated patch of 40 ha of Myinmati Mountain. It has no confirmed sightings of Giant Nuthatch but was mentioned as a place with a high potential to have the Giant Nuthatch by a wildlife technician from WCS (Wildlife Conservation Society) (Thet Zaw Naing verbally 2017) because of the lack of disturbance.

3.2.4 Taunggyi Bird Sanctuary

Taunggyi Bird Sanctuary, the fourth forest patch was the site of the most recent published record of the Giant Nuthatch from the mid-1980s (BirdLife International 2001). This bird sanctuary was established 1906 as the Taunggyi Wildlife Reserve, and re-designated as a bird sanctuary in 1989 (Beffasti et al. 2011). Approximately 800 ha of the sanctuary is covered with mixed coniferous forest, hill deciduous and hill evergreen forests. Frequent fires, logging and turpentine oil extraction are the main threats while proximity to urban areas causes additional disturbance to wildlife (Beffasti et al. 2011). Giant Nuthatch has not been recorded during several surveys to the sanctuary by wildlife rangers from Inle Lake Wildlife Sanctuary .

3.3 Data collection

3.3.1 Preliminary locality surveys

I started searching for Giant Nuthatch on 23 November 2018, spending about one month visiting my four study areas. I walked and biked common trails used by locals and tourists for collecting forest products, bird watching and hiking. The total effort was about 40 km of trails/track walked or surveyed by motorcycle. I searched for Giant Nuthatch using playback of vocalizations, both songs and calls. I found Giant Nuthatch only in one locality, AMAM, locating my first Giant Nuthatch on 24 December 2018. I had no detections in the other three localities.

3.3.2 Point count surveys in AMAM

I established 46 sample points in three separate sites of the forest and of those, I sampled 43 points five times and three points between two and three times. Adaptive cluster sampling was used, and four adjacent points were surveyed around primary starting points — each survey point was 300 m apart in cardinal directions where possible. When adjacent points could not be established due to steep slopes, impenetrable undergrowth or unsuitable non-forest habitat like tea plantations, plots were set at greater distances in the same direction.

Point count surveys were conducted from December 2018 to March 2019. Nesting is known to occur from February to April (Livesey 1933; Round 1983; Techachoochert 2018). I conducted point-count surveys by using playback of vocalizations of Giant Nuthatch to increase the probability of detection (Bibby et al. 2000). Recordings of calls and songs were obtained from the Xeno-canto database (www.xeno-canto.org). During the surveys, the Giant Nuthatch contact call was played for 30 seconds, followed by five minutes of observation. If there was no response in the first round, the Giant Nuthatch territorial song was played instead, for 30 seconds, followed by observations for a further five minutes (following the methods of Techachoochert et al. 2018). Each session therefore lasted about 11 minutes. The surveys were conducted from sunrise until noon. The presence of the bird was recorded by either sighting or aural detection of vocalizations within an estimated 150 m radius from the centre of each survey point. When the bird was detected, I measured the distance to the bird with a tape measure and recorded the direction to the bird (degrees), and location of the bird within a tree or other substrate (they occasionally fed on the ground or on fallen trees).

3.3.3 Habitat sampling

Micro-site variables and vegetation characteristics were sampled at each point count location (also marked with a GPS). At the centre of each point, one circular plot (12.6 m in radius, 0.05 ha) was established to sample the elevation, slope, aspect and plant community. Canopy openness was estimated with an ocular tube at five distance intervals (approximately 2.5 m apart) in each of four cardinal directions (Bunnell et al. 1990). All trees (>10 cm DBH [diameter at breast height]) within the sample plots were assessed including number of stems, tree species and DBH (Sutherland 2006). Slope in degrees from the horizontal and its aspect were measured by using a SUUNTO clinometer.

3.3.4 Foraging substrate and foraging behavior

Sampling of foraging was conducted in three separate sites within AMAM to encompass a range of microhabitats within the study area. I searched for birds without using playback. For evaluating foraging substrate, I recorded the trees on which Giant Nuthatch was foraging along with two or three available trees (>10 cm DBH) nearest to each used tree to better understand the characteristics of used trees (McCallum et al.1988). I recorded the amount of time spent on each tree species and its DBH.

Detailed observations of foraging behavior were collected during 5- to 15-second behavioral samples (Adams & Morrison 1993). Sequential observations were used to reduce biases related to foraging strategies (Morrison 1984). To minimize possible effects of initial observer disturbance, no data were recorded for the first 10 seconds after a bird was sighted (Adams & Morrison 1993). Surveys were conducted throughout daylight hours during March-April 2019.

For foraging behavior, I collected substrate and foraging mode used by focal birds including the duration that the bird spent on each substrate and each mode of foraging. Substrate categories included trunk, large branch (>15 cm diameter), medium branch (5-15 cm), small branch (1-5 cm), twig (<1 cm), fallen log, fallen branches and the ground (following Adams & Morrison, 1993). Following Adams and Morrison, 1993; I defined foraging as (1) glean, to remove stationary prey from surface of substrate while perched; (2) probe, to insert bill into bark crevices or depressions in substrates in search of prey (action usually created little or no audible sound); (3) peck, to strike substrate forcefully with bill to obtain prey beneath the surface (usually creating a clearly audible sound); and (4) flake, to chip away loose particles of substrate surface. The amount of time spent travelling along the bark surface, flying and remaining stationary were also recorded.

3.3.5 Nest observations

I found a Giant Nuthatch nest on 5 April 2019. The nest was observed from approximately 10 m from the nest, upslope from the nest, mostly hidden behind a dead tree and some bushes. Observations were made with Nikon Monarch 10x42 binoculars and a camera with 210-mm telephoto lens. Nest visits to check nest contents were made once per week before hatching and once per three days after hatching. During nest checks, observers waited until the adult left the nest and then we checked inside the nest by using a flashlight and also light from mobile phone. Photographs of the contents were sometimes possible, but due to the bent nature of the cavity it was not always possible take photos during some visits. I also recorded the food items that the adults brought to the nest and the duration of feeding.

3.4 Data analysis

3.4.1 Abundance models

Data analysis was conducted only for the 46 points surveyed at AMAM. N-mixture models (Royle 2004) were used to estimate the abundance of Giant Nuthatches because N-mixture models provide unbiased estimates and require only counts of individuals without the need and the risks of capturing animals (Ficetola et al. 2018). Since two GLMs (generalized linear models) are included in N-mixture models (Poisson regression for the spatial variation in abundance and a binomial regression for the variation of the observed counts at specific sites), this enables modelling for both parameters (abundance and detection probability) simultaneously (Kéry and Royle 2015).

The time of day and survey date were included as sampling covariates. Forest structure covariates included average tree diameter at breast height (DBH), number of trees and canopy cover, proportion of pines based on total basal area, proportion of oaks based on total basal area and proportion of both pines and oaks combined at each sample plot based on their total basal area. Topographic covariates (slope, aspect, and elevation) were also included as site covariates (Table 1). Both site and sampling covariates were firstly centred to have a zero mean and scaled unit variance (one standard deviation) by subtracting the mean then dividing by one standard deviation, using the 'scale' function in program R (Crawley 2005). All variables were tested for multicollinearity using a pairwise-correlation matrix (Spearman rho, ρ) and one of each pair where the correlation coefficient was ≥0.6 was removed (Zuur et al. 2010). Only one pair of covariates, proportion of oaks and proportion of both pines and oaks combined was found to be correlated (ρ = 0.6), and not included in the same model.

For N-mixture models, parameter estimation can be biased by the K-value, which is the upper limit of the unobserved population size for any site that the model is set to allow (Kéry 2018). Therefore, to ensure that the latent abundance was larger than the observation counts, we tested three different values of K (100, 200 & 300) following Couturier et al. 2013 based on Royle 2004 to find the value of K with the minimum bias. A K-value of 100 was found to have sufficiently low bias for building the models. The global model is considered the best candidate for assessing fit statistics such as overdispersion (Burnham & Anderson 2002; Harrison et al. 2018) and it was then tested for goodness of fit by means of a Pearson chi-square test (MacKenzie et al. 2004) using parametric bootstrap resampling (1,000 resamplings). A bootstrap chi-squared goodness-of-fit test suggested that the global model performed well in fitting the data (bootstrapped P value = 0.295).

A two-step modelling approach was used to assess the variables that affected detection probability and abundance (e.g., Adams et al. 2010; Harihar et al. 2012; Robinson 2014; Kamjing et al. 2017). In the first step, we built three models to test if our two sampling covariates (time of day and date after the first survey) affected detection probability or not. We then selected the most supported model of the sampling covariates that affected detection probability and included these sampling covariates in generating the abundance models in the second step of our modelling approach.

In the second step, we tested 12 single variable models and five models comprised of combinations of five variables (average DBH, elevation, proportion of pines, proportion of oaks and proportion of both pines and oaks combined) that were considered to be influential on the habitat preference of Giant Nuthatch based on our knowledge of its ecology and relevant literature. These 17 models were used to test variables associated with the probability of nuthatch abundance (λ) and the probability of nuthatch detection (p) (Table 2).

We compared the constant model (intercept-only-model), to models containing variables of interest. Differences in Akaike's Information Criterion (ΔAIC) and AIC weights (wi) were used to compare the models (Burnham & Anderson 2002).

We undertook model averaging focusing on the top models that represented a cumulative weight of 95% of the AIC weights following Burnham and Anderson (2002) to obtain averaged estimates of beta coefficients and prediction. Confidence intervals of 85% were used to recognize variables with weighty influence on the abundance estimate: 85% confidence intervals provide model selection and parameter-evaluation criteria more congruent than narrower interval widths (Arnold 2010). We conducted the analysis in R version 3.5.0 (R Development Core Team 2013), using N-mixture models with the "unmarked" package (Fiske et al. 2011) and model averaging with the "AICcmodavg" package (Mazerolle 2013).

3.4.2 Foraging data analysis

The percentage of time spent on a particular tree species, substrate and foraging mode were compared. The data were expressed as a percentage of total observation time per individual (where each day was a sample period) and transformed into continuous variables (Adams et al. 1993). Arcsine transformation was used to transform the percentages for the proportional data (Zar 1999). Since the transformed data did not meet the assumptions of an analysis of variance (ANOVA), Kruskal-Wallis nonparametric one-way ANOVA was used to test the differences in percentage of time spent on each substrate and foraging activity (Morrison 1984; Zar 1999). Chi-squared tests were used to analyse the relationship between proportional use and proportional tree abundance, based on relative basal area of tree species surveyed during our vegetation sampling. Tree preference was analysed using a Mann-Whitney U Test to test between the DBH of used and available neighbouring trees.

Table 3.1. Descriptions, means, and standard errors 'SE' of site and landscape-scale variables in 46 sample points where Giant Nuthatch *Sitta magna* was detected or not detected.

Variable	Data type	Description	Detected		Not detected	
			Mean	SE	Mean	SE
Sampling covariates						
time	Continuous	Time of observation from 06h00 – 12h00	8.65	1.61	9.25	1.52
Day	Continuous	Day after the first survey from 1 (the first day of survey) to 89 (the last day of survey)	46.69	2.05	54.30	2.13
Site covariates						
Topographic						
EL	Continuous	Elevation (m) above sea level	1742	27	1807	32
SL	Continuous	Slope (degrees)	29.5	1.31	31.6	1.48
AS	Continuous	Aspect (degrees)	142.9	16.46	155.4	17.73
Forest structure						
Pine	Continuous	Proportion of pine trees (percentage of total basal area) at each sample plot	3.43	0.06	2.06	0.04

Variable	Data type	Description	Detected		Not detected	
			Mean	SE	Mean	SE
Oak	Continuous	Proportion of oak trees (percentage of total basal area) at each sample plot	10.60	0.06	11.40	0.05
OKP	Continuous	Proportion of pine and oak (percentage of total basal area) at each sample plot	7.97	0.06	10.54	0.05
avg.DBH	Continuous	Average DBH (cm) of trees	30.0	1.72	24.1	1.60
CN	Percentage	Canopy cover (%)	74.8	3.89	71.9	5.07
TD	Count	Total number of trees	9.8	0.90	9.5	1.02

Table 2. Model selection of Giant Nuthatch *Sitta magna* abundance in relation to site variables. Variables considered in models included forest structure covariates at each sample point including average DBH (avg.DBH) of trees in cm, canopy cover (CN) in percent, total number of trees (TD), proportion of pine (Pine) in m^2 calculated based on its total basal area, proportion of oak (Oak) in m^2 calculated based on its total basal area, proportion of both pine and oak combined in m^2 that was calculated based on their summed total basal area (OKP) and topographic covariates including elevation (EL) in m, slope (SL) in degrees, aspect (AS) in degrees, and date (date) and time of day (time) as sampling covariates.

Model	**K**	**AIC**	**ΔAIC**	w_i
λ (avg.DBH + EL+OKP) p(date+time)	7	265.86	0.00	0.72
λ (avg.DBH + EL + Oak) p(date+time)	7	270.45	4.59	0.072
λ(avg.DBH + EL) p(date+time)	6	270.74	4.89	0.062
λ(avg.DBH + EL + Pine) p(date+time)	7	271.33	5.47	0.046
λ(avg.DBH) p(date+time)	5	272.13	6.27	0.031
λ(EL) p(date+time)	5	273.55	7.69	0.015
λ(.) p(date+time)	4	274.10	8.24	0.012
λ(OKP) p(date+time)	5	274.12	8.26	0.012
λ(SL) p(date+time)	5	274.49	8.63	0.010
λ(Oak) p(date+time)	5	275.45	9.59	0.006
λ(Pine) p(date+time)	5	275.71	9.85	0.005
λ(CN) p(date+time)	5	275.99	10.13	0.005
λ(AS) p(date+time)	5	276.00	10.14	0.005
λ(TD) p(date+time)	5	276.06	10.20	0.004
λ(.) p(date)	3	281.53	15.67	0.000
λ(.) p(time)	3	283.58	17.72	0.000
λ(.) p(.)	2	290.19	24.33	0.000

"K" represents the number of parameters, "AIC" for Akaike Information Criterion, "ΔAIC" for difference in AIC and "w_i" for AIC weight. "*λ*" represents the function of abundance estimate, "*p*" for the function of detection probability and "*λ(.) p(.)*" is the null model without any covariates.

4. Results

4.1 Detection probability and abundance

At AMAM, there were detections of Giant Nuthatch at 22 points (47.8%) and no detections at 24 points (52.2%). The elevation range of detections was 1,523 to 2,098 m above sea level. At the points with detections, there was a total of 63 detections during 223 replicate surveys and no more than two birds were ever detected at a point on any single sampling occasion. At nine of the points, two birds were detected during a single count, and at the other 13 points there were only detections of single individuals.

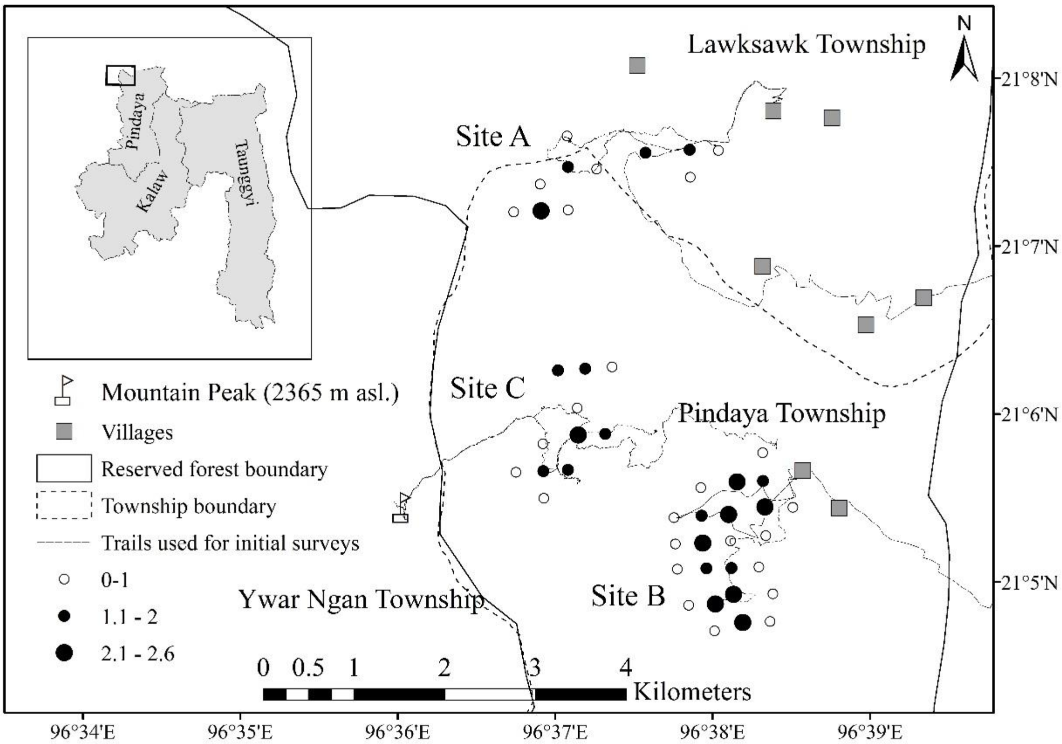

Figure 4.1. Map illustrating abundance estimates at the 46 sampling points across three separate sites (A, B and C) within Mt. Ashae Myin Anauk Myin (22 points with detections and 24 without). The three separate sites represent the locations of sample points resulting from adaptive cluster sampling, where sample points were clustered around initial detection locations. The size of the dots (representing the locations of the sample points) corresponds to the estimated abundance at each point.

Survey time and survey date likely affected detection probability, as indicated by the AICw_i of 96% and relative support over the null model, ΔAIC > 16. As expected, the detection probability was greatest in the early hours of daylight and decreased throughout the morning ($\beta_{averaged}$ = -0.51, 85% CI -0.78 – -0.23; Figure 3). Similarly, the detection probability was higher in the early period of the survey season than the later period ($\beta_{averaged}$ = -0.74, 85% CI -1.05 – -0.43; Figure 3). Thus, as mentioned above, we used models with time of day and date for assessing how site covariables potentially affected abundance (Table 2). Among our 17 models, the model which included average DBH, elevation, and proportion of both pines and oaks was found to be the most supported, with a ΔAIC > 4 compared to the second-most supported model. This model in conjunction with the next six most supported models, accounted for >95% of the cumulative AIC weights (Table 2). These top seven models were averaged to estimate the coefficients of the tested variables. The abundance of the nuthatch was associated with increasing average DBH ($\beta_{averaged}$ = 0.55; 85% CI: 0.23 – 0.87, decreasing elevation ($\beta_{averaged}$ = -0.51; 85% CI: -0.86 – -0.15) and increasing proportion of both pines and oaks ($\beta_{averaged}$ = 0.51; 85% CI: 0.22 – 0.80) (Figure 4). The sizes of the coefficients suggested that the effect sizes for each of these three variables were highly supported and similar in magnitude. The predicted mean abundance per point was 1.23 individuals (95% CI: 0.55 – 2.78) with a detection probability of 0.37 (95% CI: 0.26 – 0.51). The total population of the nuthatch in AMAM within the sampled area of 3.25 km^2 was estimated to be 56 individuals (95% CI: 25 - 128) equivalent to 17.23 individuals/ km^2 (95% CI 7.69 – 39.38).

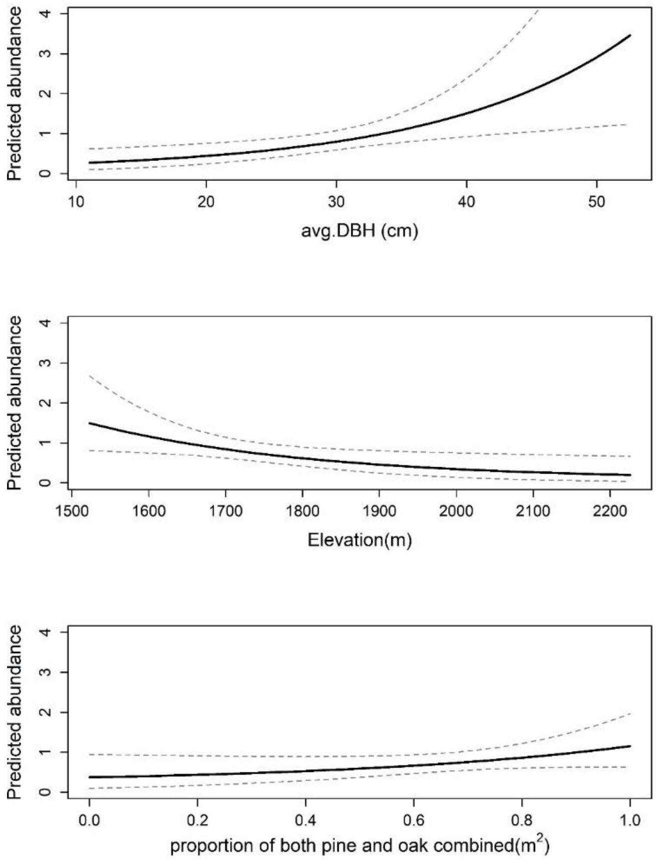

Figure 4.2. Relationship between the predicted mean abundance and average diameter at breast height (DBH) of trees (Upper). Relationship between the predicted mean abundance per sample point and elevation (Middle). Relationship between the predicted mean abundance per sample point and proportion (based on basal area) of both pine and oak combined (Lower). Solid line represents predicted mean density estimate and dashed lines represent lower and upper 85% confidence intervals.

4.2 Foraging behavior

A total of 30 unique observation events totaling 41 minutes of behaviors were recorded during 19 observation days. In total, 14, 10 and 6 observation events were recorded in Sites A, B and C respectively, using observation periods of 21,12 and 8 minutes, respectively. My analysis found that there was no significant difference in the time spent on any specific tree species relative to the proportional tree abundance in any of the three sites in AMAM (Site A,χ^2 = 5.95, P =0.51) (Site B,χ^2 = 0.19, P =0.91) (Site

C,χ^2 = 0.74, P = 0.69) (Figure 4.4). My sample sizes per site were small, however, and although the difference was not significant, it was noted that Giant Nuthatch appeared to spend more time (42%) on pine compared with available basal area of pine (28%) in Site A. The time spent on pine (6%) was roughly proportional to the pine abundance (9%) in Site B (P >0.05) while there was no pine at Site C. There was no significant difference in the foraging time spent on Fagaceae compared with other broadleaved tree species (Figure 4.4), although as already noted above the sample sizes were small.

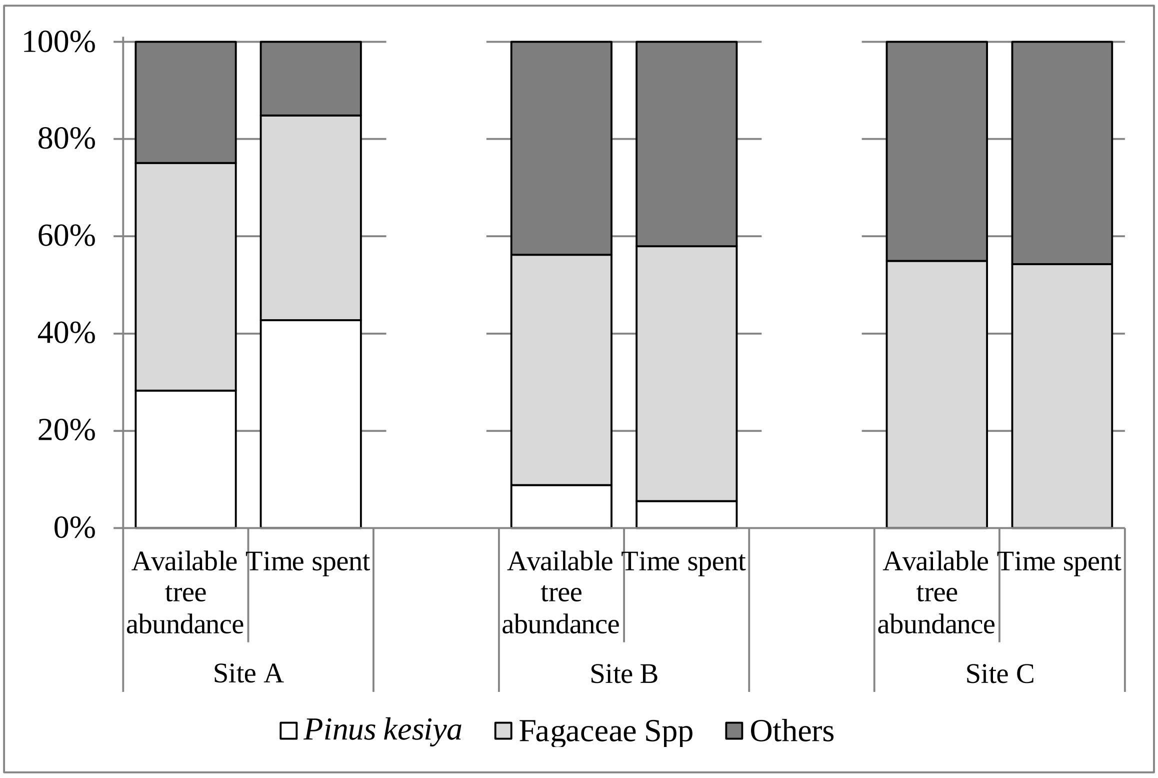

Figure 4.4. Available tree abundance and proportional use of tree species by Giant Nuthatches in Mt Ashae Myin Anauk Myin during the breeding season, 1 March 2019 – 30 April 2019. A total of 30 unique observation events totaling 41 minutes of behaviors were recorded during 19 observation days. 14, 10 and 6 observation events were sampled in Sites A, B and C totaling 21, 12 and 8 minutes respectively.

Giant Nuthatches spent most time feeding by pecking, and travelling along the trunk, and the least amount of time on gleaning (K-W ANOVA, P<0.01). Overall, the nuthatches spent 43% of time pecking, another 33% travelling, 10% flaking, 6% stationary, 5% probing, 3% flying and 1% gleaning. Giant Nuthatches spent most time foraging on tree trunks, least time on small branches, and no time on twigs (K-W ANOVA, P<0.01). Overall, the nuthatches spent 50% of the time on trunks, 28% on large branches, 21% on medium-sized branches and 1% on small branches. The diameter of the trees used for foraging (average DBH = 41.2 cm, N = 39) was significantly larger compared to the available sample of trees (average DBH = 31.5 cm, N = 90) (Mann- Whitney U Test, P <0.001).

4.3 Breeding ecology

The Giant Nuthatch nest was found in a natural cavity in a *Castanopsis indica* tree at 3.65 m height above the ground. This chestnut tree was 75 cm in DBH and 12.8 m in height. The entrance hole of the nest cavity was 7.6 cm in diameter and the cavity was about 30 cm in depth. The nest tree was located in mixed coniferous and broadleaf forest with an open canopy about 250 m far from the tea plantations and huts of local people.

The adult nuthatch was incubating when I found the nest on 5 April 2019. The male was feeding the female during incubation period and the female came out once from incubating every late afternoon. Since I found a nestling already on 10 April 2019, it was not possible to estimate the total incubation period. All three chicks fledged on 6 May 2019 and the nestling period was 27 days. Both male and female fed the nestlings during the nestling period.

During the eight visits to the nesting site, food items could be recorded 24 times. The food items recorded included 18 invertebrate items (75%) and 6 berries (25%) (*Myrica esculenta).* Most of the invertebrate items were caterpillars, moths and larvae (Order – Lepidoptera).

Figure 4.5 Photograph of a Giant Nuthatch at the nest cavity in a *Castanopsis indica* tree (This photo was taken on 7 April 2019 by Thura Soe Min Htike)

21 April 2019 (16 days old) 25 April 2019 (20 days old)

Figure 4.6 Photographs of Giant Nuthatch chicks (The left photo was taken by Rongrong Angkaew and the right photo was taken by Ko Nandar

5. Discussion

5.1 Current distribution status

I detected Giant Nuthatch only in Mt Ashae Myin Anauk Myin (AMAM), while no detections were recorded at the other two known historical locations; Taunggyi Bird Sanctuary and Yay Aye Kan reserved forest. Mt Myin Ma Hti had no historical records and was quite small (39 ha) and isolated, perhaps explaining the absence of Giant Nuthatch there. The likely extirpation from the two historical locations could be because both were previously part of larger patches of broad-leaved and coniferous forests, now fragmented by urbanization, and from which the large pine trees which have since been lost (Bezuijen et al. 2010). Although I did not assess the forest composition in detail, the denser, closed canopy moist environment of Yay Aye Kan reserved forest might not have been the preferred habitat of the Giant Nuthatch because the vegetation type of the reserved forest appeared to be notably wetter than current Giant Nuthatch sites in both AMAM and Thailand (Round, 1983; Matthysen, 1998; Techachoochert et al. 2018). While Taunggyi Bird Sanctuary supported what seemed to be suitable mixed broad-leaved and coniferous forests, increased human disturbance such as from recreation, including heavy tourist foot traffic, vehicle traffic, and frequent accidental fires in and around the sanctuary probably shrank the available habitat for Giant Nuthatch. Mt Ashae Myin Anauk Myin now appears to be the only known locality for this species in Myanmar, although here I have only surveyed a small portion of southern Shan State.

The estimated population in AMAM comprises about 1% of the global population based on the very rough current global estimates (BirdLife International 2016), therefore AMAM should be considered a globally important locality for Giant Nuthatch (Donald et al. 2019). While the range of Giant Nuthatch in Myanmar potentially represents about 30% of its global range, the estimate of the distribution and population of Giant Nuthatch in Myanmar is still unknown and natural forests within their habitat range are under substantial threat. As noted above, the annual deforestation rate of the habitat of the Giant Nuthatch in Myanmar (primarily Shan State) is high and was the highest among other regions and states in Myanmar (Wang et al. 2016).

My initial surveys and habitat samples show that Giant Nuthatch was patchily distributed in more open and drier mixed coniferous forest and avoided denser and wetter broad-leaved evergreen forests. Although AMAM (1,800 ha) was relatively large compared with my other three study areas, it probably held only a relatively small Giant Nuthatch population (likely <50 individuals). Thus, forest patches greater than 2,000 ha that support the preferred larger pines and oak trees of the species' favored habitat would be suggested as a minimum size for Giant Nuthatch population viability. The highest point at which I recorded Giant Nuthatch, 2,100 m, was a new elevational record for its range within Myanmar and should be considered when searching for other potential habitat. It is possible that extensive habitat remains in the Shan State, but detailed landscape analyses need to be conducted along with more extensive ground surveys.

5.2 Abundance in AMAM

The abundance of Giant Nuthatch increased with increasing DBH of the trees and decreasing elevation within the altitudinal range of 1,523 to 2,098 m above sea level. My generalized linear model using N-mixture analysis suggests that Giant Nuthatch prefers vegetation composed of larger diameter trees. My limited foraging data also indicated that they foraged on larger diameter trees relative to those available and that these large trees are important in their ecology. Larger, more mature trees may offer a greater area of substrate for foraging as I observed them spending most of their time on trunks and large branches. Further, since Giant Nuthatches are secondary hole-nesting species, large trees might provide more natural holes for nesting (Paillet et al. 2017).

The negative correlation with elevation differed from the findings of Techachoochert et al. 2018, but my estimate of the regression coefficient for elevation slightly overlapped zero suggesting at most a weak effect on abundance. It was possible that the negative association with abundance was because my study area was on average higher in elevation than that of Techachoochert et al. 2018, perhaps indicating the upper elevations contained lower quality habitat. However, this negative correlation might also be due to the nature of my surveys in which I started my sampling at lower elevations in the early morning and typically ended surveys late in the morning at higher elevations. Overall, the elevational range of the nuthatch's preferred habitat association in Thailand and Myanmar is found to be relatively narrow (Techachoochert et al. 2018).

The population estimate of 37 Giant Nuthatch individuals in AMAM in 3.25 km^2 of surveyed habitat was equivalent to 13.07 individuals/ km^2. My estimate is notably higher compared to the landscape estimates (~ 1 pair/ km2) of Techachoochert et al. 2018 and Han et al. 2011 possibly because my estimate was restricted to only one forest patch focusing on areas with detections, while their research was conducted over broader areas with a mix of habitats and more secondary forest. For example, Techachoochert et al. 2018 detected Giant Nuthatch at only 12 of 42 survey points (roughly 29%) compared to 22 of 46 (~48%) in my study. A recent single-site study in Thailand found somewhat higher density of Giant Nuthatch (~ 2 pairs/km2) (Techachoochert et al. unpubl). The home range size for a pair of Giant Nuthatches during the breeding season was estimated at approximately 12.2 ha by radio telemetry (Techachoochert et al. unpubl), indicating a plausible density of up to 8 pairs/km^2 in entirely saturated habitat. Taken together, these recent findings suggest that while my estimates from AMAM could be biased high, because the same individuals could have been double counted at adjacent survey points, they are nevertheless credible and imply the habitat of AMAM was probably of higher quality than at the single Thai study-site.

5.3 Foraging site selection and foraging behavior

Although samples were small, my data suggested that nuthatches spent somewhat more time on pines than other broadleaved species in one site within AMAM relative to their availability. In Thailand, they appear to use a higher proportion of *Pinus kesiya* than other species for foraging (Charonthong et al. 2009) and my results in this site were similar to this finding. However, this pattern was not evident in the other two sites in AMAM where I observed foraging. In one of these, the pines were of relatively small diameter and even-aged, presumably unsuitable, while at the other, pines were largely absent. Although others have argued that the Giant Nuthatch is a cone specialist (Pasquet et al., 2014), my data do not support this idea.

Giant Nuthatches foraged on a variety of broad-leaved tree species but appeared to prefer those with larger DBH and apportioned most of their foraging time on trunks and large branches. This finding was similar to that in Corsican Nuthatch *Sitta whiteheadi*, a pine-specialist nuthatch which preferred older stands with tall large Corsican pines *Pinus nigra laricio* (Thibault et al. 2006). Giant Nuthatches would seem to forage on trunks and large branches because trunks are typically coarser than small branches, as a result may support higher densities of arthropods (Mariani et al. 1990). Giant Nuthatches' apparent preference for foraging on trunks and large branches was also similar to other nuthatch species including Brown-headed Nuthatch (Morse 1967) and Eurasian Nuthatch (Adamík et al. 2004). Although Giant Nuthatches appear to have a broader diet, the relatively large percentage of time spent on pecking on trunks and branches versus other foraging strategies may suggest they prefer arthropods to nuts and berries during their breeding season.

5.5 Breeding ecology

The nest I found was in a chestnut tree with a large diameter (~75 cm DBH). It is possible that Giant Nuthatch depend heavily on large tree for nesting. It was also found in a large diameter tree (113.8 cm) in Thailand (Techachoochert 2018) although Round (1983) found a nest in ~25 cm diameter tree. Large trees might be important for Giant Nuthatch ecology in terms of providing nests because these trees might provide more natural holes for nesting (Paillet et al. 2017). The nest tree in this study was a Fagaceae species, *Castanopsis indica* while the nesting tree species based on other studies in Thailand include *Pinus kesiya, Lithocarpus sootepensis*, *Premna latifolia* and other unidentified species (Round 1983; Charonthong and Sritasuwan 2009; Tecahchoochert 2018) and five nests in *Alpus nepalnesis* in a study in China (Han et al. 2011). The height of the nest here (3.65 m) was in the range observed elsewhere 2-15 m (Round 1983; BirdLife International 2001; Charonthong and Sritasuwan 2009; Tecahchoochert 2018).

The total incubation period could not be recorded here, while the literature says that the incubation period took about 18 days (Charanthong and Sritasuwan 2009, Han et al. 2011; Techachoochert 2018). My Giant Nuthatch took about 27 days to fledge which is very close to 26 days reported by Techachoochert (2018), also closer to the 25 days reported by Charonthong and Sritasuwan (2009). The nestling period in China was reported as 12−15 days that seems very short and doesn't match any previous data (Han et al., 2011), and the nestling periods in other nuthatch species as 21−27 days (Harrap, 2008). Since the food items that the adults feed the chicks during my survey included the largest portion of the invertebrates about 75%, this finding is consistent with the finding of Techachoochert 2018.

5.6 Conservation implications

In Myanmar, 132 terrestrial and coastal KBAs (key biodiversity areas) have been identified as of 2012. These cover 65,304 km^2 or about 10% of the land area, but only 35 of these are in, or partly included within, protected areas (Forest Department 2015). At present only 25% of these 132 KBAs are afforded any legal protection (WCS 2013). Mt Ashae Myin Anauk Myin is not a protected area and instead is managed as a reserve forest by the Myanmar Forest Department. Greater protection for priority hill evergreen forest patches such as AMAM is essential because as I have shown, Giant Nuthatch has probably already been lost from two historical locations, almost certainly due to degradation and fragmentation of its preferred habitat.

The remaining population of Giant Nuthatch in AMAM potentially represents >1% of the global population, and therefore a globally important locality for the conservation of Giant Nuthatch (Donald et al. 2019). The threats to this remaining forest patch (nearly 1800 ha) should be assessed. The main livelihood in the area is from tea plantations while cattle ranching and extracting non-timber products including pine resin and orchids remain as alternative forms of income generation. Although human disturbance might not directly affect Giant Nuthatch, these livelihood systems are directly correlated with the destruction and degradation of forests. Thus, there is an urgent need for a risk assessment regarding the remaining Giant Nuthatch habitat in AMAM. Finally, as there is likely additional suitable habitat within Myanmar, primarily within Shan State, there is also an urgent need to conduct surveys in other large (>2000 ha) forested sites persisting at suitable elevations.

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