Habitat Use and Diet of Common Green Magpie *Cissa chinensis* Boddaert, 1783

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ABSTRACT

The Common Green Magpie *Cissa chinensis*, like all other corvids, is a nest predators of significant importance in tropical evergreen forests that is likely to have an impact on survival and nesting success of other birds in areas where it inhabits. Generally, the Common Green Magpie remains relatively understudied and currently almost no quantitative data on the aspects of its ecology exist. This study was undertaken to describe the bird's nest-site selection, diet and distribution in dry evergreen, dry dipterocarp and old planted forests. The study was conducted at Sakaerat Environmental Research Station, in Nakhon Ratchasima Province, north-eastern Thailand, between April and October 2015. Examination of habitat features at sites selected by the Common Green Magpie for nesting and randomly selected sites, found that the bird place its nests in the understory stratum of the forest in sites with greater understory cover, tree density and sparse undergrowth ground cover. Direct observations on the bird's foraging behaviour showed that it is largely insectivorous, and takes a wide range of animal prey including other birds' eggs and nestlings, small lizards and big earthworms, and relatively a small proportion of fruits. Assessment of potential insect biomass abundance in its foraging areas, showed a significant difference between the dry evergreen and old planted forests. Distance transect sampling analysis estimation of the bird's abundance and frequency of occurrence was higher in the dry evergreen than old planted forests; but the bird was not detected in the dry dipterocarp forest. The bird's occurrence in old planted forest is an indication of its response to habitat disturbance and its ability to inhabit sub-optimal habitats. With poor knowledge on the ecology of most nest predators in tropical regions, the results of this study provide baseline data that add to our understanding of one of the major nest predators in tropical lowland evergreen forests and its response to habitat disturbance.

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Christopher A. Salema

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

ACRONYMS

AIC	Akaike Information Criterion
CI	Confidence Interval
CBD	Convention on Biological Diversity
CV	Coefficient of Variation
DBH	Diameter at Breast Height
DDF	Dry Dipterocarp Forest
DEF	Dry Evergreen Forest
ER	Encounter Rate
ESW	Effective Sampling Width
GLM	Generalized Linear Model
GPS	Global Positioning System
IUCN	International Union for the Conservation of Nature
KMUTT	King Mongkut’s University of Science and Technology Thonburi, Thailand
KYNP	Khao Yai National Park
MAB	Man and Biosphere Program
OPF	Old Planted Forest
DP	Detection Probability
SE	Standard Error
SERS	Sakaerat Environmental Research Station
TISTR	Thailand Institute of Scientific and Technological Research
UNESCO	United Nations Education, Scientific and Cultural Organization
UTM	Universal Transverse Mercator

CHAPTER 1
INTRODUCTION

1.1. General Introduction

Tropical forests in Southeast Asia are being rapidly lost due to human activities including urban and infrastructure development, logging, agricultural expansion, or cleared and replaced with agroforestry plantations of rubber and oil palm trees (Whitmore, 1984; Sodhi *et al*., 2004, Phommexay *et al*., 2011). These activities lead to, and increase habitat fragmentation as well as edge effects as the size of the forests are continuously reduced into small patches that become more isolated from each other (Echeverria *et al*., 2007). Fragmentation has been recognized by the Convention on Biological Diversity (CBD) as one of the major threats to biodiversity (CBD Secretariat, 2001). Fragmentation lead to changes in the composition of animal communities within the remnant forest patches. The reduction in size and alterations to the physical and biotic conditions in the fragmented landscape structure lead to phenomenal changes in ecological interactions such as predation (Laurance *et al*., 1998; Bennett, 2003). These changes have a profound effect on bird communities as fragmentation result in changes of species composition of predators in the fragmented habitats (Belisle, 2005). Because of their large proportion of edge, small and fragmented habitats lose large predators which naturally control the population of small predators. In the absence of larger predators, the populations of small predators increase as they remain unchecked, and this leads to high rates of nest predations in the forest patches (Spanhove *et al*., 2014). Nest predation is a major cause of nest failure in fragmented and small forest patches that can lead to reduction in birds’ population or local extinction (Lahti, 2001; Stutchbury and Morton, 2001; Newmark and Stanley, 2011; Robinson and Sherry, 2012).

Studies conducted in tropical lowland evergreen forests of Southeast Asia on nest predation have shown that the Pig-tailed macaques (*Macaca nemistrina*), snakes (*Boiga spp*), and the Common Green Magpies (*Cissa chinensis*) are the major nest predators (Pierce and Pobprasert, 2013). In spite of the high rates of nest predation in tropical regions, there is poor knowledge on the ecology of most nest predators (Stutchbury and Morton, 2001). The Common Green Magpie is no exception to this as **v**ery little is known about the ecology of this nest predator corvid in areas where it is distributed. This study was undertaken to provide baseline data on the ecology of the Common Green Magpies in terms of habitat use and diet.

The survival and reproductive success of birds depend on habitat selection, especially nest-site choice (Badyaev, 1995; Clark and Shutler, 1999). Availability of nesting sites is one of the determining factors in the distribution of bird species across habitats and landscapes. Habitat features have been reported to have an influence on the quality of nesting sites and reproductive success in birds. Bird species normally select nesting sites that reduce nest predation risks in order to increase their reproduction success leading to higher fitness at both individual and population level. In selecting sites for nesting, birds operate on two spatial scales, first the nest-site features within the vicinity of the nest and the nesting patch characteristics of the habitat surrounding the nest (Martin and Roper, 1988). Vegetation structure surrounding the nest is an important factor that determine nest concealment when birds select nesting sites (Holt and Martin, 1997). Detailed information about the nesting site can provide a better understanding of those habitat features that promote higher levels of nest survival and reproductive success for a species (Purcell and Verner, 2006). Thus, decisions about nest placement are influenced by nest-site characteristics that minimize risks of predation (Martin, 1998). This explains the fact that birds preferentially select some microhabitats for nesting while others are avoided (Antonov and Atanasova, 2002). Forest songbirds are known to use vegetation structure which is ultimately tied to protection from predators as a proximate cue when selecting nesting sites (Sallabanks *et al.*, 2000).

Several factors have an influence on avian abundance and distribution across habitats and landscapes including food availability and vegetation types. Although previous studies have examined and highlighted the level of nest predation by the Common Green Magpies (Pierce and Pobprasert, 2013; Gale, unpubl. data; Khamcha unpubl. data), but little attention has been given to the bird’s diet, abundance and distribution. Moreover, we need an understanding of the Common Green Magpies' diet, potential food availability, abundance and habitat associations in order to provide some baseline information that may lend more insight into the bird's ecology, response to habitat disturbance and their impact on nest predation, nesting behaviour and reproduction strategies of other bird species. A number of studies on habitat use, nest-site selection, diet, distribution, abundance and interspecific relationships on other Magpies in the corvidae family (Veltman and Hickson, 1989; Jones and Nealson, 2003; Rollinson, 2003; Green *et al*., 2007; Balen, *et al*., 2011) have been conducted elsewhere in Asia and Australia, but none has specifically attempted to quantify nest-site selection, diet, abundance and distribution of the Common Green Magpies.

The Common Green Magpies are corvids, and like all other corvids, are nest predators that feed on eggs and nestlings of other bird species. They are one of the major nest predators in tropical evergreen forests that are likely to impact on nesting success of other bird species nesting nearby their nests or in the areas they occur (Møller, 1988). Previous studies in Khao Yai National Park (KYNP) and Sakaerat Environmental Research Station have found that the Common Green Magpies are the third most important nest predators in tropical evergreen forests of Southeast Asia (Pierce and Pobprasert, 2013; Gale, unpubl. data). These studies found that about 10 % of nests in KYNP and SERS were predated by the Common Green Magpies. Understanding the ecology of the Common Green Magpies will add to our knowledge of these nest predators, how they use resources in their habitats and how they respond to habitat disturbance in the study area and elsewhere in their distribution range. Currently there is poor knowledge on the ecology of nest predators in tropical regions despite high levels of nest predation (Robinson *et al*., 2000). So this study provides some useful baseline data from dry evergreen forest and old planted forest on nest-site selection, diet, abundance and distribution of this nest predator corvid. The Common Green Magpies remain relatively understudied (Madge and Burn, 1994; BirdLife International, 2012), and almost all aspects of their ecology are currently quantitatively undocumented. Thus, the aim of this study was to determine habitat use and diet of the Common Green Magpies.

1.2. Research questions

1.2.1. What habitat features do the Common Green Magpies use and significantly determine their nest-site selection behaviour in SERS?

1.2.2. What is the diet of the Common Green Magpies? Does the Common Green Magpies' potential food biomass availabiliy differ in the forest types in SERS?

1.2.3. Does abundance and distribution of the Common Green Magpies differ in dry evergreen, dry dipterocarp and old planted forests in SERS?

1.3. Research objectives

1.3.1. To describe nest-site selection and identify those features of the habitat that significantly influence nest-site selection by the Common Green Magpies in SERS.

1.3.2. To investigate diet and potential food biomass abundance of the Common Green Magpies in SERS.

1.3.3. To determine abundance and distribution of the Common Green Magpies in the dry evergreen, dry dipterocarp and old planted forests in SERS.

1.4. Research hypotheses

1.4.1. The Common Green Magpies select sites for nesting that have dense understory cover, tree density and sparse undergrowth ground cover beacause: (i) high dense understory cover and tree density provide cover that conceals the nests from view of predators and protects eggs and nestlings from harsh weather elements; and, (ii) sparse undergrowth ground cover limits access to the nests by semi-aboreal foraging snakes close to the ground and also increases the chance of detecting predators when they approach from the ground, thereby reducing nest predation risks.

1.4.2. The Common Green Magpies are corvids, and like all other corvids, they are largely insectivorous, as such their diet should be composed of a high proportion of insect prey; and biomass abundance of such prey is higher in the dry evegreen forest because the vegetation structure in this forest is dense and diverse thereby supporting a wide variety of insects.

1.4.3. Abundance and distribution of the Common Green Magpies in SERS is higher in the dry evergreen forest, because the Common Green Magpies are understory birds, as such the diversity and structure of the vegetation in the dry evegreen forest provide them with more understory cover and high food availability.

CHAPTER 2
LITERATURE REVIEW

The concept of habitat use is an important cornerstone in wildlife management and conservation as it provides the starting point in understanding an animal's basic ecological requirements for its survival and reproductive success. A habitat has been defined as all biological and physical resources, including special factors that are present in an area. These resources (e. g., food, water, trees, air, etc.) produce occupancy and are needed by an organism for survival and reproductive fitness (Hall *et al*., 1997; Morrison and Hall, 2002). The habitat can be used by an organism for nesting, foraging, hiding from predators, or any other life history activities (Block and Brennan, 1993). Various activities (i.e., nesting, foraging, etc.) of an animal require specific resources in its environmental that may change on a seasonal or yearly basis. The activities of an animal may divide the habitats but overlap always occurs in some areas (Krausman *et al*., 1979). Studies on how individual animal species interacts with their habitats in terms of habitat use are very crucial for their long term conservation and management in the face of dynamic changes in the ecosystems and ecological landscapes (Krausman *et al*., 1979; Canterbury *et al*., 2000; Johnson, 2007).

Habitats that make the present day SERS in north-eastern Thailand, were significantly disturbed from the effects of human activities, for example, infrastructure development, urbanization, logging and expansion of agricultural areas to satisfy human needs for a long period of time prior to its establishment in 1967 (Trisurat, 2010; TISTR, 2012). One major impact of such disturbances is habitat fragmentation and its resultant edge effects which have changed the physical and biological interactions among different animals in the forest. These have negatively affected bird species in the reserve as fragmentation resulted in changes in species composition of predators (Belisle, 2005). Small fragmented habitats have a large proportion of edge and are known to lose large predators which might control the numbers of small predators because such habitats do not satisfy the territorial range requirements for large predators. The increasing numbers of small predators result in higher rates of nest predations that may lead to population reduction or even local extinction of bird species (Robinson and Sherry, 2012). Nest predators reduce nest survival and success for birds and they are one of the major causes of nest failure in tropical regions (Robinson *et al.,* 2000; Lahti, 2001; Stutchbury and Morton, 2001; Korfanta *et al*., 2012).

Tropical forests have significantly high levels of nest predation that result in low levels of nest survival and reproductive success (Robinson *et al*., 2000; Stutchbury and Morton, 2001; Newmark and Stanley, 2011). Studies conducted on nest predation in tropical lowland evergreen forests in north-eastern Thailand have shown that the Common Green Magpies is one of the major nest predators that affect nest survival and reproductive success of other birds in moist evergreen and dry evergreen forests. The other major nest predators included the Pig-tailed Macaques and Boiga snakes, which together with the Common Green Magpies were found to be responsible for more than 75 % of the total nest predation events (Pierce and Pobprasert, 2013).

The Common Green Magpies, like all other nest predators is likely to have a significant impact on survival and nesting success of other bird species nesting in the areas they are distributed (Møller, 1988). The Common Green Magpies have been found to predate on eggs and nestlings of other bird species in SERS. Studies on nesting success in SERS have found a very low nesting success of approximately 2 % due to nest predation by the Common Green Magpies, Pig-tailed Macaques and Boiga snakes (Gale, unpubl. data). Similar studies in Khao Yai National Park (KYNP) have also found low nest success of about 16 % with the same three major nest predators being responsible for a large proportion of nest failure. The Common Green Magpies, Pig-tailed Macaque and Boiga snakes were found to be responsible for 10 %, 43.7 %, and 21.8 % of the total nest predation events respectively, while others predators were responsible for 25 % (Pierce and Pobprasert, 2013).

Despite the Common Green Magpies being one of the major nest predators in tropical forests of Southeast Asia, the aspects of the bird's ecology are poorly documented (Madge and Burn, 1993; Birdlife International, 2012). At the same time the home range of this bird species happens to be located in a tropical region that has the highest rate of forest loss and habitat conversion due to human pressure and demand for natural resources than any other tropical region in the world (Whitmore, 1984; Sodhi *et al*., 2004). These activities fragment, disturb and reduce the existing habitats for the Common Green Magpies and negatively impacting on their habitats, and ultimately on their long term survival.

Although the Common Green Magpies have a wide geographical range and distribution in Asia, almost no studies have assessed their habitat use in term of nest-site selection, abundance and habitat associations in the forests that they are known to inhabit. The few studies that have been done only showed a referent and generalized habitat use by the Common Green Magpies. For instance, Balen *et al*. (2011) and Hoogerwerf (1950) reported that the Common Green Magpies distribution and habitats are found in lowland forests. Whereas the other Green Magpies, Borneo Green Magpie (*Cissa hypoleuca*) and Java Short-tailed Green Magpie (*Cissa thalassina*) inhabit montane forests at higher altitudinal ranges possibly as result of competitive exclusion with their sister species, the Common Green Magpies in the lowlands forests.

The Common Green Magpies is a lowland forest bird. It inhabits lowland evergreen forests, including bamboo forest, clearings and scrub (Balen *et al*., 2011; BirdLife International, 2012). Its distribution is mainly in the lowland tropical evergreen forests stretching from the lower Himalayas in India to southeast Asia. The bird's abundance and distribution in the areas that they occur has not been quantified, even though the species has been reported to be relatively uncommon to locally common (Madge and Burn 1993). In the absence of information for any declines or substantial threats, the Common Green Magpies' population is suspected to be stable (BirdLife International, 2012).

In their study of Magpies in Australian agricultural farms, Green *et al*. (2005) found that habitat use and abundance of the Magpies did not differ on average between contrasting habitats, that is, farms practicing different farming systems (organic or conventional farms). But this failure to detect any differences in habitat use by the magpies were attributed to imprecision of counts, restrictions on the farms and also the fact that the farm boundaries were not ecological boundaries for the magpies which might have prevented detection of real differences in habitat use and abundance.

Magpies and corvids of similar size as that of the Common Green Magpies have been reported to select nesting sites in different tree species of the understory stratum of the forest (Vuorisalo *et al*., 1992; Antonov and Atanasova, 2002). The Short-tailed Green Magpies (*Cissa thalassina*), a congener of the Common Green Magpies, has been reported by Hoogerwerf (1950) and Balen *et al*. (2011), that despite their medium body size, the birds tended to locate their nests in tree forks close to the trunk of strong small trees in the undergrowth of primary forest at a height range of 3 - 6 m above the ground.

Magpies in general are known to seek food both on the ground, in open grassland and in the canopy of trees, and generally take animal prey of invertebrates and vertebrates (Jones and Nealson, 2003; Rollinson, 2003; Green *et al*., 2005). Very little is known about the food composition of Common Green Magpies, although the bird has been reported elsewhere (www.GrrlScientist.org), to feed on a variety of animal prey that included both invertebrates and small vertebrates. Analysis of stomach contents of its closest congener, the Short-tailed Green Magpie, has been reported by Balen (2011) to include food items like caterpillars, beetles, grasshoppers, small birds and eggs, tree frogs, lizards and cicadas among others. In addition, studies that were conducted in KYNP and in SERS have also shown that the Common Green Magpie feed on eggs and nestlings of other bird species (Pierce and Pobprasert, 2013; Khamcha, unpubl. data). However, the other food items that the Common Green Magpies feed on remain generally undocumented.

On the overall, almost no quantitative studies have so far been conducted to document the ecological aspects of the Common Green Magpies. Very little is known about the bird's basic ecology in respect of their nest-site selection behaviour, diet, abundance and distribution in the study area and elsewhere in their distribution range.

CHAPTER 3

MATERIALS AND METHODS

3.1. Study area

This study was conducted at Sakaerat Environmental Research Station (SERS), Nakhon Ratchasima Province, north-eastern Thailand (Fig. 1). SERS lies between coordinates 14° 26′ to 14° 32′ N and 101° 51′ to 101° 57′ E and has an altitudinal range of between 280 – 762 meters above mean sea level. SERS receives an average annual rainfall of 1200 mm and has a rainy season from mid-April to October, with high rainfall peaks during the months of May and September, and a dry season during the months of November to March. The mean annual temperature and relative humidity are 26.1 °C (range 19.3 to 32.8 °C) and 82.2 % (range 74 % to 87 %) respectively (TISTR, 2012; Suwanrat *et al*., 2014). SERS was designated in 1976 by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as a Biosphere Reserve of Thailand for the purpose of educational and scientific research on ecology, environment and natural sciences of the dry evergreen and dry dipterocarp forests under Man and Biosphere Program (MAB) of UNESCO. The forest covers an area of approximately 80 km^2 and is composed of a distinctive heterogeneity of vegetation that comprises two major natural forest types, namely: dry evergreen forest covering an area of 42.3 km^2 and is dominated by tree species such as *Hopea ferrea* and *Hydnocarpus ilicifolia* (Fig. 2); dry dipterocarp forest covering an area of 11.8 km^2 and is dominated by common dipterocarp trees such as *Shorea siamensis, Shorea obtusa,* and *Dipterocarpus intricatus* (Fig. 3); as well as two large patches of more than 20 year old planted (restoration) forest of mixed acacia and eucalyptus covering an area of about 17.2 km^2 (Fig. 4); and several small patches of bamboo forest and grassland (TISTR, 2012; Trisurat, 2010).

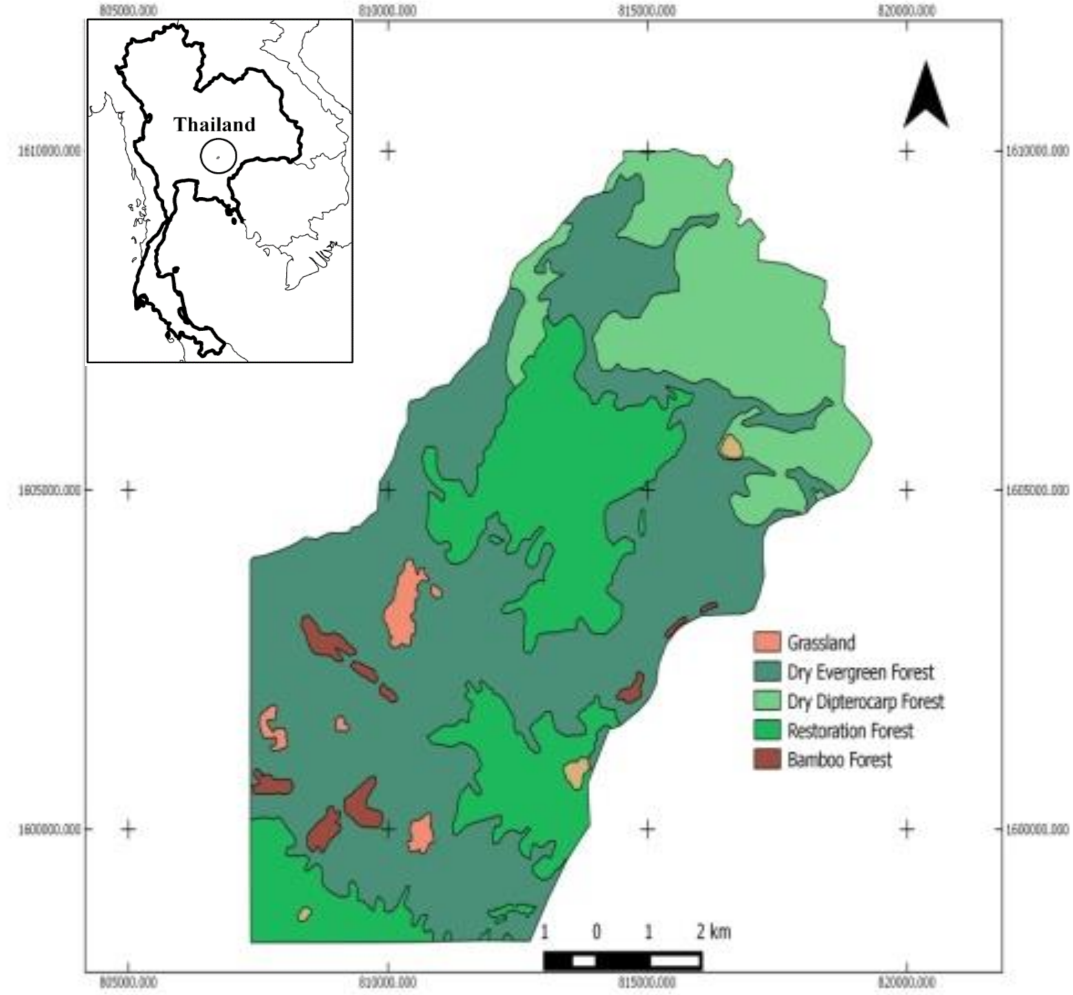

Figure 1. Map of Thailand showing the location of Sakaerat Environmental Research Station and its major vegetation types (Adapted from Daphawan Khamcha, KMUTT).

Figure 2. Dry evergreen forest in SERS (Photo by Christopher A. Salema)

Fig. 3. Dry dipterocarp forest in SERS (Photo by Christopher A. Salema).

Figure 4. Old planted forest in SERS (Photo by Christopher A. Salema).

3.2. Study species

The species chosen for this study was the Common Green Magpie *Cissa chinensis* (Boddaert, 1783) (Fig. 5). This is a bird species in the Corvidae family. The bird has a green body colour and its wings have a reddish maroonin colour. The bird has white-tipped tertial feathers that are quite long compared to the other green magpie species in its genus, namely, the Borneo Green Magpie (*Cissa hypoleuca*) and Java Short-tailed Green Magpie (*Cissa thalassina*). The Common Green Magpie's eye rims, bill and legs are red in colour. It is slightly lighter on its underside and has a thick black stripe that runs from its bill, through the eyes, up to its nape. The global distribution of the bird ranges from the lower Himalayas in north-eastern India. This range runs down in a south-easterly broad band into central Thailand, Malaysia, Sumatra and north-western Borneo. The Common Green Magpies inhabit lowland evergreen forests (including bamboo forest), clearings and scrub (BirdLife International, 2012). The global population size is not known as it has not been quantified, but the species has been reported by Madge and Burn (1993) to be relatively uncommon to locally common. However, in the absence of evidence for any declines or substantial threats, the Common Green Magpies' population is suspected to be stable and the bird is listed as a species of Least Concern (IUCN 3.1) (BirdLife International, 2012).

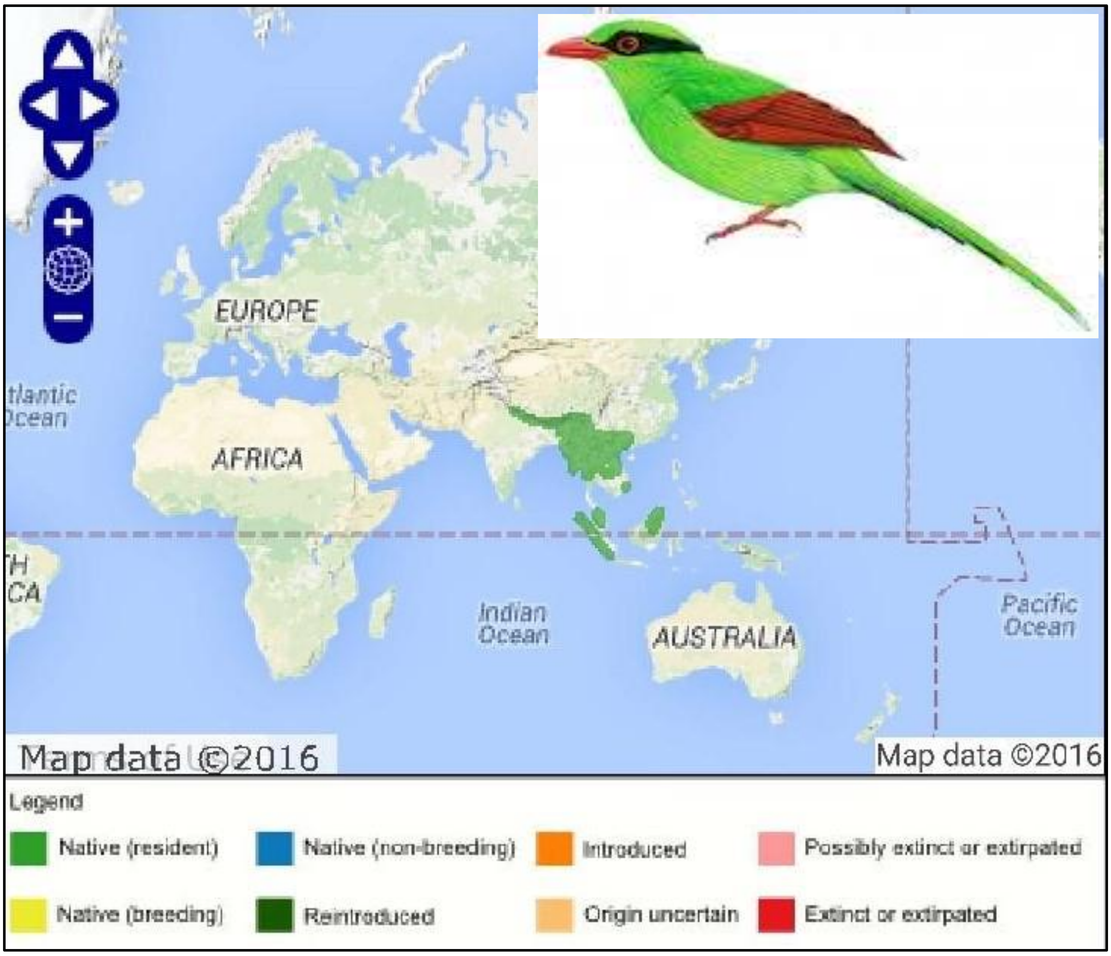

Figure 5. Global distribution of the Common Green Magpies (Map by Birdlife International, 2016).

3.3. Nest searching and monitoring

The Common Green Magpies' nests were actively searched during their breeding season in different microhabitats in the study sites from April to August, 2015. Nest searching methods included following the birds that were building nest, following birds engaged in territorial defense activities, and random visual scanning of the vegetation. Once a nest was found, Universal Transverse Mercator (UTM) co-ordinates were taken at the nest locations using a Global Positioning System unit (GPS) and the stage of the nest was recorded. Nests were marked with flagging tapes placed at least 10 - 15 m from the nest trees. Each nest was visited every 2 – 5 days and checked whether it was still active depending on the nest stage. A pole with an attached mirror (Parker, 1972) was used to check and monitor nest contents directly from the ground, or by observing the behaviour of the adult birds (e. g., incubating) at a distance of 10 - 15 m to the nest using a 60x telescope or an Olympus Olympus 8 x 40 DPS I binoculars.

3.4. Measurement of vegetation characteristics at nest-sites and random sites

Characteristics of the vegetation within a circular vegetation plot with a radius of 10 m and centered on a nest tree, were measured at 32 nest-sites using the modified James and Shugart (1970), and Martin *et al* (1997) methods. Vegetation measurement at two randomly selected non-nest points for each of the 32 nests were also sampled using the same size circular plot as that of the nest-site. The locations of the random non-nest vegetation plots were systematically set at 100 m north and south of the nest tree. The closest tree at the 100 m distance mark, able to support the Common Green Magpie's nest, alive, with a diameter at breast height (DBH) ≥ 2.4 cm, and height ≥5 m, was the centre of the plot and this tree was considered to be the 'non-nest random tree.' This criteria was followed because all the nests found were placed in trees with the above mentioned minimum DBH and tree height values, and none of the nests were placed in a dead tree. The non-nest random sites were used as reference for statistical examination of nest-site selection by the Common Green Magpies. Vegetation characteristics measured at nest-sites and random sites included, canopy cover, ground cover, tree density, number of woody climbers and basal area. Specific nest-tree variables that included nest height, nesting tree height and DBH, nest concealment index and nesting tree species were also recorded.

Nest height and total height of nest and random trees were estimated using a 15 m pole with bright colour bands at 1 m intervals and DBH was measured using a diameter tape. Tree density (number of woody trees and stems) were counted and recorded. Percentage ground cover was visually estimated following the standardized Daubenmire cover-class estimation protocol (Daubenmire, 1959), within each plot for four height classes of trees, 1 - 3 m, >3 – 5 m, >5 – 7 m and >7 m. Canopy cover was quantified as percentage frequency of vegetation ‘hits and ‘misses’ using an Ocular Tube (Noon, 1980), at 1, 2, 3, 4 to 10 meters of north, south, east and west of the nesting or random tree as a centre point within each vegetation plot (O’Donnell and Dilks, 1988; Brockelmen, 1998). The ‘misses’ or ‘hits’ were scored at four height classes of the vegetation which were the same as those of the ground cover measurements.

Nest concealment was estimated by calculating an index of nest exposure both vertically and horizontally following Hoover and Brittingham (1998) and Nudds (1977) methods. 25 red circles in five rows of 5 circles each were made on a 50 cm x 50 cm cover board. All circles were 5 cm in diameter, with their centers spaced at 10 cm apart. The cover board was placed directly at the nest height on the north, south, east and west of the nests; and also at 1 m above and beneath the nest. The number of circles on the cover board that were completely visible from each cardinal direction at a distance of 5 m, and also from above and beneath the nest were recorded and expressed as percentage exposure. The total nest concealment was calculated by subtracting the horizontal and vertical exposure percentage from 100 percent.

3.5. Field observation on foraging behaviour of the Common Green Magpies

Since Common Green Magpies feed mainly on large insects (personal observation), they were well suited to field observational diet studies. The birds were observed during their feeding from April to October 2015. Birds were actively searched in their foraging sites in the study areas and once a target bird was encountered it was followed at 30 minutes intervals until it was lost. The bird’s prey type and stratum of the forest the bird was observed foraging were recorded. All feeding observations were undertaken from 07:00 to 10:00 hours and from 15:00 to 17:00 hour in the afternoon as these times showed a higher activity by the bird (Gale, unpubl. data; personal observation). A 60x telescope or an Olympus Olympus 8 x 40 DPS I binoculars were used to make observations.

3.6. Potential insect availability assessmment

Although the Common Green Magpies do not forage directly or search for prey on the forest floor, they do come down from their perches high in the trees to catch prey on the forest floor. Arthropods and other invertebrates were sampled within the foraging areas of the Common Green Magpies from August to October 2015. This sampling was not aimed at providing a complete assessment of biodiversity and abundance of all possible invertebrates within each habitat, but more of an indication of potential food resources available to the Common Green Magpies. For instance, sampling of invertebrates only took place in areas that the bird was observed foraging (Veltman and Hickson, 1987; Rollinson, 2003; Golawski, 2006; Cooper and Whitmore, 1990). Sampling of invertebrates was done in the dry evegreen forest and old planted forest only. The dry dipterocarp forest was not sampled because the Common Green Magpies were not detected in this forest. Two sampling methods were used: pitfall sampling and aerial pan-trapping.

3.7. Pitfall sampling

To assess biomass of arthropods/invertebrates that were potentially available to the Common Green Magpies on the forest floor, 10 pitfall traps, consisting of small plastic buckets measuring 20 cm in diameter and 15 cm deep, were systematically placed along two lines of 100 m long each, spaced at 200 m apart within the Common Green Magpies' foraging areas in both the dry evegreen forest and old planted forest. To exclude rain from the traps, rain covers were suspended over each trap (Fig. 6a). Each trap was set for 10 days and the samples were collected daily, killed in an ethyl acetate killing jar and preserved in 70 % ethanol.

3.8. Aerial pan-trapping

A total of 20 pan-traps were suspended below the canopy in trees with horizontal branches at heights 1 - 15 meters within the vertical foraging range of the Common Green Magpies following the modified method of Steward *et. al.* (2013) (Fig. 6b). Each trap consisted of a blue/red plastic bucket measuring 30 cm in diameter and 25 cm deep and filled with 2 liters of salt water to preserve the captured arthropods, and a small amount of detergent to reduce surface tension. Five traps were set randomly in each of the four areas that were set at least 200 m apart. The traps were set four times per month for a period of 5 days. All collected insects were washed in fresh water and then preserved in 70 % ethanol.

3.9. Identification and grouping of diet and trapped invertebrates

The taxonomic identification of prey and sampled insects were limited to higher taxa and general categories. For the purpose of this study, it was deemed unnecessary to identify all insects to species, and instead the identification was to order level, family and general categories. Similar studies on assessment of potential food availability within foraging areas of other magpies also followed the same approach (Rollinson, 2003; Veltman and Hickson, 1987). Diet and captured prey items were identified and grouped into eleven categories, adult Lepidoptera, larval Lepidoptera, small lizard, eggs and nestlings, fruits, other insects, Cicadas, Coleoptera, Orthoptera, Phasmatodea and Megascolecidae. All trapped arthropods were measured from anterior end of the head to the apex of the abdomen for biomass abundance calculation (Rogers *et al*., 1976; Ganihar, 1997). All prey items that the Common Green Magpies were not observed foraging on were excluded from the analysis.

(a) (b)

Figure 6. Potential insect availability sampling techniques: (a) pitfall trap and (b) aerial pan-trap (Photos by Christopher A. Salema).

3.10. Bird surveys on abundance and distribution of the Common Green Magpies

Bird surveys were conducted in the three major habitats types of dry evergreen forest, dry dipterocarp forest and old planted forest in order to determine the Common Green Magpies' abundance and distribution. Transect line count sampling was used to collect data. A total of 24 transect lines were laid out, 10 in dry evergreen forest, and 7 each in dry dipterocarp and old planted forests. Starting from a random point picked on the grids of the map of the study sites, transect lines were laid systematically at a distance of 500 m apart in the vegetation types under study. Each transect line was 500 m long and was started and stopped short of the forest road networks and boundaries by 100 m to avoid edge effects. All surveys were conducted during morning from 06:00 to 08:30 hours as morning hours have the highest bird activity in this area (Gale, unpubl. data). The bird's detections were recorded as directly seen or heard by moving slowly and steadily along the transect lines at an average speed of 2.2 km/hr. Given that accuracy in distance measurement is the basis of line transect sampling and an important key factor in producing accurate abundance estimates (Bibby *et al*., 2000), perpendicular and radial distances from the transect line to individual birds or centre of group were measured using a Bushnell Scout 1000 ARC Laser Rangefinder. All radial angles from the transect lines to the birds were measured using a Silver Ranger 515 Compass. All transect were surveyed twice each month starting from 11 May to 25 October 2015.

3.11. Statistical analyses

Correlation between nesting tree DBH and nest height, and also between tree density and understory cover of trees at height >5 - 7 m were tested using Spearman's correlation test. Significant difference in habitat variables between sites selected by the Common Green Magpies for nesting and random sites were examined using Mann-Whitney *U*-test. The generalized linear model (GLM), family binomial, was used to model nest-site selection, and to identify those habitat features which had a significant influence on nest-site selection by the Common Green Magpies. Since the GLM procedures involve multiple testing steps, thereby increasing the risk of type I errors (MacNally, 2000), the significance level was set to 0.01 in order to reduce this risk. Akaike Information Criterion (AIC) was used to determine model selection whereby the step with the lowest AIC value was judged to be the 'final model' (Akaike, 1973). Chi-square was used to examine significance differences in proportions of invertebrate and vertebrates prey in the diet of the Common Green Magpies between the dry evergreen forest and old planted forest. Biomass abundance of all captured insects was calculated using Rogers *et al*. (1976) formula ($W = 0.0305L^{2.62}$, where 'W' is the dry mass of insects in milligrams, and 'L' is the length of insects in millimeters). Mann-Whitney *U*-test was used to examine significance difference in insect biomass abundance between dry evergreen forest and old planted forests. The Common Green Magpies abundance and density was estimated using program Distance version 6.2 (Thomas *et al*., 2005), and the half-normal key detection function with a cosine adjustment gave the best fit model to the observed data. Abundance and densities were first estimated based on data pooled across habitat types, and then habitat specific abundance and densities were estimated. Detection probability and encounter rate (i.e., frequency of occurrence) was used as a means to assess the distribution of the Common Green Magpies within each of the vegetation types under study. Both measures of abundance and frequency of occurrence were used to assess the importance of a habitat to the Common Green Magpies, based on both their occurrence and abundance within that habitat. All statistical test were conducted using R program version 3.2.4 software (R Development Core Team, 2015). Graphs were made in windows excel, Microsoft Office Excel 2013. All tests were two-tailed with a significant level of 0.05. Means are reported with their respective standard errors (Fowler and Cohen, 1992; Zar, 1999).

CHAPTER 4

RESULTS

4.1. Description of nest-sites habitats

A total of 38 nests were located after a total effort of 120 days of searching in different microhabitats in the study areas. Most of the nests (84 %) were found during egg laying and incubation stage of the nesting cycle. Six nests were found after they had either already failed possibly because predators had removed eggs, or they were abandoned before they were located. Such nests could not easily be determined as nests of the year because some old nests from previous year also looked new. These nests were excluded from the analysis because there was no evidence on their status after several days of monitoring. Of the 32 nests used in the analysis, 22 were found in the dry evergreen forest and 10 in old planted forest.

Nests were located in different tree species of the understory stratum of the forest with a mean (± SE) height of 8.5 ± 0.3 m (range = 5.0 – 13.0 m). A total of 10 tree species were found to be used for nesting by the Common Green Magpies. *Memecylon edule* and *Aglaia spp* were the tree species mostly used (Fig. 7). All trees used for nesting were either saplings or small trees of the understory with a DBH less than 10 cm {mean (± SE) DBH = 5.1 ± 0.3 cm; range = 2.4 – 9.5 cm}. Overall, nests were placed at a mean (± SE) height of 5.6 ± 0.3 m (range = 3.2 – 9.0 m) (Table 1).

Table 1. Specific vegetation characteristics of nest-sites and random sites trees (n = 32 nest-sites; n = 64 random sites).

Variable	Nest sites		Random sites	
	Mean ± SE	Range	Mean ± SE	Range
Nest height (m)	5.6 ± 0.3	3.2 – 9.0	-	-
Nesting tree height (m)	8.5 ± 0.3	5.0 – 13.0	9.1 ± 0.5	4.5 - 14.0
Nesting tree DBH (cm)	5.1 ± 0.3	2.4 - 9.5	5.9 ± 0.4	3.2 - 11.1
Nest Concealment (%)	32.5 ± 2.2	10.0 – 55.0	-	-

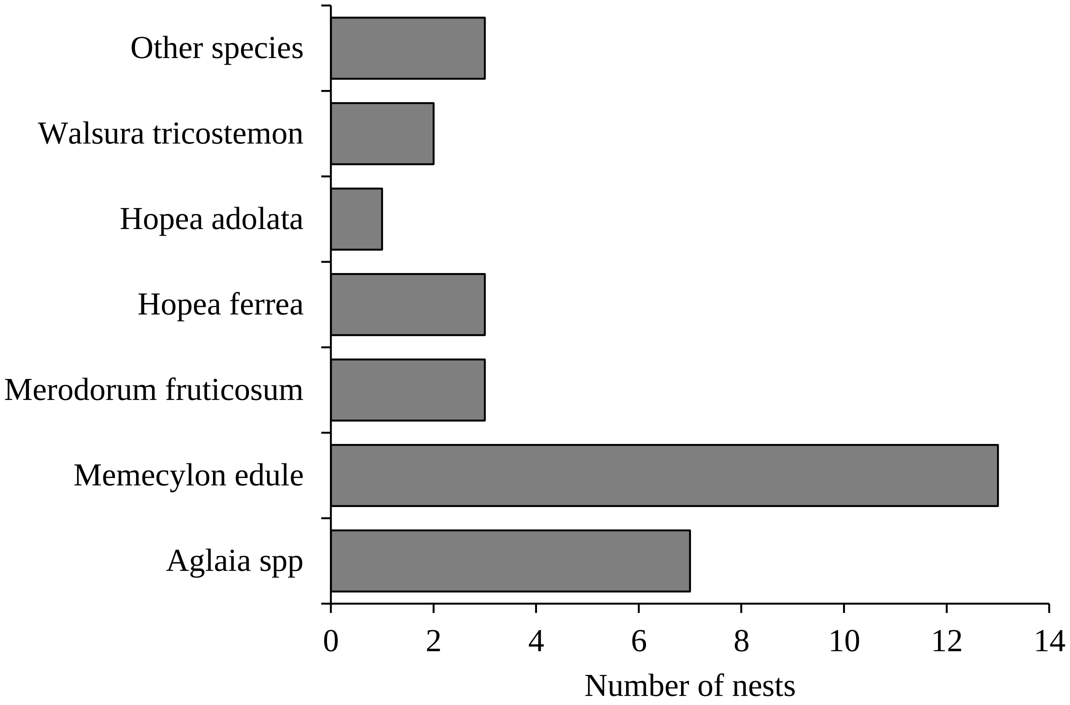

Figure 7. Tree species used for nesting by the Common Green Magpies in SERS, 2015.

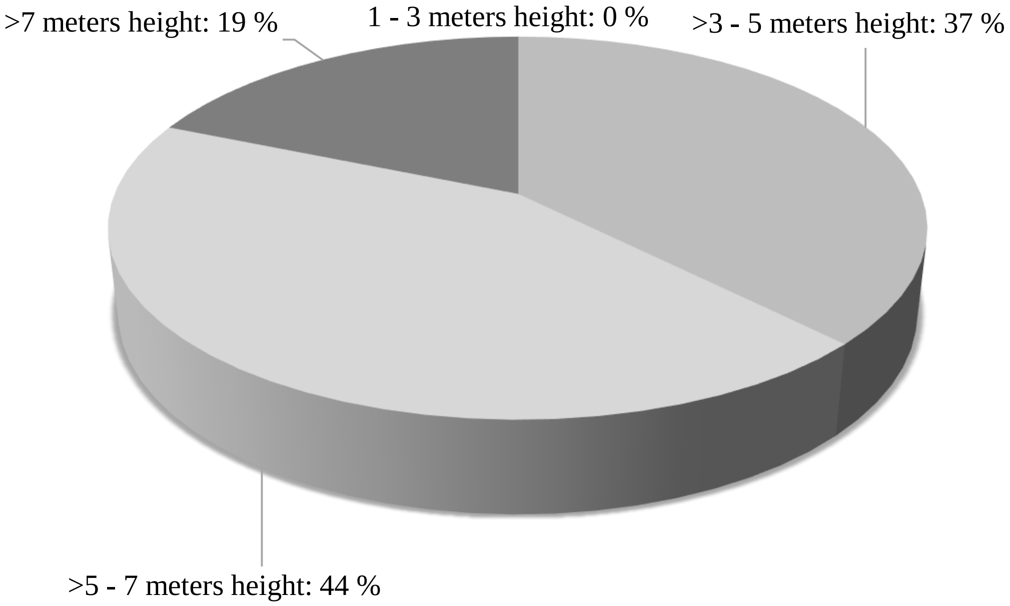

Figure 8. Percentage of the Common Green Magpies' nests in the understory stratum.

Distribution of the nest within the different height levels of the forest showed that a majority of the nests (44 %) were located at a height of >5 – 7 m of the forest stratum. In total, 81 % of the nests were located at different heights in the understory stratum of the forest between >3 – 7 m high (Figs. 8 & 9).

Figure 9. A Common Green Magpie’s nest (Photo by Kanoktip Somsiri).

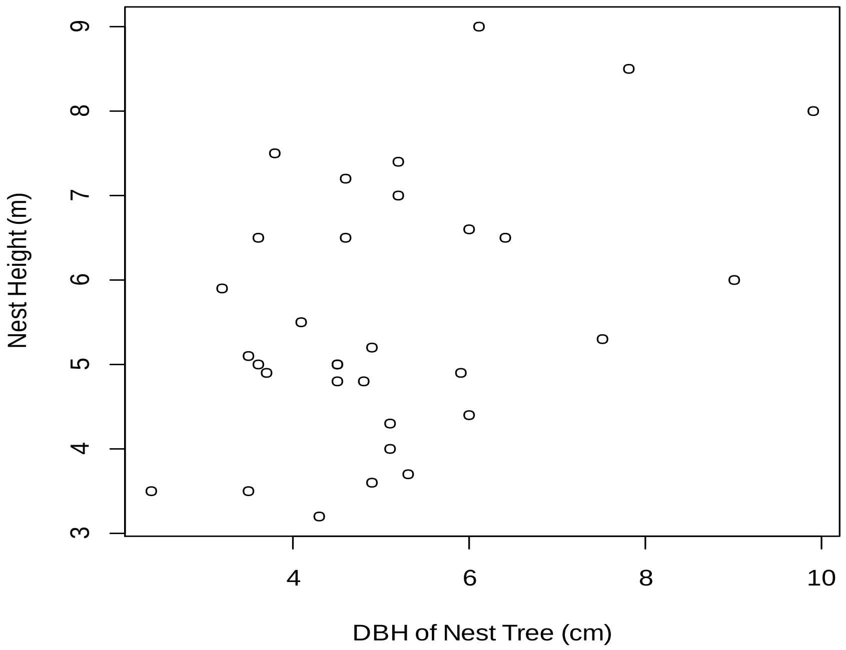

Figure 10. Correlation between nesting tree DBH and nest height.

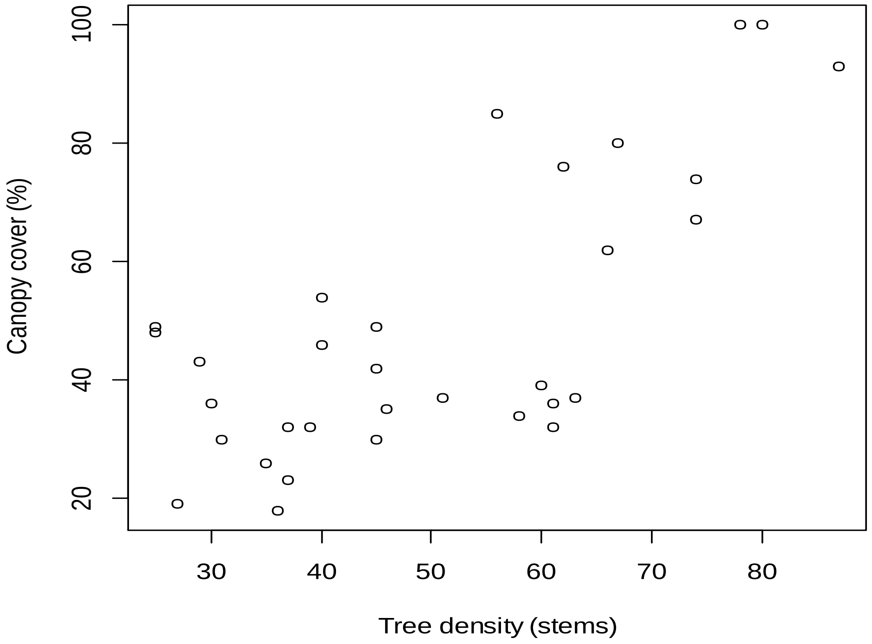

Figure 11. Correlation between tree density and understory cover.

Correlations between nest heights and DBH of nesting trees, and also between tree density and canopy cover of tree with a height of > 5 -7 m were examined using Spearman's test. There was correlation between nest height and DBH of nesting trees, and also between tree density and canopy cover at height >5 – 7 m of the understory trees. Nest height was correlated with DBH of nesting tree (Fig. 10) (r = 0.37, n = 32, *P* = 0.038). Tree density was also correlated with canopy cover (Fig. 11) (r = 0.609, *P* = 0.0002).

4.2. Comparison of vegetation characteristics between nest-sites and randomly selected sites

The sites selected by the Common Green Magpies for nesting were dominated by high tree density and high canopy cover at all tree height levels, high basal area, high ground cover by trees with a height of >3 – 5 meters, >5 – 7 meters and >7 meters. Randomly selected non-nest sites were dominated by ground cover (height 1 – 3 m), tree density (height >7 m) and woody climbers (Table 2).

There was a significant difference between sites selected the Common Green Magpies for nesting and randomly selected sites, with areas selected for nesting having higher understory cover than random plots (tree height 1 – 3 m tall, *U* = 681, *P* = 0.02; trees with a height of >3 – 5 m; *U* = 777, *P* <0.001; and trees with a height of >5 – 7 m, *U* = 1714, *P* <0.001), higher tree density than random sites (trees with a height of >3 – 5 m, *U* = 1421, *P* = 0.002, and trees with a height of >5 – 7 m ; *U* = 1649, *P* = 0.001), higher basal area (*U* = 678, *P* = 0.03), higher ground cover (height >3 - 5 m tall trees, *U* = 708, *P* = 0.01), and sparse undergrowth ground cover for trees with a height of 1 – 3 m (*U* = 204, *P* <0.001) (Table 2).

Table 2. A comparison of vegetation characteristics between nest-sites and random sites (nests, n = 32; random sites, n = 64). Results with α <0.05 are highlighted as significant.

Vegetation variable	Nest	Random	MannWhitney *U*-test	
	Mean ± SE	Mean ± SE	*U*	*P*
Basal area (m^2)	0.77 ± 0.1	0.61 ± 0.1	678	**0.03**
Woody climbers (stems)	15.1 ± 1.8	18.7 ± 2.6	582	0.35
Ground cover height 1-3m (%)	12.5 ± 1.9	20.4 ± 1.3	204	**<0.001**
Ground cover height >3-5m (%)	20.4 ± 2.6	12.7 ± 1.0	708	**0.01**
Ground cover height >5-7m (%)	10.1 ± 1.5	8.4 ± 0.8	563	0.47
Ground cover height >7m (%)	16.1 ± 1.9	12.1 ± 1.2	635	0.07
Canopy cover height 1-3 m (%)	25.9 ± 1.9	20.6 ± 1.9	681	**0.02**
Canopy cover height >3-5 m (%)	25 ± 1.7	16.5 ± 1.7	777	**<0.001**
Canopy cover height >5-7 m (%)	48.9 ± 4.2	25.6 ± 1.7	1714	**<0.001**
Canopy cover height >7 m (%)	83.9 ± 2.3	77.3 ± 2.6	657	0.05
Tree density height 1-3m (stem)	101 ± 12.4	72.9 ± 8.2	642	0.08
Tree density height >3-5m (stem)	31 ± 3.4	19.9 ± 1.5	1421	**0.002**
Tree density height >5-7m (stem)	33.9 ± 1.6	19.6 ± 1.9	1649	**0.001**
Tree density height >7 m (stem)	9.7 ± 0.7	13 ± 0.9	253	0.07

4.3. Vegetation characteristics used by the Common Green Magpies in nest-site selection

Generalized linear model (family binomial) analysis of nest-sites and random sites vegetation variables showed significant differences in understorey vegetation characteristics between sites selected for nesting and randomly selected sites. Six vegetation variables were retained in the final model. In general the results indicated that the Common Green Magpies were significantly influenced by canopy cover of trees with a height of >5 - 7 m tall (*P* <0.001), and also tree density of trees with a height of >5 – 7 meters tall, *P* <0.001, of the understory stratum when choosing nesting sites. In addition, canopy cover of trees with a height of >7m and ground cover of trees with a height of >5 – 7 m tall also influenced nest site selection, though not significantly. However, the Common Green Magpies mostly avoided nesting in sites with a higher percentage of understory ground cover of vegetation with a height of 1 - 3 m tall (Coefficient = -0.14, *P* <0.001) (Table 3).

Table 3. Results of a generalized linear model showing influence of understory vegetation characteristics on nest-site selection by the Common Green Magpies. Results with *α* <0.01 are highlighted as significant; AIC = 65.17.

Habitat Variable		Coefficient	95 % CI		SE	*P*
			Lower	Upper		
(Intercept)		-9.65	-15.60	-3.73	3.02	0.001
Ground cover	: height 1 – 3 m	-0.14	-0.22	-0.06	0.04	**<0.001**
	: height >5 – 7 m	0.12	-0.01	0.24	0.06	0.06
Canopy cover	: height >5-7m	0.14	0.06	0.22	0.04	**<0.001**
	: height >7m	0.04	-0.01	0.10	0.03	0.15
Tree density	: height 1-3m	-0.02	-0.04	-0.001	0.01	0.03
	: height >5 - 7m	0.13	0.06	0.20	0.03	**<0.001**

4.4. Diet of the Common Green Magpies

During direct observations, 89 foraging successes by the Common Green Magpies were noted, of which 82 prey items were identified into different categories, 7 insect prey items could not be identified with certainty. A total of 63 foraging successes comprising of 52 direct observations, and 11 nest predations events through camera trapping (Khamcha, unpubl. data), were recorded in the dry evergreen forest; while only 26 foraging successes were recorded in the old planted forest. The observations were of an unknown number of individual birds, but were made across the study habitats from April to October 2015 in 27.4 hours of observations in the dry evergreen forest and 21.7 hours of observations in the old planted forest.The foraging success rates was 1.9 prey/hour in the dry evergreen and 1.2 prey/hour in the old planted forest. Arthropods were the principal food constituent contributing 73.5 % of the Common Green Magpies' diet composition. Insects preyed upon by the Common Green

Magpies were diverse. However, a few prey taxa were consistently eaten by the bird. On the basis of the identified insects prey taxa, Common Green Magpies fed more frequently on larval Lepidoptera (16.9 %) and beetles (Coleoptera) (11.2 %). Other bird species' nest contents (eggs and nestlings (14.6 %) also contributed significantly to the diet of the Common Green Magpies. Food items of plant origin in the diet of the bird were relatively minimal (Table 4). Eleven nest predation events by the Common Green Magpies through camera trapping in dry evergreen forest (Khamcha, unpubl. data) were also included in the analysis as part of the diet study. Examination of prey proportions in the diet of the Common Green Magpies showed no significant difference between invertebrates and vertebrate ($\chi^2 = 0.79$, df = 1, $P > 0.05$).

Table 4. Percentage of prey categories observed in the diet of the Common Green Magpies (n = 63 prey in dry evergreen forest and, n = 26 prey in old planted forest.

Food category	Dry evergreen forest	Old planted forest	Combined
Orthoptera	7.9	15.4	10.1
Larval Lepidoptera	15.9	19.2	16.9
Adult Lepidoptera	9.5	11.5	10.1
Coleoptera	9.5	15.4	11.2
Cicadas	4.8	0.0	3.4
Other Insects	7.9	7.7	7.9
Phasmatodea	7.9	11.5	9.0
Megascolecidea	4.8	0.0	3.4
Bird eggs	12.7	7.7	11.2
Nestlings	4.8	0.0	3.4
Small Lizards	9.5	11.5	10.1
Fruits	4.8	0.0	3.4

4.5. Potential insect availability assessment

Based on trapping results for three months within the foraging areas of the Common Green Magpies, all insect groups have a higher biomass in dry evergreen forest than old planted forest. Orthoptera has the highest biomass compared to the other groups in dry evergreen forest, but when combined together Lepidopteran had the highest biomass, and the same was also true of Lepidopteran in old planted forest. Cicadidae and Phasmatodea were moderately abundant in dry evergreen forest but relatively uncommon in old planted forest. Five insect orders were found in dry evergreen forest (Lepidoptera, Coleoptera, Cicadidae, Phasmatodea and Orthoptera) and two insect orders in old planted forest (Lepidoptera and Coleoptera) (Fig. 12 & 13).

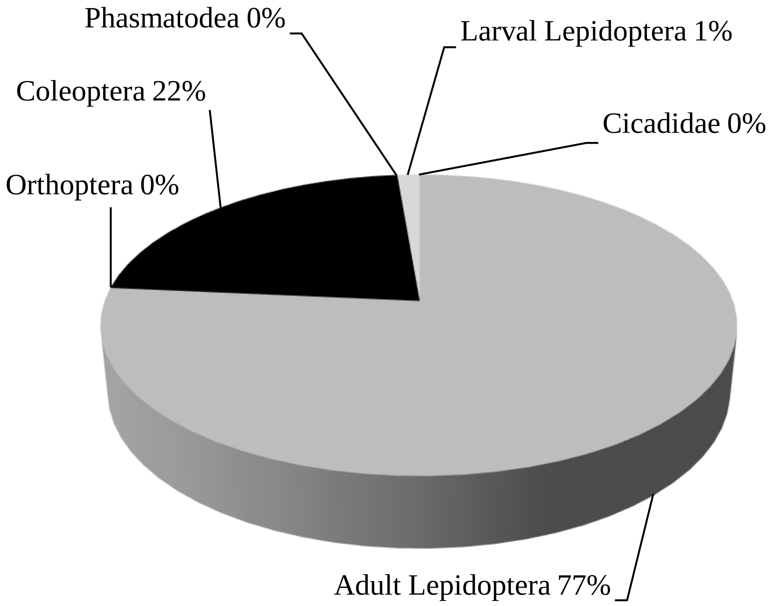

Figure 12. Percentage of insect biomass abundance in old planted forest.

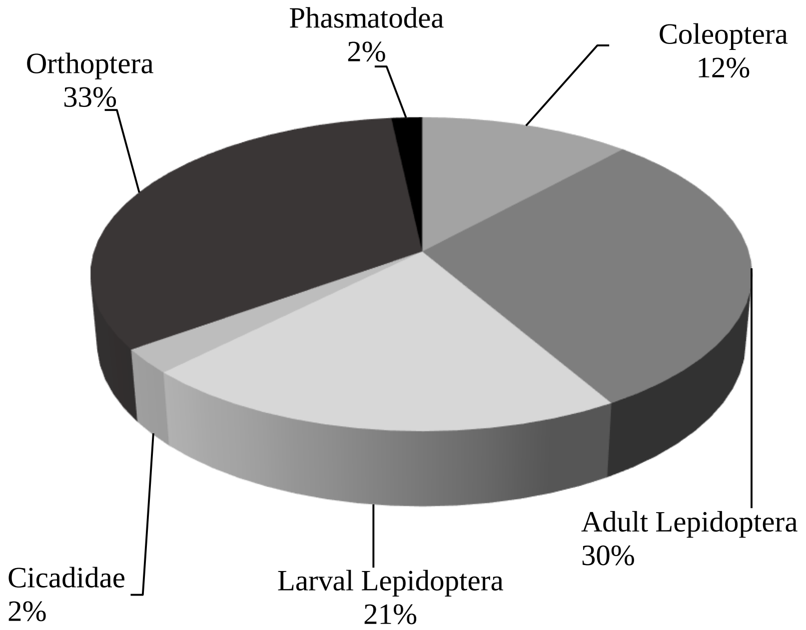

Figure 13. Percentage of insect biomass abundance in dry evergreen forest.

Insect biomass was significantly different between the dry evergreen forest (mean ± SE = 343.7 ± 37.3) and old planted forest (mean ± SE = 198.8 ± 53.9) (U = 15390, n = 227, n = 102, P <0.0001). Within three months sampling period, insect biomass was significantly different between the dry evergreen forest and old planted forest in each of the three months, August (U = 4958, n = 134, n = 56, p = 0.0005), September (U = 787.5, n = 60, n = 20, P = 0.037), and October (U = 602, n = 33, n = 26, P = 0.008) (Fig. 14).

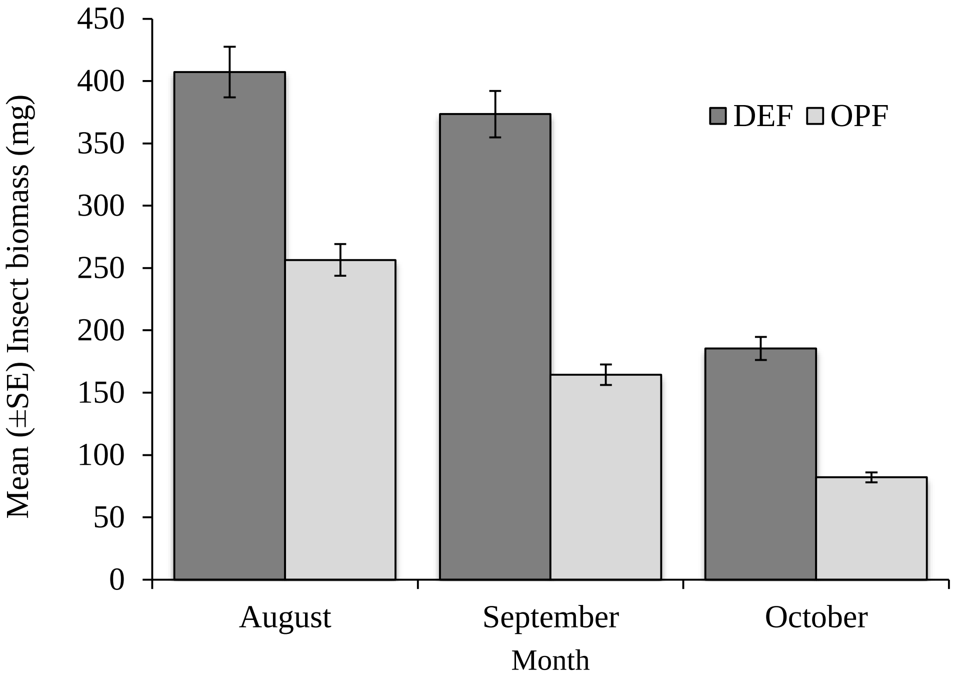

Figure 14. Comparison of Mean (± SE) values of insect biomass abundance in each sampling month between dry evergreen forest and old planted forest.

4.6. Abundance and distribution of the Common Green Magpies

A total of 91 detections were recorded in 11 surveys, representing a total effort of 132 km of transect walk, of which 55 km were in the dry evergreen forest and 38.5 km each in old planted and dry dipterocarp forests. 64.8 % (59) of the total detections were made in the dry evergreen forest and 35.2 % (32) in old planted forest. No detections of the bird were made in the dry dipterocarp forest. Most records were detections by sound/song (59 out of 91 records). Estimate of detection probability, population density and encounter rate were higher in the dry evergreen forest than old planted forest, whereas effective sampling width was higher in the old planted forest. Group size varied from 1 to 2 individuals but mean group size was the same for both habitats. Comparison of the 95 % CI of encounter rate and density estimates between dry evergreen forest and old planted forest showed some overlap indicating non-significant difference in the estimates between the two habitats (Table 5). The histograms of detections probability functions for pooled data across habitats, dry evergreen and old planted forests showed a ‘good fit model’ to the observed data using the half-normal detection function with a cosine adjustment and truncation at 110 m distance (Figs. 15, 16 & 17).

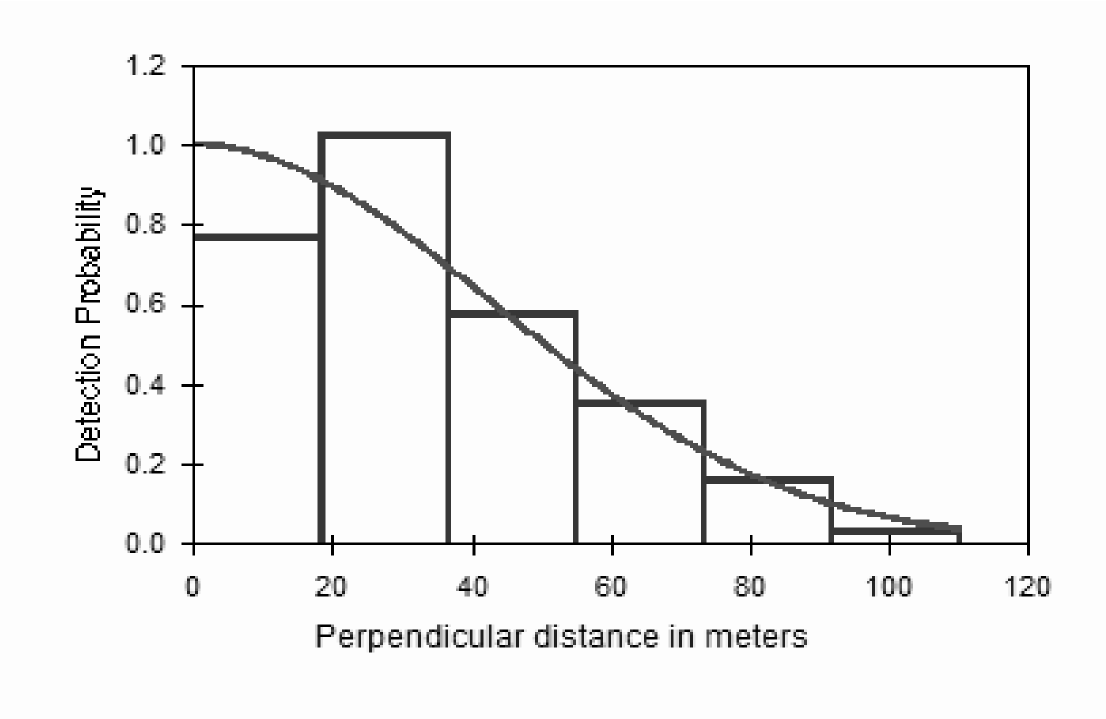

Figure 15. Histogram of detections and fitted probability detection function for Common Green Magpies in SERS (pooled data across habitats).

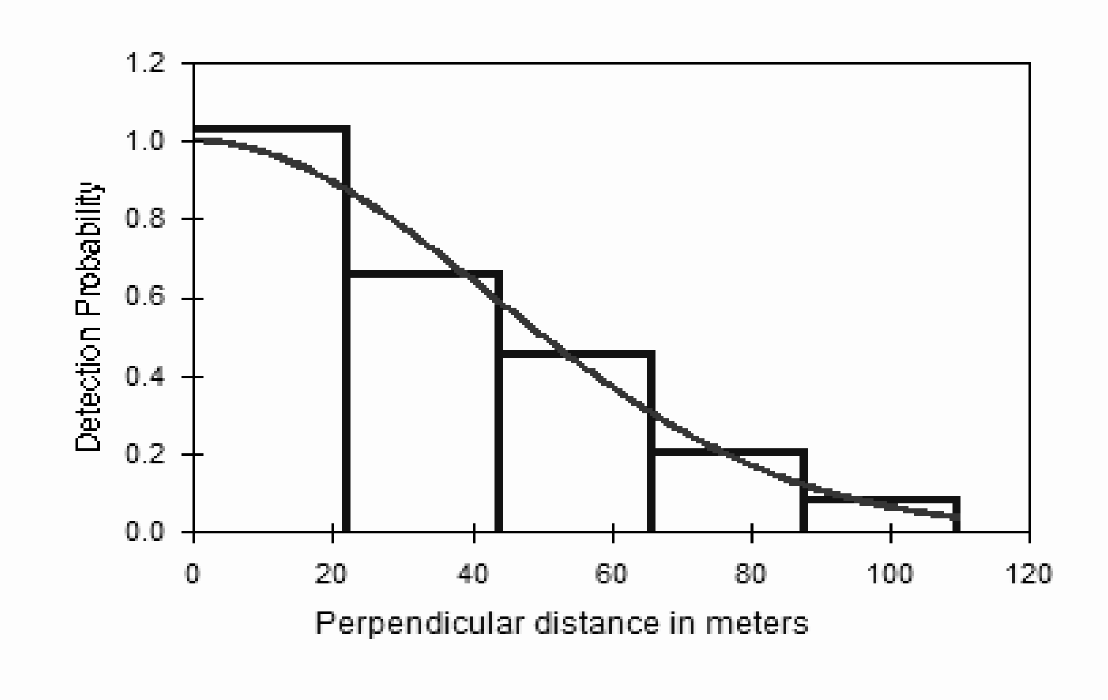

Figure 16. Histogram of detections and fitted probability detection function for the Common Green Magpies in dry evergreen forest.

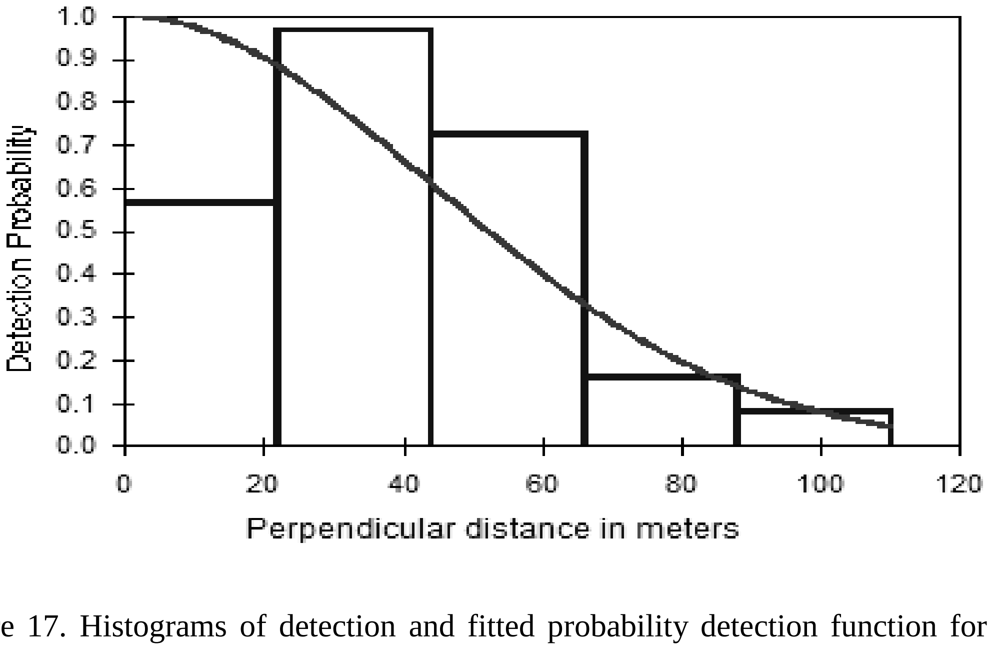

Figure 17. Histograms of detection and fitted probability detection function for the Common Green Magpies in old planted forest.

Table 5. Parameters of probability detection functions for pooled data across habitats (SERS), DEF and OPF. In the table, *P* refers to ‘detection probability’, ESW refers to ‘Effective Sampling Width’, ER refers to ‘Encounter Rate’, DEF refers to ‘dry evergreen forest, and OPF refers to ‘old planted forest’. Upper and lower 95 % CI and % CV were estimated for density; and 95 % CI only was estimated for encounter rate.

Name	*P*	ESW (m)	ER (birds/km)		Density (birds/km^2)		
			Estimate	95 % CI	Estimate	95 % CI	% CV
SERS	0.48	53.3	0.97	0.82-1.15	10.0	7.9-12.6	11.8
DEF	0.49	53.1	1.07	0.85-1.35	11.1	8.3-14.8	14.4
OPF	0.48	53.9	0.86	0.69-1.06	7.9	5.7-10.8	15.9

CHAPTER 5
DISCUSSION

5.1. Nest-site selection by the Common Green Magpies

The Common Green Magpies' nests were built between one or more small branches and the main nesting tree stems. The nesting trees generally had a small DBH and were of the understory stratum of the forest (Table 1). The Common Green Magpies used different understory tree species for nesting (Fig. 7). This is similar with data from other studies of Magpies of similar size (Vuorisalo *et al*., 1992; Antonov and Atanasova, 2002). This is also similar to the Common Green Magpie's closest congener, the Short-tailed Green Magpie (*Cissa thalassina*) from Java which has been reported by Hoogerwerf (1950) and Balen *et al*. (2011) that considering its medium body size, the bird tended to locate its nests in forks of strong small tree close to the trunk. The Short-tailed Green Magpies' nests have been reported to be placed at a height range of 3 - 6 m in trees within the undergrowth of the primary forests. Some of the tree species that were used for nesting by the Common Green Magpies are common understory trees in the study area (Rundel *et al*., 2004; TISTR, 2012). These trees provide availability of nesting trees to the bird in the study area. Use of different tree species for nesting may reduce nest predation because predators might not know that a particular type of tree often has nests, and if there are many of these trees in the same area, a predator has to search more potential trees to find a nest.

The correlation between nesting tree DBH and nest height (Fig. 8), and also between tree density and canopy cover (Fig. 9), indicated that nest height depended on the size of the nesting trees, and canopy cover depended on the tree density at the nest-sites. The positive correlation between these factors might have been due to the diverse composition and structure of trees of the understory at the nest-sites (Rundel *et al.,* 2004). The nest sites were made up of a variety of trees, naturally of several layers of vegetation, including herbaceous plants, shrubs, understory, mid-story and canopy trees. Such structural diversity of vegetation have been reported in other studies to be of significance to nesting birds because they provide dense cover and protection to the nest and its contents (Marzluff *et al*., 2000).

The Common Green Magpies seemed to prefer nesting in trees with close cover in the understory stratum of the forest (Fig. 8). Understory trees had a relatively thicker cover at height >5 - 7 m of the forest stratum (Table 2). However, the nests were not completely concealed within the vegetation as evidenced by the nest concealment index (Table 1). This showed that view of the nest surroundings may also be important as well as nest concealment. Similar studies have also suggested that nest site selection in birds may be a trade-off between good concealment and sufficient view of the surroundings for detection and flushing out when predators approach (Holway, 1991; Götmark *et al*., 1995).

The study area has a diversity of nest predators, but the Pig-tailed macaques and Boiga snakes have been found to predate the Common Green Magpies' eggs and nestlings (Pierce and Pobprasert, 2013; Khamcha, unpubl. data). Nest predators use diverse techniques when searching for prey and generally they could not be expected to be better at detecting nests at any one height level than another (Filliater *et al*., 1994). Since there are few potential nest predators for the Common Green Magpie, then locating nests at different heights of the understory stratum would be favoured by the bird. This limits the search area of the predators since they tend to specialize their foraging activities within a particular stratum of the forest. Nest concealment and diverse placement of nests have been found to be some of the specific nest-site characteristics that might influence nesting success in most bird species (Filliater *et al*., 1994; Tarvin, 1995).

5.2. Vegetation characteristics influencing nest-site selection by the Common Green Magpies

Considering the habitat factors related to vegetation characteristics within the nesting sites, the Common Green Magpies mostly used sparse ground cover, high canopy cover and high tree density of vegetation in the understory of the forest when selecting sites for nesting. The selection of sites with a higher canopy cover and tree density by the Common Green Magpies for nesting may be a response to predation risks. Many species of birds tend to use well covered vegetated areas when nesting and rearing their chicks to avoid being detected by predators (Lima, 1993; Peh *et al*., 2005). Thus, vegetation structure is often considered important for nest-site selection of many birds (Pobprasert and Gale, 2010; Wang *et al.*, 2011). According to the nest concealment hypothesis, predation risk decreases in relation to high vegetation density around the nest-site and this has been suggested to conceal the nest and interfere with visual, auditory, or chemical detection by foraging nest predators (Martin, 1993).

The use of sites with sparse undergrowth ground cover for nesting by the Common Green Magpies were useful in limiting access to nests above by foraging semi-arboreal Boiga snakes from the ground. Alternatively, locating nests in such sites can facilitate detection of predators and escape-flushing in response to an approaching predator. This is a common phenomenon which has been recorded in other bird species, which like the Common Green Magpies, nest in trees above the ground (Hanners and Patton, 1998). As was the case with the bird in this study, it can be suggested that nest predation avoidance promoted the selection of nesting sites with such vegetation characteristics.

Furthermore, the selection of sites with higher tree density (tree height >5 – 7 m) for nesting is also important to the Common Green Magpies as they provided an availability of alternative nesting trees after the first nesting attempt failed as was the case with the bird species in this study. The Common Green Magpies tended to build a new nest for a second clutch attempt not far from the trees it used earlier (personal observation). Although it might not be technically true that it was the same bird, but the fact that the Common Green Magpies become territorial during the breeding season suggested that it was likely to build a new nest within the same territory after the failure of its first clutch than establishing a new one in the course of the breeding season. For instance, of the thirty-two nests found, nine (28 %) were second attempt nests built approximately 25 – 50 m away from the first nesting tree. However, this may attract predators as they may have cues of where to find the new nests. The building of new nests in the vicinity of an earlier nesting site can also be an indication of a shortage of quality nesting sites or may be due to competition for limited nesting sites with the White-crested Laughingthrushes which seem to use nesting sites and trees similar to that of the Common Green Magpies (personal observation).

Sites with greater tree density will have higher canopy cover (Fig. 11). In this study it was found that understory cover, tree density and ground cover (height range 3 – 7 m) and basal area of trees with DBH >10 cm were higher and significantly different between sites selected for nesting than at random sites (Table 2). This made nest-sites more attractive to the breeding Common Green Magpies. The vegetation characteristics made the nest-sites habitats denser and as a result the nests were more concealed within the understory vegetation of the forest. This might make it more difficult for a predator to detect a nest and also help regulate temperature levels by providing shading cover and protection of the nest contents from radiation heat exposure, high winds and also rainfall (Hockey, 1982; With and Webb, 1993). The breeding period of the Common Green Magpies (March - July) coincides with the rainy season at the study area which starts from mid-April to October, with rainfall peaks in May and September (TISTR, 2012; Suwanrat *et al*., 2014). All these explain the reason why a high proportion of the nests were located within the higher and significant under canopy cover and tree density in the understory stratum of the forest (Fig. 8 & 9), thereby concealing them from the view of predators. This is supported by the nest concealment hypothesis, which suggests that risks of nest predation tend to decrease in direct relation to high vegetation density around the nest-sites as the vegetation conceals the nest and interfere with visual, auditory, or chemical senses of predators (Martin, 1993; Suwanrat *et al*., 2014).

5.3. Diet of the Common Green Magpies

The Common Green Magpies, also known by their old names as the green hunting crows, hunting magpies or as the hunting Cissa (Madge and Burn, 1994), perfectly describe their voracious nature. The birds seek food both on the ground and in trees, and take a very high percentage of animal prey including invertebrates and vertebrates, for example, small reptiles, small mammals, nestlings and eggs (www. GrrlScientist.org). In this this study it was found that insects formed the most important component in the diet of the Common Green Magpies, contributing as much as 73.5 % of the total prey consumed (Table 4). The proportion of invertebrates and vertebrates in the diet of the Common Green Magpies was not significantly different. This is because the Common Green Magpies can consume a wide variety of prey and they do not show preference for a particular category of animal prey (Madge and Burn, 1994; www. GrrlScientist.org).

Like all other magpies (Rollinson, 2003; Green *et al.*, 2005), the Common Green Magpies are primarily carnivorous (Table 4). In addition, the animals preyed upon by the Common Green Magpies are similar to those reported from stomach contents analysis of their sister species, the Short-tailed Green Magpie (*Cissa thalassina*) which included different types of animal prey, i. e., caterpillars, grasshoppers, eggs and nestlings, tree frogs, lizards, beetles and cicadas among many others (Balen, 2011). The Common Green Magpies were only observed on three occasions feeding on food items of plant material (i.e., Ficus fruits).

Studies on nest predation conducted in KYNP and SERS have also found that Common Green Magpie feed on nest contents (eggs and nestlings) of other birds (Pierce and Pobprasert, 2013; Khamcha, unpubl. data). In this study eleven nest predation events through camera trapping, and two direct observations in the old planted forest on the Common Green Magpies feeding on other bird species' eggs and nestlings were recorded. Bird eggs and nestlings contributed a proportion of 14.6 % to the total observed diet of the Common Green Magpies (Table 4). This is a high proportion which can have a negative impact on nesting success of other bird species considering that eleven of these predation events were all observed through camera trapping in a small study plot in the dry evergreen forest.

The Common Green Magpies were mostly observed foraging with mixed parties of other bird species. The common foraging associates of the Common Green Magpies were White-crested Laughingthrushes (*Garrulax leucolophus*) and Greater Racket-tailed Drongo (*Dicrurus paradiseus*). These foraging associates were common and regular. Such association have been reported in other birds to be of significance as they serve to enhance food finding, and also predator detection, evasion and mobbing (Morse, 1990).

5.4. Potential insect biomass abundance assessment in dry evergreen forest and old planted forest

Food availability has been shown to be an important cue influencing breeding and distribution for many bird species. Species strongly sensitive to such cues advance their abundance through reproduction recruitment in habitats where abundant food becomes available (Hahn *et al*., 1997). Most of the arthropods that were captured during the potential food assessment are herbivores that selectively feed on plants (Takacs and Gries, 1997). Their biomass abundance may be influenced by plant diversity in the habitats the assessments were conducted. The dry evergreen forest obviously has a higher plant diversity than the monoculture old planted forest with its undergrowth secondary succession (Rundel *et al.*, 2004). Thus, insect biomass abundance was higher in dry evergreen forest than old planted forest (Fig. 14). The forest characteristics such as diversity, canopy cover and understory vegetation are more complex and clustered in dry evergreen forest than old planted forest. This may result in diverse microhabitats that may support a diversity of insects thereby making the dry evergreen forest to have higher arthropod prey abundance than the old planted forest.

A gradual decrease in potential food available from the month of August to October both in the dry evergreen forest and the old planted forest (Fig. 14), resulted from real drop in prey availability in the course of the breeding season. This is supported by the food hypothesis, which suggests that breeding in birds is timed in such a way that the peak energy demands of the reproduction cycle coincide with peak food availability in the habitats (Poulin *et al*., 1992). Therefore the differences in potential food availability during the three months of sampling in the dry evergreen forest and the old planted forest is a true reflection of insect biomass abundance in the two habitats.

5.5. Abundance and distribution of the Common Green Magpies in SERS

The result of the study indicated that the bird only inhabits the dry evergreen forest and old planted forest. Most of the bird’s detections varied from 1 to 2 individuals with the majority of the observations being those of single individuals (Table 4). Pair or group observations were mostly recorded during the peak of the breeding season, between May and June. This might be due to the birds living as solitary individuals most of the times and often seen in pairs or groups during the breeding season (Madge and Burn, 1994). This may explain why most of the detections were single birds rather than pairs or groups. However, the bird was recorded in all strata of the forests although there appeared to be some preference for the dense understorey stratum (4 – 10 m). Most of the time the bird was detected in mixed parties of other birds like White-crested Laughingthrushes and Greater Racket-tailed Drongos.

Estimate of encounter rate and population density showed a higher detection probability, density and encounter rate of the Common Green Magpies in dry evergreen forest than old planted forest, although the difference was not significantly different (Table 5). However, this indicated that the bird's distribution was higher in the dry evergreen forest than in the old planted forest. In theory, the recommended number of detections for analysis using Distance is 60 sightings per species (Buckland *et al*., 2001; Thomas *et al.,* 2010). This number sometimes is difficult to achieve for most tropical forest bird species, even if more intensive surveys are carried out (Sukumal *et. al*., 2010). In this study, habitat specific detections were less than 60 in both dry evergreen and old planted forests (i.e., 59 and 32 respectively). Truncation of the distances at 110 m and application of the half-normal detection function with a cosine adjustment gave good fit models to the observed data, hence reliable estimates of abundance and densities of the Common Green Magpies (Figs. 15, 16 & 17).

The effective sampling width (ESW) was higher in old planted forest than dry evergreen forest indicating that detections were made at longer distances from the transect line in old planted forest compared to the dry evergreen forest (Table 5). This might have resulted from the openness and less clustering of the vegetation in the old planted forest which made detection of the Common Green Magpies at longer distances easier than in the dry evergreen forest. Overall, the population density estimate was 10.0 birds/km^2 for the whole SERS. This is similar to preliminary density estimate for the same species in moist evergreen forest in KYNP which was reported to be 10.1 birds/km^2 (Gale, unpubl. data).

Abundance and density estimation of animals using distance sampling depends largely on the behaviour of the target animal and survey specific factors like time of survey, weather and bird activity among others. For cryptic, shy and dense understory dwelling birds, larger groups are easier to detect and group size may be accurately estimated close to the transect line, and group sizes are poorly estimated at larger distances (Sukumal *et al*., 2010). This may lead to underestimation of both group size and perpendicular distance from the observer to the centre of a group. Some birds during surveys moved away from the line before being detected or were missed as a consequence of their cryptic and shy behaviour and/or in response to the observer (Fig. 15). In addition, the Common Green Magpies have a green body colour which made them well camouflaged or blended with the surrounding green vegetation making it difficult to detect by sight closer to the line. This could be the reason why relatively a big proportion, that is, 64.8 % of the detections were sound rather than sightings.

The Common Green Magpies are strongly arboreal tropical birds that prefers understory habitats with a close and dense cover of trees, most likely because of higher food availability but also as an anti-predator strategy to reduce predation risk during nesting. The dry evergreen forest has a higher diversity of vegetation and the vegetation is clustered thereby providing the Common Green Magpies with an optimal habitat (Rundel *et al.*, 2004). In this study, foraging successes and insect biomass were higher in dry evergreen forest than old planted forest, hence the dry evergreen forest provided more food resources to the Common Green Magpies (Table 4; Fig. 14). This explain why the Common Green Magpies abundance and density was higher in dry evergreen forest than old planted forest, though the difference between these two habitats was not significantly different. Furthermore, nest-site selection study on this bird (Chapter 4.1) has shown that there were more nesting sites in dry evergreen forest than old plated forest which might also explain why the Common Green Magpies were highly distributed and abundant in this habitat because of the availability of these resources.

Although the old planted forest has less dense understory vegetation, but the undergrowth secondary succession in this forest has proved to provide the Common

Green Magpies with sub-optimal habitats for foraging and nesting. All these are in contrast to the dry dipterocarp forest which are too open for the Common Green Magpies to inhabit. In this study the bird was not detected in the dry dipterocarp forest. However, on several occasions the bird was observed making foraging attempts on insects on the edge between dry evergreen forest and dry dipterocarp forest.

5.6. Accuracy of abundance and density estimates of the Common Green Magpies

The four critical assumptions of distance sampling technique were met in order to make abundance estimates accurate indicators of actual densities of the Common Green Magpies in the habitats under study. These assumptions are that (1) all transects are randomly placed; (2) animals on the line are detected; (3) animals are detected prior to evasive movement triggered by the observer; and (4) distances are accurately measured (Rosenstock *et al*., 2002; Gale *et al*., 2009)**.**

To meet these assumptions, all transect were placed systematically in the habitats under study starting from a random point on the grids of the map of the study sites. Most birds on the lines were detected, although it was possible that some were missed when transects passed through thick vegetation with the possibility of obscuring visibility from the observer at long distances. Some birds that were originally on the line at greater distances from the observer may have moved away before they were detected and some were not detected until they flushed out and flew away in mixed groups with other birds like White-crested Laughingthrush and Greater Racket-tailed Drongo. This only occurred at distances of less than 20 m from the line (Fig. 15). In such instances, the original locations of the birds before they were disturbed were accurately determined. The requirement that perpendicular distance of the animal from the line be precisely measured was met by use of a laser rangefinder, with a ranging accuracy of 1 meter and a maximum range of 594 - 1000 meters. It was not hard to get accurate distance readings since all detections were recorded at distances not more than 120 m. When a bird was detected at an angle to the line, both radial distance and angle from the transect line to the bird were measured and used to calculate perpendicular distances. Consequently, the distance estimates to the birds were not always exact, thereby contributing to inaccuracy in detection probability and abundance estimates. In such cases truncation of detection distances far from the transect lines (i. e., at 110 m) for analysis helped to improve the fit of the model. Generally, all the assumptions of distance sampling technique were fairly met during the data collection surveys.

Comparison of the 95 % CI of the density between the dry evergreen forest and the old planted forest showed that the estimates were not significantly different from each other (Table 5). This might have been due to small sample size as program distance requires at least sixty detections to get accurate estimates of abundance and density. This is one of the major disadvantages of estimating abundance using program distance analysis (Buckland *et al*., 2001). Coefficient of variation (CV) measures the precision of abundance estimates as calculated by program Distance. The CV for SERS (pooled data across habitats), dry evergreen forest and old planted forest were 11.8 %, 14.4 %, and 15.9 % respectively (Table 4). All CV's were below the 20 % which is recommended for estimates of abundance using distance sampling analysis (Corn and Conroy, 1998). This showed that the precision of the abundance estimates were generally fair and high enough to explain the accuracy of the estimates of the Common Green Magpies' abundance in the forest types under study, although the estimates were not significantly different between the two habitats.

CHAPTER 6
CONCLUSION AND SUGGESTIONS

The results of this study provide baseline information for further research into understanding the ecology of one of the major nest predators in tropical forests. The Common Green Magpies selected nesting sites that were located in habitats with high understory cover and tree density, and sparse undergrowth ground cover. Selection of site suggest that understory vegetation are very critical for the reproduction success and survival of this bird. Nest site selection is considered adaptive, and as such, natural selection would lead to a preference for those sites where birds expect to have greater breeding success (Martin, 1998, Clark and Shutler, 1999). It can be suggested that the Common Green Magpies selected nesting sites with features that reduce nest predation risks so as to increase their chance of nesting successfully.

Furthermore, the investigation of the bird's diet has showed that the Common Green Magpies are largely insectivorous. The dry evergreen forest supports most of the biomass abundance of arthropods and other invertebrates' available to the Common Green Magpies as compared to the old planted forest. This should explain the differences in abundance and distribution of the bird in these two major habitats. However, there is need to use radio telemetry tracking in order to understand the Common Green Magpies' foraging behaviour in detail.

Across habitat and landscapes some bird species are physiologically tolerant to both micro-climate and micro-habitat changes (Martin, 2001). If this was true for the Common Green Magpies in the present study, then distribution of the bird in the old planted forest where undergrowth secondary succession is allowed to establish itself as a management strategy, may be a consequence of the bird's tolerance and resilient in expanding its primary evergreen forest habitats and occupying areas which were severely disturbed by human activities. Extension of such management strategy in other planted forests in SERS is highly recommended as it has proved to provide alternative habitats for nesting and foraging to the Common Green Magpies and also other bird species.

It must be noted that the representativeness of the results of this study for the species as a whole across its known local and geographical distribution range, cannot be stated with certainty as the results were based on samples from one study location. Repeated surveys to collect more data in other forests where the Common Green Magpies are known to inhabit should eventually give more insights into the bird's ecology in terms of nest-site selection, diet, abundance and habitat associations. Currently no quantitative data exist regarding patterns of habitat use by the Common Green Magpies in other forests, and consequently, no comparisons could be made.

With high levels of nest predation, and poor knowledge on the ecology of most nest predators in tropical regions, especially in Southeast Asia (Robinson *et al.*, 2000; Stutchbury and Morton, 2001), knowing nest-site selection, diet, abundance and distribution of one of the major nest predators in tropical evergreen forests, adds to our understanding of the ecology of nest predators and their response to the impact of anthropogenic habitat disturbance in the areas that they are distributed.

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APPENDIXES

Appendix 1. Location of the Common Green Magpies' nests in dry evergreen forest and old planted forest in SERS

Nest No.	UTM Coordinates		Habitat	Date Found	Initial Nest Status	Final Status
	X	Y				
1	0815029	1603814	DEF	-	4 eggs	Failed eggs
2	0814987	1603805	DEF	17/04/15	Incubating 5 eggs	Failed eggs
3	0815310	1605273	DEF	15/04/15	4 eggs	Failed eggs
4	0814450	1604795	DEF	20/04/15	3 eggs	Failed eggs
5	0814370	1604341	DEF	22/04/15	Incubating 5 eggs	Failed eggs
6	0814177	1604177	DEF	25/03/15	Incubating 4 eggs	Failed eggs
7	0812719	1604619	OPF	23/04/15	Incubating 5 eggs	Failed eggs
8	0812803	1605349	OPF	25/04/15	Incubating 5 eggs	Failed chicks
9	0813129	1605258	OPF	25/04/15	1 Egg	Failed eggs
10	0815356	1605487	OPF	20/04/15	2 Eggs	Failed eggs
11	0812629	1605599	OPF	30/04/15	Incubating 4 eggs	Failed eggs
12	0815105	1605227	DEF	03/05/15	2 eggs	Failed eggs
13	0815155	1605294	DEF	07/05/15	Incubating 4 eggs	Failed eggs
14	0813046	1605043	OPF	10/05/15	3 eggs	Failed eggs
15	0814837	1604162	DEF	15/05/15	2 eggs	Failed eggs
16	0815317	1605487	DEF	16/05/15	3 eggs	Failed eggs
17	0815113	1605183	DEF	19/05/15	Nest building	Abandoned
18	0815163	1605243	DEF	19/05/15	3 eggs	Failed eggs
19	0813236	1605091	OPF	23/05/15	2 eggs	Failed eggs
20	0814413	1604553	OPF	24/05/15	3 eggs	Failed eggs
21	0812227	1605258	OPF	26/05/15	1 egg	Failed eggs
22	0815311	1605487	DEF	31/05/15	4 eggs	Failed chick
23	0815399	1605479	DEF	31/05/15	1 egg	Abandoned
24	0814413	1604175	DEF	14/05/15	1 egg	Failed eggs
25	0814180	1603682	DEF	-	2 eggs	Failed eggs
26	0814683	1604248	DEF	05/05/15	Incubating 5 eggs	Failed eggs
27	0813384	1604331	OPF	07/06/15	2 eggs	Failed eggs
28	0813092	1604178	OPF	08/06/15	1 egg	Failed eggs
29	0814386	1604307	DEF	08/06/15	2 eggs	Failed eggs
30	0812566	1604864	OPF	23/06/15	Incubating 4 eggs	Abandoned
31	0814922	1603714	DEF	27/06/15	3 eggs	Abandoned
32	0814226	1604408	DEF	21/07/15	2 egg	Failed egg

Appendix 2. Nest height and nest concealment (n = 32 nests); N, E, S & W are cardinal directions centered on the nest trees.

Habitat type	Nest height (m)	Nest concealment (%)			
		N	E	S	W
DEF	7.4	40	0	90	90
DEF	5.5	10	50	0	100
DEF	6.5	10	0	20	10
DEF	5.3	40	30	70	60
DEF	6.62	10	0	10	100
DEF	4.87	20	70	30	25
OPF	5.11	80	0	0	10
OPF	4.3	10	30	0	40
OPF	3.5	5	0	10	50
DEF	5.88	0	20	40	100
OPF	3.2	10	20	0	10
DEF	7.5	0	10	50	80
DEF	9	10	50	80	0
OPF	4.9	20	0	40	20
DEF	6.46	60	30	80	10
DEF	4.4	0	0	90	10
DEF	5	20	20	30	10
DEF	8.5	0	0	90	100
OPF	7.2	100	0	100	0
DEF	4.8	80	100	0	0
OPF	7	30	20	90	10
DEF	3.6	50	20	0	30
DEF	8	90	0	0	0
DEF	6	70	0	90	0
DEF	6.5	60	50	20	50
DEF	5	50	40	50	40
OPF	3.7	10	60	0	0
OPF	3.5	50	0	10	60
DEF	5	40	20	50	50
OPF	4	50	30	40	0
DEF	5.2	60	0	50	50
DEF	4.8	10	0	0	50

Appendix 3. Specific vegetation characteristics at nest-sites and random sites (nest-sites = 32; random sites = 64.).

Nest tree height (m)			DBH of nest and random trees (cm)		
Nest trees	Random trees		Nest trees	Random trees	
10	6	11	5.2	4.4	6.1
8	13	7.5	4.1	7.2	7.3
9	4.5	10	3.6	7.7	6.5
10	8	7.5	7.5	4.8	5.9
9.5	12	8	6	10.5	5.4
8	6	8	3.7	4	6.4
8	7.5	7.5	3.5	5.7	6.2
6.5	11	8	5.1	6.2	4.9
7.5	9.5	12	2.4	5.9	6.8
9.2	4.5	8	3.2	3.3	3.8
5.5	11	9	4.3	5.1	8
8	9.5	5	3.8	4.4	3.9
13	12	10.5	6.1	7.2	11.9
8.5	14	5.2	5.9	6.2	4.6
10.5	12	8.5	4.6	9.1	4.1
6.5	7.5	7	6	4.5	4.5
7.5	12	6.5	3.6	5.8	9.9
12	5	9	7.8	3.3	6.2
9	7	7	4.6	5.3	4.2
9	8	7.5	4.8	5.1	4.1
8.5	14	7	5.2	5.4	5.3
6.5	8	9.2	4.9	3.2	3.3
12	7	6.5	9.9	7	6.7
11	6.5	6	9	4.3	3.3
7.5	8.5	7	6.4	7.5	5.3
7.5	10.5	13	4.5	11.1	5
7	8.5	4	5.3	5.3	4.3
5	8	7.4	3.5	4.9	5.4
7	13	7	4.5	9.1	6.6
7	9	9	5.1	3.7	6.5
8	8	7.5	4.9	6.8	8.6
9.5	9.5	10	4.5	5.3	7.5

Appendix 4. Summary of biomass (mg) of prey available for the Common Green Magpies at SERS in DEF and OPF during August, September and October, 2015.

Prey category	August		September		October	
	DEF	OPF	DEF	OPF	DEF	OPF
Coleoptera	3425.5	0.0	4192.1	3465.1	1619.2	1046.3
Adult Lepidoptera	14166.7	14364.3	3925.8	808.3	5109.5	326.5
Larval Lepidoptera	12352.4	0.0	1244.4	0.0	2730.4	267.8
Cicadas	1993.81	0.0	0.0	0.0	0.0	0.0
Orthoptera	22511.63	0.0	2598.6	0.0	805.8	0.0
Phasmatodea	112.7	0.0	364.6	0.0	862.2	0.0

Appendix 5. Nest predation events by the Common Green Magpies through camera trapping in the DEF at SERS, 2015. (Khamcha, unpubl. data)

Nest species	Date found	Predation/Fail stage	UTM Coordinates	
			X	Y
Abbott's Babbler	23/02/2015	Failed egg	815015	1603720
Puff-throated Babbler	27/02/2015	Failed egg	815155	1603653
Black-headed Bulbul	19/03/2015	Failed egg	814382	1604359
White-rumped Sharma	13/04/2015	Failed egg	814014	1603654
Abbott's Babbler	06/05/2015	Failed egg	815136	1603682
Stripe-throated Bulbul	15/05/2015	Failed egg	814226	1603497
Puff-throated Bulbul	29/05/2015	Failed chick	815193	1603768
Scaly-crowned Babbler	29/05/2015	Failed egg	814405	1603382
Tickell's Blue Flycatcher	01/06/2015	Failed egg	815111	1603743
Scaly-crowned Babbler	06/07/2015	Failed chick	814019	1603816
Hainan Blue Flycatcher	18/05/2015	Failed chick	814666	1604289

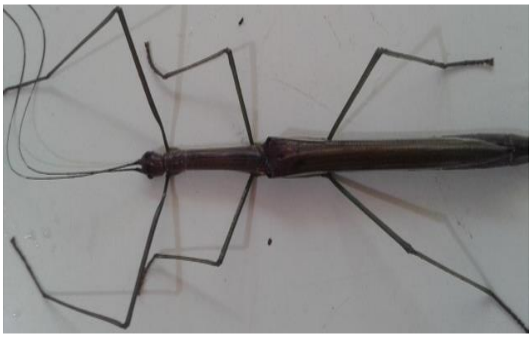
Appendix 6. Pictures of prey remains and invertebrate groups trapped in dry evergreen forest and old planted forest during field observations and potential food availability assessment for the Common Green Magpies in SERS, 2015.

Cicadas

Orthoptera

Gryllidae (Orthoptera)

Lepidoptera



Phasmatodea

Coleoptera

Megascolecidae

Orthoptera

Appendix 7. Distance transect bird count for Common Green Magpies in DEF in SERS, May – October 2015.

Transect & Survey Number		Effort (m)	Perp. Dist. (m)	No. of Birds	Date	Start Time	End Time	H/S	% Cloud Cover	Wind
1	1	5500	3.7	1	13/05	09:05	09:55	H	50	1
	2	5500	39.4	1	28/05	08:11	08:40	H	0	1
	3	5500	48.5	1	12/06	08:15	08:54	S	90	1
	4	5500	37.3	1	25/06	06:12	07:04	S	90	2
	5	5500	11.4	1	22/07	07:30	08:07	H	90	1
	6	5500	61.1	1	07/08	07:30	08:10	H	50	2
	6	5500	38.2	1	07/08	07:30	08:10	H	50	2
	7	5500		0	22/08	06:54	07:33		0	2
	8	5500	32.4	1	06/09	06:39	07:10	H	70	2
	9	5500		0	21/09	06:38	07:15		100	2
	10	5500		0	06/10	06:50	07:27		10	0
	11	5500		0	21/10	06:40	07:10		0	0
2	1	5500	19.0	1	14/05	08:10	08:50	H	80	1
	1	5500	14.7	1	14/05	08:15	08:50	H	80	1
	2	5500		0	30/05	09:10	09:58		0	1
	3	5500	47.0	1	14/06	06:02	06:52	S	50	1
	4	5500	68.9	2	26/06	07:15	07:50	S	100	1
	5	5500		0	19/07	08:05	08:30		100	1
	6	5500		0	08/08	06:28	07:00		100	1
	7	5500		0	23/08	07:30	08:13		90	1
	8	5500		0	07/09	07:30	08:05		0	2
	9	5500	77.0	1	22/09	07:10	07:43	S	0	2
	10	5500		0	07/10	07:57	08:32		0	2
	11	5500		0	22/10	06:25	07:01		0	0
3	1	5500		0	14/05	09:20	09:55		80	2
	2	5500	11.9	1	30/05	06:15	06:47	H	0	1
	2	5500	20.1	1	30/05	06:15	06:47	H	0	1
	3	5500	17.6	1	13/06	07:28	08:05	H	10	0
	4	5500	8.3	1	26/06	05:55	06:40	H	100	1
	5	5500	32.5	1	24/07	08:00	08:31	H	80	1
	6	5500	22.5	1	08/08	07:30	08:00	H	100	1
	7	5500	68.5	1	23/08	07:40	08:11	S	90	1
	8	5500		0	07/09	06:32	07:06		0	2
	9	5500		0	22/09	06:26	06:53		0	2
	10	5500		0	07/10	07:10	07:46		0	2
	11	5500		0	22/10	08:15	08:51		0	0

4	1	5500	19.2	1	15/05	06:30	07:20	H	80	2
	2	5500	14.4	1	31/05	06:53	07:37	H	0	1
	3	5500	36.0	1	15/06	07:22	08:00	H	0	1
	4	5500	68.5	1	27/06	06:01	06:39	S	90	2
	5	5500	18.5	1	25/07	06:13	06:45	H	100	0
	6	5500		0	10/08	07:10	07:45		90	1
	7	5500		0	25/08	07:40	08:11		0	2
	8	5500	22.8	1	09/09	07:38	08:17	H	95	1
	9	5500	52.1	1	24/09	07:50	08:20	S	0	1
	10	5500		0	09/10	06:25	07:01		50	2
	11	5500	16.0	2	24/10	06:45	07:18	H	0	0
5	1	5500	17.5	1	15/05	06:37	07:10	H	0	0
	2	5500	22.5	1	31/05	05:54	06:20	H	0	1
	3	5500		0	15/06	08:25	09:00		80	0
	4	5500		0	27/06	07:18	07:40		90	2
	5	5500		0	19/07	07:34	08:10		100	1
	6	5500		0	09/08	07:42	08:18		70	0
	7	5500	61.7	1	24/08	07:20	07:59	S	80	0
	7	5500	61.1	1	24/08	07:20	07:59	S	80	0
	8	5500		0	08/09	07:33	08:08		0	2
	9	5500		0	23/09	08:25	08:55		95	2
	10	5500		0	08/10	07:55	08:26		50	1
	11	5500		0	23/10	07:30	08:07		0	0
6	1	5500		0	20/05	07:07	07:40		60	1
	2	5500	14.7	1	04/06	07:55	08:40	H	50	1
	3	5500	37.2	1	19/06	05:50	06:32	H	0	1
	4	5500	0.0	0	04/07	08:08	08:52	H	100	1
	5	5500	49.4	1	26/07	06:10	06:50	S	100	1
	6	5500		0	11/08	06:40	07:17		100	2
	7	5500		0	26/08	06:57	07:30		100	2
	8	5500	17.5	1	11/09	06:35	07:10	H	100	0
	9	5500		0	26/09	06:35	07:19		70	2
	10	5500		0	11/10	07:20	07:59		80	0
	11	5500		0	26/10	08:10	08:40		0	0
7	1	5500		0	20/05	08:30	09:15		60	1
	2	5500	24.3	2	04/06	05:55	06:50	H	70	1
	3	5500	15.0	1	19/06	07:50	08:38	H	50	1
	4	5500	46.0	1	04/07	05:42	06:18	S	10	1
	5	5500	61.1	1	25/07	07:30	08:09	S	100	0
	6	5500	44.3	1	10/08	06:20	06:55	S	95	1
	7	5500	109.4	1	25/08	06:56	07:20	S	5	2
	8	5500	25.2	2	09/09	06:30	07:05	H	95	1

	9	5500		0	24/09	07:40	08:28		100	2
	10	5500		0	09/10	06:10	06:47		50	0
	11	5500		0	24/10	07:30	08:03		0	0
8	1	5500	18.3	1	18/05/	06:44	07:35	H	10	0
	2	5500	33.5	1	02/06	07:30	08:11	H	40	0
	3	5500	17.4	1	17/06	07:45	08:25	H	0	0
	4	5500	9.9	1	02/07	05:32	06:15	H	50	1
	5	5500	18.3	1	26/07	07:40	08:20	H	90	1
	6	5500		0	11/08	07:30	08:08		100	0
	7	5500	15.3	1	26/08	07:47	08:22	H	100	2
	7	5500	11.3	1	26/08	07:47	08:22	H	100	2
	8	5500	14.0	1	11/09	07:41	08:16	H	100	0
	9	5500		0	26/09	06:10	06:50		60	1
	10	5500		0	11/10	07:20	07:56		60	1
	11	5500		0	26/10	08:10	08:54		0	0
9	1	5500	20.2	1	18/05	07:47	08:22	H	40	1
	2	5500	33.9	1	02/06	05:50	06:38	H	90	0
	3	5500	17.8	2	17/06	07:30	08:05	H	30	0
	4	5500		0	02/07	08:02	08:32		10	2
	5	5500		0	19/07	06:20	06:55		100	1
	6	5500	30.3	1	09/08	07:00	07:25	H	70	1
	7	5500		0	24/08	06:46	07:10		80	0
	8	5500		0	08/09	06:52	07:17		0	0
	9	5500	26.0	1	23/09	05:50	06:38	H	90	0
	10	5500		0	08/10	06:40	07:18		50	0
	11	5500		0	23/10	06:30	07:00		80	0
10	1	5500		0	13/05	06:35	07:15		40	0
	2	5500		0	29/05	08:10	08:55		0	0
	3	5500	48.9	1	12/06	06:26	07:00	S	0	1
	4	5500	89.9	1	27/06	07:33	08:10	S	90	2
	5	5500		0	24/07	06:35	07:10		100	0
	6	5500		0	07/08	06:37	07:08		50	0
	7	5500		0	22/08	07:30	08:01		50	0
	8	5500		0	06/09	07:53	08:29		0	0
	9	5500		0	21/09	07:20	07:52		100	0
	10	5500		0	06/10	07:33	08:04		100	0
	11	5500	78.8	1	21/10	07:30	08:00	S	0	1

Appendix 8. Distance transect counts for the Common Green Magpies in OPF at SERS, May – October 2015 (H = Heard; S = Seen)

Transect & Survey Number		Effort (m)	Perp. Dist. (m)	No. of Birds	Date	Wind	% Cloud Cover	Start Time	End Time	H /S
1	1	5500	14.1	1	10/05	1	0	06:57	07:35	H
	2	5500	10.3	1	25/05	1	30	09:00	09:49	H
	3	5500		0	09/06	0	90	08:30	09:15	
	4	5500		0	24/06	1	95	06:45	07:16	
	5	5500		0	21/07	1	100	06:57	07:20	
	6	5500	26.0	1	05/08	2	95	06:50	07:20	S
	7	5500		0	20/08	0	0	07:00	07:25	
	8	5500		0	04/09	1	90	07:06	07:30	
	9	5500		0	19/09	1	0	06:50	07:20	
	10	5500		0	04/10	2	10	07:15	07:43	
	11	5500		0	19/10	0	0	06:40	07:12	
2	1	5500		0	10/05	1	0	08:15	08:40	
	2	5500		0	25/05	1	30	07:00	07:25	
	3	5500	22.3	1	09/06	0	90	07:37	08:15	H
	4	5500		0	24/06	1	95	07:50	08:18	
	5	5500		0	21/07	1	100	07:54	08:20	
	6	5500		0	05/08	2	80	07:50	08:11	
	7	5500		0	20/08	0	70	07:58	08:21	
	8	5500	70.6	1	04/09	1	50	08:04	08:35	S
	9	5500	124.9	1	19/09	1	0	07:50	08:20	S
	10	5500	18.6	1	04/10	1	0	07:50	08:20	H
	11	5500		0	19/10	0	0	07:20	07:51	
3	1	5500	9.9	1	11/05	0	0	06:52	07:35	H
	2	5500	17.4	1	26/05	1	50	07:45	08:35	H
	3	5500		0	10/06	2	10	06:45	07:18	
	4	5500		0	25/06	1	90	07:44	08:20	
	5	5500		0	23/07	1	95	07:25	07:55	
	6	5500	54.2	1	07/08	2	10	07:50	08:20	S
	7	5500		0	22/08	0	90	07:47	08:10	
	8	5500	25.2	2	06/09	1	60	08:05	08:27	H
	9	5500	22.5	1	21/09	2	100	07:30	08:07	H
	10	5500		0	06/10	1	40	06:35	07:17	
	11	5500	18.8	1	21/10	0	0	08:01	08:39	H
4	1	5500	24.3	1	11/05	0	0	08:15	08:52	H
	2	5500	45.6	1	26/05	0	10	06:50	07:29	S
	3	5500		0	10/06	1	10	07:33	08:03	
	4	5500		0	25/06	2	95	06:45	07:23	

	5	5500	89.3	1	25/07	1	30	08:13	08:42	S
	6	5500		0	07/08	2	60	08:35	09:04	
	7	5500		0	22/08	0	80	08:21	08:50	
	8	5500		0	06/09	1	100	08:30	09:03	
	9	5500		0	21/09	2	10	08:15	08:50	
	10	5500	23.5	2	06/10	0	0	06:50	07:29	H
	11	5500	78.0	2	21/10	0	0	08:00	08:33	S
5	1	5500	64.0	1	12/05	1	10	06:47	07:33	S
	2	5500	23.4	1	27/05	1	0	06:40	07:20	H
	3	5500	63.6	1	11/06	1	100	07:20	08:00	S
	4	5500		0	26/06	1	100	07:08	07:39	
	5	5500		0	22/07	0	10	06:45	07:15	
	6	5500	59.4	1	06/08	1	90	06:40	07:20	H
	7	5500		0	21/08	0	60	07:20	07:41	
	8	5500		0	05/09	1	100	07:25	07:55	
	9	5500	47.6	1	20/09	2	0	06:52	07:25	S
	10	5500	33.9	1	05/10	1	0	07:20	08:00	H
	11	5500		0	20/10	0	0	06:35	07:13	
6	1	5500		0	12/05	1	50	07:48	08:15	
	2	5500	30.0	1	27/05	1	10	09:00	09:34	H
	3	5500		0	11/06	1	95	08:30	09:00	
	4	5500	39.3	1	26/06	1	100	08:30	09:02	S
	5	5500		0	22/07	1	70	08:30	09:00	
	6	5500	30.9	1	06/08	1	20	08:30	09:00	H
	7	5500		0	21/08	0	10	08:35	09:07	
	8	5500	44.0	1	05/09	2	0	09:08	09:35	S
	9	5500		0	20/09	1	0	08:20	08:52	
	10	5500		0	05/10	0	0	06:25	07:03	
	11	5500		0	20/10	0	50	07:40	08:17	
7	1	5500		0	13/05	0	0	07:50	08:40	
	2	5500	3.4	1	28/05	1	0	06:15	07:03	H
	3	5500		0	12/06	1	100	06:15	06:54	
	4	5500	52.0	1	27/06	1	90	06:25	06:58	S
	5	5500		0	22/07	0	10	06:54	07:30	
	6	5500		0	06/08	0	90	06:30	07:01	
	7	5500		0	21/08	0	20	06:46	07:09	
	8	5500	24.3	1	05/09	1	0	06:45	07:19	H
	9	5500	19.2	1	20/09	1	0	06:15	06:45	H
	10	5500		0	05/10	0	0	07:45	08:25	
	11	5500	45.6	2	20/10	0	0	06:15	06:53	S

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List of Publication and Proceedings

Salema, C. A., G. A. Gale and S. Bumrungsri. 2016. Abundance and habitat association of a tropical nest predator corvid. Proceedings of the 14th IASTEM International Conference on Environment and Natural Sciences, p46 - 50, 14th February 2016, Baiyoke Boutique Hotel, Bangkok, Thailand.

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