BIODIVERSITAS
Volume 23, Number 4, April 2022
Pages: 1990-1997

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d230433

Spatial distribution and temporal patterns of food tree availability of hornbills (Bucerotidae) at Way Canguk Research Station, Bukit Barisan Selatan National Park, Indonesia

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Manuscript received: 16 February 2022. Revision accepted: 23 March 2022.

Abstract. *Fitriansyah RA, Setiawan A, Rustiati EL, Utoyo L, Sibarani MC. 2022. Spatial distribution and temporal patterns of food tree availability of hornbills (Bucerotidae) at Way Canguk Research Station, Bukit Barisan Selatan National Park, Indonesia. Biodiversitas 23: 1990-1997.* The presence of hornbills in an area is associated with food availability. As more food sources become available, the hornbill population in the area may increase. The purpose of this research was to determine the spatial distribution of hornbill food trees and to determine the long-term temporal fruiting pattern of hornbill food trees at Way Canguk Research Station (WCRS), Bukit Barisan Selatan National Park, Indonesia. We surveyed vegetation plots across the research station to assess the spatial distribution and analyzed long-term phenology survey data of the research station that have been collected from February 1998 to December 2020. We recorded 64 species of hornbill food trees with a total of 911 individuals in 197 of 200 survey plots. The temporal fruiting pattern of hornbill food trees during the last 22 years was relatively stable, with an average of fruiting tree percentage of 10.4% (SD: 3.2%, N: 260 months). The highest percentage of fruiting food trees occurred in September 2008, which amounted to 18.3% and the lowest percentage occurred in September 1998 with a percentage of 2.2%.

Keywords: *Ficus* spp., frugivorous animals, plant phenology, plots, survey

INTRODUCTION

Southeast Asia is experiencing a wildlife crisis (Harrison et al. 2016), primarily due to some of the highest deforestation rates in the world (Hughes 2017) and severe hunting pressures (Gray et al. 2017). Logging and hunting are two key direct threats to the survival of wildlife in the tropics and also disrupt important ecosystem processes (Naniwadekar et al. 2015). Hornbills in Asian forests are known to forage and breed in fragmented rainforests and agroforestry plantations in human-modified landscapes adjoining contiguous protected forests (Pawar et al. 2020). One of the important food sources of hornbills is figs (*Ficus* spp.) which produce fruit throughout the year and are also food sources for many frugivores. *Ficus* spp. has the potential to support frugivorous animal life during the season of food scarcity (Kattan and Valenzuela 2013). Hornbills also consume other fruit species, particularly ripe fruit. Ardiantiono et al. (2020) reported that hornbill detections and the percentage of ripe fruits were positively correlated.

One of the important areas for hornbill conservation is Way Canguk Research Station (WCRS), which is a part of the lowland forest in Bukit Barisan Selatan National Park (BBSNP), Lampung Province, Sumatra, Indonesia. (Utoyo et al. 2017; Sibarani et al. 2020). Way Canguk Research Station is also a habitat for eight species of hornbills in Sumatera, i.e., Bushy-crested hornbill (*Anorrhinus galeritus*), Oriental pied hornbill (*Anthracoceros albirostris*), Black hornbill (*Anthracoceros malayanus*), White-crowned hornbill (*Berenicornis comatus*), Great hornbill (*Buceros bicornis*), Rhinoceros hornbill (*Buceros rhinoceros*), Helmeted hornbill (*Rhinoplax vigil*), and Wreathed hornbill (*Rhyticeros undulatus*) (Sibarani et al. 2020). Therefore, it is necessary to conduct research on the existence of food trees that can support the survival of hornbills. This research aimed to determine the spatial distribution of hornbill food trees and the temporal fruiting pattern of the food trees at WCRS, BBSNP. This information is expected to be useful in hornbill conservation efforts in Sumatran forests.

MATERIALS AND METHODS

Study area

This research was conducted in the permanent research plots of the Way Canguk Research Station in Bukit Barisan Selatan National Park, Lampung Province, Indonesia. The research area at WCRS is divided into two parts which are separated by the Canguk river: the northwest plot (200 ha) and southeast plot (600 ha). Both research plots are divided into 200 m x 200 m grid systems (Figure 1).

Procedures

Spatial distribution of hornbill food trees

This research was conducted for two months, from November 2020-December 2020. We surveyed 200 vegetation plots with a size of 50 m x 10 m at WCRS: 100 plots were permanent phenology plots and the other 100 plots were new plots that were made for this research. We identified all tree species (woody standing plants with a diameter at breast height ≥10 cm) that occurred in the survey plots. The data collected in each plot were the tree species, the number of tree individuals, and the coordinates of each plot.

Temporal fruiting pattern of food trees of hornbills

We use the long-term data of tree phenology monitoring that have been conducted since February 1998 until present at WCRS. The monitoring was conducted in the first two weeks of every month in 100 permanent phenology plots at WCRS. The phenology monitoring data included information on several phenophases of trees (diameter at breast height ≥10 cm), but for this research, we were only interested in fruiting pattern of trees.

Data analysis

We obtained a list of known hornbills' food trees that were observed by Hadiprakarsa and Kinnaird (2004) and WCRS staff since circa 2000, which includes five species of hornbills, i.e., *A. galeritus*, *B. bicornis*, *B. rhinoceros*, *R. vigil*, and *R. undulatus* and 64 species of food tree species (Table 1). The list is not a comprehensive list and may be biased towards the most abundant or the most frequently observed hornbill species, but it is the best currently available data for Bukit Barisan Selatan landscape. Of all tree species identified in 200 vegetation plots for spatial distribution and 100 plots for temporal patterns, we selected the tree species that were in the hornbill food tree list. We made the spatial and temporal assessments in two levels: the food trees of all hornbills and separated for each hornbill species. To assess the spatial distribution, we counted the number of food tree individuals found in each plot and mapped the abundance using Quantum GIS version 3.10. We visually determined whether the food trees were distributed evenly or clustered in some areas of WCRS. To assess temporal patterns of the availability of hornbill food trees, we calculated the percentage of food trees that were fruiting (fruiting scores of 1-4) in each monitoring month and then plotted the patterns from February 1998 to December 2020 using R version 1.3. (Datasets from November 1998, December 1998, January 2001, and August 2007 were unavailable). From the graphs, we visually determined whether the patterns tended to be stable or fluctuate across years.

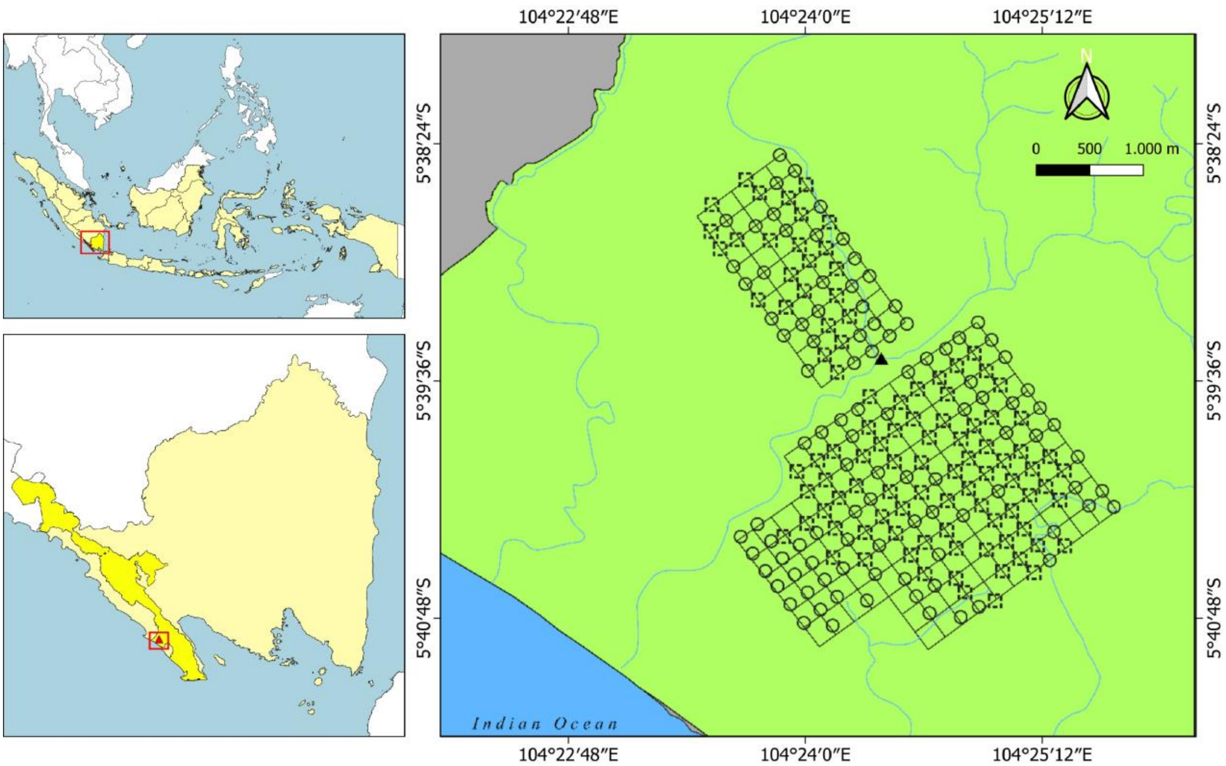

Figure 1. Map of the research plots at Way Canguk Research Station, Bukit Barisan Selatan National Park, Indonesia. The “new survey plots” were made for this study only. The “WCRS phenology plots” were the 100 permanent plots that have been monitored monthly by WCRS staff since Februari 1998-present

RESULTS AND DISCUSSION

Results

Spatial distribution of hornbill food trees

Of the 200 plots surveyed, 197 plots had hornbill food trees with a total of 911 tree individuals from 64 different species. The numbers of identified food tree species and individuals for each hornbill species were 53 species of 777 individuals for *A. galeritus*, 1 species of 4 individuals for *B. bicornis*, 42 species of 554 individuals for *B. rhinoceros*, 7 species of 14 individuals for *R. vigil*, and 55 species of 776 individuals for *R. undulatus* (Table 1).

Based on the obtained results, the spatial distribution pattern of all hornbills' food trees in the 200 plots was evenly distributed across WCRS research plots and hornbill food trees species were absent in only three plots (Figure 2).

Food tree species of *A. galeritus* were distributed in 193 plots. The number of food trees found was 777 individual food trees with a food tree density of 0.007 trees/ha. The spatial distribution pattern of *A. galeritus* food trees was evenly distributed across the research area and only a few plots did not have food trees. The minimum number of food trees available in one plot was one individual and the maximum number of was 13 individuals. The food tree species of the *B. bicornis* were only found in 4 plots, with each plot having 1 individual food tree with a food tree density of 0.00001 tree/ha. The food tree species was only *Ficus altissima* Blume. The distribution pattern of the food tree species of *B. bicornis* found in the 4 plots was clustered because it was only spread over a few research plots. The food tree species of *B. rhinoceros* were distributed in 178 plots with a minimum number of food trees per plot of one individual and a maximum number of nine individuals. The number of food trees found was 554 individual food trees with a food tree density of 0.005 tree/ha. Based on these results, the spatial distribution pattern of *B. rhinoceros* food trees was evenly distributed in almost all research plots.

The food trees of *R. vigil* were distributed in 13 research plots. The number of food trees of *R. vigil* was 14 individuals with a food tree density of 0.0001 tree/ha. All of these food tree species were *Ficus* spp., which consisted of 7 different species. The minimum number of food trees per plot was one individual and the maximum number was only two individuals. The distribution pattern of food trees from *R. vigil* had a clustered pattern because they were scattered only in a few research plots. The food trees of *R. undulatus* were found in 189 plots with a total of 776 individual food trees and a food tree density of 0.007 tree/ha. The minimum number of food trees per plot was one individual and the maximum number was 11 individuals. The distribution pattern of *R. undulatus* food trees was evenly distributed because the trees were spread in almost all research plots.

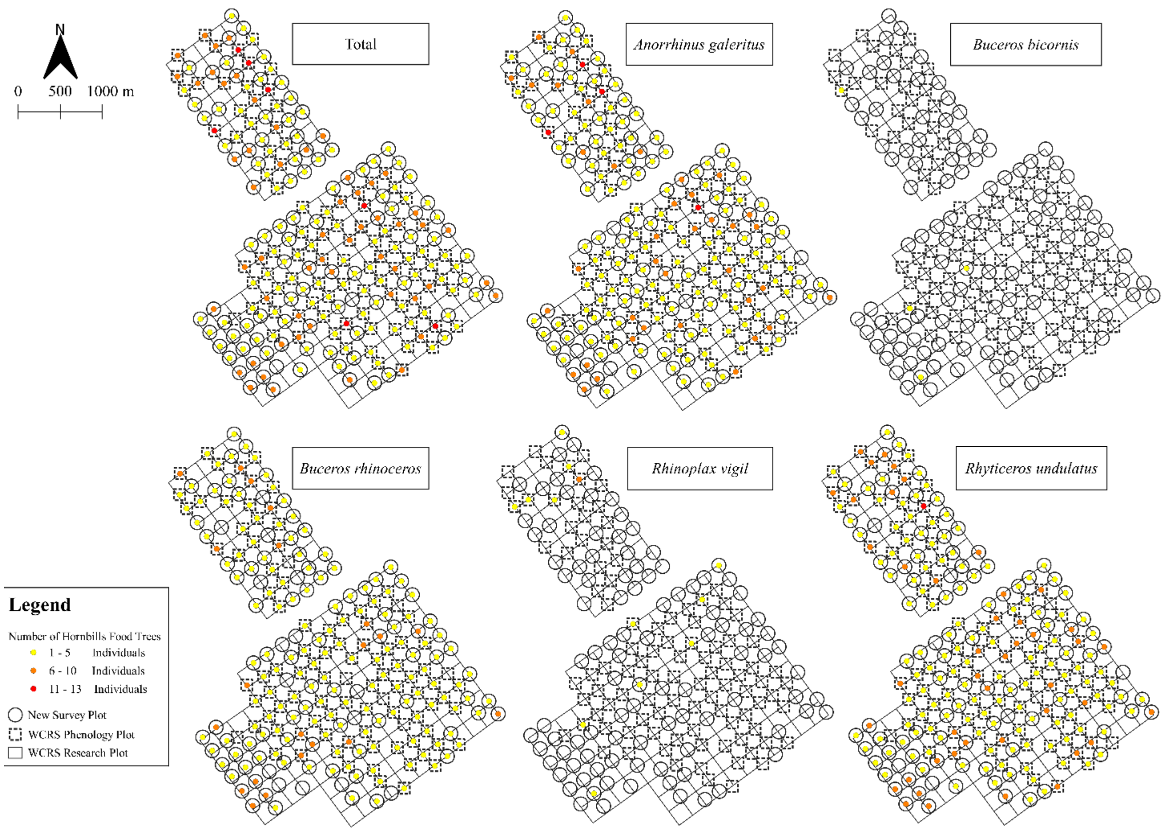

Figure 2. Spatial distribution map of hornbill food trees in the 200 research plots

Table 1. Food tree species of five hornbill species based on Hadiprakarsa and Kinnaird (2004) and *ad libitum* observation data from WCS-IP (2020, *unpublished*)

Family	Food tree species	Hornbill species				
		A. galeritu	***B. bicornis***	***B. rhinoceros***	***R. vigil***	***R. undulatus***
Lauraceae	*Actinodaphne borneensis* Meisn.	✓	-	✓	-	✓
Lauraceae	*Actinodaphne* sp.	✓	-	✓	-	✓
Lauraceae	*Alseodaphne albiramea* Kosterm.	✓	-	✓	-	✓
Lauraceae	*Alseodaphne falcata* (Blume) Boerl.	✓	-	✓	-	✓
Lauraceae	*Alseodaphne helophila* Kosterm.	✓	-	✓	-	✓
Moraceae	*Antiaris toxicaria* (J.F.Gmel.) Lesch.	✓	-	✓	-	✓
Lauraceae	*Beilschmiedia dictyoneura* Kosterm.	✓	-	✓	-	✓
Lauraceae	*Beilschmiedia lucidula* (Miq.) Kosterm.	✓	-	✓	-	✓
Annonaceae	*Cananga odorata* (Lam.) Hook.f. & Thomson	✓	-	✓	-	✓
Burceraceae	*Canarium denticulatum* Blume	✓	-	✓	-	✓
Burceraceae	*Canarium* sp.	-	-	-	-	✓
Rubiaceae	*Canthium glabrum* Blume	✓	-	✓	-	✓
Salicaceae	*Casearia grewiaefolia* Vent.	✓	-	-	-	✓
Meliaceae	*Chisocheton ceramicus* Miq.	✓	-	✓	-	✓
Meliaceae	*Chisocheton patens* Blume	-	-	✓	-	✓
Meliaceae	*Chisocheton* sp.	✓	-	✓	-	✓
Lauraceae	*Cryptocarya ferrea* Blume	✓	-	✓	-	✓
Lauraceae	*Cryptocarya infectoria* (Blume) Miq.	✓	-	✓	-	✓
Burceraceae	*Dacryodes incurvata* (Engl.) H.J.Lam	✓	-	-	-	✓
Burceraceae	*Dacryodes rostrata* (Blume) H.J.Lam	✓	-	-	-	✓
Burceraceae	*Dacryodes rugosa* (Blume) H.J.Lam	✓	-	-	-	-
Ebenaceae	*Diospyros truncata* Zoll. & Moritzi	-	-	-	-	✓
Anacardiaceae	*Dracontomelon dao* (Blanco) Merr. & Rolfe	-	-	-	-	✓
Meliaceae	*Dysoxylum arborescens* (Blume) Miq.	✓	-	✓	-	✓
Meliaceae	*Dysoxylum densiflorum* (Blume) Miq.	✓	-	-	-	✓
Meliaceae	*D. excelsum* (Spreng.) Blume ex G.Don	✓	-	✓	-	✓
Meliaceae	*D. macrocarpum* (Spreng.) Blume ex G.Don	✓	-	✓	-	✓
Meliaceae	*Dysoxylum parasiticum* (Osbeck) Kosterm.	✓	-	-	-	-
Meliaceae	*Dysoxylum* sp.	✓	-	✓	-	✓
Elaeocarpaceae	*Elaeocarpus glaber* Blume	-	-	✓	-	✓
Myristicaceae	*Endocomia macrocoma* (Miq.) W.J.de Wilde	✓	-	✓	-	✓
Moraceae	*Ficus albipila* (Miq.) King	✓	-	✓	✓	✓
Moraceae	*Ficus altissima* Blume	✓	✓	✓	✓	✓
Moraceae	*Ficus benjamina* L.	✓	-	✓	✓	✓
Moraceae	*Ficus depressa* Benth.	✓	-	✓	✓	✓
Moraceae	*Ficus microcarpa* L.f.	-	-	-	✓	-
Moraceae	*Ficus stupenda* Miq.	✓	-	✓	✓	✓
Moraceae	*Ficus sumatrana* (Miq.) Miq.	✓	-	✓	✓	✓
Clusiaceae	*Garcinia dioica* Blume	-	-	-	-	✓
Myristicaceae	*Horsfieldia sucosa* (King) Warb.	-	-	✓	-	-
Myristicaceae	*Knema laurina* (Blume) Warb.	✓	-	✓	-	✓
Myristicaceae	*Knema* sp.	✓	-	-	-	-
Lauraceae	*Litsea angulata* Blume	✓	-	✓	-	✓
Lauraceae	*Litsea noronhae* Blume	✓	-	✓	-	✓
Lauraceae	*Litsea resinosa* Blume	✓	-	✓	-	✓
Lauraceae	*Litsea robusta* Blume	✓	-	✓	-	✓
Lauraceae	*Litsea* sp.	-	-	-	-	✓
Lauraceae	*Litsea velutina* (Blume) Boerl.	✓	-	✓	-	✓
Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre	✓	-	-	-	-
Annonaceae	*Miliusa horsfieldii* (Benn.) Baill. ex Pierre	✓	-	-	-	-
Myristicaceae	*Myristica* sp.	✓	-	✓	-	✓
Euphorbiaceae	*Neoscortechinia nicobarica* (Hook.f.) Pax & K.Hoffm.	✓	-	✓	-	✓
Sapotaceae	*Payena acuminata* (Blume) Pierre	✓	-	-	-	✓
Lauraceae	*Phoebe grandis* (Nees) Merr.	✓	-	✓	-	✓
Annonaceae	*Polyalthia curtissii* Ridl.	✓	-	✓	-	✓
Annonaceae	*Polyalthia lateriflora* (Blume) Kurz	✓	-	✓	-	✓
Annonaceae	*Polyalthia rumphii* (Blume ex Hensch.) Merr.	✓	-	-	-	✓
Meliaceae	*Sandoricum koetjape* (Burm.f.) Merr.	✓	-	-	-	-
Malvaceae	*Sterculia rubiginosa* Vent.	✓	-	✓	-	✓
Malvaceae	*Sterculia* sp.	-	-	-	-	✓
Symplocaceae	*Symplocos cerasifolia* Wall. ex DC.	✓	-	-	-	✓
Symplocaceae	*Symplocos* sp.	✓	-	-	-	✓
Combretaceae	*Terminalia bellirica* (Gaertn.) Roxb.	-	-	✓	-	-
Rubiaceae	*Zuccarinia macrophylla* Blume	✓	-	-	-	✓

Note: ✓: present, -: absent

Figure 3. Temporal fruiting patterns of food tree species of all hornbill species combined and for *Anorrhinus galeritus* and *Buceros bicornis* separately

Temporal fruiting pattern of hornbill food trees

Based on the results obtained, during the period February 1998-December 2020, the pattern of fruiting food trees at WCRS in general tended to be fluctuating with an average of 10.4% (SD: 3.2%, N: 260 months). The peak of fruiting food trees was in September 2008 with a percentage of 18.3%. The lowest percentage occurred in September 1998 with a percentage of only 2.2% (Figure 3). The temporal pattern of fruiting food trees for *A. galeritus* (Figure 3) in the period February 1998-December 2020 tended to fluctuate in certain periods with an average fruiting tree percentage of 9.7% (SD: 3.4, N: 260 months). The highest percentage of fruiting trees occurred in January 2012 with a percentage of 21.1%, while the lowest percentage occurred in September 1998 with a percentage of 1.1%. The rapid increase in the availability of fruiting trees occurred five times, i.e., in January 2000, January 2004, September 2006, September 2008, and January 2012. After experiencing a significant increase, the percentage of availability decreased drastically in May 2012 and continued to decline until September 2014. After September 2014, the percentage of availability tended to increase until January 2015, before finally experiencing a significant decline in May 2016.

The species *F. altissima* is the only tree species identified as the food tree of *B. bicornis* (Figure 3). The temporal pattern of fruiting food trees of *B. bicornis* in general was stable with an average percentage of 75.8% (SD: 33.8, N: 260 months). The highest percentage of fruiting trees of 100% occurred many times, while the lowest percentage was 0% which occurred 12 times, namely in May 1998, September 1998, May 1999, September 1999, May 2000, September 2000, May 2001, January 2002, September 2003, 2006, 2008, and September 2015. This pattern happened because the sample size was low (N: 4 trees) and *F. altissima* had a year-round fruiting season and only in certain months experienced low availability.

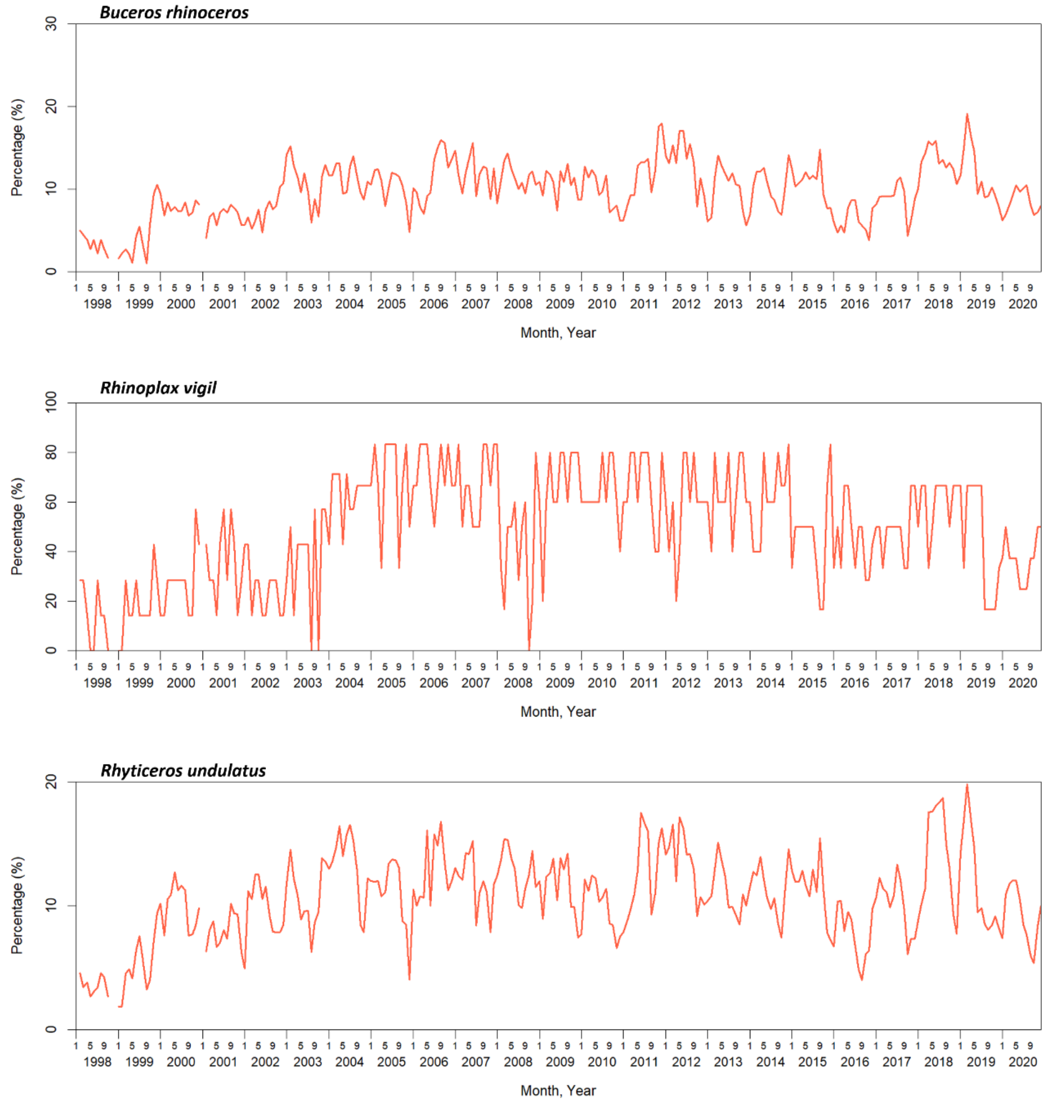

Figure 4. Temporal fruiting patterns of food tree species of *Buceros rhinoceros*, *Rhinoplax vigil*, and *Rhyticeros undulatus*

The temporal pattern of fruiting food trees for *B. rhinoceros* (Figure 4) in February 1998-December 2020 tended to fluctuate in certain periods with an average percentage of 9.8% (SD: 3.3, N: 260 months). The highest percentage of fruiting trees occurred in May 2019 with a percentage reaching 19.2%, while the lowest percentage occurred in September 1999 with a percentage of 1.1%. The increase in the availability of fruiting trees occurred five times, namely in January 2000, January 2003, September 2006, January 2012, and May 2019. The temporal pattern of fruiting food trees of *R. vigil* (Figure 4) was known to have a fairly stable availability with an average of 49.6% (SD: 22.3, N: 260 months). The highest percentage of fruiting food trees occurred ten times, i.e., in January 2005, May 2005, September 2005, January 2006, May 2006, September 2006, November 2006, January 2007, September 2007, and January 2008 with a percentage of 83.3%. Meanwhile, the lowest occurred six times, i.e., May 1998, September 1998, January 1999, August 2003, October 2003, and September 2008, with a percentage of 0%.

The temporal pattern of fruiting food trees of *R. undulatus* (Figure 4) had a fluctuating pattern with an average availability of 10.7%, (SD: 3.4%, N: 260 months). This was due to a significant increase in availability in eight periods, namely May 2000, January 2003, May 2004, September 2004, September 2006, May 2011, September 2018, and January 2019. The highest percentage of fruiting food trees of *R. undulatus* occurred in January 2019, which reached 19.8%, while the lowest occurred in January 1999 with the percentage of only 1.9%.

Discussion

In general, the temporal fruiting pattern of hornbill food trees at WCRS during February 1998-December 2020 was stable because it did not show any significant increase or decrease and only the initial period of analysis had a low level of availability due to El-Nino Southern Oscillation (ENSO) related drought in 1997. Forest fires are one of the factors that cause damage to forest ecosystems, death and loss of animals, and the opening of forest cover. Forest fires also trigger increased invasive vegetation growth for native plants in an area. Forest fires can also cause stress on animals as well as loss of shelter, low availability of food sources, and lack of home ranges for animals so that they disturb the local balance and eventually lead to the death of wildlife in the area (O'Brien et al. 1998 in Kusumastuti et al. 2016).

Meanwhile, the factor causing the high level of hornbill fruit availability at the WCRS is climatic factors, namely the rainfall that is quite high at the end of the year and produces trees that bear fruit quite abundantly at the beginning of the year. In general, the peak of the rainy season at WCRS takes place in November or December, then rainfall starts to decline from January to the driest month, namely August, and increases again from September to October. Based on the results and discussion, it can be concluded that WRCS is a habitat that supports hornbill population. This can be seen from the food trees, which were spread across the area fairly evenly and the long-term availability of fruiting food trees. For the three hornbill species in the WCRS where no food trees were found in the research area, this might mean two things, namely the lack of observations of the three hornbills during the feeding activity or the actual absence of food trees.

During this study, no hornbill species were observed to eat food other than fruit, although hornbills will eat other foods such as small insects during the breeding period. Mangangantung et al. (2015) in their research in the Tangkoko Batuangus Nature Reserve, North Sulawesi, found 13 types of food that were consumed by hornbills and consisted of eight species of fruits and five types of insects. Mangangantung et al. (2015) also stated that when female hornbills are not breeding, 80% of the food consumed is *Ficus* spp. and the rest are several other types of fruit such as *Cananga odorata* and *Dracontomelon dao*. Meanwhile, during the breeding period, fruit consumption decreased by 10% to 70%, and 30% of the types of food consumed were insects such as coconut beetles, grasshoppers, and horn beetles.

Kitamura et al. (2011) stated that seven hornbill species found in lowland dipterocarp forests in Southern Thailand, namely *A. Galeritus*, *B. comatus*, *B. bicornis*, *B. rhinoceros*, *Rhabdotorrhinus corrugatus*, *R. vigil*, and *R. undulatus*, have a preference for several fruit species. This is evident by at least 93 species of fruit from 33 families consumed by hornbills. Hornbills tend to ignore winged fruits from the Dipterocarpaceae family, seed fruits from the Fagaceae family, and shrubs from the Annonaceae, Arecaceae, and Rubiaceae families. Although various types of fruits are available in Dipterocarp forests, hornbills have a clear feeding preference for fruits with certain characteristics related to fruit shape, fruit skin thickness, fruit color, and seed diameter (Kitamura et al. 2011). There are similarities between the research results of Kitamura et al. (2011) with the results of our research at the Way Canguk Research Station, that the five hornbills observed during the study period did not consume fruit from the Arecaceae families, winged fruits such as those from the Dipterocarpaceae family, and seed fruits from the Fagaceae family. This proves that there are similarities in the type of food preferences of several hornbill species in the Dipterocarp lowland forest area in Southeast Asia.

For the species, *B. bicornis*, the type of food found in WCRS was the least. This could be due to the limited number of visual encounters of *B. bicornis* eating at the research site. According to Kamal et al. (2020), in their research on the population of *B. bicornis* in the Pocut Meurah Intan Forest Park, a hill forest in Aceh Province, stated that as many as 27 trees species from 14 families were identified as food trees from *B. bicornis*. This number is much higher than the number of food tree species *B. bicornis* that we found at WCRS during the research. Only one species of food tree was recorded, namely, *F. altissima*, which were consumed by *B. bicornis* in WCRS. However, 8 of the 27 food tree species in Pocut Meurah Intan Forest Park can also be found at WCRS. This means that we might underestimate the real number of food trees consumed by *B. bicornis* at WCRS due to a low number of observations.

An important process that drives forest diversity and genetic structure in it is closely related to human activities such as fragmentation and habitat degradation (Wang and Smith 2002 in Chasar et al. 2014). When humans decide to modify a tropical landscape, it is critically important to understand how changing habitat conditions can be affected by the importance of the range and movement of forest tree seed dispersers. The seed dispersers have a wide home range and this is very important for preserving tropical forests (Mueller et al. 2014 in Chasar et al. 2014). For example, in the rainforests of Southern Cameroon, the large hornbill belonging to the genus *Ceratogymna* (Gonzalez et al. 2013) has an important role as dispersal of forest tree seeds (Whitney and Smith 1998; Poulsen et al. 2002 in Chasar et al. 2014), quantitatively they disperse 20% of tree species seeds around the parent tree (Whitney et al. 1998 in Chasar et al. 2014) and qualitatively more than 80% of the seeds they ingest are dispersed well beyond the parent tree area (Holbrook and Smith 2000 in Chasar et al. 2014).

Another example that supports that the hornbills an animal that needs to be preserved is the research of Holbrook et al. (2002) in Chasar et al. (2014) which states that the Ceratogymna hornbills in West Africa have a fairly wide home range, reaching 290 km. This suggests that hornbills may not only play a fundamental role in forest seed dispersal but also help maintain local tree species diversity by dispersing seedlings from primary forest to secondary forest as well as to surrounding agricultural areas. Poaching activities in forest areas have also resulted in the loss of other large fruit-eating animals whose job is to disperse tree seeds in the rainforests of South Cameroon, such as mammals and primates. Given the declining population of these fruit-eating animals, it is likely that hornbills are playing an increasingly important role in the maintenance of tropical rainforests and the potential for forest regeneration in many parts of Central Africa (Chasar et al. 2014). Naniwadekar et al. (2019) in their research at the Pakke Tiger Reserve (PTR) in northeastern India on how far the Asian forest hornbill disperses seeds, stated that there is a difference seed dispersal between the breeding and non-breeding species of *B. bicornis* with the breeding *R. undulatus*. According to Naniwadekar et al. (2019), median seed dispersal distance of great hornbills was 294 m and 254 m in the breeding and non-breeding season, respectively, and the distribution tail was shorter for breeding birds (2.5 km) than non-breeding birds (13 km).

The potential research that can be continued to develop this research is the effect of seed dispersion by hornbills to the availability of food plant species in an area. This is one of the factors that can determine whether the level of availability of food sources for hornbills in an area is sufficient or not. This research is also useful in assessing the role of hornbills as natural seed dispersers so that they can regenerate forest areas with a large home range. The more seeds the hornbills scatter over a large area, the more food sources will be available. This research can also be used to make decisions for hornbill habitat management strategy at BBSNP, especially in WCRS. The even distribution of food trees and the stable availability of food trees make WCRS a good habitat for hornbills. However, the food availability across the whole BBSNP is still unknown and needs further research. Hornbills, especially helmeted hornbills, are still hunted for illegal wildlife market (Bruyns et al. 2012; Azlan et al. 2016; Beastall et al. 2016; Nijman et al. 2016). Other than deterring poachers in the forests where hornbills are hunted, making sure the availability of food sources is also important in ensuring the survival of hornbills. This needs to be supported by good cooperation between BBSNP and its partners in increasing research on hornbill habitat so that the hornbill habitat at BBSNP can be managed properly.

ACKNOWLEDGEMENTS

The authors would like to thank the Bukit Barisan Selatan National Park and Wildlife Conservation Society-Indonesia Program as the institutions that manage the Way Canguk Research Station for allowing the authors to conduct this research. The authors would also like to thank the WCRS field staff (Mr. Sukarman, Mr. Rahman, Mr. Wiroto, Mr. Seti, Mr. Danang, and Mr. Amin) and all the people who were actively involved in helping the authors to complete the research.

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