Mass Mortality of Wild Malayan Flying Lemurs (Galeopterus variegatus) and Its Underlying Causes

Authors: Tsuji, Yamato, Prayitno, Bambang, Widayati, Kanthi Arum, and Suryobroto, Bambang

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Short communication

Mass mortality of wild Malayan flying lemurs (*Galeopterus variegatus*) and its underlying causes

Yamato Tsuji[1,]*, Bambang Prayitno[2], Kanthi Arum Widayati[3] and Bambang Suryobroto[3]

[1] *Primate Research Institute, Kyoto University, 41-2 Kanrin, Inuyama 484-8506, Aichi, Japan*
[2] *Natural Resources Conservation Center, Jl Kidang Pananjung Cagar Alam KSDA Pangandaran, Jawa Barat, 46396, Indonesia*
[3] *Bogor Agricultural University, Gedung Biologi, Kampus IPB Bogor, Jawa Barat, 16680, Indonesia*

Abstract. Between August and October 2015, we found five carcasses of the wild Malayan flying lemurs (*Galeopterus variegatus*) in the Pangandaran Nature Reserve in West Java, Indonesia. Such short-term mortality events have never been reported for this species. In order to address the potential factors causing it, we firstly compared the estimated population density of the flying lemurs before and after the mortality events. Secondary we collected data on temperature, monthly rainfall, and food availability (in terms of phenology scores), from which we extracted unique feature(s) when the mortality events occurred. Mean (± *SD*) population size within the study site (38 ha) was 27 ± 24, and the five carcasses accounted for 10–20% of the population. The availability of young leaves, monthly rainfall, and maximum temperature were significantly lower during mortality events than in other years. The rainfall was the lowest in the past ten years. This suggests that drought accompanied by food scarcity likely causes the mortality. However, other potential underlying causes such as epidemics and the recent development of a resort near the study site cannot be ruled out. After the mortality events, the population size started to recover.

Key words: die-off, drought, food scarcity, rainfall, temperature.

Mass mortality has been observed in a variety of mammals (Young 1994). In case of large-sized (larger than rodents, Young 1994) mammals, harsh climatic conditions such as drought, storm, and heavy rainfall along with food scarcity and disease (Hamilton 1985; Gould et al. 1999; Hanya et al. 2004; Li et al. 2009; Milton and Giacalone 2014) are the primary underlying causes of the observed mass mortality (reviewed by Young 1994). In order to draft realistic conservation plans, it is important to understand the factors likely to result in the mortality of these species.

Between August and October 2015, we found five fresh carcasses of the wild Malayan flying lemur (*Galeopterus variegatus*) (two animals on August 22, one on September 2, one on September 9, and one on October 3) in the northern part of the Pangandaran Nature Reserve (PNR) in West Java, Indonesia (Tsuji et al. 2016; Fig. 1). Based on the length of their head and body (range: 28.0–39.0 cm), we inferred that they were likely to be adults. One female was with an infant. Two out of five carcasses were partly eaten by carnivorous animals (we found their feces near the carcasses) (Tsuji et al. 2016), however, no external injuries were observed. Such a large number of deaths have not been reported since 1990s. Several researchers have found carcasses of this species (Dzulhelmi and Suriyanti 2012; Lim 2014), but such short-term mass mortality has never been reported. The flying lemurs are not considered as threatened by global extinction, but their habitat is being destroyed throughout its range (Lim 2007). In order to establish long-term viability, studying about their population dynamics are important. Thus, we attempted to address the potential factor(s) causing the mass mortality. Environmental factors, such as rainfall, temperature, and food availability have been reported to cause mortality of large-sized mammals (Young 1994). We hypothesized that similar factors may be responsible for causing the increase in mortality of the flying lemurs.

**To whom correspondence should be addressed. E-mail: ytsuji1002@gmail.com*

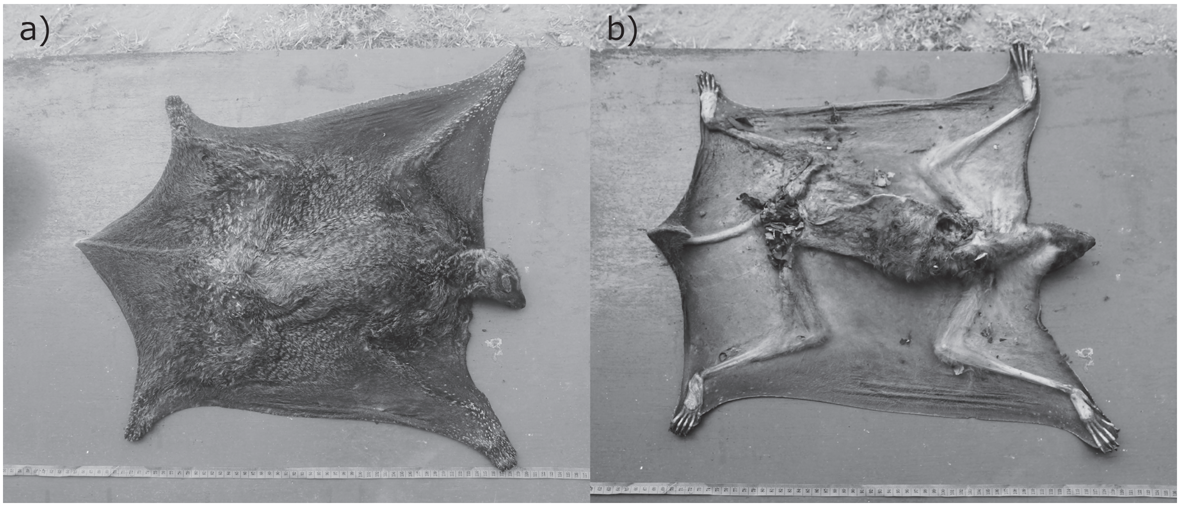

Fig. 1. a) Dorsal and b) ventral view of a fresh carcass of the Malayan flying lemur collected on 3rd October 2015 at Pangandaran Nature Reserve in West Java, Indonesia.

Materials and methods

Study site

PNR is located on the southern coast of West Java, Indonesia (7°43'S, 108°40'E) (Sumardja and Kartawinata 1977). The PNR is divided into two sections, namely, the northern 38 ha forest park (Taman Wisata Alam) where we conducted the study, and the southern 370 ha restricted nature reserve (Cagar Alam). The PNR has an average elevation of 100 m above sea level (Tsuji et al. 2015). Though the forest park is primarily covered by secondary forest, there are several areas of *Tectona grandis* and *Swietenia macrophylla* (Tsuji et al. 2015). Three carcasses were found at the eastern part of the forest park, whereas two were found at the northern part of the forest park that was dominated by grassland and high trees were scarce because of recent resort development (Tsuji et al. 2016). Inter-carcass distances within each part were less than 200 m (Tsuji et al. 2016).

Population census

In this study site, we started field surveys on flying lemurs from 2011 (Tsuji et al. 2015). In order to compare the estimated population density of flying lemurs within the forest park before/during and after the mortality events, we utilized daytime population census data obtained between March 2015 and October 2015 ($n = 16$) and between November 2015 and March 2016 ($n = 10$). For each time, a pre-existing path (ca. 2.5 km in length) inside the forest park was covered on foot (Tsuji et al. 2015), and we recorded the location and number of flying lemurs (including infants) along both sides of the path (5 m in width). We then normalized the number of animals along the forest path (2.5 km × 5 m × 2 sides = 2.5 ha) into the number of animals within the forest park (38 ha).

Rainfall and temperature

We obtained information on daily rainfall (mm) at PNR from two sources. Data between 2005 and 2012 were obtained from Parigi Weather Station, ca. 10 km west of PNR. Data between 2012 and 2015 were obtained from AccuWeather.com (http://www.accuweather.com, accessed on July 31, 2017). For the latter, we also obtained the minimum and maximum temperatures (°C) for each day. From these data, we calculated the monthly rainfall (2005–2015) and averaged minimum and maximum temperatures (2012–2015).

Dietary availability

The Malayan flying lemurs feed on young leaves, fruits (both mature and immature), and flowers (Agoramoorthy et al. 2006; Lim 2007; Baba 2008; Dzulhelmi and Abdullah 2009; Tsuji et al. 2015). Therefore, we tried to evaluate the availability of these types of food. Before this study, we had set 675 monitoring trees (of 72 species, including 101 *Pterospermum javanicum* trees, 77 *Tectona grandis* trees, 73 *Swietenia macrophylla* trees, and 43 *Dysoxylum caulostachyum* trees) along the forest path. Between January 2012 and March 2016 (92 times in total), we recorded the availability of (1) young leaves, (2) flowers, (3) fruits, and (4) young fruits. We classified the availability of the aforementioned parts of each monitoring tree into three categories: 0 (none), 1 (moderate), or 2 (abundant) based on an eye estimation. We defined it as “phenology score” of the target part. We calculated the standardized phenology score (*PS*) in a given time by using the following formula:

$$PS = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n} A_{i,j}}{675 \times 2} \times 100,$$

where $A_{i,j}$ is the phenology score of the target part of tree i of species j, and m and n represent total number of tree and species, respectively. The *PS* ranges from 0 (none) to 100 (whole monitored trees of all species had abundant target part). Due to lack of detailed information on flying lemur food species, we could not evaluate species-level availability.

Statistical analyses

In order to test the difference in population density of flying lemurs within the forest park before and after the mortality events, we conducted the Mann-Whitney *U* test. In order to address characteristics of the season when the mass mortality occurred, we conducted a series of generalized linear mixed models (GLMM). We set climatic conditions (namely monthly rainfall, minimum and maximum temperatures) and diet availability (phenology scores, averaged for each month) of young leaves, flowers, mature and immature fruits as dependent variables, while year (2015 and average years), phase (we separated the former and the latter halves, Phase I: January–May, Phase II: June–October), and year*phase interaction were included as explanatory variables. We assumed that the error structure of the dependent variables would follow Gaussian distribution, and we set the calendar month as a random factor. We used the statistical software R (version 3.2.4) (R Development Core Team 2016), and standard significance was set at 0.05.

Results

Population census

Total numbers of sighted animals before/during and after the mortality events were 28 and 7, respectively. The estimated number (mean ± *SD*) of flying lemurs within the forest park before/during the mortality events was 26.6 ± 23.9 ($n = 16$). After the mortality events, estimated number of animals decreased to 10.6 ± 20.3 ($n = 10$), but the difference between the two periods was not significant (Mann-Whitney *U* test, $U = 112.5$, $P = 0.074$) (Fig. 2).

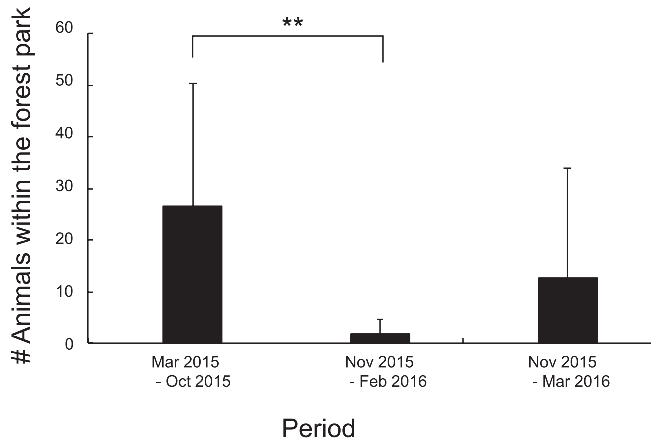

Fig. 2. Estimated population size of the Malayan flying lemurs within the forest park (38 ha) before/during the mortality events (between March–October 2015, $n = 16$, left) and after the mortality events (center: November 2015–February 2016, $n = 8$; right: November 2015–March 2016, $n = 10$). **: $P < 0.01$.

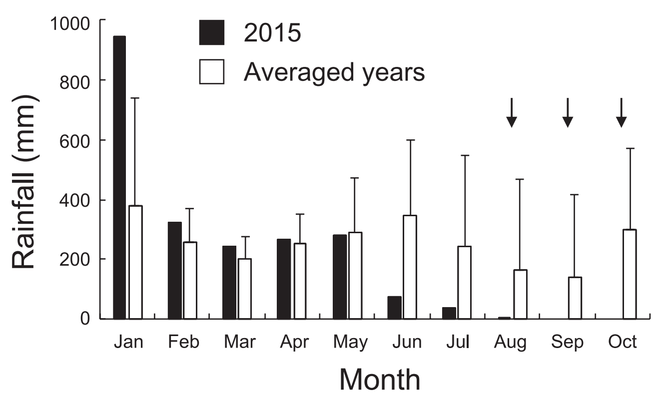

Fig. 3. Monthly change in rainfall (mm) in Pangandaran Nature Reserve, West Java, Indonesia in 2015 (filled bars) and in averaged years (open bars, mean ± *SD*). Arrows represent months when fresh carcasses of the flying lemurs were found.

However, estimated number in February 2016 was 1.9 ± 5.4, and increase in population between February and March was rapid; when we compared the estimated number of animals before/during the mortality events with that based on the censuses between November 2015 and February 2016 ($n = 8$), the inter-period difference was significant (Mann-Whitney *U* test, $U = 104$, $P = 0.009$).

Inter-annual variation in environments

Rainfall in phase II (June–October) in 2015, when the mortality events occurred, was significantly lower than averaged years, while rainfall in phase I (January–May) was similar to that observed in averaged years (GLMM, phase: $t = -3.84$, $P = 0.005$, year: $t = -1.71$, $P = 0.127$,

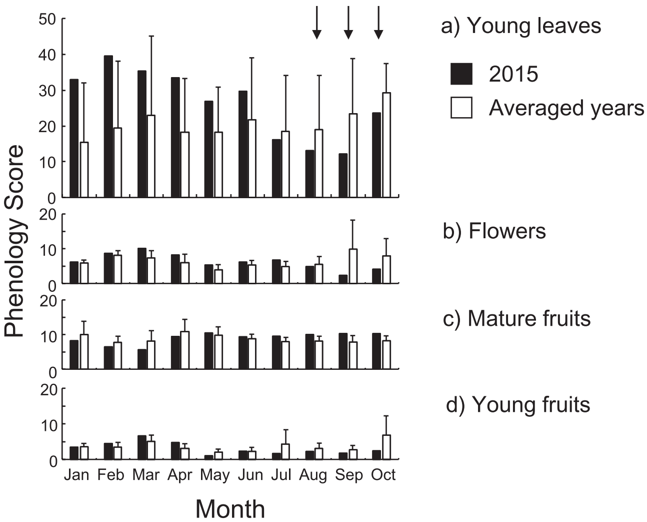

Fig. 4. Monthly change in phenology scores (range: 0–100) of a) young leaves, b) flowers, c) mature fruits, and d) young fruits in Pangandaran Nature Reserve, West Java, Indonesia in 2015 (filled bars) and in averaged years (open bars, mean ± *SD*). Arrows represent months when fresh carcasses of the flying lemurs were found.

phase × year: $t = 3.12$, $P = 0.014$) (Fig. 3).

Temperature in phase II was significantly lower than phase I ($t = -6.95$, $P < 0.001$ for the maximum temperature, $t = -2.087$, $P = 0.021$ for the minimum temperature). The maximum temperature in the phase II in 2015 was significantly lower than averaged years, but the minimum temperature was not ($t = 2.40$, $P = 0.043$ for the maximum temperature, $t = 0.93$, $P = 0.705$ for the minimum temperature). Effect of year on temperature was not detected ($t = 0.68$, $P = 0.513$ for the maximum temperature, $t = 1.72$, $P = 0.125$ for the minimum temperature).

Availabilities (in terms of the phenology scores) of young leaves and young fruits in the phase II in 2015 were significantly lower than those in averaged years ($t = 4.83$, $P = 0.001$ for young leaves, $t = 2.51$, $P = 0.037$ for young fruits), while the corresponding value of mature fruits in phase II in 2015 was significantly greater than those in averaged years ($t = -4.87$, $P = 0.001$). Finally, the value of flower in phase II was significantly lower than the former phase ($t = -2.40$, $P = 0.043$) (Fig. 4).

Discussion

The estimated number (mean ± *SD*) of flying lemurs within the forest park before the mortality events was 26.6 ± 23.9. We thought this estimation was appropriate, because it was similar to the value obtained by dividing the area by mean home range (available data is only Baba (2011), obtained from animals inhabiting coconut palm plantation, 1.26 ha for females ($n = 7$) and 1.79 ha for males ($n = 12$). The mean home range is 1.5 ha): 38/1.5 = 25.3 animals. Since home range size might differ between plantation and secondary forest, in future we need to confirm the home range size of the flying lemurs in our study site. Between August and October 2015, we collected five fresh carcasses, which represent 10–20% of the population size. Estimated population size decreased to 1.9 ± 5.4 by February 2016, but increased to 10.6 ± 20.3 by March 2016. Thus, population recovery after the mortality events was quick, likely due to immigration of animals from surrounding restricted nature reserve between February and March 2016. Another possibility is that higher density in phase I is exceptional due to higher availability of young leaves in this phase (Fig. 4). In order to confirm these speculations on population dynamics, long-term population and environment monitoring is necessary.

We are not sure about the determinants of the mass mortality events in 2015. Several researchers have found carcasses of the Malayan flying lemurs (Bako National Park, Malaysia: Dzulhelmi and Suriyanti 2012, Bukit Timah, Singapore: Lim 2014). However, they could not determine the cause of the death. Their carcasses did not show any sign of injury (Dzulhelmi and Suriyanti 2012; Lim 2014), which was similar to the characteristics of those found in our study site. It is possible that the animal had attempted to glide from one side to the other, but landed short of the intended destination (i.e., landed on the ground).

A potential factor behind the mass mortality events in the 2015 was a drastic reduction of rainfall and lower maximum temperature in the latter half of the year (June–October). The flying lemurs can be seen on tree barks obtaining water, nutrient, salts, and minerals (Lim 2007). Another unique feature in the phase II of 2015 was lower availability of young leaves and fruits. Young leaves are a principle component of the diet of flying lemurs (Agoramoorthy et al. 2006; Lim 2007; Baba 2008; Dzulhelmi and Abdullah 2009; Tsuji et al. 2015). Direct effects of drought and its subsequent effects on food scarcity in 2015 might alter activity including feeding, and usage of forest strata of the flying lemur, leading to mass mortality. Some carcasses of other herbivore, Javan lutungs (*Trachypithecus auratus*) and lesser mouse deer (*Tragulus javanicus*) also found within the area (Tsuji et al. 2016).

However, the possibility that epidemics could be a reason behind the mass mortality cannot be ruled out.

Unfortunately, after the DNA sampling, we buried the carcasses and did not conduct the necropsy to address other possible causes of death. In order to address the proximate factors of the death of these animals, collaboration with veterinarians is necessary. Another probable cause behind the mass mortality is the recent environmental changes caused by humans. Since the commencement of the development of a resort around the study site at the end of 2014, many tall trees were cut down, whose leaves and fruits constitute an important part of the diet of the folivorous animals, including the flying lemurs. In the same period, one group of Javan lutungs started invading human settlements in search of food, and several deaths occurred (Y. Tsuji, personal observation). Similar difficulties may have occurred for the flying lemurs. In order to test the effects of these factors, we need to conduct a systematic monitoring of the environmental fluctuations at the study site.

Our study shows that arboreal flying lemurs inhabiting seemingly stable habitats show fluctuations in demographic parameters under natural conditions. It is necessary to consider such stochastic events in order to arrive at a realistic model on population dynamics, which in turn would help in preparing conservation plans.

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