# Confirmation of feeding and weather conditions for daytime flight of the birdlike noctule (*Nyctalus aviator*)

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**Abstract**：Insectivorous bats typically fly at night but are occasionally seen flying during the day. Most daytime flight reports were of the birdlike noctule *Nyctalus aviator* and were gathered in spring and fall. We surveyed *N. aviator*’s daytime emergences at a roost in Saitama Prefecture and its daytime activities in fall 2012, spring 2013, fall 2013, spring 2014, and fall 2014. Daytime emergences were seen from early March to early April and from late October to late November. The confirmation of feeding buzzes, predatory behavior, and the remains of diurnal insects in the feces suggest that the purpose of *N. aviator*'s daytime flight is to feed. Daytime flight was recorded just before and after hibernation when bats needed energy. We suggest they make up for nightly forage shortfalls when diurnal insect availability is high.

**Keywords**：daytime activities, daylight foraging, Shinkansen, roost, fecal analysis

## Introduction

Insectivorous bats are normally nocturnal and feed on nocturnal insects, but are occasionally seen flying during the day (Aoki, 2007; Fujii, 2010; Hirakawa, 2006; Maeda, 1973; Okazaki, 2008; Sakuyama & Shiraishi, 2007; Tachibana, 1971). Most daytime flight reports in Japan were presumed to be the birdlike noctule (*Nyctalus aviator*), however, most of the cases are incidental.

We have been doing research on the bats in narrow spaces of elevated railroad of the Joetsu Shinkansen in Kojima area of Kumagaya City throughout the years since 2011 (Osawa *et al*., 2013; Osawa *et al*., 2015; Sato *et al*., 2016). *N. aviator* lives in this area of the Shinkansen railroad from fall to spring. During these seasons, we can sometimes see *N. aviator* flying in the daytime. Conducting daytime emergence surveys at the roost may bring us better information in quality and quantity than the surveys of collecting accidental observations which have been reported so far, for example we can exclude the possibility that emergence is a result of human disturbance or predation. Although *N. aviator* roosts at many points in the Shinkansen railroad in Saitama Prefecture (Sato *et al*., 2013; Sato *et al*., 2016), the particular spot where we conducted this daytime flight survey is ideal for analysis as we can easily count all the bats in the roost. Although the purpose of daytime flight has been suggested to be feeding (Speakman, 1990), confirmation of feeding behavior with a bat detector is rare. There have been few cases in which the insects the bats had caught were identified. We surveyed the daytime activities of *N. aviator* which roost in this narrow space in spring and fall and will discuss the relation between daytime emergence of the bat and the climate data, fecal analysis, and predatory behavior to analyze why *N. aviator* sometimes flies during the day specifically at this time of the year.

## Study Area and Methods

**Study site**： Surveys of the daytime emergence and return were conducted at a roost in a narrow space of elevated railroad of the Joetsu Shinkansen in Kojima area of Kumagaya City (Fig. 1) (36.1526N, 139.3416E, alt 45 m) in fall 2012, spring 2013, fall 2013, spring 2014, and fall 2014. This roost is used by *N. aviator* mainly from September to May and the peak number of bats in the roost was 177 (Sato *et al*., 2016). This bat stays in this roost in winter but we have never seen it emerge during the day. The same place is used by

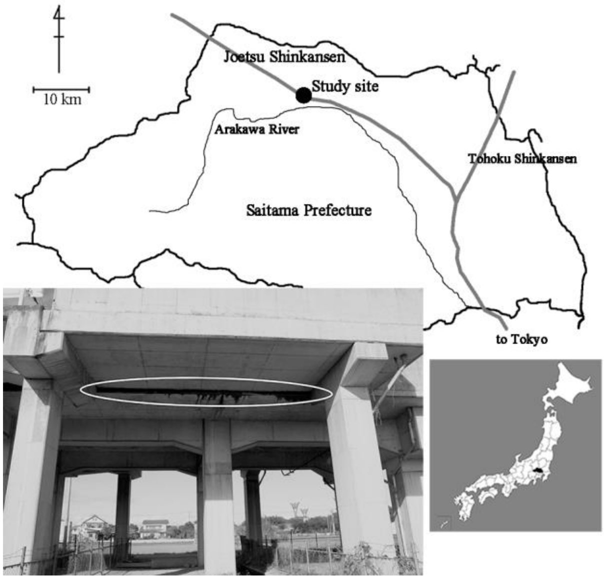


Fig. 1. Location of the study site and the roost of *N. aviator* between the Shinkansen railroad and an access ramp.

Fig. 2. *N. aviator* flying with a dragonfly in its mouth at 14:50 on November 8, 2012.

*Vespertilio sinensis* as a maternity roost from April to September but this bat did not use the roost when *N. aviator*'s daytime flight was observed.

**Emergence and Return survey**： The survey was conducted by visual surveillance and/or by video surveillance over 62 days in total. Before the survey, we counted and identified each bat in the roost by taking pictures sometime during the day. We assume that taking pictures did not affect the emergence of bats as we conducted this count frequently on days when the emergence survey was not conducted.

As it is not uncommon for *N. aviator* to emerge just before sunset (Fukui, 2011), we defined daytime as more than one hour after sunrise to more than one hour before sunset following the definition of Speakman (1990).

Table 1. Survey dates and hours as well as the number of bats in the roost, bats emerged and returned during the day.

| Date (YYYY/MM/DD) | Suvey time | Number of bats in the roost | Number of bats emerged | Percentage of bats emerged | Number of bats returned |
|---|---|---|---|---|---|
| Spring | | | | | |
| 2013/2/28 | 11:06-18:30 | 4 | 0 | 0.0 | 0 |
| 2013/3/1 | 10:55-18:10 | 8 | 0 | 0.0 | 0 |
| 2013/3/6 | 13:30-15:45 | 8 | 0 | 0.0 | 0 |
| 2013/3/9 | 13:25-18:40 | 7 | 1 | 14.3 | 4 |
| 2013/3/13 | 10:56-18:30 | 22 | 1 | 4.5 | 1 |
| 2013/3/17 | 09:50-13:30 | 25 | 0 | 0.0 | 0 |
| 2013/3/25 | 14:05-15:30 | 50 | 0 | 0.0 | 0 |
| 2013/3/29 | 11:30-19:00 | 62 | 21 | 33.9 | 31 |
| 2013/4/4 | 05:35-19:20 | 69 | 18 | 26.1 | 18 |
| 2013/4/5 | 10:55-19:00 | 82 | 0 | 0.0 | 0 |
| 2013/4/9 | 10:57-19:30 | 76 | 0 | 0.0 | 0 |
| 2013/4/13 | 10:35-19:00 | 70 | 0 | 0.0 | 0 |
| 2014/3/19 | 10:30-13:00 | 16 | 0 | 0.0 | 0 |
| 2014/3/28 | 12:40-18:54 | 35 | 0 | 0.0 | 0 |
| 2014/4/1 | 11:00-18:50 | 54 | 0 | 0.0 | 0 |
| 2014/4/7 | 12:25-19:00 | 65 | 0 | 0.0 | 0 |
| Total | | | 41 | | 54 |
| Fall | | | | | |
| 2012/11/12 | 12:25-17:50 | 86 | 39 | 45.3 | 0 |
| 2012/11/13 | 11:35-17:30 | 61 | 23 | 37.7 | 15 |
| 2012/11/14 | 08:15-17:30 | 58 | 3 | 5.2 | 3 |
| 2012/11/15 | 10:45-17:25 | 58 | 0 | 0.0 | 0 |
| 2012/11/18 | 08:10-14:30 | 57 | 0 | 0.0 | 0 |
| 2013/9/21 | 10:06-18:30 | 22 | 0 | 0.0 | 0 |
| 2013/10/21 | 10:56-19:00 | 72 | 0 | 0.0 | 0 |
| 2013/10/27 | 12:00-16:00 | 104 | 0 | 0.0 | 0 |
| 2013/10/28 | 11:00-18:20 | 100 | 0 | 0.0 | 0 |
| 2013/10/30 | 10:02-17:40 | 103 | 99 | 96.1 | 7 |
| 2013/10/31 | 10:30-18:00 | 93 | 90 | 96.8 | 0 |
| 2013/11/1 | 13:00-18:30 | 117 | 24 | 20.5 | 0 |
| 2013/11/2 | 13:00-17:07 | 106 | 36 | 34.0 | 0 |
| 2013/11/3 | 10:45-18:00 | 92 | 47 | 51.1 | 11 |
| 2013/11/4 | 11:30-17:40 | 87 | 2 | 2.3 | 1 |
| 2013/11/5 | 10:30-17:20 | 94 | 0 | 0.0 | 0 |
| 2013/11/6 | 11:17-17:20 | 91 | 24 | 26.4 | 3 |
| 2013/11/7 | 14:40-17:20 | 86 | 0 | 0.0 | 0 |
| 2013/11/8 | 10:40-17:40 | 94 | 0 | 0.0 | 0 |
| 2013/11/9 | 11:25-17:03 | 91 | 0 | 0.0 | 0 |
| 2013/11/10 | 13:00-17:10 | 95 | 1 | 1.1 | 0 |
| 2013/11/11 | 11:28-17:10 | 91 | 0 | 0.0 | 0 |
| 2013/11/12 | 11:35-17:07 | 94 | 0 | 0.0 | 0 |
| 2013/11/16 | 11:15-17:20 | 93 | 12 | 12.9 | 5 |
| 2013/11/17 | 10:30-17:10 | 88 | 18 | 20.5 | 10 |
| 2013/11/18 | 11:18-18:30 | 79 | 21 | 26.6 | 8 |
| 2013/11/20 | 11:15-17:10 | 62 | 0 | 0.0 | 0 |
| 2013/11/21 | 10:50-17:05 | 63 | 0 | 0.0 | 0 |
| 2013/11/24 | 11:30-17:02 | 62 | 4 | 6.5 | 4 |
| 2013/12/6 | 12:30-15:30 | 56 | 0 | 0.0 | 0 |
| 2014/10/26 | 12:00-17:30 | 143 | 1 | 0.7 | 0 |
| 2014/10/29 | 12:00-17:30 | 110 | 0 | 0.0 | 0 |
| 2014/10/30 | 11:16-18:10 | 106 | 10 | 9.4 | 9 |
| 2014/11/1 | 11:03-17:30 | 104 | 0 | 0.0 | 0 |
| 2014/11/2 | 11:00-16:00 | 107 | 12 | 11.2 | 11 |
| 2014/11/5 | 11:45-17:30 | 92 | 18 | 19.6 | 3 |
| 2014/11/6 | 10:55-18:00 | 101 | 19 | 18.8 | 7 |
| 2014/11/7 | 10:58-17:30 | 88 | 0 | 0.0 | 0 |
| 2014/11/10 | 09:30-17:30 | 76 | 0 | 0.0 | 0 |
| 2014/11/11 | 11:00-17:30 | 73 | 6 | 8.2 | 6 |
| 2014/11/12 | 11:50-18:30 | 80 | 0 | 0.0 | 1 |
| 2014/11/13 | 10:40-17:30 | 76 | 0 | 0.0 | 0 |
| 2014/11/14 | 08:30-17:02 | 71 | 0 | 0.0 | 0 |
| 2014/11/15 | 11:30-17:30 | 74 | 0 | 0.0 | 0 |
| 2014/11/22 | 11:35-17:15 | 62 | 3 | 4.8 | 1 |
| 2014/11/23 | 11:25-17:10 | 75 | 0 | 0.0 | 0 |
| Total | | | 512 | | 105 |
| Grand total | | | 553 | | 159 |

**Weather data**： Weather data was collected from the website of the Kumagaya Meteorological Office (http://www.jma-net.go.jp/kumagaya/) which is located 3.51 km east of the roost. We used maximum, minimum, and average temperature of the day, the

Table 2. Insect fragments in *N. aviator*'s feces found by visual inspection.

| Identified arthropod | | | Date of collection (YYYY/MM/DD) | | | |
|---|---|---|---|---|---|---|
| Order | Family | Species | 2012/11/13 | 2012/11/14 | 2013/03/29 | 2013/04/04 |
| Ephemeroptera | - | - | Wing, Leg | Wing | Leg | |
| Odonata | - | - | | Wing, Thorax, Leg, Abdomen | | |
| Orthoptera | - | - | Thorax | | | |
| | Acrididae | *Patanga japonica** | | | | Thorax |
| Hemiptera | - | - | Tergum | Tergum | Tergum | Tergum, Leg, Rostrum, Fore wing |
| | Miridae | - | | Rostrum | | |
| Coleoptera | - | - | Tergum, Leg | Tergum, Leg | Tergum, Leg | Tergum, Leg, Antenna, Mouthparts |
| | Carabidae | *Amara chalcites** | | | Fore wing, Thorax, Leg | Fore wing, Hind wing, Head, Thorax, Leg |
| Hymenoptera | Icheumonidae | - | | Wing, Head | Wing, Antenna, Leg | Wing, Antenna, Leg |
| | Formicidae | - | Wing, Leg | | | Wing, Mandible |
| Diptera | - | - | Leg, Tergum | Tergum,Wing, Leg | Wing, Leg | Wing, Leg, Head |
| | Syrphidae* | - | | | | Wing, Leg |
| | Chironomidae | *Stictochironomus akizukii* | | | Wing, Leg | |
| Trichoptera | - | - | Wing, Leg | Wing, Leg | Leg | Wing, Leg |
| | Apataniidae | *Apatania aberrans* | | | Genitalia, Wing, Leg | |
| Lepidoptera | - | - | | Scales | Scales, Leg | |

"-" signifies that the family or species was unidentifiable
"*" Diurnal insects

Table 3. Temperature when daytime flight was seen and was not seen.

Spring

| | Daytime flight | No daytime flight |
|---|---|---|
| Maximum temperature (℃) | 23.6 | 18.2 |
| Minimum temperature (℃) | 8.6 | 5.3 |
| Average temperature (℃) | 15.3 | 11.4 |
| Temperature at sunset (℃) | 18.1 | 14.3 |
| Temperature of the previous day's sunset (℃) | 16.8 | 12.9 |
| Sunset temperature difference (℃) | 8.1 | 4.0 |
| Previous sunset temperature difference (℃) | 6.4 | 2.3 |
| Surveyed days | 4 | 11 |

Fall

| | Daytime flight | No daytime flight | t-values | p-values |
|---|---|---|---|---|
| Maximum temperature (℃) | 19.0 | 18.1 | 1.35 | >0.05 |
| Minimum temperature (℃) | 9.1 | 7.4 | 1.72 | >0.05 |
| Average temperature (℃) | 13.7 | 12.5 | 1.61 | >0.05 |
| Temperature at sunset (℃) | 16.6 | 14.8 | 2.4 | <0.05* |
| Temperature of the previous day's sunset (℃) | 15.8 | 14.8 | 1.29 | >0.05 |
| Sunset temperature difference (℃) | 3.0 | 2.4 | 0.92 | >0.05 |
| Previous sunset temperature difference (℃) | 1.0 | 0.2 | 1.7 | >0.05 |
| Surveyed days | 23 | 22 | | |

*Significant at P<0.05

Table 4. Maximum precipitation per 10-minute period between sunset and midnight on the night before each surveyed day when daytime flight was seen and was not seen.

Spring

| Precipitation | | n1 | n2 |
|---|---|---|---|
| No rain | | 4 | 10 |
| Rain(mm) | < 0.5 | 0 | 1 |
| | < 1.0 | 0 | 0 |
| | < 1.5 | 0 | 0 |
| | < 2.0 | 0 | 0 |
| | < 2.5 | 0 | 0 |

Fall

| Precipitation | | n1 | n2 |
|---|---|---|---|
| No rain | | 14 | 16 |
| Rain(mm) | < 0.5 | 4 | 4 |
| | < 1.0 | 4 | 0 |
| | < 1.5 | 1 | 0 |
| | < 2.0 | 0 | 1 |
| | < 2.5 | 0 | 1 |

**n1**: Number of days that daytime flight occurred.
**n2**: Number of days that daytime flight didn't occur.

temperature at sunset of the day and the previous day, sunset temperature difference from the over-year average for each day (average of 1981-2010), and the previous day. We compared the average of these data with days that daytime flight occurred to when it did not occur. These data were t-tested. Relation of the incidence of precipitation during the previous night and the incidence of daytime flight was also considered. The purpose of this climate analysis is to find a reason for bat emergence and no emergence during the period when bats are likely to emerge during the day. Therefore, we selected the data from late October to early April which is the wintering period that daytime flight has been observed in Saitama Prefecture, and the data of April 13, 2013 and September 21, 2013 were excluded.

**Behavior during daytime flight** : To investigate the purpose of daytime flight, we also observed *N. aviator*'s daytime behavior when flying near the roost and the Arakawa riverside about 1.5 km south of the roost by photography and with binoculars and a bat detector (Mini-3, Ultra Sound Advice, London U.K.).

**Fecal analysis** : Behavioral observation led us to perform fecal analysis. Fecal sampling was conducted on November 13 and 14 in

Table 5. Daytime flight observations of *N. aviator* in Saitama Prefecture outside of the study area that authors gathered.

| Date (YYYY/MM/DD) | Time | Place | Number of bats | Source |
|---|---|---|---|---|
| 2014/2/26 | Early afternoon | Kitamoto Nature Observation Park (Kitamoto City) | | A |
| 2016/3/6 | Around 15:00 | Kitamoto Nature Observation Park (Kitamoto City) | 1 | A |
| 2016/3/8 | Around 14:00 | Kitamoto Nature Observation Park (Kitamoto City) | 1 | A |
| 2013/3/19 | Around 11:00 | Kitamoto Nature Observation Park (Kitamoto City) | 1 | A |
| 2013/4/4 | 14:54-15:23 | Arakawa Oaso Park (Kumagaya City) | 2+ | C |
| 2014/8/2 | | Kitamoto Nature Observation Park (Kitamoto City) | | A |
| 2010/11/4 | | Arakawa Oaso Park (Kumagaya City) | 10 | A, B |
| 2012/11/4 | Around 14:30, Around 15:30 | Kitamoto Nature Observation Park (Kitamoto City) | | A |
| 2012/11/5 | Around 12:10 | Kitamoto Nature Observation Park (Kitamoto City) | 1 | A |
| 2010/11/6 | | Arakawa Oaso Park (Kumagaya City) | | A |
| 2010/11/8 | | Arakawa Oaso Park (Kumagaya City) | 15-20 | A |
| 2012/11/8 | 14:40-16:10 | Kitamoto Nature Observation Park (Kitamoto City) | 3+ | A, C |
| 2012/11/9 | 12:28-14:03 | Arakawa Oaso Park (Kumagaya City) | 1+ | C |
| 2012/11/9 | | Kitamoto Nature Observation Park (Kitamoto City) | | A |
| 2012/11/11 | 14:30-14:40 | Kitamoto Nature Observation Park (Kitamoto City) | 1 | A |
| 2012/11/11 | Daytime | Nukata (Konosu City) | 1 | B |
| 2010/11/12 | | Kitamoto Nature Observation Park (Kitamoto City) | | A |
| 2014/11/12 | 15:30-16:15 | Shinkawa (Kumagaya City) | 2-4 | B |
| 2012/11/13 | 12:45-13:40 | Arakawa Oaso Park (Kumagaya City) | 2+ | C |
| 2012/11/13 | 13:00-16:00 | Kitamoto Nature Observation Park (Kitamoto City) | 7-8 | A |
| 2012/11/14 | Around 13:10-14:00 | Kitamoto Nature Observation Park (Kitamoto City) | 3 | A |
| 2010/11/15 | Around 15:00 | Arakawa Oaso Park (Kumagaya City) | 5 | A |
| 2006/11/22 | | Kitamoto Nature Observation Park (Kitamoto City) | 2 | A |

A: Park office staff B: Natural Eye; news letter of Eco-Saitama C: Authors
Empty cells represent no information
Data are organized by season rather than year

Table 6. Daytime flight of *N. aviator* reported from outside of Saitama Prefecture.

| Date (YYYY/MM/DD) | Time | Place | Reference |
|---|---|---|---|
| 2010/4/1 | 11:30 | Sagamigawa Shizennomura Park, Sagamihara City, Kanagawa | Fujii, 2010 |
| 2007/4/8 | Around 12:00-12:10, Around 13:40-14:20 (including a rest on a tree trunk) | Sagami River bank, Sagamihara City, Kanagawa | Aoki, 2007 |
| 2005/4/18 | Around 12:30 | Shimokuriya River, Morioka City, Iwate | Sakuyama & Shiraishi, 2007 |
| 2005/4/26 | Around 15:00 | Shimokuriya River, Morioka City, Iwate | Sakuyama & Shiraishi, 2007 |
| 2005/4/27 | Around 12:30 | Shimokuriya River, Morioka City, Iwate | Sakuyama & Shiraishi, 2007 |
| 2005/5/8 | Around 12:30 | Shimokuriya River, Morioka City, Iwate | Sakuyama & Shiraishi, 2007 |
| 1965/5/9 | 13:40 | Hokkaido University Botanic Garden, Sapporo City,Hokkaido | Maeda, 1973 |
| 1966/10/21 | Early afternoon | Hokkaido University Botanic Garden, Sapporo City, Hokkaido | Maeda, 1973 |
| 1953/10/24 | 12:05 | Hokkaido University, Sapporo City, Hokkaido | Maeda, 1973 |
| 2004/11/3 | Around 15:00-16:00 | Shimokuriya River, Morioka City, Iwate | Sakuyama & Shiraishi, 2007 |
| 2003/11/19 | Around 12:30 | Shimokuriya River, Morioka City, Iwate | Sakuyama & Shiraishi, 2007 |

Other than those above, Hirakawa (2006) has 2 reports of *N. aviator*'s daytime flight.
Data are organized by season rather than year

2012, and March 29 and April 4 in 2013 by collecting feces on a tarp placed under the roost during the day. We soaked each piece of feces in an ethanol solution separately, dispersed the contents, then collected identifiable parts with tweezers and identified them under a stereo microscope (Olympus SZ4045, Tokyo, Japan). As the roost is a vertical crevice, the feces fall directly underneath, although there is the possibility that some of the feces might be defecated by the bats that had not emerged or might not be fresh.

**Daytime flight reports of *N. aviator* outside our research area**: To determine the seasons when daytime flight occurs most frequently, we sought the observation reports of *N. aviator*'s daytime flight in Saitama Prefecture as well as references of *N. aviator*'s daytime flight outside Saitama Prefecture.

## Results

### Number of bats emerged and returned, and the percentage of bats emerged during the daytime

Either emergence, emergence and return, or return during the daytime was observed for 27 out of 62 surveyed days. In total, 553 bats (41 in spring, 512 in fall) were seen emerging and 159 bats (54 in spring, 105 in fall) were seen returning during the daytime (Table 1). The number of bats emerged for each day when daytime flight was observed varied between 1 and 99 and the percentage of bats emerged from the total number of bats in the roost also varied between 0.7% and 96.8 % (Table 1).

### Feeding activities of the bats flying during the daytime and fecal analysis

We confirmed echolocation calls of *N. aviator* through a bat detector at the Arakawa riverside on April 4, 2013. We also confirmed the *N. aviator*'s feeding buzzes multiple times near the roost and near the riverbank of the Arakawa on November 1, 2013 and November 11, 2014 during the daytime. In addition, we often observed *N. aviator* chasing insects after it emerged from the roost during the daytime. On one occasion, we were lucky enough to photograph one *N. aviator* flying with a dragonfly in its mouth at Kitamoto Natural Observation Park which is located about 20 km from our survey area at 14:50 on November 8, 2012 (Fig. 2).

One of the reasons we did fecal analysis was because of our direct observation of such predatory behavior during daytime flight. In total, we identified the fragments of insects of 9 orders (Table 2) in the feces.

### Daytime emergence and weather conditions

In fall, the temperature at sunset on days that daytime flight was observed is significantly higher than the temperature at sunset on days that daytime flight was not seen (t-test $P < 0.05$). All other temperatures, including the temperature of the previous day's sunset, also tend to be higher on days that daytime flight was observed, although they are not significantly (Table 3). In spring, daytime flight was seen only on four days and it was not t-tested, but all temperatures including the previous sunset time, also tend to be higher on days that daytime flight was observed (Table 3).

Table 4 indicates that precipitation is not a factor affecting daytime emergence. In spring, precipitation was recorded on only one night and precipitation recorded was less than 0.5 mm per 10 minutes on the preceding night of days that daytime flight was not observed and all the other nights had no rain during this survey. In fall it sometimes rained on the preceding night of days that daytime flight was observed as well as days when no flight was observed.

### Daytime flight reports of *N. aviator* outside our research area

23 cases of daytime flight of *N. aviator* in Saitama Prefecture have been reported including our own observations (Table 5). 11 cases of daytime flight of *N. aviator* from Hokkaido, Iwate, and Kanagawa Prefectures have been reported in references (Table 6). None of these flight reports mentioned emergence from roosts (Table 5, Table 6).

## Discussion

Why is *N. aviator* seen more often than other insectivorous bat species flying during the daytime? The risk of avian predation may be one of the main reasons that insectivorous bats do not frequently feed during the daytime (Speakman, 1991a, 1991b, 1995; Speakman *et al.*, 1994; Mikula *et al.*, 2016). According to Speakman (1991a), the success rate of predator attacks on bats flying during the daytime varied with the size of the bats. Of eight observed attacks on small bats in Speakman(1991a), five were successful while none of the five attacks on large bats were fatal. The birdlike noctule *N. aviator* is a large bat and a swift flyer, therefore predation risk may not be high.

As *N. aviator* is large and conspicuous, it easily grabs people's attention when flying during the day. Therefore, there is a possibility that its daytime flight is overestimated. Although *V. sinensis* and *Pipistrellus abramus* share the nearby roosts at the Shinkansen railroad with *N. aviator* (Osawa *et al*., 2013; Osawa *et al*., 2015), they never flew out during our daytime survey. These two species are smaller than *N. aviator*, therefore their predation risk might be higher.

Daytime flight was observed from early March to early April and from late October to late November in this survey. Daytime flight of *N. aviator* outside our research areas in Saitama Prefecture has been reported in February, March, April, August, and November and the most flights were recorded in November (Table 5). Daytime flight outside Saitama Prefecture was recorded in April, May, October, and November (Table 6). *N. aviator* seems to fly during the daytime in spring and fall. Why?

We confirmed that one *N. aviator* was feeding on an insect by photograph (Fig. 2). It is certain that one of the main purposes of daytime flight is to feed. Other factors that led us to this conclusion were the confirmation of feeding buzzes, predatory behavior, and the remains of diurnal insects found in the feces (Table 2). Although it is not appropriate to suggest that all insect fragments shown in the feces are consumed during the daytime, *Patanga japonica* is predominantly diurnal. *Amara chalcites* flies during the daytime in spring (Inoue, 1972). Flower flies (order Diptera, family Syrphidae) are flower visiting insects (Shiraki, 1981), thus are active during the day.

The temperature data shows that in fall, the temperature at sunset on days that daytime flight was observed is significantly higher than the temperature at sunset on days that daytime flight was not seen. All other temperatures also tend to be higher on days that daytime flight was observed (Table 3). In spring, all temperatures also tend to be higher on days that daytime flight was observed (Table 3). Hirakawa (2006) suggested from a case of daytime flight of an unknown bat species in May and another case of daytime flight of one *Murina ussuriensis* in September that low air temperature of several consecutive nights before each daytime flight, therefore the shortage of food intake, might cause the daytime flight of insectivorous bats. Aoki (2007) and Fujii (2010) reported separate cases of daytime flight of one *N. aviator* in April following several consecutive cool nights. Their results are inconsistent with ours. However, Speakman (1990) compared monthly daytime flight reports in Britain with some climate data and it is only in April that the minimum temperature of the preceding night before the days that daytime flight was observed was significantly lower than the minimum temperature of the preceding night before the days that no daytime flight was observed. From May to September, no significant effect of weather conditions was seen. From October to March maximum temperatures on days that daytime flight was seen were significantly warmer than days of no flight. Speakman (1990) also found that the peak of daytime flight occurred during the last three weeks of April and from the second week of August until the end of September. Speakman (1990) explained these results by noting that in April bats are faced with low insect availability and low fat reserves although energy requirement is as high as that of the rest of summer. So, the peak of activity in April is the response of individuals trying to make up for a shortfall between energy availability and demand. The significant effect of minimum temperature of the previous nights of the days that daytime flight was seen supports this hypothesis as low temperature amplifies the low insect availability during the previous night. From May to July, as summer progresses, bats reserve fat from rich insect availability. In this time of the year, minimum temperature during the night becomes warmer than in April, consequently insects are more abundant than in April. These facts might make daytime feeding less frequent and the effect of the lowest temperature during the night might become less important. August and September is the time when juvenile bats start flying and as they are ineffective hunters, they might experience a shortage of energy despite high insect availability. That may explain the peak activity of daytime flight from August to September. The fact that there is no effect of the previous night temperature on daytime flight supports the hypothesis that these bats would be juveniles. From October to March which is just before, during, and just after hibernation, daytime flight occurred on days which were significantly warmer because such days have high insect availabilities to replenish depleted fat reserves.

In our results, there is a tendency for the days that daytime flight is observed to be warmer. It is consistent with Speakman (1990)'s result from October to March. Although there is a difference of climate, severity of winter, and bat fauna between Saitama Prefecture and Britain, our results support Speakman (1990)'s view that daytime flight at this season coincides with high insect availability, hence it occurs on the warmest days to compensate for fat deficit.

During our daytime flight survey, we often stayed at the study site until one or two hours after sunset and found that on days when daytime flight was observed, the usual evening emergence was observed in all cases. However, we noticed that the bats often returned to the roost less than one hour after their evening emergence. Therefore, we suspect that nighttime foraging is not sufficient. Spring and fall are the times just before and after hibernation so bats must need a lot of energy. This might force bats into daytime feeding on warm days when insects are abundant. As the temperature of the previous night was not low in our survey, it might not be the feeding deficit of the preceding several nights but insufficiency of the fat reserve due to the nocturnal insect scarcity of a certain period and/or an individual bat's hunting skills that causes daytime feeding as Speakman (1990) mentioned.

The feces of *N. aviator* more often contained bird feathers in spring and fall, and it is certain that this species preys on birds (Fukui *et al*., 2013; Katsuta *et al*., 2014). In the future, the relationship between bird predation and daytime flight should be investigated, as bird predation could supply enough energy at once to make daytime flight unnecessary.

We have not discussed year variation as the data is not sufficient, but considering no daytime flight was seen in spring of 2014 (Table 1) there may be a difference year by year in daytime flight. The relationship between year variation and accumulated fat reserves before hibernation, along with temperature during winter, should also be investigated in the future.

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# ヤマコウモリ（*Nyctalus aviator*）の日中飛翔における採餌行動の確認と気象条件

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**要　旨**　食虫コウモリは通常夜飛翔するが，希に日中飛翔が目撃される．ヤマコウモリの例が多く, 春と秋に見られている. 埼玉県のヤマコウモリのねぐらにおいて, 2012 年秋, 2013 年春，2013 年秋，2014 年春，2014 年秋に，日中の出巣の状況と出巣後の行動を観察した．日中の出巣は 3 月上旬から 4 月上旬および 10 月下旬から 11 月下旬に見られた．日中飛翔中のフィーディングバズや昆虫を追う行動の確認，糞の内容物に昼行性の昆虫が含まれることから，日中飛翔は採餌が目的であると考える．日中飛翔の時期は冬眠前後でコウモリはエネルギーが必要な時期であり，夜間の採餌の不足分を，昆虫の多い日の日中に補っているのではないかと推察した．

**キーワード**：日中活動，日中採餌，新幹線，ねぐら，糞分析