JOURNAL OF
ECOLOGY AND ENVIRONMENT
http://www.jecoenv.org

Research Paper
J. Ecol. Environ. 38(4): 415-424, 2015

A study on breeding ecology and nest characteristics of oriental scops owl (*Otus sunia stictonotus*) in South Korea

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Abstract

This research was conducted to reveal the characteristics of breeding ecology of oriental scops owl (*Otus sunia stictonotus*) inhabiting in South Korea according to the nest types during the breeding season from march to October for two years (2011 and 2012). Oriental scops owl nested in woodpecker's nest holes (46.1%), natural tree holes (38.5%), and artificial wood boxes (15.4%). These nests were located on following trees: *Zelkova serrata, Paulownia coreana, Celtis sinensis, Salix chaenomeloides, Salix babylonica, Fraxinus rhynchophylla, Robinia pseudoacacia and Platanus occidentalis.* The hatching success was 91.4%, fledging success was 83.0%, and breeding success was 75.9%. The factors of the breeding failure were falling (57.1%), abandonment (28.6%), hatching failure (7.1%), and others with unknown cause of death (7.1%). According to nest types, the fledging success (69.2%) of woodpecker's nest holes were low and the hatching success (79.2%) of natural tree holes were also low due to hatching failure and abandonment. However, hatching success, fledging success, breeding success were high in the artificial nests as all the eggs hatched and succeeded in fledging. Therefore, we suggested that artificial nests can cover the weaknesses of natural nests as well as increasing the breeding success. However, long-term research on installation place, height, and hole sizes of the artificial nest are required in order to clearly reveal the effects on the breeding success of oriental scops owl.

Key words: breeding ecology, breeding failure factors, breeding success, nest characteristics

INTRODUCTION

Owl species of order Strigiformes are classified into two families: Tytonidae and Strigidae (Gill and Donsker 2014). In South Korea, 11 species representing 8 genera (The Ornithological Society of Korea, OSK 2009) were reported among 220 species representing 29 genera (Gill and Donsker 2014). The Strigidae, part of the family that groups most of the owls, are protected internationally (National Institute of Biological Resources, NIBR 2011).

The subject of this research is oriental scops owl (*Otus sunia stictonotus*) which belongs to genus *Otus* of family *Strigidae* under order *Strigiforms*. It is designated as a natural monument No. 324-6 (Hwang et al. 2014) and species of least concern (NIBR 2011).

Oriental scops owl (*Otus sunia stictonotus*) in South Korea was widely known as Eurasian scops owl (*Otus scops*) in the past but it has been designated as oriental scops owl (*Otus sunia stictonotus*) once 'Checklist of the Birds of Korea (OSK 2009)' was published. Similar species, Eurasian scops owl (*Otus scops*), breeds around Northeastern Africa, Iberian Peninsula, and Lake Baikal but it spends

http://dx.doi.org/10.5141/ecoenv.2015.044

Received 7 May 2015, **Accepted** 17 July 2015

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pISSN: 2287-8327 eISSN: 2288-1220

the winter season in Northern, and Central Africa. However, oriental scops owl (*Otus sunia*), breeds around, Pakistan, India, Malay Peninsula, Eastern and Southern China, Korea, and Primorsky Krai of Russia. It distinguished itself by spending the winter season in Malay Peninsula and Sumatra but both of these species were studied interchangeably due to their extremely similar appearance (Bird life international 2014).

The research on oriental scops owl has barely been done domestically and internationally. On the contrary, various researches have been conducted on similar species, *Otus scops*, in countries such as Japan and Pakistan. However, most of the research subjects seemed to be *Otus sunia* rather than *Otus scops* which have low probability of visitation when classified according to their breeding range (OSK 2009, NIBR 2011, Bird life international 2014, Gill and Donsker 2014).

The first breeding record of *Otus scops* in Shikoku, Japan (Hiromu et al. 1996), Song and Call analysis (Kabaya and Higuchi 1977), the anatomical research using electron microscope (Emura et al. 2009), and the research on vocalization of *Otus* genus Strigidae in Pakistan have been reported overseas (Roberts and King 1986). The karyological analysis by C-banding method (Lee et al. 1989) and molecular phylogeny research (Ryu and Park 2003) were carried out domestically on 2 species of genus *Otus*, *Otus scops* and *Otus bakkamoena*. Nevertheless, the studies on genus *Otus* were limited and there were no reports on their basic ecology, such as breeding ecology, nests, and habitat characteristics.

It has been reported that oriental scops owl should be excluded from being a national monument because it was an easily observed summer visitor in the entire region of Korean Peninsula (Song 2005). However, consequential extinction is concerned because the population size is continuously decreasing due to the destruction of its habitat and polluted food (NIBR 2011).

There is an emphasis on the importance of conducting a research on the usage of ecology and habitats for the preservation and management of species (Grisham et al. 2014, Wagner and Islam 2014). In other words, the birds choose their nest sites according to environmental features such as nest tree, vegetation, altitude, temperature, climate and flood (Park et al. 2012, Meniaia et al. 2014, Rico and Sandoval 2014). Most of the birds with their own territory choose and maintain nesting places that has the highest breeding success rate based on their breeding experience from the previous year (Baran and Adkins-Regan 2014). The research on habitats is a crucial factor in understanding species breeding ecology because the selection of nesting sites is directly linked to the successful breeding of the birds (Lee et al. 2010, Park et al. 2012). In addition, nest-site selection is a critical process in the life history of animals because it directly influences the survival of their offspring and parental fitness (Oswald et al. 2015).

Therefore, the nest types of oriental scops owl, characteristics of trees with nests, incubation period, brooding period, hatching asynchrony, hatching success, fledging success, and breeding success according to clutch size were analyzed in this study.

The purpose of this study was to understand the breeding ecology of oriental scops owls by revealing the main cause of breeding failure and to provide basic data for the preservation and management of the species.

MATERIALS AND METHODS

Research area

The nests of oriental scops owl were 13 in total which was located in Daejeon (1), Chungcheongnam-do Buyeo-gun (4), Gongju-si (3), Nonsan-si (2), Geumsan-gun (1), Chungcheongbuk-do Okcheon-gun (1), and in Yeongdong-gun (1) (Fig. 1).

Research period

This research was conducted over two years from March 2011 to October 2012. The trees where oriental scops owls nested in the past or might nest in the future were researched over the non-breeding season (September through March). The nest characteristics, clutch size, incubation period, brooding period, hatching asynchrony, hatching success, fledging success, breeding success, and breeding failure were investigated respectively in the region confirmed with actual breeding during the breeding season (April through August).

Research method

The nests were visited twice (10 am-8 pm) a day during the breeding season to confirm the first and last eggs were laid. Once the oviposition was complete, we visited the nests once a day until the last fledgling left the nest. The endoscopic camera (Coms GL-8806; Light Communication Co., Seoul, Korea) and digital camera (5D MarkIII and EF 600mm F4 L IS USM; Canon Inc., Tokyo, Japan), infrared digital camera (M-100; Moultrie Feeders Co., Ala-

Fig. 1. Map of study area.

Fig. 2. Nest types of oriental scops owl. (a,b) natural tree holes, (c) woodpecker's nest holes, (d) artificial wood boxes.

baster, AL, USA) were used for photos and videos because it was difficult to approach places such as woodpecker's nests and natural tree holes. In non-breeding season, we searched for trees with cavity size greater than 7 cm in diameter and observed them at least once a month with naked eyes. The condition and coordinates of holes were also recorded. We made 20 artificial wood boxes in total and they were installed in Buyeo. The artificial wood boxes were installed on trees located in proximity to both forests and open area. The trees with height greater than 10 m were selected to be installed with artificial wood boxes and they were installed 3 m above the ground by using the ladder.

The following characteristics of nest trees were measured for 13 nests in total: height of trees (H), height of nests (NH), diameter at breast height (DBH), and diameter at nest height (DNH). The nests were studied and classified into three types based on their shapes once the

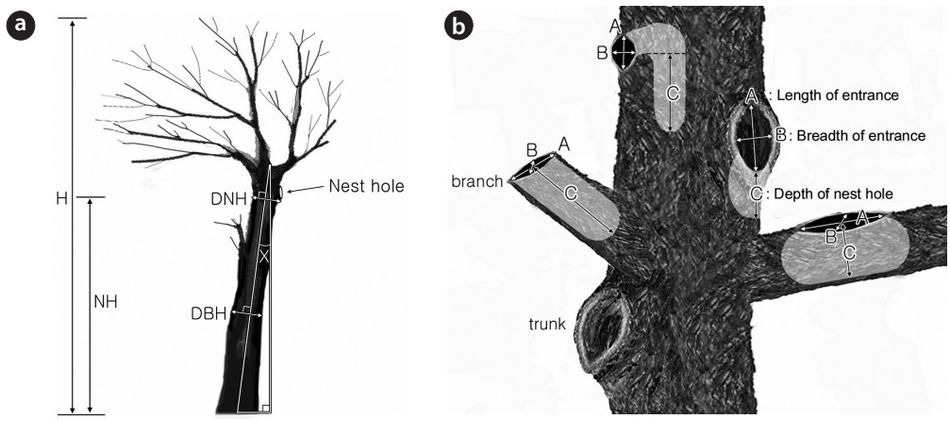

Fig. 3. Measurement method of characteristic of nest trees (a) and nest holes (b). H, height of trees; NH, height of nests; DNH, diameter at nest height; DBH, diameter at breast height.

breeding of oriental scops owl was identified. Firstly, they were classified as woodpecker's nest holes if the shape of entrance was circular or oval not so long after it was built by woodpecker. Secondly, they were classified as natural tree holes if the hole was created by a damage or decomposition of the tree and if the shape of entrance is not intact because it has been long since woodpecker's nest was built. Thirdly, they were classified as artificial wood boxes (width 21 cm × length 21 cm × height 30 cm, diameter of the hole 7 cm) made of wood (Fig. 2). The artificial wood boxes were excluded from nest location investigation and only 11 nest holes (woodpecker's nest holes and natural tree holes) were studied. The nest location was distinguished into two parts, trunks and branches. Furthermore, the length, breadth, and depth of entrances were measured as part of nest holes characteristics (Fig. 3).

The clutch size was defined as the number of eggs present when the oriental scops owl finished laying its eggs. The incubation period was defined as the period from incubation of the first egg until hatching of the last egg. The brooding period was defined as the period from hatching of the first fledgling until last fledgling leaves the nest. Lastly, hatching asynchrony was defined as the interval from hatching of the first egg until hatching of the last egg.

The hatching success is the ratio (%) of hatched eggs over laid eggs, the fledging success is the ratio (%) of fledged individual over hatched fledglings, and breeding success is the ratio (%) of fledged individual's total eggs that were laid. The hatching was defined as the state where the fledgling was totally out of its eggshell, and fledging was defined as the state where the fledgling stably flew to top of the tree once leaving the nest.

The factors of the breeding failure were classified into cases of unsuccessful hatching and unsuccessful fledging respectively. It was assorted into 4 types: unhatched if the

Table 1. Characteristics of tree species with nests of oriental scops owl (*N* = 13)

Scientific name (*N*)	Status of nest trees*		
	L	L/D	D
Zelkova serrata (4)		4	
Paulownia coreana (3)	1	1	1
Celtis sinensis (1)		1	
Salix chaenomeloides (1)	1		
Salix babylonica (1)		1	
Fraxinus rhynchophylla (1)		1	
Robinia pseudoacacia (1)	1		
Platanus occidentalis (1)		1	
Frequency (%)	23.1	69.2	7.7

*L, a live tree not including dead branches; L/D, a live tree including dead branches; D, dead tree.

Table 2. Characteristics of nest trees of oriental scops owl (*N* = 13)

Nest types (*N*)	Characteristics of nest trees (m)			
	Height of tree	Height of nest	Diameter at breast height	Diameter at nest height
Woodpecker's nest hole (6)	11.8 ± 1.4	2.5 ± 0.4	0.7 ± 0.2	0.3 ± 0.1
Natural nest hole (5)	15.6 ± 3.9	3.4 ± 0.5	1.1 ± 0.3	0.3 ± 0.1
Artificial wood box (2)	10.4 ± 0.5	3.3 ± 0.4	0.3 ± 0.1	0.2 ± 0.1
Mean ± SD	13.0 ± 3.4	3.0 ± 0.6	0.8 ± 0.4	0.3 ± 0.1

egg did not hatch within 30 days due to unfertilization or malformation, abandonment if the parent got into an accident or gave up on incubating for over a week due to external stimulus, falling is the fledgling dies by falling off the tree or gets preyed upon, and others if the cause of death was unspecified or unidentifiable.

The feeding sources and rates were studied from only one nest. In addition, we measured type of feeding sources and its time of delivery at intervals of 2 days to study how parents feed their chicks during brooding period by analyzing 910 pictures and videos.

We used Kruskal-Wallis test (SPSS ver. 12.0; SPSS Inc., Chicago, IL, USA), a statistical analysis, on incubation, fledging period and hatching asynchrony according to the nest types and performed regression analysis on the clutch size.

RESULTS

Species and status of nest trees

The trees that had the nests of oriental scops owl were 13 in total and they were *Zelkova serrata* (4), *Paulownia coreana* (3), *Celtis sinensis* (1), *Salix chaenomeloides* (1), *Salix babylonica* (1), *Fraxinus rhynchophylla* (1), *Robinia pseudoacacia* (1), and *Platanus occidentalis* (1). The status of trees with nests were in the following order: live trees with dead branches (69.2%), trees with live trunks and branches (23.1%), and dead trees (7.7%). The nest holes were mostly found on trunks (54.5%) and branches (45.5%) of trees with dead branches (Table 1).

The following are the measurements taken: height of the trees (H) were 13.0 ± 3.4 m, height of the nests (NH) were 3.0 ± 0.6 m, diameters at breast height (DBH) were 0.8 ± 0.4 m, and diameters at nest height (DNH) were 0.3 ± 0.1 m (Table 2).

Nest types and location

The nests of oriental scops owl consisted of 6 woodpecker's nest holes (46.1%), 5 natural tree holes (38.5%), and 2 artificial wood boxes (15.4%) (Tables 2 and 3).

The examined 11 nests, woodpecker's nest holes and natural tree holes, were located on trunks (54.5%) and branches (45.5%). The woodpecker's nest holes were mainly located on trunks (83.3%) and natural tree holes were located on branches (80.0%) according to nest types. (Table 3).

Characteristics of nest holes

The nest holes were measured and the result was as follows: Length of entrance was 23.5 ± 26.0 cm, breadth was 12.9 ± 5.0 cm, and depth of nest holes were 25.3 ± 12.8 cm. The measurements of natural tree holes showed relatively high value when compared with the measurements of woodpecker's nest holes (Table 4).

Table 3. Part of the tree with the nest holes of oriental scops owl (*N* = 11)

Nest types (*N*)	Part of the tree where the nest	
	Trunk	Branch
Woodpecker's nest hole (6)	5	1
Natural nest hole (5)	1	4
Frequency (%)	54.5	45.5

Table 4. Characteristics of nest holes of oriental scops owl (*N* = 11)

Nest types (*N*)	Characteristics of nest holes (cm)		
	Length of entrance	Breadth of entrance	Depth of nest hole
Woodpecker's nest hole (6)	13.8 ± 4.7	10.8 ± 4.0	20.6 ± 5.1
Natural nest hole (5)	35.0 ± 36.9	15.3 ± 5.3	30.8 ± 17.5
Mean ± SD	23.5 ± 26.0	12.9 ± 5.0	25.3 ± 12.8

Table 5. Relationship between clutch size and breeding period of oriental scops owl (*N* = 13)

Clutch size (*N*)	No. of eggs	Breeding period(day)		
		Incubation period	Brooding period	Hatching asynchrony
3 (1)	3	22	22	2
4 (5)	20	24.0 ± 0.8	23.0 ± 2.9	3.3 ± 0.5
5 (7)	35	25.0 ± 0.8	24.0 ± 2.7	3.9 ± 0.4
Mean ± SD	4.5 ± 0.7	24.4 ± 1.2	23.5 ± 2.6	3.5 ± 0.7

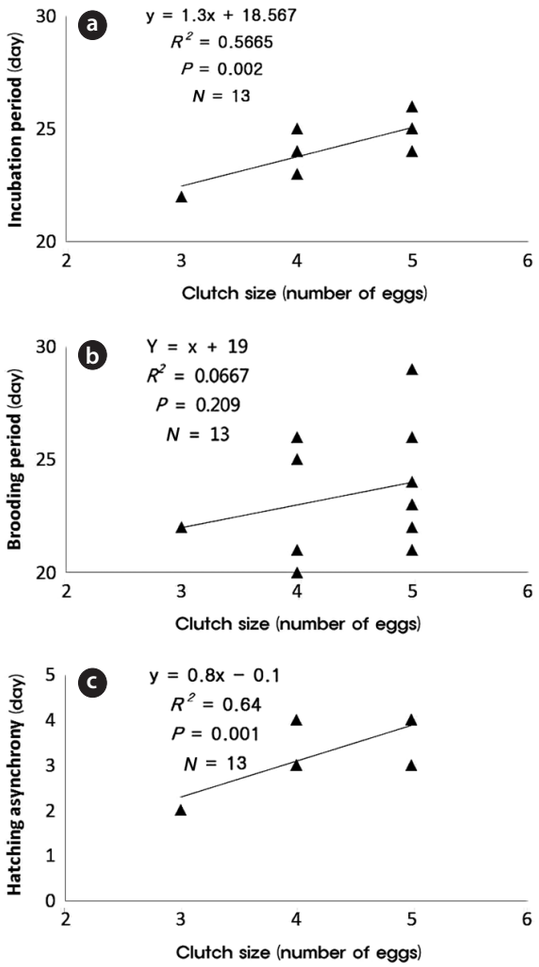

Fig. 4. Regression analysis between clutch size and breeding period of oriental scops owl (*N* = 13). (a) incubation period, (b) brooding period, (c) hatching asynchrony.

Clutch size, incubation and brooding period

The average clutch size of oriental scops owls were 4.5 ± 0.7 eggs (minimum 4 and maximum 5 eggs). The average incubation period of these owls were 24.4 ± 1.2 days and average brooding period was 23.5 ± 2.6 days. Oriental scops owl is a bird with hatching asynchrony and it took 3.5 ± 0.7 days from the first hatch until the last hatch (Table 5).

It was found that incubation period and hatching asynchrony increased in proportion to the clutch size according to the analysis on clutch size. However, clutch size did not affect the brooding period (Table 5 and Fig. 4). It did not affect incubation period and hatching asynchrony but showed a difference in the brooding period according to the nest types (Table 6).

Hatching, fledging, breeding success and failure factor

Hatching success rate, fledging success rate, and breeding success rate of oriental scops owl were 91.4%, 83.0%, and 75.9%, respectively. All the eggs in the woodpecker's nests were successfully hatched with relatively low fledging success (69.2%) and their breeding success was 69.2%. On the other hand, natural tree holes had lower hatching success (79.2%) but had relatively high fledging success (94.7%) amounting to breeding success of 75.0%. The eggs laid in artificial nests were all successfully led to fledging resulting in having the highest breeding success (Table 7). The breeding failure factors were unhatched (7.1%), abandonment (28.6%), falling (57.1%), and others with

Table 6. Relationship between nest types and breeding period of oriental scops owl (*N* = 13)

Nest types (*N*)	Breeding period (day)		
	Incubation period	Brooding period	Hatching asynchrony
Woodpecker's nest hole (6)	24.2 ± 1.5	25.2 ± 2.5	3.3 ± 0.8
Natural nest hole (5)	24.4 ± 1.2	23.0 ± 1.6	3.8 ± 0.5
Artificial wood box (2)	24.5 ± 0.7	20.5 ± 0.7	3.5 ± 0.7
Mean ± SD	24.3 ± 1.2	23.6 ± 2.5	3.5 ± 0.7
*P**	0.856	0.039	0.675

*Kruskal-Wallis test.

Table 7. hatching, fledging and breeding success in different nest types of oriental scops owl (*N* = 13)

Variables (%)	Nest types (*N*)			Total
	Woodpecker's nest hole (6)	Natural nest hole (5)	Artificial wood box (2)	
Hatching Success	100	79.2	100	91.4
Fledging Success	69.2	94.7	100	83.0
Breeding Success	69.2	75.0	100	75.9

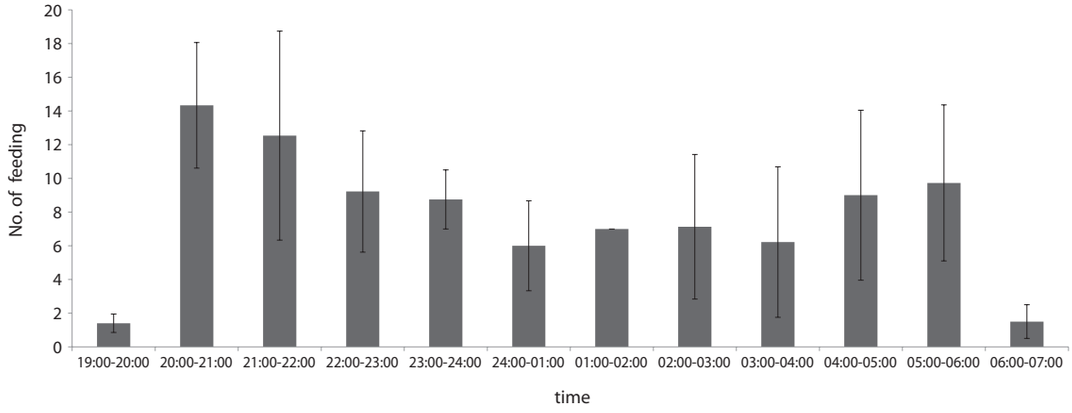

Fig. 5. Frequency of feeds by oriental scops owls (*N* = 910).

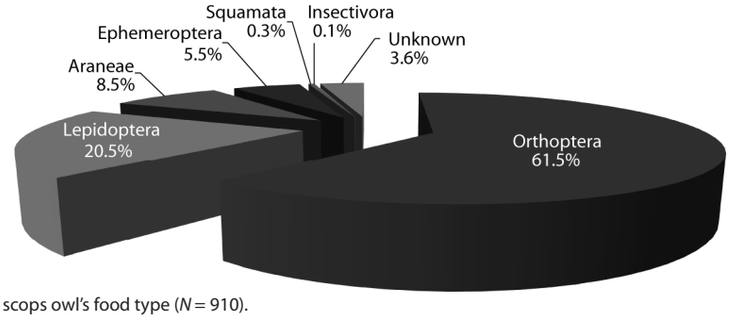

Fig. 6. Frequency of oriental scops owl's food type (*N* = 910).

unknown cause of death (7.1%). Falling (87.5%) was the main breeding failure factor in case of woodpecker's nest holes but other factors had low possibility (12.5%). Abandonment (66.7%) was also the main breeding failure factor in case of natural tree holes where unhatched and falling (each 16.7%) were confirmed (Table 8).

Feeding source and rate

The oriental scops owl's food delivery began around 20:00 and over around 06:00. Food delivery times were higher in the early evening and fell in the middle night. But, early in the morning, they temporarily increased. The type of feed was identified as the order level because resolution of the image was low (Fig. 5). The types of feed were Orthoptera (61.5%), Lepidoptera (20.5%), Ataneae (8.5%), Ephemeroptera (5.5%), Squamata (0.3%), Insectivore (0.1%) and unknown (3.6%) in order (Fig. 6).

Food delivery was growing at 35 times the initial incubation and increased by up to 117 times in 17 days. But, thereafter, feeding delivery number gradually decreased. Food delivery was entirely dedicated by male owls in initial breeding, but the female owls participated from 9 days after hatching. Thereafter, the closure fledging period, the proportion of male and female feeding rate became almost equal (Fig. 7).

Table 8. Factors of breeding failed (*N* = 14)

Variables (%)	Nest types (*N*)		Total
	Woodpecker's nest hole (8)	Natural nest hole (6)	
Unhatched	-	16.7	7.1
Abandon	-	66.7	28.6
Falling	87.5	16.7	57.1
etc.	12.5	-	7.1

DISCUSSION

Oriental scops owls are used to nesting on trees that have similar height and DBH like Japanese zelkova (*Zelkova serrata*), Korean paulownia (*Paulownia coreana*), etc. These owls are used to having natural tree holes, woodpecker's nest holes, and artificial wood boxes as their nests. But, they are more used to relatively low height and DBH

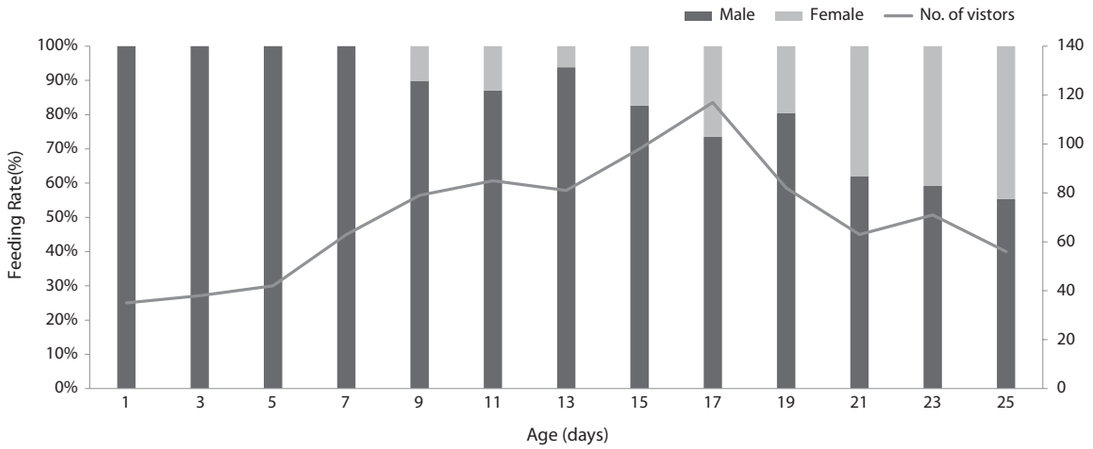

Fig. 7. Frequency of feeding by male and female oriental scops owl (*N* = 910).

of trees such as black locust (*Robinia pseudoacacia*) in the case of artificial nests. The size of nest entrance seemed to be the determining factor for oriental scops owls rather than the tree species and nest types. In particular, the entrance of artificial nests with hole diameter greater than 7 cm were suitable for breeding. Therefore, it seems like oriental scops owl select artificial wood boxes as their nests because holes with that size are not easy to find in the forest. There are not many studies done on what type of trees and vegetation they prefer but it was reported that they breed in natural tree holes, woodpecker's nest holes, and in nearby forests (Bird life international 2014). Concealed places like natural tree holes and woodpecker's nest holes are safe and it can protect them from unfavorable environmental conditions such as wind, temperature fluctuations, and radiation resulting in higher breeding success rate (Rico and Sandoval 2014).

It has been reported by a precedent study that the clutch size of oriental scops owl is about 3-6 eggs (NIBR 2011). Such differences are known be caused by immaturity, aging, health of the female owl or by abundance of food in the breeding region (Price and Liou 1989).

Oriental scops owl's hatching period and hatching asynchrony were extended along with the increase in clutch size but brooding period of artificial wood boxes and natural tree holes did not differ. We assumed that this result was affected by small number of samples and we estimated that this result could change with greater number of samples. The brooding period differed for each nest type. The brooding period was relatively short in artificial wood boxes but it was long in woodpecker's nest holes. This result shows that fledglings of oriental scops owl could not practice their wing stroke or exercise their wing muscles in woodpecker's nest holes because the entrance size was too small. Thus, the fledging period can be shortened if sufficient space is available in artificial and natural nests.

The fledglings of birds go under fledging process (leaving the nest) after it hatches. The fledglings of black-winged stilt (*Himantopus himantopus*) which is a precocial species start walking and feeding activity with its parents after 12 hours of hatching (Cho and Kim 2001). However, Eurasian eagle owls (*Bubo bubo*), an altricial species, come out the nest normally around 7 weeks after hatching but they get fed by the parents for 5 months (Shin and Paek 2008).

Oriental scops owls are altricial species so the fledglings during their fledging period jump off the nest onto the ground and climb back up the tree. They stably complete the fledging process as they get fed by the parents until they learn to fly. But the entrance of woodpecker's nest holes were found more on trunks than on branches unlike natural tree holes (Table 2). In addition, it has been reported that woodpeckers generally drill the nest entrance horizontally or downwards instead of upwards (Kwon et al. 2012). Therefore, the fledglings of oriental scops owl cannot directly climb the tree coming out of the nest entrance so it has to come down to the bottom first in order to climb on the trunk of a tree. This causes greater possible exposure to risks such as falling and being preyed upon. On the other hand, natural tree holes had relatively wider nest entrance than woodpecker's nest holes and artificial wood boxes. The natural tree holes are open-shaped and entrance of nest holes head upwards. It is favorable for the fledglings of oriental scops owl to climb the tree coming out of the nest but the nest is eas-

ily exposed to poor climate such as strong wind and rain which can lead to possible unhatching of eggs.

On the contrary, it is determined that artificial nest can supplement the weaknesses of woodpecker's nests and natural tree holes even though the statistical significance cannot be verified because only two artificial nests were studied. The entrance of artificial wood boxes are smaller than natural tree holes. It has been reported that the quality, type, and location of the nest holes are major factors that affect the breeding success according to advanced research (Alatalo et al. 1988). Thus, the hatching rate can be relatively high because of less exposure to environmental factors such as rain, wind, and so on (Alatalo et al. 1988). In addition, artificial nests can be installed in habitats with stable environment where trees have many branches or in habitats overgrown with shrubs.

Therefore, fledglings can avoid jumping directly onto the ground when they fledge and they can climb up the tree into their nests easily. As a result, fledglings of oriental scops owl can be relatively safe from the threat of predators and crashing.

It has been reported that artificial wood boxes are good resources to birds that use natural tree holes as their nests (Kim and Oh 2013) and it plays a role in increasing the diversity of species in the damaged ecosystem (Saarikivi and Herczeg 2014). However, more studies are required in the future because not many studies were done on the relationship between nest types and breeding success.

Most of the studies reported oriental scops owls feeding on small nocturnal animals but we took into consideration the type of nest, location of the habitat, and clutch size which influences the type of feed. But, this study was limited to studying only one nest which made it was difficult to accurately identify these factors in detail.

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