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Use of an Infrared Monitor to Record the Frequency and Timing of Parental Nest Visitation by the Blue Rock Thrush *Monticola solitarius*

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Toshimitsu Nuka, Yoshitaka Morikawa, and Christopher P. Norman (2011) Use of an infrared monitor to record the frequency and timing of parental nest visitation by the Blue Rock Thrush *Monticola solitarius*. *Zoological Studies* **50**(1): 16-23. We observed the nest visitation behavior of the Blue Rock Thrush *Monticola solitarius* by setting up an infrared monitoring system (IMS) at the entrance of a Blue Rock Thrush nest hole. Furthermore we carried out visual observations and video image analysis to confirm the IMS data and discuss the efficiency of the IMS. Two consecutive broods in 1999 (Apr.-July) and 1 brood in 2006 (Apr.-June) were monitored. The IMS recorded a consistent nest visitation pattern in all 3 broods. During the incubation stage, about 20 ± 8 (mean ± S.D., $n = 33$) responses per day were recorded as the female emerged from the nest hole to feed at regular intervals. During the nestling stage, about 105 ± 47 (mean ± S.D., $n = 42$) responses per day were recorded as the parents visited the nest hole to feed the chicks at about 10 min intervals. From the light intensity and IMS data, the daily activity pattern of the Blue Rock Thrush showed clear diurnal activity from before sunrise (-0.209 log Lum/m^2) to after sunset (-0.100 log Lum/m^2). The efficiency of the IMS was verified using video and visual observations, and around an 87% accuracy was confirmed. We concluded that after an initial confirmation of the efficiency of the IMS, the visitation behavior of Blue Rock Thrush in the incubation and nestling stages can be estimated using IMS data. For general monitoring of behavioral patterns, the IMS is weatherproof, requires minimal maintenance, and can be used for long-term monitoring. We concluded that the IMS is more efficient than using a video camera for monitoring hole-nesting animals because the time required for analysis is greatly reduced. http://zoolstud.sinica.edu.tw/Journals/50.1/16.pdf

Key words: Incubation, Infrared monitoring system, Light intensity, Nest hole, Nestling.

It is often difficult to observe the activity of animals that use holes or crevices for nest sites by direct visual or video observations because of the high costs and manpower required. A variety of methods (e.g., light- or mechanically triggered systems, time-lapse systems, and so on) for hole-dwelling and -nesting animals can be used as reviewed by Cutler and Swann (1999). In this study, an infrared monitoring system (IMS) was used to record the nest visitation time of the Blue Rock Thrush *Monticola solitarius* by setting up the IMS at the entrance of a nest hole. The IMS is weatherproof and inexpensive and has been demonstrated to be effective for monitoring activity patterns (Morikawa et al. 2003). The IMS has the potential to monitor the movement patterns of various animals that inhabit holes, especially during low-light-intensity (dusk and dawn) periods, when direct observations are difficult.

The Blue Rock Thrush is distributed in southern Europe and North Africa to East and Southeast Asia, and inhabits rocky shores and

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*To whom correspondence and reprint requests should be addressed. E-mail:tnuka@hotmail.co.jp mountain cliffs (Cramp 1988). The total length of this bird is 20-23 cm (Cramp 1988, Clement 2000). In Japan, the subspecies *M. s. philippensis* occurs on rocky shores and island areas (Kiyosu 1978), and is a resident species along the rocky shores of Kamogawa, Chiba (Chiba Prefecture 1976, Nuka et al. 2003). *Monticola s. philippensis* is sexually dimorphic with the male having a rufous-chestnut breast and blue upperparts, while the female is brown over the entire body (Cramp 1988), and therefore sexes are easily distinguishable. However, details of the ecology of the Blue Rock Thrush in Japan remain unclear. It is difficult to observe aspects of the reproductive ecology (e.g., egg incubation and visitation frequency until fledging) in the field without an extensive research effort such as continuous observations because this species nests in holes (Kiyosu 1978, Hayashi 1997, Cramp 1988).

In this study, we assessed the nest-visitation behavior during the incubation and nestling stages of the Blue Rock Thrush using an IMS and discuss the parental activity and potential advantages of using the IMS.

MATERIALS AND METHODS

This study was carried out during 30 Mar.-9 Aug. 1999 and 15 Apr.-31 July 2006 at the Marine Biosystems Research Center, Chiba Univ. (35° 07'02"N, 140°11'20"E). The laboratory is located on the west coast of Uchiura Bay, Kamogawa, Boso Peninsula, southeastern Chiba Prefecture, and faces the Pacific Ocean (Fig. 1). This area has a warm coastal climate (Marine Biosystems Research Center, Chiba University 2001). The landform is of a rias coastal morphology, and the vegetation consists of evergreen and broadleaf forests.

There are 2 round holes which extend into horizontal cavities in a concrete wall which faces the shore in front of the laboratory (Fig. 1). The holes were originally a water drain for the laboratory but now are blocked, and no water drains. These holes are 20 cm in diameter and

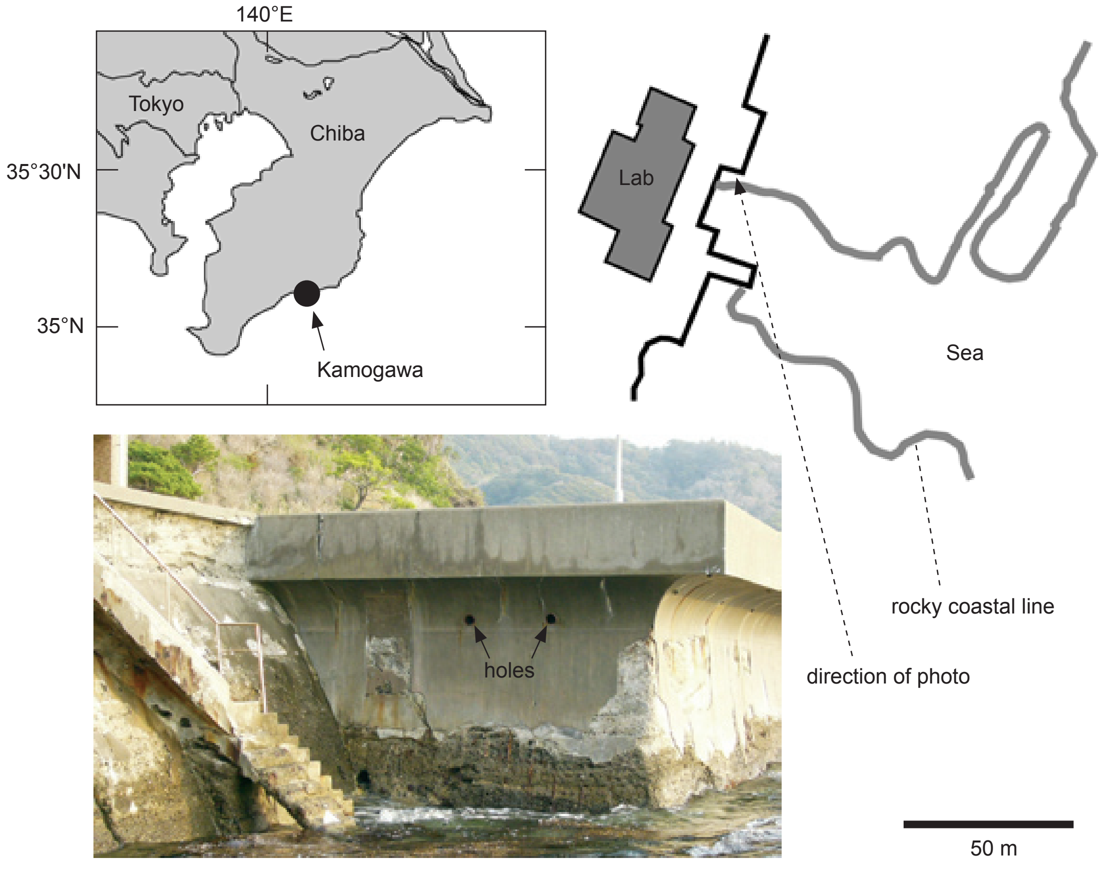

Fig. 1. Study area. Arrows on the photograph indicate the site of the nest hole. The gray, thick line, marked "rocky coastline", indicates the tidal level at low water at the spring tide.

~55 cm deep. The size and position of the holes horizontally set in a vertical concrete wall largely prevent disturbance by potential predators such as snakes, crows, rats, and birds of prey. Prior to the study years, the Blue Rock Thrushes were annually observed to nest in these holes (T. Nuka, pers. observ.). In the study years, the potential nest hole was identified by the nest building behavior of the female.

An IMS, consisting of an infrared (IR) sensor to detect the passage of objects and a battery to run the sensor and data logger, was used to record the response time of the IR sensor (Morikawa et al. 2003, costing ~US$300, and includes a PS-3051 infrared sensor and beam source, EK Japan, Fukuoka, Japan, and an H06-001 data logger, Onset Computers, Hobo, Bourne, MA, USA). In 1999, the system described in Morikawa et al. (2003) was used. This system was originally designed for use in seawater and was packed with silicon bond to weatherproof the system. In 2006, the system (Fig. 2) was reconstructed (with a smaller-sized protective case) to reduce the volume of the sensor and beam source parts (achieving an 80% reduction) and also to increase the capacity of the battery (a 1400% increase in continuous work time). Changes in the system between 1996 and 2006 led to improved sensitivity as the position of the IR beam was set closer to the hole mouth.

The IMS was installed at the entrance of the nest hole during 4 Apr.- 28 July 1999 and 15 Apr.- 31 July 2006 (Fig. 1). After problems with data downloading during the 1st brood in 1999, battery exchange and data downloading were carried out once every 2 d. Nest visitation frequencies based on the IMS data are presented as the frequency per day or as mean values (± standard deviation; S.D.) per hour. There were no data from 12:00 on 3 May to 11:00 on 17 May in 1999 because of battery-system failure. We verified the IMS precision by visual observations in 1999 and by recording and analyzing video images of the entrance of the nest hole in 2006.

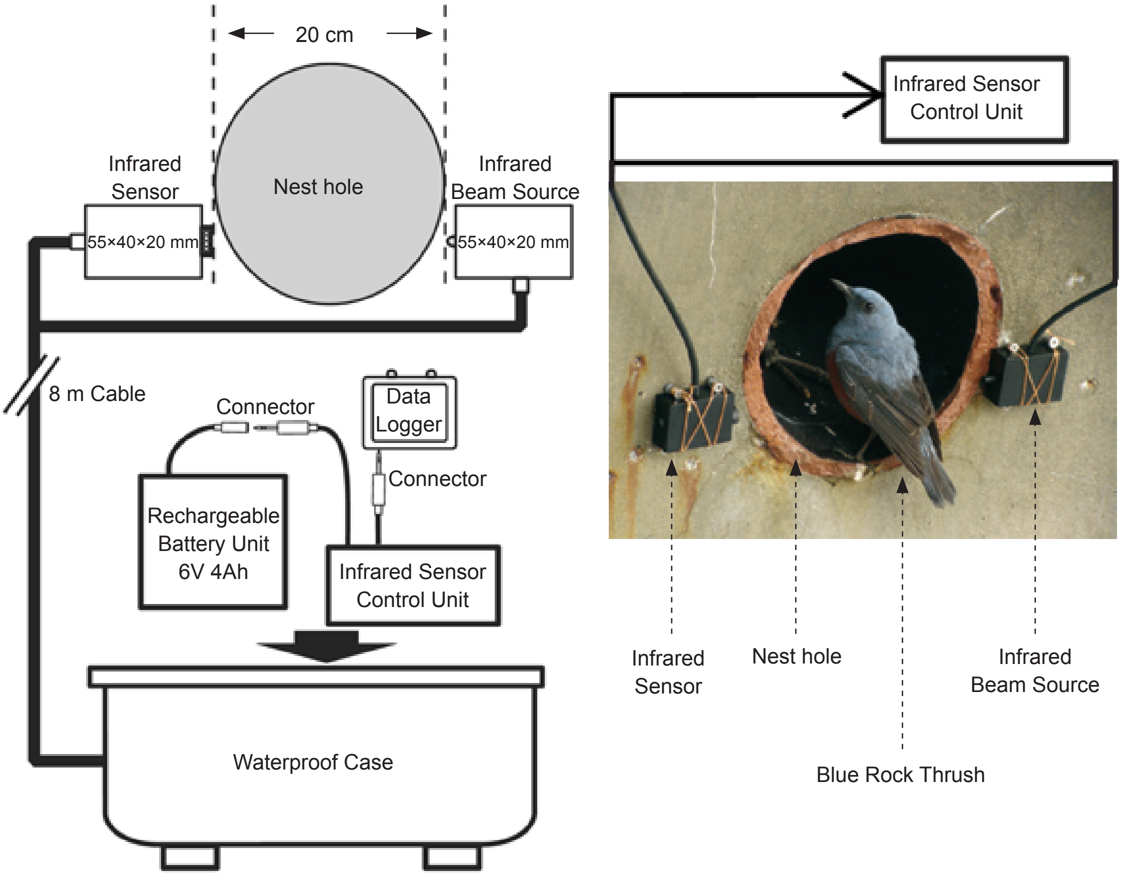

Fig. 2. Schematic diagram of the weatherproof infrared monitoring system. The photograph is of the male *Monticola solitarius* when it had alighted at the entrance of the nest hole, directly obscuring the beam of the IMS.

The IMS and video were programmed/downloaded using the same computer, and the time setting of the computer was based on the news (NHK) time signal of the national broadcasting network. Similarly during visual observations, the observer set his watch using the NHK news time signal; differences between the IMS and observer quoted times were minimal. In 1999, using 8x binoculars and a 20-45x telescope, visual observations were made opportunistically in the daytime for 68 d (for a total of 97.4 h over 46 d for the 1st brood and 21.2 h over 22 d for the 2nd brood) from the rooftop of the laboratory which is about 40 m from the nest hole, from where we could see the opening of the nest hole. In 2006, we set up a video camera to record the entrance of the nest hole opportunistically during the daytime for 24 d (for a total of 160.4 h) during the study period. The video camera was about 20 m from the entrance of the nest hole.

The number of visitations by adult birds may be affected by environmental factors (Lin et al. 2007). To study the effect of physical factors on bird activities, the effects of rainfall (to examine if rainfall affects the chick-feeding behavior) and light intensity (to examine if there are night behaviors which cannot be observed visually) on nest visitation frequency were analyzed. A light-intensity sensor (StowAway, Onset Computers, Bourne, MA, USA) was installed in the field on 6-22 May and 24 June- 3 July 1999. Mean values are presented with the S.D. Rainfall data were obtained from the online database of the Japan Meteorological Agency (http://www.jma.go.jp/jma/index.html).

In this study, we assessed the visitation frequencies during the incubation stage as the female Blue Rock Thrush left the nest hole to feed during incubation of the eggs and during the nestling stage when both parents brought food items to feed the chicks. The incubation stage was defined as the duration from the day a female remained for an extended period (more than 30 min) in the nest hole to the day before the chicks hatched, which was estimated from observations of when the parents began to carry prey items to the nest hole. The nestling stage was defined as the duration from the day the parents began to carry prey items to the day before the fledglings left the nest hole. Initiation of incubation and the day of hatching were also confirmed by direct observations at night using a step ladder and flashlight on 20 Apr. and 6 June 1999 and by use of a camera fixed to a telescope on 29 Apr. 2006 to check whether the female stayed in the nest and whether there were nestlings in the nest, respectively.

RESULTS

In total, 3 broods, 2 in 1999 and 1 in 2006, were measured using the IMS. The IMS data showed a similar pattern for all 3 broods. Comparing the results of the video image analysis with the IMS data, responses of the IMS were recorded according to the nest visitation of the parents (Fig. 3). Responses showed the following 4 patterns: 1) there were 2 IMS responses, one when a parent entered and one when it left the nest hole; 2) only 1 response was recorded either when a parent entered or left the nest hole; 3) multiple responses were recorded; and 4) there was no response. However, during the observations (a total of 160.4 h over 24 d on 16 Apr.- 10 July 2006), the most common response

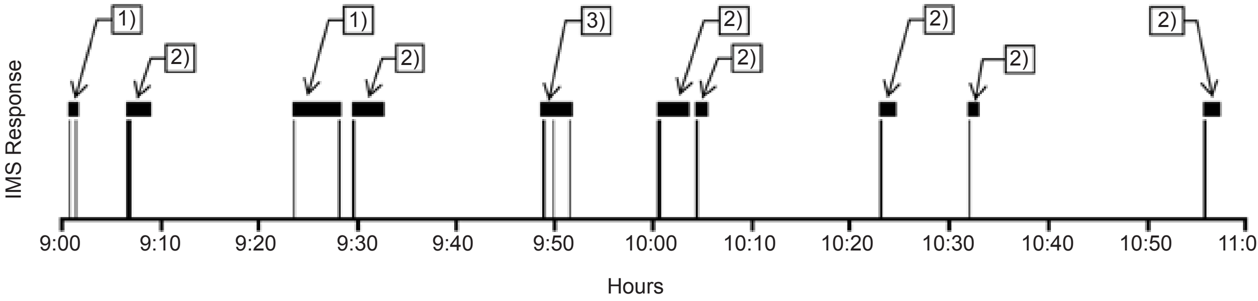

Fig. 3. Presence of *Monticola solitarius* in the nest hole based on infrared monitoring system (IMS) data and video image analysis at 09:00-11:00 on 15 May 2006. Black horizontal bars above the bar graphs indicate the presence of *Monticola solitarius* in the nest hole, which was confirmed by the video image analysis. The thickness of the vertical bars in the graph indicates the duration that the parents stayed at the entrance of the nest hole. 1), 2), and 3) indicate each of the response patterns (see explanation in “RESULTS”).

patterns were 1), 2), and 3) (*n* = 47, 130, and 21, respectively; totaling 87% of the visually confirmed visitations), and there were few instances (*n* = 29) of pattern 4) of no response. Based on visual observations and the video-image analysis, multiple responses occurred because the parents remained near the entrance of the nest hole and the body or tail section triggered IMS responses. The cause of no response was because the parent bird did not cross or only partially crossed the optical axis of the IMS, when it flew directly into the nest without alighting at the entrance of the hole or it launched directly into flight from within the nest and flew above the optical axis. However, in most cases, the parent birds stopped at the entrance of the hole when they entered or left the nest.

Based on the daily response frequency of the IMS, the breeding stages were deduced, and these were confirmed by visual observations and video-image analysis (Fig. 4). Based on the visual observations, during the incubation stage, the female handled all of the egg incubation. The female came out of the nest hole about once an hour during daylight hours (Table 1), and 20.0 ± 8.8, (*n* = 33) response frequencies per day were recorded by the IMS (including type 1, 2, and 3 response patterns). Based on the IMS data (Fig. 4), the incubation stage was 14 d, estimated to be

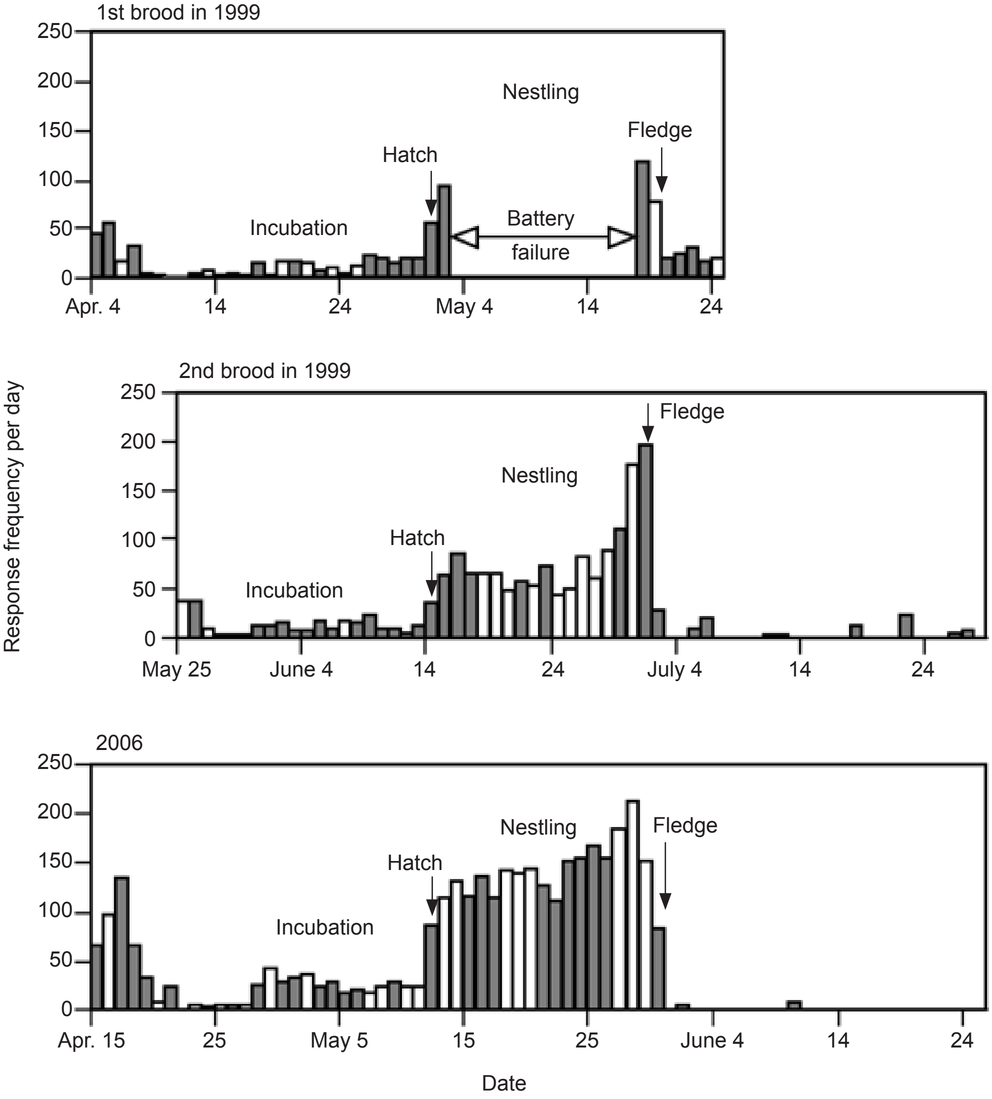

Fig. 4. Daily response frequency of the infrared monitoring system (IMS) and breeding stages of *Monticola solitarius* assessed from the IMS response patterns for the 1st and 2nd broods in 1999 and the brood in 2006. Each brood is vertically aligned in the figure to the day of hatching. White bars indicate days that rainfall exceeded 1 mm.

17-30 Apr. for the 1st brood and 31 May- 13 June for the 2nd brood in 1999 and 28 Apr.- 11 May 2006. In the nestling stage, because both male and female visited the nest hole to feed nestlings and to carry droppings outside at about once every 10 min (Table 2), response frequencies per day were higher than in the incubation stage (Mann-Whitney *U*-test, 1st 1999 brood n_1 = 11, n_2 = 3, U = 0, p = 0.0101; 2nd 1999 brood n_1 = 8, n_2 = 17, U = 0, p < 0.0001; 2006 brood n_1 = 14, n_2 = 19, U = 0, p < 0.0001), when 105.8 ± 47.3 (n = 42) responses per day were recorded. In the nestling stage, all observed prey items brought by the parents were insects or lizards; centipedes were the most frequent prey item (T. Nuka, unpubl. data). In the latter part of the nestling stage, response frequencies were about 200 responses per day, due to the grown nestlings coming to the hole entrance (the IMS was triggered by the nestlings) prior to fledging, and adults coming to the entrance to urge the nestlings to fledge. Therefore, the IMS was effective in recording the frequency of nest visits by the adults until the nestlings begin to move to the entrance of the nest hole in preparation to fledge. Nestlings fledged after 18 (2nd brood in 1999) and 19 d (1st brood in 1999 and in 2006) from the estimated day of hatching. After fledging, except for the 1st brood of 1999 when the nest was reused, the response frequencies of the IMS were significantly fewer (Mann-Whitney *U*-test, 1st 1999 brood n_1 = 3, n_2 = 13, U = 0, p = 0.0087; 2nd 1999 brood n_1 = 17, n_2 = 10, U = 0, p < 0.0001; 2006 brood n_1 = 19,

Table 1. Mean time period (minutes: seconds) that the female was out of and in the nest hole during the incubation stage (data based on direct observations and IMS data). Hyphens indicate no visual confirmation of the data

Brood	Out of the nest hole		
	Mean	SD	N
1st, 20 to 30 Apr. in 1999	12m50s	3m46s	12
2nd, 6 to 13 June in 1999	-	-	-
28 Apr. to 11 May in 2006	13m57s	3m56s	21

Brood	In the nest hole		
	Mean	SD	N
1st, 20 to 30 Apr. in 1999	53m30s	11m2s	4
2nd, 6 to 13 June in 1999	-	-	-
28 Apr. to 11 May in 2006	68m54s	43m29s	20

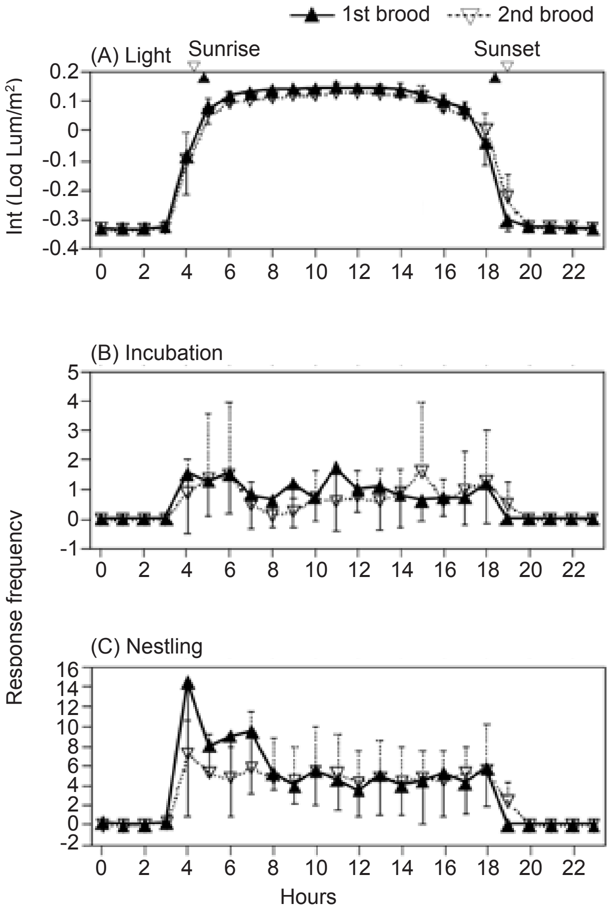

Fig. 5. Light intensity and activity time of *Monticola solitarius* in 1999. Black triangles with continuous lines and standard deviation (minus direction) are for the 1st brood. Open triangles with broken lines and standard deviation (plus direction) are for the 2nd brood. (A) Light intensity per hour. Data for the 1st brood were based on the period of 6-20 May and the 2nd brood of 24 June- 1 July. The mean sunrise and sunset times during each breeding period are indicated by black and open triangles, respectively, at the top of the figure. (B) Response frequency of the IMS per hour in the incubation stage for the 1st (20-30 Apr.) and 2nd broods (6-13 June). (C) Response frequency of the IMS per hour in the nestling stage for the 1st (during 2-3 and then 17-19 May; see explanation in MATERIALS AND METHODS) and 2nd broods (15 June- 1 July).

Table 2. Interval (minutes: seconds) between parental visits to the nest hole in the nestling stage (data based on direct observations and infrared monitoring system data)

Brood	Mean	SD	N
1st, 2 to 19 May in 1999	8m15s	7m25s	217
2nd, 14 June to 1 July in 1999	11m13s	11m54s	28
12 to 30 May in 2006	10m57s	11m17s	188

n_2 = 10, U = 0, p < 0.0001). The number of fledglings was 3 birds in the 1st and 2nd broods in 1999 and 4 birds in 2006. Since the IMS response patterns for the 3 broods were similar, we deduced that the incubation stage was ~14 d and nestling stage was 18-19 d in this study area.

IMS data of 4-7 Apr. 1999 and 15-21 Apr. 2006, before the incubation stage, was due to visitation at the entrance of the hole to seek and build the nest by the parents. IMS data of 20-27 May 1999 occurred due to reusing the nest. IMS data after fledging on 2 June 1999 and 1 July 2006 occurred by occasional visits of parents to look for prey items. These behaviors were observed by video images and/or visual observations.

The relation between rainfall and IMS response frequencies was studied to determine if weather affected Blue Rock Thrush activity. In the incubation and nestling stages, the correlation coefficients between daily rainfall and nest visitation frequency (only for the hours that rainfall was > 1 mm/h between 04:00 and 19:00) were calculated. However, with the exception of when rainfall was particularly heavy at 19 mm/h at 6:00-7:00 on 20 May 2006 (only 1 response), it was found that there was no effect of rainfall (see black and white bars in Figure. 4, 1st 1999 brood n = 27, r = -0.212, p = 0.2907; 2nd 1999 brood n = 8, r = -0.603, p = 0.1186; 2006 brood n = 26, r = -0.056, p = 0.7877; no data for 1st nestling in 1999, 2nd 1999 brood; n = 31, r = 0.333, p = 0.0667; 2006 brood n = 38, r = -0.252, p = 0.1271).

From the IMS data and light intensity measured by the light sensor (Figs. 5, 6), response frequencies were negligible at night (1.3 ± 6.9 per night; n = 40). The Blue Rock Thrush exhibited a clear diurnal activity pattern. Particularly during the nestling stages, parental activity of bringing food to the chicks began as soon as it became light before sunrise (-0.209 ± 0.088 log Lum/m^2) and finished shortly after sunset (-0.100 ± 0.046 log Lum/m^2; Fig. 5). Light was significantly brighter at the end of activity than at the initiation of activity (Mann-Whitney U-test, n_1 = 10, n_2 = 9, U = 10, p = 0.0042). Since the diurnal length of the 2nd brood in 1999 was longer than that of the 1st brood, the activity time was also longer (Table 3).

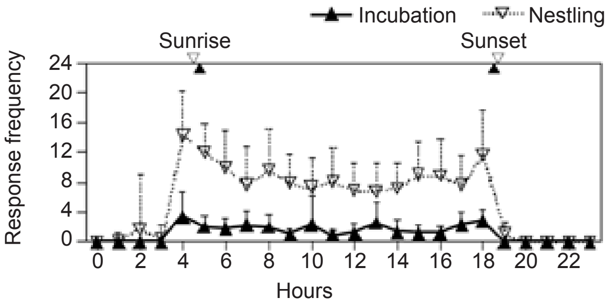

Fig. 6. Response frequency of the infrared monitoring system per hour in 2006. Black triangles with continuous lines are for the incubation stage. Open triangles with broken lines are for the nestling stage. The mean sunrise and sunset times are indicated by black and open triangles, respectively, at the top of the figure.

DISCUSSION

From the results of the visual observations in which the parents brought prey items to their chicks in the nestling stage of the 1st brood as frequently as during the 2nd brood in 1999, the behavioral pattern in the 1st nestling stage was considered to be the same as for the IMS response pattern in the 2nd brood (Fig. 5).

The incubation (~14 d) and nestling (19 and 18 d) periods were deduced using the IMS in this study, and these were similar to the incubation period (12-15 d) and nestling period (~18 d) in Europe as described by Cramp (1988). The

Table 3. Daily initiation and termination of activity time and the duration of activity (hours: minutes) in the incubation and nestling stages measured by the infrared monitoring system

Stage	Period	Initiation time			Termination time			Duration of activity		
		Mean	SD	N (Day)	Mean	SD	N (Day)	Mean	SD	N (Day)
Incubation	20 to 30 Apr. in 1999	6:05	2:24	11	18:12	0:31	11	12h7m	2h47m	11
	6 to 13 June in 1999	6:01	2:50	8	18:32	0:45	8	12h31m	2h40m	8
	28 Apr. to 11 May in 2006	4:41	0:15	14	18:41	0:12	14	14h	25m	14
Nestling	2 to 19 May in 1999	4:12	0:09	4	18:46	0:10	3	14h41m	20m	2
	14 June to 1 July in 1999	4:09	0:14	18	19:06	0:21	18	14h57m	25m	18
	12 to 30 May in 2006	4:09	0:07	19	18:59	0:07	19	14h51m	12m	19

activity time of the Blue Rock Thrush in the breeding period measured by the IMS extended from immediately before sunrise to immediately after sunset, which was similar to the activity time (from before sunrise to after sunset) described in western Spain (Cramp 1988). Therefore the durations of the incubation and nestling stages, the hatching day, fledging day, and activity time could be elucidated from the response pattern of the IMS.

During the incubation stages in 1999, the daily time at which activity was initiated varied, ranging about 04:03-12:36, whereas the termination time was more regular (Table 3). However, during the nestling stage, both the initiation and termination times of activity showed minimal variations. If some exceptionally late times in the incubation stage in 1999 were excluded (09:17, 09:17, and 10:44 in the 1st brood and 12:36, 06:21, 06:09, and 05:56 in the 2nd brood), then the daily initiation times of activity in 1999 were 04:41 ± 00:15 (mean ± S.D., $n = 8$) in the 1st and 04:15 ± 00:12 ($n = 4$) in 2nd, and the initiation time of activity was 04:41 ± 00:15 ($n = 14$) in the incubation stage in 2006. We could not find a reason why the daily initiation time of activity in the incubation stages showed such variability. However, possibilities include responses to some perceived predation threat, variability in the birds' behavior, or the IMS was not triggered (response pattern 4) on entering/exiting the hole.

Based on the response pattern of the IMS in the 1st brood in 1999, the high manpower requirement for visual observations was reduced in the 2nd brood. The direct visual observation time on the 2nd brood (a total of 21.2 h for 22 d) was far less than the 1st brood (a total of 97.4 h for 46 d), although the IMS requires an initial period of visual observations to relate the IMS responses to actual behaviors. For long-term usage, apart from periodic maintenance to remove dust etc. that may obscure the infrared sensor and/or beam source, the IMS only requires occasional hard image/observational data for confirmation of the response patterns. We suggest that the IMS is potentially effective for continuous, non-intrusive monitoring of entrance/exit patterns of hole-dwelling birds, as well as other creatures which change activity patterns depending on the breeding stage.

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