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红胁蓝尾鸲(*Tarsiger cyanurus*)在中国东北部帽儿山地区的迁徙中途停歇生态

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摘要:中国迁徙鸣禽类的保护面对着与世界其他地区如欧洲和北美洲鸟类保护相似的挑战。迁徙鸣禽类具有复杂生活周期和很大的空间关联。迁徙过程中发生的事件对迁徙鸣禽类种群动态具有决定作用。对于鸣禽类迁徙中途停歇期的生态,比如停歇期的长短,能量的积累,生境的利用等,了解还非常有限。在中国东北部的一个鸟类迁徙停歇地对红胁蓝尾鸲(*Tarsiger cyanurus*)的中途停歇生态包括迁徙时间、停歇时间、能量状态和性比进行了研究。2002 年秋和 2003 年春分别捕获了 1751 只和 684 只红胁蓝尾鸲。红胁蓝尾鸲的体重在秋季迁徙时要比在春季迁徙时重。春季雌性红胁蓝尾鸲停歇时的能量状态指数最低;而秋季的红胁蓝尾鸲比春季的红胁蓝尾鸲停歇时间更长。无论季节和性别,红胁蓝尾鸲的能量状态指数和第 1 次捕获的时间早晚成正相关,间接证明红胁蓝尾鸲在停歇期间能够比较快地积累能量。秋季雄性红胁蓝尾鸲日体重净增率最大。估测秋季停歇期的每日能量净增能维持红胁蓝尾鸲雌性 0.6h 和雄性 3.1h 的飞行。红胁蓝尾鸲的中途停歇生态与北美和欧洲一些迁徙鸣禽类很相似。比如,春季迁徙过境的时间和脂肪积累的变化与自然选择对雄性的要求:当食物和气候适宜时尽快到达繁殖地的假设是一致的。对迁徙中途的停歇生态研究有利于更好地了解鸟类的迁徙行为和更有效地保护迁徙鸣禽类。

关键词:鸟类保护;鸟类迁徙;中途停歇生态;中途停歇地;红胁蓝尾鸲 Red-flanked Bush Kobin(*Tarsiger cyanurus*)
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Stopover ecology of *Tarsiger cyanurus* at Maoershan of northeast China

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Abstract: The conservation of songbird migrants in China faces challenges similar to those in other parts of the world such as Europe and North America. Songbird migrants have complex life history and are associated with large spatial scale. The events occurred during migration play a critical role in determining population status. Little is known about stopover behavior of migratory songbirds in China during passage, including stopover duration, energetic condition (e.g., the amount of fat stores), and habitat use of these birds. We investigated migration timing, stopover duration, change of energetic condition, and sex-related variations among Red-flanked Bush Robin (*Tarsiger cyanurus*) at a stopover site in northeast China. A total of 1,751 and 684 Red-flanked

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Bush Robins were captured in fall 2002 and in spring 2003, respectively. Body mass of fall birds was higher than that of spring birds. Condition index (i.e., body mass adjusted for body size) was lowest among spring females. Birds were more likely to stay longer in fall than in spring. We detected a positive relationship between time of initial capture and condition index regardless of season or sex, suggesting birds were able to replenish energy stores. The net daily mass gain was the highest among males in fall (3% body mass). The net daily mass gain would sustain a flight of 0.6 h for females and 3.1 h for males in fall. The stopover biology of Red-flanked Bush Robins is similar to some songbird migrants of Europe and North America. For example, spring passage time and fat store variation between sexes agree with the hypothesis that males are selected to arrive at their breeding grounds as early as food resources or climatic conditions are adequate in spring. Further research on stopover ecology is urgently needed in China for a better understanding of the migratory behavior and for the conservation of these songbird migrants.

Key words: bird conservation; bird migration; stopover ecology; stopover site; *Tarsiger cyanurus*

The conservation of migratory birds is challenging because of their complex life history and the spatial scale over which these migrants travel. Migratory birds spend about one-third of their lifetime in migration. The events associated with migration play a critical role in determining the population status of migratory songbirds[1]. Migration is an energetically expensive event. Anticipating the energetic demand of migration and uncertainties en route, most songbird migrants accumulate fat deposits for use as energy source during migration. However, these fat deposits usually are not sufficient for the entire migration journey, birds have to periodically replenish depleted fat stores during migration at the stopover sites along their migration route. During stopover birds must contend with fluctuations in food availability, the likelihood of inter- and intra-specific competition, and limited resources at stopover sites[2]. The habitat quality, behavioral and physiological responses of the stopover birds, and the relationship between them are the main focus of avian stopover ecology[3-7].

Songbirds are one of the most abundant avifauna groups in China, and about one-third of these species are migratory[8]. The effort to conserve migratory songbirds in China is facing challenges similar to those in other parts of the world such as Europe and North America. Suitable habitats for many migratory bird species are declining on breeding grounds, wintering grounds, and at stopover sites, and songbird migrants in China probably are affected more severely by human-induced environmental and habitat changes than their counterparts in the North America. China's natural resources are more limited. For example, currently, China's forest land is only about 10% that of North America's; and China is one of the nations that had the highest rate of forest depletion in the world over the past 50 year[9]. China's human population has increased about 2.5 times, and timber production has more than tripled since later 1940's[9]. Forest exploitation and monoculture in China has led to adverse consequence including degradation of forests and landscapes, loss of biodiversity, unacceptable levels of soil erosion, and catastrophic flooding[10]. Over 61% of wildlife species in China have suffered from habitat loss[11]. China is among the countries with the most threatened birds and mammals in the world[12]. The conservation of migratory songbirds in China is further hindered by the lack of available data. Ornithological research has been limited in both quantity and quality in China. For example, between 1924 and 1989, China had only 715 research papers dealing with songbirds, 10 of them addressed songbird migration[8] and, to our knowledge, there is no published research on stopover ecology of migratory songbirds.

In the early 1980's, the Chinese government initiated a national bird banding program, and since then several migratory bird protection agreements have been signed between China and other countries including Japan, United States, and Australia[8]. Whereas the main objective of this banding program is to identify migratory routes, the program provides an opportunity to collect other vital information such as site fidelity, life span, and habitat use of many bird species including both migratory and nonmigratory bird species.

In this study, we used mist-netting data collected at one of the banding sites operated by the Chinese Bird Banding

Office in northeast China and examined several stopover parameters of Red-flanked Bush Robin (*Tarsiger cyanurus*). Specifically, we examined (1) timing of spring and fall migration, (2) stopover duration, (3) change in energetic condition during stopover, and (4) sex related variations including body mass and rate of mass change. This study is also intended to provide an indirect assessment of habitat suitability of the study site for the Red-flanked Bush Robins and those songbird migratory species with similar habitat requirements during stopover. We hope that this research will promote the study of stopover ecology of migratory songbirds in China.

1 METHODS

1.1 Study species Red-flanked Bush Robin is a small migratory passerine species of the Old World Turdidae. The species breeds in boreal and mountain thick mossy conifer forest in Russia, north Asia to the Himalayas and western China, and is most abundant in taiga of moist soil with undergrowth. It is an insectivore, but also feeds on fruits and seeds during the nonbreeding seasons, foraging in low trees, shrubs, and on ground. It nests on the ground in hollows among tree roots, in bankholes, or slightly above the ground in stumps or fallen logs. The species winters in Southeast Asia including the area south of the Yangtze River in China, Taiwan, and the Hainan Islands. There are two subspecies in China: *T. c. cyanurus* and *T. c. rufilatus*[13]. The former is the northern long-distance migratory subspecies breeding in northern Eurasia; and the latter is the southern subspecies, breeding in the Himalayan region, exhibiting mainly short-distance altitudinal movements, although some birds reach Assam, Burma, and northern Thailand. The individuals in this study belong to the first subspecies. Although the study site is within the breeding region of this subspecies[13], individuals captured are migrating birds because (1) there is no breeding population at the study site or adjacent areas, and the nearest breeding populations are over 100 km north on the northern slope of Xiaoxinganling Mts (Chang pers. obs.); and (2) few individuals were recaptured in subsequent season or years at the study site (Chang pers. obs.).

1.2 Study site The study was conducted at Laoyeling Banding Station (45°22′N, 127°32′E) located within the Maoershan Experiment Forest of Northeast Forestry University in Heilongjiang Province of northeast China[13]. Northeast China is one of the few areas in China that still supports extensive natural forests. The Experiment Forest covers an area of 30km × 20 km, about 26,507 hm^2, and is located in the northwest remnant hills of Zhangguangchai of the Changbai Mountains. The average elevation of the study site is 300 m above sea level with a 10 ~ 15° slope. The area experiences cold winters and warm summers with an annual average precipitation of 723 mm. Natural vegetation is deciduous broadleaf forest dominated by oak or a mixture of hardwood species. Canopy species are comprised of Japanese white birch (*Betula platyphylla*), aspen (*Populus davidiana*), Mongolian oak (*Quercus mongolica*), Manchurian ash (*Fraxinus mandshurica*), Manchurian walnut (*Juglans mandshurica*), Amur cork-tree (*Phellodendron amurense*), color maple (*Acer mono*), Tilia amurensis, and elm (*Ulmus propinqua*). Stands of Scotch pine (*Pinus sylvestris*) and Korean pine (*Pinus koraiensis*) occur in some places. Common shrub species include willow bushes (*Salix* spp.), Amur maple (*Acer ginnala*), Amur lilac (*Syringa amurensis*), bushclover (*Lespedeza bicolor*), honeysuckle (*Lonicera* spp.), red elderberry (*Sambucus racemosa*), hazel (*Corylus heterophylla*), Dahurian buckthorn (*Rhamnus dahuricus*), hawthorn (*Crataegus pinnatifida*), and Dahurian rose (*Rosa dahurica*).

1.3 Capture and recapture We collected data in fall from 5 August to 27 October 2002 and in spring from 10 March to 22 May 2003. We used 173 mist nets (10 m long, 2.5 m high, 5 tiers, 30 mm mesh), which were permanently established as three clusters within the banding station. Nets were placed opportunistically among forest, shrub, grassland, and edges of agriculture fields and fish ponds to maximize the capture rate. The maximum distance among the three netting clusters is about 3 000 m. Mist nets remained open through the banding season. Nets were checked every 1 ~ 1.5 h between 6 am and 8 pm daily, travel among the nets were assisted with bicycles. We took all birds captured to a central location for data collection and banding. We measured body mass (± 0.5 g) using a spring scale and unflattened wing chord (± 0.5 mm) with a wing ruler. Each bird was banded with a uniquely numbered metal leg band issued by the Center of Bird Banding of China and released immediately after measurements were taken. Recaptured birds were re-weighed. Identification of the species and sex is based on several resources[14-16]. No attempt was made to identify the age of the birds because the information or technique for reliably identifying age (e.g., skull ossification) of this species has not been documented yet. Handling time was usually less than 30 min.

1.4 Data analysis Netting effort was constant among dates during the study period. We estimated stopover duration by subtracting the date of first capture from the date of last capture of recaptured birds. This method yielded a conservative estimate because we assumed that birds arrived on the day of initial banding and departed on the day of last recapture[17]. Individuals that were not recaptured were assumed to have departed from the study site on the same day they were banded, and were assigned a stopover duration of zero. We refer to birds captured after the day of initial capture as "recaptures" and all other birds as "non-recaptures." Rate of body mass change during stopover of recaptured birds was estimated

$$\text{Mass change (g/d)} = (M_l - M_i) \times \text{Stopover duration}^{-1} \qquad (1)$$

where M_i is body mass (g) at initial capture, and M_l is body mass at last capture after adjusted to body mass at 12 pm using a regression approach between body mass and the time of capture. Following Winker's method[18], we calculated a condition index for every individual:

$$\text{Condition index} = 100 \times \text{mass} \times \text{wing}^{-1} \qquad (2)$$

where wing is the wing chord (mm), and mass is the initial body mass. Condition index provides an estimate of body mass adjusted for body size[18]. We then regressed condition index on the time of initial capture with a linear model to estimate the daily body mass change. The capture time was transformed to decimal unit and time since sunrise before the regression analysis. The slopes of the regression models provide an estimation of the hourly condition change (g/(100 mm·h)). We used analysis of covariance to test the equality of the slopes of these regression models among sex-season groups. We estimated the mass change of an average individual during a 24-h stopover by first calculating the gross daily gains of an individual with average body mass and wing chord and an assumed 8 h each day available for gaining body mass during the netting period. The average day length was about 13 h during spring and 12 h during fall at the study site. Our estimate of mass change is a more conservative index than that of Winker's method[18], which calculated average daily gain based on the actual average day length at his study site in Veracruz, Mexico. A nocturnal loss of 4.5% of body mass[18,19] is then subtracted from gross gain to obtain the net body mass gain, and the net mass gain is then divided by body mass at initial capture to estimate the percentage of mass gain. We estimated flight cost for each sex group in each season by using a statistical model developed by Castro and Myers[20]:

$$\text{Metabolism (kJ/h)} = 2.23 \times M^{1.407} \times W^{-1.381} \qquad (3)$$

where M = average body mass in g, and W = average wing chord in cm. The values for metabolic rate are converted using the equivalent of 39.5 kJ/g of fat. We assume that water gain or loss during stopover is negligible, and mass change reflects the variation of the amount of fat deposit[18,21,22]. The likelihood ratio chi-square test was used to examine if the recapture rate differed between spring and fall and between males and females. To test the effect of season and sex and their interaction on body mass, wing chord, and condition index, we used a two-way ANOVA (General Linear Model). Means and standard deviations (SD) are reported throughout the manuscript, and a statistical significance level of α = 0.05 (two-tailed) is used unless indicated otherwise. All analyses were conducted with SAS V8.2[23] or SPSS/PC V10.2[24].

2 RESULTS

We captured a total 1,751 and 684 Red-flanked Bush Robins during fall 2002 and spring 2003, respectively. We randomly measured body mass and wing chord for a subsample of 769 individuals (390 females, 367 males, and 12 unknown) during the fall of 2002 and 572 individuals (187 females, 383 males, and 2 unknown) during the spring of 2003 (Table 1). The median capture date was Julian day 276 (October 4) ± 9 in fall, and Julian day 106 (April 17) ± 6 in spring (Fig. 1). We were not able to assess sex and age related variation because gender was not identified for all birds, and age identification was not performed. Two high capture periods occurred in fall: the first on 24 and 25 September with about 200 captures each day; the second on 14 October with 358 captures. During spring, daily capture rate was relatively constant between 10 and 23 April, with the maximum capture of 65 individuals on 22 April. Males (Julian day 106 ± 6) moved through the site earlier than females (Julian day 108 ± 7).

Table 1 Sample size, condition index, body mass, and wing chord (mean ± SD) **of Red-flanked Bush Robin** (*Tarsiger cyanurus*) **captured during fall** (2002) **and spring** (2003) **migration in Heilongjiang Province of northeast China**

	All birds				Recaptured birds			
Sex	n(%[a])	Condition index	Mass(g)	Wing chord (mm)	n (%)[c]	Mass(g)	Stopover	Mass change (g/d)[e]
				Fall				
Female[f]	390(51)	17.8 ± 1.4	13.5 ± 1.1	76.0 ± 2.0	17(4)	13.6 ± 1.2	6.9 ± 4.8	0.1 ± 0.2
Male	367(48)	17.6 ± 1.4	13.6 ± 1.1	77.4 ± 2.1	22(6)	13.4 ± 1.2	4.8 ± 3.7	−0.1 ± 0.4
Unknown	12(2)	16.7 ± 1.7	12.7 ± 1.2	76.3 ± 2.7				
				Spring				
Female	187(33)	16.9 ± 1.3	12.3 ± 1.0	76.8 ± 1.7	6(3)	12.8 ± 1.0	4.0 ± 3.9	0.2 ± 0.
Male	383(67)	17.2 ± 1.4	13.4 ± 1.1	78.3 ± 1.8	11(3)	13.6 ± 1.1	2.8 ± 3.2	−0.3 ± 0.3
Unknown	2(< 1)	16.4 ± 0.7	12.5 ± 0.0	76.5 ± 3.5				
F statistics from two-way ANOVA[f]								
Sex		< 1.1 ns	19.2***	16.0***		< 1.5 ns	2.1 ns	8.3**
Season		64.2***	29.3***	60.3***		< 1.2 ns	4.0*	< 1.2 ns
Sex × Season		6.0*	7.3**	< 1.1 ns		2.0 ns	< 1.4 ns	< 1.3 ns

a Percent of total captures of the season; b Condition index = mass × wing^{-1} × 100 (Winker 1995); c Percent of capture for each sex group in each season; d Stopover duration for birds recaptured after the initial capture date (recaptures); e Mass change per day of recaptures; f F statistics from two-way ANOVA (sex by season) with unknown individuals excluded from analysis: ns = not significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The average body mass of captured birds was higher ($t_{1339} = 4.1$, $p < 0.001$) in fall ((13.5 ± 1.1)g) than in spring ((13.3 ± 1.1)g). Two-way ANOVA suggested that body mass had a significant interaction between season and sex (Table 1). This interaction is because body mass of females was lower in spring than that in fall while males had similar body mass between the two seasons (Table 1). Body mass of males was higher than that of females in spring ($t_{568} = 4.7$, $p < 0.001$); body mass between males and females was not different in fall (Table 1). Males had longer wing chords ((77.9 ± 2.0) mm) than females ((76.3 ± 2.0) mm); $F_{1,1323} = 168.0$, $p < 0.001$). The condition index, which adjusted the body mass by body size (wing chord), showed the same pattern of body mass variation: a significant interaction between season and sex (Table 1). Females and males had similar condition upon capture in fall, while the males had a higher condition index than females in spring (Table 1).

The recapture rate was not different between fall (39 birds, 2.2% of total capture) and spring (17 birds, 2.5% of total capture), and the recapture probability was not affected by sex (Likelihood-ratio test) in either seasons. Recaptured birds tended to stay longer ($F_{1,52} = 4.0$, $p < 0.05$) in fall ((5.7 ± 4.3) d) than in spring ((3.4 ± 3.4) d); and males tended to stay shorter than females in both seasons although it was not statistically significant (Table 1). Among recaptures, females (4.7% ± 12.3%) gained mass while males lost mass (− 1.5% ± 5.9%) during their stopover (Table 1).

The linear regression analysis suggested that there is a positive relationship between condition index and initial time of capture for each sex group in both seasons (Fig. 2). The slopes are similar among sex-season groups except females in spring which had a lower rate of mass change ($F_{3,1319} = 3.4$, $p < 0.05$). The males had higher gross daily mass gain than

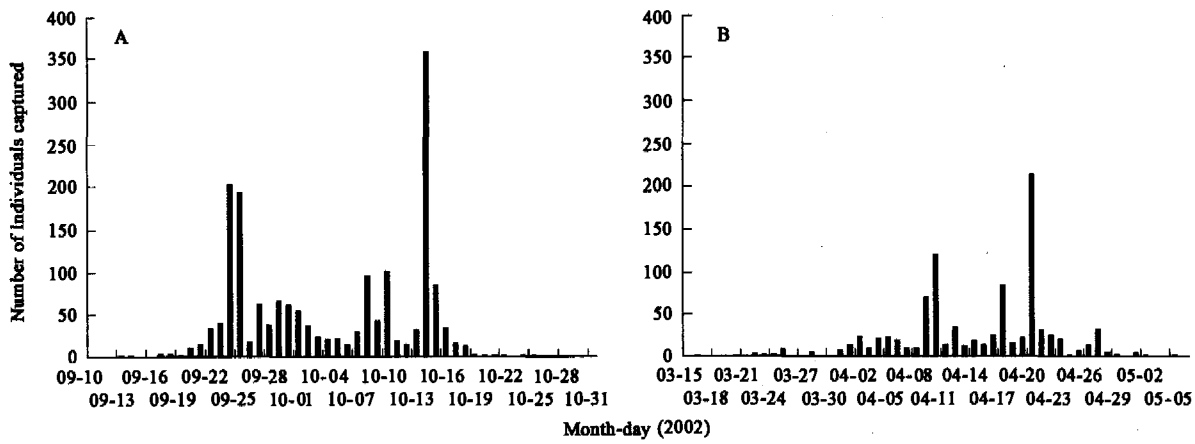

Fig.1 Migration timing of the Red-flanked Bush Robin during fall (A) and spring (B) at Laoyeling Banding Station of Maoershan Experiment Forest of Northeast Forestry University in Heilongjiang Province of China

females both in spring and fall (Table 2). The nocturnal metabolic loss of body mass was about 0.6 g on average based on the estimation of 4.5% of body mass. It is apparent that on average the birds had a positive net body mass gain for a 24h diel cycle, except females in spring (Table 2). The net gain was the highest among the fall males. Assuming the net gain was the fat deposit, the net daily mass gain of average individuals could sustain a flight of 0.6 h for females and 3.1h for males in fall and a flight of 0.5 h for males in spring (Table 2). Average females in spring did not gain enough fat for migration at this site based our calculation.

3 DISCUSSION

Red-flanked Bush Robins in this study winter mostly south of the Yangtze River and breed in northeastern China. Our study site is within the species' reported breeding range although no local breeding population was detected at the site (Chang pers. obs.). Many birds captured in this study have almost arrived at their breeding grounds in spring and just initiated their migration journey to their wintering grounds in fall. Two high capture periods were detected in fall. Such multiple high capture periods are also common among songbird migrants in North America[17, 25, 26]. We suspect that the two peaks of capture in spring and fall may reflect populations that have different breeding and/or wintering distributions. Although we did not identify gender of all individual captured, we observed that in general males tended to move through our site earlier than females both in spring and fall (Chang pers. obs.). This pattern is consistent with some species in Europe and North America[26, 27].

Table 2 Estimated daily body mass changes using the regression models in Figure 3 for average individuals in each sex group and season of Red-flanked Bush Robin (*Tarsiger cyanurus*) captured during fall (2002) and spring (2003) migration in Heilongjiang Province of northeast China

Sex	Gross gain (g/day)^a	Nocturnal loss (g)^b	Net gain (g/day)^c	Mass gain (%)^d	Flight cost (g/h)^e	Flight duration (h)^f
			Fall			
Female	0.7	0.6	0.1	0.6	0.1	0.6
Male	1.1	0.7	0.4	3.0	0.1	3.1
			Spring			
Female	0.3	0.6	-0.3	-2.2	0.1	0.0
Male	0.7	0.6	0.1	0.5	0.1	0.5

a, Mass gain during one day stopover for individuals of the average wing length and an 8 h day estimated from regression models in Figure 2; b, Body fat used in nocturnal metabolism = 4.5% of mean body mass after one day stopover (mean arrival body mass + diurnal mass change); c, Net daily mass gain in 24-h period after subtracting nocturnal metabolic loss; d, Net daily mass gain as a percentage of arrival body mass; e, Flight cost estimated based on $M = 2.23 \times Mass^{1.407} \times Wing^{-1.381} \times 39.5^{-1}$[19]; f, Potential flight duration for nocturnal migration gained from one day stopover assuming net gain is all fat

The gross daily mass gain of Red-flanked Bush Robin about 1g/day was similar to that of Bluethroat (*Luscinia s.*

svecica) in Europe[28]. We expected that the body mass would be higher in fall than in spring because our study site is near the breeding grounds, and the birds captured at our site just started migration in fall while they were almost on their breeding grounds in spring. Interestingly, we found seasonal body mass variation was mainly due to lower body mass of females in spring, while females in fall and males in both season had similar body mass. Wilson's Warblers (*Wilsonia pusilla*) in New Mexico of USA showed similar patterns between seasons and between sexes[29]. The higher fat stores and faster rate of mass gain of males in spring may indicate that the selective pressures of stopover are different from that of females. Like many songbird species, male Red-flanked Bush Robins usually arrive at breeding grounds earlier than females (Chang pers. obs.). These patterns are consistent with the hypothesis that males are selected to arrive at their breeding grounds as early as food resources or climatic conditions are adequate, whereas females arrive later, closer to the time when they can successfully begin nesting[30]. Ellegren[28] found that the stopover patterns including rate of fat accumulation were similar between sexes in Bluethroats during fall migration in Europe.

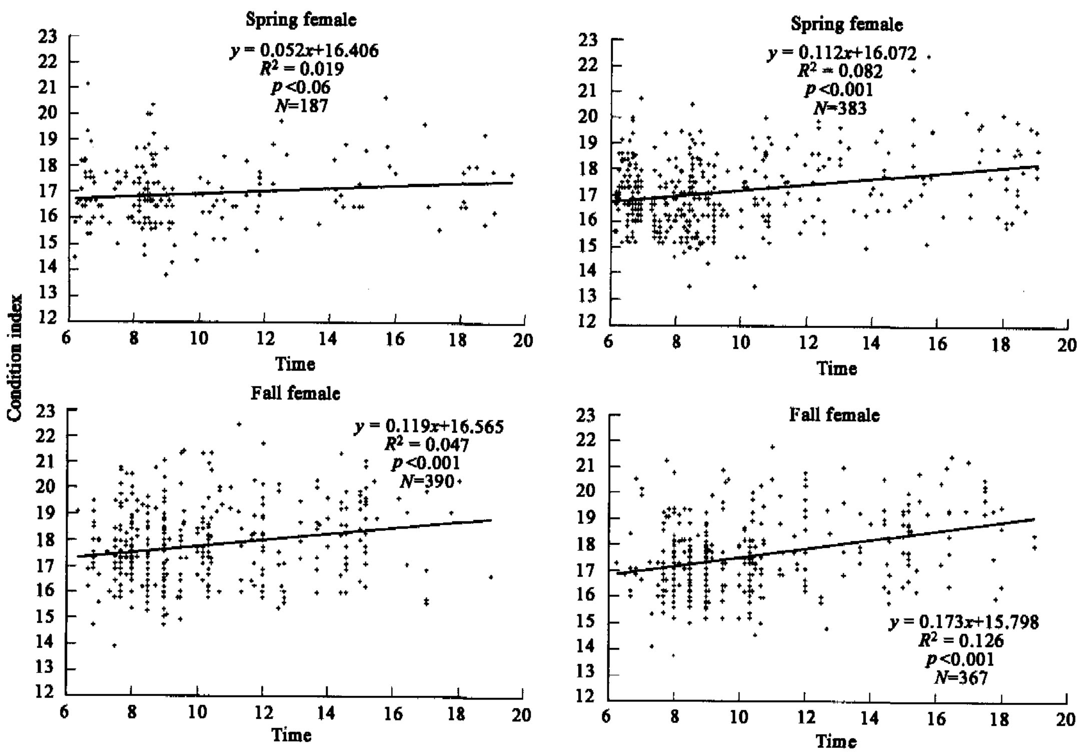

Fig.2 Seasonal and sex related daily body condition change based on linear regressions between condition index and capture time

The condition index was estimated as body mass × wing chord^{-1} × 100[17]

The estimates of body mass gain and rate of mass gain based on recaptured birds were lower than the estimates of the same variables based on the regression analysis between condition index and time of initial capture of all the birds. Capturing birds might interrupt birds' normal behavior, cause stress, and lead to body mass decline, which was observed in other studies[31,32]. Recaptured male birds lost body mass while female gained mass while the pattern was reversed based on the regression analyses of all birds captured. These differences are probably because recaptured birds may reflect a biased sample of all the birds that used our stopover site. Carlisle *et al*.[33] found general agreement between regression data and mass change among recapture birds. Average females in spring did not gain enough fat for migration on daily base at this site based on our estimation. However no local breeding population was detected. This suggests that females might have to stay longer to gain energy stores for further migration; our recapture data did suggest that females tended to have longer stopover duration both in spring and fall. The other possibility is that females already had sufficient energy stores for migrating to their breeding grounds during sprint stopover, our capture data did support this possibility: females had higher body mass than that of males in spring. Bairlein[34] found that many trans-Saharan songbird migrants used an intermittent migratory strategy, with regular stopovers during the day and flight at night. The female Red-flanked Bush Robins in spring might stop at our stopover site for resting and continued migration at night.

Migrants require suitable stopover sites for resting and replenishing depleted fat stores[35]. The suitability of stopover habitats in relation to migrants' fitness is difficult to measure directly; indirect measurements include the fat load at departure and stopover duration of stopover birds[25,36]. The optimal time minimization model of migration[37] predicts that migrants should deposit fat stores faster and depart sooner at suitable stopover habitat than at a lower quality site. The quick mass gain, short stopover duration, and low recapture rate of stopover Red-Flanked Bush Robins might suggest that the habitat at our study sites is suitable for this species. To our knowledge, this is the first study of stopover ecology of songbird migrants in China. Because financial and logistic limitations, we did not collect similar data for other species or from other locations for the same species, which excludes the possibility for comparisons to our results. Collect and analysis of data for other migrant species, and for the same species in multiple years should give us a better understanding of the spatial and temporal dynamics of mass gain during migration of these birds and their associated habitat[36].

Northeast China is one of the last remaining areas that preserves natural habitat including grasslands and forests in China. However, these habitats are under threat because of demands for economic development such as urban encroachment, agricultural expansion, and timber production. In 1998, the Chinese government established the Natural Forest Conservation Program (NFCP). One of the main objectives of this program is to protect existing natural forests. Most forest lands in the Northeast China are listed as the first priority for protection and conservation by this program. The fact that Red-flanked Bush Robins are able to gain body mass, and to do so quickly, at our study site is encouraging. We know little about migration routes, patterns of habitat use, and stopover behavior of songbird migrants in China. Avian ecologists such Bairlein[38] called for migration research aiming at much more comparative research and a more integrative approach at various spatial and temporal scales and using currently advance research techniques. To determine patterns observed in Red-flanked Bush Robin hold up among other migratory songbird species at our study site, and at other stopover habitats along migration routes, further study of stopover behavior is urgently needed for understanding the evolution of migration systems in songbirds, and for the conservation of these species in China.

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References:

[1] Sillett T S, Holmes R T. Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology, 2002, 71: 296 ~ 308.

[2] Moore F R, Gauthreaux S A Jr, Kerlinger P, *et al*. Habitat Requirements During Migration: Important Link in Conservation. In: Martin T E, Finch D M eds. Ecology and Management of Neotropical Migratory Birds: A Synthesis and Review of Critical Issues. Oxford; Oxford University Press, 1995. 121 ~ 144.

[3] Wang Y, Finch D M, Moore F R, *et al*. Stopover ecology and habitat use of migratory Wilson's Warbler. Auk, 1998, 115:829 ~ 842.

[4] Alerstam T. Bird migration. Cambridge: Cambridge University Press, 1990.

[5] Ma Z J, Li B, Chen J K. Study on the utilization of stopover sites and migration strategies of migratory birds. Acta Ecologica Sinica, 2005, 25:1404 ~ 1412.

[6] Ma Z J, Wang, Y, Chen J K. Physiological ecology of migratory birds during the stopover periods. Acta Ecologica Sinica, 2005, 25(11): 3067 ~ 3075.

[7] Wang Y, Moore F R. Long-distance bird migrants adjust their foraging behavior in relation to energy stores. Acta Zoologica Sinica, 2005, 51(1): 12 ~ 23.

[8] Zhang F Y, Yang L L. Bird migration research of China. Beijing: China Forestry Publisher, 1997.

[9] World Resources Institute. An assessment of the resource base that supports the global economy. Washington DC: World Resources Institute, 1987.

[10] Zhang P, Shao G, Zhao G, *et al*. China's forest policy for the 21st century. Science, 2000, 268: 2135 ~ 2136.

[11] Li W. China's biodiversity. Beijing: China's Scientific Publishing House, 1999.

[12] Liu J, Ouyang Z, Pimm S L, *et al*. Protecting China's biodiversity. Science, 2003, 300:1240 ~ 1241.

[13] Cheng T H. A synopsis of the avifauna of China. Beijing: Science Press and Berling: Paul Parey Scientific Publishers, 1987.

[14] Sonobe K A. *Field guide to the birds of Japan*. Tokyo: Kodansha International LTD. 1982.

[15] Chang J C, Karsura C, Lui B W, *et al*. A Field Guide to the Birds of Northeast China. Harbin: Heilongjiang Science and Technology Press, 1995.

[16] Mullarney K, Svensson L, Zetterström D, *et al*. Birds of Europe. Princeton: Princeton University Press, 1999.

[17] Moore F R, Kerlinger P. Stopover and fat deposition by North American wood warblers (Parulinae) following spring migration over the Gulf of Mexico. Oecologica 1987,74:47 ~ 54.

[18] Winker K. Autumn stopover on the Isthmus of Tehuantepec by woodland Nearctic-Neotropic migrants. Auk, 1995, 112:690 ~ 700.

[19] Baldwin S P, Kendeight S C. Variations in the weights of birds. Auk, 1938, 55:416 ~ 467.

[20] Castro G, Myers J P. A statistical method to estimate the cost of flight in birds. Journal of Field Ornithology, 1988, 59:369 ~ 380.

[21] Nisbet I C T, Drury W H Jr, Baird J. Weight loss during migration. Part I. Deposition and consumption of fat by the Blackpoll Warbler. Bird-Banding, 1963, 34:107 ~ 159.

[22] Rogers D T Jr, Odum E P. A study of autumnal postmigrant weights and vernal fattening of North American migrants in the tropics. Wilson Bulletin, 1966, 78:415 ~ 433.

[23] SAS INC. The SAS system V8.2. Cary: SAS Institute Inc, 2001.

[24] SPSS INC. SPSS Base 10.2. Chicago: SPSS Inc, 1999.

[25] Rimmer C C, McFarland K P. Migrant stopover and postfledging dispersal at a montane forest site in Vermont. Wilson Bulletin, 2000, 112:124 ~ 136.

[26] Wang Y, Finch D M. Stopover ecology of landbirds migrating along the Middle Rio Grande in spring and fall. Ashville: USDA Forest Service General Technical Report RMRS-GTR-99, 2002.

[27] Francis C M, Cooke F. Differential timing of spring migration in wood warblers (Parulinae). Auk, 1986, 103:548 ~ 556.

[28] Ellegren H. Stopover ecology of autumn migrating Bluethroats *Luscinia s. svecica* in relation to age and sex. Ornis Scandinavica, 1991, 22:340 ~ 348.

[29] Wang Y, Finch D M, Moore FR, and J. F. Kelly. Stopover ecology and habitat use of migratory Wilson's Warbler. Auk, 1998, 115:829 ~ 842.

[30] Smith R J, Moore F R. Arrival fat and reproductive performance in a long-distance passerine migrant. Oecologia, 2003, 134:325-331.

[31] Winker K D, Warner W, Weisbrod A R. Daily mass gains among woodland migrants at an inland stopover site. Auk, 1992, 109:853-862.

[32] Wang Y, Moore F R. Spring stopover of intercontinental migratory thrushes along the northern coast of the Gulf of Mexico. Auk, 114:263 ~ 278.

[33] Carlisle J D, Kaltenecker G S, Swanson D L. Stopover ecology of autumn landbird migrants in the Boise foothills of southwestern Idaho. Condor, 2003, 107:244 ~ 258.

[34] Bairlein F. Recent prospects on trans-Saharan migration of songbirds. Ibis, 1992, 134 Suppl; 1:41 ~ 46.

[35] Moore F, Wang Y. Evidence of food based competition during migratory stopover. Behavioral Ecology Sociobiology, 1991, 28:85 ~ 90.

[36] Dunn E H. Temporal and spatial patterns in daily mass gain of magnolia warblers during migratory stopover. Auk, 2000, 117:12 ~ 21.

[37] Alerstam T, Lindström Å. Optimal bird migration: the relative importance of time, energy, and safety. In: Gwinner E. ed. *Bird migration: the physiology and ecophysiology*. Berlin: Springer-Verlag, 1990. 331 ~ 351.

[38] Bairlein F. The study of bird migrations——some future perspectives: capsule routes and destinations have been unveiled but modern techniques offer the chance to explore much more. Bird Study, 2003, 50: 243 ~ 253.

参考文献:

[5] 马志军,李博,陈家宽. 迁徙鸟类对中途停歇地的利用及迁徙对策. 生态学报,2005,25(6):1404 ~ 1412.

[6] 马志军,王勇,陈家宽. 迁徙鸟类中途停歇期的生理生态学研究. 生态学报,2005,25(11): 3067 ~ 3075.

[7] 王勇,弗兰克.摩尔.长距离迁徙鸟类对应于能量积累状态的取食行为调整 动物学报,2005,51(1):12 ~ 23.

[8] 张孚允,杨若莉. 中国鸟类迁徙研究. 北京:中国林业出版社, 1997.

[13] 郑作新. 中国鸟类区系纲要. 北京:科学出版社和柏林: Parey Scientific Publishers, 1987.

[15] 常家传,桂千惠子,刘伯文,等. 东北鸟类图鉴. 哈尔滨:黑龙江科学技术出版社, 1995.