Based on Citizen-data: Annual and Seasonal Movement Characteristics on Migration Pattern of Thrush

Meixu Chen[1], Feixia Wang[1], Ying Chen[2,*]

[1]Department of Forestry, University of British Columbia, Vancouver V6T 1Z4, Canada

[2]Department of Forestry, Fujian Agriculture and Forestry University, Fuzhou 350002, China

*Corresponding author: yingchen@fafu.edu.cn

Keywords: thrush; migration pattern; citizen-data; seasonal migration; temporal variation; data analysis; china.

Abstract: Due to the impact of food resources, environmental changes and diseases, birds have certain differences in the general north-south migration pattern. Currently, citizen data is applied to the study of bird migration. We collect citizen database information from China Bird Report Center, and use statistical analysis and data visualization technology, based on the R programming language to analyze the migration patterns of thrush birds. We select five species of Thrush, including *Turdus ruficollis*, *Turdus atrogularis*, *Geokichla citrina*, *Turdus obscurus* and *Turdus pallidus*, for checklists of Thrush observation from 2015 to 2021 as representatives, to discuss annual and seasonal variation in migration patterns of Thrush in China. Our results show that the spring migration time span of Thrush is longer than the autumn migration time span. The migration routes of Thrush mainly include a northern channel in east-west direction as well as the eastern channel, the central channel and the western channel in north-south direction.

1. Introduction

Bird migration refers to the large-scale back and forth movement of birds between their breeding and wintering grounds each year [1]. Generally speaking, birds living in the northern hemisphere tend to migrate north in spring to take advantage of the prosperous insect numbers, the abundance of germinating plants, and diverse nesting locations in the north. However, in the autumn, these birds tend to migrate to the south because the food supply in the north is insufficient [1]. In addition to north-south migration, birds also migrate east-west, along rivers and vertically. Two kinds of Swainson's Thrush populations were found in western British Columbia, Canada [2]. Among them, coastal populations migrated southward along the coastline to Mexico, while inland populations migrated eastwards through the Rocky Mountains [2]. The main purpose of bird migration is to obtain abundant food resources, find suitable nesting sites, avoid predators and diseases, and adapt to the changing environment [1]. Some birds mainly feed on a particular food, and their migration varies with the abundance of that food [2]. For example, the main food for crossbills is spruce seeds [2]. The amount of cones produced by the spruce tree reaches a peak every three years on average [2]. The number of spruce seeds is unevenly distributed in space. In order to have the adequate food supply, they must migrate from areas where spruce seeds are scarce to areas where spruce seeds are plentiful [2].

In global community, many applications and websites have been designed to study and track bird migration. BirdCast developed migration tools, which mainly use weather surveillance radar data to predict and monitor bird migration [3]. Its function includes bird migration forecast maps that can predict the location and time of bird migration, live bird migration maps that can record real-time migration paths, and local bird migration alerts that can warn citizens whether birds will pass through human settlements [3]. Cornell Lab of Ornithology and Audubon jointly developed a free online database called eBrid [4]. On eBrid, people can record observed bird information, including location, number, species, and etc. [4]. At the same time, it is also a large shared database to provide scientists, researchers and amateurs with real-time bird distribution and numbers [4]. China Bird Report Center

  DOI: 10.25236/gemfe.2022.009

is a birdwatching record website frequently used by bird watchers in China. It records more than 1,400 kinds of bird data [5]. It provides services for data query, bird distribution query, bird watching management to the public. [5]. iBird Pro is a bird recognition application [6]. The clear pictures of birds on it can record the basic characteristics of different birds, including scale, color and location. It can help bird watchers to better identify the species of bird [6].

In this study, we collected the citizen data of Thrush from the website of the China Bird Report Center using a web scraper, and used statistical analysis and data visualization technology, based on R programming language, to analyze the migration of Thrush in China in spatial and temporal patterns. The seasonal bird migration in China is discussed in this paper further.

This paper is organized as follows: Section 2 involves existing researches about the analysis of bird migration patterns based on citizen data and machine learning methods. The source, selecting and processing methods of citizen data is discussed in Section 3. Section 4 illustrates the results of the temporal and spatial migration patterns of Thrush. Conclusion and discussion are placed in Section 4.

2. Literature review

Citizen data is usually used to study bird migration. Supp et al. recorded the daily migration trajectories of five North American hummingbird species from 2008 to 2013, based on eBird's citizen database [7].They discussed the change of migration patterns in different years and seasons, and found that the start time of spring migration tends to change less than the arrival time of autumn migration [7]. Weisshaupt and Rodríguez-Pérez resampled citizen data of Wood Warblers from Spain and Switzerland to compare the habitat use and land cover types of the 2015 spring migration [8]. The results proved that Wood Warblers used many types of habitats during spring migration, but most of them chose to breed in forest areas [8]. Frank et al., based on eBird data, examined the completeness of the global bird survey from 2002 to 2018 on scales of time resolution and spatial resolution [9]. The areas with high bird survey integrity are mainly in North America, Europe and India. In terms of spatial and temporal resolution, nearly 4%-14% of the earth's terrestrial surface has a survey completeness of more than 90% [9]. Dennhardt et al. proposed to use the citizen data of Golden Eagles recorded at five major collection points in Kittatinny Ridge between 2002 and 2011 in November to estimate the number of Golden Eagles migrating based on the simulation of recapture rules [10]. It is calculated that the mean population abundance of Golden Eagles is 1,354 ± 117 SE (range: 873–1,938) [10].

Data science and machine learning methods can also be used to study bird migration. Pancerasa et al. proposed to use machine learning algorithms to replace manual tasks to pre-process the raw data recorded by Geolocators, and use predictor variables to classify each twilight event binary to distinguish noisy and natural twilight events [11]. They used more than 100 geolocators to track the records of barn swallows during the spring and autumn migrations, constructed three different machine learning algorithms, including logistic regression, random forest and deep neural network [11]. The results showed that the accuracy of the migration route of the automatic pre-processing of the machine learning complex algorithms, such as random forest and deep neural network, is equivalent to the accuracy of the migration route of the manual pre-processing [11]. Lin et al. developed a deep convolutional neural network calledMistNet, which can distinguish precipitation from organisms in radar scans to finely predict bird migration activities and reduce the detection defects of large networks of weather radars [12]. They improved the convolutional neural network, used dualpolarization radar products to automatically collect noise training labels, and adopted the transfer learning technique starting from the convolutional neural network trained on image recognition tasks, so that the detected error biomass of MistNet was up to 1.3 % [12]. The biomass retained by MistNet is 15% higher than traditional scanning methods. Bird et al. combined radiotelemetry data with a traditional method called capture–mark–recapture to estimate population size with radiotelemetry data [13]. They tracked the data recorded by the telemetry tags implanted in the captured species to model the transition probability of entering and leaving the sampling area, which reduces the possibility of deviation from the actual population abundance by temporary migration [13].

3. Methods

3.1. Data

Based on a data crawler software called HTTrack, we collect citizen data of Thrush from China Bird Report Center between 2010 and 2021. It includes record user, observation time, observation location, coordinate position, bird species number, common name, Latin name and etc. We import each species of Thrush into excel and made checklists of Thrush observations. In total, we collect 23 species of Thrush and more than 40,000 records. According to Checklist on the A Classification and Distribution of the Birds of China and A Field Guide to the Birds of China, Thrush in China is divided into migratory and resident birds [14] [15]. In this study, we only analyze migratory birds. Through these two books and comparing with the contents of the original data table, only five kinds of Thrush are finally selected to further study as migratory birds, including: *Turdus pallidus*, *Turdus obscurus*, *Turdus ruficollis*, *Turdus atrogularis* and *Geokichla citrina*. The following are the checklists of Thrush observations among these five Thrush in 2020. From Fig 1, we can see that the checklists of *Turdus pallidus* and *Turdus ruficollis* are abundant, 346 and 205, respectively.

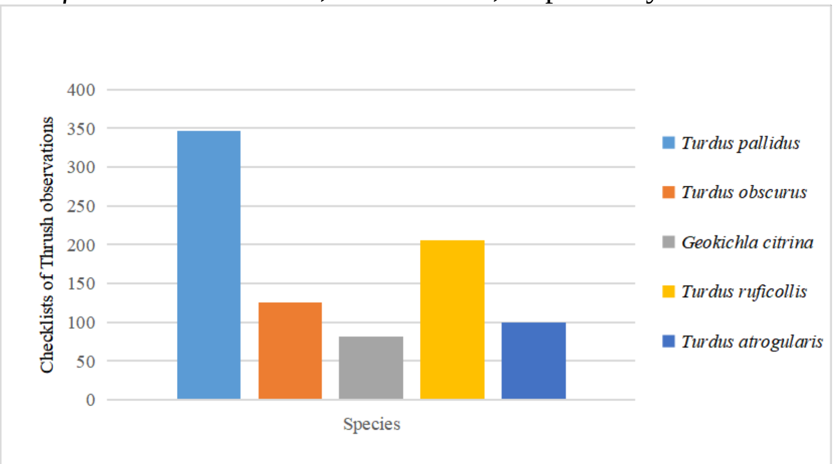


Fig. 1 The checklists of Thrush observations in 2020

3.2. Analysis of spatial and temporal patterns of Thrush

In order to calculate the time difference of various migratory species, we divided the dates into 1-365 Julian Days and assumed 1-182 days as spring migration period and 183-365 days as autumn migration period. By combining the Julian Day with the China City Map based on ArcGIS, we get a map showing the spring migration and autumn migration of these 5 Thrush species in different cities. The time of the spring and autumn migration of each specie is indicated by the depth of city colors. Based on the map, we can roughly determine the migration pathways of these 5 Thrush species, which are used to summarize the migratory pattern of Thrush in China.

3.3. Statistical analysis of the data

The stat.desc () command in the "pastecs" package of the R software was used to count the longitude, latitude and date of passage of each species of thrush to obtain the maximum, minimum, median and span. A box plot was drawn using the geom_boxplot () command of the "ggplot2" package. The spatial data from the birdwatching reports were analysed using ArcGIS to produce a latitude-date variation map of the spring and autumn movements of the main thrush in China.

4. Results

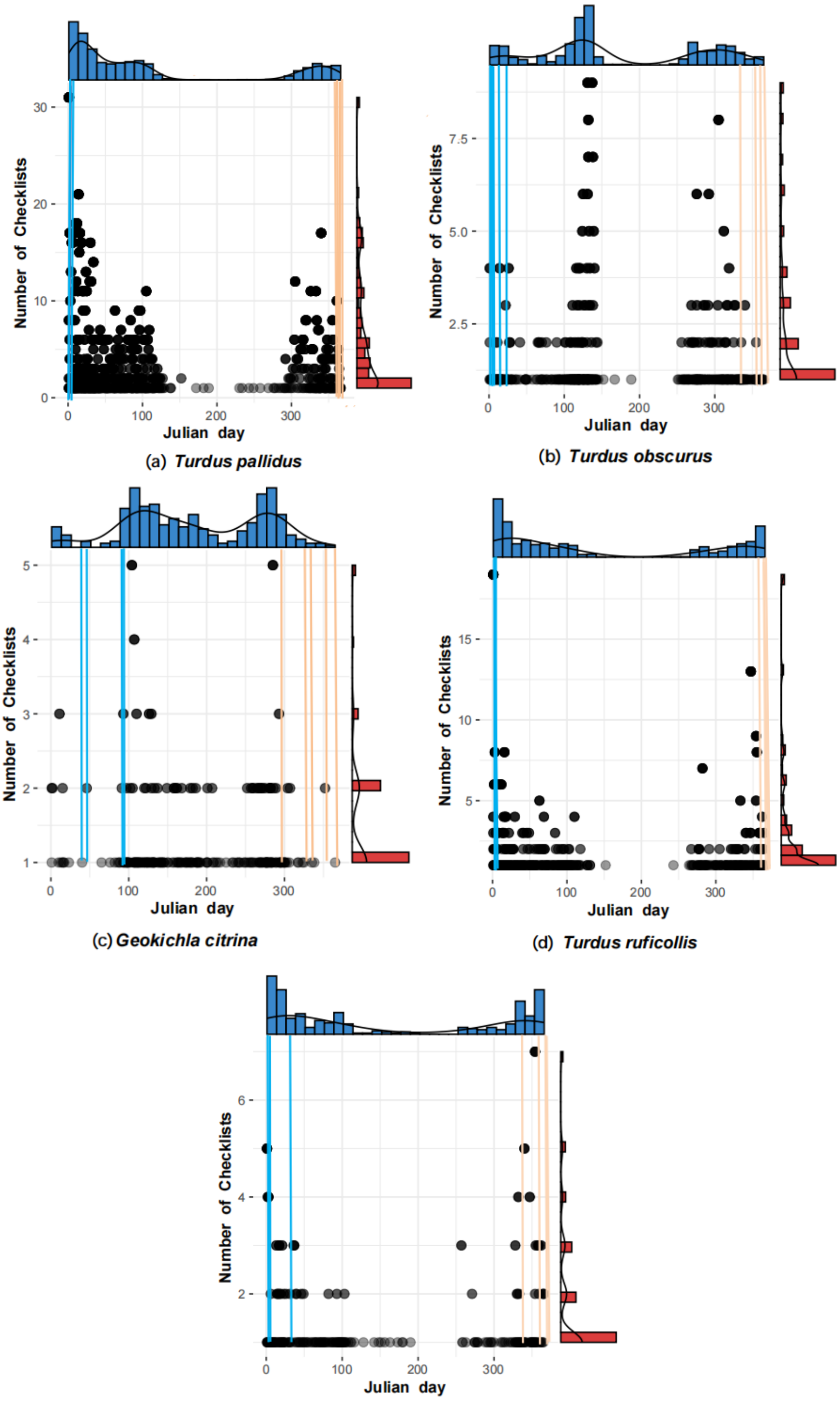
4.1 Differences in the spring and autumn migration patterns of 5 Thrush species in China.

Table 1 Julian Day in spring and autumn migration of Thrush in China

Species Scientific Name	Spring Migration			Autumn migration			Significance of differences
	Julian day minimum	Julian day maximum	Julian day Span Values	Julian day minimum	Julian day maximum	Julian day Span Values	
Turdus pallidus	109.13	125.32	16.19	113.30	130.09	16.79	p<0.01
Turdus obscurus	97.95	126.69	28.74	97.57	122.48	24.91	p<0.01
Turdus ruficollis	84.63	130.70	46.07	86.00	125.32	39.31	p<0.01
Turdus atrogularis	84.91	116.47	31.56	75.44	118.22	42.78	p<0.01
Geokichla citrina	97.54	121.98	24.44	97.58	118.57	20.99	p<0.01

Table 2 Migration period of Thrush in China

Species	Spring Migration			Autumn migration			Significance of differences	Duration Ratio of spring migration to autumn migration(%)
	Start Date	Duration	End Date	Start Date	Duration	End Date		
Turdus pallidus	1	138	138	276	91	366	p<0.01	151.6%
Turdus obscurus	1	152	152	258	107	364	p<0.01	142.1%
Geokichla citrina	82	136	217	230	109	338	p<0.01	124.8%
Turdus ruficollis	1	131	131	266	86	351	p<0.01	152.3%
Turdus atrogularis	1	190	190	249	118	366	p<0.01	161.0%



(a) *Turdus pallidus*
(b) *Turdus obscurus*
(c) *Geokichla citrina*
(d) *Turdus ruficollis*
(e) *Turdus cardis*

Fig. 2 The number of checklists submitted (2015–2021) across the study area at a daily timestep for each species (using all the data).

Table 2 shows Thrush distribution of Julian day in spring and autumn migration, including Julian day minimum, Julian day maximum and Julian day span values. The start and end times of Table 2 are calculated based on the peak value of Table 1. From table 2, we can clearly see that the duration of spring migration of five Thrush species is longer than that of autumn migration. The duration of spring migration is almost 1.5 times that of autumn migration. The peak time reported in Table 1 from 2015 to 2021 is presented in some straight lines on Fig. 2. The blue line represents the estimated start of spring migration, and the orange line represents the end of autumn migration.. Most of the observations fall between the blue and orange lines denoting migration period. The green line often falls close to a dip in overall observation, which might be expected, assuming that detectability decreases during the nesting period. In Fig. 2, we observe a clustering trend in checklists of 5 species over the year, with significant differences in the timing and interval of reported peaks and gaps. Among them, *Turdus obscurus* and *Turdus ruficollis* have obvious discontinuity in their migration time, and the checklists of Thrush observations with different frequency accumulates on the head and tail in a year. Moreover, a steady gap of less than one checklists of Thrush observations can be found between 150 and 250 Julian Day.

4.2 Differences in the spatial patterns of spring and autumn migration of 5 species in China.

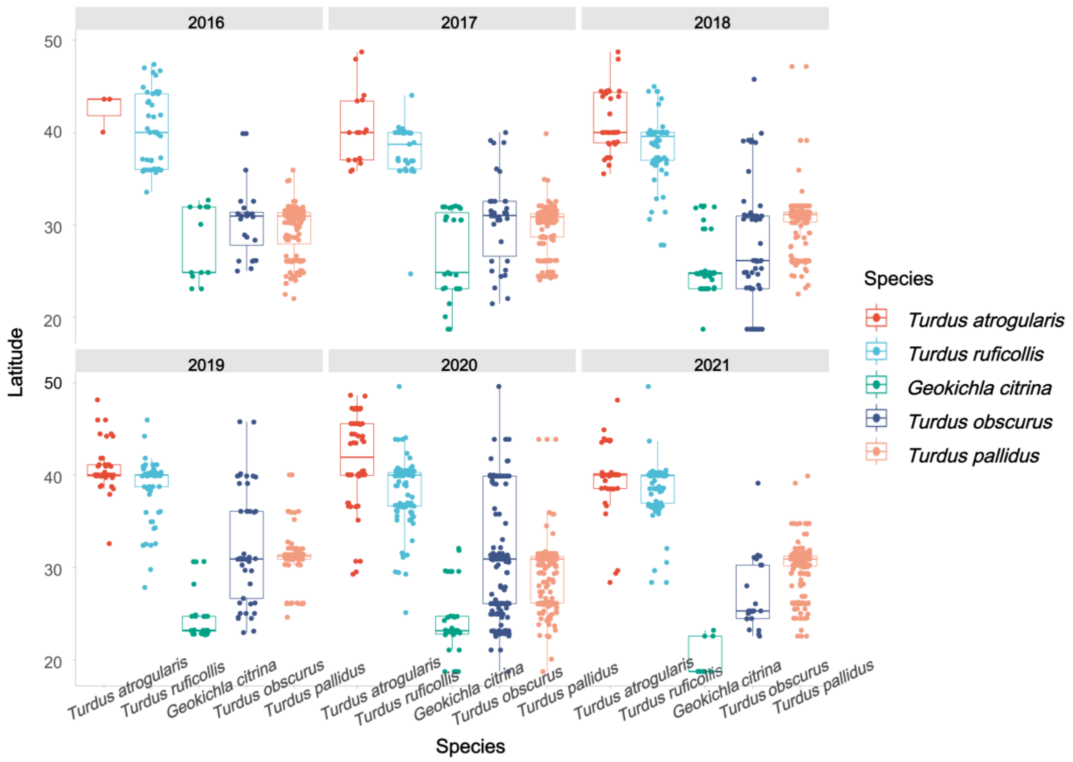
Table 3 Statistical of the migration latitude of Thrush in China

Species	Spring Migration			Autumn migration			Significance of differences
	Latitude minimum	Latitude maximum	Latitude Span Values	Latitude minimum	Latitude maximum	Latitude Span Values	
Turdus pallidus	20.08	43.86	23.79	22.50	43.86	21.36	$p<0.01$
Turdus obscurus	21.07	45.76	24.70	18.73	40.02	21.29	$p<0.01$
Turdus ruficollis	29.45	47.38	17.93	27.82	49.58	21.76	$p<0.01$
Turdus atrogularis	29.52	48.73	19.21	36.61	48.73	12.12	$p<0.01$
Geokichla citrina	18.73	32.06	13.33	18.73	32.06	13.33	$p<0.01$

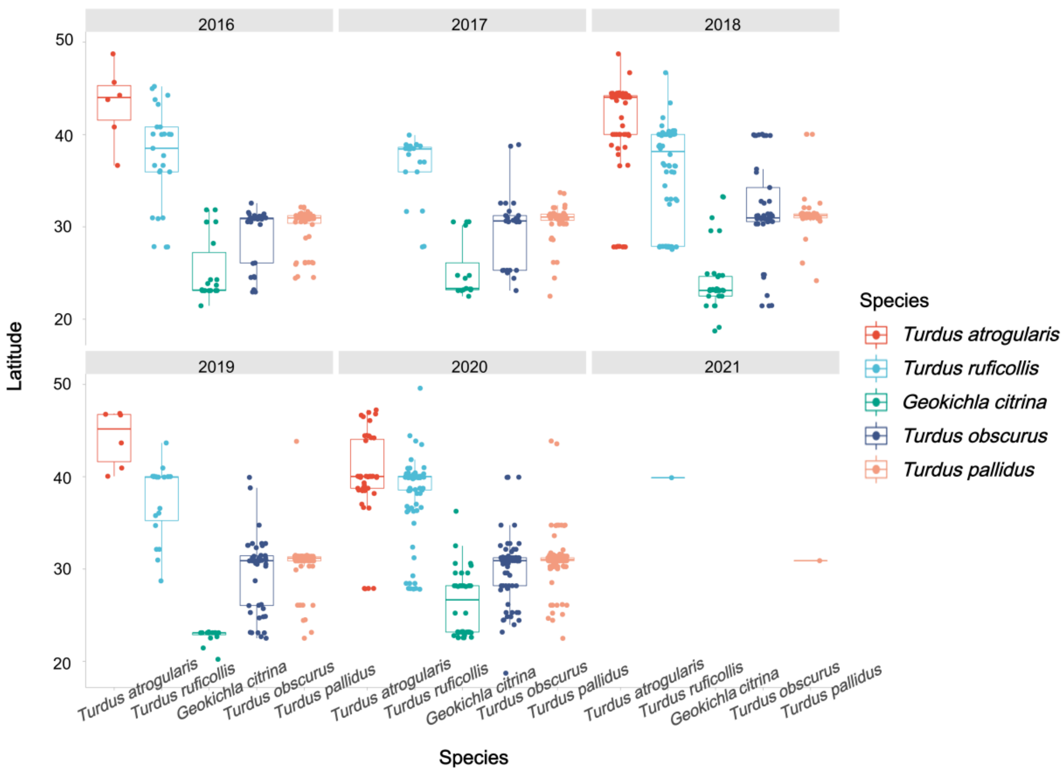
Table 4 Migration longitude of Thrush in China

Species	Spring Migration			Autumn migration			Significance of differences
	Longitude minimum	Longitude maximum	Longitude Span Values	Longitude minimum	Longitude maximum	Longitude Span Values	
Turdus pallidus	109.13	125.32	16.19	113.30	130.09	16.79	$p<0.01$
Turdus obscurus	97.95	126.69	28.74	97.57	122.48	24.91	$p<0.01$
Turdus ruficollis	84.63	130.70	46.07	86.00	125.32	42.78	$p<0.01$
Turdus atrogularis	84.91	116.47	31.56	75.44	118.22	39.31	$p<0.01$
Geokichla citrina	97.54	121.98	24.44	97.58	118.57	20.99	$p<0.01$

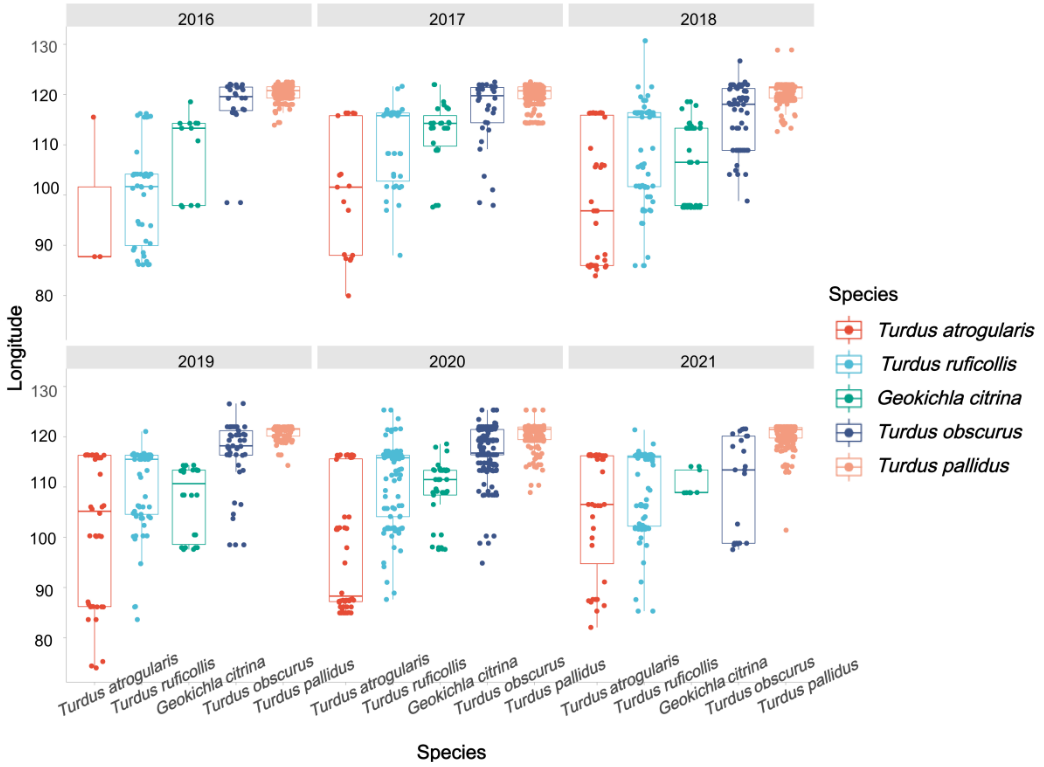
According to Table 3, we find that the latitude span of the autumn migration is greater than that of spring migration in the majority. From Table 4, the latitude concentration of 3 species in autumn migration is greater than that of spring migration. They are *Turdus pallidus*, *Turdus obscurus* and *Turdus atrogularis*. As for Table 4, the longitude concentration of the autumn migration is also greater than that of the spring migration in the majority.



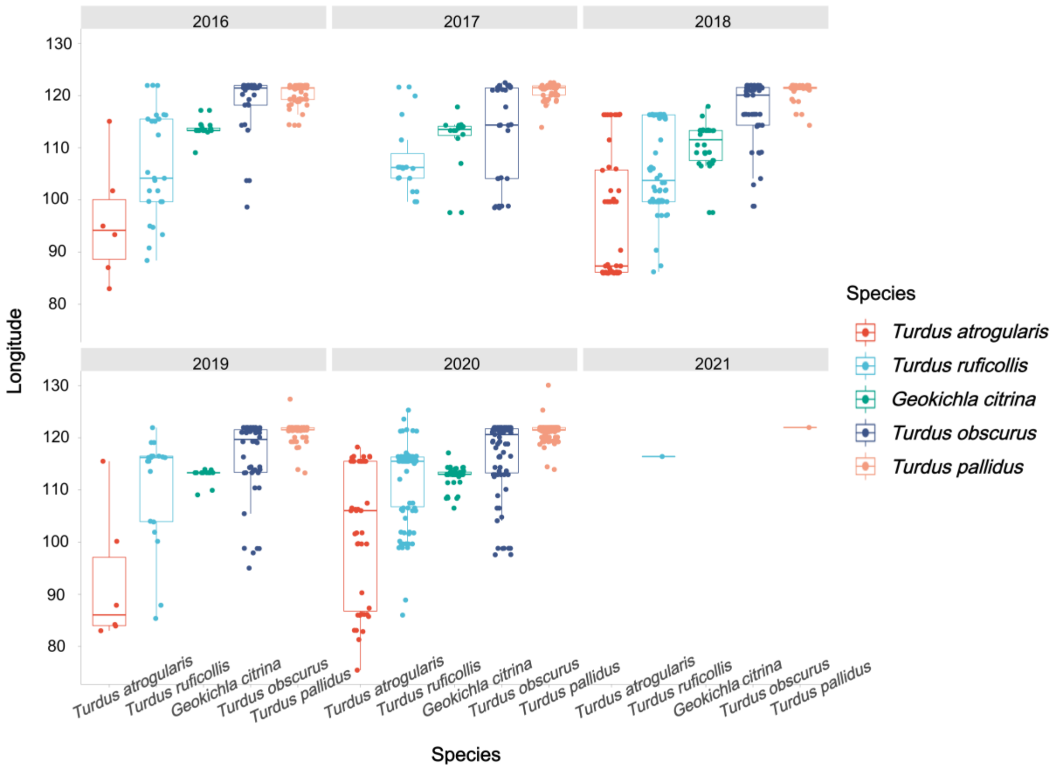
(a) Latitude distribution in spring migration



(b) Latitude distribution in winter migration

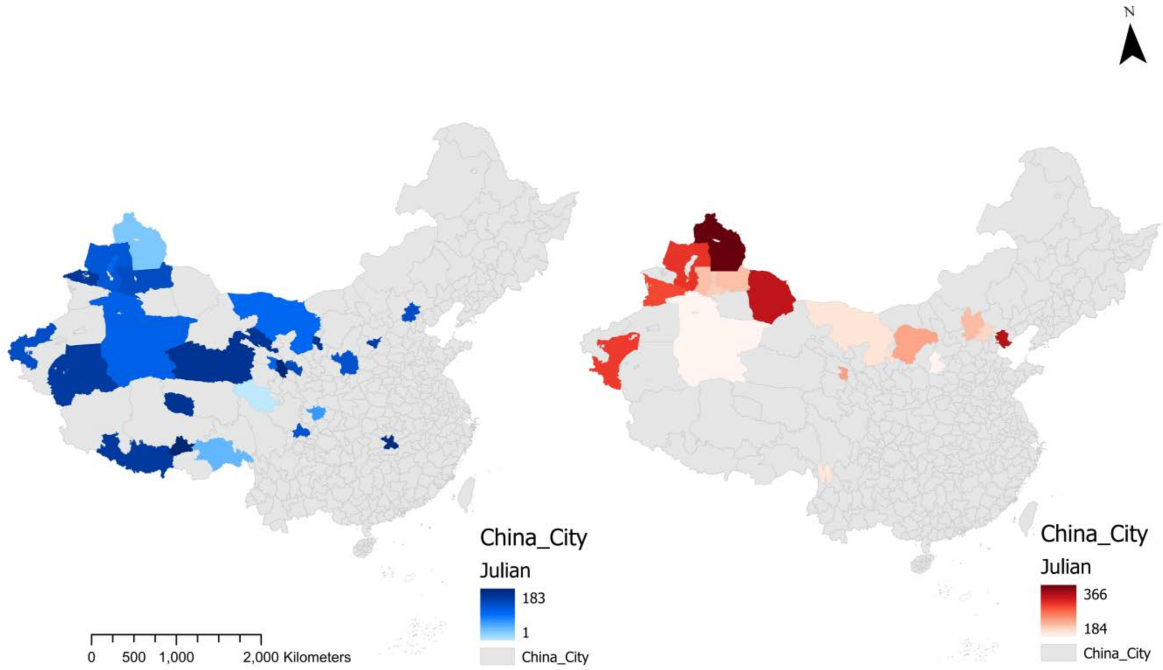


(c) Longitude distribution in spring migration

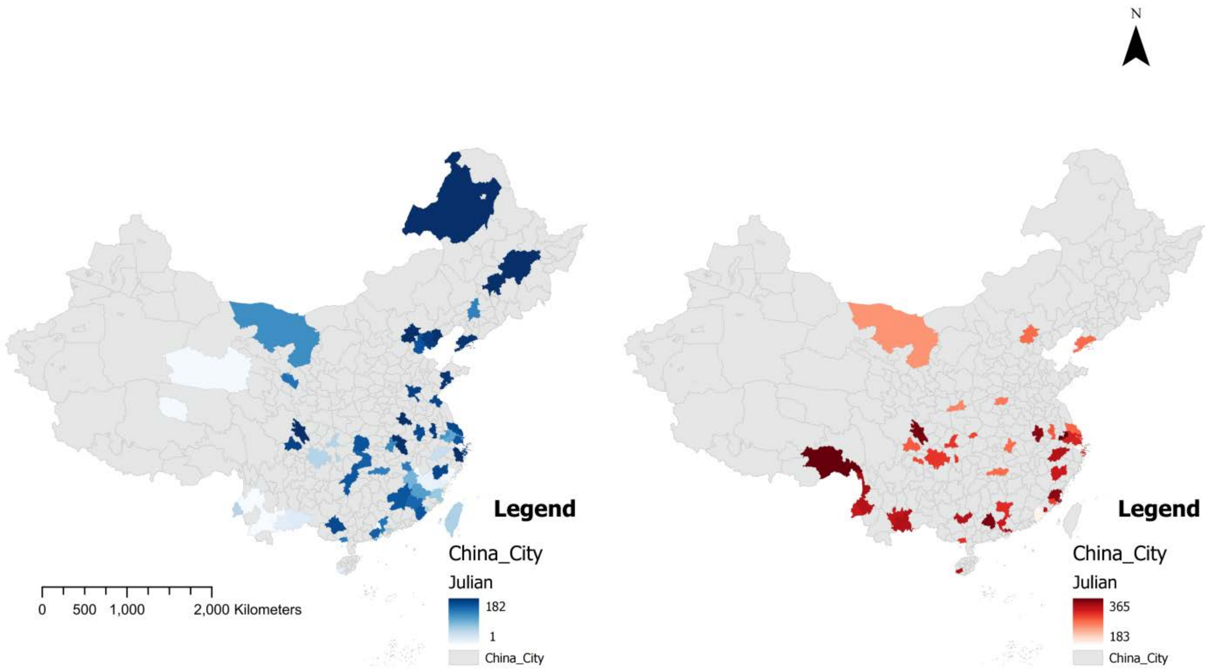


(d) Longitude distribution in winter migration

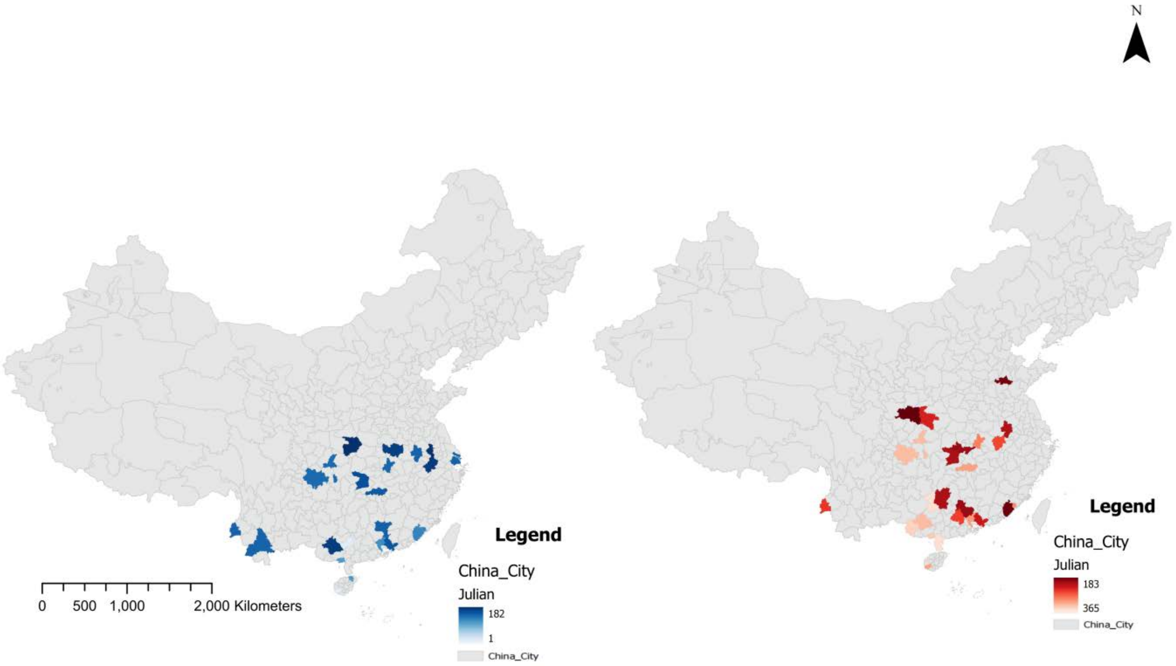
Fig. 3. The longitude and latitude distribution of checklists submitted (2015–2021) across the study area at spring migration and Autumn migration for each species (using all the data).



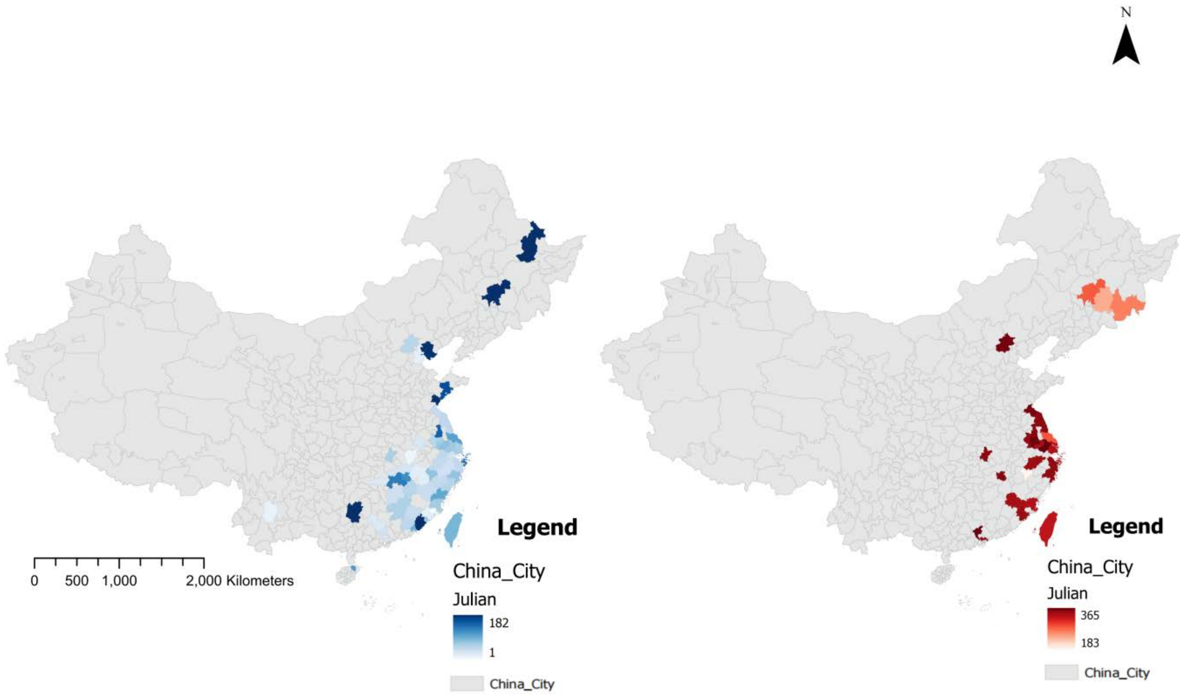
(a) *Turdus atrogularis*



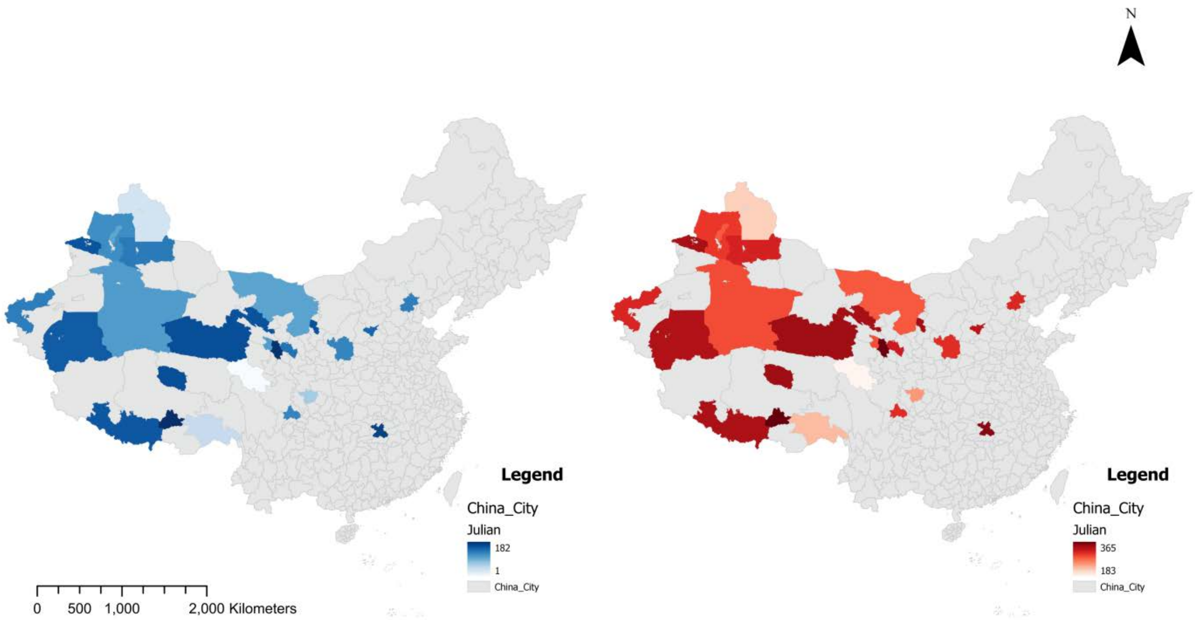
(b) *Turdus obscurus*



(c) *Geokichla citrina*



(d) *Turdus pallidus*



(e) *Turdus ruficollis*

Fig. 4 The temporal and spatial pattern of migration of Thrush in China.

In Fig. 3, the longitudinal and latitudinal distributions of the five species all show gradient differences. Based on the data of 5 species of Thrush in Fig. 3, we use ArcGIS to visualize the data on the urban map of China and generate Fig. 4. In Fig. 4, the intensity of the color represents the time of migration. The darker the color, the later the migration time. Among them, blue represents spring migration, and yellow-orange-red represents autumn migration. Fig. 4 report the migration routes of four major thrush species in China, which can be divided into north-south and east-west channels. Among them, the north-south channel includes the eastern channel, the central channel and the western channel, while the east-west channel includes a northern channel. The migration channel of *Turdus pallidus*, *Turdus obscurus* and Turdus *atrogularis* shows the eastern channel pattern, which runs through the eastern coastal provinces of Guangdong, Fujian, Jiangxi and Zhejiang. A schematic view of the *Geokichla citrina* has shown a central passage pattern through Guangdong, Guizhou, Hubei, Hunan and other places. The migration pathway of *Turdus atrogularis* and *Geokichla citrina* indicates a central channel pattern, which passes through Yunnan, Sichuan and Tibet. The migration pathway of *Turdus ruficollis* and *Turdus atrogularis* also shows the trend of the northern channel, which passes through provinces of Xinjiang, Inner Mongolia, Gansu and Jilin. In the spatial migration pattern, the spring migration of five species is more scattered, and the autumn migration is more concentrated. Checklists of Thrush observations for the spring migration come from more different cities, showing a higher spatial diversity.

5. Conclusion

The patterns of bird migration are diverse around the world. One of the most common ones is the migration in the north-south direction. Currently, many application websites and applications in the world are used to record and track bird migration, including a shared citizen database called eBird. We crawl 31 species on checklists of Thrush observations from China Bird Report Center between 2000 and 2021. Among 31 species, we select *Turdus ruficollis*, *Turdus atrogularis*, *Geokichla citrina*, T*urdus obscurus* and *Turdus pallidus* as our main analysis objects. With the help of R software, the maximum, minimum, median and span values of these five thrushes in the three parameters of longitude, latitude, and date of passage are obtained. In ArcGIS, the depth of city color is used to express the early or late migration of different species of thrush in spring and autumn among various cities. The above data are used to analyze the temporal and spatial patterns of spring and autumn migrations of Thrush in China.

Even though in the current stage the analysis result is reasonable, some limitations still exist. Firstly, according to the IUCN list, up to thirty species of thrushes in transit in China. In contrast, we found only 23 species of birds reported from China Bird Report Center. Secondly, due to the lack of data from earlier years and incomplete reporting data, we only ended up with five species reported over a six-year period. The five-year time span is somewhat unconvincing for the study of changes in bird migration strategies and factors influencing bird migration and climate change. Thirdly, the data quality of our citizen data is not high and the degree of accuracy in identifying birds is influenced by the experience of users. As a result, misidentification and misclassification of bird species may occur. The density of data distribution is very uneven, depending on the user or the range of activity. The coordinates of checklists of Thrush observations are concentrated in economically developed areas such as North, Shanghai and Guangzhou, with a high concentration of universities. Fourthly, we note that the distribution of reported coordinates from inland or less densely populated areas is also positively influenced by the distribution of bird ringing stations. The combination of individual and citizen data will be a future direction for studying the spatial and temporal migration patterns and population dynamics of Thrushes.

Acknowledgements

This study was funded by Mingxi Forestry Bureau. We are grateful for the support from Mingxi Bird Banding and Migration Research Program, whose expertise and advice greatly assisted the research. We would also like to show our gratitude to Professor Chen Ying from the College of Forestry, Fujian Agriculture and Forestry University, for her support of research guidance and research methods, and Postdoctoral Researcher Shang Chen for his advice on data processing, whose help greatly improved the paper.

References

[1] The Cornell Lab. (2021, August 1). *The Basics Of Bird Migration: How, Why, And Where.* https://www.allaboutbirds.org/news/the-basics-how-why-and-where-of-bird-migration/

[2] Denny, M., & ebrary, I. (2016). *Long hops: Making sense of bird migration. University of Hawai'i* Press. https://uhpress.hawaii.edu/title/long-hops-making-sense-of-bird-migration/

[3] BirdCast. (2021, November 3). *Migration tools.* https://birdcast.info/migration-tools/

[4] Strycker, N. (2015, January 1). *How to Use eBird.* https://www.audubon.org/news/how-use-ebird

[5] China Bird Report Center. (2021, November 3). *Regional record statistics.* http://www.birdrecord.cn/

[6] App Store Preview. (2021, November 3) *iBird Pro Guide to Birds.* https://apps.apple.com/us/app/ibird-pro-guide-to-birds/id308018823

[7] Supp, S. R., Sorte, F. A. L., Cormier, T. A., Lim, M. C. W., Powers, D. R., Wethington, S. M., Goetz, S., & Graham, C. H. (2015). *Citizen-science data provides new insight into annual and seasonal variation in migration patterns.* Ecosphere (Washington, D.C), 6(1), art15-19. https://doi.org/10.1890/ES14-00290.1

[8] Weisshaupt, N., & Rodríguez-Pérez, J. (2017). *Habitat use of the wood warbler phylloscopus sibilatrix during spring migration versus breeding season based on citizen science data.* Bird Study, 64(3), 386-392. https://doi.org/10.1080/00063657.2017.1364696

[9] Frank A. La, S., & Somveille, M. (2020). *Survey completeness of a global citizen‐science database of bird occurrence.* Ecography (Copenhagen), 43(1), 34-43. https://doi.org/10.1111/ecog.04632

[10] Dennhardt, A. J., Duerr, A. E., Brandes, D., Katzner, T. E., & West Virginia Univ., Morgantown, WV (United States). (2017). *Applying citizen-science data and mark–recapture models to estimate numbers of migrant golden eagles in an important bird area in eastern north America.* The Condor (Los Angeles, Calif.), 119(4), 817-831. https://doi.org/10.1650/CONDOR-16-166.1

[11] Pancerasa, M., Sangiorgio, M., Ambrosini, R., Saino, N., Winkler, D. W., & Casagrandi, R. (2019). *Reconstruction of long-distance bird migration routes using advanced machine learning techniques on geolocator data.* Journal of the Royal Society Interface, 16(155), 20190031-20190031. https://doi.org/10.1098/rsif.2019.0031

[12] Lin, T., Winner, K., Bernstein, G., Mittal, A., Dokter, A. M., Horton, K. G., Nilsson, C., Van Doren, B. M., Farnsworth, A., La Sorte, F. A., Maji, S., Sheldon, D., & Freckleton, R. (2019). *MistNet: Measuring historical bird migration in the US using archived weather radar data and convolutional neural networks.* Methods in Ecology and Evolution, 10(11), 1908-1922. https://doi.org/10.1111/2041-210X.13280

[13] Bird, T., Lyon, J., Nicol, S., McCarthy, M., Barker, R., & O'Hara, R. B. (2014). *Estimating population size in the presence of temporary migration using a joint analysis of telemetry and capture–recapture data.* Methods in Ecology and Evolution, 5(7), 615-625. https://doi.org/10.1111/2041-210X.12202

[14] Zheng, G. M. (2017). A c*hecklist on the Classification and Distribution of the Birds of China (3rd ed.).* Beijing: Science Press.

[15] MacKinnon, J. R., Phillipps, K., & He, F. (2000). *A field guide to the birds of china*. Oxford University Press.