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INFLUENCE OF ASTRONOMICAL (LUNAR)/ METEOROLOGICAL FACTORS IN ONSET OF DAWN SONG CHORUS IN THE PIED BUSH CHAT (*SAXICOLA CAPRATA*)

Navjeevan Dadwal and Dinesh Bhatt

Avian Diversity and Bioacoustics Lab, Dept. of Zoology and Environmental Science

Gurukula Kangri University, Haridwar, Uttarakhand, India

Email: - navjeevan.dadwal@gmail.com

Abstract

Climatic factors which prevail during the breeding season of avian species in spring and early summer may trigger the onset of singing behavior in songbirds. To understand the effect of climatic variables on the onset of dawn song chorus we conducted a study, in the natural habitats of a tropical songbird, the Pied Bush Chat *Saxicola caprata*, located in Haridwar, Himalayan Foothills, India during early spring. The results of present study indicated that the dependency of onset time of dawn chorus was on a number of environmental factors (singly or jointly) such as daily temperatures, rain rate, bright sunshine hours, photoperiod, lunar phase, indices of apparent temperatures, dew point, sunrise timings and day length. The dependency of song bout length was on daily temperatures, rain rate, wind direction, photoperiod, lunar phase, indices of apparent temperatures, dew point, sun rise timing and day length whereas, the song rate depended on daily temperature, photoperiod, indices of apparent temperatures, dew point, sun rise timing and day length. Further, stepwise multiple regressions revealed that onset time of dawn chorus was dependent on photoperiod and lunar phase while the song bout length and song rate were influenced by day length and sun rise timing respectively.

Introduction

The mutual relationship between the sun and seasons may affect the animal behavior severely as a change in climatic variables may activate specific behavioral patterns among animals [1,2]. The onset of the dawn chorus in songbirds is one such visible change that has been the focus of many scientific studies for a number of decades [3–6].

The dawn chorus of passerines is a classic example of the twilight peaks in sexual signalling and territorial displays that occur across a range of *taxa* where environmental factors have been marked to be important in this context [7] and it has been accepted that the effect of sunrise timings and other microclimatic conditions may influence the onset of chorus [8,9]. It has long been projected that each species has its own particular awakening time and the regularity with which birds first sing in the morning is under the influence of sun rise timing [3]. It is also believed that birds have a highly developed sense of time as their biological clock can perceive the changes in the quality of light and day length which may trigger the course of breeding in birds [10,11].

Other than annual fluctuations in day length and sun rise timing, it has also been proposed that moonlight may also influence the start of a bird's singing [12–14] and the weak light intensities preceding the beginning of civil twilight are also sufficient to stimulate daybreak singing in many temperate zone avian species such as the Field Sparrow (*Spizella pusilla*), Catbird (genus *Ailuroedus*) and cardinal (genus *Paroaria*). It has also been pronounced that even the low light dawn singing is apparent, a reliable indicator of male quality perhaps more so than singing at other time of the day [15].

Recently, it has been projected that lunar cycles may affect the behavior of diurnal species, especially those which carry out their breeding protocols in the twilight period which has received little direct empirical testing [16,17]. Additionally, the climatic variables such as the rise in temperature and decrease in relative humidity could also pose the similar effects on the onset of singing behavior [18]. It is believed that the songbirds have their singing pattern tuned to the change in the climatic variables and the seasonal attenuation in daily high temperature, low temperature and a gradual rise in the temperature [19,20]. It has been suggested that lower temperature and high humidity at dawn may restrict the activity of birds [21]. In contrast lower wind speeds in this period are more energetic-efficient and favorable for sound travel with consistency [7]. A positive relationship between the amount of singing and ambient temperature has been documented [19,20,22,23]. However, quantifying climatic factors which attribute towards the change in the seasons may be difficult to segregate as sometime a given variable may not act independently on the biological behavior. It has been argued that temperature or humidity alone may not precisely successful in terms of their impact on the singing behavior [18,24]. The interaction of two or more parameters can significantly alter the impact of themselves when acting singly. It may be mentioned that the study of dial pattern in song have received little attention than the song repertoire size and song learning the quantitative documentation of patterns of song output remains unusual [25–27].

In the light of above background, we conducted a field study to demonstrate how, whether, and to what degree the astronomical (lunar) and meteorological factors influence the onset of dawn song chorus during the beginning of the breeding season in a tropical songbird, the Pied Bush Chat (*Saxicola caprata*).

Materials and Methods

The Pied Bush Chat (Order *Passeriformes*, Family *Muscicapidae*) is a tropical songbird that occurs discontinuously from *Transcaspia* and the Indian subcontinent to South-East Asia, the Philippines, Indonesia, New Guinea and New Britain. The breeding season is mainly February to August with a peak in March to June. The natural habitat of Pied Bush Chat is majorly an open cultivated landscape or a grassland, especially paddy and sugar cane fields.

The present study was carried out during 1^{st} January to 28^{th} February 2015 (59 days) in Haridwar (Himalayan Foothills; $29^{0}55^{'}$ N and $78^{0}08^{'}$E) India. The males Pied Bush Chats usually start their singing activities from the last week of January and there singing behavior becomes quantifiable from the first week of February. The biological variables (singing parameters) considered for this study were onset time of dawn chorus (°hours) it is the time when males initiated their dawn song chorus (uttered first phrase), song bout length i.e. the total duration of dawn song delivery (minutes), and song rate (song types per minute). The biological variables are the average (Mean± S.D.) of six individuals per day. The onset timing was considered of whichever individual male sang earliest.

We selected 12 male Pied Bush Chats in their respective territories and observed six males each morning during the study period. For the identification purposes, the males were ringed with plastic colour bands in the beginning of breeding season. The male Pied Bush Chats generally delivered their song bouts from regular song posts (perches) throughout the breeding season. In a given day all six males were attended/recorded by six different observers simultaneously. The males were observed from the initiation of their dawn song chorus till they terminated their daily song delivery. The onset time was noted with the help of stop synchronised stop watches. We recorded the timing of the onset of the dawn song delivery of each male at alternative days.

Sennheiser ME 67 directional microphone attached to a Marantz PMD 660 and 670 digital sound recorders was used for recording of singing behavior of Pied Bush Chats. We collected about 180 (30 days×6 males) recordings by the end of February. Recordings were saved as WAV format with input sampling frequency of 24000 Hz and amplitude format of 16 bit. Spectrograms were prepared for the calculation of song rate with Avisoft SAS Lab Pro 4.1 software[8].

For climatic factors we used the data that were received from a weather station mounted at the department of zoology and environmental science, Gurukula Kangri University, Haridwar, Uttarakhand, India, which was connected to a display devise (Davis) Vantage Pro2 ™. The climatic data was recorded at each hour via a data logger attached to a stationary computer system for 24 hours during the study period. All study sites were open cultivated landscapes, open scrub or grasslands, sparse bushes (as mentioned above) and within 3 KM radius from the location of the weather station. The climatic factors inculcates a range of variables such as photoperiod i.e. the period of time each day during which study species received illumination (hours), lunar phase i. e. the shape of the illuminated (sunlit) portion of the moon as seen by an observer on Earth. (% age visibility), solar radiations i. e. energy radiated from the sun in the form of electromagnetic waves, including visible and ultraviolet light and infrared radiation (Watt/m^2), daily solar energy i.e. radiant light and heat from the sun (Langley: 1Langley = 11.622 Watt-hour per square meter and 41.84 kilojoules per square meter), bright sunshine hours measuring the duration of sunshine in given period (usually, a day) for a given location on earth, (hours), sun rise timing, the instant at which the upper edge of the sun appears over the horizon in the morning (°hours), mean temperature (°C), high temperature (°C), low temperature (°C), rain rate (Inches), wind speed (km/h), wind direction (°), humidity (%), dew point (°C) and day length (hours). The interactions of parameters were also considered. For instance the combined effect of daily temperature, humidity and wind speed was calculated via apparent temperatures such as THWI (This index uses temperature, humidity and wind to calculate an apparent temperature that incorporates the cooling effects of wind on the perception of temperature) and the combined effect of temperature, humidity, solar radiation and wind was tested via THSWI (This index uses temperature, humidity heating effect of direct solar radiation and cooling effect of the wind to calculate an apparent temperature). The definitions of all climatic factors and indexes (combined parameters) studied were adopted from the manual of the weather link 5.7.1 (Available at http://www.davisnet.com/product_documents/weather/manuals/07395-234_IM_06312.pdf). The recording of all the windy and rainy days were included in the observation chart.

We used NCSS Statistical Graphics and Sample Size Software for analysis of data. We used circular interval scale for time of day, where a day was divided into twenty-four equal intervals, called hours. One hour of a day corresponds to 150 (i.e., 3600/24) of a circle, and 10 of a circle corresponds to four minutes of a day. In general, we converted X time units to an angular direction (A, in degrees hours), where X has been measured on a circular scale having k time units in the full cycle: A = (3600) (X)/ k. For example, to convert a time of day (X, in hours) to an angular direction, k=24 hr. A spearman's rho correlation (two-tailed) was performed to find the correlation between song parameters and climatic factors. We applied the stepwise multiple regression to determine the effect of independent variables climatic factors on the dependent variable such as onset time of dawn chorus, song bout length, and song rate.

Results and **Discussions**

The correlation analysis in the present study showed that the onset time of dawn chorus depends on daily temperatures, rain rate, bright sunshine hours, photoperiod, lunar phase, indices of apparent temperatures (THWI and THSWI), dew point, sunrise timings and day length. Similarly, song bout length was found to be correlated with daily temperatures, rain rate, wind direction, photoperiod, lunar phase, indices of apparent temperatures, dew point, sun rise timing and day length and song rate appears to be influenced by daily temperature, photoperiod, indices of apparent temperatures, dew point, sun rise timing and day length. The correlations (+/-) among climatic factors and onset time of dawn chorus, song bout length and song rate are summarized in table 1 and figs 1-3.

Step wise multiple regression (climatic factors vs. onset time of dawn chorus, song bout length and song rate: The onset time of dawn chorus was found to be influenced by photoperiod (Standard coefficient=-1.1,T-Value=-8.34, probability level=0) and lunar phase (Standard coefficient=-0.29,T-Value =-2.24, probability level=0.03) while, the song bout length was influenced by day length (Standard coefficient=0.86,T-Value=8.35, probability level=0). The song rate was inclined towards sun rise timing (Standard coefficient=-0.7, T-Value =-4.86, probability level=0.000059).

Discussions

In the wild, the success of the survival of a species depends on upon its ability to breed at the most propitious time of the year and the prediction of the favourable season is based on the interaction of annual changes in day length with the biological clock mechanism of the species [29,10]. It appears that male Pied

Bush Chats can efficiently read the photoperiodic cues as all the parameters related to singing behavior such as onset time of dawn song chorus, song bout length and song rate were found significantly correlated with photoperiod and multiple regression has also pronounced the impact of photoperiod on the onset time of dawn song chorus. It has been predicted that start of dawn chorus should be mostly affected by variations in the light intensities [6]. The song output of Pied Bush Chat was coherent with sun rise timing and bright sunshine hours have also influenced the onset time of dawn song chorus. The multiple regression models have indicated the impact of day length and sun rise timing on the song bout length and song rate respectively. Since the weak light intensity preceding the beginning of morning civil twilight is sufficient to stimulate day break song in Pied Bush Chats, the early singers may harvest benefits in terms of territory defense, mate attraction and mate guarding [30].

It has been reported that the full moon has apparently affected the morning awakening time of some bird species [14]. It is interesting to see that during the initial signing performances the moon phase is of utter importance for the Pied Bush Chats in order to trigger the commencement of the daily signing activity. The similar behavior has been reported in many previously conducted studies [12,25,26]. Our data indicated that the lunar phase was positively correlated with the onset time of dawn chorus of Pied Bush Chats. The similar behavior has been reported in White-browed sparrows (*Plocepasser mahali*) and it was argued that the bird might sing earlier when the moon is full [31]**.** On the other hand, the male Pied Bush Chats composed smaller song bouts when the moon was full and vice versa as the lunar phase was found negatively correlated with song bout length. It is believed that predators eavesdropping may increase the vulnerability of a continuously vocalizing bird from a constant song post, particularly during twilight. Theoretically, if the light is low then chances are that the prey is at some advantage and may deliver a longer song bout. Thus, if moonlight is more than the song bout length should be less and vice versa [32]. Hence, it can be said that male Pied Bush Chats may have tailored their initial daily dawn singing time according to moon phases.

It is generally presumed that the environmental conditions under which signals are generated can affect receiver's response. Such variations in sexual signals can convey information about the quality of signallers [33]. For example, an individual singing in the cold may infer his quality to tolerate cold as singing in cold weather is thermally challenging [4]. The daily song cycle of the male Pied Bush Chats shows the gradual influence of increased abiotic factors as the onset time of dawn chorus, song bout length and song rate were found to be accelerated by the daily temperature. Also, male Pied Bush Chats tend to sing at low temperature while the coherence in the progression of singing behavior under the regular increase in the seasonal heat was well displayed by male Pied Bush Chats. It was suggested that song rates in Great Tit (*Parus major*) may be influenced by the air temperature [19]. The increase in song rate is supposed to have a connection with mate choice [34,35] and song rate may advance with the gradual rise in temperature level [23]. The similar results have been reported in Pied flycatcher (*Ficedula hypoleuca*) where song rate was found highly correlated with air temperature and timing /date of the season [5,36]. Interestingly, in an another study, it has been reported that the Female Linkon Sparrows (*Melospiza lincolnii*) showed behavioral biases toward the song produced in cold as song production in low temperature is thermally challenging [37].

Upon considering the combined effect of individual parameters in terms of THWI and THSWI in Pied Bush Chats it is apparent that onset time of dawn song chorus, song bout length and song rate were impacted by the combined climatic factors while the independent effects of parameters such as humidity or the wind were lesser influential but upon combining with other parameters such as temperature, the indexes showed greater effects on the singing parameters. In other studies, it has been pointed out that strong wind and rain both may affect the daily timing of the dawn song chorus [5]. The rain and wind can act directly through increased noise, reducing the ability to communicate efficiently or through increased cost of singing such as thermoregulation [38]. Our study also indicated that that Pied Bush Chat sings at regular perches and if the occupied perch is constantly confronted by a directional wind the males may stop their dawn song chorus as the communication occurred in such manner may not be that efficient. Hence, such directional winds may leave the males with the smaller song bouts [5,39–43].

Conclusion

This is the first report from any avian species of the Indian subcontinent indicating that climatic factors can significantly influence the onset of dawn singing. We found that in natural habitats of Pied Bush Chats the timing and sequence in which Pied Bush Chat starts and stops singing were consistent and predictable. Results further revealed that the onset time of dawn chorus, song bout length and song rate might be regulated by daily temperature, photoperiod and sunrise timing etc. It is interesting to note that despite experiencing lesser changes in annual day length and seasons as compared to temperate zone birds the onset of dawn chorus of the tropical Pied Bush Chat can be influenced by climatic factors.

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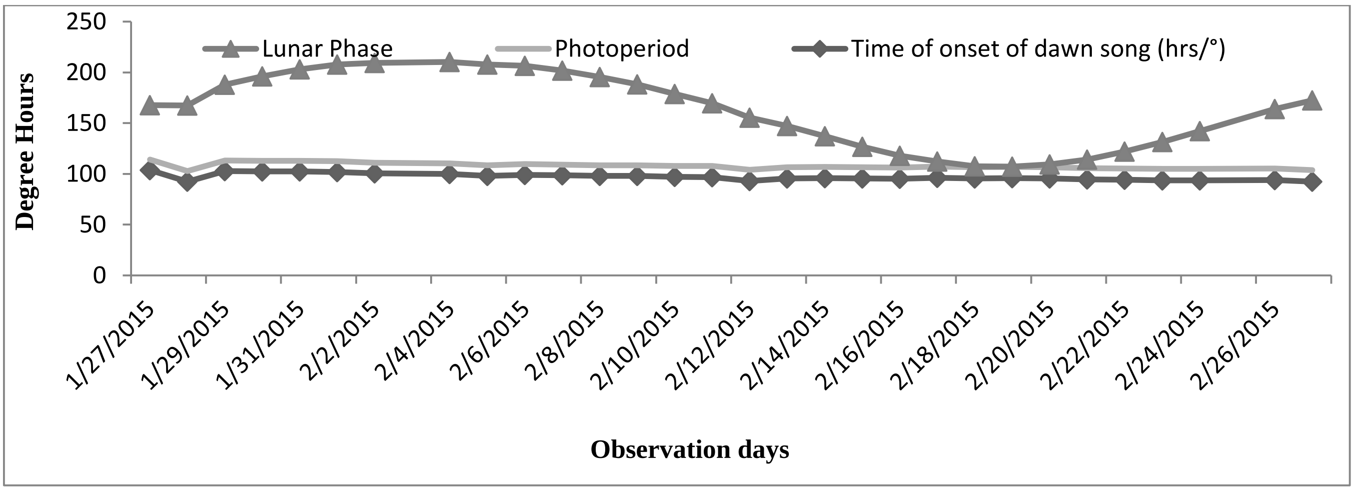

Fig. 1 Showing the progression of time of onset of dawn song vs. photoperiod and lunar phase

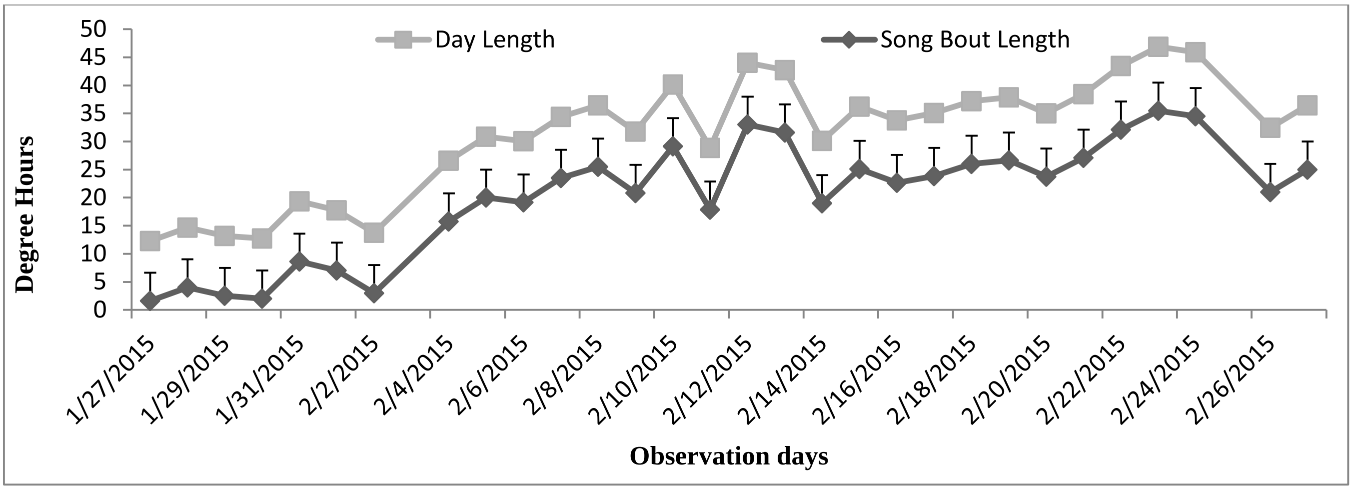

Fig. 2 Showing the progression of song bout length and day length

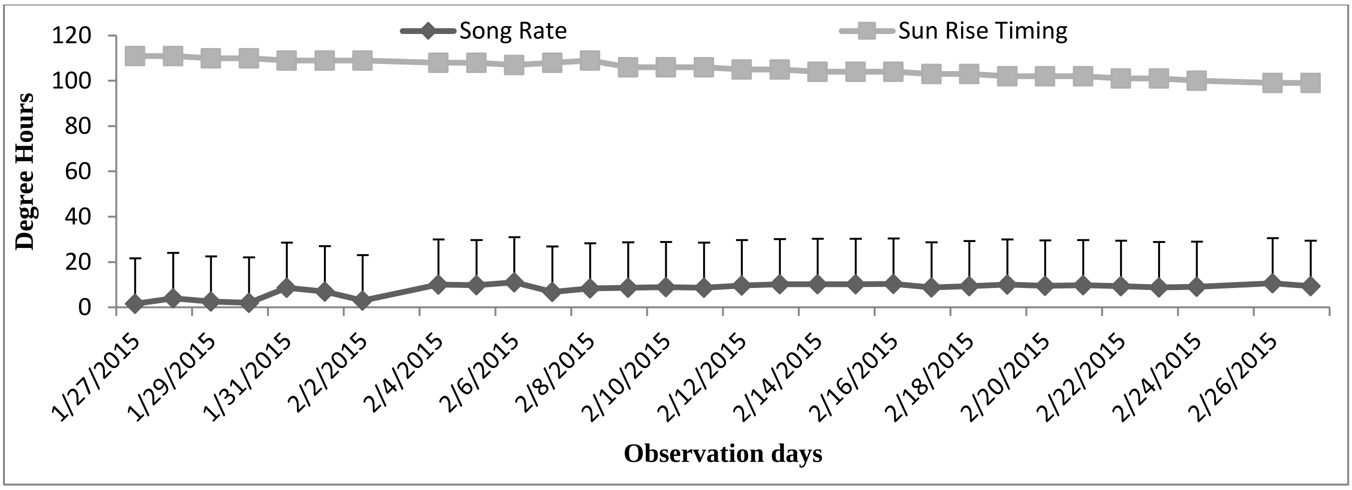

Fig. 3 Showing the progression of song rate and sunrise timing

Table 1. Showing the correlations among climatic factors and various song parameters (onset time of dawn chorus, Song Bout Length and Song Rate)

Sr. no.	Climatic Factors	Correlation	Sr. no.	Climatic Factors	Correlation
	onset time of dawn chorus vs. climatic factors				
1	mean temperature	n=30, r_s=-0.61, t=-4.1, df=28, p=0.0003	10	THWI	n=30, r_s=-0.61, t=-4.16, df=28, p=0.0002
2	high temperature	n=30, r_s=-0.58, t=-3.79, df=28, p=0.0007	11	THSWI	n=30, r_s=-0.63, t=-4.35, df=28, p=0.0001
3	low temperature	n=30, r_s=-0.56, t=-3.63, df=28, p=0.001	12	humidity	n=30, r_s=0.21, t=1.18, df=28, p=0.247
4	rain rate	n=30, r_s=0.55, t=3.52, df=28, p=0.001	13	solar radiation	n=30=, r_s=0.09, t=0.52, df=28, p=0.6
5	wind speed	n=30, r_s=0.18, t=1.01, df=28, p=0.32	14	solar energy	n=30, r_s=0.09, t=0.52, df=28, p=0.6
6	wind direction	n=30, r_s=-0.17, t=-0.93, df=28, p=0.36	15	dew point	n=30, r_s=-0.55, t=-3.53, df=28, p=0.001
7	bright sunshine hours	n=30, r_s=0.45, t=2.67, df=28, p=0.01	16	sun rise timing	n=30, r_s=0.73, t=5.81, df=28, p=0.000003
8	photoperiod	n=30, r_s=-0.76, t=-6.22, df=28, p=0.000001	17	day length	n=30, r_s=-0.76, t=6.22, df=28, p=0.000001
9	lunar phase	n=30, r_s=0.59, t=3.87, df=28, p=0.0005			
	Song Bout Length vs. climatic factors				
1	mean temperature	n=30, r_s=0.67, t=4.89, df=28, p=0.000037	9	lunar phase	n=30, r_s=-0.42, t=-2.5, df=28, p=0.01
2	high temperature	n=30, r_s=0.74, t=5.87, df=28, p=0.000003	10	THWI	n=30, r_s=0.69, t=5.08, df=28, p=0.000022
3	low temperature	n=30, r_s=0.53, t=3.34, df=28, p=0.002	11	THSWI	n=30, r_s=0.7, t=5.28, df=28, p=0.00001
4	rain rate	n=30, r_s=-0.53, t=-3.38, df=28, p=0.002	12	humidity	n=30, r_s=-0.34, t=-1.96, df=28, p=0.06
5	wind speed	n=30, r_s=-0.15, t=-0.82, df=28, p=0.419	13	solar radiation	n=30, r_s=0.19, t=1.07, df=28, p=0.2937

6	wind direction	n=30, r_s=0.41, t=2.4, df=28, p=0.02	14	solar energy	n=30, r_s=0.2, t=1.13, df=28, p=0.268
7	bright sunshine hours	n=30, r_s=-0.05, t=-0.31, df=28, p=0.758	15	dew point	n=30, r_s=0.58, t=3.78, df=28, p=0.00075
8	photoperiod	n=30, r_s=0.77, t=6.4, df=28, p=0.000001	16	sun rise timing	n=30, r_s=-0.73, t=-5.8, df=28, p=0.000003
			17	day length	n=30, r_s=0.77, t=6.4, df=28, p=0.000001
	Song Rate vs. climatic factors				
1	mean temperature	n=30, r_s=0.46, t=2.75, df=28, p=0.01	9	lunar phase	n=30, r_s=-0.32, t=-1.82, df=28, p=0.079
2	high temperature	n=30, r_s=0.36, t=2.1,df=28, p=0.044	10	THWI	n=30, r_s=0.48, t=2.96,df=28, p=0.0062
3	low temperature	n=30, r_s=0.46, t=2.81,df=28, p=0.008	11	THSWI	n=30, r_s=0.46, t=2.8, df=28, p=0.009
4	rain rate	n=30, r_s=-0.28, t=-1.6, df=28, p=0.12	12	humidity	n=30, r_s=-0.11, t=-0.59, df=28, p=0.559
5	wind speed	n=30, r_s=-0.05, t=-0.3, df=28, p=0.76	13	solar radiation	n=30, r_s=0.007, t=0.04, df=28, p=0.96
6	wind direction	n=30, r_s=0.17, t=,0.93, df=28, p=0.36	14	solar energy	n=30, r_s=0.02, t=0.11, df=28, p=0.913
7	bright sunshine hours	n=30, r_s=-0.14, t=-0.75, df=28, p=0.45	15	dew point	n=30, r_s=0.51, t=3.19, df=28, p=0.0034
8	photoperiod	n=30, r_s=0.57, t=3.69, df=28, p=0.009	16	sun rise timing	n=30, r_s=-0.61, t=-4.15, df=28, p=0.00028
			17	day length	n=30, r_s=0.57, t=3.69, df=28, p=0.0009