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ROOSTING BEHAVIOUR OF HOUSE CROW *(CORVUS SPLENDENS)* IN RELATION TO ENVIRONMENTAL VARIABLES

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ABSTRACT. - Evening roosting behaviour of house crow *(Corvus splendens)* was monitored from 27 locations in the heavily urbanised mainland of Singapore. This paper describes the general roosting behaviour of house crows. I analysed the relationships between crows' roosting times and environmental parameters (such as sunset time, temperature, light intensity and relative humidity). Sunset time was significantly correlated with all the roosting parameters: first arrival time, half arrival time, last arrival time and last vocalisation time. My study suggested that the roosting behaviour might be influenced by several environmental variables.

KEY WORDS. - House crow, *Corvus splendens,* roosting behaviour, environmental conditions, Singapore.

INTRODUCTION

Numerous studies have investigated communal roost as to aid in management of the bird species that affect or are affected by humans. Descriptive studies have focused on roosting behaviour (e.g., Jumber, 1956; Davis & Lussenhop, 1970; Swingland, 1976; Reebs, 1987), preferred roost site characteristics and site fidelity (e.g., Reebs, 1987; Morrison & Caccamise, 1990; Gorenzel & Salmon, 1995). However, communal roosts of house crows (*Corvus splendens*) are not well studied. No recent published research is available on the roosting behaviour of house crow in Southeast Asia. Hails (1985) investigated the population size and distribution of house crow in Singapore, identified problems caused by the crows, and suggested means of managing those problems. In 1980s, house crows were mainly coastal birds in Singapore, found near coastal parks, rivers, canals, harbours, dockland areas and on offshore islands (Hails, 1985). During the recent years, the crows have become common in the urban areas of Singapore. Their behaviour of roosting in these built-up areas is also becoming a common phenomenon. Therefore there is a need to investigate the roosting behaviour of urban crows in Singapore. Such study might have important implications for the design and preparation of appropriate control measures against the problems caused by roosting birds.

My study had the following objectives: to describe the general roosting behaviour of house crow, particularly on the times of entrance to the roost sites and to examine the relations of environmental factors such as temperature, relative humidity, light intensity and sunset time to the roosting times of these urban crows.

MATERIALS AND METHODS

Study subject. - House crow is not an indigenous bird of Singapore. Its natural distribution extends from South Asia which covers Pakistan, India and Sri Lanka to southern China and some parts of Indochina that include southern-western Thailand (Madge & Burn, 1994). This crow has become widespread by introduction or self-introduction to many countries around Indian Ocean and other parts of the world such as Hokkaido, Japan and New Jersey, eastern USA (Madge & Burn, 1994). It is also recorded in the far-away cities such as Durban, South Africa and Melbourne, Australia. In 1920s, the attempt to introduce house crow in Singapore was unsuccessful (Bucknill & Chasen, 1927). The present established population in Singapore originated from self-introduced birds that were probably transported by ships from India and Sri Lanka in 1940s (Hails & Jarvis, 1987; Madge & Burn, 1994).

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Study area. - My study was on the mainland of Singapore (1°37'N, 103°75'E). Singapore is a small city-state of 647.8 km^2 with a population of 3.9 million (Singapore Department of Statistics, 1999). It is highly urbanised with more than half the main island developed for housing, industrial or recreational purposes (Corlett, 1992). Open land, which consists of turfed area, golf courses and farms occupies about 6500 ha. Exotic trees, shrubs and climbers are widespread, planted in the urban areas especially along roadsides and in housing estates (K. S.-H. Peh, pers. obs.). Singapore has an equatorial climate with a daily temperature range of 23 to 34°C (Singapore Meteorological Service). The average daily relative humidity ranges from 90% in the morning to around 60% in the mid-afternoon (Singapore Meteorological Service).

Roosting behaviour. - From 12 July to 15 August 1999, I observed 27 roost sites. Observations were then repeated at 25 roost sites from 19 August to 13 October 1999. During the period of study, two roost sites experienced regular shooting after the first observation. I observed the roosting crows from the most advantageous points, for instance the elevated spot in a building or open space. Although these observation sites were usually more than 50 m away from the roosts, I could still carry out the surveys without optical equipment. Observations began at 1630 hours when the crows started to return to the roost sites and continued until it was too dark to count the crows accurately (usually about 30 min after sunset). I counted the number of the crows that flew towards roost trees every five minutes. Simultaneously, departing crows that left the roost sites were also counted. Each five-minute interval, the number of roosting crows was considered the total count for the arrivals minus the number of departures.

I recorded the sunset time, temperature, relative humidity and illumination during each roost observation. Sunset times were obtained from the Singapore Meteorological Service. The temperature and relative humidity were measured using a digital thermo-hydrometer. Illumination was measured in lux using Li-COR photometric sensor. I recorded all measurements 45 min before sunset. The value used was the average of two measurements taken within a 5 minute interval.

In addition, I recorded the exact time of first arrival, last arrival and last vocalisation during each observation. Time of first arrival was defined as the time after which the first crow was roosting continuously in the roost site (Engel et al., 1992). Time of last arrival was considered the time after which the last crow settled in the roost tree before it was too dark to observe. Time of last vocalisation was the time after which the roosting crows ceased calling completely. Time at which 50% of the population arrived was calculated from the count. The environmental measurements and sunset times were then examined in relation to those observed aspects of roosting behaviour.

Data analyses. - Data analyses were carried out using the analysis programme, Statistical Analysis System (SAS) following standard techniques (SAS Institute, 1990). The environmental measurements and the times of sunset were correlated with the time of first arrival, time of half arrival, time of last arrival and time of last vocalization. Since it is essential to test if the possible effects on times of entrance to the roosts were due to the roost sites, I compared the data from the first count and those of the second count of all roost sites using Spearman rank-order correlation coefficient. Because the data from repeated counts were not significantly correlated ($P > 0.05$) with those from the first, observation data collected from both counts were considered independent and were pooled together for statistical tests (i. e. n = 52).

Spearman rank-order correlation coefficient was employed to examine the effects of the environmental variables on all the roost arrival variables. Because more than one environmental variable was significantly correlated with time of roost arrival, the standard Bonferroni technique (Rice, 1989) was used to exclude those variables that were judged to be significantly correlated by chance alone. The *P*-value was therefore set at < 0.16. Furthermore, Spearman partial rank-order correlations were calculated to determine if the significantly correlated environmental variables were independent of one another.

OBSERVATIONS AND RESULTS

Roosting behaviour. - Between 12 July and 13 October 1999, I observed 52 evening crow arrivals at 27 roost sites. Despite the consistency in climate of Singapore, there were still variations in environmental conditions. The sun set at 1916 hours at the beginning and gradually set at 1853 hours at the end of the study. The range of light intensity measured before sunset was from 0 to 6700 lux. Values of relative humidity ranged from 54 to 90% and temperature from 26.2 to 34.9 °C.

Fig. 1 shows that the maximum count of the roosting crows at each site exceeded 200, except Sin Ming and Tanjong Pagar. The highest count at a single roost site (Jalan Pelikat) was 2095 on 21 August 1999. In order of decreasing size, other roosts with maximum sizes greater than 1000 included Redhill Close, Guillemard, East Coast, Kitchener and Ang Mo Kio. The lowest count was 57 crows at Simon. The relative sizes of each roost varied considerably during the period of observations. During the second count, Toa Payoh and Newton which experienced regular shooting, decreased in size by 72% and 71%, respectively. On the other hand, roost size increased about 14 times at Simon during the second count and at Beng Wan size increased about 20 times.

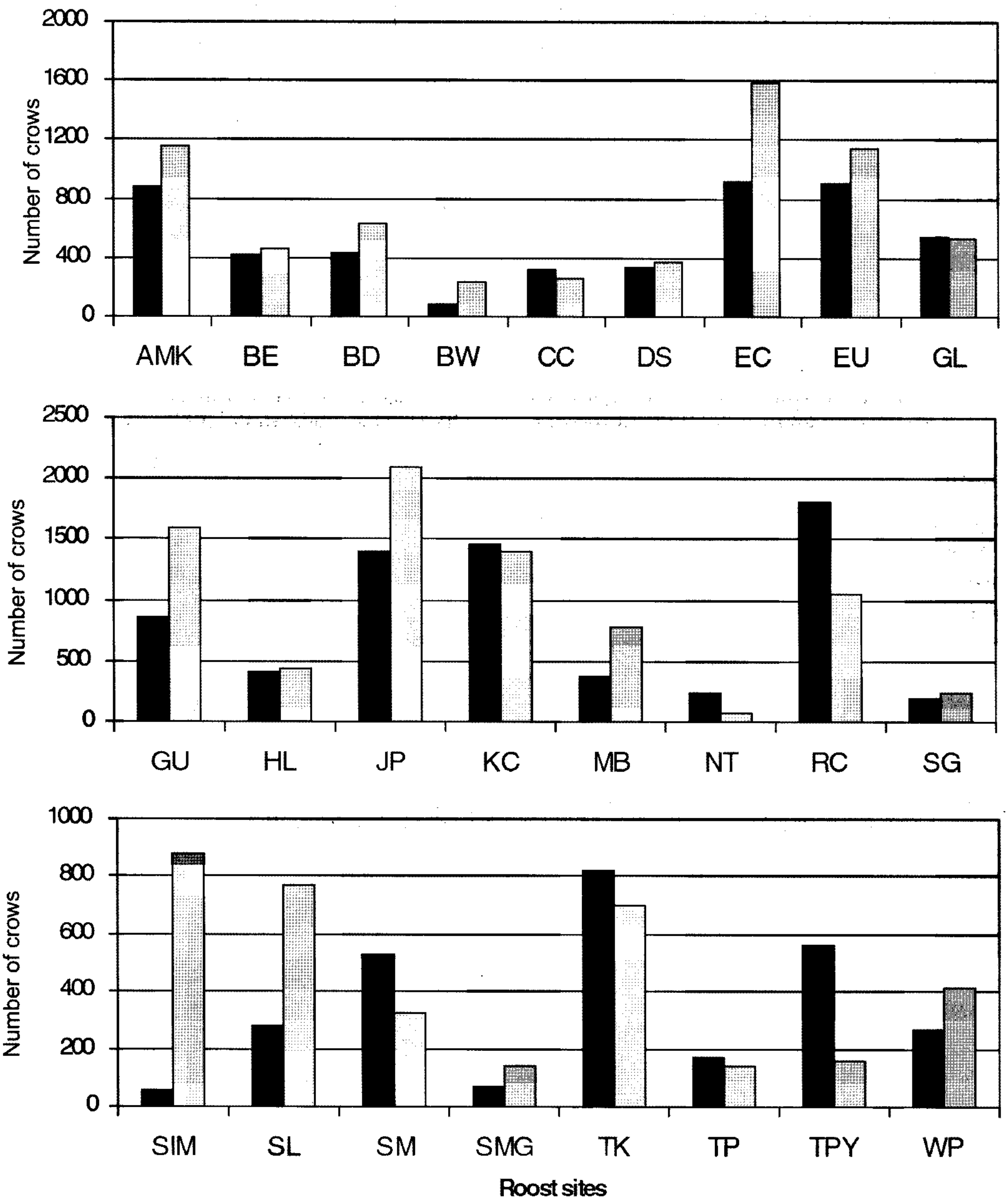

Fig. 1. Temporal trends of the populations of urban House Crows at 25 roost sites in Singapore. Black bars represent the first count from 12 July to 15 August 1999 and grey bars the second count from 19 August to 13 October 1999. Both counts of each site were at least one month apart. All roost sites are indicated by letters: AMK Ang Mo Kio; BE Beach; BD Bedok; BW Beng Wan; CC Circuit; DS Dorset; EC East Coast; EU Eunos; GL Geylang Lorong 40; GU Guillemard; HL Havelock; JP Jalan Pelikat; KC Kitchener; MB Mountbatten; NT Newton; RC Redhill Close; SG Sungei; SIM Simon; SL Siglap; SM Simei; SMG Sin Ming; TK Telok Kurau; TP Tanjong Pagar; TPY Toa Payoh; WP Whampoa.

Within each roost site, numbers of the roost trees used by the crows were consistent which ranged from 4 (Whampoa) to 24 (Redhill Close) trees. The mean length of roost was 129.4 ± 14.4 m. At each roost site, crows tended to congregate on the more attractive roost trees. It was only when the number had grown too large, that some of them would 'spillover' to the other roost trees to join the late arrivals. Prior to flying into roost trees, crows gathered from all directions to form small groups near roost sites. These pre-roosting aggregations often perched on TV antennas, rooftops, wayside trees and open fields. The crows fed, drank and preened during such aggregations. As the evening progressed, individuals shifted to the roost trees singly, in pairs or in groups up to more than 20 individuals. The entrance to the roosts was gradual spanning 42-161 min. Food carrying to the roost trees was observed on two occasions and feeding of fledglings by a parent within the family group was also observed in the roost trees.

Crows began to roost on trees between 140 min before and 40 min after sunset. Maximum counts were always obtained during the final count interval. Mean time of first arrival on roost trees was 98 ± 3 min before sunset (n = 52). Times of first arrival neither correlated significantly with light intensity ($r_s = 0.21$, $N = 52$, $P = 0.14$) nor with temperature ($r_s = 0.29$, $N = 52$, $P = 0.04$). However, the first arrival times tended to be earlier when the relative humidity was higher ($r_s = -0.39$, $N = 52$, $P = 0.004$). The first arrival time also was correlated significantly with sunset time ($r_s = 0.67$, $N = 52$, $P = 0.0001$). The correlation between the first arrival time and sunset time remained significant even after statistically controlling for relative humidity (Table 1). Therefore, the crow's first arrival time based on sunset time was independent of relative humidity. However, on the basis of partial rank-order correlation coefficient, first arrival time based on relative humidity was dependent on sunset time (Table 1).

The mean time of half arrival was 26 ± 3 min before sunset. Times of half arrival showed a correlation with all the environmental variables. Thus, 50% of the roosting population tended to arrive earlier on cooler days ($r_s = 0.35$, $N = 52$, $P = 0.01$), on dark cloudy afternoons ($r_s = 0.41$, $N = 52$, $P = 0.003$) and when sun set earlier ($r_s = 0.51$, $N = 52$, $P = 0.0001$). Time of half arrival was also negatively correlated with the relative humidity ($r_s = -0.46$, $N = 52$, $P = 0.0007$). The correlations between time of half arrival and each environmental variable was independent of other variables, except that half arrival time based on temperature was dependent on relative humidity (Table 1).

The last crows usually arrived on the roost trees in the dark. The mean time of last arrival was 17 ± 2 min after sunset. There was no correlation between the time of last arrival and light intensity.. However, the last arrival time was delayed when sun set later ($r_s = 0.59$, $N = 52$, $P = 0.0001$) and when temperature was higher ($r_s = 0.25$, $N = 52$, $P = 0.01$). The last crows also tended to arrive later when relative humidity was lower ($r_s = -0.33$, $N = 52$, $P = 0.0007$). The last arrival time based on sunset was independent of temperature and relative humidity (Table 1). Partial correlation coefficient analysis indicated the time that the last crows arrived

Table 1: Spearman partial rank-order coefficients for the significant correlations between roost arrival times and environmental variables with the effect of other variables held constant. * indicates $P < 0.16$, showing the correlation failed to remain significant.

Correlation between		Controlling for			
Roost arrival variables	Environmental variables	Sunset time	Light intensity	Relative humidity	Temperature
First arrival time	Sunset time	---	0.66	0.59	0.64
	Relative humidity	-0.05*	-0.34	---	-0.24
Half arrival time	Sunset time	---	0.48	0.35	0.45
	Light intensity	0.37	---	0.23	0.29
	Relative humidity	-0.25	-0.32	---	0.33
	Temperature	0.24	0.18	-0.09*	---
Last arrival time	Sunset time	---	0.71	0.63	0.69
	Relative humidity	-0.14*	-0.38	---	-0.37
	Temperature	0.19	0.22	-0.13*	---
Last vocalisation time	Sunset time	---	0.65	0.59	0.63
	Relative humidity	-0.02*	-0.3	---	-0.28

based on temperature was dependent on relative humidity and that based on relative humidity was dependent on sunset time (Table 1).

After the entire roosting population had arrived, vocalizations gradually faded and then stopped completely. The mean time of last vocalization was 25 ± 2 min after sunset time. The cessation of the crows' vocalization was delayed on the days when sun set later (r_s = 0.52, N = 52, P = 0.0001) and when relative humidity was lower (r_s = -0.27, N = 52, P = 0.006). The time when the vocalization ceased based on sunset time was independent of relative humidity but the last vocalization time based on relative humidity was strongly dependent on sunset time (Table 1).

DISCUSSION

The environmental conditions in Singapore may vary for two reasons: the effect of (1) the weather and (2) the time of the year. For the latter reason, the sunset time decreased throughout the study. Sunset time was found to correlate significantly with all studied aspects of house crow's roosting behaviour: first arrival time, half arrival time, last arrival time and last vocalization time. Time of sunset therefore may serve as proximate cue for roost approach. However, the correlation was insufficient to conclude that there was a seasonal shifts in arrival times relative to time of sunset. The recent research on other species such as common myna (*Acridotheres tristis*) and white-vented myna (*A. javanicus*) had also shown that the times of roosting birds arrived at roost sites significantly associated with evening sunset times (e.g., Kang & Yeo, 1993; Gupta & Goel, 1994; Jayson & Mathew, 1995). Generally, house crows, like black-billed magpie *Pica pica* (Reebs, 1987) always arrive at roost sites earlier relative to sunset. This may imply that the food resources for these birds are abundant and, therefore they are able to secure their daily food requirement before sunset. In contrast, Zammuto & Franks (1981) reported that chimney swifts (*Chaetura pelagica*) returned to roost site later relative to sunset times. Eiserer (1984) reviewed that there was no satisfactory explanation available for this difference in roosting behaviour among species. However, it was suggested that a circadian rhythm might play a role in controlling the roosting times (Swingland, 1976). A light sensitive mechanism might cause a gradual shift in the timing of roost arrivals with the change in the times of sunset.

Many researchers have demonstrated that light intensity is correlated with the roosting times in several species (e.g. Jumber, 1956; Swingland, 1976). This was consistent with my observations. On 14 August 1999 at Mountbatten, the crows were seen flying to their roost site on a dark cloudy afternoon and their half arrival time was 70 min preceding sunset as compared to the mean half arrival time of 26 ± 3.1 min before sunset. The half arrival time that was much earlier relative to sunset was also recorded on a cloudy afternoon at Newton on 14 July 1999. Cloud cover probably affects the light intensity and the times of roost approach. In my study, light intensity measured using photometer was closely associated with the arrival time of 50% of roosting crows. The inability to detect a relationship between light intensity and roosting time found in some works was probably due to their method of measurement (e.g. Engel et al., 1992). The lack of such relationship might also be the result of difficulties in separating the pre-roosting and roosting assembly as the pre-roosting sites sometimes were within or in close proximity to roosting area (Jumber, 1956). The pre-roosting sites and roosting proper of house crow in this case were distinct. Though the crows may arrive at roost sites earlier on cloudy days than on clear days, their first arrival time, last arrival time and time of last vocalization have no significant relation to light intensity. Davis & Lussenhop (1970) suggested that light intensity may correlate better with the time at which the birds begin to fly towards their roost sites from feeding ground than with time of arrival at roost sites. The former may influence the flying speed, distance covered and behavioural interactions on the route back to roost site. In addition to simply providing some threshold at dusk, light intensity may affect roosting behaviour in other ways. The high rate of change in light intensity at dusk and the total amount of daily solar radiation may be important stimuli on roosting behaviour (Eiserer, 1984).

Many environmental factors, which do not relate to light intensity, facilitate its effects (Eiserer, 1984). The relative humidity was found to be negatively correlated with the time at which 50% of the crows arrived. Hence, most of the crows arrived earlier at roost sites on a day with higher relative humidity. The relative humidity varied according to the amount of precipitation. For instance, the relative humidity could reach up to 100% after a prolonged rainfall (Singapore Meteorological Service). This may imply that the amount of precipitation is a stimulus on roosting behaviour of house crow as well. Zammuto & Franks (1981) also reported similar finding in their studies of chimney swift. It was observed that chimney swifts entered their roost earlier on rainy days. My study shows that the relative humidity was also negatively correlated to other aspects of roosting behaviour such as the first arrival time, last arrival time and time of last vocalization. However, partial correlation coefficient analysis revealed that such correlations were dependent upon the relationship between the sunset time and roosting behaviour. Therefore the effect of relative humidity was of secondary importance.

Some researchers had found that temperature has a significant effect on the daily roosting times in black-billed magpie (Reebs, 1986), chimney swift (Zammuto & Franks, 1981) and starling (*Sturnus vulgaris*) (Jumber, 1956). The temperature was also found to be correlated with 50% arrival time and last arrival time of house crows. However, data showed that the influence of temperature was dependent upon the interaction between sunset time and roosting behaviour. Thus, temperature played only a small part in the role as a stimulus on the roosting time of house crow. Such a less pronounced effect of temperature on roosting time was expected in the climate of Singapore as there was a lack of extreme temperature throughout the study. The climate would never be so cold that the crows had to decrease their general activity level and return to their roost sites earlier. The coolest roosting time during the period of study was only 26.2 °C and under such temperature, food availability may not be reduced and may not make foraging less profitable.

This study demonstrates the relations of roosting behaviour of house crow to several environmental variables. Sunset time was significantly correlated with all the roosting parameters: first arrival time, half arrival time, last arrival time and last vocalisation time. Such better understanding of roosting behaviour of house crow might be useful pertaining to the management of such species in the highly urbanised Singapore.

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