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Pre-Roosting Assemblages in Birds: An Observation of American Crows in the Portland Park Blocks

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Pre-Roosting Assemblages in Birds: An Observation of American Crows in the Portland Park Blocks

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Abstract

The first objective of this study is to describe the seasonal patterns of variation in crow numbers and to assess the extent to which crow numbers vary with weather over the course of the winter in the Portland State University Park Blocks. The second objective of this study is to draw on current literature to help determine a possible explanation for the crow gatherings that occur at the Portland State University Park Blocks. I observed the population of crows from October 23rd 2016 to March 31st 2016 with a restricted survey area around Millar Library on the Portland State University Campus and Market St (a five block area). I made observations two days a week for periods lasting between 1.25 and 3 hours, while making both qualitative and quantitative observations of crow numbers and activity. Seasonal variation of crows in the Park Blocks on PSU campus increased from mid-fall into the winter season in a non-linear fashion. Weather influenced flocking behavior as crow numbers exhibited a weak tendency to peak at intermediate values of precipitation and to increase with wind speed. This study can serve as a base for the future work to help explain why American Crows use communal roosts during the winter months.

Acknowledgements

I would like to thank my mentor, Dr. Michael Murphy, for all of his support and guidance through this process. His help was invaluable to the completion of this thesis and I am deeply grateful for all of his help.

INTRODUCTION

Different species of animals have adapted to become more social with other members of their population. The cost of this adaptation includes increased competition for mates, food, and territory as well as increased chance of the spread of disease within a population. Group living may also make it easier for predators to locate prey. Although sociality has costs, in some species the benefits outweigh the costs of being social. For example, some social species including Meerkats (*Suricata suricatta*) have lookouts that sound alarm calls in response to danger (Alcock 1975). Although this may not be beneficial for the individual who raised the alarm, it warns the rest of the population, many of whom are kin, that a threat is close by. Cumulative benefits of enhancing kin survival seemingly outweigh the personal costs (Alcock 1975). Other benefits of sociality include decreased risk of individual predation and proximity to mates. The decreased risk of individual predation is due to either the dilution effect (individual is one out of a 100 instead of one in five) or the confusion effect (a moving mass of 500 birds may make it hard to pick one individual out). Schooling fish, for instance, gain individual benefits because, presumably, it becomes increasingly harder for a predator to pick out an individual fish. Sociality might also evolve for the benefits accrued from group foraging. For example, wolves hunt in packs because this method yields more food. Even though the pack shares the food the overall gain is more than if each wolf hunted individually (Mech, 2003). Another example, is the group hunting of Harris' Hawks (*Parabuteo unicinctus*). They form groups of two to six individuals during the non-breeding season in order to hunt. The group is able to distract and harass their prey into exhaustion so that it is easier to capture. The overall benefits for this include increased prey capture success, decreased individual energy usage, and increased prey size captured (Bednarz 1988). There are also potential benefits in huddling together as a group and saving energy. For example, the Golden-crowned Kinglet (*Regulus satrapa*) travel in groups of two to four individuals and huddle together on branches during the winter. This is thought to do with the potential thermodynamic benefit to counteract the small size of the bird. Huddling in groups provides temperature to the individuals so that they do not have to expend as much energy to maintain their body temperature (Heinrich 2003).

Animals are sometimes social only at certain times of the year, or even at only certain times of the day, which might give us a clue as to why they are social. For instance both Cliff Swallows (*Hirundo pyrrhonota*) and American Crows (*Corvus brachyrhynchos)* are passerine birds but they are social at different times of the year. Cliff Swallows are highly social during the breeding season and throughout their day. Cliff swallows are social during the breeding season because the breeding colony serves as an information center. Unsuccessful foraging individuals locate a successful individual and follow them to their food source (Brown 1986). By contrast, American Crows are social during both the summer and the winter. In the summer crows often exhibit cooperative breeding (Caffrey 1992), but during the winter they are most obviously social late in the day when they go to roost. Breeding may play a role in the sociality of the crows during the winter, but if it does it is probably a minority role that comes into play only late in winter as young individuals begin to seek mates.

The American Crow is among a small number of bird species that use communal roosting and diurnal activity centers. Communal roosts are sites that a large flock of birds use to roost together at night. The size of these roosts can vary from hundreds to thousands of birds (Caccamise and Morrison et. al 1986). Diurnal activity centers are foraging sites that small groups of crows use to gather resources to survive. The relationship between these communal roosts and diurnal activity centers is that small groups of birds use the diurnal activity centers during the day and travel to the communal roost site to combine as a larger group at night (Caccamise et. al 1997)

The reason(s) why crows and other species communally roost are debated. One line of reasoning suggests that roosts serve as “information-centers” where information about a foraging sites abundance can be learned. . When the birds come together they have a system for telling which birds look well fed and that indicates their success at the foraging site. Then the following day the birds will follow the individuals that showed more success so that they may go to a better foraging site, and they themselves be more successful (Ward and Zahavi 1973). The “thermo-regulation” hypothesis is that communal roosts are used for group heating that reduces the need for individuals to expend as much energy on producing heat (Knopf et. al 1983). The golden-crowned kinglets as stated above use communal roosts to maintain their body heat and reduce energy expenditure (Heinrich 2003). The “anti-predation” hypothesis is that communal roosts are used to reduce the individual risk of predation by staying in larger groups. The larger the group is the lower the risk is that the individual will get preyed on, especially if they are located towards the middle of the roost (Knopf and Knopf 1983). “The patch-sitting” hypothesis is that communal roosts are used to gain access to distant foraging sites during the day that would otherwise be to far away. These distant foraging sites have a larger amount of recourses at the location but are usually too far away from the diurnal activity center to be logistically favorable for a there and back flight. Communal roosts provide a midway location where individuals can roost, and then either fly to the diurnal activity center or to the distant foraging sites. Usually during winter months food resources at the diurnal activity center are limited so more individuals use the communal roost to gain access to the distant foraging sites that still have food. Communal roosts allow individuals to gain maximum resources while still maintaining group cohesion of the diurnal activity center. (Caccamise and Reed 1997).

These hypotheses are not necessarily mutually exclusive and organisms may roosts for benefits gained for multiple reasons. For instance, it is possible the individuals may benefit from information obtained near others and at the same time reduce chances of being killed by predators. It explains that birds use communal roosts as a sort of pecking order. Birds with superior foraging abilities are correlated with dominance that allows them access to central positions within the roost. These positions are more protected from predation because of the surrounding subordinate individuals that act as a buffer. The peripheral subordinate individuals are willing to bear the brunt of predation because the costs of doing so are exceeded by the benefits that come from following the dominant birds to their foraging sites. It is easier for the subordinate individuals to locate the better foragers because they have the better positions (Weatherhead et. al 1983). For example, Long-tailed tits (*Aegithalos caudatus)* are also known to use communal roosts during the nonbreeding season. It is thought that better placement within the roost reduces the predation risk and the thermoregulatory costs. Better placement within the roost is related to better benefit from using the communal roost. Long-tailed tits were seen competing for positions within the roost and that an individual’s roost position was related to the dominance status of that individual (McGowan et al. 2006).

Different seasons pose different challenges to birds and their behavior often changes to meet their immediate needs. Winter is often the most challenging season for birds because of the lower temperatures and decreased food supplies. One response to combat the challenging season is to become more social and form groups. For example, Black-capped Chickadees (*Poecile atricapillus*) breed as solitary pairs and are very territorial, but during winter they live in stable flocks of typically 6-8 individuals. Within this group of 6-8 there is a strict dominance hierarchy that exists (Smith 1991).

American Crows also change their behavior seasonally, and part of this change includes frequent roosting in large groups numbering in the hundreds to possibly thousands (Emlen 1952). The dynamics of crow roosts changes with time of day, season, and quite likely by physical factors such as light intensity and weather. Lower light intensity, greater cloud cover, and higher wind speeds are correlated with earlier entry into the communal roost and a larger numbers of crows within these roosts (Obrecht et al. 2008). The number of individuals using the roost is probably also determined by social factors. There is a relationship between attraction and repulsion factors that determine how close the crows will tolerate one another. For instance, if the birds want five feet between each other this limits the amount of birds that can fit in a given space compared to if the birds want only two feet between each other (Emlen et. al 1952).

My research pertains to the gathering of individuals at the diurnal activity center prior to their movement to nightly communal roosts. I thus mainly focus on an intermediate destination that crows use to gather and form larger varied groups before they flock to the communal roost. My questions thus pertained to the seasonal dynamics of their assembly late in the day in pre-roosting flocks at the Portland State University's

Park Blocks. These intermediate sites are where the crows form larger groups before heading to the final roost.

The city of Portland, OR, has an abundance of parks and green spaces including a strip of heavily treed blocks running north-south in the middle of the city known as the Park Blocks. The southern portion of the Park Blocks is contained within the Portland State University (PSU) campus and in recent years crows have begun to gather in PSU's portion of the Park Blocks over the winter period. My research is attempting to add more information on the question: What are the seasonal changes in pre-roosting flocking patterns in crows? The purpose of this study is to determine seasonal changes in how crows gather in flocks prior to relocating to their final roosting destination. My study will focus on the seasonal changes from October 23rd, 2016 to March 31st, 2016 because this it the time that the crow phenomenon I am studying is reported to occur. At the Portland State University park blocks there are large flocks of American Crows that gather in the evening and this phenomenon appears to change seasonally to the casual eye. These crows behave very actively during this time period including flying and cawing excessively. As darkness sets in during the evening the population size of crows in the park blocks decreases and the activity returns to a low level. My objective is to describe seasonal patterns of variation in crow numbers, assess the extent to which crow numbers vary with weather over the course of the winter season, and draw on the current literature to help determine a possible explanation for the crow gatherings that occur at the Portland State University park blocks.

METHODS

Field observations.–I observed population of crows utilizing the Park Blocks located on the campus of Portland State University park blocks from late October (October 23rd 2016) to the end of March (March 31st 2016). The Park Blocks study area extend over 12 city blocks in a linear array running north to south between Jackson St and Salmon St. I restricted my survey to the area around Millar Library on the Portland State University campus and Market St. (Fig. 1), a five block area. I made observations two days a week for periods lasting between 1.25 and 3 hours. The time that I observed the crow population varied depending on season because I needed to observe the crows close to sunset, and in mid-winter this was considerably earlier than in either late fall or early spring. Another factor that caused the time of observation to vary is that the crows arrived at slightly different times within the season. Thus, ideal start time and length of observation was often difficult to pinpoint on any given day.

During each observation I walked the study area to make both qualitative and quantitative observations of crow numbers and activity. For both types of data I split my observation period into 15-min intervals. Quantitative data consisted of approximating the maximum number of crows seen in each 15-min interval. The quantitative data were used to describe seasonal changes in flocking patterns. The qualitative data consisted of observations of the activity of the crow population and their behavior. This included the amount of activity (mild, moderate, or high amount of cawing, flying, and flights in and out of area), area inhabited (ground level, mid-tree level, or high tree level), group size, directions they were entering and exiting the Portland State Park blocks survey area, flying patterns, etc. (Fig. 1). I then used my general observations to derive hypotheses for the seasonal variations in pre-roosting flocking behavior that occurred at this study location.

Data analysis.–I binned my estimates of crow numbers for each 15-min interval into groups of 25 (e.g., 0-25 crows or 125-150 crows). Each day was treated as a single observation point in my analyses (see below) and therefore I averaged the number of crows seen in all 15-min observation periods to obtain a single estimate of maximum number of crows seen on each date. My objective was to attempt to identify factors associated with seasonal variation in crow numbers and therefore I examined each day's estimates in relation to date, time of day, weather during the observation period, and lunar phase. Calendar date was converted into a continuous variable by assigning the date of my first observation a value of 0 that continued until the final date of observation (March 31st 2016, or the continuous date 160). Weather variables included total precipitation (in), average wind speed (mph), and temperature at midpoint time (F^{o}). I obtained the time of civil twilight time and civil sunset so that my analyses reflected time from each (i.e., civil twilight – midpoint time of observation). Thus, all time measurements were standardized to be made in relation to civil twilight and sunset. Lunar phase was represented by the percentage of the full moon (full moon being 100%). All weather and lunar phase data were obtained from Weather Underground, which is a database that stores weather and climate information from around the world (Weather history for KPDX).

I used STATISTIX software to conduct my statistical analyses. Data were visually examined to check that the data conformed to assumptions of normality, and appropriate transformations applied. Midpoint crow numbers were $\log_{10}$ transformed.

The data were then examined for simple correlation of each independent predictor variables with the transformed crow numbers. Next, best subsets regression analysis was used to examine all possible combinations of predictor variables to identify those that best fit the data. An information theoretic approach was used to identify that the best model was used using the Akaike information Criterion for small sample size (AICc).

Hypotheses. –The predictor variables were chosen based on previous studies done on communal roosting. Continuous date was used because numerous studies have provided evidence that communal roosting is affected by the season/time of year. Most studies of crow communal roosting suggest that communal roosts are used more frequently and increase in number during late fall to early spring (Shoemaker et al. 2011). Civil twilight and civil sunset predictor variables were used because, based on previous work studying crows, they participate in communal roosting close to the time of sunset (Caccamise et al. 1997). Weather conditions such as precipitation, wind, and temperature were used because studies that focused on external factors affecting communal roosting provided evidence to support the argument that these variables affect communal roosting. For instance multiple studies have shown that higher levels of wind and precipitation correlate with an increased number of crows in the communal roost. Lower temperatures are correlated with an increased number of crows in the communal roost (Obrecht et al. 2008). Lunar phase was used because, based on previous work studying rodents, there was a decrease in activity during nights when the moon provided more light (full moon) because light was available for predators to see the rodents (Brown et al. 1988). I chose to extend this variable in the study of crow's pre-roosting behavior to determine if an increase in light (full moon) affects the roost size. Predator avoidance is one of the possible reasons why crows use communal roosts, so an increase in light could result in an increase in roost size due to decrease the risk of predation (Caccamise et al. 1997).

American Crow "flocking study" **Date**________________________

Start time___________ **End time**______________

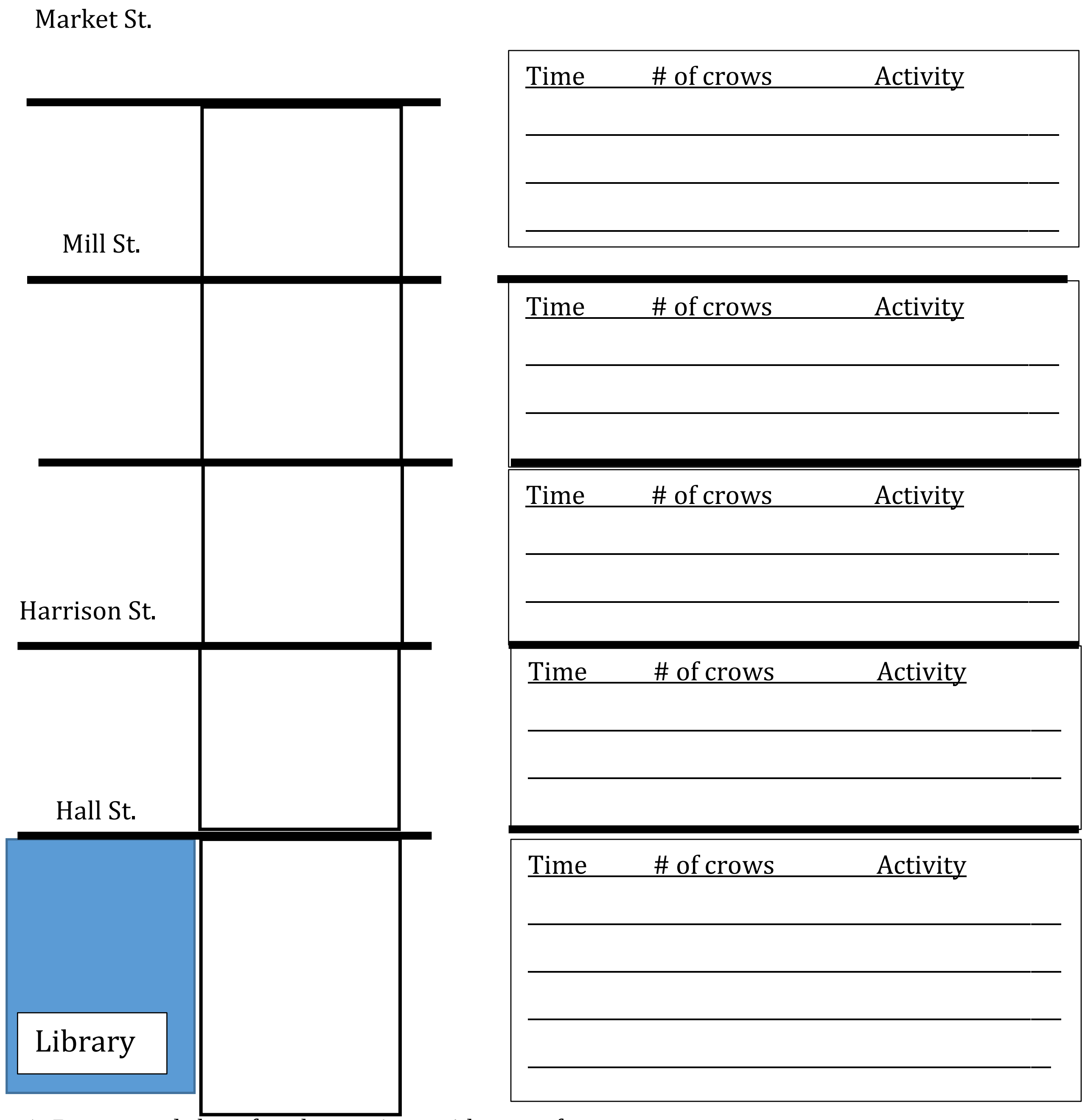

Figure 1: Data record sheet for observations with map of survey area.

RESULTS

Seasonal variation.–Civil sunset hit its expected earliest value on the winter solstice, and with the exception of my first few days of sampling, I began to survey 1 to 2 hours before sunset (Fig. 1). Over the course of my study ambient temperature reached its low in early to mid-January (Fig. 2A), while precipitation initially rose to peak in early to mid-December, and then gradually decline to remain relatively stable over the remainder of my sample period (Fig. 2B). By contrast, wind speed varied greatly from day-to-day over the entire sample period (Fig. 2C). With the exception of a strong positive correlation between wind speed and precipitation, temperature, precipitation and wind speed varied independently of one another (Table 1); rainy days also tended to be windy days.

Crow abundance.–The correlations between crow numbers and factors potentially influencing crow numbers are given in Table 1. I report correlations with both the untransformed and $\log_{10}$ transformed values of crow numbers for the sake of completeness, but my later analyses and conclusions are based on $\log_{10}$ crow numbers because the transformed values for crow numbers better fit the assumptions of a normal distribution and produced stronger correlations with the other variables (with only the exception of lunar phase; Table 1). Log_{10} crow numbers exhibited a significant positive correlation with date indicating that crow numbers increased from mid-fall into the winter season (Table 1), and nearly 30% of the variation in crow numbers were accounted for by date ($r^2 = 0.299$, $P < 0.001$). However, the seasonal trend was clearly not linear and a second order polynomial regression raised the explained variation in crow numbers to nearly 50% ($\text{logCrow} = 1.31 + 0.019\text{Date} - 0.000090\text{Date}^2$, $r^2 = 0.496$, $P < 0.001$). Crow numbers were independent of ambient temperature at the time of surveys (Fig. 4A), but in the case of other weather variables, crow numbers tended to peaked at intermediate values of precipitation (Fig.4B; logCrow = 1.95 + 0.720Precipitation – 0. 418Precipitation^2, r^2 = 0.076, P = 0.176) but especially wind speed (Fig. 4C; logCrow = 1.36 + 0.133Wind – 0. 0053Wind^2, r^2 = 0.121, P = 0.059). Finally, $\log_{10}$ crow numbers were independent of time of civil sunset (Table 1), phase of the moon (Table 1), but did vary with the difference between the midpoint of my observations and civil sunset (Fig. 5). The latter result was attributable to the several late surveys that occurred close to sunset at the start of my study (Figs. 1 and 5).

As a final analysis of daily variation in crow numbers I combined all variables in a best subsets regression analysis. Best subsets regression compares all possible combination of variables to find the combination of variables that best fits the data (i.e., leads to the maximum explained variation [maximum adjusted R^2]). Given the tendency for nonlinear relationships between crow numbers and date, precipitation, and wind speed I also included their quadratic terms (i.e., the square of each variable) in the analysis. As described above, the second-order polynomial of date accounted for nearly 50% of the variation in crow numbers and Date and Date^2 were included in the top model from the best subsets regression (Table 2). The square of wind speed also contributed significantly to variation in crow numbers, while the square of precipitation made a marginally significant contribution also. Thus, maximum crow numbers were detected in mid-winter when wind speeds were high but precipitation tended to be low (Table 2). The addition of wind speed^2 to the combination of Date and Date^2 raised the explained variation from

49.6% to 55.4%, and with the further addition of precipitation^2, the explained variation increased to 58.5%.

Table 1. Correlation coefficients describing the relationships between American Crow abundance and time and weather in the Park Blocks located on the campus of Portland State University, Portland, OR. The upper number represents the correction coefficient and the lower is the P-value. Data were collected on 47 days between late October, 2015, and the end of March, 2016. Potential correlates of crow abundance included date, temperature (Temp), precipitation (Precip), wind speed (Wind), lunar phase, and difference in time between the midpoint of observations and civil sunset (Time difference). Date was counted continuously beginning on 23 October (= 0; 1 November = day 8).

	Log Crow #	Crow Midpoint	Date	Civil Sunset	Time Diff	Temp	Precip	Wind
Crow Midpoint	0.869 0.000							
Date	0.542 0.000	0.410 0.004						
Civil Sunset	0.074 0.622	0.047 0.753	0.678 0.000					
Time Difference	0.232 0.117	-0.041 0.784	0.360 0.013	0.088 0.555				
Temperature	-0.137 0.357	-0.071 0.633	0.154 0.303	0.561 0.000	0.067 0.652			
Precipitation	0.098 0.513	0.087 0.560	-0.192 0.195	-0.368 0.011	0.131 0.381	-0.104 0.486		
Wind	0.259 0.078	0.177 0.234	-0.064 0.671	-0.139 0.351	0.165 0.269	0.044 0.769	0.586 0.000	
Lunar Phase	-0.012 0.933	0.049 0.744	0.041 0.782	0.241 0.102	-0.112 0.454	-0.010 0.949	-0.153 0.304	0.030 0.839

Table 2. The top model from the best subsets regression analysis of variation in the number of American Crows (log10 transformed) detected in the Park Blocks of the Portland State University campus between October, 2015, and March, 2016. Potential predictor variables included the full set listed in Table 1, plus the square of date (counted continuously from the 23rd of October), wind speed (Wind) and precipitation.

Variables	Coefficient	SE	*P*	Model R^2 (P)
Intercept	0.127	9.03	0.000	0.585 (0.000)
Date	0.020	0.0034	0.000	
$Date^2$	-0.000094	0.00002	0.000	
$Wind^2$	0.0018	0.00062	0.005	
$Precipitation^2$	-0.134	0.0763	0.086	

Fig 1.

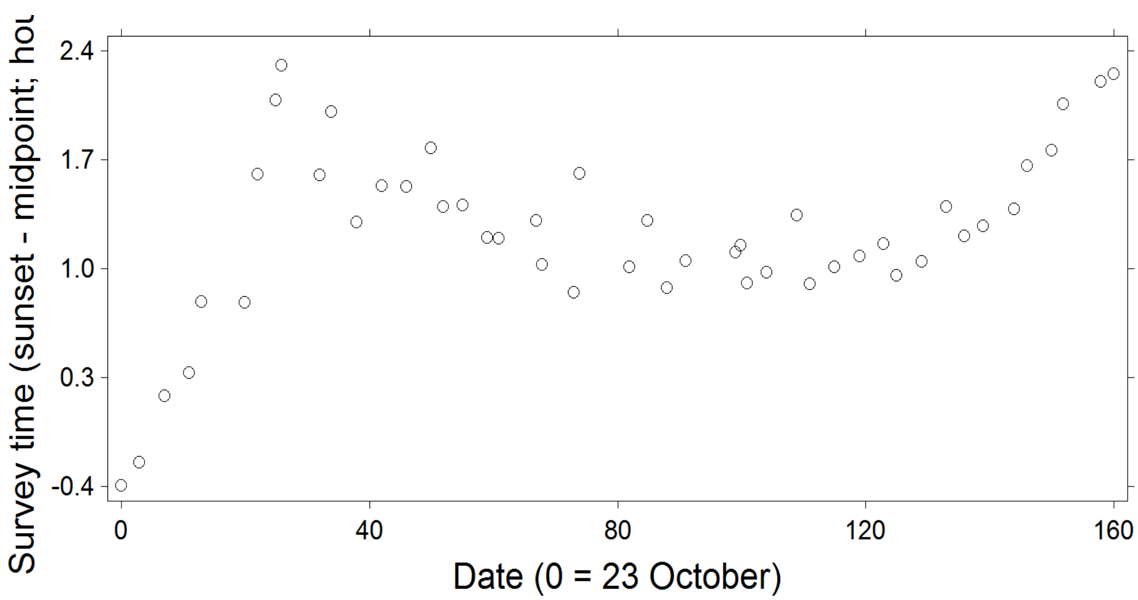

Fig. 2.

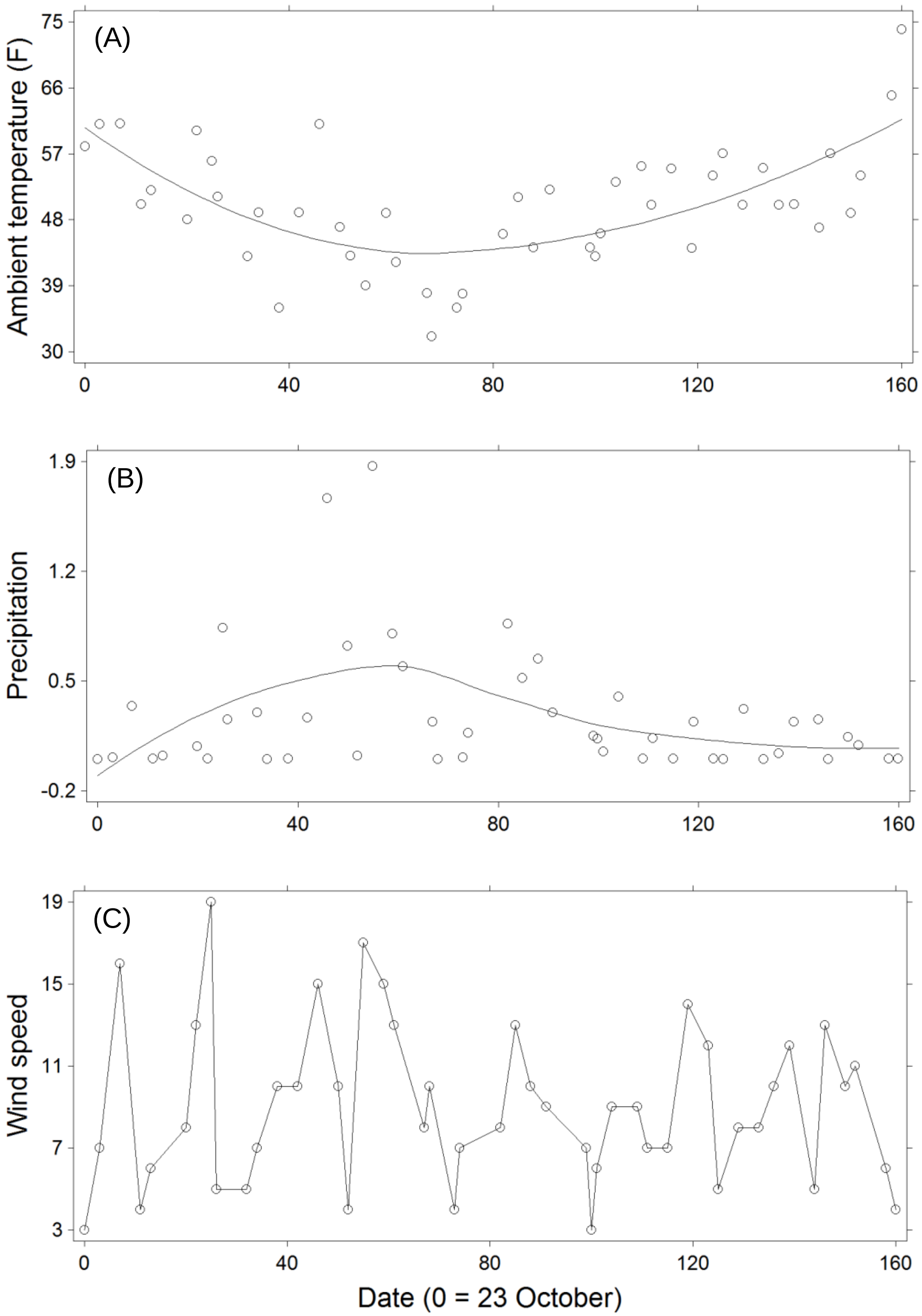
(A)
Ambient temperature (F)
75
66
57
48
39
30
(B)
Precipitation
1.9
1.2
0.5
-0.2
(C)
Wind speed
19
15
11
7
3
0
40
80
120
160
Date (0 = 23 October)

Fig. 3.

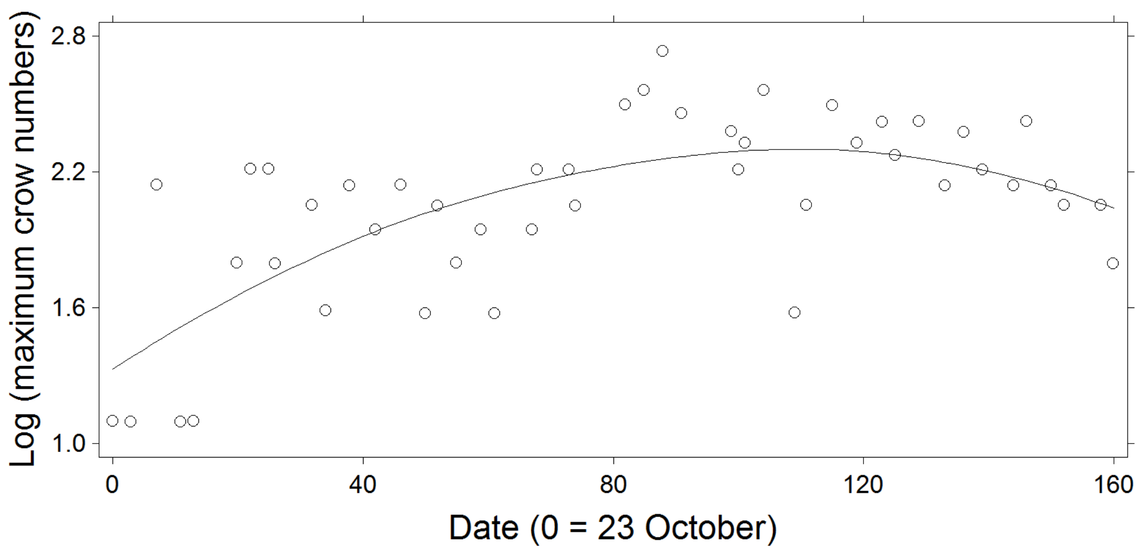
Log (maximum crow numbers)
2.8
2.2
1.6
1.0
0
40
80
120
160
Date (0 = 23 October)

Fig. 4.

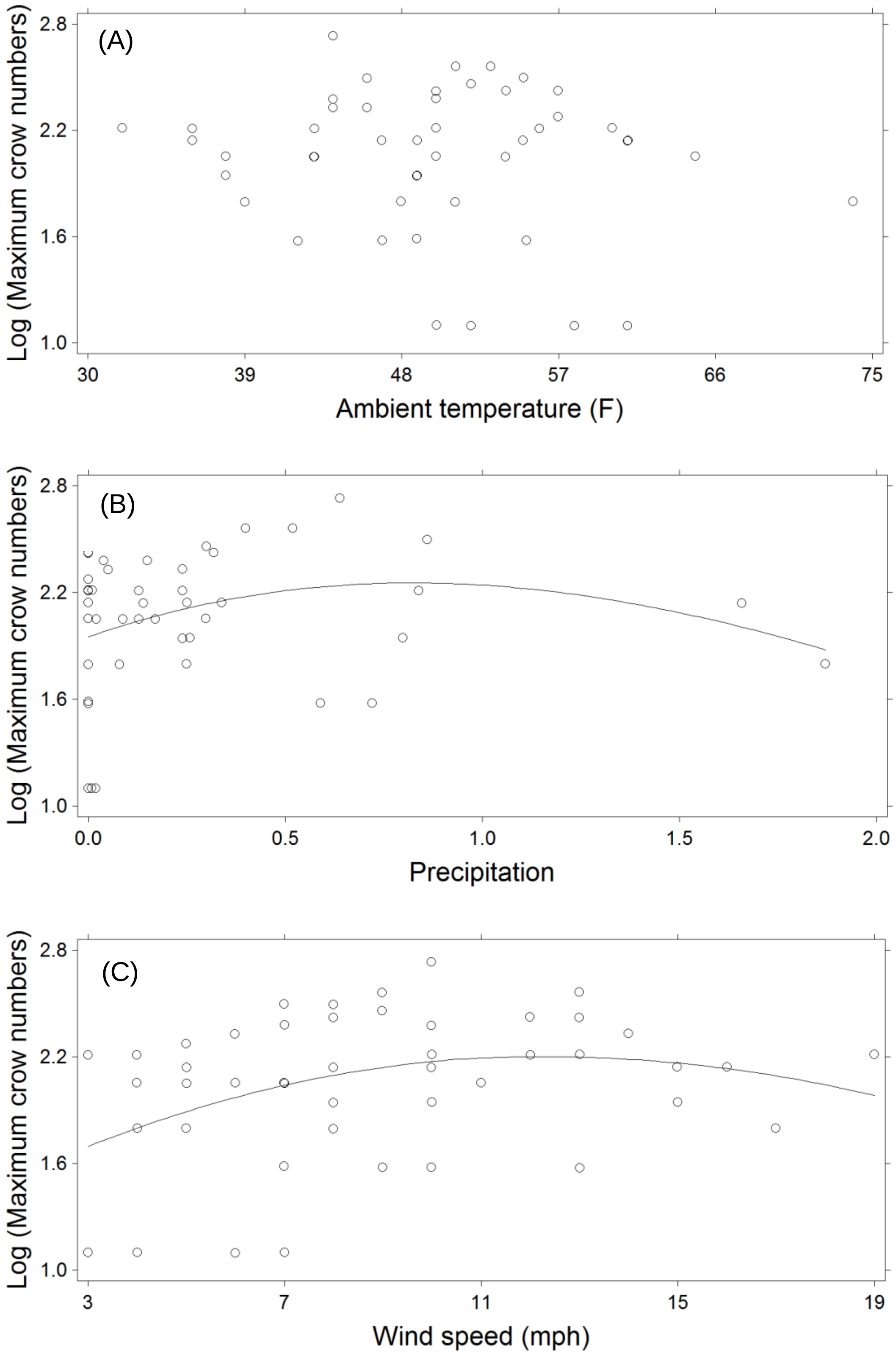
(A)
Log (Maximum crow numbers)
2.8
2.2
1.6
1.0
30
39
48
57
66
75
Ambient temperature (F)
(B)
Log (Maximum crow numbers)
2.8
2.2
1.6
1.0
0.0
0.5
1.0
1.5
2.0
Precipitation
(C)
Log (Maximum crow numbers)
2.8
2.2
1.6
1.0
3
7
11
15
19
Wind speed (mph)

Fig. 5.

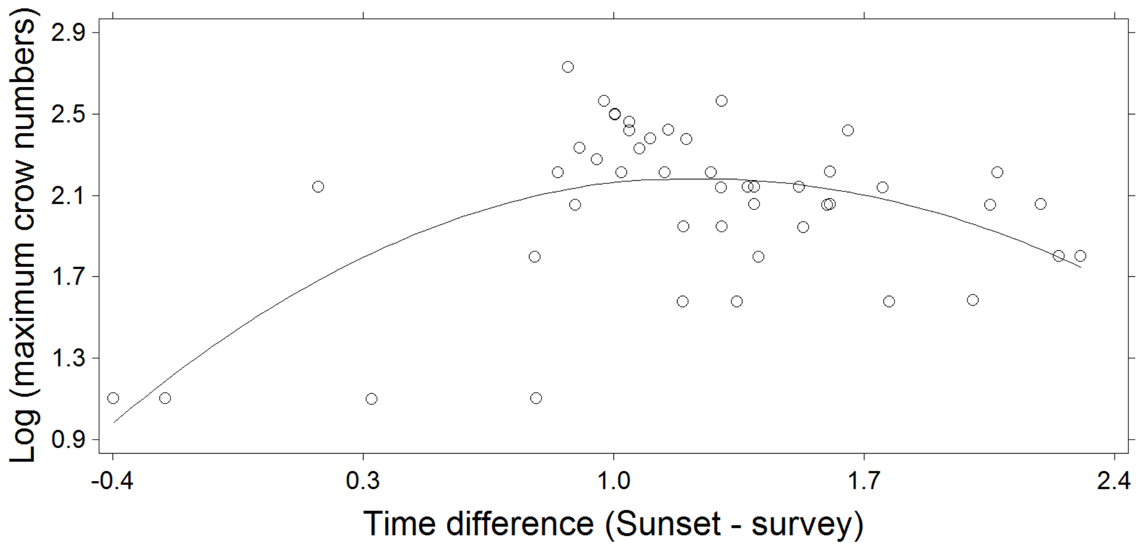

Figure legends

Fig. 1. Scatterplot expressing the correlation between survey time and date (1=October 23rd 2016) between the study time period (late October-end of March) in the Portland State park blocks, Portland, OR.

Fig. 2. Scatterplots expressing the correlation between ambient temperature, wind speed, precipitation, and date (1=October 23rd 2016) between the study time period (late October-end of March) in the Portland State park blocks, Portland, OR.

Fig. 3. Scatterplot expressing the correlation between log crow numbers and continuous date (1=October 23rd 2016) between the study time period (late October-end of March) in the Portland State park blocks, Portland, OR. Loess smoothing plotting program was used to generate the curve with an alpha of 1.5 and quadratic degree.

Fig. 4. Scatterplot expressing the correlation between residual crow numbers and wind (mph), ambient temperature, and precipitation between the study time period (late October-end of March) in the Portland State park blocks, Portland, OR. Residual crow numbers is corrected for seasonal variation and a linear regression was used.

Fig. 5. Scatterplot expressing the correlation between log of maximum crow numbers and time difference (sunset-survey) between the study time period (late October-end of March) in the Portland State park blocks, Portland, OR. A linear regression was used.

DISCUSSION

The social behavior of animals is tremendously variable both within, but mostly, among species. The variability within species is sometimes expressed as seasonal variation as some animals are sometimes only social during certain times of the year. Cliff Swallow, for instance, are social during the breeding season, whereas others such as the American Crow are social throughout the year, but the form of sociality changes between the breeding and nonbreeding season. The reasons for being social are potentially many and some of the reasons do not depend on the time of the year. The summer sociality of American Crows is based mainly on a cooperative breeding in which former young remain with parents to assist in the rearing of siblings. On the other hand, winter sociality of crows occurs for another reason and the information center hypothesis provides a possible explanation for why American Crows and Cliff Swallows are social in the nonbreeding and breeding seasons, respectively.

The most obvious expression of sociality in Cliff Swallows manifests itself as tight clusters of nests during the breeding season. The tight packing of nests, which often literally touch one another, allows adults to observe the condition of neighbors and gain information about food sites; individuals that have had poor success while foraging can follow other individuals that have fed successfully. This seems to likely be one of the main reasons for their sociality while breeding. However, large aggregations may also be more successful at driving predators away from nesting colonies. An additional incidental outcome of the close packing of nests, that is both a benefit and cost of sociality, is the ability to intraspecifically parasitize the parental care provided by other individuals (Anderson et al. 1997). Female Cliff Swallows have been observed to literally pick up and move an egg from their own nest to a neighbor's and in so doing reduce her parental effort while increasing that of her neighbor. While group defense of nesting colonies is obviously only a benefit during the breeding season, information sharing regarding foraging can occur at any season and is most likely to occur when resources are clumped but distributed unpredictably across the landscape. Sociality in species such as the Harris' Hawk (*Parabuteo unicinctus*) occurs because of the ability of cooperating groups to kill prey larger than any single individual predator could kill, Increased efficiency at killing prey is the major driving force of sociality in Harris' Hawk (Bednarz 1988) and a variety of large mammalian predators.

Other than foraging success, the benefits of sociality potentially also include decreased risk of individual predation, thermal benefits, and proximity to mates. However, costs of sociality also exist and include increased competition for mates, food, and territory as well as the increased chance of the spread of disease within the population. And while groups may be better able to defend themselves against predators, living in groups may also make it easier for predators to locate their prey.

One of my goals was to describe seasonal variation in the social behavior of American Crows and to that end I found that the crow population in the Park Blocks on the PSU campus increased from mid-fall into the winter season in a non-linear fashion (Fig. 3). Indeed, about 50% of the variation in crow numbers were associated with the seasonal increase and then seasonal decline in numbers. Seasonal change in crow numbers might have been driven by seasonally driven change in ambient temperature, but this did not appear to be case. Weather nonetheless influenced flocking behavior as crow numbers exhibited a weak tendency to peak at intermediate values of precipitation (Fig. 4) and to increase with wind speed (Fig. 4). Of the weather variables, wind speed had the strongest association with crow numbers as it was the only weather variable to have a statistically significant effect on crow numbers when the effects of date were removed in the regression analysis. Crow numbers were also independent of time of civil sunset and phase of moon.

The association between season and crow abundance has been seen in numerous other populations of crows including a population in Ohio (Shoemaker and Richard 2011). This population of crows aggregated in the thousands over the same time period that I studied the Park Block's crows. The Ohio study also found a correlation between wind and crow numbers in the communal roost, but also a correlation with temperature. Winter in Ohio is much colder than winter in Portland, OR, and this may explain why temperature and crow numbers exhibited a much stronger association in Ohio (Shoemaker and Richard 2011).

A very thorough study of the flocking behavior of a population of crows by C. L. Edwards (1888) in Mississippi is noteworthy because the behavior that he described from a premodern and rural environment continues to be exhibited today in a highly modified urban environment. He found that although the population of crows was scattered during the daytime, during the wintering months (October-May) they would start gathering in large groups shortly after sunset. He noticed a good deal of calling ('caws') and perching. But at intervals over the course of the night the population of crows would become disturbed, leave the trees, and fly back and forth through the air. The population of crows he studied was immensely larger than the population I studied, numbering close to 10,000 individuals (Edwards 1888), but the account he described is very similar to the behavior observed for the population of crows in Portland State Park Blocks.

Over the course of the late afternoon/early evening crows would migrate in from all directions in mostly small groups of under seven with occasional large groups of over thirty. They would settle into the high tops of the trees and loudly and continuously call for my entire observation period. Approximately once or twice over the 1-2 hour observation period, most of the crows would all suddenly take flight and exhibit group flying patterns that appeared random and uncoordinated; individuals moved in multiple directions simultaneously. These group flying episodes would last approximately five minutes before the crows would settle back into the trees. These events appeared random. Throughout my observation period individuals in the murder of crows shifted positions but the entire flock occupied the same location. Finally, right before sunset the increasing number of crows would start leaving in small groups of under five in all directions with the occasional larger group comprising over 30 individuals. By the end of the day's observation period approximately 75% of the crow population left the Park Blocks entirely, and by judging by what I saw in the early mornings after as I was walked through the Park Blocks, the groups that left did not return and the group that did not leave at dusk spent the night roosting in the trees near PSU's library.

The winter communal roosts of American Crows is a behavior that has captured the attention of humans for well over a century. It occurs in crow populations occupying a variety of environments across the country, including the population in Portland State Park Blocks. Although there is no consensus as to why American Crows use communal roosts, I hypothesize that, for the population that I studied, more than one explanation is likely. It seems reasonable that a major reason may that they serve as an information center for foraging, but it's also likely that roosting in large numbers provides individual benefits in reducing the chances of being taken by a predator. Thermal benefits might also be a possibility, but this seems less likely given that the size of the pre-roosting flocks was independent of ambient temperature. Weather seems unlikely to have played a large role in seasonal variation in numbers, but the association with wind is worthy of further study. More study of the Parks Block winter crow population is needed if we are to disentangle the possible explanations that exist for roosting behavior. For now, my study can serve as a foundation for that future work to help explain why American Crows use communal roosts during the winter months.

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