Crow Density and Anthropogenic Subsidies Near the Venice, California Least Tern Colony

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Abstract

Crow predation on California Least Tern colonies is a well-documented activity and decreases tern breeding success. In an effort to learn more about these generalist predators and their increases in urban environments, we investigated their spatial distribution around the Least Tern colony in Venice, California. In order to accomplish this we surveyed crows and food subsidies within a semicircle area of 5.52 square kilometers around the colony in the 2 months leading up to the 2011 tern nesting season. We mapped these location data with ArcGIS and used land use data to determine correlations between food subsidies and crow density. An increase in food subsidies, especially around developed parks, correlated with an increase in crow sightings. We also observed more crows on weekends than weekdays. The data conclusively showed that crows are found within all land use types; because of this, landscape management will likely not have a significant impact on deterring crow distribution from the Venice Least Tern Colony. While this research is novel in that it is the first crow survey done around this colony, further research is needed to determine seasonal variation and larger scale patterns in crow density before any conclusive recommendations can be made to enhance Tern nest viability.

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Introduction

The constant expansion of human settlement along the California Coast has provided conditions that have increased the number of synanthropic generalist predators; this increase has lead to high rates of predation on local beach-nesting bird populations. At the Venice Beach, the endangered California Least Tern (*Sternula antillarum browni*) has been under substantial predation pressure by the American Crow (*Corvus brachyrynchos*). The California Least Tern is a migratory bird and is only present at the Venice Beach Least Tern Colony during its breeding season during the months of April through August. Crows regularly prey on California Least Tern eggs and fledglings, because terns are most vulnerable at these stages. Once the terns reach adulthood, though still small (22-24 cm long, 39-52 g), they are much less likely to be predated and are more likely to survive to reach sexual maturity (Delnevo et. al., 2009). Predation by crows has imposed such a strong pressure on the reproductive success of terns at Venice Beach that in 1999, 2002, 2004, 2005, 2008, 2009, and 2010 they were unable to fledge any young (Delnevo et al., 2009).

The American crow is an omnivorous terrestrial avian species that will eat a variety of marine and terrestrial organisms ranging from many different types of plants, small vertebrates (mice), invertebrates (insects), carrion, other birds' eggs, and human anthropogenic subsidies (Hernandez 2007). Studies suggest that within urbanized areas there will be an increased amount of foraging crows due to the increased abundance of food subsidies (Higuchi 2006). Availability of shelters or perches also play a key role in increasing crow population within urban areas and as a consequence are also possibly increasing predation on sensitive species such as the California Least Tern (Bui et al., 2010; Withey and Marzluff, 2009).

Food subsidies appear in the form of human refuse as well as anthropogenic surfaces such as lawns, roads, landfills, and other urban landforms (Kristin and Boarman, 2007; Liu et al., 2008; Marzluff and Neatherlin, 2006). The generalist nature of crows allows them to use areas with road kill and fresh refuse as prime foraging territory (Coates and Delehanty, 2010). Crows within urban areas were also found feeding directly on garbage from picnic areas, dumpsters, and parking lots (Yaremych et al., 2004). Parks and lawns provide great habitats for grubs and other insects that crows feed on as well (Withey and Marzluff 2009).

Shelter and hunting perches are the other major anthropogenic subsidy for crows. Man-made structures such as planted trees, transmission towers, telephone poles, and fences provide crows with places to roost and from which to hunt (Bui et al., 2010; Coates and Delehanty, 2010; Ryan and Vigallion, 2010; Withey and Marzluff, 2009). While at these perches, crows will often survey the area and pounce on prey when it becomes available. Most often while foraging, crows tend to go after items that are the most abundant in their foraging area. Many of the urban foraging sites and perches that crows find attractive provide obstructive cover that lowers the risk of predation. Attractiveness of foraging sites may be influenced by temperature and frequency of human presence (Ward 1997).

According to a study on crow roosts by Gorenzel and Salmon, trees in which crows roost have significantly warmer temperatures than non-roost trees (1995). Furthermore, vigilance in American Crows was determined to vary according to temperature-specifically, when crows were in an area of low human disturbance, vigilance decreased as temperature increased, and in areas of high human disturbance, vigilance increased as temperature increased (Ward and Low, 1997). Essentially, crows show to be affected by temperature, both behaviorally and in their habitat. This led us to hypothesize that observable crow density would be affected by ambient air temperature on the day of observation.

Crows have smaller home ranges and greater reproductive success in areas of human settlement and recreation (Marzluff and Neatherlin 2006). Crow survivorship is also positively correlated to proximity of human developments, likely due to anthropogenic subsidies (Marzluff and Neatherlin, 2006). Crows' foraging areas tend to be smaller when high amounts of anthropogenic food sources are available. Crows will often favor foraging in these areas because less energy expenditure is required. These factors explain why crows are found breeding and populating areas that are very close (<5 km) to areas of high human activity (Marzluff 2001).

Abundant populations of American Crows near the Venice Least Tern Colony threaten the continued survival of the California Least Tern, so population management practices have been recommended (Ryan and Vigallon 2010). The most discussed management practices for urban crow populations revolve around reducing the availability of anthropogenic subsidies (Marzluff et al., 1998). This focuses on reducing roosting and nesting locations or access to such locations. It also focuses on reducing food subsidies. This could include restrictions on feeding birds, covering garbage containers, eliminating bird feeders, etc. (Marzluff et al., 1998).

Crows in Venice Beach have had a substantial and harmful effect on the colony of Least Terns that come to breed on the beach year after year, even completely eliminating the entirety of the fledgling population in more than half of the past 10 years. Why are the crows able to exert such a strong effect on the endangered Least Terns? Are they already abundantly present in the areas surrounding the Least Tern colony? To recommend a management plan for the crow population of the surrounding area it must be understood how the crows are distributed, and why. We propose that anthropogenic subsidies that need to be taken into consideration and studied before determining an appropriate crow management plan.

By gathering crow density data over a study area surrounding the colony and correlating these densities to a particular land use type, we hope to gain insight into the role anthropogenic subsidies play on crow distribution. Currently, no data are available that describes crow density by land use or associated human subsidies in this area. This research will aid in determining the best course of action for managing the crow population around the Least Tern colony. Our research question is: How do anthropogenic subsidies, temporal variations, and land use type affect American Crow density and distribution around the Venice Least Tern Colony?

Significance of the Study

With the increasing abundance of the common American Crow, it is important for our study to outline the effects of this increased population on our urban environment and other coexisting species. The California Least Tern is one of the species that is greatly affected by the predation of the crows on their already scarce breeding colonies. The protection of the endangered Least Terns is our primary incentive for our crow research. Due to their specific breeding biology, the California Department of Fish and Game has set up protective fences around the Tern colony's breeding grounds to ensure successful reproduction of the species. However, this isolation also provides the crows with a great opportunity to feed on the eggs and newly hatched chicks. From 1999 to 2003, the proportion of fledglings produced in Venice Beach colony has dropped from 12.4 percent to 6.9 percent. There was no productivity in 2003, 2004, 2005, 2009, and 2010, which can be attributed to crow predation (Ryan and Vigallon 2010). Having more knowledge with regard to crow behavior and their attraction to the area, we may be able to prevent further harm to the tern colonies and other surrounding species that may also be disturbed.

Another purpose of our research is to provide useful data and statistics regarding crow distribution around Venice Beach in order to aid others in their future efforts to reduce crow numbers and their nuisance behavior.

Methods

The study site is a circle centered on the Venice Beach Least Tern colony. Because nearly half of this area is ocean or other water, the land area surveyed is a semicircle of 5.52 square kilometers, consisting of beach, urban, and residential areas, as well as some natural areas within the boundaries of the Ballona Wetlands (Figure 1). We wanted to compare crow density on different types of land use within our study area, similar to a Marzluff and Withey (2009) study on crows using many different types of landscapes. In a study conducted on crows in Manitoba, it was found that crows regardless of age occupied approximately 7.2-square kilometers for their home range (Yarymych, et. al., 2004). We chose the size of our study area to be as close as possible to this value and to be large enough to encompass all of the crows potentially preying on the tern colony. For the areas within the Ballona Wetlands Ecological Reserve, we were able to obtain inclusion in a Department of Fish and Game permit by association with the Santa Monica Bay Restoration Commission. This gave us access to previously off-limits areas to survey them for the presence of crows.

We divided our study area into four parts, based on the amount of time it took to survey a portion of the study area on a trial run conducted prior to beginning the surveys. The four “quarters” are made up of a variety of different types of land uses, some much more dense residential, and some having larger stretches of beach and wetlands. The “quarters” are of different sizes, but they took approximately equal amounts of time to survey, with the difference attributable to travel logistics and the openness of the environment. This approach kept survey effort constant across the study area.

We established a designated driving route for each quarter. This was to minimize surveying areas multiple times and to minimize time as an independent variable. Most of the surveying was done in vehicles while areas that were inaccessible to cars were surveyed on foot. In most instances each person in the two-person team would look for crows and the passenger would go out on foot to survey areas inaccessible to vehicles. The windows were down in order to better hear crows. Each team was equipped with binoculars, stickers, and maps to record data.

The maps were printed in black and white images downloaded from Google Earth. They were saved at an elevation of around 1400 feet above sea level, which allowed an adequate resolution with a manageable number of maps. When crows were spotted they were indicated on the maps by either a blue or a yellow sticker. The blue sticker indicated a crow that was on the ground while a yellow sticker indicated one that was flying. For instances of multiple crows a number, representing the number of crows in that area, was written on the sticker. We marked anthropogenic subsidies with red stickers for water subsidies and green stickers for food sources. These food sources included open trashcans, dumpsters, food trucks, people feeding birds or other animals, and stationary bird feeders.

All surveys were conducted between February 23, 2011 and April 14, 2011. The first 4 weeks of surveying was restricted to 1 quarter per visit and the last 2 weeks was increased to 2 quarters per visit in order to accommodate our timeline. Each location was surveyed six times, with visits split between weekdays and weekends. In all, the entirety of the study area was surveyed three times on weekdays and three times on weekends, to observe any possible correlation between differences in human and activity during different times of the week and corresponding crow density. Two weeks were not surveyed due to scheduling conflicts. Some surveys were started as early as 10 a.m., and all surveys were completed by 3 p.m.. Our main concern in timing the surveys was to go out later than sunrise and earlier than sunset, to observe the crows during a time period when they might have been out foraging or otherwise away from the roosting sites. Each survey includes the temperature, start and end times, and the date. Surveys were rescheduled in incidents of inclement weather.

We digitized our data in ArcGIS for further analysis. The crow and subsidy locations were entered onto aerial images of our study area and each data point was attached to its features such as date, temperature, whether it was a weekday or weekend, and foraging status (flying, foraging, or neither). One data point represented one crow. To evaluate crow density by land use, we used the Southern California Association of Governments land use map. To organize and present our data, we utilized both ArcGIS and Microsoft Excel to generate maps, images, charts, and tables.

We grouped land-use types into 7 categories to easier manipulate the data. We plotted our other variables against our land-use categories in order to examine possible causal relationships between land-use and crow densities. Crow density was also plotted against temperature independent of land-use in order to examine a possible relationship. Food density by land-use was plotted against crow density by land-use and a linear regression was performed to determine if food subsidies influenced crow density by land-use.

Results

Study Area Land Use

The study area is located in the Venice/Marina Del Rey/Playa Del Rey area of Los Angeles California. It is a half circle with a radius of 1.63 kilometers and area of 5.52 kilometers squared centered on the Venice Least Tern colony shown in purple (Figure 1). There are many different land-use types within the study area, which we sorted into categories (Table 1). When broken down into categories, multi-family residential, water, and protected open space land uses make up the majority of the study area. Appendix 1 shows the land-use categories location on the map.

Figure 1. Study area surrounding Venice Least Tern Colony (purple) in Marina del Rey, CA. Survey area is indicated by the shaded red region.

Table 1. The land-use categories, their included land-use types, and the respective areas and percentages of the study area are shown. The land-use types were sorted into categories based on similar ground cover and accessibility.

Land-Use Category	Area km^2	% of Study Area
Multi-Family	**1.27**	**23.02**
Duplexes, Triplexes and Townhouses	0.04	0.74
Low-Rise Apartments, Condominiums, and Townhouses	0.29	5.30
Medium-Rise Apartments and Condominiums	0.62	11.25
Mixed Residential	0.32	5.73
Single Family	**0.78**	**14.17**
High-Density Single Family Residential	0.78	14.17
Commercial	**0.30**	**5.43**
Low- and Medium-Rise Major Office Use	0.02	0.40
Maintenance Yards	0.02	0.35
Attended Pay Public Parking Facilities	0.01	0.19
Hotels and Motels	0.02	0.39
Police and Sheriff Stations	0.01	0.20
Modern Strip Development	0.11	2.07
Non-Attended Public Parking Facilities	0.01	0.25
Older Strip Development	0.09	1.57
Protected Open Space	**1.21**	**21.93**
Natural Gas and Petroleum Facilities	0.02	0.41
Other Open Space and Recreation	0.06	1.13
Vacant Undifferentiated	1.13	20.39
Developed Parks	**0.08**	**1.43**
Developed Local Parks and Recreation	0.08	1.43
Beach Parks	**0.63**	**11.44**
Beach Parks	0.63	11.44
Water	**1.25**	**22.59**
Marina Water Facilities	0.47	8.53
Water, Undifferentiated	0.78	14.06

Distribution of Crows

American Crow location was mapped using ArcGIS on to a map of the study area (Figure 2). Crows were seen mainly over land and tended to avoid open spaces without trees such as beach parks and wetlands. Areas of high crow density are circled in white. These circled locations are both developed parks within the study area.

Figure 2. This figure shows crow sightings designated by a green dot over the study area outlined in red. The white circles represent parks in which there were "hot spots" of crow density.

Crow density was calculated by land-use and by day of the week (Figure 3). Developed parks had the highest density by far at around 720 crows/km^2 on the weekend and beach parks had the lowest density at around 22 crows/km^2 on the weekend. Crow density was higher on weekend with the greatest difference in density between the weekend and weekday in the park land-use category. The greatest percent change in crow density was found in the Single Family Land- Use category. In total 538 crows were observed with 218 crows being spotted on weekdays and 320 being spotted on weekends (Table 2).

Table 2. Percent increase in crow density among land-use categories from the weekend to the weekday. All land-uses increased in density on the weekend with the exception of beach parks.

Land-Use Category	**Percent Change from Weekday to Weekend**
Multi-Family	13.3
Single Family	26.4
Commercial	11.6
Protected open space	4
Developed Parks	20
Beach Parks	-6.6
Water	17.8

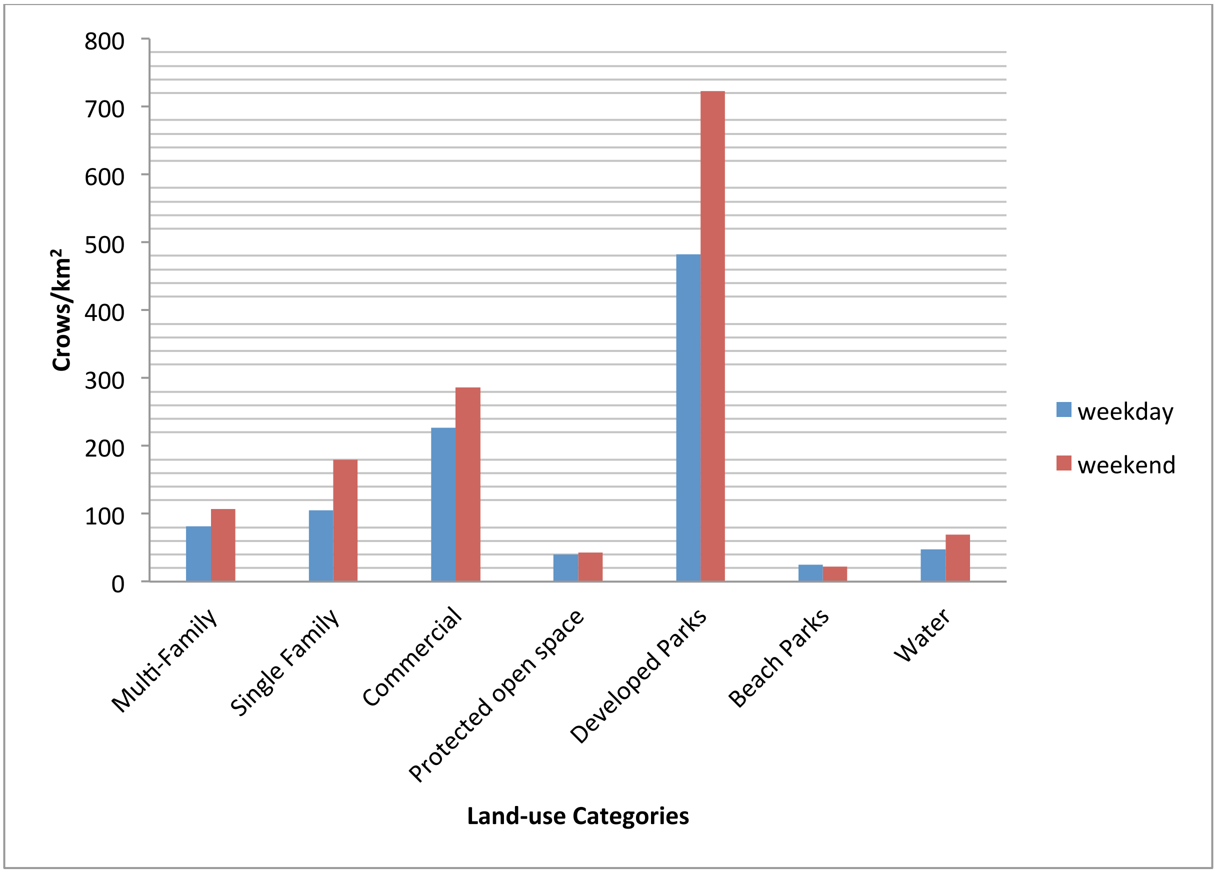

Figure 3. This chart shows the densities of crows (crows/km^2) by land use type on both the weekday (blue) and the weekend (green). Crow density increased on the weekend in most of the land-use types and increasd greatest in the parks category.

Crow density was also plotted against temperature for each day surveyed (Figure 4). Temperatures ranged from as low as 55 degrees Fahrenheit to as high as 82 degrees. There was no correlation between the outside temperature and the densities of crows within our study area.

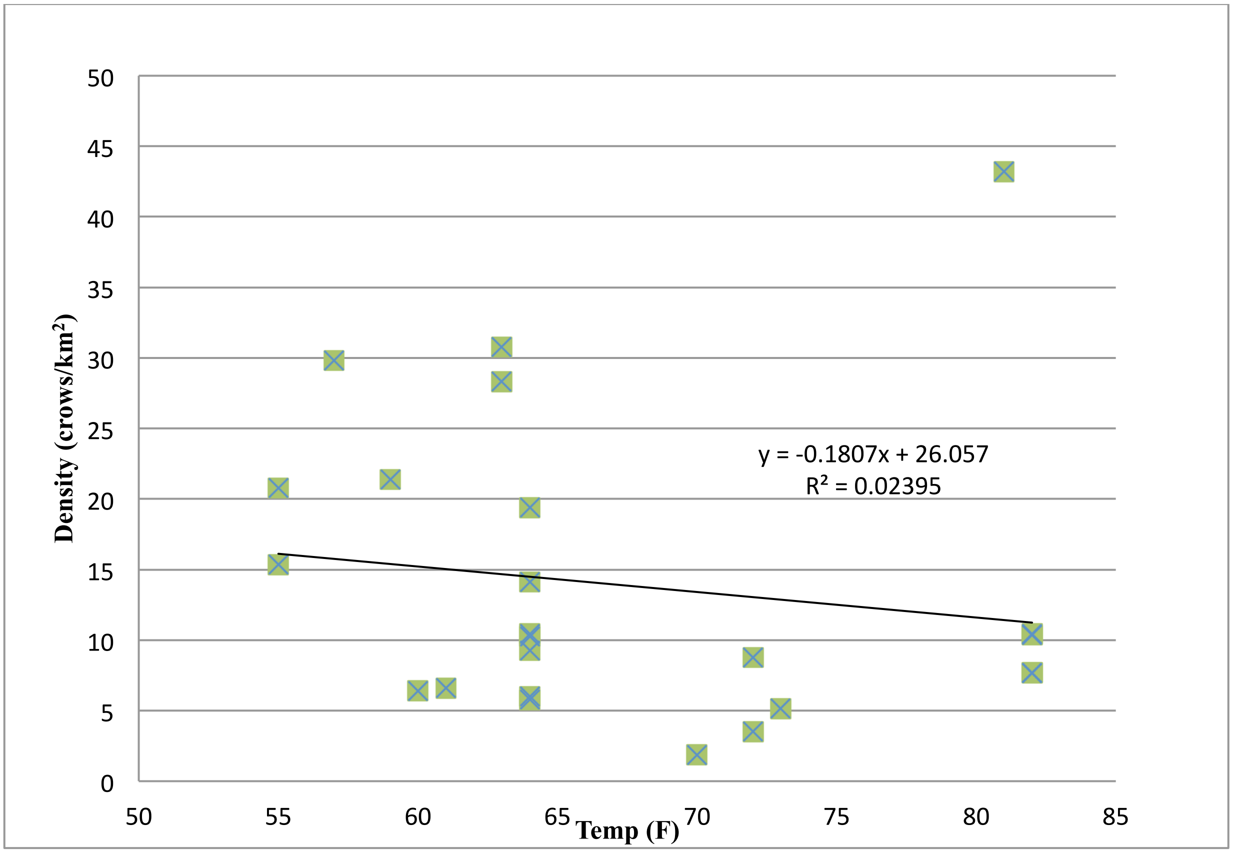

Figure 4. This graph shows the temperature plotted against crow densities on each day surveyed. The R value = .0239 shows that there is no trend between outside temperature variation and the density of crows within the study area.

Food Distribution

Food subsidies were mapped in the same manner as the crows (Figure 5). Unlike the crow sightings, food subsidies seemed to be clustered in certain areas and completely absent in others (Figure 6). The developed parks had the highest density of anthropogenic food subsidies, while water and residential areas had very little accessible food subsidies (Figure 6). Crow density per land-use type was highly correlated with density of food subsidies per land-use type (Figure 7). A positive correlation was discovered between increased anthropogenic food subsidies and increased crow density within the study area (r^2=0.8668).

Figure 5. This map shows each food subsidy marked in red. The study area is outlined in red while the Least Tern colony is denoted by the purple area. Accessible food subsidies tended to be less ubiquitous than crow sightings.

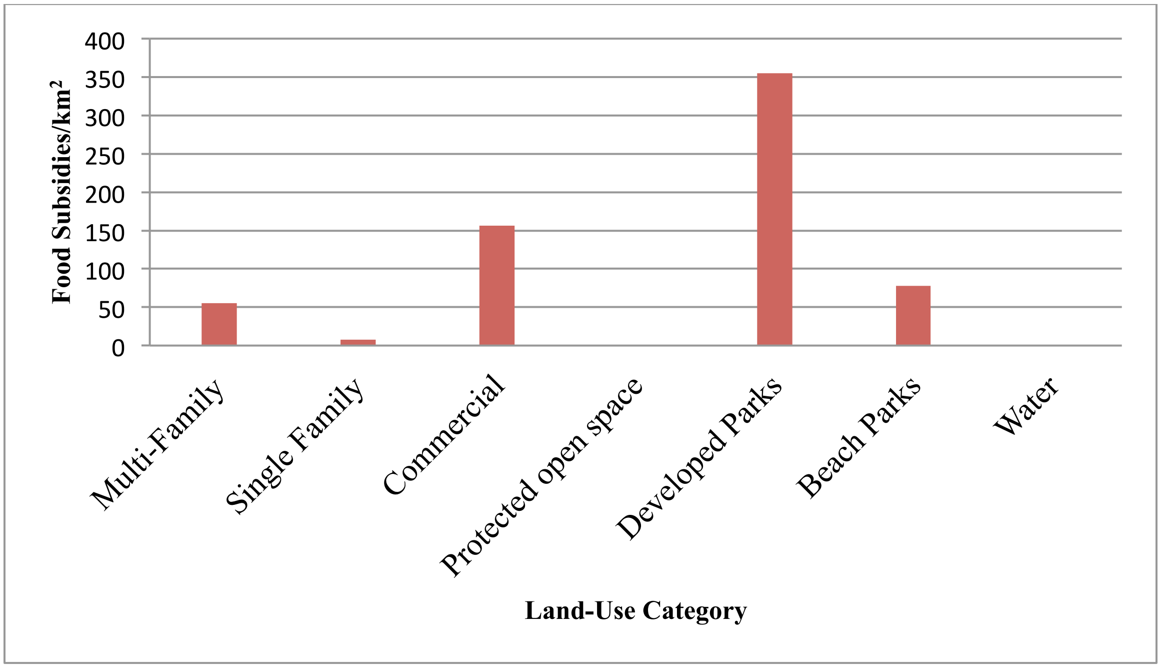

Figure 6. This is food density per land-use category. Developed parks have the highest density of food subsidies per km^2. Not surprisingly there are no anthropogenic food subsidies in the water and there are very few accessible food subsidies in the residential land-use categories.

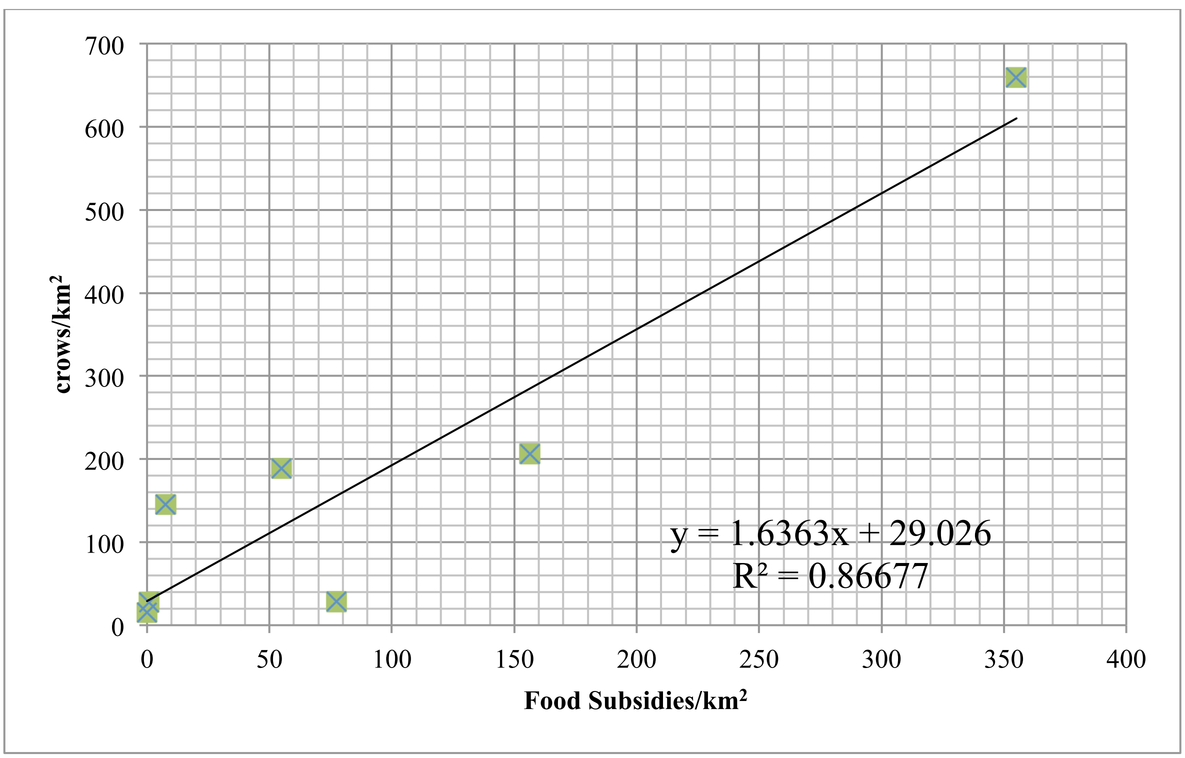

Figure 7. Crow density per land-use vs. food density per land-use. As food subsidy density increases crow density increases as well. An R^2 value of 0.8668 shows that the points lie on a reasonably straight line.

Discussion

Crows and Food subsidies

Our data supported our hypothesis that crow density is dependent on accessible food subsidies. According to several studies looking at garbage and either density or reproductive success of certain birds, higher densities of garbage result in greater numbers of scavenging birds (Kurosawa et al., 2003). In most of these studies, land-use was used to determine food density rather than an actual survey of the anthropogenic food subsidies available in the study site. We counted each anthropogenic food subsidy and calculated their densities (Figure 5 and 6) as well as looked at land-use type. The results support the idea that increased food subsidies may be the reason for increased urban crow densities (Marzluff and Neatherlin, 2006). While a correlation was found between food density and crow density, it would be premature to assume this as a causal relationship. If the developed parks land use category were to be removed from the data, the R^2 value would drop to 0.3371, which shows much less correlation. Areas of increased accessible food subsidies such as developed parks may offer other beneficial anthropogenic subsidies to crows such as shelter. Regardless of the mechanism, developed parks contribute to higher crow densities, and the distance to these park areas from the least tern colony may effect crow predation on least tern eggs. The Venice least tern colony is well within the foraging range of crows from the parks in the study area.

While the theory that increased food subsidy density causes increased crow density may hold some weight, there may also be several confounding variables. The data show that different land-use categories have different attributes such as abundance of food, crow perches or roosting sites, use by people, and that certain attributes may or may not contribute to an increased number of crows in that particular land-use category. In our study area we witnessed people actively feeding birds. Our analysis assumed that every food subsidy carried the same weight while in truth one open trashcan may not contribute the same amount of food as a person actively feeding. To determine a causal relationship more experiments should be done both in a lab setting and in the field while controlling for more variables. Although urban crow ranges are greatly reduced from their wild counterparts their possible home ranges far exceed our study area. The experiments done outside the laboratory should be performed on a larger scale than our survey to correct for natural crow movement.

Crow Density and Land Use Distribution

The study area was broken down into seven main land use types: Multi-Family Residential, Single-Family Residential, Commercial, Protected Open Space, Developed Parks, Beach Parks and Water. The area of each particular land use can be found in Table 2. The land use type that had the most area represented in the study was Multi-Family Residential, although this area only had the fourth highest density of crows. The buildings within the Multi-Family Residential were multi-storied and were higher up on the skyline compared to the other buildings in the area. This would make these buildings very attractive to crows as perches for use in foraging. Often crows were sighted perched on the corners of these buildings, on lampposts or scaffolding. It has been shown that predator-hunting success is greatly increased by availability of high perches due to the increased visibility, and that both man-made and natural perches were used (Andersson 2009). The second and third largest areas represented in the study are Water and Protected Open Space, respectively. These areas had two out of the three lowest crow densities found in the study, the lowest of which was found in Beach Parks, which only represented the fifth largest land use area in the study. The lack of crow presence in these areas can be largely attributed to the limited amount of tree cover and buildings that can be used for perches or roost sites, as well as the limited amount of anthropogenic. The fourth largest land use type, Single Family Residential showed the third highest crow density in the study. Single Family Residential showed more crow density than Multi-Family Residential. Although these buildings were not as tall as the buildings represented in the Multi-Family Residential, they included more tree cover and lawn area, which would make good areas for shelter and foraging for the crows. The sixth largest land use area is Commercial; this area showed the second highest density of crows which also had the second highest abundance of food subsidies as discussed in earlier sections. These findings are supported by data collected by Withey and Marzluff (2009), which found that crow density increased in land use types that also provided anthropogenic resources. Heavy traffic by people and cars may have had a negative impact on the amount of crows present. The smallest represented area in the study is developed parks, which had the highest observed crow density in the entire study. This area contained higher amounts of human presence and tree cover compared to other land use areas. Frequently within the parks people were seen feeding the birds. This provision of resources and increased crow density is similar to that documented by Morishita et al. (2003) in Ueno Park in Tokyo, Japan, where people were found feeding bread and other food to the crows. The availability of food and roost sites resulted in an increase in the population of crows that was similar to what was observed in the field. Other studies showed similar trends in density between land-uses but none of them sampled an analogous set of land-uses and the data was not listed in crows/km^2.

Weekly Variation

Nearly 20% more crows were observed during the weekend compared to weekdays. This could very well be due to the higher human activity in the study area on the weekends. We observed numerous parties and picnics at the different parks and beaches within our study area on weekends. An increase in the number of people results in an increase in trash and other food sources that may have led to higher crow observations on the weekends. Similar studies that support this theory have indicated that crows and ravens have higher reproduction near human settlements and recreation (Marzluff and Neatherlin, 2006), although we are unaware of any studies comparing weekday to weekend densities of crows. The crows are well aware that more humans indicate more feeding opportunities.

Although we noticed the recreational areas had higher human activity during the weekends, the increase in sightings was relatively uniform over land use types although non-Beach parks had the highest increase in crow sightings (Table 2). This can be attributed to increased use of parks and recreational areas on the weekends. Higher human activity in these areas may correlate to the 20% increase in crow sightings on the weekends.

Temperature

As can be seen in Figure 5, there is no correlation between Temperature and crow density. Temperatures ranged from as low as 55 degrees Fahrenheit and as high as 82 degrees Fahrenheit. Crow density ranged from as low as 1.88 crows/km^2 to as high as 43.2 crows/km^2. The highest level of density occurred at a temperature of 82 degrees, and the lowest level of density occurred at a temperature of 70 degrees.

Perhaps with a greater range of temperatures or with a larger number of data points a relationship would emerge. It would be interesting to see crow density versus temperature over an entire yearlong period.

Recommendations/Future Research

Future research is recommended in order to observe the seasonal variations in crow density. Our research was conducted in late winter and early spring. It would especially beneficial to observe the crows during the breeding season of the Least Terns, from April to August, as this is the time period in which crows prey upon the Least Tern eggs and young. Continuing to survey during this time period would determine how much the presence of the Least Terns modifies the distribution of crows in the vicinity.

Regardless of the results of any future research, the conclusions of our study are clear, and we offer some recommendations for controlling crow predation at the Venice Least Tern Colony. Though we concluded that land use type does play a role in the density of crows, there are no recommendations we can make that will alleviate the problem of tern predation based on this result. It is entirely unfeasible to suggest that structures be torn down so crows will not perch on them, or that parks be demolished to discourage crows from gathering there. Therefore, we conclude that there are no preventive measures that can be taken in discouraging crows from inhabiting or frequenting a certain area, beyond covering garbage cans at all times and discouraging feeding of animals in parks. The bottom line is that crows are ubiquitous. Where there are people, there will be crows.

Our recommendation, then, is to take a reactionary approach in protecting the terns from predation. That is, taking steps at the site of the Tern colony itself to stop crows from, or deter them, from preying on the terns. Some existing techniques to haze crows include screamers, hand-clappers, and pistols, all intended to use noise to scare crows away from an area (Gorenzel and Salmon, 1992). In a study on raven predation on Least Terns, it was suggested that conditioned taste aversion allows continued habitation of the landscape while lowering predation on a sensitive species (Avery, et. al., 1995). In other words, placing bad tasting eggs in the Least Tern enclosure and allowing the crows to eat them will discourage crows from going back again. The basis of all these measures is aversive conditioning, in which the crows come to associate a negative experience with feeding on the terns, and are thus “taught” to stay away from the tern colony. These reactionary techniques can all be employed using volunteers, similar to the volunteer monitoring program already in place that keeps track of the success of the Least Terns (Delnevo, et. al., 2009).

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Appendix

Appendix 1. Each land-use category within the study area is designated by a different color