HABITAT USE AND BEHAVIOR OF GREAT-TAILED GRACKLES (*QUISCALUS MEXICANUS*) IN URBAN AND PERI-URBAN HABITATS OF SAN MARCOS, HAYS COUNTY, TEXAS

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HABITAT USE AND BEHAVIOR OF GREAT-TAILED GRACKLES (*QUISCALUS MEXICANUS*) IN URBAN AND PERI-URBAN HABITATS OF SAN MARCOS, HAYS COUNTY, TEXAS

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ABSTRACT

HABITAT USE AND BEHAVIOR OF GREAT-TAILED GRACKLES (*QUISCALUS MEXICANUS*) IN URBAN AND PERI-URBAN HABITATS OF SAN MARCOS, HAYS COUNTY, TEXAS

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Great-tailed grackles (*Quiscalus mexicanus*) are habitat generalists occupying a wide variety of environments, except dense forests and prairies lacking nearby water sources. Suitable habitat, such as golf courses, campuses, lawns, parks, and streets are also inhabited in urban and suburban areas. There are seasonal differences in habitat use by great-tailed grackles; however, habitat use and behavior have not been examined in urban environments. The goal of this study was to document seasonal use by great-tailed grackles of urban and peri-urban habitats in San Marcos, Hays County, Texas. I also documented behaviors observed in the different habitat types. I compared habitat use by season and behavior by season and habitat. I used program Presence to apply the best fit model explaining occupancy within habitats. Chi-square goodness of fit tests indicated no differences in behavior between seasons and habitat types. Principal components analysis suggested differences in woody vegetation among study sites. The best fit model incorporated occupancy, colonization and detection with habitat type and time of day as covariates. I found great-tailed grackles selected developed areas (85%) over open (60%) and wooded (27%) habitats based on occupancy modeling. Great-tailed grackle behavior did not change by season or by habitat type.

CHAPTER I

INTRODUCTION

Great-tailed grackles (*Quiscalus mexicanus*: Icteridae) are large blackbirds 38-46 cm in length. Adult males are iridescent black with a slight purple sheen on the head, yellow eyes, and a large keel-shaped tail (Johnson and Peer 2001). Adult females are considerably smaller than males with a brown body and darker wings; iridescence is only on the upper dorsal region, the tail is not keeled and smaller than in males (Johnson and Peer 2001). The current range extends northward from Central America into portions of Kansas, Colorado, Utah, Nevada, and California, western Missouri, southern Nebraska, northern Colorado, and northern Utah. The eastern boundary follows the Oklahoma and Texas borders extending into southern Louisiana with the western boundary extending to California (Dinsmore and Dinsmore 1993, Johnson and Peer 2001, Wehtje 2003). Two subspecies, *Q. m. monsoni* and *Q. m. prosopidicola*, of eight subspecies occur in Texas (Johnson and Peer 2001), with only *Q. m. prosopidicola* inhabiting my study area.

Great-tailed grackles are habitat generalists occupying a wide variety of environments, except dense forests and prairies lacking nearby water sources (Selander and Giller 1961). They also inhabit human developments, such as golf courses, campuses, lawns, parks, and streets (Johnson et al. 2000). Range expansion has followed irrigation and tree planting in grasslands and deserts where water is scarce (Dinsmore and Dinsmore 1993). Furthermore, new colonies are often established near natural and man-made marshes and other wetlands (Faanes and Norling 1981, Dinsmore and Dinsmore 1993). Human activities, such as fire suppression and cattle grazing, increase open environments with patchy, woody vegetation preferred by great-tailed grackles. In central Texas, colonies are often located in live oak (*Quercus fusiformis*) and cedar elm (*Ulmus crassifolia*) trees near ranches and urban areas (Selander and Giller 1961).

Great-tailed grackles often form large, mixed flocks near agricultural areas used for row-cropping and livestock grazing during the non-breeding season in Texas (Arnold and Folse 1977). Large roosts also occur in parking lots of large commercial retail developments (Johnson and Peer 2001). Great-tailed grackles disperse over large areas in summer but form large, dense flocks during winter over smaller areas with resident populations (Arnold and Folse 1977). Great-tailed grackles are generally a resident species and only migratory at the northernmost edge of the range (Johnson and Peer 2001).

During breeding season (spring/summer), other bird species generally do not roost or nest in trees with great-tailed grackles; however, mourning (*Zenaida macroura*) and white-winged doves occasionally nest in the same tree with great-tailed grackles (Johnson et al. 2000, Eitniear 2009). Female great-tailed grackles defend nests from conspecifics, and steal nesting materials from other females (Johnson et al. 2000). Male great-tailed grackles arrive at nesting grounds in early February to establish territories, seek females by March, and consistently defend territories (Selander and Hauser 1965). A territory often consists of part of a tree to several trees with several males along with nests used by females in close proximity (Johnson et al. 2000). The first brood typically occurs in early April with a second brood between March and July if the first brood was unsuccessful (Selander and Hauser 1965). Females select nest sites near standing water and grasslands for foraging (Johnson and Peer 2001). Nests are usually built in trees but may also be on man-made structures (Selander and Giller 1961, Pratt et al. 1977). The greatest densities in the United States occur in south Texas where night-time roosts have as many as 500,000 birds (Johnson and Peer 2001).

Significant increases in populations of great-tailed grackle have occurred within the range and maybe the greatest range expansions of any native bird species in the western United States (Marzluff et al. 1994). Dinsmore and Dinsmore (1993) proposed three primary reasons for the rapid expansion of great-tailed grackles since the early 1900s: a) a propensity of great-tailed grackles to disperse beyond the normal range, b) a high rate of colonization after a few pioneers arrive, and c) establishment of nesting and breeding populations within only a few years of colonizing an area.

Currently, the great-tailed grackle is considered a nuisance species that benefits from human activity (Johnson and Peer 2001). Management in urban areas has been ineffective and difficult because of proximity to humans (Johnson and Peer 2001). They have been implicated in the decline of white-winged doves (*Zenaida asiatica*) (Blankinship 1966). However, Hayslette et al. (1996) disagreed with Blankinship's assessment.

I examined foraging behavior and habitat use by great-tailed grackles in an urban environment. Great-tailed grackles are a nuisance and invasive species in urban areas and on agricultural croplands. In urban areas noise and feces are exacerbated by the occurrence of large flocks particularly during winter. An understanding of habitats occupied year-round and seasonally will provide basic information for management plans and techniques to deter or attract great-tailed grackles to specific areas. My objectives were: 1) document seasonal habitat use by great-tailed grackles in urban and peri-urban environs in the San Marcos area; 2) record behaviors observed in different habitat types; and 3) compare observed behaviors by habitat and season.

CHAPTER II

STUDY AREA

I studied great-tailed grackle habitat us and observed behaviors at 40 sites in San Marcos, Hays County, Texas (29° 52’ N, 97° 56’ W, Fig. 1). San Marcos is a typical mid-size city with areas of dense commercial development, areas of less-dense residential developments and areas of protected green space. It is located on the eastern boundary of the Balcones Escarpment with the Edwards Plateau ecoregion to the west and the Blackland Prairie ecoregion to the east (Gould et al. 1960). My study area consisted of approximately 2,990 ha with 1,963.8 ha of developed land, 677.9 ha open land and 324.8 ha of wood land. Typical vegetation includes live oak (*Quercus fusiformis*), Texas oak (*Quercus buckleyi*), Texas persimmon (*Diospyros texana*), and Ashe juniper (*Juniperus ashei*). The climate is temperate with mean annual precipitation of 88 cm and an average daily temperature of 20° C.

All sites were located adjacent to public roads or in public green spaces and easily accessible with the exception of two accessible by foot only. Study sites showed the patchiness of an urban environment with wooded areas, open areas, and developed areas intermixed.

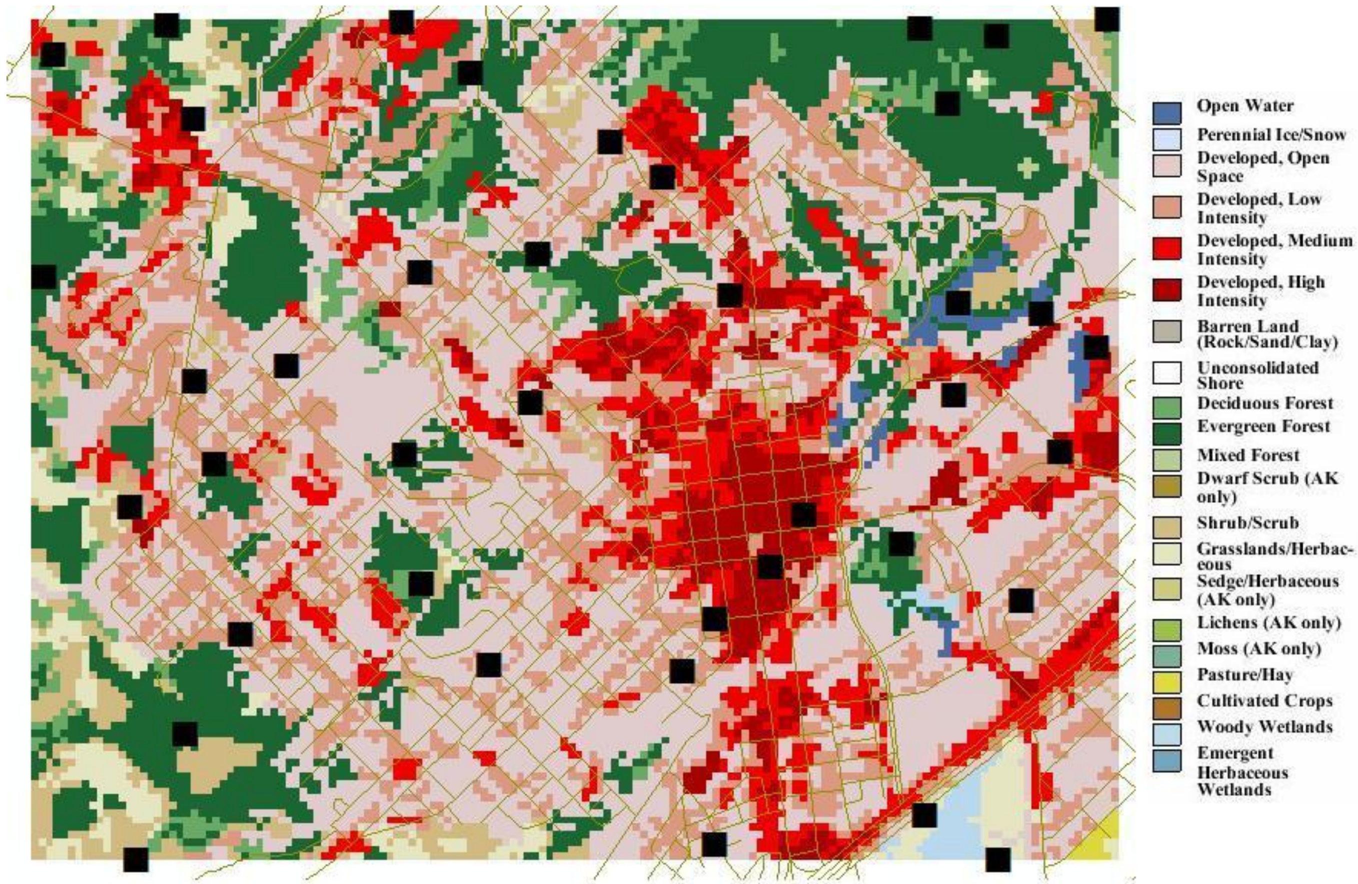

Figure 1. GIS map of San Marcos, TX with observation sites indicated by black squares. This map was created from the 2001 NLCD using ArcGIS v. 9.3 and Hawth's Tools.

CHAPTER III

METHODS

I used GIS data from the 2001 National Land Cover Database (NLCD) from the United States Geological Service (MRLC Consortium Viewer, http://gisdata.usgs.gov/website/mrlc/viewer.htm, accessed June 6, 2009) to designate habitat types within the study area. Habitat type databases are based on definitions from the Environmental Protection Agency through the Multi-Resolution Land Characteristics Consortium. I chose the 2001 NLCD because of high accuracy (over 70% for land cover, imperviousness and tree canopy) and usefulness in differentiating urban development from surrounding habitats (Homer et al. 2004). Nine categories present within the San Marcos, Texas area from the NLCD 2001 are shown in Figure 1 and Appendix 1. The categories present within the San Marcos, Texas, area include developed (low, medium and high intensity), open space, deciduous forest, evergreen forest, mixed forest, shrub/scrub and grassland/herbaceous. I used ArcGIS v. 9.3 (Environmental Systems Research Institute, Redlands, CA) to randomly choose 40 observation sites in proportion to the area of each habitat type identified within the San Marcos city limits (Fig. 1). I visited each site eight times seasonally during a four-week period, with four visits in the morning and four visits in the evening. Visits were done during the three hours after sunrise and three hours before sunset. It was not possible to visit all 40 sites randomly, so

I divided the sites into three driving routes and reversed the routes each time. I defined seasons traditionally; summer (June 21-Sep. 21), fall (Sep. 22-Dec. 21), winter (Dec. 22-Mar. 21) and spring (Mar. 22-June 21).

I used standard methodology for a 50 m fixed radius point count with each point a minimum of 250 m apart and an 8 min observation time at each point (Ralph et al. 1995). I recorded date, habitat type, number of great-tailed grackles present via scan sampling, behavior of great-tailed grackles, associated species and number present, general weather conditions, time of day, and GPS coordinates. During the 8 min observation period, I recorded types of behavior observed (not individual performances) including nest-building, foraging, alert, and in-flight. Nest-building was defined as a bird transporting materials, such as vegetation, mud, or trash in its beak, to another location. Foraging included walking on the ground, digging with the feet or pecking at the ground. When a bird was perched and still, not actively foraging or nest-building, I recorded the behavior as alert. I recorded great-tailed grackles in-flight passing overhead. I used 40x binoculars in my observations of great-tailed grackles.

I used a 3-factor analysis of variance (ANOVA) to compare observations of great-tailed grackles by season, habitat, and time of day and interactions among the three variables. I used Tukey's Multiple Comparison of Means test as a post-hoc analysis to determine specific differences in 2-way comparisons of season, habitat and time of day.

I used program PRESENCE v. 2.4 (United States Geological Service, Laurel, MD, 2006) to compare occupancy and detection of great-tailed grackles across seasons. I created a model that best explained trends of occupancy and detection and used Akaike

Information Criterion (AIC) to determine the best model. Some models were simple with no covariates and others included habitat type and time of day as covariates. No reliable model was generated by Program Presence using estimates of the original nine habitat types (Fig. 2), so I combined habitat types to produce three types: developed, wooded, and open. Developed habitats consisted of low, medium and high intensity. The types of development included neighborhoods, apartment complexes, strip malls and large commercial buildings. Wooded habitats consisted of deciduous forest, evergreen forest and mixed forest. Neighborhoods with numerous large trees and large-size lots on the perimeter of San Marcos as well as green spaces were classified into this category. Open habitats consisted of those areas designated as developed open space, shrub/scrub and grassland/herbaceous. Fields, pastures, parks and some neighborhoods with few trees grouped into this category.

I analyzed behavioral data using chi-square test of independence and goodness of fit test. I performed two chi-square tests of independence with one comparing behavior and season and behavior and habitat type. I calculated expected behavior by multiplying all observed behaviors per season by number of observations of each behavior per season and dividing by total number of observations per year. I also compared behavior and time of day (morning, evening) for the year and each season using Fisher's Exact test. I compared foraging and alert behaviors by time of day in more detail using Fisher's Exact test. I did not analyze in-flight and nest-building behaviors in more detail by time of day because there was very limited data for nest-building and flyovers are not necessarily indicative of actual habitat use.

I measured and recorded vegetative data (canopy cover, distance to woody vegetation < 2 m height and > 2 m height and height of woody vegetation > 2 m) at each site. I measured canopy cover using a spherical convex densiometer and an Opti-Logic 400 LH Laser Rangefinder/Hypsometer (Opti-Logic Corporation, Tullahoma, TN) was used to measure distance to and height of woody vegetation. I used Excel (Microsoft Corporation, Redmond, Washington) to calculate mean distances and height of vegetative data. I used program R (R development core team 2005) to perform a principal components analysis (PCA) on the vegetative data. Excel was then used to create a scatter plot of the loadings of the principal components.

CHAPTER IV

RESULTS

I observed great-tailed grackles at 40 sites within the San Marcos city limits. The 40 sites were composed of the following habitat types: 14 developed, 13 open, and 13 wooded (Appendix I). I observed 1,836 grackles in a year with 421 in spring, 341 in summer, 490 in fall, and 584 in winter (Table 1, Appendix 3). I recorded three species, red-wing blackbirds (*Agelaius phoeniceus*), european starlings (*Sturnus vulgaris*) and common grackles (*Quiscalus quiscalus*), associated with great-tailed grackles during my observations.

Overall, great-tailed grackles increased in San Marcos during fall and winter. The smallest number of great-tailed grackles observed occurred in summer (Fig. 2). Great-tailed grackle numbers varied among habitat types by season (Fig. 3), with largest numbers in developed habitat in fall and open habitat during winter. Great-tailed grackle numbers appear to stabilize in morning by season (Fig. 4); however, evening numbers followed the similar pattern as shown in Fig. 3. Evening numbers (Fig. 4) increased during fall and winter. When great-tailed grackle numbers were analyzed by time of day and habitat, a different trend emerged. Great-tailed grackle numbers in wooded habitats were stable, while numbers in developed and open habitats increased from morning to evening (Fig. 5).

Number of great-tailed grackles observed differed significantly according to habitat type (F_2 = 20.7, P = 0.002; Table 2) and time of day (F_1 = 6.48, P = 0.04; Table 2). Season (F_3 = 1.05, P = 0.44; Table 2) and any interactions among factors were not significant (Table 2). There was no replication in my study, so I could not examine third level interactions among season, habitat and time of day. The post-hoc Tukey's Multiple Comparison of Means test indicated significant differences in number of great-tailed grackles observed at different habitat types with wooded being significantly less than developed and open habitats.

The top two models included occupancy, colonization, and detection, while the next two models included extinction as well (Table 3). Since the top two models did not include extinction, I concluded the great-tailed grackle population grew over the course of the study; however, it is more likely seasonal shifts in the distribution of great-tailed grackles accounts for the discrepancy. The best fit model determined by program PRESENCE included occupancy, colonization, and detection with habitat as a site covariate and time of day as a sampling covariate applied to occupancy and detection, respectively. Habitat type and time of day were important with regard to occupancy and detection since the best fit model included those covariates. Occupancy (ψ) for developed habitats was 0.85, open habitats 0.60 and wooded habitats 0.27. Detection (P) by season was 0.48, 0.26, 0.19 and 0.28 for spring, summer, fall and winter, respectively.

Performance of behaviors did not differ by season ($\chi^2_9 = 8.22$, $P = 0.51$; Table 4; Fig. 6) and by habitat type ($\chi^2_6 = 6.65$, $P = 0.35$; Table 5; Fig. 7). Foraging and nest-building behaviors occurred more often in morning (Table 6). Alert and in-flight behaviors were similar morning to evening (Table 6). Foraging and alert behaviors did not occur equally from morning to evening (Fisher's Exact test, $P = 0.04$). Foraging and alert behaviors differed from morning to evening during summer (Fisher's Exact test, $P = 0.02$) and fall (Fisher's Exact test, $P = 0.008$). Foraging and alert behaviors did not differ from morning to evening during spring (Fisher's Exact test, $P = 0.84$) and winter (Fisher's Exact test, $P = 1$).

Vegetation data for each site are summarized in Appendix IV. Mean canopy cover was 32% (range = 0%-100%) for all sites. Mean distance to woody vegetation < 2 m in height was 19.3 m, while mean distance to woody vegetation > 2 m in height was 14.3 m. Mean height for vegetation > 2 m was 10.6 m. Principal component (PC) axes I and II explained 71% of the variance in habitat among all sites (Fig. 8). Strongest negative loadings for PC I were at site 5 (-4.25) and site 7 (-2.30). Strongest positive loadings for PC I (canopy cover) were at site 15 (2.09) and site 31 (2.03). Strongest negative loadings for PC II (distance to woody vegetation < 2 m tall) were site 36 (-3.05), site 7 (-2.04) and site 9 (-2.02). Strongest positive loadings for PC II were site 20 (1.51) and site 27 (1.48). Sites with low loadings for PC I and PC II had low canopy cover and little woody vegetation < 2 m in height. Principal component II and PC III (distance to woody vegetation ≥ 2 m) accounted for only 42% of the variance, while PC I and PC III accounted for 58% of the variance. PC I accounted for the majority of the total variance at 47%. Sites 5, 7, 9, and 36 were different from other sites (Fig. 9, Fig. 10). I graphed only canopy cover, distance to vegetation < 2 m and distance to vegetation > 2 m because they accounted for ~89% of variation.

Table 1. Number of great-tailed grackles categorized by season, habitat and time of day. Numbers were from 40 sites in San Marcos, TX.

	Spring		Summer		Fall		Winter	
	AM	PM	AM	PM	AM	PM	AM	PM
Developed	109	105	94	86	168	245	67	176
Wooded	3	1	4	3	0	0	10	5
Open	88	113	69	86	11	68	39	286

Table 2. Results of ANOVA. Results of analysis of variance (ANOVA) comparing season, time of day, and habitat type of observed great-tailed grackles at 40 points in San Marcos, TX.

Factor	**Df**	**Sum Sq.**	**Mean Sq.**	**F-value**	**Pr(>F)**
Season	3	5292	1764	1.0465	0.437734
Habitat	2	69643	34822	20.656	0.00204
Time	1	10923	10923	6.4793	0.043758
Season:Habitat	6	26809	4468	2.6505	0.130354
Season:Time	3	12674	4225	2.5061	0.155907
Habitat:Time	2	7834	3917	2.3237	0.178951
Residuals	6	10115	1686		

Table 3. Results of model selection from program PRESENCE. Results were based upon observations of great-tailed grackles at 40 points in San Marcos, TX. Habitat type (Developed, Wooded, and Open) was a covariate of occupancy(ψ) and time of day (morning or evening) was a covariate of detection (P).

Model	AIC	deltaAIC	AIC wgt	AICc	Model Likelihood	No. of Parameters	-2*Loglikelihood
psi(habitat),gamma(.),p(time)	1041.71	0	0.82	1041.85	1	9	1023.71
psi(habitat),gamma(.),p(.)	1045.38	3.67	0.1309	1045.49	0.1596	8	1029.38
psi(habitat),gamma(.),eps(.),p(time)	1047.85	6.14	0.0381	1048.02	0.0464	10	1027.85
psi(habitat),gamma(.),eps(.),p(.)	1051.57	9.86	0.0059	1051.71	0.0072	9	1033.57
psi(.),gamma(.),p(time)	1053.13	11.42	0.0027	1053.22	0.0033	7	1039.13
psi(.),gamma(.),eps(.),p(time)	1053.99	12.28	0.0018	1054.1	0.0022	8	1037.99
psi(.),gamma(.),p(.)	1056.83	15.12	0.0004	1056.9	0.0005	6	1044.83
psi(.), gam(.), eps(.), p(.)	1057.71	16	0.0003	1057.8	0.0003	7	1043.71

Table 4. Observed behaviors by season of great-tailed grackles. Observations were at 40 points in San Marcos, TX. Expected behavior was calculated by multiplying the total percentage of each behavior per season by the total percentage of behaviors by each season and then dividing by the total percentage of observations. (*n* = 400)

Season	Behavior	Observed	Expected
Spring	Foraging	46	47
Spring	Alert	28	30
Spring	Nest-building	3	1
Spring	In-flight	23	22
Summer	Foraging	72	47
Summer	Alert	12	30
Summer	Nest-building	0	1
Summer	In-flight	16	22
Fall	Foraging	39	47
Fall	Alert	37	30
Fall	Nest-building	0	1
Fall	In-flight	24	22
Winter	Foraging	30	47
Winter	Alert	45	30
Winter	Nest-building	0	1
Winter	In-flight	25	22

Table 5. Observed behaviors by habitat type of great-tailed grackles. Observations were at 40 points in San Marcos, TX. Expected values were calculated by multiplying the total percentage of behaviors observed in each habitat type by the total percentage observed for each behavior and divided by the total percentage of observations (n = 300).

Habitat Type	**Behavior**	**Observed**	**Expected**
Developed	Foraging	43	47
Wooded	Foraging	46	47
Open	Foraging	53	47
Developed	Alert	35	24
Wooded	Alert	15	24
Open	Alert	21	24
Developed	Nest-building	3	1
Wooded	Nest-building	0	1
Open	Nest-building	0	1
Developed	In-flight	19	28
Wooded	In-flight	39	28
Open	In-flight	26	28

Table 6. Observed behaviors of great-tailed grackles by time of day. Observations were at 40 points in San Marcos, TX.

Behavior	**AM**	**PM**	**Total**
Foraging	101	62	163
Alert	49	52	101
In-flight	35	41	76
Nest-building	4	1	5
Total	189	156	345

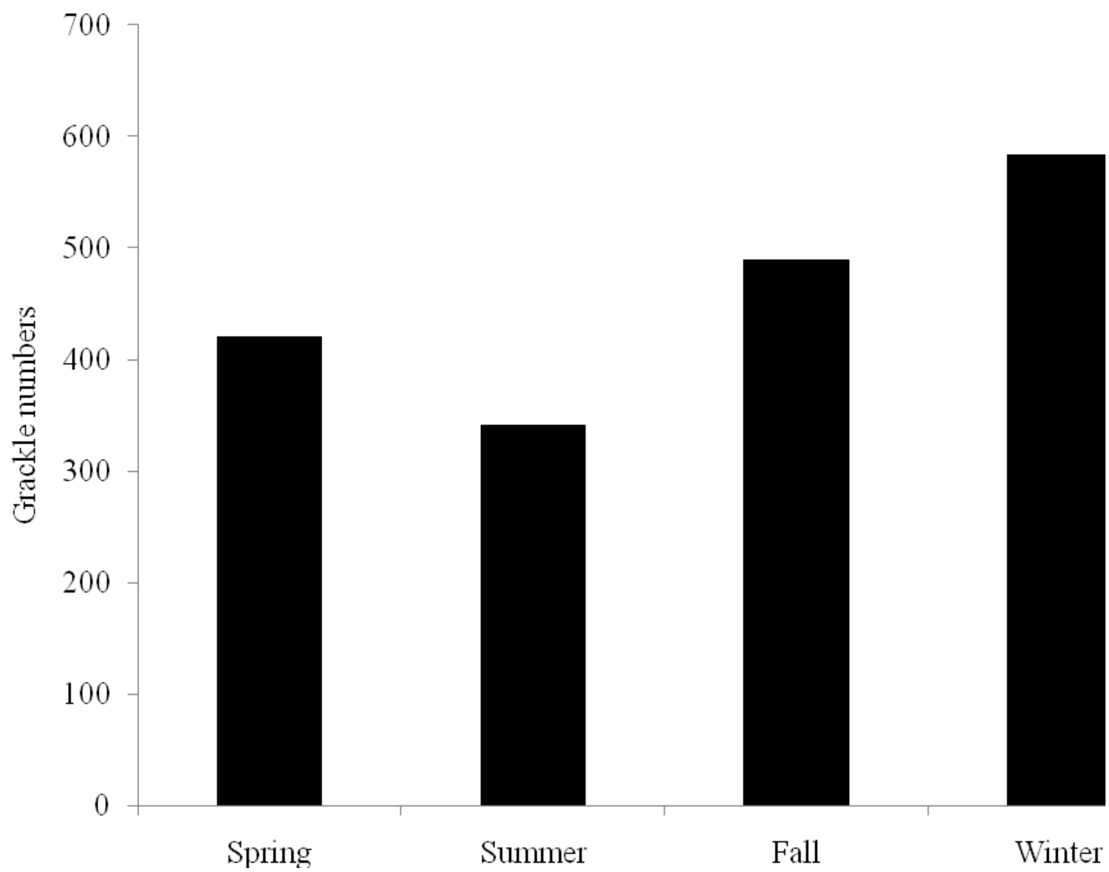

Figure 2. Number of great-tailed grackles by season. Numbers were from 40 points in San Marcos, TX.

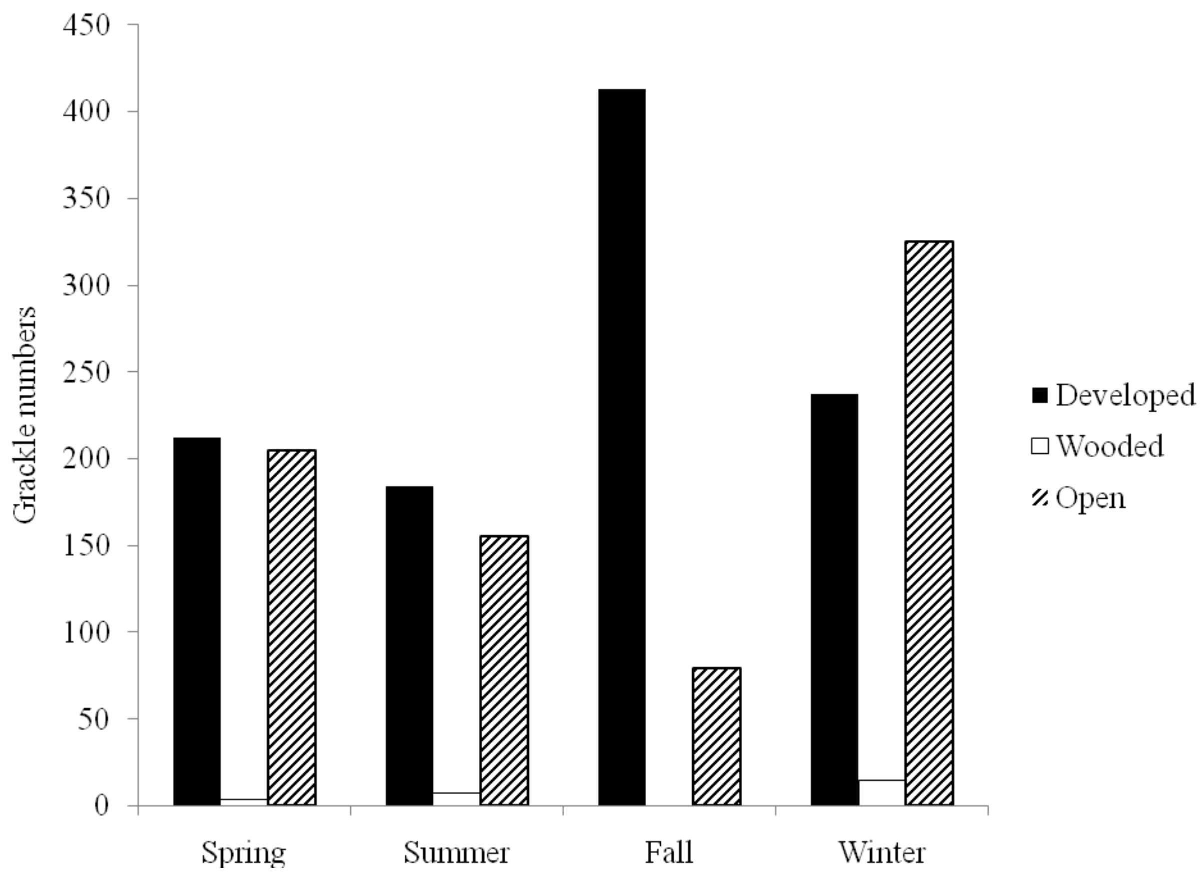

Figure 3. Number of great-tailed grackles by season and habitat type. Numbers were from 40 points in San Marcos, TX.

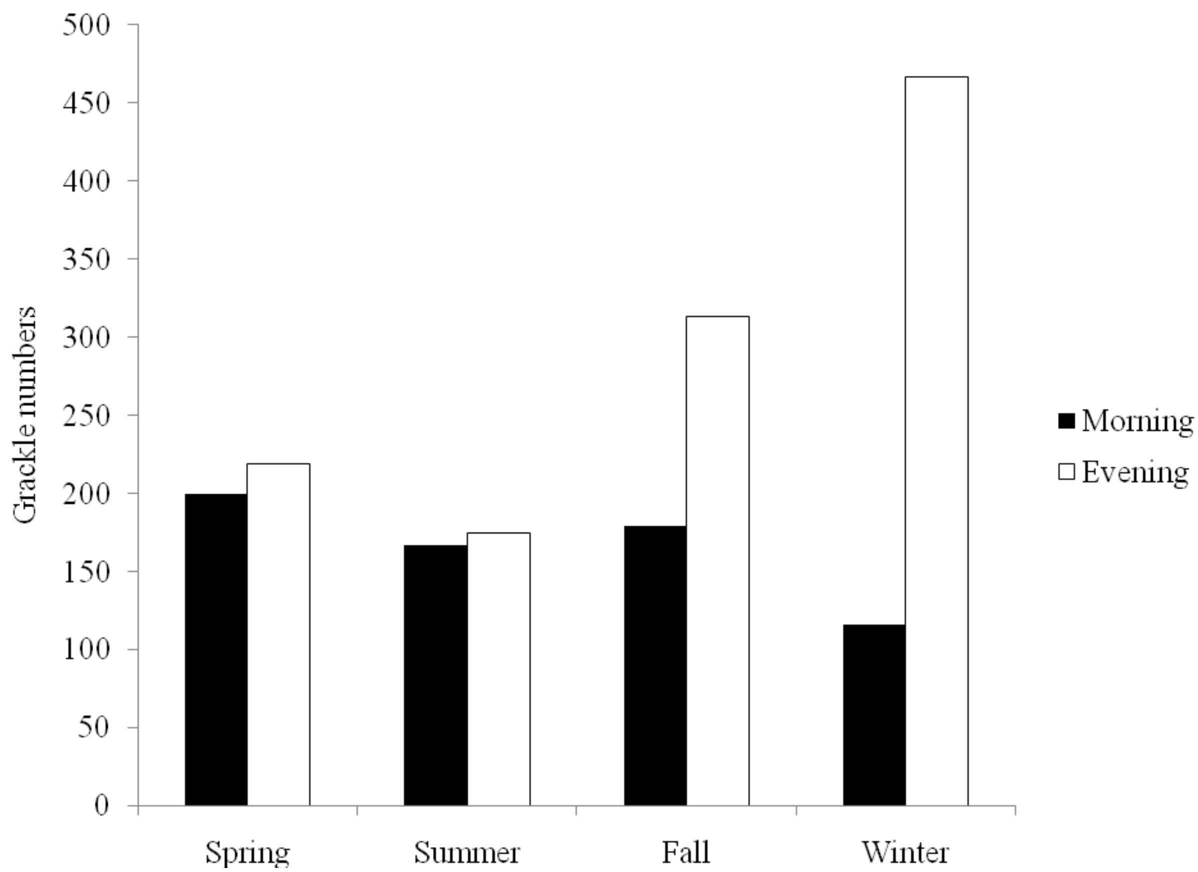

Figure 4. Number of great-tailed grackles by season and time of day. Numbers were from 40 points in San Marcos, TX.

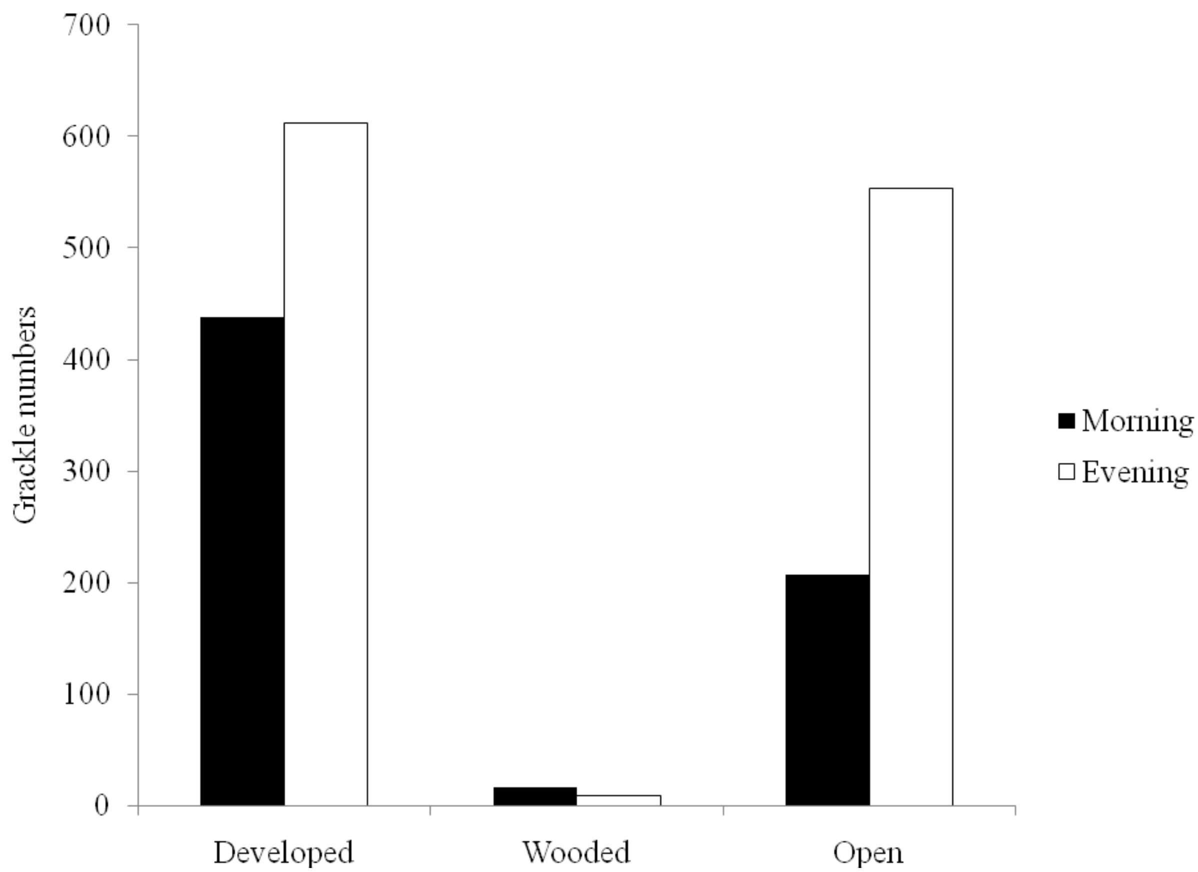

Figure 5. Number of great-tailed grackles by habitat type and time of day. Numbers were from 40 points in San Marcos, TX.

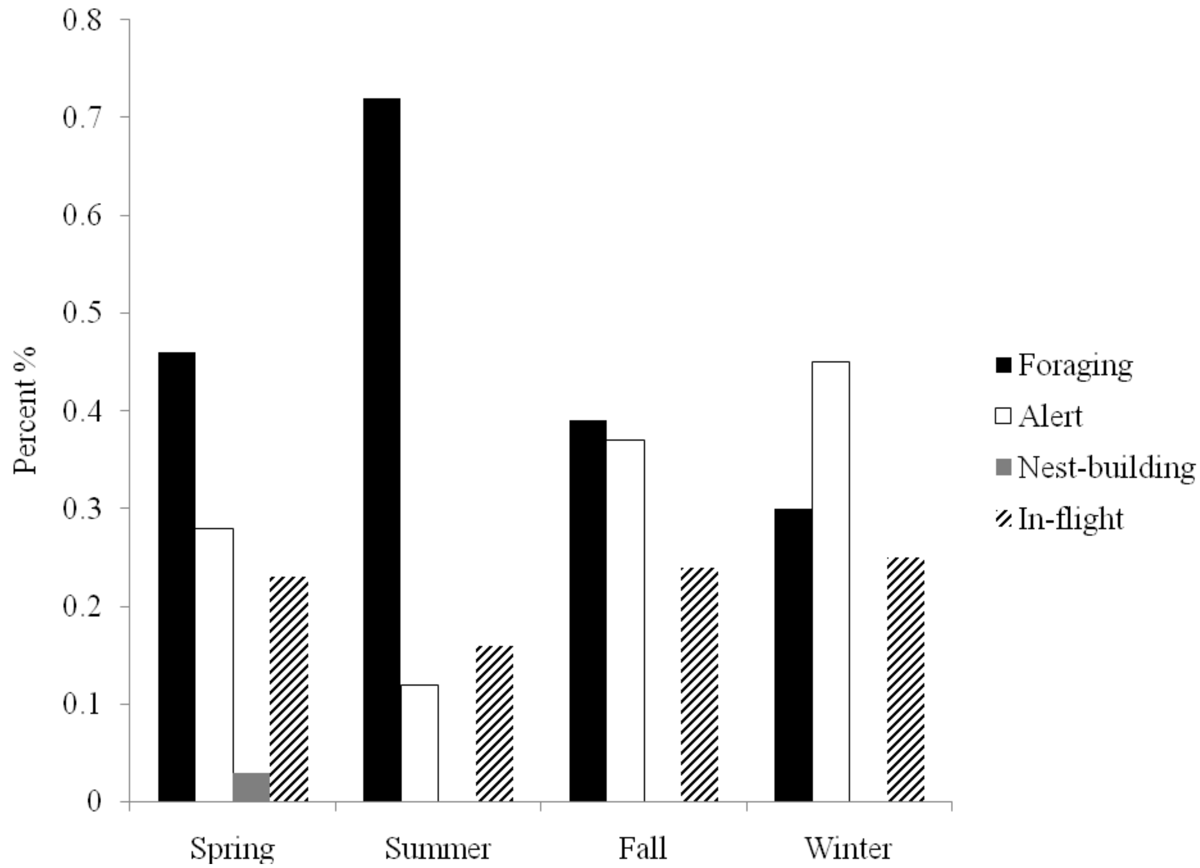

Figure 6. Percentage of behaviors by season exhibited by great-tailed grackles. Percentages were from 40 points in San Marcos, TX. Behavior percentage was calculated by dividing the number of each individual behavior by the total observed behaviors for each season.

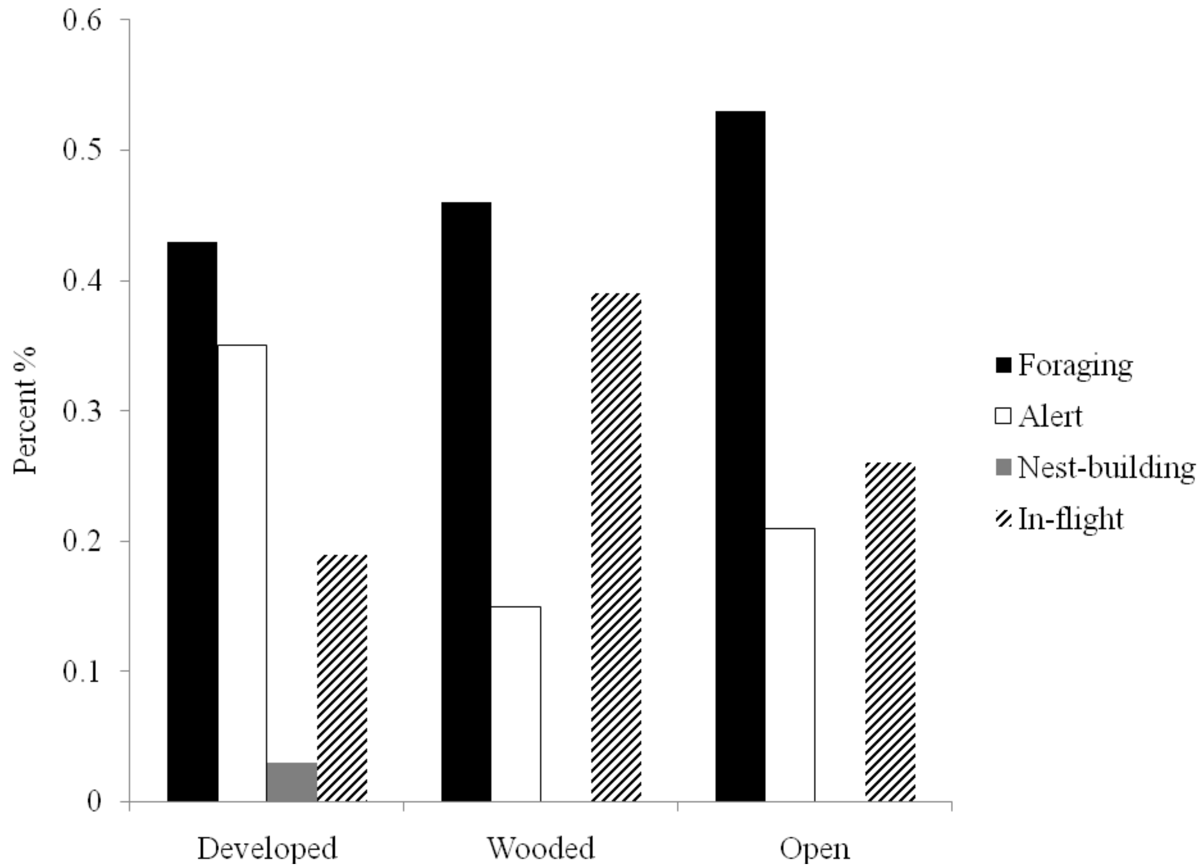

Figure 7. Percentage of behaviors by habitat type exhibited by great-tailed grackles. Percentages were from 40 points in San Marcos, TX. Behavior percentage was calculated by dividing the number of each individual behavior by the total observed behaviors for each habitat type.

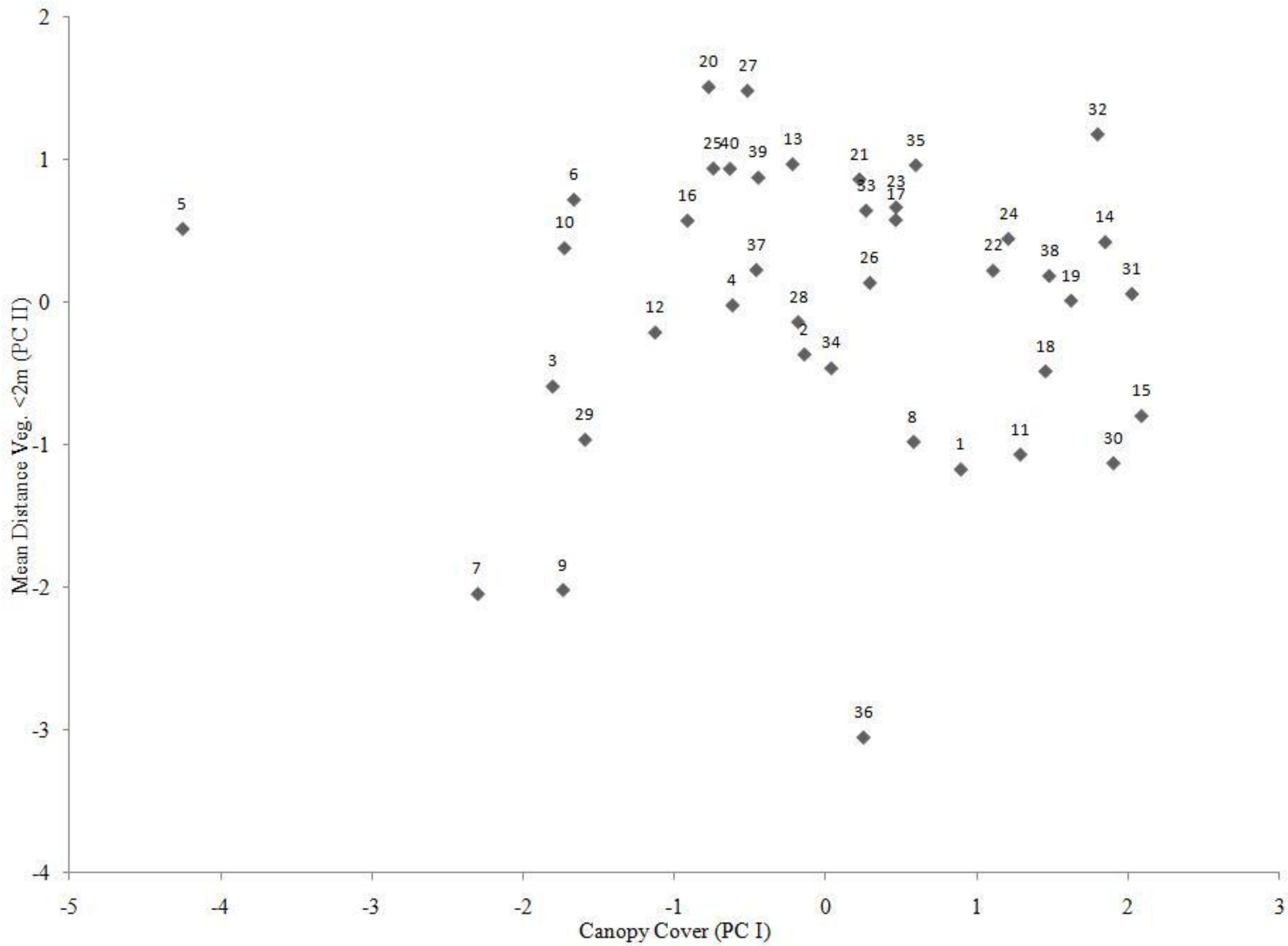

Figure 8. Graph of principal component I and principal component II. The 40 points represent observation points of great-tailed grackles in San Marcos, TX.

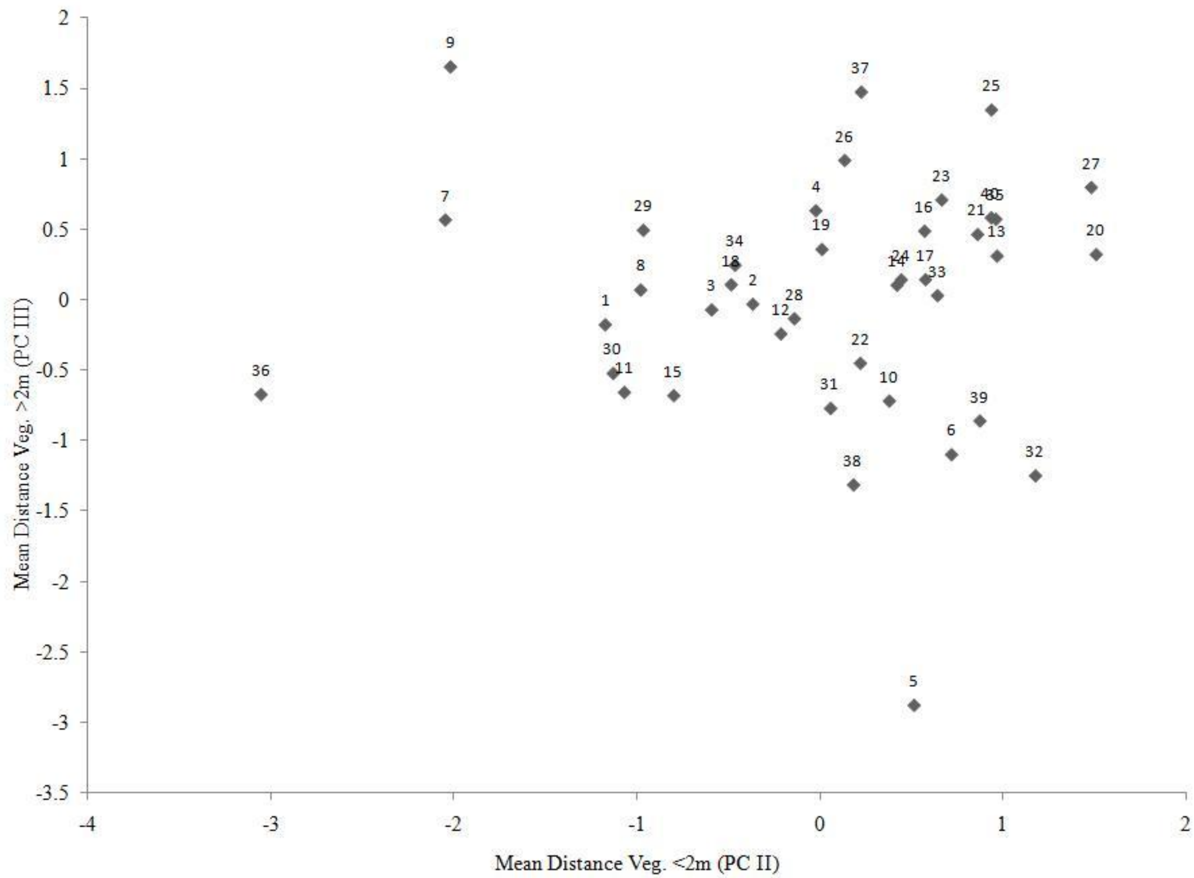

Figure 9. Graph of principal component II and principal component III. The 40 points represent observation points of great-tailed grackles in San Marcos, TX.

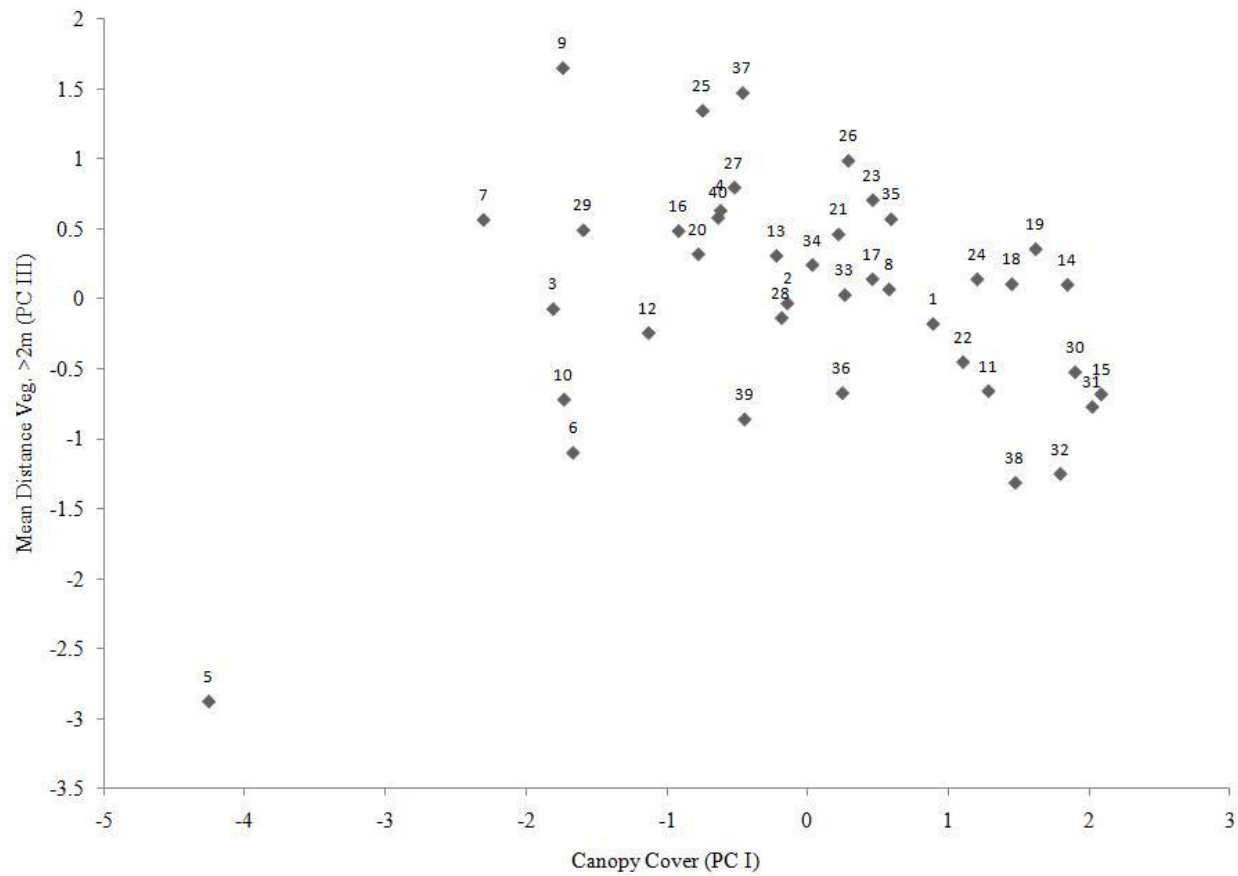

Figure 10. Graph of principal component I and principal component III. The 40 points represent observation points of great-tailed grackles in San Marcos, TX.

CHAPTER V

DISCUSSION

Previous research on great-tailed grackle habitat use has focused on basic life history and nuisance issues (Johnson and Peer 2001). My research examined how great-tailed grackles used habitats within an urban environment. Great-tailed grackle occupancy data showed a preference for developed habitats in contrast to open and wooded habitats. Rappole et al. (1989) showed great-tailed grackle habitat use in urban environments changed seasonally with similar usage patterns in spring and summer and fall similar to winter. When observations of great-tailed grackles in San Marcos are broken down into habitat types the pattern becomes less clear. In spring and summer developed and open habitats were used in approximately equal amounts. In fall, habitat use was skewed heavily towards developed habitat types. A contributing factor may be the availability of food source in the form of discarded food products at large sporting events such as football games (university and high school). The trend reversed during winter with habitat use skewed towards open habitats. Fewer large outdoor events occurred during winter months, so great-tailed grackles foraged more in open habitats. Habitat type and time of day were the most significant factors in relation to number of great-tailed grackles in an area across all seasons.

The fluctuating nature of great-tailed grackle populations across seasons emerged in evening numbers, but were not indicated in the morning numbers. These suggested individual great-tailed grackles may move between multiple roosts more so in the evening. This trend did not appear tied to habitat type as great-tailed grackle numbers increased for developed and open habitats. The other possibility is I simply missed some great-tailed grackles in the morning or they left before I arrived at sites to perform surveys, which is the most likely possibility. Great-tailed grackles typically leave in the morning to forage and return to roosting sites in evening (Selander and Hauser 1965). Behavior differed from morning to evening as well; however, I had insufficient data to make any conclusions as to why it differs. Foraging appears to be different, while alert and in-flight appears to be stable from morning to evening. There was insufficient data on nest-building behavior to draw any conclusions on differences in time of day. Future research should address differences in behavior from morning to evening, particularly with nest-building behavior. Additionally, future studies should be long-term, so higher levels of interactions between habitat, season, time of day and environmental parameters can be analyzed.

The best model from program PRESENCE included occupancy, colonization and detection as variables with covariates of habitat type and time of day. Extinction was dropped as a variable because estimates had very high standard error, which indicated overall an increasing great-tailed grackle population. This model also supported habitat type and time of day as important factors explaining the presence or absence of great-tailed grackles in a given area. San Marcos is located close to large metropolitan areas, Austin and San Antonio, which also have large great-tailed grackle populations. The increase in the population in San Marcos could be the results of dispersal from metropolitan areas or smaller satellite roosts in smaller towns near San Marcos. Another possibility is the model simply did not capture the fluctuating nature of the great-tailed grackle population in San Marcos.

I did not find published studies on great-tailed grackle behavior in urban habitats. I found no difference in behaviors across seasons and habitat types. Davis and Arnold (1972) reported summer was unique because females fed their young early in the season; however, by the end great-tailed grackles switched from insectivory to granivory. In San Marcos foraging was similar for developed and open habitats, but different for wooded habitats. Great-tailed grackles favored open and developed habitats because these habitats may provide superior foraging resources. Foraging was the most common behavior observed in spring and summer and observed most often in developed and open habitats. The decline in observed foraging behaviors in fall and winter may be due to large flights leaving urban areas in the morning to forage in surrounding agricultural fields and returning in the evening to roosts. It is unclear as to how great-tailed grackles disperse on a local and regional scale.

The principal components analysis reinforced preference by great-tailed grackles for more open habitat types. The graph of canopy cover (PC I) and mean distance to woody vegetation < 2 m height (PC II) shows that great-tailed grackles favored open habitats as there were high negative loadings for both components. The graph of mean distance to woody vegetation < 2 m height (PC II) and mean distance to woody vegetation > 2 m height (PC III) also shows that great-tailed grackles favored open habitats as there were high negative loadings for both components. The sites that stood out as different did not have differences in occupancy from other sites.

I chose the 2001 NLCD for my analysis because it appeared to clearly distinguish between a variety of habitats in urban areas. However, I found major limitations to the database particularly with regard to developed habitats. The database indicated areas as developed with high levels of impervious cover. However, upon visiting the site, areas classified as developed had a large amount of woody vegetation and open space. Future studies incorporating the 2001 NLCD need to take these differences into account as the database is coarse in scale and fails to capture differences in vegetation.

Overall, great-tailed grackles selected developed habitats, but also used open habitats while seldom using wooded habitats. Great-tailed grackles are considered a nuisance species in urban environments (Johnson and Peer 2001). Management of great-tailed grackles should target developed habitats within urban regions. A management plan should encourage large commercial developments to focus on reducing the amount of trash great-tailed grackles target as foraging resources. Results from future habitat and behavior studies of great-tailed grackles can be compared to my study to determine whether trends in San Marcos are similar in other urban areas. Future studies should also look at larger urban areas and compare how great-tailed grackles use urban areas and if usage patterns differ throughout a larger region.

APPENDIX I

2001 NLCD descriptions of land use/land cover classes for San Marcos, TX.

Land Classification	NLCD 2001 description
Developed, Open Space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Developed, Low Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.
Developed, Medium Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.
Developed, High Intensity	Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.
Deciduous Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

Mixed Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
Shrub/Scrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Grassland/Herbaceous	Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

APPENDIX II

List of 40 observation sites of great-tailed grackles in San Marcos, TX.

Site #	Site Name	Habitat Class	N	W
1	Craddock Ave.	Developed	29° 54' 0.83"	97° 57' 22.1"
2	Oakridge Dr.	Wooded	29° 54' 14.2"	97° 56' 41.9"
3	Leuders Dr.	Wooded	29° 53' 10.8"	97° 56' 55.8"
4	Stonehaven Dr.	Wooded	29° 53' 23.3"	97° 58' 23.0"
5	Edward Gary St.	Developed	29° 53' 0.27"	97° 56' 20.5"
6	Walgreens Parking Lot	Developed	29° 53' 11.0"	97° 55' 37.8"
7	Stadium Parking Lot	Developed	29° 53' 30.8"	97° 55' 23.0"
8	Spring Lake	Open	29° 53' 37.0"	97° 55' 49.2"
9	New Target	Developed	29° 50' 45.8"	97° 58' 09.6"
10	Prime Outlets	Developed	29° 49' 53.1"	97° 58' 42.9"
11	Camaro Way	Wooded	29° 53' 58.0"	97° 57' 13.0"
12	Holland St.	Developed	29° 53' 50.5"	97° 56' 54.3"
13	Chestnut St.	Developed	29° 53' 41.7"	97° 56' 40.6"
14	W. Hillcrest Dr.	Wooded	29° 53' 37.2"	97° 57' 02.8"
15	Coers Dr.	Developed	29° 53' 32.5"	97° 57' 22.3"
16	Country Estates Dr.	Wooded	29° 54' 0.28"	97° 58' 18.9"
17	Hamilton Ave.	Developed	29° 53' 18.3"	97° 57' 53.7"
18	Dale and Perkins	Open	29° 53' 20.9"	97° 57' 41.5"
19	Franklin and Furman	Wooded	29° 53' 07.3"	97° 57' 52.3"
20	Franklin and Dartmouth	Open	29° 52' 58.7"	97° 58' 00.7"
21	Hazleton St.	Open	29° 52' 45.4"	97° 57' 46.3"
22	Gillett St.	Wooded	29° 52' 44.5"	97° 57' 21.4"
23	Loop St.	Open	29° 53' 08.2"	97° 57' 26.0"
24	Belvin and Mitchell	Open	29° 52' 41.3"	97° 57' 09.6"
25	Prospect Park	Wooded	29° 52' 28.5"	97° 57' 44.7"
26	Behind Aquarena	Wooded	29° 53' 49.4"	97° 55' 48.2"
27	Lime Kiln Rd.	Open	29° 54' 10.9"	97° 55' 43.1"
28	Aquarena Visitor Map	Open	29° 53' 26.8"	97° 55' 47.3"
29	Jowers	Open	29° 53' 18.0"	97° 55' 54.4"
30	Field St.	Developed	29° 52' 49.7"	97° 55' 48.8"
31	Riviera Dr.	Wooded	29° 52' 55.5"	97° 55' 59.8"
32	Courthouse Square	Developed	29° 52' 56.1"	97° 56' 24.8"
33	MLK Dr.	Developed	29° 52' 46.0"	97° 56' 36.0"
34	Centre St.	Open	29° 52' 42.8"	97° 56' 37.5"
35	Hofheinz St.	Wooded	29° 52' 09.1"	97° 57' 55.9"
36	Patton St.	Open	29° 52' 17.6"	97° 56' 32.9"
37	I-35 Frontage Rd.	Open	29° 52' 13.8"	97° 56' 11.3"
38	Barbara Dr.	Open	29° 52' 19.5"	97° 55' 41.6"
39	Sessom and LBJ	Developed	29° 53' 31.0"	97° 56' 28.3"
40	Eastwood Ln.	Wooded	29° 54' 09.8"	97° 57' 36.2"

APPENDIX III

Number of great-tailed grackles observed at 40 observation points in San Marcos, TX.

Site #	Spring	Summer	Fall	Winter	Total per site
1	1	1	0	0	2
2	0	1	0	0	1
3	1	0	0	2	3
4	0	0	0	0	0
5	26	7	13	3	49
6	67	46	196	74	383
7	24	27	117	44	212
8	2	5	0	0	7
9	2	46	37	28	113
10	13	6	0	0	19
11	0	0	0	0	0
12	2	5	13	1	21
13	3	0	0	1	4
14	0	2	0	0	2
15	15	3	27	57	102
16	0	0	0	0	0
17	2	0	0	4	6

18	1	5	0	0	6
19	2	3	0	0	5
20	9	3	2	0	14
21	5	1	0	4	10
22	0	0	0	0	0
23	0	0	0	0	0
24	0	1	0	0	1
25	0	0	0	0	0
26	0	0	0	0	0
27	0	0	0	0	0
28	29	15	1	14	59
29	79	55	75	276	485
30	3	1	3	1	8
31	1	1	0	13	15
32	27	33	0	1	61
33	27	4	5	30	66
34	26	10	0	2	38
35	0	0	0	0	0
36	24	32	1	14	71
37	29	25	0	0	54
38	1	3	0	15	19
39	0	0	0	0	0
40	0	0	0	0	0
Total	421	341	490	584	1836

APPENDIX IV

Summary of vegetation data from 40 observation sites in San Marcos, TX including % canopy cover, mean distance to woody vegetation < 2 m height, mean distance to woody vegetation > 2 m height, and mean height of woody vegetation > 2 m height.

Site #	% Canopy Cover	Mean Dist. Veg. < 2m	Mean Dist. Veg. > 2m	Mean Height Veg.> 2m
1	0.75	27.8	12.4	12.4
2	0.01	26.7	15.5	14.8
3	0.00	31.3	22.2	6.9
4	0.00	24.2	12.6	9.8
5	0.00	17.0	50.0	0.0
6	0.09	13.3	27.9	6.6
7	0.00	50.0	20.5	5.6
8	0.50	28.6	12.0	13.0
9	0.06	50.0	10.9	4.5
10	0.00	18.8	25.8	7.1
11	0.90	24.0	14.0	13.6
12	0.00	25.8	20.6	10.1
13	0.08	10.8	12.7	9.6
14	0.90	6.8	5.9	11.1
15	1.00	18.9	10.9	15.9
16	0.00	17.3	14.4	7.4
17	0.04	14.8	11.5	15.0
18	0.72	19.7	8.0	13.4
19	0.95	11.8	5.2	9.4
20	0.00	5.8	14.5	6.6
21	0.13	11.3	10.0	11.0
22	0.40	14.0	13.0	16.0
23	0.15	13.5	7.5	11.7
24	0.23	13.7	8.6	16.6
25	0.00	14.0	7.7	5.0
26	0.42	17.8	6.3	7.5
27	0.00	6.5	10.3	6.6
28	0.42	20.0	15.9	8.9
29	0.05	35.8	17.7	6.5
30	0.88	24.4	10.8	16.8
31	1.00	8.7	11.3	14.0
32	0.30	1.7	15.4	21.2
33	0.50	9.7	12.6	8.0
34	0.37	24.6	12.7	10.3

35	0.25	8.7	7.7	10.8
36	0.76	50.0	19.2	14.4
37	0.04	21.9	6.1	7.1
38	0.64	10.5	17.3	17.3
39	0.06	10.7	21.6	12.3
40	0.00	12.8	12.5	7.8

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VITA

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