Technical Report Documentation Page

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| TX-96/1983-2 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| THE INTERACTIONS BETWEEN AVIAN PREDATORS AND GOLDEN-CHEEKED WARBLERS IN TRAVIS COUNTY, TEXAS | April 1996 |
| | 6. Performing Organization Code |
| 7. Author(s)<br>Keith A. Arnold, Cade L. Coldren, and Mark L. Fink | 8. Performing Organization Report No.<br>Research Report 1983-2 |
| 9. Performing Organization Name and Address<br>Texas Transportation Institute<br>The Texas A&M University System<br>College Station, Texas 77843-3135 | 10. Work Unit No. (TRAIS)<br><br>11. Contract or Grant No.<br>Study No. 7-1983 |
| 12. Sponsoring Agency Name and Address<br>Texas Department of Transportation<br>Research and Technology Transfer Office<br>P. O. Box 5080<br>Austin, Texas 78763-5080 | 13. Type of Report and Period Covered<br>Interim:<br>March 1993 - January 1996<br><br>14. Sponsoring Agency Code |

15. Supplementary Notes

Research performed in cooperation with Texas Department of Transportation
Research Study Title: The Interactions Between Avian Predators and Golden-cheeked Warblers in Travis County, Texas

16. Abstract

This report documents the results of a three-year study of Golden-cheeked Warblers (*Dendroica chrysoparia*) and their interactions with potential avian predators. We conducted avian censuses at 100 sites in Travis County, Texas, from mid-March through June of 1993, 1994, and 1995. Golden-cheeked Warblers were found at 63 of 100 sites which ranged in size from 6.5 to 731.5 ha. Twenty species of potential avian predators were found occurring in warbler habitat. No single species or group of species appears responsible for excluding warblers from apparently suitable habitat. In fact, sites which support warblers were more likely to be occupied by the eight most commonly occurring predator species than were sites without warblers. Warblers were not consistently found in habitat patches smaller than 23 ha, suggesting that habitat patch size has an important influence upon warbler presence.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| Golden-cheeked Warbler,<br>Predator Exclusion,<br>Nest Predation,<br>Human Development,<br>Behavioral Interactions | No restrictions. This document is available to the public through NTIS:<br>National Technical Information Service<br>5285 Port Royal Road<br>Springfield, Virginia 22161 |

| 19. Security Classif.(of this report) | 20. Security Classif.(of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 128 | |

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

# THE INTERACTIONS BETWEEN AVIAN PREDATORS AND GOLDEN-CHEEKED WARBLERS IN TRAVIS COUNTY, TEXAS

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Research Report 1983-2
Research Study Number 7-1983
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Sponsored by the
Texas Department of Transportation

January 1996

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
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## IMPLEMENTATION STATEMENT

This report documents the results of a three-year study of Golden-cheeked Warblers (*Dendroica chrysoparia*) and their interactions with potential avian predators. We conducted avian censuses at 100 sites in Travis County, Texas, from mid-March through June of 1993, 1994, and 1995. Golden-cheeked Warblers were found at 63 of 100 sites which ranged in size from 6.5 to 731.5 ha. Twenty species of potential avian predators were found occurring in warbler habitat. No single species or group of species appears responsible for excluding warblers from apparently suitable habitat. In fact, sites which support warblers were more likely to be occupied by the eight most commonly occurring predator species than were sites without warblers. Warblers were not consistently found in habitat patches smaller than 23 ha, suggesting that habitat patch size has an important influence upon warbler presence.

The results of this study indicate:

1) While Golden-cheeked Warblers do react to the presence of certain avian predators, the presence of predators does not exclude warblers from suitable habitat.
2) Measured vegetational characteristics do not seem to explain the absence of warblers from study sites.
3) Habitat patch size seems to have an important effect on both warbler presence and warbler reproductive success.
4) Agriculture is the most compatible land use adjacent to sites supporting warblers; however, warblers will occupy sites near commercial and residential development.

5) Predator species tend to be found in larger sites, regardless of adjacent land uses.
6) Warbler nests located near habitat edges may have a slightly greater risk of nest predation than nests located within habitat interiors.

# DISCLAIMER

## ACKNOWLEDGEMENTS

We thank Mr. Cal Newnam of the Texas Department of Transportation for his time and assistance on this project. We wish to thank the following landowners for graciously granting permission to use their properties in this study: The City of Austin, Balcones Canyonlands National Wildlife Refuge, Lower Colorado River Authority, Texas Nature Conservancy, Steiner Ranch, 3M Corporation, and the many private landowners too numerous to list here. This study would not have been possible without the contributions of numerous field and office assistants. In these regards, we thank Stevan Hawkins, Mary Coldren, Sharon King, Jeff Childs, Andrew Pesek, Mike Janis, Robert Tizzard, Dawn Goranowski, Mary Austin, Mitchell Lockwood, Carla Weinkauf, Wade Harris, Suzanne Mondoux, Tracy Hesp, Jason Phillips, Kimberly Chesler, Grant Benatar, Alix Dowling, Cynthia Wilson, Matt Hausler, Kenneth Floyd, Thornton Wood, Ron White, Paul Fushille, and Cathy Gibbons. This study was funded by the Texas Department of Transportation.

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## SUMMARY

This report documents the results of a three-year study of Golden-cheeked Warblers (*Dendroica chrysoparia*) and their interactions with potential avian predators. We conducted avian censuses at 100 sites in Travis County, Texas, from mid-March through June of 1993, 1994, and 1995. Golden-cheeked Warblers were found at 63 of 100 sites which ranged in size from 6.5 to 731.5 ha. Twenty species of potential avian predators were found occurring in warbler habitat, but no species or suite of species appears responsible for excluding warblers from apparently suitable habitat. All predator species more likely occupied sites that also supported warblers. Measured differences in vegetation cannot explain warbler absence from potential habitat. We observed behavioral interactions between warblers and many of their avian predators. Warblers responded most strongly to *Accipiter* hawks, but they also responded to several species which are unlikely to pose a threat. Additionally, some species' calls appear to elicit a response, indicating that warblers recognize those species as possible threats. Water does not appear to be a limiting factor for warblers or to influence the warbler's ability to produce young. Patch size appears to be important in determining the presence of warblers, with 23 ha representing a possible threshold size for occupation of a site and consistent production of young. Agriculture appears to be the most compatible land use near warbler sites, but all land uses may be suitable if patch size is sufficiently large. In summary, predation does not appear to be a major process affecting the presence of warblers or the relationship between nearby land uses and patch size.

# 1. INTRODUCTION

The Golden-cheeked Warbler[1] breeds in central Texas with a range that coincides with that of Ashe Juniper (Pulich 1976). In 1990, the warbler was listed as endangered under the Endangered Species Act. Its declines have been attributed to habitat destruction, loss of suitable habitat due to habitat fragmentation, and nest failure (USFWS 1990). Loss of habitat and fragmentation of the remaining habitat results from clearing for urban development and range management. The primary causes of nest failure are brood parasitism by the Brown-headed Cowbird and nest predation (Pulich 1976). Additionally, fragmentation may contribute to levels of brood parasitism and nest predation (Yahner and Scott 1988), although this has not been documented for the Golden-cheeked Warbler.

A variety of avian predators occur within the range of the Golden-cheeked Warbler, many of which have been known to prey on birds. Birds make up a large percentage of the diets of the Sharp-shinned Hawk, Cooper's Hawk, and Red-shouldered Hawk (Sherrod 1978). Additionally, several other diurnal raptor species prey on small songbirds to some extent, including Red-tailed Hawk and American Kestrel (Sherrod 1978). Great Horned Owls and Barred Owls will depredate small songbirds, including other species of warbler (Bent 1961). Eastern Screech-Owls are known to prey upon other warbler species, with the greatest rates of predation coinciding with the peak of Golden-cheeked Warbler nesting (Witmer 1982).

Small songbirds, including several other species of warblers, have been preyed upon by Blue Jays (Johnson and

[1] See Appendix C for scientific names.

Johnson 1976, Graber et al. 1987), Florida Scrub-Jays (Curry 1990), American Crows (Putnam 1992), Common Grackles (Davidson1994), and Greater Roadrunners (Bent 1989). Additionally, concern has been expressed regarding the possible effects of predation by Great-tailed Grackles (USFWS 1992). However, all evidence of predation by jays, crows, grackles, and roadrunners is anecdotal.

Other interactions between predator and prey may have more subtle effects on prey populations, making them more difficult to determine than actual rates of predation. Antipredator behavior, mobbing, and defense have costs which may impact prey fitness (Endler 1991). Possible results of these effects include lowered reproductive success and predator exclusion of the prey species from potentially suitable habitat. Since several of the predators within the Golden-cheeked Warbler range are more closely tied to habitat types other than the juniper woodlands used by the warbler for nesting (Oberholser 1974), the nature of the land use matrix around warbler habitat may affect the impact these predators have on the warbler. No study on the Golden-cheeked Warbler has examined the effects of a variety of potential predators, either on predation rates or on warbler-predator interactions.

This study investigated the interactions between avian predators and Golden-cheeked Warblers in Travis County. The objectives were: 1) to determine the presence of Golden-cheeked Warblers or avian predators in designated warbler habitat patches; 2) to study interactions at sites where warblers and predators were sympatric; 3) to determine the distance of Golden-cheeked Warbler territories and avian predator occurrences to agricultural, residential, commercial, or industrial development; 4) to determine the distance of Golden-cheeked Warbler territories and avian predator occurrences to water; and 5) to determine the relationship between the presence/absence of Golden-cheeked Warblers and the presence/absence of avian predators in varying size blocks of habitat to development within 100, 500, 1000, and 2000 m of the site. A supplemental objective was to determine relative rates of predation and brood parasitism on artificial nests placed in forest interior and edge areas of Golden-cheeked Warbler sites.

## 2. METHODS

From 1993 through 1995, we surveyed 100 study sites, 99 in Travis County and one in Williamson County, for the presence of Golden-cheeked Warblers and all avian predators. We selected study sites as follows. We generated random latitude-longitude coordinates and overlaid them on a map showing all potential warbler habitat in western Travis County. Each potential study site was chosen as the habitat block nearest to each latitude-longitude coordinate. We based site boundaries on recent aerial photographs. We then attempted to gain landowner permission to survey each site. Some sites were composed of multiple parcels with different owners. In several cases, we were not able to gain access to the complete habitat block and surveyed only those blocks where we had access to an area greater than 5 ha to allow the inclusion of at least one warbler territory.

We conducted a minimum of three censuses in each site for warblers and avian predators. All censuses were conducted in good weather and between the following dates to meet U.S. Fish and Wildlife Service guidelines for warbler censuses: 16 March to 31 May 1993, 20 March to 12 May 1994, and 20 March to 10 May 1995. We used tapes of warbler song to verify the absence of warblers. We attempted to cover each site as completely as possible, with exact routes for each site based on the particular natural and man-made features of each site.

We spot-mapped all individual warblers and avian predators using standard mapping techniques (International Bird Census Committee 1970) and registered their locations using Trimble Pathfinder Basic Global Positioning System (GPS) units. This reduced our dependence on physical markers which may have attracted predators and affected our location data.

We monitored warbler reproductive success by surveying for fledglings at the 63 study sites with warblers. Fledgling young are most easily found by listening for the rapid "chipping" given by the young when begging or by the adults while feeding the young (Pulich 1976). The locations of all young were registered via GPS. We did not attempt to locate warbler nests due to concern over the possibility of increased risks from nest predation and parasitism.

We observed all warblers as long as possible without knowingly disrupting their natural behaviors. During the course of these observations, we noted all instances of interactions with avian predators. We then assigned each interaction to one of the following categories: 1) predation on adult warbler, 2) predation on fledgling warbler, 3) attack by avian predator on adult warbler, 4) attack by avian predator on fledgling warbler, 5) movement by predator toward warbler with aggressive response by warbler, 6) movement by predator toward warbler with avoidance response by warbler, 7) presence of predator with aggressive response by warbler, 8) presence of predator with avoidance response by warbler, and 9) presence of predator with no response by warbler. Observation data included predator species, the number, age, and sex of warblers, time, date, location within the site, and the sequence of events.

During the course of the surveys, we noted the presence of water on each site. We attempted to locate the nearest source of water for all sites in which we were unable to find water within the site boundaries. Additionally, we mapped land uses within 2000 m of each site and assigned to one of four categories. Agricultural areas included those under cultivation and those currently being used for grazing cattle, sheep, or goats. Commercial areas included businesses, churches, parks, and golf courses. Quarries, electrical substations, highway construction, and water treatment plants were considered industrial uses. Residential areas ranged from isolated homesteads off paved roads to subdivisions and multiple-family housing. In some cases, we could not reliably determine the land uses due to lack of access; therefore, we did not include these areas in the analyses.

To determine if the absence of warblers correlated to differences in vegetative characteristics, we conducted vegetation analysis at each site. We conducted these analyses in July of each year, after the end of the warbler breeding season. Vegetative measurements were taken at the geometric center of non-warbler sites and at the location of the first visually recorded warbler for all other sites. We included only trees greater than 1 m tall and with a diameter greater than 3 cm, measured 10 cm above ground (Ladd 1985). We measured the diameter and height of all trees found in a 2 m wide by 50 m long area in each of the cardinal directions from the sample point. We measured canopy cover at 10 m intervals in each of the cardinal directions using a spherical densiometer (Lemmon 1956) and then averaged those measurements to obtain a mean canopy cover for each site. We measured slope with a compass/clinometer at 10 m intervals and averaged those measurements to obtain a mean slope for each site.

We placed artificial nests in April 1994 and 1995, coinciding with the beginning of the nest-building and egg-laying period of the warbler (Pulich 1976). We selected five sites where breeding warblers were present and which were sufficient in size to contain all artificial nests. At each of the five sites, we placed artificial nests along five pairs of transects that were spaced randomly along the length of the site. One transect from each pair ran parallel to the edge at a distance of 10 m; the second transect of the pair lay parallel to the first at a distance of 100 m from the edge. Each transect was 100 m in length, and four nests were placed at intervals of roughly 30 m.

Artificial nests were of the commercially available straw variety with a diameter of 10 cm and a depth of 5 cm. We placed two Japanese Quail eggs in each nest. Although Pulich (1976) reports that the Golden-cheeked Warbler generally lays a clutch of three or four eggs, we placed only two quail eggs per nest in order to compensate for their larger size. To reduce human scent, nests were left outdoors for a period of one month prior to the start of the trials. We place all artificial nests Ashe juniper, in close proximity to the trunk, and at about 4.5 m from the ground, thereby approximating placement of nests by the warbler (Pulich 1976). We used light-gauge wire to secure nests in the trees in order to prevent their spilling due to inclement weather. We inspected nests for evidence of predation or parasitism on the third and sixth days after placement and one final time on the eighth day. By performing a second eight-day trial immediately following the first, using new nests and nest trees, the average egg-laying and incubation period of the warbler, 12 to 14 days (Pulich 1976), was approximated. In all cases, a nest was considered preyed upon if either of the eggs was missing, damaged, or destroyed.

All GPS locations of warblers and predators were input into Arc/Info, a Geographic Information System (GIS) software package at the Texas A&M University Center for Computing Sciences. We generated separate covers for warblers and for avian predators. We mapped site boundaries, water, and land uses on U.S.G.S. 7.5 minute topographic quadrangle maps (scale 1:24000) based on field observations and recent aerial photographs. These maps were digitized at the Texas A&M University Center for Mapping Sciences and entered into the GIS. In the GIS, four buffer covers were built around the land use areas for each of the four land use categories, producing a total of 16 buffer covers. The buffers corresponded to the following distance classes outward from the mapped land uses: within 100 m, 100 m to 500 m, 500 m to 1000 m, and 1000 m to 2000 m. Each of the buffer covers was then overlaid onto the warbler and predator covers to determine the number of individuals found within each distance class for each land use category. We used the GIS site boundary cover to calculate patch size.

## 3. STATISTICAL ANALYSES

Because each study site was chosen as a separate habitat patch, all 100 sites are considered statistically independent. Most variables were non-normally distributed; therefore, we used non-parametric tests in all cases. All statistical analyses were performed on Statistical Analysis Software (SAS) located in the Department of Wildlife and Fisheries Sciences, Texas A&M University. Alpha levels for all tests were set at 0.05.

We used the vegetative measurements to determine the following parameters for each site: slope, canopy cover, density of understory junipers, density of canopy junipers, density of understory hardwoods, density of canopy hardwoods, basal area of understory junipers, basal area of canopy junipers, basal area of understory hardwoods, basal area of canopy hardwoods, average height of understory junipers, average height of canopy junipers, average height of understory hardwoods, and average height of canopy hardwoods. We defined understory trees as those shorter than 4.5 m. All variables were input into a principal components analysis with the mapped symbol representing the presence or absence of warblers.

Contingency tables (2x2) of the number of sites in which warblers and predators co-occurred were constructed and analyzed using chi-square goodness-of-fit tests. We compared predator abundances at warbler and at non-warbler sites using Wilcoxon ranked sum tests.

Many of the behavioral interaction codes were rarely observed. Therefore, we lumped all interaction codes involving a warbler response (Codes 5 through 8) into a "response" category for comparison with Code 9 ("no warbler response"). We compared Warbler responses to each predator species with chi-square goodness-of-fit tests. We conducted separate analyses on the age of the responding warblers and on the stage of breeding. We grouped interactions based on the age of the responding bird to see if adults responded differently when in the presence of young. Age categories used were "adult," which consisted of solitary adults and groups of adults which ranged in number up to three males and one female, and "hatch-year," which consisted of adults with young and young that seemed independent. We used chi-square goodness-of-fit tests to compare the responses based on these age categories. For the stage of breeding, we divided the reproductive cycle into the following three periods. Settlement was the period when males returned and set up territories and attempted to attract a mate (early March to 31 March); nesting was the time of nest building, egg laying, incubation, care of nestlings (from 1 April to 15 May); and the fledgling period was the time when most young had fledged and family groups were foraging together (from 16 May to 1 July). These dates are based on the different stages of breeding as outlined in Pulich (1976). We made comparisons of warbler responses during the stages of breeding with chi-square goodness-of-fit tests.

We used chi-square goodness-of-fit tests to compare the numbers of individuals of each species in each of the distance classes relative to the four land uses. We performed three analyses on the warbler data. First, we considered the total number of warbler territories to look for land use effects on territory location. Next, we looked at the number of hatch-year warblers to see if the land uses affected the total production of young. Last, we examined the number of territories in which we found young to see if the land uses affected which territories produced young, regardless of the number of young produced in those territories. Since the sizes of each of the distance class buffers differed, we corrected the chi-square expected values based on those different areas. We calculated four area-ratios for each land use. The first ratio was based on the area contained within the 100 m buffer relative to the area of the mapped land use. The second ratio was based on the area of the 500 m buffer relative to the area of the 100 m buffer. The third and fourth ratios were based on the 1000 m and 2000 m buffers relative to the 500 m and 1000 m buffers, respectively. We then calculated the expected values from the four area-ratios so that the total expected number equaled the actual number determined from the GIS overlays.

To determine the distance from bird sightings to the nearest water source, we overlaid the warbler and predator covers onto the water cover. We then used the GIS to determine the distance to the nearest water source. We compared the distance to water for warbler territories with young with the distance to water for warbler territories in which we did not find young with the Wilcoxon ranked sum test. We compared the distances to water for each predator species using the Kruskal-Wallis multiple comparison test.

We used simple linear regression to investigate the relationship between species presence/absence, distance to land use, and patch size. We performed eight regressions for each species: one for species presence and one for species absence for each of the four land uses. The dependent variable was distance to land use, while the independent variable was patch size.

We investigated the relationship between species presence/absence, distance to land use, and patch size using the previously described distance class buffers. Using the Wilcoxon ranked sum test, we compared patch size for sites with each species to patch size for sites without each species. A separate test was run for each distance class with each land use, resulting in 16 tests per species.

# 4. RESULTS

## OBJECTIVE 1

In 1993, we surveyed 25 study sites and found Golden-cheeked Warblers in 11 of those sites. We carried eight of those warbler sites over into 1994 and added 39 new ones, 29 of which supported warblers. In 1995, 36 new sites were added, of which 23 supported warblers. We carried over 11 sites from the two previous years and found warblers on 10 of them. Thus, of the 100 study sites surveyed, 63 supported warblers.

Table 1 (Page 33) lists all avian predator species encountered and the number of sites in which they occurred. Due to insufficient sample sizes for many of these species, further analyses will primarily be restricted to the following: American Crow, Blue Jay, Common Grackle, Greater Roadrunner, Great-tailed Grackle, Red-tailed Hawk, and Western Scrub-Jay. In addition to these predator species, the Brown-headed Cowbird, a known brood parasite of the warbler, was included in all analyses. Other predator species do not appear to pose a major threat to the warbler due to their low densities.

Contingency tables of warbler and predator co-occurrences are listed in Table 2 (Page 34). Only three species show significant trends. The Brown-headed Cowbird, Greater Roadrunner, and Red-tailed Hawk are more likely to occur in sites with warblers than without warblers. Due to the small number of sites without Western Scrub-Jays, the significance level shown for the Western Scrub-Jay may not be valid; however, the trend for Western Scrub-Jays is similar to the three previously mentioned species.

Table 3 (Page 35) shows the abundances of the various predator species in sites without warblers compared to those sites with warblers. Only one species, the Great-tailed Grackle, showed a significantly higher number of individuals in non-warbler sites than in sites with warblers. All other species showing a significant difference were more common in sites with warblers than in sites without warblers.

**OBJECTIVE 2**

We observed no instances of predation or direct attacks on a Golden-cheeked Warbler. Most of the responses consisted of one or more warblers, including males, females, and young, exhibiting an avoidance response to the presence of a potential predator. Commonly, this involved cessation of vocalizing. On several occasions, warblers actively sought perches in dense vegetation, became still, or flew out of sight under the canopy. A cessation of vocalizing usually accompanied these responses. Generally the warbler vocal activity would resume within three minutes. On several occasions, other species of passerine in the vicinity, including Bewick's Wren, Northern Cardinal, Tufted Titmouse, Carolina Chickadee, and Black-and-white Warbler would respond in similar fashion to the presence of a potential predator.

Table 4 (Page 36) shows the breakdown by species and interaction code for all behavioral interactions observed between warblers and avian predators. Sufficiently large totals for statistical inferences were available for only four species. Interaction code 9 (no response to predator presence) was more common than all other interaction codes in relation to Blue Jays ($X^2$=3.903, df=1, P<0.05), Red-tailed Hawks ($X^2$=4.500, df=1, P<0.05), and Western Scrub-Jays

($X^2$=39.063, df=1, P<0.0001). No difference was seen in responses to Greater Roadrunner ($X^2$=0.333, df=1, P>0.1). For species with small sample sizes, several trends are apparent. Warblers responded strongly to the presence of *Accipiter* hawks. The one case of "no response" to the presence of a Cooper's Hawk may have occurred when the warbler was unaware of the hawk's presence. We observed an avoidance response in all interactions with owls. The presence of several other species elicited an avoidance response by warblers although those species are not normally considered a threat: Osprey, Swainson's Hawk, and Turkey Vulture.

A look at the age of the responding birds (Table 5 [Page 37]) showed that adult warblers were as likely to respond to predators as were family groups and individual hatch-year warblers ($X^2$=0.068, df=1, P=0.794). Additionally, the degree of response did not differ during the different stages of the reproductive cycle ($X^2$=1.426, df=2, P=0.490).

**OBJECTIVE 3**

Table 6 (Page 38) shows the number of individuals of each species in each of the distance classes relative to the four land use categories. The total number of warbler young and number of warbler territories producing young show similar trends when compared to the total number of warbler territories. Thus, our ability to find young warblers does not appear to be biased by the nature of the surrounding land uses or the location of a territory within a site. Warblers tended to occur closer to agricultural development and away from industrial, commercial, and residential developments.

Most predator species showed higher numbers than expected by chance in the 100 m distance class, regardless of land use.

Many also showed higher numbers than expected by chance in the 500 m distance class. The exception was the Red-tailed Hawk. It was more likely to occur closer to agriculture and away from the other land uses, in a pattern similar to that of the warbler. The strongest relationship of any species to a land use category occurred with Blue Jays and residential areas. We found few Blue Jays greater than 500 m away from residential areas.

Chi-square values for residential land use may be inflated somewhat by the numbers of birds found in the 2000 m distance class. Fewer individuals occurred in the 2000 m distance class than in the 1000 m class, increasing that cell's contribution to the overall chi-square total and increasing the likelihood of a p-value less than 0.05. An explanation may lie in the spatial distribution of residential areas in Travis County. Residential areas, large and small, are distributed throughout the county. Few sites lie greater than 1000 m from the nearest residential area, resulting in fewer individuals than expected being found in the 2000 m distance class. Thus, the 2000 m distance class may represent an artificial category and possibly be excluded from future analyses.

**OBJECTIVE 4**

The determination of the distance of each species to water did not include all 100 study sites. Due to limited access from landowners, we could not determine the water source nearest to several of our sites, particularly for sites that did not have a water source within their boundaries. Therefore, we did not include the bird locations within these sites in the analyses. Distances for all species are listed in Table 7 (Page 43). Distances from Golden-cheeked Warbler territories in which we found young did not differ significantly from those territories in which we did not find young (Wilcoxon ranked sum test, z=0.2018, P=0.8401). Therefore, water availability appears to have little influence on a warbler's ability to produce young. Also shown in Table 7 are the average distances from each predator species location to water. For comparison, we considered only the eight species previously mentioned. The distances from water to Great-tailed Grackle and Blue Jay sightings were significantly smaller than the distances from water to all other predators and to warbler territories (Kruskal-Wallis multiple comparison, P=0.0001).

**OBJECTIVE 5**

Site sizes ranged from 6.56 ha to over 730 ha (Table 8 [Page 44]). The smallest site that supported Golden-cheeked Warblers was 10.12 ha. Of the 25 smallest sites, warblers occurred in only seven, and their presence in these sites was sporadic. We regularly found warblers in only one of these seven sites, with an area of 19 ha. The smallest site in which we found warbler young was 23.43 ha. We consistently found young in sites larger than this. At sites without warblers, we spent more time per unit area than in sites that supported warblers, although this difference was not significant (Wilcoxon ranked sum test, z=0.969, P=0.3327). For only those sites which supported warblers, regression analysis of time per unit area vs. patch size rules out the possibility of sampling effort biasing our results on the consistency of finding warblers. In fact, we spent significantly more time per unit area in the smaller sites than the larger ones (P<0.0001).

The simple linear regression plots of distance to human development vs. patch size are shown in Figures 1 through 36 (Pages 59-94). The regression lines (of the form "y=a+bx") are shown for all species. We placed the distances to human development on a logarithmic scale in order to more easily show the distribution of points; however, the regression lines appear curvilinear as a result. Only four species show a significant relationship between distance to human development and patch size. For patch size and the distance to agriculture, Great-tailed Grackle shows a negative relationship (P=0.034). The absence of Brown-headed Cowbird and Red-tailed Hawk shows a positive relationship between patch size and distance to agriculture (P=0.040 and P=0.021, respectively). The absence of Western Scrub-Jay shows a positive relationship between patch size and distance to residential areas (P=0.001). The regression plots do not allow tests of the relationship between presence/absence, distance to human development, and patch size for each species.

Table 9 (Page 47) shows the relationship of presence/absence of a species, patch size, and distance to human development. For all statistically significant cases, sites in which we found the species of interest were consistently larger than the sites where we did not find the species of interest. The land use categories and distance classes which showed the most consistent effects on species presence and site size were residential and 100 m (affecting Golden-cheeked Warbler, Brown-headed Cowbird, Western Scrub-Jay, Red-tailed Hawk, and Greater Roadrunner), followed by commercial and 100 m (affecting the warbler, Brown-headed Cowbird, and Western Scrub-Jay) and commercial and 500 m (affecting Red-tailed Hawk and Great-tailed Grackle).

Patch size relative to landuse and distance appeared most important for Greater Roadrunner with six out of 16 cases showing a significant difference in patch size, followed by Golden-cheeked Warbler with five cases, Red-tailed Hawk with four cases, Brown-headed Cowbird and Western Scrub-Jay with two each, and Great-tailed Grackle with only one instance. Three species (American Crow, Blue Jay, and Common Grackle) showed no relationship between patch size, distance, land use, and species presence.

**SUPPLEMENTAL OBJECTIVE**

The artificial nest study yielded 50 interior transects and 50 edge transects per year, for a total of 200 transects and 794 nests over the two years of the study. Due to the difficulty in obtaining suitable new study sites for 1995, we replicated the procedure from 1994, thereby doubling our sample size. Table 10 (Page 54) summarizes the extent of nest depredation over all four trials. Over 63% (508/794) of artificial nests were depredated through the course of the study. We noted no instances of nest parasitism by the Brown-headed Cowbird. Results from 1994 differed significantly from 1995 results (Chi-square test, $X^2$=10.27, P<0.001). Trials 1 and 2 also differed significantly for both years (1994: $X^2$=5.97, P<0.01; 1995: $X^2$=7.45, P<0.006). Figure 37 (Page 95) shows predation levels for all five sites by trial. Only trial 1 of 1994 showed a significant difference in predation rates between edge and interior ($X^2$=3.87, P<0.049), and then for only one site (Shellberg Site: $X^2$= 6.1, P<0.01). Three of the four trials showed no significant increase in edge predation over interior predation.

# 5. DISCUSSION

## PREDATOR EXCLUSION

A variety of avian predators occur in Golden-cheeked Warbler habitat, but none appear to exclude warblers from sites with suitable habitat. Of the eight avian predator species with sufficient sample sizes for analysis, all were more likely to occur at sites with warblers than at sites without warblers. The same is true for species with small sample sizes (Tables 1 and 2). Additionally, with the exception of Great-tailed Grackle, abundances of predator species were higher at sites with warblers than at sites without warblers. Thus, it appears that no species excluded warblers from our study sites.

Some predator species, such as Cooper's Hawk and Sharp-shinned Hawk, may prey on the warbler. However, they probably do not pose a serious threat due to their low density and patchy distribution. Other prey species found in warbler habitat, such as Mourning Dove and Northern Cardinal, may be energetically more beneficial as prey because of their larger body size and lower maneuverability, thus relative ease of capture, compared to the warbler.

Vegetational characteristics measured in this study (Figures 38 and 39 [Pages 96 and 97] and Appendix C [Page 99]) do not seem to explain the absence of warblers from some of our study sites. Principal component analysis results show a great deal of overlap in all vegetative characteristics between occupied sites and unoccupied sites.

In contrast to Engels and Sexton (1994), we did not find a negative correlation between Blue Jays and warbler presence. Although not statistically significant, we found a positive relationship. When Blue Jays were present, a majority of our sites also supported warblers. Anecdotal evidence obtained during the course of this study may provide a clue. On several occasions, we encountered a vocalizing Blue Jay within a known warbler territory, while not simultaneously finding the warbler. However, at later times, often that same day, we would find a warbler in the very same area where we had earlier found the Blue Jay. Thus, the warbler may become silent when Blue Jays are present and vocalizing, making the warbler more difficult to locate. Further analysis may reveal whether this lowered vocal activity influenced warbler reproductive success.

## PREDATION ON ARTIFICIAL NESTS

Although levels of nest predation were generally higher along edges than within interiors, this difference was significant in 1994 at only one study site and at no site in 1995. Thus, the rate of predation on nests near the edge does not seem to differ from the rate of predation on nests in the interior. It is possible that nests located farther than 100 m from an edge have a lower rate of predation because fewer predators may infiltrate habitat interiors (Wilcove 1985). However, habitat patches of this size are not common in Travis County. As is evident from Figure 37 (Page 95), the greatest variation in the extent of predation occurs between study sites. Learning by predators in the area likely attributed to the increase in predation levels exhibited between trials for both years.

## BEHAVIORAL INTERACTIONS

The degree of response shown by warblers to predator presence did not differ over the course of the breeding season or with the presence of fledged young. Thus, warbler perception of threat by predation appears to be uniform throughout the breeding season. Spatially within a territory, this may not be so. Since we did not search for nests during this study, we could not determine if warblers become more responsive to the threat of predation with decreasing distance from a nest.

The responses to some species of predators indicate that warblers seem to respond to shape and movement of potential predators and not necessarily to specific species. One illustration of this is our one observed response to Turkey Vultures. Three vultures were flying rapidly along a ridge, just above the tree tops, when they passed over a male warbler singing near the top of a live oak. As they passed overhead, the male flew downslope below the canopy and out of sight. Several minutes later he returned to the same perch and resumed singing. An hour later, we observed this male still singing in the same tree.

Conversely, warblers seem to recognize the calls of certain avian predators. During many of the interactions involving an avoidance response, the location of the predator was not known to the observer. It is not known whether the warbler was aware of the predator before it vocalized. However, all responses occurred at the onset of calling, indicating the warbler probably did not know of the predator's presence beforehand. Although warblers responded to the calls of many of the predator species, the strength of response was most noticeable with regard to Eastern Screech-Owl, Red-shouldered Hawk, and Cooper's Hawk.

## PATCH SIZE AND LAND USES

Size of habitat patch does seem to have an influence on warbler presence. Warblers did not occur in patches smaller than 10 ha and not reliably in patches smaller than 23 ha. In patches larger than 23 ha, not only were warblers reliably found, but the warblers consistently produced young. Thus, patch size of about 23 ha seems to represent a threshold size for warbler occupation and consistent production of young. These results are not biased by differences in sampling effort between large and small sites.

The relationship of patch size, presence/absence, and distance from various land uses is not as straightforward. Warblers occur in larger sites, regardless of nearby land uses. The patch size of occupied sites is highest nearest residential and commercial developments and lower for industrial and agricultural uses. Warbler numbers are higher near agriculture and lower near the other three land use categories. This may be due to the tendency of warbler family groups to wander (Pulich 1976). Our observations show they will move out of the closed canopy forest used for nesting and forage, at least to some extent, in the forest edge. Agriculture may result in more edge availability for foraging compared to comparably sized patches near residential and commercial areas. The impact of industrial areas on warblers does not appear as severe as commercial or residential because the industrial areas may not be disturbed as intensively as commercial or residential areas. Industrial areas were commonly electrical substations, quarries, or water treatment plants, and all were likely to have buffer zones around them which may have provided the edge needed for foraging. Thus, it appears that agriculture is the most compatible land use adjacent to sites supporting warblers. However, warblers will occupy sites near commercial and residential areas if those sites are of sufficient size.

Predators tend to occur in larger sites than in smaller ones, regardless of land use. They also occur in greater abundances within 100 m of all land uses. Most of the more common predator species encountered tend to associate with edges, open areas, or human development (Oberholser 1974). Therefore, it is not surprising that they occur more often than expected closer to those areas. This is particularly true for American Crow, Blue Jay, Common Grackle, and Great-tailed Grackle. For the Brown-headed Cowbird, time of day of our surveys may have influenced our results. Females tend to search for and lay their eggs in host nests at dawn (Neudorf and Sealy 1994) and then move to open areas for foraging (Lowther 1993). None of our surveys were conducted at dawn. In our experience, we find warblers more easily by their vocal activity later in the morning. Thus, we probably missed some female cowbirds searching for nests deep in patches. This possibility is further supported by the high numbers of cowbirds observed near agricultural areas. The Red-tailed Hawk is the species least likely to nest and forage in areas of intensive human activities. Although it may occur in developed areas, an open area is usually nearby for foraging (Palmer 1988). As a result, Red-tailed Hawks were more abundant near agricultural areas and less abundant than expected near commercial, industrial, or residential areas.

In summary, a variety of avian predators occur in warbler habitat, but no species or suite of species appears responsible for excluding warblers from apparently suitable habitat. All predator species more likely occupied sites that also supported warblers. Measured differences in vegetation cannot explain warbler absence from potential habitat. We observed behavioral interactions between warblers and many of those avian predators. Warblers responded most strongly to *Accipiter* hawks, but they also responded to several species which are unlikely to pose a threat. Additionally, some species' calls appear to elicit a response, indicating that warblers recognize those species as possible threats. Water does not appear to be a limiting factor for warblers or to influence the warbler's ability to produce young. Patch size appears to be important in determining the presence of warblers, with 23 ha representing a possible threshold size for occupation of a site and consistent production of young. Agriculture appears to be the most compatible land use near warbler sites, but all land uses may be suitable if patch size is sufficiently large. In summary, predation does not appear to be a major process affecting the presence of warblers or the relationship between nearby land uses and patch size.

## LITERATURE CITED


Bent, A.C. 1961. Life histories of North American birds of prey, Vol. 2. Dover Publications, New York, NY.

Bent, A.C. 1989. Life histories of North American cuckoos, goatsuckers, hummingbirds, and their allies. Dover Publications, New York, NY.

Curry, R.L. 1990. Florida Scrub Jay kills a mockingbird. Condor 92:256-257.

Davidson, A.H. 1994. Common Grackle predation on adult passerine. Wilson Bulletin 106:174-175.

Endler, J.A. 1991. Interaction between predators and prey. Pp. 169-196 in Behavioural Ecology, an Evolutionary Approach, 3rd ed. (J.R. Krebs and N.B. Davies, eds.). Blackwell Scientific Publications, Oxford, UK.

Engels, T.M., and C.W. Sexton. 1994. Negative correlation of Blue Jays and Golden-cheeked Warblers near an urbanizing area. Conservation Biology 8:286-290.

Graber, J.W., R.R. Graber, and E.L. Kirk. 1987. Illinois birds: Corvidae. Ill. Natural History Survey Biological Notes 126:2-42.

International Bird Census Committee. 1970. Recommendations for an international standard for a mapping method in bird census work. Audubon Field Notes 24:723-726.

Johnson, K.W., and J.E. Johnson. 1976. An incident of Blue Jay predation on a Yellow-rumped Warbler. Wilson Bulletin 80:509.

Ladd, C.G. 1985. Nesting habitat requirements of the Golden-cheeked Warbler. M.S. thesis, Southwest Texas State University, San Marcos, TX.

Lemmon, P.E. 1956. A spherical densiometer for estimating forest overstory density. Forestry Science 2:314-320.

Lowther, P.E. 1993. Brown-headed Cowbird (*Molothrus ater*). *In* The Birds of North America, No. 47. (A. Poole and F. Gill, eds.). Academy of Natural Sciences, Philadelphia, PA.

Neudorf, D.L., and S.G. Sealy. 1994. Sunrise nest attentiveness in cowbird hosts. Condor 96:162-169.

Oberholser, H.C. 1974. The bird life of Texas. University of Texas Press, Austin, TX.

Palmer, R.S., ed. 1988. Handbook of North American Birds, Vol. 5. Yale University Press, New Haven, CT.

Pulich, W.M. 1976. The Golden-cheeked Warbler: A bioecological study. Texas Parks and Wildlife Department, Austin, TX.

Putnam, M.S. 1992. American Crow captures House Sparrow in flight. Passenger Pigeon 54:247-249.

Sherrod, S.K. 1978. Diets of North American Falconiformes. Journal of Raptor Research 12:49-121.

U.S. Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants: proposed rule to list the Golden-cheeked Warbler as endangered. Federal Register/Vol. 55, No. 87/ Friday, May 4, 1990/Proposed Rules.

U.S. Fish and Wildlife Service. 1992. Golden-cheeked Warbler (*Dendroica chrysoparia*) recovery plan. Albuquerque, NM.

Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66:1211-1214.

Witmer, M.C. 1982. Sexual size dimorphism in relation to breeding behavior in Screech Owls. M.S. thesis, Texas A&M University, College Station, TX.

Yahner, R.H., and D.P. Scott. 1988. Effects of forest fragmentation on depredation of artificial nests. Journal of Wildlife Management 52:158-161.

# APPENDIX A
# TABLES

Table 1. Occurrence of predator and brood parasite species by year. Values are number of sites (% of total sites).

| Species | 1993 | 1994 | 1995 | Total Number of Sites | Number of Sites With Golden-cheeked Warblers |
|---|---|---|---|---|---|
| American Crow | 7 (28) | 8 (17) | 9 (19) | 24 | 15 (62) |
| American Kestrel | 1 (4) | 2 (4) | 3 (6) | 6 | 6 (100) |
| Barred Owl | . | 1 (2) | 1 (2) | 2 | 1 (50) |
| Bronzed Cowbird | . | 1 (2) | . | 1 | 1 (100) |
| Brown-headed Cowbird | 12 (48) | 25 (53) | 29 (62) | 60 | 49 (82) |
| Blue Jay | 16 (64) | 27 (57) | 35 (74) | 70 | 41 (59) |
| Broad-winged Hawk | 2 (8) | 3 (6) | 3 (6) | 8 | 6 (75) |
| Common Grackle | 14 (56) | 23 (49) | 23 (49) | 51 | 36 (71) |
| Common Raven | 1 (4) | 1 (2) | 2 (4) | 4 | 4 (100) |
| Cooper's Hawk | 4 (16) | 9 (19) | 4 (9) | 16 | 14 (87) |
| Eastern Screech-Owl | 1 (4) | 4 (9) | 4 (9) | 9 | 9 (100) |
| Ferruginous Hawk | 1 (4) | . | . | 1 | 1 (100) |
| Great Horned Owl | . | 1 (2) | 4 (9) | 4 | 4 (100) |
| Greater Roadrunner | 7 (28) | 27 (57) | 28 (60) | 52 | 43 (83) |
| Great-tailed Grackle | 6 (24) | 10 (21) | 17 (36) | 32 | 17 (53) |
| Mississippi Kite | 3 (12) | 2 (4) | . | 5 | 4 (80) |
| Osprey | . | 2 (4) | 1 (2) | 3 | 3 (100) |
| Prairie Falcon | . | 1 (2) | . | 1 | 1 (100) |
| Red-shouldered Hawk | 4 (16) | 5 (11) | 10 (21) | 15 | 14 (93) |
| Red-tailed Hawk | 13 (52) | 24 (51) | 22 (47) | 44 | 41 (93) |
| Sharp-shinned Hawk | 1 (4) | 3 (6) | 3 (6) | 7 | 7 (100) |
| Swainson's Hawk | 2 (8) | 3 (6) | 4 (9) | 9 | 8 (89) |
| Western Scrub-Jay | 21 (84) | 44 (94) | 43 (91) | 90 | 63 (70) |

Table 2. Co-occurrence of avian predators and Golden-cheeked Warblers (GCWA). P-values are based on Chi-square tests of 2x2 contingency tables with one degree of freedom.

| Predator Species | Number of Sites Without Predator Species | | Number of Sites With Predator Species | | P-values |
|---|---|---|---|---|---|
| | Without GCWA | With GCWA | Without GCWA | With GCWA | |
| American Crow | 28 | 48 | 9 | 15 | 0.954 |
| Blue Jay | 8 | 22 | 29 | 41 | 0.161 |
| Brown-headed Cowbird | 26 | 14 | 11 | 49 | 0.0001 |
| Common Grackle | 22 | 27 | 15 | 36 | 0.109 |
| Greater Roadrunner | 28 | 20 | 9 | 43 | 0.0001 |
| Great-tailed Grackle | 22 | 46 | 15 | 17 | 0.161 |
| Red-tailed Hawk | 34 | 22 | 3 | 41 | 0.0001 |
| Western Scrub-Jay | 10 | 0 | 27 | 63 | 0.0001 [a] |

[a] Chi-square may not be appropriate due to small number of sites without Western Scrub-Jays.

Table 3. Abundances of avian predators relative to occurrence of Golden-cheeked Warbler (GCWA). Values are mean ± standard deviation. P-values are based on Wilcoxon ranked sum test.

| Predator Species | Number of Individuals of each Species: Sites without GCWA (n=37) | Number of Individuals of each Species: Sites with GCWA (n=63) | P-value |
|---|---|---|---|
| American Crow | 0.46 ± 1.04 | 0.56 ± 1.24 | 0.9581 |
| Blue Jay | 4.97 ± 5.24 | 3.76 ± 6.64 | 0.0876 |
| Brown-headed Cowbird | 0.54 ± 1.02 | 3.25 ± 5.39 | 0.0001 |
| Common Grackle | 0.89 ± 1.65 | 1.20 ± 1.95 | 0.1711 |
| Greater Roadrunner | 0.30 ± 0.57 | 1.52 ± 1.62 | 0.0001 |
| Great-tailed Grackle | 1.51 ± 2.67 | 0.35 ± 0.77 | 0.0430 |
| Red-tailed Hawk | 0.08 ± 0.28 | 1.34 ± 1.70 | 0.0001 |
| Western Scrub-Jay | 4.57 ± 4.61 | 21.27 ± 14.57 | 0.0001 |

Table 4. Summary of all interactions between Golden-cheeked Warblers and avian predators. Code values are 5 - movement toward warbler, aggressive response; 6 - movement toward warbler, avoidance response; 7 - presence of predator, aggressive response; 8 - presence of predator, avoidance response; 9 - presence of predator, no response.

| Species | Number of Interactions | | | | |
|---|---|---|---|---|---|
| | Code 5 | Code 6 | Code 7 | Code 8 | Code 9 |
| *Accipiter* sp. | . | . | . | 1 | . |
| American Crow | . | . | . | . | 3 |
| American Kestrel | . | . | . | 1 | . |
| Barred Owl | . | . | . | 1 | . |
| Brown-headed Cowbird | . | . | 1 | . | 2 |
| Blue Jay | . | . | . | 10 | 21 |
| Broad-winged Hawk | . | . | . | . | 3 |
| Common Grackle | . | . | . | 2 | 3 |
| Cooper's Hawk | . | 1 | . | 4 | 1 |
| Eastern Screech-Owl | . | . | . | 2 | . |
| Greater Roadrunner | . | . | . | 5 | 7 |
| Great-tailed Grackle | . | . | . | 1 | 2 |
| Osprey | . | . | . | 1 | . |
| Red-shouldered Hawk | . | . | . | 3 | 4 |
| Red-tailed Hawk | . | . | . | 16 | 19 |
| Sharp-shinned Hawk | . | 1 | . | . | . |
| Swainson's Hawk | . | . | . | 2 | 1 |
| Turkey Vulture | . | . | . | 1 | . |
| Western Scrub-Jay | 1 | 9 | 2 | 66 | 178 |
| Totals | 1 | 11 | 3 | 116 | 244 |

Table 5. Response by Golden-cheeked Warblers to potential avian predators by age class and by stage of reproduction. P-values are based on Chi-square tests of 2x2 (one degree of freedom) and 2x3 (two degrees of freedom) contingency tables.

| | No Response | Response | P-value |
|---|---|---|---|
| A. By Age: | | | |
| Adult | 211 | 112 | |
| Hatch-year | 33 | 19 | |
| Total | 244 | 131 | 0.794 |
| B. By Reproductive Stage: | | | |
| Settlement | 42 | 27 | |
| Nesting | 98 | 56 | |
| Fledgling | 104 | 48 | |
| Total | 244 | 131 | 0.490 |

Table 6. Distances of Golden-cheeked Warbler territories and avian predators to human development. Values for each distance class are actual number of birds encountered (first row) and expected number of birds after compensating for differences in area (second row). P-values are based on Chi-square tests with three degrees of freedom. Land uses are Agricultural (Ag), Commercial (Com), Industrial (Ind), and Residential (Res).

| Species | Land Use | Total | Distance Class (m) | | | | $X^2$ | p-value |
|---|---|---|---|---|---|---|---|---|
| | | | 100 | 500 | 1000 | 2000 | | |
| Golden-cheeked Warbler | Ag | 423 | 33 | 60 | 102 | 228 | 17.367 | 0.001 |
| | | | 16.72 | 69.49 | 101.45 | 235.33 | | |
| | Com | 492 | 2 | 91 | 135 | 264 | 41.810 | 0.001 |
| | | | 24.44 | 116.77 | 142.80 | 207.98 | | |
| | Ind | 333 | 2 | 23 | 49 | 259 | 31.351 | 0.001 |
| | | | 5.80 | 39.12 | 78.04 | 210.04 | | |
| | Res | 689 | 26 | 239 | 330 | 94 | 239.141 | 0.001 |
| | | | 75.40 | 220.66 | 175.75 | 217.18 | | |
| Golden-cheeked Warbler young | Ag | 233 | 17 | 40 | 55 | 121 | 7.250 | n.s. |
| | | | 9.21 | 38.28 | 55.88 | 129.63 | | |
| | Com | 280 | 0 | 27 | 88 | 165 | 56.270 | 0.001 |
| | | | 13.91 | 66.46 | 81.27 | 118.36 | | |
| | Ind | 177 | 2 | 7 | 21 | 147 | 30.841 | 0.001 |
| | | | 3.08 | 20.79 | 41.48 | 111.64 | | |
| | Res | 376 | 9 | 142 | 162 | 63 | 100.535 | 0.001 |
| | | | 41.15 | 120.42 | 95.91 | 118.52 | | |

Table 6, continued.

| Species | Land Use | Total | Distance Class (m) 100 | 500 | 1000 | 2000 | $X^2$ | p-value |
|---|---|---|---|---|---|---|---|---|
| Golden-cheeked Warbler territories with young | Ag | 143 | 9 | 25 | 37 | 72 | 3.008 | n.s. |
| | | | 5.65 | 23.49 | 34.30 | 79.56 | | |
| | Com | 165 | 0 | 22 | 49 | 94 | 24.175 | 0.001 |
| | | | 8.20 | 39.16 | 47.89 | 69.75 | | |
| | Ind | 112 | 1 | 7 | 12 | 92 | 17.535 | 0.001 |
| | | | 1.95 | 13.16 | 26.25 | 70.64 | | |
| | Res | 235 | 6 | 90 | 104 | 35 | 70.996 | 0.001 |
| | | | 25.72 | 75.26 | 59.94 | 74.08 | | |
| American Crow | Ag | 43 | 9 | 12 | 8 | 14 | 39.428 | 0.001 |
| | | | 1.70 | 7.06 | 10.31 | 23.92 | | |
| | Com | 39 | 4 | 10 | 17 | 8 | 9.474 | 0.05 |
| | | | 1.94 | 9.26 | 11.32 | 16.49 | | |
| | Ind | 32 | 0 | 2 | 8 | 22 | 1.577 | n.s. |
| | | | 0.56 | 3.76 | 7.50 | 20.18 | | |
| | Res | 48 | 6 | 24 | 15 | 3 | 15.293 | 0.01 |
| | | | 5.25 | 15.37 | 12.24 | 15.13 | | |
| Blue Jay | Ag | 303 | 11 | 35 | 74 | 183 | 5.726 | n.s. |
| | | | 11.98 | 49.78 | 72.67 | 168.57 | | |
| | Com | 489 | 38 | 225 | 177 | 49 | 238.977 | 0.001 |
| | | | 24.29 | 116.06 | 141.93 | 206.71 | | |
| | Ind | 255 | 11 | 54 | 67 | 123 | 38.767 | 0.001 |
| | | | 4.44 | 29.96 | 59.76 | 160.84 | | |

Table 6, continued.

| Species | Land Use | Total | Distance Class (m) 100 | 500 | 1000 | 2000 | $X^2$ | p-value |
|---|---|---|---|---|---|---|---|---|
| Blue Jay | Res | 498 | 257 | 201 | 37 | 3 | 978.022 | 0.001 |
| | | | 54.50 | 159.49 | 127.03 | 752.38 | | |
| Brown-headed Cowbird | Ag | 206 | 38 | 39 | 40 | 89 | 117.738 | 0.001 |
| | | | 8.14 | 33.84 | 49.41 | 114.61 | | |
| | Com | 146 | 6 | 26 | 41 | 73 | 4.484 | n.s. |
| | | | 7.25 | 34.65 | 42.38 | 61.72 | | |
| | Ind | 149 | 12 | 15 | 21 | 101 | 40.533 | 0.001 |
| | | | 2.59 | 17.51 | 34.92 | 93.98 | | |
| | Res | 237 | 28 | 85 | 106 | 18 | 78.612 | 0.001 |
| | | | 25.94 | 75.90 | 60.45 | 74.71 | | |
| Common Grackle | Ag | 84 | 8 | 4 | 16 | 56 | 16.242 | 0.01 |
| | | | 3.32 | 13.80 | 20.15 | 46.73 | | |
| | Com | 124 | 8 | 42 | 50 | 24 | 26.777 | 0.001 |
| | | | 6.16 | 29.43 | 35.99 | 52.42 | | |
| | Ind | 57 | 7 | 23 | 6 | 21 | 86.332 | 0.001 |
| | | | 0.99 | 6.70 | 13.36 | 35.95 | | |
| | Res | 150 | 42 | 66 | 40 | 2 | 90.032 | 0.001 |
| | | | 16.42 | 48.04 | 38.26 | 47.28 | | |
| Greater Roadrunner | Ag | 104 | 10 | 12 | 30 | 52 | 11.564 | 0.01 |
| | | | 4.11 | 17.09 | 24.94 | 57.86 | | |
| | Com | 87 | 5 | 17 | 25 | 40 | 1.036 | n.s. |
| | | | 4.32 | 20.65 | 25.25 | 36.78 | | |

Table 6, continued.

| Species | Land Use | Total | Distance Class (m) 100 | 500 | 1000 | 2000 | $X^2$ | p-value |
|---|---|---|---|---|---|---|---|---|
| Greater Roadrunner | Ind | 58 | 0 | 11 | 12 | 35 | 3.837 | n.s. |
| | | | 1.01 | 6.81 | 13.59 | 36.58 | | |
| | Res | 117 | 24 | 41 | 49 | 3 | 53.540 | 0.001 |
| | | | 12.80 | 37.47 | 29.84 | 36.88 | | |
| Great-tailed Grackle | Ag | 52 | 4 | 5 | 13 | 30 | 3.369 | n.s. |
| | | | 2.06 | 8.54 | 12.47 | 28.93 | | |
| | Com | 84 | 19 | 34 | 23 | 8 | 83.984 | 0.001 |
| | | | 4.17 | 19.94 | 24.38 | 35.51 | | |
| | Ind | 47 | 4 | 19 | 2 | 22 | 54.621 | 0.001 |
| | | | 0.82 | 5.52 | 11.01 | 29.65 | | |
| | Res | 87 | 50 | 30 | 7 | 0 | 210.077 | 0.001 |
| | | | 9.52 | 27.86 | 22.19 | 27.42 | | |
| Red-tailed Hawk | Ag | 88 | 20 | 22 | 14 | 32 | 90.649 | 0.001 |
| | | | 3.48 | 14.46 | 21.11 | 48.96 | | |
| | Com | 76 | 2 | 13 | 11 | 50 | 17.729 | 0.001 |
| | | | 3.78 | 18.04 | 22.06 | 32.13 | | |
| | Ind | 74 | 1 | 6 | 23 | 44 | 2.898 | n.s. |
| | | | 1.29 | 8.69 | 17.34 | 46.67 | | |
| | Res | 113 | 9 | 33 | 57 | 14 | 41.862 | 0.001 |
| | | | 12.37 | 36.19 | 28.82 | 35.62 | | |

Table 6, continued.

| Species | Land Use | Total | Distance Class (m) 100 | 500 | 1000 | 2000 | $X^2$ | p-value |
|---|---|---|---|---|---|---|---|---|
| Western Scrub-Jay | Ag | 1254 | 137 | 191 | 267 | 659 | 161.169 | 0.001 |
| | | | 49.58 | 206.01 | 300.76 | 697.65 | | |
| | Com | 1388 | 50 | 313 | 425 | 600 | 7.549 | n.s. |
| | | | 68.56 | 329.44 | 402.86 | 586.75 | | |
| | Ind | 801 | 13 | 71 | 161 | 556 | 14.641 | 0.01 |
| | | | 13.95 | 94.10 | 187.72 | 505.23 | | |
| | Res | 1822 | 271 | 748 | 682 | 121 | 531.433 | 0.001 |
| | | | 199.40 | 583.52 | 464.76 | 574.32 | | |

Table 7. Distance from Golden-cheeked Warbler territories and predator species to nearest source of water.

| Species | Distance (m) | | |
|---|---|---|---|
| | mean | stand. dev. | n |
| Golden-cheeked Warbler | | | |
| 1. Territories with young | 227.27 | 208.68 | 211 |
| 2. Territories where young were not found | 221.13 | 204.46 | 395 |
| American Crow | 245.60 | 315.91 | 40 |
| American Kestrel | 181.00 | 117.10 | 5 |
| Barred Owl | 227.00 | 117.38 | 2 |
| Brown-headed Cowbird | 255.94 | 222.58 | 216 |
| Blue Jay | 137.14 | 163.77 | 450 |
| Broad-winged Hawk | 232.63 | 280.54 | 8 |
| Common Grackle | 199.62 | 168.32 | 138 |
| Cooper's Hawk | 235.38 | 250.04 | 13 |
| Common Raven | 312.50 | 201.30 | 4 |
| Eastern Screech-owl | 235.57 | 186.88 | 7 |
| Great Horned Owl | 192.50 | 143.87 | 4 |
| Greater Roadrunner | 283.72 | 263.81 | 105 |
| Great-tailed Grackle | 119.87 | 111.23 | 68 |
| Mississippi Kite | 104.20 | 78.84 | 5 |
| Osprey | 248.67 | 8.96 | 3 |
| Red-shouldered Hawk | 196.43 | 201.28 | 21 |
| Red-tailed Hawk | 311.12 | 270.64 | 102 |
| Sharp-shinned Hawk | 152.17 | 78.26 | 6 |
| Swainson's Hawk | 112.70 | 81.85 | 10 |
| Western Scrub-Jay | 239.59 | 236.02 | 1668 |

Table 8. Patch size for all sites, showing presence/absence of Golden-cheeked Warblers and whether young were present. Sites are sorted in increasing order of size.

| Size (ha) | Presence of GCWA | Presence of GCWA young |
|---|---|---|
| 6.56 | 0 | 0 |
| 8.69 | 0 | 0 |
| 8.85 | 0 | 0 |
| 10.12 | 1 | 0 |
| 12.27 | 0 | 0 |
| 12.52 | 1 | 0 |
| 12.68 | 0 | 0 |
| 12.81 | 0 | 0 |
| 12.88 | 0 | 0 |
| 13.11 | 0 | 0 |
| 13.47 | 1 | 0 |
| 13.65 | 0 | 0 |
| 14.96 | 0 | 0 |
| 15.90 | 1 | 0 |
| 16.49 | 0 | 0 |
| 17.03 | 0 | 0 |
| 17.30 | 1 | 0 |
| 17.41 | 0 | 0 |
| 17.79 | 0 | 0 |
| 17.96 | 0 | 0 |
| 19.19 | 1 | 0 |
| 19.70 | 0 | 0 |
| 19.95 | 0 | 0 |
| 20.83 | 0 | 0 |
| 21.95 | 1 | 0 |
| 23.43 | 1 | 1 |
| 23.58 | 1 | 0 |
| 24.04 | 0 | 0 |
| 24.61 | 1 | 1 |
| 25.06 | 1 | 1 |
| 25.33 | 1 | 1 |
| 25.51 | 1 | 0 |
| 25.91 | 1 | 1 |
| 26.39 | 1 | 1 |
| 26.45 | 0 | 0 |
| 26.65 | 0 | 0 |
| 27.82 | 0 | 0 |

Table 8, continued.

| Size (ha) | Presence of GCWA | Presence of GCWA young |
|---|---|---|
| 28.81 | 0 | 0 |
| 29.06 | 1 | 1 |
| 30.71 | 0 | 0 |
| 31.10 | 1 | 0 |
| 31.27 | 1 | 0 |
| 32.41 | 0 | 0 |
| 33.19 | 0 | 0 |
| 33.19 | 1 | 1 |
| 33.61 | 0 | 0 |
| 37.14 | 0 | 0 |
| 37.91 | 1 | 1 |
| 38.05 | 1 | 1 |
| 39.41 | 0 | 0 |
| 39.43 | 1 | 1 |
| 41.28 | 1 | 1 |
| 41.76 | 1 | 1 |
| 41.99 | 0 | 0 |
| 42.34 | 1 | 1 |
| 43.34 | 0 | 0 |
| 43.42 | 1 | 1 |
| 44.92 | 1 | 1 |
| 46.28 | 0 | 0 |
| 46.82 | 1 | 1 |
| 47.56 | 1 | 1 |
| 49.28 | 1 | 0 |
| 50.09 | 1 | 1 |
| 51.14 | 1 | 0 |
| 55.21 | 1 | 0 |
| 59.19 | 1 | 0 |
| 59.34 | 1 | 1 |
| 61.62 | 1 | 1 |
| 63.08 | 1 | 0 |
| 66.40 | 1 | 0 |
| 69.31 | 1 | 1 |
| 72.38 | 1 | 1 |
| 73.91 | 1 | 1 |
| 77.34 | 1 | 1 |
| 81.76 | 0 | 0 |
| 84.75 | 1 | 1 |
| 91.47 | 0 | 0 |

Table 8, continued.

| Size (ha) | Presence of GCWA | Presence of GCWA young |
|---|---|---|
| 101.95 | 1 | 0 |
| 126.98 | 1 | 1 |
| 132.92 | 0 | 0 |
| 154.80 | 1 | 1 |
| 164.32 | 1 | 1 |
| 175.93 | 1 | 1 |
| 198.59 | 1 | 1 |
| 200.02 | 1 | 1 |
| 202.71 | 1 | 1 |
| 226.68 | 1 | 1 |
| 253.61 | 1 | 1 |
| 272.53 | 1 | 1 |
| 276.14 | 1 | 1 |
| 314.07 | 1 | 1 |
| 343.38 | 1 | 1 |
| 361.58 | 1 | 1 |
| 363.86 | 1 | 1 |
| 450.76 | 1 | 1 |
| 453.32 | 1 | 1 |
| 731.53 | 1 | 1 |

Table 9. Patch size relative to species presence/absence and distance to human development. Values are mean ± standard deviation (n). P-values are based on Wilcoxon ranked sum tests. Land uses are Agricultural (Ag), Commercial (Com), Industrial (Ind), and Residential (Res).

| Species | Land Use | Distance Class (m) | Area of Sites Without Species (ha) | Area of Sites With Species (ha) | P-value |
|---|---|---|---|---|---|
| Golden-cheeked Warbler | Ag | 100 | 25.34 ± 11.68 (5) | 99.46 ± 137.80 (14) | 0.2472 |
| | | 500 | 31.44 ± 11.15 (6) | 68.41 ± 61.09 (11) | 0.1748 |
| | | 1000 | 18.95 ± 5.50 (3) | 111.43 ± 123.30 (18) | 0.0500 |
| | | 2000 | 35.10 ± 35.18 (14) | 159.06 ± 211.89 (12) | 0.0040 |
| | Com | 100 | 29.00 ± 28.24 (23) | 124.76 ± 137.09 (12) | 0.0033 |
| | | 500 | 35.73 ± 25.40 (7) | 170.42 ± 207.89 (15) | 0.0570 |
| | | 1000 | 35.40 ± 9.32 (2) | 127.92 ± 107.39 (10) | 0.1626 |
| | | 2000 | 12.96 ± 0.96 (2) | 72.18 ± 96.43 (14) | 0.0955 |
| | Ind | 100 | 38.01 ± 43.84 (7) | 73.05 ± 71.99 (5) | 0.1439 |
| | | 500 | 21.86 ± 12.61 (4) | 96.71 ± 81.30 (8) | 0.0508 |
| | | 1000 | . | 129.25 ± 170.62 (13) | . |
| | | 2000 | 32.64 ± 26.43 (8) | 154.79 ± 190.12 (14) | 0.0185 |
| | Res | 100 | 25.83 ± 16.35 (31) | 148.52 ± 168.13 (28) | 0.0001 |
| | | 500 | 72.80 ± 85.02 (2) | 102.54 ± 121.63 (18) | 0.6592 |
| | | 1000 | 47.71 ± 48.16 (2) | 88.62 ± 124.36 (7) | 0.6605 |
| | | 2000 | . | 59.51 ± 33.18 (8) | . |
| American Crow | Ag | 100 | 39.67 ± 41.93 (12) | 149.01 ± 180.49 (7) | 0.1632 |
| | | 500 | 50.22 ± 46.84 (10) | 62.71 ± 61.72 (7) | 0.5259 |
| | | 1000 | 104.69 ± 123.56 (17) | 70.73 ± 104.05 (4) | 0.2266 |
| | | 2000 | 59.76 ± 78.91 (23) | 341.88 ± 361.30 (3) | 0.1990 |

Table 9, continued.

| Species | Land Use | Distance Class (m) | Area of Sites Without Species (ha) | Area of Sites With Species (ha) | P-value |
|---|---|---|---|---|---|
| American Crow | Com | 100 | 55.11 ± 71.08 (28) | 88.72 ± 160.13 (7) | 0.6062 |
| | | 500 | 96.94 ± 134.89 (16) | 209.24 ± 271.12 (6) | 0.4389 |
| | | 1000 | 121.93 ± 110.62 (10) | 65.38 ± 51.72 (2) | 0.5912 |
| | | 2000 | 46.10 ± 50.04 (13) | 145.69 ± 190.79 (3) | 0.5905 |
| | Ind | 100 | 39.19 ± 36.72 (10) | 119.72 ± 113.55 (2) | 0.2374 |
| | | 500 | 89.43 ± 79.30 (9) | 18.74 ± 8.18 (3) | 0.0961 |
| | | 1000 | 81.97 ± 141.16 (9) | 235.62 ± 203.78 (4) | 0.1427 |
| | | 2000 | 73.03 ± 72.27 (15) | 190.39 ± 262.01 (7) | 0.7245 |
| | Res | 100 | 65.05 ± 86.66 (46) | 151.31 ± 219.72 (13) | 0.2170 |
| | | 500 | 111.85 ± 127.29 (15) | 62.72 ± 78.14 (5) | 0.3370 |
| | | 1000 | 35.71 ± 22.11 (7) | 232.91 ± 185.20 (2) | 0.0570 |
| | | 2000 | 62.59 ± 34.58 (7) | 37.91 . (1) | 0.3827 |
| Blue Jay | Ag | 100 | 59.50 ± 107.97 (10) | 102.68 ± 138.71 (9) | 0.0942 |
| | | 500 | 38.79 ± 16.24 (7) | 66.97 ± 65.31 (10) | 0.5259 |
| | | 1000 | 145.25 ± 205.91 (4) | 87.15 ± 94.33 (17) | 0.6869 |
| | | 2000 | 31.82 ± 13.56 (7) | 114.63 ± 178.44 (19) | 0.3702 |
| | Com | 100 | 25.07 ± 12.95 (6) | 69.44 ± 101.06 (29) | 0.3934 |
| | | 500 | 171.11 ± 244.43 (3) | 120.69 ± 177.86 (19) | 0.7019 |
| | | 1000 | 42.36 ± 25.92 (3) | 135.89 ± 110.18 (9) | 0.1956 |
| | | 2000 | 64.01 ± 113.22 (9) | 65.77 ± 63.84 (7) | 0.2040 |
| | Ind | 100 | 21.56 ± 5.33 (2) | 58.82 ± 61.01 (10) | 0.4521 |
| | | 500 | 29.27 ± 14.57 (4) | 93.00 ± 84.69 (8) | 0.3502 |
| | | 1000 | 140.82 ± 185.22 (7) | 115.75 ± 168.21 (6) | 0.8303 |
| | | 2000 | 27.17 ± 11.07 (4) | 128.86 ± 174.31 (18) | 0.0810 |

Table 9, continued.

| Species | Land Use | Distance Class (m) | Area of Sites Without Species (ha) | Area of Sites With Species (ha) | P-value |
|---|---|---|---|---|---|
| Blue Jay | Res | 100 | 26.78 ± 13.45 (9) | 94.36 ± 139.71 (50) | 0.1487 |
| | | 500 | 80.49 ± 140.85 (9) | 115.18 ± 97.79 (11) | 0.1489 |
| | | 1000 | 95.21 ± 150.22 (5) | 59.93 ± 39.55 (4) | 0.7133 |
| | | 2000 | 43.63 ± 21.18 (5) | 85.97 ± 35.72 (3) | 0.1360 |
| Brown-headed Cowbird | Ag | 100 | 32.11 ± 15.49 (8) | 114.75 ± 153.09 (11) | 0.5357 |
| | | 500 | 34.99 ± 16.93 (6) | 66.47 ± 61.61 (11) | 0.2913 |
| | | 1000 | 56.53 ± 67.28 (7) | 119.06 ± 134.48 (14) | 0.2183 |
| | | 2000 | 97.58 ± 203.02 (12) | 87.80 ± 109.28 (14) | 0.3412 |
| | Com | 100 | 42.40 ± 73.60 (18) | 82.40 ± 109.12 (17) | 0.0153 |
| | | 500 | 121.30 ± 247.74 (8) | 131.15 ± 142.89 (14) | 0.1087 |
| | | 1000 | 33.87 ± 30.19 (2) | 128.23 ± 106.66 (10) | 0.1626 |
| | | 2000 | 63.30 ± 59.26 (8) | 66.25 ± 120.95 (8) | 0.1278 |
| | Ind | 100 | 37.48 ± 53.45 (5) | 63.42 ± 61.17 (7) | 0.0740 |
| | | 500 | 56.71 ± 73.07 (6) | 86.81 ± 80.33 (6) | 0.4712 |
| | | 1000 | 37.79 ± 15.07 (4) | 169.90 ± 193.76 (9) | 0.6997 |
| | | 2000 | 105.38 ± 221.55 (10) | 114.53 ± 99.33 (12) | 0.0806 |
| | Res | 100 | 65.06 ± 140.83 (30) | 103.70 ± 118.85 (29) | 0.0033 |
| | | 500 | 69.07 ± 43.17 (4) | 107.20 ± 129.12 (16) | 0.8873 |
| | | 1000 | 22.44 ± 7.93 (3) | 108.07 ± 128.79 (6) | 0.0528 |
| | | 2000 | 58.06 ± 15.90 (2) | 59.99 ± 38.60 (6) | 0.9999 |

Table 9, continued.

| Species | Land Use | Distance Class (m) | Area of Sites Without Species (ha) | Area of Sites With Species (ha) | P-value |
|---|---|---|---|---|---|
| Common Grackle | Ag | 100 | 77.82 ± 124.38 (12) | 83.61 ± 127.39 (7) | 0.8327 |
| | | 500 | 39.84 ± 19.38 (8) | 69.17 ± 67.98 (9) | 0.4705 |
| | | 1000 | 151.39 ± 184.79 (5) | 81.60 ± 91.41 (16) | 0.7102 |
| | | 2000 | 90.22 ± 194.09 (13) | 94.41 ± 114.42 (13) | 0.6816 |
| | Com | 100 | 50.10 ± 98.78 (19) | 75.76 ± 87.66 (16) | 0.3453 |
| | | 500 | 153.15 ± 241.43 (10) | 106.25 ± 120.20 (12) | 0.4483 |
| | | 1000 | 77.35 ± 78.28 (3) | 124.22 ± 112.33 (9) | 0.5791 |
| | | 2000 | 54.27 ± 68.42 (7) | 72.95 ± 110.43 (9) | 0.6720 |
| | Ind | 100 | 20.63 ± 16.66 (2) | 59.01 ± 60.65 (10) | 0.2374 |
| | | 500 | 89.09 ± 76.69 (4) | 63.09 ± 77.68 (8) | 0.1488 |
| | | 1000 | 169.62 ± 219.26 (6) | 94.65 ± 123.02 (7) | 0.9999 |
| | | 2000 | 117.07 ± 220.87 (10) | 104.79 ± 100.39 (12) | 0.3390 |
| | Res | 100 | 75.00 ± 152.33 (29) | 92.80 ± 108.00 (30) | 0.1949 |
| | | 500 | 131.13 ± 165.93 (6) | 86.04 ± 93.69 (14) | 0.4833 |
| | | 1000 | 37.27 ± 30.36 (4) | 113.33 ± 143.27 (5) | 0.1779 |
| | | 2000 | 46.63 ± 20.32 (6) | 98.14 ± 40.78 (2) | 0.1336 |
| Greater Roadrunner | Ag | 100 | 18.46 ± 10.67 (7) | 115.83 ± 143.04 (12) | 0.0035 |
| | | 500 | 53.37 ± 59.78 (8) | 57.14 ± 47.65 (9) | 0.5317 |
| | | 1000 | 24.49 ± 12.24 (5) | 121.26 ± 127.60 (16) | 0.0232 |
| | | 2000 | 40.90 ± 51.28 (16) | 174.58 ± 226.04 (10) | 0.0013 |
| | Com | 100 | 47.77 ± 69.51 (26) | 102.44 ± 139.56 (9) | 0.0930 |
| | | 500 | 56.88 ± 70.29 (6) | 154.08 ± 204.87 (16) | 0.2532 |
| | | 1000 | 31.15 ± 13.82 (4) | 153.18 ± 105.47 (8) | 0.0085 |
| | | 2000 | 21.67 ± 13.95 (7) | 98.31 ± 113.32 (9) | 0.0081 |

Table 9, continued.

| Species | Land Use | Distance Class (m) | Area of Sites Without Species (ha) | Area of Sites With Species (ha) | P-value |
|---|---|---|---|---|---|
| Greater Roadrunner | Ind | 100 | 61.46 ± 68.11 (8) | 34.91 ± 22.28 (4) | 0.9323 |
| | | 500 | 52.27 ± 82.17 (5) | 85.68 ± 72.37 (7) | 0.1044 |
| | | 1000 | 38.28 ± 28.59 (5) | 186.11 ± 199.58 (8) | 0.2134 |
| | | 2000 | 26.45 ± 11.18 (10) | 180.31 ± 195.52 (12) | 0.0011 |
| | Res | 100 | 37.91 ± 59.99 (32) | 138.74 ± 167.82 (27) | 0.0001 |
| | | 500 | 62.82 ± 65.02 (9) | 129.64 ± 142.97 (11) | 0.1286 |
| | | 1000 | 41.49 ± 35.72 (3) | 98.55 ± 133.16 (6) | 0.5186 |
| | | 2000 | 30.14 ± 23.58 (2) | 69.29 ± 31.16 (6) | 0.1336 |
| Great-tailed Grackle | Ag | 100 | 89.64 ± 131.08 (16) | 28.28 ± 14.32 (3) | 0.6956 |
| | | 500 | 49.81 ± 45.23 (11) | 65.55 ± 66.07 (6) | 0.3397 |
| | | 1000 | 87.69 ± 121.97 (13) | 115.33 ± 118.44 (8) | 0.5382 |
| | | 2000 | 60.55 ± 68.38 (18) | 163.78 ± 259.33 (8) | 0.6973 |
| | Com | 100 | 85.41 ± 119.09 (19) | 33.83 ± 34.85 (16) | 0.0945 |
| | | 500 | 75.73 ± 115.94 (16) | 265.79 ± 259.32 (6) | 0.0296 |
| | | 1000 | 110.98 ± 94.34 (6) | 114.03 ± 121.34 (6) | 0.8102 |
| | | 2000 | 70.00 ± 101.48 (13) | 42.13 ± 27.85 (3) | 0.7879 |
| | Ind | 100 | 36.20 ± 16.60 (5) | 64.33 ± 73.52 (7) | 0.8710 |
| | | 500 | 81.11 ± 78.71 (10) | 24.99 ± 26.06 (2) | 0.3337 |
| | | 1000 | 143.60 ± 182.28 (11) | 50.33 ± 48.68 (2) | 0.6217 |
| | | 2000 | 98.38 ± 102.72 (10) | 120.36 ± 202.96 (12) | 0.8175 |
| | Res | 100 | 83.68 ± 106.80 (37) | 84.68 ± 166.49 (22) | 0.2366 |
| | | 500 | 76.22 ± 119.98 (13) | 142.94 ± 105.91 (7) | 0.0476 |
| | | 1000 | 87.76 ± 115.16 (8) | 13.65 . (1) | 0.1752 |
| | | 2000 | 58.11 ± 35.59 (7) | 69.31 . (1) | 0.6625 |

Table 9, continued.

| Species | Land Use | Distance Class (m) | Area of Sites Without Species (ha) | Area of Sites With Species (ha) | P-value |
|---|---|---|---|---|---|
| Red-tailed Hawk | Ag | 100 | 25.06 ± 14.17 (9) | 129.36 ± 154.39 (10) | 0.0247 |
| | | 500 | 36.82 ± 16.35 (9) | 76.23 ± 70.23 (8) | 0.3606 |
| | | 1000 | 53.21 ± 59.15 (11) | 147.73 ± 148.59 (10) | 0.0845 |
| | | 2000 | 84.81 ± 174.32 (17) | 106.48 ± 122.62 (9) | 0.3320 |
| | Com | 100 | 48.63 ± 70.89 (25) | 94.84 ± 133.63 (10) | 0.0895 |
| | | 500 | 84.57 ± 187.19 (14) | 202.82 ± 155.29 (8) | 0.0127 |
| | | 1000 | 36.79 ± 17.38 (5) | 166.59 ± 106.29 (7) | 0.0094 |
| | | 2000 | 56.73 ± 82.85 (5) | 68.43 ± 99.55 (11) | 0.3079 |
| | Ind | 100 | 38.11 ± 47.83 (6) | 67.11 ± 66.15 (6) | 0.1282 |
| | | 500 | 71.27 ± 88.95 (7) | 72.45 ± 59.60 (5) | 0.3299 |
| | | 1000 | 45.17 ± 28.08 (4) | 166.62 ± 195.62 (9) | 0.8170 |
| | | 2000 | 103.66 ± 221.75 (10) | 115.96 ± 98.79 (12) | 0.1379 |
| | Res | 100 | 59.56 ± 124.58 (40) | 135.62 ± 131.83 (19) | 0.0003 |
| | | 500 | 52.16 ± 41.08 (8) | 131.18 ± 140.95 (12) | 0.2318 |
| | | 1000 | 41.49 ± 35.72 (3) | 98.55 ± 133.16 (6) | 0.5186 |
| | | 2000 | 99.68 ± 38.61 (2) | 46.11 ± 19.57 (6) | 0.0668 |
| Western Scrub-Jay | Ag | 100 | . | 79.95 ± 121.95 (19) | . |
| | | 500 | 28.81 . (1) | 57.03 ± 53.22 (16) | 0.4750 |
| | | 1000 | 19.70 . (1) | 102.14 ± 120.09 (20) | 0.2831 |
| | | 2000 | 43.42 ± 41.64 (3) | 98.69 ± 164.83 (23) | 0.7481 |
| | Com | 100 | 14.98 ± 5.03 (6) | 71.52 ± 100.10 (29) | 0.0242 |
| | | 500 | 55.58 ± 50.75 (2) | 134.77 ± 189.39 (20) | 0.6073 |
| | | 1000 | 28.81 . (1) | 120.11 ± 105.12 (11) | 0.2466 |
| | | 2000 | . | 64.78 ± 92.02 (16) | . |

Table 9, continued.

| Species | Land Use | Distance Class (m) | Area of Sites Without Species (ha) | Area of Sites With Species (ha) | P-value |
|---|---|---|---|---|---|
| Western Scrub-Jay | Ind | 100 | 8.85 . (1) | 56.59 ± 58.09 (11) | 0.1475 |
| | | 500 | 19.70 . (1) | 76.49 ± 76.63 (11) | 0.3848 |
| | | 1000 | . | 129.25 ± 170.62 (13) | . |
| | | 2000 | 38.45 ± 35.80 (4) | 126.35 ± 175.16 (18) | 0.1870 |
| | Res | 100 | 25.54 ± 25.46 (9) | 94.59 ± 139.32 (50) | 0.0158 |
| | | 500 | . | 99.57 ± 117.05 (20) | . |
| | | 1000 | . | 79.53 ± 110.52 (9) | . |
| | | 2000 | . | 59.51 ± 33.18 (8) | . |

Table 10. Predation (%) on artificial Golden-cheeked Warbler nests, 1994-1995.

| | Site | Edge | Interior | Total |
|---|---|---|---|---|
| 1994 | | | | |
| Trial 1 | | | | |
| | Lago Vista | 60.0 | 50.0 | 55.0 |
| | Reed | 40.0 | 45.0 | 42.5 |
| | Oasis | 30.0 | 20.0 | 25.0 |
| | Shellberg | 70.0 | 15.0 | 42.5 |
| | Ivanhoe | 60.0 | 45.0 | 52.5 |
| | Total | 52.0 | 35.0 | 43.5 |
| Trial 2 | | | | |
| | Lago Vista | 60.0 | 50.0 | 55.5 |
| | Reed | 55.0 | 60.0 | 57.5 |
| | Oasis | 55.0 | 75.0 | 65.0 |
| | Shellberg | 95.0 | 55.0 | 75.0 |
| | Ivanhoe | 55.0 | 40.0 | 47.5 |
| | Total | 64.0 | 56.0 | 60.0 |
| Total 1994: | | 58.0 | 45.5 | 51.75 |
| 1995 | | | | |
| Trial 1 | | | | |
| | Lago Vista | 90.0 | 75.0 | 82.5 |
| | Reed | 70.0 | 50.0 | 60.0 |
| | Oasis | 85.0 | 95.0 | 90.0 |
| | Shellberg | 45.0 | 25.0 | 35.0 |
| | Ivanhoe | 60.0 | 85.0 | 72.5 |
| | Total | 70.0 | 66.0 | 68.0 |

Table 10, continued.

| Site | Edge | Interior | Total |
|---|---|---|---|
| Trial 2 | | | |
| Lago Vista | 100.0 | 100.0 | 100.0 |
| Reed | 95.0 | 95.0 | 95.0 |
| Oasis | 94.7 | 100.0 | 97.0 |
| Shellberg | 45.0 | 60.0 | 52.5 |
| Ivanhoe | 75.0 | 70.0 | 72.5 |
| Total | 81.8 | 84.8 | 83.3 |
| Total 1995: | 75.87 | 75.37 | 75.63 |
| Two-year Total: | 67.25 (267/397) | 60.7 (241/397) | 63.98 (508/794) |

# APPENDIX B

# FIGURES

# Golden-cheeked Warbler

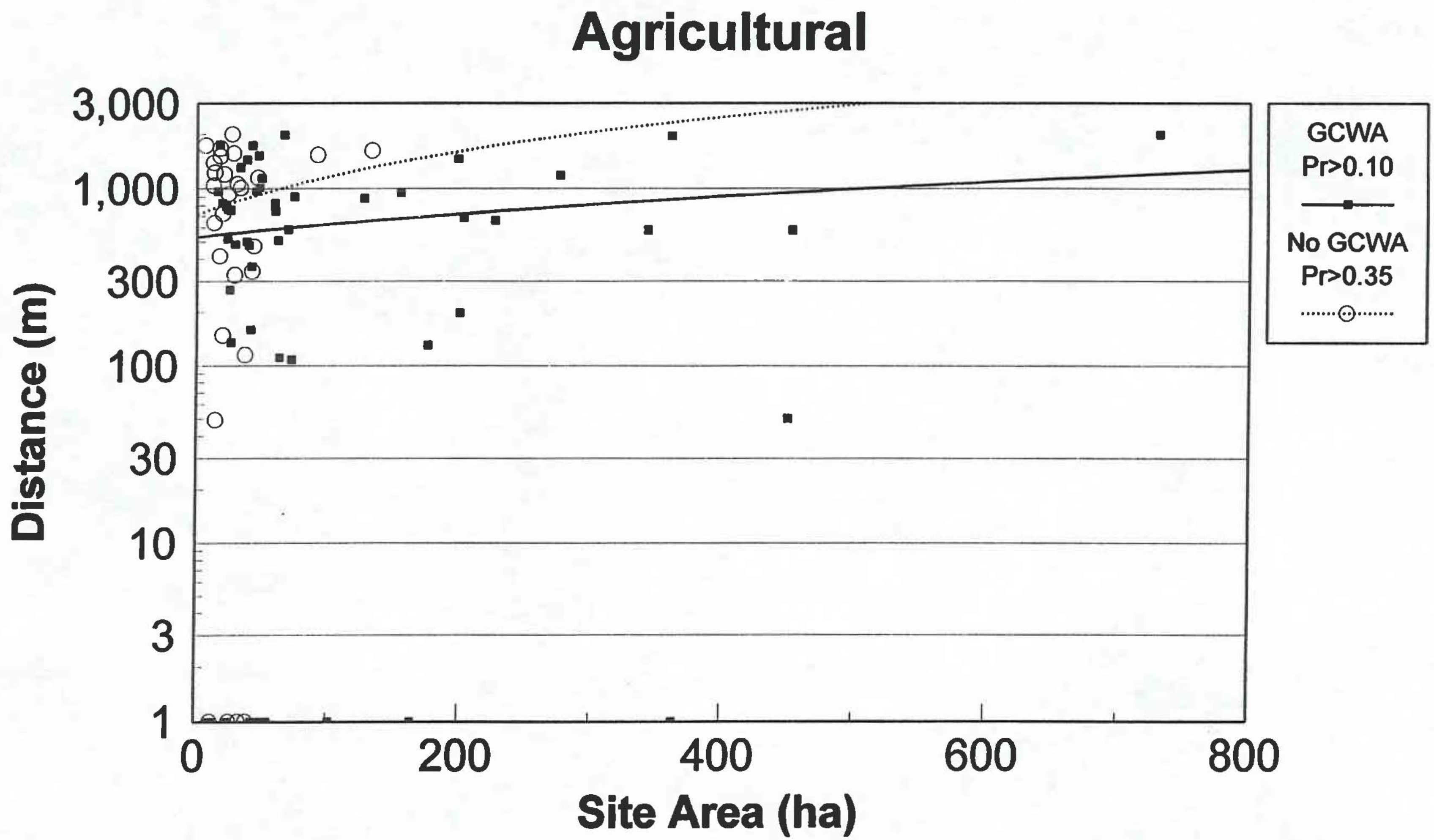



Figure 1

# Golden-cheeked Warbler

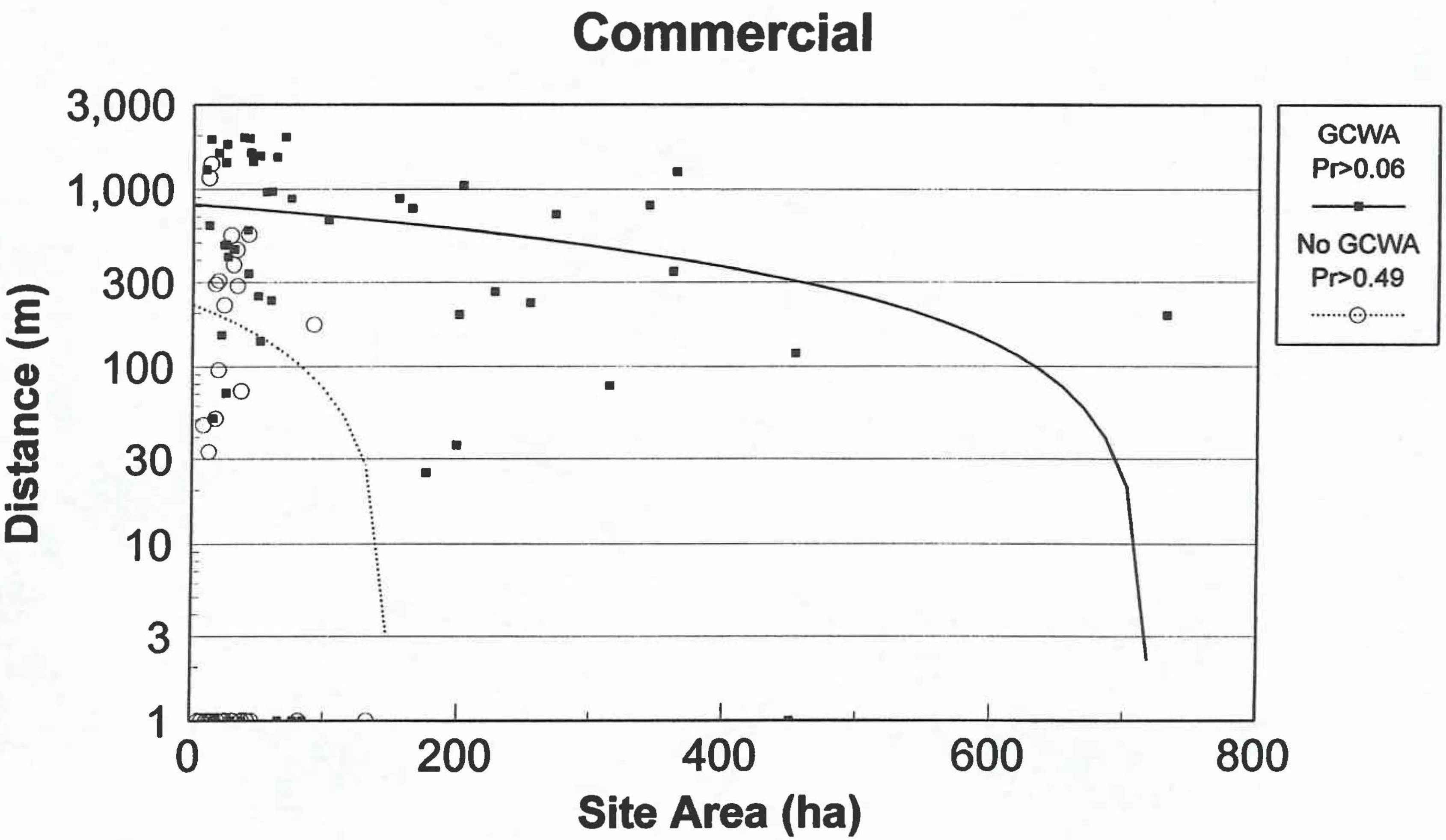



Figure 2

# Golden-cheeked Warbler

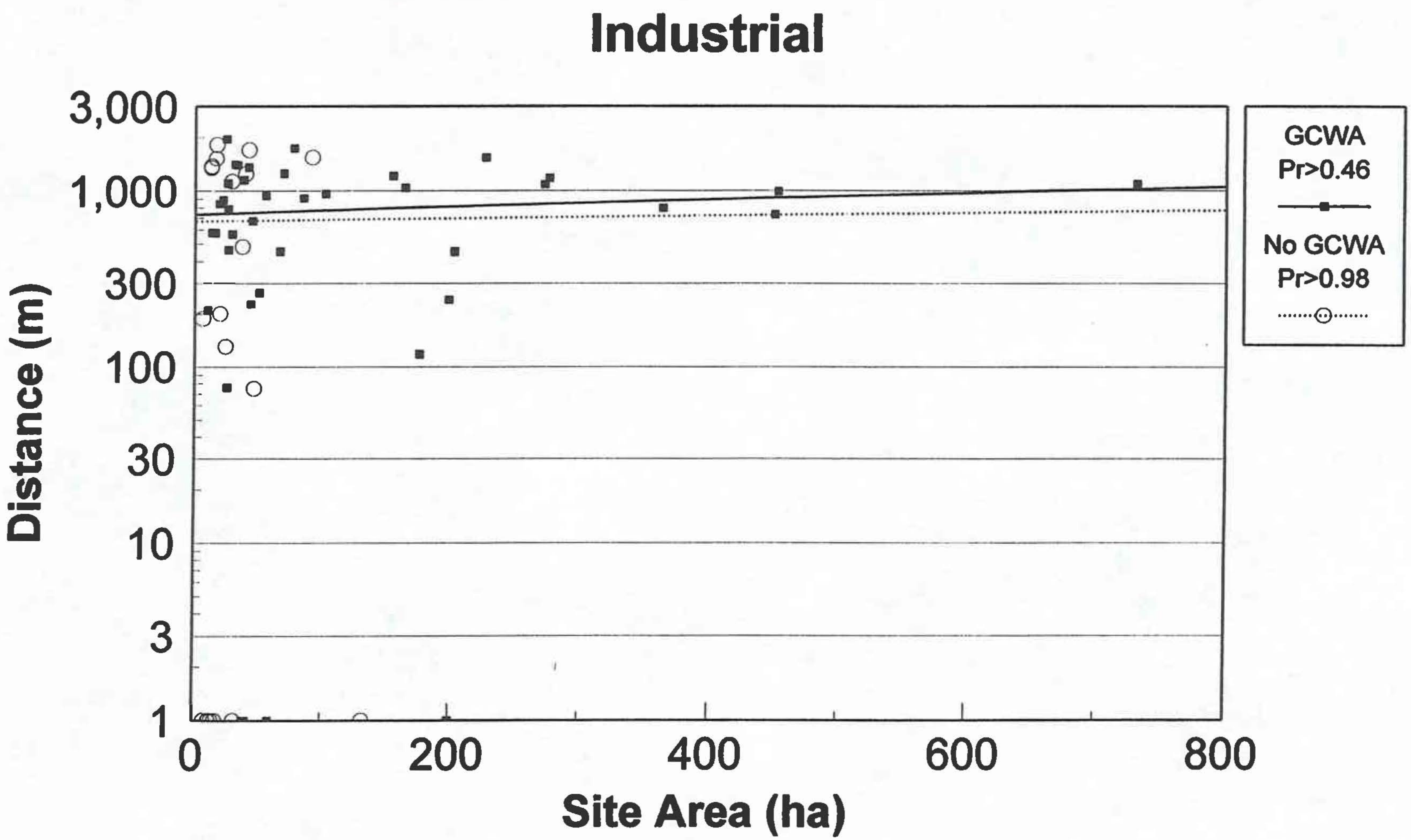



Figure 3

# Golden-cheeked Warbler

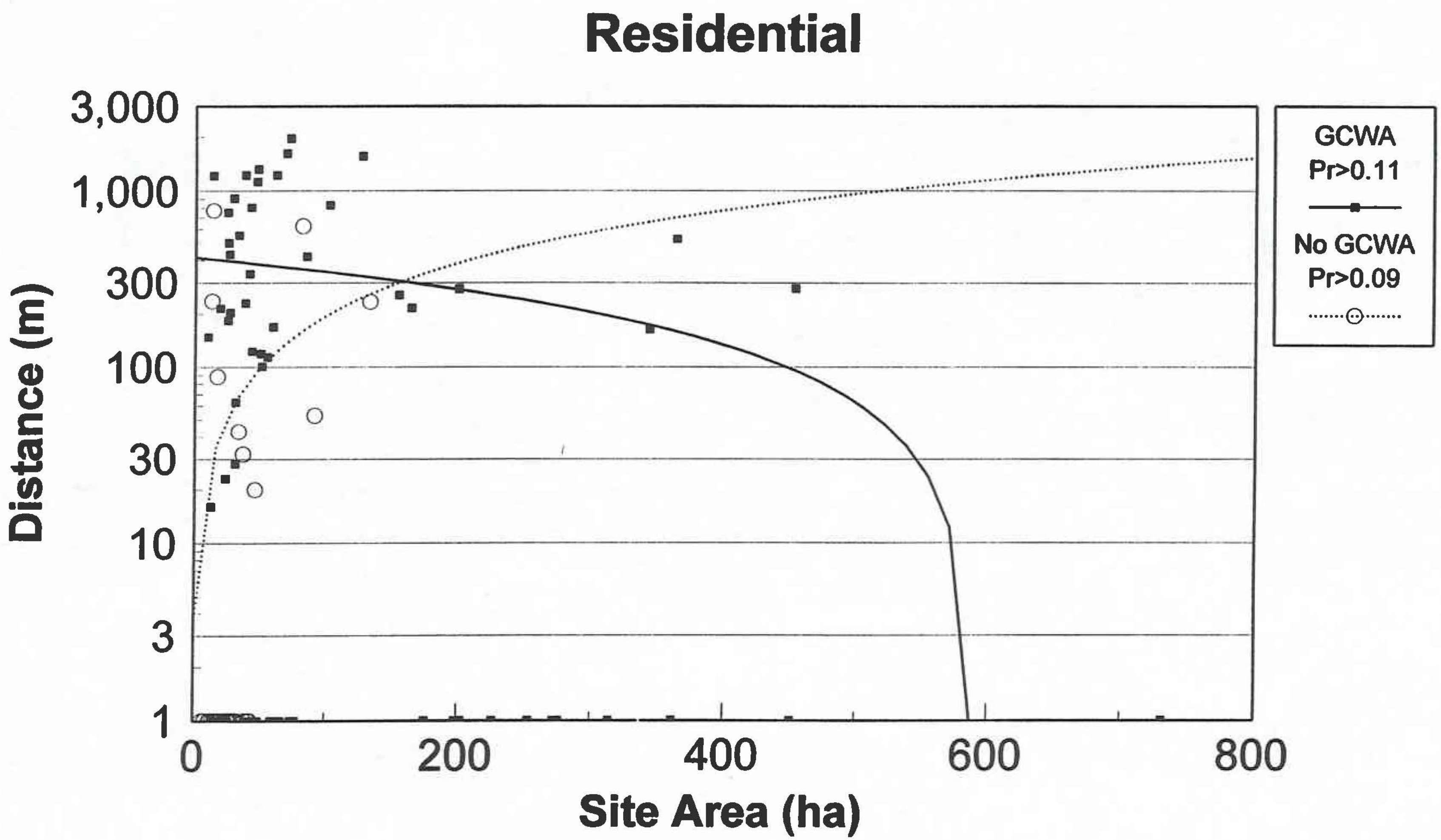



Figure 4

# American Crow

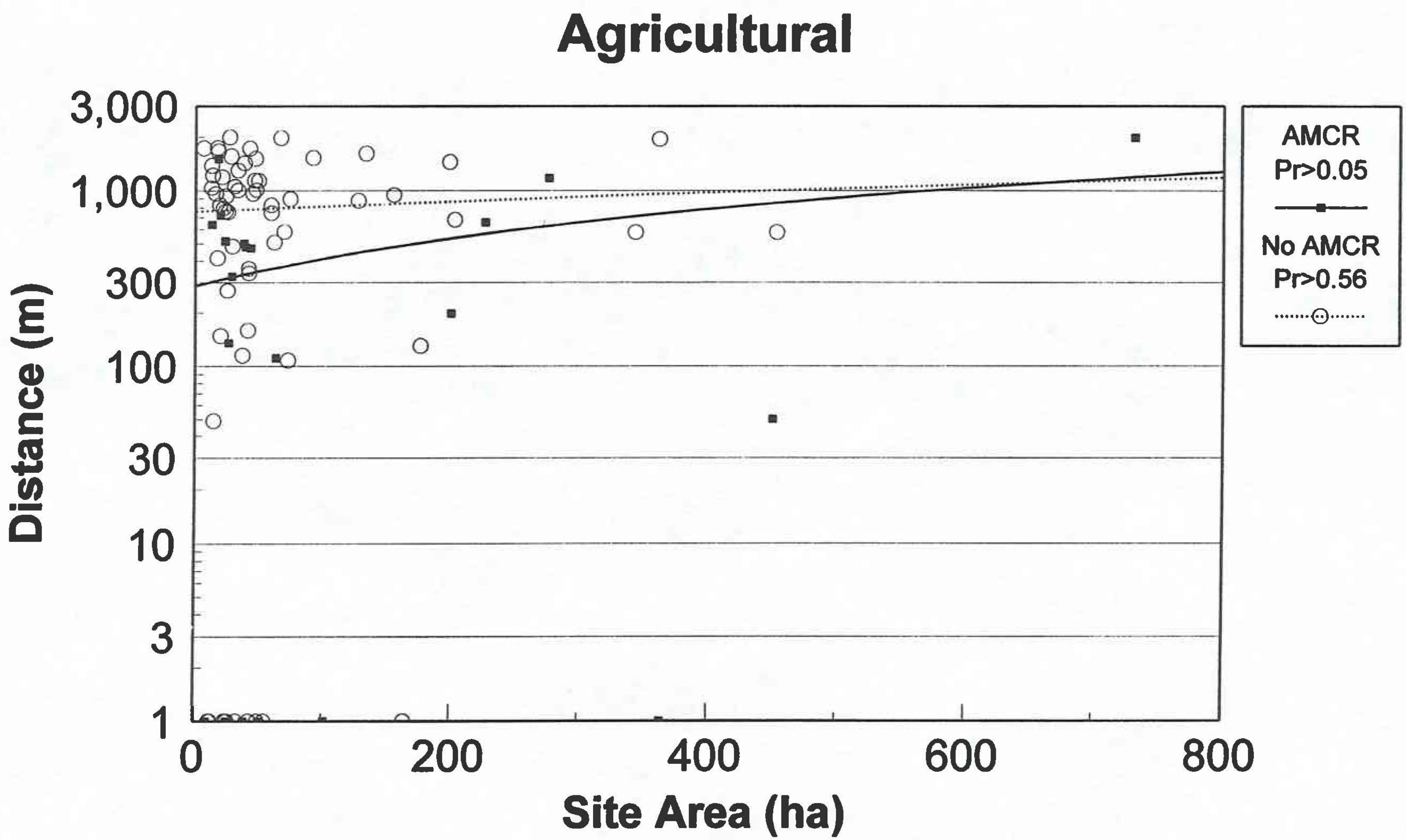



Figure 5

# American Crow

## Commercial

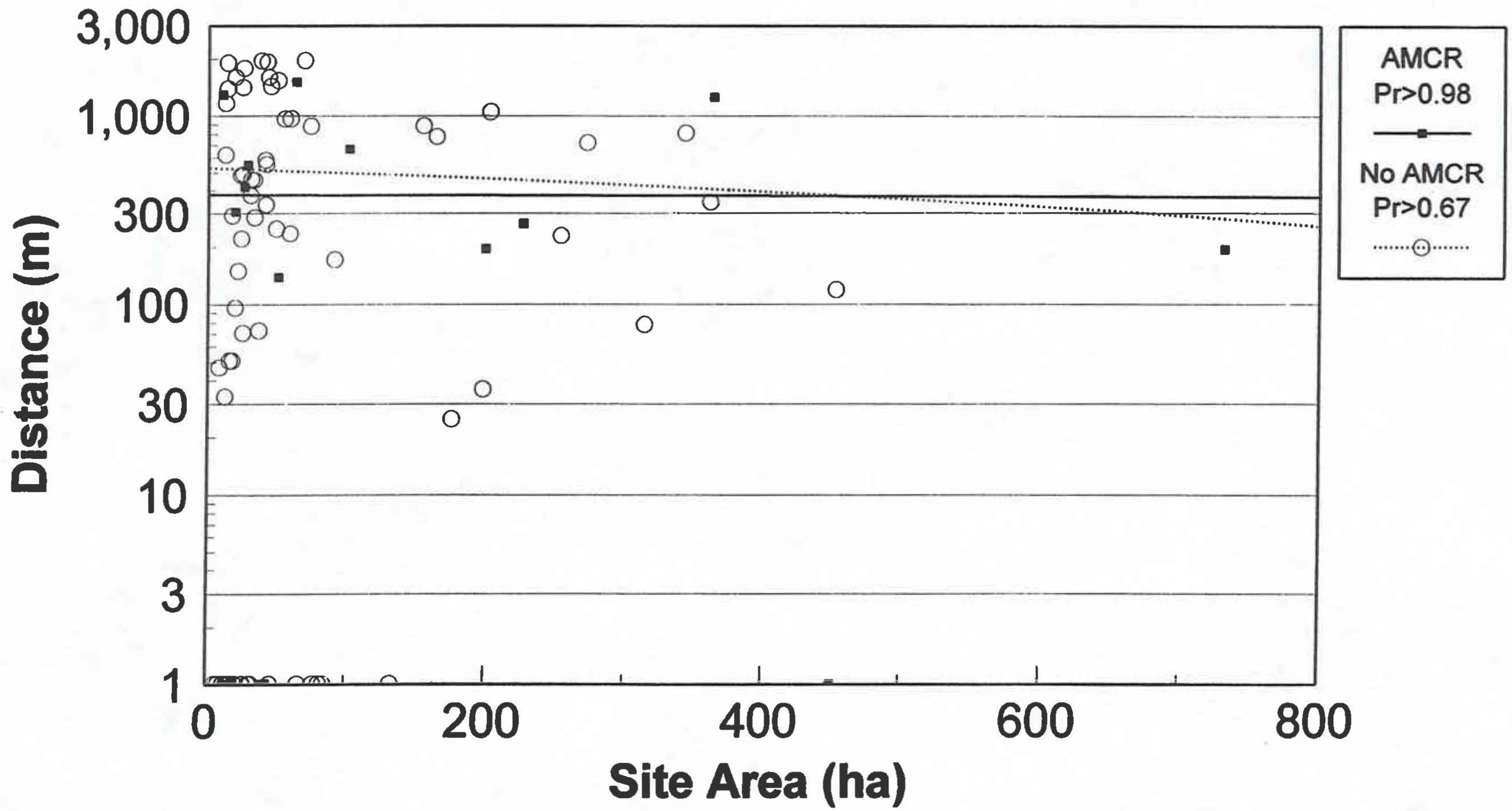



Figure 6

# American Crow

## Industrial

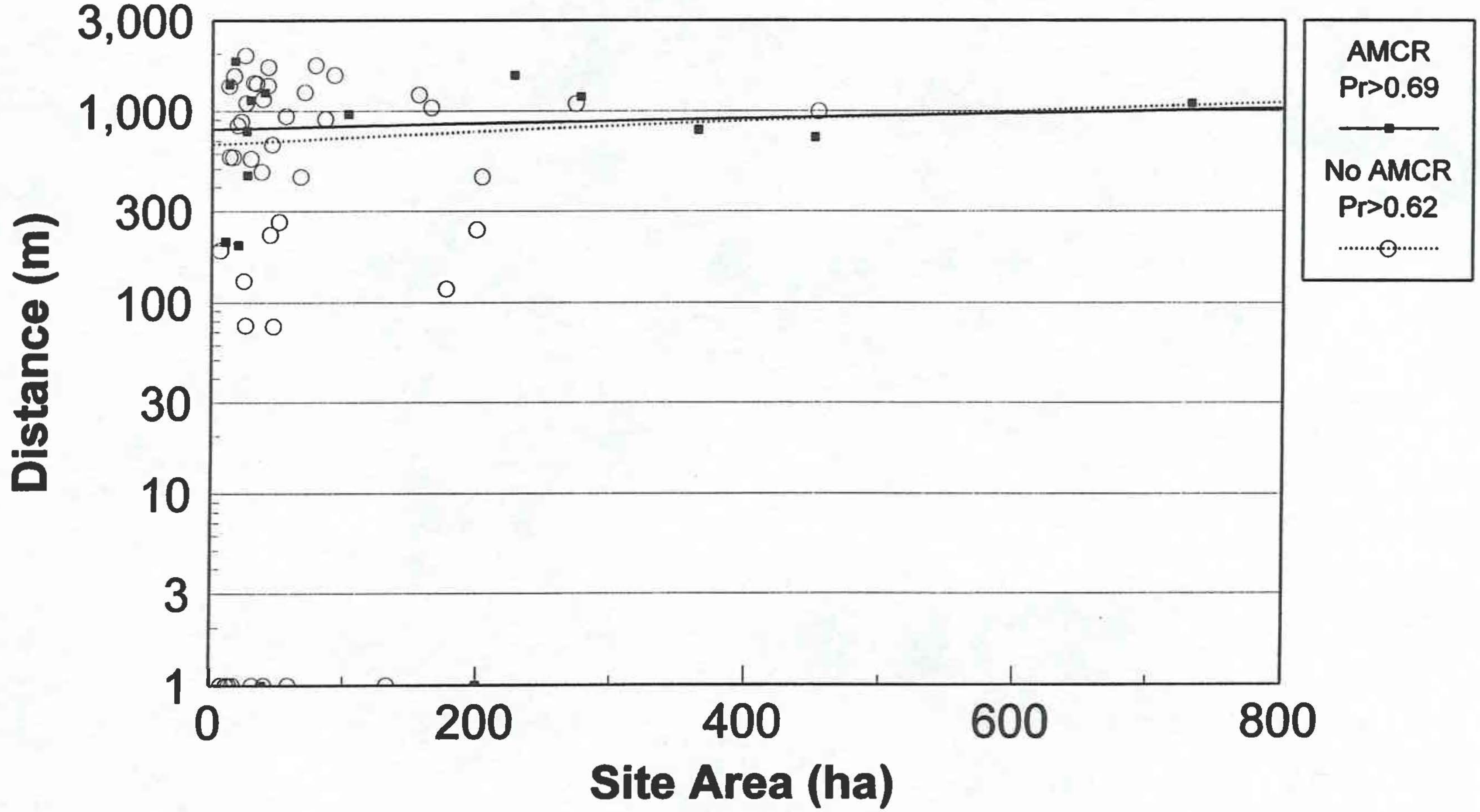



Figure 7

# American Crow

## Residential

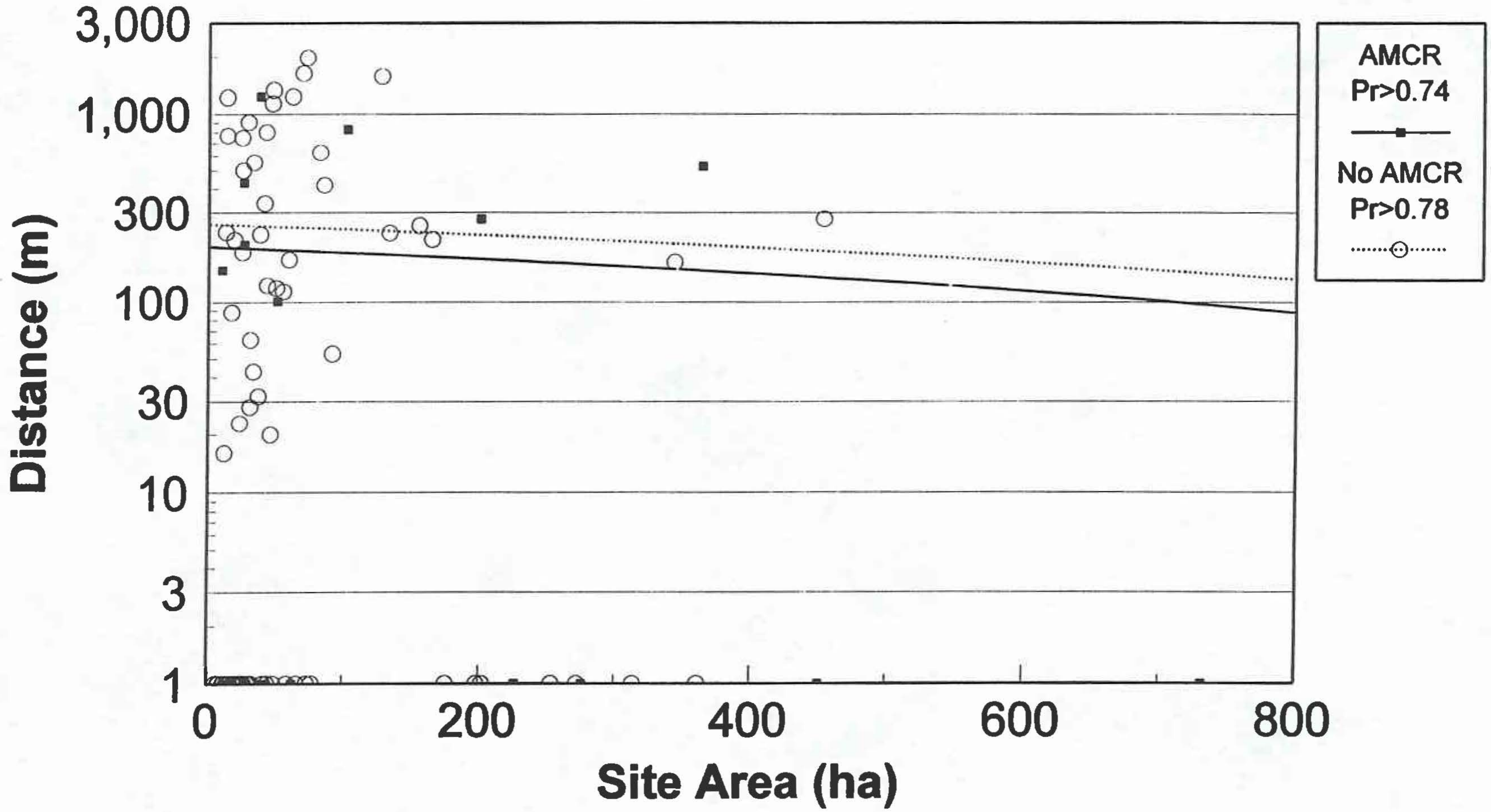



Figure 8

# Blue Jay

## Agricultural

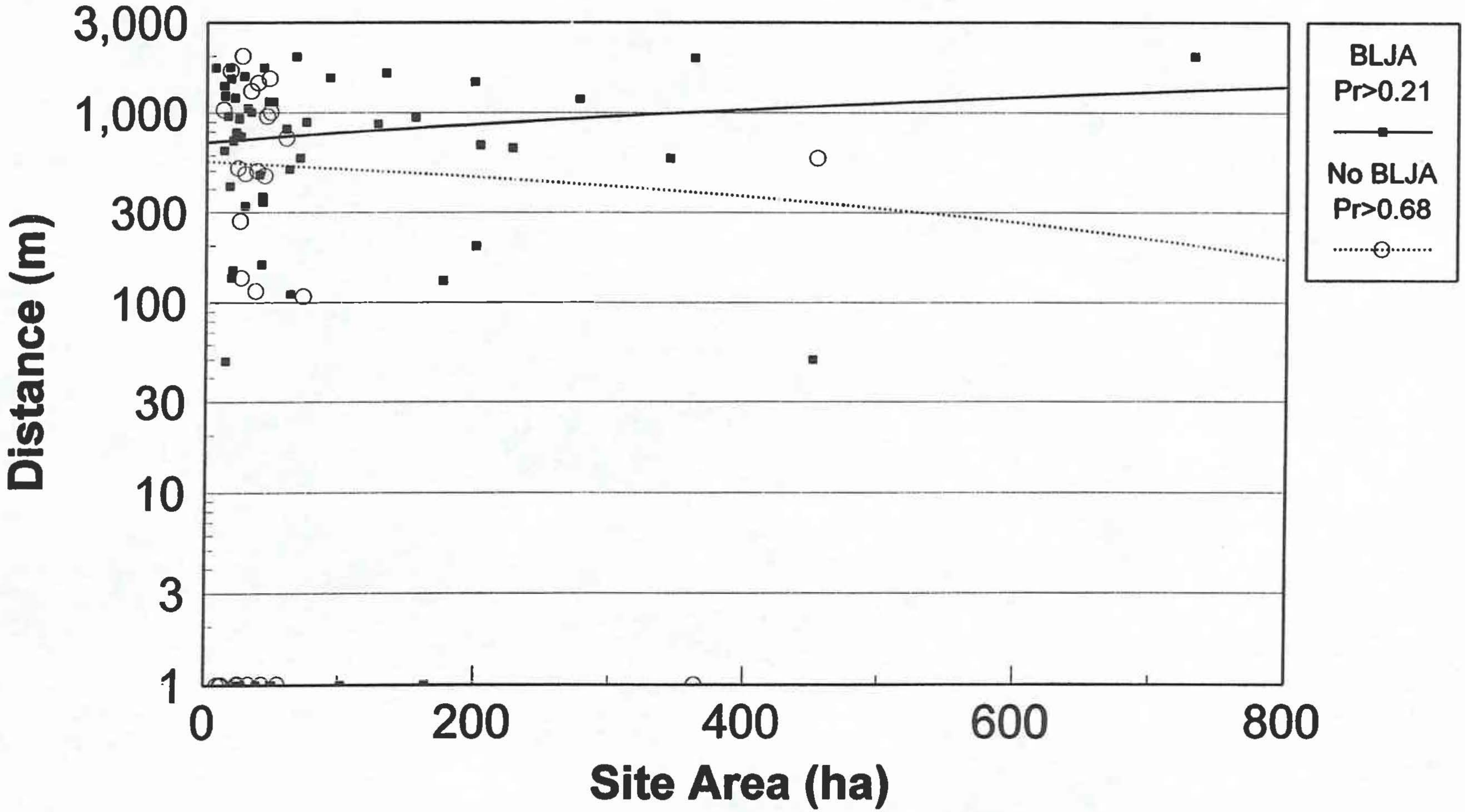



Figure 9

# Blue Jay

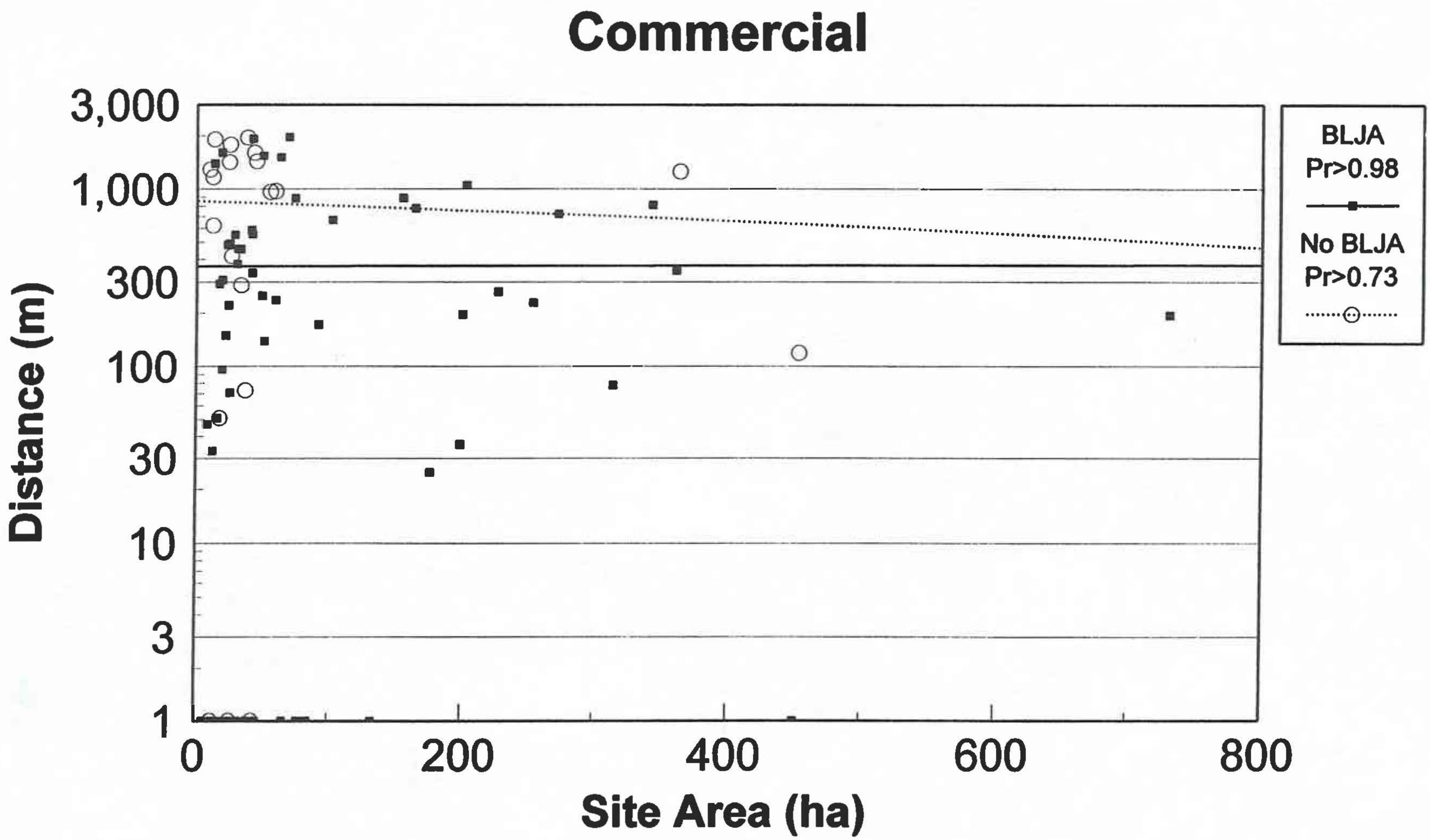



Figure 10

# Blue Jay

## Industrial

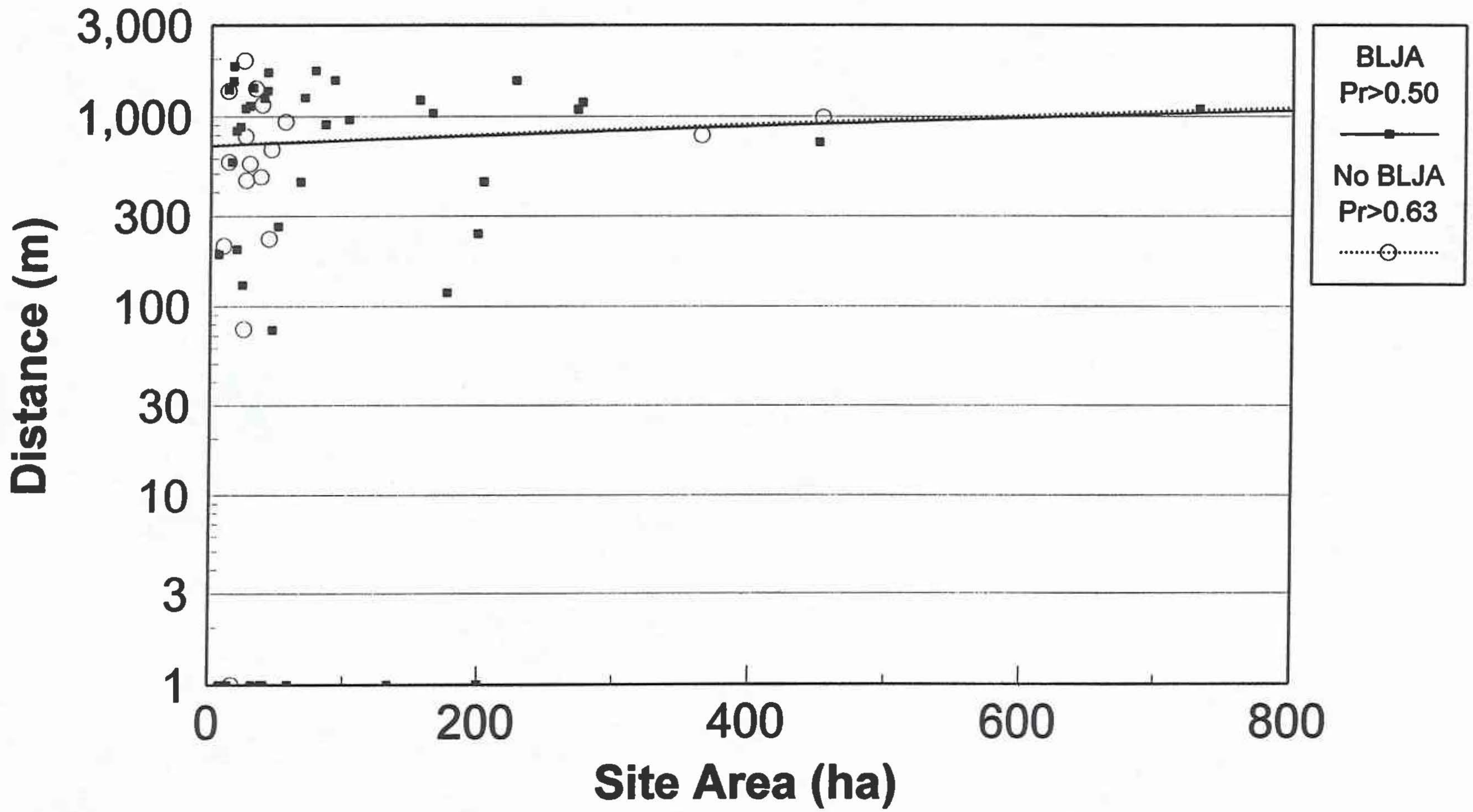



Figure 11

# Blue Jay

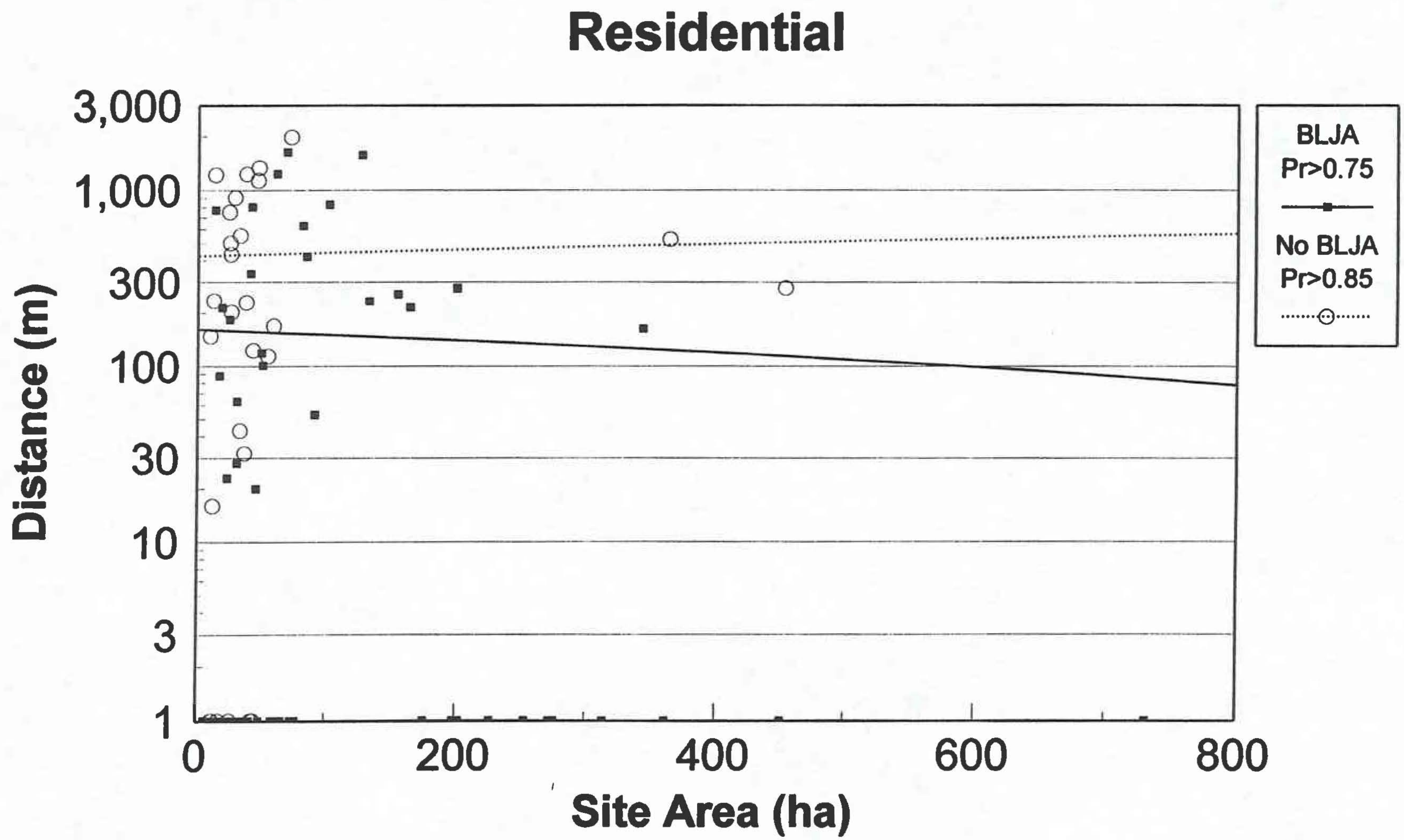



Figure 12

# Brown-headed Cowbird

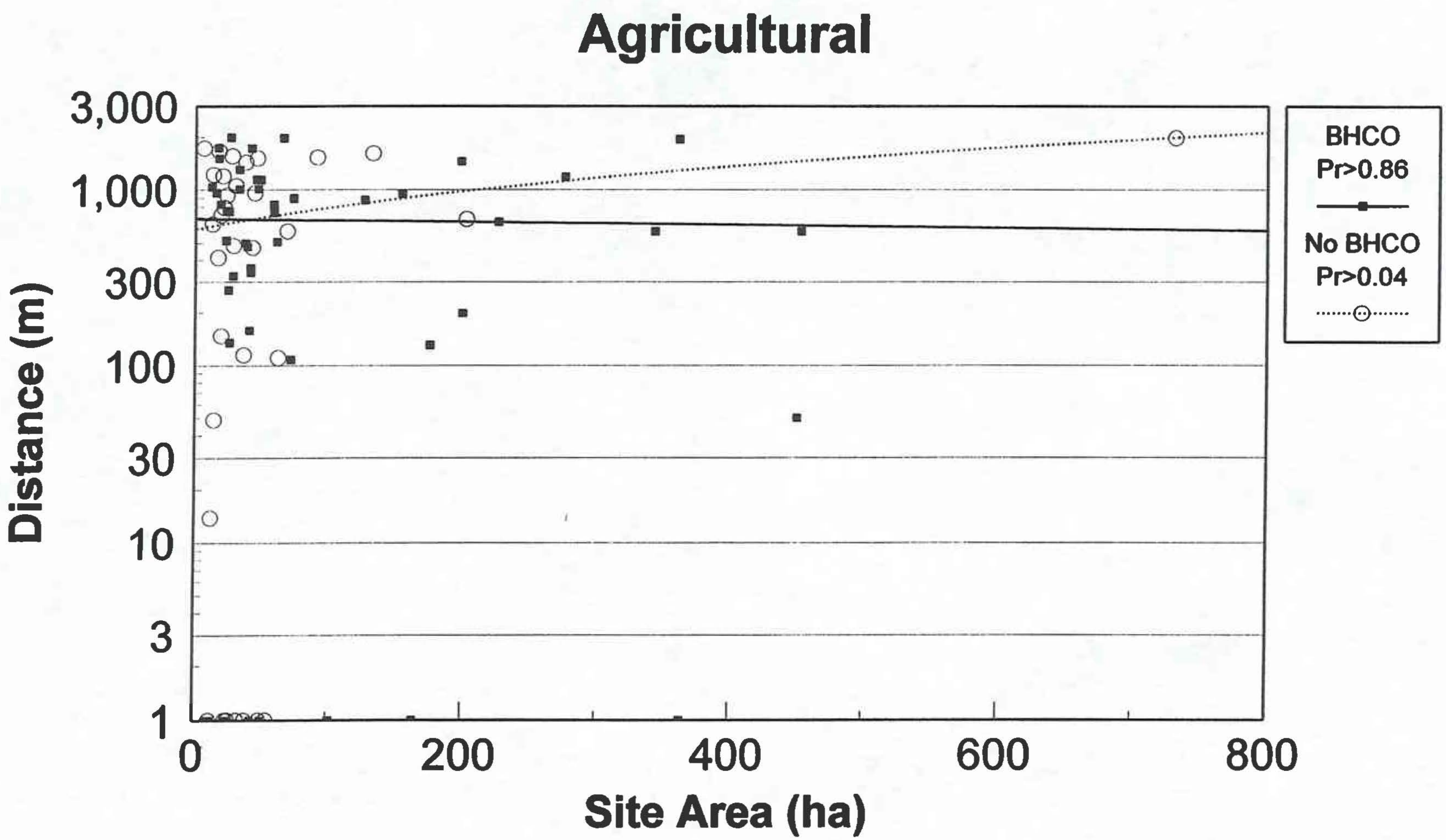



Figure 13

# Brown-headed Cowbird

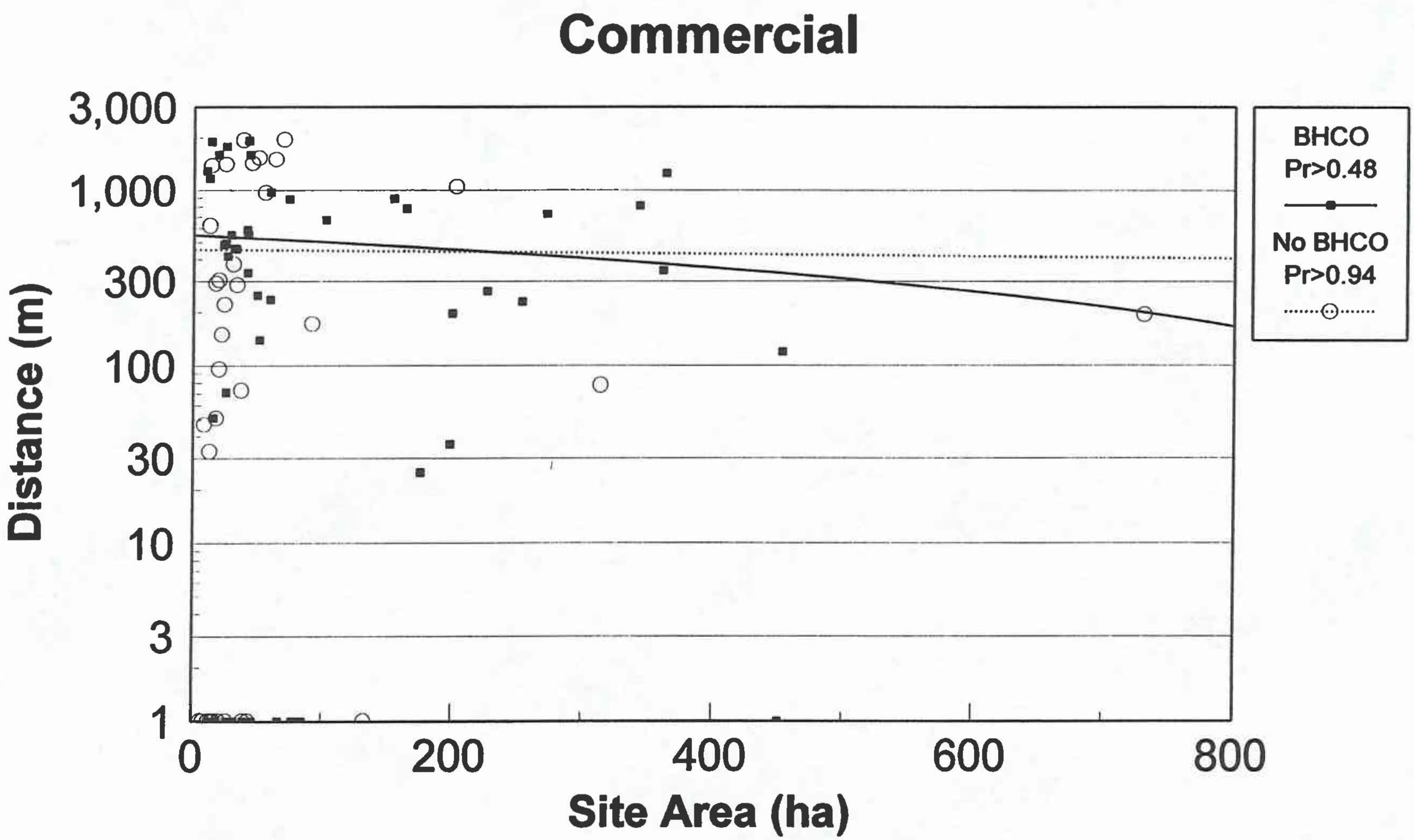



Figure 14

# Brown-headed Cowbird

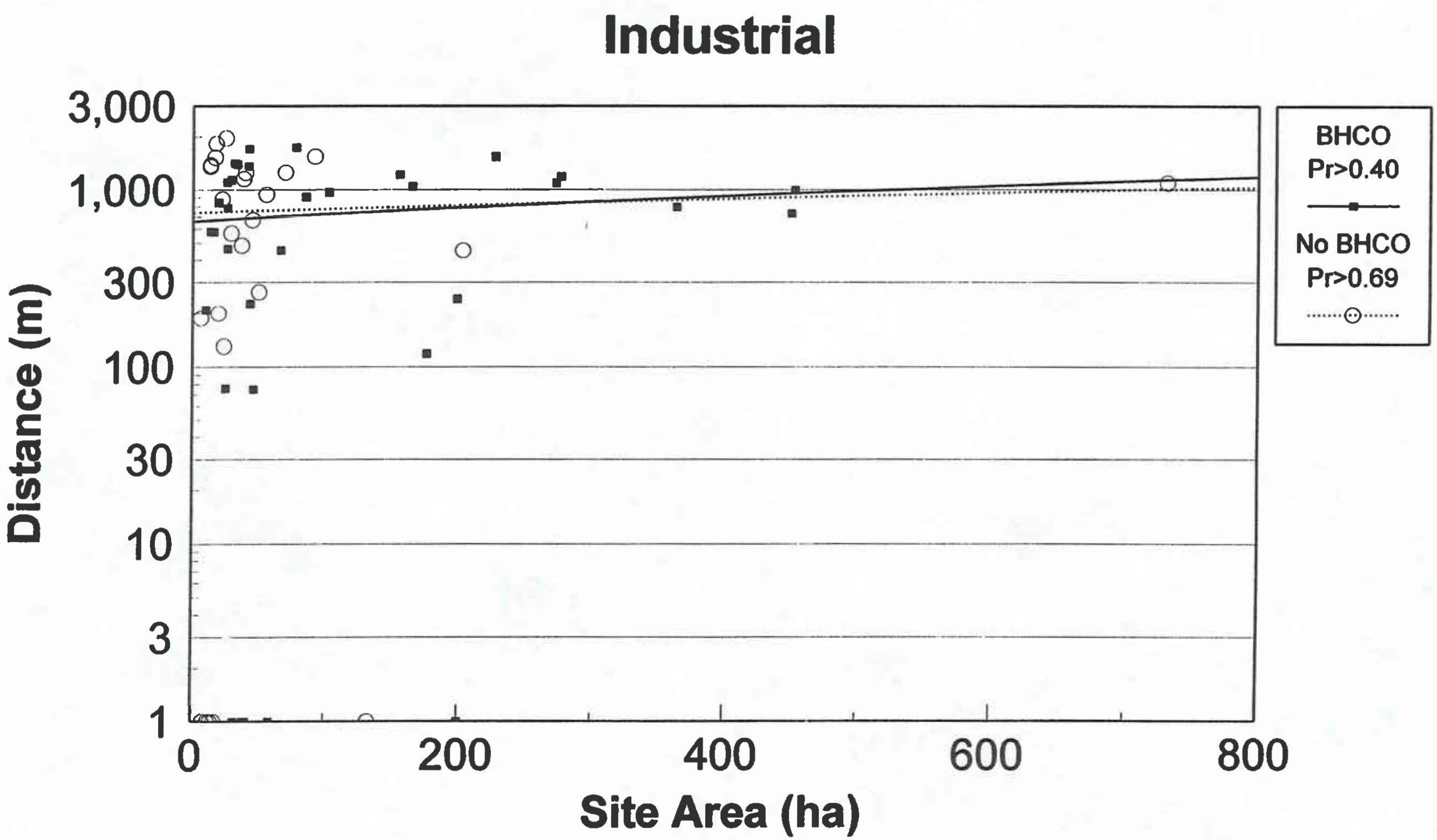



Figure 15

# Brown-headed Cowbird

## Residential

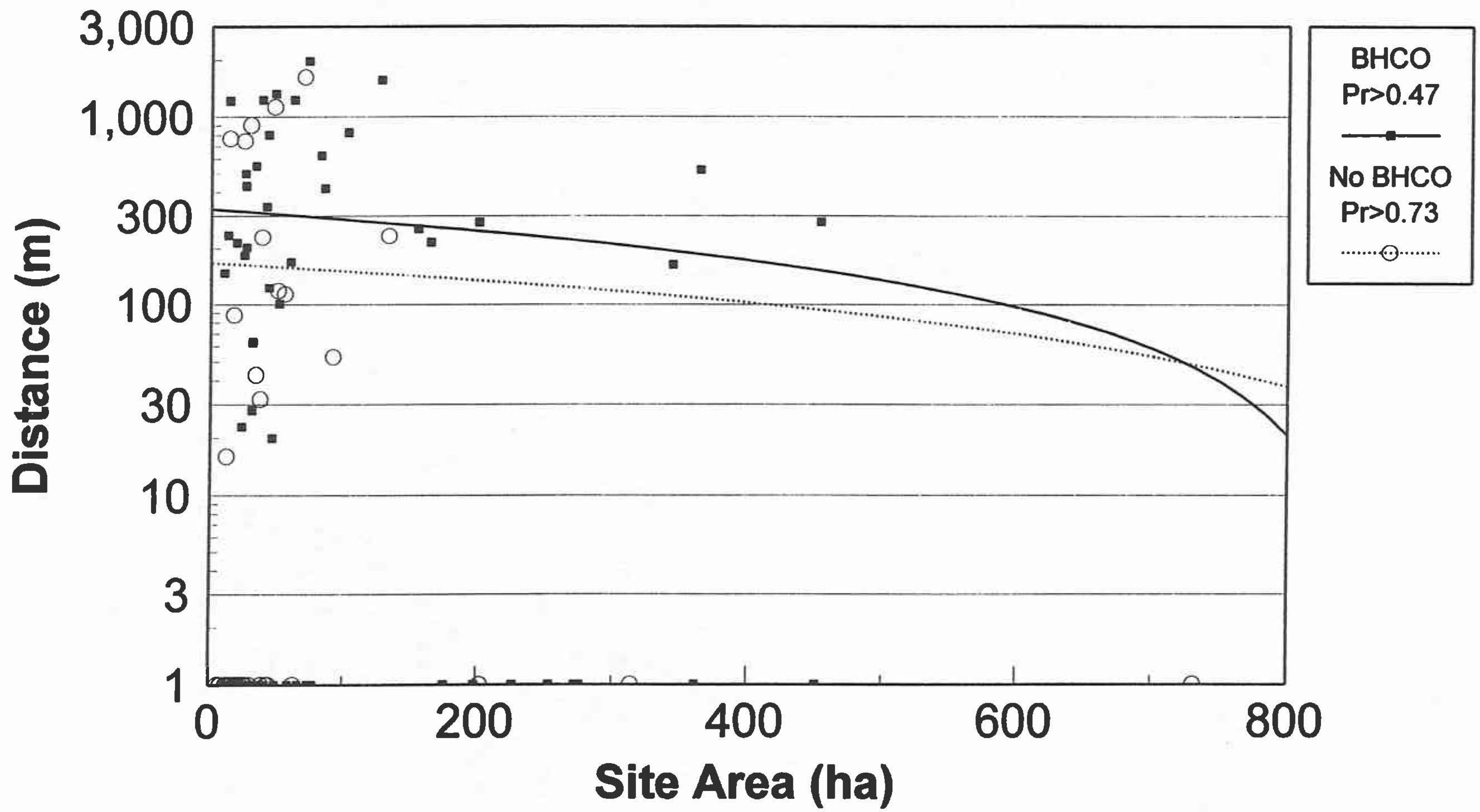



Figure 16

# Common Grackle

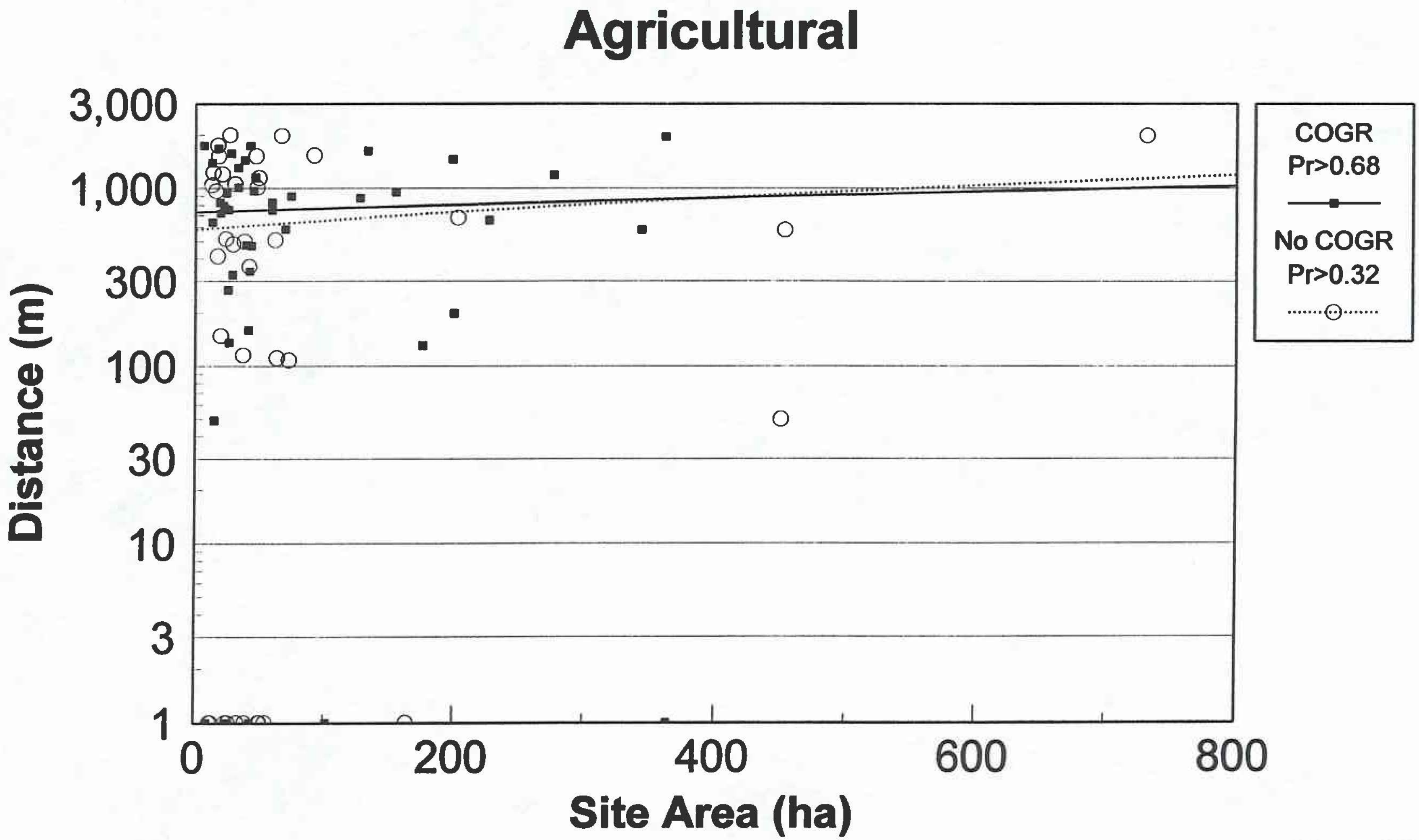



Figure 17

# Common Grackle

## Commercial

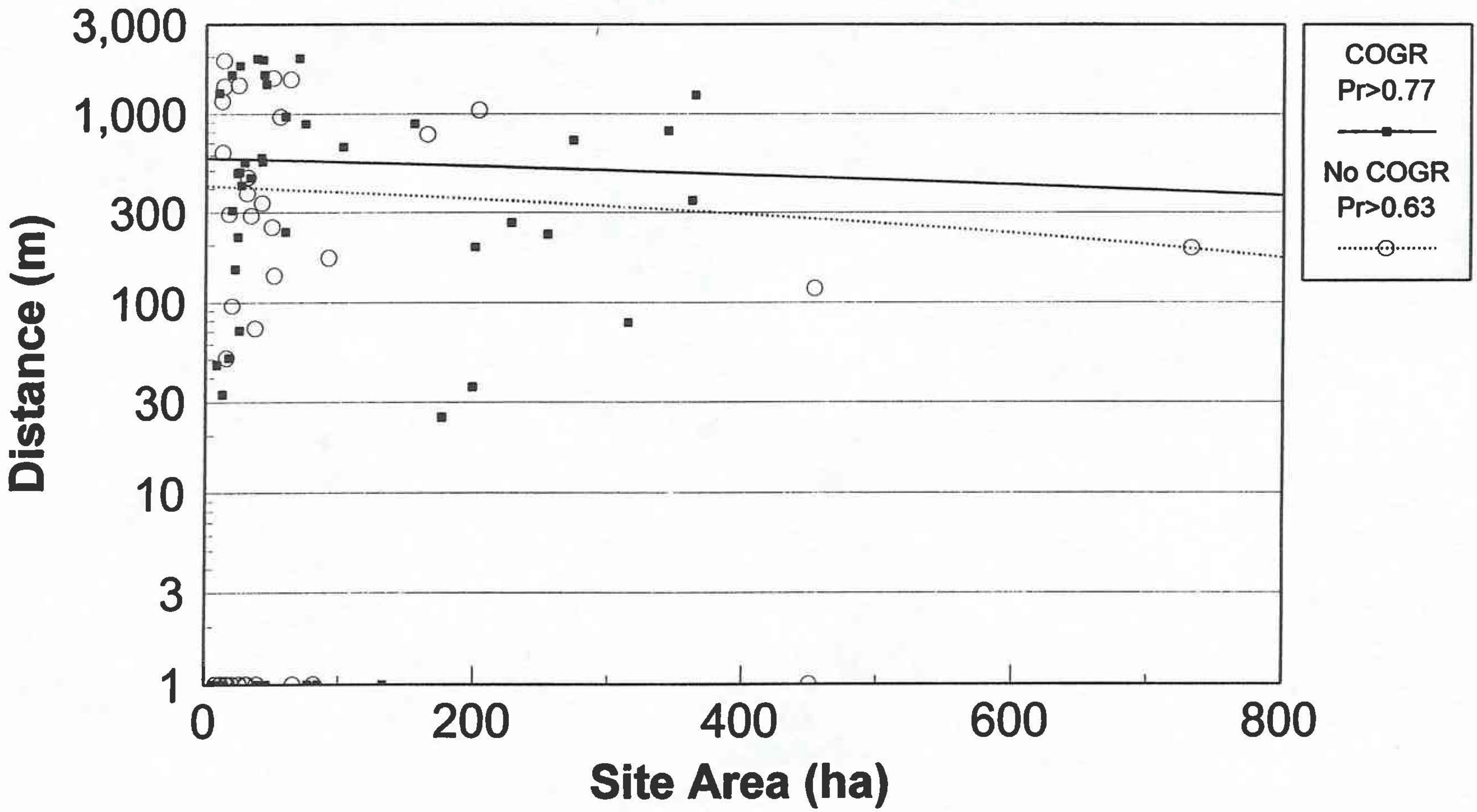



Figure 18

# Common Grackle

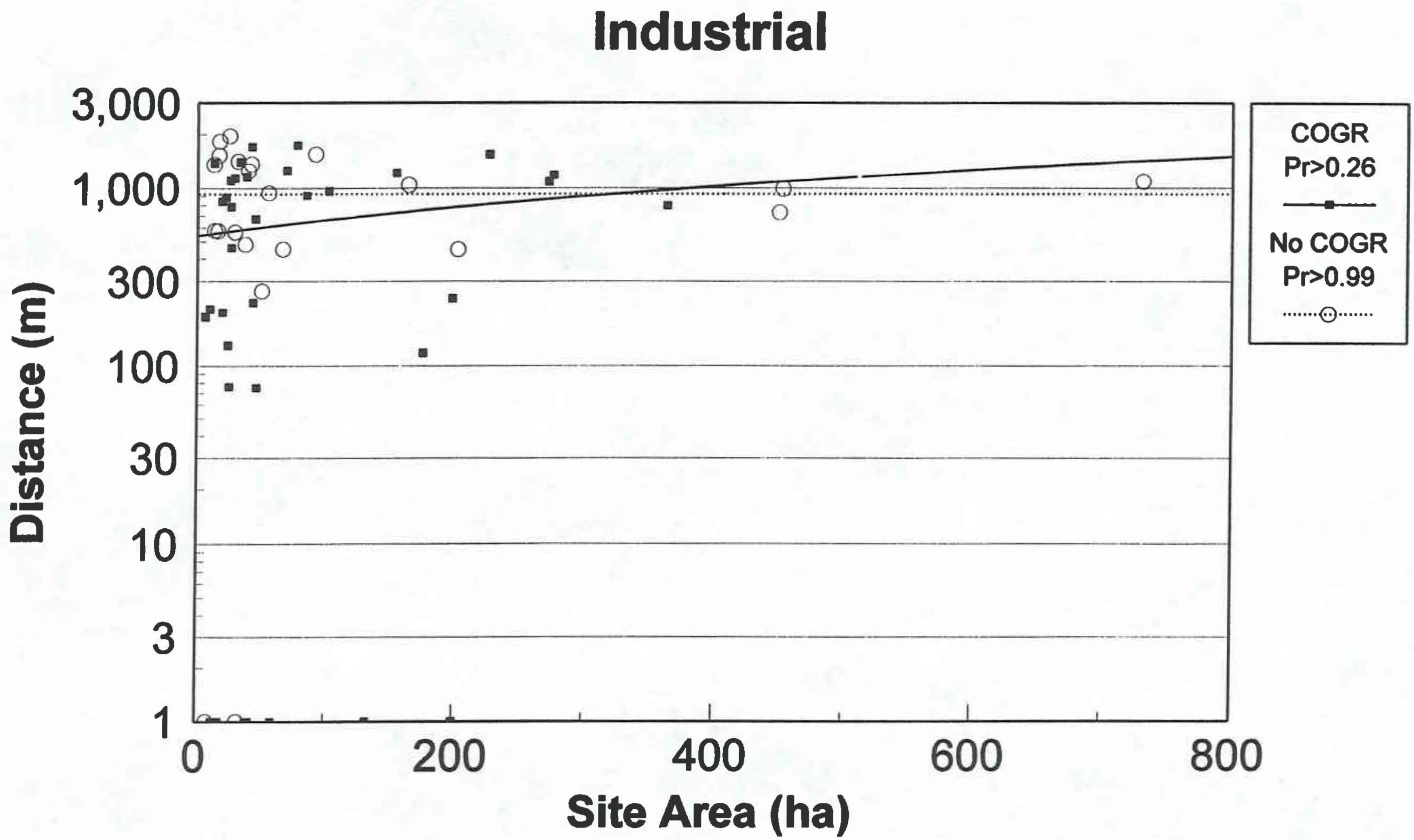



Figure 19

# Common Grackle

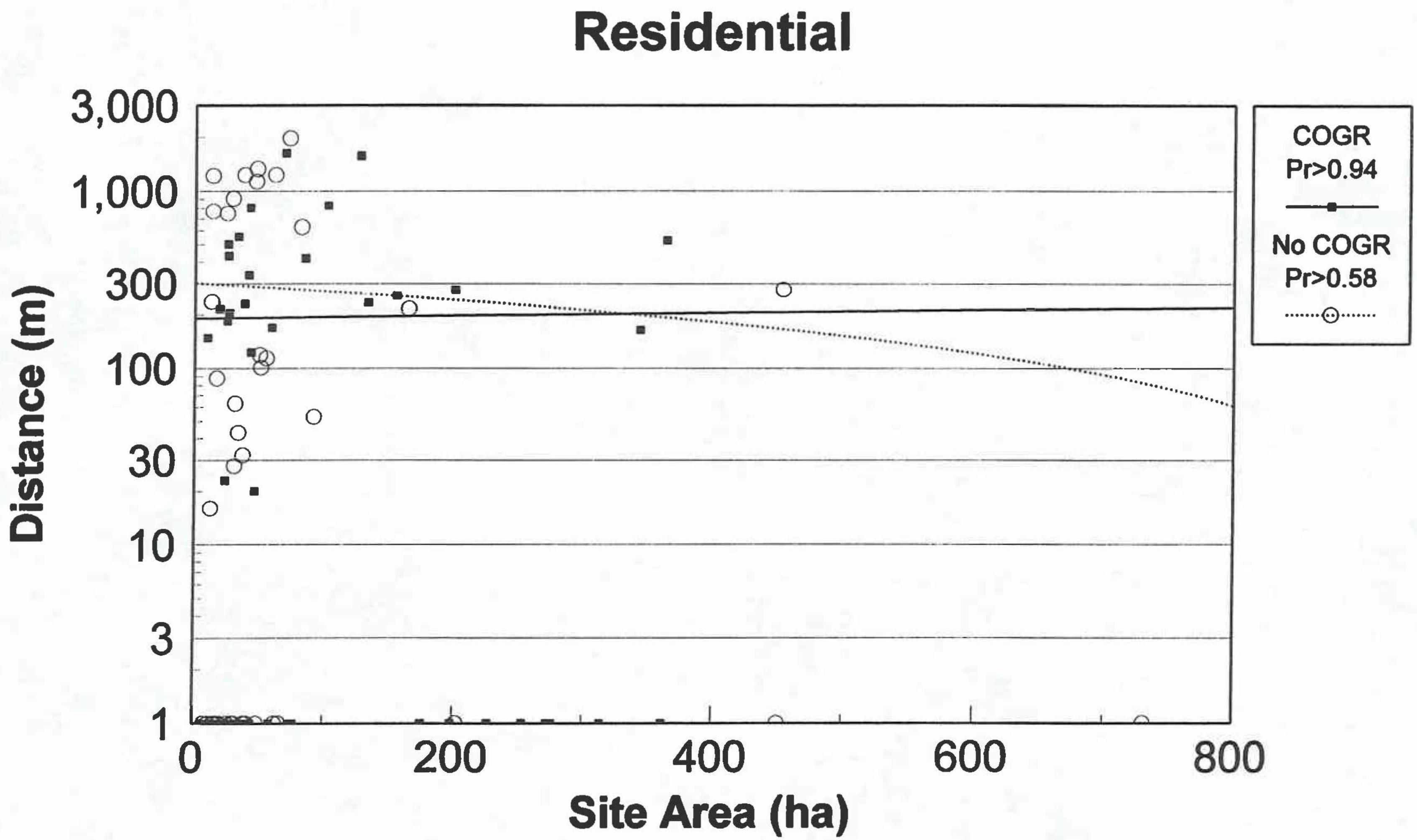



Figure 20

# Greater Roadrunner

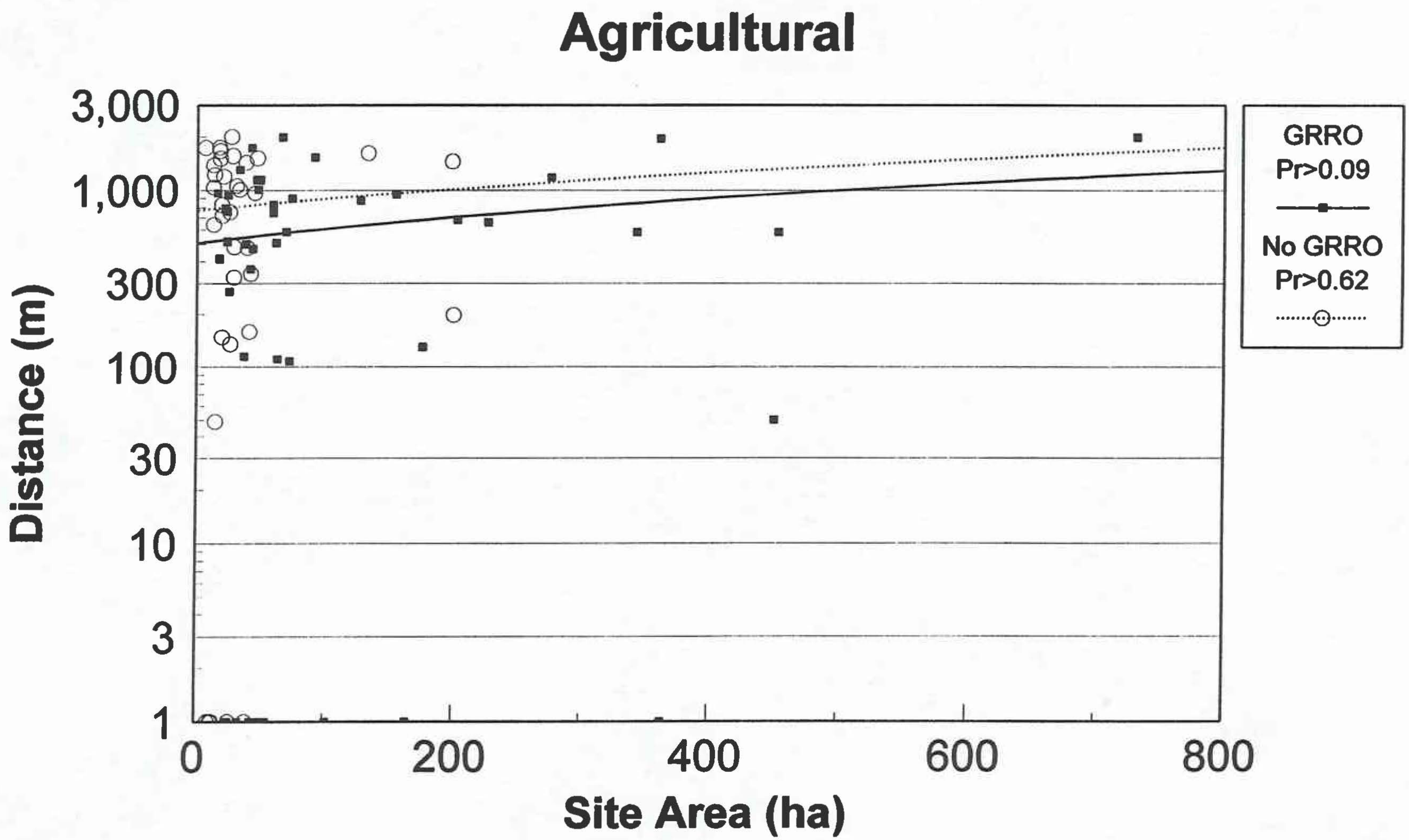



Figure 21

# Greater Roadrunner

## Commercial

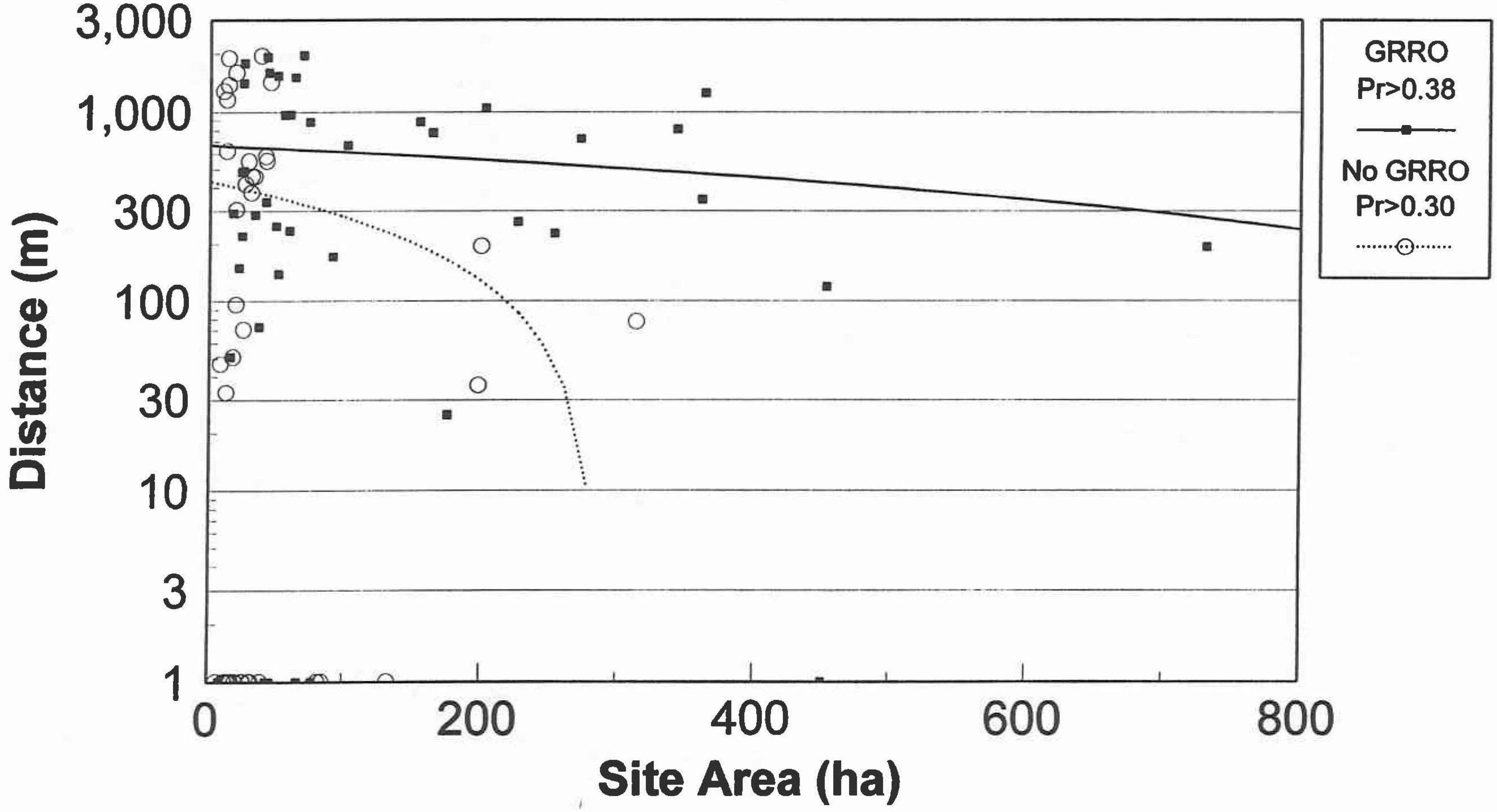



Figure 22

# Greater Roadrunner

## Industrial

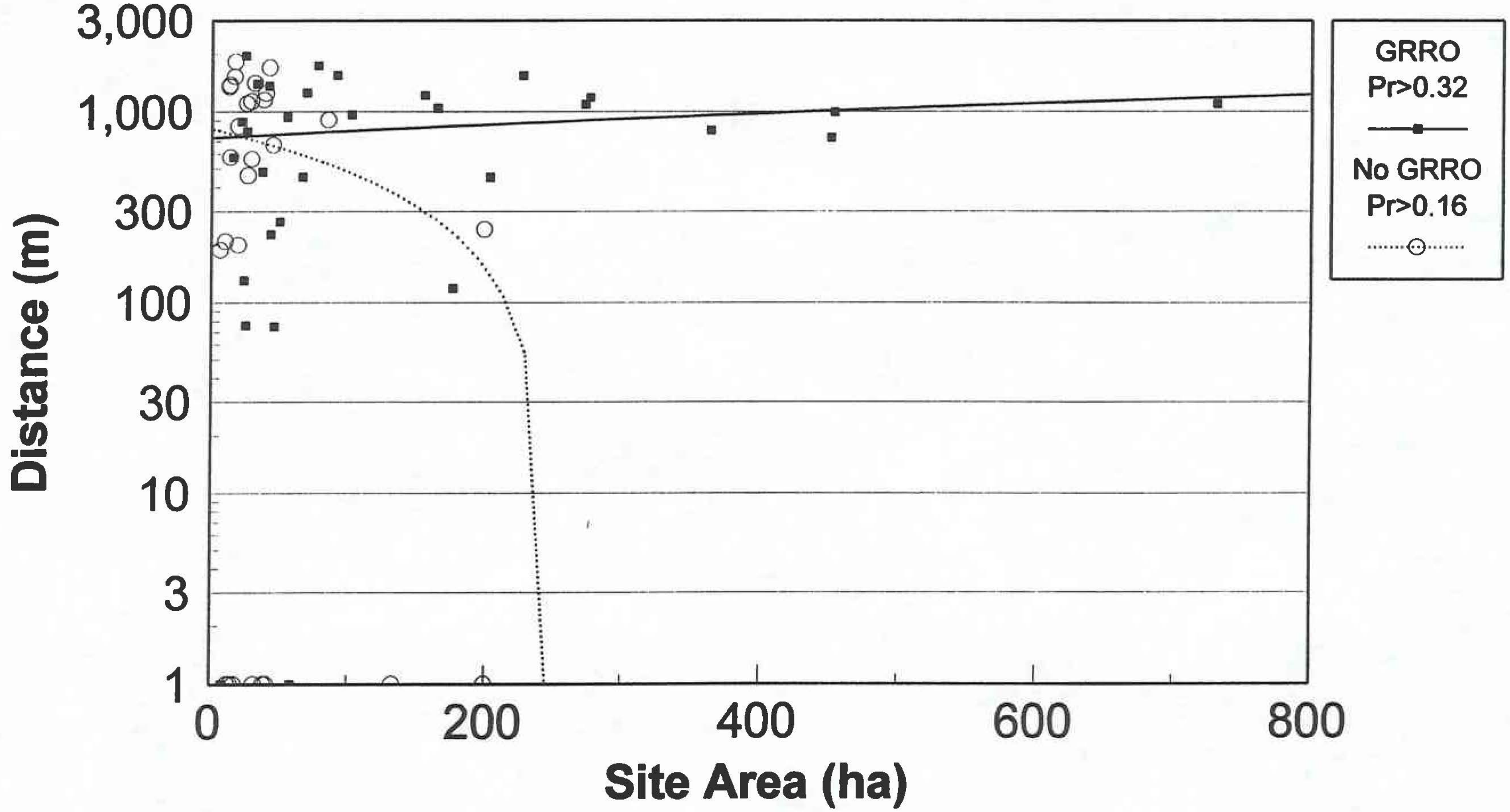



Figure 23

# Greater Roadrunner

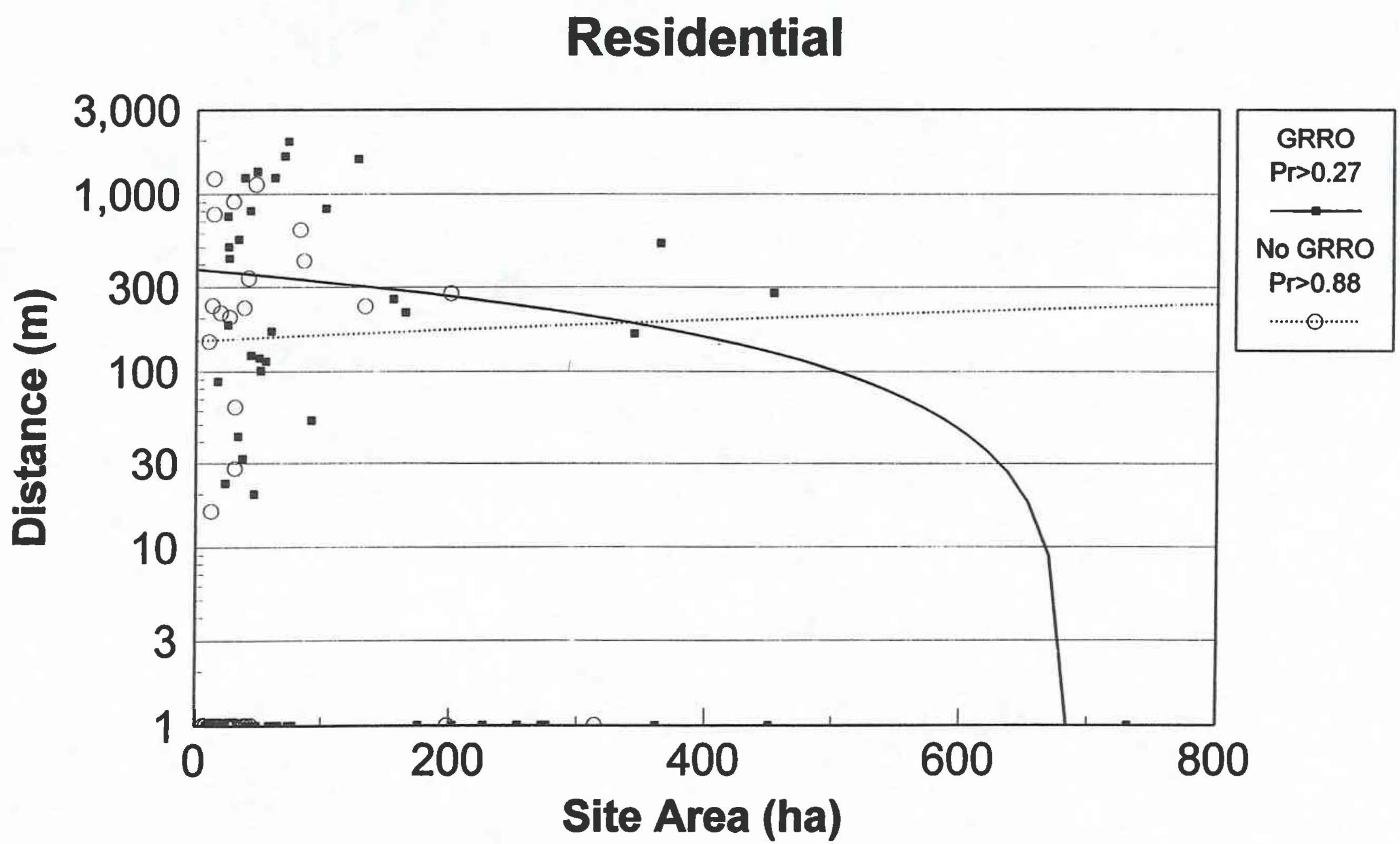



Figure 24

# Great-tailed Grackle

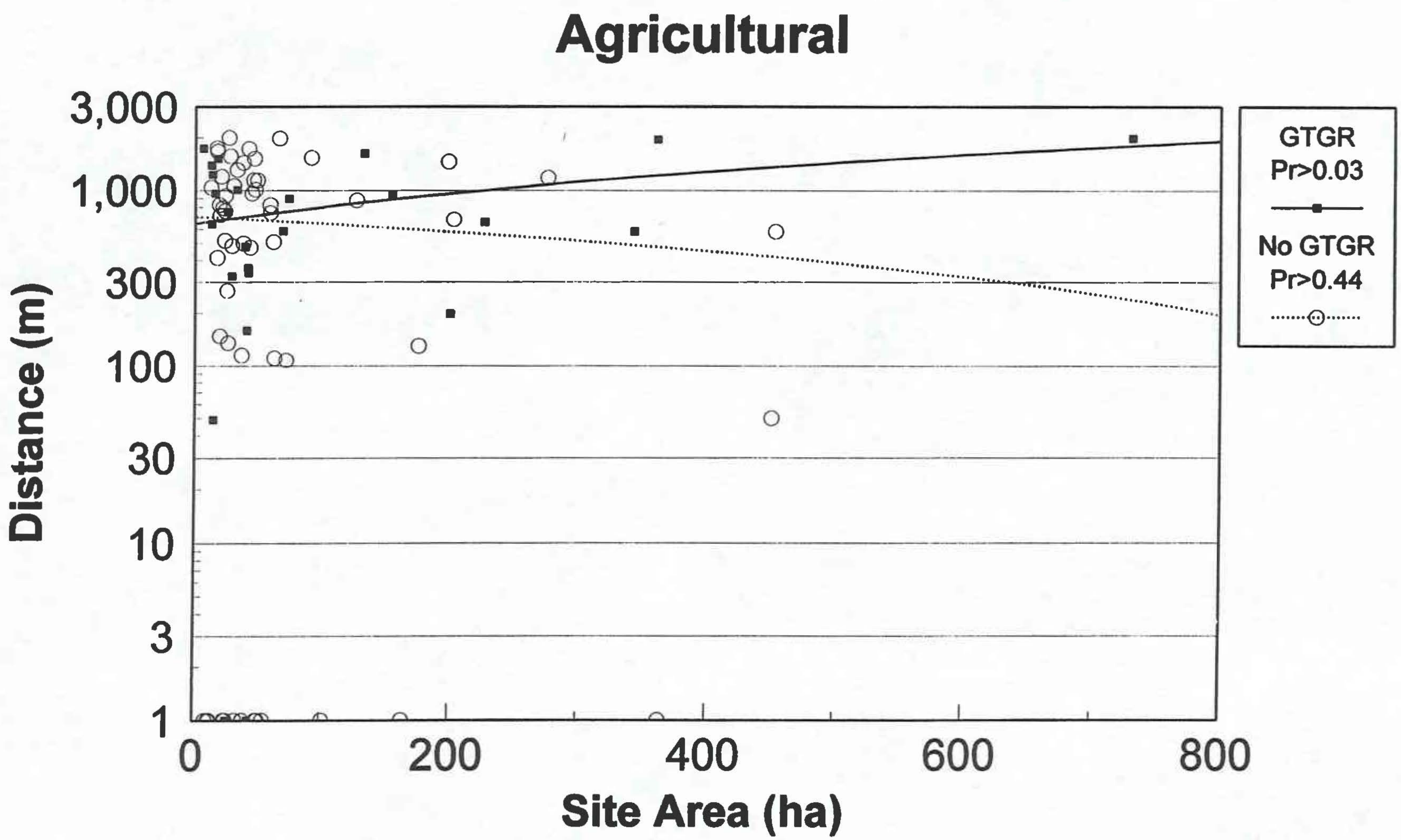



Figure 25

# Great-tailed Grackle

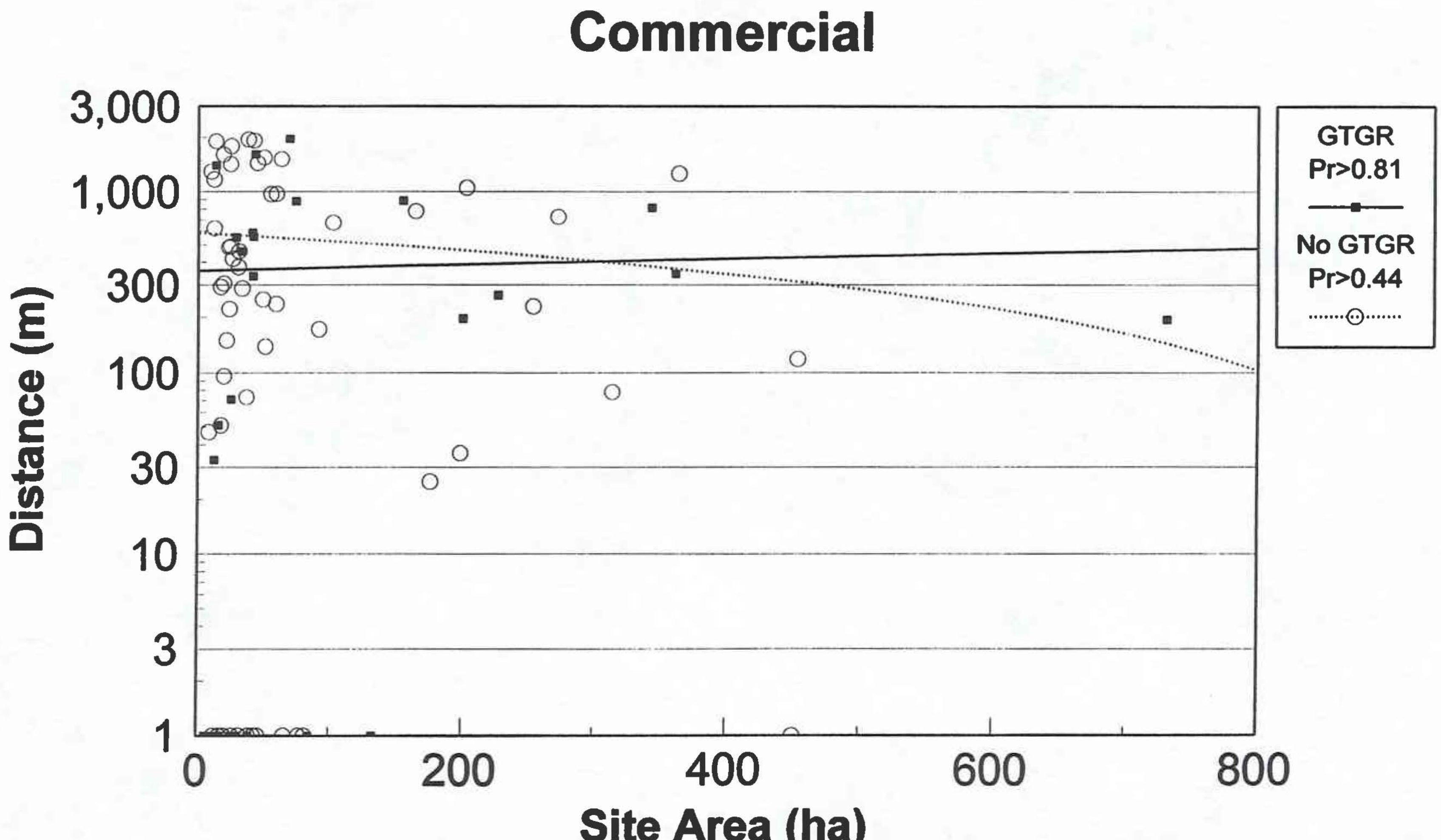



Figure 26

# Great-tailed Grackle

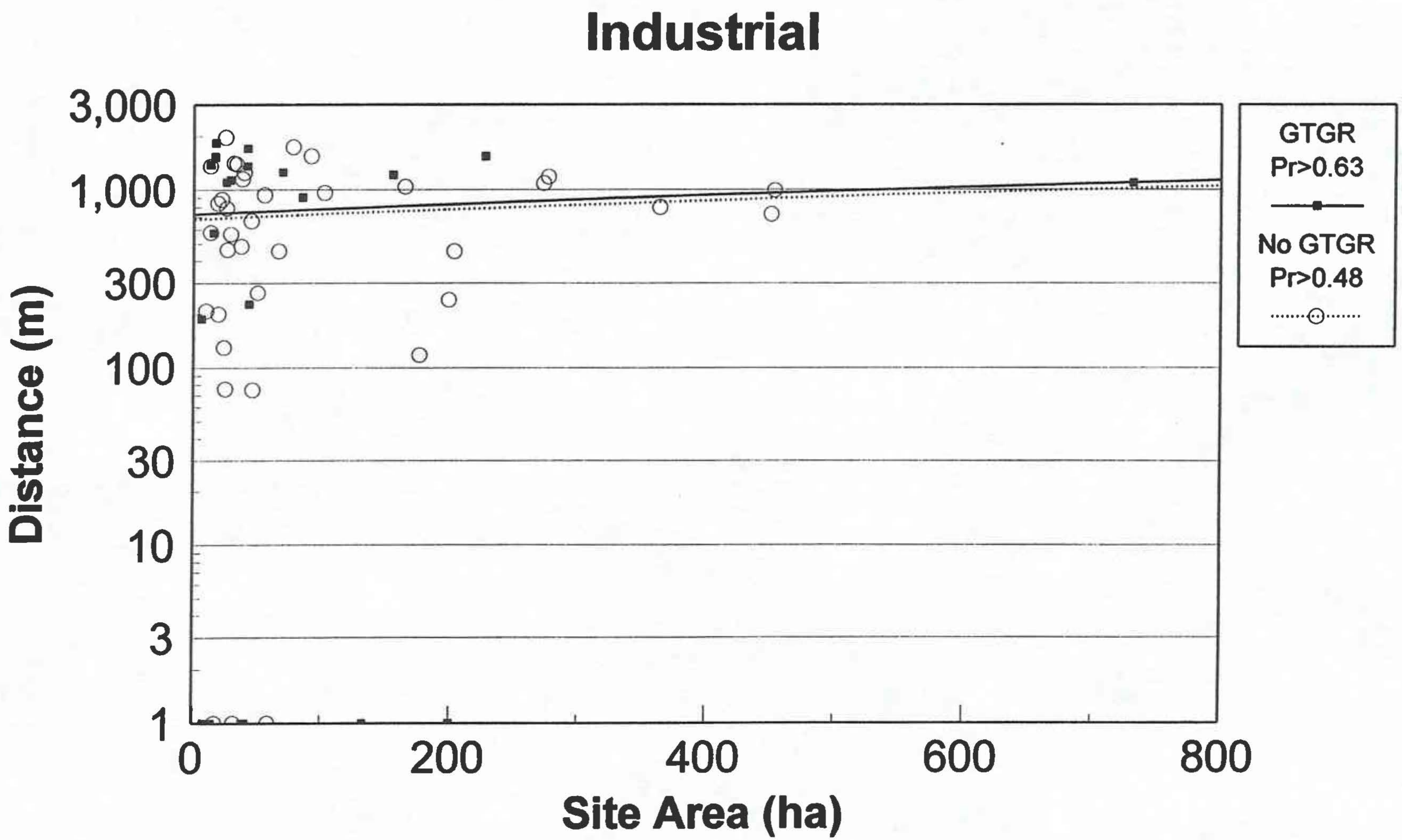



Figure 27

# Great-tailed Grackle

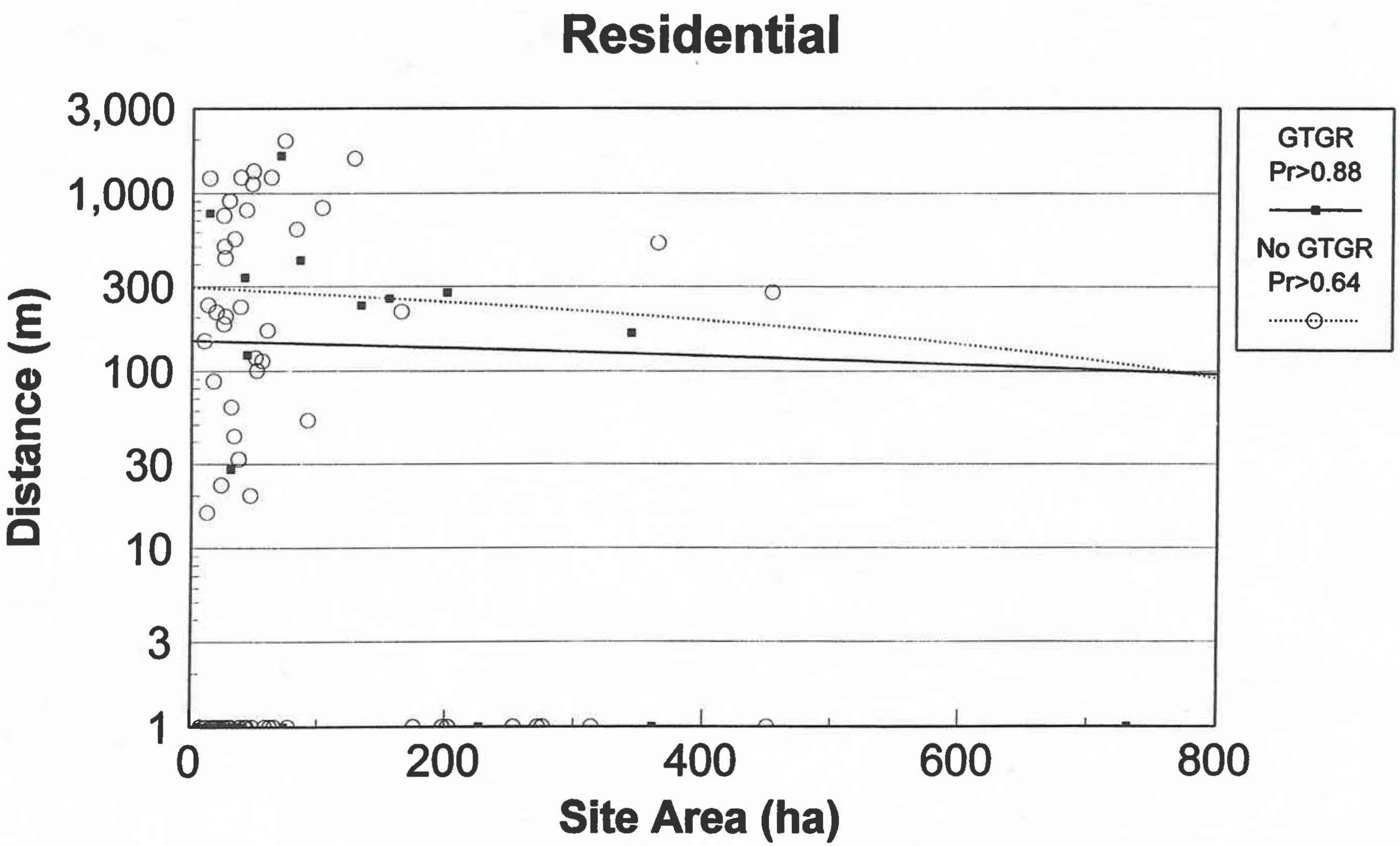



Figure 28

# Red-tailed Hawk

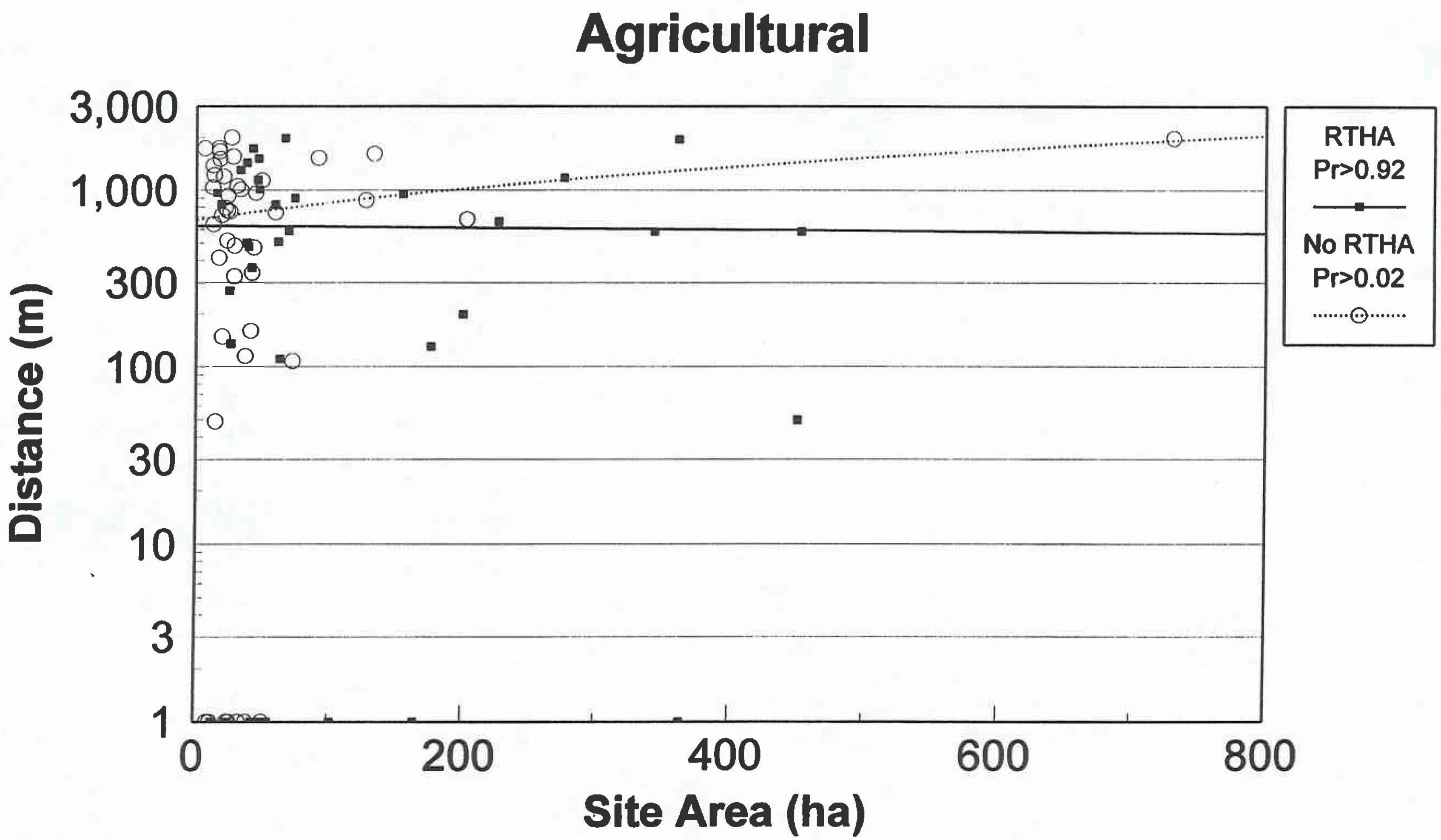



Figure 29

# Red-tailed Hawk

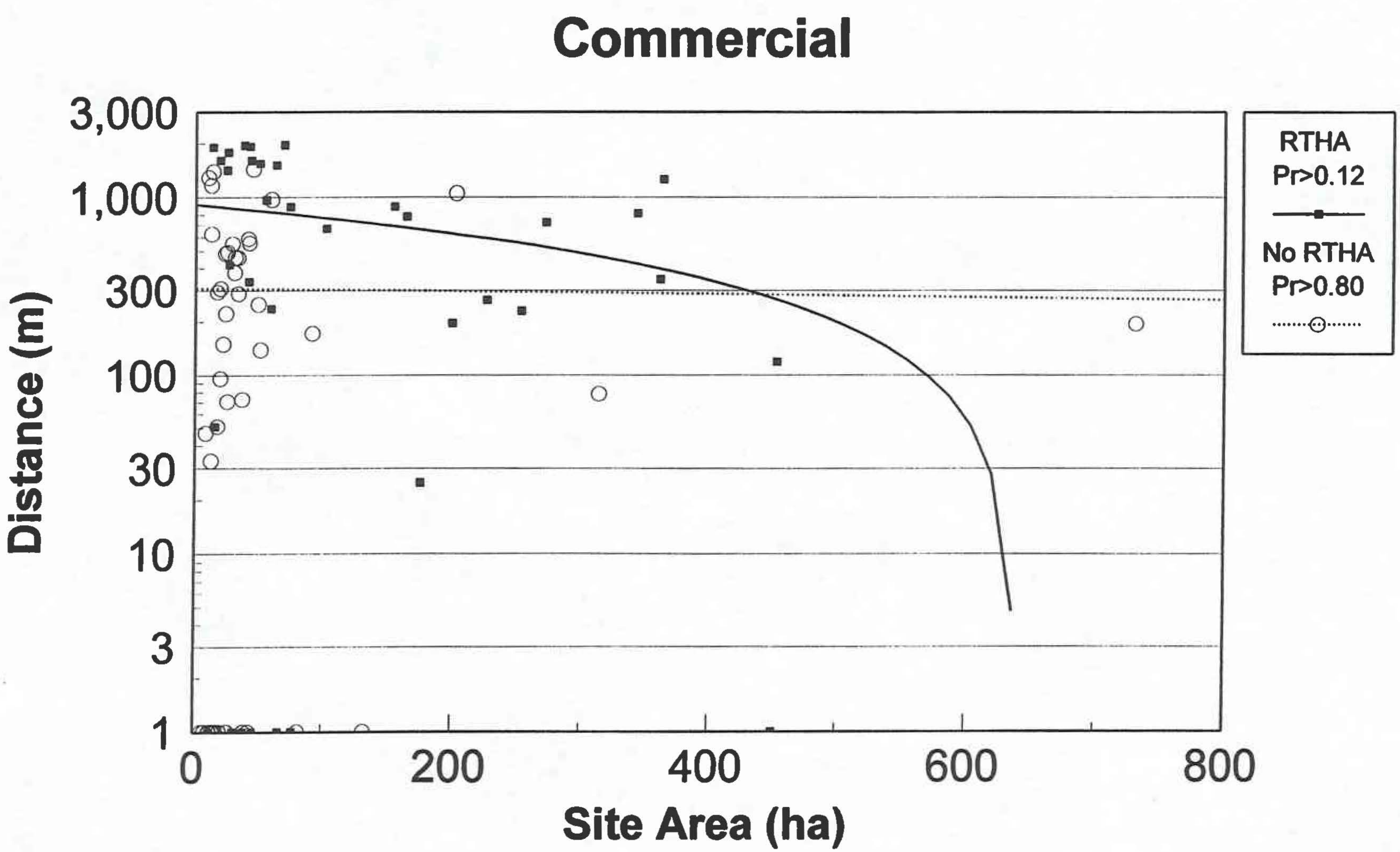



Figure 30

# Red-tailed Hawk

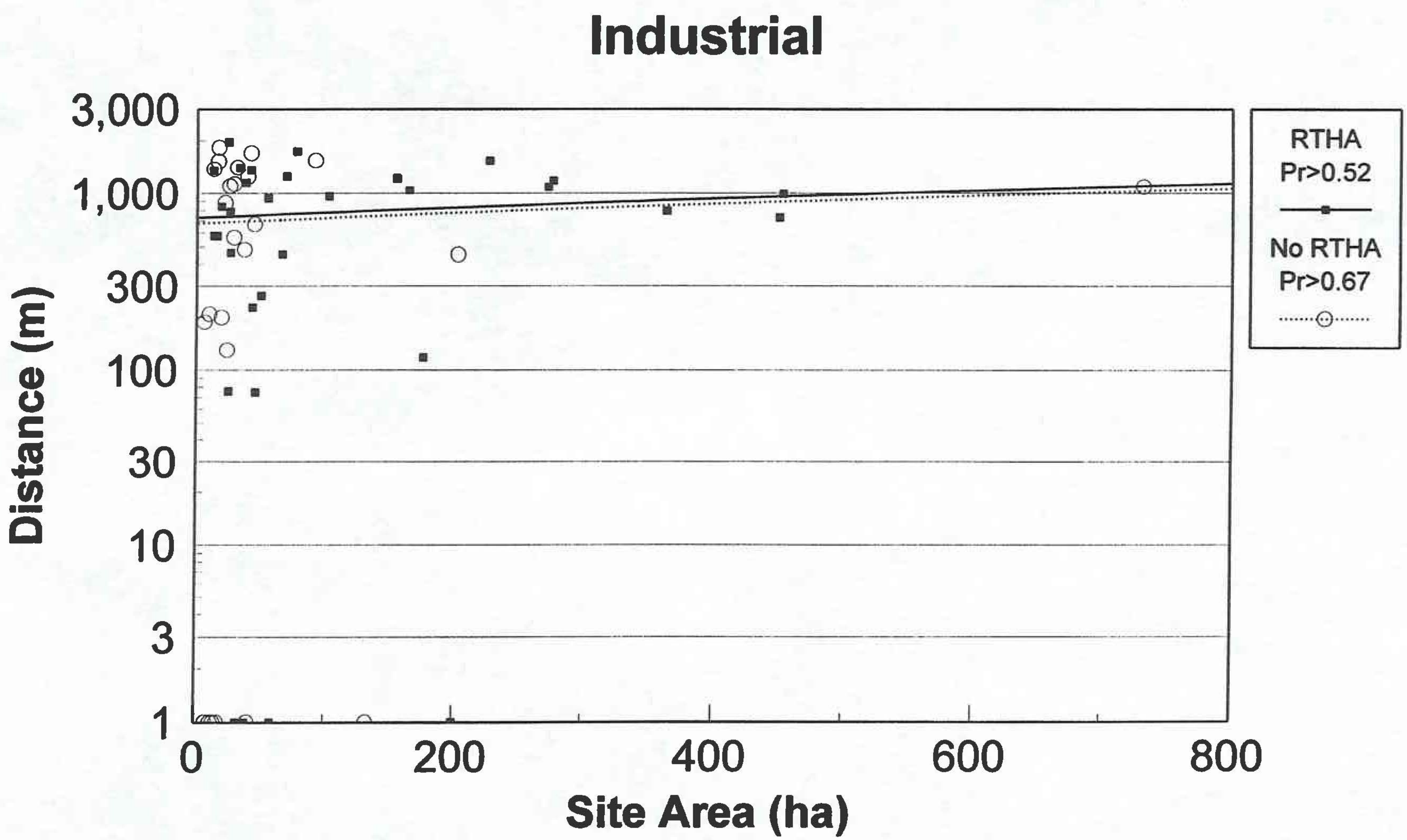



Figure 31

# Red-tailed Hawk

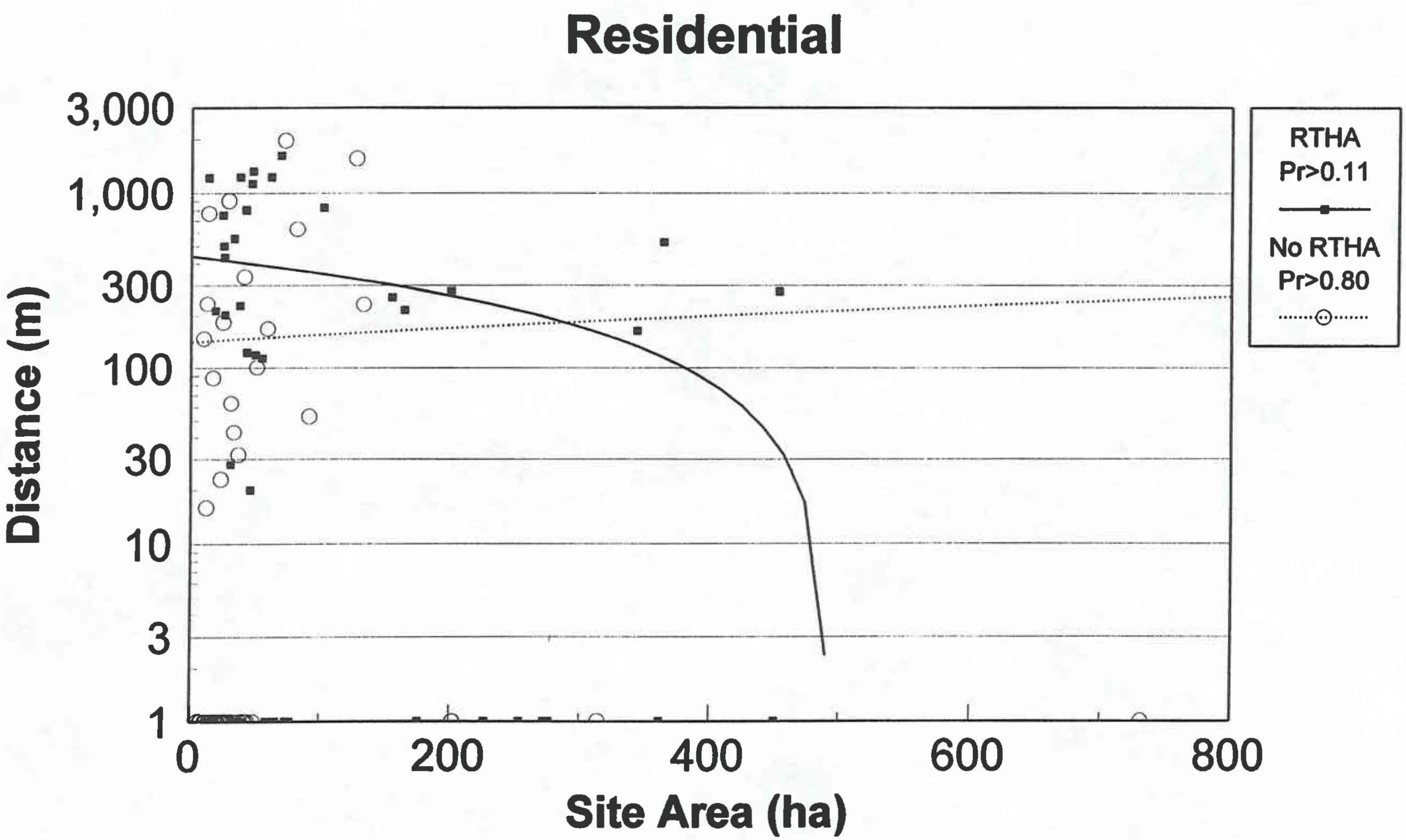



Figure 32

# Western Scrub-Jay

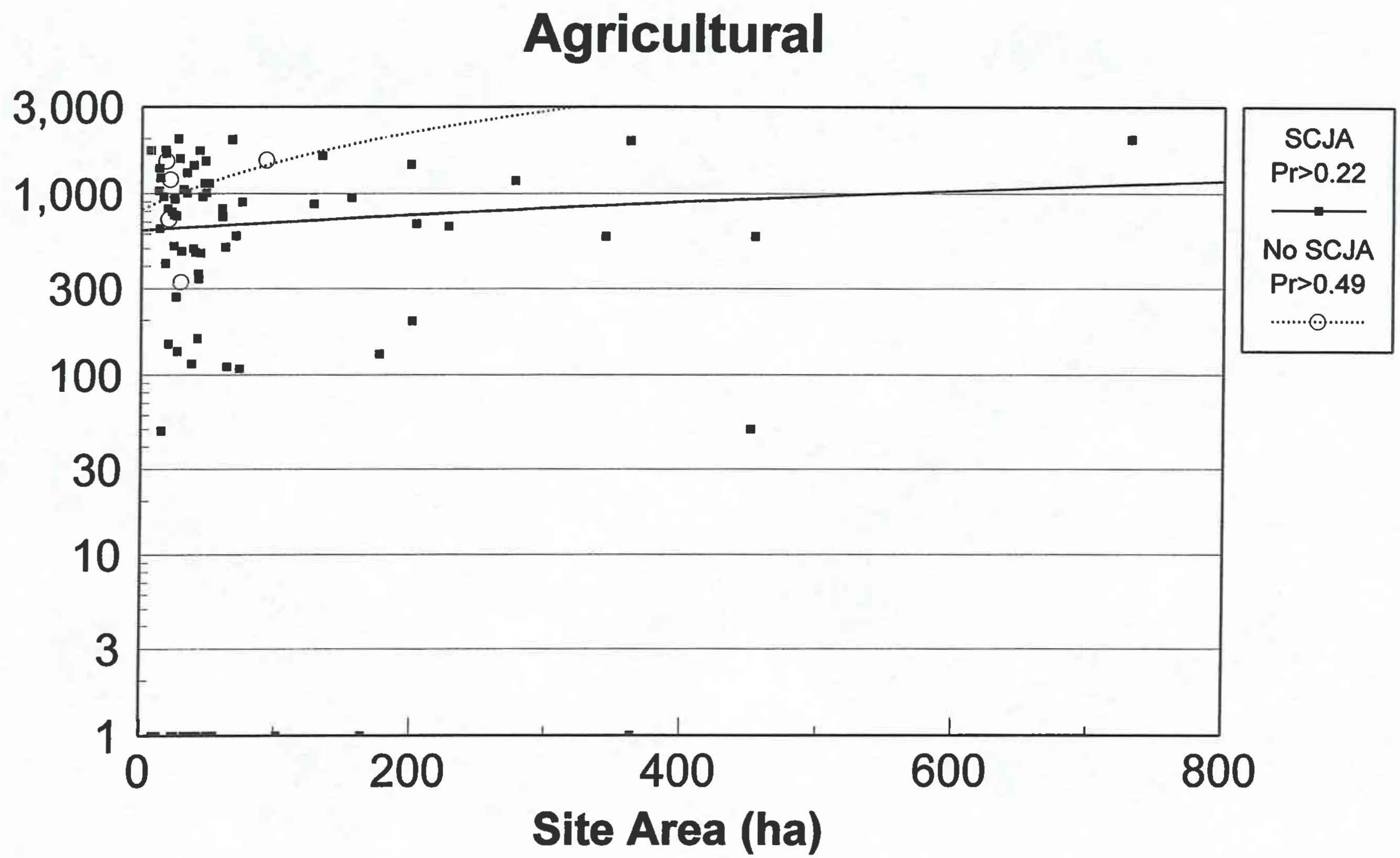



Figure 33

# Western Scrub-Jay

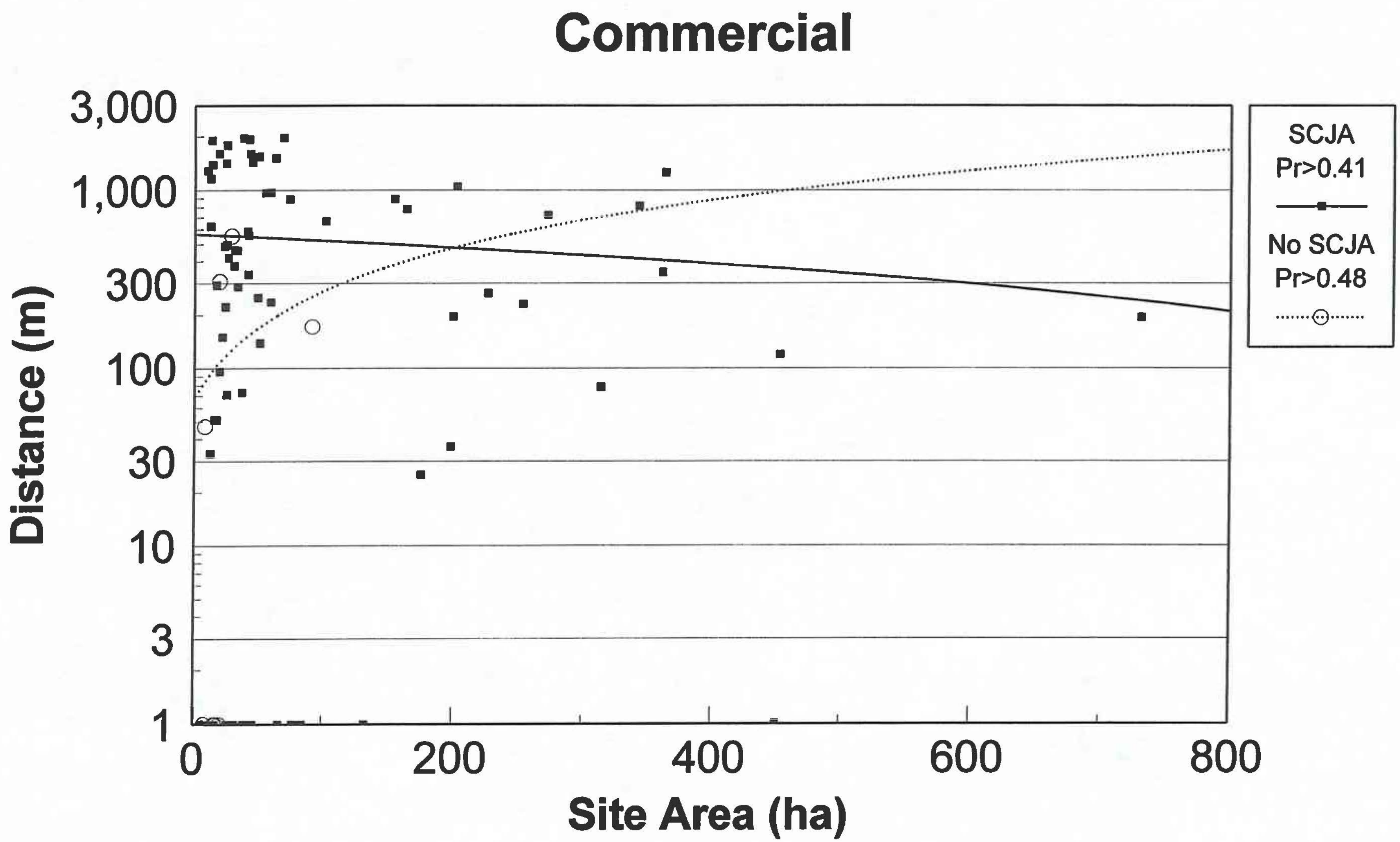



Figure 34

# Western Scrub-Jay

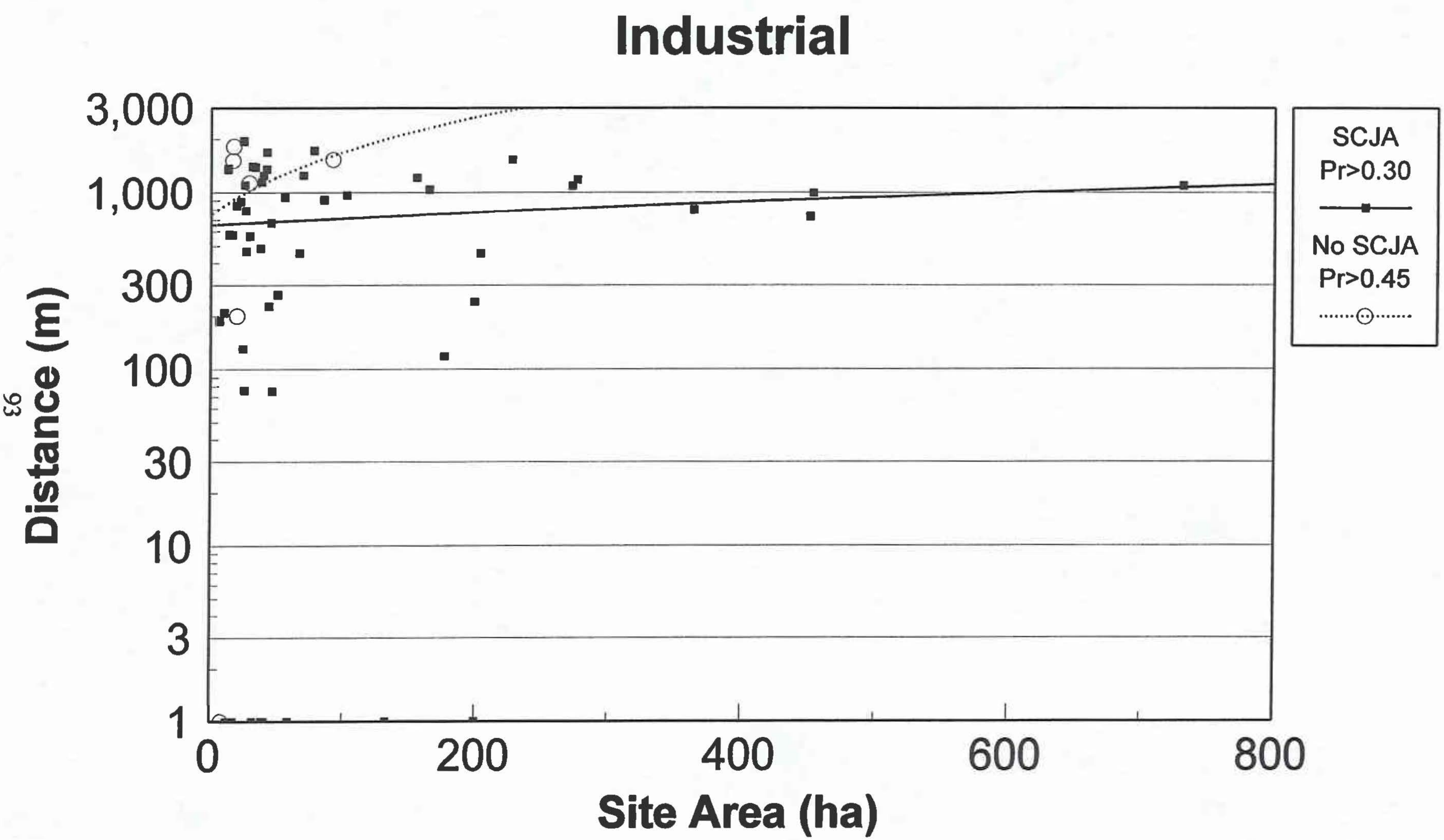



Figure 35

# Western Scrub-Jay

## Residential

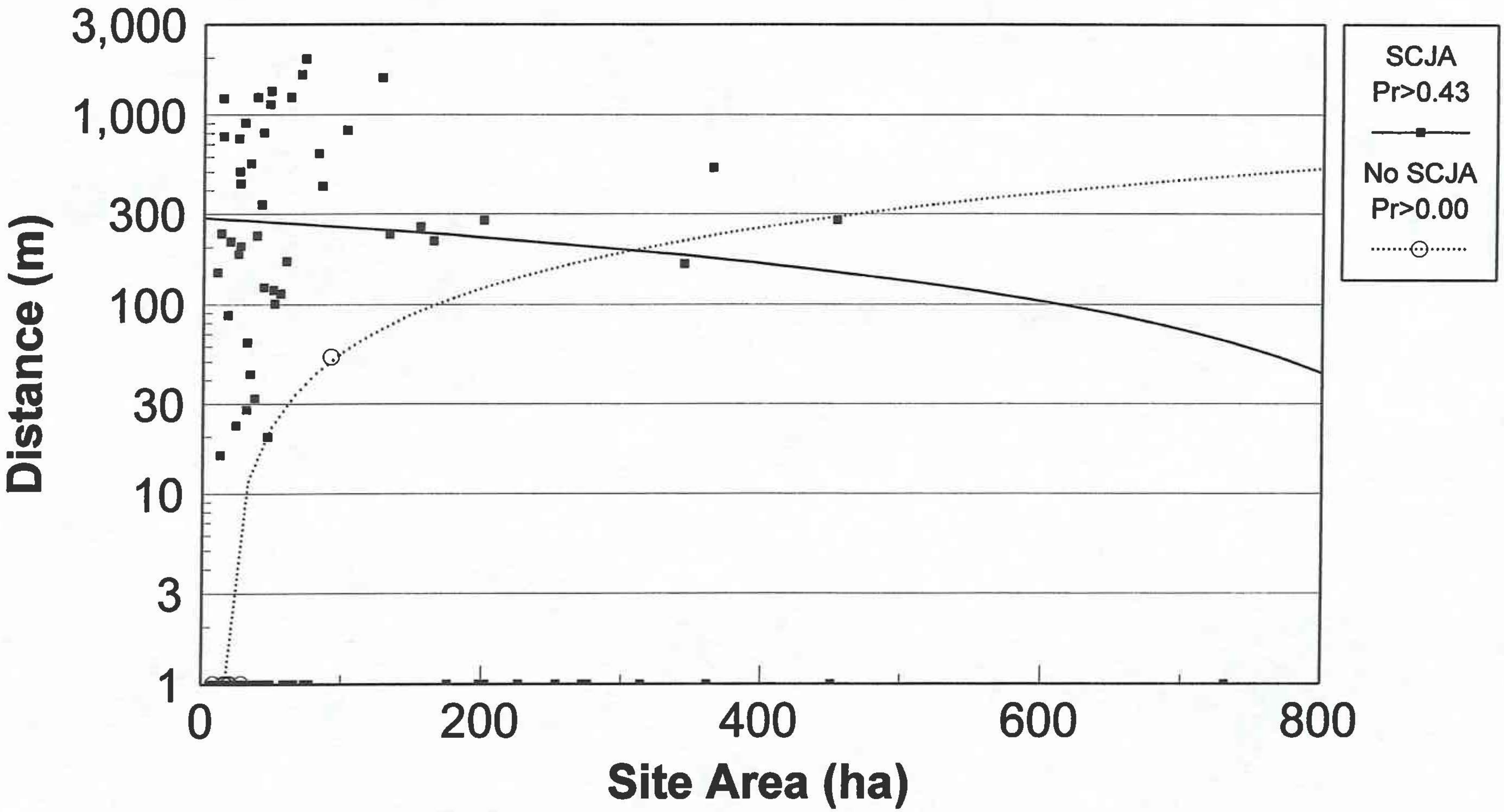
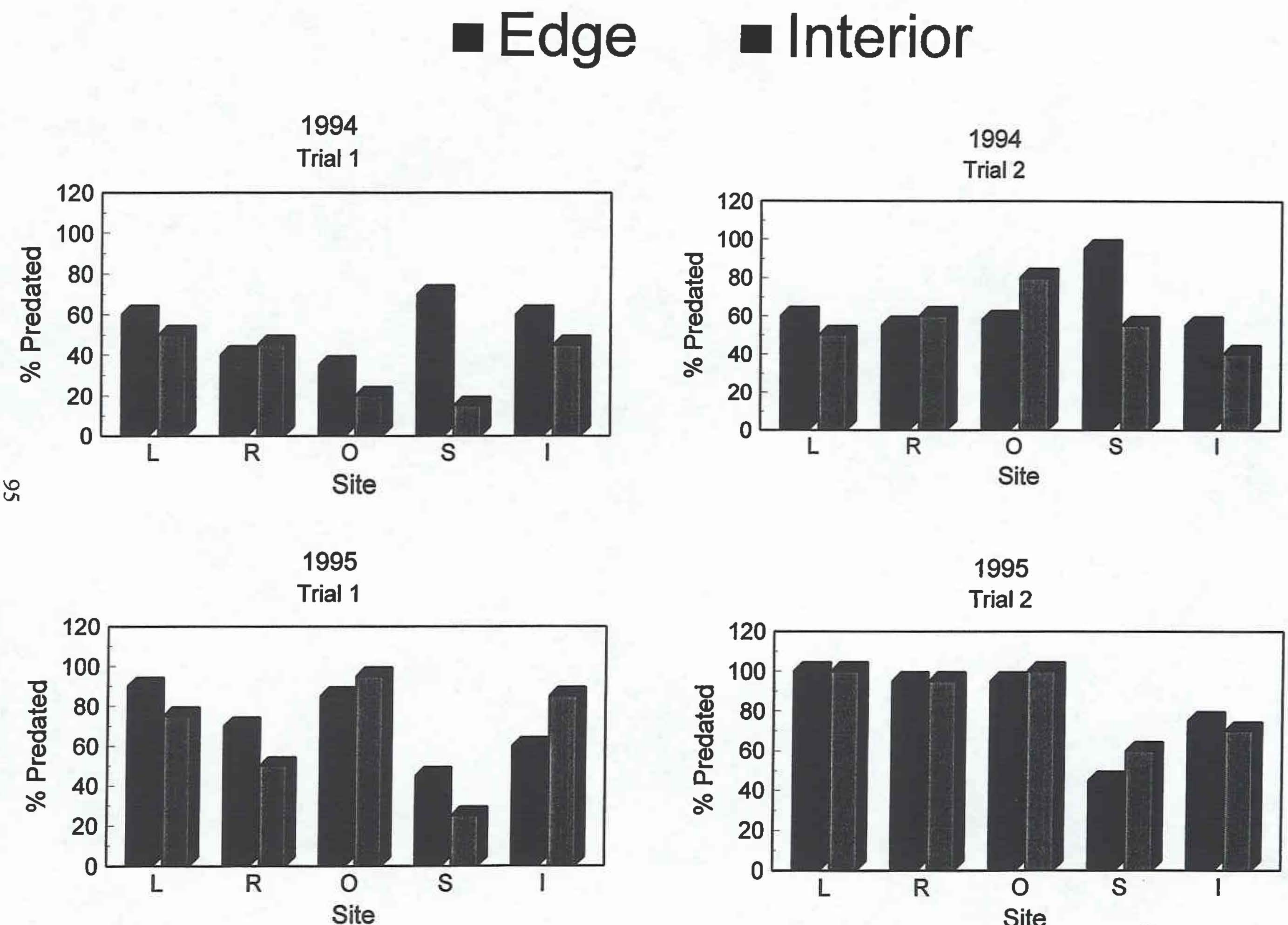



Figure 36



Edge
Interior
1994
Trial 1
1994
Trial 2
1995
Trial 1
1995
Trial 2
% Predated
0
20
40
60
80
100
120
L
R
O
S
I
Site


Figure 37

# Vegetation Analysis

## Principle Component Analysis

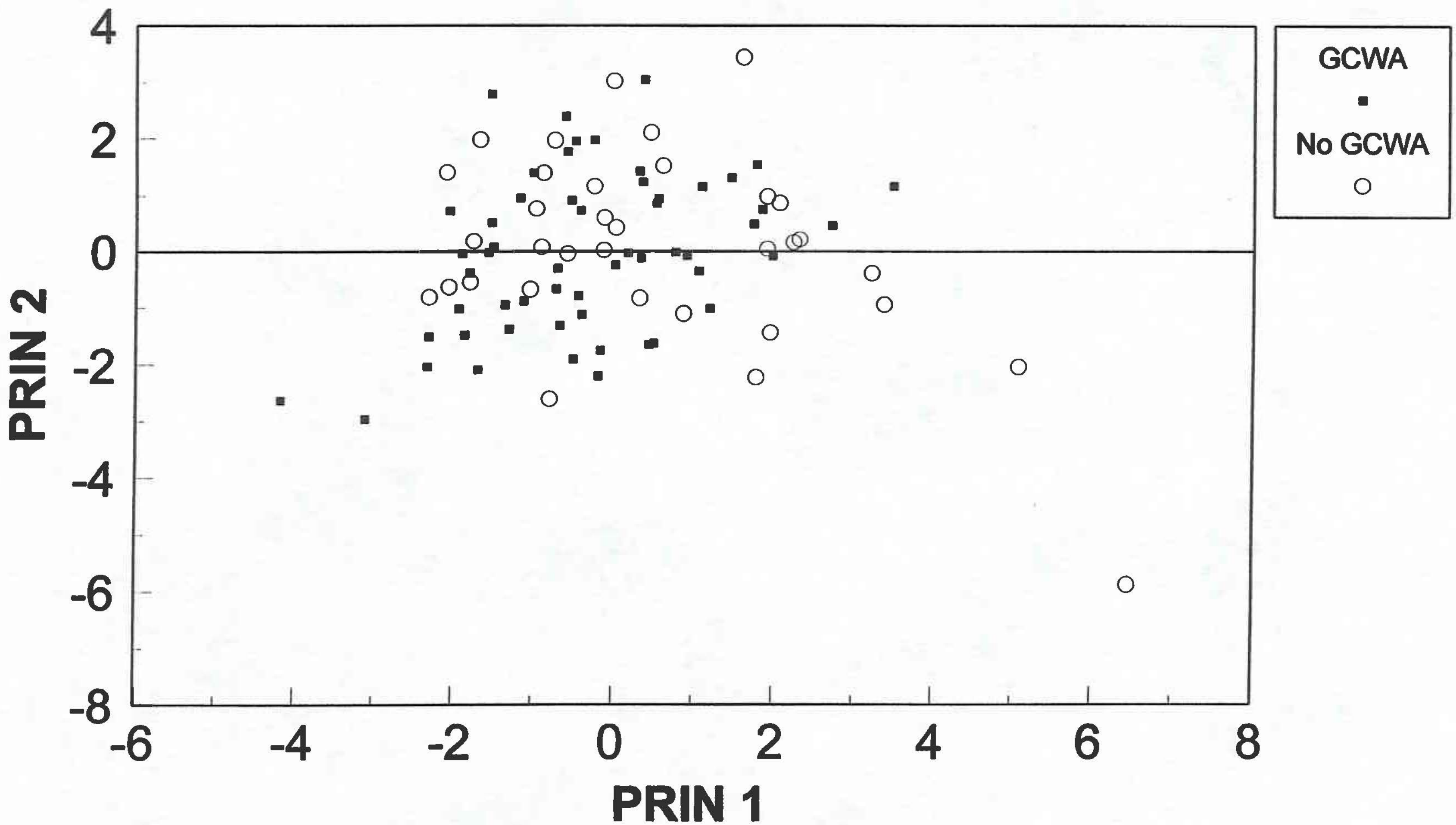



Figure 38

# Vegetation Analysis

## Principle Component Analysis

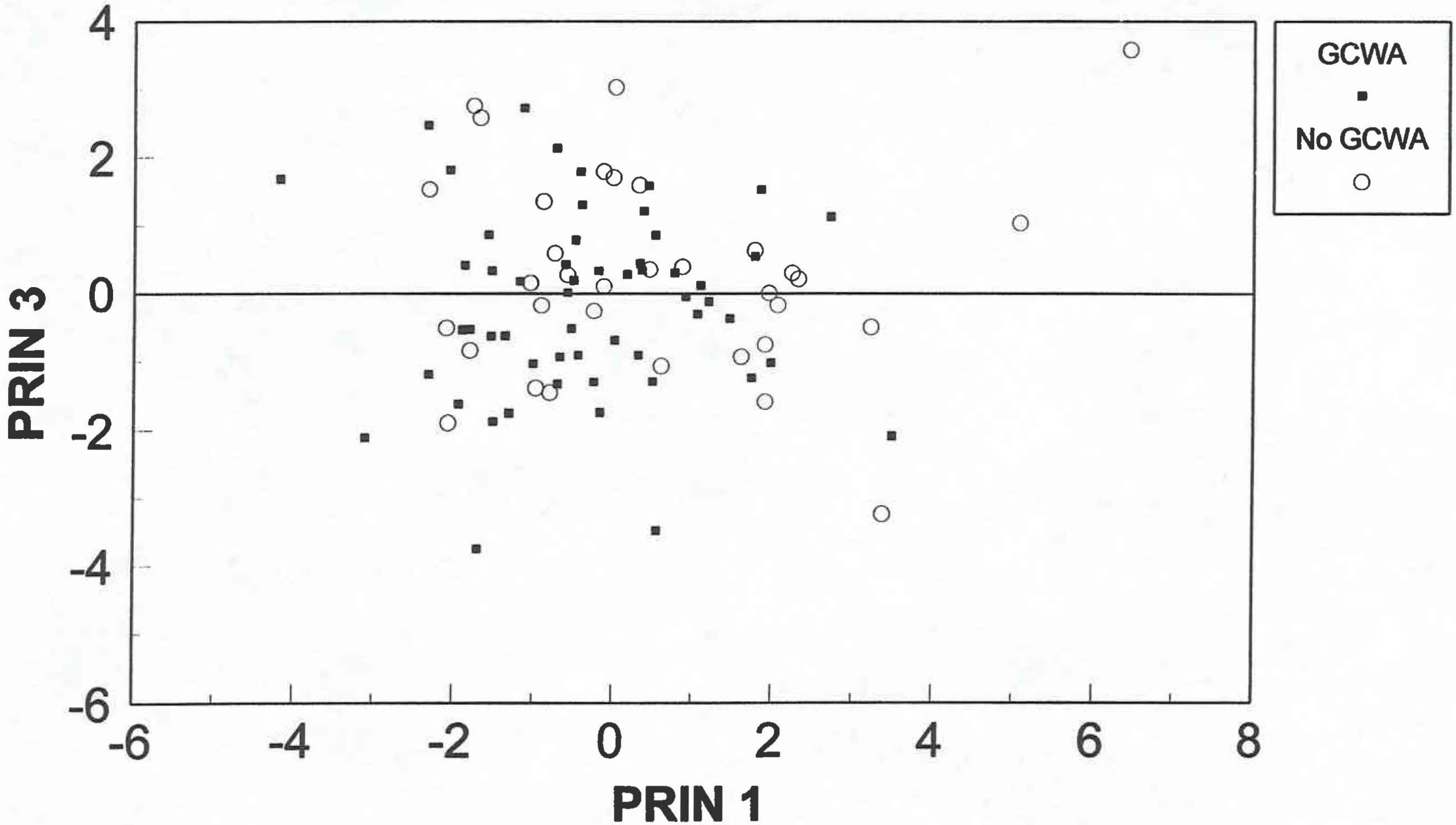



Figure 39

# APPENDIX C

# VEGETATIVE SUMMARIES

Appendix C Table 1. Scientific names for bird species.

| | |
|---|---|
| Turkey Vulture | *Cathartes aura* |
| Osprey | *Pandion haliaetus* |
| Mississippi Kite | *Ictinia mississippiensis* |
| Sharp-shinned Hawk | *Accipiter striatus* |
| Cooper's Hawk | *Accipiter cooperii* |
| Red-shouldered Hawk | *Buteo lineatus* |
| Broad-winged Hawk | *Buteo platypterus* |
| Swainson's Hawk | *Buteo swainsoni* |
| Red-tailed Hawk | *Buteo jamaicensis* |
| Ferruginous Hawk | *Buteo regalis* |
| American Kestrel | *Falco sparverius* |
| Prairie Falcon | *Falco mexicanus* |
| Japanese Quail | *Coturnix japonica* |
| Mourning Dove | *Zenaida macroura* |
| Greater Roadrunner | *Geococcyx californianus* |
| Eastern Screech-Owl | *Otus asio* |
| Great Horned Owl | *Bubo virginianus* |
| Barred Owl | *Strix varia* |
| Blue Jay | *Cyanocitta cristata* |
| Florida Scrub-Jay | *Aphelocoma coerulescens* |
| Western Scrub-Jay | *Aphelocoma californica* |
| American Crow | *Corvus brachyrhynchos* |
| Common Raven | *Corvus corax* |
| Carolina Chickadee | *Parus carolinensis* |
| Tufted Titmouse | *Parus bicolor* |
| Bewick's Wren | *Thryomanes bewickii* |
| Golden-cheeked Warbler | *Dendroica chrysoparia* |
| Black-and-white Warbler | *Mniotilta varia* |
| Northern Cardinal | *Cardinalis cardinalis* |
| Great-tailed Grackle | *Quiscalus mexicanus* |
| Common Grackle | *Quiscalus quiscula* |
| Bronzed Cowbird | *Molothrus aeneus* |
| Brown-headed Cowbird | *Molothrus ater* |

Appendix C Table 2. Scientific names for tree and shrub species encountered during habitat evaluations, 1993 through 1995.

| | |
|---|---|
| Agarita | *Berberis trifoliolata* |
| American Beautyberry | *Callicarpa americana* |
| American Elm | *Ulmus americana* |
| Arizona Walnut | *Juglans major* |
| Ashe Juniper | *Juniperus ashei* |
| Carolina Buckthorn | *Rhamnus caroliniana* |
| Catclaw | *Acacia* sp. |
| Cedar Elm | *Ulmus crassifolia* |
| Chinaberry | *Melia azedarach* |
| Chinese Tallow | *Sapium sebiferum* |
| Coma | *Bumelia lanuginosa* |
| Common Fig | *Ficus carica* |
| Deciduous Holly | *Ilex decidua* |
| Eastern Redbud | *Cercis canadensis* |
| Escarpment Black Cherry | *Prunus serotina* |
| Evergreen Sumac | *Rhus virens* |
| Fragrant Sumac | *Rhus aromatica* |
| Hackberry | *Celtis reticulata* |
| Honey Mesquite | *Prosopis glandulosa* |
| Hop Tree | *Ptelea trifoliata* |
| Kidneywood | *Eysenhardtia texana* |
| Lacey Oak | *Quercus glaucoides* |
| Ligustrum | *Ligustrum japonicum* |
| Lilac Chaste-tree | *Vitex agnus-castus* |
| Lime Prickly Ash | *Zanthoxylum hirsutum* |
| Mexican Buckeye | *Ungnadia speciosa* |
| Mexican Plum | *Prunus mexicana* |
| Pecan | *Carya illinoinensis* |
| Plateau Live Oak | *Quercus fusiformis* |
| Post Oak | *Quercus stellata* |
| Povertyweed | *Baccharis neglecta* |
| Prairie Sumac | *Rhus lanceolata* |
| Red Buckeye | *Aesculus pavia* |
| Red Mulberry | *Morus rubra* |
| Roughleaf Dogwood | *Cornus drummondii* |
| Rusty Blackhaw | *Viburnum rufidulum* |
| Scaleybark Oak | *Quercus sinuata* var. *breviloba* |
| Silktassel | *Garrya ovata* |
| Sugarberry | *Celtis laevigata* |
| Sycamore | *Platanus occidentalis* |
| Texas Ash | *Fraxinus americana* subsp. *texensis* |
| Texas Mountain Laurel | *Sophora secundiflora* |

Appendix C Table 2, continued.

| | |
|---|---|
| Texas Mulberry | *Morus microphylla* |
| Texas Oak | *Quercus buckleyi* |
| Texas Persimmon | *Diospyros texana* |
| Water Oak | *Quercus nigra* |
| Western Soapberry | *Sapindus drummondii* |
| Yaupon | *Ilex vomitoria* |

Appendix C Table 3. Summary of tree density by species at sites with and without Golden-cheeked Warblers. Values are mean ± standard deviation (number of sites).

| Species | Sites without Warblers (stems/ha) | Sites with Warblers (stems/ha) |
|---|---|---|
| Agarita | 25.25 . (1) | 25.25 ± 0 (3) |
| American Beautyberry | . | 25.25 . (1) |
| American Elm | 50.51 . (1) | . |
| Arizona Walnut | 25.25 . (1) | 28.86 ± 9.54 (7) |
| Ashe Juniper | 1477.27 ± 718.46 (37) | 1629.58 ± 671.50 (63) |
| Carolina Buckthorn | 25.25 . (1) | 25.25 ± 0 (2) |
| Catclaw | 25.25 . (1) | . |
| Cedar Elm | 195.01 ± 200.31 (18) | 55.92 ± 48.70 (14) |
| Chinaberry | . | 63.13 ± 53.57 (2) |
| Chinese Tallow | 75.76 . (1) | . |
| Coma | 33.67 ± 14.58 (3) | 39.68 ± 13.50 (7) |
| Deciduous Holly | 187.59 ± 312.65 (7) | 75.76 ± 76.08 (14) |
| Eastern Redbud | 25.25 . (1) | 75.76 . (1) |
| Escarpment Black Cherry | . | 27.78 ± 7.99 (10) |
| Evergreen Sumac | 84.17 ± 102.06 (3) | 86.58 ± 92.04 (7) |
| Fragrant Sumac | . | 25.25 . (1) |
| Hackberry | 67.34 ± 44.43 (15) | 35.35 ± 12.81 (15) |
| Honey Mesquite | 58.92 ± 38.02 (6) | 42.08 ± 29.16 (3) |
| Hop Tree | 25.25 ± 0 (2) | 50.51 ± 43.74 (3) |
| Kidneywood | 25.25 . (1) | . |
| Lacey Oak | . | 25.25 ± 0 (2) |
| Ligustrum | 75.76 . (1) | . |
| Lilac Chaste-tree | . | 126.26 . (1) |

Appendix C Table 3, continued.

| Species | Sites without Warblers (stems/ha) | Sites with Warblers (stems/ha) |
|---|---|---|
| Lime Prickly Ash | 378.79 . (1) | 25.25 ± 0 (2) |
| Mexican Buckeye | 33.67 ± 14.58 (3) | 84.17 ± 38.57 (3) |
| Mexican Plum | . | 25.25 . (1) |
| Pecan | 50.51 . (1) | . |
| Plateau Live Oak | 196.32 ± 253.51 (31) | 106.19 ± 103.66 (39) |
| Post Oak | 37.88 ± 17.86 (2) | . |
| Povertyweed | 25.25 . (1) | . |
| Prairie Sumac | 56.82 ± 47.80 (4) | 25.25 ± 0 (4) |
| Red Buckeye | . | 176.77 . (1) |
| Red Mulberry | 25.25 . (1) | . |
| Roughleaf Dogwood | 67.34 ± 72.90 (3) | 33.67 ± 20.62 (6) |
| Rusty Blackhaw | 75.76 ± 71.42 (2) | 63.13 ± 53.57 (2) |
| Scaleybark Oak | 174.83 ± 215.13 (13) | 236.93 ± 296.59 (34) |
| Silktassel | 101.01 ± 92.74 (5) | 135.73 ± 175.44 (8) |
| Sugarberry | 50.51 ± 35.71 (5) | 25.25 ± 0 (3) |
| Sycamore | 50.51 ± 25.25 (3) | 88.38 ± 89.28 (2) |
| Texas Ash | 79.37 ± 132.37 (7) | 99.33 ± 67.81 (15) |
| Texas Mountain Laurel | 984.85 ± 1249.94 (2) | 25.25 . (1) |
| Texas Mulberry | . | 25.25 . (1) |
| Texas Oak | 263.35 ± 307.96 (14) | 233.45 ± 272.09 (45) |
| Texas Persimmon | 133.48 ± 149.64 (21) | 96.23 ± 149.73 (37) |
| Water Oak | . | 25.25 . (1) |
| Western Soapberry | 101.01 . (1) | . |
| Yaupon | 542.93 ± 1110.62 (10) | 180.37 ± 270.18 (7) |

Appendix C Table 4. Summary of average tree height by species at sites with and without Golden-cheeked Warblers. Values are mean ± standard deviation (number of sites).

| Species | Sites without Warblers (m) | Sites with Warblers (m) |
|---|---|---|
| Agarita | 1.50 . (1) | 1.17 ± 0.58 (3) |
| American Beautyberry | . | 3.50 . (1) |
| American Elm | 17.00 . (1) | . |
| Arizona Walnut | 5.00 . (1) | 7.64 ± 2.87 (7) |
| Ashe Juniper | 4.72 ± 1.06 (37) | 4.25 ± 0.96 (63) |
| Carolina Buckthorn | 4.00 . (1) | 5.00 ± 0 (2) |
| Catclaw | 5.00 . (1) | . |
| Cedar Elm | 5.51 ± 2.43 (18) | 6.28 ± 3.41 (14) |
| Chinaberry | . | 9.38 ± 3.71 (2) |
| Chinese Tallow | 4.83 . (1) | . |
| Coma | 2.08 ± 0.14 (3) | 3.93 ± 2.07 (7) |
| Deciduous Holly | 3.64 ± 0.88 (7) | 3.82 ± 1.03 (14) |
| Eastern Redbud | 3.50 . (1) | 2.33 . (1) |
| Escarpment Black Cherry | . | 7.90 ± 3.40 (10) |
| Evergreen Sumac | 2.31 ± 0.27 (3) | 1.98 ± 0.48 (7) |
| Fragrant Sumac | . | 2.00 . (1) |
| Hackberry | 3.08 ± 1.25 (15) | 5.14 ± 2.40 (15) |
| Honey Mesquite | 4.17 ± 1.23 (6) | 3.94 ± 0.58 (3) |
| Hop Tree | 3.00 ± 1.41 (2) | 3.25 ± 0.43 (3) |
| Kidneywood | 2.00 . (1) | . |
| Lacey Oak | . | 5.50 ± 0.71 (2) |
| Ligustrum | 5.33 . (1) | . |
| Lilac Chaste-tree | . | 2.50 . (1) |

Appendix C Table 4, continued.

| Species | Sites without Warblers (m) | Sites with Warblers (m) |
|---|---|---|
| Lime Prickly Ash | 2.28 . (1) | 4.37 ± 3.71 (2) |
| Mexican Buckeye | 3.58 ± 1.51 (3) | 5.95 ± 4.29 (3) |
| Mexican Plum | . | 6.50 . (1) |
| Pecan | 9.00 . (1) | . |
| Plateau Live Oak | 5.67 ± 1.42 (31) | 5.34 ± 1.97 (39) |
| Post Oak | 8.37 ± 0.88 (2) | . |
| Povertyweed | 3.50 . (1) | . |
| Prairie Sumac | 2.80 ± 1.18 (4) | 5.25 ± 3.28 (4) |
| Red Buckeye | . | 3.93 . (1) |
| Red Mulberry | 4.00 . (1) | . |
| Roughleaf Dogwood | 3.97 ± 2.28 (3) | 4.61 ± 1.08 (6) |
| Rusty Blackhaw | 3.45 ± 0.64 (2) | 3.63 ± 0.53 (2) |
| Scaleybark Oak | 4.46 ± 1.64 (13) | 4.55 ± 1.86 (34) |
| Silktassel | 2.80 ± 0.81 (5) | 3.22 ± 1.00 (8) |
| Sugarberry | 4.53 ± 1.92 (5) | 2.67 ± 1.53 (3) |
| Sycamore | 12.28 ± 3.75 (3) | 7.29 ± 6.07 (2) |
| Texas Ash | 6.87 ± 2.38 (7) | 6.76 ± 1.90 (15) |
| Texas Mountain Laurel | 2.42 ± 0.59 (2) | 1.50 . (1) |
| Texas Mulberry | . | 2.50 . (1) |
| Texas Oak | 6.93 ± 2.91 (14) | 6.29 ± 1.08 (45) |
| Texas Persimmon | 2.88 ± 0.88 (21) | 2.62 ± 0.99 (37) |
| Water Oak | . | 6.00 . (1) |
| Western Soapberry | 5.25 . (1) | . |
| Yaupon | 3.32 ± 0.77 (10) | 3.42 ± 0.69 (7) |

Appendix C Table 5. Summary of tree basal area by species at sites with and without Golden-cheeked Warblers. Values are mean ± standard deviation (number of sites).

| Species | Sites without Warblers ($m^2$/ha) | Sites with Warblers ($m^2$/ha) |
|---|---|---|
| Agarita | 0.0197 . (1) | 0.0778 ± 0.0496 (3) |
| American Beautyberry | . | 0.0252 . (1) |
| American Elm | 23.6429 . (1) | . |
| Arizona Walnut | 0.1256 . (1) | 1.9144 ± 2.4646 (7) |
| Ashe Juniper | 28.2291 ± 11.8293 (37) | 31.0213 ± 13.3523 (63) |
| Carolina Buckthorn | 0.0339 . (1) | 0.0753 ± 0.0426 (2) |
| Catclaw | 0.4069 . (1) | . |
| Cedar Elm | 4.1689 ± 4.2755 (18) | 1.5651 ± 2.3981 (14) |
| Chinaberry | . | 2.6221 ± 0.2444 (2) |
| Chinese Tallow | 0.3089 . (1) | . |
| Coma | 0.0335 ± 0.0096 (3) | 0.1358 ± 0.1131 (7) |
| Deciduous Holly | 0.4813 ± 0.8239 (7) | 0.4602 ± 0.6943 (14) |
| Eastern Redbud | 0.0222 . (1) | 0.1194 . (1) |
| Escarpment Black Cherry | . | 1.4044 ± 2.1110 (10) |
| Evergreen Sumac | 0.1367 ± 0.1769 (3) | 0.2499 ± 0.2503 (7) |
| Fragrant Sumac | . | 0.0209 . (1) |
| Hackberry | 0.3889 ± 0.4562 (15) | 0.4637 ± 0.4854 (15) |
| Honey Mesquite | 0.6601 ± 0.6725 (6) | 0.2631 ± 0.0787 (3) |
| Hop Tree | 0.0201 ± 0 (2) | 0.1357 ± 0.0712 (3) |
| Kidneywood | 0.1063 . (1) | . |
| Lacey Oak | . | 0.6066 ± 0.4256 (2) |
| Ligustrum | 0.4154 . (1) | . |
| Lilac Chaste-tree | . | 0.3800 . (1) |

Appendix C Table 5, continued.

| Species | Sites without Warblers ($m^2$/ha) | Sites with Warblers ($m^2$/ha) |
|---|---|---|
| Lime Prickly Ash | 2.7238 . (1) | 0.4123 ± 0.4578 (2) |
| Mexican Buckeye | 0.0865 ± 0.0750 (3) | 3.4144 ± 5.6624 (3) |
| Mexican Plum | . | 0.4825 . (1) |
| Pecan | 2.4193 . (1) | . |
| Plateau Live Oak | 7.4577 ± 11.2923 (31) | 4.2975 ± 5.4847 (39) |
| Post Oak | 2.8969 ± 0.2396 (2) | . |
| Povertyweed | 0.2073 . (1) | . |
| Prairie Sumac | 0.1029 ± 0.1099 (4) | 0.3626 ± 0.5170 (4) |
| Red Buckeye | . | 0.6079 . (1) |
| Red Mulberry | 0.0289 . (1) | . |
| Roughleaf Dogwood | 0.2338 ± 0.2127 (3) | 0.1345 ± 0.0689 (6) |
| Rusty Blackhaw | 0.2104 ± 0.2095 (2) | 0.1685 ± 0.0417 (2) |
| Scaleybark Oak | 1.1590 ± 1.0636 (13) | 1.5867 ± 2.2177 (34) |
| Silktassel | 0.2472 ± 0.2621 (5) | 0.2043 ± 0.2139 (8) |
| Sugarberry | 0.7616 ± 1.5340 (5) | 0.1228 ± 0.0337 (3) |
| Sycamore | 5.2992 ± 3.1704 (3) | 7.7031 ± 10.7858 (2) |
| Texas Ash | 1.0226 ± 1.0505 (7) | 2.5680 ± 2.4957 (15) |
| Texas Mountain Laurel | 6.3528 ± 8.7451 (2) | 0.0266 . (1) |
| Texas Mulberry | . | 0.0090 . (1) |
| Texas Oak | 4.7569 ± 4.7188 (14) | 4.9886 ± 4.5698 (45) |
| Texas Persimmon | 0.4023 ± 0.7513 (21) | 0.3454 ± 0.7489 (37) |
| Water Oak | . | 0.0222 . (1) |
| Western Soapberry | 0.6503 . (1) | . |
| Yaupon | 1.8615 ± 3.7227 (10) | 0.4642 ± 0.8036 (7) |

Appendix C Table 6. Summary of vegetative characteristics at sites with and without Golden-cheeked Warblers. Values are mean ± standard deviation (number of sites).

| | Sites without Warblers | Sites with Warblers |
|---|---|---|
| Juniper | | |
| Understory density (stems/ha) | 759.22 ± 563.20 (37) | 996.55 ± 621.76 (63) |
| Canopy density (stems/ha) | 777.09 ± 445.16 (36) | 638.50 ± 359.84 (62) |
| Understory height (m) | 3.14 ± 0.30 (37) | 2.93 ± 0.35 (63) |
| Canopy height (m) | 6.08 ± 0.77 (36) | 6.07 ± 0.80 (62) |
| Understory basal area ($m^2$/ha) | 6.76 ± 5.98 (37) | 6.86 ± 6.80 (63) |
| Canopy basal area ($m^2$/ha) | 22.92 ± 11.86 (36) | 24.11 ± 12.09 (62) |
| Hardwoods | | |
| Understory density (stems/ha) | 542.60 ± 808.44 (35) | 307.20 ± 291.59 (60) |
| Canopy density (stems/ha) | 422.20 ± 469.51 (34) | 299.89 ± 259.82 (60) |
| Understory height (m) | 2.88 ± 0.49 (35) | 2.94 ± 0.58 (60) |
| Canopy height (m) | 6.61 ± 1.12 (34) | 6.59 ± 1.18 (60) |
| Understory basal area ($m^2$/ha) | 2.19 ± 4.24 (35) | 1.52 ± 1.65 (60) |
| Canopy basal area ($m^2$/ha) | 13.03 ± 12.22 (34) | 8.64 ± 7.74 (60) |
| Average Canopy Cover (%) | 80.54 ± 16.06 (37) | 80.82 ± 14.65 (63) |
| Average Slope (°) | 6.53 ± 4.36 (37) | 9.42 ± 4.31 (63) |