DEFINING HABITAT FOR THE RECOVERY OF

OCELOTS (*LEOPARDUS PARDALIS*)

IN THE UNITED STATES

THESIS

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by

Amy Rosamond Connolly, B.S.

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The ocelot (*Leopardus pardalis*) was placed on the United States federal endangered species list in 1982. Historically these felids were hunted for their pelts, but other factors have contributed over the years to their placement on the list. Today, the major factor that causes ocelots to be endangered is loss of habitat. Previous research has demonstrated that ocelots prefer habitats of dense shrubs with greater than 95% canopy cover. However, little else is known about the total composition of vegetation in their habitat. The objectives of our study were to develop a geographic information system

(GIS) containing vegetation, soil and satellite imagery for seven counties (Willacy, Cameron (Laguna Atascosa National Wildlife Refuge), Starr, Hidalgo, Jim Hogg, Kenedy, and Zapata) in South Texas to enhance prior research and define areas suitable to support ocelots. Ground-truthing on vegetation transects on public and private land across these counties was performed using a densiometer, vegetation profile board (VPB), and Daubenmire frame techniques to determine key vegetative characteristics that comprise ocelot habitat. Through principal components analysis (PCA), we analyzed slope and intercept (VPB measures), percent canopy cover (overstory), percent grass, litter, bare ground, and forbs from Daubenmire frames, woody species richness, woody plant density, woody plant diversity, and average woody plant height per transect. We found the majority of ocelot habitat was characterized by greater plant diversity, greater vertical cover density at ground level, greater canopy cover, smaller shrubs, and more ground litter than habitat not occupied by ocelots. Along an east-west gradient in South Texas, eastern sites were more similar to ocelot habitat. Comprehensive vegetation information (i.e. plant density, percent grass, etc.) is lacking on satellite/ land-use images. Therefore, comparing habitat data through PCA analysis would be more effective in delineating ocelot habitat.

CHAPTER I

INTRODUCTION

The ocelot (*Leopardus pardalis*) was listed by the United States Fish and Wildlife Service (USFWS) as a federally endangered species in 1982. Historically these spotted cats were hunted for their pelts, and subjected to predator control due to perceived competition for livestock and game (Broad 1987). However, the major cause for decline in ocelot populations in the U.S is loss of habitat (Murray and Gardner 1997). During the 1800s ocelots ranged from Peru and Argentina, northward to Arizona, Texas, Louisiana and Arkansas in the United States (Haines, et al. 2006). Today, only an estimated 30-100 ocelots remain in the United States (Laack, et al. 2005) on the Yturria Ranch and Laguna Atascosa National Wildlife Refuge (LANWR) in Willacy and Cameron County in South Texas. Outside of the United States, ocelots inhabit a wide variety of ecosystems, including swamps, marshes, grasslands, tropical-humid forests, and evergreen forests, but their movement patterns indicate that they are strongly associated with dense forests, suggesting that they are habitat specialists (Murray and Gardner 1997). A comparison of ocelots and bobcats (a felid similar in size and life history) showed that ocelots selected areas with more closed cover while bobcats favored mixed and open cover (Horne et al. 2009). Ocelots also required areas with high rodent density (Emmons 1988), further justifying the habitat specialist theory. The principle habitat in which the majority of ocelots are found in the United States is dense thorny chaparral of the Rio Grande Valley, also known as Tamaulipan Thorn Scrub (Schmidly 1977). Over 95% of ocelot habitat has been converted to agricultural and residential uses (Shindle and Tewes 1998). Consequently there is little Tamaulipan Thorn Scrub habitat between Yturria Ranch and LANWR, and the remaining habitat is extremely fragmented. A recent habitat population viability analysis concluded that the best plan for ocelot survival would be one that included reduction of road mortality, translocation and habitat restoration (Haines 2006a).

Based on a recent telemetry study, a habitat suitability regression was performed, and found that ocelots inhabited areas with or adjacent to closed canopy, and ocelots were furthest from areas with open cover/bare ground (Haines et al. 2005). Ocelots have also been found to select habitat with >95% horizontal cover and avoid habitat with <75% cover (Harveson et al. 2004). A species-type analysis was performed for all woody species >0.5m tall and granjeno (*Celtis pallida*), brasil (*Condalia hookeri*), crucita (*Eupatorium odoratum*), colima (*Zanthoxylum fagara*), whitebrush (*Alloysia gratissima*), lotebush (*Zizyphus obtusifolia*), and desert olive (*Forestiera angustifolia)* were common in ocelot territories (Shindle and Tewes 1998). Ocelots also prefer medium-sized areas with closed canopy, avoid small areas of this habitat type, and avoid large areas of open canopy (Jackson et al. 2005).

In order for certain types of vegetation to grow, specific soil types must be present. Harveson et al. (2004) determined that ocelots select habitat with four soil types (Camargo, Laredo, Olmito, and Point Isabel) and avoid 11 types (Barrada, Benito, Delfina, Harlingen, Latina, Lyford, Raymondville, Sejita, Willacy, Willamar, and Other).

In agreement with vegetative studies of habitat selection, ocelots selected for 82% of the soil series found in dense cover (Harveson et al. 2004).

Modelling with GIS will assist in identifying relocation sites that contain suitable habitat. Spatial habitat analysis using GIS can identify necessary core areas that will have a level of protection sufficient to buffer populations against human-caused mortality (Carroll et al. 2001). Habitat components including road density (increases mortality), soil structure, canopy cover, and home range can be used as layers for such a model. A recent study done in 2003 found ocelot density in the Pantanal to be 2.82 individuals per 5 km^2 (Trolle and Kery 2003). Estimated home range size in Texas was 1.56 km^2. Based on a RAMAS/gis spatial data model, 11 habitat patches were identified in Texas with an area greater than 3.71 km^2, which was deemed large enough to potentially support at least one breeding male ocelot per patch, but overall could only support a total carrying capacity of 82 ocelots (Haines et al. 2005). In addition to home range, many other variables need to be considered such as prey density, the vegetation structure of reproductive dens, and herbaceous species. Little, if anything, is known about these components for ocelots in the United States. For recovery of any species, many habitat requirements need to be known in order to provide the best chances for survival.

A few studies have acknowledged the importance of vegetation (Shindle and Tewes 1998, Young and Tewes 2004, Laack et al. 2005) for ocelots, however little is known about vegetative structure. The objectives of our study were to a) gather spatial data of vegetation and soil characteristics using satellite imagery and available GIS layers for seven counties (Willacy, Cameron, Starr, Hidalgo, Jim Hogg, Kenedy, and Zapata) to expand on prior research (Shindle et al. 1998, Harveson et al. 2004, Sternberg and

Donnelly, USFWS, in review) for defining existing habitat suitable to support an ocelot population of 200 individuals in Texas (USFWS, 2006), b) assess vegetative components of habitat currently occupied by ocelots in South Texas, adding additional habitat parameters (vertical structure of woody vegetation, herbaceous ground cover, etc.) beyond those currently defined in the literature and, c) “ground-truth” selected sites based on available GIS layers and satellite imagery. Our objectives would help fulfill the first goal of the USFWS’ Plan for Translocation of Northern Ocelots to “assess sufficient habitat… to support viable populations of the ocelot in the borderlands of the U.S. and Mexico” (USFWS Translocation Team, 2009).

CHAPTER II

STUDY AREA

We collected vegetative data from known ocelot habitat on Laguna Atascosa National Wildlife Refuge (LANWR) in Cameron County, Texas (Fig. 1).

Figure 1. Map of Laguna Atascosa National Wildlife Refuge

The refuge consists of 18,287 hectares with multiple management techniques for wintering migrating birds and re-establishing native brushlands on land converted for agricultural practices. Typical vegetation at LANWR is dominated by Tamaulipan Thorn Scrub, including species such as honey mesquite (*Prosopis glandulosa*), prickly pear (*Opuntia lindheimeri*) and persimmon (*Diospyros virginiana).* The climate is temperate and subtropical with mean annual precipitation of 19 cm and an average daily temperature of 13°C.

Defining and evaluating potential ocelot habitat was conducted on nine sites across South Texas along an east-west line in Willacy (three sites), Hidalgo (two sites), Brooks (one site), and Starr (two sites) counties (Fig. 2), approximately 60 km north of the Lower Rio Grande Valley.

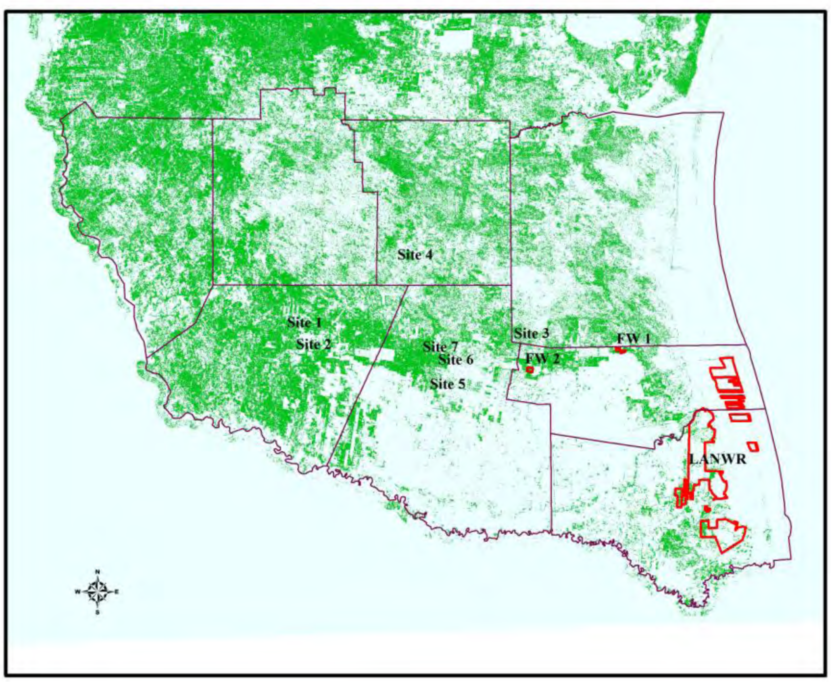

Figure 2. Map of all study sites across S. Texas overlaid on C-CAP shrub/scrub classification

Sites ranged in size from 81 to 12,141 ha with land management ranging from conservation/ecotourism to agriculture/cattle. Three sites were owned by United States Fish and Wildlife Service (USFWS) (two containing ocelots). Seven sites were located on privately-owned ranches with no known occurrences of ocelots. This area contains Tamaulipan Thorn Scrub mixed in a grassland ecosystem (Bezanson 2001). Soil types included sands, clays, loams, and caliche, with some saline, alkaline, and gypseous soils (Bezanson 2001).

CHAPTER III

METHODS

COVER MAP

I downloaded the Texas 2005 land cover maps from Coastal Change Analysis Program (C-CAP) created by the National Oceanic and Atmospheric Administration Coastal Services Center. (http://www.csc.noaa.gov, 11/2009). I chose C-CAP data over other readily obtainable databases (i.e. TX-GAP) for two reasons. First, the satellite images are classified into distinctive subcategories such as palustrine aquatic bed, deciduous forest, low intensity developed (Appendix A), whereas other land cover maps are classified only into major categories such as water, forest, and developed. Both supervised and unsupervised classification techniques were used to create their images. Second, C-CAP has the only land cover map that has an overall target accuracy of 85 percent, which is verified through field assessment. This meets the minimum standard for classification criteria needed for management and planning purposes (Anderson et al. 1976).

Ocelot telemetry points (unpublished data, USFWS, 1991 – 2005) were overlaid on the land cover layer using arcMAP (Environmental Systems Research Institute, Version 9.3) (Fig. 3).

Fig. 3. Radio-telemetry points overlaid on top of C-CAP land-cover layer

For each ocelot with a significant number of telemetry points (>100), 50% and 100% minimum convex polygons were created using Home Range Tools (Centre for Northern Forest Ecosystem Research) and Hawth's Tools (Beyer 2004). The 100% MCPs encompassed the entire range of available habitat and therefore was used for analysis of land-use. Land-use was determined using Biotas (Ecological Software Solutions) by clipping each ocelot's MCP as well as the MCP for all ocelots with the land cover map and was analyzed using Neu's method (Ecological Software Solutions). The preferred land cover class was then clipped across the entire area of South Texas to get a map of potential ocelot habitats and corridors. The overlay of all of the telemetry points on land-use imagery showed that ocelots selected scrub/shrub, palustrine scrub/shrub wetland, and grassland categories more than expected and avoided water, cultivated, palustrine emergent wetland, estuarine aquatic beds, and shore ($\chi^2_{(21)}$= 31.41, p< 0.001; Table 1).

Table 1. Land-use types preferred/avoided by ocelots

Land-use Type	Observed Count	Expected Use
Evergreen forest	2	6
Mixed forest	2	4
shrub/scrub*	6602	2280
Palustrine forested wetland	125	101
Palustrine shrub/scrub*	2358	779
Palustrine emergent wetland*	1956	3549
Estuarine shrub/scrub	0	1
Estuarine emergent wetland	34	153
Unconsolidated shore*	467	1136
High intensity developed	3	6
Bare	46	182
Water*	170	1073
Palustrine aquatic bed	14	50
Estuarine aquatic bed*	17	416
Medium intensity developed	53	129
Low intensity developed	639	358
Developed open space	100	167
Cultivated*	494	3974
Pasture/Hay	36	107
Grassland*	2984	1756
Deciduous Forest	212	88

* represents $p<.001$

I initially defined the three selected categories as "suitable" categories, but when extrapolated across South Texas, these categories resulted in resolution too coarse for habitat suitability. For a more clearly defined habitat suitability map, I chose the shrub/scrub category to identify usable potential habitat more specifically (Fig. 2).

Soil classification was also determined using Biotas and analyzed using Neu's method (Ecological Software Solutions). Soil data were obtained from National Resource Conservation Service Soil Data Mart. Neu's method allowed for analysis of observed/expected use. The method was performed on the ocelot habitat at LANWR and then compared with soil types on all vegetation transects.

FIELD METHODS

Analysis of current ocelot habitat was conducted on LANWR in Cameron County, Texas. Using Hawth's Tools, I randomly chose 30 telemetry points from areas that were travelled frequently by multiple ocelots from 1990-2005. I ground-truthed each point by measuring vegetation parameters along 50-meter transects. Azimuth of each transect was randomly chosen using the statistical program R (R development core team 2005).

Along each transect I measured canopy cover and abundance of woody species using line-intercept method. I recorded an additional measure of canopy cover every 10 m using a bull-horn densiometer (Geographic Resources Solutions, Arcata, California), taken at 1m height, sufficient height to provide cover for an ocelot. Vertical screening cover was measured at 0, 25, and 50 m along each transect using a vegetation profile board (VPB) (Nudds 1977). The board was placed 10 m in both directions perpendicular from the transect. Generally at distances > 10 m, vegetation obscured the board completely. Percentages of forbs, grasses, bare ground, and litter were measured every 10 m using a Daubenmire frame (Daubenmire 1959). Density of woody vegetation was measured every 10 m using the point center quarter method (Bryant, et al. 2004).

I analyzed vegetation baseline data (i.e. means, abundances, etc.) using program R (R Development Core Team, 2005) and Excel (Microsoft Corporation, Redmond, Washington). Analysis of VPB data was performed in Excel by calculating the mean percent vertical vegetative obstruction (VVO) for each 0.5 m vertical section of the board for each transect and calculating a linear regression equation for means for each 0.5 m vertical section. The y-intercept represents the mean percent VVO for section 1 (ground level, where ocelots reside), and the slope represents the mean change in percent VVO for each section on the board. An ANCOVA type III sums of squares was used to test for any correlation between the type of habitat and the sections of the VPB. T-tests were used to determine similarities in woody species between transects. I calculated mean density measurements per transect. Simpson's index (D) was used to determine diversity for each transect.

Vegetative measurements on private lands across South Texas were done in the same manner as the analysis of current ocelot habitat, using the same vegetation parameters. We recorded vegetative data from at least one transect per 1500 acres, the same amount performed at LANWR, with minimum of two transects per site. Scientific names of woody plants were obtained from the Lady Bird Johnson Wildflower Center website (http://www.wildflower.org/plants, 11/2009).

Data were pooled from both current habitat at LANWR and potential habitat in South Texas, and analyzed through principal component analysis (PCA). I used a) slope and intercept (VPB measures), b) percent canopy cover (overstory), c) percent grass, litter, bare ground, forbs from Daubenmire frames, d) woody species richness, e) woody plant density, f) woody plant diversity and, g) average woody plant height per transect. I compared sites to determine similarities/differences in three ways: 1) between LANWR and all other sites, 2) between LANWR and the three FWS tracts, and 3) between all sites along the east-west line. The eastern section of sites used in the analysis contained LANWR and two FWS tracts (combined into one) known to contain ocelots. The middle section contained one FWS tract known to contain ocelots, along with five privately-owned ranches. The western section was composed of two privately-owned ranches (Fig. 2). Analysis of VPB was conducted in the same manner using the regression formulas. T-tests were performed to determine the significance of those comparisons.

CHAPTER IV

RESULTS

Analysis of soils revealed that 66 different soils occurred in ocelot habitat at LANWR. Five soils were significantly used more than expected, while 12 were significantly used less than expected ($\chi^2_{(65)}$=84.82, $p < 0.001$; Table 2).

Table 2. Soils preferred and avoided by ocelots

Soil name	Soil type	observed/expected
Chargo	silty clay	202/105
Harlingen, saline	silty clay	196/37
Laredo	silty clay loam	3853/759
Olmito	silty clay	662/280
Point Isabel	clay loam	736/180
Barrada	clay	72/316
Benito	clay	7/224
Harlingen	clay	97/484
Hidago	sandy clay loam	0/218
Mercedes	clay	0/175
Racombes	sandy clay loam	0/198
Raymondville	clay loam	0/503
Rio Grande	silt loam	0/94
Sejita	silty clay loam	173/451
Ustifluvents	clayey	0/105
Willacy	fine sandy loam	0/274
Willamar	sandy clay loam/ clay loam	103/221

Species richness at LANWR consisted of 25 woody plants (Table 3), with the majority consisting of granjeno (*Celtis ehrenbergiana*) (13%), snake-eyes (*Phaulothamnus spinescens*) (13%), fiddlewood (*Citharexylum berlandieri*) (9%), coyotillo (*Karwinskia humboldtiana*) (9%), coma (*Sideroxylon celastrinum*) (9%) and amargoso (*Castela erecta*) (9%).

Table 3. Number of woody species throughout South Texas sites

WOODY SPECIES	LANWR	Other
Brasil (*Condalia hookeri*)	65	57
Granjeno (*Celtis ehrenbergiana*)	148	117
Guayacan (*Guaiacum angustifolium*)	2	9
Snake-eyes (*Phaulothamnus spinescens*)	144	135
Texas Olive (*Cordia boissieri*)	10	31
Fiddlewood (*Citharexylum fruticosum*)	102	0
Huisache (*Acacia farnesiana*)	6	14
Honey mesquite (*Prosopis glandulosa*)	81	168
Guajillo (*Acacia berlandieri*)	1	56
Coyotillo (*Karwinskia humboldtiana*)	99	40
Blue sage (*Salvia ballotiflora*)	4	0
Coma (*Sideroxylon celastrinum*)	100	0
Colima (*Zanthoxylum fagara*)	82	83
Ebony (*Ebenopsis ebano*)	59	3
Amargoso (*Castela erecta texana*)	96	13
Leucophyllum (*Leucophyllum frutescens*)	27	35
Persimmon (*Diospyros texana*)	9	27
Southwest Bernardia (*Bernardia myricifolia*)	8	13
Yucca (*Yucca* spp.)	3	2
Whitebrush (*Aloysia gratissima*)	39	13
Condalia (*Condalia hookeri*)	2	0
Prickly pear (*Opuntia engelmannii*)	9	39
Chiliquipin (*Capsicum annum*)	1	0
Star cactus (*Astrophytum asterias*)	1	0
Lotebush (*Ziziphus obtusifolia*)	1	22
Elbowbush (*Forestiera angustifolia*)	0	26
Kidneywood (*Eysenhardtia texana*)	0	34
Blackbrush (*Acacia rigidula*)	0	41
Leatherstem (*Jatropha dioica*)	0	59
Pencil cactus (*Cylindropuntia leptocaulis*)	0	29
All-thorn (*Koeberlinia spinosa*)	0	3
Cat claw (*Acacia wrightii*)	0	10
TOTAL	1099	1079

The mean plant density was 21.6/100 m^2, with individual transects ranging from 10.0/100 m^2 to 64.0/100 m^2. Woody plant abundance for all 28 transects was 1099, with a mean of 34.3 individuals.

Woody plant species richness outside of LANWR consisted of 26 woody plants (Table 3), with the majority being honey mesquite (*Prosopis glandulosa*) (16%), snake-eyes (13%), and granjeno (11%). The mean plant density was 29.2/100 m^2, with individual transects ranging from 12.0/100 /m^2 to 100.0/100/m^2. Individual woody plant abundance for all 40 transects was 1079, with a mean of 33.7 individuals. A Welch Two Sample t-test performed on species richness for LANWR versus the rest of South Texas showed no difference ($t_{53,35} = 0.354$, $p = 0.725$). Shindle and Tewes (1998) determined that granjeno, snake-eyes, crucita, desert olive, colima, whitebrush, brasil, and lotebush could be important components in delineating ocelot habitat, but species should not be the only component considered. Means of other components studied in this project are listed in Table 4.

Table 4. Means of habitat components from all transects on each site

Habitat component	LANWR	FWS1	FWS2	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Percent canopy cover	68.45	87.50	75.00	58.33	75.00	54.17	38.89	45.83	45.83	33.33
Canopy height (m)	9.71	15.00	12.50	11.80	8.50	20.00	14.00	18.75	13.75	20.50
Diversity (D)	0.22	0.29	0.46	0.18	0.12	0.62	0.41	0.15	0.41	0.30
Percent grass	15.74	2.50	17.81	30.00	10.42	34.35	22.78	22.13	15.31	20.21
Percent forb	15.80	6.98	2.5	15.08	20.41	6.46	7.78	20.31	6.46	9.79
Percent litter	52.86	81.56	70.73	36.92	37.92	52.40	28.89	26.78	48.96	50.35
Percent bare	19.20	12.92	12.92	21.17	19.38	6.04	38.19	22.19	28.85	21.81
Percent cover 0-.5m	84.52	90.00	85.83	86.67	83.33	52.50	74.44	57.50	83.33	58.33
Percent cover .5-1.0m	82.61	90.00	73.33	84.67	83.33	35.00	72.22	47.50	77.50	52.22
Percent cover 1.0-1.5m	80.71	90.00	65.83	79.00	90.00	45.83	80.00	53.33	73.33	53.33
Percent cover 1.5-2.0m	74.05	90.00	67.50	73.67	90.00	47.50	68.89	49.17	73.33	49.44
Percent cover 2.0-2.5m	69.17	90.00	66.67	68.33	88.33	50.83	68.89	49.17	70.83	46.67

At LANWR, the regression equation for VPB vertical vegetative obstruction was y=90-3.929x, with a mean VVO of plants at ground level (0.5 m) of 90.17%, and a change in percent VVO of -3.93. Mean ground level VVO on all sites across South Texas was 76.05% with a mean vertical screening percent decrease of 2.342. Results from ANCOVA type III sums of square showed there is no significant interaction between type of habitat and the sections of the VPB ($F_{4,335}$= 0.59 , , p= 0.67). Habitat type has no influence on percent VVO ($F_{1,335}$=0.92, p=0.34) but section of the VPB influences the percent VVO significantly ($F_{4,335}$= 8.61, p= 0.01). The regression equation for VVO on a VPB in ocelot habitat is Y= 90 - 3.929x (Fig 4).

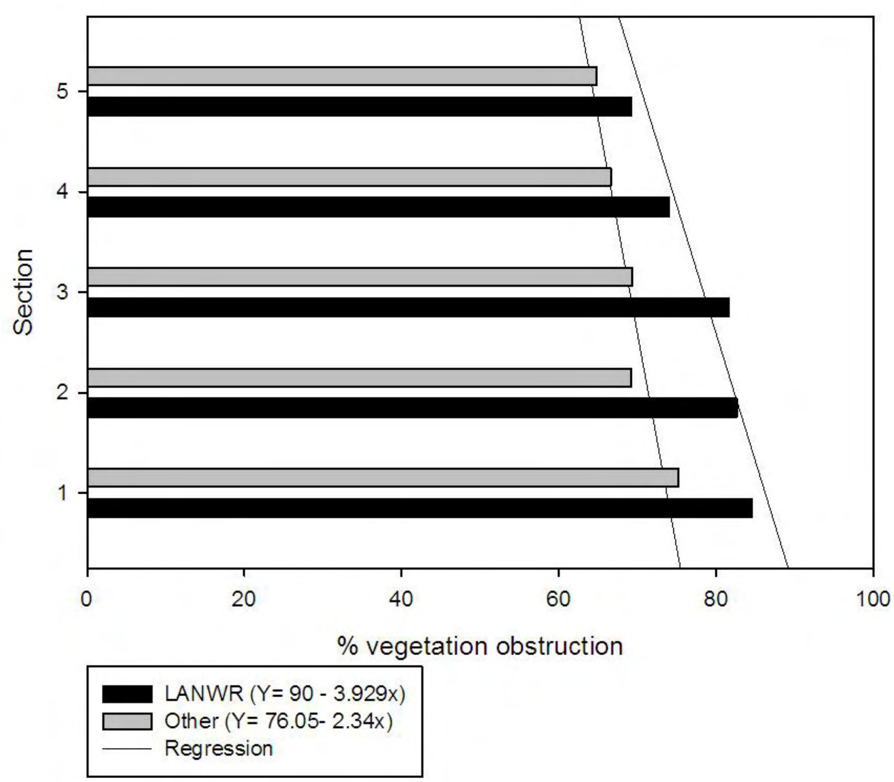

Fig 4. VPB for LANWR vs. Other

Comparing LANWR with other FWS tracts containing ocelots, mean VVO at ground level on FWS tracts was 87.55%, a change in percent VVO of -2.208, equaling a regression equation of Y= 87.542-2.208x. Both sites with resident ocelots have similar VVO at ground level. Results from ANCOVA type III sums of square showed there is no significant interaction between type of habitat and the sections of the VPB ($F_{4,170}$= 0.68, p= 0.60). Both habitat type and section of the VPB have no differences ($F_{1,170}$= 2.55, p= 0.11 and $F_{4,170}$= 0.68, p= 0.60, respectively; Fig. 5).

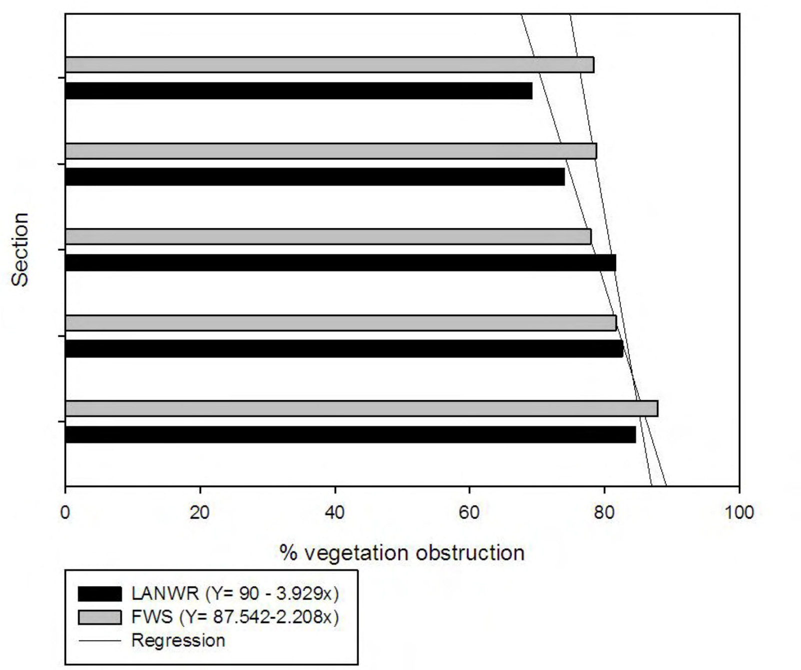

Fig 5. VPB for LANWR vs. FWS

Comparing VVO along an east-west line the eastern portion (sites 1 and 2) had a mean ground level VVO of 89.85% with a regression equation of y= 90 - 3.4375x (Fig. 6). The central section (sites 3-7 and FWS 2) had a mean ground level VVO of 65.18%, a change in percent VVO of -1.73, equaling a regression equation of y= 65.03-1.73x. The western section (FWS1, and LANWR) had a ground level VVO of 90.97%, a change in percent VVO of -3.69, equaling a regression equation of y= 90.9722-3.69x, which was similar to the eastern section.

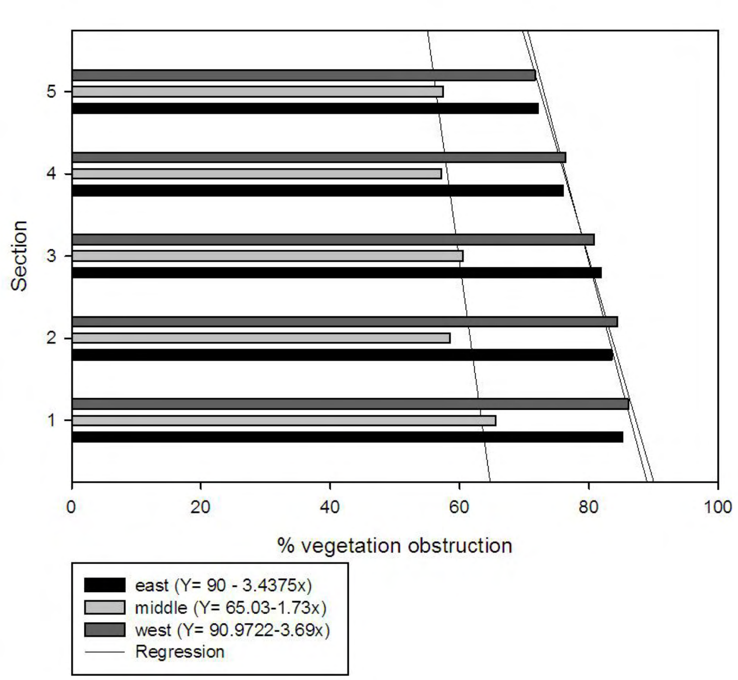

Fig. 6. VPB comparing sites east-west

Results from ANCOVA type III sums of squares showed there is no significant interaction between type of habitat and the sections of the VPB ($F_{8,327}$=0.46, p= 0.87). Vegetation Profile Board data differed between habitats found in the eastern, central, and western sections of the potential habitat as indicated by the canopy cover map. Both habitat type and section of the VPB are significantly different between habitat types ($F_{2,327}$=5.81, p =.003, and $F_{4,327}$=3.61, p =.006 respectively).

Principal component (PC) axes I and II explained 55% of the variation in habitat among all sites (Fig. 7). Strongest negative loadings for PC I were number of individuals (-0.46), number of species (-0.40), diversity (-0.37) and intercept (-0.38). The strongest positive loadings for PC I was woody plant height (0.35). The strongest negative loadings for PC II was represented by percent bare ground (-0.43). Strongest positive loadings for PC II were percent litter (0.50) and canopy cover (0.44).

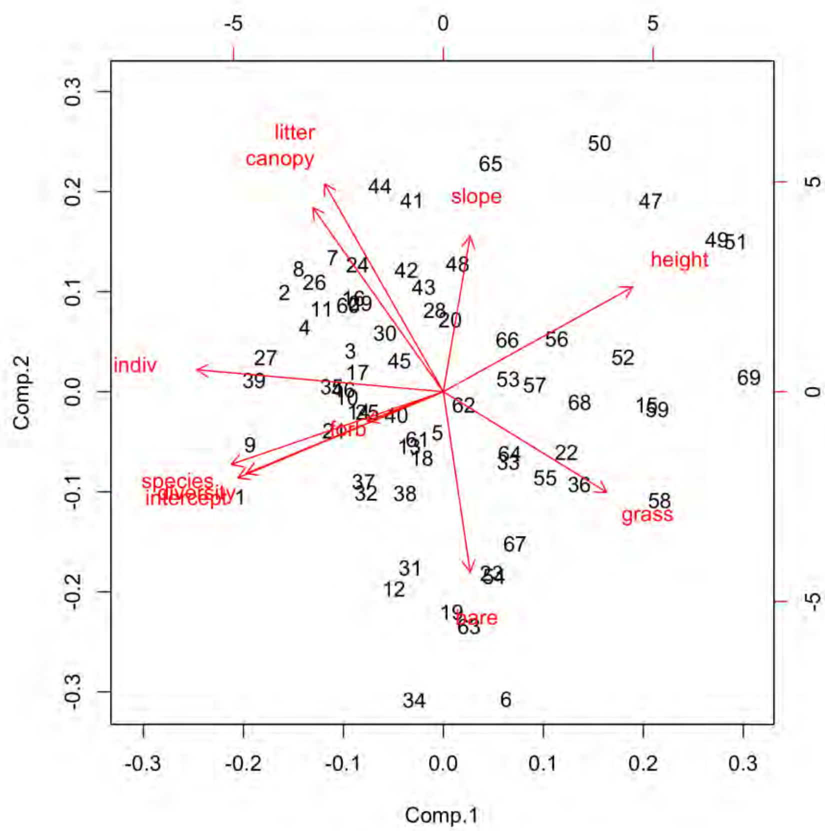

Fig. 7. PCA biplot for all transects

The majority of the habitat at LANWR was characterized by increased plant density and diversity, more vertical screening cover at ground level, more canopy cover, smaller shrubs and more litter on the ground. A few outliers had more grass, more bare ground and lower species abundance. The majority of FWS tracts fell into the same grouping as LANWR, but with generally more canopy cover and more litter (Fig. 8).

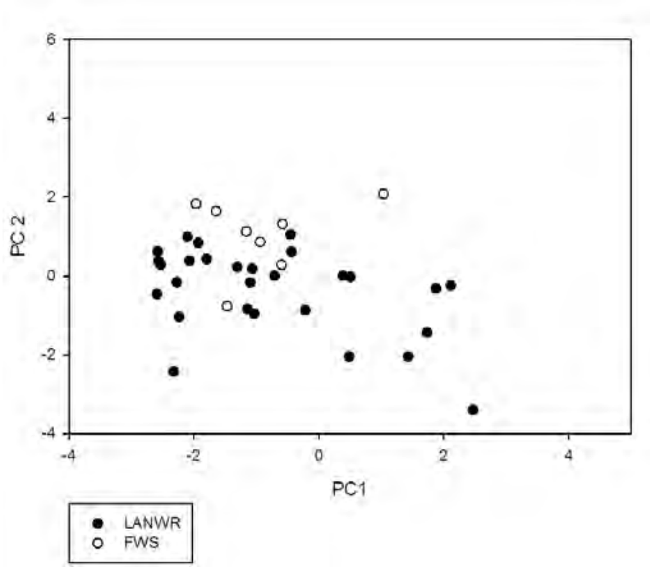

Fig. 8. PCA for LANWR vs. FWS

Along the east-west line, habitats in the east were similar to LANWR with more diversity, more canopy cover, smaller shrubs and more ground litter. The western habitats (sites 1 and 2) were similar, except there were several transects that had more grass and more bare ground. The middle group (sites 3-7 and FWS 2) were characterized by less diversity, taller shrubs, more positive slopes, more grass, and more bare ground (Fig 9).

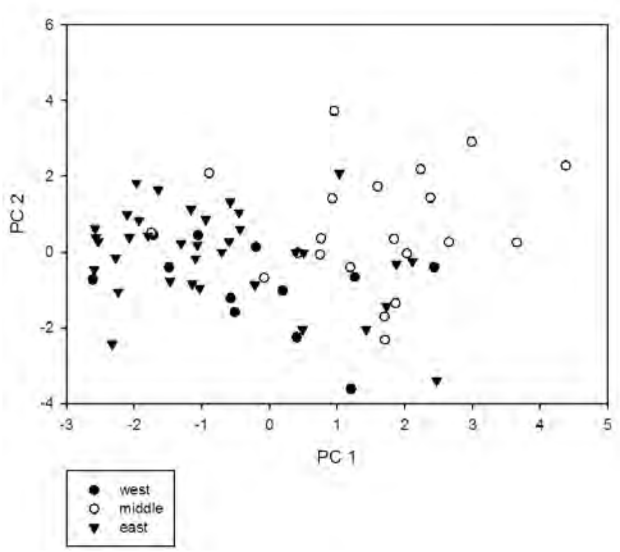

Fig. 9. PCA for sites east-west

Only one transect contained a positive VPB slope (more cover in shrubs at 2.0-2.5 meters than at 0-0.5 meters). Habitat at site 1 followed the grouping of LANWR, also containing a few outliers with more grass, bare ground, and lower abundance. Habitat at site 6 was similar to LANWR, but was not as diverse. Habitats at sites 3 and 5 were less diverse, with taller shrubs and a positive slope. Other habitats tended to fall in between the two extremes of diversity (Fig. 10).

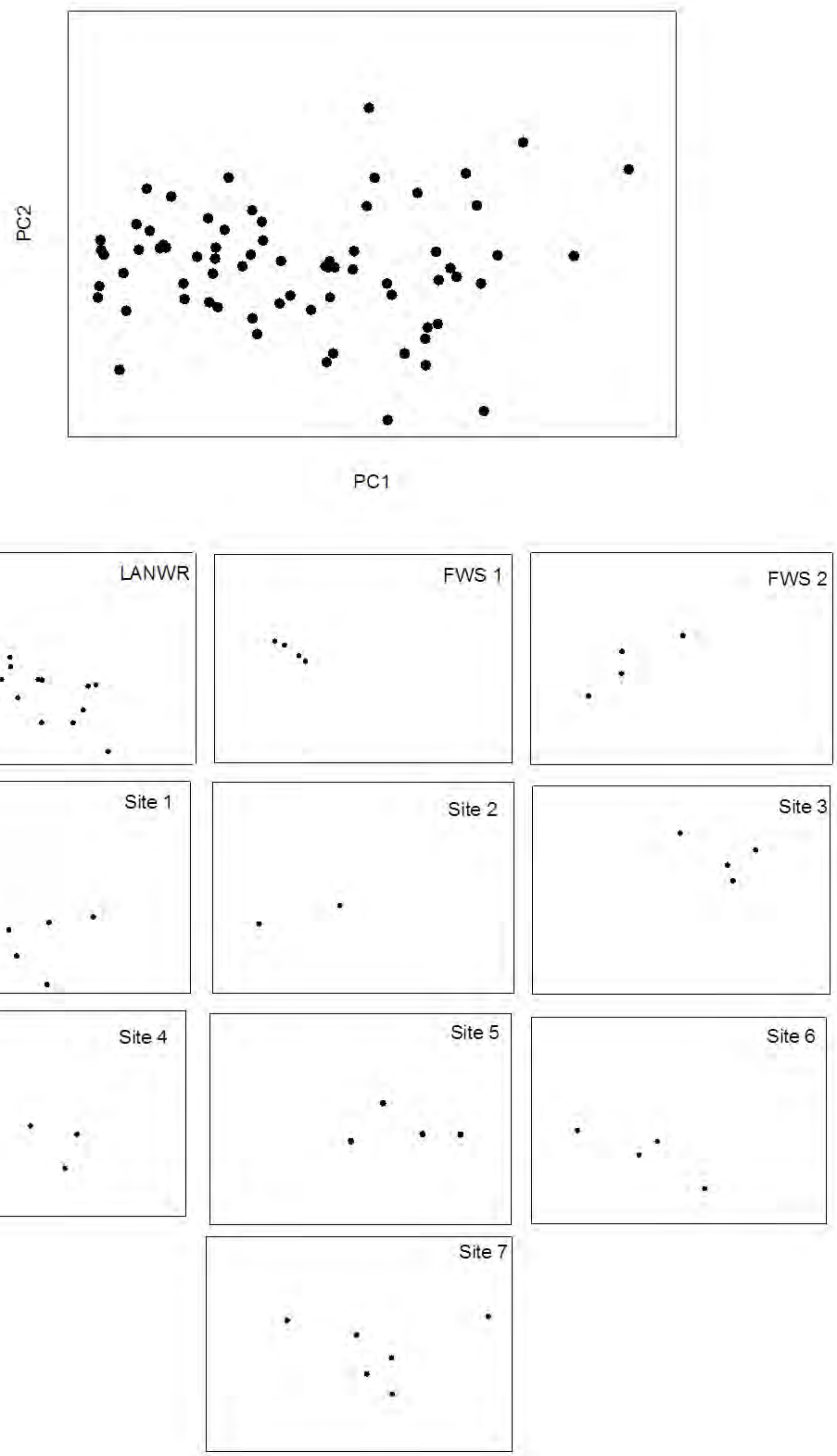

Fig. 10. PCA comparing individual sites with scatterplot

CHAPTER V

DISCUSSION

The majority of previous research on ocelot habitat and recovery plans has focused on canopy cover. My research identifies additional components that might be important in designating potential ocelot habitat. First, our analysis of C-CAP data showed that ocelots preferred shrub/scrub, palustrine shrub/scrub, and grassland. Previous research has shown that four of 11 ocelot dens were located in alkali sacaton grass, *Sporobolus airoides*, and the den chamber consisted of grass bases (Laack et al. 2005). Therefore, habitat with some grasses interspersed throughout dense shrub cover could be beneficial for reproductive considerations. The C-CAP defines the palustrine shrub/scrub category as a tidal and non-tidal wetland dominated by shrubs. My research showed that ocelots selected for palustrine shrub/scrub, but we chose to remove it from the cover map because it produced too coarse of a scale. Future research should look into possible relationships of ocelots and these habitats, especially since prey are likely to be near water and vegetation near water is more dense. My research showed that transects located near intermittent water drainages were generally more dense. These areas are easily found on any satellite image (i.e. Google Earth, Texas Natural Resources Information System) and could be considered as ocelot travel corridors between habitats.

Plant species richness and density were components of ocelot habitat shown to be important. Transects containing lower richness and density of plants generally were dominated by honey mesquite shrubs with a high percentage of grass and tended to be in areas grazed by cattle. Another instance where lower richness and abundance occurred was on a FWS tract, next to La Sal Vieja, a large salt lake. The border around the salt lake contained Willamar soil, a fine sandy loam. Willamar is moderately to strongly alkaline at all horizons according to NRCS, which could prevent certain shrubs from growing.

Soil analysis was identical to Harveson et al. (2004), but I decided to identify the soil composition for each series to determine a key factor in soil use. While most of the preferred soils were silty clay loams, half of the avoided soils were of a similar loam type. All soils contained a substantial amount of clay. Box (1961) looked at relationships between soil and similar plants (lotebush, blackbrush, brasil), and determined that no significant differences existed between clay content in the soil samples of different plant communities. I considered focusing on soil orders for this study but according to NRCS, soil orders in South Texas are broken up from east to west, from Vertisols, Mollisols, and Inceptisols. Vertisols generally have more clay that tends to shrink and swell with moisture content. Mollisols are enriched with organic matter and are naturally fertile. More to the west are Inceptisols which have weakly developed subsurface horizons. In the northern counties are Alfisols, which contain more clay and ≥35% base saturation. The region for Mollisols lined up with sites 3-7, which were least similar to ocelot habitat based on the PCA results. Box (1961) also determined that there was a strong negative correlation between potassium and shrub cover, suggesting that these shrubs grow best in soils with low potassium. Consideration of chemical content in soil would likely be more beneficial than focusing on soil texture/type or soil orders.

Vegetation profile board results were beneficial in determining the vertical structure of vegetation cover. When identifying potential ocelot habitat, it is best to follow a regression of Y= 90 - 3.929x for vertical structure. Transects that had a similar regression were found to be similar to ocelot habitat in PCA analysis. Similar transects had a higher intercept representing more VVO at ground level, and a more negative slope representing greater change in VVO from ground level to 2.5 meters. The transects in the middle section (sites 3-7 and FWS 2) of the map were least similar to ocelot habitat and had a VVO at ground level of 65.18%. The minimum VVO at ground level on ocelot habitat was 88%, which proved to be important on PCA, suggesting that dense cover at ground level should be accounted for when searching for potential ocelot habitat, not just canopy cover as stated in previous literature (Shindle and Tewes 1998, Harveson et al. 2004).

Overall, potential ocelot habitat is characterized by greater plant diversity, more dense shrubs at ground level, more canopy cover, smaller shrubs and more litter on the ground.

CHAPTER VI

MANAGEMENT IMPLICATIONS

Based on my results, potential habitat could be initially found using the brush map produced by Sternberg (FWS, 2009), which delineates 75% canopy cover (Fig 11). Our brush map uses shrub/scrub that C-CAP defines >20% of the total vegetative cover, so a more specific map would be beneficial. Once potential habitat is identified, field measurements need to be conducted on a wide array of vegetative parameters. Results from future field research can be compared with our data to determine if habitat falls into the same range on the PCA scatterplot. Additional parameters such as soil chemistry might also be included in the analysis because of its influence on plant growth.

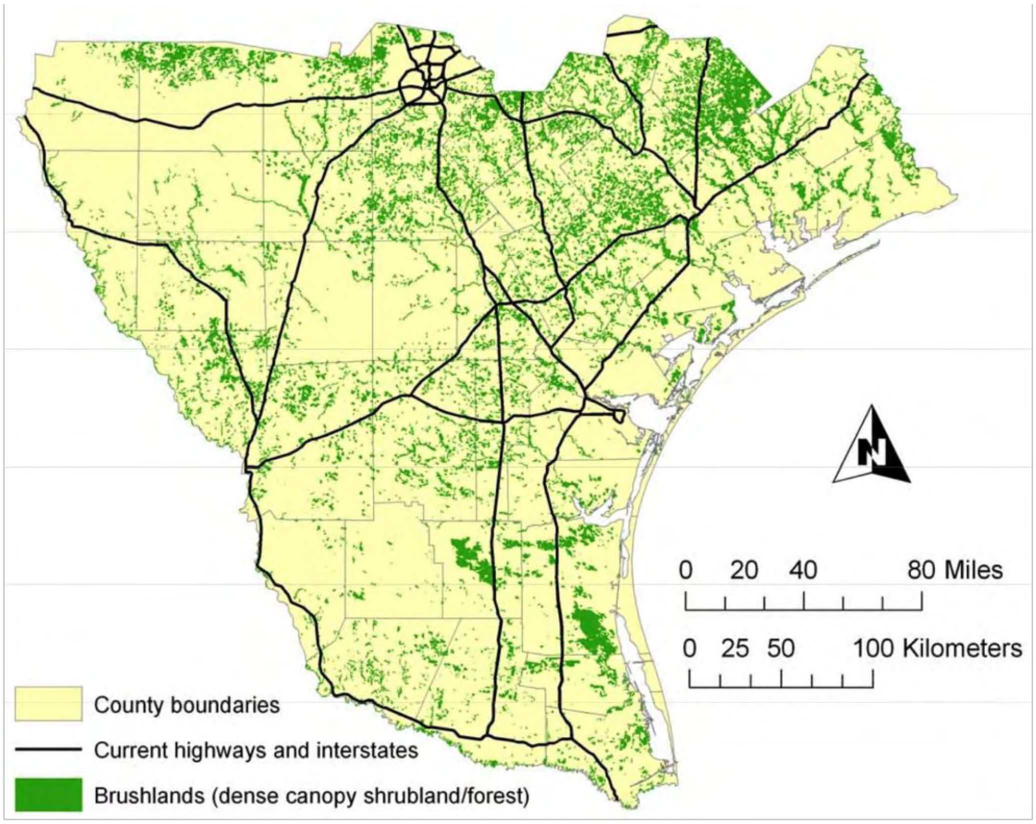

Fig. 11. Shrub/scrub cover map for South Texas produced by Sternberg (FWS, 2009)

The clearing of Tamaulipan brushland has eliminated more than 95% of all brushland habitat. This habitat loss because of agriculture in addition to urbanization and economic development has altered the area along the Texas-Mexico border (Chapman et al. 1998). In order to compensate for this, agricultural lands need to be converted to conservation lands to provide contiguous habitat for ocelots. Ocelots play a large role in conserving the native habitat, primarily because they are considered a flagship species. Conservation of land for ocelots also conserves land for other species in South Texas such as the burrowing owl (*Athene cunicularia)*, desert tortoise (*Gopherus agassizii)*, whitetail deer (*Odocoileus virginianus)*, and white-wing dove (*Zenaida asiatica)*. Conserving land has proven effective to restoring species. After conservation land was designated for the grizzly bear (*Ursus arctos*), the species recolonized back from 2% to almost 50% of its original habitat (Pyare, 2004). A landscape with carnivores, implying intact food web, has high potential for ecological integrity (Noss et al. 1996). It is important when designating conservation land to consider the habitat requirements of carnivore species to improve the umbrella function (Noss et al. 1996). To do so, we should turn to private landowners who own large tracts of potential ocelot habitat (Haines et al. 2005). Programs such as the Conservation Reserve Program (CRP) offered through the Farm Bill and the Landowner Reserve Program (LRP) offered by Texas Parks and Wildlife provide private landowners incentive to conserve land. At least half of the sites I studied would not provide suitable habitat for ocelots today. Conservation incentives could be used to restore native shrubland by using brush control to encourage basal sprouting, and by planting adapted native shrubs (Campbell and Armstrong 1997). Managers interested in restoring their land can construct shelters to enhance seedling growth and establishment (Young and Tewes 1994).

Evaluation of release sites will begin in 2010 and translocation shall begin in 2011 (Translocation Team 2009). It is now known that ocelots require more than just canopy cover for ideal habitat and other vegetative components (i.e. VVO and plant diversity) can be analyzed to identify potential habitat. Ocelot habitat can now be defined as requiring >75% canopy cover, a mean plant density of >20 individuals/100 m^2, high plant diversity (<0.20 D), <15% grasses, >50% litter, and a VVO regression of Y= 90 - 3.929x. The most important components to identify in the field would be number of woody plant individuals and number of woody species, percent bare ground, percent litter and canopy cover. Importance of plant diversity and density could be a correlation with prey (rodents, birds, etc.) availability/density. Future research should identify prey availability on potential habitat. Generally areas with high number of mesquite trees had less overall plant diversity, density, and more grass. It's possible that areas with high mesquite can immediately be ruled out of the potential habitat selection process. Furthermore areas along the Rio Grande (the Lower Rio Grande Valley) are subjected to high urbanization with high road density (fig.11). The USFWS Translocation Plan recommends to avoid roads with high-speed and/or high-volume traffic. Therefore I recommend biologists to search for potential habitat along the northern border of Willacy and Starr counties and further north and to avoid the northern border of Hidalgo county which is inundated with a geological sand sheet, creating less ideal habitat, as stated in the "middle" section of my study area. Areas containing intermittent water drainages may be used as corridors between habitats. Incentive programs offered by local and national governments may be used to build corridors and/or restore native shrubland. With the cooperation of the government, biologists, and private landowners, there is a chance to recover ocelots.

APPENDIX

C-CAP descriptions of land-use/land-cover classes

Land classification	C-CAP description
high intensity developed	Includes highly developed areas where people reside or work in high numbers. Impervious surfaces account for 80 to 100 percent of the total cover.
medium intensity developed	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover.
low intensity developed	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 21 to 49 percent of total cover.
developed open space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover.
cultivated	Areas used for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
pasture/hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled.
grassland	Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
deciduous forest	Areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
evergreen forest	Areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

mixed forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
shrub/scrub	Areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation.
palustrine forested wetland	Includes all tidal and nontidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent.
palustrine scrub/shrub wetland	Includes all tidal and non tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent.
palustrine emergent wetland	Includes all tidal and nontidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Plants generally remain standing until the next growing season. Total vegetation cover is greater than 80 percent.
estuarine forested wetland	Includes all tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.
estuarine scrub/shrub wetland	Includes all tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.

unconsolidated shore	Unconsolidated material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms representing this class.
bare land	Generally, vegetation accounts for less than 10 percent of total cover.
water	All areas of open water, generally with less than 25 percent cover of vegetation or soil.

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VITA

Amy R. Connolly was born in Santa Fe, N.M. to Susan DeLong and R. Perry Connolly in 1978. She came to Texas as quick as she could and aspired to be involved with the welfare of animals. She worked as the head animal caretaker at a local animal sanctuary while she attended Texas State University-San Marcos. She graduated with a B.S. in Biology in 2002. During her undergraduate studies, she was inspired by Dr. Simpson to pursue a career in wildlife research. This inspiration made her enter the M.S. Wildlife Ecology program in 2007, with Dr. Simpson as her advisor. She immersed herself in multiple research projects and served as secretary for the Student Chapter of The Wildlife Society. Amy's passion for wildlife and the outdoors serves as the motivation for her life's work and she is grateful for the never-ending support from her friends and family.

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