INFLUENCE OF HUMAN RECREATIONAL ACTIVITIES AND VEGETATIVE CHARACTERISTICS ON WATERBIRD ABUNDANCE

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INFLUENCE OF HUMAN RECREATIONAL ACTIVITIES AND VEGETATIVE CHARACTERISTICS ON WATERBIRD ABUNDANCE

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INFLUENCE OF HUMAN RECREATIONAL DISTURBANCE AND VEGETATIVE CHARACTERISTICS ON WATERBIRD ABUNDANCE

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Recreational human activities along waterways may influence the occurrence and abundance of waterbirds. I investigated the possible impacts of recreational activity and vegetative characteristics on the relative abundance of waterbirds along a heavily used river, the San Marcos River, in central Texas. The abundance of waterbirds and human disturbance was estimated by conducting point counts for 20 minutes at 30 randomly determined locations along the San Marcos River. Measurement of riparian characteristics at representative transects along the San Marcos River system were conducted to examine correlations between certain vegetative and aquatic parameters and bird occurrence and abundance using multi-variate statistics. A Principle Component Analysis test was run to analyze the difference between the three *a priori* reaches of the river, divided by the amount of disturbance present, as well as variance partitioning, a test utilizing the Canonical Correspondence Analysis test. With only 2 percent of the explained variation in the occurrence and abundance of waterbirds coming from human disturbance, out of 25 percent explained in total, its apparent that the birds may have habituated out of necessity and that the river vegetative composition is the major deciding factor in determining bird occurrence and abundance.

Keywords: waterbirds, human disturbance, recreational activities, riparian characteristics, multivariate analysis

I. INTRODUCTION

The extent and impact of human disturbance on waterbird species is unclear (Custer and Osborn, 1977; Tremblay and Ellison, 1979; Safina and Burger, 1983; Hafner and Kushlan, 2000). Some of the ways that human disturbance could negatively impact waterbirds includes the reduction of feeding times (Stolen, 2003; Thomas et al., 2003), alteration of habitat use (Burger, 1981), increased energetic demands (Ydenberg and Dill 1986), and increasing competitor density or decreasing individual quality (Gill and Sutherland, 2001). The impact of disturbance on waterbirds is a complex issue; it does not necessarily result in direct mortality, its effects though could be viewed as the perceived risk of mortality (Gill and Sutherland, 2001). Bouton et al. (2005) stated that alarm or disturbance behavior may indicate biologically meaningful stress, it is not clear that the lack of an overt reaction indicates a lack of disturbance. Even the type of "overt reaction" that researchers are looking for when studying disturbance has great variety. Vos et al. (1985) found in his study of nesting Great Blue Herons that the birds' response to disturbance depended on the type of intruder. Burger et al. (1995) and Klein et al. (1995) found similar results in waterbird colonies when looking at foraging disturbance and its effect on waterbird distribution.

Nesting Disturbance

Two of the areas that researchers contend are most affected by human disturbance are nesting success and foraging. Nisbet (2000) described human disturbance as "Any human activity that changes the contemporaneous behavior or physiology of one or more individuals within a breeding colony of waterbirds." Disturbance can be further described and categorized based on disturbance type. Carney and Sydeman (1999) discussed three types of disturbance; scientific research, ecotourism, and recreation. The first type involves conducting research by scientific investigators which in some cases can be the most detrimental to the birds depending on what the investigator may be doing. Actions such as handling eggs or fledglings, drawing blood, or taking various measurements may be very harmful; but most scientists are aware of the possible impact and try to limit their intrusion to as few individuals as possible and/or as brief as possible. The second category is ecotourists, which Carney and Sydeman (1999) separates from the third category, recreators, due to length and repetitiveness of their disturbances. Carney and Sydeman (1999) collectively refer to ecotourists and recreationists as visitors. The biggest problem with visitation by the general public to areas where waterbirds are present is the fact that often times people are simply unaware of the potential negative impact their presence may have on waterbirds. Human presence, coupled with their unpredictable nature and peak usage coinciding with most birds' breeding season (summer), can lead to disastrous results (Burger et al., 1995; Klein et al., 1995).

In a study of a Wood Stork (*Mycteria americana)* colony, Bouton et al. (2005) found that her "boat disturbed group" had dramatically decreased nest success. The next year when boats were excluded from the study, colony nesting success did not differ from that of the control group, thus lending support to the first decline in nest success being caused by boat disturbance and not some outside factor. Tremblay and Ellison (1979) found that researcher disturbance can also have negative impacts; nest checking and marking provoked abandonment of new nests, discouraged late season nesters, and intensified predation of the nests by ravens and gulls. However, there are too many factors involved in nesting disturbance to conclude that disturbance has an equal effect on all species under all conditions. The effect of disturbance during breeding varies between species (e.g. the ability or lack thereof to habituate) and degree of disturbance (e.g. severity, length) can also have a major effect. Bouton (2005) noted mounting evidence demonstrating that some colonially nesting birds will habituate to human presence (Burger, 1981; Rodgers and Smith, 1995; Nisbet, 2000) especially if they are able to discern that the humans pose no threat (Burger and Gochfeld, 1981).

Foraging Disturbance

Much research has been done on the effects of humans on foraging of various waterbird species. Burger (1981, 1986) and Skagen et al. (1991) found that recreational activities could disrupt both foraging and social behavior. Kaiser and Fritzell (1984) found in their study of Green Herons (*Butorides virescens*) that increased human traffic, mostly canoe trips, on the Ozark National Scenic Riverway during the weekend and holidays had many negative effects. These effects included decreased use of the main river channel, reduced length of foraging bouts, and decreased foraging effort by Green

Herons. Kaiser (1981) said that during his observations, green herons spent most of their time on the river foraging and so displacement from the river channel could affect the energy budget of herons at the times when their demand is at its highest. Edington and Edington (1986) found similar results, other studies provide evidence that eventually these effects can be negated due to habituation (Goehring and Cherry, 1971; Keller, 1989; Fowler, 1999 and Nisbet, 2000). Hinde (1970) defined habituation as the waning of a response from repeated stimulation that is not followed by any kind of reinforcement. Keller (1989) noted that 41, 33, and 49 percent, respectively, of Great Egrets (*Ardea alba)*, Green Herons, and Yellow-crowned Night Herons (*Nyctanassa violacea)* tolerated the presence of humans until approached "closely." Current research has shown that each species has a different threshold for disturbance (Batten, 1977; Vaske et al., 1983) and that the level of disturbance accepted before an overt response is shown can also depend on if the bird is a resident or a migrant to the area (Burger, 1981; van der Zande et al., 1980). Nisbet (2000) even went so far as to say that habituation should be purposefully promoted for research, educational, and recreational disturbances. He stated that there was little to no scientifically acceptable evidence that shows either herons or gulls were substantially affected by human disturbance and that most or all species of colonial waterbirds were capable of developing a tolerance or habitation to human disturbance.

Buffer Zones

One of the most common methods put forth by the scientific community to mitigate negative effects from human disturbance is the buffer zone. A buffer zone is some set perimeter distance that humans are not allowed to breach at either a waterbird colony or a body of water where waterbirds are known to be present. The size of the buffer zone is determined by the distances the target species becomes disturbed by the presence of humans. Rogers and Smith (1995) recommended buffer distances of 30 - 32 m for Black-Crowned Night heron (*Nycticorax nycticorax*) and the Great Egret, 88 m for Tricolored Herons and 100 m for the Great Blue Heron. There does not seem to be any set standard buffer distance. For each species' the amount of space needed before agitation and eventual flushing differs. Burger et al. (1995) reported that a buffer zone of 50 meters was sufficient. The area that was visited had tourists on it daily and suffered no short term reproductive losses. She reported that the birds generally seemed unconcerned with human presence near the colony. On the other hand distance as high as 600 meters were recommended for Brown Pelicans (Anderson, 1988). Burger (1995) notes that an unwardened site in her study area had nest mortality rates as high as 15 to 28% when tourists were allowed entrance. Other possible ways to mediate disturbance either from researchers or the general public are as varied as the birds themselves. Tremblay and Ellison (1979) suggested many things for researchers such as delaying visiting nests until one week before hatching, limiting visitation to once every 3 days, avoiding colonies during inclement weather and obtaining reproductive data at a distance when possible. Rodgers and Smith (1995) suggested rules for visitors such as limiting public visits during the late nesting phases and constructing blinds or observation posts for the general public at a safe distance away from colonies.

At its headwaters, the San Marcos River is an urban river flowing 6.4 km through the city of San Marcos, population ~ 40,000. The river, known for its clarity and year-round cool water temperature, 21.1 to 22.5° C is a popular place for recreational activities including swimming, canoe/kayaking, and tubing. The goal of my thesis was to examine the effects of human disturbance and riparian characteristics on the relative occurrence and abundance of waterbirds during the breeding season. Specifically, my objectives were:

Objectives

1. To examine if the varying degrees of human disturbance from recreational activities affects the relative abundance of waterbirds and, if so, which kind(s) of disturbance has the most negative effect(s).

2. To determine how the relative abundance of waterbirds is influenced by riparian and stream characteristics and specifically, which of these factors has the largest effect.

3. To determine if the occurrence and abundance of waterbirds is more affected by human disturbance or riparian and stream characteristics, and to examine any interactions between riparian characteristics, human disturbance and waterbird abundance.

I will test the following hypotheses related to my objectives:

1. H_o: Human disturbance will have no affect on the relative abundance of waterbirds in the study area.

H_a: Human disturbance will negatively affect the relative abundance of waterbirds in the study area. The type of disturbance that will be most adverse in its effect will be pedestrians due to possible presence of pets amplifying their negative impact.

2. H_o: The relative abundance of waterbirds will not be affected by the various stream and riparian characteristics.

H_a: The relative abundance of waterbirds will be strongly affected by various stream and riparian characteristics with the most important being water depth and bank slope.

3. H_o: The interaction of Riparian, stream characteristics and human disturbance will have no effect on the relative abundance of waterbirds.

H_a: Riparian, stream characteristics and human disturbance will have a significant interaction and affect the relative abundance of waterbirds.

II. METHODS

Study Area

The San Marcos River arises from Spring Lake at Aquarena Springs in San Marcos, Hays County, Texas (at 29E56' N, 97E55' W). The San Marcos flows southeast for 6.4 km downriver from the springs where it then merges with the Blanco River. The San Marcos River flows for a total of 120.7 km forming the boundary between Guadalupe and Caldwell counties and part of the boundary between Gonzales and Caldwell counties, before reaching its mouth on the Guadalupe River, 3.2 km west of Gonzales (at 29E29' N, 97E28' W). Spring Lake (at 29E53' N, 97E56' W) is produced from San Marcos springs, which has an average daily flow of 5.67×10^8 to 1.13×10^9 liters a day, half a dozen other large outlets from the Edwards Aquifer, and a many small seepages. These combine to form the San Marcos River. The lake lies at the foot of the Edwards Plateau, some 48 km south of Austin and 129.5 km north of San Antonio. The San Marcos River itself was chosen for this study due to the fact that it is exposed to a wide range of human disturbance types and severity as well as its variety of riverine characteristics and easy accessibility (Smyrl, 1996). Within the headwaters, the water temperature remains steady, varying from 21.1 to 22.5 º C. The pH increases rapidly as it comes out of the springs in the headwater until it reaches 8.0 which is typical of a limestone dominated drainage. Dissolved oxygen concentrations are within 20% of the temperature dependent saturation concentration and although the river becomes increasingly turbid as you go downstream, its overall turbidity is not very high at approximately 1.9 BTU (Groeger et al.,1997). The San Marcos River was divided *a priori* into three reaches based on perceived human activity: high, medium, and low. Recreational traffic along the river decreases considerably along the river from the spring-fed falls past several water-control structures and dams. The first reach of the river is the reach of perceived high human disturbance and starts at the spillway from the spring-fed pond and goes until the Rio Vista Dam approximately 1.46 km away. The middle reach is the moderate disturbance reach and goes from Rio Vista Dam until Thompson's Island which is 1.78 km away. The third reach, with perceived low human disturbance, goes downstream from Thompson's Island for 2.7 kilometers and ends before the confluence with the Blanco River.

Point Counts

Point count surveys were conducted during two breeding seasons, from March through August in 2006 and from April through August in 2007 to examine the relationship between overall occurrence and abundance of wading birds and the amount of disturbance at each of the reach. To measure the occurrence and abundance of wading birds along the river, I conducted point count surveys four times a week from randomly determined locations. These locations were randomly determined using a geographic information system (GIS) and observations were made from these locations in 20-minute intervals. Surveys were conducted randomly in respect to time and day to minimize any temporal bias. Point survey locations, although randomly selected, were checked to ensure as complete a coverage of the river system as possible since the river varies in degree of recreational activity. Each reach of the river contained 10 fixed locations for a total of 30 point count stations. All point count locations were a minimum of 100 m apart from one another and were located in areas that gave the maximum amount of visual range. All surveys were conducted with two observers from a canoe using binoculars. To determine bird occurrence and abundance, I recorded the number of all waterbird species. I also monitored human activity at the point count locations by counting the number of people that pass the stationary point or were in visual distance and recorded the length (min) and nature of their disturbance. Disturbance was divided into several groups including swimmers, kayakers, and personal flotation devices which includes such items as inner tubes and from now on will be referred to as PFD's .

Riparian and Stream Characteristics

I measured riparian and stream characteristics to examine the effects of habitat characteristics on waterbird occurrence and abundance. These measurements were taken at three representative transects in each of the three river reaches to adequately capture as much of the variation present within each of my predefined reaches of river. The measurements were taken three times each field season, in May, June, and July to measure any temporal changes that may occur. I measured the following stream characteristics: water depth (m), shoreline depth (m), width of the river (m), current velocity (m/s), substrate type (organic, silt, mud, sand, gravel, cobble, boulder, clay, bedrock), river habitat type (run, riffle, rapid, chute), bank slope angle, canopy cover (%), vegetative composition along the riparian corridor (tree, vine, emergent, herbaceous), instream cover (%), percent aquatic macrophytes, and percent algae. Current velocity (CV) was gathered from the United States Geological Services website (http://www.usgs.gov/, USGS 08170500). Bank slope, water depth and shoreline depth were calculated from data collected with a surveying scope. Canopy cover was measured using a densiometer while substrate type was quantified visually using a modified Wentworth scale and both percent aquatic macrophyte and algae was determined though the use of a 30 x 30 cm quadrat. Several different parameters including water temperature, pH, dissolved oxygen, and turbidity, have been shown to be stable within and between year and were therefore recorded only once during the study (Groeger et al., 1997).

Analysis

Principle Component Analysis (PCA) was conducted on environmental parameters to assess similarities and differences in habitat among stream reaches. Data were Z score transformed. In addition, diversity (H'), evenness (J') and species richness were determined to compare each reach of the river during the duration of the study. Diversity was determined with the Simpson's complement which indicates the probability of drawing, at random, a pair of individuals of different species and evenness, which is referred to as homogeneity or relative diversity, by the Equitability index.

I used Canonical Correspondence Analysis (CCA) (terBraak and Smilauer, 2002) which is a multivariate statistical test, to assess the relationships among riparian/stream characteristics, human disturbance and waterbird occurrence and abundance. Calculation of the CCA was done by Canoco version 4.5 (terBraak and Smilauer, 2002). Variance partitioning analysis was used to determine the amount of variation present in the assemblage structure due to the riverine habitat and recreational human disturbance. This is done via a series of partial Canonical Correspondence Analysis which are similar in function to partial regression techniques (Quinn and Keough, 2002). For each variable of interest, the other factor was used as a covariate in the analysis to assess its pure effect due to the potential for 2-way interactions (Quinn and Keough, 2002; Williams et al., 2002). For each partial CCA, a Monte Carlo test with 1,000 global permutations was used (terBraak and Smilauer, 2002). After the initial calculations several variables were parsed from the data to reduce redundant or insignificant variables due to problems with multicolinearity issues. Rare species were also down weighted and all of the data were log transformed.

III. RESULTS

Habitat Attributes

San Marcos River is a relatively narrow and shallow river with predominantly run and riffle geomorphic units and gravel substrate (Table 1 & Figure 1-3). Among sites, mean stream width (± SE) ranged from 15.9 ± 0.44 to 23.74 ± 1.52 m; mean depth ranged from 0.72 ± 0.004 to 1.18 ± 0.12 m; and mean current velocity ranged from 0.16 ± 0.02 to 0.29 ± 0.05 m/s. The river is fairly wide and shallow upstream and although though the mean river depth decreased from the first to second reaches of the river it increases between the second and third reach to a depth even higher than that of the first reach. Current velocity predictably increased downstream as the river's width decreased. The amounts of several substrate types including gravel, organics, silt, cobble, and mud all followed a similar pattern, decreasing from the first to the second reach of the river and then increasing in the third reach of the river. Gravel returned to the level seen in reach one while organics and silt come close to their original levels and cobble and mud actually appeared in a great amount in the third reach than they did in the first.

The first three PCA axes explained 52.45% of the total variation in the environmental parameters. PCA axis 1 explained 23% of the total variation and described a vegetation and macrophytes and stream morphology gradient (Figure 4). Habitats with the highest negative loadings on PCA axis 1 were riffles with few aquatic macrophytes, low levels of herbaceous material and high amounts of canopy cover. Habitats with highest positive loading on PCA axis 1 were chutes with a boulder substrate, high amounts of herbaceous material and aquatic macrophytes and little to no canopy cover. PCA axis 2 explained 16.03% of the total variation and was primarily a substrate gradient. Habitats with the highest negative loadings on PCA axis 2 was those with greater amounts of cobble and gravel substrate, greater mean water depth, low levels of aquatic macrophytes and a higher amount of artificial structures. Habitats with the highest positive loadings on PCA axis 2 had greater amounts of clay and bedrock substrates, shallower depths, and a higher amount of large woody debris and aquatic macrophytes. The third PCA axis explained 13.1% of the total variation and was primarily a water depth and substrate gradient. The habitats with the highest negative loadings on PCA axis 3 were those with a predominantly sand and cobble substrate, higher amounts of aquatic macrophytes and shallower mean water depth and thus a higher current velocity. Habitats with the highest positive loadings on PCA axis 3 were runs with greater water depths, lower current velocities and thus a predominantly silt and organic substrate.

Reach one tended towards higher amounts of macrophytes due to its clear and shallower water. Due the to the city parks the reach tends to have lower amounts of vegetation and canopy cover. The second reach is highly varied in some of its attributes, having parts that had very shallow, fast moving, clear water as well as very deep, slow moving, turbid water. The shoreline vegetation was fairly stable mirroring the third reach. The second reach serves as a type of transitional zone between the more urban reach one and the more natural reach three and thus has some attributes of each. Reach three is generally deeper than the first two reaches and due to the increased depth has lower levels of riverine vegetation. Also since it is so far from the head waters this reach is in a more natural state and thus has increased amounts of shoreline vegetation present. With is distance downstream the city lead annual river clean up does not reach that far and thus there is more trash and litter present.

Taxa Structure and Distribution

A total of 381 birds representing seven families and 18 species as well as various domesticated ducks and geese were observed on the San Marcos River (Table 2). The most dominant family was Anataidae with 47.5%, followed by Ardeidae (45.14%), Rallidae (2.36%), Phalacrocoracidae (1.83%), Alcedinidae (1.57%), Podicipedidae (1.04%) and Scolopacidae (0.52%). For the three reaches of the river, the numbers of bird sightings 280 in the first reach, 82 in the second, and 19 in the third and human disturbance (total number of events, total time: 1364, 1755 min; 165, 374 min; 48, 175 min), decreased with each reach downstream. The family Anataidae was dominant on the first reach with 51.8% of the total sightings while on the subsequent reaches Ardeidae was dominant with 51.2% and 73.7% of the sightings respectively. While every family listed above was found on the river's first reach (Table 3), families Phalacrocoracidae and Rallidae were absent on the second, and on the third reach only Alcedinidae, Aredeidae, and Rallidae were present (Figure 5). Several species were rare, having two or fewer sightings, including the Gadwall, *Anas strepera*, Spotted Sandpiper, *Actitis macularia,* Great Egret, *Ardea alba,* Green Kingfisher, *Chloroceryle americana,* American Widgeon, *Anas Americana,* Blue-winged Teal, *Anas discors,* Little Blue Heron, *Egretta caerulea,* and Double-Crested Cormorants, *Phalacrocorax auritus*. Associations or correlations made with a rare species would be highly suspect and thus will be left out of further discussion.

Diversity and Evenness

The highest number of species and the area with the most unique species was the first reach of the river. Downstream the number of species decreased and there was only one unique species in the third reach of the river with none in the second. The first two reaches of the river had a high level of diversity at 0.7997 and 0.8664 respectively and the third, moderate at 0.5066. The evenness of the species composition varied greatly between the three reaches of the river with the first reach at 0.7959, the second at 0.4356, and the third at 0.2135. This shows that although the number of species in each reach was relatively high, in later reaches more so than the earlier ones, the distribution was skewed to a few species.

Canonical Correspondence Analysis

Twenty five percent of the bird assemblage was explained by environmental parameters and disturbance variables. The pure effects of the environmental or disturbance variables did not explain significant amounts of the assemblage variability, 23% (P = 0.77) for environmental variables and 2% (P = 0.99) for the disturbance factors. There was no shared variation in the data set.

Habitat factors with the highest positive centroids, followed by their biplot scores, on the first environmental axis of the CCA were bedrock (0.67), run (0.51) and PDF time (0.55). Factors with the highest negative centroids were canoe presence (-1.04), small woody debris (-0.75), riffle (-0.69) and artificial structures (-0.55). Species positively associated with axis one included green kingfisher (1.84), belted kingfisher (1.57), American coot (1.29), great blue heron (0.80), green heron (0.57), gadwall (.49), great egret (0.40), neotropic cormorant (0.09) and double-crested cormorant (0.09). Species negatively associated with axis one included Domestic Ducks (-1.67), Mexican Mallards (-1.40), Spotted Sandpipers (-0.63), Little Blue Herons (-0.47), Pied-Billed Grebes (-0.44), Domestic Geese (-0.41), Mallards (-0.38), Muscovy Ducks (-0.23), Yellow-crowned Night Herons (-0.12), Graylag Geese (-0.08) and Blue-winged Teal (-0.07) (Figure 6-7).

IV. DISCUSSION

Use of Landscape Approach

The aim of the landscape approach to disturbance studies is to demonstrate the spatial effect of human disturbance on the abundance, presence/absence, or behavior of birds in relation to the presence of certain landscape variables (Burton, 2007). One criticism of this approach is the degree to which one can draw inferences that the results are a concrete conclusion and not just an implication that disturbance is the causal factor to the spatial patterns observed. According to Burton (2007), the extent to which one can be sure of their results comes from the extent that the other explanatory variables are considered. Velazquez and Navarro (1993) and Yates et al. (1993) stated that this is particularly true when variation in different factors such as substrate and water depth could affect the distribution of waterbirds; this is the case in my study area. Therefore, by directly measuring riparian and stream characteristics and removing all spatially autocorrelated variables from the final analysis, this should allow for inferences to be drawn from my results. Additionally, this study does not examine the effects of disturbance on the fitness of any individual bird and thus effects on the local populations. Burton (2007) further describes the landscape method as capable of several things including, offering a framework for more detailed investigations on the mechanisms of disturbance, possibly providing further insight on the tolerances of different species to the types of disturbance associated with human landscape features, and offering a first step towards site management. My results provide such a framework for further investigations into disturbance and its effects on a variety of species.

Generally, the two major families, Anataidae (ducks/geese) and Ardiedae (herons/egrets), respectively decreased substantially with each successive reach of river with Anataidae being completely absent from the third reach. There were a few exceptions to this such as the Great Egret, Green Heron, Great Blue Heron grouping's association with the third reach of the river and some of the rare taxa such as the Blue-winged Teal and American Widgeon, which were only found in the first reach of the river and the Little Blue Heron who was only found in the second reach. The smaller families differed greatly in their associations of river reaches. Kingfishers were only observed in the third reach of the river, while the Grebes and Sandpipers were found only on the first and second, the American Coot only on the first and third and the Cormorants only on the first. All of the rare species above were cited on the adjacent Spring Lake in far greater numbers, with flocks of Grebes and Blue-winged Teal at times reaching up into the high 20's, and with greater frequency, with Little Blue Herons being the exception which used Spring Lake only as a stop on their migration and stayed for only 3 or 4 days at a time (Polak, unpublished data). Although Spring Lake is the headwaters for the San Marcos River and receives moderate, to at times high, levels of human disturbance, human presence for the most part is limited to a board walk and the birds tend to stay at least a dozen meters from the human presence. In addition to the humans on the boardwalk, the Aquerena Center on Spring Lake houses a golf course and a major highway for the city of San Marcos runs parallel to the lake. This shows that although habituation appears to have take place here as it did on the river, that the differing habitat like placid lake conditions and massive vegetative mats floating throughout the lake to feed on and serve as stable feeding platforms is the determining factor in the presence of certain species. Though it is possible that the deciding factor for these species was some factor that was not measured, perhaps prey size or type. Hockin et al. (1992) and Hill et al. (1997) said that factors such as resource availability could affect things such as habitat quality, use of space and reaction to disturbance.

Habituation

Contrary to my a priori predictions, the greatest number of bird sightings occurred where the greatest amount of human disturbance occurred (Table 4). These results might indicate voluntary acceptance of the human presence, also know as habituation, but does not imply that this indicates preference for this locale, but rather a necessary association for foraging requirements. Based on habitat suitability surrogates such as turbidity, bank slope, current velocity, and water depth, it appears that for most species of waterbirds that I observed, habitat suitability decreases with distance downstream from springs. Specifically, turbidity of the water increases, the bank slopes increase denying birds suitable hunting habitat, and the current velocity and water depth increase due to a decreased river width; majority of suitable habitat on the river is near its headwaters region. Similar results were obtained by Lafferty's (2001) research on shorebirds, whereas although some birds may exhibit a response to human disturbance, this was not evident in the birds' patterns of site use. Lafferty reported over 70% of the observed shorebirds flush when they were disturbed, although disturbance was less of an influence than season, tides, and habitat use on decisions at a landscape scale patterns of beach use. McKinney et al. (2001) showed that landscape characteristics explained a significant amount of the variation in species abundance and richness of waterbirds in an urban environment. In my results, the increase in local rainfall in the 2007 field season over the 2006 season (Figure 8) may have been a factor in the increase in total bird sighting between the two years. If the hydrologic conditions for lakes and rivers were in poorer conditions in other regions, this may have resulted in birds exhibiting less avoidance of areas associated with high levels of human disturbance when under stress from drought conditions (Gill et al., 2001).

Total Variation Explained

The total variation explained was relatively low at 25% but according to Carleton et al (1996) and Okland (1996), this is not a problem because variances as low as five percent are ecologically interpretable. But low total variation explained, (TVE), like this is to be expected, even when the data have a high number of carefully selected variables; they used 30 variables as an example and I used 47 variables. In a constrained ordination tests such as CCA, TVE is normally only 20 to 50% (Okland and Eilertsen, 1994; T. Okland, 1996; Wiser et al., 1996). Okland (1999) defended the use of variance partitioning as long as the focus was shifted away from unexplained variation (described by Borcard et al., 1992; Rydgren, 1994; Heikkinen and Birks, 1996) as unmeasured environmental variables, complex spatial relationships, and stochasticity in biological processes such as dispersal, establishment and mortality and noise, and towards the relative amounts of variation explained by sets of variables.

Species Associations

In the CCA analysis, several species showed generalist tendencies by their central placement in the matrix. These included the Graylag Goose, Mallard, Muscovy Duck, and Domesticated Geese. These species showed associations that tended towards higher vegetative densities and higher pedestrian traffic, although their placement near the CCA axes origin indicates that they showed no strong preferences. This grouping's presence upstream adjacent several city parks is consistent with predictions of domesticated waterfowl occurring in urban areas. Domesticated waterfowl exhibited little fear of humans, habituated to the point that close contact is possible before any overt avoidance reaction is seen (Polak, unpublished data). The Green Heron and Great Blue Heron grouping favored the areas downstream with lower pedestrian traffic and lower vegetative densities with muddy banks and a slight inclination towards larger amounts of large woody debris. For the Great Blue Heron this would be within the range of its feeding habitat tolerances but not for its preferred nesting area due to the lower amounts of vegetative cover (Butler, 1992). However, no nests were observed and Great Blue Herons can travel considerable distances between foraging sites and nests (Butler, 1992). The occurrence of Green Herons, which are habitat generalists, along riparian zones was also in accordance with the published literature (Davis and Kushlan, 1994). Though the two species were in observed in typical foraging habitat, their presence down stream and subsequent relative absence upstream would appear to indicate an aversion to human presence. On many occasions, I witnessed Green Herons flushing as soon I came within 10 - 15 m, and would often continuously flush and move down stream some times for great distances. The Yellow-crowned Night Heron and the Neotropic Cormorant were found to prefer areas with a higher current velocity, bedrock substrate, higher levels of emergent vegetation and overhanging canopy, but avoided areas with higher amounts of pedestrians and aquatic macrophytes. For the Neotropic Cormorant, a diving bird, the selection of areas with large amounts of overhanging canopy for perching and avoidance of areas with aquatic macrophytes makes biological sense due to its preference for low turbidity and indifference to shoreline emergent vegetation (Telfair and Morrison, 2005). The cormorants seen on the river presumably came from the colony at adjacent Spring Lake; foraging bouts on the river usually ended with the birds flying in the direction of Spring Lake (Polak, unpublished data). Yellow-crowned Night Herons, frequently forage on crustaceans, including crayfish (*Procambarus clarkii*), commonly occur along rivers (Watts, 1995). The vast majority of my sightings were made while the bird was patrolling the banks, usually hidden within the emergent vegetation looking for its prey. The Mexican Mallard and Domesticated Ducks showed associations with areas low in large woody debris but high in small woody debris. They also occurred in areas with riffles and higher canoe traffic. The Pied-Billed Grebe showed heavy associations with both pedestrians and vegetative density; while it is unclear if they prefer areas with pedestrians, grebes were often seen being fed by patrons upstream at two city parks. My results are in accordance with other studies; grebes are usually associated with dense stands of emergent vegetation and nearby open water (Muller and Storer, 1999). Though grebes were sighted occasionally on the river, their relative abundance was considerably higher on nearby Spring Lake, presumably due to the lack of current. The Belted Kingfisher showed slight associations with runs downstream, but this is not their typical habitat. Belted Kingfishers are known for inhabiting areas with riffles (Hamas, 1994), due to the fact that the association is only weak I would assume that my sighting were not for birds foraging but rather moving back and forth though their territory. The American Coot preferred areas with higher levels of canopy cover.

Management Implications

Although a flushing response from the birds was seen in the presence of active human disturbance, waterbird presence was still highest where disturbance was greatest on the San Marcos River; results similar to other studies (Hockin et al., 1992; Hill et al., 1997). Peters and Otis (2006) had similar results and came to the conclusion that whether individuals eventually abandoned a site was determined by several factors outside those of human disturbance such as quality of the site being occupied, distance to and quality of other suitable sites and the risk of predation and competition at said sites. Due to the urban location and current recreational use of the San Marcos River, decreasing human traffic and setting up buffer zones would be difficult and is unlikely to occur. Concessions have to be made to minimize the effects of disturbance on waterbirds. While decreasing recreational traffic along the river may be difficult, the habitat could be improved to provide more suitable habitat as well minimize the habitat loss from recreational use (e.g. vegetation trampling). But in situations outside of small lakes and limited reaches of river this can quickly become economically unfeasible; therefore the best option may be through public education targeting recreational users of the river. For situations such as the one facing the San Marcos River, bodies of water within urban areas, the well-intentioned but uninformed patrons of the river could be your best allies. Public users who enjoy the river presumably want to protect the resource so they can continue to enjoy it;

they may be just ignorant to the detrimental impact their presence may have even when they follow the rules and regulations (Thompson et al., 1987). Public and visitor education should stress reducing the incidence of approaching the animals on foot and how human presence may negatively influence feeding opportunities and access to foraging habitat (Klein, 1993). Studies have shown (Buell, 1967; Seketa, 1978; Shay, 1980; Duda 1987) that if people understand the effects of their actions on animal populations, the public is more likely to support future changes.

Some species may not regularly exhibit signs of avoiding disturbance such as herons and egrets (Klein et al., 1995); this lack of response may lead managers to assume protection or mitigating the effects of disturbance are not necessary. Since the aim is to maintain or increase the population size at a site then an assessment of whether disturbance causes the birds to leave would be appropriate (Gill et al., 2001). But to do this future studies need to understand several factors such as density dependence in the system and how changes in the behavioral responses to disturbance could affect demographic parameters such as survival, reproductive success and fecundity and thus overall population size (Gill et al., 2001).

TABLES AND FIGURES

Table 1. – Mean habitat variables plus or minus standard error for each sampling reach across collection dates March 2006 through August 2007 for the San Marcos River.

	Reach 1		Reach 2		Reach 3	
Habitat variables	Mean	SE	Mean	SE	Mean	SE
Depth	0.891	0.038	0.722	0.004	1.179	0.119
Current Velocity	0.161	0.018	0.253	0.041	0.294	0.049
Chute	0.407	0.142	0.000	0.000	0.000	0.000
Run	0.443	0.144	0.509	0.145	0.430	0.144
Riffle	0.150	0.104	0.491	0.145	0.528	0.145
Rapid	0.000	0.000	0.000	0.000	0.051	0.065
Width	23.738	1.516	21.291	1.248	15.905	0.443
Slope Right	3.120	0.244	3.696	0.321	2.917	0.000
Slope Left	3.035	0.239	2.169	0.187	4.000	0.421
Vegetation Density	69.866	5.322	77.870	2.971	65.361	5.232
Percent Aquatic Macro.	59.573	5.245	25.303	5.296	9.985	4.484
Percent Algae	8.660	3.729	5.640	2.204	1.377	0.722
Canopy Bank	58.883	13.225	94.798	1.903	86.890	5.961
Canopy River	36.337	9.758	71.178	4.289	81.066	6.334
Herbaceous vegetation	2.478	0.209	1.400	0.227	1.667	0.276
Emergent vegetation	1.200	0.175	1.407	0.233	1.200	0.177

Table 1 continued. - Mean habitat variables plus or minus standard error for each sampling reach across collection dates March 2006 through August 2007 for the San Marcos River.

	Reach 1		Reach 2		Reach 3	
Habitat variables	Mean	SE	Mean	SE	Mean	SE
Vines	1.604	0.245	2.376	0.269	2.681	0.183
Trees	1.859	0.223	2.983	0.053	2.917	0.118
Small Woody Debris	0.483	0.216	0.797	0.197	0.476	0.145
Large Woody Debris	0.533	0.145	0.967	0.052	0.144	0.103
Artificial Structure	0.033	0.053	0.392	0.141	0.731	0.130
Overhead Cover	0.659	0.157	2.586	0.276	1.059	0.103
Leaf Litter	0.817	0.113	0.650	0.138	0.177	0.112
Aquatic macrophytes	2.676	0.203	1.370	0.250	0.573	0.216
Algae	0.993	0.108	0.844	0.151	0.481	0.173
Mud substrate	0.680	0.136	0.331	0.136	0.907	0.085
Clay substrate	0.287	0.131	0.509	0.145	0.000	0.000
Silt substrate	0.967	0.053	0.534	0.145	0.907	0.085
Sand substrate	0.713	0.131	0.771	0.122	0.126	0.098
Gravel substrate	1.000	0.000	0.796	0.117	1.000	0.000
Cobble substrate	0.713	0.131	0.491	0.145	1.000	0.000
Boulder substrate	0.680	0.136	0.000	0.000	0.033	0.053
Bedrock substrate	0.000	0.000	0.204	0.117	0.000	0.000
Organic substrate	0.967	0.053	0.534	0.145	0.907	0.085
Herbaceous vegetation, right	2.278	0.238	1.150	0.154	1.794	0.285
Emergent vegetation, right	1.711	0.278	1.000	0.000	1.000	0.000
Vines, right	1.604	0.245	2.254	0.257	1.904	0.287
Trees, right	2.115	0.267	2.794	0.134	2.170	0.287

Table 2. – Complete listing of species found along the San Marcos River, March 2006 through August 2007.

Family	Common Name	Species
Alcedinidae	Green kingfisher	*Chloroceryle americana*
	Belted kingfisher	*Ceryle alcyon*
Anataidae	Graylag geese	*Anser anser*
	Gadwall	*Anas strepera*
	Mallard	*Anas platyrynchos*
	American wigeon	*Anas americana*
	Blue wing teal duck	*Anas discors*
	Muscovy duck	*Cairina moschata*
	Domestic geese	
	Domestic ducks	
Ardeidae	Great blue heron	*Ardea herodias*
	Green heron	*Butorides virescens*
	Yellow crown night heron	*Nyctanassa violacea*
	Little blue heron	*Egretta caerulea*
	Great egret	*Ardea alba*
Phalacrocoracidae	Neotropic cormorant	*Phalacrocorax brasilianus*
	Double crested cormorant	*Phalacrocorax auritus*
Podicipedidae	Pied bill grebe	*Podilymbus podiceps*
Rallidae	American coot	*Fulica americana*
Scolopacidae	Spotted sandpiper	*Actitis macularia*

Table 3. – Mean species richness and number of unique taxa among the 3 stretches of the San Marcos River. Within each stretch the mean and standard error of species richness, diversity, and evenness is given.

	species richness							
Reach	Mean	Total	SE	Number of unique	Diversity	SE	Evenness	SE
Reach 1	7	18	0.4438	7	0.7997	0.0135	0.7950	0.0185
Reach 2	3	13	0.5075	0	0.8664	0.0348	0.4356	0.0893
Reach 3	1	1	0.3015	1	0.5066	0.1340	0.2135	0.0322

Table 4. – Number of birds sighted at each survey point by sampling effort and year.

	Year 1						Year 2					
Survey	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
1	0	2	1	1	0	1	0	0	0	2	0	0
2	2	4	3	4	2	0	0	0	6	0	0	6
3	3	6	9	2	4	7	0	5	2	2	0	1
4	3	5	6	6	0	10	3	4	13	0	0	0
5	2	3	4	0	0	1	3	6	0	0	0	0
6	0	0	0	3	1	2	0	1	4	0	0	2
7	1	0	0	0	5	4	2	2	0	2	3	1
8	2	2	1	1	1	1	0	0	2	6	4	2
9	0	0	1	0	2	2	0	1	0	1	4	6
10	1	0	-	-	6	2	13	12	8	11	0	0
11	0	0	-	-	0	1	8	5	13	8	2	5
12	0	0	0	0	0	1	0	0	2	0	1	1
13	1	0	0	0	1	0	1	0	0	6	0	0
14	0	0	1	0	0	0	1	0	1	0	2	0
15	2	2	0	1	1	0	1	1	0	1	0	2
16	0	-	0	1	1	0	1	0	0	0	0	1
17	0	2	0	1	0	0	1	3	0	0	0	1
18	0	0	0	0	1	0	0	0	0	0	1	0
19	0	0	1	0	0	1	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	1	0
21	0	0	1	0	0	0	0	0	0	0	0	0
22	0	0	2	0	0	0	1	1	0	0	0	0
23	1	0	0	0	0	0	0	0	0	0	0	0
24	-	0	2	1	0	1	0	0	0	0	0	0
25	0	0	1	1	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	1	0	0	2	1	0	0	-	0	0
28	0	0	0	0	1	0	0	0	0	-	0	0
29	0	0	0	0	0	0	0	0	0	-	0	0
30	0	0	0	0	2	0	0	0	0	-	0	0

- Signifies no survey conducted for that point and date

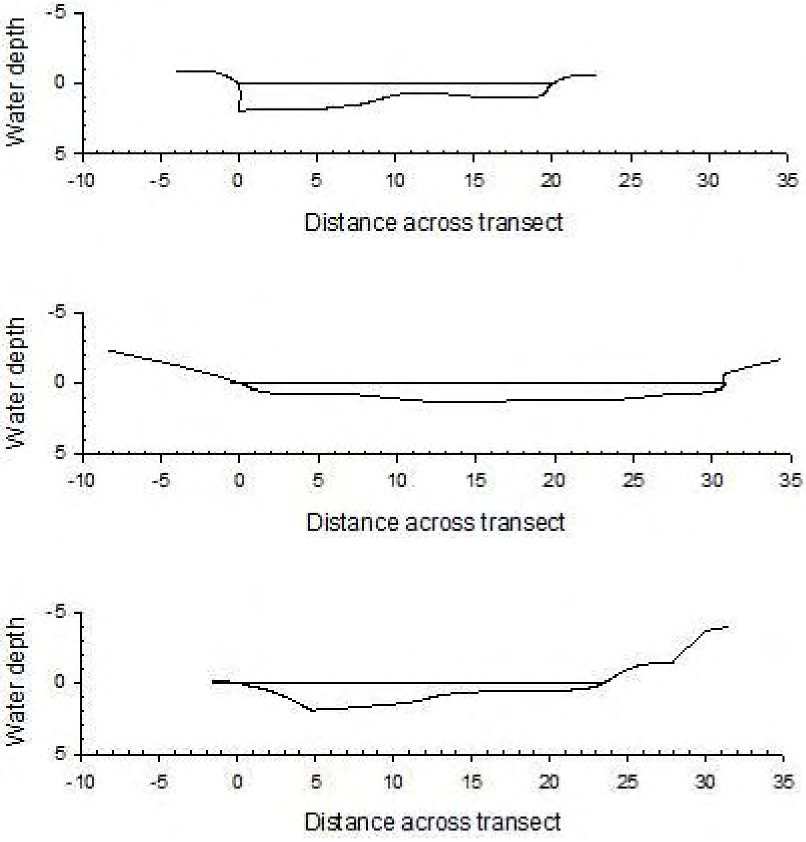

Figure 1. – Representative survey transects 1 though 3 of the San Marcos River. Distances are in meters

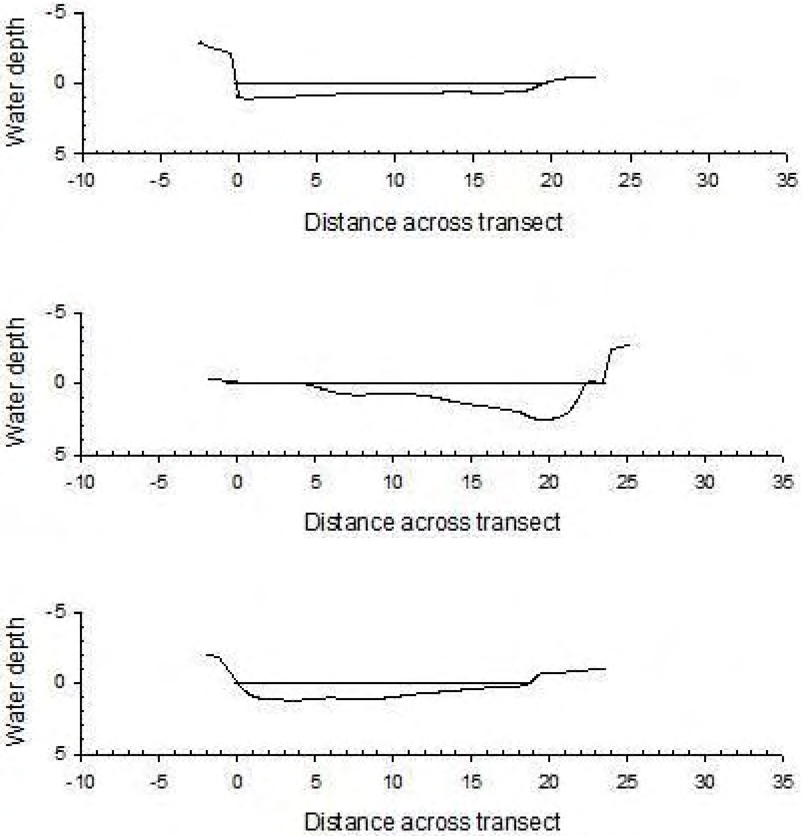

Figure 2. – Representative survey transects 4 though 6 of the San Marcos River. Distances are in meters

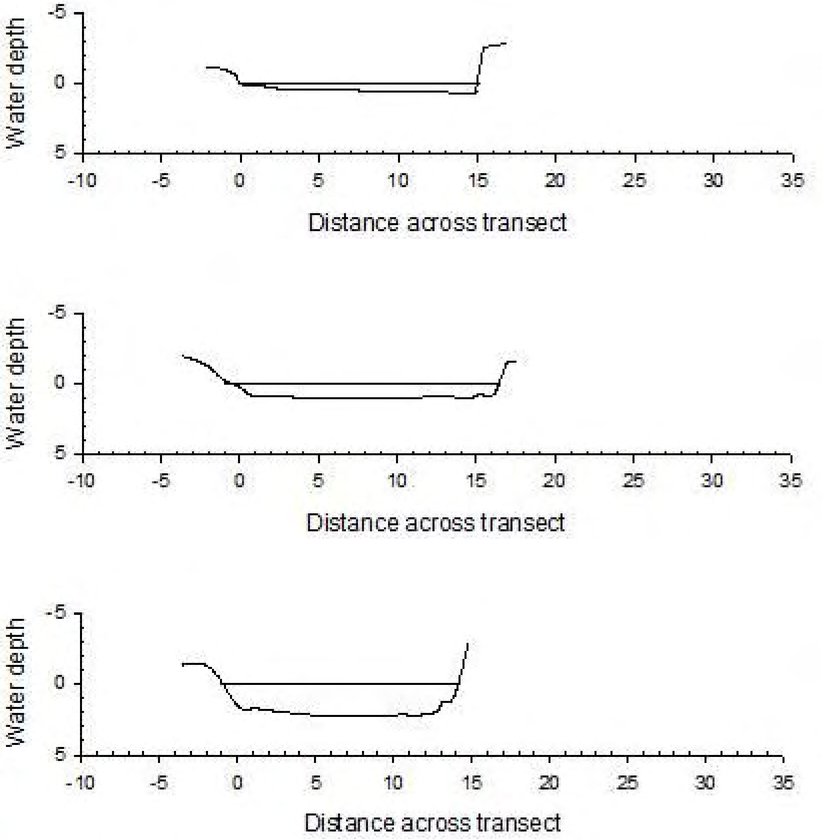

Figure 3. – Representative survey transects 7 though 9 of the San Marcos River. Distances are in meters

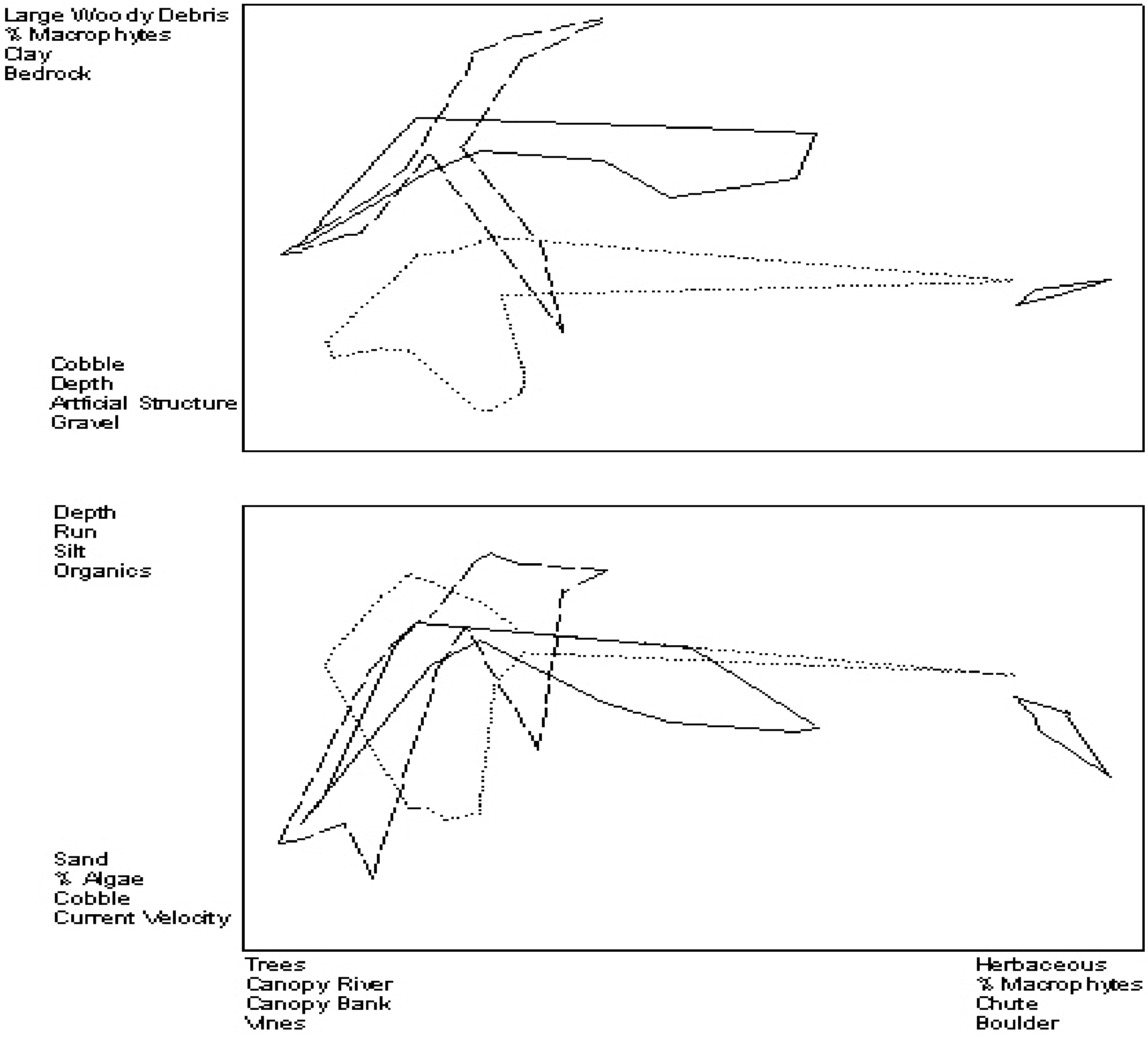

Figure 4. - PCA representation of the 3 river reaches. Reach 1 is the solid line, reach 2 is the dashed and reach 3 is the dotted line. PCA axis 1 is represented by the text at the bottom of the figure, top left is PCA axis 2 and bottom left is axis 3.

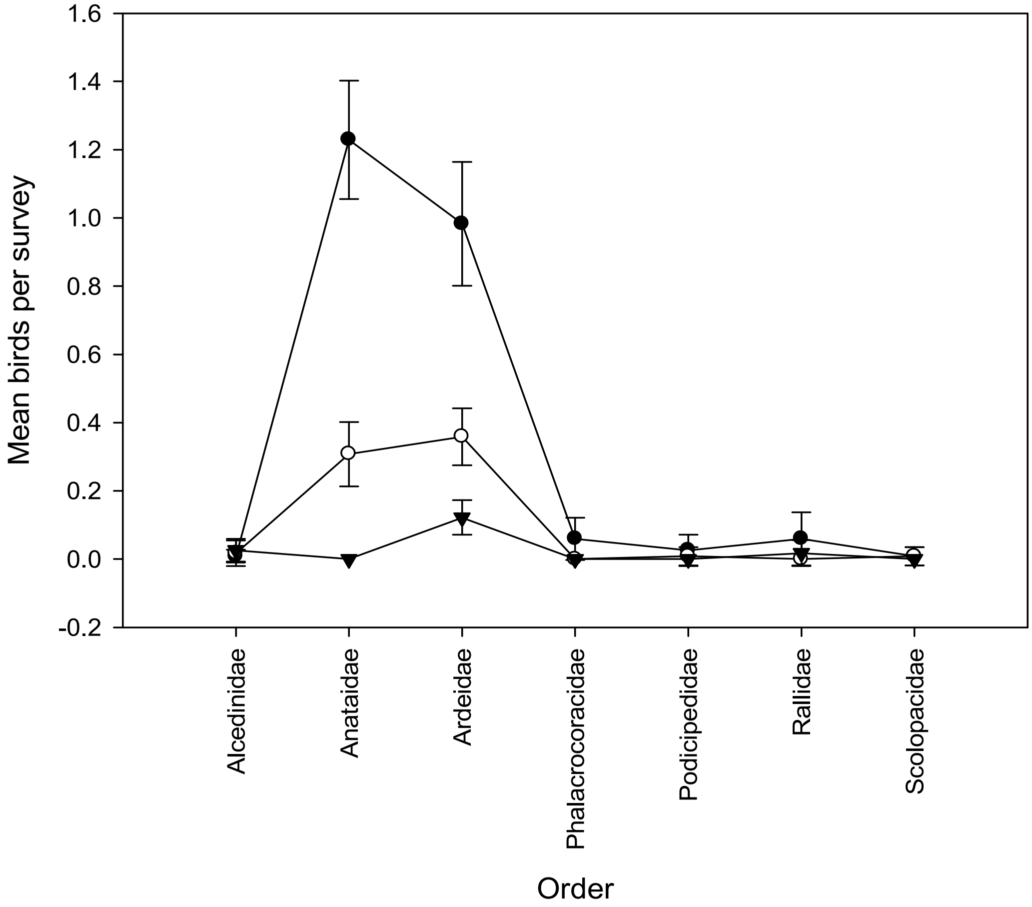

Figure 5. – Mean number of bird sightings by family for each point count. Standard error bars included.

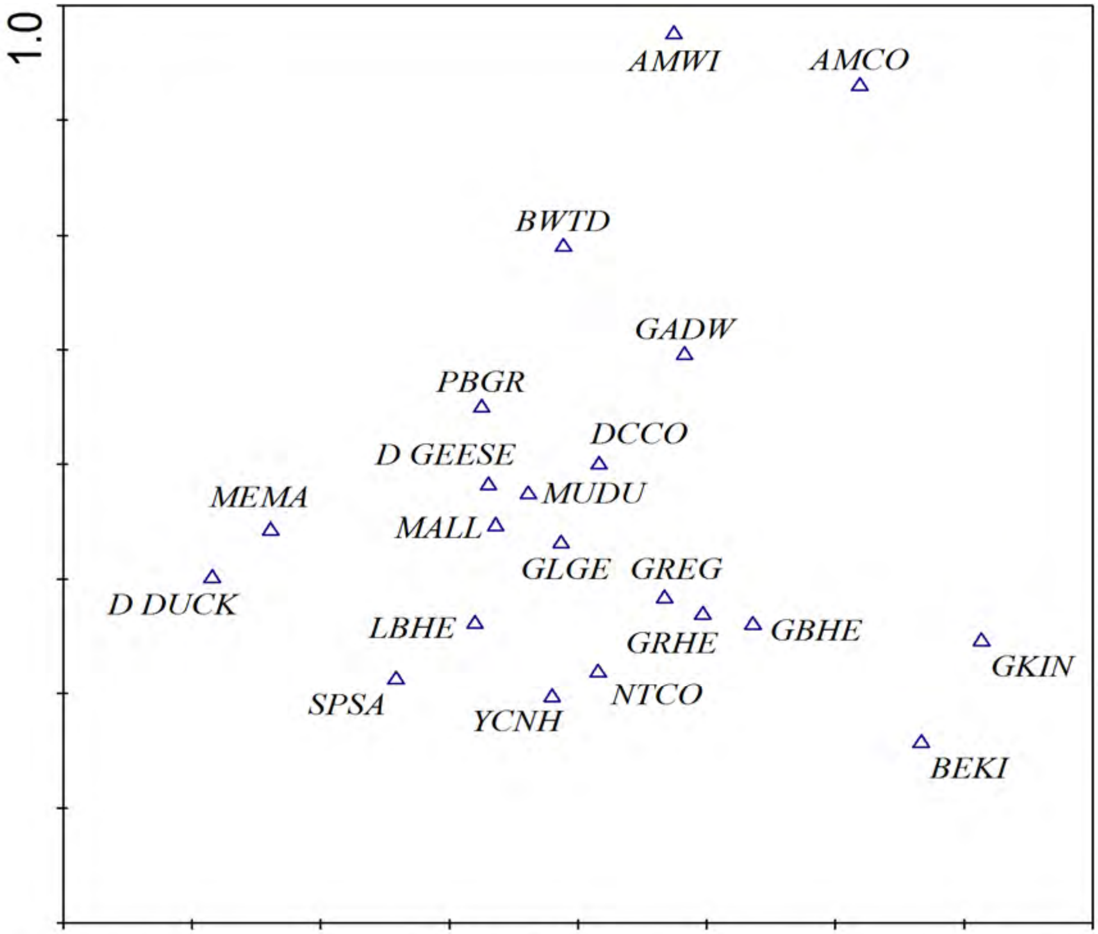

Figure 6. - Canonical correspondence ordination of the waterbird species. Overlay with figure 7 for the complete CCA matrix.

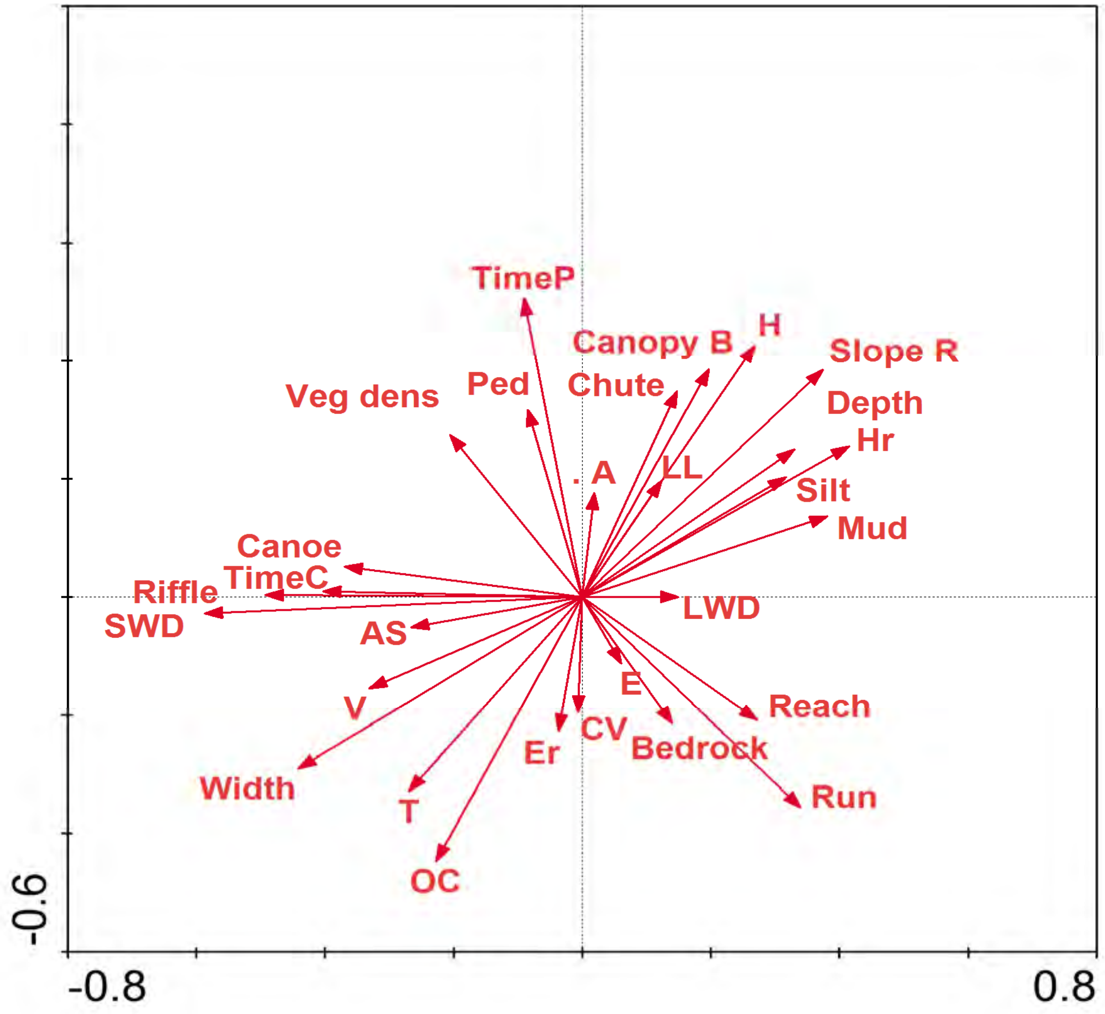

Figure 7. - Habitat and disturbance variables of the CCA. AS is artificial structures, OC is overhanging canopy, V is vines, T is trees, E is emergent vegetation, H is herbaceous vegetation, CV is current velocity, Ped is pedestrians, Veg dens is vegetative density, Time C is time spent canoeing, Time P is time spent my pedestrians, .A is percent algae, LL is leaf litter, Canopy B is bank canopy, Slope is right bank slope, HR is herbaceous on the right bank, LWD is large woody debris, SWD is small woody debris.

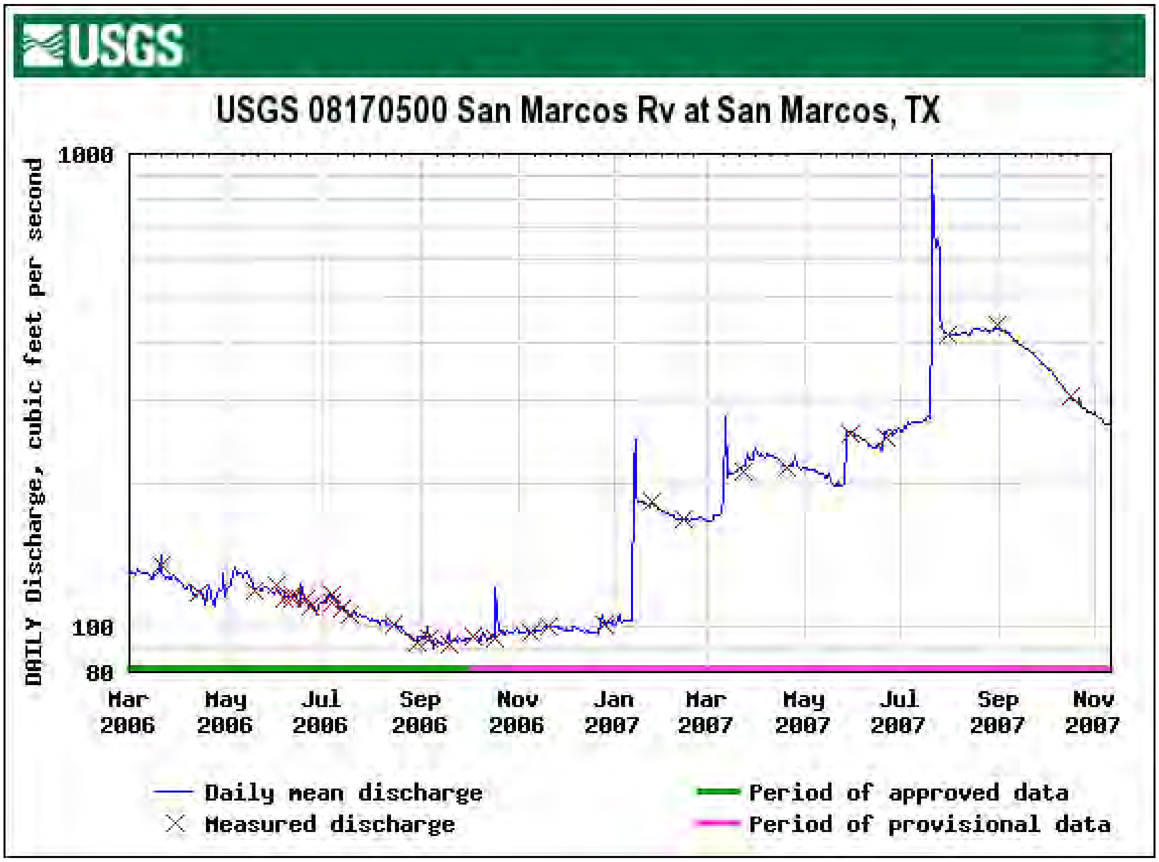

Figure 8. - United States Geological Service hydrograph of the San Marcos River during the 2 field seasons of the study.

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