THE EFFECT OF GIANT REED (*Arundo donax*) ON THE SOUTHERN CALIFORNIA RIPARIAN BIRD COMMUNITY

A Thesis

Presented to the

Faculty of

San Diego State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Biology

---

by

David A. Kisner

Spring 2004

THE UNDERSIGNED FACULTY COMMITTEE APPROVES

THE THESIS OF DAVID A. KISNER:

Barbara E. Kus, Co-Chair
Department of Biology

3/12/04
Date

James E. Diffendorfer, Co-Chair
Department of Biology

Douglas H. Deutschman
Department of Biology

John F. O'Leary
Department of Geography

SAN DIEGO STATE UNIVERSITY

Spring 2004

DEDICATION

To my friends, family, and the little birds,
without whom I would not have made it this far.

TABLE OF CONTENTS

PAGE

LIST OF TABLES ... vii

LIST OF FIGURES ... viii

INTRODUCTION ... 1

Degradation of Riparian Areas ... 1

Natural History of *Arundo donax* ... 1

Importance of Riparian Areas to Birds ... 3

Project Objectives ... 5

METHODS ... 8

Study sites ... 8

Study Design ... 9

Point Count Protocol ... 10

Vegetation Photoplots ... 10

Statistical Analyses ... 11

RESULTS ... 15

Birds Detected ... 15

Bird Species Richness as a Function of *Arundo donax* Cover ... 17

Bird Species Guilds and Sensitive Species ... 18

Residency Guilds ... 18

Foraging Guilds ... 21

Listing Status ... 24

Bird Abundance ... 26

Individual Species Responses ... 28

Community Composition ... 28

Additional Factors Affecting Bird Species Richness ... 33

DISCUSSION ... 35

Vegetation Model ... 37

Management and Conservation Implications ... 38

PAGE

DISCUSSION (continued)

Future Research 38

ACKNOWLEDGEMENTS..40

REFERENCES 41

APPENDICES

A. GEOGRAPHIC COORDINATES OF POINT COUNT CIRCLES 45

B. SPECIES AND NUMBER OF BIRDS DETECTED BY SEASON AND DRAINAGE...47

ABSTRACT 51

LIST OF TABLES

TABLE PAGE

1. Endangered, threatened, and sensitive bird species of riparian areas 5
2. Modified Daubenmire vegetation assessment scale and category midpoints 11
3. Guild assignments and listing status of species detected 13
4. Bird species richness as a function of drainage and season 15
5. Bird abundance as a function of drainage and season 15
6. Bird species richness as a function of season, *A. donax* cover, and season * *A. donax* cover 18
7. Comparison of relationships between species richness and abundance and percent cover *A. donax* 29
8. Seasonal response of individual species as a function of *A. donax* cover 30
9. Best fit general linear model of bird species richness as a function of the cover of *A. donax*, willow, mule fat, leaf litter, dead snag, exotic woody vegetation, and herbaceous vegetation, amount of sky, soil, and study site 34

LIST OF FIGURES

FIGURE PAGE

1. Map of San Diego County study sites 8
2. Idealized distribution of sampling points of varying *A. donax* cover along a drainage 9
3. Box plot of average species richness per point count station during each season 16
4. Box plot of average abundance per point count station during each season 16
5. Bird species richness as a function of *A. donax* cover by season 17
6. Regression lines of species richness against lowest 14 cover values of *A. donax* and all 16 values of *A. donax* cover 19
7. Species richness of resident species as a function of *A. donax* cover by season 20
8. Species richness of migratory breeders as a function of *A. donax* cover by season 21
9. Species richness of ground gleaners as a function of *A. donax* cover by season............22
10. Species richness of foliage gleaners as a function of *A. donax* cover by season............23
11. Odds ratios of the presence/absence of a hover gleaners and hawking species for a 25% decrease of *A. donax* cover..................24
12. Species richness of non-listed species as a function of *A. donax* cover by season.........25
13. Species richness of listed species as a function of *A. donax* cover by season 26
14. Abundance of ground gleaners as a function of *A. donax* cover by season....................27
15. Proportion of abundance by guilds as a function of *A. donax* cover by season..............31
16. Proportion of species richness by guilds as a function of *A. donax* cover by season 32

INTRODUCTION

The riparian zone is an ecotone between freshwater aquatic and terrestrial systems. It contains diverse plant communities, wildlife, and fisheries, and is an important water resource. Riparian areas encompass sharp gradients of environmental factors, ecological processes, and plant communities (Gregory et al. 1991, Naiman et al. 1993) and have large energy, nutrient, and biotic interchange with the aquatic and terrestrial ecosystems (Bowler 1990). These interactions include modification of microclimates (e.g., light, temperature, and humidity), alteration of nutrient inputs from uplands, contribution of organic matter to streams and floodplains, and retention of organic matter and water (Gregory et al. 1991). Because of these interactions, riparian zones are extremely valuable biologic areas and have a high level of biodiversity.

Degradation of Riparian Areas

Riparian zones of southern California have been reduced in acreage by as much as 95% (Faber et al. 1989) and are now endangered (Johnson and Haight 1984, Bowler 1990). Much of the remaining habitat is fragmented or otherwise degraded (Katibah et al. 1984). As a result, many bird species dependent on riparian habitats have declined, some to the point of endangerment. Although human development, land conversion, water consumption, water diversion projects, pollution, and agriculture have all played major roles in the decline of southern California riparian areas, invasion of non-native plant species is viewed as perhaps the primary threat to remaining riparian habitat and associated communities. *Arundo donax* is one of the primary invasive exotic plants in southern California riparian areas.

Natural History of *Arundo donax*

Arundo donax, or giant reed, is native to southern Asia or Europe (Munz 1974, Hickman 1993). Originally introduced to California for bank stabilization, *A. donax* was so common along the Los Angeles River by 1820 that it was being gathered for roofing material (Robbins et al. 1951). It has continued to spread through other drainages in California and elsewhere in the U.S., further altering and degrading remaining riparian habitat. For instance, of the 46% of the Santa Ana River in Los Angeles County that still supports riparian vegetation, approximately 50-60% is dominated by *A. donax* (Douthit 1994). Douthit (1994) believes *A. donax* may be the "final blow" to many southern California riparian areas, and Jackson et al. (1993) identify *A. donax* as the biggest problem in coastal southern California riparian systems, especially in the Santa Ana, Santa Margarita, Santa Clara, and Tijuana watersheds.

A combination of characteristics makes this species an aggressive and formidable contender in riparian plant communities. It is one of the taller members of the grass family (Poaceae), attaining heights of 6-8 meters. *Arundo donax* reproduces vegetatively through root shoots or resprouting of buried stems and rhizomes (Else 1996, Jones and Stokes 2000), and spreads through drainages by being washed downstream. It tends to grow in thick stands sometimes covering more than a hectare (Bell 1994). It is not known to reproduce sexually in southern California (Else 1996) or elsewhere in North America (Dudley in press). *Arundo donax* can sustain an average growth rate of four cm per day (Jones and Stokes 2000). It also exhibits broad tolerance to various soil types and salinities, but grows best in well-drained soil with ample moisture from freshwater to semi-saline water sources (Dudley in press). *Arundo donax* is able to resprout quickly from rhizomal masses after fire has swept through an area (Bell 1998).

Arundo donax is highly flammable (Scott 1994), and where it is abundant, can change a riparian zone from a "flood-defined" to a "fire-defined" ecosystem where the riparian zone is characterized by periodic fires rather than periodic flooding and deposition events. Additionally, the presence of *A. donax* reduces the natural firebreak properties of the riparian zone and increases the likelihood and intensity of fires within the riparian zone (Bell 1998).

Arundo donax appears to have little intrinsic habitat value in California with regard to supporting native species; however this topic has not been well studied. A four-year study at the San Luis Rey river in San Diego County showed a greater abundance of arthropods in a site without *A. donax* than in pure *A. donax* sites (K. Williams pers. comm.). A similar study on Sonoma Creek in Sonoma, California, found that stands of pure willow (*Salix* spp.) contained greater insect diversity and abundance than either stands of mixed *A. donax -Salix* or pure *A. donax* (Herrera 1997). The reduced invertebrate community in *A. donax*-

dominated plant communities may be attributed to chemical compounds such as triterpines and sterols (Chaudhuri and Ghosal 1970) found within leaves of *A. donax*.

Another characteristic of *A. donax* that adversely impacts southern California is its water consumption rate. Iverson (1994) reported:

> … [*A. donax*] uses about three times as much water as [native plants] do. There are no specific studies on the evapotranspiration rates of [*A. donax*]. Horticulture experts, however, estimate [*A. donax*] evaporates water at approximately the same rate as rice. This means that every acre of [*A. donax*] uses about 5.62 acre-feet of water per year. Native species use only about two thirds this amount, 1.87 acre-feet per year.

This high rate of water consumption by *A. donax* leaves less water in the riparian corridor for other plants and animals, and reduces the quantity of water available for human consumption as well. Iverson (1994) calculates that just over 4000 hectare of *A. donax* within the Santa Ana River basin consume the equivalent of $18,000,000 worth of untreated drinking water, $12,000,000 more than that consumed by the same extent of native vegetation.

Importance of Riparian Areas to Birds

Remaining riparian areas in southern California are critically important to a suite of birds, including neotropical migrants. For example, Zembal (1990) identified a total of 150 species of birds along the Santa Margarita River in San Diego County; 97 species were closely associated with the riparian community and 53 species were common in both the riparian and upland communities. The highest level of breeding bird diversity that Zembal recorded was 50 species per 40.5 ha plot. Historically, emphasis has been placed on preserving habitat for breeding birds, neglecting the equally important use during the non-breeding season and as foraging and roosting habitat during migration. Zembal (1994) characterized the Santa Margarita River as "important to migrant and wintering bird species", having recorded an additional 94 non-breeding species. The importance of conservation efforts to preserve and restore remaining riparian habitat, which is used year-round by numerous species of birds, cannot be overemphasized (Rappole 1995).

Most birds in riparian zones can be classified as neotropical migrants, residents, or wintering species. Neotropical migrants breed in temperate regions and winter in Central and South America. The Yellow Warbler (*Dendroica petechia*) and Southwestern Willow Flycatcher (*Empidonax traillii extimus*) are two examples. Resident species such as Song

Sparrows (*Melospiza melodia*) and Bewick's Wrens (*Thryomanes bewickii*) are present year-round, though migrants from interior and northern regions augment many of these species' local populations. Wintering bird species breed in other habitats in southern California or far to the north or inland, and spend the non-breeding season in riparian areas. The ubiquitous Yellow-rumped Warbler (*Dendroica coronata*) and Hermit Thrush (*Catharus guttatus*) are two examples of wintering species in southern California riparian areas.

Many bird species in riparian habitats are listed at the Federal or State level as endangered, threatened, or sensitive (Table 1). These birds receive special consideration from regulatory agencies with the goal of retaining viable populations throughout their ranges. In addition to these bird species, numerous other endangered, threatened, and sensitive species of flora and fauna are dependent on riparian areas.

All sensitive species, regardless of the level of listing, warrant attention since it is much easier to stop a decline early when the species is still robust and widespread. As the U.S. Fish and Wildlife Service *Migratory Nongame Birds of Management Concern in the United States: the 1995 List* (1995; page 1) aptly states:

> … "an ounce of prevention is worth a pound of cure." We fervently believe that a well-designed program that addresses resource-management at an early stage, thereby preventing species from having to be listed as Threatened or Endangered, will be more cost-effective than a full blown recovery effort required once a species is Federally listed. … Since species are the major building blocks of the communities and ecosystems of which they are a part, we also hope that this list will promote greater study and protection of the habitats and ecological communities upon which these species depend.

The main threat common to all of these species is the loss or degradation of riparian habitats. The trend in riparian species declines in southern California can be expected to continue unless preservation and restoration of remaining habitat becomes a priority. If we can expand populations of these sensitive and listed species, the species can be delisted. Reducing adverse impacts, restoring lost habitat, re-establishing connectivity of riparian corridors, and improving the quality of existing riparian areas will be necessary to improve and stabilize populations of many of these species.

Table 1. Endangered, threatened, and sensitive bird species of riparian areas (CDFG 1999 and 2000, and USFWS 1995).

Common Name (*Scientific name*)	Use	Federal	State
White-tailed Kite (*Elanus leucurus*)	Resident	SC	--
Northern Harrier (*Circus cyaneus*)	Resident	--	SC
Coopers Hawk (*Accipiter cooperi*)	Resident	--	SC
Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)	Migrant, Breeder	--	E
Costa's Hummingbird (*Calypte costae*)	Migrant, Breeder	SC	--
Southwestern Willow Flycatcher (*Empidonax traillii extimus*)	Migrant, Breeder	E	E
Pacific-slope Flycatcher (*Empidonax difficilis*)	Migrant, Breeder	SC	--
Least Bell's Vireo (*Vireo bellii pusillus*)	Migrant, Breeder	E	E
Bank Swallow (*Riparia riparia*)	Migrant, Breeder		T
Bewick's Wren (*Thryomanes bewickii*)	Resident	SC	--
Swainson's Thrush (*Catharus ustulatus*)	Migrant, Breeder	--	PSC
California Thrasher (*Toxostoma redivivum*)	Resident	SC	--
Yellow Warbler (*Dendroica petechia*)	Migrant, Breeder	--	SC
Yellow-breasted Chat (*Icteria virens*)	Migrant, Breeder	--	SC
Tricolored Blackbird (*Agelaius tricolor*)	Resident	SC	SC
Lawrence's Goldfinch (*Carduelis lawrencei*)	Resident	SC	--

(Federal/State: E = endangered, SC = "special concern", PSC = proposed "special concern", T = threatened)

Project Objectives

Although southern California riparian zones are a rare and valuable resource to many listed and sensitive species, and the negative influences of *A. donax* on the environment are numerous, little work has been done to scientifically quantify these impacts. In particular, no research has addressed the effect of *A. donax* on terrestrial vertebrates. This study quantifies the effect of *A. donax* on the riparian bird community. Specifically:

- What is the effect of *A. donax* on riparian bird species richness and abundance, and is it similar between the winter, migration, and breeding seasons?

- Are certain foraging or residency guilds, or sensitive species of birds, affected more strongly than others?
- In addition to *A. donax*, what other vegetation and physical characters of riparian zones influence bird species richness?

Because of fewer associated arthropods and poorer nest sites, I hypothesized that as *A. donax* cover increases, bird richness and abundance will decrease. I expected low densities of *A. donax* would have little or no impact on bird richness and abundance; however, as *A. donax* cover increased, there would be a point of inflection and a pronounced decrease in bird richness and abundance.

I expected that as *A. donax* cover increased, migrating bird richness and abundance would decline most rapidly, breeding birds would be least responsive, and wintering birds would be intermediate in their response. Migrating birds are non-territorial and engaged in foraging on high energy foods such as arthropods. Since *A. donax* has fewer arthropods than native vegetation, I hypothesized that most migrants would minimize their time in *A. donax* in order to maximize foraging. During the breeding season, birds should be more closely associated with *A. donax* since birds are restricted to territories at this time of year and cannot range widely. Although *A. donax* lacks a suitable vegetative structure for most birds' nests and has fewer invertebrates than native vegetation, breeding birds are more likely to be found within *A. donax* during the breeding season because it is within the birds' territories. When habitat is limiting, which is likely the case since so little riparian habitat remains in southern California, competition results in birds defending sub-optimal territory or being forced to forego breeding for that year. During the winter, birds have a broader, more plastic diet and may be able to find seeds beneath *A. donax* washed there by winter rains. Additionally, *A. donax* may be the best refuge for birds since most herbaceous plants are dead during the winter and willows are deciduous.

Of the foraging guilds, I predicted that bark and foliage gleaners would decrease in richness and abundance most rapidly as *A. donax* cover increased, because there is less food on or within *A. donax*. Seedeaters are the most likely to be able to find food in association with *A. donax* since periodic flooding of the riparian system can deposit food well away from its original source. Seedeaters foraging on these dispersed food items would be associated with *A. donax*, though the food is not a product of *A. donax*.

Though listed species, species considered threatened or endangered at a state or federal level, do not necessarily share any life history traits, they all have shown precipitous declines in population size and/or range during the last 30 years. Because of this "sensitivity" to human-induced change, I expected listed species to be sensitive to disturbance and that they would decrease more rapidly in richness and abundance as *A. donax* cover increased than non-listed species.

I predicted that willow cover would have a strong, positive relationship with bird species richness and abundance, and that *A. donax* cover would reduce richness and abundance by reducing the cover of other more beneficial plant species. Since space is limited, *A. donax* cover would have a strong inverse relationship with willow and other vegetation cover.

METHODS

Study Sites

To quantify the impact of *Arundo donax* on the riparian bird community, I compared sites with different levels of *A. donax* cover within three drainages in San Diego County, California, and quantified bird species richness and abundance. The sites selected for this study were the Santa Margarita River on Marine Corps Base Camp Pendleton between Stuart Mesa Road and Rifle Range Road, City of San Diego property on San Dieguito River / Santa Ysabel Creek upstream of I-15, and the Tijuana River within the Tijuana River National Estuarine Research Reserve (Figure 1). These sites were selected because they are similar hydrologically and have broad floodplains, reducing potential "edge" effects. All three sites contain relatively intact riparian habitat as well as varying densities of *A. donax*.

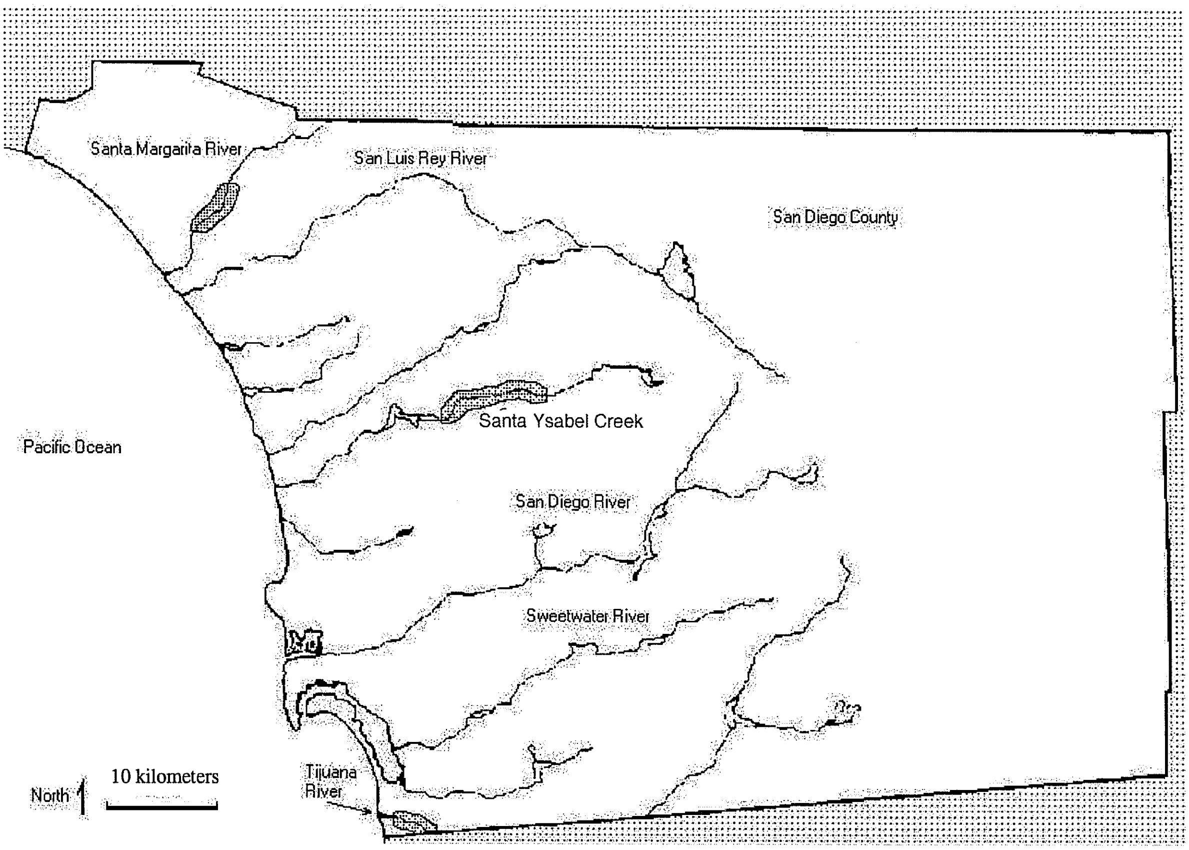

Figure 1. Map of San Diego County study sites

Study Design

I used a stratified random block design (Mead 1988) with each drainage divided into four blocks. Aerial photographs and vegetation maps were used to quantify the cover of *A. donax* within drainages, using four cover categories (0-5%, 6-33%, 34-66% and >67%). Sixteen sampling points per drainage were randomly selected with the condition that they were at least 250 meters apart (Figure 2). I attempted to include four points representing the four *A. donax* cover categories within each block. However, due to the heterogeneous nature of *A. donax* distribution and rarity of large, monotypic patches (>50 m diameter) of *A. donax*, most blocks did not contain a point from each category. The maps and aerial photographs did not accurately account for the density of *A. donax* in a given area because of the time lag since the photographs were taken, the lack of resolution, and/or canopy trees over-shadowing *A. donax*.

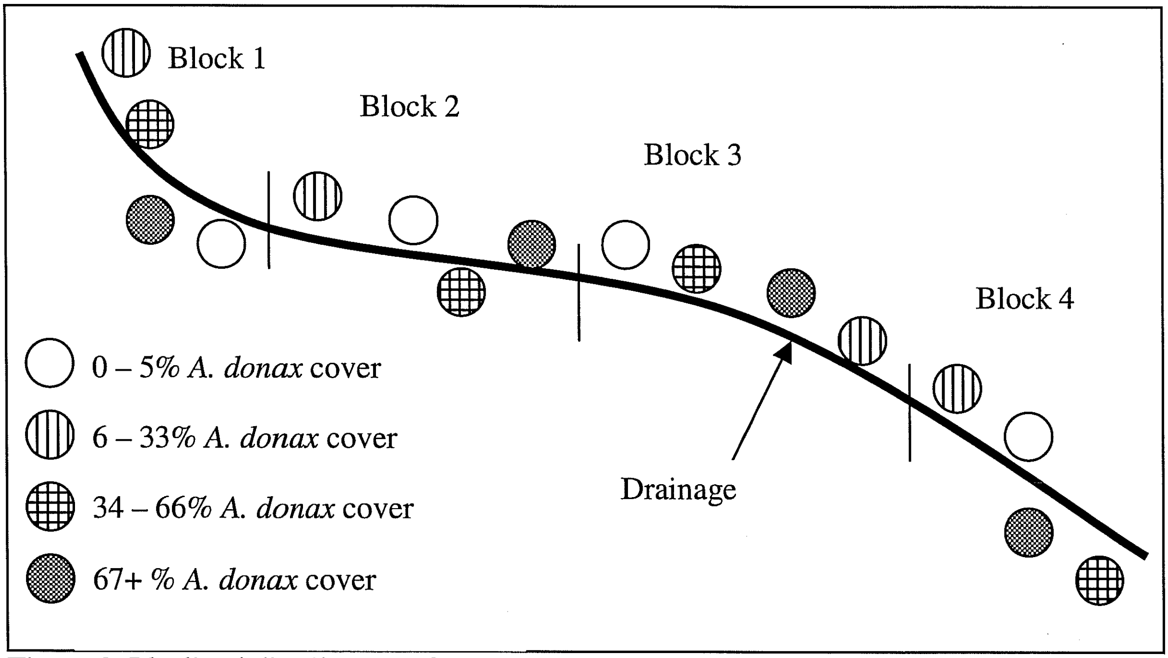

Figure 2. Idealized distribution of sampling points of varying *A. donax* cover along a drainage.

Once points were identified on the vegetation maps, I located them in the field, recorded their locations using a GPS unit (Appendix A), and flagged the area so that the points could be relocated on future surveys.

Point Count Protocol

Fifty-meter radius point counts were used to assess bird species abundance and richness at the 48 sampling points (Ralph et al. 1995). Ten-minute counts were conducted during favorable weather conditions (little or no wind and no rain), starting ten minutes before sunrise and continuing until bird activity decreased, usually 1030. Counts were "passive" and did not employ the use of tapes or other means to attract birds.

I conducted counts during four sampling periods in 2001: Winter (January 23 to February 12), Spring (March 19 to April 4), Breeding 1 (May 8 to May 23), and Breeding 2 (June 5 to June 16). Each count circle was sampled twice during each of sampling periods. Half of each drainage was sampled one morning and the other half the next morning or as soon thereafter as was logistically feasible. Once a drainage had been completely sampled, the next drainage was sampled. The order of the drainages remained fixed but the order of point counts was reversed between the first and second visit during each period.

I used the maximum number of individuals per species per point for each sampling period as the measure of abundance. This avoided counting an individual twice during the same season or under-representing the number of individuals that were within an area. Species richness was defined as the total number of unique species detected at a point during a season.

Vegetation Photoplots

Photoplots (Elzinga et al. 1998) using four photographs were taken with a Kodak DC5000 digital camera during each sampling period at each point. Photographs were taken in the four cardinal directions such that the camera was oriented with the long axis perpendicular to the horizon and held at eye level (170 cm). The center point of the viewfinder was aimed at the idealized horizon line. The camera was set at the standard 30mm setting, "better" quality, and high resolution (1760 x 1168 pixels).

Photographs were downloaded into a jpeg viewing program for analysis. An acetate sheet was placed over the monitor, dividing each photograph into six squares (three rows by two columns). The composition of each of the six squares was assessed using a modified

Daubenmire cover class scale (Daubenmire 1959) with each component factor (e.g., willow, *A. donax*, sky, sand, etc.) given a cover score of 1 to 8 (Table 2).

The percent cover of each component factor was calculated by averaging all four cardinal cover scores. This created a separate cover value for each component at each point.

Table 2. Modified Daubenmire vegetation assessment scale and category midpoints.

Assigned Score	Percent Cover (low	high)	Midpoint Used for Analyses
1	0	<1	1%
2	≥1	<5	3%
3	≥5	<10	8%
4	≥10	<25	18%
5	≥25	<50	38%
6	≥50	<75	63%
7	≥75	<95	85%
8	≥95		98%

Statistical Analyses

To evaluate potential differences between drainages and seasons in bird abundance and richness, I used ANOVAs to analyze square root transformed abundance and richness data. Least significant difference pairwise multiple comparisons (LSD) were used to test for significant differences between seasons.

I used linear regression to determine the effect of *A. donax* cover on bird species richness and abundance in each season. I used a general linear model (GLM) to test for seasonal differences in the effect.

I assigned birds to guilds based on their residency within California riparian areas, primary foraging techniques, and listing status (Table 3). The residency guilds were developed based on the natural history of birds detected within the area of study. Kus and Beck (2003) developed the foraging guild classification for birds of western San Diego County. Listing status of each species was taken from the most current state and federal listing information as of September 2002 (USFWS 1995, CDFG 2000).

I analyzed guilds for all seasons in which sample sizes were sufficient, using linear regression to analyze the relationships between *A. donax* cover and species richness and abundance. To evaluate presence/absence of guilds with too few species or detections for linear regression, I used logistic regression with cover of *A. donax*, drainage, and season as independent variables. All four seasons were used for hover gleaner logistic regression, and Breeding 1 and 2 for the hawking species logistic regression.

I evaluated the response of individual species to *A. donax* cover for all species with at least 50 detections over the four seasons, using linear regression to analyze the effect of *A. donax* cover on species abundance. I evaluated the change in the abundance and species richness of the community composition as a function of *A. donax* cover by comparing the proportion of each guild in four categorical cover classes of *A. donax* in each season. I used Pearson's chi-squares to test for differences between categorical values of *A. donax* cover and guild abundance and species richness.

An iterative, hierarchical GLM was used to explain changes in bird species richness as a function of the cover of *A. donax*, willow (*Salix* species), mule fat (*Baccharis salicifolia*), leaf litter, dead snag, exotic woody vegetation, herbaceous vegetation, amount of sky (i.e. no vegetation cover), soil, and study site. This model was generated by evaluating the change in the predictive power of the model as factors were added individually. If the p-value was significant and the increase in predictive power was greater than +%10, the factor was added.

The statistical package SYSTAT v.10 was used for all statistical analyses, with an alpha level of 0.05.

Table 3. Guild assignments and listing status of species detected, in taxonomic order. Residency guild: R = resident, MB = migrant breeder, and W = winter visitor. Foraging guild: BG = bark glean, FG = foliage glean, GG = ground glean, HG = hover glean, H = hawking, O = other. Listing status: S = sensitive, and E = endangered

Common Name	Scientific Name	Residency Guild	Foraging Guild	Listing status
Great Egret	*Ardea alba*	R	O	
Northern Harrier	*Circus cyaneus*	R	O	S
White-tailed Kite	*Elanus leucurus*	R	O	S
Sharp-shinned Hawk	*Accipiter striatus*	W	O	
Cooper's Hawk	*Accipiter cooperii*	R	O	S
Red-tailed Hawk	*Buteo jamaicensis*	R	O	
California Quail	*Callipepla californica*	R	GG	
Mourning Dove	*Zenaida macroura*	R	GG	
Common Ground Dove	*Columbina passerina*	R	GG	
Greater Roadrunner	*Geococcyx californianus*	R	GG	
Barn Owl	*Tyto alba*	R	O	
Anna's Hummingbird	*Calypte anna*	R	HG	
Black-chinned hummingbird	*Archilochus alexandri*	MB	HG	
Downy Woodpecker	*Picoides pubescens*	R	BG	
Nuttall's Woodpecker	*Picoides nuttallii*	R	BG	
Northern Flicker	*Colaptes auratus*	R	BG	
Pacific-slope Flycatcher	*Empidonax difficilis*	MB	H	S
Willow Flycatcher	*Empidonax traillii*	MB	H	E
Black Phoebe	*Sayornis nigricans*	R	H	
Ash-throated Flycatcher	*Myiarchus cinerascens*	MB	H	
Cassin's Kingbird	*Tyrannus vociferans*	MB	H	
Warbling Vireo	*Vireo gilvus*	MB	FG	
Least Bell's Vireo	*Vireo bellii pusillus*	MB	FG	E
Hutton's Vireo	*Vireo huttoni*	R	FG	
Common Raven	*Corvus corax*	R	GG	
American Crow	*Corvus brachyrhynchos*	R	GG	
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	MB	O	
Tree Swallow	*Tachycineta bicolor*	MB	O	
Cliff Swallow	*Petrochelidon pyrrhonota*	MB	O	
Oak Titmouse	*Baeolophus inornatus*	R	FG	
Bushtit	*Psaltriparus minimus*	R	FG	
Bewick's Wren	*Thryomanes bewickii*	R	GG	S
House Wren	*Troglodytes aedon*	R	GG	
Wrentit	*Chamaea fasciata*	R	FG	
Ruby-crowned Kinglet	*Regulus calendula*	W	FG	
Blue-gray Gnatcatcher	*Polioptila caerulea*	R	FG	
Western Bluebird	*Sialia mexicana*	R	FG	
American Robin	*Turdus migratorius*	R	GG	
Swainson's Thrush	*Catharus ustulatas*	MB	FG	
Hermit Thrush	*Catharus guttatus*	W	GG	
California Thrasher	*Toxostoma redivivum*	R	GG	S
European Starling	*Sturnus vulgaris*	R	GG	
Orange-crowned Warbler	*Vermivora celata*	R	FG	

Table 3. (continued). Guild assignments and listing status of species detected, in taxonomic order. Residency guild: R = resident, MB = migrant breeder, and W = winter visitor. Foraging guild: BG = bark glean, FG = foliage glean, GG = ground glean, HG = hover glean, H = hawking, O = other. Listing status: S = sensitive, and E = endangered

Common Name	Scientific Name	Residency Guild	Foraging Guild	Listing status
Yellow Warbler	*Dendroica petechia*	MB	FG	S
Yellow-rumped Warbler	*Dendroica coronata*	W	FG	
Townsend's Warbler	*Dendroica townsendi*	W	FG	
Common Yellowthroat	*Geothlypis trichas*	R	FG	
Wilson's Warbler	*Wilsonia pusilla*	MB	FG	
Yellow-breasted Chat	*Icteria virens*	MB	FG	S
Northern Cardinal	*Cardinalis cardinalis*	R	FG	
Black-headed Grosbeak	*Pheucticus melanocephalus*	MB	FG	
Blue Grosbeak	*Guiraca caerulea*	MB	GG	
Lazuli Bunting	*Passerina amoena*	MB	GG	
Spotted Towhee	*Pipilo maculatus*	R	GG	
California Towhee	*Pipilo crissalis*	R	GG	
White-crowned Sparrow	*Zonotrichia leucophrys*	W	GG	
Song Sparrow	*Melospiza melodia*	R	GG	
Brown-headed Cowbird	*Molothrus ater*	R	GG	
Bullock's Oriole	*Icterus bullockii*	MB	FG	
Hooded Oriole	*Icterus cucullatus*	MB	FG	
House Finch	*Carpodacus mexicanus*	R	GG	
Lawrence's Goldfinch	*Carduelis lawrencei*	R	FG	S
Lesser Goldfinch	*Carduelis psaltria*	R	FG	
American Goldfinch	*Carduelis tristis*	R	FG	

RESULTS

Birds Detected

A total of 3,275 individuals and 64 species of birds were detected during point counts (Appendix B). Bird species richness and abundance differed significantly between seasons but not between drainages (Tables 4 and 5). Significantly more species and individuals were detected during Breeding 1 and 2 than either Spring or Winter, and significantly more species and individuals were detected during Spring than Winter (Figures 3 and 4).

The relationships between bird species richness and *A. donax* cover were very similar to those between abundance and *A. donax* cover. Approximately 59% of species observed at a point during a season were detections of a single individual. Thus I detail the relationships between species richness and *A. donax* cover, and then summarize the species abundance relationships. Finding no differences between drainages, bird species richness and abundance data were pooled in subsequent analyses.

Table 4. Bird species richness as a function of drainage and season. $r^2 = 0.41$, N = 192

Factors	s.s.	d.f.	*F*	*p*
Drainage	0.28	2	0.86	0.424
Season	19.30	3	40.04	0.001
Drainage * Season	0.41	6	0.43	0.860
Error	28.92	180		

Table 5. Bird abundance as a function of drainage and season. $r^2 = 0.32$, N = 192

Factors	s.s.	d.f.	*F*	*p*
Drainage	1.47	2	1.60	0.205
Season	36.27	3	26.36	0.001
Drainage * Season	1.33	6	0.48	0.820
Error	82.56	180		

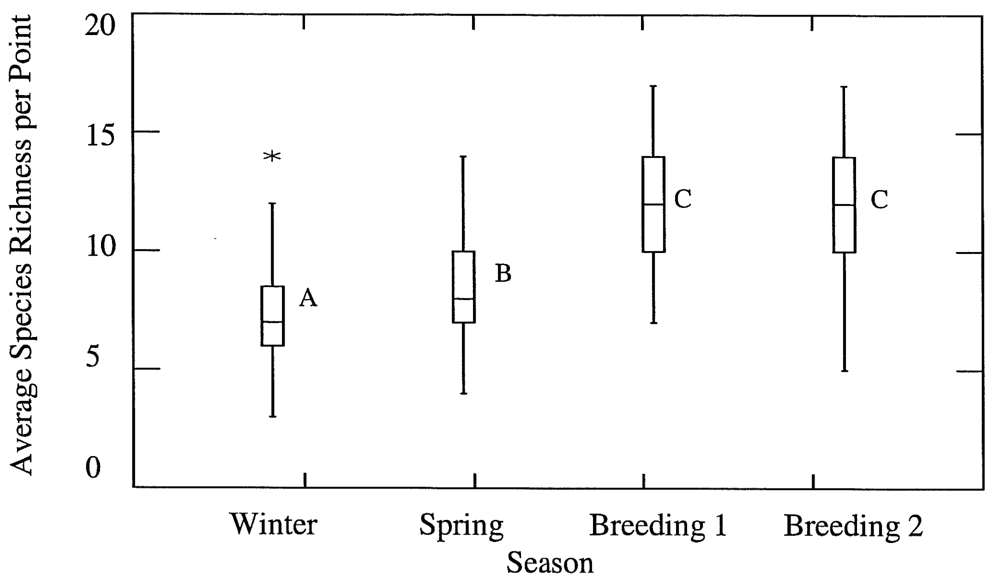

Figure 3. Box plot of average species richness per point count station during each season. Points with different letters are significantly different from one another. * = observation that is between 1.5 and 3 times the interquartile range (IQR).

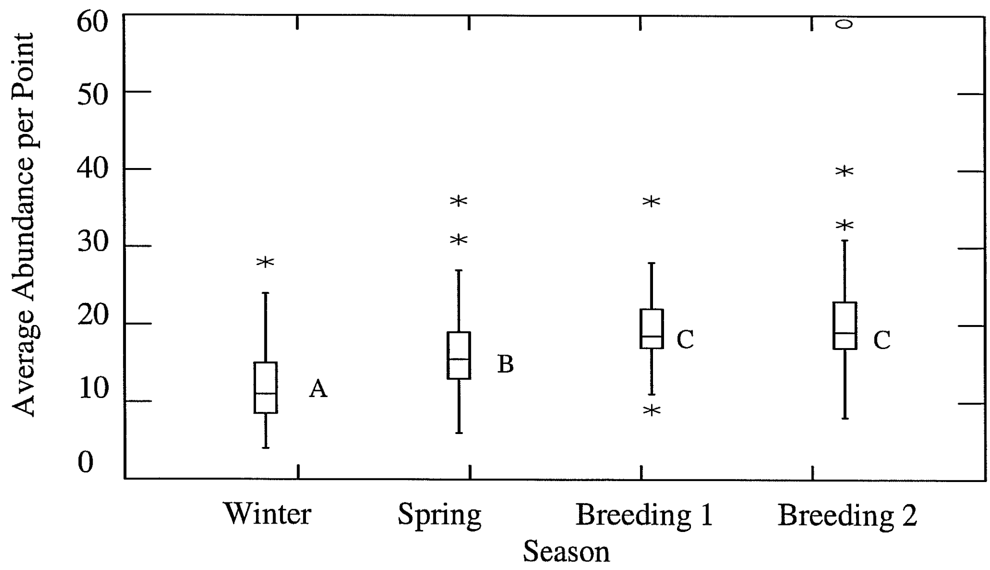

Figure 4. Box plot of average abundance per point count station during each season. Points with different letters are significantly different from one another. * = observations that are between 1.5 and 3 times the IQR. o = observation that is greater than 3 times the IQR.

Bird Species Richness as a Function of *Arundo donax* Cover

Riparian bird species richness was significantly and negatively related to *A. donax* cover in all four seasons examined (Figure 5). Depending on the season, an estimated 16-25% of bird species were lost when *A. donax* cover increased from 0% to 50%. The effect of *A. donax* on bird species richness did not vary significantly from season to season (Table 6). Despite the negative relationship, *A. donax* cover explained a relatively small amount of variation in species richness during the first three seasons (between 14 and 18%) but explained 37% of the variation detected in the Breeding 2 season.

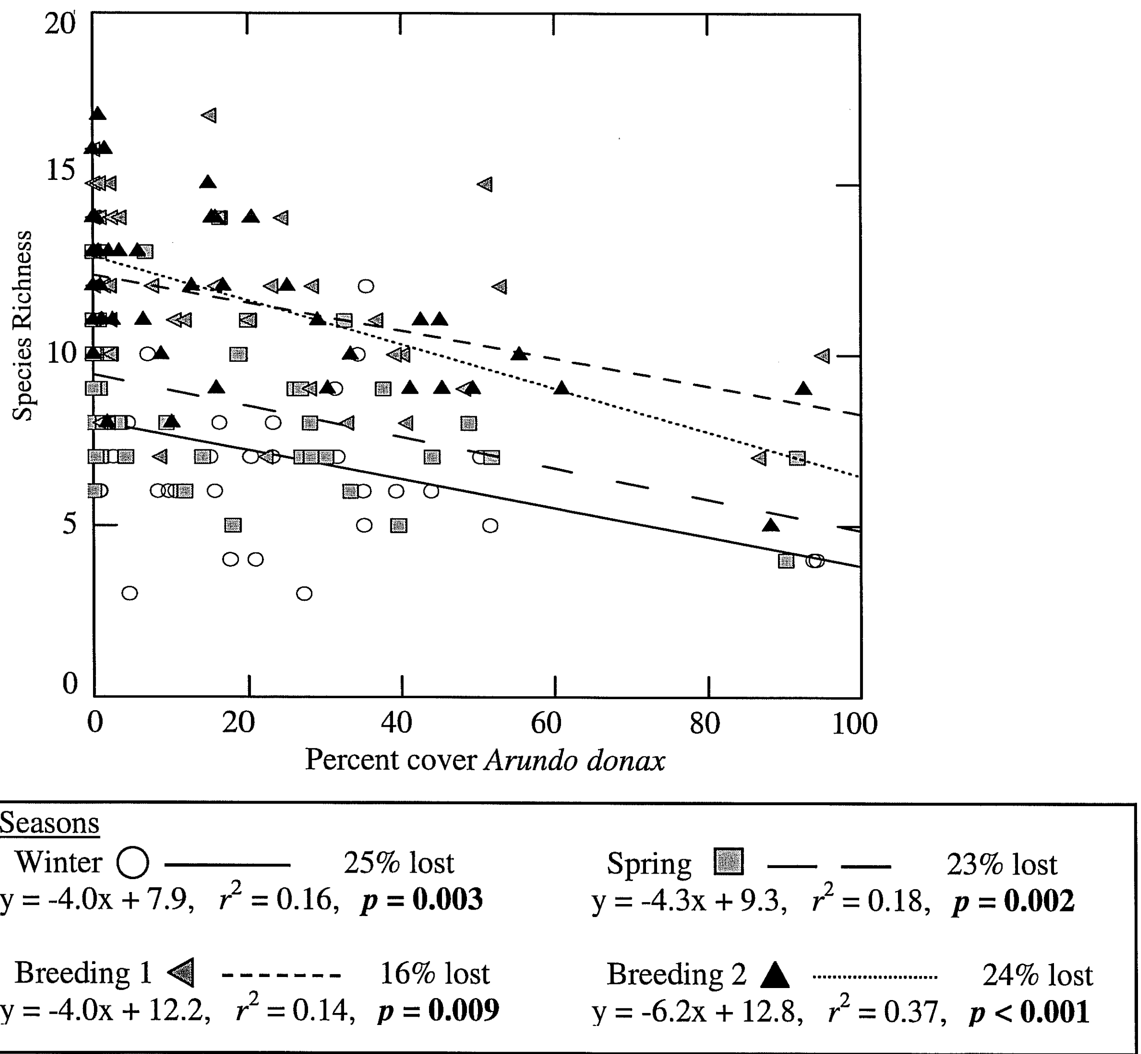

Figure 5. Bird species richness as a function of *A. donax* cover by season. “Percent Lost” refers to percent of species lost as *A. donax* cover increased from 0-50%.

Table 6. Bird species richness as a function of season, *A. donax* cover, and season * *A. donax* cover. $r^2 = 0.53$

Source	s.s.	d.f.	*F*	*p*
Season	12.37	3	32.91	<0.001
A. donax cover	6.31	1	50.38	<0.001
Season* *A. donax* cover	0.18	3	0.48	0.698
Error	23.04	184		

The distribution of *A. donax* within the drainages was such that only two points had greater than 66% cover of *A. donax* and 46 of 48 points had less than 66% cover of *A. donax.* I therefore tested the effect of these two high values on my results, and found that they did not drive the regression (Figure 6). Vegetation composition at each point is detailed in Appendix D.

Bird Species Guilds and Sensitive Species

Residency Guilds

Resident species (39 species, Table 3) at the three sites combined exhibited a significant decline in species richness as cover of A. donax increased in Winter, Spring, and Breeding 2 (Figure 7). Richness in Breeding 1 declined with increasing cover of A. donax, but not significantly. Between 11 – 23% of species were lost as A. donax cover increased from 0 - 50%. During the three seasons where the effect of A. donax was significant, the variation in richness explained solely by A. donax cover ranged from 12 – 19%.

Migratory species that breed in southern California and winter in other regions (19 species, Table 3) exhibited a significant decline in species richness associated with increasing *A. donax* cover in Breeding 1 and Breeding 2 (Figure 8). No migratory breeders were present during Winter, and too few species were present during Spring to analyze. Migrant breeders from both the Santa Margarita and Tijuana River sites showed a negative trend in species richness associated with increasing *A. donax* cover, while breeders at the Santa Ysabel site showed no response. From 32 – 41% of species were lost as *A. donax* cover increased from 0 - 50%. The variation in richness of breeders explained solely by *A. donax* cover ranged from 15 – 51%.

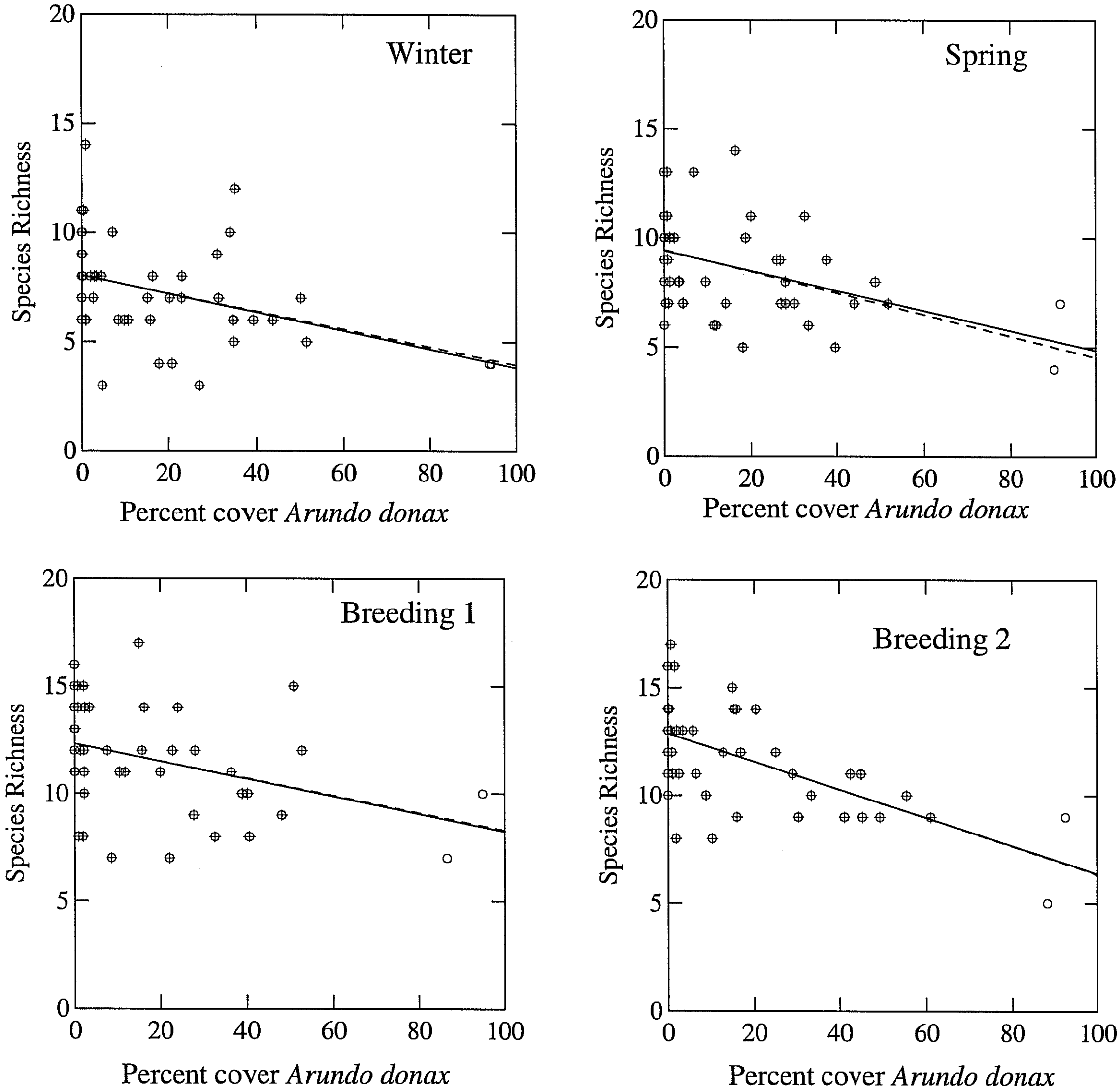

Figure 6. Regression lines of species richness against lowest 14 cover values (+, - - - -) of *A. donax* and all 16 values (○, ——) of *A. donax* cover.

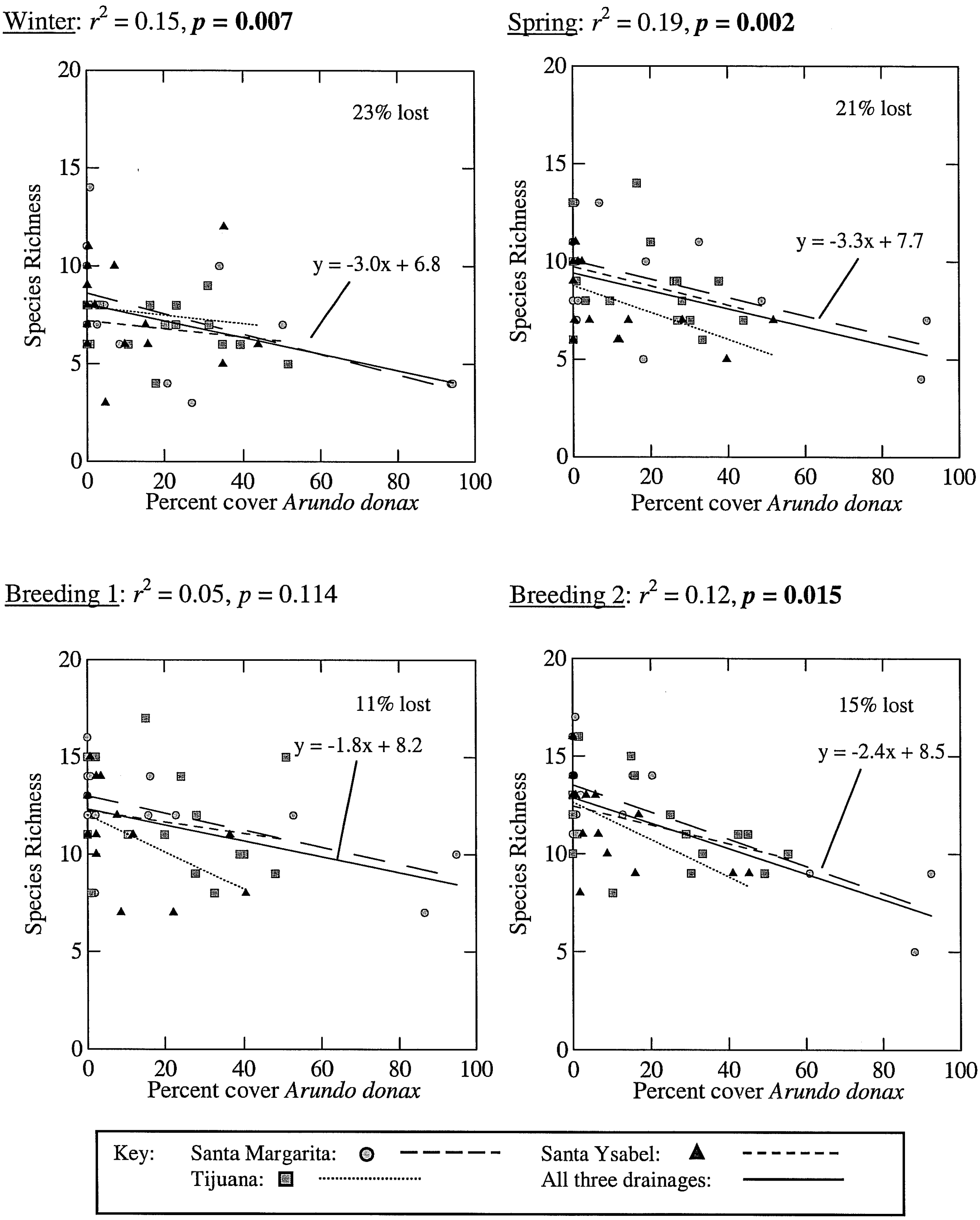

Figure 7. Species richness of resident species as a function of *A. donax* cover by season. Percent lost equals the percentage of species lost as *A. donax* cover increased from 0-50% cover. Line equations, r^2, and p-values are for all three drainages combined.

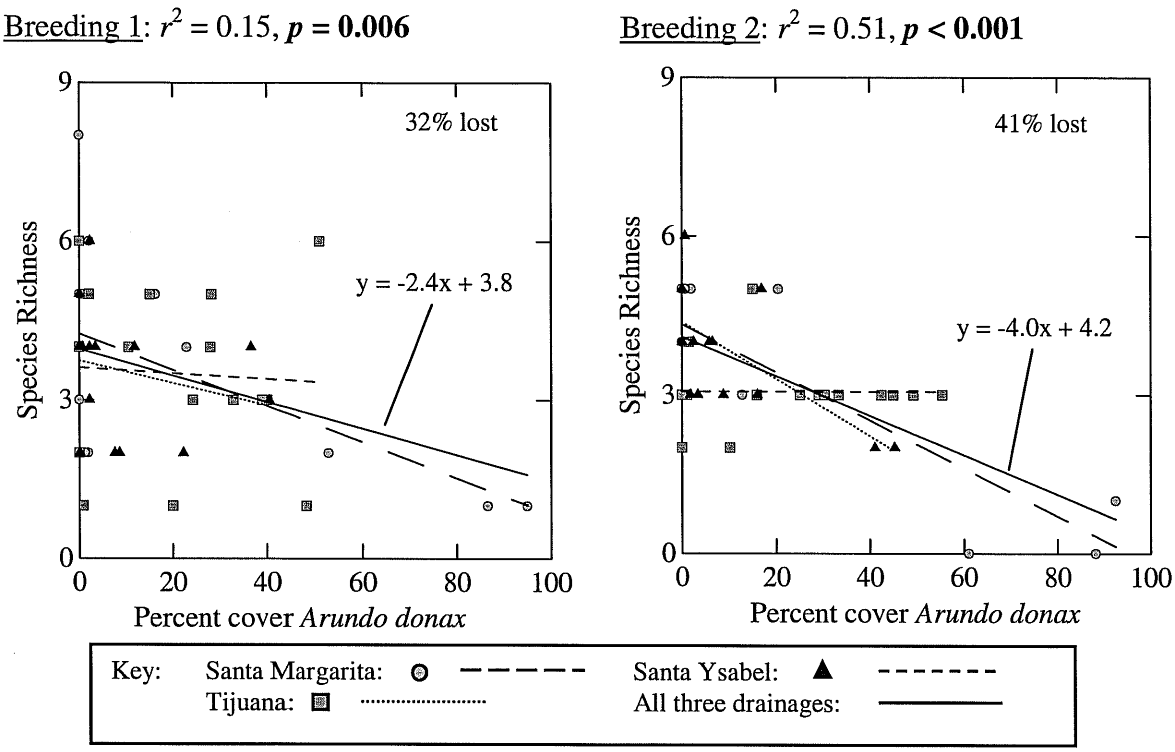

Figure 8. Species richness of migratory breeders as a function of *A. donax* cover by season. Percent lost equals the percentage of species lost as *A. donax* cover increased from 0-50% cover. Line equations, r^2, and p-values are for all three drainages combined.

Foraging Guilds

When data from all three sites are combined, both ground (20 species) and foliage (24 species) gleaning species (Table 3) declined in richness with increasing A. donax cover in all four seasons (Figures 9 and 10). These relationships were significant only during the Spring and Breeding 2 seasons. Ground gleaning species richness declined overall except at the Tijuana River site in Winter where it increased as A. donax cover increased. Foliage gleaning species richness at the Santa Ysabel site showed a positive trend during Winter and Breeding 1 and 2 as A donax cover increased. Ground gleaners lost between 15 – 25% of species, and foliage gleaners were reduced by 12 – 21% as A. donax cover increased from 0-50%. For ground gleaning species, 13% of the variation in richness was explained by A. donax cover alone during both Spring and Breeding 2. Arundo donax cover explained between 8 and 19% of the variation in foliage gleaning species richness during Spring and Breeding 2, respectively.

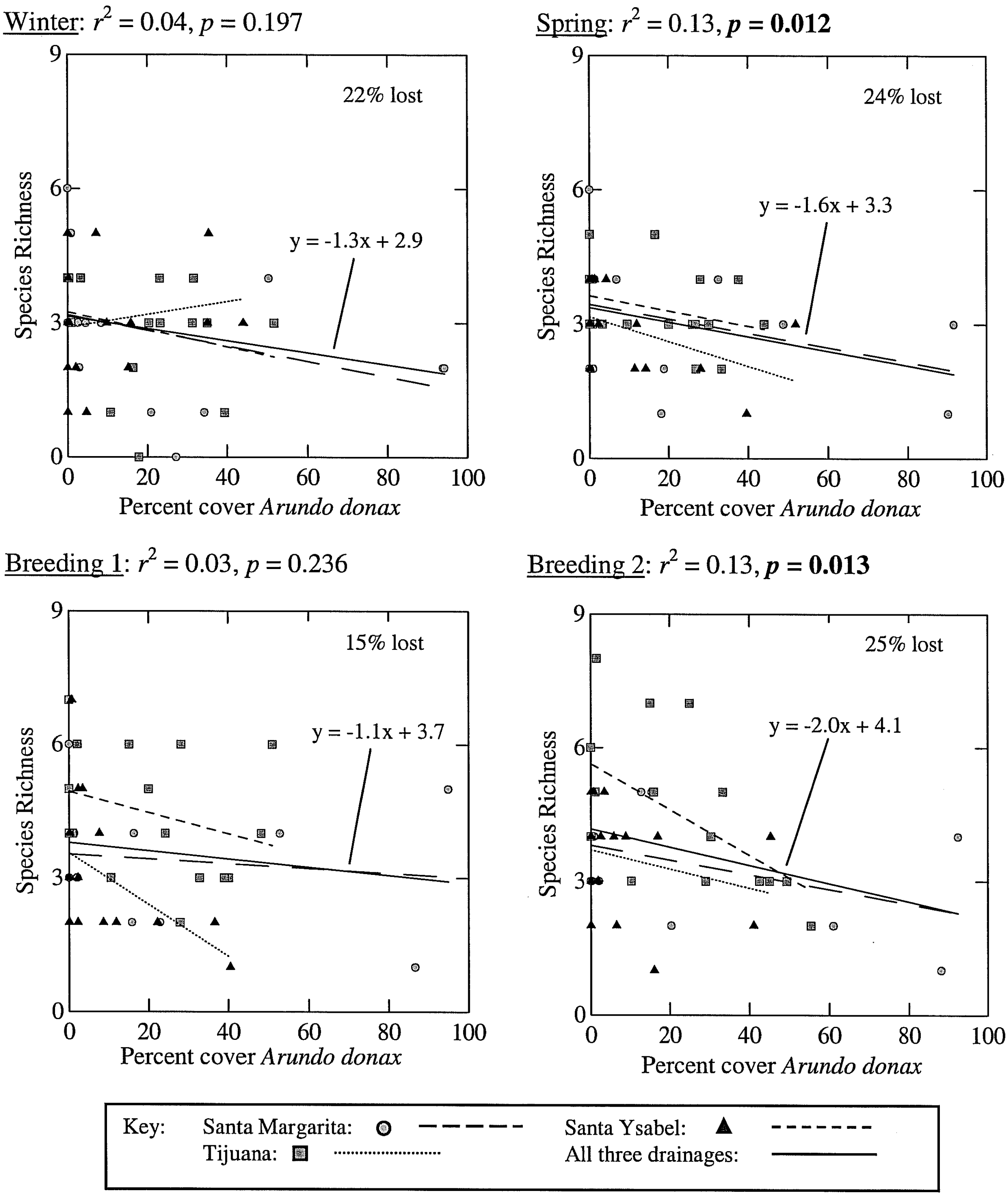

Figure 9. Species richness of ground gleaners as a function of *A. donax* cover by season. Percent lost equals the percentage of species lost as *A. donax* cover increased from 0-50% cover. Line equations, r^2, and p-values are for all three drainages combined.

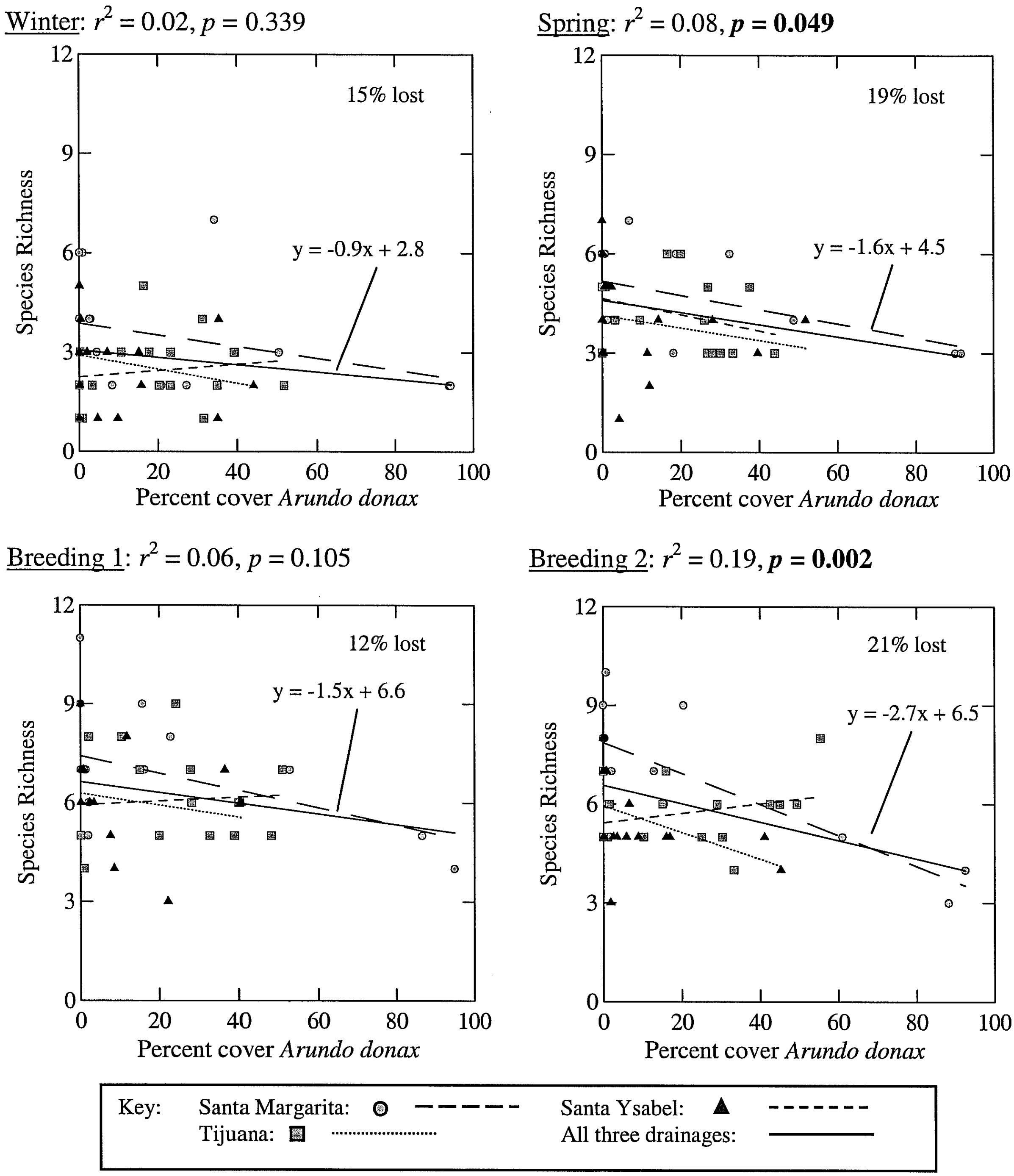

Figure 10. Species richness of foliage gleaners as a function of *A. donax* cover by season. Percent lost equals the percentage of species lost as *A. donax* cover increased from 0-50% cover. Line equations, r^2, and p-values are for all three drainages combined.

With only three species and 71 detections, there were too few species and individuals of bark gleaners to analyze. Bark gleaners were detected at sites with as much as 92.5% *A. donax* cover, but the averaged *A. donax* cover at points where they were detected was 15 ± 22%.

The best fit logistic regression model for the two species of hover gleaners did not identify cover of *A. donax* as a significant predictor of occurrence in any season (Figure 11; $p = 0.10$). A best fit logistic regression model for the six hawking species indicated that there was a significant 2-fold increase in their likelihood of occurrence with a 25% reduction in *A. donax* cover (Figure 11; $p = 0.02$) during Breeding seasons 1 and 2.

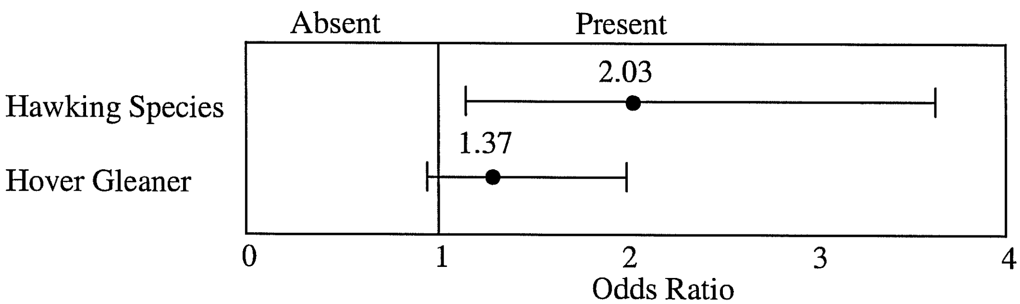

Figure 11. Odds ratios of the presence/absence of hover gleaners and hawking species for a 25% decrease of *A. donax* cover. Odds ratio is represented by the dot with 95% confidence intervals.

Listing Status

Non-listed species (20 species, Table 3) exhibited a significant decline in species richness in relation to A. donax cover during all four seasons (Figure 12). On a site-by-site basis, as cover of A. donax increased, the richness of non-listed species declined at all sites in all seasons except at the Tijuana River and Santa Ysabel sites during Winter, where no response was detected. Between 22 – 41% of non-listed species were lost as A. donax cover increased from 0 – 50%.

Only two species of endangered species were detected [Least Bell's Vireo (*Vireo bellii pusillus*) and Southwestern Willow Flycatcher (*Empidonax traillii extimus*)]; no threatened species were detected. When all three sites are combined, the 13 listed species (Table 3) showed a significant decline during both Breeding 1 and 2 (Figure 13). Between 37 - 45% of listed species were lost as *A. donax* cover increased from 0 – 50%. When

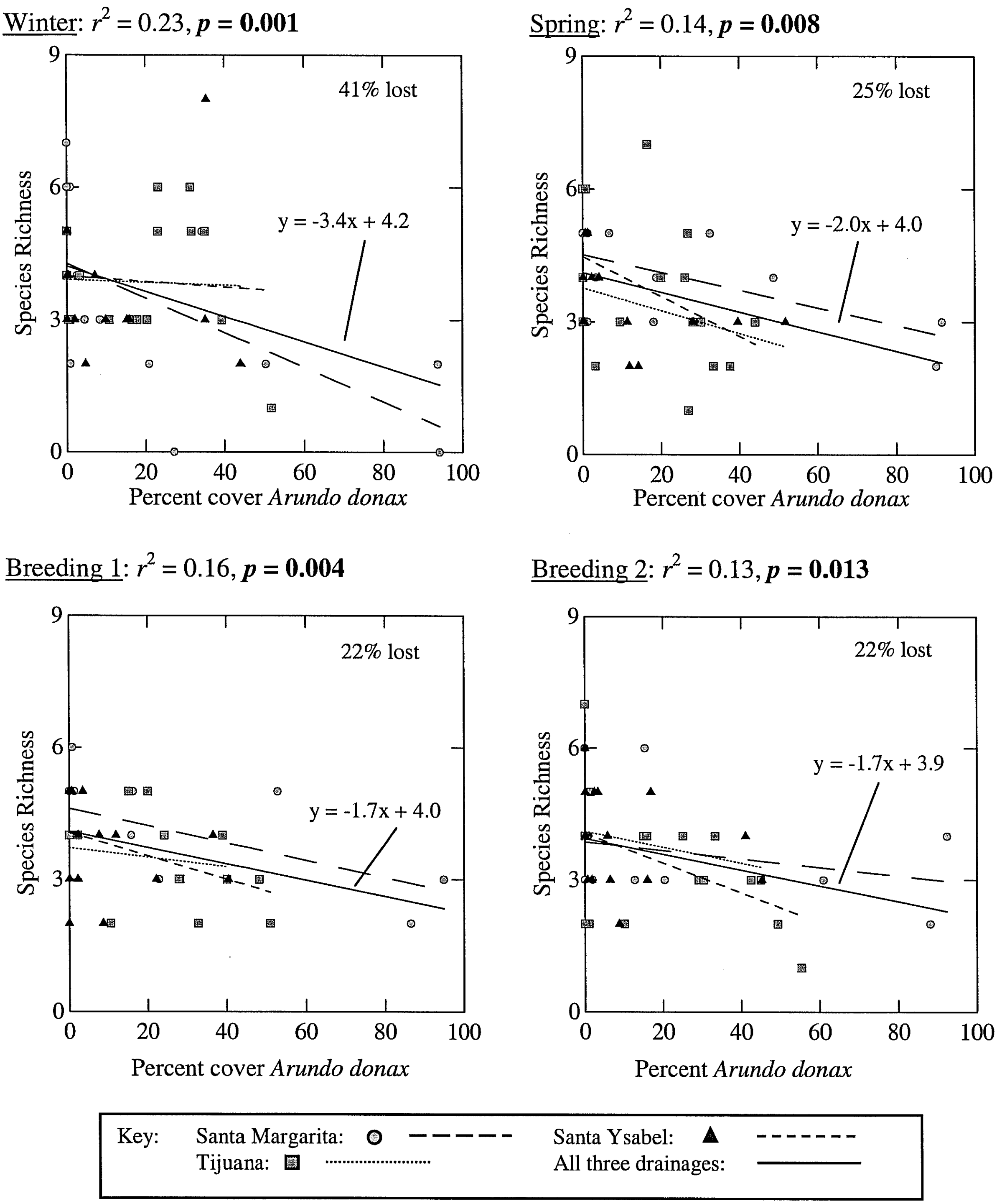

Figure 12. Species richness of non-listed species as a function of *A. donax* cover by season. Percent lost equals the percentage of species lost as *A. donax* cover increased from 0-50% cover. Line equations, r^2, and p-values are for all three drainages combined.

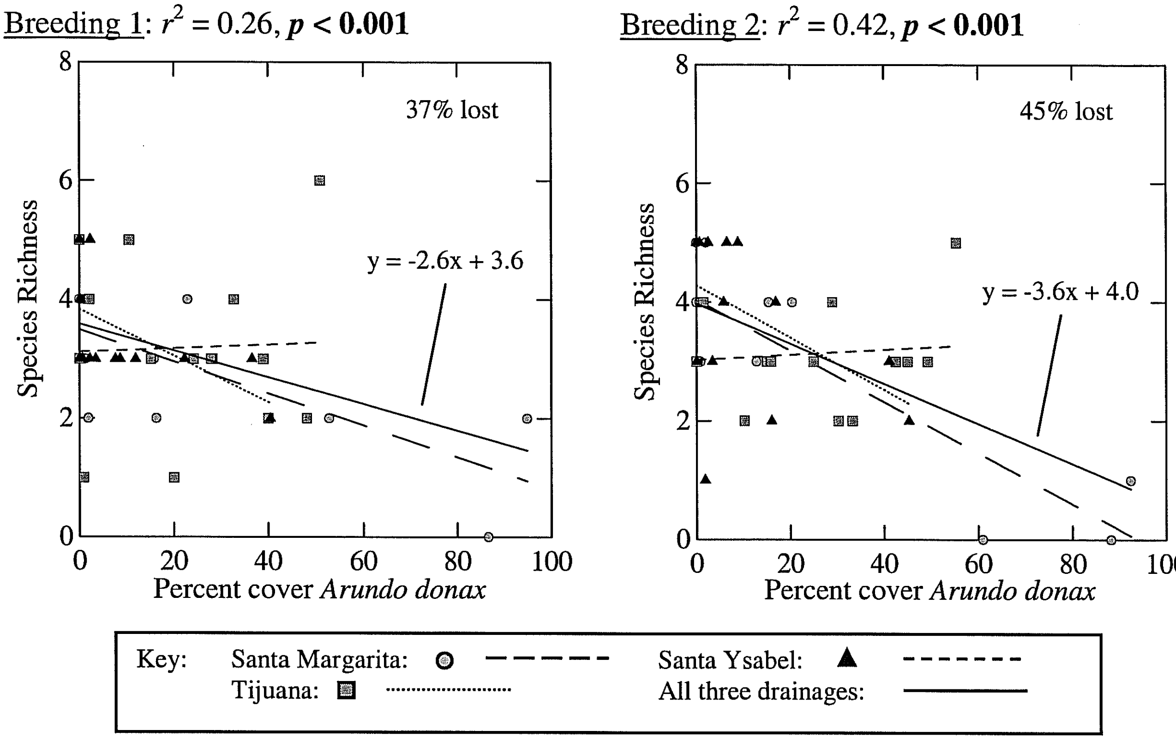

Figure 13. Species richness of listed species as a function of *A. donax* cover by season. Percent lost equals the percentage of species lost as *A. donax* cover increased from 0-50% cover. Line equations, r^2, and p-values are for all three drainages combined.

examined on a site-by-site basis, the relationship between listed species richness and *A. donax* cover was negative in both Breeding 1 and 2 for both the Tijuana River and Santa Margarita sites; there was no relationship at the Santa Ysabel site.

Across seasons, *A. donax* cover explained 13 - 23% of the variation in non-listed species richness (Figure 12). Twenty-six to 41% of the variation in listed species richness was explained by *A. donax* cover (Figure 13).

Bird Abundance

Species richness and abundance showed the same overall trends with regard to *A. donax* cover, with no reversals in sign of the relationships (Table 7). However, in two instances the magnitude of the effect of *A. donax* cover on abundance differed from that on richness. First, increasing *A. donax* cover resulted in significant declines in abundance of ground gleaners in all four seasons (Figure 14), whereas it produced significant declines in richness only during Spring and Breeding 2 (Figure 9). The high abundance of Song

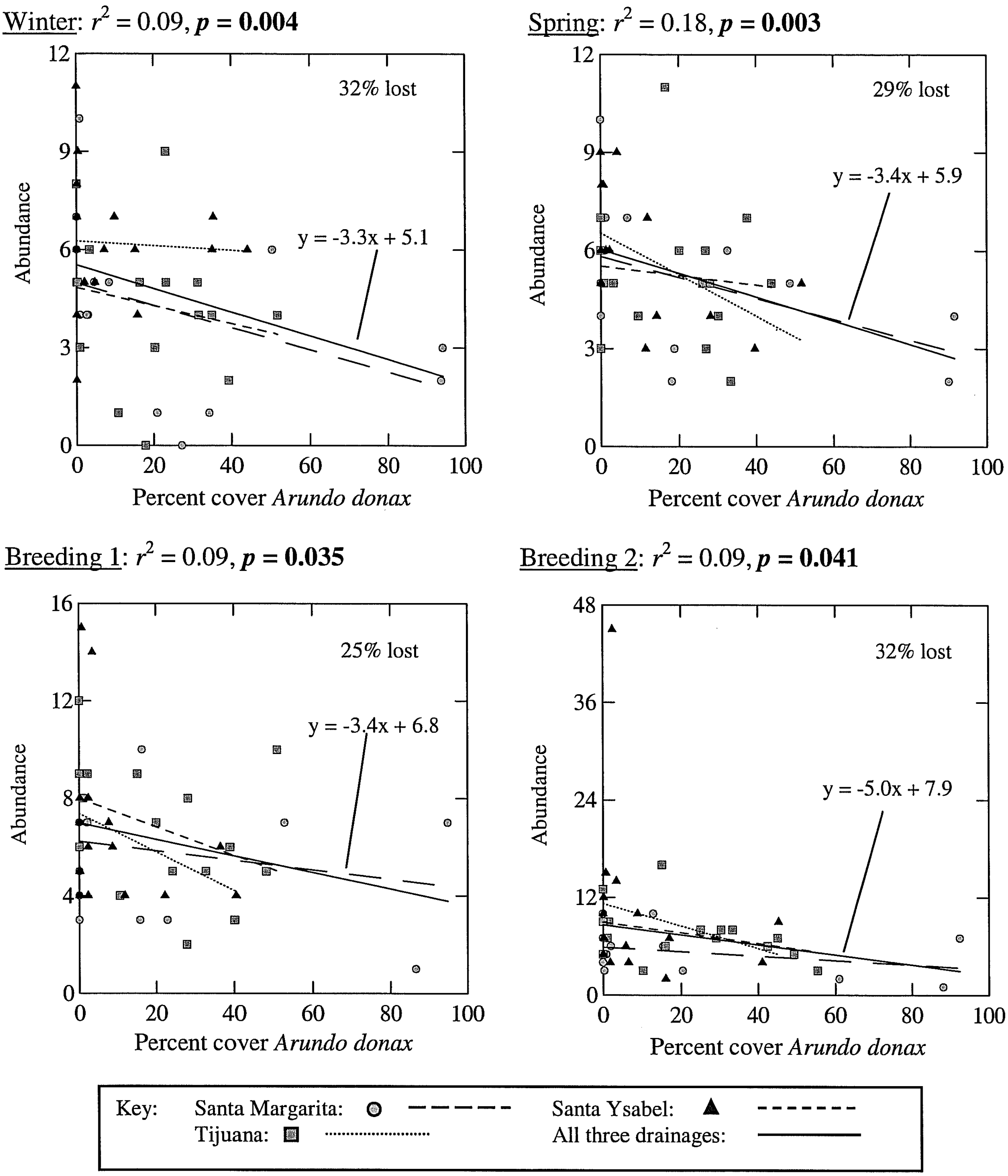

Figure 14. Abundance of ground gleaners as a function of *A. donax* cover by season. Percent lost equals the percentage of species lost as *A. donax* cover increased from 0-50% cover. Line equations, r^2, and *p*-values are for all three drainages combined.

Sparrows in Winter and Breeding 1 seasons generated a stronger "signal" than did species presence. On a site-by-site basis, ground gleaning abundance declined except at the Tijuana River, where no trend was evident. Nine to 18% of the variation in abundance of ground gleaners was explained by *A. donax* cover.

Second, species richness of non-listed species declined significantly in all seasons as *A. donax* cover increased, but abundance declined significantly only in Winter, Spring and Breeding 2 (Table 7). This difference can not be attributed to one species or obvious effect.

Individual Species Responses

Of the 17 species with maximum abundance exceeding 50 individuals over the course of the study, nine species showed a significant response to *A. donax* cover (Table 8). Two species [Song Sparrow and Lesser Goldfinch (*Carduelis psaltria*)] responded significantly during two seasons; while the other seven species showed significant responses during only one season. Two species [Lesser Goldfinch (Winter and Breeding 1) and American Goldfinch (*C. tristis*)(Winter)] increased in abundance with an increase in cover of *A. donax*. The other seven species declined in response to increasing cover of *A. donax*. The amount of variation in abundance explained by *A. donax* cover in the significant relationships ranged from 8 – 21% for the nine species(Table 8).

Community Composition

Community composition as assessed by the relative proportions of total abundance of ground, foliage, and hover gleaners varied significantly over the four categories of *A. donax* cover in Winter ($\chi^2 = 17.1$, df = 6, $p = 0.009$), but not in Spring ($\chi^2 = 1.8$, df = 6, $p = 0.940$), Breeding 1 ($\chi^2 = 9.2$, df = 6, $p = 0.162$), or Breeding 2 ($\chi^2 = 7.0$, df = 6, $p = 0.316$; Figure 15). The differences observed in Winter appears to be driven by changes in abundance of the hover gleaner guild, since removing the hover gleaner guild from the analysis resulted in no differences in community composition across the four seasons [Winter ($\chi^2 = 2.4$, df = 3, $p =$ 0.502), Spring ($\chi^2 = 1.0$, df = 3, $p = 0.809$), Breeding 1 ($\chi^2 = 2.5$, df = 3, $p = 0.468$), and Breeding 2 ($\chi^2 = 2.1$, df = 3, $p = 0.562$;]. There was also a significant difference in relative richness of ground, foliage, and hover gleaners across the four categories of *A. donax* cover in Winter ($\chi^2 = 17.1$, df = 6, $p = 0.009$) and Breeding 2 ($\chi^2 = 13.5$, df = 6, $p = 0.035$), but not

Table 7. Comparison of relationships between species richness and abundance and percent cover of *A. donax*. Significant relationships are in bold and relationships that differ between analyses are italicized. % lost = loss in richness or abundance as *A. donax* cover increased from 0 to 50% cover.

Factor	Richness/ Abundance	Season	Slope	% lost	r^2	p
Overall	Richness	Winter	-4.0	25	0.16	**0.003**
		Spring	-4.3	23	0.18	**0.002**
		Breeding 1	-4.0	16	0.14	**0.009**
		Breeding 2	-6.2	24	0.37	**<0.001**
	Abundance	Winter	-6.6	26	0.12	**0.016**
		Spring	-11.0	31	0.27	**<0.001**
		Breeding 1	-6.7	17	0.12	**0.017**
		Breeding 2	-12.1	27	0.21	**0.001**
Resident	Richness	Winter	-3.0	23	0.15	**0.007**
		Spring	-3.3	21	0.19	**0.002**
		Breeding 1	-1.8	11	0.05	0.114
		Breeding 2	-2.4	15	0.12	**0.015**
	Abundance	Winter	-5.1	23	0.10	**0.029**
		Spring	-7.9	27	0.27	**<0.001**
		Breeding 1	-2.6	9	0.03	0.235
		Breeding 2	-7.1	22	0.09	**0.037**
Migrant	Richness	Breeding 1	-2.4	32	0.15	**0.006**
		Breeding 2	-4.0	46	0.51	**<0.001**
	Abundance	Breeding 1	-3.9	36	0.13	**0.011**
		Breeding 2	-5.1	46	0.45	**<0.001**
Ground Gleaner	Richness	*Winter*	*-1.3*	22	*0.04*	*0.197*
		Spring	-1.6	24	0.13	**0.012**
		Breeding 1	*-1.1*	*15*	*0.03*	*0.236*
		Breeding 2	-2.0	25	0.13	**0.013**
	Abundance	*Winter*	*-3.3*	*32*	*0.09*	***0.004***
		Spring	-3.4	29	0.18	**0.003**
		Breeding 1	*-3.4*	*25*	*0.09*	***0.035***
		Breeding 2	-5.0	32	0.09	**0.041**
Foliage Gleaner	Richness	Winter	-0.9	15	0.02	0.339
		Spring	-1.6	19	0.08	**0.049**
		Breeding 1	-1.5	12	0.06	0.105
		Breeding 2	-2.7	21	0.19	**0.002**
	Abundance	Winter	-0.1	2	0.00	0.945
		Spring	-6.0	32	0.17	**0.004**
		Breeding 1	-0.3	2	0.00	0.888
		Breeding 2	-4.9	21	0.12	**0.018**
Non-listed Species	Richness	Winter	-3.4	41	0.23	**0.001**
		Spring	-2.0	25	0.14	**0.008**
		Breeding 1	*-1.7*	22	*0.16*	***0.004***
		Breeding 2	-1.7	22	0.13	**0.013**
	Abundance	Winter	-5.9	26	0.10	**0.028**
		Spring	-10.3	32	0.26	**<0.001**
		Breeding 1	*-4.4*	*14*	*0.05*	*0.111*
		Breeding 2	-7.4	22	0.10	**0.033**
Listed Species	Richness	Breeding 1	-2.6	37	0.26	**<0.001**
		Breeding 2	-3.6	45	0.42	**<0.001**
	Abundance	Breeding 1	-2.2	24	0.09	**0.042**
		Breeding 2	-5.0	46	0.42	**<0.001**

Table 8. Seasonal response of individual species as a function of *A. donax* cover (significant interactions are in bold).

Species	Winter				Spring				Breeding 1				Breeding 2			
	Slope	r^2	F	p	Slope	r^2	F	p	Slope	r^2	F	p	Slope	r^2	F	p
Anna's Hummingbird	-1.19	0.21	12.05	**0.001**	-0.32	0.02	0.75	0.392	-0.59	0.05	2.63	0.112	-0.16	0.01	0.22	0.638
Bell's Vireo	--	--	--	--	0.14	0.01	0.43	0.514	-0.57	0.06	2.69	0.107	-0.70	0.09	4.58	**0.037**
Bushtit	-0.29	0.01	0.32	0.572	-0.93	0.10	5.12	**0.028**	-0.44	0.02	0.97	0.330	-0.41	0.01	0.50	0.482
Bewick's Wren	-0.33	0.02	0.75	0.393	0.05	<0.01	0.02	0.891	-0.29	0.02	0.71	0.405	-0.64	0.07	3.29	0.076
House Wren	-0.07	0.01	0.58	0.449	-0.39	0.03	1.61	0.211	-0.74	0.07	3.60	0.064	-0.69	0.09	4.39	**0.042**
Wrentit	-0.39	0.03	1.23	0.274	-0.48	0.03	1.61	0.211	-0.60	0.08	4.13	**0.048**	-0.32	0.02	0.69	0.409
Orange-crowned Warbler	-0.15	0.01	0.34	0.562	-0.66	0.04	2.11	0.153	0.08	<0.01	0.03	0.858	-0.31	0.01	0.58	0.449
Yellow Warbler	--	--	--	--	-0.01	<0.01	0.00	0.982	-0.58	0.05	2.35	0.133	-0.69	0.09	4.64	**0.036**
Yellow-rumped Warbler	-0.61	0.04	1.84	0.182	-0.65	0.02	1.05	0.311	0.14	0.04	2.12	0.152	--	--	--	--
Common Yellowthroat	-0.30	0.01	0.60	0.441	0.04	<0.01	0.03	0.864	0.20	0.02	0.89	0.350	0.05	<0.01	0.03	0.865
Yellow-breasted Chat	--	--	--	--	0.06	0.01	0.40	0.533	-0.58	0.05	2.43	0.126	-0.65	0.07	3.22	0.080
Spotted Towhee	-0.55	0.05	2.31	0.135	-0.27	0.01	0.43	0.515	-0.13	<0.01	0.15	0.700	-0.23	0.01	0.54	0.466
California Towhee	0.14	<0.01	0.17	0.686	0.04	<0.01	0.02	0.899	0.26	0.02	0.74	0.392	0.26	0.01	0.45	0.508
Song Sparrow	-1.08	0.18	10.28	**0.002**	-0.29	0.03	1.52	0.224	-0.55	0.09	4.77	**0.034**	-0.36	0.03	1.37	0.248
House Finch	0.14	<0.01	0.16	0.696	-0.25	0.01	0.51	0.479	-0.71	0.06	3.17	0.082	-0.88	0.03	1.64	0.207
Lesser Goldfinch	0.95	0.14	7.28	**0.010**	-0.21	0.01	0.37	0.544	0.94	0.09	4.67	**0.036**	-0.05	<0.01	0.01	0.909
American Goldfinch	0.95	0.08	4.09	**0.049**	0.05	<0.01	0.01	0.927	0.45	0.02	1.06	0.308	-0.35	0.02	0.88	0.352

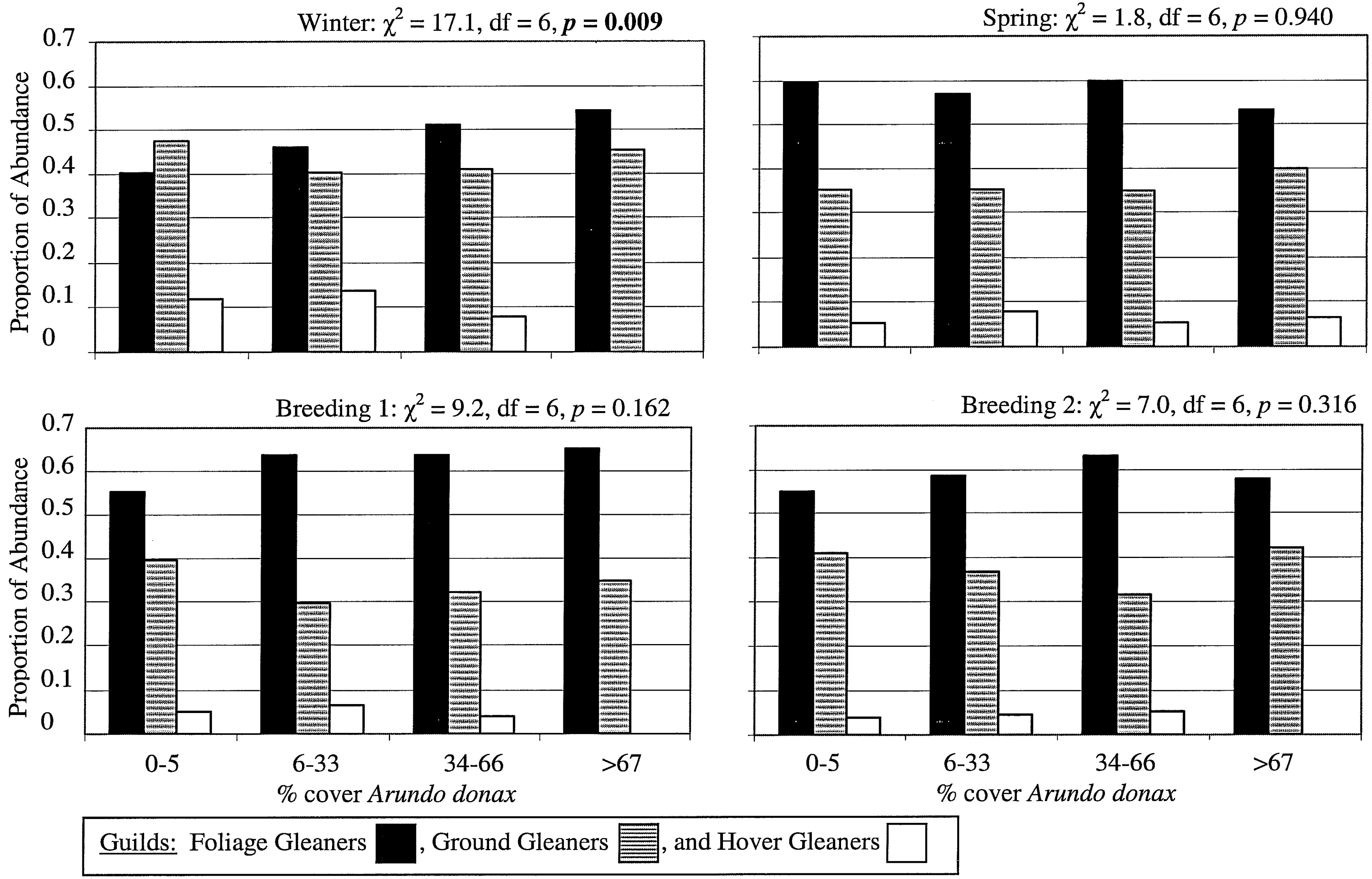

Figure 15. Proportion of abundance by guilds as a function of *A. donax* cover by season.

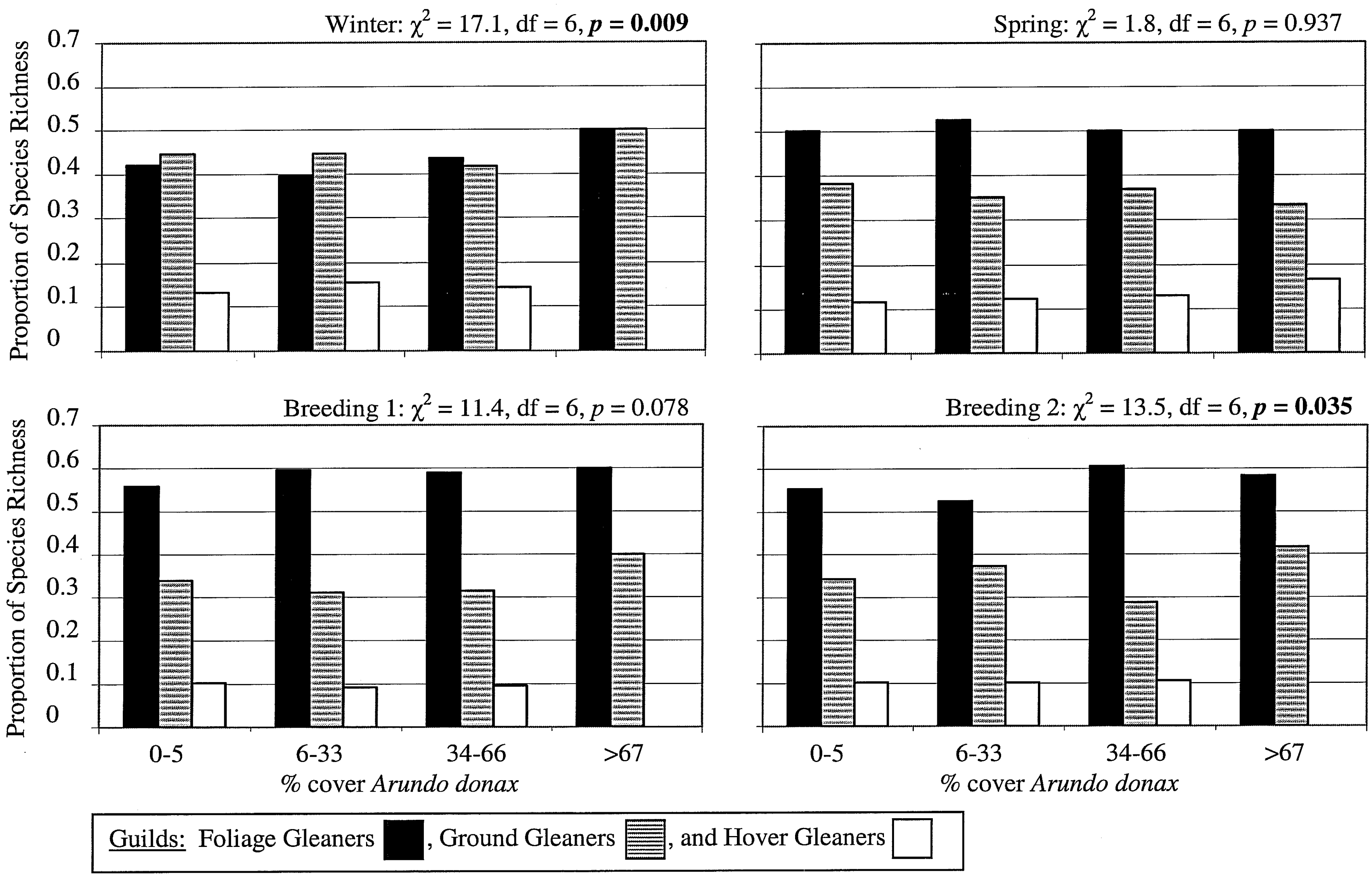

Figure 16. Proportion of species richness by guilds as a function of *A. donax* cover by season.

in Spring ($\chi^2 = 1.8$, df = 6, $p = 0.937$) or Breeding 1 ($\chi^2 = 11.4$, df = 6, $p = 0.078$; Figure 16). Again, these relationships appear to be driven by changes in the hover gleaner guild since removing the hover gleaner guild from the analysis resulted in no significant differences in relative richness of guilds in all four seasons [Winter ($\chi^2 = 0.3$, df = 3, $p = 0.957$), Spring ($\chi^2 = 0.3$, df = 3, $p = 0.951$), Breeding 1 ($\chi^2 = 0.9$, df = 3, $p = 0.832$), and Breeding 2 ($\chi^2 = 2.3$, df = 3, $p = 0.517$;].

Additional Factors Affecting Bird Species Richness

The best single factor model predicting species richness was the "season" model (Table 9). *Arundo donax* cover increased the predictive power of the "season" model the most. Adding a third factor to the "Season and *A. donax* cover" model did not increase the model's predictive power more than 1.7%. Study site, mule fat cover, and willow cover all were significant components in a three factor model, but none increased the predictive power dramatically. An increase in the predictive power of the model from 52.5% to 54.2% was not considered to be biologically significant.

Table 9. Best fit general linear model of bird species richness as a function of the cover of *A. donax*, willow, mule fat, leaf litter, dead snag, exotic woody vegetation, and herbaceous vegetation, amount of sky, soil, and study site.

Model	**Additional Factors**	r^2	**Change in r^2**	***p*-value**
Season		39.5%		**< 0.001**
	A. donax cover	52.5%	13.0%	**< 0.001**
	Willow cover	46.1%	6.6%	**< 0.001**
	Exotic cover	42.3%	2.8%	**0.003**
	Leaf Litter	41.1%	1.6%	**0.023**
	Herbaceous cover	41.0%	1.5%	**0.028**
	Study Site	40.0%	0.5%	0.417

Season- *A. donax* cover		52.5%		**< 0.001**
	Study Site	54.2%	1.7%	**0.033**
	Mule fat cover	53.9%	1.4%	**0.019**
	Willow cover	53.5%	1.0%	**0.045**
	Sky	53.4%	0.9%	0.062
	Season* *A. donax* cover	52.9%	0.4%	0.698
	Leaf Litter	52.8%	0.3%	0.248
	Soil	52.8%	0.3%	0.292
	Snag cover	52.7%	0.2%	0.334
	Exotic woody cover	52.7%	0.2%	0.435
	Herbaceous cover	52.6%	0.1%	0.644

DISCUSSION

This is the first study to quantify that as *A. donax* cover increases in an area, bird species richness and abundance decrease. In all four seasons, *A. donax* cover and bird species richness were significantly and negatively related. Contrary to my original hypothesis, the relationship was linear and did not show evidence of a threshold response by birds. This indicates that even a small increase in *A. donax* cover will have an adverse effect on bird species richness and abundance.

The relationship between *A. donax* cover and bird species richness did not vary significantly between seasons despite seasonal changes in bird species composition, richness and abundance. The direction and significance of the responses in richness to *A. donax* cover were similar to the responses in abundance to *A. donax* cover. Because 60% of the species detected in my study were represented by one individual, species richness can be used as a measure of how the community is affected by *A. donax*. The slope of the relationship was similar in the first three seasons, but slightly steeper late in the breeding season, suggesting that the effect of *A. donax* cover is greatest after nests have either fledged or failed. During the breeding season, males established and defended territories, presumably competing for high quality sites (Brown 1969). As MacArthur and MacArthur (1961) stated "… birds [may] use some fairly subtle differences in local habitat as criteria for habitat selection". Territoriality may have been a confounding variable, with less successful males potentially forced to breed in lower quality sites (i.e. with higher *A. donax* cover) or forego breeding and become "floaters" or surplus individuals (Brown 1969). Later in the breeding season after nests had either fledged or failed, territoriality of birds had relaxed. With relaxed territoriality, birds with "poor" territories or "floaters" may have been free to move into higher quality habitats and vacate the higher *A. donax* cover sites.

These results are consistent with the findings of Schroeder's (1993) work in the California Mojave Desert. Schroeder found higher bird species richness and abundance in stands of native riparian vegetation than in monotypic stands of another invasive exotic plant species, *Tamarix ramosissima*. However, Ferree (2002) found no evidence that tamarisk affected nest success or nest site selection in Bell's Vireos, Yellow-breasted Chats (*Icteria virens*), or Yellow Warblers at the level of nest patch and territory.

My hypotheses regarding the response of various foraging guilds were correct with regard to the direction of the response to increased *A. donax* cover but inaccurate regarding which guilds would be most responsive. Ground gleaners showed a stronger response to *A. donax* cover than did foliage gleaners, contrary to my prediction. One possible reason for this results from the amount of movement involved with foraging. Ground gleaners often forage by finding a "good spot" and searching and digging for food, whereas foliage gleaners tend to move through a larger area and cover a greater distance in the same amount of time. This would increase the likelihood of a foliage gleaner entering an *A. donax*-dominated area in a heterogeneous landscape. I was not able to detect enough bark gleaners (only 71 detections out of 1909 total detections) to conduct a meaningful analysis.

Migrant breeders and resident species both showed a negative relationship with *A. donax* cover as I had hypothesized. I had expected a weaker response to *A. donax* cover in the breeding season, but I had not expected a difference between migrant breeders and resident species. The strong response of migratory breeders could be a result of lower "saturation" of suitable habitat. If there were fewer migrants, they could select and defend higher quality habitat. Conversely, if resident species are abundant, then high quality habitats would be taken, forcing migrant birds into lower quality habitat. Once territoriality relaxes, the birds can move around more freely and vacate the lower quality – *A. donax* dominated sites. Whatever the reason, migratory breeders were more strongly affected by *A. donax* cover than any other guild considered in this study, with 51% of the variability in species richness, and 49% of the variability in abundance, explained by *A. donax* cover alone.

My prediction that listed species would respond more strongly than non-listed species to *A. donax* cover was supported. Non-listed species had a significant, negative relationship with *A. donax* cover in all but the early breeding season. The listed species showed a significant negative relationship in both the early and late breeding season. These results are very similar to the results for resident and migrant breeding species since 70 to 80% of migrant breeders were listed species (i.e. Yellow Warbler, Yellow-breasted Chat, and Least Bell's Vireo).

On a species-by-species basis, the majority of species showed a negative relationship with *A. donax*, though the relationship only explained between 8 and 21% of the variation in abundance. Over the course of the four study periods, eight significant negative relationships and three significant positive relationships were detected. All three significant positive seasonal responses were by goldfinch species. Both the American and Lesser Goldfinch are "nomadic," far-ranging species even during the breeding season. They showed a propensity to land in *A. donax* and use it as a "look out;" they were not seen to forage on *A. donax.*

Community composition as defined by proportions of foliage, ground and hover gleaners differed significantly between the four categories of *A. donax* cover in Winter for both abundance and richness and in Breeding 2 for richness. However, these relationships appear to be driven predominantly by the presence or absence of hover gleaners in the highest cover class of *A. donax*. Otherwise, guild composition did not vary across the range if *A. donax* cover.

Vegetation Model

Vegetation and other physical factors (sky and soil) are all interrelated due to the fact that space is limited. The more there is of one species or element, the less of another (i.e. the more willow cover, the less sky). The model I created indicates that season was by far the strongest single factor explaining changes in bird species richness. Adding *A. donax* cover to the model, since it was the strongest second factor, swamped out willow and other vegetative factors. Thus, *A. donax* is the dominant vegetative factor driving bird species richness in southern California riparian systems.

Arundo donax has a very simple structure – tall and slender with very little horizontal structure. The vegetation structure of a site may have a strong influence on bird species richness and abundance. Additionally, when *A. donax* dominates a region, there is a loss of herbaceous material, the shrub layer, and potentially a loss of the canopy trees with enough time. The strength of *A. donax* cover as a predictor of bird species richness may be a combination of its simplified structure coupled with a loss of food resources.

Management and Conservation Implications

The health of the southern California riparian bird community, as defined by abundance and richness, is greater in areas with less *A. donax* cover. In light of this, the removal of *A. donax* would appear highly beneficial to the riparian bird community's richness and abundance especially, for neotropical migrants.

The short and long-term impact of *A. donax* removal has been debated. Currently, there are efforts to remove *A. donax* from many drainages throughout southern California, including large portions of the Santa Margarita, Santa Ysabel, and the Tijuana Rivers. Within the Tijuana River valley, the Tijuana River National Estuarine Research Reserve is undertaking a large-scale removal project. Marine Corp Base Camp Pendleton has been using mechanical removal of existing stands of *A. donax* followed by five years of chemical treatment of the removal areas with herbicide. The sites that I surveyed on the Santa Margarita River were pre-*A. donax* removal areas but many of the sites have since been cleared of *A. donax*. My data could be used as a baseline for a follow up project to acquire a deeper understanding of the impacts of *A. donax* removal.

Another finding from this study indicates that a species list would be as effective as more detailed abundance data to assess the effect of *A. donax* cover on the riparian bird community or changes in the community before, during, and after *A. donax* removal. Species lists are easier to collect, less expensive, and faster to compile than a complete census of all species.

Aerial photographs proved to be far less useful than expected for assessing the cover of *A. donax* in an area. The major problem was that aerial photographs did not capture the understory of a site. If there were canopy trees present, the aerial photographs did not convey any information on the understory, which in some of my sites, was dominated by *A. donax*.

Future Research

Though the results of my study were consistent with my hypothesis that higher quality habitat supports more birds and higher richness, my study did not measure fitness or survivorship, assess breeding effort or success, nor track movement of individuals between seasons. Higher numbers of individuals and/or species are not necessarily indicative of "better" habitat or higher fitness (Martin 1992 and 1998 and Petit and Petit 1996). Numerous individuals in an area may increase density-dependent mortality through competition for limited resources such as food or nest sites. Predators, disease, or parasites may be more common in areas with high richness or abundance, thus lowering fitness. An examination of nesting success, fledging rates, and long-term survival of species and individuals would better answer questions regarding *A. donax*'s impact on fitness.

The influence of *A. donax* cover on habitat selection, seasonality of territorial behavior, territory size, and the prevalence of "floaters" could be very interesting and of biologic importance. Additional work comparing foraging rates in or near *A. donax* and differences between various guilds would elucidate the role of non-native plants on the food web of the riparian bird community.

ACKNOWLEDGEMENTS

I would like to thank Camp Pendleton Marine Corp Base, the Tijuana River National Estuarine Research Reserve, San Diego County, and the City of San Diego for granting me access to my study sites.

Funding through the San Diego State Field Station, Crouch Avian scholarship, and USGS/BRD was greatly appreciated.

I would like to thank my thesis committee for their hard work and genuine interest in my project and me. I would like to thank the past and present members of the lab (Peter Beck, Kerry Kenwood, Barbara Kus, Bonnie Peterson, Jay Rourke, Bryan Sharp, Mike Wellik) for their friendship, insight, and assistance. Additionally, I would like to thank Andrea Atkinson for her assistance with many of my statistical quagmires.

Last but not least, I would like to thank my family and friends for their direct and indirect help – playful harassment, support, and willing ears.

REFERENCES

Bell, G. P. 1994. Biology and growth habits of giant reed (*Arundo donax*). Pages 1-6 in N. E. Jackson, P. Frandsen, and S. Douthit, editors. November 1993 *Arundo donax* workshop proceeding. Ontario, California.

Bell, G. P. 1998. Ecology and Management of *Arundo donax*, and approaches to riparian habitat management in southern California. Pages 103-113 in J.H. Brock, M. Wade, P. Pysek and D. Green, editors. Plant invasions: studies from North America and Europe. Blackhuys Publishers, Leiden, The Netherlands.

Bowler, P. A. 1990. Riparian woodlands: an endangered habitat in southern California. Pages 80-97 in A. A. Schoenherr editor. Endangered plant communities of Southern California. Southern California Botanists, Special Publication No. 3.

Brown, J. L. 1969. Territorial behavior and population regulation: a review and re-evaluation. Wilson Bulletin **81**:293-329.

Chandhuri, R. K. and S. Ghosal. 1970. Triterpines and sterols from the leaves of *Arundo donax*. Phytochemistry **9**: 1895-1896.

Daubenmire, R. 1959. A canopy-coverage method of vegetation analysis. Northwest Sciences **33**:43-64.

Douthit, S. 1994. *Arundo donax* in the Santa Ana River Basin. Pages 7-10 in N. E. Jackson, P. Frandsen, and S. Douthit, editors. November 1993 *Arundo donax* workshop proceeding. Ontario, California.

Dudley, T. L. 2000. *Arundo donax*. Pages 53-58 in C. C. Bossard, J. R. Randall, and M. C. Hoshovsky, editors. Invasive plants of California's wildlands. University of California Press, Berkeley, California.

Else, J. 1996. Post-flood establishment of native woody species and an exotic, *Arundo donax*, in a southern Californian riparian system. M.Sc. thesis, San Diego State University.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. BLM Technical Reference 1730-1. Bureau of Land Management, U.S. Department of the Interior, Denver, Colorado.

Faber, P. A., E. Keller, A. Sands, and B. M. Massey. 1989. The ecology of riparian habitats of the southern California coastal region: a community profile. U.S. Fish and Wildlife Service Biology Report 85 (7.27).

Ferree, K. 2002. Nest site selection and nest success of yellow warbler, Bell's vireo, and yellow-breasted chat in a desert riparian ecosystem. M.Sc. thesis, San Diego State University, CA.

Frandsen, P. and N. Jackson. 1994. The impact of *Arundo donax* on flood control and endangered species. Pages 13-16 in N. E. Jackson, P. Frandsen, and S. Douthit, editors. November 1993 *Arundo donax* workshop proceeding. Ontario, CA.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An Ecosystem perspective of riparian zones. Bioscience **41**:540-551.

Herrera, A. M. 1997. Invertebrate community reduction in response to *Arundo donax* invasion at Sonoma Creek. Pages 94-105 in T. Dudley, J. Reynolds, and M. Poteet editors. The science and policy of environmental impacts and recovery. Berkeley, California.

Herrera, A. M. and T. L. Dudley. 2003. Reduction of riparian arthropod abundance and diversity as a consequence of giant reed (*Arundo donax)* invasion. Biological Invasions **5**:167-177.

Hickman, J. C., editor. 1993. The Jepson manual: higher plants of California (3rd edition). University of California Press, Berkeley.

Iverson, M. E. 1994. The impact of *Arundo donax* on water resources. Pages 19-25 in N. E. Jackson, P. Frandsen, and S. Douthit, editors. November 1993 *Arundo donax* workshop proceeding. Ontario, California.

Jackson, N. E., P. Frandsen, and S. Duthoit, editors. 1993. *Arundo donax* workshop proceedings. California Exotic Pest Council, Riverside, California.

Johnson, R. R. and L. T. Haight. 1984. Riparian problems and initiatives in the American southwest: A regional perspective. Pages 23-29 in R. E. Warner, and K. M. Hendrix editors. California riparian systems: ecology, conservation, and management. University of California Press.

Jones and Stokes. 2000. Biological studies of *Arundo* at U.S. Marine Corp Base, Camp Pendleton, California. Sacramento, California.

Katibah, E. F., K. J. Dummer, and N. E. Nedeff. 1984. Current condition of riparian resources in the Central Valley of California. Pages 314-321 in R. E. Warner, and K. M. Hendrix editors. California riparian systems: ecology, conservation, and management. University of California Press.

Kus, B. E. and P. P. Beck. 2003. A approach for monitoring bird communities to assess development of restored riparian habitat. Pages 396-406 in Faber, P. M. editor. California riparian systems: processes and floodplain management, ecology, and restoration. Riparian Habitat Joint Venture, Sacramento, California.

MacAurthur, R. H. and J. W. MacAurthur. 1961. On bird species diversity. Ecology **42**:594-598.

Martin, T. E. 1998. Are microhabitat preferences of coexisting species under selection and adaptive? Ecology **79**:656-670.

Martin, T. E. 1992. Breeding productivity considerations: what are the appropriate habitat features of management? Pages 455-473 in J. M. Hagan and D. W. Johnston, editors. Ecology and conservation of neotropical migrants. Smithsonian Institute Press, Washington, D. C., USA.

Mead, R. 1988. The design of experiments: statistical principals for practical application. University Press, Cambridge.

Munz, P. A. 1974. A flora of southern California. Univ. of California Press, Berkeley.

Naiman, R. J., H. Decamps, M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications **3**:209-212.

Petit, L. J. and D. R. Petit. 1996. Factors governing habitat selection by prothonotary warblers: field tests of the Fretwell—Lucas models. Ecological Monographs **66**:367-387.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook for field methods for monitoring landbirds. General Technical Report PDW-GTR-144. U.S. Forest Service, Pacific Research Station, Albany, California.

Ralph, J. C., J. R. Sauer, and S. Droege, technical editors. 1995. Monitoring bird populations by point count. General Technical Report PDW-GTR-149. U.S. Forest Service, Pacific Research Station, Albany, California.

Rappole, J. H. 1995. The Ecology of Migrant Birds: A Neotropical Perspective. Smithsonian Institution Press. Washington and London.

Robbins, W. M., M. K. Bellue and W. S. Ball. 1951. Weeds of California. California Department of Agriculture, Sacramento.

Schroeder, A. M. 1993. Effects of tamarisk removal on avian distribution at Camp Cady Wildlife Area in the California Mojave Desert. M.Sc. thesis, California State University, Fullerton.

Scott, G. D. 1994. Fire threat from *Arundo donax*. Pages 20-21 in N. E. Jackson, P. Frandsen, and S. Douthit, editors. November 1993 *Arundo donax* workshop proceeding. Ontario, California.

State of California. 1999. California Department of Fish and Game natural diversity database: special status plants, animals, and natural communities of San Diego County. The Resource Agency, California Department of Fish and Game, Sacramento.

State of California. 2000. State and federal listed endangered and threatened animals of California. The Resource Agency, California Department of Fish and Game, Sacramento.

U.S. Fish and Wildlife Service. 1995. Migratory nongame birds of management concern in the United States: the 1995 list. Washington D.C.: 25 pp.

Zembal, R. 1990. Riparian habitat and breeding birds along the Santa Margarita and Santa Ana Rivers of southern California. Pages 98-114 in A. A. Schoenherr editor. Endangered plant communities of Southern California. Southern California Botanists, Special Publication No. 3.

APPENDIX A

GEOGRAPHIC COORDINATES OF POINT COUNT CIRCLES

GEOGRAPHIC COORDINATES OF POINT COUNT CIRCLES

	Santa Margarita River		Santa Ysabel Creek		Tijuana River	
Point	Lat.	Long.	Lat.	Long.	Lat.	Long.
01	33.24740	117.38190	32.53649	117.11276	33.09455	116.94415
02	33.24941	117.38185	32.54101	117.10927	33.09468	116.94843
03	33.25119	117.38009	32.55164	117.09267	33.09452	116.95184
04	33.25479	117.37795	32.55144	117.08960	33.09363	116.95399
05	33.25383	117.37983	32.55157	117.08003	33.09103	116.96454
06	33.25682	117.37827	32.55301	117.07743	33.09014	116.96800
07	33.25917	117.37737	32.55391	117.07487	33.08948	116.97151
08	33.26247	117.37658	32.55463	117.07159	33.08817	116.97508
09	33.26445	117.37623	32.54771	117.07134	33.08725	116.97828
10	33.26271	117.37426	32.54865	117.07564	33.08678	116.98102
11	33.26075	117.37483	32.54894	117.07896	33.08591	116.98374
12	33.25768	117.37387	32.55035	117.08171	33.08439	116.98753
13	33.26710	117.37436	32.56065	117.10573	33.08411	116.99377
14	33.26998	117.37405	32.55913	117.10702	33.08365	116.99678
15	33.27253	117.37255	32.55822	117.10399	33.08341	116.99992
16	33.27493	117.37341	32.55974	117.10224	33.08264	117.00524

APPENDIX B

SPECIES AND NUMBEROF BIRDS DETECTED
BY SEASON AND DRAINAGE

SPECIES AND NUMBEROF BIRDS DETECTED BY SEASON AND DRAINAGE

Species	Winter Santa Margarita	Winter Santa Ysabel	Winter Tijuana	Spring Santa Margarita	Spring Santa Ysabel	Spring Tijuana	Breeding 1 Santa Margarita	Breeding 1 Santa Ysabel	Breeding 1 Tijuana	Breeding 2 Santa Margarita	Breeding 2 Santa Ysabel	Breeding 2 Tijuana
Great Egret			1									
Northern Harrier			1						1			2
White-tailed Kite			2	1		1	1					
Sharp-shinned Hawk			1									
Cooper's Hawk		1	1			2		1				2
Red-tailed Hawk			2									
Raptor species												1
California Quail				2								
Mourning Dove	4	3	2	1	2	2	6	3	7	4	4	6
Common Ground Dove					1			2			3	
Greater Roadrunner								1			1	
Barn Owl					1							
Anna's Hummingbird	12	19	31	7	9	16	5	5	17	1	4	15
Black-chinned Hummingbird					2		2	1	4			6
Hummingbird species				3	9	1	3	2	6	5	4	5
Downy Woodpecker	2	1	2	4	1	1	2	2	2	7	3	7
Nuttal's Woodpecker	4	5	2	4	4		4	2	1	4	3	
Northern Flicker	8				2	1				2		
Woodpecker species							1					1
Pacific Slope Flycatcher				3	1	3	6	5	10	5	3	10
Willow Flycatcher							3			3		1
Empidinax species									1			
Black Phoebe		6	3							1	1	
Ash-throated Flycatcher							2			2		1

Species	Winter Santa Margarita	Winter Santa Ysabel	Winter Tijuana	Spring Santa Margarita	Spring Santa Ysabel	Spring Tijuana	Breeding 1 Santa Margarita	Breeding 1 Santa Ysabel	Breeding 1 Tijuana	Breeding 2 Santa Margarita	Breeding 2 Santa Ysabel	Breeding 2 Tijuana
Cassin's Kingbird								1				
Warbling Vireo							2					
Least Bell's Vireo				1	4		10	17	9	16	22	10
Hutton's Vireo	7	1	4	3		3	5	1		5		2
Common Raven											2	
American Crow				2				2		4	8	
Northern Rough-winged Swallow					2							
Tree Swallow				1			5		1	1		
Cliff Swallow									15			1
Oak Titmouse		1								1		
Bushtit	2	25	5	21	27	26	21	21	18	17	39	25
Bewick's Wren	14	9	13	10	6	13	10	9	9	11	10	10
House Wren	1			12	1		19	6	2	9	6	2
Wren species					1							
Wrentit	15	1	2	16		4	10		4	18	8	4
Ruby-crowned Kinglet	10	10	2	3	5	1						
Blue-gray Gnatcatcher			4									
Western Bluebird								1				
American Robin			1									
Swainson's Thrush					1		5		5	2		
Hermit Thrush	1	2	1	1	1	3						
California Thrasher	1		6			4	1		2			6
European Starling					1							
Orange-crowned Warbler	3		5	31	1	18	34	4	17	19	2	14
Yellow Warbler				5	3	6	15	25	23	17	20	19

Species	Winter			Spring			Breeding 1			Breeding 2		
	Santa Margarita	Santa Ysabel	Tijuana	Santa Margarita	Santa Ysabel	Tijuana	Santa Margarita	Santa Ysabel	Tijuana	Santa Margarita	Santa Ysabel	Tijuana
Yellow-rumped Warbler	9	18	9	20	15	13		1				
Townsend's Warbler									2			
Common Yellowthroat	7	8	19	46	40	49	31	37	44	51	43	53
Wilson's Warbler				1		1	3			2		
Yellow-breasted Chat					1		10	11	19	16	14	22
Northern Cardinal						1			1			1
Black-headed Grosbeak							3	6	3	1	2	3
Blue Grosbeak								5	1	2	3	3
Lazuli Bunting							1	2	2			
Spotted Towhee	9	11	8	14	18	14	13	18	8	14	17	11
California Towhee	2	10	4		9	2	1	10	2	2	18	5
White-crowned Sparrow			1			3						
Song Sparrow	30	28	50	39	34	51	41	39	62	33	37	59
Sparrow species			6									
Brown-headed Cowbird								2				
Bullock's Oriole				1	1	1	3	1		1	4	
Hooded Oriole					1		1	5		5	2	3
House Finch	6	6	7	2	10	2	2	9	12	7	11	57
Lawrence's Goldfinch								4			1	
Lesser Goldfinch	11	7		3	12	1	5	23	7	13	11	5
American Goldfinch	14	28	7	15	19	15	14	16	14	9	11	5
Goldfinch species	1						2	2	1	1	1	1

ABSTRACT

ABSTRACT

The giant reed, *Arundo donax*, is an invasive exotic plant dominant in many of California's riparian areas, and is thought to offer little feeding or nesting habitats for birds. I investigated the relationship between *A. donax* and riparian bird richness and abundance within three drainages in San Diego county, California during four seasons (winter, spring, and early and late breeding) in 2001. We used aerial photographs and a stratified random block design to select 16 points per drainage with varying *A. donax* cover. Point counts were used to survey birds and photoplots were used to quantify *A. donax* cover at each point in each season. We hypothesized that the relationship between *A. donax* and bird richness and abundance would be negative and would vary by season, guilds (foraging and residency), and cover of other vegetation. Overall bird species richness and abundance decreased significantly as cover of *A. donax* increased during all seasons and at all drainages. Species richness decreased by 16% to 25% as *A. donax* cover increased from 0 – 50%. Resident species richness declined significantly with increasing *A. donax* cover during the winter, spring, and late breeding seasons but non-significantly during the early breeding season. Migrant breeding species richness declined significantly with increasing *A. donax* cover in both early and late breeding seasons, but migrants were too sparse in winter and spring for analysis. Ground and foliage gleaners showed the same general negative relationship with increasing *A. donax* cover. An analysis of vegetative and physical factors showed that season and *A. donax* accounted for 52.5% of the variation in bird species richness. Willow was not a biologically significant factor in a general linear model. The results of this study suggest that removing *A. donax* from southern California riparian areas would benefit richness and abundance of birds.