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Predicting the Ecological Response to Increased Base Flows in Ephemeral Texas Streams: Results from Field Investigations

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The combined effects of fire exclusion and continuous livestock grazing has led to shrub invasion into may of the semi-arid grasslands of the US (Van Auken 2000). The ultimate outcome is a conversion of prairies and savannahs into woodland habitats (Scholes and Archer, 1997). Prevailing range management systems in the Edwards Plateau of Texas have allowed ashe juniper (*Juniperus ashei*), redberry juniper (*Juniperus pinchotii*), and mesquite (*Prosopis glandulosa*) to become invasive species across a major portion of the region. These species are now the most conspicuous woody species in the region, contributing to declining grassland habitats and associated loss of ecosystem functions (Conner et al. 2000). One such public concern is the loss of water yield in rangeland watersheds that are now dominated by woody vegetation.

Some public and private efforts to restore watershed function through brush control have had promising results (e.g., Wright 1996). In general, these have not yet been well documented. Likewise, the projected response from brush management efforts has previously been based on scenarios that largely ignore the need to retain certain areas of brush for native wildlife habitats and operational safety (e.g., TAES 2000).

A landscape-scale brush management program may provide a unique opportunity to restore grassland habitats on the Edwards Plateau. Although grassland species could benefit from changing brush dominated areas to grasslands, careful planning is required to ensure that results mimic historical landscape patterns as much as possible. Observations from the 1860's indicate that the Edwards Plateau was a mosaic of grasslands, savannas, and scrub forest (Weniger 1988). In order to meet objectives of restoring ecological function, properly designed brush management plans should account for the habitat requirements needed to maintain viable populations of brush or woodland associated species while improving habitat for grassland-associated species. However, as there is with any change in habitat, any brush management strategy implemented across the landscape will result in a shift in the wildlife community resulting in gains or losses for particular species, depending on changes in habitat. Likewise, analyses of brush management scenarios should account for the likely consequences to aquatic ecosystems. The studies reported here are some of the first to incorporate the likely consequences of brush management programs on these biological resources at the landscape level.

OBJECTIVES & APPROACH

We report on two projects designed to evaluate changes in hydrology and biological diversity associated with brush management in Central Texas watersheds. In the first project, we modeled landscape features and assessed biological diversity of two Central Texas watersheds (Project I). We also describe the research protocol and rational for a new study that examines biotic responses to brush removal in first-order streams of the Pedernales River Basin in Central Texas (Project II).

Project I. **--** Our objectives for Project I were to 1) establish baseline assessments of our chosen species groups, correlating these to habitat structure and composition at the landscape

scale; 2) at landscape scale, project the habitat changes likely to result from alternative brush management scenarios; and 3) project the likely influence of alternative brush management scenarios on the chosen species groups.

We assessed the likely response of terrestrial and aquatic systems to specified brush management strategies over time. For five future scenarios, we modeled changes in landscape structure and assessed the related changes in biological diversity for two Central Texas watersheds (Twin Buttes and Edwards Aquifer Recharge – Figure 1). Birds were selected as ecological indicators for terrestrial systems, while fishes and aquatic macroinvertebrates were selected as aquatic ecological indicators. The specific brush management scenarios are described in Table 1.

We first determined the current association of bird species and guilds with brush cover in the two watersheds, then predicted changes in habitat occupancy under five brush management scenarios ranging from additional brush encroachment to steady state to variable degrees of brush removal. Using land-cover categories and data from extensive bird surveys, logistic regression models were built for seven guilds plus several grassland obligate species. Logistic regression models were then used to predict relative changes in bird species and guilds to brush management scenarios.

For the aquatic assessment, fishes and macroinvertebrates were surveyed throughout the Twin Buttes and Edwards Recharge watersheds. Data were used to create an index of biotic integrity (IBI): one based on fishes and another based on macroinvertebrates. Regression models were created to predict IBI values based on land cover attributes in sub-watersheds. These regression models then were used to predict IBI changes in response to brush management scenarios.

Project II. -- This study compares landscape units with and without a history of brush management to estimate the relative importance of brush management in influencing stream and riparian fauna and flora. We are developing statistical models of ecological response in aquatic and riparian zones to variation in landscape vegetation cover within sub-watersheds. These models will then be used to determine relationships among stream and riparian habitats and biota in watersheds subjected to various levels brush control.

RESULTS & CONCLUSIONS

Brush Cover Conditions. – The total brush cover on the Twin Buttes was estimated at 23.7 percent, most of which was mesquite and juniper (Figure 2). Concentrations of juniper were aggregated in the more central portions of the study area, whereas concentrations of mesquite were more widely distributed. Scenario I was projected to reduce total brush cover by 73 percent. The exclusion of riparian areas from brush removal in Scenario II resulted in a modest effect on overall brush cover. However, the 40 percent retention constraints of Scenario III resulted in only a 32.1 percent reduction of total brush cover. If in fact, the changes projected under future Scenario V were to occur (i.e., continued brush encroachment), then we projected total brush cover to almost double, much of the increase coming from expansion of juniper.

The total brush cover on the Edwards was estimated at 48.7 percent, most of which was juniper and oak, as well as mixed brush which is primarily a juniper/oak mix (Figure 3). With the exception of scattered aggregations of more open country in major drainage bottoms, the concentrations of juniper, oak and mixed brush were well distributed across the area. Because the

present condition includes heavy concentrations of juniper on slopes >15 percent (where mechanical brush management is not feasible), the differences among Scenarios I, II, and III were only slight; resulting a in a 24.4 to 22.4 percent decrease in total brush cover. Continued brush encroachment under Scenario V was projected to result in a 32.6 percent increase in total brush cover with 64.6 percent of the total landscape dominated by one or more species of brush.

Bird Community Response. – During the spring surveys on Twin Buttes we detected 3,874 individuals of 76 species within the 100-m sampling radius of 295 sample locations (Appendix B1). On average, we detected 8.8 species at each location (SE = 0.2, SD = 2.7). The maximum number of species detected at a sample site was 19. The most common species recorded was the Northern Mockingbird; and greater than 63 percent of total individuals detected were represented by only 12 species. On the Edwards watersheds we detected 2,941 individuals of 79 species within the 100-m sampling radius of 201 sample locations (Appendix C1). On average, we detected 9.8 species at each location (SE = 0.2, SD = 3.0). The maximum number of species detected at a sample site was 19. The most common species was the Tufted Titmouse; and greater than 43 percent of total individuals were represented by eight species. For scenario analysis, we divided the bird communities into habitat use guilds, and used logistic regression to develop habitat occupancy models for relating projected brush cover to probability of occurrence for one or more species of each guild in a specific landscape radius.

Greatest projected response to brush removal was by grassland obligate, grassland facultative and riparian guilds, as well as individual grassland obligate species. The grassland guilds appeared to be the best indicator groups for gauging the restoration of grassland ecosystems. While each of the component species are likely to respond to habitat changes not accounted for here, they do appear to genuinely respond to changes in landscape level brush concentrations. As brush cover increased under the scenarios in the Twin Buttes, the probability of occurrence for grassland obligates decreased from 0.824 in Scenario I to 0.594 in Scenario V. In the Edwards watersheds, the probability of occurrence of the grassland guild decreased from 0.319 in Scenario I to 0.028 in Scenario V.

Aquatic Community Response. – Field sampling produced biological and physical data from 131 sites spread across 22 regional sub-basins. To evaluate potential relationships between landscape-scale land-cover estimates and Fish IBI values (F-IBI), a multiple regression of sub-basin mean F-IBI scores was performed against the proportion of each sub-basin covered by the seven land-cover categories. The complete model (including all seven land cover categories: cedar, mesquite, mixed, oak, pasture, urban, cropland) was a good predictor of the mean F-IBI ($r^2 = 0.62$, $p = 0.027$). Because the amount of cedar and mesquite land cover is of particular interest to this project, we evaluated the two factor model including only these two land cover classes (cedar, mesquite) and found them to be reasonable predictors of the mean F-IBI score ($r^2 = 0.35$, $p < 0.017$).

Analyses based on the fish IBI indicated improved ecological integrity of streams under each of three brush management scenarios, with greater benefits predicted for the Twin Buttes region. F-IBI predictions based upon scenario-based land cover characteristics indicate the Twin Buttes watershed would experience a greater change in aquatic communities compared to the Edwards recharge zone (Table 2). Qualitatively, Table 2 clearly indicates Scenarios I, II, and III result in increased health of aquatic communities in both the Edwards and Twin Buttes watersheds. Scenario V, which represents no brush management and succession of vegetation

communities through time, results in depressed aquatic community health with some sub-basins showing average F-IBI scores indicative of "Poor" conditions. Quantitative comparison between Scenario IV and Scenarios I, II, and III reveals an average improvement of F-IBI scores among Edwards sub-basins of 4-5 points. However, mean F-IBI score increased 22, 20, and 10 points for the Twin Buttes basin for Scenarios I, II, and III, respectively. Similarly, Scenario V results in a mean reduction of 2 F-IBI points for Edwards sub-basins, but Twin Buttes sub-basins decline by an average of 17 points. Thus, this analysis indicates that brush management would have potential benefits for stream ecosystem health and aquatic fauna in both regions, with greatest benefits in the Twin Buttes watershed.

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Figure 1. Location of watersheds included in study.

Table 1. Management scenarios for projecting the ecological consequences of landscape-scale brush management for the Twin Buttes and Edwards watersheds of the Edwards Plateau in Texas.

Scenario	Description
Scenario I	Brush is controlled on all of a treatment area except on slopes greater than 15 percent. This scenario allows for the greatest amount of brush control.
Scenario II	In addition to no brush control where there is a slope greater than 15 percent, this scenario also does not treat brush within 75 meters of a mapped stream course (150 meter buffer along a stream course).
Scenario III	This scenario adds another constraint to the level of brush treatment in addition to the 15 percent slope and 150 meter buffer requirements. Namely, that brush remaining after treatment will be 40 percent of the total land area within each sub-basin for each of the eight watersheds.
Scenario IV	This constitutes the base from which the other scenarios are compared. The assumption is that current conditions continue into the future with no change.
Scenario V	The last scenario was developed whereby the current condition was allowed to become more brush infested over time. In this case, light brush was shifted to moderate, moderate brush moved to heavy brush.

Figure 2. Estimated total percent brush cover under 5 management scenarios, Twin Buttes study area. Scenario IV represents present condition; scenarios I, II, and III represent alternative futures under different brush management program constraints; while scenario V is a projected future condition given no brush control program on the area.

Figure 3. Estimated total percent brush cover under 5 management scenarios, Edwards study area. Scenario IV represents present condition; scenarios I, II, and III represent alternative futures under different brush management program constraints; while scenario V is a projected future condition given no brush control program on the area.

Table 2. Mean observed F-IBI score by sub-basin, and F-IBI scores by scenario by sub-basin as predicted by the two factor (cedar and mesquite) model.

Watershed	Sub-basin Number	Observed	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V
Edwards	2010301	76	68	67	67	63	62
Edwards	2010401	60	65	64	64	60	59
Edwards	2010501	68	71	71	71	68	66
Edwards	2010601	64	68	67	67	64	63
Edwards	2020201	66	70	73	73	68	65
Edwards	2020303	79	75	74	73	68	65
Edwards	6010101	77	75	75	74	71	68
Edwards	6010301	63	69	68	68	65	64
Edwards	6010501	61	67	66	66	63	62
Edwards	6010503	61	68	68	68	65	64
Edwards	6010801	75	73	73	73	69	67
Edwards	6060101	65	65	64	64	60	59
Edwards	6060201	62	64	63	63	59	59
Edwards	6060301	61	72	72	72	69	66
Edwards	6060501	59	77	76	74	72	68
Edwards	7060105	59	69	68	68	60	59
Twin Buttes	MC 25	40	76	74	64	54	36
Twin Buttes	MC 27	60	76	75	64	53	36
Twin Buttes	SC 16	71	77	75	66	55	39
Twin Buttes	SD 13	43	76	74	65	51	36
Twin Buttes	SD 15	44	76	76	66	57	39
Twin Buttes	SD 21	66	77	76	66	58	41