

Flora of the San Pedro Riparian National Conservation Area, Cochise County, Arizona

Elizabeth Makings

School of Life Sciences, Arizona State University, Tempe, AZ

Abstract—The flora of the San Pedro Riparian National Conservation Area (SPRNCA) consists of 618 taxa from 92 families, including a new species of *Eriogonum* and four new State records. The vegetation communities include Chihuahuan Desertscrub, cottonwood-willow riparian corridors, mesquite terraces, sacaton grasslands, rocky outcrops, and cienegas. Species richness is enhanced by factors such as perennial surface water, unregulated flood regimes, influences from surrounding floristic provinces, and variety in habitat types. The SPRNCA represents a fragile and rare ecosystem that is threatened by increasing demands on the regional aquifer. Addressing the driving forces causing groundwater loss in the region presents significant challenges for land managers.

Introduction

Understanding biodiversity has the potential to serve a unifying role by (1) linking ecology, evolution, genetics and biogeography, (2) elucidating the role of disturbance regimes and habitat heterogeneity, and (3) providing a basis for effective management and restoration initiatives (Ward and Tockner 2001). Clearly, we must understand the variety and interaction of the living and non-living components of ecosystems in order to deal with them effectively. Biological inventories are one of the first steps in advancing understanding of our natural resources and providing a foundation of information for a variety of fields.

A flora is defined as an inventory of plants growing within a specific geographic boundary (Palmer et al. 1995). Floras represent one of the most comprehensive sources of data to assess biodiversity (Withers et al. 1998). They can range from simple checklists of small areas to multivolume, descriptive and analytical floras of continental regions. Floristic data have been used in a variety of ways in academia: to study plant distribution and diversity, test premises of island biogeography, assess biological species concepts, and determine the prevalence of exotic species (Barkley 2000; Palmer et al. 1995). Local floras are valuable for historical information, documenting range extensions, providing baseline information on immigrant or extinct species, and providing data for regional floristic comparisons (Bowers 1981). Local floras in Arizona have been used to fill in gaps in species distribution, study geographic patterns of endemism, and identify floristic elements on a regional scale (McLaughlin 1986, 1995). Agency scientists use floras to document endangered or vulnerable species, plan and conduct restoration projects, and monitor commercial and recreational activities (Charlet 2000). Floristic information is relevant to applied fields such as horticulture, crop development, resource management, ecological consulting, mining, and environmental law (Wilken et al. 1988). Additionally, the

potential value of a species-level botanical inventory may not be realized until well into the future.

Study Site

San Pedro Riparian National Conservation Area

In 1988 Congress designated the San Pedro Riparian National Conservation Area (SPRNCA) as a protected repository of the disappearing riparian habitat of the arid Southwest. The SPRNCA was the Nation's first riparian NCA and extends from the United States/Mexican border to the town of St. David, Arizona (figure 1). The SPRNCA is a narrow strip approximately 69 kilometers (43 miles) long and 4 kilometers (2.5 miles) wide encompassing 19,291 hectares (47,668 acres, 74 m²), at an average elevation of 1,200 meters (~4,000 feet). Significant concerns over water quality and quantity, protection of cultural and paleontological resources, as well as conservation of natural resources are among the challenges for current and future land managers. Currently, there is a moratorium on historical land use activities such as livestock grazing, sand and gravel mining, and off-road vehicular traffic.

The SPRNCA is positioned in a crossroads of biological regions and is one of the most diverse areas in the United States. It is also one of the most important migratory corridors in the Western Hemisphere (The Nature Conservancy 2003). Millions of birds take advantage of the north-south orientation, surface water, and resource abundance. The southwestern willow flycatcher (*Empidonax traillii extimus*) and the Huachuca water umbel (*Lilaeopsis schaffneriana* var. *recurva*) are two endangered species found within the SPRNCA (United States Fish and Wildlife Service 2003).

The San Pedro is a low-gradient, alluvial desert river originating from the Sierra La Mariquita, Sierra San Jose, and

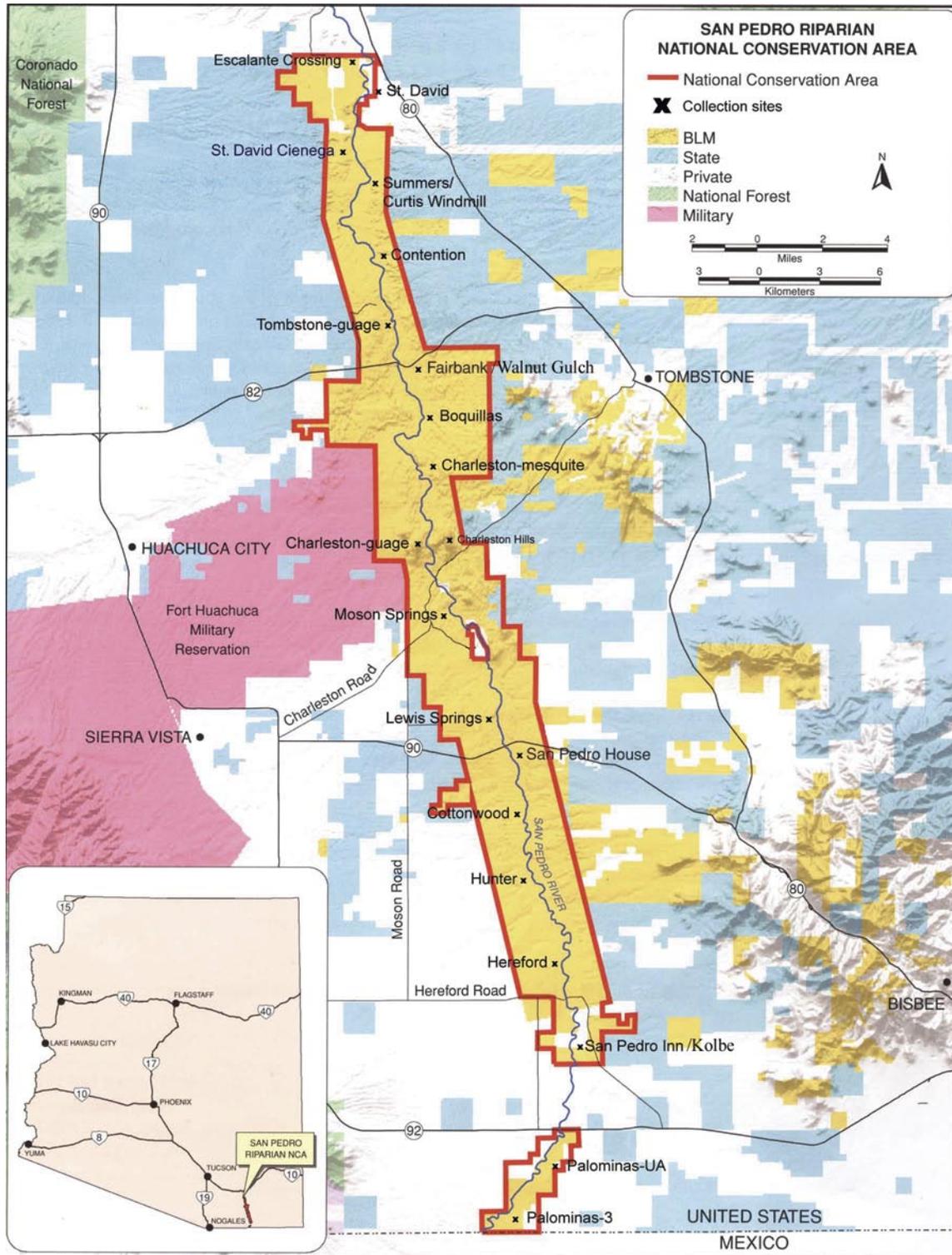


Figure 1—San Pedro Riparian National Conservation Area boundary, showing surrounding land ownership and commonly accessed collection sites. Map provided by Bureau of Land Management, used with permission (U.S. Government Printing Office: 2001-673-079/43005 Region No. 8).

Sierra Los Ajos in north-central Sonora, Mexico. It flows north approximately 240 kilometers (145 miles) to its confluence with the Gila River near the town of Winkelman, Arizona. The free-flowing hydrology of the San Pedro River is notable. Uncontrolled rivers are relatively rare in the region, making the

San Pedro River an important reference for degraded riparian ecosystems throughout the Southwest.

A complex sub-surface geology creates a surface hydrology of perennial and intermittent reaches along the upper San Pedro River. Shallow bedrock helps to maintain perennial

flows, i.e., reaches that have surface flow throughout the year. Intermittent reaches typically lack surface flow during periods of drought and the summer dry months. The upper San Pedro River also has a number of spring sources with localized perennial surface water.

An episode of arroyo cutting and channel trenching in the region probably began between 1890 and 1908 due to a combination of factors (Bryan 1925; Hastings 1959). Severe drought followed by a series of large floods, beaver extirpation, woodcutting for mining operations, overgrazing, and a sizeable earthquake transformed the San Pedro River from an almost imperceptible bed lined with bottomland marshes and grasses, to the current two-tiered floodplain where banks are often separated from the stream bed by several meters.

The St. David Cienega is an area of rare hydrology along the upper San Pedro River valley. Cienegas, the regional name for marshes, are wetlands where water permanently intersects the surface of the ground. Broadly speaking, the marshy character of the St. David Cienega is probably a function of the low relief and topographic gradient, specific geology, deep soils, and presence of springs.

The climate of the upper San Pedro valley is typical of the Chihuahuan Desertscrub region characterized by hot summer temperatures, moderately cold winter temperatures, and low levels of annual precipitation (Brown 1994). Average annual precipitation is 335 mm (13.2 inches). June and July are the hottest months with maximum average temperatures of 36 C (97 F). December lows average -2.3 C (18 °F). Intense, localized convective thunderstorms in late summer provide nearly two-thirds of the annual rainfall.

The upper San Pedro valley separates the Dragoon and Mule Mountains in the east from the Whetstone and Huachuca Mountains in the west. Elevation range along the River is a moderate 291 m (955 ft). The highest point in the SPRNCA is 1,411 m (4,628 ft) in the Charleston Hills (a subset of the Tombstone Hills), a localized set of rocky outcrops near the center of the study site.

Methods

The SPRNCA was explored on foot, and collections were made over the course of 3 years mainly during the spring, summer, and fall growing seasons of 2001, 2002, and 2003. Voucher specimens are deposited at the Arizona State University Herbarium (ASU). Herbarium searches at regional herbaria added six taxa that were not collected during the study: *Eragrostis barrelieri* (Mediterranean lovegrass), *Eragrostis intermedia* (plains lovegrass), *Euphorbia spathulata* (warty spurge), *Flaveria trinerva* (clustered yellowtops), *Phyla nodiflora* (common frogfruit), and *Samolus velarandi* ssp. *parviflorus* (water pimpernell). An additional ten collections from other researchers working within the SPRNCA are also vouchered and included in the flora: *Boerhavia spicata* (creeping spiderling), *Cynanchum ligulatum* (milkweed vine), *Cuscuta tuberculata* (tubercle dodder), *Echeandia flavescens* (Torrey's craglili), *Erigeron concinnus* (fleabane), *Fraxinus gooddingii* (Goodding's ash), *Melampodium leucanthum* (plains black-foot), *Milla biflora* (Mexican star), *Pectis linifolia* (romero macho), and *Penstemon stenophyllus* (beardtongue).

A digital database was compiled with information on each plant's form, phenology, lifespan, wetland indicator score (USFWS 1996), native/exotic status (based on USDA PLANTS database), and habitat. Collection data such as latitude/longitude coordinates, plant description, associated species, and habitat were entered in the ASU collections database and made available on the World Wide Web at seinet.asu.edu/collections/selection.jsp. Many photographs have been digitized and entered into the ASU images database and are displayed online with the checklist of the upper San Pedro River. The complete list of the flora can be viewed at <http://lifesciences.asu.edu/herbarium/upper-san-pedro/index.html>, or click the link to "flora projects" from the ASU Vascular Plant Herbarium Web page.

Vegetation Types

In general, plant distributions can be explained in terms of variations in available moisture, as well as topographical gradient, geological substrate, disturbance, and elevation. The major vegetation types within the SPRNCA are Chihuahuan Desertscrub, mesquite terraces, cottonwood-willow riparian corridors, sacaton grasslands, rocky outcrops, and cienegas.

Chihuahuan Desertscrub

Chihuahuan Desertscrub vegetation covers the largest area within the SPRNCA, characterized by an abundance of long-lived, microphyllous shrubs such as *Larrea tridentata* (creosote), *Acacia constricta* (whitethorn acacia), *A. neovernicosa* (viscid acacia), and *Flourensia cernua* (tarbush). *Prosopis velutina* (mesquite), in its low, shrubby xerophytic form is also common in the desert uplands.

Mesquite Terraces

The distinct terrace vegetation on pre-entrenchment alluvium above the River channel is dominated by *Prosopis velutina* of various age classes. Mature mesquite forests with dense canopies are known as "bosques," the Spanish word for "forests." Examples of remnant mesquite bosques remain on river terraces throughout the SPRNCA.

Cottonwood-Willow Riparian Corridors

The riparian plant community is characterized by species and life forms strikingly different from that of the immediate non-riparian surroundings. The broadleaf deciduous trees of the riparian corridor represent the "signature" vegetation of the SPRNCA, maintained by relatively permanent water sources. *Populus fremontii* (Fremont cottonwood) are the giants of this gallery forest, creating a ribbon of green that stands out against the desert background in summer months.

Sacaton Grasslands

Sporobolus wrightii (sacaton) is the dominant herbaceous species within the SPRNCA. Sacaton grasslands cover large areas of lower alluvial terrace not previously cleared for agriculture. In summer months the flowering panicle can reach heights of greater than 2 m, creating sacaton "seas."

Rocky Outcrops

The San Pedro valley is abruptly broken by an isolated set of rocky outcrops known as the Charleston Hills. Roughly 10% of the SPRNCA species were restricted to the unique edaphics, geology, and topography of this area. In general, the shrubs *Aloysia wrightii* (oreganilla), *Acacia greggii*, *Mimosa aculeaticarpa* var. *biuncifera* (cat's claw mimosa), *Prosopis velutina*, *Acacia constricta*, and *A. neovernicosa* represent the dominant species. *Janusia gracilis* (slender Janusia), *Fouquieria splendens* (ocotillo), *Agave palmeri* (Palmer's agave), and *Ferocactus wislizeni* (barrel cactus) occur with greater frequency as one moves higher up the slopes.

Cienegas

The plant community of the St. David Cienega, located in the northern end of the SPRNCA, is primarily composed of aquatic and semi-aquatic graminoids and forbs such as *Schoenoplectus americanus* (chairmaker's bulrush), *Lythrum californicum* (California loosestrife), *Berula erecta* (cutleaf water parsnip), *Carex praegracilis* (clustered field sedge), *Eleocharis rostellata* (beaked spike rush), and *Juncus arcticus* var. *balticus*. Along the immediate perimeter, soils become less saturated and increasingly saline, and species such as *Anemopsis californica* (yerba mansa), *Muhlenbergia asperifolia* (alkali muhly), *Distichlis spicata* (salt grass), *Sporobolus airoides* (alkali sacaton), and *Almutaster pauciflorus* (alkali marsh aster) thrive.

Flora Composition

The flora of the San Pedro Riparian National Conservation Area includes 618 documented taxa from 608 species, 9 additional infraspecific taxa, and 1 interspecific hybrid. Ninety-two families are represented. Asteraceae (composites), Poaceae (grasses), and Fabaceae (legumes), are the largest, which combined, account for 42% of the flora. The best represented families and genera are shown in figure 2 and table 1, respectively. Figure 3 is a summary of lifespan and growth forms of the SPRNCA flora. Percentage of the total flora is noted in parentheses after growth form category. Annuals account for

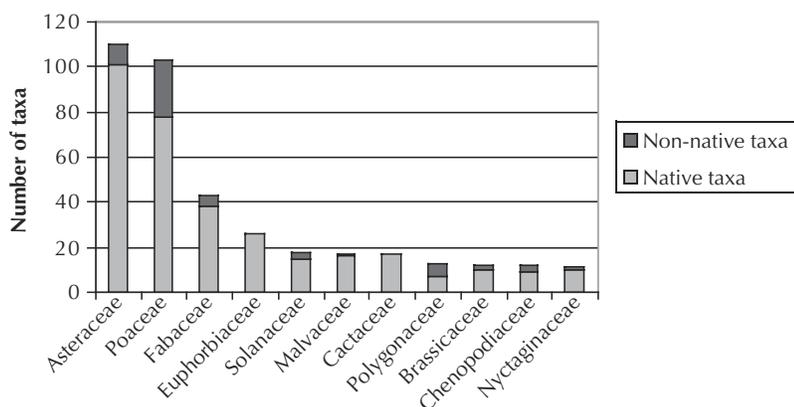


Figure 2—Best represented families in the San Pedro Riparian National Conservation Area.

38% of the flora (figure 4), and wetland plants comprise 15% of the flora (table 2).

Taxa of Interest

The SPRNCA flora is by nature capricious and unpredictable, since it represents influences from entire watersheds and beyond. The vagaries of this riparian ecosystem are exemplified by the occurrence of several novel taxa.

Range Extensions

The upper San Pedro River has been at best moderately collected, especially in the last 50 years, so it is not surprising to find plants new to the State flora. Three of the four State flora additions, *Carlowrightia texana* (Texas wrightwort), *Mancoa pubens* (Transpecos cress), and *Psilactis brevilingulata* (Transpecos tansyaster), represent moderate range extensions from their previously known distributions. *Carlowrightia texana* and *P. brevilingulata* are previously known from New Mexico, Texas, and the Mexican States of Chihuahua and Sonora. *Mancoa pubens* is previously known from three counties in southwest Texas and northwestern Chihuahua, Mexico, and the Arizona plants represent a disjunct of some 500 kilometers (Makings 2002). *Psilactis brevilingulata* was fairly common in the SPRNCA, collected in mesquite terrace, marsh, and cottonwood-riparian habitats, suggesting an established presence. *Mancoa pubens* and *Carlowrightia texana* are probably more recent arrivals, restricted to single locales and few individuals.

Tagetes minuta (wild marigold) is the fourth new State record, and was collected in the SPRNCA near the international border. Its annual habit, proximity to the San Pedro River, and “invasive” label suggest a likely recent introduction, probably within the last few years. Originally from Argentina, this plant is listed as a “noxious weed” on the USDA's Plants Database. Previous collections are from north-central California and several southeastern Atlantic states, making the San Pedro population highly disjunct.

New Species

A new shrubby species of *Eriogonum* (*Eriogonum terrenatum* Reveal sp. nov., ined.) was discovered within the boundaries of the SPRNCA, the type locality near the ruins of the old Spanish Presidio of Terrenate. The species is apparently restricted to late Tertiary lacustrine deposits, isolated in patches of limey tuffs in noticeably contrast with surrounding soil conditions. The occurrence of “*E. terrenatum*” and possibly other rare taxa can be explained in the context of the regional geology. The mid-Miocene Basin and Range Disturbance created a series of fault block mountains in central and southeastern Arizona (Damon et al. 1984; Smiley 1984). The resulting closed basins accumulated lacustrine (lake bed) deposits that were partially eroded during later Pleistocene glacial periods. These exposed limey tuffs and relatively

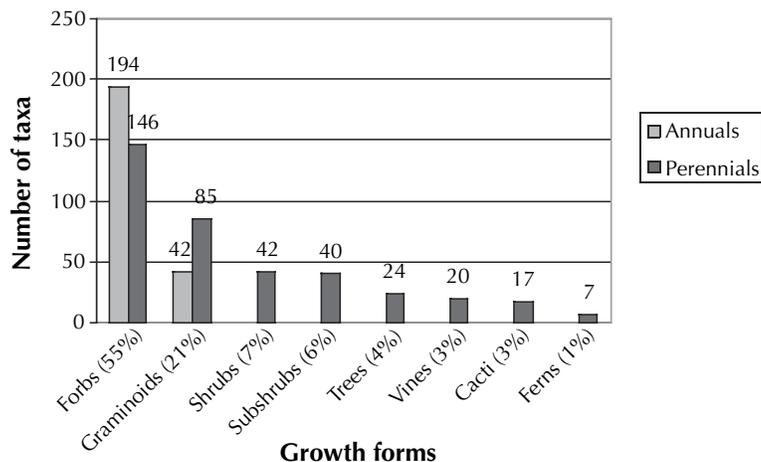


Figure 3—Lifespan and growth forms of San Pedro Riparian National Conservation Area flora.

Table 1—Best represented genera in the San Pedro Riparian National Conservation Area.

Genus	Number of taxa
<i>Chamaesyce</i>	13
<i>Bouteloua</i>	9
<i>Eragrostis</i>	9
<i>Baccharis</i>	7
<i>Dalea</i>	7
<i>Panicum</i>	7
<i>Boerhavia</i>	6
<i>Cryptantha</i>	6
<i>Eriogonum</i>	6
<i>Ipomoea</i>	6
<i>Mentzelia</i>	6
<i>Muhlenbergia</i>	6

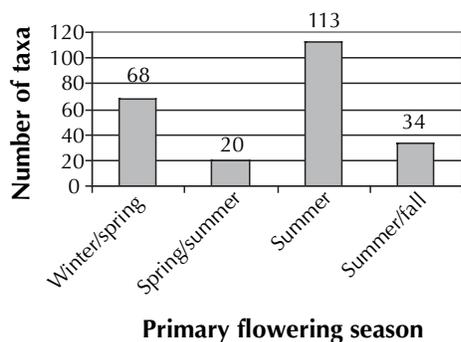


Figure 4—Number of taxa during different flowering seasons in the San Pedro Riparian National Conservation Area.

infertile azonal soils have been shown to host endemic and disjunct species (Anderson 1996). Coincidentally, another taxon of interest, *Hymenopappus filifolius* var. *pauciflorus* (yellow cutleaf), was found among “*E. terrenatum*,” and fairly disjunct from known floristic areas, reinforcing the concept of the role of late Tertiary deposits as edaphic refugia. It is possible that further exploration of these deposits may reveal other interesting floristic patterns. Table 3 is a list of other rare and/or under-collected taxa within the SPRNCA.

Discussion

Diversity Influences

Aspects of spatio-temporal diversity at multiple scales interact in complex ways in the San Pedro Riparian National Conservation Area, resulting in a botanically rich ecosystem. Broadly speaking, the species richness of the study site is enhanced by a combination of the following factors, (1) influences from surrounding geographical provinces, (2) influences from regional watersheds, (3) spatial heterogeneity within the SPRNCA, and (4) hydrological processes.

At the broad regional scale, diversity is related to influences from surrounding geographic regions and floristic provinces (McLaughlin 1986, 1995). The San Pedro River is a part of the Colorado River basin, where many geographic elements converge, including clockwise from southeast, (1) Chihuahuan Desert, (2) Sonoran Desert, (3) Mohave Desert, (4) Great Basin Desert, (5) Rocky Mountains, and (6) Southern Great Plains.

The species richness of the SPRNCA can also be explained in the context of adjacent watersheds. The sky islands of southeastern Arizona are rich reservoirs of biological diversity (McAuliffe and Burgess 1995). The diversity of plant life is reflected in the ecological variability created by a complex regional geology, abrupt topography, and climatic gradients. Riparian valley floors such as the San Pedro, situated between such areas, echo the diversity of their surroundings, and may play a role in maintaining regional biodiversity (Naimen et al. 1993). Further, they may harbor displaced taxa not only from surrounding uplands, but remote environs as well. Additionally, the SPRNCA flora has a number of sky island endemics listed by McLaughlin (1995), including *Agave palmeri* (Palmer’s century plant), *Brickellia floribunda* (Chihuahuan brickellbush), *Phacelia arizonica* (Arizona phacelia), and *Bouteloua eludens* (Santa Rita grama).

Within the SPRNCA, species diversity is also high due to habitat heterogeneity and hydrological processes. Patterns in species assemblages exist in the SPRNCA from a fine patch scale, to a larger landscape one, and environmental gradients influence vegetation associations (sacaton grasslands, cienegas, rocky outcrops, etc.) at the intermediate scale. Within the SPRNCA, longitudinal environmental gradients are minimal due to the lack of significant elevation range, but lateral environmental gradients are abundant and produce a diversity of vegetation associations. Spatial complexity is positively correlated with species diversity in the SPRNCA, as multiple habitat types offer niche opportunities for variety in vegetation associations, and therefore, increased numbers of species (Ward and Tockner 2001).

Table 2—Best represented wetland plant families of the San Pedro Riparian National Conservation Area^a.

Family	Genera	Native taxa	Non-native taxa	Total taxa
Poaceae	12	11	5	16
Asteraceae	12	14	1	15
Cyperaceae	4	10	0	10
Polygonaceae	2	1	5	6
Salicaceae	2	5	0	5
Scrophulariaceae	3	4	0	4
Apiaceae	3	3	0	3
Onagraceae	2	3	0	3
Juncaceae	1	2	0	2
Lemnaceae	1	2	0	2
Lythraceae	2	2	0	2
Ranunculaceae	2	2	0	2
Typhaceae	1	2	0	2

^a Defined as having ≥ 66% chance of being found in wetlands.

Table 3—Rare and/or under-collected species in the San Pedro Riparian National Conservation Area*.

Species	Localities of Arizona collections held at ASU
<i>Achnatherum eminens</i>	Southern Huachuca Mts., Cochise Co., Parfitt and Christy 5088 in 1991.
<i>Astragalus vaccarum</i>	None.
<i>Ammannia coccinea</i>	Lake Pleasant, Maricopa Co., Lehto 4300 in 1964. Hooker Cienega, Cochise Co., Thornber s.n. in 1905.
<i>Bouchea prismatica</i>	Sycamore Canyon, Santa Cruz Co., Fishbein 2,879 in 1996. Keil, Pinkava, Lehto 9911 in 1967.
<i>Carlowrightia linearifolia</i>	Near Portal, Cochise Co., Cazier 236 in 1966.
<i>Carlowrightia texana</i>	None. New State record.
<i>Cissus trifoliata</i>	Santa Teresa Mts., Graham Co.: Beugge 1129, 1133 in 1999.
<i>Cryptantha pusilla</i>	Southern Huachuca Mts., Cochise Co., Parfitt 4903 in 1991. Pinal Mts., Gila Co., Keil 4672 in 1969.
<i>Cynanchum ligulatum</i>	None
<i>Cyperus spectabilis</i>	Southern Huachuca Mts., Cochise Co., Parfitt 4435 in 1990.
<i>Digitaria insularis</i>	Sierrita Mts., Pima Co., John and Charlotte Reeder 7975 in 1986.
<i>“Eriogonum terrenatum”</i>	SE of Vail, AZ, Pima Co., Anderson 84-71 in 1984. New species of <i>Eriogonum</i> .
<i>Eryngium sparganophyllum</i>	Near Tanque Verde Wash, Pima Co., Titus s.n. in 2001. Agua Caliente, Pima Co., Thornber 2812 in 1908.
<i>Gleditsia triacanthos</i>	Yavapai Co: Pase 2146 in 1976; Baker 10856, in 1993; Forster s.n., in 1969.
<i>Halimolobos diffusa</i>	Lean Peak, Mohave County, Butterwick/Parfitt 5448 in 1979; Santa Catalina Mts., Pima Co., Bertelsen s.n. in 1988.
<i>Hermannia pauciflora</i>	Santa Catalina Mts., Pima Co., Keil 4303 (no date).
<i>Lilaeopsis schaffneriana</i> ssp. <i>recurva</i>	Federally listed endangered plant (several ASU collections).
<i>Mancoa pubens</i>	None. New State record.
<i>Psilactis brevilingulata</i>	None. New State record.
<i>Mirabilis jalapa</i>	No wild or non-cultivated collections.
<i>Pyrrhopappus pauciflorus</i>	O'Donnel Cienega, Santa Cruz, Co., Lehto 24526 in 1980.
<i>Salvia tiliifolia</i> *	None.
<i>Sphinctospermum constrictum</i>	None.
<i>Tagetes minuta</i> *	None. New state record.
<i>Tridens albescens</i>	Near Santa Cruz River at Casa Grande, Pinal Co., J.R. & C.G. Reeder 4598 in 1997. College Farm, Mesa, Maricopa Co., Judd s.n. in 1939. Recently recorded in Arizona.

* Indicates non-native

Finally, measures of species diversity in the SPRNCA are explained in the context of the fluvial processes of the San Pedro River. The two most important factors as they relate to the San Pedro hydrology are perennial surface water and flood dynamics (Decocq 2002; Hupp and Osterkamp 1996). Within the riparian zone, water is not a limiting resource along major portions of the upper San Pedro River. Perennial surface water and low depth-to-groundwater conditions amid a desert environment have resulted in an ecosystem with rare aquatic and wetland habitat types. With more than 15% of the flora as wetland species, the presence of perennial water is likely one of the most important factors influencing species diversity.

The presence of relatively natural fluvial dynamics on the San Pedro River results in an active floodplain with high structural diversity. While upper topographic levels offer a relatively steady habitat, flooding in the riparian zone results in a dynamic environment characterized by instability. Flood patterns of variable magnitude, frequency, and duration drive active successional processes. Disturbance from flooding results in high seral diversity due to shifting microtopography and patchy resources (Lyon and Sagers 1998). Because different successional stages contain distinct species associations, species richness also increases with successional diversity (Ward and Tockner 2001; Pollock et al. 1998).

Considerations for the future

The discovery of outliers, disjuncts, and rare taxa along the San Pedro River underscores the importance of floristic studies in the region. Botanically rich areas such as the San Pedro River deserve conservation status, not only for protection of endangered species like the diminutive Huachuca water umbel, but for their botanical potential. This inherently dynamic ecosystem will continue to harbor novel taxa, and welcome immigrant species as long as steps are taken to maintain its functional integrity. Given the enormous complexity of ecosystem processes at multiple scales within the SPRNCA, clear advice about priorities for conservation is difficult. One effective strategy is to identify the dominant ecological processes that structure the ecosystem and focus efforts there (Folke et al. 1996). On the San Pedro River, perennial surface water is the key component sustaining biodiversity. A simplified strategy regulating the demands on the regional aquifer must be implemented if this fragile and rare ecosystem is to survive. Addressing the social, cultural, and economic driving forces causing groundwater loss in the region presents significant challenges for land managers. Ultimately, the preservation of the San Pedro River ecosystem will only be accomplished through an interplay of stakeholder planning and regulation, public participation, and input from the scientific community.

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